



September 2016

## NORTH KENT WIND ENERGY PROJECT

### Evaluation of Potential Turbine Foundation Influences on Water Supply Wells from Alleged Geological, Geotechnical, Hydrogeological and Radiological Conditions

REPORT



Report Number: 1662594-R01





## Executive Summary

This report presents an evaluation of alleged concerns related to the influences of wind power turbines on the geotechnical engineering, hydrogeology and radiological conditions of the North Kent Wind 1 project area in the Municipality of Chatham-Kent, Ontario as illustrated on Figure 1. Golder Associates Ltd. (Golder) has completed this work for North Kent Wind 1 LP, through its counsel Davies Ward Phillips & Vineberg LLP (DWPV), as related to a Notice of Appeal under the Environmental Protection Act and the Environmental Bill of Rights (1993) regarding Renewable Energy Approval Number 5272-A9FHRL issued June 29<sup>th</sup>, 2016.

The Notice of Appeal alleges that the proposed driven pile foundations that are to be constructed for support of the wind turbines and the subsequent operation of the turbines will cause harm to the environment and human health through contamination by radionuclides, including radon, of groundwater used in water wells. The means by which the pile foundations are alleged to influence the groundwater at the North Kent Wind 1 site, and to have allegedly already influenced the groundwater conditions in the area of Dover Centre, appear to include the foundations' alleged influences on subsurface rock and sediments containing radionuclides being transported to the water wells during construction and subsequent operation of the turbines.

To consider the allegations in the Notice of Appeal, Golder organized a multi-disciplinary team. This team took into account the properties of radionuclides (including radon) and identified for investigation the mechanisms by which water supply wells might be influenced by radionuclides. Given that groundwater quality data for the area of the proposed wind turbine project are limited in scope and detail and do not constitute a sufficient set of baseline data against which to evaluate pre- and post-construction conditions in individual water supply wells, this report uses analytical models to evaluate and test the hypothesis that the wind turbine foundations and their construction and operation could adversely affect groundwater quality in water supply wells, with a focus on radionuclides and, in particular, radon.

The review of published information and the engineering, hydrogeologic and radiological evaluations completed during preparation of this report lead to the following summary conclusions:

- The influence of pile foundation construction and turbine operation on radon concentrations within well water and atmospheric conditions in the area, if any, is likely to be insignificant.
- The influence of ground vibrations generated during pile foundation construction and turbine operation on well water conditions, if any, is likely to be insignificant.
- Ground vibrations generated during construction and subsequent turbine operation are expected to be significantly below published thresholds for human perception at the residence locations.
- Ground-borne vibrations will not influence the rate of radon generation or radon concentration within the groundwater.
- There is no plausible mechanism by which fine rock particles, and their radionuclide constituents (if present) can be transported tens or hundreds of metres from turbine foundation pile locations to water supply wells.
- Other groundwater chemistry or quality measurements (e.g., turbidity, total suspended solids, dissolved metals, etc.) for water well uses in the vicinity of the wind energy project are unlikely to be affected by turbine



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## **PRIVILEGED AND CONFIDENTIAL NORTH KENT WIND 1**

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construction or operation. Such water well quality issues are more likely to be affected by regional natural water quality characteristics and their natural variability, near-well conditions (with a few metres), well construction details, well and pump conditions and pump operations.

- Published turbine off-set distances for vibrations as related to sensitive scientific instrument and research stations are not relevant to the concerns expressed for this project.
- In light of the analytical modelling and evaluations and planned setback distances, the only significant influences on the quality of water within and drawn from water wells in the project area are currently associated with natural background conditions and those in the immediate vicinity of the wells and this will continue to be the case during construction and operation of the project.

Based on the analysis and conclusions presented in this report we can conclude to a reasonable degree of scientific certainty that the construction and operation of the turbines at the planned setback distances will not cause harm to groundwater quality either at the wells or in the broader subsurface groundwater environment as alleged in the Notice of Appeal.



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## **1.0 INTRODUCTION**

This report presents an evaluation of alleged concerns related to the influences of wind power turbines on the geotechnical engineering, hydrogeology and radiological conditions of the North Kent Wind 1 project area in the Municipality of Chatham-Kent, Ontario as illustrated on Figure 1. Golder Associates Ltd. (Golder) has completed this work for North Kent Wind 1 LP, through its counsel Davies Ward Phillips & Vineberg LLP (DWPV), as related to a Notice of Appeal under the Environmental Protection Act and the Environmental Bill of Rights (1993) regarding Renewable Energy Approval Number 5272-A9FHRL issued June 29<sup>th</sup>, 2016.

The Notice of Appeal alleges that the proposed driven pile foundations that are to be constructed for support of the wind turbines and the subsequent operation of the turbines will cause harm to the environment and human health through contamination by radionuclides, including radon, of groundwater used in water wells. The means by which the pile foundations are alleged to influence the groundwater at the North Kent Wind 1 site, and to have allegedly already influenced the groundwater conditions in the area of Dover Centre, appear to include the foundations' alleged influences on subsurface rock and sediments containing radionuclides being transported to the water wells during construction and subsequent operation of the turbines.

To consider the allegations in the Notice of Appeal, Golder organized a multi-disciplinary team. This team took into account the properties of radionuclides (including radon) and identified for investigation the following mechanisms by which water supply wells might be influenced by radionuclides:

- 1) direct transmission of groundwater with increased concentrations of radon arising from fracturing of rock by pile foundation construction;
- 2) groundwater transport of other radionuclides (as a component of particulates) to the water supply wells; and
- 3) the influences of ground-borne vibrations on particulates and radionuclides (including radon) existing at and proximate to the wells.

Given that groundwater quality data for the area of the proposed wind turbine project are limited in scope and detail and do not constitute a sufficient set of baseline data against which to evaluate pre- and post-construction conditions in individual water supply wells<sup>1</sup>. This report uses analytical models to evaluate and test the hypothesis that the wind turbine foundations and their construction and operation could adversely affect groundwater quality in water supply wells, with a focus on radionuclides and, in particular, radon.

Numerical modelling and analytical exercises have scientific value in the determination of the potential effects a given course of action or actions may have on highly complex groundwater flow systems, both from a water quantity and quality perspective. By incorporating key assumptions of the conceptual hydrogeological model (that represents the real system) into the numerical model, potential effects on groundwater flow systems can be tested. Previous experience in similar environments and expertise in evaluating the circumstances controlling the fate and movement of solutes in such environments allows for a more accurate conceptual (and numerical) model. Accurate numerical models then allow testing of the groundwater flow system's sensitivity to any uncertain input variables.

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<sup>1</sup> . While data exists related to near-surface and atmospheric radon conditions no suitable set of groundwater radon concentration data exist for the area. Geologic and groundwater data that is available for the area suggests widely varying groundwater quality, as measured by a few quality or chemistry parameters, and variable subsurface conditions.



The intent of the report is to document multi-disciplinary engineering, geology, hydrogeology and radiological sciences evaluations that form the basis for opinions provided by the authors to North Kent 1 LP. This report is organized in two parts:

**Part A - Review of Project Background and Available Information:** All published documents disclosed by the Appellant along with witness statements submitted as part of the Notice to Appeal proceedings have been reviewed in preparation of this report. Key documents disclosed by the Ontario Ministry of the Environment and Climate Change (MOECC) have also been reviewed. A list of the documents made available as part of the proceedings is provided in Appendix A. Published scientific and other references directly cited in this report are listed at the conclusion of the text under the References heading. Appendix B includes a list of well and turbine setback distances prepared for North Kent Wind 1 LP by AECOM and Appendix C includes property addresses as compared to proposed turbine locations, also prepared by AECOM. Documents included in Appendices A through C were provided to Golder through DWPV.

**Part B - Analysis of Potential Turbine Foundation Influences on Soil and Groundwater:** Published information and available documents were used to develop an analytical model of the site conditions and allow evaluation of influence of turbine construction on the subsurface radiological and hydrogeologic environment. Published information was also used as a basis for calibrating the model to known conditions, when appropriate, and comparison of modelling result to known conditions. Computer-aided simulations of the subsurface conditions and changes in these conditions were completed along with other analytical and empirical (comparisons to published evidence) analyses and evaluations that were based on engineering, hydrogeology and radiological principles. This work allowed testing of the hypotheses underlying the manner by which the construction and operation of the turbines are alleged to possibly influence the subsurface conditions using variations of input information to better understand the complex interaction of subsurface conditions and to address uncertainties associated with available background information.

To assist with describing the analytical model of the site conditions, Figures 2A through 2D, provided as context for the Notice of Appeal and this report, schematically illustrate a cross-section of the existing and proposed future subsurface conditions relevant to this site:

- 1) the existing conditions, described from the ground surface down, consist of:
  - a. a layer of sand and silt near the ground surface (typically 1 to 2 m thick);
  - b. a thick layer of silty clay (some 10 to 15 m thick);
  - c. water-bearing sand and gravel (aquifer) underlying the silty clay (average of slightly less than 2 m thick); and
  - d. the uranium-bearing Kettle Point Formation shale bedrock;
- 2) water supply wells have been drilled through the sand and silt, through the silty clay and include a screen zone drilled into and installed within the sand and gravel and underlying weathered bedrock from which water is drawn;
- 3) an excavation at the proposed turbine site is proposed to permit foundation construction;



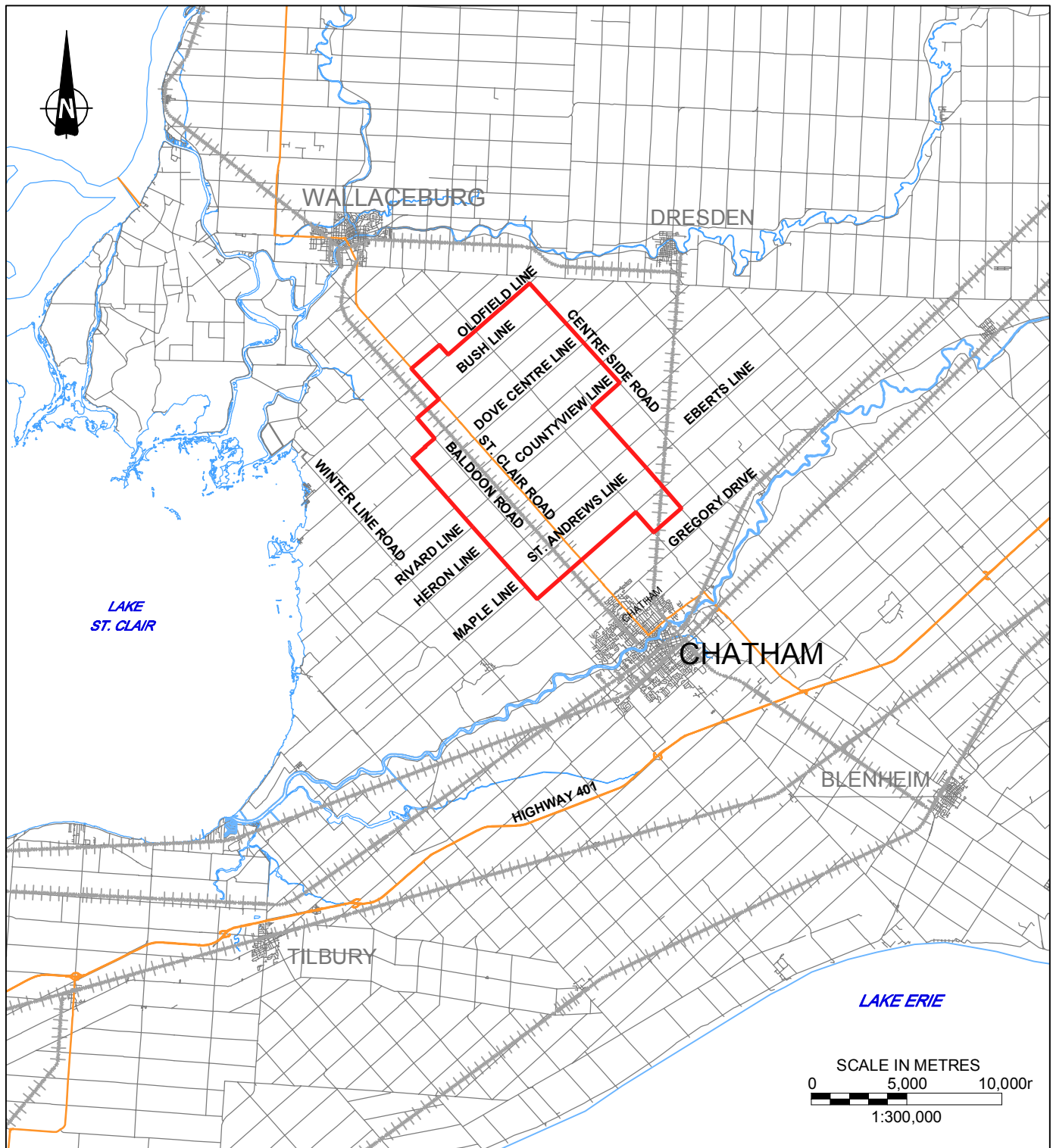
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## **PRIVILEGED AND CONFIDENTIAL NORTH KENT WIND 1**

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- 4) the foundation would consist of between 30 and 40 steel H piles driven in a circle from the bottom of the excavation to the top of bedrock or to the point that the pile hammer cannot drive the piles without further damaging the piles;
- 5) once the piles are in place, a reinforced concrete foundation would be constructed and the excavation will be backfilled with soil materials; and
- 6) the turbine components will be erected and the system will become operational.

Summary conclusions are provided at the end of this report relating the outcome results of this work to the allegations in the Notice of Appeal.



## LEGEND

— SITE

## REFERENCE

DRAWING BASED ON CANMAP STREETFILES V2008.4.

## NOTES

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ALL LOCATIONS ARE APPROXIMATE.

### PROJECT

EVALUATION OF POTENTIAL TURBINE FOUNDATION INFLUENCES ON WATER SUPPLY WELLS FROM ALLEGED GEOLOGICAL, GEOTECHNICAL, SEISMIC, HYDROGEOLOGICAL AND RADIOLOGICAL CONDITIONS

### TITLE

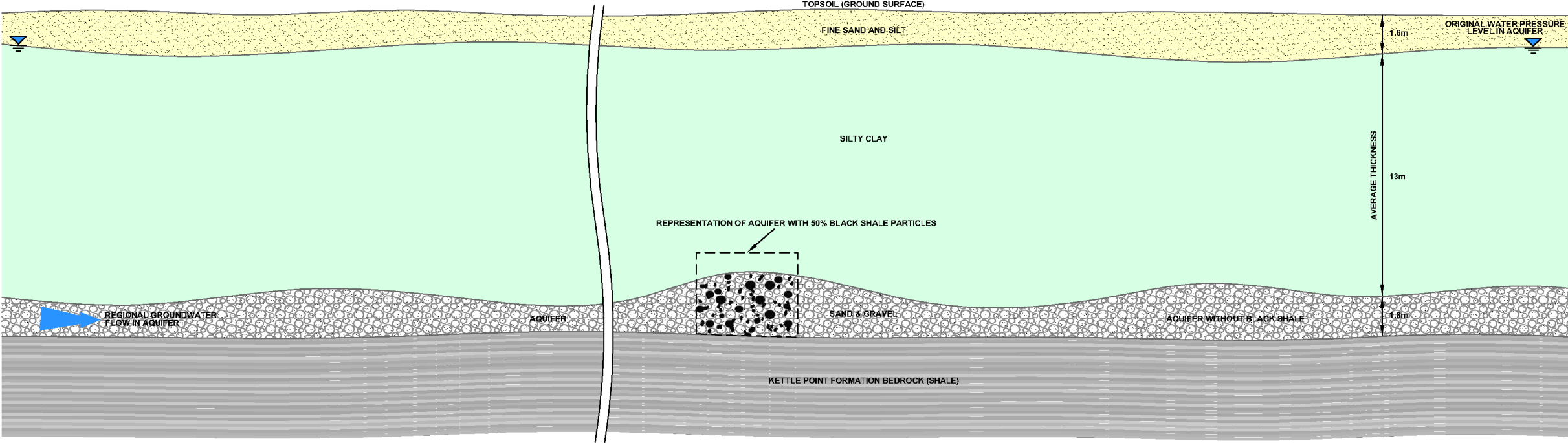
## SITE LOCATION PLAN



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**FIGURE 1**

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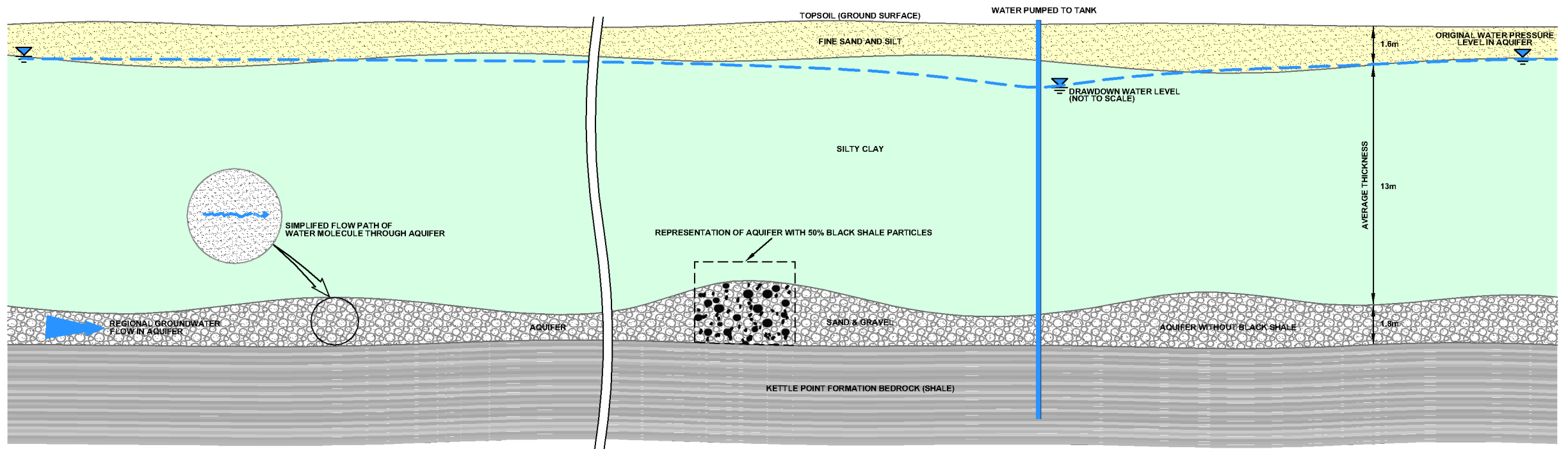
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| EVALUATION OF POTENTIAL TURBINE FOUNDATION INFLUENCES ON WATER SUPPLY WELLS FROM ALLEGED GEOLOGICAL, GEOTECHNICAL, SEISMIC, HYDROGEOLOGICAL AND RADIOLOGICAL CONDITIONS |  |                |  |
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| EXISTING CONDITIONS                                                                                                                                                     |  |                |  |
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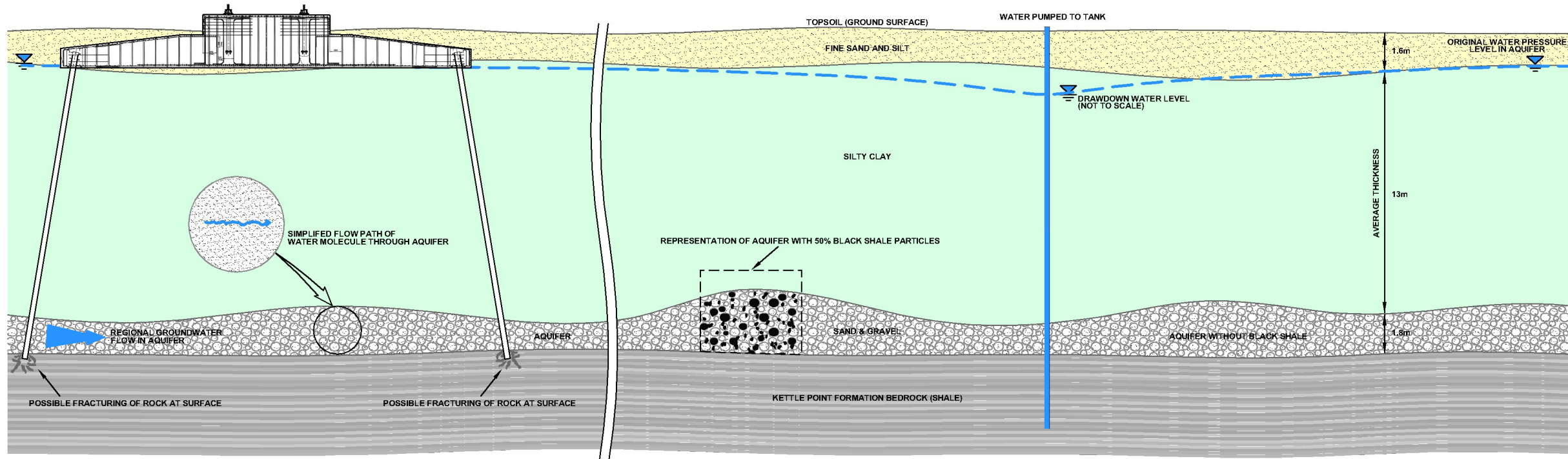


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| PROJECT                                                                                                                                                                 |                     |     |                         |           |
| EVALUATION OF POTENTIAL TURBINE FOUNDATION INFLUENCES ON WATER SUPPLY WELLS FROM ALLEGED GEOLOGICAL, GEOTECHNICAL, SEISMIC, HYDROGEOLOGICAL AND RADIOLOGICAL CONDITIONS |                     |     |                         |           |
| TITLE                                                                                                                                                                   |                     |     |                         |           |
| DOMESTIC WELL INSTALLED                                                                                                                                                 |                     |     |                         |           |
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|                                                                                                                                                                         |                     |     |                         | FIGURE 2B |

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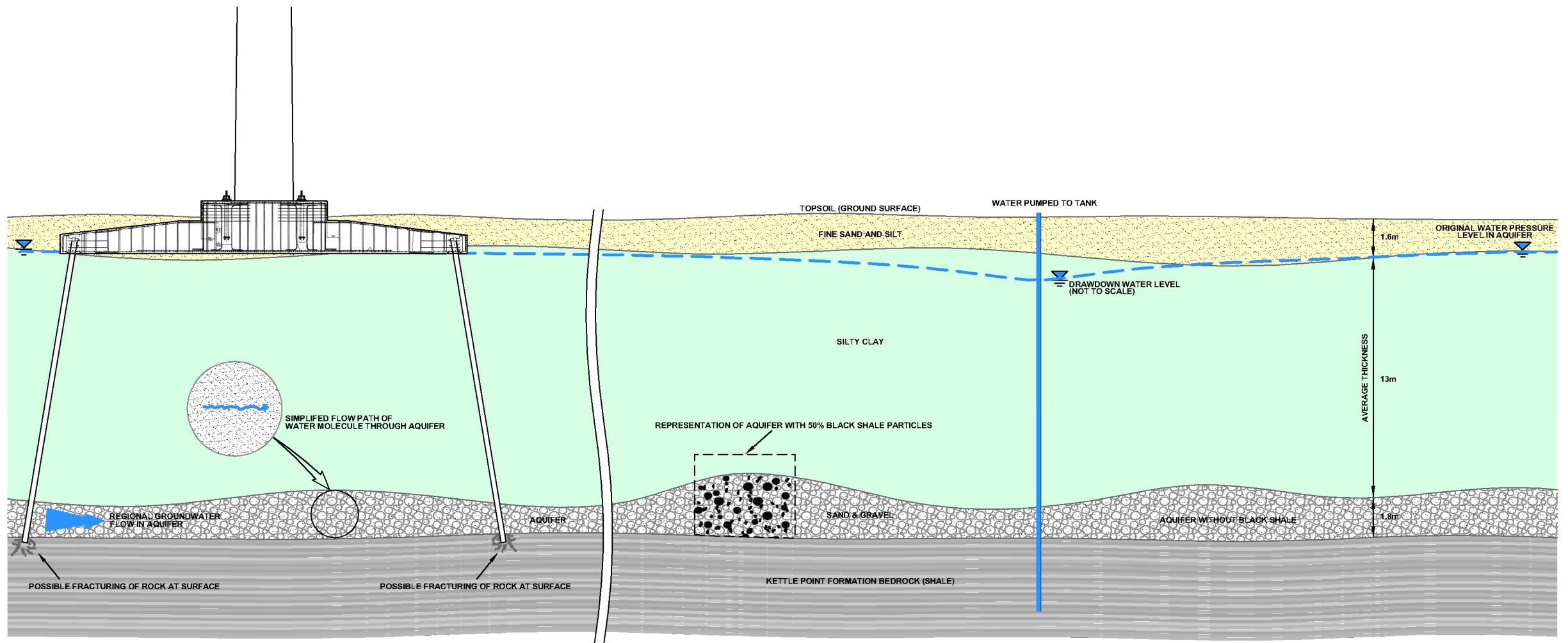


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| PROJECT                                                                                                                                                                       |             |          |                         |
| EVALUATION OF POTENTIAL TURBINE FOUNDATION INFLUENCES ON WATER<br>SUPPLY WELLS FROM ALLEGED GEOLOGICAL, GEOTECHNICAL, SEISMIC,<br>HYDROGEOLOGICAL AND RADIOLOGICAL CONDITIONS |             |          |                         |
| TITLE                                                                                                                                                                         |             |          |                         |
| EXCAVATION FOR FOUNDATION, DRIVEN<br>PILES, AND BACKFILL OF FOUNDATION                                                                                                        |             |          |                         |
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| FIGURE 2C                                                                                                                                                                     |             |          |                         |

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| EVALUATION OF POTENTIAL TURBINE FOUNDATION INFLUENCES ON WATER SUPPLY WELLS FROM ALLEGED GEOLOGICAL, GEOTECHNICAL, SEISMIC, HYDROGEOLOGICAL AND RADIOLOGICAL CONDITIONS |             |         |                         |
| TITLE                                                                                                                                                                   |             |         |                         |
| TURBINE OPERATING                                                                                                                                                       |             |         |                         |
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| FIGURE 2D                                                                                                                                                               |             |         |                         |



**PART A – PROJECT BACKGROUND AND  
REVIEW OF AVAILABLE INFORMATION**



## **2.0 PROJECT SUMMARY**

The North Kent Wind 1 project is planned to include 34 wind turbines, producing 100 MW of electrical power, constructed over a 12-month period within the Municipality of Chatham-Kent. The turbines are planned to be located in an area generally between Wallaceburg and Chatham, Ontario, bound by Bear Line on the west, Centre Side Road on the east, Oldfield Line on the north and Darrell Line and Pine Line on the south. In the project region the site topography is relatively flat and the primary land use is agricultural.

## **3.0 SUBSURFACE CONDITIONS**

Available background information relating to the subsurface conditions of the project site and surrounding area was reviewed to develop an appropriate geologic, hydrogeologic, geotechnical and radiological model of the mechanisms by which it has been alleged that water supply wells might be affected by the planned wind turbine foundations. The subsurface conditions are described below from the ground surface down and separated into the various major geologic units followed by a discussion of the hydrogeologic conditions.

The project site lies in the St. Clair Clay Plains Physiographic region of Southwestern Ontario (Chapman and Putnam 1984). The subsurface conditions, described from the surface down, can be generally characterized as follows:

- topsoil is commonly encountered near the surface and, in many areas, represents tilled and worked farmlands;
- in some areas, below the topsoil, deposits of sand and silt exist ranging in total thickness between 0 and 8.2 metres (m) with an average of 1.7 m, based on the boreholes completed for this project (AMEC 2016a);
- below the sand and silt, where present, the majority of the soils consist of a regionally extensive deposit of very soft to firm silty clay, ranging in thickness at the planned turbine sites from 10.5 to 17.5 m with an average of 13.2 m (AMEC 2016a);
- sand and gravel soils<sup>2</sup> (aquifer), with varying proportions of silt, either representing ice-contact outwash or basal glacial till soils, are found between the overlying thick silty clay deposits and the underlying bedrock and these soils represent the local aquifer and range in thickness from 0 m to 10.4 m with an average of about 2.2 m (AMEC 2016a); and
- bedrock of the Kettle Point Formation.

The three major subsurface units that affect this project are the thick deposits of silty clay, the granular soils under the silty clay and the bedrock. Each of these units is described in greater detail below.

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<sup>2</sup> In the context of this report, the word soil is used to describe mineral particles deposited naturally by a variety of geologic mechanisms and is not to be confused with soil definitions as used for agronomy or other soil sciences.



## **3.1 Soil Stratigraphy**

### **3.1.1 Silty Clay**

The near-surface soils in the area are mapped largely as being of glaciolacustrine or glaciomarine origin, having been deposited in large lakes formed during the last retreat of continental glacial ice, beginning some 14,000 years ago (Chapman and Putnam 1984, Barnett et al. 1991) during the late Pleistocene Era. Below the sand and silt soils, where present, the regionally extensive and thick silty clay was deposited either from the base of floating ice sheets without significant stratification and/or as fine glacial sediment settling within large glacial meltwater lakes. In many areas, these soils possess a distinctively till-like structure with a small fraction of sand and gravel sized particles distributed randomly throughout. As a result, these silty clay deposits are often called “till” or “black till” in publications, though the soils are not consistent with “basal” till soils that immediately overlie the bedrock and represent materials abraded, crushed and transported at and near the active margin between continental ice sheets and bedrock or previously-deposited sediments. For the purposes of this report, only those dense or hard soils that exist between the bedrock and overlying softer or looser sediments are referred to as “till”. Silt deposits, pockets and lenses of sandy silt to silty sand of varying thicknesses are occasionally present within the silty clay.

The silty clay soils in the geographic region are generally composed of “rock flour” of silt- and clay-size particles with activity [plasticity index (PI) divided by percent <0.002 mm clay] typically less than about 0.6 and often closer to 0.4. The sediment minerals mainly consist of illite, chlorite, quartz, feldspar, and carbonates; swelling minerals such as smectite (montmorillonite) and vermiculite are seldom present in more than trace amounts (Boone and Luttenegger 1997). Typical Atterberg limits determinations indicate that the soils are often low to medium plasticity ( $2 < PI < 30$ ), typically plot just above the “A” line, and are within the ranges reported for illite soils. Typical ranges of Atterberg limits of the soils investigated by AMEC (2016a) for the wind turbine facility indicated plasticity values ranging from 11 to 24 based on 5 tests. The silty clays in the region are derived, in part, from the Kettle Point Formation shales and, therefore, their mineralogy is defined in some measure by the mineralogy of the parent materials (Lesarge and Boone 2013). Clasts of Kettle Point Formation black shale make up about 5% of the silty clay and, to some degree, the fine-grained particles also include finely-ground rock flour originating from the Kettle Point Formation (Fitzgerald 1979, Lesarge and Boone 2013). Trace metals are found within the cohesive silty clay soils of the region that are also found in the Kettle Point Formation mineralogy (Lesarge and Boone, Tilsley et al. 1993) and these metals include uranium. Tilsley et al. (1993) suggest that on a proportional basis, the average uranium content of the silty clay would be on the order of 1 ppm.

The near surface silty clay soils of the region are typified by a stiff, brown and fissured “crust” where these soils are not overlain by saturated silt and sand soils or where such granular deposits are relatively thin. Below the “crust”, if and where present, the silty clay is saturated, gray and the strength diminishes until very near the bedrock surface where the strength may then increase somewhat. Based on the AMEC (2016) data, the undrained shear strength of this soil ( $S_u$ ) typically ranges from about 15 to 35 kilopascals (kPa) with an average of about 21 kPa. These soils are considered normally consolidated (not having experienced any stresses in excess of present-day stresses) to lightly overconsolidated. The hydraulic conductivity<sup>3</sup> ( $K$ ) of this soil ranges from  $1 \times 10^{-10}$  metres/second (m/s) to  $2 \times 10^{-8}$  m/s, with an average of about  $5 \times 10^{-10}$  m/s based on laboratory and field testing (e.g., Desautniers et al. 1981, Rowe and Mabrouk 2007). Typical shear wave velocity through the soils at the turbine sites, based on

<sup>3</sup> In this report, the terms hydraulic conductivity and permeability are used synonymously.



multichannel analysis of surface waves ranged from 186 m/s to 239 m/s with an overall average of about 269 m/s (AMEC 2016a).

### **3.1.2 Granular and Basal Till Deposits (Aquifer)**

The granular soils (silt, sand and gravel) and basal till soils that form all or part of the aquifer overlying the bedrock in the area are the result of glacial action along the bedrock surface during advances and retreats of the continental ice sheets that occupied the area. Based on publicly available data through the MTO (see references) and Golder files from projects in the Chatham-Kent area, the grain size distribution characteristics for these soils are summarized in the table below. Compositionally, these materials are formed of a wide variety of mineral types including fragments of hard igneous and metamorphic rocks as well as sedimentary rocks that were ground and transported from regions to the north, northeast and northwest at and within the base of the ice sheets. Fragments of the Kettle Point shale are also intermixed with the other mineral types. The Kettle Point shale fragments, however, likely do not form the entire mass of material since shale is more easily broken down by stresses and abrasion from glacial action as compared to harder rock types that would remain as larger particles. Based on observations of these soil particles in a limited number of individual specimens, shale particles form between 0 and 70 per cent of the total mass by weight based on examination of well sediments by Carter<sup>4</sup> and visual examination of the fraction of aquifer soil samples greater than 0.425 mm as recovered by during drilling on site (AMEC 2016b).

Standard penetration test (American Society for Testing and Materials standard ASTM D1586) values ranged from about 10 to 103 blows per 0.3 m of sampler penetration (10<sup>th</sup> to 90<sup>th</sup> percentile values, respectively) with an average value of about 50 blows per 0.3 m of sampler penetration. This standard penetration test data indicate that the aquifer largely can be characterised as compact to very dense. Other relevant test data and estimations of engineering characteristics are summarized in the table below based on the testing completed by AMEC (2016b). Permeability (hydraulic conductivity) of these granular soils varies significantly, depending on the amount of silt and clay-size particles within the soil mass. Monitoring well investigations by Raven et al. (1990) indicated an average hydraulic conductivity of about  $5 \times 10^{-6}$  m/s.

**Table 1: Summary of Engineering and Hydrogeologic Parameters for Aquifer**

| <b>Parameter</b>                                       | <b>10<sup>th</sup><br/>Percentile</b> | <b>50<sup>th</sup><br/>Percentile</b> | <b>90<sup>th</sup><br/>Percentile</b> |
|--------------------------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|
| Thickness (m)                                          | 0.8                                   | 1.7                                   | 3.6                                   |
| Vertical permeability, $k_v$ (m/s) <sup>a</sup>        | $1 \times 10^{-6}$                    | $1 \times 10^{-4}$                    | $1 \times 10^{-3}$                    |
| Horizontal permeability, $k_h$ (m/s) <sup>a</sup>      | $2 \times 10^{-6}$                    | $2 \times 10^{-4}$                    | $2 \times 10^{-3}$                    |
| Water content (% by weight)                            | 8                                     | 14                                    | 20                                    |
| Saturated Density, $\gamma_{sat}$ (Mg/m <sup>3</sup> ) | 2.10                                  | 2.23                                  | 2.39                                  |
| Voids Ratio, e                                         | 0.22                                  | 0.38                                  | 0.54                                  |
| Porosity, n                                            | 0.18                                  | 0.27                                  | 0.35                                  |

<sup>4</sup> Witness statement provided by Dr. T. Carter indicates that examination of sediments within wells suggests that as much as 50 per cent of the particles consist of black shale.



| Parameter                                   | 10 <sup>th</sup><br>Percentile | 50 <sup>th</sup><br>Percentile | 90 <sup>th</sup><br>Percentile |
|---------------------------------------------|--------------------------------|--------------------------------|--------------------------------|
| Key Grain Size Distribution Characteristics |                                |                                |                                |
| D <sub>85</sub> (mm) <sup>b</sup>           | 5.8                            | 11.0                           | 18.2                           |
| D <sub>60</sub> (mm)                        | 0.4                            | 2.3                            | 10.2                           |
| D <sub>50</sub> (mm)                        | 0.12                           | 0.53                           | 6.28                           |
| D <sub>30</sub> (mm)                        | 0.019                          | 0.085                          | 2.05                           |
| D <sub>15</sub> (mm)                        | 0.005                          | 0.0115                         | 0.437                          |
| D <sub>10</sub> (mm)                        | 0.003                          | 0.0065                         | 0.092                          |
| Finer than 0.075 mm “fines” (%)             | 9.4                            | 29.6                           | 46.7                           |

Notes: a) based on grain size distribution characteristics as reported by AMEC (2016b) and values reported in published literature; b) screen size opening and effective particle diameter D for which the subscript indicates the percentage of the sample by weight smaller than the indicated size;

## 3.2 Bedrock

Above the Precambrian bedrock, southwest Ontario is underlain by Palaeozoic sedimentary rock formed in shallow seas within the Michigan and Appalachian Basins. The limestone and dolostone of the Devonian Dundee, Hamilton Group, and the underlying Detroit River Group of formations are typically the upper-most bedrock strata in the immediate vicinity of Windsor and London, Ontario outside the area geologically known as the Chatham Sag (Brigham 1971). The Upper Devonian Kettle Point Formation disconformably overlies the limestones and calcareous grey shales of the Hamilton Group in the Chatham-Kent Region and is as much as 75 m thick in some areas (Singer et al. 2003, Bingham-Koslowski 2015). With respect to mineralogy and, specifically, trace metals, and Uranium 238 in particular, the Kettle Point Formation in Ontario and the correlated Antrim and Ohio Shale Formations in Michigan and Ohio, respectively, are relevant to the southwest Ontario glacial soil deposits. The Electric Fault is one of the two largest faults in southwestern Ontario and forms the northern edge of the Chatham Sag. The east-west trending Electric Fault is observed within Silurian rocks, as well as the underlying units (Armstrong and Carter 2010) and is apparent on the surface of the underlying Precambrian rock formations (Brigham 1971). The maximum observed vertical displacement of this fault is approximately 100 m.

