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ENVIRONMENT, ENERGY, & ACOUSTICS



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# **Final Monitoring Protocol**

Kingdom Community  
Wind

**April 2012**

DATA ■ ANALYSIS ■ SOLUTIONS



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## 1.0 INTRODUCTION

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The Vermont Public Service Board (Board) issued a Certificate for Public Good (CPG) for the Kingdom Community Wind Project (Docket #7628). As part of the CPG, post-construction sound monitoring is required to assure conformance with stated noise standards. The conditions of the CPG related to the monitoring condition are:

39. The Petitioners shall construct and operate the proposed project so that the turbines emit no prominent discrete tones pursuant to ANSI standards<sup>[1]</sup> at the receptor locations, and project-related sound levels at any existing surrounding residences do not exceed 45 dBA(exterior)(Leq)(1 hr) or 30 dBA (interior bedrooms)(Leq)(1 hr).

41. Prior to commencement of construction, Petitioners shall prepare a Noise Monitoring Plan, subject to review by the parties and approval by the Board, which is consistent with the Plan recently approved by the Board in Docket 7156, but which extends from construction through the first two years of operations and includes: (a) monitoring for low frequency sound with the same regularity as monitoring for all frequencies; (b) a monitoring program to confirm under a variety of seasonal and climactic conditions compliance with the maximum allowable sound levels described above; (c) a means for ensuring that noise monitoring events shall be timed to coincide with those time periods when Petitioners' modeling indicates the likelihood that the noise reduced operation ("NRO") mode will be triggered; (d) monitoring reports that document every instance when NRO mode is triggered, with a description of how NRO affected operations; (e) at the request of a homeowner, monitoring to ensure compliance with the interior noise standard; and, (f) a process for complaint resolution shall be established for the entire life of the project.

This report describes a monitoring plan that meets the conditions of the CPG. It is consistent with the plan submitted in Docket 7156 (Sheffield), with supplements to incorporate the additional items required under CPG Condition 41.

## 2.0 MONITORING PLAN

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### 2.1 Third-party review

A neutral third-party observer, chosen in accordance with the Board's April 3, 2012 order, shall be used during the first two-week monitoring period to assess compliance with the noise-monitoring requirements of the CPG and Order. The third party's role shall include review of the placement of microphones at the monitored locations, as well as review of the data collected. The Petitioners shall consult with the third party

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<sup>1</sup> A "prominent discrete tone" as defined in ANSI S12.9/Part 3 1993 Quantities and Procedures for Description and Measurement of Environmental Sound." A tone is said to exist if the 1/3 octave band containing the suspected tone exceeds the arithmetic average of the two adjacent bands by 15 dB for frequencies below 125 Hz, 8 dB for frequencies between 160 and 400 Hz, and 5 dB for frequencies above 500 Hz.



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in selecting a monitoring location along Eden Rd. The third party will file a report with the Board within 30 days of the completion of the first two-week monitoring period setting forth his/her opinion as to the sufficiency of the data collected, whether the turbine's sound levels were accurately captured at the monitoring locations, and, if any, recommendations for alternations to the plan to ensure that maximum project sound levels are being captured by the monitoring. The third party may be asked by the Board to review additional monitoring periods. Costs associated with the third-party monitor shall be borne by GMP.

## 2.2 Duration

Each monitoring period shall be a continuous period at least two weeks in duration, and meant to capture a variety of meteorological and seasonal conditions. The conditions shall include periods when at least 90% of the wind turbines are expected to be operating at their maximum sound power, and when Petitioners' modeling indicates it is likely that the noise reduced operation (NRO) mode will be triggered, and identified monitoring periods will avoid periods when turbines are expected to be out of service, when heavy rain or storms comprise a large portion of the monitoring period, or when normal operations are expected to be affected by safety concerns, grid reliability or other issues, to the extent they can be forecast reliably.

Any departure from ideal monitoring conditions shall be noted in the report.

## 2.3 Frequency of Monitoring Periods

Nine periods of monitoring shall take place. One period shall take place during construction, and the remaining eight periods shall occur during winter, spring, summer, and fall, over the first two years of operation. Monitoring may also take place at other times, for example, to establish background sound levels or investigate complaints.

GMP shall immediately notify the Board each time the NRO protocols are changed. If the NRO is reduced or eliminated after the two-year initial monitoring period is completed, then one additional year of monitoring shall be conducted to confirm that the sound limits are met.

