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IN THE MATTER OF AN ARBITRATION
UNDER ANNEX 14-C OF THE CANADA-UNITED STATES-MEXICO AGREEMENT (CUSMA), CHAPTER ELEVEN OF THE NORTH AMERICAN FREE TRADE AGREEMENT AND THE 2013 UNCITRAL ARBITRATION RULES

BETWEEN:

WINDSTREAM ENERGY LLC

Claimant

and

GOVERNMENT OF CANADA

Respondent

CLAIMANT'S THIRD BOOK OF EXPERT REPORTS
VOLUME 3 OF 3

TAB NOS. 8 - 13

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TAB 8

Two Dogs Projects Ltd.

Windstream Energy Inc.

Wolfe Island Shoals
Offshore Wind Farm
Wind Turbine Generator Selection

18 February 2022

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Glossary

Abbreviation or Term	Definition
AEP	Annual energy production.
AWS	The wind energy consultancy AWS Truewind.
Baird	The coastal and river engineering consultancy Baird.
Capex	Capital expenditure associated with construction of WIS.
COWI	The multi-disciplinary engineering consultancy Baird.
GBF	Gravity based foundation.
GLGH	The wind energy consultancy GL Garrad Hassan.
IEC Class	Wind speed classification limits specified by IEC 61400-1.
LCOE	Levelized cost of energy.
LIDAR	**Li**ght **D**etection **a**nd **R**anging.
MECP	Ministry of Environment, Conservation and Parks.
Met Mast	Meteorological mast.
MNR	Ministry of Natural Resources.
Opex	Operational expenditure associated with operating WIS.
Ortech	The wind energy consultancy Ortech.
PPA	Power purchase agreement.
TI	TI or Turbulence Intensity is defined as the ratio of standard deviation of fluctuating wind velocity to the mean wind speed, and it represents the intensity of wind velocity fluctuation.
RTI	Representative turbulence intensity is the mean TI plus 1.28 times the standard deviation of data around the mean.
SGRE	Siemens Gamesa Renewable Energy.
SODAR	**SO**nic **D**etection **A**nd **R**anging is a device used to deduce wind speed and direction from pulses of sound emitted from the instrument that are reflected to the instrument from atmospheric turbulence.
V_{ave}	Maximum annual average wind speed.
V_{e50}	50-year return extreme 3 second gust.
V_{ref}	50-year return extreme 10-minute wind speed.
Weeks	Weeks Marine.
Wind Shear	Wind shear is the difference in horizontal wind speed at two heights in the atmosphere. Regarding WTGs, the heights of interest are across the WTG rotor disc. That is, WTG hub height +/- Rotor Radius.
Wind Shear Coefficient, α	The Wind Shear Coefficient, α, is used to determine the wind speed V_2 at height H_2 from the wind speed V_1 measured at height H_1 in the formula: $V_2 = V_1*(H_2/H_1)^{\alpha}$.

Abbreviation or Term	Definition
WIS	Wolfe Island Shoals Offshore Wind Farm.
Wood	The wind energy consultancy Wood.
WTG	Wind turbine generator.

1 Introduction

As an employee of SgurrEnergy (now Wood plc), I previously conducted studies for Windstream Energy Inc. (Windstream) filed in arbitration proceedings under the North American Free Trade Agreement in respect of the Wolf Island Shoals (WIS) offshore wind farm (referred to in this report as NAFTA 1).

The studies commissioned by Windstream in relation to NAFTA1 were to assess the technical feasibility of WIS. Based on the data provided by Windstream and SgurrEnergy's extensive knowledge of the then state-of-the-art of offshore wind industry practices, WIS was considered to be technically feasible. That is, WIS could be constructed and be operational within the required deadlines.

I understand that, on 18 February 2020, the Ontario Government notified Windstream that the power purchase agreement (feed-in tariff contract) issued for the Project had been cancelled by them. In response, Windstream submitted a Notice of Intent (February 2020) and a Notice of Arbitration (November 2020), as the initial steps in a second round of NAFTA arbitration proceedings (referred to in this report as NAFTA2).

In support of NAFTA2, Two Dogs Projects Limited was asked to conduct a wind turbine generator (WTG) selection process and to provide an updated opinion on the preferred WTG selection. This study considers recent information and experience since NAFTA1 and provides an opinion on the preferred WTG should the Project have been allowed to proceed in February 2020 in the absence of ("but for") restrictions imposed by various government agencies (outlined below).

Windstream has asked me to assume that the Ontario Government did not adopt an indefinite-term moratorium on offshore wind development on February 11, 2011. Instead, Windstream has asked me to assume that the following would have occurred by **18 February 2020**:

a) Ministry of Environment, Conservation and Parks (MECP, formerly MOE) would have confirmed its proposed regulatory amendment to include a five-kilometre setback, or confirmed that it would not proceed with any regulatory amendment (such that setbacks for offshore wind projects would continue to be assessed on a site-specific basis);

b) Ministry of Natural Resources (MNR) would have fulfilled its commitment to discuss the reconfiguration of Windstream's applications for Crown land for the Project (if a five-kilometre setback was confirmed) and would have thereafter fulfilled its commitment to "move as quickly as possible through the remainder of the application review process so that the Project may obtain Applicant of Record status in a timely manner.";

c) MECP and MNR would have fulfilled their commitment to process the Project's application for a Renewable Energy Approval (REA) within the six-month service guarantee;

d) MNR would have permitted Windstream to proceed through MNR's Crown land application process and granted Windstream site release;

e) the Ontario Government would have dealt with Windstream in good faith and not have subjected the Project to unreasonable regulatory delays; and

f) the FIT Contract was not cancelled.

The report has been prepared to document the process employed by Windstream to select an appropriate wind turbine generator (WTG) for WIS.

Analysis of the WIS wind regime and the precedent set by existing and proposed offshore wind farms using GBFs led to the conclusion that that standard onshore IEC Class II_B WTGs on the shortest standard towers were suitable for deployment on GBFs in the offshore, non-saline environment of Lake Ontario. While many WTGs comply with IEC Class II_B requirements, only the top five onshore and offshore WTG manufacturers were considered to reduce technology risk. From these viable WTG options, the Vestas V136-3.45MW and V136-4.2MW and SGRE SG 3.4-132 and SG 4.5-145 were selected for further analysis, as they were believed to present the lowest technology risk and were shown to meet the WIS selection criteria.

The WTG selected for WIS was the SGRE SG 4.5-145, as this yielded the lowest cost of energy of the candidate WTGs. That is, of the WTGs assessed, the SGRE SG 4.5-145 was the most economically attractive option.

Section 2 of this report provides a summary of the relevant experience and expertise of the author of this report and Two Dogs Projects Limited.

Section 3 of this report reviews the extensive wind data recoded by Windstream and the analysis performed by multiple consultants with relevant expertise in wind farm development to determine the appropriate IEC class of WTG to deploy at WIS.

Section 4 of this report identifies several potential WTGs that would be suited to WIS from the world's top five WTG suppliers in 2019. From this initial group of WTGs four candidate WTGs are identified for further analysis and confirmation that the candidate WTGs meet the WIS selection criteria.

Section 5 of this report determines an appropriate hub height for the candidate WTGs based on the precedent set by operational or planned offshore wind farms employing gravity-based foundations (GBF).

Section 6 of this report selects a WTG for WIS based on annual energy production from realistic WIS layouts, approximate capital costs of each layout and approximate operational costs, in effect the WTG selected is that which yields the lowest levelized cost of energy (LCOE).

Section 7 of this report confirms that the WTG selected is compatible with operation in the WIS layout and therefore expected to meet or exceed the specified 20-year design life.

2 Relevant Experience and Expertise

2.1 Ian Irvine and Two Dogs Projects

I have been at the forefront of the development of the renewable energy industry for over 30 years. My career in the renewable energy industry has included senior management roles in the UK electricity utility ScottishPower and subsequently the engineering consultancy Ingenco, which included establishing ScottishPower's internal renewable energy technical team in the early 1990s, generating business and internal management of resources, leading a team of 25 staff as the Development Group Manager for Ingenco supporting the development of fossil fuel plant, CHP, biomass, hydro-energy and wind projects and electrical infrastructure developments.

I established SgurrEnergy, an engineering consultancy focussed on the renewable energy industry, in 2002. I led, directed and grew the company from a team of two to over 300 dedicated professionals working on several hundred renewable energy projects worldwide. SgurrEnergy became a leader and innovator within the renewable energy industry. In 2016, I sold SgurrEnergy to Wood Group. I exited the business in 2017 and now work as an independent consultant, offering engineering consulting services through Two Dogs Projects.

I have been on the board of Point and Sandwick Power Limited, the UK's largest community owned wind farm, since 2017. Since 2019 I have been on the board of Clir Renewables Inc., a rapidly growing software start up, developing a world leading cloud-based renewable energy asset management and reporting software tool that optimises the performance of wind and solar assets.

2.2 Relevant Experience

I have been involved in offshore wind since undertaking technical due diligence on the world's first project financed offshore wind farm, the 120MW Princess Amalia wind farm (Q7), located off the coast of the Netherlands. I continued to provide expert technical advice on numerous offshore wind farms to developers and financiers regarding offshore wind measurement campaigns, WTG selection, wind farm design, WTG performance assessment, WTG enhancement and monitoring, technical due diligence and operation and maintenance.

