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 29th, 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

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.

Table of Contents

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

TABLES

FIGURES

APPENDICES

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 29th, 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[1]. 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.

[1] . 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 citied 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:

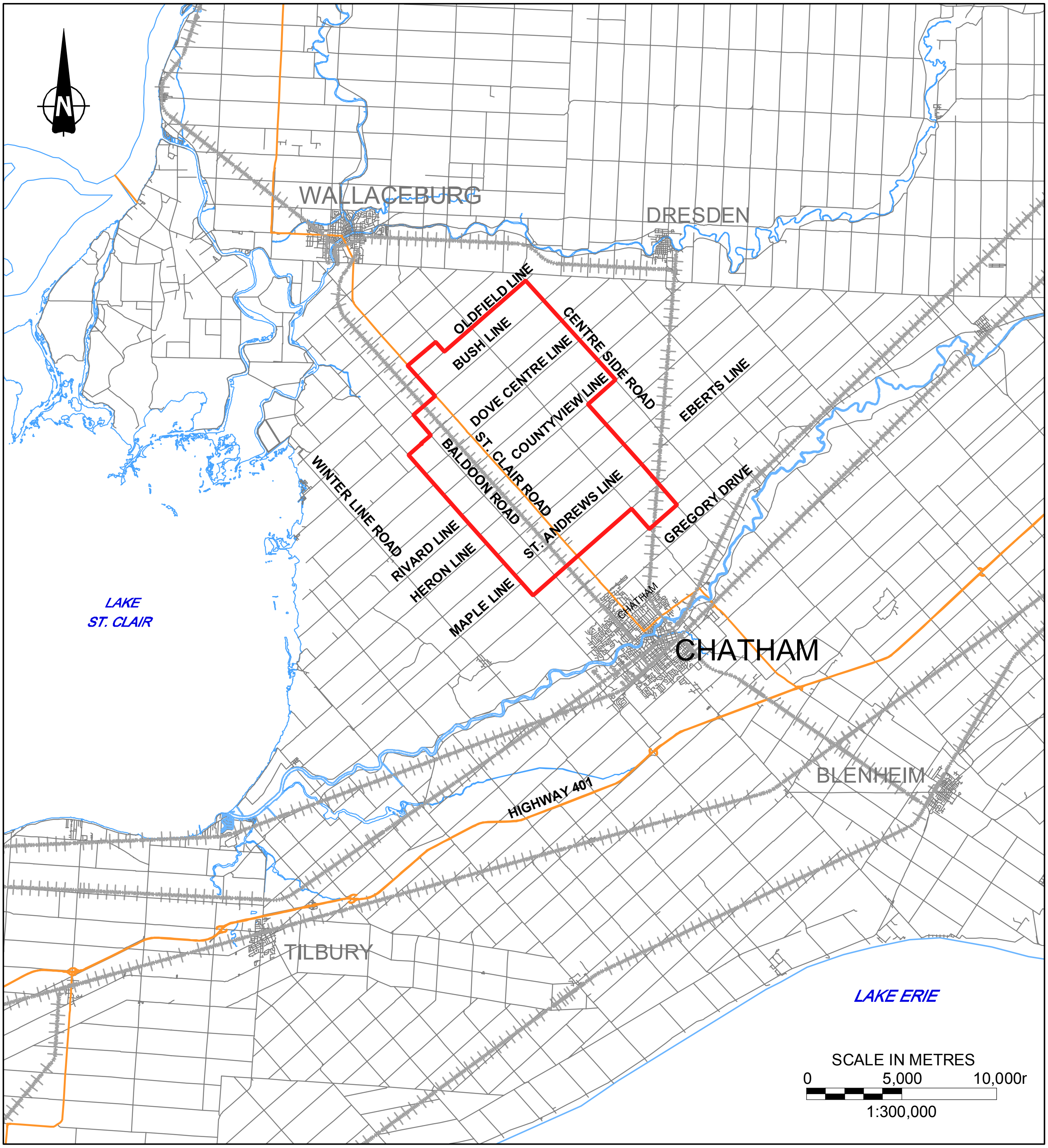
1) the existing conditions, described from the ground surface down, consist of:
   a. a layer of sand and silt near the ground surface (typically 1 to 2 m thick);
   b. a thick layer of silty clay (some 10 to 15 m thick);
   c. water-bearing sand and gravel (aquifer) underlying the silty clay (average 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;

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

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

ALL LOCATIONS ARE APPROXIMATE.

