TERM OF COMMISSION: November Session of the November Adjourned Term

PLACE OF MEETING: Roger B. Wilson Boone County Government Center

Boone County Commission Chambers

PRESENT WERE: Presiding Commissioner Daniel Atwill

District I Commissioner Justin Aldred

District II Commissioner Janet Thompson

Director of Resource Management Bill Florea

Planner Uriah Mach

Human Resources Hiring & Retention Coordinator Sharry Charest

Boone County Counselor CJ Dykhouse

Deputy County Clerk Jodi Vanskike

Public: Tim Opitz with Renew Missouri, Tom Weislocher, Jeff Turner

Conference Call Information:

Number: 425-585-6224 Access Code: 802-162-168

The meeting was called to order at 7:00pm.

P & Z

1. **Request by Jon Adam Sapp to approve a Final Development Plan for Harvest Acres on 10.0 acres zoned A-1 (Agriculture) with pending A-1P (Planned Agriculture) located at 12200 S Hwy DD, Ashland**

Director of Resource Management Bill Florea read the following staff report: The Planning and Zoning Commission reviewed this request at its October 21, 2021 meeting and voted to recommend approval on a unanimous vote. Staff recommended approval of the final plan. The Boone County Zoning and Subdivision Regulations are entered into the record of this meeting. The property is located on the west side of State Highway DD approximately 1200 feet north of the intersection of Biggs Road and State Highway DD. The parent property is 73.5-acres in size and zoned A-1 (Agriculture). This proposal seeks to rezone 10-acres of the parent parcel to A-1P to facilitate a land division creating a 5.59-acre buildable lot and to define the remaining portion of the 10-acres as a non-developable portion of the parent parcel. The property scored 60 points on the point rating system. An A-1P rezoning and Review Plan were approved on this property in August of 2021 under Commission Orders 359-2021 & 360-2021.

The Zoning Regulations state that the Commission shall approve a Final Development Plan when it is satisfied that:

- All required information is accurately portrayed on the plan
- The Final Plan conforms to the approved review plan
- The Final Plan demonstrates compliance with all conditions, which the County Commission may have imposed on the Review Plan.

Staff has reviewed the final plan. All information is accurately portrayed on the plan and conforms with the approved review plan. A family transfer is proposed to create the desired land division.

No conditions were placed on this proposal at the time of its hearings before the Planning & Zoning Commission or County Commission.

Commissioner Thompson moved now on this day the County Commission of the County of Boone **approves** the request by Jon Adam Sapp to approve a Final Development Plan for Harvest Acres on 10.0 acres zoned A-1 (Agriculture) with pending A-1P (Planned Agriculture) located at 12200 S Hwy DD, Ashland.

Commissioner Aldred seconded the motion.
The motion carried 3 to 0. **Order #465-2021**

2. **Eagles Tres Estates. S9-T46N-R12W. A-2. Cari & Travis Nichols, owners. Steven Proctor, surveyor.**

Director of Resource Management Bill Florea read the following staff report:

The Planning and Zoning Commission approved the plat of Eagles Tres by consent. Director Florea asks that the Commission waives the reading of the staff report and authorize the clerk to insert the it into the meeting minutes. The conditions imposed by P&Z have been met. The property is located on State Route DD, approximately 600' northwest of the city limits of the City of Ashland. The property is proposed to be divided into two lots, one at 9.83 acres in size, and the other at 10 acres in size. The western lot has a single-family residence, shop, and on-site wastewater system present. The eastern lot is currently undeveloped. The property is 19.85 acres in size and zoned A-2(Agriculture). The surrounding property is also zoned A-2. This is all original 1973 zoning.

The subject property has access to State Route DD. This access is direct in the case of the western lot, and via an access easement in the case of the eastern lot. The applicant has submitted a request to waive the traffic study requirement.

The property is in Consolidated Public Water Service District #1 for water service, the Boone Electric Cooperative for electrical service, and the Southern Boone County Fire Protection District for fire protection. Water service is provided off a Consolidated Public Water Service main along Highway DD.

The existing home has an on-site wastewater system. Wastewater development on the eastern lot will be done under permit with Columbia/Boone County Health Department. The applicant has submitted a request to waive the wastewater cost-benefit analysis.

The property scored 58 points on the rating system.

Staff recommended approval of the plat and granting the requested waivers.

Commissioner Aldred moved now on this day the County Commission of the County of Boone does hereby receive and accept the plat of Eagles Tres Estates. S9-T46N-R12W. A-2. Cari & Travis Nichols, owners. Steven Proctor, surveyor and authorizes the Presiding Commissioner to sign it and directs the Clerk to insert the staff report into the meeting minutes.

Commissioner Thompson seconded the motion.
The motion carried 3 to 0. **Order #466-2021**

3. **First and Second Reading: Approval of the revision and re-adoption of the Boone County Zoning Regulations, Sections 1 through 28. This includes revisions to Section 2, Definitions, Section 15 Administration, and adoption of Section 29 Wind Energy Conversion Overlay District (WECOD)**

Commissioner Atwill stated as most people know, the intent of the windfarm regulations was to provide a procedure for construction of wind power generators in Boone County, and to give residents a voice in areas where construction was proposed. Commissioner Atwill stated he wanted to compliment the Boone County Planning and Zoning Commission, which worked very hard to come up with the regulations that will be presented tonight. Commissioner Atwill stated he wanted to compliment the Boone County staff who worked at least as hard, maybe harder, to do the same thing. Commissioner Atwill stated the Planning and Zoning Commission held three public hearings, held fourteen public work sessions, and had done lots of staff research that went into what will be presented later, and the County Commission itself held three separate public hearings at different locations around the County. Commissioner Atwill stated they heard from proponents and opponents, many documents were presented which are included in the record and emphasis has been on transparency and consideration of all points of view. Commissioner Atwill stated there is no way to satisfy everyone or every point of view, and today we take up, for approval or disapproval, proposed regulations that are the product of all these hearings, work sessions and countless hours of staff work. Commissioner Atwill stated Boone County adopted zoning regulations beginning in 1973. Commissioner Atwill stated without basic zoning requirements, this process would be much different. Commissioner Atwill stated many counties still do not have zoning regulations, and without Planning and Zoning, we would not be able to require the rules included in the proposal. Commissioner Atwill said to keep in mind that all rules are subject to modification at a later date to meet the changing needs of the community. Commissioner Atwill stated there are regulations that deal with areas of square mile sections and quarter sections that can be confusing. Commissioner Atwill stated there are 691 square miles of area in Boone County, which equals 442,240 acres. Commissioner Atwill stated one square mile equals 640 acres and one square mile also equals one section of land by survey and one quarter section equals 160 acres. Commissioner Atwill stated one of things that has been of concern by a lot of citizens is the ice and debris that can be thrown from blades, so setbacks are required. Commissioner Atwill stated overlay districts are contemplated by the regulations, there is an area test and an ownership test that must be satisfied concurrent with the submission of any application. Commissioner Atwill stated the overlay process requires a super majority of the owners and the proposed district, to sign approval of the application to be submitted by the developer. Commissioner Atwill stated there is a required buffer area from the property line or to a public road. Commissioner Atwill stated farm area is the area most likely to be the target of a windmill farming operation, so we will look a little bit at the concept of farming in Boone County. Commissioner Atwill stated in 2007 Boone County had 258,734 acres in farming. Commissioner Atwill stated in 2017, that had gone down to 212,732 acres in farming, a reduction in land area for farming of 12%. Commissioner Atwill stated the area used for farming continues to shrink as the population of the County continues to grow. Commissioner Atwill stated farming is currently involved with less than 1/3 of the County land available and density per square mile is a concern. Commissioner Atwill stated Boone County, with a population of 183,000, has a density of 263 people per square mile, with a 12.2% growth rate since the last census. Commissioner Atwill stated other counties have been educational in review of how they have handled this and what their situation is. Commissioner Atwill stated Schuyler County has a population of 4,431 and a density per square mile of 6.9 people, compared to 263 in Boone County. Commissioner Atwill stated Atchison County, another wind farm county, has a density per square mile of 7.29, a total population of 5,229, and in 2019 they experienced a 10% decrease in population. Commissioner Atwill stated Dekalb County has a density per square mile of 18.15 with a total population of 11,029, so these which have allowed the creation of wind farms in their areas, are much smaller counties. Commissioner Atwill stated these rules would allow the creations of wind farms under rules that have been made available over the internet and by hard copy for many weeks now. Commissioner Atwill stated he will now ask if the other Commissioners have any comments before they go on to the staff report. Commissioner Aldred stated he would also like to thank the Resource Management staff, the Planning and Zoning Commission and the citizens who have made their voices heard. Commissioner Atwill stated he will have some questions for Director Florea after his report is made. Commissioner Thompson stated she too would like to thank Resource Management for their diligence and in shepherding this project to Planning and Zoning, and she appreciates the incredible work and dedication shown to this County and the time spent delving into something that was a new area of expertise, and to the people of Boone County who were the first to host a meeting. Commissioner Thompson stated she will never forget the first meeting in Harrisburg when people came together to talk about the possibility of wind farms coming to Boone County. Commissioner Thompson stated it will be forever in her mind because she went to the meeting with the former Director of Resource Management Stan Shawver and they listened to people talking on both sides, and it was very clear that this is a question of balancing of interests. Commissioner Thompson stated this is not something that has all the interest on one side, this is an issue in which interest must be balanced. Commissioner Thompson stated she applauds the Planning and Zoning Commission for their work in crafting these regulations, and she applauds the work of Resource Management in their work of listening to the commentary of citizens on both sides, and looking at the proposed regulations to say "Is this the appropriate balance?" Commissioner Thompson stated that process shows that they are doing this regulatory process right by having a very transparent and open process in which citizens can participate.

Director of Resource Management Bill Florea read the following staff report: As a result of the public comments that were received, staff has drafted several amendments to the proposed regulations:

Section 2 Definitions: Several definitions were added for clarity.

Section 29.1 Intent and Purpose: Language was added to provide a more robust statement of purpose.

Section 29.5.1.8 Visual Impact Assessment: New language was added to replace the requirement for a computer-generated visual simulation which, was perceived by many to be of questionable value. The new language describes several steps for assessment of the visual impact of a proposed wind farm. Those steps include:

- Viewshed analysis to determine actual visibility;
- Inventory of views to provide the basis for evaluating the extent of visibility;
- Photographic and/or virtual simulations; and
- A summary of key findings and proposed mitigation techniques.

29.8.4 Visual Impacts: The initial proposal stipulated a maximum height of 355 feet with the provision that towers of up to 400 feet could be approved on a case by case basis. Height was measured from the ground to the tip of the blade at its highest point. Public comment indicated that this was impossible due to limitations of the sizes of towers that are available in the North American market.

Staff research found that the industry standard for measuring height is from the ground level to the center of the turbine hub, or hub height. Towers are manufactured at several different hub heights, the shortest hub height tower for which there are multiple manufacturers is 80-meters or approximately 261 feet.

The regulations before the Commission tonight stipulate the maximum height to be 80-meters at the hub. Each of three manufactures that were researched manufacture only one rotor for each 80-meter tower. This imposes a natural limit on the overall height of the wind turbine structure, including the rotor. The tallest structure with an 80-meter hub height was found to be 138 meters or 452 feet.

This adjustment in maximum height did not cause a revision to the setback requirement. The setback back of 1,750 feet was based on an article that identified blade tip speed, not tower height, as the controlling factor for establishing a setback. Blade tip speed is largely controlled by the generating capacity of the turbine. The generating capacity of the 80-meter towers aligns with the expected generating capacity that was considered when Planning and Zoning Commission identified the 1,750 setbacks.

Section 29.9.2 Abandonment: In response to comments received, language was added to clarify that a wind farm would not be considered to be abandoned in cases of a repowering or casualty event and there was an approved schedule of completion not to exceed 5-years.

The draft regulations brought before the Commission tonight are the result of many hours of work by the Planning and Zoning Commission, the public, the County Commission and staff. Director Florea stated he too, would like to extend special gratitude to the volunteers on the Planning and Zoning Commission and to the public who volunteered their time as well.

Commissioner Thompson moved now on this day the County Commission of the County of Boone takes up the revision and re-adoption of the Boone County Zoning Regulations, Sections 1 through 29. This includes revisions to Section 2, Definitions, Section 15 Administration, and adoption of Section 29 Wind Energy Conversion Overlay District (WECOD).

WHEREAS, the Boone County Planning and Zoning Commission conducted three (3) public hearings, after due public notice, into the issue of re-adoption of the Boone County Zoning Regulations, Sections 1 through 29. This includes revisions to Section 2, Definitions, Section 15 Administration, and adoption of Section 29 Wind Energy Conversion Overlay District (WECOD); and

WHEREAS, the Boone County Planning and Zoning Commission (P&Z) has recommended that the County Commission readopt those regulations including revisions to Section 2, Definitions, Section 15 Administration, and adoption of Section 29 Wind Energy Conversion Overlay District (WECOD); and

WHEREAS, the County Commission conducted a public hearing on re-adoption of those regulations on July 27, 2021; and

WHEREAS, all required notices have been given and all required public hearings have been held;

NOW, THEREFORE, the County Commission of the County of Boone does hereby adopt the Boone County Zoning Regulations Sections 1 through 29. This includes revisions to Section 2, Definitions, Section 15 Administration, and adoption of Section 29 Wind Energy Conversion Overlay District (WECOD), copies of which are attached and incorporated by reference, along with the following attachments:

1. Notice of the first P&Z hearing, affidavit of newspaper publication, affidavit of posting in the Boone County Government Center, and the hearing minutes.
2. Notice of the second P&Z hearing, affidavit of newspaper publication, affidavit of posting in the Boone County Government Center (northern district), and the hearing minutes.
3. Notice of the third P&Z hearing, affidavit of newspaper publication, affidavit of posting in the Boone County Government Center (southern district), and the hearing minutes.
4. Minutes from the P&Z meeting with recommendation for adoption.
5. Notice of public hearing before the County Commission on July 27, 2021, affidavit of newspaper publication, affidavit of posting in Boone County Government Center, and the hearing minutes showing the public hearing was opened for the re-adoption of the zoning regulations and adoption of revisions to Sections 2 and 15, and new Section 29.
6. Complete copy of Zoning Regulations.
6A. Revisions to Sections 2, and new Section 29.
6B. Revisions to Section 15.
7. U.S. Fish and Wildlife Service Land-Based Wind Energy Guidelines
8. A method for defining wind turbine setback standards, Wind Energy, 2011.
9. World Health Organization (WHO) Environmental Noise Guidelines for the European Region.
10. ANSI S12.9-2005/Part 4, Quantities and Procedures for Description and Measurement of Environmental Sound-Part 4: Noise Assessment and Prediction of Long-term Community Response.
11. Demographic and Economic Comparison of Four Missouri Counties.
12. Maps of Boone County showing parcels capable of 1,750-foot radius buffer and population density.
13. Maps of Adair County showing parcels capable of 1,750-foot radius, existing wind turbine locations, and population density.
14. Map showing Boone County Block Level Census 2010 population density per square mile.
15. Map showing Adair County Block Level Census 2010 population density per square mile.
16. List of manufactures of 80-meter hub height wind turbine towers.

Commissioner Aldred seconded the motion.
The motion carried 3 to 0. **Order #467-2021**

Human Resources

4. **First and Second Reading: Request for Extending an Overlap Period for Training in Position 441**

Human Resources Hiring and Retention Coordinator Sharry Charest stated finding candidates to fill open positions in this current market is very difficult and the current staffing level in the

Facilities Department means they won't be able to sustain their vacancy and maintain their current operations. Ms. Charest stated Human Resources wants to advertise right now for a custodian position that will be vacated on December 31, 2021, however, if they were to find a good candidate right away, that person probably would not wait weeks to begin work. Ms. Charest stated therefore, they ask that the extended overlap period be six weeks for this position.

Commissioner Aldred moved now on this day, the County Commission of the County of Boone does hereby approve a request for an extended employee overlap/training period, in excess of the ordinary "Two Week Training Period for New Employees" as approved in Commission Order 147-2005, for position 441, Custodian, Housekeeping & Custodial Services. The extended overlap period is approved up to six weeks.

Commissioner Thompson seconded the motion.
The motion carried 3 to 0. **Order #468-2021**

Purchasing

5. **Second Reading: Amendment 1 to Contract 148-123119SS - GrayKey iOS and Android Forensic Software - Boone Co. Sheriff (First Reading: 11.02.21)**

Commissioner Thompson moved now on this day, the County Commission of the County of Boone does hereby approve Amendment #1 to Contract 148-123119SS for Gray Key iOS, Android Forensic License and Support for the Boone County Sheriff's Office which was awarded November 26, 2019 (Commission Order 505-2019) which is being amended to upgrade the iOS license to include Android devices.

All other terms, conditions and prices of the original agreement remain unchanged.

Payments will be paid from Department 1253 – GF Sheriff Grants, Account 70050 – Software Service Contract: $27,995.00.

Commissioner Aldred seconded the motion.
The motion carried 3 to 0. **Order #469-2021**

Emergency Management

6. **Second Reading: State Homeland Security Program Grant Award (First Read 11.02.21)**

Commissioner Aldred moved now on this day, the County Commission of the County of Boone does hereby approve the State Homeland Security Program Grant award letter, submitted by the Emergency Management Department.

It is further ordered the Presiding Commissioner is hereby authorized to sign the attached grant award.

Commissioner Thompson seconded the motion.

The motion carried 3 to 0. **Order #470-2021**

Sheriff's Office

7. **Second Reading: 2021 Edward Byrne Memorial Justice Assistance Grant Award (First Reading: 11.02.21)**

Commissioner Thompson moved now on this day, the County Commission of the County of Boone does hereby approve the acceptance of the 2021 Edward Byrne Memorial Justice Assistance Grant (JAG), awarded to the Boone County Sheriff's Office.

It is further ordered the Presiding Commissioner is hereby authorized to sign the attached grant award.

Commissioner Aldred seconded the motion.
The motion carried 3 to 0. **Order #471-2021**

Commission

8. **First and Second Reading: Organizational use of Boone County Conference Rooms: Early Childhood Positive Behavior Support Program Team Retreat**

Commissioner Aldred moved now on this day, the County Commission of the County of Boone does hereby approve the Organizational Use of the Boone County Government Center Conference Room 311 by Early Childhood Positive Behavior Support (ECPBS) Program on Monday, November 22, and Tuesday, November 23, 2021, from 8:30AM until 2:30PM.

Commissioner Thompson seconded the motion.
The motion carried 3 to 0. **Order #472-2021**

9. Public Comment

Tim Opitz, General Counsel for Renew Missouri and Three Creeks Township Democratic Committeeman stated right now there are world leaders in Glascow trying to come up with solutions to combat our climate emergency, and he wants to congratulate the Commissioners on becoming the first county in Missouri to ban wind. Tom Weislocher stated he has followed the wind issue closely for the past three years and he would like to echo the earlier comments of congratulating Planning and Zoning, the Commissioner and the volunteers for all their work. Mr. Weislocher stated he would like to thank Planning and Zoning for allowing his input, he felt like all of it was listened to, even though not all of it was acted upon. Mr. Weislocher stated he feels like his opinions, and those of others, were taken into consideration and that overall the County has done the best possible job they could. Jeff Turner stated he also wanted to thank the Boone County Commission for working so hard to please everyone in Boone County. Mr. Turner stated he thinks this is a good start and though you can't please everyone, he knows the Commissioners will be watching the process take place and move forward.

10. Commissioner Reports

Commissioner Aldred stated he believes these revisions will better suit wind industry standards and best practices while remaining in keeping with the property owners rights that are expected in a Planned and Zoned County such as Boone. Commissioner Aldred stated ultimately the Planning and Zoning regulations are a living document and should these regulations cause any unseen, adverse effects in the future, they can be amended through the same process of public input and data analysis that Planning and Zoning put into crafting this original policy.

Daniel K. Atwill

Presiding Commissioner

Attest:

Brianna L. Lennon

Clerk of the County Commission

Justin Aldred

District I Commissioner

Janet M. Thompson

District II Commissioner

ATTACHMENT 1

Boone County
Resource Management

ROGER B. WILSON GOVERNMENT CENTER
801 E. WALNUT ROOM 315 COLUMBIA, MO 65201-7730
(573) 886-4330 FAX (573) 886-4340

DIRECTOR, BILL FLOREA

PLANNING - INSPECTIONS - ENGINEERING

AGENDA – WORK SESSION
PLANNING & ZONING COMMISSION
COMMISSION CHAMBERS, 801 E Walnut St, Columbia

April 8, 2021 - 6:00 P.M.

The work session and public hearing will be held in person and by phone conference. Those wishing to provide comments by phone or video are required to pre-register.

To attend by phone please call: 701-801-1211. When prompted, enter access code: 758-401-651.

To attend by video go to https://www.startmeeting.com, click "join" in the upper right-hand side. The online meeting ID for this hearing is "boonecounty2". If you need to use your phone for audio, please use the phone number and access code above. If you have a microphone and speakers, or a headset on your computer/device, you will not need to dial into a phone number.

Work Session – 6:00 PM

1. Distribute packets for April 15, 2021 meeting.
2. Adjourn Work Session

Public Hearing – Wind Farm Regulations; 6:30 PM

1. Call to Order
2. Roll Call
3. Opening Statement
4. Staff Presentation
5. Open for comments or questions from pre-registered speakers
6. Open for comments or questions from non-registered speakers
7. Close public hearing
8. Adjourn

Visit our website for more information: www.showmeboone.com/resource-management
Written comments may be submitted to: WECOD@boonecountymo.org

Posted 4/7/21 11:05 am

COLUMBIA DAILY TRIBUNE

P.O. Box 798 • Columbia, MO • 65205-0798

ADVERTISING INVOICE and STATEMENT

BILLING PERIOD	ADVERTISER/CLIENT NAME
03/01/21 - 03/31/21	BC RESOURCE MANAGEMENT

TOTAL AMOUNT DUE	*UNAPPLIED AMOUNT	TERMS OF PAYMENT
138.96		NET DUE 28 DAYS

CURRENT NET AMOUNT DUE	30 DAYS	60 DAYS	OVER 90 DAYS
138.96	0.00	0.00	0.00

INVOICE NUMBER	PAGE #	BILLING DATE	BILLED ACCOUNT NUMBER	PARENT ACCOUNT NUMBER
1476237	1	03/31/2021	12525	12525

BILLED ACCOUNT NAME & ADDRESS

BC RESOURCE MANAGEMENT
***
801 E WALNUT ST
COLUMBIA MO 65201-4890

PLEASE DETACH AND RETURN UPPER PORTION WITH YOUR REMITTANCE

DATE	REFERENCE	PUB	DESCRIPTION - OTHER COMMENTS / CHARGES	SIZE/PAGES	TIMES	RATE	BALANCE
			BALANCE FORWARD				156.61
03/22	ACH		PAYMENT				(156.61)
03/24	90868	CDT	WIND FARM HEARING	2 X 4.50	1	15.44	138.96

CONTRACT NAME:	EXPIRES	COMMITMENT	PERIOD	TO DATE	TO FULFILL
Net Dollar Volume	04/29/2021	24000.00	2887.99	36021.80	-12021.80

STATEMENT OF ACCOUNT AGING OF PAST DUE AMOUNTS

CURRENT NET AMOUNT DUE	30 DAYS	60 DAYS	OVER 90 DAYS	*UNAPPLIED AMOUNT	TOTAL AMOUNT DUE
138.96	0.00	0.00	0.00		138.96

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*UNAPPLIED AMOUNTS ARE INCLUDED IN TOTAL AMOUNT DUE

INVOICE NUMBER	ADVERTISER INFORMATION			
	BILLING PERIOD	BILLED ACCOUNT NUMBER	PARENT ACCOUNT NUMBER	ADVERTISER / CLIENT NAME
1476237	03/01/21 - 03/31/21	12525	12525	BC RESOURCE MANAGEMENT

AFFIDAVIT OF PUBLICATION

BC RESOURCE MANAGEMENT

I, Hayley Shipley, being duly sworn according to law, state that I am one of the publishers of the Columbia Daily Tribune, a daily newspaper of general circulation in the County of Boone, State of Missouri, where located; which newspaper has been admitted to the Post Office as periodical class matter in the City of Columbia, Missouri, the city of publication; which newspaper has been published regularly and consecutively for a period of three years and has a list of bona fide subscribers, voluntarily engaged as such, who have paid or agreed to pay a stated price for a subscription for a definite period of time, and that such newspaper has complied with the provisions of Section 493.050, Revised Statutes of Missouri 2000, and Section 59.310, Revised Statutes of Missouri 2000. The affixed notice appeared in said newspaper on the following consecutive issues:

*** SEE ATTACHED***

1st Insertion	03/24/21
2nd Insertion	
3rd Insertion	
4th Insertion	
5th Insertion	
6th Insertion	
7th Insertion	
8th Insertion	
9th Insertion	
10th Insertion	
11th Insertion	
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15th Insertion	
16th Insertion	
17th Insertion	
18th Insertion	
19th Insertion	
20th Insertion	
21st Insertion	
22nd Insertion	

$138.96

By Hayley Shipley

Subscribed and sworn to before me this 6th of April, 2021

Sandra L Rother

Notary Public

SANDRA L ROTHER
Notary Public - Notary Seal
STATE OF MISSOURI
Comm. Number 15638071
Boone County
My Commission Expires: Sep. 9, 2023

NOTICE OF PUBLIC HEARINGS

Notice is hereby given that the Boone County Planning and Zoning Commission will conduct Public Hearings on proposed Boone County Wind Farm Regulations on the following dates:

Thursday, April 8, 2021, 6:30 PM; Boone County Government Center, Commission Chambers, 801 E. Walnut St., Columbia, MO

Tuesday, April 20, 2021, 6:30 PM; Harrisburg High School Gymnasium, 801 S. Harris St., Harrisburg, MO

Thursday, April 29, 2021, 6:30 PM; Southern Boone Schools, Central Office Board Room, 5275 W. Red Tail Dr., Ashland, MO

These hearings are being held for the purpose of gaining input on the proposed **Boone County Wind Farm Regulations** as part of the Boone County Zoning Regulations. All members of the public are welcome to provide comments however time restrictions per speaker may be implemented due to crowd size.

Copies of the proposed regulations may be obtained on or after April 1, 2021 at the office of Boone County Resource Management, 801 E. Walnut St., Rm. 315, Columbia or on our website at: www.showmeboone.com/resource-management/

To submit comments or questions please email: WECOD@boonecountymo.org by May 1, 2021.

AFFIDAVIT OF NOTICE OF PUBLIC HEARING

STATE OF MISSOURI) ss
County of Boone)

I hereby swear that the affixed notice of public hearing was posted at the Boone County Government Center, 801 E. Walnut St., Columbia, Missouri, on the

24th day of March, 2021

Paula Evans date 3/24/21
Paula Evans

Subscribed & sworn to before me this 24th day of March, 2021

Christina L Crane
Notary Public

Christina L. Crane
Printed Name

CHRISTINA L. CRANE
Notary Public - Notary Seal
STATE OF MISSOURI
Boone County
My Commission Expires: May 21, 2021
Commission # 13705616

COUNTY OF BOONE MISSOURI

DIRECTOR
BILL FLOREA

Boone County Resource Management

ROGER B. WILSON GOVERNMENT CENTER
801 E. WALNUT ROOM 315 COLUMBIA, MO 65201-7730
(573) 886-4330 FAX (573) 886-4340

PLANNING - INSPECTIONS - ENGINEERING

NOTICE OF PUBLIC HEARINGS

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www.showmeboone.com/resource-management/

To submit comments or questions please email:
WECOD@boonecountymo.org by May 1, 2021.

BOONE COUNTY PLANNING & ZONING COMMISSION
WORK SESSION & WIND FARM REGULATIONS PUBLIC HEARING

BOONE COUNTY GOVERNMENT CENTER, COMMISSION CHAMBERS
801 E. WALNUT, COLUMBIA, MISSOURI
(573) 886-4330

Minutes	**6:00 P.M.**	**Thursday, April 8, 2021**

Commissioners present: Boyd Harris, Eric Kurzejeski, Michael Poehlman, Greg Martin, Steve Koirtyohann, Bill Lloyd, Rhonda Proctor, Jeff McCann, Fred Furlong, Randal Trecha

Absent: Daniel Mings

Staff: Bill Florea, Thad Yonke, Uriah Mach, Cece Riley, Paula Evans

Chairperson Harris called the work session to order at 6:00 PM

Staff informed the Commission of the items on the April 15, 2021 Planning and Zoning Commission meeting and gave a brief summary of each.

Worksession adjourned 6:15 PM

The first public hearing to receive comments and questions regarding the proposed Wind Farm regulations was called to order at 6:30 PM.

Chairperson Harris read the following statement:

Good evening and welcome to tonight's hearing regarding the proposed Boone County Wind Farm Regulations. An informational presentation will be given which will explain the proposed regulations. After the presentation, the Commission will call upon those who have pre-registered to speak, after those who have pre-registered have spoken, anyone present who wishes to make comments may do so. In the interest of time, responses to questions may not be given this evening. However, a record of all questions and comments will be kept and responses may be made directly to the individual, by posting on our website, or both. Forms have been made available for those who prefer to submit their questions in writing.

If you choose to provide testimony this evening and have not pre-registered, please complete the "Request to Speak" form and place in the box on the table. Please be concise and we ask that you not be repetitious with your remarks, we also ask that you restrict your comments to the proposed regulations. We recognize that this issue can be quite emotional, in that regard we ask that you refrain from applause, cheers or other signs of support or displeasure. Please be considerate of everyone here.

In order to give everyone an opportunity, speakers will be limited to five minutes each. Time limits may be changed depending on how the hearing progresses. If you feel that your allotted time is not enough, you are welcome to attend later public hearings or submit your additional comments in writing. Comments and questions can be submitted in writing and by email until May 1, 2021, to: WECOD@boonecountymo.org.

This is the first of three public hearings to be held by the Planning and Zoning Commission. No decision will be made tonight. After the public hearings are completed, Resource Management will review and organize the comments and questions and forward them to the Planning and Zoning Commission. The Commission may make changes to the proposed regulations as a result of the comments received, or they may make a recommendation for approval or denial to the County Commission. The County Commission will hold another public hearing regarding the final draft. The County Commission may approve or deny the regulations, or they may refer them back to the Planning and Zoning Commission for further consideration.

The progress of the proposed regulations will be updated regularly on our website at:
www.showmeboone.com/resource-management/WECOD

Staff gave a power point presentation which included a brief summary of the requirements for establishing a wind farm in Boone County. This power point is available on the previously mentioned website.

The floor was open for comments:

Susan Goodman, 11581 N Trimble Rd, Harrisburg

Note: Ms. Goodman presented several displays but did not leave any for the record.

Ms. Goodman spoke about property values and proposed that a property value guarantee agreement be required. Ms. Goodman states that according to NASA research they were surprised that they received complaints from a dozen families within a three-kilometer radius of turbines. According to Mike McCann there is a property value devaluation, it goes down 25% and it can go down 40% and even 100% if the property becomes uninhabitable. If we have a property value guarantee agreement then we can do something about it and they will have to buy your property. Two years later Mr. McCann said that is not far enough within three miles, it is better if it is three megawatt turbines because they have more impact.

Ms. Goodman also spoke about noise levels (page 13, Section 29.8.1.1) stating that according to the World Health Organization, at 40-55 decibels adverse health effects are observed among the exposed people, children, the elderly and people with chronic diseases are affected more. Above 55 decibels is considered increasingly dangerous to the public health. Adverse health effects occur frequently, a sizable amount of the population have them and are sleep disturbed and there is evidence of increased risk of cardiovascular disease. Ms. Goodman provided a link of 1500 pages of documents from Madison County, Iowa Health Department who declared wind turbines to be a health hazard. Ms. Goodman referred to 15 peer-reviewed articles of the adverse health effects of wind turbine noise. She also referred to Australia stating that the larger wind turbines produce more noise in the infrasound range and low frequency and operate at lower RPMs. A retired fire-chief wrote that pieces of blades have been documented as traveling over 4200 feet.

Ms. Goodman stated operators should maintain project-wide windfarm general liability insurance.

Chairperson Harris asked Ms. Goodman if she lives or owns property in the general area where the project has been proposed in Boone County. Ms. Goodman stated yes.

Chairperson Harris called Allison Kite attending by video. Ms. Kite did not answer.

Chairperson Harris called Jenna Rose attending by video. Ms. Rose did not answer.

Tom Weislocher, 11581 N Trimble Rd, Harrisburg

Regarding Section 29.7.4.1, Historical, Cultural and Archeological Resources Mr. Weislocher asked if close proximity means 1000 feet, 2000 feet or two miles? Mr. Weislocher believes it should be more specific. He also asked if Sensitive Historical, Cultural and Archeological resources included churches, cemeteries, or multi-generational family farms and stated that there are a lot of those in this area.

Section 29.8.5.5 states that individual turbine heights and markings shall comply with FAA regulations. If lighting of turbines or other structures are required, daytime white, nighttime red shall be the only type of lighting allowed unless prohibited by law. Mr. Weislocher stated one of the big complaints that homeowners near the wind farms have is that the night sky is ruined by the constant, unsynchronized flashing of red lights. There are already several FAA approved solutions to this problem, most commonly involving a system that keeps the lights off at night and uses radar within the turbines to detect approaching aircraft and automatically activates the flashing red lights only while aircraft are in the area.

Mr. Weislocher stated he is not aware of any industrial windfarms in Missouri that are utilizing these systems. Given that Boone County is densely populated relative to other areas where commercial windfarms exist, he thinks that lights off at night, except when activated by approaching aircraft, should be a requirement.

The draft regulation does not state where the power goes. Part of the attraction of this area is the proximity to power transmission lines but there has been no mention of any developer having encamped a cell tower to any utility within Boone County. It will more likely be transmitted up the line to the highest bidder. Given that the City of Columbia's ordinance specifies that 30% of direct electric retail usage come from eligible renewable energy resources by 2028, I think the county regulations should require that the project owner give first option to purchase power at competitive rates to utilities within Boone County. It would be a shame to allow destruction of the rural landscape and not be able to reap the benefit of the energy being produced.

Mr. Weislocher spoke about the reduction of property values and believes the developer should provide additional security to Boone County to be escrowed by the county for the purpose of compensating the property owners who are not leasing land to the developer in the event that their property becomes affected by it as demonstrated by appraisal. If no one applies for and is approved to receive this compensation then those escrowed funds would be returned to the developer at the end of a specified period.

Mr. Weislocher continued that the proposed regulations are a complex system of inter-related moving parts, changing any one thing would send ripples through the workings and would necessitate other changes. For example, if a developer should request approval to build a turbine taller than 355 feet then that would entail a corresponding proportional increase in the 1750 feet setback distance.

Hazardous material during the construction and operation phase. Each turbine typically has a pad mounted transformer containing up to 500 gallons of mineral oil, these are shipped empty and filled onsite. In addition, each substation transformer, where the project connects to the grid, may contain up to 12,000 gallons of mineral oil. Once online each turbine requires copious amounts of hazardous fluids on an ongoing basis such as glycol, hydraulic oil, and lubricating oil. All these fluids must be drained and replaced on a regular basis. If kept onsite, whether above ground or below ground they present a risk of soil, stream, and ground water contamination. I propose that no onsite storage of hazardous fluids, new or used, should be allowed.

Regarding enforcement, if the County detects wind turbines out of compliance due to noise levels, location or hazards and the county issues a order to repair, modify, or cease desist, if that order is not complied with in a timely manner then the county shall retain the authority to shut-down and remove power or take the turbines offline.

<u>James Owen,</u> Executive Director, Renew Missouri, 409 Vandiver Dr, Ste 205, Columbia

Mr. Owen stated that Renew Missouri works frequently with industries working on renewable energy, including the wind industry. In the conversations I have had with individual companies and national and regional organizations representing the wind industry in this Country we have talked about this proposed set of regulations and while we are encouraged that Boone County is taking steps toward looking to offer guidelines on how this can be done we believe that these rules, as written, will not allow for any meaningful or significant wind farm opportunities for any industry anywhere. I think it is important to address that. My objectivity may be called into question, but it is important to look at how these ordinances are drafted and how they compare to other parts of the country and state where there is zoning.

Looking at the requirements for signatures and setbacks, it presents so many geographical challenges to it that you would never be able to find anyone or any project that would meet those elements. With the 1750 feet setback from public roads and other private property lines the reality is I am not sure there are very many places at all in Boone County where you could have more than one or two turbines in a specific location. If you look at what has been done in Kansas and Oklahoma, you will find that there are regulations that look at 1750 and 1000 feet. We are not asking for a free pass to let them put them where they want to, I think we should be mindful of the practicality of what the industry has to look at. I know there are a lot of residents who are concerned. If you look at Adair County it is a very similar setup, they have small towns around a larger town, and they have seen incredible benefits from wind. They've seen increases to their property tax base and farmers who benefit from the income from the leases. Wind technicians make an average of $65,000 per year. Those economic elements are enough to say that we should be looking at regulations that are going to allow for something to be put here.

I know there is a lot of concern and a lot of issues. Any time that you look at doing something different there is going to be concern from people. I think that the concerns are outweighed by the benefits. If these regulations were to be put in to place, we wouldn't see anything happen. I would encourage this Commission to look at what they have already put together and work with people in the industry and some of the organizations that have technical expertise in this. They have dealt with it in other counties and know what the problems and challenges and also know what the opportunities are.

Jay Hasheider, 1812 Cliff Drive, Columbia

Mr. Hasheider stated he is not financially involved in this debate but is an advocate for climate. Mr. Hasheider wants to keep the climate we have; wind energy is a renewable energy that would help reduce the amount of carbon produced. The regulations that are being proposed for wind development is an intimidating amount of rules, guidelines, and requirements that is essentially going to eliminate any development in this county. I can't image anyone going through all of that labor and expense just to apply. It is a waste of the Commission's time; you could have just said no wind development in Boone County from what I am seeing from the regulations. I can't believe there is such a daunting set of rules in any other place. If you look at some of the other developments for energy such as the Peabody coal mine, they came in and tore up the county. This seems like a targeted set of guidelines for one particular industry which is an industry that is beneficial for the good of all of us in the sense of producing energy without creating a climate problem. The interest of Boone County is not simply to not see windmills but there is an interest to provide benefits to all of the citizens. These interests include doing something in a positive way for the climate. Making a decision to clamp down with such severe regulations is not going to be something that would sit well with me going into the future as you hear more about climate problems. We need wind generation and solar panels, we need to reduce ourselves from fossil fuels, the landscapes you are trying to protect are not going to stay the way they are because climate is going to take care of them.

Chairperson Harris called Carolyn Chrisman attending by video. Ms. Chrisman did not answer.

Jenna Rose, attending by video, 2308 Berry View Ct, Columbia

Ms. Rose stated she has spent most of her career as an advocate and communicator for bio-based products and renewable energy. Ms. Rose stated she mostly works in biodiesel and has a deep appreciation for diversification of energy, especially renewable energy, we need an all of the above approach and that includes wind. We should not be looking for one single technology or fuel, we need them all and that makes our energy economy stronger. We shouldn't have ordinances that are too restrictive for an all of the above approach and we need to make sure we have reasonable ordinances that allow energy to be made locally and to benefit local farmers. Biodiesel is a good example of something that allows farmers to participate in the energy economy and that is better for all of us. This is the direction we need to be heading as a society and as a community. It feels like the tide is finally turning in a meaningful way in favor of renewable energy. With many companies and states taking bold action on carbon I see that we are on the edge of a decade that will bring irreversible change and we can be a part of that and have some say in how we contribute, or we can have it done for us and to us. I would rather see my community, which has always leaned green, be a part of the solution rather than resisting change and trying to keep the status quo. Wind is an area we need to go and work toward. I would like to urge the Commission to adopt reasonable ordinances that will allow energy to be made locally and benefit the local economy.

Chairperson Harris called Allison Kite, attending by video.

Allison Kite indicated she did not wish to add any comments.

Rex Smith, 12700 N Rte J, Harrisburg

Mr. Smith stated he lives in the area the wind farm was originally proposed. We do need renewable energy, but you don't want to put a nuclear reactor in New York City either. The population in Boone County has gotten to the point that this would really be burdensome to a lot of people. You can go one county north or west and find a lot of land that would be less impacted by a wind development than what you would see in Boone County. It doesn't have to be here. I don't want to step out and listen to the frogs at night and hear the windmill turning. There are better places to put it, there are a lot of acreages in a short distance that this could be placed.

No one else wished to speak.

Chairperson Harris stated the next public hearing would be on April 20, 2021 in the Harrisburg High School Gym at 6:30 PM. There will be no video or phone capability in Harrisburg, if you wish to speak you will have to do so in person or send written comments to WECOD@boonecountymo.org.

The work session adjourned at 7:22 PM.

Meeting notes prepared by Paula Evans, Administrative Coordinator, Boone County Resource Management

ATTACHMENT 2

Boone County Resource Management

ROGER B. WILSON GOVERNMENT CENTER
801 E. WALNUT ROOM 315 COLUMBIA, MO 65201-7730
(573) 886-4330 FAX (573) 886-4340

DIRECTOR, BILL FLOREA

PLANNING - INSPECTIONS - ENGINEERING

AGENDA – PUBLIC HEARING
PLANNING & ZONING COMMISSION
HARRISBURG HIGH SCHOOL GYMNASIUM
801 S Harris St, Harrisburg, MO

April 20, 2021 - 6:30 P.M.

The public hearing will be held in person only. Pre-registration is not required however, those pre-registered will be called upon first.

Public Hearing – Wind Farm Regulations; 6:30 PM

1. Call to Order
2. Roll Call
3. Opening Statement
4. Staff Presentation
5. Open for comments or questions from pre-registered speakers
6. Open for comments or questions from non-registered speakers - non-registered speakers must complete and submit a "Request to Speak" form
7. Close public hearing
8. Adjourn

Visit our website for more information: www.showmeboone.com/resource-management
Written comments may be submitted to: WECOD@boonecountymo.org

AFFIDAVIT OF NOTICE OF PUBLIC HEARING

STATE OF MISSOURI) ss
County of Boone)

I hereby swear that the affixed notice of public hearing was posted inside the city of Harrisburg, Missouri at H-Town Market located at 241 E. Sexton St, on the

23rd day of March, 2021

Paula Evans date 3/24/21
Paula Evans

Subscribed & sworn to before me this 24th day of March, 2021

Christina L Crane
Notary Public

Christina L Crane
Printed Name

CHRISTINA L. CRANE
Notary Public - Notary Seal
STATE OF MISSOURI
Boone County
My Commission Expires: May 21, 2021
Commission # 13705616

NOTICE OF PUBLIC HEARINGS

Notice is hereby given that the Boone County Planning and Zoning Commission will conduct Public Hearings on proposed Boone County Wind Farm Regulations on the following dates:

Thursday, April 8, 2021, 6:30 PM; Boone County Government Center, Commission Chambers, 801 E. Walnut St., Columbia, MO

Tuesday, April 20, 2021, 6:30 PM; Harrisburg High School Gymnasium, 801 S. Harris St., Harrisburg, MO

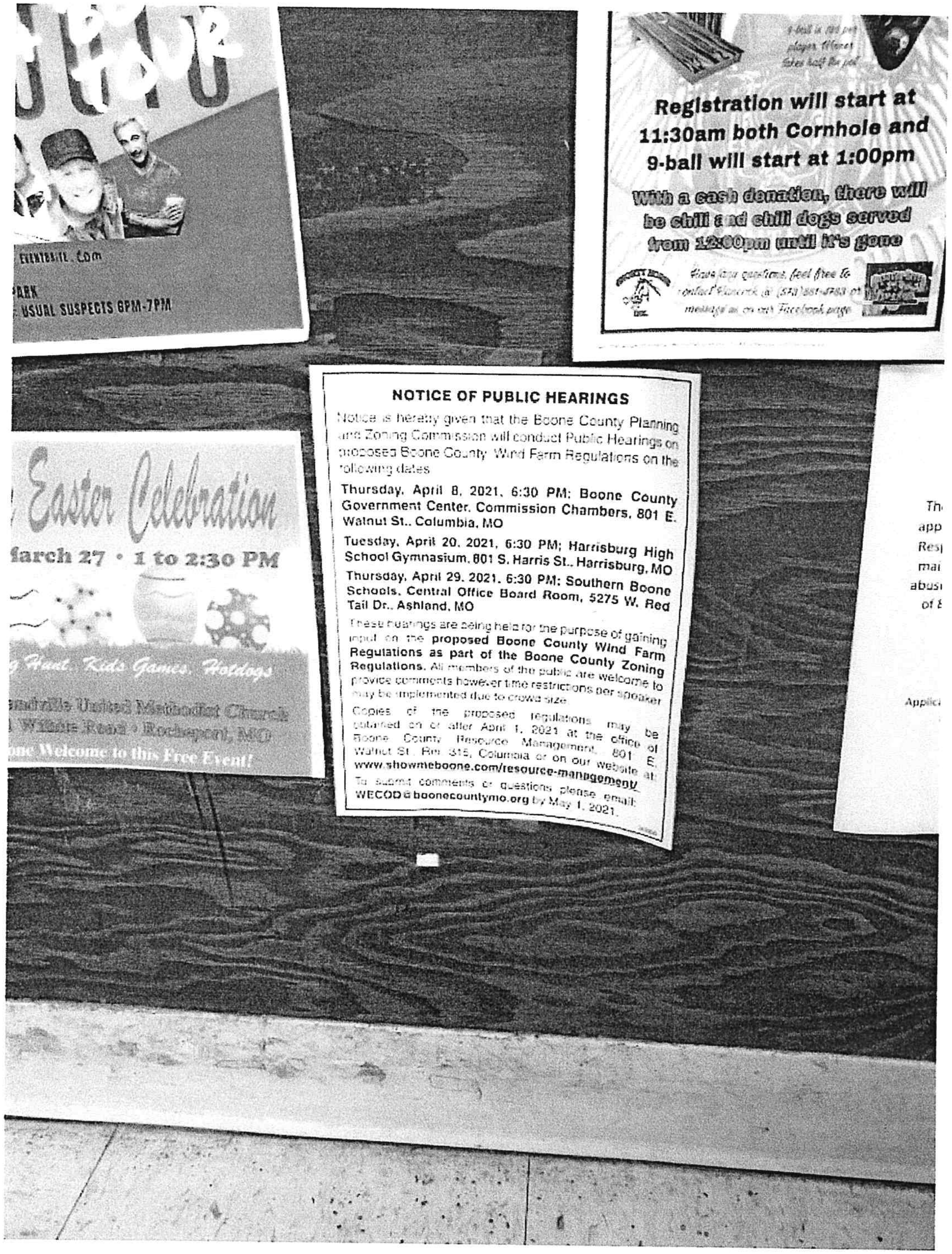
Thursday, April 29, 2021, 6:30 PM; Southern Boone Schools, Central Office Board Room, 5275 W. Red Tail Dr., Ashland, MO

These hearings are being held for the purpose of gaining input on the **proposed Boone County Wind Farm Regulations as part of the Boone County Zoning Regulations.** All members of the public are welcome to provide comments however time restrictions per speaker may be implemented due to crowd size.

Copies of the proposed regulations may be obtained on or after April 1, 2021 at the office of Boone County Resource Management, 801 E. Walnut St., Rm. 315, Columbia or on our website at: **www.showmeboone.com/resource-management/**

To submit comments or questions please email: **WECOD@boonecountymo.org** by May 1, 2021.

90868



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Registration will start at 11:30am both Cornhole and 9-ball will start at 1:00pm
With a cash donation, there will be chili and chili dogs served from 12:00pm until it's gone
Easter Celebration
March 27 • 1 to 2:30 PM
Hunt, Kids Games, Hotdogs
Welcome to this Free Event!
USUAL SUSPECTS 6PM-7PM

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P.O. Box 798 • Columbia, MO • 65205-0798

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STATEMENT OF ACCOUNT AGING OF PAST DUE AMOUNTS

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138.96	0.00	0.00	0.00		138.96

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*UNAPPLIED AMOUNTS ARE INCLUDED IN TOTAL AMOUNT DUE

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1476237	03/01/21 - 03/31/21	12525	12525	BC RESOURCE MANAGEMENT

AFFIDAVIT OF PUBLICATION

BC RESOURCE MANAGEMENT

I, Hayley Shipley, being duly sworn according to law, state that I am one of the publishers of the Columbia Daily Tribune, a daily newspaper of general circulation in the County of Boone, State of Missouri, where located; which newspaper has been admitted to the Post Office as periodical class matter in the City of Columbia, Missouri, the city of publication; which newspaper has been published regularly and consecutively for a period of three years and has a list of bona fide subscribers, voluntarily engaged as such, who have paid or agreed to pay a stated price for a subscription for a definite period of time, and that such newspaper has complied with the provisions of Section 493.050, Revised Statutes of Missouri 2000, and Section 59.310, Revised Statutes of Missouri 2000. The affixed notice appeared in said newspaper on the following consecutive issues:

*** SEE ATTACHED***

1st Insertion	03/24/21
2nd Insertion	
3rd Insertion	
4th Insertion	
5th Insertion	
6th Insertion	
7th Insertion	
8th Insertion	
9th Insertion	
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19th Insertion	
20th Insertion	
21st Insertion	
22nd Insertion	

$138.96

By Hayley Shipley

Subscribed and sworn to before me this 6th of April, 2021

Sandra L Rother

Notary Public

SANDRA L ROTHER
Notary Public - Notary Seal
STATE OF MISSOURI
Comm. Number 15638071
Boone County
My Commission Expires: Sep. 9, 2023

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To submit comments or questions please email: WECOD@boonecountymo.org by May 1, 2021.

BOONE COUNTY PLANNING & ZONING COMMISSION
WORK SESSION & WIND FARM REGULATIONS PUBLIC HEARING

HARRISBURG HIGH SCHOOL, GYMNASIUM
801 S. HARRIS ST., HARRISBURG, MISSOURI
(573) 886-4330

Minutes	**6:30 P.M.**	**Thursday, April 20, 2021**

Commissioners present: Boyd Harris, Eric Kurzejeski, Greg Martin, Steve Koirtyohann, Rhonda Proctor, Jeff McCann, Fred Furlong, Randal Trecha

Absent: Michael Poehlman, Bill Lloyd, Daniel Mings

Staff: Bill Florea, Thad Yonke, Uriah Mach, Cece Riley, Paula Evans

The second public hearing to receive comments and questions regarding the proposed Wind Farm regulations was called to order at 6:30 PM.

Chairperson Harris read the following statement:

Good evening and welcome to tonight's hearing regarding the proposed Boone County Wind Farm Regulations. An informational presentation will be given which will explain the proposed regulations. After the presentation, the Commission will call upon those who have pre-registered to speak, after those who have pre-registered have spoken, anyone present who wishes to make comments may do so. In the interest of time, responses to questions may not be given this evening. However, a record of all questions and comments will be kept and responses may be made directly to the individual, by posting on our website, or both. Forms have been made available for those who prefer to submit their questions in writing.

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This is the second of three public hearings to be held by the Planning and Zoning Commission. No decision will be made tonight. After the public hearings are completed, Resource Management will review and organize the comments and questions and forward them to the Planning and Zoning Commission. The Commission may make changes to the proposed regulations as a result of the comments received, or they may make a recommendation for approval or denial to the County Commission. The County Commission will hold another public hearing regarding the final draft. The County Commission may approve or deny the regulations, or they may refer them back to the Planning and Zoning Commission for further consideration.

The progress of the proposed regulations will be updated regularly on our website at:
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Staff gave a power point presentation which included a brief summary of the requirements for establishing a wind farm in Boone County. This power point is available on the previously mentioned website.

The floor was open for comments:

Tom Weislocher, 11581 N Trimble Rd, Harrisburg

I live on Trimble Road near Harrisburg, adjacent to land leased to a German wind company. The primary obligation of County officials is to protect the health, safety, and welfare of their citizens. A wind company's obligation is to earn a return on investment for their shareholders. Therefore, the burden should not be on the county to make it easy for them to develop here. The burden should be on the wind companies to show that the proposed benefits of their project outweigh its pitfalls and to assure that persons adversely affected will be compensated.

These modern wind turbines are amazingly huge machines, roughly comparable in height and width to the St. Louis Arch. They have no resemblance to the old farm windmills of centuries past and they dwarf the tiny wind turbine currently on the University of Missouri campus. Can you imagine a group of seventy St. Louis Arches surrounding your home, only 1750-feet away? The rotor diameter on just one of these wind turbines is equivalent to the combined total wingspan of three Boeing 707s sitting side by side. That's how big they are. So how close should we allow them to someone else's property? Looking at places with a longer history of wind development, France now requires setbacks of 5280 feet, just under a mile. Germany is also at 5280 feet. That means there are few, if any places left in Germany where they can continue to build. Is it any wonder that German companies are rushing to central Missouri where we don't yet mandate these safe setbacks so that they can hook into our transmission lines and sell the power to the highest bidder out of state? Manitoba, Canada requires 6500 feet setbacks, more than a mile. Riverside County, CA, one of the earliest adopters of wind power in the United States in the 1980's, now requires 10560-foot setbacks, almost two miles. And we are talking 1750 feet? That would make us sitting ducks for predatory wind development, and it doesn't seem right.

A peer reviewed paper published by the Department of Wind Energy at the Technical University of Denmark demonstrates ice throw range of 328 to 2300 feet normal conditions, and blade throw up to 1.2 miles during an overspeed event when the wind is blowing hard. That would indicate one and a quarter miles is the minimum setback for safety.

Boone County's current draft specifies that sound shall not exceed 65 decibels (dB). Yet the World Health Organization (WHO) says that outside noise levels of just 30-40 dB at night cause body movements, awakening, sleep disturbance, and arousal, with chronically ill and elderly populations affected to a greater degree. In 2018 the WHO updated their guidelines, now saying wind turbine noise levels shall be kept below 45 dB daytime, 40 dB evening, and 35 dB at night. So why are we looking at 65 dB for Boone County? That needs to be corrected. Even NextEra, a prominent wind company, has this to say on their website: "The Ontario Ministry of Environment's sound guidelines for rural areas establish maximum permissible sound levels at 40 dB, which is consistent with the standards set by the United States Environmental Protection Agency." If a wind company and the EPA can both agree on 40 dB maximum, Boone County should also adopt 40 dB maximum daytime, 35 dB at night.

What about infrasound generated by wind turbines? These very low frequency vibrations travel through the ground for miles and affect earthquake detection systems. The effects of infrasound on people have been studied and documented for decades, primarily by the US military. Infrasound can disorient the enemy, make them nauseous, cause spontaneous bowel movements, and incapacitate them for fighting. All without firing a shot or any visible appearances of aggression. It is the ultimate unseen and unheard weapon. It is definitely not what we want near our homes, schools, or livestock that many here derive a living from.

Separate independent studies at eight locations showed a 14-59% loss in value for properties located within two miles of wind turbines. Since developers insist that there is no risk to property values, the county should require them to put up a guarantee for that, as well as an enforcement escrow account to protect the county from being bullied by the deeper pockets of a wind company. Experience shows no one will be happy with wind turbines at 1750 feet away when they finally go online, and then it will be too late. Let's do the right thing now and put the setbacks at 1.25 miles with sound limits at 40dB daytime and 35 dB at night.

Susan Goodman, 11581 N Trimble Rd, Harrisburg

Susan Goodman asked for a show of hands of people who would consider moving if wind turbines are built near their homes. Approximately 15 people raised their hand.

That will affect the tax base. I have sent the P & Z Committee the information and links from my April 8th presentation. It includes property value guarantee agreements from expert witness real estate appraiser Michael McCann, NASA research starting in 1979, 21 peer reviewed turbine health hazard articles and an eight-page testimony from cardiologist Ben Johnson. Also, Madison County, Iowa Health Department files that led them to state that wind turbines are a health hazard and they call for one-mile setbacks. I also included an article on the military use of infrasound as a weapon which the turbines do create. I closed my statement with a fire chief's statement that burning debris has been thrown 4200 feet, it is imperative that we require the wind companies to provide liability insurance from construction through removal and I provided the name of an insurance company.

We have a list of wind turbine problems and I have copies. There were 31 when I printed that and now there are 35. The language of the proposed energy regulations interests me. In most places in regard to environmental protection, the word "should" is used rather than "must" or "required". Section C.29.7.1 Natural and Biological resources. To me that indicates preference and permission as in we would prefer it be done this way, but you can have permission to do it otherwise. That appears to give the wind company great latitude with our natural resources and what we have seen them do to the environment and other parts of Missouri and the world is not pretty. At the pony express lake conservation area, the conservation department asked them to build three miles from the natural area and they built right up next to it and now hunting there isn't good anymore. What enforcement do we have for these regulations? We have been told there is no budget for it. Wind turbine building continued in Oklahoma after they were served a legal cease and desist order. Are we leaving the wind companies to operate on the honor system? The list of lawsuits against all the wind companies, including the one planning to build here is long. The one that wants to build here has had trouble in Texas, Oregon, Indiana and Illinois. They have not repaired the roads like they said they were going to. In Texas there were 23 residents who had leases and were getting the money and the tax breaks on their own land and sued this wind company and said they misrepresented themselves; that turbines do create noise, reduce property values, destroys the countryside, creates pulsations that negatively affect residents health and interfere with internet, TV, and satellite. A County Commissioner said he no longer enjoys sitting outside his home because of the noise. A local justice of the peace said he can't keep his windows open because of the noise and it interferes with his sleep. Some people were forced to abandon their homes, it was intolerable.

I read a wind company article that the new technology has corrected the sound and harmonic problems with wind turbines but my research turned up no information at all as to the accuracy of that statement. If anyone can give me any documentation that is known to show proof of that please do so. So much more could be said, we are in contact with farmers and families in Dekalb and Schuyler Counties who are being hurt by turbines now.

Susan Goodman gave examples of families in Kirksville with health problems.

Greg Toul, 9515 N Rte. E, Harrisburg

I wanted to thank the Planning and Zoning Commission of doing a great job and trying to protect us. This is a huge undertaking for them with the impact it has on the nature, wildlife, and the people of the area. The regulations say there needs to be an overlay district plan drawn to scale during the application process. One of my concerns on this is it says the approximate proposed grading and removal of natural vegetation. Is there an allowable acreage that is going to be destroyed? How much of this land is going to be stripped and be replaced with windmills?

The section about environmental assessment that needs to be done during the application process. After reading through this I wondered why this is not done prior to even considering a windmill coming to the area because of the impact it already has? We know they have impacts on a lot of things and I don't know who is going to be accountable for all of these studies and what the rules are going to be for them to adhere to. How soon will their application be kicked out if they don't meet the guidelines from the studies?

One of the sections in the assessment was also about the risk of fire. I wondered if the county has gone to the fire protection district and talked about the training that we will have to have to take care of us if we have the windmills here with the dangers they present? I came here because I am concerned like a lot of people are and I want to tell the county that they have done a great job with these regulations but I think they have a huge opportunity to show the citizens of Boone County and this community that they care and put an end to this and say no, we will not have them here.

Carolyn Crisman, 315 S Franklin St, Kirksville

I am from Kirksville; I am an economic developer in Adair County. We are currently home to the state's largest windfarm, 400 megawatts, 175 turbines spanning two counties. I was asked to come here to share some of the good things that have come about from that project. Some of the short-term benefits were that we were told 350 to 450 construction workers were going to come to our area during the 18-month build process and that came true. It was really important because ten of those months was during the Covid shutdown. Those construction workers kept our hotels full; restaurants being eaten at and gas stations used; our taxes did not see a dip because of Covid. When you are in a rural community of 26,000 in our county that means a lot. I am excited about some of the long-term benefits, the project just went online at the end of December, one of those long-term benefits is job creation. 25 wind technician jobs have been created in our area and 90% of those have gone to local people in Adair, Schuyler, and Scotland Counties. 75% of the jobs went to veterans. It is exciting when local kids have gotten to come back to our community.

Carolyn Crisman gave examples the local residents who took the technician jobs.

$3.2 million is being made per year by the landowners, 70% of them are local and I have seen renovations take place in old farmhouses, new vehicles are being purchased, and farmers are deciding to retire because they have another source of income and they have been able to turn the farm over to the next generation. Also, one of the benefits we are seeing are the taxes being paid to our taxing districts, over $2 million is going to be coming into the taxing districts, most of which will go to the local school. Schuyler County's population has been declining year after year and so has the school population. In 2019 when the school was discussing how much money they were going to see from the project the Superintendent stated that eight teachers will not lose their jobs now because this project is coming. In Schuyler County that school is the lifeblood of that community as well as the county's largest employer. So, eight teachers saved their jobs instantly. One of the things we are hoping to see is because these turbines are connected by fiber, we are hoping the internet providers are able to hook up to some of that fiber and provide broadband to the area because we have some connectivity issues there as well. I won't tell you that it is all roses, the roads are bad and they didn't finish building out the wind farm until the end of 2020 and we had a terrible winter so MoDot hasn't been able to fix the roads but they said May 1st is when they are going to start that so we anticipate the roads getting better. Some people don't like the aesthetics, they don't think the turbines look pretty. Beauty is in the eye of the beholder. I live in the city limits of Kirksville and I have a water tower out my window and it is ugly, but I like water.

Robert Dochler, 11600 N Rte E, Harrisburg

I watched the April 8th meeting and there were three people that commented on the regulations stating that they were too restrictive. I read the regulations and I disagree. One of the people, Mr. Owens, asked you to compare these regulations with those in other parts of the country and the state and included Adair County as one of those places to compare too. I thought this was an odd comparison, so I did my own research using the website and census data. In 2019, data shows that Boone County population was 180,000 with a density of 240 people per square mile. Adair County had a population of only 25,000 with a density of four people per square mile. I looked up the populations for Atchison, Gentry, Nodaway, Schuyler and Worth County, all of which have windfarms, and the combined total populations of those six counties equal just under 66,000 people and an average density of 20 people per square mile. Clearly this is not an apples to apples comparison and should not be treated as one. Five out of the six counties have experienced negative growth rates and, in my opinion, the growth rates do not reflect booming prosperity. Mr. Owens said the setbacks and signatures for the WECOD present geographical challenges and make it impossible for any project to meet the elements. In my opinion, your job as the Commissioners is to consider the interests and wellbeing of the residents of Boone County and not to produce regulations to meet the needs of an industry wanting to exploit our resources. I believe the regulations for the WECOD and CUP demonstrate that the Commission did their homework and listened to the concerns of the Boone County residents and took into consideration mistakes made in other communities. You've drafted regulations that attempt to mitigate those concerns while maintaining a level of reasonableness which is important. I agree with everything that Mr. Weislocher. Dr. Goodman, and Mr. Toul said in their presentations. I believe the proposed WECOD brings fairness to this process and allows the people who are closest to, and most effected by the proposed turbine sites to have an equal voice in this matter.

Section 29.5.1.5 requires a narrative explaining why the proposed project sites were chosen over alternative locations. I think this is very good for transparency purposes. I would like to know why the densely populated rolling hills of Harrisburg and the surrounding area were chosen over flat areas east of highway 63 between Hallsville and Sturgeon that are more consistent with the topography of other wind projects in the state.

Section 29.7.2.6 talks about the burying of power lines. The word "shall" is used which I agree with. However, it is followed by four potential outs for the company to use to get out of burying the lines. The one potential out that I have problems with deals with the one on economic infeasibility. I request that this one and the one that follows it be removed. I don't think it is the Commission's responsibility to allow them an exception based on a lack of economic feasibility to the company. We already have to deal with the unsightly turbines and if it is infeasible for them then maybe they should consider this not a feasible site for the project.

In the section regarding noise management, everything talks about decibel levels and what is allowed. I would like to consider for the people that do have to live in close proximity it seems like the majority of complaints regarding sound aren't so much about the noise level but the consistency and the inability to get away from it. I wonder if we could consider an option where those people that are in a certain designated area that have any level of constant noise be allowed some type of relief where the power generation of the turbines are shut down for a designated amount of time on schedule to give them some relief from the constant noise.

Brent Voorheis, 10877 N Rte. J, Harrisburg

I have lived in Boone County and on the family farm for over 68 years. I graduated from Harrisburg School and I served 24 years on the School Board, I was Board President when we started building the new high school campus. School funding was and is a challenge. We were the first to sign the lease with the wind development company. After being contacted by the wind development company it took my wife and I six months of research before we signed the lease agreement. We talked with farmers, landowners, and residents of Nolan County, Texas where there is another wind farm. We visited with Ken Becker, the economic director of Sweetwater, Texas, and we stood under wind turbines in operation. We didn't sign the lease blindly and we thought it would be good for the school's tax base, good for the planet and I won't deny that we will receive some financial value. Our grandson attends Blackwell School District in Texas, south of Sweetwater. The school board has set up advanced education funding. For each year he attends, Blackwell School District places $3000 in an account. When he graduates, he will receive $39,000 toward his education. That money is from the wind farm taxes.

Did Boone County Resource Management or the Planning and Zoning Commission have any correspondence with the wind development company? Have you seen the sample lease agreement? Did you ask for one? The reason I ask these questions is that reading some of the proposed regulations it seems to me that Boone County is trying to reinvent the wheel. Did you know that our lease already has a decommissioning bond built in? Did you know that the wind farm development company, through an independent firm, has been conducting an ongoing bat study? That guy comes in about once a month from Kansas City to take readings and those readings are coming off the met tower. Did you know that the wind farm development company, through an independent company, has been conducting an ongoing eagle study? Did you know that these and other studies are required by the Federal government? I do know, in addressing Mr. Weislocher's question, that the wind company is in negotiations with Columbia and MU to sell electricity at some point in time.

Again, we didn't go into this agreement lightly and we thought it would be beneficial for our community. I have lived here 68 years and I am not planning on moving off the family farm.

Terrie Nagel, 5501 W Tracy Ct, Columbia

I have lived on Tracy Court for 30 years.

Ms. Nagel read the following statement:

Regarding Section 29.5.1.3:

The petition should make it very clear what the property owners are signing. Should a *minimum* number of signatures be required, when a single property owner owns sufficient acreage to make up one or more primary districts?

Those signing the petition should also acknowledge in writing that they have read the adverse conditions documents described in section 29.5.1.10 and that they are aware of the length of the leases (30 years): FULL DISCLOSURE. Property owners in the proposed overlay district and surrounding area (including Boone and contiguous counties) have the right to the same information.

Regarding Section 29.5.1.9:
The number of construction jobs and estimated construction payroll sentence should be edited to indicate subtotals for Boone County jobs and estimated payroll will be provided, in addition to non-Boone county construction jobs and estimated payroll.

The number of permanent jobs and estimated continuing payroll sentence should be edited to indicate subtotals for Boone County permanent jobs and estimated payroll will be provided, in addition to non-Boone county permanent jobs and estimated payroll.

Other projected economic benefits and costs of the project; in other areas where wind energy has been added, consumer electric bills have increased significantly, as much as 30 percent. Boone County should have the right to negotiate a fair value for the purchase of the wind energy, such that it does not raise rates significantly to consumers, including residents and businesses.

Regarding Section 29.5.1.10: an environmental assessment

This environmental assessment should include potential adverse impacts on the community, individuals and local populations including children and senior citizens, displaced ground animals, and livestock. Again, these potential adverse impact documents should be shared with all those potentially affected by the overlay district.

For example,
An assessment that identifies the anticipated hours per year of shadow flicker expected to be perceived at each residence, educational facility, workplace, health care setting, outdoor or indoor public gathering area, other occupied building and roadway within a minimum of one mile of any turbine;

A plan for fire protection for the proposed facility that is prepared by or in consultation with a fire safety expert; and an assessment of the risks that determines whether the proposed facility will interfere with the weather radars used for severe storm warning or any local weather radars.

Location of all sensitive receptors, including schools, day care centers, healthcare facilities, residences, residential neighborhoods, places of worship and elderly care facilities.

Regarding section 29.8.3.3 Distinct groupings or clusters of machines shall be limited to no more than 12 machines per cluster. Each cluster must be greater than 1.25 times the minimum spacing distance from another cluster.
If we are still talking about turbines, use the word "turbines" instead of "machines." The second sentence may be missing words. Should it be "Each cluster must be **located more** than 1.25 times the minimum spacing distance from another cluster?

Section 29.8.3.6 inoperable turbines. What are the consequences if they aren't repaired within 90 days? Is it considered abandoned and subject to reclamation?

Section 29.8.5 Safety: The setback number of 1,750 feet is inadequate, given the adverse health and safety issues that wind turbines entail.

Lawmakers in Kansas have proposed the Wind Generation Permit and Property Protection Act that would require turbines be placed 1 mile from any property line of nonparticipating real property, 1.5 miles from a residence and 3 miles from an airport, federal wildlife refuge, public park, or hunting area. Any industrial wind turbine that is installed may not generate noise levels that exceed 40 decibels. Only one turbine would be allowed per square mile, in addition to other restrictions on sound and light emitted. Any industrial wind turbine that is installed may not generate noise levels that exceed 40 decibels. I propose similar setbacks, decibel levels, and a maximum of one turbine per square mile in the proposed overlay districts, in these Boone county regulations.

Wind energy is neither clean nor reliable and will desecrate our Boone county landscape, causing health and noise issues.

Ms. Nagel ran out of time to finish her testimony. She submitted her written statement for the record which included the following:

Wind energy is neither clean nor reliable and will desecrate our Boone county landscape, causing health and noise issues, killing our bald eagles, bats and birds, and running off our wildlife. Turbine construction, installation and maintenance all depend heavily on fossil fuels. Wind energy is intermittent and inefficient. There's no adequate storage technology for the electricity produced. Natural gas is used as a backup when there isn't enough wind, which will create more stress on the grid in Boone County, causing potential rolling blackouts like those in Kansas and Texas. Take away the tax subsidies and wind turbine production will halt, since wind energy is not sustainable. We can do better than this.

Stephen Nagel, 11295 N Rte E, Harrisburg

I moved here in 2015 and I own property on Route E just south of highway 124. I grew up in Middletown, Missouri on a cattle ranch and joined the Navy and moved back home. I had no intention of getting involved in this but after doing some research it became a little daunting. Boone County has 442,000 acres and 180,000 people, that is 2.45 acres per person. Howard County has 301,000 acres and 9700 people, that is 31 acres per person. To give you a perspective to think about, this is a very populated county even in Harrisburg. Driving in this evening most houses along the road have five to ten acres and it is very populated, it is not a 9000-person county. I don't think the 1750-foot setback is far enough, that is only 583 yards, people hunt at that range. A wind turbine with blades is about 500-foot tall, if it falls that leaves 1200-feet. Wind turbine blades are 100-180 feet long, they spin at 200 mph at the tip, if anything comes off or fails I've heard other people talk about how far that goes, I didn't read the data but simple logic tells you that will fly quite a way. In researching the infra-noise there are as many articles that say it is no problem as there are that say there is a problem but I do know that the US Military uses it to disburse crowds and that is probably what ran the American diplomats out of Cuba a few months ago, which was 20Hz. It caused the same symptoms on them as it does with people that live close to the farms. Aeroacoustics noise and flicker all add to your inability to enjoy your property and it is like working a job at a factory where you have a lot of noise and commotion and you go home to a quiet place but when you have a wind farm next to you there is no quiet place; it is 24/7 infra-noise, the aeroacoustics and flicker.

There is an article called "High-voltage Transmission Lines and Rural Western Real Estate Values, published in Appraisal Journal by James Chalmers. He is qualified as an expert witness in over 20 states and he found that residential properties near transmission lines sold for 20-50% less than comparable properties. Michael McCann of McCann Appraisal based in Chicago indicated that residential property values are adversely and measurably impacted by close proximity of industrial scale wind energy turbine projects to the residential properties up to two miles in a range of 25% up to 40% loss of value. That is a concern, I am not planning on selling my house and moving but I don't feel like it is fair that I should have to pay with my property value for another person to gain on their own property. We aren't powering the City of Columbia or the City of Harrisburg with this, the energy is being sold out of state and I don't think it is a fair trade.

Keller Colley, 14631 N Hwy NN, Harrisburg

Mr. Voorheis brought up some good points, he has been an integral part of this community and we appreciate him. My main concern with this wind energy project is the loss of the value of my home; I have a brand-new house and I would hate to see it depleted. I can look around and see at least two other people in this room that have just built brand new houses as well. We just dumped a bunch of money into something that would be an awful thing to lose. I would like to thank the Commission and everyone who has come up with these regulations. As a safety professional myself, these are basic guidelines, I don't see the wind developers going above and beyond and take care of you, they are in it for monetary value. They are not looking out for the citizens. I wish there was an easy way to make this work together, but I don't see it.

Emily Furlong, 4401 W Voorheis Rd, Sturgeon

I appreciate some of the things Mr. Voorheis said about trying to improve the community. I am not from Harrisburg, I moved here in 2014 from a very suburban community and I love being here, I love the peace and quiet and being able to walk outside and not see anyone. Those are some of the reasons I love living here and one of the reasons I don't want to leave this community. I feel like that would be greatly disturbed and disrupted if my neighbor decided to put up a turbine. I would hate to have our peace and quiet and our home devalued and disturbed in that manner. We have heard a lot of talk about this being beneficial to farmers. While this area has large tracts of land many people have moved to this area from the suburban areas like Columbia so they could have their piece of the pie, that piece of pie may only be five or ten acres for some people and it is sad to think about the fact that those people that have moved here to enjoy the same lifestyle and same quiet that we enjoy, would have that disrupted by the unsightliness of a wind turbine. This dream for many is built on the expectation of avoiding intrusive and obtrusive industrial objects in their community, this is not a primary farming community from what I am able to see so I fail to see the benefit to the majority of our community but more of a benefit to the minority.

We have also heard that this is great for the environment. I encourage the Commission to educate themselves about what happens to these structures once they are disassembled. This discarded material is not recycled or disintegrated in a landfill, it is just piled up and buried underground. This is not something that I would like to see in Boone County when these structures are disassembled and discarded. Many people have talked about the population, these communities in northern Missouri that have these turbines are not comparing apples to apples when you look at Boone County and Atchison and Scotland County. When this was first brought up, former Commissioner Fred Parry was on the radio discussing it and at that time there was concert venue that they were trying to put in south of Columbia and his comment was that it is not allowed, the County Commission did not allow this concert venue to go in south of Columbia because the people that live there have an expectation of quiet, peace and privacy. I would second that. We also have that expectation where we live and not be disrupted and have our peace of the pie ruined by the unsightliness of a turbine in our backyard. We are not talking about a concert venue, but we are talking about infra-sound.

<u>Steve Proctor</u>, 7001 Stidham Rd, Harrisburg

I drove up to Iowa a couple of weeks ago and drove through Schuyler County. It is not something I want to wake up and look at every morning. People don't even like to see power poles; everyone prefers their power lines be buried. I don't know how much taller a wind turbine is, but it is something I don't want to see. I work with the county all of the time and I don't agree with some of their regulations, but I abide by them because they are looking at the best interest of the county. I would never consider leaving Harrisburg, but I am not saying I wouldn't if the wind turbines show up. The revenue that we get from the wind turbines, if the value of property goes down it is just like other things it will be a replacement. There are many more cons than pro with wind turbines in my opinion.

I would like to see wind turbines stay strictly to A-1 zoning districts. It would be more suitable north of Hallsville, Sturgeon and Centralia. Like traveling through Texas you may see a house every three or four miles, it's the same way in Illinois, they are way off the road and as many as they have in the distance it is not something I want to see.

<u>Robert Hall</u>, 730 County Rd 104E, Harrisburg

I live in Howard County, but I have a Harrisburg address. We have been appalled by the wind turbine project ever since it first came up. I am opposed to it, I think the Boone County plan is very intriguing and I see that there is one element that I don't find in it, typically in a situation like this where you have a utility, there would be a requirement for easements that all the property owners would have to sign that would run with the land. Property is bought and sold all the time, and this puts a burden on the land.

No one else wished to speak.

Chairperson Harris stated the next public hearing would be on April 29, 2021 at the Southern Boone County Schools Central Board Office, 5275 W Red Tail Drive, Ashland at 6:30 PM.

The work session adjourned at 7:48 PM.

Meeting notes prepared by Paula Evans, Administrative Coordinator, Boone County Resource Management

ATTACHMENT 3

Boone County Resource Management

ROGER B. WILSON GOVERNMENT CENTER
801 E. WALNUT ROOM 315 COLUMBIA, MO 65201-7730
(573) 886-4330 FAX (573) 886-4340

DIRECTOR, BILL FLOREA

PLANNING - INSPECTIONS - ENGINEERING

AGENDA – PUBLIC HEARING
PLANNING & ZONING COMMISSION
SOUTHERN BOONE COUNTY SCHOOLS, CENTRAL BOARD OFFICE
5275 W. Red Tail Drive, Ashland

April 29, 2021 - 6:30 P.M.

The public hearing will be held in person and by video. Pre-registration is required to speak by video, those speaking in person are encouraged to pre-register. Those attending by video who have not pre-registered will not be called upon to speak.

Public Hearing – Wind Farm Regulations; 6:30 PM

1. Call to Order
2. Opening Statement
3. Staff Presentation
4. Open for comments or questions from pre-registered speakers
5. Open for comments or questions from in-person, non-registered speakers - non-registered speakers must complete and submit a "Request to Speak" form
6. Close public hearing
7. Adjourn

Visit our website for more information: www.showmeboone.com/resource-management
Written comments may be submitted to: WECOD@boonecountymo.org

COLUMBIA DAILY TRIBUNE
P.O. Box 798 • Columbia, MO • 65205-0798

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INVOICE and STATEMENT

BILLING PERIOD	ADVERTISER/CLIENT NAME		
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138.96		NET DUE 28 DAYS	
CURRENT NET AMOUNT DUE	30 DAYS	60 DAYS	OVER 90 DAYS
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INVOICE NUMBER	PAGE #	BILLING DATE	BILLED ACCOUNT NUMBER	PARENT ACCOUNT NUMBER
1476237	1	03/31/2021	12525	12525

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			BALANCE FORWARD				156.61
03/22	ACH		PAYMENT				(156.61)
03/24	90868	CDT	WIND FARM HEARING	2 X 4.50	1	15.44	138.96

CONTRACT NAME:	EXPIRES	COMMITMENT	PERIOD	TO DATE	TO FULFILL
Net Dollar Volume	04/29/2021	24000.00	2887.99	36021.80	-12021.80

STATEMENT OF ACCOUNT AGING OF PAST DUE AMOUNTS

CURRENT NET AMOUNT DUE	30 DAYS	60 DAYS	OVER 90 DAYS	*UNAPPLIED AMOUNT	TOTAL AMOUNT DUE
138.96	0.00	0.00	0.00		138.96

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*UNAPPLIED AMOUNTS ARE INCLUDED IN TOTAL AMOUNT DUE

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	BILLING PERIOD	BILLED ACCOUNT NUMBER	PARENT ACCOUNT NUMBER	ADVERTISER / CLIENT NAME
1476237	03/01/21 - 03/31/21	12525	12525	BC RESOURCE MANAGEMENT

AFFIDAVIT OF PUBLICATION

BC RESOURCE MANAGEMENT

I, Hayley Shipley, being duly sworn according to law, state that I am one of the publishers of the Columbia Daily Tribune, a daily newspaper of general circulation in the County of Boone, State of Missouri, where located; which newspaper has been admitted to the Post Office as periodical class matter in the City of Columbia, Missouri, the city of publication; which newspaper has been published regularly and consecutively for a period of three years and has a list of bona fide subscribers, voluntarily engaged as such, who have paid or agreed to pay a stated price for a subscription for a definite period of time, and that such newspaper has complied with the provisions of Section 493.050, Revised Statutes of Missouri 2000, and Section 59.310, Revised Statutes of Missouri 2000. The affixed notice appeared in said newspaper on the following consecutive issues:

*** SEE ATTACHED***

1st Insertion	03/24/21
2nd Insertion	
3rd Insertion	
4th Insertion	
5th Insertion	
6th Insertion	
7th Insertion	
8th Insertion	
9th Insertion	
10th Insertion	
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18th Insertion	
19th Insertion	
20th Insertion	
21st Insertion	
22nd Insertion	

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By Hayley Shipley

Subscribed and sworn to before me this 6th of April, 2021

Sandra L Rother

Notary Public

SANDRA L ROTHER
Notary Public - Notary Seal
STATE OF MISSOURI
Comm. Number 15638071
Boone County
My Commission Expires: Sep. 9, 2023

NOTICE OF PUBLIC HEARINGS

Notice is hereby given that the Boone County Planning and Zoning Commission will conduct Public Hearings on proposed Boone County Wind Farm Regulations on the following dates:

Thursday, April 8, 2021, 6:30 PM; Boone County Government Center, Commission Chambers, 801 E. Walnut St., Columbia, MO

Tuesday, April 20, 2021, 6:30 PM; Harrisburg High School Gymnasium, 801 S. Harris St., Harrisburg, MO

Thursday, April 29, 2021, 6:30 PM; Southern Boone Schools, Central Office Board Room, 5275 W. Red Tail Dr., Ashland, MO

These hearings are being held for the purpose of gaining input on the proposed Boone County Wind Farm Regulations as part of the Boone County Zoning Regulations. All members of the public are welcome to provide comments however time restrictions per speaker may be implemented due to crowd size.

Copies of the proposed regulations may be obtained on or after April 1, 2021 at the office of Boone County Resource Management, 801 E. Walnut St., Rm. 315, Columbia or on our website at: www.showmeboone.com/resource-management/

To submit comments or questions please email: WECOD@boonecountymo.org by May 1, 2021.

AFFIDAVIT OF NOTICE OF PUBLIC HEARING

STATE OF MISSOURI) ss
County of Boone)

I hereby swear that the affixed notice of public hearing was posted at the Ashland City Hall, 109 W. Broadway, Ashland, Missouri on the

23rd day of March, 2021

date 3-23-21
Darin Ratermann

Subscribed & sworn to before me this 23rd day of March, 2021

Notary Public

Paula L. Evans
Printed Name

PAULA L. EVANS
Notary Public - Notary Seal
STATE OF MISSOURI
Boone County
My Commission Expires: Mar. 4, 2022
Commission # 14398153

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Thursday, April 29, 2021, 6:30 PM; Southern Boone Schools, Central Office Board Room, 5275 W. Red Tail Dr., Ashland, MO

These hearings are being held for the purpose of gaining input on the **proposed Boone County Wind Farm Regulations as part of the Boone County Zoning Regulations.** All members of the public are welcome to provide comments however time restrictions per speaker may be implemented due to crowd size.

Copies of the proposed regulations may be obtained on or after April 1, 2021 at the office of Boone County Resource Management, 801 E. Walnut St., Rm. 315, Columbia or on our website at: **www.showmeboone.com/resource-management/**

To submit comments or questions please email: **WECOD@boonecountymo.org** by May 1, 2021.

90868

BOONE COUNTY PLANNING & ZONING COMMISSION
WIND FARM REGULATIONS PUBLIC HEARING
SOUTHERN BOONE COUNTY SCHOOLS, CENTRAL BOARD OFFICE
5275 W. REDTAIL DRIVE, ASHLAND, MISSOURI
(573) 886-4330

Minutes	6:30 P.M.	Thursday, April 29, 2021

Commissioners present: Rhonda Proctor, Bill Lloyd

Attending by video: Jeff McCann

Absent: Boyd Harris, Eric Kurzejeski, Greg Martin, Steve Koirtyohann Michael Poehlman, Fred Furlong, Daniel Mings, Randal Trecha

Staff: Bill Florea, Thad Yonke, Uriah Mach, Cece Riley, Paula Evans

The third public hearing to receive comments and questions regarding the proposed Wind Farm regulations was called to order at 6:30 PM.

Commissioner Proctor read the following statement:

Good evening and welcome to tonight's hearing regarding the proposed Boone County Wind Farm Regulations. An informational presentation will be given which will explain elements of the proposed regulations. After the presentation, the Commission will call upon those who have pre-registered to speak, after those who have pre-registered have spoken, anyone present who wishes to make comments may do so. In the interest of time, responses to questions may not be given this evening. However, a record of all questions and comments will be kept and responses may be made directly to the individual, by posting on our website, or both. Forms have been made available for those who prefer to submit their questions in writing.

If you choose to provide testimony this evening and have not pre-registered, please complete the "Request to Speak" form and place in the box on the table. Please be concise and we ask that you not be repetitious with your remarks, we also ask that you restrict your comments to the proposed regulations. We recognize that this issue can be quite emotional, in that regard we ask that you refrain from applause, cheers or other signs of support or displeasure. Please be considerate of everyone here.

In order to give everyone an opportunity, speakers will be limited to five minutes each. Time limits may be changed depending on how the hearing progresses. If you feel that your allotted time is not enough, you are welcome to submit your additional comments in writing. Comments and questions can be submitted in writing and by email until April 30, 2021, to: WECOD@boonecountymo.org.

This is the last of three public hearings to be held by the Planning and Zoning Commission. No decision will be made tonight. After the public hearings are completed, Resource Management will review and organize the comments and questions and forward them to the Planning and Zoning Commission. The Commission may make changes to the proposed regulations as a result of the comments received, or they may make a recommendation for approval or denial to the County Commission. The County Commission will hold another public hearing regarding the final draft. The County Commission may approve or deny the regulations, or they may refer them back to the Planning and Zoning Commission for further consideration.

The progress of the proposed regulations will be updated regularly on our website at:
www.showmeboone.com/resource-management/WECOD

Director, Bill Florea gave a power point presentation which included a brief summary of the requirements for establishing a wind farm in Boone County. This power point is available on the previously mentioned website.

The floor was open for comments:

Speaking by video:

Hilary Clark, 1501 M St NW, Ste 900, Washington, DC

Hilary Clark: I am the Social License Director at American Clean Power Association. We represent a broad range of businesses into energy, including wind energy. Wind energy development provides a significant economical benefit to Missouri and to the community. In 2020 clean energy provided an estimated $8.2 million in property taxes. The restrictive nature to the proposed update to the wind energy conversion overlay district will create business uncertainty placing development opportunities in jeopardy for Boone County farmers and small businesses. We sent a letter to the Planning and Zoning Commission on April 28, 2021. Wind energy developers have good success in being responsible to community members and business partners throughout the United States. Our members recognize the importance of engaging with the host community to site and safely operate their projects. There is currently no evidence to support any additional public safety benefit from longer setbacks. Longer setback requirements, like the 1750' proposed, would impede wind energy development and unnecessarily restrict landowners who wish to install wind turbines on their property. The setback equal to or slightly greater than the tower height is sufficient to protect public health and safety from the rare event of equipment failures. Wind companies manage risks through detailed study and analysis, careful engineering and cautious standard operating procedures. To date, there has not been one report of injury to a member of the public from a wind turbine failure. Most jurisdictions across the US have a setback requirement of 1.1 to 1.5 times the total turbine height from a non-participating property owner's property line and also from public right of ways.

With regard to regulations and sound limits there is some ambiguity. It appears the intent is to establish a limit at the property line and that limit is reduced if a (inaudible) is present, however c-weighted criteria is introduced which is substantially less than the a-weighted level. A wind turbine study concluded that there was no additional gain by analyzing the data using c-weighted levels. The proposed regulations impose a maximum turbine height restriction of 400-feet, however since 2012 the median turbine height has been 420-feet. As of 2019 utility scale wind turbines were closer to 499-feet with many commercial wind turbines reaching 695-feet by this year. Taller wind turbines are more efficient making it possible to cost effectively capture the stronger wind resources at higher levels, therefore fewer turbines are needed on the landscape. As technology advances and the industry innovation grows it is important that regulatory frameworks allow for flexibility and height. A maximum height restriction of 400 feet is not consistent with current industry growth and would restrict wind development in the county. We urge the Commission to work with the wind industry to understand the types of requirements that allow development to move forward while still protecting the interests of the community.

Carolyn Amparan, 4804 Shale Oaks Ave, Columbia

Carolyn Amparan: The input I am providing is on behalf of the Osage Group Executive Committee. I have submitted a more detailed version of our remarks and input to the WECOD address. The Sierra Club recognizes that all forms of power generation entail environmental tradeoffs and that there are drawbacks to wind development. The most contentious issues include visual and wildlife impacts. Still the Sierra Club believes that in most instances many of the negative impacts of wind can be managed and we believe that with adequate site planning the benefits of wind power, in reducing the threat of global warming and pollution will substantially outweigh those negative impacts. However, we feel that the proposed regulations are too limiting and are likely to restrict wind development in viable areas of Boone County.

To summarize a few specific inputs regarding the permit process we feel that the property owners should not be the only ones who can instigate the initiative of the overlay district, we feel the wind energy companies should be able to do this on behalf of the owners with their permission; this would be a cost burden for individual land owners. Additionally we feel like with the application process it would be more cost effective if the applications were allowed to include more than 2 to 6 wind turbines at a time and that would be able to give everyone a bigger view of the scope of the project. Regarding the primary district and buffer area requirements, we would like to see the primary district be less than 640 acres and not require four contiguous quarter-sections, we feel like this is potentially unequitable to smaller landowners and we would like the buffer requirements to be based more on the presence of building structures or public roads and associated to the height of the towers.

Regarding property values, most of the regulations that we were able to reference in other states don't include any such regulation on property values. Although we feel that basing the analysis of property values are statistically valid, comparable studies is reasonable, we really couldn't find much research that offered this kind of information. In our detailed input we do include two studies that we found that might offer some information on this, but it seems that this is going to be something that would be difficult to comply with. Under natural and biological resources, the Sierra Club supports the projection and preservation of natural and biological resources as identified in Section 29.7.1. We would like to add the request that developers should carefully record the methodology used for wildlife studies so that procedures resulting in problems sites can be accurately identified and modified in the future. Regarding visual uniformity and impact, we too feel that the regulations should allow for turbines of taller height than what is specified given that technology has already changed, and the median height of turbines is already higher.

Regarding setbacks we would suggest a setback based on turbine height. We have provided a sample ordinance from the state of Pennsylvania that bases the setbacks on the turbine height at 1.5 to 5 times the turbine, or hub height depending on if it is an occupied building on the landowners property or the neighbor's property, whether it is a property line or a public road. We encourage the Boone County Commissioners to realize that wind power represents an advantageous and necessary enterprise for our state, and we applaud the Commission on the advanced planning on this area of regulations on a growing industry. We all face a dire threat of extreme weather and climate change and a balance needs to be struck.

Tom Weislocher, 11581 N Trimble Road, Harrisburg.

Tom Weislocher: I am glad the height question has been brought up. A wind company representative told me in 2018 that they were planning 499-foot vestas turbines for Boone County, although they would prefer 600 foot plus if they could deal with the extra FAA regulations. Fast-forward three years the newest generation of wind turbines are 820 feet, considerably higher than the St. Louis Arch which is only 630-feet. In general, communities are free to regulate the height of structures on the basis of appearance, that is why many zoning ordinances restrict new homes to only two or three stories, even though four or five story homes could safely be built. Wind turbines are no different than any other lawful use, you may restrict their size on the basis of appearance. An 820-foot turbine is the height equivalent of a 59-story building; I am pleased with the proposed turbine height limit for Boone County at 355-feet, the equivalent of 25-stories but I have reservations. We have all seen the videos of flaming wind turbines on YouTube with no one even attempting to put the fire out. That is because traditional firefighting equipment can't reach that high. Aesthetics aside, does the Boone County Fire Protection District have equipment to reach wind turbine heights in the event of a nacelle or rotor fire? They haven't yet responded to my question which I entered on their website, but I doubt that they have it since the tallest building in Boone County is currently Jesse Hall at 180-feet. Will it be possible to purchase equipment reaching twice that height or more and if so, who will foot the bill?

Nordex, one of the world's largest wind turbine manufacturers states in their safety manual that during a storm event their employees are to remain 3280 feet from a wind turbine and inside a vehicle. That is for people already trained to deal with wind turbine emergencies. Should we put them only 1750-feet from a landowner who has no training in how to handle that? Just because 1750-foot setbacks may have been adopted elsewhere with mixed perception, that doesn't make them appropriate here, particularly when the population density of Boone County is ten times that of more rural counties. That said, I think individual property owners should retain the right to encumber their own property by waiving or shortening the setback requirement as it applies to them as long as it doesn't violate the safeguards protecting other property owners. I am concerned about where power generated by local wind might be sold. Being in talks with local utilities is not the same as having regulations mandating the sale of power to them at pre-negotiated, discounted, competitive prices; that should be required.

The energy policy institute at the University of Chicago released a 2019 paper on the cost-effectiveness of renewable mandates. It examined the effects of renewable portfolio standards programs adopted by 29 states and found that they raised retail electricity prices considerably while reducing Co2 emissions only modestly. April 21, 2021, US Special Presidential Envoy for Climate, John Kerry, told Washington Post Live that even if both the US and China could go to zero emissions it still wouldn't solve the climate problem. That being the case there is no reason to sacrifice Boone County under the illusion that we are changing the world for the better. All we will be doing is hurting people by lowering their property values, decreasing their quality of life, and simultaneously increasing the cost of electricity for all. I am concerned that the company that has already leased 15,000 acres of land in Boone and Howard Counties is German. Germany is currently our ally but that was not always the case, in today's fast-paced world, global loyalties can change a lot during the 30-year lease lockup period. In the event we ever end up on the wrong side of the table from our German friends would we want foreign nationals tied into our grid and power systems and the accompanying communication systems that operate them? That presents a risk to the availability of local power at the time when we would need it most as well as a national security risk. Permits should be limited to US-based wind companies. It is tempting to look at the upfront lure of a few dollars in a few pockets now but let's not mortgage our future for the short-term gain of a few when the unexpected fallout from this could have us all licking our wounds because once these things go up they are up there for a long time and our land and our lives are changed forever.

Commissioner Proctor called Jack Meinzenbach, attending by video. Mr. Meinzenbach did not wish to speak.

Commissioner Proctor called Skylar Laird, attending by video. Ms. Laird did not wish to speak.

Terrie Nagel, 5501 W Tracy Ct, Columbia

Terrie Nagel: Regarding the definition of cluster on the first page. I believe you mean for it to match the information on page 14, changing the wording from "less than 1.25 times the minimum spacing distance from the least one other WECS in the group" to "no greater than 1.25 times the minimum spacing distance.."

Regarding the section on page 14 about unacceptable noise levels, what are the consequences if unacceptable noise levels continue? Should those turbines causing issues be turned off until they are fixed? Several of the requirements in the regulations do not list any consequences if requirements are not followed. Should a statement be added to the regulations indicating what the consequences should be, including a county-initiated shutdown or permanent shutdown, especially when issues affect health and safety? Concerning avoiding important wildlife migratory corridors and staging areas, do we already have information on migratory corridors in Boone County, particularly for migrating birds? In just the past few years we have seen bald eagles visiting our lake and an increase of migrating birds such as trumpeter swans and Canadian geese following migratory paths that will be disrupted by the turbines with many birds killed. The American Bird Conservancy estimates 1.4 million bird deaths per year if the US expands wind-energy generation facilities to produce just 20% of the electricity demand. Wind turbines also kill more bats than any other human industry or activity.

Regarding the height of the wind turbines proposed, in order to provide some scale for those, they are taller than the Statue of Liberty and twice as tall as Jesse Hall. Wind turbines this size weigh 267 tons, mostly steel and concrete, and rest 6 to 30 feet in the ground. Foundations are even more massive and weigh several thousand tons.

Regarding section 29.9.2 abandonment, the 4-foot removal of underground equipment and foundation systems does not seem adequate accordingly so you might want to change that to say take it all out when it is time. I was worried about that when I read that it goes 6 to 30 feet in the ground. I know that others are proposing that the turbines be bigger and I brought a picture of a 500' wind turbine in relation to a property. (attached at the end of these minutes)

Commissioner Proctor called Margaret Gray attending by video. Ms. Gray chose not to speak.

Susan Goodman, 11581 N Trimble Rd, Harrisburg

Susan Goodman read the following invitation which was posted on Facebook:

Hey all, my name is Carrie March and I am your Missouri neighbor to the north. I live in Schuyler County, Missouri in the middle of the new High Prairie wind project. This is my personal invitation to come sit on my porch for a day if you are questioning signing a lease or wondering how bad it really is. Message me and I will give you directions, you are more than welcome. The closest turbine to us is 2100 feet, we have 16 within 1.8 miles on all sides. I provided a few videos here but have many more if you'd like to view entire Google drives. Even with almost no wind they still aren't silent. The noise is every single day. Our roads are destroyed, our newly built home is destroyed, relationships in our county are destroyed, our peaceful, quiet rural life is gone. I would challenge you to answer the question, what is the health, safety and well-being of Boone & Howard County residents worth? Should it be for sale?

Susan Goodman: I would like to thank the committee for their work on the regulations, you have obviously studied and made a deep dive in to the realities, people who are advocating wind turbines for financial gain or because they still believe they are green and renewable and have not been motivated to study so deeply. Organizations like the Sierra Club are standing with who have names that sound like environmentalists are admittedly just lawyers and lobbyists for big wind companies, so they aren't motivated to tell the whole story, but people who live around them are. There is much regret all over the world from people who believed the consistently promoted untruths about industrial wind turbines. I am sending the link to a leaseholder story titled "What have I done", it is an ad that was put in a Wisconsin newspaper to share experiences (attached at the end of these minutes). If we run out of fossil fuel, then why do we use so very much of what we have left to build giant machines that depend on fossil fuels for every stage? Germany world renewable leaders shut down a number of its coal plants in January only to find eight days later they had to reopen them in order to meet demand because of low wind. Their setbacks are 5280 feet. Too bad wind turbines don't work without drawing a large amount of electricity from the grid.

Why should it be the resident's responsibility to wait for the noise that we know happens then make complaints, wait for noise studies and some kind of mitigation. In Kirksville their response to Carrie March was "they are built now there is nothing we can do". Wind turbine companies must have the responsibility to provide each home with a noise box in advance that it is tested as soon as they turn the turbines on and the turbines are turned off whenever they go over the limit. There must be a county representative with the ability to turn them off 24-hours a day. Numerous stories are being told of turbines making bad and unusual noises being reported and not fixed for many months and then having a runaway event such as fire or blade throw, these can be life or death situations and the County is responsible for it if we do not insist on the ability to turn them off when we need to. The wind companies have not demonstrated that they will necessarily do it in a timely manner. There is a turbine near Carrie March's home that must have something bad like a warped bearing and it makes noise when it is not even running. When it is running it sounds really bad and Carrie is fearful for the life of her family. Should she have to live like this? Should we?

Greg Toul, 9515 N Route E, Harrisburg

Greg Toul: Everyone is saying the regulations are too restrictive, but they need to be restrictive because the regulations are in place to protect the people just like building inspections. They are there to protect the people, not special interest groups. One thing I saw in the regulations that seemed to be open-ended was not to put any of the turbines in scenic areas and wildlife refuges. I am not sure what is considered a scenic area, but I live on Route E and it is a very scenic area. There is no specification on what a scenic area is. Something missing from the regulations is the accountability factor. Who is accountable for all of these negative, detrimental effects on people's health? No one is being held accountable and someone needs to be.

No one else wished to speak.

Commissioner Proctor stated that no decision will be made tonight. This is the last public hearing regarding the regulations to be held by the Planning and Zoning Commission. Now, staff will compile the comments and bring them to the Planning and Zoning Commission. The commission will consider all the comments may make changes based on the comments or they may make a motion to recommend or deny the regulations to the County Commission, the County Commission will hold another public hearing and either approve the regulations or refer them back to the Planning and Zoning Commission for additional changes. This is not the end of the process.

The meeting adjourned at 7:22 PM.

Meeting notes prepared by Paula Evans, Administrative Coordinator, Boone County Resource Management

ATTACHMENT 4

BOONE COUNTY PLANNING & ZONING COMMISSION
BOONE COUNTY GOVERNMENT CENTER, COMMISSION CHAMBERS
801 E. WALNUT, COLUMBIA, MISSOURI
(573) 886-4330

Minutes	**7:00 P.M.**	**Thursday, June 17, 2021**

I. Chairperson Harris called the meeting to order at 7:00 p.m. with a quorum present.

II. Roll Call:

a. Members Present:

Boyd Harris, Chairperson	Centralia Township
Eric Kurzejeski, Vice Chairperson	Missouri Township
Michael Poehlman, Secretary	Rock Bridge Township
Gregory Martin	Katy Township
Rhonda Proctor	Perche Township
Randal Trecha	Cedar Township
Steve Koirtyohann	Rocky Fork Township
Jeff McCann	County Engineer

b. Members Attending by Phone:

Bill Lloyd	Three Creeks Township

c. Members Absent

Fred Furlong	Bourbon Township
Daniel Mings	Columbia Township

d. Staff Present:

Bill Florea, Director	Thad Yonke, Senior Planner
Uriah Mach, Planner	Cece Riley, Planner
Paula Evans, Staff	

III. Approval of Minutes:

Minutes from the May 20, 2021 meeting were approved as presented by acclamation.

IV. Chairperson Statement

Chairperson Harris read the following statement:

The Boone County Planning and Zoning Commission is an advisory commission to the County Commission. The commission is made up of individuals representing each township of the county and the county engineer.

The Planning and Zoning Commission makes recommendations to the County Commission on matters dealing with land use. Tonight's agenda includes one rezoning request and three plats.

In general, the Planning and Zoning Commission tries to follow Robert's Rules of Order, however, it is authorized by the Missouri state statutes to follow its own by-laws. The by-laws provide that all members of the commission, including the chairperson, enjoy full privileges of the floor. The chairperson may debate, vote upon or even make any motion.

The following procedure will be followed:

This meeting is being conducted in compliance with County Commission order 238-2021 which recommends all persons who have not completed their COVID-19 vaccination process, and who are 10 years of age or older continue to wear a face mask in any public areas of the Government Center.

We will follow a partial virtual format. Several Commissioners are present in the Chambers. A number of other Commissioners may be attending the meeting through an audio link. The audio link is open to members of the public who wish to follow the proceedings.

Announcement of each agenda item will be followed by a report from the planning department staff. The applicant or the applicant's representative may make a presentation to the commission after the staff report. The commission may request additional information at that time, or later following the public hearing. After the applicant's presentation, the floor will be opened for a public hearing. Those wishing to speak in support of the request will be allowed to speak, then the floor will be given over to those opposed to the request. There may be individuals that neither support nor oppose a request. Those individuals are welcome to address the commission at any time during the public hearing.

Please direct all comments or questions to the commission, be concise and restrict your comments to the matter under discussion. Please be considerate of everyone here. We ask that you please not be repetitious with your remarks. We also recognize that some issues can be quite emotional. In that regard we ask that you refrain from applause, cheers, or other signs of support or displeasure. Please afford those with a different point of view than yours the same respect and consideration you would like yourself.

Please give your name and mailing address when you address the commission. Please sign the sheet on the table after you testify. Also, we ask that you turn off your cell phones.

Any materials that are presented to the commission, such as photographs, written statements or other materials will become a part of the record for these proceedings. If you would like to recover original material, please see the staff during regular business hours.

After those opposed to the request have had a chance to speak the public hearing will be closed and no further comments will be permitted from the audience unless requested by the Commission. The applicant will then have an opportunity to respond to any concerns expressed during the public hearing. Next the staff will be given an opportunity for any additional comments. The commission will then discuss the matter and may ask questions of anyone present during the discussion. Finally, a motion will be made to either recommend the approval or denial of the request to the county commission. Please note that the Boone County Zoning Regulations and Subdivision Regulations are considered to be a part of the record of these proceedings.

All recommendations for approval are forwarded to the County Commission. They will conduct another public hearing on Tuesday, June 29th. Interested parties will again be able to comment on the requests at that time. The County Commission generally follows the recommendations of the Planning and Zoning Commission; however, they are not obligated to uphold any recommendation.

Requests that are denied will not proceed to the County Commission unless the applicant files an appeal form within 3 working days. Please contact the planning office to see if a request that has been denied has filed an appeal, as there will be no further public notification due to the short time between the hearing tonight and the County Commission hearing. The County Commission hearing scheduled for Tuesday, June

29th will begin at 7:00 p.m. and will convene in this same room. That meeting will also be conducted in compliance with the current Covid-19 health order and may use the same format as this meeting.

V. Rezoning Requests

1. Request by Crown Power & Equipment to rezone 3.43 acres from R-D (Two-Family Residential) and 1.68 acres from R-M (Moderate-Density Residential) to C-G (General Commercial) located at 7106 E I-70 Drive SE, Columbia.

Planner, Thad Yonke gave the following staff report:

This property is located approximately 800 feet north of the nearest portion of the Columbia municipal limits that fall on the south side of I-70 Dr. SE and approximately 1 mile east of the Lake of the Woods interchange on I-70. The parcel is approximately 5.11-acres in area and is currently split zoned with the north 3.4-acres zoned R-D (residential duplex) and the remaining 1.7-acres zoned R-M (residential moderate density). These zonings went into effect in August of 1993 having been rezoned from R-S (residential single family). The site currently has a small residential structure on it that is proposed to be removed if the site is redeveloped. The surrounding zoning to the south, and west is R-S and is all original 1973 zoning. The municipal limits adjoin the subject property across I-70 to the north and this northern property is used for commercial/industrial uses. Property to the east is zoned C-G after having been rezoned from R-S in 2019 to legitimize a legal nonconforming use. This property was part of a C-GP (planned commercial) request submitted in 2004. The planned request was withdrawn by the applicant during the Planning & Zoning hearing.

The Master Plan designates this property as suitable for residential land use. The Master Plan identifies a "sufficiency of resources" test for determining whether there are sufficient resources available for the needs of the proposal. Failure to pass the test should result in denial of a request. Success in passing the test should allow the request to be considered and evaluated based on accepted planning principles.

The resources used for this analysis can generally be broken down into three categories, Utilities, Transportation, and Public Safety Services.

Utilities: Public Water Supply District 9 provides water service to the property. There is a 2.5-inch water main across the entire frontage of the property, which is not capable of producing commercial fire flow. A main extension from Wester Lane, approximately 1100-feet west, would allow connection to an 8-inch main. It is unknow whether that connection would provide adequate fire flow. A water study would likely be needed.

There is a Boone County Regional Sewer District line on the adjoining property to the east that connects to the Columbia treatment plant. The existing building is not connected to the sewer line. Connection to the line will likely require the owner to enter an annexation agreement with the City of Columbia. We do not have any documentation that this process has been requested or approved, nor what conditions would be tied to such an approval. Until the situation about access to the central sewer is resolved we can't consider it available at this time.

Boone Electric provides power.

Transportation: The subject tract has frontage on and direct access to I-70 Drive SE. The drive access appears to be shared. The other properties sharing the access are all residentially zoned.

Public Safety Services: The property is approximately two miles from the Boone County Fire station at 5910 E. St. Charles Road.

Stormwater: The site is not developed and new development or redevelopment on the site will be required to comply with the Boone County Stormwater Regulations.

Zoning Analysis:

The property is in the Master Plan and the East Area Plan. Both plans designate this property as suitable for residential land use. There is no evidence that this property was ever used in a commercial capacity and its historic use and current zoning show the role of the property in the neighborhood as residential. The existing zoning supports the East Area Plan goal of encouraging multiple types of housing in the area as it allows for higher density housing without rezoning. The proposed rezoning to C-G conflicts with several of the Goals of the East Area Plan. The plan indicates that commercial areas need to be nodal, the proposal is not. Making the outer road a commercial strip is to be discouraged according to the plan. This request promotes speculative strip commercial development. Under the sub-area plan commercial areas are supposed to be supportive of the residential uses of the neighborhood. As an open C-G request, it is questionable whether the actual use would fit this criterion. Of the existing commercial zoning and legal non-conforming commercial uses of the area almost none are what would be considered supportive commercial uses. Therefore, if rezoned as proposed it is unlikely that this property would be developed with supportive commercial uses. Unless the request was a planned rezoning there is no mechanism which could limit development to such uses. The requested zoning, general commercial (C-G) is an open zoning district upon which conditions of approval can't be placed. Under open zoning, the property must be able to support all Permitted Uses in the C-G district; this has not been shown. It has not been shown that central sewer is available at this time and is subject to approval by the City of Columbia. Water sufficient to provide commercial fire flow is not available at the property nor has been shown to be available, therefore the proposal fails to pass the sufficiency of resources test in addition to the conflicts with the East Area Plan.

Staff notified 71 property owners about this request. The property scored 65 points on the rating system.

Staff recommends denial of the rezoning for failure to pass the sufficiency of resource test and because of conflicts with the adopted East Area Plan.

Present representing the request:

<u>Ben Ross</u>, Engineering Surveys & Services, 1113 Fay St, Columbia
<u>Harold Chapman Jr</u>, Crown Power & Equipment, 5793 N Hwy PP, Columbia

The applicants made a power point presentation.

Harold Chapman: Crown Power came into existence in 1992, we are located on Prathersville Road. We purchased this property and the property to the east in 2004. We were running a small Cub Cadet dealership. We were told by the brand that we would need more land so we bought this 5.1 acres. We did some consolidation and moved everything to our Prathersville Road location. This property has been vacant for some time now. We employ 190 employees and we travel from Macon to Monett, Missouri. We have been successful and have been part of the community, we are active with the fair and other youth events. We feel like we have been a good neighbor and a good business for Boone County. We would like to sell this property and we need to rezone in order to be able to resell.

Ben Ross: The second slide of the power point shows an overall view of the property, there is a commercial use to the east and north. There is an old house on the property which will likely be removed. We reached out to the adjacent property owners and one of them is in support and the other two are not in opposition.

The neighbor to the east has been a commercial use since 1938, in 1973 the County adopted zoning and gave it R-S zoning. In 1983 it was rezoned to R-D and R-M which is what it is now. Since 1980 the community has grown 180%; you would think there would be a demand for housing and nothing has happened on this property since the 1980's. The property was in default and Crown Power bought it from the bank in 2004. In 2019 the neighbor to the east rezoned because they wanted to have a legal commercial property so if their structure ever burned down or had more than 75% loss they wouldn't be able to rebuild without proper zoning.

I reached out to John Kuhlman at MoDot. There is good sight distance east and west and Mr. Kuhlman told me that a commercial driveway could be constructed on the property. There is a drainage easement we will have to work around but I don't see that as a problem. Access is good for this property for a commercial use. Things have changed since the original zoning in 1973 and even since the rezoning in 1983. The biggest change is that it was just announced that a new subdivision will be built to the south of this property and it will be 348 lots; it is going to be in the City of Columbia. Those property owners will want some commercial uses close by. To the east of that new development Olivet Road will be extended and it will be a future arterial extension. The pavement will be about 50-feet wide with curb and gutter and a 100-foot wide right of way; it will eventually go north toward Battle High School and there will be an overpass over I-70. We think it will also have a connection to the outer road. There will be a new, major roadway just ¼ mile away from the property we are asking to rezone. In the future, transportation is going to call for some commercial growth in the area. In 1988 there were 28,000 vehicles per day on I-70 and today there are over 45,000. The property has good frontage and visibility from I-70 and it makes sense to have a commercial property along the high visibility corridor.

I reached out to Roger Ballew regarding the water service. The closest eight-inch pipe to the property on the south side of I-70 is about 1000-feet to the west. Mr. Ballew indicated it has over 1000 gallons per minute (gpm) capacity which would be good for a smaller commercial development. If you are going to build a big hotel that might not be enough. Right now the property is zoned Multi-family Residential, to develop in the current zoning the water main would still have to be extended. The water main is just down the street and is close enough to make it economically viable to extend it for a commercial development. There is a fire hydrant the next street over and it is between 500-1000 gpm. The ability to get commercial fire flow for smaller to moderate commercial uses is very viable for this site.

A sanitary sewer line is located on the neighboring property; ES & S designed that about six or seven years ago for the Boone County Regional Sewer District. The easement is contiguous with this lot so they would be able to connect to that. I have never heard of a case where BCRSD or the City of Columbia would deny someone connecting to the sewer; it is the most economical and environmentally friendly way to treat wastewater. The eight-inch sewer main would support about anything you would build on that site from a commercial standpoint. There is a petroleum pipeline that crosses the property, it is a 12-inch steel line. If I was going to build a house I wouldn't want to be anywhere near that. A commercial parking lot over that would be a better use. The pipeline is a detriment to any kind of residential development on the property. We think this is a great site for commercial development, it is right along I-70. The utilities are close enough to meet the sufficiency test.

Chairperson Harris: Is the pipeline active?

Ben Ross: I am not sure. They defend their right of way zealously. The pipeline crosses through Columbia diagonally through town, we have encountered it in several places. It is the Magellan pipeline and in Tulsa they have an engineering staff and you have to get permits for it. You can pave over it but no building.

Harold Chapman: I believe it is active. There are two pipes with it, one is running fiber. Any time we do anything out there we call Magellan and they send someone out.

Commissioner Trecha: What is currently on the commercial lot to the east?

Ben Ross: It is Columbia Golf cars.

Chairperson Harris: The statement was made that water and sewer would have to be upgraded to exercise the existing zoning, is that correct?

Thad Yonke: Yes.

Chairperson Harris: No matter what happens to it, that has to be fixed?

Bill Florea: Correct.

Open to public hearing.

Present speaking in favor:

Paul Land, Real Estate Broker, 4104 Joslyn Ct, Columbia

Paul Land: I represented this property owner in 1992 when they moved to the Prathersville location and in recent years on this property and the property to the east of this. For the last three years we have marketed this property and have fielded commercial requests, not a single residential request. The fact that the traffic counts have gone up by 25,000 cars per day in 20-years makes it unlikely that this property will ever develop as a residential property. The south side of I-70 seems to be the ideal place for commercial development, it has an outer road that spans from Lake of the Woods to the Route Z exit providing access unlike the north side of the interstate with the outer road of ABC Lane which does not connect to Lake of the Woods. I think this is an appropriate spot for commercial development. We have seen a sprawl of development in Callaway County of businesses that probably wouldn't mind being in Boone County except for the lack of zoning that allows them the same features in Callaway. I hate to see that development go to another county when it could come to Boone County. The uses that are defined within the C-G district are the uses that are appropriate for this area. I spoke to each of the adjoining property owners and they have no objection to this request. Notice was sent to 71 property owners; I will be surprised if anyone is here to speak in opposition tonight.

Mr. Land presented traffic count maps and population charts.

No one spoke in opposition to the request.

Closed to public hearing.

Chairperson Harris: Does Crown Power own the C-G zoned property to the east?

Harold Chapman: We sold it.

Thad Yonke: We took one phone call from a property owner in the area and his concern was if they got the rezoning was whether they would have to put in the water improvements. I explained that there is nothing inherent about the zoning that requires the water to be put in but that the development of the property would require it. He was concerned because he had requested commercial zoning for his property and was denied because he didn't have the water.

Commissioner Poehlman: Since you own the property and you feel strongly about it getting it rezoned then why didn't you go ahead and make a plan for it?

Harold Chapman: We aren't going to develop the property, whoever buys it will. When we purchased this property, the property to the east is where we had our retail outlet but the brand that we were dealing with told us we had to have more acreage, so we purchased this property. If we had stayed over there we probably would have asked to rezone and cleared this property to display equipment.

Chairperson Harris: The commercial use to the east exists because it is pre 1973 zoning?

Bill Florea: It may have been a non-conforming use, but we have not checked for a certificate of occupancy for non-conforming use.

Thad Yonke: The reasoning and justification for the C-G rezoning that exists there was because it was legitimizing an existing, legal non-conforming use. It had already existed and continued to exist on that property. That was the justification for that C-G zoning.

Commissioner Kurzejeski: If we go east from this property is there any residential along I-70?

Thad Yonke: Yes. You have Sunrise Estates but there are also other houses along the outer road.

Commissioner Lloyd: How many properties along the outer road between Lake of the Woods and Route Z are zoned commercial?

Thad Yonke: I don't know.

Commissioner Lloyd: Would it be safe to say there are several?

Thad Yonke: There are several.

Commissioner Kurzejeski: I don't remember why there was concern about this being a commercial node during the East Area Plan discussions.

Thad Yonke: Because they didn't want it to be strip commercial where the entire frontage was commercial, they felt it should be nodal, which is at intersections and concentration points. Not because you have commercial zoning so the property next door should also be commercial.

Commissioner Kurzejeski: It is not nodal at this point.

Thad Yonke: No.

Chairperson Harris: While the theory is wonderful the reality is the existing residential surrounds a mix of commercial property that is in a strip.

Commissioner Lloyd: If the master plan was being developed today would this property still be declared suitable for low-density residential or would the plan say it should be commercial for a good portion of this stretch of properties?

Thad Yonke: The East Area Plan was done after the master plan and it did designate this area as residential. I would say that answer has been made and it was that this area was suitable for residential. They did indicate that the residential should be a mix of residential uses which is exactly why the R-M and R-D is supported by the area plan. While it might not be the most attractive spot for a single-family home it is developable as an apartment complex with a parking lot on the front like what you would find with a commercial development. Also, to clarify, there was a statement that the City of Columbia doesn't deny sewer access.

Within the last couple of weeks, they did just that and they have been more insistent upon having conditions placed upon pre-annexation agreements for getting access to the sewer. The question about whether you have access to sewer and what that entails is important to have clarified before the right to have a zoning of that type is ascertained.

Commissioner Martin: That was going to be my question. Why have the applications not pursued and obtained an agreement from the sewer district so that you know you have it? It is concerning to put the zoning out there and now you can't have access to sewer.

Thad Yonke: One of the standard conditions the sewer district has been placing is that you must meet city fire flows which is 1500 gpm for commercial, not 1000.

Commissioner Trecha: Is the water available currently that would support development for the residential densities that are currently allowed?

Thad Yonke: It could for a duplex or some types of multi-family. You can put a multi-family in that requires the same as commercial. It depends on how many units you are developing.

Commissioner Kurzejeski: Does the pipeline through there impede the potential for residential development in any way?

Paul Land: I don't know; it impedes the usability of the tract, so that impedes the density. We are not seeking a building permit tonight; we are seeking the appropriateness for commercial zoning at this location. The answer to why we haven't pursued some of that is because we don't know what capacity we are asking for. It would be better to know what capacity we are asking for and the first leg of that is to get the zoning.

Commissioner Kurzejeski: Any commercial use is still going to have to deal with the sewer and water.

Chairperson Harris: The existing zoning will have to deal with the sewer and water as well. The water and sewer, regardless of what zoning label we put on it doesn't make a difference, they both have the same dilemma.

Commissioner Martin: As a Commission we also must look at the fact that it doesn't meet the resource requirements.

Commissioner Lloyd: Does it make any sense to table the request to allow the applicant to get with the sewer district and the city to see if there could be a definitive answer to connection?

Commissioner Poehlman: Shouldn't the applicant ask for that?

Chairperson Harris: The applicant would have to ask the Commission to table the request.

Commissioner Martin: I believe the Commission should make their decision and allow this to move forward one way or another. I am not comfortable making that decision based upon the sufficiency of resources because we can't okay it carte blanche.

Chairperson Harris: The existing sewer line goes under I-70?

Ben Ross: Correct.

Chairperson Harris: Is it Boone County Regional Sewer or the City of Columbia sewer?

Ben Ross: We were working for the Boone County Regional Sewer District; I don't know if that was a service area they kept or how it worked out. In my experience, if you have public sewer next to your property you can hook on to it. I can look up those details and report to the County Commission.

Thad Yonke: Even if it is the Boone County Sewer District you still have to get the agreement because it is ultimately treated by the City of Columbia, so you have to get it worked out.

Chairperson Harris: The question becomes if this is an appropriate use of land in this location. If this was the only spot that this zoning is being requested along that stretch of road I would say probably not. The problem is the precedent is set in both directions. From a development perspective, while I fully understand the East Area Plan looking at that as residential, you tend to find a lot of major roadways with commercial property that fronts it and the residential comes up behind it so that the residential isn't right next to all the traffic.

Commissioner Poehlman: There wasn't anyone voicing concern about it either. Without a plan I am hesitant.

Commissioner Kurzejeski: I can see you not having a plan if you are just selling it because you don't know who the buyer is going to be or what the use will be.

Commissioner Martin: They are still going to have to have those resources.

Commissioner Poehlman: It would be easier to accommodate those resources if you knew what the plan was.

Chairperson Harris: In light of the existing uses and the fact that the existing zoning is no more compliant with the sufficiency of resources than the proposal, and with respect to Staff, I will make a motion to approve the rezoning request.

Chairperson Harris made and Commissioner Koirtyohann seconded a motion to approve the request by Crown Power & Equipment to rezone 3.43 acres from R-D (Two-Family Residential) and 1.68 acres from R-M (Moderate-Density Residential) to C-G (General Commercial) located at 7106 E I-70 Drive SE, Columbia:

Boyd Harris – Yes
Michael Poehlman – NO
Bill Lloyd – Yes
Steve Koirtyohann – Yes
Jeff McCann – NO
Eric Kurzejeski – Yes
Greg Martin – NO
Rhonda Proctor – Yes
Randal Trecha – Yes

Motion to approve the request passes 6 YES 3 NO

Chairperson Harris informed the applicants that this request would go to the County Commission on Tuesday, June 29, 2021 and the applicants need to be present for the hearing.

VI. Plats

The following plats were placed on consent agenda:

1. Cochran Subdivision Plat 2. A-2. S25-T51N-R14W. Allen & Judy Cochran and Sean & Angela Cochran, owners. Steve Proctor, surveyor.

The following staff report was entered into the record:

The property is located just south of the intersection of Carr Lane and State Route F, approximately 3 ½ miles north of Harrisburg. The subject property is 11.13 acres in size. This proposal creates two lots, one at 5.56 acres, the other at 5.57 acres. Both lots are already developed with single-family residences and on-site wastewater systems. This proposal revises the previously-platted Cochran Subdivision to include the adjacent property to the north and the lake between both properties. This plat consolidates a not-for-development tract with the two lots, making that area developable. The subject property is zoned A-2(Agriculture) and is surrounded by A-2 zoning. This is all original 1973 zoning.

The lot has direct access to State Route F. The applicant has submitted a request to waive the requirement to provide a traffic analysis.

Water service to the lot is provided by Public Water Service District #10 and electrical service is provided by Boone Electric Cooperative.

Existing on-site systems provide wastewater disposal for the single-family residences. The applicant has submitted a request to waive the requirement to provide a wastewater cost-benefit analysis.

The property scored 36 points on the rating system.

Staff recommends approval of the plat and the requested waivers.

2. Higher Ground Subdivision Plat 1. S24-T50N-R14W. A-2. Gems Hilltop Acres LLC, owner. Steven Proctor, surveyor.

The following staff report was entered into the record:

The subject property is located at the northwest corner of the intersection of N Bethlehem Road and W Gray Rd, approximately 1.5 miles to the southeast of the City of Harrisburg. The subject property is 40.07 acres in size and zoned A-2 (Agriculture). It is surrounded by A-2 zoning, all of which is original 1973 zoning. This proposal divides two tracts into three lots and reconfigures the remainder into a 20+ acre simple survey. The three lots proposed to be platted are 5.00, 5.09, and 5.38 acres, respectively. The property within this plat proposal is currently undeveloped.

The subject property has direct access onto Gray Rd and Bethlehem Rd, both being gravel roads with publicly-dedicated, publicly-maintained right of way. The applicant has submitted a request to waive the traffic study requirement.

The subject property is located in Consolidated Water District #1, the Boone Electric Cooperative service area, and the Boone County Fire Protection District. Wastewater has been proposed as on-site lagoons. The health department has been made aware of this proposal and has indicated no foreseen issues at this time. Any new development on these property's on-site wastewater treatment systems will require permitting from the Columbia/Boone County Health Department.

The property scored 30 points on the rating system.

Staff recommends approval of the plat and granting the requested waivers.

3. Quarry Farms Subdivision Plat 1. S26-T51N-R13W. A-2. Tim Burke, owner. Steven Proctor, surveyor.

The following staff report was entered into the record:

The subject property is located on West Creed Road, approximately 7 miles to the southwest of the City of Sturgeon. The property is 24.8 acres in size and zoned A-2 (Agriculture). It is surrounded by A-2 zoning, all of which is original 1973 zoning. This proposal divides the north 4.8 acres away from the remaining 20-acre tract. The property is currently undeveloped.

The subject property has direct access on to W Creed Rd, a gravel road, with publicly-dedicated, publicly-maintained right of way. The applicant has submitted a request to waive the traffic study requirement. The subject property is located in Public Service Water District #10, the Boone Electric Cooperative service area, and the Boone County Fire Protection District.

Wastewater has been proposed as an on-site lagoon. The health department has been made aware of this proposal and has indicated no foreseen issues at this time. Any new development on this property's on-site wastewater treatment system will require a permit from the Columbia/Boone County Health Department. The property scored 35 points on the rating system.

Staff recommends approval of the plat and granting the requested waivers.

Commissioner Martin made, and Commissioner Kurzejeski seconded a motion to approve, as recommended, items on consent agenda

All members voted in favor.

VII. Old Business

Update on Commission action.

Bill Florea updated the Commission of the decisions of the County Commission as follows:

The final development plan for Danny Hill/Lot 4 Concorde South Plat 2 was approved.

The plats that went forward to the County Commission were also approved.
(Trade Winds Park Plat 1-B, Montague Subdivision, Bellaridge Subdivision Plat 5)

VIII. New Business

Wind Farm Regulations

Director, Bill Florea gave the following staff report:

Nearly three years ago, on July 31, 2018, after having received a recommendation of approval from the Planning and Zoning Commission, the County Commission approved a Conditional Use Permit for a meteorological mast in northern Boone County.

The applicant, Mike Sivore, with E.ON Climate and Renewables, testified that there are several factors that his company considers when deciding on a location for a windfarm: a supportive community, the ability to transmit or ship the electricity, and wind. Mr. Sivore stated that he felt the first two factors were present, which left wind and the need for the met mast.

In March 2019, a community meeting was held in the Harrisburg High School Gym to discuss a potential windfarm. At the meeting, then Director of Resource Management Stan Shawver stated that changes in County regulations would be necessary for a windfarm to move forward. Shortly thereafter, the County Commission directed Resource Management to work with the Planning and Zoning Commission to address the issue of utility scale wind powered energy generation in Boone County.

P&Z has held 14 work sessions on this issue. Several of the work sessions were held jointly with the Columbia/Boone County Energy and Environment Commission.

Over time, it became clear that the Commission's work on this issue focused on several priorities including
- A high level of community support for all proposed wind farms;
- A high commitment to public safety, health, and welfare;
- Minimizing impacts to non-participating properties and property owners;
- Ensuring mitigation of any degradation of public transportation infrastructure;
- Minimizing impacts to the natural environment;
- Ensuring a fair process.

In order to ensure community support of a proposed wind farm, P&Z chose to use established Boone County policy for creating a Character Preservation Overlay District as a model. That process requires the applicant to obtain the notarized signatures of a super majority of property owners in a defined area where the windfarm is proposed. This procedure blends well with E. ON's desire to locate in an area with strong community support.

The Commission has carefully considered information from a variety of resources. In establishing a setback requirement the Commission considered setbacks of varying distance, reviewed maps provided by staff, testimony from the Columbia/Boone County Commission on Energy and Environment and the peer reviewed article *A method for defining wind turbine setback standards* published in the academic journal WIND ENERGY.

In establishing noise standards, the Commission considered the World Health Organization *Environmental Noise Guidelines for the European Region* and the_American National Standard *Quantities and Procedures for Description and Measurement of Environmental Sound – Part 4: Noise Assessment and Prediction of Long-term Community Response (ANSI 12.9-2005/Part 4).*

Concerning the natural and built environment, applicants are require to follow United States Fish and Wildlife Service *Land-Based Wind Energy Guidelines* and prepare a comprehensive environmental assessment that addresses things such as flora and fauna, noise generation, waste generation, fire risk, water quality and soil erosion, impacts to historic and cultural resources, visual impacts including shadow flicker and blade glint, and impacts to public transportation infrastructure.

The Commission held three public hearings on the following dates:
- April 8, 2021 in the Boone County Commission Chambers
- April 20, 2021 in the Harrisburg High School Gymnasium
- April 29, 2021 in the Southern Boone County School District Offices in Ashland.

Written comments were accepted from April 1, 2021 through April 30, 2021. The draft regulations brought before the Commission tonight are the result of many hours of work by the Commission and staff as well as a significant amount of time and effort from the general public.

The most recent drafts of both the WECOD and the WECS-C CUP Regulations were included in your work session packets and are displayed on the screen for your consideration.

Chairperson Harris: The Commission has gone through the proposed regulations line by line and addressed all of the comments and questions raised by the public. After review, the Commission asked Staff to make recommended changes and bring it back before the Commission and this is the finalized draft version.

Commissioner Koirtyohann made, and Commissioner Martin seconded a motion to accept the proposed regulations and forward them to the County Commission for consideration:

Boyd Harris – Yes	Eric Kurzejeski – Yes
Michael Poehlman – Yes	Greg Martin – Yes
Bill Lloyd – Yes	Rhonda Proctor – Yes
Steve Koirtyohann – Yes	Randal Trecha – Yes
Jeff McCann – Yes	

The motion passed unanimously.

Chairperson Harris stated that the Commission has accepted the proposed regulations and recommend they be forwarded to the County Commission for consideration. The County Commission will hold at least one public hearing and a 15-day notice will be provided prior to the hearing.

Bill Florea stated that we will keep the public up-to-date on the Wind Farm Regulations website at: https://www.showmeboone.com/resource-management/WECOD/ . The County Commission has not set a meeting date yet.

IX. Adjourn

Being no further business, the meeting was adjourned at 8:01 p.m.

Respectfully submitted,

Secretary
Michael Poehlman, Secretary

Minutes approved on this 15th day of July, 2021

ATTACHMENT 5

COLUMBIA DAILY TRIBUNE
P.O. Box 798 • Columbia, MO • 65205-0798

ADVERTISING
INVOICE and STATEMENT

BILLING PERIOD	ADVERTISER/CLIENT NAME	
07/01/21 - 07/31/21	BC RESOURCE MANAGEMENT	

TOTAL AMOUNT DUE	*UNAPPLIED AMOUNT	TERMS OF PAYMENT	
134.10		NET DUE 28 DAYS	
CURRENT NET AMOUNT DUE	**30 DAYS**	**60 DAYS**	**OVER 90 DAYS**
134.10	0.00	0.00	0.00

INVOICE NUMBER	PAGE #	BILLING DATE	BILLED ACCOUNT NUMBER	PARENT ACCOUNT NUMBER
1480832	1	07/31/2021	12525	12525

BILLED ACCOUNT NAME & ADDRESS
BC RESOURCE MANAGEMENT
***
801 E WALNUT ST
COLUMBIA MO 65201-4890

PLEASE DETACH AND RETURN UPPER PORTION WITH YOUR REMITTANCE

DATE	REFERENCE	PUB	DESCRIPTION – OTHER COMMENTS / CHARGES	SIZE/PAGES	TIMES	RATE	BALANCE
			BALANCE FORWARD				0.00
07/11	92009	CDT	3C WIND FARM HEARING	2 X 4.50	1	14.90	134.10

CONTRACT NAME:	EXPIRES	COMMITMENT	PERIOD	TO DATE	TO FULFILL
Net Dollar Volume	04/29/2022	24000.00	6336.82	7586.35	16413.65

STATEMENT OF ACCOUNT AGING OF PAST DUE AMOUNTS

CURRENT NET AMOUNT DUE	30 DAYS	60 DAYS	OVER 90 DAYS	*UNAPPLIED AMOUNT	TOTAL AMOUNT DUE
134.10	0.00	0.00	0.00		134.10

COLUMBIA DAILY TRIBUNE
101 North 4th Street • P.O. Box 798
Columbia, MO 65205 • (573) 815-1500

*UNAPPLIED AMOUNTS ARE INCLUDED IN TOTAL AMOUNT DUE

INVOICE NUMBER	ADVERTISER INFORMATION			
	BILLING PERIOD	BILLED ACCOUNT NUMBER	PARENT ACCOUNT NUMBER	ADVERTISER / CLIENT NAME
1480832	07/01/21 - 07/31/21	12525	12525	BC RESOURCE MANAGEMENT

AFFIDAVIT OF PUBLICATION

BC RESOURCE MANAGEMENT

I, Christian Crawford, being duly sworn according to law, state that I am one of the publishers of the Columbia Daily Tribune, a daily newspaper of general circulation in the County of Boone, State of Missouri, where located; which newspaper has been admitted to the Post Office as periodical class matter in the City of Columbia, Missouri, the city of publication; which newspaper has been published regularly and consecutively for a period of three years and has a list of bona fide subscribers, voluntarily engaged as such, who have paid or agreed to pay a stated price for a subscription for a definite period of time, and that such newspaper has complied with the provisions of Section 493.050, Revised Statutes of Missouri 2000, and Section 59.310, Revised Statutes of Missouri 2000. The affixed notice appeared in said newspaper on the following consecutive issues:

1st Insertion	07/11/21
2nd Insertion	
3rd Insertion	
4th Insertion	
5th Insertion	
6th Insertion	
7th Insertion	
8th Insertion	
9th Insertion	
10th Insertion	
11th Insertion	
12th Insertion	
13th Insertion	
14th Insertion	
15th Insertion	
16th Insertion	
17th Insertion	
18th Insertion	
19th Insertion	
20th Insertion	
21st Insertion	
22nd Insertion	

NOTICE OF PUBLIC HEARING

Notice is hereby given that the Boone County Commission will conduct a Public Hearing for the purpose of readopting the Boone County Zoning Regulations, including revisions to Section 2, Definitions; Section 15.G, Conditional Use Permits for Commercial Wind Energy Conversion Systems; and Section 29, Wind Energy Conversion Overlay District on the following date:

Tuesday, July 27, 2021 at 7:00 PM: Boone County Government Center, Commission Chambers, 801 E. Walnut St., Columbia, MO

The Boone County Commission will also hold two Public Meetings for citizens to provide comments regarding the above regulations on the following dates:

Wednesday, August 11, 2021 at 6:30 PM: Southern Boone Schools, Central Office Board Room, 5275 W. Red Tail Drive, Ashland, MO

Tuesday, August 24, 2021 at 6:30 PM: Harrisburg High School Gymnasium, 801 S. Harris St, Harrisburg, MO

Copies of the proposed regulations may be obtained at the office of Boone County Resource Management, 801 E. Walnut St., Rm. 315, Columbia, or on our website at: www.showmeboone.com/resource-management/WECOD

By ____ $134.10

Subscribed and sworn to before me this 2nd of August, 2021

Notary Public

SANDRA L ROTHER
Notary Public - Notary Seal
STATE OF MISSOURI
Comm. Number 15638071
Boone County
My Commission Expires: Sep. 9, 2023

AFFIDAVIT OF NOTICE OF PUBLIC HEARING

STATE OF MISSOURI) ss
County of Boone)

I hereby swear that the affixed notice of public hearing was posted at the Boone County Government Center, 801 E. Walnut St., Columbia, Missouri, on the

12th day of July, 2021

Paula Evans date 7/12/21
Paula Evans

Subscribed & sworn to before me this 12th day of July, 2021

Christina L Crane
Notary Public

Christina L. Crane
Printed Name

CHRISTINA L. CRANE
NOTARY PUBLIC - NOTARY SEAL
STATE OF MISSOURI
COMMISSIONED FOR BOONE COUNTY
MY COMMISSION EXPIRES MAY. 21, 2025
ID #13705616

Boone County Resource Management

ROGER B. WILSON GOVERNMENT CENTER
801 E. WALNUT ROOM 315 COLUMBIA, MO 65201-7730
(573) 886-4330 FAX (573) 886-4340

DIRECTOR
BILL FLOREA

PLANNING - INSPECTIONS - ENGINEERING

NOTICE OF PUBLIC HEARING

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TERM OF COMMISSION: July Session of the July Adjourned Term

PLACE OF MEETING: Roger B. Wilson Boone County Government Center
County Commission Chambers / Conference Call

PRESENT WERE: Presiding Commissioner Daniel Atwill
District I Commissioner Justin Aldred
District II Commissioner Janet Thompson
Director of Joint Communications Chad Martin
Director of Resource Management Bill Florea
Planner Uriah Mach
Planner CeCe Riley
Deputy County Clerk Jodi Vanskike

Public: Robert Hall, Tim Opitz, Mike Sivore, Brent Voorheis, Warren Wood, Jay Hasheider, Richard Fray, Zack Dunn, Tom Weislouher, Nakila Blessing, Carrie March, Susan Goodman, Terrie Nagel, David Nagel, Greg Toul, Stephen Nagel

Conference Call Information:

Number: 425-585-6224 Access Code: 802-162-168

The meeting was called to order at 7:00pm.

Joint Communications

1. **First Reading: Approval of Budget Revision for Purchase of VHF receivers**

Director of Joint Communications Chad Martin stated they are requesting approval for a budget revision for five Astroteck receivers in the amount of $5,975.00. Director Martin stated this would be to move money from a contingency fund to an operating budget classification fund for the receivers at five sites, to fix an immediate need for the Boone County Fire frequencies that have some interference.

Commissioner Atwill stated this is a first reading and requested the Deputy County Clerk schedule this item for a second reading at the next available commission meeting with appropriate order for approval.

P&Z

2. **Goen Acres Plat No. 1. S13-T50N-R13W. A-2. Goen LLC, owner. David Butcher, surveyor.**

Director of Resource Management Bill Florea asked to waive the reading of the report and asked that the clerk be authorized to submit the report into the record with the minutes.

Commissioner Thompson moved now on this day, the County Commission of the County of Boone does hereby receive and accept the following subdivision plat and authorizes the Presiding Commissioner to sign it:

1. Goen Acres Plat No. 1. S13-T50N-R13W. A-2. Goen LLC, owner. David Butcher, surveyor.

Commissioner Aldred seconded the motion.
The motion carried 3 to 0. **Order #302-2021**

3. **A Public Hearing for the purpose of readopting the Boone County Zoning Regulations, including revisions to Section 2, Definitions; Section 15.G, Conditional Use Permits for Commercial Wind Energy Conversion Systems; and Section 29, Wind Energy Conversion Overlay District.**

Commissioner Atwill stated many months ago it came to the Commission's attention that there was an interest in wind farms in Boone County. Commissioner Atwill stated they did not have any regulatory mechanism in place for that, so they asked the Planning and Zoning Commission to take a look at the issues involved and to report back to the Commission. Commissioner Atwill stated the Planning and Zoning Commission took several months to look at things and prepared a comprehensive report. Commissioner Atwill stated since this is now being presented officially to the Commission at this meeting, the purpose this evening is to hear public comment that will have to do with whether or not this should be adopted as is; if it should be modified and adopted; or if it should be rejected. Commissioner Atwill stated there will be two other public meetings about this issue: one in Harrisburg for the Northern District of Boone County and one in Ashland for the Southern District of Boone County. Commissioner Atwill stated, after those town halls are concluded, the issue will come back before the Commission for approval, denial, or modification. Director of Resource Management Bill Florea presented a slide show and copies of that slideshow have been attached to the official minutes for public review. After the slide show presentation, Commissioner Atwill opened the public hearing. Tim Opitz stated he is there on behalf of Renew Missouri. Mr. Opitz stated they are a renewable energy and energy efficiency advocacy group and stated his group brings a lot of experience in this area. Mr. Opitz stated based on his experience, his group is very concerned about the ordinance being discussed. Mr. Opitz stated, in addition to their own policy research, they have reached out to a national group, The American Clean Power Association, who has assisted. Mr. Opitz stated he has a letter from that association that details environmental and economic benefits that wind energy can bring. Mr. Opitz stated the letter also details concerns about the ordinances and offers input on best practices. Mr. Opitz stated he would like to raise a few concerns tonight. First, this ordinance is not a reasonable restriction. Mr. Opitz stated this ordinance is a ban on wind energy in Boone County. Secondly, this ban will be used to justify limitations on wind energy around the state as unreasonable restrictions. Mr. Opitz stated, when his group went to Resource Management over a year ago to impose reasonable regulations, their Executive Director was told by a staff member that Boone County didn't need the extra revenue and that the wind farms should be built elsewhere. Mr. Opitz stated the ban that was proposed sends a loud and clear message to the County: Boone County doesn't want the economic benefits of wind, Boone County doesn't want environmental benefits of wind, and Boone County doesn't want land owners to be able to earn money from wind farms on their property. Mr. Opitz stated, "In other words, Boone County is closed for business." Michael Sivore from RWE Renewables stated, as one of the largest developers of wind projects in the world, these restrictions as proposed would prevent them from moving forward with their project and will prevent other developers from being able to do anything with wind farms in Boone County. Mr. Sivore stated he would like to request that the Commission consider the letter from American Clean Power. Brent Voorheis, from Harrisburg, MO stated he also believes the regulations as presented will not allow for wind development in Boone County. Mr. Voorheis stated he lives on a family farm where his family has lived since the 1950's. Mr. Voorheis stated he has six generations within this County and he would do nothing that he thought would be a detriment to northwest Boone County or anyone living in northwest Boone County. Mr. Voorheis stated he started this process for a few reasons. Mr. Voorheis stated he could see the benefits to school districts; he could see benefits for green energy; and the third reason was there would be benefits to him. Mr. Voorheis stated, while the money wouldn't change his lifestyle, it might change his kids' or grandkids' lifestyles. Warren Wood, Ameren Missouri Vice President of Regulatory & Legislative Affairs, stated he lives on a farm with an energy pipeline running through his property. Mr. Wood stated Ameren Missouri views the regulations being proposed as an effort to ensure that wind energy projects are good neighbors to the community, and they agree with and support that effort. Mr. Wood stated with that said, they are very concerned that some of the regulations would prohibit wind energy from being built in the County. Mr. Wood stated Ameren is committed to providing affordable and reliable electricity to their customers and producing this energy in Missouri if feasible. Mr. Wood stated they are currently making a transformational change to serve their customers now and in the future. Mr. Wood stated renewable energy, wind especially, is a very important part of this transition. Jay Hasheider stated what he would like to address is the issue of climate change and how wind energy has direct bearing on that issue. Mr. Hasheider stated climate change is happening right now as you look at floods, forest fires, sea level rises, or high temperatures. Mr. Hasheider stated climate change is here and it's bad but tomorrow it will be worse. Mr. Hasheider stated the right thing to do is stop the use of fossil fuels and to start using renewables. Mr. Hasheider stated he would like to discuss the regulations and how they would effectively be a ban on wind energy in Boone County. Mr. Hasheider stated he urges the Commission to look at what other states like Iowa, Minnesota, and Wisconsin are requiring for their wind regulations and he urges the Commission to do the right thing. Richard Fray stated he is currently one of the members building the wind farm in the northern counties of Missouri, referred to as High Prairie Wind. Mr. Fray stated he has been working at the High Prairie Wind Farm for a couple of years now, doing erosion control and transporting. Mr. Fray stated, this project has provided him good, consistent work that has allowed him to earn an honest paycheck. Mr. Fray stated from his experience, much of the crew in High Prairie is from out-of-state. Mr. Fray stated local area, higher provisions ensure money being paid to workers is being spent in the communities we live in. Mr. Fray stated he joined his union because he wanted a good paying career, not just a job. Mr. Fray stated, like any job, he went through training, learning both in the classroom and on the job site. Mr. Fray stated, as an apprentice, he learned how to safely perform a wide variety of work and that not every guy on the worksite has the same level of training as he does. Mr. Fray stated in addition to provisions seeking local higher commitments, he urges the Commission to consider adding a Department of Labor recognized apprenticeship program to all contractors and subcontractors seeking work on a wind farm. Mr. Fray stated by doing this, it would help maintain the safety of workers and the safety of neighbors who rely on the wind turbines to be built properly. Zack Dunn, Director, Governmental Affairs at Eastern Missouri Laborers' District Council, stated in 2018, their international union conducted a study on the impact of wind farm local hiring practices in Minnesota. Mr. Dunn stated developers were bringing work crews from other states to complete the construction and out-of-state work crews would often receive a per diem of $100.00 per day, which was often the only money they spent while in these communities. Mr. Dunn stated, when the project was complete, the workers would take their wages and go to other parts of the country to their next project. Mr. Dunn stated, with local workers, they live in the communities where they are building these wind farms and spend their money at local businesses and hospitals and pay various taxes in the community. Mr. Dunn went on to say his company thinks the Commission should add language to seek these commitments from developers, contractors and subcontractors that apply for a WECON permit. Mr. Dunn stated this provision would support local workers, local businesses and the overall community. Tom Weislouker stated he hasn't found much favorable about wind energy except what's listed on the wind companies' websites. Mr. Weislouker stated he has attended many Planning and Zoning Commission meetings and has followed the process they went through and he feels they did a "bang up job" on the regulations. Mr. Weislouker stated he found Planning and Zoning consulted multiple sources; they have reworked and clarified their wording; they have considered input from multiple interest groups, public and private sources, experts, and layman, and drafted regulations that would be fair while protecting the values of both interested and non-interested citizens, including property owners. Mr. Weislouker stated he has heard many people say that these regulations are effectively a ban on wind energy, but he would like to state that the regulations are where they need to be. Mr. Weislouker stated Boone County is ten times more densely populated than other areas that have wind farms and he states they haven't worked all that well in some of those areas. Mr. Weislouker stated there are two people in attendance from Schuyler County, MO, and he hopes they get a chance to speak and tell their story. Nakila Blessing stated she has brought some pictures of her home and land in Schuyler County for the official record. Ms. Blessing stated she lives in the middle of a 400-megawatt project that includes 175 2.2-megawatt and 3.45-megawatt wind turbines that are approaching 500 feet tall. Ms. Blessing stated the closest turbine to her home is 3400 feet and there are 13 turbines within two miles. Ms. Blessing stated what she, her family, and her neighbors had hoped for their future was stolen from them. Ms. Blessing stated she is jealous of people who can peacefully sleep in their homes, enjoy a quiet night on their deck listening to the sounds of nature, and people who get to spend their days without wind turbines or construction traffic. Ms. Blessing stated she would like the Commission to take into consideration what they are willing to sacrifice. Ms. Blessing asked if the Commission was willing to sacrifice residents, any resident of Boone County, for promised tax revenue. Ms. Blessing asked if the Commission was willing to consider any resident collateral damage for so called progress. Ms. Blessing stated if one person, one family or one home is affected, is it worth it? Where do you draw the line? Ms. Blessing stated as more wind and solar are being brought online, more electricity prices will increase because wind and solar are unreliable. Ms. Blessing stated if the wind doesn't blow or the sun doesn't shine, they can't produce. Robert Hall stated he fully supports the Planning and Zoning proposed regulations. Mr. Hall stated, as others have pointed out, the regulations written are rational and very well-supported by public hearings. Mr. Hall stated, if the concern is the proposed regulation would make it very difficult for a wind energy project to meet the requirements, then it's obvious that the land patterns in this area are simply incompatible with wind turbine. Carrie March from Schuyler County, MO, stated her husband and she built their farm in Northwest, MO, on land where they planned to spend the rest of their lives. Ms. March stated she was first approached regarding wind energy in 2018 and today her property is surrounded by wind turbines. Ms. March stated, the closest turbine to her home is 2100 feet away and they have 16 wind turbines within 1.8 miles of their home. Ms. March stated, when they were approached by a wind rep, they were told they were the last ones on their road to sign and that they were holding the project up for the rest of their neighbors. Ms. March stated in the end, five neighbors on their road signed and four did not. Ms. March stated after taking her contract to a lawyer and realizing it would give the companies too much control of her land, they decided it was not for them. Ms. March stated her neighborhood was turned into a construction zone, all trucks had out of state license plates and the roads were tore up by the concrete trucks that often ran people off the road. Ms. March stated the noise of construction was tough to get used to and having so many strangers around always was unsettling. Ms. March stated the crews would shut down roads for twenty minutes at a time without any warning and she would urge anyone living in a neighborhood where wind turbines are going in to move completely out during construction, though her roads are still not fixed two years later. Ms. March stated turbines immediately changed the landscape at her house, but one of the worst parts was how suffocating they felt. Ms. March stated they had destroyed all the beauty that had previously been there, and she was not prepared for the first time she heard the audible noise. Ms. March stated the wind turbine was 1.6 miles away and she couldn't believe they could hear it at all, but the closer the wind turbine was, the worse the sound was. Ms. March stated the turbine 1 mile away was the one that drove them inside, but the day they turned on the turbine at 2100 feet from their house was the day that Ms. March and her husband knew they would have to leave. Ms. March stated by the time they had all the turbines functional, the sound was unbearable. Ms. March stated it's hard to describe going from such a quiet setting to this level of noise. Ms. March stated there are days that the wind turbines are off or the noise isn't as loud but never knowing when or how long the days of unrelenting noise will last starts to control your life. Ms. March stated there are times they can hear the wind turbine one mile away louder than one at 2100 feet and it's completely unpredictable. Ms. March stated, when the windows in her house are shut, it is more like a pulse or a throbbing but with the windows open, it's like having the turbine in your backyard. Ms. March stated they must leave the curtains closed because there is something spinning or flashing out every window. Ms. March stated, her oldest son has experienced more headaches and she has twice had to pick her sons up from school, which also has wind turbines within a mile, with headaches so bad they were vomiting. Ms. March had a handout she asked to be included in the official minutes. Susan Goodman stated she lives in Harrisburg, MO right in the middle of where the wind farm project would be. Ms. Goodman stated she is shocked to find out the truth about wind energy. Ms. Goodman stated three and a half years ago she was a pro renewable advocate and then when she found out they wanted to put them within a thousand miles of her house, she was motivated to investigate it deeper. Ms. Goodman stated unless you are personally affected, you can believe all the things you're being told but when you do dig deeper you find something else. Ms. Goodman stated she has found smaller turbines hold up better with less health effects, so she is here today to support the regulations. Terrie Nagel stated she lives in the area that will be affected by the wind farm and stated when she read the article in the Missourian, she was shocked to find out the problems with these industrial wind factories. Ms. Nagel stated most of the people in Harrisburg don't want the wind farms in their area. Ms. Nagel stated there was an article in the Tribune recently discussing the wind turbines that were just left by a company in Oklahoma with no plan on how to remove them. Ms. Nagel stated this is one reason why regulations are needed. David Nagel stated he has been a Northwest Boone County resident for 35 years and retired from the MU Power Plant after 35 years of service. Mr. Nagel stated he's been retired now about three years and one thing he enjoys is sitting on his back porch to have his coffee in the morning while watching the sunrise. Mr. Nagel stated these wind turbines would lower his quality of life and asked who is going to want his property if they come in. Mr. Nagel stated he knows other people who have recently bought property in Northern Boone County for the purpose of building on it but aren't sure they want to drop anymore money into the property. Mr. Nagel stated in conclusion, he is all for green energy, just not in his backyard. Greg Toul stated he lives in Harrisburg, MO and is here to speak against wind turbines. Mr. Toul stated he, along with many others in his town, aren't sure why this is occurring not just in their back yard but to anybody, anywhere, anytime. Mr. Toul stated one concern is the loss of property value which is 40%-60% across the board. Mr. Toul stated if these wind farms are allowed, the value of people's homes are going to go down and so far, no one has taken accountability for that. Stephen Nagel stated he would like to thank the Planning and Zoning Commission for the number of hours they put into putting the presentation together. Mr. Nagel stated he lives on North Route E in Boone County and is here to ask the Commission to protect the small landowners of the County who vote and pay taxes here. Commissioner Atwill stated if there is no one else wishing to speak, he will now close the Public Hearing. Commissioner Atwill stated there will be two more public hearings being held at town halls, one in Ashland and one in Harrisburg. Commissioner Atwill stated after those are completed, the information gathered at those will be compiled into our record. There will then be a discussion with all three Commissioners, who will come to some sort of conclusion. Commissioner Atwill stated good points have been made tonight and thanked everyone for coming.

Sheriff's Office

4. **Second Reading: St. Charles City K-9 Basic Training Contract (First Read 07.22.21)**

Commissioner Aldred moved now on this day, the County Commission of the County of Boone does hereby approve the attached K-9 Cooperative Training Agreement between Boone County and the following:

- St. Charles City Police Department

Terms of the agreement are stipulated in the attached Agreement. It is further ordered the Presiding Commissioner is hereby authorized to sign said K-9 Cooperative Training Agreement.

Commissioner Thompson seconded the motion.

The motion carried 3 to 0. **Order #303-2021**

Road & Bridge

5. **Second Reading: The Missouri Department of Conservation CART program participation (First Read 07.22.21)**

Commissioner Thompson moved now on this day, the County Commission of the County of Boone does hereby authorize participation in the Missouri Department of Conservation's County Aid Road Trust (CART) program as contemplated in the attached program mailing packet.

The Presiding Commissioner and Director of Road & Bridge are authorized to execute the documents reasonably necessary to effectuate Boone County's participation in this CART program.

Commissioner Aldred seconded the motion.
The motion carried 3 to 0. **Order #304-2021**

IT

6. **Second Reading: Budget Amendment CAD to CAD Data Exchange / MO 911 Service Board Grant (First Read 07.15.21) Open Public Hearing**

Commissioner Atwill open and closed the public hearing.

Commissioner Aldred moved now on this day, the County Commission of the County of Boone does hereby approve the Budget Amendment for the CAD to CAD Data Exchange / MO 911 Service Board Grant.

The terms of the agreement are stipulated in the attached Agreements. It is further ordered that the Presiding Commissioner is authorized to sign said Agreements.

Commissioner Thompson seconded the motion.
The motion carried 3 to 0. **Order #305-2021**

Purchasing

7. **Second Reading: Contract Amendment #3 for Signature for Boone County: 129-123116SS - Computer Aided Dispatch System (First Read 07.20.21)**

Commissioner Thompson moved now on this day, the County Commission of the County of Boone does hereby approve the Sole Source Contract 129-123116SS - Computer Aided Dispatch System which was approved by Commission for award to SunGard Public Sector LLC on March 24, 2016, Commission Order 148-2016.

This Amendment assigns the contract to CentralSquare Technologies, LLC (CentralSquare) and it adds the Tellus Unify product.

$26,590 is budgeted for this purchase.

Commissioner Aldred seconded the motion.
The motion carried 3 to 0. **Order #306-2021**

Commission

1. Public Comment

none

2. Commissioner Reports

none

Attest:

Brianna L. Lennon

Clerk of the County Commission

Daniel K. Atwill

Presiding Commissioner

Justin Aldred

District I Commissioner

Janet M. Thompson

District II Commissioner

Staff Report for County Commission
RE: P&Z Agenda Items
July 27, 2021

Plats

At its July 15, 2021 meeting, the Planning and Zoning Commission approved the plat of *Goen Subdivision* by consent. I ask that you waive the reading of the staff report and authorize the clerk to insert the it into the meeting minutes.

Goen Subdivision

The property is located on E Highway 124, approximately 4 miles west of the City of Hallsville. The property is 10.01 acres in size and was created by administrative survey in June of 2021. It is zoned A-2 (Agriculture) and is surrounded by A-2 zoning, all of which is original 1973 zoning. This proposal divides the administrative survey tract into three lots, each being 3.19, 3.18, 3.26 acres, respectively. The property within this plat proposal is currently undeveloped.

The property has frontage on W Hwy 124; however, MODOT has stated that Lot 6 does not have direct access due to site distance criteria. A paired driveway with proposed lot 5 or 7 has been identified as the only solution that will meet regulations. The applicant has submitted a request to waive the traffic study requirement.

The subject property is located in Consolidated Water #1, the Boone Electric Cooperative service area, and the Boone County Fire Protection District. Wastewater has been proposed as on-site lagoons. The health department has been made aware of this proposal and has indicated no foreseen issues at this time. Any new development on these property's on-site wastewater treatment systems will require permitting from the Columbia/Boone County Health Department.

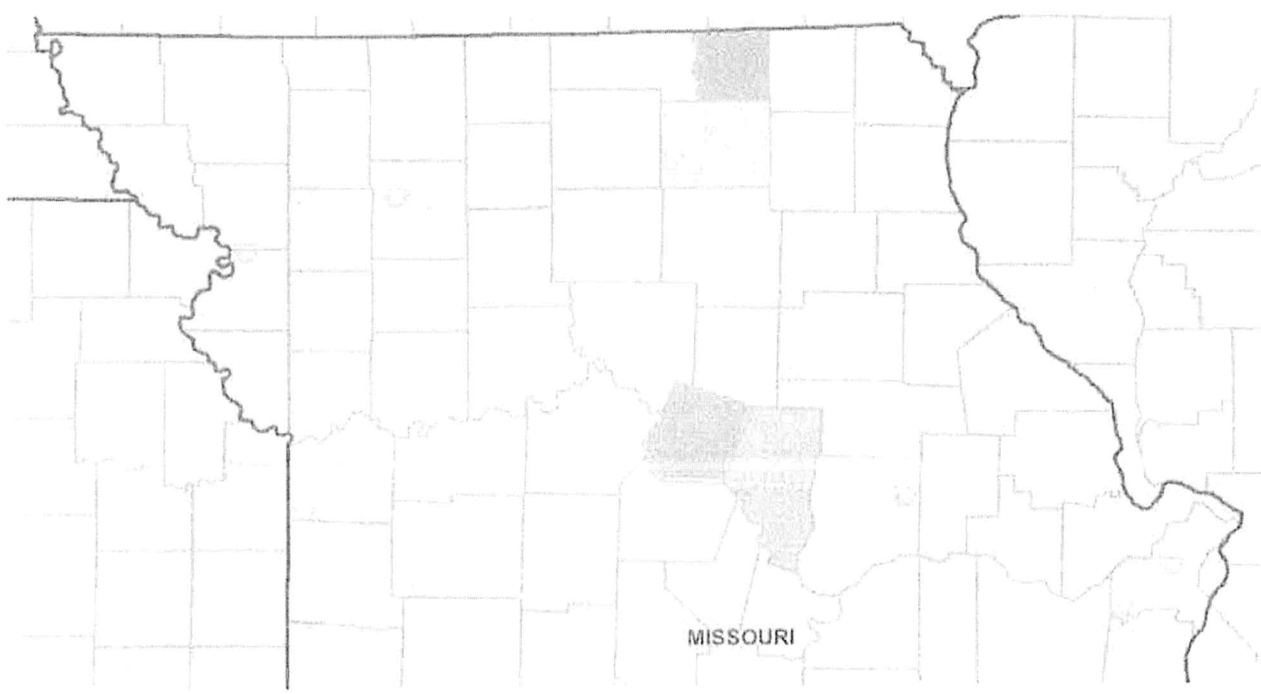
The property scored 31 points on the rating system.

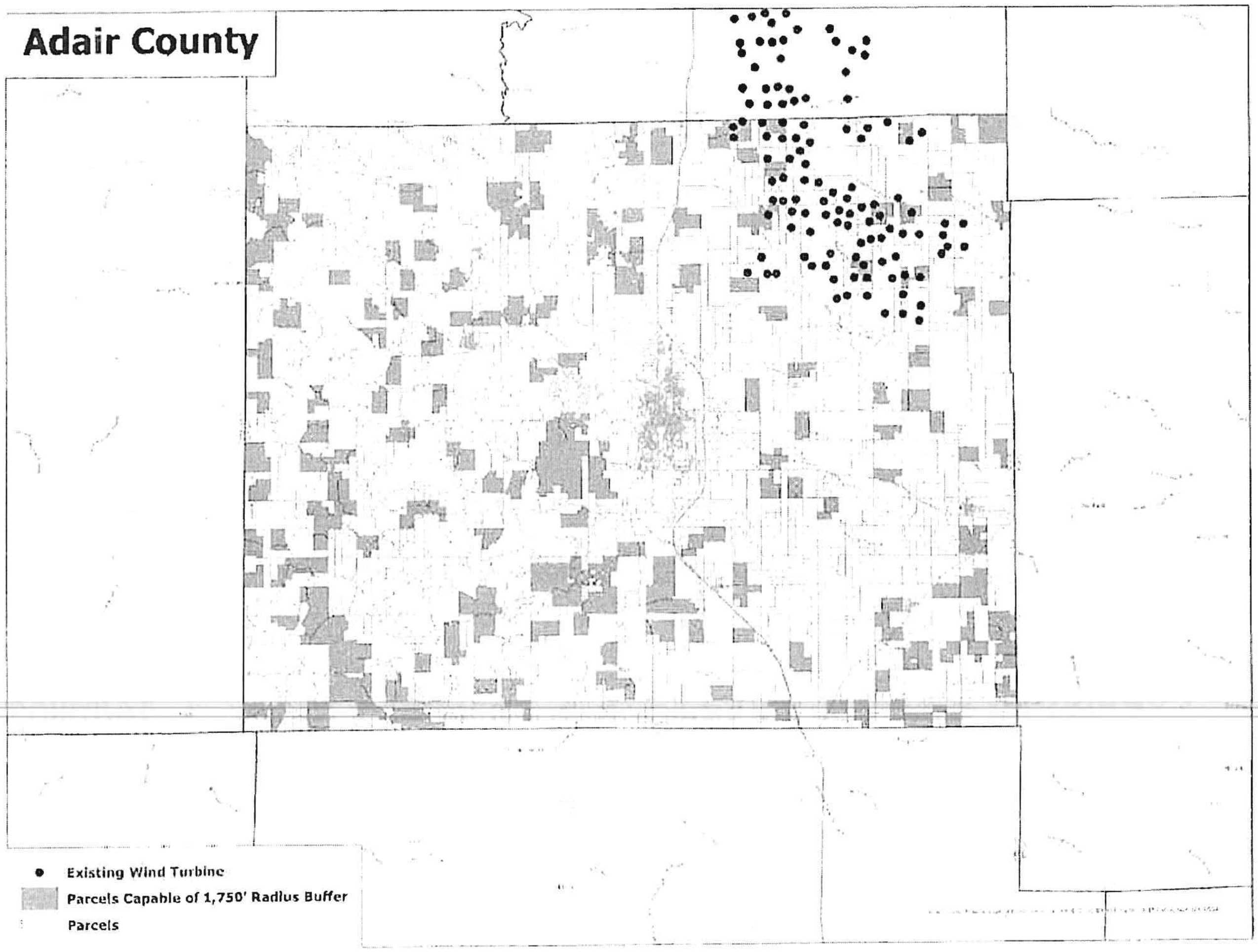
Staff recommended **approval** of the plat subject to the following condition that has been satisfied:

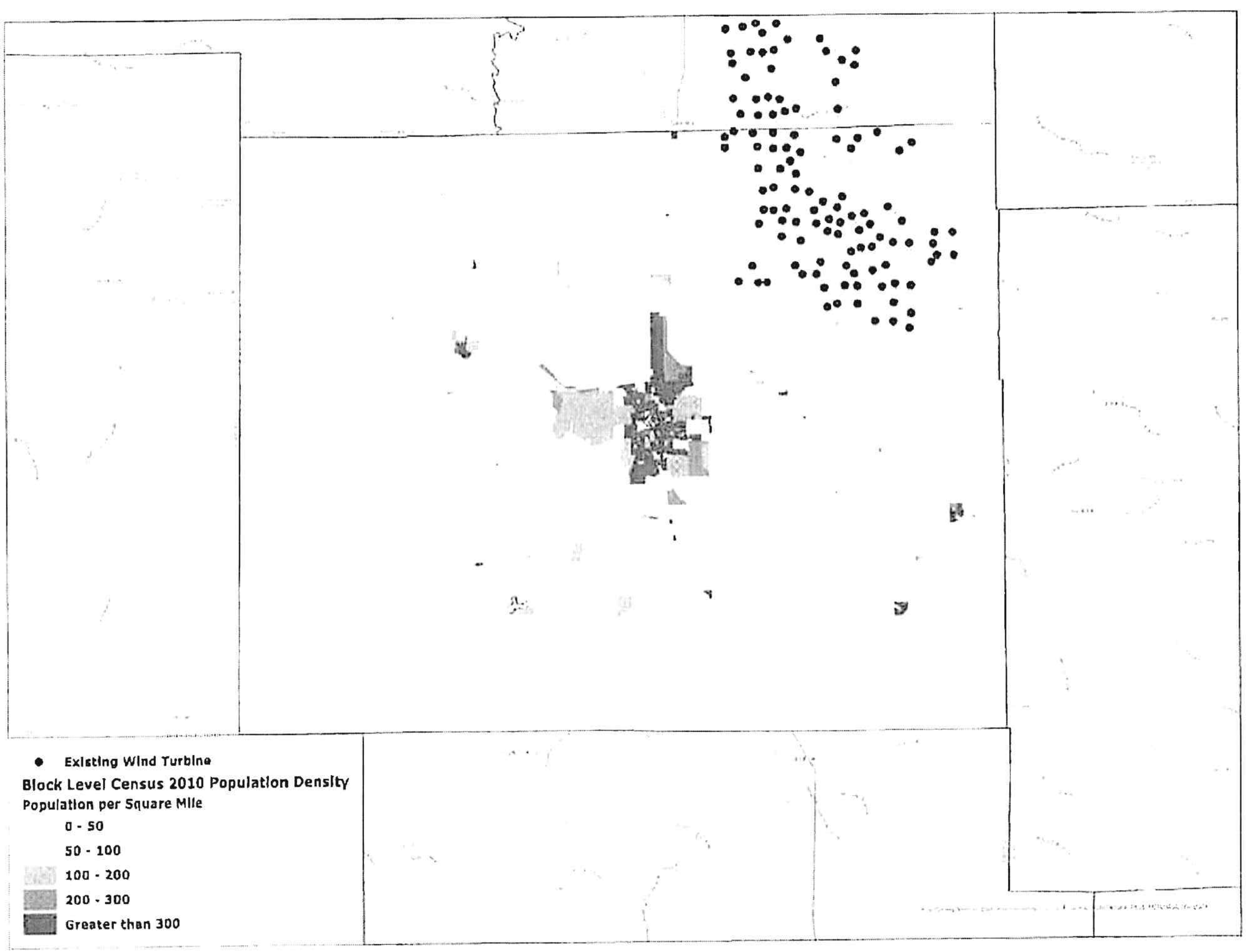
1. Access for Lot 6 is subject to the approval of both MODOT and the Director.

	Boone	Adair	Howard	Schuyler
2020 Population	180,463	25,343	10,001	4,660
Population % Change	▲ 11%	▼ -1%	▼ -1.4%	▲ 5.2%
2010 Population	162,642	25,607	10,144	4,431
Area	691 mile²	569 mile²	253 mile²	308 mile²
Population Density people per square mile	240/mile²	45/mile²	21/mile²	14/mile²
Housing Units	77,314	11,542	4,591	2,106
Assessed Valuation	3.1 Billion	343 Million	133 Million	74 Million

Source: data.census.gov 2019
Missouri Association of Counties



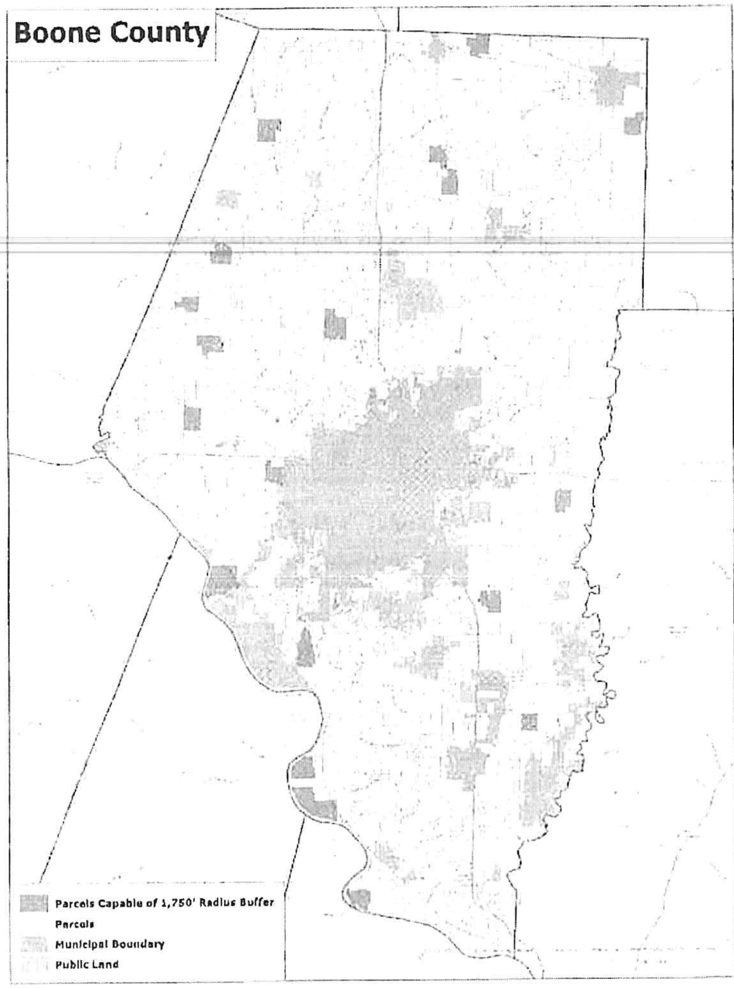

Adair County
Existing Wind Turbine
Parcels Capable of 1,750' Radius Buffer
Parcels


Existing Wind Turbine
Block Level Census 2010 Population Density
Population per Square Mile
0 - 50
50 - 100
100 - 200
200 - 300
Greater than 300

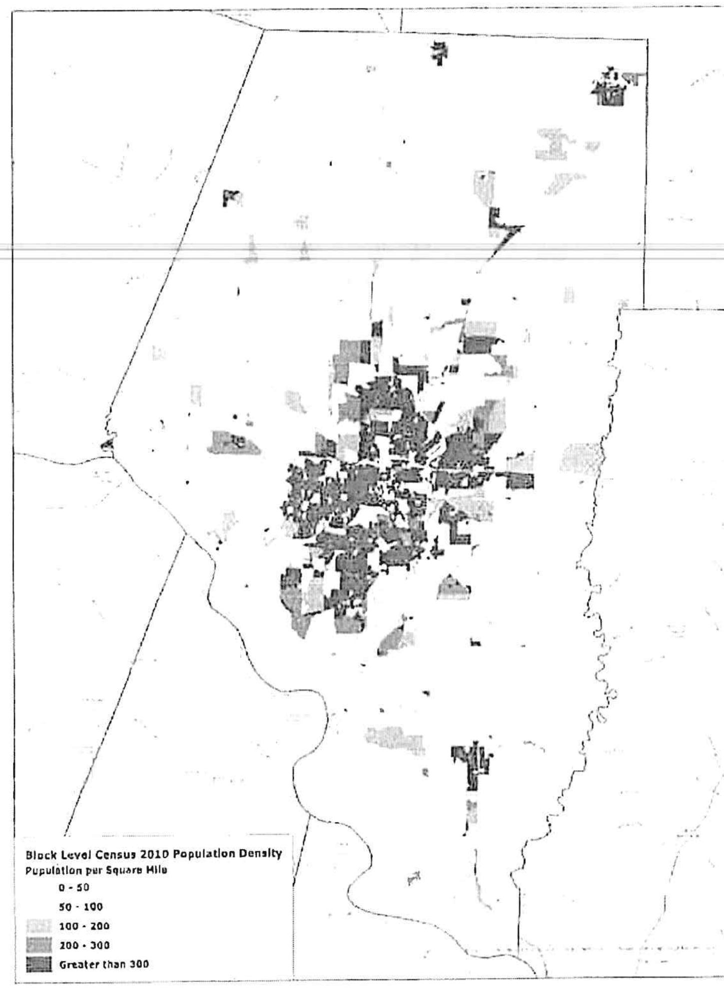
Boone County Wind Farm Regulations Timeline

as of 7/26/21

2018	July	County Commission approved a Conditional Use Permit for a met mast tower in northern Boone County.
2019	February	A private company (E.ON) sent several residents near Harrisburg letters stating the company's intent to explore whether a wind farm could be viable in the area.
	March	Harrisburg residents organized an informal public meeting to discuss their questions and concerns regarding the proposed wind farm project
	April	The County Commission directed Resource Management to work with the Planning and Zoning Commission to draft policies regarding commercial scale wind farms PZ began holding work sessions to discuss details. In total there would be 14 work sessions between April 2019 and May 2021
	May	A series of guiding principles became clear that the Planning and Zoning Commission would use to prioritize discussion regarding Wind Regulations: • A high level of community support for all proposed wind farms; • A high commitment to public safety, health, and welfare; • Minimizing impacts to non-participating properties and property owners; • Ensuring mitigation of any degradation of public transportation infrastructure; • Minimizing impacts to the natural environment; • Ensuring a fair process
	June	Energy and Environment Commission presented findings to the Planning and Zoning Commission
	July	The PZ Commission, after thorough research & guidance from the EEC, began making preliminary decisions regarding setback distance and interest in modeling the wind regulations on existing Character Preservation Overlay District
	December	The Wind Energy Conversion Overlay District framework was established, and staff began drafting regulations. This framework also included the intent for each turbine to apply for a Conditional Use Permit in addition to the District
2020	January	The PZ Commission further discussed their interest in having a high amount of public input & requiring wind farm applicants to successfully attain a clear majority of neighbor's approval before applying for a WECOD
	March	The COVID-19 Pandemic temporarily delayed progress on regulations and hosting public meetings.
2021	January	The PZ Commission reviewed past findings and refined draft regulations presented by staff with intent to host Public Hearings in the coming months
	April	Three Public Hearings were hosted in Harrisburg, Ashland, and Columbia. Staff collected public comment provided both at hearings and through the dedicated WECOD email address
	May	After reviewing public input, staff presented an updated draft of the WECOD Regulations and a Wind Turbine specific Conditional Use Permit (WECS-C CUP) to the PZ Commission. The drafts were approved unanimously.
	July	Draft regulations were brought to the County Commission for consideration



Boone County
Parcels Capable of 1,750' Radius Buffer
Parcels
Municipal Boundary
Public Land



Block Level Census 2010 Population Density
Population per Square Mile
0 - 50
50 - 100
100 - 200
200 - 300
Greater than 300

Wind Farm Regulations 2021
Public Hearing Presentation

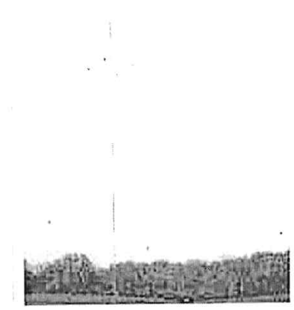
July 27, 2021

Background

In July 2018 County Commission approved a Conditional Use Permit for a met mast tower in northern Boone County.

