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November 17, 2017

Mr. Nick Colella
Ministry of the Environment and Climate Change
Environmental Approvals Branch
135 St. Clair Avenue West
1st Floor
Toronto, ON, M4V 1P5
By email to: Nick.Colella@ontario.ca

Dear Mr. Colella,

Please find attached one part of the future Phase 3 Vibration Monitoring work plan to carry out vibration monitoring upon Commercial Operation of the North Kent Wind 1 facility (Project).

- Phase 3A: Operational Vibration Monitoring Program Instrumentation Design, North Kent 1 Project, Chatham-Kent, Ontario, dated November 17, 2017, and prepared by Storer J. Boone, Ph.D., P.Eng., Golder Associates Ltd.

As with previous vibration monitoring, this work plan has been developed by Golder Associates Ltd. on behalf of the Project and as part of Section H1 of the Renewable Energy Approval (REA) 5272-A9FHRL issued by the Ontario Ministry of the Environment and Climate Change (MOECC). To facilitate approvals and address construction scheduling, the Phase 3 work plan is separated into two components: *Phase 3A: Instrumentation Design*; and *Phase 3B: Monitoring Program*. Planning and decisions related to the data collection and reporting will be finalized and submitted to the Ministry in due course under a Phase 3B program work plan.

Yours sincerely,

North Kent Wind 1 LP

cc. Mohsen Keyvani, Director, Ministry of Environment and Climate Change
Jody Law, Pattern Energy
Joshua Vaidhyan, Samsung Renewable Energy

November 17, 2017 Project No. 1668031-1000-L02

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PHASE 3A: OPERATIONAL VIBRATION MONITORING PROGRAM INSTRUMENTATION DESIGN
NORTH KENT WIND 1 PROJECT
CHATHAM-KENT, ONTARIO

This letter summarizes one part of a future Phase 3 work plan to carry out vibration monitoring during operation of wind turbines within the North Kent Wind 1 facility (Project). As with previous vibration monitoring, this work plan is developed as part of Section H1 of the Renewable Energy Approval (REA) 5272-A9FHRL issued by the Ontario Ministry of the Environment and Climate Change (MOECC). This monitoring plan shall commence after the NK1 wind Project Commercial Operation Date following the commissioning period.

Background

Thirty-four wind turbines will be constructed for the Project. These turbines have been grouped into seven clusters for the purposes of vibration monitoring. Each turbine is supported by a 17-metre (m) diameter reinforced concrete base and 18 closed-end pipe piles driven into the ground to support each turbine tower base. As previously described, these piles will be stopped on or above bedrock, anchored to the bedrock by drilling and grouting a steel anchor bar in place and filling the pile with concrete. As part of the Phase 1 vibration monitoring program, six boreholes were drilled in proximity to the proposed location of the foundation for T42. The boreholes were drilled in pairs with one borehole extending into the bedrock and another terminating within the subsurface above the bedrock. The borehole pairs are located, 10 m, 30 m and 50 m, away from the driven test pile. These boreholes were fitted with a series of accelerometers to measure subsurface vibrations during test pile installation, as described in the finalized test pile monitoring report “North Kent 1, Surface and Subsurface Vibration Monitoring Report, Test Piles T5 and T42,” dated June 16, 2017.

To facilitate approvals and address design aspects of the foundations and construction scheduling, the Phase 3 work plan is separated into two components:

- Phase 3A: Instrumentation Design
- Phase 3B: Monitoring Program

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Installation of fixed accelerometers must be completed as the foundation structure is completed since the accelerometers must be physically coupled to the final foundation. Decisions related to the frequency and continuity of data collection and reporting will be finalized in due course under the Phase 3B program, but the physical limitations of the foundation structure require earlier consideration.

Phase 3A Work Plan – Instrumentation Design

Of note, within the program below, emphasis is placed on use of uniaxial Meggit 731A (or PCB equivalent) and triaxial PCB356B18 accelerometers for turbine base structure monitoring, since these were also installed and used as part of the MOECC-approved Phase 1 program. The PCB356B18 triaxial sensors, while capturing vibration amplitudes in 3 orthogonal directions, are not as sensitive as the Meggit 731A sensors, but offer the advantages of capturing larger vibrations that might occur and can measure these simultaneously in 3 directions. Monitoring of the planned Project-specific new well casings (described below) will be carried out using the same PCB393A03 accelerometer systems as currently in use for the Phase 2 well monitoring program.

The Phase 3 Work Plan Instrumentation Design includes additions to the existing instrumentation at turbine T42 that was the focus of the Phase 1 Test Pile Vibration Monitoring program. Additional instrumentation within the Project will be installed on three more separate turbine sites. Figure 1, attached, illustrates the locations of all instrumented turbine sites.