## 2.4 Locations

The noise report for the project included preconstruction sound monitoring at seven locations, representing unique soundscapes around the project. Four of these locations represent homes that are closest to the project. The other three locations represent a camp close to Farm Road (location 5), Cheney Road, which is further away from the Project than the Route 100 location (Location 4) and a second location at the Nelson Farm (Location 1).

These locations are all within 1.5 miles (2.5 km) of the turbine array (Figure 1) because the modeled 40 dBA contour (i.e., 5 dBA less than the Board's standard) extends no further than this distance.

Based on these factors, there shall be four monitoring locations,:

- 1) Nelson Farm
- 2) Eden Road - The monitoring location here will be moved to a site with a lower background sound level as compared with the preconstruction monitoring site. The monitoring location will be designed to capture maximum sound levels that will be experienced by the residences on Eden Road, and will be selected in consultation with the third-party observer. A representative location on the Gebbie Property may be used.



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- 3) Farm Road (Day residence)
  - 4) VT 100, south of (and including) Stewart Hill Road (closer to the Project than the Christiansen residence if possible or at that residence). GMP shall, in consultation with the third-party observer, secure an appropriate monitoring location in the vicinity of the Christiansen residence that is designed to capture maximum sound levels from the project, and, if reasonably possible, at a location representative of the closest residence to the project in this area.

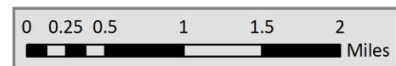
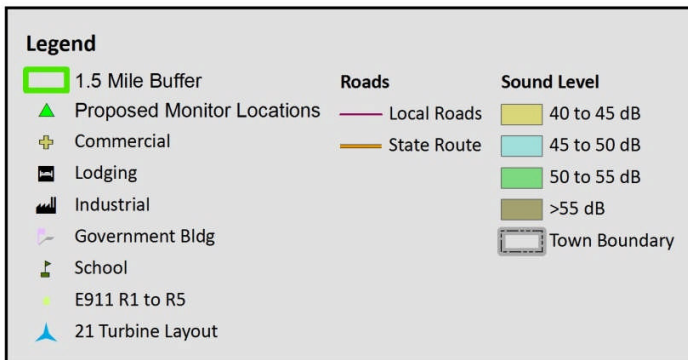
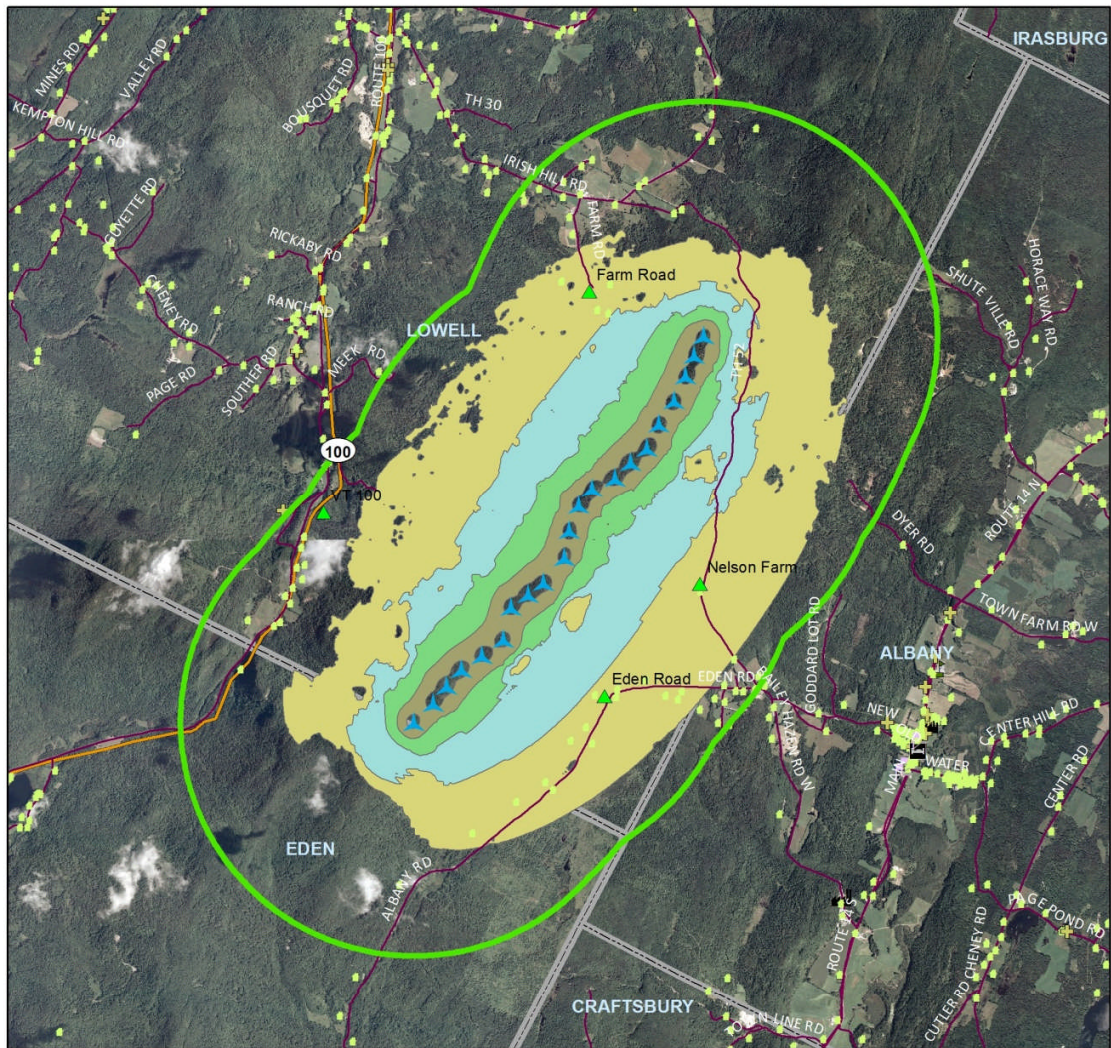
To the extent permission is granted, monitors shall be set near individual homes closest to the project at these locations. If permission is not granted, then alternative homes shall be contacted, or monitors will be placed in public right-of-ways that are representative of a home, at a similar or lesser distance from the project.

