APPENDICES

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Appendix 1.1 FAA Determination on Turbine 1

Federal Aviation Administration
Air Traffic Airspace Branch, ASW-520
2601 Meacham Blvd.
Fort Worth, TX 76137-0520

Aeronautical Study No.
2008-ANE-276-OE

Issued Date: 11/04/2008

Rob Rizzo
Mount Wachusett Community College
444 Green Street
Gardner, MA 01440

**** DETERMINATION OF NO HAZARD TO AIR NAVIGATION ****

The Federal Aviation Administration has conducted an aeronautical study under the provisions of 49 U.S.C., Section 44718 and if applicable Title 14 of the Code of Federal Regulations, part 77, concerning:

Structure:	Wind Turbine MWCC Wind Turbine 1
Location:	Gardner, MA
Latitude:	42-35-26.13N NAD 83
Longitude:	71-59-03.39W
Heights:	415 feet above ground level (AGL)
	1573 feet above mean sea level (AMSL)

This aeronautical study revealed that the structure would have no substantial adverse effect on the safe and efficient utilization of the navigable airspace by aircraft or on the operation of air navigation facilities. Therefore, pursuant to the authority delegated to me, it is hereby determined that the structure would not be a hazard to air navigation provided the following condition(s) is(are) met:

As a condition to this Determination, the structure is marked and/or lighted in accordance with FAA Advisory circular 70/7460-1 K Change 2, Obstruction Marking and Lighting, white paint/synchronized red lights - Chapters 4,12&13(Turbines).

It is required that FAA Form 7460-2, Notice of Actual Construction or Alteration, be completed and returned to this office any time the project is abandoned or:

__X__ At least 10 days prior to start of construction (7460-2, Part I)
__X__ Within 5 days after the construction reaches its greatest height (7460-2, Part II)

See attachment for additional condition(s) or information.

While the structure does not constitute a hazard to air navigation, it would be located within or near a military training area and/or route.

This determination expires on 05/04/2010 unless:

(a) extended, revised or terminated by the issuing office.
(b) the construction is subject to the licensing authority of the Federal Communications Commission (FCC) and an application for a construction permit has been filed, as required by the FCC, within

6 months of the date of this determination. In such case, the determination expires on the date prescribed by the FCC for completion of construction, or the date the FCC denies the application.

NOTE: REQUEST FOR EXTENSION OF THE EFFECTIVE PERIOD OF THIS DETERMINATION MUST BE POSTMARKED OR DELIVERED TO THIS OFFICE AT LEAST 15 DAYS PRIOR TO THE EXPIRATION DATE.

This determination is subject to review if an interested party files a petition that is received by the FAA on or before December 04, 2008. In the event a petition for review is filed, it must contain a full statement of the basis upon which it is made and be submitted in triplicate to the Manager, Airspace and Rules Division - Room 423, Federal Aviation Administration, 800 Independence Ave., Washington, D.C. 20591.

This determination becomes final on December 14, 2008 unless a petition is timely filed. In which case, this determination will not become final pending disposition of the petition. Interested parties will be notified of the grant of any review. For any questions regarding your petition, please contact Office of Airspace and Rules via telephone -- 202-267-8783 - or facsimile 202-267-9328.

This determination is based, in part, on the foregoing description which includes specific coordinates, heights, frequency(ies) and power. Any changes in coordinates, heights, and frequencies or use of greater power will void this determination. Any future construction or alteration, including increase to heights, power, or the addition of other transmitters, requires separate notice to the FAA.

This determination does include temporary construction equipment such as cranes, derricks, etc., which may be used during actual construction of the structure. However, this equipment shall not exceed the overall heights as indicated above. Equipment which has a height greater than the studied structure requires separate notice to the FAA.

This determination concerns the effect of this structure on the safe and efficient use of navigable airspace by aircraft and does not relieve the sponsor of compliance responsibilities relating to any law, ordinance, or regulation of any Federal, State, or local government body.

This aeronautical study considered and analyzed the impact on existing and proposed arrival, departure, and en route procedures for aircraft operating under both visual flight rules and instrument flight rules; the impact on all existing and planned public-use airports, military airports and aeronautical facilities; and the cumulative impact resulting from the studied structure when combined with the impact of other existing or proposed structures. The study disclosed that the described structure would have no substantial adverse effect on air navigation.

An account of the study findings, aeronautical objections received by the FAA during the study (if any), and the basis for the FAA's decision in this matter can be found on the following page(s).

A copy of this determination will be forwarded to the Federal Communications Commission if the structure is subject to their licensing authority.

If we can be of further assistance, please contact Michael Blaich, at (770) 909-4329. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2008-ANE-276-OE.

Signature Control No: 564066-103636290 (DNH)
Kevin P. Haggerty
Manager, Obstruction Evaluation Service

Attachment(s)
Additional Information
Map(s)

Additional information for ASN 2008-ANE-276-OE

Proposal: To build a Wind Turbine to a height of 415 feet above ground level, 1573 feet above mean sea level (AMSL).

Location: The structure will be located 2.82 nautical miles northeast of the Gardner Municipal Airport (GDM) reference point.

Wind Turbine exceeds Instrument Flight Rule (IFR) Departure 40:1 at GDM RWY 36. It would require amending/increasing take-off minimums to 700-3 or standard with minimum climb gradient of 240 feet per nautical mile until 1800. The current take-off minimums is 500-2. This increase is not considered substantial and would not require public circularization, for comment. However, the proponent is required to give at least 6 weeks prior notice of construction so that the appropriate action may be taken to revise the procedure.

There are no impacts to any airport or IFR/VFR terminal or en route current or planned procedures. There is not a cumulative impact to any airport, nor is there any impact to any airport plan on file.

An aeronautical study for Visual Flight Rules (VFR) disclosed that the proposed structure would not affect VFR navigation. The proposed structure would have to exceed 500 feet Above Ground Level (AGL) to penetrate the vertical confines of any VFR route.

The proposed structure was found to have no substantial adverse effect on the VFR traffic patterns in the vicinity of the site.

Details of the structure were not circularized to the aeronautical public for comment.

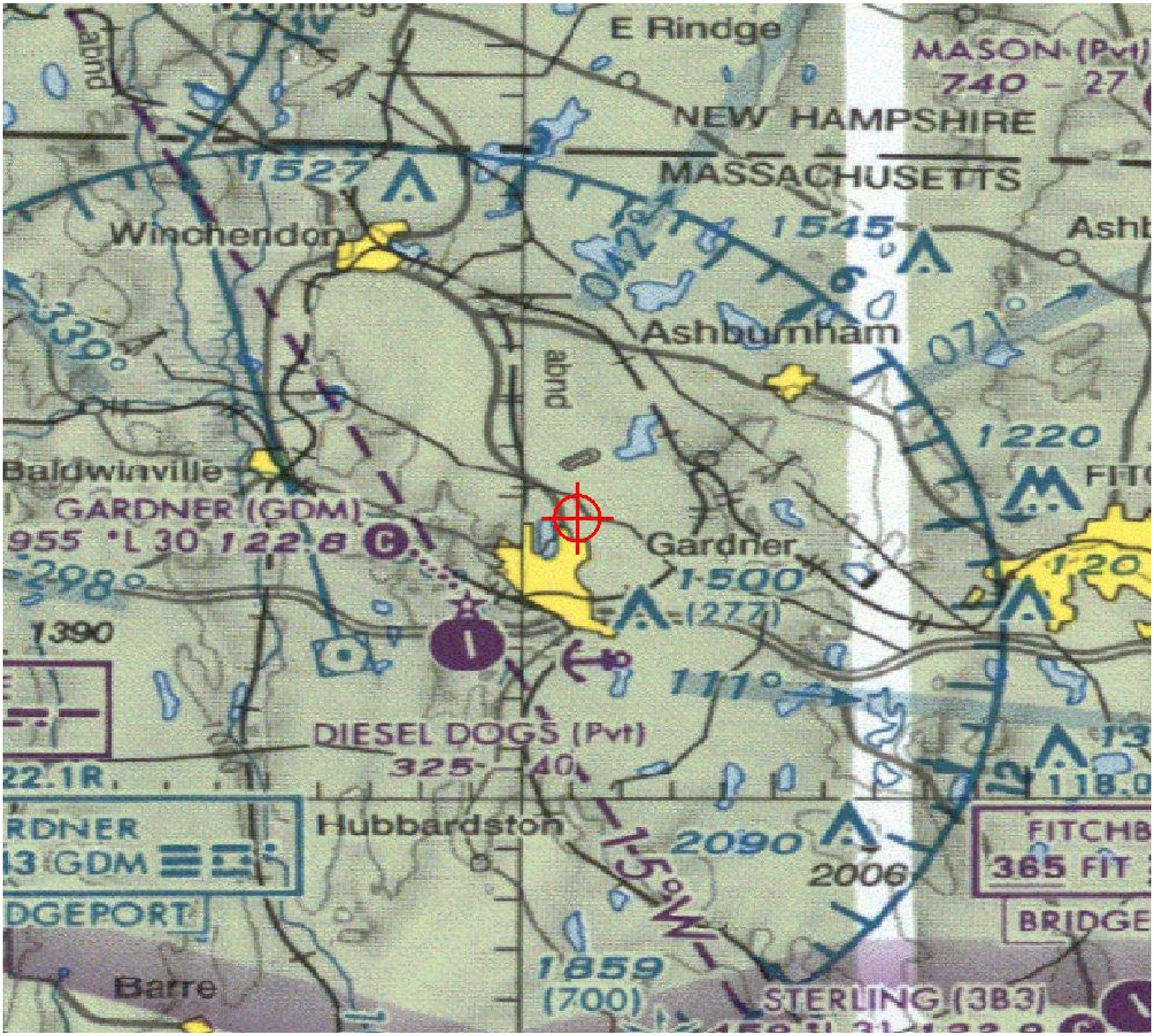
The impact on arrival, departure, and en route procedures for aircraft operating under VFR/IFR conditions at existing and planned public use airports, as well as aeronautical facilities, was considered during the analysis of the structure.

The aeronautical study disclosed that the structure, at the height shown on page 1 of this determination, would have no substantial adverse effect upon any terminal or en route instrument procedure or altitude.

The cumulative impact resulting from the structure, when combined with the impact of other existing or proposed structures was considered and found to be acceptable.

Therefore, it is determined that the structure will have no substantial adverse effect upon the safe and efficient utilization of the navigable airspace by aircraft or on the operation of navigational facilities and would not be a hazard to air navigation.

Sectional Map for ASN 2008-ANE-276-OE



Appendix 1.2 FAA Determination on Turbine 2

Federal Aviation Administration
Air Traffic Airspace Branch, ASW-520
2601 Meacham Blvd.
Fort Worth, TX 76137-0520

Aeronautical Study No.
2008-ANE-277-OE

Issued Date: 11/04/2008

Rob Rizzo
Mount Wachusett Community College
444 Green Street
Gardner, MA 01440

**** DETERMINATION OF NO HAZARD TO AIR NAVIGATION ****

The Federal Aviation Administration has conducted an aeronautical study under the provisions of 49 U.S.C., Section 44718 and if applicable Title 14 of the Code of Federal Regulations, part 77, concerning:

Structure:	Wind Turbine MWCC Wind Turbine 2
Location:	Gardner, MA
Latitude:	42-35-16.97N NAD 83
Longitude:	71-59-02.88W
Heights:	415 feet above ground level (AGL)
	1573 feet above mean sea level (AMSL)

This aeronautical study revealed that the structure would have no substantial adverse effect on the safe and efficient utilization of the navigable airspace by aircraft or on the operation of air navigation facilities. Therefore, pursuant to the authority delegated to me, it is hereby determined that the structure would not be a hazard to air navigation provided the following condition(s) is(are) met:

As a condition to this Determination, the structure is marked and/or lighted in accordance with FAA Advisory circular 70/7460-1 K Change 2, Obstruction Marking and Lighting, white paint/synchronized red lights - Chapters 4,12&13(Turbines).

It is required that FAA Form 7460-2, Notice of Actual Construction or Alteration, be completed and returned to this office any time the project is abandoned or:

__X__ At least 10 days prior to start of construction (7460-2, Part I)
__X__ Within 5 days after the construction reaches its greatest height (7460-2, Part II)

See attachment for additional condition(s) or information.

While the structure does not constitute a hazard to air navigation, it would be located within or near a military training area and/or route.

This determination expires on 05/04/2010 unless:

(a) extended, revised or terminated by the issuing office.
(b) the construction is subject to the licensing authority of the Federal Communications Commission (FCC) and an application for a construction permit has been filed, as required by the FCC, within

6 months of the date of this determination. In such case, the determination expires on the date prescribed by the FCC for completion of construction, or the date the FCC denies the application.

NOTE: REQUEST FOR EXTENSION OF THE EFFECTIVE PERIOD OF THIS DETERMINATION MUST BE POSTMARKED OR DELIVERED TO THIS OFFICE AT LEAST 15 DAYS PRIOR TO THE EXPIRATION DATE.

This determination is subject to review if an interested party files a petition that is received by the FAA on or before December 04, 2008. In the event a petition for review is filed, it must contain a full statement of the basis upon which it is made and be submitted in triplicate to the Manager, Airspace and Rules Division - Room 423, Federal Aviation Administration, 800 Independence Ave., Washington, D.C. 20591.

This determination becomes final on December 14, 2008 unless a petition is timely filed. In which case, this determination will not become final pending disposition of the petition. Interested parties will be notified of the grant of any review. For any questions regarding your petition, please contact Office of Airspace and Rules via telephone -- 202-267-8783 - or facsimile 202-267-9328.

This determination is based, in part, on the foregoing description which includes specific coordinates, heights, frequency(ies) and power. Any changes in coordinates, heights, and frequencies or use of greater power will void this determination. Any future construction or alteration, including increase to heights, power, or the addition of other transmitters, requires separate notice to the FAA.

This determination does include temporary construction equipment such as cranes, derricks, etc., which may be used during actual construction of the structure. However, this equipment shall not exceed the overall heights as indicated above. Equipment which has a height greater than the studied structure requires separate notice to the FAA.

This determination concerns the effect of this structure on the safe and efficient use of navigable airspace by aircraft and does not relieve the sponsor of compliance responsibilities relating to any law, ordinance, or regulation of any Federal, State, or local government body.

This aeronautical study considered and analyzed the impact on existing and proposed arrival, departure, and en route procedures for aircraft operating under both visual flight rules and instrument flight rules; the impact on all existing and planned public-use airports, military airports and aeronautical facilities; and the cumulative impact resulting from the studied structure when combined with the impact of other existing or proposed structures. The study disclosed that the described structure would have no substantial adverse effect on air navigation.

An account of the study findings, aeronautical objections received by the FAA during the study (if any), and the basis for the FAA's decision in this matter can be found on the following page(s).

A copy of this determination will be forwarded to the Federal Communications Commission if the structure is subject to their licensing authority.

If we can be of further assistance, please contact Michael Blaich, at (770) 909-4329. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2008-ANE-277-OE.

Signature Control No: 564071-103636314 (DNH)
Kevin P. Haggerty
Manager, Obstruction Evaluation Service

Attachment(s)
Additional Information
Map(s)

Additional information for ASN 2008-ANE-277-OE

Proposal: To build a Wind Turbine to a height of 415 feet above ground level, 1573 feet above mean sea level (AMSL).

Location: The structure will be located 2.69 nautical miles northeast of the Gardner Municipal Airport (GDM) reference point.

Wind Turbine exceeds Instrument Flight Rule (IFR) Departure 40:1 at GDM RWY 36. It would require amending/increasing take-off minimums to 700-3 or standard with minimum climb gradient of 239 feet per nautical mile until 1800. The current take-off minimums is 500-2. This increase is not considered substantial and would not require public circularization, for comment. However, the proponent is required to give at least 6 weeks prior notice of construction so that the appropriate action may be taken to revise the procedure.

There are no impacts to any airport or IFR/VFR terminal or en route current or planned procedures. There is not a cumulative impact to any airport, nor is there any impact to any airport plan on file.

An aeronautical study for Visual Flight Rules (VFR) disclosed that the proposed structure would not affect VFR navigation. The proposed structure would have to exceed 500 feet Above Ground Level (AGL) to penetrate the vertical confines of any VFR route.

The proposed structure was found to have no substantial adverse effect on the VFR traffic patterns in the vicinity of the site.

Details of the structure were not circularized to the aeronautical public for comment.

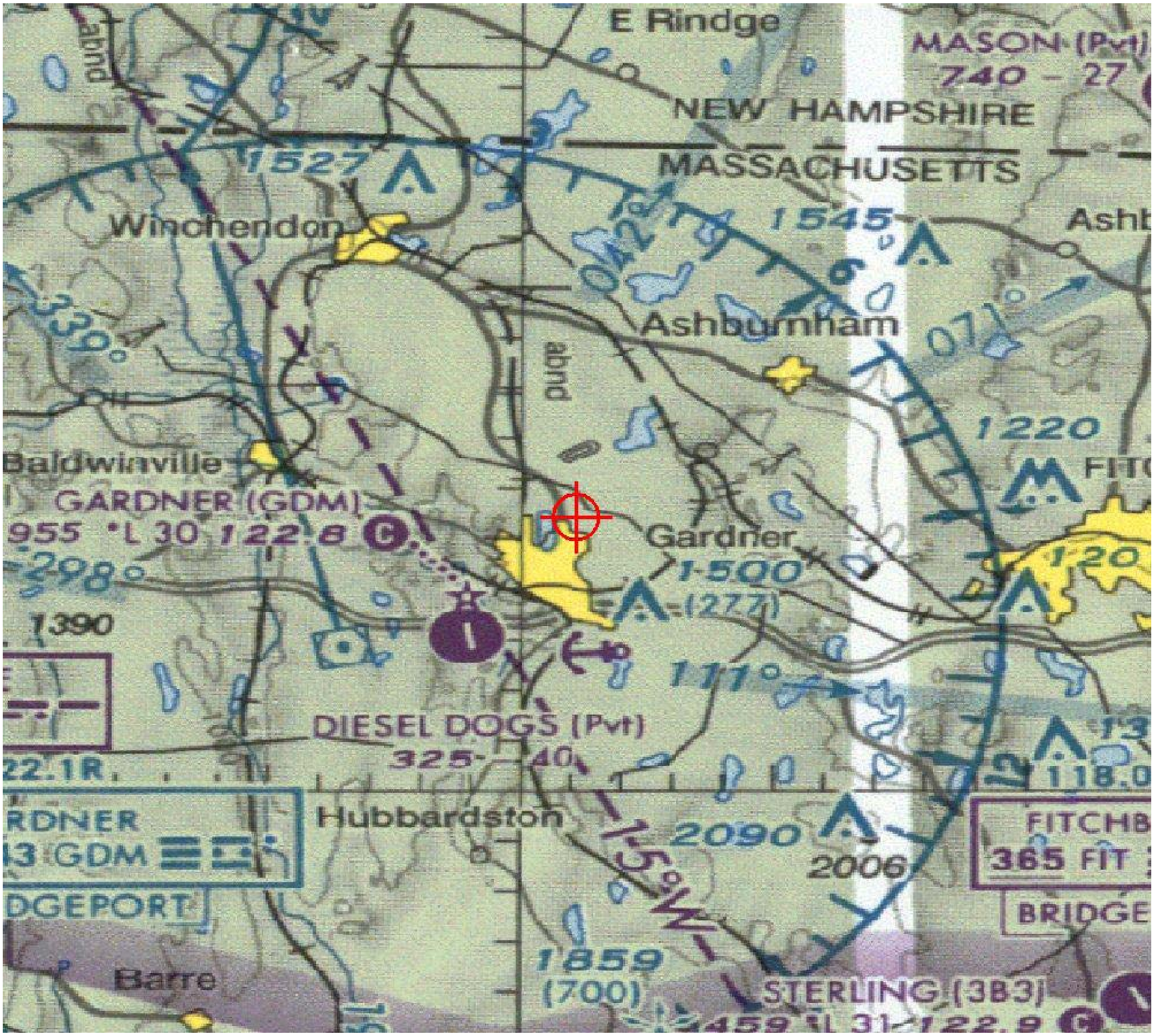
The impact on arrival, departure, and en route procedures for aircraft operating under VFR/IFR conditions at existing and planned public use airports, as well as aeronautical facilities, was considered during the analysis of the structure.

The aeronautical study disclosed that the structure, at the height shown on page 1 of this determination, would have no substantial adverse effect upon any terminal or en route instrument procedure or altitude.

The cumulative impact resulting from the structure, when combined with the impact of other existing or proposed structures was considered and found to be acceptable.

Therefore, it is determined that the structure will have no substantial adverse effect upon the safe and efficient utilization of the navigable airspace by aircraft or on the operation of navigational facilities and would not be a hazard to air navigation.

Sectional Map for ASN 2008-ANE-277-OE



Appendix 1.3 FAR Part 77 Airspace Obstruction Report

Date: DEC 0 6 2006

To: Aaron Bouchane
Massachusetts Tech Collaborative
75 North Drive
Westborough, MA 01581

ASI #: 06-N-0448.010
Client Site ID: Gardner #1
FAA #:

We are sending you herewith the following via:

☑ **US Mail** ☐ **Overnight** ☐ **Fax** ☑ **Email** ☐ **2nd Day**

☑ ASI FAR Part 77 Airspace Obstruction Report
☐ Search Area Study Report
☐ Copies of our filing(s) with FAA and/or State
☐ Responses from FAA and/or State
☐ ASI Opinion Letter
☑ Quad Chart
☐ See attachments for Airport Runway data and/or AM Stations(s)
☐ Certified Survey

Note Operational Impact

Comments:

Sincerely,

Aviation Systems, Inc.

By:

23430 Hawthorne Blvd. • Suite 200, Skypark Building 3 • Torrance, CA 90505
Tel: 310.378.3299 • Fax: 310.791.1546 • email: asi@aviationsystems.com • ww.aviationsystems.com

AVIATION SYSTEMS, INC.
Phone: 310-530-3188 Fax: 310-530-3850
crisj@aviationsystems.com
www.aviationsystems.com

FAR PART 77 AIRSPACE OBSTRUCTION REPORT

To:

Aaron Bouchane
Massachusetts Tech Collaborative
75 North Drive
Westborough, MA 01581

Date: December 5, 2006

Location: Gardner, MA
Client Case No: Gardner #1
ASI Case No: 06-N-0448.010

SUMMARY OF FINDINGS:

At this location any structure over 200 feet AGL will have to be filed with the FAA. A structure up to 322 feet AGL should receive a routine approval. A structure over 322 feet AGL should not be approved. Refer to Findings and Comment Section for additional information.

SITE DATA:

Note Operational Impact

Structure: Wind Turbine

Coordinates: 42°-35'-26.20" / 071°-59'-04.48" **[NAD 27]**
42°-35'-26.52" / 071°-59'-02.76" **[NAD 83]**

Site Ground Elevation:	1,158 ' **[AMSL]**
Studied Structure Height (with Appurtenances):	397 ' **[AGL]**
Total Overall Height:	1,555 ' **[AMSL]**

SEARCH RESULTS:

- The nearest public use or military air facility subject to FAR Part 77 is Gardner Muni Airport.
- The studied structure is located 2.66 NM / 16,161 feet NorthEast (034 ° True) of the Gardner Muni Airport Runway 18.
- Other public or private airports or heliports within 3 NM: ☑ None ☐ Printout attached
- AM radio station(s) within 3NM: ☐ None ☑ Printout attached

Highlighted AM stations on printout require notice under FCC Rules and Policy (Ref.: 47 CFR 73.1692).

FINDINGS

- **FAA Notice (Ref.: FAR 77.13 (a)(1); FAR 77.13 (a)(2) i, ii,iii):**
  - ☐ Not required at studied height.
  - ☑ Required at studied height.
  - ☑ The No Notice Maximum height is 200 feet AGL.

  IMPORTANT: Our report is intended as a planning tool. If notice is required, actual site construction activities are not advisable until an FAA Final Determination of No Hazard is issued.

- **Obstruction Standards of FAR Part 77 (Ref.: FAR 77.23 (a)(1),(2),(3),(4),(5)):**
  - ☐ Not exceeded at studied height.
  - ☑ Exceeded at studied height and Extended Study may be required.
  - ☑ Maximum nonexceedance height is 322 feet AGL.

- **Marking and Lighting (Ref.: AC 70/7460-1K, Change 1):**
  - ☐ Will not be required.
  - ☐ Will be required at studied height, if structure exceeds:
    - ☐ 200 feet AGL
    - ☐ Obstruction Standard

Note Operational Impact

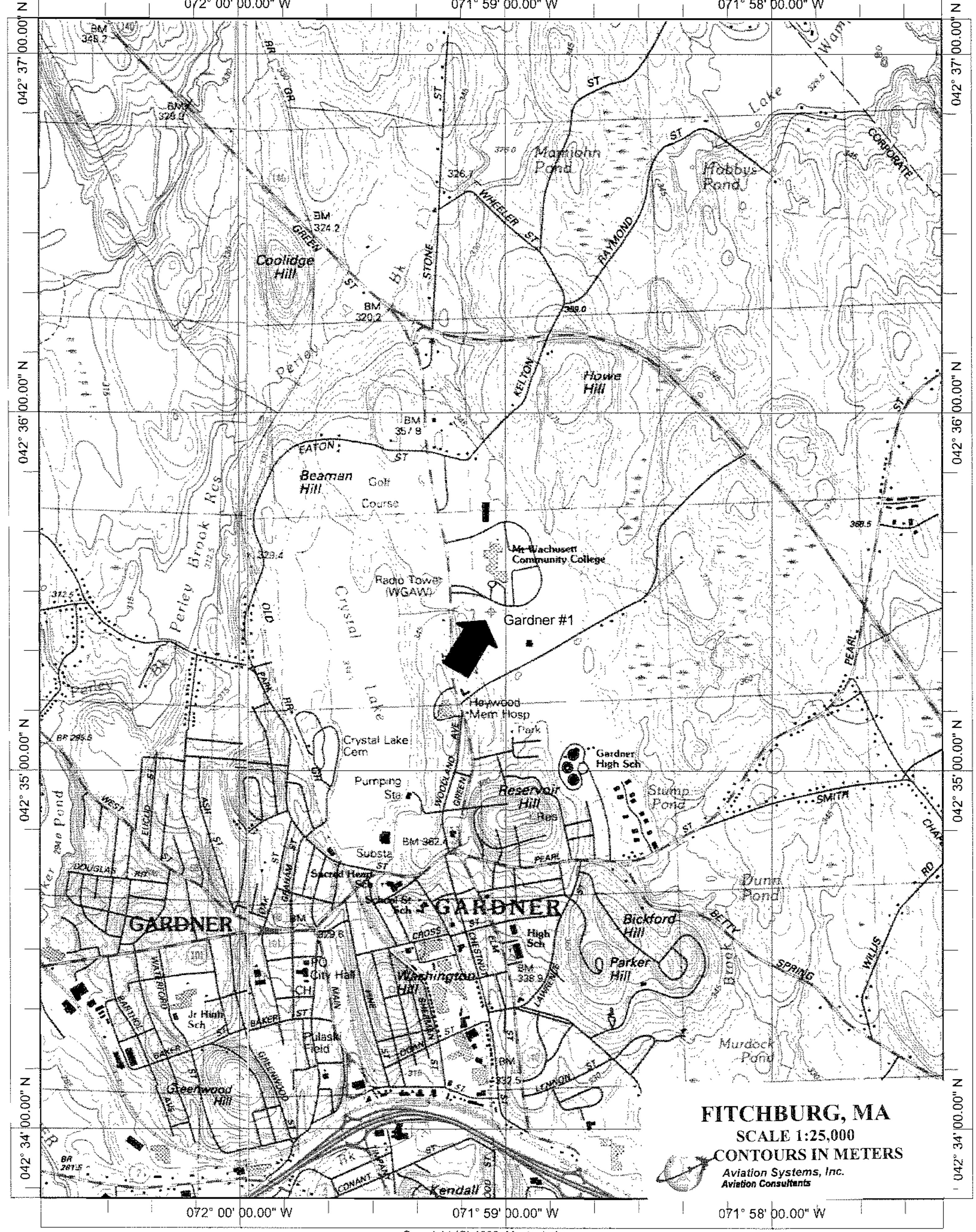
- **Operational Procedures (Ref.: FAR 77.23 (a)(3), (4); FAA Order 7400.2; FAA Order 8260.3B):**
  - ☐ Not affected at studied height (FAA should issue a Determination of No Hazard.)
  - ☑ Affected at studied height and the FAA will consider the studied structure to be a hazard to air navigation.
  - ☑ Maximum height that would not affect operational procedures is 322 feet AGL/ 1,480 feet AMSL.

Conclusions/Comments

- The proposed structure at this site would penetrate airspace for IFR Departure Procedures at Gardner Muni Airport, protected by Federal Aviation Regulations.
- The Cummington Joint Use Long Range Radar Sites is within 60 NM (44.15 NM) of the site.
- The Air Force has published a memo establishing the following policy: "The DOD/DHS Long Range Joint Program Office Interim Policy is to contest any establishment of windmill farms within radar line of site of the National Air Defense and Homeland Security Radars." Therefore, the FAA may object to this proposal, until an individual assessment is performed.

Actions:

ASI will file with FAA Region and State ☐ Yes ☑ No



072° 00' 00.00" W
071° 59' 00.00" W
071° 58' 00.00" W
042° 37' 00.00" N
042° 36' 00.00" N
042° 35' 00.00" N
042° 34' 00.00" N
FITCHBURG, MA
SCALE 1:25,000
CONTOURS IN METERS
Aviation Systems, Inc.
Aviation Consultants
Gardner #1
Mt Wachusett Community College
Radio Tower (WGAW)
Crystal Lake
Beaman Hill
Golf Course
Coolidge Hill
Howe Hill
Mamiohn Pond
Hobbs Pond
Perley Brook Res
Heywood Mem Hosp
Crystal Lake Cem
Gardner High Sch
Pumping Sta
Reservoir Hill
Stump Pond
Dunn Pond
Bickford Hill
Parker Hill
Murdock Pond
Washington Hill
Greenwood Hill
GARDNER
Sacred Heart Sch
Jr High Sch
Pulaski Field
PO City Hall
High Sch
Substa
Kendall

AM Stations

Search Latitude: 42-35-26 **Search Radius:** 3

Search Longitude: 071-59-04 **Height (MSL):**

Freq	Call Sign	State	City	Latitude	Longitude	Power KW	Domestic Status	Hours Of Oper	Antenna Mode	Complete Schedule	Last Update	Distance NM	Distance Feet	Bear
1340	WGAW	MA	GARDNER	42-35-33N	071-59-20W	100	L	U	ND1	U		0.23	1,389	300.68

Appendix 2. Avian Risk Assessment

PHASE I AVIAN RISK ASSESSMENT

Mount Wachusett Community College Wind Energy Project

Worcester County, Massachusetts

Report Prepared for:

Mount Wachusett Community College

October 2008

Report Prepared by:

Paul Kerlinger, Ph.D. and John Guarnaccia

Curry & Kerlinger, L.L.C.
P.O. Box 453
Cape May Point, NJ 08212
(609) 884-2842, fax 884-4569
PKerlinger@comcast.net
JAGuarnaccia@gmail.com

Phase I Avian Risk Assessment

Mount Wachusett Community College Wind Energy Project

Worcester County, Massachusetts

Executive Summary

Mount Wachusett Community College (MWCC) proposes to construct one or two wind turbines on its campus in Gardner, Worcester County, Massachusetts. Although the turbine model has not yet been specified, it would likely be about a between 900 and 1,650 kW turbine. Although final turbine dimensions have yet to be determined, with the rotor tip in the 12 o'clock position, the wind turbines could reach a maximum height of between 252 and 397 feet above ground level (agl. One or both turbines would be lit according to the Federal Aviation Administration (FAA) advisory circular, probably with red strobe-like lights or newer LED's (FAA type L-864) on the nacelle.

This report details a Phase I Avian Risk Assessment and a breeding bird census conducted for the Mount Wachusett Community College Wind Energy Project (hereafter referred to as the "Project"). The purpose of a Phase I Avian Risk Assessment is to determine potential collision and displacement risk to birds from project construction and operation at a proposed site. The risk-assessment process is based on: 1) a site visit, 2) a literature and database search, and 3) written consultations with wildlife agencies regarding special-interest species, as well as other wildlife concerns.

A review of the literature on avian mortality at wind plants reveals nearly 30 post-construction fatality studies at wind plants in the U.S. Bird fatalities at these facilities range from zero to more than seven birds per turbine per year. Birds involved have mostly been common species and none have been federally endangered or threatened. Fatalities have not been considered to be biologically significant and overall fatalities at wind plants in the U.S. were revealed to be orders of magnitude less than fatalities caused by communication towers, roads, buildings, transmission lines, pesticides, cats, oil pits, hunting, and other human activities such as habitat destruction.

The site visits were conducted on April 15 and 16, and June 3, 4, and 5, 2008. The Project site is located in a small, isolated field on the outskirts of an urban center. Habitat surrounding the 13-acre field includes a small pond and wetland, fragmented secondary woodland, and commercial development (a college campus, parking lots, district court, hospital, golf course, and a highway). Given the poor habitat quality, the breeding-bird community has relatively low species diversity and bird abundance. According to the Massachusetts Division of Fisheries and Wildlife (MADFW)/ Natural Heritage and Endangered Species Program (NHESP) and U. S. Fish and Wildlife Service (USFWS; letters provided in Appendix D), no Massachusetts-listed or federally species are at the site, but a small breeding population of the *Yellow WatchList*[1] Willow

[1] The recently published *2007 WatchList for United States Birds* highlights all the highest priority birds for conservation in the United States. See Section 4.1 discussion.

Flycatcher has established itself in the shrub zone bordering the pond, wetland, and field. Despite the field's small size, it was found to attract three male Bobolinks, whose displays in turn attracted two females. Nonetheless, no other obligate grassland birds were found to use the field to breed. Breeding Bird Atlas (BBA) and Breeding Bird Survey (BBS) data support these findings.

There are no ecological magnets or barriers that would attract or concentrate migrating birds in large numbers at the Project site or nearby. In the case of night-migrating songbirds, raptors, and waterbirds, migration will be broad front in nature and generally at altitudes above the sweep of the wind turbine rotors.

Christmas Bird Count (CBC) data indicate that the Project site will have very few birds in winter. Outside of the Massachusetts special-concern Sharp-shinned Hawk, no listed or *WatchList* species appears likely to occur at the Project site in winter. In the case of the hawk, occasional individuals found to forage at the site would probably not be from the Massachusetts breeding population.

The Project site does not overlap an Important Bird Area (IBA), nor is its habitat distinct in character, habitat, or ornithological importance from surrounding landscape. Instead, the Project site is a small, isolated field on the outskirts of an urban center. Given these findings, no sensitive habitats and increased avian risk are indicated.

Regarding avian risk from the Project, disturbance and displacement effects resulting from the Project are expected to be minor. Project construction will be of limited duration and unlikely to affect species of greatest conservation concern, which do not occur at the site. Habitat modification may affect the small Bobolink population, but there is reason to consider reducing the grassland further in favor of shrubland to provide habitat for *Yellow WatchList* species, such as Willow Flycatcher. Turbine operation could potentially displace breeding Bobolinks, but the presence of Bobolinks is already significantly threatened by various demographic and environmental events, including annual mowing of hay. Displacement of some birds may occur, although Bobolinks have been shown to tolerate the proximity of wind turbines.

Regarding collision risk, post-construction fatality studies, particularly those that have taken into account searcher efficiency in finding carcasses, as well as carcass removal by scavengers, have demonstrated that fatalities are relatively infrequent events at wind farms. In a 2005 review of the literature on U.S. wind farms, mortality estimates were similar among projects, averaging 2.51 birds per turbine per year and 3.19 birds per MW per year. Rates were slightly higher in the Eastern U.S. than in the West, likely because of denser nocturnal migration of song and other birds in eastern North America. No federally listed endangered or threatened species have been recorded, and only occasional raptor, waterfowl, or shorebird fatalities have been documented. In general, the documented level of fatalities has not been large in comparison with the source populations of these species, nor have the fatalities been suggestive of biologically significant impacts to these species.

Fatality numbers and species impacted at the Project site are likely to be similar, on a per turbine per year basis, to those found at Eastern and Midwestern U. S. projects that have been studied.

Because there will be only one or two turbines, the absolute numbers of fatalities will in all likelihood be very small and when distributed among several species, are not likely to be biologically significant. When compared with most other wind power facilities, collision risk factors for raptors are minimal. Collision risk to night-migrating songbirds is likely to be similar to other sites examined because the altitude of migration is generally above the sweep of the wind turbine rotors.

The following recommendations have been formulated to minimize avian risk:

Construction Guidelines

- Electrical lines within the project site should be underground between the turbines.

- Permanent meteorology towers should be freestanding (i.e., without guy wires) to prevent the potential for avian collisions.

- Size of roads and turbine pads should be minimized to disturb as little habitat as possible. After construction, any natural habitat should restored as close to the turbines and roads as possible to minimize habitat fragmentation and disturbance/displacement impacts. To accomplish this, topsoil or marsh should be replaced as a means of encouraging plant growth.

- Lighting of turbines and other infrastructure (turbines, substations, buildings) should be minimal to reduce the potential for attraction of night migrating songbirds and similar species. Federal Aviation Administration (FAA) night obstruction lighting should be only flashing beacons (L-864 red or white strobe) with the longest permissible off cycle. Steady burning (L-810) red FAA lights should not be used. Sodium vapor lamps and spotlights should not be used at any facility (e.g., lay-down areas or substations) at night except when emergency maintenance is needed.

Recommended Post-construction Studies

- A mortality study following best practices should ideally be conducted during a two-year period post-construction, with the second year contingent on what is found during the first year. If fatalities are recorded at levels that could be construed as biologically significant, or if significant numbers of special-status species are involved, a second year of study would be called for. The design of the post-construction protocol should follow the designs now being used and refined at existing wind-power sites and approved by various government agencies, including MADFW and U. S. Fish and Wildlife Service (USFWS). Such a study could be integrated into MWCC's environmental program. Students and faculty of MWCC would conduct the study with technical support from a biologist trained in conducting post-construction fatality studies.

- Results of the fatality study should be compared with impacts to birds from other types of power generation now supplying electricity in Massachusetts. This comparison would facilitate long-term planning with respect to electrical generation and wildlife impacts.

The study should seek information from USFWS and MADFW on existing energy-generation impacts to wildlife. If information is not available, as our preliminary review appears to reveal, these agencies should consider providing financial support for such studies. This project should be conducted by a team involving faculty, students, and a wind industry consultant.

Recommended Habitat Enhancement

- The most significant breeding bird that presently occurs at the Project site is the *Yellow WatchList* Willow Flycatcher, which nests in the shrubland zone between the field and pond. We recommend developing a habitat management plan that would expand shrubland habitat to increase this flycatcher's population (presently at six territorial males). This step also has the potential to attract two other *Yellow WatchList* species to the site: the Blue-winged and Prairie Warblers, both of which were recorded regionally in the Breeding Bird Atlas and more recently in Breeding Bird Surveys. Ideally, MWCC students should be involved in the development and implementation of this plan. It should be noted, however, that increasing the shrubland zone will likely reduce habitat for the Bobolinks that presently display and possibly nest in the field. Nonetheless, the future of this Bobolink population is uncertain, given that it is so small and isolated. Furthermore, the flycatcher's status on the *Yellow WatchList* makes it of higher conservation concern. In any event, the field should not be mowed until about July 15, after Bobolink young have fledged (if they are nesting in the field). A discussion of the impacts from hay mowing is provided in this report.

Agency Coordination

Early coordination letters were sent to MADFW and NHESP, and the USFWS . Response letters from those agencies are provided in an Appendix to this report. This coordination and the work done for this report helps to meet the recommendation of the MADFW, that potential impacts to birds be considered during the Project's design and permitting process.

The U.S. Fish and Wildlife Service (USFWS) recommended that three years of pre-construction radar study be conducted. We do not believe that such a study is warranted because it will not improve on this risk assessment. Radar has never been documented to be a precise or reliable predictor of risk at wind power or other structures. As discussed in Section 4.2.1, the nocturnal migration pattern (in terms of traffic, altitude, percent of birds flying at rotor height, etc.) has been well documented at more than 20 sites across the northeastern U.S. The weight of these studies gives no reason to believe that the migration pattern would be substantially different at the Project site. Furthermore, as discussed in Section 6.1.2, all post-construction fatality studies at wind energy facilities have established that the average fatalities per turbine per year are relatively low (averaging perhaps three night migrants per turbine per year at wind farms in the northeastern US.), and no mass or large-scale fatality events have ever been recorded. Therefore, detailed knowledge of night-to-night and year-to-year variation in nocturnal migration at a site will not improve on our mortality forecast.

USWFS has also recommended that the effects of habitat fragmentation be considered. With regard to birds, we find that the creation of an access road and one or two turbine-construction areas in the field will reduce functional grassland by a small percentage. The Project will not fragment woodland, which is already heavily fragmented and degraded, nor will it modify shrubland, wetland, or other native habitat.

Conclusion

Based on our extensive studies at wind power facilities in many states, the literature gathered on impacts to birds at wind power facilities, and on our site specific work, the MWCC project appears to be one of the lowest risk wind power facilities that we have studied. With only one or two turbines situated in an area without significant avian nesting, foraging, migrating, or wintering habitat, significant collision and displacement impacts are highly improbable. In addition, we do not recommend further pre-construction study at this site. Finally, the avian mitigation measures recommended in this report, combined with a post-construction fatality study, will certainly prevent or reduce avian impacts to non-significant levels.

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Appendices

Figure 1. Project Location in Worcester County, Massachusetts.

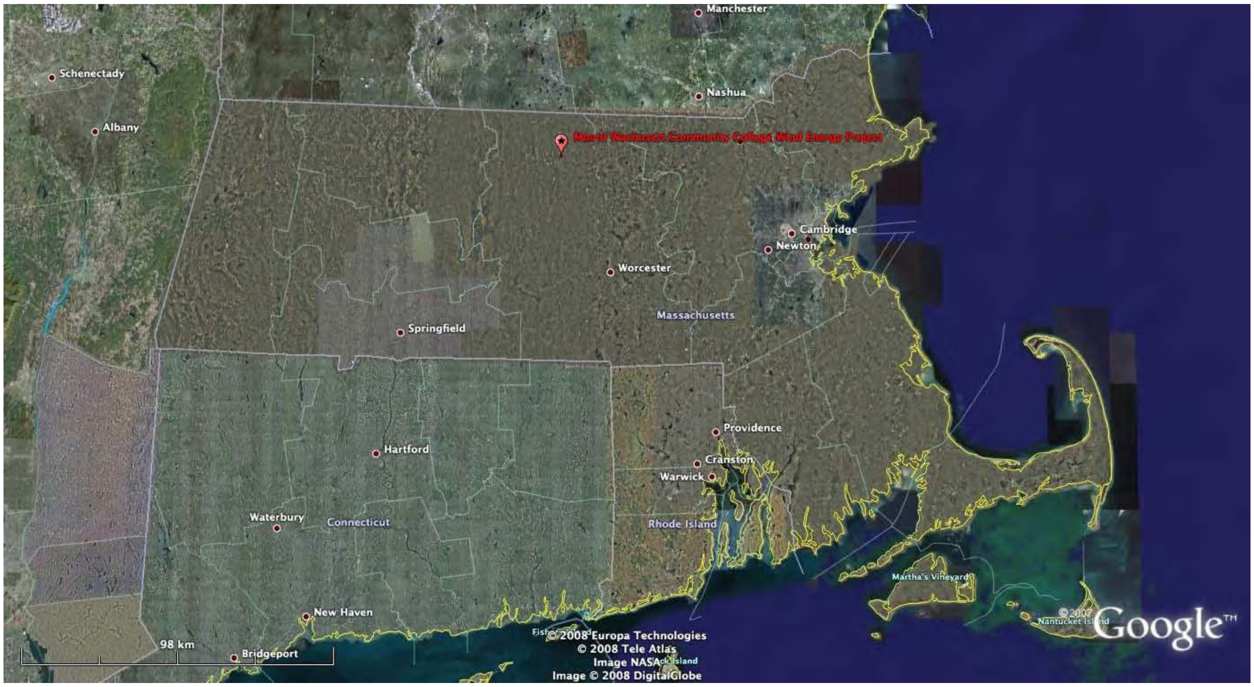

Figure 2. Regional View of Project Site in Outskirts of Gardner, Massachusetts.

Figure 3. Satellite View of Project Site (boundary approximate).

Figure 4. Topographic Map View of Project Site (boundary approximate).

1.0 Introduction

Mount Wachusett Community College (MWCC) proposes to construct one or two wind turbines on its campus in Gardner, Massachusetts (see Figures 1 through 4). This report details a Phase I Avian Risk Assessment conducted for the Mount Wachusett Community College Wind Energy Project (hereafter referred to as the "Project").

The purpose of a Phase I Avian Risk Assessment is to determine potential risk to birds from project construction and operation at a proposed site. Birds are generally at risk from collisions with turbine rotors and meteorology tower guy wires, and from disturbance and displacement by construction activities (e.g., habitat clearing) and new, large infrastructure. The Phase I Avian Risk Assessment walks developers, regulators, environmentalists, and other stakeholders through a risk assessment process at a particular site, including how evaluation of potential impacts may require further study. The process is based on: 1) a site visit, 2) a literature and database search, and 3) written consultations with wildlife agencies regarding special-interest species, as well as other wildlife concerns. The Phase I also addresses compliance issues and recommendations set forth by the U.S. Fish and Wildlife Service (USFWS) in its *Interim Guidelines to Avoid and Minimize Wildlife Impacts from Wind Turbines* (USFWS 2003; see Appendix A).

An avian expert skilled in bird identification and habitat evaluation undertakes the site visit. Over a two or three-day period, this researcher conducts a thorough tour of the site by car and on foot, noting the different bird habitats present and recording the birds seen or heard. The expert also documents the various landscape features and habitats with photographs. In the field, habitats and topography are evaluated with special consideration for: 1) federal and state-listed endangered, threatened, and other special-status bird species; and 2) probable avian use during the nesting, migration, and winter seasons. The site visit is not intended to be an exhaustive inventory of species presence and use. Nonetheless, it adequately records habitat and topographic features so that a list of species that might conceivably be present at different times of the year can be assembled and the potential for risk to those birds from a wind power project can be assessed.

Avian literature and databases examined include records of the USFWS and the Massachusetts Division of Fisheries and Wildlife (MADFW), as well as data from the Massachusetts Breeding Bird Atlas (BBA, 1974-1979), North American Breeding Bird Survey (BBS), Audubon Christmas Bird Counts (CBC), hawk migration literature (e.g., Hawk Migration Association of North America), Important Bird Areas (IBA), and other information on birds that might nest, migrate, forage, winter, or concentrate at the site. An additional part of the literature search focuses on the empirical findings of studies that have focused on wind turbine impacts to birds.

Consultations are conducted via letter with wildlife agency biologists – in this case, MADFW and USFWS – to request information they may have on listed species at or near the Project site. These letters seek to improve knowledge of the site's avifauna and of the potential risk to birds that are likely to be present. Additionally, such consultations can determine the scope of work that may be needed to further assess risk after the avian risk assessment has been completed.

Based on the process outlined above, this report summarizes known and likely bird use of the Project site's habitats, compares the Project site with wind-energy projects where risk has been determined (with special consideration given to wind-power projects in the Eastern U.S.), determines the potential risks birds may face from the construction and operation of wind turbines at the site, and presents recommendations for further studies and potential mitigation, if warranted.

2.0 Project and Site Description

2.1 Project Description

The Mount Wachusett Community College Wind Energy Project is proposed for north-central Massachusetts, more specifically northern Worcester County (Figure 1). The Project is located within the city limits of Gardner, just outside the city center (Figures 2 and 4).

Mount Wachusett Community College (MWCC), the Project proponent, proposes to construct one or two wind turbines. Although the turbine model has not yet been specified, it would likely be about a between 900 and 1,650 kW turbine. Although final turbine dimensions have yet to be determined, with the rotor tip in the 12 o'clock position, the wind turbines could reach a maximum height of between 252 and 397 feet above ground level (agl).

The turbines would be mounted on steel tubular towers and one or both would be lit according to Federal Aviation Administration (FAA) guidelines. As with most modern wind farms, FAA lighting would probably be red strobe-like lights or newer LED's (FAA type L-864) on the nacelle. Electrical collection lines between the turbines would be underground. An electric substation is not needed, although each turbine would have a pad mounted transformer (90" per side) immediately adjacent to the base of the turbine. There will also be a pad-mounted switching assembly at the turbine closest to the campus buildings. That strcture would be 6 feet tall by 6 feet deep by 12 feet long.

2.2 Site Description

Various literature sources and Internet sites, the Massachusetts Atlas & Gazetteer (DeLorme 2004), satellite imagery viewable through Google Earth Pro, USGS topographic maps viewable through National Geographic's TOPO! mapping software were consulted to understand the Project site's physiography, topography, and habitat. This information was checked against a site visit conducted by an avian researcher on June 3, 4, and 5, 2008.

The Project site is located in the Worcester/Monadnock Plateau of the Northeastern Highlands ecoregion, which Petersen and Meservey (2003) describe as follows:

> This is a large and important subregion that includes most of the mountainous and hilly areas of the central uplands of Massachusetts. Elevations range from 500 to 1,400 feet (150 to 425 m), with the exception of Mount Watatic (1,832 feet [559 m]) and Mount Wachusett (2,006 feet [612 m]), both of which provide easterly outposts for northern breeding species more typical of the higher elevations of western Massachusetts. Forest types are largely transitional and northern hardwoods, with pockets of spruce on the higher hilltops.

The Project site is relatively flat, with elevations ranging from 1,130 to 1,165 feet (345 to 355 m). As may be noted in Figures 2 through 4, the site is located in the outskirts of an urban center. Beyond the city, land cover is mostly forest/woodland with interspersed fields and lakes. Residential development is also a significant land use.

3.0 Results of Site Visit and Avian Census

An experienced field ornithologist visited the MWCC site on April 15 and 16, June 3, 4, and 5, 2008. The latter site visit was at the peak of the nesting bird season. During the June visit time was spent listening for nocturnal species on two days after sunset and two mornings before sunrise. Weather during the first visit was mild and clear. And during the second visit was cool and overcast, with some fog, drizzle, and rain on June 4.

The entire site and adjacent areas were walked. The region around the Project site was explored by car to improve understanding of bird distribution. Photographs in Appendix B show the site's major habitats and landscape features.

The Project site is a 13-acre (5.2-ha) field located about 600 feet (180 m) south of the main building on the MWCC campus (Figure 3). Low, secondary oak-pine woodland and the Gardner District Court abut the site to the east. Matthews Road forms the site's southern boundary, across which taller, secondary oak-pine woodland occurs. To the west, the field descends to a 2-acre (0.8-ha) pond surrounded by a 9-acre (3.6-ha) wet, shrubby meadow. Beyond the pond to the west is a narrow band of upland habitat bordering Green Street, a major traffic artery, across which a golf course and Haywood Hospital are located.

During the June 2008 site visit a nesting bird census was conducted. A census is an attempt to record all species that likely nest at a given site. This census included visits to the site at dusk and into darkness to determine which, if any, nocturnal species were present. The MWCC site is small enough to permit a census to be done. In total, 43 species (Appendix C) were recorded at and immediately adjacent to the Project site. Of the 43 species that were observed, about 20-22 nest within the grassy field, forested edge adjacent to the field, or around the pond and wetlands adjacent to the field. The remaining species either nested within 200-400 m from turbine locations and some nested farther away. The species observed were mostly songbirds of upland fields and forest edges. A few, such as Ovenbird and Black-and-white Warbler, as well as Wood Thrush, are species of forest interior habitats. Those species would not nest in the field where turbines would be placed, nor would they nest at the adjacent wetlands and forested edge. Raptors do not nest in the turbine area, nor do shorebirds such as American Woodcock or Wilson's Snipe.

Of particular interest were three male Bobolinks displaying in the field. Most of the time, they were perched in the tops of the shrubs forming the western border of the field, and most of their singing occurred from those perches. Occasionally, however, they would perform flight displays at low altitudes (less than 50 feet [15 m]) over the field and alight on tall grasses and forbs and on the few trees and shrubs occurring in the field. On one occasion, one of the Bobolinks landed on a guy wire of the met tower. Two females were also seen, strongly suggesting that Bobolinks breed in the field or adjacent wet meadow. Bobolink was the only obligate grassland bird found to use the field. Savannah Sparrow, for example, was not encountered.

Another bird of interest was the Willow Flycatcher, a species on the *Yellow WatchList*[2]. Five territorial males were found in the shrubland zone bordering the pond, and another male was found in shrubland bordering the golf course across Green Street. Other birds using the pond, marsh, and shrubland zone were Green Heron, Eastern Kingbird, Tree Swallow, House Wren, American Robin, Gray Catbird, Yellow Warbler, Common Yellowthroat, and Red-winged Blackbird.

One Wood Thrush (*Yellow WatchList*) and two Overbirds were heard singing from the taller woodland across Matthews Road. Pine Warbler and Yellow-rumped Warbler were found in pine plantings bordering the campus parking lots.

Birds noted in flight in the vicinity of the field were Canada Goose (flocks graze on the lawns of the MWCC campus), Mallard, Double-crested Cormorant, Great Blue Heron, Rock Pigeon, Chimney Swift, American Crow, Tree Swallow, Barn Swallow, European Starling, Bobolink (see above), Common Grackle, and American Goldfinch.

No federal or state-listed species were encountered, nor were any deemed likely to nest, stopover, or winter at or adjacent to the site, given the small size and isolation of the field and adjacent habitats. The Massachusetts endangered Bald Eagle, threatened Northern Harrier, and special-concern Common Loon and Sharp-shinned Hawk may occur over the site in migration, but individuals of those species would likely not originate from Massachusetts breeding populations.

4.0 Avian Overview of the MWCC Site

The North American Landbird Conservation Plan (Rich et al. 2004) locates the Project site at the southern end of the Atlantic Northern Forest (Bird Conservation Region # 14) of the Northern Forest Avifaunal Biome, a region covering much of northern North America. The New England/Mid-Atlantic Coast Bird Conservation Region (# 30) begins just to the east of the Worcester/Monadnock Plateau.

Based on information in the document, *DRAFT: Blueprint for the Design and Delivery of Bird Conservation in the Atlantic Northern Forest* (Dettmers, in preparation; visit http://www.acjv.org/documents/bcr14_blueprint.pdf), Northern Hardwood forest is the forest type covering the Project region. The dominant trees of this association are beech, birch, and maple species. Its characteristic birds include Ruffed Grouse, Yellow-bellied Sapsucker, Blue-headed Vireo, Wood Thrush, Veery, Black-throated Blue Warbler, American Redstart, Overbird, and Rose-breasted Grosbeak. Where this forest type has been logged or disturbed, the resulting early successional/shrubland habitats contain such characteristic birds as American Woodcock, Ruffed Grouse, Chestnut-sided Warbler, Mourning Warbler, and Whip-poor-will. Where

[2] The *2007 WatchList for United States Birds* highlights all the highest priority birds for conservation in the United States. See Section 4.1 discussion.

wetland habitats occur, characteristic birds include American Black Duck, Wood Duck, Common Loon, American Bittern, Bald Eagle, and Spotted Sandpiper.

Bird conservation issues in the Atlantic Northern Forest (see Dettmer, in preparation) revolve around balancing forest management for timber resources with the maintenance of forest successional stages. In the southern portion of the Atlantic Northern Forest region, including the Worcester/Monadnock Plateau of Massachusetts, declines in the availability of early successional forest habitats are of particular concern. Other concerns include forest health issues, mainly the spread of various invasive forest pest species and atmospheric deposition of toxic substances (such as mercury and acid rain), the latter resulting mainly from fossil fuel-based electricity generation. Wind-power development along forested ridgelines has also been flagged as a concern, as has urban sprawl and recreational development.

According to Rich et al. (2004), the Northern Forest Avifaunal Biome is a core breeding range for Neotropical migrants, particularly warblers, thrushes, vireos, and flycatchers. About 90% of the birds that breed in this region migrate out for the winter, with some wintering as far south as northern South America. Between 121 and 150 landbird species are recorded as breeding in the various habitats of the Northern Forest region of New Hampshire, but only between 41 and 80 landbird species occur there in winter (Rich et al. 2004).

A seasonal look at the avifauna at the Project site follows.

4.1 Breeding Birds

Table 4.1-1 (below) summarizes the MADFW and USFWS lists of endangered, threatened, and special-concern species. Given their special status, these species have been given particular attention in assessing avian risk at the Project site. Based on the site visit and other data sources. The suitability of habitat for nesting on the Project site was graded as suitable (S), marginally suitable (MS), or not suitable (NS) as listed in Table 4.1-1. Where there is uncertainty in this assessment, it is indicated by a question mark.

It is worth noting that a few of the species listed in Table 4.1-1 are also included in the recently published *2007 WatchList for United States Birds* (Butcher et al. 2007). Developed collaboratively by Audubon and the American Bird Conservancy (ABC), the *WatchList* highlights all the highest priority birds for conservation in the United States. It is based on the species assessment methodology that Partners in Flight (PIF; see Rich et al. 2004) has employed to rate the conservation status of landbirds. Audubon and ABC have taken PIF's standards and applied them to the other bird groups.

The *WatchList* is divided into two categories: 1) *Red WatchList: Highest National Concern* (59 species, including Piping Plover, Golden-winged Warbler, and Henslow's Sparrow on the Massachusetts list) and 2) *Yellow WatchList: Declining or Rare Species* (119 species, including King Rail, Roseate Tern, and Short-eared Owl on the Massachusetts list).

Some *Watchlist* species not listed in Table 4.1-1 may also occur at the Project site. Examples from the site visit were the *Yellow WatchList* Willow Flycatcher and Wood Thrush. The occurrence of *WatchList* species will be highlighted in the various data sources checked below.

USFWS and MADFW have responded to written inquiries about records of listed species in the Project vicinity. Their letters may be found in Appendix D. In summary, neither agency has records of listed species from the Project site or immediate vicinity, and neither has mapped the site as critical habitat. MADFW recommends that potential impacts to birds be considered during the Project's design and permitting process. USFWS, however, recommends that "1) the spatial and temporal uses of the rotor-swept zone be identified and evaluated using radar and remote sensing techniques for a period of three years, and 2) the local site environs be evaluated to determine the presence and magnitude of habitat fragmentation syndrome of effects that would be implicated by project construction and/or operation." We will comment on the two USFWS recommendations in Sections 7.0 and 8.0 of this report. Based on past agency consultations related to Eastern U.S. wind-power projects, the extensive information and data sources checked for this report generally address most concerns of the wildlife agencies.

Table 4.1-1. Massachusetts Listed Species and Habitat Suitability for Nesting at Project Site

Species	MA (Federal) Status[1]	Recorded Site Visit	Recorded BBA Block[2]	Recorded BBS Route[3]	Habitat Suitability at Site[4]
Endangered/Threatened[5]					
Pied-billed Grebe	E	No			NS
Leach's Storm-Petrel	E	No			NS
American Bittern	E	No	+	+	NS
Least Bittern	E	No			NS
Bald Eagle	E	No			NS
Northern Harrier	T	No			NS
Peregrine Falcon	E	No			NS
King Rail (*Yellow WatchList*)	T	No			NS
Piping Plover (*Red WatchList*)	T (E)	No			NS
Upland Sandpiper	E	No			NS
Roseate Tern (*Yellow WatchList*)	E (E)	No			NS
Short-eared Owl (*Yellow WatchList*)	E	No			NS
Sedge Wren	E	No			NS
Golden-winged Warbler (*Red WatchList*)	E	No			NS
Northern Parula	T	No			NS
Vesper Sparrow	T	No	+		NS
Grasshopper Sparrow	T	No			NS
Henslow's Sparrow (*Red WatchList*)	E	No			NS
Special Concern[5]					
Common Loon	SC	No			NS
Sharp-shinned Hawk	SC	No	+		NS
Common Moorhen	SC	No			NS
Common Tern	SC	No			NS
Arctic Tern	SC	No			NS
Least Tern	SC	No			NS
Barn Owl	SC	No			NS
Long-eared Owl	SC	No			NS
Blackpoll Warbler	SC	No			NS
Mourning Warbler	SC	No			NS

[1] E = Endangered, T = Threatened, SC = Special Concern – Federal status in parentheses
[2] BBA = Breeding Bird Atlas. Please see Table 4.1.1-1 for details.
[3] BBS = Breeding Bird Survey. Please see Table 4.1.2-1 for details.
[4] S = Suitable, MS = Marginally Suitable, NS = Not Suitable. Suitability determined by Consultant Evaluation and habitat observed on site.
[5] From http://www.mass.gov/dfwele/dfw/nhesp/species_info/mesa_list/mesa_list.htm (accessed 6/3/08). *WatchList* species are designated as *Red WatchList* or *Yellow WatchList* (see Section 4.1 discussion)

In addition to the breeding bird census that was conducted on site, two other data sources of breeding bird data were examined. These additional data sources are described in the following sections. One is the Massachusetts Breeding Bird Atlas (BBA, 1974-1979), because its coverage overlapped the Project site. It was checked for the occurrence of special-status species. The other source was the last ten years of available data from nearby routes of the Breeding Bird Surveys (BBS) of the U.S. Geological Survey (USGS). One of these routes was analyzed in detail to profile the breeding bird community. If Massachusetts endangered, threatened, or special-concern species, or *WatchList* species, are indicated in these analyses, they have been noted.

4.1.1 Breeding Bird Atlas (BBA) Analysis

Conducted from 1974 to 1979 and modeled after *The Atlas of Breeding Birds in Britain and Ireland* (Sharrock 1976), the Massachusetts Breeding Bird Atlas (BBA) was one of the first BBA projects conducted in the U.S. Based on the grid of 189 topographical quadrangle maps produced by the U.S. Geologial Survey to cover Massachusetts, the BBA project divided these quadrangles into six equal blocks roughly covering 10 square miles (25 km^2). This created a statewide grid of 989 blocks. Blocks were assigned to volunteer birdwatchers, who visited the various habitats within their assigned blocks in order to record evidence of breeding for the birds they saw. Evidence of breeding was graded as *Possible* (i.e., a species is simply observed in possible nesting habitat), *Probable* (i.e., a species exhibits certain behaviors that indicate breeding, such as territoriality, courtship and display, or nest building), or *Confirmed* (i.e., a species is observed nesting or engaged in behaviors associated with nesting, such as distraction display, carrying a fecal sac, carrying food for young, feeding young, etc.).

Results are mapped in the *Massachusetts Breeding Bird Atlas* (Petersen and Meservey 2003). Table 4.1.1-1 reports the special-status species recorded in the Gardner Quadrangle (D-13) overlapping the Project site and in the eight quadrangles surrounding it (C-12, C-13, C14, D-12, D-14, E-12, E-13, and E-14). This analysis gives some indication of the likelihood of finding special-status species in the Project vicinity, even though bird distributions have changed somewhat in the nearly thirty years since the Atlas was conducted.

As noted in Table 4.1.1-1, only the Massachusetts threatened Vesper Sparrow was recorded in the Gardner Quadrangle, but the Massachusetts endangered American Bittern and special-concern Sharp-shinned Hawk were recorded in surrounding quadrangles. Each was recorded in two of nine quadrangles. Of the 48 blocks represented in these nine quadrangles, Vesper Sparrow was recorded in three (including two in the Gardner Quadrangle), while American Bittern and Sharp-shinned Hawk were recorded in two. The highest breeding status for all was probable. The paucity of records indicates that these species were rare breeders in the Worcester/Monadnock Plateau in the late 1970s. It is likely that the sparrow's population has decreased further (if it has not been extirpated), as fields have been abandoned and have reverted to woodland.

Six *Yellow WatchList* species were recorded. Wood Thrush, Prairie Warbler, and Canada Warbler were recorded in the Gardner Quadrangle and in between six and eight of the surrounding quadrangles. Of them, however, only Wood Thrush was widely distributed, recorded in 42 of 48 blocks. Olive-sided Flycatcher, Willow Flycatcher, and Blue-winged Warbler were much more localized in their distributions.

Table 4.1.1-1. Special-Status Species Records in 1974-1979 Massachusetts BBA[1]

Special-Status Species[2]	Recorded in Gardner Quad	% in 9 Quads[3]	% in 48 Blocks	Highest Breeding Status
American Bittern (MA-E)		**22%**	**6%**	**Probable**
Vesper Sparrow (MA-T)	**+**	**22%**	**4%**	**Probable**
Sharp-shinned Hawk (MA-SC)		**22%**	**4%**	**Probable**
Olive-sided Flycatcher (*Yellow WatchList*)		11%	4%	Confirmed
Willow Flycatcher (*Yellow WatchList*)		44%	8%	Probable
Wood Thrush (*Yellow WatchList*)	+	100%	88%	Confirmed
Blue-winged Warbler (*Yellow WatchList*)		44%	8%	Probable
Prairie Warbler (*Yellow WatchList*)	+	77%	21%	Probable
Canada Warbler (*Yellow WatchList*)	+	88%	50%	Confirmed

[1] Data from Petersen and Meservey 2003.

[2] Massachusetts listed species are indicated in boldface; see Table 4.1-1. *WatchList* species are indicated as *Red WatchList* or *Yellow WatchList*; see discussion in Section 4.1.

[3] Includes Gardner Quadrangle and eight surrounding quadrangles.

4.1.2 Breeding Bird Survey (BBS) Analysis

Now overseen by the Patuxent Wildlife Research Center of the U.S. Geological Survey (USGS), the North American Breeding Bird Survey (BBS) is a long-term, large-scale, international avian monitoring program that tracks the status and trends of North American bird populations. Each year during the height of the breeding season (normally June), mainly volunteer participants skilled in avian identification collect bird population data along roadside survey routes. Each survey route is 24.5 miles (39.4 km) long with stops at 0.5 mile (0.8 km) intervals, for a total of 50 stops. At each stop, a three-minute point count is conducted. The total survey time over the entire route, therefore, is 2.5 hours. At each point count, every bird seen within a 0.25 mile (0.4 km) radius or heard is recorded. Surveys start one-half hour before local sunrise and take about five hours to complete. Surveys are sometimes repeated several times each spring during the nesting season.

Two BBS routes survey countryside within 15 miles (24 km) of the Project site (see Table 4.1.2-2). The closest of these routes – North Orange – has been analyzed closely to gain a recent vantage of the breeding bird community in the Project area and to evaluate the likelihood of the occurrence of listed and other species as breeders. Based on satellite imagery, this route surveyed countryside with forest/woodland, agricultural fields, lakes, wetlands, and residential areas.

To profile the breeding bird community, Appendix E was prepared, listing the species recorded at least once during the last ten years on the North Orange route. Species are listed both in taxonomic order and in order of their average abundance. To calculate average abundance, the average number of birds per year over the ten-year period was divided by the survey time of 2.5 hours. This measure indicates which birds are likeliest to be found in habitats at the Project site.

Ninety-five species were recorded on the North Orange BBS route over the last ten years, of which 20 were recorded above 10 birds/hr and can be considered very common and 48 were recorded between 1 and 10 birds/hour and may be considered common (birds recorded in the site visit are indicated with an asterisk). They were:

Red-eyed Vireo*	51.11	Pine Warbler*	4.22
American Robin*	37.11	Baltimore Oriole*	4.11
Ovenbird*	37.00	Hermit Thrush	3.89
Black-capped Chickadee*	30.56	Barn Swallow*	3.78
American Crow*	27.44	House Wren*	3.78
Blue Jay*	27.22	White-throated Sparrow	3.67
Mourning Dove*	23.67	Black-throated Blue Warbler	3.56
Chipping Sparrow*	23.33	Downy Woodpecker	3.44
European Starling*	19.11	Wild Turkey	3.33
Chimney Swift*	13.33	Rock Pigeon*	3.22
Common Yellowthroat*	12.78	Yellow-bellied Sapsucker	2.89
Scarlet Tanager	11.78	Least Flycatcher	2.89
Black-and-white Warbler*	11.67	Yellow Warbler*	2.89
Red-winged Blackbird*	11.56	Great Crested Flycatcher	2.78
Tufted Titmouse	11.44	Eastern Kingbird*	2.78
American Goldfinch*	10.78	Blue-headed Vireo	2.67
Tree Swallow*	10.67	Hairy Woodpecker	2.56
Cedar Waxwing*	10.22	Canada Goose*	2.44
Eastern Phoebe	10.00	Red-breasted Nuthatch	2.44
Gray Catbird*	10.00	Eastern Towhee	2.11
American Redstart	9.56	Swamp Sparrow	2.11
Wood Thrush* (*Yellow WatchList*)	9.22	House Finch*	2.11
Chestnut-sided Warbler	8.56	Wood Duck	1.78
Veery	8.22	Northern Flicker*	1.56
Eastern Wood-Pewee	7.78	Brown Creeper	1.44
Yellow-rumped Warbler*	7.00	Great Blue Heron*	1.33
Bobolink*	6.78	Alder Flycatcher	1.33
Song Sparrow*	6.67	Northern Waterthrush	1.33
White-breasted Nuthatch	5.44	Purple Finch*	1.22
Common Grackle*	5.33	House Sparrow*	1.22
Brown-headed Cowbird*	5.33	Winter Wren	1.11
Black-throated Green Warbler	4.78	Nashville Warbler	1.11
Rose-breasted Grosbeak	4.56	Dark-eyed Junco	1.11
Northern Cardinal*	4.33	Barred Owl	1.00

Together, individuals of these 64 species made up 96% of all individuals recorded on the BBS route over the ten-year period. Thirty-one species, on the other hand, were recorded below 1 bird/hr and can be considered uncommon to rare species (see Appendix E).

Based on the most common birds, the bird fauna in the Project region is dominated by species of forest-interior, forest-edge, shrubland, and residential habitats. It is interesting that grassland bird diversity in the BBS route was minimal, with only one obligate grassland bird recorded: Bobolink, at 6.78 birds/hour. This matches what was found at the Project site. This was also confirmed in a reconnaissance by car of habitats in the Project region. Wherever there were sizeable fields, Bobolinks were invariably found, but no other grassland birds were encountered. An example is the Lake Wampanoag Wildlife Sanctuary of the Massachusetts Audubon Society.

Regarding special-status species (see Table 4.1.2-1), the only Massachusetts-listed species recorded in nearby BBS routes was the endangered American Bittern. It was recorded once (likely heard) on the North Orange route. Petersen and Meservey (2003) categorize it as rare and local in freshwater marshland and moist meadows.

The same six *WatchList* species as recorded in the BBA were registered in the two BBS routes sampled. Of them, only Wood Thrush was relatively widespread, found every year on the two BBS routes. Willow Flycatcher, Blue-winged Warbler, and Prairie Warbler appeared to be locally common. Olive-sided Flycatcher and Canada Warbler were locally uncommon.

4.1.3 Breeding Birds, Conclusions

The site visit was conducted at the peak of the nesting bird season. It is likely that all nesting species were noted during the census of birds on and adjacent to the property. The Project site is a small, isolated field on the outskirts of an urban center. Habitat surrounding the 13-acre field includes a small pond and wetland, fragmented secondary woodland, and commercial development (a college campus, district court, hospital, and golf course). Given the poor habitat quality, the breeding-bird community has relatively low species diversity and bird abundance. No Massachusetts-listed species are at all likely to breed at the site, but a small breeding population of the *Yellow WatchList* Willow Flycatcher has established itself in the shrub zone bordering the pond, wetland, and field. Despite the field's small size, three male Bobolinks were observed displaying, in turn attracting two females. Nonetheless, no other obligate grassland birds were found to use the field to breed.

4.1.2-1. Special-Status Species Records in BBS, 1996-2005

Route #	Route Name	County	Distance / Bearing from Site	# Years Surveyed	Species Min-Max	Special-Interest Species[1]	% Years Recorded	Range Birds per Year
47017	N. Orange	Worcester -Franklin	6.5 mi NNW	9	65-69	**American Bittern (MA-E)**	**11%**	**1**
						Olive-sided Flycatcher (*Yellow WatchList*)	11%	1
						Willow Flycatcher (*Yellow WatchList*)	44%	1-2
						Wood Thrush (*Yellow WatchList*)	100%	6-15
						Blue-winged Warbler (*Yellow WatchList*)	11%	1
						Canada Warbler (*Yellow WatchList*)	22%	1
47900	Ware River	Worcester	12.5 mi WSW	10	52-62	Wood Thrush (Yellow WatchList)	100%	2-8
						Blue-winged Warbler (Yellow WatchList)	100%	1-4
						Prairie Warbler (*Yellow WatchList*)	80%	1-3
						Canada Warbler (*Yellow WatchList*)	10%	1

[1] Massachusetts-listed species are indicated in boldface; see Table 4.1-1. WatchList species are indicated as *Red WatchList* or *Yellow WatchList*; see discussion in Section 4.1.

4.2 Migratory Birds

This section sheds light on how migratory birds are likely to use the Project site, particularly its airspace. Because bird migration is a complex phenomenon, this report examines the major migratory bird groups separately: nocturnal songbirds, raptors, and waterbirds (waterfowl, shorebirds, and others).

4.2.1 Nocturnal Songbird Migration

Night-migrating songbirds and allies are the most numerous of birds migrating over Massachusetts. Species include cuckoos, woodpeckers, flycatchers, vireos, nuthatches, wrens, kinglets, gnatcatchers, thrushes, catbirds, thrashers, warblers, tanagers, and sparrows. Based on the population estimates provided in Rich et al. (2004) for Northern Forest breeding birds, migratory songbird traffic above Massachusetts is probably on the order of tens to hundreds of millions of birds per season. In Massachusetts, songbird migration is concentrated from mid-March to early June (spring migration) and from late August through mid-November (fall migration) (Veit and Petersen 1993).

It is important to bear in mind that nocturnal migration across North America may be classified as broad front. In other words, there is no evidence that songbirds follow topographic structures such as coastlines, ridges, and valleys during night flight; instead, most night migration occurs along broad fronts (Berthold 2001, Alerstam 1993, Eastwood 1967). Berthold (2001) went so far as to say, “Individuals originating from geographically dispersed breeding areas cross all geomorphological features (lowlands, mountains, rivers, and so on) along their routes without deviating much from the orientation of their initial tracks.”

Because radar has been used for more than a half-century as a scientific tool to study migration, it has been recommended by the USFWS and others as a tool for potentially assessing risk at wind power facilities. In theory, the number of birds observed on radar and their behavior (altitude, flight direction, etc.) should be related to risk. Unfortunately, radars data varies greatly depending on the type of radar, power of the radar, the settings (attenuation, etc.) used, the manner in which the data are collected (manually vs. automated), the topographic situation, habitat at the study site, and the operator. In addition, there are disagreements among the experts as to how to filter out insects, whether birds, bats, and water droplets can be differentiated, and what the data actually mean. Radar has never been shown to be a useful or reliable predictor of risk to avian species. Despite these issues, there are valid scientific uses of radar. Some radar studies that have focused on wind power sites are summarized in the following paragraphs.

Radar studies conducted in the Eastern U.S., where the topography is pronounced, provide strong evidence that migration is generally broad front (Cooper et al. 1995, Cooper and Mabee 1999, Cooper et al. 2004a, 2004b). Perhaps the best evidence from eastern North America to support the contention that birds do not follow topographic features is a study by Cooper et al. (2004) from a ridge in West Virginia, and a comparison of radar studies on ridges in southwestern Pennsylvania, Maryland, and West Virginia (Kerlinger 2005). These studies showed that night migrants simply cross the southwest-northeast-oriented ridges of the Appalachians at oblique angles rather than following them. These same birds were not concentrated in large numbers on the ridges, nor were they flying at low altitudes that would suggest ridge following. These findings are consistent with the phenomenon of broad front migration and would appear to refute a ridge-following hypothesis.

There are two accounts from the northeastern U.S. that appear to suggest that birds do, at times, change migration direction when confronted by topographic features. In New Hampshire, at Franconia Notch, at the northern edge of the White Mountains, birds appear to turn when they encounter the massive topographic features of these mountains (Williams et al. 2001). This is similar to the European findings of birds flying through passes in the Alps and diverting around the Alps (Bruderer and Liechti 1999). However, the Williams et al. (2001) report provides little information on high-flying migrants or migrants flying in other than a restricted location near Franconia Notch, so there is limited information from this site. A study done at two New York sites (one along the Hudson River, the other in the Helderberg Mountains, near Albany) suggested that birds might have been following the Hudson River (or the lights along the River) during fall migration (Bingman et al. 1982) when winds were strong from the west.

A bioacoustical study of noctural songbirds conducted by Evans and Rosenberg (1999) appeared to have demonstrated that night migrants in the central New York region follow topographic features. But, this study had significant flaws. Evans and Rosenberg attempted to quantify numbers of migrants and determine species composition of nocturnal migrants at seven sites across central New York State in the early 1990s. Evans (pers. comm.) found that, in general, during the fall migration, fewer birds migrated over the western portion of the state south of Lake Ontario than farther east. Evans also suspected that fewer birds fly over the hilltops than through the valleys, because as they come south they encounter the hills between the Finger Lakes and follow valleys so as not to utilize large amounts of energy to climb the steep hills. He stated that birds did fly over the hilltops and some were judged to fly at less than 300 feet (93 m) above the ground.

There is no foundation in the scientific literature for the contention that night migrating birds follow ridges or valleys at topographic situations other than those similar to the Alps or other massive topographic structures. Because the acoustical devices used by Evans and Rosenberg (1999) are unlikely to detect higher flying migrants, studies based on acoustical devices are typically biased toward lower flying birds. In addition, a recent report by Farnsworth et al. (2004), in which results from acoustical studies were compared with those from radar studies, indicated that the acoustical methods proved a poor indicator of the numbers of birds aloft. The degree of correlation between the two methods was so low (mostly not significant) as to discount the use of acoustical studies for estimating traffic rates of night migrants at given sites. Furthermore, there has never been confirmation that the acoustical method is a valid means of determining the volume of migration at a particular site.

The above studies indicate that neither the location nor the topography or habitat of the Project site suggests anything but broad-front migration. Therefore, nocturnal migrants are not likely to be concentrated at or above the Project site.

Regarding the traffic rate, altitude, and direction of nocturnal migration above the Project site, Kerlinger, J. Plissner, and others (in preparation) have reviewed marine surveillance radar studies conducted at more than 15 sites in the eastern U.S. These sites were distributed in western Maine (1), Vermont (2), northern (5) and western (3) New York (including studies from the Tug Hill Plateau adjacent to the Project site), southwestern Pennsylvania (3), western Maryland (1), eastern West Virginia (2), and western Virginia (1). Sites were studied in the spring, fall, or in both seasons. The number of sites studied in the spring (11) was fewer than those studied in the fall (17).

The amount of migration at all sites, in terms of numbers of birds passing through a one kilometer corridor during one hour (targets/km/hr, the standard of measurement), ranged from 135 to 661 targets/km/hr in the fall and from 42 to 473 targets/km/hr in the spring. It is important to note that these are mean seasonal rates. Within each season, there was significant variation from night to night.

While migration traffic rates at eastern U.S. sites appear to range widely, comparisons with radar study sites in the southeastern U.S. provide a dramatic perspective. Mean seasonal migration rates from Louisiana, Georgia, and South Carolina were in the thousands of birds per kilometer per hour in both fall and spring. Traffic rates in Louisiana averaged 9,000 to 10,000 targets/km/hr during fall, with some nights having on the order of 30,000-plus targets/km/hr. In spring, these sites registered flights averaging 3,000 to 50,000 targets/km/hr (Able and Gauthreaux 1975, Gauthreaux 1971, 1972, 1980). Similar, but slightly lower, migration traffic rates were reported by Able and Gauthreaux (1975) and Gauthreaux (1972, 1980) at a site near Athens, Georgia, and at a site in South Carolina. In Georgia during fall, the rate was between 1,500 and 3,250 targets/km/hr, and at both sites there were nights with tens of thousands of birds per kilometer per hour passing overhead.

In other words, migration traffic over the northeastern U.S. is less than along the Gulf Coast and southern U.S. region, where birds are concentrated before or after crossing the formidable ecological barrier presented by the Gulf of Mexico.

Mean migration altitude at northeastern U.S. sites surveyed ranged from 148 m (485 feet) to 583 m (1,912 feet) agl (above ground level) in the fall, and from 130 m (426 feet) and 528 m (1,732 feet) AGL in the spring. But, if radar measurements prior to 2000 are excluded, the range of mean altitudes for the sites in fall was 365 m to 583 m (1,197-1,912 feet) agl. For sites in the spring, it was 401 m to 528 m (1,315-1,732 feet) agl. This exclusion is important because the less powerful radar employed prior to 2000 was biased toward lower flying birds.

Another measurement routinely made by radar operators is the percentage of migrants below 125 m (~410 feet). This measurement is approximately equal to the height of turbines and is used to determine the potential for risk, although it has never been validated empirically as an indicator of the numbers of fatalities of night migrants at turbine sites. Excluding pre-2000 data, the fall percentage of migrants that fly below 125 m ranges from less than 4% of all migrants tracked with radar to about 13%. In spring, the percentage ranges between 4% and 12%. This means that between about 4% and 13% of migrants fly within the height of modern wind turbine rotors.

From the mean altitudes reported above, it is clear that most migration occurs well above the rotor-swept height of turbines. These measurements are consistent with the mean altitude of nocturnal migrants reported by several authors who have reviewed radar studies from other parts of the United States, Canada, and Europe (Kerlinger 1995, Kerlinger and Moore 1989; Able 1970). These measurements are also similar to measurements from the southeastern United States taken with weather radar. From these studies, it does not appear that there is a great difference with respect to altitude of night migrating birds in diverse geographic settings or diverse topographies. This should also be the case in West Virginia.

Flight direction of migrants tracked with radar in the Eastern U.S. did not vary greatly among sites. The numerical means of the mean directions reported for fall and spring migration were 190° in fall and 38° in spring. These correspond to south-southwesterly migration in fall and northeasterly migration in spring. The standard deviations (actually angular deviations using circle-based statistics) around each site in the eastern United States are in the range of 40 to 80°. In other words, about 75% of all migrants tracked within 40° to 80° of the mean direction of migration. What is noteworthy is that in fall the mean migration directions reported from all of the eastern sites range between 219° and 175°, a range of 44°.

Young and Erickson (2006) have also reviewed radar studies at proposed and existing wind-energy projects in the Eastern U.S. (see NRC 2007). Based on 21 studies, they found similar mean passage rates in spring and fall (258 versus 247 targets/km/hr, respectively). Mean height of flight was 409 m agl in spring and 470 m agl in fall, with 14% of targets below 125 m (410 feet) in spring and 6.5% below that height in fall. Mean flight directions were NNE (31 degrees) in spring and SSW (193 degrees) in fall. These averages are in line with Kerlinger and Plissner's analysis.

In summary, nocturnal songbird migration above the Project site will be part of an extensive broad-front migration over central Massachusetts. Given that the site is located away from the Atlantic coast and other ecological barriers and magnets that tend to concentrate nocturnal migrants during fallout events, it is likely that the characteristics of migration above the site will be similar to those determined by radar studies at many other sites in the Eastern U.S. Those studies demonstrate that migration traffic is low to moderate and that most birds fly well above the rotor-swept area. Only a relatively small percentage of night-migrating songbirds may be expected to fly in the rotor-swept area.

4.2.2 Hawk Migration

The Hawk Migration Association of North America (HMANA; visit www.hmana.org) lists three active hawk watches within about ten miles (16 km) of the Project site. They are Mt. Wachusett, Mt. Watatic, and Barre Falls. All are active in fall, but Barre Falls is also active in spring. As may be noted in Table 4.2.2-1, the three sites average from about 5,000 to over 8,000 raptors passing from late August to late November-early December. A spring average for Barre Falls is not available, but in 2008, the total passage was 823 raptors. These figures indicate that raptor migration is greatest in fall in north-central Massachusetts.

As shown in Table 4.2.2-1 (thanks to information available at HawkCount.org), Broad-winged Hawk is the most common migrant, occurring in the thousands of birds. Broad-wing passage peaks in mid to late September, when large flocks ("kettles") of these soaring hawks migrate southwestward over north-central Massachusetts in rising columns of air, known as thermals. Studies demonstrate that Broad-winged and other hawks using thermals generally migrate at altitudes ranging from 600 up to 1,500 feet (200 to 450 m) or even higher at midmorning, and up to altitudes up to 3,500 to 4,000 feet (1,100 to 1,200 m) or higher by mid-afternoon, when thermals reach their maximum (Kerlinger 1989). At such high altitudes, most hawks are not always perceptible to observers.

Table 4.2.2-1. Data from Nearby Hawk Watches

	Mt. Wachusett[1] 8.4 miles SE 8/20-11/20		Mt. Watatic[2] 8.6 miles NE 8/31-12/01		Barre Falls[3] 11 miles S 8/20-12/07	
Species[4]	Average	High	Average	High	Average	High
Black Vulture	-	-	-	-	1	1
Turkey Vulture	29	94	2	2	323	459
Osprey	107	140	123	162	304	454
Bald Eagle (MA-E)	19	38	16	26	60	102
Northern Harrier (MA-T)	18	34	10	19	56	90
Sharp-shinned Hawk (MA-SC)	275	426	146	224	1,117	1,769
Cooper's Hawk	25	35	29	45	103	170
Northern Goshawk	2	4	2	3	10	26
Red-shouldered Hawk	14	29	2	2	81	160
Broad-winged Hawk	5,049	9,059	4,488	12,117	5,409	17,322
Red-tailed Hawk	67	159	11	31	497	980
Rough-legged Hawk	1	1	-	-	3	5
Golden Eagle	3	5	1	1	4	5
American Kestrel	62	144	49	89	200	304
Merlin	13	17	9	18	48	90
Peregrine Falcon (MA-E)	3	4	3	9	12	16
Unidentified Raptor	18	30	63	108	64	106
	5,705		4,954		8,292	

[1] From http://hawkcount.org/siteinfo.php?rsite=228

[2] From http://hawkcount.org/siteinfo.php?rsite=229

[3] From http://hawkcount.org/siteinfo.php?rsite=181

[4] Massachusetts-listed species are in boldface: E = Endangered, T = Threatened, and SC = Special Concern.

At the three local hawk watches, Sharp-shinned Hawk, Osprey, and Red-tailed Hawk have averaged in the hundreds of birds. Except for the special-concern Sharp-shinned Hawk, none of the Massachusetts-listed raptors are common migrants at these sites, although average tallies of the endangered Bald Eagle and Peregrine Falcon and threatened Northern Harrier are a little more than double at Barre Falls than at Mt. Wachusett and Mt. Watatic.

It is worth noting that north-central Massachusetts lacks long, linear ridges that would concentrate migrating hawks on updrafts, such as occurs at Hawk Mountain, where about 20,000 raptors are tallied each fall (see http://hawkcount.org/siteinfo.php?rsite=109). Therefore, hawks migrating across Massachusetts rely mostly on thermals. Given the random nature of thermal development, the resulting migration pattern is broad front, with hawks dispersed over the landscape. This explains the moderate numbers of hawks recorded in fall at the Massachusetts sites when compared with a globally significant site such as Hawk Mountain. Given their height, Mt. Wachusett and Mt. Watatic are good vantage points for viewing hawk migration, especially of raptors that fly close to these monadnocks to take advantage of updrafts on their slopes.

Given that the Project site is not a monadnock, hawk migration above the site would be broad front at altitudes generally well above rotor height of wind turbines. Hawk migration in fall would be a magnitude greater than that in spring. In fall, Broad-winged Hawk would be the most common species, with peak passage in mid to late September.

4.2.3 Waterbird Migration

In his maps of waterfowl migration corridors, Bellrose (1980) shows between 5,000 and 25,000 geese migrating over New England between the east coast of Labrador and the Mid-Atlantic coastal region. Duck migration crossing New England between the Prairie Pothole region and the New England coastal region is bracketed at 50,000 and 225,000. These numbers are low compared with other U.S. regions. Comparable numbers are not available for shorebirds and other waterbirds. Nonetheless, the Western Hemisphere Shorebird Reserve Network (http://www.whsrn.org/google_map.php) does not list any significant shorebird stopover sites in north-central Massachusetts. The closest significant site is Great Marsh on the North Shore of Massachusetts, located about 60 miles (96 km) east of the Project site.

In the Project vicinity, there are no large lakes, marshes, mudflats, or other types of ecological magnets that would attract waterbirds, including geese, ducks, loons, grebes, cormorants, herons, rails, shorebirds, gulls, and terns in significant numbers. A small pond, however, abuts the Project site, but it would not attract more than small numbers of waterbirds to stopover.

Aviation reports from the Midwest indicate that most Canada Geese fly at about 2,000 feet above the ground in fall, with 52% of flocks between 1,000 and 3,000 feet and some flocks as low as 500 feet and others as high as 11,000 feet; spring aviation records show the average altitude even higher, at 2,500 feet (Bellrose 1980). Most migration of waterfowl and other waterbirds takes place at night, but some extends to daylight hours, depending on the distance traveled. Radar studies show altitudes of 500 to 1,000 feet (152 to 304 m) or more at many locations for ducks, geese, loons, and other birds (Kerlinger 1982, Kerlinger 1995, reviewed by Kerlinger and Moore 1989). It should be noted that migrating geese do make stopovers to feed on corn and other seeds in agricultural fields during fall and spring migration, but there is no such habitat in the Project's vicinity.

4.2.4 Migratory Birds, Conclusions

There are no ecological magnets or barriers that would attract or concentrate migrating birds in large numbers at the Project site or nearby. The habitat on site is not suggestive of important stopover habitat for migrants. In the case of night-migrating songbirds, raptors, and waterbirds, migration will be broad front in nature and generally at altitudes above the sweep of the wind turbine rotors.

4.3 Wintering Birds

Audubon's Christmas Bird Count (CBC) provides an excellent overview of the birds that inhabit an area or region during early winter. Counts take place on a single day during a three-week period around Christmas, when dozens of birdwatchers comb a 15-mile (24 km) diameter circle (177 mi^2 [453 km^2] in area) to tally up all the bird species and individuals they see. In preparation for count day, participants also scout for birds during the "count week" period. While most of these birdwatchers are unpaid amateurs, they are usually proficient or highly skilled observers.

Available at http://audubon2.org/birds/cbc/hr/count_table.html, CBC data are used by scientists, wildlife agencies, and environmental groups to monitor bird populations. The results over the last ten years for the Westminster CBC have been examined to understand the winter bird populations likely to occur at the Project site. As noted in Table 4.3-1, this CBC overlaps the Project site and was active in each of the ten years sampled. Observer participation per count during the analysis period varied from a minimum of 6 observers to a maximum of 28.

Table 4.3-1. CBC Analyzed, 1998-2007

Count Name (Code)	Center County	Distance / Bearing from Site	Years Analyzed	# Participants	# Species Min-Max
Westminster (MAWE)	Worcester	0 mi SE	10	6-28	47-60

The number of species recorded in this count ranged between 60 and 47 species. Because this CBC included significant open-water and wetland habitat, it recorded waterfowl and other waterbirds that are unlikely to occur at the small pond present at the Project site. It also included a wide range of upland habitats, including no doubt high-quality representatives of some habitat types. Given its small size and low habitat diversity and quality, the Project site would be expected to have fewer species and lower bird abundances than this CBC.

To understand the winter bird profile in the Project region, Appendix F has been prepared. Sorted in taxonomic and abundance orders, this table displays the average frequency of birds, measured in birds/hour, for the Westminster CBC. Yearly abundances for species were determined by dividing the number of individuals by the total number of party hours. These values were then averaged using the last ten years of available data (1998 to 2007).

A total of 85 species were recorded on the Westminster CBC over the last ten years. Of these birds, 20 species were recorded above 1 bird/hour and can be considered common. Individuals of these species made up 95% of all individuals recorded on the count. They were:

American Crow	19.63	American Goldfinch	4.31
Black-capped Chickadee	15.30	Great Black-backed Gull	2.76
European Starling	12.94	Mourning Dove	2.60
Herring Gull	12.46	Tufted Titmouse	2.41
Dark-eyed Junco	7.94	House Finch	1.97
Rock Pigeon	7.44	White-breasted Nuthatch	1.96
House Sparrow	7.29	American Tree Sparrow	1.55
Blue Jay	6.45	American Robin	1.50
Mallard	5.82	Canada Goose	1.25
Cedar Waxwing	5.64	Downy Woodpecker	1.19

Listed in Appendix F, the other 65 species were uncommon or rare.

Four of the commonest birds were waterbirds (out of 15 waterbird species recorded). Of them, Mallard is probably most likely to occur in winter at the pond adjacent to the Project site. Some of the commonest landbirds (e.g., European Starling, Rock Pigeon, and House Sparrow) were introduced species that thrive in heavily impacted landscapes. Many individuals of the Black-capped Chickadee, Dark-eyed Junco, Blue Jay, American Goldfinch, Mourning Dove, Tufted Titmouse, and others were probably recorded at bird feeders around houses. The high abundance of crows may represent a roost.

Eight species of raptors were recorded. Red-tailed Hawk (0.16) was the only relatively abundant species. All others were scarce, ranging from 0.03 to less than 0.005 birds/hour, including Sharp-shinned Hawk (MA special-concern), Cooper's Hawk, Northern Goshawk, Red-shouldered Hawk, Rough-legged Hawk, American Kestrel, and Merlin.

Table 4.3-2. CBC Records for Special-Status Species, 1998-2007

Species[1]	CBC	Percent Years Recorded	Range Number Recorded
Sharp-shinned Hawk (MA-SC)	**Westminster**	**80%**	**1-4**
Iceland Gull (*Yellow WatchList*)	Westminster	20%	1

[1] Massachusetts-listed species are indicated in boldface; see Table 4.1-1. *WatchList* species are indicated as *Red WatchList* or *Yellow WatchList*; see discussion in Section 4.1.

Regarding special-status species, the only Massachusetts-listed species registered was the special-concern Sharp-shinned Hawk, but it is likely that the individuals recorded did not originate from Massachusetts-breeding populations. It is significant that the endangered Bald Eagle was not recorded, which indicates that few Bald Eagles winter in north-central

Massachusetts. Among *WatchList* species, only the *Yellow WatchList* Iceland Gull was recorded infrequently.

In conclusion, Christmas Bird Count (CBC) data and the habitat present on site strongly suggest that the Project site will have limited bird use in winter. Outside of the Massachusetts special-concern Sharp-shinned Hawk, no listed or *WatchList* species appear likely to occur at the Project site in winter. In the case of the hawk, occasional individuals found to forage at the site would probably not be members of the Massachusetts breeding population.

5.0 Important Bird Areas, Reserves, and Sensitive Habitats in Project Vicinity

The avian risk analysis checks databases to see if Important Bird Areas (IBAs) or federal, state, or private protected areas overlap with the Project site or are in close proximity. The presence or proximity of such areas could indicate sensitive habitats and increased avian risk.

5.1 Important Bird Areas (IBAs)

A program of BirdLife International and Audubon, the Important Bird Area (IBA) Program seeks to identify and protect essential habitats for one or more species of breeding or non-breeding birds. The sites vary in size, but usually they are discrete and distinguishable in character, habitat, or ornithological importance from surrounding areas. In general, an IBA should exist as an actual or potential protected area, with or without buffer zones, or should have the potential to be managed in some way for birds and general nature conservation. An IBA, whenever possible, should be large enough to supply all or most of the requirements of the target birds during the season for which it is important.

According to information available at http://www.massaudubon.org/Birds_and_Birding/IBAs/, 79 IBAs have been approved in Massachusetts. Three are located within 10 miles (16 km) of the Project site.

Measuring 63,000 acres, the Ware River Watershed IBA reaches within 5 miles (8 km) of the Project site (to the south). It is considered significant for its breeding populations of Neotropical migrants, including vireos, thrushes, warblers, and tanagers. The Massachusetts endangered American Bittern and special-concern Sharp-shinned Hawk have been recorded as breeders. The area is also considered significant as a major stopover site for passerine migration.

Measuring 2,000 acres, the Wachusett Mountain IBA is located about 6 miles (9.6 km) southeast of the Project site. Considered significant for its hawk migration, it was discussed above in Section 4.2.2.