Turbine T42 Instrumentation Design

The Phase 3A vibration monitoring instrumentation design for the T42 site is summarized below and illustrated on the attached Figure 2. The intent of this additional instrumentation is to measure and correlate tower, base and bedrock vibrations to the extent that the existing in-ground accelerometers survive their in-ground embedment. To date, the three sensitive Meggit 731A uniaxial accelerometers that have already been installed in rock at the T42 site, located at 10, 30 and 50 m from the turbine piles, have been checked, are functioning and will be utilized for this program as these provide the highest resolution of potential bedrock vibrations. If all of these in-rock instruments at the T42 site become inoperable within 6 to 12 months following the Project Commercial Operation Date, and sufficient data is not available for development of correlations to other instrument data, a contingency for installation of a mock well (as described below) has been included in this plan.

New vibration monitoring equipment at the T42 site will include:

1) A pair of instruments, consisting of one Meggit 731A uniaxial and one PCB356B18 triaxial accelerometer, will be installed and rigidly coupled to the surface of the reinforced concrete foundation at each of the following locations as illustrated on the attached Figure 2:

    a. above the pile radially aligned with the in-ground sensors (Accelerometer Pair No. 1); and

    b. near a pile oriented radially at 90 degrees from the line of in-ground sensors (Accelerometer Pair No. 2);

    Mounting the instruments near the perimeter of the concrete foundation allows for monitoring vibrations associated with “rocking” motions of the foundation and the consequent tension and compression-related vibrations transmitted to the piles.

    The instruments will be mounted to the foundation concrete and covered by a protective steel box. The accelerometers will be oriented so that the uniaxial accelerometer is vertical and the triaxial accelerometer

has one vertical axis and one of the horizontal axes is oriented toward the existing in-ground Phase 1 program accelerometers for Accelerometer Pair No. 1. The triaxial sensor for Accelerometer Pair No. 2 will have one vertical axis with one of the horizontal axes radially oriented at 90 degrees to that of Pair No. 1. The accelerometers will be rigidly mounted to the reinforced concrete foundation structure using threaded rods. Given the structural reinforcing requirements, the sensors will not be embedded within the concrete structure. Once backfilling and installation of the electrical grounding rings around the base of the turbine tower is completed, the accelerometers will no longer be accessible for future replacement or maintenance. In the event that these instruments malfunction, new similar instruments will be attached to the turbine pedestal, where accessible, and correlations will be made to permit comparisons between monitoring data obtained from the different sensor positions.

2) Following tower installation, two PCB 356B18 triaxial accelerometers will be installed on the tower structure, with one sensor installed approximately midway up the tower and one sensor near the top of the tower, to capture vibrations of the structure driven by wind forces so as to correlate these with responses of the reinforced concrete foundation, piles, and already installed in-ground sensors (see schematic on Figure 2). These accelerometers will be attached to the tower using a conventional magnetic mounting system.

   The intention of installing accelerometers to the one turbine tower is to be able to correlate tower movements induced by wind and operation to those of the base. This work plan includes use of the PCB356B18 triaxial accelerometers for the tower monitoring since they are sufficiently sensitive for the anticipated tower movements and give readings in 3 directions simultaneously, whereas the more sensitive accelerometers measure in only one direction (hence the pairing of accelerometer types for the in-ground systems). The tower itself is expected to exhibit greater amplitudes of vibrations/movements as compared to the tower base and ground and it will be more important to capture directionality of these movements. The movement of the base, however, is of most concern. Having one turbine for which the tower-base vibration relationship is defined should suffice when meteorological data from the facility can also be provided. The characteristics of the towers themselves should be well known since these are manufactured systems. The important aspect is how the base responds to meteorological input on the tower. Three turbines (T23, T41 and T51) will have their bases monitored as described below. Data from the four bases can be compared in their response characteristics to understand if there are measurable differences amongst the bases that might be attributable to different ground conditions. The intent is to use the four instrumented bases, three mock wells (as described below) and the in-ground instrumentation at T42 to ascertain if there are measurable ground responses and constructive interferences when multiple turbines are operating. Additional turbine tower monitoring is not considered of essential value.

3) Prior to, and during, the installation of the vibration monitoring equipment described above, Golder staff will coordinate with RES and their subcontractors to install the sensors as required with nominal interference with normal construction practices.