Once the sites are selected, KCW shall file a map showing:

- The installed turbine and met tower locations
- The exact monitoring locations



Figure 1: Sound contours from 21 Vestas V112 3.0 MW wind turbines (no NRO), showing 1.5 mile buffer





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## 2.5 Logistics

The exact location of the microphones shall be chosen on site and based on the following list of site condition priorities:

- 1) Sound monitoring shall be conducted approximately 25 feet away from any structure, unless a longer distance is needed to avoid reflection or other interference.
- 2) Microphones shall be placed in a location to avoid potential noise contamination from sources such as flowing water, wind chimes, air conditioners, noises from homes, etc.
- 3) Microphones shall be placed at a height approximately 3 feet above grade.
- 4) Microphones shall not be placed such that any structure blocks the line of sight between the microphone and wind farm (if otherwise visible).
- 5) GMP shall, in consultation with the third-party observer, make every reasonable effort to site microphones in a manner that will maximize the probability of capturing the maximum noise levels at each monitoring location, taking into account all relevant factors such as minimizing line-of-sight obstructions between microphones and the project, and maximizing the number of turbines in line-of-sight of the microphones at each monitoring location.

In some cases, these limitations may mean that the best monitoring location for a specific residence may be several hundred feet away from the primary residential structure. Every effort shall be made to ensure that locations selected are representative of the noise exposure at subject homes.

Because of the frequency of the tests, some equipment, like microphone mounts, may be left at each location, until the conclusion of the two-year test period.

Sites may include meteorological instrumentation logging data in not more than 10 minute increments, which can include one or more of the following:

- Anemometer (all sites)
- Wind vane (one site)
- Temperature sensor (one site)
- Rain sensor (one site)

All sound level meters will meet Type II or better specifications for accuracy, and will be calibrated before and after each measurement period. All monitors will collect 1/3 octave band data from 20 Hz to 10 kHz for consecutive periods not to exceed 10 minutes. Monitors will also collect audio recordings where permission is granted by the property owner. To protect the privacy of neighbors, audio recordings shall be released to the PSB upon request and only under a confidentiality agreement.

## 2.6 Outside to inside test

Sound tests of turbine operations will be limited to exterior measurements. This is because the 30 dB limit established by the PSB is sufficiently low that the sound test is easily contaminated by normal activities that occur indoors. In addition, frequent sound monitoring inside a residence is intrusive. To minimize the impact to residents, interior sound levels will be calculated based on the exterior sound level minus the tested outside to inside noise reduction (OINR) of the house, as described below.