Measuring about 1,500 acres, the Mt. Watatic IBA is located about 8 miles (12.8 km) northeast of the Project site. Discussed above in Section 4.2.2, it is also considered significant for its hawk migration. Its spruce-covered summit hosts a number of northern breeding species, such as *Yellow WatchList* Olive-sided Flycatcher. The Massachusetts special-concern Sharp-shinned Hawk has also been recorded as a breeder.

The American Bird Conservancy (ABC) has published a directory of the 500 most important bird areas in the United States (ABC 2003). The closest IBAs to the Project site would be Crane Beach and the Parker River National Wildlife Refuge, located about 60 miles (96 km) east along the Atlantic Ocean. They are highlighted for their breeding Piping Plovers (Massachusetts endangered and *Red WatchList*) and migrating shorebirds.

5.2 Federal, State, County, and Private Protected Areas

A number of state forests and wildlife management areas (WMAs) are located within 10 miles (16 km) of the Project site. The closest is High Ridge WMA, located about one mile (1.6 km) east of the site.

The 772-acre Lake Wampanoag Reserve of Massachusetts Audubon is located about one mile northeast of the Project site. A description available at http://www.massaudubon.org/ does not mention any particular avian significance.

In conclusion, the Project site does not overlap an Important Bird Area (IBA), nor is its habitat distinct in character, habitat, or ornithological importance from surrounding landscape. Instead, the Project site is a small, isolated field on the outskirts of an urban center. Given these findings, no sensitive habitats and increased avian risk are indicated.

6.0 Review of Risk to Birds at Wind Power Plants in the United States and Europe

Assessing risk to birds at a prospective wind-energy site may be accomplished by comparing a site's avian use (abundance and behavior) with similar sites where avian risk has been determined through post-construction research. By comparing the types of species present or likely to be present, numbers of individuals, seasonality, and behavior of birds that nest, forage, migrate, or winter at a proposed wind-power site with existing facilities where risk has been determined, probabilistic assessments of risk can be made.

In this section, we review what is known about avian risk at existing wind-power facilities. Two general types of impacts have been documented: 1) disturbance and displacement of birds as a result of the construction and operation of wind turbines and related infrastructure, and 2) fatalities resulting from collisions with turbines, meteorology towers, and other infrastructure. These two types of impacts are detailed below.

6.1.1 Disturbance and Displacement

Disturbance and habitat alteration resulting from the construction and operation of wind turbines and other wind-farm infrastructure has sometimes been found to make a site unsuitable or less suitable for nesting, foraging, resting, or other bird use. Avoidance and displacement has been documented in some species, but subsequent habituation to wind power project infrastructure has also been demonstrated.

The footprint of turbine pads, roads, and other infrastructure required for a wind facility is generally a small percentage of a project site, often estimated at two to four percent. Therefore, in general, overall land use is minimally changed by wind-power development, and actual habitat loss is generally small. This is particularly true in agricultural landscapes. But, in forested landscapes, the construction of a large wind farm and its connection to the electricity grid may fragment habitat in a significant way, affecting wildlife populations (NRC 2007).

Despite the relatively small footprint of a wind facility, the true amount of wildlife habitat altered by a wind-power project sometimes extends beyond. This results from the presence and operation of the wind turbines and increased human activity to construct and maintain them. Various studies have examined the presence of tall wind turbines in landscapes to determine whether birds avoid or are displaced from an area as a result of these new features.

In the U.S., studies documenting disturbance, avoidance, and displacement have focused mainly on birds living in grassland and other open country habitats, including farm fields. At the Buffalo Ridge Wind Resource Area in southwestern Minnesota, Conservation Reserve Program (CRP) grasslands without turbines and CRP areas located 180 m (590 feet) from turbines were found to support higher densities of grassland birds than CRP areas within 80 m (260 feet) of turbines (Leddy et al. 1999). At the bases of turbines, mean bird density was measured at 58.2 males/100 ha; at 40 m, 66.0 males/100 ha; and at 80 m, 128.0 males/100 ha. At 180 m, mean bird density rose to 261.0 males/100 ha. In CRP control plots, it was calculated at 312.5 males/100 ha. Bobolinks, Red-winged Blackbirds, and Savannah Sparrows were the commonest species in CRP grasslands with turbines, whereas Bobolinks, Sedge Wrens, and Savannah Sparrows were commonest in CRP grasslands without turbines. Other birds recorded were Common Yellowthroat, Clay-colored Sparrow, Grasshopper Sparrow, Le Conte's Sparrow, Dickcissel, Western Meadowlark, and Brown-headed Cowbird.

The Buffalo Ridge study appears to demonstrate that disturbance was greatest close to turbines and decreased with distance from turbines. This indicates that, after turbine construction, some birds either did not nest or forage near the turbines or did so at lower densities. Nonetheless, it should be noted that the Buffalo Ridge turbines are shorter than those proposed for the Project, and closer together. These characteristics may have greater impacts than larger, more widely spaced turbines. Furthermore, the Buffalo Ridge study was conducted in the first year after construction, when vegetation at turbine construction sites may not have been fully restored and birds had not had a chance to habituate to the project.

At the Foote Creek Rim Wind Plant in Wyoming, the numbers of nesting Mountain Plovers (a grassland-nesting species) declined after erection of turbines. Plover productivity also declined (Johnson et al. 2000), although successful nesting of Mountain Plovers was noted within 200 m (660 feet) of operating turbines. Thus, the area impacted extended beyond the actual footprint of the project.

O'Connell and Piorkowski (2006, reviewed in Mabey and Paul 2007) studied the effects of wind-power development on grassland and other bird populations at the Oklahoma Wind Energy Center, where 35 1.5-MW turbines were in operation. They measured breeding bird densities in native mixed-grass prairie, cropland (wheat), and Eastern red cedar-dominated habitats using 200-m (660-foot) point-count surveys along road transects at three distances: adjacent to turbines, intermediate (1 to 5 km away), and distant (5 to 10 km away).

Of the 66 species recorded in the point counts, 23 were common enough for analysis, including many grassland birds. In cropland, Killdeer was found to be most abundant at intermediate distances from turbines. Greater Roadrunner and Western Meadowlark were found to be most abundant at distant sites. These results are somewhat surprising because, in other studies (see Maple Ridge and Erie Shores below), Killdeers have been found to use turbine pads as nesting habitat. Paul Kerlinger (personal observation) has recorded apparent habituation in Western Meadowlarks that were perched on the lattice towers of older wind turbines in the Altamont Pass Wind Resource Area (APWRA) in California.

Returning to the Oklahoma study, Northern Bobwhite, Scissor-tailed Flycatcher, Horned Lark, Bewick's Wren, Cassin's Sparrow, Grasshopper Sparrow, Painted Bunting, Dickcissel, and Eastern Meadowlark showed no differences in breeding density in relation to proximity to wind turbines. The same was true of an analysis of all breeding birds combined. The authors concluded that most breeding grassland birds had experienced no negative effects that would translate into a reduction of breeding density. Nevertheless, Mabey and Paul (2007) point out that the sample sizes were low and the statistical power to detect differences was probably insufficient, but they consider this study one of the best efforts at controlled study of the population-level effects of wind turbines on birds.

At the Maple Ridge Wind Power Project in Lewis County, New York, an impact gradient study (Kerlinger and Dowdell 2008) was conducted to determine whether birds nesting in hay/grassland fields were displaced by wind turbines erected the previous year. Ten impact gradient transect/plots (100 m x 300 or 400 m; 3-4 ha) were established beneath turbines and five reference plots were established in fields between 400 and 1,600 m of turbines. Each plot was sampled three times prior to the first hay mowing.

Overall density of all birds (nine species) was 15.2/ha in turbine plots and 18.5/ha in reference plots. Savannah Sparrows and Bobolinks accounted for 57.1% and 40.6% of all birds observed within the turbine plots and for 47.8% and 48.9% of birds observed in the reference plots, respectively. Densities for Savannah Sparrow and Bobolink were similar to those reported for similar habitat at sites in New York, Michigan, Wisconsin, and Quebec, but they were greater than those reported at prairie sites.

There were marginally lower male Bobolink densities at turbine vs. reference plots. The pattern for Bobolink densities (all individual and males) revealed lower densities within 75 m of turbines. Bobolink densities from 0 m to 100 m increased exponentially, and from 100 to 400 m did not appear to change. Savannah Sparrow showed no difference in density between turbine and reference plots, and there did not seem to be an increase in density going out from the turbines. Killdeer were more abundant in turbine plots as opposed to reference plots, as they nested on the bare earth and gravel pads beneath the turbines, indicating that turbine construction actually created or enhanced habitat for them.

The authors of the study pointed out that habitat around the bases of turbines probably affected the results. Below many turbines, vegetation had not recovered to hay field; instead, there were bare earth and dirt piles out to 50+ m. This may have explained the lower Bobolink densities within 75 m of the turbines. For Savannah Sparrows, dirt piles serving as singing perches may have attracted males from nearby territories. Nevertheless, the data strongly suggested that densities of these birds beyond 75-100 m were not impacted by the presence of turbines. It was also likely that, beyond 100 m of turbines, these two species had habituated to the turbines. In other words, if displacement was occurring, it was only evident within 75-100 m of the turbines.

A second year of study will be conducted once habitat beneath turbines has fully recovered. Kerlinger and Dowdell (2008) also noted that hay mowing in the days after the gradient study eliminated all nests in hay fields where turbines were situated as well as reference fields. They concluded that impacts from turbines were orders of magnitude lower than displacement by turbines, if the latter occurred.

At the Erie Shores Wind Farm in Port Burwell, along the shore of Lake Erie in Ontario (James 2008), Killdeer nested at distances of 3 to 40 m (10 nests) from the bases of towers, Horned Larks at 15, 21, 37 and 40 m, Vesper Sparrow at 30 m, and Savannah Sparrow at 16 and 20 m. The author concluded that these species were more affected by the farming practices, including hay mowing and tilling, than by turbines.

A recent study from Europe (Devereux et al. 2008) has demonstrated that turbine locations did not affect the distribution of four functional groups of wintering farmland birds (seed-eaters, crows and allies, gamebirds, and European Skylarks) at distances ranging from 0-150 m to 600-750 m. A further analysis of data collected at 0-75 m and 75-150 m from turbines found no evidence to suggest that farmland birds avoided areas close to wind turbines. This study appears to indicate that the present and future location of large numbers of wind turbines on European farmland is unlikely to have detrimental effects on farmland birds, at least for those species studied.

Curiously, at Tarifa, Spain, some songbirds nested at higher densities and with higher productivity on a ridge with wind turbines than on two other ridges without wind turbines (de Lucas et al. 2004). A sheltering effect from passerine predators (e.g., Booted Eagles) by wind turbines has been suggested, but the study did not analyze habitat differences between sites to exclude that possibility.

The Altamont Pass Wind Resource Area of California (APWRA) hosts very large numbers of raptors and grassland-nesting songbirds, which regularly perch on the lattice towers and guy wires of the site's older turbines. In a study in the APWRA, Red-tailed Hawks trained for falconry in Idaho were exposed to turbines in order to study their flight behavior near those structures. Upon first seeing the turbines at 100 feet (30 m), the birds would not fly. Within weeks, however, they appeared to habituate to the turbines in a manner comparable to resident Red-tailed Hawks (R. Curry, personal communication). Unlike most other wind power sites in the United States, turbines have been present in the APWRA for about 20 years, and resident birds have had ample time to habituate to them.

At Erie Shores Wind Farm (James 2008), construction activity in 2006 displaced a pair of Bald Eagles nesting 400 m (1,310 feet) of a proposed turbine location, but the pair established a new nest about 900 m (2,950 feet) away and successfully raised two young. This pair returned to the new nest in 2007, but the nest failed for unknown reasons. These adults and juveniles were seen perched within 200 m (660 feet) of active turbines, and on a few occasions they were observed flying closer than 100 m (330 feet) of rotating blades. Over the course of two years, Bald Eagles were noted flying past active turbines within 300 m (985 feet) of the towers on about 170 occasions. Most of these were along the Lake Erie shore, where they routinely soared past at less than 200 m (660 feet) away (137 times noted), but only 5 or 6 occasions were they seen less than 50 m (165 feet) of turning blades.

Also at Erie Shores Wind Farm (James 2008), a pair of Red-tailed Hawks nested within 135 m (215 feet) of a turbine under construction (!). The turbine was in operation about a month before the young had fledged, during which time the adults made hundreds of trips to the nest. They were observed on numerous occasions negotiating the airspace around the spinning rotors. In 2007, possibly the same pair returned to nest, but they moved to 265 m (870 feet) from the same turbine. This location was in the middle of a quadrangle of turbines instead of on the edge of the wind farm. Cooper's Hawk nests were found at 112 (367 feet) and 175 m (574 feet) away from the closest turbines.

Hötker et al. (2006) have reviewed studies conducted in Europe on displacement impacts. They found that 40 species have been analyzed in at least six studies each, allowing a statistical test as to whether their populations were affected negatively or positively (including no apparent effect) by the construction and operation of wind facilities. Species analyzed for the breeding season included Mallard, Common Buzzard, two gamebirds, four shorebirds (including Black-tailed Godwit, Redshank, Oystercatcher, and Lapwing), and various songbirds (20 species). Negative population impacts could not be statistically verified for any breeding birds. Only shorebirds and gamebirds displayed reduced numbers in connection with wind facilities. Positive or neutral effects predominated in the other species. Interestingly, only two species showed statistically more positive or neutral reactions toward wind farms than negative reactions. Both were songbirds inhabiting marshes (Marsh Warbler and Reed Bunting).

When Hötker et al. looked at studies outside the breeding season, a different picture emerged. The suite of species analyzed was different, including various geese (analyzed together), three ducks, Grey Heron, three raptors, four shorebirds (Curlew, Oystercather, Lapwing, and Golden Plover), three gulls, and various songbirds (five species). Negative impacts predominated and were statistically more negative than positive in various geese, European Wigeon, Lapwing, and Golden Plover. The exception was Starling, for which effects were statistically more positive than negative. For most species, however, effects either way could not be statistically verified.

Regarding avoidance distance to wind facilities, Hötker et al. analyzed 28 species (mostly a subset of the previous analysis) for which data from at least five studies each were available. The data showed a wide range of values (i.e., some studies recording a species within 50 m of turbines, while others found the same species not approaching within hundreds of meters), but one trend was apparent, namely, avoidance distances during the breeding season were smaller than outside the breeding season. They found that birds of open habitats, such as geese, ducks, and shorebirds, generally avoided turbines by several hundred meters, but there were some notable exceptions, namely, Grey Heron, raptors, Oystercatcher, gulls, European Starling, and crows.

Hötker et al. also examined the relationship between the hub height of turbines and avoidance distance at four wind farms. Only in non-breeding Lapwings was there a statistically significant relationship, with avoidance distance increasing linearly with increasing hub height. Nonetheless, the authors noted clear tendencies, with breeding birds (particularly songbirds, but also Oystercatcher and Redshank) being less affected by tall turbines than by small ones. Lapwing and Black-tailed Godwit were exceptions. In non-breeding birds (with the exception of Grey Heron, diving ducks, Oystercatcher, and Common Snipe), the taller the turbines, the greater the avoidance distance. These differences may have more to do with the different suites of species analyzed in the two seasons, with larger species of open habitats predominating in the non-breeding season.

To gauge habituation (i.e., avoidance reactions decreasing over time), Hötker et al. examined 11 studies with at least two years of observation after wind farm construction. Each study analyzed several species, resulting in 122 data sets (ranging from 1 to 13 per species). Species included waterfowl, raptors, shorebirds, gulls, and songbirds. For breeding birds, 38 of 84 data sets (45%) indicated habituation. For non-breeding birds, 25 of 38 data (66%) indicated habituation. In other words, about half of the species analyzed demonstrated habituation. For individual species, sufficient data were available to analyze three. For Lapwing, two of eight studies during the breeding season indicated habituation, while three of five during the non-breeding season did so. For breeding Skylarks and Meadow Pipits, three of six studies each indicated habituation.

Hötker et al. comment that the observed degree of habituation in most cases was small. They conclude that habituation cannot be ruled out, but it appears not to be a widespread or strong phenomenon.

Regarding specifics from European studies, in the Netherlands, shorebirds (mostly migrants) were displaced by 250-500 m (800-1,650 feet) from turbines (Winkelman 1990). In Denmark, some migrant shorebirds were displaced by up to 800 m (2,600 feet) by the presence of turbines (Pederson and Poulsen 1991). Other Danish studies have demonstrated species-specific differences in avian avoidance patterns near wind turbines (Larsen and Madsen 2000, Percival 1999, Kruckenberg and Jaene 1999). In general, Pink-footed Geese (Larsen and Madsen 2000) would not forage within 50 m (160 feet) of wind turbine rows and did not forage within 150 m (500 feet) of a cluster of wind turbines. Fewer of these geese foraged within 100 m (325 feet) of wind turbines than foraged farther from the turbines. Barnacle Geese, however, foraged within about 25 m (80 feet) of turbines, showing they are less sensitive than Pink-footed Geese (Percival 1999). Nonetheless, White-fronted Geese did not forage within about 400 to 600 m (1,300 to 1,950 feet) of wind turbines (Kruckenberg and Jaene 1999).

In contrast to some European studies, two years of post-construction studies at the Top of Iowa Wind Plant (Koford et al. 2005) revealed that Canada Geese were not displaced significantly by the construction of 89 turbines. That study, designed by Iowa State University and the Iowa Department of Natural Resources, was the first disturbance/displacement study of waterfowl in the United States. Anecdotal information from the Fenner Wind Power facility in New York State (Paul Kerlinger) suggests that Canada Geese forage in close proximity to large wind turbines.

At the Erie Shores Wind Farm (James 2008), Canada Geese appeared not to be inhibited from flying through the wind farm or from using fields and ponds within 200 m of operating turbines. Goose tracks were found within 25 m (80 feet) of turbines on five occasions, with some of the tracks within 10 m (33 feet) of a tower. Tundra Swans appeared to differentiate between operating and non-operating turbines. Of 280 swans seen flying less than 300 m (990 feet) from operating turbines at rotor height, only three got to within 100 m (330 feet). But, of 240 swans seen flying past non-operating turbines, just over 20% were less than 50 m (165 feet) from those turbines.

Drewitt and Langston (2006) speculate that some wind farms may create barriers for some species that alter migratory or local flight paths, increase energy expenditure, and disrupt linkages between feeding, roosting, molting, and breeding areas to such an extent that they may, under certain circumstances, lead indirectly to population-level impacts. This phenomenon is more of a concern in offshore and coastal wind projects, where significant changes in flight direction by waterbirds have, in some cases, been noted. Drewitt and Langston's review of the literature suggests that none of the barrier effects identified so far have had significant population-level impacts. They have also not noted whether birds habituate to turbines and are impacted less over a period of years following construction of new wind power projects.

Regarding evidence of barrier effect or lack thereof at coastal wind farms, Dierschke and Garthe (2006) have reviewed studies from five coastal wind farms in Europe.

At Bythe Harbor in northeastern England, nine, fairly short turbines (rotor diameter 25 m, total height 38 m) were constructed on a pier at 200 m intervals. Dierschke and Garthe report that, during a seven-year study (Still et al. 1995, Painter et al. 1999), large numbers of Great Cormorants, Common Eiders, Black-headed Gulls, Herring Gulls, and Great Black-backed Gulls were present for several months of the year. Great Cormorants were found to cross the turbine string regularly, with 10% flying at rotor height and the rest below. In the first years, eiders flew between the turbines to enter the harbor, but later, they entered the harbor only by swimming. Birds flying between turbines were mostly gulls (80%), but many more gulls flew along the turbine row (20-300 flights per ten minutes) than between them (0.7-1.5 flights per ten minutes). Great Black-backed Gulls and Herring Gulls crossed the turbines at rotor height 16% and 13% of the time respectively, with most crossing below rotor height and very few above. There were also anecdotal reports of Northern Fulmars, Black-headed Gulls, Black-legged Kittiwakes, and Sandwich Terns passing through the wind farm.

At Maasvlakte wind farm in the Netherlands two rows of nine and 13 turbines were built on a seawall near a breeding colony of gulls and Common Terns. The turbines were at 130-m intervals with heights of 56.5 m and rotor diameters of 35 m. According to Dierschke and Garthe, van den Bergh at al. (2002) observed flight behavior of breeding birds in July of 2001. At both rows of turbines, 92% of seabirds at one turbine row and 62% at the other crossed below rotor height. Of those birds, 3.1% of gull flocks and 5.3% of Common Tern flocks exhibited a behavioral reaction, but only one gull turned back. Among gulls, this was about the same reaction rate as gulls flying above the turbines (3.0%). The authors concluded that there was no apparent barrier effect for foraging flights. They saw their results as showing a rapid habituation (or reduced sensitivity) to the presence of the turbines.

At Zeebrugge in Belgium, Everaert et al. (2003) studied flight behavior at 23 turbines of different dimensions (but all small in comparison with modern turbines) that were constructed on a pier. Thirteen turbines were located on the shoreline at close distance to a tern colony. The terns as well as gulls breeding elsewhere in the harbor regularly crossed the wind farm to forage at sea. According to Dierschke and Garthe's summary of the study, the majority of birds (54-82%) crossed the turbines below rotor height; only a small fraction (1-14%) crossed above. Depending on species and flight altitude, the percentage of avoidance reactions varied. We highlight the results for Common Tern, a species of special concern in many U.S. states. At 50-m tall turbines, 498 Common Terns were recorded passing. Of the 408 birds (81.9% of total) passing at 0-15 m, 15 (3.7%) showed an avoidance reaction. Of the 35 birds (7.0%) passing at 16-50 m (rotor height), 11 (31.4%) exhibited avoidance behavior. Of the 55 birds (11.0%) passing at 51-65 m, 6 (10.9%) exhibited avoidance behavior. Interestingly, very few Least Terns exhibited avoidance behavior at any height class (5 of 1860 birds [0.2%], including 4 of 828 birds [0.5%] at rotor height; none of the 1,010 flying below rotor height demonstrated avoidance).

At Den Oever in the Netherlands, a single turbine was constructed in the morning and evening flight paths of Black Terns and Common Terns. Dierschke and Garthe report a study during the 1997 breeding season (Dirksen et al. 1998a) in which visual and radar observation were employed to record the flight behaviors of up to 15,000 Black Terns and up to 6,500 Common Terns. These birds deviated their flight courses on both sides of the turbine, keeping a distance of 50-100 m from the turbine. Therefore, the direct vicinity of the turbine was used less than adjacent areas.

At Lely wind farm in the Netherlands, four turbines were constructed 800 m (0.5 miles) offshore in a freshwater lake. These turbines had a total height of 60 m, rotor diameters of 41 m, and spacing of 200 m. Dierschke and Garthe report that Dirksen et al. (1998b) used radar to study the flight paths of two diving ducks (Pochard and Tufted Duck) whose flight paths between diurnal roosts and nocturnal feeding grounds intersected the wind farm. On moonlit nights, the ducks could apparently perceive the wind farm, because a higher proportion of ducks flew close to the wind farm and included a low rate of flights between turbines. No birds turned back, but detour reactions were common. On moonless nights, these ducks avoided approaching the wind farm; instead, they flew parallel to it. The authors also found that resident birds, in contrast to migrants stopping over, habituated to the presence of turbines, even if they constituted a barrier to their regular movements. A second study (Dirksen et al. 2000, van der Winden et al. 2000) demonstrated the same results for Greater Scaup.

Hötker et al. (2006) have reviewed European studies examining barrier effect at onshore (including coastal) sites in a wide variety of birds, including waterfowl, storks, cranes, shorebirds, gulls, and songbirds. They assumed a barrier effect was operative if 5% of individuals or flocks showed a measurable reaction to wind farms. This was demonstrated in 104 of 168 data sets, covering 81 species. The authors found that geese, kites, cranes, and many small bird species were particularly sensitive to wind farms. But, some large birds (Great Cormorant and Grey Heron), ducks, some birds of prey (Sparrowhawk [an accipiter], Common Buzzard, and Kestrel), gulls and terns, European Starling, and crows were all less sensitive and less willing to change their original migration heading when approaching wind farms. These species and species groups also avoided wind farms less often and their local populations were less influenced by wind farms (Hötker et al. 2006).

Regarding forest-breeding species, a post-construction study of 11 turbines located on a ridgeline in Searsburg, Vermont, appears to be the only applicable study on disturbance and displacement impacts (Kerlinger 2000a, 2002b). Point count surveys for breeding birds done before and after the turbines were erected showed that some forest-nesting birds – such as Blackpoll Warbler, Yellow-rumped Warbler, White-throated Sparrow, and Dark-eyed Junco – appeared to habituate to the turbines within a year of construction. On the other hand, Swainson's Thrush, and perhaps some other species, appeared to be displaced by the turbines. This study could not document whether or not the former species nested close to the turbines, but it certainly demonstrated that they foraged and sang within forest edge about 100 feet (30 m) from the turbine bases. A visit to the site during the 2003 nesting season revealed that Swainson's Thrushes were singing (and likely nesting) within the forest adjacent to turbines, and many other species were present close to the turbines. It is not known if overall numbers of nesting birds were the same as prior to construction, but letting the forest grow up to turbines and roadways may have reduced the fragmentation impacts at that site. It is also possible that habituation had occurred.

At Erie Shores Wind Farm (James 2008; John Guarnaccia, personal observation), some turbines are situated at the edge of woodlots, but resident woodland and woodland-edge birds appeared to habituate readily to their presence, including forest-interior species, such as Wood Thrush. Forest-edge birds lived as close as habitat allowed, including below the rotating turbine blades.

In a recent review of the literature on the ecological effects of wind-energy development (NRC 2007), the following conclusions and recommendations were made regarding effects on forest ecosystems (pg. 91):

1. Forest clearing resulting from road construction, transmission lines leading to the grid, and turbine placements represents perhaps the most significant potential change through habitat loss and fragmentation for forest-dependent species.
2. Changes in forest structure and the creation of openings may alter microclimate and increase the amount of forest edge.
3. Plants and animals throughout the ecosystem respond differently to these changes, and particular attention should be paid to species of concern that are known to have narrow habitat requirements and whose niches are disproportionately altered.

Nevertheless, the effects of wind-energy projects on ecosystem structure and bird habitats depend on the pre-construction conditions. For example, the influences of a project at a previously logged site will be different than those at a previously undisturbed site (NRC 2007).

Regarding migratory birds, there is a study of three ridges (one with turbines, two without) at Tarifa, Spain, where over 72,000 migrating birds (principally Black Kites, White Storks, House Martins, and Swallows) were recorded during nearly 1,000 hours of observation from fixed observation points (Janss 2000, de Lucas et al. 2004). Observations of flight behavior indicated that birds were aware of, and possibly avoided, the turbines. Changes in flight direction were recorded more often over the wind farm than over the other two areas. Migrants also tended to fly higher over the wind farm. Abundance also did not appear affected by the presence of wind turbines. These findings could indicate avoidance by migrating birds, but no comparable data were obtained prior to operation of the turbines. In contrast, resident Griffon Vultures were not observed to fly higher over the wind farm. Possibly they were more accustomed to the turbines.

Observations of autumn hawk migration in Vermont showed that the numbers of hawks that flew close to a hill with newly constructed turbines was less than in the year prior to turbine construction and operation (Kerlinger 2000a, 2002b). These migrants may have been avoiding the novel structures.

The Erie Shores Wind Farm in Ontario (James 2008) is located within two miles of Lake Erie in a well-documented, fall raptor migration corridor. Also located along the shore of Lake Erie, Hawk Cliff Hawk Watch is less than 20 miles [32 km] west of Erie Shores and averages 37,000 raptors per fall season (Zalles and Bildstein 2000).

The James study logged more than 2,300 observations of Sharp-shinned Hawks passing through the wind farm area, with 1,534 passing within 300 m (990 feet) of the turbines. Few birds, if any, hesitated to fly near an operating wind turbine, and there were only seven instances in which single birds got close enough to spinning rotors to be judged at risk. Indeed, just over 21% of birds made course changes that brought them closer to turbines. Most of these involved birds moving along a woodland edge or a “fencerow” of trees. Had birds not changed their headings, they would have passed turbine towers at distances greater than 100 m (330 feet), but shifting course to continue to follow tree lines brought them within 50 m (160 feet) of a turbine tower. Overall, there was nothing to indicate that the turbines were an impediment to the migration of Sharp-shinned Hawks. A concurrent mortality study found one Sharp-shinned Hawk carcass in two years of study.

Other autumn migrant raptors observed at Erie Shores flying within 300 m of wind turbines were Turkey Vulture (about 1,000 observations), Osprey (12), Bald Eagle (170), Northern Harrier (115), Cooper’s Hawk (60), Northern Goshawk (6), Red-shouldered Hawk (4), Broad-winged Hawk (3), Red-tailed Hawk (300), Golden Eagle (4), American Kestrel (463), Merlin (21), and Peregrine Falcon (8). In all cases, the wind farm appeared to pose no impediment to migration, and birds appeared to negotiate the wind farm without hesitation or difficulty.

In summary, some types of birds appear to be disturbed and displaced more by wind turbine construction and operation than others. Differences between species are also evident, with some species being displaced farther than others, while others habituate to turbines. Disturbance and displacement effects have been documented in some grassland and prairie birds and in some (not all) waterfowl. Some European studies have demonstrated displacement of shorebirds, but a recent study suggests that large numbers of wind turbines on European farmland are unlikely to displace farmland birds. Forest birds, on the other hand, do not generally appear to be disturbed or displaced in a significant way by wind turbine operation; but forest fragmentation, as a result of wind facility construction, may impact forest-interior birds that are sensitive to edge effects and removal of forest canopy. Resident raptors may be displaced by construction activities during nesting season, but they appear to habituate to the turbines after the construction phase. In Spain, migrating raptors were shown to detect the presence of turbines and divert their course around them, because they changed their flight direction when they flew near them, but their abundance in the area appeared not to be affected. More research is required to fine tune understanding of displacement and habituation.

It should be noted that the vast majority of studies have been conducted on large utility scale wind farms. It would be reasonable to expect that the impacts of a small one or two turbine project on avian species would be considerably less than on a large scale project impacting large areas of habitat.

6.1.2 Collision Fatalities

6.1.2.1 Collision Mortality in Context

Collision mortality is well documented at wind-power sites in the United States. An estimated 20,000 to 37,000 birds were killed at about 17,500 wind turbines of 6,374 MW of total capacity in the United States in 2003 (Erickson et al. 2005), yielding on average mortalities of 2.11 birds per turbine per year and 3.04 birds per MW per year. To date, there have been more than 20 fatality studies at wind turbine facilities across the continent and a total of more than 25,000 individual carcass searches have been done at turbines in the United States. This research exceeds post-construction wildlife impact research at practically all other types of electrical generation (coal, natural gas, nuclear, hydro, etc.). From the large number of studies now available, fatalities were spread among dozens of species, revealing taxonomic differences in collision susceptibility. Studies from the Eastern United States reveal slightly greater fatality levels than farther west.

Erickson et al. (2005) have attempted to put this mortality in context. Based on various studies reviewed in their paper, they estimated that annual bird mortality from human-caused sources may easily approach one billion birds in the U.S. alone. Of this estimate, collisions from wind turbines amounted to <0.01%. The major mortality sources were buildings (550 million, 58.2%; Klem 1990), power lines (130 million, 13.7%; Koops 1987), cats (100 million, 10.6%; Coleman and Temple 1996), automobiles (80 million, 8.5%; Hodson and Snow 1965, Banks 1979), pesticides (67 million, 7.1%), and communications towers (4.5 million, 0.5%; M. Manville, personal communication). Erickson et al. did not, however consider hunting, which takes some 100 million birds in the U.S. and Canada annually. While the uncertainties in the estimates are large, the numbers are so large that they cannot be obscured even by the uncertainties (NRC 2007).

Based on best available estimates, Erickson et al. (2005) figure that human-caused mortality may take approximately 5% to 10% of the U.S. landbird population each year. The biological significance of this take to populations is as yet uncertain, but the best wildlife management practices routinely allow takes at or above these levels for waterfowl populations, including species of conservation concern. For example, some 20 million waterfowl are shot in the U.S. and Canada annually, apparently without significant impact to any species (Martin and Padding 2002).

Waterfowl and gamebird harvest rates are predicated on the theory of density-dependent population growth (Hilborn et al. 1995, cited in Johnson and Conroy 2005). This theory predicts a negative relationship between population growth and population density, because the members of a species compete for finite resources. When populations are harvested, they should respond by increasing reproductive output or decreasing mortality, because more resources are available per individual. Resource managers attempt to maximize sustainable harvest by adjusting population density to a level that maximizes population growth (Beddington and May 1977, cited in Johnson and Conroy 2005). However, if populations are below carrying capacity, compensatory mortality or reproduction are sometimes moot points.

The wildlife effects of wind power can be quantified with reasonable precision through mortality studies and other research. But, traditional forms of electric power generation also affect wildlife populations. Their impacts are different and, in many cases, indirect and difficult to quantify (e.g., effects of acid rain, mercury bioaccumulation, habitat fragmentation, and climate change). The reason is because impacts can occur at various stages in the life cycle of electric generation, aside from the actual generation process. In addition, the (life cycle) impacts extend hundreds (sometimes thousands) of miles outward from the point sources. Some documentation exists, however, to help link the indirect impacts of traditional electric power generation with wildlife losses. For example, acid rain from power plant emissions has been linked with extraordinary decreases in aquatic life in some lakes and streams (Likens and Bohrmann 1974), as well as with eggshell thinning in birds (Glooschenko et al. 1986). There are also direct impacts to bird populations, especially from forest removal from strip mining and stream subsidence from long-wall, underground mining, neither of which have been quantified by scientists or environmental agencies.

In the case of Wood Thrush, a forest-interior species that breeds in the eastern North America (downwind of Midwest power-plant emissions), a Cornell University study (Hames et al. 2002) has demonstrated a strong correlation between acid rain occurrence and decreases in Wood Thrush numbers. The suspected reason is decreased reproductive success as a result of eggshell thinning or scarcity of calcium in the diets of developing birds. Other major threats to the Wood Thrush include forest destruction and fragmentation on both the breeding (sometimes from strip mining) and wintering grounds, and increased nest predation and parasitism in fragmented breeding habitat (Roth et al. 1996). In migration, Wood Thrushes are also at risk of collision with wind turbines. With a global population of about 14 million birds (Rich et al. 2004) decreasing at 1.7 percent per year (Hames et al. 2002), some of the estimated annual loss of about 240,000 birds could conceivably be assigned to acid rain originating from Midwest power plants, mountaintop removal in Appalachia to supply power plants with coal, or collisions with wind turbines supplying consumers with electricity.

In other words, all electricity choices have wildlife implications. The Wood Thrush example strongly suggests that power plants are having a measurable impact on bird populations in North America. No one, including federal and state wildlife agencies, has attempted to calculate how a coal-based electricity choice compares with wind energy on a bird impacts (death and displacement) per MW basis, but it would hardly be surprising if the wildlife cost of coal exceeded wind (without considering global warming). The negative impacts of fossil fuel-based electricity on other wildlife taxa, such as fish, mammals, herps, plants, and invertebrates, are outside the scope of this study, but in all likelihood, they are immense. Unfortunately, there are few data available from which comparisons can be made, primarily because post-construction avian or other wildlife impact studies of fossil fuel-fired plants have not been required or have rarely been required by federal or state wildlife agencies, and such studies have not been requested by agencies when permitting such projects.

Table 6.1.2-1. Mortality Reported at U.S. Wind-Energy Projects (from NRC 2007)

Wind Project	# Turbines	Turbine MW	Project MW	All Bird Mortality Turbine per year	All Bird Mortality MW per year	Reference
Pacific Northwest						
Stateline, OR/WA[1]	454	0.66	300	1.93	2.92	Erickson et al. 2004
Vansycle, OR[1]	38	0.66	25	0.63	0.95	Erickson et al. 2004
Combine Hills, OR[1]	41	1.00	41	2.56	2.56	Young et al. 2005
Klondike, OR[1]	16	1.50	24	1.42	0.95	Johnson et al. 2003
Nine Canyon, WA[1]	37	1.30	62	3.59	2.76	Erickson et al. 2003b
Rocky Mountain						
Foote Creek Rim, WY, Phase I[2]	72	0.60	43	1.50	2.50	Young et al. 2001
Foote Creek Rim, WY, Phase II[2]	33	0.75	25	1.49	1.99	Young et al. 2003
Upper Midwest						
Wisconsin[3]	31	0.66	20	1.30	1.97	Howe et al. 2002
Buffalo Ridge, MN, Phase I[3]	73	0.30	33	0.98	3.27	Johnson et al. 2002
Buffalo Ridge, MN, Phase I[3]	143	0.75	107	2.27	3.03	Johnson et al. 2002
Buffalo Ridge, MN, Phase II[3]	139	0.75	104	4.45	5.93	Johnson et al. 2002
Top of Iowa[3]	89	0.90	80	1.29	1.44	Koford et al. 2004
East						
Buffalo Mountain, TN[4]	3	0.66	2	7.70	11.67	Nicholson 2003
Mountaineer, WV[4]	44	1.50	66	4.04	2.69	Kerns and Kerlinger 2004

[1] Agricultural/grassland/Conservation Reserve Program (CRP) lands

[2] Shortgrass prairie

[3] Agricultural

[4] Forest

Returning to collision impacts from wind turbines, the standard method for studying them requires systematic searches below turbines to record the bird and bat carcasses found. This number is then adjusted to include searcher efficiency (because searchers do not find all the carcasses) and carcass removal (because scavengers may remove some carcasses before searchers look for them). According to best practices (Anderson et al. 1999, NRC 2007), searcher efficiency and carcass removal tests should be regularly conducted to account for different habitats, seasonal changes in ground cover, and fluctuations in scavenger populations.

A criticism sometimes made is that mortality studies at wind-power projects underestimate mortality because searcher efficiency and carcass removal are not adequately determined or taken into account. The best answer to this criticism is the most recent survey of the environmental impacts of wind-energy development (NRC 2007). This survey found that data allowing accurate estimates of bird fatalities at wind-energy projects in the United States are limited, but fourteen studies have been conducted using a survey protocol for an annual period and incorporating searcher-efficiency and scavenging biases into estimates. Although the protocols used in these studies varied, all generally followed the guidance in Anderson et al. (1999).

As can be seen in Table 6.1.2-1, there were some differences in the type and number of turbines at these projects, as well as in the geographic location, topography, and habitats where the projects were constructed. Mortality estimates were similar among projects, however, averaging 2.51 birds per turbine per year and 3.19 birds per MW per year, despite the differences in methodology, geography, and habitat. This suggests that the results of these studies were quantitatively robust. The values at the Tennessee site are slightly greater than other sites, but they do not suggest significant biological impacts at the regional, or local level (see human-caused mortality and waterfowl harvest discussions above).

Recently, however, 15 additional turbines were constructed at the Tennessee site. The new 1.8-MW turbines were larger than the three original 660-kW turbines, extending maximum height of the new turbines was 395 feet (120 m) AGL, versus 290 feet (88 m). A subset of the new turbines were equipped with red flashing strobes as opposed to white strobes that were on original turbines. Surprisingly, when all the wind turbines were recently studied, nine bird fatalities (all songbirds) were recorded in searches, yielding an overall adjusted mortality rate of 1.8 birds per turbine per year (Fiedler et al. 2007). This rate is significantly less than the 7.3 birds per turbine per year recorded in the previous study, and more in line with the 2.51 birds per turbine per year reported above.

6.1.2.2 Review of Avian Mortality Studies

What follows is a review of studies of avian mortality at wind farms (for a summary, see Appendix G). Except when noted, the numbers given are the numbers of carcasses found. As explained above, the number of fatalities would be higher when searcher-efficiency and the carcass-removal rates were factored in.

In Europe, collisions of birds with wind farms have been less comprehensively investigated than in the U.S. (Hötker et al. 2006). Dürr (2001, 2004), however, has assembled the most comprehensive data set on collision victims at European wind farms, reporting data from eight European countries, including 14 wind farms in Germany. In reviewing Dürr's publications, Hötker et al. (2006) note that the highest mortalities have been recorded at wind farms along mountain ridges and at wetlands. At mountain sites, mortality has been notably high among resident birds of prey, especially Griffon Vulture (see below). At wetland sites, gulls and raptors have been notably affected.

Among raptors, Dürr's compilation shows that mortality has been particularly high among Griffon Vulture (133 victims, all from Spain), White-tailed Eagle (13, all from Germany), Red Kite (43, of which 40 from breeding populations in Germany), Common Buzzard (27), and Kestrel (29). According to ornithologist and wind-energy consultant Jan Blew (personal communication), Red Kite mortality occurs where wind turbines are placed in pastures and fallow fields, where birds hunt for rodents. Altering land-use around the turbines, such as by surrounding wind turbines with cropland, appears to be an effective method for reducing mortality. Montagu's Harrier, on the other hand, forages in the same grassland habitats, but it is barely affected (one collision victim reported by Dürr). According to Blew, the reason is that it usually flies low and does not enter the rotor-swept area.

Blew sees no easy solution for reducing White-tailed Eagle mortality in northeastern Germany, where there is a breeding concentration. He believes it is collision-prone because of it is a soaring bird that demonstrates no fear of wind turbines. White-tailed Eagle mortality has also been recently reported from the island of Smola in Norway. To date, its close relative, the Bald Eagle, has not been recorded in mortality studies.

Hötker et al (2006) find that species or species groups that show little avoidance reaction to wind farms are more likely to be collision victims than species that tend to avoid wind farms. In other words, birds of prey, gulls, and starlings are more frequently found as collision victims relative to geese and shorebirds, which avoid wind farms more. A notable exception, however, are crows, which do not avoid wind farms, yet they are rarely killed.

In a review, Dierschke and Garthe (2006) feature two mortality studies from coastal wind farms. For a ten-year study at the 23-turbine Zeebrugge wind farm in the Netherlands (Everaert et al. 2002), mortality rates ranged between 11 and 29 birds per turbine per year when corrected for recovery probability. In one year, 49 (89%) of 55 dead birds found were seabirds (44 gulls and 5 terns). The highest mortality was at a turbine row perpendicular to the main flight direction, where a maximum of 120 collision victims per year was recorded at one turbine (assumed corrected for recovery probability).

Dierschke and Garthe report that a six-year study (Painter et al. 1999) found that mortality at the nine turbines constructed on the pier at Blyth Harbor in the U.K. was six birds per turbine per year when corrected for recovery probability. Ninety-seven percent of mortality was of seabirds, including Common Eiders (12 carcasses). Most of the victims were gulls. The percent of local eiders (up to 3,200 birds) taken by turbine collisions (when corrected for recovery probability) was calculated annually. Values ranged from 0% to 1.3% (approximately 42 birds).

Fatalities of migrants have been relatively rare at most other European sites. Of particular interest is the relative lack of fatalities, given the migration traffic, at Tarifa, Spain, where several hundred thousand soaring birds, including more than 100,000 raptors, and millions of other birds, converge on the Straits of Gibraltar to cross between Europe and Africa (Marti Montes and Barrios Jaque 1995, Janss 2000, Barrios and Rodriguez 2004, and de Lucas et al. 2004). Not only have mortality studies recorded few migrants, but studies of birds exhibiting behaviors that put them at risk of collision (i.e., flying within 5 m [16 feet] of wind turbines) show that most migratory species do not exhibit these behaviors (Barrios and Rodriguez 2004). The birds that do exhibit these behaviors at Tarifa are resident raptors, particularly Griffon Vulture and Kestrel. In the case of the Griffon Vulture, mortality was concentrated in the fall and winter, when absence of strong thermals forced resident birds to use slopes for lift. Most mortality occurred during light winds, when birds probably could not maneuver as well. In the case of the Kestrel, most deaths occurred during the annual peak of abundance in summer and appeared to be related to wind turbine location in preferred hunting habitat (Barrios and Rodriguez 2004). Similar Griffon Vulture mortality did not occur at all Tarifa wind farms (de Lucas et al. 2004).

Elsewhere in Spain, significant Griffon Vulture mortality has been recorded at wind farms in the Pyrenees Mountains of Navarre. The causes for this relatively high mortality appear to be closely spaced turbine placements on ridges habitually used for soaring by a resident population (Lekuona 2001). Mortality was found to be higher under low wind conditions, when birds likely could not maneuver well.

In the United States, the Altamont Pass Wind Resource Area (APWRA) is the only wind-power site where risk to birds has been suggested to have been significant. Over 15 years of studies have shown that Golden Eagles, Red-tailed Hawks, American Kestrels, and other species collide with turbines in varying numbers. These findings suggest that raptors are the most collision-susceptible group of birds (Anderson et al. 2000), but fatalities at the APWRA have not impacted regional populations. A long-term study of the Altamont Golden Eagle population by Hunt (2002) concluded that, despite the high fatality rate, the population remains stable. Large numbers of gulls, ravens, vultures, grassland songbirds, and other species fly amongst the APWRA turbines and rarely collide with them.

The raptor fatalities in the APWRA appear to be an anomaly, because they have not been demonstrated elsewhere. Other studies conducted at U.S. wind power facilities outside of the APWRA have not revealed large numbers of raptor fatalities.

Several factors are believed to contribute to raptor risk in the APWRA, and some can be generalized to other species. These factors act alone or together to produce the collision mortality documented in the APWRA (Howell and DiDonato 1991, Orloff and Flannery 1992, 1996). They are:

- Large numbers of turbines (presently about 5,400, down from about 7,000 several years ago) concentrated in a small area and providing many obstacles to flight
- Closely spaced turbines (less that 10 m [30 feet] rotor-to-rotor distance) that may not permit birds to fly safely between them

- Extraordinary numbers of foraging raptors throughout the year, the result of a superabundant population of California ground squirrels
- Steep topography with turbines placed in valleys and along valley and canyon edges, where collision risk is greater
- Turbine rotors that sweep down to less than 10 m (30 feet) from the ground, affecting airspace where raptors forage extensively
- Turbines mounted on lattice-type towers that encourage perching and provide shade and cover from sun and rain
- Small turbine rotors that revolve at high rates (40-72 rpm) making the rotor tips difficult to see

Recent studies from Texas and Oklahoma, however, have demonstrated surprising mortality among Turkey Vultures, a species frequenting many U.S. wind farms, but which had been infrequently recorded in mortality studies. At the Buffalo Gap I Windfarm near Abilene, Texas, a study was conducted during 2006 of 21 of the 67 operating turbines. It recorded 21 avian casualties, including fifteen Turkey Vultures and one Red-tailed Hawk (Tierney 2007). Most of the Turkey Vultures that could be aged were juveniles, suggesting that younger birds may be more prone to collision. The author noted that Turkey Vultures were frequently seen flying near turbines, and that adult birds appeared to be quite adept at maneuvering around the rotating blades. When searcher efficiency and carcass removal were factored in, estimated fatality rates were 0.24 Turkey Vultures per turbine per year, 0.19 other raptors per turbine per year, and 1.94 small/medium birds per turbine per year. This yields an overall rate of 2.37 birds per turbine per year (Tierney 2007).

At the Blue Canyon II Wind Power Project in southwestern Oklahoma, a study was conducted during 2006 of 50 of 84 operating turbines. This study recorded 15 avian casualties, of which eleven were Turkey Vultures and two were Red-tailed Hawks (Schnell et al. 2007). The authors did not report the ages of the Turkey Vultures; therefore, it is uncertain whether the juvenile mortality pattern was evident there too. With searcher efficiency and scavenger removal factored in, mortality rates were reported as 0.27 small passerines per turbine per year and 0.25 raptors (including Turkey Vultures) per turbine per year. This yields an overall rate of 0.52 birds per turbine per year (Schnell et al. 2007).

West of the Rocky Mountains, avian mortality resulting from collisions with wind turbines has been studied at sites in California, Oregon and Washington State. With the exception of the APWRA, reported fatality numbers have been small. At San Gorgonio Pass and in the Tehachapi Mountains, relatively few birds were killed in two years of searches, including very low representation of raptors (Anderson 2000). One Golden Eagle has been found in the San Gorgonio Wind Resource Area in more than two years of study. At a new wind power site in Oregon, at which there are 38 turbines in farmland, a one-year study documented no raptor fatalities, eight songbird fatalities, and four game bird fatalities (three of which were alien species). The estimated number of actual fatalities was greater (N = 24 fatalities; 0.63 fatalities per turbine per year), when searcher efficiency and carcass removal (scavenging) estimates were factored in.

The State Line project on the Washington/Oregon border is one of the world's largest wind power facilities. As presented in Table 6.1.2-1, the fatality rate per turbine per year has been found to be slightly less than two birds per turbine per year (Erickson et al. 2002, 2003, 2004). That project now has 454 turbines. Among the fatalities were a variety of species, with Horned Larks (locally nesting birds) accounting for 46% of all birds found. Six raptors from three species were killed, and about 24% of fatalities were night migrating songbirds. The rates of avian fatalities at smaller wind power sites in Oregon (Klondike) and Washington (Nine Canyon) averaged slightly lower and higher, respectively. Birds killed were divided among night migrants, resident species, very few waterfowl, and small numbers of raptors. The rate of night migrants killed in the far west has been roughly one bird per turbine per year or less, which includes carcass removal and searcher efficiency correction factors

Most of the projects in the western United States discussed above were situated in tilled agricultural fields or pasture/prairie-like habitats. It should be noted that many of the turbines involved in California studies were less than 200 feet in height and did not have FAA lights. All turbines in Oregon and Washington were taller than 275 feet and a subset (perhaps one in three to one in four) of them had FAA lights (the presence or absence of lights is significant, because, as discussed below, lighting has been implicated in large-scale fatality events at communication towers). There has been no suggestion of population impacts at any of these facilities, nor have fatalities involved endangered or threatened species.

In the Rocky Mountain region, after five years of systematic searches at 29 modern turbines (expanded to 45 in the third year) in a short-mixed grass prairie/pasture land in northern Colorado, small numbers of fatalities were documented (Kerlinger, Curry and Ryder, unpublished). The fatalities were mostly Horned Larks, with fewer McCown's Longspur, White-throated Swifts, one teal, one American Kestrel, one Lark Bunting, and some other songbirds. The prevalence of Horned Larks on the fatality lists is likely a result of their aerial courtship flight during which they display and sing at the height of the rotors.

In Wyoming, at the Foote Creek Rim project (presented in Table 6.1.2-1), also in a short-mixed grass prairie habitat, 90 fatalities were recorded, 75 of which were at wind turbines and 15 of which were at meteorology towers with guy wires (Young et al. 2003). Thus about 20% of the fatalities resulted from collisions with guy wires at the meteorology towers and likely would have been avoided by using free-standing towers. This means the fatality rate per structure is about two to four times greater at the guyed meteorology tower than at the turbines. (Virtually no birds are known to be killed at free-standing meteorology towers.) Few raptors were found dead at the Foote Creek Rim project (three American Kestrels and one Northern Harrier) and 48% of the fatalities were night migrating birds. Of the migrants, no species accounted for more than five to seven individuals (including Chipping and Vesper Sparrows).

In the upper Midwest, a number of projects have been studied. In Kansas, Young (2000) noted no fatalities at the two turbines in the Jeffrey Energy Center in Pottawatomie County. In Minnesota, at the Buffalo Ridge wind power facility (approximately 400 turbines; see Table 6.1.2-1) near Lake Benton, relatively small numbers of fatalities have been reported (Johnson et al. 2002) during four years of searching at subsets of the turbines. The fatality rates per turbine ranged between about one bird per turbine per year to about four birds per turbine per year. The species composition included a variety of birds, including one raptor (Red-tailed Hawk), very few waterbirds, and a number of night-migrating songbirds (about 70% of the 53 documented fatalities). Only about five ducks and coots were found during the study, despite their regular presence around the wind power site and the fact that the wind farm is within a major migration area for waterfowl (Bellrose 1970).

In Iowa, a study at a small wind plant reported no fatalities (Demastes and Trainor 2000). A two year study recently completed by Iowa State University and the Iowa Department of Natural Resources at the Top of Iowa Wind Power Project site revealed no fatalities to Canada Geese or other waterfowl (Koford et al. 2005). This study is important because the 89 turbines were located within one to two miles of three waterfowl management areas. Despite intense use of the turbine fields by waterfowl (>1.5 million duck and goose-use-days per year), none were killed. In addition, no shorebirds were killed, but one raptor (perhaps two) was recorded in the mortality study. As presented in Table 6.1.2-1, fewer than 1.5 birds per turbine per year were found to be killed at this site.

In Wisconsin, two years of carcass searches under 31 turbines situated in farm fields in the Kewaunee County peninsula found about two dozen songbird fatalities, mostly migrants. Perhaps six of the documented fatalities were night migrants. One Mallard and one Herring Gull were the only two waterbirds found dead at this site (Howe et al. 2002). The authors estimated that each turbine killed between one and two birds per year, when searcher efficiency and carcass removal rates were factored into the estimates. A study of two modern wind turbines at Shirley revealed one night migrating songbird fatality during a year-long study (Howe and Atwater 1999).

In the northeastern United States, where wind farms have been developed only since the late 1990s and early 2000s, there are fewer in depth studies of collision fatalities at turbines than in the west. But, there is information from eight wind power facilities in the eastern United States and one across Lake Erie in Canada that are relevant to the Project site, involving many of the same species and migration behaviors, especially among night migrants.

At the Meyersdale Wind Energy Center, located in southwest-central Pennsylvania, a total of 13 avian carcasses, representing six or more species, were found below 20 turbines during searches from July 30 to September 13, 2004. Two studies have been conducted at the Mountaineer Wind Energy Center on Backbone Mountain in West Virginia. This site has 44 turbines, twelve of which were lit with FAA-certified red strobes. In 2003, Kerns and Kerlinger (2004; see Table 6.1.2-1) found a mortality rate of about four birds per turbine per year, including about three night migrants per turbine per year. One duck and three raptors (two Turkey Vultures and one Red-tailed Hawk) were also found. In 2004, Arnett et al. (2005) found a total of 15 avian carcasses during a six-week period, with 13 of those individuals representing night-migrating songbirds or songbird-like species. The other two birds were a Turkey Vulture and a Sharp-shinned Hawk. Both these sites experience a fairly heavy fall raptor migration, but raptor mortalities have been minimal, limited apparently to mostly resident birds.

At a facility with eight modern turbines (four with red-flashing FAA lights approximately 280 feet [85 m] tall) located in farmland at Garrett, Somerset County, Pennsylvania, seventeen rounds of fatality searches conducted from June 2000 through May 2001 revealed no avian fatalities (Kerlinger 2001).

In central New York State, the Madison and Fenner Wind Power Projects are located in cropland. The Madison site has seven modern turbines that reach a maximum height of about 120 m (390 feet) tall and are all lit with FAA red strobes (type L-864). Four collision fatalities have been recorded at the turbines, plus one at a guyed meteorological tower (Kerlinger 2002a). During the spring and fall migrations, each turbine was searched five and six times, respectively. If carcass removal and searcher efficiency rates at the Madison site were similar to those at other projects, the numbers of fatalities would likely be on the order of two to four-plus birds per turbine per year. Of these fatalities, most would be night-migrating songbirds and similar species. The Fenner project has 20 turbines. In mid 2004, the plant manager reported no fatality events for raptors or other large birds (Paul Kerlinger, pers. comm.). Nevertheless, biologists from the New York State Department of Environmental Conservation (NGPC) made a site visit during 2004 and found small numbers of dead bats.

In upstate New York, on the Tug Hill Plateau of Lewis County, several months of daily searches during spring and autumn migration beneath two unlit wind turbines (168 feet [51 m] tall) located in open fields revealed no carcasses (Cooper et al. 1995). At Searsburg in southeastern Vermont, searches done in June through December 1997 (nesting through fall migration) revealed no fatalities at eleven new, unlit turbines (192 feet [58 m] tall) situated on a forested hilltop (Kerlinger 2000a and 2002b).

As noted in Section 6.1.2.1, the greatest fatality rate found for birds at turbines in the United States was about close to eight birds per turbine per year under three turbines on a forested mountaintop in eastern Tennessee. The two-year study of the 290-foot (88-m) turbines equipped with white strobes revealed several dozen fatalities, mostly night migrating songbirds (Nicholson 2003). Lighting may have played an important role in these fatalities, but it is also possible that the larger rate of fatalities is the result of the more southerly latitude of this project, where migrants are more concentrated. But a recent study at this site has shown a much lower rate – 1.8 birds per turbine per year (Fiedler et al. 2007).

In coastal New Jersey, the Atlantic County Utilities Authority (ACUA) has erected a demonstration project of 5 turbines on a filled island surrounded by salt marsh with tidal creeks and channels. Avian use was very high at the site, as was noted one year of pre-construction studies. Eight carcasses were found at that site from July through December 2007, including two listed raptors (Osprey and Peregrine Falcon), two gulls, two shorebirds, and two night migrating songbirds (New Jersey Audubon 2008). Fatalities were not corrected for searcher efficiency and scavenging (carcass removal), but it appears that the fatality rate was low and not biologically significant, despite the fact that two listed species were killed.

In Canada, at the Erie Shores Wind Farm in Ontario, (James 2008), a two-year mortality study included searcher-efficiency and carcass-removal trials. It estimated mortality to be between 2.0 and 2.5 birds/turbine/year, including a rate of 0.04 birds/turbine/year for raptors.

Some patterns of mortality were apparent. Mortality was higher at wind turbines within 200 m (660 feet) of the Lake Erie shore bluffs. Turbines even 250-400 m (820-1,310 feet) showed no elevated mortality. The steady red aviation-warning lights on a subset of the turbines also appeared to contibute to somewhat elevated mortality. Based on this finding, Environment Canada has requested that aviation-warning lights be changed to flashing red. In addition, the presence of woodlands at less than 50 m (165 feet) from turbine bases appeared to have some small effect on the mortality level, but beyond that distance, no effect was apparent. It was mainly the turbines near trees in near-shore areas that were most significant to bird mortality.

In future installation of wind farms in the Great Lakes area, James recommends that all turbines be kept at least 250 m (820 feet) away from shore bluffs or shores, aviation-warning lights should be flashing, and turbine bases should be kept at least 50 m (165 feet) of trees.

James conducted two other fatality studies at single wind turbine installations in Ontario. One was along the shore of Lake Ontario in a park in Toronto, and the other was adjacent to Pickering Marsh, a few miles inland from Lake Ontario. The turbines at both sites were tall, modern turbines. The two studies revealed mortality levels similar to the Erie Shores study.

In summary, studies at these and other sites have shown fatalities to be relatively infrequent events at wind farms. No federally endangered or threatened species have been recorded, and only occasional raptor, waterfowl, or shorebird fatalities have been documented. In general, the documented level of fatalities has not been large in comparison with the source populations of these species, nor have the fatalities been suggestive of biologically significant impacts to these species.

7.0 Avian Risk Assessment for the Mount Wachusett Community College Wind Energy Project

7.1.1 Disturbance and Displacement Risk at the Mount Wachusett Project

Disturbance and displacement impacts may occur at the Project site as a result of Project construction, habitat modification, and wind-turbine operation.

Construction: Some birds may be displaced temporarily during the Project's construction phase, as heavy equipment, trucks, and workers pass through the area. In addition, clearing for the road and turbine areas, may displace birds. This impact is expected to be ephemeral, decreasing markedly when construction ends. Such impacts would have a greater effect during the breeding season than in the non-breeding season. Effects would potentially be greatest on any federal or Massachusetts-listed species, because their breeding populations are small. Data sources, including letters from the MAFWD and USFWS indicate that such species are unlikely to breed or forage at the site.

Habitat Modification: The access road and one or two turbine-construction areas that will be created in a small field will reduce functional grassland by a small percentage. The Project will not fragment nearby woodlands, which are already heavily fragmented and degraded, nor will it modify shrubland, wetland, or other native habitat.

It should be noted that the habitat effects of Project construction would be minor in comparison with the effects of mowing or natural vegetation succession on grassland birds. Unless the field is managed appropriately for grassland birds, those birds are likely to disappear whether or one or two turbines are constructed. In addition, given that the grassland patch is so small and isolated, the presence of Bobolinks is already significantly threatened by succession to shrubland, as well as random events (Noss et al. 1997).

According to Rob Rizzo, MWCC Director of Operations (personal communication to the authors), the college is interested in following management recommendations that would enhance bird diversity at the site, especially since the development of the plan could involve the college's students. Two management options are possible. First, delaying mowing of the field until after Bobolinks have fledged their young (after July 15) is an obvious recommendation that should be followed. Such mowing would also ensure that the grassy field is protected from succession of grassland to shrub land and forest. Second, increasing the shrubland zone around portions of the pond merits serious consideration as a means of increasing the population of the *Yellow WatchList* Willow Flycatcher and possibly attract the *Yellow WatchList* Blue-winged and, or Prairie Warblers. This measure would increase the site's biodiversity and conservation value.

Turbine Operation: Research summarized in Section 6.1 indicates that displacement and disturbance of grassland birds by turbine placements and operation have not been consistently demonstrated. Where displacement has been demonstrated, densities of breeding birds were found to be lower within about 25-200 m (78-657 feet) of turbine placements. In the context of the Project, potentially affected species would be limited to Bobolink.

Because forest-interior birds, waterbirds, and raptors do not nest on site or within hundreds of meters of the turbines, displacement impacts to those species are unlikely. It is important to note that foraging raptors and waterfowl have been shown to habituate to turbines, regularly feeding in fields near these structures.

In summary, disturbance and displacement effects resulting from the Project are expected to be minor. Project construction will be of limited duration and unlikely to affect species of greatest conservation concern, which do not occur at the site. Habitat modification may affect the small Bobolink population, but there is reason to consider reducing the grassland further in favor of shrubland to provide habitat for *Yellow WatchList* species, such as Willow Flycatcher. Turbine operation could potentially displace breeding Bobolinks, but because studies in the northeast show that these birds will nest near turbines, this impact is unlikely.

7.2.1 Collision Risk at the Mount Wachusett Community College Wind Energy Project

Given that collision risk varies with bird type, we treat the various bird groups separately. These groups are nocturnal migrant songbirds, raptors, waterbirds. Listed species are not present at the site according to the MADFW and USFWS.

7.2.2.1 Nocturnal Migrant Songbirds

Table 6.1.2-1 provides the results of mortality studies where searcher-efficiency and carcass-removal rates were included (NRC 2007). At these fourteen projects, the percentage of night-migrating songbirds killed increased from west to east, presumably in response to migration traffic. At the Stateline, Washington, project in the West, the percentage of night migrants killed was 24%; at Foote Creek Rim, Wyoming, in the Rocky Mountains, 48%; at Buffalo Ridge in Minnesota, 70%; and at Mountaineer, West Virginia, in the East, 70.8%. At the Maple Ridge site in northern New York, the percentage of night migrants was about 80% (Jain et al. 2007). Finally, in Tennessee, nearly all birds killed in four years of study were night migrants (Fiedler et al. 2007, Nicholson 2002).

Most reports of night-migrant fatalities are of single birds, unlike the large-scale events documented over the past sixty years at communication towers greater than 500-600 feet (152-183 m) in height (Avery et al. 1980). That nocturnal migrants collide at a lower rate with wind turbines than with tall communication towers is related to the much greater height of the communication towers that were involved, as well as to the presence of guy wires (Kerlinger 2000b) and steady-burning FAA red lights (L-810 obstruction lights) on communication towers.

The communication towers that are responsible for the largest numbers of avian fatalities, including virtually all of those where large numbers have been killed in a single night, are almost entirely taller than 500-600 feet (152-183 m; from literature and recent unpublished studies). Such towers are much taller than the turbines proposed for the Project site. The most recent literature surveys conducted by the USFWS and the U.S. Department of Energy (Trapp 1998, Kerlinger 2000b, Kerlinger 2000c) reveal virtually no large scale mortality events at communication towers less than 500-600 feet in height. It should be noted that the few communication towers less than 500 feet in height associated with reports of large-scale fatality events have been immediately adjacent to bright lights. At these sites, steady burning sodium vapor lights or other bright lights have been shown to be present (Kerlinger 2004a, b). Very attractive to birds, sodium vapor lights are very different from the lights stipulated by the FAA for wind turbines.

The fact that there are no guy wires on modern wind turbines is of critical importance, because it is the guy wires of tall communication towers that account for almost all of the collisions. The literature does not reveal many fatalities at free-standing communication towers that are as tall as 475 feet (Gehring and Kerlinger 2007a and 2007b). These studies were conducted at 400-475 foot tall unguyed communication towers revealed between about zero and two birds killed per tower per year. No published studies have revealed collision fatalities at freestanding towers, including freestanding meteorology towers at wind power sites (W. Erickson personal communication, Kerns and Kerlinger 2004).

The last risk factor that has been implicated in collisions of night migrating birds with tall structures is lighting (Kerlinger 2000b). The lights of communication towers and some other structures (smoke stacks, cooling towers, and tall buildings) have been demonstrated to attract migrants that then collide with the structures. On the 1,000-foot tall communication towers where large fatality events have occurred, all have been equipped with up to twelve steady-burning red L-810 obstruction lights as well as several flashing L-864 red flashing strobe-like lights (often incandescent lights that do not go entirely black between flashes).

The lighting on wind turbines is very different (see FAA Advisory Circular). Wind turbines almost never have the steady-burning red lights (L-810 obstruction lights) that are present on communication towers. Instead, a subset of turbines has single flashing L-864 red flashing strobes.

Research by Kerns and Kerlinger (2004) and Kerlinger (2004a, 2004b, Kerlinger et al. in review) has not demonstrated any large-scale fatality events at wind turbines, nor has it shown any difference in numbers of fatalities at lit versus unlit turbines. Similar results from wind plants in Washington, Oregon, and Minnesota have supported this finding. At the Mountaineer Wind Energy Facility in West Virginia, Kerns and Kerlinger (2004) reported a fatality event involving about 30 night migrating songbirds in May 2003. That event occurred on a very foggy night at an electrical substation involving mostly one turbine and the substation fencing. Birds were apparently attracted to four sodium vapor lamps on the substation and collided with the three closest turbines (mostly the closest turbine) and the substation infrastructure. Almost no birds were found at the 41 other turbines at that project, despite 11 of them being lit with red flashing, L-864 strobe-like lights.

There are two wind plants that are noteworthy because they have some steady burning, L-810 lights and have had slightly elevated fatality rates at turbines with those lights. At Buffalo Ridge in Minnesota, a smaller fatality event involving 14 migrants at two adjacent turbines (seven under each turbine) at Buffalo Ridge in Minnesota was probably the result of the steady burning red lights on one of the turbines. At Erie Shores, turbines with lighting (in all cases steady red) had more night migrant fatalities than unlit turbines. For this reason, Environment Canada has requested that the lighting be changed to flashing red. This suggests that steady burning red lights (L-810) can attract birds.

The fact that no large scale mortality events involving night migrating birds have been documented at wind turbines anywhere, combined with the fact that there is no difference between the numbers of birds killed at turbines lit with L-864 red flashing strobes versus unlit wind turbines, strongly suggests that FAA obstruction lighting for wind turbines (red flashing, L-864 strobe-like lights) does not have the same attractive effect as the steady burning red lights (L-810) that are on communication towers (Kerlinger 2004a, 2004b). Furthermore, the FAA does not stipulate that all wind turbines be lit. Research by Gehring and Kerlinger (2007b) and Gehring et al. (in press - 2008) at communication towers in Michigan has provided the first evidence that L-810 lights are far more attractive to birds than flashing L-864 lights. Tower fatalities studied in Illinois and elsewhere have consistently been at towers in excess of 600-800 feet AGL, although some have exceeded 1,500 feet AGL (Seets and Bohlen 1977, Bohlen 2004, Graber 1958, Larkin and Frase 1988). These towers have all been equipped with guy wires and a combination of flashing red (L-864 type incandescent) and steady burning (L-810 type) lights. Some of these towers have been equipped with more than 12-15 lights, staggered at various levels from just above the ground to more than 1,000 feet above the ground. Overall, the structure and lighting of these communication towers is very different from that of wind turbines.

Conclusion

Wind turbines essentially lack the major risk factors implicated in large-scale mortality events involving nocturnal migrants at communication towers. In contrast, wind turbines: 1) are relatively low in height when compared with tall communication towers, 2) lack guy wires, and 3) have FAA obstruction lights that appear not to attract nocturnal migrants.

As explained in Section 4.2.1, studies strongly indicate that nocturnal migration above the Project site would occur on a broad front mostly at altitudes above the sweep of wind-turbine rotors. A small percentage of migrants would fly below 120 m (394 feet, roughly the height of a modern wind turbine) and be at risk of collision.

At dawn, nocturnal-migrant songbirds land in woodland and other habitats, where they feed to replenish the fat reserves that power their migration. During this descent, and during the evening ascent when they resume migration, these birds may be at greater risk of collision, particularly if birds are concentrated in the habitats adjacent to wind turbines. Nonetheless, concentrated migratory fallout is not anticipated at the Project site, as wooded habitats are abundant, not concentrated, in the Project region.

Overall, it is likely that collision mortality will be similar both in numbers and species composition of migrants to what has been recorded at other sites. The fact that there will be only one or two turbines at the MWCC site further suggests that collision mortality will not be great. It is important to remember that even if fatality rates at these one or two turbines is the highest rate yet reported (perhaps 7-9 per turbine per year), the absolute numbers of fatalities will not be great. In addition, fatalities at wind turbine sites generally are divided among many species, so if

7-9 birds are killed per turbine per year, this would amount to only one or two individuals of the most common of species. This level of mortality is not likely to be biologically significant.

7.2.2.2 Raptors

Risk factors for raptors are well documented at the Altamont Pass Wind Resource Area (APWRA; see Section 6.1.2 discussion). We use the Altamont Pass as a worst case scenario because that site is the only wind power facility with potentially significant risk to raptors. Table 7.2.2.2-1 compares the APWRA risk factors with the project contemplated at the MWCC site. As will be seen, the known or suspected risk factors for raptors are minimal at the Project site.

Table 7.2.2.2-1. Comparison of Collision Risk Factors

Known or Suspected Risk Factors Altamont Pass Wind Resource Area (APWRA)	Comparison of Risk Factors Proposed Mount Wachusett Project
Large concentration of turbines (about 5,400 in 2002)	1 or 2 turbines
Lattice towers that encourage raptors to perch	Tubular towers, no perching
Fast rotating turbine blades (40-72 rpm)	Slow rotating blades (12-18 rpm)
Closely spaced turbines (less than 30 m [100 feet] apart)	Widely spaced turbines (greater than 250 m [800 feet])
Turbines in steep valleys and canyons	Turbines in a flat, open field
Large prey base that attracts raptors	Small prey base
Turbine rotors sweep to less than 10 m (30 feet) from ground	Turbine rotors sweep down to about 40 m (131 feet) above the ground, although this will depend on the turbine make and model
High raptor and susceptible species use of area	Low raptor use of area, nesting unlikely

Risk factors aside, raptor mortality is generally low at U.S. wind farms. The combined average raptor mortality reported in fourteen U.S. studies analyzed by the National Research Council (NRC 2007; see Table 6.1.2-1) was 0.03 birds per turbine/year and 0.04 per MW/year.

Conclusion

At the Project site, few if any raptor fatalities are expected. Species most at risk would be those that nest or winter in the vicinity of the site and become habituated to the wind turbines, as opposed to migrating raptors that pass through the site or general area. In this regard, Red-tailed Hawk and Turkey Vultures (technically not a raptor) are probably the only species likely to become habituated to the Project. Raptor migration at the Project site is likely to be minimal and take place across a broad geographic front at altitudes well above the sweep of wind-turbine rotors.

7.2.2.3 Waterbirds (Waterfowl, Shorebirds, Etc.)

Waterbird mortality at U.S. wind farms has been demonstrated to be relatively low. In a review of bird collisions reported in 31 studies at wind-energy facilities, Erickson et al. (2001, cited in NRC 2007) reported that 5.3% of fatalities were waterfowl, 3.3% waterbirds (mainly rails and coot), and 0.7% shorebirds. It is interesting that waterfowl and shorebirds are nocturnal migrants, but they appear not to be attracted to lights (FAA or other types). They are also known to migrate mostly at high altitudes (Kerlinger and Moore 1989, Bellrose 1980).

Conclusion

At the Project site, there are no significant wetland habitats that would concentrate waterbirds at any time of the year. The adjacent pond and wetland are too small to attract waterbirds in significant numbers, although Canada Geese and Mallards nest nearby and use the pond at times. Impacts to waterfowl are likely to be negligible and certainly not biologically significant.

7.2.2.4 Summary Collision Risk, Conclusions

The MWCC project is likely to result in similar numbers of fatalities as has been reported at other wind power facilities in the eastern United States. Those fatalities will consist of small numbers of night migrating songbirds and very few or no raptors, waterbirds, and other species. These fatalities will not likely result in biologically significant impacts to any species. In addition, impacts to listed species is highly unlikely.

Post-construction fatality studies, particularly those that have taken into account searcher efficiency in finding carcasses, as well as carcass removal by scavengers, have demonstrated that fatalities are relatively infrequent events at wind power projects. In a recent review of the literature on U.S. wind farms, mortality estimates were similar among projects, averaging 2.51 birds per turbine per year and 3.19 birds per MW per year. Rates have been slightly greater in the Eastern U.S. than in the West, presumably because of denser nocturnal migration of songbirds in eastern North America. No federally listed endangered or threatened species have been recorded in any of the studies undertaken, and only occasional raptor, waterfowl, or shorebird fatalities have been documented. In general, the documented level of fatalities has not been large in comparison with the source populations of these species, nor have the fatalities been suggestive of biologically significant impacts to these species.

Fatality numbers and species impacted at the Project site are likely to be similar, on a per turbine per year basis, to those found at Eastern and Midwestern U. S. projects that have been studied. These fatalities, when distributed among many species, are not likely to be biologically significant. When compared with the Altamont Pass Wind Resource Area, collision risk factors for raptors are minimal. Collision risk to night-migrating songbirds is likely to be similar to other sites examined because the altitude of migration is generally above the sweep of the wind turbine rotors.

8.0 Recommendations / Response to Wildlife Agency Comments

The following recommendations for the proposed Mount Wachusett Community College Wind Energy Project are based on: 1) an on-site examination of the habitat and birdlife, and 2) literature and database searches regarding the Project site's avifauna and what is known about the potential risks to birds from wind-power development in the United States and Europe.

Construction Guidelines

- Electrical lines within the project site should be underground between the turbines.

- Permanent meteorology towers should be freestanding (i.e., without guy wires) to prevent the potential for avian collisions.

- Size of roads and turbine pads should be minimized to disturb as little habitat as possible. After construction, any natural habitat should restored as close to the turbines and roads as possible to minimize habitat fragmentation and disturbance/displacement impacts. To accomplish this, topsoil or marsh should be replaced as a means of encouraging plant growth.

- Lighting of turbines and other infrastructure (turbines, substations, buildings) should be minimal to reduce the potential for attraction of night migrating songbirds and similar species. Federal Aviation Administration (FAA) night obstruction lighting should be only flashing beacons (L-864 red or white strobe) with the longest permissible off cycle. Steady burning (L-810) red FAA lights should not be used. Sodium vapor lamps and spotlights should not be used at any facility (e.g., lay-down areas or substations) at night except when emergency maintenance is needed.

Post-construction Studies

- A mortality study following best practices should ideally be conducted during a two-year period post-construction, with the second year contingent on what is found during the first year. If fatalities are recorded at levels that could be construed as biologically significant, or if significant numbers of special-status species are involved, a second year of study would be called for. The design of the post-construction protocol should follow the designs now being used and refined at existing wind-power sites and approved by various government agencies, including MADFW and USFWS. Such a study could be integrated into MWCC's environmental program. Students and faculty of MWCC would conduct the study with technical support from a biologist trained in conducting post-construction fatality studies.

- Results of the fatality study should be compared with impacts to birds from other types of power generation now supplying electricity in Massachusetts. This comparison would facilitate long-term planning with respect to electrical generation and wildlife impacts. The study should seek information from USFWS and MADFW on existing energy-generation impacts to wildlife. If information is not available, as our preliminary review appears to reveal, these agencies should consider providing financial support for such studies. This project should be conducted by a team involving faculty, students, and a wind industry consultant.

Habitat Enhancement

- The most significant breeding bird that presently occurs at the Project site is the *Yellow WatchList* Willow Flycatcher, which nests in the shrubland zone between the field and pond. We recommend developing a habitat management plan that would expand shrubland habitat to increase this flycatcher's population (presently at six territorial males). This step also has the potential to attract two other *Yellow WatchList* species to the site: the Blue-winged and Prairie Warblers, both of which were recorded regionally in the Breeding Bird Atlas and more recently in Breeding Bird Surveys. Ideally, MWCC students should be involved in the development and implementation of this plan. It should be noted, however, that increasing the shrubland zone will likely reduce habitat for the Bobolinks that presently display and possibly nest in the field. Nonetheless, the future of this Bobolink population is uncertain, given that it is so small and isolated. Furthermore, the flycatcher's status on the *Yellow WatchList* makes it of higher conservation concern. In any event, the field should not be mowed until about July 15, after Bobolink young have fledged (if they are nesting in the field).

Response to Agency Comments

This report helps to meet the recommendation of MADFW that potential impacts to birds be considered during the Project's design and permitting process.

Regarding the recommendation of the USFWS (Appendix D) to do three years of pre-construction radar study, we do not believe that such a study is warranted, because it will not improve on this risk assessment. As discussed in Section 4.2.1, the nocturnal migration pattern (in terms of traffic, altitude, percent of birds flying at rotor height, etc.) has been well documented at more than 20 (perhaps 30) sites across the northeastern U.S. These studies provide no suggestion that the migration pattern at MWCC would be substantially different at the Project site. In fact, these studies suggest a broadly diffuse migration across New England and the northeastern states, which is called a broad front migration. In addition, altitude of flight of these birds is similar among sites and there have been no sites found where the predominant altitude of nocturnal migration is even close to the rotor swept height of turbines. In other words, there is no reason to believe that migrants over the MWCC site are concentrated. Furthermore, as discussed in Section 6.1.2, all post-construction fatality studies at wind energy facilities have established that the average fatalities per turbine per year are relatively low (averaging perhaps three to five night migrants per turbine per year at wind farms in the northeastern US.). In addition, no mass or large-scale fatality events have ever been recorded at any wind turbines project. Therefore, detailed knowledge of night-to-night and year-to-year variation in nocturnal migration at a site will not improve on our mortality forecast. Radar has simply never been documented to be a precise or reliable predictor of risk, nor has it been validated as a research tool for assessing risk to birds.

USWFS has also recommended that the effects of habitat fragmentation at the MWCC site be considered. With regard to birds, we find that the creation of an unpaved access road and one or two turbine-construction areas in the field will reduce functional grassland by a small percentage. The Project will also not fragment woodland, which are not really on the Project site. Adjacent woodlands will not be impacted by the project and they are already heavily fragmented and degraded . Finally, the Project will not modify shrubland, wetland, or other native habitat, other than to improve such habitat through the voluntary efforts of the college.

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Appendix A. Conformance with U. S. Fish and Wildlife Service (USFWS) Guidelines

This addendum addresses the U.S. Fish and Wildlife Service's *Interim Guidelines to Avoid and Minimize Wildlife Impacts from Wind Turbines* (USFWS 2003). The Federal Register published these guidelines in July 2003, and USFWS briefed the National Wind Coordinating Committee on them on July 29, 2003. USFWS has emphasized that the guidelines are interim and voluntary. In April 2004, USFWS Director Williams sent a letter to the Service's state offices directing them regarding the implementation of the guidance document and its recommendations. The guidance document was posted on the Federal Register and a comment period was opened in July 2003 and closed in July 2005. Public and avian experts outside of the USFWS have now reviewed the guidance document, but the USFWS has not revised the document based on public comments, new scientific findings, and peer review. Currently, a FACA committee (Federal Advisory Committee Act) is being formed that would oversee the revision of the original 2003 draft guidance document. The role of a FACA committee is to ensure that advice from advisory committees is objective and accessible to the public.

It should be noted that the risk assessment conducted for the Project relied on methods similar to those presented in the USFWS voluntary and interim guidelines, as well as methods, many of which exceed what is requested in that document. For example, the breeding bird census we conducted is not called for by the guidance document. Also, we have reviewed the empirical literature on actual wind turbine impacts, whereas the USFWS approach does not rely on this detailed method of risk assessment. For many years, the standard Phase I Avian Risk Assessment process has incorporated many of the guidelines and recommendations made by USFWS, particularly those that have been shown to be scientifically valid. Therefore, the risk assessment presented above fulfills the intent of the guidance document and follows its recommendations to avoid or minimize impacts to wildlife, specifically birds and their habitats.

For background information, it is our understanding that the USFWS guidance document was written specifically for projects of five turbines and larger. This was made clear by Rob Hazelwood of USFWS, one of the authors of the USFWS guidance document, during a March 2004 meeting between that agency and the American Wind Energy Association. Hazelwood responded to a question about small wind projects stating that small projects, those less than about five turbines were exempt from the Service's guidance document. Thus, it would seem that for the MWCC project, the guidance document is not applicable to the MWCC project. However, this risk assessment does include many of the methods and procedures proscribed by that guidance document.

Specific Conformance to Guidelines

<u>Teaming With Agencies</u>. Letters have been sent to the Massachusetts Division of Fish and Wildlife (MADFW) and to USFWS requesting information on listed species and species of special concern, as well as other bird information. Agency response letters may be found in Appendix D. In addition, an in person meeting was held on site involving one of the authors of this report (Paul Kerlinger), principals from MWCC, Fred Unger from Heartwood Group, Inc., and Vernon Lang of the USFWS. Early coordination with the agency and the MADFW meets the recommendation by USFWS that developers should attempt to team with or involve such

agencies in the site evaluation process. Because this project is using federal funding, there is a federal permitting nexus (NEPA) for the Project with respect to wildlife. If work within wetlands is required for roads or turbine locations, a federal nexus may occur through the U.S. Army Corps of Engineers (USACOE), which often defers to USFWS with respect to wildlife issues.

Reference Sites. The Mount Wachusett Community College Wind Energy Project was compared to other wind power facilities in the United States, including projects in the East and Midwest, as well as projects in the western United States, Canada, and Europe. Selecting a worst-case scenario site for comparison with the Project site was not possible because choosing such sites would necessitate tenuous assumptions about high risk to birds at wind power projects that have not been demonstrated. Selection of a worst-case scenario site at this time cannot be based on biologically documented impacts. None of the other wind power projects in the United States, with the possible exception of the Altamont Pass Wind Resource Area (APWRA) of California, have resulted in biologically significant impacts to birds. In terms of collision risk to birds, on a per turbine or per megawatt basis, comparisons made suggest that risk at the Mount Wachusett site would be, in all likelihood, no greater than at other wind power facilities in the United States.

While it is not possible to compare the Project with a site that could be construed as worst-case scenario, comparisons to the APWRA and sites where risk has been documented to be negligible were made. Clearly, the Project does not have the collision risk factors present in the APWRA (see Table 6.2.2.2-1), although other potential risks are present.. Further comparisons were made to the impacts of communication towers of various sizes, lighting specifications, and construction types (guyed versus unguyed). This type of comparison is particularly important because there is a large body of research on communication towers, including towers in the Eastern and Midwestern U.S.

The potential for biologically significant fatalities at wind power facilities was assessed by comparing numbers of likely fatalities at the Project with the hundred-plus millions of bird fatalities permitted by the USFWS via depredation, hunting, and falconry permits. Some of the species permitted to be harvested have much smaller populations than those killed by wind turbines. In other cases, the harvested species have experienced long-term declines, yet the harvests are not considered to be deleterious (significant) to the populations of these species. This comparison strongly suggests that impacts of wind turbines are not biologically significant. These comparisons are relevant because they provide actual numbers of takings permitted by the USFWS and various state agencies.

With respect to habitat disturbance and displacement of nesting birds, comparisons were made with various sites where such disturbance has been determined to occur. Nonetheless, no significant disturbance or displacement effects are anticipated at the Project site.

Alternate Sites. This report has not considered alternate sites. It should be noted a NEPA review may require addressing an alternatives analysis. The Phase I Avian Risk Assessment did compare potential impacts at the Project site to other wind power projects.

<u>Checklists</u>. Instead of using the PII and checklists supplied in the USFWS guidelines, the Phase I assessment included detailed descriptions of the habitat and topography of the site and surrounding areas. For example, the risk assessment included determination of actual or potential migration pathways and the presence of ecological magnets and/or other attractive habitats located within or adjacent to the Project boundary. This included descriptions of the habitats, wildlife and natural areas, degree of habitat fragmentation, and degree of landscape alteration, by farming and other land use practices, within and around the site that could influence avian impacts potentially resulting from the proposed development.

Regarding other specific guidance and recommendations, in the area of site development, the Phase I Avian Risk Assessment addresses the following issues and concerns:

- Letters of inquiry were sent to USFWS and MADFW requesting records of listed species. In addition, habitat was examined to determine whether listed avian species are likely to nest or use the site.

- The Mount Wachusett site does not appear to be located on a known, specific migration corridor for raptors, songbirds, shorebirds, or waterfowl. In any event, wind turbines have not been shown to have biologically significant impacts on migrating birds. The Phase I assessment explains this.

- Raptor use of the area appears to be relatively low, and topography is moderate throughout much of the turbine area, so setbacks from soaring and updraft locations do not appear to be applicable. Raptor fatalities at wind power projects outside of the 5,400-turbine APWRA have totaled very few birds. Even in the APWRA, mortality does not appear to be biologically significant. It should be noted that none of the turbines at the Mount Wachusett site would be at the edge of steep terrain that could be used for soaring.

- The USFWS recommendation to configure turbines in ways that would avoid potential mortality has not been demonstrated empirically to reduce or prevent impact, because fatality numbers are small to begin with.

- Habitat fragmentation issues have been addressed in this risk assessment.

- Greater Prairie-Chickens are not present at the Mount Wachusett site. Disturbance or displacement effects on them and other grassland nesting species have been addressed in the Phase I assessment.

- Road areas and habitat restoration are addressed in this risk assessment.

- Carrion availability is not applicable at the Project site.

Regarding wind turbine design and operation, many of the USFWS recommendations are either covered in this risk assessment or routinely done at modern wind plants. Some USFWS recommendations, however, are incorrect or not applicable.

- Tubular (unguyed) towers will be used to prevent perching.

- Permanent meteorology towers have been recommended to be free-standing, without guy wires, in the risk assessment. However, no meteorology towers are planned.

- The USFWS recommendation that only white strobes should be used at night to avoid attracting night migrants is only partially correct. That red lights should be avoided is also only partially correct. There is strong evidence (Kerlinger 2004a, 2004b; Gehring et al. 2007, 2008) that, in the absence of steady burning red L-810 lights, red strobe-like Federal Aviation Administration (FAA) lights do not attract birds to wind turbines. Red strobe-like lights (L-864) are likely to be recommended by the FAA for the Mount Wachusett Project. This has been addressed in detail in the text of this risk assessment.

- Adjustment of tower/rotor height is problematic and cannot be addressed in this report. However, the turbines that are proposed are less than 500 feet in height and, therefore, unlikely to cause large-scale fatality events, such as those at tall communication towers. Such turbines have not been documented to cause biologically significant impacts to migrants.

- Underground electric lines and APLIC guidelines have been recommended in the risk assessment. Because all energy generated will be used on site, there will be no need for transmission lines at MWCC.

- Seasonal concentrations of birds are addressed in the risk assessment. The appropriateness of shutting down turbines or other mitigation is dependent on the level of demonstrated impacts, which cannot be determined during the pre-construction phase.

- The USFWS guidance document stipulates that radar or other remote sensing methodologies should be used if large concentrations of night migrants are suspected. A detailed discussion of the geographic and topographic patterns of migration is presented in this Phase I assessment. This discussion provides strong evidence that concentrated migration does not occur at the Project site. Thus, there is no scientific reason to suspect that there will be extraordinary concentrations of night migrants at the Project site. Therefore, radar or other remote sensing is not recommended. The radar issue is explored in detail in this report.

- Post-construction fatality monitoring would provide a means of determining the Project's impact to birds and has been recommended in this risk assessment.

Appendix B. Photographs of representative habitats at the proposed Mount Wachusett Community College Wind Energy Project site, Worcester County, Massachusetts. Upper photo: View of meadow from met tower. Lower photo: View of meadow toward met tower.

<u>Appendix B.</u> Photographs of representative habitats at the proposed Mount Wachusett Community College Wind Energy Project site, Worcester County, Massachusetts. Upper photo: Shrubland bordering pond. Lower photo: Pond with meadow in background.

<u>Appendix C.</u> Birds recorded during site visit on June 3, 4, and 5, 2008. For *WatchList* species, see Section 4.1 discussion. The list includes species nesting on and immediately adjacent to the Project site. Some species nest in the forests and fields that surround the Project. Others may nest miles away and forage onsite. Pr = Probable Nesting; Po = Possible Nesting; Co = Confirmed Nesting; On = Onsite (area within open field, surrounding pond, and along the tree edge surrounding site. Species that are not identified as nesting Onsite are likely to be nesting 200-400 m from the actual site.

Canada Goose – Pr
Mallard – Pr
Double-crested Cormorant
Great Blue Heron
Green Heron
Rock Pigeon
Mourning Dove – Po - On
Chimney Swift
Northern Flicker – Po - On
Willow Flycatcher (*Yellow WatchList*) – Co - On
Eastern Kingbird – Pr – On
Warbling Vireo – Po – On?
Red-eyed Vireo – Pr
Blue Jay – Pr - On
American Crow – Pr
Tree Swallow – Po – On?
Barn Swallow - Po
Black-capped Chickadee - Po
House Wren - Pr
Wood Thrush (*Yellow WatchList*) - Po
American Robin – Co - On
Gray Catbird - Co
Northern Mockingbird – Pr - On
European Starling – Co - On
Cedar Waxwing - Pr
Yellow Warbler – Pr-Co - On
Yellow-rumped Warbler - Po
Pine Warbler - Pr
Black-and-white Warbler - Pr
Ovenbird - Pr
Common Yellowthroat – Co - On
Chipping Sparrow – Co - On
Song Sparrow – Co - On
Northern Cardinal – Co - On
Bobolink – Pr-Co - On
Red-winged Blackbird – Co - On
Common Grackle – Pr - On
Brown-headed Cowbird – Pr-Co - On
Baltimore Oriole - Pr
Purple Finch - Po
House Finch – Pr - On
American Goldfinch – Pr - On
House Sparrow – Pr – On?

43 species

United States Department of the Interior

FISH AND WILDLIFE SERVICE

New England Field Office
70 Commercial Street, Suite 300
Concord, NH 03301-5087
http://www.fws.gov/northeast/newenglandfieldoffice

March 5, 2008

Reference:	Project	Location
	Wind turbines	Gardner, MA

Maryann Magner
Jacobs Edwards and Kelcey
343 Congress St.
Boston, MA 02210

Dear Ms. Magner:

This responds to your recent correspondence requesting information on the presence of federally-listed and/or proposed endangered or threatened species in relation to the proposed project referenced above.

Based on information currently available to us, no federally-listed or proposed, threatened or endangered species or critical habitat under the jurisdiction of the U.S. Fish and Wildlife Service are known to occur in the project area(s). Preparation of a Biological Assessment or further consultation with us under Section 7 of the Endangered Species Act is not required.

This concludes our review of listed species and critical habitat in the project location(s) and environs referenced above. No further Endangered Species Act coordination of this type is necessary for a period of one year from the date of this letter, unless additional information on listed or proposed species becomes available.

Operation of wind turbines can adversely affect a variety of wildlife species, including migratory birds and bats. In order to assess the level of risk and the scope of species potentially present in a wind turbine project area, this office recommends that 1) the spatial and temporal uses of the rotor-swept zone by wildlife be identified and evaluated using radar and other remote sensing techniques for a period of three years, and 2) the local site environs be evaluated to determine the presence and magnitude of habitat fragmentation syndrome of effects that would be implicated by project construction and/ or operation. These effects may include the direct loss of habitat; an increase in edge habitat; increased nest parasitism and predation; increased isolation of remaining forest; a decrease in abundance and diversity of area-sensitive species; a decrease in size of remaining forest patches; increased human disturbance; a decrease in habitat suitability for area-sensitive species and a concurrent increase in habitat suitability for edge or generalist species; and interruption of travel corridors, displacement and other behavioral effects.

We recommend that the above pre-construction surveys be conducted to inform the project proponent, as well as the Service, of potential wildlife conflicts during the site selection and planning stages. With this information, risks can be assessed, and methods to avoid, minimize and mitigate impacts to wildlife may be accommodated. Without these pre-construction surveys, operational disruptions could reduce the benefits of this important alternative energy source while attempting to avoid impacts to wildlife. Absent adequate pre-construction surveys and careful analysis of subsequent data, the siting, construction and operation of a wind project that results in mortality to wildlife would likely result in violation of federal laws, such as the Migratory Bird Treaty Act and the Endangered Species Act.

Thank you for your coordination. Please visit the Wind Energy page on the New England Field Office's website for useful links, including guidance documents for avoiding and minimizing impacts to wildlife (http://www.fws.gov/northeast/newenglandfieldoffice/FedActivities-WindEnergyProj.htm). Please contact Vernon Lang or myself at 603-223-2541 if we can be of further assistance.

Sincerely yours,

Anthony P. Tur

Anthony P. Tur
Endangered Species Specialist
New England Field Office

Commonwealth of Massachusetts

Division of Fisheries & Wildlife

MassWildlife

Wayne F. MacCallum, *Director*

3/3/2008

Maryann Magner
Jacobs Edwards and Kelcey
343 Congress St
Boston MA 02210

RE:	Project Location:	Mt Wachusett Community College
	Town:	GARDNER
	NHESP Tracking No.:	**08-24193**

To Whom It May Concern:

Thank you for contacting the Natural Heritage and Endangered Species Program ("NHESP") of the MA Division of Fisheries & Wildlife for information regarding state-listed rare species in the vicinity of the above referenced site.

Based on the information provided, the NHESP has determined that at this time the site is not mapped as Priority or Estimated Habitat and the NHESP database does not contain any state-listed species records in the immediate vicinity of this site. However, we recommend that potential impacts to birds be considered during the design and permitting process for all wind turbines.

This evaluation is based on the most recent information available in the NHESP database, which is constantly being expanded and updated through ongoing research and inventory. If you have any questions regarding this letter please contact Emily Holt, Endangered Species Review Assistant, at (508) 389-6361.