4) The existing steel casings housing the cables from the Phase 1 in-ground systems must be partially excavated and cut such that they are 1 m below the surface to avoid interference with future farming. Conduit containing the cables for the underground sensors will be installed via trench to the T42 foundation area (see attached Figure 2).

All instrumentation will be linked via cables to a centralized data logger and data remote uplink system within the T42 tower base. We anticipate using power from within the turbine base to supply voltage for those instruments installed on the turbine base, in the tower and the in-ground instruments at the T42 site. A remote data uplink systems will be used for these instruments.

Instrumentation Design for Three Additional Turbine Sites

Three additional turbine sites have been selected for installation of additional instruments. These three turbines are located at T23, T41 and T51. Rationale for the selected turbine locations is provided in a subsequent section of this work plan (below). At each of the three selected turbine sites, instrumentation will be installed as follows:

1) One pair of accelerometers will be mounted within a protective housing rigidly attached to the turbine base near the perimeter of the foundation as described under item 1, above. While item 2 identifies two pairs for T42, only one pair will be installed for the additional turbine bases, as illustrated on Figure 3.

   T42 includes two pairs of accelerometers mounted to the foundation. These are used to assist with 3-dimensional resolution of the various tower and base movements along with the radial line of in-ground instruments at the T42 site and the wind direction causing the tower movements. The remaining turbines T23, T41 and T51 will be fitted with one triaxial and one uniaxial accelerometer pair. These pairs will be radially oriented (via compass bearing) in the same direction as one of the pairs on T42. Given that all pairs include a triaxial instrument, two pairs of accelerometers are not considered necessary on the three separate turbines T23, T41 and T51.

2) One mock well casing will be installed and fitted with three accelerometers in accordance with the methodology used in the Phase 1 Test Pile and Phase 2 Construction Vibration Monitoring programs. This well casing will be used as a means for direct comparison to conditions that could be experienced by the similar privately-owned well casings in the Project area. The mock well will be installed using conventional water well drilling methods with a casing installed to and cemented into the top of the bedrock. The mock well will be installed at a location along the turbine access road where property access and use is available. Further, the mock well will be installed from about 100 m to as much as 300 m from the nearby municipal roads to reduce the influence of vibrations associated with traffic passing over the transverse joints of the composite broken concrete and asphalt surface roads that are ubiquitous in the area.

Turbine	Schematic Turbine to Mock Well Distance (m)	Schematic Mock Well to Road Distance (m)
T23	500	300
T41	150	100
T51	250	250
T42 Contingency	50	83

The schematic locations of the mock well locations are illustrated on Figure 1; however, the final locations may be subject to refinements based on site-specific conditions. The mock well locations are intended to balance the need to be distant from the municipal roads for the reasons as described above as well as to provide variable turbine to in-rock instrument distances. The locations are described as schematic since these may require adjustment to address agricultural or property owner needs and the final layout of the permanent access roads to minimize the potential for the instrumentation to be struck by farm equipment or turbine access equipment (e.g., during snow removal).

While these wells will not be used for water supply, the intent is that by installing and monitoring the mock wells, conditions at other wells within the Project can be assessed using the resulting data and distance relationships, and the construction (materials, depths, diameters, sand packs, seals, grouting, installation

techniques, and aquifers) of the mock wells will be understood and appropriately documented. These mock wells will be installed at distances to turbine sites that are closer than domestic water wells to turbine sites within the Project. Additionally, while many domestic water wells in the region are installed to contact the rock or are installed into the rock, these are not cemented to the bedrock. Vibration measurements taken on a mock well casing physically cemented into the rock, however, should produce measurements that would be equal to or greater than those for a typical domestic water well (thus producing a "worst case" measurement).

3) One pair of accelerometers (as described above) will be enclosed within a sealed steel housing and grouted into the bedrock at the bottom of each mock well. If the accelerometers that are grouted into the bedrock become non-functional at some future time, data gathered until such a time will be correlated with simultaneous data obtained from the accelerometers mounted on the casings. This correlation will then be used with long-term casing vibration data to judge longer-term subsurface vibration characteristics. If the accelerometers mounted at the top of the well casing cease to function at some future date, these can be readily replaced at the surface.

   Instrument cables for subsurface instruments installed in the bedrock at the bottom of the mock wells will be enclosed within a small diameter PVC pipe to protect against long-term strains that might be associated with temperature fluctuations of the steel casing, movements of the surrounding ground (e.g., frost heave) and long-term consolidation of filler materials within the steel well casing. Cables will be installed within the pipe with excess slack and the pipes will be sealed at each end. These pipes will, however, also be isolated from the surface of the grout to avoid influencing vibration measurements. Relatively soft bentonite clay filler material will be used in the annular gap between the PVC pipe and steel well casing to minimize differences in well casing mass as compared to typical well casings while at the same time reducing the potential for the electronics cables to be fully immersed in water for the duration of monitoring and avoiding use of inflexible grout within the full height of the casing.

