Appendix F-2
McNeilan Windfarm
Ground Conditions Report

McNeilan & Associates

converting challenges into opportunities

Windfarm Ground Conditions

Icebreaker Wind Demonstration Project

Lake Erie

Submitted to:

Lake Erie Energy Development Corporation

Cleveland, Ohio

McN&A Project No. 16-02

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McNeilan & Associates, LLC
Norfolk, Virginia

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INTRODUCTION

PROJECT BACKGROUND

The Icebreaker Wind Demonstration Project is proposed by the Lake Erie Energy Development Corporation (LEEDCo) as the first offshore wind demonstration project in the freshwater Great Lakes. The project (Figure 1) will include six, 3.45 MW wind turbine generators offshore from Cleveland, Ohio. Each wind turbine will be supported by a mono-pole substructure founded on a suction bucket foundation (mono-bucket).

The Icebreaker wind turbines will be located approximately 13.1 to 17.8 km offshore from Cleveland. The turbines will be spaced about 750 meters apart and located along a north-northwest to south-southeast alignment (Figures 1 and 2). As shown, seven possible locations (ICE1 to ICE7) have been identified for the six turbines. Locations ICE1 through ICE6 are designated as the primary locations, while ICE7 is an optional location. Nominal water depths at the seven sites increase from about 17.1 meters (relative to IGLD85, low water datum) at ICE1 to about 18.4 meters at ICE7.

Energy generated from the turbine generators will be transmitted through an export cable from the offshore project area to the project substation located at the former Cleveland Public Power (CPP) generating facility on North Marginal Road. The in-harbor portion of the export cable will be installed within a horizontally directional drilled (HDD) casing.

PURPOSE OF REPORT

This report describes the physical ground conditions on and below the lake-bottom in the wind turbine development area. This description is based on geologic conditions, relevant historical references, and project-specific design studies. It is intended to provide an overview of the physical conditions that underlie the project site and to be used as a reference document for various project permitting and environmental evaluation activities. The summary description has, to a large degree, been extracted from various project-specific site characterization and design studies.

AUTHORIZATION

This report was completed as part of the scope of work authorized by LEEDCo's signed acceptance of McNeilan & Associates' Professional Service Agreement for McNeilan & Associates' Proposal Number 16-02 r3, dated February 29, 2016.

PROJECT DATUM

The project datum are:

- Horizontal – WGS84, UTM Zone 17N, meters, and
- Vertical – Lake Erie Chart Datum, which is 173.5 meters above the International Great Lakes Datum (IGLD) 1985, low water datum (LWD) – this datum is subsequently referred to as *chart datum*.

HISTORICAL GEOPHYSICAL AND GEOTECHNICAL EXPLORATION PROGRAMS

HISTORICAL REFERENCES

In the early-mid 1970s, Dames and Moore provided a report (Dames and Moore, 1974) for the Lake Erie Regional Transportation Authority as part of the First Phase of the "Airport Feasibility Study." The Dames & Moore report presents the results of a regional geophysical and geotechnical survey conducted across a 12- by 20-mile area offshore the Cleveland shoreline that includes the proposed location for the Icebreaker Wind Demonstration Project.

PRELIMINARY PROJECT-SPECIFIC ACTIVITIES

In the early 2010s, LEEDCo contracted for a geophysical survey and initial geotechnical exploration (preliminary G&G program) within the proposed turbine development area. Those activities included:

- A geophysical survey conducted by Alpine Ocean Seismic Survey (Alpine) in September 2010. This survey included basic data acquisition to characterize the conditions of the lake-bottom and the subsurface stratigraphy beneath the project site. The area covered by the Alpine geophysical survey is show on Figure 2.
- Preliminary geotechnical exploration conducted by Conestoga-Rovers in 2013. This exploration included one boring and three cone penetration test (CPT) soundings at the windfarm site.
- A supplemental geophysical survey, performed by VanZandt Engineering, in June 2015, in the portion of the turbine development area not included in the prior 2010 Alpine survey.

PROJECT-SPECIFIC, DESIGN-PHASE PROGRAMS

The design-phase geotechnical exploration for the turbine structures was conducted in the summer of 2015. The field program for that effort included one or two sample borings plus two or three CPT soundings at each of the planned six turbine positions (ICE1 through ICE6) as well as one alternate position (designated as ICE7). The exploration included a boring and/or multiple CPT soundings advanced to 20+-meter depth at each potential turbine location. Figure 2 shows the locations of the 2015 exploration. The factual data from that investigation is documented in McNeilan & Associates, 2016)

The design-phase survey of the inner array cables between turbine locations (and the export cable from the windfarm area to Cleveland Harbor) was conducted in August to October 2016. That program also included piston core and box core sampling and additional in situ CPT soundings at the turbine locations. The results of the geophysical components of the program are provided in Canadian Seabed Research, 2016, and the results of the geotechnical exploration are provided in TDI-Brooks, 2017. The integrated site characterization interpretation and geotechnical evaluations, based on the 2015 and 2016 programs, are provided in McNeilan & Associates, 2017a and 2017b, respectively.

GEOLOGY AND SUBSURFACE CONDITIONS

REGIONAL GEOLOGIC HISTORY

Today's subsurface stratigraphy beneath Lake Erie has been affected by regional geologic evolution during the Precambrian era and Paleozoic era, and due to glaciation and deglaciation during the Quaternary period (Bolsenga and Herdendorf, 2005).

During the Precambrian, deep basement structures were formed. Modern-day seismicity within the region has been attributed to weak zones in the North American plate caused by faults created by these basement structures. Sediments deposited in the shallow seas during the Paleozoic era eventually were lithified into bedrock and subsequently faulted during the Appalachian Orogeny (Grabau, 1901).

Beneath Lake Erie, the bedrock is now shallowly buried, and is commonly exposed near the lake shore. Some modern-day seismicity is attributed to faults within the bedrock. Fault zones have been inferred from subsurface geophysical data.

During the Quaternary period (last 1.6 million years), geologic processes shaped the surficial landscape and deposited unconsolidated sediments that overlie bedrock. Repeated episodes of glacial advance and retreat covered the Great Lakes region at least six times during the Quaternary (Kindle and Taylor, 1913). Four glacial lobes (Forsythe, 1971; Holcombe, et al, 2005) extended to Lake Erie and produced end moraine deposits. As the glaciers advanced they eroded the landforms, and re-worked and re-deposited the sediments. When the glaciers receded, their meltwaters re-deposited sediments from within the glaciers.

The present-day lakebed and subsurface topography is the result of these repeated episodes of erosion of unconsolidated sediment deposits and bedrock, as well as re-deposition of the sediment during and after glaciation.

GLACIAL PROCESSES

As advancing glaciers carve into and ground underlying bedrock materials they typically form U-shaped valleys in the underlying materials and bedrock. The advancing glaciers also form lateral and terminal moraines along their flanks and in front of the maximum advance and retreat hiatus positions. Those landforms are generally composed of sands, gravels, and boulders

Other glacial features left behind as glaciers melt and retreat include: outwash, kames, eskers, and glacial lakes. Sediments deposited in glacial lakes are Glacio-lacustrine deposits that are commonly composed of fine-grained sediments, sometime layered or varved, and frequently containing some quantity of coarser material (sand, gravel, cobbles or boulders) embedded in the fine-grained sediment matrix.

Because the deposits from earlier periods of glaciation are often eroded during subsequent phases of glaciation, the preserved glacial deposits are primarily created during most recent, Wisconsian glacial period. The Wisconsian-period glacier advanced into present day Ohio about 24,000 years ago and retreated about 14,000 years ago. Lobe deposits from this glacier blanket western, central, and northern Ohio. Sediments generally consist of a mixture of clay silt and sand (i.e. till). During its retreat, the glacier paused (reached a hiatus) about 18,000 years ago and formed end moraines at its snout and along its perimeters.