The Kettle Point/Antrim Shale Formation is a black, siliclastic, organic-rich shale and siltstone with minor green-grey, organic-poor, shale and siltstone interbeds and was deposited in a deep, stagnant and oxygen-poor marine environment (Easton 1992). During the late Devonian, black shale deposition occurred in most intracratonic basins of eastern North America. Evidence indicates that the Kettle Point Formation is approximately equivalent to the Antrim Shale in the Michigan Basin and the Ohio Shale in the Appalachian Basin (Algeo et al., 2007; Russell, 1985). Armstrong and Carter (2010) state that the Kettle Point Formation “...are not known to contain oil or water in the subsurface in Ontario” but further state that the upper 1 to 3 m of the formation may form part of the contact aquifer and that “...shows of low-pressure natural gas are not uncommon in Kent County and southwestern Lambton County.”

Silt-sized detrital quartz dominates the Kettle Point Formation mineralogy accounting for up to 50 per cent by weight (Armstrong 1986). Other minerals within the Kettle Point Formation include illite (forming about 22 per cent by weight), pyrite, feldspars, chlorite, glauconite, dolomite, and rutile in decreasing weight proportions (Bingham-Koslowski 2015). Calcite, siderite, gypsum, barite, marcasite, and apatite also occur in minor proportions. As is



common for black shales, the Kettle Point Formation is enriched with respect to trace elements and heavy metals such as vanadium, boron, zinc, molybdenum, nickel, copper, cerium, mercury, neodymium, arsenic, tin, uranium, selenium, cadmium, samarium, bismuth, and silver (Tourtelot 1970; Holland 1979). With reference to radon, the uranium content of the Kettle Point Formation shale has been reported to an average of about 32 to 34 ppm with maximum values of as much as 75 ppm for individual small laboratory specimens (Armstrong 1986). Within the same black shale formation in Ohio (known as the Ohio Shales) Harrell and Kumar (1989) indicate uranium concentrations of 10 ppm to 40 ppm in tested specimens.

In general, the Kettle Point Formation is of relatively high strength compared to other shale formations in southern Ontario, but is also fissile and has a low tensile strength across its bedding planes (Dusseault and Loftsson 1985). This rock formation is also of low porosity. During subsurface exploration at the North Kent Wind 1 turbine sites, standard penetration testing could not drive the samplers into the rock and augers could not penetrate the rock. Laboratory testing for the North Kent Wind 1 project included four unconfined compressive strength (UCS) tests on core samples and the results ranged from about 49 megapascals (MPa) to 72 MPa. These values are consistent with UCS test values reported in the literature ranging from about 50 to 100 MPa (e.g., Dusseault and Loftsson 1985, Lo and Hori 1979). Tensile strength of the rock (Brazilian tensile test) ranges from about 7 to 17 MPa (Dusseault and Loftsson 1985). Rock quality designation (RQD) data reported by AMEC (2016) ranged between a minimum of 20 per cent to 99 per cent, with an average of about 76 per cent. This same RQD data indicated that there was only a 10 per cent chance that the RQD value would be below 50 per cent for any given core run (i.e., 10<sup>th</sup> percentile value).

The Kettle Point shale exhibits “...*extremely low porosity and permeability*...” with porosity ranging from about 0.02 to 0.055 (Dusseault and Loftsson 1985). Weaver et al. (1995) suggested a porosity as high as 0.1 for the local shale units. Published values of permeability for shales range from as low as  $1 \times 10^{-13}$  to about  $2 \times 10^{-10}$  m/s (Raven et al. 1990; Freeze and Cherry 1989). While fracturing would result in higher permeability, subsequent weathering may actually result in a decrease in permeability as shale subject to in situ weathering transitions to clay mud. These low permeability values contrast, to some degree, with reported domestic water well yields in the area (e.g., Singer et al. 2003). It is likely that the water supply well yields represent a combination of yields from both the upper few metres of the Kettle Point Formation and the overlying sand, gravel and granular glacial (basal) till units. The low hydraulic conductivity (permeability) values are considered representative of the overall rock formation rather than the upper few metres from which water is extracted for domestic use.

### **3.3 Regional Hydrogeology**

About 90 per cent of the water supply wells in nearby Lambton County, also situated over the Kettle Point Formation, obtain water from the sand and gravel near the top of the bedrock” (Kent et al. 1986), commonly referred to as the “interface” or “content” aquifer. Minimum and maximum specific capacity ranged from about 0.5 to 37.3 l/min/m (10<sup>th</sup> and 90<sup>th</sup> percentile values) for a sample set of about half of the 6,145 wells installed into the Kettle Point Formation (Singer et al. 2003). Singer et al. (2003) also reported that the aquifer overlying the Kettle Point Formation in the nearby Wallaceburg area consists of sand and gravel deposits of about 1 m thickness near the top of rock. Wells within this aquifer have specific capacities<sup>5</sup> between 10 and 50 l/min/m, similar to the Kettle

<sup>5</sup> Specific capacity or specific yield relate to a measure of the water flow rate as a function of the aquifer thickness through which the well is screened and is approximately correlated to the average hydraulic conductivity of the aquifer.



Point Formation aquifer near the rock surface (Singer et al. 2003). Wells screened into these aquifers produce water of low quality, with concentrations of total dissolved solids, sodium, chloride and iron commonly exceeding Ontario Drinking Water Standards (ODWS) with a mean hardness concentration of about 99 mg/L (Singer et al. 2003). Within the set of 22 samples tested by Singer et al. (2003), measurements of individual water quality parameters ranged by more than three orders of magnitude in some cases indicating significant natural variability.

The interface aquifer is confined by the overlying Quaternary deposits of silty clay, which forms a regional aquitard. The presence of an underlying aquitard, consisting of competent Devonian age shales of Kettle Point Formation, suggests that upward migration of groundwater from the competent shale to the interface aquifer would be limited.

The flow direction in the interface aquifer is influenced by bedrock topography, with flow generally toward Lakes St. Clair and Huron depending on location (Husain et al. 2004). Published groundwater gradients in the vicinity of the North Kent Wind 1 area are on the order of 10 m pressure head change over a distance of 15 to 20 km (gradient of about 0.7 m/km). Research by Hussain et al. (2004) suggests that the North Kent Wind 1 project is near the margins of an area of groundwater flow “stagnation” within the interface aquifer. Groundwater within this aquifer has persisted since the deposition of the overlying low permeability glaciolacustrine sediments, which confine the aquifer, approximately 10,000 years ago. These waters have persisted due to flow stagnation resulting from the combined regional influences of stratigraphy, topography and hydraulic conductivity distribution. Low yields and relatively poor water quality have resulted in only limited use of the bedrock contact aquifer as a water supply in the region, allowing these waters to continue to persist in recent time (Husain et al. 2004). Based on mapping by Husain et al. (2004), the stagnation zone is centered northwest of the project area.

## **4.0 WATER SUPPLY WELLS**

Rural water supplies for domestic and relatively small agricultural businesses in the project area typically originate from one of three sources:

- 1) surface water (e.g., streams, ponds, rivers, etc.);
- 2) shallow groundwater (e.g., within the near-surface sand and silt); and
- 3) water within the aquifer at the contact with the underlying bedrock.

For this evaluation, only the water source from the aquifer in contact with the Kettle Point Formation bedrock is relevant. Further, this evaluation excludes larger commercial and municipal groundwater supply systems. For the evaluation summarized in this report, an understanding of well construction is required as background context to the operation of water supply wells and the resulting water quality. To test the hypothetical mechanisms associated with groundwater and radon flow toward wells, a rational range of well pumping rates was needed. These issues are discussed in more detail below.

### **4.1 Typical Construction Details**

In general, domestic and some smaller agricultural operation water supply wells range in diameter from about 100 to 250 mm and are usually drilled with rotary techniques using water, air or drilling mud for circulation of cuttings. Most of the larger agricultural and commercial operations in the project area obtain their water supply from surface



water sources. Once the well hole is drilled, a permanent casing is installed and sealed into the ground above the water bearing soils or rock in order to minimize the possibility for surface water or contamination entering the well. Well casings in southern Ontario are typically constructed of steel or specialized fibreglass materials in some cases. A well screen is installed in the bottom of the well within the water-bearing formation. Common well screens are constructed of slotted stainless steel pipes or are fabricated from stainless steel wire wound around a stainless steel cylindrical frame unit. Well screen openings are selected to reasonably match the characteristics of the water-bearing formation to minimize the potential for intake of sand and larger particles into the well that could damage the pump or lead to clogging of the wells. In some cases, sand or gravel of a selected or manufactured gradation is installed between the well screen and the water-bearing formation to assist with controlling ingress of soil or rock particles. Alternatively, pre-manufactured filter packs composed of glass or ceramic beads are also used for this purpose and to minimize the difficulties associated with installing sand or gravel filter packs.

Once the well screen is installed in the ground, a “packer” or seal may also be installed between the top of the well screen and the well casing to minimize ingress of soil or rock particles into the well. For deep wells, a submersible pump is installed near the bottom of the well. A common domestic water supply well is about 100 mm diameter and ranges in power from  $\frac{3}{4}$  to 5 horsepower depending on the well depth and flow rate needed. Submersible pumps for deep wells are hung in the well on the water pipe, along with safety cables (in case of a pipe break) and centralizers and torque arrestors maintain connection between the pump and well screen and/or casing to minimize stress on the pipe and connections (e.g., Flotec 2012, Red Lion 2016). Check valves are often connected within the pipe leading from the pump to the surface. Near the ground surface, the water pipe passes through and is commonly attached to the well casing as it passes to a temporary storage tank and treatment systems, if used. In other cases, where the water level within the well is sufficiently high, pumps can be mounted near the ground surface (e.g., in basements) that use suction through a smaller diameter pipe installed into the top section of the well casing for drawing water from the well.

## **4.2 Water Supply Well Use**

As noted above, modelling of issues associated with groundwater flow and water supply wells require an understanding of well pumping rates. Without specific water use details from individual wells, a standardized approach to estimating water well usage was adopted for the purposes of this report.

Ontario Ministry of Environment and Climate Change (MOECC) regulations stipulate that all non-domestic surface and groundwater uses (water supply or controlling water in construction) of more than 50,000 litres per day (about 35 litres per minute) are required to apply for and obtain a Permit to Take Water (PTTW). Data from these permits is published by the MOECC in a public database ([www.ontario.ca/data/permit-take-water](http://www.ontario.ca/data/permit-take-water)). Based on a review of the PTTW database for records within the project area, the majority of water takings in the area rely on a surface water source. Within the project limits, there were two PTTWs identified that had combined surface water and groundwater sources listed. A summary of these two records is provided in Table 2 below.



**Table 2: Summary of PTTWs with Groundwater Sources**

| Permit No.  | Purpose                | Location                           | Source Type              | Source      | Max. L/Day | Max. Days/Yr | Max. Hrs/Day | Max. L/Min |
|-------------|------------------------|------------------------------------|--------------------------|-------------|------------|--------------|--------------|------------|
| 2410-8TMJCE | Golf Course Irrigation | 25393 St. Clair Rd<br>Dover Centre | Surface and Ground Water | Big Creek   | 784,800    | 100          | 24           | 545        |
| 2410-8TMJCE | Golf Course Irrigation | 25393 St. Clair Rd<br>Dover Centre | Surface and Ground Water | Dugout Pond | 2,400,000  | 180          | 8            | 5,000      |

As shown above, the sources of the two PTTWs are Big Creek, a surface water source, and a dugout pond, which may be fed by shallow groundwater and/or surface water runoff. Alternatively, the dugout pond may be used primarily as a storage pond for irrigation that is filled from Big Creek.

For the wells of concern in this evaluation, water usage was based on the MOECC document titled “Procedure D-5-5 Technical Guideline for Private Wells: Water Supply Assessment” (1996) as follows:

- the minimum well yield for a residential development on private wells is 450 litres per day per person; and
- peak demand occurs for a period of 120 minutes each day, corresponds to a pumping rate of 3.75 litres per minute (lpm) per person.

For assessments of water taking, Procedure D-5-5 requires that the number of people per household be assumed to correspond to the number of bedrooms plus one and, unless otherwise established, the minimum number of bedrooms is to be four. Therefore, for a minimum of five people per household the total water taking corresponds to 2,250 litres per day per household, or an average rate of 18.75 lpm per household.

## **4.3 Common Water Supply Well Problems**

The evidence of the Appellant’s participant witnesses regarding alleged water quality problems raise the question of establishing cause and effect. There may be many explanations for such water quality problems and various factors would have to be ruled out to ascertain a true cause.

Groundwater wells, whether used for domestic, commercial or construction purposes are subject to a number of potential operational problems. Table 15, included following the text of this report, summarizes many of these common problems.

These problems include water discolouration or discolouration of other materials exposed to the water (e.g., equipment, laundry, etc.) from iron and iron bacteria, tannins (from surface water introduction into well annulus or through shallow wells and aquifers), hydrogen sulphide and manganese-bearing soils. Mineral deposits (iron, calcium, magnesium) as well as particulate sediments such as fine rock fragments/particles, sand and silt also cause problems for use of well water. Some of these problems can be identified under the general term “turbidity” as described below.

The terms “turbidity”, “suspended sediments” and “suspended solids” have been used within documents provided as part of the Notice of Appeal to describe existing or potential problems with well water, with particular reference to particulate described as rock fragments, sand, silt or sediment. Turbidity is a measure of solids (mineral and organic matter) that do not settle out of water and is measured by how much a light beam is scattered when the



light passes through water in a special instrument (ASTM 2012). In this case, measurements of turbidity are not necessarily related to solids that are particles of the underlying rock; rather, fine rock particles, if found suspended within water, would be a subset of all types of solid materials that might be suspended within the water sample. Turbidity, can be the result of many factors including:

- sand, silt, clay, or suspended mineral particles in water arising from:
  - corrosion of and loss of well screen;
  - well screen damage (e.g., removal, replacement of pumps);
  - mechanical surging of wells (e.g., as completed during well development);
  - dislodging of mineral deposits or biofilms on well screen, pumps and piping (e.g., iron, calcium, etc.); from mechanical surging, well vibrations or well maintenance;
  - improper installation too close to the bottom of the well and well screen;
- suspended matter from surface water entering the well annulus; and
- organic matter such as algae in water among other causes.

Turbidity is reduced or eliminated by filtration, coagulation and flocculation and a variety of treatment systems are available for this purpose (Driscoll 1986).

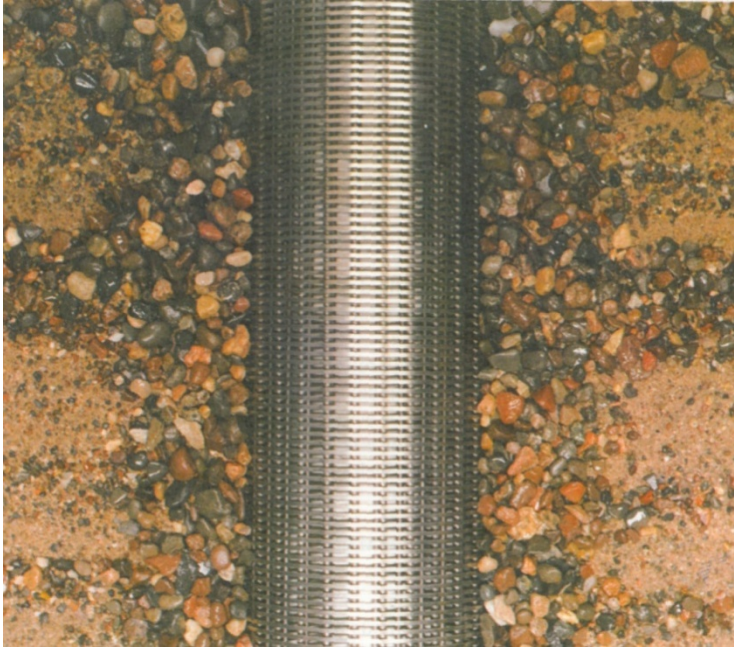
## **4.4 Filtration of Groundwater**

One of the most important filtration mechanisms for water supply wells is the use of filter sand ("filter pack") between the well screen and natural ground and the capability of the natural water-bearing formation to create a filter zone. As summarized by Driscoll (1986), when developing (initial pumping) a well without a filter pack a highly permeable zone is created in the natural ground immediately around the well screen that can be understood as follows (paraphrased from Driscoll, 1986):

- 1) in the zone just outside the well screen, water pumping removes most particles smaller than the screen openings, leaving only the coarsest materials in place;
- 2) a little farther out, some medium-sized grains remain mixed with the coarse sediment (by progressively lodging against formation pore spaces smaller than the grain size); .
- 3) beyond that zone, the material gradually grades back to the original character of the water-bearing formation (through progressive blocking of grains of smaller and smaller sizes);
- 4) fine particles initially brought into the screen in this process are removed by continued pumping (development);
- 5) development work is continued until the movement of fines from the formation becomes negligible; and
- 6) by creating this succession of grades zones around the screen, development stabilizes the formation and prevents further movement of sediment into the well.



Figure 3, below, illustrates these conditions.



*Figure 3: Illustration of natural filter formation around a well screen (from Driscoll, 1986, Figure 15.3)*

Design of graded sand filters for groundwater wells, dewatering systems, dam drainage systems or other civil engineering purposes is common and guidance is readily available (e.g., NAVFAC 1982, Driscoll 1986, Powers et al. 2007). While in theory, the thickness of sand or graded filter materials need only be on the order of about 12 mm, constructability issues control the actual dimensions of such filters (references as above).

Summarizing a variety of research, Xu and Saiers (2009) noted that colloid straining (filtration) rates are sensitive to mean colloid size, colloid shape, grain size distribution of the filter (soil), pore water ionic strength, particle size distribution and concentration of colloid suspensions passing through a filter. Their study indicated that straining is sensitive to interactions between different-sized particles, natural groundwater suspensions exhibit greater particle size heterogeneity than the uniform or nearly uniform suspensions of earlier research and that straining of heterogeneous colloidal suspensions may be greater through filters of heterogeneous grain size distribution. These characteristics are common to development of natural filters surrounding wells, clogging of man-made or natural filters, infiltration basins and the development of colloidal slurry “filter cakes” in boreholes, well drilling and tunneling applications.

## **5.0 TURBINE FOUNDATIONS**

To develop appropriate analytical models and understandings of the planned foundation conditions, project data was reviewed in conjunction with typical foundation construction practices in the area. Since the soil conditions in the area are relatively soft the turbines are proposed to be supported by driven steel H-pile foundations. Based on past project experience, the turbine foundations are likely to be a reinforced concrete mass, approximately octagonal in plan shape, measuring about 18 to 21 m between opposite sides, about a metre thick at the outer edges and increasing in thickness to about 2.7 m near the turbine tower pedestal. About 40 steel HP310x110 H-



piles will be required around the foundations and these are usually driven at an angle of 1 horizontal to 6 vertical to resist overturning, lateral and uplift loads. At the rock surface, the tips of the piles will therefore be arranged in a roughly circular pattern with a diameter of about 24 m. The underside of the pile cap and tower base is to be approximately 2.7 m below the ground surface. The approximately 256 cubic metre concrete section of the foundation and pedestal will weigh approximately 6 MN.

## **5.1 Driven Pile Foundation Construction and Regional Prevalence**

Driven pile foundations are a common foundation solution for supporting heavy structures or resisting overturning loads for towers (e.g., elevated water tanks) and other infrastructure when the ground conditions are poor (e.g., soft clay or loose sand) and have been used for more than 400 years. In southern Ontario, many structures built before the 1950s have been supported by driven timber piles (see Table 3) and since the mid-20<sup>th</sup> century, driven steel piles are more common. In the Chatham-Kent area, most of the larger buildings and bridges are supported on some form of deep foundations. Examples of local transportation structures supported by driven pile foundations are summarized in the table below where data is available through public sources. Golder has been involved in many projects in the Chatham-Kent region where driven steel piles are used for road and highway bridges, rail bridges, elevated water tanks, apartment buildings, larger multi-story commercial structures and industrial facilities.

**Table 3: Summary of local buildings and bridges supported by driven pile foundations**

| <b>Reference</b>            | <b>Project Name &amp; Location</b>                                                                                 |
|-----------------------------|--------------------------------------------------------------------------------------------------------------------|
| 40J08-023 <sup>ac</sup>     | Essex County Rd. 19 and CPR Overpass, Essex County Rd. And Essex County Rd. 22 (Lat.: 42.472477, Lon.: -82.270271) |
| 40J08-027 <sup>a</sup>      | Dillon Sideroad Bridge 9.3 Mi E Of E Limits Of Tilbury (Lat.: 42.427468, Lon.: -82.158327)                         |
| 40J08-028 <sup>a</sup>      | Location: CPR Crossing Bridge – 2.0 mi E. of Hwy 40 (Lat.: 42.373768, Lon.: -82.225253)                            |
| 40I12-013 <sup>a</sup>      | Thames River and County Rd. Between Wardsville and Rodney Bridge (Lat.: 42.551057, Lon.: -81.975517)               |
| 40J09-014 <sup>a</sup>      | Location: Otter Creek And Con. Rd. Con.3 Lots 15-16 Near Wallaceburg (Lat.: 42.604242, Lon.: -82.469734)           |
| 40J09-016 <sup>a</sup>      | Location: Mcmillan Bridge Reconstruction (Lat.: 42.593833, Lon.: -82.432934)                                       |
| 40J09-018 <sup>a</sup>      | Hwy. 40 (Old) & Whitebread Drain #1 Bridge (Lat.: 42.594512, Lon.: -82.179457)                                     |
| 40J09-019 <sup>a</sup>      | Molly Creek Tributary Culvert Replacement (Lat.: 42.593513, -82.420993)                                            |
| 40J09-020 <sup>a</sup>      | Running Creek Bridge Replacement (Lat.: 42.5674, Lon.: -82.380767)                                                 |
| 40I12-19 <sup>a</sup>       | White Ash Creek Bridge 5.7 Mi N Of 401 and 21 (Lat.: 42.545975, -81.969188)                                        |
| 40I12-018 <sup>a</sup>      | Auchrim Bridge -Twp. Rd. Over Sydenham River Lots 30-31 (Lat.: 42.54026, -81.963298)                               |
| Specifications <sup>e</sup> | 5 <sup>th</sup> Street Bridge over Thames River, Chatham (timber piles)                                            |
| MTO <sup>b</sup>            | Murray Street Bridge over Sydenham River, Wallaceburg                                                              |
| DHO <sup>c</sup>            | McNaughton Avenue (Lord Selkirk) Bridge over Sydenham River, Wallaceburg                                           |
| Dillon <sup>d</sup>         | Libby Street/Base Line Bridge over Sydenham River, Wallaceburg                                                     |



| Reference                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Project Name & Location |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| Notes: a) Ministry of Transportation Ontario GEOCREST Library Data ( <a href="http://www.mto.gov.on.ca/FoundationLibrary/">http://www.mto.gov.on.ca/FoundationLibrary/</a> ); b) Biennial Bridge Inspection Report, Murray Street Over Sydenham River No. 4716715N17386791E, November 26, 2015; c) Department of Highways Ontario, Revised Piling Plan for Bridge at Mary Street, TWP 102-7-1-B, 19, Drawing D-3017-1, Sept. 1948; d) Libby Street/Baseline Road Bridge, General Arrangement, Drawing Sheet S-1, Feb. 1993, Dillon Consulting Engineers Ltd.; e) Specifications for the Superstructure of the Bridge over the River Thames at Fifth Street, Chatham, Ontario, 1930; |                         |

The intent of driving steel piles to bedrock is to derive support of the structure on the bedrock without damaging the pile during construction. Typically, piles are driven to “refusal” to penetration or to a specific number of hammer blows for a specific drive distance. Once “refusal” to driving is achieved, pile driving is stopped, regardless of the type of formation or penetration depth into a specific formation so that the pile is not damaged. For the planned steel H piles, it is unlikely that the piles will penetrate as much as 1 m into the bedrock. The Ministry of Transportation Ontario completed a number of pile load tests (MTO 1993) around the province and of 41 tests, three included steel H piles driven to weathered shale bedrock. These tests are summarized below as examples of piles driven to bear near or on shale bedrock.

**Table 4: Summary of MTO piles driven to shale bedrock**

| Site                 | Pile Type                 | SPT N Value in Materials at Pile Tip (blows/0.3 m) | Distance Pile Driven into Rock (m) |
|----------------------|---------------------------|----------------------------------------------------|------------------------------------|
| 9 (Piles 4, 6 and 9) | 324 mm Diameter Tube Pile | 38 in weathered shale                              | 0.34                               |
|                      | HP 370x108                |                                                    | 0.34                               |
|                      | HP 370x108                |                                                    | 0.34                               |
| 17 (Pile 2)          | HP 310x110                | >45 in glacial till                                | Could not penetrate glacial till   |
| 37 (Piles 1 and 2)   | HP 310x79                 | >33 in glacial till and dense sand                 | 0.28                               |
|                      |                           |                                                    | Could not penetrate glacial till   |

## 5.2 Ground Vibrations Caused by Pile Driving

Steel pile foundations are usually driven into the ground using one of two different hammer types – either impact hammers or vibratory hammers. Impact hammers deliver energy to the pile by a falling weight or by a weight driven by internal combustion of diesel fuel (diesel hammers). Typical impact hammers used in Ontario strike the piles at a frequency of about 30 to 60 blows per minute. Vibratory hammers are operated using electric or hydraulic motors powering rotating eccentric weights, typically operating at a driving frequency between 5 and 30 Hertz (Hz). The energy imparted to the steel pile from impact and vibratory hammers is taken up by compression and rebound of the steel, horizontal vibrations of the steel above ground, compression and rebound of the various hammer components and displacement of the ground through which the pile is being driven.

Ground vibrations from pile driving and other construction activities (e.g., blasting, soil compaction) is typically measured by the frequency of vibrations in cycles per second (Hertz, noted Hz) and the peak particle velocity (PPV). Peak particle velocity is the maximum oscillation speed of a particular particle (of ground in this case) as it driven by a passing displacement wave. Typically, peak particle velocity is measured in three mutually



perpendicular directions and maximum vector resultant is used to describe the vibration intensity. Other systems measure, report and limit vibrations based on the root mean square (RMS) velocity. The RMS velocity is the square root of the average of individual velocity measurements squared, typically calculated over a time interval of one second. The RMS amplitude is always less than the peak particle velocity and the two can be related through a “crest factor” that is defined as the peak particle velocity divided by the RMS velocity. The US Federal Transit Administration guidance on noise and ground-borne vibration notes that the crest factor is “...*always greater than 1.71, although a crest factor of 8 or more is not unusual for impulsive signals.*” Sometimes, vibrations are also reported in terms of decibels (VdB) calculated as 20 times the logarithm (base 10) of RMS velocity divided by a reference velocity. Accepted reference vibration velocities are  $1 \times 10^{-6}$  inches/second in the U.S. and  $1 \times 10^{-8}$  m/s or  $5 \times 10^{-8}$  m/s elsewhere (FTA 2006).

At the North Kent Wind 1 site, the piles are proposed to be driven through loose and soft soils until they reach refusal conditions in the compact to dense glacial deposits (aquifer) overlying bedrock or bedrock. In general, ground vibrations from pile driving are generally reported to be greater in stiff or dense soils as compared to loose or soft soils. (e.g., D’Appolonia, 1971; Attewell and Farmer 1973; Wiss 1967, 1981; Wood and Theissen 1982; Whyley and Sarsby 1992; Dowding, 1996; Woods, 1997; Hope and Hiller 2000; and CALTRANS 2004 among others). The model used by the California State Department of Transportation (CALTRANS 2004) uses the following approach:

$$PPV_{(\text{Impact Hammer})} = PPV_{\text{Ref}} (25/D)^n (E_{\text{equip}}/E_{\text{Ref}})^{0.5}$$

Where:

$PPV_{\text{Ref}}$  = 0.65 in/sec for a reference pile driver at 25 feet (ft) distance

D = distance from pile driver to the receiver in ft.

n = a value related to the vibration attenuation rate through ground (see Figure 4 below)

$E_{\text{Ref}}$  = 36,000 ft-lb (rated energy of reference pile driver)

$E_{\text{equip}}$  = rated energy of impact pile driver in ft-lbs.



| <b>Soil Class</b> | <b>Description of Soil Material</b>                                                                                                                                                                                              | <b>Value of “n” measured by Woods and Jedgele</b> | <b>Suggested Value of “n”</b> |
|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------|-------------------------------|
| I                 | Weak or soft soils: loose soils, dry or partially saturated peat and muck, mud, loose beach sand, and dune sand, recently plowed ground, soft spongy forest or jungle floor, organic soils, top soil. (shovel penetrates easily) | Data not available                                | 1.4                           |
| II                | Competent soils: most sands, sandy clays, silty clays, gravel, silts, weathered rock. (can dig with shovel)                                                                                                                      | 1.5                                               | 1.3                           |
| III               | Hard soils: dense compacted sand, dry consolidated clay, consolidated glacial till, some exposed rock. (cannot dig with shovel, need pick to break up)                                                                           | 1.1                                               | 1.1                           |
| IV                | Hard, competent rock: bedrock, freshly exposed hard rock. (difficult to break with hammer)                                                                                                                                       | Data not available                                | 1.0                           |

*Figure 4: Exponents for estimation of vibration attenuation in different soil and rock materials (CALTRANS 2004)*

Ground vibrations induced by vibratory pile hammers at various distances from the pile can be estimated using the equation as above. Figure 5 and Table 5, below, illustrate example estimated vibration attenuation curves for driving steel piles in soft soil or to rock based on use of an ICE ID-19 diesel hammer. Using the CALTRANS (2004) methodology, it would be expected that at a distance of 100 m, the ground vibrations from driving piles through soft soil would be on the order of 1 mm/s or less and near the lower thresholds for human perception. Many publications have documented the effects of pile driving and other ground-borne vibrations on nearby structures and how ground-borne vibrations are perceived by people, as summarized in the examples of Table 5 and Table 6, below. Figure 5 developed using the CALTRANS (2004) method illustrates that ground vibration intensity diminishes dramatically within the first 20 m distance from the pile location.

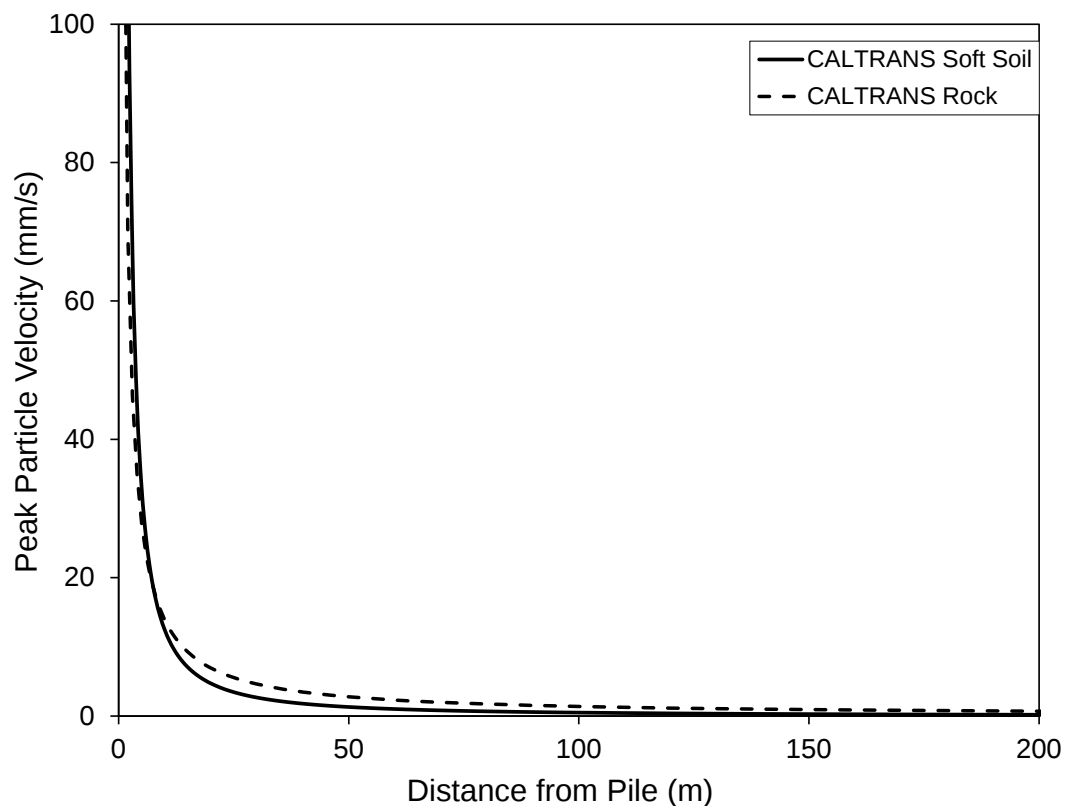


Figure 5: Example vibration attenuation curves for pile driving (using CALTRANS 2004 method)

**Table 5: Vibration attenuation at selected distances**

| Distance from Pile (m) | Proportion of Peak Vibration Amplitude (%) |        |
|------------------------|--------------------------------------------|--------|
|                        | Soft Soil                                  | Rock   |
| 1                      | 100.00                                     | 100.00 |
| 2                      | 37.89                                      | 50.00  |
| 4                      | 14.36                                      | 25.00  |
| 8                      | 5.44                                       | 12.50  |
| 16                     | 2.06                                       | 6.25   |
| 32                     | 0.78                                       | 3.13   |
| 64                     | 0.30                                       | 1.56   |
| 128                    | 0.11                                       | 0.78   |
| 256                    | 0.04                                       | 0.39   |
| 512                    | 0.02                                       | 0.20   |



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**Table 6: Examples of ground vibrations measured near pile driving in urban areas.**

| Site                                  | Vibration Amplitude, PPV (mm/s)                                                                   | Major Soil Strata                                                                     |
|---------------------------------------|---------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Foley Square, New York City           | ≈5                                                                                                | Layered outwash sand and varved silt                                                  |
| Back Bay                              | 6.4 – 15                                                                                          | Granular fill, silty clay; medium-dense sand and gravelly sand                        |
| Brooklyn, NY(South)                   | 17.5                                                                                              | Fill; hydraulically-placed sand; medium-dense                                         |
| Brooklyn, NY (West)                   | 2.5 – 15.2                                                                                        | Fill; hydraulically placed sand, organic silty clay, peat; loose to medium dense sand |
| Cedar Creek                           | 5 – 10                                                                                            | Fill; organic silty clay, peat, sand; sand, medium, loose to medium dense, saturated  |
| Embarcadero, San Francisco, CA        | 1 – 5                                                                                             | Fill, loose to medium dense sand                                                      |
| Leningrad, Russia                     | 2.8                                                                                               | Saturated silty sand                                                                  |
| Lesaka, Russia                        | 17.5                                                                                              | Fine silty sand                                                                       |
| Northbrook, IL                        | 2.8                                                                                               | Loose sand and soft silt                                                              |
| Tri-beca, NY                          | 2.5 – 18                                                                                          | Medium compact sand                                                                   |
| O'Connell St. Bridge, Providence, RI  | < 12 at 4.25 m distance                                                                           | Fill, Low plasticity silt                                                             |
| Test Piles, Windsor ON (Golder Files) | Pile 1: 10 at 7.5 m (15 Hz); 4 at 15 m (8 Hz)<br>Pile 2: 6.2 at 7.5 m (12.5 Hz); 3 at 15 m (9 Hz) | Soft clay, steel H piles driven to 10 m, B-4505 diesel impact hammer                  |

See Lacy and Gould (1985), Drabkin et al. (1996), Taylor (2011), Bradshaw et al. (2007)

**Table 7: Examples of the effects, thresholds or conditions associated with ground vibrations of various magnitudes.**

| PPV (mm/s)                                                                                           | Effect or Condition                  |
|------------------------------------------------------------------------------------------------------|--------------------------------------|
| <b>Human Response to Steady-State and Traffic Vibrations (Reiher and Meister 1931, Whiffen 1971)</b> |                                      |
| 90 (at 2 Hz) – 10 (at 20 Hz)                                                                         | Very disturbing                      |
| 18 (at 2 Hz) – 4 (at 20 Hz)                                                                          | Disturbing                           |
| 10 to 15                                                                                             | Unpleasant                           |
| 5                                                                                                    | Annoying                             |
| 2.5                                                                                                  | Strongly perceptible/begins to annoy |
| 2 – 2.5                                                                                              | Distinctly/strongly perceptible      |
| 1                                                                                                    | Readily perceptible                  |
| 0.3                                                                                                  | Slightly perceptible                 |



| PPV (mm/s)                                                                           | Effect or Condition                                                                                        |
|--------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|
| 0.15 – 0.5                                                                           | Threshold of perception                                                                                    |
| <b>Human Response to Transient Vibrations (Wiss 1981)</b>                            |                                                                                                            |
| 50                                                                                   | Severe                                                                                                     |
| 23                                                                                   | Strongly perceptible                                                                                       |
| 6                                                                                    | Distinctly perceptible                                                                                     |
| 1                                                                                    | Barely perceptible                                                                                         |
| <b>Steady-State Vibration Thresholds for Occupied Spaces (ISO 1989)</b>              |                                                                                                            |
| 0.8                                                                                  | Workshop                                                                                                   |
| 0.4                                                                                  | Office                                                                                                     |
| 0.2                                                                                  | Residence                                                                                                  |
| 0.1                                                                                  | Hospital operating room                                                                                    |
| <b>Steady-State Vibration Thresholds for Building Damage or Equipment Operations</b> |                                                                                                            |
| 6.5 (40 to 100 Hz)                                                                   | Historic and sensitive buildings (Konan 1985)                                                              |
| 3 – 6.5 (10 to 40 Hz)                                                                |                                                                                                            |
| 3 (1 to 10 Hz)                                                                       |                                                                                                            |
| 0.050                                                                                | Optical microscopes to 400X, microbalances, optical balances                                               |
| 0.013                                                                                | Lithography and inspection equipment (including electron microscopes) to 1 µm detail size.                 |
| 3 – 9                                                                                | Vibration limits (RMS velocity) for pumps ranging from 10 hp to 3000 hp (ANSI/HI 2009; API 2010; ISO 2014) |
| <b>Transient Vibration Thresholds for Building Damage</b>                            |                                                                                                            |
| 25 – 38                                                                              | Engineered structures without plaster (AASHTO 1990)                                                        |
| 10 – 13                                                                              | Residential buildings in good repair with gypsum wall boards (AASHTO 1990)                                 |
| 5 – 7.6                                                                              | Residential buildings, plastered walls (AASHTO 1990)                                                       |
| 2.5                                                                                  | Historic sites or other critical locations (AASHTO 1990)                                                   |
| 13 (40 to 100 Hz)                                                                    | Historic and sensitive buildings (Konan 1985)                                                              |
| 6.5 - 13 (10 to 40 Hz)                                                               |                                                                                                            |
| 6.5 (1 to 10 Hz)                                                                     |                                                                                                            |

**Table 8: Examples of ground vibrations and their magnitudes**

| PPV (mm/s) | Effect or Condition                                                                                          |
|------------|--------------------------------------------------------------------------------------------------------------|
| 15.2 m/s   | Mass blowout of concrete from explosives (Tart et al. 1980)                                                  |
| 635        | Explosive near buried pipe, no damage (Siskind and Stagg 1993)                                               |
| 21 – 220   | Water wells, no change in well performance (Robertson et al. 1980, Rose et al. 1991, Straw and Shinko, 1994) |
| 178        | Major damage to residential structure possible (Nichols et al. 1971)                                         |
| 23         | Close-proximity nail driving in residential structure (Stagg and Engler 1980)                                |
| 7.6        | Equivalent to jumping on floor of residential structure (Stagg and Engler 1980)                              |



| PPV (mm/s) | Effect or Condition                                                                                   |
|------------|-------------------------------------------------------------------------------------------------------|
| 5.3        | Vibratory roller at 7.6 m (CALTRANS 2004)                                                             |
| 4.6 – 8.2  | Train at 6 m (Siskind 2000)                                                                           |
| 2.5 – 12   | Equates to normal daily family activity within residential structure (Stagg and Engler 1980)          |
| 2.5        | Truck traffic on bumpy road at 16 m (Siskind 2000)                                                    |
| 2.3        | Large bulldozer at 7.6 m (CALTRANS 2004)                                                              |
| 2.3        | Caisson drilling at 7.6 m (CALTRANS 2004)                                                             |
| 2 – 30     | Pile driving in soft ground at 1 to 3 m from hammer using vibratory and impact hammers (Deckner 2013) |
| 1.9        | Loaded trucks at 7.6 m (CALTRANS 2004)                                                                |
| 0.9        | Jackhammer at 7.6 m (CALTRANS 2004)                                                                   |
| 0.8        | Equivalent to walking on floor of residential structure (Stagg and Engler 1980)                       |
| 0.8        | Small bulldozer at 7.6 m (CALTRANS 2004)                                                              |
| 0.76       | Noticeable house rattling and response from vibration (Siskind 2000)                                  |
| 0.76       | Vehicle traffic at 16 m (Siskind 2000)                                                                |
| 0.25       | Threshold of human perception (Siskind 2000)                                                          |
| 0.025      | Quiet background (Siskind 2000)                                                                       |

### 5.3 Operational Foundation Vibrations

While driving the piles for foundations during the construction phase represent more significant ground-borne vibrations that the construction sites will experience, ground-borne vibrations that are generated during operation of the turbines are also of interest for this report. Therefore, relevant published literature is also reviewed below.