The applicant, Mike Sivore, with E.ON Climate and Renewables, testified that there are several factors that his company considers when deciding on a location for a windfarm, namely:

- Supportive community;
- Ability to distribute the electricity;
- Ample wind.



Met Mast tower in Harrisburg, standing 199' tall.
Provided by Missourian article published May 21, 2019

Mr. Sivore stated that he felt the first two factors were present, which left *wind* and thus the need for the met mast.

Background

In March 2019, Harrisburg residents organized an informal public meeting to discuss their questions and concerns regarding the proposed wind farm project

- A County Commissioner and then Director of Resource Management were in attendance.

In April 2019, PZ Commission began to draft policies regarding commercial scale wind farms

- PZ began holding work sessions to discuss details. In total there would be 14 work sessions between April 2019 and May 2021

Through these work sessions the following guiding principles emerged:

- A high level of community support for all proposed wind farms;
- A high commitment to public safety, health, and welfare;
- Minimizing impacts to non-participating properties and property owners;
- Ensuring mitigation of any degradation of public transportation infrastructure;
- Minimizing impacts to the natural environment;
- Ensuring a fair process

Process overview

Express interest in establishing WECS-C (Commercial Wind Farm)

Step 1: Apply for Wind Energy Conversion Overlay District (WECOD)

Step 2: Apply for Conditional Use Permits for towers and accessory structures within WECOD

Applicant must meet **all** criteria for approval, pay fees, and meet established timeline

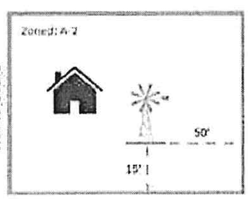
Clarification

Existing Regulations

WECS-S Small Residential Turbines

On-site **personal** use
Location: Agriculture or Residential Zoned

not to scale



Setback: 6'- 50'

Height: 35'

In excess: +1' height = +1' setback

Neighbor support not necessary

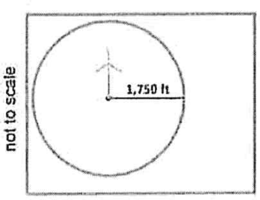
CUP required **<u>IF</u>** height over 100'
Mailed notice to all property owners within 1000'

Proposed Regulations

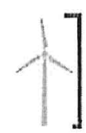
WECS-C Commercial Wind Turbines

Off-site **commercial** use
Location: Agriculture or Industrial Zoned

not to scale



Setback: 1750'



Height: 355'

Neighbors would need to support

WECOD required
CUP required

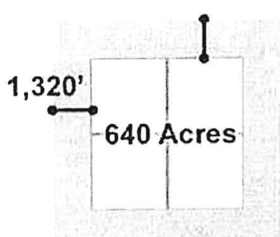
WECOD (Wind Energy Conversion Overlay District)

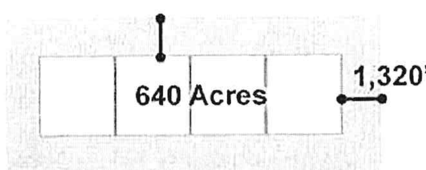
WECOD is composed of two parts:

- Primary District
- Buffer Area

Primary District: This is the area wind turbines may be located in. It's based on location of property proposing to establish a Wind Farm. The minimum size is **640 Acres** (4 contiguous Quarter-Sections)

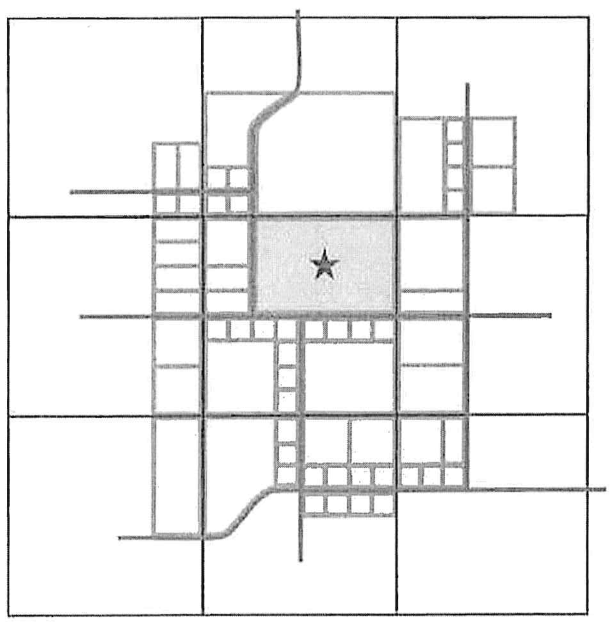
Buffer Area: **NO** wind turbines may be constructed here. The buffer extends outward from the perimeter of the Primary District to **1,320 feet** (1/4 mile)





WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR**



KEY

= Property Line

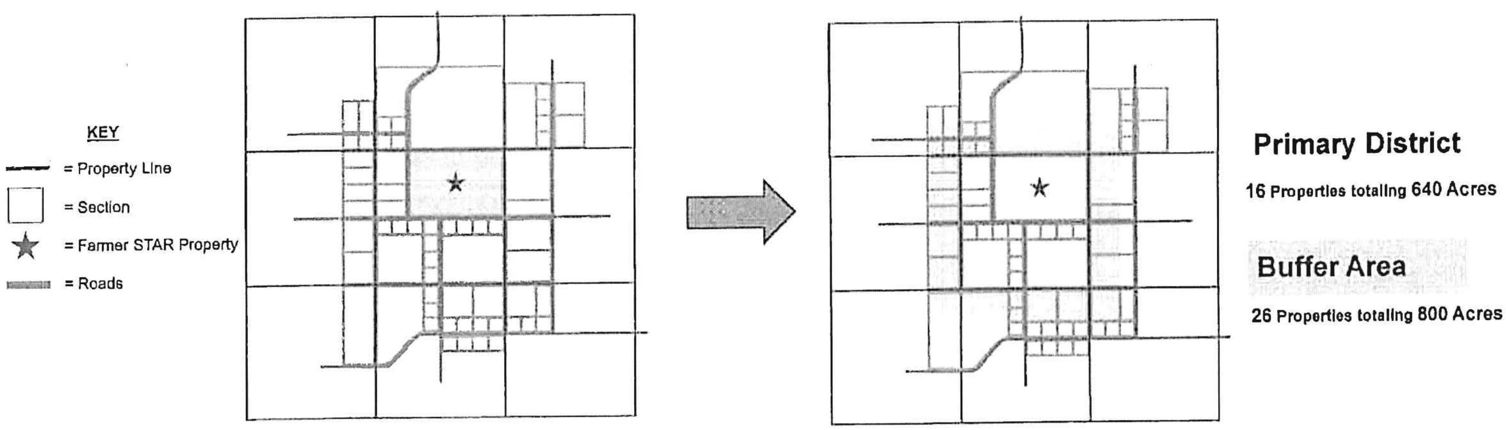
= Section

= Farmer STAR Property

= Roads

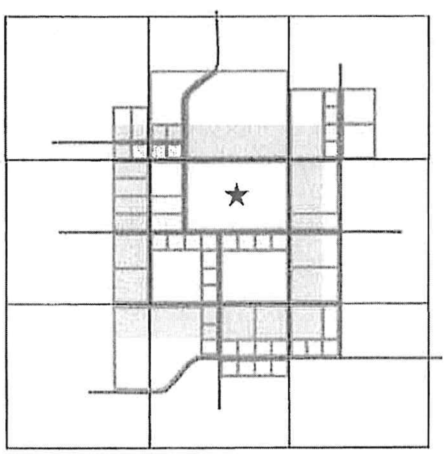
WECOD (Wind Energy Conversion Overlay District)

Example: If Farmer **STAR** wanted to establish a Commercial Wind Farm on his 240-acre piece of land he would need to apply for a WECOD that contains 4 contiguous quarter sections.



WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to **submit a petition** to the Director of Resource Management which includes the notarized signatures of:



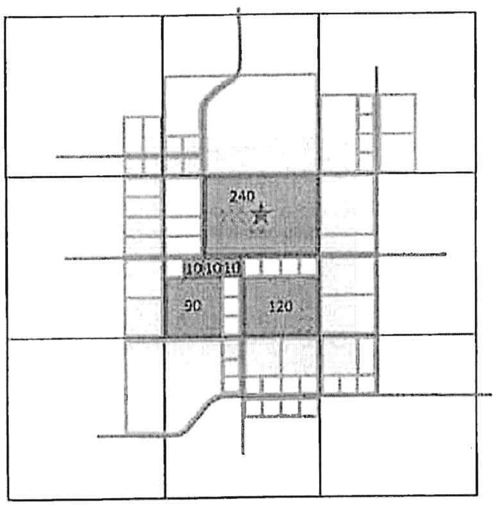
A.) The owners of at least 75% of the ***total acreage*** within the primary district

B.) at least 67% of the ***property-owners*** within the primary district

C.) at least 67% of the ***property-owners*** within the buffer area

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to submit a petition to the Director of Resource Management which includes the notarized signatures of:



6 owners (240+120+90+10+10+10) = **480**

A.) The owners of at least 75% of the total acreage within the primary district

B.) at least 67% of the property-owners within the primary district

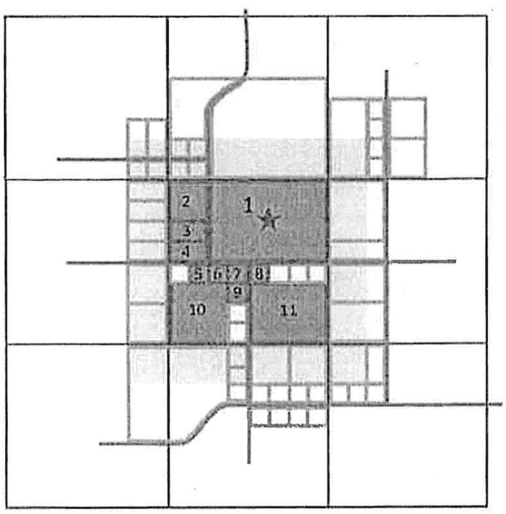
C.) at least 67% of the property-owners within the buffer area

Equation:
Primary District includes: 640 Acres

640 x 75% = **480** Acres ~ Petition signers must own at least 480 Acres

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to submit a petition to the Director of Resource Management which includes the notarized signatures of:



A.) The owners of at least 75% of the total acreage within the primary district.

B.) at least 67% of the property-owners within the primary district

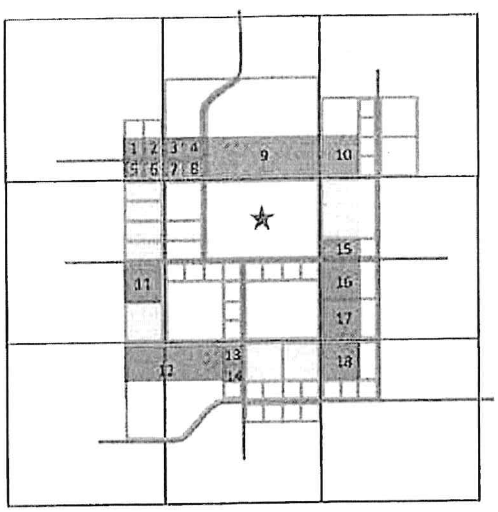
C.) at least 67% of the property-owners within the buffer area

Equation:
Primary District includes: 17 owners (including Farmer **STAR**)

17 x 67% = 11.39 ~ rounds to **11** property-owners must sign petition

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to submit a petition to the Director of Resource Management which includes the notarized signatures of:



A.) The owners of at least 75% of the total acreage within the primary district.

B.) at least 67% of the property-owners within the primary district.

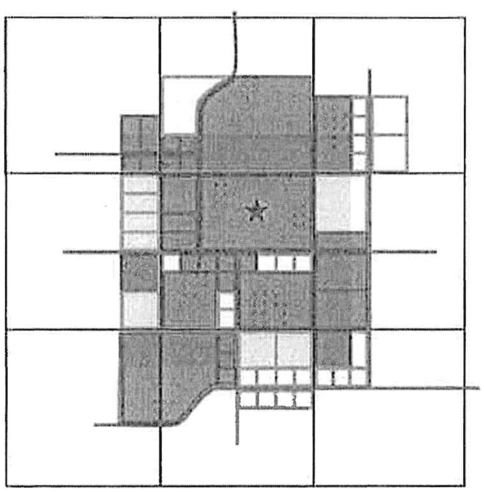
C.) at least 67% of the property-owners within the buffer area

Equation:
Buffer Area includes: 26 owners

26 x 67% = 17.72 owners ~ rounds up to **18** owners must sign petition

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** must meet **ALL** of the signature requirements in order to be **considered*** for a WECOD



A.) The owners of at least 75% of the ***total acreage*** within the primary district

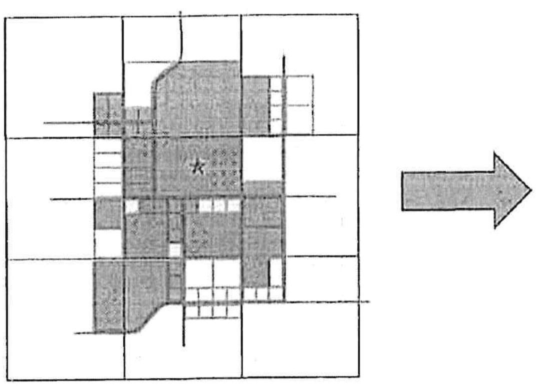
B.) at least 67% of the ***property-owners*** within the primary district

C.) at least 67% of the ***property-owners*** within the buffer area

*Policy based on existing regulations regarding Character Preservation Overlay Districts

WECOD (Wind Energy Conversion Overlay District)

Example: IF Farmer **STAR** can get the required signatures on the petition, THEN he would need to meet **series of criteria**

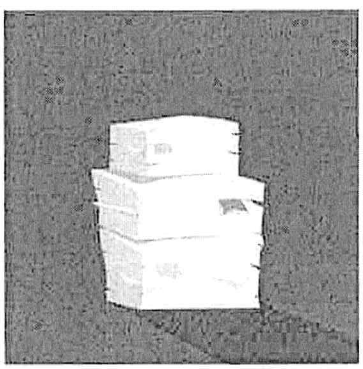


- Submit Complete Application
- Pay Fees
- Notify Neighbors
- Meet Approval Standards
- Meet Siting and Performance Standards

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to submit a **completed application** including an:

Overlay District Plan



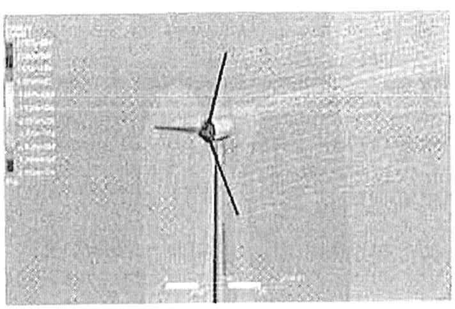
includes, but not limited to:

- Legal Description of land
- Aerial Photography of region
- Location and dimensions of **existing** structures
- Location and dimensions of **proposed** structures
- All environmentally sensitive areas within WECOD

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to submit a **completed application** including a:

Computer Generated Visual Simulation



includes, but not limited to:

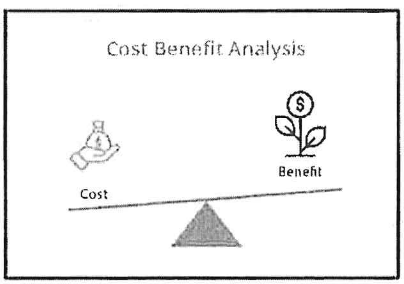
- Impacts from turbine blades on surrounding area
- Viewpoints from houses who did **not** sign the Petition for Application within District
- Viewpoints from houses 1000' outside of WECOD boundary
- Additional key viewpoints as determined by PZ Commission

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to submit a **completed application** including an:

Economic Cost Benefit Analysis

includes, but not limited to:



- Impact of the project on local and state economy
- Amount of **property** taxes to be generated
- Amount of **sales** taxes to be generated
- Number of permanent jobs gained and estimated payroll
- Costs associated with impact on County infrastructure

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to submit a **completed application** including an:

Environmental Assessment

includes, but not limited to:

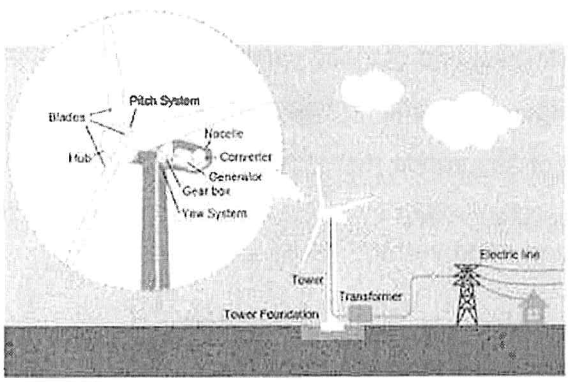
- Must follow United States Fish and Wildlife Service Land Based Wind Energy Guidelines
- Impact on wildlife and wildlife habitat
- Impact on soil erosion, and water quality
- Noise levels, shadow flicker and blade glint

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to submit a **completed application** including a:

Description of Turbine(s)

includes, but not limited to:



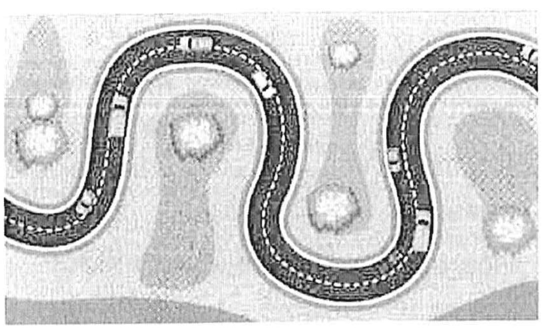
- Type of Turbine, Model number
- Size of tower, blades, foundation, etc.
- Construction Materials
- Color Scheme
- Performance, safety, and noise characteristics

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to submit a **completed application** including a:

Traffic Plan

includes, but not limited to:



- Anticipated volume of traffic during/ after construction
- Routes for oversized and heavy equipment
- Method of assurance regarding road repair to public entities
- A Transportation and Infrastructure Mitigation Plan shall be developed approved by County Chief Engineer

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to pay **all associated costs** including:

Pay Fees

includes, but not limited to:

- Public Notice Fees
- Costs of completing application documentation
- Review fee determined by County Commission

WECOD (Wind Energy Conversion Overlay District)

Example: County will **notify** the following when public hearings occur on Farmer **STAR**'s behalf:

Notice Procedures

includes, but not limited to:

- All property owners within the proposed WECOD
- All property owners within 1000' of the boundary of WECOD
- Newspaper with circulation in their area including a locality map, such as:
  - Columbia Daily Tribune
  - Centralia Fireside Guard
  - Boone County Journal

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to pass Commission **Approval Standards** including demonstrating:

Natural and Biological Resources

includes, but not limited to:

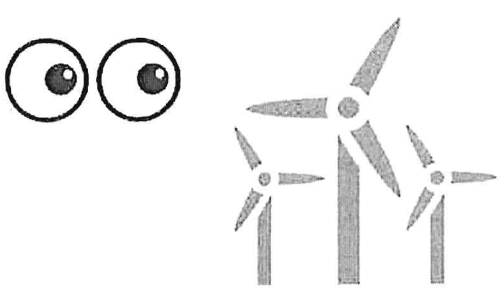
- Turbines should not be located in areas that have a large potential for biological conflicts
- Avoid large intact areas of native vegetation that haven't been disturbed by man made developments
- Avoid areas that would interfere with important wildlife migratory corridors and staging areas.

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to pass Commission **Approval Standards** including demonstrating:

Visual Impacts

includes, but not limited to:



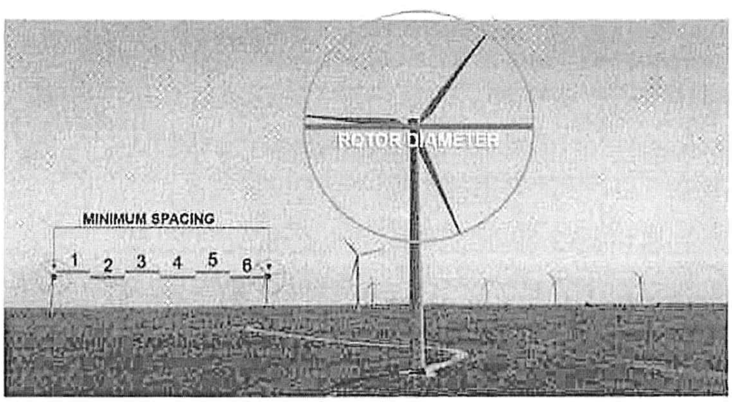
- Avoid sites that are visible from scenic byways, scenic overlooks, public parks, Conservation Areas, and Wildlife Refuges
- Supporting structures, roads, and fences on the site should be minimized
- Turbines should appear similar and shall be a shade of white

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to pass Commission **Approval Standards** including demonstrating:

Visual Impacts

includes, but not limited to:



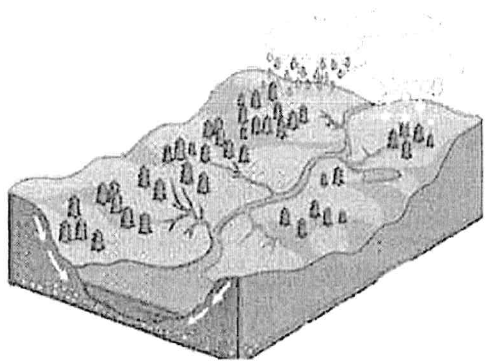
- Each turbine shall maintain a minimum spacing of six (6) times the diameter of its rotor from any other turbine
- Intra-project power lines having a voltage of 34,500 volts or less shall be buried
- Transformers and other electric equipment should be hidden from view

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to pass Commission **Approval Standards** including demonstrating:

Soil Erosion and Water Quality

includes, but not limited to:



- Avoid construction activities on slopes that are steep or susceptible to erosion
- The number of improved private access roads and construction staging areas should be kept to a minimum
- One-lane private access roads are recommended
- The number and size of staging areas should be minimized

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to **meet siting and performance standards** including:

Noise Management

includes, but not limited to:

- The average adjusted total day-night sound exposure shall not exceed 45 dBA Ldn
    - Acceptable noise level in accordance with applicable guidelines* and standards** available
- The measurements, modeling, and analysis of said study must conform to strict standards
- If the WECS-C is determined to be out of compliance, it shall be shut down until compliance can be demonstrated

* Policy based on findings from: W.H.O. ***Environmental Noise Guidelines*** *for the European Region*

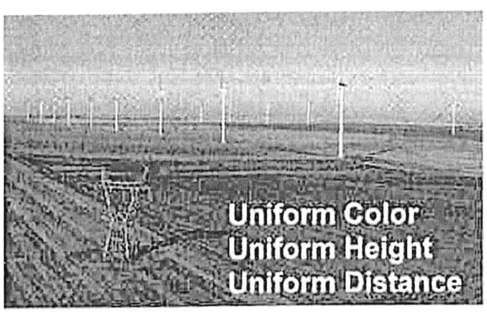
** ANSI ***Quantities and Procedures for Description and Measurement of Environmental Sound –***
Part 4: Noise Assessment and Prediction of Long-term Community Response

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to **meet siting and performance standards** including:

Visual Impacts

includes, but not limited to:



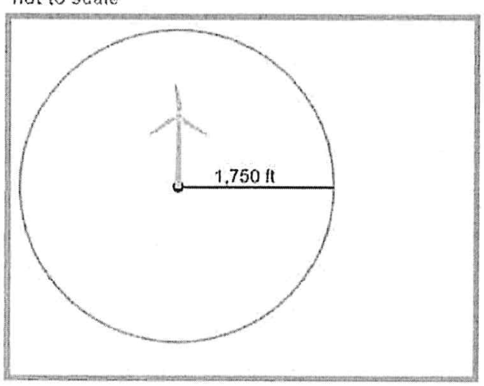
- Turbines shall have the same number of rotor blades, spinning in the same direction
- Turbines should have the same height from blade tip to the ground
- Clusters of machines shall be limited to no more than 12 machines per cluster.
- The maximum height of the turbines should be 355 feet.
- Outdoor storage is generally not permitted, except during construction

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to **meet siting and performance standards** including:

Safety

not to scale



includes, but not limited to:

- Turbine shall maintain a minimum clearance of 15-feet from the ground
- Individual wind turbines shall be set back 1,750-feet from all public road rights of way and all property lines
  - Planning and Zoning commission considered several setback* requirements as a balance between safety, equity, and other community concerns
- All WECS-C shall be equipped with an automatic fire suppression system.

* Policy based on findings from: "A method for defining wind turbine setback standards" published in the academic journal Wind Energy

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to **meet siting and performance standards** providing:

Financial Security

Ensures that the project owner provides adequate funding to pay the costs associated with:

- Decommissioning and Site Reclamation
- Removal of individual turbines and accessory structures in the event of abandonment.

Any entity providing Security must be authorized to provide such Security in the State of Missouri and must be acceptable to the County Commission.

Security = Estimated Decommissioning and Site Reclamation Cost x (1.5)

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to **meet siting and performance standards** providing:

Reclamation

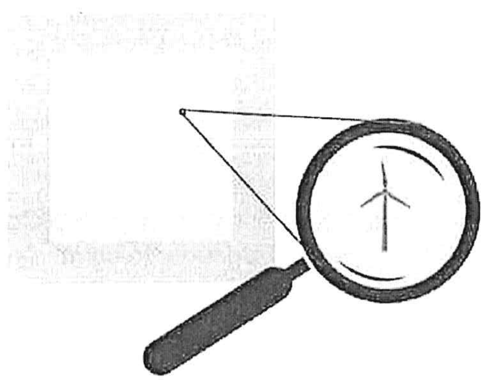
Owner Initiated: When the project has completed its life span, the owner shall abide by County standards to reclaim land. Financial Security will be released.

County Initiated: If owner has abandoned project, the County may use provided Financial Security to complete the reclamation of land after a public hearing process is completed.

Tax dollars are <u>not</u> to be spent on County Initiated Reclamation

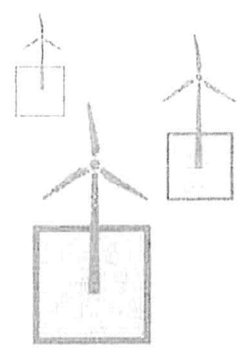
WECOD

(Wind Energy Conversion Overlay District)



CUP

(Conditional Use Permit)



CUP (Conditional Use Permit)

WECS-C Wind Turbine = CUP

Every turbine and accessory structure must be covered by a Conditional Use Permit –

- Applicant must apply for a CUP
- The CUP application must provide details ***specific*** to the structure's location and conditions

CUP (Conditional Use Permit)

The applicant would need to provide a wide variety of documentation **in addition to** the application from the *corresponding* WECOD for each CUP

including, but not limited to:

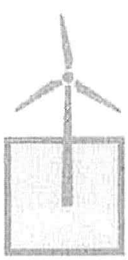
- Project Owner Information
- A detailed Site Plan
- Environmental Assessment
- A summary of the Transportation and Infrastructure Mitigation Plan
- Detail Description of Turbine(s) including size, height, rotor material, etc.
- A plan for the physical security of the individual site

CUP (Conditional Use Permit)

The WECS-C CUP **must comply with Section 15** within the Zoning Regulations in addition to the criteria laid out within these regulations.

Standard Conditions

includes, but not limited to:



- Limitation on future subdividing of land
- An annual report detailing the monthly power generated by each WECS-C
- Continually comply with U.S. Fish and Wildlife Service Land Based Wind Energy Guidelines
- All WECS-C shall be equipped with an automatic fire suppression system that meets the applicable NFPA standard or is otherwise approved by the fire district with jurisdiction.

Failure to Perform

WECOD

The County Commission shall have the authority, after a public hearing, to remove the WECOD if it determines that no WECS-C have been constructed in the District within a period of **ten (10) years** from the date of the County Commission Order that established the WECOD.

CUP

Any approved conditional use permit should be utilized within **one (1) year** of approval by the County Commission.

An invalidated permit can only be renewed by reapplication and approval as outlined within Section 15 of the Zoning Regulations.

If an applicant fails to meet **any** of the criteria outlined within the regulations, then the application shall fail. Whether or not an application meets all requirements is ultimately the decision of the County Commission.

Thank you

Events to follow:

Public Hearing – **Columbia**, Tuesday July 27, 2021

Public Meeting – **Ashland**, Wednesday, August 11, 2021

Public Meeting – **Harrisburg**, Tuesday, Aug 24, 2021

Consideration of amendment adoption to occur at a later date.

More information can be found on the Boone County website

www.showmeboone.com/resource-management/WECOD

You can also find:

- Links to the draft Regulations
- Copy of this presentation
- Wind Farm Frequently Asked Questions

Wind Farm Frequently Asked Questions

For official definitions of the following terms, please review the proposed or existing regulations.

WECOD: Wind Energy Conversion Overlay District
WECS-C: Wind Energy Conversion Systems – Commercial (aka wind turbine)

What is an "Overlay District"?
A regulatory tool that layers on top of an existing zoning district. The Overlay District modifies or supplements the regulations of the base zoning district to address special circumstances. The effect is to create a special zoning district which is placed over, and in addition to, the existing zoning.

What is a Conditional Use Permit?
A permit granted by the County Commission to allow a conditional use to occur on a specific lot.

The regulations mention "sections" and "quarter-sections" What does this mean?
Between 1815 and 1855, Missouri was surveyed into one-mile squares called sections; each section contains 640 acres. Quarter-sections are 1/4 (one-fourth) of a section containing 160 acres.

What is a Primary District in relation to a WECOD?
This is the area wind turbines may be located in. It's based on location of property proposing to establish a Wind Farm. The minimum size is 640 Acres (4 contiguous Quarter-Sections).

What is a Buffer?
A Buffer, as it relates to a Wind Energy Conversion Overlay District, is the area surrounding a Primary District and must be 1,320 feet outward (1/4 mile) around the entire Primary District. No wind turbines may be placed in the buffer area.

What happens when a wind farm is no longer commercially viable?
The owner is required to submit a Decommissioning and Land Reclamation Plan as part of the WECOD application. The owner is also required to provide financial security, in a form approved by the County Commission, that will ensure that money is available to implement the Decommissioning and Land Reclamation Plan.

Has the Boone County Resource Management office received any applications for commercial scale wind farms?
As of 7/26/2021: No

Is a wind farm, a WECS-C, and a turbine all the same thing?
WECS-C is the technical term used for a commercial turbine. The proposed regulations discuss "Clusters" of WECS-C's and this is synonymous with wind farms. (i.e. multiple turbines)

If someone attempted to build a wind farm right now, what would happen?
A commercial scale wind turbine is currently only allowed within Industrial zoning districts. Assuming that a turbine of this nature would be rather tall, then there would be an additional foot of setback for every foot the structure is above 45' tall. (i.e. 245' tall structure would have an additional 200' of setback in all directions from the standard setback requirements.) Any structure over 100' tall also requires a Conditional Use Permit subject to the approval of the County Commission

Do the proposed regulations limit the use of residential windmills for power generation?
No. Residential windmills (identified in the draft regulations as WECS-S) are currently allowed as an Accessory Use in Agriculture and Residential zoning districts. The proposed regulations only address windmills proposed for commercial power generation.

How does all of this affect the property owners?
If the proposed regulations are passed, there will be a "path" for commercial wind operations to apply to the County Commission for an Overlay District and then Conditional Use Permits for each WECS-C.
Before the application can be submitted, the property owner would need to submit a petition to the Director of Resource Management which would include a required super majority of neighbor's signatures in the proposed primary and buffer areas. If the neighbors do not feel the project is appropriate for their area, they would be able to reflect this through not signing the petition for application & the process would not move forward. However, if the neighbors *do* feel this is an appropriate use of the land then the opposite is true as well & the project can go through the application process.

What happens next?
There are 3 meetings scheduled:
Public Hearing – **Columbia**, Tuesday July 27, 2021
Public Meeting – **Ashland**, Wednesday, August 11, 2021
Public Meeting – **Harrisburg**, Tuesday, Aug 24, 2021

Consideration of adopting amendments to occur at a later date.
The County Commission will continue to review the proposed regulations after all above said meetings occur and a date has not been established for when WECOD Regulations will be up for a vote.

For more information and any updates please refer back to the dedicated Boone County Wind Farm Website: www.showmeboone.com/resource-management/WECOD

AMERICAN CLEAN POWER

July 26, 2021

Boone County Commission
801 E. Walnut St.
Columbia, Missouri

Re: Proposed Wind Energy Conversion Overlay District Regulations

Dear Presiding Commissioner Atwill, Commissioner Aldred, and CommissionerThompson:

The American Clean Power Association (ACP) appreciates the opportunity to provide additional comments on the proposed wind energy regulations. As stated in our letter to the Planning and Zoning Commission on April 26, 2021, the restrictive nature of the Wind Energy Conversion Overlay District (WECOD) regulations will make it functionally impossible to build a wind farm in the county, placing current and future development opportunities for Boone County farmers and small businesses in jeopardy. We urge you to consider our below recommendations as you evaluate adopting the proposed WECOD for Boone County.

ACP is a national trade association representing a broad range of businesses in clean energy, including wind. The wind energy industry has a long track record of success across the United States, including Missouri. Nationwide there are 171,415 megawatts (MW) of operating wind, solar, and storage capacity, that supports 300,000 clean energy jobs. In 2020, clean energy provided an estimated $1.5 billion in local communities across the U.S. through state and local property taxes, and provided an estimated $1.1 billion to U.S. farmers, ranchers, and other private landowners in the form of lease payments.[1]

Missouri has approximately 1,266 MW of operating clean energy capacity and a combined clean energy workforce of 3,200. In 2020, clean energy provided an estimated $8.2 million in state and local property taxes, and approximately $13 million in lease payments to private landowners.[2]

To continue to expand the environmental and economic benefits provided by wind energy to Missouri and Boone County, there needs to be a reasonable pathway to securing project permits. The current draft WECOD, however, does not provide such

[1] American Clean Power Association (ACP). United States Fact Sheets. https://cleanpower.org/facts/state-fact-sheets/
[2] ACP. Missouri Clean Energy Fact Sheet. https://cleanpower.org/wp-content/uploads/2021/01/Missouri-clean-energy-factsheet.pdf

202.383.2500 | 1501 M St. NW, Suite 900, Washington, DC 20005 | www.cleanpower.org

a pathway. We address some of the more restrictive components of the draft regulations below, including areas of overlap with state and federal authority, visual impacts, safety and setbacks, shadow flicker, sound, height restrictions, and decommissioning.

Definitions

"Furling" – This term is not commonly included in wind energy ordinances. It is unclear why this is included. If "furling" is interpreted by the county as pitch control, it should be noted that all modern turbines are pitch controlled; therefore, this inclusion is unnecessary and could be misinterpreted.

"Ice Throw" – The definition is misleading. An ice throw event is rare, and to date, no member of the public has been injured by an ice fragment released from a wind turbine blade and no structure has been impacted by an ice fragment. Turbines are equipped with sensors that recognize turbine blade icing, which triggers the shutdown of the turbine thereby stopping the blades from spinning. The data acquisition systems make it possible to analyze why a turbine shuts down, for example, or what may lead to one type of turbine failure or another. This analysis will lead to further improvements in operation and maintenance to maximize wind power output, as well a further reduction in what are already rare occurrences.

"Shadow Flicker" – The shadow flicker definition in the proposed regulations is too broad and misleading. Shadow flicker occurs when rotating wind turbine blades pass between the sun and an individual's home or occupied structure, casting a periodic shadow that may result in a flickering phenomenon. Shadow flicker cumulatively only occurs for a few hours per year and is more common around sunrise and sunset when the sun is low on the horizon resulting in longer shadows from the blades. There are many factors that influence duration and intensity of the shadows. ACP developed a shadow flicker factsheet[3] that provides additional information and recommendations that reasonably balance community and industry interests. The definition as written could result in unnecessary restrictions on landowners' properties, precluding landowners and residents who wish to install wind turbines from entering into agreements with a wind energy developer.

"Visual Dominance Zone" – The inclusion of this definition is problematic and adds an additional, overly burdensome "setback." It is unclear what criteria the county used to define "perceived as dominating the visual landscape," as perception is subjective, and what criteria was used to establish a visual setback of twenty (20) times the total height of the turbine. The establishment of this zone sets overly

[3] ACP. Wind Turbines and Shadow Flicker: Facts and Proven Mitigation Strategies. November 2020. https://cleanpower.org/wp-content/uploads/2021/02/Final_Shadow-Flicker-Fact-Sheet.pdf.

restrictive setback distances in addition to the Buffer Area Requirements established in Section 29.3.1.2 and the Safety Setbacks established in Section 29.8.6. of the proposed regulations. Establishment of multiple layers of setbacks would eliminate wind energy development in the county and unnecessarily restrict landowners and residents who wish to install wind turbines on their land.

"Well Designed Braking System" – The inclusion of this definition in the proposed siting regulations is unclear as is the criteria by which the county developed this definition and determined what defines "well designed." All commercially used wind turbines include braking systems designed by world-class engineers employed by the original equipment manufacturers, so this definition is unnecessary.

Intent and Purpose

Section 29.1.2 –Inclusion of this provision is unclear since wind farms are typically built-in agricultural areas on large, rural properties. Additionally, the use of "reasonably assumable future land uses" is too broad and it is unclear what the county considers reasonably assumable. Broad interpretation of this provision could result in the exclusion of large parts of the county from wind energy development, unnecessarily impeding wind energy development and disproportionately restricting landowners and residents who wish to install wind turbines on their land now in favor of some imagined future use opportunity which may never materialize.

Buffer Area Requirements

Section 29.3.1.2 – The reason for establishment of a buffer area in addition to the safety setbacks identified in Section 29.8.6 is unclear. Setback requirements are designed to protect a wind turbine's neighbors in the rare event of a tower failure, blade failure, or ice shedding from a blade while it is spinning; therefore, the addition of a 1,320-foot buffer area is duplicative of the safety setbacks, overly restrictive, and only serves to hinder wind development.

Natural and Biological Resources, and Historical, Cultural, and Archaeological Resources

Sections 29.7.2 and 29.7.5 requires an analysis of potential impacts of the project site to wildlife and vegetation, cultural, historical, and architectural resources, and landmarks with historic, religious, archaeological, scenic, natural, or other cultural significance; however, it is unclear the county's authority to regulate these resources and the process by which the county consults with the federal and state regulatory agencies that oversee the permitting process if impacts to these resources are identified. For example, the U.S. Army Corps of Engineers is responsible for review and permitting impacts to waters of the U.S. under Section

404 of the Clean Water Act, including wetlands and aquatic vegetation associated with wetlands; the U.S. Fish and Wildlife oversees the permitting process under the Endangered Species Act and the Bald and Golden Eagle Protection Act; Missouri's Department of Natural Resources oversees potential impacts to State listed threatened and endangered species and waters of the State. The Missouri State Historic Preservation Office reviews impacts to historic resources under Section 106 of the National Historic Preservation Act. Section 106 is only triggered by a federal action. The inclusion of prescriptive and duplicative processes would result in unnecessary, overly burdensome restrictions to project siting and development timelines.

Visual Impacts

Section 29.5.1.8 states that a visual simulation prepared by a "County approved third-party" is required; however, it is unclear the county's approval process and selection criteria for approving a third-party consultant. Unless a county has already established a list of county-approved qualified consultants from which a developer can choose, a project developer typically selects a qualified consult through a "request for proposal (RFP)" process.

This provision also states that the visual simulations should also include an analysis of "Any government-designated scenic byways, government-designated scenic overlooks, public parks, Conservation Areas, and Wildlife Refuges from which the project is readily visible as determined by the Resource Management Department in consultation with the applicant." "Any government" is ambiguous and misleading of the regulatory authority over these resources. Federal and state agencies such as the Department of Transportation, Wildlife agencies, and National Park Service have the regulatory authority over the official designation of and impacts to these resources. It is unclear the county's authority to designate and regulate these resources. Broad interpretation of this provision could result in the exclusion of wind energy development in the county and unnecessarily restrict landowners and residents from installing wind turbines on their land.

The criteria for determining the project requirements around minimizing "visual clutter," creating "visual unity," and avoiding "objectional density" in Section 29.7.3 is unclear. The use of vague and subjective measures in determining potential impacts is problematic and may result in broad interpretation of the regulations.

Sound

Section 29.8.2.1 requires a sound study to be conducted by "an acoustical engineer or other qualified professional as approvedby the Director of Resource Management"; however, it is unclear the county's approval process and selection criteria for approving a qualified professional. Unless a county has already established a list of county-approved qualified acoustical engineers or qualified professionals from which a developer can choose, a project developer typically selects a qualified consult through a "request for proposal (RFP)" process.

This section also states "...to demonstrate that the system does not exceed an adjusted total day- night sound exposure (Ldn) of 45 measured from the property line." This statement is problematic as "adjusted" can be interpreted in several ways and the purpose of the Ldn based limit is unclear given the 50 dBA daytime and 40 dBA nighttime limitations identified in Section 29.8.2.2. Additionally, the limitations set forth in this provision at a property line are problematic. Typically, sound limits are applied to the nearest dwelling or occupied structure, as people are likely to spend more time in their house than standing on their property line.

"Sound exposure" is unclear and could be misinterpreted. There should be clarification to mean sound level attributable to the project. For example, on a windy day or just normal ambient, one may find that without turbines the sound exposure is 45 Ldn because of interpretation of the measurement, as stated above.

Sound and Health
Peer-reviewed, scientific evidence overwhelmingly finds that properly sited wind turbines do not harm human health. The credible, scientific peer-reviewed literature on this subject is expansive (more than 80 studies worldwide). Health Canada (the Canadian equivalent of the U.S. Department of Health and Human Services) and Statistics Canada published the most comprehensive multi-disciplinary field study to date (including surveys and objective health measurements), which found that self-reported sleep issues, illnesses and stress were "not found to be associated with WTN [wind turbine noise] exposure."[4]

With respect to objective health measurements, Health Canada and Statistics Canada found, "WTN was not observed to be related to hair cortisol concentrations, blood pressure, resting heart rate or measured sleep (e.g., sleep latency, awakenings, sleep efficiency) following the application of multiple regression models."[5] Health Canada's findings were also published in Environmental Research, a professional peer reviewed journal.[6]

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[4] Health Canada. Wind Turbine Noise and Health Study: Summary of Results. https://www.canada.ca/en/health-canada/services/health-risks-safety/radiation/everyday-things-emit-radiation/wind-turbine-noise/wind-turbine-noise-health-study-summary-results.html.

[5] Ibid.

[6] Feder, K., Michaud, D. S., Keith, S. E., Voicescu, S. A., Marro, L., Than, J., Guay, M., Bower, T.J., Whelan, C., van den Berg, F. (2015). An assessment of quality of life using the WHOQOL-BREF among participants living in the vicinity of wind turbines. Environmental Research, 142, 227–238. http://doi.org/10.1016/j.envres.2015.06.043

A 2019 joint research paper from the Environmental Health Sciences Research Center at the University of Iowa College of Public Health, Iowa Policy Project, and the Iowa Environmental Council[7] similarly resulted in the following key findings:

- "To date, no peer reviewed scientific journal articles demonstrate a causal link between people living in proximity to modern wind turbines, the noise (audible, low frequency noise, or infrasound) they emit and resulting physiological health effects ..."
- "Given the evidence and confounding factors, and the well-documented negative health and environmental impacts of power produced with fossil fuels, we conclude that development of electricity from wind is a benefit to the environment. We have not seen evidence that wind turbines pose a threat to neighbors. We conclude that wind energy should result in a net positive benefit to human health."

In 2014, the Massachusetts Institute of Technology (MIT) issued a comprehensive review of scientific literature on wind turbines and human health titled "Wind Turbines and Health: A Critical Review of the Scientific Literature." The peer reviewed report prepared by a multidisciplinary team with expertise in environmental medicine, epidemiology, acoustics, otolaryngology, clinical psychology, and public health was published online in the *Journal of Environmental and Occupational Medicine*.[8] The report included a literature review of over 160 references. The findings, summarized below, are consistent with the findings of other epidemiological studies related to wind and health, including the Health Canada study:

- Measurements of low-frequency sound, infrasound, tonal sound emission, and amplitude-modulated sound show that infrasound is emitted by wind turbines. The levels of infrasound at customary distances to homes are typically well below audibility thresholds.
- No cohort or case–control studies were in this updated review of the peer-reviewed literature. Nevertheless, among the cross-sectional studies of better

[7] Thorne, Peter S., Osterberg, David, and Johannsen, Kerri. Wind Turbines and Health. https://www.iowapolicyproject.org/2019docs/190131-Wind-Health.pdf.

[8] McCunney, Robert J. MD, MPH; Mundt, Kenneth A. PhD; Colby, W. David MD; Dobie, Robert MD; Kaliski, Kenneth BE, PE; Blais, Mark PsyD. Wind Turbines and Health: A Critical Review of the Scientific Literature. Journal of Occupational and Environmental Medicine: November 2014 - Volume 56 - Issue 11 - p e108-e130. Available online at: http://journals.lww.com/joem/Fulltext/2014/11000/Wind_Turbines_and_Health_A_Critical_Review_of_the.9.aspx.

quality, no clear or consistent association is seen between wind turbine noise and any reported disease or other indicator of harm to human health.
- Components of wind turbine sound, including infrasound and low frequency sound, have not been shown to present unique health risks to people living near wind turbines.

Annoyance associated with living near wind turbines is a complex phenomenon related to personal factors. Noise from turbines plays a minor role in comparison with other factors in leading people to report annoyance in the context of wind turbines.

Safety Setbacks

Wind turbines consist of rugged but also sophisticated equipment, and operate under high wind conditions, subject to constant motion and sometimes challenging environments. Given these challenging operating conditions, wind turbines are remarkably reliable. Turbines are equipped with sensors and data acquisition systems that make it possible to analyze why a turbine shuts down or what may lead to one type of turbine failure or another. Wind companies manage this risk through detailed study and analysis, careful engineering, and cautious standard operating procedures.

As stated previously, setback requirements are designed to protect a wind turbine's neighbors in the rare event of a tower failure, blade failure, or ice shedding from a blade while it is spinning. There are more than 60,000 utility-scale wind turbines operating across the United States with blade or tower failures limited to just a few incidents in any given year. To date, there has not been one report of injury to a member of the public or a blade or ice fragment impacting a neighboring residence or structure.

A setback equal to or slightly greater than the total tower height is common and accepted practice across jurisdictions in the United States with successfully operating wind projects. There is currently no evidence to support any additional public safety benefit from longer setback requirements like the one proposed in Section 29.8.6.1 of the regulations (1,750 feet). A setback requirement of 1,750 feet would unnecessarily impede wind energy development in the county and restrict landowners from installing wind turbines on their land. In addition, as stated above, the proposed regulations impose a "visual dominance zone" setback of 20 times the total turbine height and a buffer area requirement of 1,320 feet from the wind conversion overlay district. As interpreted, a wind project would potentially be subject to setback requirements ranging from 1,750 feet to 11,070 feet – more than

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two miles (assuming a total turbine height of 400 feet), which would essentially ban wind turbines in the county.

Fire Safety

Although uncommon, fires can occur due to various reasons, including lightning strikes or short circuiting. Photos of these incidents can seem alarming, but the fires are quickly contained. Wind turbines are continuously monitored by numerous sensors and data acquisition systems that detect when there is a system failure. The sensors make it possible to analyze why a turbine shuts down, for example, or what may lead to one type of turbine failure or another. Additionally, wind turbines go through regular inspection and maintenance during the life of the project.

Smoke or fire alarm systems work in a way that detects fire through smoke, heat, flame, or gas combustion – depending on the system. Typical fire suppression systems are designed to suppress fires in various sources – isolation of the fuel, reduction of temperature, reduction of oxidizing agent (oxygen), or breaking the reaction. Given the nature of the wind turbine, there is not a one size fits all solution that would ensure that a fire would be suppressed in all possible conditions. Given the nature of the wind turbine design, many of the systems and options are limited (with the openings, joints, and rotating parts). In certain cases, a system would put the workers at a high risk and impact their safety and health.

There are several passive fire protection practices such as various engineering solutions:

- Continuous condition monitoring systems (CMS): Continuous CMS are standard within the industry. The health of the wind turbine and wind plant site is essential for optimal efficiency and reliability for the operation of a wind energy.
- Standards that design for comprehensive protection systems that include lightning and fire protection:
    - IEC 61400-1
    - IEC 61400-24
    - IEC 61400-30
    - NFPA 850, 780 and 70
- Use of different non-combustible hydraulic and lubricant oil.
- Use of flame retardant materials.

Maximum Turbine Height

The proposed regulations impose a maximum total turbine height restriction of 355 feet with a case-by-case allowance of 400 feet; however, technology innovations from the U.S. Department of Energy, other research institutions, and industry have allowed wind turbine hub heights and sizes of blades to grow and increase energy production.[9] As technology advances and industry innovation grows, it is important that regulatory frameworks allow for flexibility. In 2019, the average utility-scale wind turbine had a nameplate capacity of 2.55 MW. The average rotor diameter was 121 meters (397 feet), and the average hub height was 90 meters (295 feet)[10], resulting in an average total height of 493 feet. As of 2021, the median height of all operating wind turbines in the United States is 420 feet.[11] The maximum height restriction of 355 to 400 feet would restrict wind development in the county as it may not be feasible or economical to use smaller turbines. In fact, such a restriction may be counter-productive to the County, as it could force a developer to deploy more, but less-efficient turbines, creating more potential visual disturbance which the ordinance itself claims to want to avoid.

In 2019, utility-scale wind turbines were reaching 499 feet or taller, with many commercial wind turbines reaching 695 feet by 2021.[12] Taller wind turbines are more efficient, making it possible to cost-effectively capture the stronger wind resources at higher levels; therefore, fewer turbines are needed on the landscape. Needlessly restricting turbine height to decade-old and outdated technologies not only thwarts the innovations achieved in the industry but also would negatively impact reliability and cost-savings benefits achieved by a the constantly innovating clean power sector. Industry practice is to provide cost-effective clean energy that results in lower prices to the consumer.

Lighting

Section 29.8.6.5 indications that "lighting of turbines shall be radar activated and in compliance with the FAA [Federal Aviation Administration] Aircraft Detection Lighting System regulations." For aviation detection lighting systems (ADLS), the FAA requires the lighting be activated and flashing if an aircraft is at or below 1,000 feet above the tallest wind turbine and is approaching a three-statute mile (SM; 4.8 kilometers) perimeter around the project. Although the FAA's guidance has been published and ADLS vendors have been certified, this does not mean ADLS can automatically be installed on a project. For each project that is considering using ADLS, a request must be made to the FAA, and the FAA evaluates each request on a

[9] Department of Energy, Wind Energy Technologies Office. https://www.energy.gov/eere/wind/articles/wind-energy-grows

[10] Lawrence Berkeley Lab. Wind Energy Technology Data Update: 2020 Edition. Slide 36. https://emp.lbl.gov/sites/default/files/2020_wind_energy_technology_data_update.pdf

[11] US Wind Turbine Database Version USWTDB V4.0. https://eta-publications.lbl.gov/sites/default/files/uswtdb_v4_0_20210409_memo.pdf

[12] Ibid.

turbine-by-turbine basis.[13] The FAA can deny the ADLS usage on certain turbines due to proximity to airports, low-altitude flight routes, military training areas, or other areas of frequent activity. As a result, the county should allow developers the flexibility to work through the feasibility of such systems on wind farms with the FAA. For wind turbines to comply with FAA determinations and to ensure the safety of the National Airspace System, marking and lighting must be installed in compliance with FAA's conditions and guidance.

Decommissioning

In 2020, ACP published wind industry recommendations[14] for key provisions of decommissioning plans / rules, including specific measures that reasonably balance community and industry interests. We encourage the planning commissioners to review the industry recommendations specifically, the recommended financial assurance (security) and timing provisions.

Conclusion

It is important to note that the Lawrence Berkeley National Laboratory (LBNL) survey, the largest, most comprehensive study of its kind in the United States, found that: (1) fewer Americans than Europeans say they can hear the wind farm outside their home and fewer report being strongly annoyed by turbine sound; and (2) if a person was opposed to the project during the development phase, that person was more likely to report being able to hear the turbines and be annoyed by the noise. The LBNL study also found that, on average, most residents (92 percent) near wind projects had positive-leaning attitudes towards the wind project. The study found the positive attitudes tended to improve over time as individuals self-select into communities near existing wind projects. [15]

Overall, wind energy developers have good success at being responsible community members and business partners in Missouri and throughout the U.S. As the facilities they construct will be operating for 30+ years, our members recognize the need for extensive public engagement to fully address community concern to the greatest extent possible. We strongly urge you to engage with the wind energy industry to understand what types of requirements strike a balance that allows development to move forward while still protecting the interests of the community. We appreciate

[13] FAA Advisory Circular 70/7460-1M, last updated November 16, 2020. Chapter 13 is specific to lighting and marking of wind turbines. https://www.faa.gov/documentLibrary/media/Advisory_Circular/Advisory_Circular_70_7460_1M.pdf.

[14] ACP. Wind Project Decommissioning: Industry Recommendations. https://cleanpower.org/wp-content/uploads/2021/01/Decommissioning-Fact-Sheet.pdf

[15] Hoen, Ben, Jeremy Firestone, Joseph Rand, Debi Elliott, Gundula Hübner, Johannes Pohl, Ryan H Wiser, Eric Lantz, Ryan Haac, and Ken Kaliski. "Attitudes of U.S. Wind Turbine Neighbors: Analysis of a Nationwide Survey." Energy Policy 134 (2019).

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the opportunity to provide comments on the proposed regulations. Thank you for your consideration of the issues raised.

Sincerely,

Hilary Clark
Director, Social License

Jeff Danielson
Central Region Director, State Affairs

Daniel Hall
Central Region Director, Electricity & Transmission

Hello my name is Kendra Talbert. My husband and I live on an 80-acre Farm in Northeast Missouri, with our three kids. Our oldest, Warren, will be 15 in December, and has nonverbal autism. Our twin daughters, Avril and Vaden, will be 11 in September. They are also on the Spectrum and would have a PDD NOS diagnosis if there were still different classifications. I'll start with a short back story. Warren was born in 2006. Everything was typical, typical pregnancy, typical birth, and typical happy/healthy baby. At 3m, we noticed things were off. At 6m, it was more noticeable. At 18m, we visited Dr. Stroud at the Thompson Center, here in Columbia. When I say Warren was "off", I mean, he didnt make eye contact, he didnt really react to facial expressions, he had like 6 words. After exhausting evaluations, they determined he had some autistic tendencies, but due to his age, advised us to wait until he was a little older and if we still had concerns to come back. We recieved his official diagnosis at age 3 and it's been years of intense therapy ever since. I'm not gonna go into all the different therapy's and avenues and trainings that we've done and continue to do and he ages. For those that dont know, it's mentally, physically, emotionally, exhausting and draining!! I only want what's best for my kids, as all parents should. Warren's happiness is instrumental in how our family runs. If he's upset, it effects EVERYTHING!! With him being nonverbal, his actions and behaviors are what we watch to determine what the "problem" may be.

Last year, the Wind Turbine project was brought to my attention. We had been contacted and offered a turbine a year prior. We chose not to get one for 2 reasons. 1) we didnt work, suffer, and sacrifice to buy our farm, to destroy it with a turbine. 2) we didnt know how it would effect Warren. We heard nothing more from the turbine reps or the county about the project going ahead. So when I found out that the county was going ahead with the project I was shocked. I started researching all the effects of turbines on autistic children. Every autistic person is different and because of that I didn't know how the turbines would affect Warren. But I did know that there would be nothing I could do about it after they were constructed. I approached the Commissioners in the zoning board with some data that I had found about other family's experiences with turbines and their autistic children. I asked for further setbacks from my property line. There were two of the turbines going to be less than a mile from my property line and two turbines going to be just a little over a mile from my property line. I asked that the turbines and or transmission lines to be set back at least a mile from my property line. I had a meeting with one of the Commissioners and one of the representatives from the turbine project. I voiced my concerns about my son. They both understood and agreed that yes once the project was complete and I found out that there was issues that really there was nothing I can do to get the turbine taken down. They asked me about the two turbines that we're under a mile from my property line. Of the two they asked if the farthest one could stay if they can maybe do something about the one that was the closest. We stated that the one that was the closest was definitely the one that we were most concerned about we were not sure about the one that was second closest. I later found out through an outside source that the turbine that was in question was now being scrapped and they were going to use the alternate location. But the second closest turbine would remain. Warren went from being a kid. Was outside all the time. You would hear the door slam at 9 at night and he would be outside jumping on the trampoline. He was either swimming swinging jumping on the trampoline playing outside with the dogs whatever he can do outside whenever he could be outside and that's where he was. As soon as the truck started rolling in with all the equipment we started noticing that he wouldn't come outside. Then when he was outside he would stand and hold his hands over his ears. We'd have to force him to come out and try to do something and when he when he did he we just scream and cry until we finally just let him go back in the house and then he would be fine. That was just when they were rolling the equipment in and doing dirt work. When they actually started the construction that's when it got really bad. That's when behaviors started happening that we had never ever seen before. And it only got worse the further the construction went. Now he absolutely detest being outside, even when the turbines are not running he hates it. The flashing life drive him crazy. He has to wear a jacket when he goes outside so he can put the hood over his face and shield his eyes from the flashing lights. When the blades are turning he has to Shield his eyes from the Turning blades. When they're actually running to the point you can hear them then he has to plug his ears. It is miserable for him at our house. And it breaks my heart to think that he is so miserable that he can't even go outside and do the things that he absolutely love to do before. One of his favorite things to do at school was to swing. The teacher said that when they asked if he wanted to go swing he would always tell them no. But they would make him go outside anyway and he would go and get underneath a piece of equipment to where he could not see the turbines and cover his eyes and cover his ears and set underneath it until they were ready to go back in. He lives a life of misery oh, because of the turbines. So in turn my husband and I and his sisters live a life of misery also. This is just my experience, I'm here to share what we have gone through. It is going to take numerous extra hours and dollars for therapy to try to just get him back to where he was before this whole thing started. I'm not saying every family is going to be like that but I would hate for anybody to take that chance. About four months ago I ran into a gentleman that had been a representative 4 wind turbines. He was the one that went around and sold people on getting one. I overheard him talking about it and I started asking him questions and I told him my situation. He told me he was glad that he didn't work for a wind turbine company anymore. And that there is actually an "autism clause" that states no turbines within 1 mile of all property lines of autism families. I hope my story helps someone and reaches ears that need to hear it.

kendrajo1979@gmail.com

Zack Dunn
Director of Government Affairs
Missouri and Kansas Laborers District Council

June 27, 2021

I want to thank the commissioners for holding public hearings and for the work they are doing on this issue. My name is Zack Dunn. I am a resident of Columbia, and I have the pleasure of serving as the Director of Government Affairs for the Missouri and Kansas Laborers District Council. Our organization represents more than 200 members in Boone County. On the behalf of our members, I would like to provide input to the commissioners and seek three fundamental changes to the proposed WECOD regulations.

In 2018 our international union conducted a study on the impact windfarm local hiring practices had on communities in Minnesota. Much like Missouri is today, Minnesota was experiencing a flux of wind development across the state. Developers were bringing work crews from other states to complete the construction. Out of state work crews would often receive a per diem of $100 a day. That per diem would be the only money they spent while working on a project. When the project was complete, the workers left for different parts of the country taking their wages with them. Local workers, in comparison, live in the communities near the wind projects, and will spend their wages at local businesses, hospitals, and pay various taxes. This resulted in just one local worker contributing $40,000 more to their local community when compared to the out of state transient worker. When you compare projects that secured local hire commitments to ones that did not, the communities with local hire commitments received tens of millions of dollars more in local economic activity and tax revenue. We believe the commissioners should add local hire language that seeks commitments from developers, contractors, and subcontractors who apply for a WECOD permit. This provision would support local workers, local businesses, and our overall local community.

In addition to local hire provisions, we believe the commission should add to existing language to establish an apprenticeship program requirement. Department of Labor registered apprenticeship programs help create careers in construction and provide a highly trained workforce. Contractors who bring on an apprentice provide on the job learning and a guarantee the apprentice will have a position on their crew beyond the current project. This ensures new construction workers have a career rather than finish a project and go on an unemployment list. Additionally, contractors and subcontractors responsible for the construction of wind farms will have a trained work crew who experience fewer workplace injuries and are trained to adhere to environmental best practices.

Finally, it is clear to us that as the regulations are written, they act as an outright ban on windfarm development within the county. This status quo would mean the loss of hundreds of jobs and millions in local economic spending and tax revenue. Whether we like transition to renewable energy or not, the change is inevitable. Boone County should be a leader for other communities across the state and for the workers and businesses in our community.

I thank the Commissioners for their time and their consideration this evening.

Laborers Local 955
404 Tiger Lane
Columbia, MO 65203

26 July 2021

Boone County Commission
Daniel Atwill, Presiding Commissioner
Janet Thompson, Commissioner
Justin Aldred, Commissioner

Re: Proposed Boone County Wind Energy Conversion Overlay Regulations

Dear Board of Commissioners,

The Missouri and Kansas Laborers District Council and Laborers Local 955 represents over 200 members in Boone County. On the behalf of our members, Laborers Local 955 and the Missouri and Kansas Laborers District Council would like to submit input to the Boone County Commission and seek three fundamental changes to the proposed WECOD regulations.

The Laborers International Union has been on the forefront of studying the impacts of windfarm development on local communities. Most notably, in the state of Minnesota, we conducted a study to determine the impact local hire commitments had on local communities that were developing windfarms. We found that because non-local workers often receive a per diem, they will only spend their per diem in the community, and once the job is complete, they leave the area. This results in local workers spending on average $40,000 more in a year than a non-local worker in the community.[1] Large national and multinational developers frequently use transient work crews that will travel from job to job all over the country. Communities that do not seek local hire commitments in the permitting process will lose tens of millions of dollars in local spending and tax dollars. Boone County should adopt language that seeks to reach local hiring commitments from its developers, contractors, and sub-contractors.

Second, we have heard the concerns from community members about the safety and environmental impacts of large projects like a windfarm. One proven way to reduce safety and environmental concerns is through registered apprenticeship programs. Contractors and subcontractors that are a part of a Department of Labor registered apprenticeship program experience less workplace injuries.[2] This is because of the immense training to learn about the risks associated with the job, how to avoid those risks, and how to properly perform the job at hand. Additionally, many apprenticeship programs require classes that address issues like soil erosion or how to properly dispose of toxic waste. Safety and environmental concerns can be mitigated by a highly trained workforce.

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[1] Local spending differential between local and non-local workers can be found on table 3 in Catching the Wind 2.0. Study found here: https://d3ciwvs59ifrt8.cloudfront.net/19d28156-d283-4f19-aa25-a3a81dcfffdf/5d62076d-cfaa-4d0d-b4c2-82a55b767446.pdf

[2] "Investment in training and skill upgrading translates into fewer workplace injuries and fewer job interruptions." https://illinoisepi.org/site/wp-content/themes/hollow/docs/wages-labor-standards/pcmr-ilepi-impactofapprenticeshipprograms_newcover.pdf

Richard Fray
Boone County Commission Testimony
July 27, 2020

My name is Richard Fray, I live in Moberly, Missouri, and I am a proud member of Laborers Local 955 here in Columbia, MO. I am currently one of the workers building a wind farm in High Prairie. I am here today to share my experience working on a wind development and join my union in advocating for changes to the proposed regulations.

I have been working at the High Prairie wind farm for about a year now. My work has been erosion control, hauling and transporting, and various dirt work around the work site. This project has provided me good, consistent work, that has allowed me to earn a honest paycheck. There are a lot of guys that would love to work on a project like this if they were given the chance. From my experience in High Prairie much of the work crew is out of state. It is clear more needs to be done to ensure local workers have an opportunity to work on the wind farm developments that are happening around the state.

Boone County can seek local area hire commitments from developers applying for permits for wind farm developments. I support all efforts to secure those commitments. This allows workers like me to be a part of the transition to renewable energy and building wind turbines that the community can be proud of. Local area hire provisions also ensure money being paid to workers is being spent here in the communities we live in.

I joined my union because I wanted a good paying career, not just a job. Like any career, I had to go through training where I learned both in a classroom and on a job site. As an apprentice I learned how to safely and properly perform a wide variety of work. Not every guy on the high prairie worksite has the same level of training as me, and it shows. In addition to provisions seeking local hire commitments, I urge the commissioners to consider adding a department of labor recognized apprenticeship program partnership requirement to all contractors and subcontractors seeking work on a windfarm. This helps maintain the safety of workers and the safety of neighbors who rely on the wind turbines to be built properly.

Boone County can create hundreds of good paying construction jobs here in our communities. I would love an opportunity to work on a wind farm much closer to home. Based on testimony we have heard in the planning and zoning commission and here today, I am worried that the proposed regulations, as they are written, will prevent any wind farm project from ever being built. This would hurt our local businesses, our local governments, and most importantly our local workers. I ask you make changes necessary to provide working people an opportunity for a better living.

Thank you for the opportunity to be here today and thank you to the commissioners for sharing their time with me this evening.

Smaller Turbines Hold Up Better and with Less Health Effects

NIRTANA GOODMA · SUNDAY, 4 APRIL 2021 ·

"Dr Alan Watts of the Carcoar Medical Centre submitted that :

Small increases in the diameter of a wind turbine's rotor area can lead to substantial increases in the effects of wind speed (because the area of a circle is ([illegible] which thus results in an exponential increase in the production of sound waves (specifically infrasound or low frequency vibration). This is a problem with modern wind turbines where increasing size will potentially cause intensifying infrasound related health problems."
https://www.aph.gov.au/.../201.../impactruralwindfarms/index

The longer the turbine's blades, the more pressure is put on internal mechanisms.
Shutterstock

Taller turbines generate more power, which puts greater loads on the gearbox and transmission system, requiring mechanical engineers to develop new ways of converting the ever-increasing torque into electrical power. Taller wind turbines also need stronger support towers and foundations. The list of challenges is long.

As turbines grow, so too does the noise they make. The dominant source of noise occurs at the outer edge of the blades. Here, turbulence caused by the blade itself creates a "hissing" sound as it passes over the trailing edge. More noise is created when the blade chops through atmospheric turbulence in the wind as it blows into the tower."
https://theconversation.com/taller-faster-better-stronger-wind-towers-are-only-getting-bigger-120492

https://www.power-technology.com/features/bigger-is-not-always-better-how-small-scale-wind-turbines-could-save-the-sector/

330–600+ feet high

Blades sweeping
1–2 acres vertical area,
tip speed 150–200 mph

Dead birds and bats

Displaced ground animals

Noise and vibration

Hundreds of tons of concrete
and steel in each foundation

Storm runoff, altered hydrology

Roads and transmission lines

Fragmented wildlife habitat

Shadow flicker

Strobe lights day and night

Visual intrusion and distraction

Degradation of social and
natural environments

Misplaced public funds

Unreliable contracts

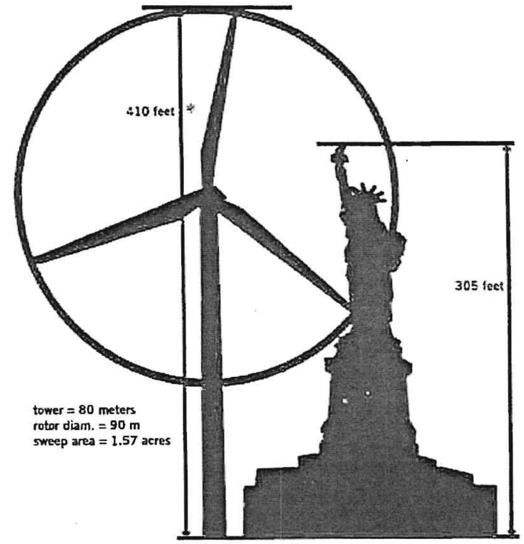
Unproven benefits

Learn more!

National Wind Watch
(www.wind-watch.org)

Industrial Wind Energy Opposition
(www.aweo.org)

Haystack and Jay Peak, Vermont. Used by permission.



SAY NO!
to destroying the environment and our communities

NO INDUSTRIAL WIND!

**New wind turbines are now over 600 feet in height.*

1. Audible sound
2. Inaudible sound and vibration/pulsation
3. Accompanying sleep deprivation that
4. May cause negative health issues.
5. Higher electricity rates
6. Loss of property value
7. Shadow flicker
8. Barely 35% efficient. Need back up fossil fuel plants that run constantly creating nothing but pollution.
9. Trespass Zoning (uncompensated easement without permission)
10. Miles and miles and miles of additional transmission lines above and below ground.
11. Red flashing warning lights
12. Weak or NO decommissioning language in wind ordinances that can result in eye sores for generations.
13. Oil leaks from wind turbine
14. Ice throw
15. Blade throw
16. Fire in the Nacelle
17. Wind turbine collapse
18. Stray/Induced Voltage
19. Possible damage to water in water wells depending on layout and location of wind turbine.
20. Aesthetics
21. Damage to wildlife, domestic and farm animals
22. Bird and BAT kills especially raptors
23. MASSIVE gov't handouts oil. nuclear, and natural gas don't receive anywhere near that amount.
24. Reduction in economic growth and expansion
25. Interference with emergency radio, tv, and cell phone reception.
26. Interferes with crop dusting
27. Mercy flight interference
28. Damaging to economy of tourist areas
29. Destruction of the social fabric in smaller communities
30. Toxic/radioactive pollution from mining rare earth minerals used in wind turbine magnets.
31. Interference with weather radar

PUBLIC HEALTH STATEMENT

Re:

Injunction Proceedings against High Prairie Wind Farm

by

Mariana Alves-Pereira, Ph.D.

August 5th, 2019

Brief Biographical Background
(Full *Curriculum Vitae* and *List of Publications* is included in Appendix 1 of this Statement.)

Mariana Alves-Pereira holds a B.Sc. in Physics (State University of New York at Stony Brook), a M.Sc. in Biomedical Engineering (Drexel University) and a Ph.D. in Environmental Sciences (New University of Lisbon). She joined the multidisciplinary research team investigating the biological response to infrasound and low frequency noise in 1988, and was the team's Assistant Coordinator from 1999 until 2015. Recipient of three scientific awards, and author and co-author of over 50 scientific publications (including peer-reviewed and conference presentations), Dr. Alves-Pereira is currently Associate Professor at Lusófona University (Lisbon, Portugal) having taught Biophysics and Biomaterials in health science programs (nursing and radiology), as well as Physics and Hygiene in workplace safety & health programs. Additionally, she now actively contributes to an International Consortium of Scientists investigating the health effects of infrasound and low frequency noise among human and animal populations, in both occupational and residential settings. Prof. Alves-Pereira is a U.S. citizen and can readily be reached at: m.alvespereira@gmail.com.

To the Presiding Judge,
Missouri Circuit Court

I respectfully request that my Statement be considered within these proceedings given the grave nature of Public Health issues that are at stake for the citizens of Schuyler (and Adair) counties.

1. Purpose of this Statement

On August 1, 2019, I received an email from Ms. Carrie March, of Queen City, MO, requesting that I submit this Statement, given my extensive expertise on the matter of the health effects caused by long-term exposure to *infrasound and low frequency noise*—a type of toxic pollutant that is generated by wind turbines.

2. Why is there an issue?

Under the current proposal for the High Prairie Wind Power Station (a.k.a. 'wind farm'), the home of Ms. Carrie March will be surrounded by 16 turbine towers within a 1.8-mile radius (approximately 3 km or 10 000 ft)[1]. (See Figs. 1 thru 3.)

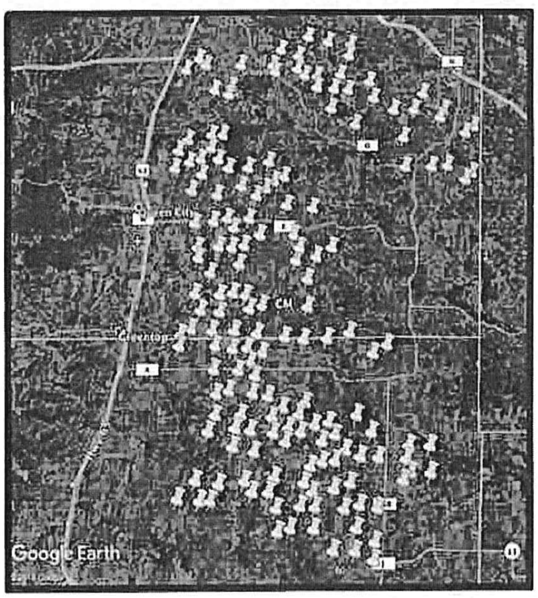


Figure 1. Google Earth image showing the proposed High Prairie Wind Power Station, with wind turbine towers in yellow and the home of Ms. Carrie March in red (CM). (North points upward.)

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[1] A 3 km (1.8 mile) cutoff was decided upon for the presentation of this Statement to facilitate comparison with other (scientifically published) cases and that will also be presented herein.

Figure 2. Google Earth image showing a closer view of the wind turbine towers (yellow) and the home of Ms. Carrie March (red-CM).

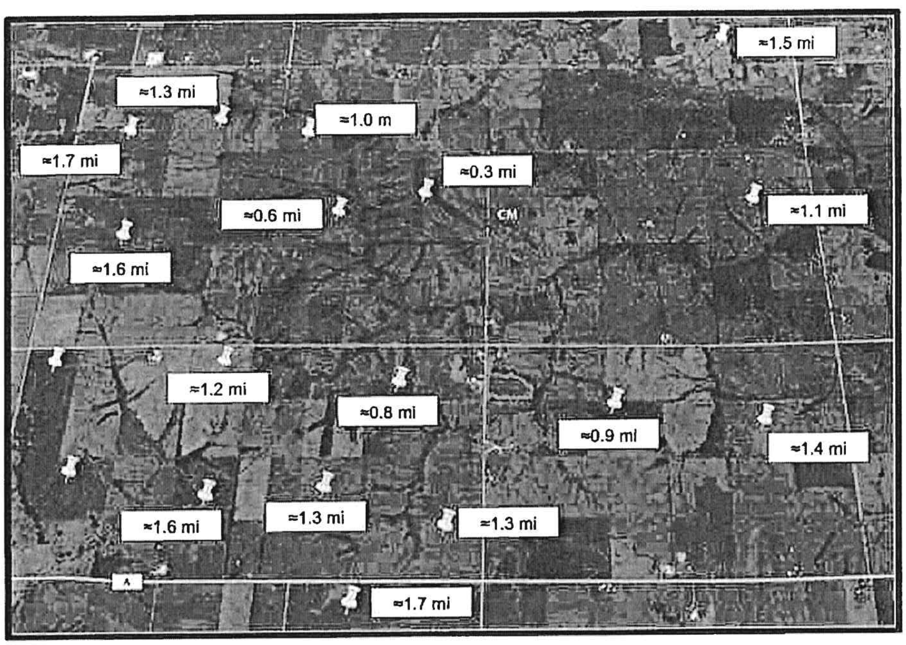

Figure 3. Google Earth image showing the turbine towers (yellow) located within ≈1.8 miles (≈ 3 km) from the Carrie March home (red-CM). (North points upward.)

3. What is this Toxic Pollutant?

Formally, it is called "infrasound and low frequency noise" (ILFN).
Typically, it comes under the category of 'noise' and / or 'non-ionizing radiation.'
In the Unites States, this type of 'noise' is not legislated.

4. What happens to people's health when this toxic pollutant is in their homes due to the close proximity of wind power stations?

It is a gradual process—not like a 'zapping' action. Initially, after wind power stations are fully commissioned near residential dwellings, families may not feel an immediate impact. This lulls them into a sense that "everything will be fine," and they remain within the toxic environment.

However, often within the first 5-7 months of exposure, family members will begin to wake up tired. They will begin to feel increasingly annoyed and more aggressive, particularly if there is a history of prior ILFN exposure (such as military duty, for example), or if family members are pubescent or pre-pubescent adolescents. In ILFN-contaminated homes, families *sleep in* the toxic environment, greatly accelerating the onset of debilitating disease.

Sleep deprivation and the likely development of brain lesions in the hippocampus (as seen in laboratorial experiments) and brainstem (as seen in exposed workers), begin to explain the cognitive impairment displayed by these individuals, sometimes accompanied by uncontrolled emotional states or transient absences of consciousness. As exposure time accumulates, increasingly disabling health conditions develop. These can comprise the respiratory and gastrointestinal systems, as well as the organs of vision and hearing. Since citizens are forced to remain in their homes under these toxic circumstances, severe and debilitating health deterioration is merely a question of time.

Until recently, the effects of ILFN on health were mostly investigated within the context of occupational settings. These studies were designed to investigate various types medical outcomes while simulating occupational exposures, i.e., large amounts of infrasound exposure during several hours per day. When ILFN is in the home, levels can be significantly lower than in occupational settings, but *exposure time is much longer and can occur during sleep-time*, i.e., the worker goes home (ceases exposure) at the end of the work-shift, but no such respite exists in situations of residential contamination.

Appendix 2 provides a Book Chapter[2] dedicated to this topic, as well as a Summary of the chapter for laypersons.

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[2] Alves-Pereira M, Rapley B, Bakker HHC, Summers R. (2019) Acoustics and Biological Structures, IN: Acoustics of Materials. Abiddine ZE, Ogam E (eds). IntechOpen, London. — Appendix 2
DOI: 10.5772/intechopen.82761. https://www.intechopen.com/online-first/acoustics-and-biological-structures

5. How could this possibly be true? There would be sick people everywhere!

- **Case Report 1[3]: Ireland—Abandoned Home**

Figure 4 shows a home in Ireland that had to be abandoned given the onset of severely debilitating health issues (*ongoing legal proceedings*).

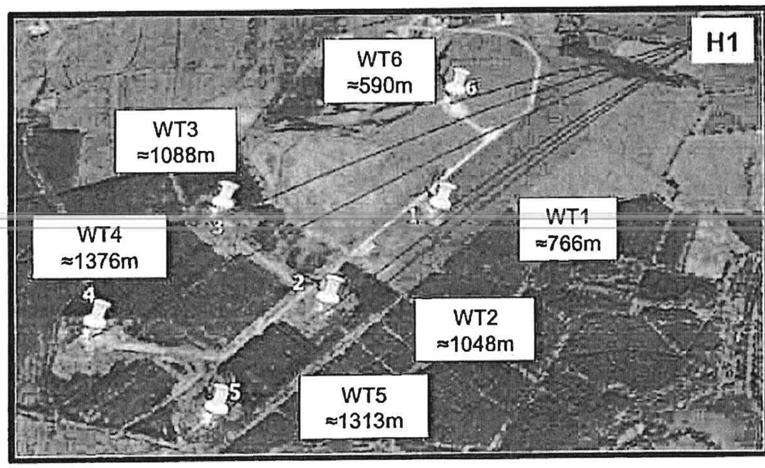

Figure 4. Google Earth image showing 6 wind turbine towers (yellow) located between ≈0.3 miles (590 m) and ≈0.8 miles (1376 m) from a residential dwelling (H1) —Ireland. (North points upward.)

Please note the reduced amount of wind turbines as compared to the Carrie March home (6 *versus* 16).

Also note that the 6 wind turbines in Ireland do not surround the home on all cardinal directions, contrary to what occurs with the March home which has turbine towers in practically all directions (see Fig 3).

In this home, the youngest child (age 7) was formally diagnosed with epilepsy. The oldest child (age 19) was formally diagnosed with post-traumatic stress disorder.

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[3] Alves-Pereira M, Bakker HHC, Rapley B, Summers R (2018). Infrasound and Low Frequency Noise – Does it affect human health? Engineers Ireland Journal, Jan 23. — Appendix 3. http://www.engineersjournal.ie/2018/01/23/ilfn-infrasound-low-frequency-noise-turbine-health/

- **Case Report 2[4]: Germany—Abandoned Bedroom & Bunker Bedroom**

Figure 5 shows a home in Germany where 20 turbine towers were erected in the southern and eastern sides of the home (*ongoing legal proceedings*).

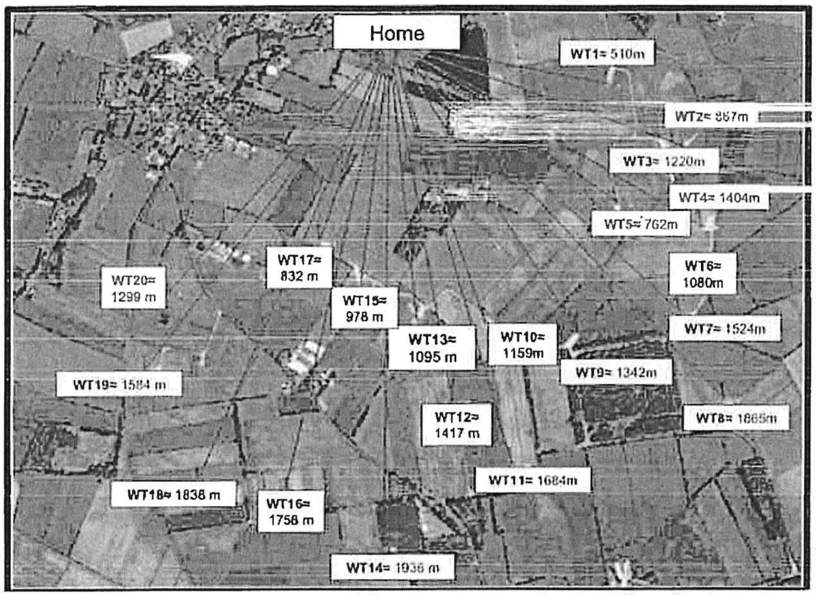


Figure 5. Google Earth image showing 20 wind turbine towers located between ≈0.3 and ≈1.2 miles (0.5—2 km) from a residential dwelling —Germany. (North points upward.)

Again, as with the Irish home, the turbine towers do not surround the home in all cardinal directions, although there is a slightly larger density of machines in this German case than in the March home.

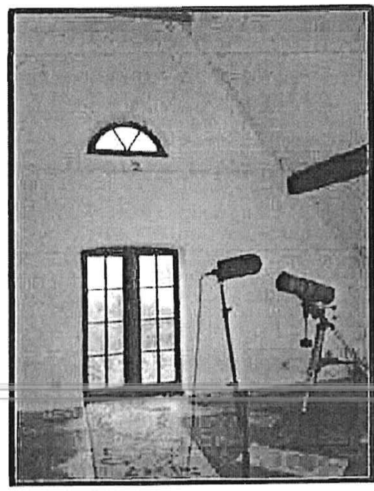
These German homeowners develop their business at this location and are, therefore, unable to abandon their home. Their teenage children, however, were promptly sent away to boarding schools given their accelerated and very evident behavioral and metabolic changes. The health deterioration of this family has been documented in the German media (see Appendix 4).

In order to be able to continue running their business, this German family was forced to abandon their master bedroom and construct an underground bunker so as to achieve some sort of respite against the aggression of this toxic pollutant. Figure 6 shows the abandoned and bunker bedrooms.

[4] Alves-Pereira M, Krough C, Bakker HHC, Summers R, Rapley B (2019) Infrasound and low frequency noise guidelines – Antiquated and irrelevant for protecting populations. Proceedings of the 26th International Congress on Sound & Vibration, Montreal, Canada, July 7-11, 2019—Peer-Reviewed Conference Paper. – Appendix 4

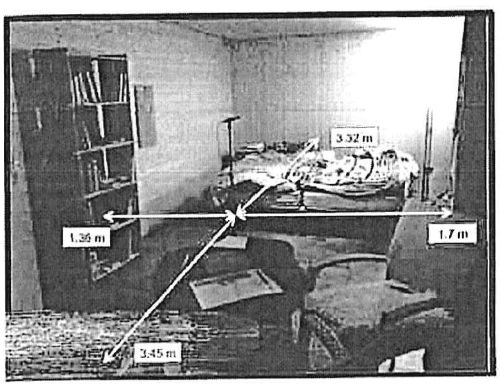
Figure 6.

A



(A)
The Master Bedroom facing East and overlooking the neighboring lake (see Fig. 5) — Abandoned due to ILFN contamination.

B



(B)
The Bunker Bedroom is built deep underneath the home, where respite from the toxic pollutant is achieved "except when the winds are from the East."

In the Bunker Bedroom, respite from the toxic pollutant is achieved "except when the winds are from the East." This is easily explained by looking at Figure 5, showing the towers closest to the home on the eastern side of the property.

This family seeks to sleep away from their home as frequently as possible.

- **Case Report 3[5]: Denmark—Abandoned Home and Collapsed Business**

Figure 7 shows a home in Denmark where the owners owned and operated a mink farm since 1990 (*ongoing legal proceedings*).

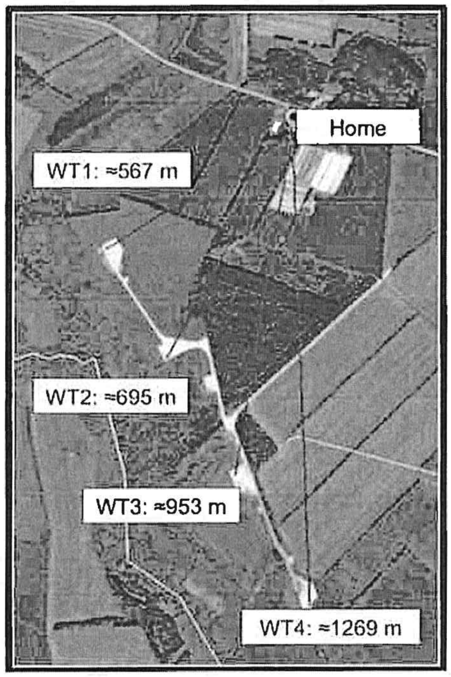


Figure 7. Google Earth image showing 4 wind turbine towers located between ≈0.3 and 0.7 miles (567 - 1269 m) from a residential and mink farm complex —Denmark. (North points upward.)

These 4 turbine towers began operating in 2013. The home was abandoned in 2015. Even though the family no longer inhabited the home, the mink farm continued operations, requiring the property- and farm-owner to remain on the location for extended periods of time.

In 2018, the 57-year-old property owner was formally diagnosed with post-traumatic stress disorder. The mink farm formally closed down in January 2019, after massive amounts of (documented) animal death.

The residence of Ms. Carrie March is slated to have 16 towers within ≈0.3 and 1.8 miles.

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[5] Alves-Pereira M, Bakker HHC (2017) Occupational and Residential Exposures to Infrasound and Low Frequency Noise in Aerospace Professionals: Flawed Assumptions, Inappropriate Quantification of Acoustic Environments, and the Inability to Determine Dose-Response. Scientific J Aerosp Eng Mech 1(2):83-98. — Appendix 5.

6. If it is really the case that wind turbines produce a toxic acoustic pollutant, then why are wind power stations being built all over the world?

Apparently, mostly due to ignorance, but perceived economic benefits are also playing an important role.

7. What is the safe distance between wind power stations and residential areas?

Science does not know.

Wind turbine acoustics signatures have been documented in a home 12 km (≈7.4 miles) away from the nearest tower (unpublished data gather by our field-studies).

Other teams in Finland (The Aunio Group[6]) and Australia (Flinders University[7]) have also documented infrasound levels in homes 'far away' from the wind power station responsible for the emissions.

8. *You will be told that:* Infrasound cannot be heard by humans and therefore poses no threat to human health.

This position perpetuates a scientifically indefensible position: *what you can't hear won't hurt you.*

This is an ancient assumption, stemming from early 20th century work on the telephone. Given the necessity of focusing on human speech intelligibility and hearing in order to perfect telephone communications, all parts of 'sound' that were inaudible to humans were deemed irrelevant.
Please see the publication offered in Appendix 3 for more historical details.

There are countries that *do have* specific legislation enacted in order to protect their populations against infrasound.

Figure 8 gives an example of permissible exposure levels for *both* occupational and residential situations, specifically for 2, 4, 8 and 16 Hz—all within the infrasound range.

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[6] https://www.auniogroup.com
[7] https://news.flinders.edu.au/blog/2019/06/19/wind-farm-noise-recorded-almost-9km-away/

No.	Premise	Sound pressure levels, dB, in octaval bands of averaged geometric frequencies, Hz				General sound pressure level dB "Lin"
		2	4	8	16	
1.	Different jobs inside industrial premises and production areas:					
	- Different physical intensity jobs	100	95	90	85	100
	- Different intellectual emotional tension jobs	95	90	85	80	95
2.	Populated area	90	85	80	75	90
3.	Living and public premises	75	70	65	60	75

Figure 8. Legislated permissible exposure levels for infrasound in different situations.[8]

9. *You will be told that:*
Wind power stations exist in many countries and no one is complaining.

That would be an untruth.

10. *You will be told that:*
Because of 'global warming,' wind power stations are of crucial importance.

That would be another untruth, even recently verified by researchers from Harvard University:

> *In two papers — published today in the journals Environmental Research Letters and Joule — Harvard University researchers find that the transition to wind or solar power in the U.S. would require five to 20 times more land than previously thought, and, if such large-scale wind farms were built, would warm average surface temperatures over the continental U.S. by 0.24 degrees Celsius.*[9]

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[8] In: Stepanov, V. Biological Effects of Low Frequency Acoustic Oscillations and their Hygienic Regulation. State Research Center of the Russian Federation: Moscow (2000). https://apps.dtic.mil/dtic/tr/fulltext/u2/a423963.pdf

[9] Burrows, L (2018) The down side to wind power. The Harvard Gazette, 4 October. https://news.harvard.edu/gazette/story/2018/10/large-scale-wind-power-has-its-down-side/

11.
Residential ILFN Contamination

Figures 2 and 3 refer specifically to the residence of Ms. Carrie March.
Figure 1, however, suggests that many more residential dwellings may impacted by the High Prairie Wind Power Station.

Figures 9 and 10 provide a view of several, other residences located near the home of Ms. Carrie March, and some of the wind towers in *their* vicinity.

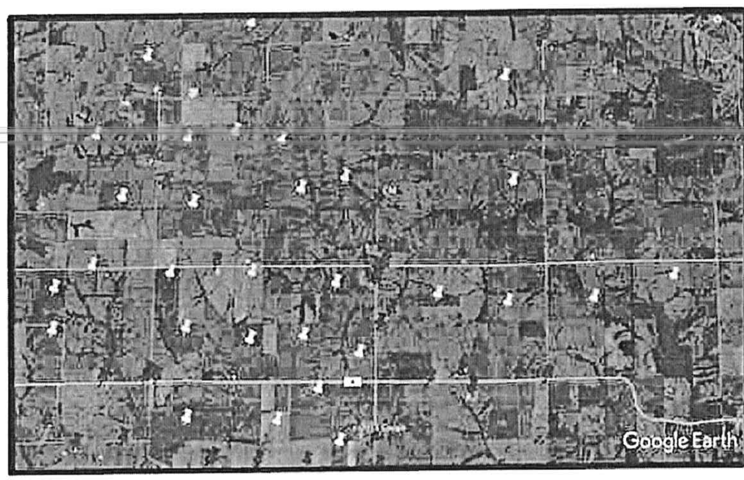

Figure 9. Google Earth image showing other homes (red) near the Carrie March residence (CM) and that are also in close proximity to turbine towers (yellow).

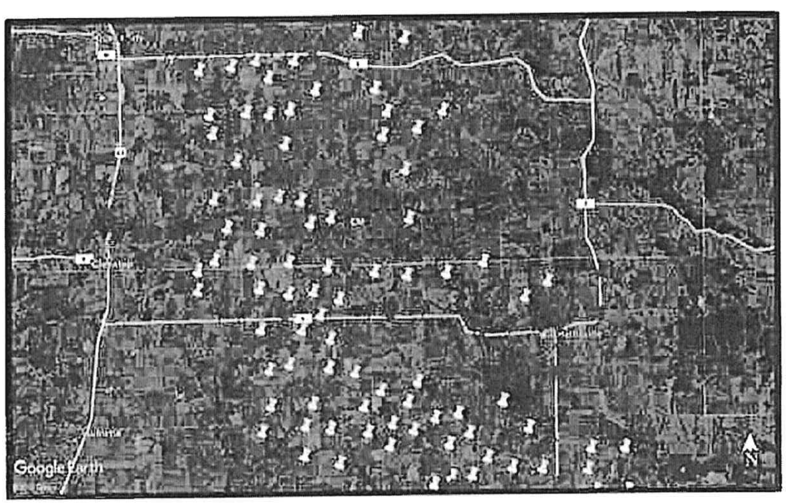

Figure 10. Google Earth image showing other homes (red) near the Carrie March residence (CM) and that are also in close proximity to turbine towers (yellow).

A perusal of Figures 9 and 10 shows that many other family dwellings have a very high probability of having ILFN contamination in their homes.

In my opinion, it is highly likely that in each and every one of these homes, citizens' health will become severely impacted.

12.
Precautionary Principle

The very debilitating adverse health effects caused by ILFN exposure have been scientifically documented in occupational settings since the 1960's.
Science already knows what happens to the (proverbial) canary in the mine.

Wind power stations are the latest type of industrial complexes that are bringing toxic ILFN into the homes, often continuously over a 24-hour period.

To my knowledge, there is no formal 'noise' guideline or ordinance in the State of Missouri that can provide any basis for curtailing the emissions of this agent of disease.

Just as with asbestos, second-hand smoking, and leaded fuels or, more recently, plastics and glyphosate products, the health effects were made evident *before* legislative bodies enacted clauses for the specific purpose of protecting the health of human populations.

Curriculum Vitae

Personal information

First name / Surname **Mariana Alves-Pereira**

Address Rua do Viveiro, 402, 1E
Estoril 2765-294 Portugal

Telephone Mobile: +351-961753209

E-mail m.alvespereira@gmail.com
Skype marianna-alves-pereira

Nationality USA/ EU

Academic Background

Date 2010
Title of qualification awarded **Doctoral degree in Environmental Sciences**
Name and type of organisation providing education Universidade Nova de Lisboa, Caparica, Portugal

Date 2000
Title of qualification awarded **Masters degree in Biomedical Engineering**
Name and type of organisation providing education Drexel University
Philadelphia, PA, USA

Date 1995
Title of qualification awarded **Bachelors degree in Physics**
Name and type of organisation providing education State University of New York
Stony Brook, NY, USA

Dates 1990
Title of qualification awarded **12th year High School Diploma**
Name and type of organisation providing education Algés Secondary School
Lisbon, Portugal

Dates 1988
Title of qualification awarded **10th-11th years High School – Area of Technological Sciences**
Name and type of organisation providing education Fontes Pereira de Melo Secondary School
Porto, Portugal

Scientific Awards

2006 - Prevent More Live Better Scientific Research Award
Diagnosis of Vibroacoustic Disease for Legal & Forensic Purposes.
Attributed by the Instituto de Segurança Higiene e Saúde no Trabalho (Portuguese Governmental Institute for Safety, Hygiene & Health in the Workplace).

2005 - Thomé Villar/Boehringer Ingelheim Research Award
Participation of the Central Airways in Vibroacoustic Disease.
Attributed by the Portuguese Lung Society (Sociedade Portuguesa de Pneumologia).

1999 - Young Investigator Award Finalist
Pericardial Thickening in Commercial Airline Flight Crew.
Attributed by the Space Medicine Branch of the Aerospace Medical Association (USA).

Expertise

Acoustics	Infrasound and low frequency noise (ILFN) exposure. Conducted extensive acoustical measurements and analyses in 1/3- and 1/36-octave band, dB Linear, within industrial, urban and residential areas.
Clinical Medicine	Design, implementation and data analyses of clinical studies pertaining to ILFN-exposed populations, including gathering of patient medical and noise exposure histories.
Cellular Biology	Interpretation of light and electron microscopy imaging comparing ILFN-exposed vs. non-exposed cell and tissues of both human and animal models. Analyses of the biological responses to ILFN exposure based on principles of materials and structural engineering and on cytoskeleton dynamics.
Bioengineering	Analysis and interpretation of the response of actin- and tubulin-based structures to ILFN exposures. First to associate cellular and tissue tensegrity architecture to better understand the biological response observed in ILFN-exposed specimens.
International Expert Witness & Consultant	-- Vibroacoustic Disease -- Effects of ILFN on occupationally- or environmentally-exposed human populations.

Teaching Experience

Associate Professor since 2010
Adjunct Professor since 2005.
Assistant Professor since 2002

Dates	Since 2009	
Main activities and responsibilities	Coordinating/ Teaching:	Physics (Occupational Safety & Health Program) Epidemiology (Occupational Safety & Health Program) Workplace Safety & Health (Safety & Security Program)
Name and address of employer	School of Economic Sciences & Organizations Universidade Lusófona Campo Grande 376, 1749-024 Lisbon, Portugal	
Type of business or sector	Higher education	
Dates	2007-2013	
Main activities and responsibilities	Teaching:	Biophysics Lab (Pharmaceutical Sciences Program)
Name and address of employer	School of Health Sciences and Technologies Universidade Lusófona Campo Grande 376, 1749-024 Lisbon, Portugal	
Type of business or sector	Higher education	
Dates	2005-2007	
Main activities and responsibilities	Teaching: Coordinating/ Teaching:	Physics (Nursing Program), Biomaterials (Pre-Bologna Radiology Program) Non-ionizing Radiation (Pre-Bologna Radiology Program) Experimental Statistics (Pre-Bologna Radiology Program)
Name and address of employer	Ribeiro Sanches School of Health Sciences Universidade Lusófona Rua dos Telhais aos Olivais, 8-8ª, 1900-693 Lisbon, Portugal	
Type of business or sector	Higher education	
Dates	2002-2005	
Main activities and responsibilities	Coordinating/ Teaching:	Acoustical Pollution (Environmental Engineering Program)
Name and address of employer	Department of Environmental Sciences & Engineering Universidade Nova de Lisboa Quinta da Torre, 2829-516 Caparica, Portugal	
Type of business or sector	Higher education	

Work Experience

Dates	1988-2013
Occupation or position held	**Senior researcher, Assistant Coordinator for the Vibroacoustic Disease Project**
Main activities and responsibilities	Measure low frequency noise; Patient interviews; Interpreting electron microscopy imaging; Data analyses; Preparation of scientific papers for publication; Oral presentations at international scientific meetings and conferences; Organization of scientific conferences; Expert court witness.
Name and address of employer	Centro da Performance Humana, Estrada Nacional 10, Edificio Cinema, 1º Piso, 2615 Alverca, Portugal
Type of business or sector	Biomedical research in occupational medicine (non-for-profit enterprise)

Dates	2010-2012
Occupation or position held	**Administrator**
Main activities and responsibilities	Liaison between NASA officials and European Governmental officials and private enterprises; Procure projects, actions and activities related to sustainable energy and environmental issues of mutual interest to NASA; Preparation of status reports; Oral presentations of ongoing projects at NASA/C3P Annual Technical Workshops.
Name and address of employer	Center for Pollution Prevention (C3P)
Type of business or sector	Ministry of Environment (non-for-profit enterprise)

Dates	2002-2005
Occupation or position held	**Fellowship recipient**
Main activities and responsibilities	Write, enact and develop research project funded by Portuguese Government (POCTI/FCT): "Low frequency noise in public transportation systems in the Greater Lisbon area"
Name and address of employer	IMAR – Instituto do Mar, Pólo da Faculdade de Ciênicias e Tecnologia, Universidade Nova de Lisboa, Quinta da Torre, 2829-516 Caparica, Portugal
Type of business or sector	Higher education / Research

Dates	Feb-Jul 2000
Occupation or position held	**Associate researcher**
Main activities and responsibilities	PCR studies investigating the genetic expression of ubiquitin and ciclogenase-2 in cells exposed to cadmium.
Name and address of employer	Department of Biological Sciences, Hunter College, City University of New York
Type of business or sector	Higher education / Research

Dates	1991-1995
Occupation or position held	**Librarian**
Main activities and responsibilities	Catalogue new books and scientific journals; Manage book lending; Assist with inquiries.
Name and address of employer	Math/Physics Library State University of New York, Stony Brook, NY, USA
Type of business or sector	Academic

Dates	1988-1990
Occupation or position held	**Technical translator**
Main activities and responsibilities	Quality control inspection manuals for the Lockheed C-130 Hercules, P-3P Orion, and Aerospatiale SA-330 Puma aircraft; Avionics, fuel systems and ground support equipment manuals; Scientific research papers developed by the Medical Division Research Team.
Name and address of employer	OGMA-Indústria Aeronautica de Portugal Parque Aeronautico de Alverca, 2615-173 Alverca, Portugal
Type of business or sector	Aeronautical industry

Dates	1982-1985
Occupation or position held	**Summer-hire** (Commercial Section, US Air Force Section, US Information Services)
Main activities and responsibilities	Administrative tasks; Written and simultaneous translations; Public relations. In 1985, collaborated in the organization of President Ronald Reagan's official visit to Lisbon.
Name and address of employer	United States Embassy Av. das Forças Armadas, 1600-081 Lisbon, Portugal

Training Programs

Dates	2001
Title of qualification awarded	**Epidemiological Surveillance Technician**
Name and type of organisation providing education	Institute of Preventive Medicine, School of Medicine, University of Lisbon
Dates	1990
Title of qualification awarded	**C-130 Hercules: Specialization in Engine, Propellers and Auxiliary Power Unit.**
Name and type of organisation providing education	Lockheed Martin Official Training Center OGMA-Indústria Aeronautica de Portugal Parque Aeronautico de Alverca, 2615-173 Alverca, Portugal
Dates	1987
Title of qualification awarded	**Computer programmer** (DOS, DBase III, Cobol, WordStar)
Name and type of organisation providing education	Instituto de Tecnologia Avançada para a Educação Porto, Portugal

Languages

Native speaker:	**English/Portuguese**
Other languages:	**French, Spanish**

Relevant publications

Alves-Pereira M, Bakker HHC (2017) *Occupational and residential exposures to infrasound and low frequency noise in aerospace professionals: Flawed assumptions, inappropriate quantification of acoustic environments, and the inability to determine dose-response.* Scientific Journal on Aerospace Engineering and Mechanics, 1(2):83-98.

Alves-Pereira M, Castelo Branco NAA (2007) *Vibroacoustic disease: Biological effects of infrasound and low frequency noise explained by mechanotransduction cellular signaling.* Progress Biophysics & Molecular Biology, 93: 256-279.

Alves-Pereira M, Joanaz de Melo J, Castelo Branco, NAA (2005) *Pericardial biomechanical adaptation to low frequency noise stress.* In: A. Méndez-Vilas (ed.) Recent Advances in Multidisciplinary Applied Physics. Elsevier: London, 2005: 363-7. (ISBN: 978-0-08-044648-6)

Alves-Pereira M (1999) *Noise-induced extra aural pathology. A review and commentary.* Aviation, Space and Environmental Medicine, 70 (3, Suppl.): A7-A21.

(Annex I: Complete List of Publications)

LISTING OF SCIENTIFIC PUBLICATIONS

Mariana Alves-Pereira, Ph.D.

2019

Alves-Pereira M, Rapley B, Bakker HHC, Summers R. (2019) **Acoustics and Biological Structures** IN: Acoustics of Materials. Abiddine ZE, Ogam E (editors). IntechOpen, London. DOI: 10.5772/intechopen.82761.
https://www.intechopen.com/online-first/acoustics-and-biological-structures

Alves-Pereira M, Bakker HHC, Rapley B, Summers R. (2019) **Residential acoustical environments with predominant lower-frequency components: Why measuring inside the home is important. – Submitted for publication**

Alves-Pereira M, Krough C, Bakker HHC, Summers R, Rapley B (2019) **Infrasound and low frequency noise guidelines – Antiquated and irrelevant for protecting populations. – Submitted for publication**. Proceedings of the 26th International Congress on Sound & Vibration, Montreal, Canada, July 7-11, 2019. (Peer-Reviewed Conference Paper, No. 682)

2018

Alves-Pereira M, Bakker HHC, Rapley B, Summers R. (2018). **Infrasound and Low Frequency Noise – Shall we measure it properly?** Engineers Ireland Journal. (Jan 23)
http://www.engineersjournal.ie/2018/01/23/ilfn-infrasound-low-frequency-noise-turbine-health/

2017

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Infrasound and Low Frequency Noise – Shall we measure it properly?

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On the *Engineers Ireland* website, a search on "infrasound" or "low frequency noise" yields zero results. A search on "noise" however, yields 39 results. Why is it that infrasound and low frequency noise (ILFN) is still such a taboo subject? While it is improbable that this particular question will be answered here, an exposé of ILFN will be provided with a brief historical account of how and why ILFN was ultimately deemed irrelevant for human health concerns.

Infrasound and Low Frequency Noise (ILFN) are airborne pressure waves that occur at frequencies ≤ 200 Hz. These may, or may not, be felt or heard by human beings. In order to clarify concepts, in this report the following definitions are used: *acoustic phenomena:* airborne pressure waves that may or may not be perceived by humans; *sound:* acoustic phenomena that can be captured and perceived by the human ear; *noise*: sound that is deemed undesirable; *vibration:* implies a solid-to-solid transmission of energy.

Harvey Fletcher, the Telephone and the deciBel

In the early part of the 20th-century, Harvey Fletcher of the Western Electrics Laboratories of AT&T, was tasked with improving the quality of reception in the telephone. To generate the sounds in a telephone earpiece, he used an a.c., voltage and had some of his colleagues rate the loudness of the sound received compared to the quietest tone heard. The company was already using a logarithmic scale to describe the power in an electrical cable and it made sense to rate the loudness of the sounds also on a logarithmic scale related to the quietest voltage that could just be heard. Initially he called this metric a "sensation unit" but later to commemorate their founder Alexander Graham Bell, they renamed it the "Bel." A tenth of a Bel became known as the deciBel, corrupted to decibel, which has stuck with the scientific community to this day.

Fletcher-Munson Equal Loudness Curves and the dBA metric

To address the problem of industrial noise in the early 20th century, measurement was essential, as was a metric. At that time, researchers were critically aware that the readings on a sound level meter did not represent how loud or intense the sound was with respect to the subject's perception of hearing. From a biomedical perspective, this concept of perception is subjective, and changes between individuals and over timescales from minutes to decades. These serious constraints notwithstanding, it was acknowledged that some average measure of loudness would have some value for medicine and public health.

Harvey continued his research with Wilden Munsen, one of his team, by varying the frequency of the electricity to give pure tones, to which it is understood twenty-three of his colleagues listened to different levels of loudness, again through a simple telephone earpiece. (It is assumed they all had good hearing). They were then asked to score the sounds for equal loudness to that generated by an alternating current at 1000 cycles per second. The level of the sound of course depended on the voltage applied, which could be measured. It is important to note two significant constraints here: The sounds were 'pure' sine waves, which are not common in nature, and the headphones enclosed the ear of the subject. This is a very unnatural way to listen to a very unnatural sound.

The numerical results of this study are known as the Fletcher-Munsen Curves (Fig 1). The (logarithmic) units of these curves are known as "phons," and the inverse of the 40 phon curve forms the basis of the A-frequency weighting scale used everywhere today (Fig 2).

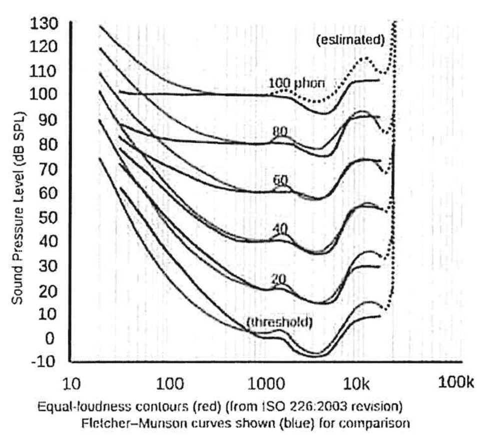

Figure 1. Fletcher Munson Curves [2]

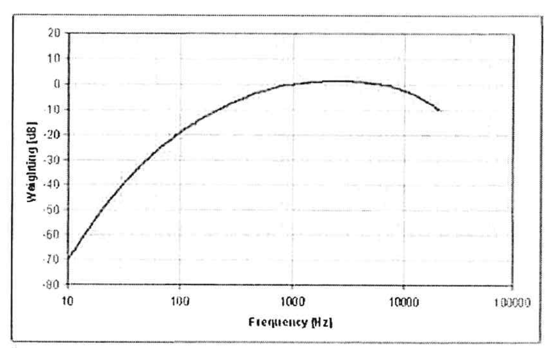

Figure 2. A-weighting frequency response curve [3]

The minimum pressure required for humans to perceive sound at 1000 Hz is considered to be 20 micropascal, or an intensity of 10^{-12} watts per square meter. This corresponds to 0 phon on Figure 1, and 0 dBA in Figure 2. For all its shortcomings, the A-Weighting has endured for decades and has become the *de facto* standard for environmental noise measurement. But is the A-weighting sufficient for all circumstances? The answer is an emphatic "No." It relates to the perception of loudness, which heavily discounts all frequencies below 1000 Hz and ends at 20 Hz. This 20-Hz limit was a consequence of equipment limitations of the 1920s and 30s, but has remained as the lower limit of human hearing to this day. The assumption that harm from excessive noise exposure is directly related to the perception of loudness has also remained to this day. Observe in Fig 2 that, at 10 Hz, there is a 70-dB difference between what is measured and what is, *de facto*, present in the environment. In other words, three-and-a-half orders of magnitude of energy are discounted at this frequency. The implications for public health are considerable, and within this line of reasoning, any event below 20 Hz becomes of no consequence whatsoever, and more so because it is not implicated in the classical effects of excessive noise exposure: hearing loss.

There are also issues of time and frequency resolution. Acoustic phenomena are time varying events. A 10-min average of acoustic events can hide more than it reveals. Similarly, segmenting frequencies into octave or 1/3-octave bands for analysis can also hide much that needs to be seen. Today, affordable and highly portable equipment can record acoustical environments, and allow for post-analysis in sub-second time increments and 1/36-octave resolution. Waveform analysis from the sound file directly can achieve an even better resolution.

Preliminary Results from Field Studies Conducted in Ireland

The following results, recently obtained in field-studies conducted in Ireland (Jul-Nov 2017), show why such resolution is needed to understand ILFN-rich environments. The classical metric (in dBA, 10-min averages and 1/3-octave bands) will be contrasted with what is needed for human health-related concerns (in dB with no frequency weighting, and resolutions of 0.2s and 1/36-octave bands), and not merely compliance with regulations.

Equipment and Methods

Acoustical environments were recorded with a SAM Scribe FS recording system, a 2-channel recorder with sampling rates up to 44.1 kHz at 16-bit resolution and linear response down to almost 0.1 Hz [4-6]. Recordings were saved as uncompressed WAV files including the 1000 Hz/94 dB reference calibration tone prior to and after measurements. Windshields were placed on both microphones during the entire measurement sessions. Microphones were attached to tripods at approximately 1.5 m above the ground.

Location

Five homes located around the same industrial wind turbine (IWT) development have been the object of study. The data presented here refers to Home 1 (Fig 3). Table 1 shows the dates and times of all recordings that have been made to date in this Home. The recordings selected for analysis and presentation herein were chosen on their educational value.

Table 1.
Dates and times of recordings.

Home No.	Date	Time	Blue Channel	Red Channel
1	04 Jul	04:05 – 06:48	In child's bedroom-1	In child's bedroom-2
	05 Jul	15:33 – 17:50		
	10 Oct	17:40 – 18:43		

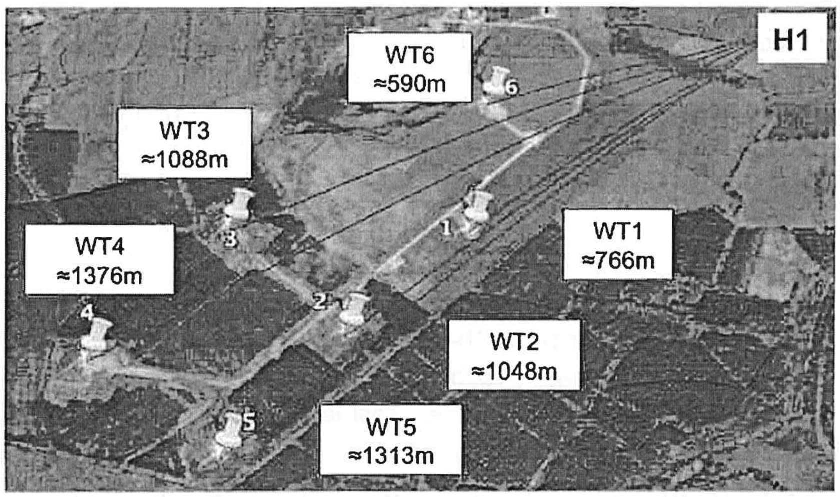

Figure 3. Reconstruction using a Google Earth Image and showing the relative position of Home 1 and each of the six industrial wind turbines.

Results

The information classically obtained with the dBA metric, 1/3-octave bands and 10-min averaging (on October 10th, 2017, at 18:30) is given in Figures 4 and 5. Weather conditions obtained from Met Éireann for the closest weather tower at this time were as follows: Air temperature: 14ºC, Precipitation: 0.1 mm, Mean Sea-Level Pressure: 1006.0 hPa, Wind Speed: 5.1 m/s (10 kt), Wind Direction: Southwest (200º az).

The values obtained for the sound pressure level and 1/3-octave bands are seen in Figures 4 and 5. The overall dBA metric (red bars labelled "Tot") reflects the sound that humans would hear if they were present in this environment. The sound pressure level in dBLin metric (grey bars labelled "Tot"), reflect the amount of acoustic energy to which humans are concomitantly exposed. The growing discrepancy between the two can be seen as the frequency falls below 1000 Hz.

Figure 6 shows the sonogram corresponding to the same 10-min period. This visual representation of time- and frequency-varying acoustic events provides much more information than the classical approach (Figs 4 and 5). Here short-term events can be seen in the region of 20-50 Hz (Fig 6). Tonal components can be seen at 10 Hz and 20 Hz that are not steady in amplitude and may be amplitude modulated, i.e., where the amplitude of the pressure is not continuous and varies periodically with time. The 10-min averages, used in almost all legislation, hide these variations and are representative only of tonal components that are essentially unvarying over the 10-min period in question.

The periodogram (Fig 7) over the same 10 minutes shows that there are distinct tonal components that form a harmonic series. When IWTs are the source of ILFN, the rotating blades generate repeated pressure waves as each blade replaces the previous one at any position. A harmonic series is formed with the "blade pass frequency" as the fundamental frequency (0.8 Hz here). These harmonics constitute what is called the *wind turbine signature* [7], which is impossible to identify using the classical dBA, 1/3-octave, 10-min averaging methodology.

Final Thoughts

Health concerns associated with excessive exposure to ILFN in the workplace have been around since the industrial boom in the 1960s [8]. In recent years, however, residential neighbourhoods have also begun to be flooded with ILFN [9-14]. The Family living in Home 1, for example, has abandoned their residence due to severe health deterioration in all family members. *Accredited acousticians cannot ascertain compliance levels for ILFN because there are none* - the vast majority of regulations worldwide do not cover this part of the acoustic spectrum. Nevertheless, Public Health Officials and Agencies should fulfil their job descriptions by becoming aware of the limitations of current noise guidelines and regulations. Alternatives exist to gather the acoustic information relevant to the protection of human populations, in both occupational and residential settings. Noise regulations and guidelines need urgent updating in order to appropriately reflect ILFN levels that are dangerous to human health.

Home 1 – A-weighting, 1/3 octave bands (0.5 Hz – 4000 Hz), 10–min average - Red Channel

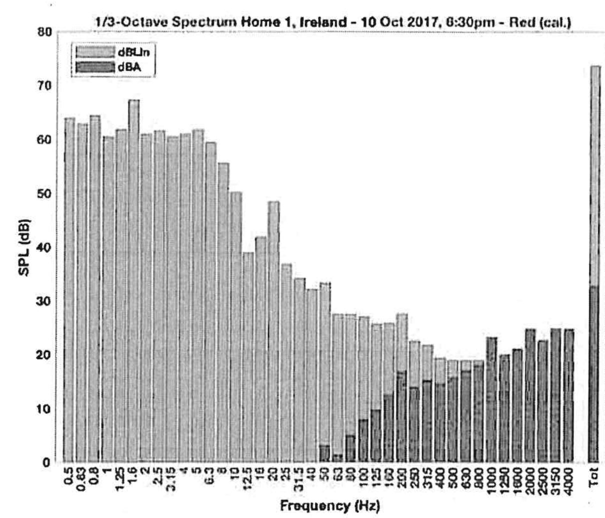

Figure 4. Data covers a 10-min interval analyzed between 0.5–4000 Hz, in 1/3-octave bands, as recorded in Home 1, on 10 Oct 2017, at 18:30 (red microphone, i.e. inside child's bedroom-2).
The red bars are A-weighted values, while the gray bars indicate the acoustic energy that is, *de facto* present, in dBLin. In this environment, the human being would perceive through the ear an overall A-weighted pressure-level of approximately 34 dBA (Tot - red bar), while being concomitantly exposed to an overall acoustic pressure-level of approximately 74 dBLin (Tot – grey bar).

Home 1 – A-weighting, 1/3 octave bands (0.5 Hz – 1000 Hz), 10–min average - Red Channel

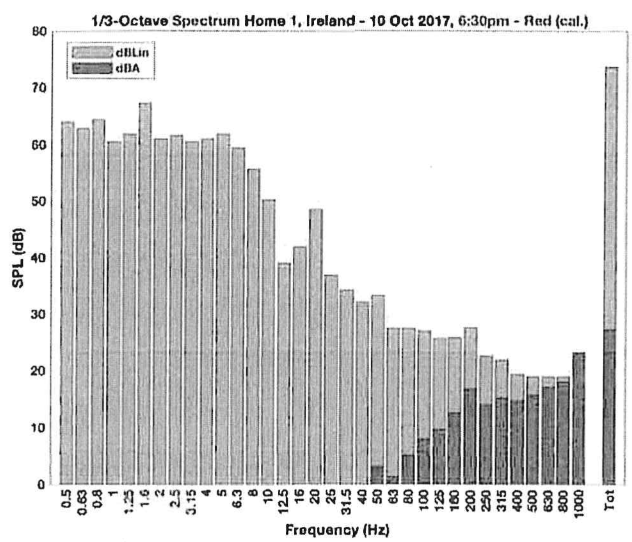

Figure 5. Data covers a 10-min interval analyzed between 0.5–1000 Hz, in 1/3-octave bands, as recorded in Home 1, on 10 Oct 2017, at 18:30 (red microphone, i.e. inside child's bedroom-2). The red bars are A-weighted values, while the gray bars indicate the acoustic energy that is, *de facto* present, in dBLin. In this environment, the human being would perceive through the ear an overall A-weighted pressure-level of approximately 26 dBA (Tot - red bar), while being simultaneously exposed to an overall acoustic pressure-level of approximately 74 dBLin (Tot – grey bar).

Home 1 – No weighting, 1/36 octave bands (0.5 Hz – 1000 Hz), 0.2 s average - Red Channel

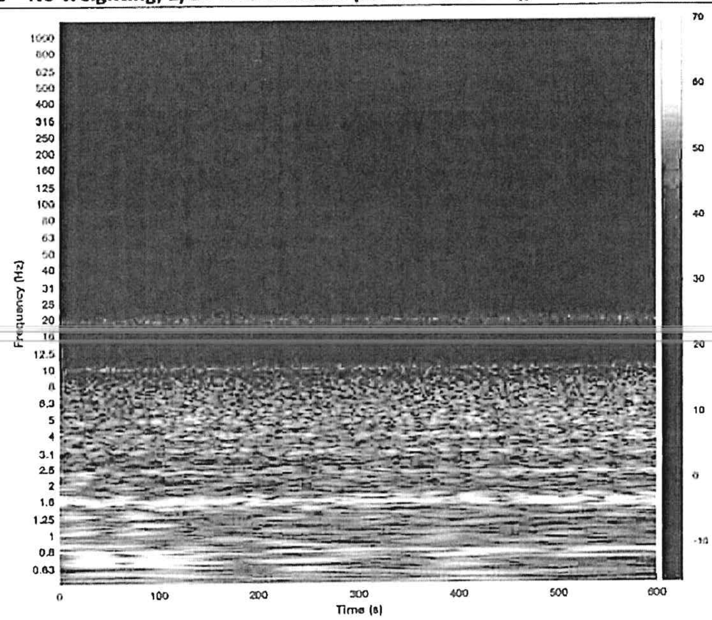

Figure 6. Sonogram that covers the same 10-min interval (600 s) as in Figures 4 and 5 showing time-varying features. The colour-coded bar on the right indicates sound pressure level values in dB Linear (no weighting). The horizontal line seen at 20 Hz is not a continuous tone because over the 600 s, its pressure level (colour-coded data) varies. A strong (yellow) acoustic phenomenon can be seen to exist at 1.6 Hz and also at 0.8 Hz.

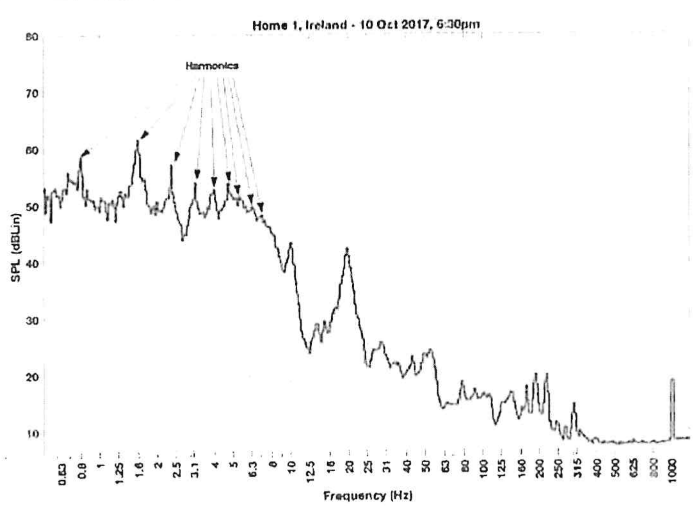

Figure 7. Periodogram covering the same 10-min interval (600 s) as in Figs 4-6, and analyzed between 0.5–1250 Hz. The blade pass frequency of the IWT is 0.8 Hz. Harmonics of this fundamental frequency are

shown in the figure. Each frequency band composing the harmonic series has a well-defined peak, e.g., the horizontal line seen in Figure 7 at 20 Hz is represented here as a peak at 20 Hz.

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INFRASOUND AND LOW FREQUENCY NOISE GUIDELINES: ANTIQUATED AND IRRELEVANT FOR PROTECTING POPULATIONS

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Background: Over the past two decades, the increasing and unregulated production of infrasound and low frequency noise (ILFN, ≤200 Hz) has led to a considerable rise in associated noise complaints and health-related issues. The most recent of such ILFN sources are industrial wind turbines (IWT). Acoustical field-data was collected within a home located in the vicinity of IWT, to which the AUC Rule 012 and its requirements were applied. In Ontario, IWT noise complaints were gathered under the Freedom of Information legislation. **Goal:** To explore the usefulness of current noise control rules when protecting human populations against ILFN generated by IWT.

Keywords: industrial wind turbines, residential exposure, health, dBA, acoustic signatures

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1. Background

The unbridled installation of industrial wind turbines (IWT) in different countries on different continents has brought a *very old problem* [1] to centre stage: the health effects induced by excessive exposure to anthropogenic (i.e., artificially generated, human-made) airborne pressure waves occurring within the lower ranges of the acoustical frequency spectrum (a.k.a. infrasound (<20 Hz) and low frequency noise (≤200 Hz), or, ILFN, given the absence of a more precise nomenclature). The goal of this report is to (yet again) emphasize the long-standing problem of anthropogenic ILFN impacting human health, this time using IWT as a source-example.

2. Industrial wind turbine 'noise' in Canada

2.1 IWT 'noise' complaints in Ontario

The government of Ontario, Canada has a process for reporting environmental pollution that offers a pollution reporting "hotline," managed by the Ministry of Environment, Conservation and Parks (MOECP), and which includes noise pollution complaints [2]. People living in proximity to IWT projects have used this service to submit Incident Reports/Complaints (IR/C) regarding environmental noise and associated adverse health effects. In order to evaluate the effectiveness of this process of reporting IWT 'noise,' government IR/C records were obtained through a request made under the province of Ontario's Freedom of Information legislation [3] by the community group coalition Wind Concerns Ontario [4].

Findings were presented during a citizen appeal of an IWT project held before the Ontario Environmental Review Tribunal [4]. Testimony included factual evidence based on the official government IR/C records submitted by residents living in proximity to operating IWT [5]. The total number of Incidents filed officially with the MOECP between 2006 and the end of 2016 was 4,574. Only 1% of the reports received a "priority" response, another 30% were deemed as "deferred," and records showed that in more than 50% of the Complaints, there was no ministry response [5]. Regarding health effects, notes by the Ministry's Provincial Officers included statements from citizens reporting "headache, sleep deprivation, annoyance, and ringing or pressure sensation in the head and ears" [5]. These health effects were reported many times, and also included children [5].

2.2 Rule 012 for Noise Control in Alberta

In the Province of Alberta, the Utilities Commission has Rule 012 [6] dedicated to *Noise Control* that encompasses "an avenue for the submission of noise complaints relating to a facility and the process for addressing noise complaints" [7]. Rule 012 imposes a limit based on a minimum basic sound level to which various adjustments are made:

Permissible Sound Level	=	Basic sound level	+	Daytime adjustment	+	Class A adjustment	+	Class B Adjustment	+	Class C adjustment

The basic sound level begins at 40 dBA L_{eq} and increases depending on the number of houses nearby and proximity of heavily travelled roads. The Daytime adjustment is an increase of 10 dBA between 7 am and 10 pm. Class A adjustments address seasonal variation and non-representative ambient monitoring. Class B adjustments are made for temporary increases in noise generation. Class C adjustments are made when the ambient wind increases to a level that masks the generated noise. On the matter of low-frequency components, Section 3.2 states: "If available, C-weighted sound pressure level (dBC) minus the A-weighted sound pressure level (dBA) is to be considered in the noise model…to identify the potential for low frequency noise impacts." The procedure then described in

Section 4.5 and Appendix 5 is required only when low frequency noise is identified subsequent to the complaint investigation. Therefore, the difference between the overall C-weighted sound level and the A-weighted sound level must be calculated for all pertinent recordings and the periodograms analysed for sharp peaks in the 20–250-hertz region. Only if both the dBC – dBA difference is greater than 20 dB *and* sharp peaks are identified, is a more comprehensive investigation of ILFN required.

3. IWT in Germany – Case Report

3.1 Background

Beginning in 2014, the Hogeveen family residing in Schleswig-Holstein, Germany, described the symptoms (to the media) that they and their children had been developing after 20 IWT were commissioned within a 2-km radius of their home [8-10]. The children—who exhibited increased aggressiveness and unexplained nosebleeds—were promptly sent to boarding school to avoid further health deterioration. The Hogeveens had to remain in the home since it is also their place of work (sports medicine and physical therapy centre), while persistently enduring dizziness, headaches, sensations of pressure on the chest and lungs, ear-aches, swollen tonsils, and ocular and oral inflammations [8-10]. But, they abandoned their upstairs bedroom and constructed a bunker-bedroom deep in the basement of the home. This has provided some respite, except when winds are easterly. Acoustical recordings were conducted simultaneously in both abandoned and bunker bedrooms, taking wind conditions into account.

3.2 Materials and methods for acoustic capture

Data were captured with a SAM Scribe FS (Full Spectrum) system (Model: Mk1, Atkinson & Rapley, Palmerston North, New Zealand) [11,12]. This two-channel recorder measures at sampling rates up to 44.1 kHz, and delivers data streams via USB to a Windows notebook computer, storing it as uncompressed wav files to hard disk. GPS information is also stored as metadata in the files, and this includes a digital signature. The manufacturer's frequency response curve shows a microphone capsule very close to linear over the 1-1000 Hz range used in this study (0.5-1000 Hz: ± 0.5 dB; 1-10 kHz: ± 2dB; 10-20 kHz: ± 4dB) (custom-made Model No.: EM246ASS'Y, Primo Co, Ltd, Tokyo, Japan) [13]. Acoustic data was processed in Matlab (The MathWorks, USA) using narrow-band filters complying with the ANSI® S1.11-2004 and IEC 61260:1995 standards. All data presented herein were captured a sampling rate of 11.025 kHz and recorded as uncompressed WAV files, including the required reference calibration tone (Type I Calibrator, 1000 Hz/94 dB). Windshields were placed on both microphones during the entire measurement periods. Microphones were attached to tripods at approximately 1.5 m above the ground. The recordings selected for analysis and presentation herein were chosen on their educational value, and are shown in Table 1.

Table 1: Samples selected for analysis and presentation herein.

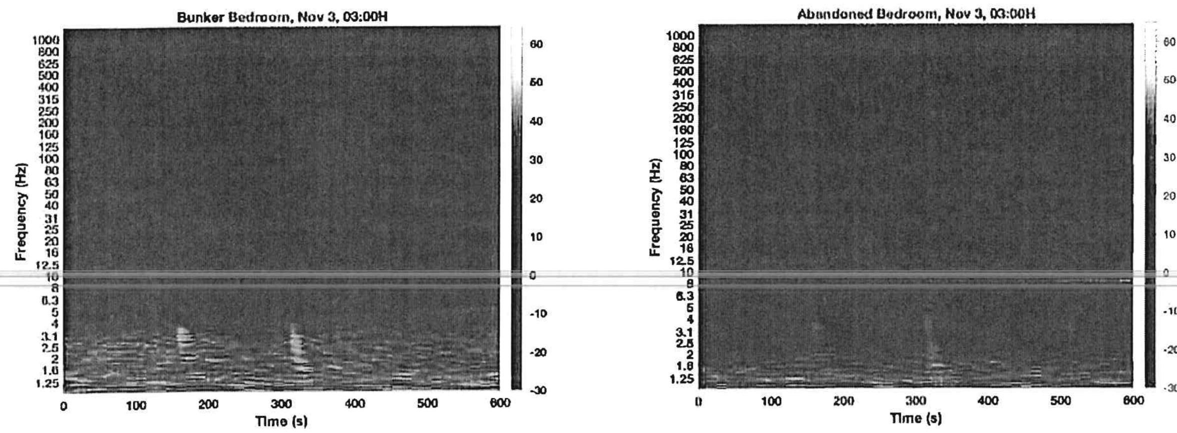
Sample	Date	Time	Wind Speed (m/s)	Wind Direction
Lo wind	03NOV17	03:00	0.9	290°
Hi wind	01NOV17	14:00	7.6	290°

3.3 Abandoned vs. Bunker bedrooms

Significant and distinctive differences were found between the two environments that survived changes in wind speed and wind direction. Figure 2A-D compares the sonograms of the simultaneous recordings captured in both locations, under both wind speeds. All disclose some tonal components (horizontal lines) although these appear more prominent in the abandoned bedroom than in the bunker bedroom. The abandoned bedroom discloses larger SPL values between approximately 5-40 Hz in low wind conditions (0.9 m/s, Fig. 2B), and between 6.3-40 Hz in the high-wind conditions (7.6 m/s,

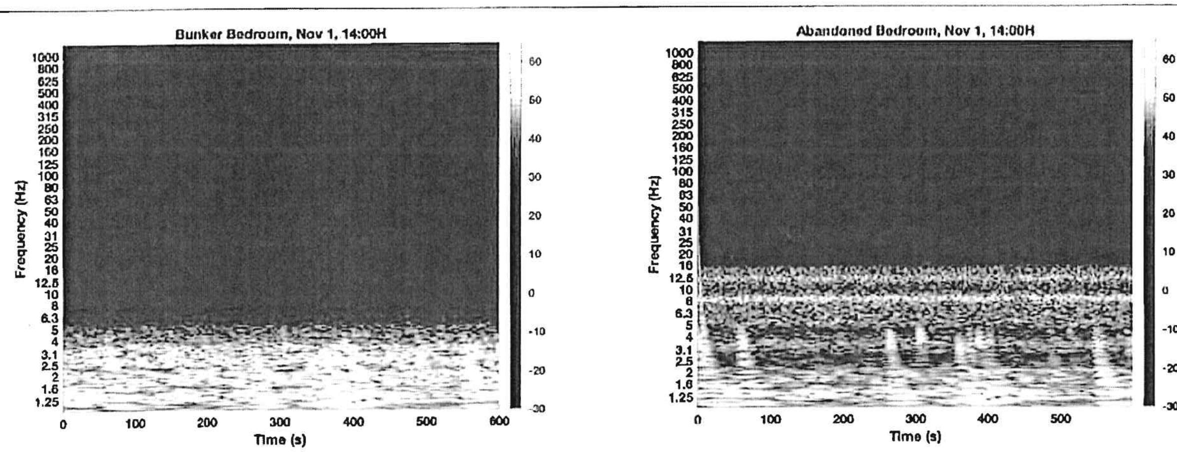
Fig. 2D). Within those frequency bands, distinct peaks at 8 and 12 Hz, as well as a peak at 80 Hz, are present in the abandoned bedroom, but absent from the bunker bedroom. Apart from some wind-gust noise—seen as vertical features broadening and moving to the right with decreasing frequency—the sonograms tend to show that the character of the sound does not change throughout the 10-minute periods and so the periodograms, shown in Figure 3, are representative of the sound over those intervals. (The continuous, 1000-Hz tone seen in the quieter recordings is due to electronic noise within the SAM Scribe Mk1, eliminated in the more recent SAM Scribe models.)

Wind speed 0.9 m/s and westerly wind (290°) on 03 Nov 2017, at 03:00H.



A. Bunker bedroom. **B.** Abandoned bedroom.

Wind speed 7.6 m/s and westerly wind (290°) on 01 Nov 2017, at 14:00H.

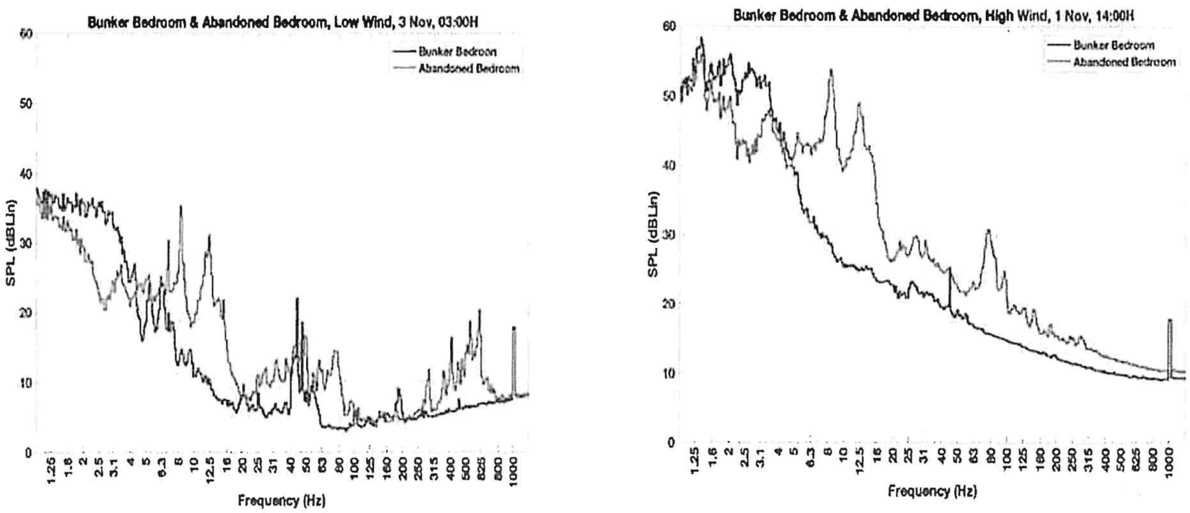


C. Bunker bedroom. **D.** Abandoned bedroom.

Figure 2: Sonograms covering a 10-min interval (600 s) and analyzed between 1–1250 Hz. The color-coded bar on the right indicates SPL in dBLin.

In the abandoned bedroom, the shapes and positions of the peaks at the three frequencies (8, 12 and 80 Hz, Fig. 3) are quite distinct, are clearly identifiable and independent of wind speed. Particularly visible in Fig. 3 is the similarity in the profile, occurring simultaneously in both locations, at the lower limiting frequencies of these measurements, i.e., approximately from 0.1 Hz to 2.5 Hz or to 4.5 Hz. The acoustical events responsible for these readings seem to impact both locations in the same manner, independent of wind conditions. The wavelengths corresponding to the airborne acoustical events at these frequency values are, approximately, 76 m (4.5 Hz) to 3430 m (at 0.1 Hz). The source of these phenomena remains unclear.

At low wind speed (0.9 m/s), the bunker bedroom displays a continuous tone at approximately 50 Hz. This can be seen as a horizontal line in the sonograms (Fig. 2A and 2C), as peaks in the classical analysis (Fig. 4), and as narrow peaks in the corresponding periodogram (Fig. 3). Usually, these tones are attributed to electrical appliances that may be present in the environment, and that do not vary with wind conditions. This is much less obvious in the abandoned bedroom (Fig. 2B and 2D) since no appliances are currently present. In the abandoned bedroom, tones that are not present in the bunker bedroom can be identified at 8 Hz, 12.5 Hz and 80 Hz (Fig. 3). These tones are present at low wind speed and increase in sound pressure level with higher wind speeds, while maintaining the consistency of their shape.



A. Bunker vs. Abandoned bedrooms. Wind speed 0.9 m/s, westerly wind (290°), 03 Nov 2017, at 03:00H.

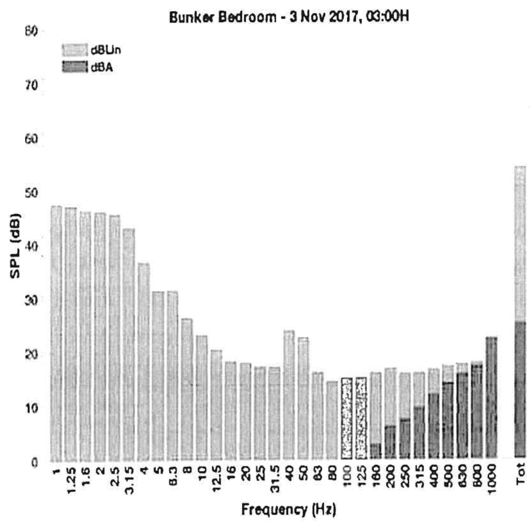
B. Bunker vs. Abandoned bedrooms. Wind speed 7.6 m/s, westerly wind (290°), 01 Nov 2017, at 14:00H

Figure 3: Periodograms covering the same 10-min intervals as in Figure 2 (analyzed between 1–1250 Hz), comparing the bunker and abandoned bedrooms at low and high wind speeds. The abandoned bedroom has consistently higher SPL levels than the bunker bedroom within the 4-40 Hz range, with very distinct shapes. At the lowest frequencies (≤2 Hz), SPL variations in both rooms have similar shapes and positions.

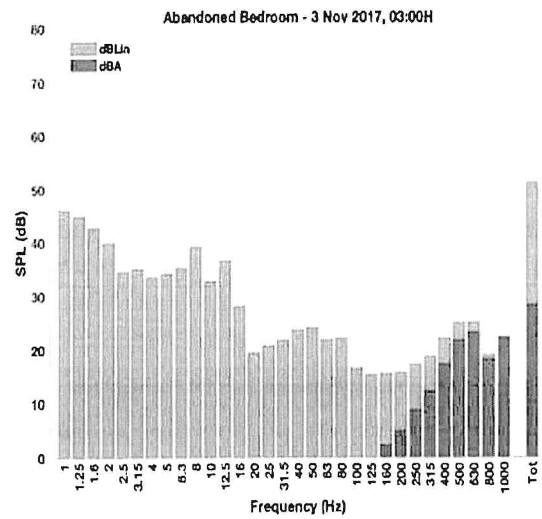
4. Discussion and Conclusions

Figure 4 shows ⅓-octave analyses obtained from a 10-min average, corresponding to the period shown in Figure 2A-B. In the bunker bedroom, the unweighted SPLs (Fig. 4A, grey bars) show a broad peak at about 50 Hz (or two narrower peaks on slightly either side). The highest SPLs are recorded below about 4 Hz. Unweighted SPLs in the abandoned bedroom (Fig. 4B, grey bars) show peaks at 8 and 12.5 Hz. There is relatively more energy in the abandoned bedroom above 4 Hz, but less below this. In both cases A-weighted SPLs (red bars) merely reflect that which humans would *hear* if present. As per Rule 012, this is the type of data required to establish permissible exposure levels.

Rule 012 was informally applied to the data obtained from the Hogeveen home. No recordings were made outside of the residence so the interior recordings used would a) be quieter than outside recordings and b) have a higher proportion of ILFN. The basic sound level is the lowest, 40 dBA, since it has less than 9 nearby dwellings within a 451-metre radius and is further than 500 m from a heavily travelled road. (Since outside night-time levels in the absence of IWT were impossible to measure, a 35-dBA level is assumed for the remainder of these calculations.)



A. Bunker Bedroom.



B. Abandoned bedroom.

Figure 4: These ⅓-octave frequency histograms cover the same 10-min interval as shown in Fig. 2A and B, wind speed 0.9 m/s and westerly wind (290°) on 03 Nov 2017, at 03:00H.

Two Class A adjustments are required. Assuming that a complaint is made in wintertime (the season during which these recordings were made), there is a +5 dBA adjustment. The ambient sound level with operational IWT is already 5 dBA below the basic sound level of 40 dBA, therefore, the adjustment is the maximum of +10 dBA. Since the sum of these two is +15 dBA, the maximum possible of +10 dBA is taken. For the Class B adjustment, two cases were considered: no increase occurs and one increase occurs for up to 60 days. This will give an adjustment of 0 dBA for the first case and +5 dBA for the second. The night time limit is therefore 40 dBA + 10 dBA + 0 dBA = 50 dBA for the base case, and 55 dBA is permissible for one period a year of up to 60 days. The daytime limit is the night-time value + 10 dBA = 60 dBA. The C-weighted and A-weighted overall sound levels for the 10-minute intervals captured on 01 and 03 November are shown in Table 2.

Table 2: dBC-dBA applied to the German data

	dBA Leq 10-min	dBC Leq 10-min	Difference
Bunker bedroom (01Nov)	35.7	56.2	20.5
Abandoned bedroom (01 Nov)	39.4	60.9	21.5
Bunker bedroom (03 Nov)	30.9	39.9	9.0
Abandoned bedroom [03 Nov)	33.7	42.7	9.0

Since these aspects of Rule 012 are stipulated in A-weighted sound levels, and the controversial features of IWT emissions are all in the ILFN regions, it is not surprising to find that these thresholds would very rarely be breached by IWT. The conclusion is that these aspects of Rule 012 are largely irrelevant. Moving, then, to the sections of Rule 012 dealing with ILFN, the question of whether significant components exist is determined by section 3.2 [7]. The difference in C-weighted and A-weighted sound levels must be 20 dB or more *and* there must be prominent, sharp peaks between 20 and 250 Hz. Figure 3 shows that there are prominent, sharp peaks in the bunker bedroom (blue lines) between 40 and 50 Hz. The abandoned bedroom does not show sharp peaks, therefore, they are not considered tonal, even though they are prominent. From the differences in the C-weighted and A-weighted sound levels, it can be seen that only the recording made on November 1, with high wind speeds, exceeds the 20-dB threshold. Ironically, this is because of the increased wind noise in the

ILFN regions. Section 4.5 (4) however, states that measurements should not be taken during high-wind-speed conditions for exactly this reason. Therefore, this aspect of the Rule also fails to catch the important soundscape features. Had it done, and the requirements of section 4.5 were met, the maximum penalty would be the addition of 5 dBA to the measured sound levels. If these then exceeded the limits (between 50 dBA and 60 dBA as above) then the operator would be required to implement noise attenuation measures and confirm that ILFN was no longer an issue.

When IWT are the source of ILFN, the rotating blades generate a series of pressure pulses at the 'blade pass frequency' (BPF), which is seen as a harmonic frequency series called *wind turbine signature* [14]. When synchronous IWT rotate at a constant rate, regardless of the wind speed, they will share a common harmonic series [15]. The IWT near the Hogeveen home are asynchronous, their BPF changes with wind speed. Given the sheer number of these IWT at the site, a single ('clean') IWT signature was not a reasonable expectation. Nevertheless, an analysis of the existence of harmonic series was conducted on the recordings of the abandoned bedroom, at low and high wind speeds.

Figure 5 shows the 1–100-Hz region of Fig. 3 with the harmonic series starting at 1.36 Hz added as dashed lines. The two main peaks at 8 and 12 Hz appear on this harmonic series as the 6th and 9th harmonics (H6 and H9). There is a large peak at 1.36 Hz for the higher wind speed. The 8 and 12 Hz peaks also appear on the harmonic series starting at 2.04 Hz; there is a small peak at 2.04 Hz. There is also a peak at 6.8 Hz on this series for the lower wind speed. A further harmonic series starting at 0.68 Hz includes these three peaks (1.36 Hz, 2.04 Hz and 6.8 Hz) as well as the broad peak at 3.45 Hz. There is no suggestion that peaks have moved between the two wind speeds although neither of the peaks (1.36 and 2.04 Hz) is seen at the lower wind speed. Note that the resonant frequencies of the bedroom are in the order of 60 Hz and upwards, with the peak just below 80 Hz likely being one such. The peaks discussed above are therefore less than $^1/_{10}$ of the cavity resonant frequencies and are not likely to be attributable to these phenomena.

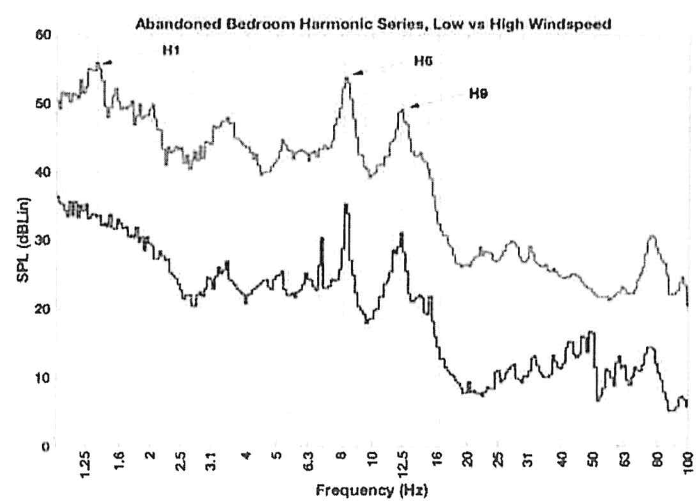


Figure 5: Comparison of data captured in the abandoned bedroom, at low (0.9 m/s-blue) and high (7.6 m/s-red) wind speeds, and same wind directions (290°). Harmonics of 1.36 Hz are shown as vertical, dashed lines.

A re-evaluation of legislation regarding population exposure to ILFN has been urgently required for decades [1]. The Canadian regulations here applied are similar to other regulations worldwide, and equally unsuitable *if* the goal is to protect human health against chronic ILFN exposures. Symptomatic complaints currently being ignored and/or misdiagnosed will predictably lead to a burden on future healthcare costs. Although the proliferation of IWT is bringing this agent of disease [16] to centre stage, the biases regarding how human health is impacted by airborne pressure waves (audible or not and whatever the source) continue to impede a proper scientific investigation [17], and consequently, proper protection of human populations and their offspring.

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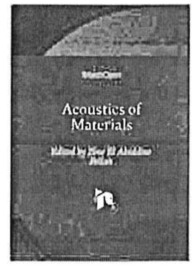
CHAPTER SUMMARY

Acoustics and Biological Structures

M. Alves-Pereira, B. Rapley, H. Bakker, R. Summers



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A.E.A. Fellah (editor), IntechOpen, London, UK, 2019
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This chapter consolidates what is known to date of the biological effects of airborne pressure waves occurring within the infrasonic and lower frequency ranges of the acoustical spectrum, and that are commonly referred to as infrasound and low frequency noise (ILFN).

In the **Introduction**, three reasons are given as to why there is a shortage of studies that properly evaluate the biological response to ILFN:

1) The rudimentary segmentation of the acoustical spectrum, as shown in Figure 1 (compare to the much greater segmentation of the electromagnetic spectrum);
2) The inappropriate use of the dBA metric to quantify ILFN, as explained by Figures 2-4; and
3) The indoctrinated, but scientifically indefensible, notion that "what you can't hear can't hurt you".

The basic principles related to biomaterials as related to ILFN exposure are provided in the section **Biomaterials and Human Anatomy**. The viscoelastic properties of biological materials impart a non-linear response to biological outcomes. Knowledge on cellular and tissue architecture, as well as on the basic human anatomy of the fasciae, can provide insight as to how airborne pressure waves can cause lesions in biological tissues, leading to clinically verifiable pathology.

The subsequent section, **Laboratorial Studies, Field Studies and Biological Outcomes**, describes the three most prevalent study setups: laboratory and field-laboratory studies within occupational or residential environments. Advantages and disadvantages of each type of experimental setup are explored.

In Laboratory studies:

a) Acoustic parameters can be precisely quantified and varied;
b) Exposure time can be precisely controlled;
c) There are numerous biological outcomes that can be examined.

In Occupational field-laboratories:

a) Acoustic parameters can be quantified but not varied in a scientifically controlled manner.
b) Concomitant non-occupational exposures (after the end of the workday) must be accounted for.
c) Prior ILFN exposures (fetal, childhood, adolescence) must be tallied.
d) The type of biological outcomes that can be explored are much more restricted.

In Residential field-laboratories:

a) Acoustic parameters are more difficult to quantify because, typically, they vary more with time than in occupational field-laboratories.
b) All areas internal and external to the residence must be acoustically characterized.

c) Concomitant ILFN exposures occurring outside of the home (occupational, recreational) must be accounted for.

d) Prior ILFN exposures (fetal, childhood, adolescence) must be tallied.

e) The types of biological outcomes that can be explored are very limited.

Specific biological outcomes in ILFN exposed humans and animal models are described in Section 4, **Past Relevant Studies**. Specifically,

1) Vascular structures,
2) Collagen and connective tissue,
3) Heart cells and tissues, and
4) The hippocampus region of the brain.

Vascular structures

Under ILFN exposures, the demands of the organism's blood flow can be substantial, leading to the development of twisted and tortuous arteries in the ocular (Table 1) and gastric structures, in both human and animal models. This could partially explain the reduced vision acuity reported in ILFN-exposed individuals, as well as the gastrointestinal complaints documented in citizens living near airports, or in "noise-exposed" industrial workers. Hemorrhagic events and other vascular abnormalities were observed in respiratory system structures in animal models, and in humans exposed to occupational or residential ILFN (Table 2).

Collagen and connective tissue

Collagen is considered to be the steel of the human body. Under long-term ILFN exposure, there is an increased production of collagen in the vascular and respiratory system structures than can manifest as clinical symptoms. This feature is partially explained by the architectural and viscoelastic properties of biomaterials, as explained in Section 2.

Heart cells and tissues

ILFN exposed individuals commonly report heart arrhythmias. Laboratory studies have shown that conditions associated with ventricular arrhythmias develop in animals exposed to ILFN. Additionally, cardiomyocytes exposed to ILFN developed abnormal structures that persisted much time after ILFN exposure ceased.

The Hippocampus

Learning and memory impairment develops in animals exposed to ILFN. It has been shown that ILFN-induced neuronal death can occur in the hippocampus, and can therefore be responsible for the observed cognitive deficits (unrelated to sleep disorders).

In **Conclusion,** exposure to infrasonic and lower frequency airborne pressure waves can cause cellular and tissue damage depending on frequency, dB-level, and exposure time, while the viscoelastic properties inherent to biological tissues impart a nonlinear response to this type of acoustic stressor. The underlying objectives of most of the studies discussed herein are related to occupational exposures and do not consider continuous exposures at less than 90 dB, nor are pressure pulsed trains presented within the laboratorial acoustic environments. In residential environments however, these attributes are often present. The simulation of residential exposures does not appear to have yet been integrated into laboratory settings and protocols. The whole-body response also elicits the immune system, affects organs of the reproductive system, changes receptor cells in the vestibular semi-canals and auditory cochlea, and induces genotoxic effects, including teratogenesis. This is a pioneering field of science, still in its infancy and urgently requiring scientists from multi-disciplinary areas of study because, ultimately, the health of human populations and their offspring must be protected.

Chapter

Acoustics and Biological Structures

Mariana Alves-Pereira, Bruce Rapley, Huub Bakker and Rachel Summers

Abstract

Within the context of noise-induced health effects, the impact of airborne acoustical phenomena on biological tissues, particularly within the lower frequency ranges, is very poorly understood. Although the human body is a viscoelastic-composite material, it is generally modeled as Hooke elastic. This implies that acoustical coupling is considered to be nonexistent at acoustical frequencies outside of the human auditory threshold. Researching the acoustical properties of mammalian tissue raises many problems. When tissue samples are investigated as to their pure mechanical properties, stimuli are not usually in the form of airborne pressure waves. Moreover, since the response of biological tissue is dependent on frequency, amplitude, and time profile, precision laboratory equipment and relevant physiological endpoints are mandatory requirements that are oftentimes difficult to achieve. Drawing upon the viscoelastic nature of biological tissue and the tensegrity model of cellular architecture, this chapter will visit what is known to date on the biological response to a variety of different acoustic stimuli at very low frequencies.

Keywords: infrasound, low frequency noise, health, cellular biology, tissue morphology

1. Introduction

Airborne pressure waves are ubiquitous in all human environments and have played vital roles in the survival, evolution, and development of the human species. Under certain conditions, airborne pressure waves can be perceived as "sound" by the human auditory system. Under other conditions, they may be perceived as a whole-body or partial-body vibration. Some airborne pressure waves are not consciously perceived at all. As human societies developed and became more technological, airborne pressure waves emanating from human-made devices became ubiquitous and "noise" became a more serious issue. By the late nineteenth century, noise and health studies began to flourish. In the early twentieth century, the telephone and growing industrialization led to more in-depth studies of the human hearing function. In 2011, a WHO document on the burden of diseases reflected the seriousness of the ongoing "noise problem" [1].

The only airborne pressure waves considered of consequence for human health were those that could be *heard*, i.e., "what you can't hear can't hurt you" (**Figure 1**). This notion justified the development of acoustic measuring devices and methodologies that concentrated solely on the audible portion of the acoustical spectrum.

Within the audible segment (20–20,000 Hz), human auditory acuity is not evenly distributed, and is more sensitive within the 800–7000 Hz range than it is to air-borne acoustic events occurring below 500 Hz or above 15,000 Hz. Thus, early on, scientists understood that in order to protect human hearing function and speech intelligibility, the entire audible segment need not be considered, but rather, only the frequencies at which the acuity was highest: 800–7000 Hz range. The development of the A-frequency weighting and the resulting deciBel-A (dBA) metric allowed acousticians and health professionals to assess acoustical environments simulating this variability of human auditory acuity.

Figure 2 shows the frequency response curve for the dBA metric, clearly following the human auditory response to airborne acoustic pressure waves.

While the dBA metric proved to be key for the protection of hearing and speech intelligibility, it was insufficient for the assessment of airborne pressure waves occurring outside of the 800–7000 Hz range. **Figure 3** emphasizes the 800–7000 Hz range within the dBA metric, and **Figure 4** shows its application at 10 Hz. The dBA metric is, therefore, unsuited for evaluating airborne pressure waves occurring at frequencies below 800 Hz. Health effects that may be developing due to exposures

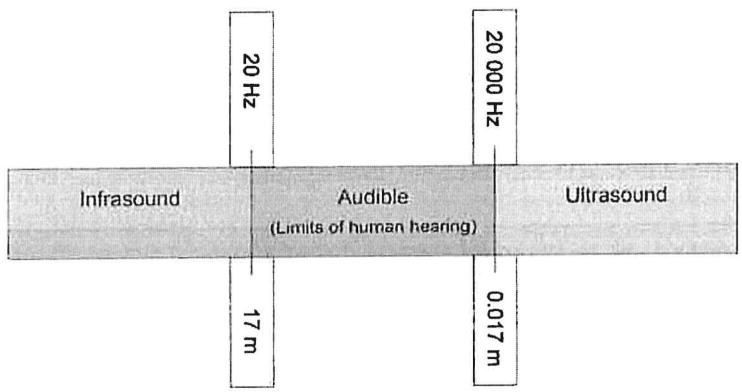

Figure 1.
Acoustical spectrum showing the classical three segments (infrasound, audible, and ultrasound) with the frequency and wavelength indicated at the cutoff of each segment.

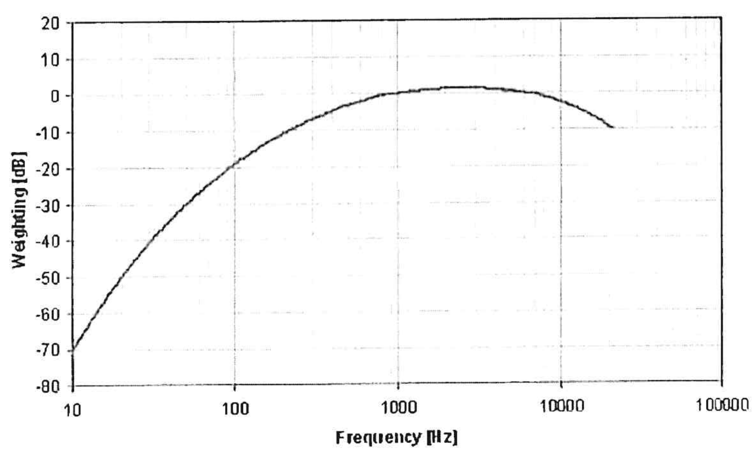

Figure 2.
Frequency response curve for the deciBel-A metric (dBA) commonly used in noise-related legislation [2].

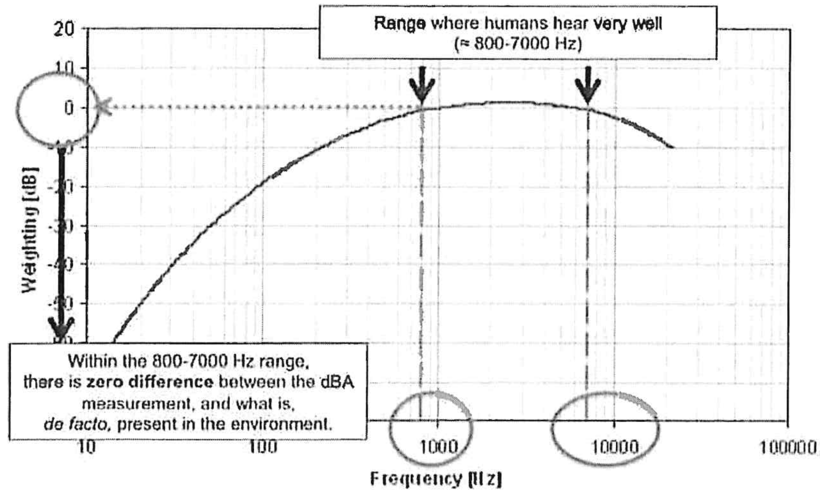

Figure 3.
Frequency response curve for the dBA metric applied to the range of highest human auditory acuity. Within this frequency range, the dBA measurement will accurately reflect the airborne acoustical energy present in the environment.

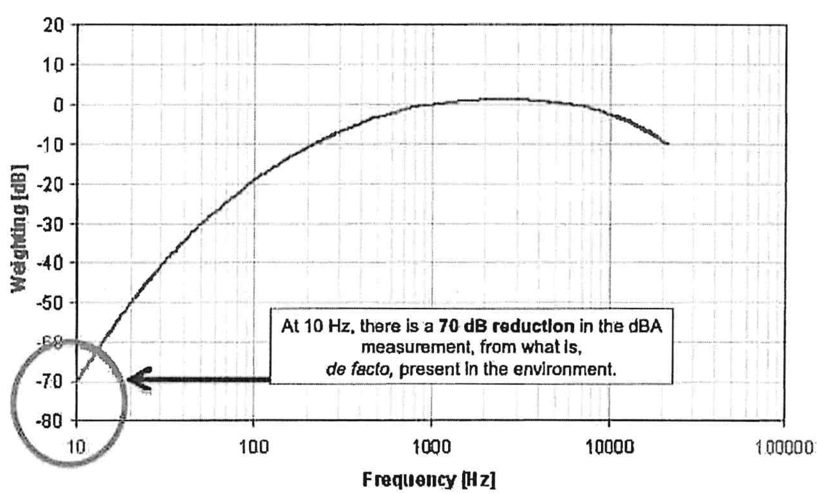

Figure 4.
Frequency response curve for the dBA metric applied to infrasonic frequency ranges, showing a 70 dB difference when evaluated at 10 Hz. Within these lower frequency ranges, the dBA metric will significantly underestimate the airborne acoustical energy present in the environment.

at these lower frequencies cannot be properly studied if the dBA metric is being used to characterize acoustical environments.

There is a shortage of studies that properly evaluate the biological response to infrasonic (≤20 Hz) or lower frequency (≤200 Hz) airborne pressure waves. Three important reasons for this have been provided above: the rudimentary segmentation of the entire acoustical spectrum into merely three "blocks" (compare to segmentation of the electromagnetic spectrum), the unsuitability of the dBA metric to quantify airborne acoustical pressure waves at these lower frequencies, and the ingrained notion that "what you can't hear can't hurt you." These major hindrances have been crystallized into mainstream science [3] and have served to significantly impede scientific inquiry and human health protection.

The goal of this chapter is to consolidate what is known on the biological response to airborne pressure waves occurring within the infrasonic and lower frequency ranges. A biomedical engineering approach is taken, whereby biological organisms are viewed as structures of composite materials, with significant visco-elastic components and organized in accordance with the principles of tensegrity architectures. When airborne pressure waves impact these types of structures, the biological response will depend on the type of biomaterial under study, it will exhibit anisotropic properties, and it will vary nonlinearly with exposure time. Depending on the physical properties of the airborne pressure waves (including time profiles) and on the biostructure under study, mechanical perturbations are relayed into cells and tissues through a variety of different pathways that, to date, still remain unclear.

2. Biomaterials and human anatomy

2.1 Viscoelasticity

Viscoelasticity is an attribute given to bodies that exhibit both viscous and elastic behaviors beyond the classical Hooke's elastic model [4]. Viscoelastic materials have three distinct properties not contemplated by Hookean models: creep, stress relaxation, and hysteresis. Most biological materials have viscoelastic behaviors.

In a Hookean (or purely elastic) material, total deformation depends on total load, and no further deformation occurs even if load is maintained. In viscoelastic materials, however, when sufficient stress is applied and maintained, they may continue to deform, even though stress load remains unaltered. This property is called *creep*.

In a purely elastic material, the strain within the material is constant throughout the application of the load; it does not vary with time, but only with the amount of applied stress. In viscoelastic materials, when stress is applied and maintained, strain can decrease with time. This property is called *stress relaxation*.

Consider repetitive or cyclical loads on materials. In purely elastic materials, periodic loads will not alter the stress-strain curve. The pathway taken by the material to deform is exactly the same pathway it takes to return to its original, equilibrium position. In viscoelastic materials, however, the return to equilibrium may be different than the pathway used to get to the point of deformation (The word pathway is here loosely used, and is meant to encompass all spatial, temporal and energetic components of these types of movements.) This property is called *hysteresis*.

2.2 Tensegrity structures

Many structures in the natural world are organized in accordance with the principles of tensegrity architecture—elements providing discontinuous compression are held together through elements of continuous tension [5]. **Figure 5** shows several examples of tensegrity structures.

Depending on the properties of the airborne pressure waves and biomaterial under study, the propagation of mechanical perturbations throughout these types of structures can reach long distances, without loss of structural integrity.

2.3 Cellular and tissue mechanotransduction

Cells and tissues are organized in accordance with the principles of tensegrity architecture [8, 9]. This means that in addition to biochemical signaling,

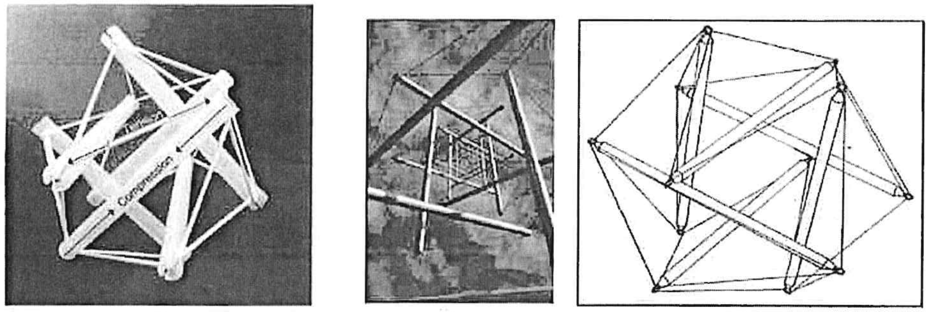

Figure 5.
Tensegrity structures. A. Model showing elements of continuous tension and discontinuous compression. B. Needle tower, by Kenneth Snelson, in the Hirshhorn sculpture garden (USA) [6]. C. Icosahedron, first designed by Buckminster Fuller in 1949 [7].

cells also communicate with their surroundings through mechanical signals. Mechanosensitive receptors exist on cell surfaces, and mechanosensitive junctions interconnect cells, thus forming tissues. Depending on the physical properties of the airborne pressure waves and biomaterials under study, external airborne mechanical perturbations can elicit a mechanical response, which, in a larger, macroscopic view, can lead to clinically pathological situations.

2.4 The fasciae

The fascia is a sheet of connective tissue that uninterruptedly extends from head to toe, suspended from the skeleton, and that provides the integrated supporting framework for maintaining anatomical and structural form [10, 11]. That external mechanical perturbations elicit responses at large distances away from the point of entry is a well-known concept among scientists and health professionals who study fasciae. When presented with external airborne pressure waves, fasciae can respond by changing their structural properties: *from a mechanical point of view, the fasciae are organized in chains to defend the body against restrictions. When a restriction goes beyond a specific threshold, the fasciae respond by modifying their viscoelasticity, changing the collagenic fibers, and transforming healthy fascial chains into lesioned chains* [10]. One of the fascia's key roles is that of shock absorption.

Connective tissue structures are ubiquitous forming all external surfaces of vessels, nerves, organs, and muscles, and at the cellular level, the extra-cellular matrix that surrounds and communicates with each individual cell. In addition to maintaining structural integrity, the fasciae are the first line of defense against external perturbations, playing important physiological roles in mobilizing the immune system.

3. Laboratorial studies, field studies, and biological outcomes

Studying the effects of infrasonic or lower-frequency airborne pressure waves on biological structures is a very complex undertaking, whether it be on cell cultures, on animal models, or on human populations. Laboratorial studies, occupational field studies, and residential field studies all have their own strengths and weaknesses. When the latter go unrecognized, however, experimental design flaws can ensue. In this section, the attributes of these different experimental setups are discussed, and their weaknesses and strengths are explored. Together with the preceding section, this serves as a preamble to Section 4, where the results of experimental studies are described in detail.

3.1 Laboratorial studies

Laboratories where infrasonic and lower frequency airborne pressure waves can be applied in a controlled manner are in short supply worldwide, and those that do exist are mostly associated with military installations. Laboratories emitting airborne pressure waves with infrasonic and lower frequency components cannot be randomly placed within residential environments; issues with neighbor disturbance and public health would curtail its use. Moreover, the equipment used to generate the airborne pressure waves is, typically, very large and very expensive, and few sectors of society (other than military or space exploration industries) would have the need for an extensive use of these types of installations.

In these laboratory settings, continuous or pulsed-trains of single-tone airborne pressure waves can be applied, as well as, broadband exposures that can be accurately characterized. The fact that exposure times and acoustic parameters can be precisely controlled is one of the strengths of laboratorial studies, allowing for continuous time exposures, or occupationally simulated exposure schedules. Immediate (hours or days) versus long-term (weeks or months) effects can also be explored.