As the Wisconsian glacier retreated north from the Erie Basin, a large, melt-water lake was formed in advance of the glacier, within the valley of the pre-glacial, Erigans River. As icebergs calved from the retreating glacier, they floated into the glacial lake, melted, and the sediment contained within the icebergs was deposited on the bottom of the glacial lake. Thus, the distribution of grain sizes of the glacial-fluvial deposits may be varied and the stratigraphy is often complex due to: variation of sediments contained in the icebergs, seasonal variations in temperature, variable iceberg melt rates, and many other factors.

These glacial processes have produced variable burial depths of bedrock as well as variable thickness and spatial extents of unconsolidated sediments overlying bedrock beneath Lake Erie. Recent, lake-bottom sediments overlie the glacial deposits

REGIONAL STRATIGRAPHY AND GEOLOGIC UNITS

Recent, Holocene-aged sediments blanket the lake bottom in the Icebreaker project area. Those Holocene-age sediments are extremely soft to soft, fine-grained, and unconsolidated to normally consolidated. Within the windfarm vicinity, the lake-bottom sediment is predominantly composed of clay-sized particles with a lesser percentage of silt-sized particles, which trend to increase with depth.

Other, Recent, Holocene-aged sediments can include loose to medium dense sandy deposits that are present nearshore and at the mouths of rivers. These sediments generally become finer as the depositional energy decreases with distance offshore and water depth. Site-specific exploration indicates that those deposits do not extend out to the windfarm area.

Extensive and variable late Pleistocene-age, glacial deposits underlie the geologically-Recent, lake-bottom sediments. The glacial deposits are variable and complex in nature due to the various factors noted previously. They include various types of deposits such as Glacio-lacustrine, moraine, outwash and till deposits.

Within the windfarm vicinity, the subsurface exploration suggests that the Glacio-lacustrine sediments, deposited in glacial lakes, consist of a fine-grained (silt and clay), thinly- laminated (or varved) sequence of sediments. The Glacio-lacustrine deposits can include variable amounts of larger-size material embedded in the fine-grained matrix.

Lateral and terminal moraine deposits are present along the flanks, and at the locations of maximum glacial advance and at retreat hiatus positions. These deposits are typically elongated in plan dimensions and comprised of sand, gravel, cobbles, and possibly boulders. Such deposits are not present beneath the Icebreaker windfarm site.

Glacial Outwash consists of sand and gravel deposited from melt waters. These deposits include the characteristics of fluvial deposition. The site-specific exploration shows the presence of layers of such deposits interlayered with other glacio-fluvial layers.

Glacial till is comprised of rock fragments in a matrix of soil. The rock fragments may be of variable size, percentage, and lithology. They may range from fine gravel up to (less commonly) boulder size. The rock fragments may comprise a small percentage of the material volume or appreciable amounts. The soil matrix is typically stiff, overconsolidated clay or silt of varying plasticity. The data from the site vicinity indicate the possible presence of a relatively-thin, layer of till and outwash between the base of a relatively-thick, glacial-lacustrine clay and underlying bedrock.

Bedrock materials beneath Lake Erie may consist of shale, siltstone, sandstone, and limestone. Bedrock is: a) exposed at the lake-bottom along portions of the lake perimeter, b) shallowly buried, or c) may be buried by more than 30 meters of unconsolidated Quaternary sediments. Bedrock exposures along the shoreline of Lake Erie are common. Rock strength is reflected in its resistance to erosion from past glacial processes and modern coastal processes.

SEISMICITY AND SEISMIC ACTIVITY

Earthquakes of moderate to low intensity have been reported near the project area. According to the USGS seismicity map, the suburbs of East Cleveland, Euclid, and Willoughby experience above average seismic activity. Although most seismic activity in that area is less than magnitude (M) 4, seismic events greater than 4 have been recorded. The USGS seismic hazard map indicates the peak ground acceleration (PGA) associated with a 2 percent probability of occurrence over a 50-year period is between 0.10 to 0.14g.

The largest, recorded seismic event occurring below the Lake Erie region occurred in January 1986. The epicenter of that event was about 17 km south of the Perry nuclear power plant in Lake County (Nicholson et al 1988). The earthquake was felt in 11 states and generated short-duration, relatively high accelerations of about 0.18g.

WATER DEPTH AND LAKE-BOTTOM ELEVATION

The seven potential turbine locations are aligned along a south-southeast to north-northwest trending alignment (Figures 1 and 2). The lake-bottom in the turbine-development area generally slopes to the north-northwest at an average inclination of about 0.055 to 0.06 percent. The data show the lake-bottom to be flat and featureless.

The lake-bottom (Figure 3) as measured by the 2016 multi-beam echo-sounder (MBES) system slopes downward from a water depth (re: to the chart datum) of about 17.1 meters at ICE1 to about 18.4 meters at ICE7. These depth measurements may reflect the top of a layer of suspended solids, and therefore, the lake-bottom elevation may be slightly (several decimeters) deeper than indicated by those MBES measurements.

Precise measurement of the water depth at the turbine locations is complicated by the presence of extremely soft, lake-bottom deposits and a layer of suspended sediment overlying the lake-bottom. The suspended sediment creates the possibility that acoustic, (geophysical) echo-sounder measurements may underestimate the water depth due to beams being reflected off the surface of or from within the suspended sediments.

In contrast, settlement (sinkage) of drill strings and seafloor frames into the extremely soft lake-bottom sediments create the possibility that such geotechnical measurements may over-estimate the water depth. Hence, those measurements can be skewed by sinkage of the weighted tape, Roson frame, and drill pipe into the extremely soft, lake-bottom sediments and create the possibility that such geotechnical measurements may over-estimate the water depth.

Those complications were mitigated using multiple geophysical techniques and different exploration techniques. Figure 4 shows both the: a) acoustic and geotechnical water depth measurements and b) the “best estimate” of water depth. Also shown are the interpreted minimum and maximum water depths.

LAKE-BOTTOM AND SUBSURFACE CONDITIONS

LAKE-BOTTOM CONDITIONS

The turbine alignment is underlain by extremely soft lake-bottom sediments. The site-specific data indicate:

- The lake-bottom sediments include a single layer without internal (geophysical) reflectors at and to the south-southeast of ICE4
- At and to the north-northwest of ICE5, the lake-bottom sediments increase in thickness and an internal (geophysical) reflector (designated as R1) is imaged within the lake-bottom sediments.

Those conditions are illustrated by the three examples of the shallow, geophysical sub-bottom records (from the low-frequency dual-frequency echo-sounder system) shown at the top of Figure 5. The three snippets from the geophysical show (from left to right):

- An example record that is representative of the shallow sub-bottom conditions that underlie ICE 5 through ICE7,
- The record showing where the internal reflector (reflector R1) onlaps the deeper stratigraphic contact (reflector R2) about 300 meters to the north-northwest of location ICE4, and
- An example record that is representative of the shallow sub-bottom conditions that underlie ICE 1 through ICE4.

LAKE-BOTTOM SEDIMENT THICKNESS

As shown on Figure 6, the lake-bottom sediment thickness as measured with the gravity (g) CPT soundings compares favorably with the interpretation from the geophysical records. This direct correlation is true for both the total thickness of the sediments and the layer thicknesses where the sediment includes two layers.

The comparison of the measurements also provides confidence that the lake-bottom sediments thickness is relatively constant at each potential turbine location. Hence, the elevation of the underlying, older sediment surface is inferred to be relatively uniform beneath the individual turbine locations.