Several studies have been undertaken to monitor the effects of ground-borne vibrations associated with operating wind turbines. The Geological Survey of Canada (Edwards 2015) conducted observations of background seismic “noise” (vibrations) related to the Summerside, Prince Edward Island wind turbine. The turbines were built using large reinforced concrete spread foundations, similar in size and shape to the foundation pile caps planned for the North Kent Wind 1 project, bearing on the clayey sand glacial till or weathered sandstone bedrock (AMEC 2008). At 125 m from the turbine base, the seismometer at location HC1P indicated unfiltered ground motions including those generated by the wind turbine as less than about 2,000 nm/s (RMS), or about 100 times smaller than the threshold of human perception for peak particle velocity measurements. Edwards (2015) concluded that “...it is unlikely that seismic noise generated by the turbines would be perceived by area residents.” At monitoring station HC1P the turbine-generated seismic noise was about 0.001 mm/s (RMS), far below the threshold for human perception by more than 2 orders of magnitude.

Data presented by Styles et al. (2005) indicated maximum RMS velocities on the turbine base of about 0.07 mm/s, well below the threshold for human perception for peak particle velocities (which are larger amplitudes than corresponding RMS velocity values). Fiori et al. (2009) studied vibrations associated with wind turbine foundations supported by sandy soils. Their published information indicates that the maximum foundation vibration intensity was on the order of 0.15 mm/s or less as measured on the foundation. A study by Snow (1997) in the United Kingdom observed that the maximum ground vibration intensity (at any frequency) at sensors 100 m from the



nearest wind turbine did not exceed 0.015 mm/s (RMS), about 10 times less than the lowest threshold for human perception for peak particle velocity. Botha (2013) reported ground vibrations measured 92 m away from a turbine foundation supported by weathered rock in New Zealand showed typical vibration intensity levels of less than 0.01 mm/s (RMS) under high turbine power output with occasional peaks near 0.015 mm/s. The levels under high power output were generally less than 0.01 mm/s (RMS). The New Zealand turbines were founded on weathered rock. Styles et al. (2005) completed a study in Scotland during which vibrations on wind turbine towers and in the ground near and far from the towers was measured using accelerometers. The intent of the study was to evaluate background seismic “noise” that might influence highly sensitive seismic monitoring equipment at a nearby government science facility. Dr. Buckingham’s witness statement and supporting studies (see Appendix A for reference) also estimate that the amplitude of ground-borne vibrations associated with operational wind turbines at far distances (greater than 100 m) could be on the order of nanometres. The estimated amplitudes of ground-borne vibrations, at distances relevant to the residences and wells, as summarized in Dr. Buckingham’s witness statement and those within the referenced supporting documents are far below thresholds of human perception and are relevant only to highly sensitive and specialized scientific measurement equipment.

## **6.0 RADON IN BEDROCK, SOIL AND GROUNDWATER**

The alleged concern for this evaluation is the presence of radionuclides and radon gas within the bedrock, soil and groundwater. As noted in Section 3.2 above, the Kettle Point Formation includes uranium within its mineralogy. Radon is related to uranium through radioactive decay. Relevant aspects of the uranium decay chain, mobility of radon in subsurface materials and subsequent release to the atmosphere are described below. In the absence of externally-induced and large-scale chemical changes in the aquifer (e.g., significant changes in pH) radionuclides other than radon will remain constituents of bedrock and aquifer particles derived from the bedrock and would be of concern only if they could be transported via water to the water supply wells. That is, there is no mechanism in these circumstances by which radionuclides would be caused to dissolve into the groundwater in excess of the existing chemical equilibrium.

### **6.1 Uranium-238 Decay Chain**

Uranium 238 (U-238) is a naturally occurring radioactive substance that is ubiquitous in the earth’s crust, generally at low concentrations<sup>6</sup>. As U-238 undergoes radioactive decay, it produces other radioactive substances, which in turn decay, leading to a chain of radioactive materials. Table 9 shows the complete U-238 radioactive decay chain. The half-life shown in the table below is the time required for a radioactive substance to decay to half of its original activity.

**Table 9: Uranium 238 Decay Chain**

| <b>Nuclide</b> | <b>Decay Mode</b> | <b>Half Life</b>          | <b>Progeny</b> |
|----------------|-------------------|---------------------------|----------------|
| U-238          | α                 | 4.468 x 10 <sup>9</sup> a | Th-234         |
| Th-234         | β-                | 24.10 d                   | Pa-234         |

<sup>6</sup> Uranium 235, while an isotope of uranium, represents less than 1 per cent of all naturally-occurring uranium and is not relevant in this case.



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| Nuclide | Decay Mode          | Half Life | Progeny |
|---------|---------------------|-----------|---------|
| Pa-234  | $\beta^-$           | 6.70 h    | U-234   |
| U-234   | $\alpha$            | 245500 a  | Th-230  |
| Th-230  | $\alpha$            | 75380 a   | Ra-226  |
| Ra-226  | $\alpha$            | 1602 a    | Rn-222  |
| Rn-222  | $\alpha$            | 3.82 d    | Po-218  |
| Po-218  | $\alpha$ 99.98 %    | 3.10 min  | Pb-214  |
|         | $\beta^-$ 0.02 %    |           | At-218  |
| At-218  | $\alpha$ 99.90 %    | 1.5 s     | Bi-214  |
|         | $\beta^-$ 0.10 %    |           | Rn-218  |
| Rn-218  | $\alpha$            | 35 ms     | Po-214  |
| Pb-214  | $\beta^-$           | 26.8 min  | Bi-214  |
|         |                     |           |         |
| Bi-214  | $\beta^-$ 99.98 %   | 19.9 m    | Po-214  |
|         | $\alpha$ 0.02 %     |           | Tl-210  |
| Po-214  | $\alpha$            | 0.1643 ms | Pb-210  |
| Tl-210  | $\beta^-$           | 1.30 min  | Pb-210  |
| Pb-210  | $\beta^-$           | 22.3 a    | Bi-210  |
| Bi-210  | $\beta^-$ 99.99987% | 5.013 d   | Po-210  |
|         | $\alpha$ 0.00013%   |           | Tl-206  |
| Po-210  | $\alpha$            | 138.376 d | Pb-206  |
| Tl-206  | $\beta^-$           | 4.199 min | Pb-206  |
| Pb-206  | -                   | Stable    | -       |

Legend: a = annum; d = days; h = hours; m = minutes; s = seconds; ms = milliseconds.

Note: As shown in Table 1, the radioactive decay of U-238 leads to the formation and subsequent decay of thirteen (primary) radioactive isotopes before the decay series ends in lead-206 (Pb-206) which is stable (non-radioactive).

As listed in Table 9, U-238 has a half-life of 4.468 billion years, much longer than the half-lives of the subsequent members of the U-238 decay chain. It follows that, in undisturbed rock or soil, the subsequent members of the decay chain will be populated as the U-238 undergoes radioactive decay. Eventually, after hundreds of thousands of years, all the members of the decay chain will be in secular equilibrium. In other words, within undisturbed rock, all the members of the decay chain will exhibit the same specific radioactivity. For example sediments that originally contain U-238 at a specific activity of 1 Becquerel<sup>7</sup> per gram (Bq/g) will eventually contain all the members of the decay chain, each with a specific activity of 1 Bq/g.

Radon gas (Rn-222) is produced by the radioactive decay of radium (Ra-226), one of the products of the uranium decay chain. When radium decays, alpha radiation is emitted (alpha particle,  $\alpha$ ) and at the same time a radon atom is produced and experiences rebound energy as the alpha particle is emitted. In the context of Ra-226 bound within the rock, the recoil may be sufficient to move the radon atom into the rock pore space while Ra-226 atoms

<sup>7</sup> Becquerel: The System International (SI) unit of radionuclide activity. One Becquerel is equal to one disintegration per second (1 Bq = 1 s<sup>-1</sup>). Conversion: 1 Curie (Ci) = 3.7×10<sup>10</sup> Bq = 37 GBq.



that are located more deeply within the rock particles will produce Rn-222 atoms that remain trapped within the rock grains or particles in which they were created. If and where rock pores are then connected sufficiently to allow water migration, Rn-222 atoms can bind to the water molecules and flow with the water.

If Ra-226 is uniformly distributed throughout the rock particles, only a fraction of the radon produced escapes to the pore spaces if and where the pore spaces occur in sufficiently close proximity to particular Ra-226 atoms. The maximum travel distance of a radon atom through rock (not pore space) as a reaction to the alpha particle emission energy is on the order of a few microns (micrometers, or thousandths of a millimetre). In Figure 6, below the Ra-226 atom is schematically shown (not to scale) by the red circle and the radon atom by the white circle<sup>8</sup>. Emission of radon is, therefore, related more to the surface area of any given uranium-bearing rock particle or mass instead of the volume of a uranium-bearing rock mass.

Fundamentally, ground-borne vibrations do not affect the degree or rate at which uranium-bearing rock emits radon during decay since this process is governed by the energy of nuclear decay from radium to radon, the decay time and is controlled by the distance of any given radium atom within a solid rock particle or mass to the nearest free surface of the same rock (e.g., face of rock fragment, pore space, fracture surface, fissure surface, rock formation surface, etc.) that is on the order of a few micrometres (as above). Further, the nuclear energies at the atomic scale are far greater than the energy of any vibration at that same scale. The decay time of an atom of radium to radon occurs over a time of  $10^{-12}$  seconds, far outside the range of vibration frequencies relevant for this case. Ground-borne vibrations also do not affect the degree to which radon gas atoms do or do not bind to water molecules.

Relevant to this report, radon has a half-life of 3.82 days. Table 10, below, provides a brief summary of the change in specific activity for different decay time periods, illustrating that after 25 days only 1 per cent of the specific activity remains.

**Table 10: Relationship between Half-Life Decay and Specific Activity for Radon**

| Decay Time (days) | Proportion of Specific Activity (%) |
|-------------------|-------------------------------------|
| 1                 | 83                                  |
| 10                | 16                                  |
| 25                | 1                                   |
| 100               | $1.2 \times 10^{-6}$                |
| 1000              | $6.1 \times 10^{-78}$               |

<sup>8</sup> Shale thin-section microscopic image from The James Weir Fluids Laboratory at the University of Strathclyde (<http://www.jwfl.org.uk/>) used only for background illustration purposes.

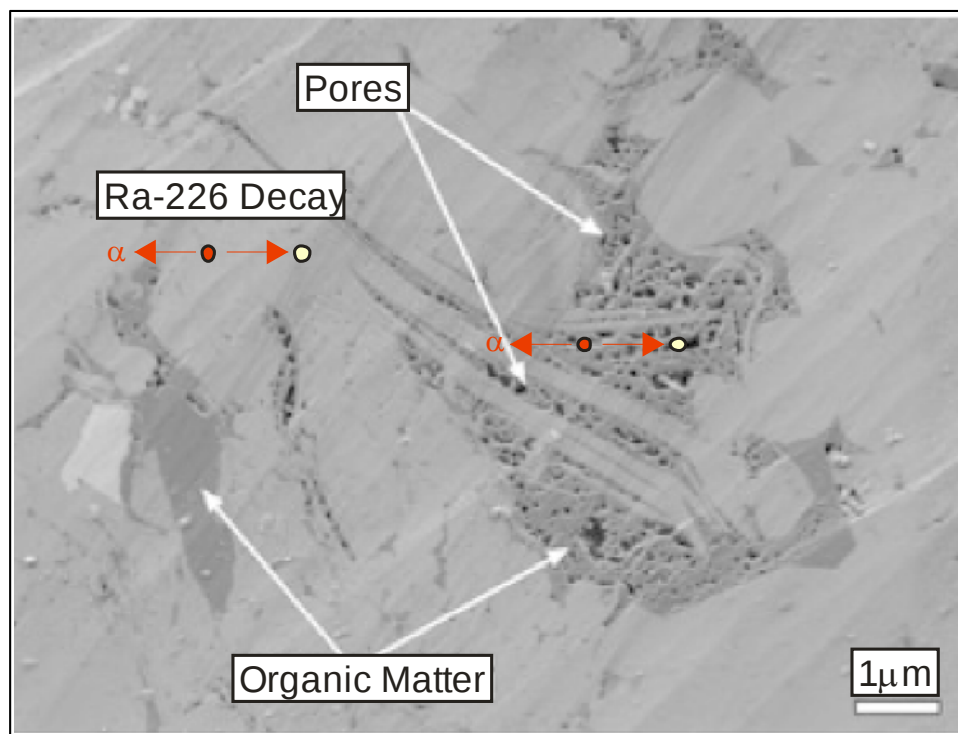


Figure 6: Schematic illustration (not to scale) of radium atoms (red circle) decay, producing alpha particles and radon atoms (white circle) as related to radon escape to pore spaces in shale.

## 6.2 Movement of Radon Gas in Soils/Rocks

The radioactive element of interest for this project is Rn-222 which is released naturally into soil and rock as a product of U-238 decay. Radon is a noble gas and does not readily bind chemically to other elements. As a result, provided sufficient reaction energy is generated from alpha particle emission at the time of decay, each atom of Rn-222 can migrate out of the soil or rock particle in which it is produced and to move through any available openings or pore spaces. Radon gas can move through the earth's crust by two mechanisms; via diffusion through air (by Brownian motion and atmospheric conditions), and by attaching itself to ground water. These two mechanisms are described below.

### 6.2.1 Diffusion

For dry or unsaturated media, the radon gas can diffuse through air within the pore spaces between the soil/rock particles until it either reaches the surface of the earth or it undergoes radioactive decay. The rate of transport of gaseous radon through unsaturated porous media, and therefore the rate of radon flux from the ground surface, is influenced by several factors, including the grain size, porosity, conductivity, degree of water saturation, pore water and air pressures, barometric pressure and radon concentration gradients. The effective diffusion length is primarily a function of soil permeability, which in turn is a function of soil porosity and pore space connectivity. Once Rn-222 has migrated to the surface it will disperse through the air column and migrate via solar heating and wind currents, similarly to other gases, throughout the remainder of its decay period. Given the half-life and an



inability to chemically bind to other materials (e.g., other solid minerals or elements in soils or rock), Rn-222 is free to move through unsaturated materials under a suitable combination of conditions; however, as the soil moisture approaches saturation, the diffusion of radon gas through the water-saturated soils decreases by orders of magnitude (USNRC, 1984).

## **6.2.2 Groundwater Transport**

In saturated conditions, radon is no longer as free to move by diffusion in water as compared to air. Radon gas atoms will weakly bind to water molecules and the strength of this bond decreases rapidly with increases of temperature (51.0, 22.4, 13.0 mL/100 mL at 0°C, 25°C and 50°C, respectively) (IARC, 1988). Radon is volatile and is readily released from water (NCRP, 1988). Groundwater that has passed through radium-bearing rocks and soils can be a source of radon in homes that derive their water from wells. The relationship between the emission of radon from rock formations and particles and the subsequent concentration of radon in the water supply and in indoor air depends on several factors, including the rate and type of usage of the water (e.g., drinking water, showers, laundry), the loss or transfer of radon from the water to the air, and the characteristic ventilation of the house. The rate of release of radon from water depends on such factors as agitation, surface area, and temperature. Numerous authors (Cothorn, 1987; UNSCEAR, 1988; Life Systems Inc., 1991; U.S. EPA, 1991) have reported a water-to-air transfer factor of  $10^{-4}$  for a typical residential dwelling, which would mean that a radon concentration of 1,000 Bq/L in drinking water would, on average, increase the indoor air radon concentration by 100 Bq/m<sup>3</sup>, with the highest concentration being expected in the rooms where radon is released (UNSCEAR, 1988). Nazaroff et al. (1987) estimated that, based on measurements in U.S. homes and water supplies, public supplies derived from groundwater serving 1,000 or more persons contribute about 2% to the mean indoor radon concentration for houses using these sources.

## **6.3 Radon Exposure Guidelines**

### **6.3.1 Radon in Water**

Average doses from radon in drinking water have been calculated as being as low as 0.025 milliSieverts/year<sup>9</sup> (mSv/year) via inhalation and 0.002 mSv/year via ingestion, compared with the background inhalation dose of 1.1 mSv/year from air (UNSCEAR, 2000). Health Canada (2014) notes that “...if concentrations in drinking water exceed 2000 Bq/L actions should be taken to reduce release into indoor air (e.g. proper venting of drinking water supply).” The United States Environmental Protection Agency (USEPA 2008) has considered setting the maximum contaminant level of 4,000 picoCuries per litre (148 Bq/l) for radon in drinking water for systems that serve less than 10,000 people.

<sup>9</sup> Sievert: the SI unit of equivalent radiation dose which is a measure of the dose to a tissue or organ designed to reflect the amount of harm caused to the tissue or organ to allow for the biological effectiveness of the various types of radiation in causing harm to tissue.



### 6.3.2 Radon in Indoor Air

When radon enters an enclosed space, such as a building, it can accumulate to high concentrations. The known health risk associated with exposure to radon is an increased risk of developing lung cancer. The level of risk depends on the concentration of radon and the length of exposure. Although there is no regulation that governs an acceptable level of radon in Canadian homes or public buildings (considered as “dwellings”), Health Canada, in partnership with the provinces and territories, has developed a guideline. This guideline provides Canadians with guidance on when remedial action should be taken to reduce radon levels.

Table 11 listed the recommended action levels and a time frame over which these actions should be taken.

**Table 11: Health Canada Guidelines**

| Radon Concentration                                     | Recommended Remedial Action Time |
|---------------------------------------------------------|----------------------------------|
| Greater than 600 Bq/m <sup>3</sup>                      | In less than 1 year              |
| Between 200 Bq/m <sup>3</sup> and 600 Bq/m <sup>3</sup> | In less than 2 years             |
| Less than 200 Bq/m <sup>3</sup>                         | No action required               |

Health Canada Guide for Radon Measurements in Residential Dwellings (2008)

### 6.3.3 Mean Provincial Outdoor Radon Concentrations

Outdoor radon levels in Canada are known to vary regionally. An example of the regional variation of radon levels across Canada can be found in a report by the Geological Survey of Canada (GSC 1994), who measured the mean outdoor radon levels at various locations in every province in the summers of 1990 and 1991. Table 12 presents the average provincial outdoor radon levels measured in the summer of 1990.

**Table 12: Mean Provincial Outdoor Radon Levels (Summer 1990)**

| Province             | Mean Outdoor Radon Concentration (Bq/m <sup>3</sup> ) |
|----------------------|-------------------------------------------------------|
| Newfoundland         | 13                                                    |
| Nova Scotia          | 9                                                     |
| Prince Edward Island | 23                                                    |
| New Brunswick        | 15                                                    |
| Quebec               | 14                                                    |
| Ontario              | 12                                                    |
| Manitoba             | 55                                                    |
| Saskatchewan         | 60                                                    |
| Alberta              | 41                                                    |
| British Columbia     | 31                                                    |



**PART B – ANALYSIS OF POTENTIAL TURBINE FOUNDATION  
INFLUENCES ON SOIL AND GROUNDWATER**



## **7.0 ANALYSIS OF POTENTIAL TURBINE FOUNDATION INFLUENCES ON WELLS**

### **7.1 Foundation Pile Driving and Bedrock Integrity**

The geotechnical report (AMEC 2016a) for the project indicated that the piles might be driven to as much as 1 m into the bedrock. Typically, such recommendations are provided to allow for some uncertainties in the degree of weathering and as a measure of conservatism when ordering pile steel. As compared to the MTO pile load test example sites (summarized in 5.1) and past project experience, it is Golder's opinion that it is unlikely that the piles will actually be driven as much as 1 m into the bedrock for the following reasons (in no particular order):

- the shale bedrock is relatively strong where UCS values were typically above 50 MPa and RQD values were typically greater than 50 per cent with an average of 76 per cent (see Section 3.2);
- MTO pile load test data indicated that steel H piles were driven into shale bedrock less than 0.5 m when the shale could be penetrated by standard split spoon sampling whereas the shale at the North Kent site could not be penetrated by similar sampling methods (see Section 3.1.2);
- where the aquifer materials are thick they are very dense (average SPT N value about 50 blows/0.3 m, see Section 3.1.2) and the pile may not be able to be driven to the rock surface;
- confinement of the pile tip position by overlying materials will be relatively low (typically less than 4 m of dense aquifer sand and gravel or glacial till);
- there is no need to achieve penetration into the rock to achieve structure support requirements – only refusal to driving at specified driving hammer energies is required; and
- excessive driving of the pile to solely and deliberately achieve penetration into the rock will damage the pile rather than achieve penetration and, provided pile driving inspection is carried out, pile driving would be terminated to minimize pile damage.

Based on these views, we have assume that the piles penetrate an average of 0.5 m into the bedrock for the purposes of these analyses.

### **7.2 Foundation Pile Driving Vibrations**

Considering that the piles for the turbine foundations will likely be driven by diesel impact hammers common to southern Ontario, the analytical approach to attenuation of vibrations described in Section 5.2 was used to evaluate possible vibrations at various distances from the pile driving. Using the attenuation estimation approach used by CALTRANS (2004) the magnitudes of vibrations at different distances from piling are summarized in the Table 13 using the rated energy of an example diesel pile driving hammer typically available in southwestern Ontario (Berminghammer B-4505 with 64 kJ of impact energy). These estimates indicate that at about 40 m the vibrations may be equivalent to a loaded transport truck passing at about 7.5 m distance and, by a distance of 150 m may be at the lower end of the threshold for human perception. At 500 m, the CALTRANS (2004) attenuation estimation method indicates that the vibrations could be on the order of half the threshold value used for operating rooms and near the threshold associated with using high-magnification optical microscopes (see Section 5.2) and below the



lowest level for direct human perception. While these estimates provide theoretical means to predict vibration intensities, the estimated magnitudes are greater than regional experience would suggest might actually occur (see Section 5.2, Table 3).

**Table 13: Estimated vibration magnitudes and distances from pile driving**

| <b>Distance from Piling (m)</b> | <b>Peak Particle Velocity (mm/s)</b> |
|---------------------------------|--------------------------------------|
| 1                               | 324.6                                |
| 10                              | 12.9                                 |
| 20                              | 4.9                                  |
| 40                              | 1.9                                  |
| 60                              | 1.1                                  |
| 80                              | 0.7                                  |
| 100                             | 0.5                                  |
| 150                             | 0.3                                  |
| 300                             | 0.1                                  |
| 500                             | 0.05                                 |

All pumps with rotating components vibrate because of improper installation, improper balancing of pump rotor(s)/impeller(s), excessively turbulent fluid flow, pressure fluctuations, cavitation, and normal pump wear. These vibrations affect all components attached to the pumps including piping, well casings, floors, support brackets and other fixtures as applicable. At the anticipated foundation-to-well distances, vibrations caused by pile driving are likely to be one or more orders of magnitude below acceptable operational vibration limits for water well pumps of about 3 to 9 mm/s (see Section 5.2). The effects of pile driving on water wells is likely to be negligible at distances on the order of 40 m or more based on the vibration attenuation model above and published threshold values as summarized in Section 5.2. Given that typical pump operational vibration intensity thresholds are on the order of 3 to 9 mm/s (RMS) it is highly unlikely that vibrations caused by pile driving at lower vibration intensity values will result in dislodgement of near-well (within 1 m of casing and screen) fine particles that would not be otherwise dislodged by the vibrations of the pump, well casing and related components from the pumping action or by fluid flow velocities during pumping.

It is alleged that dislodgement of fine black shale particles by ground-borne vibrations that subsequently enter the wells could cause increases of radionuclides (as a constituent of the fine rock particles) and radon in the water at the wells. As described below, in Section 7.6, transport of particulates over distances of tens or hundreds of metres through the aquifer and bedrock is not a plausible mechanism for increasing black shale particulates in wells. Therefore, any black shale particulates entering the well must originate within the immediate vicinity of the wells (less than a metre or so). The quantity and concentration of radon generated by black shale bedrock or particles thereof in the immediate well vicinity will remain unchanged, regardless of the spatial position of this material in the short distances surrounding the well. Further, radon generation and its transport by groundwater is unaffected by vibrations (see Section 6.0). As described in Section 4.4, particulates that enter wells are commonly related to short and long-term generation of natural filtration zones immediately surrounding wells. Initial development during well installation deliberately moves fine particles from the surrounding ground into the well by pumping and surging the water levels and forcing these particles to move by water velocity. Depending on pumping rates and cycling,



long-term movement of particulates into water supply wells is to be expected. Any additional dislodgement of fine particles as associated with extremely small ground vibration intensities (on the order of tenths of millimetres to micrometres per second) during pile driving is likely to be an insignificant fraction of particulates that enter the well under the normal course of development and operation and is highly unlikely to change existing levels of radionuclides at the well.

### **7.3 Turbine Foundation Operational Vibrations**

A review of published research indicates that ground-borne vibrations from wind turbine facilities might be of concern for highly sensitive seismic monitoring, scientific instruments or underground scientific laboratories it is highly unlikely that vibrations from operational wind turbines will be perceived by human senses at distances similar to the residence-to-tower distances contemplated for the North Kent Wind 1 facility. Suggested turbine exclusion zones with respect to highly sensitive seismic and scientific laboratories and published vibration intensity data of concern for such facilities are typically on the order of micrometres and nanometres per second, or 10 to 1,000 times smaller than the lowest values suggested as the threshold of human perception<sup>10</sup>. In general, turbine exclusion zones for the purposes of highly sensitive scientific instruments and laboratories should not be confused with those for normal human occupancy. Since ground-borne vibration intensities associated with turbine operation are orders of magnitude smaller than those induced by pile driving, it is highly unlikely, if not impossible, that the extremely small ground vibrations caused by turbine operation will result in dislodgement of near-well fine particles that would not be otherwise dislodged by pumping system vibrations and the normal course of water flow velocity changes during well operation.

### **7.4 Transport of Radon in Groundwater**

As noted in this report (see Section 6.0), there is no suitable data set from which to discern existing background concentrations of radon and other radionuclides in groundwater. Therefore, to test the hypotheses that flow of radon to wells could be exacerbated by the proposed construction it was necessary to estimate a range of background concentrations based on known information about the uranium content of the bedrock (Section 3.2), radiological and geologic principles and other evidence.

#### **7.4.1 Radon Sources and Concentrations**

The issue addressed in this report is the potential release of radon from the bedrock or uranium-bearing and radon-producing rock particles in the aquifer as a result of construction activities and turbine operations. Available literature indicates that uranium is present in the black shale within the Chatham-Kent region at an average uranium concentrations of about 32 ppm<sup>11</sup>(see Section 3.2). Two contributors to radon production and groundwater flow have been considered in the evaluation discussed in this report:

<sup>10</sup> Ground vibration amplitudes as estimated and summarized in Dr. Buckingham's witness statement are also on the order of nanometers and orders of magnitude below levels necessary for human perception.

<sup>11</sup> It is appropriate in this case to use average values for the formation given that the samples tested in the laboratory are of a mass in the range of fractions of or a few kilograms whereas the bedrock mass contributing to the radon production associated with the aquifer and distances of interest is many orders of magnitude greater.



- 1) upward flow of water through the Kettle Point Formation associated with a relatively low upward hydraulic gradient (see discussion in Section 3.3); and
- 2) regional horizontal flow of water through the contact aquifer (see discussion in Section 3.3).

The evaluations described in this report recognise that the concentration of radon within the bedrock pore water could be different than the concentration of radon within the aquifer pore water. Further, the speed at which water can flow and the volumes of water that pass through the bedrock and aquifer are very different (see Sections 3.1.2, 3.2 and 3.3). Both of these two possible contributors are evaluated below.

### ***Radon Contribution from Bedrock***

Where an upward hydraulic gradient exists the groundwater released from the surface of the bedrock has been assumed to contain radon gas that was acquired as the water moved through pores, fissures and fractures within the bedrock.

Water moving slowly up through the bedrock will acquire radon gas generated within the rock. Since Rn-222 has a half-life of 3.82 days, some of the Rn-222 will decay within the water as it moves. The collection of radon gas and its subsequent decay is described by the formula:

$$\frac{dN(t)}{dt} = R - \lambda N(t)$$

Where R is the rate at which the radon atoms are being collected,  $N(t_1)$  is the number of radon atoms remaining in the water at time  $t_1$ , and  $\lambda$  is the decay constant of Rn-222 ( $2.1 \times 10^{-6} \text{s}^{-1}$ ). This differential equation can be solved to yield:

$$N(t_1) = \frac{R}{\lambda} [1 - e^{-\lambda t_1}]$$

The water upwelling through the bedrock can be expected to have a very long residence time because of the very low hydraulic conductivity of the rock. For this case the formula reduces to:

$$N = \frac{R}{\lambda}$$

The concentration of Rn-222 within the ground water moving up through the bedrock will depend on

- the concentration of U-238 in the rock;
- the density of the rock;
- the fraction of the rock occupied by pores spaces and fissures; and
- the fraction of Rn-222 released from the rock particles into the pore spaces.



Based on measurements of Rn-222 emerging from rock with known concentrations of U-238 the proportion of Rn-222 that can be liberated from the rock into the pore spaces is about 5 per cent of the total Rn-222 generated within the rock particles from decay of U-238 (Cigar Lake, 1995). For the purposes of this evaluation, a value of 10 per cent of the available radon has been used as a basis for the radon liberated to the pore water within the bedrock. Based on the available data, the equilibrium radon activity within the bedrock pore water has been estimated to be about  $1.02 \times 10^6$  Bq/m<sup>3</sup> (1,020 Bq/l).

### **Radon Contribution from Bedrock**

For estimating the concentration of Rn-222 within the aquifer water, the following simplifying conditions were used based on all available data:

- 1) a baseline residence time of water within the aquifer equal to infinity (to mathematically represent geologic time within the bounds of these estimates); and
- 2) an average proportion of black shale particles within the overall aquifer mass equal to 50 per cent<sup>12</sup>.

Using this approach, the Rn-222 concentration is equal to about  $1.2 \times 10^5$  Bq per cubic metre (120 Bq/l) of water throughout the aquifer neglecting any contribution from the bedrock.

## **7.4.2 Hydrogeologic Model**

Hydrogeologic evaluations were completed to test the hypothesis that foundation installation and turbine operation might have on the potential for radon transport to nearby water wells. For these evaluations, any geologic, hydrogeologic and other parameter input values needed were deliberately chosen to be biased toward the potential for more adverse radon transmission effects on the wells, while remaining within realistic ranges based on the information summarized in Sections 3.0 through 6.0 of this report.

### **7.4.2.1 Computer-Aided Hydrogeological Modelling**

A conceptual hydrogeological model (CHM) of the North Kent region was developed for constructing computer-aided simulations (numerical modelling) of water flow through turbine and water supply well areas. The basis for the model simulated dimensions, hydrogeological parameters and radon concentrations utilized the site conditions and principles described under Part A of this report. A steady-state three-dimensional (3D) computer simulation model was constructed to approximate the conditions set forth in the CHM using the HydroGeoSphere finite-difference analysis software (Aqanty Inc. 2015).

The essential elements of the model were based on the conditions summarized in Part A of this report and are summarized below:

- The aquifer was modelled as being laterally extensive and the numerical grid (representing simulated geometric points of elevation and distance at which calculations are completed) was selected to represent a

<sup>12</sup> Dr. Carter's witness statement notes that the proportion of black shale particles in the examined well sediments ranged from zero to 50 per cent and the AMEC examination of samples obtained from the aquifer ranged from below 10 to as much as approximately 70 per cent. Given these measurements, an average proportion of 25 to 40 per cent might be reasoned. As previously noted for the bedrock, it is appropriate in this case to use average values for the aquifer given that the samples tested in the laboratory are of a mass in the range of fractions of a kilogram whereas the aquifer mass contributing to the radon production and distances of interest is many orders of magnitude greater.



2.5 km square region of ground to minimize the effects of assigned model boundary conditions on the model calculations.