Sincerely,

Thomas W. French

Thomas W. French, Ph.D.
Assistant Director

Appendix E. Average Breeding Bird Frequency on N. Orange BBS Route (47017)

Taxonomic Sort[1]	Avg. birds/hr
Canada Goose	2.44
Wood Duck	1.78
Mallard	0.33
Hooded Merganser	0.11
Ring-necked Pheasant	0.11
Ruffed Grouse	0.22
Wild Turkey	3.33
American Bittern (MA-E)	**0.11**
Great Blue Heron	1.33
Turkey Vulture	0.11
Cooper's Hawk	0.11
Red-shouldered Hawk	0.22
Broad-winged Hawk	0.22
Red-tailed Hawk	0.11
Killdeer	0.44
Rock Pigeon	3.22
Mourning Dove	23.67
Yellow-billed Cuckoo	0.22
Barred Owl	1.00
Chimney Swift	13.33
Ruby-throated Hummingbird	0.78
Belted Kingfisher	0.11
Yellow-bellied Sapsucker	2.89
Downy Woodpecker	3.44
Hairy Woodpecker	2.56
Northern Flicker	1.56
Pileated Woodpecker	0.67
Olive-sided Flycatcher (*Yellow WatchList*)	0.11
Eastern Wood-Pewee	7.78
Alder Flycatcher	1.33
Willow Flycatcher (*Yellow WatchList*)	0.67
Least Flycatcher	2.89
Eastern Phoebe	10.00
Great Crested Flycatcher	2.78
Eastern Kingbird	2.78
Blue-headed Vireo	2.67
Warbling Vireo	0.44
Red-eyed Vireo	51.11
Blue Jay	27.22
American Crow	27.44

Frequency Sort[1]	Avg. birds/hr
Red-eyed Vireo	51.11
American Robin	37.11
Ovenbird	37.00
Black-capped Chickadee	30.56
American Crow	27.44
Blue Jay	27.22
Mourning Dove	23.67
Chipping Sparrow	23.33
European Starling	19.11
Chimney Swift	13.33
Common Yellowthroat	12.78
Scarlet Tanager	11.78
Black-and-white Warbler	11.67
Red-winged Blackbird	11.56
Tufted Titmouse	11.44
American Goldfinch	10.78
Tree Swallow	10.67
Cedar Waxwing	10.22
Eastern Phoebe	10.00
Gray Catbird	10.00
American Redstart	9.56
Wood Thrush (*Yellow WatchList*)	9.22
Chestnut-sided Warbler	8.56
Veery	8.22
Eastern Wood-Pewee	7.78
Myrtle Warbler	7.00
Bobolink	6.78
Song Sparrow	6.67
White-breasted Nuthatch	5.44
Common Grackle	5.33
Brown-headed Cowbird	5.33
Black-throated Green Warbler	4.78
Rose-breasted Grosbeak	4.56
Northern Cardinal	4.33
Pine Warbler	4.22
Baltimore Oriole	4.11
Hermit Thrush	3.89
Barn Swallow	3.78
House Wren	3.78
White-throated Sparrow	3.67

Common Raven	0.67
Tree Swallow	10.67
Barn Swallow	3.78
Black-capped Chickadee	30.56
Tufted Titmouse	11.44
Red-breasted Nuthatch	2.44
White-breasted Nuthatch	5.44
Brown Creeper	1.44
House Wren	3.78
Winter Wren	1.11
Eastern Bluebird	0.22
Veery	8.22
Hermit Thrush	3.89
Wood Thrush (*Yellow WatchList*)	9.22
American Robin	37.11
Gray Catbird	10.00
Northern Mockingbird	0.11
European Starling	19.11
Cedar Waxwing	10.22
Blue-winged Warbler (*Yellow WatchList*)	0.11
Nashville Warbler	1.11
Yellow Warbler	2.89
Chestnut-sided Warbler	8.56
Black-throated Blue Warbler	3.56
Myrtle Warbler	7.00
Black-throated Green Warbler	4.78
Blackburnian Warbler	0.44
Pine Warbler	4.22
Black-and-white Warbler	11.67
American Redstart	9.56
Ovenbird	37.00
Northern Waterthrush	1.33
Louisiana Waterthrush	0.22
Common Yellowthroat	12.78
Canada Warbler (*Yellow WatchList*)	0.22
Scarlet Tanager	11.78
Eastern Towhee	2.11
Chipping Sparrow	23.33
Song Sparrow	6.67
Swamp Sparrow	2.11
White-throated Sparrow	3.67
Dark-eyed Junco	1.11
Northern Cardinal	4.33
Rose-breasted Grosbeak	4.56
Indigo Bunting	0.78

Black-throated Blue Warbler	3.56
Downy Woodpecker	3.44
Wild Turkey	3.33
Rock Pigeon	3.22
Yellow-bellied Sapsucker	2.89
Least Flycatcher	2.89
Yellow Warbler	2.89
Great Crested Flycatcher	2.78
Eastern Kingbird	2.78
Blue-headed Vireo	2.67
Hairy Woodpecker	2.56
Canada Goose	2.44
Red-breasted Nuthatch	2.44
Eastern Towhee	2.11
Swamp Sparrow	2.11
House Finch	2.11
Wood Duck	1.78
Northern Flicker	1.56
Brown Creeper	1.44
Great Blue Heron	1.33
Alder Flycatcher	1.33
Northern Waterthrush	1.33
Purple Finch	1.22
House Sparrow	1.22
Winter Wren	1.11
Nashville Warbler	1.11
Dark-eyed Junco	1.11
Barred Owl	1.00
Ruby-throated Hummingbird	0.78
Indigo Bunting	0.78
Pileated Woodpecker	0.67
Willow Flycatcher (*Yellow WatchList*)	0.67
Common Raven	0.67
Killdeer	0.44
Warbling Vireo	0.44
Blackburnian Warbler	0.44
Mallard	0.33
Evening Grosbeak	0.33
Ruffed Grouse	0.22
Red-shouldered Hawk	0.22
Broad-winged Hawk	0.22
Yellow-billed Cuckoo	0.22
Eastern Bluebird	0.22
Louisiana Waterthrush	0.22
Canada Warbler (*Yellow*	0.22

		WatchList)	
Bobolink	6.78	Hooded Merganser	0.11
Red-winged Blackbird	11.56	Ring-necked Pheasant	0.11
Common Grackle	5.33	**American Bittern (MA-E)**	**0.11**
Brown-headed Cowbird	5.33	Turkey Vulture	0.11
Baltimore Oriole	4.11	Cooper's Hawk	0.11
Purple Finch	1.22	Red-tailed Hawk	0.11
House Finch	2.11	Belted Kingfisher	0.11
American Goldfinch	10.78	Olive-sided Flycatcher (*Yellow WatchList*)	0.11
Evening Grosbeak	0.33	Northern Mockingbird	0.11
House Sparrow	1.22	Blue-winged Warbler (*Yellow WatchList*)	0.11
95 Total Species		**Cumulative Frequency**	**585.7**

[1] Massachusetts listed species are indicated in boldface; see Table 4.1-1. *WatchList* species are indicated as *Red WatchList* or *Yellow WatchList*; see discussion in Section 4.1.

Appendix E. Average Wintering Bird Frequency on Westminster CBC (MAWE)

Taxonomic Sort[1]	Avg. birds/hr
Canada Goose	1.25
Wood Duck	0.00
American Wigeon	0.00
American Black Duck	0.76
Mallard	5.82
Northern Pintail	0.00
Common Goldeneye	0.02
Hooded Merganser	0.10
Common Merganser	0.08
Ring-necked Pheasant	0.04
Ruffed Grouse	0.05
Wild Turkey	0.64
Great Blue Heron	0.00
Sharp-shinned Hawk (MA-SC)	**0.03**
Cooper's Hawk	0.01
Northern Goshawk	0.00
Red-shouldered Hawk	0.00
Red-tailed Hawk	0.16
Rough-legged Hawk	0.00
American Kestrel	0.00
Merlin	0.00
Common Snipe	0.01
Ring-billed Gull	0.50
Herring Gull	12.46
Iceland Gull (*Yellow WatchList*)	0.00
Glaucous Gull	0.01
Great Black-backed Gull	2.76
Rock Pigeon	7.44
Mourning Dove	2.60
Eastern Screech-Owl	0.00
Great Horned Owl	0.02
Barred Owl	0.03
Northern Saw-whet Owl	0.01
Belted Kingfisher	0.02
Red-bellied Woodpecker	0.04
Downy Woodpecker	1.19
Hairy Woodpecker	0.27
Northern Flicker	0.01
Pileated Woodpecker	0.03
Northern Shrike	0.02
Blue Jay	6.45
American Crow	19.63

Frequency Sort[1]	Avg. birds/hr
American Crow	19.63
Black-capped Chickadee	15.30
European Starling	12.94
Herring Gull	12.46
Dark-eyed Junco	7.94
Rock Pigeon	7.44
House Sparrow	7.29
Blue Jay	6.45
Mallard	5.82
Cedar Waxwing	5.64
American Goldfinch	4.31
Great Black-backed Gull	2.76
Mourning Dove	2.60
Tufted Titmouse	2.41
House Finch	1.97
White-breasted Nuthatch	1.96
American Tree Sparrow	1.55
American Robin	1.50
Canada Goose	1.25
Downy Woodpecker	1.19
Northern Cardinal	0.88
American Black Duck	0.76
Wild Turkey	0.64
Common Redpoll	0.57
Ring-billed Gull	0.50
Golden-crowned Kinglet	0.49
Evening Grosbeak	0.49
White-throated Sparrow	0.29
Hairy Woodpecker	0.27
Red-breasted Nuthatch	0.24
Eastern Bluebird	0.22
Red-tailed Hawk	0.16
Northern Mockingbird	0.13
Brown Creeper	0.12
Song Sparrow	0.12
Hooded Merganser	0.10
Common Merganser	0.08
Purple Finch	0.08
Pine Grosbeak	0.07
Pine Siskin	0.07
Ruffed Grouse	0.05
Common Raven	0.05

Common Raven	0.05
Horned Lark	0.02
Black-capped Chickadee	15.30
Tufted Titmouse	2.41
Red-breasted Nuthatch	0.24
White-breasted Nuthatch	1.96
Brown Creeper	0.12
Carolina Wren	0.03
Winter Wren	0.00
Golden-crowned Kinglet	0.49
Ruby-crowned Kinglet	0.00
Eastern Bluebird	0.22
Hermit Thrush	0.01
American Robin	1.50
Gray Catbird	0.00
Northern Mockingbird	0.13
European Starling	12.94
American Pipit	0.00
Cedar Waxwing	5.64
American Tree Sparrow	1.55
Chipping Sparrow	0.00
Fox Sparrow	0.01
Song Sparrow	0.12
Swamp Sparrow	0.00
White-throated Sparrow	0.29
Dark-eyed Junco	7.94
Lapland Longspur	0.00
Snow Bunting	0.02
Northern Cardinal	0.88
Red-winged Blackbird	0.01
Eastern Meadowlark	0.00
Common Grackle	0.00
Brown-headed Cowbird	0.00
Pine Grosbeak	0.07
Purple Finch	0.08
House Finch	1.97
Red Crossbill	0.00
White-winged Crossbill	0.02
Common Redpoll	0.57
Pine Siskin	0.07
American Goldfinch	4.31
Evening Grosbeak	0.49
House Sparrow	7.29
85 Total Species	

Ring-necked Pheasant	0.04
Red-bellied Woodpecker	0.04
Sharp-shinned Hawk (MA-SC)	**0.03**
Barred Owl	0.03
Pileated Woodpecker	0.03
Carolina Wren	0.03
Common Goldeneye	0.02
Great Horned Owl	0.02
Belted Kingfisher	0.02
Northern Shrike	0.02
Horned Lark	0.02
Snow Bunting	0.02
White-winged Crossbill	0.02
Cooper's Hawk	0.01
Common Snipe	0.01
Glaucous Gull	0.01
Northern Saw-whet Owl	0.01
Northern Flicker	0.01
Hermit Thrush	0.01
Fox Sparrow	0.01
Red-winged Blackbird	0.01
Wood Duck	0.00
American Wigeon	0.00
Northern Pintail	0.00
Great Blue Heron	0.00
Northern Goshawk	0.00
Red-shouldered Hawk	0.00
Rough-legged Hawk	0.00
American Kestrel	0.00
Merlin	0.00
Iceland Gull (*Yellow WatchList*)	0.00
Eastern Screech-Owl	0.00
Winter Wren	0.00
Ruby-crowned Kinglet	0.00
Gray Catbird	0.00
American Pipit	0.00
Chipping Sparrow	0.00
Swamp Sparrow	0.00
Lapland Longspur	0.00
Eastern Meadowlark	0.00
Common Grackle	0.00
Brown-headed Cowbird	0.00
Red Crossbill	0.00
Cumulative Frequency	**129.23**

[1] Massachusetts listed species are indicated in boldface; see Table 4.1-1. *WatchList* species are indicated as *Red WatchList* or *Yellow WatchList*; see discussion in Section 4.1.

<u>Appendix G.</u> Annotated Review of Avian Fatality Studies in North America

The numbers of fatalities provided are, in most cases, recorded fatalities. Estimates of fatalities per turbine per year include searcher efficiency and carcass removal rates, thereby accounting for carcasses missed by searchers and carcasses removed by scavengers. Modern turbines ranged between about 58.5 m (192 feet) and about 122 m (400 feet) in height. Older turbines were less than 50 m (164 feet) in height. None of the turbines in these studies had guy wires.

Western States – Prairie and Farmland

- **California** - Altamont Pass Wind Resource Area (APWRA), 5,400 older turbines mostly on lattice towers in grazing and tilled land, many years, large numbers of raptor fatalities (>400 reported) and some other birds; Howell and DiDonato,1991, Howell 1997, Orloff and Flannery 1992, 1996, Kerlinger and Curry 1997, Thelander and Rugge 2000

- **California –** Montezuma Hills, 237 older turbines, 11 modern turbines in tilled farmland, two-plus years of study, 30-plus fatalities found (including 10 raptors, two songbirds, one duck); Howell 1997

- **California** - High Winds, 90 modern turbines in tilled farmland, two year study, 4,220 turbine searches, 163 (183 including incidental finds) fatalities found, 7 raptor species, one-third songbirds, few waterbirds, 2.0-2.9 fatalities per turbine per year; Kerlinger et al. 2006

- **California** - San Gorgonio Pass Wind Resource Area, thousands of older turbines, 120 studied in desert, two year of study, 30 fatalities, nine waterfowl, two raptors, four songbirds, <1 fatality per turbine per year; Anderson et al. 2000

- **California** - Tehachapi Pass Wind Resource Area, thousands of turbines, 100's of mostly older turbines studied, in Mojave Desert mountains (grazing land and scrub), two-plus years of study, 84 fatalities (raptors, mostly songbirds, few waterbirds); Orloff 1992, Anderson et al. 2000

- **Washington –** Nine Canyons, 37 modern turbines, prairie and farmland, one year, 36 fatalities, mostly songbirds, one kestrel, one Short-eared Owl, no diurnal raptors, 3.6 fatalities per turbine per year; Erickson 2003

- **Oregon-Washington –** Stateline Project, 124 of 399 modern turbines in farmland searched, 1.5 years of study, 106 fatalities, seven raptors, 28+ bird species, few waterbirds, 1.7 fatalities per turbine per year, 1.0 night migrant fatality per turbine per year; Erickson et al. 2003

- **Oregon –** Klondike, 16 modern turbines in rangeland and shrub-steppe, one year, eight fatalities, songbirds, including 50% night migrants, plus two Canada Geese, no raptors, 1.3 fatalities per turbine per year; Johnson et al. 2003

- **Oregon –** Vansycle, 38 modern turbines in farm and rangeland, one year, 11 fatalities, seven songbirds, including about four night migrants, and four game birds (no raptors or waterbirds); Erickson et al. 2000

- **Wyoming –** Foote Creek Rim, 69 modern turbines in prairie/rangeland, two years of study, 75 fatalities, songbirds, 48% night migrants, 4 raptors), 1.8 fatalities per turbine per year, 15 additional fatalities were at guyed meteorology towers; Young et al. 2003

- **Colorado –** Ponnequin, 29 (44 in 2001) modern turbines in rangeland, five years of study - 1999-2003, approx. two dozen birds per year, one duck, one American Kestrel fatality; Curry & Kerlinger unpublished data

<u>Midwest - Farmland</u>

- **Kansas –** St. Mary's, 2 modern turbines in grassland prairie adjacent to a coal-fired plant, 2 migration seasons; 33 surveys, 0 fatalities; Young 1999

- **Minnesota –** Buffalo Ridge near Lake Benton, 200+ modern turbines (some older turbines) in farm and grassland, four years of study (1996-1999), 53 fatalities, 2-4 fatalities per turbine per year (mostly songbirds and one Red-tailed Hawk); Johnson et al. 2002

- **Illinois –** Crescent Ridge, 33 modern turbines in farmland, fall and spring migration, 10 fatalities, ~1 fatality per turbine per year; 1,363 turbine searches, mostly night migrants, 1 Red-tailed Hawk; Kerlinger et al. 2007

- **Iowa –** Algona, 3 modern turbines in farmland, 3 migration seasons, zero fatalities; Demastes and Trainer 2000

- **Iowa –** Top of Iowa, 89 modern turbines (26 studied) in tilled farmland, 2 years of study, 7 fatalities, approx. 1 fatality per turbine per year, mostly songbirds, 2 Red-tailed Hawks, no shorebirds or waterfowl; Jain 2005, Koford et al. 2005

- **Wisconsin –** Kewaunee County Peninsula, 31 modern turbines in farmland, 2 years of study (four migration seasons), 25 fatalities, 1.3 fatalities per turbine per year, three waterfowl, 14 songbirds (including some night migrants), no raptors; Howe et al. 2002

- **Wisconsin –** Shirley, 2 modern turbines in farmland, 54 surveys, 1 year study (spring and fall migration seasons), 1 fatality (a night migrating songbird), no raptors or waterbirds; Howe and Atwater 1999

- **Texas –** Buffalo Gap I, 67 turbines (21 studied), one year, 21 avian casualties, including fifteen Turkey Vultures and one Red-tailed Hawk; adjusted mortality rate of 2.37 birds per turbine per year; Tierney 2007

- **Oklahoma** – Blue Canyon II, 84 turbines (50 studied), one year, 15 avian casualties, of which eleven were Turkey Vultures and two Red-tailed Hawks; adjusted mortality rate reported at 0.52 birds per turbine per year; Schnell et al. 2007

Eastern States – Farmland, Forest, and Salt Marsh

- **New York** - Tug Hill Plateau, 2 older turbines in farmland, 2 migration seasons, zero fatalities; Cooper et al. 1995

- **New York –** Maple Ridge Wind Farm (Tug Hill Plateau), 120 modern turbines in farmland adjacent to fragmented forest, June-November (2,244 turbine searches), ~2-9 fatalities per turbine, 80% songbirds, 1 American Kestrel, few waterfowl; Jain et al. 2007

- **New York –** Madison, 7 modern turbines in farmland, 1 year study, 4 fatalities, 2 migrant songbirds, 1 owl, and 1 woodpecker, no diurnal raptors or waterbirds; Kerlinger 2002

- **New Jersey –** Atlantic County Utility Authority, 5 modern turbines in filled marsh adjacent to waterways, July-December 2007, 8 fatalities noted (no extrapolation from searcher efficiency and scavenging), 2 raptors, 2 gulls, 2 night migrating songbirds, and 2 shorebirds; New Jersey Audubon Society 2008

- **Pennsylvania –** Garrett (Somerset County), 8 modern turbines in farm fields, 1 year study, 0 fatalities; Kerlinger 2001

- **Pennsylvania –** Meyersdale (Somerset County), 20 modern turbines on a forested ridge top, more than 20 searches of all turbines from July 30 to September 13, 2004; 13 avian carcasses found of 6 known species – mostly migrant songbirds, no raptors or waterbirds; Arnett et al. 2005

- **West Virginia –** Mountaineer Wind Energy Center, 44 modern turbines on forested ridge, one-year study in 2003 (22 searches of all turbines), 69 fatalities found, ~200-plus total fatalities when corrected for searcher efficiency and scavenging (4+ fatalities per turbine per year; ~3 night migrating songbirds per turbine per year, two Turkey Vultures and one Red-tailed Hawk); Kerns and Kerlinger 2004. In 2004, more than 20 searches from July 31 to September 11 found 15 avian carcasses of 10 known species (Arnett et al. 2005).

- **Vermont –** Searsburg near Green Mountain National Forest, 11 modern turbines on forested mountain top, studied during nesting and fall migration seasons, 0 fatalities; Kerlinger 2002

- **Massachusetts** - Hull, 1 modern turbine, open grassy fields adjacent to school and ferry terminal on island in Boston Harbor, informal searches for at least 1 year on dozens of occasions have revealed no fatalities; Malcolm Brown, personal communication, 2002

- **Tennessee –** Buffalo Mountain, 3 modern turbines on forested/strip-mined mountain, three years, approximately 7 fatalities per turbine per year (night migrating song and other birds) when adjusted for searcher efficiency and scavenger removal (Nicholson 2001, 2002, and personal communication); studied again in 2005, after 15 taller turbines were added, adjusted mortality rate calculated at 1.8 fatalities per turbine per year (Fiedler et al. 2007), much less than previously.

Canada

- **Ontario –** Pickering Wind Turbine, 1 modern turbine near a marsh, 2 migration seasons, 2 fatalities (night migrating songbirds), probably about 4-5 fatalities per turbine per year; James, unpublished report

- **Ontario –** Exhibition Place, 1 modern turbine in Toronto on lakefront, 2 migration seasons, 2 fatalities, European Starling and American Robin; mortality projected at 3 fatalities per turbine per year; James and Coady 2003

- **Ontario –** Erie Shores Wind Farm, 66 modern turbines in farmland with woodlots, two migration seasons; overall mortality estimated at 2.0 to 2.5 birds/turbine/year, including 0.04 birds/turbine/year for raptors; James 2008

Appendix H. Resume and publication list of Paul Kerlinger, Ph.D. and resume of John Guarnaccia.

PAUL KERLINGER, Ph.D.
Curry & Kerlinger, L.L.C.
P.O. Box 453
Cape May Point, NJ 08212
(609) 884-2842, fax 884-4569
email: pkerlinger@comcast.net

PROFESSIONAL EXPERIENCE

Environmental Consultant and Principal, Curry & Kerlinger, L.L.C. (also Adjunct Professor, Collaborative Conservation Program, St. Francis University, Ebensburg, PA, 2005)	1994-
Director of Research - New Jersey Audubon Society and Director - Cape May Bird Observatory	1987-1994
Assistant Professor - University of Southern Mississippi	1985-1986
Postdoctoral Fellow - University of Calgary	1983-1985
Assistant Professor - Clemson University, South Carolina	1982-1983

EDUCATION

State University of New York at Albany	Ph.D., Biology	1982
	M.S., Biology	1981
State College of New York at Oneonta	B.A., Biology	1976

PROFESSIONAL AND POPULAR PUBLICATIONS: Outstanding publication record in scientific and popular literature - 50+ papers (published in 4 countries), 5 books, 40+ popular articles, 100s of technical reports. List and samples available upon request.

BOOKS PUBLISHED:

Kerlinger, P. 1989. *Flight Strategies of Migrating Hawks*. University of Chicago Press, Chicago, IL. pp. 374.

Kerlinger, P. 1995. *How Birds Migrate*. Stackpole Press, Harrisburg, PA. pp. 250.

Fowle, M., and P. Kerlinger. 2001. New York City Audubon Society Guide to Finding Birds in the Metropolitan Area. Cornell University Press, Ithaca, NY.

Blanchard, P., and P. Kerlinger. 2001. An Islanded Nature: Natural Area Conservation and Restoration in Western Staten Island including the Harbor Herons Region. Published by: Trust for Public Land and New York City Audubon, New York, NY.

Vezo, T., and P. Kerlinger. 2001. Wings in the Wild, Habits and Habitats of North American Birds. Stackpole Books, Mechanicsburg, PA.

HONORS/DISTINCTIONS: Letters of Commendation - Director of US Fish & Wildlife Service – 1995; Governor of New Jersey – 1996; Expert Witness for State of New Jersey Department of Environmental Protection and US Justice Dept. (Endangered Species and Wetlands) – 1988-1995; Reviewer for National Academies of Science National Research Council - wind power and wildlife report - 2007

MEMBERSHIP: National Wind Coordinating Committee – Wildlife Working Group (since 1996); U. S. Fish and Wildlife Service's Communication Tower Working Group – Research Committee (since 1999)

EXPERIENCE IN WIND POWER AND COMMUNICATION INDUSTRY (1993-2004)

Expertise: Provide expert advice to corporations and nonprofit organizations regarding avian and habitat issues related to windpower and communication tower impacts to birds in North America, Europe, the Caribbean, and Central America

- Design and conduct Avian Risk Assessments at proposed wind power and communication tower sites (initial siting issues and assessment of overall avian risks)
- Design and conduct postconstruction impact studies at wind turbine and communication tower facilities
- Design and conduct avian research prior to, during, and after construction of wind power facilities (monitoring)
- Consult on design of wind plants and communication towers for avian safety
- Provide expertise on reduction of risk at proposed and existing wind power and communication tower facilities
- Provide expertise regarding habitat management at proposed and existing wind power facilities

Serve as a liaison to conservation community and regulatory community for wind power developers
Provide expert testimony for permitting and other processes

** Consulting to nonprofit environmental organizations on wildlife, habitat, and conservation issues and research.

PUBLICATION LIST - BOOKS:

Kerlinger, P. 1989. *Flight Strategies of Migrating Hawks*. The University of Chicago Press. Chicago. 375 pp.

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Dunne, P.J., R. Kane, and P. Kerlinger. 1990. *New Jersey at the Crossroads of Migration*. New Jersey Audubon Society. Franklin Lakes, NJ, 74 pp.

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Blanchard, P., and P. Kerlinger. 2001. An Islanded Nature: Natural Area Conservation and Restoration in Western Staten Island including the Harbor Herons Region. Published by: Trust for Public Land and New York City Audubon, New York, NY.

Vezo, T., and P. Kerlinger. 2001.   Wings in the Wild, Habits and Habitats of North American Birds. Stackpole Books, Mechanicsburg, PA.

JOURNAL ARTICLES, CHAPTERES IN VOLUMES, REVIEW PAPERS – (Peer Reviewed)

Kerlinger, P. 1981. Habitat disturbance and the decline of dominant avian species in pine barrens of the northeastern United States. *American Birds* 35:16-20.

Kerlinger, P. 1980. The migration of Common Loons through eastern New York. *Condor* 84:97-100.

Bingman, V.P., K.P. Able, and P. Kerlinger. 1982. Wind drift, compensation and the use of landmarks by nocturnal bird migrants. *Animal Behaviour* 30:49-53.

Kerlinger, P. and P.H. Lehrer. 1982. Owl recognition and anti-predator behavior of Sharp-shinned Hawks. *Zeitschrift fur Tierpsychologie* 58:163-173.

Kerlinger, P. and P.H. Lehrer. 1982. Anti-predator responses of Sharp-shinned Hawks. *Raptor Research* 16:33-36.

Able, K.P., W. Gergits, V.P. Bingman, and P. Kerlinger. 1982. Field studies of avian nocturnal migratory orientation. II: Experimental manipulation in white-throated sparrows released aloft. *Animal Behaviour* 30:768-777.

Kerlinger, P., J. Cherry, and K. Powers. 1983. Records of migrant hawks from the North Atlantic Ocean. *Auk* 100:488-490.

Kerlinger, P. and S.A. Gauthreaux, Jr. 1984. Flight behaviour of sharp-shinned hawks during migration. I: Over land. *Animal Behaviour* 32:1021-1028.

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Kerlinger, P., V.P. Bingman and K.P. Able. 1985. Comparative flight behaviour of migrating hawks studied with tracking radar during autumn in central New York. *Canadian Journal of Zoology* 63:755-761.

Kerlinger, P. 1985. Water crossing behavior of migrating hawks. *Wilson Bulletin* 97:109-113.

Kerlinger, P. and S.A. Gauthreaux, Jr. 1985. Seasonal timing, geographic distribution, and flight behavior of Broad-winged Hawks during spring migration in south Texas: A radar and visual study. *Auk* 102:735-743.

Kerlinger, P., M.R. Lein, and B.J. Sevick. 1985. Distribution and population fluctuations of wintering Snowy Owls (*Nyctea scandiaca*) in North America. *Canadian Journal of Zoology* 63:1829-1834.

Kerlinger, P. and M.R. Lein. 1986. Differences in winter range among age-sex classes of Snowy Owls (*Nyctea scandiaca*) in North America. *Ornis Scandinavica* 17:1-7.

Moore, F.R. and P. Kerlinger. 1987. Stopover and fat deposition by North American wood-warblers (Parulinae) following spring migration over the Gulf of Mexico. *Oecologia* 74:47-54.

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Russell, R., P. Dunne, C. Sutton, and P. Kerlinger. 1991. A visual study of migrating owls at Cape May Point, NJ. *Condor* 93:55-61.

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Mabey, S.E., J. McCann, L.J. Niles, C. Bartlett, and P. Kerlinger. 1993. The Neotropical migratory songbird coastal corridor study, final report. A report of the Virginia Council on the Environment to the NOAA. pp. 72. (not peer reviewed)

Mabey, J.M., S.E. Mabey, L.J. Niles, C. Bartlett, and P. Kerlinger. 1993. A regional study of coastal migrtatory bird stopover habitat for Neotropical migrant songbirds: land management implications. Transactions 58th North American Wildlife & Natural Resources Conference, pages 358-407.

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Kerlinger, P., J. Gehring, and W.P. Erickson. In prep. Federal Aviation Administration obstruction lighting and night migrant fatalities at wind turbines in North America: A review of data from existing studies. Reviewed at **Wilson Bulletin** – now being revised for publication.

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1987. *The Migration of Hawks*. by D.S. Heintzelman. in *The Auk*.

1989. *Peregrine Falcon Populations, Their Manage. and Recov*. edited by T.J. Cade *et al*. in *BioScience*.

1991. *Rapaci in Volo*. by Luisella Carretta. in *Wilson Bulletin*.

2006. Hawks from Every Angle, by Jerry Liguori, in *Birding*.

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Kerlinger, P., and J. Kerns. 2003. FAA lighting of wind turbines and bird collisions. Proceedings of the **National Wind Coordinating Committee** Meeting, November 18, 2003, Washington, DC.

Gehring, J., P. Kerlinger, and A.M. Manville. 2004. Avian collisions with communication towers: a quantification of the associated tower variables.

Kerlinger, P. 2004. Wind turbines and avian risk: lessons from communication towers. Presented at the **American Bird Conservancy-American Wind Energy Association** Meeting, May 18-19, 2004, Washington, DC.

Kerlinger, P. 2004. Attraction of night migrating birds to FAA and other types of lights. **National Wind Coordinating Committee – Wildlife Working Group** Meeting, November 3-4, 2004, Lansdowne, VA.

Gehring, J., P. Kerlinger, and A.M. Manville. 2004. Avian collisions with communication towers: a quantification of some associated tower variables. Paper presented at the **American Ornithologist's Union** annual meeting, Quebec City, Quebec.

Kerlinger, P. 2005. Appalachian ridge following by night migrating birds? A test of the hypothesis using marine surveillance radar in three states. Paper accepted for the joint **Wilson Ornithological Society/Association of Field Ornithologists** Meeting, April 2005, Laurel, MD.

Gehring, J.A., P. Kerlinger, and A. M. Manville, II. 2005. Avian collisions with communication towers: a comparison of tower support systems and tower height categories**. Wilson Ornithological/Association of Field Ornithologists** joint annual meeting, April 2005.

PUBLICATIONS AND REPORTS ON BIRDING ECONOMICS/ECOTOURISM STUDIES AS CONSERVATION TOOLS

The publications that follow represent a unique body of conservation research that has been used by numerous environmental organizations, government agencies, and citizens groups to promote open space conservation. Those noted by an asterisk have been peer reviewed and published in the journal or volume indicated.

*Wiedner, D. S. and P. Kerlinger. 1990. Economics of birding: a national survey of active birders. American Birds 44:209-213.

*Kerlinger, P. and D. S. Wiedner. 1991. The economics of birding at Cape May, New Jersey. In Ecotourism and Resource Conservation, A collection of papers. 2nd International Symposium Ecotourism and Resource Conservation, 1991, Miami, Florida, J. A. Kusler, Jr., ed., vol. 1, pp. 324-334.

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*Wiedner, D.S. and P. Kerlinger. 1992. Economic impact of birding in Cape May, New Jersey. Human Dimensions in Wildlife Newsletter 8(3):23-24.

*Kerlinger, P. 1993a. Birding economics as a tool for conserving Neotropical migrants. Transactions of the 58th N. Amer. Wildlife and Nat. Res. Conf. pp. 438-443. Washington, DC.

Kerlinger, P. 1993. Birding economics and birder demographics studies as conservation tools. *Proc. Status and Managem. of Neotrop. Migr. Birds.* eds. D. Finch and P. Stangel, Rocky Mntn For. and Range Exper. Station, Fort Collins, CO. USDA For. Serv. Gen. Tech. Rept. RM-229, pp. 32-38.

*Eubanks, T., P. Kerlinger, and R. H. Payne. 1993. High Island, Texas: a case study in avitourism. Birding 25:415-420.

Kerlinger, P. 1994. The economic impact of birding ecotourism on the area surrounding Whitefish Point, Michigan. Report to National Fish and Wildlife Foudation and the US Fish and Wildlife Service.

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Kerlinger, P. 1994. The economic impact of birding ecotourism on the area surrounding the Quivira National Wildlife Refuge, Kansas. Report to National Fish and Wildlife Foundation and the US Fish and Wildlife Service.

Kerlinger, P. 1994. The economic impact of birding ecotourism on the area surrounding the Salton Sea National Wildlife Refuge, California. Report to National Fish and Wildlife Foundation and US Fish and Wildlife Service.

Kerlinger, P., T. Eubanks, and R. H. Payne. 1994. The economic impact of birding ecotourism on the area surrounding the Santa Ana National Wildlife Refuge, Texas. Report to National Fish and Wildlife Foundation and the US Fish and Wildlife Service.

Kerlinger, P. 1994. The economic impact of birding ecotourism on the area surrounding The Nature Conservancy's Ramsey Canyon Preserve, Arizona. Report to National Fish and Wildlife Foundation and The Nature Conservancy.

Kerlinger, P. 1995. The economic implications and demographics of birding ecotourists in Trinidad and Tobago. Report to National Fish and Wildlife Foundation and New England Biolabs Foundation.

Kerlinger, P. 1995. The economic implications and demographics of ecotourists at the Chan Chich Lodge, Belize. Report to National Fish and Wildlife Foundation and the New England Biolabs Foundation.

Kerlinger, P. and J. Brett. 1995. Hawk Mountain Sanctuary: a case study of birder visitation and birding economics. pp. 271-280, in Wildlife and recreation: coexistence through management and research, R. L. Knight and K. J. Gutzwiller, eds. Island Press, Washington, DC.

Kerlinger, P. and T. Eubanks. 1995. Birds and bucks. Birding 27:21-23.

Kerlinger, P. 1995. Birders as ecotourists. Birders World (April):74-76.

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Kerlinger, P., T. Eubanks, and R.H. Payne. 1995. The economic impact of birding ecotourism on the Sabal Palm Grove Sanctuary (National Audubon Society) area, Texas, 1994-1995. Report to National Fish and Wildlife Foundation and National Audubon Society.

Kerlinger, P. 1995. Preliminary report on the economic impact of ecotourists on the communities surrounding Mohonk Preserve, New York. Report to the Mohonk Preserve, Inc.

Kerlinger, P. 1995. Paying our fair share, birders should back the Wildlife Diversity Funding Initiative. Living Bird 14(4):8-9.

*Kerlinger, P. 1998. Establishing an economic basis for protecting bird habitat at the local level. eds. R. Bonney, L. Niles, and D. Pashley. 1996 Partners in Flight Workshop volume from Cape May, New Jersey 1995 meeting volume.

PUBLICATIONS - TECHNICAL REPORTS FOR NONPROFIT ORGANIZATIONS

Kane, R., P. Kerlinger, and R. Radis. 1990. Arthur Kill Tributary and Greenway Project: Wildlife and Habitat Inventory. pp. 88. New Jersey Audubon Society, Franklin Lakes, NJ.

Kerlinger, P. and J. Palumbo. 1990. Raccoon Creek Tributaries Greenway Project (1990). pp. 68. New Jersey Audubon Society, Franklin Lakes, NJ.

Kane, R., P. Kerlinger, and K. Anderson. 1992. Delaware Bay and River Tributaries Greenway Project (1991-1992). pp. 112. New Jersey Audubon Society, Franklin Lakes, NJ.

Kane, P. and P. Kerlinger. Raritan Bay Habitat and Wildlife Inventory, 1992-1993. pp. 74. New Jersey Audubon Society, Franklin Lakes, NJ.

(Many others)

PUBLICATIONS - POPULAR LITERATURE/MAGAZINES

Natural History - 1995, 1996 (American Museum of Natural History)
Birders' World - 1994, 1995; 2000-2006 (Birds on the Move – a regular column)
Wild Bird - 1993, 1994, 1995, 1996
Atlantic Coast - 1993
New Jersey Outdoors 1995, 1997
The Conservationist (NYS Dept Envior. Conservation)
Birding (American Birding Association
Kingbird (NY State Federation of Bird Clubs)
New England Bird Observer (Mass Audubon Society)
Peregrine Observer (Cape May Bird Observatory)
Newsletter of the Hawk Migration Assoc. of North America
New Jersey Audubon Magazine
Records of New Jersey Birds (1988-1994)
Bird Watcher's Digest
Cape May Bird Report - 1987 - by David A. Sibley (Kerlinger published this book)
Winging It (ABA Newsletter)
The Living Bird - 1998, 1995, 1992 (Cornell Lab of Ornithology)
The Eyas (Raptor Research Society)

Geographic Extent of Projects and Consulting: Vermont, New Hampshire, Maine, Massachusetts, New York, New Jersey, West Virginia, Ohio, Virginia, Maryland, Pennsylvania, Illinois, Michigan, Iowa, Colorado, Wisconsin, Kansas, Oklahoma, Kentucky, Nevada, Montana, Washington, Texas, New Mexico, California, Newfoundland, Puerto Rico, Mexico, Spain (Andalucia, Galicia)

Companies: Zilkha Renewable Energy, PPM, Horizon, FPL Energy, Invenergy, Illinois Wind Power, Midwest Wind Energy, SeaWest Inc., Kenetech Windpower Inc., Atlantic Renewable Energy Corporation, Green Mountain Energy, Green Mountain Power Corporation, Vermont Deparment of Public Service, Public Service Company of Colorado, Excel, enXco, Distributed Generation Corporation, Cape Winds, US Cellular, Sprint, AT&T Wireless, KRKO Radio, Superior Renewable Energy, US Wind Force, PPM, RES, AES, Cape Wind, Gamesa, Babcock & Brown, Community Energy, etc.

Nonprofit Clients: U. S. Fish and Wildlife Service, Conservation Law Foundation, New York City Audubon Society, New York City Department of Parks and Recreation, Michigan State Police and Attorney General's Office, US DOE - National Renewable Energy Laboratory, Federal Aviation Administration, St. Francis University, Texas Parks and Wildlife, Fermata Inc., Cape May County Municipal Utility Authority, etc.

REFERENCES: A list of references from industry, academia, and, or the nonprofit conservation sector (including agencies) are available upon request

Appendix 3.1. Bat Risk Assessment

PHASE I BAT RISK ASSESSMENT

Mount Wachusett Community College Wind Energy Project

Worcester County, Massachusetts

Prepared for:

Mount Wachusett Community College

Prepared by:

D. Scott Reynolds, Ph.D. and Jacques Veilleux, Ph.D.

North East Ecological Services
52 Grandview Road
Bow, NH 03304

05 December, 2008

Phase I Bat Risk Assessment

Mount Wachusett Community College Wind Energy Project

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Phase I Bat Risk Assessment

Mount Wachusett Community College Wind Energy Project

Worcester County, Massachusetts

EXECUTIVE SUMMARY

Mount Wachusett Community College ("MWCC") has proposed the construction of a one- or two-turbine wind project on its campus in Gardner (Worcester County), Massachusetts. As part of the environmental assessment of this proposal, North East Ecological Services (NEES) was contracted to conduct a Phase I Bat Risk Assessment. The purpose of the risk assessment was to determine the potential for habitat loss and collision mortality to bats from the construction and operation of the MWCC wind project. The risk assessment involved 1) an on-site evaluation to determine habitat features that may be predictive of bat usage, including roosting habitat, foraging habitat, and hibernacula; 2) a literature search to determine known populations of bats near the project site; and 3) consultation with appropriate MADFW and US Fish and Wildlife Service biologists to determine the presence of protected species or hibernacula near the project site.

The on-site evaluation was conducted on 21 August, 2008 by a NEES biologist (J. Veilleux). The proposed turbine location is an old-field habitat surrounded by second growth forest, wetland, open water, and open grassland habitats. A walking survey of the area revealed a low density of appropriately-sized snags that could contain roosting habitat for cavity- and bark-roosting bat species. The southeast corner of the project area did, however, contain some taller snags that would receive adequate insolation to provide suitable roosting habitat. There appeared to be very little exposed rock habitat that could be used as roost sites by the eastern small-footed myotis (MA Species of Special Concern). Several small ponds and marshes surrounded the project site and could be used as foraging habitat by local bats.

NEES has been contracted to conduct pre-construction acoustic monitoring at the project site for the Summer 2008 and Fall 2008 migratory season. This study has recently been completed and data analysis has commenced. Based on the data collected during the risk assessment and a preliminary overview of the acoustic data collected at the project site, NEES makes the following recommendations:

1) Ground-based acoustical monitoring should be conducted during the early summer near the exposed rock habitat and adjacent to the wetland habitat to document the presence of bats roosting in either of these habitats. If data collected during this monitoring suggests the presence of either the eastern small-footed myotis or the Indiana myotis, additional monitoring or mist-net sampling may be needed to confirm the presence of these protected species.
2) Any habitat alteration involving the southeast corner of the project area should be conducted during the winter months to minimize impact of project construction on bat roosting habitat

3) The wind turbine(s) should not be placed on the field edge or adjacent to the pond and wetland habitat where commuting and foraging bats would be at higher density
4) MWCC should conduct additional pre-construction acoustic monitoring in the Spring 2009 migratory season to document the complete migratory cycle of bats at the project site.
5) MWCC should create a Technical Advisory Committee to ensure that all additional study protocols meet the recommendations of the MADFW, USFWS, and other interested parties.
6) MWCC should conduct an appropriate post-construction mortality survey under the technical guidance of biologists familiar with fatality studies at wind turbine facilities
7) MWCC should conduct post-construction acoustic monitoring to help generate predictive models that would provide effective operational controls to mitigate bat mortality.

A review of published and gray literature, including analysis of New England Bat Colony database (S. Reynolds, unpublished data) revealed that the Worcester County region has a relatively diverse bat community. These data suggest that house-roosting bats are common throughout the region. Consultation with Massachusetts Division of Fisheries and Wildlife (MADFW) and the U.S. Fish and Wildlife Service (USFWS) revealed relatively little information about the presence of protected species or migratory tree-bats in the region. MADFW was helpful in identifying caves and abandoned mines near the project site, but none of these sites were considered potential hibernacula. Therefore, it is unlikely that the MWCC project site contains resident populations of either species of concern.

Based on the results of the risk assessment, NEES concludes that fatality numbers at the project site are likely to be similar in both composition and magnitude (on a per turbine basis) to other wind projects sites in the eastern United States. However, given the small size of the project, total impact of the project is unlikely to significantly impact local bat populations. Based on the on-site survey and consultation with the MADFW and USFWS, there are no data to suggest that protected bat species reside on or near the MWCC project site; therefore, it is unlikely that populations of either the eastern small-footed myotis or the Indiana myotis will be impacted by development of the MWCC project site.

1.0 PROJECT OVERVIEW

1.1 The Mount Wachusett Community College Wind Project

The Mount Wachusett Community College (hereafter termed MWCC) Wind Project proposal is for the construction and operation of one or two 1.5 MW wind turbines (estimated 1.5 to 3.0 MW total capacity) on the MWCC campus located in northern Worcester County, Massachusetts (Fig. 1). The project layout encompasses approximately 4.5 ha. The project consists of a single parcel of publicly owned land, located within the City of Gardner, approximately 1.5 km south/southeast of the intersection of SR-140 and Green Street.

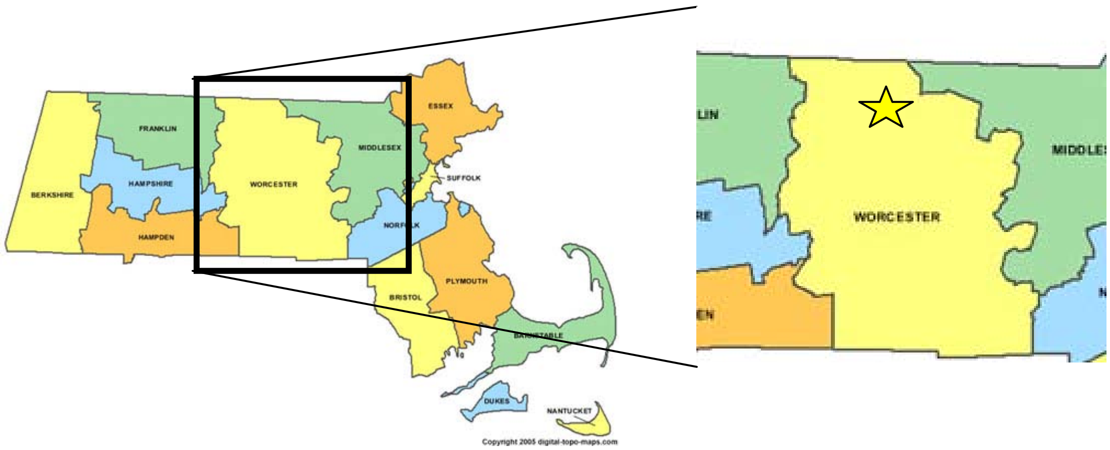

Figure 1: General location of the MWCC Wind Project in Massachusetts

1.2 Phase I Habitat Assessment

The proposed MWCC Wind Project is located in northern Worcester County within the Worcester/Monadnock Plateau of the Northeastern Highlands EcoRegion (Omernik, 1987). A habitat assessment of the Project site was conducted on 21 August, 2008. Habitat was assessed by foot along the proposed turbine site and within an approximate 0.5 km radius area surrounding the turbine site. Additional regional features were assessed by vehicle. The site visit assessed major habitat features associated with roosting and foraging activity by the species of bats likely to occur on or near the project area (e.g. dominant tree species, presence of tree snags, general tree size (height and dbh), presence of exposed rock outcrops, available water, and open field habitat).

The elevation of the project site is approximately 355 m (asl), with topography sloping to the west (elevation change = - 22 m to Crystal Lake) and rising to the northwest (elevation gain of 27 m at Howe Hill). Another hill (Reservoir Hill) rises to the south (elevation gain of 41 m). The project area is generally characterized by gentle rolling hills, containing a heterogeneous habitat landscape. Natural habitat types occurring with the project area include mainly second growth forest, open water habitat, wetland/marsh habitat, and old field habitat. Additional open space, such as the Gardner Municipal Golf Course, occurs adjacent to the project area. The city of Gardner is located approximately 15 km south of the project site, offering a more urbanized environment.

The site assessment began at the proposed location for the wind turbines. The proposed turbine location(s) is located within an approximately 4.5 ha old field, with very few invading trees. Herbaceous ground cover was dominated by various grasses (*Poa* spp.), goldenrod (*Solidago* spp.), wild carrot (*Carota dioca*), and purple clover (*Trifolium purpureum*). The old field was bordered by a second growth forest to the east, which extended to both the east and northeast. Dominant overstory tree species within the forest border and interior included eastern white pine (*Pinus strobus*), northern red oak (*Quercus rubra*), ornamental spruce (*Picea* spp.), black cherry (*Prunus serotina*), white ash (*Fraxinus americana*), red maple (*Acer rubrum*), sugar maple (*A. saccharum*), and eastern hemlock (*Tsuga canadensis*). Dominant understory tree species included red maple, mountain laurel (*Kalmia latifolia*), aspen (*Populus* spp.), staghorn sumac (*Rhus typhina*; located on forest/field edges), and American beech (*Fagus grandifolia*). Several small dbh (e.g. ≤ 20 cm) snags (mainly trembling aspen, white pine, and red oak) with visible hollows and/or exfoliating bark were observed along the forest/field edge. Canopy height within the forested regions of the project area was approximately 20 to 25 m, with mean tree dbh of approximately 35 cm (ranging from approximately 25 to 85 cm dbh). Overstory tree snags were observed at relatively low numbers throughout the project area, with most snags observed within the forested border located on the southeast edge of the project area. Northern red oak and white pine snags, in various stages of decay, were observed in this area. Snags contained exfoliating bark and/or crevices and interior hollows. Most of the observed snags were exposed to sunlight throughout most of the day. Very little exposed rock habitat (i.e. roosting habitat for the eastern small-footed myotis; see Section 2.2.2) was observed. A relatively long (at least 100 m), narrow (~ 2 m width) area of rock jumble was observed along the east edge of the project field, and approximately 3 to 6 m into the forest interior. This area of rocks was composed of medium and large size boulders, which likely constituted a historical stone wall. The boulders occurred mainly at ground level, and since the rocks were shaded by overstory trees, received only intermittent exposure to the sun.

Perennial water commonly occurs both within the project area and regionally. Within a 2 km radius of the project area, a relatively large number of open water and wetland habitats were observed during the site assessment. A small (0.75 ha) open water pond borders the project field to the west. The pond is surrounded by a cat-tail/*Phragmites* marsh. Additional wetlands occur to the east of the project field, including a small red maple swamp located approximately 150 m east/northeast of the project field. Several large pond and lakes were observed, including Crystal Lake and Perley Brook Reservoir to the west, Lake Wampanoag, Mamjohn Pond, and Hobby's Pond to the northeast, and Dunn Pond to the southeast. Several additional small ponds were observed both on the MWCC campus property and within the adjacent golf course to the west.

Consultation with Massachusetts Division of Fisheries and Wildlife (Dr. Tom French, Assistant Director of Natural Heritage and Endangered Species, pers. comm.) was initiated to determine the possible presence of abandoned mines within, and adjacent to, the project boundary that could serve as hibernation sites. Although several open pit mines and quarries are present in northern Worcester County, no known underground mines that could serve as bat hibernacula are known from the MWCC project area (T. French, pers. comm.).

2.0.0 CURRENT STATE OF KNOWLEDGE ON BAT SPECIES

2.1.0 Bats in the State of Massachusetts

There are nine species of bats that have been observed in the state of Massachusetts, with eight species having been documented in the region of Worcester County (Table 1; Appendix One. Two listed bat species have been observed in Massachusetts: the federally endangered Indiana myotis (*Myotis sodalis*) and the state Species of Special Concern, the eastern small-footed myotis (*M. leibii*).

Table 1: Bat species occurring in Massachusetts and their distribution relative to the MWCC Wind Project (species in bold are Federal or State Listed Species)

Species Name	Scientific Name	Regional Record[1,2]	County Record[1,2]	Section Reference[3]
Little brown myotis	*Myotis lucifugus*	yes	yes	2.4.1
Indiana myotis	***Myotis sodalis***	**no**	**no**	**2.2.1**
Northern myotis	*Myotis septentrionalis*	yes	yes	2.4.2
Eastern small-footed myotis	***Myotis leibii***	**yes**	**no**	**2.2.2**
Hoary bat	*Lasiurus cinereus*	yes	yes	2.3.1
Silver-haired bat	*Lasionycteris noctivagans*	yes	yes	2.3.2
Eastern red bat	*Lasiurus borealis*	yes	yes	2.3.3
Eastern pipistrelle	*Perimyotis subflavus*	yes	yes	2.3.4
Big brown bat	*Eptesicus fuscus*	yes	yes	2.4.3

1. Based on data from surrounding counties: Franklin, Hampden, Hampshire, Middlesex and Norfolk Counties (MA) and Cheshire and Hillsborough Counties (NH).
2. Distribution data based primarily museum records (Museum of Comparative Zoology (MCZ), Harvard University; Peabody Museum (YPM), Yale University; U.S. National Museum (USNM), Washington, D.C.) unpublished data (J. Veilleux, pers. comm.), primary literature reports, and data from the MADFW web-site.
3. Refers to the report section that details the distribution, biology, and/or relative risk for a particular species.

2.2.0 Distribution and Brief Biology of Listed Species in Massachusetts

2.2.1. Indiana myotis, *Myotis sodalis*

The U.S. Fish and Wildlife Service listed the Indiana myotis as federally-endangered in 1967 because of dramatic population declines and destruction of key maternity roosts and hibernacula (Trumbulak et al., 2001; Clawson, 2002). Despite over forty years of protection, Indiana myotis populations continue to decline in their core range, although the cause of the decline remains unclear (Clawson, 2002). In their core range, the distribution pattern of the Indiana myotis is associated with cavernous limestone areas (Thomson, 1982: Kurta et al., 1993). Indiana myotis hibernacula are classified as Priority I, II, III or VI, generally depending on current or historical population size at the cave or mine (*see* USFWS, 2007 for specific details; Table 2; Fig. 2). Currently, most of the known population of Indiana myotis exist in 23 Priority I hibernacula mainly located in Indiana, Kentucky, and Missouri (USFWS, 2007).

Indiana myotis typically spend at least 190 days in hibernation (Menzel et al., 2001), and appear to prefer lower ambient temperatures but higher humidity and airflow than other *Myotis* species (Menzel et al., 2001). Indiana myotis begin to leave hibernacula in late March through April (Richter et al., 1993; Hicks, 2003). Females tend to leave hibernation first, so that by early May, only males are still emerging from the hibernacula (Humphrey et al., 1977).

No extant Indiana myotis hibernacula are known from Massachusetts (USFWS, 2007). The only available valid historical record is from 1939, when approximately 60 individuals were observed within the Chester Mine located in Hampden County (T. French, pers. comm.; Fig. 2). Although the Massachusetts Natural Heritage endangered species fact sheet for the Indiana myotis (MassNH, 2008) indicates historical records in both Worcester and Berkshire Counties, these records are currently considered in error (mistaken identification) and should not be considered valid occurrence records (T. French, pers. comm.).

Figure 2. Historical county distribution of the Indiana myotis hibernaculum record in Massachusetts

Table 2: Historical record of the single Indiana myotis hibernaculum in the state of Massachusetts by Priority level (USFWS, 2007). No Indiana myotis have been documented at the single Priority III hibernaculum since 1939.

Hibernaculum Category	Population Size Range	Massachusetts Hibernacula
Priority I	≥ 10,000	0
Priority II	1000 – 10,000	0
Priority III	50 - 1000	1
Priority IV	< 50	0

During the reproductive season, Indiana myotis have a life history similar to other *Myotis* bats. Upon emergence from their hibernacula in the spring, Indiana myotis migrate to their summer range. Indiana myotis are known to migrate up to 532 km to reach their summer territory (Kurta and Rice, 2002), although most migratory events in the northeast tend to be less than 50 km (Griffin, 1970; Hicks, 2003). This appears to be particularly true for males, which often live near the hibernacula all summer (Fenton and Downes, 1981; Hicks, 2003). Upon reaching their summer range, adult females form reproductive colonies to raise their young. These 'maternity' colonies remain relatively intact from June through August and are generally located under exfoliating bark or in tree cavities (Kurta and Rice, 2002). Although Indiana myotis are known to use man-made structures (Butchkoski and Hassinger, 2002), including bathouses (Carter et al., 2001; Carter, 2002), most maternity colonies are formed in tree roosts. Roost trees are generally located in riparian, floodplain and bottomland forest habitat. Indiana myotis roosts appear to have key characteristics that are generally independent of the tree species (Scherer, 1999). Specifically, roost trees are large (greater than 36 cm dbh), tall, near water, and in direct sunlight most of the day (Kurta et al., 1993: Menzel et al., 2001: Kurta and Rice, 2002). Within these roosts, each female within the colony (typically 5 – 45 females) raises a single pup that is born by the end of June and reaches adult size by the end of August. During the summer months, females use multiple roosts and appear to switch between them on a regular basis (Hicks, 2003). During the summer months, adult males are believed to live alone or in small groups under exfoliating bark (Ford et al., 2002).

Foraging by the Indiana myotis is generally concentrated in riparian habitat. Although the standard protocol suggests that Indiana myotis predominantly forage over water (USFWS, 1999), there is a considerable amount of research that suggests they are more diverse in habitat selection (Kurta et al., 1993: Menzel et al., 2001: Carroll et al., 2002). This diversity of habitat use is supported by fecal analysis studies which have shown the Indiana myotis consuming at least twelve different Orders of insects and arthropods (Murray and Kurta, 2002), many of which are not commonly found along rivers. Capture data suggests that most Indiana myotis fly below the canopy at a height between 2 and 4 m (Fenton and Downes, 1981; Gardner et al., 1989), with some individuals foraging around the canopy at 28m (Humphrey et al., 1977: Fenton and Downes, 1981). In Pennsylvania, Butchkoski and Hassinger (2002) determined general foraging patterns of six Indiana myotis (one male and five females). Their data show that individuals foraged mainly in interior forests, and in hollows with intermittent streams. Foraging areas ranged from 39-122 ha, and bats foraged between 275 and 375 m in elevation. The maximum travel distance between a day roost and foraging area was 4.5 km.

Data pertaining to the distribution of Indiana myotis in Massachusetts (and adjacent New Hampshire counties) during the summer period were assessed through published literature, gray literature, museum records, and through personal communications with MADFW (T. French, pers. comm.). The literature search, museum records, and personal communications with state biologists yielded no summer records for the Indiana myotis in Massachusetts (or adjacent New Hampshire counties).

2.2.2 Eastern small-footed myotis, *Myotis leibii*

The eastern small-footed myotis has an extensive distribution (from Ontario to New England, southward to Georgia and Westward to Oklahoma), although it is not considered common anywhere within its range. The status of the eastern small-footed myotis has been the subject of regular revision throughout the 20th century. Prior to its current classification as *M. leibii* in 1984 (van Zyll de Jong, 1984), the eastern small-footed myotis was considered a subspecies (*Myotis leibii leibii*) of neartic small-footed bats (Glass and Baker, 1968). Prior to 1968, this species was referred to as *M. subulatus* (Miller and Allen, 1929 cited in Thomas, 1993). This taxonomic discontinuity has most likely played a significant role in the lack of federal protection afforded to this species, considering the eastern small-footed myotis is one of the rarest bats in North America (Griffin, 1940) and 'without doubt the least known of all northeastern bat species' (Thomas, 1993). Although *M. leibii* is not federally protected, it is considered a species of management concern and has conservation status in most of the New England states (including Species of Special Concern in Massachusetts), and several states in the mid-Atlantic region, including Pennsylvania, Maryland, West Virginia, Tennessee, and Kentucky.

Because of its relative rarity, the eastern small-footed myotis has proven difficult to research in significant numbers, and therefore most of our knowledge of this species comes from individual captures and hibernacula surveys. Summer records of reproductive eastern small-footed myotis are relatively rare, and recent capture data (post-1980) are often limited to a few individuals within any state. Although they appear to exhibit some summer flexibility in roost use, with some roosts reported from hollow trees, exfoliating bark, abandoned tunnels, and even human structures (Thomas, 1993; Best and Jennings, 1997), available data suggest that reproductive groups (pregnant females and their offspring) typically use rock outcrops and talus slopes as maternity roosts during the summer months (J.P. Veilleux, Franklin Pierce University, unpublished data). Summer populations of eastern small-footed myotis appear to have a patchy distribution throughout their range, and activity is often concentrated around hibernacula (Thomas, 1993; Johnson and Gates, 2008). No data are available that describe foraging habitat used by eastern small-footed myotis, although recent data indicate that this species feeds primarily on moths, flies, and beetles (Moosman et al., 2007).

Most records of eastern small-footed myotis are from hibernacula surveys. They appear to be a relatively cold-tolerant species, choosing to hibernate near entrances in narrow crevices (Best and Jennings, 1997), often hanging low along the wall or even among rock debris (Thomas, 1993). They enter hibernation later than most other species and leave earlier (Thomas, 1993; Best and Jennings, 1997), giving them a substantially longer active season that other hibernating species. Recent data from spring emergence studies in Maryland indicate that some eastern small-footed bats leave their winter hibernaculum for summer roosts sites between 13 March and 04 April (Johnson and Gates, 2008), while in southern New Hampshire, individuals have been observed at their summer roost area as early at 06 April (J.P. Veilleux, unpublished data). Additional recent data on spring migration patterns suggest that some eastern small-footed myotis travel extremely short distances between winter hibernacula and summer roost areas. In Maryland, Johnson and Gates (2008) reported migration distances of between 0.1 and 1.1 km from hibernacula to summering locations for four female eastern small-footed myotis.

Few data are available in the published literature pertaining to the distribution of eastern small-footed myotis in Massachusetts during both summer (reproductive) and winter (hibernation) periods. The only published winter record of eastern small-footed myotis in Massachusetts was provided by Veilleux (2007). A total of five eastern small-footed myotis was observed within Bat's Den Cave, in the town of

Egremont, Berkshire County (128 km southwest of MWCC). The only additional winter records of the eastern small-footed myotis in Massachusetts are from the town of Chester, Hampden County (90 km southwest of MWCC; T. French, pers. comm.), where individuals have been observed within both the Chester Emery Mine and the Macia Mine. A single individual was observed in the Macia Mine in 1981, while 20 surveys of the Chester Emery Mine conducted between 1937 and 1999 yielded between one and five individuals on six survey occasions (Veilleux, 2007).

No summer colonies are known from Massachusetts, although regional summer occurrences are available for both Cheshire and Hillsborough Counties, New Hampshire. In Cheshire County, the largest summer population known for this species across its range is present at an Army Corps of Engineers dam installation (Surry Mountain Dam), located in the town of Surry (55 km northwest of MWCC). At least 120 individuals have been captured at the Surry Mountain Dam during summers of 2005 through 2008 (J.P. Veilleux, unpublished data). A second summer population is known from the New Boston Air Force Station (NBAFS), located in New Boston (Hillsborough County), NH (48 km northeast of MWCC). During three summer sampling efforts at the NBAFS (2002, 2006, 2007), 12 eastern small-footed myotis were captured (LaGory et al., 2002; LaGory et al., 2008). Radiotelemetry data indicated that individuals roost along an exposed south/southeast facing rock face of Joe English Hill.

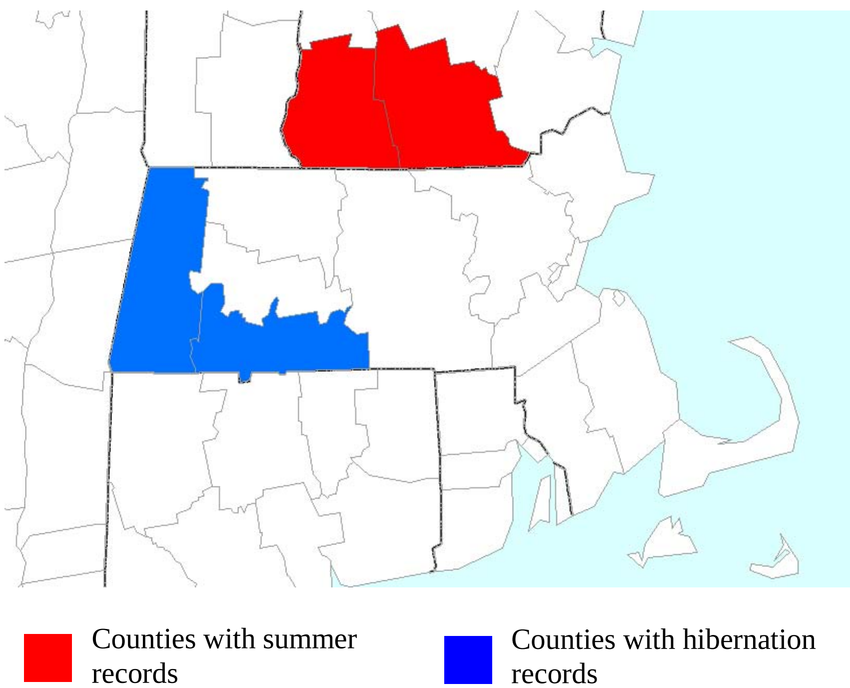

Fig. 3. County distribution of winter (hibernacula) and summer records of the eastern small-footed bats in Massachusetts (and regional counties relative to the MWCC project county)

2.3 Bats At Higher Risk of Turbine Collision Mortality

Post-construction mortality surveys at wind turbine sites have revealed a relatively consistent pattern of bat mortality despite diverse methodologies and sampling periods. Surveys from across North America suggest that migratory tree bats are being killed at higher rates than other species (Table 3). For example, a summary of mortality data from nine wind facilities in the United States showed 86% of the identified mortality came from three species (hoary bats, red bats, and silver-haired bats: Erickson et al., 2002). A more recent review of wind development by Johnson (2005) suggests that 83% of the total mortality involves these same three species. Projects in the eastern United States also see a relatively large number of eastern pipistrelle mortalities. The reason for these species being at higher risk of collision mortality is uncertain. The hoary bat and silver-haired bat are found across North America and are therefore potentially found at any wind development site in this region. The other two species (eastern red bat and eastern pipistrelle bat) are more regional in distribution than these pan-continental species, but still have geographic ranges that extend over thousands of miles. It is likely that these large geographic ranges and the long-distance migratory behavior of these species (except pipistrelles) expose them to a higher risk of turbine-related collision mortality.

Table 3: The percent of bat mortality attributed to the 'high-risk' species (hoary bat, silver-haired bat, red bat, and eastern pipistrelle).

Wind Development Site	Percent of Migratory Bats (total bats killed) [1]	Literature Source
Nine Canyon (WA)	100% (27)	Erickson et al., 2003
Buffalo Mountain (TN)	98% (120)	Fiedler, 2004
Buffalo Ridge (MN)	93% (151)	Johnson et al., 2004
Vancycle (OR)	90% (10)	Erickson et al., 2000
Locust Ridge (PA), 2007	90% (211)	S. Whitten, unpublished
Foot Creek Rim (WY)	88% (79)	Young et al., 2003
Mountaineer (WV), 2003	86% (466)	Kerlinger and Kerns, 2004
Mountaineer (WV), 2004	87% (466)	Arnett, 2005
Meyersdale (PA)	87% (299)	Arnett, 2005
Maple Ridge (NY)	74% (383)	Jain et al., 2007
Top of Iowa (IA)	63% (108)	Koford et al., 2005
Solano (CA)	59% (116)	Kerlinger et al., 2006
Klondike (OR)	50% (6)	Johnson et al., 2003b
Overall	86% (3,247)	

[1] percentage of total mortality attributable to migratory bat species

Although the determination of relative risk is somewhat arbitrary in the absence of site-specific population densities for each species, it is clear that these species are being killed at a higher rate than would be predicted based on the abundance of these species from capture surveys. For example, at the Mountaineer facility in West Virginia, these four species represented 85.7% of the total mortality but only 22.6% of the total bats captured in a 1999-2000 statewide survey, resulting in mortality rates that ranged from 2.5 – 34.0 times the rate at which they were captured (Kerlinger and Kerns, 2004). Similar mortality bias has been observed at other wind projects where local bat surveys have been conducted (Johnson et al., 2004; Johnson, 2005; Jain et al., 2007).

2.3.1 Hoary bat, *Lasiurus cinereus*

The hoary bat occurs throughout much of North and South America (Cryan, 2003). In Massachusetts, hoary bats are likely found statewide (Godin, 1977), particularly during spring and fall migration, with records available for eight Massachusetts counties (Godin, 1977). Regional summer records (relative to the project site) exist from Worcester (Worcester County; 24 km southeast of MWCC; Godin, 1977), Surry (Cheshire County, NH; 55 km northwest of MWCC; J. Veilleux, unpublished data), and New Boston (Hillsborough County, NH; 48 km northeast of MWCC; Veilleux et al. *in press*).

There are no detailed data that describe migration patterns of this species in Massachusetts. Generally, female and male hoary bats winter in more southern latitudes. Both males and females appear to migrate to northern latitudes during spring, with males migrating to more western regions and females to more eastern regions, although there are scattered exceptions to these generalities (Cryan, 2003, Perry and Thill, 2007).

Summer roosting habits of hoary bats are not well documented (Whitaker and Hamilton, 1998; Willis and Brigham, 2005), and no roosting data are available for Massachusetts. Roosts are located primarily in foliage, but are also known from other atypical sites such as woodpecker holes and squirrel nests (Shump and Shump 1982a). Neither adult female nor male hoary bats are colonial. Except for reproductive females roosting with their young, they are believed to roost alone during all times of the year (Shump and Shump 1982a). Females give birth to twins and wean their young within the foliage roosts.

The nearest data on summer roost use by hoary bats relative to the MWCC project area were reported from New Hampshire (Veilleux et al., *in press*). A single mother/pup group was radiotracked to its roost sites. The bats roosted near the tops of eastern hemlock trees and all trees were located within a 0.5 ha area. Willis and Brigham (2005) radio-tracked 21 reproductive females and four juveniles to 32 roost sites (19 roosts were included in the analyses) in Saskatchewan, Canada. All roosts but one were located within the foliage of white spruce (*Picea glauca*), with the one additional roost being located in a trembling aspen (*Populus tremuloides*). In Arkansas, Perry and Thill (2007) reported roosts used by nine hoary bats (4 males and 5 females). Roosts were typically located in foliage along the eastern edge of white oaks, post oaks (*Q. stellata*), and shortleaf pines (*P. echinata*). Mean roost height was 16.5 m, and, on average, roosts were larger (height and DBH) than a random set of trees used for comparison. In terms of habitat surrounding roost trees used by hoary bats, Willis and Brigham (2005) found reduced forest density on the roosting side of roost trees, possibly providing an open 'flyway' for bats returning to and leaving the roost. In terms of landscape level patterns, hoary bats roosted at lower elevations, possibly due to the increased number of white spruce and lower wind levels in such areas. In Pennsylvania, Hart et al. (1993) found hoary bats utilizing forested and aquatic habitats as foraging habitat (based on echolocation recordings) in greater proportions than non-forested and non-aquatic habitats. In New Hampshire, Veilleux et al. (*in press*) reported foraging data for a single juvenile hoary bat. Most foraging activity occurred in forested habitats (nearly 70%), with less foraging occurring in open fields (17%) or wetlands (15%).

Hoary bats have been documented migrating throughout their range and there is evidence to suggest some individuals remain in the same area but move towards higher elevation sites during the winter (Dalquest, 1943; Vaughan and Krutzsch, 1954; Cryan, 2003). Although this species does not hibernate to the extent of the cave bats, the use of torpor at low temperatures has been documented in this species (Brisbin, 1966; Cryan and Wolf, 2003; Genoud, 1993).

2.3.2 Silver-haired bat, *Lasionycteris noctivagans*

The silver-haired bat occurs throughout much of the majority of southern Canada and the United States (Kunz, 1982). In Massachusetts, silver-haired bats are likely found statewide (Godin, 1977), particularly during spring and fall migration, with records available for ten Massachusetts counties (Godin, 1977). Regional summer records (relative to the project site) exist from Harvard (Worcester County; 35 km east/southeast of MWCC; Godin, 1977), Tyngsboro (Middlesex County; 46 km east/northeast of MWCC; MCZ database), and New Boston (Hillsborough County, NH; 48 km northeast of MWCC; LaGory et al., 2002).

There are no detailed data that describe migration patterns of this species in Massachusetts. Female appear to migrate to northern latitudes during spring to give birth, while males appear to remain closer to their winter range (Cryan, 2003). Although this species is likely widely distributed in Massachusetts (Godin, 1977), particularly during spring and fall migration, few data are available that indicate its population status in the state.

The silver-haired bat is a tree-roosting species and during summer months roosts in tree hollows (e.g. Vonhof, 1996; Betts, 1998; Crampton and Barclay, 1998). Most of the data on roost use by this species are from studies in the northwestern United States and southwestern Canada (i.e. Campbell et al., 1996; Vonhof and Barclay, 1996; Betts, 1998; Crampton and Barclay, 1998). Crampton and Barclay (1998) examined aspects of the roosting ecology of silver-haired bats in Alberta, Canada. Individuals preferred to roost in deep cavities within trembling aspen (*Populus tremuloides*) and other aspen species. In Oregon, Betts (1998) found pregnant and lactating female silver-haired bats roosting in ponderosa pine (*Pinus ponderosa*), western larch (*Larix occidentalis*), douglas fir (*Pseudotsuga menziesii*), and grand fir (*Abies grandis*). In Washington, Campbell et al. (1996) found silver-haired bats mainly roosting in ponderosa pine and white pine (*Pinus monticola*). In British Columbia, Vonhof (1996) found silver-haired bats preferring to roost in trembling aspen and lodgepole pine (*Pinus contorta*). Parsons et al. (1986) described characteristics of a maternity roost of silver-haired bats from Ontario. The roost was located in a dead section of a basswood tree (*Tilia americana*) within an abandoned woodpecker hollow located 5.4 m from the ground.

In terms of landscape level choice, Betts (1998) found most roosts used by silver-haired bats in mature rather than young stands. Campbell et al. (1996) found roost sites located > 100 m from riparian areas, on slopes averaging 38%, and the slope aspect for 11 of 15 roosts within 70° of north. The maternity roost described by Parsons et al. (1986) was located within a mixed-wood stand dominated by sugar maple (*Acer saccharum*), eastern white cedar (*Thuja occidentalis*), and white birch (*Betula papyrifera*). The roost tree was located near (8 m) an actively used building, and approximately 500 m from a large (400 ha) marsh. Major foods of silver-haired bats include moths, true bugs, flies, beetles, and caddisflies (Kunz, 1982). Foraging typically occurs near conifer or mixed coniferous/deciduous woods that are located relatively close to a pond or stream (Schmidly, 2004).

The best available data on migratory behavior of the silver-haired bat comes from a study conducted by Barclay et al. (1988) that examined the roosting habits of females moving through Manitoba during spring. A total of 177 bats was located in 36 roosts in nearly as many trees (n = 32). Most bats roosted alone, although 15 pairs and eight groups of 3 to 6 bats were observed. Bats roosted in folds of bark and crevices in trunks, preferentially choosing large trees of species that were likely to have furrowed bark, splits, and cracks. Some roost sites were used on multiple occasions both within and between years. On several occasions, bats did not emerge from roosts on cold nights, suggesting that they wait for warmer temperatures before they continue migrating. Other documented spring roosts of silver-haired bats include a torpid bat found beneath ground debris in western Oregon (Sanborn, 1953), crevices in sandstone ledges, and a cave in West Virginia (Frum, 1953). The latter bats had enough food in their systems to suggest they had recently fed (Frum, 1953). Silver-haired bats have historically been seen migrating in large groups along the Atlantic coast (Miller, 1897; Mackiewicz and Backus, 1956), although specimen collections from Canada suggest they are also migratory in the western United States (Schowalter et al., 1978). Data from California and New Mexico suggest that silver-haired bats would be more common early in the summer (Jones, 1965), although there is evidence of non-migratory individuals throughout their range (Heady and Frick, 1999). Although this species does not hibernate to the extent of the cave bats, the use of torpor at low temperatures has been documented (Neuhauser and Brisbin, 1969)

2.3.3 Eastern red bat, *Lasiurus borealis*

The eastern red bat is a common resident of much of the United States and extends its range to Central and South America (Shump and Shump, 1982b). In Massachusetts, eastern red bats are likely found statewide (Godin, 1977), particularly during spring and fall migration, with records available for nine Massachusetts counties (Godin, 1977; MCZ museum records). Regional summer records (relative to the project site) exist from Worcester (Worcester County; 24 km southeast of MWCC; Godin, 1977), Surry (Cheshire County, NH; 55 km northwest of MWCC; J. Veilleux, unpublished data), and New Boston (Hillsborough County, NH; 48 km northeast of MWCC; LaGory et al., 2002; LaGory et al., 2008).

Eastern red bats are one of the best known migratory tree bats. In the spring, they migrate into the northern region of their distribution. During migration, they appear to use a variety of roosts; including woodpecker holes (Fassler, 1975) and leaf litter (Saugey et al., 1998; Boyles et al., 2003). Although this species does not hibernate to the extent of the cave bats, the use of torpor at low temperatures has been documented (Davis and Lidicker ,1956; Genoud, 1993).

During summer months, eastern red bats roost in the foliage of trees (Shump and Shump, 1982b; Whitaker and Hamilton, 1998). Neither adult female nor male eastern red bats are colonial, but roost singly during all times of the year (except for reproductive females roosting with their young; Mumford, 1973, Shump and Shump, 1982b, Hutchinson and Lacki, 2000). Females give birth and wean their young within these foliage roosts.

Three studies by Menzel et al. (1998), Mager and Nelson (2001), and Hutchinson and Lacki (2000) examined summer roosting habits of eastern red bats in Georgia/South Carolina, Illinois, and Kentucky, respectively. Menzel et al. (1998) located eastern red bat roosts in 18 tree species, but oaks (*Quercus* spp.) and sweetgum (*Liquidambar styraciflua*) were the preferred roost tree types. Mager and Nelson (2001) located eastern red bats in oaks, sweetgum, black walnut (*Juglans nigra*), maples (*Acer* spp) and hickories (*Carya* spp.). Hutchinson and Lacki (2000) located eastern red bat roosts in hickories, yellow poplar (*Liriodendron tulipifera*), American beech (*Fagus grandifolia*) and white oak (*Quercus alba*).

In terms of overall habitat preference, both Menzel et al. (1998) and Hutchinson and Lacki (2000) found that the majority of roost trees used by eastern red bats were located in hardwood forests and in upland areas. Roost trees are typically located relatively close to permanent water sources. For example, Hutchinson and Lacki (2000) reported roosts located at approximately 500 m or less from available water. Major foods of eastern red bats include moths, beetles, and leafhoppers (Schmidly, 2004). Foraging takes place above tree top level early in the evening, and eventually takes place at or below canopy level (Shump and Shump, 1982b).

2.3.4 Eastern pipistrelle bat, *Perimyotis subflavus*

The eastern pipistrelle bat occurs throughout much of the eastern United States, north to extreme southeastern Canada, and south through Honduras (Fujita and Kunz, 1984). The eastern pipistrelle is widely distributed in Massachusetts (records exist for seven counties), and likely occurs statewide where suitable habitat exists (Godin, 1977). Regional summer records (relative to the project site) exist from East Templeton (Worcester County; 5 km southwest of MWCC; Godin, 1977) and Harvard (Worcester County; 40 km east of MWCC: S. Reynolds, unpublished data). Additional records from adjacent counties include Erving (Franklin County; 40 km west of MWCC: S. Reynolds, unpublished data) and Surry (Cheshire County, NH; 55 km northwest of MWCC; J. Veilleux, unpublished data). Additional current distribution data for eastern pipistrelles relative to the MWCC project were requested from MADFW, but were not provided for this report.

During summer months female eastern pipistrelles typically form small maternity colonies (under 10 individuals) in dead leaf clusters or in live foliage (Veilleux et al., 2003), although larger (approximately 15 individuals) maternity colonies are also formed in buildings (Whitaker, 1998). In Missouri, maternity colonies have been reported from caves (Humphrey et al., 1976), but this is a very rare roosting behavior. In terms of roost tree preference, eastern pipistrelles prefer oak trees (*Quercus* spp.) over other available tree species, but maples (*Acer* spp.), yellow poplar (*Liriodendron tulipifera*), eastern cottonwood (*Populus deltoides*), and hackberry (*Celtis occidentalis*) are used relatively often as well (Veilleux et al., 2004a). Capture data indicate that eastern pipistrelles are captured with equal frequency in upland, riparian, and bottomland forests, but prefer to roost in trees within upland forests and riparian woodlands (Veilleux et al., 2003). Eastern pipistrelles appear to exhibit philopatry, including female natal philopatry. Veilleux and Veilleux (2004) reported individual female eastern pipistrelles returning to the same specific summer habitat area across years.

Female eastern pipistrelles give birth to two young, typically in late June through early July (Veilleux and Veilleux, 2004), and the young become volant at approximately three to four weeks of age (Whitaker, 1998). Summer foraging habitat includes bottomland hardwood forests, pine stands, and upland hardwoods (Carter et al., 1999). Eastern pipistrelles appear to remain relatively close to roost sites while foraging. Veilleux et al. (2003) reported minimum foraging distances ranging from 0.05 to 2.61 km (mean = 0.72 km) from roost sites. Major foods of eastern pipistrelles include leafhoppers, beetles, flies, and moths (Whitaker and Hamilton, 1998).

During winter, caves and mines are typically used as hibernation sites. Eastern pipistrelles tolerate warmer temperatures within their hibernaculum than most other bat species (Raesly and Gates, 1987; Briggler and Prather, 2003). This species does not form large hibernating congregations, but instead roosts singly or in small groups (Fujita and Kunz, 1984), although up to 750 individuals have been reported from a single hibernacula (Hicks, 2003).

Little is known of the migration behavior of eastern pipistrelles. Some researchers believe that individuals travel short distances from summering areas to local hibernacula (caves or mines), while others believe that the relatively high mortality rates of this species at some wind turbine sites may indicate a longer migration route along defined migratory pathways. The largest reported distance traveled by eastern pipistrelles from summer areas to winter hibernacula is approximately 137 km (Griffin, 1940). In Indiana, Veilleux et al. (2004b) reported that eastern pipistrelles first arrived at their summering areas during the first two weeks of May, and most individuals appeared to leave their summering area for their hibernation site by late August. In Missouri, LaVal and LaVal (1980) reported eastern pipistrelles leaving summering areas for hibernacula during late July through August.

2.4 Other Bats Likely to Occur Near the MWCC Wind Project Site

Each of the eight species regularly occurring in Massachusetts (Indiana myotis not considered a regularly occurring species in Massachusetts) have geographical ranges that occur with the Project county, or in the surrounding counties (Table 1). Neither listed species (the Indiana myotis and eastern small-footed myotis) have been identified as occurring within the Project region. Four species (hoary bat, silver-haired bat, eastern red bat, and eastern pipistrelle) that occur regionally have been identified as species at higher potential risk of turbine collision mortality (Section 2.3). None of the remaining three species (little brown myotis, northern myotis, and big brown bat) are provided federal or state legal protection . A brief summary of biology and known distribution of these three species is presented below.

2.4.1 Little brown myotis, *Myotis lucifugus*

The little brown myotis occurs throughout most of North America (Fenton and Barclay, 1980), and is one of the most common species encountered throughout its range. The little brown myotis is likely the most common species in Massachusetts and likely occurs statewide (Godin, 1977), with records available for 11 Massachusetts counties. Regional summer records (relative to the project site) exist from 12 towns in Worcester County (Godin, 1977; S. Reynolds, unpublished data), with additional records from adjacent counties, including two towns in Franklin County, four towns in Middlesex County, 7 towns in Hillsborough County, NH, and five towns in Cheshire County, NH (S. Reynolds, unpublished data).

In late spring and early summer, females form maternity roosts which are nearly always located in human made structures (e.g. barns, attics, etc.). Colonies can be small (under 100 individuals), but also may reach sizes of several thousand bats, with the largest known colony in the eastern United States (located in Pennsylvania) estimated at approximately 20,000 bats (Butchkoski and Hassinger, 2002). Females give birth to a single young between mid-June and mid-July (depending on latitude and regional climate patterns) within these maternity roosts, and young are volant and weaned by approximately 4 weeks old (Whitaker and Hamilton, 1998). In contrast to females, males do not roost with the nursery colonies, but rather roost alone or in small groups in other locations. These roosts are more variable, including buildings and other structures such as lumber piles, under tar paper, or even in caves (Fenton and Barclay, 1980). Forest edges along streams and lakes appear to be preferred summer foraging habitat (Fenton and Bell, 1979), and data indicate a foraging home range of up to 30 ha (Henry et al., 2002). In southeastern Canada, little brown myotis will travel up to 1 km from roosts to foraging areas (Henry et al., 2002). Major foods of the little brown myotis include midges, flies, beetles, leaf hoppers, caddisflies, and moths (Whitaker and Hamilton, 1998).

During winter, little brown myotis typically hibernate within caves and mines (Fenton and Barclay, 1980). There is variability in the timing that individuals arrive at and enter hibernacula in fall and exit hibernacula in spring. This variability follows a latitudinal gradient, with individuals entering hibernacula earlier and leaving later in the north, while the converse is typical at lower latitudes. For example, in Ontario, little brown myotis enter hibernation in early September and leave hibernacula by early to middle May (Fenton and Barclay, 1980). At lower latitudes, hibernation may not begin under November and end by mid-March (Fenton and Barclay, 1980). Regardless of when hibernation begins, individuals arrive at caves and mines (which may or may not serve as hibernacula) during early fall and initiate swarming behavior. During fall swarming, individuals gather in large numbers near the entrance to a cave or mine. Fall swarming behavior may function in mate choice and reproduction (i.e. the time of copulation), as well as familiarize juvenile bats with potential hibernacula (Fenton and Barclay, 1980). Soon after fall swarming, individuals enter their hibernaculum and commence hibernation. Raesly and Gates (1987) reported that the little brown myotis preferred hibernacula with temperatures near 7.5° C. Little brown myotis often prefer to roost on the side walls of hibernacula, rather than the ceiling (Raesly and Gates, 1987).

2.4.2 Northern myotis, *Myotis septentrionalis*

The northern myotis ranges throughout much of the eastern United States, and much of the lower Canadian provinces (Caceres and Barclay, 2000). This species is forest-dependent, and is likely widespread in Massachusetts (records are available for eight Massachusetts counties) where suitable habitat exists. Regional summer records (relative to the project site) exist from East Templeton and Harvard (Worcester County, 5 km southwest and 35 km east/southeast of MWCC, respectively), with additional records from adjacent counties, including two towns in Cheshire County, NH (J. Veilleux, unpublished data; S. Reynolds, unpublished data) and two towns from Hillsborough County, NH (LaGory et al., 2008; S. Reynolds, unpublished data).

During summer, the northern myotis roosts primarily within trees, either within tree hollows, crevices, or under exfoliating bark (Foster and Kurta, 1999). Tree species used as roosts are variable. In Michigan, major tree species used as roosts include silver maples (*Acer saccharinum*), red maples (*A. rubrum*), and green ash (*Fraxinus pennsylvanicus*). In Nova Scotia, major trees species used by northern myotis include sugar maple (*A. saccharum*), yellow birch (*Betula alleghaniensis*), and red spruce (*Picea rubens*; Broders and Forbes, 2004). In West Virginia, roost trees include red maple, northern red oak (*Quercus rubra*), sassafras (*Sassafras albidum*), American basswood (*Tilia americana*), Fraser magnolia (*Magnolia fraseri*), black cherry (*Prunus serotina*), and black locust (*Robinia pseudoacacia*; Menzel et al., 2002). In West Virginia, Owen et al. (2003) found that the majority of roost trees used by *M. septentrionalis* were located in intact forests (70-90 year old forests with no timber harvest activity within 10-15 years). Data indicate that the northern myotis forages within upland forested sites, rather than in lowland riparian woodlands or in bottomland forests (Harvey et al., 1999; Owen et al., 2003). Data from Owen et al. (2003) indicate a mean foraging area of 65 ha for reproductive female northern myotis. Females form small maternity colonies during summer, with less than 30 bats typically found in a particular roost (*see* Foster and Kurta, 1999; Menzel et al., 2002; Owen et al., 2003). Females give birth to a single young, with parturition commencing in early June and juveniles becoming volant by late-June (Feldhamer et al., 2001). No data are available that describe the migratory behavior of the northern myotis.

During winter, the northern myotis requires cave or mine habitat that provides adequate characteristics for successful hibernation. Such characteristics mainly include the proper microclimate (i.e. temperature stability) and a low level of human disturbance. During hibernation, the northern myotis often retreats into small holes, cracks, and crevices along the walls and ceiling (John Whitaker, Indiana State University, pers. comm.; Durham, 2000), although they will also cling to the wall and ceiling surface. It is unknown whether the northern myotis hibernates preferentially in caves and mines with large numbers of small crevices discussed above. Northern myotis are often found deeper within a mine shaft (Durham, 2000), although it is not clear what influences this preference. Northern myotis bats are known to use caves and mines year-round and often maintain some activity throughout the winter months (Whitaker and Rissler, 1992).

2.4.3 Big brown bat, *Eptesicus fuscus*

The big brown bat occurs throughout the entire United States, where suitable roosting habitat exists (Kurta and Baker, 1990). Following the little brown myotis, the big brown bat is the next most common bat species in Massachusetts and likely occurs statewide (Godin, 1977), with records available for 11 Massachusetts counties. Regional summer records (relative to the project site) exist from six towns in Worcester County (Godin, 1977; S. Reynolds, unpublished data), with additional records from adjacent counties including 17 towns in Middlesex County, MA (S. Reynolds, unpublished data), 12 towns in Hillsborough County, NH (LaGory et al., 2008; S. Reynolds, unpublished data) and two towns in Cheshire County, NH (J. Veilleux, unpublished data; S. Reynolds, unpublished data).

During summer, populations of big brown bats in eastern North America typically roost within human related structures (attics, barns, etc.), while in western North America roost in buildings, as well as trees, rock outcrops, and other natural roosts (Kurta and Baker, 1990). In the east, females form maternity roosts to give birth to young; these roosts range in size from several dozen up to 600 bats (Whitaker and Hamilton, 1998). Males are mainly solitary during this period, and may roost in the same building as the maternity colony, but not within the colony itself (Whitaker and Hamilton, 1998). In the east, females give birth to two young, typically during late May through the middle of June (parturition may occur earlier at warmer, southern latitudes). Young are volant and weaned by approximately four weeks old (Whitaker and Hamilton, 1998). Big brown bats forage in a variety of habitats, including over water, along woodland edges, within woodlands, and in urban areas (Kurta and Baker, 1990). In Alberta (Canada), big brown bats were found to prefer riparian habitat for foraging, over prairie or urban habitats (Wilkinson and Barclay, 1997). Foraging distances for big brown bats range from 1 to 2 km, and individuals often forage at a height of approximately 50 m early in the evening, and descending to under 15 m later in the evening (Kurta and Baker, 1990). The major food item of big brown bats is beetles, although leafhoppers, ants, caddisflies, mayflies, and flies are consumed as well (Whitaker and Hamilton, 1998).

During winter, eastern populations of big brown bats hibernated in cave and mines, as well as in buildings with suitable attic temperatures. Hitchcock et al. (1984) reported that big brown bats prefer to hibernate in the cooler sections of hibernacula located in southeastern Ontario. Raesly and Gates (1987) reported a mean hibernacula temperature of 7.1° C where big brown bats were found roosting. Many big brown bats hibernate singly, but small groups are often formed as well (Kurta and Baker, 1990)

3.0 MIGRATORY BEHAVIOR OF BATS

Insectivorous bats that inhabit temperate forests of North America during the summer months face important challenges as the seasons change. During winter, insect prey (energy) is generally unavailable, and these species are unable to fulfill the energetic requirements of remaining active. Therefore, these species generally avoid the energetic stresses of winter in one of three ways: 1) by hibernating at regional caves, mines, or other suitable hibernacula, or 2) by migrating into different latitudes where prey sources remain available (Cryan and Veilleux, 2007), and 3) by migrating into different elevations where prey sources remain available. Although considerable variation exists in migratory behavior, North American migratory bats can be categorized into two general groups: long-distance and short-distance migrants. Long-distance migratory species include the 'tree bats', such as the eastern red bat (*L. borealis*), hoary bat (*L. cinereus*), and the silver-haired bat (*Lasionycteris noctivagans*). Some individuals of these species undergo seasonal trans-continental migrations, traveling hundreds of miles between winter and summer habitat areas. Upon reaching their wintering grounds, some individuals remain active if insect prey is available, while others may enter torpor for prolonged periods. Short-distance migrants include those species that travel from summer habitat areas to regional caves, mines, and other suitable structures that serve as hibernation sites during late fall through early spring. Regardless of migration strategy, individuals undergo such movements twice per year: once when leaving wintering ground for summering areas, and another for the return trip from summer to wintering grounds.

3.1 Long-Distance Migratory Bats

Seasonal migrations of long distance migratory bats can surpass 500 km in each northward and southward direction. Unfortunately, the lack of suitable technology (e.g. miniature satellite transmitters) limits our current understanding of migration behavior and movement patterns in these species. Despite the lack of extensive data (although see Cryan, 2003), it is believed that most of the tree-roosting bat species have extensive migratory ranges. Forty-six bat species occur north of Mexico, and over half (n = 24) are known to use trees as roosts during some portion of the year (Kunz and Reynolds, 2004). The majority of these species roost in trees only during late spring through early autumn before moving to caves, mines, buildings, or other structures for the winter. Such species enter long-term torpor bouts during winter within these thermally stable sites and are often referred to as either "hibernating" or "cave" bats. This section focuses on the classic tree- and foliage-roosting bats within the Family Vespertilionidae that are found in the eastern United States. These species include the eastern red bat (*L. borealis*), the hoary bat (*L. cinereus*), and the silver-haired bat (*Lasionycteris noctivagans*). Data on the distribution of tree bats indicate that few leave the continent during winter and it is likely that individuals use torpor to some degree while within their winter range.

During the winter, North American tree bats generally occur at latitudes below 40ºN and in coastal regions where freezing temperatures are infrequent. Species-specific data are presented in Section 2.3 for all the eastern migratory tree-roosting bats. However, our knowledge of migratory behavior and winter roosting habits is incomplete because tree bats use torpor, roost in situations where they are not readily observed, and are rarely sought out by biologists during winter. Thus far, it has been ineffective to use banding efforts to determine detailed movement patterns in tree bats. However, mapping regional distribution records (Cryan, 2003; Findley and Jones, 1964) and analysis of stable isotopes (Cryan et al., 2004) have helped reveal patterns of bat migration. Cryan (2003) used museum data to summarize the potential seasonal movements of several tree-roosting bats in North America. Four important patterns emerged in the seasonal distributions of these wide-ranging species, including, 1) the migration route of each species is apparently contained within the continent of North America (i.e. there is no mass movement of individuals to extreme south latitudes, 2) individuals of each species may occur in the majority of available forested habitat in North America (within their geographic range) during some part of the year, 3) the timing and nature of local habitat usage, as well as the population structure of bats in a particular area, will vary regionally, and 4) there are apparent differences in the migratory movements of males and females. Specifically, females appear to migrate in advance of the males, travel greater distances, and often exhibit disparate distributions from the males. For example, data from the hoary bat and silver-haired bat suggest sex-biased summer distributional differences in the range of hundreds of kilometers (Cryan, 2003; Findley and Jones, 1964). Data pertaining to the seasonal whereabouts and migratory movements of these species are lacking.

3.2 Short-Distance Migratory Bats

Although the longest migratory patterns are typically seen in the tree-roosting bats, the majority of data that describe migration come from mark-recapture (banding) studies using colonial species (e.g., Brazilian free-tailed bat, cave myotis, and little brown myotis) that winter in caves. Although we have categorized these as 'short-distance migratory bats', several studies have documented long-distance movements of individuals. For example, banding studies of little brown myotis (Humphrey and Cope, 1976) and the Indiana myotis (Kurta and Murray, 2002) revealed travel distances between winter and summer habitats of 455 and 532 km, respectively. Detailed reviews of seasonal movement patterns of colonial hibernating bats can be found in Griffin (1970), Baker (1978), and Fleming and Eby (2003). However, bat species that winter in subterranean structures generally make shorter migrational movements, and those movements are less influenced by latitude, than tree bats (Baker, 1978). Such subterranean roosts are thermally stable and roost microclimate is relatively independent of latitude compared to aboveground structures. Hence, the autumn migratory movements of bat species that hibernate during winter in underground sites are typically influenced by geography, and oriented toward nearby regions with suitable conditions for hibernation rather than areas with warm surface temperatures.

3.2.1 Hibernating Bats

The best data on short-distance migratory bats comes from the Family Vespertilionidae. In particular, the best historic data on migration come from the seasonal movement of hibernating *Myotis* bats. Most of these data were collected as the result of large-scale mark-recapture studies conducted on the east coast. These include research conducted by Davis and Hitchcock (1965) in Vermont, which showed the little brown myotis radiated up to 300 km from a single hibernaculum to at least seven states and the province of Quebec. Their data also suggested that most of the bats were using a narrow migration corridor. Data from Indiana (Humphrey, 1971) suggest that individuals are capable of migrating over 450 km to reach their summer foraging areas. More recent data from Pennsylvania (Chenger, 2004) suggests these bats "carefully avoided high elevation hilltops" during the spring migration.

3.2.2 Regional and Elevational Migrants

Other species remain semi-active by migrating regionally into more moderate climates (towards the coast, into lower elevation, or migrating into more southern latitudes). In their wintering range, they may become torpid (inactive) during cold periods and feed on warmer nights. Other species may migrate into colder climates (moving inland or to higher elevation sites) and remain inactive throughout the winter months. Furthermore, migration along gradients of elevation may occur in hibernating or migratory species (Cryan et al., 2000). For example, big brown bats (*Eptesicus fuscus*) that spend the warmer months in buildings around Fort Collins, Colorado (elevation 1,500 m) move into the nearby Rocky Mountains during autumn, where they spend the winter in rock crevices at higher-elevation (> 1,600 m) sites (D. Neubaum, U.S. Geological Survey, pers. comm.).