I played a central and critical role in two major offshore wind studies for the Chinese Government in 2007 and 2009 (part-funded by the World Bank and EU respectively). I have also advised on numerous offshore wind farms throughout the UK, Europe, Asia and North America, exposing me to most of the offshore wind turbine technologies currently in operation. These include, but are not limited to, East Anglia, Burbo Bank, Humber Gateway, Beatrice, Neart na Gaoithe, Veja Mate, Galloper, London Array, MEG 1, Westermost Rough, Cape Wind, Nordsee Ost and North Hoyle.

I was Project Director on a major offshore wind R&D project involving the deployment of three scanning lidar units on 5MW Areva turbines in the Alpha Ventus offshore wind farm, between 2012 and 2014, an R&D programme sponsored by Areva, Mitsubishi and SSE, known as the Efficient Offshore Wind Project (EWOP). This programme investigated wind inflow conditions to large scale wind turbines and the behaviour and structure of wind turbine wakes, revealing the true characteristics and complexity of the wind and the resulting response of wind turbines.

3 Wolfe Island Shoals Wind Regime

3.1 Wind Measurement Campaign and Wind Regime Characterisation

There are several characteristics of wind flow that are calculated from wind flow measurements to determine the response of a WTG to wind flow at the site under investigation.

The characteristics of wind flow that are typically determined from a wind regime measurement campaign, during development of a wind farm, are listed in Table 1, along with the main uses of the characteristic.

Characteristic	Primary Use	Secondary Use
Annual average wind speed and wind speed distribution	Annual energy production	Structural and aerodynamic load calculation.
Gust wind speeds	Structural and aerodynamic load calculation.	
Turbulence intensity	Structural and aerodynamic load calculation.	Annual energy production
Wind shear	Structural and aerodynamic load calculation.	Annual energy production

Table 1 – Measured Wind Flow Characteristics

Additionally, ambient temperature, pressure, and relative humidity are measured to determine air density, the probability of the occurrence of icing and whether there are any periods of extreme (high or low) temperature, during which the WTG will not be able to operate.

Two aspects of the wind flow measurement campaign that will significantly impact the accuracy of wind flow characterisation are the heights at which the measurements are made and the duration of the measurement campaign.

3.1.1 Measurement Heights

Wind speeds were measured using an 80m meteorological (met) mast at Long Point on Wolfe Island. Long Point is a narrow peninsula that protrudes 2km into Lake Ontario from Wolfe Island. The wind regime at this location is like that observed in the offshore environment. The location of this mast relative to the proposed wind farm site is shown in Figure 1. The Long Point mast was approximately 10km from the centre of the WIS development area. The elevation of the mast at Long Point was approximately 3m above the mean water level of Lake Ontario, giving an effective measurement height of 83m above the mean water level of Lake Ontario.

Ideally, wind speed measurements would be made at the hub height of candidate WTGs to reduce the error associated with extrapolation of measurements made at lower elevations. The larger the distance between the highest measurement height and the proposed hub height of the candidate *WTG*s the larger the extrapolation error. This potential extrapolation error was mitigated in the WIS Project's wind measurement campaign by employing a sonic detection and ranging (SODAR[1]) system, capable of measuring wind speed and direction at 11 heights, between 30m and 200m above the base of the Long Point met mast. As a result, wind speed and direction data exist across the plane of the rotor of the candidate WTGs, that can be used to minimise extrapolation error.

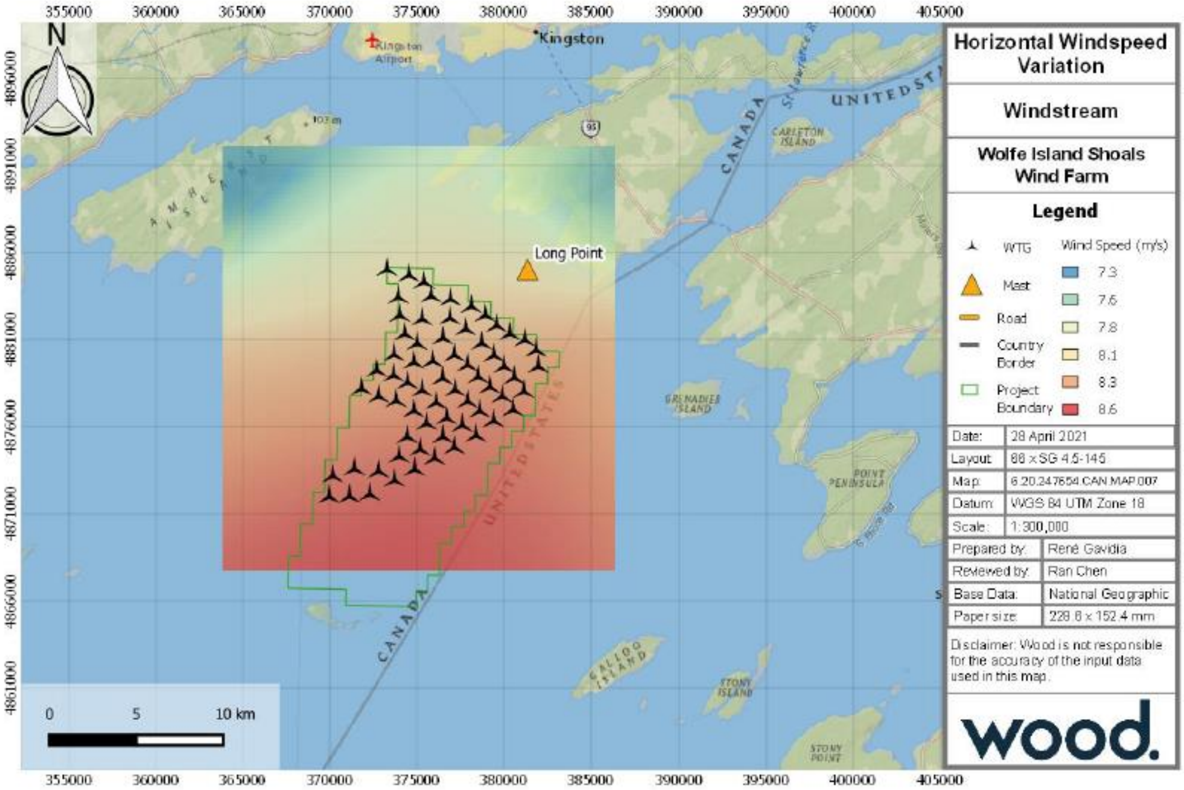

Figure 1 – Long Point 80m Mast Location

The number of measurement heights on the met mast also impacts the extrapolation error, whereby the fewer the measurement heights the larger the extrapolation error. To address this, the wind measurement campaign employed multiple measurement heights, which reduces extrapolation error. This is further solidified by the SODAR measurements.

The way the instrumentation is fixed to the met mast has an impact on measurement accuracy. Several independent consultants[2] have determined that the configuration of instrumentation on the Long Point met mast was broadly compliant with the mounting guidelines in IEC 61400-12-1, the standard used to determine the response of WTGs to wind flow.

That Windstream used an 80m met mast (effective height 83m above water level) with five appropriately configured measurement heights. This approach minimises the extrapolation error and results in an accurate calculation of the *Wind Shear Coefficient*, which is used to determine wind speed from the highest measurement height to the hub height of the candidate *WTG*s.

[1] SODAR systems emit sound pulses and determine wind speed and direction at different heights above the deployment location from the reflections of these pulses by atmospheric turbulence.

[2] **CER-SgurrEnergy** Document No.: 14/7017/001/USA/0/ER/001, Revision B1, Section 5.1 (A review of multiple reports issued by Helimax Energy, Zephyr North, ORTEC, GLGH, and AWS Truepower between 2009 and 2013). GLGH Canada Inc., Document No. 800450-CAVA-T-01, Wolfe Island Shoals Wind Farm, Issue C (This included a site visit to the Long Point met mast).

Additionally, as noted above, Windstream deployed a SODAR system adjacent to the Long Point met mast. This measurement campaign was able to confirm the *Wind Shear Coefficient* at Long Point up to 200m, effective height 203m above the mean level of Lake Ontario.

The meteorological mast measurements can be used to accurately characterise wind flow regarding candidate WTGs with an effective hub height of up to 203m above the mean level of Lake Ontario. Above 203m effective hub heights, the accuracy of the characterisation will reduce with increasing height.

3.1.2 Measurement Campaign Duration

Wind characteristics vary continuously. For example, the variation in wind speed is driven by temperature and pressure differences that vary throughout the day and seasonally, throughout the year. As a result, the accuracy of the long-term prediction in a wind measurement campaign is linked to the duration of the measurement campaign, whereby the longer the measurement campaign is run, the more accurate is the prediction of long-term wind regime characteristics.

Windstream collected approximately three and a half years of wind data from the Long Point met mast between December 2011 and March 2014, culminating in a bankable energy analysis. This is significantly more than that required to accurately characterise wind flow at a site (typically 12 months of contiguous data, which can be extrapolated to determine long-term wind regime characteristics) and will lead to more accurate calculations and predictions of wind flow characteristics.

3.1.3 Conclusions on Wind Measurement Campaign and Wind Regime Characterisation

The heights at which the measurements were made at the Long Point met mast using conventional instrumentation on an 80m met mast, supported by SODAR measurements up to 200m and the duration of the measurement campaign, generated a dataset that could be used to accurately quantify the wind flow characteristics listed in Table 1, up to an effective WTG blade tip height of approximately 200m above the mean level of Lake Ontario.