Upon the request of a monitored residence, an outside-to-inside test will be conducted to establish the interior sound level when the turbines are operating. The test will be conducted in accordance with ASTM





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Standard E966-10, *Standard Guide for Field Measurement of Airborne Sound Insulation of Building Facades and Façade Elements (2010)*.<sup>2</sup> In general, this test involves broadcasting a broadband sound source outside the house (on the wind turbine side of the house). Measurements of 1/3 octave band sound levels are then taken outside the home and inside the bedroom to determine the noise reduction potential of the building.<sup>3</sup> Any deviations from the standard necessitated by field conditions will be detailed in the report.

For any monitored home that does not grant permission, a 15 dB overall reduction shall be assumed.

## 2.7 Background sound measurements

In order to accurately measure the sound impact of the project, it will be important to be able to subtract out background sound levels to establish a turbine-only sound level.

There are five primary ways to eliminate background sound from operational measurements:

- 1) **Disallow sound level readings in all but a limited set of conditions representing the worst-case sound levels during a time of very low background sound levels.** This would be during a nighttime stable atmosphere, between the hours of 10 pm and 6 am, where the turbines are operating at their maximum rated sound power, and ten-meter wind speeds near the sound level meter are below 2 to 3 m/s. During these conditions, sound propagation is best, sound power is highest, wind-induced noise at the monitoring site is minimal, and nearby traffic levels and human activity is low. The advantage of this methodology is that background sound levels can be ignored as being very low during these periods, and compliance can be assessed quickly without extensive monitoring. The disadvantage is that a 10-meter high meteorological mast must be set up at each side of the mountain, and the monitoring is limited to a narrow set of weather conditions that are difficult to forecast. Thus, it may take a long time to get sufficient data given the limited times that these conditions are met. The 10-meter met towers consists of a 10 meter guyed monopoles (2"-4" diameter), located in a cleared areas on the eastern and western side of Lowell Mountain. Since they may take a considerable time to set up, these met towers may be installed weeks or months prior to the narrow sound monitoring window.<sup>4</sup>
- 2) **Turn off wind turbines at regular intervals.** Turning off wind turbines allows a direct comparison between periods with and without turbines operating. The advantage is that background levels during the particular time and place are easily identified. The disadvantage is that many shutdowns may be required, affecting system reliability. Under ideal situations, the turbines would only be shut off when sound levels exceeded 45 dBA, but that would require continuous manned observations or wireless telemetry over the two-week period.
- 3) **Add a microphone opposite the turbine side of the home.** If the microphone is 3 to 5 feet from the house, the home would act as a barrier to the wind turbine noise. The advantage of this method is that levels can be measured at the home in question. The disadvantage is that low frequencies may

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<sup>2</sup> The E966 standard is copyrighted. For those who wish to review the standard, but not purchase it, one can be made available for review at KCW or RSG offices.

<sup>3</sup> Interior measurements shall be made with windows open and closed. The methodology for calculating a single attenuation value based on these measurements shall be submitted to the Board, Department and affected landowners for review, prior to issuance of the monitoring reports.

<sup>4</sup> A 10-meter met tower may need an additional permit or permits to install.



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not be attenuated to the extent required for an accurate background measurement and other noise sources on the turbine side of the house, such as traffic, are attenuated as well.

- 4) **Measure background at off-site locations.** Choose a background measurement location that is 2 miles or more from the subject property. This location would have similar topography and traffic, such that the background levels would be similar. The background site and subject site are measured simultaneously, and the background is subtracted after the measurements are complete.
- 5) **Create a model of background sound based on time-of-day and wind speed.** Using data from pre-operation monitoring, a model is created of background sound level at each location based on the time of day (a surrogate for traffic volumes) and wind speed. For each hour, the background level is thus based on the time of day and wind speed during the actual test.

As a comparison, Options 1 through 4 are undertaken for all monitoring periods and Option 5 is undertaken once. All five options shall capture sound levels at no less than 10 minute intervals.