   If the in-rock instruments at the mock wells become inoperable within 6 to 12 months following the Project Commercial Operation Date, and sufficient data is not available for development of correlations to the casing-mounted accelerometer data, the contingency plan outlined below will be implemented:

   - drill and install new instruments in an additional mock well in close proximity to the location(s) where in-rock sensors have become inoperable within the 6 to 12 month period; or
   - remove filler materials within the mock well and install new accelerometers and re-grout these into the mock well (i.e., at the top of the grouted section that enclosed the original accelerometers) as long as these would be expected to produce data similar to the former sensors placed within the depth interval of the mock well within the rock.

4) Remote instruments installed on the mock well casings and into the bottom of the mock wells will require solar power and remote data logging and uplink systems. To the degree practicable, these systems will be housed in a locking steel box to reduce the potential for tampering, vandalism, and damage.

5) We anticipate using power from within the turbine base to supply voltage for those instruments installed on the turbine bases. Remote data uplink systems will also be used for these instruments.

6) Additional details regarding the data management systems will be provided under the forthcoming Phase 3B Monitoring program submittal.

Instrumented Turbine Locations

A total of four turbine sites will be monitored within, or in close proximity to, Cluster 7. The following turbine sites will be instrumented: T42 (as discussed above) along with T23 (Cluster 6), T51 (Cluster 6), and T41 (Cluster 7). Turbine T51, within the T19/T51 group, is identified for monitoring because the access road opens onto a road less travelled (in this area) as compared to St. Clair Road. Turbine T19 is not recommended for additional monitoring because of its proximity to the very busy St. Clair Road and background vibrations from traffic would likely dominate the monitoring results for any mock well located near the road.

As previously documented in the Phase 1 Test Pile program, vibration magnitudes and frequencies change and diminish with increasing distance from the source. Locating vibration instrumentation at large geographic separation distances would negatively affect the potential to evaluate the combined effects of multiple turbines. Therefore, the instrumented turbine locations have been chosen:

- to result in a diversity of turbine to turbine and turbine to mock well distances;
- to offer a potential for evaluating hypotheses related to constructive vibration interference because of the clustered locations;
- because of proximity to the more heavily instrumented T42 site; and
- to potentially reduce the influence of background conditions by selecting sites for mock wells as far as practicable from busy roads.

Monitoring of a turbine foundation and mock well at a site with two closely spaced turbines (T19/T51) also offers the advantage, when coupled with data from the other sites, of additional insight into the ground responses associated with two turbines operating independently as single turbines, or simultaneously, depending on operational conditions.

Closure

Phase 3B work plans, detailing data logger systems, instrument reading frequency, data management, and data analysis and reporting aspects of the Phase 3B Turbine Operation Vibration Monitoring Program will be provided in due course and prior to the operations phase of the Project.

We thank you for the opportunity to submit this work plan. North Kent Wind 1 will not commence the Operations Phase of the Project until a ground-borne vibration monitoring program for Project operations is submitted to, and approved in writing by, the Director. If you have any other questions regarding the proposed work plan or require further clarification, please contact this office.

Yours truly,

GOLDER ASSOCIATES LTD.

Jordan Kiss, MESc., E.I.T.
Geotechnical Engineer in Training

Storer J. Boone, Ph.D., P.Eng.
Principal

JK/SJB/MAS/vf

CC: J. Vaidyan, Samsung
Jody Law, Pattern Energy

Attachments: Figure 1: Instrumentation Location Plan
Figure 2: Structure Instrumentation Design T42
Figure 3: Structure Instrumentation Design