3.2 Wind Regime Analysis

3.2.1 Wind Flow Modelling

Over 12 months of wind data recorded during the measurement campaign discussed in Section 2.1 were analysed by two independent consultants, namely:

- AWS Truewind, July 2013[3] (AWS)
- GL Garrad Hassan, September 2013[4] (GLGH)

Using the best available wind flow modelling techniques, AWS and GLGH used the data collected at Windstream's Long Point met mast to determine wind speeds at WTG locations within the proposed offshore wind farm.

[3] **CER-SgurrEnergy** AWS Report: Wind Resource and Energy Production Summary, July 9, 2013.

[4] **CER-SgurrEnergy** GLGH Report: Wolfe Island Shoals Wind Farm Preliminary Energy Assessment, 800450-CAVA-T-01, 30 September 2013.

Ortech Consulting also undertook wind flow modelling using the Long Point mast data in 2014[5], refining the analysis in subsequent reports it prepared in 2015[6] and 2017[7]. In 2021, Wood repeated the analysis of the full measured wind data set and developed another wind flow model[8]. Where different consultants employ similar analytical tools and techniques to predict wind flow over a potential wind farm site, it is reasonable to expect that the results of their respective analyses to be broadly consistent, which is what was observed in a comparison of the ORTEC and Wood reports.

As Wood's analysis is most recent and utilises its collective, cumulative experience and knowledge of wind flow analysis and offshore wind farm design, it is this analysis that is referenced in the subsequent sections of this report.

3.2.2 Average and Extreme Wind Speeds

As discussed in Section 3.1.2, the longer the measurement campaign, the more accurate the prediction of long-term wind regime characteristics. While this is important to the average annual wind speed it is also important to the prediction of extreme wind speeds, as more data are collected in the higher wind speed ranges from which long-term extreme wind speeds are predicted.

The key figures predicted by Wood at the Long Point met mast location at **100m** above ground level are:

- Long-term Annual Average Wind Speed, V_{ave}: **8.2m/s**
- Maximum 50-year return extreme 3 second gust, V_{e50}: **50.0m/s** in 240° Sector
- Maximum 50 year return extreme 10-minute wind speed, V_{ref}: **44.3m/s** in 150° Sector

As the Long Point mast is 3m above the mean level of Lake Ontario the effective prediction height is 103m above Lake Ontario.

Table 2 lists the wind speeds for each IEC 61400-1 (2005) wind class corresponding to V_{ave}, V_{ref} and V_{e50}.

Parameter	IEC Class I (m/s)	IEC Class II (m/s)	IEC Class III (m/s)	IEC Class IV (m/s)
Maximum Annual Average Wind Speed, V_{ave}	10	8.5	7.5	6
50-year return extreme 3 second gust, V_{e50}	70	59.5	52.5	42
50-year return extreme 10-minute wind speed, V_{ref}	50	42.5	37.5	30

Table 2 – IEC 61400-1 Wind Speed Classes

[5] **C-2004** Ortech 2014 Report: WRA for Wolfe Island Shoals Offshore Wind Project Using SWT2.3MW-113 Turbine - Report #70347-5.

[6] **C-2017,** Ortech 2015 Report: WRA for Wolfe Island Shoals Offshore Wind Project – Report #70347-6 (May 26, 2015).

[7] **C-2099,** Ortech 2017 Report: WRA for Wolfe Island Shoals Offshore Wind Project – Report #70802 (June 5, 2017).

[8] **CER-Wood** Wood Report: Wolfe Island Shoals Wind Farm Energy Yield Assessment 04 June 2021 191540.CAN.AM.REP.01 B4.

The predicted V_{ave} of 8.2m/s is below the IEC Class II limit of 8.5m/s.

There is a clear margin between the IEC Class II V_{e50} wind speed of 59.5m/s versus the predicted maximum mast V_{e50} of 50.0m/s. That is, while an IEC Class II WTG will be capable of withstanding the forces produced by an extreme gust of 59.5m/s of three seconds duration, the maximum three second gust predicted for the mast location is well below this at 50.0m/s and is in fact lower than the corresponding IEC Class III V_{e50} of 52.5m/s.

The predicted maximum V_{ref} of 44.3m/s is slightly above the IEC Class II limit of 42.5m/s in the 150° sector, to which the WTGs will be oriented for approximately 9% of the operational life. This exceedance would merit a mechanical loads assessment be undertaken by the WTG supplier during the negotiation of the WTG supply agreement.

Except for the V_{ref} exceedance in the 150° sector, the Long Point mast indicates that the WIS site is nominally IEC Class II. V_{ave}, V_{e50} and V_{ref} are predicted by Wood at each of the WTG locations in the final layout for the WTG selected in this report. This is discussed in Section 7 of this report.

3.2.3 Turbulence Intensity

Turbulence intensity (TI) is the ratio of standard deviation of varying wind speed to the mean wind speed. TI is a measure of the variability of wind speed. The higher the TI, the more variable the wind speed.

The significance of this wind flow characteristic is that it affects the life of a WTG. For example, a WTG exposed to and annual average wind speed of 8.5m/s with a low TI will last longer that the same WTG exposed to an annual average wind speed of 8.5m/s with a high TI.

To put this into context, the combination of average hub height wind speed and TI is analogous to structural fatigue loading, where the average cyclic load on a structure (wind speed) and the number of cycles (TI) of the load the structure is subjected to before the structure fails.

Each of the IEC Classes listed in Table 2 has a TI subclass associated with it. This is defined as TI_{ref}, where the reference wind speed is 15m/s. The TI levels associated with each IEC 61400-1 subclass are listed in Table 3.

Parameter	IEC Class I	IEC Class II	IEC Class III	IEC Class IV
Subclass A **$TI_{ref, 15m/s}$**	0.16			
Subclass B **$TI_{ref, 15m/s}$**	0.14			
Subclass C **$TI_{ref, 15m/s}$**	0.12			

Table 3 – IEC 61400-1 Turbulence Intensity Subclasses

The turbulence intensity analysis at the Long Point met mast location undertaken by Wood was based on 3696 x 10-minute wind speed and standard deviation measurements records from the 15m/s measurement bin and analysed as specified in IEC 61400-1.

Representative turbulence intensity (RTI) is defined as the mean TI plus 1.28 times the standard deviation of data around the mean to provide a factor of safety on the measured data.

The average TI_{15} at the Long Point met mast was 0.05, well below the IEC subclass B TI_{15} of 0.14. The average RTI_{15} was 0.08, half of the IEC subclass B RTI_{15} of 0.16, which is shown in Figure 2. While some 30° direction sectors showed RTI_{15} levels close or at the IEC subclass B RTI_{15} limit of 0.14, there are very few measurements in these sectors. For example, the 60° sector shows an RTI_{15} of 0.14, which is based on four records out of 3696. While fewer data points may affect the accuracy of the analysis, the fact that the highest values of TI are infrequent lessens the impact on WTG life.

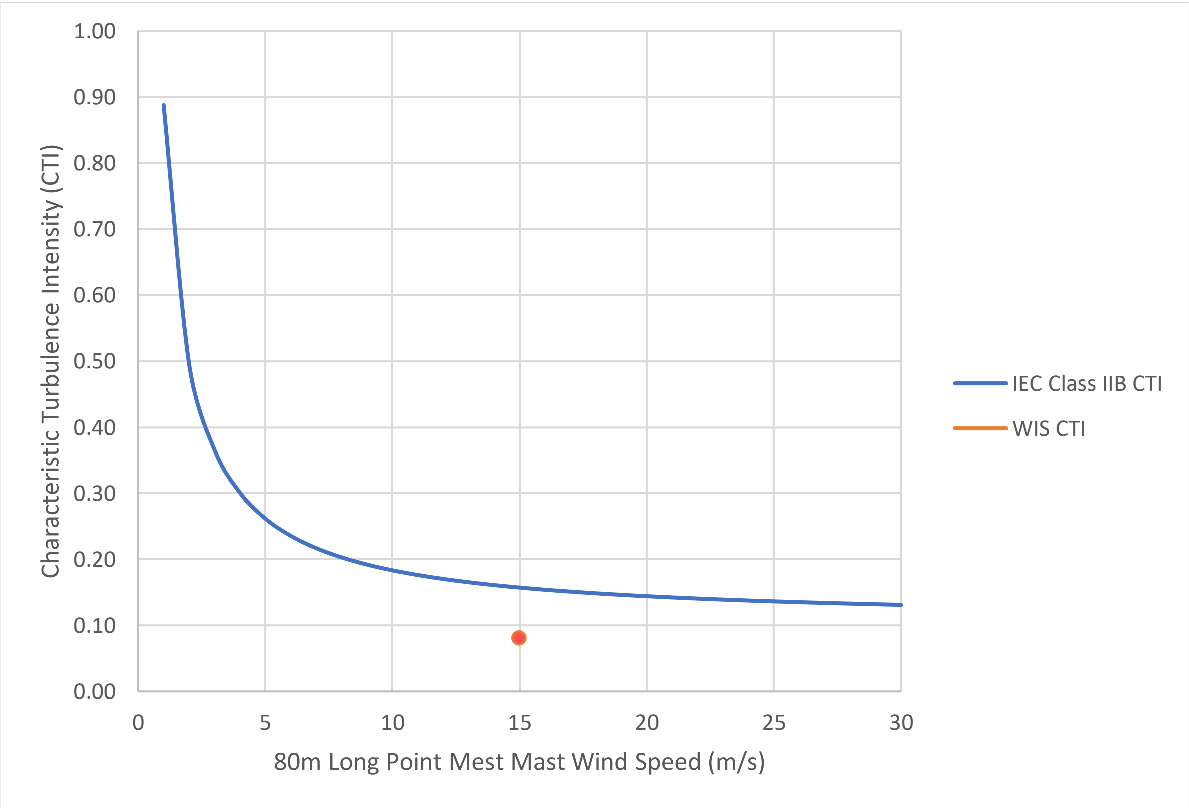

Figure 2 – IEC Class II_B CTI versus Wind Speed with Long Point Met Mast CTI at 15m/s

The significance of this result is that TI and RTI are very low at Long Point met mast and will most probably be lower across the WIS site due to its exposed, low surface roughness location. Consequently, IEC Class II_B WTGs should be able to achieve the 20-year design life at a higher annual average hub height wind speed of 8.5m/s.