PROJECT

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

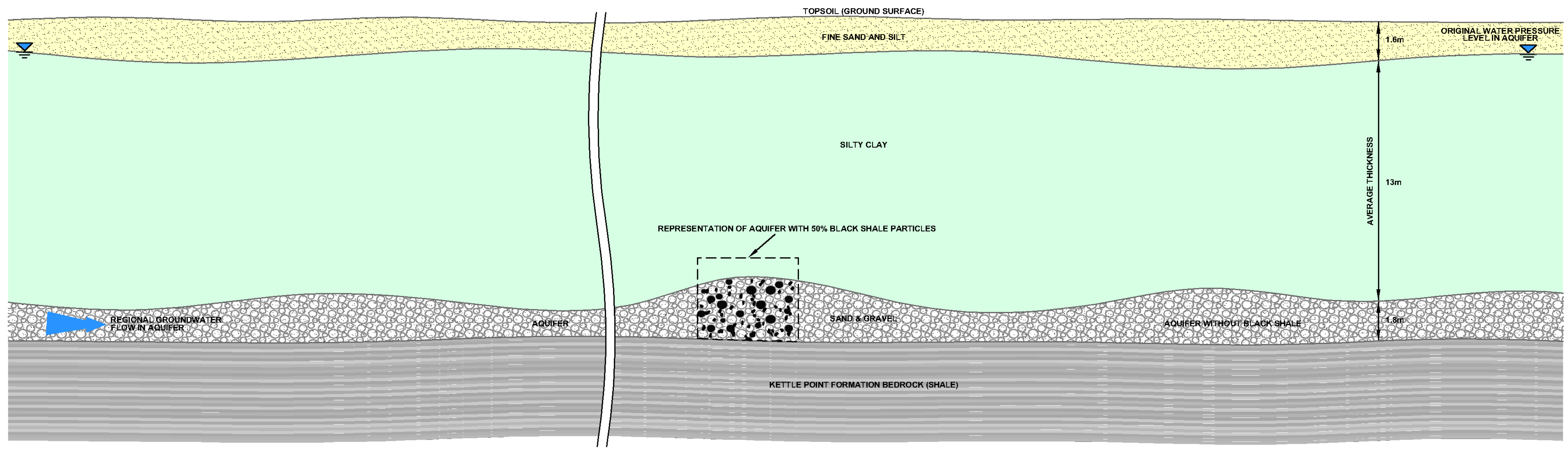
TITLE

SITE LOCATION PLAN

Golder Associates

PROJECT No.		1662594	FILE No.	1662594–R01001
			SCALE AS SHOWN	REV.
CADD	DCH	Sept 23/16		
CHECK			**FIGURE 1**	

Drawing file: 1662594–R01001.dwg   Sep 23, 2016 – 8:06am



NOTES

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

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

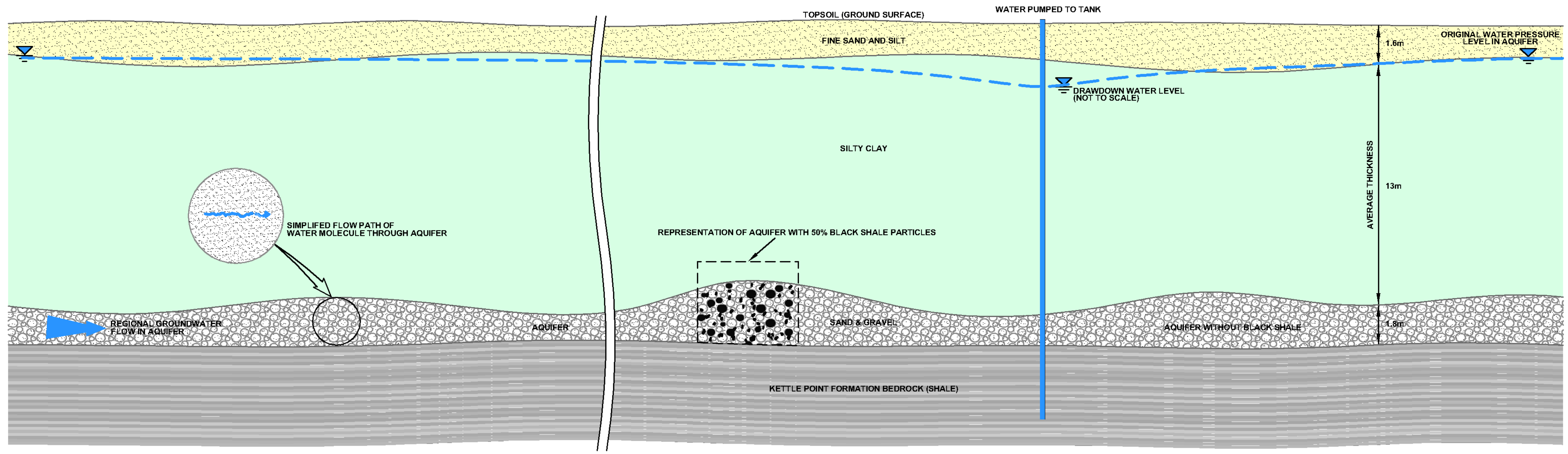
EXISTING CONDITIONS

Golder Associates

PROJECT No.		1662594	FILE No.	1662594–R01002
			SCALE	AS SHOWN
CADD	DCH	Sept 23/16	REV.	
CHECK				

FIGURE 2A

Drawing file: 1662594–R01002.dwg Sep 23, 2016 – 8:08am



NOTES

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

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

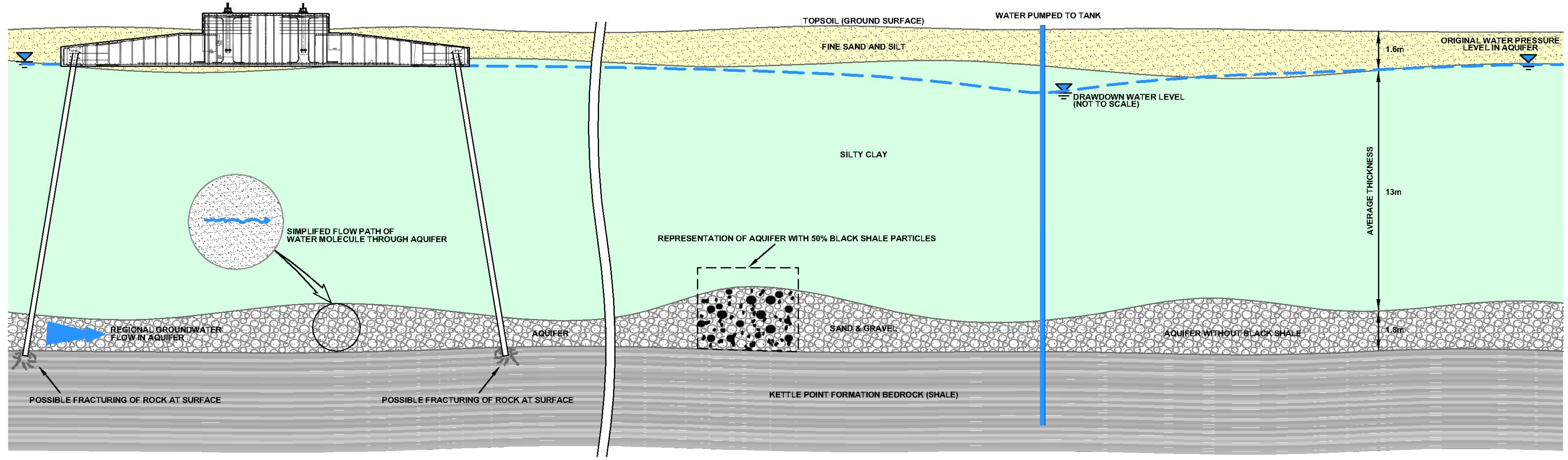
DOMESTIC WELL INSTALLED

Golder Associates

PROJECT No.	1662594	FILE No.	1662594-R01002
		SCALE	AS SHOWN
CADD	DCH	Sept 23/16	REV.
CHECK			

FIGURE 2B

Drawing file: 1662594-R01002.dwg Sep 23, 2016 - 8:08am



NOTES

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

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

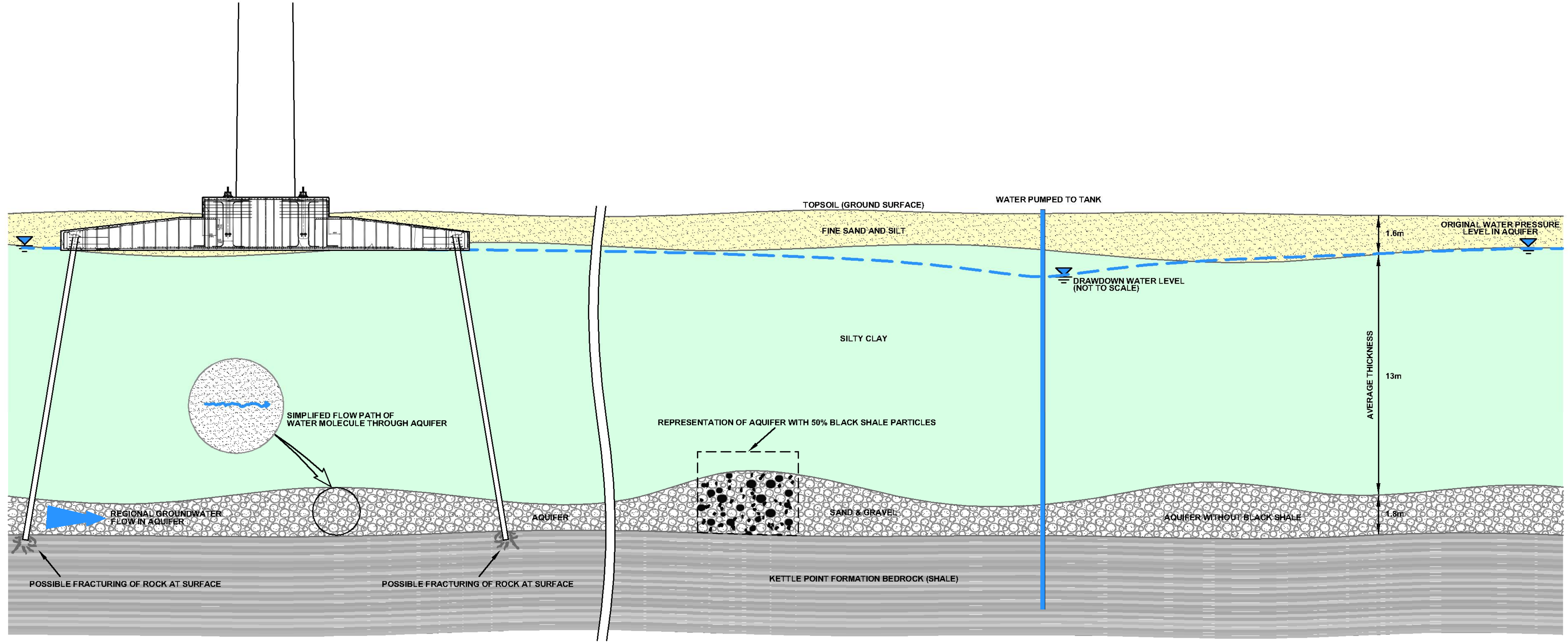
EXCAVATION FOR FOUNDATION, DRIVEN PILES, AND BACKFILL OF FOUNDATION

Golder Associates

PROJECT No.	1662594	FILE No.	1662594-R01002	
		SCALE	AS SHOWN	REV.
CADD	DCH	Sept 23/16		
CHECK				

FIGURE 2C

Drawing file: 1662594-R01002.dwg Sep 23, 2016 - 8:08am



NOTES

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

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

TURBINE OPERATING

Golder Associates

PROJECT No.	1662594	FILE No.	1662594–R01002
		SCALE	AS SHOWN
CADD	DCH	Sept 23/16	REV.
CHECK			

FIGURE 2D

Drawing file: 1662594–R01002.dwg Sep 23, 2016 – 8:07am

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[2] (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.