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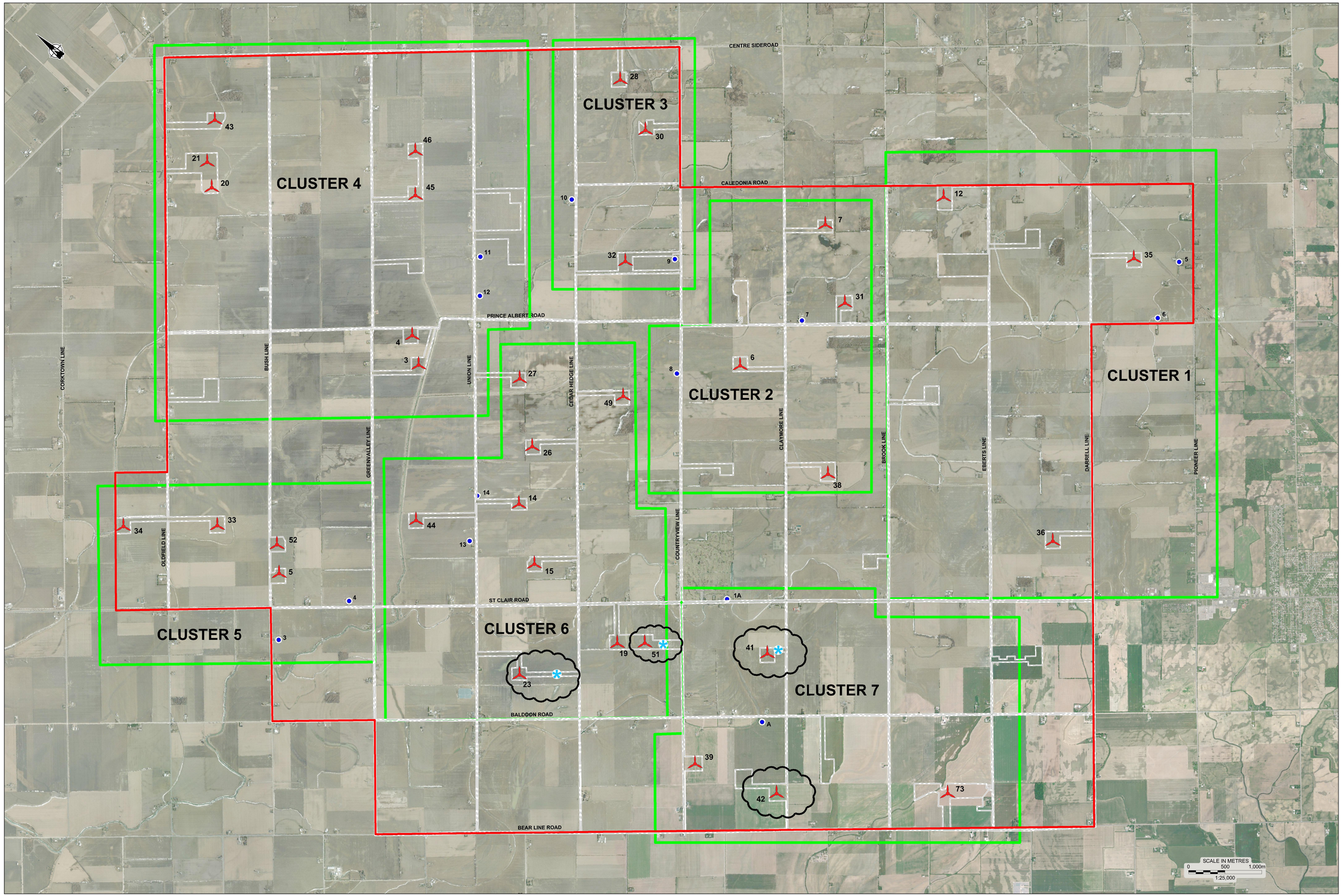

LEGEND

- WATER WELL
- TURBINE BEING CONSTRUCTED
- MONITORING CLUSTER BOUNDARY
- PROJECT STUDY AREA BOUNDARY
- MOCK WELL (LOCATION APPROXIMATE)

LONG TERM VIBRATION MONITORING SITE

- INSTRUMENTED TURBINE SITE

REFERENCE

DRAWING BASED ON BING IMAGERY AS OF SEPTEMBER 28, 2017, (IMAGE DATE UNKNOWN).

NOTES

THIS DRAWING IS SCHEMATIC ONLY AND IS TO BE READ IN CONJUNCTION WITH ACCOMPANYING TEXT.

BING IMAGERY USED FOR ILLUSTRATION PURPOSES ONLY AND NOT TO BE USED FOR MEASUREMENTS.

ALL LOCATIONS ARE APPROXIMATE.