Consistent with the Sheffield Protocol, two of the options will be used, with a priority order of Options 4, 3, and 2 (or Options 1 or 5, only, if Options 2, 3, and 4 are not available), in addition to a monitor on the turbine side of the residence, depending on the site, based on the following considerations:

- **Method 4** - Background sites for the monitoring locations will be chosen that are at least 2 miles from the project. A test will be run prior to the operation of the wind farm to determine how well the background sites correlate to the subject sites. If the correlation is unacceptable ( $p < 0.95$  or the standard deviation of the hourly difference in sound levels is greater than 2 dB), then either a new site will be chosen and retested, or the Primary Site Method, described below will be used.
- **Method 3** – This method is used if Method 4 is not practical. At each site for which this technique is used, measurements will be made on the turbine side and opposite side of the building or nearby other outbuilding when the wind turbine is in operation. If attenuation for each octave band sufficient to eliminate Project sound can be achieved by the building, then this method will be used for background measurements. If not, then the following, Turbine Shutdown Method will be used.
- **Method 2** – During the measurement program, the 12 turbines closest to the monitoring site will be shut down for 20 minutes at a time no less than every eighth hour that the hub height wind speeds are at 6 m/s or above. Alternatively, the turbines can be shut down for 20 minutes only when monitoring indicates 45 dBA is exceeded at the sound monitoring location.

### 3.0 DATA PROCESSING

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The background sound level for each period shall be logarithmically subtracted from the subject sound level (ie Sheffield formula). If the background level is higher, then the Project-only level is indeterminate for that measurement period. Descriptors Leq and L90 shall be used uniformly for all quantities in this calculation. The L90 measure has the quality of filtering out sporadic noise events, such as cars passing by on nearby roads, planes, dogs barking, etc. whereas the CPG sound limit is expressed as an Leq value.

Data during some periods will be removed from the results. These include periods when:

- Wind speeds (average or gusts) at a monitoring site are above 5 m/s
- The temperature is below 14°F (per ANSI Standard)
- Rain is present
- Spikes are present that are not consistent with wind turbine operation
- Times when the wind farm is not operating (Not applicable to Method 2)



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Certain background sounds such as insects and birds can be filtered by employing a low pass filter without affecting the sound monitored from the wind turbines. If these types of sources are found, a low pass filter may be used, consistent with that described in “Proposed ‘Ai’-weighting; A weighting to remove insect noise from A-weighted field measurements”, Paul D. Schomer, Ian M. Slauch, and George F. Hessler, *InterNoise Proceedings*, Volume 221, pp. 3991-4000 (2010).

Events over the 45.0 dBA criteria shall be investigated by listening to the audio tape of the event and determining if the cause is wind turbine noise. If the exceedence is due to a background event, then it shall be eliminated.

For the purposes of compliance with the 45 dBA exterior and 30 dBA interior standards, no rounding will be considered.

## 4.0 REPORTS

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A report shall be prepared for each monitoring session. The preliminary report, to be provided once permission for all monitoring locations has been secured, will show:

- A map of the turbine and met tower locations and numbers, monitoring locations, including background monitoring locations, distances of the monitoring locations to the closest turbine, and the 1.5 mile distance contour
- Details of any tests to determine background sound levels
- Details of outside-to-inside noise reduction tests and the results

Each monitoring report shall include:

- A description of any changes in operation made since the last report, special operating conditions, or turbine maintenance issues found during the test procedure.
- A summary of all data collected, including sound levels, meteorological data at the monitoring stations, and turbine operating conditions.
- Times of potential exceedences of the outdoor, indoor, or tonal standard, and the results of investigations into those exceedences.
- Date, time, and turbines for which NRO was implemented. For each event, a description of how NRO affected operations since the previous report, including relative change in wind farm power output.
- Conclusions
- An appendix containing 10-minute data for each turbine including wind speed, electrical output, and NRO mode.

For the winter season, two separate reports will be prepared. The first will include sound levels during periods when the temperature is below 14°F and the second report will exclude those sound periods. GMP may include in its reports, any information it that believes suggests that the sound level meters are not producing accurate data during times when the temperature falls below 14°F.

Reports shall be submitted within six weeks of the end of each test and any allegedly confidential information will be provided only to the PSB, Department of Public Service and any person executing an appropriate protective agreement.

The Petitioners will also provide an annual report documenting every instance in which the NRO mode is



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triggered and how it affected operations.