[2] 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 glaciolactustrine 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 overly 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 Lutenegger 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 (Su) 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[3] (K) of this soil ranges from $1x10^{-10}$ metres/second (m/s) to $2x10^{-8}$ m/s, with an average of about $5x10^{-10}$ m/s based on laboratory and field testing (e.g., Desaulniers et al. 1981, Rowe and Mabrouk 2007). Typical shear wave velocity through the soils at the turbine sites, based on

[3] 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[4] 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 (10th to 90th 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 5×10^{-6} m/s.

Table 1: Summary of Engineering and Hydrogeologic Parameters for Aquifer

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

[4] 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	10th Percentile	50th Percentile	90th Percentile
Key Grain Size Distribution Characteristics			
D_{85} (mm)[b]	5.8	11.0	18.2
D_{60} (mm)	0.4	2.3	10.2
D_{50} (mm)	0.12	0.53	6.28
D_{30} (mm)	0.019	0.085	2.05
D_{15} (mm)	0.005	0.0115	0.437
D_{10} (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., 10th 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 $1x10^{-13}$ to about $2x10^{-10}$ 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 (10th and 90th 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[5] between 10 and 50 l/min/m, similar to the Kettle

[5] 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 ¾ 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). 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 Dover Centre	Surface and Ground Water	Big Creek	784,800	100	24	545
2410-8TMJCE	Golf Course Irrigation	25393 St. Clair Rd 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.

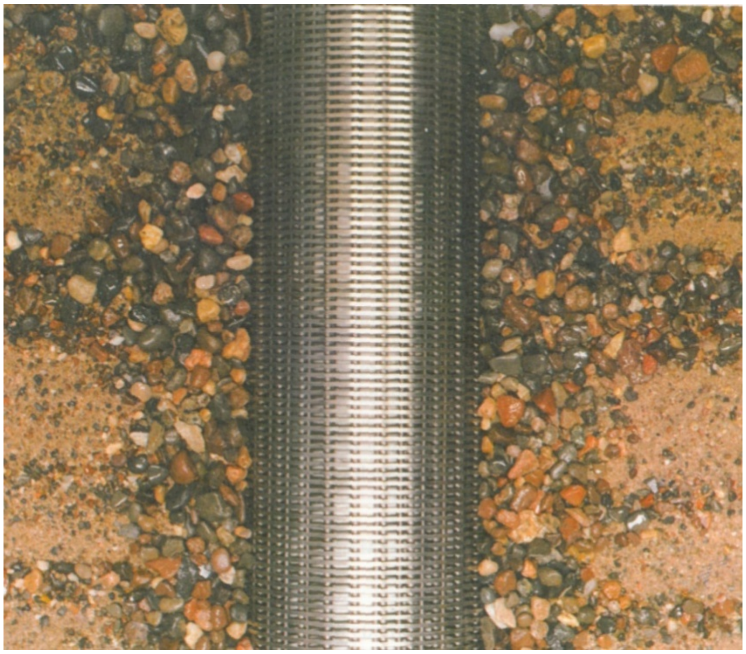


Figure 3: Illustration of natural filter formation around a well screen (from Driscoll, 1986, Figure 15.3)

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-20th 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

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

Reference	Project Name & Location
Notes: a) Ministry of Transportation Ontario GEOCRES Library Data (http://www.mto.gov.on.ca/FoundationLibrary/); 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 $1\text{x}10^{-6}$ inches/second in the U.S. and $1\text{x}10^{-8}$ m/s or $5\text{x}10^{-8}$ 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:

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

Where:

PPV_{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_{Ref} = 36,000 ft-lb (rated energy of reference pile driver)

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

Soil Class	Description of Soil Material	Value of "n" measured by Woods and Jedele	Suggested Value of "n"
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.

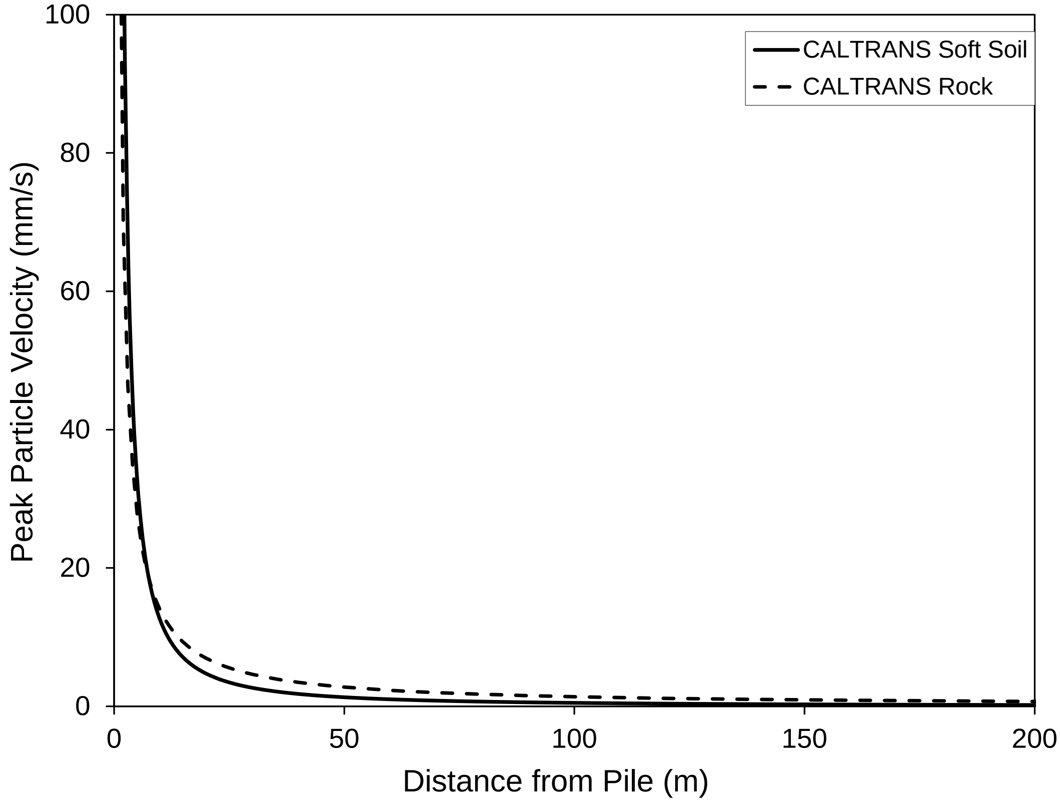


Figure 5: Example vibration attenuation curves for pile driving (using CALTRANS 2004 method)

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

.

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) 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
Human Response to Steady-State and Traffic Vibrations (Reiher and Meister 1931, Whiffen 1971)	
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
Human Response to Transient Vibrations (Wiss 1981)	
50	Severe
23	Strongly perceptible
6	Distinctly perceptible
1	Barely perceptible
Steady-State Vibration Thresholds for Occupied Spaces (ISO 1989)	
0.8	Workshop
0.4	Office
0.2	Residence
0.1	Hospital operating room
Steady-State Vibration Thresholds for Building Damage or Equipment Operations	
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)

Transient Vibration Thresholds for Building Damage	
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[6]. 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

Nuclide	Decay Mode	Half Life	Progeny
U-238	α	4.468×10^9 a	Th-234
Th-234	β-	24.10 d	Pa-234

[6] 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.