PROJECT

NORTH KENT 1
PHASE 3 VIBRATION MONITORING PROGRAM

TITLE

INSTRUMENTATION LOCATION PLAN

Golder Associates

PROJECT No.	1668031	FILE No.	1668031-1000-L02001
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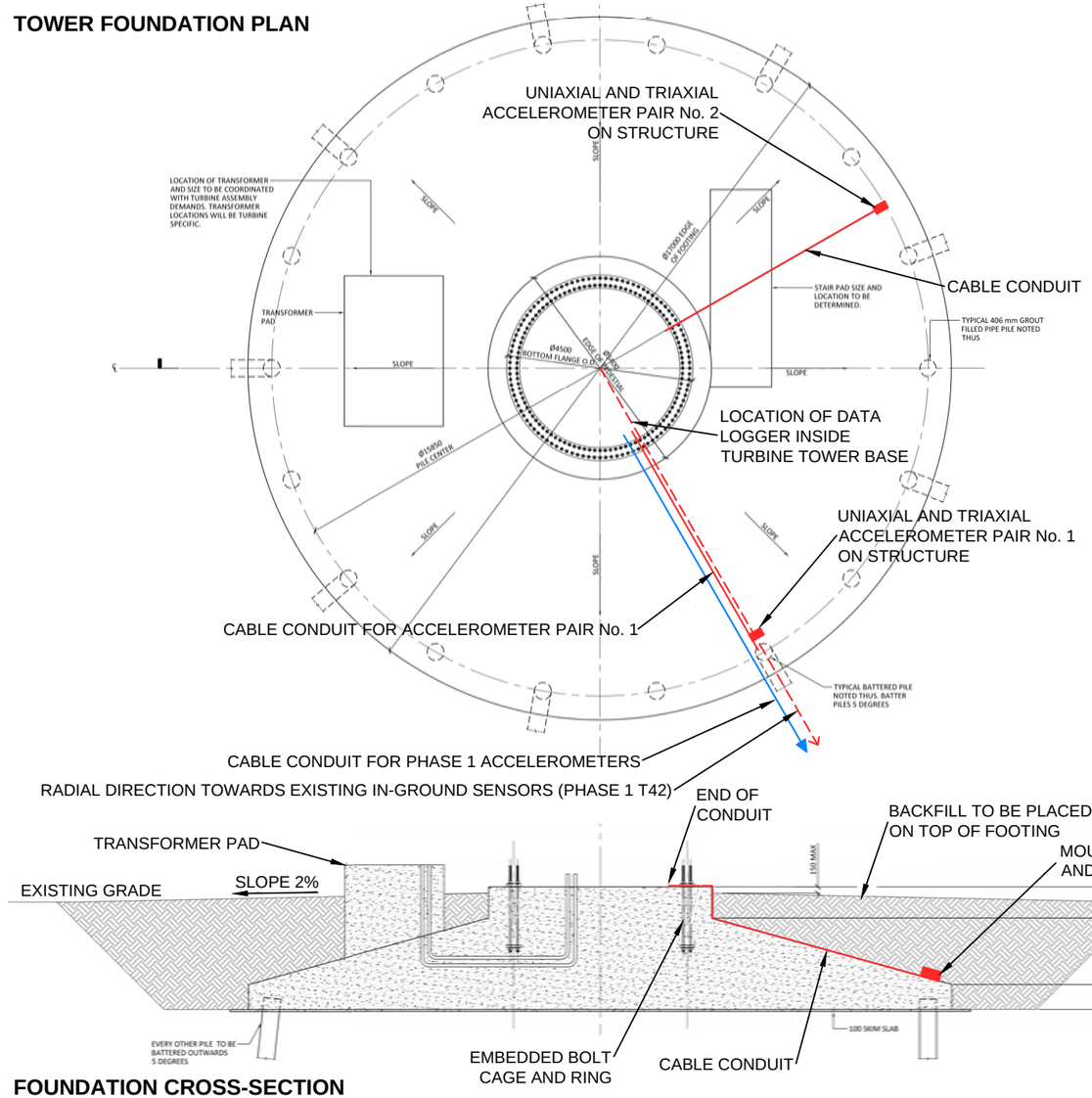
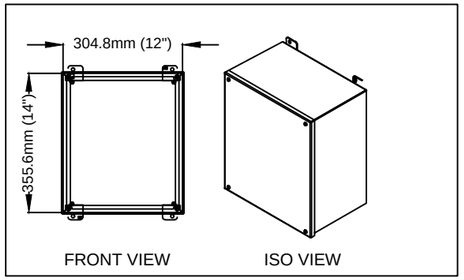
FIGURE 1

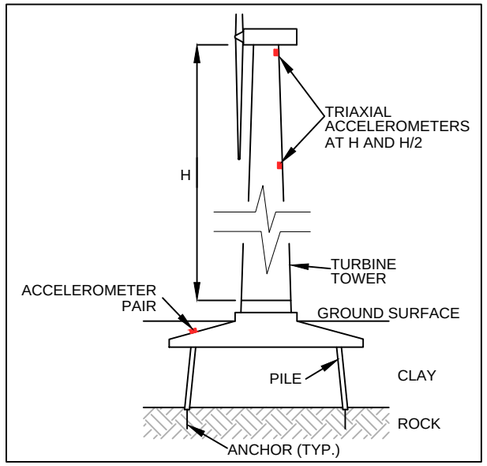
TOWER FOUNDATION PLAN



FOUNDATION CROSS-SECTION



FOUNDATION SURFACE-MOUNTED ACCELEROMETER HOUSING



SCHEMATIC PROFILE OF TURBINE TOWER AND FOUNDATION INSTRUMENTATION (Refer to Details on this Sheet)