3.2.4 Wind Shear

Wind shear is the variation in wind speed with height above ground level and in the zone of interest, the heights occupied by the WTG rotor blades, nominally 25m to 200m. Wind speed typically increases with height above ground level. This relationship is defined by:

- $V_1/V_2 = (H_1/H_2)^{\alpha}$, where:

  V_1 = wind speed at height, H_1

  V_2 = wind speed at height, H_2

  α = the wind shear coefficient

The larger the difference between wind speeds at two heights, the higher the wind shear coefficient, α. The higher the wind shear coefficient the larger the load imbalance between the top and bottom of the WTG rotor. Like TI, this imbalance is cyclic and impacts the life of the WTG by introducing a cyclic fatigue load on the WTG blades that transmits through to the WTG foundation.

Wood analysed the data from the Long Point met mast and produced wind shear coefficients for each 30° direction sector, calculating the average wind shear coefficient at 0.12. The maximum wind shear coefficient specified in IEC 61400-1 is 0.2. Figure 3 compares the average measured wind speed versus height profile with that based on the in IEC 61400-1 design wind shear coefficient of 0.2.

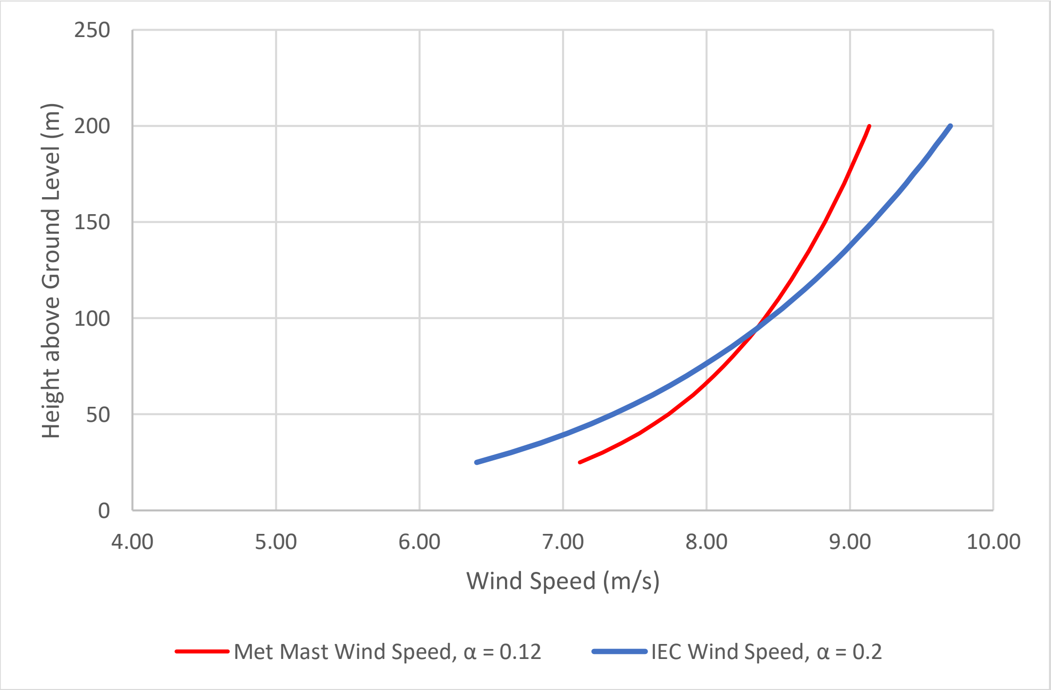

Figure 3 – Site versus IEC Wind Shear Coefficient

It can be seen from Figure 3 that the wind speed versus height profile at the Long Point met mast is steeper than that allowed by IEC 61400-1. This will result in a lower loading imbalance across the rotor disc than is allowed by IEC 61400-1, extending the fatigue life, and by default, the operational life of the WTGs.

Wood calculated wind shear coefficients at the Long Point met mast in 12 x 30° sectors and observed wind shear coefficients of 0.22 in two sectors, namely 90° and 150°. This is not considered an issue as wind flows in these sectors occur approximately 12.5% of the time.

In conclusion, wind shear at WIS is considered low and will result in significantly less fatigue loading on WIS WTGs compared to that allowed for in the design of an IEC Class II_B WTG.

3.2.5 Discussion on Wind Regime Analysis

The ultimate purpose of the wind regime analysis is to determine the wind flow characteristics at each WTG installed in WIS. To complete this analysis, the WTG needs to be selected and an appropriate wind farm layout designed. The first step in this process is to determine which IEC classification is most likely to be observed at WIS based on wind speed measurements made at the Long Point met mast.

The Long Point met mast was located on a narrow peninsula and measured wind characteristics that are like those observed at WTGs in WIS.

The predicted long term annual average wind speed at the Long Point mast at 100m above ground level, V_{ave}, is 8.2m/s and is below the IEC Class II limit if 8.5m/s. The average wind shear, α, measured at the Long Point mast is 0.12 and well below the IEC 64100-1 design basis wind shear of 0.2. Similarly, the representative turbulence intensity of 8% at 15m/s, RTI_{15}, is well below the IEC 64100-1 design basis of 16%. The 20-year design life of a WTG specified in IEC 61400-1 is based on the lifetime fatigue loading derived from, V_{ave} = 8.5m/s, α = 0.2 and RTI_{15} =16%. Each of these parameters at the Long Point mast is less than the IEC Class II_B limit. Therefore, given that the Long Point mast location is considered representative of the WIS wind farm location, it is likely that the design life of WTGs located there will exceed 20 years. Additionally, given the margin between the IEC 61400-1 limits for α and RTI_{15} and those measured at the Long Point met mast, WTGs in the WIS Project could achieve the IEC 61400-1 20-year design life if exposed to a V_{ave} higher than 8.5m/s, which could be expected should a WTG hub height higher than 100m be selected for WIS.

The extreme wind speed analysis shows a clear margin between the IEC Class II V_{e50} (three second gust) wind speed of 59.5m/s and the predicted maximum V_{e50} of 50.0m/s at the Long Point met mast. The predicted maximum V_{ref} (10-minute gust) wind speed of 44.3m/s is slightly above the IEC Class II limit of 42.5m/s in the 150° sector.

While the V_{ref} exceedance in the 150° sector would merit further investigation by the WTG manufacturer during the negotiation of the WTG supply agreement, the Long Point met mast indicates that the WIS site is nominally IEC Class $II_{B,}$ and it is recommended that IEC Class II_B WTGs are considered for the WIS layout. Modelling of IEC Class IIB WTGs for the WIS site is consistent with previous work undertaken for the WIS Project. Further, IEC Class IIB WTGs are in use in the immediate vicinity of WIS and throughout Ontario, which indicates that this IEC Class of WTG is appropriate for the WIS Project.

3.3 Operational Wind Farms near WIS

Table 4 lists details from several operational wind farms in the vicinity of the WIS site.

Wolfe Island Wind Farm, which is located 4km north of the Long Point met mast, would be exposed to the same wind regime as the Long Point met mast in the 150° sector. Specifically, further to the discussion in Section 3.2.2, the WTGs located at Wolfe Island Wind Farm are likely to be subject to a similar V_{ref} as the WIS Project, and therefore could be subject to a V_{ref} exceedance in the 150° sector, although this may be lower than that predicted at the Long Point met mast at 100m as these WTGs have a hub height of 80m.

Ernestown Wind Farm is located 25km northwest of the Long Point met mast and, as the hub height for these WTGs is 98m, it is probable that the same V_{ref} exceedance in the 150° sector would be predicted for WTGs at this wind farm, based on the Long Point met mast measurements.

Amherst Island Wind Farm is located 17km northwest of the Long Point met mast and, as the hub height for these WTGs is 99.5m, it is probable that the same V_{ref} exceedance in the 150° sector would be predicted for WTGs at this wind farm, based on the Long Point met mast measurements.

Project	Rating (MW)	WTG	Hub Height (m)	IEC Class	Commissioning Year	Latitude	Longitude
Wolfe Island Wind Farm	197.8	Siemens SWT 2.3-101	80	IIB	2009	44.192	-76.376
Ernestown Wind Farm	10	Enercon E-82/2000	98	IIA	2015	44.236	-76.728
Amherst Island Wind Farm	75	Siemens SWT 3.2-113	99.5	IIA	2018	44.124	-76.729

Table 4 – Operational Wind Farms Near WIS

The conclusion that can be drawn from these observations is that while these wind farms carry a similar risk of the IEC Class II V_{ref} limit of 42.5m/s being exceeded in the 150° sector, the owners and WTG suppliers were able to either mitigate or better quantify the V_{ref} exceedance risk to facilitate construction and successful operation of these wind farms. This precedent confirms that IEC Class II WTGs will be suitable for the WIS site.

3.4 Conclusions

Windstream measured and recorded extensive data during the Long Point met mast and SODAR deployments that adequately characterises the wind regime at the Long Point met mast location.