Nuclide	Decay Mode	Half Life	Progeny
Pa-234	β-	6.70 h	U-234
U-234	α	245500 a	Th-230
Th-230	α	75380 a	Ra-226
Ra-226	α	1602 a	Rn-222
Rn-222	α	3.82 d	Po-218
Po-218	α 99.98 %	3.10 min	Pb-214
	β- 0.02 %		At-218
At-218	α 99.90 %	1.5 s	Bi-214
	β- 0.10 %		Rn-218
Rn-218	α	35 ms	Po-214
Pb-214	β-	26.8 min	Bi-214
Bi-214	β- 99.98 %	19.9 m	Po-214
	α 0.02 %		Tl-210
Po-214	α	0.1643 ms	Pb-210
Tl-210	β-	1.30 min	Pb-210
Pb-210	β-	22.3 a	Bi-210
Bi-210	β- 99.99987%	5.013 d	Po-210
	α 0.00013%		Tl-206
Po-210	α	138.376 d	Pb-206
Tl-206	β-	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[7] 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, α) 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

[7] Becquerel: The System International (SI) unit of radionuclide activity. One Becquerel is equal to one disintegration per second (1 Bq = 1 s^{-1}). Conversion: 1 Curie (Ci) = 3.7×10^{10} 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[8]. 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 that 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	1.2×10^{-6}
1000	6.1×10^{-78}

[8] 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.

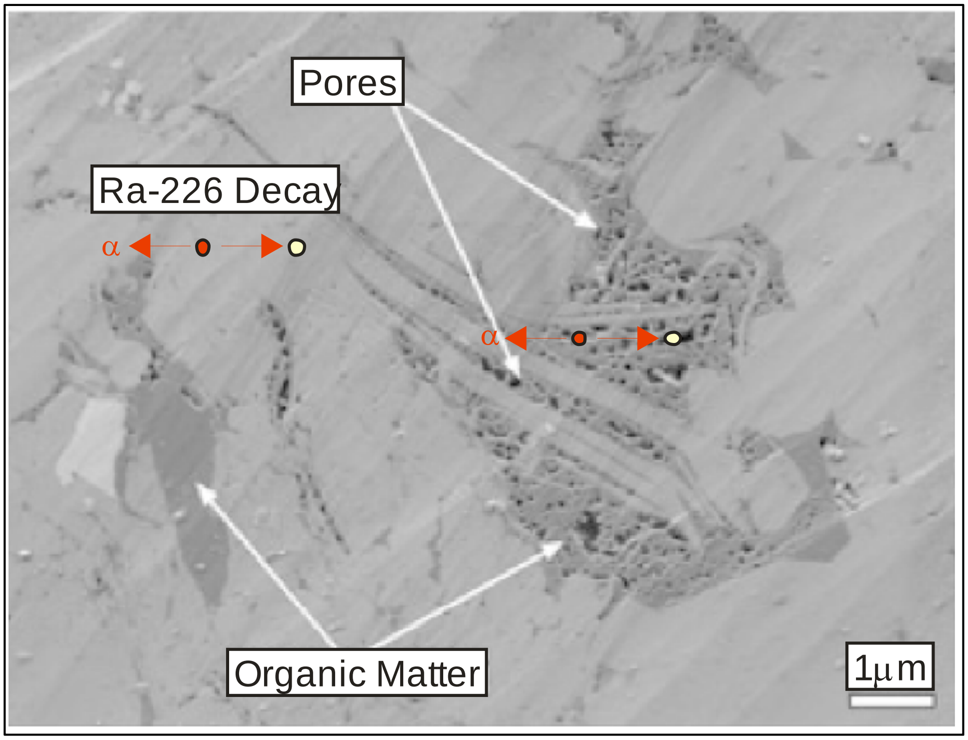


Figure 6: Schematic illustration (not to scale) of radium atoms (red circle) decay, producing alpha particles and radon atoms (white circle) as related to radon escape to pore spaces in shale.

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 (Cothern, 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^3, 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 milliSeiverts/year[9] (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.

[9] Sievert: the SI unit if 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^3	In less than 1 year
Between 200 Bq/m^3 and 600 Bq/m^3	In less than 2 years
Less than 200 Bq/m^3	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^3)
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

Distance from Piling (m)	Peak Particle Velocity (mm/s)
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 if 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[10]. 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[11](see Section 3.2). Two contributors to radon production and groundwater flow have been considered in the evaluation discussed in this report:

[10] 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.

[11] 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 though 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 λ is the decay constant of Rn-222 ($2.1 \times 10^{-6} s^{-1}$). This differential equation can be solved to yield:

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

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 1.02×10^6 Bq/m^3 (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[12].

Using this approach, the Rn-222 concentration is equal to about 1.2×10^5 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 (Aquanty 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

[12] 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[13] 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).

[13] Model north and south directions are used for convenience of presentation and do represent geographic north or south.

- The aquifer was assigned horizontal and vertical hydraulic conductivities of 2.4×10^{-4} m/s and 1×10^{-4} m/s, respectively, and a porosity of 0.3 (dimensionless).
- The intact shale bedrock was assigned horizontal and vertical hydraulic conductivities of 5×10^{-9} m/s and 1×10^{-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 1×10^{-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^3/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 1×10^{-9} m^2/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^3/day (see Section 7.4.1) which produces an equilibrium concentration of 1.02×10^6 Bq/m^3 (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^3/day, which produces an equilibrium radon concentration of 1.2×10^5 Bq/m^3 (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.

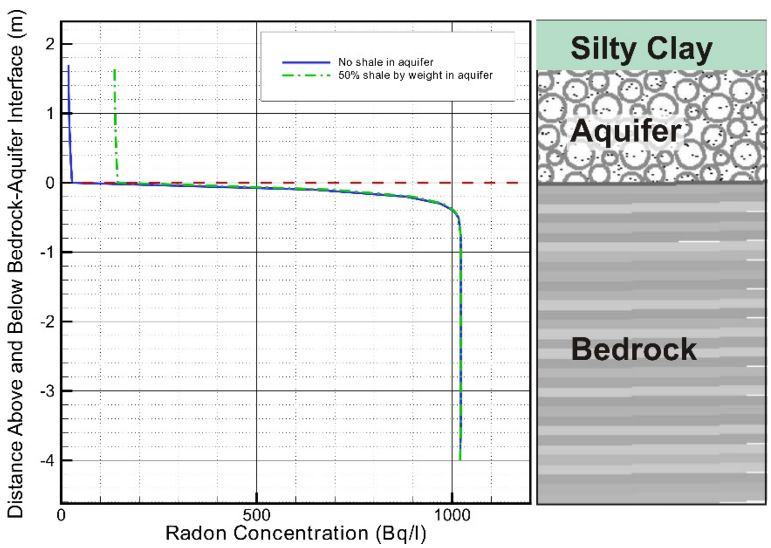


Figure 7: Radon concentration versus depth for Background Conditions Stages and Trials 1a and 1b. The dashed red line indicates the aquifer/shale bedrock contact.

- **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^3/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.