GENERAL NOTES

1. Refer to foundation drawing: Wind Turbine Foundation, North Kent, ON, Foundation Plan, Drawing No. NK1-WG)-C-FD-P01-01, prepared by Entuitive Corporation, Rev. 2, Issued for Construction, dated 2017-06-21.
2. Foundation details shown for illustration only.
3. Accelerometer pair will consist of one Meggit 731A uniaxial and one PCB356B18 triaxial accelerometer, supplied by Golder Associates Ltd.

SURFACE-MOUNTED ACCELEROMETERS

4. Accelerometers shall be mounted in a protective steel housing securely attached to concrete foundation by bolting
5. Threaded bolts/bars shall be embedded a minimum of 150 mm into concrete. Template shall be used to ensure proper casting or drilling position for bolts and cover.
6. Protective cover shall be Hammond Manufacturing Part No. 1436K or equivalent
7. Protective steel housing shall be protected from damage during compaction of backfill

CONDUITS

8. Sch. 40 PVC conduit shall be provided with a minimum inside diameter of 25 mm between pile and surface-mounted housing and 37mm from housing to tower.
9. Turns in conduit piping shall have a radius of no smaller than 100 mm or shall be composed of 45 degree angle elbows attached in series. No 90 degree elbows with a turn radius of less than 100 mm shall be permitted.
10. Junctions between conduit and pile and conduit and steel accelerometer housing shall be sealed from ingress of concrete