3.3 Evidence of Bats Migrating in Groups

Although mainly solitary (*Lasiurus* spp.) or forming small colonies (*L. noctivagans*) during summer, data indicate that some tree bats migrate in groups (Fleming and Eby, 2003) and may even form mixed species groups or 'flocks' similar to migratory birds. For example, Mearns (1898) reported "great flights of [red bats, *L. borealis*] during the whole day" in the Hudson Highlands of New York. During late September in Washington D.C., Howell (1908) reported a diurnal migration of what he presumed to be red bats and/or silver-haired bats. Several reports of flocking behavior in tree bats indicate migratory movement. Carter (1950) reported two red bats collected in late September from a flock of an estimated 200 bats that circled a ship 65 miles off the New England coast. During early September, Thomas (1921) reported silver-haired bats and red bats being collected from a group of approximately 100 bats that landed on a ship 20 miles off the North Carolina coast. Byre (1990) observed groups of two to four individuals of silver-haired bats and red bats during autumn mornings as they reached shoreline following an apparent migration over Lake Michigan. Reports of daytime flights of hoary bats are available from Minnesota (Jackson, 1961) and Nevada (Hall, 1946).

Observations of roosting bats also provide evidence of larger aggregations and mixed-species groups during migration. Roosting groups of migrating hoary bats on Southeast Farallon Island, approximately 32 km off the coast of California, sometimes number up to 60 individuals in a single tree (A. Brown, *pers. comm.*). During late August in the North Bay Area of California, Constantine (1959) found a group of approximately 15 western red bats (*L. blossevillii*) roosting in an apricot tree, whereas none were found in the area later in winter. Grinnell (1918) noted "many" western red bats roosting together with a hoary bat during April in California.

Survey efforts have documented both spring and autumn migratory "waves" of tree bats moving across a landscape; these data show multiple individuals being captured (Barclay et al., 1988; Findley and Jones, 1964; Mumford, 1963; 1973; Vaughan, 1953) or acoustically detected (Reynolds, 2006) within a relatively short time period. The details of how North American tree bats form and maintain aggregations during migratory periods are unknown, but evidence of communication does exist. Downes (1964) observed red bats using specific roost sites during autumn and noted that different individuals somehow found and used the exact same roost on subsequent days. Constantine (1966) observed a similar phenomenon where both red bats and hoary bats used the same foliage roost on different days. In Georgia, Seminole bats (*L. seminolus*) and red bats also used the same roost, although others were available (Constantine, 1958). Barclay et al. (1988) noted that migrating silver-haired bats somehow (e.g., olfactory clues) found roosts previously used by others but, as with all of these cases, were unable to determine the method of communication.

Although tree bats sometimes possess fat reserves during autumn and winter (Gosling, 1977; Layne, 1958; Tenaza, 1966; van Gelder, 1956), some species apparently feed during autumn migration. Miller (1897) observed both silver-haired bats and red bats foraging during a migration stopover on the Atlantic Coast and a female hoary bat collected while migrating through Florida was feeding during late October (Zinn and Baker, 1979).

3.4 Potential Threats to Migratory Bats

There are certain factors that make migratory bats particularly susceptible to population decline (Fleming and Eby, 2003). First, migratory bats often require contiguous, yet seasonally distinct, habitats that sometimes span hundreds of kilometers along their annual migration pathway. Degradation of a single region along such annual circuits has the potential to negatively impact populations that move through the area. For example, if some disturbance along a migration corridor disrupts the ability of bats to locate summering grounds, hibernacula, or mating grounds, individual fitness may be reduced and mortality increased. Secondly, bat populations may concentrate in small areas during migration, rendering them vulnerable to mass mortality events. There is currently no means by which to monitor the population status of migratory tree bats (O'Shea and Bogan, 2004), nor do we possess a clear understanding of their habitat needs or mortality risks during migration and winter.

Evidence indicates that tree bats may sometimes migrate with, or under similar conditions as, birds and therefore be susceptible to similar mortality factors. For example, dead red bats were found among migratory birds that washed ashore after both spring and autumn storms on Lake Michigan (Mumford, 1973; Mumford and Whitaker, 1982). There are numerous reports of tree bats found among dead birds that collided with human-made structures. Most of these incidents transpired during autumn and involved multiple species: silver-haired bats, red bats, and hoary bats at a lighthouse on Lake Erie (Saunders, 1930); red bats at a television tower in Kansas (van Gelder, 1956); red bats, hoary bats, Seminole bats, and eastern yellow bats at a television tower in Florida (Crawford and Baker, 1981); red bats and silver-haired bats at a building in Chicago (Timm, 1989); and red bats at the Empire State Building in New York City (Terres, 1956). For many of these collision events, tens to hundreds of birds were reported as killed, whereas only a few bats were encountered. For example, Crawford and Baker (1981) reported 54 bats killed on 49 nights over 25-year monitoring period and Timm (1989) reported 79 bats killed over an 8-year period. In addition to the perils of collisions during flight, migrating bats may be susceptible to predation both during migration and on the wintering grounds. Stomach contents of predators captured during winter revealed the remains of both *L. noctivagans* and *L. borealis* (Sperry, 1933). If trees with adequate roost sites are not available during migration or on the wintering grounds, torpid bats may be vulnerable to higher rates of predation. Unlike the mortality data from buildings, wind turbines appear to impact migratory tree bats at high rates. Although the causes of this mortality are unknown, wind turbines clearly represent an additional mortality risk for these species.

4.0 SOURCES OF MORTALITY FOR BATS

Potential sources of mortality for bats are numerous, but observations concerning mass mortality, predation, or accidents are sporadic at best (Booth, 1965, Gillette and Kimbrough, 1970). Potential impacts on bats include many species of opportunistic predators, including mammals, birds, reptiles, amphibians, fish, and insects (summarized in Gillette and Kimbrough, 1970). All the available data suggest that predation is not a significant source of mortality for bat populations due to the fact that predators are opportunistic and have only a localized impact on bats. Bats are also known to succumb to several abiotic factors such as cold stress, hypothermia, and collisions with vegetation (Gillette and Kimbrough, 1970; Reynolds, pers. obs.), but again these events are generally considered to be relatively infrequent and minor at the population level and the cumulative impact of these stresses are likely to be localized (for a given hibernaculum or maternity colony) and age-dependent (due to the lower fat loads and agility of young bats). In fact, the only natural source of mortality that appears to play a large role for bats is over-winter mortality (Davis and Hitchcock, 1965).

Bats are also susceptible to the impact of humans on their environment, including pesticide poisoning (Geluso et al., 1976; Clark et al., 1988), traffic casualties (Kiefer et al., 1995), collisions with fixed structures (see Section 3.4), habitat fragmentation or loss (Grindal and Brigham, 1988), and disturbance during hibernation (Johnson and Brack, 1998). For commensal (house-roosting) species such as the big brown bat (*Eptesicus fuscus*) and the little brown myotis, the impact of physical exclusions and other pest control operations probably represents the largest population-level source of mortality (Kunz and Reynolds, 2004). Although there is some evidence for a decline in the abundance of house-roosting bat species (Kunz and Reynolds, 2004), historical data for non-commensal species is sporadic at best. Data from winter hibernation surveys (containing both commensal and non-commensal species) throughout New England and New York over the last ten years suggests a slightly increasing wintering population. Although part of this increase is due to conservation efforts at several major hibernacula (Trombulak et al., 2001), most of the sites have seen stable or increasing populations despite not receiving any form of physical protection. Unfortunately, little historic data exist for the non-hibernating migrating species.

5.0 THE IMPACT OF WIND POWER ON BATS

Data from wind projects throughout the United States have shown that bats and birds collide with wind turbines. A summary of bat mortalities at nineteen wind projects in 15 states and several international sites show estimated annual mortality rates between 0.1 – 63.9 bats per turbine (Table 4). Concern has been raised over the level of bat mortality experienced at several sites in the eastern United States, and existing data suggest eastern wind development sites experience higher rates of bat mortality than western sites (Johnson, 2005). These post-construction mortality surveys have shown that the migratory bats are more susceptible to wind turbines than other bats (Gruver, 2002; Johnson et al., 2003a). The migratory bats, specifically the hoary bats, red bats, and silver-haired bats account for 52%, 24%, and 9%, respectively, of all reported bat mortalities. Temporal analysis of these same data show that most of this mortality occurs in the month of August (53.8% of total mortality) when these bats would be beginning their fall migration. Therefore, the distribution and timing of mortality seems to be biased toward non-hibernating migratory bats.

Table 4: Overall of Turbine-Related Bat Mortality at Wind Resource Areas

Project Name	No. turbines	Completion Date	Estimated mortality [1]	References
Buffalo Ridge, Phase 1 (MN)	73	1998	0.3	Johnson et al., 2003a
Vancycle (OR)	38	1999	0.7	Erickson et al., 2000
Castle River (Alberta, CA)	41	2001	0.9	Barclay et al., 2007
Buffalo Mountain (TN)	3	2001	20.8	Fiedler, 2004
Butler Ridge (WI)	33	2001	4.3	Howe et al., 2002
Pickering (Ontario, CA)	1	2001	10.7	Barclay et al., 2007
Klondike Phase I (OR)	16	2002	1.2	Johnson et al., 2003b
Foote Creek Rim (WY)	105	2002	1.3	Young et al., 2003
Buffalo Ridge, Phase 2 (MN)	281	2002	3.0	Johnson et al., 2004
Nine Canyon (WA)	37	2003	3.2	Erickson et al., 2003
High Winds (CA)	90	2003	3.4	Kerlinger et al., 2006
McBride Lake (Alberta, CA)	115	2003	0.5	Barclay et al., 2007
Top of Iowa (IA)	89	2003	5.9	Koford et al., 2005
Mountaineer (WV)	44	2003	47.5	Kerlinger and Kerns, 2004
Meyersdale (PA)	20	2004	23.0	Arnett, 2005
Mountaineer (WV)	44	2004	38.0	Arnett, 2005
Freiburg (Germany)	32	2004	37.1	Brinkmann et al., 2006
Summerview (Alberta, CA)	39	2004	18.5	Barclay et al., 2007
Buffalo Mountain (TN)	15	2004	63.9	Fiedler et al., 2007
NPPD Ainsworth (NE)	15	2005	1.91	Derby et al., 2007
Maple Ridge (NY)	195	2006	24.5	Jain et al., 2007
Judith Gap (MT)	20	2006	13.4	TRC, 2008
Locust Ridge (PA)	13	2007	43.0	Whitten, unpublished

1. *bat mortality per turbine per migratory season*

It is difficult to identify the key physiogeographic features that increase bat mortality at any proposed wind turbine project. However, the three sites with the highest rates of bat mortality are in the east coast. Across the east coast, there also appears to be more mortality at the southern sites. Given the negative correlation between bat biodiversity and latitude (Heithaus et al., 1975), it is possible that these sites are causing more mortality because bats are more abundant in this region. These studies also identify a knowledge gap that results from the absence of baseline population surveys or migratory surveys. Without knowing how many bats are resident or migrating near a wind turbine project, the significance of any mortality that occurs at a site cannot be accurately assessed.

The reasons for such disproportionate kills during autumn are unknown. Curiously, unusual encounters with migrating tree bats typically happen during autumn rather than spring (Cryan, 2003). It is possible that spring migration by tree bats is relatively low-altitude, whereas autumn movement occurs at greater heights. For example, hoary bats fly low (1-5 m off the ground) within riparian areas while migrating through New Mexico during spring, but apparently not during autumn (P. Cryan, *in prep.*). Similarly, Reynolds (2006) documented hoary bats flying low (<10 m off the ground) during spring in New York. In contrast, a hoary bat collided with an airplane 2,438 m above Oklahoma during October (Peurach, 2003).

6.0 EXISTING DATA RELEVANT TO THE PROPOSED PROJECT

The data on the potential impact of wind development on bats is constantly improving, and there are data available from several wind power projects that have received or are seeking regulatory approval. Although the data collected from the MWCC project site has not been analyzed to date, there are data from other wind projects that should be informative for identifying potential risks at the Project site.

6.1 HOOSAC Wind Project (Massachusetts), 2006

The Hoosac Wind Project is a proposed 20-turbine wind farm in Berkshire and Franklin Counties of western Massachusetts. The project has two turbine fronts (Bakke Mountain and Crum Hill) which run north-northeast along the Hoosac Range in the Taconic Mountains Ecoregion at an elevation of up to 867 m asl. The Hoosac Wind Project is located approximately 25 miles north of the Chester Mine complex (containing *M. leibii*) and approximately 35 miles east of Hale's Cave (Albany, New York) where approximately 500 *M. sodalis* hibernate.

NEES and Bat Conservation International (BCI) began a long-term pre-construction acoustic monitoring project at the Hoosac site in 2006 using five meteorological towers situated across the project site. Bat activity was divided into high frequency bats (HIGH; *Myotis* bats, red bats, and eastern pipistrelle) and low-frequency bats (LOW; big brown bat, hoary bat, and silver-haired bat). Data from these four towers revealed that bat activity was generally highest in the early evening with seasonal peaks in late July, early August, and mid-September (Arnett et al., 2007). The low microphones (10 m altitude) had more total bat activity and this activity was predominantly from the HIGH bats. The high microphones (39 m altitude) had less total activity but a higher proportion of LOW bats. The data show that bat activity is correlated with wind speed and ambient temperature, with HIGH bat activity more sensitive to temperature than LOW bat activity.

6.2 Locust Ridge Wind Project (Pennsylvania), 2006-2008

The Locust Ridge I wind project is a 13-turbine project that runs 12.7 km along the ridge of Locust Mountain in Schuylkill County. Pre-construction acoustic monitoring was initiated on 06 April, 2006 and operated continuously until 06 December, 2006, for a total of 245 days of sampling. Acoustic monitoring was performed using two vertical acoustic arrays set up on existing meteorological ('met') towers at the site. Three microphones were installed on each met tower and designated as Low (10m), Mid (30m), and High (49m); see Reynolds (2006) for system details. There was no bat activity detected for the first five days of monitoring, and very little activity detected after mid-October, suggesting the entire active period was monitored at the project site (Reynolds, 2007). Data revealed a general increase in bat activity in late July and early August, more bat activity near the ground than in the rotor-swept zone (5.7 calls/night vs 1.2 calls/night), and almost twice as much bat activity on the eastern side of the project relative to the western side. *Myotis* bats represented almost 35% of all calls and were 10-fold more likely to be heard at the Low microphones relative to the High microphones. The migratory tree bats were the dominant bats heard within the rotor sweep zone, with activity peaking in late July for the East Tower and early September for the West Tower.

Post-construction carcass surveys were supervised by Dr. Howard Whitten of East Stroudsburg University, Pennsylvania. These surveys were conducted from 01 May through 17 November at the project site following protocols from the Pennsylvania Game Commission's Wind Energy Voluntary Cooperative Agreement. A total of 202 daily mortality surveys were conducted, resulting in the documentation of 211 bats and 10 bird carcasses. The total estimated mortality at the project site was 391 bats per year. Six bat species were documented, including the red bat (32%), hoary bat (28%), eastern pipistrelle (16%), silver-haired bat (14%), big brown bat (5%), and little brown myotis (5%). Temporal analysis of the carcasses show a large increase in bat mortality beginning the first week in August and remained high into the second week of September. Too few bats were found on the nets to reach any conclusions about their effectiveness as a sampling protocol.

6.3 Mountaineer Wind Project (West Virginia), 2003-2004

The Fall 2003 post-construction mortality survey was a watershed event that raised concern among the wind industry and state and federal agencies. Prior to this survey, turbine-related bat mortality was generally considered low and unlikely to impact local populations. However, the Mountaineer survey found 475 dead bats (estimated to represent a total actual mortality of 2,092 bats) at an estimated mortality rate of 47.5 bats per turbine (Kerlinger and Kerns, 2004). Similar levels of mortality were documented during the Fall 2004 migratory period (38 bats/turbine: Arnett, 2005). Most of the bats that were killed were migratory bats such as the hoary bat (33%) and the red bat (24%). There were also a significant number of migratory hibernators such as the eastern pipistrelle (24%) and little brown myotis (13%). Although the sampling interval was limited, temporal analysis from both years suggests that most of the mortality occurred in August. It is also known from the transect surveys that most bat carcasses were found within 30m of the base, with 42% found within 15m of the base. The mortality was also distributed across the site, with 43 of the 44 turbines causing at least one collision event (Kerlinger and Kerns, 2004).

6.4 Meyersdale Wind Energy (Pennsylvania), 2004

The Meyersdale Wind Energy Center is a 20-turbine wind facility located in Somerset County, Pennsylvania. Meyersdale is located on a ridgetop at approximately 850m asl and began operation in December 2003. In the fall of 2004, Meyersdale was part of an extensive study on the impact of wind projects on bat mortality (Arnett, 2005).

During a six-week period starting in August, 262 bat carcasses were located with a 500 search hour sampling effort. Similar to Mountaineer, the mortality was predominantly hoary bats (46%), red bats (27%), and eastern pipistrelles (7.7%). Total *Myotis spp*. mortality was lower at Meyersdale than at the Mountaineer location. The overall mortality rate was estimated at 13.1bats/turbine/season in 2004 (Arnett, 2005).

6.5 Casselman Wind Energy (Pennsylvania), 2006

The Negro Mountain project site (Casselman Project) is a 23-turbine wind project in Somerset County, Pennsylvania. The project consists of two turbine strings, with 15 turbines on the western string and 8 turbines on the eastern string (Arnett et al., 2006). The project site is within the Appalachian mixed mesophytic forest, with most of the western turbines in dense second-growth hardwood forest habitat and all of the eastern string turbines on open grassland on a reclaimed coal strip mine. A multi-year research project is currently underway at the project site under the coordination of Ed Arnett from Bat Conservation International. Currently, there are 12 monitoring platforms at the Casselman study site (5 met towers and 7 portable towers) that are monitoring bat activity at the project area.

The first set of data was completed in 2006. During the period of August 01 through November 01, a total of 9,162 bat calls were recorded across the project site. This results in an acoustic activity average of 3 calls/night/tower across the project site for high-frequency bats and 2.5 calls/night/tower for the low-frequency bats. Most of the bat activity was recorded from mid-August through mid-September but the pattern was highly variable across each night. Most of the bat activity was heard soon after sunset and declined throughout the evening until sunrise. The preliminary findings of these data are that 1) most of the acoustic activity occurs at the ground level (1.5m) microphones, 2) most of the variation between towers occurs at the ground-level microphone, 3) there was more bat activity in the forest habitat (versus the grassland) at the ground microphone and the canopy (22m) microphone, but not at the rotor height microphone, 4) there was relatively little spatial variation in bat activity at the rotor height microphones (44m) in terms of habitat or tower location. Comparison of bat activity data with weather data suggests that bat activity increased with increasing ambient temperature, but that most of this increase was documented at the ground microphone. Bat activity appeared to decline with increasing wind speed across all habitats and microphone heights, with an 11% - 39% decrease in bat activity for each 1 m/s increase in wind speed.

6.6 Maple Ridge Wind Project (New York), 2004-2008

The Maple Ridge Wind Project is a 198 turbine project that began operation in 2006. The area encompassed approximately 67 km^2 within the Northeastern Highland Ecoregion of western New York (Omernik, 1987). Vegetation within the study area was Northern Hardwood Forest, although much of the current regional land use was devoted to agricultural crops. The Maple Ridge study site has a mean elevation of 545 m above sea level (asl), rising from 300 m asl at the eastern margin up to 600 m asl along the western edge of the plateau. The wind energy project was 32 km southeast of a Priority II hibernaculum for the endangered Indiana myotis and wholly within the geographic distribution of the eastern small-footed myotis, a New York State Species of Special Concern. This combination of cropland, lowland forest, mixed hardwood forest, and slow-moving water made the Tug Hill Plateau, and the adjacent Black River watershed, potential roosting and foraging habitat for most of the bat species found in the Northeast.

Pre-construction research was conducted at this site by North East Ecological Services in 2004, and all data outlined below are from Reynolds (2006). Mist nets and ground-level acoustic monitoring were used across the Project site from 22 June through 05 July, 2004. A total of 35 bats of 3 species were captured during 130 net-nights across 24 sampling sites, yielding a 0.3 bats/net-night capture success. A total of 4,259 bat passes were recorded during 208 detector-hours across 28 sampling sites, yielding a mean activity level of 20.6 calls/hr. The median activity level was only 6.2 calls/hr across the project site, with 96% of the calls from *Myotis* spp. bats. Migratory behavior was acoustically monitored during the spring 2005 migratory season (10 Apr through 22 Jun) at two locations using vertical acoustic arrays set up on a 50m meteorological tower. A total of 459 bat passes were recorded during 5,328 hours of acoustic monitoring, yielding an acoustic capture rate of 0.09 bat passes/hr. Major findings of this study were that 1) most of the variation in migratory activity was temporal, 2) bat activity generally declined with altitude across the three sampling heights, 3) there are high-activity events that could represent migratory flocks of bats moving across the project site, 4) bat migratory activity decreased with increasing wind speed, with most of the activity occurring on days with minimum wind speeds below 1.2 m/s, 5) bat migratory activity increased with higher ambient temperatures, 6) wind direction did not appear to influence migratory activity levels.

Post-construction monitoring has been conducted at the Maple Ridge project site from 2006 through November, 2008. Mortality data from 2005 and 2006 have revealed a mortality rate of 24.5 bats/turbine/year, with most of the mortality during the late summer and fall migratory period (Jain et al., 2007). NEES, in cooperation with the New Jersey Audubon Society, has been conducting long-term bird and bat monitoring at the Maple Ridge project site to help identify the causes of these mortality events, but these data have not yet been analyzed.

6.7 Overview of Data Relevant to the MWCC Wind Project

An overview of six comparison sites outlined above represent a summary of some of the potentially relevant wind development projects that may be informative for the MWCC wind project. The data represent the complete spectrum of activity, from pre-construction field surveys (Hoosac, Locust Ridge, Casselman, and Maple Ridge) through post-construction mortality surveys (Mountaineer, Meyersdale, and Maple Ridge). Although the sites differ in location, elevation, habitat, and size and type of turbines, there are consistencies between them:

1) migratory tree bats (hoary bat, red bat, silver-haired bat) appear to be at the greatest risk of turbine collision;
2) when measured, bat migratory activity appears to decrease at high wind speeds and increase with high ambient temperatures
3) when measured, most of the variation in bat migratory activity appears to be temporal (across the migratory season) and vertical (more bats at lower microphones) rather than spatial (at different locations across the project site).

6.8 Other Data Relevant to the Construction and Operation of the MWCC Wind Project

In addition to the findings summarized in Section 6.7, there are other data available that may be relevant to the construction or operation of the MWCC Wind Project.

6.8.1 Current Hypotheses on the Cause of Wind-Related Bat Mortality

There are currently twelve hypotheses relating to why bats collide with wind turbines (Kunz et al., 2007):

a. Linear Corridor Hypothesis – the linear corridors produced during the construction of wind projects creates linear landscape elements that attract bats during summer foraging and seasonal migration;
b. Roost Attraction Hypothesis – turbines are tall and conspicuous and perceived as potential roosts by bats;
c. Landscape Attraction Hypothesis – modifications to the landscape that occur during construction of the wind project, such as access roads and clearings, create favorable habitat that attracts bats;
d. Insect Attraction Hypothesis – insects are attracted to the white turbines, or heat generated from the turbines, and bats are struck by the rotating blades while foraging on these insects;
e. Motion Attraction Hypothesis – bats are attracted to the movement of the turbine blades visually or through the production of false echolocation targets;
f. Visual Attraction Hypothesis – bats, or the insects they prey upon, are attracted to the physical characteristics of the turbines (color, FAA lighting, etc.) and are struck by the rotating blades when in their proximity;
g. Acoustic Attraction Hypothesis – bats are attracted to sounds produced by the turbines (audible or ultrasonic);
h. Echolocation Failure Hypothesis – migratory bats fail to detect wind turbines while flying in proximity to them;
i. Visual Distortion Hypothesis – lights reflecting off the white turbine blades alter celestial or other visual cues used by bats during migration;
j. Electromagnetic Field Distortion Hypothesis – wind turbines produce complex EM fields near the nacelle that disorient migratory bats;
k. Decompression Hypothesis – bats flying near turbines would pass through the helical vortex wake, causing injury or disorientation;
l. Thermal Inversion Hypothesis – the migratory altitude of bats is influenced by thermal inversions on a large scale, and may also be influenced by small scale inversions created by the turbines;

The first seven hypotheses all presume that bats are attracted to some features of a wind project such that there local abundance would increase after construction of a project. Bach (2001) found that some bat species appear to be more abundant following construction of wind turbines, and attributed this attraction to the increase in linear elements (Hypotheses 1 and 3). However, he also noted that the bats modified their foraging behavior (flying closer to the ground) to reduce their risk of impact (Bach, 2001). Ahlén (2003) has also shown that wind turbines typically generate infrasound rather than ultrasound, and that bats show no attraction to such noise (Hypothesis 7).

Data collected in the northeast and throughout the mid-Atlantic Highlands shows that migratory bats do echolocate. Data collected by Ahlén (2003) in Sweden also show migratory bats echolocating. These data, in conjunction with the relatively low mortality associated with communication towers, buildings, and other fixed structures, suggests that it is unlikely bats are colliding with wind turbines due to their inability to detect the towers.

Collectively, there is little data available to evaluate any of the hypotheses put forward by the BWEC committee, and many of the hypotheses are not mutually-exclusive. However, they do represent some of the most reasonable proximate factors that may be causing the high levels of bat mortality seen at some wind projects. In addition to these hypotheses, Barclay et al. (2007) has suggested that tower height may play a significant role in the increased bat mortality seen at wind projects over the last five years.

6.8.2 The National Research Council Assessment

The National Research Council (NRC) was charged by Congress to address the impact of wind development on bats. The NRC report provides recommendations for both pre-construction analysis and post-construction surveys (NRC, 2007). The siting assessments outlined by the NRC include evaluation of the cumulative impact of wind development across the mid-Atlantic Highlands. However, in the absence of federal coordination of research efforts, the lack of certainty about federal energy policies, and a general lack of baseline research that is beyond the resources of individual developers, the NRC concedes that pre-construction assessments that accurately predict population-level impacts are difficult to achieve (Kunz et al., 2007).

In reference to post-construction monitoring, the NRC recommends multi-year, full-season evaluations of mortality that includes an assessment of the number, composition, and timing of mortality across the project site (NRC, 2007). These data should then be used to look at small-scale and large-scale impacts on bats and inform adaptive management options and experimentation on mitigation techniques (NRC, 2007). The NRC also recommends research that is both methodological (to improve tools and monitoring protocols) and hypothesis-driven in nature, recognizing that the resources (both human and economic) necessary to conduct such research will require collaboration at multiple levels.

6.8.3 The European Union EUROBAT Advisory Committee

The European Union, under the guidance of the EUROBAT Advisory Committee, has recently produced a guidance document for assessing the impact of wind development on bats (Rodrigues et al., 2006). Although collision rates are typically lower in Europe than in the eastern United States, bats are protected throughout the European Union. In Germany, for example, a survey of 13 project sites revealed 245 dead bats from ten species (Rodrigues et al., 2006). In response to similar numbers throughout the European Union, the EUROBAT Advisory Committee has carcass searches be performed at greater than 50% of the turbines on a 2-5 day rotation. These surveys should be done for five years, with the first two years focusing on pre-construction correlation in a BACI analysis and the last three years focusing on long-term trends in bat populations (Rodrigues et al., 2006).

6.8.4 Bats and Wind Energy Cooperative

The Bats and Wind Energy Cooperative (BWEC) was formed in 2004 to address concerns created after the post-construction mortality surveys conducted at the Mountaineer Wind Energy facility in West Virginia (Kerlinger and Kerns, 2004). The BWEC group is composed of academic bat biologists, federal agencies (USFWS), non-profit organizations (Audubon Society, Bat Conservation International), and industry representatives (AWEA, FPL). Members of the BWEC group recently published a paper outlining their recommendations for wind development (Kunz et al., 2007). The recommendations include full-season (April through October) pre- and post-construction surveys that determine species composition and temporal and geographic variation in species distribution for both local and migratory bats. They also recommend establishing standardized protocols for such surveys and methodological research to determine the effectiveness of different research tools (such as ceilometry, radar, thermal imaging, and acoustic monitoring). Lastly, the BWEC researchers recommend research on potential deterrent technologies and the development of predictive models at the local and regional scale.

Although many of these recommendations are well beyond the scope of effort that is likely to be required for the MWCC project, any research conducted for this project should be consistent in nature and scope. This includes correlating bat activity and mortality events with meteorological data collected on site, comparing the impact of feathering wind turbines during peak migratory periods, and creating an adaptive management strategy that remains flexible enough to incorporate new research as it becomes available.

6.8.5 California Bat Working Group

The California Bat Working Group (CBWG) has recently completed a draft survey protocol designed to 1) reduce the impact of wind development on bats in California, 2) provide state and federal biologists with information collected from bat biologists throughout the region, and 3) help wind developers by producing standardized research requirements that can be used to determine the economics of a project early in the siting process. The CBWG protocol calls

> for daily carcass searches for 33% - 50% of the turbines for large projects, and at least some turbines daily for small projects, from March through October (Hogan, 2006). They also call for acoustic monitoring in a post-construction environment, but do not think ground-based monitoring can adequately assess migratory activity (Hogan, 2006); this is consistent with data collected by NEES at sites throughout the east coast, and Fiedler (2004) in Tennessee. In case of high mortality, the CBWG recommends thermal imaging surveys to document the collision behavior and estimate total mortality (Hogan, 2006).

7.0 FUTURE RESEARCH RECOMMENDATIONS

The projects outlined in Sections 6.1 through 6.6 above each have different objectives and methodologies, making it difficult to draw conclusions that would be directly informative for the MWCC project. However, consistencies between these projects and recent improvements in both our understanding of bat migration and the technology available to monitor migration, suggest that site-specific research is warranted at these project sites. The research below, listed in decreasing priority, would be a key step in would greatly improve our ability to assess the potential impact of the Project site on bats in Massachusetts.

7.1 Post-Construction Impact Analysis

The need to document and understand the impact of wind resource development on bats has become an increasingly important priority, and most of these data have come from post-construction surveys at operating wind resource areas. Unlike the biological assessment and the pre-construction surveys, post-construction analysis quantifies the actual risk and impact of wind development on bats. For this reason, it is imperative that well-designed post-construction monitoring be performed at the MWCC project site. This should include a carcass search protocol that will identify the distribution, species composition, and timing of all bat and bird mortality across the project site. In addition, the protocol should include acoustic monitoring during the migratory season so that a Before-After Control Impact (BACI) study can be performed to determine the impact of the project site on migratory behavior. These protocols should be appropriate for the size and terrain of the project. In addition to these conditions, a truly informative post-construction impact analysis should also include resources for impact mitigation through the development of adaptive management protocols (to account for meteorological influences on migratory behavior) and possibly physical deterrents to reduce bat mortality.

Data collected from several wind development sites have shown that most bat activity (Reynolds, 2006) or bat mortality (Arnett, 2005; Bach and Rahmel, 2006) occurs on warm, low wind nights before after bad weather. Data collected in Germany by Bach and Rahmel (2006) has shown that restricting turbine operations when wind speeds are less than 5 m/s significantly reduces mortality. Although the actual ‘threshold’ wind speeds may differ in the mid-Atlantic Highlands region, this type of information may be extremely helpful in minimizing bat mortality while also minimizing the economic impact of such operational constraints.

7.2 Pre-Construction Migratory Monitoring

Most bat mortality appears to occur during migration. Consequently, an understanding of the baseline migratory activity across the MWCC project site during both the fall and spring migratory period is critical in understanding the potential impact of these projects on bats. Data collected from these efforts will help inform biologists and managers about the scale of geographic, altitudinal, and temporal variation in bat activity across the project areas. This, in turn, should help identify the potential impact of wind turbine development and provide quantitative data for BACI comparison following construction of the project. These studies have been completed for the summer breeding season and the fall migratory season using a protocol that is consistent with the recommendations of the National Research Council (NRC, 2007) guidelines (Appendix Two). Additional monitoring during the spring migratory season (15 March – 14 June) may also be helpful so that a complete year of site-specific bat activity data will be available. . The United States Fish and Wildlife Service recommends multi-year, multi-season pre-construction monitoring (USFWS, 2003), however these recommendations were initially drafted as interim guidelines in the absence of pre-existing monitoring data. NEES is unaware of any discussion of multi-year pre-construction acoustic monitoring at the MWCC project site. NEES has been retained to conduct additional migratory monitoring during the Spring 2009 migratory season.

7.3 Summer Mist-netting Survey

Mist-netting is primarily used to assess habitat usage and species composition of bat communities during the summer months. Mist net surveys general follow the US Fish and Wildlife Service Indiana Bat Mist-Netting Guidelines (USFWS, 2007) in terms of sampling effort, sampled habitats, and equipment. If any species of concern were captured, detailed habitat usage data could be collected by attaching radiotransmitters to each bat and documenting foraging areas and roost locations. Although mist-netting is a valuable research tool that provides critical information about the biology and community ecology of bats, it is relatively uninformative in regards to the potential impact of wind development at a project site for five reasons.

First, the summer months are periods of relatively low bat mortality, with many wind farms documenting less than 10% of all mortality across the summer months (Erickson et al., 2000; Johnson & Strickland, 2003; Johnson et al., 2003b; Kerlinger & Kerns, 2004; Johnson, 2005; Kerlinger, 2006; Fiedler et al., 2007). Second, mist-netting has a known taxonomic bias that favors low-flying bats such as *Myotis spp.*, big brown bats (*Eptesicus fuscus*), and the eastern pipistrelle (*Perimyotis subflavus*); these are not the primary species being impacted by wind development in the United States (Table 3). Third, mist-netting is limited in the types of habitats that can be sampled and by the relatively small sampling area of the net (Kunz & Brock, 1975; O'Farrell & Gannon, 1999); for wind project risk assessment, this limitation is most evident in our inability to sample bats near the rotor sweep zone. Fourth, mist-netting is not an effective long-term monitoring technique at a fixed location (a necessity for monitoring the extensive active season of bats), with capture rates declining rapidly as bats become habituated to the presence of the nets (Kunz & Brock, 1975, Heady & Frick, 1999). Last, there is no evidence that mist-netting samples are predictive of bat mortality at wind project sites. Specifically, bat mortality data has not been consistent with the composition of the local bat population based on mist-netting results (EPRI, 2003; Gruver, 2002; Schmidt et al., 2003; Jain et al., 2007).

8.0 CONCLUSION

The need to document and understand the impact of wind resource development on bats has become an increasingly important priority in the United States. These data show that bat mortality is likely to occur at the project site, particularly among the migratory tree bats; these are the bats that are killed at the highest rates at other wind projects throughout North America. Data collected in the generation of this report suggest that the MWCC project site is unlikely to contain resident populations of the eastern small-footed myotis (State Species of Special Concern) and the Indiana bat (federally Endangered Species). Consequently, the MWCC project site represents a negligible mortality risk for these two species of concern. The pre-construction monitoring done by NEES for the summer and fall migratory season should provide valuable data on the scale and temporal distribution of bat activity across the project site, and the methodologies employed were consistent with the general recommendations of the U.S. Fish and Wildlife Service (USFWS, 2003), the National Research Council (NRC, 2007), and the Bats and Wind Energy Cooperative. Because of the lack of correlation between mist-net sampling data and subsequent bat mortality, NEES does not recommend site-specific mist-netting at the MWCC project site for the purposes of mortality risk assessment.

Following approval of the MWCC project, NEES would recommend the establishment of a Technical Advisory Committee that will interface with interested parties to design post-construction research protocols, collect and analyze mortality data, and make the results available to the public. The post-construction monitoring protocol established by the TAC should utilize adaptive management techniques that are flexible enough to incorporate new research as it becomes available. For example, if the MWCC project encounters unacceptable levels of bat mortality, shutting down the turbines at low wind speed is one potentially useful technique that might reduce bat mortality significantly. As we learn more about predictive factors for bat and avian collisions, we should be able to provide management options that substantially reduce mortality risk while minimally impact project viability.

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APPENDIX ONE, Page 1 of 1: Bats of Massachusetts with Basic Ecological Properties

Common Name	Scientific Name	Summer Roost	Habitat Association	Winter Pattern	Regional Abundance and status [1]
little brown myotis	*Myotis lucifugus*	commensal	generalist	migratory hibernator	common
northern myotis	*Myotis septentrionalis*	commensal, tree roosting	interior forest	migratory hibernator	common
eastern small-footed myotis	*Myotis leibii*	rock roosting	water unknown	migratory hibernator	rare *State-threatened*
Indiana bat	*Myotis sodalis*	tree roosting	riparian habitat	migratory hibernator	historic and incidental *Federally-endangered*
big brown bat	*Eptesicus fuscus*	commensal	fields open areas	hibernator	common
eastern pipistrelle bat	*Perimyotis subflavus*	commensal, tree roosting	water, fields, forest edges	migratory hibernator	common
eastern red bat	*Lasiurus borealis*	foliage roosting	deciduous forest, artificial lights	migratory	common
hoary bat	*Lasiurus cinereus*	foliage roosting	coniferous forest artificial lights	migratory	uncommon
silver-haired bat	*Lasionycteris noctivagans*	tree roosting	forests	migratory	uncommon

1. the terms ‘accidental’, ‘common’, ‘uncommon’, ‘rare’, and ‘unlikely’ are relative capture estimates and do not imply total population size.

Appendix 3.2. Bat Acoustic Studies

- **February 2, 2009, Summer-Fall 2008 Monitoring Report**
- **August 26, 2009, Spring 2009 Monitoring Report**

PRE-CONSTRUCTION ACOUSTIC MONITORING

Mount Wachusett Community College Wind Project

Worcester County, Massachusetts

Prepared for:

Mount Wachusett Community College
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02 February, 2009

Pre-Construction Acoustic Monitoring

Mt. Wachusett Community College Wind Project

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EXECUTIVE SUMMARY

The Mount Wachusett Community College ("MWCC") Wind Project proposal is for the construction and operation of a 1-2 turbine wind project on the Mount Wachusett Community College campus in Gardner (Worcester County), Massachusetts. As part of the environmental assessment of this proposal, North East Ecological Services (NEES) was contracted to conduct pre-construction acoustic monitoring to determine the potential impact of project construction and operation on bats.

Based on data collected through acoustic monitoring, NEES makes the following conclusions:

1) Roost surveys of Worcester County and bat activity data at the project site suggests a significant resident bat population in the area that is dominated by the big brown bats and little brown myotis.

2) 80% of the total bat activity was detected at the LOW microphone, well below the rotor sweep zone of the turbine. Less than 1% of the total bat activity was heard at the HIGH microphone within the rotor sweep zone of the turbine.

3) Overall levels of bat activity were similar to other pre-construction acoustic monitoring surveys

4) *Myotis spp.* represented 30.6% of the total bat activity. Over 90% of the bat activity from *Myotis spp.* occurred at the LOW microphone and none occurred at the HIGH microphone within the rotor sweep zone of the proposed wind turbine. The *Myotis spp.* group contains four species including the federally-endangered Indiana myotis, *M. sodalis* and the state Species of Special Concern eastern small-footed myotis, *M. leibii*.

5) Bats within the *Myotis spp.* group cannot be reliably identified using acoustic signatures. Given the lack of documented *M. leibii* and *M. sodalis* within 50 km of the project site and the proximity of the MWCC project site to suburban landscapes, it is likely that most, if not all of the *Myotis spp.* activity can be attributed to the little brown myotis, *M. lucifugus*.

6) Acoustic monitoring of Patterns of bat activity (evening temporal data, altitudinal variation, and species composition) are more consistent with summer foraging and commuting activity than migratory activity.

7) Acoustic monitoring of migratory bats suggests that all species of tree bats (red bat, hoary bat, and silver-haired bat) were detected at the project site.

8) Hoary bats, the most commonly killed bat at wind development sites, represented almost 11% of the total bat activity; this is a lower percentage of total activity than seen at many pre-construction acoustic monitoring surveys.

9) The MWCC data, compared to other pre-construction wind projects, suggest medium levels of bat activity throughout both the summer sampling period and fall migratory sampling period.

10) NEES recommends that additional monitoring be carried out during the spring migratory season (15 March – 14 June) to document an entire active season for bats near the project site.

11) Based on these data, NEES concludes that fatality numbers at the project site are likely to be similar in composition but lower in magnitude (on a per turbine basis) to other wind projects sites in the northeastern United States. Given the size of the project, it is unlikely to have a significant impact on bat populations in the region.

1.0 PROJECT OVERVIEW

1.1 The MWCC Wind Project

The MWCC Wind Project proposal is for the construction and operation of one or two 1.5 MW wind turbines (estimated 1.5 to 3.0 MW total capacity) on the MWCC campus located in northern Worcester County, Massachusetts (Fig. 1). The project layout encompasses approximately 4.5 ha. The project consists of a single parcel of publicly owned land, located within the City of Gardner, approximately 1.5 km south/southeast of the intersection of SR-140 and Green Street.

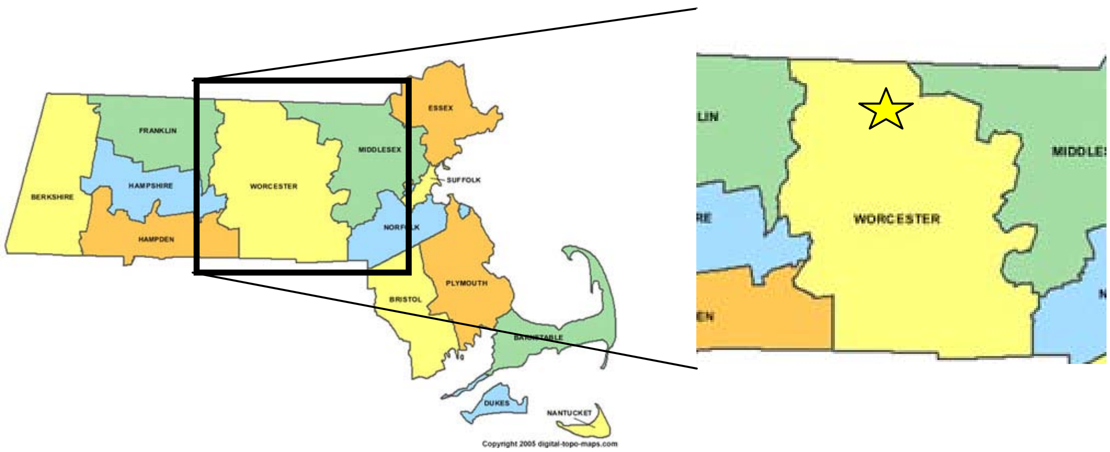

Figure 1: General location of the MWCC Wind Project in Massachusetts

2.0 PRE-CONSTRUCTION ACOUSTIC SURVEY

Most bat mortality appears to occur during migration. Consequently, an understanding of the baseline migratory activity at the MWCC project site during the fall migratory period is critical in understanding the potential impact of this project on bats. Data collected from these efforts will help inform biologists and managers about the scale of geographic, altitudinal, and temporal variation in bat activity across the project areas. This, in turn, should help identify the potential impact of wind turbine development and provide quantitative data for BACI (Before-After Control Impact) comparison following construction of the project. These studies have been completed for the summer breeding season and the fall migratory season using a protocol that is consistent with the recommendations of the National Research Council (NRC, 2007) guidelines.

2.1 Equipment Calibration and Data Collection

Data were collected using Anabat™ SD-1 ultrasonic detection systems placed at various heights on an existing meteorological ('Met') tower (Figure 2). Microphones were placed on the Met tower using a pulley system that allowed the microphones to be adjusted, replaced, or relocated without lowering the met tower. The microphones were housed in a weather-tight PVC housing and oriented towards the ground to prevent moisture from collecting on the transducer. A 10 cm^2 square Lexan sheet was mounted below the microphone at 45 degrees from horizontal to deflect sound up towards the microphone. Due to the length of the cables, we used Titley™ HI-MIC pre-amplified microphones. The microphones were attached to the Anabat ultrasonic detector using customized cables (EME Systems, Berkeley, California) based on a Canare Starquad™ video cable with an additional preamplifier soldered into the terminal end of the cable to increase signal strength.

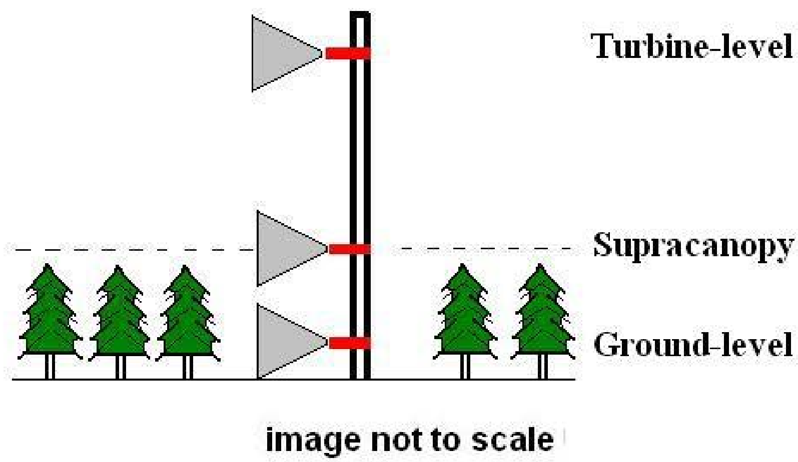

Figure 2. Schematic of Meteorological Tower microphone array

The Anabat™ SD-1 interface module stores bat echolocation signals on removable CF-flash cards. The detectors were placed in a NEMA-4 weatherproof enclosure mounted to the base of the Met tower and powered by a 30W photovoltaic charging system. All microphones and cables were calibrated (before installation and after de-construction) in a test facility using a Binary Acoustics AT-100 multifrequency tonal emitter (BAT, Las Vegas, Nevada) to confirm minimum performance standards for six different ultrasonic frequencies (20kHz, 30kHz, 40kHz, 50kHz, 60kHz, and 70kHz). In addition, a minimum cone of receptivity (15° off-center) was verified by rotating the microphone horizontally on a platform using the AT-100 as a sound source.

The Anabat monitoring systems were programmed to monitor for ultrasonic sound from 18:00 – 08:00 each night throughout the sampling period (05 June – 11 November, 2008). Data cards were retrieved by MWCC personnel (Robert Rizzo) at approximately weekly intervals. At each visit to the Met tower site, the data cards were removed from each recording system and replaced with new cards. All card removals and replacements were documented on field sheets provided and stored in each tower enclosure. Data cards were mailed to NEES in protective envelopes for analysis.

2.2 Data Analysis Protocol

Data were analyzed using the Analook™ 4.9j graphics software. Bat echolocation recordings were separated from non-bat sounds based on differences in time-frequency representation of the data (Table 1). Files that were determined to be of bat origin were analyzed semi-quantitatively using a dichotomous key that distinguishes species based on a variety of call features. Species identification was conservative to minimize identification error and maximize total number of calls included in the analysis. Specifically, high variation in calls within the genus *Myotis* precludes reliable species identification (Murray et al., 2001). We grouped silver-haired bats (*Lasionycteris* *noctivagans*) and big brown bats (*Eptesicus fuscus*) into a single group (Lnoct-Efus) to reduce errors in identification of these two species. For those calls that were not of a high enough quality to extract diagnostic features, an "Other Bat" category was used to document total bat activity.

Table 1. Descriptive breakdown of acoustic file source origins

Category	**General Description of Time-Frequency Analysis of Data**	**Probable Source(s)**
Wind Noise	random pixilation with little to no pattern	wind
Mechanical	Long calls (> 100 ms) with high constant-frequency (CF) component and drifting characteristic frequency (Fc)	cable resonance EM interference
Biological (non-bat)	Frequency-modulated (FM) call structure with ascending pitch or with characteristic frequency in audible range	insects birds, flying squirrels
Bat Activity	FM or CF dominated data file with species-specific call durations, pitch changes, or other attributes	bats

2.3 Data Assumptions and Presentation Format

The following data were collected in order to characterize the bat activity that occurs at the Project site. Several assumptions were made in order to characterize this activity:

a) bat activity recorded at the Met tower adequately represents bat activity across the Project site.
b) the microphones are properly oriented to record echolocation calls of bats as they fly across the Project site
c) there is relatively little bat activity during the daytime (0800 – 1800)
d) the sampling period (05 June through 11 November) accurately represents the seasonal activity period of bats at the Project site
e) the echolocation calls recorded on unique data files are independent and do not represent the same individual over multiple sampling periods
f) echolocation calls within the same data file can be treated as a set of calls from a single individual

Assumption a) is based on the technological and methodological constraints that exist at a wind development project. Prior to the concern about turbine-related bat mortality, there were only a few studies that attempted to acoustically document bat migratory activity (for example, Zinn and Baker, 1979; Barclay, 1984). Even fewer studies attempted to document bat activity at altitudes above the tree canopy (for example, Davis et al., 1962; McCracken, 1996). This lack of emphasis was due to the difficulty of recording ultrasonic sound over large periods of time (limitations of recording equipment), wide areas of space (high signal attenuation of ultrasonic wavelengths), or at high altitude. Although most project sites contain appropriate sampling platforms to collect these data (meteorological towers), they are generally non-mobile and often spatially limited across the Project site. However, they are generally sited where turbines will ultimately be constructed and therefore may adequately represent the relevant air space that is available for migratory bats at the project site. Assumption b) is a technical limitation of the condenser microphones used by the ultrasonic recording equipment.

Assumption c) has been validated by numerous field studies and therefore is strongly supported by existing data. Assumption d) is not valid because bats are known to be active well before early June. Conducting additional monitoring during the spring (15 March – 14 June) will validate this assumption. Assumptions e) and f) relate to how bat calls are recorded and represented. Although there is a wide range of opinion on how to interpret echolocation calls, there is a general agreement that researchers should not use echolocation call files as a measure of species abundance unless those calls are independent. This requires that data are collected and analyzed to ensure the spatial- and temporal-independence of each recording. Spatial independence is created by placing microphones in non-overlapping sampling environments. Temporal independence can be created by making assumptions about the time individual bats will remain within the sampling space. Because we do not have adequate research on migratory activity, we cannot make well-grounded assumptions about temporal independence of individual calls. For example, two bat calls recorded at the LOW microphone within ten seconds may represent a single bat flying near the microphone. However, two calls recorded 60 minutes apart are unlikely to represent the same bat. To avoid this potential non-independence, this report will focus on total bat activity, not species abundance or species eveness (relative abundance of each species).

Table 2. Summary of terms and definitions used to describe bat activity

bat activity	Activity estimate calculated from the total number of echolocation calls recorded
high risk species	bats species known to collide with wind turbines at rates higher than predicted based on their abundance during capture (e.g. mist netting) sampling
calls/detector-hour (calls/dh)	Standardized measure of bat activity (controlling for variation in total sampling effort at each site)
peak 7-day activity	estimate of peak sustained migratory activity
fall migration	bat activity from 16 August through 10 November
spring migration	bat activity from 15 March through 31 May
summer activity	bat activity from 01 June through 15 August

2.4 Acoustic Monitoring Station

The MWCC project site had a pre-existing temporary Met tower at the project site. The Met Tower was located within an approximately 4.5 ha old field, with very few invading trees. The old field was bordered by a second growth forest to the east, which extended to both the east and northeast. A relatively long (at least 100 m), narrow (~ 2 m width) area of rock jumble was observed along the east edge of the project field, and approximately 3 to 6 m into the forest interior. This area of rocks was composed of medium and large size boulders, which likely constituted a historical stone wall. The boulders occurred mainly at ground level, and since the rocks were shaded by overstory trees, received only intermittent exposure to the sun. A small (0.75 ha) open water pond borders the project field to the west. Additional wetlands occur to the east of the project field, including a small red maple swamp located approximately 150 m east/northeast of the project field. Several large pond and lakes were observed, including Crystal Lake and Perley Brook Reservoir to the west, Lake Wampanoag, Mamjohn Pond, and Hobby's Pond to the northeast, and Dunn Pond to the southeast. Several additional small ponds were observed both on the MWCC campus property and within the adjacent golf course to the west. Additional details about the site are provided in the Phase I Bat Risk Assessment (NEES, 2008).

The acoustic monitoring system was installed on the Met Tower on 05 June, 2008. All microphones were mounted facing north (azimuth of 0°) to face the direction of probable fall migration. Although the Massachusetts Division of Fisheries and Wildlife does not prescribe sampling conditions, north-facing microphones are recommended in New York State (NYDEC, 2007). The low microphone (LOW) was installed at 10 m altitude, the middle microphone (MID) was installed at 30 m altitude, and the high microphone (HIGH) was installed at 60 m altitude.

3.0 ACOUSTIC MIGRATORY SURVEY RESULTS

3.1 Sampling Effort

Bat activity was monitored from 05 June through 11 November, 2008. The total sampling period in 2008 was 161 days, or 2,254 hours per detector. Due to the potential for data overload, failure to swap cards, card reading failures, or equipment malfunction, the actual sampling effort of each microphone is generally less than this maximal potential sampling effort. The sampling effort at the MWCC project site is summarized in Table 3.

Table 3. Acoustic Sampling Effort at the MWCC Wind Project Site

Microphone	Total Days Monitoring	Percent of Total Monitoring	Reasons for Data Loss (days of loss)
LOW	133	82.6%	failure to swap cards (6) card failure (22)
MID	149	92.5%	failure to swap cards (12)
HIGH	122	75.8%	failure to swap cards (12) card overload (9) card failure (18)
AVERAGE	**133.3**	**83.6%**	

3.2 Overall Data

A total of 218,391 files was recorded by the acoustic monitoring equipment. After analysis, 2,150 files (1.0%) were determined to be of bat origin. Although the vast majority of the acoustical activity was wind noise, there were some files that appeared to be mechanical and non-bat biological in origin. Combining data from all microphones, bat activity was documented on 118 of the sampling days (76.1%); 78.4% of the non-activity days occurred during the final five weeks (29 of 37 days). Mean daily bat activity was 13.4 calls per night.

A depiction of overall bat activity at each tower is shown in Figure 3. Each pie graph is scaled to represent total relative activity (with actual bat calls identified by the numbers next to each graph).

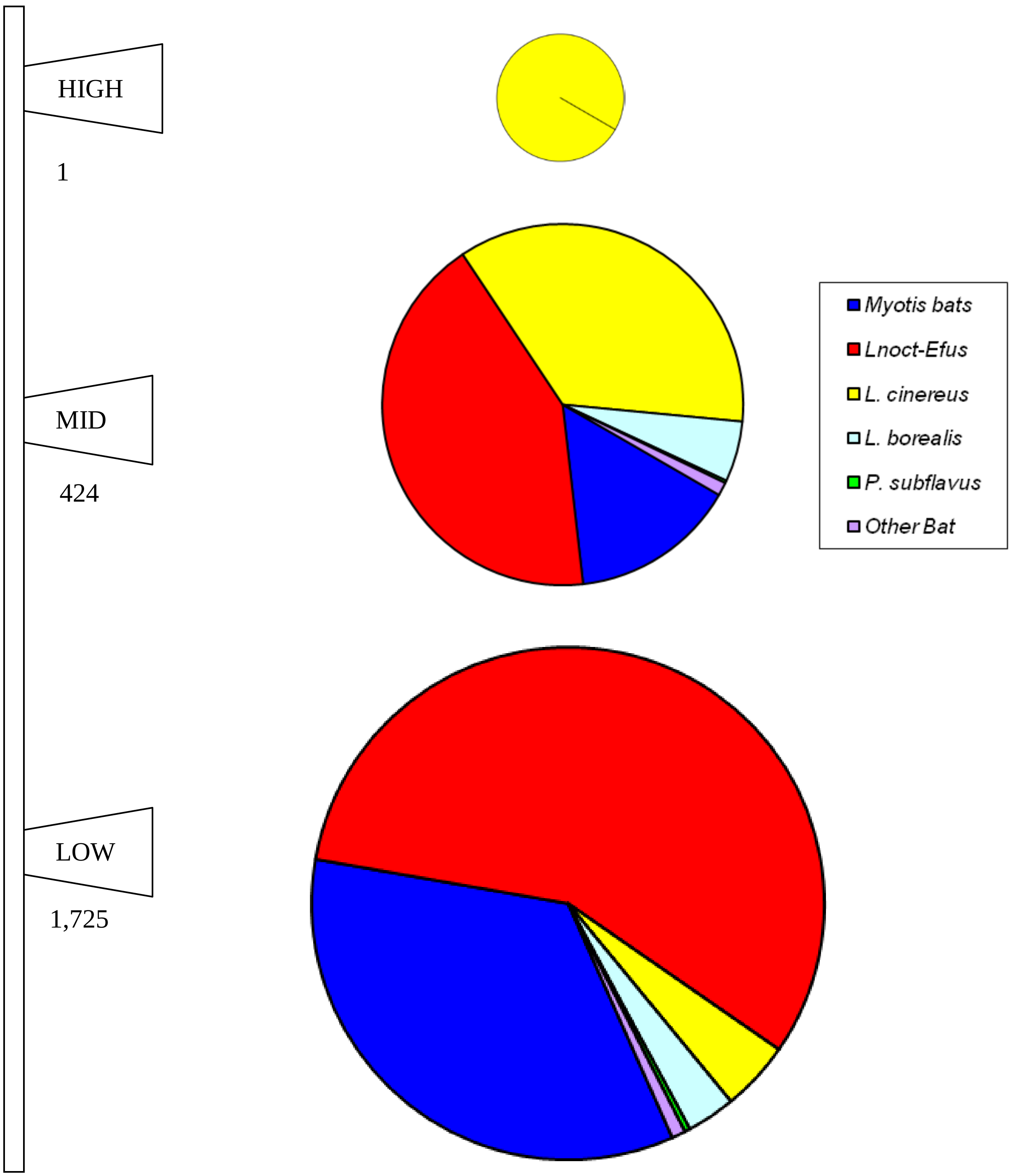

Figure 3: Distribution of Bat Calls across Microphone Heights by Species

3.3 MWCC Met Tower

3.3.1 Low Microphone

During the period from 05 June through 11 November, 2008, a total of 5,690 files were recorded and analyzed. It was determined that 1,725 files were of bat origin. A minimum of five species or species groups were detected at the LOW microphone. The silver-haired/big brown group (*Lnoct-Efus*) and the *Myotis* spp. group (*Myotis* bats) were the dominant bats heard at the LOW microphone, comprising 56.9% and 34.4% of all calls, respectively (Figure 4).

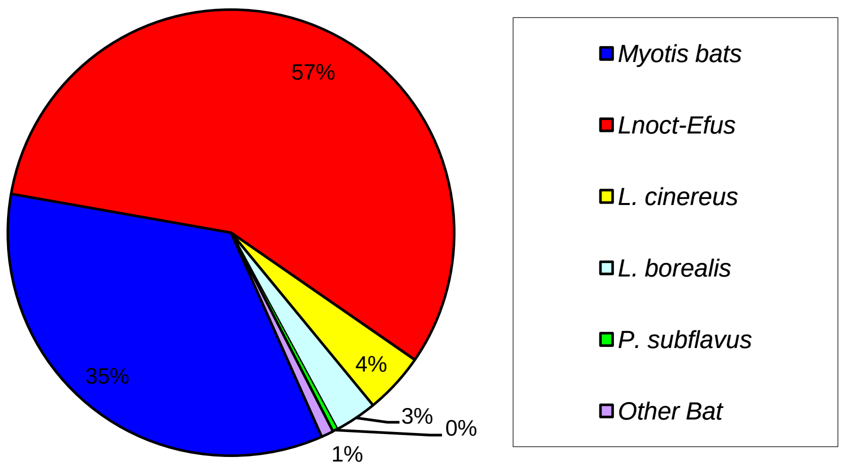

Figure 4: Distribution of Bat Calls at the MWCC Tower LOW Microphone

Looking across the entire sampling period, one gradual activity peak was recorded at the LOW microphone; this peak occurred during the seven-day period beginning 01 September (Figure 5). No bat activity was heard after 01 November.

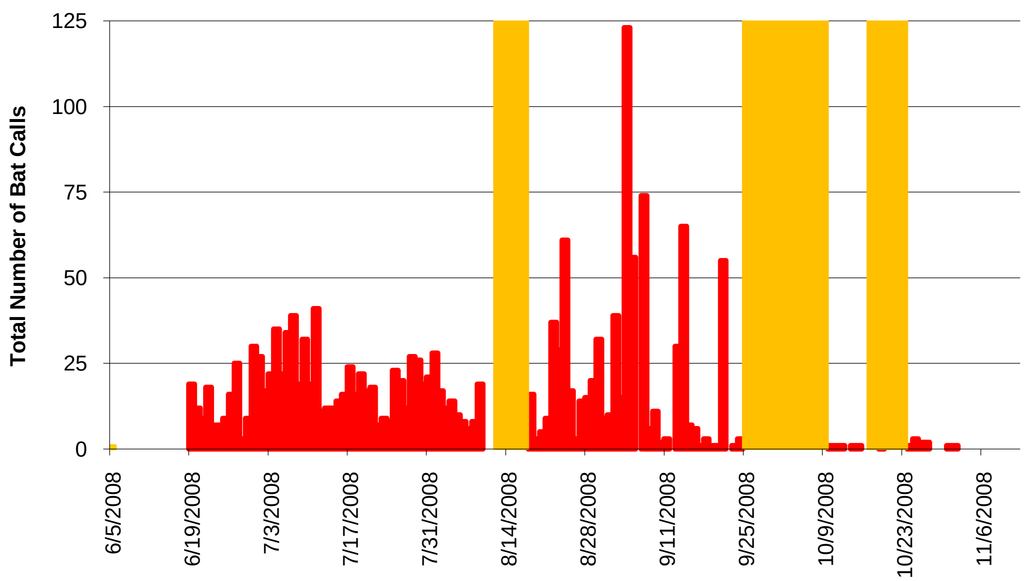

Figure 5: Seasonal Distribution of Bat Calls at the MWCC Tower LOW Microphone (yellow bars are periods of no data)

3.3.2 MID Microphone

During the period from 05 June through 11 November, 2008, a total of 141,887 files were recorded and analyzed. It was determined that 424 files were of bat origin. A minimum of five species or species groups were detected at the MID microphone. The silver-haired/big brown bat group (*Lnoct-Efus*) and the hoary bat (*L. cinereus*) were the dominant groups heard at the MID microphone, comprising 42.5% and 35.8% of all calls, respectively (Figure 6).

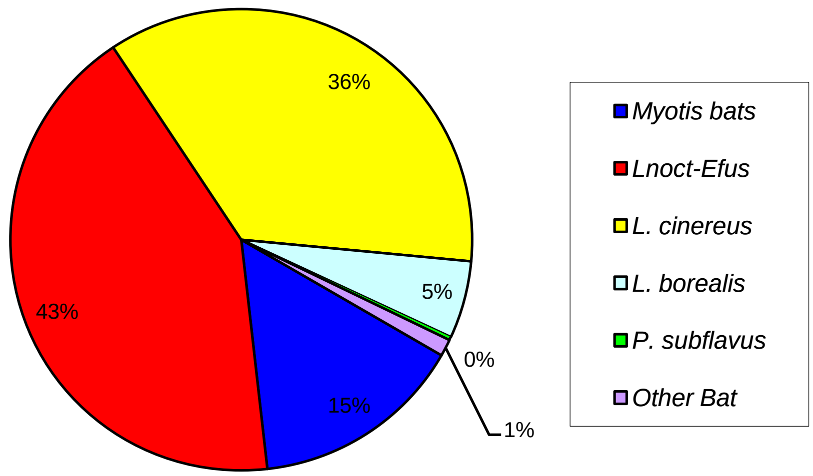

Figure 6: Distribution of Bat Calls at the MWCC Tower MID Microphone

Looking across the entire sampling period, two small activity peaks were recorded at the MID microphone; the first peak was in late June and the second peak occurred during the seven-day period beginning 24 August (Figure 7). With the exception of three calls detected on 27 October, no bat activity was recorded after 12 October.

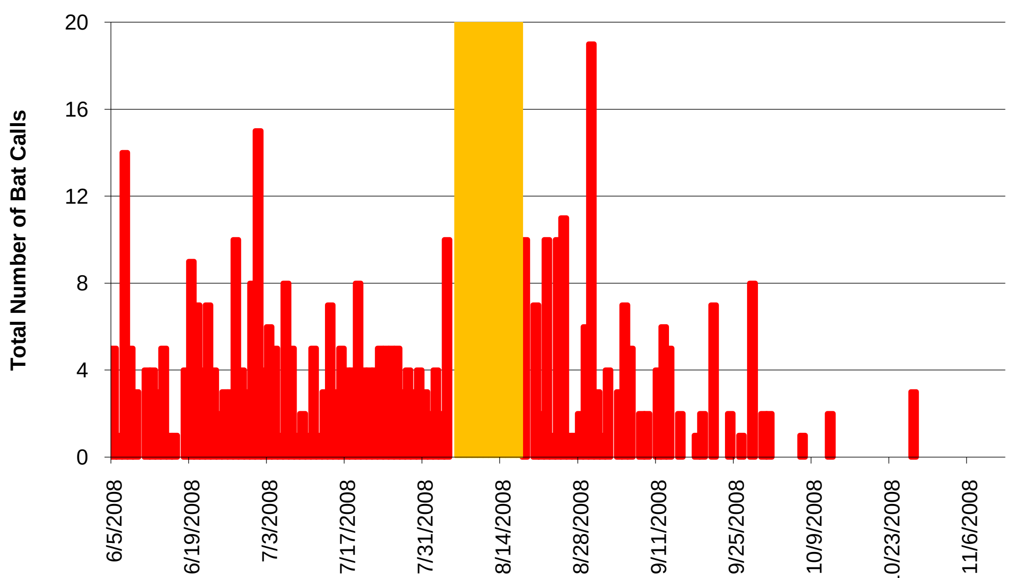

Figure 7: Seasonal Distribution of Bat Calls at the MWCC Tower MID Microphone (yellow bars are periods of no data)

3.3.3 High Microphone

During the period from 05June through 12 November, 2008, a total of 70,814 files were recorded and analyzed. It was determined that only one file was of bat origin. This was a single hoary bat (*L. cinereus*) call detected on 20 July (Figure 8).

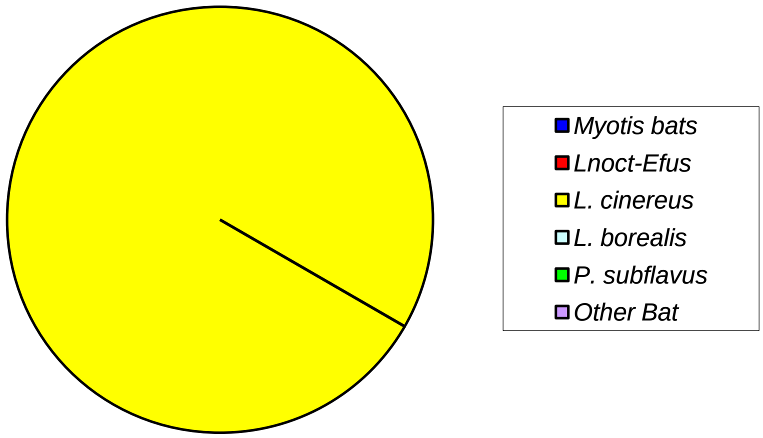

Figure 8: Distribution of Bat Calls at the MWCC Tower HIGH Microphone

The single bat call was heard on 20 July (Figure 9). Due to the lack of activity, no peak periods were evident at the High microphone.

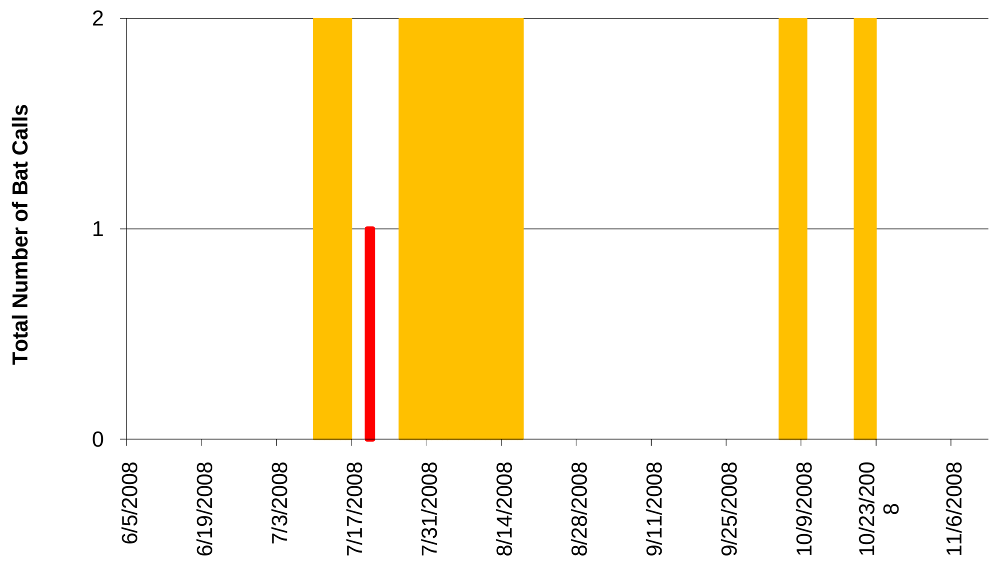

Figure 9: Seasonal Distribution of Bat Calls at the MWCC Tower HIGH Microphone (yellow bars are periods of no data)

3.4 Vertical Distribution of Bat Activity

The highest level of bat activity was observed at the LOW microphone (80.2% of total activity). There was a substantial decline in bat activity with altitude across the project site (Figure 10). When bat activity was standardized by total sampling effort, the LOW microphone had a higher level of activity (13.0 calls/dn) than either the MID microphone (2.8 bats/dn) or HIGH microphone (0.0 bats/dn).

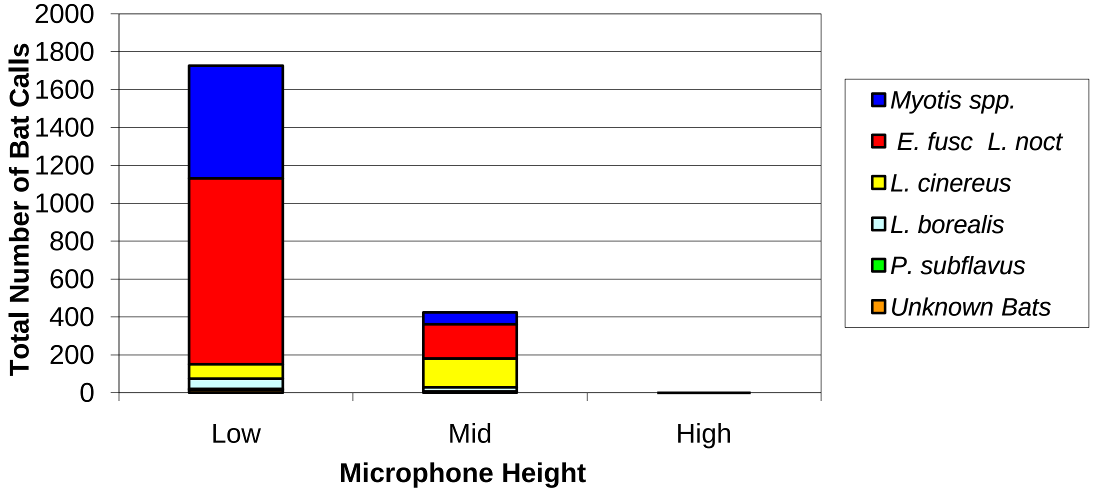

Figure 10: Distribution of Bat Activity Across Microphone Heights by Species

There were also species-group patterns in bat activity. For example, most of the *Myotis* spp. and silver-haired/big brown bat group (*Lnoct-Efus*) calls were recorded at the LOW microphone (Figure 11). Conversely, hoary bats (*L. cinereus*) were most frequently detected at the MID microphone (66.4% of total activity).

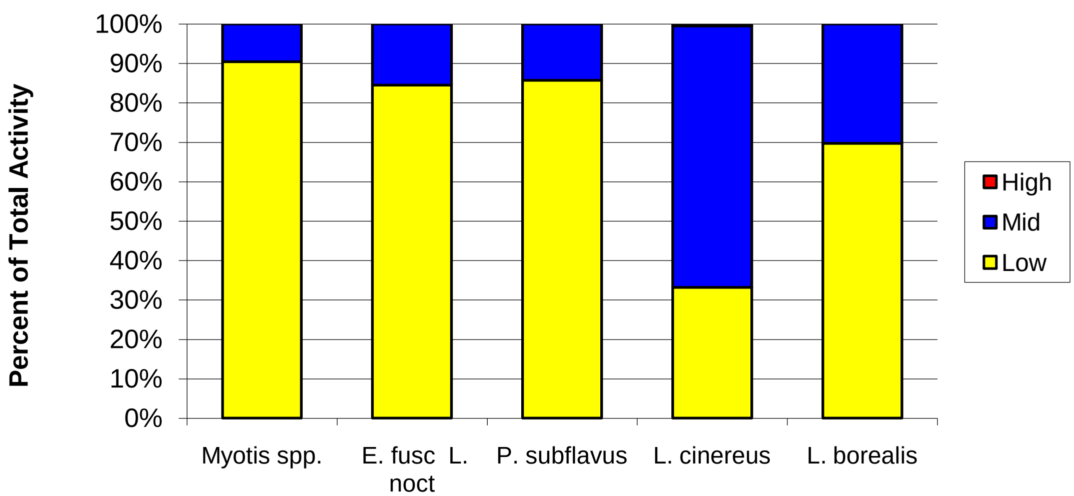

Figure 11: Vertical Distribution of Bat Activity by Species Group

3.5 Temporal Distribution of Bat Activity Across The Year

Pooling all data, there was a general low level of bat activity at the MWCC project site during the monitoring period; however, this was highly influenced by the lack of detectable bat activity at the HIGH microphone. Bats were already active at the project site at the commencement of monitoring, but increased substantially in early July and again in late August before declining to low levels by late September (Figure 12). The general lack of bat activity during the final six weeks of the survey period suggests that we sampled across the entire fall migratory period at the project site. Specifically, these last six weeks represent 26.1% of the entire sampling period, but only 1.0% of the total bat activity. Standardized for sampling effort, the summer period (05 June through 14 August: 7.24 bats/dn) had a similar level of bat activity as the peak fall migratory period (15 August through 30 September: 7.08 bats/dn). These data are consistent with the use of the project site as a summer foraging area for *Myotis* and big brown (*E. fuscus*) bats. However, the presence of bat activity throughout the fall migratory season suggests the project site is also within the migratory corridor of some bats, particularly hoary bats.

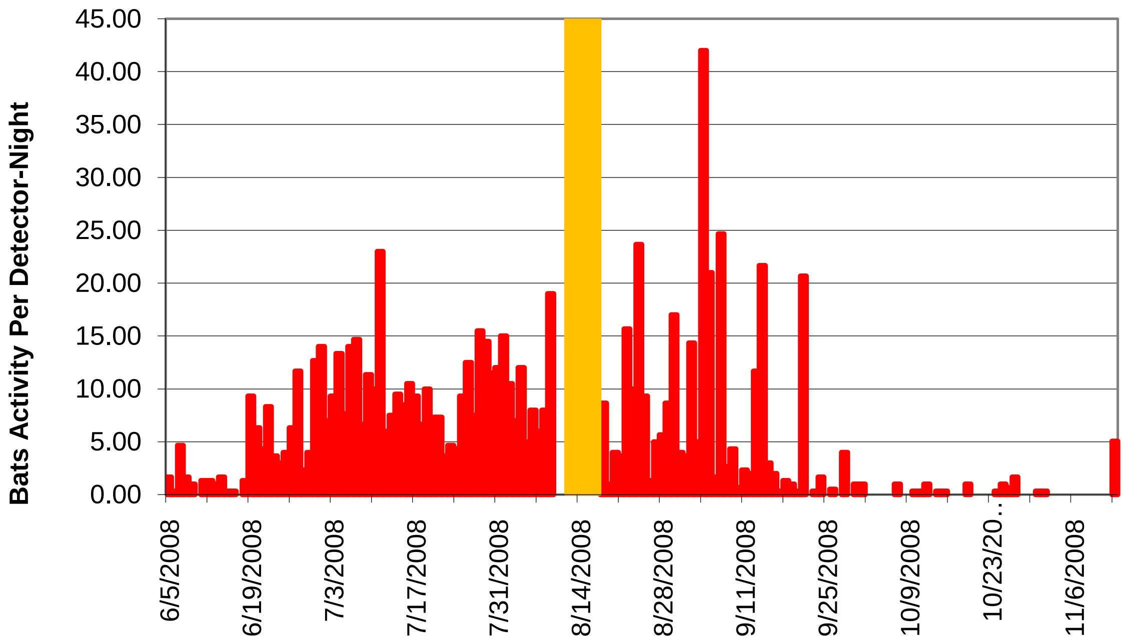

Figure 12: Distribution of Bat Activity Across the Sampling Period

3.6 Temporal Distribution of Bat Activity Across The Night

Data were pooled across the sampling period and analyzed for nightly activity patterns in 15-minute intervals. This showed very little bat activity during the first hour and during the last 120 minutes (0.14% of total bat activity) of the nightly sampling period; only 0.46% of the total bat activity was recorded during the last three hours of sampling. These data strongly suggest that the 14-hour sampling protocol is more than adequate to document bat activity at the project site. Bat activity at the project site was characterized by a rapid increase in activity early in the evening (starting at approximately 19:00) that peaked at approximately 20:00 before declining steadily throughout the evening (Figure 13).

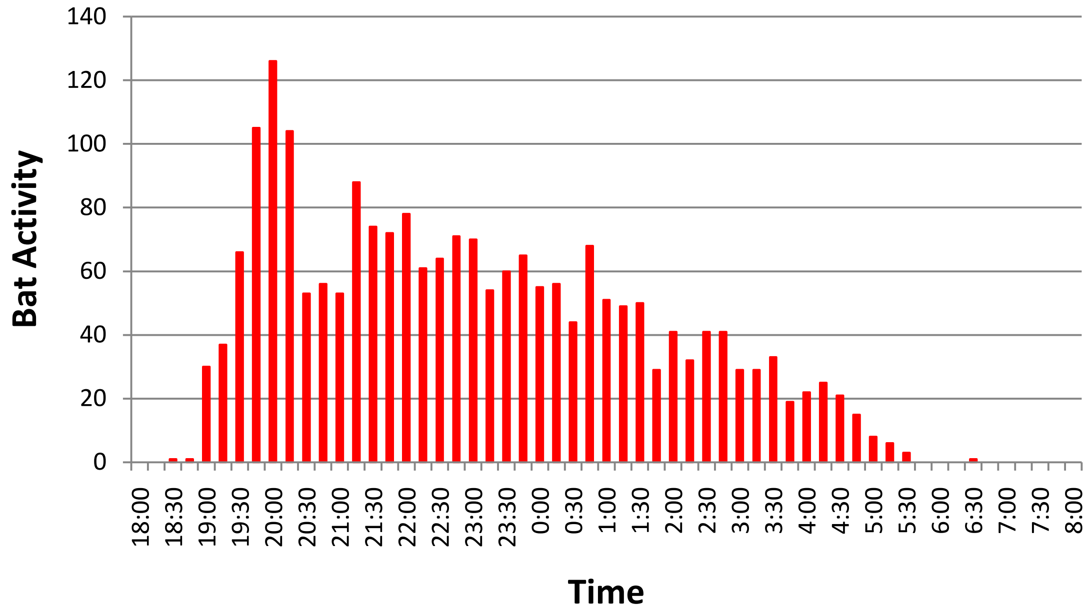

Figure 13: Temporal Distribution of Bat Activity Across the Evening

When the bat activity is analyzed across the vertical sampling array, the data show that the rapid increase in bat activity early in the evening is the result of ground-level bat activity (Figure 14).

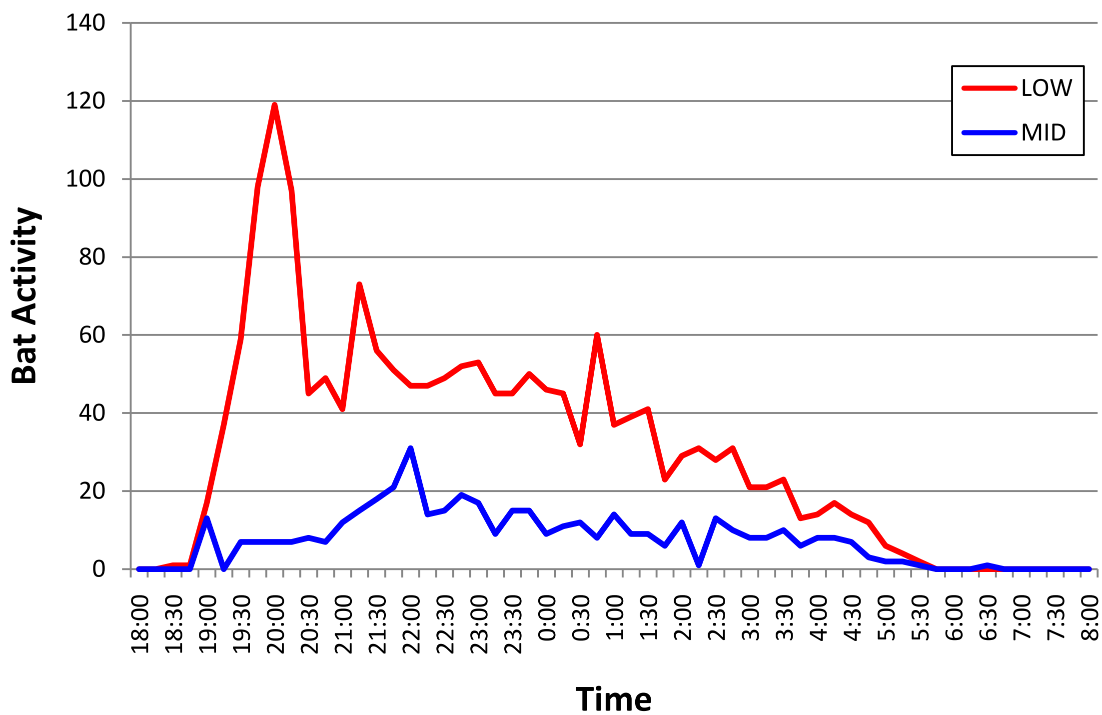

Figure 14: Temporal Distribution of Bat Activity Across LOW and MID Microphones

3.7 Overview of Bat Migratory Acoustic Data

During the 161 days of monitoring at the MWCC project site, a total of 2,150 bat calls was recorded and identified. Analysis of these data suggests the following:

a) wind generated the most data files, with only 1.0% of the data files containing echolocating bats.
b) more calls were heard at the LOW microphone (13.0 calls/detector-night) compared to the MID microphone (2.8 calls/dnh) and the HIGH microphone (0.0 calls/dn).
c) Only one bat (a hoary bat on July 20, 2008) was detected on the HIGH microphone throughout the 122 days of sampling at this height. Microphone calibration before and after use confirm the sensitivity and operation of the detector.
d) across all microphones, the highest percent of activity came from the silver-haired/big brown bat (*Lnoct-Efus*) group (54.0%), followed by the *Myotis spp.* group (30.6%) and the hoary bat (*L. cinereus*: 10.7%).
e) Given the relatively urban landscape surrounding the MWCC project site, it is highly likely that most of the calls from the silver-haired/big brown (*Lnoct-Efus*) species group were from the big brown bat (*E.fuscus*), a house-roosting bat that is well documented within the area and most often found in cities such as Keene and Nashua New Hampshire, as well as Worcester and Leominster, Massachusetts (Reynolds, *pers. obs.*).
f) *Myotis spp.*, which contains five species including the federally-endangered Indiana myotis (*Myotis sodalis*) and the state Species of Special Concern eastern small-footed myotis (*Myotis leibii*), represented 30.6% of the total bat activity. The inability to reliably identify these two species from the other species within the genus *Myotis* limits the use of these data to quantify the potential presence or use of the MWCC project site by these species. However, a bat risk assessment of the project site determined that no *M. sodalis* have been documented during the summer in the state of Massachusetts and there are no documented *M. leibii* within 50 km of the project site. Given the proximity of the MWCC project site to suburban landscapes, it is likely that most, if not all of the *Myotis spp*. can be attributed to the little brown myotis (*M. lucifugus*).
g) Within the *Myotis spp.* group, most of the activity was detected at the LOW microphone (90.4%), well below the rotor sweep zone of the turbines.
h) The hoary bat (*L. cinereus*) was the third most commonly-detected bat during the sampling period, representing 10.7% of all recorded bat activity. The hoary bat was the only bat detected at the HIGH microphone and 66.4% of the activity from the hoary bat was detected at the MID microphone.
i) All species of migratory tree bat, the hoary bat (*Lasiurus cinereus*), red bat (*Lasiurus borealis*), and the silver-haired bat (*L. noctivagans*) were detected during the sampling period.
j) The migratory tree bats that could be acoustically isolated (hoary bat and red bat) represented 14.2% of the total bat activity; 57.7% of this activity was detected at the MID microphone.

k) The fact that there was virtually no bat activity during the last two weeks of monitoring (30 September October-12 October) suggests that the sampling protocol captured the vast majority of fall migratory bat activity at the project site.
l) Bat activity at the MWCC project site generally peaked in late July and again in late August. The first peak may represent increased foraging activity at the project site and the volancy of juveniles from nearby summer colonies. The late August peak may represent the beginning of fall migratory activity, but most of this activity was at the LOW microphone.
m) Most of the bat activity at the project site peaked early in the evening and declined steadily throughout the night. This is typical of acoustic sampling of summer activity and therefore probably does not represent migratory activity across the project site.

4.0 ACOUSTIC BAT MIGRATORY DATA CONCLUSION

The utility of conducting pre-construction studies of potential bat use at wind project sites has historically been limited due to the lack of appropriate technology; in particular the inability to monitor bat activity within the rotor sweep zone of the turbine. When acoustic monitors are deployed at ground level, there is an inability to detect a correlation between activity levels and mortality (Erickson et al., 2002) because the monitors do not sample at rotor height. The protocol used in the current study has resolved this issue, but there are not enough studies currently available to determine whether pre-construction activity surveys are predictive of post-construction bat mortality. However, the requirement of fixed elevated monitoring stations limits the ability to sample across the project site. One limitation of the current study is the inability to reliably identify species within the genus *Myotis*. This inability is well documented throughout the range of this genus (Ahlén, 2004; Jones et al., 2004), and therefore does not represent a limitation of the current protocol *per se*. The inability to distinguish within the genus *Myotis* does, however, limits our ability to use these data to quantitatively predict risk for threatened and endangered species.

The timing of the present migratory study is consistent with other pre-construction wind farm projects (Erickson et al., 2002; Reynolds, 2006; 2007a; 2007b; 2008a); therefore these data most likely present an accurate picture of migratory activity within the project area. These data suggest a general level of bat activity (within the detection range of the equipment) in the range of 5.3 calls per detector per night. These data are similar to acoustic data collected at other wind development sites in Pennsylvania (2.9: Reynolds, 2007b; 7.2: Reynolds, 2008a;), Virginia (2.7: NEES, 2006), Wyoming (2.6: Young et al., 2003) and Minnesota (2.2: EPRI, 2003), and lower than data collected from other sites in Pennsylvania (16.4: Reynolds, 2007b) and New York (34.4: Reynolds, 2009).

Bat activity during both the summer sampling period (05 June – 15 August) had an average of 7.2 bats/dn, compared to the fall sampling period (16 August – 12 October) activity level of 7.1 bats/dn. Although this could be interpreted as evidence of fall migratory activity at the project site, it may also represent late seasonal activity of the big brown bat, a species that likely remains active in the area well into the fall because it hibernates locally in buildings surrounding the project site. Overall, these data confirm that the MWCC project site is used predominantly by bats that are known to be abundant in Worcester County. Although the project may result in mortality of residential bats, data from projects throughout North America strongly suggest that these species are killed in low numbers.

A reduction in bat activity with sampling altitude is commonly observed using acoustic monitoring (Reynolds, 2004a; 2004b; 2005; 2006; 2007a; Arnett et al., 2006; 2007; NEES, 2006). The MWCC represents the most extreme decline in bat activity documented to date by NEES, with the LOW microphone representing 80.2% of all the bat activity, followed by the MID microphone (19.7%) and the HIGH microphone (0.05%). The MWCC site is consistent with other pre-construction monitoring surveys in that more migratory tree bat activity was heard at the higher microphone (in this case, the MID microphone) relative to ground-based microphone.

During the present study, we found that the nightly peak in bat activity occurred in the early evening (approximately 20:00) and declined steadily throughout the evening. This is inconsistent with many other pre-construction acoustic monitoring surveys that document bat activity throughout the evening (Reynolds, 2004a; 2005; 2007a; 2007b; 2008a; 2008b). The data from MWCC are more consistent with summer foraging and commuting activity than with sustained migratory activity throughout the evening.

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APPENDIX ONE.

Acoustic Monitoring Protocol

Fixed Platform Monitoring

Prepared by:

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Bow, NH 03304
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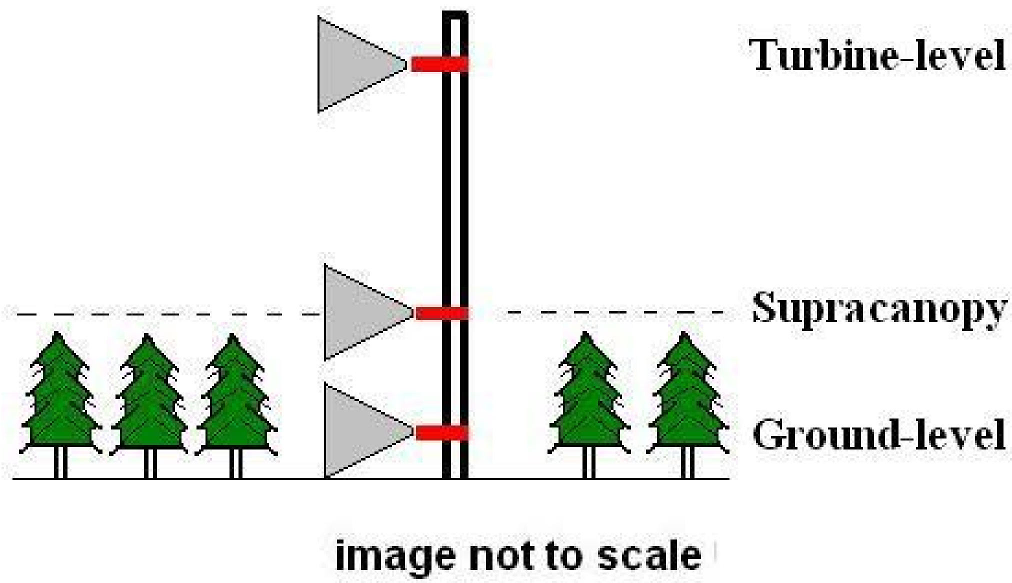
October, 2007

Acoustic Monitoring
Fixed Platform Protocol

The bat detectors are programmed to operate overnight (1800 – 0800) for fourteen hours. Data will be collected at multiple locations across the Project site using pre-existing meteorological tower. Met towers create an ideal sampling platform for the microphones for three reasons. First, they are typically at least 50m in height and therefore allow us to sample within the proposed rotor sweep zone. Second, met towers are located within the proposed project area, thereby allowing us to sample for bat activity at the Project site. Lastly, met towers have trails and service roads leading to them, and these trails and the edge habitat created by the clearing will provide ideal travel corridors to monitor ground-level bat activity.



Three acoustic monitors (Anabat II or SD-1 ultrasonic detectors: Titley Electronics) will be set up on each Met tower as shown above. Each microphone samples the air space at ground level (roughly 10m above ground), supracanopy level (about 30m above ground), and turbine level (49m above ground). Each microphone is capable of detecting the echolocation calls of approaching bats up to 20m away with a potential sampling volume of $254m^3$ (Larson & Hayes, 2000). The met tower will hold the ultrasonic microphones at altitude, while a shielded cable will transmit data from the microphone to the detector housing stored in a NEMA Type 4 weatherproof box placed on the tower near ground level. Each detector will process and store data on-site using 512MB CF flash cards (this will allow us to store approximately 14,000 individual bat passes). The detectors will be connected to a 12 volt power supply maintained by a 34W photovoltaic charging system.

Each acoustic call heard will be recorded by the monitoring equipment and stored for subsequent analysis. The following data will be collected and recorded for each acoustic call:

Date – Month/Day/Year

Time – Hour/Minute/Second

Height – the detector height that recorded the call (turbine, canopy, or ground)

Species – The species or species group identified through call analysis

Researcher – person conducting the acoustic analysis

For each night of observation, the following information will be collected:

Number – Number of individual calls heard

For each migratory season, the following analysis will be conducted:

Activity Level: the average activity level (in calls/night)

Peak Migratory Activity: the seven-day period of peak migratory activity

Biodiversity Index: the total number of species detected, including indices of species richness and evenness.

Spatial Distribution: the percent of activity detected at each height.

APPENDIX 2: Equipment Calibration Records (1 of 2)

Project Name: Mt Wachusett

Site Name:

Monitoring Season: SUMMER/FALL 2008

Project Start Date: —

Acutal Start Date: 6/05/08

Project End Date: —

Actual End Date: 11/12/08

Tower Height: m

Tower Type: (lattice, monopole, other)

Habitat Description:

Contact Name: Fred Unger Heartwood Group / Rob Rizzo MWCC

Phone: 401 861 1650

Access Code:

Other Access Information:

PV Panel:

Box ID:

Key:

Battery:

Mike Mount: square bracket (fixed, square bracket pulley, pole pulley, other)

	Mike Number	Mike Height	Mike Orientation	Cable Number
LOW	NEES 12	10m	0° (N)	56
MID	NEES 10	30m	0° (N)	57
HIGH	NEES 20	60m	0° (N)	58

	Detector (or SD1)	ZCAIM	Sensitivity Setting	Other Comments
LOW	0195	0157	7	
MID	0112	0201	7 → 6	
HIGH	0196	0138	7 → 5	

Other Installation Comments:

APPENDIX 2: Equipment Calibration Records (2 of 2)

Microphone Calibration - Initiation

Mike ID	Status (G/B)	20 kHz	30 kHz	40 kHz	50 kHz	60 kHz	70 kHz	Angle Test
NCCS 12	G	70	64	56	<50	56	65	3/4
NCCS 10	G	70	64	56	<50	<50	59	OK
NCCS 20	G	68	64	56	<50	<50	59	OK

Sensitivity Settings: 30 kHz
Angle Settings: 30 kHz
Sound Level: 75 dB
Distance: 9 m
Sensitivity: 7

Microphone Calibration - Termination

Mike ID	Status (G/B)	20 kHz	30 kHz	40 kHz	50 kHz	60 kHz	70 kHz	Angle Test
NCCS 12	G	75	59	56	<50	56	62	
NCCS 10	G	84	71	59	<50	<50	64	
NCCS 20	G	77	64	56	<50	<50	62	

Sensitivity Settings: 30 kHz
Angle Settings: kHz
Sound Level: 75 dB
Distance: 9 m
Sensitivity: 7

Detector Calibration - Initiation

Detector ID	Firmware	Start Time	Calibration Date	End Time	Calibration Date
0157	v 4019g			+3,481	12 2008
0201	v 4019g			+3,611	12 2008
0138	v 4019g			+3,656	12 2008

PRE-CONSTRUCTION ACOUSTIC MONITORING

Mount Wachusett Community College Wind Project

Worcester County, Massachusetts

Spring 2009

Prepared for:

Mount Wachusett Community College
444 Green Street
Gardner, MA 01440

Prepared by:

D. Scott Reynolds, Ph.D.
North East Ecological Services
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26 August, 2009

Pre-Construction Acoustic Monitoring

Mt. Wachusett Community College Wind Project

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Spring 2009

EXECUTIVE SUMMARY

The Mount Wachusett Community College ("MWCC") Wind Project proposal is for the construction and operation of a 1-2 turbine wind project on the Mount Wachusett Community College campus in Gardner (Worcester County), Massachusetts. As part of the environmental assessment of this proposal, North East Ecological Services (NEES) was contracted to conduct pre-construction acoustic monitoring to determine the potential impact of project construction and operation on bats.

Based on data collected through acoustic monitoring, NEES makes the following conclusions:

1) Roost surveys of Worcester County and bat activity data at the project site suggests a significant resident bat population in the area that is dominated by the big brown bats and little brown myotis.