- The numerical grid was discretized into cells sizes of uniform dimensions with a 300 m by 300 m area of increased mesh refinement (smaller distance between grid points) included within the centre of the model. The increased resolution area was included to better capture details of flow and radon concentration changes in the area around the zone where piles would contact the rock and around the well. The cell sizes (defined by the grid points) ranged from 2 m by 2 m (length and width) in the central refined area and were increased to 50 m by 50 m at the model boundaries. Numerical grid elements were also refined vertically near the aquifer/shale contact in order to better capture the radon concentration profile and the location of the simulated area of the piles.
- An average aquifer thickness of 1.7 m was assigned was based on the AMEC (2016a) drilling data and was considered to represent a contact aquifer consisting of sand and gravel and weathered/fractured/glaciated bedrock with the same hydraulic conductivity.
- The aquifer is confined by a layer of silty clay of low permeability (AMEC 2016a).
- A simulated thickness of 4 m was used for the underlying uranium-bearing, low-permeability and intact shale bedrock. The modelled shale thickness was considered sufficient to ensure that a bedrock zone of uniform radon concentration beneath the aquifer was achieved and maintained even under conditions of pumping.
- For the purposes of modelling and as an extreme case, it was assumed that piles driven into the shale bedrock create a fully fractured zone about half a metre thick and 24 m in diameter (within the full perimeter of driven piles) rather than the more likely fracturing that would occur within the immediate vicinity of each pile. It was further assumed that the permeability and porosity of the fractured bedrock zone would be instantaneously increased to match the overlying aquifer permeability and porosity and cause preferential groundwater flow through this zone (as compared to the competent bedrock), under the hypothesis that enhanced flow might increase the concentrations of radon gas downstream of the pile zone. The radon source strength in this zone was maintained at the higher strength consistent with those within the bedrock formation.
- A water supply well, screened to fully penetrate the confined aquifer to the top of sound rock, was included in the model 40 m directly downstream of the simulated pile zone.

Hydrogeologic conditions and parameter values assigned to the model were based on information summarized in Part A and included:

- Specified water pressure head boundary conditions were applied to the north and south model boundaries<sup>13</sup> to simulate a regional hydraulic gradient in the aquifer on the order of 0.005 m/m (about 5 m of pressure head change over a distance of 1 km, or about 8 times published research values) from model north to model south. This represents a more extreme and adverse case than as justifiable based on existing information (see Section 3.3).

<sup>13</sup> Model north and south directions are used for convenience of presentation and do not represent geographic north or south.



- The aquifer was assigned horizontal and vertical hydraulic conductivities of  $2.4 \times 10^{-4}$  m/s and  $1 \times 10^{-4}$  m/s, respectively, and a porosity of 0.3 (dimensionless).
- The intact shale bedrock was assigned horizontal and vertical hydraulic conductivities of  $5 \times 10^{-9}$  m/s and  $1 \times 10^{-9}$  m/s, respectively, and a porosity of 0.1 (dimensionless).
- No-flow boundary conditions were applied to the east and west model boundaries, which represent equipotential flow lines.
- A specified upward water flux boundary condition of  $1 \times 10^{-10}$  m/s was applied at the base of the shale to produce an upward gradient of 0.10 m/m in the shale.
- The well was pumped at a rate of 2.25 m<sup>3</sup>/day (see Section 4.2) water was extracted from the model node located at the bottom of the well screen to represent the pump intake location.
- No groundwater recharge was applied at the top model surface, which implies that the aquifer is fully confined with no downward leakage from the hydrostratigraphic units above it.
- Longitudinal and transverse dispersivity values of 20 m and 5 m respectively (e.g. Gelhar 1999), and a free-solution diffusion coefficient of  $1 \times 10^{-9}$  m<sup>2</sup>/s (Freeze and Cherry 1989) were assumed to apply over the entire model domain.

Radiological considerations included:

- The intact shale was assumed to produce radon at a rate of 18.65 Bq/m<sup>3</sup>/day (see Section 7.4.1) which produces an equilibrium concentration of  $1.02 \times 10^6$  Bq/m<sup>3</sup> (1,020 Bq/l) in the water (see Section 7.4.1).
- The aquifer produces radon at a rate that is proportional to the amount of shale bedrock it contains. Two scenarios were considered:
  - the aquifer contains no shale bedrock fragments (i.e., no radon is produced by the aquifer particles) to directly evaluate the contributions to downstream radon concentrations associated with the modelled changes in the bedrock character at the pile foundations; and
  - the aquifer contains 50 per cent shale bedrock fragments, with this value being in excess of the average proportions that might be rationalized based on available measurements, and radon is produced at a rate of 6.57 Bq/m<sup>3</sup>/day, which produces an equilibrium radon concentration of  $1.2 \times 10^5$  Bq/m<sup>3</sup> (120 Bq/l) as described in Section 7.4.1.
- A specified radon concentration boundary condition was applied at the upstream model boundary. In this case, a concentration of zero was applied, which implies that fresh water is entering at the upstream end of the model domain.



### 7.4.2.2 Modelling and Results

Modelling was carried out to evaluate three major chronological stages representing:

- 1) background (i.e., undisturbed) conditions without any water supply wells (Figure 2A);
- 2) the addition of a single water supply well located at either 40 or 80 m directly downgradient from the centre of the pile zone (Figure 2B); and
- 3) the addition of a zone of bedrock fractured by driving turbine foundation piles (Figure 2C).

Two trials were simulated for each of the major stages identified above and these trials were chosen to represent:

- a) the aquifer composition excluding black shale particles; and
- b) the aquifer composition including 50 per cent (by weight) of black shale particles;

for the reasons described above. These chronological stages and analysis scenarios are summarized in the table below. For each of the trials radon concentrations were calculated for wells at 40 m and 80 m to define the relationship of downstream distance, radon decay and resulting radon concentration at the wells.

**Table 14: Summary of Hydrogeologic Model Trials**

| Model Stage                               | Aquifer Composition Trial |                                |
|-------------------------------------------|---------------------------|--------------------------------|
|                                           | No Black Shale Particles  | With 50% Black Shale Particles |
| 1. Background (no wells or piles)         | 1a                        | 1b                             |
| 2. Wells Installed and Pumping (no piles) | 2a                        | 2b                             |
| 3. Piles Installed and Well Pumping       | 3a                        | 3b                             |

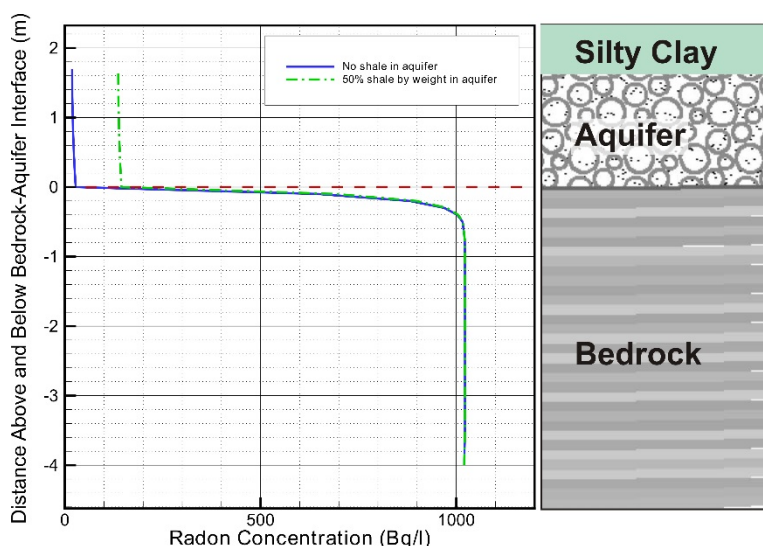
The results of each of these modelling scenarios are discussed below.

- **Background Conditions Stage 1:** At the upstream boundary, freshwater entering the contact aquifer quickly equilibrates with radon coming up through the competent shale and a relatively uniform radon concentration is achieved that is maintained as water moves downstream. This uniform radon concentration is mainly controlled by the relatively short half-life of radon and the ultimate concentration reached is a function of the relative inflows to the contact aquifer (from model north and upwards from the competent shale) as well as the different source strengths of radon in the aquifer and underlying bedrock. Slow upward flow of water from the competent shale bedrock to the contact aquifer causes a slight progressive increase in the hydraulic head toward the downstream end of the model domain. This causes a slight increase in the radon concentration within the contact aquifer at the model downstream end (by about 3 per cent over 2.5 km).
- **Trial 1a:** Figure 7 shows the background radon concentration versus depth prior to pumping at the downstream well location for the case of an aquifer without black shale particles (solid blue line). The competent shale bedrock and interface aquifer contact is indicated by the dashed red line. Concentrations in the overlying aquifer are fairly uniform vertically and at this location range from 27.7 Bq/l at the base



of the aquifer to 18.6 Bq/l at the top. Lateral flow in the overlying aquifer causes a zone of radon depletion that extends down about 0.8 m into the shale. Radon concentrations reach their highest level of about 1,020 Bq/l below the zone of radon depletion in the competent shale bedrock.

- **Trial 1b:** Figure 7 also shows the background radon concentration versus depth prior to pumping at the downstream well location for the case of an aquifer with 50 per cent by weight of black shale particles (dash-dotted green line). Concentrations in the overlying aquifer are still fairly uniform vertically but now range from 144.5 Bq/l at the base of the aquifer to 136.4 Bq/l at the top of the aquifer. The increase in radon concentration in the aquifer is due to the presence of the shale particles, and is higher than the equilibrium concentration (120 Bq/l) due to upwards flow from the underlying competent shale bedrock.



*Figure 7: Radon concentration versus depth for Background Conditions Stages and Trials 1a and 1b. The dashed red line indicates the aquifer/shale bedrock contact.*

- **Water Supply Well Stage 2:** The results (steady-state hydraulic heads and concentrations) at the end of the Background Conditions Stage 1 simulation (above) are used as the initial condition for the Water Supply Well Stage 2 simulation. The water supply well pumping rate of 2.5 m<sup>3</sup>/day is applied to the model node at the bottom of the well screen, to simulate pumping from close to the bedrock, and is maintained for the duration of the Stage 2 simulation. The simulation is continued until all water flow, radon decay and radon transport processes have achieved a new equilibrium (of all variables) with the imposed pumping stress.
- **Trial 2a:** Figure 8 shows the impact of pumping on the radon concentration in the well for the case of an aquifer without black shale particles and pumping wells located 40 m (solid blue line) or 80 m (square blue symbols) downgradient of the centre of the pile zone. Initially, the concentration is at the background of 28.5 Bq/l (i.e., near background established in Stage 1), and rises rapidly to a peak of about 42.7 Bq/l before declining to a long-term value of about 40.4 Bq/l. The peak is due to the change in water travel velocities (reduced decay time) near the well and influx of water derived from the near surface of the underlying shale bedrock which has a higher initial concentration of radon.



- **Trial 2b:** Figure 8 also shows the impact of pumping on the radon concentration in the well for the case of an aquifer with 50% by weight of black shale particles and pumping wells located 40 m (solid green line) or 80 m (square green symbols) downgradient of the centre of the pile zone. In this case, the initial concentration starts at a higher value of 147.8 Bq/l (i.e., near background established in Stage 1), and rises rapidly to a peak of about 233.6 Bq/l before declining to a long-term value of about 231.6 Bq/l. Again, a peak exists due to the changed water velocities, decay time and contributions from the underlying shale bedrock.

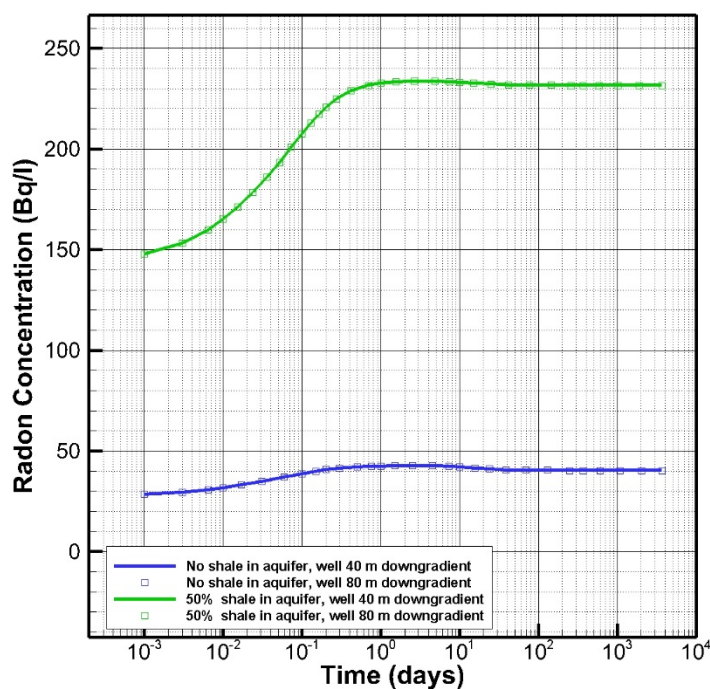


Figure 8: Radon concentration versus time for water supply well Stages and Trials 2a and 2b simulations.

- **Pile Fracture Zone Stage 3:** The results (steady-state hydraulic heads and concentrations) at the end of the Water Supply Well Stage 2 simulation (above) are used as the initial condition for the pile installation Stage 3 simulation. The zone of bedrock that is assumed to be fully fractured by the pile driving is simulated by increasing its permeability and porosity as was described above in Section 7.1. The simulation is again continued until all hydrogeologic and radiological decay processes have achieved a new equilibrium with the altered properties of the pile zone.

Figure 9 shows streamlines (fluid particle paths) near the 24 m diameter zone of assumed bedrock fracturing in both plan and oblique views. In the plan view, the streamlines exhibit a slight convergence as they approach the zone assumed to be fractured by the piles because of preferential flow through the local higher hydraulic conductivity zone (as compared to the surrounding shale bedrock). Coincidentally, the capture zone of the well is also roughly the same diameter as the zone assumed to be fractured by the piles. The oblique view



clearly shows that some upstream water moving horizontally through the aquifer changes direction to flow down through the pile zone then back up to the aquifer.

- **Trial 3a:** Figure 10 shows the effect that the zone assumed to be fractured by the piles has on the radon concentration for the case of an aquifer without black shale particles at the pumping wells located 40 m (solid blue line) or 80 m (square blue symbols) down gradient of the centre of the pile zone. Figure 11 (left panel) shows the response using an expanded y-axis scale. The well located 40 m down gradient shows more influence from the pile zone as compared to the well 80 m down gradient. At the 40 m well, the initial concentration starts at a value of 40.4 Bq/l (established at end of Stage 2), drops slightly to 40.2 Bq/l, rises to a peak of 42.2 Bq/l and then levels off at a long-term equilibrium concentration of 42.0 Bq/l. This represents an increase of about 4 per cent of the starting concentration. The peak represents the effect of the initial increase in radon discharged from the pile zone, on account of the simulated instantaneous change in rock porosity and the volume of water that now passes through the pile zone.
- **Trial 3b:** Figure 10 also shows the effect that the zone assumed to be fractured by the piles has on the radon concentration for the case of an aquifer with 50% by weight of black shale particles in the pumping wells located 40 m (solid green line) or 80 m (square green symbols) down gradient of the centre of the pile zone, while Figure 11 (right panel) shows the response using an expanded y-axis scale. Again, the well located 40 m down gradient shows more influence from the pile zone than the well 80 m down gradient, and has the same general shape as the Trial 3a response described above (i.e., initial drop, rise to a peak then a decline to a long-term value). In this case though, the initial concentration starts at a higher value of 231.7 Bq/l (due to the presence of shale particles in the aquifer) and declines to a long term equilibrium value of 232.6 Bq/l, which represents an increase of about 0.4 per cent of the concentration as compared to Stage 2.

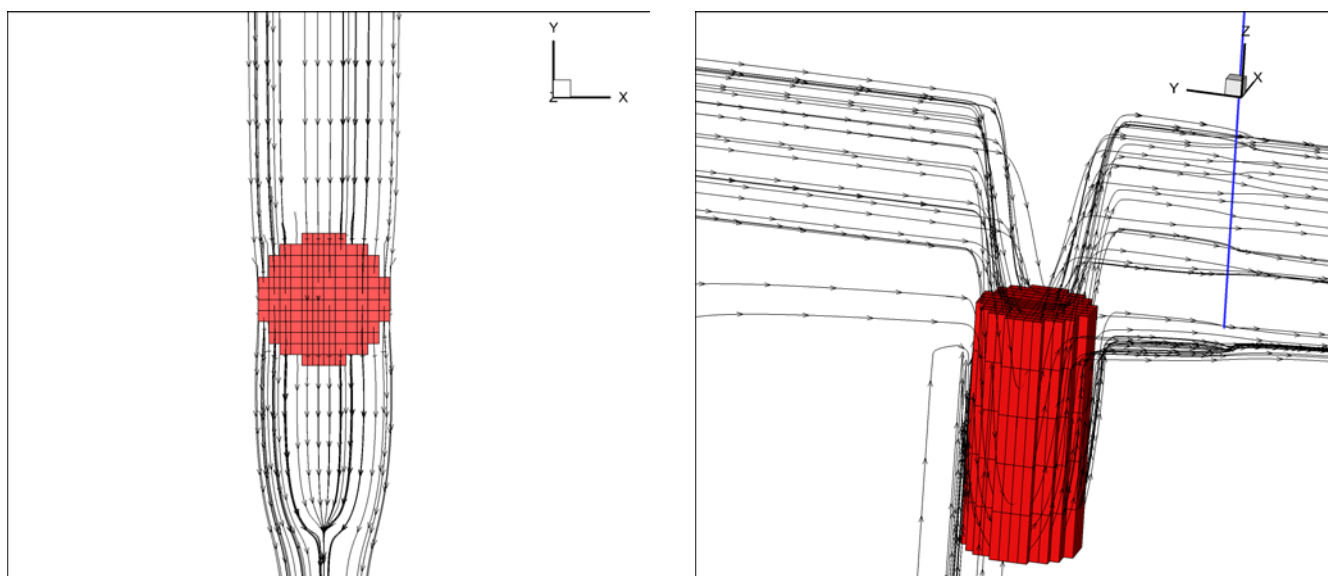


Figure 9: Plan-view, or "birds-eye" view, (above left) and oblique, or angled, view (above right) of the steady-state streamline patterns near the pile zone (red cylinder, vertically exaggerated view) and water supply well 40 m down gradient (blue line).

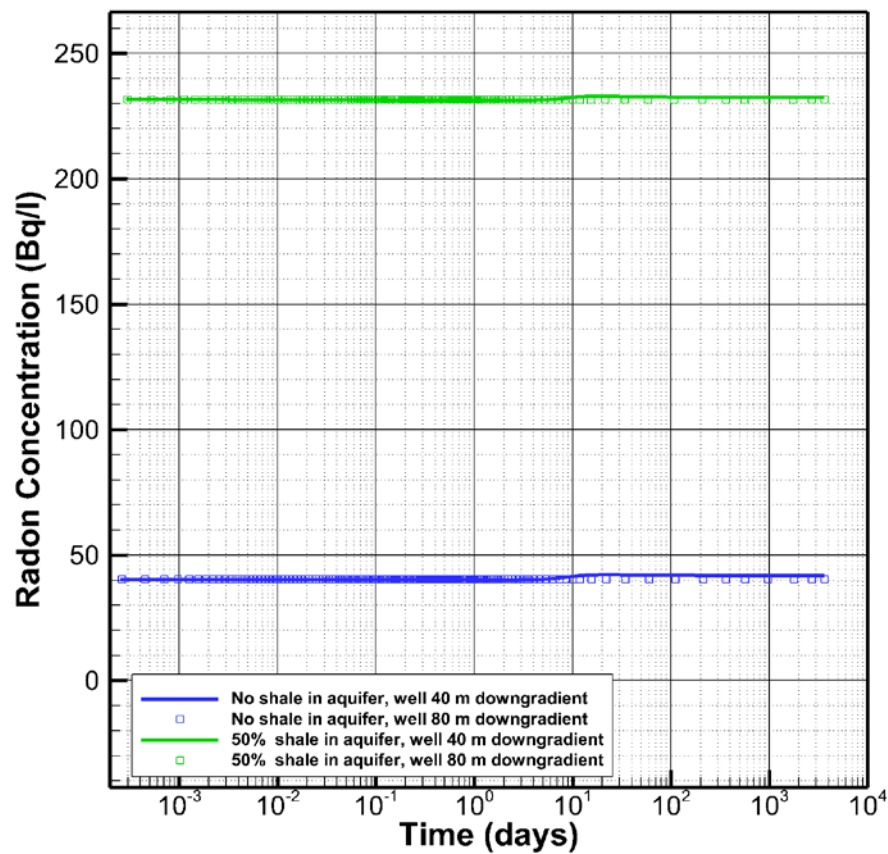


Figure 10: Radon concentration versus time for Turbine Stages and Trials 3a and 3b simulations.

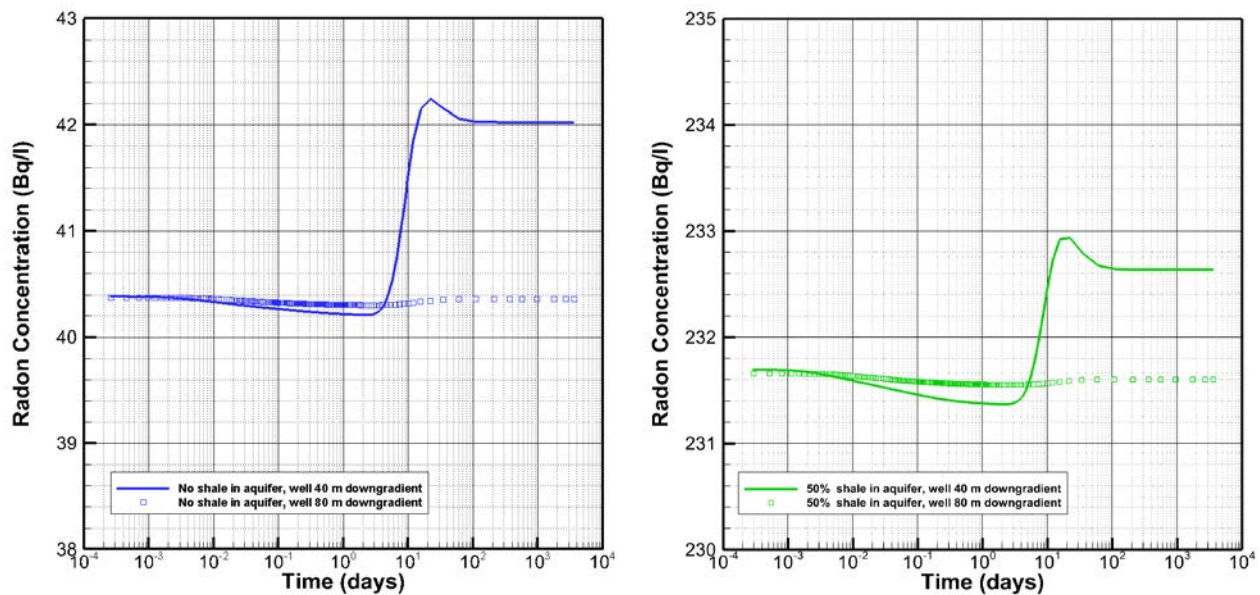


Figure 11: Radon concentration versus time for Turbine Stages and Trials 3a and 3b simulations (exaggerated scale).



In addition to the trials and stages described and discussed above, simulations of these trials were also carried out using a pumping rate of 10 times the value described above. Even at this greatly increased pumping rate, at a well distance of 40 directly downgradient of the piles, the changes in radon concentration were less than 10 and 0.2 per cent for the aquifer without shale particles and 50 per cent shale particles, respectively. For the well 80 m directly downgradient of the piles, the change in radon concentration was less than 0.2 per cent for both aquifer composition assumptions and higher pumping rate.

In spite of the input parameter values being biased toward conditions that might exaggerate the influence of pile foundation construction on groundwater radon concentrations at water supply wells, the results of the modelling leads to the following conclusions:

- a) The relationship between radon concentration changes at the well location associated with pile driving is highly non-linear (i.e., concentration decreases disproportionately quickly as compared to distance) and the relative influence of pile driving diminishes rapidly such that at 160 m distant from the turbine, the relative concentration changes are negligible for both aquifer conditions (i.e.; with and without black shale particles) under the worst-case conditions.
- b) The relative radon concentration changes associated with pile driving are inversely related to the baseline concentrations in the aquifer; i.e., relative radon concentration changes induced by pile driving, on a percentage basis, are lower when the proportions of black shale particles within the aquifer are higher (higher background levels of radon in the water).
- c) Well yield (specific capacity) from the simulations, being about 46 l/min/m of well screen, is at the high end of the published range reported for wells installed into the contact aquifer (see Section 3.3) that ranges between 0.5 to 50 l/min/m (Singer et al. 2003). The comparison to published data confirms that the input parameter values are biased toward higher flow rates that would result in higher estimated concentrations of radon at wells.

#### **7.4.2.3 Simplified Analytical Evaluation**

The computer-aided modelling can be checked using a highly simplified approach, whereby the velocity of groundwater flow can be estimated using well-known principles. The velocity of laminar groundwater flow through a porous medium is governed by the following equation:

$$v = ki/n$$

where

$v$  = groundwater velocity;

$k$  = hydraulic conductivity (permeability);

$i$  = hydraulic gradient; and

$n$  = porosity.



The horizontal hydraulic conductivity of the aquifer is on the order of  $2 \times 10^{-4}$  m/s and the porosity is on the order of about 0.27. Therefore, under a regional hydraulic gradient of about 0.005 m/m (about 8 times published research values), the groundwater velocity is about  $3.7 \times 10^{-6}$  m/s, or about 0.3 m/day. For a half-life period of 3.8 days, any additional radon contributed by pile driving to the background levels would diminish to less than 1 percent of its original concentration contribution in less than 9 m over a period of about 26 days (see Section 6.1). Increasing the hydraulic gradient or permeability by an order of magnitude would still result in the concentration contribution reducing to less than 1 per cent of the initial contribution (at the foundation locations) within less than 90 m distance based on this simplified approach.

## **7.5 Migration of Radon to Surface at Foundations**

Driven pile foundations will penetrate the surficial sand and silt (where present) and then the thick silty clay deposit. In some cases, driven pile foundations can produce a conduit that allows flow of water under artesian pressures (water will emerge and flow at the ground surface) or gas along the boundary between the pile steel and surrounding soil. These conditions are usually only observed when:

- piles are equipped with specialized reinforcing tips (either prefabricated tips or welding of additional steel to the pile) to help guard against damage and these tips are of dimensions that are larger than the exterior dimensions of the rest of the pile – thus creating a gap between the ground and steel along the length of the steel above the tip; and
- when groundwater pressures at the pile tip depth are sufficient to overcome gravity and frictional losses along the soil-steel gap and result in flowing water at the ground surface; and
- when the full soil depth is sufficiently stiff that the soil does not close around the pile after it is driven.

When there is a chance that such conditions might develop and the soils are susceptible to erosion (e.g., silt and fine sand), a blanket of sand is usually placed around the piles and immediately beneath the concrete pile cap (foundation unit) to allow for controlled flow of any such water that might develop in the future.

In this case, the potential for flow of groundwater, and any radon that might travel with the water, up along the piles is highly improbable for the following reasons (in no particular order):

- the silty clay soils in the project vicinity typically include relatively thick soft and very soft zones, where the ratio of stress from overlying ground as compared to the soil's undrained shear strength is such that the soils behave as squeezing ground (e.g., Peck 1969) and the squeezing ground would readily close any soil-steel gap caused by using tip protection measures;
- the sensitivity of the silty clay to disturbance will increase its tendency to squeeze around the piles;
- pile protection measures have not been recommended in the geotechnical engineering report (AMEC 2016);
- artesian flow of sufficient pressure to overcome the squeezing ground is not anticipated in the area based on published literature and other geotechnical exploration and testing in the vicinity (see Section 5.1); and



- where the underside elevation for the concrete foundations is within the silty clay soils, casting the concrete or a thin concrete working slab is cast (as recommended by AMEC 2016) against the silty clay will have an additional sealing effect unless a sand blanket has been placed.

When driven H piles are installed, sometimes the interior zones of the H shape can form a “plug” of soil because of the friction and adhesion of soil to the pile steel. This plug is sometimes relied upon when using piles to support structures through the load carrying capacity generated primarily by friction at the soil-steel boundary and some component of the end-bearing area of the tip (also called “friction piles”). The soils in the North Kent project area are not suitable to support the turbines using friction piles and the piles must be driven to the bedrock. It is highly improbable that plugging of the H section might lead to formation of pathways along which water and gas might travel for the same reasons as listed above.

Radon discharge to the atmosphere during foundation construction will be associated with excavation and movement of near-surface unsaturated soils, rather than any migration along driven pile foundations. Excavations for the turbine bases are anticipated to be on the order of 900 to 1,000 m<sup>3</sup>, comparable to routine excavations for building basements completed throughout the region. Contributions to atmospheric radon from such work is expected to be negligible as compared to other routine disturbances of near-surface soils of the region for agricultural uses, highway and utility construction and other civil purposes.

## **7.6 Transport of Soil or Rock Particles by Groundwater Flow**

Typically, as piles are driven into soft or loose soils the soil particles are displaced vertically and laterally rather than being crushed into finer particles. As soil conditions become stiff to hard or dense, breaking of soil particles may occur during pile driving. When driving into weathered bedrock, crushing of rock particles may also occur at and near the tip. Given the relatively heterogeneous grain size distribution of the aquifer (see Section 3.1.2), it is highly improbable that fine rock and soil particles generated in the immediate vicinity of the pile tip could be mobilized and travel beyond the immediate vicinity of the pile. Well-known filtration behaviour of natural and man-made filter systems (see Section 4.4) demonstrate that a relatively heterogeneous concentration of fine particles created by pile driving could not travel distances on the order of metres except under the most extraordinary of circumstances. There is no plausible mechanisms for fine soil and rock particles created or displaced during pile driving to migrate beyond the immediate vicinity of the turbine foundation location in the ground conditions in the area of the North Kent Wind 1 project.

## **8.0 SUMMARY AND CONCLUSIONS**

The review of published information and the engineering, hydrogeologic and radiological evaluations completed during preparation of this report lead to the following summary conclusions:

- The influence of pile foundation construction and turbine operation on radon concentrations within well water and atmospheric conditions in the area, if any, is likely to be insignificant at wells greater than 80 m distant from the turbines. The analyses completed for this report were developed and completed with input parameters specifically chosen toward exacerbating the possibility of increasing radon concentrations at wells while still remaining within reasonable ranges. In spite of these adversely biased input values, the modelled



changes in radon concentrations at model wells within 80 m of the turbine locations were about 0.1 per cent or less for all trials.

- The influence of ground vibrations generated during pile foundation construction and turbine operation on well water conditions, if any, is likely to be insignificant.
- Ground vibrations generated during driven pile foundation construction and subsequent turbine operation will likely be significantly below published thresholds for human perception at the receptor (residence) locations.
- Ground-borne vibrations will not influence the rate of radon generation or radon concentration within the groundwater.
- There is no plausible mechanism by which fine rock particles, and their radionuclide constituents (if present), can be transported tens or hundreds of metres from turbine foundation pile locations to water supply wells.
- Other related groundwater chemistry or quality parameters (e.g., turbidity, total suspended solids, dissolved metals, etc.) for water well uses in the vicinity of the wind energy project are unlikely to be affected by turbine construction or operation. Such water well quality issues are more likely to be affected by regional natural water quality characteristics and their natural variability, near-well conditions (with a few metres), well construction details, well and pump conditions and pump operations.
- Published turbine off-set distances for sensitive scientific instrument and research stations are not relevant to the concerns expressed for this project.
- In light of the analytical modelling and evaluations and planned setback distances, the only significant influences on the quality of water within and drawn from water wells in the project area are currently associated with natural background conditions and those in the immediate vicinity of the wells and this will continue to be the case during construction and operation of the project.

Based on the analysis and conclusions presented in this report we can conclude to a reasonable degree of scientific certainty that the construction and operation of the turbines at the planned setback distances will not cause significant harm to groundwater quality either at the wells or in the broader subsurface groundwater environment as alleged in the Notice of Appeal.



## Report Signature Page

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**Table 15: Summary of Common Water Quality Problems in Groundwater Wells (after Driscoll, 1986)**

| <b>Impurity or Contaminant</b> | <b>Symptom</b>                                                                                                | <b>Cause</b>                                                                                                                                                                       |
|--------------------------------|---------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Hard water                     | Soap curd and scum in wash basins and bathtub. Whitish scale deposits in pipes, water heater, and tea kettle. | Calcium and magnesium salts in raw water measuring 42.8 mg/L (2.5 grains per gal) or higher as calcium carbonate.                                                                  |
| Grittiness                     | Abrasive texture to water when washing, or residual left in sink.                                             | Excessively fine sand, silt in water passing through well screen or coagulation treatment step.                                                                                    |
| Odour                          | Musty, earthy, or wood smell                                                                                  | Generally, harmless organic matter.                                                                                                                                                |
|                                | Chlorine smell.                                                                                               | Excessive chlorination                                                                                                                                                             |
|                                | Rotten-egg odour.                                                                                             | Dissolved hydrogen sulfide gas in water supply.                                                                                                                                    |
|                                |                                                                                                               | Presence of sulfate-reducing bacteria in water supply.                                                                                                                             |
|                                | Detergent odour, water foams when drawn.                                                                      | Action of magnesium rod in hot water heater and soft water.                                                                                                                        |
|                                | Gasoline or oil smell.                                                                                        | Seepage of septic discharge into underground water supply.                                                                                                                         |
|                                | Methane gas (caution required).                                                                               | Leak in fuel oil tank or gasoline tank seeping into water supply.                                                                                                                  |
|                                |                                                                                                               | Caused by naturally decaying organics found in (a) shallow water wells near swamps, (b) housing areas built above or near former landfills and (c) aquifers overlying well fields. |
|                                | Phenol (chemical) smell                                                                                       | Industrial waste seeping into aquifers.                                                                                                                                            |



## PRIVILEGED AND CONFIDENTIAL NORTH KENT WIND 1

| Impurity or Contaminant                                                                                        | Symptom                                                                                                                                                                                                                                                                    | Cause                                                                                                                                                                                                                                                                                                                                                                     |
|----------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Pesticides, herbicides (DDT 2-4 D, Silvex, methoxychlor, lindane, endrin, chlordane, etc.)</p> <p>Taste</p> | <p>Sharp chemical odour in water.</p> <p>Salty or brackish.</p> <p>Alkali taste.</p> <p>Metallic taste.</p>                                                                                                                                                                | <p>Excessive agricultural spraying and surface water run-off to lakes and ponds.</p> <p>High sodium content.</p> <p>High total dissolved solids alkalinity.</p> <p>Very low pH water (3-5.5)</p> <p>Heavy iron concentration in water above 3mg/L.</p>                                                                                                                    |
| Turbidity                                                                                                      | Silt, clay, or suspended particles in water.                                                                                                                                                                                                                               | <p>Suspended matter from surface water.</p> <p>Silt or sand from well.</p> <p>Organic matter such as algae in water.</p>                                                                                                                                                                                                                                                  |
| Acid water                                                                                                     | <p>Green stains on sinks and other porcelain bathroom fixtures.</p> <p>Blue-green cast to water.</p>                                                                                                                                                                       | Water with high carbon dioxide content (pH below 6.8) reacts with brass and copper pipes and fittings.                                                                                                                                                                                                                                                                    |
| <p>Discoloured water</p> <p>Reddish (iron) water</p>                                                           | <p>Reddish-brown stains on fixtures, dishes, and laundry.</p> <p>Water turns reddish-brown in cooking or upon heating.</p> <p>Clothing becomes discoloured.</p> <p>Brownish cast; does not precipitate.</p> <p>Reddish colour in water sample after standing 24 hours.</p> | <p>More than 0.3 mg/L dissolved iron in water causes staining. Water appears clear when first drawn at cold-water faucet.</p> <p>Precipitated iron (water not clear when drawn).</p> <p>Precipitated iron (water not clear when drawn).</p> <p>Iron dissolved from old pipe with water having a pH below 6.8.</p> <p>Organic (bacterial) iron.</p> <p>Colloidal iron.</p> |
| Yellow water                                                                                                   | Yellowish cast to water after softening and/or filtering.                                                                                                                                                                                                                  | Tannins (humic acids) in water are picked up when water passes through peaty soil and decaying vegetation.                                                                                                                                                                                                                                                                |
| Black cast to water                                                                                            | Blackish staining of fixtures and laundry.                                                                                                                                                                                                                                 | Interaction of carbon dioxide or organic matter with manganese-bearing soils. (Manganese content above 0.05 mg/L causes stains). Usually found in combination with iron.                                                                                                                                                                                                  |