SUBSURFACE STRATIGRAPHY

The subsurface conditions in the turbine area consist, in descending sequence, of:

- The surface layer of very soft to soft, lake-bottom sediment (designated as the Lake-bottom Deposits; Unit LD).
- A discontinuous, layered sequence of late glacial- and post glacial-aged sediments, generally interpreted to include three stratigraphic units; namely:
  - An upper sequence of primarily granular layers (designated as the upper, Glacial Outwash deposits; Unit GO1),
  - A middle sequence of primarily fine-grained sediments (designated as the Glacio-Lacustrine deposits; Unit GL1), and
  - A lower sequence of primarily granular layers (designated as the lower, Glacial Outwash deposits; Unit GO2).
- A thick sequence of normally consolidated to slightly over-consolidated, Glacio-lacustrine clay (designated as Glacio-Lacustrine deposits; Unit GL2).
- A thin sequence of glacial deposits that can include: till, outwash, and reworked bedrock.
- Bedrock.

While the general sequence of strata is similar beneath the seven potential turbine locations, the details with respect to the layers that encompass the different strata vary considerably at the different turbine locations.

Two examples of the geophysical records using a Chirp sub-bottom profiler are shown at the bottom of Figure 5. The record at the lower right is representative of the records collected beneath the south-southeastern ICE locations, while the record at the lower left is representative of the records beneath the north-northwestern ICE locations.

The geophysical sub-bottom data show:

- The internal reflector (reflector R1) within the post-glacial lake-bottom deposits is continuous to the northwest of where it onlaps reflector R2 to the north-northwest of turbine position ICE4
- Reflector R2 that defines the base of the lake-bottom sediments is distinct (indicating a definitive acoustic contrast) and continuous.
- The mapped and unmapped reflectors within the depth interval equivalent to the post- and late-Glacial deposits are laterally discontinuous, which is consistent with the layering observed in the geotechnical exploration.
- The geophysical interpretation that the deeper layer of glacial sand and gravel outwash only underlies part of the site is consistent with the geotechnical interpretation that layer GO2 pinches out beneath ICE6.

- The geophysical interpretation that reflector B1 defines the base of the thick glacio-fluvial clay is consistent with the depth to the thin deposit of layered sediments encountered in the 2015 borings and CPT soundings at the base of Unit GL2.
- The geophysical interpretation of multiple subtle variations in the stratigraphy and conditions that are present beneath the ICE1 to ICE4 versus the stratigraphy and condition present the beneath the ICE5 to ICE7 locations is consistent with the geotechnical exploration.

GEOTECHNICAL UNIT DESCRIPTIONS

GEOLOGICALLY-RECENT LAKE-BOTTOM DEPOSITS – UNIT LD

The lake-bottom deposits consist of very soft to soft clay that grades to silty clay with depth. The sediments are of high plasticity at the lake-bottom, and the plasticity of the sediments trends to decrease with depth. The water content decreases with depth, but is above the Liquid Limit throughout the stratum.

These sediments are interpreted to increase from 0.7-meters-thick at ICE1 to 1.3-meters thick at ICE4. Beneath those four locations, the lake-bottom deposits include no internal geophysical reflectors and the changes in the character and strength of the sediments is relatively uniform throughout the full depth of the deposit.

To the north-northwest of ICE4, the sediments increase in thickness. The maximum thickness of Unit LD is at ICE6, where the lake-bottom deposits are about 3.9-meters-thick. The geophysical records image an internal reflector (reflector R1), which is sub-parallel to the lake-bottom, at about mid-depth in Unit LD. The internal reflector onlaps the base reflector about 300 meters to the north-northwest of ICE4 (Figure 9).

POST-GLACIAL OR LATE-GLACIAL DEPOSITS – UNITS GO1, GL1 AND GO2

The geologically-recent lake-bottom sediments (Unit LD) are underlain by about 3 to 6 meters of late-glacial and post-glacial sediments beneath the turbine alignment. These deposits are highly layered. Individual layers are commonly a few centimeters to several tens of centimeters thick, but can be about one meter thick. Some individual layers are continuous between adjacent turbine locations; other are not.

The layered sequence generally contains more granular layers at the top and bottom of the sequence, and is more fine-grained in the middle of the sequence. Thus, for simplicity, the sequence was grouped into three Units: 1) an upper, primarily granular unit; 2) a middle, primarily cohesive unit; and 3) a lower primarily granular unit. Those units are designated as Units GO1, GL1 and GO2, in descending sequence. The characteristics and layering within the three units is not uniform beneath the entire turbine alignment.

GLACIAL LAKE DEPOSITS – LOWER GLACIO-LACUSTRINE UNIT GL2

The late- and post-glacial sediments are underlain by a 12- to 15-meters-thick layer of Glacio-lacustrine clay, designated as Unit GL2. The top of Unit GL2 is encountered at a depth of

5.4 to 7.6 meters and an elevation of about 147.5- to 150-meters (re: Chart Datum). The top of Unit GL2 is shallowest at ICE1 and deepest at ICE6.

Unit GL2 has a crust-like shear strength profile, which initially deceases with depth below the top of the unit, and then subsequently increases with further depth. However, at locations ICE3 to ICE7, the depth to the peak undrained shear strength is overlain by a layer of stiff clay (or silty clay). These deposits are judged to be lightly overconsolidated. The combined thickness of that upper clay layer and crust is typically about 1 to 2 meters.

Unit GL2 extends down to a layer of older glacial till, outwash, and/or weathered rock. The basal layer appears to correspond to a geophysical reflector in the boomer seismic reflection data near the breakwater.