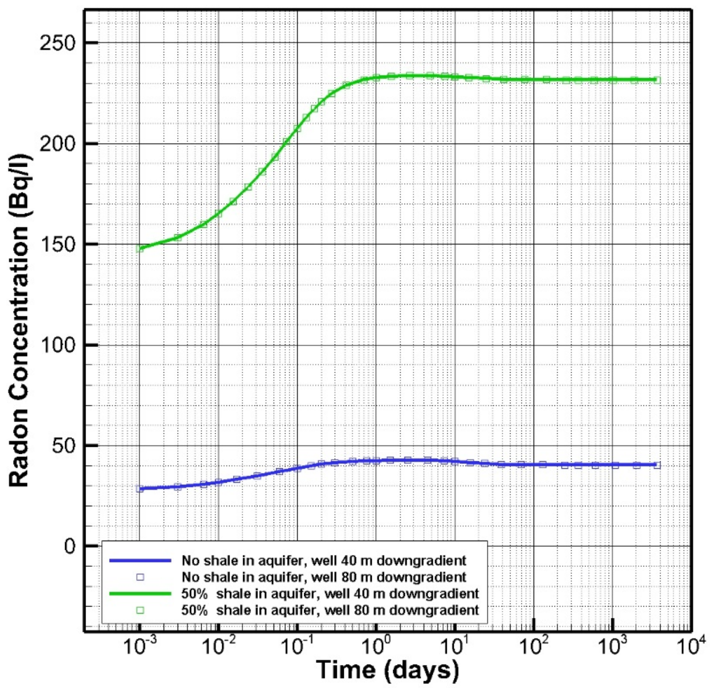


Figure 8: Radon concentration versus time for water supply well Stages and Trials 2a and 2b simulations.

- **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.

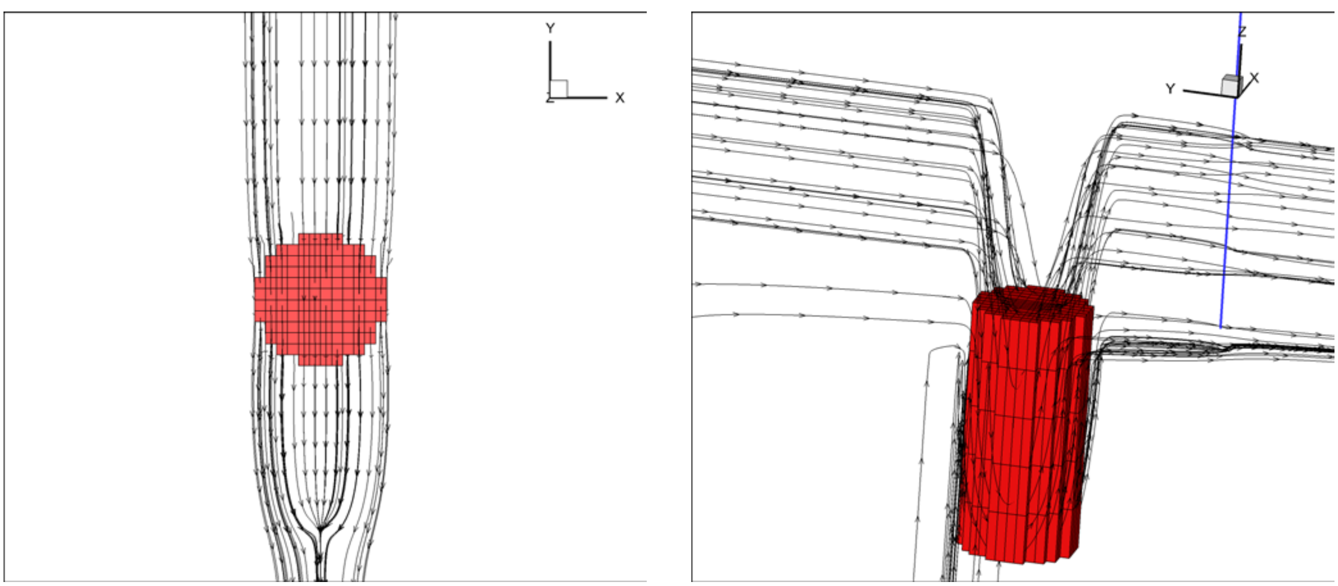


Figure 9: Plan-view, or "birds-eye" view, (above left) and oblique, or angled, view (above right) of the steady-state streamline patterns near the pile zone (red cylinder, vertically exaggerated view) and water supply well 40 m down gradient (blue line).

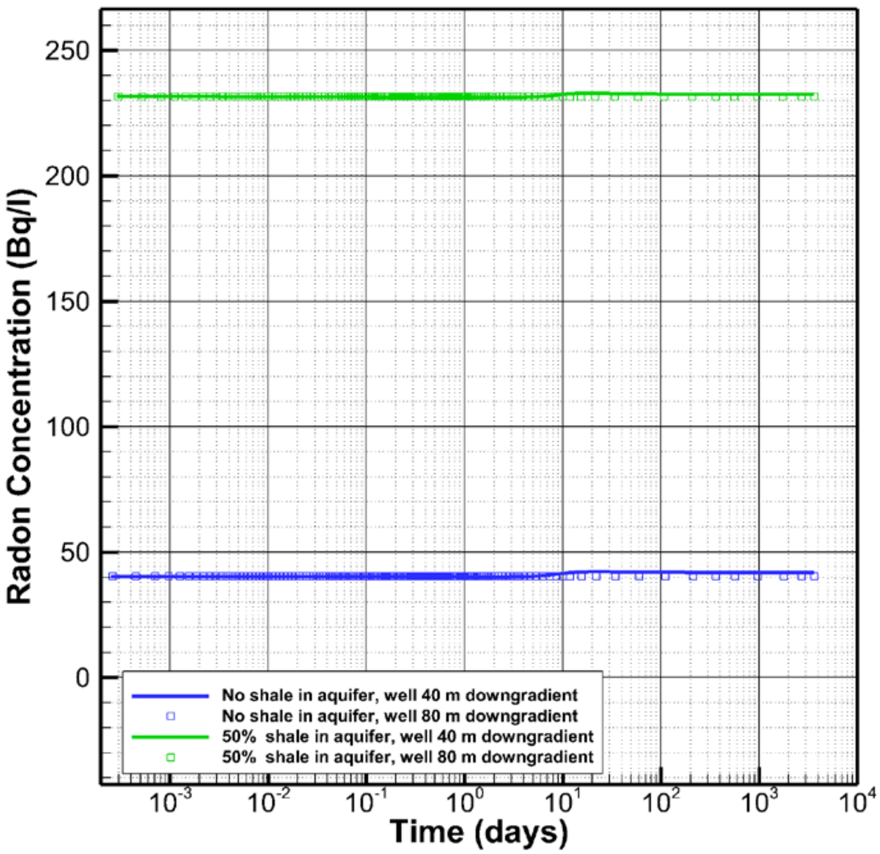


Figure 10: Radon concentration versus time for Turbine Stages and Trials 3a and 3b simulations.

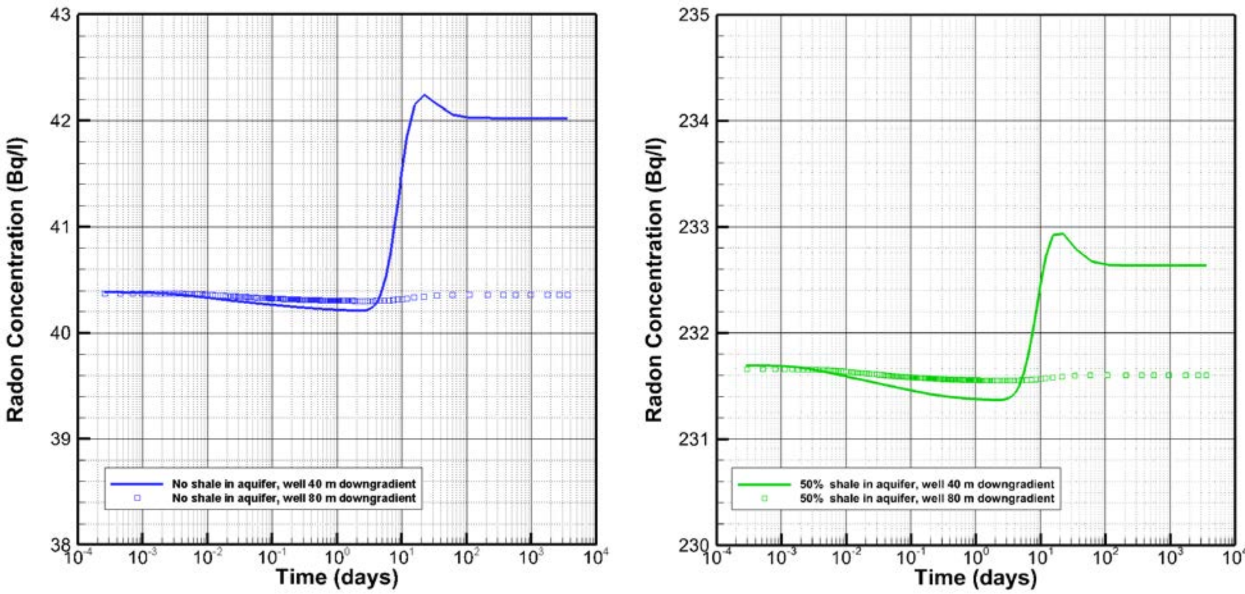


Figure 11: Radon concentration versus time for Turbine Stages and Trials 3a and 3b simulations (exaggerated scale).