## PRIVILEGED AND CONFIDENTIAL NORTH KENT WIND 1

| Impurity or Contaminant                   | Symptom                                                                                                                                                        | Cause                                                                                                                                                                                                                                                                                                                                                            |
|-------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Milky water                               | Cloudy water when drawn.                                                                                                                                       | Some precipitated sludge created during heating of water.<br>High volume of air in water from poorly functioning pump.<br>Excessive coagulant-feed being carried through filter.                                                                                                                                                                                 |
| High chloride content in water            | Blackening and pitting of stainless steel sinks and stainless ware in commercial dishwashers.                                                                  | Excessive salt content.<br>High-temperature drying creates chloride concentration, accelerating corrosion.                                                                                                                                                                                                                                                       |
| Excess fluorides                          | Yellowish mottled teeth of children.<br>No visible colour, taste, or odour in water.                                                                           | Fluoride above 1 – 2 mg/L in natural water supply.                                                                                                                                                                                                                                                                                                               |
| Nitrates                                  | No visible colour, taste, or odour in water. Maximum contaminant level set by U.S. EPA. (Above 10 mg/L as N considered health hazard for infants).             | Nearby human or animal waste disposal sites located near wells.<br>Heavy use of commercial fertilizers with residual NO <sub>3</sub> getting into groundwater.<br>Disposal of corrosion inhibitors containing nitrates (from boiler cleanout), which enter groundwater supplies.                                                                                 |
| Radioactive contaminants                  | Notices by public health authority.<br>No visible colour, taste, or odour.<br>Radium 226 above 5 pCi/L and strontium-90 above 10 pCi/L considered health risk. | Naturally occurring in deep wells caused by leaching of radium from phosphate rock or radium-bearing rock strata.<br>Atmospheric fallout from man-made explosions producing contamination of surface water supply sources; or stray isotopes getting in water supply from escape of nuclear waste.<br>Radon gas given off by decaying radium dissolved in water. |
| Heavy metals: lead, zinc, copper, cadmium | No visible colour, taste, or odour in water. Maximum contaminant level set by U.S. EPA for many metals.                                                        | Industrial waste pollution.<br>Corrosion products from piping caused by low-pH waters.                                                                                                                                                                                                                                                                           |
| Arsenic <sup>^</sup>                      | No visible colour, taste, or odour.<br>Maximum contaminant level set by U.S. EPA. (Above 0.05 mg/L considered health risk).                                    | Natural groundwater contaminant in local areas.<br>Industrial waste contaminating water supply.<br>Herbicides/pesticides.                                                                                                                                                                                                                                        |
| Barium                                    | No visible colour, taste, or odour.<br>Maximum contaminant level set by U.S. EPA. (Above 1 mg/L considered health risk)                                        | Naturally occurring in certain geographic regions.                                                                                                                                                                                                                                                                                                               |



## PRIVILEGED AND CONFIDENTIAL NORTH KENT WIND 1

| Impurity or Contaminant | Symptom                                                                      | Cause                                                                               |
|-------------------------|------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Boron                   | Inhibits normal plant growth. (Above 1mg/L considered undesirable).          | Naturally occurring in Southwest and other areas.                                   |
| Cyanide                 | No visible colour, taste, or odour. (Above 0.2 mg/L considered health risk). | Industrial waste pollution from electroplating, steel, and cooking facilities.      |
| Trichloroethylene (TCE) | Notice from Public Health Department                                         | Waste degreasing and dry cleaning solutions entering surface or groundwater supply. |



# **APPENDIX A**

## **Disclosed Documents of the Appellant**

**A. DISCLOSED DOCUMENTS OF THE APPELLANT**

| No. | Title of Document                                                                                                                                                  | Author                                                                                            |
|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| 01. | A clean energy solution – from cradle to grave                                                                                                                     | Siemens                                                                                           |
| 02. | Assessing the Value of Groundwater                                                                                                                                 | The Environment Agency                                                                            |
| 03. | AWEA Operations & Maintenance Recommended Practices (Draft)                                                                                                        | American Wind Energy Association                                                                  |
| 04. | Black shale as an environmental hazard: a review of black shales in Canada                                                                                         | Reichenbach, I.                                                                                   |
| 05. | Calculating Vibration Amplitudes                                                                                                                                   | Zeigler, J.M.                                                                                     |
| 06. | Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM)                                                                         | Health Canada                                                                                     |
| 07. | Construction Vibration Damage Guide for Homeowners                                                                                                                 | Zeigler, J.M.                                                                                     |
| 08. | Contamination of Agricultural Soils with Radionuclides                                                                                                             | Efremova, M. et al.                                                                               |
| 09. | Costs and Benefits associated with the Remediation of Contaminated Groundwater: Application and Example                                                            | Hardisty, P.E. et al.                                                                             |
| 10. | Cross-Canada Survey of Radon Concentrations in Homes                                                                                                               | Health Canada                                                                                     |
| 11. | Distribution of natural radionuclides and <sup>137</sup> Cs in soils of southwestern Ontario                                                                       | VandenBygaart, A.J. et al.                                                                        |
| 12. | Ground Vibrations Induced by Impact Pile Driving                                                                                                                   | Massarsch, K.R. et al.                                                                            |
| 13. | Guidelines for Canadian Drinking Water Quality – Radiological Parameters                                                                                           | Health Canada                                                                                     |
| 14. | Guidelines for Canadian Drinking Water Quality Summary Table                                                                                                       | Health Canada                                                                                     |
| 15. | Health Risks from exposure to low levels of ionizing radiation                                                                                                     | National Research Council, Board on Radiation Effects Research Division on Earth and Life Studies |
| 16. | Inertial Sensors for Low-Frequency Seismic Vibration Measurement                                                                                                   | Collette, C. et al.                                                                               |
| 17. | International Joint Commission Annual Report for 2008                                                                                                              | International Joint Commission                                                                    |
| 18. | Ionizing Radiation, Part 2: Some Internally Deposited Radionuclides                                                                                                | World Health Organization, International Agency for Research on Cancer                            |
| 19. | Letter to Ariel Bautista dated October 1, 2015                                                                                                                     | Jakubec, Kevin                                                                                    |
| 20. | Letter to Jody Law dated October 1, 2015                                                                                                                           | Jakubec, Kevin                                                                                    |
| 21. | Letter to Mark Van Der Woerd dated October 1, 2015                                                                                                                 | Jakubec, Kevin                                                                                    |
| 22. | Long-Term Used Nuclear Fuel Waste Management – Geoscientific Review of the Sedimentary Sequence in Southern Ontario                                                | Mazurek, M.                                                                                       |
| 23. | Paleozoic black shale deposition: A lithographical, stratigraphical, and geochemical analysis of the Upper Devonian Kettle Point Formation in southwestern Ontario | Bingham-Koslowski, N. et al.                                                                      |

| No. | Title of Document                                                                                                                 | Author                                                                 |
|-----|-----------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| 24. | P-wave traveltimes tomography for a seismic characterization of black shales at shallow depth on Bornholm, Denmark                | Baumann-Wilke, M. et al.                                               |
| 25. | Quaternary Geology of the Chatham-Wheatley Area, Southern Ontario                                                                 | Kelly, R.I.                                                            |
| 26. | Radiation – A Review of Human Carcinogens                                                                                         | World Health Organization, International Agency for Research on Cancer |
| 27. | Radionuclides as a Chemical of Mutual Concern in the Great Lakes Basin                                                            | Jackson, J.                                                            |
| 28. | Radon – Reduction Guide for Canadians                                                                                             | Health Canada                                                          |
| 29. | Radon and Health                                                                                                                  | Canadian Nuclear Safety Commission                                     |
| 30. | Reaps Moss Wind Farm Planning Conditions – Private Water Supply Protection Plan                                                   | Elliott Environmental Surveyors Ltd.                                   |
| 31. | Recommended Practice for Compliance of Large Land-Based Wind Turbine Support Structures                                           | American Wind Energy Association                                       |
| 32. | Reduced complexity, increased profitability                                                                                       | Siemens                                                                |
| 33. | Review of sensors for low frequency seismic vibration measurement                                                                 | Collette, C. et al.                                                    |
| 34. | Seismic Noise by Wind Farms: A Case Study from the VIRGO Gravitational Wave Observatory, Italy                                    | Saccorotti, G. et al.                                                  |
| 35. | Soil Radon Gas Study of Southern Ontario                                                                                          | Tilsley, J.E. et al.                                                   |
| 36. | Soil-Gas Radon-222 Anomalies in South Central Ontario, Canada                                                                     | Je, I.                                                                 |
| 37. | Sonic Pile Driving: The History and Resurrection of Vibration Free Pile Driving                                                   | Janes, M.                                                              |
| 38. | St. Clair Region Source Protection Area Assessment Report                                                                         | Thames-Sydenham and Region Source Protection Committee                 |
| 39. | The Mechanical Properties of the Kettle Point Oil Shales                                                                          | Dusseault, M.B. et al.                                                 |
| 40. | The Spirit of Innovation: Outstanding Performance with Reduced Complexity – Siemens Direct Drive Turbines                         | Siemens                                                                |
| 41. | Transportation and Construction Vibration Guidance Manual                                                                         | California Dept. of Transportation                                     |
| 42. | Wind farms and groundwater impacts – A guide to EIA and Planning considerations                                                   | Department of the Environment (Ireland)                                |
| 43. | Analysis of Measured Wind Turbine Seismic Noise Generated from the Summerside Wind Farm, Prince Edward Island                     | Edwards, W.N.                                                          |
| 44. | Microseismic and Infrasound Monitoring of Low Frequency Noise and Vibrations from Windfarms                                       | Styles, P. et al.                                                      |
| 45. | Monitoring and Mitigation of Low Frequency Noise from Wind Turbines to Protect Comprehensive Test Ban Seismic Monitoring Stations | Styles, P. et al.                                                      |
| 46. | Predicted Ground Borne Vibrations at North Kent Wind Farm – Technical Submission                                                  | Xi Engineering Consultants Ltd.                                        |
| 47. | Seismic vibration produced by wind turbines in the Eskdalemuir region                                                             | Xi Engineering Consultants Ltd.                                        |

| No. | Title of Document                                                                                                                   | Author                                                     |
|-----|-------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|
| 48. | Ambient Groundwater Geochemistry Data for Southern Ontario, 2007-2014                                                               | Hamilton, S.M.                                             |
| 49. | Aquifer Systems in Southern Ontario: Hydrogeological Considerations for Well Drilling and Plugging                                  | Carter, T. R. et al.                                       |
| 50. | Deep groundwater systems in southern Ontario: Base of fresh water, water types, and flow directions                                 | Carter, T.R. et al.                                        |
| 51. | Gas Assessment of the Devonian Kettle Point Formation                                                                               | Otis, C.B.                                                 |
| 52. | Geological, Geotechnical and Geophysical Data from the Kettle Point Formation Drilling Program, Southern Ontario                    | Otis, C.B.                                                 |
| 53. | Origin, distribution and hydrogeochemical controls on methane occurrences in shallow aquifers, southwestern Ontario, Canada         | McIntosh, J.C. et al.                                      |
| 54. | Southern Ontario Hydrogeological Region                                                                                             | Sharpe, D.R. et al.                                        |
| 55. | The persistence of a large stagnation zone in a developed regional aquifer, southwestern Ontario                                    | Husain, M. et al.                                          |
| 56. | Trace Element Geochemistry and Petrology of the Kettle Point Formation (Upper Devonian), A Black Shale Unit of Southwestern Ontario | Armstrong, D.K.                                            |
| 57. | Email Correspondence                                                                                                                | Jakubec, Kevin and others                                  |
| 58. | Letter to Mark van der Woerd and Jody Law dated November 12, 2015                                                                   | Jakubec, Kevin                                             |
| 59. | Initial study of seismic ground vibration data from mega-watt class wind turbines                                                   | Bowers, D.D.                                               |
| 60. | Shear Wave Velocity, Geology and Geotechnical Data of Earth Materials in the Central U.S. Urban Hazard Mapping Areas                | Bauer, R.A.                                                |
| 61. | SEIS-UK 6 <sup>th</sup> & ESPD Field Methods                                                                                        | Brisbourne, A. et al.                                      |
| 62. | North Ayrshire, East Ayrshire and South Ayrshire Mineral Resources Map Sheet                                                        | British Geological Survey                                  |
| 63. | Code of Practise for noise and vibration control on construction and open sites – Part 2: Vibration                                 | BSI British Standards                                      |
| 64. | A study of the seismic disturbance produced by the wind park near the gravity wave detector GEO-600.                                | Fiori, I. et al.                                           |
| 65. | Observations and modeling of seismic background noise                                                                               | Petersen, J.                                               |
| 66. | Seismic Measurements at the Stateline Wind Project                                                                                  | Schofield, R.                                              |
| 67. | Initial study of ground vibration data recorded from near Craig Wind Farm                                                           | Xi Engineering Consultants Ltd.                            |
| 68. | Ken Wade Well Contractor Licence and Well Technician Licence                                                                        | Ontario MOECC                                              |
| 69. | OWRA Water Well Records – Dover Township and Chatham Township                                                                       | Ontario MOE                                                |
| 70. | Sources and Effects of Ionizing Radiation                                                                                           | UNSCEAR                                                    |
| 71. | Occurrence and geochemistry of radium in water from principal drinking-water aquifer systems of the United States                   | Szabo, Z. et al.                                           |
| 72. | Radiological and Chemical Fact Sheets to Support Health Risk Analyses for Contaminated Areas                                        | Argonne National Laboratory Environmental Science Division |
| 73. | Survey of Blasting Effects on Ground Water Supplies in Appalachia                                                                   | Berger & Associates, Inc.                                  |

| No.  | Title of Document                                                                                                                              | Author                                                                       |
|------|------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|
| 74.  | Project Report – East Lake St. Clair Wind Turbine                                                                                              | Birmingham Foundation Solutions Limited                                      |
| 75.  | East Lake St. Clair Wind Farm Notice for Public Open House                                                                                     | International Power GDF Suez                                                 |
| 76.  | Environmental Chemistry of Uranium                                                                                                             | Zavodska, L. et al.                                                          |
| 77.  | Potential Health Effects of Indoor Radon Exposure                                                                                              | Radford, E.P.                                                                |
| 78.  | The Environmental Transport of Radium and Plutonium: A Review                                                                                  | Smith B. et al.                                                              |
| 79.  | Essex Region / Chatham-Kent Region Groundwater Study Volume 1: Geologic / Hydrogeologic Evaluation                                             | Dillon Consulting Limited and Golder Associates Ltd.                         |
| 80.  | Hydraulic Fracturing and Your Health: Water Contamination                                                                                      | Physicians for Social Responsibility                                         |
| 81.  | Radium in Drinking Water                                                                                                                       | Minnesota Department of Health                                               |
| 82.  | Radionuclides in Ohio's Ground Water – Fact sheet                                                                                              | Ohio Environmental Protection Agency                                         |
| 83.  | Radionuclides in Ohio's Ground Water – Report                                                                                                  | Ohio Environmental Protection Agency                                         |
| 84.  | Impact Assessment of Ionising Radiation on Wildlife                                                                                            | Copplestone, D. et al.                                                       |
| 85.  | Groundwater Information Sheet – Radionuclides                                                                                                  | State Water Resources Control Board, Division of Water Quality (California)  |
| 86.  | Toxicological Profile for Radium                                                                                                               | Agency for Toxic Substances and Disease Registry, U.S. Public Health Service |
| 87.  | The Environmental Behaviour of Radium: Revised Edition                                                                                         | International Atomic Energy Agency                                           |
| 88.  | Excerpts from Panhandle Reinforcement Project: Environmental Report – Final Report                                                             | Stantec Consulting Ltd.                                                      |
| 89.  | General Guidance Document on Well Water Monitoring in Advance of High Volume Horizontal Hydrofracturing                                        | Otsego County Soil and Water Conservation District                           |
| 90.  | North Kent Wind 1 Project Hydrogeological Assessment and Effects Assessment                                                                    | Aecom                                                                        |
| 91.  | Geochemistry of and Radioactivity in ground water of the Highland Rim and Central Basin Aquifer Systems, Hickman and Maury Counties, Tennessee | U.S. Geological Survey                                                       |
| 92.  | Heavy Metals Toxicity and the Environment                                                                                                      | Tchounwou, P.B. et al.                                                       |
| 93.  | Speciation of Heavy Metals and Radioisotopes                                                                                                   | Keepax, R.E. et al.                                                          |
| 94.  | Radioactivity and Radiation                                                                                                                    | Argonne National Laboratory                                                  |
| 95.  | Radon in Air and Water                                                                                                                         | Appleton, J.D.                                                               |
| 96.  | Radon in Your Well Water                                                                                                                       | Connecticut Department of Public Health                                      |
| 97.  | Risk of lung cancer associated with residential radon exposure in south-west England: a case-control study                                     | Darby, s. et al.                                                             |
| 98.  | Risk Assessment of Radon in Drinking Water                                                                                                     | National Research Council                                                    |
| 99.  | Residential Radon Gas Exposure and Lung Cancer                                                                                                 | Field, R.W. et al.                                                           |
| 100. | Spatial Variation of Residential Radon Concentrations: The Iowa Radon Lung Cancer Study                                                        | Fisher, E.L. et al.                                                          |

| No.  | Title of Document                                                                        | Author                              |
|------|------------------------------------------------------------------------------------------|-------------------------------------|
| 101. | Uranium – Guidelines for Canadian Drinking Water Quality: Supporting Documentation       | Health Canada                       |
| 102. | Radon and Public Health – Report of the independent Advisory Group on Ionising Radiation | Health Protection Agency            |
| 103. | Residential Radon Exposure and Lung Cancer in Sweden                                     | Pershagen, G. et al.                |
| 104. | Exposure to Radon/Radon Decay Products in Waterworks                                     | Schmitz, J. et al.                  |
| 105. | Radon: The Invisible Intruder                                                            | State of New York, Attorney General |
| 106. | Guidelines for Drinking-water Quality – Volume 1 – Recommendations                       | World Health Organization           |
| 107. | Letter dated August 8, 2012 from Monte McNaughton, MPP to Hon. Chris Bentley, MPP        | McNaughton, M.                      |

## **B. WITNESS STATEMENTS OF THE APPELLANT**

- I      UPDATED WITNESS STATEMENT OF PAUL BUCKINGHAM (August 11, 2016 with additional document list August 22, 2016)
- II     WITNESS STATEMENT OF DR. WILLIAM SAWYER (August 20, 2016)
- III    SUPPLEMENTAL WITNESS STATEMENT OF DR. WILLIAM SAWYER (August 22, 2016)
- IV    WITNESS STATEMENT OF DR. WILLIAM SAWYER (Supplemental) (September 2, 2016)
- V     WITNESS STATEMENT OF KEN WADE (August 11, 2016)
- VI    SUPPLEMENTARY WITNESS STATEMENT OF KEN WADE (September 2, 2016)
- VII   WITNESS STATEMENT OF TERRY CARTER (August 11, 2016)
- VIII   TERRY CARTER WORK PLAN
- IX    WITNESS STATEMENT OF TERRY CARTER (Supplemental) (September 1, 2016)

|                                                                                                                                             |
|---------------------------------------------------------------------------------------------------------------------------------------------|
| Armstrong, O.K., and Dodge, J.E.P., 2007. Paleozoic geology of southern Ontario; Ontario Geological Survey, Miscellaneous Release Data 219. |
|---------------------------------------------------------------------------------------------------------------------------------------------|

- X      WITNESS STATEMENT OF WILLIAM SHAILOR CLARKE (August 10, 2016)
- XI    WITNESS STATEMENT OF WILLIAM SHAILOR CLARKE (Supplemental) (August 24, 2016)

|                                                                                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| Armstrong, D.K., and Carter, T.R., 2010. The subsurface Paleozoic stratigraphy of southern Ontario; Ontario Geological Survey, Special Volume 7, 301 p. |
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|                                                                                                                                      |
|--------------------------------------------------------------------------------------------------------------------------------------|
| Armstrong, D.K., and Dodge, J.E.P. Paleozoic geology of southern Ontario; Ontario Geological Survey, Miscellaneous Release Data 219. |
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- XII WITNESS STATEMENT OF KEVIN JAKUBEC (August 12, 2016)
- XIII SUPPLEMENTARY WITNESS STATEMENT OF KEVIN JAKUBEC (September 2, 2016)
- XIV WITNESS STATEMENT OF MICHELE HOWES (August 11, 2016)
- XV WITNESS STATEMENT OF LAURIER CARTIER (August 12, 2016)
- XVI WITNESS STATEMENT OF PETER J. HENSEL (August 12, 2016)

**C. DISCLOSED DOCUMENTS OF THE MINISTRY OF ENVIRONMENT AND CLIMATE CHANGE**

| 1   | 00-00-1988  | Weather Factors Affecting Soil-Gas Radon Concentrations at a Single Site in the Semiarid Western US               | RR Schumann, DE Owen and S Asher-Bolinder |
|-----|-------------|-------------------------------------------------------------------------------------------------------------------|-------------------------------------------|
| 2   | 00-00-2011  | Guidelines for Drinking-water Quality (Fourth Edition)                                                            | World Health Organization                 |
| 8   | 30-Mar-2016 | Letter from Joshua Vaidhyan (SRE) to Nick Colella (MOECC) re: response to MOECC questions during technical review | Joahua Vaidhyan (SRE)                     |
| 10  | 17-May-2016 | Letter from Joshua Vaidhyan to Nick Colella re: detailed response to MOECC questions dated April 11               | Joahua Vaidhyan (SRE)                     |
| 16  | 11-Apr-2016 | Memorandum from Bruce Harman (MOECC) to Nick Colella (MOECC) re: groundwater comments April 11                    | Bruce Harman (MOECC)                      |
| 17  | 10-Jun-2016 | Memorandum from Bruce Harman (MOECC) to Nick Colella (MOECC) re: groundwater comments June 10                     | Bruce Harman (MOECC)                      |
| 19  | 00-00-2015  | Analysis of Measured Wind Turbine Seismic Noise Generated from the Summerside Wind Farm, PEI                      | Natural Resources Canada                  |
| 21  | 00-May-2004 | Radon Reduction Guide for Canadians                                                                               | Health Canada                             |
| 23  | 00-00-1993  | Soil Radon Gas Study of Southern Ontario                                                                          | MNDM                                      |
| 120 | 2006        | Piling in Layered Ground, Risks to Groundwater and Archaeology                                                    | UK Environment Agency                     |

**D PARTICIPANTS AND PRESENTERS**

- I. LAURA POLAND: STATUS REQUEST FORM AND PARTICIPANT STATEMENT
- II. CALVIN SIMMONS: STATUS REQUEST FORM AND PARTICIPANT STATEMENT
- III. DOROTHY TRAVIS: STATUS REQUEST FORM AND PARTICIPANT STATEMENT
- IV. MAUREEN GEDDES: PRESENTER STATEMENT



# **APPENDIX B**

## **Well and Turbine Setback Distances**

| Borehole ID | Well ID | Completed  | Depth | Depth to Bedrock | Static Level | Participation Status | Closest turbine number | Distance to turbine (m) | Turbine Latitude | Turbine Longitude |
|-------------|---------|------------|-------|------------------|--------------|----------------------|------------------------|-------------------------|------------------|-------------------|
| 23051658    | 7051658 | 10/15/2007 | 0     | 0                | 0            | Non-Participating    | 4                      | 641.194398              | 42.527399        | -82.277222        |
| 10186043    | 3301888 | 6/8/1947   | 25    | 22.6             | 2.7          | Non-Participating    | 48                     | 803.489842              | 42.453372        | -82.285417        |
| 10186046    | 3301891 | 8/29/1967  | 18.3  | 17.4             | 8.5          | Non-Participating    | 51                     | 906.963357              | 42.466196        | -82.299023        |
| 10186048    | 3301893 | 6/16/1959  | 18    | 17.1             | 5.2          | Non-Participating    | 51                     | 790.351339              | 42.480694        | -82.289578        |
| 10186066    | 3301911 | 6/7/1950   | 19.2  | 18.9             | 3            | Non-Participating    | 72                     | 1005.924657             | 42.443092        | -82.277024        |
| 10186069    | 3301914 | 4/7/1965   | 20.7  | 20.1             | 5.5          | Non-Participating    | 40                     | 710.166765              | 42.466196        | -82.299023        |
| 10185363    | 3301208 | 6/24/1961  | 15.8  | 12.8             | 0            | Non-Participating    | 15                     | 580.33222               | 42.497399        | -82.292063        |
| 10185365    | 3301210 | 6/29/1961  | 17.4  | 12.8             | 0            | Non-Participating    | 15                     | 572.198054              | 42.497399        | -82.292063        |
| 10185367    | 3301212 | 7/11/1961  | 13.4  | 13.1             | 2.1          | Non-Participating    | 15                     | 678.236366              | 42.497399        | -82.292063        |
| 10185374    | 3301219 | 5/18/1965  | 16.8  | 14.6             | 7.3          | Non-Participating    | 15                     | 623.336497              | 42.503776        | -82.28634         |
| 10185375    | 3301220 | 9/5/1950   | 16.8  | 0                | 3            | Participating        | 26                     | 555.046227              | 42.507245        | -82.277719        |
| 10185376    | 3301221 | 6/27/1947  | 16.8  | 15.8             | 4.6          | Non-Participating    | 27                     | 669.758085              | 42.513992        | -82.270698        |
| 10185260    | 3301105 | 11/16/1965 | 22.9  | 22.3             | 3.7          | Participating        | 41                     | 744.303409              | 42.468573        | -82.277346        |
| 10185263    | 3301108 | 4/5/1952   | 20.4  | 17.4             | 0            | Non-Participating    | 6                      | 655.99219               | 42.494783        | -82.244573        |
| 10185264    | 3301109 | 4/9/1952   | 19.2  | 17.4             | 0            | Non-Participating    | 6                      | 736.421456              | 42.494783        | -82.244573        |
| 10185432    | 3301277 | 6/27/1955  | 14.9  | 13.7             | 2.1          | Participating        | 45                     | 517.927772              | 42.538634        | -82.259452        |
| 10185083    | 3300928 | 12/1/1955  | 21    | 20.7             | 4.6          | Non-Participating    | 35                     | 2043.3149               | 42.467347        | -82.18753         |
| 10185085    | 3300930 | 10/2/1958  | 23.2  | 21.3             | 3.7          | Non-Participating    | 35                     | 1695.922234             | 42.467347        | -82.18753         |
| 10185123    | 3300968 | 7/12/1963  | 18.3  | 0                | 3            | Non-Participating    | 36                     | 1192.61031              | 42.451567        | -82.231678        |
| 10185280    | 3301125 | 4/18/1956  | 15.2  | 0                | 4.3          | Non-Participating    | 51                     | 1318.178026             | 42.480694        | -82.289578        |
| 10185293    | 3301138 | 4/15/1963  | 13.4  | 13.1             | 0            | Non-Participating    | 17                     | 921.851921              | 42.52929         | -82.247949        |
| 10185295    | 3301140 | 4/17/1963  | 13.4  | 13.1             | 0            | Non-Participating    | 17                     | 954.635793              | 42.52929         | -82.247949        |
| 10185296    | 3301141 | 4/18/1963  | 13.7  | 13.4             | 0            | Non-Participating    | 17                     | 939.395416              | 42.52929         | -82.247949        |
| 10185297    | 3301142 | 4/18/1963  | 13.7  | 13.4             | 0            | Non-Participating    | 17                     | 945.833154              | 42.52929         | -82.247949        |
| 10185302    | 3301147 | 4/10/1959  | 12.8  | 0                | 0            | Non-Participating    | 30                     | 779.684501              | 42.529298        | -82.222338        |
| 10185303    | 3301148 | 4/11/1959  | 12.8  | 0                | 0            | Non-Participating    | 30                     | 769.760248              | 42.529298        | -82.222338        |
| 10185307    | 3301152 | 10/13/1948 | 15.5  | 15.2             | 3            | Non-Participating    | 28                     | 813.693539              | 42.529298        | -82.222338        |
| 10185133    | 3300978 | 9/2/1958   | 23.5  | 22.6             | 2.4          | Non-Participating    | 35                     | 811.597524              | 42.467347        | -82.18753         |
| 10185134    | 3300979 | 9/21/1967  | 20.4  | 0                | 4.3          | Non-Participating    | 35                     | 866.822989              | 42.467347        | -82.18753         |
| 10185135    | 3300980 | 8/21/1967  | 23.2  | 21.3             | 0            | Non-Participating    | 35                     | 829.50135               | 42.467347        | -82.18753         |
| 10185154    | 3300999 | 5/5/1955   | 23.8  | 0                | 3.7          | Non-Participating    | 36                     | 594.590991              | 42.451567        | -82.231678        |
| 10185156    | 3301001 | 12/3/1952  | 24.7  | 24.4             | 0            | Participating        | 36                     | 225.904744              | 42.451567        | -82.231678        |
| 10185157    | 3301002 | 7/1/1954   | 24.4  | 22.9             | 0            | Non-Participating    | 36                     | 613.556569              | 42.451567        | -82.231678        |
| 10185159    | 3301004 | 5/3/1951   | 21.6  | 0                | 3.7          | Non-Participating    | 36                     | 1121.738468             | 42.451567        | -82.231678        |
| 10185170    | 3301015 | 5/12/1965  | 21    | 0                | 4.6          | Non-Participating    | 9                      | 654.695245              | 42.478519        | -82.195908        |
| 10185172    | 3301017 | 10/9/1964  | 20.1  | 18.9             | 3.7          | Non-Participating    | 9                      | 783.238868              | 42.478519        | -82.195908        |
| 10189330    | 3305179 | 10/27/1970 | 17.1  | 15.2             | 3.4          | Non-Participating    | 19                     | 711.014587              | 42.483246        | -82.292731        |
| 10193163    | 3309223 | 6/10/1996  | 20.7  | 0                | 0            | Non-Participating    | 24                     | 146.451605              | 42.541021        | -82.306467        |
| 10188990    | 3304835 | 4/10/1969  | 19.8  | 18.6             | 5.2          | Non-Participating    | 23                     | 1102.928736             | 42.489656        | -82.307565        |
| 10190821    | 3306693 | 11/17/1977 | 28.7  | 22.3             | 0            | Non-Participating    | 34                     | 596.568523              | 42.5383          | -82.333104        |
| 10185225    | 3301070 | 4/3/1957   | 23.2  | 19.8             | 0            | Non-Participating    | 38                     | 768.546                 | 42.466711        | -82.254429        |
| 10190356    | 3306216 | 4/23/1975  | 21.3  | 19.8             | 0            | Participating        | 1                      | 442.044164              | 42.466711        | -82.254429        |
| 10189419    | 3305269 | 4/17/1971  | 21.3  | 20.7             | 6.1          | Non-Participating    | 36                     | 1468.149063             | 42.451567        | -82.231678        |
| 10189442    | 3305300 | 5/14/1971  | 19.2  | 0                | 5.2          | Non-Participating    | 12                     | 718.293586              | 42.489881        | -82.201002        |
| 10189018    | 3304864 | 4/3/1969   | 17.1  | 16.5             | 5.2          | Non-Participating    | 51                     | 818.987124              | 42.480694        | -82.289578        |
| 10191473    | 3307351 | 11/10/1980 | 21.3  | 20.4             | 3            | Non-Participating    | 5                      | 3734.892791             | 42.489656        | -82.307565        |

| Borehole ID | Well ID | Completed  | Depth | Depth to Bedrock | Static Level | Participation Status | Closest turbine number | Distance to turbine (m) | Turbine Latitude | Turbine Longitude |
|-------------|---------|------------|-------|------------------|--------------|----------------------|------------------------|-------------------------|------------------|-------------------|
| 10190623    | 3306491 | 5/2/1976   | 20.7  | 20.1             | 6.4          | Non-Participating    | 35                     | 962.906823              | 42.467347        | -82.18753         |
| 10185462    | 3301307 | 6/16/1950  | 14    | 0                | 1.8          | Non-Participating    | 52                     | 1060.596952             | 42.522667        | -82.318272        |
| 10185465    | 3301310 | 7/2/1966   | 15.8  | 14.9             | 0            | Non-Participating    | 3                      | 955.053563              | 42.524388        | -82.280192        |
| 10185469    | 3301314 | 4/29/1962  | 16.2  | 15.5             | 4.3          | Non-Participating    | 43                     | 959.999984              | 42.563296        | -82.272404        |
| 10185473    | 3301318 | 4/14/1960  | 38.1  | 21.3             | 0            | Non-Participating    | 43                     | 1610.533225             | 42.563296        | -82.272404        |
| 10185478    | 3301323 | 10/25/1960 | 16.8  | 16.5             | 4.3          | Non-Participating    | 46                     | 2096.277734             | 42.542265        | -82.253956        |
| 10185491    | 3301336 | 9/25/1952  | 21.9  | 0                | 3            | Non-Participating    | 33                     | 722.981605              | 42.52971         | -82.322566        |
| 10192672    | 3308648 | 10/19/1990 | 18.9  | 16.5             | 0            | Non-Participating    | 39                     | 685.511686              | 42.466196        | -82.299023        |
| 10185494    | 3301339 | 6/18/1967  | 18.6  | 18.3             | 0            | Non-Participating    | 33                     | 518.759645              | 42.52971         | -82.322566        |
| 10185496    | 3301341 | 6/20/1967  | 18.9  | 18.3             | 8.5          | Non-Participating    | 52                     | 703.416226              | 42.52971         | -82.322566        |
| 10185501    | 3301346 | 7/5/1967   | 19.8  | 19.2             | 8.5          | Non-Participating    | 33                     | 455.438932              | 42.52971         | -82.322566        |
| 10185502    | 3301347 | 7/7/1967   | 18.9  | 18.3             | 8.5          | Non-Participating    | 33                     | 372.789104              | 42.52971         | -82.322566        |
| 10185505    | 3301350 | 10/20/1956 | 18.6  | 0                | 2.4          | Non-Participating    | 24                     | 956.702781              | 42.541021        | -82.306467        |
| 10185508    | 3301353 | 9/21/1951  | 16.5  | 0                | 6.1          | Non-Participating    | 20                     | 678.432001              | 42.558017        | -82.281159        |
| 10185512    | 3301357 | 9/27/1954  | 21.9  | 18               | 0            | Participating        | 21                     | 544.314827              | 42.560527        | -82.27849         |
| 10185513    | 3301358 | 9/28/1954  | 21.3  | 18.3             | 0            | Participating        | 21                     | 566.150641              | 42.560527        | -82.27849         |
| 10185516    | 3301361 | 11/15/1966 | 17.1  | 15.8             | 0            | Non-Participating    | 43                     | 1015.289408             | 42.563296        | -82.272404        |
| 10191728    | 3307610 | 7/29/1982  | 4.6   | 0                | 0.9          | Participating        | 37                     | 586.02848               | 42.474435        | -82.227029        |
| 10190019    | 3305878 | 11/30/1973 | 20.7  | 20.1             | 0            | Non-Participating    | 41                     | 807.199318              | 42.468573        | -82.277346        |
| 10190020    | 3305879 | 1/26/1974  | 20.4  | 0                | 4.9          | Non-Participating    | 41                     | 790.100893              | 42.468573        | -82.277346        |
| 10190061    | 3305920 | 3/19/1974  | 24.4  | 17.7             | 0            | Non-Participating    | 40                     | 790.616772              | 42.466196        | -82.299023        |
| 10190062    | 3305921 | 3/22/1974  | 21.3  | 18.9             | 7            | Non-Participating    | 40                     | 859.424343              | 42.466196        | -82.299023        |
| 10190064    | 3305923 | 2/27/1974  | 25.9  | 18.3             | 0            | Non-Participating    | 40                     | 766.626609              | 42.466196        | -82.299023        |
| 10190066    | 3305925 | 3/6/1974   | 22.9  | 17.4             | 0            | Non-Participating    | 40                     | 832.774633              | 42.466196        | -82.299023        |
| 10185525    | 3301370 | 9/17/1949  | 22.9  | 19.5             | 0            | Non-Participating    | 34                     | 1558.773368             | 42.5383          | -82.333104        |
| 10185544    | 3301389 | 12/10/1959 | 21.6  | 0                | 5.2          | Non-Participating    | 34                     | 923.904415              | 42.5383          | -82.333104        |
| 10189539    | 3305397 | 10/4/1971  | 15.8  | 15.2             | 0            | Non-Participating    | 49                     | 674.416465              | 42.503044        | -82.261339        |
| 10189545    | 3305403 | 9/27/1971  | 15.8  | 0                | 5.8          | Non-Participating    | 6                      | 497.978298              | 42.494783        | -82.244573        |
| 10189547    | 3305405 | 9/24/1971  | 16.8  | 0                | 0            | Non-Participating    | 6                      | 433.230352              | 42.494783        | -82.244573        |
| 10189548    | 3305406 | 9/23/1971  | 18.3  | 17.7             | 0            | Non-Participating    | 6                      | 451.821409              | 42.494783        | -82.244573        |
| 10186346    | 3302191 | 11/24/1958 | 23.5  | 18.9             | 3.7          | Non-Participating    | 36                     | 1581.230366             | 42.451567        | -82.231678        |
| 10193041    | 3309101 | 2/1/1994   | 20.4  | 19.8             | 4.3          | Non-Participating    | 23                     | 2553.456137             | 42.489656        | -82.307565        |
| 10191751    | 3307633 | 4/23/1983  | 20.1  | 18.3             | 3.4          | Non-Participating    | 37                     | 943.825549              | 42.474435        | -82.227029        |
| 10191752    | 3307634 | 3/15/1983  | 23.8  | 18               | 3.4          | Non-Participating    | 9                      | 917.928068              | 42.478519        | -82.195908        |
| 10191754    | 3307636 | 3/12/1983  | 19.8  | 18.3             | 0            | Non-Participating    | 9                      | 997.304362              | 42.478519        | -82.195908        |
| 10190555    | 3306421 | 6/15/1976  | 22.9  | 22.9             | 0            | Non-Participating    | 35                     | 796.682522              | 42.467347        | -82.18753         |
| 10193214    | 3309274 | 12/5/1996  | 15.2  | 14.3             | 3.7          | Non-Participating    | 3                      | 472.98258               | 42.524388        | -82.280192        |
| 10188807    | 3304652 | 5/6/1968   | 14.3  | 0                | 0            | Non-Participating    | 32                     | 665.195935              | 42.513906        | -82.244364        |
| 10188810    | 3304655 | 6/1/1968   | 14.3  | 14               | 4.6          | Non-Participating    | 32                     | 593.066807              | 42.513906        | -82.244364        |
| 10186070    | 3301915 | 9/26/1953  | 18.6  | 0                | 4.3          | Non-Participating    | 23                     | 961.472859              | 42.489656        | -82.307565        |
| 10186072    | 3301917 | 3/11/1959  | 19.2  | 18.3             | 4            | Non-Participating    | 23                     | 1136.946147             | 42.489656        | -82.307565        |
| 10186073    | 3301918 | 2/18/1963  | 16.8  | 0                | 3.7          | Non-Participating    | 23                     | 998.451806              | 42.489656        | -82.307565        |
| 10189623    | 3305482 | 2/16/1972  | 15.8  | 14.6             | 2.4          | Participating        | 45                     | 608.871374              | 42.542265        | -82.253956        |
| 10189635    | 3305494 | 9/2/1971   | 32.6  | 19.5             | 8.8          | Non-Participating    | 50                     | 616.957759              | 42.443312        | -82.24831         |
| 10191758    | 3307640 | 4/4/1983   | 21.6  | 21.3             | 4.6          | Non-Participating    | 35                     | 1182.061522             | 42.467347        | -82.18753         |
| 10191944    | 3307831 | 5/17/1984  | 22.3  | 15.8             | 0            | Non-Participating    | 30                     | 494.70162               | 42.522823        | -82.225798        |