AWS, GLGH, ORTECH and Wood performed best practice wind flow analysis to predict the long-term wind regime at the Long Point met mast and all analyses indicate that this wind regime closely matches that specified for IEC Class II_B.

One IEC Class II extreme wind speed parameter, V_{ref}, is exceeded in the 150° sector. However, the precedent set by operational wind farms in the immediate vicinity of the Long Point met mast and the WIS site demonstrate that this risk can be mitigated to facilitate construction and operation of IEC Class II WTGs in this area. The extent to which mitigation is required would be investigated with the WTG manufacturer while negotiating a WTG supply agreement.

4 Candidate WTGs

4.1 WTG Selection Criteria

Candidate WTGs for the WIS had to satisfy the following criteria:

- Be circa 4MW rated and at least IEC Class II_B certified
- Be available in Canada in 2020
- Comply with the FIT Contract and expected to be approved through the Renewable Energy Approval (REA) process
- Be capable of utilising the original COWI gravity-based foundation (GBF) without major modification
- Be capable of being installed using a vessel(s) with access to the St. Lawrence Seaway (e.g., Weeks Marine Inc. using the vessel R.D MacDonald)

4.2 Candidate WTGs

Due to the rapidly evolving technology options for both offshore and onshore wind projects, many alternatives for WTG selection exist. However, current WTG models designed for offshore applications have evolved in size to the point where they are no longer suitable for installation on lake environments.

WTG models that meet the above selection criteria are either older offshore models that have been superseded, and are therefore no longer available, or onshore models that best meet the selection criteria and have been deployed in offshore environments. Therefore, as far as is practicable, candidate WTGs aligning with the second WTG model category were investigated. WTGs aligning with the second category will have additional benefit of technological improvement compared to superseded models and a proven track record in the offshore environment.

4.2.1 Suitability of Onshore WTGs in the Offshore Environment of Lake Ontario

Except for ice loading, which only affects WTG foundation design, Lake Ontario is benign compared to the offshore environment in which wind turbines are currently being deployed.

The metocean conditions (the combined wind, wave and climatic conditions) observed at WIS were previously confirmed by Baird as being less aggressive than the metocean conditions observed in typical offshore wind developments in Europe and North America. That is, the wind regime is IEC Class II_B compared to IEC Class I_B for North Sea offshore wind farms, the wave heights are lower, and the atmosphere is non saline.

Therefore, IEC Class II_B WTGs are appropriate for use in the offshore environment of Lake Ontario. Indeed, this approach is consistent with other projects where WTGs that are predominantly used for onshore projects have been deployed offshore. The following Siemens Gamesa press release is an example:

Siemens Gamesa will supply the SG 4.5-145 for its first nearshore project in Vietnam.

The company will supply seven SG 4.5-145 for the first phase of the No. 5 Thanh Hai wind farm project (32 MW), located between 2 km and 5 km off the coast. It will also provide service and maintenance for 10 years.

Siemens Gamesa leveraged its offshore wind power leadership to develop a special configuration of its onshore wind turbines adapted to a nearshore environment.[9]

The adaptations described by Siemens Gamesa are most likely required due to the saline environment in that location. This is not an issue for the WIS Project, which is located on a freshwater lake.

Given the close match of the selection criteria and modern onshore WTG models, and global experience with their deployment offshore, the most suitable WTG selection for this Project is larger modern IEC Class II_B onshore models.

4.2.2 Candidate WTG Manufacturers

Table 5 shows the 2019 market share for the world's top five WTG manufacturers in three categories: global share, onshore share and offshore share.

The WTG manufacturers that consistently feature in the top five categories are Vestas/MHI Vestas, Siemens Games Renewable Energy (SGRE), Goldwind, GE Renewable Energy and Envision. It was considered appropriate to consider WTGs from this group of the most successful onshore and offshore WTG manufacturers to reduce technology risk.

Each of these WTG manufacturers offer WTGs of around 4MW:

- Vestas: V136-3.45MW, V136-4.2MW
- SGRE: SG 3.4-132, SG 4.5-145
- Goldwind: GW 136-4.8
- GE Renewable Energy: GE 3.8-130
- Envision: EN 130-4.0, EN 136-4.3, EN 148-4.5

While any of these WTGs could be considered for further assessment against the criteria listed in Section 4.1, it was decided that the Vestas and SGRE WTGs would be explored further for two reasons. First, this selection of WTGs will provide an insight into effect of WTG size on Project economics. Second, with around one third of the global and onshore markets and over half of the offshore markets, WTGs from these manufacturers are considered to present the lowest technology risk.

[9] C-2225, Siemens Gamesa Nearshore Project Vietnam (July 22, 2019).

Top 5 wind turbine suppliers in annual global market in 2019
Vestas – 18.0%
Siemens Gamesa Renewable Energy – 15.7%
Goldwind – 13.2 %
GE Renewable Energy – 11.6%
ENVISION – 8.6%
Top 5 onshore wind turbine suppliers in annual global market in 2019
Vestas (20.10%)
Goldwind (13.61%)
Siemens Gamesa Renewable Energy (12.97%)
GE Renewable Energy (12.45%)
Envision (8.55%)
Top 5 offshore wind turbine suppliers in annual global market in 2019
Siemens Gamesa Renewable Energy (39.77%)
MHI Vestas (15.70%)
Sewind (10.04%)
Envision (9.53%)
Goldwind (9.37%)

Table 5 – WTG Manufacturer's Market Share[10]

4.2.3 Candidate WTGs

Table 6 lists the candidate WTGs, namely:

- Vestas: V136-3.45MW, V136-4.2MW
- SGRE: SG-3.4-132, SG 4.5-145

These are compared with the original WIS WTG proposed during NAFTA1, the Siemens SWT-2.3-113. Substantial numbers of these WTG types have been sold globally, demonstrating that the technology is proven and mitigating the technology risk further.

4.2.4 Comparison of Candidate WTGs with Selection Criteria

WTG selection criteria are listed in Section 4.1.

The WTGs listed in Section 4.2.3 are all around the required 4MW rating, at least IEC Class II_B certified, and all were available in Canada in 2020.

The WTGs, and more specifically the preferred option (SG 4.5-145) would be expected to meet environmental approval requirements under the Renewable Energy Approval (REA) and other permitting processes as described in updated reports prepared by other Windstream

[10] https://gwec.net/wind-turbine-sizes-keep-growing-as-industry-consolidation-continues.

technical experts (WSP, WF Baird & Associates, Aercoustics). Appendix A confirms that the largest WTG, the SG 4.5-145, can be installed on the original COWI gravity-based foundation (GBF) without modification with a 90m hub height tower. Therefore, all other lower capacity WTGs are considered compliant with this criterion at similar hub heights.

Appendix B confirms that the heaviest WTG, the SG 4.5-145, is capable of being installed by a sample vessel (the R.D MacDonald) in a two-lift process. Therefore, all other lower capacity and lighter WTGs can be installed either in a single or two lift process.

To refine the WTG selection, the most appropriate WTG hub height needs to be determined, which is the subject of Section 5.

WTG	Hub Heights (m)	Effective Tip Height[11] (m)	IEC Class	Operating Temperature Range (°C)	Project References
Siemens SWT-2.3-113	80	146.5	II_B		
Vestas V136-3.45MW	82, 112, 132	160, 190, 210	II_B/III_A	-20 to +45 Derating above +30 -30 option available	
Vestas V136-4.2MW	*82, 112, 132*	160, 190, 210	II_B/S	-20 to +45 Derating above +30 -30 option available	[12]2020 [13]2020 [14]2020 [15]2019 [16]2018
Siemens Gamesa SG 3.4 - 132	84, 97, 101.5, 108, 114, 134, 154, 165	160, 173, 177.5, 184, 190, 210, 230, 241	I_A/II_A	-20 to +30 High and low temperature options available	[17]2020 [18]2020 [19]2019 [20]2018
Siemens Gamesa SG 4.5 - 145	90, 107.5, 127.5, 157.5	172.5, 190, 210, 240	II_B	-20 to +35 High and low temperature options available	[21]2020

Table 6 - Candidate WTGs

[11] Effective Tip Height is Tip Height relative to ground level +10m to account for height of GBF above mean lake level.

[12] **C-2301,** News article titled "Vestas to deliver 11 turbines for Oosterschedldekering Wind Optimization project" (May 15, 2020).

[13] **C-2305,** Press Release titled "Vesta wins 249 MW order in USA (June 23, 2020)**.**

[14] **C-2314,** Yahoo Finance News Article titled "Wind farm Bäckhammer successfully completed and delivered to KGAL" (August 31, 2020).

[15] **C-2258,** News Release from Vestas Asia Pacific titled "Vesta wins first V136-4.2 MW order in South Korea" (December 27, 2019).

[16] **C-2489,** News Release from Vestas-American Wind Technology – "Vestas received first V136-4.2 MW order in North America with 146 MW in Canada" (September 27, 2018)

[17] **C-2316,** News article titled "SGRE to supply 301MW to wind farm in southern Morocco" (September 3, 2020).

[18] **C-2292,** ReNews.Biz News article titled "Djbouti debut for Siemens Gamesa" (February 25, 2020).

[19] **C-2207,** News article titled "Siemens Gamesa will supply 36 units of its SG 3.4-132 wind turbine for the Voltalia wind project in Brazil" (January 25, 2019).

[20] **C-2181,** News article titled "Siemens Gamesa to supply 92 wind turbines of its latest models to ten wind farms in Spain" (October 7, 2018) (https://keyfactsenergy.com/news/1165/view/.