There are numerous types of biological outcomes that can be studied under laboratorial conditions. Light-, electron- and atomic-force microscopy can be used to study cellular and tissue structural properties, as well as their chemical composition and content of bio-reactive elements. Polymerase chain reaction (PCR) techniques can provide information on messenger RNA (mRNA) expression, allowing for the identification of key pathways. With pharmacological intervention or gene knockout specimens, specific signaling molecules and pathways involved in the elicited responses can be pinpointed. Additionally, control populations for comparison are fairly easy to achieve—they are simply not subjected to the laboratorial exposures.

3.2 Occupational field laboratories

Occupational environments are exceptional field laboratories, as both short-term (several months) and long-term (years) effects can be investigated in more realistic acoustic environments. Typically, different workstations have different acoustical features that can greatly depend on different machinery regimens. For occupational field laboratories, acoustical characterizations of the workplace(s) must be comprehensively undertaken and time exposures to each type of environment should be scored.

Exposure times at work must be differentiated from exposure times away from work, i.e., when the work shift ends, workers leave the field laboratory, but additional exposures to infrasonic or lower frequency airborne pressure waves may be incurred (e.g., recreational, transportation). These must be documented. Significant confounding factors may be introduced unless each subject's residential area is scrutinized and prior-exposure histories probed for fetal, childhood, and adolescent exposures.

Possible biological outcomes within occupational field studies are more limited when compared to laboratory exposures. Noninvasive testing can be imprecise, and the minimally invasive testing (such as a blood chemistry analysis, X-ray, or MRI) may also not be sufficiently precise to yield relevant data. It is also the case that scientific knowledge on relevant biological outcomes that can be noninvasively evaluated in exposed humans is still absent or, at best, very incomplete.

Survivorship bias is a well-known confounding factor in human population studies. In occupational environments, workers with more time on-the-job are those who have survived throughout the years of professional activity, while workers with less time in professional activity may exhibit more severe biological outcomes. This phenomenon is often misinterpreted leading to inconclusive or erroneous conclusions.

Control populations for exposures to infrasonic and lower frequency airborne pressure waves have been a very difficult proposition, given the ubiquitous nature of this stressor. One of the solutions to this profound problem is the scoring of subjects into different groups as per their exposure. Within this context, control groups are composed of individuals who have the least amount of cumulative (prior and present) exposure, and not of individuals with zero exposure.

Different professions can provide different field laboratories, both in terms of acoustic environment and time exposure schedules. For example, long-haul truck drivers are typically exposed for more than 8 hours daily and, oftentimes, sleep in the truck while it is idling, or while refrigeration systems are continuously operating. Workers onboard ships, submarines, offshore oilrigs, aircraft, and spacecraft (for example) can be exposed to significant amounts of infrasonic and lower frequency airborne pressure waves for weeks or months at a time. The wealth of information waiting to be gleaned from these types of field laboratories is breathtaking.

3.3 Residential field laboratories

Field laboratories in urban, suburban, and rural residential settings are generally designed to investigate environmental health effects due to human-made infrasonic and lower frequency airborne pressure waves. Typically, these sources are associated with industrial complexes or infrastructure that, in turn, are usually linked with important economic interests. In general, the amount and type of infrasonic and lower frequency airborne pressure waves contaminating a home will depend on the machine operation and/or the use of the infrastructure. For example, in most urban and suburban areas, airports must close down between the hours of midnight and 5 am. Some factories do not have night shifts and therefore also have daily shutdown periods. Large refrigeration units, hydroelectric dams, and large volume highways, however, must be kept running 24/7 and can also be viewed as continuous sources of infrasonic and lower frequency airborne pressure waves. Wind turbines are the latest addition to these type of sources although they are almost exclusively within rural areas.

Comprehensive characterization of the acoustic environments in the different residential areas must be undertaken (e.g., master bedroom, children's bedrooms, living-lounge areas), since room-resonance phenomena can significantly modify the acoustic environment that is originally being induced and driven by external, incoming airborne pressure waves. Additionally, wind can also influence the spectrum, intensity and type of infrasonic and lower frequency airborne pressure waves that exist within a room. This differentiation is readily achieved with proper acoustic evaluations.

Residential exposure times are much more difficult to control, as they can differ from room to room and on an hourly basis. Moreover, subjects may also be sleeping within the "contaminated" environments, which can severely aggravate biological outcomes. If exposure is concomitantly occurring during sleep and waking hours (e.g., homemakers, workers from home, farmers), then biological outcomes may be further aggravated. Leaving the home can be equated with a biological recovery period (i.e., nonexposure period).

Short-, medium- and long-term effects can be studied in residential settings when the implementation of a new infrastructure or industrial complex is known to be coming to the area. Biological outcomes should strive to be either noninvasive or minimally invasive, and prior-exposure histories are fundamental for achieving useful statistical data.

4. Past relevant studies

Numerous studies conducted over the decades have shed light on the biological response to infrasonic and lower frequency airborne pressure waves and associated symptomatic complaints. Due to space limitations, this discussion will only deal with some of the vascular and collagenous abnormalities, cardiomyocyte changes, and the hippocampus responses, as induced by different types of exposures. For reasons explained in the section "Introduction," all studies using the dBA metric have been eliminated from consideration (with one exception in an occupational setting). Selected studies mostly focus on the cellular and tissue changes observed in laboratory, occupational, and residential settings, using light and electron microscopy. The sequence in which the studies are presented does not follow the classical anatomical order.

4.1 Vascular changes

In the mid-1960s, within a military setting, the immediate exposure to 10–60 Hz, at 118–140 dB, for 2 minutes, induced disturbances of the visual field as reported by all five human subjects [12]. In 1985, laboratorial animal studies exposed rats to tonal 8 Hz at 100–140 dB, 3 hours daily, for 5, 10, 15, or 25 days, and examined the blood and lymph networks of the palpebral (eyelid) and bulbar (eye globe) conjunctiva. *Day 5*: narrowing of all parts of the conjunctiva blood network was observed, with decreased blood capillary lumens. Capillaries, precapillaries, and arterioles were twisted, and blood component agglomerations were identified in venous vessels. *Day 10*: conjunctiva capillaries were twisted and large vessel diameters were decreased. *Day 15:* blood and lymph vessel tonus had changed, and stagnation was present. *Day 25:* failure of tissue homeostasis was aggravated. Capillary penetration was increased, as seen through tissue enlargement, and significant agglutination was observed in the large vessels [13].

In a similar study, animals were exposed to 8 Hz at 100 dB, or to 16 Hz at 100 dB, 3 hours daily, for 1 month. Clinical and morphological evaluations were conducted at days 3, 7, 15, 30, and also post-exposure at days 30, 60, and 90. *Day 3:* clinical changes were not observed, but morphological changes were present: edema in the upper and middle areas of the eyelid derma and heterogeneous blood filling of vessels with extra-vascular erythrocytes were also observed. Fine focal hemorrhages were identified under the corneous layer of the eyelid. Sclera exhibited edema, and blood vessels were filled heterogeneously with stasis and extra-vascular intraconjunctive hemorrhages. In the 8-Hz group, moderate edema was present near the optical nerve, and the 16-Hz group exhibited perineural hemorrhages in the optical nerve. *Day 7:* in both groups, conjunctiva blood vessels had expanded and arteries in the oculus fundus were narrower and twisted. Eyelid edema of the derma was identified in both groups. The most pronounced vascular changes were found in the eyelid conjunctiva: stasis, edema, and pericapillary hemorrhages. Sclera capillaries were overfilled with blood and extra-vascular hemorrhages were observed. *Day 15:* in both groups, conjunctiva vessels were narrower and twisted, and ocular globe conjunctiva exhibited nonvascularized areas. Vascular changes as seen previously were more expressed: edema, paresis state in capillaries (erythrocyte stasis), and extra-vascular erythrocytes. The iris exhibited narrower vessels. *Day 30:* narrowed and twisted vessels were clinically detected, with ocular fundus arteries and veins significantly narrowed and twisted, more pronounced in the 16-Hz group. In the eyelid conjunctiva, derma exhibited the same vascular changes seen before: edema and erythrocyte stasis. Sclera arteries and veins were larger, overfilled with blood, and with the presence of extra-vascular focal and diffuse hemorrhages with conjunctiva involvement. At all time points, the 16-Hz group disclosed more destruction than the 8-Hz group. *Day 60 (30 days post-exposure)*: clinical evaluations revealed less twisted and narrow arteries and veins, but morphological recovery was slower. In the 8-Hz group, moderate regeneration was observed in the eyelid conjunctiva epithelium. In the 16-Hz group, predominant retinal damage persisted. *Day 90:* no clinical changes were observed in either group [14].

Within an occupational setting (reinforced concrete factory), vessel changes in the palpebral and bulbar conjunctiva, and in the retina, were investigated among 214 workers (age range: 20–58 years), with 1–30 years of employment. Workers were divided into two groups:

- *Control group* (n = 54): not occupationally exposed to significant levels of infrasonic and lower frequency airborne pressure waves.

- *Exposed group* (n = 160): tonal 8 and 16 Hz at 96–100 dB, simultaneously with non-tonal 20–500 Hz at 91–93 dBA.

The exposed group was divided into subgroups as per years of professional activity. **Table 1** describes each subgroup and the vessel abnormalities found. No such abnormalities were found in the control population [14].

Within a different occupational setting (aircraft industry), ocular changes were studied in 23 male workers (average age: 42, range: 32–58 years). Lesions

Occupational exposure time	1–2 yrs	3–10 yrs	11–20 yrs	20–30 yrs
Number of workers	21	84	36	19
Palpebral and bulbar arteries (%)				
Enlarged	0	82	8	0
Narrow	0	17	91	100
Twisted	0	80	100	100
Retinal arteries (%)				
Enlarged	0	0	0	0
Narrow	0	91	100	100
Twisted	0	90	100	100
Retinal veins (%)				
Enlarged	0	87	11	0
Narrow	0	13	88	100
Twisted	0	75	97	100

Table 1.
Percentage of abnormal vessel changes seen in the palpebral and bulbar conjunctiva and retina among occupationally exposed workers [14].

were observed in the blood-retinal barrier in 19 workers (lesion types: 13 inactive, 2 active, 4 mixed). Choroidal circulation was altered in 14 workers (late perfusion with chronic features). Changes in retinal circulation were observed in four workers (type: 1 occlusive, 1 exudative, 2 mixed). Three workers presented with optic neuropathy (1 papillitis, 2 optic atrophy), and one exhibited sensorial retinal macular detachment [15]. The immediate effects of tonal exposures with 8 Hz at 130 dB, 2 hours daily, for 1, 7, 14 and 21 days, also revealed a breakdown of the blood-retinal barrier in the rat eye [16].

These studies strongly suggest that under the impact of infrasonic and lower frequency airborne pressure waves, a vascular response is mounted by ocular structures and could be related to decreased visual acuity in workers. Data in **Table 1** seem to indicate that, as exposure time progressed, vessels that were initially enlarged ceased to exist, apparently being replaced with narrower and twisted vessels. Enlarged vessels usually suggest the need for an increased blood supply. However, given the sustained mechanical insult, making the vessels narrower and twisting them throughout the structures may, in fact, reflect a more efficient blood delivery system.

This concept is further reinforced by the observation of narrow and twisted blood vessels in the gastric mucosa of rats, exposed to non-tonal, occupationally simulated (aircraft industry) acoustic environments characterized as 6.3–25 Hz at 70–90 dB and 40–500 Hz at 90–100 dB. Continuous exposure was applied, and evaluations occurred at 1, 3, 5, 9, and 13 weeks. In *3–5 weeks*, the gastric submucosal layer exhibited significantly increased thickness, when compared to non-exposed controls. This increased thickness was due to the proliferation of type IV collagen. Arterial walls disclosed significant intima and media thickening, ruptured internal elastic lamina, and thrombotic changes. In *9–13 weeks,* neoangiogenesis was observed, with the appearance of tortuous and twisted vessels. The authors concluded that, in the stomach, continuous exposure induced fibrosis that could be linked with neoangiogenesis, since collagen type IV is also an early marker of neoangiogenesis [17]. One of the earliest studies investigating the long-term effects of airborne pressure waves on gastric complaints was conducted in 1968, in a residential setting where changes in gastric function were associated with aircraft noise [18]. Within occupational settings, an increase in gastric complaints was documented among boiler-plant workers, 2 years after the implementation of mandatory hearing protection devices [19]. Among aircraft industry workers, gastrointestinal problems were among the earliest to appear after 1–4 years of professional activity [20].

Vascular changes were also identified in the liver structures of animals exposed to 2, 4, 8, or 16 Hz, at 90–140 dB, 3 hours daily, for 5–40 days. Exposures to 2 or 4 Hz induced less damage than exposures to 8 and 16 Hz. *Single, 3-hour exposures:* with 2 or 4 Hz and 90 dB, no changes were observed in the hepatic structures, while at 100–110 dB, liver parenchyma disclosed single fine hemorrhages. At 120 dB, increased arterial wall diameters were observed, as well as capillary lumen expansion, indicating the development of ischemia. At 130–140 dB, the number of hemorrhagic events increased, as did the number of affected hepatocytes. With 8 or 16 Hz exposures, damaged hepatocytes were present in the ischemic and non-ischemic areas. *Days 5–15:* more pronounced hepatocyte changes were seen. *Days 25–40*: a gradual death of changed hepatocytes was observed [21].

Hemorrhagic events in the lung were documented as early as 1969, within the Soviet and US space exploration studies, in dogs exposed to occupationally simulated (spaceflight) wide-band frequency range at 105–155 dB, for 1.5 or 2 hours. Hemorrhages up to 3 mm in diameter were observed beneath the pleura. As exposure time and decibel level increased, the number of hemorrhages increased but never exceeded 3 mm in diameter. Microscopic analyses of the hemorrhagic sections disclosed ruptured capillaries and larger blood vessels [22]. In a laboratory setting, rats received tonal exposures to 2, 4, 8, or 16 Hz at 90–140 dB, 3 hours daily, for 40 days. Analysis time points were conducted after 3 hours, at 5, 10, 15, 24, and 40 days of exposure, as well as during post-exposure times. *Single, 3-hour exposures:* with 2 or 4 Hz at 90–110 dB, mosaic hemorrhages were observed under the pleura, covering the entire lung surface. With 8 Hz at 110 dB, more hemorrhagic expression was observed. With 8 or 16 Hz at 120–140 dB, larger hemorrhagic foci were disclosed. Within the alveolar capillary network and postcapillary venules, vessel diameters were increased with 2 or 4 Hz at 90–110 dB, leading to large hemorrhages and perivascular edema. Erythrocyte overflow in alveolar capillaries was observed with 8 or 16 Hz at 110 dB. With 8 or 16 Hz at 120 or 140 dB, lung tissue exhibited large hemorrhagic foci in the connective tissue septa of the bronchi-pulmonary segments. In all exposure types, capillary changes were followed by alveolar epithelium desquamation and basal membrane denudation. *Longer exposures:* with 8 Hz at 120 dB, acinuses became filled with erythrocytes, and interstitial hemorrhagic foci caused a strong deformation of the respiratory bronchioles. With 8 or 16 Hz at 140 dB, ruptured vascular walls were observed leading to decreased alveolar lumen [23].

The highly invasive bronchoscopic evaluation with biopsy was performed among a group of volunteer subjects, with occupational or residential exposures to infrasonic and lower frequency airborne pressure waves, as detailed in **Table 2**.

Bronchoscopic observations in all patients revealed small submucosal, vascular-like lesions ("pink" lesions), located distally in both tracheal and bronchial trees, and uniformly distributed bilaterally near the spurs. Biopsies were performed on the abnormal mucosa (pink lesions) and on the apparently normal mucosa (outside of the pink lesions). In the non-pink areas, some vessel wall thickening was visible. In the pink areas, the basal membrane disclosed abnormal neovascularization, with thickened blood vessel walls and scarce lumen. No gender differences were identified [24].

4.2 Collagen and connective tissue

Collagen, composed of triple-helix tropocollagen chains, is the most abundant protein in the human body, a key component of the fasciae, and is produced by fibroblast cells. It has long since been considered as the "steel" of the human body [25], but its energy storage capacity has been shown to be 10 orders higher than in spring steel [26]. Different types of collagen have different mechanical properties. Type IV collagen (increased in the exposed gastric mucosa [17]—see above), is organized into X-shaped structures and is commonly found in the basal membrane of arterial walls, hence its increased expression during angiogenesis.

In *day 5* of the eyelid-and-bulbar-conjunctiva animal studies (see above [13]), collagen fibers in the connective tissue were enlarged, as were some fibroblast nuclei; on *day 10*, adipose cells in the connective tissue had been redistributed and positioned in the vascular areas of the conjunctiva. In the second animal study described above [14], *day 3* included edema of the sclera causing separation of collagen filaments in the 16 Hz group, and by *day 7,* this was observed in the 8-Hz group as well; *day 15:* focal and disseminated disorganization of sclera collagen fibers was observed in both groups; *day 30:* homogenization and disorganization of collagen in the derma while, in the sclera, collagen fibers were persistently separated due to edema, with some undergoing dystrophic and necrotic changes. Slow regeneration was observed during the post-exposure periods.

In the lungs of dogs studied within the scope of space exploration (see above [22]), focal enlargement of the alveoli involved the stretching of connective tissue

Profession/type of exposure	Gender	Age	Smoking
Aircraft technician	Male	48	Mild
Aircraft technician	Male	52	No
Aircraft technician	Male	59	Mild
Combat pilot	Male	61	No
Helicopter pilot	Male	59	Moderate
Aircraft pilot	Male	54	No
Merchant marine	Male	37	No
Military helicopter nurse	Female	56	No
Flight attendant	Female	36	No
Flight attendant	Female	39	No
Flight attendant	Female	40	No
Homemaker	Female	54	Mild
Homemaker	Female	59	No

Table 2.
Description of subjects who received bronchoscopic evaluations with biopsy [24].

structures of alveoli walls. In the biopsy images of the bronchoscopic study (see above [24]), non-pink areas disclosed a thickened basement membrane with abnormal amounts of collagen, while the pink areas disclosed an even thicker membrane with very large amounts of collagen. The abnormal neovascularization was embedded within collagen bundles. Retraction of structures neighboring the collagen fibers was not observed. A marked reinforcement of the cytoskeleton and intercellular junctions was seen in the pink areas, as compared to non-pink areas. The five individuals that disclosed images of collagen fiber degeneration and disruption also tested positive for antinuclear antibodies.

Under an occupationally simulated acoustic environment, characterized as 20–200 Hz at 70–90 dB (aircraft industry), and occupationally simulated exposure schedules (8 hours daily, 5 days weekly, weekends in silence), focal interstitial fibrosis was found in the lung parenchyma of rats after a cumulative 4000-hour exposure. Additionally, thickened alveoli walls and dilated alveoli were observed [27]. Tracheal epithelium in similarly exposed rats disclosed significant subepithelial fibrosis [28, 29], and with longer occupationally simulated exposures, the subepithelial layer became composed of hyperplastic collagen bundles, some with a degenerative pattern. Cellular edema was also observed [28, 30].

Within an occupational setting (aircraft industry) and investigating long-term outcomes, high-resolution CT scans of the lungs and respiratory function tests were provided to 21 nonsmoker male workers, who were divided into two groups: with ($n = 7$, average age: 42) and without ($n = 15$, average age: 36) complaints of airflow limitations. There was a significant relationship between the presence of symptoms and images of lung fibrosis through the CT scan. No differences existed among the groups when comparing the percentage of predicted values of lung function [31].

Fasciae abnormalities have been most prominently studied in the pericardia of exposed workers, subsequent to autopsy findings in an aircraft industry worker that disclosed a grossly thickened pericardium [32]. Pericardial morphological changes were studied among 12 male workers: three aircraft technicians, four fixed-wing aircraft pilots, four helicopter pilots, and one long-haul truck driver. Pericardial samples were removed with informed consent of the patient and Ethics Committee approval, at the beginning of cardiac surgery (prescribed for other reasons by the National Healthcare Service). In all cases, there were no visual adherences, or inflammatory aspects and pericardia were grossly thickened. The classical, three pericardial layers were identified: serosa, fibrosa, and epipericardium. However, in all cases, the fibrosa had split in two and, in between, a new layer of loose tissue was observed, consisting of vessels, nerves, arteries, and lymphatics surrounded by adipose tissue. Both fibrosa layers were composed almost entirely by wavy, interwoven collagen bundles, surrounded by numerous cytoplasmic extensions (whose mother cell was difficult to identify), and interspersed with some elastic fibers. The new, loose tissue layer sandwiched in between the split fibrosa contained blood and lymphatic vessels, adipose tissue, and nerves. Both the loose tissue layer and the fibrosa layers contained macrophages and vascular hyperplasia, also seen in lymphatic vessels [33–36]. Pericardial and cardiac valve thickening has also been confirmed through echocardiography studies in occupational settings (aircraft [37] and commercial-airline industries [38]), with thickness increasing with increasing exposure time. In residential settings, pericardial and valve thickening [39] and increased arterial stiffness [40] were observed in populations chronically exposed to military-training exercises [39], and transportation systems [40].

4.3 Heart cells and tissues

In 1983, electron microscopy techniques were used to study animal myocardia exposed to single and multiple infrasonic exposures of 4–16 Hz at 90–150 dB, 3 hours daily, for 45 days, and post-exposure time points were included. No changes were observed with single exposures at 4–6 Hz and at less than 100 dB, when compared to non-exposed controls. *Single exposure with 4–10 Hz at 120–125 dB:* induced decreased arterial diameter and capillary expansion, with resulting focal ischemia. Images of intracellular myocytolysis were frequently found. These processes were reversible. *Multiple exposures with 4–10 Hz at 120–125 dB for 5–25 days*: ventricle fibrillation and subsegmental contractures in ischemic foci were identified. Myofibril fragmentation was observed in the Z-line, sarcoplasmic reticulum structures were absent, cell nuclei were deformed, and chromatin was found accumulated under the nuclear membrane. *post-exposure*: intracellular regeneration was concomitant with damaged cells. In surviving cells, mitochondria were increased in number and size, and both myofilaments and sarcoplasmic reticulum elements were being created. Intracellular regeneration was slow and ended with the creation of Z-lines, after which myofibrils became normal and myocardiocytes completely recovered. *Single exposure with 10–15 Hz at 135–145 dB:* more pronounced myocardial damage, with partial death of myocardiocytes, resulting in myocardiocyte dystrophy. Damaged cells included chromatin condensation and redistribution to the nuclei membrane. Less damaged cells regenerated after 5–10 days post-exposure. *Multiple exposures with 10–15 Hz at 135–145 dB:* persistent myocardial ischemia related to vascular changes and accompanied by cardiocyte damage. After 15–25 days post-exposure, recovered cells began functioning normally despite the presence of abnormal structures within the cellular cytoplasm, namely, giant mitochondria [41].

Cardiac injury was studied in rat cardiomyocytes exposed to tonal 5 Hz at 130 dB, 2 hours daily, for 1, 7, or 14 days. *Days 1–7:* SERCA2 (sarcoplasmic reticulum Ca^{2+} ATPase 2, an enzyme with calcium-transporting properties and involved in the decomposition of ATP into ADP) was significantly increased, and swollen mitochondria were observed in the cardiomyocytes. *Day 7:* SERCA2 was significantly decreased and an increased number of swollen mitochondria were observed. *Day 14:* SERCA2 was significantly decreased and platelet aggregation was found in the intercellular substance. Intercellular calcium ion (Ca^{2+}) concentration significantly increased with increasing exposure time [42]. With similar exposure protocols, another study repeated the SERCA2 and intercellular Ca^{2+} concentrations, but also included evaluations of the expression of whole cell L-type Ca^{2+} currents (WLCC) and the mRNA expression of a subunit of the L-type Ca^{2+} channel (LCC). SERCA2 and intercellular Ca^{2+} concentrations behaved as described immediately above, while the expression of WLCC and mRNA expression of LCC increased with increasing exposure time [43].

For three continuous months, rats were exposed to non-tonal, occupationally simulated (aircraft industry) acoustical environments characterized as 6.3–25 Hz at 70–90 dB and 40–500 Hz at 90–100 dB. Ventricular cardiac muscle and interstitial fibrosis were quantified and compared to non-exposed controls. Exposed rats disclosed a 97.5% increase in fibrosis in the left ventricle, an 81.5% increase in the interventricular septum, and an 83.7% increase in the right ventricle. No significant differences were found in the mean values of cardiac muscle in the left and right ventricles, when compared to non-exposed controls. However, the fibrosis-to-muscle ratio was significantly higher in the exposed rats, indicating significant ventricular myocardial fibrosis [44].

In another study, rats were exposed to a non-tonal, occupationally simulated (textile mill) environment rich in infrasonic and lower frequency components, under an occupationally simulated schedule (8 hours daily, 5 days weekly, weekends in silence), for 1, 3, 5, and 7 months. Ventricular coronary artery caliber, artery wall thickness, and size of arterial perivascular tissue were quantified in a total of 130 arteries (61 exposed and 69 controls). No changes were observed in arterial lumen caliber, and in arterial wall thickness, when compared to non-exposed controls. Perivascular tissue was more prominent in the exposed samples and seemed to exhibit fibrotic development. Lumen-to-wall ratio showed no differences, while wall-to-perivascular-tissue ratio showed a significant increase, as compared to non-exposed controls [45].

In animals exposed to 2–20 Hz peaking at 114 dB, for 28 continuous days, ventricular arteries were studied as to the dimensions of lumen, wall, and perivascular space. An additional group of animals received the same exposure but were treated with dexamethasone (a corticosteroid). Blind evaluation of 31 arteries disclosed increased perivascular spaces in the exposed groups, reflected in the significantly reduced wall-to-perivascular-space ratio, as compared to non-exposed controls. No changes were observed in the lumen-to-wall ratio. With dexamethasone treatment and exposure, no differences were observed in the wall-to-perivascular-space ratio, as compared to controls, suggesting an underlying inflammatory mechanism [46].

Gap junctions are a fundamental component of intercellular communication, allowing inorganic ions and small water-soluble molecules to pass directly from one cell's cytoplasm to another. Gap junctions are formed by protein complexes (connexons) each composed of six subunits made of the protein connexin. Cardiac connexin43 (Cx43) is a component of gap junctions, and its reduction in combination with increased collagen deposition and interstitial fibrosis has been associated with ventricular arrhythmias [47]. Within this context, rats were exposed to non-tonal, occupationally simulated (aircraft industry) acoustical environments characterized by 6.3–25 Hz at 70–90 dB and 40–500 Hz at 90–100 dB, for three continuous months. Immunohistochemical quantification of Cx43 was conducted on the left ventricle, interventricular septum, and right ventricle. Significantly decreased Cx43-to-muscle ratios were found in the exposed rats, as compared to non-exposed controls, suggesting the possibility of arrhythmogenic consequences [48].

4.4 The hippocampus

Prior studies have shown that the hippocampus is involved in learning and memory impairment, such as that seen in rodents after infrasound exposure [49]. The hippocampus—located between the cerebral hemispheres and the brainstem—was classically considered as part of the limbic system. The hippocampus proper is divided into four regions (CA1, CA2, CA3, and CA4), each with different input and output pathways. The Dentate Gyrus (DG) is an additional hippocampus structure and that contributes to the formation of new episodic memories, and spontaneous exploration of novel environments. In the central nervous system (CNS), neuroglia consists of the non-neuronal cells (oligodendrocytes, astrocytes, ependymal cells, and microglia) and is often referred to as the connective tissue of the brain. Glial cells surround neurons to hold them in place, supply them with oxygen and nutrients, insulate them from one another, destroy pathogens, and remove dead neurons.

Glial fibrillary acidic protein (GFAP) is an intermediate filament protein expressed by numerous cells within the CNS, and although its exact function remains unknown, it appears to be involved in maintaining the mechanical strength of astrocytes. The expression of GFAP was studied in the brains of mice exposed to 16 Hz at 130 dB, 2 hours daily, for 1, 7, 14 21, or 28 days. GFAP expression was increased in the hippocampus, cortex, and hypothalamus in a time-dependent manner [50].

Corticotrophin releasing hormone (CHR) is a peptide hormone involved in the stimulation of the pituitary synthesis of ACTH (adrenocorticotropic hormone) as part of the hypothalamic-pituitary-adrenal axis' response to stress. Corticotrophin releasing hormone-receptor 1 (CHR-R1) has wide expression in the CNS. It plays important roles in fear learning and consolidation in the amygdala, in stress-related modulation of memory function in the hippocampus, and in arousal regulation in the brainstem. Prior studies showed that infrasound exposures caused an upregulation of CRH and CRH-R1 in neurons of the hypothalamic paraventricular nucleus [51]. Recent studies have also shown that CRH is expressed in activated microglial cells [52]. Within this context, rats and *in vitro* cultured microglial cells were exposed to 16 Hz at 130 dB for 2 hours, after which changes in CHR-R1 were examined. *In vivo* exposure disclosed activation of microglial cells and an upregulation in the expression of CRH-R1 in the hypothalamic periventricular nucleus. *In vitro* exposure disclosed that, in the absence of neurons, microglial cells were activated and CRH-R1 expression was upregulated. These data suggest that both neurons in the hypothalamic periventricular nucleus and microglial cells are effector cells for infrasound-elicited responses [51].

The transient receptor potential cation channel, subfamily V, member 4 (TRPV4) protein acts as a calcium channel that is also mechanosensitive. It plays important roles in the systemic regulation of osmotic pressure by the brain, in skeletal growth and structural integrity, in airway and lung function, retinal and inner ear function, and in pain. Animals were exposed to 8 or 16 Hz at 90, 100 or 130 dB, 2 hours daily, for 14 days. Rat learning and memory abilities were most severely impaired with 16 Hz at 130 dB at days 7 and 14, with prominent loss of hippocampal CA1 neurons, as compared to non-exposed controls. Significant astrocyte and microglial activation was seen in the hippocampus after days 1 and 7, and before neuronal apoptosis became evident. *In vivo* pharmacological intervention causing the inhibition of glial activation protected against neuronal apoptosis. *In vitro*, exposed glial cells released proinflammatory cytokines, a key factor for neuronal apoptosis. In both *in vivo* and *in vitro*, expression levels of

TRPV4 were increased as compared to non-exposed controls. Pharmacological or knock-out intervention of TRPV4 in cultured glial cells decreased the levels of inflammatory cytokines and attenuated neuronal apoptosis. This study also demonstrated the involvement of calmodulin and protein kinase C signaling pathways in the response to infrasonic exposures. These data suggest that TRPV4 expressed by glial cells is potentially a key factor in infrasound-induced neuronal impairment [53].

Neonatal rat hippocampal astrocyte cultures were exposed to 16 Hz at 130 dB for 15, 30, 60, 90, 120, and 240 minutes. Extra-cellular glutamate levels increased with increasing exposure time, and at 90 min, there was a 100% increase over baseline. The astroglial expression of Cx43 (connexin43—see above) was increased, as compared to non-exposed controls, as was the synthesis of Cx43 mRNA. Through additional evaluations using pharmacological and knock-out interventions, the authors concluded that infrasonic exposures induced astrocytes to release glutamate, and that Cx43 gap junctions were required for the exposure-induced glutamate release [54].

The endocannabinoid system includes lipid-based retrograde neurotransmitters, expressed throughout the CNS, and involved in fertility, pregnancy, pre-and postnatal development, appetite, pain-sensation, mood, and memory. Animals were exposed to 16 Hz at 130 dB, 2 hours daily, for 14 days. Cannabinoid (CB) receptors 1 and 2 in the CA1 hippocampal region of the exposed rats were down-regulated in a time-dependent manner, as compared to non-exposed controls. Apoptotic cells in the CA1 only became obvious after day 5, and cell death coincided with the decreased expression of CB receptors. Through pharmacological intervention, activation of CB receptors significantly reduced the number of apoptotic cells, ameliorated the behavior performance of exposed rats, and reduced the infrasound-elevated levels of proinflammatory cytokines. These data suggest that CB receptors could potentially serve as promising targets for future treatments against infrasound-induced injury [55].

Fibroblasts synthesize extracellular matrix (glycosaminoglycans, reticular, and elastic fibers) and collagen, and, in addition to their structural role, fibroblasts are also important for mounting the immune response to tissue damage. Fibroblast growth factors (FGF) signal through fibroblast growth factor receptors (FGFR). The fibroblast growth factor 2/fibroblast growth factor receptor 1 (FGF2/FGFR1) signaling pathway was investigated in animals and in cultured astrocytes, exposed to 16 Hz at 150 dB, 2 hours daily, for 1, 3, or 7 days. In both experimental models, astrocyte activation increased with exposure time and astrocyte-expressed FGFR1 was downregulated as compared to non-exposed controls. Pharmacological intervention using FGF2 exerted an inhibitory effect on infrasound-induced astrocyte activation, inhibited the elevation of proinflammatory cytokines, upregulated the expression of FGFR1, and alleviated neuron loss in CA1 hippocampus region. Inhibition of the FGF2/FGFR1 pathway aggravated astrocyte-mediated inflammation after infrasonic exposure. The authors concluded that astrocyte-mediated inflammation was involved in infrasound-induced neuronal damage and that the FGF2/FGFR1 pathway played a key role [56].

In a laboratory setting, rats were exposed to tonal 8 Hz at 140 dB, 2 hours daily, for 3 days. A post-exposure, 1-week time point was also established. Significant damage of hippocampus morphology was observed in exposed rats, and recovery was seen after 1 week of post-exposure. Neuronal apoptosis was significantly increased after 24- and 48-hour exposures, as compared to non-exposed controls, and then decreased after 1 week post-exposure. Expression of heat shock protein 70 (HSP70) peaked at 24 hours and was decreased at 48 hours [57].

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5. Conclusions

Exposure to infrasonic and lower frequency airborne pressure waves can cause cellular and tissue damage depending on frequency, dB-level, and exposure time, while the viscoelastic properties inherent to biological tissues impart a nonlinear response to this type of acoustic stressor. The complex mechanosensitive and biochemical cellular signaling pathways mediating this cellular damage have not yet been pinpointed, although fasciae structures and connective tissues (including the neuroglia) seem to be the most sensitive under longer term exposures. Immediate exposures appear to induce inflammatory processes that do not seem to be maintained with longer exposures.

Widespread vascular involvement (not limited to the biological structures addressed herein) was observed in palpebral and bulbar conjunctiva and retina, gastric mucosa, liver structures, lungs, pleura and tracheae, alveoli, pericardia, and coronary arteries. This vascular response may (unsuspectingly) be the underlying cause of many symptomatic complaints. Cognitive deficits oftentimes documented within residential field laboratories may not merely be due to sleep deprivation, but also to hippocampal neuronal damage. Fasciae morphogenesis speaks to the demand on the whole-body structural integrity elicited by this type of external mechanical insult, while collagenous growths and hemorrhagic events of a focal nature may reflect concomitant resonance phenomena.

Recovery periods are not linear, and 2-hour daily exposures imply a 22-hour nonexposure period. This presents a problem for continuous exposures, such as those encountered in some professional activities and most residential environments. The underlying objectives of most of the studies discussed herein are related to occupational exposures and do not consider continuous exposures at less than 90 dB, nor are pressure pulsed trains presented within the laboratorial acoustic environments. In residential environments, however, these attributes are often present. The simulation of residential exposures does not appear to have yet been integrated into laboratory settings and protocols.

The whole-body response also elicits the immune system, affects organs of the reproductive system, changes receptor cells in the vestibular semicanals and auditory cochlea, and induces genotoxic effects, including teratogenesis. This is a pioneering field of science, still in its infancy and urgently requiring scientists from multidisciplinary areas of study because, ultimately, the health of human populations and their offspring must be protected.

Conflict of interest

None.

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MDC invites public comments

MDC invites public comments on potential catfish regulation changes on the Mississippi, Missouri, and St. Francis rivers

Regulation considerations designed to meet the desires of big rivers catfish anglers and harvesters.

The Missouri Department of Conservation (MDC) is seeking public input on potential regulation changes for both recreational and commercial catfish harvest in some big rivers of the state.

People can learn about and comment on the potential regulation changes by going to https://mdc.mo.gov/contact-engage/public-commenting-opportunities/big-rivers-catfish-assessment.The comment period will end August 15, 2021.

Blue catfish and flathead catfish support important sport fisheries on the Mississippi and Missouri rivers, as well as a commercial fishery on the Mississippi River and a small portion of the St. Francis River. Our studies confirmed that current management approaches continue to support healthy and sustainable blue catfish and flathead catfish populations in the Mississippi and Missouri rivers, and regulation changes do not appear to be necessary to maintain these populations or prevent overfishing. However, MDC is considering changes to management strategies and harvest regulations to better meet the desires of big rivers catfish anglers and harvesters.

"These potential regulation changes can help MDC manage catfish fisheries on Missouri's big rivers, but we need to understand Missourian's opinions about catfish angling and harvest before moving forward," said Joe McMullen, an MDC scientist who's involved with catfish management in the state. "After we collect public comments, we can tailor our management strategies to meet the desires of fishers and implement harvest regulations that can improve both sport and commercial fisheries accordingly. Depending on public sentiment we may also decide to retain our current management strategies and harvest regulations."

Potential sport fishery regulations include:

Establish a minimum length limit of 18, 21, or 24 inches for blue catfish and flathead catfish on the Mississippi and/or Missouri rivers (currently there is no minimum length limit).

Maintain the current daily limit of 5 blue catfish per day on the Missouri River but establish that only 1 blue catfish over 30-inches in length may be kept as a part of that limit.

Potential commercial fishery regulations include:

Establish a minimum length limit of 18, 21, or 24 inches for blue catfish and flathead catfish on the Mississippi and St. Francis rivers (currently the minimum length limit is 15-inches).

People can learn more about the regulations being considered and view associated research reports and summaries at: https://research.mdc.mo.gov/project/big-rivers-catfish-assessment.

NOTICE OF PUBLIC HEARING

Notice is hereby given that the Boone County Commission will conduct a Public Hearing for the purpose of readopting the Boone County Zoning Regulations, including revisions to Section 2, Definitions; Section 15.G, Conditional Use Permits for Commercial Wind Energy Conversion Systems; and Section 29, Wind Energy Conversion Overlay District on the following date:

Tuesday, July 27, 2021 at 7:00 PM; Boone County Government Center, Commission Chambers, 801 E. Walnut St., Columbia, MO

The Boone County Commission will also hold two Public Meetings for citizens to provide comments regarding the above regulations on the following dates:

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Copies of the proposed regulations may be obtained at the office of Boone County Resource Management, 801 E. Walnut St., Rm. 315, Columbia, or on our website at: www.showmeboone.com/resource-management/WECOD

BoCo Journal Proof.

COLUMBIA DAILY TRIBUNE
P.O. Box 798 • Columbia, MO • 65205-0798

BILLING PERIOD	ADVERTISER/CLIENT NAME		
07/01/21 - 07/31/21	BC RESOURCE MANAGEMENT		
TOTAL AMOUNT DUE	*UNAPPLIED AMOUNT	TERMS OF PAYMENT	
134.10		NET DUE 28 DAYS	
CURRENT NET AMOUNT DUE	30 DAYS	60 DAYS	OVER 90 DAYS
134.10	0.00	0.00	0.00

ADVERTISING INVOICE and STATEMENT

INVOICE NUMBER	PAGE #	BILLING DATE	BILLED ACCOUNT NUMBER	PARENT ACCOUNT NUMBER
1480832	1	07/31/2021	12525	12525

BILLED ACCOUNT NAME & ADDRESS

BC RESOURCE MANAGEMENT
***
801 E WALNUT ST
COLUMBIA MO 65201-4890

PLEASE DETACH AND RETURN UPPER PORTION WITH YOUR REMITTANCE

DATE	REFERENCE	PUB	DESCRIPTION – OTHER COMMENTS / CHARGES	SIZE/PAGES	TIMES	RATE	BALANCE
			BALANCE FORWARD				0.00
07/11	92009	CDT	3C WIND FARM HEARING	2 X 4.50	1	14.90	134.10

CONTRACT NAME:	EXPIRES	COMMITMENT	PERIOD	TO DATE	TO FULFILL
Net Dollar Volume	04/29/2022	24000.00	6336.82	7586.35	16413.65

STATEMENT OF ACCOUNT AGING OF PAST DUE AMOUNTS

CURRENT NET AMOUNT DUE	30 DAYS	60 DAYS	OVER 90 DAYS	*UNAPPLIED AMOUNT	TOTAL AMOUNT DUE
134.10	0.00	0.00	0.00		134.10

COLUMBIA DAILY TRIBUNE
101 North 4th Street • P.O. Box 798
Columbia, MO 65205 • (573) 815-1500

*UNAPPLIED AMOUNTS ARE INCLUDED IN TOTAL AMOUNT DUE

INVOICE NUMBER	ADVERTISER INFORMATION			
	BILLING PERIOD	BILLED ACCOUNT NUMBER	PARENT ACCOUNT NUMBER	ADVERTISER / CLIENT NAME
1480832	07/01/21 - 07/31/21	12525	12525	BC RESOURCE MANAGEMENT

AFFIDAVIT OF PUBLICATION

BC RESOURCE MANAGEMENT

I, Christian Crawford, being duly sworn according to law, state that I am one of the publishers of the Columbia Daily Tribune, a daily newspaper of general circulation in the County of Boone, State of Missouri, where located; which newspaper has been admitted to the Post Office as periodical class matter in the City of Columbia, Missouri, the city of publication; which newspaper has been published regularly and consecutively for a period of three years and has a list of bona fide subscribers, voluntarily engaged as such, who have paid or agreed to pay a stated price for a subscription for a definite period of time, and that such newspaper has complied with the provisions of Section 493.050, Revised Statutes of Missouri 2000, and Section 59.310, Revised Statutes of Missouri 2000. The affixed notice appeared in said newspaper on the following consecutive issues:

1st Insertion	07/11/21
2nd Insertion	
3rd Insertion	
4th Insertion	
5th Insertion	
6th Insertion	
7th Insertion	
8th Insertion	
9th Insertion	
10th Insertion	
11th Insertion	
12th Insertion	
13th Insertion	
14th Insertion	
15th Insertion	
16th Insertion	
17th Insertion	
18th Insertion	
19th Insertion	
20th Insertion	
21st Insertion	
22nd Insertion	

NOTICE OF PUBLIC HEARING

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By CHC $134.10

Subscribed and sworn to before me this 2nd of August, 2021

Sandra Rother
Notary Public

SANDRA L ROTHER
Notary Public - Notary Seal
STATE OF MISSOURI
Comm. Number 15638071
Boone County
My Commission Expires: Sep. 9, 2023

AFFIDAVIT OF NOTICE OF PUBLIC HEARING

STATE OF MISSOURI) ss
County of Boone)

I hereby swear that the affixed notice of public hearing was posted at Ashland City Hall, located at 109 W. Broadway, Ashland, Missouri on the

12 day of July, 20 21

[signature] date 7-13-21
Darin Ratermann

Subscribed & sworn to before me this 13th day of July, 20 21

Paula L Evans
Notary Public

Paula L. Evans
Printed Name

PAULA L. EVANS
Notary Public - Notary Seal
STATE OF MISSOURI
Boone County
My Commission Expires: Mar. 4, 2022
Commission # 14398153

COUNTY OF BOONE MISSOURI
DIRECTOR
BILL FLOREA

Boone County Resource Management

ROGER B. WILSON GOVERNMENT CENTER
801 E. WALNUT ROOM 315 COLUMBIA, MO 65201-7730
(573) 886-4330 FAX (573) 886-4340

PLANNING - INSPECTIONS - ENGINEERING

NOTICE OF PUBLIC HEARING

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BOONE COUNTY COMMISSION
PUBLIC MEETING ON PROPOSED WIND FARM REGULATIONS

SOUTHERN BOONE COUNTY SCHOOLS, CENTRAL BOARD OFFICE
5275 W. REDTAIL DRIVE, ASHLAND, MISSOURI
(573) 886-4330

Minutes	**6:30 P.M.**	**Wednesday, August 11, 2021**

Present: Southern Boone County Commissioner, Justin Aldred; Resource Management Director, Bill Florea; Resource Management Planner, Cece Riley.

This meeting is being held to discuss proposed Boone County Wind Farm Regulations.

Southern Boone County Commissioner Justin Aldred welcomed everyone in attendance and stated that this meeting is to hear public comments in relation to readopting the Boone County Zoning Regulations, conditional use permits for Commercial Wind Energy Conversion Systems (WECS-C), and Wind Energy Conversion Overlay Districts (WECOD). The Boone County Planning and Zoning Commission has gone through an extensive process of collecting public comment and research.

Resource Management Director, Bill Florea stated that the Planning and Zoning Commission held 14 work sessions between April 2019 and May 2021. During these work sessions, there were several guiding principles that emerged. A high level of community support for all proposed wind farms, a high commitment to public safety, health and welfare, minimizing impacts to non-participating properties and property owners, ensuring mitigation of any degradation of public transportation infrastructure, minimizing impacts to the natural environment, and ensuring a fair process.

Mr. Florea stated that the Planning and Zoning Commission took into consideration recommendations from the Columbia Commission on Energy and Environment. They based their findings on a document titled *A Method for Defining Wind Turbine Setback Standards* which is published in the Academic Journal *Wind Energy*. The Commission weighed a variety of different factors including safety, equity and community concerns.

Resource Management Director, Bill Florea gave a power point presentation which included a brief summary of the requirements for establishing a wind farm in Boone County. This presentation is available on the Resource Management website at: https://www.showmeboone.com/resource-management/WECOD/

Commissioner Aldred opened the floor for comments from those who would like to see revisions to the proposed regulations:

Jeff Aboussie, International Union of Operating Engineers, 330 Shetland Valley, Chesterfield, MO

Mr. Aboussie stated he is here to talk about wind farm construction as a whole and believes it is an intricate part of renewable energy. The Governer's Office has put a great deal of emphasis on work force development and the need to continue to look for way to increase people to get involved in job opportunities. Mr. Aboussie stated he would like to see some language that look at opportunities for developing wind farms to include apprenticeship language. An infrastructure bill was passed by the US Senate and it has language in it for renewable energy. We have witnessed a number of wind farms that have been developed over the past few years around Missouri and we have seen contractors come out of state and brought their workforce here and they have taken their money home and not spent it here. Taxation will be a benefit for this county, but we think that providing good career opportunities for young people to get started in this sector, which will be very prevalent in the next decade, is also critical. To touch on some of the downfalls that have happened on various other projects around the state, we've seen people get cheated out of a lot of money, some of our contractors were owed a lot of money and these people have left and left our contractors holding the bag for millions of dollars, a couple of them have gone out of business. We believe to help prohibit that is to hire local, both from the contracting side as well as the employee side. It helps build good communities and pays great wages and benefits.

Mr. Aboussie submitted revisions to the proposed regulations.

Philip Fracica, Director of Programs for Renew Missouri, 409 Vandiver Drive, Columbia.

Mr. Fracica stated he is here to speak in support of the project but to also submit revisions to the regulations that Renew Missouri's legal team has put together. Mr. Fracica stated that wind projects can be good neighbors and good for communities and the State of Missouri; they can also create strong economic development opportunities locally. They can also be done in a way to address local environmental and safety concerns which is detailed in the revisions as well as some language around apprenticeships and local work force involvement on these projects. This could be a strong project for the county and we want to make sure the regulations moving forward are done in a good way that can help other projects and keep Boone County as an attractive opportunity for developers and growing clean energy in the State of Missouri.

Mr. Fracica submitted revisions to the proposed regulations.

Commissioner Aldred opened the floor for comments from those who would like to see the regulations adopted as presented.

Tom Weislocher, 11581 N Trimble Rd, Harrisburg

Mr. Weislocher stated he has followed the development process of the regulations and they have been very well thought out and researched. Mr. Weislocher supports adoption of the regulations as written and does not object to adding language in the regulations to facilitate the hiring of local people and creating job opportunities. There are many things about wind farms that Mr. Weislocher is opposed to and stated that if we have to have them then we should get the benefit of local people getting some of the jobs to keep the revenue and quality of life that it affords in the county. Mr. Weislocher is in favor of the wording of most of the distances even thought some weren't quite what he wanted but understands the reason they were chosen. Boone County is already too densely populated to accommodate too many wind turbines but if we are going to regulate it, lets regulate it in the best way we can which we have done and let the wind developers decide if they want to develop here, somewhere else, or not at all.

Commissioner Aldred opened the floor for anyone with comments to speak.

Rex Smith, 12700N Route J, Harrisburg

Mr. Smith asked what enforcement mechanism is in the regulations that the County Commission can enforce if, for instance, they are tearing up the roads. We have heard testimony at other meetings where there was no way to enforce things like that.

Commissioner Aldred stated there are regulations written in regarding roads.

Bill Florea stated that the mitigation plan would include a mitigation agreement so it would stipulate the terms under which the wind farm company would be able to use the county roads. That would have an enforcement mechanism built into it; it would be custom designed for each different wind farm.

Mr. Smith asked if that would be enforced through the County Court.

Bill Florea stated it might be, but it might be an escrow account that the developer will fund. There are a lot of different ways it could be done.

Matt Enloe, Business Representative, International Union of Operating Engineers, 4201 Laura Ave, (city not provided)

Mr. Enloe stated we have 4200 members in the eastern half of Missouri, many of the members live in Boone County and have been a part of every major project from the hospitals to the bridges and roads. The importance of giving our members and any local resident the chance to work on a project like this is imperative. Mr. Enloe agrees with the apprenticeship language to encourage trades and skills.

Warren Wood, Vice-President of Legislative and Regulatory Affairs, Ameren Missouri, 5300 E Hayes Rd, Columbia

Mr. Wood stated he lives on a small farm on an energy pipeline with a cell tower overlooking his house and a CAFO a couple of miles away. Mr. Wood understands the impacts of utilities on the quality of life in the country and sees it as a fair concern. Ameren Missouri views the regulations being proposed as an effort to ensure that wind energy projects are good neighbors to the community and Ameren agrees with that effort. Mr. Wood stated that Ameren is concerned about several aspects of the regulations being proposed. Renew Missouri is looking at providing some suggested changes to the regulations; Ameren has reviewed the changes proposed by Renew Missouri and find those to be good amendments in the direction of being able to be a good neighbor and yet not prohibit wind project construction in Boone County. As an electric service provider, Ameren is focused on affordable, reliable power and building that in Missouri, if feasible. As we look at future energy, we look at change in policy, the age of our generation mix now and we see wind energy as a very important part of that future energy in the State of Missouri. Looking at the setbacks and height limitations we think the Missouri Renew suggestions make it much more possible that a project can be built in Boone County. When you move down the path of forcing wind projects in the state you are also building more transmission which is also problematic for many of the communities of major transmission projects, if we can't build it here we have to transport it here to be able to serve the populations.

Tom Weislocher, 11581 N Trimble Rd, Harrisburg

Mr. Weislocher stated he had additional comments regarding height and setback requirements. The people that live in the area think that the height should be shorter and the setbacks should be further. The people that want to develop believes the height should be taller and the setbacks shorter. When we look at the history of wind development, not just in Missouri and not just in the United States, but in Europe where wind power took hold and they were held out as the example, why can't we do this in America? If we look at Germany, development has virtually stopped there and it is because they have modified their regulations on setbacks instead of 1000 or 2000 feet, they are now five miles in most areas and that makes it essentially prohibitive to build wind turbines there. This is why we have a German company coming to Missouri wanting to build here because we don't have that history and people are fairly naïve and don't know what it is like to live that close to a wind turbine. Mr. Weislocher stated he has heard people say the setback should be the fall distance. The regulations say 1750-feet and that was some effort of compromise to allow turbines to be built but also to protect property owners. When we listen to people that have lived near them and how it has affected their lives, which isn't apparent on day one, it seems to be an accumulation of experience, 1750-feet doesn't seem to be a large enough setback. At the Columbia meeting someone brought pictures of turbines around her home that were two to five miles away and they looked like they were right over her head. We are already looking at something a lot closer than that. Mr. Weislocher stated he has heard some of his neighbors say that if they build these they will have to move and take a loss on their property. Projects can't benefit everyone, there are going to be some losers and some winners. Mr. Weislocher doesn't want to be one of the losers and appreciates the Planning and Zoning Commission trying to find a fair solution. The priorities as a county government should be not the short-term benefits to a few but the long-term benefits to the County. If we get a short increase in tax revenue will that offset people fleeing from Boone County to live elsewhere because their quality of life has been affected so much? If the setbacks and heights are changed it will cause a ripple effect and will affect everything else and several other things will have to change. All of that was taken into consideration when the numbers were decided upon. For Boone County, with our density and land layout, those numbers are where they need to be. Mr. Weislocher doesn't believe the intention is to drive these developments to other counties, the intention is to promote the safety, welfare and long-term prosperity of Boone County. We cannot juggle the numbers for special interest groups.

End of public comments.

The County Commission will hold another public meeting in Harrisburg on Tuesday, August 24, 2021 at 6:30 PM in the Harrisburg High School gymnasium. Consideration of the amendments to, or adoption of the proposed regulations will occur at a later date.

Meeting notes prepared by Paula Evans, Administrative Coordinator, Boone County Resource Management

Centralia Fireside Guard

PO Box 7
Centralia MO 65240
Phone: (573) 682-2133
Fax: (573) 682-3361

INVOICE/STATEMENT

BILLING DATE	PAYMENT DATE
07/31/2021	08/15/2021

BILLED ACCOUNT

Paula Evans
Boone County Resource Management
801 E. Walnut Room 315
Columbia, MO 65201

BILLED ACCOUNT NO.	AGENCY/CLIENT
00029104	00029104

NAME OF AGENCY/CLIENT

Boone County Resource Management

DATE	TRANS #	DESCRIPTION	INS	SAU	INCHES	AMOUNT	TOTAL
06/30/2021		Balance Forward					0.00
07/14/2021	300644835	Wind Farm Ad - 00252027 Wind					105.00
		M071 Centralia Fireside Guard -	1	3 x 4	12.00	105.00	

CURRENT	AGING 1 - 30	31 - 60	61 - 90	91 - 120
$ 105.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00

TOTAL NET AMOUNT DUE

$ 105.00

PLEASE RETURN THIS PORTION
WITH YOUR REMITTANCE

If you desire to charge this amount to your credit card, please complete the following information and return to the address below: [ ] Visa [ ] Mastercard [ ] Discover [ ] American Express

Acct# ______________________ Exp Date: ______________

Signature ______________________________

Thank you for your business.

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00029104	Boone County Resource Management	

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Centralia Fireside Guard
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Morristown TN 37815

Phone: (423) 581-5630
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Payment in full is due upon receipt of the statement. A service charge on all balances over 30 days will be computed by a 'Periodic Rate' of 1-1/2% per month, which is an ANNUAL PERCENTAGE RATE OF 18%, this applies to the previous balance after deducting current payments and credits appearing on your statement.

Remittance Advice

AFFIDAVIT OF PUBLICATION

STATE OF MISSOURI)
SS.
COUNTY OF BOONE)

I, James Smith, being duly sworn according to law, state that I am the Editor
(Editor, Publisher)
of the CENTRALIA FIRESIDE GUARD, a weekly newspaper of general circulation in the county of BOONE, where located; which newspaper has been admitted to the Post Office as periodical class matter in the City of Centralia, Missouri, the city of publication; which newspaper has been published regularly and consecutively for a period of 152 years and has a list of bona fide subscribers voluntarily engaged as such who have paid or agreed to pay a stated price for a subscription for a definite period of time, and that such newspaper has complied with the provisions of Section 493.050 Revised Statues of Missouri 2004, and Section 59.310, Revised Statues of Missouri 2004. The affixed notice appeared in said newspaper on the following consecutive issues.

From July 14, 2021 to July 14, 2021

First insertion July 14, 2021
Second insertion
Third insertion
Fourth insertion
Fifth insertion
Sixth insertion

(Signed) James Smith
(Editor, Publisher)

Subscribed and sworn before me this 10th day of August, 2021.

Leah Smoot Notary Public

My commission expires August 10, 2021.

NOTARY PUBLIC NOTARY SEAL STATE OF MISSOURI

LEAH SMOOT
My Commission Expires
August 10, 2021
Audrain County
Commission #13512683

Classifieds

CLASSIFIEDS
$1.76
PER INCH
$8.80
MINIMUM

DISPLAY
CLASSIFIEDS
$8.80
PER COLUMN
INCH

DEADLINE FOR NEWS AND ADS IS NOON MONDAY

Check out the Centralia Fireside Guard on Facebook & Instagram!!!

600 Employment

490 Yard Sale

Garage Sale: Antiques, household goods & much, much more. Inside and outside. 8949 Ball Road. Follow the signs. Friday 9-3. Saturday 7-3.

460 Feed

Hay bales, small and large, few bales from 2020 & new hay. Mexico area, delivery is available. 573-473-8045 or 573-721-0088.

820 Services

Save $50 when you buy select tires at Jim Butler Chevrolet of Centralia. 573-682-2146. See dealership for details.

Order your prescriptions through our mobile Good Neighbor Pharmacy app. Select Kinkead Pharmacy as your preferred pharmacy. Order with a click of a button!

129 Trespassing Notices

Six Months, $11 - One Year, $15

Milton & Kathy Vassos Property Audrain County 3-4-22

John Selby-Selby Lane Prop., Audrain & Boone County 4-1-22

Beth Selby Herod Farm 4-1-21

Grace Davenport Farm 9-16-21

820 Services

Excavator & skid loader work, rock hauling. Call for estimates, 573-473-2569 or 573-473-8045.

Check out other services in our Service Directory

101 Statewide Classifieds

EMPLOYMENT

Get paid to care for your loved ones at home. Medicaid required. 314-375-6602. www.helpfulhandsinhomecare.com

HOME IMPROVEMENT

Eliminate gutter cleaning forever! LeafFilter, the most advanced debris-blocking gutter protection. Schedule a FREE LeafFilter estimate today. 15% off Entire Purchase. 10% Senior & Military Discounts. Call 1-844-713-4600

GENERAC Standby Generators provide backup power during utility power outages, so your home and family stay safe and comfortable. Prepare now. Free 7-year extended warranty ($695 value!). Request a free quote today! Call for additional terms and conditions. 1-866-686-8347

The **Generac PWRcell**, a solar plus battery storage system. SAVE money, reduce your reliance on the grid, prepare for power outages and power your home. Full installation services available. $0 Down Financing Option. Request a **FREE**, no obligation, quote today. Call 1-855-904-3857

WANTED TO BUY

OLD MOVIE POSTERS WANTED from the 1920s, 1930s, 1940s and 1950s. Cash paid. Call 515-370-3203

WANTED TO BUY

FREON WANTED: We pay $$$ for cylinders and cans. R12 R500 R11 R113 R114. Convenient. Certified Professionals. Call 312-291-9169 or visit RefrigerantFinders.com

130 Public Notice

NOTICE OF PUBLIC HEARING

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Patriots

Save Our Constitution

Arise USA!

In Central Missouri
July 25, 2021 - Sunday 4-7 p.m.

Centralia Town Square – Centralia, MO

Bring a Lawn Chair

Guest Speakers: Mayor Chris Cox, David & Stacy Whited with The Flyover Conservatives, Larry Wayland with Modern Arms, Sheriff Dwayne Carey of Boone County Sheriff Dept., Alex Dixon of Centralia and Pastor Paul Klepees of PGUMC.

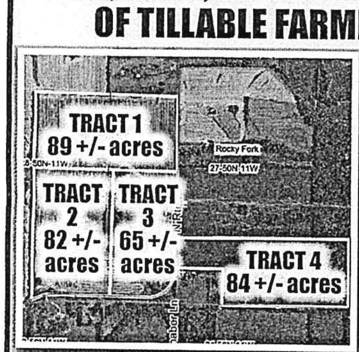
150 Auction

Boone County
REAL ESTATE AUCTION
• FRIDAY, JULY 23, 2021 AT 10 AM •

AUCTION LOCATION: Section 27 & 28 of Rocky Fork Township (T.50N.-R.11W) Boone County, MO. Auction will be held on Tract 3 off of Route Z

Directions: From Hallsville: At intersection of Route B and Route OO in Hallsville travel 5 miles east on OO to route Z continue straight on Z approximately 3/4 of a mile to the farm. From Centralia: Travel 8.5 miles south on route Z to the farm on both sides of road. From Interstate 70: Take exit 133 and travel north on route Z approximately 10 miles to the farm on both sides of road

OFFERING 319 +/- ACRES IN 4 TRACTS IN T50N, R11W, SEC. 27 AND 28 TO 34 +/- ACRES OF TILLABLE FARMLAND AND WOODS



Tract 1: Consists of 89 +/- acres and according to the FSA office there are approximately 86 cropland acres. This tract is primarily productive tillable farm land. It is accessed on the west side of Route Z and is located in Section 27 & 28 in Rocky Run Township. Wheeler Auctions has contacted MODOT and they have granted an additional access of off Route Z to Tract 1. It will be at the buyer's expense to have this put in.

Tract 2: Consists of 82 +/- acres and according to the FSA office there approximately 72 cropland acres. This tract is primarily productive tillable farm land. It is accessed on the north side of Route Z and is located in Section 28 in Rocky Run Township.

Tract 3: Consists of 65 +/- acres and according to the FSA office there approximately 46 cropland acres. This consists of the former farmstead and has 3 grain bins and one useable machine shed. This tract contains tillable farm land, some grass land, and wooded draws. It is accessed on the west Side of Route Z and is located in Section 27 in Rocky Run Township.

Tract 4: Consists of 84 +/- acres and according to the FSA office there approximately 78 cropland acres. This tract consists of tillable farm land, grass land, and wood draws. It is accessed on the east side of west Side of Route Z and is located in Section 27 in Rocky Run Township.

SELLERS: DONALD D. & BARBARA A OSBURN FAMILY TRUST

Wheeler AUCTIONS & REAL ESTATE
23101 HWY. 24, PARIS, MO 65275 | 660-327-5890
WWW.WHEELERAUCTIONS.COM

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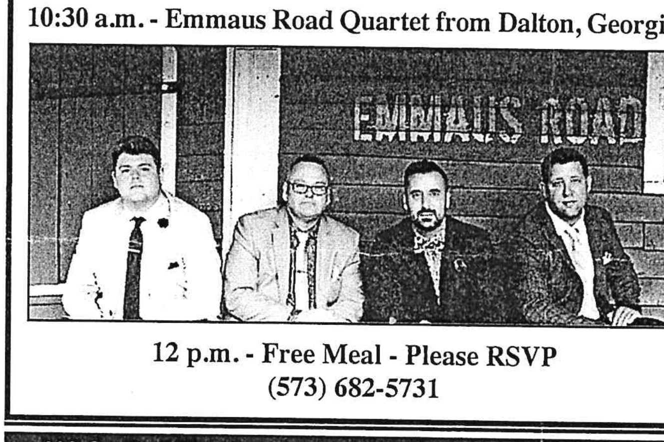
FOR MORE INFORMATION
Kirby Fecht | 217-248-2906
wheelerauctions.com

Family & Friends Day

Crossroads Cathedral
229 S. Allen • Centralia, Mo.
July 18, 2021

10:30 a.m. - Emmaus Road Quartet from Dalton, Georgia



12 p.m. - Free Meal - Please RSVP
(573) 682-5731

110 Card of Thanks

Our hearts are overwhelmed by the outpouring of love and kindness shown our family at the time of the passing of our loved one, Charlie Dawson. Thank you for the many cards, the food brought to our home, and the other numerous acts of kindness. Because of this outpouring of love and kindness and the fact that we know he is now with his Lord and Savior, Jesus Christ, our burden has been made lighter. Thank you! May God bless each of you!

The Family of Charles H. Dawson

Thank you for the cards, food, flowers, memorial donations, and kindness during this difficult time losing our mom, Marcia Salisbury.
Tim Salisbury & Family
Kimball Salisbury & Family
Rhonda Kottwitz & Family

Visit us at firesideguard.com

COLUMBIA DAILY TRIBUNE
P.O. Box 798 • Columbia, MO • 65205-0798

ADVERTISING
INVOICE and STATEMENT

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07/01/21 - 07/31/21	BC RESOURCE MANAGEMENT		
TOTAL AMOUNT DUE	*UNAPPLIED AMOUNT	TERMS OF PAYMENT	
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INVOICE NUMBER	PAGE #	BILLING DATE	BILLED ACCOUNT NUMBER	PARENT ACCOUNT NUMBER
1480832	1	07/31/2021	12525	12525

BILLED ACCOUNT NAME & ADDRESS

BC RESOURCE MANAGEMENT
***
801 E WALNUT ST
COLUMBIA MO 65201-4890

PLEASE DETACH AND RETURN UPPER PORTION WITH YOUR REMITTANCE

DATE	REFERENCE	PUB	DESCRIPTION – OTHER COMMENTS / CHARGES	SIZE/PAGES	TIMES	RATE	BALANCE
			BALANCE FORWARD				0.00
07/11	92009	CDT	3C WIND FARM HEARING	2 X 4.50	1	14.90	134.10

CONTRACT NAME:	EXPIRES	COMMITMENT	PERIOD	TO DATE	TO FULFILL
Net Dollar Volume	04/29/2022	24000.00	6336.82	7586.35	16413.65

STATEMENT OF ACCOUNT AGING OF PAST DUE AMOUNTS

CURRENT NET AMOUNT DUE	30 DAYS	60 DAYS	OVER 90 DAYS	*UNAPPLIED AMOUNT	TOTAL AMOUNT DUE
134.10	0.00	0.00	0.00		134.10

COLUMBIA DAILY TRIBUNE
101 North 4th Street • P.O. Box 798
Columbia, MO 65205 • (573) 815-1500

*UNAPPLIED AMOUNTS ARE INCLUDED IN TOTAL AMOUNT DUE

INVOICE NUMBER	ADVERTISER INFORMATION			
	BILLING PERIOD	BILLED ACCOUNT NUMBER	PARENT ACCOUNT NUMBER	ADVERTISER / CLIENT NAME
1480832	07/01/21 - 07/31/21	12525	12525	BC RESOURCE MANAGEMENT

AFFIDAVIT OF PUBLICATION

BC RESOURCE MANAGEMENT

I, Christian Crawford, being duly sworn according to law, state that I am one of the publishers of the Columbia Daily Tribune, a daily newspaper of general circulation in the County of Boone, State of Missouri, where located; which newspaper has been admitted to the Post Office as periodical class matter in the City of Columbia, Missouri, the city of publication; which newspaper has been published regularly and consecutively for a period of three years and has a list of bona fide subscribers, voluntarily engaged as such, who have paid or agreed to pay a stated price for a subscription for a definite period of time, and that such newspaper has complied with the provisions of Section 493.050, Revised Statutes of Missouri 2000, and Section 59.310, Revised Statutes of Missouri 2000. The affixed notice appeared in said newspaper on the following consecutive issues:

1st Insertion	07/11/21
2nd Insertion	
3rd Insertion	
4th Insertion	
5th Insertion	
6th Insertion	
7th Insertion	
8th Insertion	
9th Insertion	
10th Insertion	
11th Insertion	
12th Insertion	
13th Insertion	
14th Insertion	
15th Insertion	
16th Insertion	
17th Insertion	
18th Insertion	
19th Insertion	
20th Insertion	
21st Insertion	
22nd Insertion	

NOTICE OF PUBLIC HEARING

Notice is hereby given that the Boone County Commission will conduct a Public Hearing for the purpose of readopting the Boone County Zoning Regulations, including revisions to Section 2, Definitions; Section 15.G, Conditional Use Permits for Commercial Wind Energy Conversion Systems; and Section 29, Wind Energy Conversion Overlay District on the following date:

Tuesday, July 27, 2021 at 7:00 PM: Boone County Government Center, Commission Chambers, 801 E. Walnut St., Columbia, MO

The Boone County Commission will also hold two Public Meetings for citizens to provide comments regarding the above regulations on the following dates:

Wednesday, August 11, 2021 at 6:30 PM: Southern Boone Schools, Central Office Board Room, 5275 W. Red Tail Drive, Ashland, MO

Tuesday, August 24, 2021 at 6:30 PM: Harrisburg High School Gymnasium, 801 S. Harris St, Harrisburg, MO

Copies of the proposed regulations may be obtained at the office of Boone County Resource Management, 801 E. Walnut St., Rm. 315, Columbia, or on our website at: www.showmeboone.com/resource-management/WECOD

By CHC $134.10

Subscribed and sworn to before me this 2nd of August, 2021

Sandra L Rother
Notary Public

SANDRA L ROTHER
Notary Public - Notary Seal
STATE OF MISSOURI
Comm. Number 15638071
Boone County
My Commission Expires: Sep. 9, 2023

AFFIDAVIT OF NOTICE OF PUBLIC HEARING

STATE OF MISSOURI) ss
County of Boone)

I hereby swear that the affixed notice of public hearing was posted on the Community Bulletin Board located at 111 W. Sexton Street, Harrisburg, Missouri on the

11th day of July, 2021

Paula Evans date 7/12/21
Paula Evans

Subscribed & sworn to before me this 12th
day of July, 2021

Christina L. Crane
Notary Public

Christina L. Crane
Printed Name

CHRISTINA L. CRANE
NOTARY PUBLIC - NOTARY SEAL
STATE OF MISSOURI
COMMISSIONED FOR BOONE COUNTY
MY COMMISSION EXPIRES MAY. 21, 2025
ID #13705616

Boone County
Resource Management

ROGER B. WILSON GOVERNMENT CENTER
801 E. WALNUT ROOM 315 COLUMBIA, MO 65201-7730
(573) 886-4330 FAX (573) 886-4340

DIRECTOR
BILL FLOREA

PLANNING - INSPECTIONS - ENGINEERING

NOTICE OF PUBLIC HEARING

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COMMUNITY SCOOP

BOONE COUNTY COMMISSION
PUBLIC MEETING ON PROPOSED WIND FARM REGULATIONS

HARRISBURG PUBLIC SCHOOL, HIGH SCHOOL GYMNASIEUM
801 S HARRIS ST, HARRISBURG, MISSOURI
(573) 886-4330

Minutes	**6:30 P.M.**	**Tuesday, August 24, 2021**

Present: Northern Boone County Commissioner, Janet Thompson; Resource Management Director, Bill Florea; Resource Management Planner, Cece Riley.

This meeting is being held to discuss proposed Boone County Wind Farm Regulations.

Northern Boone County Commissioner Janet Thompson welcomed everyone in attendance and stated that this meeting is to hear public comments in relation to readopting the Boone County Zoning Regulations, conditional use permits for Commercial Wind Energy Conversion Systems (WECS-C), and Wind Energy Conversion Overlay Districts (WECOD).

Resource Management Director, Bill Florea presented the timeline in creating the proposed Wind Farm Regulations. This timeline is attached to the end of this document and also available on the WECOD website at: https://www.showmeboone.com/resource-management/WECOD/Timeline_07-27-2021.pdf

Resource Management Director, Bill Florea gave a power point presentation which included a brief summary of the requirements for establishing a wind farm in Boone County. This presentation is available on the Resource Management website at: https://www.showmeboone.com/resource-management/WECOD/ .

Commissioner Thompson stated that this is the last of three hearings that the Commission is holding on these proposed regulations and it will go forward to the County Commission. Commissioner Thompson asked that speakers not be repetitious with their remarks and to remain polite and respectful of others.

Commissioner Thompson opened the floor for comments from those who are in favor of the proposed regulations:

Present speaking in favor of the regulations:

Tom Weislocher, 11581 N Trimble Rd, Harrisburg

Mr. Weislocher stated he is in favor of the regulations as written. Mr. Weislocher expressed concern about a German company building a wind farm in Boone County as the money won't stay in this country but in Germany, as well as possible violations and how to address the violation if the company is based a different country. Mr. Weislocher also expressed concern about Germany being tied into our power grid and the computers that control it stating that it is a threat to National security. Mr. Weislocher stated that Germany now requires turbines to have a five-mile setback, the turbines didn't make Germany green and they now import over half of their energy.

Mr. Weislocher stated that he is surprised that the idea of a wind farm in northern Boone County has gained this much traction, but now that it has, we should deal with it appropriately and we should adopt the regulations as written. The proposed regulations don't prohibit wind development in Boone County, they are safeguards so that it will be done in a matter that protects property rights, safety and long-term health and wellbeing of our citizens. Regarding the suggested changes, Mr. Weislocher believes the height limitation of 355-feet is taller than anything we are accustomed to seeing; for comparison, the state capital in Jefferson City is 238-feet and Jesse Hall in Columbia is 180-feet. When you put 50 to 100 turbines in a concentrated area they are going to dominate the landscape.

With regard to incorporating language to hire locally and provide apprenticeships, Mr. Weislocher stated he sees both sides of this issue but doesn't know if it is desirable for Boone County to mandate a certain number of local hires; either workers would get a job for a year and then be out of work or they would get a job for a year and then move out of the county to work on wind farms being constructed in other areas. Mr. Weislocher stated mandating local hires could result in making Boone County less attractive to a wind company looking to develop here. Mr. Weislocher supports hiring local workers for construction and having apprenticeships to learn the energy building trades but questions whether regulatory language would have the desired effect. Mr. Weislocher stated he is in favor of adopting the proposed regulations as written.

Also speaking in favor of the proposed regulations:

Nirtana Goodman, 11581 N Trimble Rd, Harrisburg

Ms. Goodman stated she is in favor of the proposed regulations, but they don't include everything that was asked for. Ms. Goodman stated she asked for property value guarantees, the wind companies have said there is no loss in property value where these go in. If that is the case, Ms. Goodman wonders why they don't take responsibility and provide property value guarantees and stated it is because they know property values do go down. Ms. Goodman wants longer setbacks and stated that Planning and Zoning has done a good job but believes they dropped the ball on setbacks. The fire department has documented burning debris from turbines going 4000-feet so 1750-foot away is in danger. Regarding sound levels, Ms. Goodman doesn't want noise at her home when she spent a lot of money to buy a quiet place in the country. Ms. Goodman stated she is in support of the proposed regulations because Planning and Zoning worked hard and tried to give something to everyone; they made it possible for wind companies to build here but they need to build in decent and responsible ways. Ms. Goodman stated if any of the proposed regulations are changed then it all needs to be reconsidered because it all works together.

Also speaking in favor of the proposed regulations:

David Nagel, 5501 W Tracy Ct, Columbia

Mr. Nagel stated he has lived in northwest Boone County for 35 years and is in favor of the proposed regulations as written to protect the citizens, property values, families and their quality of life.

Also present speaking in favor of the proposed regulations:

Keller Colley, 14631 N Hwy NN, Harrisburg

Mr. Colley stated he is generally in favor of the proposed regulations. Mr. Colley stated he is a safety professional and it is his job to go above and beyond for his company and would like to see a few things added to the definitions. Mr. Colley stated there are two major waterways, one being Prairie Creek on the west side of Route J which eventually goes into the Moniteau Creek, Mr. Colley stated if there are a lot of turbines put in that will mean a substantial amount of oil and the possibility that the oil will penetrate into the groundwater and into the waterways. On the east side is Callahan Creek which falls into Perche Creek. Mr. Colley would like to see that added to the regulations. Mr. Colley stated in 30 years those turbines will be decommissioned and most of us won't be around for that, but he would hate to see his family have to bear seeing those for the rest of their lives. Mr. Colley also stated he was concerned about property values as he just built a new house.

Also speaking in favor of the proposed regulations:

Stephen Nagel, 11295 N Rte E, Harrisburg

Mr. Nagel stated he can't see how a wind farm will increase the value of his property. If this wind farm is sold, as it has been sold once before, the tax revenue will be gone and the local school will not benefit.

Speaking neither in favor or opposition:

Greg Sublett, P.O. Box 83, Harrisburg

Mr. Sublett stated that he was a lineman with the City of Columbia for 31 years and his dad worked at the power plant for 44 years so he knows about kilowatts and has sat in on a lot of meetings. At that time, the idea was to get 17% of green power by 2021. Mr. Sublett wonders how many homes one of these towers will create electricity for, for a year and stated that a lot of things hinge on that but probably 33%. Mr. Sublett stated he looked it up and it states one turbine will power 460 homes. Mr. Sublett is for green power and the noise doesn't bother him but a lot of land has been bought that our kids will not have a chance to purchase in order to build a nice home. The taxes paid on that land doesn't compare to what you pay on a nice home; we need to slow down. We have to find ways to create power that is healthy for us, but do some research, Mr. Sublett wonders if they are worth what they do.

(At this time there was a back-and-forth conversation between Mr. Sublett and an unknown attendee which was not completely picked up on audio; this conversation was unable to be adequately transcribed). Partial discussion picked up on audio referred to megawatts and coal.

Mr. Sublett stated he is not opposed to all of this but felt compelled to encourage the Commission to do their research.

Present speaking in favor of the proposed regulations:

Terrie Nagel, 5501 W Tracy Ct, Columbia

Ms. Nagel stated she has lived in the area for 35 years and is in favor of the proposed regulations because we need to have a mechanism to enforce rules for the wind turbine companies. Ms. Nagel stated wind turbines are not green energy; they are full of fossil fuels. These don't last 30 years, they are falling apart after five, seven and ten years; they are very dangerous and throw ice. For these reasons, Ms. Nagel believes we need these regulations. Ms. Nagel also encouraged the Commission to do their research and stated we should go back to the drawing board because she believes there are better devices than wind turbines.

An attendee asked how many turbines can be placed in one square mile.

Mr. Florea stated that there are variables to take into consideration, so he didn't know the answer. There are setbacks to consider and limitations on spacing and all of those are factors would have to be looked at.

Commissioner Thompson opened the floor to those in opposition to the proposed regulations.

Present to speak in opposition to wind farms in general:

David Comegys, 9000 Gray Rd, Harrisburg

Mr. Comegys stated that he has lived in this community for 45 years and taught at the high school, he has a degree in chemistry and physics and was a firefighter for the City of Columbia for 20-plus years. Mr. Comegys also worked as a boiler maker building coal fire power plants. A lot of the smoke you see coming out of the stacks of the power plant is little more than a water vapor. This country sits on a pile of coal. Mr. Comegys is not in favor of wind turbines in any shape or form, they use up the natural elements like copper and lead and the blades are made out of fiberglass. What generally ruins them is the edge of the fiberglass wings get dinged and worn out; their solution to that is to cut the wings up and take them to Wyoming or somewhere and bury them. Mr. Comegys stated he does not want these in his community, he has friends who live in Texas and Wyoming and the life span for these things is only 25 years. Mr. Comegys doesn't see these as being a viable source of electricity in our community and they will be nothing but a noise, an eyesore and something that Mr. Comegys doesn't want. The Commission should take that into consideration.

Present speaking in opposition to the proposed regulations:

Tim Opitz, 409 Vandiver Dr, Columbia

Mr. Opitz submitted documentation and stated that the documentation shows that the central components of these proposed regulations are unreliable and that the Planning and Zoning Commission knows, or has reason to know that these are designed to ban wind in Boone County. Mr. Opitz stated he has documents that show that these regulations are being sent to other counties to ban wind development there too.

Exhibit 1: An email from Paula Evans to the Planning and Zoning Commission forwarding comments from Eric Lidholm.

Mr. Opitz stated that Mr. Lidholm states that he is an engineer and that he relies on a study to develop setbacks in these regulations. Within the email Mr. Lidholm goes on to offer what he claims is a professional opinion on setbacks.

Exhibit 2: A chain of emails from April 29, 2021.

Mr. Opitz stated that the initial email is from the Climate and Environment Commission outlining problems with the current wind regulations. Within that document, Commissioner Thompson emails Bill Florea saying "we probably need to sit down and least internally draft responses to each of these complaints, don't you think?". Mr. Opitz stated that someone did sit down and develop responses.

Exhibit 3: An email from Bill Florea to Commissioner Dan Atwill.

Mr. Opitz stated that the email contains talking points to respond to the Climate and Environment Commission's concerns. On page 6 regarding setbacks, Mr. Opitz stated that the setback was derived from an article published in the journal, Wind Energy, titled "A Method for Defining Wind Turbine Setback Standards". This article was mentioned during the presentation and is the same article as submitted by Mr. Lidholm.

Exhibit 4: An email chain from June 28 & 29, 2021

Mr. Opitz stated this email is where Bill Florea sends the draft regulations to a County Commissioner in Knox County. Mr. Opitz stated that Mr. Florea tells the Commissioner from Knox that the setback is based upon a peer reviewed journal article, Mr. Florea states in the email that he attached the article and that the highlighting and annotations were provided by Eric Lidholm, P.E. and continued that Eric is a structural engineer who advised the Planning and Zoning Commission.

Mr. Opitz stated that these documents show that the Planning and Zoning Commission relied on Mr. Lidholm to develop and defend these draft regulations; they cite him as an expert and send these regulations to other counties. Mr. Opitz stated that these next documents show that is a big mistake.

Exhibit 5: A petition of all of the people who want to ban all wind developments in Boone County.

Mr. Opitz stated Eric Lidholm signed this petition and the Planning and Zoning Commission received copies of this petition from anti-wind people early on in the process. Mr. Opitz stated he can't fathom how Planning and Zoning thought it was reasonable to rely exclusively on someone with a clear, articulated, anti-wind bias. Once it was discovered the fact that Planning and Zoning continued relying on this gentleman for regulations in Boone County and also touting him as a reliable expert to other Commissions is disqualifying. Mr. Opitz stated not only is Mr. Lidholm an anti-wind activist but his interpretation of the study he cites is dead-wrong. Mr. Opitz reached out to the author of that study, Dr. Jonathan Rodgers, PHD who is the CEO of Persimia LLC and is the Lockheed Martin Associate Professor of Aerospace and Mechanical Engineering at Georgia Tech. Mr. Opitz stated he provided the ordinances and some of the information discussed tonight to Dr. Rodgers, and how the Planning and Zoning Commission used his study. Dr. Rodgers informed Mr. Opitz that he was dismayed that Boone County is using this paper to justify these setbacks in this way. Dr. Rodgers explained to Mr. Opitz that the paper is outdated and there are more current assessment methodologies and that the local engineer misapplies the study and offers what only amounts to his personal opinion rather than actual engineering.

Exhibit 6: A letter from Dr. Jonathan Rodgers referenced previously.

Mr. Opitz stated as he continues to go through the documents and sources that the Planning and Zoning Commission relied upon, one thing is clear, it is not just the setbacks. Every aspect of these ordinances is designed to ban wind in the county in a variety of ways, Mr. Opitz stated that no one can say that these are reasonable restrictions. Mr. Opitz urges the Commission to reject these draft regulations and tell the Planning and Zoning Commission to get to work with actual experts to develop reasonable regulations to benefit the county. Mr. Opitz stated that Renew Missouri is ready to help, RWE, Ameren Missouri, the American Clean Power Association have all commented, and Dr. Rodgers has volunteered to participate. Mr. Opitz stated that bias opinions of anti-wind activists have no role in developing regulations for open and transparent government. Mr. Optiz asked that the Commission recognize that the approach and methods taken by Planning and Zoning are unsound, flawed and replete with anti-wind bias. To be anti-wind is to be anti-environment, anti-economic development, anti-jobs, and anti-property rights. The Commission should be aware that this is a ban, Mr. Opitz asked that the Commission be transparent with citizens if that is what they intend to do. If the Commission wants reasonable regulations reject this ban and work with real experts.

Speaking with questions for Mr. Opitz:

<u>Emily Furlong</u>, 4401 W Voorheis Rd, Sturgeon

Mrs. Furlong asked where Mr. Opitz lived and guessed that he doesn't live in this community. Mrs. Furlong asked what agency Mr. Opitz worked for.

Mr. Opitz stated he worked for Renew Missouri located at 409 Vandiver Drive, Columbia.

Mrs. Furlong asked what their major funding source is.

Mr. Opitz stated he didn't know.

Mrs. Furlong asked who his paycheck comes from.

Mr. Opitz stated Renew Missouri.

Mrs. Furlong asked what the major funding resource is for Renew Missouri.

Mr. Opitz stated he didn't know.

There was back and forth conversation between Mrs. Furlong and an unknown attendee which was not picked up on the audio recording. This portion of the meeting is unable to be transcribed.

Additional questions were asked of Mr. Opitz from members of the audience that were not audible.

An attendee asked Mr. Opitz why turbines can't be placed in city parks or the landfill.

Mr. Opitz stated that with the proposed regulations you couldn't put them up anywhere in Boone County, even if it is a park or landfill.

Mr. Opitz stated the Planning and Zoning Commission developed the proposed regulations, Mr. Opitz stated he is offering his comment that they are not based on facts and they are unusable.

Mrs. Furlong asked if she understood correctly that Mr. Opitz was not going to tell who his funding source is.

Mr. Opitz stated he doesn't know who they are and from his understanding Renew Missouri isn't going to tell who it is but interested parties can look up the form 990s online for free. Mr. Opitz asked if the premise of Mrs. Furlong's interrogation is that he is an out of state person who only wants to put wind turbines here and is only commenting on the regulations because he is being paid by some group. Mr. Opitz stated he is being paid by Renew Missouri to advocate for policies in advanced renewable energy and energy efficiency.

An audience member reminded the audience that Mr. Opitz is volunteering to answer questions, but he is not required to.

Mrs. Furlong stated there have been prior Planning and Zoning meetings that have been open to the public and open to suggestions and comments as the regulations were being developed. Mrs. Furlong asked Mr. Opitz if he attended any of those meetings and provided feedback.

Mr. Opitz stated he personally did not offer comments at the Planning and Zoning meetings but was involved in developing comments on what would be reasonable regulations at the Planning and Zoning stage. At that time, which was several years ago, other members of our staff delivered those comments to members of the Planning and Zoning Commission and were told by members of the Planning and Zoning Commission that they don't need wind here and don't want the revenue.

Mrs. Furlong asked as the regulations were being developed, the information that was being used by the members of the Planning and Zoning Commission, you didn't have a comment on it then. Mrs. Furlong stated that Mr. Opitz had stated that he attended one of those meetings.

Mr. Opitz stated he attended the Planning and Zoning meeting in Ashland as a citizen of Boone County when they received comments before final editing of the draft.

Mrs. Furlong asked if he provided comments about where they were getting their information.

Mr. Opitz stated the information was not made known to him until he received it from the county about two weeks ago.

Mrs. Furlong stated that they didn't know that Mr. Opitz felt they were getting faulty information when they were developing the regulations.

Mr. Opitz stated that Renew Missouri communicated with members of the Planning and Zoning Commission that their information was incorrect and the proposed regulations were unreasonable.

Mrs. Furlong asked Mr. Opitz to provide a suggestion where she should go to get what he believes to be the correct information regarding setbacks.

Mr. Opitz stated that he guessed you could look at the American Clean Power Association or NREL (National Renewable Energy Laboratory) and suggested that you don't look at outdated studies, if inclined, you could reach out to Dr. Jonathan Rodgers.

Mrs. Furlong asked Mr. Opitz if he was aware that the community has asked for setbacks that are higher than what is proposed.

Mr. Opitz stated he is aware that there are members of this community that have opposed all wind in Boone County.

Mrs. Furlong admitted that she is one of those but wanted to make sure that Mr. Opitz was aware that 1750-feet is less than what the majority of the community asked for. Mrs. Furlong stated the amount of time that went into creating these regulations has been insane; the men and women that did this deserve gratitude for doing something that protects our community should this happen, they gave up time with their families to protect our community.

Also present speaking in opposition to the regulations:

Brent Voorheis, 10877 N Route J, Harrisburg

Mr. Voorheis stated he and his wife were the first ones approached about a wind farm and the first ones to sign a lease. He stated that he didn't sign the lease blindly and did six months of research before entering into the agreement. Mr. Voorheis stated he went to Sweetwater, Texas and visited with Ken Becker who was the Economic Director of Nolan County, Texas. Mr. Becker indicated that the wind farms had brought good paying jobs to Nolan County and had been a wonderful source of revenue for the schools. Mr. Voorheis stated he stood under the turbines and visited with several homeowners near the windfarm and none of them had anything negative to say about the windfarm. Mr. Voorheis stated that when Harrisburg was founded it was founded on the premise that a railroad would run through it due to the abundance of coal in the area, however it was soft coal and was outlawed by the government. Mr. Voorheis stated he is sure there were health concerns regarding a railroad being built in the area. People also had concerns about the rural electrification act by Roosevelt in 1936, there were also health concerns about nuclear power plants and cellphones. Mr. Voorheis stated he is not trying to down-play the people who say they have health problems because of wind farms and believes some people are affected and some are not. Mr. Voorheis stated a concern mentioned was a reduction of property values, one person said that he heard his property value could be reduced by 50%. Mr. Voorheis stated he asked this question numerous times when he was in Texas and was told that during the construction phase real estate sales slowed with reduced prices and after construction prices came back and demand grew. Mr. Voorheis stated his family has about 700 acres in the Harrisburg School District with a value of $5,000 or $6,000 per acre; if the wind farm were to reduce property values by 50% that would be like our family giving 350 acres away for a wind turbine that may generate an income of $16,000 per year. We started this journey because we saw the benefit to our schools, Mr. Voorheis spent 24 years on the school board and served as President so he knows that funds are tight and the wind farm could help. From the get-go this was to be 150-megawatt project that would use approximately 50 wind turbines on 10,000 – 15,000 acres, they would not be that close together. E Climate and Renewables develop, maintain and retain ownership in their wind farm projects, plus they sell electricity. The proposed regulations as presented will not allow a wind farm to be built in Boone County and will push this project into Howard County. People will still see the wind turbines but our school will not receive any benefit. Mr. Voorheis stated he always thought that Boone County was a progressive area but it seems to be progressive until the nimby (not in my back yard) takes effect.

An audience member asked how many people live in Nolan County, Texas.

Mr. Vooheis stated he didn't know.

An audience member stated there are 14,000 people there; Columbia has 100,000 people plus people in rural Boone County.

An audience member asked about property values for everyone else; Mr. Voorheis will have income from the windmill. (more back and forth conversation that was not picked up on audio).

Mr. Voorheis stated that he was told that during the construction phase in Nolan County, TX, property values decreased but went back up after the wind farm was built.

An audience member stated you can't compare Nolan County, TX and Boone County due to the large difference in population.

Mr. Voorheis stated he didn't start this to hurt the community but thought it would be a benefit.

Additional comments and questions were made by audience members that were not picked up on the recording and many speakers did not provide their names. Some audible comments referred to temperatures in Boone County and that the turbines used oil.

An audience member asked how long the met mast has been on Mr. Voorheis' property.

Bill Florea stated the conditional use permit was approved in 2018.

Mr. Voorheis stated a lidar unit was installed and the mast was taken down once to install bat monitors, Mr. Voorheis doesn't believe they would have invested more money to do that if they didn't have sufficient wind.

Also present speaking in opposition to the proposed regulations:

Zack Dunn, Laborers District Council for Missouri and Kansas, 5511 Hunley Ct, Columbia

Mr. Dunn stated he is here to advocate for good paying jobs. Mr. Dunn stated he is here to ask for revisions to the proposed regulations, as written they act as a ban in Boone County. We've also asked the Commission to enact a local hire clause in the regulations that will set a goal for the developers and contractors to hire local workers within the community. These jobs will provide revenue for the schools, hospitals and small businesses.

Mr. Dunn presented a study by Lucas Franco, Ph.D titled "Maximizing the Benefits of Wind Energy Development in Boone County, Missouri"

Mr. Dunn read a statement from Dr. Franco which stated that he is a regional research manager for the Laborers International Union in North America and that he has done extensive research on the impact of different hiring practices in the renewable energy industry. Dr. Franco encouraged the Commission to make modifications to the proposed regulations and without changes the Commission will undercut the social-economic benefits of wind energy. Wind energy projects create good paying jobs for local workers and pathways to family-supporting careers. The proposed regulations have prevented the development of this project. The Commission can embrace the WECOD regulations proposed by Renew Missouri which make important modifications to include encouragement of wind energy developments, encouraging the use of local labor rather than out of state workers, and encouragement of the use of registered apprentices on new wind farm projects. The proposed regulations by Renew Missouri will help foster the new wind energy development and ensure that projects are built the right way by encouraging the use of skilled local labor. Dr. Franco's statement continued to encourage the Commission to adopt the changes proposed by Renew Missouri.

Mr. Dunn stated he is here to advocate for good paying jobs; some of the Union members probably live in this community.

Also present speaking in opposition to the proposed regulations:

Josh Wright, Stalker Lane, Montgomery City, MO

Mr. Wright stated he is the Apprenticeship Advisor and Assistant Director of Training for Laborers and Contractors Training Center in High Hill, Missouri. Mr. Wright stated he began his construction career as an apprentice, and it was a large part of his success in the construction industry. Mr. Wright spoke about the apprenticeship program and the required hours and training that apprentices are required to have. The center in High Hill it is a registered apprenticeship program with the United States Department of Labor. He continued speaking of salaries and benefits that apprentices will have. Mr. Wright hopes that the Commission will add requirements for all contractors and sub-contractors to utilize registered apprenticeship programs.

End of public comments.

Commissioner Thompson stated that the comments that have been made during the last three meetings will be collated and considered by the County Commission. Once the Commission has gone through all of the comments there will be a first and second reading; those meeting agendas will be posted on the county website.

Meeting notes prepared by Paula Evans, Administrative Coordinator, Boone County Resource Management

ATTACHMENT 6

freestanding signs shall be limited to eight-feet above the established street grade.

25.3.2.2 Home occupations are permitted one (1) façade sign on the structure in which the home occupation is located, which shall not exceed three (3) square feet (432 square inches) in area. Such signs shall be unlit and shall use non-flashing, non-reflective materials.

25.3.2.2.1 The area of the sign shall be calculated using the following formula: height x width = area. For example if a sign was 21 inches high and 20 inches wide the area would be calculated by multiplying the height of 21 inches x the width of 20 inches, which equals 420 square inches (21 x 20 = 420).

25.3.3 Non-commercial signs. Residential uses shall each be permitted façade signage and/or one freestanding sign per adjacent public street frontage provided the signage does not convey a commercial message. Total signage for such a use shall not exceed 32 square feet in area. The height of freestanding signs shall not exceed eight-feet above the adjacent grade.

25.4 Signs in Commercial, Industrial and Planned Recreation Districts.

25.4.1 Freestanding or Projecting Signs in Development Complexes. On each public street frontage each development complex shall be permitted one freestanding development complex sign or one projecting development complex sign, but not both. Freestanding or projecting signs, which are based on the length of one street frontage, shall not be placed on a different street frontage.

25.4.1.1 The base allowable sign area for each development complex sign shall be two square feet of sign area for each 5 lineal feet of street frontage, not to exceed 80 square feet of sign area. A bonus sign area of 10 additional square feet per business, enterprise, institution or franchise, within the development complex, is allowed provided that such bonus shall not exceed 50% of the base allowable sign area. Total Freestanding Sign Area is calculated as follows:

- Base Allowable Sign Area (BASA) in square feet = (lineal feet of street frontage ÷5) x 2 or 80 square feet, whichever is less.

- Bonus Sign Area (BSA) in square feet = Number of businesses, etc. x 10 or BASA ÷ 2, whichever is less
- Total Freestanding Sign Area = BASA + BSA or 120 square feet, whichever is less.

25.4.1.2 Businesses that are within a development complex shall not be allowed an individual freestanding or projecting sign

25.4.2 Freestanding or Projecting Signs for Businesses. Each business not within a development complex may be permitted a freestanding sign or one projecting sign, but not both, subject to compliance with the applicable standards.

25.4.2.1 The base allowable sign area for each freestanding or projecting business sign shall be two square feet of sign area for each 5 lineal feet of street frontage, not to exceed 80 square feet of sign area. Total Freestanding Sign Area is calculated as follows:

- (Lineal feet of street frontage ÷5) x 2 or 80 square feet, whichever is less.

25.4.3 Business Signs. Each enterprise, institution or business shall be permitted façade signs and one under canopy sign per street frontage, subject to the following requirements. Businesses that are not within a development complex shall be permitted one freestanding or projecting sign, but not both. Businesses that are within a development complex shall not be allowed an individual freestanding or projecting sign.

25.4.3.1 Maximum Façade Sign Area. Total area of façade signage shall not exceed 2 square feet for each lineal foot of the building wall to which the sign is attached up to a maximum of 80 square feet. Maximum façade sign area in square feet shall be calculated as follows:

- Lineal feet of building wall x 2 or 80 square feet, whichever is less.

25.4.3.2 Maximum Freestanding Sign Area. Two square feet for each 5 lineal feet of street frontage, not to exceed 80 square feet. Only one freestanding sign is allowed per parcel except as provided for in development complexes. Maximum freestanding sign area in square feet shall be calculated as follows:

- (lineal feet of street frontage ÷ 5) x 2 or 80 square feet, whichever is less

25.4.3.3 Parapet Mounted Sign Area shall be calculated the same as and counted as part of the allowed façade signs.

25.4.3.4 Maximum Projecting Sign Area. Two square feet for each 5 lineal feet of street frontage, not to exceed 80 square feet. Only one projecting sign is allowed per parcel. Maximum projecting sign area in square feet shall be calculated as follows:

- (lineal feet of street frontage ÷ 5) x 2 or 80 square feet, whichever is less

25.4.3.5 Maximum Suspended Sign Area. The maximum allowable sign area shall be 1 square foot for each lineal foot of width of the canopy, awning, marquee or other structural element of a building from which the sign is suspended, as measured perpendicular to the building wall.

25.4.4 Freestanding Signs for Boat Services on the Missouri River. Businesses that provide boat services such as fuel and pump out may have one freestanding sign subject to the following:

25.4.4.1 The maximum allowable sign area shall be 64-square feet.

25.4.4.2 Maximum sign height is 30-feet, measured vertically, from the edge of the river bank as defined by the line of vegetation.

25.4.4.3 The sign must be within 25-feet, measured horizontally, of the river bank as defined by the line of vegetation.

2.4.4.4 The sign may be composed of one or two faces. The face(s) of the sign must be oriented toward the river and must be within 0° to 25° of parallel to the centerline of the river at the location of the sign.

25.4.5 Non-commercial signs. Commercial and industrial uses that are located in commercial or industrial zoning districts shall each be permitted façade signage and/or freestanding signs provided the signage does not convey a commercial message. Such signs shall not exceed 32 square feet in area and shall not be displayed for more than six months in each calendar year. The height of freestanding signs shall not exceed eight-feet above the adjacent grade.

25.5 General Sign Regulations. The following regulations apply to all signs.

25.5.1 Sign Illumination. Except for billboards, sign illumination may be from backlighting, an internal source or floodlight projection. Lighting shall be shielded to preclude glare visible from public rights of way and neighboring properties.

25.5.2 Measurement of Sign Area. The square footage of a sign made up of letters, words or symbols within a frame shall be determined from the outside edge of the frame itself. The square footage of a sign composed of only letters, words or symbols shall be determined from imaginary straight lines drawn around the entire copy or grouping of such letters, words or symbols. Double-faced signs shall be calculated as the area of one side only. Three-dimensional or signs other than single or double-faced signs shall be calculated as the cumulative area of all faces of the sign.

25.5.3 Maximum Sign Height. Maximum height of any sign is 35 feet unless a more restrictive standard is established elsewhere in these regulations.

25.5.4 Measurement of Sign Height The height of a sign shall be measured from average grade to the highest point of the sign or its supporting structure. Signs do not qualify for increased height due to increase in setback.

25.5.5 Condition and Maintenance. All signs shall be of rust-inhibitive or rot-inhibitive material or treatment, and shall be maintained in good condition in the opinion of the Director. All signs, together with all of their supports, braces, guys and anchors shall be kept in good repair and in a safe state of preservation. The display surfaces of all signs shall be kept neatly painted or posted at all times.

25.5.6 Electronic Message Signs. Electronic message signs that provide changing messages are permitted provided such signs do not blink or flash at a frequency of less than one blink or flash per 3 seconds.

25.5.7 All signs must meet or exceed the setback requirements established for the zoning district in which the sign is located. No portion of any sign shall overhang or encroach on the setback area, public right of way or public easement.

25.5.8 Vehicle Clearance Area. When a sign is placed over a private area where vehicles travel or are parked, the bottom of the sign structure must be at least 15 feet above the ground. Vehicle areas include but are not limited to driveways, alleys, parking areas, loading and maneuvering areas. Exceptions are prohibited.

25.5.9 Signs, which are allowed based on the length of or adjacency to one street frontage, shall not be placed on a different street frontage.

25.5.10 Prohibited Signs. The following devices and locations are specifically prohibited:

25.5.10.1 Signs located in such a manner as to obstruct or otherwise interfere with an official traffic sign, signal or device or obstruct or interfere with a driver's view of approaching, merging or intersecting traffic.

25.5.10.2 Signs encroaching upon or overhanging public right of way or easement dedicated for use by the public. No sign shall be attached to any utility pole, light standard, street tree or any other public facility located in the public right of way or public easement.

25.5.10.3 Cloth, paper, soft plastic or similar advertising signs or devices other than in rigid frames as provided herein.

25.5.10.4 Signs that blink, flash or are animated by lighting in any fashion that would cause such signs to have the appearance of traffic safety signs and lights, or municipal vehicle warnings from a distance.

25.5.10.5 Portable signs.

25.5.10.6 Any sign attached to or placed on a vehicle or trailer parked on public or private property. The prohibition of this subsection does not prohibit the identification of a firm or its principal products on a vehicle being operated during the normal course of business or being taken home.

25.5.10.7 Pennants, banners and private flags bearing any logo, product name, business name or other advertising.

25.5.10.8 Signs in any district except as specifically authorized by these regulations.

25.5.10.9 Rotating signs and roof-mounted signs and searchlights.

25.5.10.10 Any sign, other than a billboard that is located on a parcel that is otherwise undeveloped, except as otherwise permitted by these regulations.

25.5.11 Signs, variances not allowed except. No variance from the provisions of Section 25, Sign Regulations is allowed except in accordance with Section 15.C(4)(f) of these regulations.

25.6 Specific Sign Requirements

25.6.1 Billboards

25.6.1.1 Billboards are only allowed in the General Commercial (C-G), Planned General Commercial (CG-P), Light Industrial (M-L), Planned Light Industrial (ML-P), General Industrial (M-G) and Planned General Industrial (MG-P) districts and must be within 100 feet of the U.S. 63 or I-70 right of way.

25.6.1.2 Maximum sign area is 288 square feet.

25.6.1.3 Minimum ground clearance is 8 feet.

25.6.1.4 Minimum setback from all public rights of way is 50 feet with no portion of the sign overhanging the setback area.

25.6.1.5 Minimum setback from a side or rear property line, not abutting a public right of way, is 10 feet with no portion of the sign overhanging the setback area.

25.6.1.6 Minimum distance from Agriculture, Transition, Residential, Commercial Office (C-O) or Neighborhood Commercial (N-C) zoning districts or municipal limits of any city or town is 200 feet, based upon the location of the zoning district boundary or municipal limits in effect at the time the building permit for the billboard is issued.

25.6.1.7 Minimum distance from other billboards is 2,640 feet.

25.6.1.8 Minimum distance from any street intersection is 200 feet.

25.6.1.9 All freestanding billboards shall be mounted on a monopole mast.

25.6.1.10 Billboards consisting of two faces are permitted only if the planes formed by the two faces are parallel, the same size and shape and mounted at the same elevation.

25.6.1.11 Billboards consisting of more than two faces are prohibited.

25.6.1.12 Billboards shall not be illuminated.

25.6.1.13 Maximum number of billboards per parcel is one.

25.6.1.14 Billboards shall comply with all specific requirements for freestanding, projecting or facade signs, as appropriate, unless a stricter standard applies.

25.6.2 Freestanding Signs

25.6.2.1 All freestanding signs shall maintain a clear vision area as specified in this ordinance.

25.6.2.2 For purposes of calculating the number of freestanding signs allowed on a parcel, a billboard constitutes 1 freestanding sign.

25.6.2.3 Any freestanding sign that is not a billboard shall be a minimum of 35 feet from any public street intersection.

25.6.2.4 Freestanding signs shall be placed on a parcel so that they are no more than 150 feet from the public right of way.

25.6.2.5 In Commercial, Industrial or Planned Recreation Districts a freestanding sign cannot be placed closer than 50 feet to another freestanding sign.

25.6.2.6 There shall be no freestanding sign on the same street frontage where there is a projecting sign on the same parcel and street frontage.

25.6.3 Parapet-Mounted Signs. Signs projecting above the point of intersection of the exterior wall of the building with its roof shall be mounted on a parapet.

25.6.4 Projecting Signs

25.6.4.1 A projecting sign shall not extend above the line defined by the intersection of the planes formed by the building wall and the roof.

25.6.4.2 No supporting structure shall be visible above the sign face.

25.6.4.3 The edge of the sign shall not be more than one foot from the building wall.

25.6.4.4 A minimum of 8 feet must be maintained between the lowest point of the sign and the ground unless a stricter standard applies.

25.6.4.5 A projecting sign shall not project more than 10 feet from the building wall to which it is attached.

25.6.5 Suspended Signs

25.6.5.1 The maximum allowable horizontal length of a suspended sign shall be equal to the width of the canopy, awning, marquee other structural element of a building from which the sign is suspended, as measured perpendicular to the building wall, minus 2 feet.

25.6.5.2 The sign must be hung at least 1 foot from the outside building wall and at least 1 foot from the outside edge of the canopy, awning, marquee or similar structure from which the sign is hung measured at the location at which the sign is to be hung.

25.6.5.3 The minimum vertical clearance between the lowest edge of an under-canopy sign and the ground shall be 8 feet.

25.6.5.4 The sign must be hung perpendicular to the direction of the building wall at the location where the sign is to be hung.

SECTION 26 STREAM BUFFER REGULATIONS

26.1 Title, Purpose and Intent

26.1.1 Title. This chapter shall be known as the "Stream Buffer Regulations of Boone County, Missouri."

26.1.2 Purpose. The County Commission of Boone County, Missouri has determined that these regulations are necessary for the purpose of promoting the health, safety, comfort, and/or general welfare; and conserving the values of property throughout the County; and lessening or avoiding undue impact of stormwater runoff on adjoining properties and the environment. Buffers adjacent to stream systems provide numerous environmental protection and resource management benefits which can include the following:

- Restoring and maintaining the chemical, physical and biological integrity of the water resources,
- Removing pollutants delivered in urban storm water,
- Reducing erosion and controlling sedimentation,
- Stabilizing stream banks,
- Providing infiltration of storm water runoff,
- Maintaining the base flow of streams,
- Contributing the organic matter that is a source of food and energy for the aquatic ecosystem,
- Providing tree canopy to shade streams and promote desirable aquatic organisms,
- Providing riparian wildlife habitat,
- Furnishing scenic value and recreational opportunity,
- Protecting the public from flooding, property damage and loss, and
- Providing sustainable, natural vegetation.

26.1.3 Intent. It is the purpose of this section to establish minimum acceptable standards for the design of stream buffers to protect the streams, wetlands, floodplains and riparian and aquatic ecosystems of the County of Boone, and the implementation of specifications for the establishment, protection and maintenance of vegetation along all stream systems and/or waterbodies within our County's authority. It is the desire of the County to protect and maintain_natural vegetation in riparian and wetland areas by implementing specifications for the establishment, protection and maintenance of buffer vegetation along stream systems and/or waterbodies within our County's authority.

26.1.4 Jurisdictional Area – These regulations apply to all unincorporated lands within Boone County.

26.1.5 Authority – These regulations are adopted pursuant to the provisions of Sections 64.825 – 64.885 and 64.907, Revised Statutes of Missouri.

26.1.6 Applicability

26.1.6.1 This article shall apply to:

26.1.6.1.1 All proposed development except as provided in Section 26.1.6.2

26.1.6.1.2 Activities that involve clearing, earthwork and excavation within the buffer zone as defined herein.

26.1.6.1.3 All tracts and parcels of land in the County except as provided in Section 26.1.6.2.

26.1.6.2 This article shall not apply to:

26.1.6.2.1 Development which prior to the effective date of this article:

- Is covered by a plat recorded of record in accordance with subdivision regulations.
- Is covered by an approved and unexpired Preliminary Plat or Review Plan.
- Is covered by a valid, unexpired building permit.
- Has applied for a building permit.

26.1.6.2.2 This article shall not apply to surface mining operations which are operating in compliance with a State-approved surface mining permit.

26.1.6.2.3 This article shall not apply to agricultural or farming activities.

26.1.6.2.4 This article shall not be construed so as to prevent modifications to stream channels or wetlands if such modifications have been approved and permitted by a Federal Agency such as the U.S. Army Corps of Engineers.

26.1.6.2.5 Structures that exist on or before the date of adoption of this section, that do not conform to this section and cannot be made to conform by using the stream buffer averaging provisions of Section 26.5.6 shall be allowed to remain in the present location and footprint. Such structures can be expanded or enlarged if the expansion or enlargement is vertical and/or away from the stream being buffered.

26.2Administration

26.2.1 Limitation on liability. This chapter does not guarantee that properties will always be free from storm water flooding or flood damage. This chapter shall not create liability on the part of, or a cause of action against, the county or any county officer or employee for any flood damage.

26.2.2 Conflicts. Where any provision of this chapter imposes restrictions different from those imposed by any other law or regulation, whether state, federal or local, whichever is more restrictive or imposes a higher standard shall control.

26.2.3 Administration and Enforcement. The provisions of this chapter shall be administered and enforced by the Director. The Director shall receive applications required by these regulations and issue permits. He/she shall examine premises for which permits have been issued, and shall make the necessary inspections to see that the provisions of law are complied with. He/she shall, when requested by the County Commission, or when the interests of the county so require, make investigations in connection with matters referred to in these regulations and render written reports on the same. For the purpose of enforcing compliance with the law, he/she shall issue such notices or orders as may be necessary.

- Inspections: Inspections shall be made by the Director or his/her designee(s).
- Rules/ Policies: For carrying into effect its provisions, the County Commission and/or its designee may adopt rules/ policies consistent with these regulations.
- Records: The Director shall keep careful and comprehensive records of applications, of permits issued, of inspections made, of reports rendered, and of notices of orders issued. All such records shall be open to public inspection at reasonable hours, but shall not be removed from the office of the Director.

26.2.4 Appeals. Any person aggrieved by any decision of the Director in the administration or enforcement of this Chapter may appeal such decision to the Board of Adjustment.

26.2.5 Variances

26.2.5.1 Variances by the Director. The Director may grant a waiver for the following:

- Those projects or activities serving a public need where no feasible alternative is available.
- The repair and maintenance of public improvements where avoidance and minimization of adverse impacts to wetlands and associated aquatic ecosystems have been addressed.

26.2.5.1.1 Application. The applicant shall submit a written request for a variance to the Director in a form specified by the Director. The application shall include information specified by the Director and specific reasons justifying the variance and any other information necessary to evaluate the proposed variance request. The Director may require an alternatives analysis that clearly demonstrates that no other feasible alternatives exist and that minimal impact will occur as a result of the project or development.

26.2.5.1.2 Review by Director. Upon receipt of all application materials the Director shall certify the application complete. The Director shall have 10-working days from the date of the complete application in which to issue a decision. If during review of the application the Director requests additional information, then the time between when the request was made and when the information is submitted shall not count against the 10-day review period.

26.2.5.2 Other Variances. Where undue hardships or practical difficulties may result from strict compliance with this chapter, the developer may file an application for a variance. Said applications shall be directed to the Boone County Board of Adjustment organized and existing under the zoning regulations of Boone County, Missouri, which shall have the jurisdiction and shall be charged with the duty of hearing and deciding applications for variances from the strict application of the provisions of this ordinance. The Board may grant a variance only if it finds after public hearing and upon competent and substantial evidence that the applicant meets the following criteria:

- The variance shall not have the effect of nullifying the intent and purpose of these regulations;
- The granting of the variance will not be detrimental to the public safety, health or welfare, or injurious to other property or improvements.
- The conditions upon which the request for a variance is based are unique to the property for which the variance is sought, are not applicable generally to other property, and are not self-imposed.
- Because of the particular physical surroundings, shape or topographical conditions of the specific property involved, a particular hardship to the owner would result, as distinguished from a mere inconvenience, if this chapter was strictly interpreted and carried out.

26.2.5.2.1 Conditions: In recommending variances and exceptions, staff may recommend and the Board may require such conditions as will, in the judgment of each, secure substantially the objectives of the standards or requirements of this chapter.

26.2.5.2.2 Application: An application for a variance shall be submitted at the time of filing for a preliminary plat or for application for a building permit, whenever possible. The application shall be on forms provided by the County and shall state fully the grounds for the request and all facts relied upon by the practitioner. The application shall be filed with the Director and after review thereof the Director shall make a recommendation to the Board to grant or deny the application and state the reasons for his or her recommendation. Either the applicant or the Director may appeal or seek judicial review of any decision of the Board as provided by law.

26.3Definitions

Best Management Practices (BMPs) - Conservation practices or management measures which control soil loss and reduce water quality degradation mainly caused by nutrients, animal wastes, toxins, sediment in the runoff. BMPs may be either structural (grass swales, terraces, retention and detention ponds), or non-structural (disconnection of impervious surfaces, directing downspouts onto grass surfaces and educational activities).

Buffer - A vegetated area including trees, shrubs, managed lawn areas, and herbaceous vegetation which exists or is established to protect a stream system. Alteration of this natural area is strictly limited.

Development - A change in the zoning, intensity of use or allowed use of any land, building, structure or premises for any purpose. The subdivision or severance of land. The construction, erection or placing of one or more buildings or structures on land or use of land or premises for storage of equipment or materials. Making of an addition, enlargement or alteration to a building or structure, in, on, over or under land, which has the effect of increasing the size or usability thereof. Land disturbance activities such as but not limited to site-grading, excavation, drilling, removal of topsoil or the placing or dumping of fill and installation of drainage works. The use of the term shall include redevelopment, as defined in the stormwater regulations, in all cases unless otherwise specified in these regulations.

Director – The Boone County Director of Public Works or Boone County Director of Planning and Building Inspection as designated by the County Commission.

Farming Activities – See **Agriculture or Farming Activity (Zoning Regulations Section 2)**

Flood Control Structures– Use of levees, walls, ditching or reservoirs in an effort to minimize the occurrence of floods.

Indigenous Vegetation – Any species that was present in Missouri prior to European Settlement (approximately 1735 A.D.) or any plant identified as native or indigenous on lists maintained by agencies such as the Missouri Department of Conservation or United States Department of Agriculture.

Managed Lawn Areas - Any area greater than five hundred (500) square feet where the vegetative ground cover is maintained at a uniform height of less than 5-inches.

Ordinary High Water Mark – That line on the shore established by the fluctuations of water and indicated by physical characteristics such as clear natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter or debris, or other appropriate means that consider the characteristics of the surrounding area.

Pollution - Any contamination or alteration of the physical, chemical, or biological properties of any waters which will render the waters harmful or detrimental to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses; or to livestock, wild animals, birds, fish or other aquatic life.

Streams - Perennial and intermittent watercourses identified through site inspection and United States Geological Survey (USGS) maps and further defined and categorized as follows:

A. Type I Streams are defined as perennial streams shown as solid blue lines on the United States Geological Survey seven and one-half minutes series topographical map and have a drainage area of greater than 50 acres.

B. Type II Streams are defined as intermittent streams shown as dashed blue lines on the United States Geological Survey seven and one-half minutes series topographical map and have a drainage area of greater than 50 acres.

C. Type III Streams are defined as intermittent streams or natural channels which are not shown on the United States Geological Survey seven and one-half minutes series topographical map as either blue or dashed blue lines which have drainage areas of greater than 50 acres.

Wetlands - Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

26.4Stream Buffer Plan Requirements

26.4.1 General Plan Requirements. All administrative surveys, plats, development plans and building permits shall set forth an informative, conceptual and schematic representation of the proposed stream buffers by means of maps, graphs, charts, or other written or drawn documents so as to enable the Director an opportunity to make a reasonably informed decision regarding the proposed activity.

26.4.2 Specific Plan: Stream buffer plans shall contain the following information and shall be shown on one or more sheets as required by the Director:

26.4.2.1 A site plan map at a minimum scale of 1"=200'.

26.4.2.2 Field delineated and surveyed streams, springs, seeps, bodies of water, sink holes, and wetlands (include a minimum of 200 feet into adjacent properties).

26.4.2.2.1 Stream buffer plans for an individual single family or two family dwelling or an administrative survey are not required to survey the features listed above.

26.4.2.3 Delineated stream buffers.

26.4.2.4 Limits of the 100-year floodplain as shown on the adopted floodplain maps for the County of Boone.

26.4.2.5 Steep slopes greater than 15% for areas adjacent to and within 200 feet of Type I, II or III streams

26.4.3 Plan Submittal. The buffer plan shall be submitted in conjunction with the required development permit application or land disturbance plan for any development, whichever is submitted first. The buffer must be clearly delineated on the site grading plan.

26.4.3.1 Provide a note on the site grading and drainage plans or development site plan stating, "There shall be no clearing, grading, construction or disturbance of vegetation except as specifically approved by the Director."

26.4.4 Temporary Boundary Markers. Markers will be installed by the applicant prior to commencing clearing and grading operations and maintained throughout the applicant's development activities. The markers will be placed on the outside edge of the buffer zone prior to the start of any activity within 50-feet of the buffer or as shown on a land disturbance plan approved by Boone County. Markers shall be clearly visible and shall be spaced at a maximum of 100 feet. The markers shall be joined by marking tape or fencing. Orange construction fencing should be used to delineate the limits of the stream buffer.

26.4.5 Plan Preparation. Stream buffer plans, except for single family dwellings, two family dwellings or administrative surveys, shall be prepared by a professional surveyor, engineer or architect licensed to practice in the State of Missouri.

26.5 Design Standards for Stream Buffers

26.5.1 General. An adequate buffer for a stream system shall consist of a predominantly undisturbed strip of land extending along both sides of a stream and their adjacent wetlands, floodplains or slopes. The buffer width may be adjusted to include contiguous sensitive areas, such as steep slopes or erodible soils, where disturbance may adversely affect water quality, streams, wetlands, or other water bodies. All specified stream buffer widths are minimums and may be increased as specified in these regulations or on a voluntary basis by the property owner.

26.5.2 Buffer Measurement. The buffer shall begin and be measured from the ordinary high water mark of the channel during base flows.

26.5.3 Minimum Buffer Width. The required base width for all buffers shall be determined based on the type of stream being protected, as specified in TABLE I. of this ordinance below:

TABLE I. Required Minimum Stream Buffer Width	
Stream Type	Required Width (each side)
Type I	100 feet
Type II	50 feet
Type	30 feet

26.5.4 Modifications to Buffer Width. Stream buffer width shall be modified if there are steep slopes which are above the ordinary high water mark and within the required stream buffer width and drain into the stream system. In those cases, the buffer width will be adjusted according to the guidance in TABLE II. Below:

TABLE II. Modifications to Stream Buffer Width Based on Slope	
Percent Slope	Width of Buffer
0 – 14%	No Change
15% - 25%	add 25 feet
Greater than 25%	add 50 feet

26.5.5 No Buffer Required. A stream buffer shall not be required for portions of a stream that are less than 150 feet in length due to the stream having been previously enclosed within a pipe or box structure immediately upstream and downstream of the subject location. In such cases, said stream portion may be similarly enclosed in a pipe or box structure.

26.5.6 Stream Buffer Averaging. The stream buffer width may be relaxed and the buffer permitted to become narrower at some points to allow for structures existing on the date of adoption of these regulations provided:

26.5.6.1 The average width of the stream buffer must meet the minimum requirement specified in Table 1 and Table 2.

26.5.6.2 There is no reduction in the width of the Streamside Zone (Zone 1)

26.5.6.3 No new structures are built in the 100-year floodplain. This does not restrict allowable uses in the streamside zone as defined in Section 26.6.1 and 26.6.2.3.

26.6 Two Zone Stream Buffer System

26.6.1 Buffer Zones. The stream buffer shall be composed of two distinct zones, with each zone having its own set of allowable uses and vegetative targets as specified in this section. (Table III contains information that has been condensed from subsequent text. For a complete listing of uses see Section 26.6.2 and 26.6.3).

Table III. Stream Buffers

Streamside Zone (Zone 1)				Outer Zone (Zone 2)			
	Type I Stream	Type II Stream	Type III Stream		Type I Stream	Type II Stream	Type III
Width	50	25	15	Width	50	25	15
Vegetation	Indigenous Vegetation			Vegetation	Type I – Indigenous Vegetation Type II - Managed Lawns Permissible Type III – Managed Lawns Permissible		

Uses	Flood control, permeable-surfaced foot and bicycle paths, road crossings, utility crossings, stream or stream bank restoration and restoration of indigenous vegetation	Uses	All uses allowed in Streamside Zone, hard-surfaced biking/hiking paths, detention/retention structures, utility corridors, storm water BMPs, residential yards, landscaped
Function	Protect the physical and ecological integrity of the stream ecosystem	Function	Protect key components of the stream and filter and slow velocity of water runoff

26.6.1 Zone 1. Streamside Zone

26.6.1.1 Function. The function of the streamside zone is to protect the physical, biological and ecological integrity of the stream ecosystem. The vegetative target for the streamside zone is undisturbed indigenous vegetation.

26.6.1.2 Adjoining Wetlands. The streamside zone will begin and be measured as defined and extend away from the ordinary high water mark a distance as shown in Table III. Wetlands that adjoin the buffer shall be added to the buffer. There shall be a 15-foot buffer around any edge of the wetland that is not within the stream buffer (inner or outer zone).

26.6.1.3 Allowable uses in the streamside zone:

- Flood control structures, stream gauging and water quality monitoring equipment, stormwater treatment facilities in accordance with an approved plan
- Utility crossings
- Permeable surfaced foot and bicycle paths
- Road crossings
- Utilities where no practical alternatives exist as determined by the director.
- Stream restoration, stream bank restoration or restoration of indigenous vegetation in accordance with an approved plan
- Roads, that exist on or before the date of adoption of these regulations, and associated maintenance activities.

26.6.1.4 Restricted uses in the streamside zone. The following uses are prohibited except where incidental to an allowable use:

- Clearing of existing vegetation,
- Grading, stripping or other soil-disturbing practices,
- Filling or dumping,
- Draining the buffer area by ditching, underdrains or other systems,
- Use, storage or application of pesticides, except for the spot spraying of noxious weeds or other species consistent with recommendations of the Missouri Department of Conservation, Boone County Soil and Water Conservation District, United States Department of Agriculture or University of Missouri Extension Service
- Storage or operation of motorized vehicles except for maintenance or emergency use.
- Walls, solid fences, chain link fences, woven or welded wire fences
- Structures or any type of impervious surface except as provided above

26.6.2 Zone 2, Outer Zone.

26.6.2.1 Function. The function of the outer zone is to prevent encroachment into the streamside zone and to filter runoff from residential and commercial development.

26.6.2.2 Adjoining Wetlands. The outer zone will begin at the outside edge of the streamside zone and extend outward, away from the streamside zone the distances as shown in Table III. Wetlands that adjoin the buffer shall be added to the buffer. There shall be a 15-foot buffer around any edge of the wetland that is not within the stream buffer (inner or outer zone).

26.6.2.3 Allowable uses in outer zone

- All uses allowed in the streamside zone
- Utilities
- Hard-surfaced biking/hiking paths,
- Detention/retention structures,
- Storm water BMPs,

- Landscaped areas (Type II and Type III streams only) although planting of indigenous vegetation is encouraged.

26.6.2.4 Restricted Uses in Outer Zone

- Walls, solid fences, chain link fences, woven or welded wire fences
- Structures or any type of impervious surface except as provided above

26.7 Stream Buffer Management and Maintenance

26.7.1 Management, Responsible Party. The stream buffer, including wetlands and floodplains, shall be managed by the landowner to enhance and maximize the unique value of these resources. Management includes specific limitations on alteration of the natural conditions of the land and vegetation.

26.7.2 Allowed maintenance practices and activities in the streamside zone of the buffer. All allowed uses may be maintained subject to the review of the County. Any entity conducting an allowed activity within the streamside zone shall restore any disturbed area to it previous condition or in accordance with a plan approved by the Director. In addition to maintenance of allowed uses, the following maintenance activities may be conducted:

- Roads, bridges, paths, and utilities existing as of the date of adoption of these regulations.
- Rights of way for roads and utilities should be the minimum width to allow for installation, access and maintenance.
- Removal of diseased or dead trees, brush and trash.
- Maintenance of all County-approved improvements, including utilities
- Removal of debris which could cause flooding.
- Selective (spot) spraying of noxious or other vegetation consistent with recommendations from the Missouri Department of Conservation, Boone County Soil and Water Conservation District, United States Department of Agriculture or University of Missouri Extension Service

26.7.3 Restricted maintenance practices and activities within the streamside zone of the stream buffer:

- Clearing of existing vegetation.

- Soil disturbance by grading, stripping, or other practices.
- Filling or dumping.
- Drainage by ditching, under drains or other systems.
- Use, storage, or application of pesticides, except as provided for in 26.7.2 above.
- Storage or operation of motorized vehicles, except for maintenance and emergency use approved by the County or when operated on a legally established roadway.

26.7.4 Allowed maintenance practices and activities within the outer zone of the stream buffer:

- All Allowed Uses
- All maintenance practices and activities that are allowed in the Streamside Zone.

26.7.5 Restricted maintenance practices and activities within the outer zone of the stream buffer:

- Structures or buildings except as otherwise allowed by these regulations

26.7.6 Water pollution hazards – The following land uses and/or activities are designated as potential water pollution hazards and must be set back from any stream by the distance indicated below:

- Storage & use of hazardous substances 300 feet provided:
  - Up to 20 gallons of liquid fertilizer or pesticide is allowed but must remain outside of the stream buffer
  - Up to100 pounds of granular fertilizer or pesticide is allowed but must remain outside of the stream buffer

- Above- or below-ground petroleum storage facilities 300 feet provided:
  - Up to 500 gallons of heating oil, gasoline or diesel fuel is allowed but must remain outside of the stream buffer
  - Up to 1000 gallons of propane is allowed but must remain outside of the stream buffer

- Salvage yards or Automobile Recyclers 600 feet

26.8 Violations, Penalties and Remedies

It shall be unlawful for any person to violate any provision or fail to comply with any of the requirements of these regulations. A violation of or failure to comply with any of the requirements of these regulations shall constitute a misdemeanor and shall be upon conviction punished as provided by law. In addition, any person permitting, aiding, abetting or concealing a violation of this ordinance shall be deemed guilty of a misdemeanor and shall be upon conviction punished as provided by law. Each day a violation of these regulations continues shall constitute a separate offense. The penalty provided in this section shall not be construed to be exclusive but is intended to be supplemental and in addition to any other remedy provided by law or at equity. The County may institute in the circuit court of the County any appropriate action or other proceedings to prevent any unlawful activity proscribed in this ordinance or to correct any violations of this ordinance.

26.9 Conflict with Other Regulations

Where the standards and management requirements of this buffer ordinance are in conflict with other laws, regulations, and policies regarding streams, steep slopes, erodible soils, wetlands, floodplains, timber harvesting, land disturbance activities, or other environmental protective measures, the more restrictive shall apply.

26.10 Severability

If any part or parts of this Ordinance shall be held unconstitutional, invalid, or otherwise unenforceable by any court of competent jurisdiction, such decision shall not affect the validity of the remaining provisions of this Ordinance.

SECTION 27 ADDRESSING AND ROAD NAMING REGULATIONS

27.1 Applicability and Authority.

Applies to all divisions of land and related addressing and road naming. These regulation are adopted pursuant to the authority granted under the provisions of RSMo 64.825-64.885, RSMo 67.318 and the provisions of the adopted International Fire Code and International Residential Code which have been adopted by the County pursuant to the authority granted in RSMo 64.170.

27.2 Definitions. For purposes of this section, the following terms are hereby defined:

27.2.1 Addressable Structures. Structures eligible for addresses. See Section 27.11.

27.2.2 Alias Road Names. An alias road name is the name, other than the official name, commonly used for the road (See Section 27.9.15).

27.2.3 Boone County Addressing Grid System. The system used in unincorporated Boone County to assign address numbers (See Section 27.5).

27.2.4 Address Directional Prefix. An abbreviation of the main cardinal direction which precedes the official road name. There are four address directional prefix quadrants with north designated as N, south designated as S, east designated as E, and west designated as W.

27.2.5 Bulb / Bumpout. In context of roads, a condition where the right of way for a road is widened to allow for more frontage for additional lots and continues the numbering pattern, interval, and direction as a continuation from the main road (See Canterbury Dr, 27.7 Figure 1).

27.2.6 Circle. In context of roads, a road that has only one connection to the main road that acts as both the entrance and exit, and only intersects with itself which also contains parcels located in the interior of the circle (See Franklin Cir, 27.7 Figure 2).

27.2.7 Court. In context of roads, a uniquely named dead-end road with no other roads intersecting the main road and terminates in a permanent cul-de-sac.

27.2.8 Connector. In context of roads, a segment of road between two officially named roads created by a road realignment project.

27.2.9 Official Legal Road Names. The road name listed in the Boone County Road Directory as administered by Boone County Planning and Building Inspection is the official road name.

27.2.10 Vanity. In context of roads and/or addresses, an address requested by a business, organization, or individual that is not related to the Boone County Addressing Grid System.

27.3 Administration.

27.3.1 Addressing Authority. The Boone County Planning and Building Inspection Director is the Boone County addressing authority.

27.3.2 Administrative Review. If, under application of the provisions of these regulations, any existing road name or address number is required to be changed, then any person aggrieved by such a decision by the Planner or other duly-qualified employee of the County Planning and Building Inspection department assigned to make decisions about a road name or address designation under the provisions of this ordinance may file a request to review that decision with the Director of Planning and Building Inspection for Boone County by making a written request for said review within fifteen (15) days of the date of the written decision of the Planner. Said request must be on the form(s) provided by the Director of Planning's office and shall include a copy of the written decision of the Planner.

27.3.3 Appeals to Board of Zoning Adjustment. The aggrieved person, if dissatisfied with the decision of the Director, may further appeal the decision of the Director to the Board of Zoning Adjustment in the same manner as appeals from the decisions of administrative officers in applying the Zoning Ordinance for Boone County.

27.4 Purpose and Intent. The Boone County addressing and road naming regulations are to establish standards for naming public and private roads, posting official road signs, and assigning official address numbers to all addressable structures; and to assist emergency management agencies, the United States Postal Service, and the public in the timely and efficient provision of services to residents and businesses within unincorporated Boone County.

These regulations are designed to eliminate addressing confusion and to create a standard system by which addresses shall be assigned, displayed, and maintained from this time forward. These regulations are further designed to establish an official master address database and road name directory in Boone County to be maintained by Boone County Planning and Building Department. It is not the objective of these regulations to change all previously official addressed structures or to change all previously officially named duplicate road names. Changes to existing official addresses and road names will only be made when non-conformity could interfere with the accurate dispatch of emergency vehicles, postal delivery, and provision of County services.

27.5 Basis of the Boone County Addressing Grid System. The unincorporated Boone County addressing grid system shall originate at the intersection of Broadway and Garth Ave in the City of Columbia and continue to increase in all directions as they radiate outward from the origin point. Other municipalities in Boone County use the same type of numbering grid system but begin at their own origin point.

27.6 Components of an Address. An address shall contain the following components as applicable:

- Address number
- Directional prefix
- Street name
- Street type
- Directional suffix *
- Unit type **
- Unit number **
- City
- State
- Zip

* Historical component
** If applicable

27.7 Standards for Address Number Assignment. Addresses are assigned based off the primary access to the property. The standards for address number assignment are that the address number is a unique numerical identifier based on the Boone County addressing grid system and that the number can range from one to five digits depending on the location within the grid. The address numbers continue to increase in all directions as they radiate outward from the origin point.

27.7.1 Address Directional Prefix. Assignment of an address directional prefix is based on the position and orientation of the underlying road being addressed as it relates within the address grid. (See Section 27.8 for additional information).

27.7.2 Address Numbers. New address numbers shall consist entirely of numbers. Characters such as hyphens, decimals, or fractions shall not be allowed. If a structure is legally subdivided into more than one occupancy, a unit type and unit number shall be required. For example, instead of 2456.5 or 2456 ½ being issued as an address number, 2456 APT A and B, or 2456 STE 101 and 102 would be the correct issued address number, see Section 27.11 for additional information.

27.7.3 Vanity Address Numbers. Vanity address numbers shall not be allowed. All numbers shall be consistent with the address grid. For example, a business named Acme Five Company in the 1800 address grid range will not be assigned "1 Acme Dr" or "5 Acme Dr" as its address. The address shall be assigned an official address number according to the established address grid range.

27.7.4 Address Ranges. The possible address range of a road shall be identified using the Boone County address grid system to determine which addresses are eligible to be assigned along the length of a road segment. For example, an address number of 220 cannot be assigned on a block with an address range of 1000-1099.

27.7.5 Address Parity. In Boone County even numbers shall be located on the south and east sides of the road and odd numbers shall be located on the north and west sides of the road. Addresses across the road from one another should be comparable. If 645 is used on the odd-numbered side of a road, numbers close to 644 or 646 should be used on the even side.

27.7.6 Numerical Sequence. Assignment of addresses shall be done in numerical sequence along a road. Address numbers shall increase as they move away from the origin point of the address grid and they shall not be assigned out of order. For instance, 1789 should not fall between 1735 and 1741.

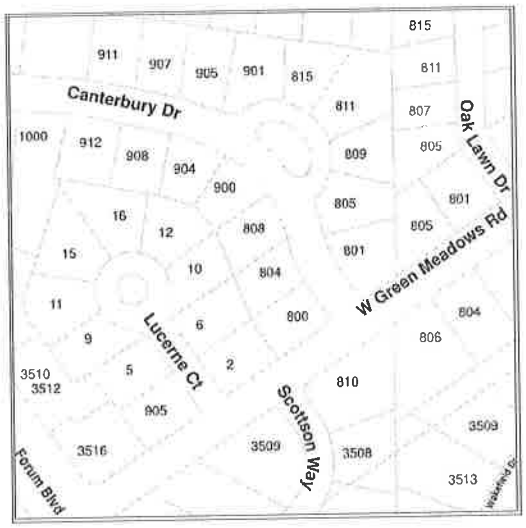
27.7.7 Address Intervals. When assigning address numbers the Director shall consider both current and future development. Address assignment shall include a large enough numbering interval to allow for expansion and growth. In most residential areas an interval of at least four addresses (310, 314, 318, etc.) should be adequate. An interval of at least eight numbers is recommended as the minimum for commercial or industrial sites. Sufficient interval shall be allowed in large lot developments to provide adequate sequential numbers in case the parcel is subdivided for new construction at a later time.

27.7.8 Duplicate Numbers. Duplicate address numbers on the same road or similarly named roads shall be avoided when at all possible especially where the road spans address directional quadrants. This includes addresses on courts or circles. For example, if there is a 5003 E Liberty Ln, then 5003 E Liberty Woods Ct should be avoided.

27.7.9 Long Blocks. New subdivision developments may have long blocks with no intersecting roads. Addresses shall correspond with the appropriate address range for each road segment of the long block. The long block numbers shall change in mid-block even if there is no separating road. This will result in two homes side-by-side numbered in two different blocks even though there is no separating road.

27.7.10 Corner Parcels. Addresses shall be numbered off a road on which the parcel has frontage and where the property is primarily accessed. A request for an address number to be assigned off of a major road shall not be allowed unless the major road physically borders that property and provides primary access.

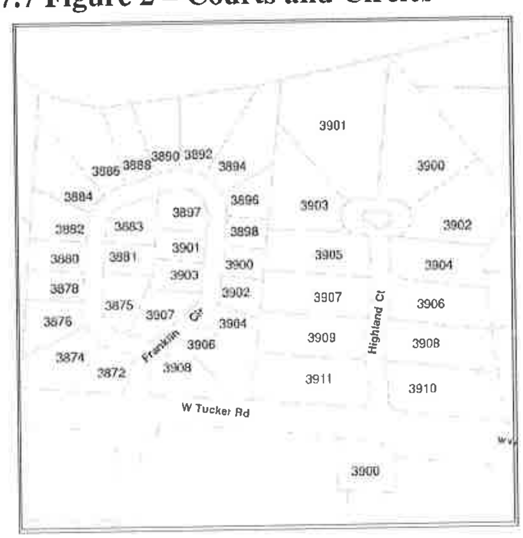
27.7 Figure 1 Bulb – Bumpout



27.7.11 Bulb / Bumpout. Bulb / Bumpout shall be addressed as if the bulb did not exist within the design of the road provided that the bulb of the main road is less than 300 feet in length or platted with six or less lots (including the corner lots) (See Canterbury Dr, 27.7 Figure 1).

27.7.12 Courts. Courts shall be addressed as if the centerline of the road bisects the cul-de-sac with odd numbers on the north or west and even numbers on the south or east. The numbers meet at the far end of the center area. In addition, if the road that the court intersects is designated as an east/west directional road, the court shall be addressed as a north/south directional road even if the two are not perpendicular (See Highland Ct, 27.7 Figure 2).

27.7 Figure 2 – Courts and Circles

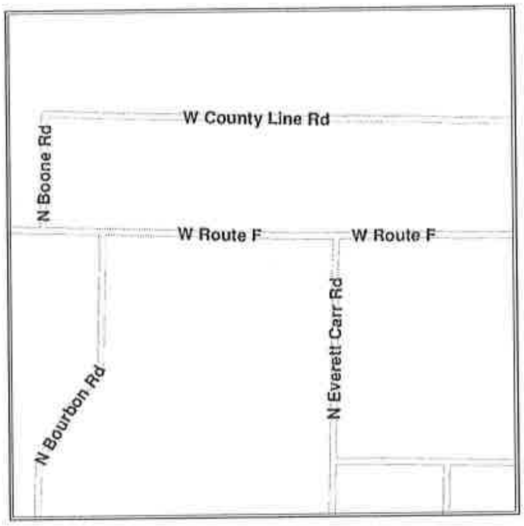


27.7.13 Circles. Circles shall be addressed with the road name, numbering pattern, interval and direction shall be flowing with the traffic direction or to the right when there is no clear traffic flow due to the road design and/or location (See Franklin Cir, 27.7 Figure 2).

27.7.14 Roads that Change Direction. There shall be two ways to contend with roads that change direction or curve significantly. For purposes of this section the Boone County Planning and Building Inspection Director has sole discretion in determining significance (See N Boone Rd, 27.7 Figure 3).

27.7.14.1 Insignificant Change of Direction. The road will retain its original address grid and range throughout its entire length no matter how many times the road turns or bends. This means the address numbers do not change direction with the road (See N Reams Rd, 27.8 Figure 1).

27.7 Figure 3 – Significant Change of Direction



27.7.14.2 Significant Change of Direction. Where overall road alignment involves a single significant change in direction and the road continues for a significant distance after the change, in relationship to its overall length, a new road name shall be assigned in the middle of the curve. This option is most appropriate where the curve is approximately a 90-degree angle changing the major direction of the road (See N Boone Rd, 27.7 Figure 3).

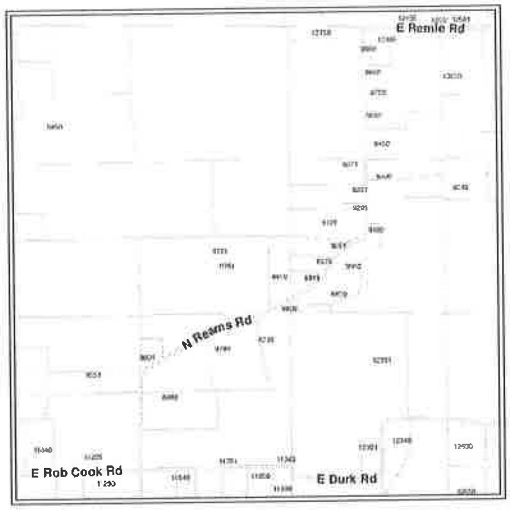
27.8 Standards for Directional Prefixes & Suffixes. Directional prefixes shall be abbreviated, capitalized, and contain no punctuation such as periods. Directional suffixes shall not be used. Standard directional prefix abbreviations include the following:

Example	Abbreviation
North	N
South	S
East	E
West	W

27.8.1 Directional Prefix. A directional prefix is mandatory on all roads but is not part of the official road name. Roads that cross a grid base line may have duplicate address ranges. For example, 301 W Williams Rd and 301 E Williams Rd, the W and E are crucial in distinguishing between the two blocks.

27.8.1.1 Retain Directional Prefix. A diagonal or curving road, having one road name for its entire length, shall be determined to be either a north/south or an east/west road and shall be assigned a single directional prefix. (See N Reams Rd, 27.8 Figure 1)

27.8 Figure 1 – Retain Directional Prefix



27.8.1.2 Change Directional Prefix. Two roads that meet at or near a 90-degree curve with no physical feature to indicate a road name change shall be dealt with as two separate roads with different names and different directional prefixes in accordance to Section 27.7.14.2.

27.9 Standards for Official Name Assignment.

27.9.1 Pronunciation. Road names shall be easy to read, pronounce, and spelled so the public, children in particular, can say the name in an emergency situation.

27.9.2 Inappropriate Road Names. Roads names shall not be names that are generally considered inappropriate or offensive.

27.9.3 Confusing, Common, or Generic Road Names. Road names that are confusing, common, or generic shall not be used. Proposed names shall also be rejected if one of the principal words in the name has already been used several times. In an effort to keep road names distinct and short, roads named after seasons, weather, tree species, common animal names, colors, or geographic features shall not be used, even within a compound road name.

Confusing Road Names	Common Road Names	Generic Road Names
Nub Buck Ln	Autumn Dr	Dead End Rd
Jay Jay Rd	Scenic Dr	Gravel Rd
Cross Rd	White Oak Dr	Nameless Rd
Waterfront Dr*	Spring Valley Dr	Private St

* Compound road name

27.9.4 Similar Sounding Road Names. Roads names shall not sound similar or duplicate, even if the spelling is different, to any other official road name found in Boone County, either incorporated or unincorporated areas.

27.9.4.1 Roads with Similar Sounding Names. Road names with similar sounding names shall not be accepted. Pearce and Pierce are not acceptable, nor will Wild and Wilde be allowed.

27.9.4.2 Similar Road Names with Different Road Types. It is not acceptable to merely change the road type if the root road name is the same, with the special exceptions of Court, Circle, or Connector provided they meet at an intersection. St James Drive and St James Court cannot both be used unless they meet at an intersection as defined in Section 27.9.11 Road Name Continuity. Further explanation of the proper use of Court, Circle, and Drive is covered in Section 27.7.

27.9.5 Road Name Length. Road names shall be eighteen characters (including spaces) or less in length. The Boone County Planning and Building Inspection Director or his designee may allow an existing official road name, exceeding eighteen characters, to be used as the official name provided the new road segment is an extension of the existing road to comply with Section 27.9.11, to maintain road name continuity.

27.9.6 Root Road Name Spacing. Root road names shall be no more than two words to eliminate unnecessary spacing. For example, Nighthawk Dr would be preferred as opposed to Night Hawk Dr since the compression does not cause confusion.

27.9.7 Numeric Road Names. Numeric road names through tenth shall be spelled out. Roads higher than tenth shall be named with numbers and include the appropriate suffix: th, rd, st, or nd. For example, 14th shall be used instead of Fourteenth or 14.

27.9.8 Abbreviations and Punctuation of Road Names. The following is a list of the only accepted abbreviations: I, HWY, RTE, or St. No other words shall be abbreviated in a road name and no punctuation, including possessives such as Scott's Blvd, is to be used as otherwise specified in these regulations.

<u>Example Abbreviation</u>
Interstate Highway 70 I 70
US Highway 63 HWY 63
Old Highway 63 Old HWY 63

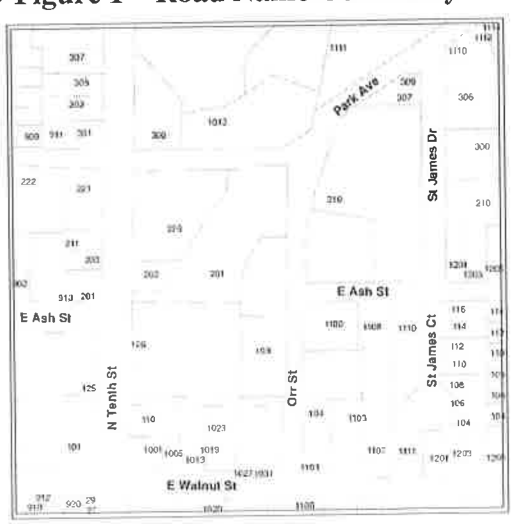
State Highway 124 HWY 124
State Route E RTE E
State Highway EE HWY EE
Saint Charles St Charles

27.9.9 Geographic Directions as Part of Road Names. Geographic directions shall not be used as part of the road name. While these do exist, such as Southgate St, North Shore Dr, South Cedar Lake Dr, Waterfront Dr South, or Southwest Way, this practice shall be avoided in future developments. To eliminate confusion, the use of north, south, east, west, and any variations shall be reserved for prefix use only. For example, when verbally giving an address, it would be impossible to distinguish between Northshore Dr and N Shore Dr.

27.9.10 Road Types as Part of Road Names. A road type shall not be used as part of the root road name even if included in a proposed compound root road name. For example, a road named Dustytrail Dr shall not be allowed since Trail and Drive are both road types. Section 27.10 covers the standard for road abbreviations types for Avenue, Court, Ridge, and Boulevard.

27.9.11 Road Name Continuity. Road name continuity is the consistent retention of one road name for the length of the road. This is not to be confused with road name duplication. Road name continuity shall be used when possible. A road with a gap should maintain the same name across the gap, as long as the road continues on the same alignment after the gap. (See E Ash St, 27.9 Figure 1).

27.9 Figure 1 – Road Name Continuity



If the road shifts off-alignment by more than 200 feet, a new road name shall be assigned. Roads that continue beyond an intersection and dead-end as courts shall be named with the same root name as the main road but designated as a Court (See St James Dr and St James Ct, 27.9 Figure 1).

27.9.12 Intersecting Road. Roads shall not cross or meet more than twice.

27.9.13 Consistent Road Name Spelling. Any new segment to an existing road shall be spelled consistent with the road name being extended provided the existing road name is in compliance with this section.

27.9.14 Official Legal Road Name Changes. When a road name is officially renamed, the new road name becomes the official road name and replaces the old official road name and is the only acceptable name for the renamed road.

27.9.15 Unofficial or Alias Road Names. Different entities sometimes refer to the same road using several different unofficial road names for the same segment of road. The road name shown on a road sign is not the official road name unless it matches the road name listed in the Boone County Road Directory. For example, Range Line St is also referenced as HWY 763.

27.9.16 Private Roads. All roadways used for access or the possibility of access to seven or more addressable structures must be named and all structures must be numbered off that roadway. All other roadways with less than seven addressable structures shall be considered private driveways or ingress/egress easements and shall not be officially named. Initiating road naming or road name changes are the responsibility of the property owner(s). The name must then be submitted for approval by the addressing authority and must adhere to the same naming standards for official public road names. Private road names must adhere to the same naming standard for public roads; approval will not be given for duplicate or confusing private road names, for example Golfview Dr and Golfview Ln, as outlined in Section 27.9.3.

27.10 Standards for Road Type Assignment. All road segments shall have a standard road type assigned by the addressing authority.

27.10.1 Correct Use of Road Types. All roads shall have a road type which shall be assigned by the addressing authority from the following list. The addressing authority reserves the right to put priority in assigning road types highlighted in grey in the following list. For example, Wagon Ridge Rd shall not be assigned as it would go against the directive that road types shall not be part of the root road name. Likewise, if a court extends off Wagon Ridge it will be assigned Wagon Ct, not Wagon Ridge Ct.

Road type	Abbreviation
Alley	Alley
Avenue	Ave
Boulevard	Blvd
Bridge	Br

Road type	Abbreviation
Meadow	Mdw
Meadows	Mdws
Park	Park
Parkway	Pkwy

Bypass	Byp
Causeway	Cswy
Circle	Cir
Connector	Conn
Court	Ct
Cove	Cv
Crossing	Xing
Drive	Dr
Establishment	Est
Expressway	Expy
Extention	Ext
Freeway	Fwy
Glen	Gln
Green	Grn
Heights	Hts
Highway	Hwy
Hill	Hl
Hills	Hls
Lane	Ln
Loop	Loop

Pass	Pass
Place	Pl
Plaza	Plz
Point	Pt
Ramp	Ramp
Ridge	Rdg
Road	Rd
Route	Rte
Run	Run
Spur	Spur
Square	Sq
Station	Sta
Street	St
Terrace	Ter
Trace	Trce
Trail	Trl
Turnpike	Tnpk
Valley	Vly
View	Vw
Village	Vlg
Walk	Walk
Way	Way

27.10.2 Root Road Names Assigned Only One Road Type. Once a root road name is assigned it must not be used again with a different road type except in the case of a Court, Circle, or Connector as shown in Section 27.9.4. For example, the use of both Maple Lane and Maple Trail shall not be acceptable.

27.11 Standards for Address Assignment. All addressable structures shall have an address number assigned by the addressing authority.

27.11.1 Addressable Structures. Only the following types of structures are eligible for official addressing. Accessory structures and non-dwelling units shall not be assigned addresses unless otherwise specified by this ordinance.

27.11.1.1 Single Family Dwellings, 2-Family, Triplexes, Multi-Family, and Condominiums. Single Family Dwellings, 2-Family, Triplexes, and Multi-Family shall be assigned separate address numbers. Buildings containing condominiums shall be assigned addresses in the same manner that is appropriate for the type of structure constructed within which the condominium is located.

27.11.1.2 Mobile Home Parks. Mobile home parks are designated by sequential, non-duplicated lot numbers with a single site address for the entire park. If additional road names are unavoidable inside a mobile home park, then they shall be addressed in the same manner as a platted subdivision.

27.11.1.3 Commercial or Industrial Buildings.

27.11.1.3.1 Contained Within a Single Structure. Businesses in shopping centers or strip malls contained within a single structure shall be assigned an address consisting of the structure address and a unique individual suite number in compliance with Section 27.11.4 with sufficient suite numbering interval to allow for one suite to be split into several future suites.

27.11.1.3.2 Contained Within a Development Complex. Businesses in shopping centers or strip malls contained within a development complex of multiple structures shall be assigned separate site address for each structure with sufficient numbering interval to allow for additional structures. Businesses contained within a given structure will be assigned individual suite numbers in compliance with Section 27.11.4 with sufficient numbering interval to allow for one suite to be split into several future suites.

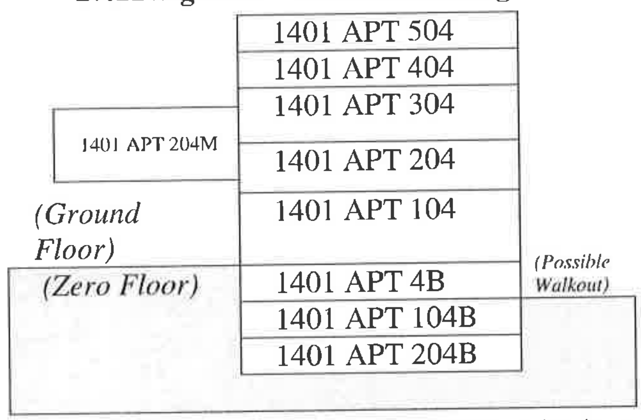
27.11.2 Address Number Assignment. Addressable structures shall be numbered off a road on which they have frontage and where the property is primarily accessed. In cases where an addressable structure is located on a property that does not have road frontage on an officially named road, the structure shall be numbered off of the officially named road where the property is primarily accessed. A request for an address number to be assigned off of a major road shall not be allowed unless the major road physically borders that property and provides primary access.

27.11.3 Unit Type Assignment. In structures with a single type of use, multiple unit types per address shall be avoided. The unit type "Apartment" shall be used to designate residential dwellings. If mixed uses are anticipated or proposed within a structure, then the unit type "Unit" shall be used. The unit type "Suite" shall be used for all other applications unless otherwise specified by this ordinance.

Unit types shall be limited to four characters. The standard abbreviations for unit types are:

Example	Abbreviation
Apartment	Apt
Building	Bldg
Department	Dept
Floor	Flr
Lot	Lot
Room	Rm
Suite	Ste
Unit	Unit

27.11 Figure 1 – Unit Numbering



27.11.4 Unit Number Assignment. Unit types are used to further define a space such as an apartment, a lot in a mobile home park, or an office suite in a large building. When assigning unit numbers, a numerical value is required. In a multi-level structure, the unit number shall reflect the floor on which it is located. For example, Apt 304 would be the fourth apartment located on the third floor or Suite 512 would be the twelfth suite on the fifth floor (See 27.11 Figure 1). The only time an alphanumeric value is allowed is to designate sub-basement floors and mezzanine levels and these are suffixed by the letter abbreviations B or M (See 27.11 Figure 1). The first floor below the floor designated as the ground floor even if it is a walkout basement is considered floor zero. Additional floors below floor zero are numbered based on the number of levels below zero floor.

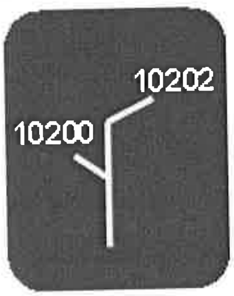
27.12 Signage Usage and Display. Only officially approved road name and address signage shall be allowed.

27.12.1 Address Signage. Use of assigned official address is mandatory. Within sixty (60) days after written notice of the assignment of or change of an address number, the owner of such property shall be required to post the number so assigned in accordance with the following standards:

27.12.1.1 Display of Official Address. All addressable structures, see Section 27.11, shall clearly display an address number, even during construction. The owner and/or occupant of each addressable structure shall be required to clearly display an address number on each addressable structure so that the location can be identified from the road.

27.12.1.2 Placement of Official Address. The official address number must be displayed at the main entrance of an addressable structure. If the main entrance of the addressable structure is not visible from the road, the official address number shall also be on the side of the addressable structure which is most visible from the road during both day and night. When an addressable structure is seventy-five (75) feet or more from a public road or driveway on which it fronts or the lot on which the building is located is landscaped such that numbers cannot be seen from the road or driveway entrance the assigned number shall also be posted at the end of the driveway or easement nearest the road which provides access to the building. Manufactured homes in mobile home parks shall display the assigned address and lot number on the side of the manufactured home closest to the road/driveway which serves the lot so that the number is clearly visible from the road/driveway at all times.

27.12 Figure 1 – Directional Address Signage



27.12.1.3 Directional Address Signage. Directional address signage shall be required for any addressable structure located off the main road or that requires specific knowledge to locate. This also applies to any driveway or private road that services multiple structures or owners. A directional sign shall be placed so that it is visible from the intersection of the driveway or private road and public road. Directional sign shall be blue with white numbers that are a minimum of four (4) inches in height and placed on a standard street sign post (See 27.12 Figure 1).

27.12.1.4 Address Signage Sizing.

27.12.1.4.1 Address Number Visibility. Address numbers shall be in a contrasting color to the color scheme of the addressable structure so that they are clearly visible and shall be maintained in a clearly visible manner. Reflective numbers are desirable but not required.

27.12.1.4.1.1 Single Family Dwelling. Single family dwelling address numbers shall be a minimum of four (4) inches in height and shall be posted so as to be legible from the road.

27.12.1.4.1.2 Multiple Dwelling Units. Multiple dwelling building address numbers shall be at least six (6) inches in height.

27.12.1.4.1.3 Manufactured Home Parks. Manufactured home parks shall erect a sign at the entrance to the park displaying the name of the park and the assigned road address with numbers at least six (6) inches in height.

27.12.1.4.1.4 Manufactured Homes in a Mobile Home Park. Manufactured homes in a mobile home park address numbers shall be a minimum of four (4) inches in height.

27.12.1.4.1.5 Commercial or Industrial Structures. Commercial/Industrial structure address numbers shall be at least six (6) inches in height.

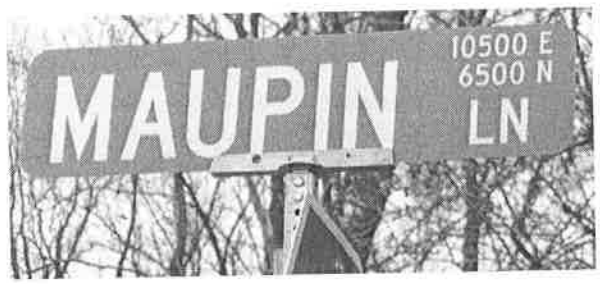
27.12.1.4.2 Address Signage Maintenance. Following the posting of the assigned number as required, the owner or occupant shall maintain such house or building numbers at all times in compliance with the above referenced standards. Address numbers shall not be obstructed from view by shrubs or vegetation as viewed from the public road.

27.12.2 Road Name Signage and Sign Sizing.

27.12.2.1 Public Road Name Signage. Signs are to be green with white letters and adhere to the Boone County Public Works Department road name signage standards and comply with all abbreviation and naming standards found within this section. The sign shall include both N-S and E-W address coordinate numbers, root road name, and suffix (See 27.12

Figure 2). Furthermore, the cross-street address coordinate number shall be located on the first line in the upper right and the through-street coordinate number shall be located directly below the cross-street address coordinate.

27.12 Figure 2



27.12.2.2 Public Road Name Sign Sizing. Public road name sign sizing shall adhere to the Boone County Public Works Department road name sign sizing standards.

27.12.2.3 Private Road Name Signage. Signs are to be white with black letters and adhere to the Boone County Public Works Department road name signage standards and comply with all abbreviation and naming standards found within this section. The sign shall include both N-S and E-W address coordinate numbers, root road name, and suffix (See 27.12 Figure 2). Furthermore, the cross-street address coordinate number shall be located on the first line in the upper right and the through-street coordinate number shall be located directly below the cross-street address coordinate.

Private road name signs located along public roads are the responsibility of the Public Works Department or designated entity. Private road name signs located within the development are the responsibility of the owners residing on the private road, and the road name signs shall match placement and height of official road name signs, and shall display the road name on both sides.

27.12.2.4 Private Road Name Sign Sizing. Private road name sign sizing shall adhere to the Boone County Public Works Department road name sign sizing standards.

27.12.3 Non-compliant Signs. Non-compliant signs within the right-of-way shall be removed by Boone County Public Works Department staff.

27.13 Penalties and Remedies. Any owner, lessee, tenant, occupier of land or other person who violates any provision of these regulations shall be deemed guilty of a misdemeanor and shall be upon conviction punished as provided by law. Each day a violation of these regulations continues shall constitute a separate offense. The penalty provided in this section shall not be construed to be exclusive but is intended to be supplemental and in addition to any other remedy provided by law or at equity. The County may institute any appropriate action or proceeding to prevent any unlawful activity proscribed in this ordinance or to correct any violation of this ordinance.

27.14 Severability. If any part or provision of these regulations is declared invalid or unconstitutional then the remainder of these regulations shall not be declared invalid or unconstitutional but shall remain in full force and effect to the greatest extent permitted by law.

27.15 Jurisdiction. These regulations shall be applicable to all unincorporated areas within Boone County, Missouri.

SECTION 28 STORM WATER ORDINANCE

*The Storm Water Ordinance was amended as Section 28 on the latest re-adoption date of March 7, 2017. Some section and sub-section references in the content of the Storm Water Ordinance were not updated. Section 28. should be added to the beginning of referenced sections and sub-sections.

28.1. General Provisions

28.1.1. FINDINGS OF FACT

It is hereby determined that:

(1) Land development activities and associated increases in site impervious cover alter the hydrologic response of local watersheds and increase stormwater runoff rates and volumes, flooding, stream channel erosion, sediment transport and deposition;

(2) This stormwater runoff contributes to increased quantities of water-borne pollutants;

(3) Illicit and non-stormwater discharges to the storm drain system can contribute a wide variety of pollutants to waterways, and the control of these discharges is necessary to protect public health and safety and water quality;

(4) Improper design and construction of stormwater best management practices (BMPs) can increase the velocity of stormwater runoff thereby increasing stream bank erosion and sedimentation;

(5) Clearing and grading during construction increases soil erosion and adds to the loss of native vegetation;

(6) Impervious surfaces allow less water to percolate into the soil, thereby decreasing groundwater recharge and stream baseflow;

(7) Substantial economic losses can result from these adverse impacts on the waters of the County;

(8) Stormwater runoff, soil erosion and nonpoint source pollution can be controlled and minimized through the regulation of stormwater runoff from land development activities;

(9) The regulation of stormwater runoff discharges from land development activities in order to control and minimize increases in stormwater runoff rates and volumes, stream channel erosion, and nonpoint source pollution associated with stormwater runoff is in the public interest and will minimize threats to public health and safety.

(10)Regulation of land development activities by means of performance standards governing stormwater management and site design will produce development compatible with the natural functions of a particular site or an entire watershed and thereby mitigate the adverse effects of stormwater runoff from development.

28.1.2 INTENT AND PURPOSE

The purpose of this ordinance is to establish minimum stormwater management requirements and controls to protect and safeguard the general health, safety, and welfare of the public residing in watersheds within Boone County. This ordinance seeks to meet that purpose through the following objectives:

(1) To protect the safety and welfare of citizens, property owners, and businesses by minimizing the negative impacts of increased stormwater discharges from new land development and redevelopment

(2) To control the rate, quality and volume of stormwater originating from development and redevelopment sites so that surface water and

groundwater are protected and flooding and erosion potential are not increased.

(3) To encourage responsible development to occur in Boone County

(4) To control nonpoint source pollution and stream channel erosion.

(5) To maintain the integrity of stream channels and networks for their biological functions, drainage, and natural recharge of groundwater.

(6) To protect the condition of state (and U.S.) waters for all reasonable public uses and ecological functions.

(7) To provide long-term responsibility for and maintenance of stormwater BMPs.

(8) To establish legal authority to carry out all the inspection and monitoring procedures necessary to ensure compliance with this ordinance.

(9) To enable Boone County Public Works to comply with the National Pollution Discharge Elimination System permit and applicable federal and state regulations.

28.1.3 APPLICABILITY

This ordinance shall be applicable to all land development, including, but not limited to, site plan applications, subdivision applications, and grading applications, unless exempt pursuant to *Section 1.4. These provisions apply to any new development or redevelopment site within Boone County that meets one or more of the following criteria:

(1) Land development that disturbs 1 acre or more.

(2) Redevelopment that creates or adds three thousand (3,000) square feet or more of impervious cover.

(3) Land development in or near an ecologically and/or environmentally sensitive area (as defined in Section 4.7) that disturbs more than 3000 square feet.

(4) Land development activities that are smaller than the minimum applicability criteria set forth above if such activities are part of a larger common plan of development, even though multiple, separate

and distinct land development activities may take place at different times on different schedules.

28.1.4 EXEMPTIONS

The following activities are exempt from this ordinance:

(1) Projects that are exclusively for agricultural and silvicultural uses. Agricultural or silvicultural roads that are used to access other lands subject to this ordinance are not exempt. Agricultural structures that are used for other uses subject to this ordinance are not exempt.

(2) Maintenance and repair to any stormwater BMP deemed necessary by Boone County Public Works.

(3) Any emergency project that is immediately necessary for the protection of life, property, or natural resources.

(4) Linear construction projects, such as pipeline or utility line installation that does not result in the creation of impervious cover or land disturbance greater than one acre, as determined by Boone County Public Works. Such projects must be designed to minimize the number of stream crossings and width of disturbance, and are subject to County erosion and sediment control practices.

(5) Any part of a land development that was approved by Boone County Planning Department prior to the effective date of this ordinance.

28.1.5. LEGAL AUTHORITY

These regulations are adopted pursuant to the authority granted in 64.907, 64.825 – 64.885, Revised Statutes of Missouri.

28.1.6. COMPATIBILITY WITH OTHER PERMIT AND ORDINANCE REQUIREMENTS

This ordinance is not intended to interfere with, abrogate, or annul any other ordinance, rule or regulation, statute, or other provision of law. The requirements of this ordinance should be considered minimum requirements, and where any provision of this ordinance imposes restrictions different from those imposed by any other ordinance, rule or regulation, or other provision of law, whichever provisions are more restrictive or impose higher protective standards for human health or the environment shall be considered to take precedence.

28.1.7. LIMITATIONS ON LIABILITY.

Floods from stormwater runoff may occur which exceed the capacity of stormwater drainage facilities constructed and maintained under this chapter. This chapter does not guarantee that property will be free from stormwater flooding or flood damage. This chapter shall not create a liability on the part of, or cause of action against, the County or any officer or employee thereof for any flood damage. This chapter does not purport to reduce the need or the necessity for obtaining flood insurance.

28.2. Definitions

Unless specifically defined below, words or phrases in this chapter shall be interpreted so as to give them the meaning they have in common usage and to give this chapter its most reasonable application:

Applicant: means a property owner or agent of a property owner who has filed an application for a permit.

Bankfull: An established river stage/elevation at a given location along a river which is intended to represent the maximum safe water level that will not overflow the river banks or cause any significant damage within the river reach.

Best Management Practice (BMP): Activities, practices and procedures which control soil loss and reduce or prevent water quality degradation caused by nutrients, animal wastes, toxins, organics and sediment in the runoff. BMPs may either be structural (grass swales, terraces, retention and detention ponds, and others); or non-structural (disconnection of impervious surfaces, directing downspouts onto grass surfaces, ordinances and educational activities).

Boone County Stormwater Design Manual: means the engineering and/or project review document maintained by Boone County Public Works containing technical standards and specifications, policies, procedures, and other materials deemed appropriate to assist with compliance with the provisions of this ordinance as adopted February 2010.

Building: means any structure, either temporary or permanent, having walls and a roof, designed for the shelter of any person, animal, or property, and occupying more than 160 square feet of area.

Channel: means a natural or artificial watercourse with a definite bed and banks that conducts continuously or periodically flowing water.

Clearing: means any activity which removes the vegetative surface cover through disturbance of the root zone.

County Commission: means the Boone County Commission.

County: is Boone County, Missouri.

Dedication: means the deliberate appropriation of property by its owner for general public use.

Detention: is the temporary storage of storm runoff in a stormwater BMP with the goals of controlling peak discharge rates and providing gravity settling of pollutants.

Developer: is a person directing or participating in the direction of improvements on and/or to land, including, but not limited to, the owner of the land, a general contractor or a commercial agent engaged for such activity.

Development: A change in the zoning, intensity of use or allowed use of any land, building, structure or premises for any purpose. The subdivision or severance of land. The construction, erection or placing of one or more buildings or structures on land or use of land or premises for storage of equipment or materials. Making of an addition, enlargement or alteration to a building or structure, in, on, over or under land, which has the effect of increasing the size or usability thereof. Land disturbance activities such as but not limited to site-grading, excavation, drilling, removal of topsoil or the placing or dumping of fill and installation of drainage works. The use of the term shall include redevelopment in all cases unless otherwise specified in these regulations.

Director: The Boone County Director of Public Works or Boone County Director of Planning and Building Inspection or his/her designee, as determined by the County Commission.

Drainage Facility: is a man-made structure or natural watercourse used for the conveyance of stormwater runoff. Examples are channels, pipes, ditches, swales, catch basins and street gutters.

Easement: means a legal right granted by a landowner to a grantee allowing the use of private land for conveyance or treatment of stormwater runoff and access to stormwater practices.

Environmentally Sensitive Area: is any area in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem; or an area of land that contributes water to the habitat of an aquatic animal that is rare or valuable; or an area of land with increased vulnerability (presence of karst features, steep terrain, highly erodable soils) where the proposed human activities would likely cause disproportional damage to the environment; or as defined in *Section 4.6.

Erosion and Sediment Control Plan: is a plan designed to minimize the loss of soil and prevent discharge of sediment from a site during, and after construction activities.

Flood Routing Path: is that part of the major storm drainage system that carries the runoff that exceeds the capacity of the designed drainage facilities. Essentially, the complete drainage system of an urban area contains two (2) separate drainage elements. The storm sewers collect the frequent events while surface drainage-ways must be provided for the major flow from more intense storms, or the event of clogging.

Grading: means excavation or fill of material, including the resulting condition thereof.

Groundwater Management Area: is a geographically defined area that may be particularly sensitive in terms of groundwater quantity and/or quality by nature of the use or movement of groundwater, or the relationship between groundwater and surface water, and where special management measures are deemed necessary to protect groundwater and surface water resources. Example includes the Devils Icebox Recharge Area.

Hazardous Materials: means any material, including any substance, waste, or combination thereof, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may cause, or significantly contribute to, a substantial present or potential hazard to human health, safety, property, or the environment when improperly treated, stored, transported, disposed of, or otherwise managed.

Illegal Discharge: means any direct or indirect non-storm water discharge to the storm drain system, except as exempted by this ordinance.

Illicit Connections: means either of the following: Any drain or conveyance, whether on the surface or subsurface, which allows an illegal discharge to enter the storm drain system. These include but are not limited to any conveyances that allow any non-storm water discharge including sewage, process wastewater, and wash water to enter the storm drain system and any connections to the storm drain system from indoor drains and sinks, regardless of whether said drain or connection had been previously allowed, permitted, or approved by an authorized enforcement agency. Illicit connections also includes any drain or conveyance connected from a commercial or industrial land use to the storm drain system which has not been documented in plans, maps, or equivalent records and approved by an authorized enforcement agency.

Impaired Waters: means those streams, rivers and lakes that currently do not meet their designated use classification and associated water quality standards under the Clean Water Act.

Impervious Cover: includes those surfaces that cannot effectively infiltrate rainfall (e.g., building rooftops, pavement, sidewalks, driveways, etc).

Industrial Stormwater Permit: means a National Pollutant Discharge Elimination System permit issued to a commercial industry or group of industries that regulates the pollutant levels associated with industrial stormwater discharges or specifies on-site pollution control strategies.

Infill Development: means land development that occurs within designated areas based on local land use, watershed, and/or utility plans where the surrounding area is generally developed, and where the site or area is either vacant or has previously been used for another purpose.

Infiltration: means the process of percolating stormwater into the subsoil.

Infiltration Facility: means any structure or device designed to infiltrate retained water to the subsurface. These facilities may be above grade or below grade.

Land Development: means a human-made change to, or construction on, the land surface that changes its runoff characteristics.

Land Disturbing Activity: means any activity that changes the volume or peak flow discharge rate of rainfall runoff from the land surface. This may include the grading, digging, cutting, scraping, or excavating of soil, placement of fill materials, paving, construction, substantial removal of vegetation, or any activity that bares soil or rock or involves the diversion or piping of any natural or man-made watercourse.

Land Disturbance Permit: an authorization for the permittee to develop land and conduct activities in accordance with County ordinances and erosion and sediment control practices outlined in an approved Stormwater pollution prevention plan.

Landowner: the legal or beneficial owner of land, including those holding the right to purchase or lease the land, or any other person holding proprietary rights to the land.

Maintenance Agreement: is a legally recorded document that acts as a property deed restriction, and that provides for long-term maintenance of stormwater BMPs.

Motorized Equipment: vehicles or equipment which are motorized except this definition shall not apply to equipment used for the farming of land, or normal yard maintenance.