| Borehole ID | Well ID | Completed  | Depth | Depth to Bedrock | Static Level | Participation Status | Closest turbine number | Distance to turbine (m) | Turbine Latitude | Turbine Longitude |
|-------------|---------|------------|-------|------------------|--------------|----------------------|------------------------|-------------------------|------------------|-------------------|
| 10188891    | 3304736 | 2/10/1968  | 20.7  | 19.8             | 0            | Non-Participating    | 24                     | 811.658284              | 42.541021        | -82.306467        |
| 10188893    | 3304738 | 2/20/1968  | 21.9  | 21.3             | 0            | Non-Participating    | 24                     | 769.905983              | 42.541021        | -82.306467        |
| 10188895    | 3304740 | 2/28/1968  | 21.3  | 19.8             | 0            | Non-Participating    | 24                     | 799.186387              | 42.541021        | -82.306467        |
| 10188899    | 3304744 | 6/14/1968  | 22.3  | 21.9             | 2.1          | Non-Participating    | 37                     | 1192.781188             | 42.474435        | -82.227029        |
| 10189498    | 3305356 | 9/3/1971   | 24.4  | 22.6             | 7.6          | Non-Participating    | 50                     | 1024.531669             | 42.443312        | -82.24831         |
| 10189022    | 3304868 | 6/16/1969  | 17.1  | 16.5             | 4.3          | Non-Participating    | 1                      | 858.164207              | 42.477774        | -82.248263        |
| 10189023    | 3304869 | 6/10/1969  | 14.6  | 14               | 2.4          | Non-Participating    | 3                      | 718.110317              | 42.513992        | -82.270698        |
| 10190115    | 3305974 | 4/2/1974   | 18    | 17.7             | 3            | Non-Participating    | 23                     | 3398.673045             | 42.489656        | -82.307565        |
| 10190907    | 3306779 | 6/4/1978   | 19.8  | 18.3             | 6.1          | Non-Participating    | 23                     | 1158.62924              | 42.489656        | -82.307565        |
| 10190252    | 3306112 | 6/8/1974   | 14.3  | 13.4             | 0            | Non-Participating    | 15                     | 472.039748              | 42.497399        | -82.292063        |
| 10190253    | 3306113 | 6/6/1974   | 13.4  | 13.1             | 0            | Non-Participating    | 15                     | 539.281543              | 42.497399        | -82.292063        |
| 10188764    | 3304609 | 5/6/1968   | 16.5  | 15.8             | 3            | Participating        | 6                      | 604.252926              | 42.494783        | -82.244573        |
| 10188766    | 3304611 | 11/15/1968 | 14.9  | 14.3             | 4.6          | Participating        | 32                     | 574.34014               | 42.513906        | -82.244364        |
| 10188798    | 3304643 | 10/28/1968 | 14.6  | 13.7             | 0            | Participating        | 32                     | 695.754985              | 42.513906        | -82.244364        |
| 10188799    | 3304644 | 10/28/1968 | 14.3  | 13.7             | 0            | Non-Participating    | 32                     | 720.144281              | 42.513906        | -82.244364        |
| 10189655    | 3305514 | 4/26/1972  | 21.3  | 20.7             | 3.7          | Non-Participating    | 9                      | 1182.536118             | 42.467347        | -82.18753         |
| 10185696    | 3301541 | 2/19/1948  | 18.9  | 17.7             | 6.1          | Non-Participating    | 43                     | 1556.718846             | 42.563296        | -82.272404        |
| 10189184    | 3305032 | 7/17/1969  | 19.8  | 0                | 4.9          | Non-Participating    | 37                     | 915.07088               | 42.474435        | -82.227029        |
| 10192842    | 3308896 | 6/15/1992  | 21.6  | 21.3             | 6.4          | Non-Participating    | 36                     | 1342.632093             | 42.451567        | -82.231678        |
| 10191580    | 3307461 | 7/8/1981   | 14.6  | 14.6             | 0            | Non-Participating    | 43                     | 1899.937867             | 42.563296        | -82.272404        |
| 10191581    | 3307462 | 7/8/1981   | 19.8  | 18.3             | 0            | Non-Participating    | 43                     | 1729.879379             | 42.563296        | -82.272404        |
| 10190147    | 3306006 | 7/23/1974  | 12.5  | 12.2             | 4.6          | Non-Participating    | 28                     | 494.661832              | 42.529298        | -82.222338        |
| 10189156    | 3305004 | 8/4/1969   | 16.2  | 15.5             | 0            | Non-Participating    | 28                     | 846.989117              | 42.522823        | -82.225798        |
| 10189157    | 3305005 | 8/8/1969   | 16.5  | 15.5             | 0            | Non-Participating    | 28                     | 826.656958              | 42.522823        | -82.225798        |
| 10189160    | 3305008 | 8/10/1969  | 16.2  | 15.5             | 3            | Non-Participating    | 28                     | 836.994173              | 42.522823        | -82.225798        |
| 10189376    | 3305225 | 4/20/1970  | 18.6  | 18               | 4.9          | Non-Participating    | 23                     | 1219.332976             | 42.489656        | -82.307565        |
| 10192698    | 3308674 | 12/19/1990 | 22.3  | 20.7             | 8.5          | Non-Participating    | 36                     | 1466.711976             | 42.451567        | -82.231678        |
| 10192008    | 3307904 | 8/30/1984  | 20.1  | 18.6             | 6.1          | Non-Participating    | 37                     | 581.814449              | 42.474435        | -82.227029        |
| 10191615    | 3307496 | 6/8/1981   | 21.3  | 20.7             | 4.9          | Non-Participating    | 34                     | 1609.467868             | 42.5383          | -82.333104        |
| 10186661    | 3302506 | 2/25/1957  | 22.9  | 0                | 8.2          | Non-Participating    | 34                     | 1624.818703             | 42.5383          | -82.333104        |
| 10190363    | 3306223 | 5/23/1975  | 12.5  | 0                | 0            | Non-Participating    | 28                     | 623.777095              | 42.529298        | -82.222338        |
| 10190375    | 3306235 | 4/17/1974  | 21.3  | 20.1             | 4.9          | Non-Participating    | 36                     | 1296.147153             | 42.451567        | -82.231678        |
| 10190403    | 3306263 | 4/15/1975  | 20.4  | 19.8             | 0            | Non-Participating    | 12                     | 909.262139              | 42.489881        | -82.201002        |
| 10190405    | 3306265 | 7/21/1975  | 13.7  | 12.8             | 3            | Non-Participating    | 17                     | 831.18802               | 42.542265        | -82.253956        |
| 10190408    | 3306268 | 9/12/1975  | 18.3  | 18               | 5.5          | Non-Participating    | 23                     | 1457.678184             | 42.489656        | -82.307565        |
| 10190991    | 3306863 | 8/21/1978  | 18.3  | 18               | 0            | Non-Participating    | 43                     | 1703.755756             | 42.563296        | -82.272404        |
| 10191651    | 3307533 | 9/2/1981   | 18.3  | 16.2             | 2.1          | Non-Participating    | 2                      | 1309.270657             | 42.487415        | -82.258872        |
| 10190493    | 3306358 | 12/12/1975 | 18    | 18               | 5.2          | Participating        | 23                     | 808.866233              | 42.489656        | -82.307565        |
| 10189570    | 3305428 | 5/7/1971   | 23.8  | 21.3             | 0            | Non-Participating    | 24                     | 629.169323              | 42.541021        | -82.306467        |
| 10189572    | 3305430 | 5/4/1971   | 23.8  | 21.3             | 0            | Non-Participating    | 24                     | 644.347732              | 42.541021        | -82.306467        |
| 10189574    | 3305432 | 5/1/1971   | 21.3  | 0                | 4.3          | Non-Participating    | 24                     | 631.767953              | 42.541021        | -82.306467        |
| 10193061    | 3309121 | 11/17/1994 | 15.2  | 0                | 2.4          | Non-Participating    | 14                     | 771.042681              | 42.503776        | -82.28634         |
| 10192912    | 3308966 | 8/14/1993  | 23.8  | 15.8             | 0            | Non-Participating    | 46                     | 1570.32214              | 42.563296        | -82.272404        |
| 10192916    | 3308970 | 8/5/1993   | 22.9  | 16.5             | 0            | Non-Participating    | 46                     | 1570.32214              | 42.563296        | -82.272404        |
| 10190959    | 3306831 | 8/9/1978   | 18.9  | 0                | 2.4          | Non-Participating    | 50                     | 2693.289045             | 42.440506        | -82.274649        |
| 10186076    | 3301921 | 6/15/1965  | 18.9  | 18.3             | 4.6          | Non-Participating    | 5                      | 2193.298061             | 42.520098        | -82.321614        |

| Borehole ID | Well ID | Completed  | Depth | Depth to Bedrock | Static Level | Participation Status | Closest turbine number | Distance to turbine (m) | Turbine Latitude | Turbine Longitude |
|-------------|---------|------------|-------|------------------|--------------|----------------------|------------------------|-------------------------|------------------|-------------------|
| 10191012    | 3306884 | 8/30/1978  | 12.2  | 0                | 2.4          | Non-Participating    | 73                     | 1513.100294             | 42.440506        | -82.274649        |
| 10188920    | 3304765 | 5/7/1968   | 21.3  | 0                | 0            | Participating        | 37                     | 876.096407              | 42.474435        | -82.227029        |
| 10188923    | 3304768 | 5/24/1968  | 20.4  | 0                | 3            | Non-Participating    | 38                     | 880.369089              | 42.477774        | -82.248263        |
| 10188924    | 3304769 | 5/16/1968  | 22.6  | 21.9             | 0            | Non-Participating    | 37                     | 855.335369              | 42.474435        | -82.227029        |
| 10188925    | 3304770 | 5/18/1968  | 20.7  | 0                | 5.2          | Non-Participating    | 37                     | 885.714069              | 42.474435        | -82.227029        |
| 10186646    | 3302491 | 6/6/1961   | 28.7  | 20.7             | 4.3          | Non-Participating    | 34                     | 1365.3155               | 42.52971         | -82.322566        |
| 10191851    | 3307734 | 8/6/1983   | 18.3  | 18.3             | 4.9          | Non-Participating    | 20                     | 875.971826              | 42.558017        | -82.281159        |
| 10189038    | 3304884 | 7/1/1969   | 24.4  | 0                | 5.5          | Participating        | 24                     | 487.578404              | 42.541021        | -82.306467        |
| 10190785    | 3306657 | 10/14/1977 | 13.4  | 13.4             | 0            | Non-Participating    | 15                     | 575.689469              | 42.497399        | -82.292063        |
| 10193253    | 3309313 | 1/26/1996  | 37.2  | 21.6             | 0            | Non-Participating    | 46                     | 2353.746847             | 42.563296        | -82.272404        |
| 10193261    | 3309321 | 4/2/1997   | 19.8  | 18               | 3            | Non-Participating    | 31                     | 623.832525              | 42.490276        | -82.225145        |
| 10189997    | 3305856 | 9/15/1973  | 15.8  | 15.5             | 8.8          | Non-Participating    | 46                     | 1823.335025             | 42.542265        | -82.253956        |
| 10190044    | 3305903 | 1/4/1974   | 35.1  | 21               | 0            | Non-Participating    | 34                     | 1377.121343             | 42.5383          | -82.333104        |
| 10192601    | 3308577 | 5/3/1990   | 27.4  | 20.7             | 4.9          | Non-Participating    | 35                     | 1416.25328              | 42.467347        | -82.18753         |
| 10192602    | 3308578 | 5/11/1990  | 19.2  | 16.2             | 2.7          | Non-Participating    | 35                     | 1441.30141              | 42.467347        | -82.18753         |
| 10192603    | 3308579 | 5/7/1990   | 19.2  | 16.2             | 2.7          | Non-Participating    | 35                     | 1441.30141              | 42.467347        | -82.18753         |
| 10191546    | 3307426 | 4/8/1981   | 17.7  | 14.6             | 0            | Non-Participating    | 43                     | 1789.553658             | 42.563296        | -82.272404        |
| 10189171    | 3305019 | 10/3/1969  | 17.1  | 16.5             | 2.4          | Non-Participating    | 51                     | 1172.060712             | 42.480694        | -82.289578        |
| 10190283    | 3306143 | 3/27/1975  | 18.3  | 18               | 1.8          | Non-Participating    | 35                     | 1384.148456             | 42.467347        | -82.18753         |
| 10186534    | 3302379 | 9/20/1965  | 20.1  | 19.2             | 4.6          | Non-Participating    | 40                     | 811.700952              | 42.460878        | -82.295508        |
| 10186563    | 3302408 | 8/9/1966   | 19.2  | 18               | 5.5          | Non-Participating    | 23                     | 1236.261174             | 42.489656        | -82.307565        |
| 10189238    | 3305087 | 3/13/1970  | 19.8  | 0                | 3.4          | Participating        | 24                     | 479.884214              | 42.541021        | -82.306467        |
| 10191381    | 3307259 | 12/15/1979 | 8.5   | 0                | 2.1          | Non-Participating    | 21                     | 677.657274              | 42.560527        | -82.27849         |
| 10192413    | 3308389 | 8/16/1988  | 24.7  | 24.4             | 4.3          | Non-Participating    | 50                     | 2532.891553             | 42.440506        | -82.274649        |
| 10192492    | 3308468 | 8/27/1989  | 15.8  | 13.7             | 2.1          | Non-Participating    | 44                     | 792.25271               | 42.511856        | -82.299774        |
| 10192493    | 3308469 | 8/17/1989  | 21.9  | 13.7             | 0            | Non-Participating    | 44                     | 800.718664              | 42.511856        | -82.299774        |
| 10192229    | 3308205 | 12/22/1987 | 7.9   | 0                | 3            | Non-Participating    | 42                     | 1035.43101              | 42.456232        | -82.293684        |
| 10191063    | 3306935 | 10/26/1978 | 4.9   | 0                | 2.1          | Non-Participating    | 51                     | 840.987576              | 42.480694        | -82.289578        |
| 10191294    | 3307171 | 10/17/1979 | 19.5  | 0                | 2.1          | Non-Participating    | 33                     | 867.612154              | 42.52971         | -82.322566        |
| 10192301    | 3308277 | 6/3/1988   | 20.1  | 18               | 3.4          | Non-Participating    | 5                      | 2133.400054             | 42.520098        | -82.321614        |
| 10191302    | 3307179 | 8/19/1979  | 19.8  | 18.3             | 0            | Non-Participating    | 12                     | 731.477688              | 42.489881        | -82.201002        |
| 10191354    | 3307232 | 8/28/1979  | 14.9  | 14.9             | 0            | Non-Participating    | 15                     | 815.052922              | 42.497399        | -82.292063        |
| 10192540    | 3308516 | 11/17/1989 | 18    | 16.8             | 2.4          | Non-Participating    | 24                     | 1038.212337             | 42.541021        | -82.306467        |
| 10191170    | 3307043 | 6/1/1979   | 18.3  | 18               | 1.8          | Non-Participating    | 38                     | 802.232583              | 42.477774        | -82.248263        |
| 10191175    | 3307048 | 3/29/1979  | 20.7  | 2.7              | 1.8          | Non-Participating    | 33                     | 650.052401              | 42.5383          | -82.333104        |
| 10193502    | 3309563 | 1/11/2000  | 0     | 0                | 0            | Non-Participating    | 36                     | 1579.44593              | 42.443312        | -82.24831         |
| 10192211    | 3308187 | 9/14/1987  | 21.3  | 19.5             | 0            | Non-Participating    | 42                     | 1020.993921             | 42.456232        | -82.293684        |
| 10191332    | 3307210 | 12/20/1979 | 13.4  | 13.1             | 0            | Non-Participating    | 28                     | 472.005429              | 42.529298        | -82.222338        |
| 10191336    | 3307214 | 12/5/1979  | 26.8  | 19.8             | 0            | Non-Participating    | 21                     | 740.423095              | 42.560527        | -82.27849         |
| 10192429    | 3308405 | 1/24/1989  | 18.9  | 18.6             | 4.9          | Non-Participating    | 23                     | 985.165527              | 42.489656        | -82.307565        |
| 10193577    | 3309638 | 11/27/2000 | 27.4  | 23.2             | 0            | Non-Participating    | 73                     | 2022.509501             | 42.440506        | -82.274649        |
| 11098387    | 3309982 | 10/30/2003 | 0     | 0                | 0            | Participating        | 37                     | 91.321358               | 42.474435        | -82.227029        |
| 10519006    | 3309671 | 5/15/2001  | 21    | 18.3             | 3.4          | Participating        | 73                     | 627.370288              | 42.440506        | -82.274649        |
| 10525652    | 3309758 | 5/27/2002  | 0     | 0                | 0            | Non-Participating    | 46                     | 2320.05119              | 42.542265        | -82.253956        |
| 10532315    | 3309777 | 7/13/2002  | 15.8  | 15.2             | 0            | Non-Participating    | 31                     | 774.167298              | 42.490276        | -82.225145        |
| 10539211    | 3309860 | 4/17/2003  | 0     | 0                | 0            | Non-Participating    | 23                     | 1232.190267             | 42.489656        | -82.307565        |

| Borehole ID | Well ID | Completed  | Depth | Depth to Bedrock | Static Level | Participation Status | Closest turbine number | Distance to turbine (m) | Turbine Latitude | Turbine Longitude |
|-------------|---------|------------|-------|------------------|--------------|----------------------|------------------------|-------------------------|------------------|-------------------|
| 10545021    | 3309887 | 6/13/2003  | 0     | 0                | 0            | Non-Participating    | 36                     | 1345.744968             | 42.451567        | -82.231678        |
| 11175194    | 3310121 | 9/22/2004  | 17.7  | 17.7             | 4.6          | Participating        | 39                     | 526.758382              | 42.466196        | -82.299023        |
| 11553130    | 3310251 | 10/24/2004 | 0     | 0                | 0            | Non-Participating    | 43                     | 737.680996              | 42.563296        | -82.272404        |
| 11763770    | 7041263 | 1/18/2007  | 3.4   | 0                | 0            | Non-Participating    | 45                     | 316.019131              | 42.538634        | -82.259452        |
| 10185119    | 3300964 | 12/22/1962 | 21.3  | 0                | 6.7          | Non-Participating    | 36                     | 1409.400224             | 42.451567        | -82.231678        |
| 10185699    | 3301544 | 10/23/1954 | 21.9  | 17.4             | 4.3          | Non-Participating    | 43                     | 2056.083224             | 42.563296        | -82.272404        |
| 10190904    | 3306776 | 5/17/1978  | 19.8  | 19.5             | 0            | Non-Participating    | 23                     | 1143.678211             | 42.489656        | -82.307565        |
| 10190112    | 3305971 | 5/6/1974   | 19.5  | 18.9             | 0            | Non-Participating    | 34                     | 1025.26091              | 42.5383          | -82.333104        |
| 1003464676  | 7158527 | 12/2/2010  | 14    | 0                | 0            | Non-Participating    | 30                     | 869.534271              | 42.522823        | -82.225798        |
| 1003464682  | 7158530 | 11/19/2010 | 14.6  | 0                | 0            | Non-Participating    | 30                     | 992.408871              | 42.522823        | -82.225798        |
| 1001506226  | 7102061 | 12/20/2007 | 2.4   | 0                | 0            | Non-Participating    | 36                     | 1698.951203             | 42.451567        | -82.231678        |
| 1001803478  | 7111629 | 8/5/2008   | 0     | 0                | 0            | Non-Participating    | 32                     | 860.008317              | 42.513906        | -82.244364        |
| 1002747806  | 7131958 | 9/2/2009   | 20.4  | 0                | 4.6          | Non-Participating    | 34                     | 1008.671803             | 42.5383          | -82.333104        |
| 1002937541  | 7139802 | 10/20/2009 | 4.6   | 0                | 0            | Non-Participating    | 35                     | 968.354583              | 42.478519        | -82.195908        |
| 1002934722  | 7139497 | 10/19/2009 | 3     | 0                | 0            | Non-Participating    | 35                     | 1086.673293             | 42.467347        | -82.18753         |
| 1003514975  | 7163653 | 5/17/2011  | 0     | 0                | 0            | Non-Participating    | 39                     | 1837.139395             | 42.466196        | -82.299023        |
| 1003696542  | 7177280 | 5/30/2011  | 0     | 0                | 0            | Non-Participating    | 28                     | 1139.811717             | 42.529298        | -82.222338        |
| 1004114350  | 7185511 | 6/18/2012  | 0     | 0                | 0            | Non-Participating    | 5                      | 2282.3566               | 42.489656        | -82.307565        |
| 1004150091  | 7186694 | 7/25/2012  | 0     | 0                | 0            | Non-Participating    | 49                     | 803.001283              | 42.503044        | -82.261339        |
| 23051657    | 7051657 | 10/10/2007 | 15.2  | 0                | 2.1          | Non-Participating    | 4                      | 641.194398              | 42.527399        | -82.277222        |
| 10186049    | 3301894 | 6/27/1959  | 17.4  | 17.1             | 0            | Non-Participating    | 51                     | 781.849215              | 42.480694        | -82.289578        |
| 10185368    | 3301213 | 1/12/1958  | 15.2  | 12.8             | 3            | Non-Participating    | 15                     | 689.183589              | 42.497399        | -82.292063        |
| 10185261    | 3301106 | 9/23/1966  | 20.4  | 20.1             | 2.1          | Non-Participating    | 41                     | 960.926479              | 42.468573        | -82.277346        |
| 10185434    | 3301279 | 2/26/1958  | 15.2  | 0                | 4.6          | Non-Participating    | 45                     | 701.46965               | 42.52929         | -82.247949        |
| 10185128    | 3300973 | 11/10/1953 | 21    | 20.7             | 1.5          | Non-Participating    | 36                     | 1249.321531             | 42.451567        | -82.231678        |
| 10185152    | 3300997 | 4/11/1955  | 25    | 24.4             | 0            | Participating        | 36                     | 530.475457              | 42.451567        | -82.231678        |
| 10185226    | 3301071 | 4/13/1957  | 23.5  | 19.8             | 3.4          | Non-Participating    | 38                     | 735.976512              | 42.466711        | -82.254429        |
| 10185230    | 3301075 | 9/14/1964  | 19.8  | 19.5             | 3.7          | Non-Participating    | 31                     | 651.609351              | 42.490276        | -82.225145        |
| 10189429    | 3305279 | 5/4/1971   | 18.3  | 17.4             | 0            | Non-Participating    | 43                     | 1474.628695             | 42.563296        | -82.272404        |
| 10192086    | 3308062 | 5/9/1986   | 19.8  | 18               | 0            | Participating        | 51                     | 708.173129              | 42.480694        | -82.289578        |
| 10185464    | 3301309 | 7/3/1966   | 16.2  | 14.9             | 0            | Non-Participating    | 3                      | 1001.505823             | 42.524388        | -82.280192        |
| 10185472    | 3301317 | 4/23/1962  | 15.8  | 15.2             | 0            | Non-Participating    | 43                     | 1021.84418              | 42.563296        | -82.272404        |
| 10186595    | 3302440 | 7/1/1967   | 18.3  | 0                | 3.7          | Non-Participating    | 44                     | 1287.304363             | 42.511856        | -82.299774        |
| 10185529    | 3301374 | 10/22/1960 | 18.6  | 17.7             | 0            | Non-Participating    | 24                     | 1005.829612             | 42.541021        | -82.306467        |
| 10191756    | 3307638 | 3/7/1983   | 24.7  | 19.8             | 0            | Participating        | 9                      | 890.123602              | 42.478519        | -82.195908        |
| 10190560    | 3306426 | 5/4/1976   | 17.7  | 0                | 0            | Non-Participating    | 37                     | 781.917924              | 42.474435        | -82.227029        |
| 10188897    | 3304742 | 6/12/1968  | 22.3  | 21.3             | 1.5          | Non-Participating    | 36                     | 766.968678              | 42.451567        | -82.231678        |
| 10189661    | 3305520 | 5/8/1972   | 20.1  | 19.2             | 4.6          | Non-Participating    | 48                     | 885.115277              | 42.453372        | -82.285417        |
| 10193385    | 3309445 | 1/9/1999   | 6.1   | 0                | 4.6          | Non-Participating    | 37                     | 1207.908956             | 42.474435        | -82.227029        |
| 10193388    | 3309448 | 10/14/1998 | 0     | 0                | 0            | Participating        | 46                     | 228.213292              | 42.542265        | -82.253956        |
| 10189161    | 3305009 | 8/12/1969  | 15.5  | 0                | 3            | Non-Participating    | 28                     | 906.962411              | 42.522823        | -82.225798        |
| 10189377    | 3305226 | 5/23/1970  | 17.4  | 17.1             | 2.4          | Non-Participating    | 51                     | 964.558814              | 42.480694        | -82.289578        |
| 10192042    | 3308018 | 7/30/1986  | 21.3  | 0                | 0            | Participating        | 24                     | 542.145413              | 42.541021        | -82.306467        |
| 10189856    | 3305715 | 1/12/1973  | 30.5  | 21               | 4            | Non-Participating    | 34                     | 1391.252533             | 42.5383          | -82.333104        |
| 10192913    | 3308967 | 8/11/1993  | 18.3  | 16.5             | 0            | Non-Participating    | 46                     | 1570.32214              | 42.563296        | -82.272404        |
| 10192958    | 3309012 | 11/16/1993 | 14.3  | 0                | 0            | Non-Participating    | 45                     | 254.482972              | 42.538634        | -82.259452        |

| Borehole ID | Well ID | Completed  | Depth | Depth to Bedrock | Static Level | Participation Status | Closest turbine number | Distance to turbine (m) | Turbine Latitude | Turbine Longitude |
|-------------|---------|------------|-------|------------------|--------------|----------------------|------------------------|-------------------------|------------------|-------------------|
| 10184592    | 3300435 | 5/29/1967  | 13.4  | 12.8             | 5.5          | Non-Participating    | 15                     | 557.603834              | 42.497399        | -82.292063        |
| 10192456    | 3308432 | 5/3/1989   | 23.2  | 22.3             | 3.7          | Non-Participating    | 50                     | 1689.116703             | 42.443312        | -82.24831         |
| 10191268    | 3307145 | 10/10/1979 | 13.7  | 13.1             | 3.7          | Non-Participating    | 15                     | 656.315601              | 42.497399        | -82.292063        |
| 10191361    | 3307239 | 9/1/1979   | 17.7  | 17.7             | 2.7          | Non-Participating    | 40                     | 1601.684087             | 42.456232        | -82.293684        |
| 10545063    | 3309929 | 7/1/2003   | 0     | 0                | 0            | Non-Participating    | 36                     | 527.74345               | 42.451567        | -82.231678        |
| 11693167    | 3310350 | 10/17/2006 | 0     | 0                | 0            | Participating        | 32                     | 677.753068              | 42.513906        | -82.244364        |
| 11765256    | 7042831 | 2/28/2007  | 7.6   | 0                | 0            | Non-Participating    | 36                     | 1711.59299              | 42.451567        | -82.231678        |
| 10193239    | 3309299 | 9/20/1996  | 17.7  | 15.8             | 3.7          | Non-Participating    | 44                     | 867.406846              | 42.511856        | -82.299774        |
| 10192915    | 3308969 | 8/9/1993   | 19.8  | 16.2             | 0            | Non-Participating    | 46                     | 1570.32214              | 42.563296        | -82.272404        |
| 10185266    | 3301111 | 6/6/1947   | 16.8  | 16.5             | 2.4          | Non-Participating    | 32                     | 846.112059              | 42.513906        | -82.244364        |
| 1001803481  | 7111630 | 8/5/2008   | 0     | 0                | 1.8          | Non-Participating    | 32                     | 864.22158               | 42.513906        | -82.244364        |
| 1002495828  | 7124690 | 4/23/2009  | 0     | 0                | 0            | Non-Participating    | 9                      | 841.435227              | 42.478519        | -82.195908        |
| 1003610449  | 7172139 | 10/12/2011 | 0     | 0                | 0            | Non-Participating    | 42                     | 1662.879133             | 42.456232        | -82.293684        |
| 10185188    | 3301033 | 12/6/1949  | 18.9  | 0                | 2.1          | Non-Participating    | 37                     | 1102.588953             | 42.474435        | -82.227029        |
| 10185116    | 3300961 | 5/24/1962  | 22.6  | 21.9             | 0            | Non-Participating    | 36                     | 1145.359811             | 42.451567        | -82.231678        |
| 10185121    | 3300966 | 6/24/1963  | 25.6  | 22.6             | 0            | Non-Participating    | 36                     | 1137.465962             | 42.451567        | -82.231678        |
| 10185281    | 3301126 | 3/16/1957  | 17.1  | 0                | 0            | Non-Participating    | 15                     | 673.325793              | 42.497399        | -82.292063        |
| 10185286    | 3301131 | 10/1/1962  | 15.5  | 14.9             | 0            | Non-Participating    | 32                     | 855.583532              | 42.513906        | -82.244364        |
| 10185288    | 3301133 | 9/12/1966  | 14.3  | 0                | 9.1          | Participating        | 32                     | 696.794777              | 42.513906        | -82.244364        |
| 10185298    | 3301143 | 4/19/1963  | 13.7  | 13.4             | 0            | Non-Participating    | 30                     | 957.101024              | 42.522823        | -82.225798        |
| 10185299    | 3301144 | 4/19/1963  | 14    | 13.7             | 0            | Non-Participating    | 17                     | 978.573963              | 42.522823        | -82.225798        |
| 10185301    | 3301146 | 4/20/1963  | 13.4  | 13.1             | 0            | Non-Participating    | 30                     | 958.038228              | 42.522823        | -82.225798        |
| 10185150    | 3300995 | 11/15/1946 | 38.1  | 0                | 3.7          | Non-Participating    | 36                     | 1249.321531             | 42.451567        | -82.231678        |
| 10185155    | 3301000 | 11/8/1966  | 15.2  | 0                | 5.2          | Non-Participating    | 36                     | 778.685369              | 42.451567        | -82.231678        |
| 10185158    | 3301003 | 7/9/1954   | 25.3  | 22.9             | 0            | Non-Participating    | 36                     | 508.174847              | 42.451567        | -82.231678        |
| 10185161    | 3301006 | 3/20/1965  | 19.8  | 19.5             | 3.4          | Non-Participating    | 37                     | 1046.531482             | 42.474435        | -82.227029        |
| 10185167    | 3301012 | 4/9/1964   | 20.7  | 19.8             | 2.7          | Non-Participating    | 9                      | 650.654368              | 42.478519        | -82.195908        |
| 10190177    | 3306036 | 8/22/1974  | 20.4  | 19.2             | 6.1          | Non-Participating    | 43                     | 1605.142142             | 42.563296        | -82.272404        |
| 10190351    | 3306211 | 6/26/1975  | 18.6  | 18.3             | 4            | Non-Participating    | 28                     | 1363.730648             | 42.529298        | -82.222338        |
| 10190473    | 3306335 | 4/20/1975  | 20.7  | 19.5             | 4.6          | Non-Participating    | 12                     | 928.512876              | 42.489881        | -82.201002        |
| 10185476    | 3301321 | 9/24/1966  | 25.9  | 19.8             | 6.1          | Non-Participating    | 43                     | 1656.325983             | 42.563296        | -82.272404        |
| 10192673    | 3308649 | 10/24/1990 | 17.4  | 17.1             | 4.6          | Non-Participating    | 39                     | 701.57028               | 42.466196        | -82.299023        |
| 10190859    | 3306731 | 5/10/1977  | 22.9  | 21.3             | 0            | Non-Participating    | 23                     | 2637.72891              | 42.489656        | -82.307565        |
| 10185546    | 3301391 | 11/10/1961 | 25    | 0                | 0            | Non-Participating    | 34                     | 1445.413571             | 42.5383          | -82.333104        |
| 10189540    | 3305398 | 10/2/1971  | 14.3  | 0                | 0            | Non-Participating    | 49                     | 387.485078              | 42.503044        | -82.261339        |
| 10193213    | 3309273 | 12/5/1996  | 0     | 0                | 0            | Non-Participating    | 3                      | 472.98258               | 42.524388        | -82.280192        |
| 10188811    | 3304656 | 6/3/1968   | 14.6  | 14               | 4.6          | Non-Participating    | 32                     | 579.222373              | 42.513906        | -82.244364        |
| 10190249    | 3306109 | 6/13/1974  | 16.5  | 12.8             | 2.7          | Participating        | 15                     | 461.631338              | 42.497399        | -82.292063        |
| 10190908    | 3306780 | 6/10/1978  | 19.5  | 19.2             | 5.5          | Non-Participating    | 23                     | 746.442712              | 42.489656        | -82.307565        |
| 10190911    | 3306783 | 6/20/1978  | 19.2  | 0                | 0            | Non-Participating    | 43                     | 1598.299474             | 42.563296        | -82.272404        |
| 10190912    | 3306784 | 6/23/1978  | 17.7  | 0                | 0            | Non-Participating    | 43                     | 1583.693608             | 42.563296        | -82.272404        |
| 10191582    | 3307463 | 7/8/1981   | 22.9  | 22.9             | 0            | Non-Participating    | 43                     | 1769.399867             | 42.563296        | -82.272404        |
| 10189372    | 3305221 | 11/25/1970 | 21.9  | 21.3             | 3.7          | Non-Participating    | 38                     | 907.372531              | 42.474435        | -82.227029        |
| 10192039    | 3308015 | 7/12/1986  | 24.4  | 23.8             | 5.8          | Participating        | 24                     | 571.085159              | 42.541021        | -82.306467        |
| 10190990    | 3306862 | 8/18/1978  | 18.3  | 17.7             | 0            | Non-Participating    | 43                     | 1691.252634             | 42.563296        | -82.272404        |
| 10191427    | 3307305 | 4/25/1980  | 17.7  | 17.7             | 0.6          | Non-Participating    | 20                     | 787.971854              | 42.558017        | -82.281159        |