[21] **C-2282,** Article titled "Suncor Energy Forty Mile Wind Power Project" (2020).

4.3 Conclusions

This WTG review and selection process has identified several standard onshore IEC Class II_B WTGs are suitable for the offshore environment of Lake Ontario.

WTGs were identified from the top five onshore and offshore WTG manufacturers to reduce technology risk. From these viable WTGs options, the Vestas V136-3.45MW and V136-4.2MW and SGRE SG 3.4-132 and SG 4.5-145 were selected for further analysis, as they are believed to present the lowest technology risk and shown to meet the selection criteria specified in Section 4.1.

As the V136-3.45MW, V136-4.2MW, SGRE SG 3.4-132 and SG 4.5-145 WTGs are offered with a variety of hub heights, the most appropriate hub height for WIS must be determined, which is the subject of Section 5.

5 Appropriate WTG Hub Height

5.1 Typical Hub Height Determination Process

WTG manufacturers offer WTG models with a variety of rotor hub heights. Using a hub height higher than the lowest, or standard, hub height offered by a WTG manufacturer is largely a matter of economics.

As discussed in Section 3.2.4, due to wind shear, wind speed increases with increasing height above ground level. Therefore, the higher a rotor is positioned above ground (or lake) level, the more energy it will capture.

The consequence of placing a rotor at a higher elevation than standard is increased WTG tower costs and increased WTG foundation costs to mitigate the greater loads.

To determine whether there is an economic advantage in using a higher hub height than standard requires analysis of annual energy production (AEP), capital expenses (Capex) and operating expenses (Opex).

As the measured wind shear coefficient at WIS is low, it was thought that the advantage of increased AEP would be outweighed by the disadvantage of increased Capex. To test this assertion, a review of operational and proposed offshore wind farms using GBFs was undertaken, as reported in Section 5.2.

5.2 Analysis of Operational and Proposed Offshore Wind Farms using GBFs

Table 7 lists operational and proposed wind farms using GBFs. The WTG rotor diameters and hub heights corresponding to the operating and proposed WTGs at each wind farm are also listed in Table 7. Table 8 lists candidate WTGs for WIS with the corresponding effective hub height. Effective hub height is the specified WTG manufacturer hub height +10m to account for the height of the GBF above the mean level of Lake Ontario.

Project/Technology	Rotor Diameter (m)	Hub Height (m)	Maximum Water Depth (m)
Karehamn/V112-3MW	112	79.6	20
Vindpark Vanern/WWD-3MW	100	90	13
Avedore Holme/SWT-3.6MW	120	93	2
Rodsand II/SWT-2.3MW	82.4	69	12
Sprogo/V90-3MW	90	70	16
Thornton Bank/RePower 5MW	126	95	27
Lillgrund/SWT-2.3MW	93	65	13
Breitling/Nordex 2.5MW	90	90	0.5
Rodsan I/SWT-2.3MW	82.4	69	10
Middelgrunden/SWT-2.0MW	76	64	6
Tuno Konb/V39-500kW	39	45	7
Vindeby/Bonus 450kW	35	35	4
Frecamp/GE 6MW	150	100	30

Table 7 – Operational & Proposed Offshore Wind Farms with GBF Foundations

The hub heights listed in Table 8 are the lowest standard hub height offered for the WTG and the next highest standard hub height. While it is recognised that WTG manufacturers can offer site specific hub heights, that is, a custom-made WTG tower can be manufactured for the site, this option has not been considered as it introduces an unnecessary technology risk (since the standard hub heights are proven to work in real-world conditions).

Technology	Rotor Diameter (m)	Effective Hub Height (m)	Maximum Water Depth (m)
SWT-2.3-113	113	90	30
V136-3.45	136	122	30
SG 3.4-132	132	118	30
SG 4.5-145	145	118	30
V136-3.45	136	92	30
SG 3.4-132	132	94	30
V136-4.2	136	122	30
V126-3.45	126	97	30
V136-4.2	136	92	30
SG 4.5-145	145	100 (= 90m[22] standard tower + 10m above mean lake level)	30

Table 8 – WIS Candidate WTGs

In Figure 4, the WTG hub height from Table 7 is plotted against WTG rotor diameter from Table 7 for the operational/proposed WTGs listed in Table 7, the blue markers. The best fitting line is fitted to these data, the dashed blue line.

Figure 4 also plots the WTG hub heights from Table 8 is against WTG rotor diameter from Table 8 for the WIS candidate WTGs listed in Table 8, the grey markers. In Figure 4, the hub height/rotor diameter data from Table 8 fall into two groups:

- Effective hub heights in the range 118m to 122m that are outliers to the dashed blue trend line.
- Effective hub heights in the range 90m to 100m that straddle the dashed blue trend line.

The latter group of hub heights represents the lowest standard hub height offering from each WTG manufacturer.

The conclusion from this analysis is, the offshore wind industry precedent indicates that using hub heights taller than the lowest standard hub height on offer from a WTG manufacturer will not yield an economic advantage. Accordingly, the lowest standard WTG hub height is preferred for WIS.

[22] Shortest standard hub height for the SG 4.5-145.

This preference is consistent with WTGs exposed to the low wind shear coefficients typically observed in the offshore environment and the additional capital expenditure associated with constructing a higher hub height WTG. That is, a higher hub height in a low wind shear environment is unlikely to be exposed to wind speeds that are high enough to justify the increased costs needed to elevate the WTG hub height. Additionally, the WIS wind regime at 100m aligns with the IEC Class II_B wind regime criteria discussed in Section 3.

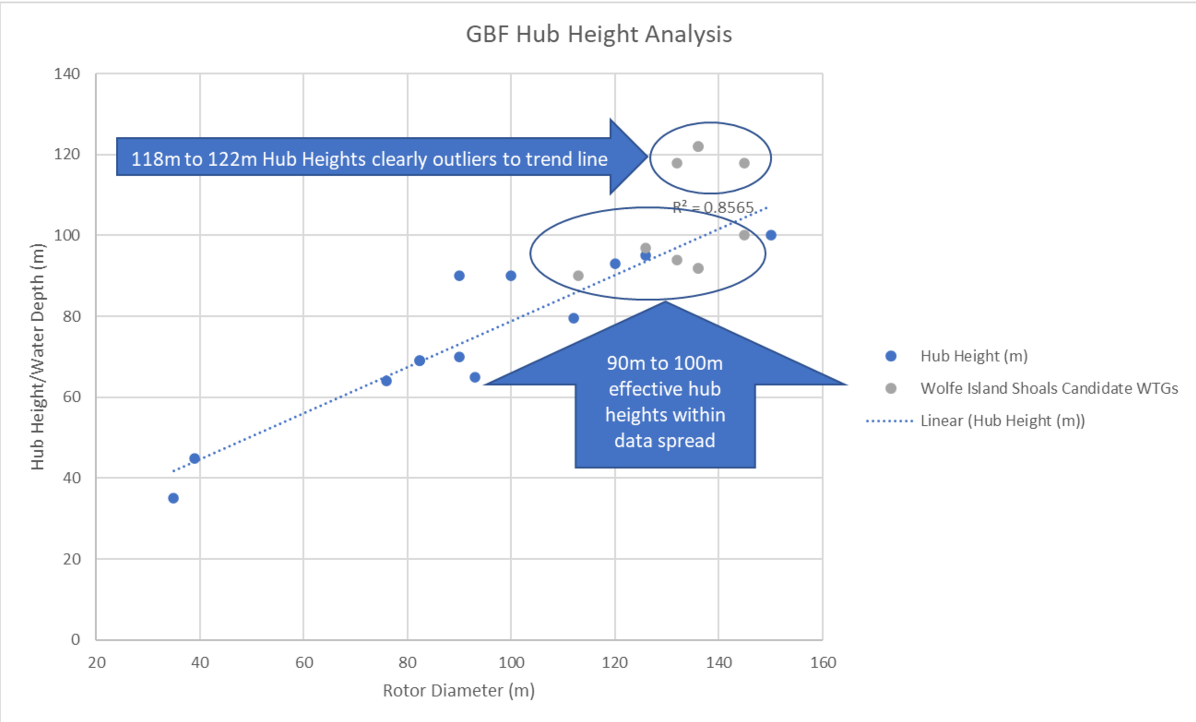

Figure 4 – GBF Hub Height Analysis

5.3 Conclusions

The precedent set by projects employing GBFs is that rotor diameters between 110m and 150m are installed at hub heights between 90m and 100m. This suggests that the shortest standard WTG tower height offered by WTG suppliers should be used on the GBFs for WIS.

6 Selection of an Appropriate WTG

6.1 WIS Layout Design and Annual Energy Production Estimate

Wood developed site specific layouts for each WIS candidate WTG using industry best practice regarding offshore wind farm layout design.

To ensure that the rated capacity of the layout design was less than the 300MW export limit specified in the FIT Contract, the number of WTGs in each layout was designed to ensure that the export limit was not exceeded.

Wood also predicted the net annual energy production (AEP) from each WIS layout at the point of connection to the Independent Electricity System Operator (IESO) controlled grid at the Lennox Generating Station.

The resulting number of WTGs in each layout, corresponding WIS rated capacity and AEP are listed in Table 9.