Municipal Separate Storm Sewer System (MS4): a publicly-owned facility by which stormwater is collected and/or conveyed, including but not limited to any roads with drainage systems, municipal streets, gutters, curbs, catch basins, inlets, piped storm drains, pumping facilities, retention and detention basins, natural and human-made or altered drainage ditches/channels, reservoirs, and other drainage structures.

National Pollutant Discharge Elimination System (NPDES) Stormwater Discharge Permit: a permit issued by the State under authority delegated pursuant to 33 USC § 1342(b), that authorizes the discharge of pollutants to waters of the State, whether the permit is applicable on an individual, group, or general area-wide basis.

Non-Stormwater Discharge: any discharge to the storm drain system that do not originate from precipitation events, such as but not limited to septic system discharges, floor drains, and laundry or commercial car wash facilities.

Non-Structural Measure: a stormwater control and treatment technique that uses natural processes, restoration or enhancement of natural systems, or design approaches to control runoff and/or reduce pollutant levels. Such measures are used in lieu of or to supplement structural practices on a land development site. Non-structural measures include, but are not limited to: minimization and/or disconnection of impervious surfaces; development design that reduces the rate and volume of runoff; creation, restoration or enhancement of natural areas such as riparian zones, wetlands, and forests; and on-lot practices such as rain barrels, cisterns, and vegetated areas that intercept rainfall and surficial runoff.

Nonpoint Source Pollution: pollution from any source other than from any discernible, confined, and discrete conveyances, and shall include, but not be limited to, pollutants from agricultural, silvicultural, mining, construction, subsurface disposal and urban runoff sources.

Ordinary High Water Mark: That line on the shore established by the fluctuations of water and indicated by physical characteristics such as clear natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter or debris, or other appropriate means that consider the characteristics of the surrounding area.

Off-Site Facility: means a stormwater BMP located outside the subject property boundary described in the permit application for land development activity.

On-Site Facility: means a stormwater BMP located within the subject property boundary described in the permit application for land development activity.

Owner: the owner or owners of the freehold of the premises or lesser estate therein, a mortgagee or vendee in possession, assignee of rents, receiver, executor, trustee, lessee or other person, firm or corporation in control of a piece of land. As used herein, owner also refers to, in the appropriate context: (i) any other person authorized to act as the agent for the owner; (ii) any person who submits a stormwater management concept or design plan for approval or requests issuance of a permit, when required, authorizing land development to commence; and (iii) any person responsible for complying with an approved stormwater management construction plan.

Perimeter Control: means a barrier that prevents sediment from leaving a site either by filtering sediment-laden runoff, or diverting it to a sediment trap or basin.

Permanent Stormwater BMP: a stormwater best management practice (BMP) that will be operational after the construction phase of a project and that is designed to become a permanent part of the site for the purposes of managing stormwater runoff.

Person: means a natural person, corporation, partnership or other entity.

Phasing: is the clearing a parcel of land in distinct phases, with the stabilization of each phase before the clearing of the next.

Point source: is any discernible, confined and discrete conveyance including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, separate storm sewer or vessel or other floating craft from which pollutants are, or may be, discharged. (Code of State Regulations – 10 CSR 20-2)

Pollutant: means anything that causes or contributes to pollution. Pollutants may include, but are not limited to: paints, varnishes, and solvents; oil and other automotive fluids; non-hazardous liquid and solid wastes and yard wastes; refuse, rubbish, garbage, litter, or other discarded or abandoned objects, ordinances, and accumulations, so that same may cause or contribute to pollution; floatables; pesticides, herbicides, and fertilizers; hazardous substances and wastes; sewage, fecal coliform and pathogens; dissolved and particulate metals; animal wastes; wastes and residues that result from constructing a building or structure; and noxious or offensive matter of any kind.

Predevelopment: The time period prior to a proposed or actual development activity at a site. Predevelopment may refer an undeveloped site or a developed site that will be redeveloped or expanded.

Professional Engineer: a licensed engineer who is registered with and authorized to practice engineering in the state of Missouri

Professional Geologist: is a licensed geologist who is registered with and authorized in the state of Missouri.

Receiving Stream or Channel: means the body of water or conveyance into which stormwater runoff is discharged.

Recharge: means the replenishment of underground water reserves.

Redevelopment: means a change to previously existing, improved property. This includes but is not limited to the demolition or building of structures, filling, grading, paving; including the conversion of gravel areas to pavement, or excavating. Redevelopment excludes ordinary maintenance activities such as remodeling of buildings on the existing footprint, resurfacing and/or repaving of existing paved areas, and exterior changes or improvements that do not materially increase or concentrate stormwater runoff or cause additional nonpoint source pollution.

Responsible Party: means any individual, partnership, co-partnership, firm, company, corporation, association, joint stock company, trust, estate, governmental entity, or any other legal entity; or their legal representatives, agents, or assigns that is named on a stormwater maintenance agreement as responsible for long-term operation and maintenance of one or more stormwater BMPs.

Riparian Zone / Riparian Buffer: is the land adjacent to streams, rivers, and lakes that actively interfaces with the waterbody through physical and chemical processes. Riparian zones filter nutrients and sediments, increase streambank stability, and provide shade that reduces stream temperatures

Runoff Reduction (RR): is defined as the total annual runoff volume reduced through canopy interception, soil infiltration, evaporation, transpiration, rainfall harvesting engineered infiltration or extended filtration.

Sediment Control: means measures that prevent eroded sediment from leaving the site.

Sensitive Area: means areas containing features that are of critical importance to the protection of ecological or environmental resources, and include bluffs, caves, sinkholes, springs, and wetlands.

Sinkhole Cluster Area: any area that contributes surface water to a sinkhole which is located in a group of two (2) or more sinkholes grouped within 500 feet.

Sinkhole Drainage Area: means the land area around a sinkhole that contributes surface water directly to the sinkhole(s).

Sinkhole: means any closed depression formed by removal (typically underground) of water, surficial soil, rock, or other material. The existence of a sinkhole shall be as indicated by the closed depression contour lines on the topographical maps of the county or as may be determined by a field survey. Its actual limits may, however, be determined by field measurements with concurrence of the Director. Sinkholes may be either circular in plan or irregular, depending upon structural control.

Sinkhole Ponding Elevation: means the maximum elevation of either the elevation as determined by using currently accepted methods of the Natural Resource Conservation Service (formerly Soil Conservation Service) to calculate the total volume of runoff from the sinkhole drainage area to the sinkhole utilizing an eight (8) inch rainfall and no sink outlet or the historical elevation or the published flood elevation. NOTE: Overflow conditions will establish maximum ponding elevation.

Stabilization: means the use of practices that prevent exposed soil from eroding.

Start of Construction: means the first land-disturbing activity associated with a development, including land preparation such as clearing, grading and filling; installation of streets and walkways; excavation for basements, footings, piers or foundations; erection of temporary forms; and installation of accessory buildings such as garages.

Stop Work Order: means an order issued that requires that all construction activity on a site be stopped except as necessary to remedy the issue(s) for which the order was issued.

Stormwater: means any surface flow, runoff, and drainage consisting entirely of water from any form of natural precipitation (such as rain or snow), and resulting from such precipitation.

Stormwater drainage system: means all drainage facilities used for collecting and conducting stormwater to, through and from drainage areas to the points of final outlets including, but not limited to, any and all of the following: Conduits and appurtenant features, canals, ditches, streams, gullies, flumes, culverts, streets, gutters and pump stations.

Stormwater Hotspot: means an area where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in stormwater.

Stormwater Management: means the use of structural or non-structural practices that are designed to reduce stormwater runoff pollutant loads, discharge volumes, peak flow discharge rates and detrimental changes in stream temperature that affect water quality and habitat.

Stormwater Pollution Prevention Plan (SWPPP): means a narrative plan, usually required by a permit, to manage stormwater associated with industrial, commercial, institutional, or other land use activities, including construction. The SWPPP commonly describes and ensures the implementation of practices that are to be used to reduce pollutants in stormwater and non-stormwater discharges.

Stormwater Retrofit: means a stormwater BMP designed for an existing development site that previously had either no stormwater BMP in place or a practice inadequate to meet the stormwater management requirements of the site.

Stormwater Runoff: is the rain or snowmelt that runs off streets, parking lots, lawns and other surfaces and drains into natural or manmade conveyance systems. Often stormwater transports accumulated material including litter, soil, nutrient, pathogens, chemicals, pesticides, oils and grease.

Stream Buffer: is a vegetated area including trees, shrubs, managed lawn area, and herbaceous vegetation which exists or is established to protect the stream system. Alteration of this natural area is strictly limited by the stream buffer ordinance dated June 1, 2009.

Water Quality Storm: is the storm event that produces less than or equal to 90 percent stormwater runoff volume of all 24-hour storms on an annual basis.

Water Quality Volume (WQv): means the storage needed to capture and treat 90% of the average annual stormwater runoff volume.

Watercourse: means a permanent or intermittent stream or other body of water, either natural or man-made, which gathers or carries surface water.

Watershed or Catchment: is the entire geographical area drained by a river and its tributaries; an area characterized by the conveyance of all runoff to the same outlet.

Watershed Management Plan: means a document, usually developed cooperatively by government agencies and other stakeholders, to protect, restore, and/or otherwise manage the water resources within a particular watershed or subwatershed. The plan commonly identifies threats, sources of impairment, institutional issues, and technical and programmatic solutions or projects to protect and/or restore water resources.

Wetland: Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas.

"Wetland Hydroperiod: means the pattern of fluctuating water levels within a wetland caused by the complex interaction of flow, topography, soils, geology, and groundwater conditions in the wetland.

28.3. Plan Submittal/Review Requirements

Each developer/owner subject to this ordinance shall submit to Boone County Public Works for review and approval a stormwater management plan as provided herein:

28.3.1. Pre-Application Meeting

All applicants shall participate in a concept review and pre-application meeting with the Public Works and Planning departments to discuss potential approaches for stormwater design and opportunities to use design techniques to reduce runoff rates, volumes, and pollutant loads. During the pre-application meeting, the applicant shall provide information regarding design considerations as outlined in the Boone County Stormwater Design Manual.

28.3.2. PRELIMINARY STORMWATER MANAGEMENT PLAN

After the pre-application review, the applicant shall prepare a preliminary stormwater management plan describing, in general, how stormwater runoff through and from the development will be treated and conveyed. Required information is provided in the Boone County Stormwater Design Manual.

(1) **Maximize Use of Techniques to Reduce Runoff by Design:** The preliminary stormwater management plan shall utilize to the maximum extent practicable site planning and design technique that reduce runoff rates, volumes, and pollutant loads. Such techniques include, but are not limited to, minimization and/or disconnection of impervious surfaces; development design that reduces the rate and volume of runoff; restoration or enhancement of natural areas such as riparian zones, wetlands, and forests; and distributed practices that intercept and treat runoff from developed areas.

(2) **Preliminary Plan Prior to Design Plan**: The preliminary stormwater management plan must be approved by Boone County Public Works prior to submission of a stormwater management construction plan (as part of the construction or final site plan) for the entire development, or portions thereof.

28.3.3. CLEARING AND ROUGH GRADING

If the developer/owner only desires to obtain a land disturbance permit for purposes of clearing and grading, they may do so upon approval of the preliminary plan, erosion and sediment control plan and a stormwater pollution prevention plan.

28.3.4. STORMWATER MANAGEMENT CONSTRUCTION PLAN

A stormwater management construction plan containing all appropriate information as specified in this Ordinance and outlined in the Boone County Stormwater Design Manual shall be submitted to Boone County in conjunction with the final subdivision plat, final development plan, final site plan, construction plan, or any other land development plan subject to this ordinance.

(1) **Application Requirements:** The stormwater management construction plan submittal shall contain:

- a completed application form provided by Boone County Public Works for any applicable permits as outlined in Section 8,
- the fee(s) required by *Section 8.5,
- a stormwater management construction plan that satisfies the requirements of this section and the Boone County Stormwater Design Manual,
- a stormwater facilities and/or BMP maintenance plan, and
- owner and developer certification stating that all requirements of the approved plan will be complied with. Failure of the owner to demonstrate that the project meets these requirements, as determined by Boone County Public Works, shall be sufficient reason to refuse review and/or deny approval of the plan.

(2) **Consistency between Preliminary Plans and Construction Plans:** A copy of the approved preliminary stormwater management plan shall be submitted with the construction plans. Boone County Public Works shall check the construction plan for consistency with the preliminary plan.

(3) **Stormwater management construction plan content:** The stormwater management construction plan shall contain maps, charts, graphs, tables, photographs, narrative descriptions, explanations, calculations, citations to supporting references, a record of all major permit decisions, and other information as may be necessary for a complete review of the plan, and as specified in the Boone County Stormwater Design Manual.

28.3.5. Construction Plan Review Procedures

(1) **Review for Completeness of Plan:** Boone County Public Works shall have a maximum of ten (10) workdays from the receipt of an application for preliminary review to determine if the application is complete. After this period, the application will be accepted for review, which will begin the thirty (30) calendar day review period, or rejected for incompleteness. For detailed procedures, refer to the Stormwater Design Manual.

(2) **Review Period:** The thirty (30) calendar day review period begins on the day the complete stormwater management construction plan is accepted for review by Boone County Public Works. During the thirty (30) day review period, Boone County Public Works shall either

approve or disapprove the plan and communicate the decision to the applicant in writing. Approval or denial shall be based on the plan's compliance with this Ordinance and the Boone County Stormwater Design Manual. Within thirty (30) days after receiving an application, the County shall, in writing:

A. approve the permit application; or

B. approve the permit application subject to such reasonable conditions as may be necessary to secure substantially the objectives of this regulation, and issue the permit subject to these conditions; or

C. disapprove the permit application, indicating the deficiencies and the procedure for submitting a revised application and/or submission.

(3) **Modifications Needed for Approval:** In cases where modifications are required to approve the plan, Boone County shall have an additional thirty (30) days to review the revised plan from the initial and any subsequent resubmission dates. If the plan is approved, one copy bearing certification of such approval shall be returned to the applicant. If the plan is disapproved, the applicant shall be notified in writing of the reasons.

(4) **Substantive Changes to Plan:** No substantive changes shall be made to an approved plan without review and written approval by the Director. The County may request additional data with a plan amendment as may be necessary for a complete review of the plan and to ensure that changes to the plan will comply with the requirements of this ordinance.

(5) **Expiration of Plan Approval:** The stormwater management construction plan is contingent on the land disturbance permit approval. These plans will expire two years from the date of approval unless work has begun on the site; or a land disturbance permit extension request from the owner or design engineer has been received by the Director. If the land disturbance and/or stormwater management construction plan approval expires and is not granted an extension, the applicant shall file with Boone County for reapproval of the stormwater management construction plan.

28.3.6. COORDINATION WITH OTHER APPROVALS AND PERMITS

(1) **Approval of Other Permits:** Unless exempt, no stormwater discharge permit or building permit shall be issued for land development without approval of a stormwater management construction plan.

(2) **Coordination with Other Plans:** Approval of the stormwater management construction plan shall be coordinated by Boone County with approval of an erosion and sediment control or construction stormwater plan with regard to the location, schedule, and/or phasing for temporary and permanent stormwater management measures. If natural drainage features or other natural areas are to be preserved, then these areas must be shown and measures provided for their protection on both the erosion and sediment control plan and the stormwater management construction plan. If other elements of the stormwater management construction plan utilize soils, vegetation, or other natural features for infiltration or treatment, then these areas must be shown on the erosion and sediment control plan and measures provided for their protection during construction

(3) **Other Permits or Approvals May Be Needed:** Approvals issued in accordance with this ordinance do not relieve the applicant of responsibility for obtaining all other necessary permits and/or approvals from other federal, state, and/or local agencies. If requirements vary, the most restrictive shall prevail. These permits may include, but are not limited to: applicable state and federal permits for stream and wetland impacts and applicable dam safety permits. Applicants are required to show proof of compliance with these regulations before Boone County will issue a land disturbance, stormwater discharge, or building permit.

(4) **Stormwater Measures within Designated Flood Hazard Areas:** Construction of stormwater measures or facilities within a Federal Emergency Management Agency (FEMA) designated floodplain or floodway shall be avoided to the extent possible. When this is unavoidable, all stormwater BMP construction shall be in compliance with all applicable requirements of the Flood Plain Management Ordinance.

28.3.7. MAINTENANCE AGREEMENT AND PLANS

Prior to approval by the Director of a stormwater management construction plan, each owner shall submit a maintenance agreement and maintenance plan in accordance with the following:

(1) **Responsible Party:** The owner shall be responsible for the operation and maintenance of such measures and shall pass such responsibility

to any successor owner, unless such responsibility is accepted by the County.

(2) **Requirement for Maintenance Agreement & Plan:** If a stormwater management construction plan requires structural or nonstructural measures, the owner shall execute a stormwater maintenance agreement prior to the Director granting final approval for the plan, or any plan of development or other development for which a permit is required under this Ordinance. The agreement shall be recorded by the responsible party in the office of the Boone County Recorder of Deeds and shall run with the land.

(3) **Required Elements for Maintenance Agreement & Plan:** The stormwater maintenance agreement shall be in a form approved by the County, and shall, at a minimum:

(a) **Designate Responsible Party:** Designate for the land development the owner, governmental agency, or other legally established entity (responsible party) which shall be permanently responsible for maintenance of the structural or non-structural measures required by the plan.

(b) **Pass Responsibility to Successors:** Pass the responsibility for such maintenance to successors in title.

(c) **Right of Entry for Stormwater Authority**: Grant Boone County Public Works and its representatives the right of entry for the purposes of inspecting all stormwater facilities and BMPs at reasonable times and in a reasonable manner. This includes the right to enter a property when Boone County Public Works has a reasonable basis to believe that a violation of this Ordinance is occurring or has occurred and to enter when necessary for correction of a violation of this Ordinance.

(d) **Maintenance Plan:** Ensure the continued performance of the maintenance obligations required by the plan and this ordinance through a maintenance plan (which may be an attachment to the actual maintenance agreement). The plan shall include a list of inspection and maintenance tasks, a schedule for routine inspection and maintenance, required maintenance actions, and other items listed in the Boone County Stormwater Design Manual.

28.4. Performance Criteria for Stormwater Management

28.4.1. General Stormwater Management Criteria

(1) Compliance with Federal & State Regulations: All stormwater facilities and conveyance systems shall be designed in compliance with all applicable state and federal laws and regulations, including the Federal Clean Water Act and all applicable erosion and sediment control, wetland and flood plain regulations.

(2) Protect Public Health, Safety & General Welfare: The design of stormwater BMPs shall consider public health, safety, and general welfare. These considerations include, but are not limited to: preventing the flooding of structures; safe passage of vehicles on roadways; preventing standing water in facilities, manholes, inlets, and other structures in a manner that promotes breeding of mosquitoes; preventing attractive nuisance conditions and dangerous conditions due to velocity or depth of water and/or access to orifices and drops; and preventing aesthetic nuisances due to excessive slopes, cuts and fills, and other conditions.

(3) Adherence to Boone County Stormwater Design Manual: All stormwater facilities and BMPs shall be designed to the standards of the Boone County Stormwater Design Manual, unless a variance is granted or the applicant is exempt from such requirements.

(4) Stormwater Authority Discretion: If hydrologic, geologic, topographic, or land use conditions warrant greater control than that provided by the minimum control requirements, the Director may impose additional requirements prior to the approval of the preliminary stormwater management plans, as deemed reasonable and necessary to control the volume, timing, rate and/or quality of runoff. The Director may restrict the use of certain stormwater BMPs, require additional pretreatment, and/or require a post-construction stormwater pollution prevention plan in certain circumstances. These include, but are not limited to: stormwater generated from stormwater hotspots, stormwater discharges that are conveyed with non-stormwater discharges, and stormwater discharged in important groundwater management areas, areas with known flooding problems, areas with slopes greater than 25%, areas discharging to impaired waterways or areas where geologic conditions are conducive to groundwater contamination (e.g., karst). The Director may use this authority to mitigate impacts anticipated by a proposed development or redevelopment project. However the

additional requirements must be proportional to the impact being mitigated.

(5) Hydrologic Computation Assumptions: Hydrologic parameters shall reflect the ultimate land development and shall be used in all engineering calculations. All pre-development calculations shall consider woods and fields to be in good condition, regardless of actual conditions at the time of application.

(6) Location of Stormwater Facilities on Lots: Stormwater facilities within residential subdivisions that serve multiple lots and/or a combination of lots and roadways shall be on a lot owned and maintained by an entity of common ownership, unless an alternative arrangement is approved by the Director. Stormwater practices located on individual lots shall be placed within an easement and either maintained by the lot owner or maintained by an entity of common ownership.

28.4.2. Engineered Systems

(1) **Replicating Pre-Development Hydrology:** Stormwater management designs shall preserve the natural hydrologic functions, stream channel characteristics, and groundwater recharge of the pre-developed site as outlined in the Boone County Stormwater Design Manual and to the maximum extent practical. This shall be accomplished by treating runoff at the source, disconnecting impervious surfaces, preserving or enhancing natural flow paths and vegetative cover, preserving or enhancing natural open spaces and riparian zones, and other measures that replicate pre-development hydrologic conditions. The Director shall exercise discretion in the application of this standard, especially in cases of infill development, redevelopment, or other unique circumstances.

(2) **Overland Flood Routes:** Overland flood routing paths shall be used to convey stormwater runoff from the 100-year storm event to an adequate receiving water resource or stormwater BMP such that the runoff is contained within the drainage easement for the flood routing path and does not cause flooding of buildings or related structures. The peak 100-year water surface elevation along flood routing paths shall be at least one foot below the finished grade elevation at the structure. When designing the flood routing paths, the conveyance capacity of the site's storm sewers shall be taken into consideration.

(3) **Velocity Dissipation:** Velocity dissipation devices shall be placed at discharge locations of the stormwater conveyance system and along

the length of any outfall to provide non-erosive flow velocity from the structure to an adequate receiving stream or channel so that the natural physical and biological characteristics and functions of the receiving stream are maintained and protected.

(4) **Discharges to Adjacent Property:** Concentrated discharges from the stormwater drainage system or stormwater best management practices shall not be discharged onto adjacent property without adequate conveyance in a natural stream or storm sewer system. Drainage easements are required when stormwater discharges must cross an adjacent or off-site property before reaching an adequately sized conveyance.

(5) **Flow toward streets**: In order to have sufficient traffic safety, any concentration of surface flow in excess of two (2) cubic feet per second (cfs) for the ten-year frequency rain shall be intercepted before reaching the street right-of-way and shall be carried by a storm drain to connect with a drainage structure at the low point in the street right-of-way or to discharge to a watercourse.

28.4.3. NATURAL SYSTEMS

Stream & Wetland Crossings: All stream and wetland crossings subject to Section 404 of the Clean Water Act and/or state stream and/or wetland regulations shall minimize impacts on streams and wetlands, to the extent practical and achievable, by crossing streams and wetlands at a right-angle, reducing the footprint of grading and fill, matching the existing stream profile grade, and utilizing bridges, open bottom arches, spans, or other structures that do not restrict or alter stream or wetland hydrology. Mimic the natural multi-stage channel shape as much as possible. If culverts are placed within streams and/or wetlands, at least one culvert shall be countersunk at least one foot (1') below the natural channel flowline, (or 10% of the pipe diameter whichever is less) to allow movement of aquatic organisms.

Limited Stream Assessment Required: A limited stream assessment as outlined in the Boone County Stormwater Design Manual is required when construction will enter the stream or streamside buffer zone.

28.4.4. STORMWATER QUANTITY AND QUALITY CONTROL

(1) Runoff Reduction: In an effort to replicate pre-development hydrologic conditions, and to promote baseflow to streams and

wetlands, ten percent (10%) of the water quality volume shall be permanently reduced. This may be accomplished through infiltration practices where soil conditions allow, by disconnecting impervious areas, maintaining or reestablishing deep-rooted vegetation, maintaining sheet flow to areas of natural vegetation such as riparian corridors and undisturbed forest lands, and/or collection and reuse of runoff.

The Director may waive the requirements of this section as specified in (A) and (B) below:

A. Risk of Groundwater Contamination: Stormwater hotspots, contaminated soils, and sites in close proximity to karst or drinking water supply wells may not be subject to groundwater recharge/infiltration requirements, as determined by the Director. The Director may impose reasonable conditions such as increased forest, buffer or pervious areas in granting such a waiver.

B. Site Constraints: Areas characterized by high water table, shallow bedrock, contaminated soils, and other constraints may be subject to reduced volume control requirements, as determined by the Director. The Director may impose reasonable conditions in granting such a waiver.

(2) Water Quality Protection: In order to protect the receiving waters from nonpoint source pollution, the remainder of the water quality volume that was not removed through runoff reduction, shall be treated through filtration BMPs such as sand filters, vegetated swales, or proprietary products.

A. Treatment of the Water Quality Volume: Post-development runoff from the water quality rainfall event that is not permanently removed through the application of the runoff reduction criterion shall be captured and treated in a water quality BMP to prevent or minimize water quality impacts from land development.

B. Vegetated Filter Strips: Up to 25%, of a site's total impervious surface may discharge in a sheet flow condition through established vegetation such as may exist in a stream buffer without otherwise being treated.

C. Pretreatment: Each stormwater BMP shall have an acceptable form of water quality pretreatment if required to provide adequate long-term operation and maintenance of the BMP.

D. Treatment of Off-Site Stormwater: Off-site stormwater conveyed through a land development shall be placed within an easement and conveyed in a manner that does not increase upstream or downstream flooding. Off-site stormwater shall be conveyed around on-site stormwater BMPs, unless the facilities are designed to manage the off-site stormwater. The Director may allow the treatment of off-site stormwater in lieu of the treatment of the entire site's water quality volume.

E. Additional Criteria for Stormwater Hotspots: In addition, stormwater discharges from stormwater hotspots may require the use of specific structural, non-structural, and/or pollution prevention practices, including enhanced pre-treatment. Discharges from a stormwater hotspot shall not be infiltrated without enhanced pre-treatment, as approved by the Director.

F. Landscape Plan: The design of vegetative stormwater BMPs shall include a landscape plan detailing both the vegetation in the BMP and the maintenance requirements, and who will manage and maintain the vegetation.

(3) Channel Protection Criteria: The stormwater system shall be designed so that post-development discharges will not erode natural channels or steep slopes. This will protect in-stream habitats and reduce in-channel erosion. The applicant shall use either Tier 1 or Tier 2 performance standards, as applicable, to meet this criterion.

A. Tier 1 Performance criteria: sites having less than 5 acres of land disturbance OR less than 20% imperviousness on the entire tract shall apply the following performance standards:

1. Wherever practical, maintain sheet flow to riparian buffers or vegetated filter strips. Vegetation in buffers or filter strips must be preserved or restored where existing conditions do not include dense vegetation.
2. Energy dissipaters and level spreaders must be used to spread flow at outfalls.
3. On-site conveyances must be designed to reduce velocity through a combination of sizing, vegetation, check dams, and filtering media (e.g., sand) in the channel bottom and sides.
4. If flows cannot be converted to sheet flow, they must be discharged at an elevation that will not cause erosion or require discharge across any constructed slope or natural steep slopes.

5. Outfall velocities must be non-erosive from the point of discharge to the receiving channel or waterbody where the discharge point is calculated.

B. Additional criteria for Tier 2 sites: Sites greater than 5 acres of land disturbance OR greater than 20% imperviousness on the entire tract shall apply the performance standards in subsection (A), in addition to the following performance standards:

Site design techniques that decrease runoff volumes and peak flows. This shall be accomplished by controlling the post-development peak discharge rate to the pre-development rate.

This criterion shall be met for the post-development 2-year, 24-hour storm event, (or equivalent storm runoff volume using other methodologies). The release rate shall be equal to or less than the pre-development 1-year, 24-hour storm event. Boone County will give credit for the application Runoff Reduction and WQv measures towards meeting the storage requirements.

OR

In an effort to encourage micro-detention and utilize stormwater BMPs to detain stormwater, the difference (increase) in the runoff volume that is predicted due to the development during the 2-year event will be stored and released at no more than 0.1 cfs/acre; providing that 75% of the water leaving the site drains through at least one storage basin, and that the volume stored accounts for the added runoff from the entire disturbed site.

(4) Flood Control Criteria: Downstream overbank flood and property protection shall be provided by controlling the post-development peak discharge rate to the pre-development rate. This criterion shall be met for the 25-year, 24 hour storm event on property zoned REC, REC-P, C-O, C-N, C-G, C-GP, M-L, M-LP, M-G, M-GP.

Stormwater BMPs that impound water shall demonstrate that the 100-year storm can safely pass through the structure without overtopping or creating damaging conditions downstream.

The Director may waive some or all of the requirements of this section as specified in (A), (B), (C) and (D) below:

A. Discharge to Large Waterbody: The land development discharges directly to a flood plain, major river or waterbody and the Director determines that waiving the flooding criteria will not harm public health and safety. The applicant shall secure drainage easements from any downstream property owners across whose property the runoff must flow to reach the flood plain, major river or waterbody. The applicant shall also demonstrate that any piped or open-channel system in which the runoff will flow has adequate capacity and stability to receive the project's runoff plus any off-site runoff also passing through the system.

B. Insignificant Increases in Peak Flow: The land development results in insignificant increases in peak flow rates, as determined by the Director.

C. Alternative Criteria Provided: The land development is subject to a floodplain study that recommends alternative criteria for flood control.

D. Increases in Downstream Peak Flows or Flood Elevations: The Director determines that complying with the requirements of this section will result increases in peak flows or downstream flooding conditions due to coincident peaks from the site and the contributing watershed or another factor.

E. Documentation for Waiver: When seeking a waiver in accordance with either (1), (2), (3) or (4) above, the applicant shall demonstrate that stormwater discharges will not unreasonably increase the extent, frequency, or duration of flooding at downstream properties and structures or have an unreasonable adverse effect on streams, aquatic habitats, and channel stability. In making its determination to allow full or partial waivers, the Director shall consider cumulative impacts and the land development's adherence to the land use plans and policies of Boone County, including the promotion of infill and redevelopment in particular areas.

28.4.5. Redevelopment Criteria

Land development that qualifies as redevelopment shall meet one of the following criteria:

(1) Reduce Impervious Cover: Reduce existing site impervious cover by at least 20%.

(2) Provide Treatment: Provide water quality treatment for at least 20% of the site's pre-development impervious cover and 100% of any new impervious cover, not to exceed 150% of the total new impervious.

A. This can be accomplished through stormwater BMPs designed in accordance with the criteria in *Sections 4.2 through 4.3 and the Boone County Stormwater Design Manual.

B. Runoff reduction may be used instead of water quality treatment on land zoned Residential, Transition or Agriculture where the lot size is at least 2.5 acres and impervious cover is less than 10%.

(3) Apply Innovative Approaches: Utilize innovative approaches to reduce stormwater impacts across the site. Examples include green roofs and pervious parking materials.

(4) Provide Off-Site Treatment: Provide equivalent stormwater treatment at an off-site facility within the same watershed and as immediately downstream of the site as feasible.

(5) Address Downstream Issues: Address downstream channel and flooding issues through channel restoration, increase in existing system capacity and/or other off-site remedies.

(6) Combination of Measures: Any combination of (1) through (5) above that is acceptable to Boone County Public Works.

28.4.6 Environmentally Sensitive Areas: Enhanced Criteria

This section shall be applicable to all land development, including, but not limited to, site plan applications, subdivision applications, and grading applications, in or draining to an environmentally sensitive area that disturbs more than 3000 square feet.

(1) These provisions apply to any stormwater discharge or drainage on new development or redevelopment sites within Boone County that meets one or more of the following criteria:

A. Within 1000 feet of and draining to a losing stream*, Outstanding National or State Resource Water*

B. Within 100 feet of a Class P Stream*, or Type 1 stream per the Stream Buffer Regulations
C. Within 1000 feet of and draining to, or changes the site hydrology of, a jurisdictional wetland as defined by the U.S. Army Corps of Engineers; or
D. Runoff that discharges to a groundwater point recharge feature such as a sinkhole or other direct conduit to groundwater such as a cave.

*See listings in Missouri Water Quality Standards 10 CSR 20-7.031. This information is also provided in the Boone County Stormwater Design Manual – Appendix C.

(2) Land Disturbance Permit Threshold Lowered: When any of the above conditions exist, permitting related to land disturbance, stormwater management and water quality control will be required for any land disturbance greater than 3000 square feet.

(3) General Stormwater Management: Drainage patterns for proposed development must be designed to protect sensitive areas from the effects of runoff from developed areas, and to maintain the drainage areas of groundwater recharge features in a natural state. Special controls must be used where necessary to avoid the effects of erosion, sedimentation, and/or high rates of flow.

(4) Buffer zone limitations and prohibitions: The natural vegetative cover must be retained within a buffer zone described in this section. All construction activities including grading and filling are prohibited. Additionally, wastewater disposal or irrigation is prohibited.

(5) Buffer zone widths: The following buffer widths are required to reduce construction activities and retain the natural vegetative cover in unique and environmentally sensitive areas throughout the County.

A. Point Recharge Feature (Sinkholes): For a point recharge feature, the buffer zone coincides with the topographically defined drainage area, except that the width of the buffer zone from the edge of the sensitive area shall not be less than 150 feet, or greater than 300 feet from the sinkhole eye.
B. Wetlands: For a wetland, the buffer zone shall be at least 50 feet.
C. Outstanding Resource Waters/Losing Streams: For national or state outstanding resource waters, the buffer zone shall be twice that of the stream buffer requirement. (Chapter 26 Boone County Zoning Regulations)

D. Other Features: For other environmentally sensitive areas, the buffer zone shall be at least 50 feet.

(6) Wetland Protection: Wetlands meeting the Army Corps of Engineers definition of a jurisdictional wetland must be protected in all watersheds. Protection methods for wetlands include:

A. Appropriate setbacks that preserve the wetlands or wetland functions;
B. Wetland mitigation, including wetland replacement;
C. Wetland restoration or enhancement.

The Director may approve the removal and replacement of a wetland as approved by the U.S. Army Corps of Engineers or the elimination of setbacks from a constructed wetland that is primary use is for water quality control.

(7) Sinkhole/Cave Protection:

A. Sinkhole Evaluation: The developer/owner of any development that will discharge runoff to a sinkhole shall submit a Sinkhole Evaluation during the pre-application meeting or preliminary plat/plan review. A professional engineer or professional geologist must complete a sinkhole evaluation, with the following information.
   i. Drainage area map
   ii. Details of the drainage path of the discharge from the development to the sinkhole (offsite sinkholes)
   iii. Sinkhole boundary map based on topography
   iv. Geological Evaluation

B. Geological Evaluation: A professional geologist or a professional engineer with a demonstrated expertise in geotechnical applications is required to prepare a geologic evaluation of off-site sinkholes to determine the structural integrity of the geology, and the stability of the formation. The geological evaluation shall provide the following information:

   i. Identification of all sinkholes as depression or collapse sinkholes.
   ii. A map of the topographic rim (highest closed contour) of all depression sinkholes, based on a 2-foot contour interval or less.

iii. A map of all depression and collapse sinkholes contributing to the groundwater recharge of the area.

iv. A map showing no-build areas for buildings and other structures based on topographic and geologic rims of depression and collapse sinkholes.

v. Detail of proposed stabilization of collapse sinkholes, if applicable.

C. Sinkhole or Cave-Related Non-Buildable Areas: The Director may, based upon the topography, geology, soils, and history of the sinkhole(s) and/or cave(s) (such as past filling) and the engineer's storm water analysis, establish sinkhole or cave-related non-buildable areas. No grading or installation of parking areas, streets or other infrastructure shall be permitted within the said non-buildable area unless otherwise authorized by the Director.

This non-buildable area shall follow the limits of the sinkhole in most cases. However, the non-buildable area may be expanded or contracted by action of the Director where warranted, due to the nature of the specific sinkhole or cave, the underlying geology, soils, drainage, and any related information, such as depth to bedrock.

In sinkhole cluster areas, the Director may require the developer to provide recommendations from a consulting engineer and a consulting hydrogeologist, based upon substantial and state-of-the-art field studies and evaluation of the specific sinkhole or cave system. These studies shall be submitted to the Director

D. Development in Sinkhole Drainage Areas without Discharge to Sinkhole: Development may occur in the immediate sinkhole drainage area if the developer provides alternative surface drainage away from the sinkhole, while keeping the water in the same surface drainage basin, and providing that the water shall not go into another sinkhole drainage area off the applicant's property. The immediate sinkhole drainage area (or portion thereof) which cannot be provided with an alternative drainage system can be deleted from the development area for calculations utilizing this information to meet regulatory requirements.

E. Development in Sinkhole Drainage Areas with Discharge to Sinkhole: For portions of the sinkhole drainage area where alternative surface drainage methods cannot be provided, the sinkhole can be used for limited surface runoff drainage of a proposed development if the following conditions are met:

i. That the runoff from the development area is either completely retained in a retention basin or detained in a detention basin. The flow rate out of the above basins shall be regulated so that it is no greater than the flow rate into the sinkhole of the development area prior to development.

ii. Enough runoff is diverted from the sinkhole drainage area so that the development of the remaining area does not increase the total quantity or deteriorate the water quality of runoff into the sinkhole. Where additional runoff is anticipated, a consulting engineer and hydrogeologist shall evaluate and show the effect of any additional quantity of runoff to the sinkhole and sinkhole system. The Director shall review the study findings and make a determination that the plan is acceptable.

iii. Where the sinkhole outlet is off site, either the runoff leaving the subject property must be shown to be no greater in flow or in quantity than that which existed before development, or easements must be obtained from owners of property where any increase in flow or quantity of water must go to reach the sinkhole outlet. Easement areas shall be approved by the Director based upon the developer's engineer's calculations of the proposed ponding elevation.

F. Filling in sinkholes and sinkhole drainage areas:

i. No street shall be placed below an elevation of at least one (1) foot above the sinkhole ponding elevation and only when collapse of the sinkhole will not adversely affect the road.

ii. No increase in the ponding elevation will be allowed by grading or filling without a storm water analysis approved by the Director.

iii. It shall be unlawful for any person to place, dump or deposit trash, debris, rubbish, brush, leaves, grass clippings, yard waste, hazardous waste or similar materials within a sinkhole.

G. Grading or alteration of land near or over Sinkhole: The alteration of land in a sinkhole by means of grading or the use of motorized equipment without a permit is a violation of this ordinance.

28. 5. Construction Site Runoff Control

28.5.1. GENERAL

Grading, erosion control practices, sediment control practices, and waterway crossings shall be adequate to prevent transportation of sediment from the site. The design and construction guidance in the Boone County Stormwater Design Manual shall be followed insofar as it is applicable. Other pollutants shall be controlled as necessary to prevent potential discharge to waters of the State.

28.5.2. CLEARING AND GRADING

(1) Clearing and grading of natural resources, such as forests and wetlands, shall not be permitted, except when in compliance with all other County regulations.

(2) Clearing techniques that retain natural vegetation and retain natural drainage patterns shall be used to the maximum extent practicable.

(3) Clearing, except that necessary to establish sediment control devices, shall not begin until all sediment control devices have been installed and have been stabilized.

(4) Cut and fill slopes shall be *no greater than 3:1*, except as approved by the County to meet other community or environmental objectives.

(5) Phasing shall be required on all sites disturbing greater than *thirty* acres, with the size of each phase to be established at plan review.

(6) Other measures may be required in order to ensure that sediment is not tracked onto public streets by construction vehicles, or washed into storm drains.

28.5.3. EROSION CONTROL

(1) Soil must be stabilized within 14 days of clearing or inactivity in construction, unless otherwise authorized, and shall be effectively maintained throughout the duration of any inactivity.

(2) Soil stockpiles must be stabilized or covered at the end of each work day unless otherwise protected from allowing sediment to leave the site.

(3) Techniques shall be employed to prevent the blowing of dust or sediment from the site.

(4) Techniques that divert upland runoff past disturbed slopes shall be employed.

28.5.4. SEDIMENT CONTROLS

(1) Sediment controls shall be provided in the form of settling basins or sediment traps or tanks, and perimeter controls.

(2) Where possible, settling basins shall be designed in a manner that allows adaptation to provide long term stormwater management.

(3) Adjacent properties shall be protected by the use of a vegetated buffer strip, in combination with perimeter controls wherever possible.

28.5.5. WATERWAYS AND WATERCOURSES

(1) When a wet watercourse must be crossed regularly during construction, a temporary stream crossing shall be provided, and an approval obtained from the U.S. Army Corps of Engineers and the Missouri Department of Natural Resources if deemed a jurisdictional stream.

(2) When in-channel work is conducted, the channel shall be stabilized before, during and after work.

(3) Stabilization adequate to prevent erosion must be provided at the outlets of all pipes and paved channels.

28.5.6. CONSTRUCTION SITE ACCESS

(1) A temporary access road or driveway shall be provided at all sites.

(2) Regardless of the amount of land disturbance at a particular site, it shall be the responsibility of the permit holder and/or property owner to ensure streets open to the public surrounding a permitted site are kept free of debris and sediment throughout construction. Upon

notification that a problem exists, the permit holder and/or property owner shall remedy the issue within 12 hours.

28.5.7. CONTROL OF OTHER CONSTRUCTION POLLUTANTS

(1) Concrete Truck Washout: Concrete truck washout shall not discharge surplus concrete or drum wash water on the site in such a manner that promotes contact with storm waters or natural streams discharging from the site.

(2) Construction Waste: All construction waste material shall be collected, deposited, and stored in a manner to prevent contact with storm waters discharging from the site and shall be disposed of by a licensed solid waste management contractor. No waste shall be buried on the site.

(3) Sanitary Waste: A state licensed sanitary waste management contractor shall collect all sanitary waste from portable units that will be maintained on a regular basis for any site that cannot provide other means of sanitary waste disposal.

(4) Petroleum Products: All construction equipment and vehicles shall be monitored for leaks and receive regular preventative maintenance to ensure proper operation and reduce the risk for leaks or spills. Petroleum products shall be stored in clearly labeled and tightly sealed containers or tanks. Fuel or oil contaminated soil shall be removed and disposed of properly.

(5) Fertilizers: Fertilizers shall be applied following manufacturer's recommendations. Fertilizers shall be stored in a covered area or in watertight containers. Partially used products shall be properly sealed and stored to avoid spills or leaks.

(6) Hazardous materials: Storage areas for hazardous materials such as oils, greases, paints, fuels, and chemicals, shall be provided with secondary containment to ensure that spills in these areas do not reach waters of the State. All hazardous waste materials shall be disposed of according to state regulation or the manufacturer's recommendations.

28.6. Ongoing Maintenance for Stormwater BMPs

28.6.1. General Maintenance Requirement

All stormwater facilities and BMPs shall be maintained in accordance with the approved and recorded stormwater maintenance agreement and stormwater maintenance plan. If no maintenance agreement or plan is in place, the owner shall maintain the facility as it was designed in order to continue the mitigation of stormwater quantity and quality impacts. This maintenance shall include removal of overgrown vegetation, repair of erosion, repairs to any inlet/outlet structures, and removal of excess silt or any other maintenance deemed necessary to provide said mitigation. The design of stormwater facilities shall incorporate maintenance accommodation and long-term maintenance reduction features.

28.6.2.Maintenance Responsibility

The responsible party named in the recorded stormwater maintenance agreement (***Section 3.7**) shall maintain in good condition and promptly repair and restore all structural and non-structural stormwater facilities and BMPs and all necessary access routes and appurtenances (grade surfaces, walls, drains, dams and structures, vegetation, erosion and sedimentation controls, and other protective devices) in order to maintain the mitigation of stormwater quantity and quality impacts. Such repairs or restoration and maintenance shall be in accordance with the approved stormwater management construction plan, the stormwater maintenance agreement, and the stormwater maintenance plan.

28.6.3.Inspection by Boone County Public Works

The County shall be permitted to enter and inspect facilities subject to regulation under this ordinance as often as may be necessary to determine compliance with this ordinance. If the site has security measures in force that require proper identification and clearance before entry into its premises, the responsible party shall make the necessary arrangements to allow access to representatives of the County.

Unreasonable delays in allowing the County access to a permitted facility is a violation of a storm water discharge permit and of this ordinance.

If the County has been refused access to any part of the premises from which stormwater is discharged, and is able to demonstrate probable cause to believe that there may be a violation of this ordinance, or that there is a need to inspect and/or sample as part of a routine inspection and sampling program designed to verify compliance with this ordinance or any order issued hereunder, or to protect the overall public health, safety, and welfare of the community, then the County may seek issuance of a search warrant from any court of competent jurisdiction.

28.6.4. Records of Maintenance Activities

The responsible party shall make records of the installation and of all maintenance and repairs, and shall retain the records for at least five (5) years. These records shall be made available to the Director during inspection of the facility and at other reasonable times upon request.

28.6.5. Failure to Provide Adequate Maintenance

In the event that the stormwater BMP has not been maintained and/or becomes a danger to public safety or public health, the Director shall notify the responsible party by registered or certified mail. The notice shall specify the measures needed to comply with the maintenance agreement and the maintenance plan and shall specify that the responsible party has thirty (30) days or other time frame mutually agreed to between the Director and the responsible party, within which such measures shall be completed. If such measures are not completed, then the Director shall pursue enforcement procedures pursuant to *Section 9 of this Ordinance.

If a responsible person fails or refuses to meet the requirements of an inspection report, maintenance agreement, or maintenance plan the Director, after thirty (30) days written notice (except, that in the event the violation constitutes an immediate danger to public health or public safety, 24 hours notice shall be sufficient), may correct a violation of the design standards or maintenance requirements by performing the necessary work to place the practice in proper working condition. The Director may assess the responsible party of the practice for the cost of repair work which shall be a lien on the property, or prorated against the beneficial users of the property, and may be placed on the tax bill and collected as ordinary taxes by Boone County.

28.6.6. Required Easements

Whenever improvements to land are made, easements for the stormwater management facilities including structural facilities, engineered channels and overflow paths, shall be provided across private property. Easements through existing developments shall be obtained as deemed necessary. Drainage easements shall include access from a convenient public street or parking lot. Minimum dimensions are as follows:

(1) Where a storm drain consists of a closed conduit, the width shall be the greater of fifteen (15) feet or the sum of the conduit diameter and twice the cover depth over the conduit.

(2) The stormwater drainage system easements shall contain the overflow from the 100 year (1% annual chance) storm event and shall indicate the highest expected water surface elevation of said event.

(3) Access easements to and around detention/retention facilities shall be a minimum of fifteen (15) feet wide with cross slopes to be safely accessible by a vehicle unless otherwise approved by the Director.

28.6.7. INTERFERENCE AND DAMAGE

No person shall damage, discharge or place any substance into the drainage system which will or may cause obstruction to flow or other interference with the operation of the stormwater drainage system. Any person violating this section or damaging the stormwater drainage system shall be liable to the County for all expense, loss or damage incurred by the County due to such violation or damage, in addition to any other penalties set forth herein.

28.7. Illicit Discharge Detection and Elimination

28.7.1. GENERAL

(1) Purpose: This ordinance is adopted pursuant to the authority granted in 64.907, 64.825 – 64.885, Revised Statutes of Missouri and are intended to regulate non-stormwater discharges to the storm drainage system to the maximum extent practicable as required by federal and state law. This ordinance establishes methods for controlling the introduction of pollutants into the municipal separate storm sewer system (MS4) in order to comply with requirements of the National Pollutant Discharge Elimination System (NPDES) permit process. The objectives of this ordinance are:

A. To regulate the contribution of pollutants to the municipal separate storm sewer system (MS4) by stormwater discharges by any user

B. To prohibit Illicit Connections and Discharges to the MS4

C. To establish legal authority to carry out all inspection, surveillance and monitoring procedures necessary to ensure compliance with this ordinance

(2) Applicability: This ordinance shall apply to all water entering the storm drain system generated on any developed and undeveloped lands unless explicitly exempted.

(3) Ultimate Responsibility: The standards set forth in this article and promulgated pursuant to this article are minimum standards. Compliance with this article does not insure that there will be no contamination, pollution or unauthorized discharge of pollutants into the waters of the United States. This article shall not create liability on the part of the County or any agent or employee of the County for any damages that result from any discharges, reliance on this article or any administrative decision made under this article.

(4) Stormwater Pollution Prevention: Any owner or operator of a commercial or industrial establishment shall provide, at their own expense, reasonable protection from accidental discharge of prohibited materials or other wastes into the municipal storm drain system or watercourses through the use of structural and non-structural BMPs. Further, any person responsible for a property or premise, which is, or may be, the source of an illicit discharge, may be required to implement, at said person's expense, additional structural and non-structural BMPs to prevent the further discharge of pollutants to the municipal separate storm sewer system. Compliance with all terms and conditions of a valid NPDES permit authorizing the discharge of storm water associated with industrial activity, to the extent practicable, shall be deemed compliant with the provisions of this section. These BMPs shall be part of a stormwater pollution prevention plan (SWPPP) as necessary for compliance with requirements of the NPDES permit.

28.7.2. PROHIBITIONS

(1) Illegal Discharges: It shall be unlawful for any person to discharge or cause to be discharged into the municipal separate storm sewer system or into any watercourse any material other than stormwater. The following discharges are exempt from the prohibitions established by this article:

A. Waterline flushing or other potable water sources;
B. Landscape irrigation or lawn watering;
C. Diverted stream flows;
D. Rising groundwater;
E. Groundwater infiltration;

F. Uncontaminated pumped groundwater;
G. Foundation or footing drains excluding active groundwater de-watering systems;
H. Crawlspace pumps, air conditioning condensation;
I. Springs;
J. Non-commercial washing of vehicles;
K. Natural riparian habitat or wetland flows;
L. Swimming pools if de-chlorinated to less than 1 ppm chlorine;
M. Fire fighting activities;
N. Other water not containing pollutants;
O. Discharges specified by the County as necessary to protect public health and safety;
P. Dye testing if notification is given to the County before the test; and
Q. Any non-storm water discharge permitted under an NPDES permit, waiver or waste discharge order issued to the discharger and administered under the authority of the Environmental Protection Agency, provided that the discharger is in full compliance with all requirements of the permit, waiver or order and other applicable laws and regulations, and provided that written approval has been granted for any discharge to the municipal separate storm sewer system.

(2) Illicit connections:

A. It shall be unlawful for any person to construct, use, maintain or have an illicit connection.

B. This section expressly applies to illicit connections made in the past even if the connection was permissible under law or practices applicable or prevailing at the time of connection.

(3) Waste disposal prohibitions: It shall be unlawful for any person to place, deposit or dump or to cause or allow the placing, depositing or dumping any refuse, rubbish, yard waste, paper litter or other discarded or abandoned objects, articles and accumulations containing pollutants into the municipal separate storm sewer system or into any waterway.

(4) Connection of sanitary sewer prohibited: It shall be unlawful for any person to connect a line conveying sewage to the municipal separate storm sewer system or to allow such a connection to continue.

(5) Industrial or construction activity discharges: It shall be unlawful for any person subject to an industrial activity or construction NPDES

storm water discharge permit to fail to comply with all provisions of such permit.

28.7.3. NOTIFICATION OF SPILLS

Notwithstanding other requirements of law, as soon as any person responsible for a facility or operation, or responsible for emergency response for a facility or operation has information of any known or suspected release of materials which are resulting or may result in illegal discharges or pollutants discharging into storm water, the storm drain system, or water of the U.S. said person shall take all necessary steps to ensure the discovery, containment, and cleanup of such release. In the event of such a release of hazardous materials said person shall immediately notify emergency response agencies of the occurrence via emergency dispatch services. In the event of a release of non-hazardous materials, said person shall notify the County in person or by phone or facsimile no later than the next business day. Notifications in person or by phone shall be confirmed by written notice addressed and mailed to the County within three business days of the phone notice. If the discharge of prohibited materials emanates from a commercial or industrial establishment, the owner or operator of such establishment shall also retain an on-site written record of the discharge and the actions taken to prevent its recurrence. Such records shall be retained for at least three years.

28.7.4. REGULATIONS AND MONITORING

(1) The County Commission may, by ordinance, adopt standards identifying best management practices (BMP) for any activity, operation or facility which may cause or contribute to pollution of storm water, the storm drain system, waters of the state or waters of the United States. These standards shall be on file at Boone County Public Works. It shall be unlawful for any person undertaking any activity or owning or operating any facility subject to such standards to fail to comply with the standards.

(2) The owner or operator of a commercial or industrial establishment shall provide reasonable protection from accidental discharge of prohibited materials or other wastes into the municipal separate storm sewer system or water courses through the use of structural and non-structural BMPs. Any person responsible for property which is or may be the source of an illicit discharge may be required to implement additional structural and non-structural BMPs to prevent further discharge. Compliance with all terms and conditions of a valid

NPDES permit authorizing the discharge of stormwater associated with industrial activity to the extent practicable shall be deemed in compliance with provisions of this section. These BMPs shall be a part of the storm water pollution prevention plan as necessary for compliance with the requirements of the NPDES permit.

28.8. Permits

28.8.1. Promulgation of Rules

The Director may promulgate rules governing the issuance of the permits required by this section and may produce forms to effectuate the intent of this ordinance.

28.8.2. Stormwater Discharge Permit

(1) Authorization to Discharge to MS4: If runoff from a land development will flow to a municipal separate storm sewer system (MS4) or other publicly-owned storm sewer system, then the applicant shall obtain authorization from the system's owner to discharge into the system. The applicant must demonstrate that the system has adequate capacity for any increases in peak flow rates and volumes.

(2) Permit Required: No stormwater drainage facility shall be constructed, altered or reconstructed without a stormwater discharge permit. To obtain a permit, the application form provided by the County shall be completed and plans must be submitted for review and approval of the Director. All such construction shall comply with the general requirements and design procedures, as set forth in this chapter, and the criteria of the Boone County Stormwater Design Manual.

(3) Prior to the issuance by the County of a permit for any type of construction, the property owner, the developer or their agent shall have a stormwater management plan approved by the County in accordance with *Section 3. The property owner, developer or their agent shall, at his own expense, submit necessary plans, designs and specifications to the County for review and approval. This plan shall:

- Include a pre- and post-development hydrologic analysis of the site
- Identify pollutants of concern for each area of the site
- Identify pollution prevention measures
- Identify controls that provide treatment and reduce stormwater volumes and velocities

- Identify any environmentally sensitive areas and provide a plan for protection of these areas per this chapter
- Identify Low Impact Development opportunities that can best mimic the natural hydrology of the site and filter pollutants from the runoff.
- Provide for long term operation and maintenance of controls

(4) Provisions of this section for plan requirement shall be waived provided no land is disturbed and no trees, shrubs, grass or vegetation is destroyed or removed for construction, reconstruction, repair or alteration of any building provided the improvement does not alter or increase the flow of water.

(5) The post-construction stormwater management plan shall show the location of any environmentally sensitive features (as listed in *Section 4.6), the sensitive feature's drainage area, any sinkhole cluster area, or portions of such items, along with ground contours, a hydrologic analysis of the drainage area and significant physical features on the property, and detailed information on the work to be performed in or near the sensitive area.

Upon review of the information presented by the applicant, the site, and such other information as may be available, the Director may issue a permit for work to be performed in or near the sensitive area. All work shall be performed in accordance with the permit. The Director may designate certain areas where grading or construction equipment is not permitted or is otherwise limited.

28.8.3. Land Disturbance Permit

(1) Applicability: No clearing, grading, borrowing or filling of land resulting in a land disturbance greater than one acre shall commence prior to obtaining a land disturbance permit. All such work shall also comply with an approved erosion and sediment control plan in conjunction with an approved site development plan. Additionally, no person shall engage in the grading of land in excess of 3000 square feet or the use of motorized equipment in or near a sinkhole, losing stream, cave, spring, wetland or other environmentally sensitive area without first securing a permit from the Director.

(2) Individual Lots Not Separate Land Development: Residential, commercial or industrial developments shall apply these stormwater management criteria to land development as a whole. Individual residential lots in new subdivisions shall not be considered separate

land development projects, but rather the entire subdivision shall be considered a single land development project.

(3) Expiration: Every approval under this subsection for clearing, grading, borrowing or filling of land shall expire within two (2) years from the date of issuance. This permit may be renewed for up to two (2) years by submitting a written request for an extension to the Director with the appropriate fee as listed in Section 8.5.

28.8.4.Performance Bond or Guarantee

(1) Performance Bond or Guarantee Required: Upon approval of the Storm Water Pollution Prevention Plan (SWPPP) and prior to issuance of a Land Disturbance Permit, the developer shall post a security in the form of a cash bond, cash or equivalent of not less than 150% of the value of all erosion and sediment control measures, which are part of the SWPPP. For land disturbance permits where no other security is required, the only type of security which will be accepted will be a cash bond. For land disturbance permits where other security is established for public improvements, the erosion control security may be added to the security for public improvements. If the bond, or other security document is placed in default, or the insurance is terminated or not maintained at a satisfactory level, then no additional permits or approvals, including building permits, shall be issued for the developer's property located in the development for which the security was given, until the improvements are completed to the satisfaction of the County.

(2) Term of Performance Bond or Guarantee: Any portion of the deposit not expended or retained by the County hereunder shall be refunded to the applicant within sixty (60) days of the closing of the Land Disturbance Permit, after soil and drainage conditions are stabilized to the satisfaction of the County

(3) Term Extended for Initial Maintenance: At the discretion of the Boone County Public Works, the performance bond or guarantee may be extended beyond the time period specified above to cover a reasonable period of time for testing the practices during storm events and for initial maintenance activities. For the purposes of this section, the time shall not exceed 2 years.

(4) Partial Release of Bond: The County shall have the discretion to adopt provisions for a partial pro-rata release of the performance bond or

guarantee on the completion of various stages or phases of development.

28.8.5. Fees

The County has the ability to require a fee to support local plan review, inspection and program administration. Each developer/owner seeking a land disturbance or stormwater discharge permit shall pay a fee upon submittal of the plans, in amounts according to the schedule set forth below.

(1) Stormwater Discharge Permit: $50.00

(2) Major Amendment to a Stormwater management construction plan: $25.00

(3) Land Disturbance Permit: $150.00

(4) Land Disturbance Permit Renewal: $50.00

28.8.6. Inspection

(1) The County may periodically inspect development sites. Through such periodic inspections, the County shall ensure that the Stormwater Pollution Prevention Plan (SWPPP) is properly implemented and any necessary amendments thereto made in order to protect the environment and the public's health, safety and welfare. The erosion and sediment control measures for the site must be maintained by the developer until the site is stabilized. Also through such periodic inspections the County shall ensure that the post-construction management plan is properly implemented. The stormwater infrastructure improvements shall be maintained by the responsible party (per *Section 6) until the infrastructure is accepted by the County.

(2) The permittee shall notify the County at least two (2) working days before the start of site clearing.

(3) The permittee or his/her agent shall make regular inspections of all control measures in accordance with the inspection schedule outlined on the approved erosion and sediment control plan(s) or in the Stormwater Pollution Prevention Plan (SWPPP). The purpose of such inspections will be to determine the overall effectiveness of the control plan, and the need for additional control measures and/or maintenance

of existing measures. All inspections shall be documented in written form and kept readily on site.

28.9. Violations, Enforcement and Penalties

28.9.1 VIOLATIONS AND PENALTIES FOR PERMITS

(1) The County may suspend or revoke any permit associated with the site or any permit associated with the person(s) holding the permit(s) for the site for non-compliance with the Land Disturbance Permit or Stormwater Discharge Permit.

(2) Procedure:

A. Upon discovery of a violation of this article, the contractor will be notified and given up to seven (7) days to remedy the violation in a Land Disturbance Permit or up to forty-five (45) days for a Stormwater Discharge Permit. Extensions of time may be granted in the Director's sole discretion.

B. If the violation has not been remedied within the time frame set forth in the notice, a stop work order may be issued and the permit(s) will be suspended. The stop work order shall state the reason for the order and the conditions under which the order and suspension will be lifted.

C. Any person, who shall continue to engage in activity for which a permit is required after having been served with a stop work order, except in such work as that person is directed to perform to remove a violation or unsafe condition, shall be a violation of this ordinance.

D. After two (2) stop work orders of a permit for the same site for similar violations, the permit(s) shall be revoked. All applicable procedures will have to be followed for re-issuance of the permit(s). Additionally, any remediation or abatement costs will be required to be paid prior to re-issuance.

E. If the stop work order has not been lifted through compliance with its terms within thirty (30) days from the date of its issuance, the permit shall be revoked. All applicable procedures will have to be followed for re-issuance of the permit(s). Additionally, any remediation or abatement costs will be required to be paid prior to re-issuance.

F. A person aggrieved by a decision to revoke any permit provided for herein may appeal the revocation to the Boone County Board of Adjustment.

(3) Engaging in activity requiring a permit without first obtaining such permit shall be a violation of this ordinance.

28.9.2. ADMINISTRATION, PENALTIES AND REMEDIES

(1) Responsibility for Administration: The provisions of this chapter shall be administered and enforced by the Director. The Director shall prescribe forms for attainment of the purposes of this chapter and for the proper enforcement thereof. The Director may delegate the administration of this chapter, or any part thereof, subject to limitations of the ordinances of the County, to duly qualified employees, deputies or agents of the County.

(2) Interpretation: The provisions of this chapter shall be the minimum requirements for the protection of the public health, safety and general welfare and shall be liberally and broadly construed and applied to the greatest extent permitted by law in order to promote and protect the public health, safety and welfare. These regulations are not intended to conflict with, abrogate or annul any other rule, law or regulation. Where any provisions of these regulations impose restrictions different from those imposed by any other regulation, rule or law, the provision which is more restrictive or imposes a higher standard shall control. These regulations are intended to be construed harmoniously and consistently with each other, the Boone County Stormwater Design Manual, and all other applicable rules, laws and regulations.

(3) Severability: If any part or provision of these regulations is declared invalid or unconstitutional then the remainder of these regulations shall not be declared invalid or unconstitutional but shall remain in full force and effect to the greatest extend permitted by law.

(4) Penalties and Remedies: Any owner, lessee, tenant, occupier of land or other person who violates any provision of these regulations shall be deemed guilty of a misdemeanor and shall be upon conviction punished as provided by law. In addition, any person permitting, aiding, abetting or concealing a violation of this ordinance shall be deemed guilty of a misdemeanor and shall be upon conviction punished as provided by law. Each day a violation of these

regulations continues shall constitute a separate offense. The penalty provided in this section shall not be construed to be exclusive but is intended to be supplemental and in addition to any other remedy provided by law or at equity. The County may institute in the circuit court of the County any appropriate action or proceedings to prevent any unlawful activity proscribed in this ordinance or to correct any violations of this ordinance.

28.9.3 TEMPORARY ABEYANCE OF DEVELOPMENT APPROVALS AND PERMITS (This section is not in effect at this time)

(1) Implementation, removal, and exceptions: The purpose of this section is to provide the criteria for imposing a six year temporary abeyance of development permits or approvals when land is cleared without a land disturbance permit and/or stream buffers are removed. This regulation will apply to all land including land that is currently being used for agricultural purposes. If an agricultural operator or owner of land used for agricultural purposes wants to avoid the temporary abeyance, then he/she may voluntarily apply for a land disturbance permit. If the clearing is done in compliance with the permit then the temporary abeyance will not be imposed. This section also provides standards for the Board of Adjustment to remove a six-year temporary abeyance, and for the director to authorize the construction of one single-family dwelling unit on a site that is subject to a six-year temporary abeyance.

A. Actions That Result in a Temporary Abeyance. The following actions shall result in a six-year temporary abeyance being imposed by the Director or his/her designee:

1. Clearing of any land, including land used for agricultural purposes, without a land disturbance permit issued by Boone County (Note: a land disturbance permit is not necessary to clear land for agricultural use except to avoid imposition of the six year temporary abeyance);

2. Removal of vegetation in violation of or in a manner that is inconsistent with the Boone County Stream Buffer Regulations;

3. Removal of vegetation within a stream buffer in a manner that is in conflict with the standards in Boone County Stream Buffer Regulations, on land used for agricultural purposes;

B. Consequences of a Temporary Abeyance.

1. Boone County shall suspend review of any application for development of land which is, or becomes, subject to a six-year temporary abeyance.

2. Boone County shall not accept applications for any development of land which is subject to a six-year temporary abeyance.

3. A temporary abeyance imposed by Boone County shall apply to all portions of the lot, tract or parcel on which the clearing activity occurred that is within 1,000 feet of the cleared or disturbed area.

C. Effective Date of the Temporary Abeyance. The property owner shall be provided ten business days to request a Pre-imposition Review.

1. If the property owner does not submit a request for Pre-imposition Review the temporary abeyance shall be imposed on the date the 10-day period expires.

2. If the property owner does submit a request for Pre-imposition review and the County Commission decides to impose the temporary abeyance it shall be effective on a date specified by the County Commission.

D. Notice of Temporary Abeyance and Pre-imposition Review

1. The Director shall send a Notice of Intent to impose the temporary abeyance to the owner of record as indicated by the records of the Boone County Assessor by Certified and Regular U.S. Mail. Said notice shall include the following:

(a) The parcel number(s) on which the clearing activity occurred

(b) The proposed date of imposition of the temporary abeyance

(c) The deadline for requesting Pre-imposition Review

2. Pre-imposition Review. The property owner shall have 10 days from the date of the Notice of Intent to file a request for pre-imposition review. Such request shall be filed with the Director in a form specified by the Director. The Director shall refer the request to the County Commission who shall hold a

public hearing on the matter before issuing a final decision whether to impose the temporary abeyance. The County Commission shall render a written decision including Findings of Fact and Conclusions of Law.

(2) Request for Removal of Temporary abeyance. A temporary abeyance may be considered for removal by the Board of Adjustment. All applications for removal shall be filed with the Director and after review thereof the Director shall make a recommendation to the Board to grant or deny the request and state the reasons for his/her recommendation. The application shall be on form(s) provided by the Director and shall be accompanied by supporting documentation and a filing fee.

A. The Board of Adjustment shall review all documentation provided by the applicant and the County, any comments received, and applicable county regulations or policies. The members of the Board may inspect the property prior to rendering a decision.

B. The Board of Adjustment may approve an application for a request to remove a temporary abeyance, approve the application with conditions, require modifications of the proposal to comply with specified requirements of local conditions, or deny the application if it fails to comply with requirements of this section.

C. Removal of a temporary abeyance may be approved by the Board of Adjustment if the following findings can be made regarding the proposal and are supported by the record

1. Any required mitigation plan has been completed or the performance thereof has been adequately bonded.

2. Any bonding required as part of a mitigation requirement has been established to county satisfaction.

3. Payment has been made of all other fees, penalties, liens, or taxes owed to the county which have been assigned to the subject parcel including reimbursement of any county expenses incurred relating to enforcement and/or preparation for the waiver hearing.

4. All permit conditions have been addressed.

5. Any environmental damage or alteration resulting from the activity that caused the six-year temporary abeyance to be imposed has been repaired and/or mitigated

6. Neither the applicant nor any person who acted in privity with the applicant:

   (a) Has circumvented any requirement of the Boone County Stormwater, Land Disturbance or Stream Buffer regulations by taking the actions for which the temporary abeyance was imposed; or
   (b) Has engaged in a pattern or practice of violations of any applicable regulations.

(3) Request for Single-Family Dwelling Exception. The Director may administratively grant an exception to the mandatory six-year temporary abeyance to allow the construction of one single-family dwelling unit and associated accessory structures pursuant to the following standards:

A. General Requirements.

1. Permitted Area. The area that is permitted to be developed pursuant to this administrative exception shall not exceed 2.5 acres in size unless site and/or well and wastewater constraints require a larger area, in which case the area developed is not to exceed five acres. Access roads shall not be included in the total area permitted to be developed.

2. Upon approval of a single-family dwelling unit exception, a memorandum of agreement (MOA), on forms provided by the Director, shall be recorded with the Boone County Recorder of Deeds by the landowner that includes a site plan depicting the area of the parcel to be dedicated for the single-family dwelling, yard area, permitted accessory structures, and access road. The MOA shall identify the action to be taken by the landowner to correct any violations of county ordinances or regulations. The land owner shall be responsible for the cost of recording the MOA.

3. The temporary abeyance shall remain in effect for the remainder of the site.

B. Review Criteria. One single-family dwelling, permitted accessory structures, lawns and landscaped area, and access road may be constructed together with site development activities necessary to construct the dwelling on land subject to a temporary abeyance provided, that:

1. The construction of the single-family dwelling, lawn and landscaping area, accessory structures, and access road are in compliance with all applicable county regulations;

2. The landowner corrects any violations of relevant stormwater, land disturbance or stream buffer requirements if any have occurred on the permitted area;

C. Required Written Findings and Determinations. A single-family dwelling unit exception may be approved by the director on a site that is subject to a six-year temporary abeyance only if all of the following findings can be made regarding the proposal and are supported by the record:

1. The single-family exception to the six-year temporary abeyance will not be detrimental to the public health, safety, and general welfare.

2. The single-family exception to the six-year temporary abeyance will not be injurious to the property or improvements adjacent to and in the vicinity of the proposal.

3. The single-family exception to the six-year temporary abeyance will not result in significant adverse environmental impacts.

4. The granting of the single-family exception to the six-year temporary abeyance is consistent with the review criteria in *subsection (3)(b) of this section.

5. The single-family exception to the six-year temporary abeyance is consistent and compatible with the goals, objectives, and policies of the Master Plan, appropriate community plan or subarea plan, and the provisions of this section.

D. Six-year temporary abeyance will be administratively removed by the director or his/her designee when it is determined that the abeyance has been attached to an incorrect parcel.

28.9.4. VARIANCES

(1) General: Where undue hardships or practical difficulties may result from strict compliance with this chapter, the developer may file an application for a variance. Said applications shall be directed to the

Boone County Board of Adjustment organized and existing under the zoning regulations of Boone County, Missouri, which shall have the jurisdiction and shall be charged with the duty of hearing and deciding applications for variances from the strict application of the provisions of this ordinance. The Board may grant a variance only if it finds after public hearing and upon competent and substantial evidence that the applicant meets the following criteria:

A. The variance shall not have the effect of nullifying the intent and purpose of this stormwater ordinance;

B. The granting of the variance will not be detrimental to the public safety, health or welfare, or injurious to other property or improvements.

C. The conditions upon which the request for a variance is based are unique to the property for which the variance is sought, are not applicable generally to other property, and are not self-imposed.

D. Because of the particular physical surroundings, shape or topographical conditions of the specific property involved, a particular hardship to the owner would result, as distinguished from a mere inconvenience, if this chapter was strictly interpreted and carried out.

(2) Conditions: In recommending variances and exceptions, staff may recommend and the Board may require such conditions as will, in the judgment of each, secure substantially the objectives of the standards or requirements of this chapter.

(3) Application: An application for a variance shall be submitted at the time of filing for a preliminary plat or for application for a building permit, whenever possible. The application shall be on forms provided by the County and shall state fully the grounds for the request and all facts relied upon by the practitioner. The application shall be filed with the Director and after review thereof the Director shall make a recommendation to the Board to grant or deny the application and state the reasons for his or her recommendation. Either the applicant or the Director may appeal or seek judicial review of any decision of the Board as provided by law.

ATTACHMENT 6A

2. DEFINITIONS

A-Weighted Sound Level (dBA): The sound pressure level in decibels utilizing the "A" weighted scale defined by ANSI for weighting the frequency spectrum to mimic the human ear.

Blade Glint: The intermittent reflection of the sun off the glossy surface of wind turbine blades.

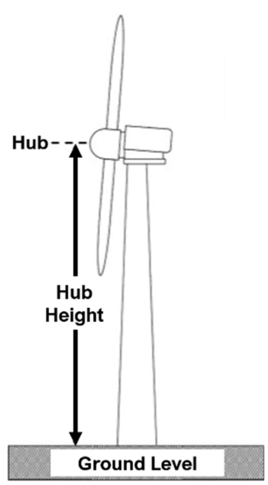
Casualty Event: The complete or partial destruction of property resulting from an identifiable event of a sudden, unexpected, or unusual nature.

Cluster: A group of WECS, contained within the same WECOD, that are geographically adjacent, and each tower is less than 1.25 times the minimum spacing distance from at least one other WECS in the group.

Decibel (dB): The unit of measure used to express the magnitude of sound pressure and sound intensity.

Furling: Action by which the wind turbine is designed to limit its power output in high winds by changing the rotor's plane of rotation to a plane that is not perpendicular to the prevailing wind direction.

Height, Hub (Wind Energy Conversion System): The distance measured from the ground immediately adjacent to the tower foundation to the center of the rotor hub.



Height, Total (Wind Energy Conversion System) : The sum of the hub height and half of the turbines rotor diameter distance, measured at the highest point on the blade tip.

Historical, Cultural, and Archeological Resources: Places which have been listed on the National Register of Historic Places or designated as a National Historic Landmark

Ice Throw: Ice build-up that is thrown by the spinning blades.

Nacelle: The enclosure located at the top of a wind turbine tower that houses the gearbox, generator and other equipment.

Property Line: A line of record bounding a lot of record that divides one lot from another lot, or from a public street, or private street, or any other public space.

Qualified Professional: A person with experience and training in the pertinent discipline, and who is a qualified expert with expertise appropriate for the relevant subject and has been approved by the County Commission in consultation with the Director of Resource Management.

Repowering Event: A planned and County approved event in which the developer replaces older turbines with new turbines or retrofits existing turbines with more efficient components subject to an approved timeline.

Rotor: The rotating part of a turbine, including the turbine blades. Rotor diameter means the cross-section dimension of the circle swept by the rotating blades

Shadow Flicker: Alternating changes in light intensity caused by the moving blades of a wind energy system which cast a repeating pattern of shadows on the ground and stationary objects, such as a window of a dwelling.

~~**Adjusted Total Day-Night**~~ **Sound Exposure, Adjusted Total Day-Night (Ldn)**: Frequency-weighted sound exposure for a 24- hour day calculated by adding adjusted sound exposure obtained during the daytime (0700-2200 hours) to the adjusted sound exposure obtained during the nighttime (0000-0700 and 2200-2400 hours) with a penalty of 10 dB added as defined by ANSI (American National Standards Institute).

Stall-Control: A braking mechanism on wind turbines where the rotor blades are bolted onto the hub at a fixed angle. The rotor blade profile is aerodynamically designed to ensure that the moment the wind speed becomes too high, it creates turbulence on the side of the rotor blade that is not facing the wind. This stall prevents the lifting force of the rotor blade from acting on the rotor.

Turbine: A wind-driven machine that converts wind energy into electrical power, also known as a wind energy conversion system (WECS).

SECTION 29 WIND ENERGY CONVERSION OVERLAY DISTRICT (WECOD)

29.1 Intent and Purpose:

29.1.1 The intent of the Wind Energy Conversion Overlay District is to establish an area or areas where Wind Energy Conversion Systems-Commercial (WECS-C) and associated maintenance facilities are allowed by Conditional Use Permit. Interested property owners in the area that is proposed for designation shall instigate the initiative for the designation.

This Section has been adopted for the following purposes:

- To assure that the development and production of commercial scale wind-generated electricity in Boone County assures the health, safety and general welfare of the public;
- To promote the safe, effective, and efficient use of commercial wind energy conversion systems (WECS-C);
- To minimize the degradation of the visual character of the area;
- To minimize impact to environmentally sensitive areas, wildlife, and wildlife habitat;
- To facilitate economic opportunities for local residents and the community;
- To facilitate the supply of renewable energy in a manner that respects the geographic, social, and environmental context of Boone County.

29.1.2 Careful consideration as to practicable suitability of an area requesting designation with respect to the existing and reasonably assumable future land uses should factor heavily in the decision of whether or not an area should be designated for WECOD status.

29.2 Qualifying Underlying Zoning Districts: A WECOD may be requested in Agriculture or Industrial zoning districts.

29.3 District Boundary Requirements:

29.3.1 Two Components: Each WECOD shall be composed of two parts, the Primary District and the Buffer.

29.3.1.1 Primary District Area Requirements:

- The smallest component of a Primary District is one-quarter (1/4) Section as defined by the Public Land Survey System. Therefore, when any portion of a lot that is included in a WECOD falls

- Acreage of the primary district;
- Acreage of the buffer;
- Location and physical dimensions of existing structures and general location and approximate physical dimensions of proposed structures, including all proposed individual wind turbines. If an exact number or dimensions of wind turbines is not known at the time of application, the site plan shall identify a maximum number and maximum dimensions that will be expected and a range from minimum number expected to the maximum;
- Identify potential staging and maintenance areas;
- Houses within one thousand feet (1,000') of the overlay district boundary and the approximate distance of such houses from the district boundary;
- Any additional houses within one-half (1/2) mile of the district boundary;
- Location of existing electrical lines and facilities, including transmission lines;
- Approximate location of proposed electrical lines and facilities, including transmission lines and whether underground or overhead;
- Existing topography;
- Approximate proposed areas to be graded;
- Approximate proposed removal of natural vegetation;
- Wind characteristics and dominant wind direction;
- Proposed setbacks of all proposed structures from the district boundary;
- Projected methods of traffic circulation within the proposed district;
- Anticipated ingress and egress locations for each proposed turbine location within the proposed district;
- Location of all public roads within the proposed district and the location and distance to public roads in all directions surrounding the proposed district boundary;

- Approximate location of any major known underground pipelines or other underground utilities;
- Approximate location of any major known utility easements;
- Location of any delineated 100-year floodplains, stream buffers, sinkholes, wetlands, and other environmentally sensitive areas.

29.5.1.8 A Visual Impact Assessment developed by a Qualified Professional. The study shall provide accurate and site-specific visualizations from key observation points and a detailed description of the methods and supporting information. The assessment shall include, at a minimum, the following:

- Virtual simulations which may include 3D Visualization Models, Photographic Simulations, and Animated Visualizations as determined necessary by Director of Resource Management;
- Viewshed Analysis to determine actual visibility and the characteristics of the views within the project area including different seasons, times of day and weather conditions;
- Inventory of Views to provide the basis for evaluating the extent of visibility. This inventory shall include written description of views, distance from proposed project, duration of view, and characteristics of the view from the following:
  - All houses located within one thousand feet (1000') of the District boundary;
  - All houses within the district whose owners did not sign the Petition for Application;
  - Any applicable historic, cultural, or archeological significant sites;
  - Any applicable public roads;
  - Any applicable government-designated scenic byways, government-designated scenic overlooks, public parks, Conservation Areas, or Wildlife Refuges.
- Photographic Simulations of key viewpoints shall be provided as determined necessary by Director of Resource Management;
- A summary of key findings and proposed mitigation techniques.

~~29.5.1.8 An accurate computer-generated visual simulation developed by a County approved third-party, including dynamic motion of the turbine blades, of the project components from the following:~~

- ~~All houses located within one thousand feet (1000') of the District boundary;~~
- ~~All houses within the district whose owners did not sign the Petition for Application;~~
- ~~Up to twelve (12) key vantage points, as determined by the Resource Management Department, in consultation with the applicant, from public roads from which the project is visible or from sites that are determined to be of historic, cultural, or archeological significance;~~
- ~~Any government-designated scenic byways, government-designated scenic overlooks, public parks, Conservation Areas, and Wildlife Refuges from which the project is readily visible as determined by the Resource Management Department in consultation with the applicant;~~
- ~~If deemed necessary by the Planning and Zoning Commission, two (2) additional locations of the Planning and Zoning Commission's choosing.~~

29.5.1.9 An estimated economic Cost/Benefit Analysis (CBA) describing the impact of the project on the local and state economy in the following respects:

- The amount of property taxes to be generated by the project;
- The amount of sales taxes to be generated by the project;
- The amount of other applicable taxes to be generated by the project;
- Any distinction in the amount of taxes that will be generated and the distribution of the tax revenue if the facility is privately owned or acquired/owned by a public entity or public utility.
- The construction dollars to be spent locally;
- The number of construction jobs and estimated construction payroll;
- The number of permanent jobs and estimated continuing payroll;

- The benefit of the electricity generated by the project;
- Any projected costs or benefits to tourism in the County;
- Other projected economic benefits and costs of the project;
- Costs associated with the impact on roads or other County infrastructure in the area and a draft Transportation Infrastructure Plan and Mitigation Agreement approved by the County Engineer and the Director.

29.5.1.10 An environmental assessment of the potential adverse impacts from the project and any proposed measures to mitigate or lessen the effects of the adverse impacts. The assessment and mitigation plan shall be conducted by a Qualified Professional and include, at a minimum, all of the following:

- Documentation that the owner/applicant has followed the United States Fish and Wildlife Service Land Based Wind Energy Guidelines and copies of all resulting studies and recommendations;
- Impact on wildlife and wildlife habitat on the site and in the proposed WECOD;
- Impact on any endangered or threatened species on the site and in the proposed WECOD;
- Impact on flora on the site;
- A report, bearing the seal of a Qualified Professional, detailing expected Adjusted Total Day-Night Sound Exposure (Ldn) at the nearest property line.
- Any wastes, either municipal solid waste or hazardous waste, generated by the project at any point in its lifespan;
- Electromagnetic fields and communications interference generated by the project;
- Risk of fire from the project, including threat of lightning strikes;
- Impact of the project on civilian and military aviation in the area;
- Impact of the project on soil erosion;
- Impact of the project on water quality and water supply in the area;
- Potential hazards from ice throws and debris throws;

29.6.1.4 Publication of a locality map in a newspaper having a weekly or daily circulation in the northern portion of the County (if any) if any part of the proposed district lies north of the north boundary of Township 49 North.

29.6.1.5 Publication of a locality map in a newspaper having a weekly or daily circulation in the southern portion of the County (if any) if any part of the proposed district lies south of the north line of Township 47 North.

29.7 Approval Standards. The following guidelines shall be considered by the Planning and Zoning Commission and the County Commission in evaluating the appropriateness of proposed locations for WECS-C and the proposed project components.

29.7.1 Purpose. The purpose of the guidelines is to assist decision-makers in uniformly analyzing the impacts of each proposed WECS-C project and thereby arrive at consistent and balanced decisions.

29.7.2 Natural and Biological Resources.

29.7.2.1 Biological Conflicts. WECS-C should not be located in areas that have a substantial potential for biological conflicts.

29.7.2.2 Vast Natural Landscape. WECS-C should avoid large intact areas, at least 640 acres in size, of native vegetation that has not been significantly disturbed by man-made developments such as power lines, gas lines, oil or gas wells, public roads, etc.

29.7.2.3 Migration Paths. WECS-C should avoid areas that would interfere with important wildlife migratory corridors and staging areas.

29.7.3 ~~Visual Impacts~~Appearance.

29.7.3.1 Nature Areas. WECS-C should avoid sites that are readily visible from government-designated scenic byways, government-designated scenic overlooks, public parks, Conservation Areas, and Wildlife Refuges.

29.7.3.2 Visual Clutter. To avoid clutter, the visual effects of ancillary structures, roads, and fences on the site should be minimized.

29.7.3.3 Visual Unity. A WECS-C project should maintain visual unity among clusters of turbines.

29.7.3.4 ~~Appearance~~Color. To promote visual uniformity, the rotors, nacelles, and towers of all turbines in an array should appear similar and shall be a shade of white in color.

29.7.3.5 Density. To avoid objectional density each WECS-C must be at least six (6) times its rotor diameter from another WECS-C beginning at the nearest point on the base of each tower.

29.7.3.6 Power Lines. To avoid visual clutter, intra-project power lines having a voltage of 34,500 volts or less shall be buried unless the applicant can sufficiently demonstrate that burying the lines will violate other governmental or industry-wide guidelines/standards, violate applicable law, or have demonstrated to the Commission that such lines will be hidden from public view.

29.7.3.7 Skyline. To avoid cluttering the skyline, transformers and other electric equipment should be hidden from view

29.7.4 Soil Erosion and Water Quality

29.7.4.1 WECS-C shall avoid construction activities on slopes that are steep or susceptible to erosion.

29.7.4.2 The number of improved private access roads and construction staging areas should be kept to a minimum.

29.7.4.3 The grading width of private access roads should be minimized. One-lane roadways with lay-bys are recommended.

29.7.4.4 The number and size of staging areas and crane pad sites should be minimized.

29.7.5 Historical, Cultural, and Archeological Resources

29.7.5.1 WECS-C should avoid sites that are less than 3,070 lineal feet from any places that have been listed on the National Register of Historic Places or designated as a National Historic Landmark.

29.7.6 Transportation Infrastructure Impacts

29.7.6.1 All impacts to the transportation network should be mitigated to the maximum extent practicable. The applicant shall work with the County Chief Engineer and, if applicable, the Missouri Department of Transportation, and local municipalities to develop a Transportation and Infrastructure Mitigation Plan.

29.8 Siting and Performance Standards.

29.8.1 Purpose. The following standards are to be achieved by each WECS-C project without exception. Because they are standards, they are considered to be requirements of any WECS-C project. The final decision on whether or not a particular standard is achieved by a WECS-C project shall be made by the County Commission after considering the recommendations of the Planning and Zoning Commission and the Resource Management Department.

29.8.2 Noise Management

29.8.2.1 Measurement, Modeling, and Analysis.

29.8.2.1.1 A noise study shall be conducted to demonstrate that the system does not exceed an Adjusted Total Day-Night Sound Exposure (Ldn) of 45 dBA measured from the property line.

29.8.2.1.2 The study shall be conducted by a Qualified Professional

29.8.2.1.3 Measurement, modeling, and analysis shall conform to the most recent version of ANSI S12.18[1], ANSI S12.9-2005[2], IEC 61400[3], and ISO 9613[4].

29.8.2.2 Sound Level. The noise level caused by the operation of the project shall not exceed fifty (50) dBA during any daytime hours and forty (40) dBA during any nighttime hours, as measured at the nearest property line. The average Adjusted Total Day-Night Sound Exposure shall not exceed 45 dBA Ldn.

29.8.2.3 Addressing complaints. Upon receipt of a complaint regarding noise from an existing WECS-C project by the Boone County Resource Management Department, which the Department

[1] **ANSI S12.18**: This standard describes methods for measuring sound pressure levels in the outdoor environment, taking into account the effects of refraction due to wind and temperature gradients, the effects of atmospheric turbulence, the effects of variable ground impedance, and wind noise.

[2] **ANSI S12.9-2005**: This Standard specifies methods to assess environmental sounds and to predict the potential annoyance response of a community to outdoor long-term noise from any and all types of environmental sounds from one or more discrete or distributed sound sources.

[3] **IEC 61400**: A set of design requirements made to ensure that wind turbines are appropriately engineered against damage from hazards within the planned lifetime. The standard concerns most aspects of the turbine life from site conditions before construction, to turbine components being tested, assembled, and operated.

[4] **ISO 9613**: This standard specifies an engineering method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise at a distance from a variety of sources

29.8.4.5 Outdoor Storage. Except during construction, re-construction or removal, outdoor storage is not permitted provided that this restriction shall not apply to the project's designated operations and maintenance facility as approved by a Conditional Use Permit.

29.8.4.6 Repair Requirements. If turbines become inoperable for any reason, they shall be repaired within 90-days unless the County Commission approves an extension upon request of the operator and showing of good cause why such extension should be granted.

29.8.4.7 Internal Components. To avoid cluttering the skyline, inverters and pendant power cables shall be located inside the wind turbine tower, nacelle or structure.

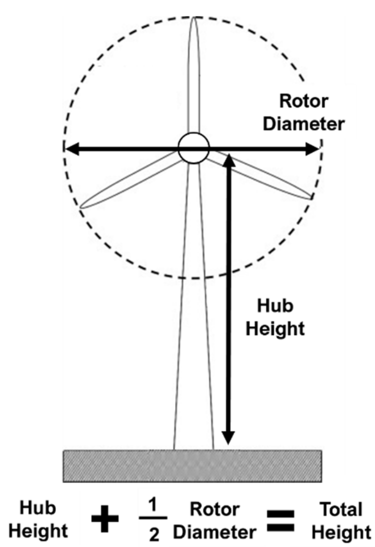
29.8.4.8 External Telecommunication. No telecommunications dishes, antennas, cellular telephone repeaters or other similar devices shall be attached to wind turbine towers unless mounted inside the tower.

29.8.4.9 Prohibited Markings. Aircraft obstruction markings of the turbines by use of alternating red and white bands shall be prohibited.

29.8.4.10 Prohibited Advertising. No billboards, logos, or advertising signs of any kind shall be located on the turbines.

29.8.4.11 ~~Maximum~~ Permitted Height. Height shall be determined by the Hub Height for each individual turbine. The maximum Hub Height shall be 80 meters (80 meters is approximately 263 feet).

29.8.4.11.1 Total Height. The overall height is determined by the sum of the Hub Height and half of the turbine's Rotor Diameter distance, measured at the highest point on the blade tip.



~~The maximum height of the turbines shall be 355 feet. Greater height, but not in excess of 400 feet, may be considered on a case by case basis if the applicant can sufficiently demonstrate that the increased height will result in increased energy efficiencies, thereby reducing the overall number of turbines in the project. However, in all cases, due consideration shall be given to the scale of the turbines in relation to the surrounding landscape.~~

29.8.5 Soil Erosion and Water Quality

29.8.5.1 Minimize Impact. Construction and maintenance shall be done in strict accordance with the erosion and sediment control plan submitted with the building permit so as to minimize soil erosion and damage to native vegetation.

29.8.5.2 Restoration. If native vegetation is damaged during construction, it shall be restored after construction is complete in areas not occupied by the WECS-C and related facilities and roads.

29.8.5.3 Stormwater Ordinance. Compliance with Section 28 is required.

29.8.6 Safety

29.8.6.1 Property Setbacks. Individual wind turbines shall be set back 1,750-feet from all property lines of the single discrete undivided lot of record upon which it is located to the nearest point on base of tower. Lease, easement, or other ownership interest of adjoining discrete lots does not remove the property lines between discrete lots from which the measurements are made.

29.8.6.2 Road Setbacks. Individual wind turbines shall be set back 1,750-feet from all public road rights of way to the nearest point on the base of the tower.

29.8.6.3 Minimum Spacing. Each WECS-C must be at least six (6) times its rotor diameter from another WECS-C beginning at the nearest point on the base of each tower.

29.8.6.4 Minimum Clearance. Each WECS-C must maintain a minimum clearance of 15-feet from the ground, immediately adjacent to the tower base, to the rotor tip at its lowest point.

29.8.6.5 Lighting. Lighting of turbines shall be radar activated and in compliance with current FAA Aircraft Detection Lighting System regulations. Any emergency reserve lighting shall follow “daytime white / nighttime red” standards.

29.9.1.5.1 Additional Security. When Required. If the County Commission has any reason to believe that the Security is insufficient, it may demand such other Security as it deems to be necessary.

29.9.1.5.2 Survival of Sale. The Security must be written so as to survive any sale or transfer of the turbines and related project property or the insolvency of the project owner. It shall further apply to all successors and assigns of the project owner. Any entity providing Security must be authorized to provide such Security in the State of Missouri and must be acceptable to the County Commission.

29.9.2 Abandonment.

29.9.2.1 Individual Turbine. An individual turbine shall be considered to have been abandoned when the turbine is incapable of producing more than 20% of the average amount of electricity produced by such turbine in comparable previous time periods (adjusted for actual wind conditions), as determined by the Resource Management Department, for a period of at least six (6) consecutive months and there is no demonstrated viable plan to restore the equipment to operating condition or if determined inoperable under Section 29.8.3.6.

29.9.2.2 Entire Project. An entire project shall be considered to have been abandoned when at least fifty percent (50%) of the individual turbines in any WECOD are abandoned or considered to be abandoned in accordance with 29.9.2.1, and there is no demonstrated viable plan to restore the equipment to operating condition. Except for any Repowering Event or Casualty Event subject to a County approved schedule of completion not to exceed 5 years.

29.9.2.3 Extension. An extension of the 6-month time period may be granted by the County Commission upon the presentation of sufficient justification by the project owner.

29.9.2.4 Excavation. All underground equipment and foundation systems of WECS-C shall be removed to a depth of at least four feet (4’) to allow for the cultivation of crops, restoration of pasture, or installation of underground utilities.

29.9.3 Reclamation

29.9.3.1 Owner Initiated. The owner/operator shall commence reclamation proceedings within 90-days of the date of abandonment of an

ATTACHMENT 6B

November 11th, 2021

SECTION 15 ADMINISTRATION

G. CONDITIONAL USE PERMITS FOR COMMERCIAL WIND ENERGY CONVERSION SYSTEMS (WECS-C)

1. PURPOSES AND GENERAL PERMIT REQUIREMENTS

1.1 These regulations are intended to regulate the placement and construction of commercial wind energy conversion systems (WECS-C) in order to protect and promote the public health, safety, and welfare, to protect the environment, to promote the efficient use of land and to preserve property values.

1.2 No WECS-C as defined herein shall be constructed, erected, maintained or operated except under Conditional Use Permit issued in accordance with these regulations in areas zoned Wind Energy Conversion Overlay District (WECOD).

1.3 All Conditional Use Permits for WECS-C shall comply with the procedures and standards of Section 15 A. of these regulations and the Wind Energy Conversion Overlay District, Section 29.

2. APPLICABILITY

2.1 These regulations apply to WECS-C facilities and accessory facilities such as staging yards, maintenance yards, maintenance buildings, or laydown yards, in a Wind Energy Conversion Overlay District (WECOD).

3.APPLICATION STANDARDS FOR A NEW WECS-C

3.1 In addition to the standards contained in Section 15 A.(5), applications for new WECS-C shall be required to meet the following standards. Any application that does not meet these requirements shall be returned to the applicant for revision and supplemental material.

3.2 Limited Number of Applications per Month:

3.2.1 Up to three (3) applications from the same project owner may be submitted per month.

3.2.2 Each application may contain up to two (2) WECS-C that are located less than 1.5 times the minimum spacing distance from each other.

3.2.3 The Director may allow groups of up to six (6) WECS-C to be included in one application if:

- All towers are in a single cluster;
- Each tower within the group is less than 1.25 times its minimum spacing distance from at least one (1) other tower in the group;
- There is sufficient room on the Planning and Zoning Commission agenda without displacing other items or resulting in an unreasonably long meeting.

3.3 Project Owner Information:

3.3.1 Name, address, phone number, and e-mail address of the project owner and the project owner's contact person for the project;

3.3.2 A statement from the project owner providing relevant information regarding an overview of the company, the company's financial condition, the company's environmental management history and the company's qualifications and experience in WECS-C development. Specific references regarding other WECS-C projects are required;

3.3.3 A description of the entity identified as the project owner and builder of the proposed project and a complete financial statement for such entity including audits or reviews, whichever are applicable, for three (3) years preceding the date of application;

3.3.4 The name, address, phone number and e-mail address of the manager of the project in the event the project is approved and the name, address and phone numbers of any proposed buyers of the project.

3.4 Site Plan:

3.4.1 A site plan drawn in sufficient detail to clearly describe the following:

- General vicinity of the project location within the County;
- Scale and north arrow;
- Acreage of the site;
- Physical dimensions of the property and the physical location of the project boundary including the property lines of the discrete lot;
- Any previous survey work of record within the project boundary and any deed work showing consolidations of separate lots into the single proposed lot upon which the project is proposed;

- Location and physical dimensions of existing structures and location and physical dimensions of proposed structures, including the proposed wind turbines and accessory structures;
- Houses within one thousand feet (1,000’) of the parcel boundary and the approximate distance of such houses from the proposed tower, and any additional houses within one-half (1/2) mile of the proposed tower;
- Location of existing electrical lines and facilities, including transmission lines and whether overhead or underground;
- Approximate location of proposed electrical lines and facilities, including transmission lines and whether overhead or underground;
- Existing topography;
- Proposed grading and removal of natural vegetation;
- Wind characteristics and dominant wind direction;
- Proposed setbacks of all proposed structures from the project boundary;
- Anticipated ingress and egress locations and projected methods of circulation on the project property;
- Location of and distance to public roads in all four directions surrounding the project perimeter;
- Approximate location of any major known underground pipelines or other underground utilities;
- Approximate location of any major known utility easements;
- Location of any delineated 100-year floodplains, stream buffers, sinkholes, wetlands, and other environmentally sensitive areas;
- Approximate area/size of land disturbance.

3.5 A summary of the economic Cost/Benefit Analysis (CBA) that was submitted and reviewed as part of the approval process for the WECOD in which the proposed WECS-C is located and:

3.5.1 A description of how the proposed WECS-C relates to the CBA;

3.5.2 A description of any mitigation measures identified in the CBA.

3.6 A summary of the environmental assessment of the potential adverse impacts from the project that was submitted and reviewed as part of the approval process for the WECOD in which the proposed WECS-C is located as well as:

3.6.1 A description of how the proposed WECS-C relates to the assessment;

3.6.2 Identification of any proposed measures to mitigate or lessen the effects of the adverse impacts that relate to the construction and operation of the proposed WECS-C.

3.7 A copy of written notification to the utility company(s) of the proposed interconnection with their corresponding service(s).

3.8 Detailed information on the type, size, height, rotor size, rotor material, color scheme, rated power output, performance, safety and noise characteristics of the proposed wind turbine model, tower and electrical transmission equipment.

3.9 A decommissioning and land reclamation plan to be implemented in the event the project is abandoned or upon the end of the useful life of the project. The plan shall include a statement specifying the anticipated useful life of the project.

3.10 A summary of the Transportation and Infrastructure Mitigation Plan developed during the approval process for the WECOD in which the proposed WECS-C is located in addition to:

3.10.1 A description of how the proposed WECS-C relates to that plan;

3.10.2 The mitigation measures that are to be implemented and a schedule of when such measures are to be completed.

3.10.3 If applicable, the Missouri Department of Transportation approval of the plan for the site-specific project.

3.10.4 If applicable, any local municipalities approval of the plan for the site-specific project.

3.11 A plan for the physical security of the site and the structure(s) authorized by the Conditional Use Permit.

3.12 A Federal Aviation Administration Determination of No Hazard (if required), or a written statement from FAA that the tower is exempt from such requirements.

3.13 The project owner has demonstrated compliance with United States Fish and Wildlife Service Land-Based Wind Energy Guidelines and compliance with all recommendations resulting there from.

4. APPROVAL STANDARDS FOR A NEW WECS-C

4.1 It is the responsibility of the project owner to provide sufficient information and documentation to allow approval of the Conditional Use Permit (CUP).

4.2 Before authorizing the issuance of a CUP for a WECS-C, the County Commission shall satisfy itself that the following approval standards are met and the requirements of Section 15 A. (2) are met:

- The project owner has addressed mitigation as identified in the economic Cost/Benefit Analysis (CBA) that was submitted and reviewed as part of the approval process for the WECOD in which the proposed WECS-C is located;
- The project owner has addressed measures to mitigate or lessen the effects of the adverse environmental impacts that relate to the construction and operation of the proposed WECS-C as identified in the environmental assessment of the potential adverse impacts that was submitted and reviewed as part of the approval process for the WECOD is which the proposed WECS-C is located;
- The project owner has notified applicable utilities of the proposed interconnection;
- The type, size, height, rotor size, rotor material, color scheme, and noise characteristics of the proposed wind turbine model and tower are similar to all other towers in the same WECOD;
- A satisfactory Decommissioning and Land Reclamation Plan has been submitted including procedures to address project abandonment or upon the end of the useful life of the project;
- The project owner has negotiated a draft agreement with Boone County to mitigate traffic and road related impacts as identified in the Transportation and Infrastructure Mitigation Plan submitted and reviewed as part of the approval process for the WECOD in which the proposed WECS-C is located;
- Adequate measures are proposed to protect the physical security of the site and the structure(s) authorized by the Conditional Use Permit;

- The project owner has submitted a Federal Aviation Administration (FAA) Determination of No Hazard (if required), or a written statement from FAA that the tower is exempt from such requirements;
- The project owner has demonstrated compliance with United States Fish and Wildlife Service Land-Based Wind Energy Guidelines and compliance with all recommendations resulting therefrom;
- The proposed WECS-C complies with all requirements and standards of the Wind Energy Conversion Overlay District, Section 29;
- The County Commission may use testimony and evidence, presented in the public hearings to establish the WECOD, to impose additional conditions on the CUP.

5. STANDARD CONDITIONS

5.1 The following conditions shall be attached to each Conditional Use Permit granted under this section, unless the County Commission specifically omits one or more.

5.1.1 Prior to construction of any structure authorized by this permit, the owner shall enter into a Transportation and Infrastructure Mitigation Agreement approved by the County Commission of the County of Boone.

5.1.2 Any alteration to any lot line, as it existed at the time of application submittal, that results in a conflict with any adopted standard or condition of approval, shall be cause for revocation of the permit in accordance with procedures established in Section 15 A. (4).

5.1.3 The owner shall submit an annual report detailing monthly power generation for each WECS-C for the previous twelve (12) months. The annual reporting period shall commence on the date the Conditional Use Permit is issued. Reports are due within 60-days of the end of each annual reporting period.

5.1.4 The owner shall continue to comply with the United States Fish and Wildlife Service Land Based Wind Energy Guidelines.

5.1.5 Any division of land, regardless of the acreage involved, on which a Conditional Use Permit (CUP) for a WECS-C has been issued is subject to review by the Director. The Director’s review is to ensure that the proposed division is compatible with the requirements of the CUP.

- If proposed division is not compatible with the requirements of the CUP, it is prohibited.
- The owner shall record, in the land records of the Boone County Recorder of Deeds, a Notice of Land Division Review (NLDR). The NLDR shall be on forms provided by the Director and shall clearly state the requirements of this condition.

5.1.6 All WECS-C shall be equipped with an automatic fire suppression system that meets the applicable NFPA standard or is otherwise approved by the fire district with jurisdiction.

ATTACHMENT 7

U.S. Fish & Wildlife Service

U.S. Fish and Wildlife Service Land-Based Wind Energy Guidelines

Cover Photo:

Wind Turbine. Photo by Stefanie Stavrakas, USFWS

OMB Control No, 1018-0148
Expiration Date: 12/31/2014

U.S. Fish and Wildlife Service Land-Based Wind Energy Guidelines

March 23, 2012

Acknowledgements

The U.S. Fish and Wildlife Service (Service) would like to recognize and thank the Wind Turbine Guidelines Advisory Committee for its dedication and preparation of its Recommendations. The Recommendations have served as the basis from which the Service's team worked to develop the Service's Land-Based Wind Energy Guidelines. The Service also recognizes the tireless efforts of the Headquarters, Regional and Field Office staff that helped to review and update these Guidelines.

Paperwork Reduction Act Statement: The Land-Based Wind Energy Guidelines contain reporting and recordkeeping requirements that require Office of Management and Budget approval in accordance with the Paperwork Reduction Act of 1995. Your response is voluntary. We collect this information in order to provide technical assistance related to addressing wildlife conservation concerns at all stages of land-based wind energy development. For each response, we estimate the time necessary to provide the information as follows:

Tier 1 – 83 hours
Tier 2 – 375 hours
Tier 3 – 2,880 hours
Tier 4 – 2,550 hours
Tier 5 – 2,400 hours

The above estimates include time for reviewing instructions, gathering and maintaining data, and preparing and transmitting reports. Send comments regarding these estimates or any other aspect of the requirements to the Service Information Collection Clearance Officer, U.S. Fish and Wildlife Service, 4401 N. Fairfax Drive, MS 2042-PDM, Arlington, VA 22203.

We may not conduct and you are not required to respond to a collection of information unless it displays a currently valid OMB control number.

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Executive Summary

As the Nation shifts to renewable energy production to supplant the need for carbon-based fuel, wind energy will be an important source of power. As wind energy production increases, both developers and wildlife agencies have recognized the need for a system to evaluate and address the potential negative impacts of wind energy projects on species of concern. These voluntary Guidelines provide a structured, scientific process for addressing wildlife conservation concerns at all stages of land-based wind energy development. They also promote effective communication among wind energy developers and federal, state, and local conservation agencies and tribes. When used in concert with appropriate regulatory tools, the Guidelines form the best practical approach for conserving species of concern. The Guidelines have been developed by the Interior Department's U.S. Fish and Wildlife Service (Service) working with the Wind Turbine Guidelines Advisory Committee. They replace interim voluntary guidance published by the Service in 2003.

The Guidelines discuss various risks to "species of concern" from wind energy projects, including collisions with wind turbines and associated infrastructure; loss and degradation of habitat from turbines and infrastructure; fragmentation of large habitat blocks into smaller segments that may not support sensitive species; displacement and behavioral changes; and indirect effects such as increased predator populations or introduction of invasive plants. The Guidelines assist developers in identifying species of concern that may potentially be affected by their proposed project, including migratory birds; bats; bald and golden eagles and other birds of prey; prairie and sage grouse; and listed, proposed, or candidate endangered and threatened species. Wind energy development in some areas may be precluded by federal law; other areas may be inappropriate for development because they have been recognized as having high wildlife value based on their ecological rarity and intactness.

The Guidelines use a "tiered approach" for assessing potential adverse effects to species of concern and their habitats. The tiered approach is an iterative decision-making process for collecting information in increasing detail; quantifying the possible risks of proposed wind energy projects to species of concern and their habitats; and evaluating those risks to make siting, construction, and operation decisions. During the pre-construction tiers (Tiers 1, 2, and 3), developers are working to identify, avoid and minimize risks to species of concern. During post-construction tiers (Tiers 4 and 5), developers are assessing whether actions taken in earlier tiers to avoid and minimize impacts are successfully achieving the goals and, when necessary, taking additional steps to compensate for impacts. Subsequent tiers refine and build upon issues raised and efforts undertaken in previous tiers. Each tier offers a set of questions to help the developer evaluate the potential risk associated with developing a project at the given location.

Briefly, the tiers address:

- Tier 1 – Preliminary site evaluation (landscape-scale screening of possible project sites)
- Tier 2 – Site characterization (broad characterization of one or more potential project sites)
- Tier 3 – Field studies to document site wildlife and habitat and predict project impacts
- Tier 4 – Post-construction studies to estimate impacts[1]
- Tier 5 – Other post-construction studies and research

The tiered approach provides the opportunity for evaluation and decision-making at each stage, enabling a developer to abandon or proceed with project development, or to collect additional information if required. This approach does not require that every tier, or every element within each tier, be implemented for every project. The Service anticipates that many distributed or community facilities will not need to follow the Guidelines beyond Tiers 1 and 2. Instead, the tiered approach allows efficient use of developer and wildlife agency resources with increasing levels of effort.

If sufficient data are available at a particular tier, the following outcomes are possible:

1. The project proceeds to the next tier in the development process without additional data collection.
2. The project proceeds to the next tier in the development process with additional data collection.
3. An action or combination of actions, such as project

[1] The Service anticipates these studies will include fatality monitoring as well as studies to evaluate habitat impacts.

modification, mitigation, or specific post-construction monitoring, is indicated.

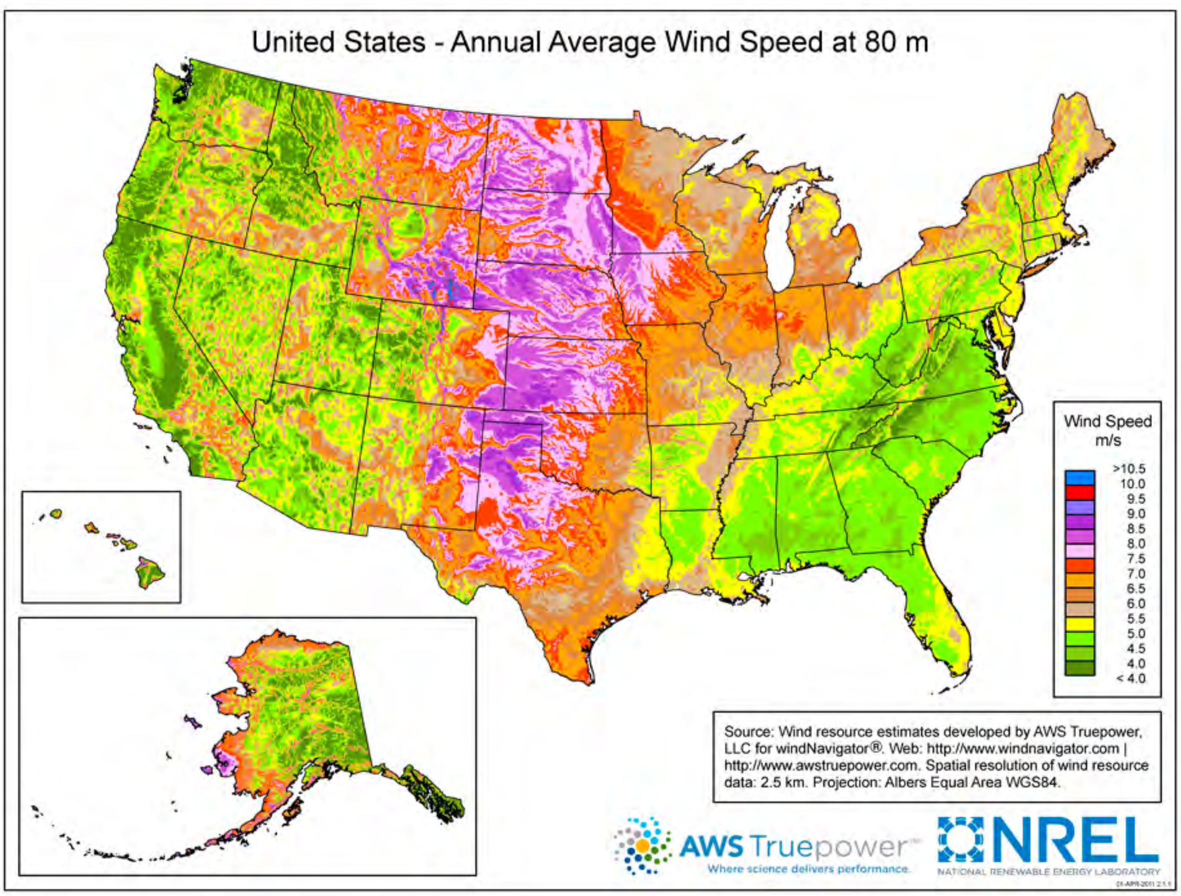
4. The project site is abandoned because the risk is considered unacceptable.

If data are deemed insufficient at a tier, more intensive study is conducted in the subsequent tier until sufficient data are available to make a decision to modify the project, proceed with the project, or abandon the project.

The most important thing a developer can do is to consult with the Service as early as possible in the development of a wind energy project. Early consultation offers the greatest opportunity for avoiding areas where development is precluded or where wildlife impacts are likely to be high and difficult or costly to remedy or mitigate at a later stage. By consulting early, project developers can also incorporate appropriate wildlife conservation measures and monitoring into their decisions about project siting, design, and operation.

Adherence to the Guidelines is voluntary and does not relieve any individual, company, or agency of the responsibility to comply with laws and regulations. However, if a violation occurs the Service will consider a developer's documented efforts to communicate with the Service and adhere to the Guidelines. The Guidelines include a Communications Protocol which provides guidance to both developers and Service personnel regarding appropriate communication and documentation.

The Guidelines also provide Best Management Practices for site development, construction, retrofitting, repowering, and decommissioning. For additional reference, a glossary of terms and list of literature cited are included in the appendices.



Wind Resource Map. Credit: NREL

Chapter 1 - General Overview

The mission of the U.S. Fish and Wildlife Service (Service) is working with others to conserve, protect and enhance fish, wildlife, plants and their habitats for the continuing benefit of the American people. As part of this, the Service implements statutes including the Endangered Species Act, Migratory Bird Treaty Act, and Bald and Golden Eagle Protection Act. These statutes prohibit taking of federally listed species, migratory birds, and eagles unless otherwise authorized.

Recent studies have documented that wind energy facilities can kill birds and bats. Mortality rates in fatalities per nameplate MW per year vary among facilities and regions. Studies have indicated that relatively low raptor (e.g., hawks, eagles) fatality rates exist at most modern wind energy developments with the exception of some facilities in California and Wyoming. Turbine-related bat deaths have been reported at each wind facility to date. Generally, studies in the West have reported lower rates of bat fatalities than facilities in the East. There is still much uncertainty regarding geographic distribution and causes of bat fatalities (NWCC 2010).

These Guidelines are intended to:

(1) Promote compliance with relevant wildlife laws and regulations;

(2) Encourage scientifically rigorous survey, monitoring, assessment, and research designs proportionate to the risk to species of concern;

(3) Produce potentially comparable data across the Nation;

(4) Mitigate, including avoid, minimize, and compensate for potential adverse effects on species of concern and their habitats; and,

(5) Improve the ability to predict and resolve effects locally, regionally, and nationally.

As the United States moves to expand wind energy production, it also must maintain and protect the Nation's wildlife and their habitats, which wind energy production can negatively affect. As with all responsible energy development, wind energy projects should adhere to high standards for environmental protection. With proper diligence paid to siting, operations, and management of projects, it is possible to mitigate for adverse effects to wildlife, and their habitats. This is best accomplished when the wind energy project developer communicates as early as possible with the Service and other stakeholders. Such early communication allows for the greatest range of development and mitigation options. The following website contains contact information for the Service Regional and Field offices as well as State wildlife agencies: http://www.fws.gov/offices/statelinks.html.

In response to increasing wind energy development in the United States, the Service released a set of voluntary, interim guidelines for reducing adverse effects to fish and wildlife resources from wind energy projects for public comment in July 2003. After the Service reviewed the public comments, the Secretary of the Interior (Secretary) established a Federal Advisory Committee[2] to provide recommendations to revise the guidelines related to land-based wind energy facilities. In March 2007, the U.S. Department of the Interior established the Wind Turbine Guidelines Advisory Committee (the Committee). The Committee submitted its final Recommended Guidelines (Recommendations) to the Secretary on March 4, 2010. The Service used the Recommendations to develop its Land-Based Wind Energy Guidelines.

The Service encourages project proponents to use the process described in these voluntary Land-based Wind Energy Guidelines (Guidelines) to address risks to species of concern. The Service intends that these Guidelines, when used in concert with the appropriate regulatory tools, will form the best practical approach for conservation of species of concern.

Statutory Authorities

These Guidelines are not intended nor shall they be construed to limit or preclude the Service from exercising its authority under any law, statute, or regulation, or from conducting enforcement action against any individual, company, or agency. They are not meant to relieve any individual, company, or agency of its obligations to comply with any applicable federal, state,

[2] Committee membership, from 2008 to 2011, has included: Taber Allison, Massachusetts Audubon; Dick Anderson, California Energy Commission; Ed Arnett, Bat Conservation International; Michael Azeka, AES Wind Generation; Thomas Bancroft, National Audubon; Kathy Boydston, Texas Parks and Wildlife Department; René Braud, EDP Renewables; Scott Darling, Vermont Fish and Wildlife Department; Michael Daulton, National Audubon; Aimee Delach, Defenders of Wildlife; Karen Douglas, California Energy Commission; Sam Enfield, MAP Royalty; Greg Hueckel, Washington Department of Fish and Wildlife; Jeri Lawrence, Blackfeet Nation; Steve Lindenberg, U.S. Department of Energy; Andy Linehan, Iberdrola Renewables; Rob Manes, The Nature Conservancy, Kansas; Winifred Perkins, NextEra Energy Resources; Steven Quarles, Crowell & Moring; Rich Rayhill, Ridgeline Energy; Robert Robel, Kansas State University; Keith Sexson, Association of Fish and Wildlife Agencies; Mark Sinclair, Clean Energy States Alliance; David Stout, U.S. Fish and Wildlife Service; Patrick Traylor, Hogan Lovells.

tribal, or local laws, statutes, or regulations. The Guidelines do not prevent the Service from referring violations of law for enforcement when a company has not followed the Guidelines.

Ultimately it is the responsibility of those involved with the planning, design, construction, operation, maintenance, and decommissioning of wind projects to conduct relevant wildlife and habitat evaluation and determine, which, if any, species may be affected. The results of these analyses will inform all efforts to achieve compliance with the appropriate jurisdictional statutes. Project proponents are responsible for complying with applicable state and local laws.

Migratory Bird Treaty Act

The Migratory Bird Treaty Act (MBTA) is the cornerstone of migratory bird conservation and protection in the United States. The MBTA implements four treaties that provide for international protection of migratory birds. It is a strict liability statute, meaning that proof of intent, knowledge, or negligence is not an element of an MBTA violation. The statute's language is clear that actions resulting in a "taking" or possession (permanent or temporary) of a protected species, in the absence of a Service permit or regulatory authorization, are a violation of the MBTA.

The MBTA states, "Unless and except as permitted by regulations … it shall be unlawful at any time, by any means, or in any manner to pursue, hunt, take, capture, kill … possess, offer for sale, sell … purchase … ship, export, import … transport or cause to be transported … any migratory bird, any part, nest, or eggs of any such bird …. [The Act] prohibits the taking, killing, possession, transportation, import and export of migratory birds, their eggs, parts, and nests, except when specifically authorized by the Department of the Interior." 16 U.S.C. 703. The word "take" is defined by regulation as "to pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to pursue, hunt, shoot, wound, kill, trap, capture, or collect." 50 CFR 10.12.

The MBTA provides criminal penalties for persons who commit any of the acts prohibited by the statute in section 703 on any of the species protected by the statute. See 16 U.S.C. 707. The Service maintains a list of all species protected by the MBTA at 50 CFR 10.13. This list includes over one thousand species of migratory birds, including eagles and other raptors, waterfowl, shorebirds, seabirds, wading birds, and passerines. The MBTA does not protect introduced species such as the house (English) sparrow, European starling, rock dove (pigeon), Eurasian collared-dove, and non-migratory upland game birds. The Service maintains a list of introduced species not protected by the Act. See 70 Fed. Reg. 12,710 (Mar. 15, 2005).

Bald and Golden Eagle Protection Act

Under authority of the Bald and Golden Eagle Protection Act (BGEPA), 16 U.S.C. 668–668d, bald eagles and golden eagles are afforded additional legal protection. BGEPA prohibits the take, sale, purchase, barter, offer of sale, purchase, or barter, transport, export or import, at any time or in any manner of any bald or golden eagle, alive or dead, or any part, nest, or egg thereof. 16 U.S.C. 668. BGEPA also defines take to include "pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest, or disturb," 16 U.S.C. 668c, and includes criminal and civil penalties for violating the statute. See 16 U.S.C. 668. The Service further defined the term "disturb" as agitating or bothering an eagle to a degree that causes, or is likely to cause, injury, or either a decrease in productivity or nest abandonment by substantially interfering with normal breeding, feeding, or sheltering behavior. 50 CFR 22.3. BGEPA authorizes the Service to permit the take of eagles for certain purposes and under certain circumstances, including scientific or exhibition purposes, religious purposes of Indian tribes, and the protection of wildlife, agricultural, or other interests, so long as that take is compatible with the preservation of eagles. 16 U.S.C. 668a.

In 2009, the Service promulgated a final rule on two new permit regulations that, for the first time, specifically authorize the incidental take of eagles and eagle nests in certain situations under BGEPA. See 50 CFR 22.26 & 22.27. The permits authorize limited, non-purposeful (incidental) take of bald and golden eagles; authorizing individuals, companies, government agencies (including tribal governments), and other organizations to disturb or otherwise take eagles in the course of conducting lawful activities such as operating utilities and airports.

Bald Eagle, Credit: USFWS

Removal of active eagle nests would usually be allowed only when it is necessary to protect human safety or the eagles. Removal of inactive nests can be authorized when necessary to ensure public health and safety, when a nest is built on a human-engineered structure rendering it inoperable, and when removal is necessary to protect an interest in a particular locality, but only if the take or mitigation for the take will provide a clear and substantial benefit to eagles.

To facilitate issuance of permits under these new regulations, the Service has drafted Eagle Conservation Plan (ECP) Guidance. The ECP Guidance is compatible with these Land-Based Wind Energy Guidelines. The Guidelines guide developers through the process of project development and operation. If eagles are identified as a potential risk at a project site, developers are strongly encouraged to refer to the ECP Guidance. The ECP Guidance describes specific actions that are recommended to comply with the regulatory requirements in BGEPA for an eagle take permit, as described in 50 CFR 22.26 and 22.27. The ECP Guidance provides a national framework for assessing and mitigating risk specific to eagles through development of ECPs and issuance of programmatic incidental takes of eagles at wind turbine facilities. The Service will make its final ECP Guidance available to the public through its website.

Endangered Species Act

The Endangered Species Act (16 U.S.C. 1531–1544; ESA) was enacted by Congress in 1973 in recognition that many of our Nation's native plants and animals were in danger of becoming extinct. The ESA directs the Service to identify and protect these endangered and threatened species and their critical habitat, and to provide a means to conserve their ecosystems. To this end, federal agencies are directed to utilize their authorities to conserve listed species, and ensure that their actions

Indiana bat. Credit: USFWS

are not likely to jeopardize the continued existence of these species or destroy or adversely modify their critical habitat. Federal agencies are encouraged to do the same with respect to "candidate" species that may be listed in the near future. The law is administered by the Service and the Commerce Department's National Marine Fisheries Service (NMFS). For information regarding species protected under the ESA, see: http://www.fws.gov/endangered/.

The Service has primary responsibility for terrestrial and freshwater species, while NMFS generally has responsibility for marine species. These two agencies work with other agencies to plan or modify federal projects so that they will have minimal impact on listed species and their habitats. Protection of species is also achieved through partnerships with the states, through federal financial assistance and a system of incentives available to encourage state participation. The Service also works with private landowners, providing financial and technical assistance for management actions on their lands to benefit both listed and non-listed species.

Section 9 of the ESA makes it unlawful for a person to "take" a listed species. Take is defined as "... to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct." 16 U.S.C. 1532(19). The terms harass and harm are further defined in our regulations. See 50 CFR 17.3. However, the Service may authorize "incidental take" (take that occurs as a result of an otherwise legal activity) in two ways.

Take of federally listed species incidental to a lawful activity may be authorized through formal consultation under section 7(a)(2) of the ESA, whenever a federal agency, federal funding, or a federal permit is involved. Otherwise, a person may seek an incidental take permit under section 10(a)(1)(B) of the ESA upon completion of a satisfactory habitat conservation plan (HCP) for listed species. Developers not receiving federal funding or authorization should contact the Service to obtain an incidental take permit if a wind

Utility-Scale Wind turbine with an anemometer tower in the background. Credit: University of Minnesota College of Science and Engineering

energy project is likely to result in take of listed threatened or endangered wildlife species. For more information regarding formal consultation and the requirements of obtaining HCPs, please see the Endangered Species Consultation Handbook at http://www.fws.gov/endangered/esa-library/index.html#consultations and the Service's HCP website, http://www.fws.gov/endangered/what-we-do/hcp-overview.html.

Implementation of the Guidelines

Because these Guidelines are voluntary, the Service encourages developers to use them as soon as possible after publication. To receive the considerations discussed on page 6 regarding enforcement priorities, a wind energy project would fall into one of three general categories relative to timing and implementation:

- For projects initiated after publication, the developer has applied the Guidelines, including the tiered approach, through site selection, design, construction, operation and post-operation phases of the project, and has communicated and shared information with the Service and considered its advice.
- For projects initiated prior to publication, the developer should consider where they are in the planning process relative to the appropriate tier and inform the Service of what actions they will take to apply the Guidelines.
- For projects operating at the time of publication, the developer should confer with the Service regarding the appropriate period of fatality monitoring consistent with Tier 4, communicate and share information with the Service on monitoring results, and consider Tier 5 studies and mitigation options where appropriate.

Projects that are already under development or are in operation are not expected to start over or return to the beginning of a specific tier. Instead, these projects should implement those portions of the Guidelines relevant to the current phases of the project per the bullets above.

The Service is aware that it will take time for Service staff and other personnel, including wind energy developers and their biologists, to develop expertise in the implementation of these Guidelines. Service staff and many staff associated with the wind energy industry have been involved with developing these Guidelines. Therefore, they have a working knowledge of the Guidelines. To further refine their training, the Service will make every effort to offer an in-depth course within 6 months of the final Guidelines being published.

The Communications Protocol on page 5 provides guidance to Service staff and developers in the exchange of information and recommendations at each tier in the process. Although the advice of the Service is not binding, a developer should review such advice, and either accept or reject it. If they reject it, they should contemporaneously document with reasoned justification why they did so. Although the Guidelines leave decisions up to the developer, the Service retains authority to evaluate whether developer efforts to mitigate impacts are sufficient, to determine significance, and to refer for prosecution any unlawful take that it believes to be reasonably related to lack of incorporation of Service recommendations or insufficient adherence with the Guidelines.

Table 1. Suggested Communications Protocol

This table provides examples of potential communication opportunities between a wind energy project developer and the Service. Not all projects will follow all steps indicated below.

TIER	*Project Developer/Operator Role*	*Service Role*
Tier 1: Preliminary site evaluation	• Landscape level assessment of habitat for species of concern • Request data sources for existing information and literature	• Provide lists of data sources and references, if requested
Tier 2: Site characterization	• Assess potential presence of species of concern, including species of habitat fragmentation concern, likely to be on site • Assess potential presence of plant communities present on site that may provide habitat for species of concern • Assess potential presence of critical congregation areas for species of concern • One or more reconnaissance level site visit by biologist • Communicate results of site visits and other assessments with the Service • Provide general information about the size and location of the project to the Service	• Provide species lists, for species of concern, including species of habitat fragmentation concern, for general area, if available • Provide information regarding plant communities of concern, if available • Respond to information provided about findings of biologist from site visit • Identify initial concerns about site(s) based on available information • Inform lead federal agencies of communications with wind project developers
Tier 3: Field studies and impact prediction	• Discuss extent and design of field studies to conduct with the Service • Conduct biological studies • Communicate results of all studies to Service field office in a timely manner • Evaluate risk to species of concern from project construction and operation • Identify ways to mitigate potential direct and indirect impacts of building and operating the project	• Respond to requests to discuss field studies • Advise project proponent about studies to conduct and methods for conducting them • Communicate with project proponent(s) about results of field studies and risk assessments • Communicate with project proponents(s) ways to mitigate potential impacts of building and operating the project • Inform lead federal agencies of communications with wind project developers
Tier 4: Post construction studies to estimate impacts	• Discuss extent and design of post-construction studies to conduct with the Service • Conduct post-construction studies to assess fatalities and habitat-related impacts • Communicate results of all studies to Service field office in a timely manner • If necessary, discuss potential mitigation strategies with Service • Maintain appropriate records of data collected from studies	• Advise project operator on study design, including duration of studies to collect adequate information • Communicate with project operator about results of studies • Advise project operator of potential mitigation strategies, when appropriate
Tier 5: Other post-construction studies and research	• Communicate with the Service about the need for and design of other studies and research to conduct with the Service, when appropriate, particularly when impacts exceed predicted levels • Communicate with the Service about ways to evaluate cumulative impacts on species of concern, particularly species of habitat fragmentation concern • Conduct appropriate studies as needed • Communicate results of studies with the Service • Identify potential mitigation strategies to reduce impacts and discuss them with the Service	• Advise project proponents as to need for Tier 5 studies to address specific topics, including cumulative impacts, based on information collected in Tiers 3 and 4 • Advise project proponents of methods and metrics to use in Tier 5 studies • Communicate with project operator and consultants about results of Tier 5 studies • Advise project operator of potential mitigation strategies, when appropriate, based on Tier 5 studies


Communication with Christy Johnson-Hughes. Credit: Rachel London, USFWS

Consideration of the Guidelines in MBTA and BGEPA Enforcement

The Service urges voluntary adherence to the Guidelines and communication with the Service when planning and operating a facility. While it is not possible to absolve individuals or companies from MBTA or BGEPA liability, the Office of Law Enforcement focuses its resources on investigating and prosecuting those who take migratory birds without identifying and implementing reasonable and effective measures to avoid the take. The Service will regard a developer's or operator's adherence to these Guidelines, including communication with the Service, as appropriate means of identifying and implementing reasonable and effective measures to avoid the take of species protected under the MBTA and BGEPA.[3] The Chief of Law Enforcement or more senior official of the Service will make any decision whether to refer for prosecution any alleged take of such species, and will take such adherence and communication fully into account when exercising discretion with respect to such potential referral. Each developer or operator will be responsible for maintaining internal records sufficient to demonstrate adherence to the Guidelines and response to communications from the Service. Examples of these records could include: studies performed in the implementation of the tiered approach; an internal or external review or audit process; a bird and bat conservation strategy; or a wildlife management plan.

If a developer and operator are not the same entity, the Service expects the operator to maintain sufficient records to demonstrate adherence to the Guidelines.

Scope and Project Scale of the Guidelines

The Guidelines are designed for "utility-scale" land-based wind energy projects to reduce potential impacts to species of concern, regardless of whether they are proposed for private or public lands. A developer of a distributed or community scale wind project may find it useful to consider the general principles of the tiered approach to assess and reduce potential impacts to species of concern, including answering Tier 1 questions using publicly available information. In the vast majority of situations, appropriately sited small wind projects are not likely to pose significant risks to species of concern. Answering Tier 1 questions will assist a developer of distributed or community wind projects, as well as landowners, in assessing the need to further communicate with the Service, and precluding, in many cases, the need for full detailed pre-construction assessments or monitoring surveys typically called for in Tiers 2 and 3. If landowners or community/distributed wind developers encounter problems locating information about specific sites they can contact the Service and/or state wildlife agencies to determine potential risks to species of concern for their particular project.

The tiered approach is designed to lead to the appropriate amount of evaluation in proportion to the anticipated level of risk that a project may pose to species of concern and their habitats. Study plans and the duration and intensity of study efforts should be tailored specifically to the unique characteristics of each site and the corresponding potential for significant adverse impacts on species of concern and their habitats as determined through the tiered approach. This is why the tiered approach begins with an examination of the potential location of the project, not the size of the project. In all cases, study plans and selection of appropriate study methods and techniques may be tailored to the relative scale, location, and potential for significant adverse impacts of the proposed site.

The Service considers a "project" to include all phases of wind energy development, including, but not limited to, prospecting, site assessment, construction, operation, and decommissioning, as well as all associated infrastructure and interconnecting electrical lines. A "project site" is the land and airspace where development occurs

[3] With regard to eagles, this paragraph will only apply when a project is not likely to result in take. If Tiers 1, 2, and/or 3 identify a potential to take eagles, developers should consider developing an ECP and, if necessary, apply for a take permit

or is proposed to occur, including the turbine pads, roads, power distribution and transmission lines on or immediately adjacent to the site; buildings and related infrastructure, ditches, grades, culverts; and any changes or modifications made to the original site before development occurs. Project evaluations should consider all potential effects to species of concern, which includes species 1) protected by the MBTA, BGEPA, or ESA (including candidate species), designated by law, regulation or other formal process for protection and/or management by the relevant agency or other authority, or that have been shown to be significantly adversely affected by wind energy development; and 2) determined to be possibly affected by the project.

These Guidelines are not designed to address power transmission beyond the point of interconnection to the transmission system.

Service Review Period

The Service is committed to providing timely responses. Service Field Offices should typically respond to requests by a wind energy developer for information and consultation on proposed site locations (Tiers 1 and 2), pre- and post-construction study designs (Tiers 3 and 4), and proposed mitigation (Tier 3) within 60 calendar days. The request should be in writing to the Field Office and copied to the Regional Office with information about the proposed project, location(s) under consideration, and point of contact. The request should contain a description of the information needed from the Service. The Service will provide a response, even if it is to notify a developer of additional review time, within the 60 calendar day review period. If the Service does not respond within 60 calendar days of receipt of the document, then the developer can proceed through Tier 3 without waiting for Service input. If the Service provides comments at a later time, the developer should incorporate the comments if feasible. It is particularly important that if data from Tier 1-3 studies predict that the project is likely to produce significant adverse impacts on species of concern, the developer inform the Service of the actions it intends to implement to mitigate those impacts. If the Service cannot respond within 60 calendar days, this does not relieve developers from their MBTA, BGEPA, and ESA responsibilities.

The tiered approach allows a developer in certain limited circumstances to move directly from Tier 2 to construction (e.g., adequate survey data for the site exists). The developer should notify the Service of this decision and give the Service 60 calendar days to comment on the proposed project prior to initiating construction activities.

Introduction to the Decision Framework Using a Tiered Approach

The tiered approach provides a decision framework for collecting information in increasing detail to evaluate risk and make siting and operational decisions. It provides the opportunity for evaluation and decision-making at each tier, enabling a developer to proceed with or abandon project development, or to collect additional information if necessary. This approach does not require that every tier, or every element within each tier, be implemented for every project. Instead, it allows efficient use of developer and wildlife agency resources with increasing levels of effort until sufficient information and the desired precision is acquired for the risk assessment.

Figure 1 ("General Framework of Tiered Approach") illustrates the tiered approach, which consists of up to five iterative stages, or tiers:

- Tier 1 – Preliminary site evaluation (landscape-scale screening of possible project sites)
- Tier 2 – Site characterization (broad characterization of one or more potential project sites)
- Tier 3 – Field studies to document site wildlife and habitat and predict project impacts
- Tier 4 – Post-construction studies to estimate impacts[4]
- Tier 5 – Other post-construction studies and research

At each tier, potential issues associated with developing or operating a project are identified and questions formulated to guide the decision process. Chapters Two through Six outline the questions to be posed at each tier, and describe recommended methods and metrics for gathering the data needed to answer those questions.

The first three tiers correspond to the pre-construction evaluation phase of wind energy development. At each of the three tiers, the Guidelines provide questions that developers should answer, followed by recommended methods and metrics to use in answering the questions. Some questions are repeated at each tier, with successive tiers requiring a greater investment in data collection to answer certain questions. For example, while Tier 2 investigations may discover some existing information on federal or state-listed species and their use of the proposed development site, it may be necessary to collect empirical data in Tier 3 studies to determine the presence of federal or state-listed species.

Developers decide whether to proceed to the next tier. Timely communication and sharing of information will allow opportunities for the Service to provide, and developers to consider, technical advice. A developer should base the decision on the information obtained from adequately answering the questions in this tier, whether the methods used were appropriate for the site selected, and the resulting

[4] The Service anticipates these studies will include fatality monitoring as well as studies to evaluate habitat impacts.

Wind turbines in California. Credit: Rachel London, USFWS

assessment of risk posed to species of concern and their habitats.

If sufficient data are available at a particular tier, the following outcomes are possible:

1. The project proceeds to the next tier in the development process without additional data collection.

2. The project proceeds to the next tier in the development process with additional data collection.

3. An action or combination of actions, such as project modification, mitigation, or specific post-construction monitoring, is indicated.

4. The project site is abandoned because the risk is considered unacceptable.

If data are deemed insufficient at a tier, more intensive study is conducted in the subsequent tier until sufficient data are available to make a decision to modify the project, proceed with the project, or abandon the project.

The tiered approach used in these Guidelines embodies adaptive management by collecting increasingly detailed information that is used to make decisions about project design, construction, and operation as the developer progresses through the tiers. Adaptive management is an iterative learning process producing improved understanding and improved management over time (Williams et al 2007). DOI has determined that its resource agencies, and the natural resources they oversee, could benefit from adaptive management. Use of adaptive management in DOI is guided by the DOI Policy on Adaptive Management. DOI has adopted the National Research Council's 2004 definition of adaptive management, which states:

"Adaptive management promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a 'trial and error' process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders."

This definition gives special emphasis to uncertainty about management effects, iterative learning to reduce uncertainty, and improved management as a result of learning. The DOI Adaptive Management Technical Guide is located on the web at: www.doi.gov/initiatives/AdaptiveManagement/index.html.

Figure 1. General Framework of Tiered Approach

TIER 1

A. Species of concern known to be present?
   1. No ……………………………………………………………proceed to Tier 2
   2. Unknown - Insufficient or inconclusive data …………proceed to Tier 2
   3. Yes……………………………………………abandon site or proceed to Tier 2

TIER 2

A. Probability of significant adverse impacts?
   1. Unknown - Insufficient or inconclusive data …………proceed to Tier 3
   2. Low……………proceed to obtain state and local permit (if required), design, and construction following BMPs
   3. Moderate ………………………………………proceed to Tier 3 and mitigate
   4. High, and:
      a. can be adequately mitigated...modify project and proceed to Tier 3
      b. cannot be adequately mitigated...............................abandon project

TIER 3

A. Probability of significant adverse impacts?
   1. Low ……………………………………………………………proceed to Tier 4
   2. Moderate to high, and:
      a. certainty regarding mitigation …………………………... proceed to Tier 4
      b. uncertainty regarding mitigation ………………………proceed to Tier 4
   3. High, and:
      a. can be adequately mitigated……………………………..proceed to Tier 4
      b. cannot be adequately mitigated ………….modify or abandon project

TIER 4a (See Table 2, pg 39)

A. Tier 3 studies indicate <u>low</u> probability of significant adverse impacts
   1. Documented fatalities are equal to or lower than predicted………………..no further studies or mitigation needed
   2. Documented fatalities are higher than predicted, but not significant, and:
      a. comparable data are available that support findings of not significant……………………………………………..no further studies needed
      b. comparable data not available to support findings of not significant…………….additional year(s) of monitoring recommended
   3. Documented fatalities are higher than predicted and are significant……………………………………………….communicate with Service

B. Tier 3 studies indicate <u>moderate</u> probability of significant adverse impacts
   1. Documented fatalities are lower than or no different predicted, and:
      a. are not significant and no ESA or BGEPA species are affected ……………………..no further monitoring or mitigation needed
      b. are significant *OR* ESA or BGEPA species are affected …………………………………………….communicate with Service
   2. Documented fatalities are greater than predicted and are likely to be significant *OR* ESA or BGEPA species are affected…………………………………………………communicate with Service

C. Tier 3 studies indicate <u>high</u> probability of significant adverse impacts
   1. Documented fatalities are less than predicted and are not significant, and no ESA or BGEPA species are affected……………………...no further monitoring or mitigation needed
   2. Documented fatalities are less than predicted but are still significant, and no ESA or BGEPA species are affected…………………further monitoring or mitigation needed
   3. Fatalities are equal to or greater than predicted and are significant OR ESA or BGEPA species are affected………………...communicate with Service regarding additional mitigation

TIER 4b (See Table 3, pg. 42)

A. Species of habitat fragmentation concern potentially present?
   1. No……………………………………………………………no further studies needed
   2. Yes, and:
      a. Tier 3 studies do not confirm presence…no further studies needed
      b. Tier 3 studies confirm presence, but no significant adverse impacts predicted, and:
         i. Tier 4b studies confirm Tier 3 predictions…………………no further studies or mitigation needed
         ii. Tier 4b studies indicate potentially significant adverse impacts ………………Tier 5 studies and mitigation may be needed
      c. Tier 3 studies confirm presence, and significant adverse impacts predicted and mitigation plan is developed and implemented, and:
         i. Tier 4b studies determine mitigation is effective …………………no further studies or mitigation needed
         ii. Tier 4b studies determine mitigation not effective………..further mitigation and, where appropriate, Tier 5 studies needed

Considering Risk in the Tiered Approach

In the context of these Guidelines, risk refers to the likelihood that adverse impacts will occur to individuals or populations of species of concern as a result of wind energy development and operation. Estimates of fatality risk can be used in a relative sense, allowing comparisons among projects, alternative development designs, and in the evaluation of potential risk to populations. Because there are relatively few methods available for direct estimation of risk, a weight-of-evidence approach is often used (Anderson et al. 1999). Until such time that reliable risk predictive models are developed regarding avian and bat fatality and wind energy projects, estimates of risk would typically be qualitative, but should be based upon quantitative site information.

For the purposes of these Guidelines, risk can also be defined in the context of populations, but that calculation is more complicated as it could involve estimating the reduction in population viability as indicated by demographic metrics such as growth rate, size of the population, or survivorship, either for local populations, metapopulations, or entire species. For most populations, risk cannot easily be reduced to a strict metric, especially in the absence of population viability models for most species. Consequently, estimating the quantitative risk to populations is usually beyond the scope of project studies due to the difficulties in evaluating these metrics, and therefore risk assessment will be qualitative.

Risk to habitat is a component of the evaluation of population risk. In this context, the estimated loss of habitat is evaluated in terms of the potential for population level effects (e.g., reduced survival or reproduction).

The assessment of risk should synthesize sufficient data collected at a project to estimate exposure and predict impact for individuals and their habitats for the species of concern, with what is known about the population status of these species, and in communication with the relevant wildlife agency and industry wildlife experts. Predicted risk of these impacts could provide useful information for determining appropriate mitigation measures if determined to be necessary. In practice in the tiered approach, risk assessments conducted in Tiers 1 and 2 require less information to reach a risk-based decision than those conducted at higher tiers.

Cumulative Impacts of Project Development

Cumulative impacts are the comprehensive effect on the environment that results from the incremental impact of a project when added to other past, present, and reasonably foreseeable future actions. Developers are encouraged to work closely with federal and state agencies early in the project planning process to access any existing information on the cumulative impacts of individual projects on species and habitats at risk, and to incorporate it into project development and any necessary wildlife studies. To achieve that goal, it is important that agencies and organizations take the following actions to improve cumulative impacts analysis:

- review the range of development-related significant adverse impacts;
- determine which species of concern or their habitats within the landscape are most at risk of significant adverse impacts from wind development in conjunction with other reasonably foreseeable significant adverse impacts; and
- make that data available for regional or landscape level analysis.

The magnitude and extent of the impact on a resource depend on whether the cumulative impacts exceed the capacity for resource sustainability and productivity.

For projects that require a federal permit, funding, or other federal nexus, the lead federal agency is required to include a cumulative impacts analysis in their National Environmental Policy Act (NEPA) review. The federal action agency coordinates with the developer to obtain the necessary information for the NEPA review and cumulative impacts analysis. To avoid project delays, federal and state agencies are encouraged to use existing wildlife data for the cumulative impacts analysis until improved data are available.

Where there is no federal nexus, individual developers are not expected to conduct their own cumulative impacts analysis. However, a cumulative impacts analysis would help developers and other stakeholders better understand the significance of potential impacts on species of concern and their habitats.

Other Federal Agencies

Other federal agencies, such as the Bureau of Land Management, National Park Service, U.S. Department of Agriculture Forest Service and Rural Utility Service, Federal Energy Regulatory Commission and Department of Energy are often interested in and involved with wind project developments. These agencies have a variety of expertise and authorities they implement. Wind project developers on public lands will have to comply with applicable regulations and policies of those agencies. State and local agencies and Tribes also have additional interests and knowledge. The Service recommends that, where appropriate, wind project developers contact these agencies early in the tiered process and work closely with them throughout project planning and development to assure that projects address issues of concern to those agencies. The definition of "species of concern" in these Guidelines includes species which are trust resources of States and of federal agencies (See Glossary). In those instances where a project may significantly affect State trust resources, wind energy developers should work closely with appropriate State agencies.

Relationship to Other Guidelines

These Guidelines replace the Service's 2003 interim voluntary guidelines. The Service intends that these Guidelines, when used in concert with the appropriate regulatory tools, will form the best practical approach for conservation of species of concern. For instance, when developers find that a project may affect an endangered or threatened species, they should comply with Section 7 or 10 of the ESA to obtain incidental take authorization. Other federal, state, tribal and local governments may use these Guidelines to complement their efforts to address wind energy development/wildlife interactions. They are not intended to supplant existing regional or local guidance, or landscape-scale tools for conservation planning, but were developed to provide a means of improving consistency with the goals of the wildlife statutes that the Service is responsible for implementing. The Service will continue to work with states, tribes, and other local stakeholders on map-based tools, decision-support systems, and other products to help guide future development and conservation. Additionally, project proponents should utilize any relevant guidance of the appropriate jurisdictional entity, which will depend on the species and resources potentially affected by proposed development.

Pronghorn Antelope. Credit: Steve Hillebrand, USFWS

Chapter 2: Tier 1 – Preliminary Site Evaluation

For developers taking a first look at a broad geographic area, a preliminary evaluation of the general ecological context of a potential site or sites can serve as useful preparation for working with the federal, state, tribal, and/or local agencies. The Service is available to assist wind energy project developers to identify potential wildlife and habitat issues and should be contacted as early as possible in the company's planning process. With this internal screening process, the developer can begin to identify broad geographic areas of high sensitivity due to the presence of: 1) large blocks of intact native landscapes; 2) intact ecological communities; 3) fragmentation-sensitive species' habitats; or 4) other important landscape-scale wildlife values.

Tier 1 may be used in any of the following three ways:

1. To identify regions where wind energy development poses significant risks to species of concern or their habitats, including the fragmentation of large-scale habitats and threats to regional populations of federal- or state-listed species.

2. To “screen” a landscape or set of multiple potential sites to avoid those with the highest habitat values.

3. To begin to determine if a single identified potential site poses serious risk to species of concern or their habitats.

Tier 1 can offer early guidance about the sensitivity of the site within a larger landscape context; it can help direct development away from sites that will be associated with additional study need, greater mitigation requirements, and uncertainty; or it can identify those sensitive resources that will need to be studied further to determine if the site can be developed without significant adverse impacts to the species of concern or local population(s). This may facilitate discussions with the federal, state, tribal, and/or local agencies in a region being considered for development. In some cases, Tier 1 studies could reveal serious concerns indicating that a site should not be developed.

Developers of distributed or community scale wind projects are typically considering limited geographic areas to install turbines. Therefore, they would not likely consider broad geographic areas. Nevertheless, they should consider the presence of habitats or species of concern before siting projects.

Development in some areas may be precluded by federal law. This designation is separate from a determination through the tiered approach that an area is not appropriate for development due to feasibility, ecological reasons, or other issues. Developers are encouraged to visit Service and other publicly available databases or other available information during Tier 1 or Tier 2 to see if a potential wind energy area is precluded from development by federal law. Some areas may be protected from development through state or local laws or ordinances, and the appropriate agency should be contacted accordingly. Service field offices are available to answer questions where they are knowledgeable, guide developers to databases, and refer developers to other agency contacts.

Some areas may be inappropriate for large scale development because they have been recognized according to scientifically credible information as having high wildlife value, based solely on their ecological rarity and intactness (e.g., Audubon Important Bird Areas, The Nature Conservancy portfolio sites, state wildlife action plan priority habitats). It is important to identify such areas through the tiered approach, as reflected in Tier 1, Question 2 below. Many of North America's native landscapes are greatly diminished, with some existing at less than 10 percent of their pre-settlement occurrence.

Attwater's prairie chicken. Credit: Gary Halvorsen, USFWS

Herbaceous scrub-shrub steppe in the Pacific Northwest and old growth forest in the Northeast represent such diminished native resources. Important remnants of these landscapes are identified and documented in various databases held by private conservation organizations, state wildlife agencies, and, in some cases, by the Service. Developers should collaborate with such entities specifically about such areas in the vicinity of a prospective project site.

Tier 1 Questions

Questions at each tier help determine potential environmental risks at the landscape scale for Tier 1 and project scale for Tiers 2 and 3. Suggested questions to be considered for Tier 1 include:

1. **Are there species of concern present on the potential site(s), or is habitat (including designated critical habitat) present for these species?**

2. **Does the landscape contain areas where development is precluded by law or areas designated as sensitive according to scientifically credible information? Examples of designated areas include, but are not limited to: federally-designated critical habitat; high-priority conservation areas for non-government organizations (NGOs); or other local, state, regional, federal, tribal, or international categorizations.**

3. **Are there known critical areas of wildlife congregation, including, but not limited to: maternity roosts, hibernacula, staging areas, winter ranges, nesting sites, migration stopovers or corridors, leks, or other areas of seasonal importance?**

4. **Are there large areas of intact habitat with the potential for fragmentation, with respect to species of habitat fragmentation concern needing large contiguous blocks of habitat?**

Tier 1 Methods and Metrics

Developers who choose to conduct Tier 1 investigations would generally be able to utilize existing public or other readily available landscape-level maps and databases from sources such as federal, state, or tribal wildlife or natural heritage programs, the academic community, conservation organizations, or the developers' or consultants' own information. The Service recommends that developers conduct a review of the publicly available data. The analysis of available sites in the region of interest will be based on a blend of the information available in published and unpublished reports, wildlife range distribution maps, and other such sources. The developer should check with the Service Field Office for data specific to wind energy development and wildlife at the landscape scale in Tier 1.

Tier 1 Decision Points

The objective of the Tier 1 process is to help the developer identify a site or sites to consider further for wind energy development. Possible outcomes of this internal screening process include the following:

1. One or more sites are found within the area of investigation where the answer to each of the above Tier 1 questions is "no," indicating a low probability of significant adverse impact to wildlife. The developer proceeds to Tier 2 investigations and characterization of the site or sites, answering the Tier 2 questions with site-specific data to confirm the validity of the preliminary indications of low potential for significant adverse impact.

2. If a developer answers "yes" to one or more of the Tier 1 questions, they should proceed to Tier 2 to further assess the probability of significant adverse impacts to wildlife. A developer may consider abandoning the area or identifying possible means by which the project can be modified to avoid or minimize potential significant adverse impacts.

3. The data available in the sources described above are insufficient to answer one or more of the Tier 1 questions. The developer proceeds to Tier 2, with a specific emphasis on collecting the data necessary to answer the Tier 2 questions, which are inclusive of those asked at Tier 1.

Chapter 3: Tier 2 – Site Characterization

At this stage, the developer has narrowed consideration down to specific sites, and additional data may be necessary to systematically and comprehensively characterize a potential site in terms of the risk wind energy development would pose to species of concern and their habitats. In the case where a site or sites have been selected without the Tier 1 preliminary evaluation of the general ecological context, Tier 2 becomes the first stage in the site selection process. The developer will address the questions asked in Tier 1; if addressing the Tier 1 questions here, the developer will evaluate the site within a landscape context. However, a distinguishing feature of Tier 2 studies is that they focus on site-specific information and should include at least one visit by a knowledgeable biologist to the prospective site(s). Because Tier 2 studies are preliminary, normally one reconnaissance level site visit will be adequate as a "ground-truth" of available information. Notwithstanding, if key issues are identified that relate to varying conditions and/or seasons, Tier 2 studies should include enough site visits during the appropriate times of the year to adequately assess these issues for the prospective site(s).

If the results of the site assessment indicate that one or more species of concern are present, a developer should consider applicable regulatory or other agency processes for addressing them. For instance, if migratory birds and bats are likely to experience significant adverse impacts by a wind project at the proposed site, a developer should identify and document possible actions that will avoid or compensate for those impacts. Such actions might include, but not be limited to, altering locations of turbines or turbine arrays, operational changes, or compensatory mitigation. As soon as a developer anticipates that a wind energy project is likely to result in a take of bald or golden eagles, a developer should prepare an ECP and, if necessary, apply for a programmatic take permit. As soon as a developer realizes endangered or threatened species are present and likely to be affected by a wind project located there, a federal agency should consult with the Service under Section 7(a)(2) of the ESA if the project has a federal nexus or the developer should apply for a section 10(a)(1)(B) incidental take permit if there is not a federal nexus, and incidental take of listed wildlife is anticipated. State, tribal, and local jurisdictions may have additional permitting requirements.

Developers of distributed or community scale wind projects are typically considering limited geographic areas to install turbines. Therefore, they would likely be familiar with conditions at the site where they are considering installing a turbine. Nevertheless, they should do preliminary site evaluations to determine the presence of habitats or species of concern before siting projects.


Open landscape with wind turbines. Credit: NREL

Tier 2 Questions

Questions suggested for Tier 2 can be answered using credible, publicly available information that includes published studies, technical reports, databases, and information from agencies, local conservation organizations, and/or local experts. Developers or consultants working on their behalf should contact the federal, state, tribal, and local agencies that have jurisdiction or management authority and responsibility over the potential project.

1. **Are known species of concern present on the proposed site, or is habitat (including designated critical habitat) present for these species?**

2. **Does the landscape contain areas where development is precluded by law or designated as sensitive according to scientifically credible information? Examples of designated areas include, but are not limited to: federally-designated critical habitat;**

high-priority conservation areas for NGOs; or other local, state, regional, federal, tribal, or international categorizations.

3. **Are there plant communities of concern present or likely to be present at the site(s)?**

4. **Are there known critical areas of congregation of species of concern, including, but not limited to: maternity roosts, hibernacula, staging areas, winter ranges, nesting sites, migration stopovers or corridors, leks, or other areas of seasonal importance?**

5. **Using best available scientific information has the developer or relevant federal, state, tribal, and/or local agency identified the potential presence of a population of a species of habitat fragmentation concern?**

6. **Which species of birds and bats, especially those known to be at risk by wind energy facilities, are likely to use the proposed site based on an assessment of site attributes?**

7. **Is there a potential for significant adverse impacts to species of concern based on the answers to the questions above, and considering the design of the proposed project?**

Tier 2 Methods and Metrics

Obtaining answers to Tier 2 questions will involve a more thorough review of the existing site-specific information than in Tier 1. Tier 2 site characterizations studies will generally contain three elements:

1. A review of existing information, including existing published or available literature and databases and maps of topography, land use and land cover, potential wetlands, wildlife, habitat, and sensitive plant distribution. If agencies have documented potential habitat for species of habitat fragmentation concern, this information can help with the analysis.

2. Contact with agencies and organizations that have relevant scientific information to further help identify if there are bird, bat or other wildlife issues. The Service recommends that the developer make contact with federal, state, tribal, and local agencies that have jurisdiction or management authority over the project or information about the potentially affected resources. In addition, because key NGOs and relevant local groups are often valuable sources of relevant local environmental information, the Service recommends that developers contact key NGOs, even if confidentiality concerns preclude the developer from identifying specific project location information at this stage. These contacts also provide an opportunity to identify other potential issues and data not already identified by the developer.

3. One or more reconnaissance level site visits by a wildlife biologist to evaluate current vegetation/habitat coverage and land management/use. Current habitat and land use practices will be noted to help in determining the baseline against which potential impacts from the project would be evaluated. The vegetation/habitat will be used for identifying potential bird and bat resources occurring at the site and the potential presence of, or suitable habitat for, species of concern. Vegetation types or habitats will be noted and evaluated against available information such as land use/land cover mapping. Any sensitive resources located during the site visit will be noted and mapped or digital location data recorded for future reference. Any individuals or signs of species of concern observed during the site visit will be noted. If land access agreements are not in place, access to the site will be limited to public roads.

Specific resources that can help answer each Tier 2 question include:

1. **Are known species of concern present on the proposed site, or is habitat (including designated critical habitat) present for these species?**

   Information review and agency contact: locations of state and federally listed, proposed and candidate species and species of concern are frequently documented in state and federal wildlife databases. Examples include published literature such as: Natural Heritage Databases, State Wildlife Action Plans, NGOs publications, and developer and consultant information, or can be obtained by contacting these entities.

   Site Visit: To the extent practicable, the site visit(s) should evaluate the suitability of habitat at the site for species identified and the likelihood of the project to adversely affect the species of concern that may be present.

2. **Does the landscape contain areas where development is precluded by law or designated as sensitive according to scientifically credible information?** Examples of designated areas include, but are not limited to: federally-designated critical habitat; high-priority conservation areas for NGOs; or other local, state, regional, federal, tribal, or international categorizations.

   Information review and agency contact such as: maps of political and administrative boundaries; National Wetland Inventory data files; USGS National Land Cover data maps; state, federal and tribal agency data on areas that have been designated to preclude development, including wind energy development; State Wildlife Action Plans; State Land and Water Resource Plans; Natural Heritage databases; scientifically credible information provided by NGO and local

Tall grass prairie. Credit: Amy Thornburg, USFWS

resources; and the additional resources listed in Appendix C: Sources of Information Pertaining to Methods to Assess Impacts to Wildlife of this document, or through contact of agencies and NGOs, to determine the presence of high priority habitats for species of concern or conservation areas.

Site Visit: To the extent practicable, the site visit(s) should characterize and evaluate the uniqueness of the site vegetation relative to surrounding areas.

3. **Are plant communities of concern present or likely to be present at the site(s)?**

Information review and agency contact such as: Natural Heritage Data of state rankings (S1, S2, S3) or globally (G1, G2, G3) ranked rare plant communities.

Site Visit: To the extent practicable, the site visit should evaluate the topography, physiographic features and uniqueness of the site vegetation in relation to the surrounding region. If plant communities of concern are present, developers should also assess in Tier 3 whether the proposed project poses risk of significant adverse impacts and opportunities for mitigation.

4. **Are there known critical areas of wildlife congregation, including, but not limited to, maternity roosts, hibernacula, staging areas, winter ranges, nesting sites, migration stopovers or corridors, leks, or other areas of seasonal importance?**

Information review and agency contact such as: existing databases, State Wildlife Action Plan, Natural Heritage Data, and NGO and agency information regarding the presence of Important Bird Areas, migration corridors or stopovers, leks, bat hibernacula or maternity roosts, or game winter ranges at the site and in the surrounding area.

Site Visit: To the extent practicable, the site visit should, during appropriate times to adequately assess these issues for prospective site(s), evaluate the topography, physiographic features and uniqueness of the site in relation to the surrounding region to assess the potential for the project area to concentrate resident or migratory birds and bats.

5. **Using best available scientific information, has the relevant federal, state, tribal, and/or local agency determined the potential presence of a population of a species of habitat fragmentation concern?**

If not, the developer need not assess impacts of the proposed project on habitat fragmentation.

Habitat fragmentation is defined as the separation of a block of habitat for a species into segments, such that the genetic or demographic viability of the populations surviving in the remaining habitat segments is reduced; and risk, in this case, is defined as the probability that this fragmentation will occur as a result of the project. Site clearing, access roads, transmission lines and turbine tower arrays remove habitat and displace some species of wildlife, and may fragment continuous habitat areas into smaller, isolated tracts. Habitat fragmentation is of particular concern when species require large expanses of habitat for activities such as breeding and foraging.

Consequences of isolating local populations of some species include decreased reproductive success, reduced genetic diversity, and increased susceptibility to chance events (e.g. disease and natural disasters), which may lead to extirpation or local extinctions. In addition to displacement, development of wind energy infrastructure may result in additional loss of habitat for some species due to "edge effects" resulting from the break-up of continuous stands of similar vegetation resulting in an interface (edge) between two or more types of vegetation. The extent of edge effects will vary by species and may result in adverse impacts from such effects as a greater susceptibility to colonization by invasive species, increased risk of predation, and competing species favoring landscapes with a mosaic of vegetation.

Site Visit: If the answer to Tier 2 Question 5 is yes, developers should use the general framework for evaluating habitat fragmentation at a project site in Tier 2 outlined below. Developers and the Service may use this method to analyze the impacts of habitat fragmentation at wind development project sites on species of habitat fragmentation concern. Service field offices may be able to provide the available information on habitat types, quality and intactness. Developers may use this information in combination with site-specific information on the potential habitats to be impacted by a potential development and how they will be impacted.

<u>General Framework for Evaluating Habitat Fragmentation at a Project Site (Tier 2)</u>

A. The developer should define the study area. The study area should not only include the project site for the proposed project, but be based on the distribution of habitat for the local population of the species of habitat fragmentation concern.

B. The developer should analyze the current habitat quality and spatial configuration of the study area for the species of habitat fragmentation concern.

   i. Use recent aerial and remote imagery to determine distinct habitat patches, or boundaries, within the study area, and the extent of existing habitat fragmenting features (e.g., highways).

   ii. Assess the level of fragmentation of the existing habitat for the species of habitat fragmentation concern and categorize into three classes:

   - High quality: little or no apparent fragmentation of intact habitat
   - Medium quality: intact habitat exhibiting some recent disturbance activity
   - Low quality: Extensive fragmentation of habitat (e.g., row-cropped agricultural lands, active surface mining areas)

C. The developer should determine potential changes in quality and spatial configuration of the habitat in the study area if development were to proceed as proposed using existing site information.

D. The developer should provide the collective information from steps A-C for all potential developments to the Service for use in assessing whether the habitat impacts, including habitat fragmentation, are likely to affect population viability of the potentially affected species of habitat fragmentation concern.

6. **Which species of birds and bats, especially those known to be at risk by wind energy facilities, are likely to use the proposed site based on an assessment of site attributes?**

   Information review and agency contact: existing published information and databases from NGOs and federal and state resource agencies regarding the potential presence of:

   - Raptors: species potentially present by season
   - Prairie grouse and sage grouse: species potentially present by season and location of known leks
   - Other birds: species potentially present by season that may be at risk of collision or adverse impacts to habitat, including loss, displacement and fragmentation
   - Bats: species likely to be impacted by wind energy facilities and likely to occur on or migrate through the site

     Site Visit: To the extent practicable, the site visit(s) should identify landscape features or habitats that could be important to raptors, prairie grouse, and other birds that may be at risk of adverse impacts, and bats, including nesting and brood-rearing habitats, areas of high prey density, movement corridors and features such as ridges that may concentrate raptors. Raptors, prairie grouse, and other presence or sign of species of concern seen during the site visit should be noted, with species identification if possible.

7. **Is there a potential for significant adverse impacts to species of concern based on the answers to the questions above, and considering the design of the proposed project?**

The developer has assembled answers to the questions above and should make an initial evaluation of the probability of significant adverse impacts to species of concern and their habitats. The developer should make this evaluation based on assessments of the potential presence of species of concern and their habitats, potential presence of critical congregation areas for species of concern, and any site visits. The developer is encouraged to communicate the results of these assessments with the Service.

Tier 2 Decision Points

Possible outcomes of Tier 2 include the following:

1. The most likely outcome of Tier 2 is that the answer to one or more Tier 2 questions is inconclusive to address wildlife risk, either due to insufficient data to answer the question or because of uncertainty about what the answers indicate. The developer proceeds to Tier 3, formulating questions, methods, and assessment of potential mitigation measures based on issues raised in Tier 2 results.

2. Sufficient information is available to answer all Tier 2 questions, and the answer to each Tier 2 question indicates a low probability of significant adverse impact to wildlife (for example, infill or expansion of an existing facility where impacts have been low and Tier 2 results indicate that conditions are similar, therefore wildlife risk is low). The developer may then decide to proceed to obtain state and local permit (if required), design, and construction following best management practices (see Chapter 7: Best Management Practices).

3. Sufficient information is available to answer all Tier 2 questions, and the answer to each Tier 2 question indicates a moderate probability of significant adverse impacts to species of concern or their habitats. The developer should proceed to Tier 3 and identify measures to mitigate potential significant adverse impacts to species of concern.

4. The answers to one or more Tier 2 questions indicate a high probability of significant adverse impacts to species of concern or their habitats that:

   a) Cannot be adequately mitigated. The proposed site should be abandoned.

   b) Can be adequately mitigated. The developer should proceed to Tier 3 and identify measures to mitigate potential significant adverse impacts to species of concern or their habitats.

Greater sage grouse, Credit: Stephen Ting, USFWS

Chapter 4: Tier 3 – Field Studies to Document Site Wildlife and Habitat and Predict Project Impacts

Tier 3 is the first tier in which a developer would conduct quantitative and scientifically rigorous studies to assess the potential risk of the proposed project. Specifically, these studies provide pre-construction information to:

- Further evaluate a site for determining whether the wind energy project should be developed or abandoned
- Design and operate a site to avoid or minimize significant adverse impacts if a decision is made to develop
- Design compensatory mitigation measures if significant adverse habitat impacts cannot acceptably be avoided or minimized
- Determine duration and level of effort of post-construction monitoring. If warranted, provide the pre-construction component of post-construction studies necessary to estimate and evaluate impacts

At the beginning of Tier 3, a developer should communicate with the Service on the pre-construction studies. At the end of Tier 3, developers should communicate with the Service regarding the results of the Tier 3 studies and consider the Service's comments and recommendations prior to completing the Tier 3 decision process. The Service will provide written comments to a developer that identify concerns and recommendations to resolve the concerns based on study results and project development plans.

Not all Tier 3 studies will continue into Tiers 4 or 5. For example, surveys conducted in Tier 3 for species of concern may indicate one or more species are not present at the proposed project site, or siting decisions could be made in Tier 3 that remove identified concerns, thus removing the need for continued efforts in later tiers. Additional detail on the design issues for post-construction studies that begin in Tier 3 is provided in the discussion of methods and metrics in Tier 3.

Turkey vulture and wind turbine. Credit: Rachel London, USFWS

Tier 3 Questions

Tier 3 begins as the other tiers, with problem formulation: what additional studies are necessary to enable a decision as to whether the proposed project can proceed to construction or operation or should be abandoned? This step includes an evaluation of data gaps identified by Tier 2 studies as well as the gathering of data necessary to:

- Design a project to avoid or minimize predicted risk
- Evaluate predictions of impact and risk through post-construction comparisons of estimated impacts
- Identify compensatory mitigation measures, if appropriate, to offset significant adverse impacts that cannot be avoided or minimized

The problem formulation stage for Tier 3 also will include an assessment of which species identified in Tier 1 and/or Tier 2 will be studied further in the site risk assessment. This determination is based on analysis of existing data from Tier 1 and existing site-specific data and Project Site (see Glossary in Appendix A) visit(s) in Tier 2, and on the likelihood of presence and the degree of adverse impact to species or their habitat. If the habitat is suitable for a species needing further study and the site occurs within the historical range of the species, or is near the existing range of the species but presence has not been documented, additional field studies may be appropriate. Additional analyses should not be necessary if a species is unlikely to be present or is present but adverse impact is unlikely or of minor significance.

Tier 3 studies address many of the questions identified for Tiers 1 and 2, but Tier 3 studies differ because they attempt to quantify the distribution, relative abundance, behavior, and site use of species of concern. Tier 3 data also attempt to estimate the extent that these factors expose these species to risk from the proposed wind energy facility. Therefore, in answering Tier 3 questions 1-3, developers should collect data sufficient to analyze and answer Tier 3 questions 4-6. High risk sites may warrant additional years of pre-construction studies. The duration and intensity of studies needed should be determined through communication with the Service.

If Tier 3 studies identify species of concern or important habitats, e.g., wetlands, which have specific regulatory processes and requirements, developers should work with appropriate state, tribal, or federal agencies to obtain required authorizations or permits.

Tier 3 studies should be designed to answer the following questions:

1. **Do field studies indicate that species of concern are present on or likely to use the proposed site?**

2. **Do field studies indicate the potential for significant adverse impacts on affected population of species of habitat fragmentation concern?**

3. **What is the distribution, relative abundance, behavior, and site use of species of concern identified in Tiers 1 or 2, and to what extent do these factors expose these species to risk from the proposed wind energy project?**

4. **What are the potential risks of adverse impacts of the proposed wind energy project to individuals and local populations of species of concern and their habitats? (In the case of rare or endangered species, what are the possible impacts to such species and their habitats?)**

5. **How can developers mitigate identified significant adverse impacts?**

6. **Are there studies that should be initiated at this stage that would be continued in post-construction?**

The Service encourages the use of common methods and metrics in Tier 3 assessments for measuring wildlife activity and habitat features. Common methods and metrics provide great benefit over the long-term, allowing for comparisons among projects and for greater certainty regarding what will be asked of the developer for a specific project. Deviation from commonly used methods should be carefully considered, scientifically justifiable and discussed with federal, tribal, or state natural resource agencies, or other credible experts, as appropriate. It may be useful to consult other scientifically credible information sources.

Tier 3 studies will be designed to accommodate local and regional characteristics. The specific protocols by which common methods and metrics are implemented in Tier 3 studies depend on the question being addressed, the species or ecological communities being studied and the characteristics of the study sites. Federally-listed threatened and endangered species, eagles, and some other species of concern and their habitats, may have specific protocols required by local, state or federal agencies. The need for special surveys and mapping that address these species and situations should be discussed with the appropriate stakeholders.

In some instances, a single method will not adequately assess potential collision risk or habitat impact. For example, when there is concern about moderate or high risk to nocturnally active species, such as migrating passerines and local and migrating bats, a combination of remote sensing tools such as radar, and acoustic monitoring for bats and indirect inference from diurnal bird surveys during the migration period may be necessary. Answering questions about habitat use by songbirds may be accomplished by relatively small-scale observational studies, while answering the same question related to wide-ranging species such as prairie grouse and sage grouse may require more time-consuming surveys, perhaps including telemetry.

Because of the points raised above and the need for flexibility in application, the Guidelines do not make specific recommendations on protocol elements for Tier 3 studies. The peer-reviewed scientific literature (such as the articles cited throughout this section) contains numerous recently published reviews of methods for assessing bird and bat activity, and tools for assessing habitat and landscape level risk. Details on specific methods and protocols for recommended studies are or will be widely available and should be consulted by industry and agency professionals.

Many methods for assessing risk are components of active research involving collaborative efforts of public-private research partnerships with federal, state and tribal agencies, wind energy developers and NGOs interested in wind energy-wildlife interactions (e.g., Bats and Wind Energy Cooperative and the Grassland Shrub Steppe Species Cooperative). It is important to recognize the need to integrate the results of research that improves existing methods or describes new methodological developments, while acknowledging the value of utilizing common methods that are currently available.

The methods and metrics that may be appropriate for gathering data to answer Tier 3 questions are compiled and outlined in the Technical Resources section, page 26. These are not meant to be all inclusive and other methods and metrics are available, such as the NWCC Methods & Metrics document (Strickland et al. 2011) and others listed in Appendix C:

Avian Radar

Sources of Information Pertaining to Methods to Assess Impacts to Wildlife.

Each question should be considered in turn, followed by a discussion of the methods and their applicability.

1. **Do field studies indicate that species of concern are present on or likely to use the proposed site?**

In many situations, this question can be answered based on information accumulated in Tier 2. Specific presence/absence studies may not be necessary, and protocol development should focus on answering the remaining Tier 3 questions. Nevertheless, it may be necessary to conduct field studies to determine the presence, or likelihood of presence, when little information is available for a particular site. The level of effort normally contemplated for Tier 3 studies should detect common species and species that are relatively rare, but which visit a site regularly (e.g., every year). In the event a species of concern is very rare and only occasionally visits a site, a determination of "likely to occur" would be inferred from the habitat at the site and historical records of occurrence on or near the site.

State, federal and tribal agencies often require specific protocols be followed when species of concern are potentially present on a site. The methods and protocols for determining presence of species of concern at a site are normally established for each species and required by federal, state and tribal resource agencies. Surveys should sample the wind turbine sites and applicable disturbance area during seasons when species are most likely present. Normally, the methods and protocols by which they are applied also will include an estimate of relative abundance. Most presence/absence surveys should be done following a probabilistic sampling protocol to allow statistical extrapolation to the area and time of interest.

Determining the presence of diurnally or nocturnally active mammals, reptiles, amphibians, and other species of concern will typically be accomplished by following agency-required protocols. Most listed species have required protocols for detection (e.g., the black-footed ferret). State, tribal and federal agencies should be contacted regarding survey protocols for those species of concern. See Corn and Bury 1990, Olson et al. 1997, Bailey et al. 2004, Graeter et al. 2008 for examples of reptile and amphibian protocols, survey and analytical methods. See Tier 3 Study Design Considerations on page 24 for further details.

2. **Do field studies indicate the potential for significant adverse impacts on affected populations of species of habitat fragmentation concern?**

If Tier 2 studies indicate the presence of species of habitat fragmentation concern, but existing information did not allow for a complete analysis of potential impacts and decision-making, then additional studies and analyses should take place in Tier 3.