| Borehole ID | Well ID | Completed  | Depth | Depth to Bedrock | Static Level | Participation Status | Closest turbine number | Distance to turbine (m) | Turbine Latitude | Turbine Longitude |
|-------------|---------|------------|-------|------------------|--------------|----------------------|------------------------|-------------------------|------------------|-------------------|
| 10189569    | 3305427 | 5/8/1971   | 21.9  | 21.3             | 0            | Non-Participating    | 24                     | 360.377613              | 42.541021        | -82.306467        |
| 10192943    | 3308997 | 11/16/1993 | 15.2  | 0                | 1.8          | Non-Participating    | 1                      | 1282.640079             | 42.466711        | -82.254429        |
| 10192973    | 3309029 | 6/10/1993  | 21.3  | 18.3             | 0            | Non-Participating    | 20                     | 821.537323              | 42.558017        | -82.281159        |
| 10189037    | 3304883 | 6/11/1969  | 23.2  | 22.6             | 5.5          | Non-Participating    | 50                     | 967.030099              | 42.443312        | -82.24831         |
| 10189101    | 3304948 | 9/12/1969  | 21.3  | 0                | 2.1          | Non-Participating    | 36                     | 907.198794              | 42.451567        | -82.231678        |
| 10186399    | 3302244 | 10/10/1950 | 22.3  | 21.9             | 0            | Non-Participating    | 72                     | 1256.746549             | 42.440506        | -82.274649        |
| 10192411    | 3308387 | 11/24/1988 | 19.2  | 18.9             | 4            | Non-Participating    | 12                     | 757.406337              | 42.489881        | -82.201002        |
| 10192296    | 3308272 | 5/25/1988  | 29.9  | 24.7             | 0            | Non-Participating    | 24                     | 775.934924              | 42.541021        | -82.306467        |
| 10191172    | 3307045 | 6/6/1979   | 17.1  | 16.8             | 0            | Non-Participating    | 2                      | 717.734758              | 42.487415        | -82.258872        |
| 10193571    | 3309632 | 12/14/2000 | 15.5  | 0                | 0            | Non-Participating    | 6                      | 1044.553663             | 42.494783        | -82.244573        |
| 10193574    | 3309635 | 12/16/2000 | 0     | 0                | 0            | Non-Participating    | 6                      | 1051.037078             | 42.494783        | -82.244573        |
| 10539210    | 3309859 | 4/17/2003  | 0     | 0                | 0            | Non-Participating    | 3                      | 943.290783              | 42.524388        | -82.280192        |
| 10545019    | 3309885 | 5/18/2003  | 17.4  | 0                | 3            | Participating        | 31                     | 119.155292              | 42.490276        | -82.225145        |
| 10185187    | 3301032 | 10/20/1967 | 23.2  | 0                | 2.7          | Non-Participating    | 36                     | 925.201207              | 42.451567        | -82.231678        |
| 1001906923  | 7116119 | 10/10/2008 | 4.5   | 0                | 0            | Non-Participating    | 36                     | 1479.208341             | 42.451567        | -82.231678        |
| 10186044    | 3301889 | 11/8/1966  | 12.2  | 0                | 2.4          | Non-Participating    | 48                     | 915.282854              | 42.453372        | -82.285417        |
| 10185370    | 3301215 | 1/23/1965  | 19.2  | 17.7             | 0            | Non-Participating    | 15                     | 758.963433              | 42.497399        | -82.292063        |
| 10185371    | 3301216 | 1/29/1965  | 19.5  | 17.7             | 0            | Non-Participating    | 15                     | 763.733767              | 42.497399        | -82.292063        |
| 10185087    | 3300932 | 8/18/1961  | 22.3  | 21.3             | 4.3          | Non-Participating    | 35                     | 1118.832085             | 42.467347        | -82.18753         |
| 10185093    | 3300938 | 8/24/1965  | 6.1   | 0                | 1.8          | Non-Participating    | 35                     | 868.400747              | 42.467347        | -82.18753         |
| 10185284    | 3301129 | 8/7/1954   | 13.7  | 0                | 9.4          | Non-Participating    | 32                     | 1013.62079              | 42.503044        | -82.261339        |
| 10185294    | 3301139 | 4/17/1963  | 14    | 13.7             | 0            | Non-Participating    | 17                     | 902.19255               | 42.52929         | -82.247949        |
| 10185304    | 3301149 | 4/14/1959  | 14.9  | 13.7             | 2.1          | Non-Participating    | 30                     | 802.340878              | 42.529298        | -82.222338        |
| 10185165    | 3301010 | 5/15/1962  | 16.8  | 16.5             | 3            | Non-Participating    | 35                     | 670.165392              | 42.467347        | -82.18753         |
| 10190906    | 3306778 | 5/29/1978  | 19.8  | 18.9             | 0            | Non-Participating    | 23                     | 1101.97058              | 42.489656        | -82.307565        |
| 10185523    | 3301368 | 6/3/1963   | 19.2  | 0                | 4.6          | Non-Participating    | 34                     | 692.727562              | 42.5383          | -82.333104        |
| 10191729    | 3307611 | 10/30/1982 | 19.5  | 0                | 4.3          | Non-Participating    | 39                     | 732.634413              | 42.466196        | -82.299023        |
| 10189543    | 3305401 | 9/29/1971  | 15.8  | 0                | 5.8          | Non-Participating    | 6                      | 516.268802              | 42.494783        | -82.244573        |
| 10189639    | 3305498 | 12/16/1971 | 27.4  | 21.3             | 0            | Participating        | 34                     | 589.075146              | 42.5383          | -82.333104        |
| 10191500    | 3307380 | 10/15/1980 | 21.9  | 21               | 4.9          | Non-Participating    | 34                     | 1528.181087             | 42.5383          | -82.333104        |
| 10190254    | 3306114 | 6/4/1974   | 14.3  | 13.1             | 0            | Non-Participating    | 15                     | 548.085927              | 42.497399        | -82.292063        |
| 10191592    | 3307473 | 3/23/1981  | 15.8  | 14.6             | 3.4          | Participating        | 28                     | 421.185353              | 42.529298        | -82.222338        |
| 10192846    | 3308900 | 1/10/1992  | 21.3  | 16.8             | 0            | Non-Participating    | 39                     | 2485.137163             | 42.466196        | -82.299023        |
| 10190412    | 3306274 | 9/23/1975  | 19.8  | 17.7             | 0            | Non-Participating    | 5                      | 1395.785305             | 42.520098        | -82.321614        |
| 10190414    | 3306276 | 9/29/1975  | 20.4  | 17.4             | 0            | Non-Participating    | 5                      | 1461.145393             | 42.520098        | -82.321614        |
| 10190985    | 3306857 | 8/7/1978   | 16.8  | 16.5             | 3            | Non-Participating    | 31                     | 820.608324              | 42.490276        | -82.225145        |
| 10190734    | 3306606 | 9/5/1977   | 16.8  | 0                | 0            | Non-Participating    | 43                     | 1932.094063             | 42.563296        | -82.272404        |
| 10192914    | 3308968 | 8/13/1993  | 21.9  | 16.5             | 0            | Non-Participating    | 46                     | 1570.32214              | 42.563296        | -82.272404        |
| 10192971    | 3309026 | 12/22/1990 | 16.8  | 0                | 9.1          | Non-Participating    | 16                     | 569.376249              | 42.524363        | -82.256034        |
| 10192972    | 3309028 | 11/7/1993  | 20.7  | 18.3             | 4.9          | Non-Participating    | 20                     | 844.008061              | 42.558017        | -82.281159        |
| 10188921    | 3304766 | 5/7/1968   | 22.6  | 22.3             | 0            | Participating        | 37                     | 829.955244              | 42.474435        | -82.227029        |
| 10191858    | 3307741 | 10/8/1983  | 18.9  | 18               | 0            | Non-Participating    | 20                     | 915.980473              | 42.558017        | -82.281159        |
| 10189826    | 3305685 | 9/7/1972   | 22.3  | 21.3             | 7.9          | Non-Participating    | 43                     | 1650.439519             | 42.563296        | -82.272404        |
| 10190042    | 3305901 | 1/12/1974  | 20.7  | 0                | 5.2          | Non-Participating    | 34                     | 1360.109002             | 42.5383          | -82.333104        |
| 10190043    | 3305902 | 1/8/1974   | 24.4  | 20.1             | 0            | Non-Participating    | 34                     | 1377.94377              | 42.5383          | -82.333104        |
| 10186405    | 3302250 | 12/6/1967  | 19.8  | 19.2             | 2.7          | Non-Participating    | 73                     | 1007.858175             | 42.440506        | -82.274649        |

| Borehole ID | Well ID | Completed  | Depth | Depth to Bedrock | Static Level | Participation Status | Closest turbine number | Distance to turbine (m) | Turbine Latitude | Turbine Longitude |
|-------------|---------|------------|-------|------------------|--------------|----------------------|------------------------|-------------------------|------------------|-------------------|
| 10189239    | 3305088 | 4/20/1970  | 19.8  | 0                | 3.4          | Participating        | 24                     | 495.35507               | 42.541021        | -82.306467        |
| 10193545    | 3309606 | 6/21/2000  | 24.7  | 14.6             | 3.7          | Non-Participating    | 49                     | 558.235702              | 42.503044        | -82.261339        |
| 10192404    | 3308380 | 1/18/1989  | 18.6  | 18.3             | 4.6          | Non-Participating    | 23                     | 1023.757959             | 42.489656        | -82.307565        |
| 10191351    | 3307229 | 8/22/1979  | 20.7  | 14.9             | 0            | Non-Participating    | 44                     | 874.393207              | 42.497399        | -82.292063        |
| 10191352    | 3307230 | 8/24/1979  | 15.8  | 14.9             | 0            | Non-Participating    | 44                     | 862.225323              | 42.497399        | -82.292063        |
| 10193573    | 3309634 | 12/6/2000  | 0     | 0                | 0            | Non-Participating    | 45                     | 648.528018              | 42.538634        | -82.259452        |
| 10539199    | 3309848 | 10/16/2002 | 0     | 0                | 0            | Non-Participating    | 24                     | 1061.777059             | 42.541021        | -82.306467        |
| 10545054    | 3309920 | 5/5/2003   | 32    | 31.4             | 2.4          | Non-Participating    | 35                     | 1931.181108             | 42.467347        | -82.18753         |
| 10545062    | 3309928 | 8/27/2003  | 0     | 0                | 0            | Non-Participating    | 36                     | 527.74345               | 42.451567        | -82.231678        |
| 11320227    | 3310178 | 4/12/2005  | 20.7  | 18               | 0            | Non-Participating    | 46                     | 1498.358967             | 42.542265        | -82.253956        |
| 11553200    | 3310321 | 6/8/2006   | 16.8  | 14               | 5.1          | Non-Participating    | 32                     | 767.930908              | 42.513906        | -82.244364        |
| 1002718616  | 7129479 | 8/19/2009  | 3.7   | 0                | 0            | Non-Participating    | 36                     | 1469.186249             | 42.451567        | -82.231678        |
| 10185372    | 3301217 | 2/10/1965  | 19.2  | 17.7             | 0            | Non-Participating    | 15                     | 734.255588              | 42.497399        | -82.292063        |
| 10185112    | 3300957 | 8/15/1958  | 25.9  | 22.3             | 0            | Non-Participating    | 36                     | 1631.743042             | 42.451567        | -82.231678        |
| 10185300    | 3301145 | 4/20/1963  | 19.2  | 13.7             | 0            | Non-Participating    | 17                     | 925.256375              | 42.52929         | -82.247949        |
| 10185720    | 3301565 | 5/17/1964  | 21.3  | 18.6             | 0            | Non-Participating    | 43                     | 1923.070253             | 42.563296        | -82.272404        |
| 10189443    | 3305301 | 5/13/1971  | 21.3  | 19.2             | 0            | Non-Participating    | 12                     | 697.446339              | 42.489881        | -82.201002        |
| 10190905    | 3306777 | 5/20/1978  | 19.8  | 19.5             | 0            | Non-Participating    | 23                     | 1129.238151             | 42.489656        | -82.307565        |
| 10192087    | 3308063 | 11/11/1986 | 8.2   | 0                | 1.2          | Non-Participating    | 51                     | 751.972808              | 42.480694        | -82.289578        |
| 10190620    | 3306488 | 10/30/1976 | 17.7  | 17.4             | 0            | Non-Participating    | 23                     | 2931.728795             | 42.489656        | -82.307565        |
| 10190621    | 3306489 | 10/29/1976 | 21.6  | 21.3             | 0            | Non-Participating    | 23                     | 3053.694688             | 42.489656        | -82.307565        |
| 10185463    | 3301308 | 7/4/1966   | 16.2  | 14.9             | 3            | Non-Participating    | 3                      | 1073.605136             | 42.524388        | -82.280192        |
| 10185475    | 3301320 | 4/21/1960  | 25.6  | 22.3             | 6.4          | Non-Participating    | 43                     | 1660.520876             | 42.563296        | -82.272404        |
| 10185481    | 3301326 | 3/24/1959  | 21.3  | 21               | 0            | Non-Participating    | 43                     | 1762.139803             | 42.563296        | -82.272404        |
| 10191839    | 3307721 | 12/15/1983 | 23.5  | 21.3             | 3.7          | Non-Participating    | 35                     | 1944.75225              | 42.467347        | -82.18753         |
| 10185506    | 3301351 | 6/25/1947  | 24.4  | 20.1             | 4.6          | Non-Participating    | 24                     | 1023.793162             | 42.541021        | -82.306467        |
| 10185527    | 3301372 | 1/14/1961  | 28.7  | 26.5             | 0            | Non-Participating    | 33                     | 981.946256              | 42.5383          | -82.333104        |
| 10190557    | 3306423 | 4/30/1976  | 16.2  | 15.8             | 4.6          | Non-Participating    | 43                     | 1132.061984             | 42.563296        | -82.272404        |
| 10188809    | 3304654 | 5/8/1968   | 14    | 0                | 4.6          | Participating        | 32                     | 632.780253              | 42.513906        | -82.244364        |
| 10189634    | 3305493 | 11/10/1971 | 29    | 19.2             | 0            | Non-Participating    | 50                     | 560.271882              | 42.443312        | -82.24831         |
| 10190113    | 3305972 | 4/11/1974  | 19.8  | 19.5             | 5.2          | Non-Participating    | 34                     | 1034.268963             | 42.5383          | -82.333104        |
| 10190913    | 3306785 | 6/27/1978  | 17.7  | 0                | 0            | Non-Participating    | 43                     | 1560.176594             | 42.563296        | -82.272404        |
| 10188767    | 3304612 | 5/4/1968   | 14.3  | 13.7             | 0            | Non-Participating    | 32                     | 780.804139              | 42.513906        | -82.244364        |
| 10188768    | 3304613 | 5/5/1968   | 14.3  | 14               | 3            | Non-Participating    | 32                     | 765.424961              | 42.513906        | -82.244364        |
| 10189658    | 3305517 | 1/7/1972   | 21.3  | 20.1             | 5.2          | Non-Participating    | 48                     | 893.922433              | 42.453372        | -82.285417        |
| 10191614    | 3307495 | 6/7/1981   | 21.9  | 20.7             | 0            | Non-Participating    | 34                     | 1556.940033             | 42.5383          | -82.333104        |
| 10190733    | 3306605 | 9/6/1977   | 18.3  | 0                | 6.4          | Non-Participating    | 43                     | 1744.945536             | 42.563296        | -82.272404        |
| 10189573    | 3305431 | 5/3/1971   | 22.9  | 21.3             | 0            | Non-Participating    | 24                     | 634.11139               | 42.541021        | -82.306467        |
| 10189576    | 3305434 | 4/29/1971  | 21.6  | 21.3             | 0            | Non-Participating    | 24                     | 618.604308              | 42.541021        | -82.306467        |
| 10193259    | 3309319 | 6/26/1997  | 34.7  | 29.9             | 4.3          | Non-Participating    | 35                     | 1341.906465             | 42.467347        | -82.18753         |
| 10186561    | 3302406 | 11/4/1964  | 18.3  | 18               | 4.6          | Non-Participating    | 23                     | 1780.787241             | 42.489656        | -82.307565        |
| 10189225    | 3305074 | 9/30/1949  | 18.6  | 0                | 0            | Non-Participating    | 43                     | 744.418503              | 42.563296        | -82.272404        |
| 10193555    | 3309616 | 9/18/2000  | 0     | 0                | 3            | Participating        | 6                      | 248.270373              | 42.494783        | -82.244573        |
| 10191303    | 3307180 | 8/20/1979  | 20.1  | 19.5             | 3.7          | Non-Participating    | 12                     | 687.036674              | 42.489881        | -82.201002        |
| 10191353    | 3307231 | 8/26/1979  | 16.8  | 14.9             | 0            | Non-Participating    | 44                     | 906.280057              | 42.511856        | -82.299774        |
| 10193501    | 3309562 | 1/11/2000  | 0     | 0                | 0            | Non-Participating    | 36                     | 1579.44593              | 42.443312        | -82.24831         |

| Borehole ID | Well ID | Completed  | Depth | Depth to Bedrock | Static Level | Participation Status | Closest turbine number | Distance to turbine (m) | Turbine Latitude | Turbine Longitude |
|-------------|---------|------------|-------|------------------|--------------|----------------------|------------------------|-------------------------|------------------|-------------------|
| 10192213    | 3308189 | 9/16/1987  | 24.4  | 19.5             | 0            | Non-Participating    | 42                     | 1065.335737             | 42.456232        | -82.293684        |
| 10192339    | 3308315 | 9/6/1988   | 20.4  | 19.5             | 4.6          | Non-Participating    | 9                      | 879.368156              | 42.478519        | -82.195908        |
| 10532348    | 3309810 | 9/25/2002  | 0     | 0                | 0            | Non-Participating    | 15                     | 633.602909              | 42.497399        | -82.292063        |
| 10539191    | 3309840 | 12/4/2002  | 0     | 0                | 0            | Non-Participating    | 37                     | 741.700795              | 42.474435        | -82.227029        |
| 10545018    | 3309884 | 5/22/2003  | 21.3  | 16.5             | 3.7          | Non-Participating    | 38                     | 1101.531244             | 42.477774        | -82.248263        |
| 10191335    | 3307213 | 12/11/1979 | 27.4  | 19.8             | 0            | Non-Participating    | 21                     | 652.44289               | 42.560527        | -82.27849         |
| 1001597966  | 7105314 | 4/3/2008   | 23.8  | 0                | 4.8          | Non-Participating    | 35                     | 626.361808              | 42.467347        | -82.18753         |
| 1002009809  | 7119001 | 2/26/2008  | 0     | 0                | 0            | Non-Participating    | 50                     | 2970.556451             | 42.440506        | -82.274649        |
| 1002009816  | 7119003 | 11/20/2008 | 22.9  | 0                | 3            | Non-Participating    | 48                     | 1014.193793             | 42.453372        | -82.285417        |
| 1002979101  | 7144778 | 2/18/2010  | 0     | 0                | 0            | Non-Participating    | 36                     | 1488.403234             | 42.451567        | -82.231678        |
| 10193579    | 3309640 | 11/24/2000 | 25.3  | 22.6             | 6.7          | Non-Participating    | 50                     | 2952.913657             | 42.440506        | -82.274649        |
| 10185377    | 3301222 | 9/10/1965  | 13.7  | 13.4             | 3.4          | Non-Participating    | 27                     | 634.678784              | 42.513992        | -82.270698        |
| 10185166    | 3301011 | 9/24/1958  | 20.4  | 19.5             | 3            | Non-Participating    | 9                      | 591.879834              | 42.478519        | -82.195908        |
| 10189278    | 3305127 | 5/21/1970  | 24.4  | 22.9             | 4.3          | Non-Participating    | 35                     | 1373.3158               | 42.467347        | -82.18753         |
| 10192085    | 3308061 | 5/8/1986   | 19.8  | 18               | 0            | Participating        | 51                     | 708.173129              | 42.480694        | -82.289578        |
| 10185466    | 3301311 | 12/2/1959  | 15.2  | 13.7             | 2.1          | Non-Participating    | 24                     | 1033.462469             | 42.541021        | -82.306467        |
| 10185499    | 3301344 | 7/5/1967   | 18.6  | 18               | 3.7          | Non-Participating    | 33                     | 499.14576               | 42.52971         | -82.322566        |
| 10189549    | 3305407 | 7/1/1971   | 18.3  | 0                | 2.4          | Non-Participating    | 34                     | 780.507283              | 42.5383          | -82.333104        |
| 10191863    | 3307746 | 10/15/1983 | 21.9  | 21.3             | 3.7          | Non-Participating    | 41                     | 888.58547               | 42.468573        | -82.277346        |
| 10190556    | 3306422 | 6/15/1976  | 22.6  | 22.3             | 0            | Non-Participating    | 35                     | 726.546849              | 42.467347        | -82.18753         |
| 10191757    | 3307639 | 3/31/1983  | 24.4  | 20.7             | 0            | Non-Participating    | 35                     | 996.734329              | 42.467347        | -82.18753         |
| 10191591    | 3307472 | 3/25/1981  | 15.2  | 14.6             | 3.4          | Participating        | 28                     | 408.555993              | 42.529298        | -82.222338        |
| 10191642    | 3307524 | 4/7/1982   | 19.5  | 19.2             | 2.4          | Non-Participating    | 31                     | 723.721003              | 42.490276        | -82.225145        |
| 10189373    | 3305222 | 11/24/1970 | 19.5  | 0                | 3.7          | Non-Participating    | 37                     | 855.843868              | 42.474435        | -82.227029        |
| 10189206    | 3305055 | 5/4/1970   | 21.3  | 20.7             | 0            | Non-Participating    | 35                     | 1312.007799             | 42.467347        | -82.18753         |
| 10190685    | 3306555 | 6/14/1977  | 18.3  | 0                | 0            | Non-Participating    | 33                     | 764.445573              | 42.52971         | -82.322566        |
| 10190439    | 3306301 | 11/28/1975 | 10.7  | 1.8              | 1.8          | Non-Participating    | 23                     | 2289.043228             | 42.489656        | -82.307565        |
| 10189865    | 3305724 | 4/30/1973  | 22.6  | 22.3             | 2.1          | Non-Participating    | 36                     | 687.015745              | 42.451567        | -82.231678        |
| 10190571    | 3306437 | 6/2/1976   | 19.5  | 18.9             | 3.4          | Non-Participating    | 35                     | 1330.799833             | 42.467347        | -82.18753         |
| 10189039    | 3304885 | 7/6/1969   | 25.9  | 23.8             | 0            | Participating        | 24                     | 579.778776              | 42.541021        | -82.306467        |
| 10189103    | 3304950 | 9/15/1969  | 22.3  | 0                | 2.4          | Non-Participating    | 36                     | 1005.421726             | 42.451567        | -82.231678        |
| 10186400    | 3302245 | 1/10/1959  | 25.6  | 21.3             | 0            | Non-Participating    | 72                     | 1184.685376             | 42.440506        | -82.274649        |
| 10186401    | 3302246 | 2/3/1959   | 23.8  | 21.3             | 0            | Non-Participating    | 72                     | 1177.986096             | 42.440506        | -82.274649        |
| 10186404    | 3302249 | 11/12/1964 | 21.9  | 21               | 5.5          | Non-Participating    | 73                     | 1962.981222             | 42.440506        | -82.274649        |
| 10186533    | 3302378 | 9/18/1965  | 19.8  | 19.2             | 4.6          | Non-Participating    | 48                     | 836.669004              | 42.460878        | -82.295508        |
| 10186557    | 3302402 | 7/3/1967   | 19.5  | 0                | 3.7          | Participating        | 19                     | 477.389134              | 42.483246        | -82.292731        |
| 10193004    | 3309064 | 6/28/1994  | 10.7  | 0                | 1.5          | Non-Participating    | 14                     | 424.310273              | 42.497399        | -82.292063        |
| 11098384    | 3309979 | 8/30/2003  | 0     | 0                | 0            | Non-Participating    | 15                     | 420.647355              | 42.497399        | -82.292063        |
| 10545057    | 3309923 | 9/12/2003  | 15.8  | 13.4             | 3            | Participating        | 3                      | 182.022245              | 42.524388        | -82.280192        |
| 11320253    | 3310204 | 6/9/2005   | 22.9  | 21               | 3.4          | Non-Participating    | 36                     | 901.246702              | 42.451567        | -82.231678        |
| 11175193    | 3310120 | 9/22/2004  | 0     | 0                | 0            | Non-Participating    | 17                     | 941.73508               | 42.542265        | -82.253956        |
| 10186064    | 3301909 | 11/10/1962 | 23.5  | 22.3             | 0            | Non-Participating    | 50                     | 1114.886877             | 42.443312        | -82.24831         |
| 10191264    | 3307141 | 9/22/1979  | 11.9  | 0                | 2.4          | Non-Participating    | 41                     | 1142.722286             | 42.480694        | -82.289578        |
| 1003464678  | 7158528 | 11/29/2010 | 14.3  | 0                | 0            | Non-Participating    | 30                     | 873.802352              | 42.522823        | -82.225798        |
| 1002914742  | 7137281 | 11/11/2009 | 0     | 0                | 0            | Non-Participating    | 9                      | 1739.159588             | 42.467347        | -82.18753         |
| 10186047    | 3301892 | 6/13/1959  | 16.8  | 15.2             | 0            | Non-Participating    | 51                     | 852.073071              | 42.480694        | -82.289578        |

| Borehole ID | Well ID | Completed  | Depth | Depth to Bedrock | Static Level | Participation Status | Closest turbine number | Distance to turbine (m) | Turbine Latitude | Turbine Longitude |
|-------------|---------|------------|-------|------------------|--------------|----------------------|------------------------|-------------------------|------------------|-------------------|
| 10185366    | 3301211 | 7/3/1961   | 16.8  | 11.3             | 0            | Non-Participating    | 15                     | 443.116666              | 42.497399        | -82.292063        |
| 10185086    | 3300931 | 6/18/1954  | 20.7  | 19.5             | 2.7          | Non-Participating    | 35                     | 1387.425037             | 42.467347        | -82.18753         |
| 10185118    | 3300963 | 6/5/1962   | 22.9  | 21.9             | 4.3          | Non-Participating    | 36                     | 1244.543681             | 42.451567        | -82.231678        |
| 10185122    | 3300967 | 8/10/1963  | 18.3  | 0                | 2.7          | Non-Participating    | 36                     | 1220.508629             | 42.451567        | -82.231678        |
| 10185132    | 3300977 | 8/26/1955  | 21.3  | 21               | 5.5          | Non-Participating    | 35                     | 1283.516188             | 42.467347        | -82.18753         |
| 10185164    | 3301009 | 5/24/1960  | 21    | 20.7             | 3.7          | Non-Participating    | 37                     | 1178.169685             | 42.474435        | -82.227029        |
| 10190819    | 3306691 | 10/21/1977 | 21.3  | 20.1             | 0            | Non-Participating    | 34                     | 623.37029               | 42.5383          | -82.333104        |
| 10190820    | 3306692 | 11/14/1977 | 22.9  | 18.9             | 0            | Participating        | 34                     | 481.280675              | 42.5383          | -82.333104        |
| 10189425    | 3305275 | 3/3/1971   | 17.4  | 17.1             | 2.4          | Non-Participating    | 51                     | 992.573604              | 42.480694        | -82.289578        |
| 10190472    | 3306334 | 10/14/1975 | 21    | 20.7             | 3            | Non-Participating    | 37                     | 934.094916              | 42.474435        | -82.227029        |
| 10190899    | 3306771 | 4/26/1978  | 9.1   | 0                | 2.4          | Participating        | 34                     | 462.452299              | 42.5383          | -82.333104        |
| 10190622    | 3306490 | 10/28/1976 | 21.9  | 21.3             | 0            | Non-Participating    | 5                      | 3117.506079             | 42.489656        | -82.307565        |
| 10190632    | 3306501 | 11/10/1976 | 15.2  | 14.3             | 4.3          | Non-Participating    | 30                     | 1184.853026             | 42.522823        | -82.225798        |
| 10185467    | 3301312 | 3/24/1953  | 19.5  | 17.4             | 3.7          | Non-Participating    | 20                     | 1369.34402              | 42.558017        | -82.281159        |
| 10185468    | 3301313 | 4/28/1962  | 16.2  | 15.2             | 0            | Non-Participating    | 43                     | 947.60328               | 42.563296        | -82.272404        |
| 10185470    | 3301315 | 4/25/1962  | 16.2  | 15.2             | 0            | Non-Participating    | 43                     | 973.108515              | 42.563296        | -82.272404        |
| 10185500    | 3301345 | 6/30/1967  | 18.9  | 18.6             | 7.9          | Non-Participating    | 33                     | 455.453654              | 42.52971         | -82.322566        |
| 10185517    | 3301362 | 11/4/1966  | 16.5  | 15.8             | 4.9          | Non-Participating    | 43                     | 970.722893              | 42.563296        | -82.272404        |
| 10185522    | 3301367 | 5/16/1963  | 21.3  | 19.5             | 4.3          | Non-Participating    | 34                     | 707.988152              | 42.5383          | -82.333104        |
| 10185526    | 3301371 | 9/21/1949  | 22.9  | 19.5             | 0            | Non-Participating    | 34                     | 1588.964371             | 42.5383          | -82.333104        |
| 10189538    | 3305396 | 10/6/1971  | 15.8  | 15.2             | 1.8          | Non-Participating    | 49                     | 658.126316              | 42.503044        | -82.261339        |
| 10189544    | 3305402 | 9/28/1971  | 15.8  | 0                | 0            | Non-Participating    | 6                      | 559.672373              | 42.494783        | -82.244573        |
| 10186345    | 3302190 | 11/15/1958 | 23.2  | 22.3             | 0            | Non-Participating    | 36                     | 1467.653021             | 42.451567        | -82.231678        |
| 10190559    | 3306425 | 5/2/1976   | 19.5  | 0                | 3            | Non-Participating    | 37                     | 763.223484              | 42.474435        | -82.227029        |
| 10188894    | 3304739 | 2/24/1968  | 22.9  | 21.6             | 0            | Participating        | 24                     | 751.226069              | 42.541021        | -82.306467        |
| 10188898    | 3304743 | 6/18/1968  | 22.3  | 21.9             | 2.4          | Non-Participating    | 50                     | 808.391308              | 42.451567        | -82.231678        |
| 10191902    | 3307789 | 6/29/1989  | 26.8  | 26.5             | 4.6          | Non-Participating    | 50                     | 2668.898001             | 42.440506        | -82.274649        |
| 10188780    | 3304625 | 3/5/1968   | 18.9  | 0                | 3            | Non-Participating    | 5                      | 2552.76479              | 42.520098        | -82.321614        |
| 10189379    | 3305228 | 8/15/1970  | 20.7  | 19.8             | 3.7          | Non-Participating    | 73                     | 1111.777569             | 42.443092        | -82.277024        |
| 10192732    | 3308708 | 7/23/1991  | 18.9  | 18.6             | 4.9          | Non-Participating    | 23                     | 1311.278735             | 42.489656        | -82.307565        |
| 10190364    | 3306224 | 5/26/1975  | 13.7  | 13.1             | 3.7          | Non-Participating    | 28                     | 562.313889              | 42.529298        | -82.222338        |
| 10190413    | 3306275 | 9/26/1975  | 24.4  | 17.4             | 0            | Non-Participating    | 5                      | 1391.592965             | 42.520098        | -82.321614        |
| 10190996    | 3306868 | 6/23/1978  | 17.4  | 17.1             | 6.4          | Non-Participating    | 39                     | 705.558613              | 42.466196        | -82.299023        |
| 10190675    | 3306545 | 6/7/1977   | 17.7  | 0                | 2.1          | Non-Participating    | 12                     | 676.782956              | 42.489881        | -82.201002        |
| 10191653    | 3307535 | 8/28/1981  | 18.6  | 18               | 6.1          | Non-Participating    | 23                     | 907.03074               | 42.489656        | -82.307565        |
| 10189575    | 3305433 | 4/30/1971  | 21.9  | 21.3             | 4            | Non-Participating    | 24                     | 609.537976              | 42.541021        | -82.306467        |
| 10192917    | 3308971 | 8/2/1993   | 18.9  | 16.2             | 0            | Non-Participating    | 46                     | 1570.32214              | 42.563296        | -82.272404        |
| 10188922    | 3304767 | 5/10/1968  | 22.9  | 21.9             | 0            | Non-Participating    | 37                     | 827.301508              | 42.474435        | -82.227029        |
| 10191852    | 3307735 | 8/9/1983   | 18.3  | 18               | 4.9          | Non-Participating    | 20                     | 876.395247              | 42.558017        | -82.281159        |
| 10189809    | 3305668 | 10/6/1972  | 27.4  | 20.4             | 0            | Non-Participating    | 34                     | 1140.320307             | 42.5383          | -82.333104        |
| 10190258    | 3306118 | 12/27/1973 | 19.8  | 19.2             | 5.8          | Participating        | 20                     | 569.382155              | 42.560527        | -82.27849         |
| 10186556    | 3302401 | 6/16/1954  | 16.8  | 15.2             | 0            | Non-Participating    | 19                     | 539.143872              | 42.483246        | -82.292731        |
| 10186560    | 3302405 | 10/16/1964 | 23.2  | 16.5             | 0            | Non-Participating    | 23                     | 2349.523625             | 42.489656        | -82.307565        |
| 10192447    | 3308423 | 4/24/1989  | 18.6  | 0                | 3.7          | Participating        | 24                     | 540.880776              | 42.541021        | -82.306467        |
| 10192497    | 3308473 | 4/22/1989  | 22.3  | 21.3             | 3.7          | Non-Participating    | 36                     | 849.632056              | 42.451567        | -82.231678        |
| 10191084    | 3306956 | 1/11/1978  | 15.2  | 14.9             | 0            | Non-Participating    | 28                     | 1383.818512             | 42.529298        | -82.222338        |

| Borehole ID | Well ID | Completed  | Depth | Depth to Bedrock | Static Level | Participation Status | Closest turbine number | Distance to turbine (m) | Turbine Latitude | Turbine Longitude |
|-------------|---------|------------|-------|------------------|--------------|----------------------|------------------------|-------------------------|------------------|-------------------|
| 10191163    | 3307036 | 5/25/1979  | 18.9  | 17.7             | 4            | Non-Participating    | 20                     | 836.511808              | 42.558017        | -82.281159        |
| 10192161    | 3308137 | 3/12/1987  | 21.6  | 20.4             | 2.4          | Non-Participating    | 35                     | 1665.131403             | 42.467347        | -82.18753         |
| 10192210    | 3308186 | 9/10/1987  | 22.3  | 19.8             | 0            | Non-Participating    | 42                     | 1055.185095             | 42.456232        | -82.293684        |
| 1001842042  | 7113691 | 10/1/2008  | 0     | 0                | 0            | Non-Participating    | 12                     | 720.048373              | 42.489881        | -82.201002        |
| 10186045    | 3301890 | 5/24/1967  | 20.1  | 18.3             | 3.7          | Non-Participating    | 48                     | 891.321444              | 42.453372        | -82.285417        |
| 10186050    | 3301895 | 6/29/1959  | 17.4  | 17.1             | 0            | Non-Participating    | 51                     | 787.056126              | 42.480694        | -82.289578        |
| 10185369    | 3301214 | 1/26/1958  | 13.7  | 13.1             | 3            | Non-Participating    | 15                     | 675.961931              | 42.497399        | -82.292063        |
| 10185262    | 3301107 | 3/20/1952  | 21.6  | 17.4             | 0            | Non-Participating    | 6                      | 731.407254              | 42.494783        | -82.244573        |
| 10185114    | 3300959 | 11/1/1958  | 23.5  | 22.3             | 3.7          | Non-Participating    | 36                     | 1481.763893             | 42.451567        | -82.231678        |
| 10185124    | 3300969 | 8/20/1963  | 18.3  | 0                | 3.7          | Non-Participating    | 36                     | 1101.433059             | 42.451567        | -82.231678        |
| 10185289    | 3301134 | 4/10/1963  | 14.3  | 13.4             | 0            | Non-Participating    | 30                     | 958.038228              | 42.522823        | -82.225798        |
| 10185160    | 3301005 | 7/30/1957  | 21    | 0                | 3            | Participating        | 36                     | 468.940876              | 42.451567        | -82.231678        |
| 10185168    | 3301013 | 9/3/1964   | 19.5  | 16.8             | 2.7          | Non-Participating    | 9                      | 687.366482              | 42.478519        | -82.195908        |
| 10185169    | 3301014 | 9/25/1964  | 19.8  | 0                | 4.3          | Non-Participating    | 9                      | 741.443291              | 42.478519        | -82.195908        |
| 10185231    | 3301076 | 6/15/1947  | 11    | 10.4             | 5.5          | Participating        | 7                      | 566.763958              | 42.498512        | -82.217547        |
| 10189472    | 3305330 | 7/15/1971  | 19.5  | 18.9             | 4.6          | Non-Participating    | 31                     | 908.919698              | 42.490276        | -82.225145        |
| 10191475    | 3307353 | 12/4/1980  | 19.5  | 0                | 4.9          | Non-Participating    | 43                     | 1530.071839             | 42.563296        | -82.272404        |
| 10185471    | 3301316 | 4/24/1962  | 16.8  | 15.2             | 0            | Non-Participating    | 43                     | 958.923807              | 42.563296        | -82.272404        |
| 10185490    | 3301335 | 10/26/1957 | 21.6  | 21               | 2.1          | Non-Participating    | 34                     | 724.965974              | 42.52971         | -82.322566        |
| 10186459    | 3302304 | 12/24/1964 | 21.9  | 19.8             | 0            | Non-Participating    | 72                     | 733.523243              | 42.443092        | -82.277024        |
| 10189542    | 3305400 | 9/30/1971  | 15.5  | 0                | 0            | Non-Participating    | 49                     | 617.370986              | 42.503044        | -82.261339        |
| 10190561    | 3306427 | 5/6/1976   | 17.7  | 0                | 3            | Non-Participating    | 37                     | 735.311216              | 42.474435        | -82.227029        |
| 10193216    | 3309276 | 5/8/1996   | 18.9  | 18.3             | 3            | Participating        | 12                     | 791.19001               | 42.489881        | -82.201002        |
| 10189908    | 3305767 | 4/12/1973  | 17.4  | 16.8             | 5.2          | Non-Participating    | 51                     | 839.21176               | 42.480694        | -82.289578        |
| 10186074    | 3301919 | 2/21/1963  | 17.1  | 0                | 3.7          | Non-Participating    | 23                     | 1055.048653             | 42.489656        | -82.307565        |
| 10191945    | 3307832 | <Null>     | 15.8  | 0                | 0            | Non-Participating    | 49                     | 719.249976              | 42.503044        | -82.261339        |
| 10190257    | 3306117 | 1/21/1974  | 20.7  | 19.2             | 5.5          | Participating        | 20                     | 575.669034              | 42.560527        | -82.27849         |
| 10188769    | 3304614 | 6/2/1968   | 14.6  | 14.3             | 3            | Non-Participating    | 32                     | 771.509865              | 42.513906        | -82.244364        |
| 10189186    | 3305034 | 4/14/1970  | 18.3  | 0                | 3.4          | Non-Participating    | 9                      | 1180.512789             | 42.478519        | -82.195908        |
| 10189154    | 3305002 | 8/13/1969  | 16.2  | 15.5             | 0            | Non-Participating    | 28                     | 939.225108              | 42.522823        | -82.225798        |
| 10190365    | 3306225 | 5/27/1975  | 12.8  | 12.5             | 3.7          | Non-Participating    | 28                     | 657.061457              | 42.529298        | -82.222338        |
| 10191650    | 3307532 | 9/2/1981   | 18.6  | 16.2             | 2.1          | Non-Participating    | 2                      | 1265.608619             | 42.487415        | -82.258872        |
| 10191652    | 3307534 | 4/16/1981  | 18.9  | 18.3             | 2.4          | Non-Participating    | 52                     | 582.148853              | 42.522667        | -82.318272        |
| 10189571    | 3305429 | 5/5/1971   | 23.8  | 21.3             | 0            | Non-Participating    | 24                     | 656.43894               | 42.541021        | -82.306467        |
| 10190923    | 3306795 | 6/1/1978   | 22.3  | 21.9             | 4.3          | Non-Participating    | 50                     | 2914.458471             | 42.440506        | -82.274649        |
| 10186634    | 3302479 | 11/15/1953 | 21.9  | 21.3             | 2.4          | Non-Participating    | 5                      | 3329.460905             | 42.489656        | -82.307565        |
| 10191854    | 3307737 | 12/8/1983  | 18.3  | 18               | 4.9          | Non-Participating    | 20                     | 840.598122              | 42.558017        | -82.281159        |
| 10186403    | 3302248 | 12/11/1967 | 21.6  | 21               | 4            | Non-Participating    | 73                     | 1007.858175             | 42.440506        | -82.274649        |
| 10186562    | 3302407 | 8/8/1966   | 19.5  | 0                | 5.5          | Non-Participating    | 23                     | 649.010912              | 42.489656        | -82.307565        |
| 10191355    | 3307233 | 8/30/1979  | 16.5  | 14.9             | 0            | Non-Participating    | 15                     | 830.592918              | 42.497399        | -82.292063        |
| 10191022    | 3306894 | 10/6/1978  | 4.9   | 0                | 2.4          | Non-Participating    | 36                     | 901.990014              | 42.443312        | -82.24831         |
| 10191177    | 3307050 | 5/1/1979   | 7.6   | 3.7              | 3.7          | Non-Participating    | 35                     | 882.790616              | 42.467347        | -82.18753         |
| 10192160    | 3308136 | 3/24/1987  | 23.2  | 22.6             | 4            | Non-Participating    | 35                     | 1414.493085             | 42.467347        | -82.18753         |
| 10192421    | 3308397 | 10/3/1988  | 13.7  | 13.4             | 3.7          | Non-Participating    | 28                     | 1039.361086             | 42.529298        | -82.222338        |
| 10193572    | 3309633 | 10/25/2000 | 14.6  | 14               | 4            | Participating        | 45                     | 509.90044               | 42.538634        | -82.259452        |
| 10532320    | 3309782 | 9/24/2002  | 0     | 0                | 0            | Non-Participating    | 19                     | 740.185061              | 42.483246        | -82.292731        |