Candidate WTG	WTG Rating (MW)	Number of WTGs in Layout	Rated Capacity of WIS (MW)	Net AEP (GWh/Annum)
Siemens Gamesa SG-3.4-132	3.4	88	299.2	1, 176.7
Vestas V136 3.45	3.45	86	296.7	1, 193.5
Vestas V136 4.2	4.2	71	298.2	1, 113.4
Siemens Gamesa SG 4.5-145	4.5	66	297.0	1, 159.9

Table 9 - WIS Turbine Numbers, Rated Capacities & Net AEP[23, 24]

If WTG selection were based solely on AEP, the V136 3.45 would be the preferred choice of WTG and the V136 4.2 would be the least favoured WTG. However, the V136 4.2 layout has 15 fewer WTGs, which reduces the capital expenditure (Capex) through, for example: fewer WTGs, fewer foundations, fewer units to install, less cabling within the WIS layout. Operational expenditure (Opex) is also reduced as there are fewer WTGs to maintain, requiring less time offshore for maintenance personnel and lower vessel costs.

To arrive at the most appropriate WTG for WIS, consideration must be given to the impact of the combination of Capex, Opex and AEP, associated with each candidate WTG layout. The

[23] CER-Wood, Wood Report: Wolfe Island Shoals Wind Farm Energy Yield Assessment 17 February 2021 191540.CAN.AM.REP.01 B2.

[24] CER-Wood, Wood Report: Wolfe Island Shoals Wind Farm Energy Yield Assessment 04 June 2021 191540.CAN.AM.REP.01 B4.

relationship between Capex, Opex and AEP is best explored though the levelized cost of energy (LCOE), which is discussed in Section 6.2.

6.2 Levelized Cost of Energy

The LCOE is defined in Figure 5.

$$LCOE = \frac{\sum_{t=-5}^{n+1} \frac{I_t + M_t}{(1+r)^t}}{\sum_{t=-5}^{n+1} \frac{E_t}{(1+r)^t}}$$

Figure 5 – LCOE Definition[25]

Where:

I_t: Investment expenditure in year t

M_t: Operation, maintenance and service expenditure in year t

E_t: Net energy generation in year t

r: Discount rate (or WACC), and

n: Lifetime of project in years

Electricity would be sold from WIS via a power purchase agreement (PPA) at a given rate of $0.19/kWh (based on the FIT Contract dated May 4, 2010, and subject to inflation adjustments). The bigger the difference between the PPA price and the LCOE, the greater the economic performance of the project. Therefore, the lower the LCOE, the more valuable the project. In other words, the candidate WTG that yields the lowest LCOE is the WTG that maximises economic performance.

This analysis uses an operational life of 20 years based on the term of the FIT Contract, even though it is likely that the WIS Project will be capable of exceeding the nominal 20-year design life due to the benign conditions at the Project location. Therefore, ***n = 20*** for WIS in Figure 5.

We can simplify the equation in Figure 5 by assuming that ***r = Discount rate = 0%***. This simplification is reasonable for the purpose of comparing WTGs rather than accurately calculating the LCOE and yields a nominal cost of energy (COE) for each WTG layout. The resulting equation is:

[25] **C2203 Guide to Offshore Wind Farm – Wind Farm Costs – BVGA**.

$$\frac{(\text{Total Investment Expenditure}, \mathbf{I_t}) + 20*(\text{Total Operational Expenditure}, \mathbf{M_t})}{20*(\text{AEP}, \mathbf{E_t})}$$

This equation will enable the WTGs to be ranked based on the nominal cost of energy. However, we first need to generate approximate Capex and Opex figures. The focus is not on the accuracy of the Capex and Opex figures themselves but the relative position of each WIS layout regarding Capex, Opex and AEP. A detailed Capex and Opex analysis of the preferred WTG (SG 4.5-145) is provided in a separate report.

6.3 Approximate Capital Cost Estimate

Appendix C reproduces an extract from the 4C report[26] that estimates the Capex associated with the development and construction of WIS for 66 x SG 4.5-145 WTGs. Using the Capex estimates presented in Appendix C as a baseline and adjusting these figures to reflect the number of WTGs in the layouts for the other candidate WTGs listed in Table 9, the Capex was estimated for each candidate WTG layout and these figures are listed in Table 10.

6.4 Approximate Operational Cost Estimate

Appendix D reproduces an extract from an information memorandum associated with the sale of an operational offshore wind farm that estimates the Opex associated with the offshore wind farm. Using the Opex figures presented in Appendix D as a baseline and adjusting these figures to reflect the number of WTGs in the layouts for the other candidate WTGs listed in Table 9, the Opex was estimated for each candidate WTG layout and these figures are listed in Table 10.

6.5 Ranking Candidate WTGs by Cost of Energy

Table 10 lists the approximate WIS Capex, Opex and AEP figures and the nominal cost of energy for each layout based on the simplified equation in Section 6.2. This exercise shows that the preferred WTG is the SG 4.5-145 based on the lowest COE.

Description	**Wolfe Island Shoals 2020: SG 4.5-145**	**Wolfe Island Shoals 2020: V136 4.2**	**Wolfe Island Shoals 2020: V136 3.45**	**Wolfe Island Shoals 2020: SG 132-3.4**
Total Capex, including GBF facility & 10% Contingency ($mCAD)	1,055	1,078	1,168	1,177
Annual Opex ($mCAD)	32.40	34.34	40.06	40.88
AEP (MWh/Annum)	1,159,900	1,113,400	1,193,500	1,176,700
Cost of Energy (20 years, $CAD/MWh)	**73**	**79**	**83**	**85**

Table 10 - Cost of Energy for WIS Layouts

[26] **CER-4C Offshore-3**.

It is worth noting that the trend observed in Table 10 is in line with current trends in offshore wind farm development, whereby offshore wind farms are composed of fewer larger capacity WTGs as this results in the lowest LCOE.

6.6 Conclusions

The COE is an appropriate basis on which to rank candidate WTGs for deployment at WIS.

The absolute LCOE is not necessary in the ranking process and the simplified COE equation will produce the same order of ranking as absolute LOCE.

The SG 4.5-145 is shown to have the lowest COE and is considered the most appropriate turbine to deploy at WIS.

7 Confirmation of SG 4.5-145 Site Specific Suitability

7.1 Wood Site Suitability Report

Wood performed a site suitability assessment for the SG 4.5-145 in Section 7 of its energy yield prediction report[27]. This exercise predicted wind speed parameters at each of the SG 4.5-145 WTG positions in the WIS layout.

The long-term annual average 100m hub height wind speed, V_{ave}, is marginally above the IEC Class II limit of 8.5m/s at several WTG locations, with the maximum predicted V_{ave} being 8.61m/s. This exceedance is not considered to be an issue for the reasons discussed in Section 3 of this report: the marginal exceedance will be more than compensated for by the low turbulence and wind shear at WIS and will not reduce the 20-year design life of the WTGs.

The 50-year extreme three second gust wind speed, V_{e50}, does not exceed the IEC Class II limit of 59.5m/s at any WTG in any direction sector.

The 50-year extreme 10-minute wind speed, V_{ref}, is exceeded at all the WTG locations in the 150° sector and several locations in the 180° sector.

7.2 Suitability of the SG 4.5-145 in the WIS Layout

The V_{ref} exceedance predicted by Wood is mitigated by several factors, which suggest that the SG 4.5-145 remains the appropriate WTG selection for the WIS Project.

SG 4.5-145 design features that allow it to operate at a range of maximum rated outputs to match wind conditions that are more or less demanding that those specified under IEC Class II.

Wind speed measurements could be made within the WIS site using floating lidar to more accurately quantify the WIS wind regime.

The WTG manufacturer would normally perform a mechanical load assessment based on the wind regime predicted for WIS and, if necessary, introduce design modifications that would ensure the WTGs were able to survive under the predicted WTG loads.

Lastly, the fact that there are IEC Class II_B WTGs on Amherst Island with hub heights of 99.5m operating within 15km of the centre of the WIS layout strongly suggests that WTGs of the same class will be appropriate for the WIS Project. That these WTGs would be exposed to the same wind regime as WIS and are currently operating demonstrates that a practical solution exists that can adequately address this risk (to the extent that mitigation is required at all, which would be the subject of further investigation by the WTG supplier during the negotiation of turbine supply agreement). Therefore, the SG 4.5-145 is considered suitable for the WIS layout.

[27] **CER-Wood,** Wood Report: Wolfe Island Shoals Wind Farm Energy Yield Assessment 04 June 2021 191540.CAN.AM.REP.01 B4.

8 Conclusions

Windstream measured and recorded extensive data during the Long Point met mast and SODAR deployments to adequately characterise the wind regime at the Long Point met mast location.

AWS, GLGH, ORTECH and Wood performed best practice wind flow analysis to predict the long-term wind regime at the Long Point met mast and all analyses indicate that this wind regime is at the upper limit of IEC Class II_B.

The low TI and wind shear observed at the Long Point met mast and the benign wind regime at the WIS Project location suggests that IEC 61400-1 Class II_B WTGs will be suitable candidates for installation at the WIS Project.

Standard onshore IEC Class II_B WTGs are suitable for the offshore, non-saline environment of Lake Ontario.

Several possible WTG options were identified and of those only the top five onshore and offshore WTG manufacturers were considered to reduce technology risk. From these viable WTGs options, the Vestas V136-3.45MW and V136-4.2MW and SGRE SG 3.4-132 and SG 4.5-145 were selected for further analysis, as they are believed to present the lowest technology risk and were shown to meet the WIS selection criteria.

The precedent set by projects employing GBFs is that rotor diameters between 110m and 150m are installed at hub heights between 90m and 100m. This precedent leads to the conclusion that the shortest standard WTG tower height could be used on the GBFs for WIS. This hub height range is also consistent with the IEC Class II_B criteria.