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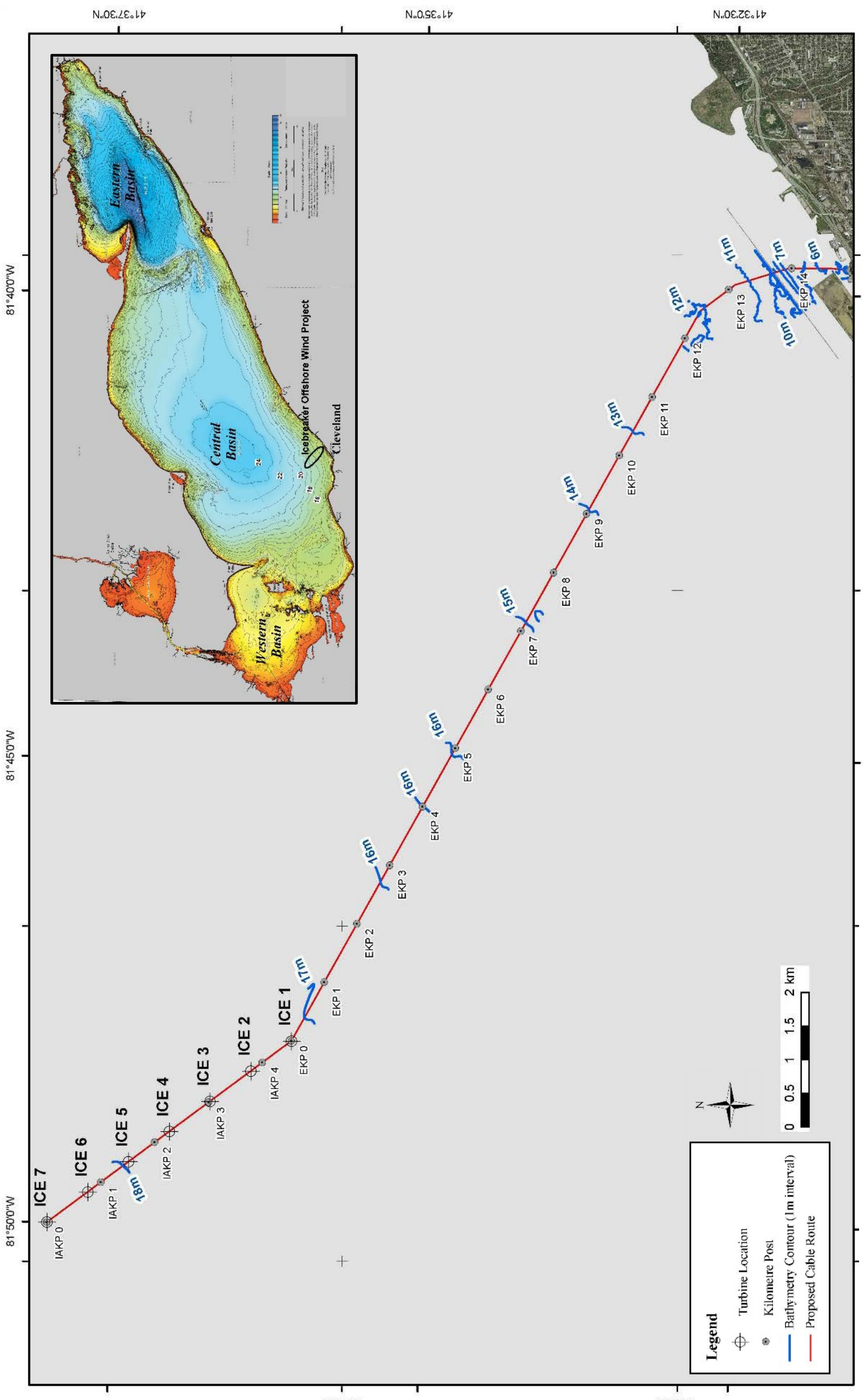
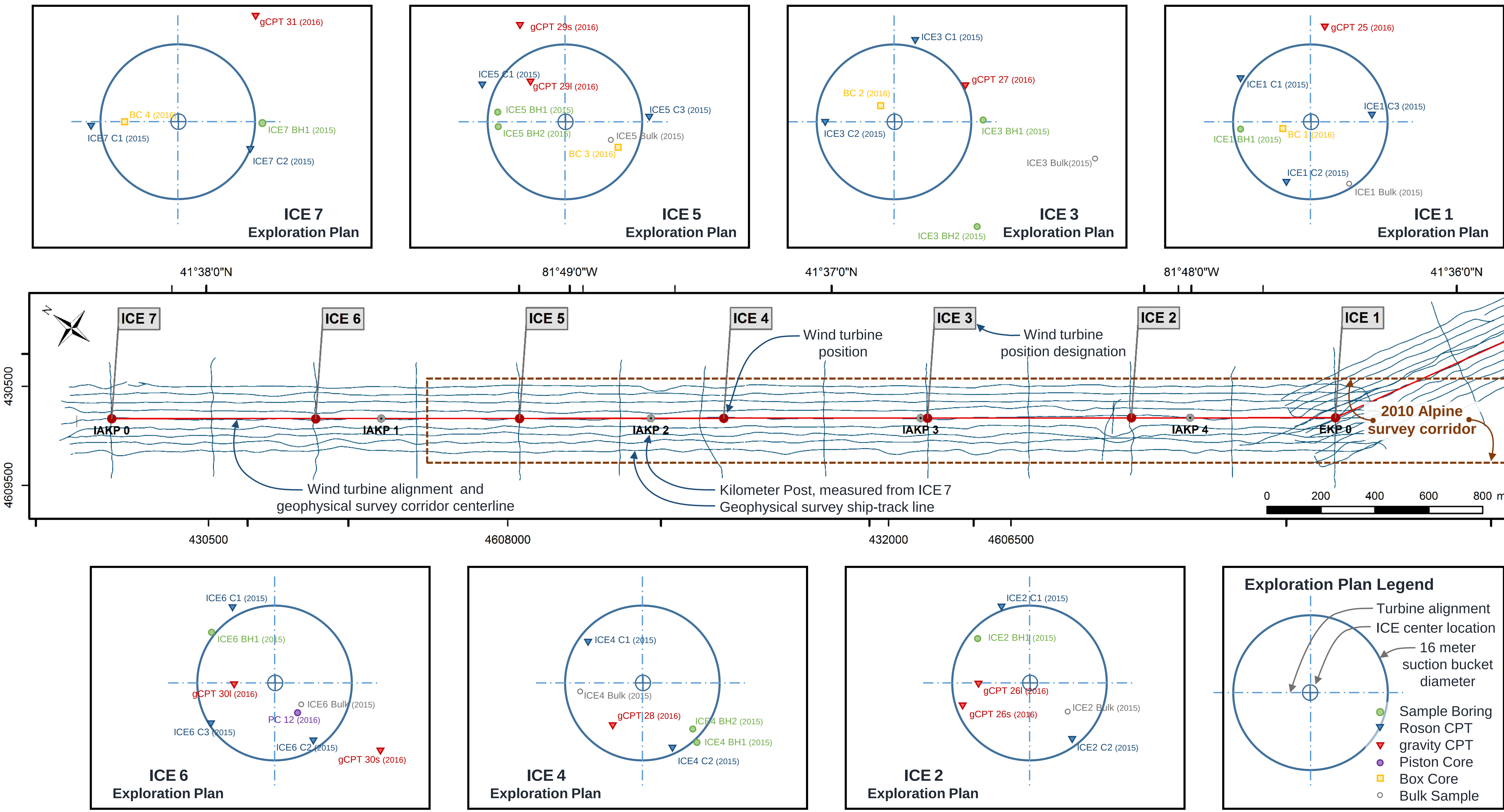


Reference: modified from McNeilan & Associates, 2017b and CSR, 2016.
Inset map modified from Holcombe, et. al. (2005).