2) 80% of the total bat activity was detected at the LOW microphone, well below the rotor sweep zone of the turbine. Less than 1% of the total bat activity was heard at the HIGH microphone within the rotor sweep zone of the turbine.

3) Overall levels of bat activity were similar to other pre-construction acoustic monitoring surveys

4) *Myotis spp.* represented 30.6% of the total bat activity. Over 90% of the bat activity from *Myotis spp.* occurred at the LOW microphone and none occurred at the HIGH microphone within the rotor sweep zone of the proposed wind turbine. The *Myotis spp.* group contains four species including the federally-endangered Indiana myotis, *M. sodalis* and the state Species of Special Concern eastern small-footed myotis, *M. leibii*.

5) Bats within the *Myotis spp.* group cannot be reliably identified using acoustic signatures. Given the lack of documented *M. leibii* and *M. sodalis* within 50 km of the project site and the proximity of the MWCC project site to suburban landscapes, it is likely that most, if not all of the *Myotis spp.* activity can be attributed to the little brown myotis, *M. lucifugus*.

6) Acoustic monitoring of Patterns of bat activity (evening temporal data, altitudinal variation, and species composition) are more consistent with summer foraging and commuting activity than migratory activity.

7) Acoustic monitoring of migratory bats suggests that all species of tree bats (red bat, hoary bat, and silver-haired bat) were detected at the project site.

8) Hoary bats, the most commonly killed bat at wind development sites, represented almost 11% of the total bat activity; this is a lower percentage of total activity than seen at many pre-construction acoustic monitoring surveys.

9) The MWCC data, compared to other pre-construction wind projects, suggest medium levels of bat activity throughout both the summer sampling period and fall migratory sampling period.

10) NEES recommends that additional monitoring be carried out during the spring migratory season (15 March – 14 June) to document an entire active season for bats near the project site.

11) Based on these data, NEES concludes that fatality numbers at the project site are likely to be similar in composition but lower in magnitude (on a per turbine basis) to other wind projects sites in the northeastern United States. Given the size of the project, it is unlikely to have a significant impact on bat populations in the region.

1.0 PROJECT OVERVIEW

1.1 The MWCC Wind Project

The MWCC Wind Project proposal is for the construction and operation of one or two 1.5 MW wind turbines (estimated 1.5 to 3.0 MW total capacity) on the MWCC campus located in northern Worcester County, Massachusetts (Fig. 1). The project layout encompasses approximately 4.5 ha. The project consists of a single parcel of publicly owned land, located within the City of Gardner, approximately 1.5 km south/southeast of the intersection of SR-140 and Green Street.

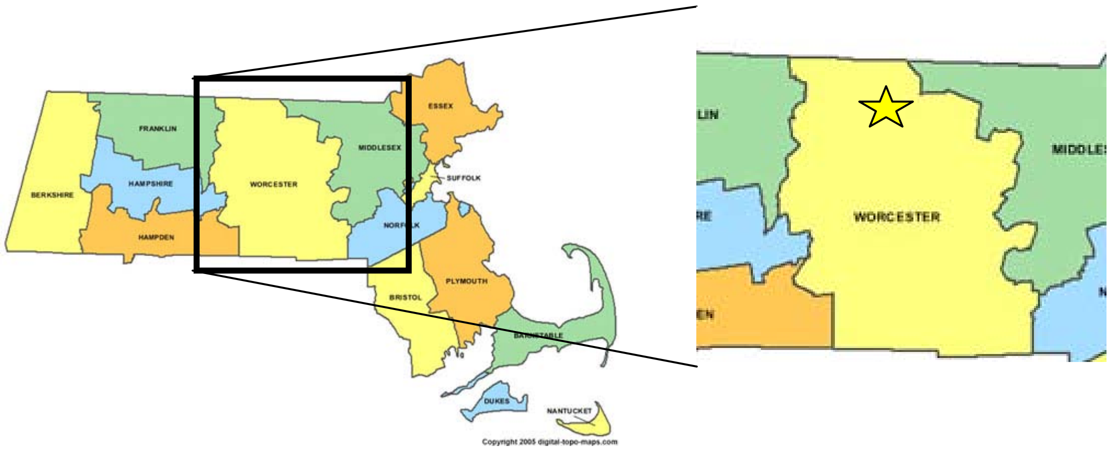

Figure 1: General location of the MWCC Wind Project in Massachusetts

2.0 PRE-CONSTRUCTION ACOUSTIC SURVEY

Most bat mortality appears to occur during migration. Consequently, an understanding of the baseline migratory activity at the MWCC project site during the fall and spring migratory period is critical in understanding the potential impact of this project on bats. This report summarizes data collected during the Spring 2009 migratory period. Previous data were collected from the summer breeding season and the fall migratory season and presented in a separate reported dated 02 February, 2009. Collectively, these data provide a complete year of bat activity at the project site that should help inform biologists and managers about the scale of geographic, altitudinal, and temporal variation in bat activity across the project areas. This, in turn, should help identify the potential impact of wind turbine development and provide quantitative data for BACI (Before-After Control Impact) comparison following construction of the project. All data were collected using a protocol that is consistent with the recommendations of the National Research Council (NRC, 2007) guidelines.

2.1 Equipment Calibration and Data Collection

Data were collected using five Anabat™ SD-1 ultrasonic detection systems placed at two locations. Three microphones were placed at 10m (LOW), 30m (MID), and 50m (HIGH) heights on an existing meteorological (‘Met’) tower (Figure 2). Microphones at the Tower site were all oriented to face south (azimuth of 180°) to document potential migratory activity. Microphones at the Tower site were placed on the Met tower using a pulley system that allowed the microphones to be adjusted, replaced, or relocated without lowering the met tower. The other two microphones were placed at two locations next to a wetland on the project site. Microphones at the Wetlands site were placed on 1.5m metal poles at the edge of the wetlands area and oriented over the water facing west (azimuth of 180°) and southwest (azimuth of 215°).

All microphones were housed in a weather-tight PVC housing and oriented towards the ground to prevent moisture from collecting on the transducer. A 10 cm^2 square Lexan sheet was mounted below the microphone at 45 degrees from horizontal to deflect sound up towards the microphone. Due to the length of the cables, we used Titley™ HI-MIC pre-amplified microphones. The microphones were attached to the Anabat ultrasonic detector using customized cables (EME Systems, Berkeley, California) based on a Canare Starquad™ video cable with an additional preamplifier soldered into the terminal end of the cable to increase signal strength.

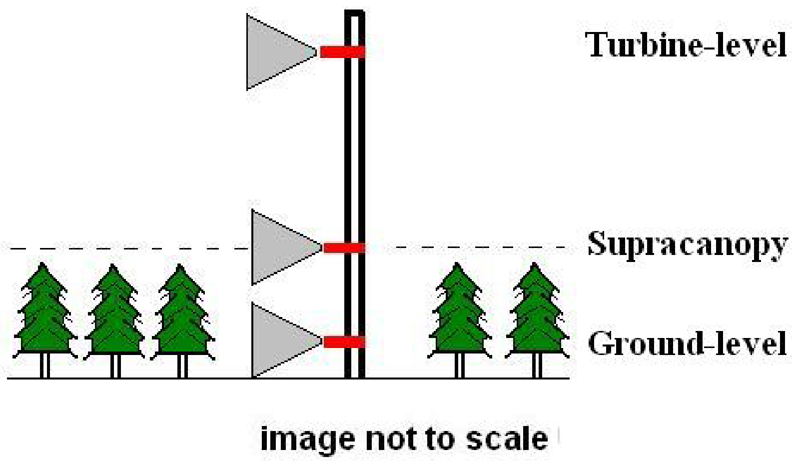

Figure 2. Schematic of Meteorological Tower microphone array

The Anabat™ SD-1 interface module stores bat echolocation signals on removable CF-flash cards. The detectors were placed in a NEMA-4 weatherproof enclosure mounted to the base of the Met tower and powered by a 30W photovoltaic charging system. All microphones and cables were calibrated (before installation and after de-construction) in a test facility using a Binary Acoustics AT-100 multifrequency tonal emitter (BAT, Las Vegas, Nevada) to confirm minimum performance standards for six different ultrasonic frequencies (20kHz, 30kHz, 40kHz, 50kHz, 60kHz, and 70kHz). In addition, a minimum cone of receptivity (15° off-center) was verified by rotating the microphone horizontally on a platform using the AT-100 as a sound source.

The Anabat monitoring systems were programmed to monitor for ultrasonic sound from 18:00 – 08:00 each night throughout the sampling period (19 March – 15 July, 2009). Data cards were retrieved by NEES personnel (Jacques Veilleux) at approximately biweekly intervals. At each visit to the Met tower site, the data cards were removed from each recording system and replaced with new cards. All card removals and replacements were documented on field sheets provided and stored in each tower enclosure. Data cards were mailed to NEES in protective envelopes for analysis.

2.2 Data Analysis Protocol

Data were analyzed using the Analook™ 4.9j graphics software. Bat echolocation recordings were separated from non-bat sounds based on differences in time-frequency representation of the data (Table 1). Files that were determined to be of bat origin were analyzed semi-quantitatively using a dichotomous key that distinguishes species based on a variety of call features. Species identification was conservative to minimize identification error and maximize total number of calls included in the analysis. Specifically, high variation in calls within the genus *Myotis* precludes reliable species identification (Murray et al., 2001). We grouped silver-haired bats (*Lasionycteris noctivagans*) and big brown bats (*Eptesicus fuscus*) into a single group (Lnoct-Efus) to reduce errors in identification of these two species. For those calls that were not of a high enough quality to extract diagnostic features, an "Other Bat" category was used to document total bat activity.

Table 1. Descriptive breakdown of acoustic file source origins

Category	General Description of Time-Frequency Analysis of Data	Probable Source(s)
Wind Noise	random pixilation with little to no pattern	wind
Mechanical	Long calls (> 100 ms) with high constant-frequency (CF) component and drifting characteristic frequency (Fc)	cable resonance EM interference
Biological (non-bat)	Frequency-modulated (FM) call structure with ascending pitch or with characteristic frequency in audible range	insects birds, flying squirrels
Bat Activity	FM or CF dominated data file with species-specific call durations, pitch changes, or other attributes	bats

2.3 Data Assumptions and Presentation Format

The following data were collected in order to characterize the bat activity that occurs at the Project site. Several assumptions were made in order to characterize this activity:

a) bat activity recorded at the Met tower adequately represents bat activity across the Project site.
b) the microphones are properly oriented to record echolocation calls of bats as they fly across the Project site
c) there is relatively little bat activity during the daytime (0800 – 1800)
d) the sampling period (19 March through 15 July) accurately represents the spring migratory activity period of bats at the Project site
e) the echolocation calls recorded on unique data files at the Tower site are independent and do not represent the same individual over multiple sampling periods. No assumption of independence was made for the Wetlands site.
f) echolocation calls within the same data file from the Tower site can be treated as a set of calls from a single individual. No assumption of individuality was made for the Wetlands site.

Assumption a) is based on the technological and methodological constraints that exist at a wind development project. Prior to the concern about turbine-related bat mortality, there were only a few studies that attempted to acoustically document bat migratory activity (for example, Zinn and Baker, 1979; Barclay, 1984). Even fewer studies attempted to document bat activity at altitudes above the tree canopy (for example, Davis et al., 1962; McCracken, 1996). This lack of emphasis was due to the difficulty of recording ultrasonic sound over large periods of time (limitations of recording equipment), wide areas of space (high signal attenuation of ultrasonic wavelengths), or at high altitude. Although most project sites contain appropriate sampling platforms to collect these data (meteorological towers), they are generally non-mobile and often spatially limited across the Project site. However, they are generally sited where turbines will ultimately be constructed and therefore may adequately represent the relevant air space that is available for migratory bats at the project site. Assumption b) is a technical limitation of the condenser microphones used by the ultrasonic recording equipment.

Assumption c) has been validated by numerous field studies and therefore is strongly supported by existing data. Assumption d) is not valid because bats are known to be active well before early June. Conducting additional monitoring during the spring (15 March – 14 June) will validate this assumption. Assumptions e) and f) relate to how bat calls are recorded and represented. Although there is a wide range of opinion on how to interpret echolocation calls, there is a general agreement that researchers should not use echolocation call files as a measure of species abundance unless those calls are independent. This requires that data are collected and analyzed to ensure the spatial- and temporal-independence of each recording. Spatial independence is created by placing microphones in non-overlapping sampling environments. Temporal independence can be created by making assumptions about the time individual bats will remain within the sampling space. Because we do not have adequate research on migratory activity, we cannot make well-grounded assumptions about temporal independence of individual calls. For example, two bat calls recorded at the LOW microphone within ten seconds may represent a single bat flying near the microphone. However, two calls recorded 60 minutes apart are unlikely to represent the same bat. To avoid this potential non-independence, this report will focus on total bat activity, not species abundance or species evenness (relative abundance of each species).

Table 2. Summary of terms and definitions used to describe bat activity

bat activity	Activity estimate calculated from the total number of echolocation calls recorded
high risk species	bats species known to collide with wind turbines at rates higher than predicted based on their abundance during capture (e.g. mist netting) sampling
calls/detector-hour (calls/dh)	Standardized measure of bat activity (controlling for variation in total sampling effort at each site)
peak 7-day activity	estimate of peak sustained migratory activity
fall migration	bat activity from 16 August through 10 November
spring migration	bat activity from 15 March through 31 May
summer activity	bat activity from 01 June through 15 August

2.4 Acoustic Monitoring Station

The MWCC project site had a pre-existing temporary Met tower at the project site. The Met Tower was located within an approximately 4.5 ha old field, with very few invading trees. The old field was bordered by a second growth forest to the east, which extended to both the east and northeast. A relatively long (at least 100 m), narrow (~ 2 m width) area of rock jumble was observed along the east edge of the project field, and approximately 3 to 6 m into the forest interior. This area of rocks was composed of medium and large size boulders, which likely constituted a historical stone wall. The boulders occurred mainly at ground level, and since the rocks were shaded by overstory trees, received only intermittent exposure to the sun. A small (0.75 ha) open water pond borders the project field to the west. Additional wetlands occur to the east of the project field, including a small red maple swamp located approximately 150 m east/northeast of the project field. Several large pond and lakes were observed, including Crystal Lake and Perley Brook Reservoir to the west, Lake Wampanoag, Mamjohn Pond, and Hobby's Pond to the northeast, and Dunn Pond to the southeast. Several additional small ponds were observed both on the MWCC campus property and within the adjacent golf course to the west. Additional details about the site are provided in the Phase I Bat Risk Assessment (NEES, 2008).

The acoustic monitoring system was installed on the Met Tower on 05 June, 2008. All microphones were mounted facing north (azimuth of 0°) to face the direction of probable fall migration. Although the Massachusetts Division of Fisheries and Wildlife does not prescribe sampling conditions, north-facing microphones are recommended in New York State (NYDEC, 2007). The low microphone (LOW) was installed at 10 m altitude, the middle microphone (MID) was installed at 30 m altitude, and the high microphone (HIGH) was installed at 50 m altitude.

3.0 ACOUSTIC MIGRATORY SURVEY RESULTS

3.1 Sampling Effort at the Tower Site

Bat activity was monitored from 19 March through 15 July, 2009. The total sampling period in 2009 was 119 days, or 1,666 hours per detector. Due to the potential for data overload, failure to swap cards, card reading failures, or equipment malfunction, the actual sampling effort of each microphone is generally less than this maximal potential sampling effort. The sampling effort at the MWCC project site is summarized in Table 3.

Table 3. Acoustic Sampling Effort at the MWCC Wind Project Site

Microphone	Total Days Monitoring	Percent of Total Monitoring	Reasons for Data Loss (days of loss)
LOW	116	97.5%	card overload (3)
MID	119	100.0%	
HIGH	118	99.2%	card overload (1)
AVERAGE	**117.7**	**98.9%**	

3.2 Overall Data

A total of 198,857 files was recorded by the acoustic monitoring equipment. After analysis, 604 files (0.3%) were determined to be of bat origin. Although the vast majority of the acoustical activity was wind noise, there were some files that appeared to be mechanical and non-bat biological in origin. Combining data from all microphones, bat activity was documented on 79 of the sampling days (66.4%); 45.0% of the non-activity days occurred during the first three weeks (18 of 21 days) of the survey period. Mean daily bat activity was 5.1 calls per night.

A depiction of overall bat activity at each tower is shown in Figure 3. Each pie graph is scaled to represent total relative activity (with actual bat calls identified by the numbers next to each graph).

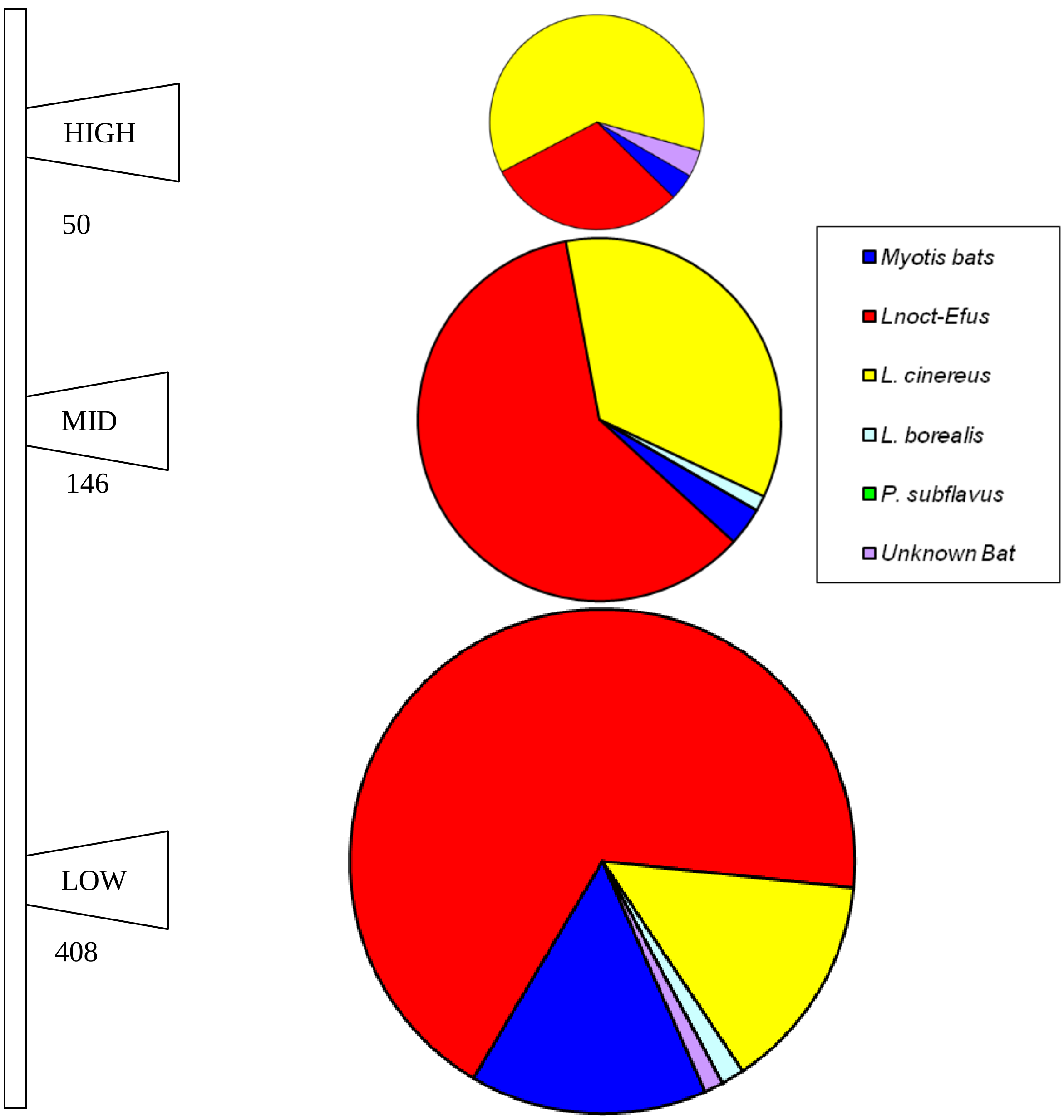

Figure 3: Distribution of Bat Activity across Microphone Heights by Species

3.3 MWCC Met Tower

3.3.1 Low Microphone

During the period from 19 March through 15 July, 2009, a total of 77,495 files were recorded and analyzed. It was determined that 408 files were of bat origin. A minimum of four species or species groups were detected at the LOW microphone. The silver-haired/big brown group (*Lnoct-Efus*) was the dominant bat group heard at the LOW microphone, comprising 68.1% of all calls (Figure 4).

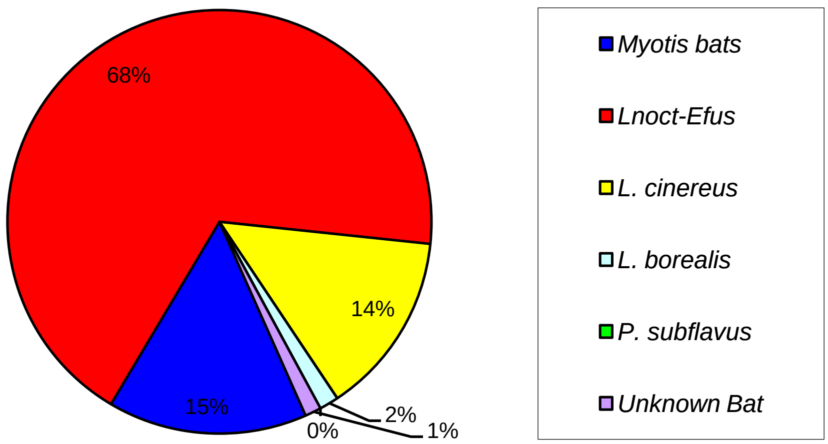

Figure 4: Distribution of Bat Activity at the MWCC Tower LOW Microphone

Looking across the entire sampling period, one gradual activity peak was recorded at the LOW microphone; this peak occurred during the seven-day period beginning 01 June (Figure 5). Activity remained relatively stable throughout June and July. No bat activity was detected prior to 25 March.

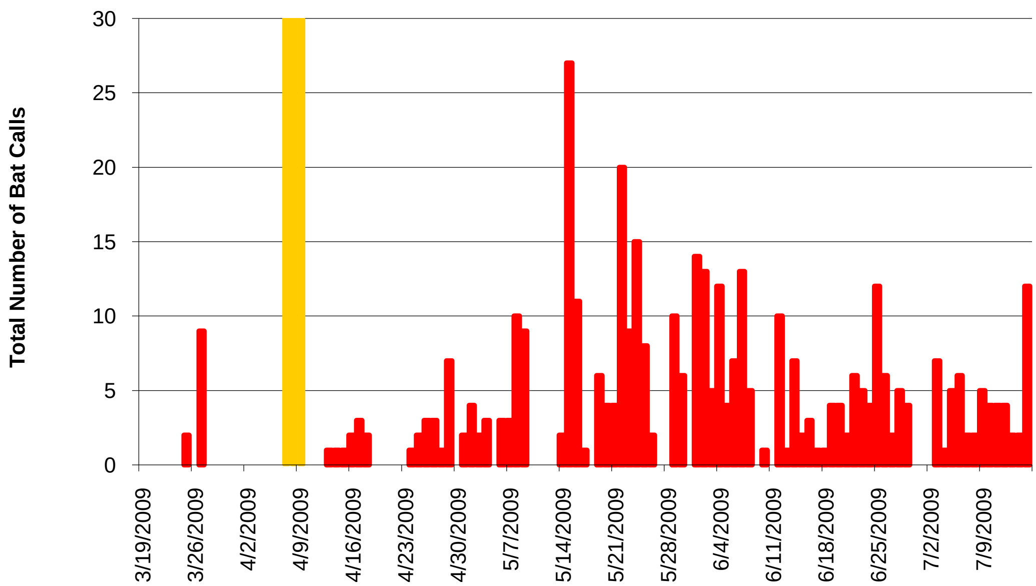

Figure 5: Seasonal Distribution of Bat Activity at the MWCC Tower LOW Microphone (yellow bars are periods of no data)

3.3.2 MID Microphone

During the period from 19 March through 15 July, 2009, a total of 85,220 files were recorded and analyzed. It was determined that 146 files were of bat origin. A minimum of four species or species groups were detected at the MID microphone. The silver-haired/big brown bat group (*Lnoct-Efus*) and the hoary bat (*L. cinereus*) were the dominant groups heard at the MID microphone, comprising 60.3% and 34.9% of all calls, respectively (Figure 6).

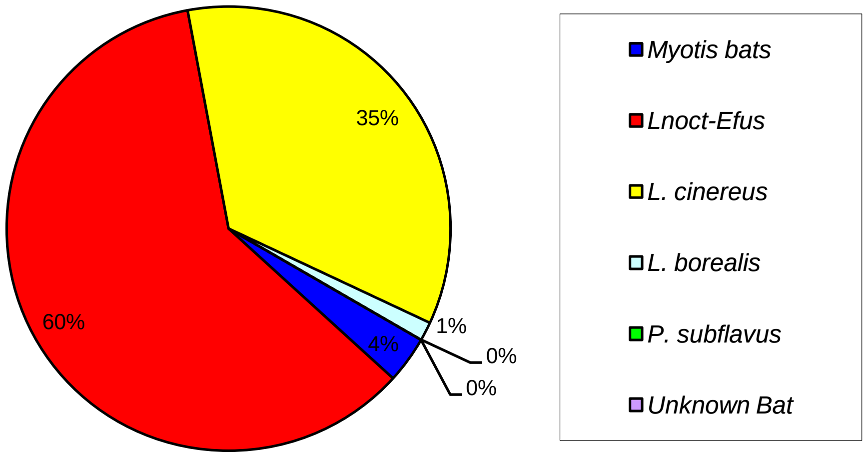

Figure 6: Distribution of Bat Activity at the MWCC Tower MID Microphone

Looking across the entire sampling period, there was a single gradual peak in bat activity recorded at the MID microphone; the peak occurred during the seven-day period beginning 06 June (Figure 7). No bat activity was detected prior to 25 March.

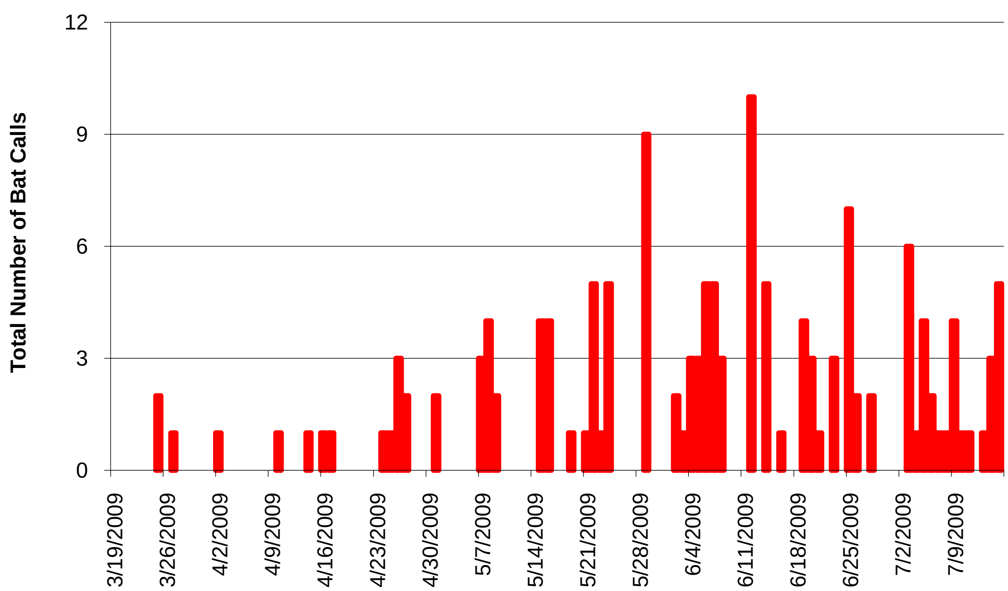

Figure 7: Seasonal Distribution of Bat Activity at the MWCC Tower MID Microphone

3.3.3 High Microphone

During the period from 19 March through 15 July, 2009, a total of 36,142 files were recorded and analyzed. It was determined that 50 files were of bat origin. A minimum of three species or species groups were detected at the HIGH microphone. The hoary bat (*L. cinereus*) and the silver-haired/big brown bat group (*Lnoct-Efus*) were the dominant groups heard at the HIGH microphone, comprising 62.0% and 30.0% of all calls, respectively (Figure 8).

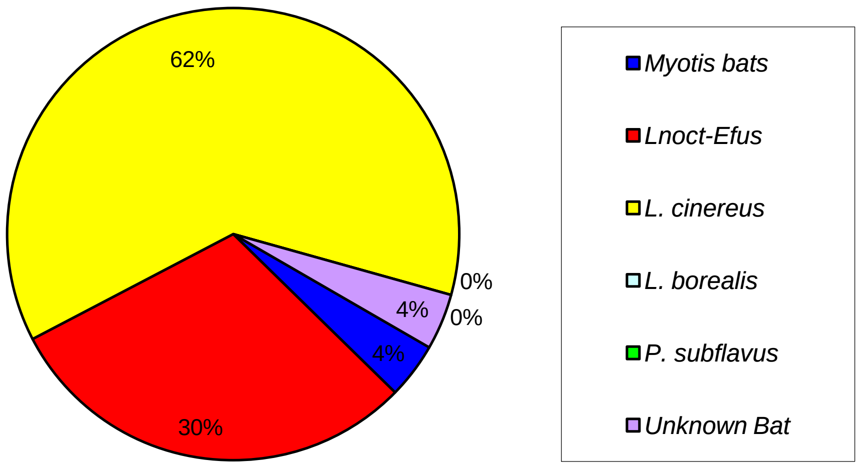

Figure 8: Distribution of Bat Activity at the MWCC Tower HIGH Microphone

Looking across the entire sampling period, one gradual activity peak was recorded at the HIGH microphone; this peak occurred during the seven-day period beginning 06 June (Figure 9). No bat activity was detected prior to 02 April and no bat activity was detected after 13 June.

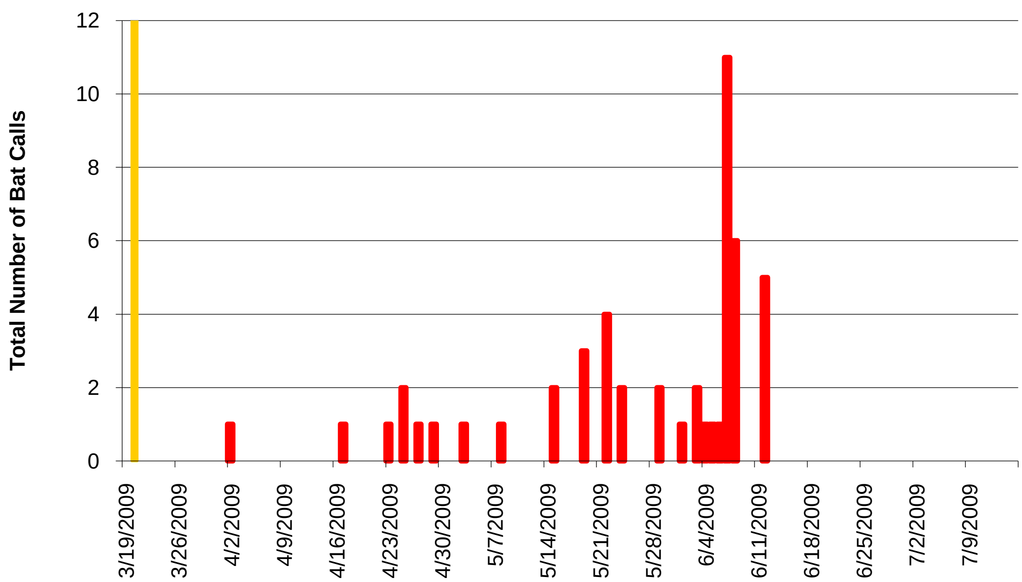

Figure 9: Seasonal Distribution of Bat Activity at the MWCC Tower HIGH Microphone (yellow bars are periods of no data)

3.4 Vertical Distribution of Bat Activity

The highest level of bat activity was observed at the LOW microphone (67.5% of total activity). There was a substantial decline in bat activity with altitude across the project site (Figure 10). When bat activity was standardized by total sampling effort, the LOW microphone had a higher level of activity (3.5 calls/detector-night) than either the MID microphone (1.2 bats/dn) or HIGH microphone (0.4 bats/dn).

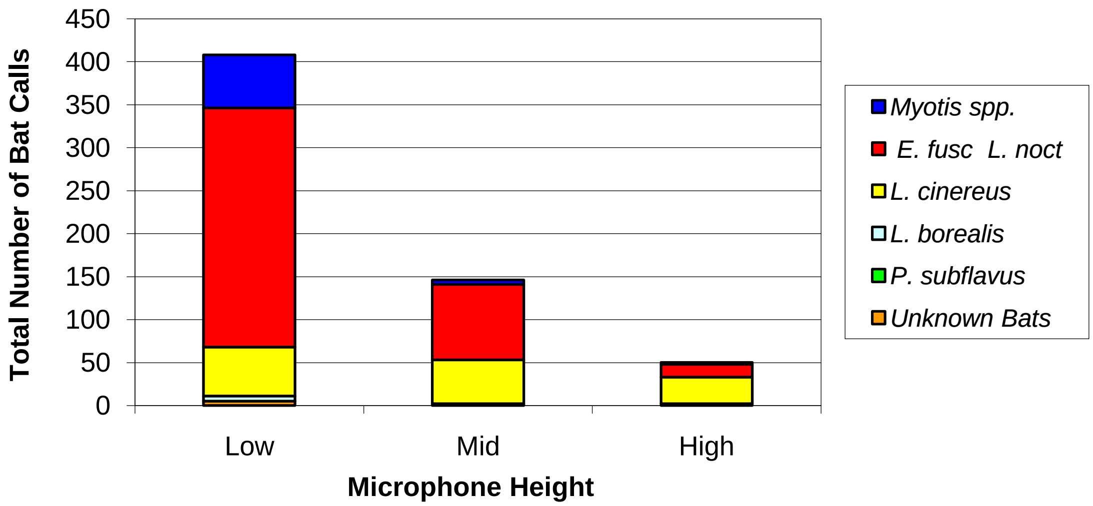

Figure 10: Distribution of Bat Activity Across Microphone Heights by Species

There were also species-group patterns in bat activity. For example, most of the *Myotis* spp., silver-haired/big brown bat group (*Lnoct-Efus*), and red bat (*L. borealis*) calls were recorded at the LOW microphone (Figure 11). Conversely, hoary bats (*L. cinereus*) were more randomly distributed across the microphone heights.

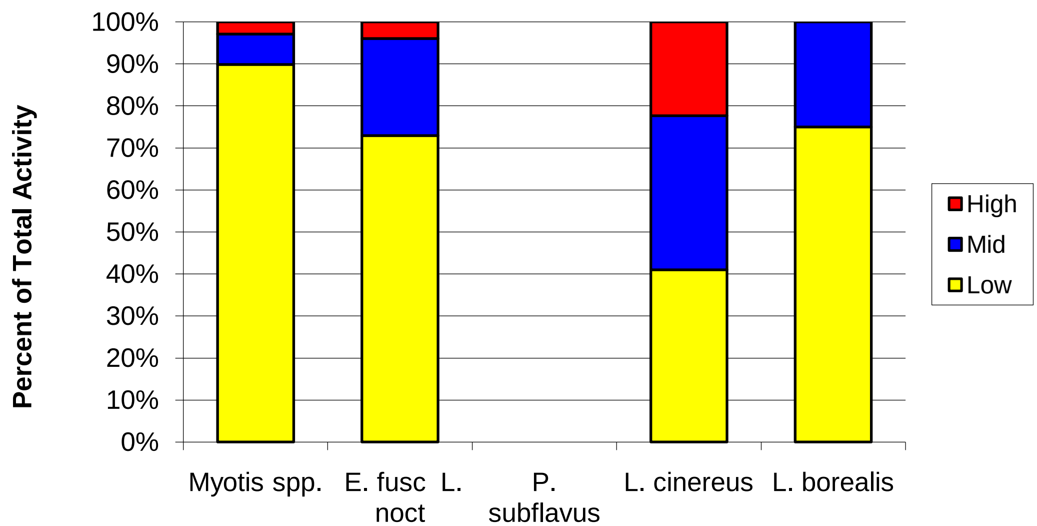

Figure 11: Vertical Distribution of Bat Activity by Species Group

3.5 Temporal Distribution of Bat Activity Across The Year

Pooling all data, there was a general low level of bat activity at the MWCC project site during the monitoring period; however, this was highly influenced by the lack of detectable bat activity at the HIGH microphone. Bats were already active at the project site at the commencement of monitoring, but increased substantially in early July and again in late August before declining to low levels by late September (Figure 12). The general lack of bat activity during the final six weeks of the survey period suggests that we sampled across the entire fall migratory period at the project site. Specifically, these last six weeks represent 26.1% of the entire sampling period, but only 1.0% of the total bat activity. Standardized for sampling effort, the summer period (05 June through 14 August: 7.24 bats/dn) had a similar level of bat activity as the peak fall migratory period (15 August through 30 September: 7.08 bats/dn). These data are consistent with the use of the project site as a summer foraging area for *Myotis* and big brown (*E. fuscus*) bats. However, the presence of bat activity throughout the fall migratory season suggests the project site is also within the migratory corridor of some bats, particularly hoary bats.

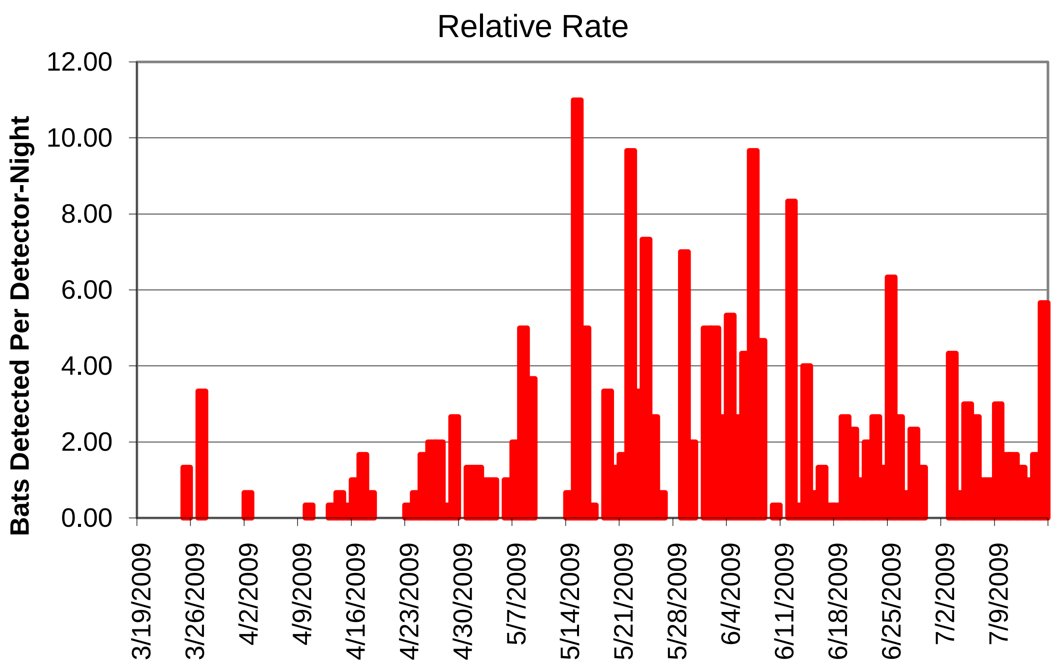

Figure 12: Distribution of Bat Activity Across the Sampling Period

3.6 Temporal Distribution of Bat Activity Across The Night

Data were pooled across the sampling period and analyzed for nightly activity patterns in 15-minute intervals. This showed very little bat activity during the first 120 minutes and during the last 120 minutes (1.0% of total bat activity) of the nightly sampling period; only one bat was heard during the during the last three hours (0500 – 0800) of nightly sampling. These data strongly suggest that the 14-hour sampling protocol is more than adequate to document bat activity at the project site. Bat activity at the project site was characterized by a rapid increase in activity early in the evening (starting at approximately 19:30) that peaked at approximately 21:00 and remained steady for approximately 150 minutes before declining steadily throughout the evening (Figure 13).

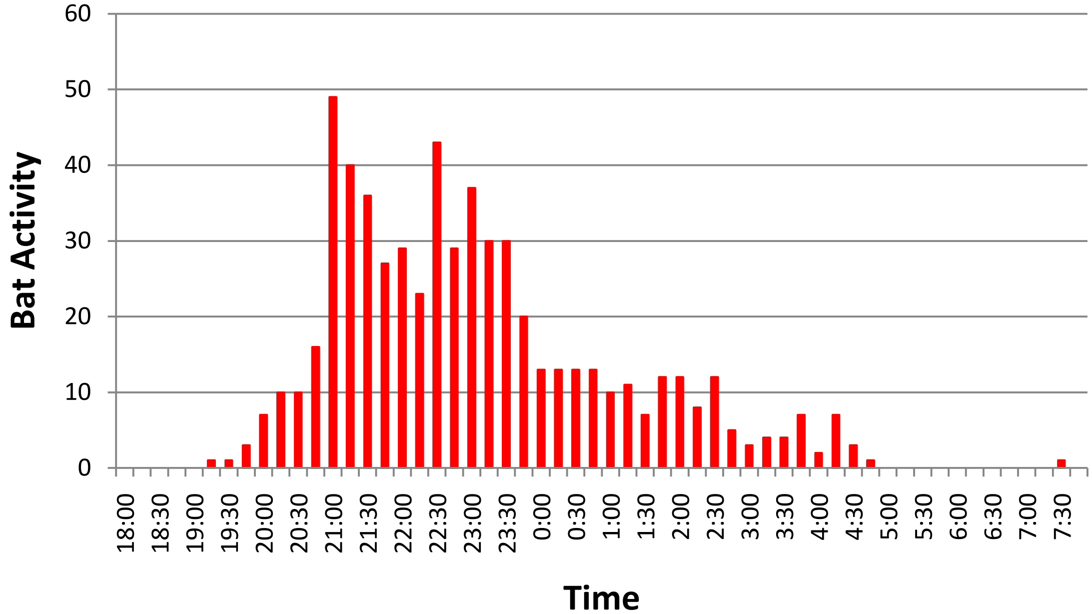

Figure 13: Temporal Distribution of Bat Activity Across the Evening

When the bat activity is analyzed across the vertical sampling array, the data show that the rapid increase in bat activity early in the evening is the result of ground-level bat activity (Figure 14).

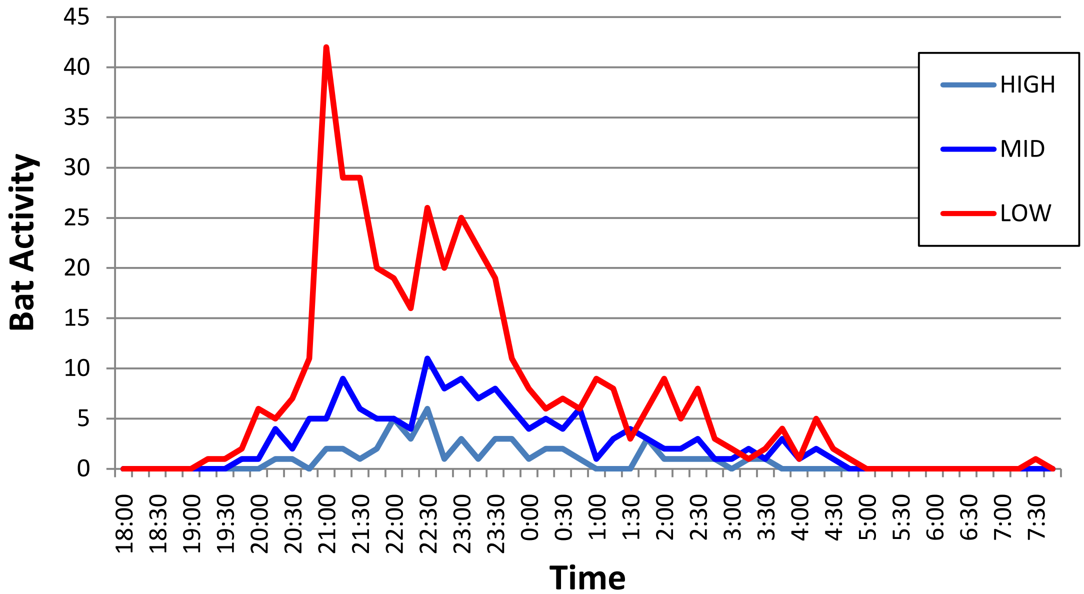

Figure 14: Temporal Distribution of Bat Activity Across The Microphones

3.7 Comparison of Summer Data for 2008 and 2009

The Fall 2008 sampling period began in the summer (05 June) and the Spring 2009 samling period extended into the summer (July 15); therefore there were 41 sampling days overlapping between the two sampling efforts. In 2009, there was a 61% decline in total bat activity relative to 2008. The largest rate of decline occurred in the *Myotis spp.*, which experienced an 89% decline in activity during the same sampling period in 2009. The silver-haired/big brown bat group (*Lnoct-Efus*) experienced a 59% decline and the hoary bat (*L. cinereus*) experienced a 4% decline.

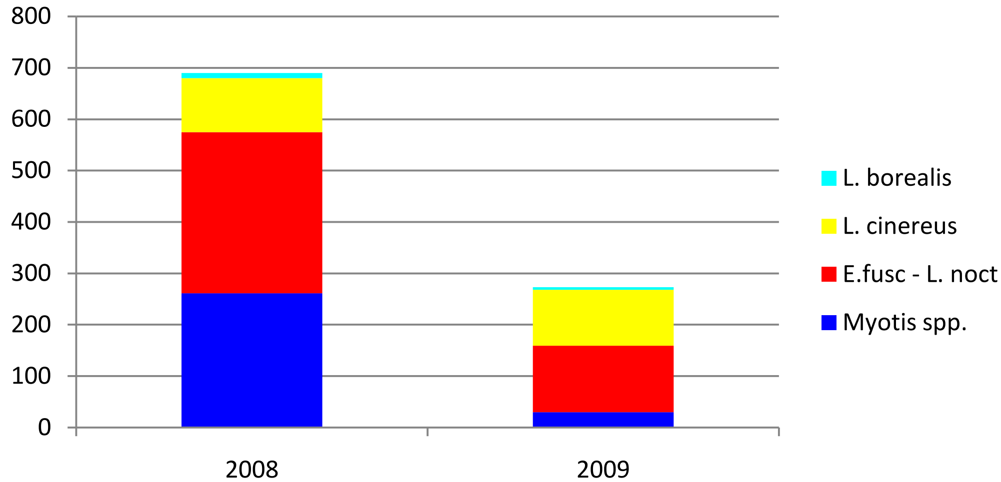

Figure 15: Relative Change in Bat Activity During Summer 2008-2009 (based on overlapping sampling from 05 June – 15 July)

3.8 Ground-Based Wetlands Monitoring

During the period from 19 March through 15 July, 2009, a total of 128,935 files were recorded at the Wetlands site. Analysis of data collected from 21 April through 15 July revealed a total of 869 files of bat origin. A minimum of three species or species groups were detected at the Wetlands site. The *Myotis* spp. group was the dominant group heard at the Wetlands site, comprising 91.5% of all the calls (Figure 16).

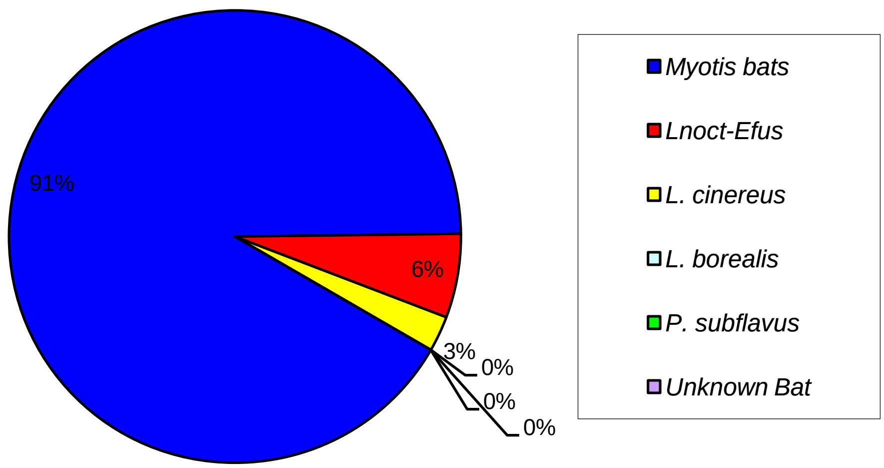

Figure 16: Distribution of Bat Activity at the MWCC Wetland Site

Bat activity at the Wetlands site was highly episodic, with a few nights accounting for a majority of the bat activity. Bat activity rates varied from 0.0 bats/dn up to 139.5 bats/dn (Figure 17). Bat activity was initially irregular in the spring but became more steady as summer progressed.

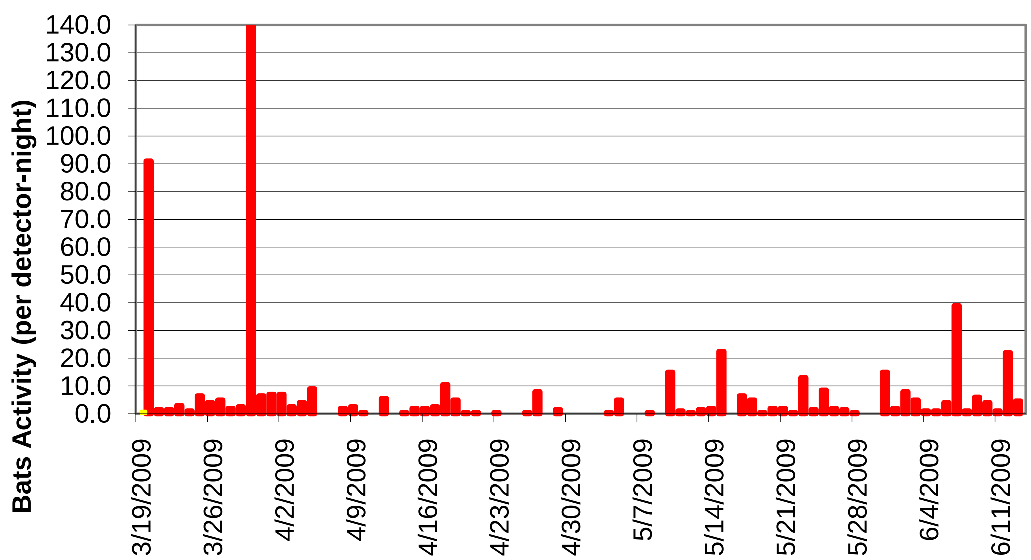

Figure 17: Seasonal Distribution of Bat Activity at the MWCC Wetland Site

Bat activity at the Wetlands site was more temporally clustered that bat activity at the Tower site. Specifically, bat activity started approximately 60 minutes later at the Wetlands site (Figure 18). The pattern of bat activity at the Wetlands site was clearly bimodal, with a strong peak in activity occurring 22:15 and a secondary peak occurring at approximately 03:00.

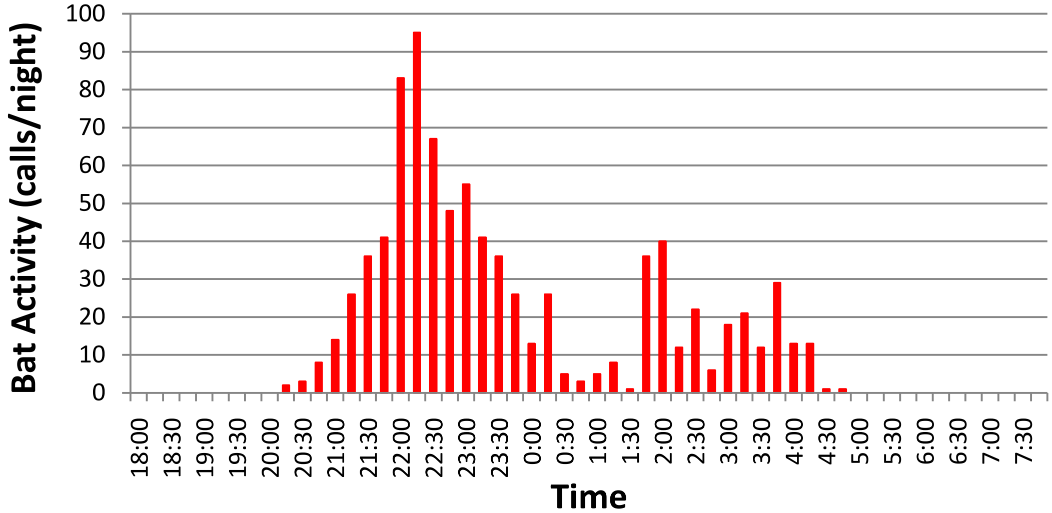

Figure 18: Temporal Distribution of Bat Activity Across the Evening at the MWCC Wetland Site

3.9 Overview of Bat Migratory Acoustic Data

During the 119 days of monitoring at the MWCC project site, a total of 604 bat calls were recorded at the Tower site and 869 calls were recorded at the Wetlands site. Analysis of these data suggests the following:

a) wind generated the most data files, with less than 1.0% of the data files containing echolocating bats.
b) At the Tower site, more calls were heard at the LOW microphone (3.5 calls/detector-night) compared to the MID microphone (1.2 calls/dn) and the HIGH microphone (0.4 calls/dn).
c) At the Wetlands site, more calls were heard at the microphone facing west (6.5 calls/detector-night) than at the microphone facing south-west (2.7 calls/dn).
d) across all microphones at the Tower site, the highest percent of activity came from the silver-haired/big brown bat (*Lnoct-Efus*) group (62.3%), followed by the hoary bat (*L. cinereus*: 23.0%) and the *Myotis spp.* group (11.4%).
e) Across both microphones at the Wetlands site, the majority of bat activity came from the *Myotis spp.* group (91.5%).
f) Given the relatively urban landscape surrounding the MWCC project site, it is highly likely that most of the calls from the silver-haired/big brown (*Lnoct-Efus*) species group were from the big brown bat (*E.fuscus*), a house-roosting bat that is well-documented within the area and most often found in cities such as Keene and Nashua New Hampshire, as well as Worcester and Leominster, Massachusetts (Reynolds, *pers. obs.*).

g) *Myotis spp.*, which contains five species including the federally-endangered Indiana myotis (*Myotis sodalis*) and the state Species of Special Concern eastern small-footed myotis (*Myotis leibii*), represented only 11.4% of the total bat activity at the Tower site. The inability to reliably identify these two species from the other species within the genus *Myotis* limits the use of these data to quantify the potential presence or use of the MWCC project site by these species. However, a bat risk assessment of the project site determined that no *M. sodalis* have been documented during the summer in the state of Massachusetts and there are no documented *M. leibii* within 50 km of the project site. Given the proximity of the MWCC project site to suburban landscapes, it is likely that most, if not all of the *Myotis spp*. can be attributed to the little brown myotis (*M. lucifugus*).
h) Within the *Myotis spp.* group, most of the activity at the Tower site was detected at the LOW microphone (89.8%), well below the rotor sweep zone of the turbines.
i) Comparing bat activity data collected during early summer of 2008 with data collected during the same time period in 2009 showed a substantial decline in total bat activity (61%); this decline was most evident in the *Myotis spp.* group which experienced an 89% reduction in total bat activity. This decline may represent the impact of White-Nose Syndrome on *Myotis* bats in Massachusetts. Data collected at hibernacula throughout the northeast and in Massachusetts specifically suggest that these bats experienced high levels of overwinter mortality during the winter of 2008-2009.
j) The hoary bat (*L. cinereus*) was the second most commonly-detected bat during the sampling period, representing 23.0% of all recorded bat activity. The hoary bat was the dominant bat species heard at the HIGH microphone and the only bat species detected at roughly equal proportions across all microphones at the Tower site.
k) All species of migratory tree bat, the hoary bat (*Lasiurus cinereus*), red bat (*Lasiurus borealis*), and the silver-haired bat (*L. noctivagans*) were detected during the sampling period.
l) The migratory tree bats that could be acoustically isolated (hoary bat and red bat) represented 24.3% of the total bat activity at the Tower site; 57.1% of this activity was detected at the MID or HIGH microphone where the bats would be at risk of colliding with rotating turbine blades.
m) The fact that there was no very little bat activity during the first three weeks of monitoring (19 March – 09 April) suggests that the sampling protocol captured the vast majority of spring migratory bat activity at the project site.
n) Bat activity at the MWCC project site generally peaked in mid-May and remained steady through mid-July was sampled ceased.
o) Most of the bat activity at the Tower site peaked early in the evening and declined steadily throughout the night. Bat activity at the Wetlands site started later than activity at the Tower site and showed a bimodal pattern typical of summer foraging behavior.

4.0 ACOUSTIC BAT MIGRATORY DATA CONCLUSION

The utility of conducting pre-construction studies of potential bat use at wind project sites has historically been limited due to the lack of appropriate technology; in particular the inability to monitor bat activity within the rotor sweep zone of the turbine. When acoustic monitors are deployed at ground level, there is an inability to detect a correlation between activity levels and mortality (Erickson et al., 2002) because the monitors do not sample at rotor height. The protocol used in the current study has resolved this issue, but there are not enough studies currently available to determine whether pre-construction activity surveys are predictive of post-construction bat mortality. However, the requirement of fixed elevated monitoring stations limits the ability to sample across the project site. One limitation of the current study is the inability to reliably identify species within the genus *Myotis*. This inability is well documented throughout the range of this genus (Ahlén, 2004; Jones et al., 2004), and therefore does not represent a limitation of the current protocol *per se*. The inability to distinguish within the genus *Myotis* does, however, limits our ability to use these data to quantitatively predict risk for threatened and endangered species.

The timing of the present migratory study is consistent with other pre-construction wind farm projects (Erickson et al., 2002; Reynolds, 2006; 2007a; 2007b; 2008a); therefore these data most likely present an accurate picture of migratory activity within the project area. These data suggest a general level of bat activity (within the detection range of the equipment) in the range of 1.7 calls per detector per night. This activity rate is generally lower than rates from other wind development sites (summarized in the Fall 2008 report), but less data are collected during the spring migratory period and most of the existing data were collected prior to the impact of WNS on bats in the northeast.

Bat activity during both the Summer 2009 sampling period (01 June – 15 July) had an average of 2.4 bats/dn, a decline of 66.7% from the Summer 2008 sampling period. Bat activity during the spring migratory period (15 April – 31 May) was 1.8 bats/dn, lower than both the summer sampling and fall migratory sampling period. Overall, these data confirm that the MWCC project site is used predominantly by bats that are known to be abundant in Worcester County. Although the project may result in mortality of residential bats, data from projects throughout North America strongly suggest that these species are killed in low numbers.

Data collected during the Fall 2008 and Spring 2009 sampling periods are completely consistent in several respects. First, both data sets show a marked reduction in bat activity with sampling altitude; this is consistent with data collected at most wind development sites in the northeast. Second, the proportion of *Myotis* spp. bats declines with altitude during both sampling periods. This is consistent with data collected at other wind development sites and is consistent with the low level of *Myotis* spp. mortality documented at operating wind farms. Lastly, both data sets suggest that bats are migrating across the project site during peak migratory periods, but that the preponderance of bat activity is the result of bat activity (foraging and commuting) across the project site during the summer activity period.

Lastly, the inclusion of the Wetlands site as an additional sampling location during the Spring 2009 sampling period supports the data collected at the Tower site. Specifically, it shows that there is a substantial amount of bat activity near the ground at the Project site. However, it is unclear what impact the development of a wind turbine at the Project site will have on this activity.

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Appendix 4. EMI Report

Gradient
CORPORATION

February 3, 2009

Mr. Robert Rizzo
Director of Sustainability and Energy Policy
Mount Wachusett Community College
444 Green St
Gardner, MA 01440

RE: Radiofrequency (RF) Impact of Mt. Wachusett Community College Wind Turbines

Dear Mr. Rizzo:

Jacobs Engineering and Mt. Wachusett Community College requested that Gradient Corporation review the electric-and-magnetic-field (EMF) aspects of the College's proposed wind-turbine installation with regard to the proximity of the 2 turbines to the nearest radio-station antenna (WGAW). I therefore have evaluated whether operation of wind turbines producing 60-Hz electric power will interfere with signal reception from the WGAW radio station in Gardner, MA. I also comment on whether the electric and magnetic fields (EMF) from the turbines *per se* and electrical interconnects would be expected to create any potential health hazards.

As explained below, my conclusions are: (1) There is no expectation that wind-power electric-generators operating at 60 cycles-per-second (or 60 Hertz [Hz]) frequencies will interfere with radio transmissions of an AM-band broadcaster under the conditions of the proposed Mt. Wachusett Community College Site. (2) The power-line EMF created by operation of the turbines will diminish very rapidly in magnitude with distance away from the turbines and underground lines, and do not pose a risk for adverse health effects.

I am a physicist and public health professional trained in and familiar with the scientific research on effects of radiofrequency (RF) energy and EMF as produced by many devices in modern society (*e.g.*, power lines, radio antennas, TV antennas), and in particular the electromagnetic characteristics differentiating power-line, 60-Hz EMF from RF electromagnetic waves in the 1,000,000-Hz (1 megahertz [MHz]) range, as typical of AM radio stations. Please refer to my attached biographical sketch for more details on my training and expertise.

The "electromagnetic spectrum" refers to oscillating (time-varying) electric and magnetic fields. Different regions of the spectrum are characterized by the oscillation frequency, as given in units of cycles per second, or "Hertz" abbreviated as Hz. The spectrum encompasses frequencies from below the kilohertz range (kHz, 1,000's of Hertz) up through microwaves (gigahertz, GHz, or billions of Hertz) and on up in frequency into infrared, light, ultraviolet, and X-rays. Visible light is the major source of electromagnetic energy in our environment. The human body, by virtue of being alive and warm, generates heat energy (electromagnetic energy in the infrared portion of the spectrum), which can be seen by an "infrared" camera, even in complete darkness. The RF portion of the electromagnetic spectrum is at a lower frequency than infrared (heat) radiation, and below the "ionizing" portion of the spectrum. There are many, common sources of RF energy in our environment:

Commercial radio (AM & FM) and commercial TV (VHF & UHF & digital)
Marine and aviation radio services, marine and aviation radar, police radar
Public emergency, ambulance, fire, and police dispatch services
Amateur (ham) radio operators, "walkie-talkies," citizens-band transmitters
Cellular telephones, pagers, Personal Communications Systems (PCS)
Microwave ovens, cordless telephones, baby monitors, wireless toys, remote door-openers
Computers, computer monitors, AM/FM radios, TV sets, CD players, computer games
Microwave links for computers, radio & television stations, and telephones
Satellite television / communications, the global positioning system (GPS)

The RF characteristics of the WGAW AM radio station are given in Appendix A to this letter. The key factors are that the radio-wave frequency is 1,350 kHz, and the wavelength of the radio waves is 224 meters (734 ft). As listed in Appendix A, there are several broadcasting antennas in the Gardner, MA, area. The relevant characteristics of the proposed wind turbines are given in Appendix B, and the key factors are that the electric power frequency of the wind turbines is 60 Hz, and the rotation frequency of the blades is 14 to 20 Hz, and the rotor diameter is about 82 to 88 meters (267 ft to 289 ft), with maximum rotor width of about 3.5 meters (11½ ft)..

There are two ways in which operating wind turbines might interfere with local communications infrastructure. First, the presence of the wind turbines could physically block reception of the radio or other communication signals. Second, physical rotation of the wind-turbine generator, and transformation of the electric power to 60 Hz, will produce electric and magnetic fields with certain frequencies on the electromagnetic spectrum, which could potentially add or partially cancel the electromagnetic waves produced by the WGAW radio station in the AM frequency range.

As noted earlier, the nearest radio station is WGAW, an AM radio station operating at 1,340 kHz. The two proposed wind turbines will be located south of the college campus on the eastern side of Green Street (Figure 1). The tower for the radio station is located on Green Street, across from the Mt. Wachusett Community College campus (Figure 2), with the proposed turbines thus being southwest of the radio antenna, at distances away of about 1,300 and 1,600 ft.

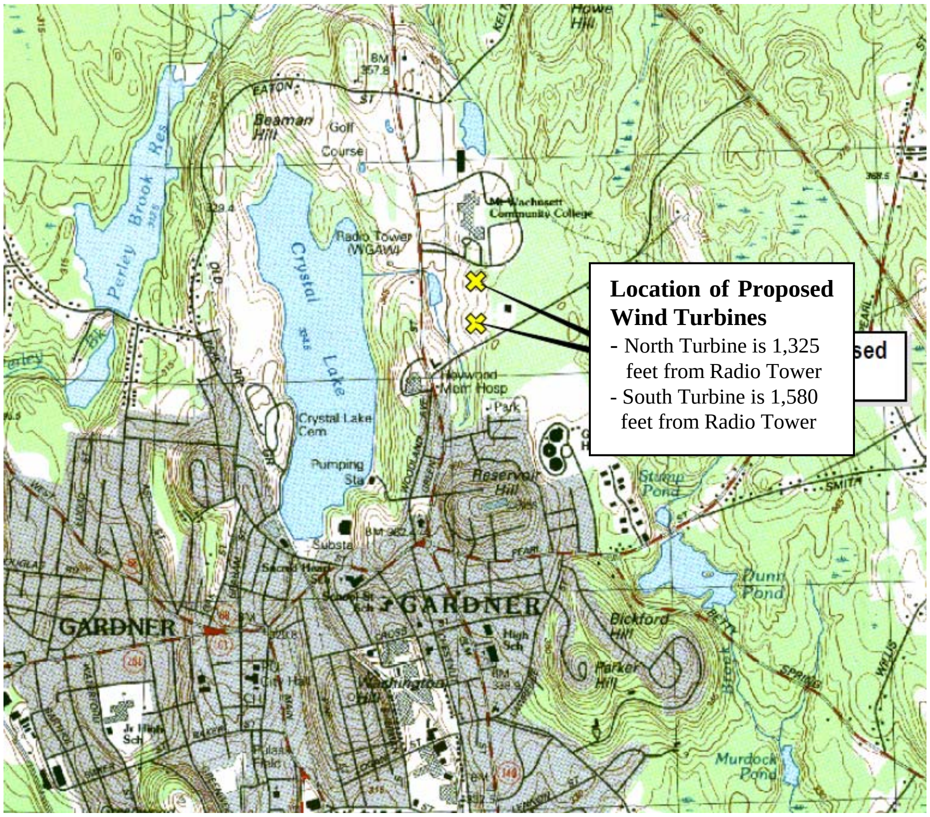


Figure 1: Map of Gardner, MA and the Mt. Wachusett Community College Campus. The radio station tower and two proposed turbine locations are indicated.

Figure 2: The single tower for radio station WGAW. The tower is a mast tower with a non-directional, circular broadcast pattern (picture courtesy of http://gallery.bostonradio.org/2004-08/worcester/100-02202-med.html)

The possible mechanisms by which communication signals are blocked are through shadowing or ghosting. Shadowing is similar to objects blocking sunlight and casting shadows, *i.e.*, large obstacles can block radio and other communication waves and cast “shadows.” However, the ability to cast a shadow depends upon the how the wavelength of the electromagnetic wave compares to the size of the blocking object. As the wavelength of the electromagnetic wave approaches and exceeds the size of the blocking object, the “shadow” becomes blurry and reception behind the object is no longer blocked. In this case, the wavelength of WGAW's broadcast frequency is about 224 meters, and the turbine blade tip-to-tip diameter is about 88 meters, with the width of the blades being far less, about 3.5 m. Turbine blades with these dimensions will are not able to block radio signals with wavelengths much larger than the turbine physical dimensions.

Ghosting is similar to shadowing but is due to intermittent reflections of the radio waves from the rotating turbine blades, which may then lead to constructive or destructive interference between direct and reflected radio waves at the reception point. As in the case of shadowing, the ability to reflect radio waves depends upon the relative size of the radio waves and the object they may reflect from. For a 224-meter wavelength radio wave, the amount of energy reflected by the wind turbine blades is tiny, and the reflected waves will have very little energy compared to the direct waves. Consequently, no ghosting interference is expected from the turbines.

It should also be noted that the electric-power transmission from the turbines to the College will be *via* underground transmission lines, and hence there will be no possibility of RF interference from above-ground utility towers *via* reflections or corona discharge.

The above discussion of shadowing and ghosting pertains to electromagnetic waves transmitted through the air, but some frequencies of electromagnetic communication can also travel closer to the ground. In ground waves, the RF signal is guided near the ground because of the differing conductivity between air and earth. Because the presence of the wind turbines will not appreciably affect ground conductivity, there is no anticipated effects for radio reception *via* ground waves.

In terms of direct electromagnetic waves from the turbines, the key point is that the turbines will rotate at anywhere from 14 to 20 rpm and will generate AC power at a 60-Hz frequency. The power generated by the turbines will be transmitted through an underground cable to Mt. Wachusett College. I considered the possibility of interference with radio-station signals *via* the mechanism whereby the two different frequencies of electromagnetic fields could add and subtract to produce harmonics at the added and subtracted frequencies. An intuitive example of this interference is the tuning of a piano. When a tuning fork and piano note are struck at the same time and the note is out of tune, a beat pattern or a fluctuation in sound will be heard. The piano is tuned by adjusting the tension of the piano wire until the beat pattern disappears. Because the frequency of electromagnetic waves from the turbine output (14 to 60 Hz) and the frequency of the radio station (1,340 kHz or 1,340,000 Hz) are so far apart, no distortion from adding and subtracting these frequencies can be expected.

Members of the public sometimes express concerns regarding health effects of power-line EMF. Levels of power-line, 60-Hz EMF from the turbines and wiring will be very low, because of the compact nature of the electric wiring within the turbine, and within underground lines, leads to field cancellation. That is, the magnetic fields created by adjacent wires that carry currents in opposite directions oppose each other, and the net resultant is much reduced compared to, say, currents in overhead power lines, where each of the individual phase currents are widely separated from each other. Electric fields will be zero because of the underground alignment of the conductors and the electrically conducting shell of the turbines. For magnetic fields, it can be expected that the power-line magnetic fields immediately nearby will be lower than 5 mG, which is lower than typical magnetic field levels found in the vicinity of some household appliances (*e.g.*, a can opener at 1 foot is about 100 mG), and the earth's field (which is a steady field) is about 550 mG. Moreover, the turbine-associated EMF will decrease rapidly in size with increasing distance. Finally, the current status of scientific research on power-line EMF does not support the idea that these weak fields can affect normal function of the human body. Hence, there is no expectation of adverse health risks.

In conclusion, on the basis of my familiarity with the EMF and RF science that has been developed with regard to how electromagnetic waves interact with each other and interact with matter, it is my opinion that the proposed electric-power wind turbines will not cause interference with radio reception from the WGAW AM radio station. Furthermore, the EMF produced by the electrical equipment associated with the turbines and their interconnects to Mt. Wachusett College will not only be localized to the immediate vicinity of this equipment, but will also be far below any available guideline levels for EMF that are protective of public health.

Sincerely yours,
GRADIENT CORPORATION

Peter A. Valberg, Ph.D.
Principal

Attachments: Dr. Valberg's "Summary of Expertise in Electric and Magnetic Fields (EMF)"
"Appendix A"
"Appendix B"

Dr. Peter A. Valberg, *Gradient Corporation*

Summary of Expertise in Electric and Magnetic Fields (EMF)

Dr. Peter A. Valberg holds a Ph.D. degree in Physics from Harvard University, Graduate School of Arts and Sciences, where he completed his doctoral research with Dr. Norman F. Ramsey, Nobel Laureate in Physics. In addition, Dr. Valberg has an M.S. degree in Human Physiology from Harvard's School of Public Health (HSPH), and an A.B. degree *summa cum laude* in Physics and Mathematics from Taylor University. Dr. Valberg taught Physics (including Electricity and Magnetism) at Amherst College before coming back to Harvard University, and working for 25 years as a researcher and teacher on the faculty of the Department of Environmental Health at Harvard University's School of Public Health.

During his tenure at HSPH, Dr. Valberg's research and teaching included environmental health, risk assessment, and Electric and Magnetic Fields / Radio Frequency (EMF / RF) Case Studies. One of Dr. Valberg's several research programs at HSPH was "Magnetic Field Effects on Macrophages," which was funded by the National Cancer Institute.

Dr. Valberg has served on EMF review/advisory panels for the National Institutes of Health (NIH), the Health Effects Institute, and the Environmental Protection Agency. At the Harvard Center for Risk Analysis, Dr. Valberg was a member of the "Harvard Advisory Committee on EMF and Human Health" as well as the "Peer Review Board on Cellular Technology and Human Health." He is a member of the Health Physics Society and the Bioelectromagnetics Society, and has served on the American National Standards Institute's (ANSI) Committee on Man and Radiation (COMAR) and the Board of Directors of the Bioelectromagnetics Society.

Dr. Valberg is the author of over 80 peer-reviewed articles on environmental health. Currently, Dr. Valberg is Principal at Gradient Corporation, and he provides expertise on the physical phenomena associated with EMF / RF and the relevant biophysical interactions. His assessments have included both measurement and modeling of EMF and RF levels.

In one example project, Dr. Valberg and Gradient assisted on a project for the Massachusetts Bay Transit Authority (MBTA) to determine the potential EMF impacts of a planned transportation corridor designated as the "Urban Ring." MBTA was evaluating a 15-mile-long circumferential corridor transportation corridor (the Urban Ring), which was proposed to pass through East Cambridge, the Massachusetts Institute of Technology area, and on to the Harvard Medical School area. Possible transportation elements included Light Rail and/or Bus Rapid Transit. Electromagnetic interference (EMI) may be produced by (1) large moving ferromagnetic objects, and (2) by the use of electric propulsion and its associated electric supply lines. Determinants of EMI potential include the magnitudes of electric currents and voltages utilized by the propulsion systems, the proximity of sensitive receptors to the Urban-Ring corridor, the pattern of current and voltage time variation, the spatial configuration of the conductors supplying electric power, the frequency and timing of transit traffic, and the degree of EMI isolation required by sensitive receptors. Dr. Valberg helped synthesize the information available on EMI produced by the surface-bus and light-rail rapid-transit alternatives being considered. The final result of the project was a report to the MBTA that listed the EMI levels expected for various alternative transportation technologies and route alignments as a function of distance from the corridor. He also helped identify and discuss possible EMI mitigation strategies.

In another project, Dr. Valberg helped prepare environmental impact statements regarding the electric and magnetic fields (EMF) that would be produced by operation of a wind-turbine electric-power-generating project to be sited in Horseshoe Shoal off the coast of Cape Cod, MA. Gradient's EMF analysis included both possible human health effects of EMF caused by on-land portions of the project, and, for the Army Corps of Engineers, concerns related to the potential EMF ecological effects for marine- and submarine-animal species, for example, potential interference with animal prey location and migration *via* electric and magnetic fields.

Dr. Valberg has been working in the area of EMF health risk for over 15 years. He published a summary document on "EMF Mechanisms" in the journal *Radiation Research*. At the request of the International Congress on Radiation Research (ICRR), Dr. Valberg organized and chaired a symposium on "*Physical aspects of EMF / RF effects on biological systems*," at the 11th Annual ICRR meeting in Dublin, Ireland. In 2006, he was asked by the International Institute for the Environment and Public Health to present a lecture in Nicosia, Cyprus, on how EMF interacts with living organisms.

For the Harvard School of Public Health, Dr. Valberg helped organize a conference in the Boston area on "*Childhood Leukemia: Electric and Magnetic Fields as Possible Risk Factors*." A summary of this workshop was published (2003) in the journal *Environmental Health Perspectives*. Dr. Valberg worked with the World Health Organization (WHO) on analyzing the EMF that occur in the context of cellular telephones, and with the State of Connecticut (Connecticut Siting Council) on how EMF health-based exposure limits relate to siting policies for electric-power transmission lines. A summary of the WHO work was published (2007) in the journal *Environmental Health Perspectives*.

APPENDIX A: WGAW Radio Station

WGAW, serving the Greater Gardner, MA, area
362 Green Street. Gardner, MA 01440
(978)630-8700 Fax: (978)630-3011 http://www.wgaw1340.com/

Programming - Spencer Marshall spencer@wgaw1340.com
Morning Show - Jim Gale Chuck Leblanc jim@wgaw1340.com
Sales - Hal Goodwin halg@wgaw1340.com
Business-Julie Meyers 978-374-4733 Julie@wxrv.com

AM Query results can be found in public files at http://www.fcc.gov/mb/databases/cdbs/

WGAW AM **1340 kHz** GARDNER, MA US **1.0 kW** Facility ID No.: 72088 N 42 35 33.00 W 71 59 20.00
COUNTY BROADCASTING COMPANY, LLC

WGAW MA GARDNER USA

Operation time: unlimited
Licensee: COUNTY BROADCASTING COMPANY, LLC

1340 kHz **Licensed**
Wavelength: 223.73 meters
Domestic Station Class: C Region 2 Station Class (corresponds to W. Hemisphere): C
Coordination Status: Canada: - Mexico: Region 2: -
File No: BL-- Facility ID No.: **72088**
CDBS Application ID No.: 312775

42° 35' 33.00" N Latitude Power: 1.0 kilowatts (kW) **Unlimited operation time**
71 ° 59' 20.00" W Longitude (NAD 27)

ND1 - Non-directional Antenna: Same constants day and night

RMS Standard: 0.00 mV/m at 1 kilometer (1 kW = 0 dBk)

RMS Theoretical: 283.24 mV/m at 1 kilometer

1 tower CDBS Ant. System ID: 19015

Tower information:

Tower No.	Field Ratio	Phase (deg)	Spacing (deg)	Orientation (degrees)	Electrical Height (deg)	Twr Ref.	-No Top Loaded or Sectionalized Tower(s)- (#0)	A	B	C	D	Antenna Structure Registration Number
1	1.000	0.00	0.00	0.00	73.60	0	0	0.00	0.00	0.00	0.00	http://www.fcc.gov/fcc-bin/link2asrn?asrn=

73.60° = Electrical Height in degrees = 45.74 meters = 0.204 wavelengths

Approximate Sunrise & Sunset Times => Eastern time zone
FCC Registration Number: 0009779455
CDBS: Station Info Application Info Mailing Address Assignments and Transfers
Application List CDBS Search Page Ownership Info EEO Call Sign Changes

Maps: Region Map Area Map Local Map

ULS: Related facilities in ULS
ASRNs within 0.5 km radius

OTHER BROADCAST TOWERS IN GARDNER, MASSACHUSETTS:

	Registration Number	Status	File Number	Owner Name	Latitude / Longitude	Structure City / State	Overall Height Above Ground (AGL)
1	1025967	Constructed	A0587068	Comcast of Massachusetts III, Inc.	42-33-33.3N 071-57-48.2W	GARDNER, MA	84.4 m
2	1059616	Constructed	A0069995	HIRONS, FRANK K	42-34-52.0N 071-58-56.0W	GARDNER, MA	27.7 m
3	1060020	Constructed	A0595211	Spectrasite Communications, Inc. through American Tower, Inc.	42-33-53.1N 071-57-28.7W	GARDNER, MA	57.3 m
4	1233048	Constructed	A0251164	National Grid USA Service Company, Inc.	42-33-56.8N 072-00-24.6W	Gardner, MA	28.3 m
5	1261676	Granted	A0583609	Gardner Fire Department	42-34-28.0N 071-59-50.5W	Gardner, MA	36.9 m

APPENDIX B: PROPOSED WIND TURBINES

TURBINE DATA RECEIVED (from Heartwood Group, Incorporated)

(1) The turbines will generate electrical power at a line frequency of 60 Hz AC.

(2) Power output and planned location: The current plan is to use two "Vestas V82" machines, with maximum power output rated at 1.65 MW each, alternatively, the project will use two "Suzlon S88" machines with maximum power output rated at 2.1 MW each.
See: Vestas V-82: http://www.vestas.com/en/wind-power-solutions/wind-turbines/1.65-mw
http://www.horizonwind.com/images_projects/arrowsmith/permit/ARR_App_4_turbine_Specs.pdf

(3) Planned location: Distance from WGAW AM radio station tower to closest turbine: 1,325 feet

(4) 60-Hz Electric Power line interconnects: Underground

(5) Voltage parameters of the turbine generators: The "Vestas V82" generates power at 480 v. The "Suzlon S88" generates power at 690 v. The output of the turbines will be transformed up to 13,800 V AC, which is the interconnection voltage, using transformers to be located near the turbines. Underground cables will transmit that power through underground ducts to the interconnection at the main electrical room of Mt. Wachusett College

(6) Based on the use of a "V82-1.65 MW" unit, each turbine will have a maximum output current of 1,914 amps, at 480 Volts, 3 phase. At the 13,800 volt 3 phase level, this is equivalent to 82.3 amps. For the two turbines, at maximum current, the 480 volt current will be about 3,828 amps, and the 13,800 volt current will be 164.6 amps.

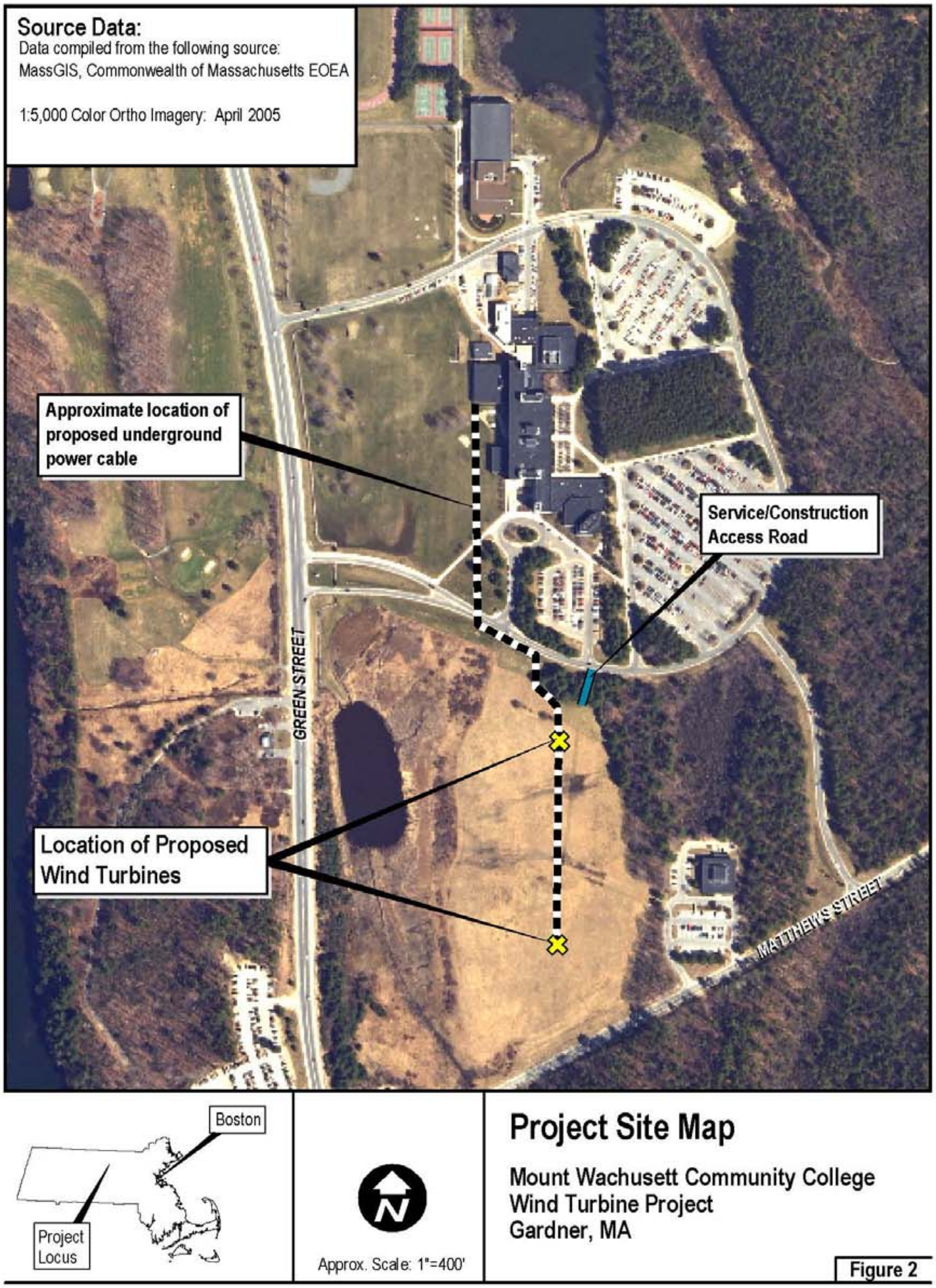
(7) Alternatively, the "2.1 MW Suzlon S88" unit will have about 1757 amps output for each turbine at 690 volts, 3 phase, and about 88 amps at 13,800 volts, three phase. For two "Suzlon 2.1 MW" units the total current at 690 volts is 3,514 amps, and at 13,800 volts, three phase, is 176 amps.

(8) All transmission between turbines and interconnection will be underground. Please note the proposed route of the underground cables in the following figure.

(9) Approximate dimensions of the wind turbines:

Vestas V-82, Hub Height at 80 meters, rotor diameter 82 meters, 3 blades, Max rotation rate: 14.4 rpm (0.24 Hz). Blade width, 0.4 to 3.5 m.

Suzlon S88, Hub Height at 80 meters, rotor diameter 88 meters, 3 blades, Max. rotation rate: 15 to 17.6 rpm (0.29 Hz) Blade width, 0.4 to 3.5 m.


Source Data:
Data compiled from the following source:
MassGIS, Commonwealth of Massachusetts EOEA
1:5,000 Color Ortho Imagery: April 2005
Approximate location of proposed underground power cable
Service/Construction Access Road
GREEN STREET
Location of Proposed Wind Turbines
MATTHEWS STREET
Boston
Project Locus
N
Approx. Scale: 1"=400'
Project Site Map
Mount Wachusett Community College
Wind Turbine Project
Gardner, MA
Figure 2

Appendix 5. Visualization Study

University of Massachusetts
Wind Energy Center

Department of Mechanical & Industrial Engineering
160 Governors Drive, Amherst, MA 01003-9265
Tel: 413-545-4359 Fax: 577-1301
www.umass.edu/windenergy

Mount Wachusett Community College Wind Turbine Visualizations

Prepared by Mary Knipe
April 30, 2009

The Wind Energy Center at the University of Massachusetts Amherst performed wind turbines photo visualizations for the proposed two turbine wind power installation at Mount Wachusett Community College Campus in Gardner, MA. The Wind Energy Center is a unique program that has distinguished the University of Massachusetts as the national leader in wind energy education, academic research, and service to government and industry for 34 years.

A potential visual impact map was prepared by UMass and provided to the project team for selection of appropriate visual impact receptor sites. This and other maps of the local area were reviewed, and the area was also driven to determine receptor sites for the study. The selected sites have the most potential for visual impact from the proposed wind project and are representative of the viewpoint from each area. Proposed receptor sites were reviewed in a meeting between the college, the NEPA permitting coordinator, the project manager, and representatives of DOE.

The photo visualizations or simulations were completed using the “Photomontage” module of WindPRO software version 2.6.0.235. The program uses turbine specifications, geometry and site-specific base-photographs to produce estimated views in the area near the turbines. Analyses were carried out for turbine model Vestas V82 1.65MW with an 80m hub height.

The photographs were taken with a Nikon D70 SLR digital camera. The location of each viewpoint is listed in Table 1 with the latitude and longitude, and distance to the turbines from the viewpoint. Figure 1 is an orthophotograph with the locations marked with green diamonds and labeled 1- 8. Each photo simulation provides a visual representation of the proposed turbines as they would appear from the viewpoint show (page 4 thru page 10).

Table 1: Eight viewpoints for the photo visualizations.

Viewpoints	Latitude (N)	Longitude (W)	Distance to turbine 1, turbine 2 (meters)	Location/Description
1	42.5955°	-71.9728°	1040, 1203	Matthews St
2	42.5871°	-71.9869°	478, 285	Hospital
3	42.5961°	-71.9879°	724, 902	Green St
4	42.5892°	-71.9788°	387, 404	Boulder St
5	42.5786°	-71.9958°	1661, 1462	Osgood St
6	42.5985°	-71.9933°	1199,1342	Golf Course
7	42.5982°	-71.9868°	883, 1080	Eaton St
8	42.5797°	-71.9950°	1519, 1322	Park St

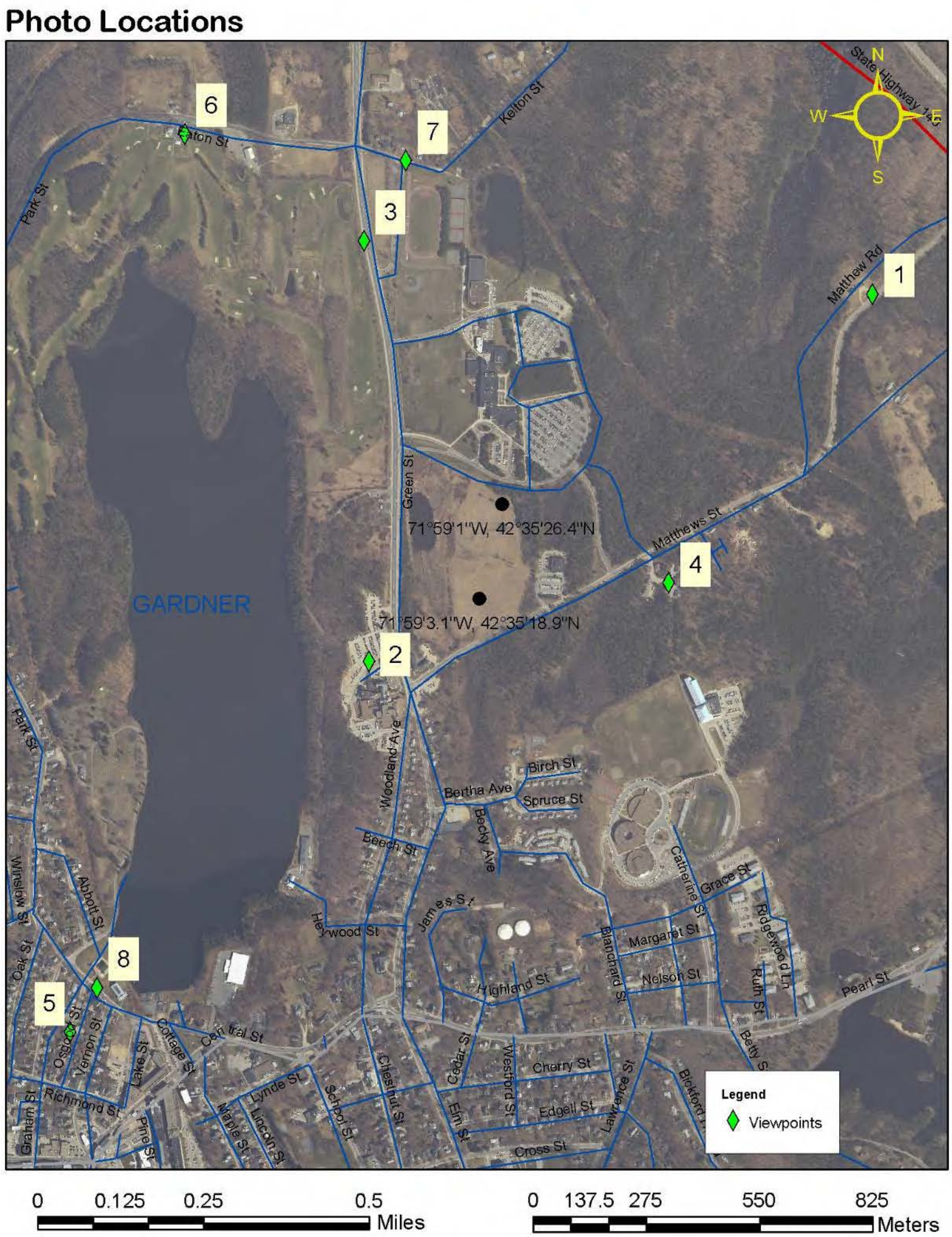


Figure 1: This orthophotograph shows the locations of the viewpoints used in the eight photo simulations. The two proposed turbine locations are marked with black dots.

Discussion of Simulation Results

The eight photo simulations show visual estimations of how the turbines will appear from a variety of viewpoints around the town of Gardner.

Viewpoint 1: Matthews Street

The blades of the north turbine are visible above the trees but the south turbine is not visible behind the evergreen trees.

Viewpoint 2: Hospital

Both turbines are very visible.

Viewpoint 3: Green Street

This is a view of the MWCC campus with both turbines clearly visible.

Viewpoint 4: Boulder Street

The tips of the turbine blades of the north turbine can be seen above the tops of the trees. The blades of the south turbine can also be seen through the bare tree branches.

Viewpoint 5: Osgood Street

The blades of both turbines can be seen through the tree branches above the rooftops of the houses.

Viewpoint 6: Golf Course Club House

From this viewpoint both of the turbines are clearly visible.

Viewpoint 7: Eaton Street

From this viewpoint both of the turbines are clearly visible.

Viewpoint 8: Park Street

The blades of both turbines are clearly visible above the tree line.

Base-photographs of other viewpoints such as at the skating rink and rotary and town monument near Maple Street were considered but were eliminated after preliminary photo simulation showed that due to tree cover or topography the turbines would not be visible.

Photo Simulation of Wind Power Project

About the Project:

Owner: Mount Wachusett Community College
Project site: MWCC Campus, Gardner, MA
Turbines: 2, Vestas V82, 1.65 MW
Diameter: 269 feet (82 m)
Hub height: 262.5 feet (80 m)
Location: 42.5896°N, 71.9839°W

About the Photo:

Viewpoint: 340 Matthews Street
Angle of View: 48 degrees
Location: 42.5955° N, 71.9728°W
Photo: Taken January 27, '09
Apparent size and location of the turbine from this viewpoint is determined geometrically using EMD WindPro software.

Wind Energy Center

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www.umass.edu/windenergy

Figure 2: Matthews Street: Viewpoint 1 listed on Table 1. Turbine 1 is visible but the view of turbine 2 is blocked by trees.

Photo Simulation of Wind Power Project

Wind Energy Center

About the Project:

Owner: Mount Wachusett Community College
Project site: MWCC Campus, Gardner, MA
Turbines: 2, Vestas V82, 1.65 MW
Diameter: 269 feet (82 m)
Hub height: 262.5 feet (80 m)
Location: 42.5896°N, 71.9839°W

About the Photo:

Viewpoint: Hospital
Angle of View: 48 degrees
Location: 42.5871° N, 71.9869°W
Photo: Taken January 27, '09
Apparent size and location of the turbine from this viewpoint is determined geometrically using EMD WindPro software.

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Figure 2: Hospital: Viewpoint 2 listed on Table 1. Both wind turbines are clearly visible.