As in Tier 2, the particulars of the analysis will depend on the species of habitat fragmentation concern and how habitat block size and fragmentation are defined for the life cycles of that species, the likelihood that the project will adversely affect a local population of the species and the significance of these impacts to the viability of that population.

To assess habitat fragmentation in the project vicinity, developers should evaluate landscape characteristics of the proposed site prior to construction and determine the degree to which habitat for species of habitat fragmentation concern will be significantly altered by the presence of a wind energy facility.

A general framework for evaluating habitat fragmentation at a project site, following that described in Tier 2, is outlined on page 27. This framework should be used in those circumstances when the developer, or a relevant federal, state, tribal and/or other local agency determines the potential presence of a population of a species of habitat fragmentation concern that may be adversely affected by the project. Otherwise, the developer need not assess the impacts of the proposed project on habitat fragmentation. This method for analysis of habitat fragmentation at project sites must be adapted to the local population of the species of habitat fragmentation concern potentially affected by the proposed development.

3. **What is the distribution, relative abundance, behavior, and site use of species of concern identified in Tiers 1 or 2, and to what extent do these factors expose these species to risk from the proposed wind energy project?**

For those species of concern that are considered at risk of collisions or habitat impacts, the questions to be answered in Tier 3 include: where are they likely to occur (i.e., where is their habitat) within a project site or vicinity, when might they occur, and in what abundance. The spatial distribution of species at risk of collision can influence how a site is developed. This distribution should include the airspace for flying species with respect to the rotor-swept zone. The abundance of a species and the spatial distribution of its habitat can be used to determine the relative risk of impact to species using the sites, and the absolute risk when compared to existing projects where similar information exists. Species abundance and habitat distribution can also be used in modeling risk factors.

Surveys for spatial distribution and relative abundance require coverage of the wind turbine sites and applicable site disturbance area, or a sample of the area using observational methods for the species of concern during the seasons of interest. As with presence/absence (see Tier 3, question 1, above) the methods used to determine distribution, abundance, and behavior may vary with the species and its ecology. Spatial distribution is determined by applying presence/absence or using surveys in a probabilistic manner over the entire area of interest. Suggested survey protocols for birds, bats, and other wildlife are found in the Technical Resources section on page 26.

Whooping crane. Credit: Ryan Hagerty, USFWS

4. **What are the potential risks of adverse impacts of the proposed wind energy project to individuals and local populations of species of concern and their habitats? (In the case of rare or endangered species, what are the possible impacts to such species and their habitats?)**

Methods used for estimating risk will vary with the species of concern. For example, estimating potential bird fatalities in Tier 3 may be accomplished by comparing exposure estimates (described earlier in estimates of bird use) at the proposed site with exposure estimates and fatalities at existing projects with similar characteristics (e.g., similar technology, landscape, and weather conditions). If models are used, they may provide an additional tool for estimating fatalities, and have been used in Australia (Organ and Meredith 2004), Europe (Chamberlin et al. 2006), and the United States (Madders and Whitfield 2006). As with other prediction tools, model predictions should be evaluated and compared with post-construction fatality data to validate the models. Models should be used as a subcomponent of a risk assessment based on the best available empirical data. A statistical model based on the relationship of pre-construction estimates of raptor abundance and post-construction raptor fatalities is described in Strickland et al. (2011) and promises to be a useful tool for risk assessment.

Collision risk to individual birds and bats at a particular wind energy facility may be the result of complex interactions among species distribution, relative abundance, behavior, weather conditions (e.g., wind, temperature) and site characteristics. Collision risk for an individual may be low regardless of abundance if its behavior does not place it within the rotor-swept zone. If individuals frequently occupy the rotor-swept zone but effectively avoid collisions, they are also at low risk of collision with a turbine (e.g., ravens). Alternatively, if the behavior of individuals frequently places them in the rotor-swept zone, and they do not actively avoid turbine blade strikes, they are at higher risk of collisions with turbines regardless of abundance. For a given species (e.g., red-tailed hawk), increased abundance increases the likelihood that individuals will be killed by turbine strikes, although the risk to individuals will remain about the same. The risk to a population increases as the proportion of individuals in the population at risk to collision increases.

At some projects, bat fatalities are higher than bird fatalities, but the exposure risk of bats at these facilities is not fully understood (National Research Council (NRC) 2007). Horn et al. (2008) and Cryan (2008) hypothesize that bats are attracted to turbines, which, if true, would further complicate estimation of exposure. Further research is required to determine if bats are attracted to turbines and if so, to evaluate 1) the influence on Tier 2 methods and predictions, and 2) if this increased individual risk translates into higher population-level impacts for bats.

The estimation of indirect impact risk requires an understanding of animal behavior in response to a project and its infrastructure, and a pre-construction estimate of presence/absence of species whose behavior would cause them to avoid areas in proximity to turbines, roads and other components of the project. The amount of habitat that is lost to indirect impacts will be a function of the sensitivity of individuals to the project and to the activity levels associated with the project's operations. The population-level significance of this indirect impact will depend on the amount of habitat available to the affected population. If the indirect impacts include habitat fragmentation, then the risk to the demographic and genetic viability of the isolated animals is increased. Quantifying cause and effect may be very difficult, however.

5. How can developers mitigate identified significant adverse impacts?

Results of Tier 3 studies should provide a basis for identifying measures to mitigate significant adverse impacts predicted for species of concern. Information on wildlife use of the proposed area is most useful when designing a project to avoid or minimize significant adverse impacts. In cases of uncertainty with regard to impacts to species of concern, additional studies may be necessary to quantify significant adverse impacts and determine the need for mitigation of those impacts.

Chapter 7, Best Management Practices, and Chapter 8, Mitigation, outline measures that can be taken to mitigate impacts throughout all phases of a project.

The following discussion of prairie grouse and sage grouse as species of concern illustrates the uncertainty mentioned above by describing the present state of scientific knowledge relative to these species, which should be considered when designing mitigation measures. The extent of the impact of wind energy development on prairie grouse and sage grouse lekking activity (e.g., social structure, mating success, persistence) and the associated impacts on productivity (e.g., nesting, nest success, chick survival) is poorly understood (Arnett et al. 2007, NRC 2007, Manville 2004). However, recent published research documents that anthropogenic features (e.g., tall structures, buildings, roads, transmission lines) can adversely impact vital rates (e.g., nesting, nest success, lekking behavior) of lesser prairie-chickens (Pruett et al. 2009, Pitman et al. 2005, Hagen et al. 2009, Hagen et al. 2011) and greater prairie-chickens over long distances. Pitman et al. (2005) found that transmission lines reduced nesting of lesser prairie chicken by 90 percent out to a distance of 0.25 miles, improved roads at a distance of 0.25 miles, a house at 0.3 miles, and a power plant at >0.6 miles. Reduced nesting activity of lesser prairie chickens may extend farther, but Pitman et al. (2005) did not analyze their data for lower impacts (less than 90 percent reduction in nesting) of those anthropogenic features on lesser prairie chicken nesting activities at greater distances. Hagen et al. (2011) suggested that development within 1 to 1 ½ miles of active leks of prairie grouse may have significant adverse impacts on the affected grouse population. It is not unreasonable to infer that impacts from wind energy facilities may be similar to those from these other anthropogenic structures. Kansas State University, as part of the National Wind Coordinating Collaborative's Grassland and Shrub Steppe Species Subgroup, is undertaking a multi-year telemetry study to evaluate the effects of a proposed wind-energy facility on displacement and demographic parameters (e.g., survival, nest success, brood success, fecundity) of greater prairie-chickens in Kansas.[5]

The distances over which anthropogenic activities impact sage grouse are greater than for prairie grouse. Based primarily on data documenting reduced fecundity (a combination of nesting, clutch size, nest success, juvenile survival, and other factors) in sage grouse populations near roads, transmissions lines, and areas of oil and gas development/production (Holloran 2005, Connelly et al. 2000), development within three to five miles (or more) of active sage grouse leks may have significant adverse impacts on the affected grouse population. Lyon and Anderson (2003) found that in habitats fragmented by natural gas development, only 26 percent of hens captured on disturbed leks nested within 1.8 miles of the lek of capture, whereas 91 percent of hens from undisturbed areas nested within the same area. Holloran (2005) found that active drilling within 3.1 miles of sage grouse lek reduced the number of breeding males by displacing adult males and reducing recruitment of juvenile males. The magnitudes and proximal causes (e.g., noise, height of structures, movement, human activity, etc.) of those impacts on vital rates in grouse populations are areas of much needed research (Becker et al. 2009). Data accumulated through such research may improve our understanding of the buffer distances necessary to avoid or minimize significant adverse impacts to prairie grouse and sage grouse populations.

When significant adverse impacts cannot be fully avoided or adequately minimized, some form of compensatory mitigation may be

[5] www.nationalwind.org

appropriate to address the loss of habitat value. For example, it may be possible to mitigate habitat loss or degradation for a species of concern by enhancing or restoring nearby habitat value comparable to that potentially influenced by the project.

6. **Are there studies that should be initiated at this stage that would be continued in post-construction?**

During Tier 3 problem formulation, it is necessary to identify the studies needed to address the Tier 3 questions. Consideration of how the resulting data may be used in conjunction with post-construction Tier 4 and 5 studies is also recommended. The design of post-construction impact or mitigation assessment studies will depend on the specific impact questions being addressed. Tier 3 predictions will be evaluated using data from Tier 4 studies designed to estimate fatalities for species of concern and impacts to their habitat, including species of habitat fragmentation concern. Tier 3 studies may demonstrate the need for mitigation of significant adverse impacts. Where Tier 3 studies indicate the potential for significant adverse direct and indirect impacts to habitat, Tier 4 studies will provide data that evaluate predictions of those impacts, and Tier 5 studies, if necessary, will provide data to evaluate the effect of those impacts on populations and the effectiveness of mitigation measures. Evaluations of the impacts of a project on demographic parameters of local populations, habitat use, or some other parameter(s) are considered Tier 5 studies, and typically will require data on these parameters prior to as well as after construction of the project.

Tier 3 Study Design Considerations

Specific study designs will vary from site to site and should be adjusted to the circumstances of individual projects. Study designs will depend on the types of questions, the specific project, and practical considerations. The most common considerations include the area being studied, the species of concern and potential risk to those species, potentially confounding variables, time available to conduct studies, project budget, and the magnitude of the anticipated impacts. Studies will be necessary in part to assess a) which species of concern are present within the project area; b) how these species are using the area (behavior); and c) what risks are posed to them by the proposed wind energy project.

Rows of wind turbines. Credit: Joshua Winchell, USFWS

Assessing Presence

A developer should assess whether species of concern are likely to be present in the project area during the life of the project. Assessing species use from databases and site characteristics is a potential first step. However, it can be difficult to assess potential use by certain species from site characteristics alone. Various species in different locations may require developers to use specific survey protocols or make certain assumptions regarding presence. Project developers should seek local wildlife expertise, such as Service Field Office staff, in using the proper procedures and making assumptions.

Some species will present particular challenges when trying to determine potential presence. For instance, species that a) are rare or cryptic; b) migrate, conduct other daily movements, or use areas for short periods; c) are small or nocturnal; or d) have become extirpated in parts of their historical range can be difficult to observe. One of these challenges is migration, broadly defined as the act of moving from one spatial unit to another (Baker 1978), or as a periodic movement of animals from one location to another. Migration is species-specific, and for birds and bats occurs throughout the year.

Assessing Site Use/Behavior

Developers should monitor potential sites to determine the types of migratory species present, what type of spatial and temporal use these species make of the site (e.g., chronology of migration or other use), and the ecological function the site may provide in terms of the migration cycle of these species. Wind developers should determine not only what species may migrate through a proposed development site and when, but also whether a site may function as a staging area or stopover habitat for wildlife on their migration pathway.

For some species, movements between foraging and breeding habitat, or between sheltering and feeding habitats, occur on a daily basis. Consideration of daily movements (morning and evening; coming and going) is a critical factor when considering project development.

Duration/Intensity of Studies

Where pre-construction assessments are warranted to help assess risk to wildlife, the studies should be of sufficient duration and intensity to ensure adequate data are collected to accurately characterize wildlife presence and use of the area. In ecological systems, resource quality and quantity can fluctuate rapidly. These fluctuations occur naturally, but human actions can significantly affect (i.e., increase or decrease) natural oscillations. Pre-construction monitoring and assessment of proposed wind energy sites are “snapshots in time,” showing occurrence or no occurrence of a species or habitat at the specific time surveyed. Often due to prohibitive costs, assessments and surveys are conducted for very low percentages (e.g., less than 5 percent) of the available sample time in a given year, however, these data are used to support risk analyses over the projected life of a project (e.g., 30 years of operations).

To establish a trend in site use and conditions that incorporates annual and seasonal variation in meteorological conditions, biological factors, and other variables, pre-construction studies may need to occur over multiple years. However, the level of risk and the question of data requirements will be based on site sensitivity, affected species, and the availability of data from other sources. Accordingly, decisions regarding studies should consider information gathered during the previous tiers, variability within and between seasons, and years where variability is likely to substantially affect answers to the Tier 3 questions. These studies should also be designed to collect data during relevant breeding, feeding, sheltering, staging, or migration periods for each species being studied. Additionally, consideration for the frequency and intensity of pre-construction monitoring should be site-specific and determined through consultation with an expert authority based on their knowledge of the specific species, level of risk and other variables present at each individual site.

Assessing Risk to Species of Concern

Once likely presence and factors such as abundance, frequency of use, habitat use patterns, and behavior have been determined or assumed, the developer should consider and/or determine the consequences to the “populations” and species.

Below is a brief discussion of several types of risk factors that can be considered. This does not include all potential risk factors for all species, but addresses the most common ones.

Collision

Collision likelihood for individual birds and bats at a particular wind energy facility may be the result of complex interactions among species distribution, “relative abundance," behavior, visibility, weather conditions, and site characteristics. Collision likelihood for an individual may be low regardless of abundance if its behavior does not place it within the “rotor-swept zone.” Individuals that frequently occupy the rotor-swept zone but effectively avoid collisions are also at low likelihood of collision with a turbine.

Alternatively, if the behavior of individuals frequently places them in the rotor-swept zone, and they do not actively avoid turbine blade strikes, they are at higher likelihood of collisions with turbines regardless of abundance. Some species, even at lower abundance, may have a higher collision rate than similar species due to subtle differences in their ecology and behavior.

At many projects, the numbers of bat fatalities are higher than the numbers of bird fatalities, but the exposure risk of bats at these facilities is not fully understood. Researchers (Horn et al. 2008 and Cryan 2008) hypothesize that some bats may be attracted to turbines, which, if true, would further complicate estimation of exposure. Further research is required to determine whether bats are attracted to turbines and if so, whether this increased individual risk translates into higher population-scale effects.

Habitat Loss and Degradation

Wind project development results in direct habitat loss and habitat modification, especially at sites previously undeveloped. Many of North America's native landscapes are greatly diminished or degraded from multiple causes unrelated to wind energy. Important remnants of these landscapes are identified and documented in various databases held by private conservation organizations, state wildlife agencies, and, in some cases, by the Service. Species that depend on these landscapes are susceptible to further loss of habitat, which will affect their ability to reproduce and survive. While habitat lost due to footprints of turbines, roads, and other infrastructure is obvious, less obvious is the potential reduction of habitat quality.

Habitat Fragmentation

Habitat fragmentation separates blocks of habitat for some species into segments, such that the individuals in the remaining habitat segments may suffer from effects such as decreased survival, reproduction, distribution, or use of the area. Site clearing, access roads, transmission lines, and arrays of turbine towers may displace some species or fragment continuous habitat areas into smaller, isolated tracts. Habitat fragmentation is of particular concern when species require large expanses of habitat for activities such as breeding, foraging, and sheltering.

Habitat fragmentation can result in increases in “edge” resulting in direct effects of barriers and displacement as well as indirect effects of nest parasitism and predation. Sensitivity to fragmentation effects varies among species. Habitat fragmentation and site modification are important issues that should be assessed at the landscape scale early in the siting process. Identify areas of high sensitivity due to the presence of blocks of native habitats, paying particular attention to known or suspected "species sensitive to habitat fragmentation."

Displacement and Behavioral Changes

Estimating displacement risk requires an understanding of animal behavior in response to a project and its infrastructure and activities, and a pre-construction estimate of presence/absence of species whose behavior would cause them to avoid or seek areas in proximity to turbines, roads, and other components of the project. Displacement is a function of the sensitivity of individuals to the project and activity levels associated with operations.

Indirect Effects

Wind development can also have indirect effects to wildlife and habitats. Indirect effects include reduced nesting and breeding densities and the social ramifications of those reductions; loss or modification of foraging habitat; loss of population vigor and overall population density; increased isolation between habitat patches, loss of habitat refugia; attraction to modified habitats; effects on behavior, physiological disturbance, and habitat unsuitability. Indirect effects can result from introduction of invasive plants; increased predator populations or facilitated predation; alterations in the natural fire regime; or other effects, and can manifest themselves later in time than the causing action.

When collection of both pre- and post-construction data in the areas of interest and reference areas is possible, then the Before-After-Control-Impact (BACI) is the most statistically robust design. The BACI design is most like the classic manipulative experiment.[6] In the absence of a suitable reference area, the design is reduced to a Before-After (BA) analysis of effect where the differences between pre- and post-construction parameters of interest are assumed to be the result of the project, independent of other potential factors affecting the assessment area. With respect to BA studies, the key question is whether the observations taken immediately after the incident can reasonably be expected within the expected range for the system (Manly 2009). Reliable quantification of impact usually will include additional study

Virginia big-eared bat. Credit: USFWS

components to limit variation and the confounding effects of natural factors that may change with time.

The developer's timeline for the development of a wind energy facility often does not allow for the collection of sufficient pre-construction data and/or identification of suitable reference areas to complete a BACI or BA study. Furthermore, alterations in land use or disturbance over the course of a multi-year BACI or BA study may complicate the analysis of study results. Additional discussion of these issues can be found in Tier 5 Study Design Considerations.

Tier 3 Technical Resources

The following methods and metrics are provided as suggested sources for developers to use in answering the Tier 3 questions.

Tier 3, Question 1

Acoustic monitoring can be a practical method for determining the presence of threatened, endangered or otherwise rare species of bats throughout a proposed project (Kunz et al. 2007). There are two general types of acoustic detectors used for collection of information on bat activity and species identification: the full-spectrum, time-expansion and the zero-crossing techniques for ultrasound bat detection (see Kunz et al. 2007 for detailed discussion). Full-spectrum time expansion detectors provide nearly complete species discrimination, while zero-crossing detectors provide reliable and cost-effective estimates of total bat use at a site and some species discrimination. Myotis species can be especially difficult to discriminate with zero-crossing detectors (Kunz et al. 2007). Kunz et al. (2007) describe the strengths and weaknesses of each technique for ultrasonic bat detection, and either type of detector may be useful in most situations except where species identification is especially important and zero-crossing methods are inadequate to provide the necessary data. Bat acoustics technology is evolving rapidly and study objectives are an important consideration when selecting detectors. When rare or endangered species of bats are suspected, sampling should occur during different seasons and at

[6] In this context, such designs are not true experiments in that the treatments (project development and control) are not randomly assigned to an experimental unit, and there is often no true replication. Such constraints are not fatal flaws, but do limit statistical inferences of the results.

multiple sampling stations to account for temporal and spatial variability.

Mist-netting for bats is required in some situations by state agencies, Tribes, and the Service to determine the presence of threatened, endangered or otherwise rare species. Mist-netting is best used in combination with acoustic monitoring to inventory the species of bats present at a site, especially to detect the presence of threatened or endangered species. Efforts should concentrate on potential commuting, foraging, drinking, and roosting sites (Kuenzi and Morrison 1998, O'Farrell et al. 1999). Mist-netting and other activities that involve capturing and handling threatened or endangered species of bats will require permits from state and/or federal agencies.

Tier 3, Question 2

The following protocol should be used to answer Tier 3, Question 2. This protocol for analysis of habitat fragmentation at project sites should be adapted to the species of habitat fragmentation concern as identified in response to Question 5 in Tier 2 and to the landscape in which development is contemplated. The developer should:

1. Define the study area. The study area for the site should include the "footprint" for the proposed facility plus an appropriate surrounding area. The extent of the study area should be based on the area where there is potential for significant adverse habitat impacts, including indirect impacts, within the distribution of habitat for the species of habitat fragmentation concern.

2. Determine the potential for occupancy of the study area based on the guidance provided for the species of habitat fragmentation concern described above in Question 1.

3. Analyze current habitat quality and spatial configuration of the study area for the species of habitat fragmentation concern.

   a. Use recent aerial or remote imagery to determine distinct habitat patches or boundaries within the study area, and the extent of existing habitat fragmenting features.

      i. Assess the level of fragmentation of the existing habitat for the species of habitat fragmentation concern and categorize into three classes:

         - High quality: little or no apparent fragmentation of intact habitat
         - Medium quality: intact habitat exhibiting some recent disturbance activity
         - Low quality: extensive fragmentation of habitat (e.g., row-cropped agricultural lands, active surface mining areas)

      ii. Determine edge and interior habitat metrics of the study area:

         - Identify habitat, non-habitat landscape features and existing fragmenting features relative to the species of habitat fragmentation concern, to estimate existing edge
         - Calculate area and acres of edge
         - Calculate area of intact patches of habitat and compare to needs of species of habitat fragmentation concern

   b. Determine potential changes in quality and spatial configuration of the habitat in the study area if development proceeds as proposed using existing site information and the best available spatial data regarding placement of wind turbines and ancillary infrastructure:

      i. Identify, delineate and classify all additional features added by the development that potentially fragment habitat for the species of habitat fragmentation concern (e.g., roads, transmission lines, maintenance structures, etc.)

      ii. Assess the expected future size and quality of habitat patches for the species of habitat fragmentation concern and the additional fragmenting features, and categorize into three classes as described above

      iii. Determine expected future acreages of edge and interior habitats

      iv. Calculate the area of the remaining patches of intact habitat

   c. Compare pre-construction and expected post-construction fragmentation metrics:

      i. Determine the area of intact habitat lost (to the displacement footprint or by alteration due to the edge effect)

      ii. Identify habitat patches that are expected to be moved to a lower habitat quality classification as a result of the development

4. Assess the likelihood of a significant reduction in the demographic and genetic viability of the local population of the species of habitat fragmentation concern using the habitat fragmentation information collected under item 3 above and any currently available demographic and genetic data. Based on this assessment, the developer makes the finding whether or not there is significant reduction. The developer should share the finding with the relevant agencies. If the developer finds the likelihood of a significant reduction, the developer should

consider items a, b or c below:

a. Consider alternative locations and development configurations to minimize fragmentation of habitat in communication with species experts, for all species of habitat fragmentation concern in the area of interest.

b. Identify high quality habitat parcels that may be protected as part of a plan to limit future loss of habitat for the impacted population of the species of habitat fragmentation concern in the area.

c. Identify areas of medium or low quality habitat within the range of the impacted population that may be restored or improved to compensate for losses of habitat that result from the project (e.g., management of unpaved roads and ORV trails).

Tier 3, Question 3

The following protocols are suggested for use in answering Tier 3, Question 3.

<u>Bird distribution, abundance, behavior and site use</u>

Diurnal Avian Activity Surveys

The commonly used data collection methods for estimating the spatial distribution and relative abundance of diurnal birds includes counts of birds seen or heard at specific survey points (point count), along transects (transect surveys), and observational studies. Both methods result in estimates of bird use, which are assumed to be indices of abundance in the area surveyed. Absolute abundance is difficult to determine for most species and is not necessary to evaluate species risk. Depending on the characteristics of the area of interest and the bird species potentially affected by the project, additional pre-construction study methods may be necessary. Point counts or line transects should collect vertical as well as horizontal data to identify levels of activity within the rotor-swept zone.

Avian point counts should follow the general methodology described by Reynolds et al. (1980) for point counts within a fixed area, or the line transect survey similar to Schaffer and Johnson (2008), where all birds seen within a fixed distance of a line are counted. These methods are most useful for pre- and post-construction studies to quantify avian use of the project site by habitat, determine the presence of species of concern, and to provide a baseline for assessing displacement effects and habitat loss. Point counts for large birds (e.g., raptors) follow the same point count method described by Reynolds et al. (1980), Ralph et al. (1993) and Ralph et al. 1995).

Point count plots, transects, and observational studies should allow for statistical extrapolation of data and be distributed throughout the area of interest using a probability sampling approach (e.g., systematic sample with a random start). For most projects, the area of interest is the area where wind turbines and permanent meteorological (met) towers are proposed or expected to be sited. Alternatively, the centers of the larger plots can be located at vantage points throughout the potential area being considered with the objective of covering most of the area of interest. Flight height should also be collected to focus estimates of use on activity occurring in the rotor-swept zone.

Sampling duration and frequency will be determined on a project-by-project basis and by the questions being addressed. The most important consideration for sampling frequency when estimating abundance is the amount of variation

Hoary bat. Credit: Paul Cryan, USGS

expected among survey dates and locations and the species of concern.

The use of comparable methods and metrics should allow data comparison from plot to plot within the area of interest and from site to site where similar data exist. The data should be collected so that avian activity can be estimated within the rotor-swept zone. Relating use to site characteristics requires that samples of use also measure site characteristics thought to influence use (i.e., covariates such as vegetation and topography) in relation to the location of use. The statistical relationship of use to these covariates can be used to predict occurrence in unsurveyed areas during the survey period and for the same areas in the future.

Surveys should be conducted at different intervals during the year to account for variation in expected bird activity with lower frequency during winter months if avian activity is low. Sampling frequency should also consider the episodic nature of activity during fall and spring migration. Standardized protocols for estimating avian abundance are well-established and should be consulted (e.g., Dettmers et al. 1999). If a more precise estimate of density is required for a particular species (e.g., when the goal is to determine densities of a special-status breeding bird species), the researcher will need more sophisticated sampling procedures, including estimates of detection probability.

Raptor Nest Searches

An estimate of raptor use of the project site is obtained through appropriate surveys, but if potential impacts to breeding raptors are a concern on a project, raptor nest searches are also recommended. These surveys provide information to predict risk to the local breeding population of raptors, for micro-siting decisions, and for developing an appropriate-sized non-disturbance buffer around nests. Surveys also provide baseline data for estimating impacts and determining mitigation requirements. A good source of information for raptor surveys and monitoring is Bird and Bildstein (2007).

Red-tailed hawk. Credit: Dave Menke, USFWS

Searches for raptor nests or raptor breeding territories on projects with potential for impacts to raptors should be conducted in suitable habitat during the breeding season. While there is no consensus on the recommended buffer zones around nest sites to avoid disturbance of most species (Sutter and Jones 1981), a nest search within at least one mile of the wind turbines and transmission lines, and other infrastructure should be conducted. However, larger nest search areas are needed for eagles, as explained in the Service's ECP Guidance, when bald or golden eagles are likely to be present.

Methods for these surveys are fairly common and will vary with the species, terrain, and vegetation within the survey area. The Service recommends that protocols be discussed with biologists from the lead agency, Service, state wildlife agency, and Tribes where they have jurisdiction. It may be useful to consult other scientifically credible information sources. At minimum, the protocols should contain the list of target raptor species for nest surveys and the appropriate search protocol for each site, including timing and number of surveys needed, search area, and search techniques.

Prairie Grouse and Sage Grouse Population Assessments

Sage grouse and prairie grouse merit special attention in this context for three reasons:

1. The scale and biotic nature of their habitat requirements uniquely position them as reliable indicators of impacts on, and needs of, a suite of species that depend on sage and grassland habitats, which are among the nation's most diminished ecological communities (Vodehnal and Haufler 2007).

2. Their ranges and habitats are highly congruent with the nation's richest inland wind resources.

3. They are species for which some known impacts of anthropogenic features (e.g., tall structures, buildings, roads, transmission lines, wind energy facilities, etc.) have been documented.

Populations of prairie grouse and sage grouse generally are assessed by either lek counts (a count of the maximum number of males attending a lek) or lek surveys (classification of known leks as active or inactive) during the breeding season (e.g., Connelly et al. 2000). Methods for lek counts vary slightly by species but in general require repeated visits to known sites and a systematic search of all suitable habitat for leks, followed by repeated visits to active leks to estimate the number of grouse using them.

Recent research indicates that viable prairie grouse and sage grouse populations are dependent on suitable nesting and brood-rearing habitat (Connelly et al. 2000, Hagen et al. 2009). These habitats generally are associated with leks. Leks are the approximate centers of nesting and brood-rearing habitats (Connelly et al. 2000, but see Connelly et al. 1988 and Becker et al. 2009). High quality nesting and brood rearing habitats surrounding leks are critical to sustaining viable prairie grouse and sage grouse populations (Giesen and Connelly 1993, Hagen et al. 2004, Connelly et al. 2000). A population assessment study area should include nesting and brood rearing habitats that may extend several miles from leks. For example, greater and lesser prairie-chickens generally nest in suitable habitats within one to two miles of active leks (Hagen et al. 2004), whereas the average distances from nests to active leks of non-migratory sage grouse range from 0.7 to four miles (Connelly et al. 2000), and potentially much more for migratory populations (Connelly et al. 1988).

While surveying leks during the spring breeding season is the most common and convenient tool for monitoring population trends of prairie grouse and sage grouse, documenting available nesting and brood rearing habitat within and adjacent to the potentially affected area is recommended. Suitable nesting and brood rearing habitats can be mapped based on habitat requirements of individual species. The distribution and abundance of nesting and brood rearing habitats can be used to help in the assessment of adverse impacts of the proposed project to prairie grouse and sage grouse.

Mist-Netting for Birds

Mist-netting is not recommended as a method for assessing risk of wind development for birds. Mist-netting cannot generally be used to develop indices of relative bird abundance, nor does it provide an estimate of collision risk as mist-netting is not feasible at the heights of the rotor-swept zone and captures below that zone may not adequately reflect risk. Operating mist-nets requires considerable experience, as well as state and federal permits.

Occasionally mist-netting can help confirm the presence of rare species at documented fallout or migrant stopover sites near a proposed project. If mist-netting is to be used, the Service recommends that procedures for operating nets and collecting data be followed in accordance with Ralph et al. (1993).

Nocturnal and Crepuscular Bird Survey Methods

Additional studies using different methods should be conducted if characteristics of the project site and surrounding areas potentially pose a high risk of collision to night migrating songbirds and other nocturnal or crepuscular species. For most of their flight, songbirds and other nocturnal migrants are above the reach of wind turbines, but they pass through the altitudinal range of wind turbines during ascents and descents and may also fly closer to the ground during inclement weather (Able, 1970; Richardson, 2000). Factors affecting flight path, behavior, and "fall-out" locations of nocturnal migrants are reviewed elsewhere (e.g., Williams et al., 2001; Gauthreaux and Belser, 2003; Richardson, 2000; Mabee et al., 2006).

In general, pre-construction nocturnal studies are not recommended unless the site has features that might strongly concentrate nocturnal birds, such as along coastlines that are known to be migratory songbird corridors. Biologists knowledgeable about nocturnal bird migration and familiar with patterns of migratory stopovers in the region should assess the potential risks to nocturnal migrants at a proposed project site. No single method can adequately assess the spatial and temporal variation in nocturnal bird populations or the potential collision risk. Following nocturnal study methods in Kunz et al. (2007) is recommended to determine relative abundance, flight direction and flight altitude for assessing risk to migrating birds, if warranted. If areas of interest are within the range of nocturnal species of concern (e.g., marbled murrelet, northern spotted owl, Hawaiian petrel, Newell's shearwater), surveyors should use species-specific protocols recommended by state wildlife agencies, Tribes or Service to assess the species' potential presence in the area of interest.

In contrast to the diurnal avian survey techniques previously described, considerable variation and uncertainty exist on the optimal protocols for using acoustic monitoring devices, radar, and other techniques to evaluate species composition, relative abundance, flight height, and trajectory of nocturnal migrating birds. While an active area of research, the use of radar for determining passage rates, flight heights and flight directions of nocturnal migrating animals has yet to be shown as a good indicator of collision risk. Pre- and post-construction studies comparing radar monitoring results to estimates of bird and bat fatalities will be necessary to evaluate radar as a tool for predicting collision risk. Additional studies are also needed before making recommendations on the number of nights per season or the number of hours per night that are appropriate for radar studies of nocturnal bird migration (Mabee et al., 2006).

<u>Bat survey methods</u>

The Service recommends that all techniques discussed below be conducted by biologists trained in bat identification, equipment use, and the analysis and interpretation of data resulting from the design and conduct of the studies. Activities that involve capturing and handling bats may require permits from state and/or federal agencies.

Acoustic Monitoring

Acoustic monitoring provides information about bat presence and activity, as well as seasonal changes in species occurrence and use, but does not measure the number of individual bats or population density. The goal of acoustic monitoring is to provide a prediction of the potential risk of bat fatalities resulting from the construction and operation of a project. Our current state of knowledge about bat-wind turbine interactions, however, does not allow a quantitative link between pre-construction acoustic assessments of bat activity and operations fatalities. Discussions with experts, state wildlife trustee agencies, Tribes, and

Tri-colored bat. Credit: USFWS

Service will be needed to determine whether acoustic monitoring is warranted at a proposed project site.

The predominance of bat fatalities detected to date are migratory species and acoustic monitoring should adequately cover periods of migration and periods of known high activity for other (i.e., non-migratory) species. Monitoring for a full year is recommended in areas where there is year round bat activity. Data on environmental variables such as temperature and wind speed should be collected concurrently with acoustic monitoring so these weather data can be used in the analysis of bat activity levels.

The number and distribution of sampling stations necessary to adequately estimate bat activity have not been well established but will depend, at least in part, on the size of the project area, variability within the project area, and a Tier 2 assessment of potential bat occurrence.

The number of detectors needed to achieve the desired level of precision will vary depending on the within-site variation (e.g., Arnett et al. 2006, Weller 2007, See also, Bat Conservation International website for up-to-date survey methodologies). One frequently used method is to place acoustic detectors on existing met towers, approximately every two kilometers across the site where turbines are expected to be sited. Acoustic detectors should be placed at high positions (as high as practicable, based on tower height) on each met tower included in the sample to record bat activity at or near the rotor swept zone, the area of presumed greatest risk for bats. Developers should evaluate whether it would be cost effective to install detectors when met towers are first established on a site. Doing so might reduce the cost of installation later and might alleviate time delays to conduct such studies.

If sampling at met towers does not adequately cover the study area or provide sufficient replication, additional sampling stations can be established at low positions (~1.5-2 meters) at a sample of existing met towers and one or more mobile units (i.e., units that are moved to different locations throughout the study period) to increase coverage of the proposed project area. When practical and based on information from Tier 2, it may be appropriate to conduct some acoustic monitoring of features identified as potentially high bat use areas within the study area (e.g., bat roosts and caves) to determine use of such features.

There is growing interest in determining whether "low" position samples (~1.5-2 meters) can provide equal or greater correlation with bat fatalities than "high" position samples (described above) because this would substantially lower cost of this work. Developers could then install a greater number of detectors at lower cost resulting in improved estimates of bat activity and, potentially, improved qualitative estimates of risk to bats. This is a research question that is not expected to be addressed at a project.

<u>Other bat survey techniques</u>

Occasionally, other techniques may be needed to answer Tier 3 questions and complement the information from acoustic surveys. Kunz et al. (2007), NAS (2007), Kunz and Parsons (2009) provide comprehensive descriptions of bat survey techniques, including those identified below that are relevant for Tier 3 studies at wind energy facilities.

Roost Searches and Exit Counts

Pre-construction survey efforts may be recommended to determine whether known or likely bat roosts in mines, caves, bridges, buildings, or other potential roost sites occur within the project vicinity, and to confirm whether known or likely bat roosts are present and occupied by bats. If active roosts are detected, it may be appropriate to address questions about colony size and species composition of roosts. Exit counts and roost searches are two approaches to answering these questions, and Rainey (1995), Kunz and Parsons (2009), and Sherwin et al. (2009) are resources that describe options and approaches for these techniques. Roost searches should be performed cautiously because roosting bats are sensitive to human disturbance (Kunz et al. 1996). Known maternity and hibernation roosts should not be entered or otherwise disturbed unless authorized by state and/or federal wildlife agencies. Internal searches of abandoned mines or caves can be dangerous and should only be conducted by trained researchers. For mine survey protocol and guidelines for protection of bat roosts, see the appendices in Pierson et al. (1999). Exit surveys at known roosts generally should be limited to non-invasive observation using low-light binoculars and infrared video cameras.

Multiple surveys should be conducted to determine the presence or absence of bats in caves and mines, and the number of surveys needed will vary by species of bats, sex (maternity or bachelor colony) of bats, seasonality of use, and type of roost structure (e.g., caves or mines). For example, Sherwin et al. (2003) demonstrated that a minimum of three surveys are needed to determine the absence of large hibernating colonies of Townsend's big-eared bats in mines (90 percent probability), while a minimum of nine surveys (during a single warm season) are necessary before a mine could be eliminated as a bachelor roost for this species (90 percent probability). An average of three surveys was needed before surveyed caves could be eliminated as bachelor roosts (90 percent probability). The Service recommends that decisions on level of effort follow discussion with relevant agencies and bat experts.

Activity Patterns

If active roosts are detected, it may be necessary to answer questions about behavior, movement patterns, and patterns of roost use for bat species of concern, or to further investigate habitat features that might attract bats and pose fatality risk. For some bat species, typically threatened, endangered, or state-listed species, radio telemetry or radar may be recommended to assess both the direction of movement as bats leave roosts, and the bats' use of the area being considered for development. Kunz et al. (2007) describe the use of telemetry, radar and other tools to evaluate use of roosts, activity patterns, and flight direction from roosts.

Mist-Netting for Bats

While mist-netting for bats is required in some situations by state agencies, Tribes, and the Service to determine the presence of threatened, endangered or other bat species of concern, mist-netting is not generally recommended for determining levels of activity or assessing risk of wind energy development to bats for the following reasons: 1) not all proposed or operational wind energy facilities offer conditions conducive to capturing bats, and often the number of suitable sampling points is minimal or not closely associated with the project location; 2) capture efforts often occur at water sources offsite or at nearby roosts and the results may not reflect species presence or use on the site where turbines are to be erected; and 3) mist-netting isn't feasible at the height of the rotor-swept zone, and captures below that zone may not adequately reflect risk of fatality. If mist-netting is employed, it is best used in combination with acoustic monitoring to inventory the species of bats present at a site.

White-Nose Syndrome

White-nose syndrome is a disease affecting hibernating bats. Named for the white fungus that appears on the muzzle and other body parts of hibernating bats, WNS is associated with extensive mortality of bats in eastern North America. All contractors and consultants hired by developers should employ the most current version of survey and handling protocols to avoid transmitting white-nose syndrome between bats.

Mule deer. Credit: Tupper Ansel Blake, USFWS

Other wildlife

While the above guidance emphasizes the evaluation of potential impacts to birds and bats, Tier 1 and 2 evaluations may identify other species of concern. Developers are encouraged to assess adverse impacts potentially caused by development for those species most likely to be negatively affected by such development. Impacts to other species are primarily derived from potential habitat loss or displacement. The general guidance on the study design and methods for estimation of the distribution, relative abundance, and habitat use for birds is applicable to the study of other wildlife. References regarding monitoring for other wildlife are available in Appendix C:

Sources of Information Pertaining to Methods to Assess Impacts to Wildlife. Nevertheless, most methods and metrics will be species-specific and developers are advised to work with the state, tribal, or federal agencies, or other credible experts, as appropriate, during problem formulation for Tier 3.

Tier 3 Decision Points

Developers and the Service should communicate prior to completing the Tier 3 decision process. A developer should inform the Service of the results of its studies and plans. The Service will provide written comments to a developer on study and project development plans that identify concerns and recommendations to resolve the concerns. The developer and, when applicable, the permitting authority will make a decision regarding whether and how to develop the project. The decision point at the end of Tier 3 involves three potential outcomes:

1. Development of the site has a low probability of significant adverse impact based on existing and new information.

   There is little uncertainty regarding when and how development should proceed, and adequate information exists to satisfy any required permitting. The decision process proceeds to permitting, when required, and/or development, and Tier 4.

2. Development of the site has a moderate to high probability of significant adverse impacts without proper measures being taken to mitigate those impacts. This outcome may be subdivided into two possible scenarios:

   a. There is certainty regarding how to develop the site to adequately mitigate significant adverse impacts. The developer bases their decision to develop the site adopting proper mitigation measures and appropriate post-construction fatality and habitat studies (Tier 4).

Little brown bat with white nose syndrome. Credit: Marvin Moriarty, USFWS

   b. There is uncertainty regarding how to develop the site to adequately mitigate significant adverse impacts, or a permitting process requires additional information on potential significant adverse wildlife impacts before permitting future phases of the project. The developer bases their decision to develop the site adopting proper mitigation measures and appropriate post-construction fatality and habitat studies (Tier 4).

3. Development of the site has a high probability of significant impact that:

   a. Cannot be adequately mitigated.

   Site development should be delayed until plans can be developed that satisfactorily mitigate for the significant adverse impacts. Alternatively, the site should be abandoned in favor of known sites with less potential for environmental impact, or the developer begins an evaluation of other sites or landscapes for more acceptable sites to develop.

   b. Can be adequately mitigated.

   Developer should implement mitigation measures and proceed to Tier 4.

Chapter 5: Tier 4 – Post-construction Studies to Estimate Impacts

The outcome of studies in Tiers 1, 2, and 3 will determine the duration and level of effort of post-construction studies.

Tier 4 post-construction studies are designed to assess whether predictions of fatality risk and direct and indirect impacts to habitat of species of concern were correct. Fatality studies involve searching for bird and bat carcasses beneath turbines to estimate the number and species composition of fatalities (Tier 4a). Habitat studies involve application of GIS and use data collected in Tier 3 and Tier 4b and/or published information. Post-construction studies on direct and indirect impacts to habitat of species of concern, including species of habitat fragmentation concern need only be conducted if Tier 3 studies indicate the potential for significant adverse impacts.

Tier 4a – Fatality Studies

At this time, community- and utility-scale projects should conduct at least one year of fatality monitoring. The intensity of the studies should be related to risks of significant adverse impacts identified in pre-construction assessments. As data collected with consistent methods and metrics increases (see discussion below), it is possible that some future projects will not warrant fatality monitoring, but such a situation is rare with the present state of knowledge.

Fatality monitoring should occur over all seasons of occupancy for the species being monitored, based on information produced in previous tiers. The number of seasons and total length of the monitoring may be determined separately for bats and birds, depending on the pre-construction risk assessment, results of Tier 3 studies and Tier 4 monitoring from comparable sites (see Glossary in Appendix A) and

A male Eastern red bat perches among green foliage. Credit: ©MerlinD.Tuttle,BatConservationInternational,www.batcon.org

the results of first year fatality monitoring. Guidance on the relationship between these variables and monitoring for fatalities is provided in Table 2.

It may be appropriate to conduct monitoring using different durations and intervals depending on the species of concern. For example, if raptors occupy an area year-round, it may be appropriate to monitor for raptors throughout the year (12 months). It may be warranted to monitor for bats when they are active (spring, summer and fall or approximately eight months). It may be appropriate to increase the search frequency during the months bats are active and decrease the frequency during periods of inactivity. All fatality monitoring should include estimates of carcass removal and carcass detection bias likely to influence those rates.

Tier 4a Questions

Post-construction fatality monitoring should be designed to answer the following questions as appropriate for the individual project:

1. **What are the bird and bat fatality rates for the project?**
2. **What are the fatality rates of species of concern?**
3. **How do the estimated fatality rates compare to the predicted fatality rates?**
4. **Do bird and bat fatalities vary within the project site in relation to site characteristics?**
5. **How do the fatality rates compare to the fatality rates from existing projects in similar landscapes with similar species composition and use?**
6. **What is the composition of fatalities in relation to migrating and resident birds and bats at the site?**
7. **Do fatality data suggest the need for measures to reduce impacts?**

Tier 4a studies should be of sufficient statistical validity to address Tier 4a questions and enable determination of whether Tier 3 fatality predictions were correct. Fatality monitoring results also should allow comparisons with other sites, and provide a basis for determining if operational changes or other mitigation measures at the site are appropriate. The Service encourages project operators to discuss Tier 4 studies with local, state, federal, and tribal wildlife agencies. The number of years of monitoring is based on outcomes of Tier 3 and Tier 4 studies and analysis of comparable Tier 4 data from other projects as indicated in Table 2. The Service may recommend multiple years of monitoring for projects located near a listed species or bald or golden eagle, or other situations, as appropriate.

Tier 4a Protocol Design Considerations

The basic method of measuring fatality rates is the carcass search. Search protocols should be standardized to the greatest extent possible, especially for common objectives and species of concern, and they should include methods for adequately accounting for sampling biases (searcher efficiency and scavenger removal). However, some situations warrant exceptions to standardized protocol. The responsibility of demonstrating that an exception is appropriate and applicable should be on the project operator to justify increasing or decreasing the duration or intensity of operations monitoring.

Some general guidance is given below with regard to the following fatality monitoring protocol design issues:

- Duration and frequency of monitoring
- Number of turbines to monitor
- Delineation of carcass search plots, transects, and habitat mapping
- General search protocol
- Field bias and error assessment
- Estimators of fatality

More detailed descriptions and methods of fatality search protocols can be found in the California (California Energy Commission 2007) and Pennsylvania (Pennsylvania Game Commission 2007) state guidelines and in Kunz et al. (2007), Smallwood (2007), and Strickland et al. (2011).

<u>Duration and frequency of monitoring</u>

Frequency of carcass searches (search interval) may vary for birds and bats, and will vary depending on the questions to be answered, the species of concern, and their seasonal abundance at the project site. The carcass searching protocol should be adequate to answer applicable Tier 4 questions at an appropriate level of precision to make general conclusions about the project, and is not intended to provide highly precise measurements of fatalities. Except during low use times (e.g. winter months in northern states), the Service recommends that protocols be designed such that carcass searches occur at some turbines within the project area most days each week of the study.

The search interval is the interval between carcass searches at individual turbines, and this interval may be lengthened or shortened depending on the carcass removal rates. If the primary focus is on fatalities of large raptors, where carcass removal is typically low, then a longer interval between searches (e.g., 14-28 days) is sufficient. However, if the focus is on fatalities of bats and small birds and carcass removal is high, then a shorter search interval will be necessary.

There are situations in which studies of higher intensity (e.g., daily searches at individual turbines within the sample) may be appropriate. These would be considered only in Tier 5 studies or in research programs because the greater complexity and level of effort goes beyond that recommended for typical Tier 4 post construction monitoring. Tier 5 and research studies could include evaluation of specific measures that have been implemented to mitigate potential significant adverse impacts to species of concern identified during pre-construction studies.

Number of turbines to monitor

If available, data on variability among turbines from existing

Wind turbine. Credit: NREL

projects in similar conditions within the same region are recommended as a basis for determining needed sample size (see Morrison et al., 2008). If data are not available, the Service recommends that an operator select a sufficient number of turbines via a systematic sample with a random start point. Sampling plans can be varied (e.g., rotating panels [McDonald 2003, Fuller 1999, Breidt and Fuller 1999, and Urquhart et al. 1998]) to increase efficiency as long as a probability sampling approach is used. If the project contains fewer than 10 turbines, the Service recommends that all turbines in the area of interest be searched unless otherwise agreed to by the permitting or wildlife resource agencies. When selecting turbines, the Service recommends that a systematic sample with a random start be used when selecting search plots to ensure interspersion among turbines. Stratification among different habitat types also is recommended to account for differences in fatality rates among different habitats (e.g., grass versus cropland or forest); a sufficient number of turbines should be sampled in each strata.

Delineation of carcass search plots, transects, and habitat mapping

Evidence suggests that greater than 80 percent of bat fatalities fall within half the maximum distance of turbine height to ground (Erickson 2003 a, b), and a minimum plot width of 120 meters from the turbine should be established at sample turbines. Plots will need to be larger for birds, with a width twice the turbine height to ground. Decisions regarding search plot size should be made in discussions with the Service, state wildlife agency, permitting agency and Tribes. It may be useful to consult other scientifically credible information sources.

The Service recommends that each search plot should be divided into oblong subplots or belt transects and that each subplot be searched. The objective is to find as many carcasses as possible so the width of the belt will vary depending on the ground cover and its influence on carcass visibility. In most situations, a search width of 6 meters should be adequate, but this may vary from 3-10 meters depending on ground cover.

Searchable area within the theoretical maximum plot size varies, and heavily vegetated areas (e.g., eastern mountains) often do not allow surveys to consistently extend to the maximum plot width. In other cases it may be preferable to search a portion of the maximum plot instead of the entire plot. For example, in some landscapes it may be impractical to search the entire plot because of the time required to do an effective search, even if it is accessible (e.g., croplands), and data from a probability sample of subplots within the maximum plot size can provide a reasonable estimate of fatalities. It is important to accurately delineate and map the area searched for each turbine to adjust fatality estimates based on the actual area searched. It may be advisable to establish habitat visibility classes in each plot to account for differential detectability, and to develop visibility classes for different landscapes (e.g., rocks, vegetation) within each search plot. For example, the Pennsylvania Game Commission (2007) identified four classes based on the percentage of bare ground.

The use of visibility classes requires that detection and removal biases be estimated for each class. Fatality estimates should be made for each class and summed for the total area sampled. Global positioning systems (GPS) are useful for accurately mapping the actual total area searched and area searched in each habitat visibility class, which can be used to adjust fatality estimates. The width of the belt or subplot searched may vary depending on the habitat and species of concern; the key is to determine actual searched area and area searched in each visibility class regardless of transect width. An adjustment may also be needed to take into account the density of fatalities as a function of the width of the search plot.

General search protocol

Personnel trained in proper search techniques should look for bird and bat carcasses along transects or subplots within each plot and record and collect all carcasses located in the searchable areas. The Service will work with developers and operators to provide necessary permits for carcass possession. A complete search of the area should be accomplished and subplot size (e.g., transect width) should be adjusted to compensate for detectability differences in the search area. Subplots should be smaller when vegetation makes it difficult to detect carcasses; subplots can be wider in open terrain. Subplot width also can vary depending on the size of the species being looked for. For example, small species such as bats may require smaller subplots than larger species such as raptors.

Data to be recorded include date, start time, end time, observer, which turbine area was searched (including GPS coordinates) and weather data for each search. When a dead bat or bird is found, the searcher should place a flag near the carcass and continue the search. After searching the entire plot, the searcher returns to each carcass and records information on a fatality data sheet, including date, species, sex and age (when possible), observer name, turbine number, distance from turbine, azimuth from turbine (including GPS coordinates), habitat surrounding carcass, condition of carcass (entire, partial, scavenged), and estimated time of death (e.g., <1 day, 2 days). The recorded data will ultimately be housed in the FWS Office of Law Enforcement Bird Mortality Reporting System. A digital photograph of the carcass should be taken. Rubber gloves should be used to handle all carcasses to eliminate possible transmission of rabies or other diseases and to reduce possible human scent bias for carcasses later used in scavenger removal trials. Carcasses should be placed in a plastic bag and labeled. Unless otherwise conditioned by the carcass possession permit, fresh carcasses (those determined to have been killed the night immediately before a search) should be redistributed at random points on the same day for scavenging trials.

Field bias and error assessment

During searches conducted at wind turbines, actual fatalities are likely incompletely observed. Therefore carcass counts must be adjusted by some factor that accounts for imperfect detectability (Huso 2011). Important sources of bias and error include: 1) fatalities that occur on a highly periodic basis; 2) carcass removal by scavengers; 3) differences in searcher efficiency; 4) failure to account for the influence of site (e.g. vegetation) conditions in relation to carcass removal and searcher efficiency; and 5) fatalities or injured birds and bats that may land or move outside search plots.

Some fatalities may occur on a highly periodic basis creating a potential sampling error (number 1 above). The Service recommends that sampling be scheduled so that some turbines are searched most days and episodic events are more likely detected, regardless of the search interval. To address bias sources 2-4 above, it is strongly recommended that all fatality studies conduct carcass removal and searcher efficiency trials using accepted methods (Anderson 1999, Kunz et al. 2007, Arnett et al. 2007, NRC 2007, Strickland et al. 2011). Bias trials should be conducted throughout the entire study period and searchers should be unaware of which turbines are to be used or the number of carcasses placed beneath those turbines during trials. Carcasses or injured individuals may land or move outside the search plots (number 5 above). With respect to Tier 4a fatality estimates, this potential sampling error is considered to be small and can be assumed insignificant (Strickland et al. 2011).

Prior to a study's inception, a list of random turbine numbers and random azimuths and distances (in meters) from turbines should be generated for placement of each bat or bird used in bias trials. Data recorded for each trial carcass prior to placement should include date of placement, species, turbine number, distance and direction from turbine, and visibility class surrounding the carcass. Trial carcasses should be distributed as equally as possible among the different visibility classes throughout the study period and study area. Studies should attempt to avoid "over-seeding" any one turbine with carcasses by placing no more than one or two carcasses at any one time at a given turbine. Before placement, each carcass must be uniquely marked in a manner that does not cause additional attraction, and its location should be recorded. There is no agreed upon sample size for bias trials, though some state guidelines recommend from 50 - 200 carcasses (e.g., PGC 2007).

Estimators of fatality

If there were a direct relationship between the number of carcasses observed and the number killed, there would be no need to develop a complex estimator that adjusts observed counts for detectability, and observed counts could be used as a simple index of fatality (Huso 2011). But the relationship is not direct and raw carcass counts recorded using different search intervals and under different carcass removal rates and searcher efficiency rates are not directly comparable. It is strongly recommended that only the most contemporary equations for estimating fatality be used, as some original versions are now known to be extremely biased under many commonly encountered field conditions (Erickson et al. 2000b, Erickson et al. 2004, Johnson et al. 2003, Kerns and Kerlinger 2004, Fiedler et al. 2007, Kronner et al. 2007, Smallwood 2007, Huso 2011, Strickland et al. 2011).

Tier 4a Study Objectives

In addition to the monitoring protocol design considerations described above, the metrics used to estimate fatality rates must be selected with the Tier 4a questions and objectives in mind. Metrics considerations for each of the Tier 4a questions are discussed briefly below. Not all questions will be relevant for each project, and which questions apply would depend on Tier 3 outcomes.

1. What are the bird and bat fatality rates for the project?

The primary objective of fatality searches is to determine the overall estimated fatality rates for birds and bats for the project. These rates serve as the fundamental basis for all comparisons of fatalities, and if studies are designed appropriately they allow researchers to relate fatalities to site characteristics and environmental variables, and to evaluate mitigation measures. Several metrics are available for expressing fatality rates. Early studies reported fatality rates per turbine. However, this metric is somewhat misleading as turbine sizes and their risks to birds vary significantly (NRC 2007). Fatalities are frequently reported per nameplate capacity (i.e. MW), a metric that is easily calculated and better for comparing fatality rates among different sized turbines. Even with turbines of the same name plate capacity, the size of the rotor swept area may vary among manufacturers, and turbines at various sites may operate for different lengths of time and during different times of the day and seasons. With these considerations in mind, the Service recommends that fatality rates be expressed on a per-turbine and per-nameplate MW basis until a better metric becomes available.

2. What are the fatality rates of species of concern?

This analysis simply involves calculating fatalities per turbine of all species of concern at a site when sample sizes are sufficient to do so. These fatalities should be expressed on a per nameplate MW basis if comparing species fatality rates among projects.

3. How do the estimated fatality rates compare to the predicted fatality rates?

There are several ways that predictions can be evaluated with actual fatality data. During the planning stages in Tier 2, predicted fatalities may be based on existing data at similar facilities in similar landscapes used by similar species. In this case, the assumption is that use is similar, and therefore that fatalities may be similar at the proposed facility. Alternatively, metrics derived from pre-construction assessments for an individual species or group of species – usually an index of activity or abundance at a proposed project – could be used in conjunction with use and fatality estimates from existing projects to develop a model for predicting fatalities at the proposed project site. Finally, physical models can be used to predict the probability of a bird of a particular size striking a turbine, and this probability, in conjunction with estimates of use and avoidance behavior, can be used to predict fatalities.

The most current equations for estimating fatality should be used to evaluate fatality predictions. Several statistical methods can be found in the revised Strickland et al. 2011 and used to evaluate fatality predictions. Metrics derived from Tier 3 pre-construction assessments may be correlated with fatality rates, and (using the project as the experimental unit), in Tier 5 studies it should be possible to determine if different preconstruction metrics can in fact accurately predict fatalities and, thus, risk.

4. Do bird and bat fatalities vary within the project site in relation to site characteristics?

Data from pre-construction studies can demonstrate patterns of activity that may depend upon the site characteristics. Turbines placed near escarpments or cliffs may intrude upon airspace used by raptors soaring on thermals. Pre-construction and post construction studies and assessments can be used to avoid siting individual, specific turbines within an area used by species of concern. Turbine-specific fatality rates may be related to site characteristics such as proximity to water, forest edge, staging and roosting sites, known stop-over sites, or other key resources, and this relationship may be estimated using regression analysis. This information is particularly useful for evaluating micro-siting options when planning a future facility or, on a broader scale, in determining the location of the entire project.

5. How do the fatality rates compare to the fatality rates from existing facilities in similar landscapes with similar species composition and use?

Comparing fatality rates among facilities with similar characteristics can be useful to determine patterns and broader landscape relationships. Developers should communicate with the Service to ensure that such comparisons are appropriate to avoid false conclusions. Fatality rates should be expressed on a per nameplate MW or some other standardized metric basis for comparison with other projects,

Big brown bat. Credit: USFWS

and may be correlated with site characteristics – such as proximity to wetlands, riparian corridors, mountain-foothill interface, wind patterns, or other broader landscape features – using regression analysis. Comparing fatality rates from one project to fatality rates of other projects provides insight into whether a project has relatively high, moderate or low fatalities.

6. What is the composition of fatalities in relation to migrating and resident birds and bats at the site?

The simplest way to address this question is to separate fatalities per turbine of known resident species (e.g., big brown bat, prairie horned lark) and those known to migrate long distances (e.g. hoary bat, red-eyed vireo). These data are useful in determining patterns of species composition of fatalities and possible mitigation measures directed at residents, migrants, or perhaps both, and can be used in assessing potential population effects.

[7] In situations where a project operator was not the developer, the Service expects that obligations of the developer for adhering to the Guidelines transfer with the project.

Table 2. Decision Framework for Tier 4a Fatality Monitoring of Species of Concern.[8]

Probability of Significant Adverse Impacts in Tier 3	*Recommended Fatality Monitoring Duration and Effort*	*Possible Outcomes of Monitoring Results*
Tier 3 Studies indicate LOW probability of significant adverse impacts	Duration: At least one year of fatality monitoring to estimate fatalities of birds and bats. Field assessments should be sufficient to confirm that risk to birds and/or bats is indeed "low."	1. Documented fatalities are approximately equal to or lower than predicted risk. No further fatality monitoring or mitigation is needed. 2. Fatalities are greater than predicted, but are not likely to be significant (i.e., unlikely to affect the long-term status of the population). If comparable fatality data at similar sites also supports that impacts are not likely to be high enough to affect population status, no further monitoring or mitigation is needed. If no comparable fatality data are available or such data indicates high risk, one additional year of fatality monitoring is recommended. If two years of fatality monitoring indicate levels of impacts that are not significant, no further fatality monitoring or mitigation is recommended. 3. Fatalities are greater than predicted and are likely to be significant OR federally endangered or threatened species or BGEPA species are affected. Communication with the Service is recommended. Further efforts to address impacts to BGEPA or ESA species may be warranted, unless otherwise addressed in an ESA or BGEPA take permit.
Tier 3 studies indicate MODERATE probability of significant adverse impacts	Duration: Two or more years of fatality monitoring may be necessary. Field assessments should be sufficient to confirm that risk to birds and/or bats is indeed "moderate." Closely compare estimated effects to species to those determined from the risk assessment protocol(s).	1. Documented fatalities after the first two years are lower or not different than predicted and are not significant and no federally endangered species or BGEPA species are affected - no further fatality monitoring or mitigation is needed. 2. Fatalities are greater than predicted and are likely to be significant OR federally endangered or threatened species or BGEPA species are affected, communication with the Service is recommended. Further efforts to address impacts to BGEPA or ESA species may be warranted, unless otherwise addressed in an ESA or BGEPA take permit.
Tier 3 studies indicate HIGH probability of significant adverse impacts	Duration: Two or more years of fatality monitoring may be necessary to document fatality patterns. If fatality is high, developers should shift emphasis to exploring opportunities for mitigation rather than continuing to monitor fatalities. If fatalities are variable, additional years are likely warranted.	1. Documented fatalities during each year of fatality monitoring are less than predicted and are not likely to be significant, and no federally endangered or threatened species or BGEPA species are affected – no further fatality monitoring or mitigation is needed. 2. Fatalities are equal to or greater than predicted and are likely to be significant - further efforts to reduce impacts are necessary; communication with the Service are recommended. Further efforts, such as Tier 5 studies, to address impacts to BGEPA or ESA species may be warranted, unless otherwise addressed in an ESA or BGEPA take permit.

[8] Ensure that survey protocols, and searcher efficiency and scavenger removal bias correction factors are the most reliable, robust, and up to date (after Huso 2009).

7. **Do fatality data suggest the need for measures to reduce impacts?**

The Service recommends that the wind project operator[7] and the relevant agencies discuss the results from Tier 4 studies to determine whether these impacts are significant. If fatalities are considered significant, the wind project operator and the relevant agencies should develop a plan to mitigate the impacts.

Tier 4b – Assessing direct and indirect impacts of habitat loss, degradation, and fragmentation

The objective of Tier 4b studies is to evaluate Tier 3 predictions of direct and indirect impacts to habitat and the potential for significant adverse impacts on species of concern as a result of these impacts. Tier 4b studies should be conducted if Tier 3 studies indicate the presence of species of habitat fragmentation concern, or if Tier 3 studies indicate significant direct and indirect adverse impacts to species of concern (see discussion below). Tier 4b studies should also inform project operators and the Service as to whether additional mitigation is necessary.

Tier 4b studies should evaluate the following questions:

1. **How do post-construction habitat quality and spatial configuration of the study area compare to predictions for species of concern identified in Tier 3 studies?**

2. **Were any behavioral modifications or indirect impacts noted in regard to species of concern?**

3. **If significant adverse impacts were predicted for species of concern, and the project was altered to mitigate for adverse impacts, were those efforts successful?**

4. **If significant adverse impacts were predicted for species of concern, and the project was altered to mitigate for adverse impacts, were those efforts successful?**

The answers to these questions will be based on information estimating habitat loss, degradation, and fragmentation information collected in Tier 3, currently available demographic and genetic data, and studies initiated in Tier 3. As in the case of Tier 4a, the answers to these questions will determine the need to conduct Tier 5 studies. For example, in the case that significant adverse impacts to species of concern were predicted, but mitigation was not successful, then additional mitigation and Tier 5 studies may be necessary. See Table 3 for further guidance.

1. **How do post-construction habitat quality and spatial configuration of the study area compare to predictions for species of concern identified in Tier 3 studies?**

GIS and demographic data collected in Tier 3 and/or published information can be used to determine predictions of impacts to species of concern from habitat loss, degradation, and fragmentation. The developer can provide development assumptions based on Tier 3 information that can be compared to post-construction information. Additional post-construction studies on impacts to species of concern due to direct and indirect impacts to habitat should only be conducted if Tier 3 studies indicate the potential for significant adverse impacts.

2. **Were any behavioral modifications or indirect impacts noted in regard to affected species?**

Evaluation of this question is based on the analysis of observed use of the area by species of concern prior to construction in comparison with observed use during operation. Observations and demographic data collected during Tier 3, and assessment of published information about the potential for displacement and demographic responses to habit impacts could be the basis for this analysis. If this analysis suggests that direct and/or indirect loss of habitat for a species of concern leads to behavioral modifications or displacement that are significant, further studies of these impacts in Tier 5 may be appropriate.

3. **If significant adverse impacts were not predicted in Tier 3 because of loss, degradation, or fragmentation of habitat, but Tier 4b studies indicate such impacts have the potential to occur, can these impacts be mitigated?**

When Tier 4b studies indicate significant impacts may be occurring, the developer may need to conduct an assessment of these impacts and what opportunities exist for additional mitigation.

4. **If significant adverse impacts were predicted for species of concern, and the project was altered to mitigate for adverse impacts, were those efforts successful?**

When Tier 4b studies indicate significant impacts may be occurring, the developer may need to conduct an assessment of these impacts and what opportunities exist for additional mitigation. Evaluation of the effectiveness of mitigation is a Tier 4 study and should follow design considerations discussed in Tier 5 and from guidance in the scientific literature (e.g. Strickland et al. 2011).

When Tier 3 studies identified potential moderate or high risks to species of concern that caused a developer to incorporate mitigation measures into the project, Tier 4b studies should evaluate the effectiveness of those mitigation measures. Determining such effectiveness is important for the project being evaluated to ascertain whether additional mitigation measures are appropriate as well as informing future decisions about how to improve mitigation at wind energy facilities being developed.

Tier 4b Protocol Design Considerations

Impacts to a species of concern resulting from the direct and indirect loss of habitat are important and must be considered when a wind project is being considered for development. Some species of concern are likely to occur at every proposed wind energy facility. This occurrence may range from a breeding population, to seasonal occupancy, such as a brief occurrence while migrating through the area. Consequently the level of concern regarding impacts due to direct and indirect loss of habitat will vary depending on the species and the impacts that occur.

If a breeding population of a species of habitat fragmentation concern occurs in the project area and Tier 3 studies indicate that fragmentation of their habitat is possible, these predictions should be evaluated following the guidance indicated in Table 3 using the protocols described in Tier 3. If the analysis of post-construction GIS data on direct and indirect habitat loss suggests that fragmentation is likely, then additional displacement studies and mitigation may be necessary. These studies would typically begin immediately and would be considered Tier 5 studies using design considerations illustrated by examples in Tier 5 below and from guidance in the scientific literature (e.g. Strickland et al. 2011).

Significant direct or indirect loss of habitat for a species of concern may occur without habitat fragmentation if project impacts result in the reduction of a habitat resource that potentially is limiting to the affected population. Impacts of this type include loss of use of breeding habitat or loss of a significant portion of the habitat of a federally or state protected species. This would be evaluated by determining the amount of the resource that is lost and determining if this loss would potentially result in significant impacts to the affected population. Evaluation of potential significant impacts would occur in Tier 5 studies that measure the demographic response of the affected population.

Black-capped Vireo. Credit: Greg W. Lasley

The intention of the Guidelines is to focus industry and agency resources on the direct and indirect loss of habitat and limiting resources that potentially reduce the viability of a species of concern. Not all direct and indirect loss of a species' habitat will affect limiting resources for that species, and when habitat losses are minor or non-existent no further study is necessary.

Tier 4b Decision Points

The developer should use the results of the Tier 4b studies to evaluate whether further studies and/or mitigation are needed. The developer should communicate the results of these studies, and decisions about further studies and mitigation, with the Service. Table 3 provides a framework for evaluating the need for further studies and mitigation. Level of effort for studies should be sufficient to answer all questions of interest. Refer to the relevant methods sections for Tier 2 Question 5 and Tier 3 Question 2 in the text for specific guidance on study protocols.

Table 3. Decision Framework to Guide Studies for Minimizing Impacts to Habitat and Species of Habitat Fragmentation (HF) Concern.

Outcomes of Tier 2	*Outcomes of Tier 3*	*Outcomes of Tier 4b*	*Suggested Study/Mitigation*
• No species of HF concern potentially present	• No further studies needed	• n/a	• n/a
• Species of HF concern potentially present	• No species of HF concern confirmed to be present	• No further studies needed	• n/a
	• Species of HF concern demonstrated to be present, but no significant adverse impacts predicted	• Tier 4b studies confirm Tier 3 predictions	• No further studies or mitigation needed
		• Tier 4b studies indicate potentially significant adverse impacts	• Tier 5 studies and mitigation may be needed
• Species of HF concern potentially present	• Species of HF concern demonstrated to be present; significant adverse impacts predicted • Mitigation plan developed and implemented	• Tier 4b studies determine mitigation plan is effective; no significant adverse impacts demonstrated • Tier 4b studies determine mitigation plan is NOT effective; potentially significant adverse impacts	• No further studies or mitigation needed • Further mitigation and, where appropriate, Tier 5 studies

Chapter 6: Tier 5 – Other Post-construction Studies

Tier 5 studies will not be necessary for most wind energy projects. Tier 5 studies can be complex and time consuming. The Service anticipates that the tiered approach will steer projects away from sites where Tier 5 studies would be necessary.

When Tier 5 studies are conducted, they should be site-specific and intended to: 1) analyze factors associated with impacts in those cases in which Tier 4 analyses indicate they are potentially significant; 2) identify why mitigation measures implemented for a project were not adequate; and 3) assess demographic effects on local populations of species of concern when demographic information is important, including species of habitat fragmentation concern.

Tier 5 Questions

Tier 5 studies are intended to answer questions that fall in three major categories; answering yes to any of these questions might indicate a Tier 5 study is needed:

1. **To the extent that the observed fatalities exceed anticipated fatalities, are those fatalities potentially having a significant adverse impact on local populations? Are observed direct and indirect impacts to habitat having a significant adverse impact on local populations?**

For example, in the Tier 3 risk assessment, predictions of collision fatalities and habitat impacts (direct and indirect) are developed. Post-construction studies in Tier 4 evaluate the accuracy of those predictions by estimating impacts. If post-construction studies demonstrate potentially significant adverse impacts, Tier 5 studies may also be warranted and should be designed to understand observed versus predicted impacts.

2. **Were mitigation measures implemented (other than fee in lieu) not effective? This includes habitat mitigation measures as well as measures undertaken to reduce collision fatalities.**

Tier 4a and b studies can assess the effectiveness of measures taken to reduce direct and indirect impacts as part of the project and to identify such alternative or additional measures as are necessary. If alternative or additional measures were unsuccessful, the reasons why would be evaluated using Tier 5 studies.

3. **Are the estimated impacts of the proposed project likely to lead to population declines in the species of concern (other than federally-listed species)?**

Impacts of a project will have population level effects if the project causes a population decline in the species of concern. For non-listed species, this assessment will apply only to the local population.

Wind turbines and habitat. Credit: NREL

Tier 5 studies may need to be conducted when:

- Realized fatality levels for individual species of concern reach a level at which they are considered significant adverse impacts by the relevant agencies.

  For example, if Tier 4a fatality studies document that a particular turbine or set of turbines exhibits bird or bat collision fatality higher than predicted, Tier 5 studies may be useful in evaluating alternative mitigation measures at that turbine/turbine string.

- There is the potential for significant fatality impacts or significant adverse impacts to habitat for species of concern, there is a need to assess the impacts more closely, and there is uncertainty over how these impacts will be mitigated.

- Fatality and/or significant adverse habitat impacts suggest the potential for a reduction in the viability of an affected population, in which case studies on the potential for population impacts may be warranted.

- A developer evaluates the effectiveness of a risk reduction measure before deciding to continue the measure permanently or whether to use the measure when implementing future phases of a project.

  In the event additional turbines are proposed as an expansion of an existing project, results from Tier 4 and Tier 5 studies and the decision-making framework contained in the tiered approach can be used to determine whether the project should be expanded and whether additional information should be collected. It may also be necessary to evaluate whether additional measures are warranted to reduce significant adverse impacts to species.

Tier 5 Study Design Considerations

As discussed in Chapter 4 Tier 3, Tier 5 studies will be highly variable and unique to the circumstances of the individual project, and therefore these Guidelines do not provide specific guidance on all potential approaches, but make some general statements about study design. Specific Tier 5 study designs will depend on the types of questions, the specific project, and practical considerations. The most common practical considerations include the area being studied, the time period of interest, the species of concern, potentially confounding variables, time available to conduct studies, project budget, and the magnitude of the anticipated impacts. When possible it is usually desirable to collect data before construction to address Tier 5 questions. Design considerations for these studies are including in Tier 3.

One study design is based on an experimental approach to evaluating mitigation measures, where the project proponent will generally select several alternative management approaches to design, implement, and test. The alternatives are generally incorporated into sound experimental designs. Monitoring and evaluation of each alternative helps the developer to decide which alternative is more effective in meeting objectives, and informs adjustments to the next round of management decisions. The need for this type of study design can be best determined by communication between the project operator, the Service field office, and the state wildlife agency, on a project-by-project basis. This study design requires developers and operators to identify strategies to adjust management and/or mitigation measures if monitoring indicates that anticipated impacts are being exceeded. Such strategies should include a timeline for periodic reviews and adjustments as well as a mechanism to consider and implement additional mitigation measures as necessary after the project is developed.

When pre-construction data are unavailable and/or a suitable reference area is lacking, the reference Control Impact Design (Morrison et al. 2008) is the recommended design. The lack of a suitable reference area also can be addressed using the Impact Gradient Design, when habitat and species use are homogenous in the assessment area prior to development. When applied both pre- and post-construction, the Impact Gradient Design is a suitable replacement for the classic BACI (Morrison et al. 2008).

In the study of habitat impacts, the resource selection function (RSF) study design (see Anderson et al 1999; Morrison et al. 2008; Manly et al. 2002) is a statistically robust design, either with or without pre-construction and reference data. Habitat selection is modeled as a function of characteristics measured on resource units and the use of those units by the animals of interest. The RSF allows the estimation of the probability of use as a function of the distance to various environmental features, including wind energy facilities, and thus provides a direct quantification of the magnitude of the displacement effect. RSF could be improved with pre-construction and reference area data. Nevertheless, it is a relatively powerful approach to documenting displacement or the effect of mitigation measures designed to reduce displacement even without those additional data.

Tier 5 Examples

As described earlier, Tier 5 studies will not be conducted at most projects, and the specific Tier 5 questions and methods for addressing these questions will depend on the individual project and the concerns raised during pre-construction studies and during operational phases. Rather than provide specific guidance on all potential approaches, these Guidelines offer the following case studies as examples of studies that have attempted to answer Tier 5 questions.

<u>Habitat impacts - displacement and demographic impact studies</u>

Rows of wind turbines. Credit: Joshua Winchell, USFWS

Studies to assess impacts may include quantifying species' habitat loss (e.g., acres of lost grassland habitat for grassland songbirds) and habitat modification. For example, an increase in edge may result in greater nest parasitism and nest predation. Assessing indirect impacts may include two important components: 1) indirect effects on wildlife resulting from displacement, due to disturbance, habitat fragmentation, loss, and alteration; and 2) demographic effects that may occur at the local, regional or population-wide levels due to reduced nesting and breeding densities, increased isolation between habitat patches, and effects on behavior (e.g., stress, interruption, and modification). These factors can individually or cumulatively affect wildlife, although some species may be able to habituate to some or perhaps all habitat changes. Indirect impacts may be difficult to quantify but their effects may be significant (e.g., Stewart et al. 2007, Pearce-Higgins et al. 2008, Bright et al. 2008, Drewitt and Langston 2006, Robel et al. 2004, Pruett et al. 2009).

Example: in southwestern Pennsylvania, development of a project is proceeding at a site located within the range of a state-listed terrestrial species. Surveys were performed at habitat locations appropriate for use by the animal, including at control sites. Post-construction studies are planned at all locations to demonstrate any displacement effects resulting from the construction and operation of the project.

The Service recognizes that indirect impact studies may not be appropriate for most individual projects. Consideration should be given to developing collaborative research efforts with industry, government agencies, and NGOs to conduct studies to address indirect impacts.

Indirect impacts are considered potentially significant adverse threats to species such as prairie grouse (prairie chickens, sharp-tailed grouse), and sage grouse, and demographic studies may be necessary to determine the extent of these impacts and the need for mitigation.

Displacement studies may use any of the study designs describe earlier. The most scientifically robust study designs to estimate displacement effects are BACI, RSF, and impact gradient. RSF and impact gradient designs may not require specialized data gathering during Tier 3.

Telemetry studies that measure impacts of the project development on displacement, nesting, nest success, and survival of prairie grouse and sage grouse in different environments (e.g., tall grass, mixed grass, sandsage, sagebrush) will require spatial and temporal replication, undisturbed reference sites, and large sample sizes covering large areas. Examples of study designs and analyses used in the studies of other forms of energy development are presented in Holloran et al. (2005), Pitman et al. (2005), Robel et al. (2004), and Hagen et al. (2011). Anderson et al. (1999) provides a thorough discussion of the design, implementation, and analysis of these kinds of field studies and should be consulted when designing the BACI study.

Studies are being initiated to evaluate effects of wind energy development on greater sage grouse in Wyoming. In addition to measuring demographic patterns, these studies will use the RSF study design (see Sawyer et al. 2006) to estimate the probability of sage grouse use as a function of the distance to environmental features, including an existing and a proposed project.

In certain situations, such as for a proposed project site that is relatively small and in a more or less homogeneous landscape, an impact gradient design may be an appropriate means to assess avoidance of the wind energy facility by resident populations (Strickland et al., 2002). For example, Leddy et al. 1999 used the impact gradient design to evaluate grassland bird density as a function of the distance from wind turbines. Data were collected at various distances from turbines along transects.

This approach provides information on whether there is an effect, and may allow quantification of the gradient of the effect and the distance at which the displacement effect no longer exists – the assumption being that the data collected at distances beyond the influence of turbines are the reference data (Erickson et al., 2007). An impact gradient analysis could also involve measuring the number of breeding grassland birds counted at point count plots as a function of distance from the wind turbines (Johnson et al. 2000).

Sound and Wildlife

Turbine blades at normal operating speeds can generate levels of sound beyond ambient background levels. Construction and maintenance activities can also contribute to sound levels by affecting communication distance, an animal's ability to detect calls or danger, or to forage. Sound associated with developments can also cause behavioral and/or physiological effects, damage to hearing from acoustic over-exposure, and masking of communication signals and other biologically relevant sounds (Dooling and Popper 2007). Some birds are able to shift their vocalizations to reduce the masking effects of noise. However, when shifts don't occur or are insignificant, masking may prove detrimental to the health and survival of wildlife (Barber et al. 2010). Data suggest noise increases of 3 dB to 10 dB correspond to 30 percent to 90 percent reductions in alerting distances for wildlife, respectively (Barber et al. 2010).

The National Park Service has been investigating potential impacts to wildlife due to alterations in sound level and type. However, further research is needed to better understand this potential impact. Research may include: how wind facilities affect background sound levels; whether masking, disturbance, and acoustical fragmentation occur; and how turbine, construction, and maintenance sound levels can vary by topographic area.

<u>Levels of fatality beyond those predicted</u>

More intensive post-construction fatality studies may be used to determine relationships between fatalities and weather, wind speed or other covariates, which usually require daily carcass searches. Fatalities determined to have occurred the previous night can be correlated with that night's weather or turbine characteristics to establish important relationships that can then be used to evaluate the most effective times and conditions to implement measures to reduce collision fatality at the project.

<u>Measures to address fatalities</u>

The efficacy of operational changes (e.g. changing turbine cut-in speed) of a project to reduce collision fatalities has only recently been evaluated (Arnett et al. 2009, Baerwald et al 2009). Operational changes to address fatalities should be applied only at sites where collision fatalities are predicted or demonstrated to have significant adverse impacts.

Tier 5 Studies and Research

The Service makes a distinction between Tier 5 studies focused on project-specific impacts and research (which is discussed earlier in the Guidelines). For example, developers may be encouraged to participate in collaborative studies (see earlier discussion of Research) or asked to conduct a study on an experimental mitigation technique, such as differences in turbine cut-in speed to reduce bat fatalities. Such techniques may show promise in mitigating the impacts of wind energy development to wildlife, but their broad applicability for mitigation purposes has not been demonstrated. Such techniques should not be routinely applied to projects, but application at appropriate sites will contribute to the breadth of knowledge regarding the efficacy of such measures in addressing collision fatalities. In addition, studies involving multiple sites and academic researchers can provide more robust research results, and such studies take more time and resources than are appropriately carried out by one developer at a single site. Examples below demonstrate collaborative research efforts to address displacement, operational changes, and population level impacts.

<u>Studies of Indirect Effects</u>

The Service provides two examples below of ongoing studies to assess the effects of indirect impacts related to wind energy facilities.

Kansas State University, as part of the NWCC Grassland Shrub-steppe Species Collaborative, is undertaking a multi-year research project to assess the effects of wind energy facilities on populations of greater prairie-chickens (GPCH) in Kansas. Initially the research was based on a Before/After Control/Impact (BACI) experimental design involving three replicated study sites in the Flint Hills and Smoky Hills of eastern Kansas. Each study site consisted of an impact area where a wind energy facility was proposed to be developed and a nearby reference area with similar rangeland characteristics where no development was planned. The research project is a coordinated field/laboratory effort, i.e., collecting telemetry and observational data from adult and juvenile GPCH in the field, and determining population genetic attributes of GPCH in the laboratory from blood samples of birds and the impact and reference areas. Detailed data on GPCH movements, demography, and population genetics were gathered from all three sites from 2007 to 2010. By late 2008, only one of the proposed wind energy facilities was developed (the Meridian Way Wind Farm in the Smoky Hills of Cloud County), and on-going research efforts are focused on that site. The revised BACI study design now will produce two years of pre-construction data (2007 and 2008), and three years of post-construction data (2009, 2010, and 2011) from a single wind energy facility site (impact area) and its reference area. Several hypotheses were formulated for testing to determine if wind energy facilities impacted GPCH populations, including but not limited to addressing issues relating to: lek attendance, avoidance of turbines and associated features, nest success and chick survival, habitat usage, adult mortality and survival, breeding behavior, and natal dispersal. A myriad of additional significant avenues are being pursued as a result of the rich database that has been developed for the GPCH during this research effort. GPCH reproductive data will be collected through the summer of 2011 whereas collection of data from transmitter-equipped GPCH will extend through the lekking season of 2012 to allow estimates of survival of GPCH over the 2011-2012 winter. At the conclusion of the study, the two years of pre-construction data and three years of post-construction data will be analyzed and submitted to peer-reviewed journals for publication.

Erickson et al. (2004) evaluated the displacement effect of a large wind energy facility in the Pacific Northwest. The study was conducted in a relatively homogeneous grassland landscape. Erickson et al. (2004) conducted surveys of breeding grassland birds along 300 meter transects perpendicular to strings of wind turbines. Surveys were conducted prior to construction and after commercial operation. The basic study design follows the Impact Gradient Design (Morrison et al. 2008) and in this application, conformed to a special case of BACI where areas at the distal end of each transect were considered controls (i.e., beyond the influence of the turbines). In this study, there is no attempt to census birds in the area, and observations per survey are used as an index of abundance. Additionally, the impact-gradient study design resulted in less effort than a BACI design with offsite control areas. Erickson et al. (2004) found that grassland passerines as a group, as well as grasshopper sparrows and western meadowlarks, showed reduced use in the first 50 meter segment nearest the turbine string. About half of the area within that segment, however, had disturbed vegetation and separation of behavior avoidance from physical loss of habitat in this portion of the area was impossible. Horned larks and savannah sparrows appeared unaffected. The impact gradient design is best used when the study area is relatively small and homogeneous.

<u>Operational Changes to Reduce Collision Fatality</u>

Arnett et al. (2009) conducted studies on the effectiveness of changing turbine cut-in speed on reducing bat fatality at wind turbines at the Casselman Wind Project in Somerset County, Pennsylvania. Their objectives were to: 1) determine the difference in bat fatalities at turbines with different cut-in-speeds relative to fully operational turbines; and 2) determine the economic costs of the experiment and estimated costs for the entire area of interest under different curtailment prescriptions and timeframes. Arnett et al. (2009) reported substantial reductions in bat fatalities with relatively modest power losses.

In Kenedy County, Texas, investigators are refining and testing a real-time curtailment protocol. The projects use an avian profiling radar system to detect approaching "flying vertebrates" (birds and bats), primarily during spring and fall bird and bat migrations. The blades automatically idle when risk reaches a certain level and weather conditions are particularly risky. Based on estimates of the number and timing of migrating raptors, feathering (real-time curtailment) experiments are underway in Tehuantepec, Mexico, where raptor migration through a mountain pass is extensive.

Other tools, such as thermal imaging (Horn et al. 2008) or acoustic detectors (Kunz et al. 2007), have been used to quantify post-construction bat activity in relation to weather and turbine characteristics for improving operational change efforts. For example, at the Mountaineer project in 2003, Tier 4 studies (weekly searches at every turbine) demonstrated unanticipated and high levels of bat fatalities (Kerns and Kerlinger 2004). Daily searches were instituted in 2004 and revealed that fatalities were strongly associated with low-average-wind-speed nights, thus providing a basis for testing operational changes (Arnett 2005, Arnett et al. 2008). The program also included behavioral observations using thermal imaging that demonstrated higher bat activity at lower wind speeds (Horn et al. 2008).

Studies are currently underway to design and test the efficacy of an acoustic deterrent device to reduce bat fatalities at wind facilities (E.B. Arnett, Bat Conservation International, under the auspices of BWEC). Prototypes of the device have been tested in the laboratory and in the field with some success. Spanjer (2006) tested the response of big brown bats to a prototype eight speaker deterrent emitting broadband white noise at frequencies from 12.5–112.5 kHz and found that during non-feeding trials, bats landed in the quadrant containing the device significantly less when it was broadcasting broadband noise. Spanjer (2006) also reported that during feeding trials, bats never successfully took a tethered mealworm when the device broadcast sound, but captured mealworms near the device in about 1/3 of trials when it was silent. Szewczak and Arnett (2006, 2007) tested the same acoustic deterrent in the field and found that when placed by the edge of a small pond where nightly bat activity was consistent, activity dropped significantly on nights when the deterrent was activated. Horn et al. (2007) tested the effectiveness of a larger, more powerful version of this deterrent device on reducing nightly bat activity and found mixed results. In 2009, a new prototype device was developed and tested at a project in Pennsylvania. Ten turbines were fitted with deterrent devices, daily fatality searches were conducted, and fatality estimates were compared with those from 15 turbines without deterrents (i.e., controls) to determine if bat fatalities were reduced. This experiment found that estimated bat fatalities per turbine were 20 to 53 percent lower at treatment turbines compared to controls.

More experimentation is required. At the present time, there is not an operational deterrent available that has demonstrated effective reductions in bat kills (E. B. Arnett, Bat Conservation International, unpublished data).

Assessment of Population-level Impacts

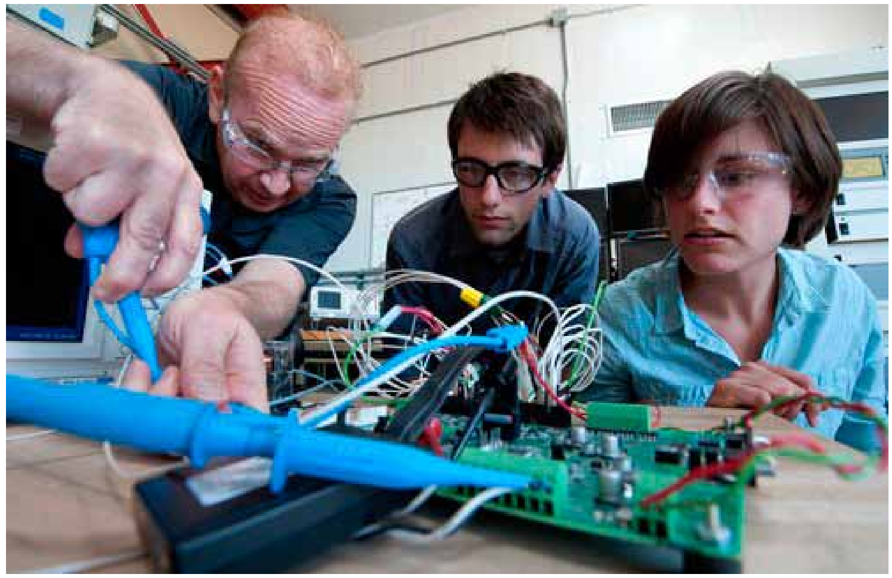
The Altamont Pass Wind Resource Area (APWRA) has been the subject of intensive scrutiny because of avian fatalities, especially for raptors, in an area encompassing more than 5,000 wind turbines (e.g., Orloff and Flannery 1992; Smallwood and Thelander 2004, 2005). Field studies on golden eagles, a long-lived raptor species, have been completed using radio telemetry at APWRA to understand population demographics, assess impacts from wind turbines, and explore measures to effectively reduce the incidence of golden eagle mortality for this area. (Hunt et al. 1999, and Hunt 2002). Results from nesting surveys (Hunt 2002) indicated that there was no decline in eagle territory occupancy. However Hunt (2002) also found that subadult and floater components of golden eagle populations at APWRA are highly vulnerable to wind turbine mortality and results from this study indicate that turbine mortality prevented the maintenance of substantial reserves of nonbreeding adults characteristic of healthy populations elsewhere, suggesting the possibility of an eventual decline in the breeding population (Hunt and Hunt 2006). Hunt conducted follow-up surveys in 2005 (Hunt and Hunt 2006) and determined that all 58 territories occupied by eagle pairs in 2000 were occupied in 2005. It should be noted however that golden eagle studies at APWRA (Hunt et al. 1999, Hunt 2002, and Hunt and Hunt 2006) were all conducted after the APWRA was constructed and the species does not nest within the footprint of the APWRA itself (Figure 4; Hunt and Hunt 2006). The APWRA is an area of about 160 sq. km (Hunt 2002) and presumably golden eagles formerly nested within this area. The loss of breeding eagle pairs from the APWRA suggests these birds have all been displaced

Golden eagle. Credit: George Gentry, USFWS

by the project, or lost due to various types of mortality including collisions with turbine blades.

Chapter 7: Best Management Practices

Site Construction and Operation


Wind electronic developers. Credit: NREL

During site planning and development, careful attention to reducing risk of adverse impacts to species of concern from wind energy projects, through careful site selection and facility design, is recommended. The following BMPs can assist a developer in the planning process to reduce potential impacts to species of concern. Use of these BMPs should ensure that the potentially adverse impacts to most species of concern and their habitats present at many project sites would be reduced, although compensatory mitigation may be appropriate at a project level to address significant site-specific concerns and pre-construction study results.

These BMPs will evolve over time as additional experience, learning, monitoring and research becomes available on how to best minimize wildlife and habitat impacts from wind energy projects. Service should work with the industry, stakeholders and states to evaluate, revise and update these BMPs on a periodic basis, and the Service should maintain a readily available publication of recommended, generally accepted best practices.

1. Minimize, to the extent practicable, the area disturbed by pre-construction site monitoring and testing activities and installations.

2. Avoid locating wind energy facilities in areas identified as having a demonstrated and unmitigatable high risk to birds and bats.

3. Use available data from state and federal agencies, and other sources (which could include maps or databases), that show the location of sensitive resources and the results of Tier 2 and/or 3 studies to establish the layout of roads, power lines, fences, and other infrastructure.

4. Minimize, to the maximum extent practicable, roads, power lines, fences, and other infrastructure associated with a wind development project. When fencing is necessary, construction should use wildlife compatible design standards.

5. Use native species when seeding or planting during restoration. Consult with appropriate state and federal agencies regarding native species to use for restoration.

6. To reduce avian collisions, place low and medium voltage connecting power lines associated with the wind energy development underground to the extent possible, unless burial of the lines is prohibitively expensive (e.g., where shallow bedrock exists) or where greater adverse impacts to biological resources would result:

   a. Overhead lines may be acceptable if sited away from high bird crossing locations, to the extent practicable, such as between roosting and feeding areas or between lakes, rivers, prairie grouse and sage grouse leks, and nesting habitats. To the extent practicable, the lines should be marked in accordance with Avian Power Line Interaction Committee (APLIC) collision guidelines.

   b. Overhead lines may be used when the lines parallel tree lines, employ bird flight diverters, or are otherwise screened so that collision risk is reduced.

   c. Above-ground low and medium voltage lines, transformers and conductors should follow the 2006 or most recent APLIC "Suggested Practices for Avian Protection on Power Lines."

7. Avoid guyed communication towers and permanent met towers at wind energy project sites. If guy wires are necessary,

bird flight diverters or high visibility marking devices should be used.

8. Where permanent meteorological towers must be maintained on a project site, use the minimum number necessary.

9. Use construction and management practices to minimize activities that may attract prey and predators to the wind energy facility.

10. Employ only red, or dual red and white strobe, strobe-like, or flashing lights, not steady burning lights, to meet Federal Aviation Administration (FAA) requirements for visibility lighting of wind turbines, permanent met towers, and communication towers. Only a portion of the turbines within the wind project should be lighted, and all pilot warning lights should fire synchronously.

11. Keep lighting at both operation and maintenance facilities and substations located within half a mile of the turbines to the minimum required:

    a. Use lights with motion or heat sensors and switches to keep lights off when not required.

    b. Lights should be hooded downward and directed to minimize horizontal and skyward illumination.

    c. Minimize use of high-intensity lighting, steady-burning, or bright lights such as sodium vapor, quartz, halogen, or other bright spotlights.

    d. All internal turbine nacelle and tower lighting should be extinguished when unoccupied.

12. Establish non-disturbance buffer zones to protect sensitive habitats or areas of high risk for species of concern identified in pre-construction studies. Determine the extent of the buffer zone in consultation with the Service and state, local and tribal wildlife biologists, and land management agencies (e.g., U.S. Bureau of Land Management (BLM) and U.S. Forest Service (USFS)), or other credible experts as appropriate.

13. Locate turbines to avoid separating bird and bat species of concern from their daily roosting, feeding, or nesting sites if documented that the turbines' presence poses a risk to species.

14. Avoid impacts to hydrology and stream morphology, especially where federal or state-listed aquatic or riparian species may be involved. Use appropriate erosion control measures in construction and operation to eliminate or minimize runoff into water bodies.

15. When practical use tubular towers or best available technology to reduce ability of birds to perch and to reduce risk of collision.

16. After project construction, close roads not needed for site operations and restore these roadbeds to native vegetation, consistent with landowner agreements.

17. Minimize the number and length of access roads; use existing roads when feasible.

18. Minimize impacts to wetlands and water resources by following all applicable provisions of the Clean Water Act (33 USC 1251-1387) and the Rivers and Harbors Act (33 USC 301 et seq.); for instance, by developing and implementing a storm water management plan and taking measures to reduce erosion and avoid delivery of road-generated sediment into streams and waters.

19. Reduce vehicle collision risk to wildlife by instructing project personnel to drive at appropriate speeds, be alert for wildlife, and use additional caution in low visibility conditions.

20. Instruct employees, contractors, and site visitors to avoid harassing or disturbing wildlife, particularly during reproductive seasons.

21. Reduce fire hazard from vehicles and human activities (instruct employees to use spark arrestors on power equipment, ensure that no metal parts are dragging from vehicles, use caution with open flame, cigarettes, etc.). Site development and operation plans should specifically address the risk of wildfire and provide appropriate cautions and measures to be taken in the event of a wildfire.

22. Follow federal and state measures for handling toxic substances to minimize danger to water and wildlife resources from spills. Facility operators should maintain Hazardous Materials Spill Kits on site and train personnel in the use of these.

23. Reduce the introduction and spread of invasive species by following applicable local policies for invasive species prevention, containment, and control, such as cleaning vehicles and equipment arriving from areas with known invasive species issues, using locally sourced topsoil, and monitoring for and rapidly removing invasive species at least annually.

24. Use invasive species prevention and control measures as specified by county or state requirements, or by applicable federal agency requirements (such as Integrated Pest Management) when federal policies apply.

25. Properly manage garbage and waste disposal on project sites to avoid creating attractive nuisances for wildlife by providing them with supplemental food.

26. Promptly remove large animal carcasses (e.g., big game,

domestic livestock, or feral animal).

27. Wildlife habitat enhancements or improvements such as ponds, guzzlers, rock or brush piles for small mammals, bird nest boxes, nesting platforms, wildlife food plots, etc. should not be created or added to wind energy facilities. These wildlife habitat enhancements are often desirable but when added to a wind energy facility result in increased wildlife use of the facility which may result in increased levels of injury or mortality to them.

Retrofitting, Repowering, and Decommissioning

As with project construction, these Guidelines offer BMPs for the retrofitting, repowering, and decommissioning phases of wind energy projects.

Retrofitting

Retrofitting is defined as replacing portions of existing wind turbines or project facilities so that at least part of the original turbine, tower, electrical infrastructure or foundation is being utilized. Retrofitting BMPs include:

1. Retrofitting of turbines should use installation techniques that minimize new site disturbance, soil erosion, and removal of vegetation of habitat value.

2. Retrofits should employ shielded, separated or insulated electrical conductors that minimize electrocution risk to avian wildlife per APLIC (2006).

3. Retrofit designs should prevent nests or bird perches from being established in or on the wind turbine or tower.

4. FAA visibility lighting of wind turbines should employ only red, or dual red and white strobe, strobe-like, or flashing lights, not steady burning lights.

5. Lighting at both operation and maintenance facilities and substations located within half a mile of the turbines should be kept to the minimum required:

   a. Use lights with motion or heat sensors and switches to keep lights off when not required.

   b. Lights should be hooded downward and directed to minimize horizontal and skyward illumination.

   c. Minimize use of high intensity lighting, steady-burning, or bright lights such as sodium vapor, quartz, halogen, or other bright spotlights.

6. Remove wind turbines when they are no longer cost effective to retrofit.

Repowering

Repowering may include removal and replacement of turbines and associated infrastructure. BMPs include:

1. To the greatest extent practicable, existing roads, disturbed areas and turbine strings should be re-used in repower layouts.

2. Roads and facilities that are no longer needed should be demolished, removed, and their footprint stabilized and re-seeded with native plants appropriate for the soil conditions and adjacent habitat and of local seed sources where feasible, per landowner requirements and commitments.

3. Existing substations and ancillary facilities should be re-used in repowering projects to the extent practicable.

4. Existing overhead lines may be acceptable if located away from high bird crossing locations, such as between roosting and feeding areas, or between lakes, rivers and nesting areas. Overhead lines may be used when they parallel tree lines, employ bird flight diverters, or are otherwise screened so that collision risk is reduced.

5. Above-ground low and medium voltage lines, transformers and conductors should follow the 2006 or most recent APLIC "Suggested Practices for Avian Protection on Power Lines."

6. Guyed structures should be avoided. If use of guy wires is absolutely necessary, they should be treated with bird flight diverters or high visibility marking devices, or are located where known low bird use will occur.

7. FAA visibility lighting of wind turbines should employ only red, or dual red and white strobe, strobe-like, or flashing lights, not steady burning lights.

8. Lighting at both operation and maintenance facilities and substations located within ½ mile of the turbines should be kept to the minimum required.

   a. Use lights with motion or heat sensors and switches to keep lights off when not required.

   b. Lights should be hooded downward and directed to minimize horizontal and skyward illumination.

Towers are being lifted as work continues on the 2 MW Gamesa wind turbine that is being installed at the NWTC. Credit: NREL

c. Minimize use of high intensity lighting, steady-burning, or bright lights such as sodium vapor, quartz, halogen, or other bright spotlights.

Decommissioning

Decommissioning is the cessation of wind energy operations and removal of all associated equipment, roads, and other infrastructure. The land is then used for another activity. During decommissioning, contractors and facility operators should apply BMPs for road grading and native plant re-establishment to ensure that erosion and overland flows are managed to restore pre-construction landscape conditions. The facility operator, in conjunction with the landowner and state and federal wildlife agencies, should restore the natural hydrology and plant community to the greatest extent practical.

1. Decommissioning methods should minimize new site disturbance and removal of native vegetation, to the greatest extent practicable.

2. Foundations should be removed to a minimum of three feet below surrounding grade, and covered with soil to allow adequate root penetration for native plants, and so that subsurface structures do not substantially disrupt ground water movements. Three feet is typically adequate for agricultural lands.

3. If topsoils are removed during decommissioning, they should be stockpiled and used as topsoil when restoring plant communities. Once decommissioning activity is complete, topsoils should be restored to assist in establishing and maintaining pre-construction native plant communities to the extent possible, consistent with landowner objectives.

4. Soil should be stabilized and re-vegetated with native plants appropriate for the soil conditions and adjacent habitat, and of local seed sources where feasible, consistent with landowner objectives.

5. Surface water flows should be restored to pre-disturbance conditions, including removal of stream crossings, roads, and pads, consistent with storm water management objectives and requirements.

6. Surveys should be conducted by qualified experts to detect populations of invasive species, and comprehensive approaches to preventing and controlling invasive species should be implemented and maintained as long as necessary.

7. Overhead pole lines that are no longer needed should be removed.

8. After decommissioning, erosion control measures should be installed in all disturbance areas where potential for erosion exists, consistent with storm water management objectives and requirements.

9. Fencing should be removed unless the landowner will be utilizing the fence.

10. Petroleum product leaks and chemical releases should be remediated prior to completion of decommissioning.

Chapter 8: Mitigation

Mitigation is defined in this document as avoiding or minimizing significant adverse impacts, and when appropriate, compensating for unavoidable significant adverse impacts, as determined through the tiered approach described in the recommended Guidelines. The Service places emphasis in project planning on first avoiding, then minimizing, potential adverse impacts to wildlife and their habitats. Several tools are available to determine appropriate mitigation, including the Service Mitigation Policy (USFWS Mitigation Policy, 46 FR 7656 (1981)). The Service policy provides a common basis for determining how and when to use different mitigation strategies, and facilitates earlier consideration of wildlife values in wind energy project planning.

Under the Service Mitigation Policy, the highest priority is for mitigation to occur on-site within the project planning area. The secondary priority is for the mitigation to occur off-site. Off-site mitigation should first occur in proximity to the planning area within the same ecological region and secondarily elsewhere within the same ecological region. Generally, the Service prefers on-site mitigation over off-site mitigation because this approach most directly addresses project impacts at the location where they actually occur. However, there may be individual cases where off-site mitigation could result in greater net benefits to affected species and habitats. Developers should work with the Service in comparing benefits among multiple alternatives.

In some cases, a project's effects cannot be forecast with precision. The developer and the agencies may be unable to make some mitigation decisions until post-construction data have been collected. If significant adverse effects have not been adequately addressed, additional mitigation for those adverse effects from operations may need to be implemented.

Mitigation measures implemented post-construction, whether in addition to those implemented pre-construction or whether they are new, are appropriate elements of the tiered approach. The general terms and funding commitments for future mitigation and the triggers or thresholds for implementing such compensation should be developed at the earliest possible stage in project development. Any mitigation implemented after a project is operational should be well defined, bounded, technically feasible, and commensurate with the project effects.

NEPA Guidance on Mitigation

CEQ issued guidance in February 2011 on compliance with the National Environmental Policy Act (NEPA) entitled, "Appropriate Use of Mitigation and Monitoring and Clarifying the Appropriate Use of Mitigated Findings of No Significant Impact." This new guidance clarifies that when agencies premise their Finding of No Significant Impact on a commitment to mitigate the environmental impacts of a proposed action, they should adhere to those commitments, publicly report on those efforts, monitor how they are implemented, and monitor the effectiveness of the mitigation.

To the extent that a federal nexus with a wind project exists, for example, developing a project on federal lands or obtaining a federal permit, the lead federal action agency should make its decision based in part on a developer's commitment to mitigate adverse environmental impacts. The federal action agency should ensure that the developer adheres to those commitments, monitors how they are implemented, and monitors the effectiveness of the mitigation. Additionally, the lead federal action agency should make information on mitigation monitoring available to the public through its web site;

Greater prairie chicken. Credit: Amy Thornburg, USFWS and should ensure that mitigation successfully achieves its goals.

Compensatory Mitigation

Compensatory mitigation as defined in this document refers to replacement of project-induced losses to fish and wildlife resources. Substitution or offsetting of fish and wildlife resource losses with resources considered to be of equivalent biological value.

- **In-kind** – Providing or managing substitute resources to replace the value of the resources lost, where such substitute resources are physically and biologically the same or closely approximate to those lost.

- **Out-of-kind** – Providing or managing substitute resources to replace the value of the resources lost, where such substitute resources are physically or biologically different from those lost. This may include conservation or mitigation banking, research or other options.

The amount of compensation, if necessary, will depend on the effectiveness of any avoidance and minimization measures undertaken. If a proposed wind development is poorly sited with regard to wildlife effects, the most important mitigation opportunity is largely lost and the remaining options can be expensive, with substantially greater environmental effects.

Compensation is most often appropriate for habitat loss under limited circumstances or for direct take of wildlife (e.g., Habitat Conservation Plans). Compensatory mitigation may involve contributing to a fund to protect habitat or otherwise support efforts to reduce existing impacts to species affected by a wind project. Developers should communicate with the Service and state agency prior to initiating such an approach.

Ideally, project impact assessment is a cooperative effort involving the developer, the Service, tribes, local authorities, and state resource agencies. The Service does not expect developers to provide compensation for the same habitat loss more than once. But the Service, state resource agencies, tribes, local authorities, state and federal land management agencies may have different species or habitats of concern, according to their responsibilities and statutory authorities. Hence, one entity may seek mitigation for a different group of species or habitat than does another.

Migratory Birds and Eagles

Some industries, such as the electric utilities, have developed operational and deterrent measures that when properly used can avoid or minimize "take" of migratory birds. Many of these measures to avoid collision and electrocution have been scientifically tested with publication in peer-reviewed, scientific journals. The Service encourages the wind industry to use these measures in siting, placing, and operating all power lines, including their distribution and grid-connecting transmission lines.

E.O. 13186, which addresses responsibilities of federal agencies to protect migratory birds, includes a directive to federal agencies to restore and enhance the habitat of migratory birds as practicable. E.O. 13186 provides a basis and a rationale for compensating for the loss of migratory bird habitat that results from developing wind energy projects that have a federal nexus.

Regulations concerning eagle take permits in 50 CFR 22.26 and 50 CFR 22.27 may allow for compensation as part of permit issuance. Compensation may be a condition of permit issuance in cases of nest removal, disturbance or take resulting in mortality that will likely occur over several seasons, result in permanent abandonment of one or more breeding territories, have large scale impacts, occur at multiple locations, or otherwise contribute to cumulative negative effects. The draft ECP Guidance has additional information on the use of compensation for programmatic permits.

Endangered Species

The ESA has provisions that allow for compensation through the issuance of an Incidental Take Permit (ITP). Under the ESA, mitigation measures are determined on a case by case basis, and are based on the needs of the species and the types of effects anticipated. If a federal nexus exists, or if a developer chooses to seek an ITP under the ESA, then effects to listed species need to be evaluated through the Section 7 and/or Section 10 processes. If an ITP is requested, it and the associated HCP must provide for minimization and mitigation to the maximum extent practicable, in addition to meeting other necessary criteria for permit issuance. For further information about compensation under federal laws administered by the Service, see the Service's Habitat and Resource Conservation website http://www.fws.gov/habitatconservation.

Bald eagle. Credit: USFWS

Chapter 9: Advancing Use, Cooperation and Effective Implementation

This chapter discusses a variety of policies and procedures that may affect the way wind project developers and the Service work with each other as well as with state and tribal governments and non-governmental organizations. The Service recommends that wind project developers work closely with field office staff for further elaboration of these policies and procedures.

Conflict Resolution

The Service and developers should attempt to resolve any issues arising from use of the Guidelines at the Field Office level. Deliberations should be in the context of the intent of the Guidelines and be based on the site-specific conditions and the best available data. However, if there is an issue that cannot be resolved within a timely manner at the field level, the developer and Service staff will coordinate to bring the matter up the chain of command in a stepwise manner.

Bird and Bat Conservation Strategies (BBCS)

The Service has recommended that developers prepare written records of their actions to avoid, minimize and compensate for potential adverse impacts. In the past, the Service has referred to these as Avian and Bat Protection Plans (ABPP). However, ABPPs have more recently been used for transmission projects and less for other types of development. For this reason the Service is introducing a distinct concept for wind energy projects and calling them Bird and Bat Conservation Strategies (BBCS).

Electricity towers and wind turbines. Credit: NREL

Typically, a project-specific BBCS will explain the analyses, studies, and reasoning that support progressing from one tier to the next in the tiered approach. A wind energy project-specific BBCS is an example of a document or compilation of documents that describes the steps a developer could or has taken to apply these Guidelines to mitigate for adverse impacts and address the post-construction monitoring efforts the developer intends to undertake. A developer may prepare a BBCS in stages, over time, as analysis and studies are undertaken for each tier. It will also address the post-construction monitoring efforts for mortality and habitat effects, and may use many of the components suggested in the Suggested Practices for Avian Protection on Power Lines (APLIC 2006). Any Service review of, or discussion with a developer, concerning its BBCS is advisory only, does not result in approval or disapproval of the BBCS by the Service, and does not constitute a federal agency action subject to the National Environmental Policy Act or other federal law applicable to such an action.

Project Interconnection Lines

The Guidelines are designed to address all elements of a wind energy facility, including the turbine string or array, access roads, ancillary buildings, and the above- and below-ground electrical lines which connect a project to the transmission system. The Service recommends that the project evaluation include consideration of the wildlife- and habitat-related impacts of these electrical lines, and that the developer include measures to reduce impacts of these lines, such as those outlined in the Suggested Practices for Avian Protection on Power Lines (APLIC 2006). The Guidelines are not designed to address transmission beyond the point of interconnection to the transmission system. The national grid and proposed smart grid system are beyond the scope of these Guidelines.

Confidentiality of Site Evaluation Process as Appropriate

Some aspects of the initial pre-construction risk assessment, including preliminary screening and site characterization, occur early in the development process, when land or other competitive issues limit developers' willingness to share information on projects with the public and competitors. Any consultation or coordination with agencies at this stage may include confidentiality agreements.

Collaborative Research

Much uncertainty remains about predicting risk and estimating impacts of wind energy development on wildlife. Thus there is a need for additional research to improve scientifically based decision-making when siting wind energy facilities, evaluating impacts on wildlife and habitats, and testing the efficacy of mitigation measures. More extensive studies are needed to further elucidate patterns and test hypotheses regarding possible solutions to wildlife and wind energy impacts.

It is in the interests of wind developers and wildlife agencies to improve these assessments to better mitigate the impacts of wind energy development on wildlife and their habitats. Research can provide data on operational factors (e.g. wind speed, weather conditions) that are likely to result in fatalities. It could also include studies of cumulative impacts of multiple wind energy projects, or comparisons of different methods for assessing avian and bat activity relevant to predicting risk. Monitoring and research should be designed and conducted to ensure unbiased data collection that meets technical standards such as those used in peer review. Research projects may occur at the same time as project-specific Tier 4 and Tier 5 studies.

Research would usually result from collaborative efforts involving appropriate stakeholders, and is not the sole or primary responsibility of any developer. Research partnerships (e.g., Bats and Wind Energy Cooperative (BWEC)[9], Grassland and Shrub Steppe Species Collaborative (GS3C)[10]) involving diverse players will be helpful for generating common goals and objectives and adequate funding to conduct studies (Arnett and Haufler 2003). The National Wind Coordinating Collaborative (NWCC)[11], the American Wind Wildlife Institute (AWWI)[12], and the California Energy Commission (CEC)'s Public Interest Energy Research Program[13] all support research in this area.

Study sites and access will be necessary to design and implement research, and developers are encouraged to participate in these research efforts when possible. Subject to appropriations, the Service also should fund priority research and promote collaboration and information sharing among research efforts to advance science on wind energy-wildlife interactions, and to improve these Guidelines.

Service - State Coordination and Cooperation

The Service encourages states to increase compatibility between state guidelines and these voluntary Guidelines, protocols, data collection methods, and recommendations relating to wildlife and wind energy. States that desire to adopt, or those that have formally adopted, wind energy siting, permitting, or environmental review regulations or guidelines are encouraged to cooperate with the Service to develop consistent state level guidelines. The Service may be available to confer, coordinate and share its expertise with interested states when a state lacks its own guidance or program to address wind energy-wildlife interactions. The Service will also use states' technical resources as much as possible and as appropriate.

The Service will explore establishing a voluntary state/federal program to advance cooperation and compatibility between the Service and interested state and local governments for coordinated review of projects under both federal and state wildlife laws. The Service, and interested states, will consider using the following tools to reach agreements to foster consistency in review of projects:

- Cooperation agreements with interested state governments.
- Joint agency reviews to reduce duplication and increase coordination in project review.
- A communication mechanism:
  - To share information about prospective projects
  - To coordinate project review
  - To ensure that state and federal regulatory processes, and/or mitigation requirements are being adequately addressed

[9] www.batsandwind.org
[10] www.nationalwind.org
[11] www.nationalwind.org
[12] http://www.awwi.org
[13] http://www.energy.ca.gov/research

- To ensure that species of concern and their habitats are fully addressed

- Establishing consistent and predictable joint protocols, data collection methodologies, and study requirements to satisfy project review and permitting.

- Designating a Service management contact within each Regional Office to assist Field Offices working with states and local agencies to resolve significant wildlife-related issues that cannot be resolved at the field level.

- Cooperative state/federal/ industry research agreements relating to wind energy -wildlife interactions.

The Service will explore opportunities to:

- Provide training to states.

- Foster development of a national geographic data base that identifies development-sensitive ecosystems and habitats.

- Support a national database for reporting of mortality data on a consistent basis.

- Establish national BMPs for wind energy development projects.

- Develop recommended guidance on study protocols, study techniques, and measures and metrics for use by all jurisdictions.

- Assist in identifying and obtaining funding for national research priorities.

Wind turbine in California.. Credit: NREL

Service - Tribal Consultation and Coordination

Federally-recognized Indian Tribes enjoy a unique government-to-government relationship with the United States. The United States Fish and Wildlife Service (Service) recognizes Indian tribal governments as the authoritative voice regarding the management of tribal lands and resources within the framework of applicable laws. It is important to recall that many tribal traditional lands and tribal rights extend beyond reservation lands.

The Service consults with Indian tribal governments under the authorities of Executive Order 13175 “Consultation and Coordination with Indian Tribal Governments” and supporting DOI and Service policies. To this end, when it is determined that federal actions and activities may affect a Tribe’s resources (including cultural resources), lands, rights, or ability to provide services to its members, the Service must, to the extent practicable, seek to engage the affected Tribe(s) in consultation and coordination.

Tribal Wind Energy Development on Reservation Lands

Indian tribal governments have the authority to develop wind energy projects, permit their development, and establish relevant regulatory guidance within the framework of applicable laws.

The Service will provide technical assistance upon the request of Tribes that aim to establish regulatory guidance for wind energy development for lands under the Tribe’s jurisdiction. Tribal governments are encouraged to strive for compatibility between their guidelines and these Guidelines.

Tribal Wind Energy Development on Lands that are not held in Trust

Indian tribal governments may wish to develop wind energy projects on lands that are not held in trust status. In such cases, the Tribes should coordinate with agencies other than the Service. At the request of a Tribe, the Service may facilitate discussions with other regulatory organizations. The Service may also lend its expertise in these collaborative efforts to help determine the extent to which tribal resource management plans and priorities can be incorporated into established regulatory protocols.

Non-Tribal Wind Energy Development – Consultation with Indian Tribal Governments

When a non-Tribal wind energy project is proposed that may affect a Tribe’s resources (including cultural resources), lands, rights, or ability to govern or provide services to its members, the Service should seek to engage the affected Tribe(s) in consultation and coordination as early as possible in the process. In siting a proposed project that has a federal nexus, it is incumbent upon the regulatory agency to notify potentially affected Tribes of the proposed activity. If the Service or other federal agency determines that a project may affect a Tribe(s), they should notify the Tribe(s) of the action at the earliest opportunity. At the request of a Tribe, the Service may facilitate and lend its expertise in collaborating with other organizations to help determine the extent to which tribal resource management plans and priorities can be incorporated into established regulatory protocols or project implementation. This process ideally should be agreed to by all involved parties.

In the consultative process, Tribes should be engaged as soon as possible when a decision may affect a Tribe(s). Decisions made that affect Indian Tribal governments without adequate federal effort to engage Tribe(s) in consultation have been overturned by the courts. See, e.g., Quechan Tribe v. U.S. Dep't of the Interior, No. 10cv2241 LAB (CAB), 2010 WL 5113197 (S.D. Cal. Dec. 15, 2010). When a tribal government is consulted, it is neither required, nor expected that all of the Tribe's issues can be resolved in its favor. However, the Service must listen and may not arbitrarily dismiss concerns of the tribal government. Rather, the Service must seriously consider and respond to all tribal concerns. Regional Native American Liaisons are able to provide in-house guidance as to government-to-government consultation processes. (See Service - State Coordination and Cooperation, above).

Non-Governmental Organization Actions

If a specific project involves actions at the local, state, or federal level that provide opportunities for public participation, non-governmental organizations (NGOs) can provide meaningful contributions to the discussion of biological issues associated with that project, through the normal processes such as scoping, testimony at public meetings, and comment processes. In the absence of formal public process, there are many NGOs that have substantial scientific capabilities and may have resources that could contribute productively to the siting of wind energy projects. Several NGOs have made significant contributions to the understanding of the importance of particular geographic areas to wildlife in the United States. This work has benefited and continues to benefit from extensive research efforts and from associations with highly qualified biologists. NGO expertise can – as can scientific expertise in the academic or private consulting sectors – serve highly constructive purposes. These can include:

- Providing information to help identify environmentally sensitive areas, during the screening phases of site selection (Tiers 1 and 2, as described in this document)
- Providing feedback to developers and agencies with respect to specific sites and site and impact assessment efforts
- Helping developers and agencies design and implement mitigation or offset strategies
- Participating in the defining, assessing, funding, and implementation of research efforts in support of improved predictors of risk, impact assessments and effective responses
- Articulating challenges, concerns, and successes to diverse audiences

Non-Governmental Organization Conservation Lands

Implementation of these Guidelines by Service and other state agencies will recognize that lands owned and managed by non-government conservation organizations represent a significant investment that generally supports the mission of state and federal wildlife agencies. Many of these lands represent an investment of federal conservation funds, through partnerships between agencies and NGOs. These considerations merit extra care in the avoidance of wind energy development impacts to these lands. In order to exercise this care, the Service and allied agencies can coordinate and consult with NGOs that own lands or easements which might reasonably be impacted by a project under review.

Appendix A: Glossary

Accuracy – The agreement between a measurement and the true or correct value.

Adaptive management – An iterative decision process that promotes flexible decision-making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Comprehensively applying the tiered approach embodies the adaptive management process.

Anthropogenic – Resulting from the influence of human beings on nature.

Area of interest – For most projects, the area where wind turbines and meteorological (met) towers are proposed or expected to be sited, and the area of potential impact.

Avian – Pertaining to or characteristic of birds.

Avoid – To not take an action or parts of an action to avert the potential effects of the action or parts thereof. First of three components of "mitigation," as defined in Service Mitigation Policy. (See mitigation.)

Before-after/control-impact (BACI) – A study design that involves comparisons of observational data, such as bird counts, before and after an environmental disturbance in a disturbed and undisturbed site. This study design allows a researcher to assess the effects of constructing and operating a wind turbine by comparing data from the "control" sites (before and undisturbed) with the "treatment" sites (after and disturbed).

Best management practices (BMPs) – Methods that have been determined by the stakeholders to be the most effective, practicable means of avoiding or minimizing significant adverse impacts to individual species, their habitats or an ecosystem, based on the best available information.

Buffer zone – A zone surrounding a resource designed to protect the resource from adverse impact, and/or a zone surrounding an existing or proposed wind energy project for the purposes of data collection and/or impact estimation.

Community-scale – Wind energy projects greater than 1 MW, but generally less than 20 MW, in name-plate capacity, that produce electricity for off-site use, often partially or totally owned by members of a local community or that have other demonstrated local benefits in terms of retail power costs, economic development, or grid issues.

Comparable site – A site similar to the project site with respect to topography, vegetation, and the species under consideration.

Compensatory mitigation – Replacement of project-induced losses to fish and wildlife resources. Substitution or offsetting of fish and wildlife resource losses with resources considered to be of equivalent biological value.

- **In-kind** – Providing or managing substitute resources to replace the value of the resources lost, where such substitute resources are physically and biologically the same or closely approximate to those lost.
- **Out-of-kind** – Providing or managing substitute resources to replace the value of the resources lost, where such substitute resources are physically or biologically different from those lost. This may include conservation or mitigation banking, research or other options.

Cost effective – Economical in terms of tangible benefits produced by money spent.

Covariate – Uncontrolled random variables that influence a response to a treatment or impact, but do not interact with any of the treatments or impacts being tested.

Critical habitat – For listed species, consists of the specific areas designated by rule making pursuant to Section 4 of the Endangered Species Act and displayed in 50 CFR § 17.11 and 17.12.

Cumulative impacts – See impact.

Curtailment – The act of limiting the supply of electricity to the grid during conditions when it would normally be supplied. This is usually accomplished by cutting-out the generator from the grid and/or feathering the turbine blades.

Cut-in Speed – The wind speed at which the generator is connected to the grid and producing electricity. It is important to note that turbine blades may rotate at full RPM in wind speeds below cut-in speed.

Displacement – The loss of habitat as result of an animal's behavioral avoidance of otherwise suitable habitat. Displacement may be short-term, during the construction phase of a project, temporary as a result of habituation, or long-term, for the life of the project.

Distributed wind – Small and mid-sized turbines between 1 kilowatt and 1 megawatt that are installed and produce electricity at the point of use to off-set all or a portion of on-site energy consumption.

Ecosystem – A system formed by the interaction of a community of organisms with their physical and chemical environment. All of the biotic elements (i.e., species, populations, and communities) and abiotic elements (i.e., land, air, water, energy) interacting in a given geographic area so that a flow of energy leads to a clearly defined trophic structure, biotic diversity, and material cycles. Service Mitigation Policy adopted definition from E. P. Odum 1971 Fundamentals of Ecology.

Edge effect – The effect of the juxtaposition of contrasting environments on an ecosystem.

Endangered species – See listed species.

Extirpation – The species ceases to exist in a given location; the species still exists elsewhere.

Fatality – An individual instance of death.

Fatality rate – The ratio of the number of individual deaths to some parameter of interest such as megawatts of energy produced, the number of turbines in a wind project, the number of individuals exposed, etc., within a specified unit of time.

Feathering – Adjusting the angle of the rotor blade parallel to the wind, or turning the whole unit out of the wind, to slow or stop blade rotation.

Federal action agency – A department, bureau, agency or instrumentality of the United States which plans, constructs, operates or maintains a project, or which reviews, plans for or approves a permit, lease or license for projects, or manages federal lands.

Federally listed species – See listed species.

Footprint – The geographic area occupied by the actual infrastructure of a project such as wind turbines, access roads, substation, overhead and underground electrical lines, and buildings, and land cleared to construct the project.

G1 (Global Conservation Status Ranking) Critically Imperiled – At very high risk of extinction due to extreme rarity (often five or fewer populations), very steep declines, or other factors.

G2 (Global Conservation Status Ranking) Imperiled – At high risk of extinction or elimination due to very restricted range, very few populations, steep declines, or other factors.

G3 (Global Conservation Status Ranking) Vulnerable – At moderate risk of extinction or elimination due to a restricted range, relatively few populations, recent and widespread declines, or other factors.

Guy wire – Wires used to secure wind turbines or meteorological towers that are not self-supporting.

Habitat – The area which provides direct support for a given species, including adequate food, water, space, and cover necessary for survival.

Habitat fragmentation – Habitat fragmentation separates blocks of habitat for some species into segments, such that the individuals in the remaining habitat segments may suffer from effects such as decreased survival, reproduction, distribution, or use of the area.

Impact – An effect or effects on natural resources and on the components, structures, and functioning of affected ecosystems.

- **Cumulative** – Changes in the environment caused by the aggregate of past, present and reasonably foreseeable future actions on a given resource or ecosystem.

- **Direct** – Effects on individual species and their habitats caused by the action, and occur at the same time and place.

- **Indirect impact** – Effects caused by the action that are later in time or farther removed in distance, but are still reasonably foreseeable. Indirect impacts include displacement and changes in the demographics of bird and bat populations.

Infill – Add an additional phase to the existing project, or build a new project adjacent to existing projects.

In-kind compensatory mitigation – See compensatory mitigation.

Intact habitat – An expanse of habitat for a species or landscape scale feature, unbroken with respect to its value for the species or for society.

Intact landscape – Relatively undisturbed areas characterized by maintenance of most original ecological processes and by communities with most of their original native species still present.

Lattice design – A wind turbine support structure design characterized by horizontal or diagonal lattice of bars forming a tower rather than a single tubular support for the nacelle and rotor.

Lead agency – Agency that is responsible for federal or non-federal regulatory or environmental assessment actions.

Lek – A traditional site commonly used year after year by males of certain species of birds (e.g., greater and lesser prairie-chickens, sage and sharp-tailed grouse, and buff-breasted sandpiper), within which the males display communally to attract and compete for female mates, and where breeding occurs.

Listed species – Any species of fish, wildlife or plant that has been determined to be endangered or threatened under section 4 of the Endangered Species Act (50 CFR §402.02), or similarly designated by state law or rule.

Local population – A subdivision of a population of animals or plants of a particular species that is in relative proximity to a project.

Loss – As used in this document, a change in wildlife habitat due to human activities that is considered adverse and: 1) reduces the biological value of that habitat for species of concern; 2) reduces population numbers of species of concern; 3) increases population numbers of invasive or exotic species; or 4) reduces the human use of those species of concern.

Megawatt (MW) – A measurement of electricity-generating capacity equivalent to 1,000 kilowatts (kW), or 1,000,000 watts.

Migration – Regular movements of wildlife between their seasonal ranges necessary for completion of the species lifecycle.

Migration corridor – Migration routes and/or corridors are the relatively predictable pathways that a migratory species travel between seasonal ranges, usually breeding and wintering grounds.

Migration stopovers – Areas where congregations of wildlife assemble during migration. Such areas supply high densities of food or shelter.

Minimize – To reduce to the smallest practicable amount or degree.

Mitigation – (Specific to these Guidelines) Avoiding or minimizing significant adverse impacts, and when appropriate, compensating for unavoidable significant adverse impacts.

Monitoring – 1) A process of project oversight such as checking to see if activities were conducted as agreed or required; 2) making measurements of uncontrolled events at one or more points in space or time with space and time being the only experimental variable or treatment; 3) making measurements and evaluations through time that are done for a specific purpose, such as to check status and/or trends or the progress towards a management objective.

Mortality rate – Population death rate, typically expressed as the ratio of deaths per 100,000 individuals in the population per year (or some other time period).

Operational changes – Deliberate changes to wind energy project operating protocols, such as the wind speed at which turbines "cut in" or begin generating power, undertaken with the object of reducing collision fatalities. Considered separately from standard mitigation measures due to the fact that operational changes are considered as a last resort and will rarely be implemented if a project is properly sited.

Passerine – Describes birds that are members of the Order Passeriformes, typically called "songbirds."

Plant communities of concern –Plant communities of concern are unique habitats that are critical for the persistence of highly specialized or unique species and communities of organisms. Often restricted in distribution or represented by a small number of examples, these communities are biological hotspots that significantly contribute to the biological richness and productivity of the entire region. Plant communities of concern often support rare or uncommon species assemblages, provide critical foraging, roosting, nesting, or hibernating habitat, or perform vital ecosystem functions. These communities often play an integral role in the conservation of biological integrity and diversity across the landscape. (Fournier et al. 2007) Also, any plant community with a Natural Heritage Database ranking of S1, S2, S3, G1, G2, or G3.

Population – A demographically and genetically self-sustaining group of animals and/or plants of a particular species.

Practicable – Capable of being done or accomplished; feasible.

Prairie grouse – A group of gallinaceous birds, includes the greater prairie-chicken, the lesser prairie-chicken, and the sharp-tailed grouse.

Project area – The area that includes the project site as well as contiguous land that shares relevant characteristics.

Project commencement – The point in time when a developer begins its preliminary evaluation of a broad geographic area to assess the general ecological context of a potential site or sites for wind energy project(s). For example, this may include the time at which an option is acquired to secure real estate interests, an application for federal land use has been filed, or land has been purchased.

Project Site – The land that is included in the project where development occurs or is proposed to occur.

Project transmission lines – Electrical lines built and owned by a project developer.

Raptor – As defined by the American Ornithological Union, a group of predatory birds including hawks, eagles, falcons, osprey, kites, owls, vultures and the California condor.

Relative abundance – The number of organisms of a particular kind in comparison to the total number of organisms within a given area or community.

Risk – The likelihood that adverse effects may occur to individual animals or populations of species of concern, as a result of development and operation of a wind energy project. For detailed discussion of risk and risk assessment as used in this document see Chapter One - General Overview.

Rotor – The part of a wind turbine that interacts with wind to produce energy. Consists of the turbine's blades and the hub to which the blades attach.

Rotor-swept area – The area of the circle or volume of the sphere swept by the turbine blades.

Rotor-swept zone – The altitude within a wind energy project which is bounded by the upper and lower limits of the rotor-swept area and the spatial extent of the project.

S1 (Subnational Conservation Status Ranking) Critically Imperiled – Critically imperiled in the jurisdiction because of extreme rarity or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the jurisdiction.

S2 (Subnational Conservation Status Ranking) Imperiled – Imperiled in the jurisdiction because of rarity due to very restricted range, very few populations, steep declines, or other factors making it very vulnerable to extirpation from jurisdiction.

S3 (Subnational Conservation Status Ranking) Vulnerable – Vulnerable in the jurisdiction due to a restricted range, relatively few populations, recent and widespread declines, or other factors making it vulnerable to extirpation.

Sage grouse – A large gallinaceous bird living in the sage steppe areas of the intermountain west, includes the greater sage grouse and Gunnison's sage grouse.

Significant – For purposes of characterizing impacts to species of concern and their habitats, "significance" takes into account the duration, scope, and intensity of an impact. Impacts that are very brief or highly transitory, do not extend beyond the immediate small area where they occur, and are minor in their intensity are not likely to be significant. Conversely, those that persist for a relatively long time, encompass a large area or extend well beyond the immediate area where they occur, or have substantial consequences are almost certainly significant. A determination of significance may include cumulative impacts of other actions. There is probably some unavoidable overlap among these three characteristics, as well as some inherent ambiguity in these terms, requiring the exercise of judgment and the development of a consistent approach over time.

Species of concern – For a particular wind energy project, any species which 1) is either a) listed as an endangered, threatened or candidate species under the Endangered Species Act, subject to the Migratory Bird Treaty Act or Bald and Golden Eagle Protection Act; b) is designated by law, regulation, or other formal process for protection and/or management by the relevant agency or other authority; or c) has been shown to be significantly adversely affected by wind energy development, and 2) is determined to be possibly affected by the project.

Species of habitat fragmentation concern—Species of concern for which a relevant federal, state, tribal, and/or local agency has found that separation of their habitats into smaller blocks reduces connectivity such that the individuals in the remaining habitat segments may suffer from effects such as decreased survival, reproduction, distribution, or use of the area. Habitat fragmentation from a wind energy project may create significant barriers for such species.

String – A number of wind turbines oriented in close proximity to one another that are usually sited in a line, such as along a ridgeline.

Strobe – Light consisting of pulses that are high in intensity and short in duration.

Threatened species – See listed species.

Tubular design – A type of wind turbine support structure for the nacelle and rotor that is cylindrical rather than lattice.

Turbine height – The distance from the ground to the highest point reached by the tip of the blades of a wind turbine.

Utility-scale – Wind projects generally larger than 20 MW in nameplate generating capacity that sell electricity directly to utilities or into power markets on a wholesale basis.

Voltage (low and medium) – Low voltages are generally below 600 volts, medium voltages are commonly on distribution electrical lines, typically between 600 volts and 110 kV, and voltages above 110 kV are considered high voltages.

Wildlife – Birds, fishes, mammals, and all other classes of wild animals and all types of aquatic and land vegetation upon which wildlife is dependent.

Wildlife management plan – A document describing actions taken to identify resources that may be impacted by proposed development; measures to mitigate for any significant adverse impacts; any post-construction monitoring; and any other studies that may be carried out by the developer.

Wind turbine – A machine for converting the kinetic energy in wind into mechanical energy, which is then converted to electricity..

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ATTACHMENT 8

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RESEARCH ARTICLE

A method for defining wind turbine setback standards

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ABSTRACT

Setback distances established by regulatory authorities to minimize the probability of blade fragment impact with roads, structures and infrastructure can often have a significant impact on wind farm development. However, these minimum distance requirements typically rely on arbitrary rules of thumb and are not based on a physical or probabilistic analysis of blade throw. The work reported here uses a probabilistic approach to evaluate the effectiveness of current standards and to propose a new technique for determining setback distances. This is accomplished through the use of a dynamic model of wind turbine blade failure coupled with Monte Carlo simulation techniques applied to three different wind turbines. It is first shown that common setback standards based on turbine height and blade radius provide inconsistent and inadequate protection against blade throw. Then, using a simplified dynamic analysis of a thrown blade fragment, it is shown that the release velocity of the blade fragment is the critical factor in determining the maximum distance fragments are likely to travel. The importance of release velocity is further verified through simulation results. Finally, a new method for developing setback standards is proposed based on an acceptable level of risk. Given specific wind turbine operational parameters and a set of failure probabilities, the new method leverages realistic blade throw modeling to produce setback standards with a valid physical foundation.

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NOMENCLATURE

h	height of turbine rotor hub
I	blade fragment moment of inertia matrix about mass center expressed in blade-fixed frame
$\vec{I}_B, \vec{J}_B, \vec{K}_B$	unit vectors in frame B
L, M, N	total external moment exerted on blade fragment about mass center expressed in blade-fixed frame
l	distance from rotor hub to nacelle vertical axis of rotation
m	mass of blade fragment
q_0, q_1, q_2, q_3	quaternion orientation parameters of the blade fragment
p, q, r	angular velocity components of the blade fragment expressed in the blade-fixed reference frame
R	rotor radius
r_{CG}	distance from blade root to blade
T_{IB}	transformation matrix from blade-fixed reference frame to inertial reference frame
u, v, w	translational velocity components of the blade fragment mass center expressed in the blade-fixed frame
x, y, z	position coordinates of the blade fragment mass center expressed in the inertial frame
X, Y, Z	total external force exerted on blade fragment
θ	rotor plane cant angle
ψ	rotor plane azimuthal angle
φ	rotor blade roll angle
Ω	rotor rotational speed

1. INTRODUCTION

Increasing demand for wind energy production has led to unprecedented wind farm development over the past decade. State and local regulations specifying required setback distances between wind turbines and property lines, roads and other infrastructure can have a significant impact on the number of turbines that can be installed on a given site. These setback standards are intended to protect people and property from rotor blade fragments released from failed wind turbine blades. However, required setbacks are often based on rules of thumb involving some combination of turbine height and blade radius and typically have little or no rigorous physical foundation. There is currently a strong demand for re-evaluation of turbine setback distances in view of both increased turbine reliability and the desire to install more large turbines on small parcels of land. Specifically, it would be desirable to provide a technique that allows regulators and wind farm developers to determine setback requirements given a specific turbine model, the site parameters and an acceptable level of risk. This new methodology would provide developers, regulators and insurers with a setback corresponding to a specific risk level that is generated through probabilistic dynamic modeling techniques rather than arbitrary rules of thumb.

Several investigators have studied blade fragment release from a failed wind turbine blade, beginning with Eggwertz *et al.*[1] The authors used a point-mass dynamic model to show that the probability of blade impact with the ground beyond 1.8 times the overall turbine height was low. Similarly, Macqueen *et al.*[2] demonstrated through the use of a point-mass model that a person being struck by a blade fragment at a distance greater than 220 m from the turbine base was extremely unlikely. Turner,[3] also employing a point-mass model, used Monte Carlo simulation techniques to construct a statistical distribution of blade fragment impact. Eggers *et al.*[4] likewise exercised a point-mass model for blade fragments using Monte Carlo methods and obtained results similar to that of Macqueen *et al.*[2] The first investigation of fragment throw using full six-degree-of-freedom modeling was performed by Montgomerie,[5] who reported very high maximum distances. Sørensen[6,7] also analysed full rigid body motion of the blade fragment and reported how maximum throw distance varied as a function of aerodynamic characteristics, fragment center of gravity location, pitch angle and wind velocity. Turner[8] provided a similar rigid body analysis and obtained results similar to those of Sørensen.[6,7] Finally, Slegers *et al.*[9] investigated blade fragment impact with power transmission lines. It was shown that transmission line impact probability is a strong function of line distance from the turbine as well as orientation of the line with respect to the axis of rotor rotation. Whereas numerous researchers have simulated the blade throw problem to determine expected impact distances, Rademakers and Braam[10] have conducted a statistical analysis of reported blade failures to determine the overall probability of blade failure occurring. Their analysis suggests an overall probability of blade failure of 2.6×10^{-4} per turbine per year, or approximately 1 in 3800. This is a non-trivial probability that further highlights the need for universal and effective setback standards to protect against blade throws.

57,636 WIND TURBINES IN THE U.S.

$\frac{57,636}{3800} = 15.2$

IMPLIES 15.2 failures per year in the U.S.

Despite significant research analysing the physics of blade fragment release and failure probabilities, many previous investigations lack clear guidance in determining safe setback distances. Furthermore, the variety of models and assumptions made by each investigator has led to differing technical conclusions. The result is that technical analyses of blade throw are often ignored and rules of thumb are employed at a local level. In California, for instance, five different counties use a variety of setback standards all based on overall turbine height to ensure the safety of the surrounding buildings, properties and roads.[11]

The work reported here first demonstrates that many setback standards currently in use provide little or no protection against blade fragment throw for several example turbine designs. A six-degree-of-freedom model is used to simulate a failed rotor blade fragment in free flight and is exercised through Monte Carlo simulations to obtain a statistical distribution of blade fragment impact with the ground. It is shown that for all three turbines studied, a significant portion of blade fragments impact outside the distance specified by example setback standards that are currently in use. Then, by using a simplified dynamic model of blade fragment motion, it is shown analytically that blade release velocity plays the largest role in maximum throw distance. This is verified through Monte Carlo simulation results. Finally, a new methodology is proposed to determine setback standards based on turbine physical parameters, failure probabilities and the regulator's acceptable level of risk. This methodology allows the setback developer to mitigate risk using probabilistic dynamic modeling of blade failure, thereby avoiding the use of arbitrary rules of thumb.

2. DYNAMIC MODEL AND SIMULATION METHODOLOGY

2.1. Blade throw dynamic model

An abbreviated version of the dynamic model used to simulate the flight of a released blade fragment is presented here. A full description of the dynamic model can be found in Slegers *et al.*[9] As shown in Figures 1 and 2, three reference frames are employed in the dynamic model of blade motion, namely, the ground-based frame I, the turbine-fixed frame R and the blade-fixed frame B. The blade-fixed reference frame B is oriented such that the $\vec{K}_B$ axis is aligned with the blade spanwise axis. The inertial reference frame is oriented such that $\vec{K}_I$ points straight down and $\vec{I}_I$ lies in a plane formed by

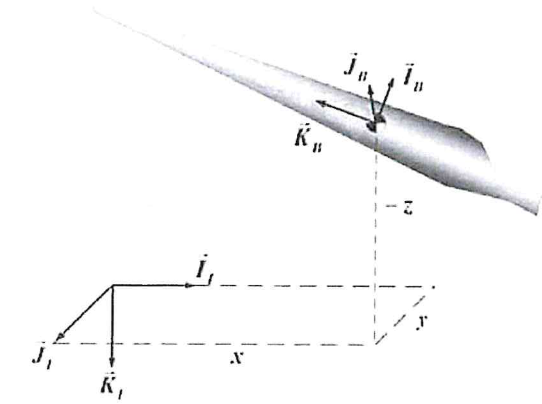

Figure 1. Blade reference frame schematic.

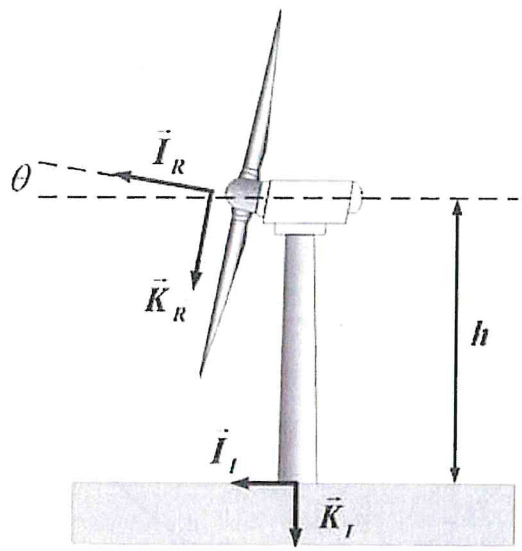

Figure 2. Turbine reference frame schematic.

the rotor hub and the turbine nacelle. The R frame is fixed to the turbine, with $\vec{I}_R$ aligned with the rotor's axis of rotation. Figures 2–4 demonstrate blade geometry including turbine azimuth angle ψ_T, wind azimuth angle ψ_W, hub cant angle θ and blade roll angle φ. As shown in Figure 4, blade roll angle is referenced from the $\vec{K}_R$ axis. Note that within this section, the following shorthand notation with be used for trigonometric functions: $\sin(\alpha) = s_\alpha$, $\cos(\alpha) = c_\alpha$ and $\tan(\alpha) = t_\alpha$.

The dynamic model of the blade fragment in free flight consists of 13 scalar differential equations, given by equations (1)–(4). The states of the system are defined as follows: blade mass center position with respect to the inertial frame (x, y, z), mass center translational velocity resolved in the blade-fixed frame (u, v, w), quaternion rotational parameters describing blade orientation (q_0, q_1, q_2, q_3) and angular velocity components resolved in the blade-fixed frame (p, q, r).

$$\begin{Bmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \end{Bmatrix} = [T_{IB}] \begin{Bmatrix} u \\ v \\ w \end{Bmatrix} \tag{1}$$

$$\begin{Bmatrix} \dot{q}_0 \\ \dot{q}_1 \\ \dot{q}_2 \\ \dot{q}_3 \end{Bmatrix} = \frac{1}{2} \begin{bmatrix} 0 & -p & -q & -r \\ p & 0 & r & -q \\ q & -r & 0 & p \\ r & q & -p & 0 \end{bmatrix} \begin{Bmatrix} q_0 \\ q_1 \\ q_2 \\ q_3 \end{Bmatrix} \tag{2}$$

DOI: 10.1002/we

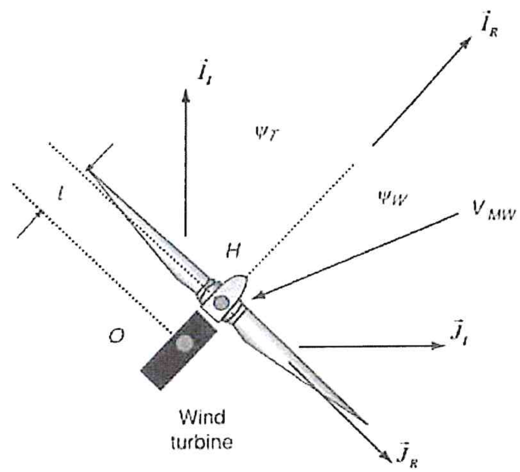

Figure 3. Rotor angle definitions.

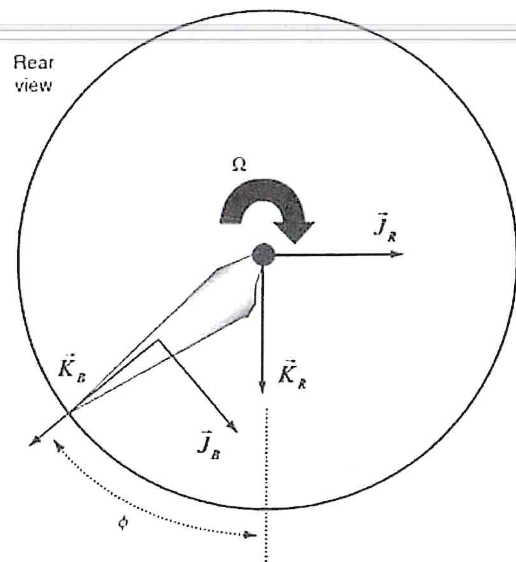

Figure 4. Blade roll angle definition.

$$\begin{Bmatrix} \dot{u} \\ \dot{v} \\ \dot{w} \end{Bmatrix} = \begin{Bmatrix} X/m \\ Y/m \\ Z/m \end{Bmatrix} - \begin{bmatrix} 0 & -r & q \\ r & 0 & -p \\ -q & p & 0 \end{bmatrix} \begin{Bmatrix} u \\ v \\ w \end{Bmatrix} \tag{3}$$

$$\begin{Bmatrix} \dot{p} \\ \dot{q} \\ \dot{r} \end{Bmatrix} = [I]^{-1} \left(\begin{Bmatrix} L \\ M \\ N \end{Bmatrix} - \begin{bmatrix} 0 & -r & q \\ r & 0 & -p \\ -q & p & 0 \end{bmatrix} [I] \begin{Bmatrix} p \\ q \\ r \end{Bmatrix} \right) \tag{4}$$

Note that in equations (3) and (4), the terms X, Y, Z and L, M, N, respectively, denote the total external force and the moment exerted on the blade in the blade-fixed frame. External force on the blade consists of the sum of aerodynamic and gravity forces, whereas aerodynamic moment is the sole source of moments on the blade. The matrix T_{IB} is the transformation matrix from the blade-fixed to inertial frames, and the matrix I is the moment of inertia matrix of the blade about its mass center with respect to blade-fixed coordinates. Aerodynamic forces were calculated using strip theory by considering the blade as a lifting surface with a general angle of attack. This angle of attack is calculated within the simulation given blade orientation and velocity and subsequently used to generate aerodynamic forces and moments on the blade. Details of aerodynamic forces, moments as well as the weight force are omitted here for brevity; however, a full description is provided in Slegers.[9]

Given a set of blade fragment release conditions, equations (1)–(4) can be integrated numerically forward in time using a Runge–Kutta algorithm until blade fragment mass center impacted with the ground. The simulation architecture, written in FORTRAN, was optimized to run Monte Carlo cases efficiently. Simulation cases were ran in an automated fashion on a computing cluster, allowing thousands of blade throws to be simulated in a reasonable amount of time.

2.2. Monte Carlo simulation description

The dynamic simulation described previously is used to generate a probabilistic analysis of wind turbine setback standards. This is accomplished through the use of tens of thousands of simulations with randomized initial conditions. The Monte Carlo simulation architecture generates initial conditions for each fragment throw by varying six different release parameters in a random fashion. These six parameters are blade roll angle (φ), cant angle (θ), azimuthal angle (ψ), rotor rotational speed (Ω), wind speed and wind angle (ψ_W). Note that all Monte Carlo results are relative to a nominal prevailing wind value, with the assumption that the turbine is nominally facing into the wind. All parameter distributions are assumed to be normal with the exception of roll angle and wind speed. Blade roll angle at release is a uniform random variable between 0 and 360°. Wind speed is varied according to a Rayleigh distribution assuming a median value of 8.5 m s^{-1}. Note that this distribution reflects standard winds expected at an International Electrotechnical Commission Class 2 wind farm installation. Table I describes the statistics associated with each parameter for all cases in Section 3.

Given a randomized set of these six parameters, as well as physical characteristics of the turbine, the initial conditions for all the states of the blade fragment at release were generated. Blade fragment position and velocity at the time of release were determined using

$$\begin{Bmatrix} x \\ y \\ z \end{Bmatrix} = \begin{Bmatrix} l c_{\psi_T} \\ l s_{\psi_T} \\ -h \end{Bmatrix} + [T_{IB}] \begin{Bmatrix} 0 \\ 0 \\ r_{CG} \end{Bmatrix} \tag{5}$$

$$\begin{Bmatrix} u \\ v \\ w \end{Bmatrix} = \begin{Bmatrix} 0 \\ -r_{CG}\Omega \\ 0 \end{Bmatrix} \tag{6}$$

more equations & reasons why applicable to use

where r_{CG} represents the distance from the blade root to the blade center of mass and l is the distance between the rotor hub and the origin. The initial orientation and the angular velocity of the thrown blade fragments were calculated according to

$$q_0 = \cos\left(\frac{\psi_T}{2}\right)\cos\left(\frac{\theta}{2}\right)\cos\left(\frac{\phi}{2}\right) + \sin\left(\frac{\psi_T}{2}\right)\sin\left(\frac{\theta}{2}\right)\sin\left(\frac{\phi}{2}\right) \tag{7}$$

$$q_1 = \cos\left(\frac{\psi_T}{2}\right)\cos\left(\frac{\theta}{2}\right)\cos\left(\frac{\phi}{2}\right) - \sin\left(\frac{\psi_T}{2}\right)\sin\left(\frac{\theta}{2}\right)\cos\left(\frac{\phi}{2}\right) \tag{8}$$

$$q_2 = \cos\left(\frac{\psi_T}{2}\right)\sin\left(\frac{\theta}{2}\right)\cos\left(\frac{\phi}{2}\right) + \sin\left(\frac{\psi_T}{2}\right)\cos\left(\frac{\theta}{2}\right)\sin\left(\frac{\phi}{2}\right) \tag{9}$$

$$q_3 = \sin\left(\frac{\psi_T}{2}\right)\cos\left(\frac{\theta}{2}\right)\cos\left(\frac{\phi}{2}\right) - \cos\left(\frac{\psi_T}{2}\right)\sin\left(\frac{\theta}{2}\right)\sin\left(\frac{\phi}{2}\right) \tag{10}$$

Table I. Monte Carlo simulation random parameter statistics.

Parameter	Mean	Standard deviation
Roll angle, φ (degree)	0.0	−180 to 180 (uniform)
Cant angle, θ (degree)	4.0	1.0
Azimuthal angle, ψ_T (degree)	0.0	10.0
Rotor rotational speed (rad s^{-1})	Turbine dependent	0.1
Wind speed (m s^{-1})	Rayleigh distribution, median 8.5 m s^{-1}	N/A
Wind angle ψ_W (degree)	0	3.0

$$\begin{Bmatrix} p \\ q \\ r \end{Bmatrix} = \begin{Bmatrix} \Omega \\ 0 \\ 0 \end{Bmatrix} \tag{11}$$

In Section 3, Monte Carlo simulations are performed for specific turbines using various blade fragment sizes. Because of a lack of statistics regarding the likely size of thrown blade fragments, all fragment sizes were considered. Thus, blade fragment size was varied using outer 20, 40, 60 and 80% and the entire blade throws. used in analysis

> 3 5 5 100%

2.3. Simplified point-mass blade fragment analysis

Although a ballistic point-mass analysis, especially one that neglects aerodynamic effects, is highly unsuitable for a detailed dynamic analysis of blade throw, it does provide simplified expressions that can assist in characterizing the most important factors in maximum lateral throw distance (longitudinal throw distance is largely a function of prevailing wind speed and thus cannot be addressed using an analysis that neglects aerodynamics). Because lateral throw distance is often the driving factor in setback development, this simplified analysis can provide rough bounds on expected setbacks for a given set of turbine parameters. Consider the scenario shown in Figure 5 in which a blade fragment at the tip of the blade is thrown at a certain height h_T and velocity v_T. We consider the blade fragment to be a point mass that impacts the ground at a lateral distance D from the turbine base after a time of flight T. Neglecting aerodynamics and considering only two dimensions, two equations of motion are given by 2D analysis

$$h - Rc_{\theta_T} + v_T s_{\theta_T} T - \frac{1}{2} g T^2 = 0 \tag{12}$$

$$D = v_T c_{\theta_T} T \tag{13}$$

where g denotes acceleration because of gravity. Eliminating T, equations (12) and (13) can be combined to yield

$$\frac{gD^2}{v_T^2} = 2\left(h - Rc_{\theta_T}\right) c_{\theta_T}^2 + 2D s_{\theta_T} c_{\theta_T} \tag{14}$$

Equation (14) is a quadratic function of D. In order to find the angle of maximum throw as a function of h, R and v, one would typically take the derivative of equation (14) with respect to θ_T, set it equal to zero and solve for $\theta_{T_{MAX}}$ as a function of h, R and v. However, a solution in closed form cannot be found since it is not possible to solve the resulting

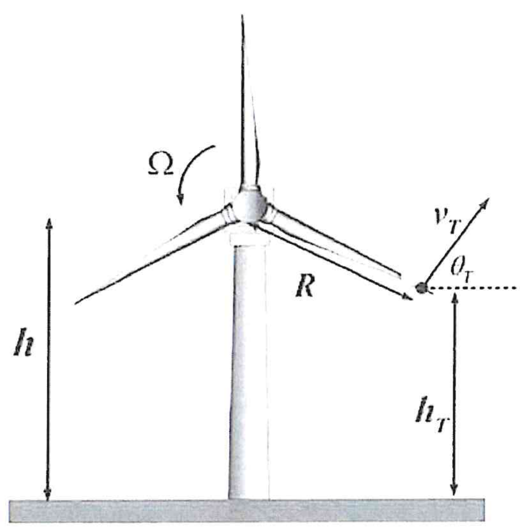

Figure 5. Blade fragment throw diagram.

expression for θ_T. Therefore, determination of the optimum release angle must be found numerically on a turbine-specific basis. Nevertheless, the roots of equation (14) are given by

$$D = \frac{v_T^2 s_{\theta_T} c_{\theta_T} \pm v_T^2 \sqrt{s_{\theta_T}^2 c_{\theta_T}^2 + 2\frac{g}{v_T^2}\left(h - Rc_{\theta_T}\right) c_{\theta_T}^2}}{g} \tag{15}$$

In equation (15), it is clear that the range of blade fragment flight is highly dependent on release velocity and release angle and less dependent on turbine height and blade radius. Specifically, lateral distance is a function of the square of the release velocity but only of the square root of turbine height and radius. Although in modern turbines there is some correlation between height, radius and release velocity (since blade fragments at the end of a longer blade travel faster than the fragments at the end of a shorter blade and longer blades are typically found on taller turbines), it is important to note that blade fragment velocity is the real driver behind maximum throw distance. As a result, setback standards based on mass center velocity of the minimum size fragment of concern will yield far more effective protection than a setback distance based on radius or height.

3. RESULTS

3.1. Monte Carlo simulation ground impact results

Monte Carlo simulations were performed for three example turbines of varying sizes, namely, 0.66, 1.5 and 3.0 MW. These turbines cover a range of size and power representative of those installed in typical modern wind farms. Table II lists the physical and operational parameters associated with each turbine.

Five Monte Carlo simulations consisting of 10,000 blade throws each were performed for each turbine, corresponding to the five blade fragment sizes of 20, 40, 60, 80 and 100% as previously outlined. As demonstrated in the Monte Carlo simulation results shown in Slegers,[9] smaller blade fragments consistently fly farther than larger fragments because of higher initial release velocity. Figures 6–11 show ground impact results of each Monte Carlo simulation for the three turbines for the 40% blade throw case. Figures 6, 8 and 10 show specific ground impact points for each turbine, whereas Figures 7, 9 and 11 show histograms of cross-range impact point location. Note that in Figures 6, 8 and 10, the turbine base is located at the origin. Also, note that the wind arrows in Figures 6, 8 and 10 specify the approximate direction of oncoming wind, since the exact direction is randomly distributed for each blade throw case. Although not shown here, plots of ground impacts for larger blade fragments showed a similar dispersion pattern but a smaller range of distances. In addition, histograms for all fragment sizes showed peaks directly below the turbine and slightly behind the turbine, as well as two lateral peaks near the maximum range of blade fragment throw. The peak directly below the turbine represents failures occurring at blade roll angles between approximately 235 and 325°, since these trajectories fly roughly straight down and are unaffected by winds because of the short time of flight. The more scattered distribution behind the turbine is due to fragments released straight upward (approximately between roll angles of 45 and 135°). The relatively long times of flight exhibited by these cases mean that they are more affected by winds.

241.1 TALL 377' TALL 410' TALL

Table II. Wind turbine physical and operational parameters.

Parameter	660 KW turbine	1.5 MW turbine	3.0 MW turbine
Blade radius (m)	77.1' 23.5	114.8' 35.0	45.0 147.6'
Blade weight (N)	21,287	49,050	64,746
Blade CG from root (m)	11.75	17.5	22.5
Blade I_{XX} (kg m^2)	100,121	511,000	1,115,840
Blade I_{YY} (kg m^2)	99,891	510,000	1,113,830
Blade I_{ZZ} (kg m^2)	282	1233	2175
Rotational speed (rad s^{-1})	2.98	2.3	1.69
Maximum blade chord (m)	2.0	2.1	3.51
Tip blade chord (m)	0.34	0.94	0.45
Root blade pitch (degree)	10.5	10.5	16.6
Tip blade pitch (degree)	−0.5	−0.5	−0.85
Hub height (m)	164.0' 50.0	80.0	80.0 262.5'

CLOSEST TO HARRISBURG WIND FARM

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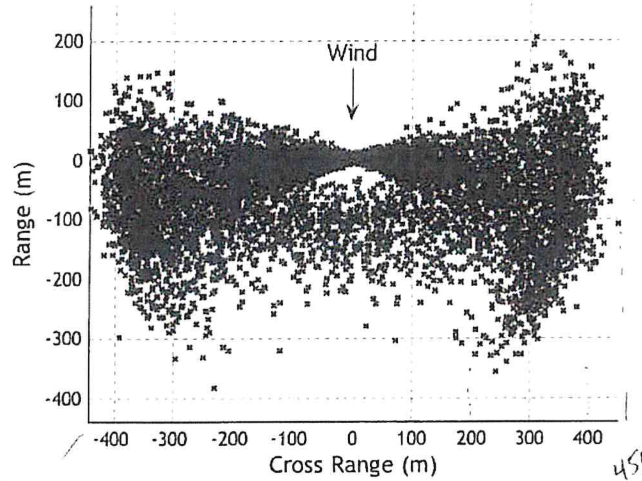
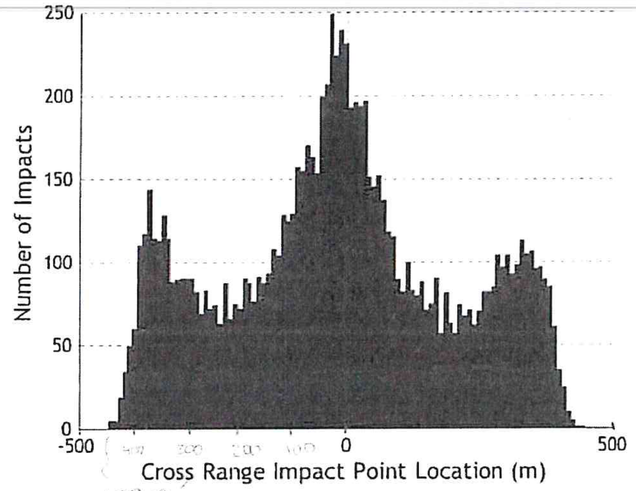


450m ≈ 1,476 Ft

450?

-450?

Figure 6. Ground impacts, 0.66 MW turbine, 40% fragment.



450m?

Figure 7. Histogram of cross-range impact location, 0.66 MW turbine, 40% fragment.

3.2. Evaluation of current setback standards

Current setback standards often rely on multiples of tower height, blade radius or both to form the basis for setback distances. To demonstrate the shortcomings typical of standards that rely on these parameters, two example setback distances are evaluated against the Monte Carlo data for three turbines shown in Section 3.1. The first setback originates from the minimum setback distances from the power transmission lines of Southern California Edison (SCE). SCE's Wholesale Generation Interconnection Technical Requirement document[12] states that 'the Producer shall not locate any part of a wind-driven wholesale generating unit … within three rotor blade diameters of an existing electric utility 220 or 500 kV transmission line right of way or future electric utility 220 or 500 kV transmission line right of way for which SCE may seek regulatory approval of construction.' The second example setback is taken from a report[13] prepared by the State of New York to provide guidance to local communities developing local ordinances governing wind energy. The report proposes the following setback requirement: 'The minimum setback distance between each wind turbine tower and all the surrounding property lines, overhead utility or transmission lines, other wind turbine towers, electrical substations, meteorological towers, public roads and dwellings shall be equal to no less than 1.5 times the sum of proposed structure height plus the rotor radius.' These two setbacks, given by three times the rotor diameter and one and a half times the total turbine height, are representative of many current setback standards and will be evaluated against the three example turbines described earlier.

EXAMPLE OF SHORT-COMINGS BASED ON TOWER HEIGHT BLADE RADIUS OR BOTH

see Figures 12, 13, & 14
3 x Diameter
1.5 x Height
vertical dashed lines

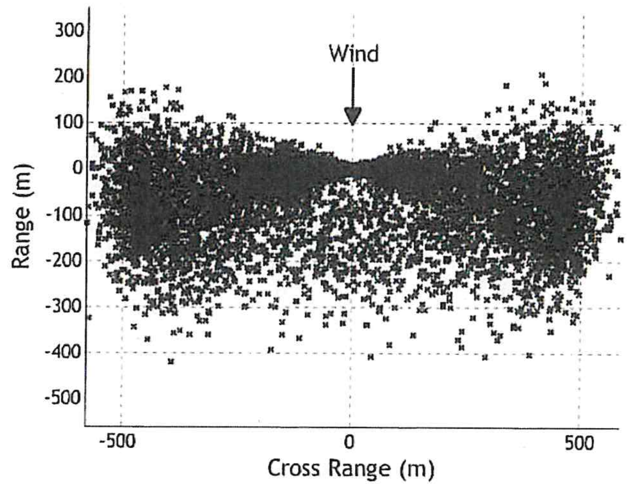
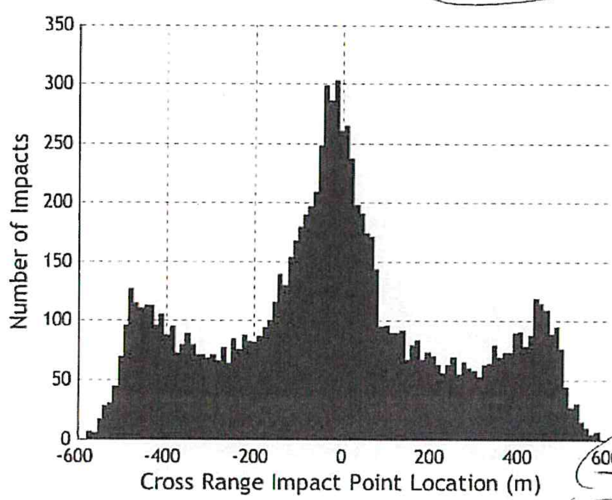


Figure 8. Ground impacts, 1.5 MW turbine, 40% fragment.

40% FRAGMENT DOES NOT "THROW" AS FAR AS A 20% FRAGMENT!



600 = 1968.5 FT

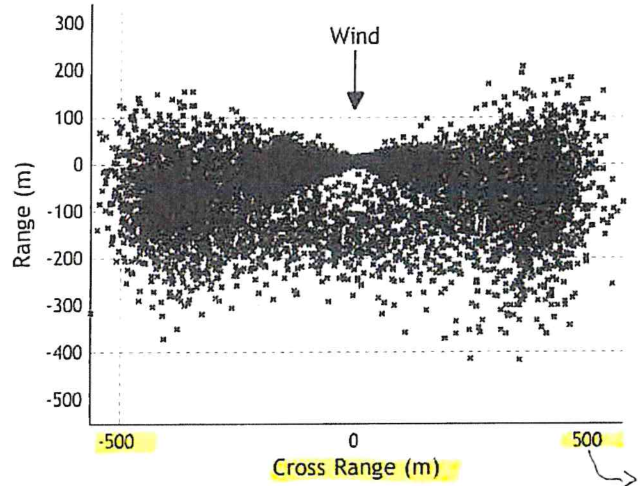
Figure 9. Histogram of cross-range impact location, 1.5 MW turbine, 40% fragment.

In order to evaluate the effectiveness of these example setbacks, circles of varying radius, centered at the turbine base, were considered for each turbine. For each circle, the percentage of blade fragment impacts that landed within this circle was determined. This was repeated for each blade fragment size, and the entire process was performed for each of the three turbines considered. Figures 12–14 show the percentage of impacts within circles of varying radii for each turbine. Also shown are the two example setback standards applied to the specific turbine under consideration.

Several interesting features are apparent in Figures 12–14. First, note that the percentage of impacts that fall within a circle varies somewhat linearly as the radius of the circle grows until greater than 95% of impacts are considered, especially for larger fragments. For smaller fragments at large throw distances, winds tend to have a more significant effect and carry the fragments farther because of longer times of flight, causing the non-linear behavior observed for small fragments at large throw distances. Second, as expected, smaller blade fragments fly farther, and thus, larger circles must be used to contain a given percentage of their impacts. Finally, note that neither of the example setbacks provides protection against a large percentage of blade fragment ground impacts for any of the three turbines. For the 0.66 MW turbine, 60–65% of ground impacts for fragment sizes of 20% fall outside these example setbacks. For the 1.5 and 3.0 MW turbines, 40–50% of ground impacts for 20% blade fragments fall outside these example setbacks. It is important to note that 20% blade fragments are close to 10 m long and can pose a significant hazard.

This analysis of representative setback standards leads to the conclusion that current methods for determining proper setback standards are inadequate. In the cases considered here, setback distances provide little or no reasonable protection

CURRENT SETBACK STANDARDS ARE INADEQUATE



= 1640'

Figure 10. Ground impacts, 3.0 MW turbine, 40% fragment.

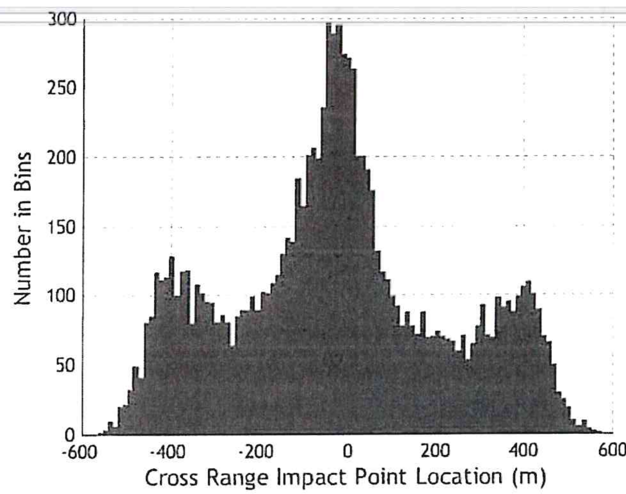


Figure 11. Histogram of cross-range impact location, 3.0 MW turbine, 40% fragment.

against blade fragment impact since there is a significant chance that a thrown blade fragment could impact beyond the setback distance. Even in the case when a setback might provide adequate protection for a specific turbine, the same setback applied to a different turbine could potentially provide no protection at all. Therefore, it would be useful to develop a methodology for determining setbacks that could provide uniform protection for various turbine sizes.

3.3. Normalization by blade fragment mass center velocity

Overlaying percentage-distance traces from Figures 12–14 for each turbine demonstrate how blade fragment throw distance varies for turbines of different size. Figure 15 shows the percentage of blade fragment ground impacts contained within circles of varying radii for 20 and 100% blade throw for each turbine. Note that although the curves have similar shape, they spread out considerably for distances greater than that corresponding to 50% of impacts contained. Furthermore, despite conventional rules of thumb stipulating that maximum throw distance increases with turbine size, Figure 15 demonstrates that the 1.5 MW turbine displays a maximum throw distance of approximately 200 m farther than the 3.0 MW turbine for 20% fragments, even though the 3.0 MW turbine has a larger blade radius and identical rotor hub height.

The fact that the largest throw distance occurs for the 1.5 MW turbine is explained by noting that this turbine has the largest tip velocity of the three examples considered. As described in Section 2.3, blade fragment release velocity is the

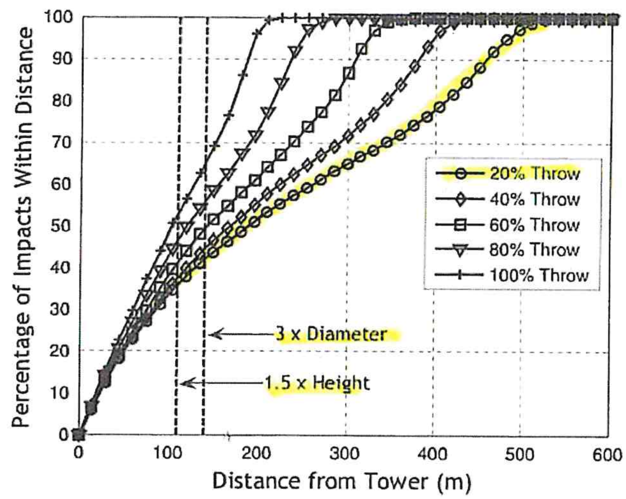
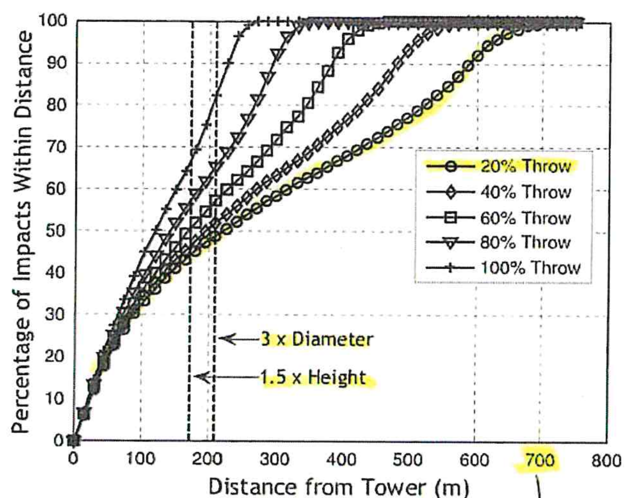


Figure 12. Percentage of impacts within distance versus distance from tower, 0.66 MW turbine.



2,296.6 Ft

Figure 13. Percentage of impacts within distance versus distance from tower, 1.5 MW turbine.

driving factor in the determination of the maximum lateral throw distance. To verify this, the expression in equation (15) was used to numerically determine the maximum theoretical lateral throw distance of each example turbine for a 20% blade fragment. The results are shown in Table III. The lateral throw distances in Table III are somewhat less than the maximum throw distances determined through Monte Carlo simulation, since the equation does not include the effect of fragments being carried by the wind, which causes significant longitudinal displacement of impacts. However, the estimates in Table III verify that the 1.5 MW turbine should achieve the largest throw distance overall, assuming that blade fragments from all turbines are equally affected by wind after release.

Normalizing throw distance by the velocity of the blade fragment mass center for each fragment size accounts for variations in tip speed for different turbine models. This normalization procedure causes all percentage-distance traces to move significantly closer to one another regardless of fragment size. Figure 16 shows percentage-distance traces normalized by fragment mass center velocity for 20 and 100% blade fragments. Unlike Figure 15, traces are much more uniform, especially for larger fragment sizes which are less affected by winds. Figure 17 generalizes this result to all fragment sizes, showing 15 different percentage-distance traces corresponding to the five different blade fragment sizes varying from 20 to 100% for the three turbines considered. For the most part, the traces are similar and close together. However, as fragment size decreases, wind effects become more pronounced, and fragments are carried farther. This accounts for the slight spreading of the curves near maximum range.