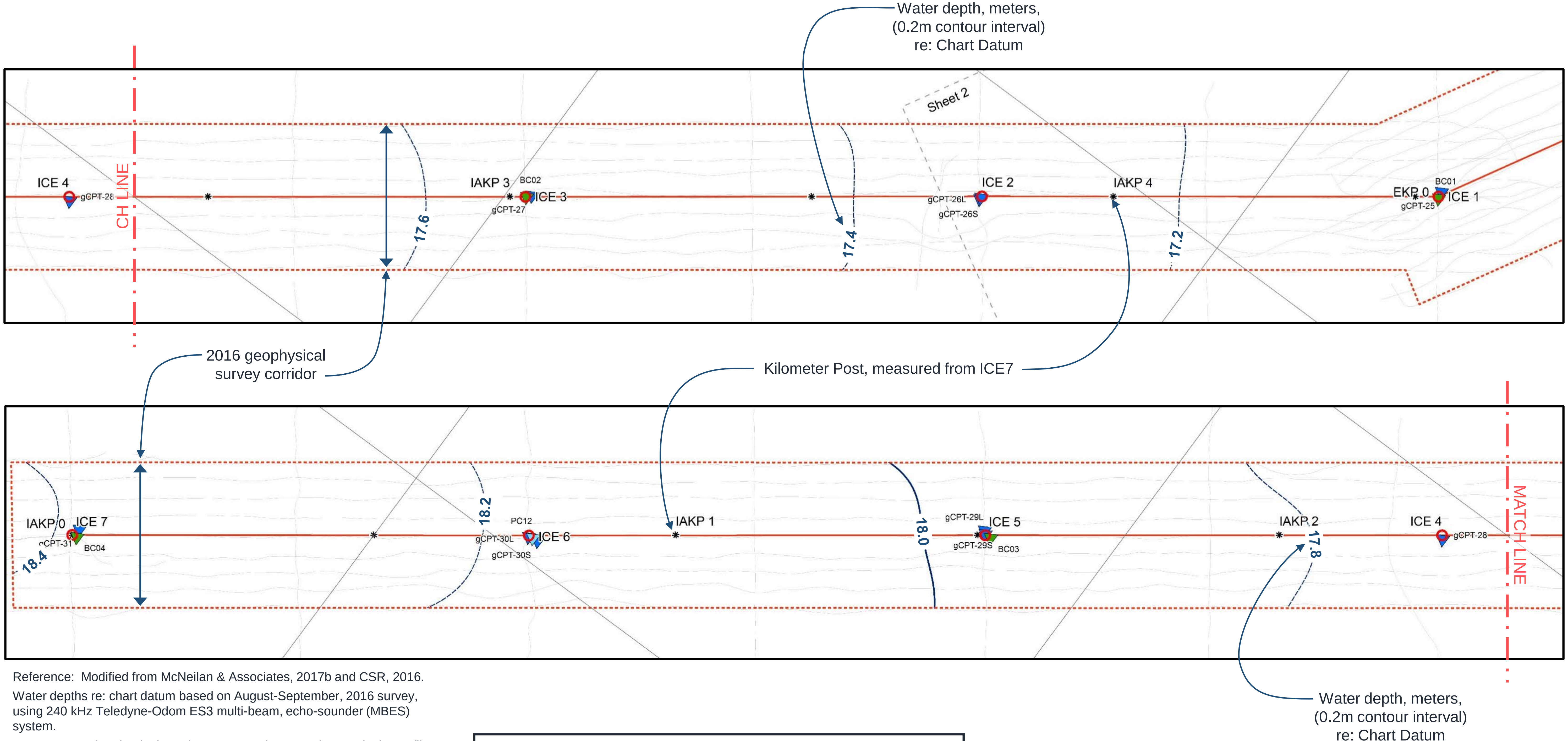
PROJECT LOCATION
Icebreaker Wind Demonstration Project



Reference: Modified from McNeilan & Associates, 2017a and 2017b

TURBINE ALIGNMENT AND EXPLORATION LOCATION PLANS
Icebreaker Turbine Alignment

McNeilan & Associates

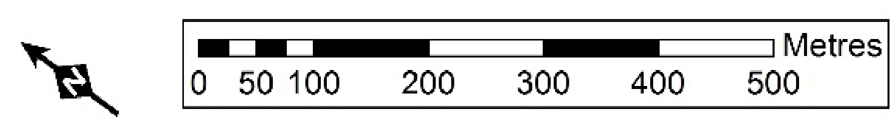


Reference: Modified from McNeilan & Associates, 2017b and CSR, 2016.

Water depths re: chart datum based on August-September, 2016 survey, using 240 kHz Teledyne-Odom ES3 multi-beam, echo-sounder (MBES) system.

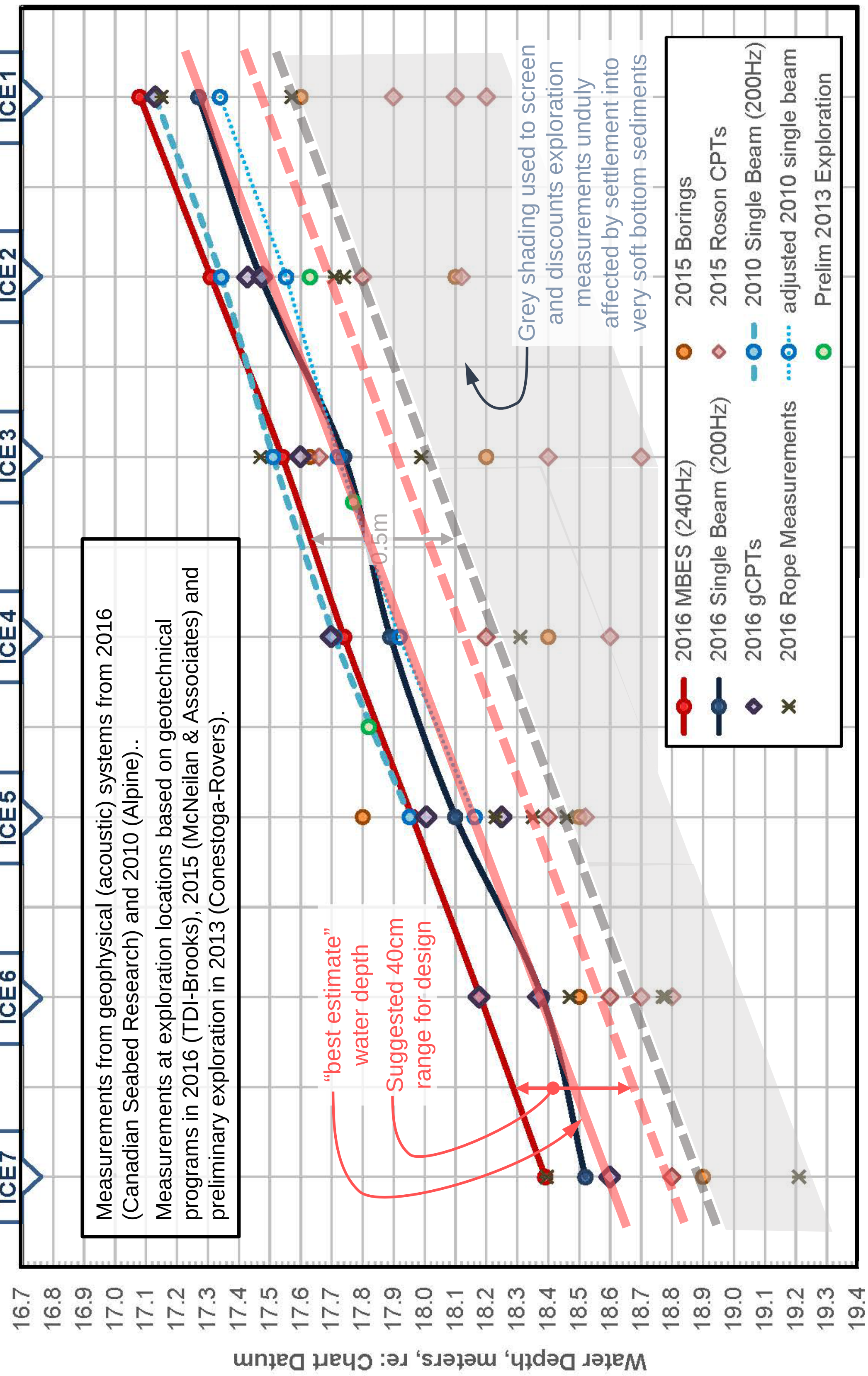
Data converted to depths based on measured water column velocity profiles that typically were between 1495 and 1500 meters/second above about 14 meters depth and between 1460 and 1465 meters/second below about 14.5 meters depth.

Water depths converted to Chart Datum based on tide data from NOAA Tide Station 9063063 (Cleveland).