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 $2x10^{-4}$ 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 $3.7x10^{-6}$ 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^3, 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

GOLDER ASSOCIATES LTD.

PROFESSIONAL GEOSCIENTISTS ONTARIO
JOHN D. McNEIL
PRACTISING MEMBER
2014

LICENSED PROFESSIONAL ENGINEER
S. J. BOONE
90559733
PROVINCE OF ONTARIO

John McNeil, M.Sc., P.Geo. Associate	Storer J. Boone, Ph.D., P.Eng. Principal
Robert McLaren, M.Sc. Senior Hydrogeologist	Daniel Corkery, B.Sc. Associate

Ernest Becker, Ph.D.
Senior Radiation Specialist

SJB/JM/EB/RM/DC/cr

n:\active\2016\3 proj\1662594 dwpv_legal north kent wind turbine project_c-k\7-correspondence\5-rpts\1662594 sept 23 16 (final) evaluation of geo north kent.docx

REFERENCES

AASHTO 1990. Standard recommended practice for evaluation of transportation-related earthborne vibrations. American Association of State Highway and Transportation Officials, Washington, DC. Available at https://bookstore.transportation.org/.

Algeo, T.J., Lyons, T.W., Blakey, R.C., and Over, J.D. 2007. Hydrographic conditions of the Devono Carboniferous North American Seaway inferred from sedimentary Mo – TOC relationships. Palaeogeography, Palaeoclimatology, Palaeoecology, Vol. 256, 204–230.

AMEC 2008. Environmental Impact Assessment, City Of Summerside Wind Farm, Final Report. AMEC Earth and Environmental.

AMEC 2016a. Geotechnical Investigation Report, Proposed North Kent Wind 1 Project, Municipality of Chatham-Kent, Ontario. AMEC Foster Wheeler Reference No. SWW167102.

AMEC 2016b. Supplementary Laboratory Testing data, North Kent Wind 1, Geotechnical Investigation Project.

ANSI/HI 2009. Standard 9.6.4., Centrifugal and Vertical Pumps - Vibration Measurements and Allowable Values, Corrected Version (2010). Hydraulic Institute. In Europump, European Association of Pump Manufacturers, Pump Vibration Standards Guidelines, 2013.

API 2011. Standard 610, Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries, Eleventh Edition. American Petroleum Institute (API). In Europump, European Association of Pump Manufacturers, Pump Vibration Standards Guidelines, 2013.

Aquanty Inc. 2015. HGS Premium: HydroGeoSphere User Manual, Release 1.0. Aquanty Inc, Waterloo, Ontario.

Armstrong, D. K., & Carter, T. R. (2010). The subsurface Paleozoic stratigraphy of southern Ontario. Ontario Geological Survey, Special Volume 7.

Armstrong, D.K., 1986. Trace element geochemistry and petrology of the Kettle Point Formation (Upper Devonian), a black shale unit of southwestern Ontario. M.S. thesis, Univ. of Waterloo, Waterloo, Ontario, Canada, 234.

ASTM 2012. Standard Test Method for the Continuous Measurement of Turbidity Above 1 Turbidity Unit (TU), Designation: D7725 – 12. American Society for Testing and Materials, West Conshocken, PA.

Attewell, P.B., and Farmer, I.W., 1973. Attenuation of Ground Vibrations from Pile Driving. Geotechnical Engineering, Vol. 63, No. 7, pp. 26 – 29.

Barnett, P.J., Cowan, W.R. and Henry, A.P. 1991. Quaternary geology of Ontario, southern sheet; Ontario Geological Survey, Map 2556. Ontario Ministry of Northern Development and Mines.

Bingham-Koslowski, N. 2015. High Resolution Stratigraphy and Paleoenvironmental Reconstruction of the Upper Devonian Kettle Point Formation, Southwestern Ontario, Canada. Thesis, University of Western Ontario.

Boone, S.J. and Lutenegger, A.J. 1997. Carbonates and Cementation of Glacially Derived Cohesive Soils in New York State and Southern Ontario. Canadian Geotechnical Journal, 34(4), 534 550.

Botha, P. 2013. Ground Vibration, Infrasound and Low Frequency Noise Measurements from a Modern Wind Turbine. ACTA Acustica United with Acustica, Vol. 99, 537 – 544.

Bradford, S.A., Yates, S.R., Bettahar, M. and Simunek, J. 2002. Physical factors affecting the transport and fate of colloids in saturated porous media. Water Resources Research, Vol. 38, No. 12, 63-1 to 63-11.

Bradshaw, A.S., Miller, H.J., Baxter, C.D.P. (2007). A Case Study of Construction-Related Ground Movements in Providence Silt. FMGM 2007: Seventh International Symposium on Field Measurements in Geomechanics, ASCE, 8 pp.

Brigham, R.J., 1971. Structural geology of Southwestern Ontario and Southeastern Michigan, Ontario Department of Mines and Northern Affairs, Petroleum Resources Section, Paper 71-2, 120p.

CALTRANS. 2004. Transportation- and construction-induced vibration guidance manual. Prepared by Jones & Stokes for California Department of Transportation, Noise, Vibration, and Hazardous Waste Management Office, Sacramento, CA.

Chapman, L.J. and Putnam, D.F. 1984. The Physiography of Southern Ontario, 3rd Edition, Ontario Geological Survey, Special Volume 2, Ontario Ministry of Natural Resources.

Cigar Lake Environmental Impact Statement: Radiological and Regional Cumulative Impact, Supporting Document No. 7, July 1995

Cothern, C.R. (1987) Estimating the health risks of radon in drinking water. J. Am. Water Works Assoc., 79(4): 153–158. Available at www.awwa.org.

D' Appolonia, D.J. 1971. Effects of Foundation Construction on Nearby Structures", Proc. 4th Panamerican Conference on Soil Mech. and Found. Eng., Vol 2, 189- 235, Puerto Rico.

Deckner, F. 2013. Ground vibrations due to pile and sheet pile driving – influencing factors, predictions and measurements. Thesis, KTH, Royal Institute of Technology, Stockholm, Sweden.

Desaulniers, D.E., Cherry, J.A. and Fritz, P. 1981. Origin, Age and Movement of Pore Water in Argillaceous Quaternary Deposits at Four Sites in Southwestern Ontario. Journal of Hydrology, 50, Elsevier, Amsterdam, 231—257.

Dowding, C.H. 1996. Construction vibrations. Prentice-Hall. Englewood Cliffs, NJ.

Drabkin, S., Lacy, H., and Kim, D.S. 1996. Estimating Settlement of Sand Caused by Construction Vibration. Journal of Geotechnical Engineering, ASCE, 122(11), 920 – 928.

Driscoll, F.D. 1986. Groundwater and Wells, Second Edition. Johnson Filtration Systems, Inc., St. Paul, Minnesota, pp. 434, 500.

Dusseault, M.B. and Loftsson, M. 1985. The Mechanical Properties of the Kettle Point Oil Shale, Ontario Geological Survey Open File Report 5560.