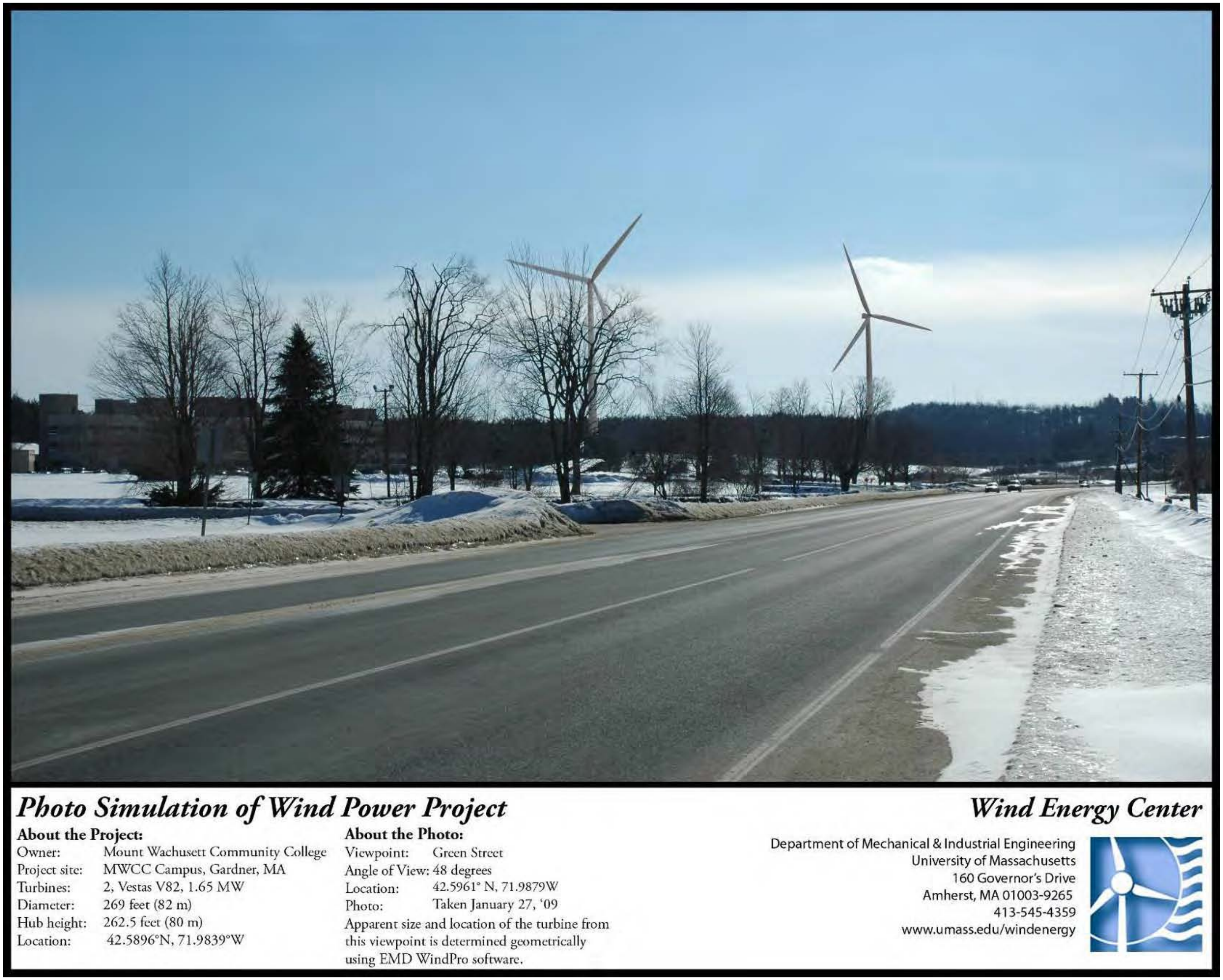

Figure 2: Green Street: Viewpoint 3 listed on Table 1. Mount Wachusett Community College is to the left of the turbines.

Figure 2: Boulder Street: Viewpoint 4 listed on Table 1. The turbines are visible through the bare tree branches.

Photo Simulation of Wind Power Project

Wind Energy Center

About the Project:

Owner:	Mount Wachusett Community College
Project site:	MWCC Campus, Gardner, MA
Turbines:	2, Vestas V82, 1.65 MW
Diameter:	269 feet (82 m)
Hub height:	262.5 feet (80 m)
Location:	42.5896°N, 71.9839°W

About the Photo:

Viewpoint:	53 Osgood Street
Angle of View:	48 degrees
Location:	42.5786° N, 71.9958°W
Photo:	Taken January 27, '09

Apparent size and location of the turbine from this viewpoint is determined geometrically using EMD WindPro software.

Note:
Blades of both turbines are partially visible through the trees at the center of photo.

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Figure 2: Osgood Street: Viewpoint 5 listed on Table 1. Both turbines are visible above the roof tops at center of photo.

Photo Simulation of Wind Power Project

Wind Energy Center

About the Project:

Owner: Mount Wachusett Community College
Project site: MWCC Campus, Gardner, MA
Turbines: 2, Vestas V82, 1.65 MW
Diameter: 269 feet (82 m)
Hub height: 262.5 feet (80 m)
Location: 42.5896°N, 71.9839°W

About the Photo:

Viewpoint: Golf Course Club House
Angle of View: 48 degrees
Location: 42.5985° N, 71.9933°W
Photo: Taken January 27, '09
Apparent size and location of the turbine from this viewpoint is determined geometrically using EMD WindPro software.

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Figure 2: Golf Course: Viewpoint 6 listed on Table 1. Both turbines are visible from this viewpoint at the club house.

Photo Simulation of Wind Power Project

Wind Energy Center

About the Project:

Owner:	Mount Wachusett Community College
Project site:	MWCC Campus, Gardner, MA
Turbines:	2, Vestas V82, 1.65 MW
Diameter:	269 feet (82 m)
Hub height:	262.5 feet (80 m)
Location:	42.5896°N, 71.9839°W

About the Photo:

Viewpoint:	Eaton Street
Angle of View:	48 degrees
Location:	42.5982° N, 71.9868° W
Photo:	Taken January 27, '09

Apparent size and location of the turbine from this viewpoint is determined geometrically using EMD WindPro software.

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Figure 2: Eaton Street: Viewpoint 7 listed on Table 1. This photo simulation shows a clear view of the turbines.

Photo Simulation of Wind Power Project

Wind Energy Center

About the Project:

Owner: Mount Wachusett Community College
Project site: MWCC Campus, Gardner, MA
Turbines: 2, Vestas V82, 1.65 MW
Diameter: 269 feet (82 m)
Hub height: 262.5 feet (80 m)
Location: 42.5896°N, 71.9839°W

About the Photo:

Viewpoint: 92 Park Street
Angle of View: 48 degrees
Location: 42.5797° N, 71.9950°W
Photo: Taken January 27, '09
Apparent size and location of the turbine from this viewpoint is determined geometrically using EMD WindPro software.

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Figure 2: Park Street: Viewpoint 8 listed on Table 1. The blades of both turbines are visible above the trees.

Appendix 6.1 Wetland Report

Haines Hydrogeologic Consulting

specialising in groundwater & wetlands

141 Old Enfield Road
Belchertown
Mass. 01007
413 323 7156
Fax 413 323 4776

Robert Rizzo
Director of Sustainability and Energy Policy
Mt. Wachusett Community College
444 Green Street
Gardner, MA 01440

November 26, 2008

Re: Wetland Evaluation – Wind Turbine Site, Mt. Wachusett Community College Campus, Gardner, Massachusetts

Dear Mr. Rizzo:

As you requested, the above-referenced site has been evaluated with respect to the presence of wetlands under jurisdiction of the Federal Clean Water Act, the Massachusetts Wetlands Protection Act, and the Gardner Wetlands Protection Ordinance. The site contains resource areas subject to these regulations, specifically Banks, Bordering Vegetated Wetlands, Land under Water, and the 100-foot Buffer Zone to these areas. Any proposed work in the resource areas must comply with the respective Performance Standards. The work must be reviewed and permitted by the Gardner Conservation Commission and the Massachusetts Department of Environmental Protection (DEP). Any filling of wetlands may require a permit from the U.S. Army Corps of Engineers under Section 404 of the Clean Water Act.

The site that was examined is the portion of the campus property where you are proposing to erect a wind turbine for the generation of electricity. It consists of the vacant land south of the campus, east of Green Street. The site includes a mix of field/meadow, pond, brook, marsh, shrubland and woods. The land drops off from Green Street to a pond, a brook and a wetland system extending across the entire site parallel to the street. The wetland system contains a pond, a brook, shallow fresh marsh, shrub swamp and wet meadow. The brook is not shown on the USGS map (Gardner Quad - 1979), and is therefore assumed to be an intermittent stream. The land then rises up to an open field. There are wooded areas in the northern portion of the site and along the eastern property line. A wet meadow extends up into the open field area.

Banks on the site consist of the edges of the pond and of the intermittent stream between the water body and the Bordering Vegetated Wetland or upland. The upper boundary of a Bank is defined as the first observable break in slope or the mean annual flood elevation, whichever is lower. The lower boundary of a Bank is the mean annual low flow level. Any proposed work in this resource area must meet the Performance Standards.

The Bordering Vegetated Wetlands on the site were delineated with numbered flags using the three technical criteria of vegetation, soils and hydrology outlined in the *"Federal Manual for Identifying and Delineation Jurisdictional Wetlands"*, prepared for the U.S. Army Corps of Engineers. Wetland Data Forms are attached. This wetland boundary delineation is subject to review and approval by the Gardner Conservation Commission and/or DEP. The locations of the boundaries were surveyed and are shown on the site plan.

The wetlands are comprised of shallow fresh marsh, shrub swamp and wet meadow. The vegetation in the wetlands includes Red Maple, Arrowwood, Red Osier Dogwood, Steeplebush, Meadowsweet, sedges (Carex spp.), rushes (Juncus spp.), goldenrods (Solidago spp.; Euthamia spp.), Dewberry, New England Aster, Cattail, and Sphagnum Moss. The soils in the wetlands consist of seasonally saturated dark brown to black silty loam over mottled to gleyed subsoil. Any proposed work within the Bordering Vegetated Wetlands must satisfy the Performance Standards, or qualify as a Limited Project.

There is an Isolated Wetland in the northwestern portion of the field. This wetland is under jurisdiction of the Federal Clean Water Act but not subject to the Massachusetts Wetlands Protection Act or the Gardner Wetlands Protection Ordinance. The wetland consists of a wet meadow containing a small upland island. The wetland was delineated using the same methodology as the Bordering Vegetated Wetland and has been surveyed and shown on the site plan.

Land under Water consists of the land beneath the pond on the site. The limit of Land under Water is the mean annual low water line. Any work within this resource area must meet the Performance Standards.

The 100-foot Buffer Zone from the Banks, Bordering Vegetated Wetlands and/or Land under Water boundary extends 100 feet landward into the upland portion of the property.

A review of the 2008 *"Massachusetts Natural Heritage Atlas"*, prepared by the Massachusetts Natural Heritage and Endangered Species Program, indicates that the site is not within Estimated Habitats of rare wetland wildlife or vernal pools, or Priority Habitats of rare species.

If you have any questions, please call.

Yours truly,

David M. Haines
Hydrogeologist/Wetland Scientist

Perley Bk
STONE ST
GRADE
Substation
Howe Hill
KELTON
TELEPHONE
EATON ST
Beaman Hill
Golf Course
Radio Tower WGAW
Crystal Lake
MATTHEWS ST
Site
Heywood Memorial Hospital
PEARL
101
Water Tank
GARDNER ST
BOUNDARY
Crystal Lake Cem
Pumping Sta
1105
WOODLAND AVE
GREEN
Reservoir Hill
Res
Stump Pond
Dunn Pond
SMITH
CHAPEL
Substa
BM 1189
Sacred Heart Sch
Fire Sta
School St Sch
PEARL ST
Mt. Wachusett Community College
High Sch
Bickford Hill
East Gardner
GARDNER
CROSS
City Hall
PO
Washington Hill
PINE
CHESTNUT
ELM ST
LAWRENCE
Parker Hill
Brook
BETTY SPRING
WILLIS RD
Ray Hill
Pulaski Field
LOGAN ST
SHERMAN ST
TEMPLE
Murdock Pond
LENNON ST
BM 1091
BM 1043
Quag Pond
Foster
SAUNDERS
BOSTON
Brook
Bk
TIMPANY
CONANT
Armory
Kendall Hill
GLENWOOD ST
WEST BROADWAY
BLVD
BM 1044
Travers Pond
MAIN ST
SUMMER
CHELSEA ST
PARTRIDGE
STREET
Barber Hill
PO
DYER
Bents Pond
South Gardner
Prospect St Sch
Green Bower Cem
Ramsdall Pond
PROSPECT ST
EAST BROADWAY
HIGH ST
Mahoney
Greenwood Pond
BM 1062
BM 1074
MINOTT
LOVEWELL
UNION

DEP Bordering Vegetated Wetland (310 CMR 10.55) Delineation Field Data Form

Applicant: Mt Wachusett Community College Prepared by: Haines Hydrogeologic Consulting Project location: 444 Green St Gardner MA DEP File #:

Check all that apply:

- ☐ Vegetation alone presumed adequate to delineate BVW boundary: fill out Section I only
- ☒ Vegetation and other indicators of hydrology used to delineate BVW boundary: fill out Sections I and II
- ☐ Method other than dominance test used (attach additional information)

15' Below Flag #42

Section I. Vegetation Observation Plot Number: 42W Transect Number: 42 Date of Delineation: 6/19/08

A. Sample Layer and Plant Species (by common/scientific name)	B. Percent Cover (or basal area)	C. Percent Dominance	D. Dominant Plant (yes or no)	E. Wetland Indicator Category*
N. Arrowood	20.5	50	y	FAC
Redosier Dogwood	20.5	50	y	FACW+
Dew Berry	20.5	100	y	FACW
Late Goldenrod	20.5	22	y	FACW
Narrow leaf Goldenrod	10.5	11	No	—
Tussock Sedge	20.5	22	y	
Carex Stipata	20.5	22	y	OBL
Soft Rush	10.5	11	No	OBL
Canada Goldenrod	10.5	11	No	—

* Use an asterisk to mark wetland indicator plants: plant species listed in the Wetlands Protection Act (MGL c.131, s.40); plants in the genus *Sphagnum*; plants listed as FAC, FAC+, FACW-, FACW, FACW+, or OBL; or plants with physiological or morphological adaptations. If any plants are identified as wetland indicator plants due to physiological or morphological adaptations, describe the adaptation next to the asterisk.

Vegetation conclusion:

Number of dominant wetland indicator plants: 6 **Number of dominant non-wetland indicator plants:** 0

Is the number of dominant wetland plants equal to or greater than the number of dominant non-wetland plants? yes no

If vegetation alone is presumed adequate to delineate the BVW boundary, submit this form with the Request for Determination of Applicability or Notice of Intent.

Page 2 Mt Wachusett Community College 6/19/04
Gardner, MA. Plot 42W Transect 42

Section II. Indicators of Hydrology

Hydric Soil Interpretation

1. Soil Survey

Is there a published soil survey for this site? yes no

title/date:

map number:

soil type mapped: 59A

hydric soil inclusions:

Are field observations consistent with soil survey? yes no

Remarks:

2. Soil Description

Horizon	Depth	Matrix Color	Mottles Color
A	0-10"	7.5yr2.5/1	
B	10-18+	7.5yr4/2	>10%

Remarks:

3. Other:

Conclusion: Is soil hydric? yes no

Other Indicators of Hydrology: (check all that apply and describe)

- ☐ Site inundated:
- ☒ Depth to free water in observation hole: 7"
- ☒ Depth to soil saturation in observation hole: 4"
- ☐ Water marks:
- ☐ Drift lines:
- ☐ Sediment deposits:
- ☒ Drainage patterns in BVW:
- ☒ Oxidized rhizospheres:
- ☐ Water-stained leaves:
- ☐ Recorded data (stream, lake, or tidal gauge; aerial photo; other) :
- ☐ Other:

Vegetation and Hydrology Conclusion

	yes	no
Number of wetland indicator plants ≥ number of non-wetland indicator plants	☒	☐
Wetland hydrology present:		
hydric soil present	☒	☐
other indicators of hydrology present	☒	☐
Sample location is in a BVW	☒	☐

Submit this form with the Request for Determination of Applicability or Notice of Intent.

DEP Bordering Vegetated Wetland (310 CMR 10.55) Delineation Field Data Form

Applicant: Mt Wachusett Community College Prepared by: Haines Hydrogeologic Consulting Project location: 444 Green St Gardner MA DEP File #:

Check all that apply:

- ☐ Vegetation alone presumed adequate to delineate BVW boundary: fill out Section I only
- ☒ Vegetation and other indicators of hydrology used to delineate BVW boundary: fill out Sections I and II
- ☐ Method other than dominance test used (attach additional information)

15' Above Flag 42

Section I. Vegetation

Observation Plot Number: 42 U Transect Number: 42 Date of Delineation: 6/19/08

A. Sample Layer and Plant Species (by common/scientific name)	B. Percent Cover (or basal area)	C. Percent Dominance	D. Dominant Plant (yes or no)	E. Wetland Indicator Category*
Orchard grass	38.0	30	yes	FACU
Canada Goldenrod	20.5	15	yes	FACU
Late Goldenrod	10.5	8	no	—
Calico aster	20.5	15	yes	
Vetch	20.5	15	yes	FACW-
Narrow leaf goldenrod	20.5	15	yes	FACU
Queen Anne's lace	10.5	8	no	FAC
Strawberry	10.5	8	no	—
Madder	10.5	8	no	—
Aster sp	10.5			—

* Use an asterisk to mark wetland indicator plants: plant species listed in the Wetlands Protection Act (MGL c.131, s.40); plants in the genus *Sphagnum*; plants listed as FAC, FAC+, FACW-, FACW, FACW+, or OBL; or plants with physiological or morphological adaptations. If any plants are identified as wetland indicator plants due to physiological or morphological adaptations, describe the adaptation next to the asterisk.

Vegetation conclusion:

Number of dominant wetland indicator plants: 2 Number of dominant non-wetland indicator plants: 3

Is the number of dominant wetland plants equal to or greater than the number of dominant non-wetland plants? yes no

If vegetation alone is presumed adequate to delineate the BVW boundary, submit this form with the Request for Determination of Applicability or Notice of Intent.

Page 2 Mt Wachusett Community College 6/19/04
GARDNER, MA. Plot # 42U TRANSECT 42

Section II. Indicators of Hydrology

Hydric Soil Interpretation

1. Soil Survey

Is there a published soil survey for this site? yes **no**

title/date:

map number:

soil type mapped:

hydric soil inclusions:

Are field observations consistent with soil survey? yes no

Remarks:

2. Soil Description

Horizon	Depth	Matrix Color	Mottles Color
A	0-9	5yr 3/1	—
B	9-18	5yr 4/6	—

Remarks:

3. Other:

Conclusion: Is soil hydric? yes **no**

Other Indicators of Hydrology: (check all that apply and describe)

- ☐ Site inundated:
- ☐ Depth to free water in observation hole:
- ☐ Depth to soil saturation in observation hole:
- ☐ Water marks:
- ☐ Drift lines:
- ☐ Sediment deposits:
- ☐ Drainage patterns in BVW:
- ☐ Oxidized rhizospheres:
- ☐ Water-stained leaves:
- ☐ Recorded data (stream, lake, or tidal gauge; aerial photo; other) :
- ☐ Other:

Vegetation and Hydrology Conclusion

	yes	no
Number of wetland indicator plants ≥ number of non-wetland indicator plants	☐	☒
Wetland hydrology present:		
hydric soil present	☐	☒
other indicators of hydrology present	☐	☒
Sample location is in a BVW	☐	☒

Submit this form with the Request for Determination of Applicability or Notice of Intent.

DEP Bordering Vegetated Wetland (310 CMR 10.55) Delineation Field Data Form

Applicant: Mt Wachusett Community College Prepared by: Haines Hydrogeologic Consulting Project location: 444 Green St Gardner MA DEP File #: ______

Check all that apply:

- ☐ Vegetation alone presumed adequate to delineate BVW boundary: fill out Section I only
- ☒ Vegetation and other indicators of hydrology used to delineate BVW boundary: fill out Sections I and II
- ☐ Method other than dominance test used (attach additional information)

15' Below Flag 88

Section I. Vegetation

Observation Plot Number: 88 W Transect Number: 88 Date of Delineation: 6/19/08

A. Sample Layer and Plant Species (by common/scientific name)	B. Percent Cover (or basal area)	C. Percent Dominance	D. Dominant Plant (yes or no)	E. Wetland Indicator Category*
Red Maple	20.5	50	yes	FAC
Red osier Dogwood	20.5	50	yes	FACW+
Dewberry	10.5	100	yes	FACW
Late Goldenrod	38.0	31	yes	FACW
Narrowleaf Goldenrod	20.5	17	yes	FAC
New England Aster	20.5	17	yes	FACW-
Carix stricta	20.5	17	yes	OBL
Soft rush	20.5	17	yes	FACW+

* Use an asterisk to mark wetland indicator plants: plant species listed in the Wetlands Protection Act (MGL c.131, s.40); plants in the genus *Sphagnum*; plants listed as FAC, FAC+, FACW-, FACW, FACW+, or OBL; or plants with physiological or morphological adaptations. If any plants are identified as wetland indicator plants due to physiological or morphological adaptations, describe the adaptation next to the asterisk.

Vegetation conclusion:

Number of dominant wetland indicator plants: 8 Number of dominant non-wetland indicator plants: 0

Is the number of dominant wetland plants equal to or greater than the number of dominant non-wetland plants? yes no

If vegetation alone is presumed adequate to delineate the BVW boundary, submit this form with the Request for Determination of Applicability or Notice of Intent.

Page 2 Mt Wachusett Community College 6/19/04
Gardner, MA. Plot # 88 W TRANSECT 88

Section II. Indicators of Hydrology

Hydric Soil Interpretation

1. Soil Survey

Is there a published soil survey for this site? yes **no**

title/date:

map number:

soil type mapped:

hydric soil inclusions:

Are field observations consistent with soil survey? yes no

Remarks:

2. Soil Description

Horizon	Depth	Matrix Color	Mottles Color
A	1-10	7.5yr 2.5/1	ox. Rhiz.
B	10+	7.5yr 4/1	yes >10%

Remarks:

3. Other:

Conclusion: Is soil hydric? **yes** no

Other Indicators of Hydrology: (check all that apply and describe)

- ☐ Site inundated:
- ☒ Depth to free water in observation hole: 5.0
- ☒ Depth to soil saturation in observation hole: 3.0
- ☐ Water marks:
- ☐ Drift lines:
- ☐ Sediment deposits:
- ☒ Drainage patterns in BVW:
- ☒ Oxidized rhizospheres:
- ☐ Water-stained leaves:
- ☐ Recorded data (stream, lake, or tidal gauge; aerial photo; other) :
- ☐ Other:

Vegetation and Hydrology Conclusion

	yes	no
Number of wetland indicator plants ≥ number of non-wetland indicator plants	☒	☐
Wetland hydrology present:		
hydric soil present	☒	☐
other indicators of hydrology present	☒	☐
Sample location is in a BVW	☒	☐

Submit this form with the Request for Determination of Applicability or Notice of Intent.

DEP Bordering Vegetated Wetland (310 CMR 10.55) Delineation Field Data Form

Applicant: Mt Wachusett Community College Prepared by: Haines Hydrogeologic Consulting Project location: 444 Green St Gardner MA DEP File #: ____________

Check all that apply:

- ☐ Vegetation alone presumed adequate to delineate BVW boundary: fill out Section I only
- ☒ Vegetation and other indicators of hydrology used to delineate BVW boundary: fill out Sections I and II
- ☐ Method other than dominance test used (attach additional information)

15' Above Flag 88

Section I. Vegetation Observation Plot Number: 88 U Transect Number: 88 Date of Delineation: 6/19/08

A. Sample Layer and Plant Species (by common/scientific name)	B. Percent Cover (or basal area)	C. Percent Dominance	D. Dominant Plant (yes or no)	E. Wetland Indicator Category*
Dewberry	10.5	100	yes	FACW
Grasses	63.0	43	yes	UPL
Yarrow	10.5	7	no	—
Queen Anne's Lace	20.5	14	yes	UPL
Red Clover	20.5	14	YES	FACU-
Madder	10.5	7	No	—
Vetch	10.5	7	No	—
Hawkweed	10.5	7	no	—

* Use an asterisk to mark wetland indicator plants: plant species listed in the Wetlands Protection Act (MGL c.131, s.40); plants in the genus *Sphagnum*; plants listed as FAC, FAC+, FACW-, FACW, FACW+, or OBL; or plants with physiological or morphological adaptations. If any plants are identified as wetland indicator plants due to physiological or morphological adaptations, describe the adaptation next to the asterisk.

Vegetation conclusion:

Number of dominant wetland indicator plants: 1 **Number of dominant non-wetland indicator plants:** 3

Is the number of dominant wetland plants equal to or greater than the number of dominant non-wetland plants? yes no

If vegetation alone is presumed adequate to delineate the BVW boundary, submit this form with the Request for Determination of Applicability or Notice of Intent.

Page 2 Mt Wachusett Community College 6/19/04
Gardner, MA. Plot # 88U Transect 88

Section II. Indicators of Hydrology

Hydric Soil Interpretation

1. Soil Survey

Is there a published soil survey for this site? yes no

title/date:

map number:

soil type mapped:

hydric soil inclusions:

Are field observations consistent with soil survey? yes no

Remarks:

2. Soil Description

Horizon	Depth	Matrix Color	Mottles Color
A	0-6	5yr 3/3	—
B	6-18+	5yr 5/6	—

Remarks:

3. Other:

Conclusion: Is soil hydric? yes no

Other Indicators of Hydrology: (check all that apply and describe)

- ☐ Site inundated:
- ☐ Depth to free water in observation hole:
- ☐ Depth to soil saturation in observation hole:
- ☐ Water marks:
- ☐ Drift lines:
- ☐ Sediment deposits:
- ☐ Drainage patterns in BVW:
- ☐ Oxidized rhizospheres:
- ☐ Water-stained leaves:
- ☐ Recorded data (stream, lake, or tidal gauge; aerial photo; other) :
- ☐ Other:

Vegetation and Hydrology Conclusion

	yes	no
Number of wetland indicator plants ≥ number of non-wetland indicator plants	☐	☒
Wetland hydrology present:		
hydric soil present	☐	☒
other indicators of hydrology present	☐	☒
Sample location is in a BVW	☐	☒

Submit this form with the Request for Determination of Applicability or Notice of Intent.

DEP Bordering Vegetated Wetland (310 CMR 10.55) Delineation Field Data Form

Applicant: Mt Wachusett Community College Prepared by: Haines Hydrogeologic Consulting Project location: 444 Green St Gardner MA DEP File #: ____________

Check all that apply:

☐ Vegetation alone presumed adequate to delineate BVW boundary: fill out Section I only

☒ Vegetation and other indicators of hydrology used to delineate BVW boundary: fill out Sections I and II ISOLATED WETLAND

☐ Method other than dominance test used (attach additional information)

15' BELOW #161

Section I. Vegetation Observation Plot Number: #161 W Transect Number: #161 Date of Delineation: 6/19/08

A. Sample Layer and Plant Species (by common/scientific name)	B. Percent Cover (or basal area)	C. Percent Dominance	D. Dominant Plant (yes or no)	E. Wetland Indicator Category*
Red maple	20.5	33	yes	FAC
Grey Birch	20.5	33	yes	FAC
White Pine	20.5	33	yes	
Steeplebush	10.5	20	yes	FACU
Highbush blueberry	20.5	40	yes	FACW
Meadow Sweet	20.5	40	yes	FACW-
			yes	FAC+
DEWBERRY	10.5	100	yes	FACW
Lanceleaf Goldenrod	10.5	25	yes	FAC
New England Aster	10.5	25	yes	FACW-
Late Goldenrod	10.5	25	yes	FACW
Soft Rush	10.5	25	yes	FACW+

* Use an asterisk to mark wetland indicator plants: plant species listed in the Wetlands Protection Act (MGL c.131, s.40); plants in the genus *Sphagnum*; plants listed as FAC, FAC+, FACW-, FACW, FACW+, or OBL; or plants with physiological or morphological adaptations. If any plants are identified as wetland indicator plants due to physiological or morphological adaptations, describe the adaptation next to the asterisk.

Vegetation conclusion:

Number of dominant wetland indicator plants: 10 Number of dominant non-wetland indicator plants: 1

Is the number of dominant wetland plants equal to or greater than the number of dominant non-wetland plants? yes no

If vegetation alone is presumed adequate to delineate the BVW boundary, submit this form with the Request for Determination of Applicability or Notice of Intent.

DEP Bordering Vegetated Wetland (310 CMR 10.55) Delineation Field Data Form

Applicant: Mt Wachusett Community College Prepared by: Haines Hydrogeologic Consulting Project location: 444 Green St Gardner MA DEP File #:

Check all that apply:

- ☐ Vegetation alone presumed adequate to delineate BVW boundary: fill out Section I only
- ☒ Vegetation and other indicators of hydrology used to delineate BVW boundary: fill out Sections I and II
- ☐ Method other than dominance test used (attach additional information)

Isolated wetland

15' Above Flag #161

Section I. Vegetation Observation Plot Number: 161 U Transect Number: 161 Date of Delineation: 6/19/08

A. Sample Layer and Plant Species (by common/scientific name)	B. Percent Cover (or basal area)	C. Percent Dominance	D. Dominant Plant (yes or no)	E. Wetland Indicator Category*
WHITE Pine	38.0	55	yes	FACU
RED MAPLE	10.5	15	NO	FACU
AMERICAN BEECH	20.5	30	yes	FACU
Grey Dogwood	38.0	78.	yes	FAC
Highbush blueberry	10.5	22.	yes	FACW-
	—			
PENN SEDGE	38.0	100	yes	UPL

* Use an asterisk to mark wetland indicator plants: plant species listed in the Wetlands Protection Act (MGL c.131, s.40); plants in the genus *Sphagnum*; plants listed as FAC, FAC+, FACW-, FACW, FACW+, or OBL; or plants with physiological or morphological adaptations. If any plants are identified as wetland indicator plants due to physiological or morphological adaptations, describe the adaptation next to the asterisk.

Vegetation conclusion:

Number of dominant wetland indicator plants: 2 **Number of dominant non-wetland indicator plants:** 3

Is the number of dominant wetland plants equal to or greater than the number of dominant non-wetland plants? yes no

If vegetation alone is presumed adequate to delineate the BVW boundary, submit this form with the Request for Determination of Applicability or Notice of Intent.

Page 2 Mt Wachusett Community College 6/19/04
GARDNER, MA. Plot # 161 U TRANSECT # 161 Isolated wetland

Section II. Indicators of Hydrology

Hydric Soil Interpretation

1. Soil Survey

Is there a published soil survey for this site? yes no

title/date:

map number:

soil type mapped:

hydric soil inclusions:

Are field observations consistent with soil survey? yes no

Remarks:

2. Soil Description

Horizon	Depth	Matrix Color	Mottles Color
A	0-8"	5Y-3/3	—
B	8"-18"+	7.5 Y 5/6	—

Remarks:

3. Other:

Conclusion: Is soil hydric? yes no

Other Indicators of Hydrology: (check all that apply and describe)

- ☐ Site inundated:
- ☐ Depth to free water in observation hole:
- ☐ Depth to soil saturation in observation hole:
- ☐ Water marks:
- ☐ Drift lines:
- ☐ Sediment deposits:
- ☐ Drainage patterns in BVW:
- ☐ Oxidized rhizospheres:
- ☐ Water-stained leaves:
- ☐ Recorded data (stream, lake, or tidal gauge; aerial photo; other) :
- ☐ Other:

Vegetation and Hydrology Conclusion

	yes	no
Number of wetland indicator plants ≥ number of non-wetland indicator plants	☐	☒
Wetland hydrology present:		
hydric soil present	☐	☒
other indicators of hydrology present	☐	☒
Sample location is in a BVW	☐	☒

Submit this form with the Request for Determination of Applicability or Notice of Intent.

Appendix 6.2 Wetland Determination

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands

WPA Form 2 – Determination of Applicability

Massachusetts Wetlands Protection Act M.G.L. c. 131, §40

A. General Information

Important: When filling out forms on the computer, use only the tab key to move your cursor - do not use the return key.

From:

Gardner
Conservation Commission

To: Applicant

Mt. Wachusett Community College
Name

444 Green St.
Mailing Address

Gardner | MA | 01440
City/Town | State | Zip Code

Property Owner (if different from applicant):

Commonwealth of Massachusetts
Name

Mailing Address

City/Town | State | Zip Code

1. Title and Date (or Revised Date if applicable) of Final Plans and Other Documents:

Title	Date
Site Plan for M.W.C.C (wetland delineation)	12/12/08

2. Date Request Filed:

12/3/08

B. Determination

Pursuant to the authority of M.G.L. c. 131, § 40, the Conservation Commission considered your Request for Determination of Applicability, with its supporting documentation, and made the following Determination.

Project Description (if applicable):

No work is proposed. Request is for wetland delineation.

Project Location:

Corner of Green St. and Matthews St.
Street Address

Gardner
City/Town

R-32
Assessors Map/Plat Number

Block 33 Lot 6
Parcel/Lot Number

B. Determination (cont.)

The following Determination(s) is/are applicable to the proposed site and/or project relative to the Wetlands Protection Act and regulations:

Positive Determination
Note: No work within the jurisdiction of the Wetlands Protection Act may proceed until a final Order of Conditions (issued following submittal of a Notice of Intent or Abbreviated Notice of Intent) or Order of Resource Area Delineation (issued following submittal of Simplified Review ANRAD) has been received from the issuing authority (i.e., Conservation Commission or the Department of Environmental Protection).

☐ 1. The area described on the referenced plan(s) is an area subject to protection under the Act. Removing, filling, dredging, or altering of the area requires the filing of a Notice of Intent.

☒ 2a. The boundary delineations of the following resource areas described on the referenced plan(s) are confirmed as accurate. Therefore, the resource area boundaries confirmed in this Determination are binding as to all decisions rendered pursuant to the Wetlands Protection Act and its regulations regarding such boundaries for as long as this Determination is valid.

Wetlands bound by flags #1 thru # 129 on plan for M.W.C.C dated 12/12/08

☐ 2b. The boundaries of resource areas listed below are not confirmed by this Determination, regardless of whether such boundaries are contained on the plans attached to this Determination or to the Request for Determination.

☐ 3. The work described on referenced plan(s) and document(s) is within an area subject to protection under the Act and will remove, fill, dredge, or alter that area. Therefore, said work requires the filing of a Notice of Intent.

☐ 4. The work described on referenced plan(s) and document(s) is within the Buffer Zone and will alter an Area subject to protection under the Act. Therefore, said work requires the filing of a Notice of Intent or ANRAD Simplified Review (if work is limited to the Buffer Zone).

☐ 5. The area and/or work described on referenced plan(s) and document(s) is subject to review and approval by:

Name of Municipality

Pursuant to the following municipal wetland ordinance or bylaw:

Name | Ordinance or Bylaw Citation

B. Determination (cont.)

☒ 6. The following area and/or work, if any, is subject to a municipal ordinance or bylaw but not subject to the Massachusetts Wetlands Protection Act:

Isolated wetland bound by flags # 150 thru # 176 on plan for M.W.C.C. dated 12/12/08

☐ 7. If a Notice of Intent is filed for the work in the Riverfront Area described on referenced plan(s) and document(s), which includes all or part of the work described in the Request, the applicant must consider the following alternatives. (Refer to the wetland regulations at 10.58(4)c. for more information about the scope of alternatives requirements):

☐ Alternatives limited to the lot on which the project is located.

☐ Alternatives limited to the lot on which the project is located, the subdivided lots, and any adjacent lots formerly or presently owned by the same owner.

☐ Alternatives limited to the original parcel on which the project is located, the subdivided parcels, any adjacent parcels, and any other land which can reasonably be obtained within the municipality.

☐ Alternatives extend to any sites which can reasonably be obtained within the appropriate region of the state.

Negative Determination

Note: No further action under the Wetlands Protection Act is required by the applicant. However, if the Department is requested to issue a Superseding Determination of Applicability, work may not proceed on this project unless the Department fails to act on such request within 35 days of the date the request is post-marked for certified mail or hand delivered to the Department. Work may then proceed at the owner's risk only upon notice to the Department and to the Conservation Commission. Requirements for requests for Superseding Determinations are listed at the end of this document.

☐ 1. The area described in the Request is not an area subject to protection under the Act or the Buffer Zone.

☐ 2. The work described in the Request is within an area subject to protection under the Act, but will not remove, fill, dredge, or alter that area. Therefore, said work does not require the filing of a Notice of Intent.

☐ 3. The work described in the Request is within the Buffer Zone, as defined in the regulations, but will not alter an Area subject to protection under the Act. Therefore, said work does not require the filing of a Notice of Intent, subject to the following conditions (if any).

☐ 4. The work described in the Request is not within an Area subject to protection under the Act (including the Buffer Zone). Therefore, said work does not require the filing of a Notice of Intent, unless and until said work alters an Area subject to protection under the Act.

B. Determination (cont.)

☐ 5. The area described in the Request is subject to protection under the Act. Since the work described therein meets the requirements for the following exemption, as specified in the Act and the regulations, no Notice of Intent is required:

____
Exempt Activity (site applicable statuatory/regulatory provisions)

____

☐ 6. The area and/or work described in the Request is not subject to review and approval by:

Gardner
Name of Municipality

Pursuant to a municipal wetlands ordinance or bylaw.

Wetlands Protection ordinance	# 1401
Name	Ordinance or Bylaw Citation

C. Authorization

This Determination is issued to the applicant and delivered as follows:

☐ by hand delivery on	☒ by certified mail, return receipt requested on
	January 14, 2009
Date	Date

This Determination is valid for **three years** from the date of issuance (except Determinations for Vegetation Management Plans which are valid for the duration of the Plan). This Determination does not relieve the applicant from complying with all other applicable federal, state, or local statutes, ordinances, bylaws, or regulations.

This Determination must be signed by a majority of the Conservation Commission. A copy must be sent to the appropriate DEP Regional Office (see Attachment) and the property owner (if different from the applicant).

Signatures:

David Beaurgard	Jack M. Bush
Norman Beauregard	Dennis H Bump
Michael R. Roy	
Jane F Cullen	

1/13/09
Date

D. Appeals

The applicant, owner, any person aggrieved by this Determination, any owner of land abutting the land upon which the proposed work is to be done, or any ten residents of the city or town in which such land is located, are hereby notified of their right to request the appropriate Department of Environmental Protection Regional Office (see Attachment) to issue a Superseding Determination of Applicability. The request must be made by certified mail or hand delivery to the Department, with the appropriate filing fee and Fee Transmittal Form (see Request for Departmental Action Fee Transmittal Form) as provided in 310 CMR 10.03(7) within ten business days from the date of issuance of this Determination. A copy of the request shall at the same time be sent by certified mail or hand delivery to the Conservation Commission and to the applicant if he/she is not the appellant. The request shall state clearly and concisely the objections to the Determination which is being appealed. To the extent that the Determination is based on a municipal ordinance or bylaw and not on the Massachusetts Wetlands Protection Act or regulations, the Department of Environmental Protection has no appellate jurisdiction.

Appendix 6.3 Wetland Order of Conditions

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands

WPA Form 5 – Order of Conditions

Massachusetts Wetlands Protection Act M.G.L. c. 131, §40

160-0526
MassDEP File Number

Document Transaction Number

Gardner
City/Town

A. General Information

Important: When filling out forms on the computer, use only the tab key to move your cursor - do not use the return key.

1. From: Gardner
Conservation Commission

2. This issuance is for (check one): a. ☒ Order of Conditions b. ☐ Amended Order of Conditions

3. To: Applicant:

Robert — a. First Name
LaBonte — b. Last Name
Mount Wachusett Community College — c. Organization
444 Green Street — d. Mailing Address
Gardner — e. City/Town
MA — f. State
01440 — g. Zip Code

4. Property Owner (if different from applicant):

a. First Name
b. Last Name
c. Organization
d. Mailing Address
e. City/Town
f. State
g. Zip Code

5. Project Location:

444 Green Street — a. Street Address
Gardner — b. City/Town
R-32 — c. Assessors Map/Plat Number
Block 33, Lot 6 — d. Parcel/Lot Number

Latitude and Longitude, if known:
42*35'24"N — e. Latitude
71*59'06"W — f. Longitude

6. Property recorded at the Registry of Deeds for (attach additional information if more than one parcel):

Worcester — a. County
b. Certificate Number (if registered land)
4754 — c. Book
229 — d. Page

7. Dates:
11/9/09 — a. Date Notice of Intent Filed
b. Date Public Hearing Closed
c. Date of Issuance

8. Final Approved Plans and Other Documents (attach additional plan or document references as needed):

Wind Turbine Project--Mt. Wachusett Community College — a. Plan Title
Jacobs Engineering Group — b. Prepared By
c. Signed and Stamped by
9/14/09 — d. Final Revision Date
1:60 — e. Scale
f. Additional Plan or Document Title
g. Date

B. Findings

1. Findings pursuant to the Massachusetts Wetlands Protection Act:

Following the review of the above-referenced Notice of Intent and based on the information provided in this application and presented at the public hearing, this Commission finds that the areas in which work is proposed is significant to the following interests of the Wetlands Protection Act (the Act). Check all that apply:

a. ☒ Public Water Supply
b. ☐ Land Containing Shellfish
c. ☐ Prevention of Pollution
d. ☐ Private Water Supply
e. ☐ Fisheries
f. ☒ Protection of Wildlife Habitat
g. ☒ Groundwater Supply
h. ☐ Storm Damage Prevention
i. ☒ Flood Control

2. This Commission hereby finds the project, as proposed, is: (check one of the following boxes)

Approved subject to:

a. ☒ the following conditions which are necessary in accordance with the performance standards set forth in the wetlands regulations. This Commission orders that all work shall be performed in accordance with the Notice of Intent referenced above, the following General Conditions, and any other special conditions attached to this Order. To the extent that the following conditions modify or differ from the plans, specifications, or other proposals submitted with the Notice of Intent, these conditions shall control.

Denied because:

b. ☐ the proposed work cannot be conditioned to meet the performance standards set forth in the wetland regulations. Therefore, work on this project may not go forward unless and until a new Notice of Intent is submitted which provides measures which are adequate to protect the interests of the Act, and a final Order of Conditions is issued. **A description of the performance standards which the proposed work cannot meet is attached to this Order.**

c. ☐ the information submitted by the applicant is not sufficient to describe the site, the work, or the effect of the work on the interests identified in the Wetlands Protection Act. Therefore, work on this project may not go forward unless and until a revised Notice of Intent is submitted which provides sufficient information and includes measures which are adequate to protect the Act's interests, and a final Order of Conditions is issued. **A description of the specific information which is lacking and why it is necessary is attached to this Order as per 310 CMR 10.05(6)(c).**

Inland Resource Area Impacts: Check all that apply below. (For Approvals Only)

3. ☒ Buffer Zone Impacts: Shortest distance between limit of project disturbance and Bank or Bordering Vegetated Wetland boundary (if available) ______ a. linear feet

Resource Area	Proposed Alteration	Permitted Alteration	Proposed Replacement	Permitted Replacement
4. ☐ Bank	a. linear feet	b. linear feet	c. linear feet	d. linear feet
5. ☐ Bordering Vegetated Wetland	a. square feet	b. square feet	c. square feet	d. square feet
6. ☐ Land Under Waterbodies and Waterways	a. square feet	b. square feet	c. square feet	d. square feet
	e. c/y dredged	f. c/y dredged		

B. Findings (cont.)

Resource Area	Proposed Alteration	Permitted Alteration	Proposed Replacement	Permitted Replacement
7. ☐ Bordering Land Subject to Flooding	a. square feet	b. square feet	c. square feet	d. square feet
Cubic Feet Flood Storage	e. cubic feet	f. cubic feet	g. cubic feet	h. cubic feet
8. ☐ Isolated Land Subject to Flooding	a. square feet	b. square feet		
Cubic Feet Flood Storage	c. cubic feet	d. cubic feet	e. cubic feet	f. cubic feet
9. ☐ Riverfront Area	a. total sq. feet	b. total sq. feet		
Sq ft within 100 ft	c. square feet	d. square feet	e. square feet	f. square feet
Sq ft between 100-200 ft	g. square feet	h. square feet	i. square feet	j. square feet

Coastal Resource Area Impacts: Check all that apply below. (For Approvals Only)

10. ☐ Designated Port Areas	Indicate size under Land Under the Ocean, below			
11. ☐ Land Under the Ocean	a. square feet	b. square feet		
	c. c/y dredged	d. c/y dredged		
12. ☐ Barrier Beaches	Indicate size under Coastal Beaches and/or Coastal Dunes below			
13. ☐ Coastal Beaches	a. square feet	b. square feet	c. c/y nourishmt.	d. c/y nourishmt.
14. ☐ Coastal Dunes	a. square feet	b. square feet	c. c/y nourishmt.	d. c/y nourishmt.
15. ☐ Coastal Banks	a. linear feet	b. linear feet		
16. ☐ Rocky Intertidal Shores	a. square feet	b. square feet		
17. ☐ Salt Marshes	a. square feet	b. square feet	c. square feet	d. square feet
18. ☐ Land Under Salt Ponds	a. square feet	b. square feet		
	c. c/y dredged	d. c/y dredged		
19. ☐ Land Containing Shellfish	a. square feet	b. square feet	c. square feet	d. square feet
20. ☐ Fish Runs	Indicate size under Coastal Banks, Inland Bank, Land Under the Ocean, and/or inland Land Under Waterbodies and Waterways, above			
	a. c/y dredged	b. c/y dredged		
21. ☐ Land Subject to Coastal Storm Flowage	a. square feet	b. square feet		

C. General Conditions Under Massachusetts Wetlands Protection Act

The following conditions are only applicable to Approved projects.

1. Failure to comply with all conditions stated herein, and with all related statutes and other regulatory measures, shall be deemed cause to revoke or modify this Order.

2. The Order does not grant any property rights or any exclusive privileges; it does not authorize any injury to private property or invasion of private rights.

3. This Order does not relieve the permittee or any other person of the necessity of complying with all other applicable federal, state, or local statutes, ordinances, bylaws, or regulations.

4. The work authorized hereunder shall be completed within three years from the date of this Order unless either of the following apply:
   a. the work is a maintenance dredging project as provided for in the Act; or
   b. the time for completion has been extended to a specified date more than three years, but less than five years, from the date of issuance. If this Order is intended to be valid for more than three years, the extension date and the special circumstances warranting the extended time period are set forth as a special condition in this Order.

5. This Order may be extended by the issuing authority for one or more periods of up to three years each upon application to the issuing authority at least 30 days prior to the expiration date of the Order.

6. Any fill used in connection with this project shall be clean fill. Any fill shall contain no trash, refuse, rubbish, or debris, including but not limited to lumber, bricks, plaster, wire, lath, paper, cardboard, pipe, tires, ashes, refrigerators, motor vehicles, or parts of any of the foregoing.

7. This Order is not final until all administrative appeal periods from this Order have elapsed, or if such an appeal has been taken, until all proceedings before the Department have been completed.

8. No work shall be undertaken until the Order has become final and then has been recorded in the Registry of Deeds or the Land Court for the district in which the land is located, within the chain of title of the affected property. In the case of recorded land, the Final Order shall also be noted in the Registry's Grantor Index under the name of the owner of the land upon which the proposed work is to be done. In the case of the registered land, the Final Order shall also be noted on the Land Court Certificate of Title of the owner of the land upon which the proposed work is done. The recording information shall be submitted to the Conservation Commission on the form at the end of this Order, which form must be stamped by the Registry of Deeds, prior to the commencement of work.

9. A sign shall be displayed at the site not less then two square feet or more than three square feet in size bearing the words,

"Massachusetts Department of Environmental Protection" [or, "MassDEP"]

"File Number 160--0526 "

C. General Conditions Under Massachusetts Wetlands Protection Act

10. Where the Department of Environmental Protection is requested to issue a Superseding Order, the Conservation Commission shall be a party to all agency proceedings and hearings before MassDEP.

11. Upon completion of the work described herein, the applicant shall submit a Request for Certificate of Compliance (WPA Form 8A) to the Conservation Commission.

12. The work shall conform to the plans and special conditions referenced in this order.

13. Any change to the plans identified in Condition #12 above shall require the applicant to inquire of the Conservation Commission in writing whether the change is significant enough to require the filing of a new Notice of Intent.

14. The Agent or members of the Conservation Commission and the Department of Environmental Protection shall have the right to enter and inspect the area subject to this Order at reasonable hours to evaluate compliance with the conditions stated in this Order, and may require the submittal of any data deemed necessary by the Conservation Commission or Department for that evaluation.

15. This Order of Conditions shall apply to any successor in interest or successor in control of the property subject to this Order and to any contractor or other person performing work conditioned by this Order.

16. Prior to the start of work, and if the project involves work adjacent to a Bordering Vegetated Wetland, the boundary of the wetland in the vicinity of the proposed work area shall be marked by wooden stakes or flagging. Once in place, the wetland boundary markers shall be maintained until a Certificate of Compliance has been issued by the Conservation Commission.

17. All sedimentation barriers shall be maintained in good repair until all disturbed areas have been fully stabilized with vegetation or other means. At no time shall sediments be deposited in a wetland or water body. During construction, the applicant or his/her designee shall inspect the erosion controls on a daily basis and shall remove accumulated sediments as needed. The applicant shall immediately control any erosion problems that occur at the site and shall also immediately notify the Conservation Commission, which reserves the right to require additional erosion and/or damage prevention controls it may deem necessary. Sedimentation barriers shall serve as the limit of work unless another limit of work line has been approved by this Order.

NOTICE OF STORMWATER CONTROL AND MAINTENANCE REQUIREMENTS

18. **The work associated with this Order (the "Project") is** (1) ☐ **is not** (2) ☒ **subject to the Massachusetts Stormwater Standards. If the work is subject to the Stormwater Standards, then the project is subject to the following conditions:**

    a) All work, including site preparation, land disturbance, construction and redevelopment, shall be implemented in accordance with the construction period pollution prevention and erosion and sedimentation control plan and, if applicable, the Stormwater Pollution Prevention Plan required by the National Pollution Discharge Elimination System Construction General Permit as required by Stormwater Condition 8. Construction period erosion, sedimentation and pollution control measures and best management practices (BMPs) shall remain in place until the site is fully stabilized.

C. General Conditions Under Massachusetts Wetlands Protection Act (cont.)

b) No stormwater runoff may be discharged to the post-construction stormwater BMPs unless and until a Registered Professional Engineer provides a Certification that:
i. all construction period BMPs have been removed or will be removed by a date certain specified in the Certification. For any construction period BMPs intended to be converted to post construction operation for stormwater attenuation, recharge, and/or treatment, the conversion is allowed by the MassDEP Stormwater Handbook BMP specifications and that the BMP has been properly cleaned or prepared for post construction operation, including removal of all construction period sediment trapped in inlet and outlet control structures;
ii. as-built final construction BMP plans are included, signed and stamped by a Registered Professional Engineer, certifying the site is fully stabilized;
iii. any illicit discharges to the stormwater management system have been removed, as per the requirements of Stormwater Standard 10;
iv. all post-construction stormwater BMPs are installed in accordance with the plans (including all planting plans) approved by the issuing authority, and have been inspected to ensure that they are not damaged and that they are in proper working condition;
v. any vegetation associated with post-construction BMPs is suitably established to withstand erosion.

c) The landowner is responsible for BMP maintenance until the issuing authority is notified that another party has legally assumed responsibility for BMP maintenance. Prior to requesting a Certificate of Compliance, or Partial Certificate of Compliance, the responsible party (defined in General Condition 18(e)) shall execute and submit to the issuing authority an Operation and Maintenance Compliance Statement ("O&M Statement) for the Stormwater BMPs identifying the party responsible for implementing the stormwater BMP Operation and Maintenance Plan ("O&M Plan") and certifying the following: *i.*) the O&M Plan is complete and will be implemented upon receipt of the Certificate of Compliance, and *ii.*) the future responsible parties shall be notified in writing of their ongoing legal responsibility to operate and maintain the stormwater management BMPs and implement the Stormwater Pollution Prevention Plan.

d) Post-construction pollution prevention and source control shall be implemented in accordance with the long-term pollution prevention plan section of the approved Stormwater Report and, if applicable, the Stormwater Pollution Prevention Plan required by the National Pollution Discharge Elimination System Multi-Sector General Permit.

e) Unless and until another party accepts responsibility, the landowner, or owner of any drainage easement, assumes responsibility for maintaining each BMP. To overcome this presumption, the landowner of the property must submit to the issuing authority a legally binding agreement of record, acceptable to the issuing authority, evidencing that another entity has accepted responsibility for maintaining the BMP, and that the proposed responsible party shall be treated as a permittee for purposes of implementing the requirements of Conditions 18(f) through 18(k) with respect to that BMP. Any failure of the proposed responsible party to implement the requirements of Conditions 18(f) through 18(k) with respect to that BMP shall be a violation of the Order of Conditions or Certificate of Compliance. In the case of stormwater BMPs that are serving more than one lot, the legally binding agreement shall also identify the lots that will be serviced by the stormwater BMPs. A plan and easement deed that grants the responsible party access to perform the required operation and maintenance must be submitted along with the legally binding agreement.

f) The responsible party shall operate and maintain all stormwater BMPs in accordance with the design plans, the O&M Plan, and the requirements of the Massachusetts Stormwater Handbook.

C. General Conditions Under Massachusetts Wetlands Protection Act (cont.)

g) The responsible party shall:
1. Maintain an operation and maintenance log for the last three (3) consecutive calendar years of inspections, repairs, maintenance and/or replacement of the stormwater management system or any part thereof, and disposal (for disposal the log shall indicate the type of material and the disposal location);
2. Make the maintenance log available to MassDEP and the Conservation Commission ("Commission") upon request; and
3. Allow members and agents of the MassDEP and the Commission to enter and inspect the site to evaluate and ensure that the responsible party is in compliance with the requirements for each BMP established in the O&M Plan approved by the issuing authority.

h) All sediment or other contaminants removed from stormwater BMPs shall be disposed of in accordance with all applicable federal, state, and local laws and regulations.

i) Illicit discharges to the stormwater management system as defined in 310 CMR 10.04 are prohibited.

j) The stormwater management system approved in the Order of Conditions shall not be changed without the prior written approval of the issuing authority.

k) Areas designated as qualifying pervious areas for the purpose of the Low Impact Site Design Credit (as defined in the MassDEP Stormwater Handbook, Volume 3, Chapter 1, Low Impact Development Site Design Credits) shall not be altered without the prior written approval of the issuing authority.

l) Access for maintenance, repair, and/or replacement of BMPs shall not be withheld. Any fencing constructed around stormwater BMPs shall include access gates and shall be at least six inches above grade to allow for wildlife passage.

Special Conditions (if you need more space for additional conditions, please attach a text document):

Standard Order of Conditions using approved Plan #C-1A requiring 2600 sq. ft. of wetland replication as shown on plan and the placing of entrenched siltation fence and hay bales on the downslope side of crane pads.

D. Findings Under Municipal Wetlands Bylaw or Ordinance

1. Is a municipal wetlands bylaw or ordinance applicable? ☒ Yes ☐ No
2. The Gardner (Conservation Commission) hereby finds (check one that applies):

a. ☐ that the proposed work cannot be conditioned to meet the standards set forth in a municipal ordinance or bylaw specifically:

1. Municipal Ordinance or Bylaw — 2. Citation

Therefore, work on this project may not go forward unless and until a revised Notice of Intent is submitted which provides measures which are adequate to meet these standards, and a final Order of Conditions is issued.

D. Findings Under Municipal Wetlands Bylaw or Ordinance (cont.)

b. ☒ that the following additional conditions are necessary to comply with a municipal ordinance or bylaw:

Gardner Wetland Protection Ordinance
1. Municipal Ordinance or Bylaw

161
2. Citation

3. The Commission orders that all work shall be performed in accordance with the following conditions and with the Notice of Intent referenced above. To the extent that the following conditions modify or differ from the plans, specifications, or other proposals submitted with the Notice of Intent, the conditions shall control.

The special conditions relating to municipal ordinance or bylaw are as follows (if you need more space for additional conditions, attach a text document):

The Gardner Conservation Commission will grant a variance to allow work within a portion of an Isolated Wetland provided that there will be replication at least equal to the amount of alteration.

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands

WPA Form 5 – Order of Conditions

Massachusetts Wetlands Protection Act M.G.L. c. 131, §40

160-0526
MassDEP File Number

Document Transaction Number

Gardner
City/Town

E. Signatures and Notary Acknowledgement

This Order is valid for three years, unless otherwise specified as a special condition pursuant to General Conditions #4, from the date of issuance.

11/23/09
1. Date of Issuance

Please indicate the number of members who will sign this form.
This Order must be signed by a majority of the Conservation Commission.

5
2. Number of Signers

The Order must be mailed by certified mail (return receipt requested) or hand delivered to the applicant. A copy also must be mailed or hand delivered at the same time to the appropriate Department of Environmental Protection Regional Office, if not filing electronically, and the property owner, if different from applicant.

Signatures:

Michael R. Roy

Norman H. Beauregard

[illegible]

Jane Cullen

[illegible] Beaurega[illegible]

Notary Acknowledgement

Commonwealth of Massachusetts County of WORCESTER

On this 24th Day of NOVEMBER Month 2009 Year

Before me, the undersigned Notary Public, personally appeared NORMAN H. BEAUREGARD
Name of Document Signer

proved to me through satisfactory evidence of identification, which was/were

MA DRIVERS LICENSE
Description of evidence of identification

to be the person whose name is signed on the preceding or attached document, and acknowledged to me that he/she signed it voluntarily for its stated purpose.

As member of GARDNER City/Town Conservation Commission

JENNIFER A. DYMEK
Notary Public
Commonwealth of Massachusetts
My Commission Expires
November 17, 2011

Jennifer A. Dymek
Signature of Notary Public

JENNIFER A. DYMEK
Printed Name of Notary Public

Place notary seal and/or any stamp above.

11-17-2011
My Commission Expires (Date)

This Order is issued to the applicant as follows:

☐ by hand delivery on

Date

☒ by certified mail, return receipt requested, on

11/24/09
Date

F. Appeals

The applicant, the owner, any person aggrieved by this Order, any owner of land abutting the land subject to this Order, or any ten residents of the city or town in which such land is located, are hereby notified of their right to request the appropriate MassDEP Regional Office to issue a Superseding Order of Conditions. The request must be made by certified mail or hand delivery to the Department, with the appropriate filing fee and a completed Request of Departmental Action Fee Transmittal Form, as provided in 310 CMR 10.03(7) within ten business days from the date of issuance of this Order. A copy of the request shall at the same time be sent by certified mail or hand delivery to the Conservation Commission and to the applicant, if he/she is not the appellant.

Any appellants seeking to appeal the Department's Superseding Order associated with this appeal will be required to demonstrate prior participation in the review of this project. Previous participation in the permit proceeding means the submission of written information to the Conservation Commission prior to the close of the public hearing, requesting a Superseding Order, or providing written information to the Department prior to issuance of a Superseding Order.

The request shall state clearly and concisely the objections to the Order which is being appealed and how the Order does not contribute to the protection of the interests identified in the Massachusetts Wetlands Protection Act (M.G.L. c. 131, § 40), and is inconsistent with the wetlands regulations (310 CMR 10.00). To the extent that the Order is based on a municipal ordinance or bylaw, and not on the Massachusetts Wetlands Protection Act or regulations, the Department has no appellate jurisdiction.

Section G, Recording Information, is available on the following page.

G. Recording Information

This Order of Conditions must be recorded in the Registry of Deeds or the Land Court for the district in which the land is located, within the chain of title of the affected property. In the case of recorded land, the Final Order shall also be noted in the Registry's Grantor Index under the name of the owner of the land subject to the Order. In the case of registered land, this Order shall also be noted on the Land Court Certificate of Title of the owner of the land subject to the Order of Conditions. The recording information on this page shall be submitted to the Conservation Commission listed below.

Gardner
Conservation Commission

Detach on dotted line, have stamped by the Registry of Deeds and submit to the Conservation Commission.

To:

Conservation Commission

Please be advised that the Order of Conditions for the Project at:

Project Location

MassDEP File Number

Has been recorded at the Registry of Deeds of:

County

Book

Page

for:

Property Owner

and has been noted in the chain of title of the affected property in:

Book

Page

In accordance with the Order of Conditions issued on:

Date

If recorded land, the instrument number identifying this transaction is:

Instrument Number

If registered land, the document number identifying this transaction is:

Document Number

Signature of Applicant

Appendix 7 Sound Analysis

University of Massachusetts
Wind Energy Center

Department of Mechanical & Industrial Engineering
160 Governors Drive, Amherst, MA 01003-9265
Tel: 413-545-4359 Fax: 577-1301
www.umass.edu/windenergy

Mount Wachusett Community College Turbine Sound Analysis

Prepared by Mary Knipe
August 27, 2009

Executive Summary

The University of Massachusetts Wind Energy Center (WEC) performed a sound analysis for the proposed two-turbine wind power installation at Mount Wachusett Community College Campus in Gardner, MA. The sound analysis was completed using the "Decibel" module of WindPRO software version 2.6.1.252. The program uses turbine specifications, topography, and site-specific data inputs to determine the estimated decibel levels coming from the turbines at each location or Noise Impact Area.

The sound impacts at five locations (Noise Impact Areas) near the proposed turbine site have been estimated. Analyses were carried out for turbine model Vestas V82 1.65MW (80m hub height).

A decibel level map for the two turbines is provided for the surrounding area (Figure 3). The estimated sound levels are provided in Appendix A. Mount Wachusett Community College is labeled with a red balloon on the map below (Figure 1).

In the most impacted area, standing outside at the courthouse, the noise level from the wind turbines is estimated to be approximately the same as the background noise in a quiet business office (see Table 3). Outside at the other potential Noise Impact Areas (NIA), the noise level from the wind turbines is estimated to be below that level, somewhere between the noise level of a residential area at night and a quiet business office. This study does not evaluate whether these levels of sound can be heard at all above ambient noise levels at the Noise Impact Areas. It is unlikely that the proposed wind turbines will have any noticeable sound impact at areas other than the selected Noise Impact Areas closest to the project site.

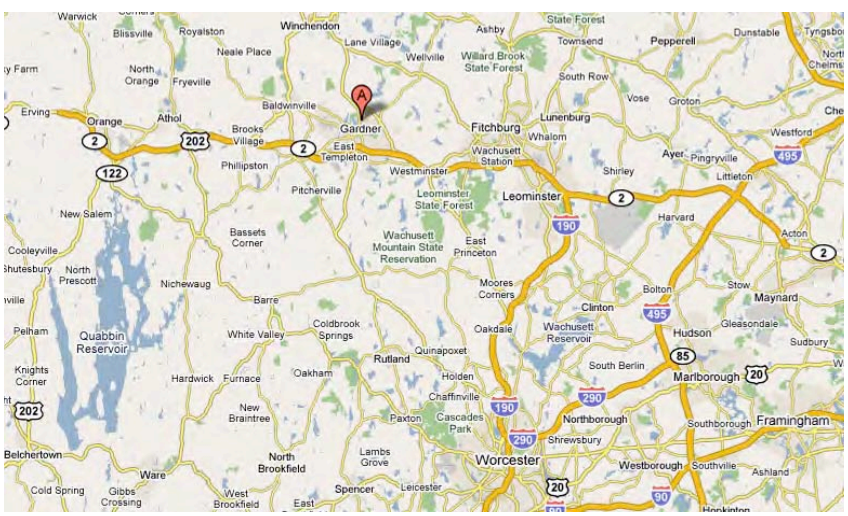

Figure 1: Location of proposed wind turbine site - (map courtesy of Google Maps).

Noise Impact Areas

Figure 2: This figure shows an orthophotograph of the proposed wind turbine installation at Mount Wachusett Community College**.** Noise Impact Areas are marked with green stars and labeled.
Orthophotograph courtesy of MassGIS.

The locations (see Figure 2) near the turbines were chosen to be used as Noise Impact Areas in the WindPRO simulation due to their proximity to the project site and their likelihood to be most impacted by sound from the wind turbines. Three of the five locations are noise sensitive receptors because they are residential, hospital or school sites. However, the college site does not have residential dormitories. Sites further away are unlikely to be impacted by sound from the wind turbines in any noticeable way.

Table 1: Locations of each Noise Impact Area. Turbine 1 is located to the north and Turbine 2 is the turbine located to the south on the map in Figure 2 and Figure 3.

NIA	Name *	Location UTM NAD 83	Distance Turbine 1, (meters)	Distance to Turbine 2 (meters)
A	Hospital Adm. Bldg	42°35'13.66"N, 71°59'8.58"W	401	192
B	Boulder Drive*	42°35'20.77"N, 71°58'44.76"W	370	380
C	MWCC Building*	42°35'32.78"N, 71°59'1.30"W	208	423
D	Hospital*	42°35'13.43"N, 71°59'12.82"W	445	250
E	Courthouse	42°35'21.76"N, 71°58'55.11"W	153	167
* Indicates Noise Sensitive Receptor				

How decibel calculation is estimated

The estimated sound levels from a wind turbine are dependent on several factors, including the:

- Wind Speed, and
- Location of a noise impact area
- Terrain

The UMass Wind Energy Center employed WindPRO to calculate sound levels that a location would be exposed to from the two wind turbines. WindPRO uses the following inputs to simulate the sound levels:

- Locations of wind turbines
- Wind turbine rotor diameter and hub height
- Turbine Statistics from WindPro catalog for specific model of turbine
- Wind Speed, set for a range from 3.5-12 meters/second.
- Location of Noise Impact Areas
- Geography: elevations, latitude & longitude

The software produces the following outputs:

- Sound level for the two turbines estimated Noise Impact Areas
- Sound level for the turbines plus ambient sound at each Noise Impact Area
- A map showing the decibel levels in the region at a wind speed of 8 m/s.

Assumptions

Ground Attenuation factor takes into account how sound varies with the conditions at the site. The range is 0-1 (0=hard non-porous to 1 most porous). The area is heavily wooded landscape. A 0.5 ground attenuation factor was used as a conservative estimate.

Ambient background sound levels are based on data collected at a nearby more rural site in Templeton, Massachusetts at which data was collected in March of 2009 (see table # 2) It is presumed that the estimated ambient sound levels are likely lower than actual since the Mount Wachusett Community College site is on a busier road with the hospital and other commercial activity nearby. Ambient sound levels vary with wind speed, as does the sound levels produced by wind turbines. Analysis was based on the Vestas V-82 wind turbine starting at the cut-in wind speed for the turbine of 3.5 m/s.

Table 2: Ambient Sound and Legal Limit Over Range of Wind

Wind Speed (m/s)	Ambient Sound (dB(A))	Noise Demand (dB(A))
0	29.6	39.6
1	31.0	41.0
2	32.5	42.5
3	33.9	43.9
4	35.4	45.4
5	36.8	46.8
6	38.3	48.3
7	39.7	49.7
8	41.1	51.1
9	42.6	52.6
10	44.0	54.0
11	45.5	55.5
12	46.9	56.9

Table from 2009 WEC report *Sound Impact Study of Proposed Wind Turbine in Templeton MA*.

Results

The table below summarizes decibel output at each of the five Noise Impact Areas for the two turbines under consideration. WindPRO adds the sound levels from each turbine to estimate the sound level that will be produced by the two turbines together. The map in Figure 3 graphically shows the different sound levels calculated from the WindPRO Decibel simulation for the two Vestas V82 turbines. The full WindPRO calculation report can be found in Appendix A. Once again, the assumptions employed in the calculations were chosen in order to arrive at a conservative estimate.

Table 3: This table shows the estimated values of maximum decibel levels for each location for two turbines, for the turbines plus ambient sound and the maximum additional exposure above ambient sound levels (last column).

NIA	**Name**	**Max Sound Levels Turbines** dB(A)	**Max Sound Levels Turbine + Ambient** dB(A)	**Max additional exposure** dB(A)
A	Hospital Adm. Bldg	46.0	49.1	6.9
B	Boulder Drive	41.8	47.6	4.0
C	MWCC Building	45.3	48.8	6.3
D	Hospital	43.9	48.2	5.4
E	Courthouse	49.2	51.0	9.6**
**Sites A and E are not Noise Sensitive Receptors				

Massachusetts regulates noise as a form of air pollution under the Air Pollution Control Regulations, 310 CMR 7.10. The DEP Noise Policy includes criteria Massachusetts Department of Environmental Protection (Mass DEP) uses to evaluate noise impacts at occupied residences, or other sensitive receptors such as schools and hospitals. If the noise level at a sensitive receptor's location increases by more than 10 decibels above ambient levels, noise mitigation would be required.

None of the locations will have an increase of 10 dB(A) over ambient levels. Although the Courthouse would have an increase of 9.6, close to the 10 threshold, the courthouse is not a sensitive receptor.

The Courthouse, NIA E, would have the highest maximum sound levels with 51.0 dB(A) which is estimated to occur at a wind speed of 11.5 m/s. The MWCC campus building, NIA A, has the next highest sound levels. The Hospital and the Boulder Drive residences see the lowest number of decibels of the areas studied.

Table 4. This table was developed by OSHAX to explain OSHA (Occupational and Safety Health Administration) regulations. The table lists decibel levels for a variety of sounds. http://www.oshax.org/

Decibel Levels of Environmental Sounds

dBA	Source
120-140	Produces Pain
130	Jet Aircraft During Takeoff (at 20 meters)
120	Snowmobile, Tractor Without Cab
110	Rock Concert
100-105	Chain Saw
95 to 100 dB	Home Lawn Mowers
90	Semi-trailers (at 20 meters)
Above 80	Discomfort Level
80	Heavy Traffic
70	Automobile (at 20 meters)
65	Vacuum Cleaner
60	Conversational Speech (at 1 meter)
50	Quiet Business Office
40	Residential Area at Night
20	Whisper, Rustle of Leaves
10	Rustle of Leaves
0	Threshold of Audibility

Sound Levels

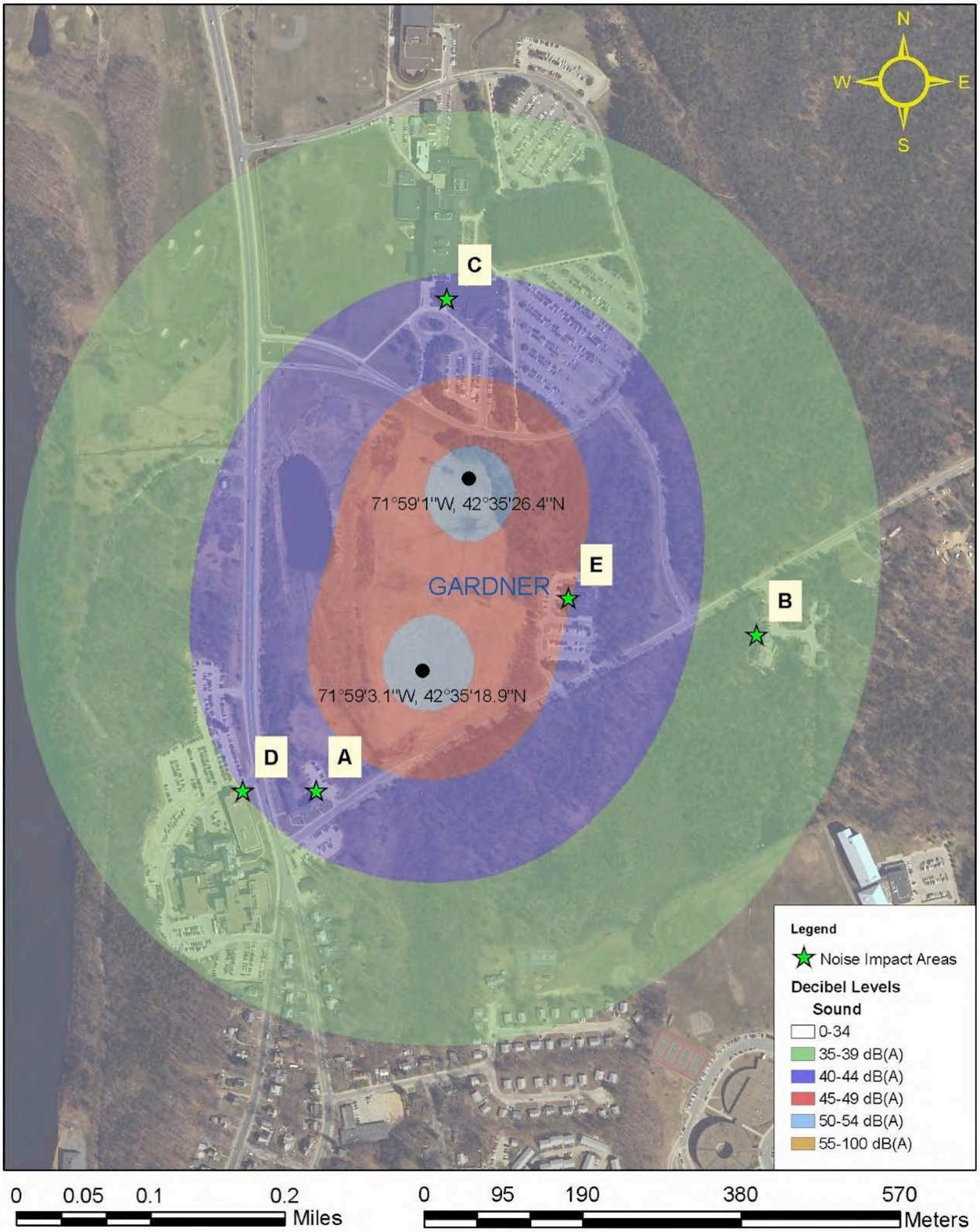

Figure 3: Orthophotograph with an overlay of estimated decibel levels at a wind speed of 8 m/s from proposed wind turbine installation in Gardner. ***Orthophotograph courtesy of MassGIS.***

It should be noted that the decibel scale is a logarithmic unit of measurement that expresses the magnitude of sound being measured. This means that the numbers on the scale increase exponentially rather than in a more intuitively easy to understand linear manner. This is probably clear from the chart above in thinking about the numbers on the scale in relationship to the sounds we experience in our environment.

Summary

The sound levels at the Noise Impact Areas have been estimated through computer simulations for five areas nearby the proposed turbine site at MWCC in Gardner, MA. Sound Level maps for the area surrounding the proposed site have been generated, and estimated sound levels at each Noise Impact Area have been tabulated. The ambient sound levels were not measured at the Gardner site. Data from a WEC study in Templeton, MA was used for the WindPRO analysis in this study. The ambient sound levels in Gardner are most likely higher since the Templeton site is a quieter setting.

The maximum additional exposure at the Courthouse site would be 9.6 which is close to 10 the Mass DEP limit for noise sensitive receptors. However, the Courthouse would not be considered a regulated sensitive receptor. In addition it is assumed that the Courthouse building is air conditioned and that all courthouse activities take place indoors. Outside at the courthouse, the noise level from the wind turbines is estimated to be approximately the same as the background noise in a quiet business office. The vegetation is not as dense at the Courthouse, Hospital and the MWCC building and the effect of ground attenuation may be lower than in a heavily wooded area such as Boulder Drive. Outside at the other Noise Impact Areas, the noise level from the wind turbines is estimated to be below that level, somewhere between the noise level of a residential area at night and a quiet business office. This study does not evaluate whether these levels of sound can be heard at all above ambient noise levels at the Noise Impact Areas. It is unlikely that the proposed wind turbines will have noticeable sound impact at areas further from the project site than the selected Noise Impact Areas.

Appendix A

Note: Locations named as Noise Impact Areas (NIA) in the text of this report are referred to as Noise Sensitive Areas (NSA) in WindPRO.

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Project:
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DECIBEL - Main Result

Calculation: GA: 0.5 with ambient speed range 3.5-12 Two Turbines at MWCC

Noise calculation model:
ISO 9613-2 General
Wind speed:
3.5 m/s - 12.0 m/s, step 1.0 m/s
Ground attenuation:
General, Ground factor: 0.5
Meteorological coefficient, C0:
0.0 dB
Type of demand in calculation:
2: WTG plus ambient noise is compared to ambient noise plus margin (FR etc.)
Noise values in calculation:
All noise values are 90% exeedence values (L90)
Pure tones:
Pure and Impulse tone penalty are added to WTG source noise
Height above ground level, when no value in NSA object:
0.0 m Don't allow override of model height with height from NSA object
Deviation from "official" noise demands. Negative is more restrictive, positive is less restrictive.:
0.0 dB(A)

Scale 1:12,500
New WTG   Noise sensitive area

WTGs

UTM NAD83 Zone: 19					WTG type						Noise data					
	East	North	Z	Row data/Description	Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Creator	Name	First wind speed	LwaRef	Pure tones	Octave data
UTM NAD83 Zone: 19			[m]					[kW]	[m]	[m]			[m/s]	[dB(A)]		
1	255,193	4,719,664	356.1	North VESTAS V82 1650 8...	Yes	VESTAS	V82-1,650	1,650	82.0	80.0	EMD	Level 0 - - - 05-2008	3.5	101.3	0 dB	Generic *)
2	255,140	4,719,453	362.5	South VESTAS V82 1650 8...	Yes	VESTAS	V82-1,650	1,650	82.0	80.0	EMD	Level 0 - - - 05-2008	3.5	101.3	0 dB	Generic *)

*)Notice: One or more noise data for this WTG is generic or input by user

Calculation Results

Sound Level

Noise sensitive area		UTM NAD83 Zone: 19				Demands		Sound Level			Demands fulfilled ?		
No.	Name	East	North	Z	Imission height	Max Additional exposure	Distance	Max From WTGs	Max Ambient+WTGs	Max Additional exposure	Noise	Distance	All
				[m]	[m]	[dB(A)]	[m]	[dB(A)]	[dB(A)]	[dB(A)]			
	A Hospital Admin a	255,014	4,719,305	355.7	0.0	10.0	300	46.0	49.1	6.9	Yes	No	No
	B Boulder Street a	255,519	4,719,480	358.6	0.0	10.0	300	41.8	47.6	4.0	Yes	Yes	Yes
	C MWCC building a	255,179	4,719,871	354.3	0.0	10.0	300	45.3	48.8	6.3	Yes	No	No
	D Hospital a	254,945	4,719,296	359.6	0.0	10.0	300	43.9	48.2	5.4	Yes	No	No
	E Courthouse a	255,301	4,719,555	360.8	0.0	10.0	300	49.2	51.0	9.6	Yes	No	No

Distances (m)

	WTG	
NSA	1	2
A	401	192
B	370	380
C	208	423
D	445	250
E	153	167

WindPRO is developed by EMD International A/S, Niels Jernesvej 10, DK-9220 Aalborg Ø, Tlf. +45 96 35 44 44, Fax +45 96 35 44 46, e-mail: windpro@emd.dk

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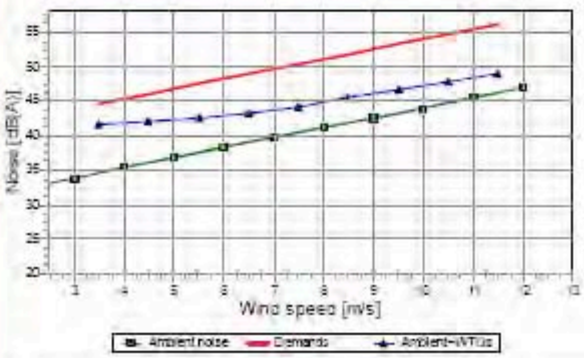
DECIBEL - Detailed results

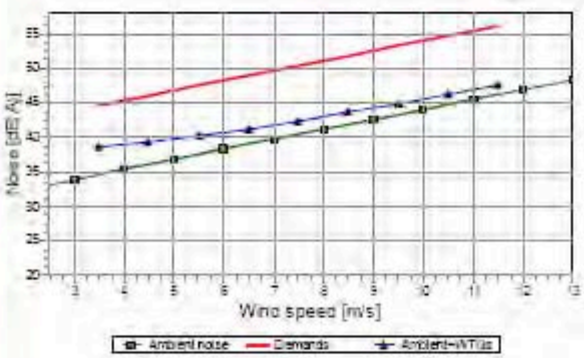
Calculation: GA: 0.5 with ambient speed range 3.5-12 Two Turbines at MWCC **Noise calculation model:** ISO 9613-2 Genera

Hospital Admin a (A)



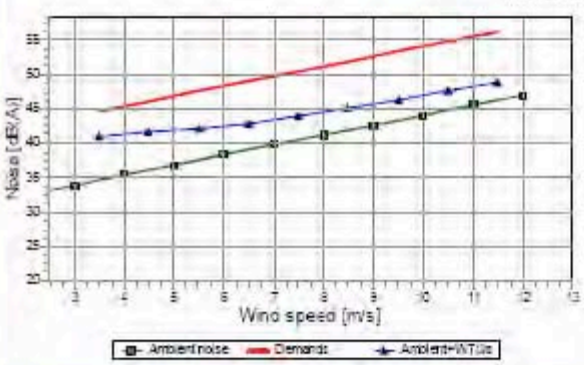
Wind speed	Ambient noise	Demande: Allowed addition exposure	Sound Level: WTG noise	Ambient+WTGs	Result: Additional exposure	Demands fulfilled ?
[m/s]	[dB(A)]	[dB(A)]	[dB(A)]	[dB(A)]	[dB(A)]	
3.5	34.7	10.0	40.6	41.5	5.9	Yes
4.5	36.1	10.0	40.6	42.0	5.9	Yes
5.5	37.5	10.0	41.0	42.6	5.1	Yes
6.5	39.0	10.0	41.3	43.3	4.3	Yes
7.5	40.4	10.0	42.0	44.3	3.9	Yes
8.5	41.8	10.0	43.0	45.4	3.6	Yes
9.5	43.3	10.0	44.0	46.7	3.4	Yes
10.5	44.8	10.0	45.0	47.9	3.1	Yes
11.5	46.2	10.0	46.0	49.1	2.9	Yes

Boulder Street a (B)



Wind speed	Ambient noise	Demande: Allowed addition exposure	Sound Level: WTG noise	Ambient+WTGs	Result: Additional exposure	Demands fulfilled ?
[m/s]	[dB(A)]	[dB(A)]	[dB(A)]	[dB(A)]	[dB(A)]	
3.5	34.7	10.0	36.4	38.6	4.0	Yes
4.5	36.1	10.0	36.6	39.4	3.3	Yes
5.5	37.5	10.0	36.8	40.2	2.7	Yes
6.5	39.0	10.0	37.1	41.2	2.2	Yes
7.5	40.4	10.0	37.6	42.3	1.9	Yes
8.5	41.8	10.0	38.6	43.6	1.8	Yes
9.5	43.3	10.0	39.6	44.9	1.6	Yes
10.5	44.8	10.0	40.6	46.2	1.5	Yes
11.5	46.2	10.0	41.6	47.6	1.4	Yes

MWCC building a (C)



Wind speed	Ambient noise	Demande: Allowed addition exposure	Sound Level: WTG noise	Ambient+WTGs	Result: Additional exposure	Demands fulfilled ?
[m/s]	[dB(A)]	[dB(A)]	[dB(A)]	[dB(A)]	[dB(A)]	
3.5	34.7	10.0	39.8	41.0	6.3	Yes
4.5	36.1	10.0	40.1	41.5	5.4	Yes
5.5	37.5	10.0	40.3	42.1	4.6	Yes
6.5	39.0	10.0	40.6	42.9	3.9	Yes
7.5	40.4	10.0	41.3	43.9	3.5	Yes
8.5	41.8	10.0	42.3	45.1	3.2	Yes
9.5	43.3	10.0	43.3	46.3	3.0	Yes
10.5	44.8	10.0	44.3	47.5	2.8	Yes
11.5	46.2	10.0	45.3	48.8	2.6	Yes

Project:
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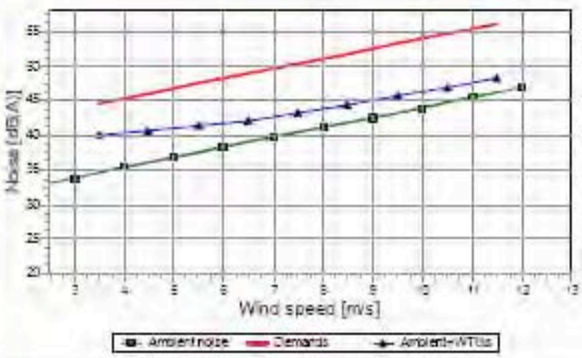
DECIBEL - Detailed results

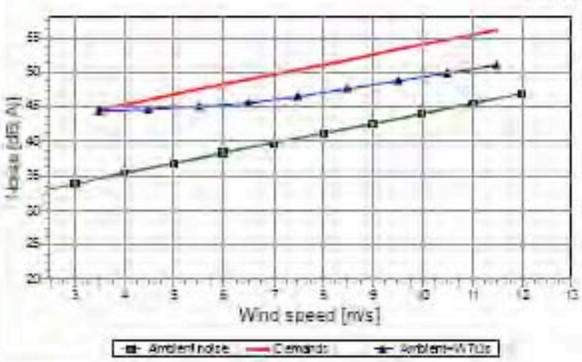
Calculation: GA: 0.5 with ambient speed range 3.5-12 Two Turbines at MWCC **Noise calculation model:** ISO 9613-2 Genera

Hospital a (D)



		Demands	Sound Level		Result	
Wind speed	Ambient noise	Allowed addition exposure	WTG noise	Ambient+WTGs	Additional exposure	Demands fulfilled ?
[m/s]	[dB(A)]	[dB(A)]	[dB(A)]	[dB(A)]	[dB(A)]	
3.5	34.7	10.0	38.5	40.0	5.4	Yes
4.5	36.1	10.0	38.8	40.6	4.5	Yes
5.5	37.5	10.0	39.0	41.3	3.8	Yes
6.5	39.0	10.0	39.3	42.1	3.1	Yes
7.5	40.4	10.0	40.0	43.2	2.8	Yes
8.5	41.8	10.0	40.9	44.4	2.6	Yes
9.5	43.3	10.0	41.9	45.7	2.4	Yes
10.5	44.8	10.0	42.9	47.0	2.2	Yes
11.6	46.2	10.0	43.9	48.2	2.0	Yes

Courthouse a (E)



		Demands	Sound Level		Result	
Wind speed	Ambient noise	Allowed addition exposure	WTG noise	Ambient+WTGs	Additional exposure	Demands fulfilled ?
[m/s]	[dB(A)]	[dB(A)]	[dB(A)]	[dB(A)]	[dB(A)]	
3.5	34.7	10.0	43.8	44.3	9.6	Yes
4.5	36.1	10.0	44.0	44.7	8.6	Yes
5.5	37.5	10.0	44.3	45.1	7.5	Yes
6.5	39.0	10.0	44.6	45.6	6.6	Yes
7.5	40.4	10.0	45.3	46.5	6.1	Yes
8.5	41.8	10.0	46.2	47.6	5.7	Yes
9.5	43.3	10.0	47.2	48.7	5.4	Yes
10.5	44.8	10.0	48.2	49.8	5.1	Yes
11.6	46.2	10.0	49.2	51.0	4.8	Yes

Project:
MWCC

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DECIBEL - Assumptions for noise calculation

Calculation: GA: 0.5 with ambient speed range 3.5-12 Two Turbines at MWCC **Noise calculation model:** ISO 9613-2 General

Noise calculation model:
ISO 9613-2 General
Wind speed:
3.5 m/s - 12.0 m/s, step 1.0 m/s
Ground attenuation:
General, Ground factor: 0.5
Meteorological coefficient, C0:
0.0 dB
Type of demand in calculation:
2: WTG plus ambient noise is compared to ambient noise plus margin (FR etc.)
Noise values in calculation:
All noise values are 90% exeedence values (L90)
Pure tones:
Pure and Impulse tone penalty are added to WTG source noise
Height above ground level, when no value in NSA object:
0.0 m Don't allow override of model height with height from NSA object
Deviation from "official" noise demands. Negative is more restrictive, positive is less restrictive.:
0.0 dB(A)
Octave data required
Air absorption

63	125	250	500	1,000	2,000	4,000	8,000
[db/km]	[db/km]	[db/km]	[db/km]	[db/km]	[db/km]	[db/km]	[db/km]
0.1	0.4	1.0	1.9	3.7	9.7	32.8	117.0

WTG: VESTAS V82 1650 82.0 !O!
Noise: Level 0 - - - 05-2008

Source	Source/Date	Creator	Edited
Manufacturer	05/31/2008	EMD	11/25/2008 11:45 AM

Verification Report: WTSE03007B2

Status	Hub height [m]	Wind speed [m/s]	LwA,ref [dB(A)]	Pure tones		Octave data 63 [dB]	125 [dB]	250 [dB]	500 [dB]	1000 [dB]	2000 [dB]	4000 [dB]	8000 [dB]
Interpolated	80.0	3.5	101.3	No	Generic data	80.8	87.8	91.2	93.8	93.6	90.7	85.9	76.4
Interpolated	80.0	4.5	101.5	No	Generic data	81.1	88.1	91.5	94.1	93.9	91.0	86.2	76.7
Interpolated	80.0	5.5	101.7	No	Generic data	81.3	88.3	91.7	94.3	94.1	91.2	86.4	76.9
Interpolated	80.0	6.5	102.0	No	Generic data	81.6	88.6	92.0	94.6	94.4	91.5	86.7	77.2
Interpolated	80.0	7.5	102.7	No	Generic data	82.3	89.3	92.7	95.3	95.1	92.2	87.4	77.9
ExtraPolated	80.0	8.5	103.7	No	Generic data	83.3	90.3	93.7	96.3	96.1	93.2	88.4	78.9
ExtraPolated	80.0	9.5	104.7	No	Generic data	84.3	91.3	94.7	97.3	97.1	94.2	89.4	79.9
ExtraPolated	80.0	10.5	105.7	No	Generic data	85.3	92.3	95.7	98.3	98.1	95.2	90.4	80.9
ExtraPolated	80.0	11.5	106.7	No	Generic data	86.3	93.3	96.7	99.3	99.1	96.2	91.4	81.9

NSA: Hospital Admin a-A
Predefined calculation standard:
Imission height(a.g.l.): Use standard value from calculation model

Ambient noise:

1.0 [m/s]	2.0 [m/s]	3.0 [m/s]	4.0 [m/s]	5.0 [m/s]	6.0 [m/s]	7.0 [m/s]	8.0 [m/s]	9.0 [m/s]	10.0 [m/s]	11.0 [m/s]	12.0 [m/s]
31.0 dB(A)	32.5 dB(A)	33.9 dB(A)	35.4 dB(A)	36.8 dB(A)	38.3 dB(A)	39.7 dB(A)	41.1 dB(A)	42.6 dB(A)	44.0 dB(A)	45.5 dB(A)	46.9 dB(A)

Margin or Allowed additional exposure: 10.0 dB(A)
Sound level always accepted: 0.0 dB(A)
Distance demand: 300.0 m

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DECIBEL - Assumptions for noise calculation

Calculation: GA: 0.5 with ambient speed range 3.5-12 Two Turbines at MWCC **Noise calculation model:** ISO 9613-2 General

NSA: Boulder Street a-B
Predefined calculation standard:
Imission height(a.g.l.): Use standard value from calculation model

Ambient noise:

Margin or Allowed additional exposure: 10.0 dB(A)
Sound level always accepted: 0.0 dB(A)
Distance demand: 300.0 m

NSA: MWCC building a-C
Predefined calculation standard:
Imission height(a.g.l.): Use standard value from calculation model

Ambient noise:

1.0 [m/s]	2.0 [m/s]	3.0 [m/s]	4.0 [m/s]	5.0 [m/s]	6.0 [m/s]	7.0 [m/s]	8.0 [m/s]	9.0 [m/s]	10.0 [m/s]	11.0 [m/s]	12.0 [m/s]
31.0 dB(A)	32.5 dB(A)	33.9 dB(A)	35.4 dB(A)	36.8 dB(A)	38.3 dB(A)	39.7 dB(A)	41.1 dB(A)	42.6 dB(A)	44.0 dB(A)	45.5 dB(A)	46.9 dB(A)

Margin or Allowed additional exposure: 10.0 dB(A)
Sound level always accepted: 0.0 dB(A)
Distance demand: 300.0 m

NSA: Hospital a-D
Predefined calculation standard:
Imission height(a.g.l.): Use standard value from calculation model

Ambient noise:

1.0 [m/s]	2.0 [m/s]	3.0 [m/s]	4.0 [m/s]	5.0 [m/s]	6.0 [m/s]	7.0 [m/s]	8.0 [m/s]	9.0 [m/s]	10.0 [m/s]	11.0 [m/s]	12.0 [m/s]
31.0 dB(A)	32.5 dB(A)	33.9 dB(A)	35.4 dB(A)	36.8 dB(A)	38.3 dB(A)	39.7 dB(A)	41.1 dB(A)	42.6 dB(A)	44.0 dB(A)	45.5 dB(A)	46.9 dB(A)

Margin or Allowed additional exposure: 10.0 dB(A)
Sound level always accepted: 0.0 dB(A)
Distance demand: 300.0 m

NSA: Courthouse a-E
Predefined calculation standard:
Imission height(a.g.l.): Use standard value from calculation model

Ambient noise:

1.0 [m/s]	2.0 [m/s]	3.0 [m/s]	4.0 [m/s]	5.0 [m/s]	6.0 [m/s]	7.0 [m/s]	8.0 [m/s]	9.0 [m/s]	10.0 [m/s]	11.0 [m/s]	12.0 [m/s]
31.0 dB(A)	32.5 dB(A)	33.9 dB(A)	35.4 dB(A)	36.8 dB(A)	38.3 dB(A)	39.7 dB(A)	41.1 dB(A)	42.6 dB(A)	44.0 dB(A)	45.5 dB(A)	46.9 dB(A)

Margin or Allowed additional exposure: 10.0 dB(A)
Sound level always accepted: 0.0 dB(A)
Distance demand: 300.0 m

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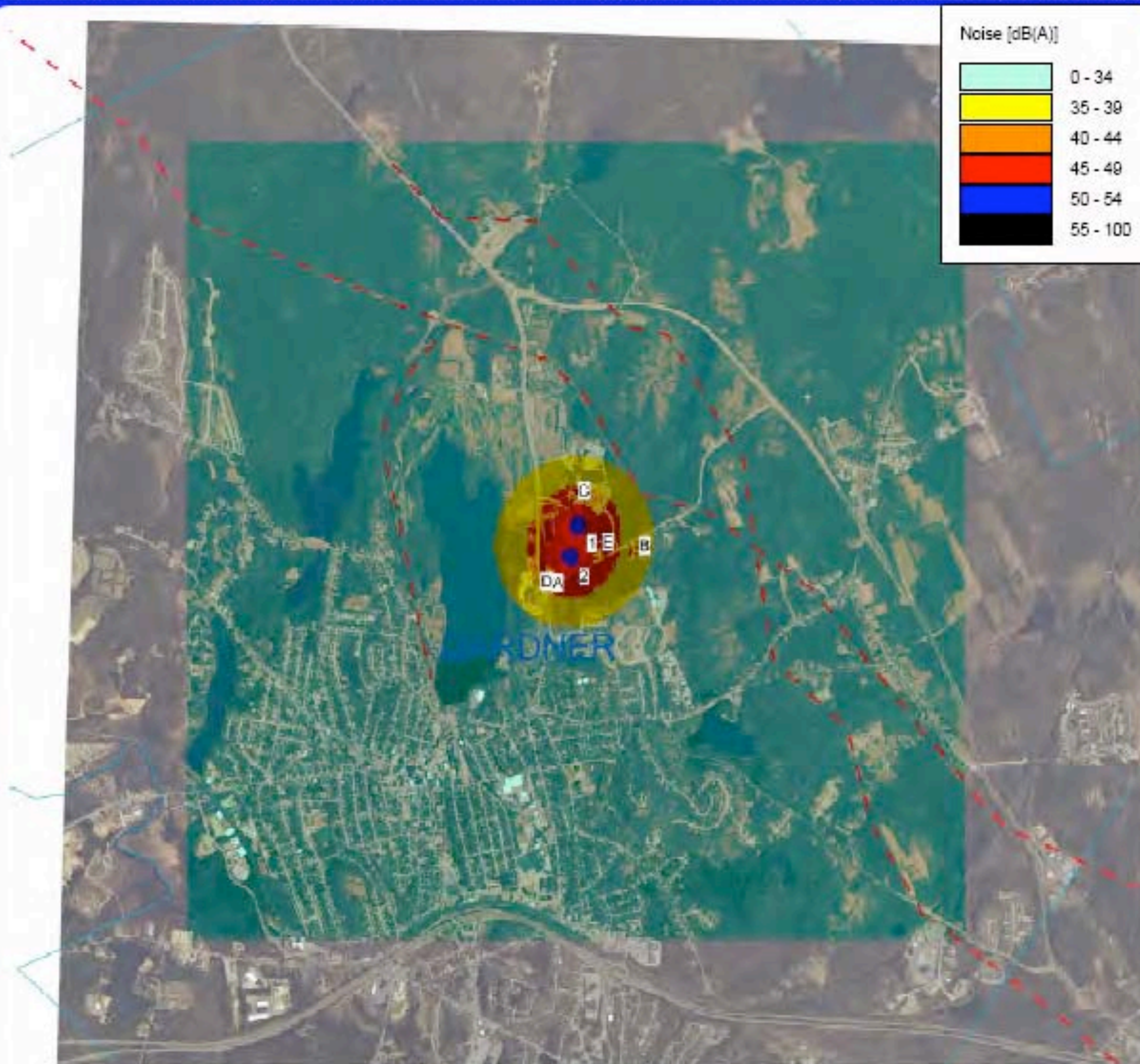
DECIBEL - ortho 600DPI

Calculation: GA: 0.5 with ambient speed range 3.5-12 Two Turbines at MWCC **File:** ORTHO Mt Wachusett Comm College WindPro set up.jpg



0 500 1000 1500 2000 m

Map: , Print scale 1:40,000, Map center UTM NAD 83 Zone: 19 East: 255,166 North: 4,719,557
Noise calculation model: ISO 9613-2 General. Wind speed: 8.0 m/s

New WTG — Noise sensitive area

Height above sea level from active line object

35.0 dB(A) — 40.0 dB(A) — 45.0 dB(A) — 50.0 dB(A) — 55.0 dB(A)

WindPRO is developed by EMD International A/S, Niels Jernesvej 10, DK-9220 Aalborg Ø, Tlf. +45 96 35 44 44, Fax +45 96 35 44 46, e-mail: windpro@emd.dk

Appendix 8 Shadow Flicker Analysis

University of Massachusetts
Wind Energy Center

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Mount Wachusett Community College: Shadow Flicker Analysis

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May 19, 2009

I. Executive Summary

The University of Massachusetts Wind Energy Center performed a shadow flicker analysis for the proposed two turbine wind power installation at the Mount Wachusett Community College in Gardner, MA. A shadow flicker analysis uses geometry and site-specific data inputs to determine an estimated number of hours per year that a flickering shadow can be cast on a given receptor site or viewing area. The actual annual duration of shadow flicker will often be shorter than the approximations given in this report due to the conservative nature of assumptions employed in calculation.