ICE symbols shown at a scale equivalent to 16m diameter suction bucket

MULTI-BEAM ECHO-SOUNDER BATHYMETRY
Icebreaker Turbine Alignment



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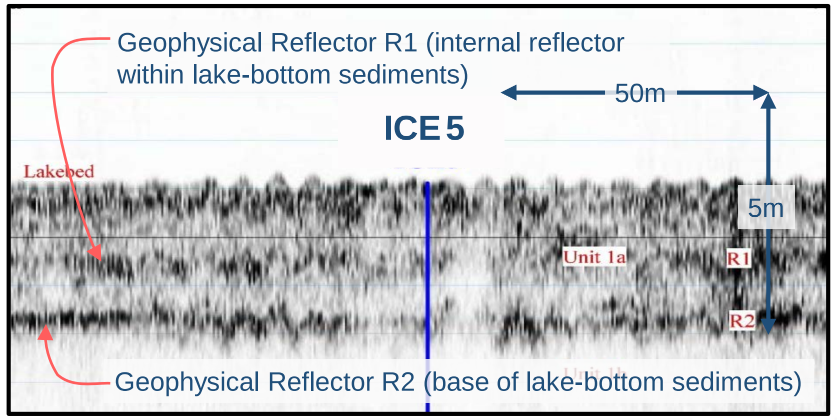
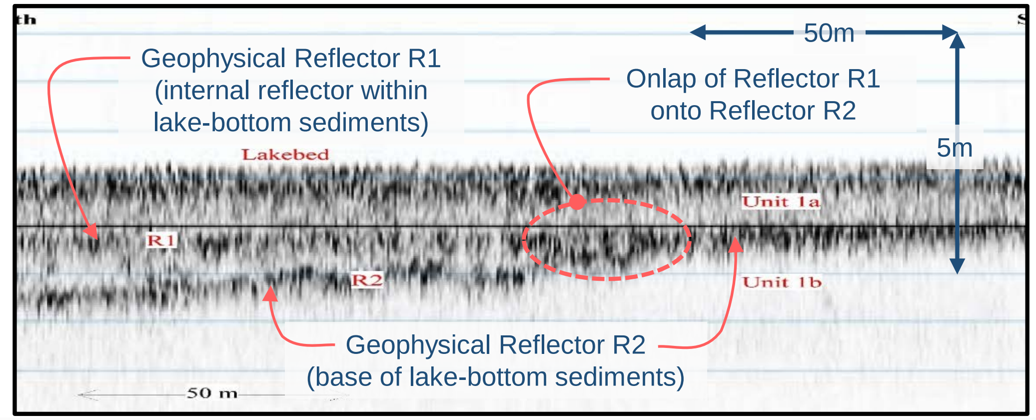
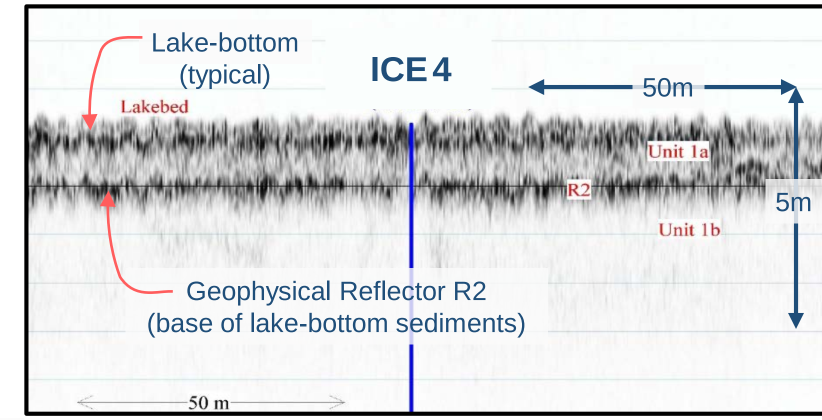
WATER DEPTH MEASUREMENTS
Icebreaker Turbine Alignment







Example Sub-bottom Profiler Records:

50 Hz sub-bottom profiler records (above)

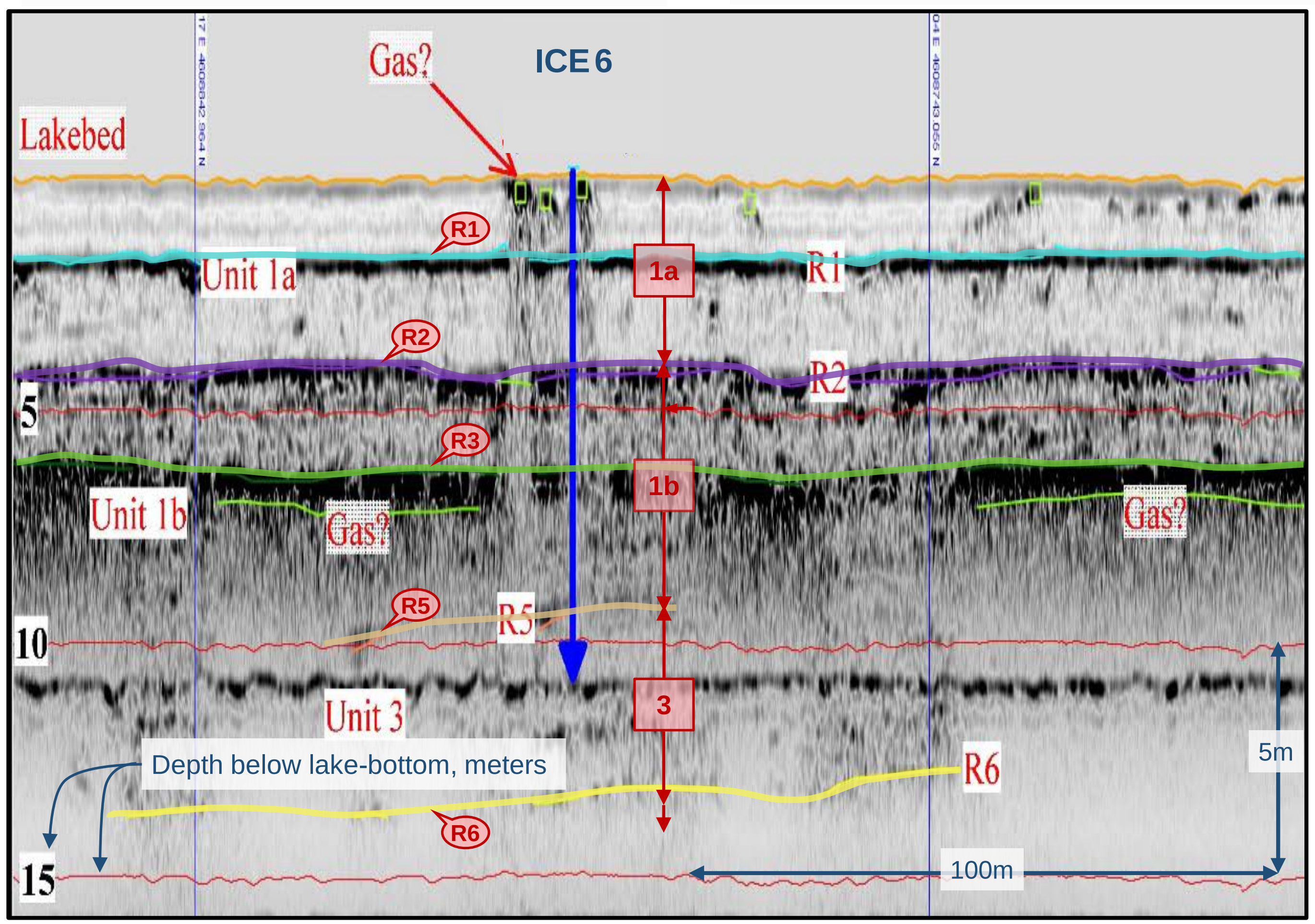
Chirp sub-bottom profiler records (below)