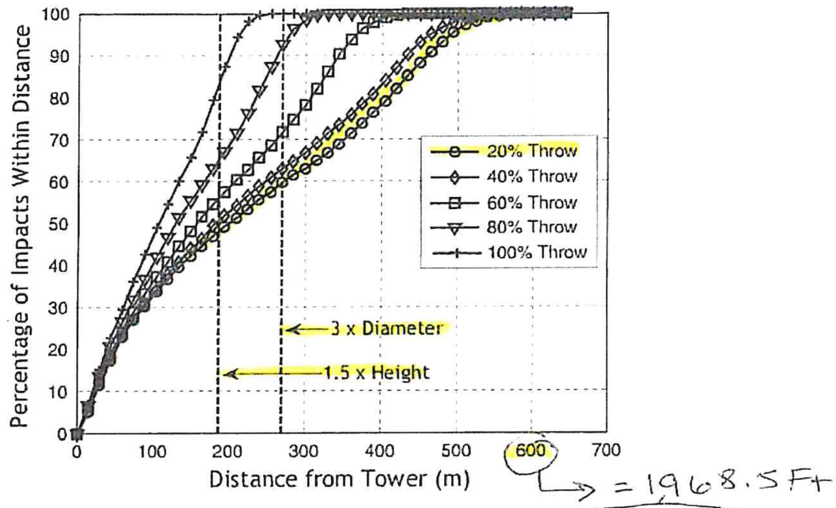


Figure 14. Percentage of impacts within distance versus distance from tower, 3.0 MW turbine.

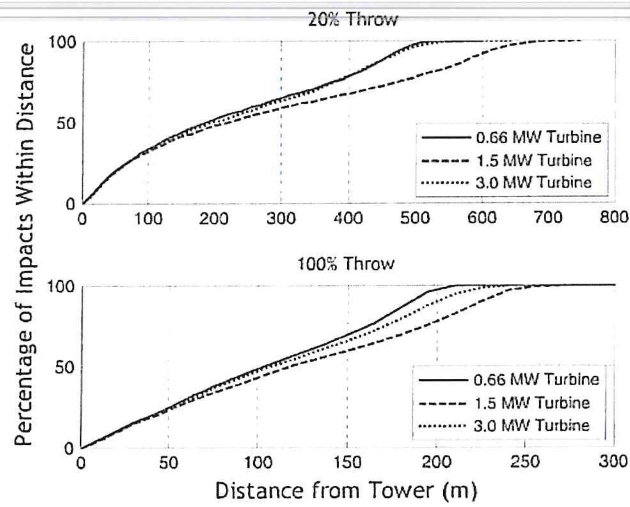


Figure 15. Percentage of impacts within distance versus distance from tower for each turbine.

Table III. Example turbine tip speed and theoretical maximum lateral throw distance of 20% fragment.

Turbine (MW)	Tip speed (rad s^{-1})	Theoretical maximum throw distribution (m)
0.66	70.03	439 – 1440'
1.5	80.50	590 – 1935'
3.0	76.05	526 — 1,726 Ft

higher speed = Farther throw distance

3.4. Risk-based setback standard development

The normalized percentage-distance curves shown in Figure 17 form the basis for the development of a new turbine setback standard. The relationship shown in Figure 17 can be accurately approximated using a best-fit line. This best-fit line, shown in Figure 18, is given by

$$\text{Percentage of impacts inside distance} = 11.9\,s^{-1} \times \frac{\text{Distance from tower (m)}}{\text{Fragment CG release velocity (m s}^{-1})} \tag{16}$$

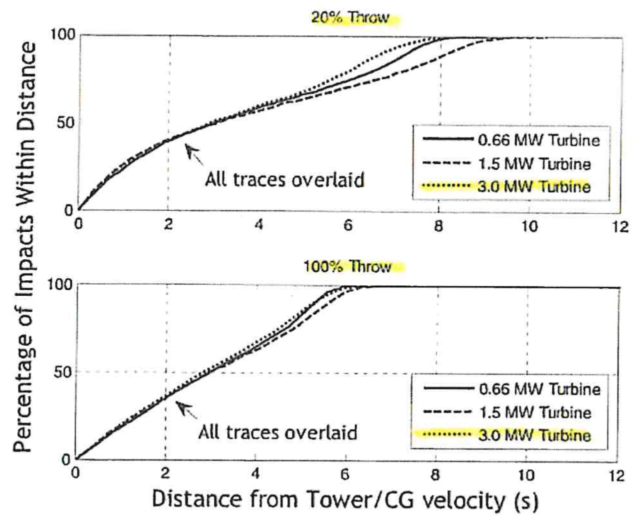


Figure 16. Percentage of impacts within distance versus normalized distance for each turbine.

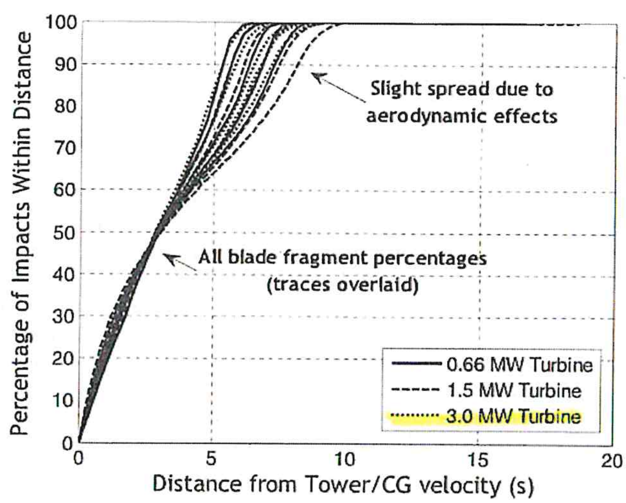


Figure 17. Percentage of impacts within distance versus normalized distance for each turbine, all fragment sizes.

It is clear based on the relationship shown in equation (16) that 99.9% of blade fragment impacts falls within a circle of radius 8.4 times the fragment CG release velocity in meters per second, where the multiplier 8.4 has the unit of seconds. Note that this can be easily computed for a specific turbine and a fragment of a given size.

Equation (16) is a powerful tool that can be used to compute appropriate setback distances for a wide variety of turbine platforms. However, this expression must be used in conjunction with several other parameters in order to produce a meaningful setback. These parameters are the probability that the turbine throws a blade or blade fragment over a given period of time, the minimum size blade fragment of concern, and the desired probability of impact greater than or equal to a certain distance if a blade throw does occur.

The following is an example case demonstrating how equation (16) can be used to determine a risk-based setback. Suppose a regulator or wind farm developer wishes to determine the proper setback distance for a single Vestas 2.0 MW turbine (Vestas Wind Systems A/S, Randers, Denmark) such that in a single year, the probability that a blade fragment will be thrown a distance equal to or beyond the setback is 5.0×10^{-5} (or one occurrence per year for every 20,000 turbines). Further, suppose that the regulator or developer is concerned only with the impact of fragments greater than or equal to 2 m in length. Table IV describes specifications of the Vestas 2.0 MW turbine under consideration here. First, by using the specifications outlined in Table IV, the 2 m blade fragment mass center release velocity is found to be 68.3 m s^{-1},

EXAMPLE PROBLEM

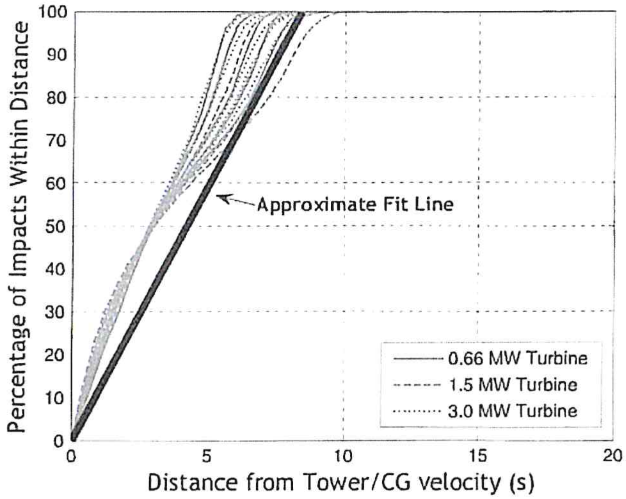


Figure 18. Linear fit to percentage versus distance data.

Table IV. Specifications for Vestas 2.0 MW turbine.

Rotor radius (m)	40
Tower height (m)	67
Rotor rotational speed (rad s^{-1})	1.75

assuming the fragment mass center is located in the middle of the fragment. Second, the probability that given a blade fragment release, the fragment lands outside the setback distance must be computed. This is accomplished by dividing the desired yearly probability that a fragment will fly to or beyond the setback by the probability that a blade failure will occur in a given year. A commonly accepted probability of blade failure per turbine per year, outlined in Rademakers and Braam,[10] is 2.6×10^{-4}. Therefore, the probability that given a fragment release, the fragment will land outside the setback distance must be equal to 0.1923. The percentage of impacts contained within the setback distance from the turbine base, the left-hand-side of equation (9), is given by $100 \times (1 - 0.1923) = 80.77\%$. Thus, equation (16) can be used to compute the desired setback distance of approximately 463 m. Note that this identical analysis can be universally applied to a variety of modern turbine designs, fragment sizes and accepted risk levels. Also, it should be noted that only the smallest fragment size of concern should be used in the proposed method of setback determination, since in general, the smallest fragments will fly farthest because of higher release velocities at the fragment mass center. Thus, all larger fragments will have a lower probability of impact outside the computed setback distance.

EXAMPLE CONT.

It is important to note that rotor overspeed situations can lead in some cases to blade throw and are not taken into account in the setback development proposed here. However, after extensive study of actual wind turbine blade failures over the course of many years, Rademakers and Braam[10] place the probability of blade failure because of an overspeed situation at 5.0×10^{-6} per turbine per year. This probability is far less than the overall blade fragment release probability of 2.6×10^{-4}, since such incidents would require the failure of multiple safety mechanisms that are becoming increasingly reliable, and thus, rotor overspeed scenarios are not included in the analysis conducted here.

4. CONCLUSION

Wind turbine setback standards designed to protect people, property and infrastructure from impact by thrown blade fragments play an important role in wind farm planning and can often be a determining factor in the number of turbines that can be placed within a given parcel of land. Given the critical importance of these regulations, there is a desire to develop setback standards based on a physical model of blade throw rather than arbitrary rules of thumb. First, a physical model for full or partial blade throw based on rigid body dynamics was described. This model, coupled with Monte Carlo simulation techniques, was used to simulate tens of thousands of blade throws for three example wind turbines of varying size. It was shown that typical current setback standards do not provide adequate protection in most cases. Then, the importance of fragment release velocity in determining maximum throw distance was analytically demonstrated, and its effect verified through analysis of Monte Carlo results. Normalizing throw distance by fragment release velocity yielded a near-linear relationship between this normalized distance and the percentage of impacts that lie within this distance from the turbine. A final example used this relationship to determine a proper setback distance for an example turbine based on an acceptable level of risk. Setback development using this methodology allows regulators to mitigate risk using valid engineering analysis rather than arbitrary rules that provide inconsistent and inadequate protection.

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ATTACHMENT 9

World Health Organization

REGIONAL OFFICE FOR Europe

ENVIRONMENTAL NOISE GUIDELINES

for the European Region

Abstract

Noise is an important public health issue. It has negative impacts on human health and well-being and is a growing concern. The WHO Regional Office for Europe has developed these guidelines, based on the growing understanding of these health impacts of exposure to environmental noise. The main purpose of these guidelines is to provide recommendations for protecting human health from exposure to environmental noise originating from various sources: transportation (road traffic, railway and aircraft) noise, wind turbine noise and leisure noise. They provide robust public health advice underpinned by evidence, which is essential to drive policy action that will protect communities from the adverse effects of noise. The guidelines are published by the WHO Regional Office for Europe. In terms of their health implications, the recommended exposure levels can be considered applicable in other regions and suitable for a global audience.

Keyword

NOISE – ADVERSE EFFECTS, PREVENTION AND CONTROL

ENVIRONMENTAL EXPOSURE – ADVERSE EFFECTS, PREVENTION AND CONTROL

GUIDELINES

EUROPE

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World Health Organization
REGIONAL OFFICE FOR Europe

Environmental Noise Guidelines for the European Region

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Foreword

Noise is one of the most important environmental risks to health and continues to be a growing concern among policy-makers and the public alike. Based on the assessment threshold specified in the Environmental Noise Directive of the European Union (EU), at least 100 million people in the EU are affected by road traffic noise, and in western Europe alone at least 1.6 million healthy years of life are lost as a result of road traffic noise.

At the request of Member States at the Fifth Ministerial Conference on Environment and Health in Parma, Italy, in March 2010, the WHO Regional Office for Europe has developed these guidelines, based on the growing understanding of the health impacts of exposure to environmental noise. They provide robust public health advice, which is essential to drive policy action that will protect communities from the adverse effects of noise.

These WHO guidelines – the first of their kind globally – provide recommendations for protecting human health from exposure to environmental noise originating from various sources. They not only offer robust public health advice but also serve as a solid basis for future updates, given the growing recognition of the problem and the rapid advances in research on the health impacts of noise. The comprehensive process of developing the guidelines has followed a rigorous methodology; their recommendations are based on systematic reviews of evidence that consider more health outcomes of noise exposure than ever before. Through their potential to influence urban, transport and energy policies, these guidelines contribute to the 2030 Agenda for Sustainable Development and support WHO's vision of creating resilient communities and supportive environments in the European Region.

Following the publication of WHO's community noise guidelines in 1999 and night noise guidelines for Europe in 2009, these latest guidelines represent the next evolutionary step, taking advantage of the growing diversity and quality standards in this research domain. Comprehensive and robust, and underpinned by evidence, they will serve as a sound basis for action. While these guidelines focus on the WHO European Region and provide policy guidance to Member States that is compatible with the noise indicators used in the EU's Environmental Noise Directive, they still have global relevance. Indeed, a large body of the evidence underpinning the recommendations was derived not only from noise effect studies in Europe but also from research in other parts of the world – mainly in Asia, Australia and the United States of America.

I am proud to present these guidelines as another leading example of the normative work undertaken in our Region in the area of environment and health. On behalf of the WHO Regional Office for Europe and our European Centre for Environment and Health in Bonn, Germany, which coordinated the development of the guidelines, I would like to express my gratitude to the large network of experts, partners, colleagues and consultants who have contributed to this excellent publication. I would also like to thank Switzerland and Germany for providing financial support to this complex project, and look forward to following the influence of the guidelines on policy and research in the years to come.

Dr Zsuzsanna Jakab

WHO Regional Director for Europe

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The WHO Regional Office for Europe, through its European Centre for Environment and Health, coordinated the development of these guidelines. The project was coordinated by Marie-Eve Héroux and Dorota Jarosinska, under the overall supervision of Elizabet Paunovic, Head of the European Centre for Environment and Health.

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Abbreviations

%HA	percentage of the population "highly annoyed"
%HSD	percentage of the population "highly sleep-disturbed"
BMI	body mass index
CI	confidence interval
CNG	WHO guidelines for community noise
DALY	disability-adjusted life-year
dB	decibel
DW	disability weight
EC	European Commission
EEA	European Environment Agency
END	European Union Directive 2002/49/EC relating to the assessment and management of environmental noise (Environmental Noise Directive)
ERF	exposure–response function
EU	European Union
GDG	Guideline Development Group
GRADE	Grading of Recommendations Assessment Development and Evaluation
ICBEN	International Commission on Biological Effects of Noise
IHD	ischaemic heart disease
JRC	Joint Research Centre [of the European Commission]
mmHg	milimeters of mercury
NNG	WHO night noise guidelines for Europe
OR	odds ratio
PECCOS	population, exposure, comparator, confounder, outcome and study [framework]
PICOS	population, intervention, comparator, outcome and study [framework]
PLD	personal listening device
RANCH	Road traffic and aircraft noise exposure and children's cognition and health [study]
RCT	randomized control trial
RR	relative risk
SCENIHR	Scientific Committee on Emerging and Newly Identified Hazards and Risk

Glossary of acoustic terms

A-weighting	A frequency-dependent correction that is applied to a measured or calculated sound of moderate intensity to mimic the varying sensitivity of the ear to sound for different frequencies
C-weighting	A frequency-dependent correction that is applied to a measured or calculated sound of moderate intensity to mimic the varying sensitivity of the ear to sound for different frequencies – C-weighting is usually used for peak measurements
FAST	Fast response has a time constant of 125 milliseconds on a sound level meter
$L_{Aeq,T}$	A-weighted, equivalent continuous sound pressure level during a stated time interval starting at t_1 and ending at t_2, expressed in decibels (dB), at a given point in space[1]
$L_{A,max}$	Maximum time-weighted and A-weighted sound pressure level within a stated time interval starting at t_1 and ending at t_2, expressed in dB[1]
L_{AF}	A-weighted sound pressure level with FAST time constant as specified in IEC 61672-1[1]
$L_{AF,max}$	Maximum time-weighted and A-weighted sound pressure level with FAST time constant within a stated time interval starting at t_1 and ending at t_2, expressed in dB
$L_{AS,max}$	Maximum time-weighted and A-weighted sound pressure level with SLOW time constant within a stated time interval starting at t_1 and ending at t_2, expressed in dB
L_E	Sound energy density level is the logarithmic ratio of the time-averaged sound energy per unit volume to the reference sound energy density Eo = 10-12 J/m^3.
$L_{ex,8h}$	L_{eq} (equivalent continuous sound level) corrected for the length of the working shift, in this case 8 hours
L_{day}	Equivalent continuous sound pressure level when the reference time interval is the day[1]
L_{den}	Day-evening-night-weighted sound pressure level as defined in section 3.6.4 of ISO 1996-1:2016[1]
L_{dn}	Day-night-weighted sound pressure level as defined in section 3.6.4 of ISO 1996-1:2016[1]
$L_{evening}$	Equivalent continuous sound pressure level when the reference time interval is the evening[1]

[1] *Source*: ISO (2016).

L_{night}	Equivalent continuous sound pressure level when the reference time interval is the night[1]
$L_{peak,C}$	Level of peak sound pressure with C-weighting, within a specified time interval
$L_{peak,lin}$	Level of peak sound pressure with linear frequency weighting, within a specified time interval
Sound pressure level	the logarithm of the ratio of a given sound pressure to the reference sound pressure in dB is 20 times the logarithm to the base ten of the ratio.
SLOW	Slow response has a time constant of 10 000 milliseconds on a sound level meter

Executive summary

Environmental noise is an important public health issue, featuring among the top environmental risks to health. It has negative impacts on human health and well-being and is a growing concern among both the general public and policy-makers in Europe.

At the Fifth Ministerial Conference on Environment and Health in Parma, Italy, in 2010, WHO was requested by the Member States in the European Region to produce noise guidelines that included not only transportation noise sources but also personal electronic devices, toys and wind turbines, which had not yet been considered in existing guidelines. Furthermore, European Union Directive 2002/49/EC relating to the assessment and management of environmental noise (END) and related technical guidance from the European Environment Agency both elaborated on the issue of environmental noise and the importance of up-to-date noise guidelines.

The WHO Regional Office for Europe has therefore developed environmental noise guidelines for the European Region, proposing an updated set of public health recommendations on exposure to environmental noise.

Objectives

The main purpose of these guidelines is to provide recommendations for protecting human health from exposure to environmental noise originating from various sources: transportation (road traffic, railway and aircraft) noise, wind turbine noise and leisure noise. Leisure noise in this context refers to all noise sources that people are exposed to due to leisure activities, such as attending nightclubs, pubs, fitness classes, live sporting events, concerts or live music venues and listening to loud music through personal listening devices. The guidelines focus on the WHO European Region and provide policy guidance to Member States that is compatible with the noise indicators used in the European Union's END.

The following two key questions identify the issues addressed by the guidelines.

- In the general population exposed to environmental noise, what is the exposure–response relationship between exposure to environmental noise (reported as various indicators) and the proportion of people with a validated measure of health outcome, when adjusted for confounders?
- In the general population exposed to environmental noise, are interventions effective in reducing exposure to and/or health outcomes from environmental noise?

In light of these questions, the guidelines set out to define recommended exposure levels for environmental noise in order to protect population health.

Methods used to develop the guidelines

The process of developing the WHO guidelines followed a rigorous methodology involving several groups with separate roles and responsibilities. Throughout the process, the Grading of

Recommendations Assessment, Development and Evaluation (GRADE) approach was followed. In particular, the different steps in the development of the guidelines included:

- formulation of the scope and key questions of the guidelines;
- review of the pertinent literature;
- selection of priority health outcome measures;
- a systematic review of the evidence;
- assessment of certainty of the bodies of evidence resulting from systematic reviews;
- identification of guideline exposure levels; and
- setting of the strength of recommendations.

Based on the defined scope and key questions, these guidelines reviewed the pertinent literature in order to incorporate significant research undertaken in the area of environmental noise and health since the community noise guidelines and night noise guidelines for Europe were issued (WHO, 1999; WHO Regional Office for Europe, 2009). In total, eight systematic reviews of evidence were conducted to assess the relationship between environmental noise and the following health outcomes: cardiovascular and metabolic effects; annoyance; effects on sleep; cognitive impairment; hearing impairment and tinnitus; adverse birth outcomes; and quality of life, mental health and well-being. A separate systematic review of evidence was conducted to assess the effectiveness of environmental noise interventions in reducing exposure and associated impacts on health.[2] Once identified and synthesized, the quality of the evidence of the systematic reviews was assessed by the Systematic Review Team. Subsequently, the Guideline Development Group (GDG) formulated recommendations, guided by the Systematic Review Team's assessment and informed by of a number of additional contextual parameters. To facilitate the formulation of recommendations, the GDG first defined priority health outcomes and then selected the most relevant health outcome measures for the outcomes. Consecutively, a process was developed to identify the guideline exposure levels with the help of the exposure–response functions provided by the systematic reviews. To reflect the nature of the research (observational studies) underpinning the relationship between environmental noise and health, the GRADE procedures were adapted to the requirements of environmental exposure studies where needed.

Noise indicators

From a scientific point of view, the best noise indicator is the one that performs best in predicting the effect of interest. There are, however, a number of additional criteria that may influence the choice of indicator. For example, various indicators might be suitable for different health end-points. Some considerations of a more political nature can be found in the European Commision's Position paper on EU noise indicators (EC, 2000).

[2] All systematic reviews are publicly available online in the *International Journal of Environmental Research and Public Health*. A detailed list of links to the individual reviews is provided in section 2.3.2 and in Annex 2 of these guidelines.

The current guidelines are intended to be suitable for policy-making in the WHO European Region. They therefore focus on the most used noise indicators L_{den} and/or L_{night} (see the glossary of acoustic terms for further details). They can be constructed using their components (L_{day}, $L_{evening}$, L_{night} and the duration in hours of L_{night}), and are provided for exposure at the most exposed façade, outdoors. The L_{den} and L_{night} indicators are those generally reported by authorities and are widely used for exposure assessment in health effect studies.

Recommendations

Specific recommendations have been formulated for road traffic noise, railway noise, aircraft noise, wind turbine noise and leisure noise. Recommendations are rated as either strong or conditional.

Strength of recommendation

- A **strong** recommendation can be adopted as policy in most situations. The guideline is based on the confidence that the desirable effects of adherence to the recommendation outweigh the undesirable consequences. The quality of evidence for a net benefit – combined with information about the values, preferences and resources – inform this recommendation, which should be implemented in most circumstances.
- A **conditional** recommendation requires a policy-making process with substantial debate and involvement of various stakeholders. There is less certainty of its efficacy owing to lower quality of evidence of a net benefit, opposing values and preferences of individuals and populations affected or the high resource implications of the recommendation, meaning there may be circumstances or settings in which it will not apply.

Alongside specific recommendations, several guiding principles were developed to provide generic advice and support for the incorporation of recommendations into a policy framework. They apply to the implementation of all of the specific recommendations.

Guiding principles: reduce, promote, coordinate and involve

- Reduce exposure to noise, while conserving quiet areas.
- Promote interventions to reduce exposure to noise and improve health.
- Coordinate approaches to control noise sources and other environmental health risks.
- Inform and involve communities potentially affected by a change in noise exposure.

The recommendations, source by source, are as follows.

Road traffic noise

Recommendation	Strength
For average noise exposure, the GDG strongly recommends reducing noise levels produced by road traffic below **53 decibels (dB)** L_{den}, as road traffic noise above this level is associated with adverse health effects.	Strong
For night noise exposure, the GDG strongly recommends reducing noise levels produced by road traffic during night time below **45 dB** L_{night}, as night-time road traffic noise above this level is associated with adverse effects on sleep.	Strong
To reduce health effects, the GDG strongly recommends that policy-makers implement suitable measures to reduce noise exposure from road traffic in the population exposed to levels above the guideline values for average and night noise exposure. For specific interventions, the GDG recommends reducing noise both at the source and on the route between the source and the affected population by changes in infrastructure.	Strong

Railway noise

Recommendation	Strength
For average noise exposure, the GDG strongly recommends reducing noise levels produced by railway traffic below **54 dB** L_{den}, as railway noise above this level is associated with adverse health effects.	Strong
For night noise exposure, the GDG strongly recommends reducing noise levels produced by railway traffic during night time below **44 dB** L_{night}, as night-time railway noise above this level is associated with adverse effects on sleep.	Strong
To reduce health effects, the GDG strongly recommends that policy-makers implement suitable measures to reduce noise exposure from railways in the population exposed to levels above the guideline values for average and night noise exposure. There is, however, insufficient evidence to recommend one type of intervention over another.	Strong

Aircraft noise

Recommendation	Strength
For average noise exposure, the GDG strongly recommends reducing noise levels produced by aircraft below **45 dB** L_{den}, as aircraft noise above this level is associated with adverse health effects.	Strong
For night noise exposure, the GDG strongly recommends reducing noise levels produced by aircraft during night time below **40 dB** L_{night}, as night-time aircraft noise above this level is associated with adverse effects on sleep.	Strong
To reduce health effects, the GDG strongly recommends that policy-makers implement suitable measures to reduce noise exposure from aircraft in the population exposed to levels above the guideline values for average and night noise exposure. For specific interventions the GDG recommends implementing suitable changes in infrastructure.	Strong

Wind turbine noise

Recommendation	Strength
For average noise exposure, the GDG conditionally recommends reducing noise levels produced by wind turbines below **45 dB** L_{den}, as wind turbine noise above this level is associated with adverse health effects.	Conditional
No recommendation is made for average night noise exposure L_{night} of wind turbines. The quality of evidence of night-time exposure to wind turbine noise is too low to allow a recommendation.	
To reduce health effects, the GDG conditionally recommends that policy-makers implement suitable measures to reduce noise exposure from wind turbines in the population exposed to levels above the guideline values for average noise exposure. No evidence is available, however, to facilitate the recommendation of one particular type of intervention over another.	Conditional

Leisure noise

Recommendation	Strength
For average noise exposure, the GDG conditionally recommends reducing the yearly average from all leisure noise sources combined to **70 dB** $L_{Aeq,24h}$ as leisure noise above this level is associated with adverse health effects. The equal energy principle[3] can be used to derive exposure limits for other time averages, which might be more practical in regulatory processes.	Conditional
For single-event and impulse noise exposures, the GDG conditionally recommends following existing guidelines and legal regulations to limit the risk of increases in hearing impairment from leisure noise in both children and adults.	Conditional
Following a precautionary approach, to reduce possible health effects, the GDG strongly recommends that policy-makers take action to prevent exposure above the guideline values for average noise and single-event and impulse noise exposures. This is particularly relevant as a large number of people may be exposed to and at risk of hearing impairment through the use of personal listening devices. There is insufficient evidence, however, to recommend one type of intervention over another.	Strong

Target audience

The guidelines are published by the WHO Regional Office for Europe. In terms of their health implications, the recommended exposure levels can be considered applicable in other regions and suitable for a global audience, as a large body of the evidence underpinning the recommendations was derived not only from European noise effect studies but also from research in other parts of the world – mainly in America, Asia and Australia.

[3] The equal energy principle states that the total effect of sound is proportional to the total amount of sound energy received by the ear, irrespective of the distribution of that energy in time (WHO, 1999).

1. Introduction

Environmental noise features among the top environmental risks to physical and mental health and well-being, with a substantial associated burden of disease in Europe (WHO Regional Office for Europe & JRC, 2011; Hänninen et al., 2014). It has negative impacts on human health and well-being and is a growing concern among both the general public and policy-makers in Europe.

WHO published community noise guidelines (CNG) and night noise guidelines (NNG) for Europe in 1999 and 2009, respectively (WHO, 1999; WHO Regional Office for Europe, 2009). Since then, significant new evidence has accumulated on the health effects of environmental noise.

The need for updated health-based guidelines originates in part from commitments made at the Fifth Ministerial Conference on Environment and Health in Parma, Italy, in 2010, where Member States asked WHO to produce appropriate noise guidelines that would include additional noise sources such as personal electronic devices, toys and wind turbines (WHO Regional Office for Europe, 2010). Furthermore, European Union (EU) Directive 2002/49/EC relating to the assessment and management of environmental noise (the END – EC, 2002a) and related technical guidance from the European Environment Agency (EEA) both elaborated on the issue of environmental noise and the importance of up-to-date noise guidelines (EEA, 2010).

The WHO Regional Office for Europe has therefore developed environmental noise guidelines for the European Region, proposing an updated set of public health recommendations on exposure to environmental noise. The main purpose of these guidelines is to provide recommendations for protecting human health from exposure to environmental noise originating from various sources: transportation (road traffic, railway and aircraft) noise, wind turbine noise and leisure noise. The guidelines focus on the WHO European Region and provide policy guidance to Member States that is compatible with the noise indicators used in the EU's END.

The following two key questions identify the issues addressed by the guidelines.

- In the general population exposed to environmental noise, what is the exposure–response relationship between exposure to environmental noise (reported as various indicators) and the proportion of people with a validated measure of health outcome, when adjusted for confounders?
- In the general population exposed to environmental noise, are interventions effective in reducing exposure to and/or health outcomes from environmental noise?

1.1 The public health burden from environmental noise

Exposure to noise can lead to auditory and nonauditory effects on health. Through direct injury to the auditory system, noise leads to auditory effects such as hearing loss and tinnitus. Noise is also a nonspecific stressor that has been shown to have an adverse effect on human health, especially following long-term exposure. These effects are the result of psychological and physiological distress, as well as a disturbance of the organism's homeostasis and increasing allostatic load (Basner et al., 2014). This is further outlined in the WHO narrative review of the biological mechanisms of nonauditory effects (Eriksson et al., 2018).

The evidence of the association between noise exposure and health effects is based on experimental work regarding biological plausibility and, in observational studies, consistency among study results, presence of an exposure–response relationship and the magnitude of the effect. Environmental noise risk assessment and risk management relies on established exposure–response relationships (Babisch, 2014).

In 2011 the WHO Regional Office for Europe and the European Commission (EC) Joint Research Centre (JRC) published a report on the burden of disease from environmental noise that quantified the healthy years of life lost in western Europeam countries as a result of environmental noise (WHO Regional Office for Europe & JRC, 2011). The burden of disease is calculated, in a single measure of disability-adjusted life-years (DALYs), as the sum of the years of life lost from premature mortality and the years lived with disability for people living with the disease or health condition or its consequences in the general population (WHO, 2014a).

Sufficient information was deemed available to quantify the burden of disease from environmental noise for cardiovascular disease, cognitive impairment in children, sleep disturbance, tinnitus and annoyance. The report, based on a limited set of data, estimated that DALYs lost from environmental noise in western European countries are equivalent to 61 000 years for ischaemic heart disease (IHD), 45 000 years for cognitive impairment in children, 903 000 years for sleep disturbance, 22 000 years for tinnitus and 654 000 years for annoyance (WHO Regional Office for Europe & JRC, 2011). These results indicate that at least one million healthy years of life are lost every year from traffic-related environmental noise in western Europe. Sleep disturbance and annoyance, mostly related to road traffic noise, constitute the bulk of this burden. Available assessments place the burden of disease from environmental noise as the second highest after air pollution (WHO Regional Office for Europe & JRC, 2011; Hänninen et al., 2014; WHO 2014b). However, a lack of noise exposure data in the central and eastern parts of the WHO European Region means that it is not possible to assess the burden of disease from environmental noise for the whole Region.

1.2 The environmental noise policy context in the EU

The EU has been working to develop a harmonized noise policy for more than two decades. 1993 saw the start of the EC's Fifth Environment Action Programme, which stated that "no person should be exposed to noise levels which endanger health and quality of life" (EC, 1993). This was followed by a Green Paper on future noise policy (EC, 1996), which reinforced the importance of noise as one of the main environmental problems in Europe and proposed a new framework for noise policy development.

The Sixth Environment Action Programme had as one of its objectives: "to achieve a quality of environment where the levels of man-made contaminants do not give rise to significant impacts on, or risks to, human health" (EC, 2002b). This paved the way for the Commission to adopt and implement the END in 2002 (EC, 2002a). The main aim of the Directive is "to define a common approach intended to avoid, prevent or reduce on a prioritized basis the harmful effects, including annoyance, due to exposure to environmental noise".

The END obliges the EC to adapt its Annexes I–III (I on noise indicators in addition to L_{den}[4] and L_{night}[5], II on noise assessment methods and III on methods for assessing harmful effects of noise) to technical and scientific progress. While work on revising Annex II was finalized in 2015 and common noise assessment methods were introduced (EC, 2015), revisions of Annex III to establish methods to assess the harmful effects of noise only started in 2015. Annex III would primarily define what exposure–response relationships should be used to assess the effect of noise on populations. EU Member States have already expressed the view that the recommendations from these environmental noise guidelines for the WHO European Region will guide the revision of Annex III. Beside this main directive, few other legislative documents cover different noise sources and other related issues in the EU (EEA, 2014: Annex I).

The Seventh Environment Action Programme, which guides European environment policy until 2020 (EC, 2014a), is committed to safeguarding the EU's citizens from environment-related risks to health by ensuring that by 2020 "noise pollution in the Union has significantly decreased, moving closer to WHO-recommended levels". A particular requirement for achieving this is "implementing an updated EU noise policy aligned with the latest scientific knowledge, and measures to reduce noise at source, and including improvements in city design".

In addition to the EU's END, several national governments also have legislation and/or limit values that apply at national and/or regional levels (WHO Regional Office for Europe, 2012). The EEA, through its European Topic Centre on Land Use and Spatial Information, gathers noise exposure data and maintains the Noise Observation and Information Service for Europe, based on strategic noise maps provided by Member States (EEA, 2018). A total of 33 EEA countries, in addition to six cooperating countries in south-eastern Europe, report information on noise exposure to the EEA, following the requirements of the END. The quality and availability of noise exposure assessment differs between EU and non-EU Member States where, even if noise legislation has been harmonized with the Directive, noise mapping and action plans are still at the planning stage (EEA, 2014; 2017a; WHO Regional Office for Europe, 2012).

1.2.1 Definition of indicators in the END

The END specifies a number of noise indicators to be applied by Member States in noise mapping and action planning. The most important are L_{den} and L_{night}.

The L_{den} indicator is an average sound pressure level over all days, evenings and nights in a year (EEA, 2010). This compound indicator was adopted by the EU in the END (EC, 2002a). The L_{den} in decibels (dB) is defined by a specific formula, where:

- L_{day} is the A-weighted long-term average sound level as defined in ISO 1996-1: 2016, determined over all the day periods of a year;
- $L_{evening}$ is the A-weighted long-term average sound level as defined in ISO 1996-1: 2016, determined over all the evening periods of a year; and
- L_{night} is the A-weighted long-term average sound level as defined in ISO 1996-1: 2016, determined over all the night periods of a year (ISO, 2016).

4 Day-evening-night-weighted sound pressure level as defined in section 3.6.4 of ISO 1996-1:20161 (ISO, 2016).
5 Equivalent continuous sound pressure level when the reference time interval is the night.

The L_{night}, according to the definition in the END, is an equivalent outdoor sound pressure level, measured at the most exposed façade, associated with a particular type of noise source during night time (at least eight hours), calculated over a period of a year (WHO Regional Office for Europe, 2009).

Annex I of the END gives technical definitions for L_{den} and L_{night}, as well as supplementary noise indicators, which might be useful for monitoring special noise situations. For example, in the case of noisy but short-lived noise like shooting noise or noise emitted by trains, $L_{A,max}$ is often used. This is a measure of the maximum sound pressure reached during a defined measurement period. It is used to set noise limits and is sometimes considered in studies to determine certain health effects (such as awakening reactions).

1.3 Perceptions of environmental noise in the WHO European Region

1.3.1 Trends at the regional level

The general population greatly values the benefits of clean and quiet environments. In Europe, people perceive noise as an important issue that affects human health and well-being (EC, 2008; 2014b). In recent years, several Europe-wide surveys have examined the perception of noise as an issue among the population. Overall, these surveys ask about generic noise, referring to "neighbourhood noise" or "noise from the street". This type of noise differs significantly in its definition from what is considered "environmental noise" in these guidelines. Nevertheless, in the absence of specific large surveys on perceptions of environmental noise as defined in these guidelines, the results provide insight into the public perception of this issue.

The European quality-of-life surveys, carried out every four years, are unique, pan-European surveys examining both the objective circumstances of lives of European citizens and how they feel about those circumstances and their lives in general. The last (fourth) survey was conducted in 2016–2017, involving nearly 37 000 citizens from all EU Member States and the five candidate countries (Albania, Montenegro, Serbia, the former Yugoslav Republic of Macedonia and Turkey). Respondents were asked whether they had major, moderate or no problems with noise in the immediate neighbourhood of their home. Almost one third (32%) reported problems with noise (ranging from 14% to 51% in individual countries), mainly in cities or city suburbs (49%) (Eurofound, 2017).

A 2010 survey of the then 27 countries in the EU, requested by the EC, showed that 80% of respondents (n = 26 602) believed that noise affects their health, either to some or to a great extent (EC, 2010).

A Eurobarometer report on attitudes of European citizens towards the environment (EC, 2014b) compiled opinions on various environmental risks from almost 28 000 respondents in 28 EU countries. Results showed that for 15% of respondents, noise pollution is one of the top five environmental issues they are worried about. Furthermore, 17% of respondents said that they lack information about noise pollution.

1.3.2 Trends at the national level

Data on perception of specific sources of environmental noise as a problem are not available for the entire WHO European Region. Nevertheless, some countries – including France, Germany, the Netherlands, Slovakia and the United Kingdom – conduct national surveys on noise annoyance, either regularly or on demand (Sobotova et al., 2006; Lambert & Philipps-Bertin, 2008; van Poll et al., 2011; Centraal Bureau voor de Statistiek, 2012; Notley et al., 2014; Umweltbundesamt, 2017).

According to these large-scale surveys, road traffic noise is the most important source of annoyance, generally followed closely by neighbour noise. Aircraft noise can also be a substantial source of annoyance. Railway noise and industrial noise are enumerated less frequently. Only limited data are available on the population's perception of newer sources of noise, such as wind turbines.

While perception surveys do not provide information on actual quantitative relationships between noise exposure and health outcomes, it is important to note that the results of such surveys represent people's preferences and values regarding environmental noise. Despite limitations and an incomplete picture, the available data on perception of environmental noise as a public health problem show concern in Europe. People are not always aware of the health impacts of noise, especially of those related to long-term noise exposure at lower levels. Greater awareness of the issue may further increase positive values and preferences.

1.4 Target audience

The environmental noise guidelines for the European Region serve as a reference for an audience made up of different groups, with varied areas of expertise including decision-making, research and advocacy. More specifically, this covers:

- various technical experts and decision-makers at the local, national or international levels, with responsibility for developing and implementing regulations and standards for noise control, urban planning and housing, and other relevant environment and health domains;
- health impact assessment and environmental impact assessment practitioners and researchers;
- national and local authorities responsible for developing and implementing relevant measures and for risk communication;
- nongovernmental organizations and other advocacy groups involved in risk communication and general awareness-raising.

These guidelines are published by the WHO Regional Office for Europe. In terms of their health implications, the recommended exposure levels can be considered applicable in other regions and suitable for a global audience, as a large body of the evidence underpinning the recommendations was derived not only from European noise effect studies but also from research in other parts of the world – mainly in America, Asia and Australia.

2. Development of the guidelines

2.1 Overview

The process of developing WHO guidelines follows a rigorous methodology and involves several groups with well defined roles and responsibilities (WHO, 2014c). These include: formulation of the scope and key questions of the guidelines; review of the pertinent literature; selection of priority health outcome measures; a systematic review of the evidence; an assessment of certainty of the bodies of evidence resulting from systematic reviews; identification of guideline exposure levels; and setting of the strength of recommendations. Throughout the process, the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach was followed (Morgan et al., 2016).

The development of environmental noise guidelines started in 2013. Following WHO's procedures, the WHO Regional Office for Europe, through its European Centre for Environment and Health in Bonn, Germany, obtained planning approval and established a Steering Group and a Guideline Development Group (GDG). The former was primarily involved in initiating, structuring and executing the guideline development process; the latter was composed of leading experts and end-users, responsible for the process of scoping the guidelines and developing the evidence-based recommendations. During the initiation meeting in October 2013 in Bonn, the GDG members defined the scope of the guidelines, decided on the key questions to be addressed, prioritized health outcomes and set a timeline for completion of the work. Furthermore, authors were appointed for background papers, systematic reviews and different guideline background chapters.

In October 2014 a main evidence review meeting was held between the GDG and the Systematic Review Team in Bern, Switzerland, to discuss the evidence review drafts. In October 2014 and May 2015 the GDG met in Bern and Bonn, respectively, to refine the scope and draft recommendations. The revision and finalization of the systematic reviews of evidence was completed in early 2017. Through a series of remote meetings and teleconferences, the GDG discussed and addressed the remaining outstanding issues and feedback from the peer review of the draft guidelines, and decided on the final formulation of the recommendations. The following sections describe the steps of the guideline development process in detail.

2.2 Scope of the guidelines

Defining the scope of the guidelines included the selection of noise sources to be considered, as well as situations in which people are exposed, and noise indicators used for the formulation of recommendations. These guidelines separately consider outdoor exposure to environmental noise from road traffic, railway traffic, aircraft, wind turbines as well as outdoor and indoor exposure during leisure activities (such as attending nightclubs, pubs, fitness classes, live sporting events, concerts or live music venues and listening to loud music through personal listening devices). The guidelines are source specific and not environment specific. They therefore cover all settings where people spend a significant portion of their time, such as residences, educational institutions, workplaces and public venues, although hospital noise is exempted from the list of public institutions owing to the unique characteristics of the population involved.

The GDG agreed not to develop specific recommendations for occupational and industrial noise. Industrial noise can affect both people working at an industrial site and those living in its vicinity. The guidelines do not consider workers' exposure to noise in industrial environments, as these are regulated by workplace standards and may, in some cases, require the wearing of protective equipment or application of other preventive and protective measures. Further, the guidelines do not explicitly consider industrial noise as an environmental noise source, affecting people living in the vicinities of industrial sites. This is mainly due to the large heterogeneity and specific features of industrial noise, and the fact that exposure to industrial noise has a very localized character in the urban population.

Likewise, the current guidelines do not provide specific recommendations for the prevention of health effects linked to neighbourhood noise. Neighbourhood noise may stem from various potential sources of noise (such as ventilation systems; church bells; animals; neighbours; commercial, recreational and occupational activities; or shooting/military). As the sources may be located in close proximity to where people live, they can cause considerable concern even at low levels (Omlin et al., 2011). Several of these sources can also produce low-frequency noise, and as such, require indoor measurements for proper exposure assessment. In general, little scientific research is available on exposure and health outcomes related to neighbourhood noise.

Moreover, the guidelines do not include recommendations about any kind of multiple exposures. In everyday life people are often exposed to noise from several sources at the same time. In Germany, for example, 44% of the population are annoyed by at least two and up to five sources of noise (Umweltbundesamt, 2015). For some health outcomes, such as obesity, new evidence indicates that combined exposure to noise from several means of transportation is particularly harmful (Pyko et al., 2015; 2017).

Research indicates that, alongside exposure to more than one source of noise, combined exposure to different factors – for example, noise and vibration or noise and air pollution – has gained increasing relevance in recent years (Sörensen et al., 2017). The EC estimates that the social cost of noise and air pollution is up to €1 trillion every year (EC, 2016a). WHO acknowledges the need to develop comprehensive models to quantify the effects of multiple exposures on human health. As the main body of evidence on environmental noise still focuses on source-specific impacts of noise on health outcomes and does not incorporate combined exposure effects of multiple noise sources or other pollutants, however, the current guidelines provide recommendations for each source of noise specifically. No attempt has been made to combine noise from multiple sources for any particular health outcome.

2.2.1 Key questions

The environmental noise guidelines for the WHO European Region seek to address two main questions, which define the issues addressed by the guideline recommendations.

- In the general population exposed to environmental noise, what is the exposure–response relationship between exposure to environmental noise (reported as various indicators) and the proportion of people with a validated measure of health outcome, when adjusted for confounders?
- In the general population exposed to environmental noise, are interventions effective in reducing exposure to and/or health outcomes from environmental noise?

2.2.2 Environmental noise indicators used in the guidelines

From a scientific point of view, the best noise indicator is the one that performs best in predicting the effect of interest. There are, however, a number of additional criteria that may influence the choice of indicator because, for example, various indicators might be suitable for different health end-points and some indicators are more practical to use or easier to calculate than others. Some of these considerations are of a more political nature, as mentioned in the EC's Position paper on EU noise indicators (EC, 2000).

The current guidelines are intended to be suitable for policy-making primarily in the WHO European Region. They are therefore based on the most frequently used average noise indicators in Europe: L_{den} and L_{night}. These are often reported by authorities and are used widely for exposure assessment in health effect studies and noise impact assessments in the Region. The L_{den} (also referred to as "DENL") indicator can be calculated as the A-weighted average sound pressure level, measured over a 24-hour period, with a 10 dB penalty added to the average level in the night (23:00–07:00 or 22:00–06:00), a 5 dB penalty added to the evening (19:00–23:00 or 18:00–22:00) and no penalty added to the daytime period (07:00–19:00 or 06:00–18:00). The penalties are introduced to indicate people's extra sensitivity to noise during the evening and night. The L_{night} indicator is the A-weighted average sound pressure level, measured over an eight-hour period during night time, usually between 23:00 and 07:00 (EC, 2002a).

In these guidelines, L_{den} and L_{night} refer to a measurement or calculation of noise exposure at the most exposed façade, outdoors, reflecting the long-term average exposure. Thus, L_{den} and L_{night} represent all the single noise events due to a specific noise source that occur over a longer period of time, such as during a year. Moreover, most health outcomes considered in these guidelines are expected to occur as a result of long-term exposure. It is generally accepted that the most relevant parts of the whole day or night, which especially account for the time when a person is at home, are correctly attributed when using average indicators like L_{den} or L_{night}.

The majority of studies that form the body of evidence for the recommendations in these guidelines – among them large-scale epidemiological studies and socioacoustic surveys on annoyance and self-reported sleep disturbance – refer to noise exposure measured outdoors, usually at the most exposed façade of dwellings. Virtually all noise exposure prediction models in use today estimate free-field exposure levels outdoors, and most noise abatement regulations refer to outdoor levels as well. These are the practical reasons why the GDG decided not to recommend any guideline values for noise indoors. Nevertheless, in certain cases it could be helpful to estimate indoor levels based on outdoor values. The differences between indoor and outdoor levels are usually estimated at around 10 dB for open, 15 dB for tilted or half-open and about 25 dB for closed windows. When considering more accurate estimation of indoor levels, using a range of different predictors, the relevant scientific literature can be consulted (Locher et al., 2018).

The GDG was aware of the fact that many countries outside the EU are not bound by the terms of the END (EC, 2002a) and/or use noise indicators other than L_{den} or L_{night} in their noise regulations. They still can make use of these guidelines, however, because energy-based average noise indicators are usually highly correlated and "rule of thumb" transformations from one indicator to another are possible with acceptable uncertainty, as long as the conversion accounts for the long-term average of populations, rather than individual exposure situations. Empirically derived generic conversion terms between a wide range of different noise indicators (including L_{den}, L_{dn}, L_{day}, L_{night} and $L_{Aeq,24h}$; see the glossary of acoustic terms for further details), with their uncertainty estimates, were published recently (Brink et al., 2018). The GDG encourages the use of these conversions, should the need arise.

In many situations, average noise levels like the L_{den} or L_{night} indicators may not be the best to explain a particular noise effect. Single-event noise indicators – such as the maximum sound pressure level ($L_{A,max}$)[6] and its frequency distribution – are warranted in specific situations, such as in the context of night-time railway or aircraft noise events that can clearly elicit awakenings and other physiological reactions that are mostly determined by $L_{A,max}$. Nevertheless, the assessment of the relationship between different types of single-event noise indicators and long-term health outcomes at the population level remains tentative. The guidelines therefore make no recommendations for single-event noise indicators.

Different noise sources – for example, road traffic noise and railway noise – can be characterized by different spectra, different noise level rise times of noise events, different temporal distributions of noise events and different frequency distributions of maximum levels. Because of the extensive differences in the characteristics of individual noise sources, these guidelines only consider source-specific exposure–response functions (ERFs) and, therefore, formulate only source-specific recommendations.

2.3 Evidence base

Based on the overall scope and key questions the current guidelines review the relevant literature in the area of environmental noise and health in order to incorporate significant research undertaken since the publication of previous guidelines. The process of evidence search and retrieval involved several steps. These include the identification, retrieval and synthesis of the evidence, followed by a systematic review and assessment (described in section 2.4).

2.3.1 Identification, retrieval and synthesis of evidence

As a first step, the GDG identified key health outcomes associated with environmental noise. Next, it rated the relevance of these health outcomes according to the following three categories:

- critical for assessing environmental noise issues
- important, but not critical for assessing environmental noise issues
- unimportant.

The GDG rated the relevance based on the seriousness and prevalence of the outcomes and the anticipated availability of evidence for an association with noise exposure. The following health outcomes were selected as either critical or important for developing recommendations on the health impacts of environmental noise.

[6] $L_{A,max}$ is the maximum time-weighted and A-weighted sound pressure level within a stated time interval starting at t1 and ending at t2, expressed in dB.

Critical health outcome	**Important health outcome**
Cardiovascular disease	Adverse birth outcomes
Annoyance[7]	Quality of life, well-being and mental health
Effects on sleep	Metabolic outcomes
Cognitive impairment	
Hearing impairment and tinnitus	

The GDG noted that research into the relationship between noise exposure and its effects on humans brings into focus several questions concerning the definition of health and the boundary between normal social reaction to noise and noise-induced ill health. As stated in WHO's Constitution: "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO, 1946). Accordingly, documenting physical health does not present a complete picture of general health; and being undisturbed by noise in all activities, including sleep, constitutes an asset worthy of protection. Therefore, in accordance with the above definition, the GDG regarded (long-term) annoyance and impaired well-being, as well as self-reported sleep disturbance due to noise, as health outcomes.

Regarding sleep disturbance, the health outcome measures considered in these guidelines largely disregard "objective" indicators of sleep disturbance, such as the probability of awakening reactions or other polysomnography parameters. The main reason for this is the nature of the body of evidence on acute, objectively measured effects of noise during sleep. Studies of physiological effects of sleep and especially polysomnographic investigations are complex and resource-demanding; they therefore include only a small number of participants, who are often healthy young volunteers not representative of the general population. For these reasons, the majority of such studies do not meet the requirements for inclusion in the GRADE framework and full-scale meta-analysis, including adjustment for confounders. Furthermore, it is currently unclear how acute physiological reactions that affect the microstructure of sleep but are less well correlated with global sleep parameters, such as total sleep time, are related to long-term health impediments, especially considering the large interindividual differences in susceptibility to noise (Basner et al., 2011).

As sleeping satisfies a basic need and the absence of undisturbed sleep can have serious effects on human health (WHO Regional Office for Europe, 2009), the GDG set self-reported sleep disturbance, in line with the WHO definition of health, as a primary health outcome. Even though self-reported sleep disturbance might differ considerably from objectively measured parameters of sleep physiology, it constitutes a valid indicator in its own right, as it reflects the effects on sleep perceived by an individual over a longer period of time (WHO Regional Office for Europe & JRC, 2011). The importance of considering both annoyance and self-reported sleep disturbance as health outcomes is further supported by evidence indicating that they may be part of the causal pathway of noise-induced cardiovascular and metabolic diseases. This is further elaborated in the narrative review on biological mechanisms (Eriksson et al., 2018).

[7] Noise annoyance is defined as a feeling of displeasure, nuisance, disturbance or irritation caused by a specific sound (Ouis, 2001). In the current guidelines, "annoyance" refers to long-term noise annoyance.

The second step in the evidence retrieval process constituted formulation of the key questions for the critical and important health outcomes and identification of the areas of evidence to be reviewed, following the PICOS/PECCOS approach defined in the WHO handbook for guideline development (WHO, 2014c). PICOS/PECCOS is an evidence-based technique that frames health care-related questions to facilitate the search for suitable studies that can provide answers to the questions at hand (Huang et al., 2006). The PICOS approach divides intervention questions into five elements: population, intervention, comparator, outcome and study design. In exposure studies, PICOS becomes PECCOS, which stands for population, exposure, comparator, confounder, outcome and study design. The specification of the elements of PICOS/PECCOS serves to construct the body of evidence that underpins each recommendation. Due to the complex nature of environmental noise, several distinct areas of evidence were defined to address each of the scoping questions comprehensively.

For each of the critical and important health outcomes a systematic review was conducted (see also section 2.3.2). Health outcomes regarded as important were given less weight in the decision-making process than critical ones. Inclusion and exclusion criteria to be regarded in the systematic evidence reviews were defined in accordance with the PICOS/PECCOS framework for the evaluation of evidence (see Table 1). All evidence that met the inclusion criteria was included in the systematic reviewing process. A detailed description of the types of measure for each of the health outcomes under consideration is provided in the protocol for conducting the systematic reviews (Héroux & Verbeek, 2018a). See Annex 2 for details of all background documents and systematic reviews used in preparation of these guidelines.

Table 1. Inclusion and exclusion criteria for evidence reviews of health effects of environmental noise

Category	Inclusion criteria	Exclusion criteria
Populations	• Members of the general population • Specific segments of the population particularly at risk (children or vulnerable groups) • People exposed to noise in occupational settings (if relevant with combined exposure to environmental noise)	• Does not meet inclusion criteria
Exposure	• Noise exposure levels, either measured or calculated and expressed in dB values • Representative of the individual exposure of study participants (for most observational studies the dwelling location or home) • Calculated levels for transportation noise (road, rail, air) based on traffic data reflecting the use of roads, railway lines and in- and outbound flight routes at airports	• Does not meet inclusion criteria; in particular: - studies using hearing loss or hearing impairment as a proxy for (previous) noise exposure - surveys assessing noise exposure or number of listening hours based on subjective ratings given by subjects in a questionnaire
Confounders	• No inclusion criteria applied since the relationship between exposure to noise and a health outcome can be confounded by other risk factors; however, possible confounders taken into account were assessed for every study	• No exclusion criteria applied; however, possible confounders taken into account were assessed for every study

Table 1. contd.

Category	Inclusion criteria	Exclusion criteria
Outcomes	• Adverse birth outcomes • Annoyance • Cardiovascular disease • Cognitive impairment • Effects on sleep • Hearing impairment and tinnitus • Metabolic outcomes • Quality of life, mental health and well-being	• Does not meet inclusion criteria
Study types	• Cohort studies • Case-control studies • Cross-sectional studies • Ecological studies (only for cardiovascular disease)	• Does not meet inclusion criteria

Alongside the systematic reviews of the critical and important health outcomes, the GDG decided to review the evidence on health effects from noise mitigation measures and interventions to reduce noise levels in order to inform and complement the recommendations.

Interventions on environmental noise were defined according to five broad categories based on the available intervention literature and the experience of decades of environmental noise management (see Table 2 and Brown & van Kamp, 2017).

Table 2. Types of noise intervention

Intervention type	Intervention category	Intervention subcategory
A	Source intervention	• change in emission levels of sources • time restrictions on source operations
B	Path intervention	• change in the path between source and receiver • path control through insulation of receiver/receiver's dwelling
C	New/closed infrastructure	• opening of a new infrastructure noise source • closure of an existing one • planning controls between (new) receivers and sources
D	Other physical intervention	• change in other physical dimensions of dwelling/neighbourhood
E	Behaviour change intervention	• change in individual behaviour to reduce exposure • avoidance or duration of exposure • community education, communication

The GDG recognized that nonacoustic factors are an important possible confounder in both ERFs between noise levels and critical health effects and the effects of acoustic interventions on health outcomes. Whereas the inclusion criteria for confounders were not specified in PECCOS for the systematic reviews of evidence, they were considered at the stage of assessing the quality of evidence, using the GRADE approach. Depending on the health effect under investigation, possible nonacoustic factors may include:

- gender
- age
- education
- subjective noise sensitivity
- extroversion/introversion
- general stress score
- co-morbidity
- length of residence
- duration of stay at dwelling in the day
- window orientation of a bedroom or living room towards the street
- personal evaluation of the source
- attitudes towards the noise source
- coping capacity with respect to noise
- perception of malfeasance by the authorities responsible
- body mass index
- smoking habits.

In noise annoyance studies nonacoustic factors may explain up to 33% of the variance (Guski, 1999). The higher the quality of evidence, the lower confounding effects of nonacoustic factors may be expected. Nevertheless, as with measurement errors, confounding cannot be avoided.

Based on the retrieval and evaluation of the pertinent literature, the GDG decided to address the association of environmental noise from different sources and health outcomes separately and individually for each source of noise, and for critical and important health outcomes.

In addition to the systematic reviews of the health effects of environmental noise, a narrative review of biological mechanisms of nonauditory effects was conducted (Eriksson et al., 2018). This covers literature related to pathways for nonauditory effects and provides supporting evidence on the association between environmental noise and health outcomes in humans, especially related to cardiovascular and metabolic diseases.

2.3.2 Systematic reviewing process

After the retrieval of the evidence based on the PICOS/PECCOS approach, systematic reviews were conducted for all critical and important health outcomes. To meet the demands of the diverse and broad nature of the evidence, it was agreed that systematic reviews could vary in type. For some areas of evidence, a novel and fully fledged systematic reviewing process was needed to summarize the existing evidence; for others, the reviewing process could build upon existing (and mostly published) systematic reviews and summaries of evidence. Thus, the process consisted of two phases.

First, a comprehensive search was conducted for available systematic reviews and meta-analyses on environmental noise effects published after 2000. Each of the reviews was assessed for both relevance and quality. To be included in the evidence review process, studies from these reviews were required to meet a high quality standard, judged according to high scores of the AMSTAR checklist.[8] In cases where quality criteria were met but the review was older than two years (published before 2012), the search of the systematic review was updated to include new papers. If no good quality systematic reviews were available, a new search for original papers was conducted. The Systematic Review Team decided how the results would affect the search strategy for individual studies as part of the second phase. This was based on the assessment of the quality of the systematic reviews and on the coherence between the main research questions of the systematic reviews and the scope of the work of the guidelines.

In the second phase a search for individual papers was conducted, with the search strategy adapted according to the outcome of the first phase. As availability of systematic reviews and meta-analyses differed for the various health outcomes considered in the guidelines, this process varied for each evidence review. The search included cohort studies, case-control studies and cross-sectional studies of people exposed to environmental noise. Where relevant – for example, for the health outcome cardiovascular disease – the search also included ecological studies.

Due to the individualized retrieval of evidence for each of the systematic reviews, the time frames of the literature included varied. An indication of the temporal coverage of the studies included in different systematic review is provided in the relevant tables in Chapter 4.

A detailed description of the methodology used to conduct the systematic evidence reviews, including individual protocols for the reviews of health effects resulting from environmental noise and from noise interventions, is available (Héroux & Verbeek, 2018b). Furthermore, all systematic reviews conducted in the guideline development process are publicly available in the open-access journal *International Journal of Environmental Research and Public Health*:

- systematic review of transport noise interventions and their impacts on health (Brown & van Kamp, 2017);
- systematic review on environmental noise and adverse birth outcomes (Nieuwenhuijsen et al, 2017);
- systematic review on environmental noise and annoyance (Guski et al., 2017);
- systematic review on environmental noise and cardiovascular and metabolic effects (van Kempen et al., 2018);
- systematic review on environmental noise and cognition (Clark & Paunovic, 2018);
- systematic review on environmental noise and effects on sleep (Basner & McGuire, 2018);
- systematic review on environmental noise and permanent hearing loss and tinnitus (Śliwińska-Kowalska & Zaborowski, 2017);
- systematic review on mental health and well-being (Clark & Paunovic, in press).

[8] AMSTAR is an instrument used to assess quality of evidence; it stands for “A MeaSurement Tool to Assess systematic Reviews” (Shea et al., 2007).

2.4 From evidence to recommendations

Once the evidence had been identified and synthesized, the Systematic Review Team assessed its quality. Subsequently, the GDG formulated recommendations, guided by this assessment and consideration of a number of other factors recognized as important. To facilitate the formulation of recommendations, it first prioritized the health outcome measures of the critical and important outcomes. A process was developed to identify the guideline exposure levels from each of the ERFs provided by the systematic reviews of evidence.

The following sections describe the assessment of the overall quality of the evidence based on the GRADE approach, selection of priority health outcome measurements, identification of guideline exposure levels and setting the strength of recommendations.

2.4.1 Assessment of overall quality of a body of evidence: the GRADE approach

As set out in the WHO handbook for guideline development (WHO, 2014c), the main framework for producing evidence-informed recommendations is the GRADE approach (Guyatt et al., 2008). This is used to assess the quality of a body of evidence synthesized in a systematic review. The assessment facilitates judgements about the certainty of effect estimates, which increases with the quality of the body of evidence. The quality can be rated high, moderate, low or very low (see Box 1).

Box 1 GRADE interpretations of quality of evidence

- **High quality:** further research is very unlikely to change the certainty of the effect estimate
- **Moderate quality:** further research is likely to have an important impact on the certainty of the effect estimate and may change the estimate
- **Low quality:** further research is very likely to have an important impact on the certainty of the effect estimate and is likely to change the estimate
- **Very low quality:** any effect estimate is uncertain

The original GRADE approach was developed specifically to rate the body of evidence resulting from a review of intervention studies. The initial quality level is set by study design: randomized control trials (RCTs) are considered high quality, whereas observational (nonrandomized) study designs are low quality. Then five factors are considered for downgrading the quality of the body of evidence resulting from RCTs or observational studies, and three factors are considered for upgrading the body of evidence resulting from observational studies alone.

The following five factors are used for downgrading the quality of evidence by one or two levels:

- study limitations or risk of bias in all studies that make up the body of evidence
- inconsistency of results between studies
- indirectness of evidence in the studies
- imprecision of the pooled effect estimate
- publication bias detected in a body of evidence.

The following three factors are used for upgrading the quality of evidence:

- high magnitude of the pooled effect
- direction of residual confounding and biases opposes an effect (i.e. when all plausible confounders are anticipated to reduce the estimated effect and there is still a significant effect)
- exposure–response gradient.

The GRADE approach was originally developed for application in the field of clinical medicine, where the majority of studies are randomized trials. However, to assess health effects resulting from an exposure such as environmental noise, randomized controlled trials are not applicable, as it would be unethical to expose participants deliberately to possibly harmful risk factors. The limitations of the application of GRADE to environmental health have been recognized and discussed in the literature (Morgan et al., 2016). Other types of study design dominate the evidence base in the domain of environmental noise research, so it was necessary to adapt the original GRADE approach to the subject of the current guidelines, as follows.

Instead of using the RCT study design as the starting-point for the quality rating, the study design most applicable and available for the field of research at hand was used. Thus, for evidence on the association between noise exposure and clinical health outcome measures, the rating of an evidence base consisting of cohort and case-control studies[9] was initially rated high quality. Cross-sectional studies and ecological studies were rated low quality and very low quality, respectively. This initial point of departure was only adapted for the evidence of the association between noise exposure and annoyance and sleep disturbance. Here, cross-sectional studies were rated high quality because annoyance and sleep disturbance are regarded as an immediate effect of exposure to environmental noise. Finally, in accordance with the original GRADE approach, the starting-point for evidence on the effect of interventions was rated low quality for observational studies. After determining the point of departure, the evidence base was rated down or up whenever one or more of the criteria for downgrading or upgrading (described above) were met. Each of the systematic reviews commissioned for these guidelines includes a detailed report on the assessment of the quality of the evidence.

A detailed discussion of the adaptations of GRADE is provided in the separate methodology publication (Héroux & Verbeek, 2018b).

2.4.2 Selection of priority health outcomes

In line with the WHO handbook for guideline development (WHO, 2014c), the GDG selected the key health outcomes associated with environmental noise at the beginning of the evidence retrieval process, and the systematic reviews were commissioned accordingly. The selection of health outcomes was based on the available evidence for the association between environmental noise and the specific outcome, as well as public concern about the health outcome resulting from noise exposure. The following health outcomes were rated critical: cardiovascular disease, annoyance,

[9] In the context of the current guidelines, "cohort studies" refer to longitudinal studies in which the occurrence of the outcome of interest in an exposed group is compared to the occurrence of that outcome in a reference group with no or lower exposure over time.

effects on sleep, cognitive impairment and hearing impairment and tinnitus. Adverse birth outcomes, quality of life, well-being and mental health, and metabolic outcomes were rated important (see also section 2.3.1).

Since all these health outcomes can be measured in various ways, the GDG evaluated each individually and prioritized different outcome measures for each in terms of their representativeness and validity. These measures were used to derive the guideline exposure levels; their prioritization was based on the impact of the disease and the disability weights (DWs) associated with the health outcome measure.[10]

The critical health outcomes, priority outcome measures identified and justifications for their selection are listed in Table 3.

Table 3. Critical health outcomes, outcome measures identified and justifications for selection

Critical health outcome	Critical health outcome measures (priority measures marked in bold)	Justification for selection
Cardiovascular disease (L_{den})	Self-reported or measured prevalence, **incidence**, hospital admission or mortality due to: • **ischaemic heart disease (IHD) (including angina pectoris and/or myocardial infarction)** • **hypertension** • stroke	Except for self-reports, these are objective measures of the outcome, affect a large proportion of the population, have important health consequences and can lead to more severe diseases and/or mortality. DW for IHD: 0.405. DW for hypertension: 0.117.
Effects on sleep (L_{night})	• **percentage of the population highly sleep-disturbed (%HSD)**, self-reported, assessed with a standardized scale • polysomnography measured outcomes (probability of additional awakenings) • cardiac and blood pressure outcome measures during sleep • motility measured sleep outcomes in adults • sleep disturbance in children	This is the most meaningful, policy-relevant measure of this health outcome. Self-reported sleep disturbances are a very common problem in the general population: they affect quality of life directly and may also lead to subsequent health impediments. Effects on sleep may be in the causal pathway to cardiovascular disease. This measure is not a proxy for physiological sleep quality parameters but is an important outcome in its own right. DW for %HSD: 0.07.
Annoyance (L_{den})	• **percentage of the population highly annoyed (%HA), assessed with standardized scale** • percentage annoyed, preferably assessed with standardized scale	This is the most objective measure of this health outcome. Large proportions of the population are affected by noise annoyance, even at relatively low exposure levels. Annoyance may be in the causal pathway to cardiovascular disease. DW for %HA: 0.02.

[10] DWs are ratings that vary between 0 and 1, in which 0 indicates no disability and 1 indicates the maximum amount of disability. The rates are derived from large population surveys in which people are asked to rank a specific disease for its impact on several abilities. The DWs have been proven useful in calculating the burden of disease.

Table 3. contd.

Critical health outcome	Critical health outcome measures (priority measures marked in bold)	Justification for selection
Cognitive impairment (L_{den})	• **reading and oral comprehension, assessed with tests** • impairment assessed with standardized tests • short and long-term memory deficit • attention deficit • executive function deficit (working memory capacity)	This outcome measure is the most meaningful: it can affect vulnerable individuals (children) and have a significant impact later in life. DW for impaired reading and oral comprehension: 0.006.
Hearing impairment and tinnitus (L_{Aeq}[11] and $L_{AF,max}$[12])	• **permanent hearing impairment, measured by audiometry** • permanent tinnitus	This outcome measure can affect vulnerable individuals (children) and have a significant impact later in life. It is the most objective measure for which there is an ISO standard (ISO, 2013), specifying how to estimate noise-induced hearing loss. DW for mild severity level (threshold at 25 dB) for childhood onset: 0.0150.

Table 4 provides a list of the important health outcomes along with the corresponding health outcome measures included in the systematic reviews. There was no prioritization of health outcome measures leading to justification of selection, since important health outcomes had less impact on the development of recommendations.

Table 4. Important health outcomes and health outcome measures reviewed

Important health outcome	Health outcome measures reviewed
Adverse birth outcomes (L_{den})	• pre-term delivery • low birth weight • congenital anomalies
Quality of life, well-being and mental health (L_{den})	• self-reported health and quality of life • medication intake for depression and anxiety • self-reported depression, anxiety and psychological distress • interviewer-assessed depressive and anxiety disorders • emotional and conduct disorders in children • children's hyperactivity • other mental health outcomes
Metabolic outcomes (L_{den})	prevalence, incidence, hospital admission or mortality due to: • type 2 diabetes • obesity

[11] L_{Aeq} is an A-weighted, equivalent continuous sound pressure level during a stated time interval starting at t1 and ending at t2, expressed in dB, of a noise at a given point in space.

[12] $L_{AF,max}$ is the maximum time-weighted and A-weighted sound pressure level with FAST time constant within a stated time interval starting at t1 and ending at t2, expressed in dB.

2.4.3 Identification of guideline exposure levels for each noise source

The GDG agreed to set guideline exposure levels based on the definition: "noise exposure levels above which the GDG is confident that there is an increased risk of adverse health effects". The identification of guideline values for each of the specific noise sources involved five distinct steps:

1. assessment of the validity of ERFs resulting from the systematic reviews of the effects of noise on each of the critical and important health outcomes;
2. assessment of the lowest noise level measured in the studies included in each of the corresponding systematic reviews;
3. assessment of the smallest risk or relative risk (RR) increase for each of the adverse health outcomes considered relevant;
4. determination of the guideline exposure level based on the ERF, starting from the lowest level measured (see step 2) and associated with the smallest relevant risk increase for adverse health outcomes (see step 3);
5. comparison of the guideline exposure levels calculated for each of the critical health outcomes of one source (for example, incidence of IHD, incidence of hypertension, %HA, permanent hearing impairment and reading and oral comprehension for road traffic noise): selection of the guideline exposure level for each noise source was based on the priority health outcome measure with the lowest exposure level for that source.

To define an "increased risk" to set the guideline exposure level, the GDG made a judgement about the smallest risk or RR of the adverse health effect it considered relevant for each of the priority health outcome measures. It is important to note that the relevant risk increases are benchmark values. The GDG agreed to set them in accordance with the guiding principles it had developed, to provide guideline values that illustrate an increased risk of adverse health effects. It used expert judgements for the determination of the benchmark values; these are elaborated further in section 2.4.3.2.

The guideline exposure levels presented are therefore not meant to identify effect thresholds (the lowest observed adverse effect levels for different health outcomes). This is a difference in approach from prior WHO guidelines, like the night noise guidelines for Europe (WHO Regional Office for Europe, 2009), which explicitly aimed to define levels indicating no adverse health effects. The approach to making choices about relevant risk increases is outlined below and summarized in Table 5.

For IHD and hypertension, RR increases were considered; for annoyance and sleep disturbance, absolute risks of %HA and %HSD were considered; and for reading and oral comprehension an average delay of reading age was defined. For the cardiovascular outcomes, incidence measures were prioritized, although much of the epidemiological evidence was based on prevalence data – particularly for hypertension – where almost no longitudinal studies were available. Prevalence data are generally derived from cross-sectional studies, where the temporal aspects are difficult to determine.

Table 5. Priority health outcomes and relevant risk increases for setting guideline levels

Priority health outcome measure (associated DW)	Relevant risk increase considered for setting of guideline level
Incidence of IHD (DW: 0.405)	5% RR increase
Incidence of hypertension (DW: 0.117)	10% RR increase
%HA (DW: 0.02)	10% absolute risk
%HSD (DW: 0.07)	3% absolute risk
Permanent hearing impairment (DW: 0.0150)	No risk increase due to environmental noise
Reading and oral comprehension (DW: 0.006)	One-month delay in terms of reading age

The DWs used to rank the priority critical health outcomes measures were retrieved from the relevant literature. For cardiovascular disease as a group and for hypertension, the burden of disease from environmental noise values (WHO Regional Office for Europe & JRC, 2011) were not considered applicable by the GDG for these guidelines. Thus, for cardiovascular disease, the DW value (DW: 0.405) specifically applied to acute myocardial infarction in the publication outlining the data sources, methods and results of the global burden of disease in 2002 (Mathers et al., 2003) was retained. Since hypertension is mainly viewed as an important risk factor and not as a health outcome, no general DW has been developed. The only other available DW value available is the DW of 0.117 for hypertensive episodes in pregnancy (Mathers et al., 1999). In the absence of any general DW, the GDG agreed on a conservative approach and decided to use this value.

The DWs for high sleep disturbance (DW: 0.07), high annoyance (DW: 0.02) and impaired reading and oral comprehension (DW: 0.006) were developed in the context of calculating the burden of disease from environmental noise (WHO Regional Office for Europe & JRC, 2011). The DW for hearing impairment was not included in that publication, but it was available from the technical paper on the burden of disease from environmental noise (WHO, 2013); the DW for permanent hearing impairment ranged from 0.0031 to 0.3342, depending on severity level. Environmental noise (leisure noise) contributes to the cumulative total noise exposure throughout the life-course, which may lead to permanent hearing impairment and cause more severe disability in the later years of life. As a result, the GDG selected a DW of 0.0150 for moderate severity level ("has difficulty following a conversation in a noisy environment, but no other hearing problems"). For cognitive impairment, the DW was derived from the estimates of the burden of disease from environmental noise (WHO Regional Office for Europe & JRC, 2011). This was at a very conservative value (DW: 0.006) for noise-related impairment of children's cognition, equivalent to a DW for contemporaneous cognitive deficit in the context of a range of cognitive impairments in children ranging from 0.468 for Japanese encephalitis to 0.024 for iron deficiency anaemia (Lopez et al., 2006).

2.4.3.1 Development of ERFs

The systematic reviews of evidence provided either an ERF or other noise exposure value/metric that could be related to a risk increase of the health outcome measure. These ERFs were used to develop guideline exposure levels; however, only those functions where noise exposure demonstrated a statistically significant effect were used.

To obtain the starting level of the ERFs derived in the systematic reviews, a weighted average of the lowest exposure values measured in the individual studies included in the meta-analyses was calculated. The weighting used the inverse of the variance of the effect estimate of the study. Thus, the lowest exposure value of studies with a small variance (usually with the largest sample size) contributed the most to the assumed onset of the ERF.

2.4.3.2 Relevant risk increase of adverse health effects

The following sections describe in detail the rationale for the selection of the relevant relative risk (RR) increase percentage for each of the priority health outcome measures considered.

Cardiovascular disease: IHD and hypertension

High-quality epidemiological evidence described in the systematic review on cardiovascular and metabolic effects of environmental noise indicates that exposure to road traffic noise increases the risk of IHD (van Kempen et al., 2018). The GDG was confident that health risks result from exposure at an RR increase in the order of 5–10% in the incidence of IHD. This is similar to the reasoning in the WHO air quality guidelines for fine particulate matter ($PM_{2.5}$) (WHO, 2006). To determine a relevant risk increase for IHD, the GDG took as a starting-point the RR increase of 5% measured in epidemiological studies of environmental noise or air pollution. Taking into account the incidence of IHD and the seriousness of the disease, it considered lowering the RR increase for IHD to 1%, as a 5% RR increase might imply a comparatively high absolute risk from a population perspective. To decide on the final benchmark value for IHD, several aspects were considered: the number of people in a population affected by IHD; whether health risks caused by noise would make up a large part of the incidence of the disease; other examples of health risks of similar magnitude leading to preventive action. For IHD, in an average EU country with 20 million inhabitants, an RR increase of 5% for IHD would lead to several thousand extra cases attributable to noise yearly. This corresponds to a proportion of cases of IHD attributable to noise exposure of less than 10%, which is still relatively small. After extensive discussion at the very end of the guideline development process, the GDG decided to adhere to 5% as the relevant risk increase.

Hypertension is a common condition and is an important risk indicator for IHD and other cardiovascular diseases. Thus, the hypertension risk increase can be transformed into a risk increase for cardiovascular disease. To derive a relevant risk increase, the GDG focused on the incidence of hypertension, owing to the nature and quality of epidemiological evidence. Since hypertension is less serious than IHD, and not all people with hypertension will progress to cardiovascular disease, the relevant risk increase in the incidence of hypertension needed to be higher than that for IHD. Therefore, the GDG agreed on an RR increase of 10% for hypertension.

Self-reported sleep disturbance and annoyance

The GDG initially considered 5%HSD and 10%HA due to noise as relevant absolute risks, not be exceeded at the guideline level. After discussion, however, members agreed that these absolute risks were too large, since a considerable proportion of the population would still be affected; they decided to lower the relevant risk from 5% being highly sleep-disturbed to 3%. In doing so, the GDG referred to the WHO night noise guidelines (WHO, 2009), which concluded that while there was insufficient evidence that physiological effects at noise levels below 40 dB L_{night} are harmful to health, there were observed adverse health effects at levels starting from 40 dB L_{night}. At 40 dB, about 3–4%

(depending on the noise source) of the population still reported being highly sleep-disturbed due to noise, which was considered relevant to health. The GDG considered it important that this level is consistent with the previous health-based approach adopted by the WHO night noise guidelines, and agreed that the absolute risk associated with the guideline value selected should not exceed 3%HSD to be health protective.

For annoyance, which is considered a less serious health effect than self-reported sleep disturbance (as indicated by the respective DWs), the relevant risk remained at 10%HA. This means the absolute risk associated with the guideline value selected should be closest to, but not above 10%HA, to be health protective.

Cognitive impairment: reading and oral comprehension

Acquiring skills in reading and oral comprehension at a young age is important for further development: a delay in acquiring these skills can have an impact later in life (Wilson & Lonigan, 2010). This impact cannot be predicted very accurately, but the GDG considered a delay of one month a relevant absolute risk.

Permanent hearing impairment

The literature on hearing impairment as a result of occupational noise exposure is extensive. A noise exposure level beyond 80 dB during 40 years of working a 40 hour work week can give rise to permanent hearing impairment. Given that environmental exposure to noise is much lower than these levels and that noise-related hearing impairments are not reversible, the GDG considered that there should be no risk of hearing impairment due to environmental noise and considered any increased risk of hearing impairment relevant.

2.4.4 Strength of the recommendations

Finally, having determined the guideline exposure levels based on the ranking of prioritized health outcome measures, setting the strength of the recommendation was set as the final step of the guideline development process. This was also guided by the GRADE methodology (Alonso-Coello et al., 2016a; 2016b). According to this approach, strength of recommendation can be set as either strong or conditional (WHO, 2014c).

- A **strong** recommendation can be adopted as policy in most situations. The guideline is based on the confidence that the desirable effects of adherence to the recommendation outweigh the undesirable consequences. The quality of evidence for a net benefit – combined with information about the values, preferences and resources – inform this recommendation, which should be implemented in most circumstances.
- A **conditional** recommendation requires a policy-making process with substantial debate and involvement of various stakeholders. There is less certainty of its efficacy owing to lower quality of evidence of a net benefit, opposing values and preferences of individuals and populations affected or the high resource implications of the recommendation, meaning there may be circumstances or settings in which it will not apply.

The GRADE approach defines a number of parameters that should be assessed to determine the strength of recommendations: quality of evidence, balance of benefits and harms, values and preference related to the outcomes of interventions to exposure, resources implications, priority of the problem, equity and human rights, acceptability and feasibility (Box 2; Morgan et al., 2016).

Box 2 Parameters determining the strength of a recommendation

Quality of evidence further represents the confidence in the estimates of effect of the evaluated evidence, across outcomes critical and important to decision-making. The higher the quality of evidence, the greater the likelihood of a strong recommendation.

Balance of benefits and harms requires an evaluation of the absolute effects of both benefits and harms (or downsides) of the intervention or exposure and their importance. The greater net benefit or net harm associated with an intervention or an exposure, the greater the likelihood of a strong recommendation in favour or against an intervention or exposure.

Values and preferences related to the outcomes of an intervention or exposure set out the relative importance assigned to health outcomes by those affected by them; how such importance varies within and across populations; and whether this importance or variability is surrounded by uncertainty. The less uncertainty or variability there is about the values and preferences of people experiencing the critical or important outcomes, the greater the likelihood of a strong recommendation.

Resource implications take into consideration how resource-intensive and how cost-effective and substantially beneficial an intervention or exposure is. The more advantageous or clearly disadvantageous the resource implications are, the greater the likelihood of a strong recommendation either for or against the intervention or exposure.

The priority of the problem is determined by its importance and frequency (the burden of disease, disease prevalence or baseline risk). The greater the importance of the problem, the greater the likelihood of a strong recommendation.

Equity and human rights considerations are an important aspect of the process. The greater the likelihood that the intervention will reduce inequities, improve equity or contribute to the realization of one or several human rights as defined under the international legal framework, the greater the likelihood of a strong recommendation.

Acceptability plays a prominent role: the greater the acceptability of an option to all or most stakeholders, the greater the likelihood of a strong recommendation.

Feasibility overlaps with values and preferences, resource considerations, existing infrastructures, equity, cultural norms, legal frameworks and many other considerations. The greater the feasibility of an option from the standpoint of all or most stakeholders, the greater the likelihood of a strong recommendation.

The GDG evaluated the strength of the recommendations based on these parameters, following a two-step procedure. Initially, the strength of each recommendation was set as strong or conditional based on an assessment of the quality of evidence. The GDG then identified and assessed contextual parameters that might have a contributory role (see Box 2 above). Based on this qualitative evaluation, the initial recommendation strength was either adapted or confirmed. It is important to note that while the initial parameter "quality of evidence" was informed by comprehensive systematic reviewing processes, the remaining contextual parameters were assessed by the informed qualitative expert judgement of the GDG.

Furthermore, the GDG agreed to decision-making rules, applied when formulating the recommendations. An evidence rating of low quality or very low quality would lead only to a conditional recommendation. Setting a strong recommendation was only considered if the evidence was at least moderate quality. The final recommendations were formulated based on the consideration of all the parameters and decision rules adopted by the GDG. A detailed exploration of all the recommendations is set out in Chapter 3.

2.5 Individuals and partners involved in the guideline development process

The process of WHO guideline development is conducted by several groups with clearly defined roles and responsibilities. Comprising WHO staff members, experts and stakeholders, these are the Steering Group, the GDG, the Systematic Review Team and the External Review Group.

The **Steering Group** includes WHO staff members with different affiliations but whose work experience is relevant to the topic of environmental noise and associated health outcomes. It is involved at all stages of planning, selecting members of the GDG and External Review Group, reviewing evidence and developing potential recommendations at the main expert meetings, as well as ongoing consultation on revisions following peer review. Details of the members of the Steering Group are listed in Table A1.1 in Annex 1.

The **GDG** consists of a group of content experts gathered to investigate all aspects of evidence contributing to the recommendations, including expertise in evidence-based guideline development. This Group defined the key questions and priorities of the research, chose and ranked outcomes and provided advice on any modifications of the scope as established by the Steering Group. The members also outlined the systematic review methods; appraised the evidence used to inform the guidelines; and advised on the interpretation of this evidence, with explicit consideration of the overall balance of benefits and harms. Ultimately the GDG formulated the final recommendations, taking into account the diverse values and preferences of individuals and populations affected. It also determined the strength of the results and responded to external peer reviews. The complete list of GDG members and their specific roles, affiliations and areas of expertise are listed in Table A1.2 in Annex 1.

The **Systematic Review Team** includes experts in the field of environmental health, commissioned by WHO staff to undertake systematic reviews of evidence. The GDG recommended a number of authors to conduct the evidence reviews and summary chapters, based on their expertise. Details of the members of the Systtematic Review Team are included in Table A1.3 in Annex 1.

The **External Review Group** is composed of technical content experts and end-users as well as stakeholders, and is balanced geographically and by gender. The experts and end-users were selected for their expertise in the field, and the Group also included representatives of professional groups and industry associations, who will be implementing the guidelines. Members were asked to review the material at different stages of the development process. The list of technical experts and stakeholders is provided in Tables A1.4 and A1.5, respectively, in Annex 1.

Management of conflict of interest is an integral part of WHO's guideline development procedure. All members of the GDG and authors of the evidence reviews completed WHO declaration of interest forms. These were reviewed by the WHO Secretariat for potential conflicts of interest. A number of conflicts of interest were declared in the forms, but following a standardized management review it was not found necessary to exclude any members of the GDG or authors from their respective roles. Members of the External Review Group (technical experts only) were also asked to complete the form when invited to participate.

In addition, at the start of the meeting of the GDG all members of the GDG received a briefing about the nature of all types of conflict of interest (financial, academic/intellectual and nonacademic) and were asked to declare to the meeting any conflicts they might have. No member of the GDG or the Systematic Review Team was excluded from his/her respective role. A summary of the conflict of interest management is presented in Annex 3.

The GDG set its own rules on how it would work and how contentious issues should be resolved – for instance, by means of a vote. The main decision-making mechanism involved reaching consensus; if a vote was required, the experts involved in developing the underlying evidence for the specific recommendation were excluded from voting, and an agreement was reached via a two thirds majority of the rest of the group.

2.6 Previously published WHO guidelines on environmental noise

Prior to this publication, WHO published community noise guidelines (CNG) in 1999 (WHO, 1999) and night noise guidelines for Europe (NNG) in 2009 (WHO Regional Office for Europe, 2009).

2.6.1 CNG

The scope of WHO's efforts to develop the CNG in 1999 was similar to that for the current guidelines. The objective was then formulated as: "to consolidate scientific knowledge of the time on the health impacts of community noise and to provide guidance to environmental health authorities and professionals trying to protect people from the harmful effects of noise in nonindustrial environments" (WHO, 1999). The guidelines were based on studies carried out up to 1995 and a few meta-analyses from some years later.

The health risk to humans from exposure to environmental noise was evaluated and guideline values derived. At that time WHO had not yet developed its guideline development process, on which the current guidelines are based (WHO, 2014c). The main differences in content are that the previous guidelines were expert-based and provided more global coverage and applicability, such as issues of noise assessment and control that were addressed in detail. They included a discussion on noise sources and measurement, including the basic aspects of source characteristics, sound propagation and transmission. Adverse health effects of noise were characterized, and combined noise sources and their effects were considered. Furthermore, the guidelines included discussions of strategies and priorities in the management of indoor noise levels, noise policies and legislation, environmental noise impact and enforcement of regulatory standards; although there were no chapters on wind turbine noise and leisure noise.

2.6.2 NNG

In 2009 the WHO Regional Office for Europe published the NNG to provide scientifically based advice to Member States for the development of future legislation and policy action in the area of assessment and control of night noise exposure.

The NNG complement the previous CNG, incorporating the advancement of research on noise and sleep disturbance up to 2006. The working group of experts reviewed available scientific evidence on the health effects of night noise and derived health-based guideline values. Again, WHO had not yet introduced its evidence-based recommendations policy and the NNG were mainly expert-based. They considered the scientific evidence on the threshold of night noise exposure indicated by L_{night} as defined in the END (EC, 2002a), and the experts concluded that a L_{night} value of 40 dB should be the target of the NNG (for all sources) to protect the public, including the most vulnerable groups such as children, chronically ill and elderly people. Further, an L_{night} value of 55 dB was recommended as an interim target for countries that could not follow the guidelines in the short term for various reasons or where policy-makers chose to adopt a stepwise approach.

2.6.3 Differences from the prior noise guidelines

The current guidelines differ from the older ones, recommending levels of exposure unlike those previously outlined (especially by the NNG). The following major differences between the previous and current guidelines explain the novel set of recommended values.

- The development process for the current guidelines adhered to a new, rigorous, evidence-based methodology, as outlined in the WHO handbook for guideline development (WHO, 2014c). WHO adopted these internationally recognized standards to ensure high methodological quality and a transparent, evidence-based decision-making process in the guideline development.
- The current guidelines consider cardiovascular disease a critical health outcome measure.
- They also consider a broader set of health outcomes, including adverse birth outcomes, diabetes, obesity and mental well-being. Wherever applicable, incidence, prevalence and mortality were considered separately.
- The current guidelines cover two new noise sources: wind turbines and leisure noise.
- Critical and important health outcomes are considered separately for each of the noise sources.
- The guideline development process included the health effects of intervention measures to mitigate noise exposure from different noise sources for the first time.
- The style of recommendations differs: the current guidelines include an exact exposure value for every health outcome regarded as critical, for each noise source. Guideline recommendation values were set for each of the noise sources separately, based on the exact exposure values and a prioritization scheme, developed with the help of DWs.
- The current guidelines apply a 1 dB increment scheme, whereas prior guidelines (CNG and NNG) formulated or presented recommendations in 5 dB steps.

- In comparison to the 1999 CNG, which defined environment-specific exposure levels, the current guidelines are source specific. They recommend values for outdoor exposure to road traffic, railway, aircraft and wind turbine noise, and indoor as well as outdoor exposure levels for leisure noise.
- Except for leisure noise, all exposure levels recommended in the current guidelines are average sound pressure levels for outdoor exposure.
- The current guidelines make use of the noise indices defined in the END: L_{den} and L_{night}.

The definition of "community noise" used in the CNG in 1999 was also adapted. The GDG agreed to use the term "environmental noise" instead, and offered an operational definition of: "noise emitted from all sources except sources of occupational noise exposure in workplaces".

The current environmental noise guidelines for the European Region supersede the CNG from 1999. Nevertheless, the GDG recommends that all CNG indoor guideline values and any values not covered by the current guidelines (such as industrial noise and shopping areas) should remain valid.

Furthermore, the current guidelines complement the NNG from 2009. Two main aspects of the NNG constitute this complementarity: the different guiding principles and the comprehensive investigation of the immediate physiological effects of environmental noise on sleep. As guiding principles the NNG defined effect thresholds or "lowest observed adverse health effect levels" for both immediate physiological reactions during sleep (i.e. awakening reactions or body movements during sleep) and long-term adverse health effects (i.e. self-reported sleep disturbance). These guideline exposure levels defined a level below which no effects were expected to occur (corresponding to 30 dB L_{night}) and proceeded to define the level where adverse effects start to occur (corresponding to 40 dB L_{night}), with the aim of protecting the whole population, including – to some extent – vulnerable groups. The development of the NNG values relied on evidence-based expert judgement. In contrast, the current guidelines formulate recommendations more strictly based on the available evidence and following the guiding principle to identify exposure values based on a relevant risk increase of adverse health effects. Thus, the recommended guideline values might not lead to full protection of the population, including all vulnerable groups. The GDG stresses that the aim of the current guidelines is to define an exposure level at which effects certainly begin.

Secondly, the NNG comprehensively investigate the immediate short-term effects of environmental noise during sleep, including physiological reactions such as awakening reactions and body movements. They also provided threshold information about single-event noise indicators (such as the $L_{A,max}$). In contrast, the current guideline values for the night time are only based on the prevalence of self-reported sleep disturbance and do not take physiological effects into account. The causal link between immediate physiological reactions and long-term adverse health effects is complex and difficult to prove. Thus, the current guidelines are restricted to long-term health effects during night time and therefore only include recommendations about average noise indicators: L_{night}. Nevertheless, the evidence review on noise and sleep (Basner & McGuire, 2018) includes an overview of single-event exposure–effect relationships.

3. Recommendations

This chapter presents specific recommendations on guideline exposure levels and/or interventions to reduce exposure and/or improve health for individual sources of noise: road traffic, railway, aircraft, wind turbines and leisure noise. The strength of each recommendation is provided (strong or conditional) and a short rationale for how each of the guideline levels was achieved is given.

The GDG discussed extensively the best way to present guideline exposure levels – either as the exact values or in 5 dB steps – and the approach to rounding the values to the nearest integer. The 5 dB increment, rounded down from the exact exposure value to the nearest 5 dB level, was initially chosen as being commonly applied in noise legislation and used in prior guidelines (WHO, 1999; EC, 2002a; WHO Regional Office for Europe, 2009). It was also used to meet the principle of precaution, since imprecision in the exposure assessment in the field of epidemiology tends to attenuate the actual effects in the population.

Use of 5 dB increments resulted in uneven magnitude of rounding down, however, raising concerns of arbitrariness. It became apparent that inclusion of both exact values and the 5 dB rounded-down values might be confusing and could affect the applicability of the guidelines. Hence, the GDG ultimately decided that formulating recommendations based on the exact calculated values, rounded only to the nearest integer, would ensure more clarity and transparency. Furthermore, it noted that adhering to a 5 dB roster might not reflect the progress in the precision of exposure assessment methods in recent decades, which would justify application of a 1 dB step.

The GDG acknowledged that the recommendations might be presented as the exact guideline exposure levels only, leaving the use of 5 dB bands to the potential policy decisions to formulate or revise noise legislation, which are beyond the scope of this publication. The WHO guideline values are public health-oriented recommendations, based on scientific evidence on health effects and on an assessment of achievable noise levels. They are strongly recommended and as such should serve as the basis for a policy-making process in which policy options are quantified and discussed. It should be recognized that in that process additional considerations of costs, feasibility, values and preferences should also feature in decision-making when choosing reference values such as noise limits for a possible standard or legislation.

In addition to the source-specific recommendations in the following sections, a short rationale for the decision-making process by the GDG for developing a particular recommendation is provided, as well as an overview of the evidence considered. This includes a recapitulation of the specific PICOS/PECCOS question (see section 2.3.1), along with a summary of evidence for each of the critical and important health effects from exposure to each of the noise sources, and for the effectiveness of interventions.

Furthermore, a description is provided of the other factors considered according to the GRADE dimensions for the assessment of the strength of recommendations (see section 2.4.4). While the quality of evidence is central to determining this, the process of moving from evidence to recommendations involves several other considerations. These include values and preferences, balance of benefits and harms, consideration of the priority of the problem, resource implications, equity and human rights aspects, acceptability and feasibility (WHO, 2014c).

3.1 Road traffic noise

Recommendations

For average noise exposure, the GDG **strongly** recommends reducing noise levels produced by road traffic below **53 dB** L_{den}, as road traffic noise above this level is associated with adverse health effects.

For night noise exposure, the GDG **strongly** recommends reducing noise levels produced by road traffic during night time below **45 dB** L_{night}, as road traffic noise above this level is associated with adverse effects on sleep.

To reduce health effects, the GDG **strongly** recommends that policy-makers implement suitable measures to reduce noise exposure from road traffic in the population exposed to levels above the guideline values for average and night noise exposure. For specific interventions, the GDG recommends reducing noise both at the source and on the route between the source and the affected population by changes in infrastructure.

3.1.1 Rationale for the guideline levels for road traffic noise

The exposure levels were derived in accordance with the prioritization process of critical health outcomes described in section 2.4.3. For each of the outcomes, the exposure level was identified by applying the benchmark, set as relevant risk increase to the corresponding ERF. In the case of exposure to road traffic noise, the process can be summarized as follows (Table 6).

Table 6. Average exposure levels (L_{den}) for priority health outcomes from road traffic noise

Summary of priority health outcome evidence	Benchmark level	Evidence quality
Incidence of IHD The 5% relevant risk increase occurs at a noise exposure level of 59.3 dB L_{den}. The weighted average of the lowest noise levels measured in the studies was 53 dB L_{den} and the RR increase per 10 dB is 1.08.	5% increase of RR	High quality
Incidence of hypertension One study met the inclusion criteria. There was no significant increase of risk associated with increased noise exposure in this study.	10% increase of RR	Low quality
Prevalence of highly annoyed population There was an absolute risk of 10% at a noise exposure level of 53.3 dB L_{den}.	10% absolute risk	Moderate quality
Permanent hearing impairment	No increase	No studies met the inclusion criteria
Reading skills and oral comprehension in children	One-month delay	Very low quality

In accordance with the prioritization process (see section 2.4.3), the GDG set a guideline exposure level of 53.3 dB L_{den} for average exposure, based on the relevant increase of the absolute %HA. It was confident that there was an increased risk for annoyance below this noise exposure level, but probably no increased risk for other priority health outcomes. In accordance with the defined rounding procedure, the value was rounded to 53 dB L_{den}. As the evidence on the adverse effects of road traffic noise was rated moderate quality, the GDG made the recommendation strong.

Next, the GDG assessed the evidence for night noise exposure and its effect on sleep disturbance (Table 7).

Table 7. Night-time exposure levels (L_{night}) for priority health outcomes from road traffic noise

Summary of priority health outcome evidence	Benchmark level	Evidence quality
Sleep disturbance 3% of the participants in studies were highly sleep-disturbed at a noise level of **45.4 dB** L_{night}	3% absolute risk	Moderate quality

Based on the evidence of the adverse effects of road traffic noise on sleep disturbance, the GDG defined a guideline exposure level of 45.4 dB L_{night}. The exact exposure value was rounded to 45 dB L_{night}. As the evidence was rated moderate quality, the GDG made the recommendation strong.

The GDG also considered the evidence for the effectiveness of interventions. The results showed that:

- addressing the source by improving the choice of appropriate tyres, road surface, truck restrictions or by lowering traffic flow can reduce noise exposure;
- path interventions such as insulation and barrier construction reduce noise exposure, annoyance and sleep disturbance;
- changes in infrastructure such as construction of road tunnels lower noise exposure, annoyance and sleep disturbance;
- other physical interventions such as the availability of a quiet side of the residence reduce noise exposure, annoyance and sleep disturbance.

Given that it is possible to reduce noise exposure and that best practices already exist for the management of noise from road traffic, the GDG made a strong recommendation.

3.1.1.1 Other factors influencing the strength of recommendations

Other factors considered in the context of recommendations on road traffic noise included those related to values and preferences, benefits and harms, resource implications, equity, acceptability and feasibility; moreover, nonpriority health outcomes (the incidence of stroke and diabetes) were considered. Ultimately, the assessment of all these factors did not lead to a change in the strength of the recommendations. Further details are provided in section 3.1.2.3.

3.1.2 Detailed overview of the evidence

The following sections provide a detailed overview of the evidence constituting the basis for setting the recommendations on road traffic noise. It is presented and summarized separately for each of the critical health outcomes, and the GDG's judgement of the quality of evidence is indicated (for a detailed overview of the evidence on important health outcomes, see Annex 4). Research into health outcomes and effectiveness of interventions is addressed consecutively.

A comprehensive summary of all evidence considered for each of the critical and important health outcomes can be found in the eight systematic reviews published in the *International Journal of Environmental Research and Public Health* (see section 2.3.2 and Annex 2).

3.1.2.1 Evidence on health outcomes

The key question posed was: in the general population exposed to road traffic noise, what is the exposure–response relationship between exposure to road traffic noise (reported as various noise indicators) and the proportion of people with a validated measure of health outcome, when adjusted for main confounders? A summary of the PICOS/PECCOS scheme applied (see section 2.3.1) and the main findings is set out in Tables 8 and 9.

Table 8. PICOS/PECCOS scheme of critical health outcomes for exposure to road traffic noise

PECO	Description	
Population	General population	
Exposure	Exposure to high levels of noise produced by road traffic (average/night time)	
Comparison	Exposure to lower levels of noise produced by road traffic (average/night time)	
Outcome(s)	For average noise exposure: 1. cardiovascular disease 2. annoyance 3. cognitive impairment 4. hearing impairment and tinnitus 5. adverse birth outcomes 6. quality of life, well-being and mental health 7. metabolic outcomes	For night noise exposure: 1. effects on sleep

Table 9. Summary of findings for health effects from exposure to road traffic noise (L_{den})

Noise metric	Priority health outcome measure	Quantitative risk for adverse health	Lowest level of exposure across studies	Number of participants (studies)	Quality of evidence
Cardiovascular disease					
L_{den}	Incidence of IHD	RR = 1.08 (95% confidence interval (CI): 1.01–1.15) per 10 dB increase	53 dB	67 224 (7)	High (upgraded for dose-response)
L_{den}	Incidence of hypertension	RR = 0.97 (95% CI: 0.90–1.05) per 10 dB increase	N/A	32 635 (1)	Low (downgraded for risk of bias and because only one study was available)
Annoyance					
L_{den}	%HA	Odds ratio (OR) = 3.03 (95% CI: 2.59–3.55) per 10 dB increase	40 dB	34 112 (25)	Moderate (downgraded for inconsistency)
Cognitive impairment					
L_{den}	Reading and oral comprehension	Not estimated	N/A	Over 2844 (1)	Very low (downgraded for inconsistency)
Hearing impairment and tinnitus					
L_{den}	Permanent hearing impairment	–	–	–	–

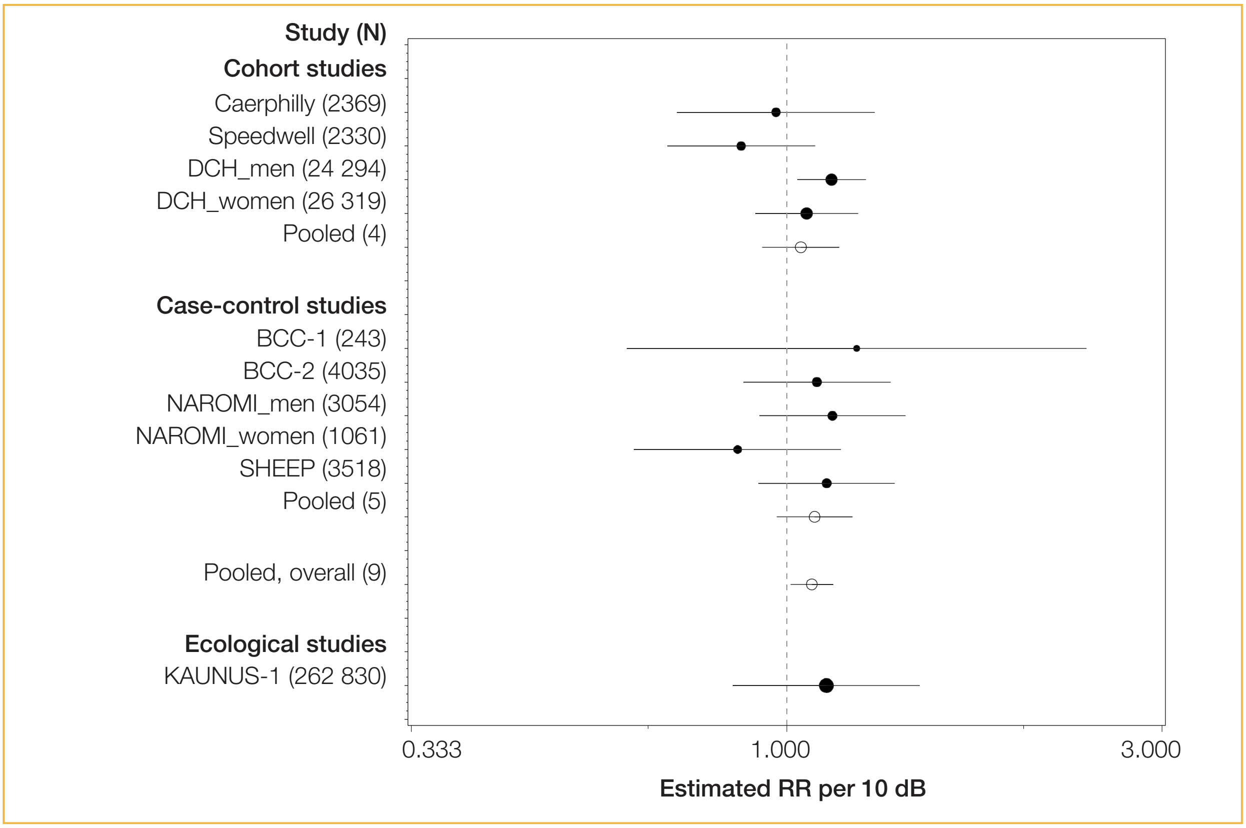
Cardiovascular disease

IHD

A total of three cohort (Babisch & Gallacher, 1990; Babisch et al., 1988; 1993a; 1993b; 1999; 2003; Caerphilly and Speedwell Collaborative Group, 1984; Sörensen et al., 2012a; 2012c) and four case-control studies (Babisch, 2004; Babisch et al., 1992; 1994; 2005a; Selander et al., 2009; Wiens, 1995) investigated the relationship between road traffic noise and the incidence of IHD. These involved a total of 67 224 participants, including 7033 cases. As identified in Fig. 1, the overall RR derived from the meta-analysis was 1.08 (95% CI: 1.01–1.15) per 10 dB L_{den} increase in noise levels, across a noise range of 40 dB to 80 dB. This evidence was rated high quality.

The data were supported by one ecological study conducted with 262 830 participants, including 418 cases, which also reported a statistically significant estimate (Grazuleviciene et al., 2004; Lekaviciute, 2007). In this study, a positive but nonsignificant association was found: RR of 1.12 (95% CI: 0.85–1.48) per 10 dB L_{den} increase in noise. This evidence was rated very low quality.

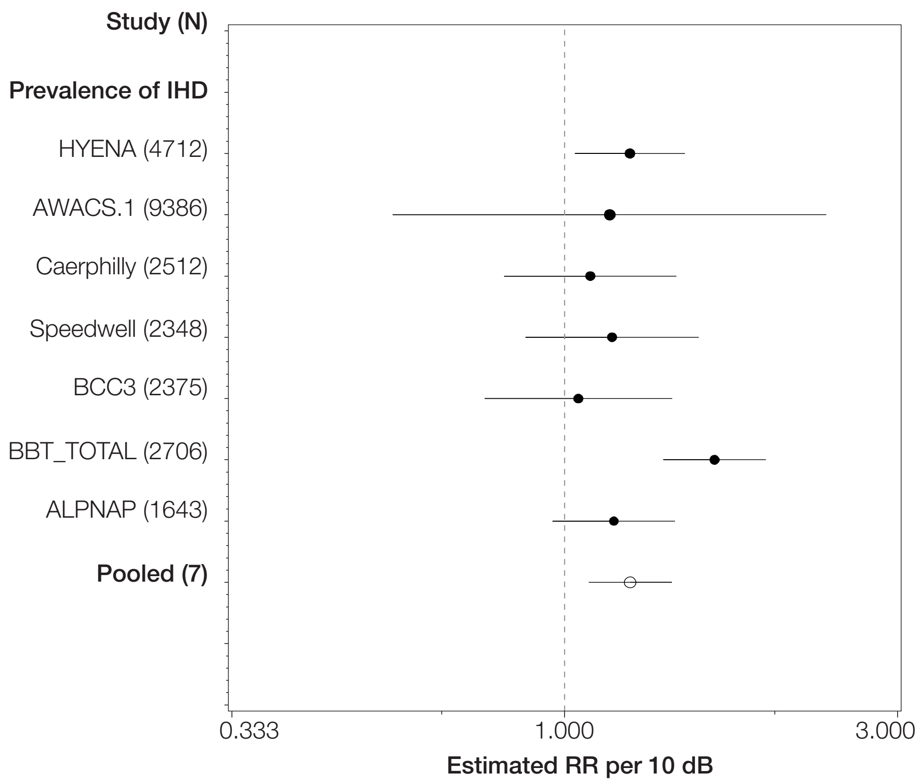
Fig. 1. The association between exposure to road traffic noise (L_{den}) and incidence of IHD



Notes: The dotted vertical line corresponds to no effect of exposure to road traffic noise. The black circles correspond to the estimated RR per 10 dB and 95% CI. The white circles represent the pooled random effect estimates and 95% CI. For further details on the studies included in the figure please refer to the systematic review on environmental noise and cardiovascular and metabolic effects (van Kempen et al., 2018).

Furthermore, additional evidence was available from eight cross-sectional studies that investigated the relationship between road traffic noise and prevalence of IHD (Babisch & Gallacher, 1990; Babisch et al., 1988; 1992; 1993a; 1993b; 1994; 1999; 2003; 2005a; 2008; 2012a; 2012b; Caerphilly and Speedwell Collaborative Group, 1984; Floud et al., 2011; 2013a; 2013b; Heimann et al., 2007; Jarup et al., 2005; 2008; Lercher et al., 2008; 2011; van Poll et al., 2014; Wiens, 1995). These studies involved a total of 25 682 participants, including 1614 cases. The overall RR was 1.24 (95% CI: 1.08–1.42) per 10 dB L_{den} increase in road traffic noise levels. The range in noise levels in the studies under evaluation was 30–80 dB. The results of the meta-analysis are presented in Fig. 2. This evidence was rated low quality.

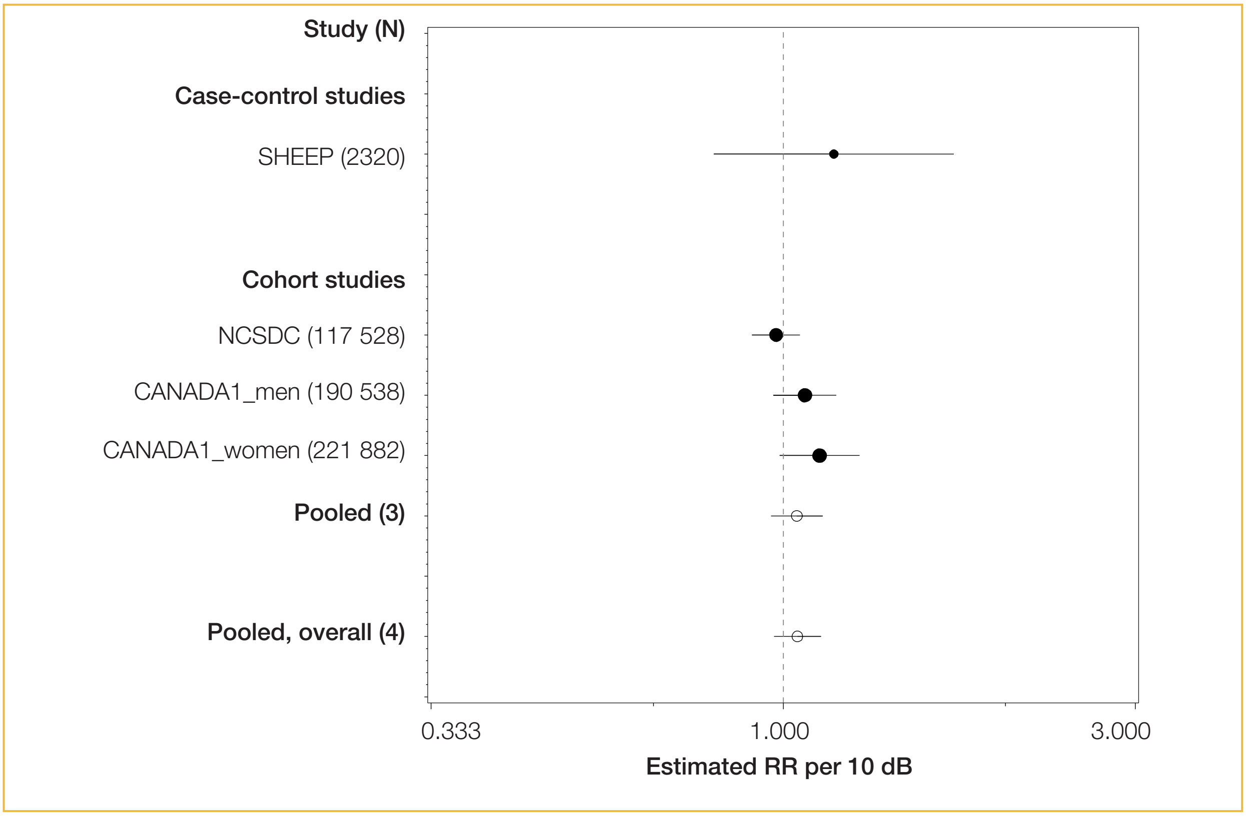
Fig. 2. The association between exposure to road traffic noise (L_{den}) and prevalence of IHD



Notes: The dotted vertical line corresponds to no effect of exposure to road traffic noise. The black circles correspond to the estimated RR per 10 dB and 95% CI. The white circle represents the pooled random effect estimates and 95% CI. For further details on the studies included in the figure please refer to the systematic review on environmental noise and cardiovascular and metabolic effects (van Kempen et al., 2018).

Mortality from IHD was also investigated in one case-control (Selander et al., 2009) and two cohort studies (Beelen et al., 2009; Gan et al., 2012), which involved 532 268 participants, including 6884 cases. The quantitative relationship between road traffic noise and mortality from IHD was RR = 1.05 (95% CI: 0.97–1.13) per 10 dB L_{den} increase in noise levels (see Fig. 3). This evidence was rated moderate quality.

Fig. 3. The association between exposure to road traffic noise (L_{den}) and mortality from IHD



Notes: The dotted vertical line corresponds to no effect of exposure to road traffic noise. The black circles correspond to the estimated RR per 10 dB and 95% CI. The white circles represent the pooled random effect estimates and 95% CI. For further details on the studies included in the figure please refer to the systematic review on environmental noise and cardiovascular and metabolic effects (van Kempen et al., 2018).

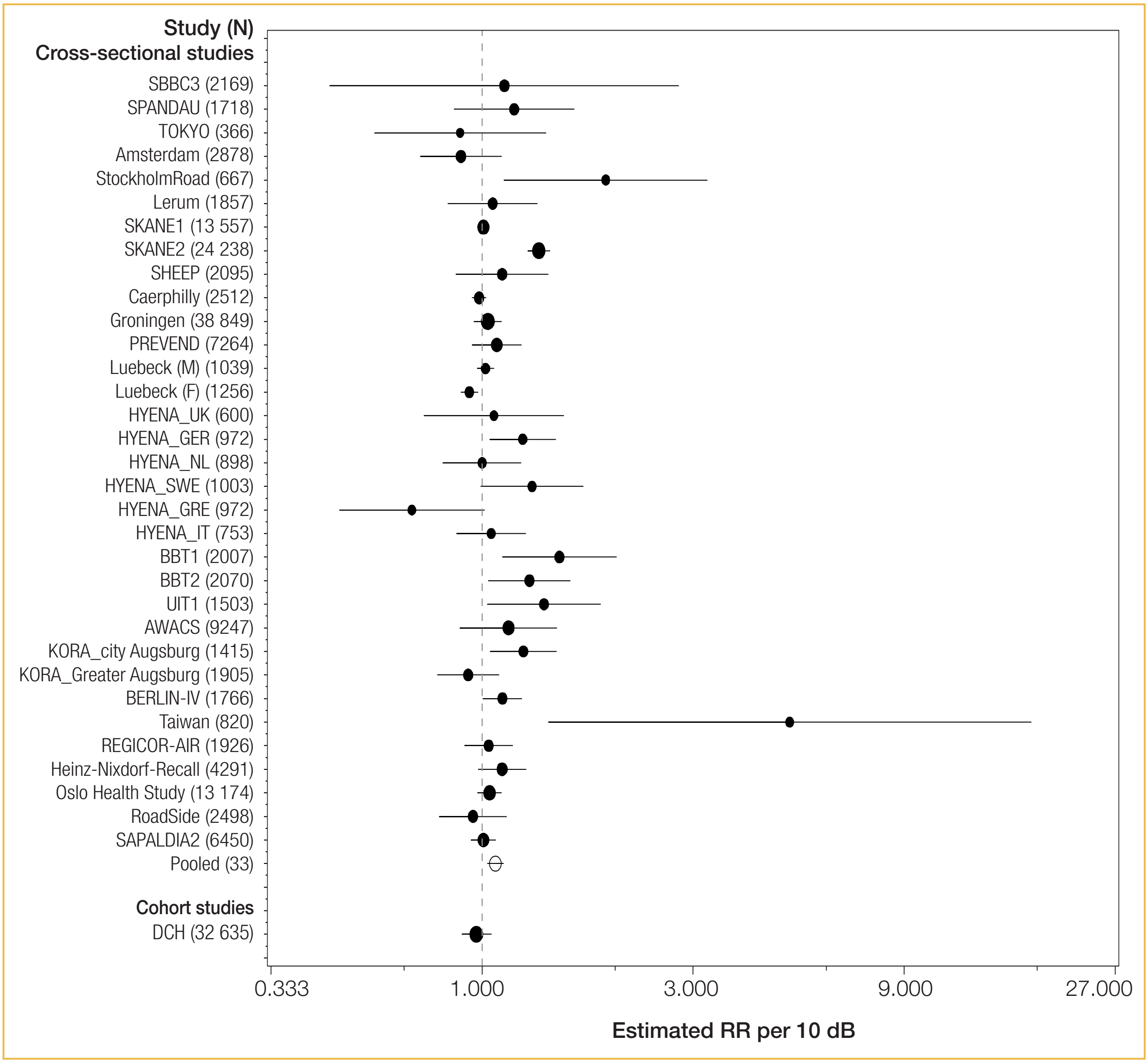
Hypertension

One cohort study into the relationship between road traffic noise and incidence of hypertension was identified; it involved 32 635 participants, including 3145 cases (Sörensen et al., 2011; 2012c). The study found a nonsignificant effect size of 0.97 (95% CI: 0.90–1.05) per 10 dB L_{den} increase in noise levels, which does not support an increased risk of hypertension due to exposure to road traffic noise. Because of the risk of bias and the availability of only one study, this evidence was rated low quality.

In addition, 26 cross-sectional studies were identified that looked at the association between road traffic noise and prevalence of hypertension (Babisch et al., 1988; 1992; 1994; 2005a; 2008; 2012a; 2012b; 2013a; 2013b; 2014b; 2014c; Barregard et al., 2009; Bjork et al., 2006; Bluhm et al., 2007; Bodin et al., 2009; Caerphilly and Speedwell Collaborative Group, 1984; Chang et al., 2011; 2014; de Kluizenaar et al., 2007a; 2007b; Dratva et al., 2012; Eriksson et al., 2012; Foraster et al., 2011; 2012; 2013; 2014a; 2014b; Fuks et al., 2011; Hense et al., 1989; Herbold et al., 1989; Jarup et al., 2005; 2008; Knipschild et al., 1984; Lercher et al., 2008; 2011; Maschke, 2003; Maschke & Hecht, 2005; Maschke et al., 2003; Oftedal et al., 2011; 2014; Selander et al., 2009; van Poll et al., 2014; Wiens, 1995; Yoshida et al., 1997). In total, these studies involved 154 398 participants, including 18 957 cases. The overall RR for prevalence of hypertension was 1.05 (95% CI: 1.02–1.08) per 10 dB L_{den} increase in noise levels. The noise range of the studies under evaluation was 20–85 dB. The overall evidence was rated very low quality.

Fig. 4 shows the association between road traffic noise and incidence and prevalence of hypertension.

Fig. 4. The association between exposure to road traffic noise (L_{den}) and hypertension



Notes: The dotted vertical line corresponds to no effect of exposure to road traffic noise. The black dots correspond to the estimated RR per 10 dB and 95% CI. The white circle represents the summary estimate and 95% CI. For further details on the studies included in the figure please refer to the systematic review on environmental noise and cardiovascular and metabolic effects (van Kempen et al., 2018).

Stroke

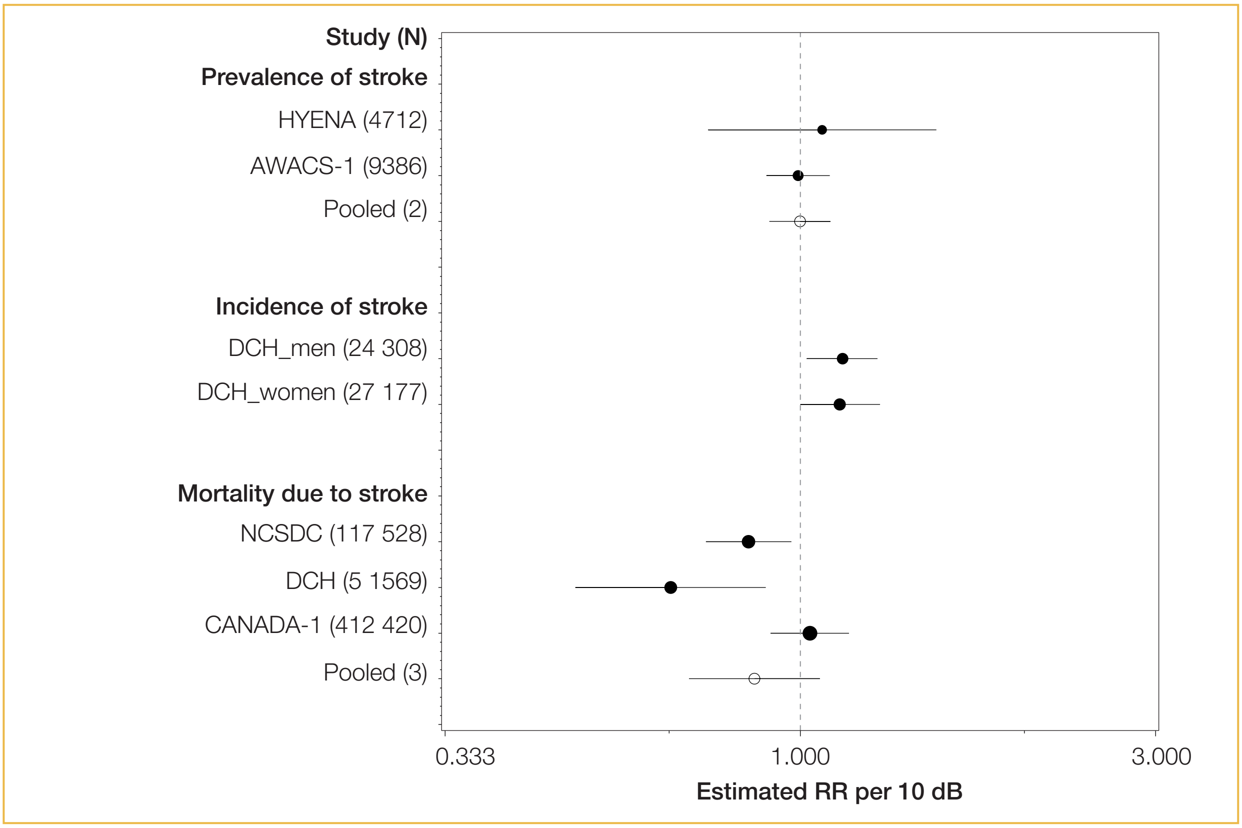
One cohort study into the relationship between road traffic noise and incidence of stroke was identified (Sörensen et al., 2011; 2012b; 2014). It involved 51 485 participants, including 1881 cases, and found an RR of 1.14 (95% CI: 1.03–1.25) per 10 dB L_{den} increase in noise levels, across a range of around 50–70 dB. The evidence was rated moderate quality.

Two cross-sectional studies on road traffic noise and prevalence of stroke involved 14 098 participants, including 151 cases (Babisch et al., 2005a; 2008; 2012a; 2012b; 2013a; Floud et al., 2011; 2013a; 2013b; Jarup et al., 2005; 2008; van Poll et al., 2014) yielded an estimated RR of 1.00 (95% CI: 0.91–1.10) per 10 dB L_{den} increase in noise levels. This evidence was rated very low quality.

Furthermore, three cohort studies investigated the relationship between road traffic noise and mortality due to stroke (Beelen et al., 2009; Gan et al., 2012; Sörensen et al., 2011; 2012b; 2014). These involved 581 517 participants, including 2634 cases, and their pooled estimate was a statistically nonsignificant RR = 0.87 (95% CI: 0.71–1.06) per 10 dB L_{den} increase in road traffic noise levels. This evidence was rated moderate quality.

Fig. 5 presents the results of the meta-analysis for road traffic noise and measures of stroke.

Fig. 5. The association between exposure to road traffic noise (L_{den}) and stroke



Notes: The dotted vertical line corresponds to no effect of exposure to road traffic noise. The black dots correspond to the estimated RR per 10 dB and 95% CI. The white circles represent the summary estimate and 95% CI.
For further details on the studies included in the figure please refer to the systematic review on environmental noise and cardiovascular and metabolic effects (van Kempen et al., 2018).

Children's blood pressure

Six cross-sectional studies investigated the change in systolic and diastolic blood pressure in children exposed to road traffic noise in residential settings (Belojevic & Evans, 2011; 2012; Bilenko et al., 2013; Liu et al., 2013; 2014; Regecova & Kellerova, 1995; van Kempen et al., 2006). In total, 4197 children were included in these studies; the number of cases was not reported. For each increase in 10 dB L_{den} in noise levels, there was a statistically nonsignificant increase in systolic and in diastolic blood pressure of 0.08 mmHg (95% CI: –0.48–0.64) and 0.47 mmHg (95% CI: –0.30–1.24), respectively. The overall evidence was rated very low quality.

Furthermore, five cross-sectional studies investigated the association between systolic and diastolic blood pressure in children and exposure to road traffic noise in educational settings (Belojevic & Evans, 2011; 2012; Bilenko et al., 2013; Clark et al., 2012; Paunovic et al., 2013; Regecova & Kellerova, 1995; van Kempen et al., 2006). In total, 4520 children were included in these studies; the number of cases was not reported. Systolic blood pressure decreased statistically nonsignificantly, at –0.60 mm (95% CI: –1.51–0.30) per 10 dB L_{den} increase in road traffic noise levels. Diastolic blood pressure increased statistically nonsignificantly, at 0.46 mm (95% CI: –0.60–1.53) per 10 dB L_{den} increase in road traffic noise levels. For both relationships, the evidence was rated very low quality.

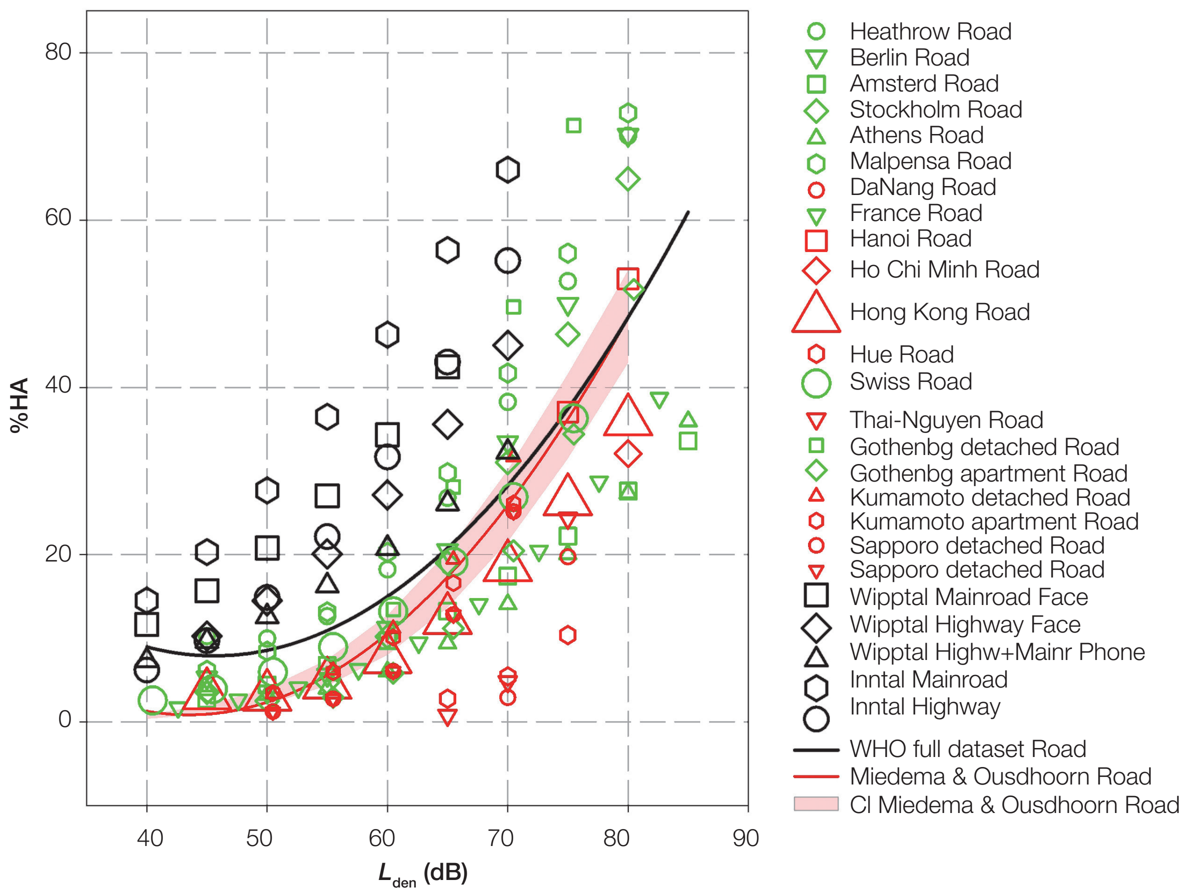
Annoyance

A vast amount of research proves the association between road traffic noise and annoyance. In total, 17 road traffic noise studies were identified that were used to model ERFs of the relationship between L_{den} and %HA (Babisch et al., 2009; Brink, 2013; Brink et al., 2016; Brown et al., 2014; 2015; Champelovier et al., 2003; Heimann et al., 2007; Lercher et al., 2007; Medizinische Universitaet Innsbruck, 2008; Nguyen et al., 2012a; Pierette et al., 2012; Sato et al., 2002; Shimoyama et al., 2014). These incorporated data from 34 112 study participants. The estimated data points of each of the studies are plotted in Fig. 6, alongside an aggregated ERF including the data from all the individual studies (see the black line for "WHO full dataset"). The lowest category of noise exposure considered in any of the studies, and hence included in the systematic review, is 40 dB, corresponding to approximately 9%HA. The benchmark level of 10%HA is reached at 53.3 dB L_{den} (see Fig 6).

Table 10 shows the %HA in relation to exposure to road traffic noise. The calculations are based on the regression equation %HA = 78.9270–3.1162 × L_{den} + 0.0342 × L_{den}^2 derived from the systematic review (Guski et al., 2017). Even though there is a large evidence base substantiating the association of average road traffic noise and noise annoyance, the overall evidence had to be rated low quality. The main reasons for downgrading included limitations regarding the acoustical data provided, the nature of study design (most of the studies in the realm of annoyance research follow a cross-sectional approach), the inconsistency of results and the variety in the questions asked.

Nevertheless, the general quality of the evidence was substantiated with the help of additional statistical analyses that apply classic health outcome measures to estimate noise annoyance. When comparing road traffic noise exposure at 50 dB and 60 dB, the analyses revealed evidence rated moderate quality for an association between road traffic noise and %HA for an increase per 10 dB (OR = 2.74; 95% CI: 1.88–4.00). Moreover, there was evidence rated high quality for the increase of %HA per 10 dB increase in sound exposure, when data on all sound classes were included (OR = 3.03; 95% CI: 2.59–3.55).

Fig. 6.Scatterplot and quadratic regression of the relationship between road traffic noise (L_{den}) and annoyance (%HA)



Notes: The ERF by Miedema & Oudshoorn (2001) is added in red for comparison.
The size of the data points corresponds to the number of participants in the respective study (size = SQRT(N)/10).
If two results from different studies fall on the same data point, the last point plotted may mask the former one.
The black curve is derived from aggregated secondary data, while the red one is derived from individual data.
There is no indication of 95% CIs of the WHO full dataset, as a weighting based on the total number of participants for each 5 dB L_{den} sound class could not be calculated; weighting based on all participants of all sound classes proved to be unsuitable. The range of data included is illustrated by the distribution of data points.
For further details on the studies included in the figure please refer to the systematic review on environmental noise and annoyance (Guski et al., 2017).

Table 10. The association between exposure to road traffic noise (L_{den}) and annoyance (%HA)

L_{den} (dB)	%HA
40	9.0
45	8.0
50	8.6
55	11.0
60	15.1
65	20.9
70	28.4
75	37.6
80	48.5

Cognitive impairment

Evidence rated very low quality was available for the association between road traffic noise and reading and oral comprehension, assessed by tests. The review identified two papers that reported the results of the cross-sectional road traffic and aircraft noise exposure and children's cognition and health (RANCH) study, which examined exposure–effect relationships (Clark et al., 2006; Stansfeld et al., 2005). The study of over 2000 children aged 9–10 years, attending 89 schools around three major airports in the Netherlands, Spain and the United Kingdom did not find an exposure–effect relationship between road traffic noise exposure at primary school, which ranged from 31 to 71 dB $L_{Aeq,16h}$, and children's reading comprehension.

Few studies have investigated other health outcome measures related to cognition. Evidence rated low quality was available for an association between road traffic noise and cognitive impairment assessed through standardized tests (Cohen et al., 1973; Lukas et al., 1981; Pujol et al., 2014; Shield & Dockrell, 2008). There was evidence rated very low quality for an association between road traffic noise and long-term memory (Matheson et al., 2010; Stansfeld et al., 2005). No studies examined effects on short-term memory.

There was evidence rated very low quality, however, that road traffic noise does not have a considerable effect on children's attention (Cohen et al., 1973; Stansfeld et al., 2005). Further, there was evidence rated low quality that road traffic noise does not have a substantial effect on executive function (working memory), with studies consistently reporting no association (Clark et al., 2012; Matheson et al., 2010; Stansfeld et al., 2005; van Kempen et al., 2010; 2012).

Hearing impairment and tinnitus

No studies were found, and therefore no evidence was available for the association between road traffic noise and hearing impairment and tinnitus.

Sleep disturbance

For road traffic noise and self-reported sleep outcomes (awakenings from sleep, the process of falling asleep and sleep disturbance), 12 studies were identified that included a total of 20 120 participants (Bodin et al., 2015; Brown et al., 2015; Hong et al., 2010; Phan et al., 2010; Ristovska et al., 2009; Sato et al., 2002; Shimoyama et al., 2014); these were cross-sectional studies, conducted in healthy adults. The health outcome was measured by self-reporting via general health and noise surveys that included questions about sleep in general, and other questions about how noise affects sleep (see Table 11).

Table 11. Summary of findings for health effects from exposure to road traffic noise (L_{night})

Noise metric	Priority health outcome measure	Quantitative risk for adverse health	Lowest level of exposure across studies	Number of participants (studies)	Quality of evidence
Effects on sleep					
L_{night}	%HSD	OR: 2.13 (95% CI: 1.82–2.48) per 10 dB increase	43 dB	20 120 (12)	Moderate (downgraded for study limitations, inconsistency; upgraded for dose-response, magnitude of effect)

The model in the systematic review (Basner & McGuire, 2018) was based on outdoor L_{night} levels between 40 dB and 65 dB only; 40 dB was chosen as the lower limit because of possible inaccuracies of predicting lower noise levels. The range of noise exposure reported in the studies reviewed was 37.5–77.5 dB L_{night}. About 2% (95% CI: 0.90–3.15) of the population was characterized as highly sleep-disturbed at L_{night} levels of 40 dB. The %HSD at other, higher levels of road traffic noise is presented in Table 12. The association between road traffic noise and the probability of being highly sleep-disturbed was OR: 2.13 (95% CI: 1.82–2.48) per 10 dB increase in noise. This evidence was rated moderate quality.

Table 12. The association between exposure to road traffic noise (L_{night}) and sleep disturbance (%HSD)

L_{night} (dB)	%HSD	95% CI
40	2.0	0.9–3.15
45	2.9	1.40–4.44
50	4.2	2.14–6.27
55	6.0	3.19–8.84
60	8.5	4.64–12.43
65	12.0	6.59–17.36

Additional analyses were conducted for other health outcome measures related to sleep, which provided supporting evidence on the overall relationship between road traffic noise and sleep disturbance. When the noise source was not specified in the question, the relationship between road traffic noise and self-reported sleep outcomes was still positive but no longer statistically significant, with an OR of 1.09 (95% CI: 0.94–1.27) per 10 dB increase (Bodin et al., 2015; Brink, 2011; Frei et al., 2014; Halonen et al., 2012). This evidence was rated very low quality.

There was evidence rated moderate quality for an association between road traffic noise and sleep outcomes measured with polysomnography (probability of additional awakenings) with an OR of 1.36 (95% CI: 1.19–1.55) per 10 dB increase in indoor $L_{AS,max}$ [13] (Basner et al., 2006; Elmenhorst et al., 2012). Further, evidence rated low quality showed an association between road traffic noise and sleep outcomes measured as motility in adults (Frei et al., 2014; Griefahn et al., 2000; Oehrstroem et al., 2006a; Passchier-Vermeer et al., 2007; Pirrera et al., 2014). Finally, there was evidence rated very low quality for an association between road traffic noise and both self-reported and motility-measured sleep disturbance in children (Ising & Ising, 2002; Lercher et al., 2013; Oehrstroem et al., 2006a; Tiesler et al., 2013).

3.1.2.2 Evidence on interventions

This section summarizes the evidence underlying the recommendation on the effectiveness of interventions for road traffic noise exposure. The key question posed was: in the general population exposed to road traffic noise, are interventions effective in reducing exposure to and/or health outcomes from road traffic noise? A summary of the PICOS/PECCOS scheme applied and the main findings is set out in Tables 13 and 14.

Table 13. PICOS/PECCOS scheme of the effectiveness of interventions for exposure to road traffic noise

PICO	Description	
Population	**General population**	
Intervention(s)	The interventions can be defined as: (a) a measures that aim to change noise exposure and associated health effects; (b) a measures that aim to change noise exposure, with no particular evaluation of the impact on health; or (c) a measures designed to reduce health effects, but that may not include a reduction in noise exposure.	
Comparison	**No intervention**	
Outcome(s)	For average noise exposure: 1. cardiovascular disease 2. annoyance 3. cognitive impairment 4. hearing impairment and tinnitus 5. adverse birth outcomes 6. quality of life, well-being and mental health 7. metabolic outcomes	For night noise exposure: 1. effects on sleep

[13] $L_{AS,max}$ is the maximum time-weighted and A-weighted sound pressure level with SLOW time constant within a stated time interval starting at t1 and ending at t2, expressed in dB.

Table 14. Summary of findings for road traffic noise interventions by health outcome

Type of intervention	Number of participants (studies)	Effect of intervention	Quality of evidence
Annoyance			
Type A – source interventions (change in traffic flow rate, improved road resurfacing, truck restriction strategy, complex set of barriers, road surfaces and other measures)	6096[a] (9)	• Changes in noise level ranged from around −15 dB to +15.5 dB (various noise metrics). • Most studies found that the intervention resulted in a change in annoyance.	Moderate (downgraded for study limitations; upgraded for dose-response)
Type B – path interventions (dwelling insulation, barrier construction, building intervention)	2970 (7)	• Changes in noise level ranged from −3 dB to −13 dB (various noise metrics). • All studies found that the intervention resulted in a change in annoyance, as estimated by an ERF.	Moderate (downgraded for study limitations; upgraded for dose-response)
Type C – changes in infrastructure (new road tunnel infrastructure)	1211 (2)	• Noise levels reduced by an average of −12 dB ($L_{Aeq,24h}$). • Both studies found lower annoyance responses post intervention, with no change in the controls.	Moderate (downgraded for study limitations; upgraded for dose-response)
Type D – other physical interventions (availability of quiet side to the dwelling, existence of nearby green space)	26 786 (6)	• Because of large variability in noise levels between most and least exposed façade (quiet side), access to quiet side and/or green space resulted in less annoyance.	Very low (downgraded for study limitations)
Sleep disturbance			
Type B – path interventions (1: façade insulation; 2: enlargement of motorway lanes but with dwelling insulation, barriers and quiet pavement)	1158 (2)	• 1: façade insulation resulted in a reduction of 7 dB for indoor noise level. • 2: enlargement led to reduction in the extent of population exposure at higher noise levels (55–65 dB) with an increase in lower levels (45–55 dB) • Both path interventions resulted in changes in sleep outcomes	Moderate (downgraded for study limitations)
Type C – changes in infrastructure (new road tunnel infrastructure)	166 (2)	• Noise levels reduced by an average of −12 dB ($L_{Aeq,24h}$). • Both studies found lower sleep disturbance indicators/ improvement in sleep post intervention, with no change in the controls.	Moderate (downgraded for study limitations)
Type D – other physical interventions (availability of quiet side to the dwelling)	100 (1)	• An absence of quiet façade resulted in increased reporting of difficulty in falling asleep.	Very low (downgraded for study limitations, inconsistency)
Cardiovascular disease			
Type D – other physical interventions (availability of quiet side to the dwelling)	9203 (4)	• Three studies found changes (including in self-reported hypertension) with and without a quiet side. One study found no change.	Very low (downgraded for study limitations)

Note: [a] This figure does not include number of participants from the studies by Langdon & Griffiths (1982) and Baughan & Huddart (1993), as the exact number of respondents was not reported.

Type A – source interventions

Most of the nine source intervention studies – Baughan & Huddart (1993), Brown (1987; 2015), Brown et al. (1985), Griffiths & Raw (1987; 1989), Kastka (1981), Langdon & Griffiths (1982), Pedersen et al. (2013; 2014), Stansfeld et al. (2009b) – showed an effect in annoyance due to changes in road traffic flow rates. In some cases these were combined with other measures like improved road resurfacing, truck restrictions or complex control measures, including barriers or road surfaces. A majority of the changes resulted in reductions of noise levels.

Regarding the strength of association between exposure and annoyance outcome, all intervention studies demonstrated that the response was of at least the magnitude estimated by a steady-state ERF. The limited available evidence on long-term effects shows that this excess response undergoes some attenuation but is largely maintained over several years. In spite of the high risk of bias in all studies, the evidence in the systematic review was initially assessed as high quality, due to an upgrade because of the dose-response effect. However, the GDG decided to downgrade this assessment in an effort to maximize consistency with the grading approach of the remaining systematic reviews. It was therefore rated moderate quality.

Type B – path interventions

Seven path intervention studies – Amundsen et al. (2011; 2013), Bendtsen et al. (2011), Gidloef-Gunnarsson et al. (2010), Kastka et al. (1995), Nilsson & Berglund (2006), Vincent & Champelovier (1993) – explored the effects on annoyance by interventions related to dwelling insulation, barrier constructions and a combination of both, as well as a full-scale building intervention. With the help of pre/post designs, the studies assessed changes in noise exposure achieved by the interventions over different periods of time. In six studies the path intervention was associated with a change in annoyance outcomes. Four of these showed that the annoyance response to the change was in the same direction and of at least the same magnitude estimated by the ERF. In spite of the high risk of bias in all studies, the evidence in the systematic review was initially assessed as high quality, due to an upgrade because of the dose-response effect. However, the GDG decided to downgrade this assessment in an effort to maximize consistency with the grading approach of the remaining systematic reviews. The evidence was therefore rated moderate quality.

Two of the studies (Amundsen et al., 2013; Bendtsen et al., 2011) assessed path interventions and sleep disturbance. The results showed a reduction in the %HSD after the interventions were conducted. One of the studies included a two-year follow-up, revealing the persistence of the effect. Risk of bias was assessed as high in both studies. The evidence was rated moderate quality.

Type C – new/closed infrastructure interventions

Two infrastructural intervention studies (Gidloef-Gunnarsson et al., 2013; Oehrstroem, 2004; Oehrstroem & Skanberg, 2000) evaluated the impact on annoyance of major reductions in road traffic flows, combined with other environmental improvements. One was a new road tunnel infrastructure, resulting in substantial traffic and noise levels reductions for residents near the previously heavy-traffic road. Both studies were pre/post designs using repeated measures of annoyance outcomes. Following the reduction in noise levels (around –12 dB $L_{Aeq,24h}$), both studies demonstrated a statistically significant lower degree of annoyance, while there was no change in the control group. Both also reported that the after-scores in the studies matched those estimated by the ERF, but both reported excess response, meaning that the response to change was in the direction estimated by the ERF but much steeper. In spite of the high risk of bias in all studies, the quality of the evidence in the systematic review was initially assessed as high, due to an upgrade because of the dose-response effect. However, the GDG decided to downgrade this assessment in an effort to maximize consistency with the grading approach of the remaining systematic reviews. The evidence was therefore rated moderate quality.

Two studies investigated the impact of new tunnels that removed traffic flow from surface roads on sleep disturbance (Oehrstroem, 2004; Oehrstroem & Skanberg, 2000; 2004). Subjective and objective measures of sleep quality were assessed before and after the intervention. Both studies demonstrated a statistically significant lower reporting of various sleep disturbance indicators post intervention. One study reported statistically significantly reduced time spent in bed after the intervention, which, according to the authors, could suggest increased sleep efficiency. Risk of bias was assessed as high, so this evidence was rated moderate quality.

Type D – other physical infrastructure interventions

No intervention studies were available to assess impacts on annoyance of other physical interventions. The only relevant studies (Babisch et al., 2012; de Kluizenaar et al, 2011; 2013; Gidloef-Gunnarsson & Oehrstroem 2007; van Renterghem & Botteldooren, 2012; 2010) did not provide direct evidence of an intervention. Instead, they provided indirect evidence on the magnitude of the likely effect of certain interventions (e.g. using the quiet side of the dwelling, green space in the neighbourhood) by comparing responses from groups with and without the intervention/feature of interest. All studies found an effect of the presence of the dimension investigated; in all but one, the effect was statistically significant. Risk of bias was assessed as high in all studies, so the evidence was rated very low quality.

One study investigated a subjective assessment of difficulty in falling asleep (van Renterghem & Botteldooren, 2012), before and after the intervention. The difference in the proportion of participants reporting difficulty falling asleep “at least sometimes” between homes with and without a quiet side was statistically significant. Absence of a quiet façade resulted in increased reporting of this sleep parameter. Confounding was adjusted for in the analyses of the ERFs, including noise sensitivity, window-closing behaviour and front-façade L_{den}. Risk of bias was assessed as high, so the evidence was rated very low quality.

Four studies that assessed the effect of other physical interventions on cardiovascular disease were identified (Babisch et al., 2012; 2014a; Bluhm et al., 2007; Lercher et al., 2011). Three of these found changes, including self-reported hypertension, with and without a quiet side of the dwelling; in two the difference was statistically significant. The risk of bias in these studies was generally high, so the evidence was rated very low quality.

3.1.2.3 Consideration of additional contextual factors

As the foregoing overview has shown, ample evidence about the adverse health effects of long-term exposure to road traffic noise exists. Based on the quality of the available evidence, the GDG set the strength of the recommendation on road traffic noise at strong. As a second step, it qualitatively assessed contextual factors to explore whether other considerations could have a relevant impact on the recommendation strength. These considerations mainly concerned the balance of harms and benefits, values and preferences, equity, and resource use and implementation.

When assessing the balance of harms and benefits of interventions to reduce exposure to road traffic noise, the GDG initially noted that road traffic is the most widespread source of noise pollution, measured in terms of the number of affected people both within and outside urban areas. The EEA estimates that more than 100 million people in Europe are exposed to L_{den} levels above 55 dB; for night-time road traffic noise, over 72 million Europeans are exposed to L_{night} levels above 50 dB (Blanes et al., 2017).[14] The amount of road traffic noise emitted is unlikely to decrease significantly: both transport demand, including for passenger cars (EC, 2016b), and the number of city inhabitants (Eurostat, 2016) are expected to increase. Considering the significant burden of disease attributable to exposure to road traffic noise (WHO Regional Office for Europe & JRC, 2011), the GDG expects substantial health benefits to evolve from implementing the recommendations to reduce population exposure to road traffic noise. Depending on the intervention measures used (such as restrictions of traffic), possible harms could include effects on the transportation of goods and on individual mobility of the population. Both can have impacts on local, national and international economies. Overall, the GDG estimated that the benefits gained from minimizing adverse health effects due to road traffic noise exposure outweigh the possible (economic) harms.

Considering values and preferences, it has been established that people appreciate quiet areas as beneficial for their health and well-being, especially in urban areas (Shepherd et al., 2013; Gidloef-Gunnarsson & Oehrstroem, 2007; Oehrstroem et al., 2006b). Nevertheless, the GDG recognized that the convenience of individual mobility with the help of passenger cars is valued overall by large parts of the population in the EU, as illustrated by the sustained high volume of passenger kilometres driven in Europe (EEA, 2016a; 2017a). In general, values and preferences are expected to vary throughout society, as exposure to environmental noise and continuous road traffic noise is not equally distributed: those of individuals directly affected by long-term road traffic exposure are likely to differ from those that are not affected. Individuals with a higher average sound pressure level of road traffic noise are, for example, more willing to pay to reduce their noise exposure (Bristow et al., 2014).

In light of the dimension of equity, the GDG highlighted the fact that the risk of exposure to road traffic noise is not equally distributed throughout society. People with lower socioeconomic status and other disadvantaged groups often live in more polluted and louder areas, including in proximity to busy roads (EC, 2016a). Moreover, socioeconomic factors are not only related to differences in exposure to environmental factors such as noise but are also associated with increased vulnerability and poorer coping capacities (Karpati et al., 2002).

With resource use and implementation considerations, the GDG recognized that no comprehensive cost–benefit analysis for the WHO European Region yet exists, so this assessment is based on informed expert judgement regarding the feasibility of implementing the recommendation for the majority of the population. As the systematic review of environmental noise interventions and their

[14] These are gap-filled figures based on the reported data and including the situation both within and outside cities, as defined by the END.

associated impact on health shows, various effective measures exist to reduce noise exposure from road traffic and improve health (Brown & van Kamp, 2017). The resources needed to implement these measures vary as they rely on the type of intervention and the context. The GDG pointed out the following four major solutions, which are known to be cost-effective: choice of appropriate tyres, use of low-noise road surfaces, building of noise barriers and installation of soundproof windows (CSES et al., 2016). Other types of intervention include limitations of speed or type of traffic allowed on roads.

Regarding feasibility of implementation, the GDG was convinced that many of the solutions can be planned as part of regular maintenance processes and accelerated fleet and road modernization. In particular, appropriate tyres and road surfaces are only slightly more expensive than existing products, and various countries have already considered or adopted similar interventions to reduce noise levels (Ohiduzzaman et al., 2016; Sirin, 2016). This indicates that solutions to achieve recommended noise levels can be implemented and carry a reasonable cost on a societal level. The GDG noted, however, that the feasibility of implementing measures can be hindered by the fact that costs and benefits are not evenly distributed. In most cases, the health benefits gained by interventions that reduce long-term road traffic exposure accrue to citizens, whereas the costs are borne by road users, private companies and public authorities. Furthermore, the GDG expects challenges in the implementation of all long-term measures that include changes in behaviour of the population, such as increased use of car-sharing or public transport. Even though the overall costs are expected to be significant, because of the large number of people affected, the benefit of implementation of the recommendation to minimize the risk of adverse health effects due to road traffic noise for a majority of the population exceeds the resources needed.

In light of the assessment of the contextual factors in addition to the quality of evidence, the recommendation remains strong.

Other nonpriority adverse health outcomes

As an additional consideration, although not priority health outcomes and coming from a single study, the GDG noted the evidence rated moderate quality for an association between road traffic noise and the prevalence of diabetes (van Kempen et al., 2018). The noise levels in the study identified ranged from around 50 dB to 70 dB L_{den}, so the recommendation proposed is thought to be protective enough for this health outcome. Thus, it did not lead to a change in the recommendation.

Additional considerations or uncertainties

Individual noise annoyance judgements of residents are to a large extent moderated by personal variables (such as noise sensitivity and coping capacity). However, further situational factors that apply to many residents should be taken into account when analysing noise annoyance from road traffic noise, as they may moderate the relationship. These include the type(s) of road being considered (highways, urban main roads, secondary roads and so on) and the related traffic composition (share of cars, motorcycles and heavy and loud trucks) and pattern (fluctuation, frequency, intermittency). Moreover, the location of settlements and/or individual dwellings, proximity to the road, and location and availability of a quiet façade can also influence the relationship when predicting health outcomes such as annoyance.

3.1.3 Summary of the assessment of the strength of the recommendations

Table 15 provides a comprehensive summary of the different dimensions for the assessment of the strength of the road traffic noise recommendations.

Table 15. Summary of the assessment of the strength of the road traffic noise recommendation

Factors influencing the strength of recommendation	Decision
Quality of evidence	**Average exposure** (L_{den}) *Health effects* • Evidence for a relevant RR increase for incidence of IHD at **59 dB** L_{den} was rated **high quality**. • Evidence for the incidence of hypertension was rated **low quality**. • Evidence for a relevant absolute risk of annoyance at **53 dB** L_{den} was rated **moderate quality**. • Evidence for a relevant RR increase for reading and oral comprehension was rated **very low quality**. *Interventions* • Evidence on effectiveness of interventions to reduce noise exposure and/or health outcomes from road traffic noise is of varying quality. **Night-time exposure** (L_{night}) *Health effects* • Evidence for a relevant absolute risk of sleep disturbance related to night noise exposure from road traffic at **45 dB** L_{night} was rated **moderate quality**. *Interventions* • Evidence on effectiveness of interventions to reduce noise exposure and/or sleep disturbance from road traffic noise is of varying quality.
Balance of benefits versus harms and burdens	Health benefits can be gained from markedly reducing exposure of the population to road traffic noise; benefits outweigh the harms of interventions to reduce continuous road traffic noise.
Values and preferences	Quiet areas are valued by the population, especially by those affected by continuous noise exposure. Some variability is possible between those who benefit from interventions to reduce road traffic noise and those who finance the interventions.
Equity	Risk of exposure to road traffic noise is not equally distributed.
Resource use and implications	No comprehensive cost–effectiveness analysis data are available; nevertheless, a wide range of solutions exists and several are being implemented, showing that effective interventions are both feasible and economically reasonable.
Decisions on recommendation strength	• **Strong** for guideline level for average noise exposure (L_{den}) • **Strong** for guideline value for average night noise exposure (L_{night}) • **Strong** for specific interventions to reduce noise exposure

3.2 Railway noise

Recommendations

For average noise exposure, the GDG **strongly** recommends reducing noise levels produced by railway traffic below **54 dB** L_{den}, as railway noise above this level is associated with adverse health effects.

For night noise exposure, the GDG **strongly** recommends reducing noise levels produced by railway traffic during night time below **44 dB** L_{night}, as railway noise above this level is associated with adverse effects on sleep.

To reduce health effects, the GDG **strongly** recommends that policy-makers implement suitable measures to reduce noise exposure from railways in the population exposed to levels above the guideline values for average and night noise exposure. There is, however, insufficient evidence to recommend one type of intervention over another.

3.2.1 Rationale for the guideline levels for railway noise

The exposure levels were derived in accordance with the prioritizing process of critical health outcomes described in section 2.4.3. For each of the outcomes, the exposure level was identified by applying the benchmark, set as relevant risk increase to the corresponding ERF. In the case of exposure to railway noise, the process can be summarized as follows (Table 16).

Table 16. Average exposure levels (L_{den}) for priority health outcomes from railway noise

Summary of priority health outcome evidence	Benchmark level	Evidence quality
Incidence of IHD No studies were available and therefore incidence of IHD could not be used to assess the exposure level.	5% increase of RR	No studies met the inclusion criteria/no studies available
Incidence of hypertension One study met the inclusion criteria. There was no significant increase of risk associated with increased noise exposure in this study.	10% increase of RR	Low quality
Prevalence of highly annoyed population There was an absolute risk of 10% at a noise exposure level of 53.7 dB $L_{den.}$	10% absolute risk	Moderate quality
Permanent hearing impairment	No increase	No studies met the inclusion criteria/no studies available
Reading skills and oral comprehension in children	One-month delay	No studies met the inclusion criteria/no studies available

In accordance with the prioritization process (see section 2.4.3), the GDG set a guideline exposure level of 53.7 dB L_{den} for average exposure, based on the relevant increase of the absolute %HA. In accordance with the defined rounding procedure, the value was rounded to 54 dB L_{den}. As the evidence on the adverse effects of railway noise was rated moderate quality, the GDG made the recommendation strong.

Next, the GDG assessed the evidence for night noise exposure and its effect on sleep disturbance (Table 17).

Table 17. Night-time exposure levels (L_{night}) for priority health outcomes from railway noise

Summary of priority health outcome evidence	Benchmark level	Evidence quality
Sleep disturbance 3% of the participants in studies were highly sleep-disturbed at a noise level of **43.7 dB** L_{night}	3% absolute risk	Moderate quality

Based on the evidence of the adverse effects of railway noise on sleep disturbance, the GDG defined a guideline exposure level of 43.7 dB L_{night}. The exact exposure value was rounded to 44 dB L_{night}. As the evidence was rated moderate quality, the GDG made the recommendation strong.

The GDG also considered the evidence for the effectiveness of interventions. The results showed that:

- intervening at the source by applying rail grinding procedures can reduce noise annoyance;
- behavioural interventions such as informing the community about noise interventions can reduce noise annoyance.

In light of the strong evidence about the adverse health effects, the GDG followed a precautionary approach and made a strong recommendation for interventions on railway noise, as it was confident that interventions are realizable and that best practices already exist for the management of noise from railways. Since the empirical evidence on the effectiveness of different types of intervention was rated either low or very low quality, the GDG felt that no recommendation could be made on the preferred type of intervention, and agreed not to recommend any specific type of intervention over another.

3.2.1.1 Other factors influencing the strength of recommendations

Other factors considered in the context of recommendations on railway noise included those related to values and preferences, benefits and harms, resource implications, equity, acceptability and feasibility; moreover, nonpriority health outcomes were considered. The assessment of all these factors – especially the values and preferences involved in railway noise – did not lead to a change in the strength of the recommendations. Further details are provided in Section 3.2.2.3.

3.2.2 Detailed overview of the evidence

The following sections provide a detailed overview of the evidence constituting the basis for setting the recommendations on railway noise. It is presented and summarized separately for each of the critical health outcomes, and the GDG's judgement of the quality of evidence is indicated (for a detailed overview of the evidence on important health outcomes, see Annex 4). Research into health outcomes and effectiveness of interventions is addressed consecutively.

A comprehensive summary of all evidence considered for each of the critical and important health outcomes can be found in the eight systematic reviews published in the *International Journal of Environmental Research and Public Health* (see section 2.3.2 and Annex 2).

3.2.2.1 Evidence on health outcomes

The key question posed was: in the general population exposed to railway noise, what is the exposure–response relationship between exposure to railway noise (reported as various noise indicators) and the proportion of people with a validated measure of health outcome, when adjusted for main confounders? A summary of the PICOS/PECCOS scheme applied and the main findings is set out in Tables 18 and 19.

Table 18. PICOS/PECCOS scheme of critical health outcomes for exposure to railway noise

PECO	Description	
Population	General population	
Exposure	Exposure to high levels of noise produced by railway traffic (average/night time)	
Comparison	Exposure to lower levels of noise produced by railway traffic (average/night time)	
Outcome(s)	For average noise exposure: 1. cardiovascular disease 2. annoyance 3. cognitive impairment 4. hearing impairment and tinnitus 5. adverse birth outcomes 6. quality of life, well-being and mental health 7. metabolic outcomes	For night noise exposure: 1. effects on sleep

Table 19. Summary of findings for health effects from exposure to railway noise (L_{den})

Noise metric	Priority health outcome measure	Quantitative risk for adverse health	Lowest level of exposure across studies	Number of participants (studies)[a]	Quality of evidence
Cardiovascular disease					
L_{den}	Incidence of IHD	–	–	–	–
L_{den}	Incidence of hypertension	RR = 0.96 (95% CI: 0.88–1.04) per 10 dB increase	N/A	7249 (1)	Low (downgraded for risk of bias and availability of only one study)
Annoyance					
L_{den}	%HA	OR = 3.53 (95% CI: 2.83–4.39) per 10 dB increase	34	10 970 (10)	Moderate (downgraded for inconsistency, directness; upgraded for dose-response)
Cognitive impairment					
L_{den}	Reading and oral comprehension	–	–	–	–
Hearing impairment and tinnitus					
L_{den}	Permanent hearing impairment	–	–	–	–

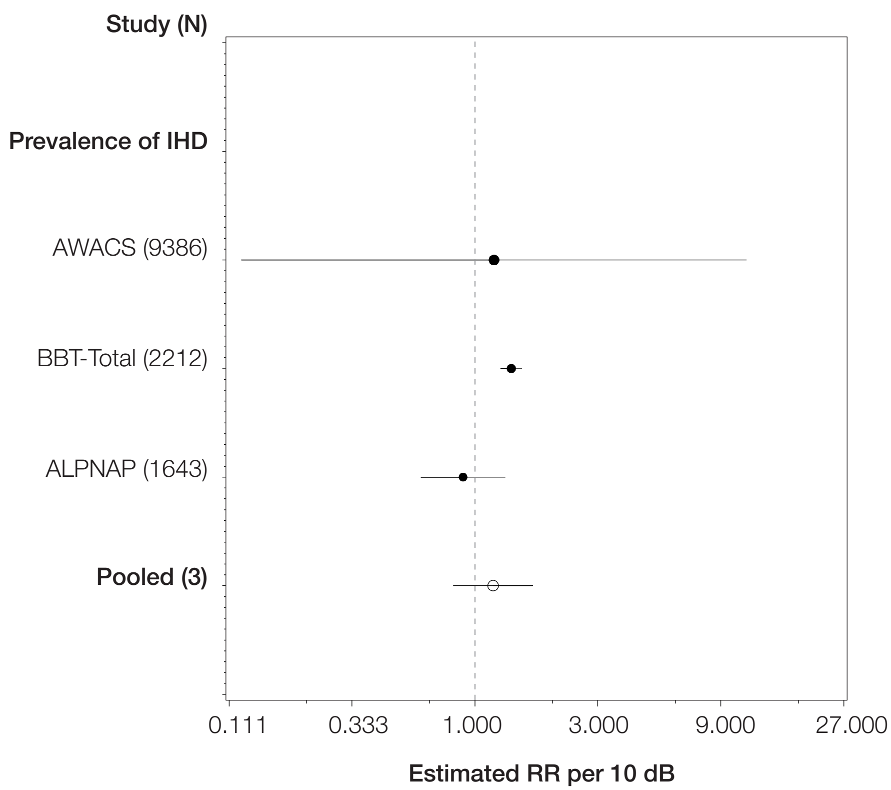
Note: [a] Results are partly derived from population-based studies.

Cardiovascular disease

IHD

No evidence was available on the relationship between railway noise and the incidence of or mortality from IHD. Four cross-sectional studies were identified, however, that assessed the prevalence of IHD in a total of 13 241 participants, including 283 cases (Heimann et al., 2007; Lercher et al., 2008; 2011; van Poll et al., 2014). The overall risk was not statistically significantly increased: the RR was 1.18 (95% CI: 0.82–1.68) per 10 dB L_{den} increase, with inconsistency across studies (see Fig. 7). The evidence was rated very low quality.

Fig. 7. The association between exposure to railway noise (L_{den}) and prevalence of IHD



Notes: The dotted vertical line corresponds to no effect of exposure to railway noise. The black circles correspond to the estimated RR per 10 dB and 95% CI. The white circle represents the pooled random effect estimates and 95% CI. For further details on the studies included in the figure please refer to the systematic review on environmental noise and cardiovascular and metabolic effects (van Kempen et al., 2018).

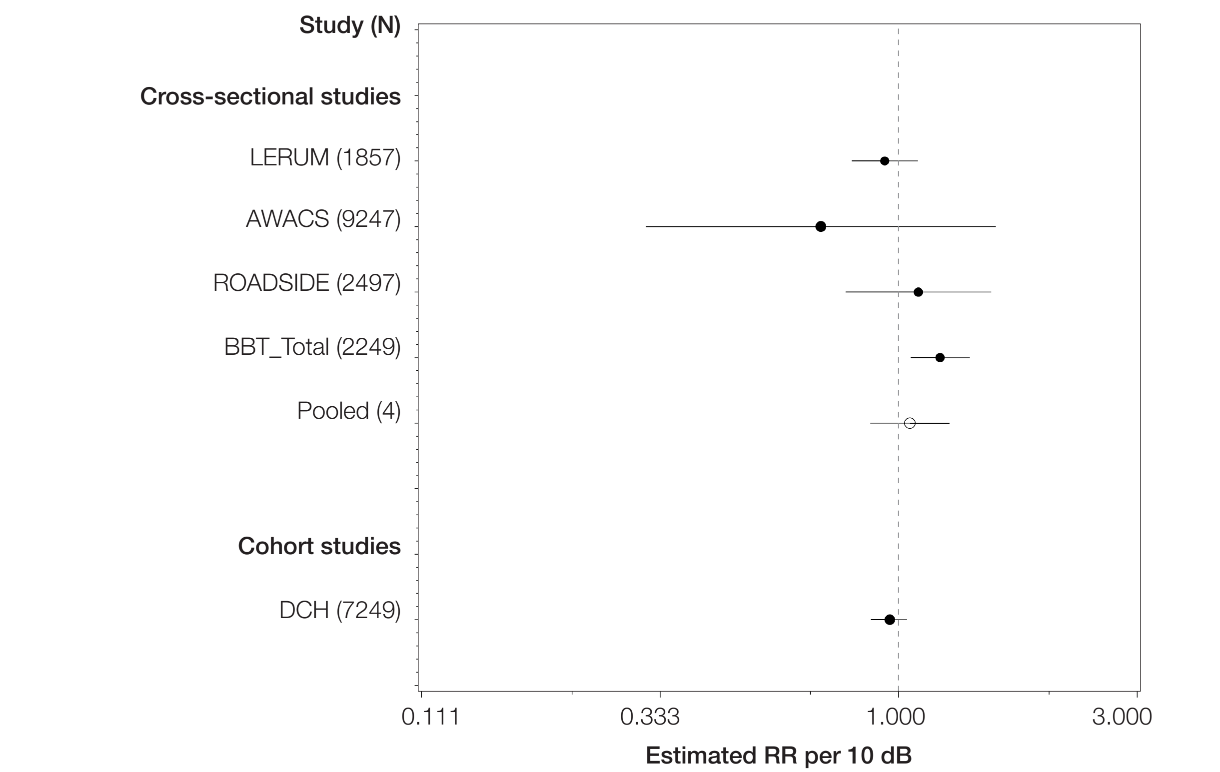
Hypertension

One cohort study on the relationship between railway noise and hypertension was identified; it assessed the incidence among people living in Denmark (Sörensen et al., 2011; 2012a). The study involved 7249 participants, including 3145 cases. The authors did not find an association between railway noise exposure and incidence of hypertension, with RR = 0.96 (95% CI: 0.88–1.04) per 10 dB L_{den} increase. This evidence was rated low quality.

In addition, five cross-sectional studies assessed the prevalence of hypertension in 15 850 participants, including 2059 cases (Barregard et al., 2009; Eriksson et al., 2012; Lercher et al., 2008; 2011; van Poll et al., 2014). The overall RR increase was not statistically significant, at 1.05 (95% CI: 0.88–1.26) per 10 dB L_{den} increase. Moreover, there was inconsistency among the results across studies. The evidence was rated very low quality.

Fig. 8 presents the studies investigating the relationship between railway noise and different measures of hypertension.

Fig. 8. The association between exposure to railway noise (L_{den}) and hypertension



Notes: The dotted vertical line corresponds to no effect of exposure to railway noise. The black dots correspond to the estimated RR per 10 dB and 95% CI. The white circle represents the summary estimate and 95% CI.
For further details on the studies included in the figure please refer to the systematic review on environmental noise and cardiovascular and metabolic effects (van Kempen et al., 2018).

Stroke

As for IHD, no evidence was available on the relationship between railway noise and incidence of or mortality from stroke. However, one cross-sectional study was identified that assessed the prevalence of stroke in 9365 participants, including 89 cases (van Poll et al., 2014). The overall risk was not statistically significantly increased, with RR = 1.07 (95% CI: 0.92–1.25) per 10 dB L_{den} increase. The evidence was rated very low quality.

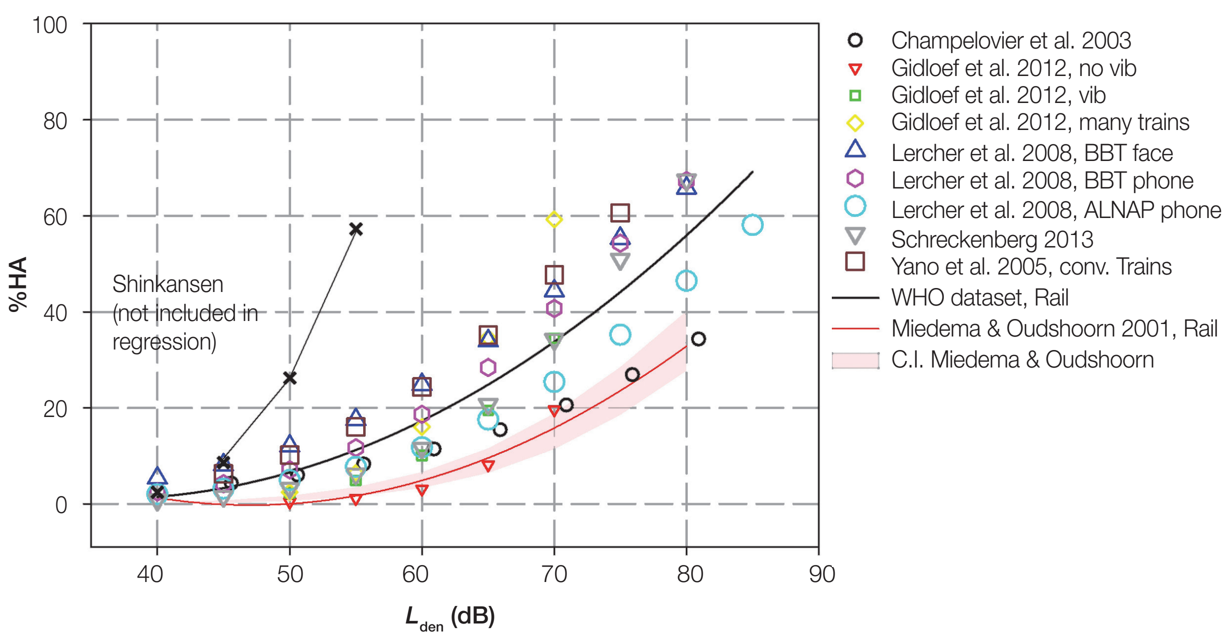
Children's blood pressure

No evidence was available for the association between railway noise and the systolic and/or diastolic blood pressure of children in residential and/or educational settings.

Annoyance

In total, 10 studies with ERFs on the association between railway noise and annoyance were included in analyses (Champelovier et al., 2003; Gidloef-Gunnarsson et al., 2012; Lercher et al., 2007; 2008; Sato et al., 2004; Schreckenberg, 2013; Yano et al., 2005; Yokoshima et al., 2008). The studies incorporated individual data from 10 970 participants. The estimated data points of each of these studies are plotted in Fig. 9, alongside an aggregated ERF including the data from all the individual studies (see the black line for "WHO dataset, Rail"). The lowest category of noise exposure considered in any of the studies, and hence included in the systematic review is 40 dB, corresponding to approximately 1.5%HA. The 10% benchmark for %HA is reached at 53.7 dB L_{den} (see Fig. 9).