Easton, R.M. 1992. The Grenville Province and Proterozoic history of central and southern Ontario; in Geology of Southern Ontario. Ontario Geological Survey, Special Volume 4, Part2, 982.

Edwards, W.N. 2015. Geological Survey of Canada, Open File 7763, Analysis of Measured Wind Turbine Seismic Noise Generated from the Summerside Wind Farm, Prince Edward Island.

Fiori, I, Giordano, L., Hild, S., Losurdo, G., Marchetti, E., Mayer, G., and F. Paoletti. 2009. A study of the seismic disturbance produced by the wind park near the gravitational wave detector. GEO-600 Third International Meeting on Wind Turbine Noise, Aalborg, Denmark.

Fitzgerald, W.D. 1979. Quaternary geology of the Wallaceburg (40J/9), St Clair Flats (40J/10E), and Chatham (40J/8) Areas, Lambton and Kent Counties, Summary of Fieldwork and Other Activities 1979, Ontario, Geological Survey, MP 90, p.131-132.

Flotec (2012). Owner's Manual, 4" Submersible Pumps, Two and Three Wire, 1/2 thru 1 1⁄2 HP, 60 Hz, Flotec, 293 Wright Street, Delavan, WI 53115.

Freeze, R. A., & Cherry, J. A. 1989. Groundwater. Englewood Cliffs, NJ: Prentice Hall.

FTA 2006. Transit Noise and Vibration Impact Assessment, FTA-VA-90-1003-06, U.S. Department of Transportation Federal Transit Administration Office of Planning and Environment, Washington, D.C., May 2006

Gelhar, L.W., Welty, C. and Rehfeldt, K.R. 1992. A critical review of data on field-scale dispersion in Aquifers. Water Resources Research, Vol. 28, No. 7, 1955 – 1974.

GSC (1994) Geological Survey of Canada, Summer Outdoor Radon Variations in Canada and their Relation to Soil Moisture. Health Physics Journal, Vol. 66, No. 2.

Health Canada 2014. Guidelines for Canadian Drinking Water Quality—Summary Table. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario.

Holland, H.D. 1979. Metals in Black Shales - a Reassessment. Economic Geology, Vol. 74, 1676-1680.

Hope, V.S. and Hiller, D.M. 2000. The prediction of groundborne vibration from percussive piling. Canadian Geotechnical Journal, Vol. 37, 700 – 711.

Husain, M.M., Cherry, J.A. and Frape, S.K. 2004. The persistence of a large stagnation zone in a developed regional aquifer, southwestern Ontario. Canadian Geotechnical Journal, Vol. 41, 943-958.

IARC (1988) Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Man-made mineral fibres and radon. Geneva: World Health Organization, International Agency for Research on Cancer.

ISO 1997. Publication ISO 2631, Guide to the evaluation of human exposure to vibration and shock in buildings (1 Hz to 80 Hz). International Standards Organization, Geneva, Switzerland.

ISO 2014. Standard 10816 ISO series (6 parts), Mechanical vibration – Evaluation of machine vibration by measurements on non-rotating parts. International Standards Organization, Geneva, Switzerland. In Europump, European Association of Pump Manufacturers, Pump Vibration Standards Guidelines, 2013.

Kent R.T., Brown, D.R., and Bentley, M.E. 1986. Subsurface injection in Ontario, Canada. 380-397.

Konon, W. 1985. Vibration criteria for historic buildings. Journal of Construction Engineering and Management 111(3):208–215. In CALTRANS 2004.

Lacy, H.S. and Gould, J.P. 1985. Settlement from Pile Driving in Sands. Vibration Problems in Geotechnical Engineering, G. Gazetas and E. Selig, eds., ASCE, 152 – 173. In Drabkin et al. 1996.

Lesarge, K.G. and Boone, S.J. 2013. Geologic Controls on Geochemistry and Disposal of Excess Soil from Construction, Proceedings, 66th Canadian Geotechnical Conference and 11th Joint CGS/IAH-CNC Groundwater Conference, Paper No. 499.

Life Systems, Inc. (1991) Radon in drinking water: Assessment of exposure pathways. Prepared for Office of Water, U.S. Environmental Protection Agency, June (TR-1242-87).

Lo, K.Y. and Hori, M. 1979. Deformation and strength properties of some rocks in southern Ontario. Canadian Geotechnical Journal, Vol. 16, 108 – 120.

MTO 1993. Pile Load and Extraction Tests, 1954 – 1992, Report EM-48, Rev. 1993, Ministry of Transportation Ontario Foundation Design Section.

Nazaroff, W.W., Doyle, S.M., Nero, A.V., and Sexton, R.G. (1987) Potable water as a source of airborne 222Rn in U.S. dwellings: A review and assessment. Health Phys., 52: 281–295 [cited in Gosink et al., 1990].

NAVFAC (1982). Design Manual 7.1 - Soil Mechanics and Design Manual 7.2 - Foundations and Earth Structures. Naval Facilities Engineering Command, U.S. Department of the Navy, Alexandria, VA. Update: 1986.

NCRP (1988) Measurement of radon and radon daughters in air. National Council on Radiation Protection and Measurements, Bethesda, MD (NCRP Report No. 97). Available at https://www.ncrppublications.org.

Nichols, H. R., C. F. Johnson, and W. I. Duvall. 1971. Blasting vibrations and their effects on structures. (Bulletin 656.) Washington, DC: U.S. Bureau of Mines.

Powers, J. P., Corwin, A.B, Scmall, P.C., Kaeck, W.E. 2007. Construction Dewatering, New Methods and Applications, Third Edition. John Wiley & Sons, New York.

Raven, K.G., Lafleur, D.W. and Sweezy, R.A. 1990. Monitoring well into abandoned deep-well disposal formations at Sarnia, Ontario. Canadian Geotechnical Journal, Vol. 27, 105 – 118

Red Lion (2016). Installation and Operating Instructions for Two- and Three-Wire 4" Deep Well Pumps, Red Lion Products, Oklahoma City, OK 73157.

Reiher, H. and F. J. Meister. 1931. The effects of vibration on people. Forshung auf dem Gebeite der Ingenieurwesens 2(2) *in* CALTRANS (2004).

Robertson, D. A., J. A. Gould, J. A. Straw, and M. A. Dayton. 1980. Survey of blasting effects on ground water supplies in Appalachia. (Contract Report J-0285029.) Washington, DC: U.S. Bureau of Mines.

Rose, R., Bowles, B. and W. Bender. 1991. Results of blasting in close proximity to water wells at the sleeper mine. In Proceedings of the Seventeenth Conference on Explosives and Blasting Technique. Cleveland, OH: International Society of Explosives Engineers.

Rowe, R.K. and Mabrouk, A. 2007. Three Dimensional Effects of Excavation on Stress Distribution, Proceedings of the Canadian Geotechnical Society Conference OttawaGeo2007, 1142 – 1147.

Russell, D.J. 1985. Depositional Analysis of a black shale using gamma-ray stratigraphy: The Upper Devonian Kettle Point Formation of Ontario. Bulletin of the Canadian Society of Petroleum Geologists, Vol. 33, 236-253.

Singer, S.N., Cheng, C.K., and Scafe, M.G. 2003. The Hydrogeology of Southern Ontario, Second Edition. Ontario Ministry of the Environment, Toronto.

Siskind, D. 2000. Vibrations from Blasting. International Society of Explosives Engineers, Cleveland, 68 – 69, 109.

Siskind, D. E. and Stagg, M.S. 1993. Response of pressurized pipelines to production-size mine blasting. U.S. Bureau of Mines, Twin Cities Research Center, Minneapolis, MN.

Siskind, D.E., and Stagg, M.S. 1989. Blast Vibration Measurements near and On Structure Foundations. United States Department of the Interior Bureau of Mines, pg. 3.

Snow, D. 1997. Low frequency noise and vibrations measurement at a modern wind farm. ETSU W/13/00392/REP, Powergen - Ratcliffe Technology Centre, Nottingham (United Kingdom), Department of Trade and Industry, London (United Kingdom).