A potential flicker impact map was prepared by UMass and provided to the project team for selection of appropriate impact receptor sites. This and other maps of the local area were reviewed, and the area was also visited to determine receptor sites for the study. Additionally, once the initial flicker analysis was made, one additional receptor site was added after seeing the overlaid maps. The areas around the selected sites have the highest potential for flicker impact from the proposed wind project.

The flicker impacts at seven locations nearby the proposed turbine sites have been estimated. Analyses were carried out for two Vestas V82 1.65 MW turbines. The duration and season of expected impact varies according to receptor location. Shadow flicker maps for the two turbines are provided for the surrounding area. Shadow calendars, which illustrate the season and time and of day flicker can be expected, are provided in the Appendix.

Two shadow receptor locations could experience more than 30 hours of flicker per year.

The Courthouse would potentially experience approximately 53 hours per year. There are trees located between the turbines and the Courthouse, which is likely to reduce the impact of flicker at this location. Potential flicker impact at the Courthouse would nearly always be after 3:00 pm.

The Boulder Street neighborhood is surrounded by trees, which are likely to reduce the number of hours of flicker at this location from that predicted in this report, especially since flicker would occur during later hours of the day when the sun angle is low. At this location, flicker from the north turbine is possible from May through July between about 6:45pm and 8 pm. Flicker from the south turbine is possible in February through early April and again between September and early November from about 5 pm to 7 pm.

The MWCC campus building (receptor E) to the north of the turbines is expected to receive approximately 25.5 hours of flicker per year. Simulations indicate that the Golf Course (receptor D) located to the west of the turbines will experience approximately 18.5 of flicker per year. The Gardner Middle School (receptor G) is expected to receive approximately 17.5 hours of flicker per year. There are also several residences located to the east of receptor C that are expected to have between 0.015-25 hours of shadow flicker per year. The hospital (receptor B) and the residences near the intersection of Eaton and Kelton Street (receptor F) are not expected to experience any flicker.

The results of this analysis are intentionally conservative. The actual number of shadow hours will likely be significantly less than estimates presented here. Tree cover is not accounted for in the measured predictions of hours of flicker impact. Areas of most significant concern are protected by tree cover.

Where shadow flicker impact is deemed unacceptable, planting new trees and/or shrubbery could be considered as a possible mitigation strategy. Shutting down the turbines during times when flicker is an issue would also mitigate the impact of shadow flicker.

The Town of Gardner is labeled with a red balloon on the map below.

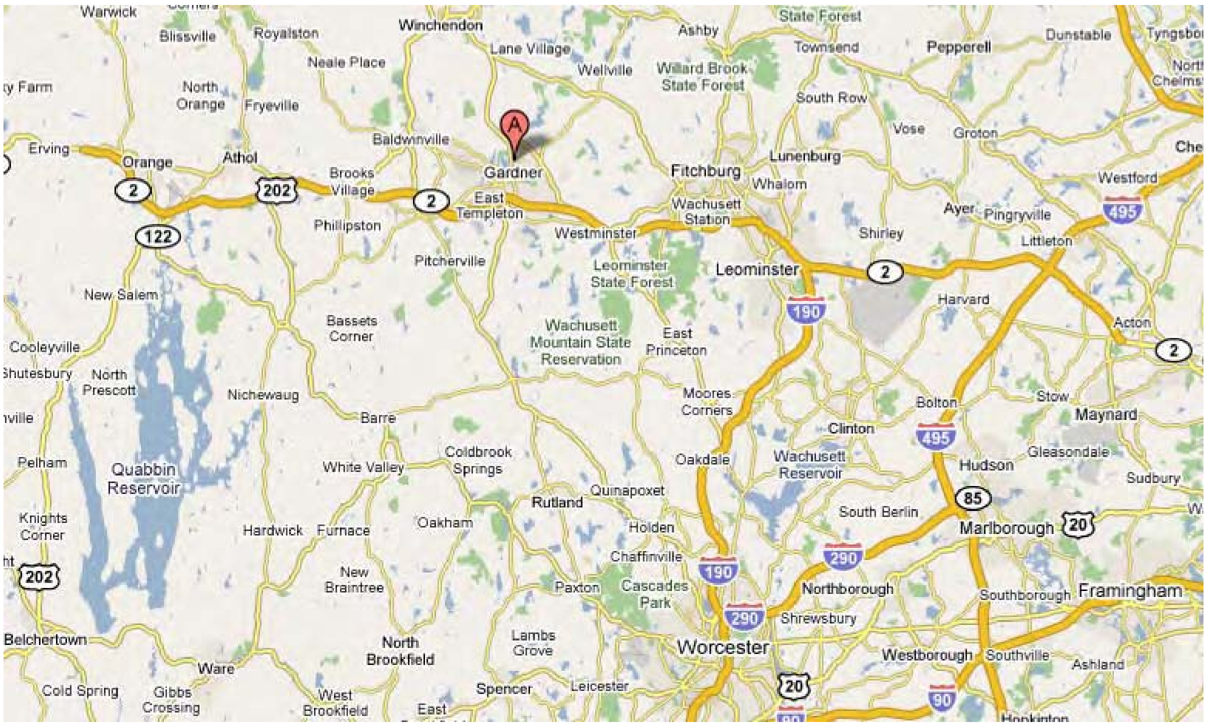

Figure 1: Location of proposed wind turbine installation (map courtesy of GoogleMaps).

For more background information

This report assumes some familiarity with wind power technology. For more information, please refer to these websites:

- RERL's Community Wind Fact Sheets, www.ceere.org/rerl/about_wind/
- American Wind Energy Association, www.awea.org
- Danish Wind Industry Association, www.windpower.org

Figure 2 is an orthophotograph of the area surrounding the proposed wind turbine installation. The locations of the proposed wind turbines are each denoted by black dots. The turbines will be located at 42°35'26.4"N, 71°59'1.0"W and 42°35'18.9"N, 71°59'3.1"W. Seven "shadow receptors" are marked on the map by green circles with the letters A – G. These shadow receptors represent the viewing areas at selected locations within the viewshed of the proposed turbine location. The locations of the shadow receptors are given in Table 3. Table 4 provides estimated shadow flicker durations for the seven locations.

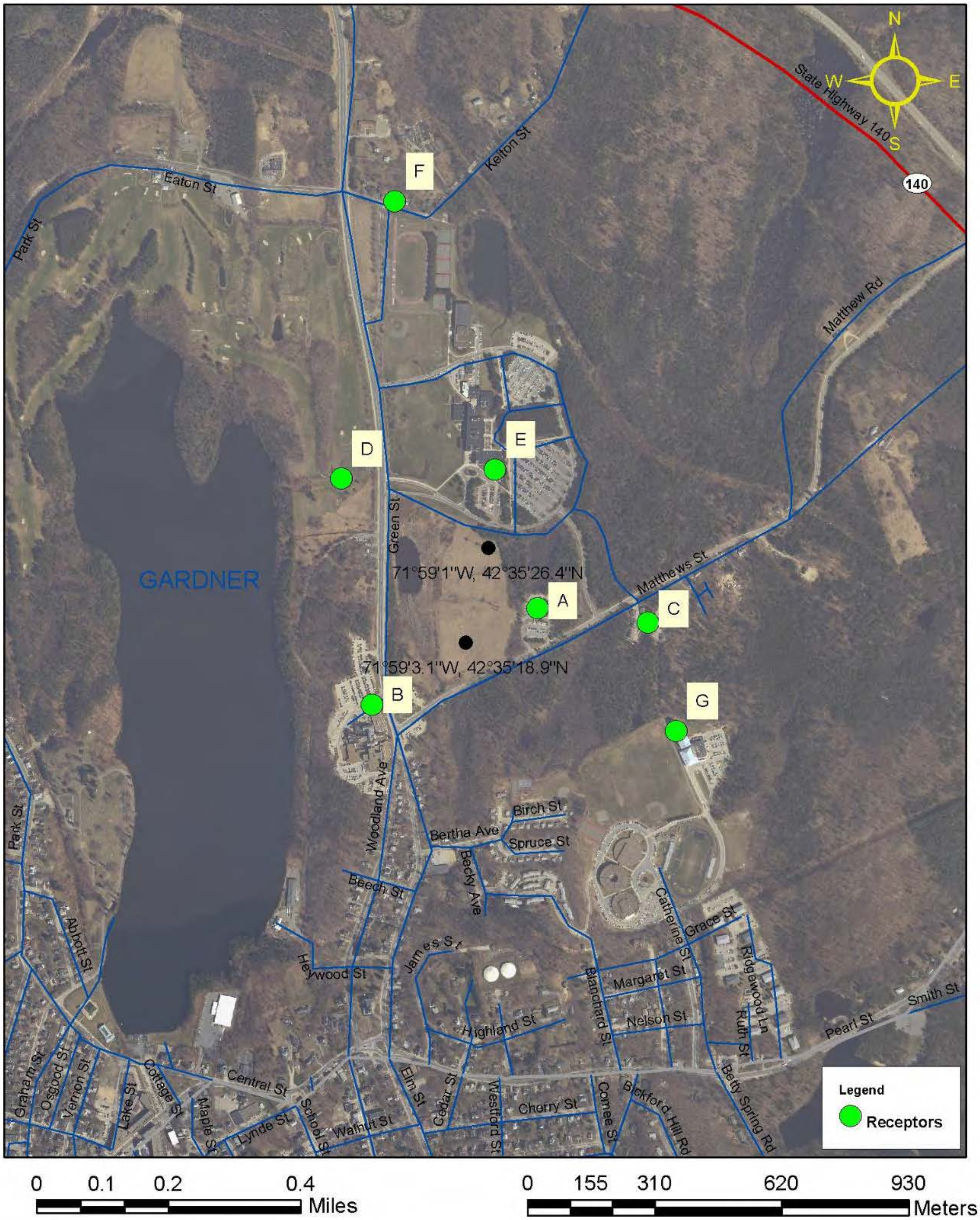

Figure 2: Orthophotograph of proposed wind turbine installation at MWCC in Gardner. The green circles indicate the receptors used in the analysis. *Orthophotograph courtesy of MassGIS.*

II. An Introduction to Shadow Flicker

About shadow flicker in general

Shadow flicker is a periodic obstruction of light. It is the term used to describe what happens when rotating turbine blades come between the viewer and the sun, causing a moving shadow. An example of shadow flicker with which many people are familiar with occurs while driving past regularly spaced trees late in the day with the sun behind the trees[1].

Modern utility-scale wind turbines (600 – 3,000 kW) are typically three-bladed machines that rotate at rates of 26 – 12 revolutions per minute (RPM), respectively. If, for example, sunlight passes through the rotor of a three-bladed wind turbine rotating at 20 RPM, then the light will flicker at a rate of 3x20=60 shadows per minute, i.e. 1 per second, or 1 Hertz (Hz). Such low frequencies are harmless in terms of health and safety[2], but under certain circumstances can be annoying, especially when trying to read or watch television.

About quantifying flicker

Shadow flicker is usually quantified by the number of hours per year during which a location would be exposed to flickering from nearby wind turbines. While this is primarily a matter of geometry, other factors must be considered; even at times when the sun is lined up geometrically with the turbine and the receptor, various factors may prevent flicker. For instance, it is not possible for shadow flicker to occur when the sun is not visible, such as on cloudy or foggy days, or if a wind turbine is not rotating. Obstacles located between a wind turbine and the viewer, such as trees, hills, and buildings, will reduce or eliminate the duration and/or intensity of shadow flicker.

This report considers flicker at distances of up to 2 km from the proposed wind site. However, at distances greater than approximately one kilometer (0.6 miles), light is sufficiently dispersed by particles in the air that the blades no longer produce distinct shadows. Consequently the rotor of a wind turbine will not cause shadow flicker, and beyond this distance shadow flicker is normally negligible[3].

Flicker is only considered an issue during times when people are home and awake, and a wind turbine is in view. If a wind turbine is not in view during the hours of estimated shadow flicker, then the flicker will go unnoticed. While there is no U.S. standard regulating the impact of shadow flicker, a tolerance of 30 hours of actual shadow flicker[4] has been established by the German judiciary. Included in these 30 hours are only times when the property is in use and people are awake.

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[1] For instance, driving 20 mph past regularly spaced trees 15 feet apart produces flicker at 2 Hz.

[2] Shedding Light on Photosensitivity, www.epilepsy.com/articles/ar_1141663451.html. Note that while flickering light in the ranges of about 5–30 Hz can cause seizures in sensitive individuals, rates of less than 2 Hz such as those associated with wind turbines do not.

[3] Shadow Variations from Wind Turbines, www.windpower.org/en/tour/env/shadow/shadow2.htm

[4] Shadow Casting from Wind Turbines, www.windpower.org/en/tour/env/shadow/index.htm

How shadow flicker is estimated

The estimated impact of shadow flicker caused by a wind turbine is dependent on several factors, including the:

- Location of the sun in the sky[5]
- Times and duration of turbine operation
- Direction of the wind (determines the direction the rotor will face)
- Likelihood of sunshine
- Terrain and landscape of an area
- Obstacles, such as trees and buildings, in the line of sight, and
- Size and location of a viewing area, such as a window or patio.

The UMass Wind Energy Center employs WindPRO software (version 2.6.1.252) for the calculation of "real expected values" of shadow flicker effects in terms of hours per year during which a location would be exposed to flickering from nearby wind turbines. WindPRO simulates the path of the sun throughout a whole year; it uses the following inputs:

- Locations of wind turbines
- Wind turbine rotor diameter and hub height
- Wind profiles to determine wind turbine operating hours and yaw directions
- Probabilities of sunshine by month
- Viewing areas & orientation of receptors (Table 3)
- Geography: elevations, latitude & longitude

The software produces the following outputs:

- Duration of flicker for each receptor
- A calendar showing the time and date of all the hours of flicker for each receptor
- A map showing the extent of flicker impacts in the region.

The following assumptions were employed in this calculation with the goal of providing the maximum duration and intensity of shadow flicker possible at selected surrounding locations.

- Turbines are always rotating
- Beyond terrain, a clear line of site exists between the turbine and the receptor (no obstructions such as trees, buildings, etc. taken into consideration)
- Shadow receptors (windows) are oriented orthogonal to (i.e. directly at) the turbine

[5] German guidelines define flicker as occurring when: (a) the angle of the sun is at least 3 degrees over the horizon, and (b) The rotating blade of the WTG covers at least 20% of the sun.

III. Shadow Flicker Analysis

This section presents the input data and assumptions that were used for the analysis of flicker in the case of the proposed MWCC wind turbine. This shadow flicker analysis assumes full exposure of the viewing areas; that is, obstacles such as trees or buildings in the line of sight (other than the shape of the geography) are not considered. Shadow flicker was calculated only when more than 20% of the sun was covered by the wind turbine rotor.

In the absence of window size and orientation data for the houses, green-house mode was used for each shadow receptor. This mode assumes that the receptor is open to flicker from all sides giving a worst case scenario. This mode will over-estimate the duration of expected flicker.

Table 1 lists the details related to Vestas V-82 machines with 80 meter hub heights.

Table 1: Proposed Turbine Specifications

Turbine	Vestas V-82
Rated Power	1650 kW
Rotor Speed	14.4 rpm
Hub Height	80 meters
Rotor Diameter	82 meters

All modern utility-scale wind turbines are yaw-controlled; that is, the turbine rotor plane orients itself in the direction of the oncoming wind. As a result, sometimes the turbine's rotor plane will be turned at an angle such that shadow flicker effect at a particular location is minimized. Wind data collected at the site were used to approximate the number of hours a turbine at the proposed site would be facing a particular direction.

The probabilities of sunshine for each month were assumed to follow data provided by City-Data.Com for the town of Gardner, MA.[6]

Table 2: Monthly Sunshine Probabilities for Gardner Massachusetts

MONTH	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Probability	48%	51%	52%	51%	52%	56%	59%	61%	59%	57%	51%	48%

[6] http://www.city-data.com/city/Gardner-Massachusetts.html

Table 3 - Latitude and longitude of shadow receptors (WGS84 datum)

Shadow Receptor	Latitude (N)	Longitude (W)	Distance to turbine 1, turbine 2 (meters)	Location/Description
A	42.5894°	-71.9821°	184, 200	Courthouse
B	42.5871°	-71.9869°	478, 285	Hospital
C	42.5892°	-71.9788°	387, 404	Boulder St
D	42.5921°	-71.9880°	398, 496	Golf Course
E	42.5924°	-71.9835°	216, 434	MWCC Building
F	42.5982°	-71.9868°	883, 1080	Eaton St
G	42.5868°	-71.9778°	626, 554	Gardner Middle School

IV. Results

The table (Table 4) below summarizes flicker duration at each of the seven sites for the two turbines under consideration. The time of the day and year when shadow flicker is possible has also been calculated, and these results are presented in Appendix A.

Once again, the assumptions employed in calculation were chosen in order to arrive at conservative estimates (over approximation) of shadow flicker duration at the sites. Actual duration is likely to be shorter. These estimates do not take into account obstructions that exist at the sites.

Table 4: Estimated values of hours of shadow flicker per year from the two turbines at each shadow receptor, disregarding obstacles.

Two Turbines				
Shadow Receptor	**Shadow, hrs/year (hours : minutes) worst case**	**Shadow days/year**	**Max Shadow hrs/day (hours : minutes)**	**Expected Shadow hrs/year (hours : minutes)**
A	135:21	119	1:29	53:07
B	0:00	0	0:00	0:00
C	88:36	135	0:52	33:10
D	58:14	107	0:47	18:47
E	90:32	76	1:26	25:23
F	0:00	0	0:00	0:00
G	47:43	96	0:37	17:26

Receptor A, the Courthouse, is located near the base of the turbine, and so shadow flicker will occur most often at this location. Shadow flicker generally decreases as the distance between a receptor and the turbines increases.

Another important result of the shadow flicker analysis is a shadow flicker map, shown in Figure 3 on the following page, for the two turbines under consideration. This map illustrates the extent of the zone of impact surrounding the proposed turbine location. The colored isolines represent locations with equal numbers of shadow flicker hours per year. The area inside an isoline is expected to experience as much or more shadow flicker than the isoline encapsulating it. There are a number of residences to the east of the turbines which are outside the orange isoline and are expected to experience less than 25 hours of shadow flicker per year.

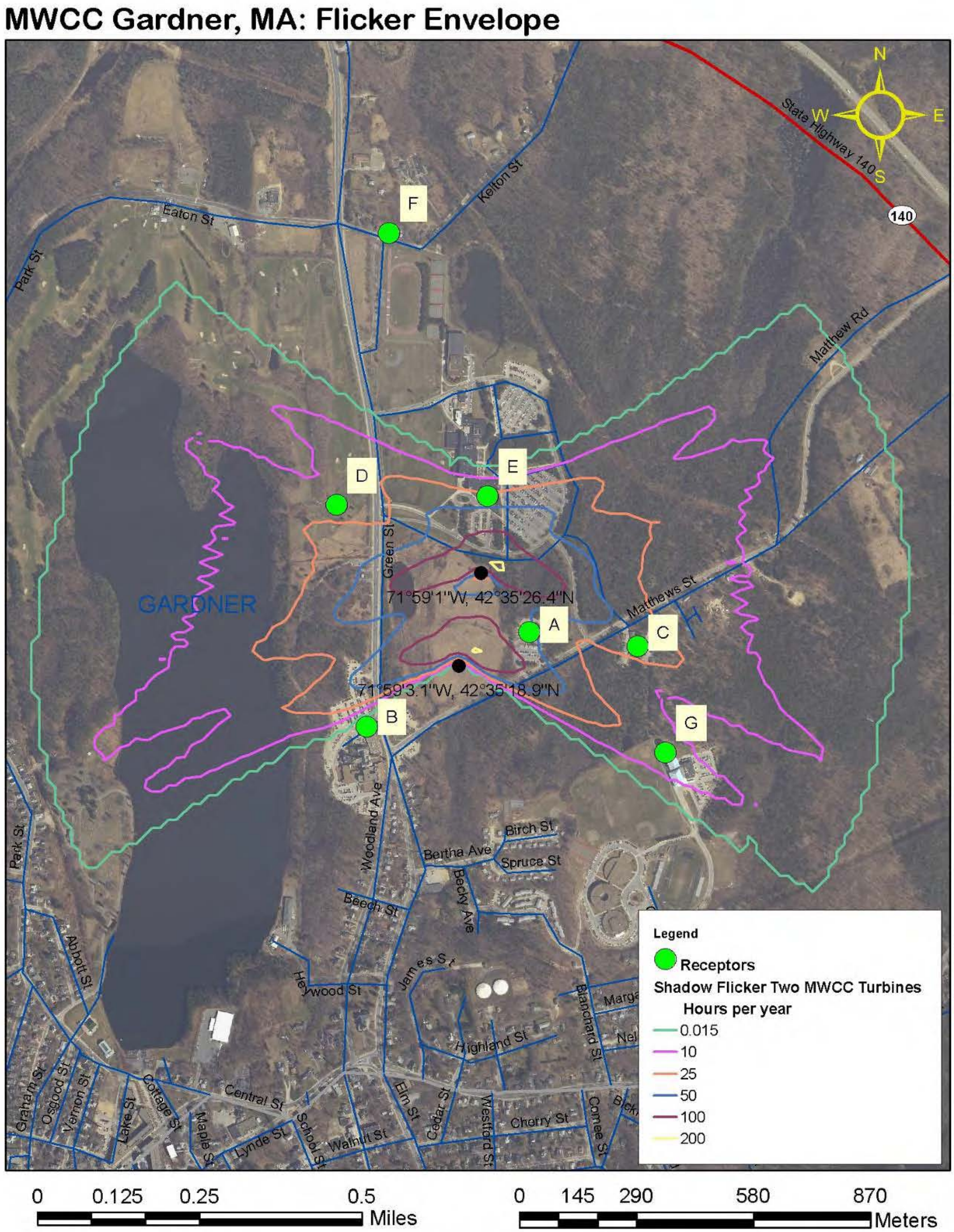


Figure 3: This figure shows an orthophotograph of MWCC turbine site with isolines showing estimated shadow flicker in hours/year. Regions inside the purple line feature expected values for shadow flicker duration of at least 10 hour per year. Receptor A (Courthouse) shown on the map above, features an expected value of 53 hours and 7 minutes (value found in **Table 4**).

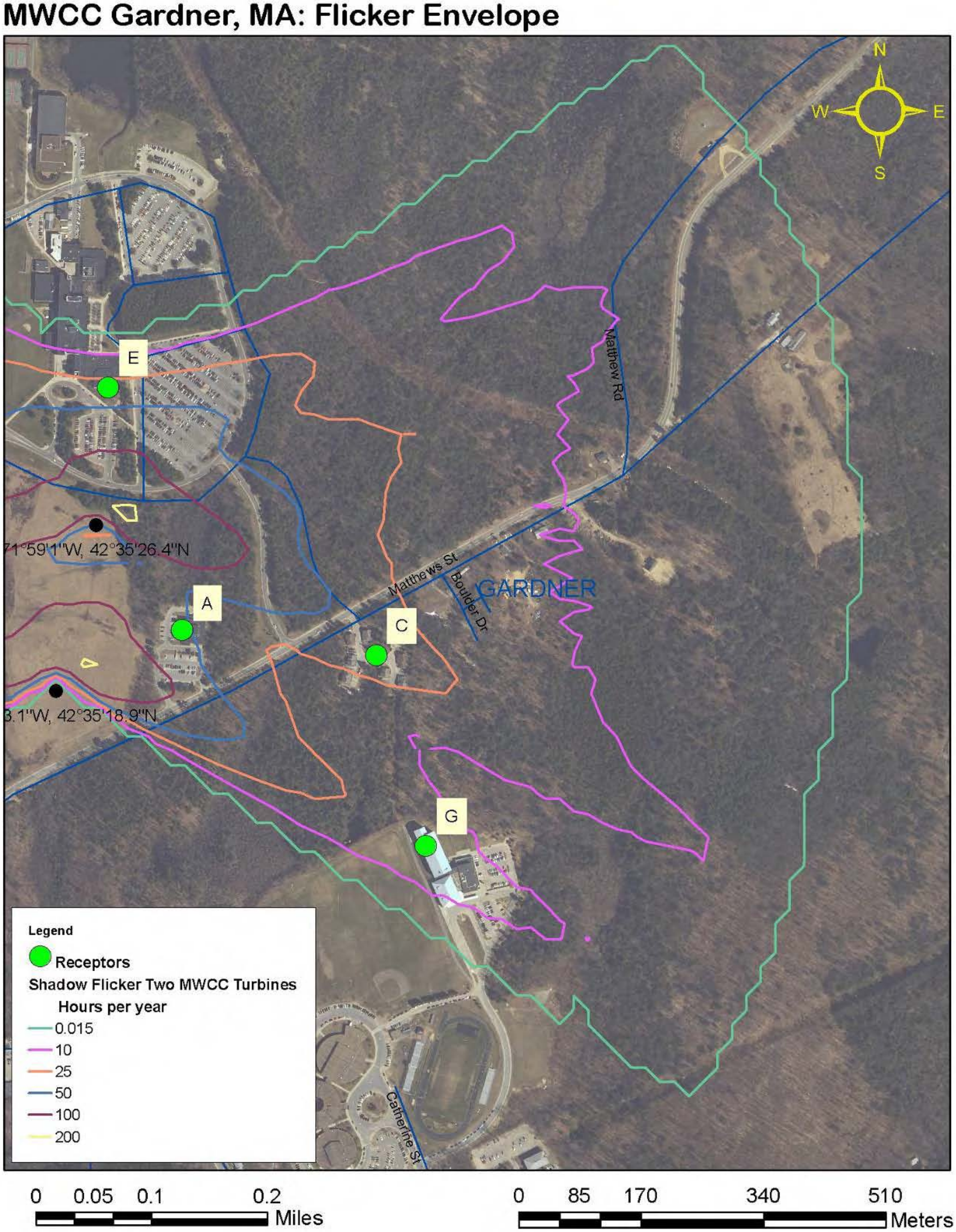


Figure 4: This figure shows the shadow flicker isolines to the east of the turbines in hours/year. Regions inside the purple line feature expected values for shadow flicker duration of at least 10 hour per year. There are several residences in the area that are expected to have between 0.015-25 hours of shadow flicker.

IV. Conclusions

The number hours of shadow flicker per year have been estimated through computer simulations for seven viewing areas (shadow receptors) nearby the proposed turbine site in Gardner, MA. Shadow flicker maps for the area surrounding the proposed site were generated, and estimated flicker durations at each receptor site have been tabulated. The results of this analysis are conservative; the actual number of shadow hours will likely be less than estimates presented here.

Two shadow receptor locations (A and C) could experience more than 30 hours of flicker per year.

The Courthouse (receptor A) would experience the greatest number of hours of flicker (53 hours, 7 minutes). This flicker would occur as a result of the southern turbine's location. There are trees located between the turbine and the Courthouse which are likely to reduce flicker impact at the Courthouse. Potential flicker impact would nearly always be after 3:00 pm.

The Boulder Street neighborhood (receptor C) is surrounded by trees that are likely to lower the number of hours of flicker at this location, especially since late in the day the sun angle is low. At this location, flicker from the north turbine is potential from May through July between about 6:45pm and 8 pm. In general, wind speeds are lower during the summer than during other seasons of the year, and so actual flicker durations may be further reduced during this time as a result of the blades not turning. Flicker from the south turbine is possible in February through early April and again between September and early November from about 5 pm to 7 pm.

Several other locations are expected to see some flicker impacts. The MWCC campus building (receptor E) to the north of the turbines is expected to receive approximately 25.5 hours of flicker per year. The results of the analysis indicate that the Golf Course (receptor D) located to the west of the turbines will experience approximately 18.5 of flicker per year. The Gardner Middle School (receptor G) is expected to receive approximately 17.5 hours of flicker per year. There are also several residences located to the east of receptor C that are expected to have between 0.015-25 hours of shadow flicker per year.

The hospital (receptor B) and the residences near the intersection of Eaton and Kelton Street (receptor F) are not expected to experience any flicker.

Where shadow flicker impact is deemed unacceptable, planting new trees and/or shrubbery could be considered as a possible mitigation strategy. Shutting down the turbines during times when flicker is an issue would also mitigate the impact of shadow flicker.

Appendix A: Shadow Receptor Details and Graphical Results

Shadow receptor calendars for the two turbines have been generated and are presented in figure 5 below. These calendars show the impacts of each turbine. Figures 6-8 show the flicker calendar for each receptor location (A–G). These figures illustrate the month and time of day during which flicker can be expected to occur. The flicker impacts are color-coded according to the receptor location. The calendar also indicates which turbine is causing the flicker. It is important to understand that multiple colors can correspond to the flicker at one particular location.

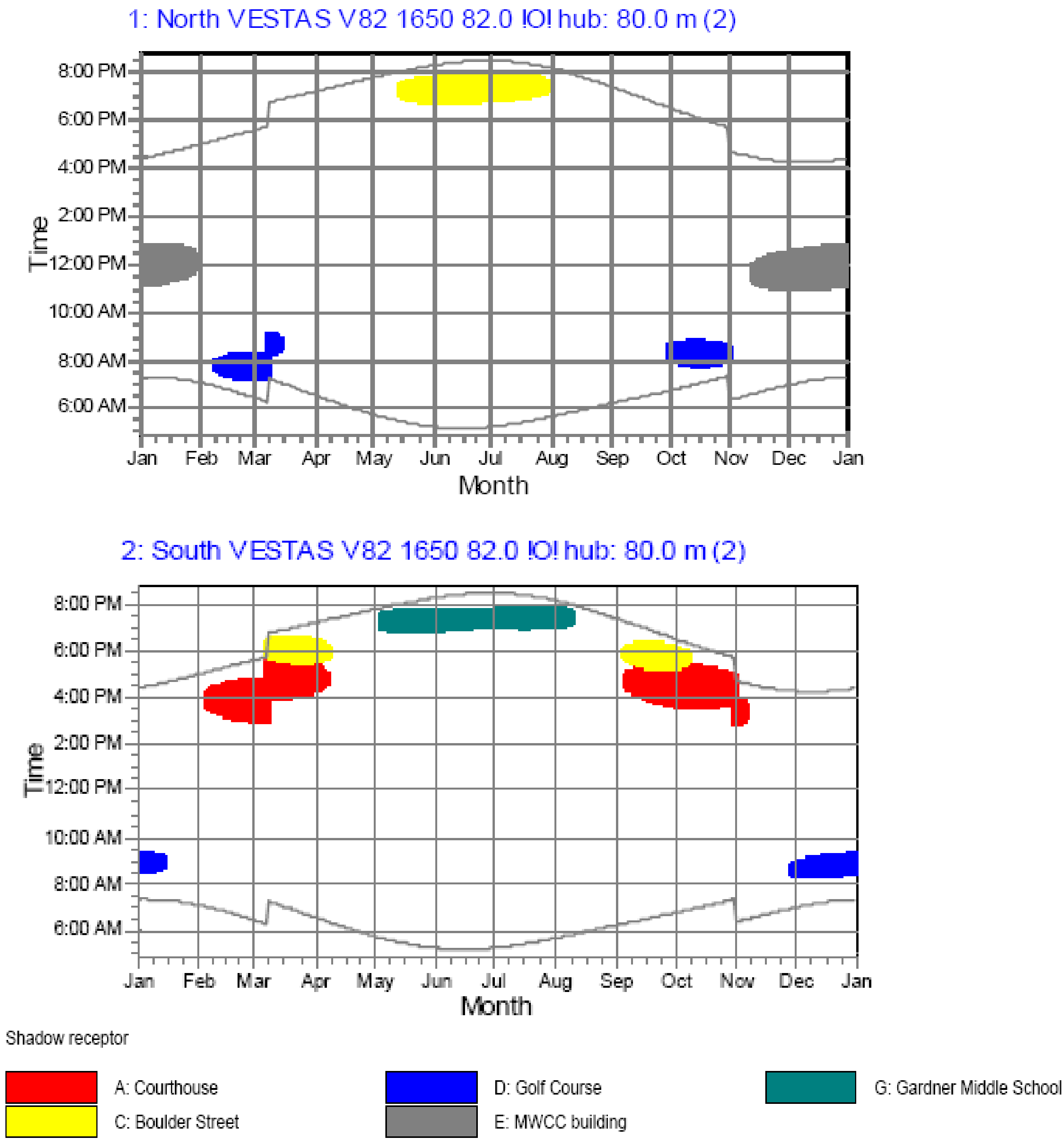


Figure 5: This figure shows the Shadow Receptor Calendar for the each of the turbines. The top graph No.1 is the turbine to the north and the bottom graph is No. 2 the turbine located to the south. The turbine No. 1 does not cause any Shadow flicker on the Courthouse or on the Gardner Middle School. The turbine No.2 does not cause any Shadow Flicker on the MWCC Building.

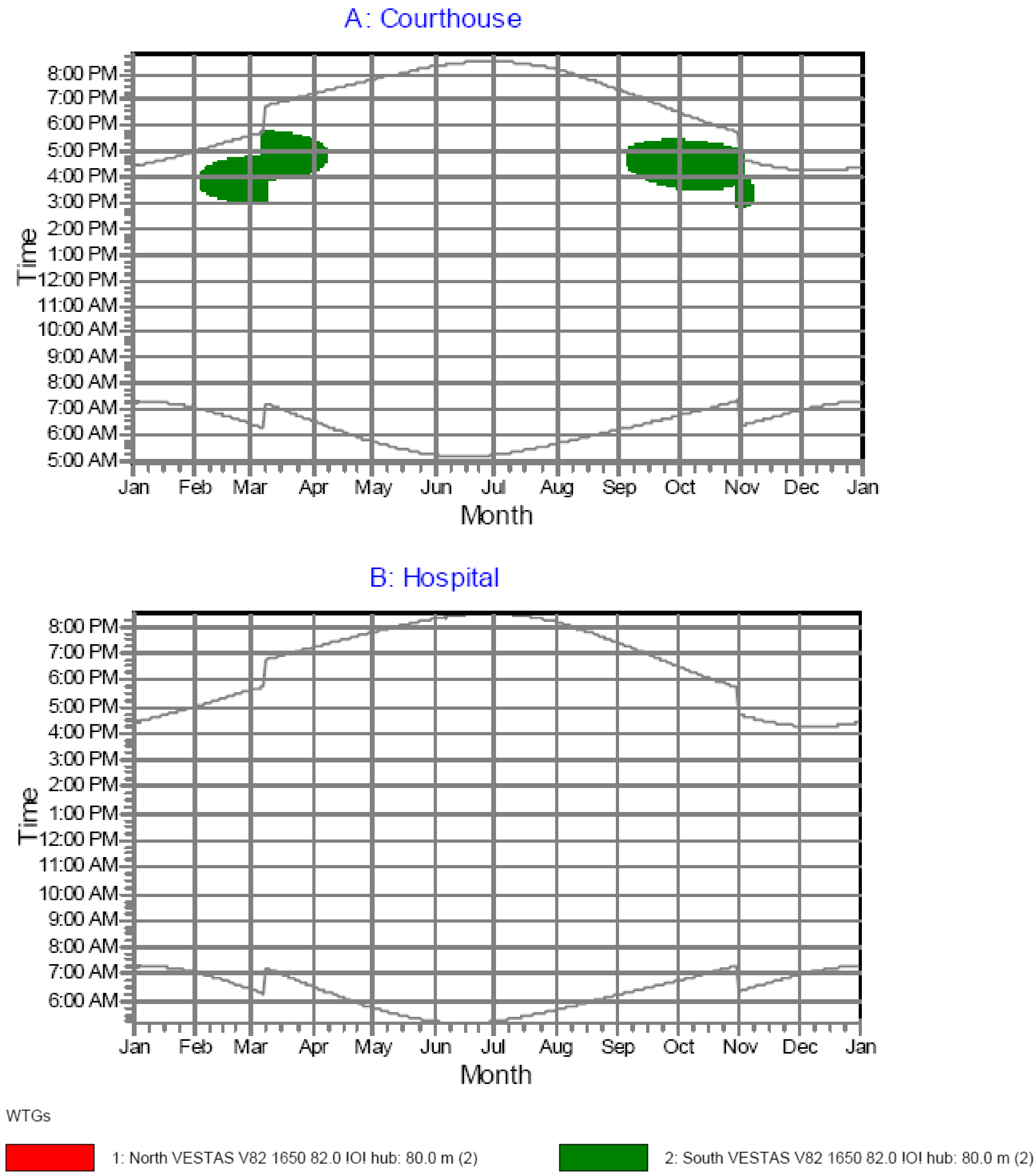


Figure 6: This figure shows the Shadow Receptor Calendar for the each Receptor A: the Courthouse, and Receptor B: the Hospital. The Courthouse is expected to experience Shadow Flicker from turbine No.2 in the afternoon hours during the spring and fall. The Hospital is not expected to experience Shadow Flicker from either turbine.

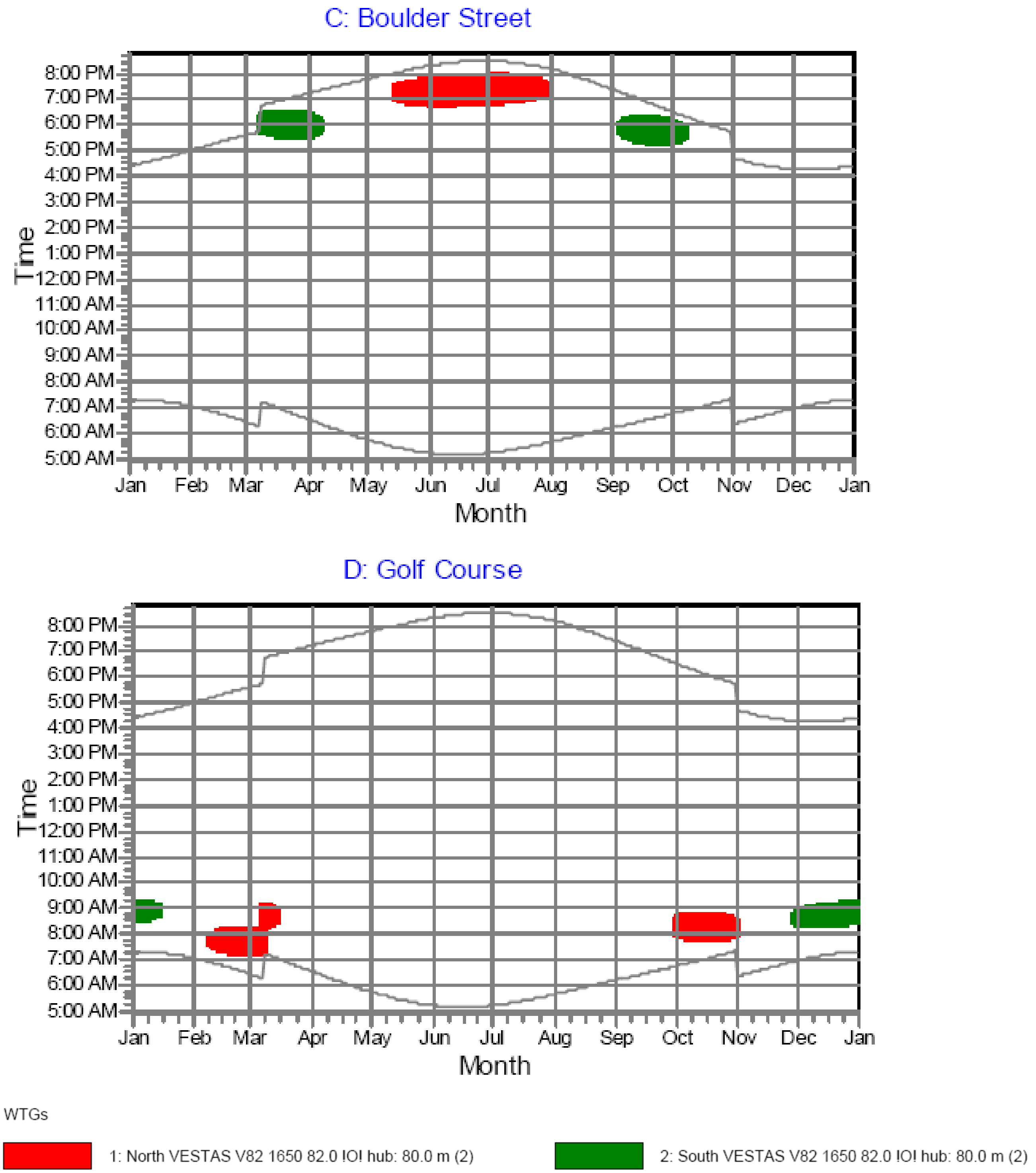
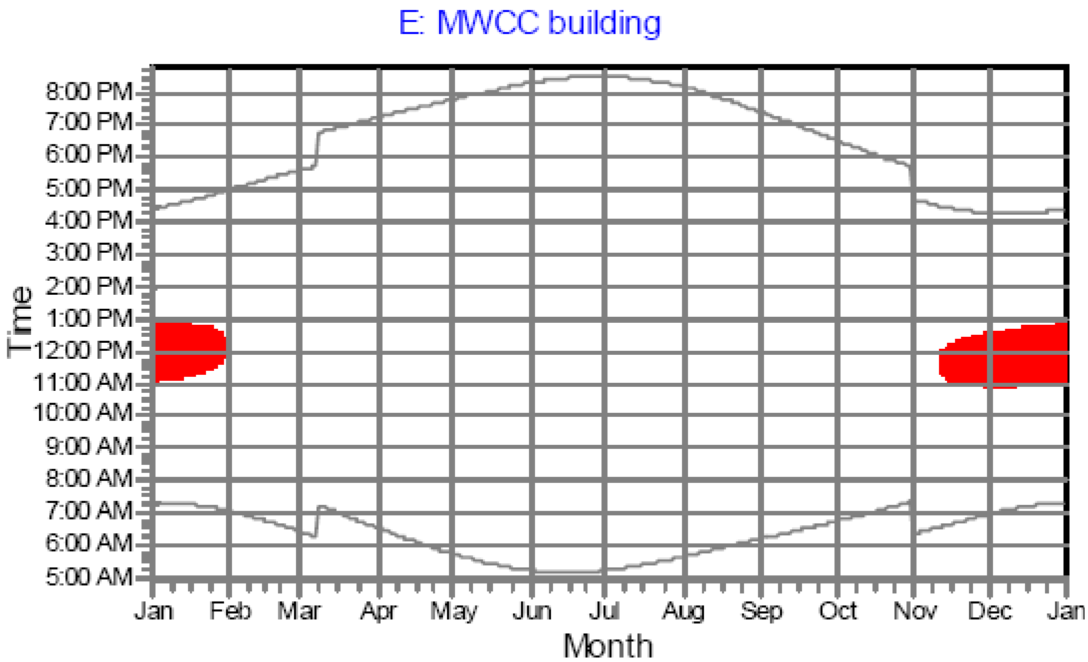


Figure 7: This figure shows the Shadow Receptor Calendar for the each Receptor C: the Boulder Street, and Receptor C: the Golf Course. Boulder Street is expected to experience Shadow Flicker during the late afternoon hours during the spring and fall and the early evening hours during the summer. The Golf Course is expected to have Shadow Flicker during the morning hours of the spring, fall and winter months.



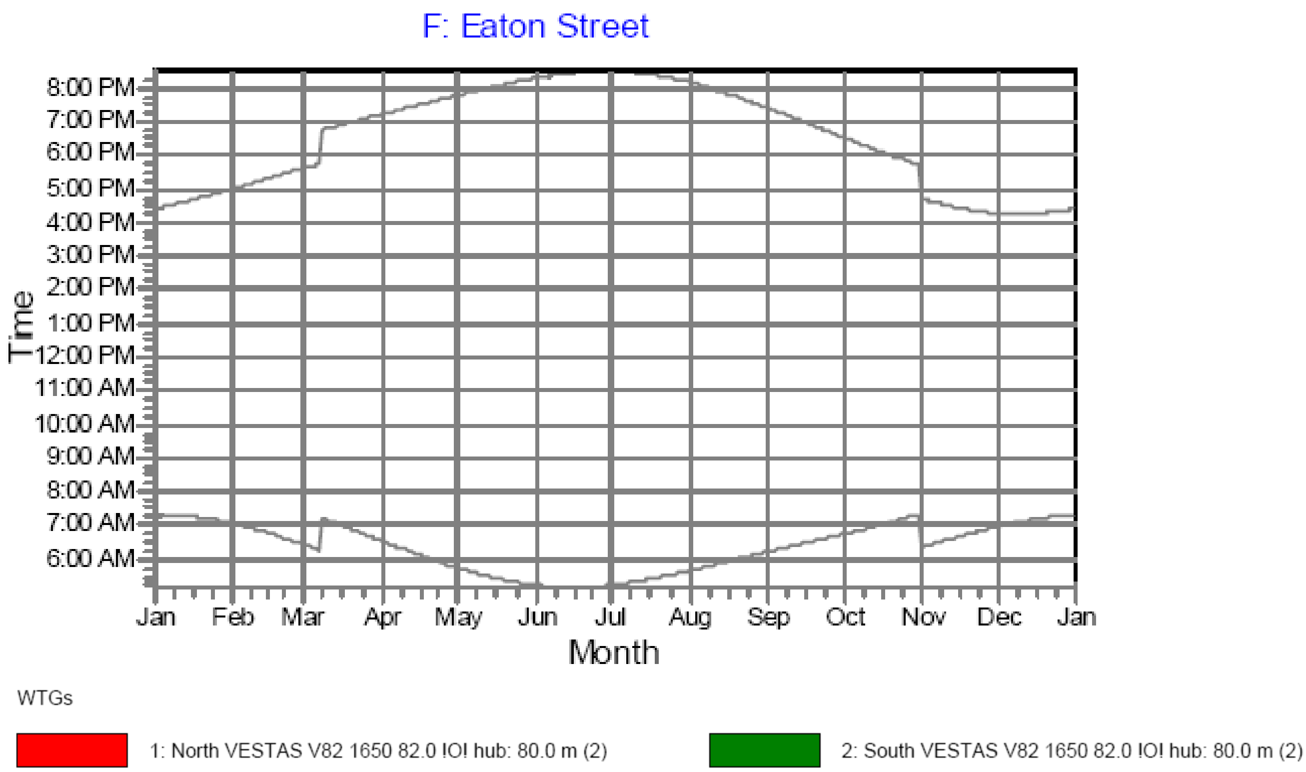


Figure 8: This figure shows the Shadow Receptor Calendar for the each Receptor E: MWCC Building, and Receptor F: Eaton Street. The MWCC building is expected to experience shadow flicker from 11am to 2 pm during the winter months. Receptor F: Eaton Street is not expected to experience Shadow Flicker from either turbine.

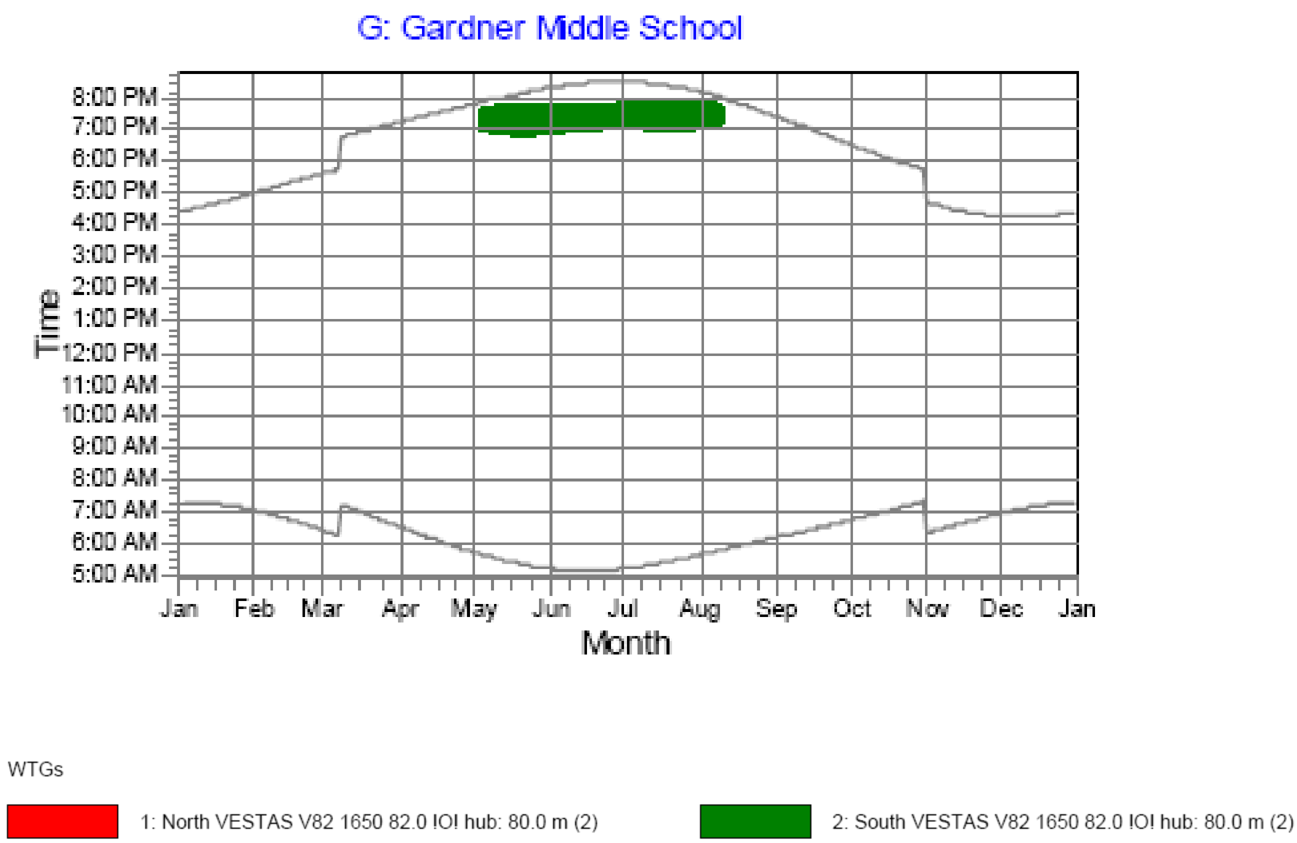


Figure 9: This figure shows the Shadow Receptor Calendar for the each Receptor G: Gardner Middle School. The Gardner Middle School is expected to experience shadow flicker from 6:30 pm to 8 pm during the summer months.

Appendix B: WindPRO Calculation Results

WindPRO version 2.6.1.252 Jan 2009

Project:
MWCC

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Licensed user:
Renewable Energy Research Lab, University of Massachusetts at Amherst
160 Governors Drive Amherst
MA 01003 USA
413 545 3914

Calculated:
05/19/2009 11:24 AM/2.6.1.252

SHADOW - Main Result

Calculation: Gardner Middle School added MWCC Two turbines with sun percentages

Assumptions for shadow calculations

Maximum distance for influence
Calculate only when more than 20 % of sun is covered by the blade
Please look in WTG table

Minimum sun height over horizon for influence	3 °	
Day step for calculation	1	days
Time step for calculation	1	minutes

Sun shine probabilities (part of time from sun rise to sun set with sun shine)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.48	0.51	0.52	0.51	0.52	0.56	0.59	0.61	0.59	0.57	0.51	0.48

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW
390	243	360	460	395	236	131	124	265	665	989	765

W	WNW	NW	NNW	Sum
1,060	1,229	910	540	8,760

To avoid flicker from WTGs not visible a ZVI calculation is performed before the flicker calculation. The ZVI calculation is based on the following assumptions
Height contours used: Height Contours: MWCC_elev.WPO (2)
Obstacles used in calculation
Eye height: 1.5 m
Grid resolution: 10 m

Scale 1:20,000
New WTG   Shadow receptor

WTGs

	UTM NAD83 Zone: 19 East	North	Z	Row data/Description	WTG type Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Shadow data Calculation distance	RPM
UTM NAD83 Zone: 19			[m]					[kW]	[m]	[m]	[m]	[RPM]
1	255,193	4,719,664	356.1	North VESTAS V82 1650 82...	Yes	VESTAS	V82-1,650	1,650	82.0	80.0	1,046	14.4
2	255,140	4,719,450	352.5	South VESTAS V82 1650 8...	Yes	VESTAS	V82-1,650	1,650	82.0	80.0	1,046	14.4

Shadow receptor-Input

No.	Name	UTM NAD83 Zone: 19 East	North	Z	Width	Height	Height a.g.l.	Degrees from south cw	Slope of window	Direction mode
				[m]	[m]	[m]	[m]	[°]	[°]	
A	Courthouse	255,322	4,719,531	360.6	1.0	1.0	1.0	-180.0	90.0	"Green house mode"
B	Hospital	254,919	4,719,273	360.0	1.0	1.0	1.0	-180.0	90.0	"Green house mode"
C	Boulder Street	255,541	4,719,495	358.7	1.0	1.0	1.0	-180.0	90.0	"Green house mode"
D	Golf Course	254,837	4,719,842	344.8	1.0	1.0	1.0	-180.0	90.0	"Green house mode"
E	MWCC building	255,207	4,719,879	354.8	1.0	1.0	1.0	-180.0	90.0	"Green house mode"
F	Eaton Street	254,954	4,720,514	357.7	1.0	1.0	1.0	-180.0	90.0	"Green house mode"
G	Gardner Middle School	255,651	4,719,237	357.0	1.0	1.0	1.0	-180.0	90.0	"Green house mode"

Calculation Results

Shadow receptor

No.	Name	Shadow, worst case Shadow hours per year [h/year]	Shadow days per year [days/year]	Max shadow hours per day [h/day]	Shadow, expected values Shadow hours per year [h/year]
A	Courthouse	135:21	119	1:29	53:07
B	Hospital	0:00	0	0:00	0:00

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Project:
MWCC

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05/19/2009 1:57 PM / 2

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Renewable Energy Research Lab, University of Massachusetts at Amherst
160 Governors Drive Amherst
MA 01003 USA
413 545 3914

Calculated:
05/19/2009 11:24 AM/2.6.1.252

SHADOW - Main Result

Calculation: Gardner Middle School added MWCC Two turbines with sun percentages

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No.	Name	Shadow, worst case Shadow hours per year [h/year]	Shadow days per year [days/year]	Max shadow hours per day [h/day]	Shadow, expected values Shadow hours per year [h/year]
C	Boulder Street	88:36	135	0:52	33:10
D	Golf Course	58:14	107	0:47	18:47
E	MWCC building	90:32	76	1:26	25:23
F	Eaton Street	0:00	0	0:00	0:00
G	Gardner Middle School	47:43	96	0:37	17:26

Total amount of flickering on the shadow receptors caused by each WTG

No.	Name	Worst case [h/year]
1	North VESTAS V82 1650 82.0 !O! hub: 80.0 m (2)	181:51
2	South VESTAS V82 1650 82.0 !O! hub: 80.0 m (2)	238:35

Project:
MWCC

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05/19/2009 1:57 PM / 3

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Renewable Energy Research Lab, University of Massachusetts at Amherst
160 Governors Drive Amherst
MA 01003 USA
413 545 3914

Calculated:
05/19/2009 11:24 AM/2.6.1.252

SHADOW - Calendar

Calculation: Gardner Middle School added MWCC Two turbines with sun percentages **Shadow receptor:** A - Courthouse

Assumptions for shadow calculations

Maximum distance for influence	2,000 m
Minimum sun height over horizon for influence	3 °
Day step for calculation	1 days
Time step for calculation	1 minutes

Sun shine probabilities (part of time from sun rise to sun set with sun shine)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.48	0.51	0.52	0.51	0.52	0.56	0.59	0.61	0.59	0.57	0.51	0.48

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
390	243	360	460	395	236	131	124	265	665	989	765	1,060	1,229	910	540	8,760

	January	February			March			April		
1	07:19	07:03			06:25		15:10 (2)	06:32		16:28 (2)
	16:25	17:01			17:37	87	16:37 (2)	19:14	43	17:11 (2)
2	07:19	07:02			06:24		15:10 (2)	06:30		16:31 (2)
	16:26	17:02			17:38	88	16:38 (2)	19:15	38	17:09 (2)
3	07:19	07:01			06:22		15:09 (2)	06:29		16:34 (2)
	16:27	17:04			17:40	88	16:37 (2)	19:16	32	17:06 (2)
4	07:19	07:00			06:20		15:09 (2)	06:27		16:37 (2)
	16:28	17:05			17:41	88	16:37 (2)	19:17	25	17:02 (2)
5	07:19	06:59			06:19		15:09 (2)	06:25		16:44 (2)
	16:29	17:06			17:42	89	16:38 (2)	19:18	12	16:56 (2)
6	07:19	06:58		15:46 (2)	06:17		15:09 (2)	06:24		
	16:30	17:08	17	16:03 (2)	17:43	88	16:37 (2)	19:19		
7	07:18	06:57		15:40 (2)	06:15		15:08 (2)	06:22		
	16:31	17:09	27	16:07 (2)	17:45	89	16:37 (2)	19:21		
8	07:18	06:56		15:37 (2)	07:14		16:08 (2)	06:20		
	16:32	17:10	34	16:11 (2)	18:46	89	17:37 (2)	19:22		
9	07:18	06:54		15:34 (2)	07:12		16:08 (2)	06:18		
	16:33	17:12	41	16:15 (2)	18:47	89	17:37 (2)	19:23		
10	07:18	06:53		15:32 (2)	07:10		16:08 (2)	06:17		
	16:34	17:13	45	16:17 (2)	18:48	88	17:36 (2)	19:24		
11	07:18	06:52		15:29 (2)	07:09		16:08 (2)	06:15		
	16:35	17:14	50	16:19 (2)	18:49	88	17:36 (2)	19:25		
12	07:17	06:50		15:28 (2)	07:07		16:09 (2)	06:13		
	16:36	17:16	53	16:21 (2)	18:51	87	17:36 (2)	19:26		
13	07:17	06:49		15:25 (2)	07:05		16:09 (2)	06:12		
	16:37	17:17	57	16:22 (2)	18:52	86	17:36 (2)	19:27		
14	07:17	06:48		15:24 (2)	07:04		16:09 (2)	06:10		
	16:39	17:18	60	16:24 (2)	18:53	86	17:35 (2)	19:28		
15	07:16	06:46		15:23 (2)	07:02		16:09 (2)	06:09		
	16:40	17:20	63	16:26 (2)	18:54	85	17:34 (2)	19:30		
16	07:16	06:45		15:21 (2)	07:00		16:10 (2)	06:07		
	16:41	17:21	66	16:27 (2)	18:55	84	17:34 (2)	19:31		
17	07:15	06:44		15:20 (2)	06:58		16:10 (2)	06:05		
	16:42	17:22	69	16:29 (2)	18:56	83	17:33 (2)	19:32		
18	07:15	06:42		15:19 (2)	06:57		16:11 (2)	06:04		
	16:43	17:23	70	16:29 (2)	18:58	81	17:32 (2)	19:33		
19	07:14	06:41		15:18 (2)	06:55		16:11 (2)	06:02		
	16:45	17:25	73	16:31 (2)	18:59	80	17:31 (2)	19:34		
20	07:13	06:39		15:16 (2)	06:53		16:13 (2)	06:01		
	16:46	17:26	75	16:31 (2)	19:00	78	17:31 (2)	19:35		
21	07:13	06:38		15:16 (2)	06:51		16:13 (2)	05:59		
	16:47	17:27	77	16:33 (2)	19:01	76	17:29 (2)	19:36		
22	07:12	06:36		15:14 (2)	06:50		16:14 (2)	05:57		
	16:48	17:29	79	16:33 (2)	19:02	74	17:28 (2)	19:38		
23	07:11	06:35		15:14 (2)	06:48		16:14 (2)	05:56		
	16:50	17:30	80	16:34 (2)	19:03	73	17:27 (2)	19:39		
24	07:11	06:33		15:13 (2)	06:46		16:16 (2)	05:54		
	16:51	17:31	82	16:35 (2)	19:05	70	17:26 (2)	19:40		
25	07:10	06:32		15:13 (2)	06:44		16:17 (2)	05:53		
	16:52	17:32	83	16:36 (2)	19:06	68	17:25 (2)	19:41		
26	07:09	06:30		15:12 (2)	06:43		16:18 (2)	05:51		
	16:53	17:34	84	16:36 (2)	19:07	65	17:23 (2)	19:42		
27	07:08	06:29		15:11 (2)	06:41		16:19 (2)	05:50		
	16:55	17:35	85	16:36 (2)	19:08	62	17:21 (2)	19:43		
28	07:07	06:27		15:11 (2)	06:39		16:20 (2)	05:48		
	16:56	17:36	86	16:37 (2)	19:09	59	17:19 (2)	19:44		
29	07:06				06:37		16:23 (2)	05:47		
	16:57				19:10	55	17:18 (2)	19:45		
30	07:05				06:36		16:24 (2)	05:46		
	16:59				19:11	52	17:16 (2)	19:47		
31	07:04				06:34		16:26 (2)			
	17:00				19:13	48	17:14 (2)			
Potential sun hours	293	295			370			401		
Total, worst case			1456			2423			150	
Sun reduction			0.51			0.52			0.51	
Oper. time red.			1.00			1.00			1.00	
Wind dir. red.			0.72			0.72			0.72	
Total reduction			0.37			0.37			0.37	
Total, real			534			906			55	

	May	June	July	August	September			October			November			December
1	05:44	05:14	05:14	05:40	06:12			06:45		15:48 (2)	06:21		15:01 (2)	06:58
	19:48	20:18	20:30	20:11	19:24			18:31	87	17:15 (2)	16:42	45	15:46 (2)	16:16
2	05:43	05:13	05:15	05:41	06:14			06:46		15:47 (2)	06:23		15:05 (2)	06:59
	19:49	20:19	20:30	20:09	19:22			18:29	87	17:14 (2)	16:41	39	15:44 (2)	16:16
3	05:42	05:13	05:15	05:42	06:15			06:47		15:46 (2)	06:24		15:07 (2)	07:00
	19:50	20:20	20:30	20:08	19:21			18:28	88	17:14 (2)	16:40	34	15:41 (2)	16:16
4	05:40	05:12	05:16	05:43	06:16			06:48		15:45 (2)	06:25		15:11 (2)	07:01
	19:51	20:20	20:30	20:07	19:19			18:26	89	17:14 (2)	16:39	26	15:37 (2)	16:16
5	05:39	05:12	05:16	05:44	06:17			06:49		15:45 (2)	06:26		15:17 (2)	07:02
	19:52	20:21	20:29	20:06	19:17			18:24	89	17:14 (2)	16:37	15	15:32 (2)	16:15
6	05:38	05:12	05:17	05:45	06:18			06:50		15:45 (2)	06:28			07:03
	19:53	20:22	20:29	20:05	19:15			18:23	89	17:14 (2)	16:36			16:15
7	05:36	05:11	05:18	05:46	06:19		16:39 (2)	06:51		15:44 (2)	06:29			07:04
	19:54	20:23	20:29	20:03	19:14	12	16:51 (2)	18:21	89	17:13 (2)	16:35			16:15
8	05:35	05:11	05:18	05:47	06:20		16:33 (2)	06:53		15:44 (2)	06:30			07:05
	19:56	20:23	20:29	20:02	19:12	23	16:56 (2)	18:19	89	17:13 (2)	16:34			16:15
9	05:34	05:11	05:19	05:48	06:21		16:28 (2)	06:54		15:43 (2)	06:31			07:06
	19:57	20:24	20:28	20:01	19:10	32	17:00 (2)	18:17	89	17:12 (2)	16:33			16:15
10	05:33	05:11	05:20	05:49	06:22		16:24 (2)	06:55		15:43 (2)	06:33			07:07
	19:58	20:25	20:28	19:58	19:08	38	17:02 (2)	18:16	88	17:11 (2)	16:32			16:15
11	05:32	05:10	05:20	05:50	06:23		16:21 (2)	06:56		15:44 (2)	06:34			07:08
	19:59	20:25	20:27	19:57	19:07	43	17:04 (2)	18:14	88	17:12 (2)	16:31			16:15
12	05:30	05:10	05:21	05:51	06:24		16:18 (2)	06:57		15:43 (2)	06:35			07:09
	20:00	20:26	20:27	19:55	19:05	48	17:06 (2)	18:12	88	17:11 (2)	16:29			16:15
13	05:29	05:10	05:22	05:52	06:25		16:16 (2)	06:58		15:43 (2)	06:36			07:09
	20:00	20:26	20:26	19:54	19:03	51	17:07 (2)	18:11	87	17:10 (2)	16:28			16:15
14	05:28	05:10	05:23	05:53	06:26		16:13 (2)	06:59		15:43 (2)	06:38			07:10
	20:01	20:27	20:26	19:52	19:01	55	17:08 (2)	18:09	86	17:09 (2)	16:28			16:15
15	05:27	05:10	05:24	05:54	06:27		16:11 (2)	07:01		15:43 (2)	06:39			07:11
	20:02	20:27	20:25	19:51	19:00	58	17:09 (2)	18:07	85	17:08 (2)	16:27			16:16
16	05:26	05:10	05:24	05:55	06:28		16:09 (2)	07:02		15:44 (2)	06:40			07:12
	20:03	20:28	20:25	19:50	18:58	61	17:10 (2)	18:06	84	17:08 (2)	16:26			16:16
17	05:25	05:10	05:25	05:56	06:30		16:07 (2)	07:03		15:44 (2)	06:41			07:12
	20:04	20:28	20:24	19:48	18:56	64	17:11 (2)	18:04	83	17:07 (2)	16:25			16:16
18	05:24	05:10	05:26	05:57	06:31		16:05 (2)	07:04		15:45 (2)	06:43			07:13
	20:05	20:28	20:23	19:47	18:54	67	17:12 (2)	18:03	81	17:06 (2)	16:24			16:17
19	05:23	05:10	05:27	05:59	06:32		16:03 (2)	07:05		15:45 (2)	06:44			07:14
	20:06	20:29	20:23	19:45	18:52	69	17:12 (2)	18:01	80	17:05 (2)	16:23			16:17
20	05:22	05:10	05:28	06:00	06:33		16:01 (2)	07:07		15:46 (2)	06:45			07:14
	20:07	20:29	20:22	19:44	18:51	72	17:13 (2)	18:00	78	17:04 (2)	16:22			16:17
21	05:21	05:11	05:29	06:01	06:34		15:59 (2)	07:08		15:47 (2)	06:46			07:15
	20:08	20:29	20:21	19:42	18:49	74	17:13 (2)	17:58	76	17:03 (2)	16:22			16:18
22	05:21	05:11	05:30	06:02	06:35		15:58 (2)	07:09		15:47 (2)	06:48			07:15
	20:09	20:30	20:20	19:40	18:47	76	17:14 (2)	17:56	75	17:02 (2)	16:21			16:18
23	05:20	05:11	05:31	06:03	06:36		15:56 (2)	07:10		15:48 (2)	06:49			07:16
	20:10	20:30	20:19	19:39	18:45	78	17:14 (2)	17:55	72	17:00 (2)	16:20			16:19
24	05:19	05:11	05:32	06:04	06:37		15:55 (2)	07:11		15:49 (2)	06:50			07:16
	20:11	20:30	20:19	19:37	18:44	79	17:14 (2)	17:53	71	17:00 (2)	16:20			16:19
25	05:18	05:12	05:33	06:05	06:38		15:54 (2)	07:13		15:50 (2)	06:51			07:17
	20:12	20:30	20:18	19:36	18:42	81	17:15 (2)	17:52	68	16:58 (2)	16:19			16:20
26	05:17	05:12	05:34	06:06	06:39		15:53 (2)	07:14		15:51 (2)	06:52			07:17
	20:13	20:30	20:17	19:34	18:40	82	17:15 (2)	17:51	65	16:56 (2)	16:19			16:21
27	05:17	05:12	05:34	06:07	06:40		15:52 (2)	07:15		15:53 (2)	06:53			07:17
	20:14	20:30	20:16	19:32	18:38	83	17:15 (2)	17:49	63	16:56 (2)	16:18			16:21
28	05:16	05:13	05:35	06:08	06:41		15:51 (2)	07:16		15:54 (2)	06:55			07:18
	20:15	20:30	20:15	19:31	18:36	84	17:15 (2)	17:48	60	16:54 (2)	16:18			16:22
29	05:15	05:13	05:36	06:09	06:43		15:50 (2)	07:18		15:55 (2)	06:56			07:18
	20:16	20:30	20:14	19:29	18:35	85	17:15 (2)	17:46	57	16:52 (2)	16:17			16:23
30	05:15	05:14	05:37	06:10	06:44		15:49 (2)	07:19		15:58 (2)	06:57			07:18
	20:16	20:30	20:13	19:27	18:33	86	17:15 (2)	17:45	53	16:51 (2)	16:17			16:23
31	05:14		05:38	06:11				07:20		16:00 (2)				07:18
	20:17		20:12	19:26				17:44	48	16:48 (2)				16:24
Potential sun hours	453	457	464	431	375			343			294			283
Total, worst case						1501			2432			159		
Sun reduction						0.59			0.57			0.51		
Oper. time red.						1.00			1.00			1.00		
Wind dir. red.						0.72			0.72			0.72		
Total reduction						0.42			0.41			0.37		
Total, real						637			997			58		

Table layout: For each day in each month the following matrix apply

Day in month	Sun rise (hh:mm)		First time (hh:mm) with flicker	(WTG causing flicker first time)
	Sun set (hh:mm)	Minutes with flicker	Last time (hh:mm) with flicker	(WTG causing flicker last time)

Project:
MWCC

Printed/Page
05/19/2009 1:57 PM / 4

Licensed user:
Renewable Energy Research Lab, University of Massachusetts at Amherst
160 Governors Drive Amherst
MA 01003 USA
413 545 3914

Calculated:
05/19/2009 11:24 AM/2.6.1.252

SHADOW - Calendar

Calculation: Gardner Middle School added MWCC Two turbines with sun percentages **Shadow receptor:** B - Hospital

Assumptions for shadow calculations

Maximum distance for influence	2,000 m
Minimum sun height over horizon for influence	3 °
Day step for calculation	1 days
Time step for calculation	1 minutes

Sun shine probabilities (part of time from sun rise to sun set with sun shine)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.48	0.51	0.52	0.51	0.52	0.56	0.59	0.61	0.59	0.57	0.51	0.48

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
390	243	360	460	395	236	131	124	265	665	989	765	1,060	1,229	910	540	8,760

	January	February	March	April	May	June	July	August	September	October	November	December
1	07:19	07:03	06:25	06:32	05:44	05:14	05:14	05:40	06:13	06:45	06:21	06:58
	16:25	17:01	17:37	19:14	19:48	20:18	20:30	20:11	19:24	18:31	16:42	16:16
2	07:19	07:02	06:24	06:30	05:43	05:13	05:15	05:41	06:14	06:46	06:23	06:59
	16:26	17:03	17:39	19:15	19:49	20:19	20:30	20:09	19:22	18:29	16:41	16:16
3	07:19	07:01	06:22	06:29	05:42	05:13	05:15	05:42	06:15	06:47	06:24	07:00
	16:27	17:04	17:40	19:16	19:50	20:20	20:30	20:08	19:21	18:28	16:40	16:16
4	07:19	07:00	06:20	06:27	05:40	05:12	05:16	05:43	06:16	06:48	06:25	07:01
	16:28	17:05	17:41	19:17	19:51	20:20	20:30	20:07	19:19	18:26	16:39	16:16
5	07:19	06:59	06:19	06:25	05:39	05:12	05:16	05:44	06:17	06:49	06:26	07:02
	16:29	17:06	17:42	19:18	19:52	20:21	20:29	20:06	19:17	18:24	16:37	16:15
6	07:19	06:58	06:17	06:24	05:38	05:12	05:17	05:45	06:18	06:50	06:28	07:03
	16:30	17:08	17:43	19:19	19:53	20:22	20:29	20:05	19:15	18:23	16:36	16:15
7	07:18	06:57	06:15	06:22	05:36	05:11	05:18	05:46	06:19	06:51	06:29	07:04
	16:31	17:09	17:45	19:21	19:54	20:23	20:29	20:03	19:14	18:21	16:35	16:15
8	07:18	06:56	07:14	06:20	05:35	05:11	05:18	05:47	06:20	06:53	06:30	07:05
	16:32	17:10	18:46	19:22	19:56	20:23	20:29	20:02	19:12	18:19	16:34	16:15
9	07:18	06:54	07:12	06:18	05:34	05:11	05:19	05:48	06:21	06:54	06:31	07:06
	16:33	17:12	18:47	19:23	19:57	20:24	20:28	20:01	19:10	18:17	16:33	16:15
10	07:18	06:53	07:10	06:17	05:33	05:11	05:20	05:49	06:22	06:55	06:33	07:07
	16:34	17:13	18:48	19:24	19:58	20:25	20:28	19:58	19:08	18:16	16:32	16:15
11	07:18	06:52	07:09	06:15	05:32	05:11	05:20	05:50	06:23	06:56	06:34	07:08
	16:35	17:14	18:49	19:25	19:59	20:25	20:27	19:57	19:07	18:14	16:31	16:15
12	07:17	06:50	07:07	06:13	05:30	05:10	05:21	05:51	06:24	06:57	06:35	07:09
	16:36	17:16	18:51	19:26	20:00	20:26	20:27	19:55	19:05	18:12	16:30	16:15
13	07:17	06:49	07:05	06:12	05:29	05:10	05:22	05:52	06:25	06:58	06:36	07:09
	16:37	17:17	18:52	19:27	20:00	20:26	20:26	19:54	19:03	18:11	16:29	16:15
14	07:17	06:48	07:04	06:10	05:28	05:10	05:23	05:53	06:26	06:59	06:38	07:10
	16:39	17:18	18:53	19:28	20:01	20:27	20:26	19:53	19:01	18:09	16:28	16:15
15	07:16	06:46	07:02	06:09	05:27	05:10	05:24	05:54	06:27	07:01	06:39	07:11
	16:40	17:20	18:54	19:30	20:02	20:27	20:25	19:51	19:00	18:07	16:27	16:16
16	07:16	06:45	07:00	06:07	05:26	05:10	05:24	05:55	06:28	07:02	06:40	07:12
	16:41	17:21	18:55	19:31	20:03	20:28	20:25	19:50	18:58	18:06	16:26	16:16
17	07:15	06:44	06:58	06:05	05:25	05:10	05:25	05:56	06:30	07:03	06:41	07:12
	16:42	17:22	18:56	19:32	20:04	20:28	20:24	19:48	18:56	18:04	16:25	16:16
18	07:15	06:42	06:57	06:04	05:24	05:10	05:26	05:58	06:31	07:04	06:43	07:13
	16:43	17:23	18:58	19:33	20:05	20:28	20:23	19:47	18:54	18:03	16:24	16:17
19	07:14	06:41	06:55	06:02	05:23	05:10	05:27	05:59	06:32	07:05	06:44	07:14
	16:45	17:25	18:59	19:34	20:06	20:29	20:23	19:45	18:52	18:01	16:23	16:17
20	07:13	06:39	06:53	06:01	05:22	05:11	05:28	06:00	06:33	07:07	06:45	07:14
	16:46	17:26	19:00	19:35	20:07	20:29	20:22	19:44	18:51	18:00	16:22	16:17
21	07:13	06:38	06:51	05:59	05:21	05:11	05:29	06:01	06:34	07:08	06:46	07:15
	16:47	17:27	19:01	19:36	20:08	20:29	20:21	19:42	18:49	17:58	16:22	16:18
22	07:12	06:36	06:50	05:57	05:21	05:11	05:30	06:02	06:35	07:09	06:48	07:15
	16:48	17:29	19:02	19:38	20:09	20:30	20:20	19:40	18:47	17:57	16:21	16:18
23	07:11	06:35	06:48	05:56	05:20	05:11	05:31	06:03	06:36	07:10	06:49	07:16
	16:50	17:30	19:03	19:39	20:10	20:30	20:19	19:39	18:45	17:55	16:20	16:19
24	07:11	06:33	06:46	05:54	05:19	05:11	05:32	06:04	06:37	07:11	06:50	07:16
	16:51	17:31	19:05	19:40	20:11	20:30	20:19	19:37	18:44	17:54	16:20	16:19
25	07:10	06:32	06:44	05:53	05:18	05:12	05:33	06:05	06:38	07:13	06:51	07:17
	16:52	17:32	19:06	19:41	20:12	20:30	20:18	19:36	18:42	17:52	16:19	16:20
26	07:09	06:30	06:43	05:51	05:17	05:12	05:34	06:06	06:39	07:14	06:52	07:17
	16:53	17:34	19:07	19:42	20:13	20:30	20:17	19:34	18:40	17:51	16:19	16:21
27	07:08	06:29	06:41	05:50	05:17	05:12	05:35	06:07	06:40	07:15	06:53	07:17
	16:55	17:35	19:08	19:43	20:14	20:30	20:16	19:32	18:38	17:49	16:18	16:21
28	07:07	06:27	06:39	05:48	05:16	05:13	05:36	06:08	06:41	07:16	06:55	07:18
	16:56	17:36	19:09	19:44	20:15	20:30	20:15	19:31	18:36	17:48	16:18	16:22
29	07:06		06:37	05:47	05:16	05:13	05:37	06:09	06:43	07:18	06:56	07:18
	16:57		19:10	19:45	20:16	20:30	20:14	19:29	18:35	17:46	16:17	16:23
30	07:05		06:36	05:46	05:15	05:14	05:38	06:10	06:44	07:19	06:57	07:18
	16:59		19:11	19:47	20:16	20:30	20:13	19:27	18:33	17:45	16:17	16:23
31	07:04		06:34		05:14		05:39	06:11		07:20		07:18
	17:00		19:13		20:17		20:12	19:26		17:44		16:24
Potential sun hours	293	295	370	401	453	457	464	431	375	343	294	283
Total, worst case												
Sun reduction												
Oper. time red.												
Wind dir. red.												
Total reduction												
Total, real												

Table layout: For each day in each month the following matrix apply

Day in month	Sun rise (hh:mm)		First time (hh:mm) with flicker	(WTG causing flicker first time)
	Sun set (hh:mm)	Minutes with flicker	Last time (hh:mm) with flicker	(WTG causing flicker last time)

Project:
MWCC

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05/19/2009 1:57 PM / 5

Licensed user:
Renewable Energy Research Lab, University of Massachusetts at Amherst
160 Governors Drive Amherst
MA 01003 USA
413 545 3914

Calculated:
05/19/2009 11:24 AM/2.6.1.252

SHADOW - Calendar

Calculation: Gardner Middle School added MWCC Two turbines with sun percentages **Shadow receptor:** C - Boulder Street

Assumptions for shadow calculations

Maximum distance for influence	2,000 m
Minimum sun height over horizon for influence	3 °
Day step for calculation	1 days
Time step for calculation	1 minutes

Sun shine probabilities (part of time from sun rise to sun set with sun shine)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.48	0.51	0.52	0.51	0.52	0.56	0.59	0.61	0.59	0.57	0.51	0.48

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
390	243	360	460	395	236	131	124	265	665	989	765	1,060	1,229	910	540	8,760

	January	February	March			April			May			June		
1	07:19	07:03	06:25			06:32		17:42 (2)	05:44			05:14		18:54 (1)
	16:25	17:01	17:37			19:14	34	18:16 (2)	19:48			20:18	46	19:40 (1)
2	07:19	07:02	06:24			06:30		17:44 (2)	05:43			05:13		18:54 (1)
	16:26	17:02	17:38			19:15	31	18:15 (2)	19:49			20:19	47	19:41 (1)
3	07:19	07:01	06:22			06:29		17:46 (2)	05:42			05:13		18:53 (1)
	16:27	17:04	17:40			19:16	27	18:13 (2)	19:50			20:20	48	19:41 (1)
4	07:19	07:00	06:20			06:27		17:47 (2)	05:40			05:12		18:54 (1)
	16:28	17:05	17:41			19:17	23	18:10 (2)	19:51			20:20	47	19:41 (1)
5	07:19	06:59	06:19			06:25		17:51 (2)	05:39			05:12		18:54 (1)
	16:29	17:06	17:42			19:18	16	18:07 (2)	19:52			20:21	48	19:42 (1)
6	07:19	06:58	06:17			06:24		17:56 (2)	05:38			05:12		18:53 (1)
	16:30	17:08	17:43			19:19	5	18:01 (2)	19:53			20:22	49	19:42 (1)
7	07:18	06:57	06:15			06:22			05:36			05:11		18:53 (1)
	16:31	17:09	17:45			19:20			19:54			20:23	49	19:42 (1)
8	07:18	06:56	07:14		18:00 (2)	06:20			05:35			05:11		18:54 (1)
	16:32	17:10	18:46	12	18:12 (2)	19:22			19:56			20:23	49	19:43 (1)
9	07:18	06:54	07:12		17:56 (2)	06:18			05:34			05:11		18:54 (1)
	16:33	17:12	18:47	20	18:16 (2)	19:23			19:57			20:24	50	19:44 (1)
10	07:18	06:53	07:10		17:53 (2)	06:17			05:33			05:11		18:53 (1)
	16:34	17:13	18:48	26	18:19 (2)	19:24			19:58			20:25	50	19:43 (1)
11	07:18	06:52	07:09		17:50 (2)	06:15			05:32			05:10		18:53 (1)
	16:35	17:14	18:49	30	18:20 (2)	19:25			19:59			20:25	51	19:44 (1)
12	07:17	06:50	07:07		17:49 (2)	06:13			05:30			05:10		18:54 (1)
	16:36	17:16	18:51	33	18:22 (2)	19:26			20:00			20:26	50	19:44 (1)
13	07:17	06:49	07:05		17:47 (2)	06:12			05:29			05:10		18:54 (1)
	16:37	17:17	18:52	36	18:23 (2)	19:27			20:00			20:26	50	19:44 (1)
14	07:17	06:48	07:04		17:45 (2)	06:10			05:28			05:10		18:54 (1)
	16:39	17:18	18:53	39	18:24 (2)	19:28			20:01			20:27	51	19:45 (1)
15	07:16	06:46	07:02		17:44 (2)	06:08			05:27			05:10		18:54 (1)
	16:40	17:20	18:54	40	18:24 (2)	19:30			20:02			20:27	51	19:45 (1)
16	07:16	06:45	07:00		17:43 (2)	06:07			05:26		19:09 (1)	05:10		18:54 (1)
	16:41	17:21	18:55	43	18:26 (2)	19:31			20:03	13	19:22 (1)	20:28	51	19:45 (1)
17	07:15	06:44	06:58		17:42 (2)	06:05			05:25		19:06 (1)	05:10		18:54 (1)
	16:42	17:22	18:56	44	18:26 (2)	19:32			20:04	19	19:25 (1)	20:28	51	19:45 (1)
18	07:15	06:42	06:57		17:41 (2)	06:04			05:24		19:03 (1)	05:10		18:54 (1)
	16:43	17:23	18:58	45	18:26 (2)	19:33			20:05	24	19:27 (1)	20:28	51	19:45 (1)
19	07:14	06:41	06:55		17:40 (2)	06:02			05:23		19:03 (1)	05:10		18:54 (1)
	16:45	17:25	18:59	46	18:26 (2)	19:34			20:06	26	19:29 (1)	20:29	52	19:46 (1)
20	07:13	06:39	06:53		17:41 (2)	06:00			05:22		19:01 (1)	05:10		18:55 (1)
	16:46	17:26	19:00	45	18:26 (2)	19:35			20:07	30	19:31 (1)	20:29	52	19:47 (1)
21	07:13	06:38	06:51		17:40 (2)	05:59			05:21		19:00 (1)	05:11		18:55 (1)
	16:47	17:27	19:01	46	18:26 (2)	19:36			20:08	32	19:32 (1)	20:29	52	19:47 (1)
22	07:12	06:36	06:50		17:39 (2)	05:57			05:21		18:59 (1)	05:11		18:55 (1)
	16:48	17:29	19:02	47	18:26 (2)	19:38			20:09	34	19:33 (1)	20:29	52	19:47 (1)
23	07:11	06:35	06:48		17:39 (2)	05:56			05:20		18:57 (1)	05:11		18:55 (1)
	16:49	17:30	19:03	46	18:25 (2)	19:39			20:10	36	19:33 (1)	20:30	52	19:47 (1)
24	07:11	06:33	06:46		17:39 (2)	05:54			05:19		18:57 (1)	05:11		18:56 (1)
	16:51	17:31	19:05	45	18:24 (2)	19:40			20:11	38	19:35 (1)	20:30	51	19:47 (1)
25	07:10	06:32	06:44		17:39 (2)	05:53			05:18		18:56 (1)	05:12		18:56 (1)
	16:52	17:32	19:06	45	18:24 (2)	19:41			20:12	40	19:36 (1)	20:30	51	19:47 (1)
26	07:09	06:30	06:43		17:39 (2)	05:51			05:17		18:55 (1)	05:12		18:56 (1)
	16:53	17:34	19:07	45	18:24 (2)	19:42			20:13	41	19:36 (1)	20:30	51	19:47 (1)
27	07:08	06:29	06:41		17:39 (2)	05:50			05:17		18:56 (1)	05:12		18:57 (1)
	16:55	17:35	19:08	44	18:23 (2)	19:43			20:14	41	19:37 (1)	20:30	51	19:48 (1)
28	07:07	06:27	06:39		17:39 (2)	05:48			05:16		18:55 (1)	05:13		18:57 (1)
	16:56	17:36	19:09	42	18:21 (2)	19:44			20:15	43	19:38 (1)	20:30	51	19:48 (1)
29	07:06		06:37		17:41 (2)	05:47			05:15		18:55 (1)	05:13		18:57 (1)
	16:57		19:10	40	18:21 (2)	19:45			20:16	44	19:39 (1)	20:30	50	19:47 (1)
30	07:05		06:36		17:41 (2)	05:46			05:15		18:54 (1)	05:14		18:58 (1)
	16:59		19:11	39	18:20 (2)	19:47			20:16	45	19:39 (1)	20:30	50	19:48 (1)
31	07:04		06:34		17:42 (2)				05:14		18:54 (1)			
	17:00		19:13	36	18:18 (2)				20:17	46	19:40 (1)			
Potential sun hours	293	295	370			401			453			457		
Total, worst case				934			136			552			1504	
Sun reduction				0.52			0.51			0.52			0.56	
Oper. time red.				1.00			1.00			1.00			1.00	
Wind dir. red.				0.71			0.71			0.64			0.64	
Total reduction				0.37			0.36			0.33			0.36	
Total, real				346			49			184			540	

Table layout: For each day in each month the following matrix apply

Day in month	Sun rise (hh:mm)		First time (hh:mm) with flicker	(WTG causing flicker first time)
	Sun set (hh:mm)	Minutes with flicker	Last time (hh:mm) with flicker	(WTG causing flicker last time)

Project:
MWCC

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05/19/2009 1:57 PM / 6

Licensed user:
Renewable Energy Research Lab, University of Massachusetts at Amherst
160 Governors Drive Amherst
MA 01003 USA
413 545 3914

Calculated:
05/19/2009 11:24 AM/2.6.1.252

SHADOW - Calendar

Calculation: Gardner Middle School added MWCC Two turbines with sun percentages **Shadow receptor:** C - Boulder Street

Assumptions for shadow calculations

Maximum distance for influence	2,000 m
Minimum sun height over horizon for influence	3 °
Day step for calculation	1 days
Time step for calculation	1 minutes

Sun shine probabilities (part of time from sun rise to sun set with sun shine)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.48	0.51	0.52	0.51	0.52	0.56	0.59	0.61	0.59	0.57	0.51	0.48

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
390	243	360	460	395	236	131	124	265	665	989	765	1,060	1,229	910	540	8,760

	July			August	September			October			November	December
1	05:14		18:57 (1)	05:40	06:12			06:45		17:27 (2)	06:21	06:58
	20:30	51	19:48 (1)	20:11	19:24			18:31	34	18:01 (2)	16:42	16:16
2	05:15		18:58 (1)	05:41	06:14			06:46		17:28 (2)	06:23	06:59
	20:30	50	19:48 (1)	20:09	19:22			18:29	31	17:59 (2)	16:41	16:16
3	05:15		18:58 (1)	05:42	06:15			06:47		17:29 (2)	06:24	07:00
	20:30	50	19:48 (1)	20:08	19:21			18:28	28	17:57 (2)	16:40	16:16
4	05:16		18:59 (1)	05:43	06:16			06:48		17:31 (2)	06:25	07:01
	20:30	49	19:48 (1)	20:07	19:19			18:26	23	17:54 (2)	16:38	16:16
5	05:16		18:59 (1)	05:44	06:17			06:49		17:35 (2)	06:26	07:02
	20:29	50	19:49 (1)	20:06	19:17			18:24	17	17:52 (2)	16:37	16:15
6	05:17		18:59 (1)	05:45	06:18		17:53 (2)	06:50		17:42 (2)	06:28	07:03
	20:29	49	19:48 (1)	20:05	19:15	3	17:56 (2)	18:23	2	17:44 (2)	16:36	16:15
7	05:18		19:00 (1)	05:46	06:19		17:46 (2)	06:51			06:29	07:04
	20:29	48	19:48 (1)	20:03	19:14	16	18:02 (2)	18:21			16:35	16:15
8	05:18		19:01 (1)	05:47	06:20		17:43 (2)	06:53			06:30	07:05
	20:29	48	19:49 (1)	20:02	19:12	22	18:05 (2)	18:19			16:34	16:15
9	05:19		19:00 (1)	05:48	06:21		17:40 (2)	06:54			06:31	07:06
	20:28	48	19:48 (1)	20:01	19:10	27	18:07 (2)	18:17			16:33	16:15
10	05:20		19:01 (1)	05:49	06:22		17:38 (2)	06:55			06:33	07:07
	20:28	47	19:48 (1)	19:58	19:08	30	18:08 (2)	18:16			16:32	16:15
11	05:20		19:02 (1)	05:50	06:23		17:36 (2)	06:56			06:34	07:08
	20:27	46	19:48 (1)	19:57	19:07	33	18:09 (2)	18:14			16:31	16:15
12	05:21		19:02 (1)	05:51	06:24		17:34 (2)	06:57			06:35	07:09
	20:27	45	19:47 (1)	19:55	19:05	36	18:10 (2)	18:12			16:29	16:15
13	05:22		19:02 (1)	05:52	06:25		17:32 (2)	06:58			06:36	07:09
	20:26	45	19:47 (1)	19:54	19:03	39	18:11 (2)	18:11			16:28	16:15
14	05:23		19:03 (1)	05:53	06:26		17:31 (2)	06:59			06:38	07:10
	20:26	44	19:47 (1)	19:52	19:01	40	18:11 (2)	18:09			16:28	16:15
15	05:24		19:04 (1)	05:54	06:27		17:30 (2)	07:01			06:39	07:11
	20:25	43	19:47 (1)	19:51	19:00	42	18:12 (2)	18:07			16:27	16:16
16	05:24		19:04 (1)	05:55	06:28		17:29 (2)	07:02			06:40	07:12
	20:25	42	19:46 (1)	19:50	18:58	43	18:12 (2)	18:06			16:26	16:16
17	05:25		19:05 (1)	05:56	06:30		17:28 (2)	07:03			06:41	07:12
	20:24	41	19:46 (1)	19:48	18:56	44	18:12 (2)	18:04			16:25	16:16
18	05:26		19:05 (1)	05:57	06:31		17:27 (2)	07:04			06:43	07:13
	20:23	40	19:45 (1)	19:47	18:54	45	18:12 (2)	18:03			16:24	16:17
19	05:27		19:06 (1)	05:59	06:32		17:26 (2)	07:05			06:44	07:14
	20:23	39	19:45 (1)	19:45	18:52	46	18:12 (2)	18:01			16:23	16:17
20	05:28		19:07 (1)	06:00	06:33		17:25 (2)	07:07			06:45	07:14
	20:22	37	19:44 (1)	19:44	18:51	46	18:11 (2)	18:00			16:22	16:17
21	05:29		19:08 (1)	06:01	06:34		17:25 (2)	07:08			06:46	07:15
	20:21	36	19:44 (1)	19:42	18:49	46	18:11 (2)	17:58			16:22	16:18
22	05:30		19:10 (1)	06:02	06:35		17:24 (2)	07:09			06:48	07:15
	20:20	33	19:43 (1)	19:40	18:47	46	18:10 (2)	17:56			16:21	16:18
23	05:31		19:11 (1)	06:03	06:36		17:24 (2)	07:10			06:49	07:16
	20:19	31	19:42 (1)	19:39	18:45	46	18:10 (2)	17:55			16:20	16:19
24	05:32		19:11 (1)	06:04	06:37		17:24 (2)	07:11			06:50	07:16
	20:19	29	19:40 (1)	19:37	18:44	45	18:09 (2)	17:53			16:20	16:19
25	05:33		19:13 (1)	06:05	06:38		17:24 (2)	07:13			06:51	07:17
	20:18	25	19:38 (1)	19:36	18:42	44	18:08 (2)	17:52			16:19	16:20
26	05:33		19:15 (1)	06:06	06:39		17:25 (2)	07:14			06:52	07:17
	20:17	21	19:36 (1)	19:34	18:40	43	18:08 (2)	17:51			16:19	16:21
27	05:34		19:17 (1)	06:07	06:40		17:25 (2)	07:15			06:53	07:17
	20:16	17	19:34 (1)	19:32	18:38	42	18:07 (2)	17:49			16:18	16:21
28	05:35		19:21 (1)	06:08	06:41		17:25 (2)	07:16			06:55	07:18
	20:15	9	19:30 (1)	19:31	18:36	41	18:06 (2)	17:48			16:18	16:22
29	05:36			06:09	06:43		17:25 (2)	07:18			06:56	07:18
	20:14			19:29	18:35	40	18:05 (2)	17:46			16:17	16:23
30	05:37			06:10	06:44		17:26 (2)	07:19			06:57	07:18
	20:13			19:27	18:33	37	18:03 (2)	17:45			16:17	16:23
31	05:38			06:11				07:20				07:18
	20:12			19:26				17:44				16:24
Potential sun hours	464			431	375			343			294	283
Total, worst case		1113				942			135			
Sun reduction		0.59				0.59			0.57			
Oper. time red.		1.00				1.00			1.00			
Wind dir. red.		0.64				0.71			0.71			
Total reduction		0.38				0.42			0.41			
Total, real		421				396			55			