PROJECT
NORTH KENT 1
PHASE 3 VIBRATION MONITORING PROGRAM

TITLE
STRUCTURE INSTRUMENTATION DESIGN TURBINE T42 ONLY

Golder Associates

PROJECT No.		1668031	FILE No. 1668031-1000-L02002
			SCALE NTS REV.
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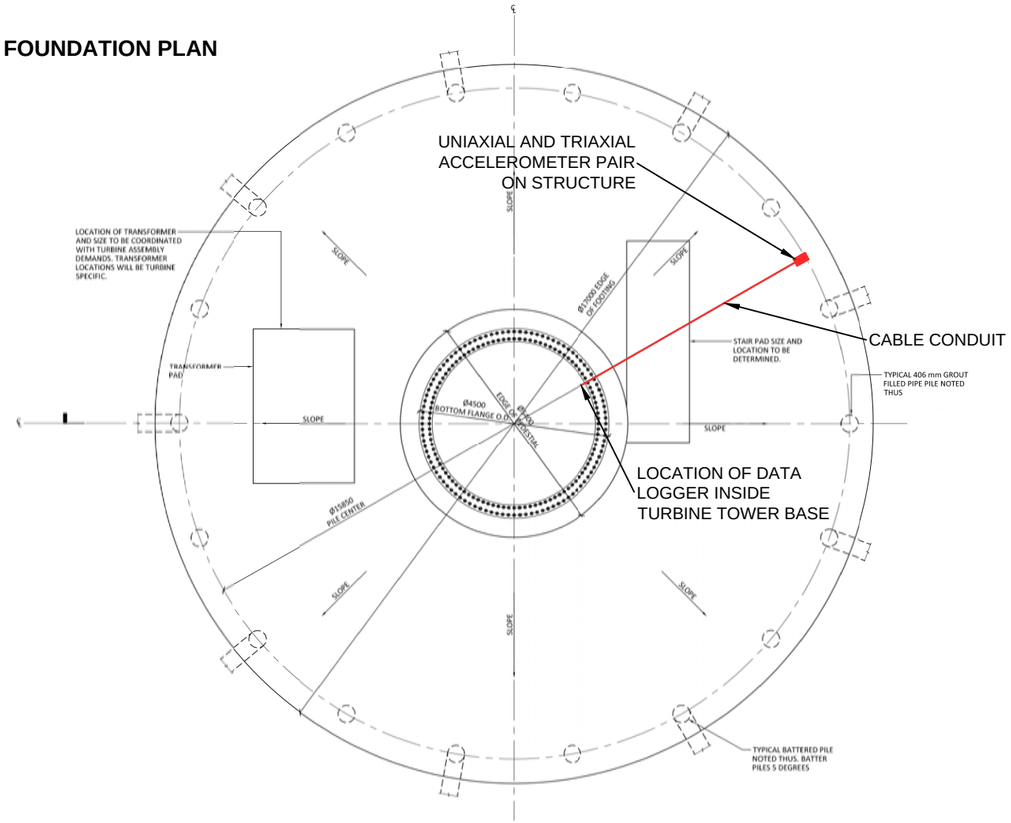
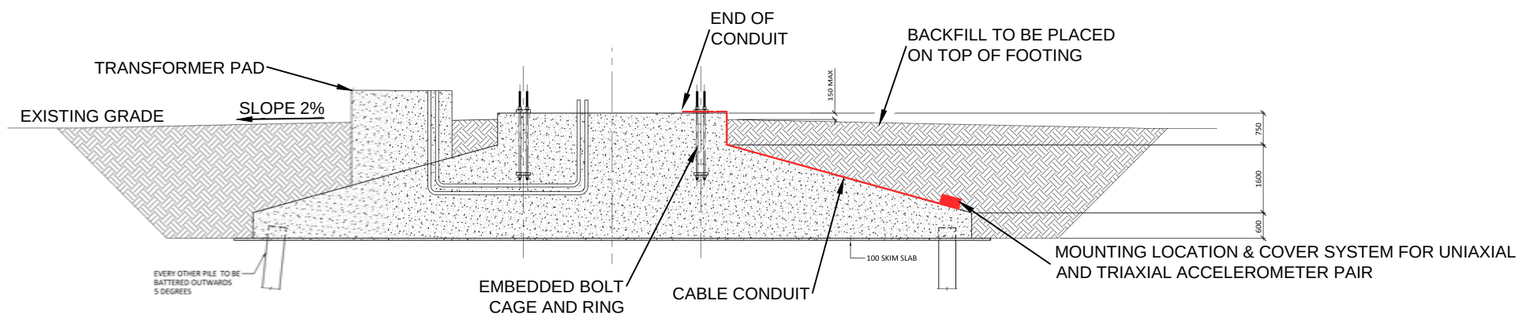
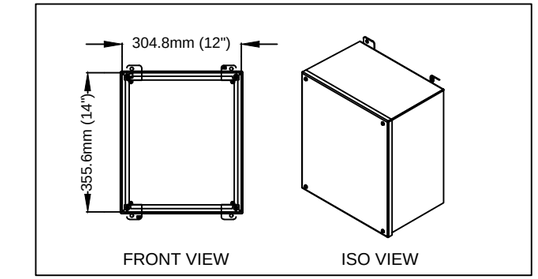
TOWER FOUNDATION PLAN





FOUNDATION CROSS-SECTION



FOUNDATION SURFACE-MOUNTED ACCELEROMETER HOUSING

GENERAL NOTES

1. Refer to foundation drawing: Wind Turbine Foundation, North Kent, ON, Foundation Plan, Drawing No. NK1-WG)-C-FD-P01-01, prepared by Entuitive Corporation, Rev. 2, Issued for Construction, dated 2017-06-21.
2. Foundation details shown for illustration only.
3. Accelerometer pair will consist of one Meggit 731A uniaxial and one PCB356B18 triaxial accelerometer, supplied by Golder Associates Ltd.

SURFACE-MOUNTED ACCELEROMETERS

6. Accelerometers shall be mounted in a protective steel housing securely attached to concrete foundation by bolting
7. Threaded bolts/bars shall be embedded a minimum of 150 mm into concrete. Template shall be used to ensure proper casting or drilling position for bolts and cover.
8. Protective cover shall be Hammond Manufacturing Part No. 1436K or equivalent
9. Protective steel housing shall be protected from damage during compaction of backfill

CONDUITS

10. Sch. 40 PVC conduit shall be provided with a minimum inside diameter of 37 mm from housing to tower.
11. Turns in conduit piping shall have a radius of no smaller than 100 mm or shall be composed of 45 degree angle elbows attached in series. No 90 degree elbows with a turn radius of less than 100 mm shall be permitted.
12. Junctions between conduit and pile and conduit and steel accelerometer housing shall be sealed from ingress of concrete

PROJECT
NORTH KENT 1
PHASE 3 VIBRATION MONITORING PROGRAM

TITLE
STRUCTURE INSTRUMENTATION DESIGN TURBINES T23, T41 AND T51

Golder Associates

PROJECT No.			1668031	FILE No. 1668031-1000-L02003
				SCALE NTS REV.
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CHECK	SJS			**FIGURE 3**

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