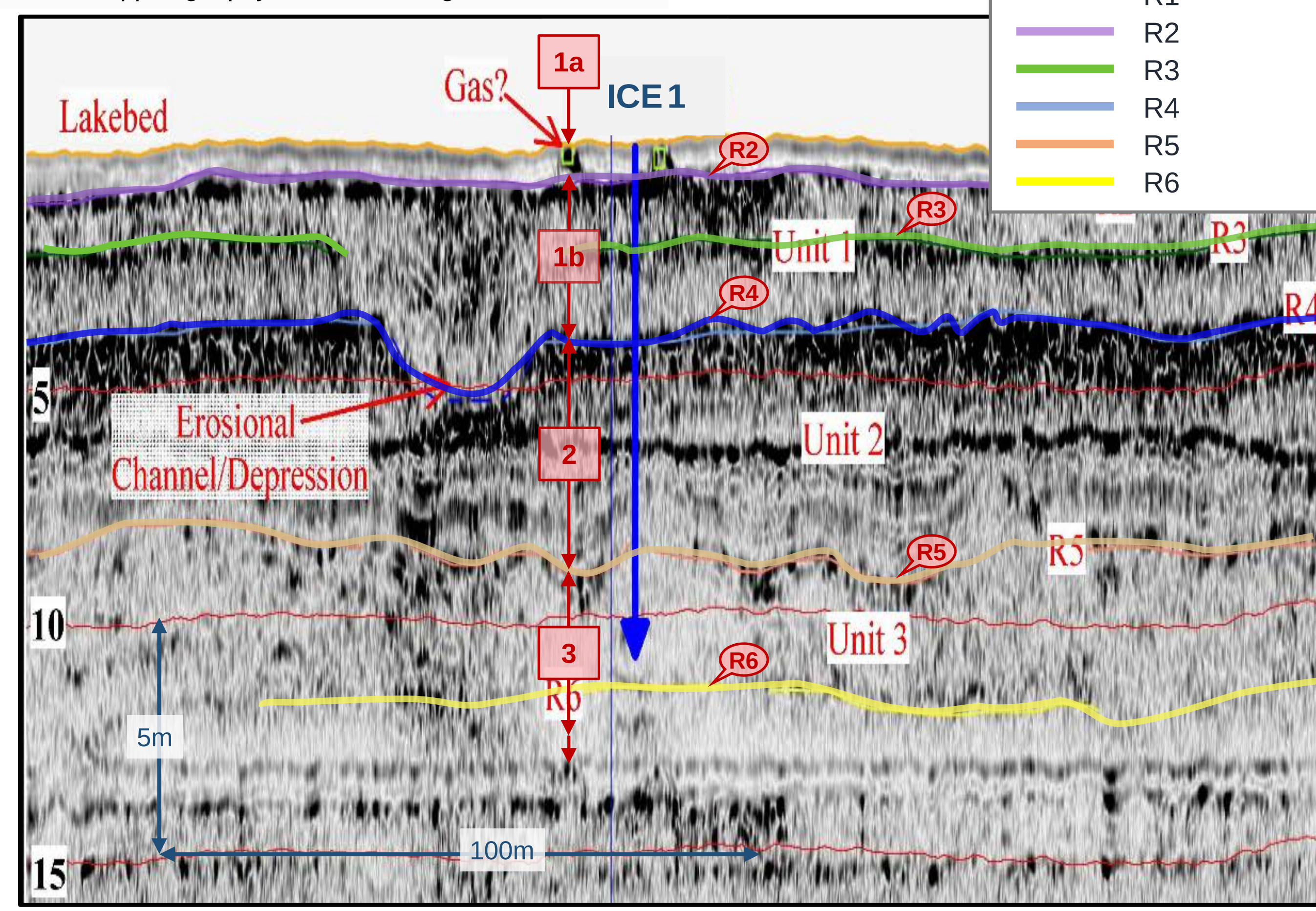
Note: Onlap of reflector R1 against reflector R2 occurs approximately 300 meters NNW of ICE4

Notes:
Vessel movement has not been suppressed from lake-bottom or underlying reflectors.
See legend to the right for color legend of mapped subsurface reflectors.
Refer to text for discussion of mapped units and relationships between mapped geophysical units and geotechnical units.