Table layout: For each day in each month the following matrix apply

Day in month	Sun rise (hh:mm)		First time (hh:mm) with flicker	(WTG causing flicker first time)
	Sun set (hh:mm)	Minutes with flicker	Last time (hh:mm) with flicker	(WTG causing flicker last time)

Project:
MWCC

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05/19/2009 1:57 PM / 7

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Renewable Energy Research Lab, University of Massachusetts at Amherst
160 Governors Drive Amherst
MA 01003 USA
413 545 3914

Calculated:
05/19/2009 11:24 AM/2.6.1.252

SHADOW - Calendar

Calculation: Gardner Middle School added MWCC Two turbines with sun percentages **Shadow receptor:** D - Golf Course

Assumptions for shadow calculations

Maximum distance for influence	2,000 m
Minimum sun height over horizon for influence	3 °
Day step for calculation	1 days
Time step for calculation	1 minutes

Sun shine probabilities (part of time from sun rise to sun set with sun shine)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.48	0.51	0.52	0.51	0.52	0.56	0.59	0.61	0.59	0.57	0.51	0.48

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
390	243	360	480	395	236	131	124	265	665	989	765	1,060	1,229	910	540	8,760

Day	January	Jan min	Jan flicker	February	Feb min	Feb flicker	March	Mar min	Mar flicker	April
1	07:19 / 16:25	30	08:37 (2) / 09:07 (2)	07:03 / 17:01			06:25 / 17:37	47	07:21 (1) / 08:08 (1)	06:32 / 19:14
2	07:19 / 16:26	29	08:38 (2) / 09:07 (2)	07:02 / 17:02			06:24 / 17:39	46	07:22 (1) / 08:08 (1)	06:30 / 19:15
3	07:19 / 16:27	29	08:38 (2) / 09:07 (2)	07:01 / 17:04			06:22 / 17:40	44	07:22 (1) / 08:06 (1)	06:29 / 19:16
4	07:19 / 16:28	28	08:39 (2) / 09:07 (2)	07:00 / 17:05			06:20 / 17:41	43	07:22 (1) / 08:05 (1)	06:27 / 19:17
5	07:19 / 16:29	26	08:41 (2) / 09:07 (2)	06:59 / 17:06			06:19 / 17:42	42	07:23 (1) / 08:05 (1)	06:25 / 19:18
6	07:19 / 16:30	25	08:42 (2) / 09:07 (2)	06:58 / 17:08			06:17 / 17:43	39	07:24 (1) / 08:03 (1)	06:24 / 19:19
7	07:19 / 16:31	23	08:42 (2) / 09:05 (2)	06:57 / 17:09			06:15 / 17:45	38	07:24 (1) / 08:02 (1)	06:22 / 19:21
8	07:18 / 16:32	21	08:44 (2) / 09:05 (2)	06:56 / 17:10			07:14 / 18:46	35	08:25 (1) / 09:00 (1)	06:20 / 19:22
9	07:18 / 16:33	20	08:45 (2) / 09:05 (2)	06:54 / 17:12			07:12 / 18:47	32	08:27 (1) / 08:59 (1)	06:18 / 19:23
10	07:18 / 16:34	17	08:46 (2) / 09:03 (2)	06:53 / 17:13	5	07:44 (1) / 07:49 (1)	07:10 / 18:48	28	08:28 (1) / 08:56 (1)	06:17 / 19:24
11	07:18 / 16:35	13	08:49 (2) / 09:02 (2)	06:52 / 17:14	16	07:38 (1) / 07:54 (1)	07:09 / 18:49	25	08:29 (1) / 08:54 (1)	06:15 / 19:25
12	07:17 / 16:36	8	08:52 (2) / 09:00 (2)	06:50 / 17:16	23	07:35 (1) / 07:58 (1)	07:07 / 18:51	19	08:32 (1) / 08:51 (1)	06:13 / 19:26
13	07:17 / 16:37			06:49 / 17:17	26	07:33 (1) / 07:59 (1)	07:05 / 18:52	10	08:36 (1) / 08:46 (1)	06:12 / 19:27
14	07:17 / 16:39			06:48 / 17:18	31	07:31 (1) / 08:02 (1)	07:04 / 18:53			06:10 / 19:28
15	07:16 / 16:40			06:46 / 17:20	33	07:30 (1) / 08:03 (1)	07:02 / 18:54			06:09 / 19:30
16	07:16 / 16:41			06:45 / 17:21	36	07:28 (1) / 08:04 (1)	07:00 / 18:55			06:07 / 19:31
17	07:15 / 16:42			06:44 / 17:22	39	07:27 (1) / 08:06 (1)	06:58 / 18:56			06:05 / 19:32
18	07:15 / 16:43			06:42 / 17:23	40	07:26 (1) / 08:06 (1)	06:57 / 18:58			06:04 / 19:33
19	07:14 / 16:45			06:41 / 17:25	42	07:25 (1) / 08:07 (1)	06:55 / 18:59			06:02 / 19:34
20	07:13 / 16:46			06:39 / 17:26	43	07:24 (1) / 08:07 (1)	06:53 / 19:00			06:01 / 19:35
21	07:13 / 16:47			06:38 / 17:27	44	07:24 (1) / 08:08 (1)	06:51 / 19:01			05:59 / 19:36
22	07:12 / 16:48			06:36 / 17:29	45	07:23 (1) / 08:08 (1)	06:50 / 19:02			05:57 / 19:38
23	07:11 / 16:50			06:35 / 17:30	46	07:23 (1) / 08:09 (1)	06:48 / 19:03			05:56 / 19:39
24	07:11 / 16:51			06:33 / 17:31	47	07:22 (1) / 08:09 (1)	06:46 / 19:05			05:54 / 19:40
25	07:10 / 16:52			06:32 / 17:32	47	07:22 (1) / 08:09 (1)	06:44 / 19:06			05:53 / 19:41
26	07:09 / 16:53			06:30 / 17:34	47	07:22 (1) / 08:09 (1)	06:43 / 19:07			05:51 / 19:42
27	07:08 / 16:55			06:29 / 17:35	47	07:21 (1) / 08:08 (1)	06:41 / 19:08			05:50 / 19:43
28	07:07 / 16:56			06:27 / 17:36	46	07:22 (1) / 08:08 (1)	06:39 / 19:09			05:48 / 19:44
29	07:06 / 16:57						06:37 / 19:10			05:47 / 19:46
30	07:05 / 16:59						06:36 / 19:11			05:46 / 19:47
31	07:04 / 17:00						06:34 / 19:13			
Potential sun hours	293			296			370			401
Total, worst case		269			703			448		
Sun reduction		0.48			0.51			0.52		
Oper. time red.		1.00			1.00			1.00		
Wind dir. red.		0.58			0.64			0.64		
Total reduction		0.28			0.32			0.33		
Total, real		75			228			148		

Day	May	June	July	August	September	October	Oct min	Oct flicker	November	Nov min	Nov flicker	December	Dec min	Dec flicker
1	05:44 / 19:48	05:14 / 20:18	05:14 / 20:30	05:40 / 20:11	06:13 / 19:24	06:45 / 18:31	15	08:13 (1) / 08:28 (1)	06:21 / 16:42			06:58 / 16:16	13	08:31 (2) / 08:44 (2)
2	05:43 / 19:49	05:13 / 20:19	05:15 / 20:30	05:41 / 20:09	06:14 / 19:22	06:46 / 18:29	22	08:09 (1) / 08:31 (1)	06:23 / 16:41			06:59 / 16:16	17	08:29 (2) / 08:46 (2)
3	05:42 / 19:50	05:13 / 20:20	05:15 / 20:30	05:42 / 20:08	06:15 / 19:21	06:47 / 18:28	27	08:06 (1) / 08:33 (1)	06:24 / 16:40			07:00 / 16:16	20	08:28 (2) / 08:48 (2)
4	05:40 / 19:51	05:12 / 20:21	05:16 / 20:30	05:43 / 20:07	06:16 / 19:19	06:48 / 18:26	31	08:04 (1) / 08:35 (1)	06:25 / 16:39			07:01 / 16:16	21	08:28 (2) / 08:49 (2)
5	05:39 / 19:52	05:12 / 20:21	05:16 / 20:29	05:44 / 20:06	06:17 / 19:17	06:49 / 18:24	34	08:03 (1) / 08:37 (1)	06:26 / 16:37			07:02 / 16:15	23	08:27 (2) / 08:50 (2)
6	05:38 / 19:53	05:12 / 20:22	05:17 / 20:29	05:45 / 20:05	06:18 / 19:15	06:50 / 18:23	37	08:01 (1) / 08:38 (1)	06:28 / 16:36			07:03 / 16:15	25	08:27 (2) / 08:52 (2)
7	05:36 / 19:54	05:11 / 20:23	05:18 / 20:29	05:46 / 20:03	06:19 / 19:14	06:51 / 18:21	39	08:00 (1) / 08:39 (1)	06:29 / 16:35			07:04 / 16:15	26	08:27 (2) / 08:53 (2)
8	05:35 / 19:56	05:11 / 20:23	05:18 / 20:29	05:47 / 20:02	06:20 / 19:12	06:53 / 18:19	41	07:58 (1) / 08:39 (1)	06:30 / 16:34			07:05 / 16:15	27	08:27 (2) / 08:54 (2)
9	05:34 / 19:57	05:11 / 20:24	05:19 / 20:28	05:48 / 20:01	06:21 / 19:10	06:54 / 18:17	43	07:57 (1) / 08:40 (1)	06:31 / 16:33			07:06 / 16:15	28	08:27 (2) / 08:55 (2)
10	05:33 / 19:58	05:11 / 20:25	05:20 / 20:28	05:49 / 19:58	06:22 / 19:08	06:55 / 18:16	44	07:56 (1) / 08:40 (1)	06:33 / 16:32			07:07 / 16:15	29	08:27 (2) / 08:56 (2)
11	05:32 / 19:59	05:10 / 20:25	05:20 / 20:27	05:50 / 19:57	06:23 / 19:07	06:56 / 18:14	45	07:56 (1) / 08:41 (1)	06:34 / 16:31			07:08 / 16:15	30	08:27 (2) / 08:57 (2)
12	05:30 / 20:00	05:10 / 20:26	05:21 / 20:27	05:51 / 19:55	06:24 / 19:05	06:57 / 18:12	46	07:55 (1) / 08:41 (1)	06:35 / 16:30			07:09 / 16:15	31	08:27 (2) / 08:58 (2)
13	05:29 / 20:00	05:10 / 20:26	05:22 / 20:26	05:52 / 19:54	06:25 / 19:03	06:58 / 18:11	46	07:55 (1) / 08:41 (1)	06:36 / 16:29			07:09 / 16:15	32	08:27 (2) / 08:59 (2)
14	05:28 / 20:01	05:10 / 20:27	05:23 / 20:26	05:53 / 19:53	06:26 / 19:01	07:00 / 18:09	47	07:54 (1) / 08:41 (1)	06:38 / 16:28			07:10 / 16:15	32	08:28 (2) / 09:00 (2)
15	05:27 / 20:02	05:10 / 20:27	05:24 / 20:25	05:54 / 19:51	06:27 / 19:00	07:01 / 18:07	47	07:54 (1) / 08:41 (1)	06:39 / 16:27			07:11 / 16:16	33	08:27 (2) / 09:00 (2)
16	05:26 / 20:03	05:10 / 20:28	05:24 / 20:25	05:55 / 19:50	06:28 / 18:58	07:02 / 18:06	47	07:54 (1) / 08:41 (1)	06:40 / 16:26			07:12 / 16:16	32	08:28 (2) / 09:00 (2)
17	05:25 / 20:04	05:10 / 20:28	05:25 / 20:24	05:56 / 19:48	06:30 / 18:56	07:03 / 18:04	47	07:54 (1) / 08:41 (1)	06:41 / 16:25			07:12 / 16:16	32	08:29 (2) / 09:01 (2)
18	05:24 / 20:05	05:10 / 20:28	05:26 / 20:23	05:58 / 19:47	06:31 / 18:54	07:04 / 18:03	46	07:54 (1) / 08:40 (1)	06:43 / 16:24			07:13 / 16:17	33	08:28 (2) / 09:01 (2)
19	05:23 / 20:06	05:10 / 20:29	05:27 / 20:23	05:59 / 19:45	06:32 / 18:52	07:05 / 18:01	45	07:54 (1) / 08:39 (1)	06:44 / 16:23			07:14 / 16:17	33	08:29 (2) / 09:02 (2)
20	05:22 / 20:07	05:10 / 20:29	05:28 / 20:22	06:00 / 19:44	06:33 / 18:51	07:07 / 18:00	45	07:55 (1) / 08:40 (1)	06:45 / 16:22			07:14 / 16:17	33	08:29 (2) / 09:02 (2)
21	05:21 / 20:08	05:11 / 20:29	05:29 / 20:21	06:01 / 19:42	06:34 / 18:49	07:08 / 17:58	44	07:55 (1) / 08:39 (1)	06:46 / 16:22			07:15 / 16:18	33	08:30 (2) / 09:03 (2)
22	05:21 / 20:09	05:11 / 20:30	05:30 / 20:20	06:02 / 19:40	06:35 / 18:47	07:09 / 17:57	43	07:55 (1) / 08:38 (1)	06:48 / 16:21			07:15 / 16:18	33	08:30 (2) / 09:03 (2)
23	05:20 / 20:10	05:11 / 20:30	05:31 / 20:19	06:03 / 19:39	06:36 / 18:45	07:10 / 17:55	42	07:55 (1) / 08:37 (1)	06:49 / 16:20			07:16 / 16:19	33	08:31 (2) / 09:04 (2)
24	05:19 / 20:11	05:11 / 20:30	05:32 / 20:19	06:04 / 19:37	06:37 / 18:44	07:11 / 17:54	39	07:57 (1) / 08:36 (1)	06:50 / 16:20			07:16 / 16:19	33	08:31 (2) / 09:04 (2)
25	05:18 / 20:12	05:12 / 20:30	05:33 / 20:18	06:05 / 19:36	06:38 / 18:42	07:13 / 17:52	38	07:57 (1) / 08:35 (1)	06:51 / 16:19			07:17 / 16:20	33	08:32 (2) / 09:05 (2)
26	05:17 / 20:13	05:12 / 20:30	05:34 / 20:17	06:06 / 19:34	06:39 / 18:40	07:14 / 17:51	35	07:58 (1) / 08:33 (1)	06:52 / 16:19			07:17 / 16:21	32	08:33 (2) / 09:05 (2)
27	05:17 / 20:14	05:12 / 20:30	05:35 / 20:16	06:07 / 19:32	06:40 / 18:38	07:15 / 17:49	33	08:00 (1) / 08:33 (1)	06:53 / 16:18			07:17 / 16:21	32	08:33 (2) / 09:05 (2)
28	05:16 / 20:15	05:13 / 20:30	05:35 / 20:15	06:08 / 19:31	06:41 / 18:36	07:16 / 17:48	30	08:01 (1) / 08:31 (1)	06:55 / 16:18			07:18 / 16:22	33	08:33 (2) / 09:06 (2)
29	05:15 / 20:16	05:13 / 20:30	05:36 / 20:14	06:09 / 19:29	06:43 / 18:35	07:18 / 17:46	26	08:03 (1) / 08:29 (1)	06:56 / 16:17			07:18 / 16:23	32	08:35 (2) / 09:07 (2)
30	05:15 / 20:17	05:14 / 20:30	05:37 / 20:13	06:10 / 19:27	06:44 / 18:33	07:19 / 17:45	21	08:06 (1) / 08:27 (1)	06:57 / 16:17	8	08:33 (2) / 08:41 (2)	07:18 / 16:23	32	08:35 (2) / 09:07 (2)
31	05:14 / 20:17		05:39 / 20:12	06:11 / 19:26		07:20 / 17:44	14	08:09 (1) / 08:23 (1)				07:18 / 16:24	31	08:36 (2) / 09:07 (2)
Potential sun hours	453	457	464	431	375	343			294			283		
Total, worst case							1159			8			907	
Sun reduction							0.57			0.51			0.48	
Oper. time red.							1.00			1.00			1.00	
Wind dir. red.							0.64			0.58			0.58	
Total reduction							0.36			0.30			0.28	
Total, real							421			2			253	

Table layout: For each day in each month the following matrix apply

Day in month	Sun rise (hh:mm)		First time (hh:mm) with flicker	(WTG causing flicker first time)
	Sun set (hh:mm)	Minutes with flicker	Last time (hh:mm) with flicker	(WTG causing flicker last time)

Project:
MWCC

Printed/Page
05/19/2009 1:57 PM / 8

Licensed user:
Renewable Energy Research Lab, University of Massachusetts at Amherst
160 Governors Drive Amherst
MA 01003 USA
413 545 3914

Calculated:
05/19/2009 11:24 AM/2.6.1.252

SHADOW - Calendar

Calculation: Gardner Middle School added MWCC Two turbines with sun percentages **Shadow receptor:** E - MWCC building

Assumptions for shadow calculations

Maximum distance for influence	2,000 m
Minimum sun height over horizon for influence	3 °
Day step for calculation	1 days
Time step for calculation	1 minutes

Sun shine probabilities (part of time from sun rise to sun set with sun shine)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.48	0.51	0.52	0.51	0.52	0.56	0.59	0.61	0.59	0.57	0.51	0.48

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
390	243	360	460	395	236	131	124	265	665	989	765	1,060	1,229	910	540	8,760

	January			February	March	April	May	June	July	August	September	October	November			December		
1	07:19		11:16 (1)	07:03	06:25	06:32	05:44	05:14	05:14	05:40	06:12	06:45	06:21			06:58		11:06 (1)
	16:25	84	12:40 (1)	17:01	17:37	19:14	19:48	20:18	20:30	20:11	19:24	18:31	16:42			16:16	76	12:22 (1)
2	07:19		11:17 (1)	07:02	06:24	06:30	05:43	05:13	05:15	05:41	06:14	06:46	06:23			06:59		11:05 (1)
	16:26	83	12:40 (1)	17:02	17:38	19:15	19:49	20:19	20:30	20:09	19:22	18:29	16:41			16:16	78	12:23 (1)
3	07:19		11:17 (1)	07:01	06:22	06:29	05:42	05:13	05:15	05:42	06:15	06:47	06:24			07:00		11:05 (1)
	16:27	83	12:40 (1)	17:04	17:40	19:16	19:50	20:20	20:30	20:08	19:21	18:28	16:40			16:16	79	12:24 (1)
4	07:19		11:18 (1)	07:00	06:20	06:27	05:40	05:12	05:16	05:43	06:16	06:48	06:25			07:01		11:05 (1)
	16:28	83	12:41 (1)	17:05	17:41	19:17	19:51	20:21	20:30	20:07	19:19	18:26	16:39			16:16	80	12:25 (1)
5	07:19		11:19 (1)	06:59	06:19	06:25	05:39	05:12	05:16	05:44	06:17	06:49	06:26			07:02		11:05 (1)
	16:29	82	12:41 (1)	17:06	17:42	19:18	19:52	20:21	20:29	20:06	19:17	18:24	16:37			16:15	80	12:25 (1)
6	07:19		11:19 (1)	06:58	06:17	06:24	05:38	05:12	05:17	05:45	06:18	06:50	06:28			07:03		11:05 (1)
	16:30	81	12:40 (1)	17:08	17:43	19:19	19:53	20:22	20:29	20:05	19:15	18:23	16:36			16:15	81	12:26 (1)
7	07:18		11:20 (1)	06:57	06:15	06:22	05:36	05:11	05:18	05:46	06:19	06:51	06:29			07:04		11:05 (1)
	16:31	80	12:40 (1)	17:09	17:45	19:21	19:54	20:23	20:29	20:03	19:14	18:21	16:35			16:15	82	12:27 (1)
8	07:18		11:21 (1)	06:56	07:14	06:20	05:35	05:11	05:18	05:47	06:20	06:53	06:30			07:05		11:05 (1)
	16:32	80	12:41 (1)	17:10	18:46	19:22	19:56	20:23	20:29	20:02	19:12	18:19	16:34			16:15	83	12:28 (1)
9	07:18		11:22 (1)	06:54	07:12	06:18	05:34	05:11	05:19	05:48	06:21	06:54	06:31			07:06		11:05 (1)
	16:33	79	12:41 (1)	17:12	18:47	19:23	19:57	20:24	20:28	20:01	19:10	18:17	16:33			16:15	83	12:28 (1)
10	07:18		11:22 (1)	06:53	07:10	06:17	05:33	05:11	05:20	05:49	06:22	06:55	06:33			07:07		11:06 (1)
	16:34	78	12:40 (1)	17:13	18:48	19:24	19:58	20:25	20:28	19:58	19:08	18:16	16:32			16:15	83	12:29 (1)
11	07:18		11:23 (1)	06:52	07:09	06:15	05:32	05:10	05:20	05:50	06:23	06:56	06:34			07:08		11:06 (1)
	16:35	77	12:40 (1)	17:14	18:49	19:25	19:59	20:25	20:27	19:57	19:07	18:14	16:31			16:15	84	12:30 (1)
12	07:17		11:25 (1)	06:50	07:07	06:13	05:30	05:10	05:21	05:51	06:24	06:57	06:35			07:09		11:06 (1)
	16:36	76	12:41 (1)	17:16	18:51	19:26	20:00	20:26	20:27	19:55	19:05	18:12	16:29			16:15	85	12:31 (1)
13	07:17		11:25 (1)	06:49	07:05	06:12	05:29	05:10	05:22	05:52	06:25	06:58	06:36			07:09		11:07 (1)
	16:37	75	12:40 (1)	17:17	18:52	19:27	20:00	20:26	20:26	19:54	19:03	18:11	16:28			16:15	84	12:31 (1)
14	07:17		11:27 (1)	06:48	07:04	06:10	05:28	05:10	05:23	05:53	06:26	06:59	06:38		11:30 (1)	07:10		11:06 (1)
	16:39	73	12:40 (1)	17:18	18:53	19:28	20:01	20:27	20:26	19:53	19:01	18:09	16:28	20	11:50 (1)	16:15	85	12:31 (1)
15	07:16		11:27 (1)	06:46	07:02	06:09	05:27	05:10	05:24	05:54	06:27	07:01	06:39		11:25 (1)	07:11		11:07 (1)
	16:40	72	12:39 (1)	17:20	18:54	19:30	20:02	20:27	20:25	19:51	19:00	18:07	16:27	30	11:55 (1)	16:16	85	12:32 (1)
16	07:16		11:29 (1)	06:45	07:00	06:07	05:26	05:10	05:24	05:55	06:28	07:02	06:40		11:21 (1)	07:12		11:08 (1)
	16:41	70	12:39 (1)	17:21	18:55	19:31	20:03	20:28	20:25	19:50	18:58	18:06	16:26	38	11:59 (1)	16:16	85	12:33 (1)
17	07:15		11:30 (1)	06:44	06:58	06:05	05:25	05:10	05:25	05:56	06:30	07:03	06:41		11:19 (1)	07:12		11:08 (1)
	16:42	68	12:38 (1)	17:22	18:56	19:32	20:04	20:28	20:24	19:48	18:56	18:04	16:25	43	12:02 (1)	16:16	86	12:34 (1)
18	07:15		11:32 (1)	06:42	06:57	06:04	05:24	05:10	05:26	05:57	06:31	07:04	06:43		11:16 (1)	07:13		11:08 (1)
	16:43	66	12:38 (1)	17:23	18:58	19:33	20:05	20:28	20:23	19:47	18:54	18:03	16:24	49	12:05 (1)	16:17	86	12:34 (1)
19	07:14		11:33 (1)	06:41	06:55	06:02	05:23	05:10	05:27	05:59	06:32	07:05	06:44		11:14 (1)	07:14		11:09 (1)
	16:45	64	12:37 (1)	17:25	18:59	19:34	20:06	20:29	20:23	19:45	18:52	18:01	16:23	52	12:06 (1)	16:17	86	12:35 (1)
20	07:13		11:34 (1)	06:39	06:53	06:01	05:22	05:10	05:28	06:00	06:33	07:07	06:45		11:13 (1)	07:14		11:09 (1)
	16:46	62	12:36 (1)	17:26	19:00	19:35	20:07	20:29	20:22	19:44	18:51	18:00	16:22	56	12:09 (1)	16:17	86	12:35 (1)
21	07:13		11:36 (1)	06:38	06:51	05:59	05:21	05:11	05:29	06:01	06:34	07:08	06:46		11:12 (1)	07:15		11:10 (1)
	16:47	59	12:35 (1)	17:27	19:01	19:36	20:08	20:29	20:21	19:42	18:49	17:58	16:22	59	12:11 (1)	16:18	86	12:36 (1)
22	07:12		11:38 (1)	06:36	06:50	05:57	05:21	05:11	05:30	06:02	06:35	07:09	06:48		11:10 (1)	07:15		11:10 (1)
	16:48	56	12:34 (1)	17:29	19:02	19:38	20:09	20:30	20:20	19:40	18:47	17:56	16:21	62	12:12 (1)	16:18	86	12:36 (1)
23	07:11		11:40 (1)	06:35	06:48	05:56	05:20	05:11	05:31	06:03	06:36	07:10	06:49		11:10 (1)	07:16		11:11 (1)
	16:49	52	12:32 (1)	17:30	19:03	19:39	20:10	20:30	20:19	19:39	18:45	17:55	16:20	64	12:14 (1)	16:19	86	12:37 (1)
24	07:11		11:42 (1)	06:33	06:46	05:54	05:19	05:11	05:32	06:04	06:37	07:11	06:50		11:09 (1)	07:16		11:11 (1)
	16:51	49	12:31 (1)	17:31	19:05	19:40	20:11	20:30	20:19	19:37	18:44	17:53	16:20	66	12:15 (1)	16:19	86	12:37 (1)
25	07:10		11:45 (1)	06:32	06:44	05:53	05:18	05:12	05:33	06:05	06:38	07:13	06:51		11:08 (1)	07:17		11:12 (1)
	16:52	43	12:28 (1)	17:32	19:06	19:41	20:12	20:30	20:18	19:36	18:42	17:52	16:19	68	12:16 (1)	16:20	86	12:38 (1)
26	07:09		11:48 (1)	06:30	06:43	05:51	05:17	05:12	05:34	06:06	06:39	07:14	06:52		11:07 (1)	07:17		11:12 (1)
	16:53	38	12:26 (1)	17:34	19:07	19:42	20:13	20:30	20:17	19:34	18:40	17:51	16:19	70	12:17 (1)	16:21	86	12:38 (1)
27	07:08		11:52 (1)	06:29	06:41	05:50	05:17	05:12	05:34	06:07	06:40	07:15	06:53		11:06 (1)	07:17		11:13 (1)
	16:55	30	12:22 (1)	17:35	19:08	19:43	20:14	20:30	20:16	19:32	18:38	17:49	16:18	72	12:18 (1)	16:21	85	12:38 (1)
28	07:07		11:58 (1)	06:27	06:39	05:48	05:16	05:13	05:35	06:08	06:41	07:16	06:55		11:07 (1)	07:18		11:13 (1)
	16:56	19	12:17 (1)	17:36	19:09	19:44	20:15	20:30	20:15	19:31	18:36	17:48	16:18	73	12:20 (1)	16:22	85	12:38 (1)
29	07:06				06:37	05:47	05:15	05:13	05:36	06:09	06:43	07:18	06:56		11:06 (1)	07:18		11:14 (1)
	16:57				19:10	19:45	20:16	20:30	20:14	19:29	18:35	17:46	16:17	75	12:21 (1)	16:23	85	12:39 (1)
30	07:05				06:36	05:46	05:15	05:14	05:37	06:10	06:44	07:19	06:57		11:06 (1)	07:18		11:15 (1)
	16:59				19:11	19:47	20:16	20:30	20:13	19:27	18:33	17:45	16:17	76	12:22 (1)	16:23	84	12:39 (1)
31	07:04				06:34		05:14		05:38	06:11		07:20				07:18		11:15 (1)
	17:00				19:13		20:17		20:12	19:26		17:44				16:24	85	12:40 (1)
Potential sun hours	293			295	370	401	453	457	464	431	375	343	294			283		
Total, worst case		1862												973			2597	
Sun reduction		0.48												0.51			0.48	
Oper. time red.		1.00												1.00			1.00	
Wind dir. red.		0.58												0.58			0.58	
Total reduction		0.28												0.29			0.28	
Total, real		516												287			720	

Table layout: For each day in each month the following matrix apply

Day in month	Sun rise (hh:mm)		First time (hh:mm) with flicker	(WTG causing flicker first time)
	Sun set (hh:mm)	Minutes with flicker	Last time (hh:mm) with flicker	(WTG causing flicker last time)

Project:
MWCC

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05/19/2009 1:57 PM / 9

Licensed user:
Renewable Energy Research Lab, University of Massachusetts at Amherst
160 Governors Drive Amherst
MA 01003 USA
413 545 3914

Calculated:
05/19/2009 11:24 AM/2.6.1.252

SHADOW - Calendar

Calculation: Gardner Middle School added MWCC Two turbines with sun percentages **Shadow receptor:** F - Eaton Street

Assumptions for shadow calculations

Maximum distance for influence	2,000 m
Minimum sun height over horizon for influence	3 °
Day step for calculation	1 days
Time step for calculation	1 minutes

Sun shine probabilities (part of time from sun rise to sun set with sun shine)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.48	0.51	0.52	0.51	0.52	0.56	0.59	0.61	0.59	0.57	0.51	0.48

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
390	243	360	460	395	236	131	124	265	665	989	765	1,060	1,229	910	540	8,760

	January	February	March	April	May	June	July	August	September	October	November	December
1	07:19	07:03	06:25	06:32	05:44	05:14	05:14	05:40	06:12	06:45	06:21	06:58
	16:25	17:01	17:37	19:14	19:48	20:18	20:30	20:11	19:24	18:31	16:42	16:16
2	07:19	07:02	06:24	06:30	05:43	05:13	05:15	05:41	06:14	06:46	06:23	06:59
	16:26	17:02	17:39	19:15	19:49	20:19	20:30	20:09	19:22	18:29	16:41	16:16
3	07:19	07:01	06:22	06:29	05:42	05:13	05:15	05:42	06:15	06:47	06:24	07:00
	16:27	17:04	17:40	19:16	19:50	20:20	20:30	20:08	19:21	18:28	16:40	16:16
4	07:19	07:00	06:20	06:27	05:40	05:12	05:16	05:43	06:16	06:48	06:25	07:01
	16:28	17:05	17:41	19:17	19:51	20:21	20:30	20:07	19:19	18:26	16:39	16:16
5	07:19	06:59	06:19	06:25	05:39	05:12	05:16	05:44	06:17	06:49	06:26	07:02
	16:29	17:06	17:42	19:18	19:52	20:21	20:29	20:06	19:17	18:24	16:37	16:15
6	07:19	06:58	06:17	06:24	05:38	05:12	05:17	05:45	06:18	06:50	06:28	07:03
	16:30	17:08	17:43	19:19	19:53	20:22	20:29	20:05	19:15	18:23	16:36	16:15
7	07:19	06:57	06:15	06:22	05:36	05:11	05:18	05:46	06:19	06:51	06:29	07:04
	16:31	17:09	17:45	19:21	19:54	20:23	20:29	20:03	19:14	18:21	16:35	16:15
8	07:18	06:56	07:14	06:20	05:35	05:11	05:18	05:47	06:20	06:53	06:30	07:05
	16:32	17:10	18:46	19:22	19:56	20:23	20:29	20:02	19:12	18:19	16:34	16:15
9	07:18	06:54	07:12	06:18	05:34	05:11	05:19	05:48	06:21	06:54	06:31	07:06
	16:33	17:12	18:47	19:23	19:57	20:24	20:28	20:01	19:10	18:17	16:33	16:15
10	07:18	06:53	07:10	06:17	05:33	05:11	05:20	05:49	06:22	06:55	06:33	07:07
	16:34	17:13	18:48	19:24	19:58	20:25	20:28	19:58	19:08	18:16	16:32	16:15
11	07:18	06:52	07:09	06:15	05:32	05:10	05:20	05:50	06:23	06:56	06:34	07:08
	16:35	17:14	18:49	19:25	19:59	20:25	20:27	19:57	19:07	18:14	16:31	16:15
12	07:17	06:50	07:07	06:13	05:30	05:10	05:21	05:51	06:24	06:57	06:35	07:09
	16:36	17:16	18:51	19:26	20:00	20:26	20:27	19:55	19:05	18:12	16:29	16:15
13	07:17	06:49	07:05	06:12	05:29	05:10	05:22	05:52	06:25	06:58	06:36	07:09
	16:37	17:17	18:52	19:27	20:00	20:26	20:26	19:54	19:03	18:11	16:28	16:15
14	07:17	06:48	07:04	06:10	05:28	05:10	05:23	05:53	06:26	07:00	06:38	07:10
	16:39	17:18	18:53	19:28	20:01	20:27	20:26	19:53	19:01	18:09	16:28	16:15
15	07:16	06:46	07:02	06:09	05:27	05:10	05:24	05:54	06:27	07:01	06:39	07:11
	16:40	17:20	18:54	19:30	20:02	20:27	20:25	19:51	19:00	18:07	16:27	16:16
16	07:16	06:45	07:00	06:07	05:26	05:10	05:24	05:55	06:28	07:02	06:40	07:12
	16:41	17:21	18:55	19:31	20:03	20:28	20:25	19:50	18:58	18:06	16:26	16:16
17	07:15	06:44	06:58	06:05	05:25	05:10	05:25	05:56	06:30	07:03	06:41	07:12
	16:42	17:22	18:56	19:32	20:04	20:28	20:24	19:48	18:56	18:04	16:25	16:16
18	07:15	06:42	06:57	06:04	05:24	05:10	05:26	05:57	06:31	07:04	06:43	07:13
	16:43	17:23	18:58	19:33	20:05	20:28	20:23	19:47	18:54	18:03	16:24	16:17
19	07:14	06:41	06:55	06:02	05:23	05:10	05:27	05:59	06:32	07:05	06:44	07:14
	16:45	17:25	18:59	19:34	20:06	20:29	20:23	19:45	18:52	18:01	16:23	16:17
20	07:14	06:39	06:53	06:01	05:22	05:10	05:28	06:00	06:33	07:07	06:45	07:14
	16:46	17:26	19:00	19:35	20:07	20:29	20:22	19:44	18:51	18:00	16:22	16:17
21	07:13	06:38	06:51	05:59	05:21	05:11	05:29	06:01	06:34	07:08	06:46	07:15
	16:47	17:27	19:01	19:36	20:08	20:29	20:21	19:42	18:49	17:58	16:22	16:18
22	07:12	06:36	06:50	05:57	05:21	05:11	05:30	06:02	06:35	07:09	06:48	07:15
	16:48	17:29	19:02	19:38	20:09	20:30	20:20	19:40	18:47	17:56	16:21	16:18
23	07:11	06:35	06:48	05:56	05:20	05:11	05:31	06:03	06:36	07:10	06:49	07:16
	16:49	17:30	19:03	19:39	20:10	20:30	20:19	19:39	18:45	17:55	16:20	16:19
24	07:11	06:33	06:46	05:54	05:19	05:11	05:32	06:04	06:37	07:11	06:50	07:16
	16:51	17:31	19:05	19:40	20:11	20:30	20:19	19:37	18:44	17:53	16:20	16:19
25	07:10	06:32	06:44	05:53	05:18	05:12	05:33	06:05	06:38	07:13	06:51	07:17
	16:52	17:32	19:06	19:41	20:12	20:30	20:18	19:36	18:42	17:52	16:19	16:20
26	07:09	06:30	06:43	05:51	05:17	05:12	05:34	06:06	06:39	07:14	06:52	07:17
	16:53	17:34	19:07	19:42	20:13	20:30	20:17	19:34	18:40	17:51	16:19	16:21
27	07:08	06:29	06:41	05:50	05:17	05:12	05:34	06:07	06:40	07:15	06:53	07:17
	16:55	17:35	19:08	19:43	20:14	20:30	20:16	19:32	18:38	17:49	16:18	16:21
28	07:07	06:27	06:39	05:48	05:16	05:13	05:35	06:08	06:41	07:16	06:55	07:18
	16:56	17:36	19:09	19:44	20:15	20:30	20:15	19:31	18:36	17:48	16:18	16:22
29	07:06		06:37	05:47	05:15	05:13	05:36	06:09	06:43	07:18	06:56	07:18
	16:57		19:10	19:46	20:16	20:30	20:14	19:29	18:35	17:46	16:17	16:23
30	07:05		06:36	05:46	05:15	05:14	05:37	06:10	06:44	07:19	06:57	07:18
	16:59		19:11	19:47	20:17	20:30	20:13	19:27	18:33	17:45	16:17	16:23
31	07:04		06:34		05:14		05:38	06:11		07:20		07:18
	17:00		19:13		20:17		20:12	19:26		17:44		16:24
Potential sun hours	293	295	370	401	453	457	464	431	375	343	294	283
Total, worst case												
Sun reduction												
Oper. time red.												
Wind dir. red.												
Total reduction												
Total, real												

Table layout: For each day in each month the following matrix apply

Day in month	Sun rise (hh:mm)		First time (hh:mm) with flicker	(WTG causing flicker first time)
	Sun set (hh:mm)	Minutes with flicker	Last time (hh:mm) with flicker	(WTG causing flicker last time)

Project:
MWCC

Printed/Page
05/19/2009 1:57 PM / 10

Licensed user:
Renewable Energy Research Lab, University of Massachusetts at Amherst
160 Governors Drive Amherst
MA 01003 USA
413 545 3914

Calculated:
05/19/2009 11:24 AM/2.6.1.252

SHADOW - Calendar

Calculation: Gardner Middle School added MWCC Two turbines with sun percentages **Shadow receptor:** G - Gardner Middle School

Assumptions for shadow calculations

Maximum distance for influence	2,000 m
Minimum sun height over horizon for influence	3 °
Day step for calculation	1 days
Time step for calculation	1 minutes

Sun shine probabilities (part of time from sun rise to sun set with sun shine)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.48	0.51	0.52	0.51	0.52	0.56	0.59	0.61	0.59	0.57	0.51	0.48

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
390	243	360	460	395	236	131	124	265	665	989	765	1,060	1,229	910	540	8,760

	January	February	March	April	May			June			July			August			September	October	November	December
1	07:18	07:03	06:25	06:32	05:44			05:14		19:02 (2)	05:14		19:11 (2)	05:40		19:13 (2)	06:12	06:45	06:21	06:58
	16:25	17:01	17:37	19:14	19:48			20:18	34	19:36 (2)	20:30	27	19:38 (2)	20:11	30	19:43 (2)	19:24	18:31	16:42	16:16
2	07:19	07:02	06:24	06:30	05:43			05:13		19:03 (2)	05:15		19:12 (2)	05:41		19:13 (2)	06:14	06:46	06:23	06:59
	16:26	17:02	17:38	19:15	19:49			20:19	33	19:36 (2)	20:30	27	19:39 (2)	20:09	29	19:42 (2)	19:22	18:29	16:41	16:16
3	07:19	07:01	06:22	06:29	05:42			05:13		19:03 (2)	05:15		19:11 (2)	05:42		19:14 (2)	06:15	06:47	06:24	07:00
	16:27	17:04	17:40	19:16	19:50			20:20	32	19:35 (2)	20:30	28	19:39 (2)	20:08	27	19:41 (2)	19:21	18:28	16:40	16:16
4	07:19	07:00	06:20	06:27	05:40			05:12		19:04 (2)	05:16		19:11 (2)	05:43		19:15 (2)	06:16	06:48	06:25	07:01
	16:28	17:05	17:41	19:17	19:51			20:20	31	19:35 (2)	20:30	29	19:40 (2)	20:07	25	19:40 (2)	19:19	18:26	16:38	16:16
5	07:19	06:59	06:19	06:25	05:39		19:12 (2)	05:12		19:05 (2)	05:16		19:12 (2)	05:44		19:16 (2)	06:17	06:49	06:26	07:02
	16:29	17:06	17:42	19:18	19:52	11	19:23 (2)	20:21	31	19:36 (2)	20:29	29	19:41 (2)	20:06	23	19:39 (2)	19:17	18:24	16:37	16:15
6	07:19	06:58	06:17	06:24	05:38		19:09 (2)	05:12		19:05 (2)	05:17		19:11 (2)	05:45		19:18 (2)	06:18	06:50	06:28	07:03
	16:30	17:08	17:43	19:19	19:53	17	19:26 (2)	20:22	30	19:35 (2)	20:29	30	19:41 (2)	20:05	19	19:37 (2)	19:15	18:22	16:36	16:15
7	07:18	06:57	06:15	06:22	05:36		19:08 (2)	05:11		19:05 (2)	05:18		19:11 (2)	05:46		19:20 (2)	06:19	06:51	06:29	07:04
	16:31	17:09	17:45	19:20	19:54	20	19:28 (2)	20:23	30	19:35 (2)	20:29	31	19:42 (2)	20:03	15	19:35 (2)	19:14	18:21	16:35	16:15
8	07:18	06:56	07:14	06:20	05:35		19:06 (2)	05:11		19:06 (2)	05:18		19:11 (2)	05:47		19:23 (2)	06:20	06:53	06:30	07:05
	16:32	17:10	18:46	19:22	19:56	24	19:30 (2)	20:23	29	19:35 (2)	20:29	32	19:43 (2)	20:02	9	19:32 (2)	19:12	18:19	16:34	16:15
9	07:18	06:54	07:12	06:18	05:34		19:05 (2)	05:11		19:07 (2)	05:19		19:11 (2)	05:48			06:21	06:54	06:31	07:06
	16:33	17:12	18:47	19:23	19:57	26	19:31 (2)	20:24	28	19:35 (2)	20:28	31	19:42 (2)	20:01			19:10	18:17	16:33	16:15
10	07:18	06:53	07:10	06:17	05:33		19:03 (2)	05:11		19:06 (2)	05:20		19:11 (2)	05:49			06:22	06:55	06:33	07:07
	16:34	17:13	18:48	19:24	19:58	28	19:31 (2)	20:25	28	19:34 (2)	20:28	32	19:43 (2)	19:58			19:08	18:16	16:32	16:15
11	07:18	06:52	07:09	06:15	05:32		19:02 (2)	05:10		19:07 (2)	05:20		19:11 (2)	05:50			06:23	06:56	06:34	07:08
	16:35	17:14	18:49	19:25	19:59	30	19:32 (2)	20:25	27	19:34 (2)	20:27	33	19:44 (2)	19:57			19:07	18:14	16:31	16:15
12	07:17	06:50	07:07	06:13	05:30		19:02 (2)	05:10		19:08 (2)	05:21		19:10 (2)	05:51			06:24	06:57	06:35	07:09
	16:36	17:16	18:51	19:26	20:00	31	19:33 (2)	20:26	26	19:34 (2)	20:27	33	19:43 (2)	19:55			19:05	18:12	16:29	16:15
13	07:17	06:49	07:05	06:12	05:29		19:01 (2)	05:10		19:08 (2)	05:22		19:10 (2)	05:52			06:25	06:58	06:36	07:09
	16:37	17:17	18:52	19:27	20:00	33	19:34 (2)	20:26	26	19:34 (2)	20:26	34	19:44 (2)	19:54			19:03	18:11	16:28	16:15
14	07:17	06:48	07:04	06:10	05:28		19:01 (2)	05:10		19:09 (2)	05:23		19:10 (2)	05:53			06:26	06:59	06:38	07:10
	16:39	17:18	18:53	19:28	20:01	33	19:34 (2)	20:27	25	19:34 (2)	20:26	35	19:45 (2)	19:52			19:01	18:09	16:28	16:15
15	07:16	06:46	07:02	06:08	05:27		19:00 (2)	05:10		19:09 (2)	05:24		19:10 (2)	05:54			06:27	07:01	06:39	07:11
	16:40	17:20	18:54	19:30	20:02	34	19:34 (2)	20:27	25	19:34 (2)	20:25	35	19:45 (2)	19:51			19:00	18:07	16:27	16:16
16	07:16	06:45	07:00	06:07	05:26		19:00 (2)	05:10		19:09 (2)	05:24		19:09 (2)	05:55			06:28	07:02	06:40	07:12
	16:41	17:21	18:55	19:31	20:03	35	19:35 (2)	20:28	25	19:34 (2)	20:25	36	19:45 (2)	19:50			18:58	18:06	16:26	16:16
17	07:15	06:44	06:58	06:05	05:25		19:00 (2)	05:10		19:10 (2)	05:25		19:10 (2)	05:56			06:30	07:03	06:41	07:12
	16:42	17:22	18:56	19:32	20:04	35	19:35 (2)	20:28	24	19:34 (2)	20:24	35	19:45 (2)	19:48			18:56	18:04	16:25	16:16
18	07:15	06:42	06:57	06:04	05:24		18:59 (2)	05:10		19:10 (2)	05:26		19:10 (2)	05:57			06:31	07:04	06:43	07:13
	16:43	17:23	18:58	19:33	20:05	36	19:35 (2)	20:28	24	19:34 (2)	20:23	35	19:45 (2)	19:47			18:54	18:03	16:24	16:17
19	07:14	06:41	06:55	06:02	05:23		19:00 (2)	05:10		19:10 (2)	05:27		19:10 (2)	05:59			06:32	07:05	06:44	07:14
	16:45	17:25	18:59	19:34	20:06	36	19:36 (2)	20:29	24	19:34 (2)	20:23	36	19:46 (2)	19:45			18:52	18:01	16:23	16:17
20	07:13	06:39	06:53	06:00	05:22		19:00 (2)	05:10		19:11 (2)	05:28		19:10 (2)	06:00			06:33	07:07	06:45	07:14
	16:46	17:26	19:00	19:35	20:07	36	19:36 (2)	20:29	24	19:35 (2)	20:22	36	19:46 (2)	19:44			18:51	18:00	16:22	16:17
21	07:13	06:38	06:51	05:59	05:21		19:00 (2)	05:11		19:11 (2)	05:29		19:10 (2)	06:01			06:34	07:08	06:46	07:15
	16:47	17:27	19:01	19:36	20:08	36	19:36 (2)	20:29	24	19:35 (2)	20:21	36	19:46 (2)	19:42			18:49	17:58	16:22	16:18
22	07:12	06:36	06:50	05:57	05:21		19:00 (2)	05:11		19:11 (2)	05:30		19:10 (2)	06:02			06:35	07:09	06:48	07:15
	16:48	17:29	19:02	19:38	20:09	36	19:36 (2)	20:29	24	19:35 (2)	20:20	37	19:47 (2)	19:40			18:47	17:56	16:21	16:18
23	07:11	06:35	06:48	05:56	05:20		18:59 (2)	05:11		19:11 (2)	05:31		19:10 (2)	06:03			06:36	07:10	06:49	07:16
	16:49	17:30	19:03	19:39	20:10	37	19:36 (2)	20:30	24	19:35 (2)	20:19	37	19:47 (2)	19:39			18:45	17:55	16:20	16:19
24	07:11	06:33	06:46	05:54	05:19		19:00 (2)	05:11		19:12 (2)	05:32		19:10 (2)	06:04			06:37	07:11	06:50	07:16
	16:51	17:31	19:05	19:40	20:11	36	19:36 (2)	20:30	24	19:36 (2)	20:19	36	19:46 (2)	19:37			18:44	17:53	16:20	16:19
25	07:10	06:32	06:44	05:53	05:18		19:00 (2)	05:12		19:12 (2)	05:33		19:10 (2)	06:05			06:38	07:13	06:51	07:17
	16:52	17:32	19:06	19:41	20:12	36	19:36 (2)	20:30	24	19:36 (2)	20:18	36	19:46 (2)	19:36			18:42	17:52	16:19	16:20
26	07:09	06:30	06:43	05:51	05:17		19:00 (2)	05:12		19:11 (2)	05:33		19:10 (2)	06:06			06:39	07:14	06:52	07:17
	16:53	17:34	19:07	19:42	20:13	36	19:36 (2)	20:30	25	19:36 (2)	20:17	36	19:46 (2)	19:34			18:40	17:51	16:19	16:21
27	07:08	06:29	06:41	05:50	05:17		19:01 (2)	05:12		19:12 (2)	05:34		19:10 (2)	06:07			06:40	07:15	06:53	07:17
	16:55	17:35	19:08	19:43	20:14	35	19:36 (2)	20:30	25	19:37 (2)	20:16	35	19:45 (2)	19:32			18:38	17:49	16:18	16:21
28	07:07	06:27	06:39	05:48	05:16		19:01 (2)	05:13		19:12 (2)	05:35		19:11 (2)	06:08			06:41	07:16	06:55	07:18
	16:56	17:36	19:09	19:44	20:15	35	19:36 (2)	20:30	25	19:37 (2)	20:15	34	19:45 (2)	19:31			18:36	17:48	16:18	16:22
29	07:06		06:37	05:47	05:15		19:02 (2)	05:13		19:11 (2)	05:36		19:11 (2)	06:09			06:43	07:18	06:56	07:18
	16:57		19:10	19:45	20:16	34	19:36 (2)	20:30	26	19:37 (2)	20:14	34	19:45 (2)	19:29			18:35	17:46	16:17	16:23
30	07:05		06:36	05:46	05:15		19:02 (2)	05:14		19:12 (2)	05:37		19:11 (2)	06:10			06:44	07:19	06:57	07:18
	16:59		19:11	19:47	20:16	34	19:36 (2)	20:30	26	19:38 (2)	20:13	33	19:44 (2)	19:27			18:33	17:45	16:17	16:23
31	07:04		06:34		05:14		19:03 (2)				05:38		19:12 (2)	06:11				07:20		07:18
	17:00		19:13		20:17	33	19:36 (2)				20:12	32	19:44 (2)	19:26				17:44		16:24
Potential sun hours	293	295	370	401	453			457			464			431			375	343	294	283
Total, worst case						853			803			1030			177					
Sun reduction						0.52			0.56			0.59			0.61					
Oper. time red.						1.00			1.00			1.00			1.00					
Wind dir. red.						0.65			0.65			0.65			0.65					
Total reduction						0.34			0.36			0.38			0.40					
Total, real						289			293			395			70					

Table layout: For each day in each month the following matrix apply

Day in month	Sun rise (hh:mm)		First time (hh:mm) with flicker	(WTG causing flicker first time)
	Sun set (hh:mm)	Minutes with flicker	Last time (hh:mm) with flicker	(WTG causing flicker last time)

Project:
MWCC

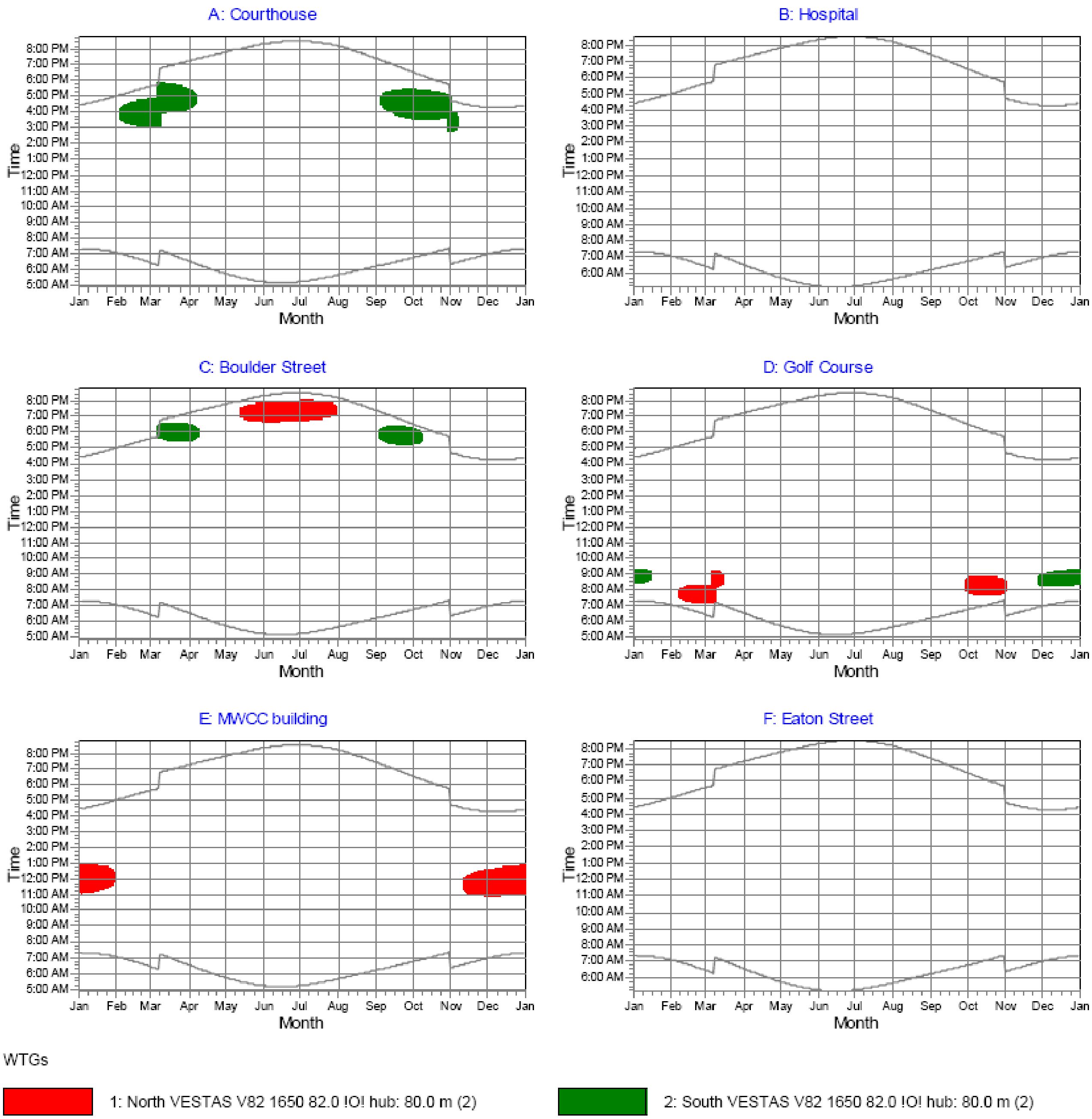
Printed/Page
05/19/2009 1:57 PM / 11

Licensed user:
Renewable Energy Research Lab, University of Massachusetts at Amherst
160 Governors Drive Amherst
MA 01003 USA
413 545 3914

Calculated:
05/19/2009 11:24 AM/2.6.1.252

SHADOW - Calendar, graphical

Calculation: Gardner Middle School added MWCC Two turbines with sun percentages



Project:
MWCC

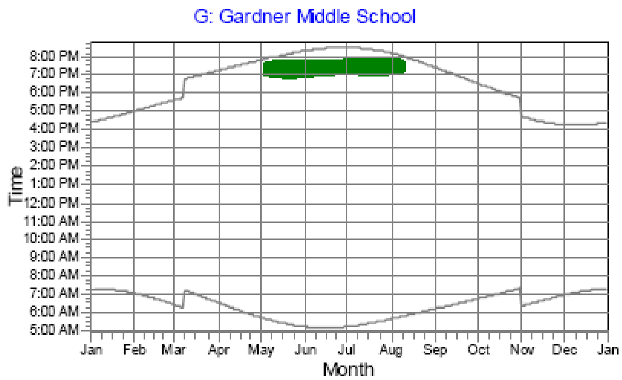
Printed/Page
05/19/2009 1:57 PM / 12

Licensed user:
Renewable Energy Research Lab, University of Massachusetts at Amherst
160 Governors Drive Amherst
MA 01003 USA
413 545 3914

Calculated:
05/19/2009 11:24 AM/2.6.1.252

SHADOW - Calendar, graphical

Calculation: Gardner Middle School added MWCC Two turbines with sun percentages



WTGs

2: South VESTAS V82 1650 82.0 !O! hub: 80.0 m (2)

Project:
MWCC

Printed/Page
05/19/2009 1:57 PM / 13

Licensed user:
Renewable Energy Research Lab, University of Massachusetts at Amherst
160 Governors Drive Amherst
MA 01003 USA
413 545 3914

Calculated:
05/19/2009 11:24 AM/2.6.1.252

SHADOW - Calendar per WTG

Calculation: Gardner Middle School added MWCC Two turbines with sun percentages **WTG:** 1 - North VESTAS V82 1650 82.0 !O! hub: 80.0 m (2)

Assumptions for shadow calculations

Maximum distance for influence	2,000 m
Minimum sun height over horizon for influence	3 °
Day step for calculation	1 days
Time step for calculation	1 minutes

Sun shine probabilities (part of time from sun rise to sun set with sun shine)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.48	0.51	0.52	0.51	0.52	0.56	0.59	0.61	0.59	0.57	0.51	0.48

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
390	243	360	460	395	236	131	124	265	665	989	765	1,060	1,229	910	540	8,760

	January		February		March		April		May		June	
1	07:19	11:16-12:40/84	07:03		06:25	07:21-08:08/47	06:32		05:44		05:14	18:54-19:40/46
	16:25		17:01		17:37		19:14		19:48		20:18	
2	07:19	11:17-12:40/83	07:02		06:24	07:22-08:08/46	06:30		05:43		05:13	18:54-19:41/47
	16:26		17:02		17:39		19:15		19:49		20:19	
3	07:19	11:17-12:40/83	07:01		06:22	07:22-08:06/44	06:29		05:42		05:13	18:53-19:41/48
	16:27		17:04		17:40		19:16		19:50		20:20	
4	07:19	11:18-12:41/83	07:00		06:20	07:22-08:05/43	06:27		05:40		05:12	18:54-19:41/47
	16:28		17:05		17:41		19:17		19:51		20:20	
5	07:19	11:19-12:41/82	06:59		06:19	07:23-08:05/42	06:25		05:39		05:12	18:54-19:42/48
	16:29		17:06		17:42		19:18		19:52		20:21	
6	07:19	11:19-12:40/81	06:58		06:17	07:24-08:03/39	06:24		05:38		05:12	18:53-19:42/49
	16:30		17:08		17:43		19:19		19:53		20:22	
7	07:18	11:20-12:40/80	06:57		06:15	07:24-08:02/38	06:22		05:36		05:11	18:53-19:42/49
	16:31		17:09		17:45		19:21		19:54		20:23	
8	07:18	11:21-12:41/80	06:56		07:14	08:25-09:00/35	06:20		05:35		05:11	18:54-19:43/49
	16:32		17:10		18:46		19:22		19:56		20:23	
9	07:18	11:22-12:41/79	06:54		07:12	08:27-08:59/32	06:18		05:34		05:11	18:54-19:44/50
	16:33		17:12		18:47		19:23		19:57		20:24	
10	07:18	11:22-12:40/78	06:53	07:44-07:49/5	07:10	08:28-08:56/28	06:17		05:33		05:11	18:53-19:43/50
	16:34		17:13		18:48		19:24		19:58		20:25	
11	07:18	11:23-12:40/77	06:52	07:38-07:54/16	07:09	08:29-08:54/25	06:15		05:32		05:10	18:53-19:44/51
	16:35		17:14		18:49		19:25		19:59		20:25	
12	07:17	11:25-12:41/76	06:50	07:35-07:58/23	07:07	08:32-08:51/19	06:13		05:30		05:10	18:54-19:44/50
	16:36		17:16		18:51		19:26		20:00		20:26	
13	07:17	11:25-12:40/75	06:49	07:33-07:59/26	07:05	08:36-08:46/10	06:12		05:29		05:10	18:54-19:44/50
	16:37		17:17		18:52		19:27		20:00		20:26	
14	07:17	11:27-12:40/73	06:48	07:31-08:02/31	07:04		06:10		05:28		05:10	18:54-19:45/51
	16:39		17:18		18:53		19:28		20:01		20:27	
15	07:16	11:27-12:39/72	06:46	07:30-08:03/33	07:02		06:09		05:27		05:10	18:54-19:45/51
	16:40		17:20		18:54		19:30		20:02		20:27	
16	07:16	11:29-12:39/70	06:45	07:28-08:04/36	07:00		06:07		05:26	19:09-19:22/13	05:10	18:54-19:45/51
	16:41		17:21		18:55		19:31		20:03		20:28	
17	07:15	11:30-12:38/68	06:44	07:27-08:06/39	06:58		06:05		05:25	19:06-19:25/19	05:10	18:54-19:45/51
	16:42		17:22		18:56		19:32		20:04		20:28	
18	07:15	11:32-12:38/66	06:42	07:26-08:06/40	06:57		06:04		05:24	19:03-19:27/24	05:10	18:54-19:45/51
	16:43		17:23		18:58		19:33		20:05		20:28	
19	07:14	11:33-12:37/64	06:41	07:25-08:07/42	06:55		06:02		05:23	19:03-19:29/26	05:10	18:54-19:46/52
	16:45		17:25		18:59		19:34		20:06		20:29	
20	07:13	11:34-12:36/62	06:39	07:24-08:07/43	06:53		06:01		05:22	19:01-19:31/30	05:10	18:55-19:47/52
	16:46		17:26		19:00		19:35		20:07		20:29	
21	07:13	11:36-12:35/59	06:38	07:24-08:08/44	06:51		05:59		05:21	19:00-19:32/32	05:11	18:55-19:47/52
	16:47		17:27		19:01		19:36		20:08		20:29	
22	07:12	11:38-12:34/56	06:36	07:23-08:08/45	06:50		05:57		05:21	18:59-19:33/34	05:11	18:55-19:47/52
	16:48		17:29		19:02		19:38		20:09		20:30	
23	07:11	11:40-12:32/52	06:35	07:23-08:09/46	06:48		05:56		05:20	18:57-19:33/36	05:11	18:55-19:47/52
	16:50		17:30		19:03		19:39		20:10		20:30	
24	07:11	11:42-12:31/49	06:33	07:22-08:09/47	06:46		05:54		05:19	18:57-19:35/38	05:11	18:56-19:47/51
	16:51		17:31		19:05		19:40		20:11		20:30	
25	07:10	11:45-12:28/43	06:32	07:22-08:09/47	06:44		05:53		05:18	18:56-19:36/40	05:12	18:56-19:47/51
	16:52		17:32		19:06		19:41		20:12		20:30	
26	07:09	11:48-12:26/38	06:30	07:22-08:09/47	06:43		05:51		05:17	18:55-19:36/41	05:12	18:56-19:47/51
	16:53		17:34		19:07		19:42		20:13		20:30	
27	07:08	11:52-12:22/30	06:29	07:21-08:08/47	06:41		05:50		05:17	18:56-19:37/41	05:12	18:57-19:48/51
	16:55		17:35		19:08		19:43		20:14		20:30	
28	07:07	11:58-12:17/19	06:27	07:22-08:08/46	06:39		05:48		05:16	18:55-19:38/43	05:13	18:57-19:48/51
	16:56		17:36		19:09		19:44		20:15		20:30	
29	07:06				06:37		05:47		05:15	18:55-19:39/44	05:13	18:57-19:47/50
	16:57				19:10		19:45		20:16		20:30	
30	07:05				06:36		05:46		05:15	18:54-19:39/45	05:14	18:58-19:48/50
	16:59				19:11		19:47		20:16		20:30	
31	07:04				06:34				05:14	18:54-19:40/46		
	17:00				19:13				20:17			
Potential sun hours	293		295		370		401		453		457	
Sum of minutes with flicker		1862		703		448		0		552		1504

Table layout: For each day in each month the following matrix apply

Day in month	Sun rise (hh:mm)	First time (hh:mm) with flicker-Last time (hh:mm) with flicker/Minutes with flicker
	Sun set (hh:mm)	First time (hh:mm) with flicker-Last time (hh:mm) with flicker/Minutes with flicker

Project:	Printed/Page
MWCC	05/19/2009 1:57 PM / 14
	Licensed user:
	Renewable Energy Research Lab, University of Massachusetts at Amherst 160 Governors Drive Amherst MA 01003 USA 413 545 3914
	Calculated:
	05/19/2009 11:24 AM/2.6.1.252

SHADOW - Calendar per WTG

Calculation: Gardner Middle School added MWCC Two turbines with sun percentages **WTG:** 1 - North VESTAS V82 1650 82.0 !O! hub: 80.0 m (2)

Assumptions for shadow calculations

Maximum distance for influence	2,000 m
Minimum sun height over horizon for influence	3 °
Day step for calculation	1 days
Time step for calculation	1 minutes

Sun shine probabilities (part of time from sun rise to sun set with sun shine)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.48	0.51	0.52	0.51	0.52	0.56	0.59	0.61	0.59	0.57	0.51	0.48

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
390	243	360	460	395	236	131	124	265	665	989	765	1,060	1,229	910	540	8,760

	July		August	September	October		November		December	
1	05:14	18:57-19:48/51	05:40	06:12	06:45	08:13-08:28/15	06:21		06:58	11:06-12:22/76
	20:30		20:11	19:24	18:31		16:42		16:16	
2	05:15	18:58-19:48/50	05:41	06:14	06:46	08:09-08:31/22	06:23		06:59	11:05-12:23/78
	20:30		20:09	19:22	18:29		16:41		16:16	
3	05:15	18:58-19:48/50	05:42	06:15	06:47	08:06-08:33/27	06:24		07:00	11:05-12:24/79
	20:30		20:08	19:21	18:28		16:40		16:16	
4	05:16	18:59-19:48/49	05:43	06:16	06:48	08:04-08:35/31	06:25		07:01	11:05-12:25/80
	20:30		20:07	19:19	18:26		16:39		16:16	
5	05:16	18:59-19:49/50	05:44	06:17	06:49	08:03-08:37/34	06:26		07:02	11:05-12:25/80
	20:29		20:06	19:17	18:24		16:37		16:15	
6	05:17	18:59-19:48/49	05:45	06:18	06:50	08:01-08:38/37	06:28		07:03	11:05-12:26/81
	20:29		20:05	19:15	18:23		16:36		16:15	
7	05:18	19:00-19:48/48	05:46	06:19	06:51	08:00-08:39/39	06:29		07:04	11:05-12:27/82
	20:29		20:03	19:14	18:21		16:35		16:15	
8	05:18	19:01-19:49/48	05:47	06:20	06:53	07:58-08:39/41	06:30		07:05	11:05-12:28/83
	20:29		20:02	19:12	18:19		16:34		16:15	
9	05:19	19:00-19:48/48	05:48	06:21	06:54	07:57-08:40/43	06:31		07:06	11:05-12:28/83
	20:28		20:01	19:10	18:17		16:33		16:15	
10	05:20	19:01-19:48/47	05:49	06:22	06:55	07:56-08:40/44	06:33		07:07	11:06-12:29/83
	20:28		19:58	19:08	18:16		16:32		16:15	
11	05:20	19:02-19:48/46	05:50	06:23	06:56	07:56-08:41/45	06:34		07:08	11:06-12:30/84
	20:27		19:57	19:07	18:14		16:31		16:15	
12	05:21	19:02-19:47/45	05:51	06:24	06:57	07:55-08:41/46	06:35		07:09	11:06-12:31/85
	20:27		19:55	19:05	18:12		16:29		16:15	
13	05:22	19:02-19:47/45	05:52	06:25	06:58	07:55-08:41/46	06:36		07:09	11:07-12:31/84
	20:26		19:54	19:03	18:11		16:28		16:15	
14	05:23	19:03-19:47/44	05:53	06:26	06:59	07:54-08:41/47	06:38	11:30-11:50/20	07:10	11:06-12:31/85
	20:26		19:53	19:01	18:09		16:28		16:15	
15	05:24	19:04-19:47/43	05:54	06:27	07:01	07:54-08:41/47	06:39	11:25-11:55/30	07:11	11:07-12:32/85
	20:25		19:51	19:00	18:07		16:27		16:16	
16	05:24	19:04-19:46/42	05:55	06:28	07:02	07:54-08:41/47	06:40	11:21-11:59/38	07:12	11:08-12:33/85
	20:25		19:50	18:58	18:06		16:26		16:16	
17	05:25	19:05-19:46/41	05:56	06:30	07:03	07:54-08:41/47	06:41	11:19-12:02/43	07:12	11:08-12:34/86
	20:24		19:48	18:56	18:04		16:25		16:16	
18	05:26	19:05-19:45/40	05:57	06:31	07:04	07:54-08:40/46	06:43	11:16-12:05/49	07:13	11:08-12:34/86
	20:23		19:47	18:54	18:03		16:24		16:17	
19	05:27	19:06-19:45/39	05:59	06:32	07:05	07:54-08:39/45	06:44	11:14-12:06/52	07:14	11:09-12:35/86
	20:23		19:45	18:52	18:01		16:23		16:17	
20	05:28	19:07-19:44/37	06:00	06:33	07:07	07:55-08:40/45	06:45	11:13-12:09/56	07:14	11:09-12:35/86
	20:22		19:44	18:51	18:00		16:22		16:17	
21	05:29	19:08-19:44/36	06:01	06:34	07:08	07:55-08:39/44	06:46	11:12-12:11/59	07:15	11:10-12:36/86
	20:21		19:42	18:49	17:58		16:22		16:18	
22	05:30	19:10-19:43/33	06:02	06:35	07:09	07:55-08:38/43	06:48	11:10-12:12/62	07:15	11:10-12:36/86
	20:20		19:40	18:47	17:56		16:21		16:18	
23	05:31	19:11-19:42/31	06:03	06:36	07:10	07:55-08:37/42	06:49	11:10-12:14/64	07:16	11:11-12:37/86
	20:19		19:39	18:45	17:55		16:20		16:19	
24	05:32	19:11-19:40/29	06:04	06:37	07:11	07:57-08:36/39	06:50	11:09-12:15/66	07:16	11:11-12:37/86
	20:19		19:37	18:44	17:53		16:20		16:19	
25	05:33	19:13-19:38/25	06:05	06:38	07:13	07:57-08:35/38	06:51	11:08-12:16/68	07:17	11:12-12:38/86
	20:18		19:36	18:42	17:52		16:19		16:20	
26	05:34	19:15-19:36/21	06:06	06:39	07:14	07:58-08:33/35	06:52	11:07-12:17/70	07:17	11:12-12:38/86
	20:17		19:34	18:40	17:51		16:19		16:21	
27	05:34	19:17-19:34/17	06:07	06:40	07:15	08:00-08:33/33	06:53	11:06-12:18/72	07:17	11:13-12:38/85
	20:16		19:32	18:38	17:49		16:18		16:21	
28	05:35	19:21-19:30/9	06:08	06:41	07:16	08:01-08:31/30	06:55	11:07-12:20/73	07:18	11:13-12:38/85
	20:15		19:31	18:36	17:48		16:18		16:22	
29	05:36		06:09	06:43	07:18	08:03-08:29/26	06:56	11:06-12:21/75	07:18	11:14-12:39/85
	20:14		19:29	18:35	17:46		16:17		16:23	
30	05:37		06:10	06:44	07:19	08:06-08:27/21	06:57	11:06-12:22/76	07:18	11:15-12:39/84
	20:13		19:27	18:33	17:45		16:17		16:23	
31	05:39		06:11		07:20	08:09-08:23/14			07:18	11:15-12:40/85
	20:12		19:26		17:44				16:24	
Potential sun hours	464		431	375	343		294		283	
Sum of minutes with flicker		1113	0	0		1159		973		2597

Table layout: For each day in each month the following matrix apply

Day in month	Sun rise (hh:mm)	First time (hh:mm) with flicker-Last time (hh:mm) with flicker/Minutes with flicker
	Sun set (hh:mm)	First time (hh:mm) with flicker-Last time (hh:mm) with flicker/Minutes with flicker

Project:
MWCC

Printed/Page
05/19/2009 1:57 PM / 15

Licensed user:
Renewable Energy Research Lab, University of Massachusetts at Amherst
160 Governors Drive Amherst
MA 01003 USA
413 545 3914

Calculated:
05/19/2009 11:24 AM/2.6.1.252

SHADOW - Calendar per WTG

Calculation: Gardner Middle School added MWCC Two turbines with sun percentages **WTG:** 2 - South VESTAS V82 1650 82.0 !O! hub: 80.0 m (2)

Assumptions for shadow calculations

Maximum distance for influence	2,000 m
Minimum sun height over horizon for influence	3 °
Day step for calculation	1 days
Time step for calculation	1 minutes

Sun shine probabilities (part of time from sun rise to sun set with sun shine)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.48	0.51	0.52	0.51	0.52	0.56	0.59	0.61	0.59	0.57	0.51	0.48

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
390	243	360	460	395	236	131	124	265	665	989	765	1,060	1,229	910	540	8,760

Day	January		February		March		April		May		June	
1	07:19	08:37-09:07/30	07:03		06:25	15:10-16:37/87	06:32	16:28-17:11/43	05:44		05:14	19:02-19:36/34
	16:25		17:01		17:37		19:14	17:42-18:16/34	19:48		20:18	
2	07:19	08:38-09:07/29	07:02		06:24	15:10-16:38/88	06:30	16:31-17:09/38	05:43		05:13	19:03-19:36/33
	16:26		17:02		17:39		19:15	17:44-18:15/31	19:49		20:19	
3	07:19	08:38-09:07/29	07:01		06:22	15:09-16:37/88	06:29	16:34-17:06/32	05:42		05:13	19:03-19:35/32
	16:27		17:04		17:40		19:16	17:46-18:13/27	19:50		20:20	
4	07:19	08:39-09:07/28	07:00		06:20	15:09-16:37/88	06:27	16:37-17:02/25	05:40		05:12	19:04-19:35/31
	16:28		17:05		17:41		19:17	17:47-18:10/23	19:51		20:20	
5	07:19	08:41-09:07/26	06:59		06:19	15:09-16:38/89	06:25	16:44-16:56/12	05:39	19:12-19:23/11	05:12	19:05-19:36/31
	16:29		17:06		17:42		19:18	17:51-18:07/16	19:52		20:21	
6	07:19	08:42-09:07/25	06:58	15:46-16:03/17	06:17	15:09-16:37/88	06:24	17:56-18:01/5	05:38	19:09-19:26/17	05:12	19:05-19:35/30
	16:30		17:08		17:43		19:19		19:53		20:22	
7	07:18	08:42-09:05/23	06:57	15:40-16:07/27	06:15	15:08-16:37/89	06:22		05:36	19:08-19:28/20	05:11	19:05-19:35/30
	16:31		17:09		17:45		19:21		19:54		20:23	
8	07:18	08:44-09:05/21	06:56	15:37-16:11/34	07:14	16:08-17:37/89	06:20		05:35	19:06-19:30/24	05:11	19:06-19:35/29
	16:32		17:10		18:46	18:00-18:12/12	19:22		19:56		20:23	
9	07:18	08:45-09:05/20	06:54	15:34-16:15/41	07:12	16:08-17:37/89	06:18		05:34	19:05-19:31/26	05:11	19:07-19:35/28
	16:33		17:12		18:47	17:56-18:16/20	19:23		19:57		20:24	
10	07:18	08:46-09:03/17	06:53	15:32-16:17/45	07:10	16:08-17:36/88	06:17		05:33	19:03-19:31/28	05:11	19:06-19:34/28
	16:34		17:13		18:48	17:53-18:19/26	19:24		19:58		20:25	
11	07:18	08:49-09:02/13	06:52	15:29-16:19/50	07:09	16:08-17:36/88	06:15		05:32	19:02-19:32/30	05:10	19:07-19:34/27
	16:35		17:14		18:49	17:50-18:20/30	19:25		19:59		20:25	
12	07:17	08:52-09:00/8	06:50	15:28-16:21/53	07:07	16:09-17:36/87	06:13		05:30	19:02-19:33/31	05:10	19:08-19:34/26
	16:36		17:16		18:51	17:49-18:22/33	19:26		20:00		20:26	
13	07:17		06:49	15:25-16:22/57	07:05	16:09-17:35/86	06:12		05:29	19:01-19:34/33	05:10	19:08-19:34/26
	16:37		17:17		18:52	17:47-18:23/36	19:27		20:00		20:26	
14	07:17		06:48	15:24-16:24/60	07:04	16:09-17:35/86	06:10		05:28	19:01-19:34/33	05:10	19:09-19:34/25
	16:39		17:18		18:53	17:45-18:24/39	19:28		20:01		20:27	
15	07:16		06:46	15:23-16:26/63	07:02	16:09-17:34/85	06:09		05:27	19:00-19:34/34	05:10	19:09-19:34/25
	16:40		17:20		18:54	17:44-18:24/40	19:30		20:02		20:27	
16	07:16		06:45	15:21-16:27/66	07:00	16:10-17:34/84	06:07		05:26	19:00-19:35/35	05:10	19:09-19:34/25
	16:41		17:21		18:55	17:43-18:26/43	19:31		20:03		20:28	
17	07:15		06:44	15:20-16:29/69	06:58	16:10-17:33/83	06:05		05:25	19:00-19:35/35	05:10	19:10-19:34/24
	16:42		17:22		18:56	17:42-18:26/44	19:32		20:04		20:28	
18	07:15		06:42	15:19-16:29/70	06:57	16:11-17:32/81	06:04		05:24	18:59-19:35/36	05:10	19:10-19:34/24
	16:43		17:23		18:58	17:41-18:26/45	19:33		20:05		20:28	
19	07:14		06:41	15:18-16:31/73	06:55	16:11-17:31/80	06:02		05:23	19:00-19:36/36	05:10	19:10-19:34/24
	16:45		17:25		18:59	17:40-18:26/46	19:34		20:06		20:29	
20	07:13		06:39	15:16-16:31/75	06:53	16:13-17:31/78	06:01		05:22	19:00-19:36/36	05:10	19:11-19:35/24
	16:46		17:26		19:00	17:41-18:26/45	19:35		20:07		20:29	
21	07:13		06:38	15:16-16:33/77	06:51	16:13-17:29/76	05:59		05:21	19:00-19:36/36	05:11	19:11-19:35/24
	16:47		17:27		19:01	17:40-18:26/46	19:36		20:08		20:29	
22	07:12		06:36	15:14-16:33/79	06:50	16:14-17:28/74	05:57		05:21	19:00-19:36/36	05:11	19:11-19:35/24
	16:48		17:29		19:02	17:39-18:26/47	19:38		20:09		20:30	
23	07:11		06:35	15:14-16:34/80	06:48	16:14-17:27/73	05:56		05:20	18:59-19:36/37	05:11	19:11-19:35/24
	16:50		17:30		19:03	17:39-18:25/46	19:39		20:10		20:30	
24	07:11		06:33	15:13-16:35/82	06:46	16:16-17:26/70	05:54		05:19	19:00-19:36/36	05:11	19:12-19:36/24
	16:51		17:31		19:05	17:39-18:24/45	19:40		20:11		20:30	
25	07:10		06:32	15:13-16:36/83	06:44	16:17-17:25/68	05:53		05:18	19:00-19:36/36	05:12	19:12-19:36/24
	16:52		17:32		19:06	17:39-18:24/45	19:41		20:12		20:30	
26	07:09		06:30	15:12-16:36/84	06:43	16:18-17:23/65	05:51		05:17	19:00-19:36/36	05:12	19:11-19:36/25
	16:53		17:34		19:07	17:39-18:24/45	19:42		20:13		20:30	
27	07:08		06:29	15:11-16:36/85	06:41	16:19-17:21/62	05:50		05:17	19:01-19:36/35	05:12	19:12-19:37/25
	16:55		17:35		19:08	17:39-18:23/44	19:43		20:14		20:30	
28	07:07		06:27	15:11-16:37/86	06:39	16:20-17:19/59	05:48		05:16	19:01-19:36/35	05:13	19:12-19:37/25
	16:56		17:36		19:09	17:39-18:21/42	19:44		20:15		20:30	
29	07:06				06:37	16:23-17:18/55	05:47		05:15	19:02-19:36/34	05:13	19:11-19:37/26
	16:57				19:10	17:41-18:21/40	19:45		20:16		20:30	
30	07:05				06:36	16:24-17:16/52	05:46		05:15	19:02-19:36/34	05:14	19:12-19:38/26
	16:59				19:11	17:41-18:20/39	19:47		20:16		20:30	
31	07:04				06:34	16:26-17:14/48			05:14	19:03-19:36/33		
	17:00				19:13	17:42-18:18/36			20:17			
Potential sun hours	293		295		370		401		453		457	
Sum of minutes with flicker		269		1456		3357		286		853		803

Table layout: For each day in each month the following matrix apply

Day in month	Sun rise (hh:mm)	First time (hh:mm) with flicker-Last time (hh:mm) with flicker/Minutes with flicker
	Sun set (hh:mm)	First time (hh:mm) with flicker-Last time (hh:mm) with flicker/Minutes with flicker

Project:
MWCC

Printed/Page
05/19/2009 1:57 PM / 16

Licensed user:
Renewable Energy Research Lab, University of Massachusetts at Amherst
160 Governors Drive Amherst
MA 01003 USA
413 545 3914

Calculated:
05/19/2009 11:24 AM/2.6.1.252

SHADOW - Calendar per WTG

Calculation: Gardner Middle School added MWCC Two turbines with sun percentages **WTG:** 2 - South VESTAS V82 1650 82.0 !O! hub: 80.0 m (2)

Assumptions for shadow calculations

Maximum distance for influence	2,000 m
Minimum sun height over horizon for influence	3 °
Day step for calculation	1 days
Time step for calculation	1 minutes

Sun shine probabilities (part of time from sun rise to sun set with sun shine)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.48	0.51	0.52	0.51	0.52	0.56	0.59	0.61	0.59	0.57	0.51	0.48

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
390	243	360	460	395	236	131	124	265	665	989	765	1,060	1,229	910	540	8,760

	July		August		September		October		November		December	
1	05:14	19:11-19:38/27	05:40	19:13-19:43/30	06:12		06:45	15:48-17:15/87	06:21	15:01-15:46/45	06:58	08:31-08:44/13
	20:30		20:11		19:24		18:31	17:27-18:01/34	16:42		16:16	
2	05:15	19:12-19:39/27	05:41	19:13-19:42/29	06:14		06:46	15:47-17:14/87	06:23	15:05-15:44/39	06:59	08:29-08:46/17
	20:30		20:09		19:22		18:29	17:28-17:59/31	16:41		16:16	
3	05:15	19:11-19:39/28	05:42	19:14-19:41/27	06:15		06:47	15:46-17:14/88	06:24	15:07-15:41/34	07:00	08:28-08:48/20
	20:30		20:08		19:21		18:28	17:29-17:57/28	16:40		16:16	
4	05:16	19:11-19:40/29	05:43	19:15-19:40/25	06:16		06:48	15:45-17:14/89	06:25	15:11-15:37/26	07:01	08:28-08:49/21
	20:30		20:07		19:19		18:26	17:31-17:54/23	16:39		16:16	
5	05:16	19:12-19:41/29	05:44	19:16-19:39/23	06:17		06:49	15:45-17:14/89	06:26	15:17-15:32/15	07:02	08:27-08:50/23
	20:29		20:06		19:17		18:24	17:35-17:52/17	16:37		16:15	
6	05:17	19:11-19:41/30	05:45	19:18-19:37/19	06:18	17:53-17:56/3	06:50	15:45-17:14/89	06:28		07:03	08:27-08:52/25
	20:29		20:05		19:15		18:23	17:42-17:44/2	16:36		16:15	
7	05:18	19:11-19:42/31	05:46	19:20-19:35/15	06:19	16:39-16:51/12	06:51	15:44-17:13/89	06:29		07:04	08:27-08:53/26
	20:29		20:03		19:14	17:46-18:02/16	18:21		16:35		16:15	
8	05:18	19:11-19:43/32	05:47	19:23-19:32/9	06:20	16:33-16:56/23	06:53	15:44-17:13/89	06:30		07:05	08:27-08:54/27
	20:29		20:02		19:12	17:43-18:05/22	18:19		16:34		16:15	
9	05:19	19:11-19:42/31	05:48		06:21	16:28-17:00/32	06:54	15:43-17:12/89	06:31		07:06	08:27-08:55/28
	20:28		20:01		19:10	17:40-18:07/27	18:17		16:33		16:15	
10	05:20	19:11-19:43/32	05:49		06:22	16:24-17:02/38	06:55	15:43-17:11/88	06:33		07:07	08:27-08:56/29
	20:28		19:58		19:08	17:38-18:08/30	18:16		16:32		16:15	
11	05:20	19:11-19:44/33	05:50		06:23	16:21-17:04/43	06:56	15:44-17:12/88	06:34		07:08	08:27-08:57/30
	20:27		19:57		19:07	17:36-18:09/33	18:14		16:31		16:15	
12	05:21	19:10-19:43/33	05:51		06:24	16:18-17:06/48	06:57	15:43-17:11/88	06:35		07:09	08:27-08:58/31
	20:27		19:55		19:05	17:34-18:10/36	18:12		16:29		16:15	
13	05:22	19:10-19:44/34	05:52		06:25	16:16-17:07/51	06:58	15:43-17:10/87	06:36		07:09	08:27-08:59/32
	20:26		19:54		19:03	17:32-18:11/39	18:11		16:28		16:15	
14	05:23	19:10-19:45/35	05:53		06:26	16:13-17:08/55	06:59	15:43-17:09/86	06:38		07:10	08:28-09:00/32
	20:26		19:53		19:01	17:31-18:11/40	18:09		16:28		16:15	
15	05:24	19:10-19:45/35	05:54		06:27	16:11-17:09/58	07:01	15:43-17:08/85	06:39		07:11	08:27-09:00/33
	20:25		19:51		19:00	17:30-18:12/42	18:07		16:27		16:16	
16	05:24	19:09-19:45/36	05:55		06:28	16:09-17:10/61	07:02	15:44-17:08/84	06:40		07:12	08:28-09:00/32
	20:25		19:50		18:58	17:29-18:12/43	18:06		16:26		16:16	
17	05:25	19:10-19:45/35	05:56		06:30	16:07-17:11/64	07:03	15:44-17:07/83	06:41		07:12	08:29-09:01/32
	20:24		19:48		18:56	17:28-18:12/44	18:04		16:25		16:16	
18	05:26	19:10-19:45/35	05:57		06:31	16:05-17:12/67	07:04	15:45-17:06/81	06:43		07:13	08:28-09:01/33
	20:23		19:47		18:54	17:27-18:12/45	18:03		16:24		16:17	
19	05:27	19:10-19:46/36	05:59		06:32	16:03-17:12/69	07:05	15:45-17:05/80	06:44		07:14	08:29-09:02/33
	20:23		19:45		18:52	17:26-18:12/46	18:01		16:23		16:17	
20	05:28	19:10-19:46/36	06:00		06:33	16:01-17:13/72	07:07	15:46-17:04/78	06:45		07:14	08:29-09:02/33
	20:22		19:44		18:51	17:25-18:11/46	18:00		16:22		16:17	
21	05:29	19:10-19:46/36	06:01		06:34	15:59-17:13/74	07:08	15:47-17:03/76	06:46		07:15	08:30-09:03/33
	20:21		19:42		18:49	17:25-18:11/46	17:58		16:22		16:18	
22	05:30	19:10-19:47/37	06:02		06:35	15:58-17:14/76	07:09	15:47-17:02/75	06:48		07:15	08:30-09:03/33
	20:20		19:40		18:47	17:24-18:10/46	17:56		16:21		16:18	
23	05:31	19:10-19:47/37	06:03		06:36	15:56-17:14/78	07:10	15:48-17:00/72	06:49		07:16	08:31-09:04/33
	20:19		19:39		18:45	17:24-18:10/46	17:55		16:20		16:19	
24	05:32	19:10-19:46/36	06:04		06:37	15:55-17:14/79	07:11	15:49-17:00/71	06:50		07:16	08:31-09:04/33
	20:19		19:37		18:44	17:24-18:09/45	17:54		16:20		16:19	
25	05:33	19:10-19:46/36	06:05		06:38	15:54-17:15/81	07:13	15:50-16:58/68	06:51		07:17	08:32-09:05/33
	20:18		19:36		18:42	17:24-18:08/44	17:52		16:19		16:20	
26	05:34	19:10-19:46/36	06:06		06:39	15:53-17:15/82	07:14	15:51-16:56/65	06:52		07:17	08:33-09:05/32
	20:17		19:34		18:40	17:25-18:08/43	17:51		16:19		16:21	
27	05:34	19:10-19:45/35	06:07		06:40	15:52-17:15/83	07:15	15:53-16:56/63	06:53		07:17	08:33-09:05/32
	20:16		19:32		18:38	17:25-18:07/42	17:49		16:18		16:21	
28	05:35	19:11-19:45/34	06:08		06:41	15:51-17:15/84	07:16	15:54-16:54/60	06:55		07:18	08:33-09:06/33
	20:15		19:31		18:36	17:25-18:06/41	17:48		16:18		16:22	
29	05:36	19:11-19:45/34	06:09		06:43	15:50-17:15/85	07:18	15:55-16:52/57	06:56		07:18	08:35-09:07/32
	20:14		19:29		18:35	17:25-18:05/40	17:46		16:17		16:23	
30	05:37	19:11-19:44/33	06:10		06:44	15:49-17:15/86	07:19	15:58-16:51/53	06:57	08:33-08:41/8	07:18	08:35-09:07/32
	20:13		19:27		18:33	17:26-18:03/37	17:45		16:17		16:23	
31	05:39	19:12-19:44/32	06:11				07:20	16:00-16:48/48			07:18	08:36-09:07/31
	20:12		19:26				17:44				16:24	
Potential sun hours	464		431		375		343		294		283	
Sum of minutes with flicker		1030		177		2443		2567		167		907

Table layout: For each day in each month the following matrix apply

Day in month	Sun rise (hh:mm)	First time (hh:mm) with flicker-Last time (hh:mm) with flicker/Minutes with flicker
	Sun set (hh:mm)	First time (hh:mm) with flicker-Last time (hh:mm) with flicker/Minutes with flicker

Project:
MWCC

Printed/Page
05/19/2009 1:57 PM / 17

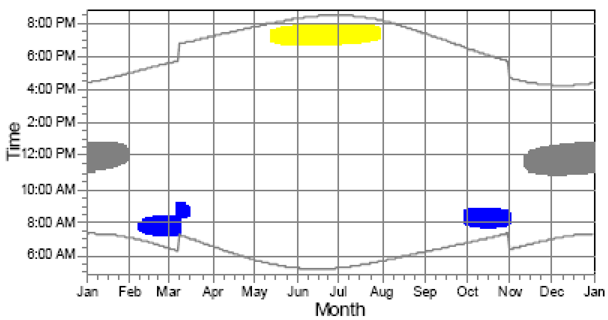
Licensed user:
Renewable Energy Research Lab, University of Massachusetts at Amherst
160 Governors Drive Amherst
MA 01003 USA
413 545 3914

Calculated:
05/19/2009 11:24 AM/2.6.1.252

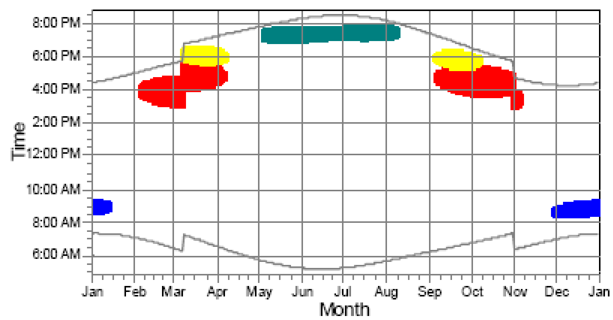
SHADOW - Calendar per WTG, graphical

Calculation: Gardner Middle School added MWCC Two turbines with sun percentages

1: North VESTAS V82 1650 82.0 !O! hub: 80.0 m (2)



2: South VESTAS V82 1650 82.0 !O! hub: 80.0 m (2)



Shadow receptor

A: Courthouse
C: Boulder Street
D: Golf Course
E: MWCC building
G: Gardner Middle School

WindPRO version 2.6.1.252 Jan 2009

Project:
MWCC

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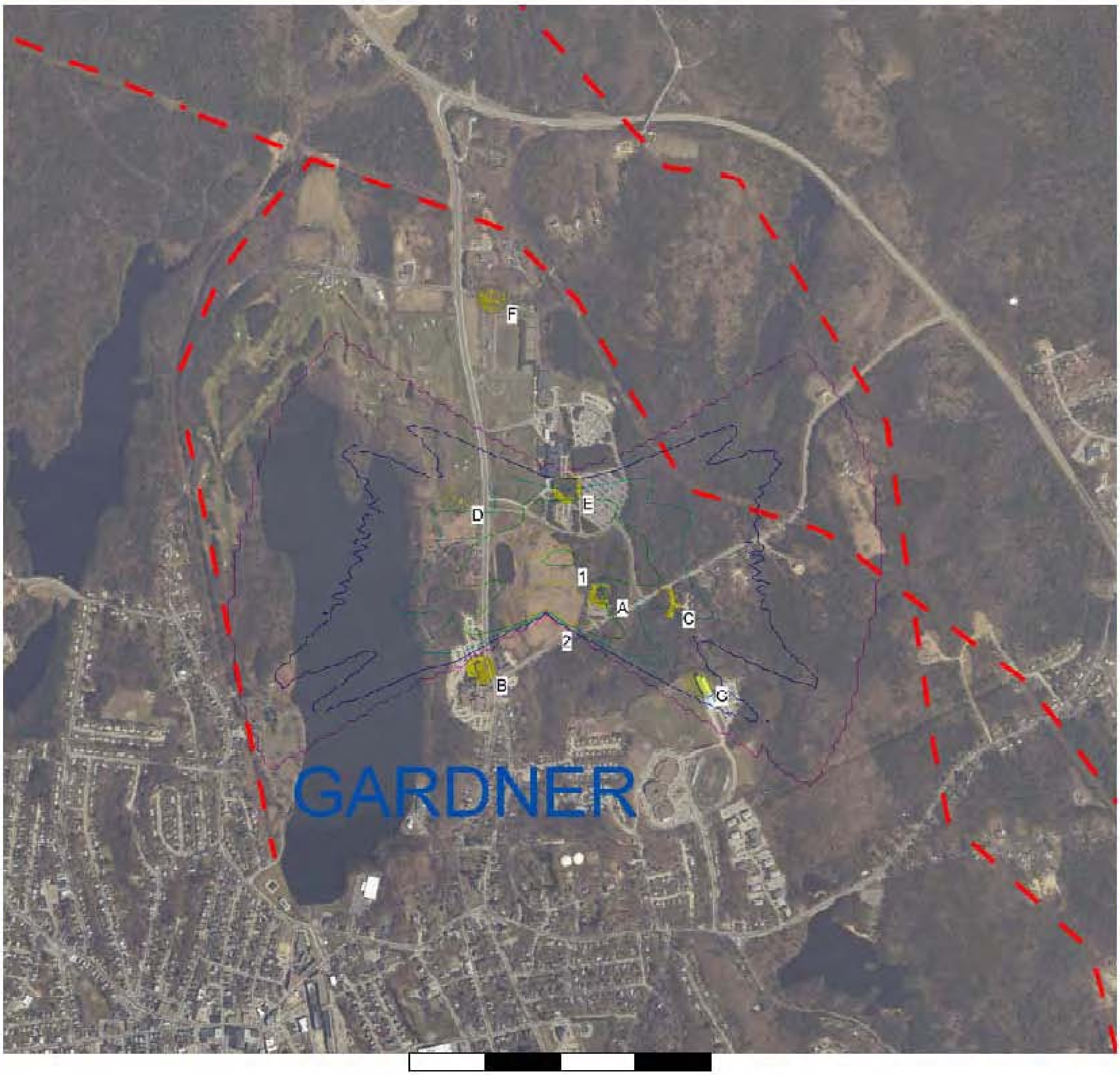
05/19/2009 1:57 PM / 18

Licensed user:
Renewable Energy Research Lab, University of Massachusetts at Amherst
160 Governors Drive Amherst
MA 01003 USA
413 545 3914

Calculated:
05/19/2009 11:24 AM/2.6.1.252

SHADOW - ortho 600DPI

Calculation: Gardner Middle School added MWCC Two turbines with sun percentages **File:** ORTHO Mt Wachusett Comm College WindPro set up.jpg



Map: , Print scale 1:20,000, Map center UTM NAD 83 Zone: 19 East: 255,177 North: 4,719,753

New WTG

Shadow receptor

Isolines showing shadow in Shadow hours per year. Real value calculation.

0 10 25 50 100 217

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