Soderman, L. G. and Kim, Y. D. 1970. Effect of groundwater levels on stress history of the St. Clair till deposit. Canadian Geotechnical Journal, 7(2): 173-193.

Stagg, M. S. and Engler, A.J. 1980. Measurement of blast-induced ground vibrations and seismograph calibration. (Report of Investigations 8506.) Washington, DC: U.S. Bureau of Mines.

Straw, J.A. and Shinko, J.P. 1994. Blast Vibration Effects Upon a Deep Injection Well and the Reduction of Ground Vibration Over Depth. Proceedings, Tenth Annual Symposium on Explosives and Blasting Research, Austin, TX, 31 – 40.

Styles, P., Stimpson, I., Toon, S., England, R. and Write, M. 2005. Microseismic and Infrasound Monitoring of Low Frequency Noise and Vibrations from Windfarms, Recommendations on the Siting of Windfarms in the Vicinity of Eskdalemuir, Scotland. Applied and Environmental Geophysics Research Group, Earth Sciences and Geography, School of Physical and Geographical Sciences, Keele University.

Tart, R. G., L. L. Oriard, and J. H. Plump. 1980. Blast damage criteria for massive concrete structure. (American Society of Civil Engineers Preprint 80–175.) Portland, OR: ASCE National Meeting, Specialty Session on Minimizing Detrimental Construction Vibrations. In CALTRANS (2004).

Taylor, O-D., S. (2011). Use of an Energy-Based Liquefaction Approach to Predict Deformation in Silts Due to Pile Driving. Ph.D. Dissertation, University of Rhode Island, 303 pp.

Tilsey, J.E., Veldhuyzen, H. and Nichols, P.R. 1993. Soil radon gas study of southern Ontario; Ontario Geological Survey, Open File Report 5847, 148 p.

Tourtelot, E.B. 1970. Selected Annotated Bibliography of Minor-Element Content of marine Black Shales and Related Sedimentary Rocks, 1930-65. U.S. Geological Survey, Bulletin 1293, 118.

Tyldesley, M., Newson, T., Boone, S., and Carriveau, R. (2013). Characterization of the geotechnical properties of a carbonate clayey silt till for a shallow wind turbine foundation. 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris, France, 2407-2410.

UNSCEAR (1988) Sources, effects and risks of ionizing radiation. United Nations Scientific Committee on the Effects of Atomic Radiation, United Nations, New York, NY. Available at: www.unscear.org/unscear/en/publications/1988.html

UNSCEAR (2000) Sources, effects and risks of ionizing radiation. United Nations Scientific Committee on the Effects of Atomic Radiation, United Nations, New York, NY. Available at: www.unscear.org/unscear/en/publications/2000_1.html

USEPA (1991) National primary drinking water regulations, radionuclides; proposed rules. U.S. Environmental Protection Agency, Washington, DC. Fed. Regist., 56(138): 33050.

USEPA 2008. Identification of Nonhazardous Materials that are Solid Waste, Wastewater Treatment Sludge. United States Environmental Protection Agency Materials Characterization Paper in support of the Advanced Notice of Proposed Rulemaking. 10.

USNRC (1984). Radon Attenuation Handbook for Uranium Mill Tailings Cover Design NUREG/CR-3533, PNL-4878, RAE-18-5, RU, United States Nuclear Regulatory Commission, Washington, D.C.

Weaver, T.R., Frape, S.K., Cherry, J.A. 1995. Recent cross-formational fluid flow and mixing in the shallow Michigan Basin. GSA Bulletin, June, Vol. 107, No. 6, 697-707.

Whiffen, A. C. 1971. A survey of traffic-induced vibrations. (Report LR419.) Crowthorne, Berkshire, England: United Kingdom Department of Environment, Road Research Laboratory. Available at https://trb.org/.

Whyley, P.J. and Sarsby, R.W. 1992. Ground borne Vibration from Piling. Ground Engineering, Vol. 26, 32-37.

Wiss, J.F. 1967. Damage effects of pile driving vibration. Pages 14–20 in Structural Construction: Five Reports, (Highway Research Record 155). Washington, DC.

Wiss, J.F. 1981. Construction vibrations: State-of-the-Art. Journal of the Geotechnical Engineering Division, ASCE, 107(2), 167 – 181.

Wiss, J.F. and H. R. Nichols. 1974. A study of damage to a residential structure from blast vibrations. New York: American Society of Civil Engineers.

Wood, W. C. and J. R. Theissen. 1982. Vibrations in adjacent structures due to pile driving. Geopile Conference ’82, San Francisco, Associated Pile and Fitting Corp., 83–107.

Woods, R. S., and L. P. Jedele. 1985. Energy-attenuation relationships from construction vibrations. Proceedings, Vibration Problems in Geotechnical Engineering, Geotechnical Engineering Division, American Society of Civil Engineers, Detroit, MI, 187 – 202. In CALTRANS (2004).

Woods, R.D. 1997. Dynamic effects of pile installations on adjacent structures. Synthesis of Highway Practice 253, National Academy Press, Washington, DC.

Woods, R.D. and Sharma, V.M. 2004. Dynamic Effects of Pile Installations on Adjacent Structures, International Edition. A.A. Balkema Publishers, New York, 163 pp.

Xu, S. and Saiers, J. 2009. Colloid straining within water-saturated porous media: Effects of colloid size nonuniformity. Water Resources Research, Vol. 45, W05501, 1 – 8.

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

Impurity or Contaminant	Symptom	Cause
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.
		Action of magnesium rod in hot water heater and soft water.
	Detergent odour, water foams when drawn.	Seepage of septic discharge into underground water supply.
	Gasoline or oil smell.	Leak in fuel oil tank or gasoline tank seeping into water supply.
	Methane gas (caution required).	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.

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

Impurity or Contaminant	Symptom	Cause
Milky water	Cloudy water when drawn.	Some precipitated sludge created during heating of water. High volume of air in water from poorly functioning pump. 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. High-temperature drying creates chloride concentration, accelerating corrosion.
Excess fluorides	Yellowish mottled teeth of children. 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. Heavy use of commercial fertilizers with residual NO_3 getting into groundwater. Disposal of corrosion inhibitors containing nitrates (from boiler cleanout), which enter groundwater supplies.
Radioactive contaminants	Notices by public health authority. No visible colour, taste, or odour. 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. 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. 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. Corrosion products from piping caused by low-pH waters.
Arsenic^	No visible colour, taste, or odour. Maximum contaminant level set by U.S. EPA. (Above 0.05 mg/L considered health risk).	Natural groundwater contaminant in local areas. Industrial waste contaminating water supply. Herbicides/pesticides.
Barium	No visible colour, taste, or odour. Maximum contaminant level set by U.S. EPA. (Above 1 mg/L considered health risk)	Naturally occurring in certain geographic regions.

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 ^{137}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 traveltime 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 6th & 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	Bermingham 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 Aquifier 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.
Armstrong, D.K., and Dodge, J.E.P. Paleozoic geology of southern Ontario; Ontario Geological Survey, Miscellaneous Release Data 219.

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

North Kent Wind 1 Project)
Client: North Kent Wind 1 LP
AECOM Project #: 60518043
Date: September 20th, 2016

PROPERTY ADDRESS LOCATION SUMMARY

APPELLANT – KEVIN JAKUBEC

ADDRESS	UTM CO-ORDINATES (m)		CLOSEST TURBINE # (NKW1)	DISTANCE (m)
	EASTING	NORTHING		
9715 Greenvalley Line R.R. #5, Dresden, ON	396016	4710702	45	663

OTHER JAKUBEC LAY WITNESSES

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

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

For more information, visit golder.com

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 44 1628 851851
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Ltd.
309 Exeter Road, Unit #1
London, Ontario, N6L 1C1
Canada
T: +1 (519) 652 0099

Golder Associates