Mapped Geophysical *Reflectors:*

- Lake-bottom
- R1
- R2
- R3
- R4
- R5
- R6

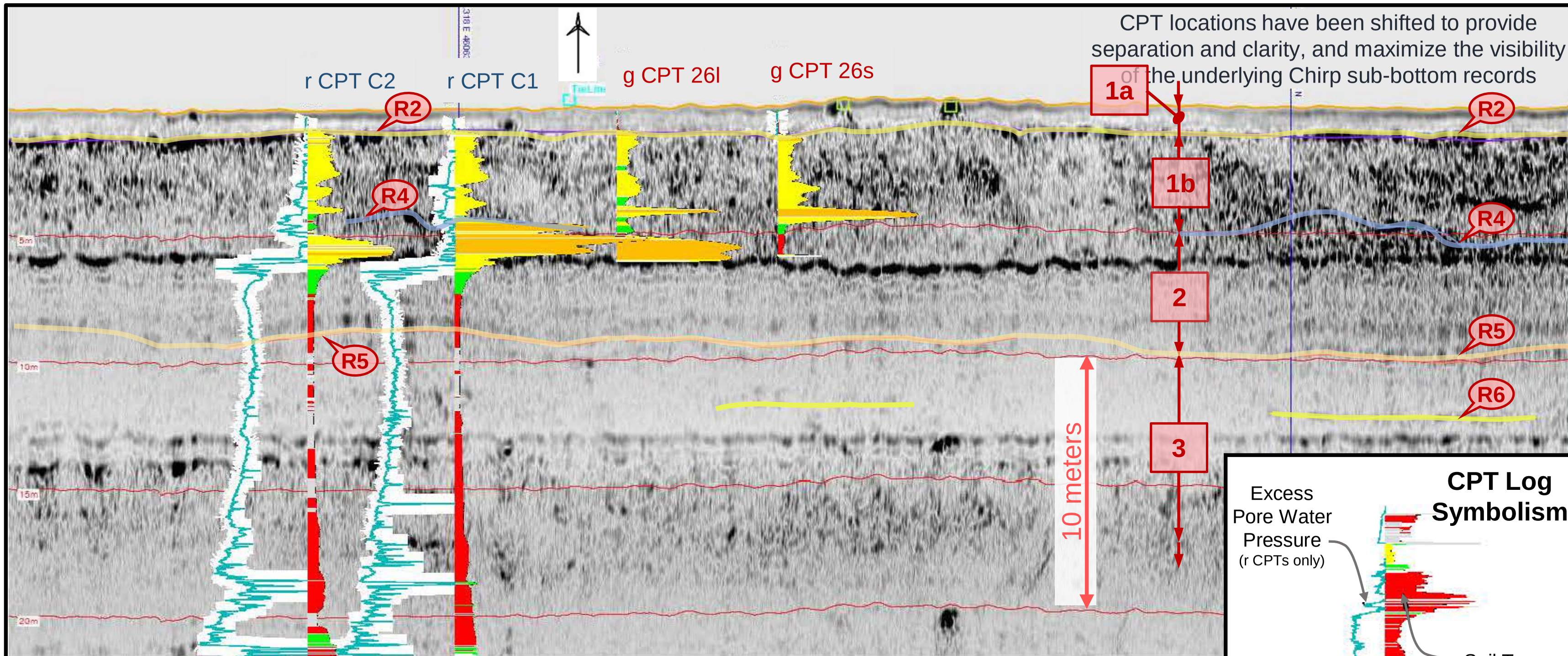


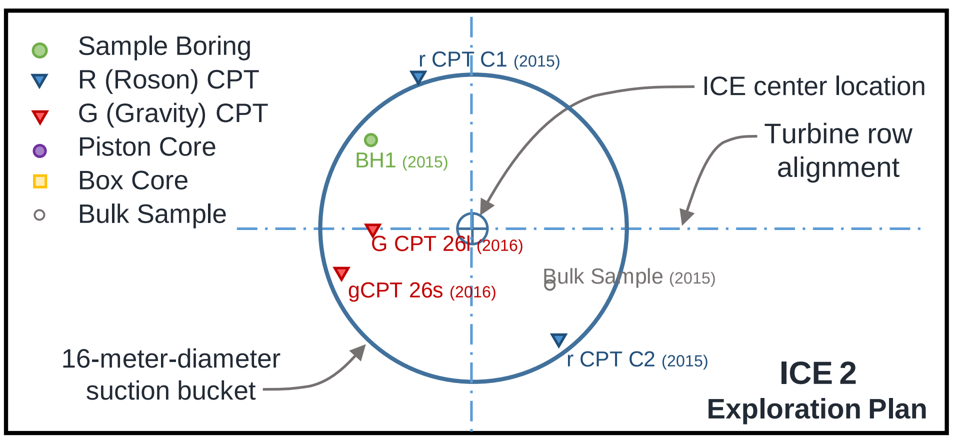


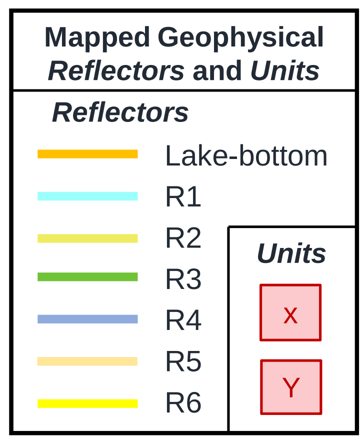
Reference: Modified from McNeilan & Associates, 2017b and CSR, 2016.

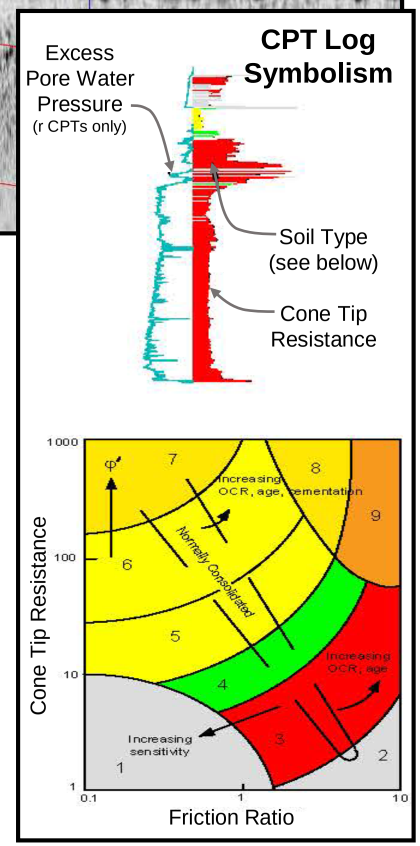
REPRESENTATIVE GEOPHYSICAL SUB-BOTTOM RECORDS
Icebreaker Turbine Alignment

McNeilan & Associates





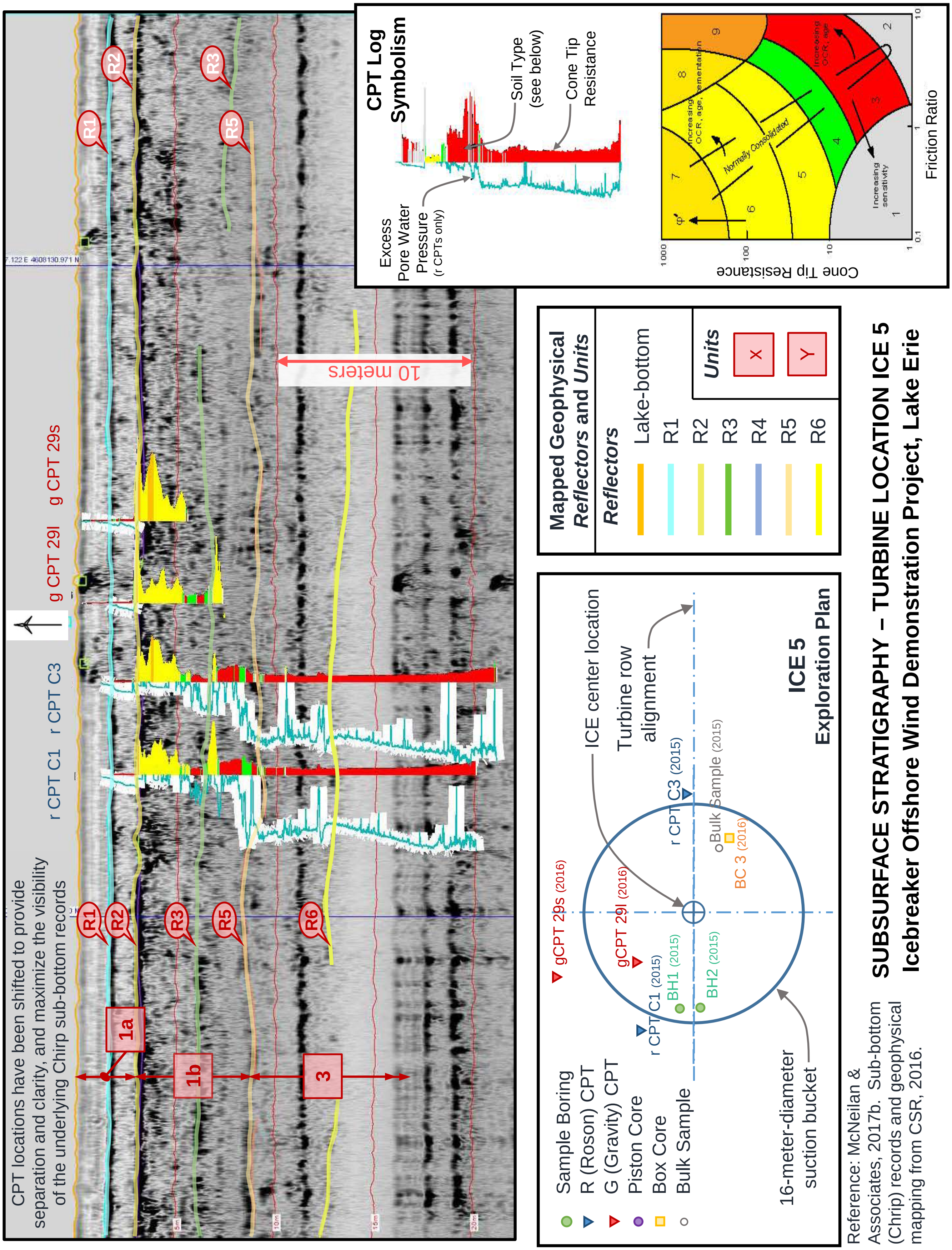




Reference: McNeilan & Associates, 2017b. Sub-bottom (Chrip) records and geophysical mapping from CSR, 2016.

SUBSURFACE STRATIGRAPHY – TURBINE LOCATION ICE 2
Icebreaker Offshore Wind Demonstration Project, Lake Erie

Figure 6a



SUBSURFACE STRATIGRAPHY – TURBINE LOCATION ICE 5
Icebreaker Offshore Wind Demonstration Project, Lake Erie

Reference: McNeilan & Associates, 2017b. Sub-bottom (Chirp) records and geophysical mapping from CSR, 2016.

Figure 6b

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