| Borehole ID | Well ID | Completed  | Depth | Depth to Bedrock | Static Level | Participation Status | Closest turbine number | Distance to turbine (m) | Turbine Latitude | Turbine Longitude |
|-------------|---------|------------|-------|------------------|--------------|----------------------|------------------------|-------------------------|------------------|-------------------|
| 11553138    | 3310259 | 12/23/2005 | 21.5  | 0                | 3            | Non-Participating    | 73                     | 671.899873              | 42.440506        | -82.274649        |
| 10191545    | 3307425 | 4/3/1981   | 21.9  | 15.2             | 0            | Non-Participating    | 43                     | 1735.723917             | 42.563296        | -82.272404        |
| 1003464680  | 7158529 | 11/24/2010 | 20.4  | 0                | 0            | Non-Participating    | 30                     | 944.982269              | 42.522823        | -82.225798        |
| 1004150088  | 7186693 | 7/25/2012  | 0     | 0                | 0            | Non-Participating    | 49                     | 798.126395              | 42.503044        | -82.261339        |
| 10186052    | 3301897 | 9/21/1962  | 16.8  | 16.5             | 5.5          | Non-Participating    | 39                     | 857.237719              | 42.466196        | -82.299023        |
| 10186067    | 3301912 | 3/27/1952  | 22.3  | 0                | 3.7          | Non-Participating    | 73                     | 1004.354589             | 42.443092        | -82.277024        |
| 10186068    | 3301913 | 5/26/1955  | 19.2  | 18.9             | 4.6          | Non-Participating    | 48                     | 710.325162              | 42.453372        | -82.285417        |
| 10185364    | 3301209 | 6/27/1961  | 21.3  | 12.8             | 0            | Non-Participating    | 15                     | 631.896359              | 42.497399        | -82.292063        |
| 10185378    | 3301223 | 8/15/1947  | 14.9  | 13.4             | 3.7          | Non-Participating    | 27                     | 831.933207              | 42.524363        | -82.256034        |
| 10185115    | 3300960 | 5/18/1962  | 22.6  | 21.9             | 4.3          | Non-Participating    | 36                     | 1196.643269             | 42.451567        | -82.231678        |
| 10185282    | 3301127 | 3/21/1957  | 18.9  | 18.6             | 3            | Non-Participating    | 15                     | 758.624896              | 42.497399        | -82.292063        |
| 10185287    | 3301132 | 10/4/1962  | 15.5  | 14.9             | 3.7          | Non-Participating    | 32                     | 838.35691               | 42.513906        | -82.244364        |
| 10185292    | 3301137 | 4/12/1963  | 13.4  | 13.1             | 0            | Non-Participating    | 30                     | 928.07884               | 42.522823        | -82.225798        |
| 10185305    | 3301150 | 10/7/1948  | 17.7  | 16.8             | 3            | Non-Participating    | 28                     | 659.404768              | 42.529298        | -82.222338        |
| 10185163    | 3301008 | 5/20/1957  | 21    | 20.1             | 3.7          | Non-Participating    | 9                      | 1306.265918             | 42.467347        | -82.18753         |
| 10186300    | 3302145 | 8/26/1954  | 22.9  | 21.6             | 0            | Non-Participating    | 73                     | 2834.299821             | 42.440506        | -82.274649        |
| 10185229    | 3301074 | 10/26/1955 | 18    | 17.7             | 4.3          | Non-Participating    | 6                      | 662.550042              | 42.494783        | -82.244573        |
| 10189409    | 3305259 | 2/19/1971  | 31.7  | 20.1             | 4.3          | Non-Participating    | 24                     | 976.502968              | 42.541021        | -82.306467        |
| 10192784    | 3308763 | 11/6/1991  | 20.7  | 19.5             | 4.3          | Non-Participating    | 7                      | 734.935603              | 42.498512        | -82.217547        |
| 10193024    | 3309084 | 5/12/1994  | 18.3  | 14.9             | 0            | Non-Participating    | 14                     | 424.310273              | 42.497399        | -82.292063        |
| 10185495    | 3301340 | 6/19/1967  | 18.6  | 18.3             | 0            | Non-Participating    | 52                     | 732.775636              | 42.52971         | -82.322566        |
| 10185504    | 3301349 | 7/10/1967  | 18.6  | 18               | 3.7          | Non-Participating    | 33                     | 526.887636              | 42.52971         | -82.322566        |
| 10185507    | 3301352 | 5/13/1962  | 23.8  | 20.7             | 0            | Non-Participating    | 24                     | 871.782009              | 42.541021        | -82.306467        |
| 10185509    | 3301354 | 6/24/1947  | 20.1  | 18.3             | 2.7          | Participating        | 20                     | 767.684052              | 42.558017        | -82.281159        |
| 10185511    | 3301356 | 9/25/1954  | 22.9  | 18.9             | 0            | Participating        | 21                     | 473.302595              | 42.560527        | -82.27849         |
| 10185514    | 3301359 | 10/29/1952 | 17.7  | 0                | 3            | Non-Participating    | 43                     | 899.571539              | 42.563296        | -82.272404        |
| 10185515    | 3301360 | 10/27/1952 | 17.4  | 0                | 5.5          | Non-Participating    | 43                     | 985.211172              | 42.563296        | -82.272404        |
| 10190018    | 3305877 | 11/8/1973  | 18.3  | 18               | 2.4          | Non-Participating    | 51                     | 865.893095              | 42.480694        | -82.289578        |
| 10185528    | 3301373 | 3/9/1961   | 29.3  | 26.5             | 0            | Non-Participating    | 33                     | 1066.119727             | 42.5383          | -82.333104        |
| 10185530    | 3301375 | 10/25/1960 | 22.3  | 19.8             | 0            | Non-Participating    | 24                     | 994.050294              | 42.541021        | -82.306467        |
| 10185531    | 3301376 | 5/27/1957  | 20.4  | 19.8             | 2.4          | Non-Participating    | 24                     | 1097.758379             | 42.541021        | -82.306467        |
| 10189541    | 3305399 | 10/1/1971  | 14.6  | 0                | 0            | Non-Participating    | 49                     | 534.418358              | 42.503044        | -82.261339        |
| 10191920    | 3307807 | 10/31/1984 | 19.8  | 0                | 3.7          | Non-Participating    | 73                     | 759.358377              | 42.440506        | -82.274649        |
| 10188779    | 3304624 | 3/1/1968   | 18.9  | 17.4             | 0            | Non-Participating    | 5                      | 2504.340035             | 42.520098        | -82.321614        |
| 10189158    | 3305006 | 8/9/1969   | 16.5  | 15.2             | 0            | Non-Participating    | 28                     | 836.497931              | 42.522823        | -82.225798        |
| 10189204    | 3305053 | 5/8/1970   | 21.3  | 20.7             | 0            | Non-Participating    | 35                     | 1347.460675             | 42.467347        | -82.18753         |
| 10192041    | 3308017 | 7/15/1986  | 29.3  | 0                | 0            | Participating        | 24                     | 631.296755              | 42.541021        | -82.306467        |
| 10186662    | 3302507 | 5/23/1963  | 21.3  | 0                | 9.8          | Non-Participating    | 34                     | 1536.273495             | 42.5383          | -82.333104        |
| 10190411    | 3306273 | 8/23/1975  | 28.7  | 14.3             | 0            | Non-Participating    | 30                     | 962.26583               | 42.522823        | -82.225798        |
| 10190724    | 3306596 | 8/24/1977  | 15.2  | 15.2             | 1.2          | Non-Participating    | 26                     | 766.758163              | 42.507245        | -82.277719        |
| 10189568    | 3305426 | 5/10/1971  | 21.3  | 20.7             | 4            | Non-Participating    | 24                     | 611.786679              | 42.541021        | -82.306467        |
| 10189577    | 3305435 | 4/28/1971  | 23.2  | 21.6             | 0            | Participating        | 24                     | 613.158908              | 42.541021        | -82.306467        |
| 10191795    | 3307677 | 9/6/1983   | 22.6  | 0                | 8.2          | Non-Participating    | 36                     | 1533.110707             | 42.451567        | -82.231678        |
| 10190759    | 3306631 | 9/9/1977   | 19.5  | 14.9             | 0            | Non-Participating    | 28                     | 1405.652973             | 42.529298        | -82.222338        |
| 10191850    | 3307733 | 10/8/1983  | 19.8  | 18               | 0            | Non-Participating    | 20                     | 915.980473              | 42.558017        | -82.281159        |
| 10193142    | 3309202 | 11/17/1995 | 21.6  | 21               | 3.4          | Non-Participating    | 9                      | 1529.435173             | 42.478519        | -82.195908        |

| Borehole ID | Well ID | Completed  | Depth | Depth to Bedrock | Static Level | Participation Status | Closest turbine number | Distance to turbine (m) | Turbine Latitude | Turbine Longitude |
|-------------|---------|------------|-------|------------------|--------------|----------------------|------------------------|-------------------------|------------------|-------------------|
| 10189170    | 3305018 | 8/14/1969  | 15.8  | 0                | 3            | Non-Participating    | 28                     | 946.947664              | 42.522823        | -82.225798        |
| 10186555    | 3302400 | 6/15/1954  | 15.5  | 15.2             | 0            | Non-Participating    | 19                     | 554.959161              | 42.483246        | -82.292731        |
| 10193544    | 3309605 | 6/21/2000  | 0     | 0                | 0            | Non-Participating    | 49                     | 558.235702              | 42.503044        | -82.261339        |
| 10191083    | 3306955 | 1/14/1978  | 15.5  | 14.9             | 0            | Non-Participating    | 28                     | 1383.818512             | 42.529298        | -82.222338        |
| 10191333    | 3307211 | 12/29/1979 | 13.4  | 13.1             | 0            | Non-Participating    | 28                     | 535.078698              | 42.529298        | -82.222338        |
| 10545064    | 3309930 | 7/1/2003   | 0     | 0                | 4.3          | Non-Participating    | 36                     | 527.74345               | 42.451567        | -82.231678        |
| 10545067    | 3309933 | 8/13/2003  | 0     | 0                | 0            | Non-Participating    | 51                     | 900.959748              | 42.483246        | -82.292731        |
| 11763852    | 7041345 | 1/17/2007  | 7.3   | 0                | 0            | Non-Participating    | 46                     | 1924.308453             | 42.563296        | -82.272404        |
| 10192843    | 3308897 | 8/5/1992   | 21    | 19.5             | 3            | Non-Participating    | 35                     | 694.866579              | 42.467347        | -82.18753         |
| 10190255    | 3306115 | 6/12/1974  | 16.5  | 13.1             | 2.7          | Participating        | 15                     | 464.131127              | 42.497399        | -82.292063        |
| 1003464674  | 7158526 | 12/10/2010 | 14.6  | 0                | 2.1          | Non-Participating    | 30                     | 943.398778              | 42.522823        | -82.225798        |
| 1002009843  | 7119006 | 9/29/2008  | 0     | 0                | 4            | Non-Participating    | 12                     | 737.014178              | 42.489881        | -82.201002        |
| 1002914739  | 7137280 | 11/11/2009 | 0     | 0                | 0            | Non-Participating    | 9                      | 1748.54158              | 42.467347        | -82.18753         |
| 1003610447  | 7172138 | 10/12/2011 | 18.3  | 0                | 2.9          | Non-Participating    | 40                     | 1661.989225             | 42.456232        | -82.293684        |
| 10193578    | 3309639 | 11/17/2000 | 29.9  | 23.8             | 0            | Non-Participating    | 50                     | 2922.255278             | 42.443312        | -82.24831         |
| 10186051    | 3301896 | 6/30/1959  | 17.4  | 17.1             | 4.9          | Non-Participating    | 51                     | 781.849215              | 42.480694        | -82.289578        |
| 10186065    | 3301910 | 11/16/1962 | 24.4  | 21.9             | 2.1          | Non-Participating    | 50                     | 1078.939606             | 42.443312        | -82.24831         |
| 10185373    | 3301218 | 2/23/1965  | 19.8  | 17.7             | 0            | Non-Participating    | 15                     | 747.784537              | 42.497399        | -82.292063        |
| 10185433    | 3301278 | 7/1/1955   | 16.2  | 15.5             | 2.1          | Non-Participating    | 45                     | 532.213474              | 42.538634        | -82.259452        |
| 10185171    | 3301016 | 10/3/1964  | 20.7  | 18.3             | 0            | Non-Participating    | 9                      | 766.354567              | 42.478519        | -82.195908        |
| 10189044    | 3304891 | 7/8/1969   | 17.7  | 16.8             | 4.3          | Non-Participating    | 1                      | 864.633907              | 42.477774        | -82.248263        |
| 10185227    | 3301072 | 5/28/1965  | 18    | 16.2             | 2.4          | Non-Participating    | 38                     | 570.161739              | 42.477774        | -82.248263        |
| 10190355    | 3306215 | 4/22/1975  | 22.9  | 21.3             | 0            | Participating        | 1                      | 509.493406              | 42.466711        | -82.254429        |
| 10185474    | 3301319 | 4/19/1960  | 24.4  | 21.9             | 0            | Non-Participating    | 43                     | 1594.894886             | 42.563296        | -82.272404        |
| 10185477    | 3301322 | 10/24/1960 | 17.1  | 16.8             | 0            | Non-Participating    | 46                     | 1784.106828             | 42.563296        | -82.272404        |
| 10185489    | 3301334 | 10/25/1957 | 21.3  | 21               | 0            | Non-Participating    | 34                     | 724.965974              | 42.52971         | -82.322566        |
| 10185492    | 3301337 | 6/15/1967  | 18.9  | 18.3             | 0            | Non-Participating    | 33                     | 628.684268              | 42.52971         | -82.322566        |
| 10192848    | 3308902 | 6/4/1992   | 18.3  | 17.1             | 2.4          | Non-Participating    | 39                     | 2485.137163             | 42.466196        | -82.299023        |
| 10190649    | 3306519 | 12/31/1976 | 14.6  | 13.7             | 4.3          | Non-Participating    | 45                     | 707.756181              | 42.538634        | -82.259452        |
| 10185497    | 3301342 | 7/3/1967   | 18.9  | 18.6             | 0            | Non-Participating    | 33                     | 838.496839              | 42.52971         | -82.322566        |
| 10191711    | 3307593 | 11/18/1982 | 21.9  | 18               | 0            | Non-Participating    | 48                     | 870.960542              | 42.443092        | -82.277024        |
| 10190060    | 3305919 | 3/15/1974  | 25.6  | 18               | 0            | Non-Participating    | 40                     | 856.300966              | 42.466196        | -82.299023        |
| 10190065    | 3305924 | 2/20/1974  | 24.4  | 18.3             | 0            | Non-Participating    | 40                     | 754.03007               | 42.466196        | -82.299023        |
| 10185535    | 3301380 | 9/30/1949  | 18.6  | 16.8             | 3.7          | Non-Participating    | 43                     | 788.584526              | 42.563296        | -82.272404        |
| 10188892    | 3304737 | 2/12/1968  | 21.3  | 0                | 0            | Non-Participating    | 24                     | 795.371431              | 42.541021        | -82.306467        |
| 10190250    | 3306110 | 6/10/1974  | 13.7  | 13.1             | 0            | Participating        | 15                     | 440.660392              | 42.497399        | -82.292063        |
| 10190251    | 3306111 | 6/11/1974  | 14.6  | 13.4             | 0            | Non-Participating    | 15                     | 504.086242              | 42.497399        | -82.292063        |
| 10188797    | 3304642 | 10/28/1968 | 13.7  | 0                | 0            | Participating        | 32                     | 682.706165              | 42.513906        | -82.244364        |
| 10189203    | 3305052 | 5/12/1970  | 21.3  | 20.7             | 5.8          | Non-Participating    | 35                     | 1355.77745              | 42.467347        | -82.18753         |
| 10192696    | 3308672 | 12/13/1990 | 29.3  | 21.9             | 0            | Non-Participating    | 36                     | 1467.602267             | 42.451567        | -82.231678        |
| 10192040    | 3308016 | 7/20/1986  | 30.5  | 0                | 0            | Participating        | 24                     | 591.193998              | 42.541021        | -82.306467        |
| 10190360    | 3306220 | 5/22/1975  | 14.3  | 13.4             | 0            | Non-Participating    | 28                     | 533.401874              | 42.529298        | -82.222338        |
| 10190683    | 3306553 | 6/17/1977  | 9.1   | 0                | 1.2          | Participating        | 51                     | 503.328524              | 42.480694        | -82.289578        |
| 10191848    | 3307731 | 10/9/1983  | 19.8  | 18.3             | 0            | Non-Participating    | 20                     | 875.971826              | 42.558017        | -82.281159        |
| 10191267    | 3307144 | 10/9/1979  | 14.3  | 13.4             | 0            | Non-Participating    | 15                     | 676.168616              | 42.497399        | -82.292063        |
| 10191348    | 3307226 | 7/3/1979   | 21    | 20.1             | 4.9          | Non-Participating    | 34                     | 848.785601              | 42.5383          | -82.333104        |

| Borehole ID | Well ID | Completed  | Depth | Depth to Bedrock | Static Level | Participation Status | Closest turbine number | Distance to turbine (m) | Turbine Latitude | Turbine Longitude |
|-------------|---------|------------|-------|------------------|--------------|----------------------|------------------------|-------------------------|------------------|-------------------|
| 10192528    | 3308504 | 11/9/1989  | 10.7  | 0                | 1.5          | Non-Participating    | 72                     | 1466.695882             | 42.440506        | -82.274649        |
| 10191331    | 3307209 | 12/15/1979 | 15.8  | 13.7             | 0            | Non-Participating    | 28                     | 649.44029               | 42.529298        | -82.222338        |
| 10539209    | 3309858 | 5/27/2003  | 0     | 0                | 0            | Non-Participating    | 34                     | 725.680361              | 42.5383          | -82.333104        |
| 10545065    | 3309931 | 7/1/2003   | 0     | 0                | 2.7          | Non-Participating    | 36                     | 527.74345               | 42.451567        | -82.231678        |
| 11763851    | 7041344 | 1/17/2007  | 7.3   | 0                | 0            | Non-Participating    | 46                     | 2240.373183             | 42.563296        | -82.272404        |
| 10191981    | 3307868 | 7/27/1984  | 18.6  | 18.3             | 4.9          | Non-Participating    | 23                     | 811.338362              | 42.489656        | -82.307565        |
| 10188808    | 3304653 | 5/7/1968   | 14.6  | 14               | 4.6          | Participating        | 32                     | 646.870552              | 42.513906        | -82.244364        |
| 1002747783  | 7131955 | 9/2/2009   | 30.5  | 0                | 0            | Non-Participating    | 34                     | 1012.589657             | 42.5383          | -82.333104        |
| 1003514363  | 7163645 | 5/2/2011   | 0     | 0                | 2.7          | Non-Participating    | 4                      | 804.954693              | 42.527399        | -82.277222        |
| 1003485009  | 7160290 | 11/4/2010  | 0     | 0                | 0            | Non-Participating    | 48                     | 834.754966              | 42.443092        | -82.277024        |
| 1003718873  | 7180172 | 3/30/2012  | 0     | 0                | 0            | Non-Participating    | 9                      | 820.496955              | 42.478519        | -82.195908        |
| 1004263365  | 7198559 | 2/1/2013   | 0     | 0                | 0            | Non-Participating    | 7                      | 1223.544525             | 42.498512        | -82.217547        |
| 10185189    | 3301034 | 3/19/1959  | 19.2  | 0                | 3.7          | Non-Participating    | 12                     | 723.756807              | 42.489881        | -82.201002        |
| 10185265    | 3301110 | 7/19/1948  | 20.4  | 18               | 4.9          | Non-Participating    | 31                     | 889.505981              | 42.498512        | -82.217547        |
| 10185089    | 3300934 | 10/15/1960 | 21.3  | 0                | 3            | Non-Participating    | 35                     | 958.220018              | 42.467347        | -82.18753         |
| 10185117    | 3300962 | 5/28/1962  | 22.6  | 21.9             | 4.3          | Non-Participating    | 36                     | 1203.334387             | 42.451567        | -82.231678        |
| 10185125    | 3300970 | 8/20/1963  | 18.3  | 0                | 3.7          | Non-Participating    | 36                     | 1119.382238             | 42.451567        | -82.231678        |
| 10185283    | 3301128 | 8/5/1954   | 14.3  | 14               | 0            | Non-Participating    | 6                      | 1050.563318             | 42.494783        | -82.244573        |
| 10185291    | 3301136 | 4/11/1963  | 16.2  | 13.4             | 0            | Non-Participating    | 17                     | 831.420138              | 42.52929         | -82.247949        |
| 10185162    | 3301007 | 12/9/1949  | 20.4  | 0                | 2.1          | Non-Participating    | 9                      | 1315.09531              | 42.478519        | -82.195908        |
| 10185173    | 3301018 | 6/5/1947   | 27.4  | 18.6             | 2.7          | Non-Participating    | 12                     | 1086.689672             | 42.489881        | -82.201002        |
| 10193330    | 3309390 | 8/26/1997  | 0     | 0                | 0            | Non-Participating    | 3                      | 1273.296043             | 42.527399        | -82.277222        |
| 10191831    | 3307713 | 10/25/1983 | 18.9  | 0                | 6.1          | Non-Participating    | 23                     | 771.117843              | 42.489656        | -82.307565        |
| 10185498    | 3301343 | 7/4/1967   | 18.6  | 18               | 0.6          | Non-Participating    | 33                     | 529.915677              | 42.52971         | -82.322566        |
| 10185510    | 3301355 | 9/7/1949   | 19.5  | 0                | 6.1          | Participating        | 21                     | 473.302595              | 42.560527        | -82.27849         |
| 10186460    | 3302305 | 12/28/1964 | 18.9  | 0                | 3.7          | Non-Participating    | 72                     | 839.442613              | 42.443092        | -82.277024        |
| 10190081    | 3305940 | 1/26/1974  | 23.5  | 20.4             | 4.9          | Non-Participating    | 34                     | 1110.670033             | 42.5383          | -82.333104        |
| 10185536    | 3301381 | 4/21/1948  | 25    | 19.2             | 5.5          | Non-Participating    | 43                     | 1418.922945             | 42.563296        | -82.272404        |
| 10185545    | 3301390 | 11/6/1961  | 25.9  | 25.6             | 0            | Non-Participating    | 34                     | 1317.934914             | 42.5383          | -82.333104        |
| 10185547    | 3301392 | 7/4/1962   | 24.4  | 20.4             | 3.7          | Non-Participating    | 34                     | 1256.354551             | 42.5383          | -82.333104        |
| 10186347    | 3302192 | 5/22/1959  | 25.6  | 22.9             | 0            | Non-Participating    | 36                     | 1440.200173             | 42.451567        | -82.231678        |
| 10191755    | 3307637 | 3/10/1983  | 19.8  | 18.9             | 0            | Non-Participating    | 9                      | 911.937711              | 42.478519        | -82.195908        |
| 10186071    | 3301916 | 2/9/1956   | 18.3  | 18               | 4.3          | Non-Participating    | 23                     | 889.766164              | 42.489656        | -82.307565        |
| 10188755    | 3304600 | 10/9/1967  | 21.6  | 20.7             | 3            | Non-Participating    | 35                     | 868.090168              | 42.467347        | -82.18753         |
| 10189653    | 3305512 | 5/24/1972  | 10.4  | 0                | 1.8          | Non-Participating    | 33                     | 1080.171131             | 42.541021        | -82.306467        |
| 10185697    | 3301542 | 7/11/1952  | 21.3  | 17.4             | 3.7          | Non-Participating    | 43                     | 1517.016317             | 42.563296        | -82.272404        |
| 10190162    | 3306021 | 8/16/1974  | 18.3  | 0                | 2.4          | Non-Participating    | 36                     | 1220.669288             | 42.451567        | -82.231678        |
| 10189155    | 3305003 | 8/6/1969   | 15.8  | 15.2             | 0            | Non-Participating    | 28                     | 846.43845               | 42.522823        | -82.225798        |
| 10190357    | 3306217 | 4/25/1975  | 21.3  | 21               | 0            | Participating        | 1                      | 515.779037              | 42.466711        | -82.254429        |
| 10191853    | 3307736 | 7/25/1983  | 18    | 18               | 4.9          | Non-Participating    | 20                     | 855.967565              | 42.558017        | -82.281159        |
| 10188819    | 3304664 | 10/30/1968 | 16.8  | 0                | 1.2          | Non-Participating    | 6                      | 558.930768              | 42.494783        | -82.244573        |
| 10193141    | 3309201 | 3/23/1995  | 17.4  | 17.1             | 3            | Non-Participating    | 51                     | 904.194654              | 42.483246        | -82.292731        |
| 10189224    | 3305073 | 6/16/1950  | 16.5  | 0                | 0            | Non-Participating    | 52                     | 1077.385399             | 42.522667        | -82.318272        |
| 10192471    | 3308447 | 4/14/1989  | 20.7  | 18.9             | 4.3          | Non-Participating    | 51                     | 757.501352              | 42.480694        | -82.289578        |
| 10191082    | 3306954 | 10/15/1978 | 19.2  | 14.9             | 0            | Non-Participating    | 28                     | 1383.818512             | 42.529298        | -82.222338        |
| 10191171    | 3307044 | 6/2/1979   | 17.1  | 16.8             | 0            | Non-Participating    | 2                      | 722.214036              | 42.487415        | -82.258872        |

| Borehole ID | Well ID | Completed  | Depth | Depth to Bedrock | Static Level | Participation Status | Closest turbine number | Distance to turbine (m) | Turbine Latitude | Turbine Longitude |
|-------------|---------|------------|-------|------------------|--------------|----------------------|------------------------|-------------------------|------------------|-------------------|
| 10539212    | 3309861 | 4/17/2003  | 0     | 0                | 0            | Non-Participating    | 23                     | 1540.728902             | 42.489656        | -82.307565        |
| 1001842039  | 7113690 | 9/24/2008  | 0     | 0                | 0            | Non-Participating    | 36                     | 1664.736936             | 42.451567        | -82.231678        |
| 1002034234  | 7120921 | 2/25/2009  | 0     | 0                | 0            | Non-Participating    | 33                     | 617.690228              | 42.52971         | -82.322566        |
| 10185186    | 3301031 | 2/7/1963   | 22.9  | 0                | 4.6          | Non-Participating    | 50                     | 1092.361835             | 42.443312        | -82.24831         |
| 10185113    | 3300958 | 8/18/1958  | 21    | 0                | 3.7          | Non-Participating    | 36                     | 1628.184232             | 42.451567        | -82.231678        |
| 10185285    | 3301130 | 10/21/1957 | 15.8  | 15.5             | 3            | Non-Participating    | 49                     | 1068.943455             | 42.513906        | -82.244364        |
| 10185290    | 3301135 | 4/11/1963  | 13.4  | 13.1             | 0            | Non-Participating    | 30                     | 969.64414               | 42.522823        | -82.225798        |
| 10185306    | 3301151 | 9/12/1966  | 14.6  | 0                | 9.1          | Non-Participating    | 28                     | 814.748948              | 42.529298        | -82.222338        |
| 10185151    | 3300996 | 4/15/1947  | 21.9  | 0                | 2.1          | Non-Participating    | 36                     | 775.405111              | 42.451567        | -82.231678        |
| 10185153    | 3300998 | 4/25/1955  | 23.2  | 17.7             | 0            | Non-Participating    | 36                     | 595.830919              | 42.451567        | -82.231678        |
| 10185228    | 3301073 | 10/17/1955 | 19.5  | 17.7             | 0            | Participating        | 6                      | 634.042354              | 42.494783        | -82.244573        |
| 10192799    | 3308778 | 3/11/1991  | 15.2  | 14.6             | 2.1          | Non-Participating    | 32                     | 705.890726              | 42.513906        | -82.244364        |
| 10185493    | 3301338 | 6/17/1967  | 18.9  | 18.3             | 0            | Non-Participating    | 33                     | 601.397895              | 42.52971         | -82.322566        |
| 10185503    | 3301348 | 7/8/1967   | 18.6  | 18.3             | 0            | Non-Participating    | 33                     | 548.843095              | 42.52971         | -82.322566        |
| 10190063    | 3305922 | 2/15/1974  | 24.7  | 18.3             | 0            | Non-Participating    | 40                     | 774.656571              | 42.466196        | -82.299023        |
| 10189546    | 3305404 | 9/25/1971  | 18.3  | 15.8             | 0            | Non-Participating    | 6                      | 491.242237              | 42.494783        | -82.244573        |
| 10193212    | 3309272 | 12/10/1996 | 21    | 15.5             | 3            | Non-Participating    | 49                     | 554.234897              | 42.503044        | -82.261339        |
| 10186075    | 3301920 | 8/1/1962   | 17.4  | 16.8             | 3.7          | Non-Participating    | 23                     | 1332.907112             | 42.489656        | -82.307565        |
| 10188781    | 3304626 | 10/7/1968  | 19.8  | 18.6             | 4.3          | Non-Participating    | 39                     | 716.728587              | 42.466196        | -82.299023        |
| 10190146    | 3306005 | 7/22/1974  | 14    | 13.1             | 0            | Non-Participating    | 28                     | 434.830723              | 42.529298        | -82.222338        |
| 10189159    | 3305007 | 8/9/1969   | 15.8  | 14.9             | 0            | Non-Participating    | 28                     | 796.767763              | 42.522823        | -82.225798        |
| 10192845    | 3308899 | 1/13/1992  | 21.3  | 16.8             | 0            | Non-Participating    | 39                     | 2485.137163             | 42.466196        | -82.299023        |
| 10190358    | 3306218 | 5/17/1975  | 21    | 19.8             | 4.9          | Non-Participating    | 41                     | 928.751217              | 42.468573        | -82.277346        |
| 10190415    | 3306277 | 9/30/1975  | 18.6  | 17.7             | 3            | Non-Participating    | 5                      | 1481.716622             | 42.520098        | -82.321614        |
| 10190992    | 3306864 | 8/24/1978  | 19.8  | 17.7             | 0            | Non-Participating    | 43                     | 1710.724375             | 42.563296        | -82.272404        |
| 10190507    | 3306372 | 5/11/1976  | 12.2  | 0                | 0.3          | Non-Participating    | 34                     | 626.22063               | 42.5383          | -82.333104        |
| 10190958    | 3306830 | 8/9/1978   | 14.6  | 7                | 4.9          | Non-Participating    | 32                     | 775.687515              | 42.513906        | -82.244364        |
| 10191794    | 3307676 | 9/2/1983   | 23.5  | 20.4             | 0            | Non-Participating    | 36                     | 1536.813193             | 42.451567        | -82.231678        |
| 10189537    | 3305395 | 10/7/1971  | 15.8  | 15.2             | 1.8          | Non-Participating    | 49                     | 737.149542              | 42.503044        | -82.261339        |
| 10188933    | 3304778 | 1/25/1969  | 16.8  | 16.5             | 7.9          | Non-Participating    | 6                      | 536.332967              | 42.494783        | -82.244573        |
| 10193302    | 3309362 | 8/7/1997   | 13.7  | 0                | 2.1          | Non-Participating    | 33                     | 444.394005              | 42.52971         | -82.322566        |
| 10191173    | 3307046 | 6/14/1979  | 17.4  | 16.8             | 3            | Non-Participating    | 2                      | 696.36952               | 42.477774        | -82.248263        |
| 10193511    | 3309572 | 8/10/1999  | 21.3  | 21               | 3.4          | Participating        | 35                     | 130.868402              | 42.467347        | -82.18753         |
| 10192403    | 3308379 | 1/17/1989  | 18.9  | 18.6             | 4.9          | Non-Participating    | 23                     | 1061.556529             | 42.489656        | -82.307565        |
| 10192428    | 3308404 | 1/23/1989  | 18.6  | 18.3             | 4.9          | Non-Participating    | 23                     | 974.385984              | 42.489656        | -82.307565        |
| 23053080    | 7053080 | 11/1/2007  | 0     | 0                | 0            | Non-Participating    | 73                     | 1034.127333             | 42.440506        | -82.274649        |
| 1003514339  | 7163633 | 5/2/2011   | 16.5  | 0                | 2.7          | Non-Participating    | 4                      | 804.954693              | 42.527399        | -82.277222        |



# **APPENDIX C**

## **Property Address Location Summary**



## PROPERTY ADDRESS LOCATION SUMMARY

### APPELLANT – KEVIN JAKUBEC

| ADDRESS                                      | UTM CO-ORDINATES (m) |          | CLOSEST<br>TURBINE #<br>(NKCW1) | DISTANCE<br>(m) |
|----------------------------------------------|----------------------|----------|---------------------------------|-----------------|
|                                              | EASTING              | NORTHING |                                 |                 |
| 9715 Greenvally Line<br>R.R. #5, Dresden, ON | 396016               | 4710702  | 45                              | 663             |

### OTHER JAKUBEC LAY WITNESSES

| ADDRESS            | UTM CO-ORDINATES (m) |          | CLOSEST<br>TURBINE #<br>(DOVER) | DISTANCE<br>(m) |
|--------------------|----------------------|----------|---------------------------------|-----------------|
|                    | EASTING              | NORTHING |                                 |                 |
| 7551 Marsh Line    | 389030               | 4706546  | N                               | 572             |
| 26918 Baldoon Road | 388632               | 4708436  | Y                               | 867             |
| 6821 Mallard Line  | 386455               | 4699563  | R                               | 720             |

### DOVER WELLS (4) MENTIONED IN WADE SUPPLEMENTAL WITNESS STATEMENT (SEPT. 2/16)

| ADDRESS               | UTM CO-ORDINATES (m) |          | CLOSEST<br>TURBINE #<br>(DOVER) | DISTANCE<br>(m) |
|-----------------------|----------------------|----------|---------------------------------|-----------------|
|                       | EASTING              | NORTHING |                                 |                 |
| 7551 Marsh Line       | 389030               | 4703546  | N                               | 572             |
| 6821 Mallard Line     | 386455               | 4699563  | R                               | 720             |
| 25989 Big Pointe Road | 385254               | 4698412  | T                               | 1,151           |
| 26918 Baldoon Road    | 388632               | 4708436  | Y                               | 867             |

### PARTICIPANTS / PRESENTERS

| ADDRESS              | UTM CO-ORDINATES (m) |          | CLOSEST<br>TURBINE #<br>(NKCW1) | DISTANCE<br>(m) | DISTANCE<br>TO NKW1<br>MET TOWER<br>(m) |
|----------------------|----------------------|----------|---------------------------------|-----------------|-----------------------------------------|
|                      | EASTING              | NORTHING |                                 |                 |                                         |
| 9387 Greenvally Line | 397030               | 4710340  | 4                               | 579             | 3,468                                   |
| 9213 Union Line      | 394997               | 4707930  | 27                              | 687             | 5,117                                   |
| 9293 Greenvally Line | 394399               | 4709344  | 3                               | 711             | 3,767                                   |
| 419 Victoria Avenue  | 401451               | 4696869  | 36                              | 4,665           | 6,546                                   |

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