Fig. 9. Scatterplot and quadratic regression of the relationship between railway noise (L_{den}) and annoyance (%HA)



Notes: The ERF by Miedema & Oudshoorn (2001) is added in red for comparison.
There is no indication of 95% CIs of the WHO dataset curve, as a weighting based on the total number of participants for each 5 dB L_{den} sound class could not be calculated; weighting based on all participants of all sound classes proved to be unsuitable. The range of data included is illustrated by the distribution of data points.
For further details on the studies included in the figure please refer to the systematic review on environmental noise and annoyance (Guski et al., 2017).

Table 20 shows the %HA for railway noise exposure. The calculations are based on the regression equation %HA = 38.1596–2.05538 × L_{den} + 0.0285 × $L_{den}{}^2$ derived from the systematic review (Guski et al., 2017). The overall evidence was rated moderate quality. Additional statistical analyses of annoyance outcomes supported these findings. When comparing railway noise exposure at 50 dB and 60 dB, the analyses revealed evidence rated moderate quality for an association between railway noise and %HA for an increase per 10 dB (OR = 3.40; 95% CI: 2.05–5.62). Moreover, evidence rated high quality was available for the increase in %HA per 10 dB increase in sound exposure, when data on all sound classes were included (OR = 3.53; 95% CI: 2.83–4.39).

Table 20. The association between exposure to railway noise (L_{den}) and annoyance (%HA)

L_{den} (dB)	%HA
40	1.5
45	3.4
50	6.6
55	11.3
60	17.4
65	25.0
70	33.9
75	44.3
80	56.1

Cognitive impairment

Studies of railway noise on children's reading and oral comprehension were lacking. Nevertheless, other measures of cognition yielded evidence rated very low quality for an association between railway noise and children with poorer performance on standardized assessment tests (Bronzaft, 1981; Bronzaft & McCarthy, 1975). Evidence for the association between railway noise and children having poorer long-term memory (Lercher et al., 2003) was rated very low quality. No studies examined effects on short-term memory.

There was no clear relation between railway noise and attention in children (Lercher et al., 2003), and this evidence was rated very low quality.

Hearing impairment and tinnitus

No studies were found, and therefore no evidence was available on the association between railway noise and hearing impairment and tinnitus.

Sleep disturbance

For railway noise and self-reported sleep outcomes (awakenings from sleep, the process of falling asleep and sleep disturbance), five studies were identified that included a total of 7133 participants (Bodin et al., 2015; Hong et al., 2010; Sato et al., 2004; Schreckenberg, 2013). The studies were cross-sectional and conducted on healthy adults. The health outcome was measured by self-reporting via general health surveys and noise surveys that included questions about sleep in general, and other questions about how noise affects sleep (Table 21).

Table 21. Summary of findings for health effects from exposure to railway noise (L_{night})

Noise metric	Priority health outcome measure	Quantitative risk for adverse health	Lowest level of exposure across studies	Number of participants (studies)	Quality of evidence
Effects on sleep					
L_{night}	%HSD	OR: 3.06 (95% CI: 2.38–3.93) per 10 dB increase	33 dB	7133 (5)	Moderate (downgraded for study limitations, inconsistency; upgraded for dose-response, magnitude of effect)

The model in the systematic review (Basner & McGuire, 2018) was based on outdoor L_{night} levels between 40 dB and 65 dB only; 40 dB was chosen as the lower limit because of possible inaccuracies in predicting lower noise levels. The range of noise exposure reported in the studies was 27.5–82.5 dB L_{night}. About 2% (95% CI: 0.79–3.48) of the population was characterized as highly sleep-disturbed for L_{night} levels of 40 dB. The %HSD at other, higher levels of railway noise is presented in Table 17. The association between railway noise and the probability of being sleep-disturbed was OR: 3.1 (95% CI: 2.4–3.9) per 10 dB increase in noise. This evidence was rated moderate quality.

Table 22. The association between exposure to railway noise (L_{night}) and sleep disturbance (%HSD)

L_{night} (dB)	%HSD	95% CI
40	2.1	0.79–3.48
45	3.7	1.63–5.71
50	6.3	3.12–9.37
55	10.4	5.61–15.26
60	17.0	9.48–24.37
65	26.3	15.20–37.33

Additional analyses were conducted for sleep quality measures, which provided supporting evidence on the overall relationship between railway noise and sleep. When the noise source was not specified in the question, the relationship between railway noise and self-reported sleep outcomes was still positive but no longer statistically significant, with an OR of 1.27 (95% CI: 0.89–1.81) per 10 dB increase (Bodin et al., 2015; Brink, 2011; Frei et al., 2014). This evidence was rated very low quality.

There was evidence rated moderate quality for an association between railway noise and the probability of additional awakenings, measured with polysomnography, with an OR of 1.35 (95% CI: 1.21–1.52) per 10 dB increase in indoor $L_{AS,max}$ (Elmenhorst et al., 2012). Finally, evidence rated low quality was available for an association between railway noise and sleep outcomes measured as motility in adults (Griefahn et al., 2000; Hong et al., 2006; Lercher et al., 2010; Passchier-Vermeer et al., 2007), and rated very low quality for an association between railway noise and both self-reported and motility-measured sleep disturbance in children (Ising & Ising, 2002; Lercher et al., 2013; Tiesler et al., 2013).

3.2.2.2 Evidence on interventions

This section summarizes the evidence underlying the recommendation on the effectiveness of interventions for railway noise exposure (Tables 23 and 24). The key question posed was: in the general population exposed to railway noise, are interventions effective in reducing exposure to and/or health outcomes from railway noise? A summary of the PICOS/PECCOS scheme applied and the main findings is set out in Tables 23 and 24.

Table 23. PICOS/PECCOS scheme of the effectiveness of interventions for exposure to railway noise

PICO	Description	
Population	**General population**	
Intervention(s)	The interventions can be defined as: (a) a measure that aims to change noise exposure and associated health effects; (b) a measure that aims to change noise exposure, with no particular evaluation of the impact on health; or (c) a measure designed to reduce health effects, but that may not include a reduction in noise exposure.	
Comparison	**No intervention**	
Outcome(s)	For average noise exposure: 1. cardiovascular disease 2. annoyance 3. cognitive impairment 4. hearing impairment and tinnitus 5. adverse birth outcomes 6. quality of life, well-being and mental health 7. metabolic outcomes	For night noise exposure: 1. effects on sleep

Table 24. Summary of findings for railway noise interventions by health outcome

Type of intervention	Number of participants (studies)	Effect of intervention	Quality of evidence
Annoyance			
Type A – source interventions (rail grinding)	81 (1)	• Changes in noise level as a consequence of the intervention ranged from around −7dB to −8 dB. • Most studies found changes in annoyance outcomes, persisting more than 12 months after the intervention.	Very low (downgraded for study limitations, inconsistency, imprecision)
Type C – changes in infrastructure (new rail infrastructure)	6000[a] (1)	• A very small increase in total noise exposure was found (most had <+1 dB change; some had +2–4 dB change). • Original noise from road traffic overwhelmed the train noise for effectively all participants.	Very low (downgraded for study limitations, inconsistency, imprecision)
Type E – behaviour change interventions (informing the community about a noise intervention)	411 (1)	• Exposure levels were not reported; emission levels reduced by 1–2 dB. • A reduction in annoyance of the community as a result of the intervention was reported.	Very low (downgraded for study limitations, inconsistency, imprecision)

Note: [a] According to Lam & Au (2008), this records the number of invitation letters sent; the response rate was not reported.

Three studies on railway noise interventions met the criteria to be included in the evidence base. All studies consisted of a pre/post design and reported annoyance outcomes at people's dwellings (Lam & Au, 2008; Moehler et al., 1997; Schreckenberg et al., 2013). They could be categorized as a source intervention, a new/closed infrastructure intervention and a communication intervention. In two of the studies, the changes in exposure after the intervention were only small, although there were significant effects on noise annoyance. The study on source interventions and annoyance revealed that a change of –10 dB in noise exposure led to a significant reduction in annoyance, which persisted over a period of 12 months after the intervention. As confounding was not addressed, and railway noise was not the dominant sound source in the studies, the evidence was rated very low quality.

3.2.2.3 Consideration of additional contextual factors

As the foregoing overview has shown, sufficient evidence about the adverse health effects of long-term exposure to railway noise exists. Based on the quality of the available evidence, the GDG set the strength of recommendation on railway noise at strong. As a second step, it qualitatively assessed contextual factors to explore whether other considerations could have a relevant impact on the recommendation strength. These contextual considerations mainly concerned the balance of harms and benefits, values and preferences, and resource use and implementation.

When assessing the balance of harms and benefits of interventions to reduce exposure to railway noise and minimize noise-associated adverse health effects, the GDG recognized that railway transportation is the second most dominant source of environmental noise in Europe. Based on EEA estimates, the number of people exposed to L_{den} above 55 dB and L_{night} above 50 dB from railway noise is 17 million and 15 million, respectively (Blanes et al., 2017).[15] In light of the burden of disease from environmental noise, and railway noise in particular, the GDG agreed that the health benefits from a reduction of long-term railway noise exposure (especially during night time) to the recommended values would be significant. Considering possible harms related to adaptation of the recommended values, the GDG noted that reliance on railway transportation has increased in recent years in Europe and is expected to increase further, as an important component of the shift towards a greener economy. At a societal level, an environmental and economic benefit from the use of rail transportation is expected: trains contribute to lower environmental pollution and carbon emission than road transportation. Therefore, there is a need to balance the expected health benefits from reduced continuous railway noise exposure and the overall positive effects on the health of the population from increased reliance on the comparatively environmentally friendly mode of railway transportation. Overall, the GDG agreed that even though fewer people are exposed to railway noise than road traffic noise, it remains a major source of localized noise pollution; therefore, considerable benefits are gained by reducing exposure to railway noise.

When exploring values and preferences, the GDG acknowledged that, in general, people value rail as an alternative and more sustainable transportation method than air or road traffic (EEA, 2016a; 2016b; 2017b). Furthermore, the values and preferences in relation to implementation of the recommendation are expected to vary: those of individuals living in the vicinity of railway tracks are expected to differ from those of the rest of the population not exposed to railway noise on a long-term basis. Economic depreciation of housing and fear of adverse health effects were assumed

[15] These are gap-filled figures based on the reported data and including the situation both within and outside cities, as defined by the END.

to be two main aspects influencing the evaluation of affected individuals. This especially applies to areas where new railway tracks are being built, as this results in considerable change for local inhabitants. Moreover, the GDG acknowledged that preferences might also vary in the policy-making domain across different countries as the implementation of the recommendations would mean a renunciation of the so-called "railway bonus".[16]

On resource use and implementation considerations, the GDG pointed out that no comprehensive cost–benefit analysis for the WHO European Region has yet been conducted, so this assessment is based on informed qualitative expert judgement regarding the feasibility of implementing the recommendation for the majority of the population. The systematic review of environmental noise interventions and their associated impact on health shows that various measures to reduce continuous noise from railway traffic exist, although knowledge about their effectiveness remains limited (Brown & van Kamp, 2017). The GDG noted that the resources needed to implement different measures may vary considerably, as they depend on the situation and the type of intervention required. Implementation of some measures is expected to be most feasible during the development of new railway tracks; such as rail pads, bi-bloc sleepers, small noise barriers and – in extreme cases – tunnels, cuttings or earthwork barriers. Other interventions include acoustic rail grinding, noise barriers built alongside the tracks, construction of quieter locomotives and wagons and replacement of brakes on freight trains. The GDG assumed that most of these solutions could be planned as part of regular maintenance or, for instance, by speeding up fleet modernization and track modernization. Even though not broadly implemented, the solutions mentioned above have already been considered or adopted to reduce noise levels from railway noise exposure. Some EU countries (such as Germany), have programmes to replace old brake blocks from freight trains with newer, quieter ones and to ban all freight trains with old brake blocks from 2020 (Umweltbundesamt, 2017). This illustrates that solutions to achieve recommended noise levels can be implemented at a reasonable cost. Overall, the GDG agreed that the benefit of implementation of the recommendation to minimize the risk of adverse health effects due to railway noise for a majority of the population exceeds the (monetary) resources needed.

In light of the assessment of the contextual factors in addition to the quality of evidence, the recommendation remains strong.

Additional considerations or uncertainties

The GDG acknowledged that the main body of evidence for the recommendations on railway noise for average exposure was based on annoyance studies, conducted mainly in Asia and Europe. Studies are few for other priority health outcomes, and the evidence was generally rated low/very low quality. There is therefore uncertainty about the effects on health outcomes. Nevertheless, as a precautionary approach, a strong recommendation is made for average exposure to L_{den}, as a broad evidence base exists for health effects from exposure to other sources of transportation noise. However, the GDG stressed the importance of further research into health effects due to long-term exposure to railway noise.

Moreover, situational factors should be taken into account when analysing annoyance from railway noise. In particular, ground-borne vibrations are sometimes an additional exposure variable in railway

[16] The "railway bonus" is a correction factor commonly applied in the noise abatement policy domain in recent decades. It subsidizes the noise rating level for railway transportation by a predefined factor (Schuemer & Schuemer-Kohrs, 1991).

noise situations – especially in the case of annoyance – which may be difficult to separate from noise effects. In the set of 11 studies included in the systematic review on railway noise and annoyance, only two explicitly mentioned ground-borne vibrations as an additional source of annoyance.

Overall, the low-carbon, low-polluting nature of railway transport, especially using electric trains, means that rail is favoured over road and air traffic. However, night-time railway traffic on busy lines, including freight traffic, can be a significant source of sleep disturbance. Thus, guideline values should be set to encourage the development of rail traffic in Europe while at the same time giving adequate protection to residents from sleep disturbance.

3.2.3 Summary of the assessment of the strength of the recommendations

Table 25 provides a comprehensive summary of the different dimensions for the assessment of the strength of the railway noise recommendations.

Table 25. Summary of the assessment of the strength of the recommendation

Factors influencing the strength of recommendation	Decision
Quality of evidence	**Average exposure** (L_{den}) *Health effects* • Evidence for a relevant absolute risk of annoyance at **54 dB** L_{den} was rated **moderate quality.** • Evidence for a relevant RR increase of the incidence of hypertension was rated **low quality**. One study met the inclusion criteria but did not find a significant increase. *Interventions* • Evidence that different types of intervention reduce noise annoyance from railways was rated **very low quality**. **Night-time exposure** (L_{night}) *Health effects* • Evidence for a relevant absolute risk of sleep disturbance related to night noise exposure from railways at **44 dB** L_{night} was rated **moderate quality**. *Interventions* • No evidence was available on the effectiveness of interventions to reduce noise exposure and/or sleep disturbance from railway noise.
Balance of benefits versus harms and burdens	Railway noise is a major source of localized pollution. The health benefits of adapting the recommendation outweigh the harms. Nevertheless, it is important to consider the relevance of railways as an environmentally friendly mode of transportation.
Values and preferences	Quiet areas are valued by the population; especially by those affected by continuous noise exposure. Some variability is expected among those directly affected by railway noise and those not affected.
Resource implications	No comprehensive cost–effectiveness-analysis data are available, although a wide range of interventions exists, indicating that measures are both feasible and economically reasonable.
Decisions on recommendation strength	• **Strong** for guideline value for average noise exposure (L_{den}). • **Strong** for guideline value for night noise exposure (L_{night}). • **Strong** for specific interventions to reduce noise exposure.

3.3 Aircraft noise

Recommendations

For average noise exposure, the GDG **strongly** recommends reducing noise levels produced by aircraft below **45 dB** L_{den}, as aircraft noise above this level is associated with adverse health effects.

For night noise exposure, the GDG **strongly** recommends reducing noise levels produced by aircraft during night time below **40 dB** L_{night}, as aircraft noise above this level is associated with adverse effects on sleep.

To reduce health effects, the GDG strongly recommends that policy-makers implement suitable measures to reduce noise exposure from aircraft in the population exposed to levels above the guideline values for average and night noise exposure. For specific interventions the GDG recommends implementing suitable changes in infrastructure.

3.3.1 Rationale for the guideline levels for aircraft noise

The exposure levels were derived in accordance with the prioritization process of critical health outcomes described in section 2.4.3. For each of the outcomes, the exposure level was identified by applying the benchmark, set as relevant risk increase to the corresponding ERF. In the case of exposure to aircraft noise, the process can be summarized as follows (Table 26).

Table 26. Average exposure levels (L_{den}) for priority health outcomes from aircraft noise

Summary of priority health outcome evidence	Benchmark level	Evidence quality
Incidence of IHD A relevant risk increase from exposure to aircraft noise occurs at 52.6 dB L_{den}. The weighted average of the lowest noise levels measured in the studies was 47 dB L_{den} and the corresponding RR in the meta-analysis was 1.09 per 10 dB.	5% increase of RR	Very low quality
Incidence of hypertension One study met the inclusion criteria. There was no significant increase of risk associated with increased noise exposure in this study.	10% increase of RR	Low quality
Prevalence of highly annoyed population There was an absolute risk of 10% at a noise exposure level of 45.4 dB L_{den}.	10% absolute risk	Moderate quality
Permanent hearing impairment	No increase	No studies met the inclusion criteria
Reading skills and oral comprehension in children A relevant risk increase was found at 55 dB L_{den}.	One-month delay	Moderate quality

Based on the evaluation of evidence on relevant risk increases from the prioritized health outcomes, the GDG set a guideline exposure level of 45.4 dB L_{den} for average exposure to aircraft noise, based on the absolute %HA. It was confident that there was an increased risk for annoyance below this exposure level, but probably no relevant risk increase for other priority health outcomes. In accordance with the defined rounding procedure, the value was rounded to 45 dB L_{den}. As the evidence on the adverse effects of aircraft noise was rated moderate quality, the GDG made the recommendation strong.

Next, the GDG considered the evidence for night noise exposure and its effect on sleep disturbance (Table 27).

Table 27. Night-time exposure levels (L_{night}) for priority health outcomes from aircraft noise

Summary of priority health outcome evidence	Benchmark level	Evidence quality
Sleep disturbance	3% absolute risk	Moderate quality
11% of participants were highly sleep-disturbed at a noise level of 40 dB L_{night}.		

Based on the evidence of the adverse effects of aircraft noise on sleep disturbance, the GDG defined a guideline exposure level of 40.0 dB L_{night}. It should be stressed that this recommendation for average aircraft noise levels at night far exceeds the benchmark of 3%HSD defined as relevant risk increase, but since no reliable acoustic data below this level were available, the GDG decided not to lower the guideline exposure level further, as an extrapolation of the exposure–response relationship to achieve these values would have been unavoidable. As the evidence was rated moderate quality, the GDG made the recommendation strong.

The GDG also considered the evidence for the effectiveness of interventions. The results showed that changes in infrastructure (opening and/or closing of runways, or flight path rearrangements) can lead to a reduction in aircraft noise exposure, as well as a decline in cognitive impairment in children and a reduction in annoyance. Moreover, examples of best practice already exist for the management of noise from aircraft, so the GDG made a strong recommendation.

3.3.1.1 Other factors influencing the strength of recommendations

Other factors considered in the context of recommendations on aircraft traffic noise included those related to values and preferences, benefits and harms, resource implications, equity, acceptability and feasibility; moreover, nonpriority health outcomes were considered. Ultimately, the assessment of all these factors did not lead to a change in the strength of the recommendations. Further details are provided in section 3.3.2.3.

3.3.2 Detailed overview of the evidence

The following sections provide a detailed overview of the evidence constituting the basis for setting the recommendations on aircraft noise. It is presented and summarized separately for each of the critical health outcomes, and the GDG's judgement of the quality of evidence is indicated (for a detailed overview of the evidence on important health outcomes, see Annex 4). Research into health outcomes and effectiveness of interventions is addressed consecutively.

A comprehensive summary of all evidence considered for each of the critical and important health outcomes can be found in the eight systematic reviews published in the *International Journal of Environmental Research and Public Health* (see section 2.3.2 and Annex 2).

3.3.2.1 Evidence on health outcomes

The key question posed was: in the general population exposed to aircraft noise, what is the exposure–response relationship between exposure to aircraft noise (reported as various noise indicators) and the proportion of people with a validated measure of health outcome, when adjusted for main confounders? A summary of the PICOS/PECCOS scheme applied and the main findings is set out in Tables 28 and 29.

Table 28. PICOS/PECCOS scheme of critical health outcomes for exposure to aircraft noise

PECO	Description	
Population	General population	
Exposure	Exposure to high levels of noise produced by aircraft traffic (average/night time)	
Comparison	Exposure to lower levels of noise produced by aircraft traffic (average/night time)	
Outcome(s)	For average noise exposure: 1. cardiovascular disease 2. annoyance 3. cognitive impairment 4. hearing impairment and tinnitus 5. adverse birth outcomes 6. quality of life, well-being and mental health 7. metabolic outcomes	For night noise exposure: 1. effects on sleep

Table 29 .Summary of findings for health effects from exposure to aircraft noise (L_{den})

Noise metric	Priority health outcome measure	Quantitative risk for adverse health	Lowest level of exposure across studies	Number of participants (studies)[a]	Quality of evidence
Cardiovascular disease					
L_{den}	Incidence of IHD	RR = 1.09 (95% CI: 1.04–1.15) per 10 dB increase	47 dB	9 619 082[a] (2)	Very low (downgraded for risk of bias; upgraded for dose-response)
L_{den}	Incidence of hypertension	RR = 1.00 (95% CI: 0.77–1.30) per 10 dB increase	N/A	4712 (1)	Low (downgraded for risk of bias and because only one study available)
Annoyance					
L_{den}	%HA	OR = 4.78 (95% CI: 2.27–10.05) per 10 dB increase	33 dB	17 094 (12)	Moderate (downgraded for inconsistency)
Cognitive impairment					
L_{den}	Reading and oral comprehension	1–2-month delay per 5 dB increase	Around 55 dB	(4)	Moderate (downgraded for inconsistency)
Hearing impairment and tinnitus					
L_{den}	Permanent hearing impairment	–	–	–	–

Note: [a] Results are partly derived from population-based studies.

Cardiovascular disease

IHD

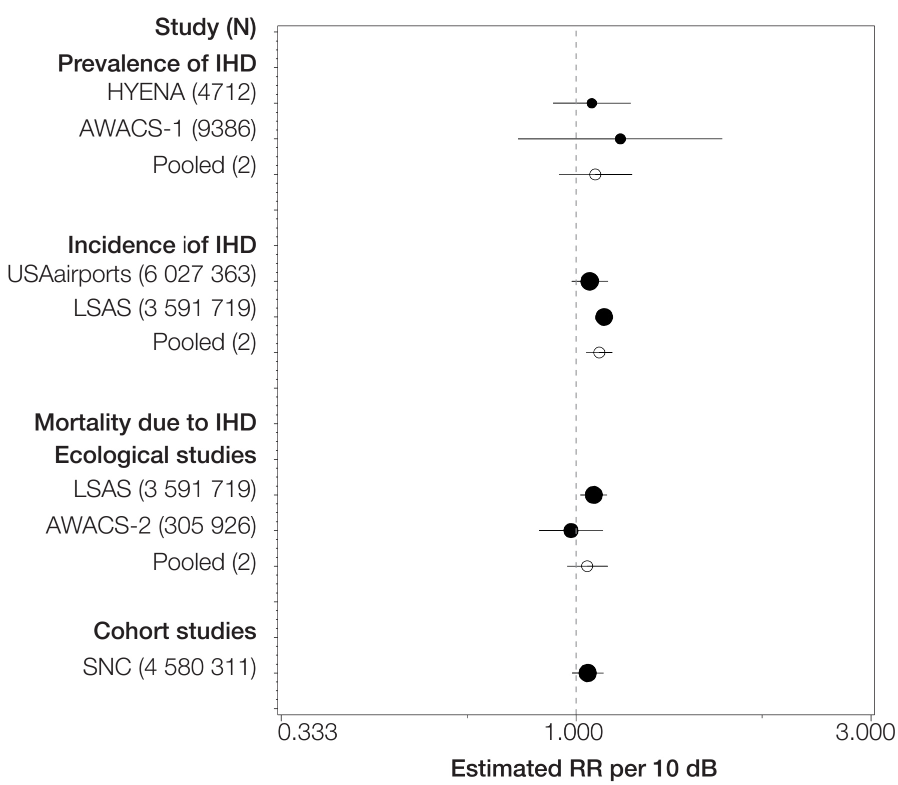
No cohort or case-control studies on the relationship between aircraft noise and IHD are available. However, two ecological studies were identified that provide information on the relationship between aircraft noise and incidence (hospital admission) of IHD (Correia et al., 2013; Hansell et al., 2013). These involved a total of 9 619 082 participants, including 158 977 cases. The RR was 1.09 (95% CI: 1.04–1.15) per 10 dB L_{den} increase, and the lowest exposure range was ≤51 dB and <45 dB. Given the weights in the meta-analysis of these two studies, the weighted average starting level was calculated as 47 dB. The evidence was rated very low quality.

Two cross-sectional studies were identified that assessed the prevalence of IHD in people living in cities located around airports in Europe. The studies involved 14 098 participants, including 340 cases (Babisch et al., 2005b; 2008; 2012a; 2012b; 2013a; Floud et al., 2011; 2013a; 2013b; Jarup et al., 2005; 2008; van Poll et al., 2014). The overall risk was RR = 1.07 (95% CI: 0.94–1.23) per 10 dB L_{den} increase. The evidence was rated low quality.

With regard to the relationship between aircraft noise and mortality due to IHD, one cohort study (Huss et al., 2010) and two ecological studies (Hansell et al., 2013; van Poll et al., 2014) were identified. The cohort study identified 4 580 311 participants, including 15 532 cases, living in Switzerland, and the authors found an RR of 1.04 (95% CI: 0.98–1.11) per 10 dB L_{den} increase in noise. The evidence was rated low quality. The two ecological studies identified a total of 3 897 645 participants, including 26 066 cases in the Netherlands and the United Kingdom. The overall RR was 1.04 (95% CI: 0.97–1.12) per 10 dB L_{den} increase in noise, and the evidence was rated very low quality.

Fig. 10 summarizes the results for the relationship between aircraft noise and different measures of IHD.

Fig. 10. The association between exposure to aircraft noise (L_{den}) and IHD



Notes: The dotted vertical line corresponds to no effect of exposure to aircraft noise. The black circles correspond to the estimated RR per 10 dB and 95% CI. The white circles represent the pooled random effect estimates and 95% CI. For further details on the studies included in the figure please refer to the systematic review on environmental noise and cardiovascular and metabolic effects (van Kempen et al., 2018).

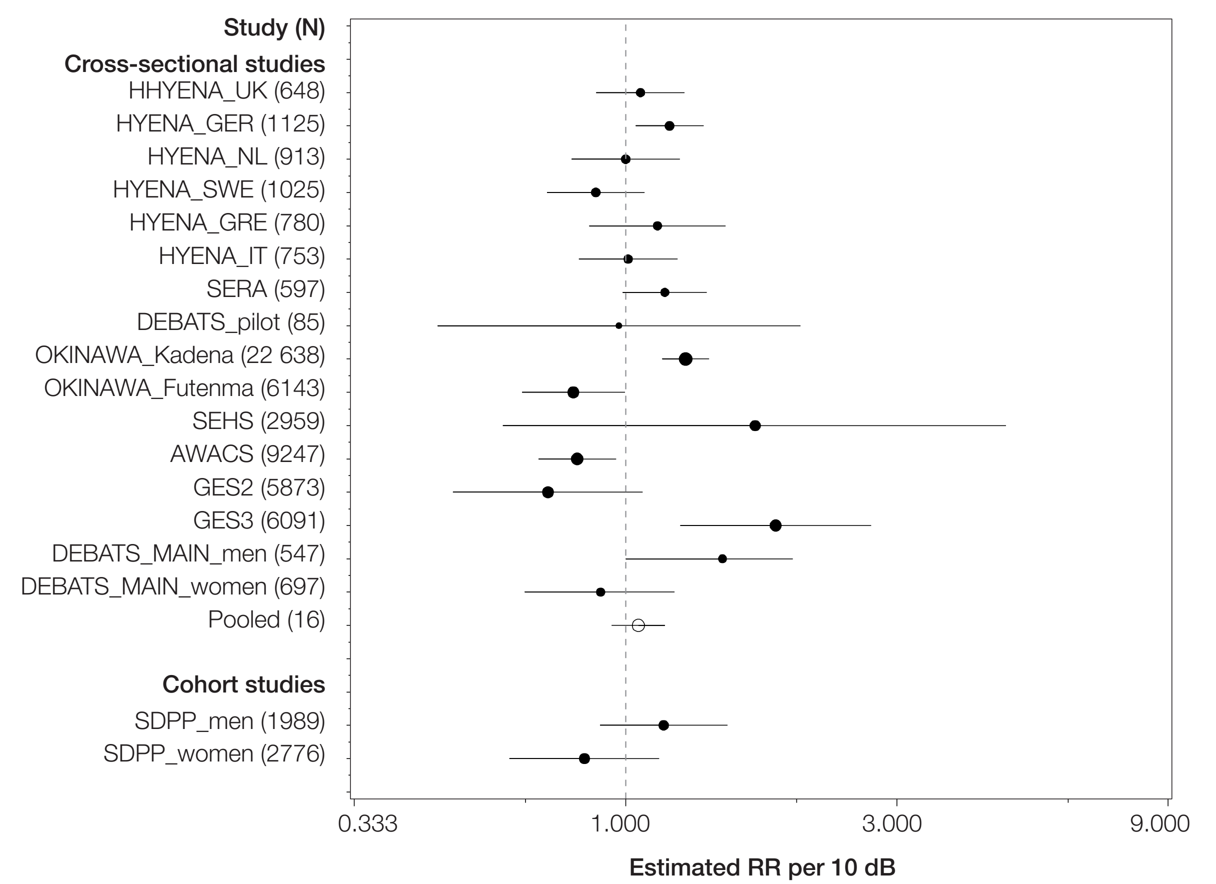
Hypertension

One cohort study was identified that assessed the relationship between aircraft noise and hypertension in people living in Sweden (Bluhm et al., 2004; 2009; Eriksson et al., 2007; 2010). The study involved 4712 participants, including 1346 cases. The authors found a nonstatistically significant effect size of RR = 1.00 (95% CI: 0.77–1.30) per 10 dB L_{den} increase. This evidence was rated moderate quality.

Furthermore, nine cross-sectional studies assessed the prevalence of hypertension in 60 121 participants, including 9487 cases (Ancona et al., 2010; Babisch et al., 2005b; 2008; 2012a; 2012b; 2013a; Breugelmans et al., 2004; Evrard et al., 2013; 2015; Houthuijs & van Wiechen, 2006; Jarup et al., 2005; 2008; Matsui, 2013; Matsui et al., 2001; 2004; Rosenlund et al., 2001; van Kamp et al., 2006; van Poll et al., 2014). The overall RR was 1.05 (95% CI: 0.95–1.17) per 10 dB L_{den} increase, with inconsistency across studies. The evidence was rated low quality.

Fig. 11 summarizes the results for both prevalence and incidence of hypertension.

Fig. 11. The association between exposure to aircraft noise (L_{den}) and hypertension in cross-sectional and cohort studies



Notes: The dotted vertical line corresponds to no effect of aircraft noise exposure. The black dots correspond to the estimated RR per 10 dB and 95% CI. The white circle represents the pooled summary estimate and 95% CI. For further details on the studies included in the figure please refer to the systematic review on environmental noise and cardiovascular and metabolic effects (van Kempen et al., 2018).

Stroke

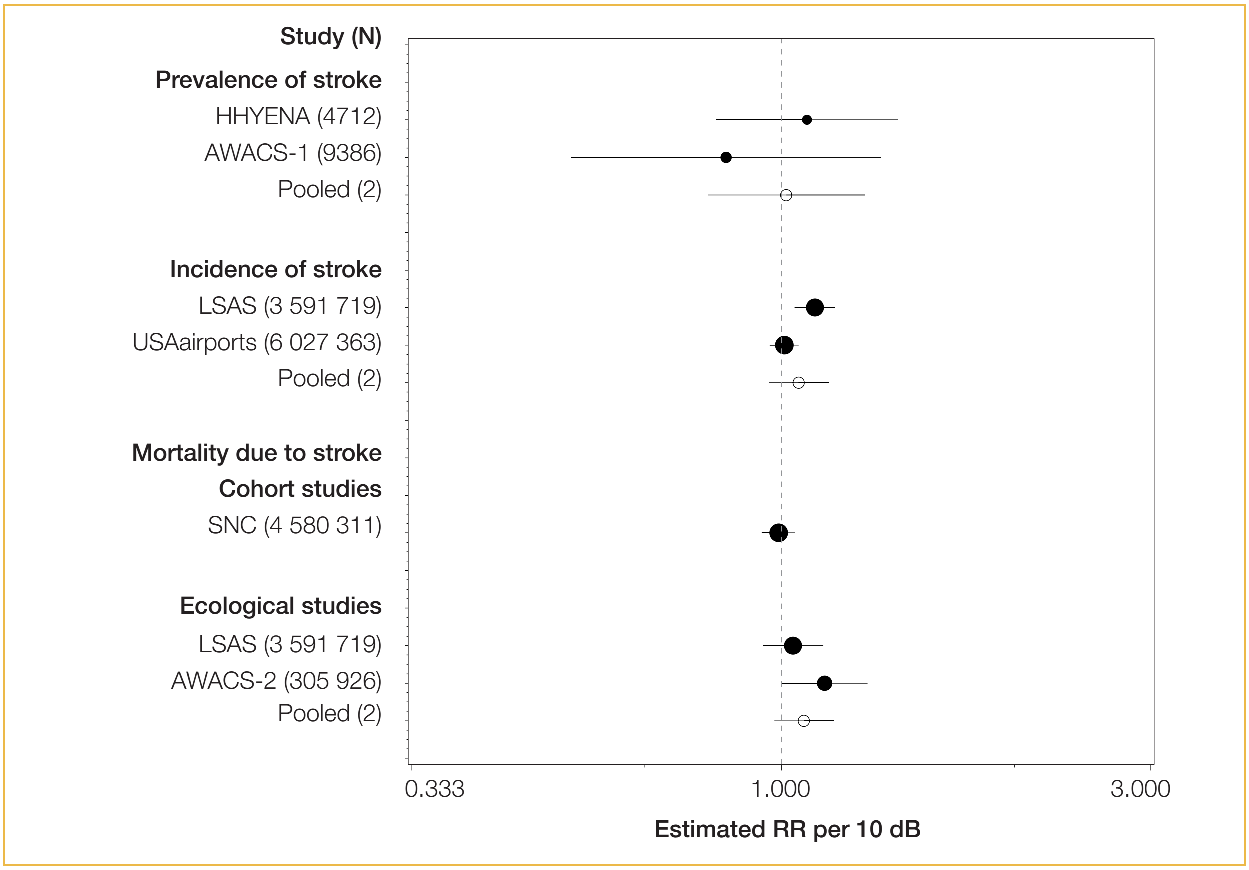
No cohort or case-control studies on the relationship between aircraft noise and incidence (hospital admission) of stroke were available, but two ecological studies were conducted in cities around airports in the United Kingdom and United States of America, involving 9 619 082 participants, including 97 949 cases (Correia et al., 2013; Hansell et al., 2013). An overall RR of 1.05 (95% CI: 0.96–1.15) per 10 dB L_{den} increase in noise was found. The evidence was rated very low quality.

Two cross-sectional studies were identified that assessed the prevalence of stroke in 14 098 participants, including 151 cases (Babisch et al., 2005b; 2008; 2012a; 2012b; 2013a; Floud et al., 2011; 2013a; 2013b; Jarup et al., 2005; 2008; van Poll et al., 2014). The overall RR was 1.02 (95% CI: 0.80–1.28) per 10 dB L_{den} increase. The evidence was rated very low quality.

On the relationship between aircraft noise and mortality due to stroke, one cohort study (Huss et al., 2010) and two ecological studies (Hansell et al., 2013; van Poll et al., 2014) were identified. The cohort study identified 4 580 311 participants, including 25 231 cases, living in Switzerland; the authors found an RR of 0.99 (95% CI: 0.94–1.04) per 10 dB L_{den} increase in noise. The overall evidence was rated moderate quality. The two ecological studies identified a total of 3 897 645 participants, including 12 086 cases, in the Netherlands and the United Kingdom. The overall RR was 1.07 (95% CI: 0.98–1.17) per 10 dB L_{den} increase in noise. The evidence was rated very low quality.

Fig. 12 summarizes the results for the relationship between aircraft noise and different measures of stroke.

Fig. 12. The association between exposure to aircraft noise (L_{den}) and stroke



Notes: The dotted vertical line corresponds to no effect of exposure to aircraft noise. The black dots correspond to the estimated RR per 10 dB and 95% CI. The white circle represents the summary estimate and 95% CI.
For further details on the studies included in the figure please refer to the systematic review on environmental noise and cardiovascular and metabolic effects (van Kempen et al., 2018).

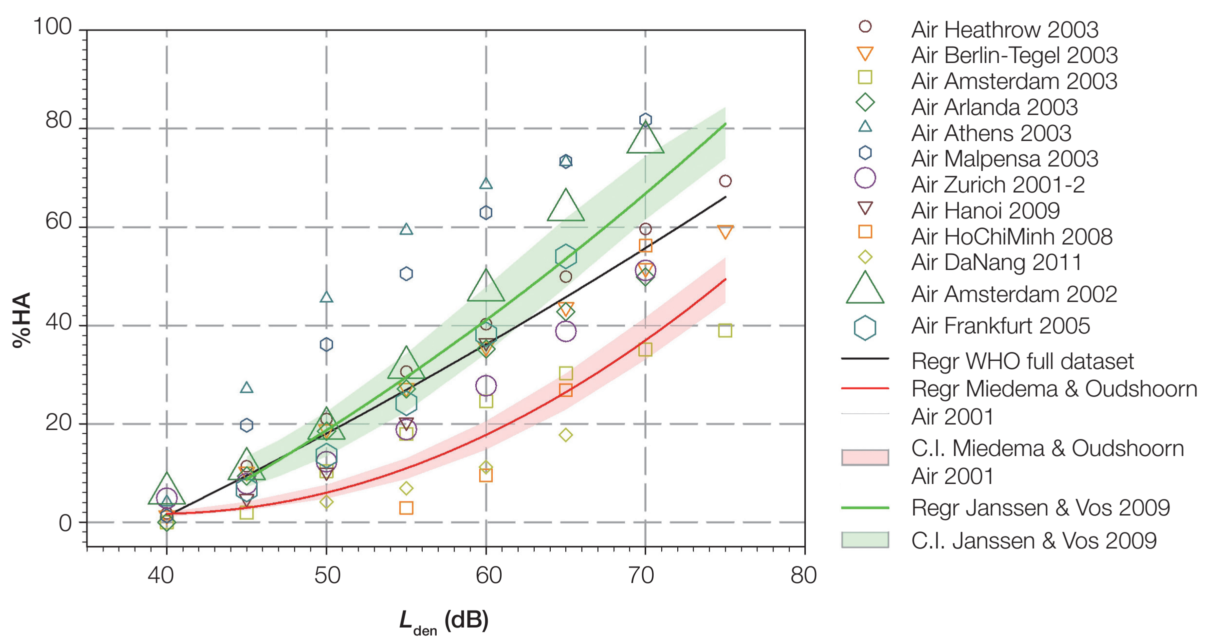
Children's blood pressure

For the association between aircraft noise and blood pressure in children, two cross-sectional studies were conducted in Australia, the Netherlands and the United Kingdom, including a total of 2013 participants (Clark et al., 2012; Morrell et al., 1998; 2000; van Kempen et al., 2006). The change in both systolic and diastolic blood pressure was assessed, in residential and/or educational settings. There was serious inconsistency in the results and therefore no overall estimate of the effect was developed. The evidence was rated very low quality.

Annoyance

A vast amount of evidence proves the association between aircraft noise and annoyance. In total, 12 aircraft noise studies were identified that were used to model ERFs of the relationship between L_{den} and %HA (Babisch et al., 2009; Bartels et al., 2013; Breugelmans et al., 2004; Brink et al., 2008; Gelderblom et al., 2014; Nguyen et al., 2011; 2012a; 2012b; Sato & Yano, 2011; Schreckenberg & Meis, 2007). These include data from 17 094 study participants. The estimated data points of each of the studies are plotted in Fig. 13, alongside an aggregated ERF including the data from all the individual studies (see the black line for "Regr WHO full dataset"). The lowest category of noise exposure considered in any of the studies, and hence included in the systematic review, is 40 dB, corresponding to approximately 1.2%HA. The benchmark level of 10%HA is reached at approximately 45 dB L_{den} (see Fig. 13).

Fig. 13. Scatterplot and quadratic regression of the relationship between aircraft noise (L_{den}) and annoyance (%HA)



Notes: ERFs by Miedema & Oudshoorn (2001, red), and Janssen & Vos (2009, green) are added for comparison. There is no indication of 95% CIs of the WHO dataset curve, as a weighting based on the total number of participants for each 5 dB L_{den} sound class could not be calculated; weighting based on all participants of all sound classes proved to be unsuitable. The range of data included is illustrated by the distribution of data points. For further details on the studies included in the figure please refer to the systematic review on environmental noise and annoyance (Guski et al., 2017).

Table 30 shows the %HA in relation to exposure to aircraft traffic noise. It is based on the regression equation $\%HA = -50.9693 + 1.0168 \times L_{den} + 0.0072 \times L_{den}^2$ derived from the systematic review (Guski et al., 2017). As the majority of the studies are cross-sectional, the evidence was rated moderate quality.

The general quality of the evidence was further substantiated with the help of additional statistical analyses that apply classical health outcome measures to estimate noise annoyance. When comparing aircraft noise exposure at 50 dB and 60 dB, the analyses revealed evidence rated high quality for an association between aircraft noise and %HA for an increase per 10 dB (OR = 3.40; 95% CI: 2.42–4.80). Moreover, there was evidence rated high quality for the increase of %HA per 10 dB increase in sound exposure, when data on all sound classes were included (OR = 4.78; 95% CI: 2.27–10.05).

Table 30. The association between exposure to aircraft noise (L_{den}) and annoyance (%HA)

L_{den} (dB)	%HA
40	1.2
45	9.4
50	17.9
55	26.7
60	36.0
65	45.5
70	55.5

Cognitive impairment

Evidence rated moderate quality was available for an association between aircraft noise and reading and oral comprehension, assessed by standardized tests. This is based on a narrative review of 14 studies that examined aircraft noise exposure effects on reading and oral comprehension (Clark et al., 2006; 2012; 2013; Evans & Maxwell, 1997; Haines et al., 2001a; 2001b; 2001c; Hygge et al., 2002; Klatte et al., 2014; Matsui et al., 2004; Seabi et al., 2012; 2013; Stansfeld et al., 2005; 2010). Of these studies, 10 were cross-sectional, and only four had a longitudinal and/or intervention design (Clark et al., 2013; Haines et al., 2001c; Hygge et al., 2002; Seabi et al., 2013). Most of the studies (10 of 14) demonstrated a statistically significant association or at least demonstrated a trend between higher aircraft noise exposure and poorer reading comprehension.

This relationship is supported by evidence on other health outcome measures related to cognition. Evidence rated moderate quality was available for an association between aircraft noise and children with poorer performance on standardized assessment tests (Eagan et al., 2004; FICAN, 2007; Green et al., 1982; Sharp et al., 2014). There was also evidence rated moderate quality on aircraft noise being associated with children having poorer long-term memory (Haines et al., 2001b). No studies examined the effects on short-term memory.

However, there was no substantial effect (evidence rated low quality) of aircraft noise on children's attention (Haines et al., 2001a; Hygge et al., 2002; Matsui et al., 2004; Stansfeld et al., 2005; 2010), or on executive function (working memory) (evidence rated very low quality), with studies consistently suggesting no association for aircraft noise (Clark et al., 2012; Haines et al., 2001a;

Haines et al., 2001b; Klatte et al., 2014; Matheson et al., 2010; Stansfeld et al., 2005; 2010; van Kempen et al., 2010; 2012).

Hearing impairment and tinnitus

No studies were found, and therefore no evidence was available on the association between aircraft noise and hearing impairment and tinnitus.

Sleep disturbance

For aircraft noise and self-reported sleep outcomes, six studies were identified that included a total of 6371 participants (Nguyen et al., 2009; 2010; 2011; 2012c; 2015; Schreckenberg et al., 2009; Yano et al., 2015). The majority of studies were cross-sectional by design and were conducted in otherwise healthy adults. The model was based on outdoor L_{night} levels between 40 dB and 65 dB only; the lower limit of 40 dB was set because of inaccuracies in predicting lower noise levels (Table 31).

Table 31. Summary of findings for health effects from exposure to aircraft noise (L_{night})

Noise metric	Priority health outcome measure	Quantitative risk for adverse health	Lowest level of exposure across studies	Number of participants (studies)	Quality of evidence
Effects on sleep					
L_{night}	%HSD	OR: 1.94 (95% CI: 1.61–2.33) per 10 dB increase	35 dB	6371 (6)	Moderate (downgraded for study limitations, inconsistency; upgraded for dose-response, magnitude of effect)

The range of noise exposure reported in studies was 37.5–62.5 dB. Over 11% (95% CI: 4.72–17.81) of the population was characterized as highly sleep-disturbed at L_{night} levels of 40 dB. The %HSD at other, higher levels of aircraft noise is presented in Table 27. The table is derived from the regression model in the systematic review specified as %HSD = 16.79–0.9293 × L_{night} + 0.0198 × L_{night}^2. The health outcome was measured in the studies by self-reporting, focusing on questions asking about awakenings from sleep, the process of falling asleep and/or sleep disturbance, where the question referred specifically to how noise affects sleep. The same relationship between aircraft noise and reporting being sleep-disturbed (all questions combined) can also be expressed as an OR of 1.94 (95% CI: 1.61–2.33) per 10 dB increase in noise. This evidence was rated moderate quality.

Table 32. The association between exposure to aircraft noise (L_{night}) and sleep disturbance (%HSD)

L_{night}	%HSD	95% CI
40	11.3	4.72–17.81
45	15.0	6.95–23.08
50	19.7	9.87–29.60
55	25.5	13.57–37.41
60	32.3	18.15–46.36
65	40.0	23.65–56.05

Additional analyses were included in the systematic review and provided supporting evidence on the association between aircraft noise and sleep. When the noise source was not specified in the survey question, the relationship between aircraft noise and self-reported sleep outcomes was still positive, although no longer statistically significant (OR: 1.17 (95% CI: 0.54–2.53) per 10 dB increase) (Brink, 2011). This evidence was rated very low quality.

Further, there was evidence rated moderate quality for an association between aircraft noise and polysomnography-measured outcomes (probability of additional awakenings), with an OR of 1.35 (95% CI: 1.22–1.50) per 10 dB increase in indoor $L_{AS,max}$ (Basner et al., 2006). Evidence rated low quality was also available for an association between aircraft noise and motility-measured sleep outcomes in adults (Passchier-Vermeer et al., 2002).

3.3.2.2 Evidence on interventions

The following section summarizes the evidence underlying the recommendation on the effectiveness of interventions for aircraft noise exposure. The key question posed was: in the general population exposed to aircraft noise, are interventions effective in reducing exposure to and/or health outcomes from aircraft noise? A summary of the PICOS/PECCOS scheme applied and the main findings is set out in Tables 33 and 34.

Seven studies examining different types of interventions on aircraft noise met the inclusion criteria to become part of the evidence base of the systematic review. Six of these investigated infrastructure interventions (Breugelmans et al., 2007; Brink et al., 2008; Fidell et al., 2002; Hygge et al., 2002), and one assessed a path intervention (Asensio et al., 2014). The majority of studies focused on annoyance as a health outcome, but two also included effects on sleep and one investigated the effects of path interventions on cognitive development in children.

Table 33. PICOS/PECCOS scheme of the effectiveness of interventions for exposure to aircraft noise

PICO	Description	
Population	**General population**	
Intervention(s)	The interventions can be defined as: (a) a measure that aims to change noise exposure and associated health effects; (b) a measure that aims to change noise exposure, with no particular evaluation of the impact on health; or (c) a measure designed to reduce health effects, but that may not include a reduction in noise exposure.	
Comparison	**No intervention**	
Outcome(s)	For average noise exposure: 1. cardiovascular disease 2. annoyance 3. cognitive impairment 4. hearing impairment and tinnitus 5. adverse birth outcomes 6. quality of life, well-being and mental health 7. metabolic outcomes	For night noise exposure: 1. effects on sleep

Table 34. Summary of findings for aircraft noise interventions by health outcome

Type of intervention	Number of participants (studies)	Effect of intervention	Quality of evidence
Annoyance			
Type B – path interventions (retrofitting dwellings close to airports with acoustic insulation)	689 (1)	• Change in noise levels was not reported. • The study found a drop in annoyance following the insulation intervention	Very low (downgraded for study limitations, inconsistency, precision)
Type C – changes in infrastructure (opening and/or closing of runways, or flight path rearrangements)	2101 (3)	• There was a wide range of changes in noise levels (from –12 dB to +13.7 dB; most between ±1 dB and 2 dB; different noise indicators used). • All studies found changes in annoyance outcomes as a result of the intervention.	Moderate (downgraded for study limitations; upgraded for dose-response)
Sleep disturbance			
Type C – changes in infrastructure (flight path changes)	1707 (2)	• Changes in noise levels were mostly between ±1 dB and 2 dB. • Both studies found changes in sleep disturbance outcomes as a result of the intervention.	Low (downgraded for study limitations)
Cognitive development of children			
Type C – changes in infrastructure (opening and/or closing of runways, or flight path rearrangements)	326 (1)	• Changes in noise levels of +9 dB at the new airport and of –14 dB at the old airport were reported. • The study found various cognitive effects on children (for both the reduction and the increase in exposure). Effects disappeared when the old airport closed, emerging after the new airport opened.	Moderate (downgraded for inconsistency)

The largest body of research concentrated on the opening and closing of runways, leading to subsequent changes in flight paths (Breugelmans et al., 2007; Brink et al., 2008; Fidell et al., 2002). It showed that changes in noise exposure as a consequence of rearrangement of flight paths, step changes or increase or removal of over-flights resulted in statistically significant changes of the annoyance ratings of residents living in the vicinity of airports. The studies investigated both increases and reductions in exposure. Moreover, all the studies provided evidence that the change in response to noise exposure was an excess response to the intervention. As all the studies either adjusted for confounding or ruled out confounding by design, and the risk of bias was high in two studies but low in one, the evidence was rated moderate quality.

Two of these studies also investigated the effects of interventions on sleep disturbance. The results indicated that the percentage of sleep disturbance changed in association with the change in noise exposure caused by flight path adaptations (Breugelmans et al., 2007; Fidell et al., 2002). Both studies adjusted for confounding, but the risk of bias was assessed as high. Thus, the evidence was rated low quality.

One study examined the impact of rearranging flight paths on the cognitive effects on children (Hygge et al., 2002), showing various effects (for both the reduction and the increase in exposure).

The study ruled out confounding by study design and the risk of bias was assessed as low. The evidence was therefore rated moderate quality.

Alongside infrastructure interventions, a Spanish study presented evidence on path interventions (Asensio et al., 2014), showing a drop in annoyance following an insulation intervention. The study did not control for confounding and the risk of bias was assessed as high. The evidence was therefore rated very low quality.

3.3.2.3 Consideration of additional contextual factors

As the foregoing overview has shown, substantial evidence about the adverse health effects of long-term exposure to aircraft noise exists. Based on the quality of the available evidence, the GDG set the strength of the recommendation of aircraft noise at strong. As a second step, it qualitatively assessed contextual factors to explore whether other considerations could have a relevant impact on the recommendation strength. These considerations mainly concerned the balance of harms and benefits, values and preferences, equity, and resource use and implementation.

When assessing the balance of harms and benefits from implementing the recommendations on aircraft exposure, the GDG acknowledged that the number of people affected was lower than for road traffic or railway noise, since aircraft noise only affects the areas surrounding airports and under flight paths. Data from the EEA show that the estimated number of people in Europe exposed to L_{den} levels above 55 dB and L_{night} levels above 50 dB is 3 million and 1.2 million, respectively (Blanes et al., 2017).[17] Nevertheless, it remains a major source of localized noise pollution and has been predicted to increase (EASA et al., 2016). Furthermore, aircraft noise is regarded as more annoying than the other sources of transportation noise (Schreckenberg et al., 2015; Miedema & Oudshoorn, 2001); it is therefore associated with a significant burden on public health, and the GDG expects substantial health benefits for the population to evolve from implementing the recommendations to reduce exposure to aircraft traffic noise. Furthermore, the GDG noted that, depending on the intervention measure implemented (such as a night flight ban), additional health benefits could evolve, resulting from a simultaneous reduction in air pollution (EC, 2016a). The GDG also acknowledged that intervention measures like night flight bans might also reduce carbon emission, thereby positively influencing the shift towards a greener and more sustainable economy. Possible harms in relation to the applied noise abatement strategy, on the other hand, could include effects on the transportation of goods, as well as individual mobility of the population. Both could have impacts on local, national and international economies. Overall, the GDG estimated that the benefits gained from minimizing adverse health effects due to aircraft noise exposure outweigh the possible (economic) harms.

Considering values and preferences, the GDG noted that negative attitudes towards aircraft noise are especially prevalent in affected individuals who can see and hear aircraft from their house, or who fear that living in proximity of airports will have an impact on their health (Schreckenberg et al., 2015) or property value (economic loss) (Bristow et al., 2014). A lack of trust in the airport and government authorities can enhance these negative attitudes towards airports and aircraft noise (Borsky, 1979; Schreckenberg, 2017). Furthermore, the GDG recognized that values and preferences of individuals living in the vicinity of different airports may vary, as the infrastructural characteristics

[17] These are gap-filled figures based on the reported data and including the situation both within and outside cities, as defined by the END.

of airports have a significant effect on the evaluation of residents. Airports with a stable number of aircraft movements in the near past and no intention to change the number in the future can give rise to a different evaluation of values and preferences than airports with relatively sustained increases in the number of aircraft movements. This can result from the fact that opening new runways or increasing the number of flights usually means considerable change in the environment for inhabitants of the affected area. It has been postulated that the change of exposure itself may be an annoying factor, and this may explain why aircraft noise annoyance is generally higher than that for other sources of transportation noise at a comparable noise level (Brown & van Kamp, 2009). The GDG acknowledged that, in general, air travel is an important means of transportation relevant for businesses, the public and the economy. In Europe, aviation is projected to be the fastest-growing sector from passenger transport demand, by 2050 (EEA, 2016a). The general population tends to value the convenience of travel by air. Moreover, the GDG pointed out that exposure to aircraft noise is not equally distributed throughout society. The preferences of people living in the vicinity of airports are expected to differ from those of the general population that does not experience the same noise burden. This might facilitate variance in the values and preference of the population, as those benefiting from the services and revenues generated by an airport may regard noise reduction measures as an additional, unnecessary extra cost, while those living around an airport and affected by aircraft noise may be in favour of noise reductions, since this concerns their health and well-being. Despite these differences, however, the GDG was confident that a majority of the population would value the minimization of adverse health effects and therefor welcome the implementation of the recommendations.

Regarding the dimension of equity, the GDG highlighted that the risk of exposure to aircraft noise is not equally distributed throughout society. Members of society with a lower socioeconomic status and other disadvantaged groups often live in more polluted and louder areas, including in close proximity to airports (EC, 2016a). In addition to the increased risk of exposure to environmental noise, socioeconomic factors are also associated with increased vulnerability and poorer coping capacities (Karpati et al., 2002).

With resource use and implementation considerations, the GDG acknowledged that the economic evaluation of the health impacts of environmental noise is most elaborate and extensive for aircraft noise (Berry & Sanchez, 2014). Nevertheless, no comprehensive cost–benefit analysis for the WHO European Region yet exists, so this assessment is based on informed qualitative expert judgement regarding the feasibility of implementing the recommendation for the majority of the population. The systematic review of interventions and their associated impact on environmental noise and health shows that various measures to reduce continuous noise from aircraft exist. Moreover, the quality of the evidence was judged to be moderate (Brown & van Kamp, 2017). The GDG noted that the resources needed to implement different intervention measures may vary considerably, because they depend on the situation and the type of intervention required. The distribution of costs also differs from that for other modes of transportation, since exposure to aircraft noise is localized in a more agglomerated way, and overall the population affected is smaller compared to other modes of transportation. The GDG furthermore recognized that multiple cost-effective intervention strategies exist (EC, 2016b). Prohibition or discouragement strategies against citizens moving to the direct proximity of airports, for example, can be implemented in the context of urban planning. Likewise, diverting flight paths above less-populated areas can lead to a reduction in exposure. In principle, such intervention measures do not involve any direct costs, although safety concerns may limit the feasibility of these strategies. Passive noise abatement measures like the installation of soundproof windows at the dwelling were also regarded as feasible and economically reasonable by the GDG, as these are implemented at several airports already. In relation to active abatement measures, the GDG acknowledged the "balanced approach" elaborated by International Civil Aviation Organization, which states that noise reduction should take place first at the source. As indicated by the Clean Sky Programme, this could, for example, entail shifting towards the introduction of new aircraft. This broad European research programme estimates that, depending on type, the shift to newly produced aircraft could lead to a reduction of approximately 55–79% of the area affected by aircraft noise, and consequently the population exposed. As this solution has been put forward by the aviation sector, it is considered feasible. Overall, this indicates that solutions to achieve recommended noise levels can be implemented and at reasonable costs. The GDG agreed that implementation of the recommendation to minimize the risk of adverse health effects due to aircraft noise for a majority of the population would require a reasonable amount of (monetary) resources. It noted, however, that the feasibility of implementing the measures could be hindered by the fact that costs and benefits are not equally distributed. In most cases, the health benefits citizens gain from interventions that reduce aircraft exposure are borne by private companies and public authorities.

In light of the assessment of the contextual factors in addition to the quality of evidence, the recommendation remains strong.

Other nonpriority adverse health outcomes

Although not a priority health outcome and coming from a single study, the GDG noted the evidence rated moderate quality for the statistically significant association between aircraft noise and the change in waist circumference (Eriksson et al., 2014). The range of noise levels in the study identified was 48 to 65 dB L_{den}, and therefore the recommendation would also be protective enough for this health outcome.

In the context of aircraft noise, when considering the impacts of exposure on cognitive impairment in children, these guideline recommendations also apply particularly to the school setting. Noise exposure at primary school and at home is often highly correlated; however, the evidence base considered comes mainly from studies designed around sampling at school and not residences.

Additional considerations or uncertainties

There is additional uncertainty when characterizing exposure using the acoustical description of aircraft noise by means of L_{den} or L_{night}. Use of these average noise indicators may limit the ability to observe associations between exposure to aircraft noise and some health outcomes (such as awakening reactions); as such, noise indicators based on the number of events (such as the frequency distribution of $L_{A,max}$) may be better suited. However, such indicators are not widely used.

The GDG acknowledged that the guideline recommendation for L_{night} may not be fully protective of health, as it implies that around 11% (95% CI: 4.72–17.81) of the population may be characterized as highly sleep-disturbed at the recommended L_{night} level. This is higher than the 3% absolute risk considered for setting the guideline level. However, the high calculation uncertainty in predicting noise levels lower than 40 dB prevented the GDG from recommending a lower level. Furthermore, lower levels would probably require a ban on night or early morning flights altogether, which is not feasible in many situations, given that the general population tends to value the convenience of air travel.

3.3.3 Summary of the assessment of the strength of recommendation

Table 35 provides a comprehensive summary of the different dimensions for the assessment of the strength of the aircraft noise recommendations.

Table 35. Summary of the assessment of the strength of the recommendation

Factors influencing the strength of recommendation	Decision
Quality of evidence	**Average exposure (L_{den})** *Health effects* • Evidence for a relevant RR increase of the incidence of IHD at **52 dB** L_{den} was rated **very low quality.** • Evidence for a relevant RR increase of the incidence of hypertension was rated **low quality**. • Evidence for a relevant absolute risk of annoyance at **45 dB** L_{den} was rated **moderate quality**. • Evidence for a relevant RR increase of impaired reading and oral comprehension at **55 dB L_{den}** was rated **moderate quality**. *Interventions* • Evidence on effectiveness of interventions to reduce noise exposure and/or health outcomes from aircraft noise was of varying quality. **Night-time exposure (L_{night})** *Health effects* • Evidence for a relevant absolute risk of sleep disturbance related to night noise exposure from aircraft at **40 dB** L_{night} was rated **moderate quality**. *Interventions* • Evidence on effectiveness of changes in infrastructure (flight path changes) to reduce sleep disturbance from aircraft noise was rated **low quality**.
Balance of benefits versus harms and burdens	Aircraft noise is a major source of localized noise pollution. The health benefits of adapting the recommendations are expected to outweigh the harms.
Values and preferences	Quiet areas are valued by the population, especially by those affected by continuous aircraft noise exposure. Some variability is expected among those directly affected by aircraft noise and those not affected.
Equity	Risk of exposure to aircraft noise is not equally distributed.
Resource implications	No comprehensive cost–effectiveness analysis data are available; nevertheless, a wide variety of interventions exist (some at very low cost), indicating that measures are both feasible and economically reasonable.
Decisions on recommendation strength	• **Strong** for guideline value for average noise exposure (L_{den}) • **Strong** for guideline value for night noise exposure (L_{night}) • **Strong** for specific interventions to reduce noise exposure

3.4 Wind turbine noise

Recommendations

For average noise exposure, the GDG **conditionally** recommends reducing noise levels produced by wind turbines below **45 dB** L_{den}, as wind turbine noise above this level is associated with adverse health effects.

To reduce health effects, the GDG **conditionally** recommends that policy-makers implement suitable measures to reduce noise exposure from wind turbines in the population exposed to levels above the guideline values for average noise exposure. No evidence is available, however, to facilitate the recommendation of one particular type of intervention over another.

3.4.1 Rationale for the guideline levels for wind turbine noise

The exposure levels were derived in accordance with the prioritizing process of critical health outcomes described in section 2.4.3. For each of the outcomes, the exposure level was identified by applying the benchmark, set as relevant risk increase to the corresponding ERF. In the case of exposure to wind turbine noise, the process can be summarized as follows (Table 36).

Table 36. Average exposure levels (L_{den}) for priority health outcomes from wind turbine noise

Summary of priority health outcome evidence	Benchmark level	Evidence quality
Incidence of IHD Incidence of IHD could not be used to assess the exposure level.	5% increase of RR	No studies were available
Incidence of hypertension Incidence of hypertension could not be used to assess the exposure level.	10% increase of RR	No studies were available
Prevalence of highly annoyed population Four studies were available. An exposure–response curve of the four studies revealed an absolute risk of 10%HA (outdoors) at a noise exposure level of 45 dB L_{den}.	10% absolute risk	Low quality
Permanent hearing impairment	No increase	No studies were available
Reading skills and oral comprehension in children	One-month delay	No studies were available

In accordance with the prioritization process, the GDG set a guideline exposure level of 45.0 dB L_{den} for average exposure, based on the relevant increase of the absolute %HA. The GDG stressed that there might be an increased risk for annoyance below this noise exposure level, but it could not state whether there was an increased risk for the other health outcomes below this level owing to a lack of evidence. As the evidence on the adverse effects of wind turbine noise was rated low quality, the GDG made the recommendation conditional.

Next, the GDG considered the evidence for night noise exposure to wind turbine noise and its effect on sleep disturbance (Table 37).

Table 37. Night-time exposure levels (L_{night}) for priority health outcomes from wind turbine noise

Summary of priority health outcome evidence	Benchmark level	Evidence quality
Sleep disturbance Six studies were available; they did not reveal consistent results about effects of wind turbine noise on sleep.	3% absolute risk	Low quality

Based on the low quantity and heterogeneous nature of the evidence, the GDG was not able to formulate a recommendation addressing sleep disturbance due to wind turbine noise at night time.

The GDG also looked for evidence about the effectiveness of interventions for wind turbine noise exposure. Owing to a lack of research, however, no studies were available on existing interventions and associated costs to reduce wind turbine noise.

Based on this assessment, the GDG therefore provided a conditional recommendation for average noise exposure (L_{den}) to wind turbines and a conditional recommendation for the implementation of suitable measures to reduce noise exposure. No recommendation about a preferred type of intervention could be formulated; nor could a recommendation be made for an exposure level for night noise exposure (L_{night}), as studies were not consistent and in general did not provide evidence for an effect on sleep.

3.4.1.1 Other factors influencing the strength of recommendation

Other factors considered in the context of recommendations on wind turbine noise included those related to values and preferences, benefits and harms, resource implications, equity, acceptability and feasibility. Ultimately, the assessment of all these factors did not lead to a change in the strength of recommendation, although it informed the development of a conditional recommendation on the intervention measures. Further details are provided in section 3.4.2.3.

3.4.2 Detailed overview of the evidence

The following sections provide a detailed overview of the evidence constituting the basis for setting the recommendations on wind turbine noise. It is presented and summarized separately for each of the critical health outcomes, and the GDG's judgement of the quality of evidence is indicated (for a detailed overview of the evidence on important health outcomes, see Annex 4). Research into health outcomes and effectiveness of intervention is addressed consecutively.

A comprehensive summary of all evidence considered for each of the critical and important health outcomes can be found in the eight systematic reviews published in the *International Journal of Environmental Research and Public Health* (see section 2.3.2 and Annex 2).

It should be noted that, due to the time stamp of the systematic reviews, some more recent studies were not included in the analysis. This relates in particular to several findings of the Wind Turbine Noise and Health Study conducted by Health Canada (Michaud, 2015). Further, some studies were omitted, as they did not meet the inclusion criteria, including, for instance, studies using distance to the wind turbine instead of noise exposure to investigate health effects. The justification for including and excluding studies is given in the systematic reviews (Basner & McGuire, 2018; Brown et al., 2017; Clark & Paunovic, 2018; in press; Guski et al., 2017; Niewenhuijsen et al.,2017; Śliwińska-Kowalska & Zaborowski, 2017; van Kempen et al., 2018; see Annex 2 for further details).

3.4.2.1 Evidence on health outcomes

The key question posed was: in the general population exposed to wind turbine noise, what is the exposure–response relationship between exposure to wind turbine noise (reported as various noise indicators) and the proportion of people with a validated measure of health outcome, when adjusted for main confounders? A summary of the PICOS/PECCOS scheme applied and the main findings is set out in Tables 38 and 39.

Table 38. PICOS/PECCOS scheme of critical health outcomes for exposure to wind turbine noise

PECO	Description	
Population	General population	
Exposure	Exposure to high levels of noise produced by wind turbines (average/night time)	
Comparison	Exposure to lower levels of noise produced by wind turbines (average/night time)	
Outcome(s)	For average noise exposure: 1. cardiovascular disease 2. annoyance 3. cognitive impairment 4. hearing impairment and tinnitus 5. adverse birth outcomes 6. quality of life, well-being and mental health 7. metabolic outcomes	For night noise exposure: 1. effects on sleep

Table 39. Summary of findings for health effects from exposure to wind turbine noise (L_{den})

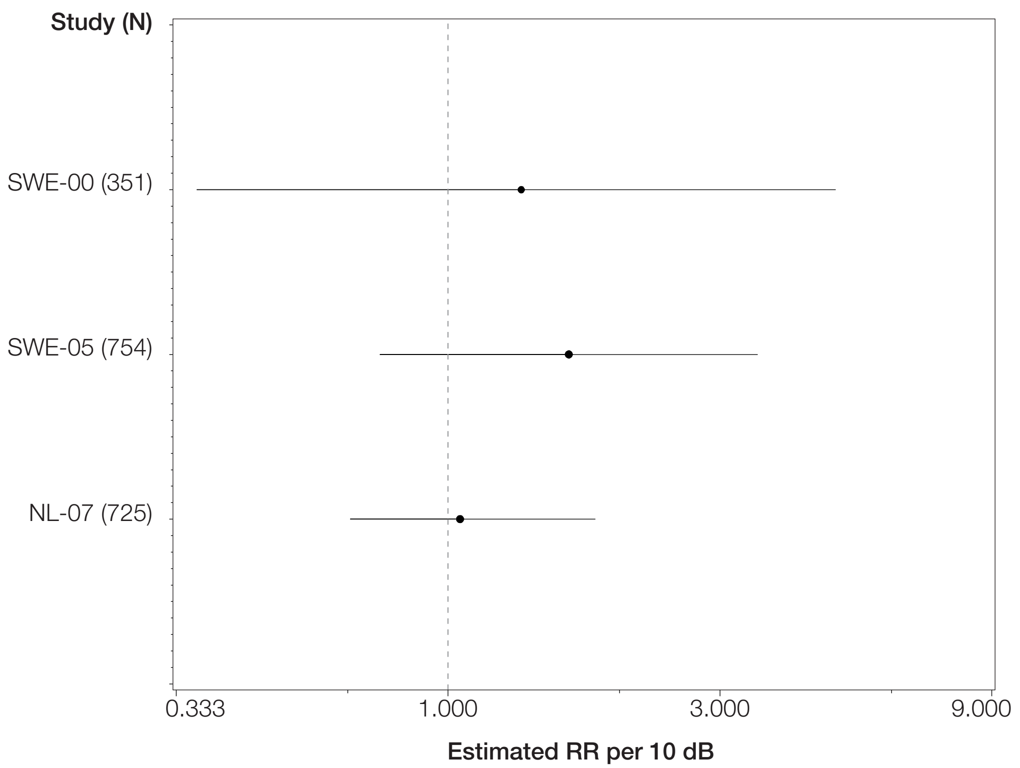
Noise metric	Priority health outcome measure	Quantitative risk for adverse health	Lowest level of exposure across studies	Number of participants (studies)	Quality of evidence
Cardiovascular disease					
L_{den}	Incidence of IHD	–	–	–	–
L_{den}	Incidence of hypertension	–	–	–	–
Annoyance					
L_{den}	%HA	Not able to pool because of heterogeneity	30 dB	2481 (4)	Low (downgraded for inconsistency and imprecision)
Cognitive impairment					
L_{den}	Reading and oral comprehension	–	–	–	–
Hearing impairment and tinnitus					
L_{den}	Permanent hearing impairment	–	–	–	–

Cardiovascular disease

For the relationship between wind turbine noise and prevalence of hypertension, three cross-sectional studies were identified, with a total of 1830 participants (van den Berg et al., 2008; Pedersen, 2011; Pedersen & Larsman, 2008; Pedersen & Persson Waye, 2004; 2007). The number of cases was not reported. All studies found a positive association between exposure to wind turbine noise and the prevalence of hypertension, but none was statistically significant. The lowest levels in studies were either <30 or <32.5 L_{den}. No meta-analysis was performed, since too many parameters were unknown and/or unclear. Due to very serious risk of bias and imprecision in the results, this evidence was rated very low quality (see Fig. 14).

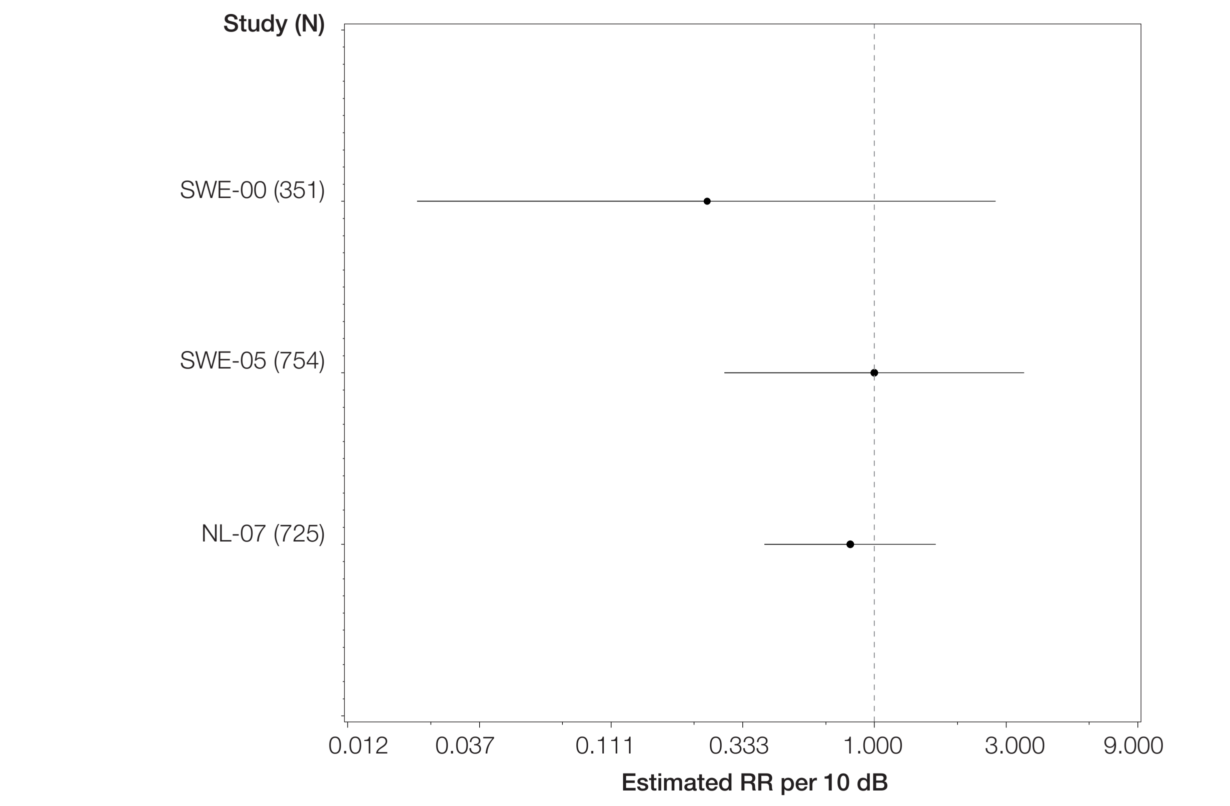
The same studies also looked at exposure to wind turbine noise and self-reported cardiovascular disease, but none found an association. No evidence was available for other measures of cardiovascular disease. As a result, only evidence rated very low quality was available for no considerable effect of audible noise (greater than 20 Hz) from wind turbines or wind farms on self-reported cardiovascular disease (see Fig. 15).

Fig. 14. The association between exposure to wind turbine noise (sound pressure level in dB) and hypertension



Notes: The dotted vertical line corresponds to no effect of exposure to wind turbine noise. The black dots correspond to the estimated RR per 10 dB and 95% CI. For further details on the studies included in the figure please refer to the systematic review on environmental noise and cardiovascular and metabolic effects (van Kempen et al., 2018).

Fig. 15. The association between exposure to wind turbine noise (sound pressure level) and self-reported cardiovascular disease



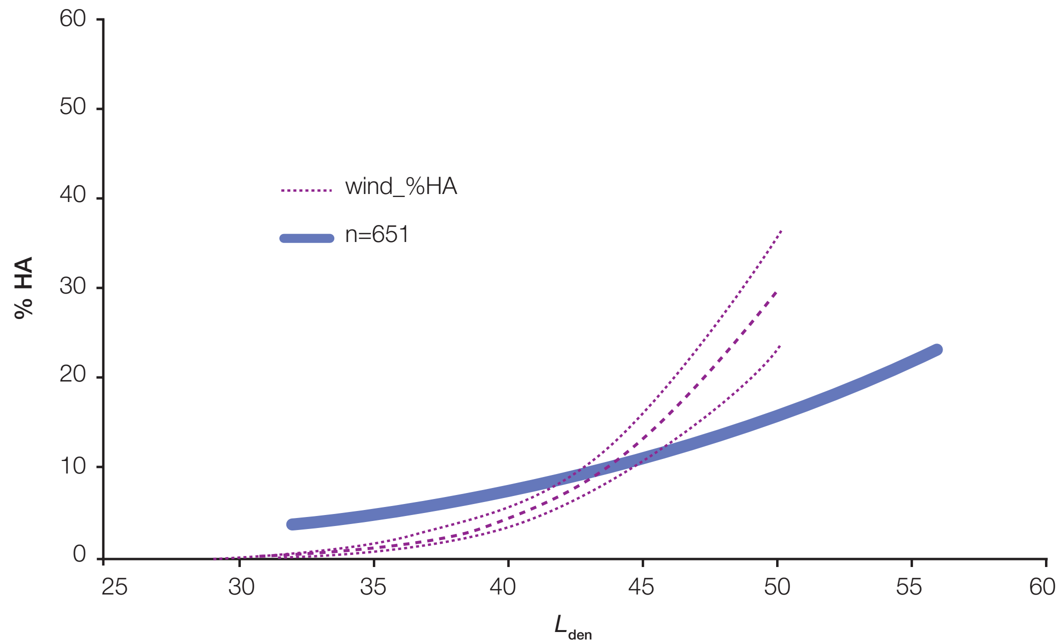
Notes: The dotted vertical line corresponds to no effect of exposure to wind turbine noise.The black circles correspond to the estimated RR per 10 dB (sound pressure level) and 95% CI. For further details on the studies included in the figure please refer to the systematic review on environmental noise and cardiovascular and metabolic effects (van Kempen et al., 2018).

Annoyance

Two publications containing descriptions of four individual studies were retrieved (Janssen et al., 2011; Kuwano et al., 2014). All four studies used measurements in the vicinity of the respondents' addresses; the noise exposure metrics used in the three original studies (Pedersen, 2011; Pedersen & Persson Waye, 2004; 2007) included in Janssen et al. (2011) were recalculated into L_{den}. The noise levels in the studies ranged from 29 dB to 56 dB. Different scales were used to assess annoyance, with slightly different definitions of "highly annoyed" and explicit reference to outdoor annoyance in the data used for the Janssen et al. (2011) curve. Construction of the ERFs provided in the two publications differed and they were therefore not further combined in a meta-analysis. Fig. 16 shows the %HA from the two publications. The 10% criterion for %HA is reached at around 45 dB L_{den} (where the two curves coincide). There was a wide variability in %HA between studies, with a range of 3–13%HA at 42.5 dB and 0–32%HA at 47.5 dB. The %HA in the sample is comparatively high, given the relatively low noise levels. There is evidence rated low quality for an association between wind turbine noise and annoyance, but this mainly applies to the association between wind turbine noise and annoyance and not to the shape of the quantitative relationship.

Further statistical analyses of annoyance yield evidence rated low quality for an association between wind turbine noise and %HA when comparing an exposure at 42.5 dB and 47.5 dB, with a mean difference in %HA of 4.5 (indoors) and 6.4 (outdoors). There is also evidence rated moderate quality for a correlation between individual noise exposure and annoyance raw scores (r = 0.28).

Fig. 16. Overlay of the two wind turbine annoyance graphs



Notes: Overlay of the two wind turbine outdoor annoyance graphs adapted from Janssen et al. (2011, red) and Kuwano et al. (2014, blue). The Kuwano et al. curve is based on L_{dn}; no correction for L_{den} has been applied.[18]
For further details on the studies included in the figure please refer to the systematic review on environmental noise and annoyance (Guski et al., 2017).

Cognitive impairment, hearing impairment and tinnitus, adverse birth outcomes

No studies were found, and therefore no evidence was available on the relationship between wind turbine noise and measures of cognitive impairment; hearing impairment and tinnitus; and adverse birth outcomes.

Sleep disturbance

Six cross-sectional studies on wind turbine noise and self-reported sleep disturbance were identified (Bakker et al., 2012; Kuwano et al., 2014; Michaud, 2015; Pawlaczyk-Luszczynska et al., 2014; Pedersen & Persson Waye, 2004; 2007). Noise levels were calculated using different methods, and different noise metrics were reported. Three of the studies asked how noise affects sleep; the other three evaluated the effect of wind turbine noise on sleep using questions that explicitly referred to noise (Table 40).

[18] L_{dn} is the day-night-weighted sound pressure level as defined in section 3.6.4 of ISO 1996-1:2016.

Table 40. Summary of findings for health effects from exposure to wind turbine noise (L_{night})

Noise metric	Priority health outcome measure	Quantitative risk for adverse health	Lowest level of effects in studies	Number of participants (studies)	Quality of evidence
Effects on sleep					
L_{night}	%HSD	1.60 (95% CI: 0.86–2.94) per 10 dB increase	31 dB	3971 (6)	Low (downgraded for study limitations, inconsistency, precision)

The risk of bias was assessed as high for all six studies, as effects on sleep were measured by self-reported data. There were a limited number of subjects at higher exposure levels. A meta-analysis was conducted for five of the six studies, based on the OR for high sleep disturbance for a 10 dB increase in outdoor predicted sound pressure level. The pooled OR was 1.60 (95% CI: 0.86–2.94). The evidence was rated low quality.

3.4.2.2 Evidence on interventions

This section summarizes the evidence underlying the recommendation on the effectiveness of interventions for wind turbine noise exposure. The key question posed was: in the general population exposed to wind turbine noise, are interventions effective in reducing exposure to and/or health outcomes from wind turbine noise? A summary of the PICOS/PECCOS scheme applied is set out in Table 41.

Table 41. PICOS/PECCOS scheme of the effectiveness of interventions for exposure to wind turbine noise

PICO	Description	
Population	**General population**	
Intervention(s)	The interventions can be defined as: (a) a measure that aims to change noise exposure and associated health effects; (b) a measure that aims to change noise exposure, with no particular evaluation of the impact on health; or (c) a measure designed to reduce health effects, but that may not include a reduction in noise exposure.	
Comparison	**No intervention**	
Outcome(s)	For average noise exposure: 1. cardiovascular disease 2. annoyance 3. cognitive impairment 4. hearing impairment and tinnitus 5. adverse birth outcomes 6. quality of life, well-being and mental health 7. metabolic outcomes	For night noise exposure: 1. effects on sleep

No studies were found, and therefore no evidence was available on the effectiveness of interventions to reduce noise exposure from wind turbines.

3.4.2.3 Consideration of additional contextual factors

As the foregoing overview has shown, very little evidence is available about the adverse health effects of continuous exposure to wind turbine noise. Based on the quality of evidence available, the GDG set the strength of the recommendation on wind turbine noise to conditional. As a second step, it qualitatively assessed contextual factors to explore whether other considerations could have a relevant impact on the recommendation strength. These considerations mainly concerned the balance of harms and benefits, values and preferences, and resource use and implementation.

Regarding the balance of harms and benefits, the GDG would expect a general health benefit from a marked reduction in any kind of long-term environmental noise exposure. Health effects of individuals living in the vicinity of wind turbines can theoretically be related not only to long-term noise exposure from the wind turbines but also to disruption caused during the construction phase. The GDG pointed out, however, that evidence on health effects from wind turbine noise (apart from annoyance) is either absent or rated low/very low quality (McCunney et al., 2014). Moreover, effects related to attitudes towards wind turbines are hard to discern from those related to noise and may be partly responsible for the associations (Knopper & Ollson, 2011). Furthermore, the number of people exposed is far lower than for many other sources of noise (such as road traffic). Therefore, the GDG estimated the burden on health from exposure to wind turbine noise at the population level to be low, concluding that any benefit from specifically reducing population exposure to wind turbine noise in all situations remains unclear. Nevertheless, proper public involvement, communication and consultation of affected citizens living in the vicinity of wind turbines during the planning stage of future installations is expected to be beneficial as part of health and environmental impact assessments. In relation to possible harms associated with the implementation of the recommendation, the GDG underlined the importance of wind energy for the development of renewable energy policies.

The GDG noticed that the values and preferences of the population towards reducing long-term noise exposure to wind turbine noise vary. Whereas the general population tends to value wind energy as an alternative, environmentally sustainable and low-carbon energy source, people living in the vicinity of wind turbines may evaluate them negatively. Wind turbines are not a recent phenomenon, but their quantity, size and type have increased significantly over recent years. As they are often built in the middle of otherwise quiet and natural areas, they can adversely affect the integrity of a site. Furthermore, residents living in these areas may have greater expectations of the quietness of their surroundings and therefore be more aware of noise disturbance. Negative attitudes especially occur in individuals who can see wind turbines from their houses but do not gain economically from the installations (Kuwano et al., 2014; Pedersen & Persson Waye, 2007; van den Berg et al., 2008). These situational variables and the values and preferences of the population may differ between wind turbines and other noise sources, as well as between wind turbine installations, which makes assessment of the relationship between wind turbine noise exposure and health outcomes particularly challenging.

Assessing resource use and implementation considerations, the GDG noted that reduction of noise exposure from environmental sources is generally possible through simple measures like insulating windows or building barriers. With wind turbines, however, noise reduction interventions are more complicated than for other noise sources due to the height of the source and because outdoor disturbance is a particularly large factor. As generally fewer people are affected (compared to transportation noise), the expected costs are lower than for other environmental sources of noise. The GDG was not aware of any existing interventions (and associated costs) to reduce harms from wind turbine noise, or specific consequences of having regulations on wind turbine noise. Therefore, it could not assess feasibility, or discern whether any beneficial effects of noise reduction would outweigh the costs of intervention. In particular, there is no clear evidence on an acceptable and uniform distance between wind turbines and residential areas, as the sound propagation depends on many aspects of the wind turbine construction and installation.

In light of the assessment of the contextual factors in addition to the quality of evidence, the recommendation for wind turbine noise exposure remains conditional.

Additional considerations or uncertainties

Assessment of population exposure to noise from a particular source is essential for setting health-based guideline values. Wind turbine noise is characterized by a variety of potential moderators, which can be challenging to assess and have not necessarily been addressed in detail in health studies. As a result, there are serious issues with noise exposure assessment related to wind turbines.

Noise levels from outdoor sources are generally lower indoors because of noise attenuation from the building structure, closing of windows and similar. Nevertheless, noise exposure is generally estimated outside, at the most exposed façade. As levels of wind turbine noise are generally much lower than those of transportation noise, the audibility of wind turbines in bedrooms, particularly when windows are closed, is unknown.

In many instances, the distance from a wind farm has been used as a proxy to determine audible noise exposure. However, in addition to the distance, other variables – such as type, size and number of wind turbines, wind direction and speed, location of the residence up- or downwind from wind farms and so on – can contribute to the resulting noise level assessed at a residence. Thus, using distance to a wind farm as a proxy for noise from wind turbines in health studies is associated with high uncertainty.

Wind turbines can generate infrasound or lower frequencies of sound than traffic sources. However, few studies relating exposure to such noise from wind turbines to health effects are available. It is also unknown whether lower frequencies of sound generated outdoors are audible indoors, particularly when windows are closed.

The noise emitted from wind turbines has other characteristics, including the repetitive nature of the sound of the rotating blades and atmospheric influence leading to a variability of amplitude modulation, which can be a source of above average annoyance (Schäffer et al., 2016). This differentiates it from noise from other sources and has not always been properly characterized. Standard methods of measuring sound, most commonly including A-weighting, may not capture the low-frequency sound and amplitude modulation characteristic of wind turbine noise (Council of Canadian Academies, 2015).

Even though correlations between noise indicators tend to be high (especially between L_{Aeq}-like indicators) and conversions between indicators do not normally influence the correlations between the noise indicator and a particular health effect, important assumptions remain when exposure to wind turbine noise in L_{den} is converted from original sound pressure level values. The conversion requires, as variable, the statistical distribution of annual wind speed at a particular height, which depends on the type of wind turbine and meteorological conditions at a particular geographical location. Such input variables may not be directly applicable for use in other sites. They are sometimes used without specific validation for a particular area, however, because of practical limitations or lack of data and resources. This can lead to increased uncertainty in the assessment of the relationship between wind turbine noise exposure and health outcomes.

Based on all these factors, it may be concluded that the acoustical description of wind turbine noise by means of L_{den} or L_{night} may be a poor characterization of wind turbine noise and may limit the ability to observe associations between wind turbine noise and health outcomes.

3.4.3 Summary of the assessment of the strength of recommendations

Table 42 provides a comprehensive summary of the different dimensions for the assessment of the strength of the wind turbine recommendations.

Table 42. Summary of the assessment of the strength of the recommendation

Factors influencing the strength of recommendation	Decision
Quality of evidence	**Average exposure (L_{den})** *Health effects* • Evidence for a relevant absolute risk of annoyance at **45 dB L_{den}** was rated **low quality.** *Interventions* • No evidence was available on the effectiveness of interventions to reduce noise exposure and/or health outcomes from wind turbines. **Night-time exposure (L_{night})** *Health effects* • No statistically significant evidence was available for sleep disturbance related to exposure from wind turbine noise at night. *Interventions* • No evidence was available on the effectiveness of interventions to reduce noise exposure and/or sleep disturbance from wind turbines.
Balance of benefits versus harms and burdens	Further work is required to assess fully the benefits and harms of exposure to environmental noise from wind turbines and to clarify whether the potential benefits associated with reducing exposure to environmental noise for individuals living in the vicinity of wind turbines outweigh the impact on the development of renewable energy policies in the WHO European Region.
Values and preferences	There is wide variability in the values and preferences of the population, with particularly strong negative attitudes in populations living in the vicinity of wind turbines.
Resource implications	Information on existing interventions (and associated costs) to reduce harms from wind turbine noise is not available.
Additional considerations or uncertainties	There are serious issues with noise exposure assessment related to wind turbines.
Decisions on recommendation strength	• **Conditional** for guideline value for average noise exposure (L_{den}) • **Conditional** for the effectiveness of interventions (L_{night})

3.5 Leisure noise

Recommendations

For average noise exposure, the GDG **conditionally** recommends reducing the yearly average from all leisure noise sources combined to **70 dB** $L_{Aeq,24h}$, as leisure noise above this level is associated with adverse health effects. The equal energy principle[19] can be used to derive exposure limits for other time averages, which might be more practical in regulatory processes.

For single-event and impulse noise exposures, the GDG **conditionally** recommends following existing guidelines and legal regulations to limit the risk of increases in hearing impairment from leisure noise in both children and adults.

Following a precautionary approach, to reduce possible health effects, the GDG **strongly** recommends that policy-makers take action to prevent exposure above the guideline values for average noise and single-event and impulse noise exposures. This is particularly relevant as a large number of people may be exposed to and at risk of hearing impairment through the use of personal listening devices (PLDs). There is insufficient evidence, however, to recommend one type of intervention over another.

3.5.1 Rationale for the guideline levels for leisure noise

As specific evidence for the relationship between leisure noise and hearing loss is of insufficient quality, the GDG decided to follow a different approach for this noise source, based on knowledge regarding prevention of hearing loss in the workplace and on the CNG (WHO, 1999). There is sufficient evidence that the nature of the noise matters little in causing hearing loss, so using the existing guidelines is a justified step to prevent permanent hearing loss from leisure noise.

In accordance with the procedures for the other noise sources, the GDG would have considered evidence on exposure–response relationships for the prioritized health outcomes. However, no such ERFs could be established in the systematic reviews for any of the health outcomes (Table 43).

Table 43. Average exposure levels ($L_{Aeq,24h}$) for priority health outcomes from leisure noise

Summary of priority health outcome evidence	Benchmark level	Evidence quality
Incidence of IHD **Incidence of hypertension** **Prevalence of highly annoyed population** **Reading skills and oral comprehension in children**		No evidence was available
Permanent hearing impairment There is an indication that PLDs have an effect on hearing impairment and tinnitus. There was no evidence (because no studies were found) for an effect of other sources of leisure noise on hearing impairment or tinnitus. The results of the studies could not be synthesized because of heterogeneity of outcome measurement.	No increase	Very low quality/no evidence

[19] The equal energy principle states that the total effect of sound is proportional to the total amount of sound energy received by the ear, irrespective of the distribution of that energy in time (WHO, 1999).

In accordance with the evidence on the effects of PLDs on permanent hearing loss from leisure noise, the GDG recommended a guideline exposure level of 70 dB $L_{Aeq,24h}$ yearly average from all leisure noise sources combined. It was confident that there was no relevant risk increase for permanent hearing impairment below this exposure level of average leisure noise. The GDG recognized that a conversion to alternative time averages for exposure to leisure noise might be helpful for regulatory purposes; thus, a detailed table converting hourly and weekly exposure into yearly averages is provided in the subsection on additional considerations or uncertainties in section 3.5.2.3, Table 49. Furthermore, the GDG recommended sticking to the CNG recommendations for single events to limit the risk of hearing impairment from leisure noise increases for both children and adults (WHO, 1999).[20] Due to the nature and limited amount of available evidence, the GDG made the recommendation conditional.

Next, the GDG assessed the evidence for night noise exposure and its effect on sleep disturbance (Table 44).

Table 44. Night-time exposure levels (L_{night}) for priority health outcomes from leisure noise

Summary of priority health outcome evidence	Benchmark level	Evidence quality
Sleep disturbance	3% absolute risk	No evidence was available

Because of a lack of evidence, the GDG was not able to formulate a recommendation addressing sleep disturbance due to leisure noise at night time.

The GDG also looked for evidence about the effectiveness of interventions for leisure noise exposure. Owing to a lack of research, however, no studies were available on existing interventions and associated costs to reduce leisure noise. As no evidence was available, it was not possible to develop a recommendation on any specific type of intervention measure. However, following a precautionary approach, to reduce possible health effects, the GDG made a strong recommendation that policy-makers take action to prevent exposures above the guideline values for average noise and single-event and impulse noise exposures. This is particularly relevant as a large number of people may be exposed to and at risk of hearing impairment through the use of PLDs. There is insufficient evidence, however, to recommend one type of intervention over another.

3.5. 1.1 Other factors influencing the strength of recommendations

Other factors considered in the context of recommendations on leisure noise included those related to values and preferences, benefits and harms, resource implications, equity, acceptability and feasibility; moreover, nonpriority health outcomes were considered. Ultimately, the assessment of all these factors did not lead to a change in the strength of recommendation. Further details are provided in section 3.5.2.3.

[20] The GDG acknowledged the scarcity of cohort study-based evidence to define a threshold for hearing damage due to single loud exposures. It initially decided to propose $L_{AF,max}$ = 110, but after much discussion it appeared that the conversion of relevant standing limits (expressed in $L_{peak,C}$ and others) lacked sufficient basis.

3.5.2 Detailed overview of the evidence

The following sections provide a detailed overview of the evidence constituting the basis for setting the recommendations on leisure noise. As noted above, however, only limited evidence was available for several of the prioritized health outcomes, so it is presented and summarized for all critical and important health outcomes where possible, along with indications of the GDG's judgement of the quality of evidence. Research into health outcomes and effectiveness of interventions is addressed consecutively.

A comprehensive summary of all evidence considered for each of the critical and important health outcomes can be found in the eight systematic reviews published in the *International Journal of Environmental Research and Public Health* (see section 2.3.2 and Annex 2).

3.5.2.1 Evidence on health outcomes

The key question posed was: in the general population exposed to leisure noise, what is the exposure–response relationship between exposure to leisure noise (reported as various noise indicators) and the proportion of people with a validated measure of health outcome, when adjusted for main confounders? A summary of the PICOS/PECCOS scheme applied and the main findings is set out in Tables 45 and 46.

Table 45. PICOS/PECCOS scheme of critical health outcomes for exposure to leisure noise

PECO	Description
Population	General population
Exposure	Exposure to high levels of noise produced by leisure activities (average/night time)
Comparison	Exposure to lower levels of noise produced by leisure activities (average/night time)
Outcome(s)	For average noise exposure: 1. cardiovascular disease 2. annoyance 3. cognitive impairment 4. hearing impairment and tinnitus 5. adverse birth outcomes 6. quality of life, well-being and mental health 7. metabolic outcomes For night noise exposure: 1. effects on sleep

Table 46. Summary of findings for health effects from exposure to leisure noise ($L_{Aeq,24h}$)

Noise metric	Priority health outcome measure	Quantitative risk for adverse health	Lowest level of exposure across studies[a]	Number of participants (studies)	Quality of evidence
Cardiovascular disease					
$L_{Aeq,24}$	Incidence of IHD	–	–	–	–
$L_{Aeq,24}$	Incidence of hypertension	–	–	–	–
Annoyance					
$L_{Aeq,24}$	%HA	–	–	–	–
Cognitive impairment					
$L_{Aeq,24}$	Reading and oral comprehension	–	–	–	–
Hearing impairment and tinnitus					
$L_{Aeq,24}$	Permanent hearing impairment	Not estimated	–	484 (3)	Very low (downgraded for study limitations, precision)

Hearing impairment and tinnitus

Several types of leisure activity are accompanied by loud sounds, such as attending nightclubs, pubs and fitness classes; live sporting events; concerts or live music venues; listening to loud music through PLDs. This recommendation is informed by a systematic review that assessed the evidence on permanent hearing loss and tinnitus due to exposure to leisure noise (Śliwińska-Kowalska & Zaborowski, 2017). The review identified two existing systematic reviews that summarized recent estimates of the risk of developing permanent hearing loss from the use of PLDs. It did not identify any studies with objective measurement of exposure to any other type of leisure noise.

The Scientific Committee on Emerging and Newly Identified Hazards and Risk (SCENIHR) (EC, 2008b) report concluded that prolonged exposure to sounds from PLDs may result in temporary hearing threshold shift, permanent hearing threshold shift and tinnitus, as well as poor speech communication in noisy conditions. However, based on the data available, there was no direct evidence for an effect of repeated, regular daily exposure to music through PLDs on development of permanent noise-induced hearing loss. Data on tinnitus were inadequate and therefore inconclusive. No meta-analysis was provided for any of the hearing effects; nor were the exposure–effect curves reported. The SCENIHR report was based on a narrative review of 30 original papers with over 2000 participants and exposure to music sounds that covered a range of 60–120 dB. Studies included in the review were carried out between 1982 and 2007.

In 2014 a second systematic review was published by Vasconcellos et al. (2014). Although the objective of this publication was to determine threshold levels of personally modifiable risk factors for hearing loss in the paediatric population, specific thresholds analyses were limited. Based on the descriptive overview of original papers, the authors identified exposure to loud music (including use of PLDs) and working on a mechanized farm as the main risk factors for hearing loss in children and teenagers. Thresholds of exposure to music, significantly associated with hearing loss in youth, were:

- more than four hours per week or more than five years of personal headphone usage;
- more than four visits per month to a discotheque.

The evidence review identified five new cross-sectional studies on noise from PLDs since the publication of the SCENIHR report (Feder et al., 2013; Levesque et al., 2010; Sulaiman et al., 2013; 2014; Vogel et al., 2014). Direct measurement of hearing thresholds with pure tone audiometry was performed only in three studies – by Feder et al. (2013) and Sulaiman et al. (2013 and 2014). In total, audiometric data from 484 subjects were analysed; among them, 449 were exposed and 35 were not exposed to PLD music. Two other studies by Levesque et al. (2010) and Vogel et al. (2014) did not perform audiometric measurement but reported on tinnitus in a total of 1067 participants.

Noise from PLDs was estimated based on direct measurement of equivalent sound pressure levels (in dB) in four studies (Feder, 2013; Levesque et al., 2010; Sulaiman et al., 2013; 2014) and based on converting volume-control setting levels of PLD into dB levels in one study (Vogel et al., 2014). The resulting exposure levels (L_{Aeq} values) had a mean of between 72 dB and 91 dB, although in two studies these data were not provided. In all studies, individual $L_{Aeq,8h}$ value was calculated based on an estimated level of music and the number of hours a day listening to the music through the PLD declared by an individual in the questionnaire. Resulting $L_{Aeq,8h}$ mean values were between 62 dB and 83 dB when provided.

Potential confounding was controlled by excluding the subjects with exposure to other sources of high-level noise or prior ear problems (Sulaiman et al., 2013), by excluding those with these factors and ototoxic drug intake (Sulaiman et al., 2014) or by controlling for these confounders by accounting for them in the statistical models. The confounders comprised socioeconomic status, demographic factors, tubes in the ear and leisure exposures in one study (Feder, 2013), and age and sex in one study (Vogel et al., 2014). One of the studies did not adjust for confounding factors (Levesque et al., 2010).

Data on permanent hearing loss were taken from audiometric measurements (Feder, 2013; Sulaiman et al., 2013; 2014), while data about permanent tinnitus were taken from self-reported responses to questionnaires (Levesque et al., 2010; Vogel et al., 2014). In one case, the outcome was defined as "permanent hearing-related symptoms", but it is not clear what proportion of subjects experienced permanent tinnitus (Vogel et al., 2014).

For permanent hearing loss, there is no pooled effect size, because the authors of the original studies either did not report data or reported in different formats. However, these studies indicate a harmful effect of listening to PLDs. For permanent tinnitus, there is no pooled effect size because the effects of noise from PLDs on permanent tinnitus were contradictory. These results are generally consistent with previous reviews by SCENIHR (EC, 2008b) and Vasconcellos et al. (2014).

The risk of bias was assessed as high for all five studies. The overall evidence for an effect of PLDs on hearing impairment and tinnitus was rated very low quality.

3.5.2.2 Evidence on interventions

The following section summarizes the evidence underlying the recommendation on the effectiveness of interventions for leisure noise exposure. The key question posed was: in the general population exposed to leisure noise, are interventions effective in reducing exposure to and/or health outcomes from leisure noise? A summary of the PICOS/PECCOS scheme applied and the main findings is set out in Tables 47 and 48.

Table 47. PICOS/PECCOS scheme of the effectiveness of interventions for exposure to leisure noise

PICO	Description	
Population	General population	
Intervention(s)	The interventions can be defined as: (a) a measure that aims to change noise exposure and associated health effects; (b) a measure that aims to change noise exposure, with no particular evaluation of the impact on health; or (c) a measure designed to reduce health effects, but that may not include a reduction in noise exposure.	
Comparison	No intervention	
Outcome(s)	For average noise exposure: 1. cardiovascular disease 2. annoyance 3. cognitive impairment 4. hearing impairment and tinnitus 5. adverse birth outcomes 6. quality of life, well-being and mental health 7. metabolic outcomes	For night noise exposure: 1. effects on sleep

Table 48. Summary of findings for interventions for leisure noise

Type of intervention	Number of participants (studies)	Effect of intervention	Quality of evidence
Hearing impairment			
Type E – behaviour change interventions (education programme/campaign)	4151 (7)	None of the studies involved measurement or estimation of exposure levels or health outcomes. Most studies found a significant effect of change in knowledge or behaviour.	–

Seven individual studies on PLDs, attendance at music venues and participation in other recreational activities where there was risk of hearing damage and/or tinnitus were included in the systematic review (Dell & Holmes, 2012; Gilles & Van de Heyning, 2014; Kotowski et al., 2011; Martin et al., 2013; Taljaard et al., 2013; Weichbold & Zorowka, 2003; 2007). All studies examined interventions directed at changes in knowledge or behaviour and hearing impairment.

The studies all sought evidence on the effectiveness of some form of educational programme or campaign aimed at children, adolescents or college students. These addressed perceptions and knowledge of the risk of high levels of noise – generally, but not exclusively, from PLD sources or from attendance at music events – and actual or intended changes to hearing damage risk behaviours, including avoidance, frequency or duration of exposure, regeneration periods when in high noise, or playback levels.

The outcome assessed in all intervention studies was the change in knowledge and behaviours towards hearing damage risk. The health outcome measures varied widely and included measurements on the youth attitude towards noise scale, participants' knowledge about hearing damage, participants' PLD usage patterns, participants' attitudes to wearing hearing protection (some in general; some at discotheques) and frequency of discotheque attendance. A majority of the studies found a significant effect of change in knowledge or behaviour. No indication on the persistence of knowledge and behavioural change was given, though.

None of the studies included objectively measured outcomes or a measured change in noise level exposure; thus, the effectiveness of the interventions could not be assessed, and the quality of the evidence was not rated according to GRADE.

3.5.2.3 Consideration of additional contextual factors

Based on the quality of the available evidence discussed in the foregoing overview, the GDG set the strength of recommendation of leisure noise to conditional. As a second step, it qualitatively assessed contextual factors to explore whether other considerations could have a relevant impact on the recommendation strength. These considerations mainly concerned the balance of harms and benefits, values and preferences, and resource use and implementation.

When assessing the balance of benefits and harms, the GDG recognized that exposure to leisure noise is widespread and frequent. In particular, as many as 88–90% of teenagers and young adults report listening to music through PLDs earphones (Pellegrino et al., 2013; Vogel et al., 2011). In 2015 WHO estimated that 1.1 billion young people worldwide could be at risk of hearing loss due to unsafe listening practices (WHO, 2015a). Furthermore, among young people aged 12–35 years in middle- and high-income countries, nearly 50% listen to unsafe levels of sound through personal audio devices (mp3 players, smartphones and others), and around 40% are exposed to potentially damaging levels of sound at nightclubs, bars and sporting events. Noise-induced hearing loss can be prevented by following safe listening practices, so the GDG concluded that health benefits can be gained from markedly reducing population exposure to leisure noise, including through actions to promote safe listening practices. A reduction of leisure noise is also assumed to reduce nuisance that can be caused to other people than those who enjoy leisure activities, such as neighbours. Furthermore, specifically for PLDs, it can reasonably be expected that a reduction of noise exposure could also lead to a reduction in accidents, injuries and other potential safety risks. In relation to possible harms and burdens, the GDG could not identify any harms (except economic costs, which are addressed in the paragraph on resource use and implementation) arising from implementation of the recommended guideline values.

Considering values and preferences, the GDG recognized that listening to music with the help of a PLD, going to concerts and attending sport events are activities regarded as enjoyable and therefore assumed to be valued by the overall population. Furthermore, it is expected that values and preferences might vary in particular with respect to the use of PLDs and embracing leisure activities involving loud noise, like concerts, and that some population groups – especially younger individuals – might voluntarily expose themselves to high levels of sound during these activities. Despite this, the GDG was confident that recommendations to lower noise levels for the prevention of hearing damage from leisure noise would be welcome by a majority of the population. Recommendations are expected to be particularly welcome when it comes to protecting the hearing of young children and teenagers, as these vulnerable groups often do not have control over their environment and the noise levels to which they are exposed, such as from noisy toys or at school.

With resource use and implementation, the GDG noted that interventions exist to reduce exposure to leisure noise from PLDs, attendance at music venues and participation in recreational activities, as aggregated by the systematic review on environmental noise interventions and their associated impacts (Brown & van Kamp, 2017). As most of these relate to implementation of a behaviour change, the reduction of exposure to leisure noise is expected to be technically feasible and cheap. None of the empirical investigations objectively measured outcomes or a measured change in noise level exposure, so the effectiveness of such measures cannot be assessed. Nevertheless, it is important to note that there is ample evidence from the occupational health field that high noise levels cause hearing damage, and that occupational interventions to reduce noise exposure are effective at lowering the risk of hearing problems or hearing damage (EC, 2003; Garcia et al., 2018; ISO, 2013; Maassen et al., 2001). In conclusion, resources needed to reduce exposure to leisure noise are not expected to be intensive, but implementation and long-term success of measures might be challenging, owing to cultural factors, as changes in behaviour are expected to be tricky to implement.

In light of the assessment of the contextual factors in addition to the quality of evidence, the recommendation remains conditional.

Additional considerations or uncertainties

The GDG considers the noise levels selected for this recommendation to be reasonable precautionary measures, in view of the rating of very low quality for the available evidence on an effect of leisure noise on permanent hearing impairment and tinnitus identified in the systematic review.

Extensive literature shows hearing impairment in populations exposed to specific types of nonoccupational environments, although these exposures are generally not well characterized. There are no studies with objective measurement of exposure to any other type of leisure noise (except PLDs) and permanent hearing impairment or tinnitus. Nevertheless, this recommendation generally applies to all leisure noise exposures, such as events in public venues (concerts halls, sports events, bars and discotheques) and educational facilities, and use of PLDs. The recommendation also applies to exposure to impulse sounds, such as those in shooting facilities or from the use of toys and firecrackers.

Hearing loss is the resultant value of combined exposures to different sources of leisure noise including, but not limited to, PLDs. Therefore, the recommendations apply to the combined noise levels from all sources.

Noise-induced hearing loss develops very slowly over years of exposure, giving rise to challenges in the assessment of the health impacts from prolonged use of PLDs and exposure to leisure noise. The induction period for the development of hearing impairment and tinnitus is long, and varying exposure conditions and changing lifestyle habits (including confounding noise sources), particularly among young people, will have an impact. Therefore, recommendations regarding leisure noise have often been inferred from the occupational field, where exposure conditions are more stable over time.

Indeed, long-term exposure to noise, objectively assessed and at levels measured in occupational settings for various professions, can lead to permanent hearing loss and tinnitus. This evidence, while not reviewed systematically as part of the work related to these guidelines, can be used as supportive evidence and justification for the need to develop a recommendation for leisure noise, given that many people could be at risk of developing hearing loss and/or tinnitus from exposure to lower levels of environmental noise. Similar otobiological mechanisms must also be considered for environmental noise.

To date, no commonly accepted method for assessing the risk of hearing loss due to environmental exposure to noise has been developed. One of the main challenges is to conduct a long-term objective exposure assessment of environmental noise and relate this to the development of permanent hearing impairment and tinnitus. The GDG underlined the strong need for research to develop a comprehensive methodology. In the absence of a method, and as long as no other tools are available, the equal energy principle outlined in the ISO standard for the estimation of noise-induced hearing loss (WHO, 1999) can be used as a practical tool for protecting public health from exposure to leisure noise. As a result, the relationship between leisure noise exposure and auditory effects can be quantified for a variety of exposure levels, duration and frequency.

Several organizations have established regulations for the protection of workers from risks to their health and safety arising from exposure to noise, and in particular risk to hearing. Of particular relevance is EU Directive 2003/10/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise) (EC, 2003). Based on the ISO 1999 standard (ISO, 2013), the Directive sets limits of exposure depending on equivalent noise level for an eight-hour working day and obliges the employer to take suitable steps if the limits are exceeded. It recommends three action levels for occupational settings, setting the lowest, most conservative value at $L_{ex,8hr}$ = 80 dB. According to the Directive, no consequences of exposure to occupational noise are expected at this level. While exposure patterns and certain characteristics of occupational and leisure noise exist, knowledge of the hearing impairment risks and preventive interventions can be used to assess health risks associated with leisure noise (Neitzel & Fligor, 2017).

The CNG recommend a limit of $L_{Aeq,24h}$ = 70 dB(A) for preventing hearing loss from industrial, commercial shopping and traffic areas, indoors and outdoors (WHO, 1999). Health and safety regulations are usually based on an exposure profile of a typical worker (eight hours per day, five days per week). Using the existing knowledge from the ISO standard and established health and safety regulations, it is possible to use the equal energy principle to derive the resulting noise exposure level for an exposure profile more appropriately suited for leisure noise. Converting 40 hours at 80 dB to a continuous exposure to noise (24 hours per day, seven days per week), this leads to a yearly average exposure of 71 dB for lifelong exposure.[21] This is the same value as the WHO recommendation of

[21] 71 dB = 80 dB (derived from ISO standard) – 6.2 dB (conversion of yearly average of 40 working hours divided by continuous exposure to noise: (10 log (2080hrs/8760 hrs)) – 3 dB (extrapolation of 40 working years to lifelong exposure).

70 dB (WHO, 1999). Table 49 presents the noise levels per hour for various time averages in order to keep within the recommended yearly average exposure, and assuming that exposure to other noise sources generally does not contribute significantly. For example, for specific events taking place for one-, two- or four-hour averages, once a week (such as visiting a discotheque or watching a loud movie), an hourly noise level of 85 dB would lead to an average yearly exposure of 63 dB, 66 dB and 69 dB, respectively. However, the same hourly exposure of 85 dB for an activity taking place for 14 hours per week (two hours per day, seven days a week) would lead to a yearly exposure of 74 dB, which exceeds the recommendations.

Table 49. Combination of hourly exposure and number of hours per week to arrive at a yearly average L_{Aeq}

Hours of exposure per week	**One-hour exposure level (L_{Aeq})**						
	70	**75**	**80**	**85**	**90**	**95**	**100**
1	48	53	58	63	68	73	78
2	51	56	61	66	71	76	81
4	54	59	64	69	74	79	84
14 (2 hours per day, 7 days per week)	59	64	69	74	79	84	89
28 (4 hours per day, 7 days per week)	62	67	72	77	82	87	92
40 (8 hours per day, 5 days per week)	64	69	74	79	84	89	94
168 (24 hours per day, 7 days per week)	70	75	80	85	90	95	100

Note: green = combinations of exposure/duration below current guideline level; red = combinations of exposure/duration above current guideline level; blue = input parameters.

The equal energy principle cannot be used to derive single-event limits because at high levels the ear starts to respond with nonlinear behaviour. The CNG provides several values, in different units: $L_{AF,max}$ = 110 dB for industrial noises (no distance stated), $L_{peak,lin}$ = 140 dB for adults and $L_{peak,lin}$ = 120 dB for children (measured at 100 mm) (WHO, 1999). EU Directive 2003/10/EC on the minimum health and safety requirements regarding the exposure of workers recommends a lower action level of $L_{peak,C}$ = 135 dB (at 100 mm). In a recent overview Hohmann (2015) provided an ERF for hearing damage caused by shooting noise, from which it appears that a safe level of L_E = 120 dB can be derived.

Although it is clear that high noise levels cause acute hearing damage, there is no agreement on a safe level. Further research is highly recommended. In the mean time, existing guidelines should be applied.

3.5.3 Summary of the assessment of the strength of recommendation

Table 50 provides a comprehensive summary of the different dimensions for the assessment of the strength of the leisure noise recommendations.

Table 50. Summary of the assessment of the strength of the recommendation

Factors influencing the strength of recommendation	Decision
Quality of evidence	**Average exposure ($L_{Aeq,24h}$)** *Health effects* • Evidence of an effect from PLDs on hearing impairment and tinnitus, in the absence of evidence for other health outcomes and absence of evidence on hearing impairment and tinnitus from other types of leisure noise besides PLDs, was rated **very low quality.** *Interventions* • No evidence was available on the effectiveness of interventions to reduce noise exposure and/or health outcomes from leisure noise.
Balance of benefits versus harms and burdens	The general benefit from reduction of leisure noise outweighs any potential harms.
Values and preferences	There is variability in the values and preferences of the general population.
Resource implications	The resources needed to reduce exposure to leisure noise are not expected to be intensive, but implementation and the long-term success of measures may be challenging, mainly due to cultural factors.
Decision on strength of recommendation	• **Conditional** for guideline level for average noise exposure ($L_{Aeq,24h}$) • **Conditional** for single-event and impulse noise • **Strong** for interventions to reduce noise exposure

3.6 Interim targets

An interim target was proposed in the NNG (WHO Regional Office for Europe, 2009), "recommended in situations where the achievement of NNG is not feasible in the short run for various reasons". The NNG emphasized that an interim target is "not a health-based limit value by itself. Vulnerable groups cannot be protected at this level".

The GDG discussed whether to propose interim targets as part of the current guidelines, and if so, what process would be needed to derive those values. The current recommendations are health-based and already provide guideline values per noise source (for both L_{den} and L_{night}). They also include information on exposure–response relationships for various health outcomes, which can be used by policy-makers or other stakeholders to inform the selection of different values, if needed. Further, interim targets may work differently in different countries and for different noise sources, and it may not be optimal to propose them Europe-wide. As a result, there was consensus among members of the GDG not to provide interim targets.

4. Implications for research

The development of these environmental noise guidelines for the WHO European Region has made evident some key knowledge gaps and research needs. The main ones specific to the guideline recommendations are presented as implications for research in the sections that follow.

4.1 Implications for research on health impacts from transportation noise

For the assessment of health effects from the main sources of transportation noise (road traffic, railways and aircraft), the various evidence reviews show the following knowledge gap: there is a need for longitudinal studies on the health impacts from exposure to environmental noise, to inform future recommendations properly (Table 51).

Table 51. Implications for research on health impacts from transportation noise (air, rail, road)

Current state of the evidence	Limited evidence is available on health impacts from transportation noise from large-scale cohort and case-control studies, with objective measurement of both noise exposure and health outcomes.
Population of interest	Research is needed into effects of exposure on children and adults exposed to environmental noise from transportation sources.
Exposure of interest	Objective measurement or calculation of transportation noise exposure is required; in particular, from studies of health effects related to combined exposure to different noise sources.
Comparison of interest	The data should be compared to the effects of lower levels of transportation noise.
Outcomes of interest	Measures of the following health outcomes is required, assessed objectively and harmonized where possible – for example, according to common protocols: • annoyance • effects on sleep • cardiovascular and metabolic effects • adverse birth outcomes • cognitive impairment • mental health, quality of life and well-being • hearing impairment and tinnitus • any other relevant health outcome.
Time stamp	The systematic review included studies between October 2014 and December 2016.

4.1.1 Specific implications for annoyance

To predict absolute %HA at the full range of levels (and the corresponding CIs), an integrated analysis of the original raw data from all of individual studies would be necessary. The evidence review conducted as part of the guidelines focused only on secondary data handling and therefore does not replace a full meta-analysis of all individual data. The development of a generic exposure–response relationship (from a full meta-analysis based on all individual data) is suggested as a priority research recommendation (see Table 52).

Table 52. Recommendation for research addressing the exposure–response relationship

Current state of the evidence	The evidence review on annoyance conducted as part of the guidelines does not provide a generalized ERF but points to significant differences compared to the curves used in the past. It shows that the available generalized ERFs are in need of adjustment, preferably as a result of undertaking a full meta-analysis. This is especially the case for the sources aircraft and railway noise, which new data show are more annoying than previously documented.
Population of interest	Research is needed into effects of exposure on children and adults exposed to air, rail and/or road traffic noise.
Exposure of interest	Objective measurement of transportation noise exposure is required.
Comparison of interest	The data should be compared to the effects of lower levels of transportation noise.
Outcomes of interest	Measures of health outcomes are required, assessed objectively according to common protocols (such as the International Commission on Biological Effects of Noise (ICBEN) scale for annoyance).
Time stamp	The systematic review included studies up to October 2014.

4.2 Implications for research on health impacts from wind turbine noise

Further research into the health impacts from wind turbine noise is needed so that better-quality evidence can inform any future public health recommendations properly. For the assessment of health effects from wind turbines, the evidence was either unavailable or rated low/very low quality. Recommendations for research addressing this priority are proposed in Table 53.

Table 53. Implications for research on health impacts from wind turbine noise

Current state of the evidence	The current evidence on health outcomes related to wind turbine noise is unavailable or of low/very low quality and mainly comes from cross-sectional studies. Methodologically robust longitudinal studies with large samples investigating the quantitative relationship between noise from wind turbines and health effects are needed.
Population of interest	Research is needed into effects of exposure on children and adults exposed and living near sources of wind turbine noise. Studies should assess subgroup differences in effects for vulnerable groups such as children, elderly people and those with existing poor physical and mental health.
Exposure of interest	Exposure to noise at a wide range of levels and frequencies (including low-frequency noise), with information on noise levels measured outdoors and indoors (particularly relevant for effects on sleep) at the residence is needed. The noise exposure should be measured objectively and common protocols for exposure to wind turbine noise should be established, considering a variety of noise characteristics specific to wind turbine noise.
Comparison of interest	The data should be compared to the effects in similar areas without wind turbines. Pre/post studies of new wind turbine installations are needed, especially if "before measures" unbiased by the stress and knowledge of potential wind turbine farm development need to be developed.
Outcomes of interest	Measures of health outcomes are required, assessed objectively – for example, according to common protocols (ICBEN scale for annoyance and self-reported sleep disturbance). The studies should include the most important situational and personal confounding variables, such as negative attitudes towards wind turbines, visual impact, economic gain and other socioeconomic factors.
Time stamp	The systematic review included studies between October 2014 (review on annoyance) and December 2016 (review on cardiovascular disease).

Alongside the defined needs for research on wind turbine noise it should be noted that research regarding industrial noise in general is required. More specifically, there is a need to investigate stationary sources (including heat, ventilation and acclimatization devices) and their impacts on health. Studies on hearing disorders from impulse and/or intermittent sounds are also needed; these would enable assessment of adverse effects created by one or several sounds of short duration with a high maximum sound level or impulse sound level.

4.3 Implications for research on health impacts from leisure noise

For the assessment of effects from leisure noise, the evidence to make a recommendation on the ERF to use for health risk assessment, or of a threshold for effects, was either unavailable or rated very low quality. This is a research gap: longitudinal studies with longer follow-up are needed; these should measure noise objectively, not only from PLDs but also from other types of leisure noise.

There is uncertainty in the measurement of early hearing disorders among young people using the tonal audiometry commonly applied. Precise methods to identify early hearing impairment and other hearing disorders are needed. Owing to long induction periods, however, adequate research may be difficult to perform, particularly among young people who change their exposure in terms of sound level and frequency as they age (for example, changing their music listening habits and venue visits). As a result, the recommendations refer to the results derived from stationary noise sources in the occupational field, in conjunction with the equal energy principle (see Table 54).

Table 54. Implications for research on health impacts from leisure noise

Current state of the evidence	Currently, no evidence is available on hearing impairment and tinnitus from large-scale cohort and case-control studies, with objective measurement of noise exposure and using a suitable method to assess hearing impairment in young people.
Population of interest	Research is needed into effects of exposure on children and adults exposed to environmental noise from different sources and in different settings.
Exposure of interest	Objective measurement of leisure noise exposure is required.
Comparison of interest	The data should be compared to the effects of no leisure noise exposure from these sources.
Outcomes of interest	The primary outcomes identified are: • hearing loss measured by audiometry; • specific threshold analyses focused on stratifying the risk of permanent hearing loss according to clearly defined levels of exposure to leisure noise, such as music through PLDs; • concise methods to identify early hearing impairment and other hearing disorders; • temporary threshold shift after exposure to leisure noise, as it may be reasonably predictive of future permanent threshold shift; • age-related hearing loss progression depending on early-age exposure to leisure noise, such as to loud music; and • tinnitus, measured objectively and subjectively.
Time stamp	The systematic review included studies up to June 2015.

4.4 Implications for research on effectiveness of interventions to reduce exposure and/or improve public health

The quality of the evidence on the effectiveness of interventions to reduce exposure to and health outcomes from environmental noise was variable. Further studies directly linking noise interventions to health outcomes are required, particularly for sources other than road traffic noise, and for human health outcomes other than annoyance.

Most studies involved road traffic noise (63%), followed by aircraft noise (13%) and railway noise (6%). The remaining interventions were for leisure noise (13%) and noise in hospital settings (4%). No interventions were identified that either addressed wind turbine noise or focused on educational settings.

Exposure-related interventions were mainly associated with a reduction in environmental noise exposure. However, in five studies (four road traffic noise studies and one aircraft noise study) some or all of the participants experienced noise exposure increases.

There is no clear evidence with respect to thresholds, which are defined as:

- the smallest change in exposure levels that results in a change in outcome; and
- the minimum before-level, regarding changes in health outcomes as a result of interventions.

The limited evidence base on the health effects of environmental noise interventions is thinly spread across different noise source types, outcomes and intervention types. Diversity exists between studies even within intervention types in terms of study designs, methods of analysis, exposure levels and changes in exposure experienced as a result of the interventions. For these reasons, carrying out a meta-analysis across studies examining the association between changes in level and changes in outcome was not possible.

To remedy this main research gap, longitudinal studies assessing noise exposure and health outcomes objectively should be developed, taking into account the most relevant confounders. The establishment of common protocols for future research is warranted (see Table 55).

Authorities should include significant funding for the design and implementation of studies to evaluate the effectiveness of interventions to reduce noise and their impact on health.

Table 55. Implications for research on effectiveness of interventions to reduce exposure and/or improve public health

Current state of the evidence	The current evidence on effectiveness of interventions to reduce health outcomes is limited and of varying quality. Few longitudinal studies have been done that take into account the most relevant confounders and measure the noise exposure and the outcomes objectively.
Population of interest	Research is needed into effects of interventions on defined populations exposed to and/or living near sources of environmental noise.
Intervention of interest	Research into any noise intervention at various points along the system pathway between source and outcome, for a variety of noise sources, is required.
Comparison of interest	The data should be compared to: • a steady-state control group, in similar areas with various exposure gradients from environmental noise sources; • the noise exposure in the same population, through a series of sequential measurements assessing the change before and after the intervention, preferably with multiple after measurements.
Outcomes of interest	Future intervention studies should use validated and, where possible, harmonized measures of exposure and outcome, as well as of moderators and confounders. The studies should use measures of exposure including noise exposure at a wide range of levels and frequencies (including low-frequency noise), with information on noise levels outdoors and indoors (particularly relevant for effects on sleep). They should also use measures of health outcomes, including the following outcomes assessed objectively – for example, according to common protocols (ICBEN scale for annoyance) – with consideration that the change in human response for some health outcomes from a step change in exposure may have a different time course to that of the change in exposure: • annoyance • effects on sleep • cardiovascular and metabolic diseases • adverse birth outcomes • cognitive impairment • mental health, quality of life and well-being • hearing impairment and tinnitus • any other relevant health outcome. Further, they should use measures of moderators and confounders, including repeated measurements of situational and personal variables such as activity interference, potential confounders such as noise sensitivity, coping strategies and a range of other attitudinal variables.
Time stamp	The systematic review included studies up to October 2014.

5. Implementation of the guidelines

5.1 Introduction

These guidelines focus on the WHO European Region and provide guidance to Member States that is compatible with the noise indicators used in the EU's END (EC, 2002a). They provide information on the exposure–response relationships between exposure to environmental noise from different noise sources and the proportion of people affected by certain health outcomes, as well as interventions that are considered efficient in reducing exposure to environmental noise and related health outcomes.

The WHO guideline values are evidence-based public health-oriented recommendations. As such, they are recommended to serve as the basis for a policy-making process in which policy options are considered. In the policy decisions on reference values, such as noise limits for a possible standard or legislation, additional considerations – such as feasibility, costs, preferences and so on – feature in and can influence the ultimate value chosen as a noise limit. WHO acknowledges that implementing the guideline recommendations will require coordinated effort from ministries, public and private sectors and nongovernmental organizations, as well as possible input from international development and finance organizations. WHO will work with Member States and support the implementation process through its regional and country offices.

5.2 Guiding principles

Four guiding principles provide generic advice and support when incorporating the recommendations into a policy framework, and apply to the implementation of all the recommendations.

The **first principle** is to reduce exposure to noise, while conserving quiet areas. The recommendations focus on reduction of population exposure to environmental noise from a variety of sources, in different settings. The general population can be exposed regularly to more than one source of noise simultaneously (including, in some cases, occupational noise), as well as to other nonacoustic factors that can modify the response to noise (such as vibration from railways, air pollution from traffic or visual aspects of wind turbines). Thus, overall reduction of exposure from all sources should be promoted. Furthermore, noise exposure reduction in one area should not come at the expense of an increase in noise elsewhere; existing large quiet outdoor areas should be preserved.

The **second principle** is to promote interventions to reduce exposure to noise and improve health. The evidence from epidemiological studies on adverse health effects at certain noise levels, used as a basis to derive the guideline values proposed in the recommendations, supports the promotion of noise interventions. The potential health impacts from environmental noise are significant, especially when considering the widespread exposure to environmental noise across the population and the high baseline rates for various health outcomes associated with environmental noise.

There are challenges in assessment of the effectiveness of interventions to reduce noise exposure and/or improve health, as there is often a significant time lag between the intervention and a measurable change in exposure and related health benefits. The lack of – or limited direct evidence for – quantifiable health benefits of some specific interventions does not imply that measures to achieve population exposure according to the proposed guidelines should be ignored.

Given the different factors that determine noise exposure, a single measure alone may not be sufficient to reduce exposure and/or improve health significantly, and a combination of methods may be warranted. Nevertheless, it is widely acknowledged that the most effective actions to reduce exposure tend to be those that reduce noise at the source. Such actions have the biggest potential, whereas other measures can be less effective or sustained over time, especially when they depend on behaviour change or noise reductions inside houses.

The **third principle** is to coordinate approaches to control noise sources and other environmental health risks. Considering the common transport-related sources of environmental noise and air pollution, and in particular the evidence of independent effects on the cardiovascular system, a coordinated approach to policy development in the sectors related to urban planning, transport, climate and energy should be adopted for policies with an impact on environmental noise, air quality and/or climate. Such an approach should yield multiple benefits through increased commitment and financial resources; increased attention to securing health considerations in all policies; and use of policy to control noise and other environmental risks such as air pollutants, including short-lived climate pollutants. There is wide consensus on the value of pursuing coordinated policies that can deliver health and other benefits, such as those associated with the local environment and economic development. Furthermore, coordinated policy-making is potentially cost-saving.

The **fourth principle** is to inform and involve communities that may be affected by a change in noise exposure. In planning new urban and/or rural developments (transport schemes, new infrastructures in less densely populated areas, noise abatement and mitigation strategies), bringing together planners, environmental professionals and public health experts with policy-makers and citizens is key to public acceptability and involvement and to the successful guidance of the decision-making proces. Potential health effects from environmental noise should be included as part of health impact assessments of future policies, plans and projects, and the communities potentially affected by a positive or negative change in noise exposure should be well informed and engaged from the outset to maximize potential benefits to health. Introducing measures incrementally may help with acceptance.

5.3 Assessment of national needs and capacity-building

National needs, including the need for capacity-building, differ between Member States in the WHO European Region. They depend on the existence and level of implementation of national and/or European and international noise policies; these are more likely to be implemented fully in EU countries thanks to the legally binding provisions of the EU's END (EC, 2002a). In most countries in the Region noise is perceived as a major and growing environmental health and public health problem. Noise mapping and action plans are carried out in accordance with the END in EU Member States, and in south-eastern European countries noise legislation has mainly been harmonized with the END. Nevertheless, significant differences still exist in the completeness and regular updating of noise exposure assessment between countries. Noise exposure assessment is a required input for noise health impact assessments, along with exposure–response relationships and population baseline data.

WHO has identified some common needs for knowledge transfer and capacity-building for health risk assessment of environment noise in the Member States that joined the EU after 2003, the newly independent states and south-eastern European countries (WHO Regional Office for Europe, 2012):

- implementation of the END and its annexes, especially in the preparation of strategic noise mapping and action plans;
- human resources development through education and training in health risk assessment and burden of diseases stemming from environmental noise;
- methodological guidance for health risk assessment of environmental noise.

These guidelines mostly recommend exposure–response relationships related to the exposure indicators L_{den} and L_{night}. They are therefore of particular relevance to EU countries and those applying the END. In countries that do not use these indicators, users of the guidelines need to convert their noise indicators into L_{den} and L_{night} before being able to apply the recommendations. Conversion between indicators is possible, using a certain set of assumptions (Brink et al., 2018).

5.4 Usefulness of guidelines for target audiences

The provision of guideline values as a practical tool for guiding exposure reduction and the design of effective measures and policies is widely seen as useful. The WHO guidelines equip policy-makers and other end-users with a range of different needs with the necessary evidence base to inform their decisions. As indicated in section 1.4, these guidelines serve as a reference for several target audiences, and for each group they can be useful in different ways.

- For technical experts and decision-makers, the guidelines can be used to provide exposure–response relationships that give insight into the consequences of certain regulations or standards on the associated health effects. They also can be useful at the national and international level when developing noise limits or standards, as they provide the scientific basis to identify the levels at which environmental noise causes a significant health impact. Based on these recommendations, national governments and international organizations can be better informed when introducing noise limits, to ensure protection of people's health.
- For health impact assessment and environmental impact assessment practitioners and researchers, these guidelines provide exposure–response relationships that give insight into the expected health effects at observed or expected noise exposure levels. They offer recommendations on the maximum admissible noise levels for some sources and provide important input to assit in deriving the health burden from noise; in that sense, they can be used when producing studies such as noise maps and action plans to obtain an evaluation of the magnitude of the health problem. The systematic reviews developed in support of these guidelines allow practitioners to raise awareness of the credibility of the issue of noise as a public health problem and to use the recommended exposure–response relationships uniformly. Researchers will also benefit from the guidelines as they clearly identify critical data gaps that need to be filled in the future to better protect the population from the harmful effects of noise.
- The guideline recommendations provide a useful tool for national and local authorities when deciding about noise reduction measures, as they provide data to estimate the health burden on the population and therefore allow comparison among different policy options. These options

can include measures to reduce the noise emitted by the sources, measures aimed at impeding the transmission of noise from the sources to people and measures aimed at better planning the location of houses (urban planning).

- The guideline recommendations can also be used by civil society, patients and other advocacy groups to raise awareness and encourage actions to protect the population, including vulnerable groups, from exposure to noise.

Regarding noise abatement and mitigation of noise sources, practical exposure–response relationships for various noise sources are useful quantitative input to determine the impact of noise on health. They can be valuable information to use in cost–effectiveness and cost–benefit analyses of various policies for noise abatement. In this respect, the guideline recommendations can be an integral part of the policy process for noise reduction by various institutions; they are of great value for communicating the health risks and potential cost-effective solutions to reduce noise.

National and local authorities and nongovernmental organizations responsible for risk communication and general awareness-raising can use these guidelines for promotion campaigns and appropriate risk communication. The guidelines provide scientific evidence on a range of health effects associated with noise and facilitate appropriate risk communication to specific vulnerable groups. They therefore need to be promoted broadly to citizens, national and local authorities and nongovernmental organizations responsible for risk communication.

5.5 Methodological guidance for health risk assessment of environmental noise

A health risk assessment is the scientific evaluation of potential adverse health effects resulting from human exposure to a particular hazard – in this case, environmental noise. The main purpose of the assessment is to estimate and communicate the health impact of exposure to noise or changes in noise in different socioeconomic, environmental and policy circumstances.

The guideline recommendations, along with the detailed information contained in the systematic evidence reviews, can be used to assess health impacts in order to answer a variety of policy questions on:

- the public health burden associated with current or projected levels of noise;
- the human health benefits associated with changing a noise policy or applying a more stringent noise standard;
- the impacts on human health of emissions from specific sources of noise for selected economic sectors (and the benefits of policies related to them); and
- the human health impacts of current policy or implemented action.

The results from a health risk assessment are usually reported as the number of attributable deaths, number of cases, years of life lost, years lost due to disability or DALYs.

The quantification of the impacts for one combination of noise source, noise exposure indicator and health outcome may to some extent include effects attributable to another. Consequently, for any particular set of combinations, consideration should be given to potential double counting.

It is also important to note the uncertainties in quantification of the health impacts. One set of uncertainties relates to the CIs associated with the recommended ERFs; these quantify the random error and variability attributed to heterogeneity in the epidemiological studies used for health risk assessment. Other types of uncertainty include modelling/calculation of noise exposure, estimates of population background rates for morbidity and mortality, and transferability of ERFs from locations where studies were carried out or data were otherwise gathered to another location. This is especially true for noise annoyance, for which there is often considerable heterogeneity in effect sizes of studies because estimates vary between noise sources and are to some degree dependent on the situation and context. Furthermore, cultural differences around what is considered annoying are significant, even within Europe. It is therefore not possible to determine the "exact value" of %HA for each exposure level in any generalized situation. Instead, data and exposure–response curves derived in a local context should be applied whenever possible to assess the specific relationship between noise and annoyance in a given situation. If, however, local data are not available, general exposure–response relationships can be applied, assuming that the local annoyance follows the generalized average annoyance. Despite the challenges in applying a "generalized" ERF to specific local situations, the GDG believes that the percentage of high annoyance defined in section 2.4.3 is an acceptable estimate of the "average" %HA at a certain noise level – for example, in Europe.

When performing a health risk assessment of environmental noise, it is important to note several considerations. The selection of particular noise source(s), noise exposure indicator(s) and health outcome combinations to be used for estimation of the health impacts depends on the particular policies and/or measures being assessed. These guidelines propose recommendations for four types of noise source using noise indicators L_{den} and/or L_{night} (road traffic, railway noise, aircraft noise and wind turbine noise) and one recommendation using $L_{Aeq,24h}$ (leisure noise). Any population may be exposed to different noise sources associated with the same health outcome. Estimated impacts should not be added together without recognizing that addition will, in most practical circumstances, lead to some overestimation of the true impact. Impacts estimated for only one combination will, on the other hand, underestimate the true impact of the noise mixture, if other sources of noise also affect that same health outcome.

The scientific evidence reviewed and summarized in these guidelines implies that the following health outcomes can be quantified in a health risk assessment, and that their effects are cumulative:

- from road traffic noise – incidence of IHD, annoyance and sleep disturbance, and potentially incidence of stroke and diabetes;
- from railway noise – annoyance and sleep disturbance;
- from aircraft noise – annoyance, reading and oral comprehension in children, sleep disturbance and potentially change in waist circumference and incidence of IHD;
- from wind turbine noise: annoyance.

The DWs suggested in section 2.4.3 can be used to calculate DALYs.

Data on incidence and prevalence of some health outcomes related to noise (mainly cardiovascular disease) can be found at a national level in online databases available on the WHO Regional Office for Europe website (WHO Regional Office for Europe, 2017).

General principles of relevance for environmental factors when conducting health risk assessments and quantifying the burden of disease can be found elsewhere (European Centre for Health Policy, 1999; Murray, 1994; Murray & Acharya, 1997; Murray & Lopez, 2013; Quigley et al., 2006; WHO, 2014a; 2014b; WHO Regional Office for Europe, 2016). In particular, the WHO Regional Office for Europe and JRC jointly published the first estimates of the burden of disease from environmental noise in 2011 (WHO Regional Office for Europe & JRC, 2011). The publication includes guidance on the procedure for the health risk assessment of environmental noise, exemplary estimates of the burden of the health impacts of environmental noise and a discussion of the uncertainties and limitations of the procedure to calculate the environmental burden of disease. The reader is referred to this publication for more detailed explanations on quantitative risk assessment methods for environmental noise.

5.6 Route to implementation: policy, collaboration and the role of the health sector

Preventing noise and related health impacts relies on effective action across different sectors: health, environment, transport, urban planning and so on. The health sector needs to be engaged effectively in different sectors' policy processes at national, regional and international levels. It needs to provide authoritative advice about the health impacts of noise and policy options that will bring the greatest benefits to health.

In most countries in the WHO European Region, the commitment of the health sector to engage in action to address environmental noise issues needs to be improved and better coordinated. A more coherent overall response is needed, taking into account relevant linkages with existing health priorities and concerns. Thus, some actions can be seen as aspects of the role of the health sector:

- engaging in proper communication with relevant sectors about noise exposure from different sectors and sources (environmental, urban development, transport and so on) to ensure that health issues are adequately addressed as part of international, regional, national and/or local efforts to address environmental noise – the implementation approach may differ across sectors, depending on the level of awareness of noise as a public health problem;
- promoting the guideline recommendations to policy-makers from different sectors and organizing information campaigns and awareness-raising activities in collaboration with national health authorities and WHO country offices to inform citizens and health practitioners about the health risks of environmental noise;
- using decision support instruments such as health impact and health risk assessments to quantify health risks and potential benefits associated with policies and interventions aimed at addressing environmental noise, including presenting information about the severity of the health effects (for example, with cardiovascular disease) to convey the serious impacts of noise and to try to change attitudes and behaviours of policy-makers and the general public;
- promoting the guidelines to health practitioners and physicians, especially at the community level (through associations of physicians, cardiologists and so on as part of the stakeholder group);
- supporting the establishment of national health institutions capable of initiating and developing health promotion measures, and conducting research, monitoring and reporting on health impacts from environmental noise and its different sources;

- organizing capacity-building workshops and training to increase knowledge of the guidelines as well as creating tools, skills and resources for health risk assessment and developing intersectoral collaboration, particularly in non-EU countries;
- promoting relevant research initiatives and shaping the research agenda, in part based on critical research recommendations and gaps identified in the guidelines, as well as on the impact and effectiveness of interventions and experience with their implementation;
- developing and updating guidelines and policies that influence national, regional and international benchmarks and targets related to environmental noise, as well as advocating the inclusion of the guidelines in development and shaping of national, regional and international noise policies and standards;
- working with other sectors to strengthen noise level monitoring and evaluation, particularly in non-EU countries, to ensure proper conducting of health risk assessments of environmental noise.

5.7 Monitoring and evaluation: assessing the impact of the guidelines

Exposure–response relationships and other recommendations provided by these guidelines should be incorporated into national health policies and the main related policy documents. They should be used for health impact and health risk assessments to identify health risks and potential benefits associated with policies and interventions related to environmental noise.

Population noise exposure should be monitored and assessed at a national scale, at least in urban areas. Furthermore, information on trends in occurrence of noise-related health outcomes considered in these guidelines, such as annoyance or sleep disturbance, should be gathered. These monitoring activities should be performed on a regular basis to ensure proper health risk assessments of noise.

5.8 Updating the guidelines

The progress and pace of noise and health research has intensified over the last 10 years, including new studies published after the completion of the systematic reviews done for these guidelines. This is partly related to the growing car fleet and resulting traffic, the density of urbanization, demographic changes and shifts towards renewable energy, including wind turbines, which have caused an increase in public perception and political awareness of the environmental noise problem. Noise exposure assessment has also improved, due partly to European legislation, and this has provided useful data for epidemiological studies on the health effects of environmental noise. Considering this, the recommendations proposed in these guidelines are expected to remain valid for a period of about 10 years. WHO will monitor the development of the scientific advancements on noise and health research in order to inform any updated guidance on environmental noise.

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Annexes

Annex 1. Steering, advisory and external review groups

Tables A1.1–A1.5 give details of the various teams involved in the development of the WHO environmental noise guidelines for the European Region.

Table A1.1 WHO Steering Group

Name	Role	Affiliation
Shelly Chadha	Technical Officer, Office for Hearing Impairment	WHO headquarters, Geneva, Switzerland
Carlos Dora	Coordinator	WHO headquarters, Department of Public Health and Environment, Geneva, Switzerland
Marie-Eve Héroux	Technical Officer, Air Quality and Noise	WHO Regional Office for Europe, European Centre for Environment and Health, Bonn, Germany
Dorota Jarosinska	Programme Manager, Living and Working Environments	WHO Regional Office for Europe, European Centre for Environment and Health, Bonn, Germany
Rokho Kim	Environmental Health Specialist, Team Leader	WHO Regional Office for the Western Pacific, Division of Noncommunicable Diseases and Health through the Life-Course, Manila, Philippines
Jurgita Lekaviciute	Consultant, Noise	WHO Regional Office for Europe, European Centre for Environment and Health, Bonn, Germany
Srdan Matic	Coordinator, Environment and Health	WHO Regional Office for Europe, Copenhagen, Denmark
Julia Nowacki	Technical Officer, Health Impact Assessment	WHO Regional Office for Europe, European Centre for Environment and Health, Bonn, Germany
Elizabet Paunovic	Head of Office	WHO Regional Office for Europe, European Centre for Environment and Health, Bonn, Germany
Poonum Wilkhu	Consultant, Noise	WHO Regional Office for Europe, European Centre for Environment and Health, Bonn, Germany
Jördis Wothge	Consultant, Noise	WHO Regional Office for Europe, European Centre for Environment and Health, Bonn, Germany

Table A1.2. Guideline Development Group

Area of expertise	Reference	Area of expertise	Reference
Noise sources and their measurement	1	Annoyance	6
Biological mechanisms of effects	2	Cognitive impairment, quality of life, mental health and well-being	7
Cardiovascular and metabolic diseases	3	Adverse birth outcomes	8
Sleep disturbance	4	Environmental noise interventions	9
Hearing impairment/tinnitus	5	Methodology and guideline development	10

Name	Position and affiliation	Area of expertise sought for guideline development (see reference numbers above)									
		1	2	3	4	5	6	7	8	9	10
Wolfgang Babisch	Senior Scientific Officer (retired) Federal Environment Agency Germany		X	X		X					
Goran Belojevic	Professor Institute of Hygiene and Medical Ecology Faculty of Medicine University of Belgrade Serbia			X			X				
Mark Brink	Senior Scientist Federal Office for the Environment Switzerland	X			X		X				
Sabine Janssen	Senior Scientist Department of Sustainable Urban Mobility and Safety Netherlands Organisation for Applied Scientific Research (TNO) Netherlands				X		X				
Peter Lercher (2013–2014)	Professor Medical University of Innsbruck Austria							X	X		
Marco Paviotti	Policy Officer Directorate-General for Environment European Commission Belgium	X								X	
Göran Pershagen	Professor Institute of Environmental Medicine Karolinska Institute Sweden		X	X					X		

Table A1.2. contd

Area of expertise	Reference	Area of expertise	Reference
Noise sources and their measurement	1	Annoyance	6
Biological mechanisms of effects	2	Cognitive impairment, quality of life, mental health and well-being	7
Cardiovascular and metabolic diseases	3	Adverse birth outcomes	8
Sleep disturbance	4	Environmental noise interventions	9
Hearing impairment/tinnitus	5	Methodology and guideline development	10

Name	Position and affiliation	Area of expertise sought for guideline development (see reference numbers above)									
		1	2	3	4	5	6	7	8	9	10
Kerstin Persson Waye	Professor Occupational and Environmental Medicine The Sahlgrenska Academy University of Gothenburg Sweden	X			X		X				
Anna Preis	Professor Institute of Acoustics Adam Michiewicz University Poland					X	X				
Stephen Stansfeld (Chair)	Professor/Head of the Centre for Psychiatry Barts and Queen Mary University of London United Kingdom							X			
Martin van den Berg	Senior Noise Expert Ministry of Infrastructure and Environment Netherlands	X									
GRADE methodologist											
Jos Verbeek	Senior Researcher Finnish Institute of Occupational Health Finland	X									

Table A1.3. Systematic Review Team

Systematic review topics	Experts involved	Affiliation
Cardiovascular and metabolic diseases	Elise van Kempen	National Institute of Public Health and the Environment (RIVM), Netherlands
	Göran Pershagen	Institute of Environmental Medicine, Karolinska Institute, Sweden
	Maribel Casas Sanahuja	Institute for Global Health (ISGlobal), Spain
	Maria Foraster	Barcelona Institute for Global Health (ISGlobal), Spain and Swiss Tropical and Public Health Institute, Switzerland
Sleep disturbance	Mathias Basner	Department of Psychiatry, Perelman School of Medicine at the University of Pennsylvania, United States of America
	Sarah McGuire	Department of Psychiatry, Perelman School of Medicine at the University of Pennsylvania, United States of America
Hearing impairment and tinnitus	Mariola Sliwinska-Kowalska	Nofer Institute of Occupational Medicine, Poland
	Kamil Rafal Zaborowski	Nofer Institute of Occupational Medicine, Poland
Annoyance	Rainer Guski	Department of Psychology, Ruhr-University, Germany
	Dirk Schreckenberg	ZEUS GmbH, Centre for Applied Psychology, Environmental and Social Research, Germany
	Rudolf Schuemer	Consultant for ZEUS GmbH, Centre for Applied Psychology, Environmental and Social Research, Germany
Cognitive impairment, mental health and well-being	Charlotte Clark	Ove Arup & Partners, United Kingdom
	Katarina Paunovic	Institute of Hygiene and Medical Ecology, Faculty of Medicine, University of Belgrade, Serbia
Adverse birth outcomes	Mark Nieuwenhuijsen	Institute for Global Health (ISGlobal), Spain
	Gordana Ristovska	Institute of Public Health of Republic of Macedonia, the former Yugoslav Republic of Macedonia
	Payam Dadvand	Institute for Global Health (ISGlobal), Spain
Interventions	Lex Brown	Griffith School of Environment/Urban Research Program, Griffith University, Australia
	Irene Van Kamp	National Institute of Public Health and the Environment (RIVM), Netherlands

Table A1.4. External Review Group

Area of expertise	Reference	Area of expertise	Reference
Cardiovascular and metabolic diseases	1	Cognitive impairment, mental health and well-being	5
Sleep disturbance	2	Adverse birth outcomes	6
Hearing impairment/ Tinnitus	3	Environmental noise interventions	7
Annoyance	4	Recommendations and implementation guidance	8

Name	Affiliation	Area of expertise sought for guideline development (see reference numbers above)							
		1	2	3	4	5	6	7	8
Gunn Marit Aasvang	Norwegian Institute of Public Health, Norway		X						
Bernard Berry	Berry Environmental Limited, United Kingdom							X	
Dick Botteldooren	Department of Information Technology, Ghent University, Belgium				X				
Stephen Conaty	South Western Sydney Local Health District, Australia								X
Ulrike Gehring	Institute for Risk Assessment Sciences, Utrecht University, Netherlands						X		
Truls Gjestland	SINTEF, Department of Acoustics, Norway				X				
Mireille Guay	Healthy Environments and Consumer Safety Branch, Health Canada/Government of Canada, Canada		X		X				
Ayse Güven	Audiology Department, Faculty of Heath Sciences, Baskent University, Turkey			X					
Anna Hansell	Centre for Environmental Health & Sustainability, George Davies Centre, University of Leicester, United Kingdom	X							X
Stylianos Kephalopoulos	European Commission, DG Joint Research Centre, Italy							X	X
Yvonne de Kluizenaar	The Netherlands Organization for applied scientific research (TNO), Netherlands							X	
David S. Michaud	Healthy Environments and Consumer Safety Branch, Health Canada/Government of Canada, Canada		X		X				
Arnaud Norena	Université Aix-Marseille, Fédération de Recherche, Laboratoire Cognitive Neuroscience, France			X					
Enembe Okokon	National Institute for Health and Welfare, Finland								X
Dieter Schwela	Stockholm Environment Institute, University of York, United Kingdom								X
Daniel Shepherd	AUT University, Auckland, New Zealand					X			
Mette Sörensen	Danish Cancer Society Research Centre, Denmark	X							X
Rupert Thornley-Taylor	Rupert Taylor Ltd, Noise and Vibration Consultants							X	X
David Welch	School of Population Health, Faculty of Medical and Health Sciences, University of Auckland, New Zealand			X				X	

Table A1.5. Stakeholders and end users that participated in the stakeholder consultation

Area of expertise/interest	Reference	Area of expertise	Reference
Implementation of recommendations on railway noise	1	Implementation of recommendations on wind turbine noise	4
Implementation of recommendations on aircraft noise	2	Implementation of recommendations on leisure noise	5
Implementation of recommendations on road traffic noise	3	Implementation of overall recommendations	6

Organization	Area of expertise specifically sought for Guidelines (see reference number above)					
	1	2	3	4	5	6
Airlines for Europe		X				
Airports Council International Europe (ACI)		X				
Anderson Acoustics		X				
Bundesverband der Deutschen Luftverkehrswirtschaft e.V.		X				
European Automobile Manufacturers' Association (ACEA)			X			
European Aviation Safety Agency		X				
European Express Association	X					
European Noise Barrier Federation						X
Flughafenverband (ADV)		X				
International Air Transport Association (IATA)		X				
International Civil Aviation Organization (ICAO)		X				
International Union of Railways	X					
Landesamt fuer Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen						X
Public Health Agency of Sweden						X
Stephen Turner Acoustics					X	X
Union Européenne Contre les Nuisances Aeriennes		X				
Vie en.ro.se.						X

Note: in total 53 organizations and institutions had been approached to participate in the stakeholder consultation.

Annex 2. Systematic reviews and background documents used in preparation of the guidelines

Annex 2 provides a detailed list of all the supplementary documents accompanying the WHO environmental noise guidelines for the European Region.[22]

Systematic reviews

- Basner M, McGuire S (2018). WHO environmental noise guidelines for the European Region: a systematic review on environmental noise and effects on sleep. Int J Environ Res Public Health. 15(3):pii: E519 (http://www.mdpi.com/1660-4601/15/3/519/htm).
- Brown AL, van Kamp I (2017). WHO environmental noise guidelines for the European Region: a systematic review of transport noise interventions and their impacts on health. Int J Environ Res Public Health. 14(8). pii: E873 (http://www.mdpi.com/1660-4601/14/8/873/htm).
- Clark C, Paunovic K (2018). WHO environmental noise guidelines for the European Region: a systematic review on environmental noise and cognition. Int J Environ Res Public Health. 15(2). pii: E285 (http://www.mdpi.com/1660-4601/15/2/285/htm).
- Clark C, Paunovic K (in press). WHO Environmental noise guidelines for the European Region: a systematic review on environmental noise and quality of life, wellbeing and mental health. Int J Environ Res Public Health.
- Guski R, Schreckenberg D, Schuemer R (2017). WHO environmental noise guidelines for the European Region: a systematic review on environmental noise and annoyance. Int J Environ Res Public Health. 14(12). pii:1539 (http://www.mdpi.com/1660-4601/14/12/1539/htm).
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- Śliwińska-Kowalska M, Zaborowski K (2017). WHO environmental noise guidelines for the European Region: a systematic review on environmental noise and permanent hearing loss and tinnitus. Int J Environ Res Public Health. 14(10). pii: E1139 (http://www.mdpi.com/1660-4601/14/10/1139/htm).
- van Kempen E, Casas M, Pershagen G, Foraster M (2018). WHO environmental noise guidelines for the European Region: a systematic review on environmental noise and cardiovascular and metabolic effects: a summary. Int J Environ Res Public Health. 15(2). pii: E379 (http://www.mdpi.com/1660-4601/15/2/379/htm).

[22] All references were accessed on 27 June 2018.

Background documents

- Eriksson C, Pershagen G, Nilsson M (2018). Biological mechanisms related to cardiovascular and metabolic effects by environmental noise. Copenhagen: WHO Regional Office for Europe (http://www.euro.who.int/en/health-topics/environment-and-health/noise/publications/2018/biological-mechanisms-related-to-cardiovascular-and-metabolic-effects-by-environmental-noise).
- Héroux ME, Verbeek J (2018a). Results from the search for available systematic reviews and meta-analyses on environmental noise. Copenhagen: WHO Regional Office for Europe (http://www.euro.who.int/en/health-topics/environment-and-health/noise/publications/2018/results-search-for-available-systematic-reviews-environmental-noise).
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Annex 3. Summary of conflict of interest management

All external contributors to the guidelines, including members of the GDG, Systematic Review Team and External Review Group, completed WHO declaration of interest forms in accordance with WHO's policy for experts. Further, at the initial stage of the project WHO technical staff reviewed and accepted *curricula vitae* of the candidates for the GDG.

At the beginning of the GDG meetings, the participants declared any conflict of interest by submitting declaration of interest forms. Updated declarations of interest were also collected from the members of the GDG, Systematic Review Team and External Review Group at the final stage of the project.

The conflict of interest assessment was done according to WHO procedures. If a conflict was declared, an initial review was undertaken by the WHO Secretariat to assess its relevance and significance. A declared conflict of interest is insignificant or minimal if it is unlikely to affect or to be reasonably perceived to affect the expert's judgment. Insignificant or minimal interests are: unrelated or only tangentially related to the subject of the activity or work and its outcome; nominal in amount or inconsequential in importance; or expired and unlikely to affect current behaviour.

The WHO Secretariat reviewed and assessed the declarations. In one case the legal unit was consulted for advice; in another the potential conflict was reported in the updated declaration of interest at the final stage of the process and assessed unlikely to affect expert's performance; in a further case a member of the GDG was also a co-author of a systematic review owing to the need to support systematic review authors with additional expertise, but there was no remuneration for this activity.

No member of the GDG or the Systematic Review Team was excluded from his or her role in the guideline development process. The declared conflicts of interest of the External Review Group members were considered when interpreting comments during the external review process.

Annex 4. Detailed overview of the evidence of important health outcomes

As a first step of the evidence retrieval process, the GDG defined two categories of health outcome associated with environmental noise: those considered (i) critical or (ii) important, but not critical for decision-making in the guideline development process.

The GDG relied on the critical health outcomes to inform its decisions on priority health outcomes, so only these were used to inform the recommendations. Nevertheless, as the relevance of some of important health outcomes was difficult to estimate *a priori,* systematic reviews were conducted for both critical and important health outcomes.

This annex provides a detailed overview of the evidence of the important health outcomes – namely adverse birth outcomes, quality of life, well-being and mental health and metabolic outcomes – for each of the noise sources. A comprehensive discussion of all the evidence considered (both critical and important) is available in the published systematic reviews (see section 2.3.2 and Annex 2 for details).

1. Road traffic noise

1.1 Adverse birth outcomes

In total, the systematic review found five studies (two with more or less the same population) on road traffic noise and birth outcomes and three related studies on total ambient noise, likely to be mostly road traffic noise. Too few studies for each of the various measures related to adverse birth outcomes were available to undertake a quantitative meta-analysis. There was evidence rated low quality for a relationship between road traffic noise and low birth weight (Dadvand et al., 2014; Gehring et al., 2014; Hjortebjerg et al., 2016; Wu et al., 1996); however, the estimates were imprecise and in some cases not statistically significant. Further, there was no clear relation between exposure to road traffic noise and pre-term delivery, but there was a positive association between road traffic noise and small for gestational age (OR = 1.09; 95% CI: 1.06–1.12 per 6 dB increase). The evidence for both measures of adverse birth outcomes comes from the same publications and this evidence was rated low quality (Gehring et al., 2014; Hystad et al., 2014).

This evidence was supported by one ecological time-series study published recently looking at total ambient noise and various measures related to adverse birth outcomes (Arroyo et al., 2016a; 2016b; Diaz et al., 2016).

1.2 Quality of life, well-being and mental health

Evidence rated moderate quality was found for an effect of road traffic noise on emotional and conduct disorders in childhood (Belojevic et al., 2012; Crombie et al., 2011; Hjortebjerg et al., 2015; Ristovska et al., 2004; Stansfeld et al., 2005; 2009a; Tiesler et al., 2013) and evidence rated moderate quality for an association of road traffic noise with hyperactivity in children (Hjortebjerg et al., 2015; Tiesler et al., 2013).

There was no clear relationship, however, between road traffic noise exposure and self-reported quality of life (evidence rated low quality) (Barcelo Perez & Piñeiro, 2008; Brink, 2011; Clark et al., 2012; Honold et al., 2012; Roswall et al., 2015; Schreckenberg et al., 2010b; Stansfeld et al., 2005; 2009b; van Kempen et al., 2010); medication intake for depression and anxiety (evidence rated very low quality) (Floud et al., 2011; Halonen et al., 2014); depression, anxiety and psychological distress (evidence rated very low quality) (Honold et al., 2012; Stansfeld et al., 2009b); and interview measures of depression and anxiety (evidence rated very low quality) (Stansfeld et al., 2009b).

1.3 Metabolic outcomes

1.3.1 Diabetes

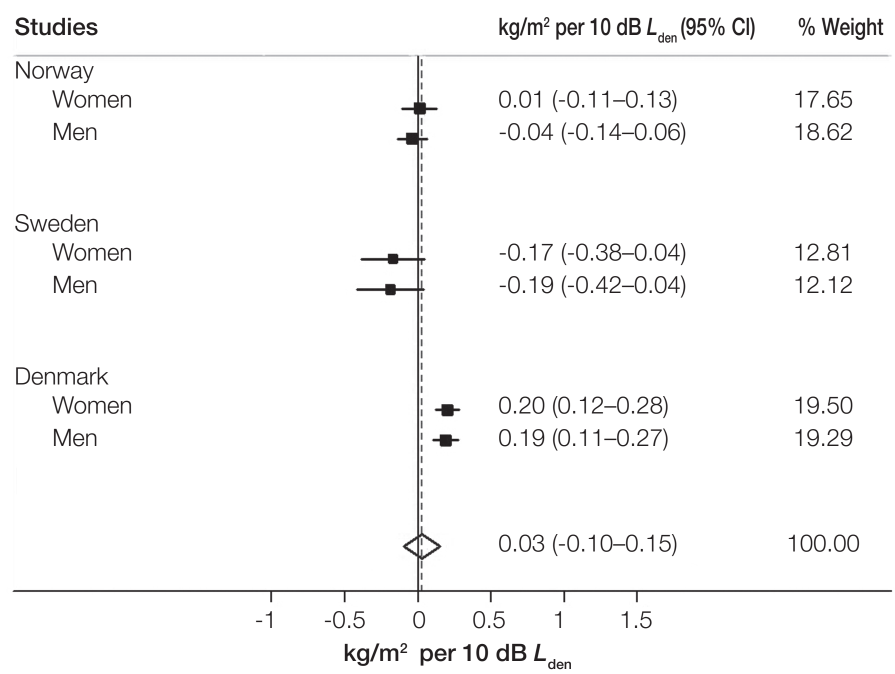
For the relationship between road traffic noise and the incidence of diabetes, one cohort study was identified, which included 57 053 participants and 2752 cases (Sörensen et al., 2013). The estimate of the effect was RR = 1.08 (95% CI: 1.02–1.14) per 10 dB L_{den} increase in noise across the range of 50–70 dB, and therefore the evidence was rated moderate quality.

Furthermore, two cross-sectional studies were identified that looked at the prevalence of diabetes (Selander et al., 2009; van Poll et al., 2014). The studies included 11 460 participants and 242 cases. Both studies reported a harmful effect of noise, and one showed a statistically significant association. However, the results were imprecise and with serious risk of bias, so the evidence was rated very low quality.

1.3.2 Obesity

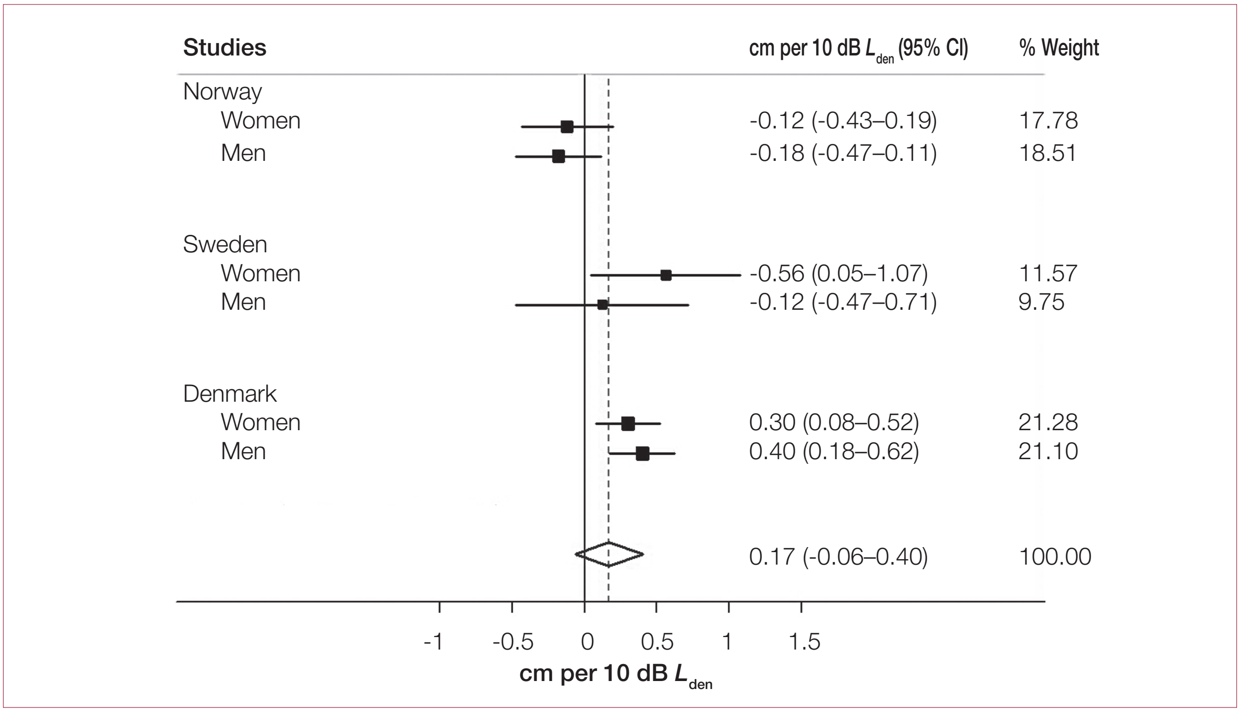
With regard to the association between road traffic noise and change in body mass index (BMI) and waist circumference, three cross-sectional studies were identified, with 71 431 participants (Christensen et al., 2016; Oftedal et al., 2014; 2015; Pyko et al., 2015). For each 10 dB increase in road traffic noise, there was a statistically nonsignificant increase in BMI of 0.03 kg/m^2 (95% CI: –0.10–0.15 kg/m^2) and in waist circumference of 0.17 cm (95% CI: –0.06–0.40 cm). There was inconsistency in the results between the studies; therefore, for both associations, the evidence was rated very low quality (Fig. A4.1 and Fig. A4.2).

Fig. A4.1 The association between exposure to road traffic noise (L_{den}) and BMI in three Nordic studies



Notes: The black vertical line corresponds to no effect of noise exposure. The black dots correspond to the estimated slope coefficients per 10 dB for each sex in each study, with 95% CIs. The diamond designates summary estimates and 95% CIs based on random effects models. The dashed red line corresponds to these summary estimates. Heterogeneity between studies: p = 0.000; heterogeneity between genders: p = 0.360; overall (I-squared = 84.4%, p = 0.000). Weights are from random effect analysis.

Fig. A4.2 The association between exposure to road traffic noise (L_{den}) and waist circumference in three Nordic studies



Notes: The black vertical line corresponds to no effect of noise exposure. The black dots correspond to the estimated slope coefficients per 10 dB for each sex in each study, with 95% CIs. The diamond designates summary estimates and 95% CIs based on random effects models. The dashed red line corresponds to these summary estimates. Heterogeneity between studies: p = 0.001; heterogeneity between genders: p = 0.842; overall (I-squared = 69.0%, p = 0.007). Weights are from random effect analysis.

2. Railway noise

2.1 Adverse birth outcomes

No studies were found, and therefore no evidence was available on the association between railway noise and adverse birth outcomes.

2.2 Quality of life, well-being and mental health

Evidence rated very low quality was found for a weak effect of railway noise exposure on self-reported quality of life or health, albeit from a limited number of studies (Roswall et al., 2015; Torre et al., 2007). There was evidence rated moderate quality for an effect of railway noise on emotional and conduct disorders in childhood (Hjortebjerg et al., 2015), but no clear relationship between railway noise and children's hyperactivity (Hjortebjerg et al., 2015); this evidence was rated moderate quality.

2.3 Metabolic outcomes

2.3.1 Diabetes

One cohort study was identified that looked at the relationship between railway noise and the incidence of diabetes (Sörensen et al., 2013). The cohort study of 57 053 participants, including 2752 cases, found evidence rated moderate quality that there was no considerable effect of railway noise on diabetes, with an RR of 0.97 (95% CI: 0.89–1.05) per 10 dB L_{den} increase in noise.

Furthermore, one cross-sectional study was identified that looked at the relationship between railway noise and the prevalence of diabetes (van Poll et al., 2014), including 9365 participants and 89 cases. An RR of 0.21 (95% CI: 0.05–0.82) per 10 dB L_{den} increase in noise was found, but the reasons for the beneficial effect were not immediately apparent. The evidence in the study was rated very low quality.

2.3.2 Obesity

Regarding the association between railway noise and change in BMI and waist circumference, two cross-sectional studies were identified, with 57 531 participants (Christensen et al., 2016; Pyko et al., 2015). Christensen and colleagues observed a statistically significant increase of 0.18 kg/m^2 (95% CI: 0.00–0.36 kg/m^2) per 10 dB for BMI and 0.62 cm (95% CI: 0.14–1.09 cm) per 10 dB for waist circumference in those exposed to railway noise, at levels above 60 dB L_{den}. Pyko and colleagues found a statistically significant increase in waist circumference of 0.92 cm (95% CI: 0.06–1.78 cm) per 10 dB L_{den}. The corresponding estimate for BMI was statistically nonsignificant, at 0.06 kg/m^2 (95% CI: –0.02–0.16 kg/m^2). The evidence was rated low/very low quality.

3. Aircraft noise

3.1 Adverse birth outcomes

Evidence rated very low quality was available for an association between aircraft noise and pre-term delivery, low birth weight and congenital anomalies, as evidenced by six studies included in the systematic review (Ando & Hattori, 1973; Edmonds et al., 1979; Jones & Tauscher, 1978; Knipschild et al., 1981; Matsui et al., 2003; Schell, 1981). The potential for risk of bias in these was high and the results tended to be inconsistent.

3.2 Quality of life, well-being and mental health

Evidence rated very low quality was available for an effect of aircraft noise on medication intake for depression and anxiety (Floud et al., 2011). There was evidence rated very low quality for an effect of aircraft noise exposure on interview measures of depression and anxiety (Hardoy et al., 2005) and rated low quality for an association of aircraft noise with hyperactivity in children (Clark et al., 2013; Crombie et al., 2011; Stansfeld et al., 2009a).

The evidence showed, however, no substantial effect of aircraft noise on self-reported quality of life or health (Clark et al., 2012; Schreckenberg et al., 2010a; 2010b; Stansfeld et al., 2005; van Kempen et al., 2010) or on emotional and conduct disorders in childhood (Clark et al., 2012; 2013; Crombie et al., 2011; Stansfeld et al., 2005; 2009a). This evidence was rated very low quality.

3.3 Metabolic outcomes

3.3.1 Diabetes

For the relationship between aircraft noise and incidence of diabetes one cohort study was identified, including 5156 participants and 1346 cases (Eriksson et al., 2014). The estimate of the effect was imprecise, with an RR of 0.99 (95% CI: 0.47–2.09) per 10 dB L_{den} increase in noise; the evidence was therefore rated very low quality.

Furthermore, one cross-sectional study was identified that looked at the prevalence of diabetes (van Poll et al., 2014), including 9365 participants and 89 cases. The RR was 1.01 (95% CI: 0.78–1.31) per 10 dB increase in aircraft noise. The evidence was rated very low quality.

3.3.2 Obesity

For the association between aircraft noise and change in BMI and waist circumference, one cohort study was identified, with 5156 participants (Eriksson et al., 2014). For each 10 dB increase in aircraft noise level, the increase in BMI was 0.14 kg/m^2 (95% CI: –0.18–0.45) (evidence rated low quality), and the increase in waist circumference was 3.46 cm (95% CI: 2.13–4.77) (evidence rated moderate quality). The range of noise levels in the study was 48–65 dB L_{den}. In the case of BMI, the change over the whole range in noise values was not statistically significant and was less than what could be considered clinically relevant (3–5% change in BMI); however, for waist circumference, the change was equivalent to an increase of 5.8 cm.

4. Wind turbine noise

4.1 Quality of life, well-being and mental health

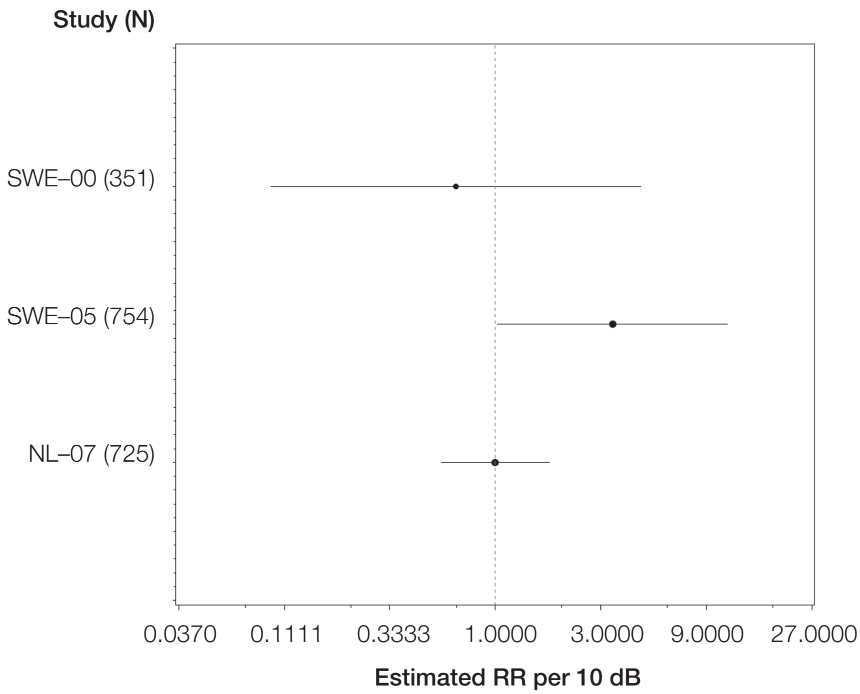
Five low-quality systematic reviews of wind turbine noise effects on mental health and well-being have been carried out (Ellenbogen et al., 2012; Kurpas et al., 2013; Merlin et al., 2013; Onakpoya et al., 2015; Schmidt & Klokker, 2014). These reviews differed in their conclusions and delivered inconsistent evidence that wind turbine noise exposure is associated with poorer quality of life, well-being and mental health. Therefore, the evidence for no substantial effect of wind turbine noise on quality of life, well-being or mental health was rated very low quality.