## 5.0 COMPLAINT RESOLUTION

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The following complaint resolution procedure will assure that concerns by neighbors regarding wind turbine noise are addressed in a timely manner while, at the same time, preventing abuse of the complaint process. The complaint resolution procedure shall be as follows:

- 1) The complaint process shall be in place for the life of the Project.
- 2) A complaint phone number and contact person shall be provided to the Town Clerks and Selectboards of Albany and Lowell.
- 3) KCW will provide an initial acknowledgement to complaints within 1 to 2 business days.
- 4) Complainants will be requested to provide KCW with the following information related to the complaint
  - a. Location of the observed sound
  - b. Time and date the sound occurred
  - c. Weather conditions (snow cover, cloud cover, wind direction and relative speed, etc)
  - d. Description of the sound
- 5) KCW shall record the complainant information, and weather, turbine operating status, and power output during the time of the complaint.
- 6) KCW will investigate as described below if the complaint represents a permanent residence within 1.5 miles of the turbine string, and, based on monitoring and/or modeling, there appears a reasonable possibility that the Project sound level is within 5 dBA of the CPG exterior noise limit at the complaint location, and not related to abnormal Project operation or maintenance.
  - a. The A-weighted sound level from the closest monitoring location shall be extrapolated to the complaint location by means of the following formula to determine whether the sound level there is likely to be within 5 dBA of the exterior sound limit:
$$L_{pc} = L_{pm} + 20 \log (D_m/D_c), \text{ in dBA}$$
Where
$$L_{pc} = \text{Estimated sound level at the complainant location}$$
$$L_{pm} = \text{Sound pressure level determined at the nearest monitoring location}$$
$$D_m = \text{Distance from the turbine string to the relevant monitoring location}$$
$$D_c = \text{Distance from the turbine string to the complainant location.}$$
  - b. If the extrapolated sound level is not within 5 dB of the exterior sound limit, then the wind farm operator will respond to the complainant, but is not required to conduct additional sound testing. Similarly, if the complaint is a result of abnormal operation, the operator will respond to the complainant and make necessary repairs, but will not be required to conduct sound testing
  - c. If, on the other hand, the sound level is within 5 dB of the exterior sound limit, then GMP will, at the homeowner's request, perform outside-to-inside testing to determine the attenuation value of the affected structure.
- 7) Sound monitoring will be conducted if (a) the sound level is within 5 dB of the exterior sound limit



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(based on the initial screening described above) and the attenuation value of the structure (based on the outside-to-inside test) does not exceed 12 dB, or (b) the sound level is within 3 dB of the exterior sound limit (based on the initial screening described above).

- 8) Complainants may be asked to log sound events over a period of time to help identify influences that affect the sound. If the factors identified above demonstrate that follow-up sound monitoring is warranted, monitors will be set up by a noise control engineer no later than four weeks after the complaint. GMP shall make all reasonable efforts to conduct such monitoring under conditions similar to those existing at the time the complaint arose.
- 9) If the complaint occurs within the first two years of operation (or during any additional Board-ordered monitoring period), the monitoring will conform to the above criteria; otherwise it will be based on a two-week monitoring period and on methods that will be developed in response to the type of complaint issued. The methods to be used will be developed based on information gained during the first two years of operation and the entire monitoring database, and will be filed for review by the parties and approval by the Board. A resident may request that the Board, by order, require an additional round of monitoring at any time, and the request shall include an explanation of why the resident believes additional monitoring is needed. If the methodology described in Section 2.6(5) is used, the condition which corresponds to the operational status during the complaint should be accounted for. For example, if the complaint occurred while NRO was in effect, the monitoring should take place while NRO is also in effect, and vice versa.
- 10) The primary method for determining the attenuation value of a particular structure shall be outside-to-inside testing. The resulting exterior sound level will be converted to an interior level based on the ASTM E966 test result at the home. If permission is not granted for outside-to-inside testing, the attenuation value will be determined by the most similar structure to those found at the primary monitoring locations that did have the testing done. If no similar structure is found, then a 15 dBA attenuation will be assumed.
- 11) Because of the complexity of complaint resolution, full cooperation of the complainant and the adherence to the above test procedures is necessary.
- 12) The Petitioners shall develop a protocol for informing a resident when it intends to conduct any exterior sound monitoring and work with the resident to determine an appropriate location for the monitoring equipment. They will also provide information on turbine functionality during the monitoring period when it provides the results of the monitoring to the resident.
- 13) The official results of the monitoring shall be contained in a report that is submitted to the complainant, the Department of Public Service and the PSB. This report will contain specific information collected during the complaint monitoring, including wind speed and direction, operational status of the turbines, sound levels, and the raw sound level data collected by the noise control engineer conducting the tests. Times when NRO is in operation will be reported, and a comparison of sound levels during NRO and non-NRO periods will be made.
- 14) If it is found that the project sound level at any permanent residence is above the allowable limit, KCW shall take all remedial steps necessary to bring the sound levels produced by the turbine(s) into compliance with allowable levels, as required by the CPG.