4.2 Metabolic outcomes

4.2.1 Diabetes

For the relationship between wind turbine noise and prevalence of diabetes, three cross-sectional studies were identified, with a total of 1830 participants (Bakker et al., 2012; Pedersen, 2011; Pedersen & Larsman, 2008; Pedersen & Persson Waye, 2004; 2007; Pedersen et al., 2009; van den Berg et al., 2008). The number of cases was not reported. The effect sizes varied across studies, and only one study found a positive association between exposure to wind turbine noise and the prevalence of diabetes; therefore, no meta-analysis was performed. Due to very serious risk of bias and imprecision in the results, this evidence was rated very low quality. As a result, there is no clear relationship between audible noise (greater than 20 Hz) from wind turbines or wind farms and prevalence of diabetes (Fig. A4.3).

Fig. A4.3 The association between exposure to wind turbine noise (sound pressure level) and self-reported diabetes



Note: The dotted vertical line corresponds to no effect of exposure to wind turbine noise. The black circles correspond to the estimated RR per 10 dB (sound pressure level) and 95% CI.
For further details on the studies included in the figure please refer to the systematic review on environmental noise and cardiovascular and metabolic effects (van Kempen et al., 2018).

5. Leisure noise

Owing to a lack of evidence meeting the critieria for systematic reviewing, no results for any of the important health outcomes can be given for exposure to leisure noise.

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The WHO Regional Office for Europe

The World Health Organization (WHO) is a specialized agency of the United Nations created in 1948 with the primary responsibility for international health matters and public health. The WHO Regional Office for Europe is one of six regional offices throughout the world, each with its own programme geared to the particular health conditions of the countries it serves.

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Noise is an important public health issue. It has negative impacts on human health and well-being and is a growing concern. The WHO Regional Office for Europe has developed these guidelines, based on the growing understanding of these health impacts of exposure to environmental noise. The main purpose of these guidelines is to provide recommendations for protecting human health from exposure to environmental noise originating from various sources: transportation (road traffic, railway and aircraft) noise, wind turbine noise and leisure noise. They provide robust public health advice underpinned by evidence, which is essential to drive policy action that will protect communities from the adverse effects of noise. The guidelines are published by the WHO Regional Office for Europe. In terms of their health implications, the recommended exposure levels can be considered applicable in other regions and suitable for a global audience.

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ATTACHMENT 10

ANSI S12.9-2005/Part 4
(Revision of ANSI S12.9-1996/Part 4)

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Quantities and Procedures for Description and Measurement of Environmental Sound – Part 4: Noise Assessment and Prediction of Long-term Community Response

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ANSI S12.9-2005/Part 4
(Revision of ANSI S12.9-1996/Part 4)

AMERICAN NATIONAL STANDARD

QUANTITIES AND PROCEDURES FOR DESCRIPTION AND MEASUREMENT OF ENVIRONMENTAL SOUND — PART 4: NOISE ASSESSMENT AND PREDICTION OF LONG-TERM COMMUNITY RESPONSE

Secretariat:

Acoustical Society of America

Approved by:

American National Standards Institute, Inc.

Abstract

This Standard specifies methods to assess environmental sounds and to predict the annoyance response of communities to long-term noise from any and all types of environmental sounds produced by one or more distinct or distributed sound sources. The sound sources may be separate or in various combinations. Application of the method of the Standard is limited to areas where people reside and related long-term land uses. This Standard does not address the effects of intrusive sound on people in areas of short-term use such as parks and wilderness areas, nor does it address other effects of noise such as sleep disturbance or health effects. This Standard does not provide a method to predict the community response to short-term, infrequent, non-repetitive sources of sound.

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Foreword

[*This Foreword is for information only, and is not a part of the American National Standard ANSI S12.9 - 2005/Part 4 American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound - Part 4: Noise Assessment and Prediction of Long-Term Community Response.*]

This standard comprises a part of a group of definitions, standards, and specifications for use in noise. It was developed and approved by Accredited Standards Committee S12 Noise, under its approved operating procedures. Those procedures have been accredited by the American National Standards Institute (ANSI). The Scope of Accredited Standards Committee S12 is as follows:

> *Standards, specifications, and terminology in the field of acoustical noise pertaining to methods of measurement, evaluation, and control; including biological safety, tolerance, and comfort, and physical acoustics as related to environmental and occupational noise.*

This standard is a revision of ANSI S12.9-1996/Part 4, which has been technically revised. The changes in this edition harmonize with the new material added to ISO 1996-1:2003. This includes a minor change to high-energy impulse noise assessment (less than 1 dB) so that it is totally in sync with ISO. Second, as appropriate, ISO assessment adjustments have been included. Also, some new cautionary notes from ISO are added to the estimation of "highly annoyed" as notes to the informative annex. A new Annex G addresses complaints in the limited situation of high-energy impulsive noise.

The current edition of ISO 1996-1:2003 actually began as the text of ANSI S12.9 - 1996/Part 4. However, the ISO standard was substantially revised during the WG and committee deliberations. For example, ISO recognizes the more general Day-Evening-Night Sound Level in contrast to S12's Day-Night Sound Level. Nighttime hours are not given in ISO because they vary from country to country. The terms "background" sound and "ambient" sound are NOT used in ISO because they have diametrically opposed meanings in different countries and regions. There are many other differences of this nature. ISO uses "rating" sound level; ANSI uses "adjusted" sound level, etc.

At the time this Standard was submitted to Accredited Standards Committee S12, Noise for approval, the membership was as follows:

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Working Group S12/WG 15, Measurement and Evaluation of Outdoor Community Noise, which assisted Accredited Standards Committee S12, Noise, in the development of this standard, had the following membership.

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Suggestions for improvements of this standard will be welcomed. They should be sent to Accredited Standards Committee S12, Noise, in care of the Standards Secretariat of the Acoustical Society of America, 35 Pinelawn Road, Suite 114E, Melville, New York 11747-3177. Telephone: 631-390-0215; FAX: 631-390-0217; E-mail: asastds@aip.org

Introduction

0.1 Part 1 of ANSI S12.9 defines day-night average sound level and other descriptors of community noise. Part 2 of ANSI S12.9 describes measurement procedures. ANSI S12.9/Part 5 provides a recommended relation between long-term usages of land and day-night average sound level for purposes of long-term land-use planning. Since the early 1970s, many agencies within the United States of America have used day-night average sound level as the fundamental descriptor to predict the community response to environmental sounds.

0.2 The 1978 seminal paper by T.J. Schultz demonstrated the efficacy of day-night average sound level for predicting the annoyance response of a community as a result of noise from highway traffic, railroad, aircraft, and some industrial sites. Implementation of the concept of day-night average sound level for prediction of community response often combined the sound exposures from such sources.

0.3 Day-night average sound level has been used to predict the annoyance response of communities to types of noises that were not included in the Schultz database for the relation between the percentage of a population expressing high annoyance and the corresponding day-night average sound level. These additional types of noises include sounds with special characteristics, such as impulsiveness, dominant pure tones, rapid onset, and strong low-frequency content.

0.4 Technical reports and articles published in refereed engineering and scientific journals demonstrated that the community response to these sounds may be predicted, provided suitable adjustments are applied. A practical procedure to apply these adjustments is provided by this Standard.

0.5 For situations where activity interference is the major concern, use of adjusted day-night average sound level or adjusted total day-night sound exposure may not be appropriate. For example, day-night average sound level without adjustments may be a better predictor of speech interference than adjusted day-night average sound level. Descriptors such as maximum A-weighted sound level, time-above, or speech interference level may be even more appropriate for predicting speech interference.

American National Standard

QUANTITIES AND PROCEDURES FOR DESCRIPTION AND MEASUREMENT OF ENVIRONMENTAL SOUND — PART 4: NOISE ASSESSMENT AND PREDICTION OF LONG-TERM COMMUNITY RESPONSE

1 Scope

1.1 This Standard specifies methods to assess environmental sounds and to predict the potential annoyance response of a community to outdoor long-term noise from any and all types of environmental sounds from one or more discrete or distributed sound sources. The sound sources may be separate or in various combinations. Application of the prediction method is limited to areas where people reside and to related long-term land uses.

NOTE The long-term period is typically one year. However, the user of this Standard can employ these methods for shorter periods of time, but they should report this change and not attempt to predict percent highly annoyed using Clause 8.3 or Annex F, since the Annex F data all represent long-term situations.

1.2 This Standard describes adjustments for sounds that have special characteristics so that the long-term community response to such sounds can be predicted by a method that is based on day-night average sound level or total day-night sound exposure. Sounds, such as from highway traffic, are evaluated directly by sound exposure or sound level without adjustment. The prediction method is directly analogous to the use of day-night average sound level to predict the response of a community to general environmental sounds.

1.3 This Standard does not address the effects of short-term exposure of people to intrusive sounds in locations such as parks and wilderness areas. The Standard also does not address other effects of noise such as sleep disturbance or health effects. This Standard does not provide a method to predict the response of a community to short-term, infrequent, non-repetitive sources of sound.

1.4 This Standard introduces the application of new descriptors: adjusted sound exposure and adjusted sound exposure level. The new descriptors are closely related to sound exposure and sound exposure level, respectively. The new descriptors are introduced to facilitate the prediction of the response of communities to the wide range of outdoor sounds covered by the scope of the Standard.

1.5 The sounds are assessed either singly or in combination, allowing for consideration, when necessary, of the special characteristics of impulsiveness, tonality, onset rate, and low-frequency content. In the same manner as sound exposure and sound exposure level are used to generate total day-night sound exposure or total day-night average sound level, adjusted sound exposure or adjusted sound exposure level are used to generate adjusted total day-night sound exposure or adjusted day-night average sound level.

1.6 Annoyance is not the only possible measure of community response. One frequently cited measure is numbers of complaints, sometimes normalized to numbers of inhabitants. Complaints can be particularly relevant near factories and plants, by airports and military installations, etc. Complaints do not correlate well with long-term average metrics such as DNL (see Refs. 7 and 8 for

example). Unfortunately, in general, metrics to predict the likelihood and prevalence of complaints do not yet exist with sufficient accuracy. One notable exception is the high-energy impulse sound generated by military activities and similar civilian noise sources, and informative Annex G provides procedures for assessing the risk of noise complaints from such sources.

1.7 The addition of adjustments eliminates the possibility to measure the total adjusted sound exposure or sound exposure level in a general situation that comprises a variety of sound sources (e.g., the combination of a highway leading to an airport and the airport itself). As a possible measurable alternative, this Standard introduces a new metric based on the equal-loudness level contours that were contained in ISO 226:1987. This new method uses the equal-loudness level contours as a set of dynamic filters that vary both with amplitude and frequency. This method is described in informative Annex H.

2 Normative references

The following referenced documents are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

[1] ANSI S1.1-1994 (R 2004) *American National Standard Acoustical Terminology.*

[2] ANSI S12.9-1988/Part 1 (R 2003) *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound - Part 1.*

[3] ANSI S12.9-1992/Part 2 (R 2003) *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound - Part 2: Measurement of Long-Term Wide-Area Sound.*

[4] ANSI S12.9-1993/Part 3 (R 2003) *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound - Part 3: Short-term Measurements with an Observer Present.*

[5] ANSI S12.9-1998/Part 5 (R 2003) *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound - Part 5: Sound Level Descriptors for Determination of Compatible Land Use.*

[6] ANSI S1.13-2005 *American National Standard Methods for the Measurement of Sound Pressure Levels in Air.*

3 Terms and definitions

For the purposes of this standard, the terms and definitions given in ANSI S1.1-1994 and the following apply:

3.1(a) adjusted sound exposure. Frequency-weighted sound exposure adjusted for the change in annoyance caused by certain impulsive sounds, the presence of prominent discrete-frequency tones, sounds that startle because of their rapid onset rate, sounds with strong low-frequency content, and the presence of masking background sound. Unit, pascal-squared second (Pa^2s); symbol, *N*.

NOTE 1 Adjustments and frequency weightings for various types of sounds are given in Clause 7.

NOTE 2 The unit of pascal-squared second for adjusted sound exposure has been abbreviated as "pasque."

3.1(b) reference sound exposure. The product of the square of the reference sound pressure of 20 μPa and the reference time of 1 s. Unit, pascal-squared second (Pa^2s); symbol, E_0.

3.1(c) adjusted sound exposure level. Ten times the base-10 logarithm of the ratio of the adjusted sound exposure to the reference sound exposure E_0. Unit, decibel (dB); symbol, L_{NE}.

3.2 adjusted total day-night sound exposure. Frequency-weighted sound exposure for a 24-hour day calculated by adding adjusted sound exposure obtained during the daytime (0700-2200 hours) to ten times adjusted sound exposure obtained during the nighttime (0000-0700 and 2200-2400 hours). Unit, pascal-squared second (Pa^2s); symbol, N_{dn}.

3.3(a) adjusted day-night average sound pressure. Square root of ratio of adjusted total day-night sound exposure to 86,400 s. Unit, pascals (Pa).

3.3(b) adjusted day-night average sound level. Ten times the base-10 logarithm of the ratio of the square of the adjusted day-night average sound pressure to the square of the reference sound pressure of 20 μPa. Unit, decibel (dB); symbol, L_{Ndn}.

3.4 impulsive sound. Sound characterized by brief excursions of sound pressure (acoustic impulses) that significantly exceed the ambient environmental sound pressure. The duration of a single impulsive sound is usually less than one second.

NOTE At the time of publication, no mathematical descriptor existed to unequivocally define the presence of impulsive sound or to separate impulsive sounds into categories.

3.4.1 highly impulsive sound. Sound from one of the following enumerated categories of sound sources: small-arms gunfire, metal hammering, wood hammering, drop hammering, pile driving, drop forging, pneumatic hammering, pavement breaking, metal impacts during rail-yard shunting operation, and riveting.

3.4.2 high-energy impulsive sound. Sound from one of the following enumerated categories of sound sources: quarry and mining explosions, sonic booms, demolition and industrial processes that use high explosives, military ordnance (e.g., armor, artillery and mortar fire, and bombs), explosive ignition of rockets and missiles, explosive industrial circuit breakers, and any other explosive source where the equivalent mass of dynamite exceeds 25 g. Normally, for single impulsive sounds of concern for this Standard, the A-weighted sound exposure level will exceed 65 dB and the C-weighted sound exposure level will exceed 85 dB.

3.4.3 regular impulsive sound. Impulsive sound that is not highly impulsive sound or high-energy impulsive sound.

3.5 onset rate. Nominally, the average rate of change of sound level during the onset of a noise event. Mathematically, onset rate is the rate of change of the A-weighted event sound level between the time the event sound level first exceeds the ambient sound level by 10 dB, and the time the event sound level first exceeds a level that is 10 dB less than the event's maximum fast-time-weighted sound level. Onset rate is defined for those event sound levels for which the maximum A-frequency-weighted, fast-time-weighted sound level exceeds the ambient sound level by at least 30 dB. Unit, decibels per second (dB/s).

NOTE 1 The nominal 125-ms time constant of fast time weighting normally is not small enough to accurately determine onset rate. Onset rate should be determined from the time variation of the level of the squared sound pressure. A digital system that provides a series of short-time-average sound levels may be used. In this case, the averaging time for each sound level in the series should be no greater than 1/10 and no less than 1/25 of the time span over which the onset rate is determined. A digital or analog system with exponential time weighting also may be used. In this case, the exponential time constant should be no greater than 1/4 and no less than 1/10 of the time span over which the onset rate is determined.

NOTE 2 A determination of onset rate should not be unduly influenced by anomalous fluctuations in the sound level.

3.6 time above. The time per stated unit time interval that the sound pressure level exceeds a criterion level (e.g., 30 s per hour). The frequency weighting or filtering (e.g., A-weighting), time weighting or integration time interval, and the unit time interval all must be stated. Typical Units: seconds (s) or minutes.

4 Descriptors for environmental sounds

4.1 Single-event sounds

4.1.1 Descriptors

Sounds from single events such as the passby of a truck, the flyby of an airplane, or an explosion at a quarry are all examples of single-event sounds. Each sound can be characterized by many descriptors. These descriptors include physical quantities and the corresponding levels in decibels. The level of a descriptor and its corresponding physical quantity form a descriptor pair. Three descriptor pairs often are used to describe the sound of single events. For each of these, frequency-weighting A is understood except for high-amplitude impulsive sounds or sounds with strong low-frequency content. The preferred three descriptor pairs are:

peak (frequency-weighted) sound pressure and peak (frequency-weighted) sound pressure level;

maximum exponential-time-weighted sound pressure and maximum sound level; and

sound exposure and sound exposure level.

NOTE 1 For the above descriptor pairs, the frequency weighting should be specified if frequency-weighting A is not employed, e.g., as peak C-weighted sound pressure level, C-weighted sound exposure level.

NOTE 2 For maximum sound pressure (and maximum sound level), the exponential-time-weighting should be specified, e.g., as fast (F) or slow (S).

4.1.2 Event duration

Event duration shall be specified relative to some characteristic of the sound such as the time of occurrence of the maximum sound level or the time some threshold was exceeded. For example, duration may be the total time that the sound level is within 10 dB of the maximum sound level.

4.2 Continuous sounds

Environmental sounds from sources such as transformers, fans, or cooling towers are examples of continuous sounds. Amplitudes of continuous sounds may be constant or slowly varying. Each sound can be characterized by many descriptors. Two descriptor pairs are commonly used to describe a continuous sound. For each of these, frequency-weighting A is commonly used. The two preferred descriptor pairs are:

maximum (exponential-time-weighted) sound and maximum sound level; and

time-average sound pressure and time-average (equivalent-continuous) sound level.

NOTE 1 For both of the above descriptors, the frequency weighting should be specified if frequency-weighting A is not employed.

3.1(b) reference sound exposure. The product of the square of the reference sound pressure of 20 μPa and the reference time of 1 s. Unit, pascal-squared second (Pa^2s); symbol, E_0.

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NOTE 2 A determination of onset rate should not be unduly influenced by anomalous fluctuations in the sound level.

3.6 time above. The time per stated unit time interval that the sound pressure level exceeds a criterion level (e.g., 30 s per hour). The frequency weighting or filtering (e.g., A-weighting), time weighting or integration time interval, and the unit time interval all must be stated. Typical Units: seconds (s) or minutes.

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maximum exponential-time-weighted sound pressure and maximum sound level; and

sound exposure and sound exposure level.

NOTE 1 For the above descriptor pairs, the frequency weighting should be specified if frequency-weighting A is not employed, e.g., as peak C-weighted sound pressure level, C-weighted sound exposure level.

NOTE 2 For maximum sound pressure (and maximum sound level), the exponential-time-weighting should be specified, e.g., as fast (F) or slow (S).

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Event duration shall be specified relative to some characteristic of the sound such as the time of occurrence of the maximum sound level or the time some threshold was exceeded. For example, duration may be the total time that the sound level is within 10 dB of the maximum sound level.

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Environmental sounds from sources such as transformers, fans, or cooling towers are examples of continuous sounds. Amplitudes of continuous sounds may be constant or slowly varying. Each sound can be characterized by many descriptors. Two descriptor pairs are commonly used to describe a continuous sound. For each of these, frequency-weighting A is commonly used. The two preferred descriptor pairs are:

maximum (exponential-time-weighted) sound and maximum sound level; and

time-average sound pressure and time-average (equivalent-continuous) sound level.

NOTE 1 For both of the above descriptors, the frequency weighting should be specified if frequency-weighting A is not employed.

NOTE 2 For maximum (exponential-time-weighted) sound (and maximum sound level), the exponential-time weighting should be specified, e.g., as fast (F) or slow (S).

NOTE 3 See Clauses 5.1.4, 5.1.5, and 5.1.6 in ANSI S12.9-1988/Part 1 (R2003) for definitions of these quantities.

4.3 Repetitive single-event sounds

Repetitive single-event environmental sounds typically are recurrences of single-event sounds. For example, during a day, the sound from traffic on a highway is the sum of the sound from multiple individual vehicle passbys. In this Standard, all repetitive single-event sounds utilize the descriptor for the particular single-event sounds and the corresponding number of events.

5 Sound measurement locations

All sounds, except high-energy impulsive sounds, shall be measured or predicted as if they had been measured by a microphone outdoors, over acoustically absorptive ground (grass), at a height of approximately 1.2 m and with no nearby reflecting surfaces except the ground. Alternative microphone locations may be used, but their acoustical characteristics shall be specified. An example of an alternative location is outside an open, upper-story window in a high-rise apartment building where the purpose is to predict or assess the environmental sound at that location. High-energy impulsive sounds shall be measured or predicted as if they had been measured by a microphone within 50 mm of a hard reflecting surface (e.g., a building wall, roof, or ground plane, as appropriate).

NOTE 1 A reflecting surface is required because sonic booms, which are one form of high-energy impulsive sounds, have traditionally been measured or predicted for a location on a reflecting ground plane or structure.

NOTE 2 To ensure comparable data, sonic booms should be measured on a reflecting ground plane or other equivalent structure.

6 Adjustments for background sound

6.1 General

Annex A discusses a general method to include adjustments for background sound. The general method is applicable to three cases: (1) the sound of concern is very noticeable and detectable in the background setting of interest, (2) the sound of concern is virtually unnoticeable and undetectable in the background setting of interest, and (3) the sound of concern is in a range such that it may be noticeable and detectable only for a portion of the time.

6.2 Specific requirements

When the conditions of 6.1(2) apply and the sound is virtually unnoticeable and undetectable in the background setting of interest, then its sound exposure shall not be included in a calculation of the total sound exposure from multiple sound sources. If some particular sound is excluded, then the physical background setting shall be specified. For example, this setting may be "urban residential not near an arterial street, outdoors," or "suburban residential indoors with windows partially open," or "urban residential near an arterial street, indoors with windows closed."

NOTE Direct measurements may be used to determine the background sound level prevailing for the environment. Procedures in Part 3 of ANSI S12.9 should be used to measure the background sound level.

NOTE 2 For maximum (exponential-time-weighted) sound (and maximum sound level), the exponential-time weighting should be specified, e.g., as fast (F) or slow (S).

NOTE 3 See Clauses 5.1.4, 5.1.5, and 5.1.6 in ANSI S12.9-1988/Part 1 (R2003) for definitions of these quantities.

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Repetitive single-event environmental sounds typically are recurrences of single-event sounds. For example, during a day, the sound from traffic on a highway is the sum of the sound from multiple individual vehicle passbys. In this Standard, all repetitive single-event sounds utilize the descriptor for the particular single-event sounds and the corresponding number of events.

5 Sound measurement locations

All sounds, except high-energy impulsive sounds, shall be measured or predicted as if they had been measured by a microphone outdoors, over acoustically absorptive ground (grass), at a height of approximately 1.2 m and with no nearby reflecting surfaces except the ground. Alternative microphone locations may be used, but their acoustical characteristics shall be specified. An example of an alternative location is outside an open, upper-story window in a high-rise apartment building where the purpose is to predict or assess the environmental sound at that location. High-energy impulsive sounds shall be measured or predicted as if they had been measured by a microphone within 50 mm of a hard reflecting surface (e.g., a building wall, roof, or ground plane, as appropriate).

NOTE 1 A reflecting surface is required because sonic booms, which are one form of high-energy impulsive sounds, have traditionally been measured or predicted for a location on a reflecting ground plane or structure.

NOTE 2 To ensure comparable data, sonic booms should be measured on a reflecting ground plane or other equivalent structure.

6 Adjustments for background sound

6.1 General

Annex A discusses a general method to include adjustments for background sound. The general method is applicable to three cases: (1) the sound of concern is very noticeable and detectable in the background setting of interest, (2) the sound of concern is virtually unnoticeable and undetectable in the background setting of interest, and (3) the sound of concern is in a range such that it may be noticeable and detectable only for a portion of the time.

6.2 Specific requirements

When the conditions of 6.1(2) apply and the sound is virtually unnoticeable and undetectable in the background setting of interest, then its sound exposure shall not be included in a calculation of the total sound exposure from multiple sound sources. If some particular sound is excluded, then the physical background setting shall be specified. For example, this setting may be "urban residential not near an arterial street, outdoors," or "suburban residential indoors with windows partially open," or "urban residential near an arterial street, indoors with windows closed."

NOTE Direct measurements may be used to determine the background sound level prevailing for the environment. Procedures in Part 3 of ANSI S12.9 should be used to measure the background sound level.

Alternatively, the nominal background sound levels given in Part 3 of ANSI S12.9 may be used for various urban environments.

7 Method to assess environmental sounds either singly or in combination

This Standard permits assessment of environmental sounds from individual sources or any combination of sources. If the sound has special characteristics or unusual community response, then adjusted sound exposure or adjusted sound exposure level shall be used to describe the source(s) of sound. In addition, the total adjusted sound environment shall include a weekend daytime adjustment, and is used to predict long-term community response.

7.1 General environmental sounds

General environmental sounds are assessed using frequency-weighting A. (Environmental sounds with special characteristics are described in 7.2.) Sound exposure, sound exposure level, total time-period sound exposure, time-average sound level, total day-night sound exposure, and day-night average sound level are the preferred descriptors. The exposure method of presentation is described in 7.1.1, the left-hand column below. The level method of presentation is described in 7.1.2, the right-hand column below.

7.1.1 Exposure method	**7.1.2 Level method**
7.1.1.1 Sound exposure Sound exposure is a descriptor for characterizing the sound from individual acoustical events. For individual single-event sounds such as vehicle passbys, sound exposure may be directly measured or predicted for the sound-producing events under consideration. For a continuous source, the total time-period sound exposure may be measured or predicted for the time period of interest. A-weighted sound exposure E_A, in pascal-squared seconds, may be calculated as the product of the time-mean-squared, A-weighted sound pressure $\overline{p_A^2}$ in pascals squared and the duration, in seconds, of the time period of interest T, i.e., as $E_A = \overline{p_A^2}T$. (1a)	**7.1.2.1 Sound exposure level** Sound exposure level is a descriptor for characterizing the sound from individual acoustical events. For individual single-event sounds such as vehicle passbys, sound exposure level may be directly measured or predicted for the sound-producing events under consideration. For a continuous source, the sound exposure level may be measured or predicted for the time period of interest. A-weighted sound exposure level L_{AE}, in decibels, may be calculated as ten times the base-10 logarithm of the ratio of the A-weighted sound exposure E_A to the reference sound exposure E_0 defined in 3.1(b), i.e., as $L_{AE} = 10 \lg (E_A/E_0)$. (1b)

7.1.1.2 Total sound exposure

Total sound exposure may be used to characterize the sound of one or more events from individual or combined sources of sound during a time period of interest such as the hour from 1600 to 1700, daytime from 0700 to 2200, or nighttime from 2200 to 2400 and 0000 to 0700. Total A-weighted sound exposure in a time period $E_{A(period)}$, in pascal-squared seconds, is the sum of the N sound exposures E_{Ai} from the i-th individual single-event sounds during the stated time period.

In mathematical notation,

$$E_{A(period)} = \sum_{i=1}^{N} E_{A\,i}\,. \tag{2a}$$

NOTE The stated time period may be of any duration such as one daytime period for one day or for any number of days up to 365 days of a year. Furthermore, the sound exposure E_{Ai} for the i-th event may be for any one sound source or a combination of sources.

7.1.2.2 Time-average sound level

Time-average sound level may be used to characterize the sound of one or more events from individual or combined sources of sound during a time period of interest such as the hour from 1600 to 1700, daytime from 0700 to 2200, or nighttime from 0000 to 0700 and 2200 to 2400. Time-average, A-weighted sound level $L_{A(period)}$, in decibels, is calculated from the total sound exposure in the period.

In mathematical notation,

$$L_{A(period)} = 10\lg\left[(T_0 / T)\sum_{i=1}^{I} 10^{0.1L_{AEi}}\right], \tag{2b}$$

where T_0 is the reference time of 1 s and T is the total time period in seconds for the duration of the time average.

NOTE For a constant time-average sound level of 60 dB, sound exposure level $L_{AE(period)}$ and sound exposure $E_{A(period)}$ are related as shown in Table 1 for selected integration time periods T.

7.1.1.3 Total day-night sound exposure

Total day-night sound exposure is a descriptor for characterizing long-term acoustical environments from sounds of one or more events from individual or combined sound sources. Total day-night sound exposure E_{Adn}, in pascal-squared seconds, is the sum of daytime sound exposures plus 10 times the sum of nighttime sound exposures where daytime is the 15 hours from 0700 to 2200 and nighttime is the nine hours from 0000 to 0700 and from 2200 to 2400 in any 24-hour day.

In mathematical notation,

$$E_{Adn} = \sum_{i=1}^{N_d} E_{A\,i} + 10\sum_{i=1}^{N_n} E_{A\,i}\,, \tag{3a}$$

$$= E_{Ad} + 10E_{An}\,,$$

where N_d is the number of daytime sound exposures and N_n is the number of nighttime sound exposures.

7.1.2.3 Day-night average sound level

Day-night average sound level is a descriptor for characterizing long-term acoustical environments from sounds of one or more events from individual or combined sound sources. Day-night average sound level, in decibels, is calculated from ten times the base-10 logarithm of the sum of the daytime sound exposures plus the nighttime sound exposures, where sound exposure levels or sound levels occurring during nighttime hours are weighted by 10 dB.

In mathematical notation,

$$L_{dn} = 10\lg\left[(15/24)(T_0 / T_d)\sum_{i=1}^{N_d} 10^{0.1L_{AEi}}\right] + 10\lg\left[(9/24)(T_0 / T_n)\sum_{i=1}^{N_n} 10^{0.1(L_{AEi}+10)}\right] \tag{3b}$$

$$= 10\lg\left[(15/24)10^{0.1L_d} + (9/24)10^{0.1(L_n+10)}\right]$$

where T_d = the 15 daytime hours or 54,000 s and T_n = the 9 nighttime hours or 32,400 s.

Table 1 — Relation between sound exposure level and sound exposure for a constant sound level of 60 dB.

T	$L_{AE(period)}$ (dB)	$E_{A(period)}$ (Pa^2s)	T	$L_{AE(period)}$ (dB)	$E_{A(period)}$ (Pa^2s)
1 s	60.0	0.0004	1 h	95.6	1.44
1 min	77.8	0.024	24 h	109.4	34.6

NOTE A day-night sound exposure of 10 Pa^2s corresponds to a nominal day-night average sound level of 55 dB. A day night average sound level of 65 dB corresponds to a nominal total day-night sound exposure of 100 Pa^2s.

7.2 Adjustments to general environmental sound

Research has shown that frequency-weighting A, alone, is not sufficient to assess sounds characterized by tonality, impulsiveness, very fast onset rates, or strong low-frequency content. Also, research has shown that frequency-weighting A, alone, under-predicts the community response to aircraft noise and to weekend daytime noise. To predict the long-term response of a community to sounds with some of those special characteristics, sources, or times of occurrence, an adjustment factor is used to multiply the sound exposure or an adjustment in decibels is added to the A-weighted sound exposure level. Annex H contains a bibliography of reports and articles describing the technical basis of the assessment and prediction methods of this Part 4.

Sound exposure and sound exposure level as discussed in 7.1.1.1 and 7.1.2.1 are descriptors for characterizing the environmental sound from individual acoustical events. Frequency weighting A is used for all sound sources except (1) high-energy impulsive sounds for which frequency-weighting C is used, and (2) sounds with strong low-frequency content. Adjusted sound exposure is the quantity used in this Standard to assess sounds without and with special characteristics with respect to the potential community response. For general environmental sounds without special characteristics (i.e., sounds assessed by the method of 7.1), adjusted sound exposure is numerically equal to A-weighted sound exposure.

For sounds with special characteristics, sources, or times of occurrence, the calculation of adjusted sound exposure or adjusted sound exposure level is performed as described below. The adjusted exposure method of presentation is described in 7.2.1, the left-hand column below. The adjusted level method of presentation is described in 7.2.2, the right-hand column below.

7.2.1 Adjusted exposure method

7.2.1.1 Adjusted sound exposure

For any sound except high-energy impulsive sound or sounds having strong low-frequency content, adjusted sound exposure N_j is given by the sound exposure E_i for the i-th single-event sound multiplied by the adjustment factor K_j for the j-th type of sound, as given in Table 2.

In mathematical notation,

$$N_j = K_j E_i. \quad (4a)$$

7.2.2 Adjusted level method

7.2.2.1 Adjusted sound exposure level

For any sound except high-energy impulsive sound or sounds having strong low-frequency content, adjusted sound exposure level L_{Nj} is given by the sound exposure level L_{Ei} for the i-th single-event sound plus the level adjustment $\overline{K}_i$ for the j-th type of sound, as given in Table 2.

In mathematical notation,

$$L_{Nj} = L_{Ei} + \overline{K_j}. \quad (4b)$$

Equations to convert between adjusted sound exposure, in pascal-squared seconds, and adjusted sound exposure level, in decibels, are:

$$\begin{aligned} L_{Nj} &= 10\,\lg(N_j / p_0^2 T_0) \\ &= 10\,\lg(N_j / T_0) + 94 \end{aligned} \tag{5a}$$

$$N_j = (T_0)10^{0.1(L_{Nj}-94)}, \tag{5b}$$

where $-10\,\lg(p_0^2) = 94$ dB and T_0 is the reference time of 1 s.

7.2.1.2 Adjusted total sound exposure

During a time period of interest such as daytime, the adjusted total sound exposure $N_{(\mathrm{period})}$, in pascal-squared seconds, is the sum of the adjusted sound exposures N_{ij} from each individual event i of I events, for each source of sound j of J sources during the stated time period.

In mathematical notation,

$$N_{(\mathrm{period})} = \sum_{i=1}^{I} \sum_{j=1}^{J} N_{ij}\,. \tag{6a}$$

The stated time period may be of any duration such as one daytime period for one day or for any number of days up to 365 days of a year. Furthermore, the adjusted sound exposure N_{ij} for the i-th event may be for any one source j or a combination of sources.

In equation (6a), sounds without special characteristics are included with an adjustment factor of 1 as shown in Table 2.

7.2.2.2 Adjusted time-average sound level

During a time period of interest such as daytime, the adjusted time-average sound level $L_{N(\mathrm{period})}$, in decibels, is calculated from the adjusted sound exposure levels L_{Nij} from each individual event i of I events, for each source of sound j of J sources during the stated time period.

In mathematical notation,

$$L_{N(\mathrm{period})} = 10\,\lg\left[(T_0 / T) \sum_{i=1}^{I} \sum_{j=1}^{J} 10^{0.1 L_{Nij}}\right]. \tag{6b}$$

The stated time period T, in seconds, may be of any duration such as one daytime period for one day or for any number of days up to 365 days of a year. Furthermore, the adjusted sound exposure level L_{Nij} for the i-th event may be for any one source j or a combination of sources.

In equation (6b), sounds without special characteristics are included with a level adjustment of 0 as shown in Table 2.

For an averaging time period T in seconds, equations to convert adjusted total sound exposure in pascal-squared seconds and adjusted time-average sound level in decibels are:

$$\begin{aligned} L_{N(\mathrm{period})} &= 10\,\lg\,(N_{(\mathrm{period})} / p_0^2 T_0) - 10\,\lg(T / T_0) \\ &= 10\,\lg\,(N_{(\mathrm{period})} / T) + 94 \end{aligned} \tag{7a}$$

$$N_{(\mathrm{period})} = (T)10^{0.1(L_{N(\mathrm{period})}-94)} \tag{7b}$$

Power Tool Institute, Inc. .... W.D. Spencer
.... M. Hickok (Alt.)

Quest Technologies, Inc. .... M. Wurm
.... P. Battenberg (Alt.)

Rubber Manufacturers Association .... S. Butcher
.... A. Hartke (Alt.)

SAE .... C. Michaels

U.S. Air Force (USAF) .... R. McKinley

U.S. Army Aeromedical Research Lab .... W. Ahroon
.... N. Alem (Alt.)

U.S. Army Center for Health Promotion and Preventive Medicine .... W.A. Russell
.... W. Whiteford (Alt.)

U.S. Army Construction Engineering Research Laboratories .... M. White
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Suggestions for improvements of this standard will be welcomed. They should be sent to Accredited Standards Committee S12, Noise, in care of the Standards Secretariat of the Acoustical Society of America, 35 Pinelawn Road, Suite 114E, Melville, New York 11747-3177. Telephone: 631-390-0215; FAX: 631-390-0217; E-mail: asastds@aip.org

Introduction

0.1 Part 1 of ANSI S12.9 defines day-night average sound level and other descriptors of community noise. Part 2 of ANSI S12.9 describes measurement procedures. ANSI S12.9/Part 5 provides a recommended relation between long-term usages of land and day-night average sound level for purposes of long-term land-use planning. Since the early 1970s, many agencies within the United States of America have used day-night average sound level as the fundamental descriptor to predict the community response to environmental sounds.

0.2 The 1978 seminal paper by T.J. Schultz demonstrated the efficacy of day-night average sound level for predicting the annoyance response of a community as a result of noise from highway traffic, railroad, aircraft, and some industrial sites. Implementation of the concept of day-night average sound level for prediction of community response often combined the sound exposures from such sources.

0.3 Day-night average sound level has been used to predict the annoyance response of communities to types of noises that were not included in the Schultz database for the relation between the percentage of a population expressing high annoyance and the corresponding day-night average sound level. These additional types of noises include sounds with special characteristics, such as impulsiveness, dominant pure tones, rapid onset, and strong low-frequency content.

0.4 Technical reports and articles published in refereed engineering and scientific journals demonstrated that the community response to these sounds may be predicted, provided suitable adjustments are applied. A practical procedure to apply these adjustments is provided by this Standard.

0.5 For situations where activity interference is the major concern, use of adjusted day-night average sound level or adjusted total day-night sound exposure may not be appropriate. For example, day-night average sound level without adjustments may be a better predictor of speech interference than adjusted day-night average sound level. Descriptors such as maximum A-weighted sound level, time-above, or speech interference level may be even more appropriate for predicting speech interference.

American National Standard

QUANTITIES AND PROCEDURES FOR DESCRIPTION AND MEASUREMENT OF ENVIRONMENTAL SOUND — PART 4: NOISE ASSESSMENT AND PREDICTION OF LONG-TERM COMMUNITY RESPONSE

1 Scope

1.1 This Standard specifies methods to assess environmental sounds and to predict the potential annoyance response of a community to outdoor long-term noise from any and all types of environmental sounds from one or more discrete or distributed sound sources. The sound sources may be separate or in various combinations. Application of the prediction method is limited to areas where people reside and to related long-term land uses.

NOTE The long-term period is typically one year. However, the user of this Standard can employ these methods for shorter periods of time, but they should report this change and not attempt to predict percent highly annoyed using Clause 8.3 or Annex F, since the Annex F data all represent long-term situations.

1.2 This Standard describes adjustments for sounds that have special characteristics so that the long-term community response to such sounds can be predicted by a method that is based on day-night average sound level or total day-night sound exposure. Sounds, such as from highway traffic, are evaluated directly by sound exposure or sound level without adjustment. The prediction method is directly analogous to the use of day-night average sound level to predict the response of a community to general environmental sounds.

1.3 This Standard does not address the effects of short-term exposure of people to intrusive sounds in locations such as parks and wilderness areas. The Standard also does not address other effects of noise such as sleep disturbance or health effects. This Standard does not provide a method to predict the response of a community to short-term, infrequent, non-repetitive sources of sound.

1.4 This Standard introduces the application of new descriptors: adjusted sound exposure and adjusted sound exposure level. The new descriptors are closely related to sound exposure and sound exposure level, respectively. The new descriptors are introduced to facilitate the prediction of the response of communities to the wide range of outdoor sounds covered by the scope of the Standard.

1.5 The sounds are assessed either singly or in combination, allowing for consideration, when necessary, of the special characteristics of impulsiveness, tonality, onset rate, and low-frequency content. In the same manner as sound exposure and sound exposure level are used to generate total day-night sound exposure or total day-night average sound level, adjusted sound exposure or adjusted sound exposure level are used to generate adjusted total day-night sound exposure or adjusted day-night average sound level.

1.6 Annoyance is not the only possible measure of community response. One frequently cited measure is numbers of complaints, sometimes normalized to numbers of inhabitants. Complaints can be particularly relevant near factories and plants, by airports and military installations, etc. Complaints do not correlate well with long-term average metrics such as DNL (see Refs. 7 and 8 for

example). Unfortunately, in general, metrics to predict the likelihood and prevalence of complaints do not yet exist with sufficient accuracy. One notable exception is the high-energy impulse sound generated by military activities and similar civilian noise sources, and informative Annex G provides procedures for assessing the risk of noise complaints from such sources.

1.7 The addition of adjustments eliminates the possibility to measure the total adjusted sound exposure or sound exposure level in a general situation that comprises a variety of sound sources (e.g., the combination of a highway leading to an airport and the airport itself). As a possible measurable alternative, this Standard introduces a new metric based on the equal-loudness level contours that were contained in ISO 226:1987. This new method uses the equal-loudness level contours as a set of dynamic filters that vary both with amplitude and frequency. This method is described in informative Annex H.

2 Normative references

The following referenced documents are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

[1] ANSI S1.1-1994 (R 2004) *American National Standard Acoustical Terminology.*

[2] ANSI S12.9-1988/Part 1 (R 2003) *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound - Part 1.*

[3] ANSI S12.9-1992/Part 2 (R 2003) *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound - Part 2: Measurement of Long-Term Wide-Area Sound.*

[4] ANSI S12.9-1993/Part 3 (R 2003) *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound - Part 3: Short-term Measurements with an Observer Present.*

[5] ANSI S12.9-1998/Part 5 (R 2003) *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound - Part 5: Sound Level Descriptors for Determination of Compatible Land Use.*

[6] ANSI S1.13-2005 *American National Standard Methods for the Measurement of Sound Pressure Levels in Air.*

3 Terms and definitions

For the purposes of this standard, the terms and definitions given in ANSI S1.1-1994 and the following apply:

3.1(a) adjusted sound exposure. Frequency-weighted sound exposure adjusted for the change in annoyance caused by certain impulsive sounds, the presence of prominent discrete-frequency tones, sounds that startle because of their rapid onset rate, sounds with strong low-frequency content, and the presence of masking background sound. Unit, pascal-squared second (Pa^2s); symbol, *N*.

NOTE 1 Adjustments and frequency weightings for various types of sounds are given in Clause 7.

NOTE 2 The unit of pascal-squared second for adjusted sound exposure has been abbreviated as "pasque."

3.1(b) reference sound exposure. The product of the square of the reference sound pressure of 20 μPa and the reference time of 1 s. Unit, pascal-squared second (Pa^2s); symbol, E_0.

3.1(c) adjusted sound exposure level. Ten times the base-10 logarithm of the ratio of the adjusted sound exposure to the reference sound exposure E_0. Unit, decibel (dB); symbol, L_{NE}.

3.2 adjusted total day-night sound exposure. Frequency-weighted sound exposure for a 24-hour day calculated by adding adjusted sound exposure obtained during the daytime (0700-2200 hours) to ten times adjusted sound exposure obtained during the nighttime (0000-0700 and 2200-2400 hours). Unit, pascal-squared second (Pa^2s); symbol, N_{dn}.

3.3(a) adjusted day-night average sound pressure. Square root of ratio of adjusted total day-night sound exposure to 86,400 s. Unit, pascals (Pa).

3.3(b) adjusted day-night average sound level. Ten times the base-10 logarithm of the ratio of the square of the adjusted day-night average sound pressure to the square of the reference sound pressure of 20 μPa. Unit, decibel (dB); symbol, L_{Ndn}.

3.4 impulsive sound. Sound characterized by brief excursions of sound pressure (acoustic impulses) that significantly exceed the ambient environmental sound pressure. The duration of a single impulsive sound is usually less than one second.

NOTE At the time of publication, no mathematical descriptor existed to unequivocally define the presence of impulsive sound or to separate impulsive sounds into categories.

3.4.1 highly impulsive sound. Sound from one of the following enumerated categories of sound sources: small-arms gunfire, metal hammering, wood hammering, drop hammering, pile driving, drop forging, pneumatic hammering, pavement breaking, metal impacts during rail-yard shunting operation, and riveting.

3.4.2 high-energy impulsive sound. Sound from one of the following enumerated categories of sound sources: quarry and mining explosions, sonic booms, demolition and industrial processes that use high explosives, military ordnance (e.g., armor, artillery and mortar fire, and bombs), explosive ignition of rockets and missiles, explosive industrial circuit breakers, and any other explosive source where the equivalent mass of dynamite exceeds 25 g. Normally, for single impulsive sounds of concern for this Standard, the A-weighted sound exposure level will exceed 65 dB and the C-weighted sound exposure level will exceed 85 dB.

3.4.3 regular impulsive sound. Impulsive sound that is not highly impulsive sound or high-energy impulsive sound.

3.5 onset rate. Nominally, the average rate of change of sound level during the onset of a noise event. Mathematically, onset rate is the rate of change of the A-weighted event sound level between the time the event sound level first exceeds the ambient sound level by 10 dB, and the time the event sound level first exceeds a level that is 10 dB less than the event's maximum fast-time-weighted sound level. Onset rate is defined for those event sound levels for which the maximum A-frequency-weighted, fast-time-weighted sound level exceeds the ambient sound level by at least 30 dB. Unit, decibels per second (dB/s).

NOTE 1 The nominal 125-ms time constant of fast time weighting normally is not small enough to accurately determine onset rate. Onset rate should be determined from the time variation of the level of the squared sound pressure. A digital system that provides a series of short-time-average sound levels may be used. In this case, the averaging time for each sound level in the series should be no greater than 1/10 and no less than 1/25 of the time span over which the onset rate is determined. A digital or analog system with exponential time weighting also may be used. In this case, the exponential time constant should be no greater than 1/4 and no less than 1/10 of the time span over which the onset rate is determined.

NOTE 2 A determination of onset rate should not be unduly influenced by anomalous fluctuations in the sound level.

3.6 time above. The time per stated unit time interval that the sound pressure level exceeds a criterion level (e.g., 30 s per hour). The frequency weighting or filtering (e.g., A-weighting), time weighting or integration time interval, and the unit time interval all must be stated. Typical Units: seconds (s) or minutes.

4 Descriptors for environmental sounds

4.1 Single-event sounds

4.1.1 Descriptors

Sounds from single events such as the passby of a truck, the flyby of an airplane, or an explosion at a quarry are all examples of single-event sounds. Each sound can be characterized by many descriptors. These descriptors include physical quantities and the corresponding levels in decibels. The level of a descriptor and its corresponding physical quantity form a descriptor pair. Three descriptor pairs often are used to describe the sound of single events. For each of these, frequency-weighting A is understood except for high-amplitude impulsive sounds or sounds with strong low-frequency content. The preferred three descriptor pairs are:

peak (frequency-weighted) sound pressure and peak (frequency-weighted) sound pressure level;

maximum exponential-time-weighted sound pressure and maximum sound level; and

sound exposure and sound exposure level.

NOTE 1 For the above descriptor pairs, the frequency weighting should be specified if frequency-weighting A is not employed, e.g., as peak C-weighted sound pressure level, C-weighted sound exposure level.

NOTE 2 For maximum sound pressure (and maximum sound level), the exponential-time-weighting should be specified, e.g., as fast (F) or slow (S).

4.1.2 Event duration

Event duration shall be specified relative to some characteristic of the sound such as the time of occurrence of the maximum sound level or the time some threshold was exceeded. For example, duration may be the total time that the sound level is within 10 dB of the maximum sound level.

4.2 Continuous sounds

Environmental sounds from sources such as transformers, fans, or cooling towers are examples of continuous sounds. Amplitudes of continuous sounds may be constant or slowly varying. Each sound can be characterized by many descriptors. Two descriptor pairs are commonly used to describe a continuous sound. For each of these, frequency-weighting A is commonly used. The two preferred descriptor pairs are:

maximum (exponential-time-weighted) sound and maximum sound level; and

time-average sound pressure and time-average (equivalent-continuous) sound level.

NOTE 1 For both of the above descriptors, the frequency weighting should be specified if frequency-weighting A is not employed.

NOTE 2 For maximum (exponential-time-weighted) sound (and maximum sound level), the exponential-time weighting should be specified, e.g., as fast (F) or slow (S).

NOTE 3 See Clauses 5.1.4, 5.1.5, and 5.1.6 in ANSI S12.9-1988/Part 1 (R2003) for definitions of these quantities.

4.3 Repetitive single-event sounds

Repetitive single-event environmental sounds typically are recurrences of single-event sounds. For example, during a day, the sound from traffic on a highway is the sum of the sound from multiple individual vehicle passbys. In this Standard, all repetitive single-event sounds utilize the descriptor for the particular single-event sounds and the corresponding number of events.

5 Sound measurement locations

All sounds, except high-energy impulsive sounds, shall be measured or predicted as if they had been measured by a microphone outdoors, over acoustically absorptive ground (grass), at a height of approximately 1.2 m and with no nearby reflecting surfaces except the ground. Alternative microphone locations may be used, but their acoustical characteristics shall be specified. An example of an alternative location is outside an open, upper-story window in a high-rise apartment building where the purpose is to predict or assess the environmental sound at that location. High-energy impulsive sounds shall be measured or predicted as if they had been measured by a microphone within 50 mm of a hard reflecting surface (e.g., a building wall, roof, or ground plane, as appropriate).

NOTE 1 A reflecting surface is required because sonic booms, which are one form of high-energy impulsive sounds, have traditionally been measured or predicted for a location on a reflecting ground plane or structure.

NOTE 2 To ensure comparable data, sonic booms should be measured on a reflecting ground plane or other equivalent structure.

6 Adjustments for background sound

6.1 General

Annex A discusses a general method to include adjustments for background sound. The general method is applicable to three cases: (1) the sound of concern is very noticeable and detectable in the background setting of interest, (2) the sound of concern is virtually unnoticeable and undetectable in the background setting of interest, and (3) the sound of concern is in a range such that it may be noticeable and detectable only for a portion of the time.

6.2 Specific requirements

When the conditions of 6.1(2) apply and the sound is virtually unnoticeable and undetectable in the background setting of interest, then its sound exposure shall not be included in a calculation of the total sound exposure from multiple sound sources. If some particular sound is excluded, then the physical background setting shall be specified. For example, this setting may be "urban residential not near an arterial street, outdoors," or "suburban residential indoors with windows partially open," or "urban residential near an arterial street, indoors with windows closed."

NOTE Direct measurements may be used to determine the background sound level prevailing for the environment. Procedures in Part 3 of ANSI S12.9 should be used to measure the background sound level.

Alternatively, the nominal background sound levels given in Part 3 of ANSI S12.9 may be used for various urban environments.

7 Method to assess environmental sounds either singly or in combination

This Standard permits assessment of environmental sounds from individual sources or any combination of sources. If the sound has special characteristics or unusual community response, then adjusted sound exposure or adjusted sound exposure level shall be used to describe the source(s) of sound. In addition, the total adjusted sound environment shall include a weekend daytime adjustment, and is used to predict long-term community response.

7.1 General environmental sounds

General environmental sounds are assessed using frequency-weighting A. (Environmental sounds with special characteristics are described in 7.2.) Sound exposure, sound exposure level, total time-period sound exposure, time-average sound level, total day-night sound exposure, and day-night average sound level are the preferred descriptors. The exposure method of presentation is described in 7.1.1, the left-hand column below. The level method of presentation is described in 7.1.2, the right-hand column below.

7.1.1 Exposure method	**7.1.2 Level method**
7.1.1.1 Sound exposure Sound exposure is a descriptor for characterizing the sound from individual acoustical events. For individual single-event sounds such as vehicle passbys, sound exposure may be directly measured or predicted for the sound-producing events under consideration. For a continuous source, the total time-period sound exposure may be measured or predicted for the time period of interest. A-weighted sound exposure E_A, in pascal-squared seconds, may be calculated as the product of the time-mean-squared, A-weighted sound pressure $\overline{p_A^2}$ in pascals squared and the duration, in seconds, of the time period of interest T, i.e., as $E_A = \overline{p_A^2}T$. (1a)	**7.1.2.1 Sound exposure level** Sound exposure level is a descriptor for characterizing the sound from individual acoustical events. For individual single-event sounds such as vehicle passbys, sound exposure level may be directly measured or predicted for the sound-producing events under consideration. For a continuous source, the sound exposure level may be measured or predicted for the time period of interest. A-weighted sound exposure level L_{AE}, in decibels, may be calculated as ten times the base-10 logarithm of the ratio of the A-weighted sound exposure E_A to the reference sound exposure E_0 defined in 3.1(b), i.e., as $L_{AE} = 10 \lg (E_A/E_0)$. (1b)

7.1.1.2 Total sound exposure

Total sound exposure may be used to characterize the sound of one or more events from individual or combined sources of sound during a time period of interest such as the hour from 1600 to 1700, daytime from 0700 to 2200, or nighttime from 2200 to 2400 and 0000 to 0700. Total A-weighted sound exposure in a time period $E_{\mathrm{A(period)}}$, in pascal-squared seconds, is the sum of the N sound exposures $E_{\mathrm{A}i}$ from the i-th individual single-event sounds during the stated time period.

In mathematical notation,

$$E_{\mathrm{A(period)}} = \sum_{i=1}^{\mathrm{N}} E_{\mathrm{A}\,i}\,. \qquad \text{(2a)}$$

NOTE The stated time period may be of any duration such as one daytime period for one day or for any number of days up to 365 days of a year. Furthermore, the sound exposure $E_{\mathrm{A}i}$ for the i-th event may be for any one sound source or a combination of sources.

7.1.2.2 Time-average sound level

Time-average sound level may be used to characterize the sound of one or more events from individual or combined sources of sound during a time period of interest such as the hour from 1600 to 1700, daytime from 0700 to 2200, or nighttime from 0000 to 0700 and 2200 to 2400. Time-average, A-weighted sound level $L_{\mathrm{A(period)}}$, in decibels, is calculated from the total sound exposure in the period.

In mathematical notation,

$$L_{\mathrm{A(period)}} = 10\lg\left[(T_0 / T)\sum_{i=1}^{\mathrm{I}} 10^{0.1 L_{\mathrm{A}Ei}}\right], \qquad \text{(2b)}$$

where T_0 is the reference time of 1 s and T is the total time period in seconds for the duration of the time average.

NOTE For a constant time-average sound level of 60 dB, sound exposure level $L_{\mathrm{A}E\mathrm{(period)}}$ and sound exposure $E_{\mathrm{A(period)}}$ are related as shown in Table 1 for selected integration time periods T.

7.1.1.3 Total day-night sound exposure

Total day-night sound exposure is a descriptor for characterizing long-term acoustical environments from sounds of one or more events from individual or combined sound sources. Total day-night sound exposure E_{Adn}, in pascal-squared seconds, is the sum of daytime sound exposures plus 10 times the sum of nighttime sound exposures where daytime is the 15 hours from 0700 to 2200 and nighttime is the nine hours from 0000 to 0700 and from 2200 to 2400 in any 24-hour day.

In mathematical notation,

$$\begin{aligned} E_{\mathrm{Adn}} &= \sum_{i=1}^{\mathrm{N_d}} E_{\mathrm{A}i} + 10\sum_{i=1}^{\mathrm{N_n}} E_{\mathrm{A}i}\,, \\ &= E_{\mathrm{Ad}} + 10E_{\mathrm{An}}\,, \end{aligned} \qquad \text{(3a)}$$

where $\mathrm{N_d}$ is the number of daytime sound exposures and $\mathrm{N_n}$ is the number of nighttime sound exposures.

7.1.2.3 Day-night average sound level

Day-night average sound level is a descriptor for characterizing long-term acoustical environments from sounds of one or more events from individual or combined sound sources. Day-night average sound level, in decibels, is calculated from ten times the base-10 logarithm of the sum of the daytime sound exposures plus the nighttime sound exposures, where sound exposure levels or sound levels occurring during nighttime hours are weighted by 10 dB.

In mathematical notation,

$$\begin{aligned} L_{\mathrm{dn}} &= 10\lg\left[(15/24)(T_0 / T_{\mathrm{d}})\sum_{i=1}^{\mathrm{N_d}} 10^{0.1 L_{\mathrm{A}Ei}}\right] + \\ &\quad 10\lg\left[(9/24)(T_0 / T_{\mathrm{n}})\sum_{i=1}^{\mathrm{N_n}} 10^{0.1(L_{\mathrm{A}Ei} + 10)}\right] \\ &= 10\lg\left[(15/24)10^{0.1 L_{\mathrm{d}}} + (9/24)10^{0.1(L_{\mathrm{n}} + 10)}\right] \end{aligned} \qquad \text{(3b)}$$

where T_{d} = the 15 daytime hours or 54,000 s and T_{n} = the 9 nighttime hours or 32,400 s.

Table 1 — Relation between sound exposure level and sound exposure for a constant sound level of 60 dB.

T	$L_{AE(period)}$ (dB)	$E_{A(period)}$ (Pa^2s)	T	$L_{AE(period)}$ (dB)	$E_{A(period)}$ (Pa^2s)
1 s	60.0	0.0004	1 h	95.6	1.44
1 min	77.8	0.024	24 h	109.4	34.6

NOTE A day-night sound exposure of 10 Pa^2s corresponds to a nominal day-night average sound level of 55 dB. A day night average sound level of 65 dB corresponds to a nominal total day-night sound exposure of 100 Pa^2s.

7.2 Adjustments to general environmental sound

Research has shown that frequency-weighting A, alone, is not sufficient to assess sounds characterized by tonality, impulsiveness, very fast onset rates, or strong low-frequency content. Also, research has shown that frequency-weighting A, alone, under-predicts the community response to aircraft noise and to weekend daytime noise. To predict the long-term response of a community to sounds with some of those special characteristics, sources, or times of occurrence, an adjustment factor is used to multiply the sound exposure or an adjustment in decibels is added to the A-weighted sound exposure level. Annex H contains a bibliography of reports and articles describing the technical basis of the assessment and prediction methods of this Part 4.

Sound exposure and sound exposure level as discussed in 7.1.1.1 and 7.1.2.1 are descriptors for characterizing the environmental sound from individual acoustical events. Frequency weighting A is used for all sound sources except (1) high-energy impulsive sounds for which frequency-weighting C is used, and (2) sounds with strong low-frequency content. Adjusted sound exposure is the quantity used in this Standard to assess sounds without and with special characteristics with respect to the potential community response. For general environmental sounds without special characteristics (i.e., sounds assessed by the method of 7.1), adjusted sound exposure is numerically equal to A-weighted sound exposure.

For sounds with special characteristics, sources, or times of occurrence, the calculation of adjusted sound exposure or adjusted sound exposure level is performed as described below. The adjusted exposure method of presentation is described in 7.2.1, the left-hand column below. The adjusted level method of presentation is described in 7.2.2, the right-hand column below.

7.2.1 Adjusted exposure method	**7.2.2 Adjusted level method**
7.2.1.1 Adjusted sound exposure For any sound except high-energy impulsive sound or sounds having strong low-frequency content, adjusted sound exposure N_j is given by the sound exposure E_i for the i-th single-event sound multiplied by the adjustment factor K_j for the j-th type of sound, as given in Table 2. In mathematical notation, $N_j = K_j E_i$. (4a)	**7.2.2.1 Adjusted sound exposure level** For any sound except high-energy impulsive sound or sounds having strong low-frequency content, adjusted sound exposure level L_{Nj} is given by the sound exposure level L_{Ei} for the i-th single-event sound plus the level adjustment $\overline{K}_i$ for the j-th type of sound, as given in Table 2. In mathematical notation, $L_{Nj} = L_{Ei} + \overline{K}_j$. (4b)

Equations to convert between adjusted sound exposure, in pascal-squared seconds, and adjusted sound exposure level, in decibels, are:

$$\begin{aligned} L_{Nj} &= 10\lg(N_j / p_0^2 T_0) \\ &= 10\lg(N_j / T_0) + 94 \end{aligned} \qquad (5a)$$

$$N_j = (T_0)10^{0.1(L_{Nj}-94)}, \qquad (5b)$$

where $-10\lg(p_0^2) = 94$ dB and T_0 is the reference time of 1 s.

7.2.1.2 Adjusted total sound exposure

During a time period of interest such as daytime, the adjusted total sound exposure $N_{(\text{period})}$, in pascal-squared seconds, is the sum of the adjusted sound exposures N_{ij} from each individual event i of I events, for each source of sound j of J sources during the stated time period.

In mathematical notation,

$$N_{(\text{period})} = \sum_{i=1}^{I} \sum_{j=1}^{J} N_{ij}. \qquad (6a)$$

The stated time period may be of any duration such as one daytime period for one day or for any number of days up to 365 days of a year. Furthermore, the adjusted sound exposure N_{ij} for the i-th event may be for any one source j or a combination of sources.

In equation (6a), sounds without special characteristics are included with an adjustment factor of 1 as shown in Table 2.

7.2.2.2 Adjusted time-average sound level

During a time period of interest such as daytime, the adjusted time-average sound level $L_{N(\text{period})}$, in decibels, is calculated from the adjusted sound exposure levels L_{Nij} from each individual event i of I events, for each source of sound j of J sources during the stated time period.

In mathematical notation,

$$L_{N(\text{period})} = 10\lg\left[(T_0 / T)\sum_{i=1}^{I} \sum_{j=1}^{J} 10^{0.1 L_{Nij}}\right]. \qquad (6b)$$

The stated time period T, in seconds, may be of any duration such as one daytime period for one day or for any number of days up to 365 days of a year. Furthermore, the adjusted sound exposure level L_{Nij} for the i-th event may be for any one source j or a combination of sources.

In equation (6b), sounds without special characteristics are included with a level adjustment of 0 as shown in Table 2.

For an averaging time period T in seconds, equations to convert adjusted total sound exposure in pascal-squared seconds and adjusted time-average sound level in decibels are:

$$\begin{aligned} L_{N(\text{period})} &= 10\lg(N_{(\text{period})} / p_0^2 T_0) - 10\lg(T / T_0) \\ &= 10\lg(N_{(\text{period})} / T) + 94 \end{aligned} \qquad (7a)$$

$$N_{(\text{period})} = (T)10^{0.1(L_{N(\text{period})}-94)} \qquad (7b)$$

Power Tool Institute, Inc. .... W.D. Spencer
.... M. Hickok (Alt.)

Quest Technologies, Inc. .... M. Wurm
.... P. Battenberg (Alt.)

Rubber Manufacturers Association .... S. Butcher
.... A. Hartke (Alt.)

SAE .... C. Michaels

U.S. Air Force (USAF) .... R. McKinley

U.S. Army Aeromedical Research Lab .... W. Ahroon
.... N. Alem (Alt.)

U.S. Army Center for Health Promotion and Preventive Medicine .... W.A. Russell
.... W. Whiteford (Alt.)

U.S. Army Construction Engineering Research Laboratories .... M. White
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U.S. Department of Transportation .... A. Konheim

U.S. Army Human Research and Engineering Directorate .... T.R. Letowski
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Introduction

0.1 Part 1 of ANSI S12.9 defines day-night average sound level and other descriptors of community noise. Part 2 of ANSI S12.9 describes measurement procedures. ANSI S12.9/Part 5 provides a recommended relation between long-term usages of land and day-night average sound level for purposes of long-term land-use planning. Since the early 1970s, many agencies within the United States of America have used day-night average sound level as the fundamental descriptor to predict the community response to environmental sounds.

0.2 The 1978 seminal paper by T.J. Schultz demonstrated the efficacy of day-night average sound level for predicting the annoyance response of a community as a result of noise from highway traffic, railroad, aircraft, and some industrial sites. Implementation of the concept of day-night average sound level for prediction of community response often combined the sound exposures from such sources.

0.3 Day-night average sound level has been used to predict the annoyance response of communities to types of noises that were not included in the Schultz database for the relation between the percentage of a population expressing high annoyance and the corresponding day-night average sound level. These additional types of noises include sounds with special characteristics, such as impulsiveness, dominant pure tones, rapid onset, and strong low-frequency content.

0.4 Technical reports and articles published in refereed engineering and scientific journals demonstrated that the community response to these sounds may be predicted, provided suitable adjustments are applied. A practical procedure to apply these adjustments is provided by this Standard.

0.5 For situations where activity interference is the major concern, use of adjusted day-night average sound level or adjusted total day-night sound exposure may not be appropriate. For example, day-night average sound level without adjustments may be a better predictor of speech interference than adjusted day-night average sound level. Descriptors such as maximum A-weighted sound level, time-above, or speech interference level may be even more appropriate for predicting speech interference.

American National Standard

QUANTITIES AND PROCEDURES FOR DESCRIPTION AND MEASUREMENT OF ENVIRONMENTAL SOUND — PART 4: NOISE ASSESSMENT AND PREDICTION OF LONG-TERM COMMUNITY RESPONSE

1 Scope

1.1 This Standard specifies methods to assess environmental sounds and to predict the potential annoyance response of a community to outdoor long-term noise from any and all types of environmental sounds from one or more discrete or distributed sound sources. The sound sources may be separate or in various combinations. Application of the prediction method is limited to areas where people reside and to related long-term land uses.

NOTE The long-term period is typically one year. However, the user of this Standard can employ these methods for shorter periods of time, but they should report this change and not attempt to predict percent highly annoyed using Clause 8.3 or Annex F, since the Annex F data all represent long-term situations.

1.2 This Standard describes adjustments for sounds that have special characteristics so that the long-term community response to such sounds can be predicted by a method that is based on day-night average sound level or total day-night sound exposure. Sounds, such as from highway traffic, are evaluated directly by sound exposure or sound level without adjustment. The prediction method is directly analogous to the use of day-night average sound level to predict the response of a community to general environmental sounds.

1.3 This Standard does not address the effects of short-term exposure of people to intrusive sounds in locations such as parks and wilderness areas. The Standard also does not address other effects of noise such as sleep disturbance or health effects. This Standard does not provide a method to predict the response of a community to short-term, infrequent, non-repetitive sources of sound.

1.4 This Standard introduces the application of new descriptors: adjusted sound exposure and adjusted sound exposure level. The new descriptors are closely related to sound exposure and sound exposure level, respectively. The new descriptors are introduced to facilitate the prediction of the response of communities to the wide range of outdoor sounds covered by the scope of the Standard.

1.5 The sounds are assessed either singly or in combination, allowing for consideration, when necessary, of the special characteristics of impulsiveness, tonality, onset rate, and low-frequency content. In the same manner as sound exposure and sound exposure level are used to generate total day-night sound exposure or total day-night average sound level, adjusted sound exposure or adjusted sound exposure level are used to generate adjusted total day-night sound exposure or adjusted day-night average sound level.

1.6 Annoyance is not the only possible measure of community response. One frequently cited measure is numbers of complaints, sometimes normalized to numbers of inhabitants. Complaints can be particularly relevant near factories and plants, by airports and military installations, etc. Complaints do not correlate well with long-term average metrics such as DNL (see Refs. 7 and 8 for

example). Unfortunately, in general, metrics to predict the likelihood and prevalence of complaints do not yet exist with sufficient accuracy. One notable exception is the high-energy impulse sound generated by military activities and similar civilian noise sources, and informative Annex G provides procedures for assessing the risk of noise complaints from such sources.

1.7 The addition of adjustments eliminates the possibility to measure the total adjusted sound exposure or sound exposure level in a general situation that comprises a variety of sound sources (e.g., the combination of a highway leading to an airport and the airport itself). As a possible measurable alternative, this Standard introduces a new metric based on the equal-loudness level contours that were contained in ISO 226:1987. This new method uses the equal-loudness level contours as a set of dynamic filters that vary both with amplitude and frequency. This method is described in informative Annex H.

2 Normative references

The following referenced documents are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

[1] ANSI S1.1-1994 (R 2004) *American National Standard Acoustical Terminology.*

[2] ANSI S12.9-1988/Part 1 (R 2003) *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound - Part 1.*

[3] ANSI S12.9-1992/Part 2 (R 2003) *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound - Part 2: Measurement of Long-Term Wide-Area Sound.*

[4] ANSI S12.9-1993/Part 3 (R 2003) *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound - Part 3: Short-term Measurements with an Observer Present.*

[5] ANSI S12.9-1998/Part 5 (R 2003) *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound - Part 5: Sound Level Descriptors for Determination of Compatible Land Use.*

[6] ANSI S1.13-2005 *American National Standard Methods for the Measurement of Sound Pressure Levels in Air.*

3 Terms and definitions

For the purposes of this standard, the terms and definitions given in ANSI S1.1-1994 and the following apply:

3.1(a) adjusted sound exposure. Frequency-weighted sound exposure adjusted for the change in annoyance caused by certain impulsive sounds, the presence of prominent discrete-frequency tones, sounds that startle because of their rapid onset rate, sounds with strong low-frequency content, and the presence of masking background sound. Unit, pascal-squared second (Pa^2s); symbol, *N*.

NOTE 1 Adjustments and frequency weightings for various types of sounds are given in Clause 7.

NOTE 2 The unit of pascal-squared second for adjusted sound exposure has been abbreviated as "pasque."

3.1(b) reference sound exposure. The product of the square of the reference sound pressure of 20 μPa and the reference time of 1 s. Unit, pascal-squared second (Pa^2s); symbol, E_0.

3.1(c) adjusted sound exposure level. Ten times the base-10 logarithm of the ratio of the adjusted sound exposure to the reference sound exposure E_0. Unit, decibel (dB); symbol, L_{NE}.

3.2 adjusted total day-night sound exposure. Frequency-weighted sound exposure for a 24-hour day calculated by adding adjusted sound exposure obtained during the daytime (0700-2200 hours) to ten times adjusted sound exposure obtained during the nighttime (0000-0700 and 2200-2400 hours). Unit, pascal-squared second (Pa^2s); symbol, N_{dn}.

3.3(a) adjusted day-night average sound pressure. Square root of ratio of adjusted total day-night sound exposure to 86,400 s. Unit, pascals (Pa).

3.3(b) adjusted day-night average sound level. Ten times the base-10 logarithm of the ratio of the square of the adjusted day-night average sound pressure to the square of the reference sound pressure of 20 μPa. Unit, decibel (dB); symbol, L_{Ndn}.

3.4 impulsive sound. Sound characterized by brief excursions of sound pressure (acoustic impulses) that significantly exceed the ambient environmental sound pressure. The duration of a single impulsive sound is usually less than one second.

NOTE At the time of publication, no mathematical descriptor existed to unequivocally define the presence of impulsive sound or to separate impulsive sounds into categories.

3.4.1 highly impulsive sound. Sound from one of the following enumerated categories of sound sources: small-arms gunfire, metal hammering, wood hammering, drop hammering, pile driving, drop forging, pneumatic hammering, pavement breaking, metal impacts during rail-yard shunting operation, and riveting.

3.4.2 high-energy impulsive sound. Sound from one of the following enumerated categories of sound sources: quarry and mining explosions, sonic booms, demolition and industrial processes that use high explosives, military ordnance (e.g., armor, artillery and mortar fire, and bombs), explosive ignition of rockets and missiles, explosive industrial circuit breakers, and any other explosive source where the equivalent mass of dynamite exceeds 25 g. Normally, for single impulsive sounds of concern for this Standard, the A-weighted sound exposure level will exceed 65 dB and the C-weighted sound exposure level will exceed 85 dB.

3.4.3 regular impulsive sound. Impulsive sound that is not highly impulsive sound or high-energy impulsive sound.

3.5 onset rate. Nominally, the average rate of change of sound level during the onset of a noise event. Mathematically, onset rate is the rate of change of the A-weighted event sound level between the time the event sound level first exceeds the ambient sound level by 10 dB, and the time the event sound level first exceeds a level that is 10 dB less than the event's maximum fast-time-weighted sound level. Onset rate is defined for those event sound levels for which the maximum A-frequency-weighted, fast-time-weighted sound level exceeds the ambient sound level by at least 30 dB. Unit, decibels per second (dB/s).

NOTE 1 The nominal 125-ms time constant of fast time weighting normally is not small enough to accurately determine onset rate. Onset rate should be determined from the time variation of the level of the squared sound pressure. A digital system that provides a series of short-time-average sound levels may be used. In this case, the averaging time for each sound level in the series should be no greater than 1/10 and no less than 1/25 of the time span over which the onset rate is determined. A digital or analog system with exponential time weighting also may be used. In this case, the exponential time constant should be no greater than 1/4 and no less than 1/10 of the time span over which the onset rate is determined.

NOTE 2 A determination of onset rate should not be unduly influenced by anomalous fluctuations in the sound level.

3.6 time above. The time per stated unit time interval that the sound pressure level exceeds a criterion level (e.g., 30 s per hour). The frequency weighting or filtering (e.g., A-weighting), time weighting or integration time interval, and the unit time interval all must be stated. Typical Units: seconds (s) or minutes.

4 Descriptors for environmental sounds

4.1 Single-event sounds

4.1.1 Descriptors

Sounds from single events such as the passby of a truck, the flyby of an airplane, or an explosion at a quarry are all examples of single-event sounds. Each sound can be characterized by many descriptors. These descriptors include physical quantities and the corresponding levels in decibels. The level of a descriptor and its corresponding physical quantity form a descriptor pair. Three descriptor pairs often are used to describe the sound of single events. For each of these, frequency-weighting A is understood except for high-amplitude impulsive sounds or sounds with strong low-frequency content. The preferred three descriptor pairs are:

peak (frequency-weighted) sound pressure and peak (frequency-weighted) sound pressure level;

maximum exponential-time-weighted sound pressure and maximum sound level; and

sound exposure and sound exposure level.

NOTE 1 For the above descriptor pairs, the frequency weighting should be specified if frequency-weighting A is not employed, e.g., as peak C-weighted sound pressure level, C-weighted sound exposure level.

NOTE 2 For maximum sound pressure (and maximum sound level), the exponential-time-weighting should be specified, e.g., as fast (F) or slow (S).

4.1.2 Event duration

Event duration shall be specified relative to some characteristic of the sound such as the time of occurrence of the maximum sound level or the time some threshold was exceeded. For example, duration may be the total time that the sound level is within 10 dB of the maximum sound level.

4.2 Continuous sounds

Environmental sounds from sources such as transformers, fans, or cooling towers are examples of continuous sounds. Amplitudes of continuous sounds may be constant or slowly varying. Each sound can be characterized by many descriptors. Two descriptor pairs are commonly used to describe a continuous sound. For each of these, frequency-weighting A is commonly used. The two preferred descriptor pairs are:

maximum (exponential-time-weighted) sound and maximum sound level; and

time-average sound pressure and time-average (equivalent-continuous) sound level.

NOTE 1 For both of the above descriptors, the frequency weighting should be specified if frequency-weighting A is not employed.

NOTE 2 For maximum (exponential-time-weighted) sound (and maximum sound level), the exponential-time weighting should be specified, e.g., as fast (F) or slow (S).

NOTE 3 See Clauses 5.1.4, 5.1.5, and 5.1.6 in ANSI S12.9-1988/Part 1 (R2003) for definitions of these quantities.

4.3 Repetitive single-event sounds

Repetitive single-event environmental sounds typically are recurrences of single-event sounds. For example, during a day, the sound from traffic on a highway is the sum of the sound from multiple individual vehicle passbys. In this Standard, all repetitive single-event sounds utilize the descriptor for the particular single-event sounds and the corresponding number of events.

5 Sound measurement locations

All sounds, except high-energy impulsive sounds, shall be measured or predicted as if they had been measured by a microphone outdoors, over acoustically absorptive ground (grass), at a height of approximately 1.2 m and with no nearby reflecting surfaces except the ground. Alternative microphone locations may be used, but their acoustical characteristics shall be specified. An example of an alternative location is outside an open, upper-story window in a high-rise apartment building where the purpose is to predict or assess the environmental sound at that location. High-energy impulsive sounds shall be measured or predicted as if they had been measured by a microphone within 50 mm of a hard reflecting surface (e.g., a building wall, roof, or ground plane, as appropriate).

NOTE 1 A reflecting surface is required because sonic booms, which are one form of high-energy impulsive sounds, have traditionally been measured or predicted for a location on a reflecting ground plane or structure.

NOTE 2 To ensure comparable data, sonic booms should be measured on a reflecting ground plane or other equivalent structure.

6 Adjustments for background sound

6.1 General

Annex A discusses a general method to include adjustments for background sound. The general method is applicable to three cases: (1) the sound of concern is very noticeable and detectable in the background setting of interest, (2) the sound of concern is virtually unnoticeable and undetectable in the background setting of interest, and (3) the sound of concern is in a range such that it may be noticeable and detectable only for a portion of the time.

6.2 Specific requirements

When the conditions of 6.1(2) apply and the sound is virtually unnoticeable and undetectable in the background setting of interest, then its sound exposure shall not be included in a calculation of the total sound exposure from multiple sound sources. If some particular sound is excluded, then the physical background setting shall be specified. For example, this setting may be "urban residential not near an arterial street, outdoors," or "suburban residential indoors with windows partially open," or "urban residential near an arterial street, indoors with windows closed."

NOTE Direct measurements may be used to determine the background sound level prevailing for the environment. Procedures in Part 3 of ANSI S12.9 should be used to measure the background sound level.

Alternatively, the nominal background sound levels given in Part 3 of ANSI S12.9 may be used for various urban environments.

7 Method to assess environmental sounds either singly or in combination

This Standard permits assessment of environmental sounds from individual sources or any combination of sources. If the sound has special characteristics or unusual community response, then adjusted sound exposure or adjusted sound exposure level shall be used to describe the source(s) of sound. In addition, the total adjusted sound environment shall include a weekend daytime adjustment, and is used to predict long-term community response.

7.1 General environmental sounds

General environmental sounds are assessed using frequency-weighting A. (Environmental sounds with special characteristics are described in 7.2.) Sound exposure, sound exposure level, total time-period sound exposure, time-average sound level, total day-night sound exposure, and day-night average sound level are the preferred descriptors. The exposure method of presentation is described in 7.1.1, the left-hand column below. The level method of presentation is described in 7.1.2, the right-hand column below.

7.1.1 Exposure method	**7.1.2 Level method**
7.1.1.1 Sound exposure	**7.1.2.1 Sound exposure level**
Sound exposure is a descriptor for characterizing the sound from individual acoustical events. For individual single-event sounds such as vehicle passbys, sound exposure may be directly measured or predicted for the sound-producing events under consideration. For a continuous source, the total time-period sound exposure may be measured or predicted for the time period of interest. A-weighted sound exposure E_A, in pascal-squared seconds, may be calculated as the product of the time-mean-squared, A-weighted sound pressure $\overline{p_A^2}$ in pascals squared and the duration, in seconds, of the time period of interest T, i.e., as	Sound exposure level is a descriptor for characterizing the sound from individual acoustical events. For individual single-event sounds such as vehicle passbys, sound exposure level may be directly measured or predicted for the sound-producing events under consideration. For a continuous source, the sound exposure level may be measured or predicted for the time period of interest. A-weighted sound exposure level L_{AE}, in decibels, may be calculated as ten times the base-10 logarithm of the ratio of the A-weighted sound exposure E_A to the reference sound exposure E_0 defined in 3.1(b), i.e., as
$E_A = \overline{p_A^2}T$. (1a)	$L_{AE} = 10 \lg (E_A/E_0)$. (1b)

7.1.1.2 Total sound exposure

Total sound exposure may be used to characterize the sound of one or more events from individual or combined sources of sound during a time period of interest such as the hour from 1600 to 1700, daytime from 0700 to 2200, or nighttime from 2200 to 2400 and 0000 to 0700. Total A-weighted sound exposure in a time period $E_{A(period)}$, in pascal-squared seconds, is the sum of the N sound exposures E_{Ai} from the i-th individual single-event sounds during the stated time period.

In mathematical notation,

$$E_{A(period)} = \sum_{i=1}^{N} E_{A\,i}\,. \qquad (2a)$$

NOTE The stated time period may be of any duration such as one daytime period for one day or for any number of days up to 365 days of a year. Furthermore, the sound exposure E_{Ai} for the i-th event may be for any one sound source or a combination of sources.

7.1.2.2 Time-average sound level

Time-average sound level may be used to characterize the sound of one or more events from individual or combined sources of sound during a time period of interest such as the hour from 1600 to 1700, daytime from 0700 to 2200, or nighttime from 0000 to 0700 and 2200 to 2400. Time-average, A-weighted sound level $L_{A(period)}$, in decibels, is calculated from the total sound exposure in the period.

In mathematical notation,

$$L_{A(period)} = 10\lg\left[(T_0 / T)\sum_{i=1}^{I} 10^{0.1 L_{AEi}}\right], \qquad (2b)$$

where T_0 is the reference time of 1 s and T is the total time period in seconds for the duration of the time average.

NOTE For a constant time-average sound level of 60 dB, sound exposure level $L_{AE(period)}$ and sound exposure $E_{A(period)}$ are related as shown in Table 1 for selected integration time periods T.

7.1.1.3 Total day-night sound exposure

Total day-night sound exposure is a descriptor for characterizing long-term acoustical environments from sounds of one or more events from individual or combined sound sources. Total day-night sound exposure E_{Adn}, in pascal-squared seconds, is the sum of daytime sound exposures plus 10 times the sum of nighttime sound exposures where daytime is the 15 hours from 0700 to 2200 and nighttime is the nine hours from 0000 to 0700 and from 2200 to 2400 in any 24-hour day.

In mathematical notation,

$$E_{Adn} = \sum_{i=1}^{N_d} E_{A\,i} + 10\sum_{i=1}^{N_n} E_{A\,i}\,, \qquad (3a)$$

$$= E_{Ad} + 10E_{An}\,,$$

where N_d is the number of daytime sound exposures and N_n is the number of nighttime sound exposures.

7.1.2.3 Day-night average sound level

Day-night average sound level is a descriptor for characterizing long-term acoustical environments from sounds of one or more events from individual or combined sound sources. Day-night average sound level, in decibels, is calculated from ten times the base-10 logarithm of the sum of the daytime sound exposures plus the nighttime sound exposures, where sound exposure levels or sound levels occurring during nighttime hours are weighted by 10 dB.

In mathematical notation,

$$L_{dn} = 10\lg\left[(15/24)(T_0 / T_d)\sum_{i=1}^{N_d} 10^{0.1 L_{AEi}}\right] + 10\lg\left[(9/24)(T_0 / T_n)\sum_{i=1}^{N_n} 10^{0.1(L_{AEi}+10)}\right] \qquad (3b)$$

$$= 10\lg\left[(15/24)10^{0.1 L_d} + (9/24)10^{0.1(L_n+10)}\right]$$

where T_d = the 15 daytime hours or 54,000 s and T_n = the 9 nighttime hours or 32,400 s.

Table 1 — Relation between sound exposure level and sound exposure for a constant sound level of 60 dB.

T	$L_{AE(\text{period})}$ (dB)	$E_{A(\text{period})}$ (Pa^{2}s)	T	$L_{AE(\text{period})}$ (dB)	$E_{A(\text{period})}$ (Pa^{2}s)
1 s	60.0	0.0004	1 h	95.6	1.44
1 min	77.8	0.024	24 h	109.4	34.6

NOTE A day-night sound exposure of 10 Pa^{2}s corresponds to a nominal day-night average sound level of 55 dB. A day night average sound level of 65 dB corresponds to a nominal total day-night sound exposure of 100 Pa^{2}s.

7.2 Adjustments to general environmental sound

Research has shown that frequency-weighting A, alone, is not sufficient to assess sounds characterized by tonality, impulsiveness, very fast onset rates, or strong low-frequency content. Also, research has shown that frequency-weighting A, alone, under-predicts the community response to aircraft noise and to weekend daytime noise. To predict the long-term response of a community to sounds with some of those special characteristics, sources, or times of occurrence, an adjustment factor is used to multiply the sound exposure or an adjustment in decibels is added to the A-weighted sound exposure level. Annex H contains a bibliography of reports and articles describing the technical basis of the assessment and prediction methods of this Part 4.

Sound exposure and sound exposure level as discussed in 7.1.1.1 and 7.1.2.1 are descriptors for characterizing the environmental sound from individual acoustical events. Frequency weighting A is used for all sound sources except (1) high-energy impulsive sounds for which frequency-weighting C is used, and (2) sounds with strong low-frequency content. Adjusted sound exposure is the quantity used in this Standard to assess sounds without and with special characteristics with respect to the potential community response. For general environmental sounds without special characteristics (i.e., sounds assessed by the method of 7.1), adjusted sound exposure is numerically equal to A-weighted sound exposure.

For sounds with special characteristics, sources, or times of occurrence, the calculation of adjusted sound exposure or adjusted sound exposure level is performed as described below. The adjusted exposure method of presentation is described in 7.2.1, the left-hand column below. The adjusted level method of presentation is described in 7.2.2, the right-hand column below.

7.2.1 Adjusted exposure method	**7.2.2 Adjusted level method**
7.2.1.1 Adjusted sound exposure For any sound except high-energy impulsive sound or sounds having strong low-frequency content, adjusted sound exposure N_j is given by the sound exposure E_i for the i-th single-event sound multiplied by the adjustment factor K_j for the j-th type of sound, as given in Table 2. In mathematical notation, $N_j = K_j E_i$. (4a)	**7.2.2.1 Adjusted sound exposure level** For any sound except high-energy impulsive sound or sounds having strong low-frequency content, adjusted sound exposure level L_{Nj} is given by the sound exposure level L_{Ei} for the i-th single-event sound plus the level adjustment $\overline{K}_i$ for the j-th type of sound, as given in Table 2. In mathematical notation, $L_{Nj} = L_{Ei} + \overline{K}_j$. (4b)

Equations to convert between adjusted sound exposure, in pascal-squared seconds, and adjusted sound exposure level, in decibels, are:

$$L_{Nj} = 10\,\lg(N_j / p_0^2 T_0) = 10\,\lg(N_j / T_0) + 94 \tag{5a}$$

$$N_j = (T_0) 10^{0.1(L_{Nj} - 94)}, \tag{5b}$$

where $-10\,\lg(p_0^2) = 94$ dB and T_0 is the reference time of 1 s.

7.2.1.2 Adjusted total sound exposure

During a time period of interest such as daytime, the adjusted total sound exposure $N_{(\text{period})}$, in pascal-squared seconds, is the sum of the adjusted sound exposures N_{ij} from each individual event i of I events, for each source of sound j of J sources during the stated time period.

In mathematical notation,

$$N_{(\text{period})} = \sum_{i=1}^{I} \sum_{j=1}^{J} N_{ij}\,. \tag{6a}$$

The stated time period may be of any duration such as one daytime period for one day or for any number of days up to 365 days of a year. Furthermore, the adjusted sound exposure N_{ij} for the i-th event may be for any one source j or a combination of sources.

In equation (6a), sounds without special characteristics are included with an adjustment factor of 1 as shown in Table 2.

7.2.2.2 Adjusted time-average sound level

During a time period of interest such as daytime, the adjusted time-average sound level $L_{N(\text{period})}$, in decibels, is calculated from the adjusted sound exposure levels L_{Nij} from each individual event i of I events, for each source of sound j of J sources during the stated time period.

In mathematical notation,

$$L_{N(\text{period})} = 10\,\lg\left[(T_0 / T) \sum_{i=1}^{I} \sum_{j=1}^{J} 10^{0.1 L_{Nij}}\right]. \tag{6b}$$

The stated time period T, in seconds, may be of any duration such as one daytime period for one day or for any number of days up to 365 days of a year. Furthermore, the adjusted sound exposure level L_{Nij} for the i-th event may be for any one source j or a combination of sources.

In equation (6b), sounds without special characteristics are included with a level adjustment of 0 as shown in Table 2.

For an averaging time period T in seconds, equations to convert adjusted total sound exposure in pascal-squared seconds and adjusted time-average sound level in decibels are:

$$L_{N(\text{period})} = 10\,\lg(N_{(\text{period})} / p_0^2 T_0) - 10\,\lg(T / T_0) = 10\,\lg(N_{(\text{period})} / T) + 94 \tag{7a}$$

$$N_{(\text{period})} = (T) 10^{0.1(L_{N(\text{period})} - 94)} \tag{7b}$$

7.2.1.3 Adjusted total day-night sound exposure	**7.2.2.3 Adjusted day-night average sound level**
Adjusted total day-night sound exposure is similar to total day-night sound exposure, but includes the adjustment factors described in Table 2. Adjusted nighttime sound exposures are weighted by a factor of 10. The mathematical formulation of adjusted total day-night sound exposure N_{dn} is similar to that for total day-night sound exposure described in 7.1.1.3.	Adjusted day-night average sound level is similar to day-night average sound level, but includes the level adjustments described in Table 2. Ten decibels are added to adjusted nighttime sound exposure levels. The mathematical formulation of adjusted day-night average sound level L_{Ndn} is similar to that for day-night average sound level described in 7.1.2.3.

For a time period T_{dn} of 24 h or 86,400 s, equations to convert adjusted day-night average sound level L_{Ndn} in decibels and adjusted total day-night sound exposure N_{dn} in pascal-squared seconds are:

$$L_{Ndn} = 10 \lg(N_{dn} / p_0^2 T_0) - 10 \lg(T_{dn} / T_0) = 10 \lg (N_{dn} / T_0) + 44.6 \tag{8a}$$

$$N_{dn} = (T_0) 10^{0.1(L_{Ndn} - 44.6)}, \tag{8b}$$

where $-10 \lg(p_0^2) - 10 \lg(T_{dn}/T_0) = 94 - 49.4 = 44.6$ dB, and $T_0 = 1$ s.

Table 2 — Adjustment factors and level adjustments for assessment of all types of environmental sounds.

Sound source		K_j		$\overline{K}_j = 10\lg(K_j)$	
Factor	Type	Symbol	Value	(dB)	Condition
without special characteristics	general broadband sound (e.g., road traffic)	K	1	0	...
Special characteristics	regular impulsive	K_I	3	5	...
	highly impulsive	K_I	16	12	...
	high-energy impulsive				see Annex B
	rapid onset rate R	K_R	1	0	$R < 15$ dB/s
		K_R	$10^{1.1\ \lg(R/15)}$	11 lg(R/15)	$15 \leq R < 150$ dB/s
		K_R	12.6	11	$R \geq 150$ dB/s
	tonal	K_t	3	5	see Annex C
	strong low-frequency content				see Annex D
Sources	aircraft	K_A	1	0	DNL<55
		K_A	10*lg(DNL-55)	DNL-55	55<DNL<60
		K_A	3	5	DNL≥60
Time of Day	nighttime	K_N	10	10	
Day of the Week	weekends, daytime	K_W	3	5	

NOTE 1 If more than one special characteristic adjustment applies to a given single sound source such as a fan, only the largest adjustment shall be applied. Time-of-day and day-of-the-week adjustments are always included in addition to other adjustments, if any.

NOTE 2 Each adjusted sound exposure N_{ij} is calculated from its corresponding sound exposure level L_{AEij} and adjustment factor K_j according to

$$N_{ij} = (K_j)[(T_0)(10^{0.1(L_{AEij}-94)})]. \tag{9}$$

NOTE 3 Each adjusted sound exposure level L_{Nij} is calculated from its corresponding sound exposure level and level adjustment $\overline{K}_j$ according to

$$L_{Nij} = L_{AEij} + \overline{K}_j . \tag{10}$$

NOTE 4 If sounds are not audible at the location of interest, then the concepts of Clause 6 apply and the adjusted sound exposure for those sounds shall not be included in the total.

NOTE 5 The assessment method for essentially continuous sounds with strong low-frequency content shall not be applied unless the time-average C-weighted sound level exceeds the A-weighted sound level by at least 10 dB.

NOTE 6 Normally, the onset rate is measured. Annex E provides an approximate method to calculate the onset rate for low-flying airplanes.

NOTE 7 If highly impulsive sounds occur at a rate greater than about 20 per second, then the sounds usually are not perceived as distinct impulses and no adjustment shall be applied. If the rate is regular and greater than 30 per second, then a tone will be perceived and a tonal adjustment may be required. If the rate is irregular and greater than 20 per second, then the highly impulsive sounds will appear to merge into a broadband noise-like sound and no adjustment shall be applied.

8 Reporting assessments of environmental sounds and prediction of long-term community annoyance response

8.1 Use of A-weighted sound exposure and day-night average sound level

If the acoustical environment includes only sounds having no special characteristics, then adjusted sound exposure is numerically equal to the sound exposure. All reporting then shall be in terms of A-weighted day-night average sound level or A-weighted sound exposure. If the acoustical environment includes any combination of sounds having special characteristics, then the numerical description of the total acoustical environment shall be reported in terms of adjusted sound exposure or adjusted sound exposure level. This procedure is required because adjusted sound exposure and adjusted sound exposure level are not measured quantities.

8.2 Assessment of environmental sounds

A measurement or calculation of the (adjusted) total sound exposure or time-average sound level shall be used to assess environmental sounds.

To predict or measure the (adjusted) total sound exposure or time-average sound level during a time period of interest, (adjusted) sound exposures shall be summed over the duration of the stated time period, typically, for some hour of the day, all day, all night, or a combination of the day-night sound or (adjusted) day-night sound exposure.

For example, for an airport, factory, or highway, one might measure or calculate the annual average total day-night sound exposure or annual average adjusted total day-night sound exposure on an average day by summing the total sound exposure or adjusted total sound exposure throughout the year using equations (1a) or (6a), respectively, and then dividing by 365.

NOTE The user of this Standard can employ these methods for shorter periods of time, but they should report this change and not attempt to predict percent highly annoyed using Clause 8.3 or Annex F, since the Annex F data all represent long-term situations

8.3 Prediction of long-term annoyance response of communities

Annual average (adjusted) total day-night sound exposure or annual average (adjusted) day-night average sound level is needed to predict the long-term annoyance response of a community.

Table F.1 in Annex F may be used to predict the percentage of a population that is likely to be highly annoyed by the environmental sound with that annual average (adjusted) total day-night sound exposure or that annual average (adjusted) day-night average sound level.

8.4 Reporting

Reporting shall include the following:

a) the stated time period (e.g., daytime, 1600 to 1700 hours);

b) the day or days included in the time average;

c) the adjusted time-period total sound exposure or adjusted time-period time-average sound level;

d) a description of the sound source or sources included in the total time period;

e) a description of the measurement or prediction site;

f) a description of any procedures used in accordance with Clause 7 and Annex A to correct for contamination by background sound and a description of the background sound; and

g) the results of the prediction of long-term annoyance response of the community.

NOTE The stated time period may be for any duration such as one daytime period for one day or for any number of days up to 365 days of a year. Furthermore, the sound exposure or adjusted sound exposure, E_{Aj} or N_j, for the j-th source, may be for any one source or a combination of sources.

Annex A

(informative)

Adjustments for background sound

A.1 Introduction

A.1.1 General

Analysis of the annoyance generated by any given source of community noise is usually based on the assumption that the given source is the primary source of noise, and that the annoyance is not influenced by the presence (or absence) of sounds from other sources. For example, airports or roadways are often assessed as if they were the only source of sound.

Because there almost always is noise from more than one source, two questions arise:

1) When does the amplitude of the sound from other sources become sufficient in magnitude to modify the annoyance generated by the source under evaluation?

2) Under what circumstances does the presence of sound from one source alter the annoyance caused by another source?

A.1.2 Background sound

Background noise is defined in ANSI S1.1 as "the total of all sources of interference in a system used for the production, detection, measurement, or recording of a signal, independent of the presence of the signal." For the purposes of this annex, background sound is the total of all sounds produced by sources other than the one for which the annoyance response is being evaluated. The amplitude of the background sound can be continuous or time-varying. Background sound may be produced by a variety of sources.

A.1.3 Background sound situations

There are at least two situations when background sound may influence or alter the presumed relation between annoyance and a physical measure of the sound for a given type of noise:

1) Masking is present when the threshold of detection of one sound is raised by the presence of another (masking) sound. Masking may be of varying degree, with complete masking resulting in the inaudibility (and resulting absence of annoyance) of the sound signal under evaluation. Given the time varying nature of many community sounds and their differences in spectral composition, the degree of masking is difficult to determine in most situations unless the differences between the time-average sound levels of the different sources are at least 20 dB.

NOTE A masking analysis requires comparison of sound pressure levels in different frequency bands. Sounds having similar A-weighted sound levels may have quite different spectral content. Hence, it is impossible to determine the degree of masking from A-weighted sound levels.

2) The presence of sound from one source may alter an evaluation of the annoyance of the sound from another source. For example, at an outdoor music concert, one might be mildly annoyed by the noise from an aircraft flyover occurring during an intermission, but be highly annoyed by a similar

noise intrusion during the musical performance, even though the background sound levels during the intermission and performance are the same.

Alternatively, one might ask whether the presence of intrusive sounds from one source alters the annoyance resulting from another intermittent sound, even though no masking of sounds may occur. (An example of this situation might be the evaluation of aircraft noise at a location exposed to noise from trains.)

NOTE The influence of interactions between sound sources, outlined in the alternative situation above, is usually difficult to determine or is unknown, and is ignored in the analysis given in this annex.

A.2 Mathematical development

A.2.1 Single-event sounds

For single-event sounds, N_{ij} is the adjusted sound exposure produced by a discrete event *i* and sound type *j*. K_{Bij} is the background sound adjustment factor for event *i* and sound type *j*. In the absence of noise from other sources, K_B equals 1. In the presence of noise from other sources K_B may vary from 1 to 0. With complete masking from other sources, $K_B = 0$.

Background sound adjustments are equivalent to changes in the noise adjustment factor K_B as a consequence of masking by other sound sources.

A.2.2 Continuous, or near-continuous, sounds and single-event sounds

For continuous, or near-continuous, sounds, time-average, A-weighted sound level is symbolized by L_{Acont} during the stated averaging time *T*.

Consider a situation where there are two sources of single-event sound [for example, (1) trains for which the adjusted sound exposures are N_{1i} and (2) aircraft for which the adjusted sound exposures are N_{2i}] and one source of continuous sound. The total adjusted sound exposure N_T for the three sources over time duration *T* is determined from

$$
\begin{aligned}
N_T = {} & \sum_{i=1}^{I1} (N_{1i})(K_{B1i}) + \\
& \sum_{i=1}^{I2} (N_{2i})(K_{B2i}) + \\
& \left[10^{0.1(L_{\mathrm{Acont}} - 94)}\right](T)(K_{\mathrm{Bcont}}).
\end{aligned}
\qquad (A.1)
$$

NOTE 1 This 3-source example may be expanded to include any number of different sources of single-event or continuous sounds.

NOTE 2 I1 is the number of trains and I2 is the number of aircraft during time duration *T*.

For the situation where the single-event sounds for each source occurring during a time period of duration *T* are nearly equal (i.e., the sound exposure levels and maximum A-weighted sound levels are nearly equal), equation (A.1) is replaced by

$$N_T = (\mathrm{I1})(N_{1i})(K_{B1i}) + (\mathrm{I2})(N_{2i})(K_{B2i}) + \left[10^{0.1(L_{Acont}-94)}\right](T)(K_{Bcont}). \quad (A.2)$$

A.3 Background sound adjustment situations

There are three groups of situations where background sound adjustments may need to be considered.

A.3.1 Situations having little need for background sound adjustments

A.3.1.1 Maximum single-event sound level much greater than the sound level of the continuous sound source

When the maximum A-weighted sound levels of individual noise events from two sources are at least 15 dB greater than the time-average A-weighted sound level of the continuous sound source, and the number of individual noise events is not large (so that the probabilities of individual noise events from the two sources occurring at the same time are small), then there is little need for background sound adjustment to the sound exposures from the individual noise events. Hence, in this situation, background sound adjustment factors K_{B1i} and K_{B2i} in equations (A.1) and (A.2) remain equal to 1.0.

A.3.1.2 Few individual noise events

The impact of sound from individual sources on the background sound adjustment factor for continuous sound K_{Bcont} is negligible if there are only a few individual noise events from the sources. In this situation there is little likelihood of K_{Bcont} changing from a value of 1.

A.3.1.3 Many individual noise events

When there are many noise events from individual sound sources, separately or in combination, the total adjusted sound exposure from these sources is likely to be much larger than the sound exposure for the continuous noise. In this situation the contribution from the continuous sound source will have little effect on the total adjusted sound exposure.

A.3.2 Situations where background sound adjustments may be needed

A.3.2.1 Maximum single-event sound level nearly equal to the sound level of the continuous sound source

When the maximum A-weighted sound levels of individual single-event sounds from either of the two example sources, or both, are within 10 dB of the time-average A-weighted sound level, background sound adjustments K_{B1} and/or K_{B2} are needed because of partial masking. In this situation, a value of K_{B1} and/or K_{B2} equal to ½ may be appropriate.

A.3.2.2 Many individual noise events from either of both sound sources

When the maximum A-weighted sound levels of individual noise events from the two example sound sources are of the same order of magnitude and when the number of noise events from one or both sources is large, background sound adjustments K_{B1} or K_{B2}, or both, are needed because of partial masking of one individual noise event by another. In this situation, a value of K_{B1} and/or K_{B2} equal to ½ may be appropriate.

A.3.3 Situations where significant background sound adjustments are needed

When the maximum A-weighted sound levels of individual noise events are at least 10 dB less than the time-average A-weighted sound level for the continuous sound, partial or complete masking of the sound from the individual events is likely to occur. In this situation, a value of zero for the background sound adjustments of K_{B1} and K_{B2} is recommended.

A.3.4 Guidance on the development of background sound adjustment factors

Appropriate background sound adjustment factors may be developed from considerations of the level of the A-weighted signal-to-noise ratio β equal to (S+N)/N, i.e., the combined level of the A-weighted signal plus the A-weighted noise, minus the level of the A-weighted noise.

In situations where the spectra of the sounds from the sound sources are vastly different, the levels of signal-to-noise ratios determined from octave- or one-third-octave-band sound pressure levels should be examined instead of A-weighted sound levels to establish background sound adjustment factors K_{Bjk} for each *j*-th source and spectral band *k*. These spectral signal-to-noise levels are then examined to determine how the sound exposures in question should be combined in the calculation of total sound exposure.

Recommended values for K_{Bjk} are:

$$K_{Bjk} = 1, \text{ for } \beta \geq 20 \text{ dB} \tag{A.3}$$

$$K_{Bjk} = \beta / 20, \text{ for } 0 < \beta \leq 20 \text{ dB} \tag{A.4}$$

$$K_{Bjk} = 0, \text{ for } \beta = 0 . \tag{A.5}$$

Annex B

(normative)

High-energy impulsive sounds

B.1 Introduction

The procedure in this annex is based on a 1996 study by the National Research Council, Committee on Hearing, Bioacoustics, and Biomechanics (CHABA); see Ref. 14. It conforms with ISO 1996:1-2003 (Ref. 6) which is also based, in part, on the CHABA study.

NOTE The CHABA study presented two methods to assess high-energy impulsive sounds. One method is amenable to the concept of adjusted sound exposure and is presented in this annex. The other method is not amenable to the concept of adjusted sound exposure.

B.2 Fundamental descriptor

For single-event, high-energy impulsive environmental sounds, the fundamental descriptor is C-weighted sound exposure E_C or C-weighted sound exposure level L_{CE}.

B.3 Measurement

C-weighted sound exposure (or C-weighted sound exposure level) shall be measured or predicted as if it had been measured by a microphone in a "free-field" and at least 15 m from any large reflecting object other than the ground which should be grass or a field.

B.4 Calculation of adjusted sound exposure level for high-energy impulsive sounds from C-weighted sound exposure level

For each single event, adjusted sound exposure level L_{NE} for high-energy impulsive sounds shall be calculated from the C-weighted sound exposure level L_{CE} according to

$$L_{NE} = 2\,L_{CE} - 93 \text{ dB for } L_{CE} \geq 100 \text{ dB} \tag{B.1}$$

$$L_{NE} = 1.18\,L_{CE} - 11 \text{ dB for } L_{CE} < 100 \text{ dB}$$

The two relations intersect at a C-weighted sound exposure level of 100 dB.

B.5 Calculation of adjusted sound exposure level from C-weighted sound exposure level

Adjusted sound exposure N for high-energy impulsive sounds is related to adjusted sound exposure level L_{NE} according to

$$N = 10^{0.1(L_{NE}-94)}. \tag{B.2}$$

Substituting equation (B.1) in equation (B.2) yields

$$N = 10^{0.1(2L_{CE} - 93 - 94)}$$
$$= 10^{0.1(2L_{CE} - 187)} \qquad \text{(B.3a)}$$

for $L_{CE} \geq 100$. .

$$N = 10^{0.1(1.18L_{CE} - 11 - 94)}$$
$$= 10^{0.1(1.18L_{CE} - 105)} \qquad \text{(B.3b)}$$

for $L_{CE} \leq 100$.

B.6 Calculation of adjusted sound exposure level from C-weighted sound exposure

C-weighted sound exposure level L_{CE} is related to C-weighted sound exposure E_C by

$$L_{CE} = 94 + 10 \lg (E_C / 1). \qquad \text{(B.4)}$$

Substituting equation (B.4) in equation (B.3) yields the relation between adjusted sound exposure N and C-weighted sound exposure E_C for high-energy impulsive sounds as

$$N = 10^{0.1\{2[94 + 10 \lg(E_C / 1)] - 187\}}$$
$$= 10^{[\lg (E_C / 1)^2 + 0.1]}$$
$$= (E_C)^2 (10^{+0.1}) \qquad \text{(B.5a)}$$
$$= 1.2589(E_C)^2$$

for $E_C \geq 3.9811$.

$$N = 10^{0.1\{1.18[94 + 10 \lg(E_C / 1)] - 105\}}$$
$$= 10^{[\lg (E_C / 1)^{1.18} + 0.592]}$$
$$= (E_C)^{1.18} (10^{+0.592}) \qquad \text{(B.5b)}$$
$$= 3.908(E_C)^{1.18}$$

for $E_C < 3.9811$.

B.7 Use of adjusted sound exposure

Adjusted sound exposures determined by the procedures in B.4, B.5, or B.6 are used in equation (6a) to provide the contributions from high-energy impulsive sounds to the total adjusted sound exposure.

Annex C

(informative)

Sounds with tonal content

The test for the presence of a prominent discrete-frequency spectral component (tone) typically compares the time-average sound pressure level in some one-third-octave band with the time-average sound pressure levels in the adjacent two one-third-octave bands. For a prominent discrete tone to be identified as present, the time-average sound pressure level in the one-third-octave band of interest is required to exceed the time-average sound pressure level for the two adjacent one-third-octave band by some constant level difference.

The constant level difference may vary with frequency. Possible choices for the level differences are: 15 dB in low-frequency one-third-octave bands (25-125 Hz), 8 dB in middle-frequency bands (160-400 Hz), and 5 dB in high-frequency bands (500-10,000 Hz).

NOTE 1 The above guidance is from Annex C of Part 3 of ANSI S12.9. Part 3 of ANSI S12.9 also contains guidance on the measurement of one-third-octave-band sound pressure levels.

NOTE 2 ANSI S1.13 Annex A presents more accurate methods for determining the presence of prominent discrete tones using narrow-band analysis.

Annex D

(informative)

Sounds with strong low-frequency content

D.1 Introduction

Sounds with strong low-frequency content engender greater annoyance than is predicted from the A-weighted sound level. The additional annoyance may result from a variety of factors including (1) less building sound transmission loss at low frequencies than at high frequencies and (2) increased growth in subjective loudness with changes in sound pressure level at low frequencies. In addition, environmental sound pressure levels in excess of 75 to 80 dB in the 16, 31.5, or 63-Hz octave bands may result in noticeable building rattle sounds. Rattle sounds can cause a large increase in annoyance. The methods in this annex may be used to assess environmental sounds with strong low-frequency content.

D.2 Analysis factors

Analysis of sounds with strong low-frequency content is based on the following three factors:

1) Generally, annoyance is minimal when octave-band sound pressure levels are less than 65 dB at 16, 31.5, and 63-Hz midband frequencies. However, low-frequency sound sources characterized by rapidly fluctuating amplitude, such as rhythm instruments for popular music, may cause annoyance when these octave-band sound pressure levels are less than 65 dB.

2) Annoyance grows quite rapidly with sound pressure level at very low frequencies. A "squared" function represents this phenomenon in this annex.

3) Annoyance to sounds with strong low-frequency content is virtually only an indoor problem.

Although windows and house walls have significant high-frequency sound transmission loss, sounds in the 16, 31.5 and 63-Hz octave bands pass through these structures to the interior with relative ease. The low-frequency sound pressure level within these structures is nearly equal to the outdoor sound pressure level because the minimal sound transmission loss of the windows and walls often is offset by modal resonance amplification in enclosed rooms.

D.3 Applicability

The procedures in this annex only should be applied to essentially continuous sounds with strong low-frequency content.

NOTE In accordance with NOTE 5 to Table 2, the adjustment factors for essentially continuous sounds with strong low-frequency content shall not be applied unless the time-average C-weighted sound level exceeds the A-weighted sound level by at least 10 dB.

D.4 Descriptor

The descriptor for sounds with strong low-frequency content is the summation of the time-mean-square sound pressures in the 16, 31.5, and 63-Hz octave bands. The result is the low-frequency, time-mean-square sound pressure p^2_{LF}. The corresponding low-frequency sound pressure level is symbolized by L_{LF}.

D.5 Adjusted sound exposures for sounds with strong low-frequency content

D.5.1 Adjusted sound exposure level from low-frequency sound pressure level

For sounds with strong low-frequency content, adjusted sound exposure level L_{NE} is calculated from low-frequency sound pressure level L_{LF} by

$$\begin{aligned} L_{NE} &= 2(L_{LF} - 65) + 55 + 10\,\lg(T / 1) \\ &= 2L_{LF} - 75 + 10\,\lg(T / 1) \end{aligned} \qquad \text{(D.1)}$$

where T is the time duration of interest, in seconds, over which the low-frequency sound is present. The factor of 2 in equation (D.1) accounts for the rapid increase in annoyance with sound pressure level at low frequencies. Equation (D.1) also accounts for the additional annoyance from rattles that begins when the low-frequency sound pressure level exceeds 75 dB.

D.5.2 Adjusted sound exposure from low-frequency sound pressure level

For sounds with strong low-frequency content, adjusted sound exposure N is calculated from low-frequency sound pressure level L_{LF} by means of

$$\begin{aligned} N &= T[10^{0.1(2L_{LF}-75-94)}] \\ &= T[10^{0.1(2L_{LF}-169)}]. \end{aligned} \qquad \text{(D.2)}$$

D.5.3 Adjusted sound exposure from low-frequency sound pressure

For sounds with strong low-frequency content, adjusted sound exposure N also may be calculated from the time-mean-square low-frequency sound pressure p^2_{LF} by use of equation (D.2) as

$$\begin{aligned} N &= T[10^{0.1(2L_{LF}-169)}] \\ &= T[10^{0.1\{2[10\lg(p^2_{LF}/1)+94]-169\}}] \\ &= T[10^{0.1[10\lg(p^4_{LF}/1)+19]}] \\ &= (T)(p^4_{LF})(10^{1.9}). \end{aligned} \qquad \text{(D.3)}$$

D.6 Use of adjusted sound exposure

Adjusted sound exposures calculated by means of equations (D.2) or (D.3) are used in equation (6a) to provide the contributions to the total adjusted sound exposure from sounds with strong low-frequency content.

D.7 Noise-induced rattles

There is evidence that noise-induced rattles are very annoying and not accounted for by direct measurement of the audible sound. The evidence suggests that rattle annoyance may be independent of the number or duration of events. To prevent the likelihood of noise-induced rattles, the low-frequency sound pressure level should be less than 70 dB.

Annex E

(informative)

Onset rate for airplane flybys

Onset rate for the sound from a low-flying airplane may be estimated if the height of the airplane above ground, lateral offset of the calculation location from the nominal ground track, groundspeed, and the A-weighted sound exposure level of the airplane flyby are known.

The following equation provides an empirical estimate for use in Table 2 of the onset rate R in decibels per second for an airplane flying past some location.

$$\begin{aligned} R = 3.7 + \exp(&-1.1668 - 0.000563z \\ &-0.000177y + 0.0045v \\ &+0.02884L_{AE}) \end{aligned} \tag{E.1}$$

where

z = aircraft height above the elevation of the calculation location (metres);

y = lateral offset from the nominal aircraft track to the calculation location (metres);

v = aircraft groundspeed (nautical miles per hour or knots); and

L_{AE} = calculated or measured A-weighted sound exposure level at the calculation location (decibels).

As an example, assume that z = 90 m, y = 150 m, v = 500 knots, and L_{AE} = 115 dB. Equation (E.1) yields R = 79.1 dB/s. The applicable formula in Table 2 indicates that the corresponding level adjustment for this rapid onset rate is given by 11 lg(79.1/15) = 7.9 dB.

In U.S. customary units of feet for aircraft height and lateral offset, equation (E.1) becomes

$$\begin{aligned} R = 3.7 + \exp(&-1.1668 - 0.00185z \\ &-0.000581y + 0.0045v \\ &+0.02884L_{AE}) \end{aligned} \tag{E.2}$$

Annex F

(informative)

Estimated percentage of a population highly annoyed as a function of adjusted day-night sound level

F.1 Introduction

In 1978, T.J. Schultz published a relation between the percentage of a population expressing high annoyance to aircraft, road traffic and railway noise and the corresponding A-weighted day-night sound level. A few years later, Kryter (see Bibliography [6]) argued that the community response to transportation noise could not be represented by one single curve: for equal day-night levels, the percentage of respondents being highly annoyed by aircraft noise was higher, and the percentage of respondents being highly annoyed by railway sounds was lower than that for road traffic noise.

Revised curves published in 1994 by Finegold *et al.* were derived from a wider set of data than the set used by Schultz. The revised data show aircraft, road traffic and railway noise separately since, as noted earlier by Kryter, there was a systematic difference among them, at least at high sound pressure levels. Recently Miedema and Vos have concluded yet another meta-analysis and found somewhat similar systematic differences.

F.2 The Dose-response function

The dose-response relationship for road traffic noise obtained by Finegold *et al.* estimates the percentages of highly annoyed respondents that were slightly lower than the percentages from the Schultz curve. The dose-response relationship for road traffic noise obtained by Miedema and Vos, however, estimates percentages of highly annoyed respondents that are slightly higher than the percentages from the Schultz curve.

The average of the curves obtained by Finegold *et al.* and by Miedema and Vos virtually coincides with the Schultz curve. Therefore, for simplicity and historical significance, the Schultz curve is taken as the curve to define the percentage of a population that is highly annoyed (%HA) to road traffic noise as a function of the day-night sound level, L_{dn} determined for the free field condition (i.e., the reflection at the building is not taken into account). The solid line in Figure F.1 shows the Schultz curve. About 90% of the grouped results from the various field surveys would fall within the two broken lines.

The equation of the Schultz curve shown in Figure F.1 is given by

$$\%HA = 100 / [1 + \exp(10.4 - 0.132\, L_{dn})] \tag{F.1}$$

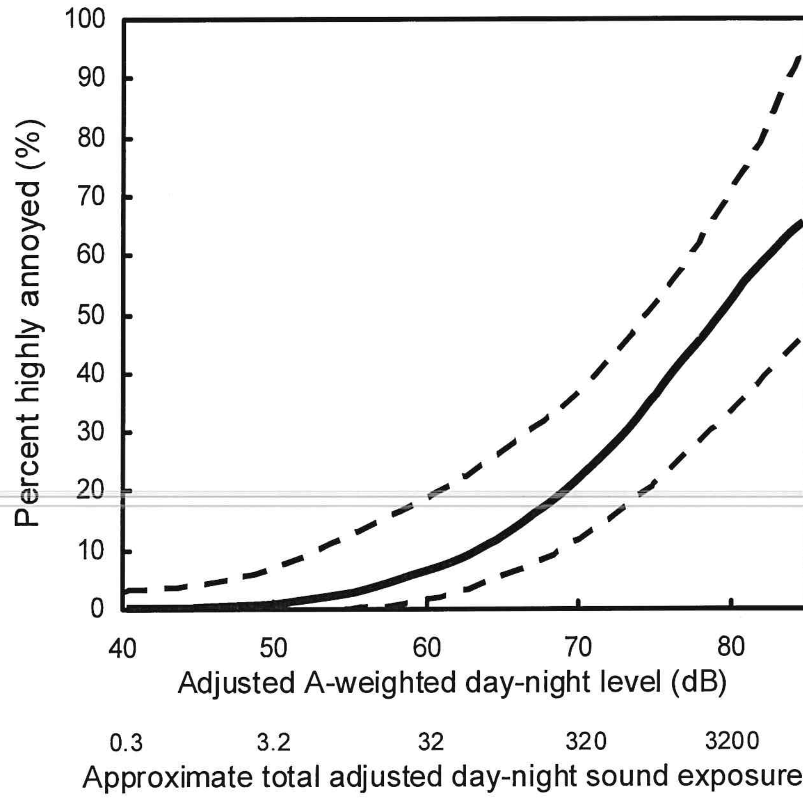

Figure F.1 — Percentage of respondents highly annoyed by road traffic sounds, as a function of the A-weighted day-night level

About 90% of the raw data points on which the average curve is based fall within the two dashed lines.

NOTE This dose-response relationship also can be used to assess the community annoyance response for other sources if the relevant source adjustments suggested in this document have been applied.

F.3 Qualifications to the dose-response function

F.3.1 Equation (F.1) is applicable only to long-term environmental sounds such as the yearly average.

F.3.2 Equation (F.1) should not be used with shorter time periods like weekends, a single season, or "busy days." Rather, the annual average or some other long-term period should be used.

F.3.3 Equation (F.1) is not applicable to a short-term environmental sound such as from an increase in road traffic due to a short-duration construction project.

F.3.4 Equation (F.1) is only applicable to existing situations.

F.3.4.1 In newly created situations, especially when the community is not familiar with the sound source in question, higher community annoyance can be expected. This difference may be equivalent to up to 5 dB.

F.3.4.2 Research has shown that there is a greater expectation for and value placed on "peace and quiet" in quiet rural settings. In quiet rural areas, this greater expectation for "peace and quiet" may be equivalent to up to 10 dB.

F.3.4.3 The above two factors are additive. A new, unfamiliar sound source sited in a quiet rural area can engender much greater annoyance levels than are normally estimated by relations like equation (F.1). This increase in annoyance may be equivalent to adding up to 15 dB to the measured or predicted levels.

For acoustical environments that include sounds with special characteristics, the annual-average adjusted day-night sound level $L_{N\mathrm{dn}}$ should be used in equation (F.1) instead of the non-adjusted annual-average day-night sound level L_{dn}.

Table F.1 provides annual-average adjusted day-night sound levels at 1-dB increments and the corresponding total adjusted day-night sound exposures and percentages of highly annoyed.

Table F.1 — Annual-average adjusted A-weighted day-night sound levels and corresponding total adjusted day-night sound exposures and percentages of a population highly annoyed

Annual-average adjusted day-night sound level (dB)	Total adjusted day-night sound exposure (Pa^2s)	Approximate total adjusted day-night sound exposure (Pa^2s)	Percentage highly annoyed (%)	Annual-average adjusted day-night sound level (dB)	Total adjusted day-night sound exposure (Pa^2s)	Approximate total adjusted day-night sound exposure (Pa^2s)	Percentage highly annoyed (%)
40	0.3	0.3	0.6	61	43.3	40	8.7
41	0.4	0.4	0.7	62	54.5	50	9.8
42	0.5	0.5	0.8	63	68.6	63	11.1
43	0.7	0.6	0.9	64	86.4	80	12.4
44	0.9	0.8	1.0	65	109	100	13.9
45	1.1	1	1.1	66	137	125	15.6
46	1.4	1.3	1.3	67	172	160	17.4
47	1.7	1.6	1.5	68	217	200	19.4
48	2.2	2	1.7	69	273	250	21.6
49	2.7	2.5	1.9	70	344	315	23.9
50	3.4	3.2	2.2	71	433	400	26.3
51	4.3	4	2.5	72	545	500	29.0
52	5.5	5	2.8	73	686	630	31.8
53	6.9	6.3	3.2	74	864	800	34.7
54	8.6	8	3.7	75	1088	1000	37.8
55	10.9	10	4.1	76	1369	1250	40.9
56	13.7	12.5	4.7	77	1724	1600	44.1
57	17.2	16	5.3	78	2170	2000	47.4
58	21.7	20	6.0	79	2732	2500	50.7
59	27.3	25	6.8	80	3440	3150	54.0
60	34.4	32	7.7	81	4330	4000	57.2

NOTE 1 The relationships in Table F.1 also apply for annual-average day-night sound levels of environmental sounds without special characteristics or unusual community response.

NOTE 2 Table F.1 is applicable only to long-term environmental sounds such as the yearly average.

NOTE 3 Table F.1 is not applicable to "busy days" such as an average for say 30 days selected from a year because those 30 days had many noise-producing events and the other 335 days had many fewer such events.

NOTE 4 Table F.1 is not applicable to a short-term transient environmental sound such as from a short-duration construction project.

NOTE 5 Table F.1 is not applicable if there is sound-induced building vibration or rattles. Some studies have shown sound-induced building vibration or rattles to increase the equivalent annoyance by at least 10 dB. (See also D.7.)

Annex G

(informative)

Assessing the complaint potential of high-amplitude impulse noise

G.1 Introduction

Several decades of experience in handling noise complaints at military installations shows that substantive complaints typically result from the louder and/or more unusual events. Thus, a long-term average noise level metric arguably is not adequate alone to predict community complaint response, or indeed to protect against valid damage claims. A viable procedure is to supplement the long-term average (e.g. DNL) noise impact assessment procedure with risk criteria for community response in terms of complaints as a function of a single-event metric. Appropriate candidate metrics are suggested in Clause 4.1.1.

This annex provides a method to assess the complaint risk from military high-amplitude impulse sound such as the sounds produced by artillery or tank gun fire, bombs, military explosives, and similar civilian sources.[1] Historically, the peak level has been used with success to predict military blast noise complaints, though it does not account for the effect of event duration. Another candidate is the sound exposure level. For historical simplicity, the wide-band peak level is used in this annex. These risk criteria are only intended to be applied to blast noise events from large weapons such as artillery and tank guns and from fairly large explosions (approximately 0.1 to 100 kg). These sources exhibit considerable low frequency sound energy, with a sound exposure level spectrum that typically peaks in the range from 10 to 100 Hz. These noise complaint risk criteria should not be used for other sources of noise such as small arms noise and aircraft noise.

G.2 Complaint criteria

A set of risk criteria was developed by the Navy (Ref. 23) to guide decisions that balance risk of noise complaints against the cost or other consequences of canceling training or testing activity. These guidelines were based on records of complaints received, sound level measurements, sound level calculations, and balloon-suspended radiosonde meteorological soundings. The guidelines were also evaluated during a subsequent study (Ref. 26) and found to be a reliable method to predict complaints resulting from the firing of large guns. The risk criteria, presented in Table G.1, are expressed in terms of degree of complaint risk as a function of the value of the unweighted peak noise metric.

G.3 Complaint risk prediction

Large caliber weapons are very strong acoustic sources. The sound from firing these weapons can be easily audible at long distances, often as far as several tens of kilometers. Change in weather conditions can profoundly influence received noise levels. Sound propagation is influenced by vertical and horizontal profiles of values of atmospheric meteorological parameters such as temperature,

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[1] For purposes of this annex, the weight of charge should be, approximately, between 0.1 and 50 kg.

humidity, wind speed and wind direction. Variation as large as 50 dB in received values of single-event noise metrics such as peak and SEL are routinely encountered (see for example Ref. 24).

The criteria presented in Table G.1 are based on the correlation of degree of risk of noise complaints for known event levels. Useful prediction of complaint risk also must take into account the expected statistical variation in received single-event peak noise level due to weather. If one predicts the mean peak level for all expected event levels, the actual noise level will be higher than the predicted mean level for 50% of all expected events, and may be higher by as much as 25 dB. This affords rather limited protection against receiving noise complaints, since a 25-dB change in event level can change complaint risk from low to high. On the other hand, basing risk of noise complaints on the maximum expected level would be far too conservative. An adequate procedure is to base assessment of complaint risk on a predicted exceedance level. As an example, consider PK15, the peak (unweighted) level that can be expected to be exceeded by 15% of expected blast noise events. A prediction of PK15 = 130 dB means that the risk of receiving a noise complaint would be expected to be high for 15% of all expected events. This strategy requires that the variance in received noise level due to weather effects are known, which is the case for blast noise from large guns.

Table G.1 – Complaint Risk Criteria

Risk of Noise Complaints	**Large Caliber Weapons Noise Level (Unweighted Peak)**
Low	< 115
Medium	115 – 130
High	130 – 140
Risk of physiological damage to unprotected human ears and structural damage claims	> 140

Annex H

(informative)

Loudness-level weighting

H.1 Introduction

The A-weighting filter can be replaced by the equal-loudness-level contours (Figure H.1) from ISO 226 (May 1987) as a dynamic filter that changes both with amplitude and with frequency. To approximate sound heard indoors, the sound is first filtered by a generalized house filter that is adjusted to approximate a window's slightly open condition—on the order of 5 cm (Figure H.2)[2]. This new method eliminates the need for the aircraft source adjustments in Table 2. Thus, with this new method, one can measure all transportation noise sources in a given situation. In effect, this new method provides a family of curves that vary systematically with sound frequency and level (Figure H.1).

Schomer (2000) shows that the use of loudness-level weighting provides for much better correlation with subjective annoyance responses than does the A-weighting. This new method uses fast-time-weighted one-third-octave-band spectra sampled every 100 ms over the duration of an event such as an aircraft flyby. Fast-time weighting is used to approximate the integration time of human hearing. Each spectral band level is replaced by its corresponding phon level using an analytical representation of Figure H.1. These phon levels are summed over time and frequency on an energy basis to form the loudness-level-weighted sound exposure level (LLSEL). The analytical representation is given in Table H.1.

H.2 The method

A sound event such as the sound of an airplane flyby or a truck passby is analyzed into one-third-octave bands. Human hearing is such that short-duration sounds are not perceived to be as loud as long-duration sounds. To be perceived with full loudness, sound must be present for a duration that is longer than the integration time of the ear. Thus, in this procedure, the one-third octave band spectra are *fast* time weighted and sampled every 100 ms. The *fast* time weighting is used to approximate the integration time of the ear which data indicate lies between 25 ms and 250 ms. Since the time constant for *fast*-time-weighting is 125 ms, 100 ms is an adequate rate with which to sample the spectra. This forms a time-series of one-third-octave-band spectra.

Equal-loudness-level contours are given in functional form in Table H.1 However, this method requires that the sound first be filtered by the house filter of Figure H.2 and as given in Table H.1. Then the analytical functions given in Table H.1 can be applied. The loudness-level functions and house filter in Table H.1 correspond to one-third-octave-band center frequencies from 20 Hz to 12,500 Hz. Each filtered one-third-octave-band sound pressure level (SPL) is assigned the phon level that corresponds to that frequency and level. For example, from Table H.1, a filtered one-third-octave-band SPL of 82 dB in the 125-Hz band would be assigned a value of 80 phon since it corresponds to a phon level of 80. Similarly, a filtered one-third-octave-band level of 82 dB in the 31.5-Hz band would be assigned a value of 51 phon.

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[2] The house filter simulates the Sound Transmission Loss (TL) of a typical house, in this case with windows open about 2 cm, when sound is transmitted from outdoors to indoors.

The overall time-integrated phon level (LLSEL) is calculated from the time and frequency energy summation of the time-series of filtered one-third-octave band spectra. This time-series of 100 ms, filtered one-third-octave-band spectra is used to calculate the overall time- and frequency-summed phon level, L_L, that is given by:

$$L_L = 10\log\left\langle \sum_j \sum_i 10^{\left(L_{Lij}/10\right)} \right\rangle \tag{H.1}$$

where L_{Lij} is the phon level corresponding to the *i*th filtered one-third-octave band during the *j*th time sample.

The quantity calculated by equation (H.1), L_L, has been designated as the loudness-level-weighted sound exposure level (LLSEL). It is similar to the A-weighted sound exposure level (ASEL) except that instead of using a filter (A-weighting) that varies only with frequency, LLSEL uses a dynamic filter that varies with both SPL and frequency. Similarly, one can calculate loudness-level-weighted equivalent level (LL-LEQ) or loudness-level weighted day-night level (LL-DNL).

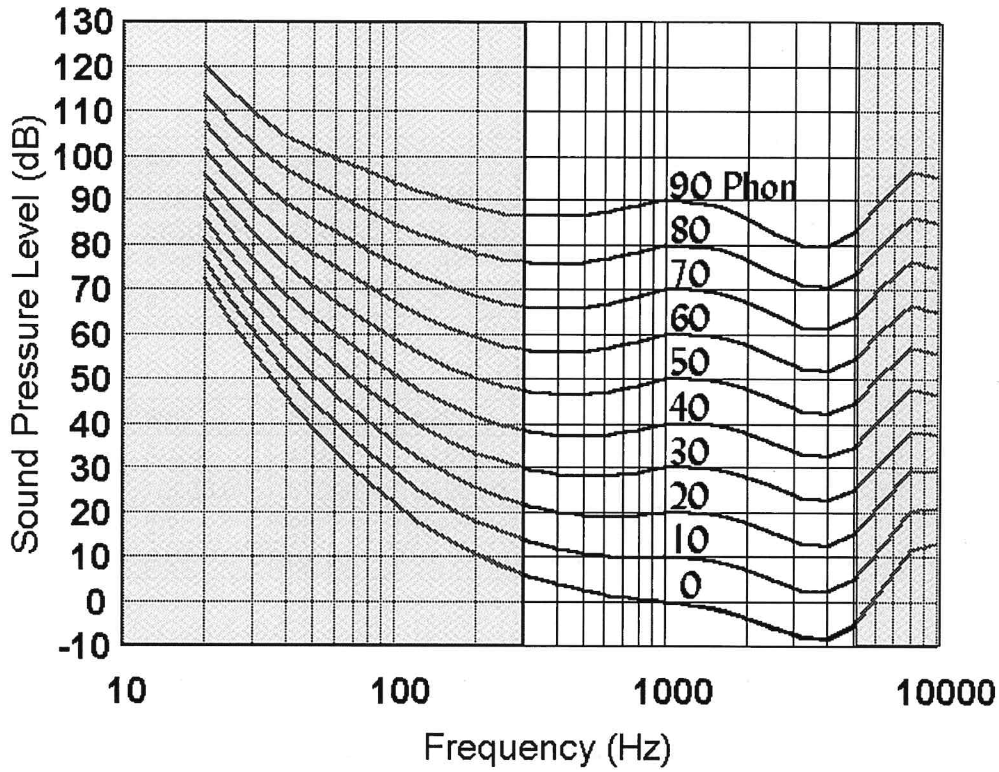

Figure H.1 — Equal loudness level contours in phons from ISO 226-1987. The non-shaded area shows the frequency range where, approximately, a 10-dB change in sound pressure level corresponds to a 10-dB change in phon level. At low frequencies this relationship does not occur. For example, at 31 Hz, a 10-dB change in sound pressure level corresponds to about a 20-dB change in phon level.

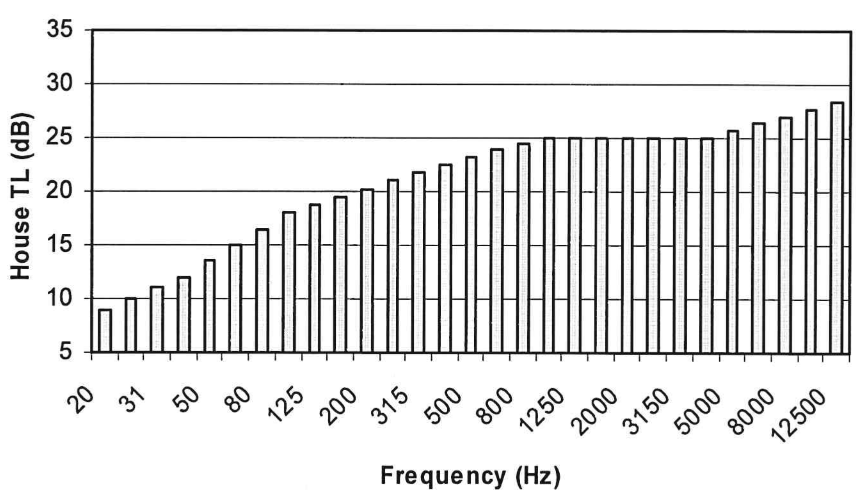

Figure H.2 — Generalized house TL for windows open on the order of 5 cm.

Frequency	20	25	31	40	50	63	80	100
af	2.347	2.190	2.050	1.879	1.724	1.597	1.512	1.466
Lu	0.00561	0.00527	0.00481	0.00404	0.00338	0.00286	0.00259	0.00257
Tf	74.3	65	56.3	48.4	41.7	35.5	29.8	25.1
House TL	9	10	11	12	13.5	15	16.5	18

Frequency	125	160	200	250	315	400	500	630
af	1.426	1.394	1.372	1.344	1.304	1.256	1.203	1.136
Lu	0.00256	0.00256	0.00254	0.00248	0.00229	0.00201	0.00162	0.00111
Tf	20.7	16.8	13.8	11.2	8.9	7.2	6	5
House TL	18.75	19.5	20.25	21	21.75	22.5	23.25	24

Frequency	800	1000	1250	1600	2000	2500	3150	4000
af	1.062	1.000	0.967	0.943	0.932	0.933	0.937	0.952
Lu	0.00052	0	-0.00039	-0.00067	-0.00092	-0.00105	-0.00104	-0.00088
Tf	4.4	4.2	3.7	2.6	1	-1.2	-3.6	-3.9
House TL	24.5	25	25	25	25	25	25	25

Frequency	5000	6300	8000	10000	12500
af	0.974	1.027	1.135	1.266	1.501
Lu	-0.00055	0	0.00089	0.00211	0.00489
Tf	-1.1	6.6	15.3	16.4	11.6
House TL	25.65	26.35	27	27.65	28.35

Table H.1 — Coefficients for calculation loudness level from band sound pressure level. The table also includes the house filter characteristics shown in Figure H.2.

For any band, loudness level is calculated from the respective band j sound pressure level, L_j by:

$$LL_j = 4.2 + [af_i\,(L_i - Tf_i)]/[1 + Lu_i\,(L_i - Tf_i)] \qquad (H.2)$$

where LL_j is the loudness level in the jth band.

The house TL is included by modifying (H.2) to:

$$LL_j = 4.2 + [af_i\,(L_i - TL_i - Tf_i)]/[1 + Lu_i\,(L_i - TL_i - Tf_i)] \qquad (H.3)$$

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NOTE The following references are available in the open literature or through the National Technical Information Service (NTIS). NTIS numbers are given at the end of each reference.

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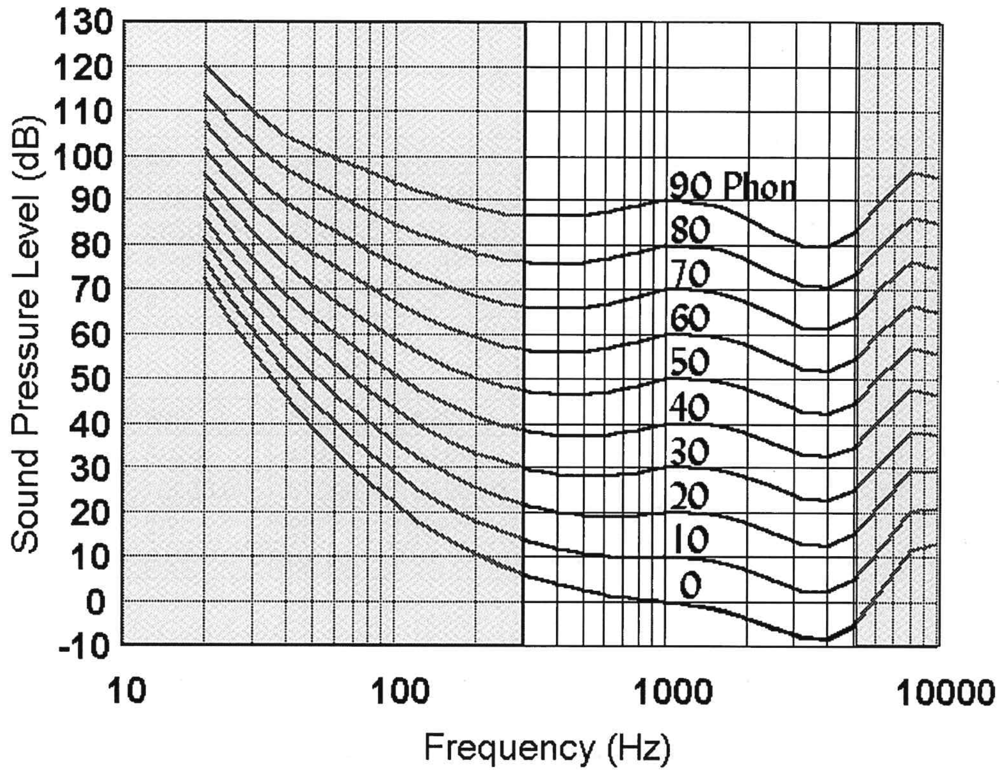

Figure H.1 — Equal loudness level contours in phons from ISO 226-1987. The non-shaded area shows the frequency range where, approximately, a 10-dB change in sound pressure level corresponds to a 10-dB change in phon level. At low frequencies this relationship does not occur. For example, at 31 Hz, a 10-dB change in sound pressure level corresponds to about a 20-dB change in phon level.

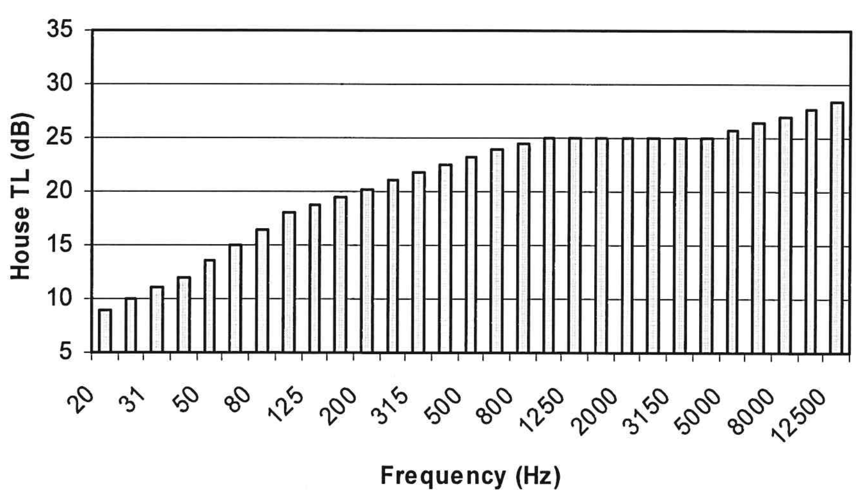

Figure H.2 — Generalized house TL for windows open on the order of 5 cm.

Frequency	20	25	31	40	50	63	80	100
af	2.347	2.190	2.050	1.879	1.724	1.597	1.512	1.466
Lu	0.00561	0.00527	0.00481	0.00404	0.00338	0.00286	0.00259	0.00257
Tf	74.3	65	56.3	48.4	41.7	35.5	29.8	25.1
House TL	9	10	11	12	13.5	15	16.5	18

Frequency	125	160	200	250	315	400	500	630
af	1.426	1.394	1.372	1.344	1.304	1.256	1.203	1.136
Lu	0.00256	0.00256	0.00254	0.00248	0.00229	0.00201	0.00162	0.00111
Tf	20.7	16.8	13.8	11.2	8.9	7.2	6	5
House TL	18.75	19.5	20.25	21	21.75	22.5	23.25	24

Frequency	800	1000	1250	1600	2000	2500	3150	4000
af	1.062	1.000	0.967	0.943	0.932	0.933	0.937	0.952
Lu	0.00052	0	-0.00039	-0.00067	-0.00092	-0.00105	-0.00104	-0.00088
Tf	4.4	4.2	3.7	2.6	1	-1.2	-3.6	-3.9
House TL	24.5	25	25	25	25	25	25	25

Frequency	5000	6300	8000	10000	12500
af	0.974	1.027	1.135	1.266	1.501
Lu	-0.00055	0	0.00089	0.00211	0.00489
Tf	-1.1	6.6	15.3	16.4	11.6
House TL	25.65	26.35	27	27.65	28.35

Table H.1 — Coefficients for calculation loudness level from band sound pressure level. The table also includes the house filter characteristics shown in Figure H.2.

For any band, loudness level is calculated from the respective band j sound pressure level, L_j by:

$$LL_j = 4.2 + [\mathrm{af}_i\,(L_i - \mathrm{Tf}_i)]/[1 + \mathrm{Lu}_i\,(L_i - \mathrm{Tf}_i)] \tag{H.2}$$

where LL_j is the loudness level in the jth band.

The house TL is included by modifying (H.2) to:

$$LL_j = 4.2 + [\mathrm{af}_i\,(L_i - \mathrm{TL}_i - \mathrm{Tf}_i)]/[1 + \mathrm{Lu}_i\,(L_i - \mathrm{TL}_i - \mathrm{Tf}_i)] \tag{H.3}$$

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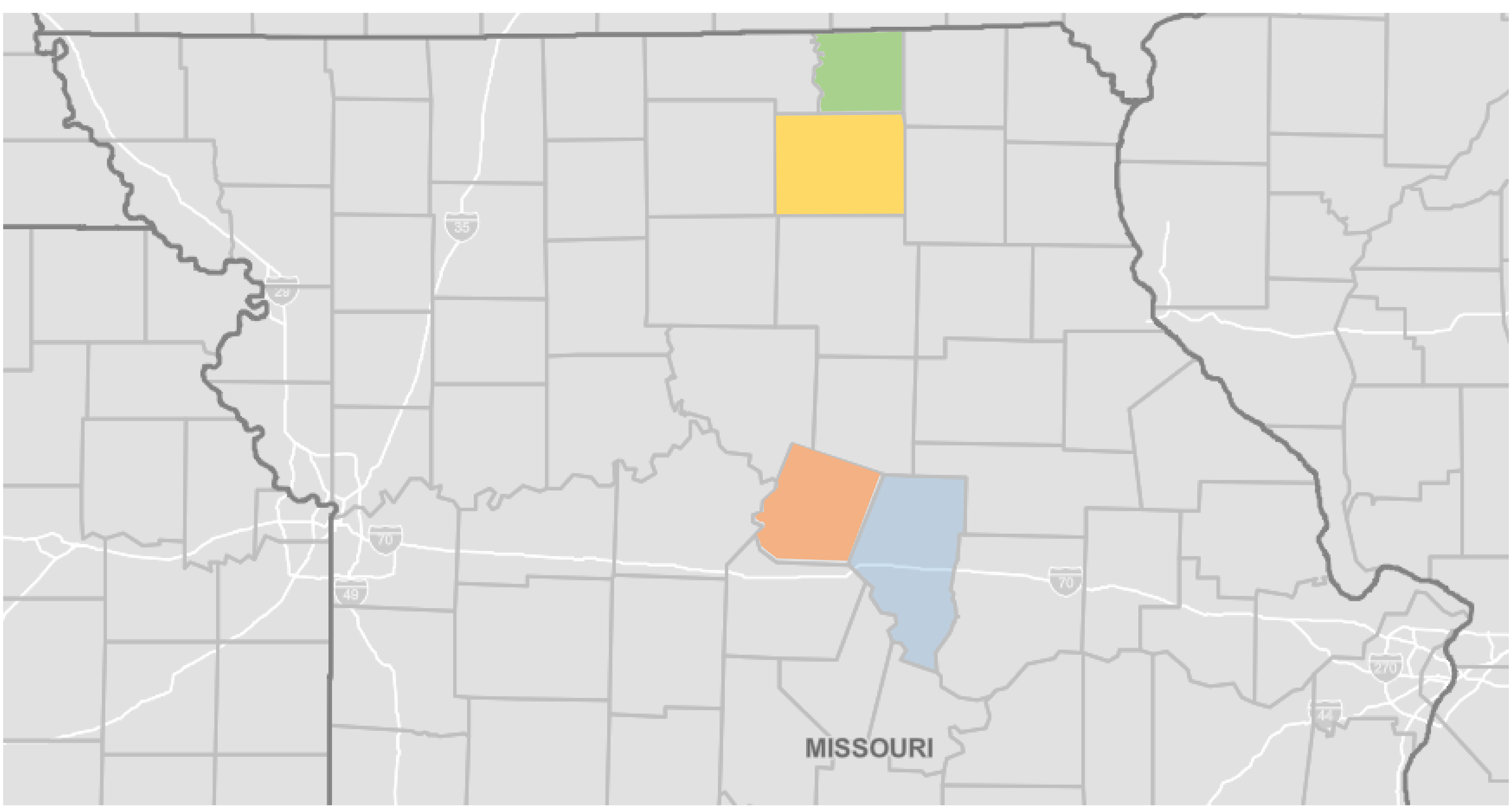
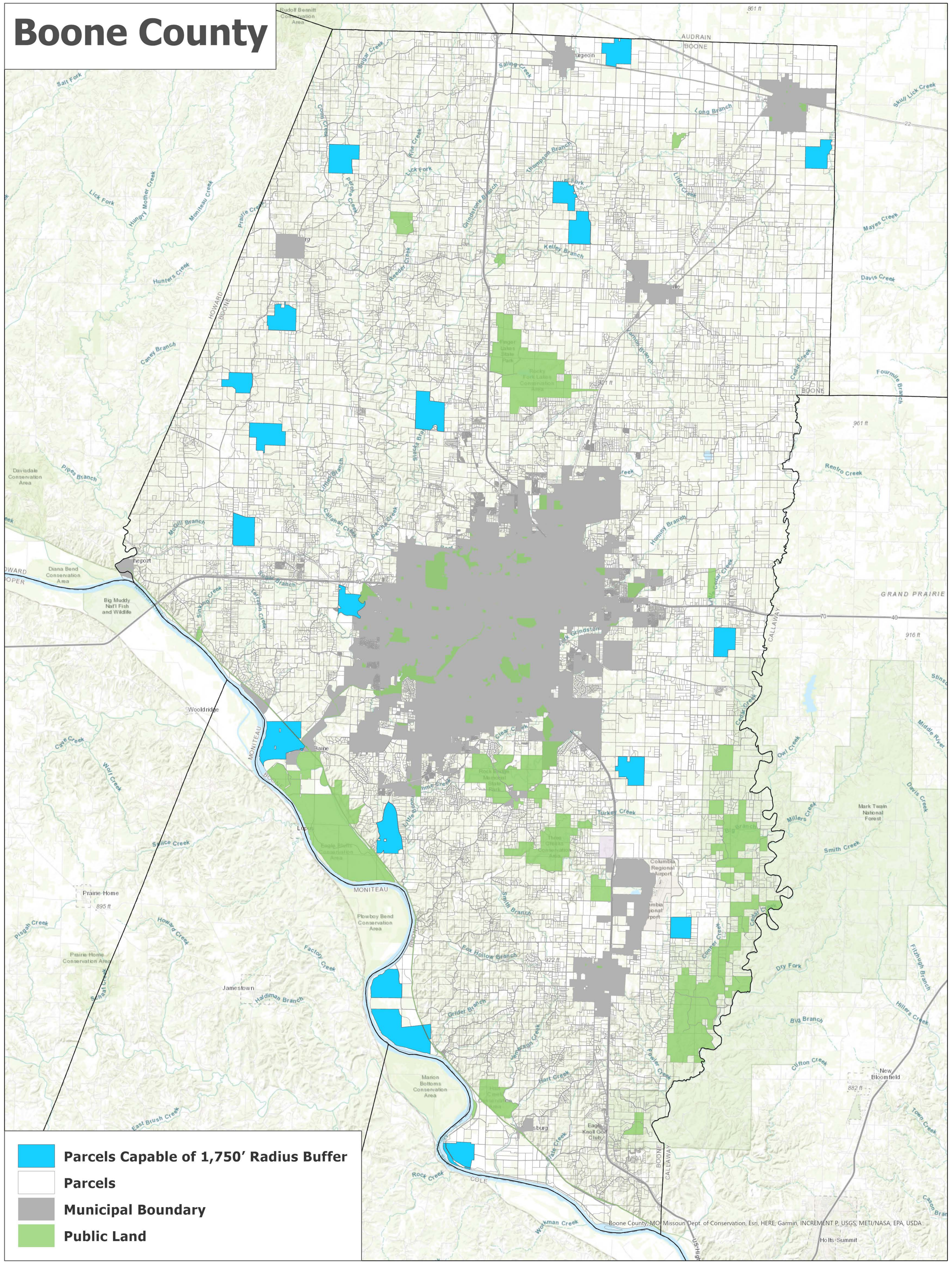
ATTACHMENT 11

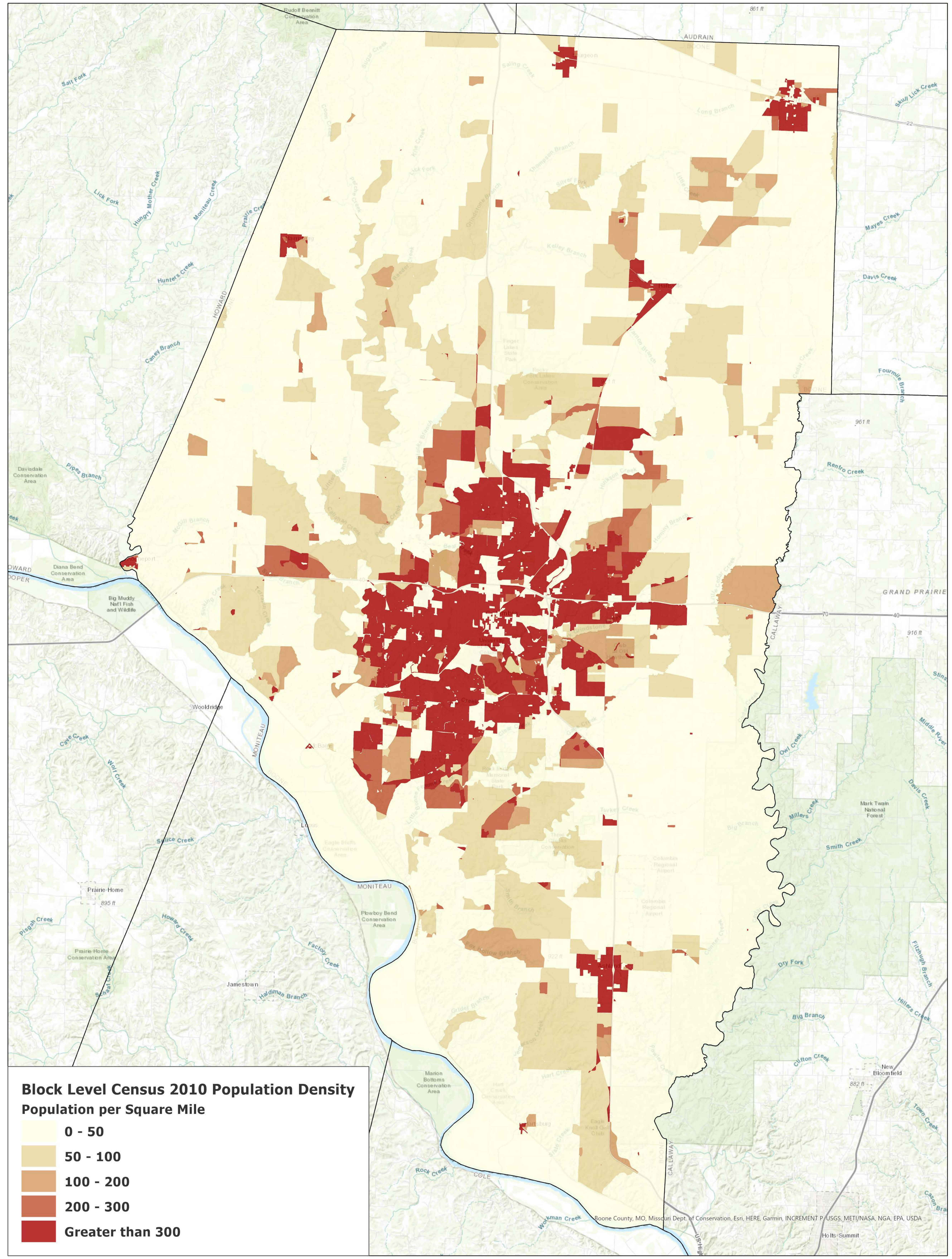
	Boone	Adair	Howard	Schuyler
2020 Population	180,463	25,343	10,001	4,660
Population % Change	▲ 11%	▼ -1%	▼ -1.4%	▲ 5.2%
2010 Population	162,642	25,607	10,144	4,431
Area	691 $mile^2$	569 $mile^2$	253 $mile^2$	308 $mile^2$
Population Density people per square mile	$240/mile^2$	$45/mile^2$	$21/mile^2$	$14/mile^2$
Housing Units	77,314	11,542	4,591	2,106
Assessed Valuation	3.1 Billion	343 Million	133 Million	74 Million

Source: data.census.gov 2019
Missouri Association of Counties

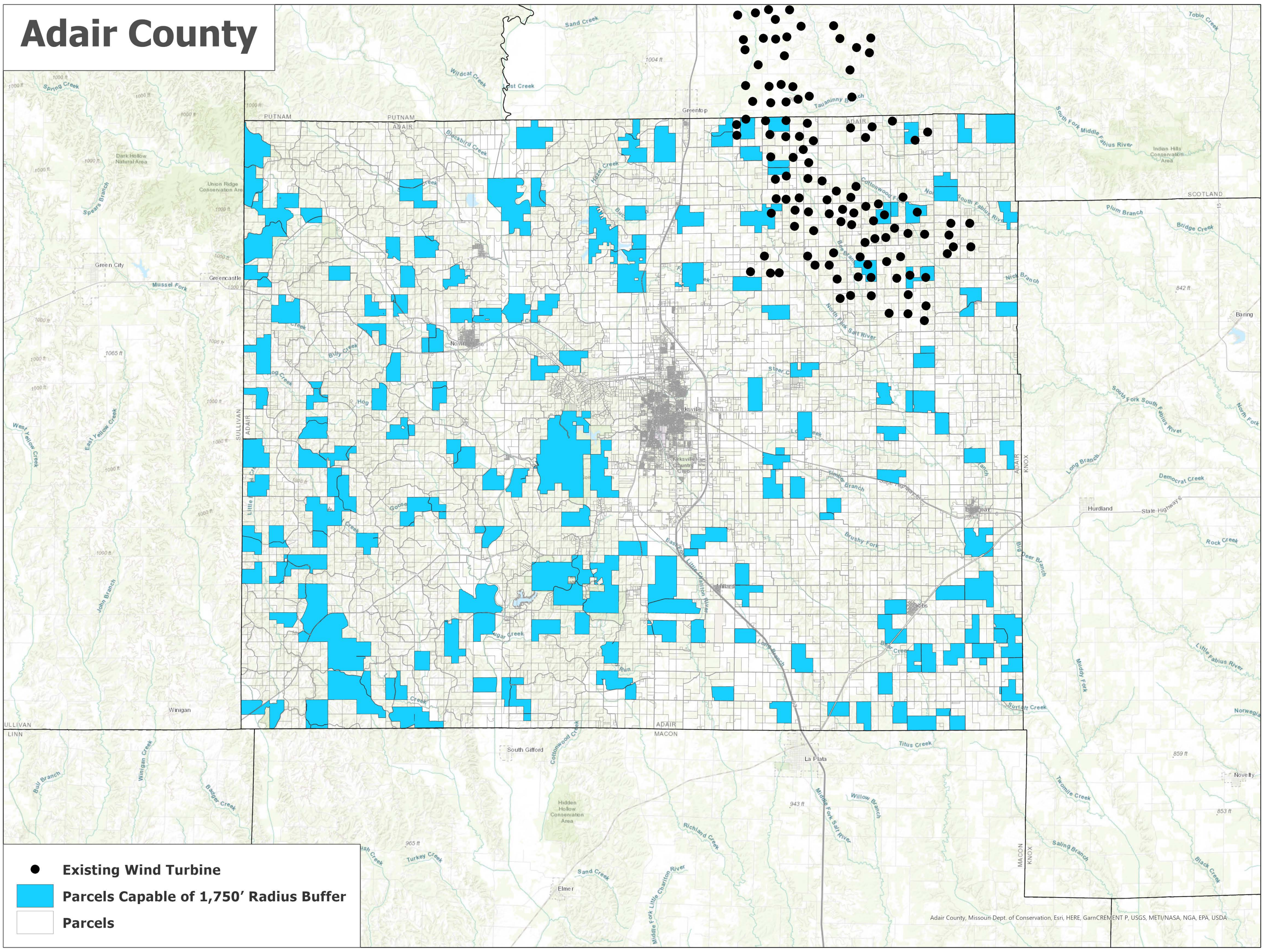


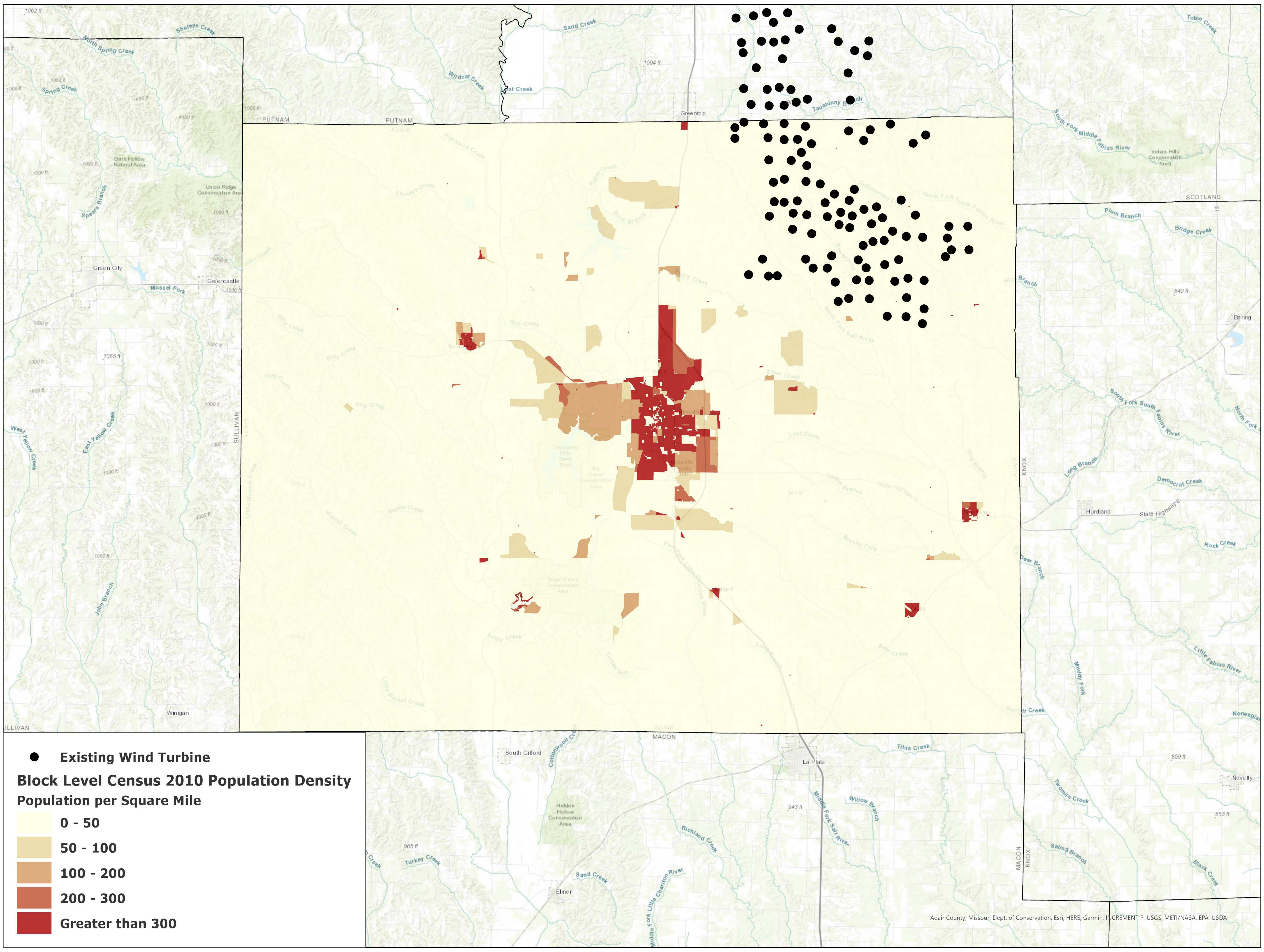
ATTACHMENT 12


Boone County
Parcels Capable of 1,750' Radius Buffer
Parcels
Municipal Boundary
Public Land

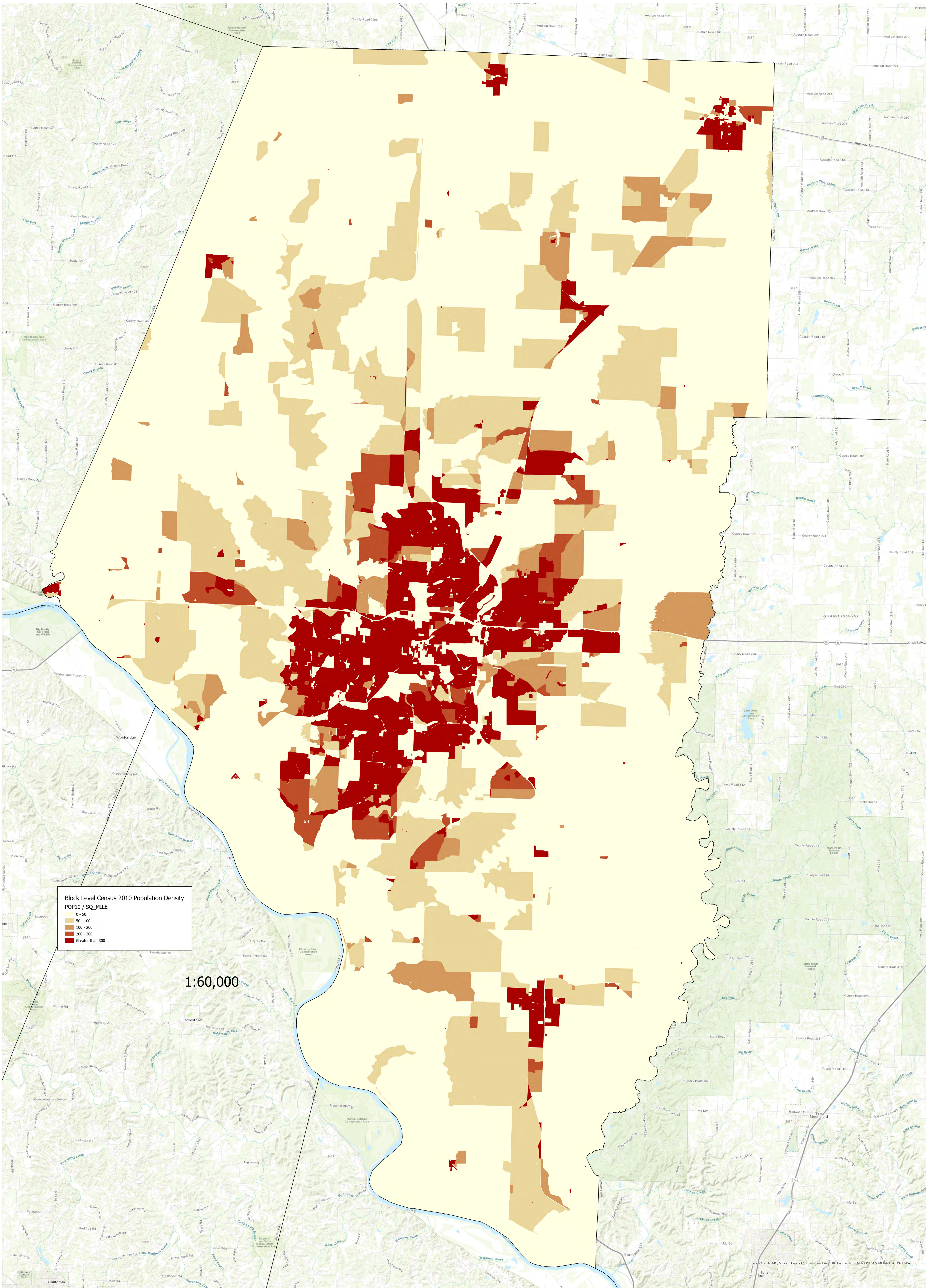

Block Level Census 2010 Population Density
Population per Square Mile
0 - 50
50 - 100
100 - 200
200 - 300
Greater than 300

ATTACHMENT 13

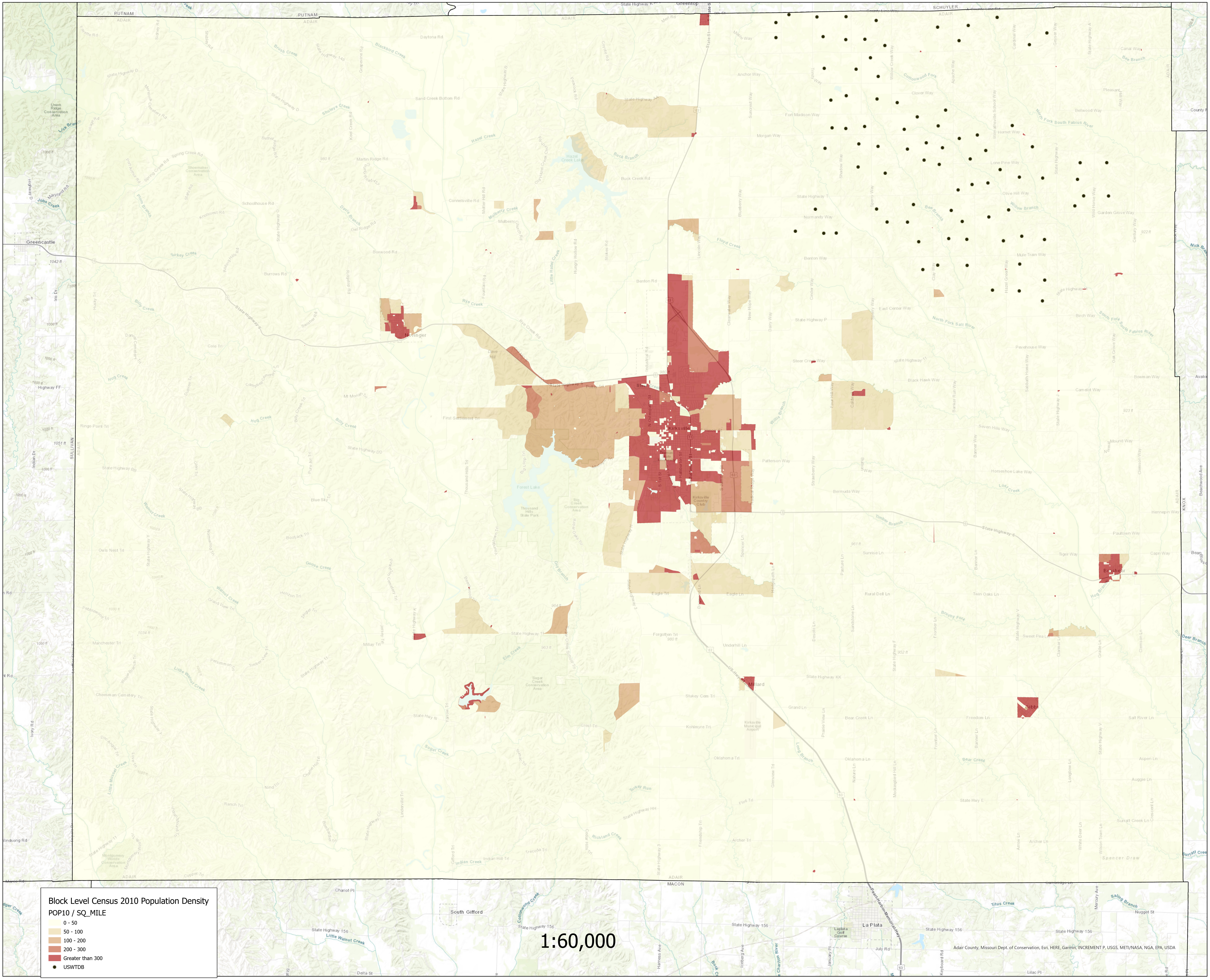

Adair County
Existing Wind Turbine
Parcels Capable of 1,750′ Radius Buffer
Parcels
Adair County, Missouri Dept. of Conservation, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA, NGA, EPA, USDA


Existing Wind Turbine
Block Level Census 2010 Population Density
Population per Square Mile
0 - 50
50 - 100
100 - 200
200 - 300
Greater than 300
Adair County, Missouri Dept. of Conservation, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA, EPA, USDA

ATTACHMENT 14


Block Level Census 2010 Population Density
POP10 / SQ_MILE
0 - 50
50 - 100
100 - 200
200 - 300
Greater than 300
1:60,000

ATTACHMENT 15


Block Level Census 2010 Population Density
POP10 / SQ_MILE
0 - 50
50 - 100
100 - 200
200 - 300
Greater than 300
USWTDB
1:60,000
Adair County, Missouri Dept. of Conservation, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA, NGA, EPA, USDA
Kirksville
Novinger
Brashear
Millard
Gibbs
Greentop
Greencastle
La Plata
South Gifford
PUTNAM
SCHUYLER
SULLIVAN
KNOX
MACON
ADAIR

ATTACHMENT 16

Manufacturer	Model	Hub height	rotor diameter	total height (m)	Total Heigh (ft)
Siemens Gamesa	SG 2.1-114	68	114	125	410
Siemens Gamesa	SG 2.1-114	80	114	137	449.36
General Electric	2MW-116	80	116	138	452.64
Vestas	V90-2.0 MW	80	90	125	410
Suzlon	S111	90	111.8	145.9	478.552
Nordex	N117/3600	84	116.8	142.4	467.072

Source
https://www.siemensgamesa.com/en-int/products-and-services/onshore/wind-turbine-sg-2-1-114
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