The SGRE SG 4.5-145 was shown to have the lowest cost of energy and is considered the most appropriate turbine to deploy at WIS.

Site specific wind regime assessment was performed at each WIS location and, subject to appropriate mitigation, demonstrates that that the SG 4.5-145 is appropriate for deployment at WIS.

Appendix A: Suitability of COWI Gravity Base Foundations (GBFs)

WTG rotors produce a horizontal thrust load, F, which is resisted by the rotor hub. This thrusts load produces an overturning moment, M, at the top of the GBF equal to F x Hub Height, as illustrated by the blue arrow in Figure 6.

The COWI GBFs have been designed to withstand an overturning moment M = 106,600 kNm in 25m water depth[28].

IEC 61400-1 lists load cases that are to be considered by WTG designers and the worst-case load case for GBF design is typically power production plus occurrence of fault. WTG suppliers specify the maximum overturing moment associated with the worst-case load case for their WTGs to facilitate foundation design.

Wood has confirmed that the candidate WTGs will not exceed the COWI maximum overturning moment where the shortest standard WTG hub height is employed.

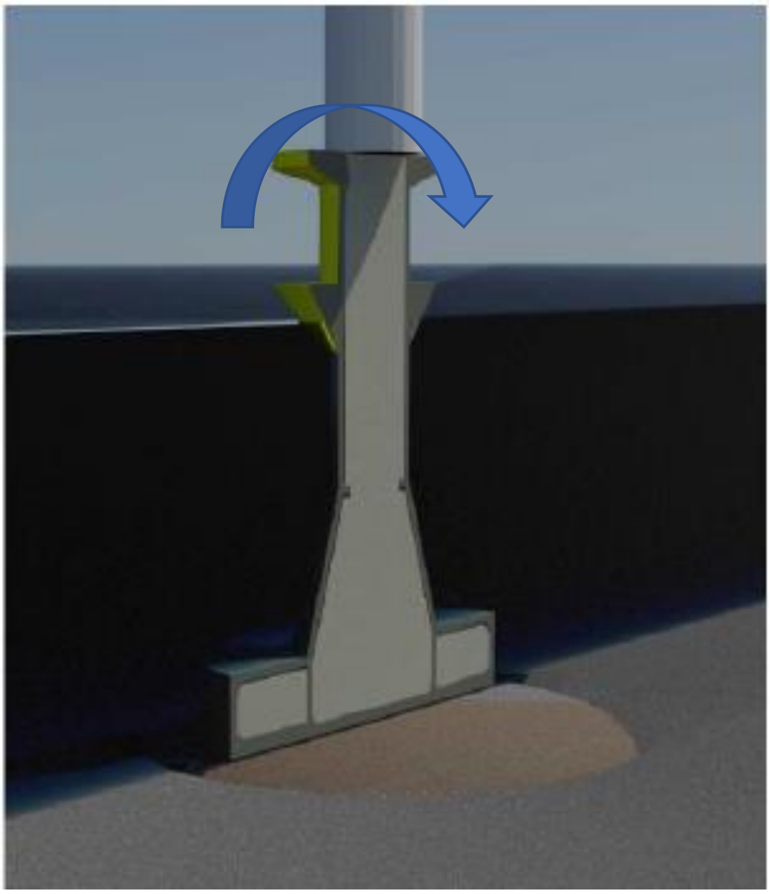

Figure 6 – Overturning Moment on COWI GBF

The WIS layout will deploy WTGs in water depths ranging from 10m to 30m. Therefore, GBFs will be constructed at different heights to accommodate the range of water depths. Appropriate

[28] **CER-COWI (Wind Turbine Gravity Base Foundation Design).**

adjustments will be made to the GBFs to ensure that the 106,600kNm overturning moment will be achieved at all water depths.

Appendix B: Lifting Capability of R.D. MacDonald

Maximum Tower Height
With reference to Figure 7, the maximum tower height that can be deployed by the R.D. MacDonald with a 400 feet long boom is equal to Z – (X + Y) + 8.3 = 116.6 – (7.5 + 4.1) + 8.3 = **113.3m**.

Maximum Nacelle Weight
The maximum weight of nacelle that can be deployed by the R.D. MacDonald with the 400 feet long boom is, with reference to the specification 10335 opposite[29], 333,800 pounds or **151, 545kg**.

The lifting height limit will rule out some of the candidate WTG hub height options listed in Table 6.

The lifting weight limit is not expected to rule out any of the candidate WTGs as the respective nacelle weights are either less than the lifting weight limit or can be broken down into lighter lifting packages.

As the tower height decreases, the lifting capability of the R.D. MacDonald increases. Therefore, the final configuration of the R.D. MacDonald regarding boom length will be determined via a lifting plan by Weeks Marine.

S/N: 10335

MANITOWOC ENGINEERING CO.
Division of The Manitowoc Company, Inc. Manitowoc, Wisconsin 54220

LIFTCRANE CAPACITIES — MEETS ANSI B30.5 REQUIREMENTS — 4600 SERIES 4
RINGER SERIES 3

BOOM NO. 65
60' RINGER ATTACHMENT ON
BLOCKING OR PEDESTALS
123,000 LB. CRANE COUNTERWEIGHT
978,700 LB. AUXILIARY COUNTERWEIGHT
360 DEGREE RATING

BOOM LGTH. FEET	OPER. RAD. FEET	BOOM ANG. DEG.	BOOM POINT ELEV. FEET	CAPACITY POUNDS
380	95	80.3	382.1	385,100•
	100	79.5	381.2	379,500•
	105	78.8	380.2	373,700•
	110	78.0	379.2	367,800•
	115	77.2	378.1	361,800•
	120	76.4	376.9	355,800•
	125	75.7	375.6	349,700•
	130	74.9	374.3	343,600•
	135	74.1	372.8	337,400•
	140	73.3	371.3	331,300•
	145	72.5	369.8	325,100•
	150	71.7	368.1	318,800•
	155	70.9	366.4	312,500•
	160	70.1	364.6	306,200•
	165	69.3	362.8	299,900•
	170	68.5	360.8	293,600•
	175	67.7	358.8	287,200•
	180	66.9	356.6	281,000•
	185	66.1	354.4	274,700•
	190	65.2	352.1	268,600•
	195	64.4	349.7	262,400•
	200	63.6	347.3	256,300•
	205	62.7	344.7	250,100•
	210	61.9	342.0	244,100•
	215	61.0	339.3	238,100•
	220	60.1	336.4	232,300•
	225	59.3	333.5	226,400•
	230	58.4	330.4	220,700•
	235	57.5	327.2	215,000•
	240	56.6	324.0	209,300•
	245	55.7	320.6	203,600•
	250	54.7	317.0	198,000•
	255	53.8	313.4	192,500•
	260	52.9	309.6	187,100•
	265	51.9	305.8	181,700•
	270	50.9	301.7	176,400•
	275	50.0	297.6	171,100•
	280	49.0	293.2	166,000•
	285	48.0	288.8	160,800•
	290	46.9	284.1	155,700•
	295	45.9	279.3	150,700•
	300	44.8	274.3	145,700•
	305	43.7	269.1	140,700•
	310	42.6	263.7	133,100•
	315	41.5	258.1	121,800•
	320	40.3	252.3	110,600•
	325	39.1	246.2	99,600•
	330	37.9	239.9	88,600•
	335	36.7	233.2	77,800•
	340	35.4	226.3	67,100•
	345	34.0	219.0	56,500•

BOOM LGTH. FEET	OPER. RAD. FEET	BOOM ANG. DEG.	BOOM POINT ELEV. FEET	CAPACITY POUNDS
400	95	80.8	402.4	333,800•
	100	80.1	401.6	329,100•
	105	79.3	400.6	324,300•
	110	78.6	399.6	319,300•
	115	77.9	398.6	314,000•
	120	77.1	397.4	308,400•
	125	76.4	396.2	302,700•
	130	75.7	395.0	296,900•
	135	74.9	393.6	291,200•
	140	74.2	392.3	285,400•
	145	73.4	390.7	279,600•
	150	72.7	389.2	273,800•
	155	71.9	387.6	268,000•
	160	71.2	385.9	262,200•
	165	70.4	384.1	256,400•
	170	69.6	382.2	250,600•
	175	68.9	380.3	244,800•
	180	68.1	378.3	239,000•
	185	67.3	376.2	233,300•
	190	66.6	374.1	227,700•
	195	65.8	371.8	222,000•
	200	65.0	369.5	216,300•
	205	64.2	367.1	210,800•
	210	63.4	364.6	205,200•
	215	62.6	362.0	199,800•
	220	61.8	359.4	194,400•
	225	60.9	356.6	189,100•
	230	60.1	353.8	183,800•
	235	59.3	350.8	178,500•
	240	58.5	347.7	173,300•
	245	57.6	344.6	168,200•
	250	56.7	341.3	163,100•
	255	55.9	338.0	158,100•
	260	55.0	334.5	153,100•
	265	54.1	330.9	148,200•
	270	53.2	327.2	143,400•
	275	52.3	323.3	138,600•
	280	51.4	319.4	133,900•
	285	50.5	315.3	129,200•
	290	49.6	311.0	124,600•
	295	48.6	306.7	120,100•
	300	47.6	302.1	113,700•
	305	46.7	297.4	103,600•
	310	45.7	292.6	93,700•
	315	44.6	287.6	83,800•
	320	43.6	282.4	74,100•
	325	42.6	277.0	64,400•
	330	41.5	271.4	54,800•

[29] **CER-Weeks-2**.

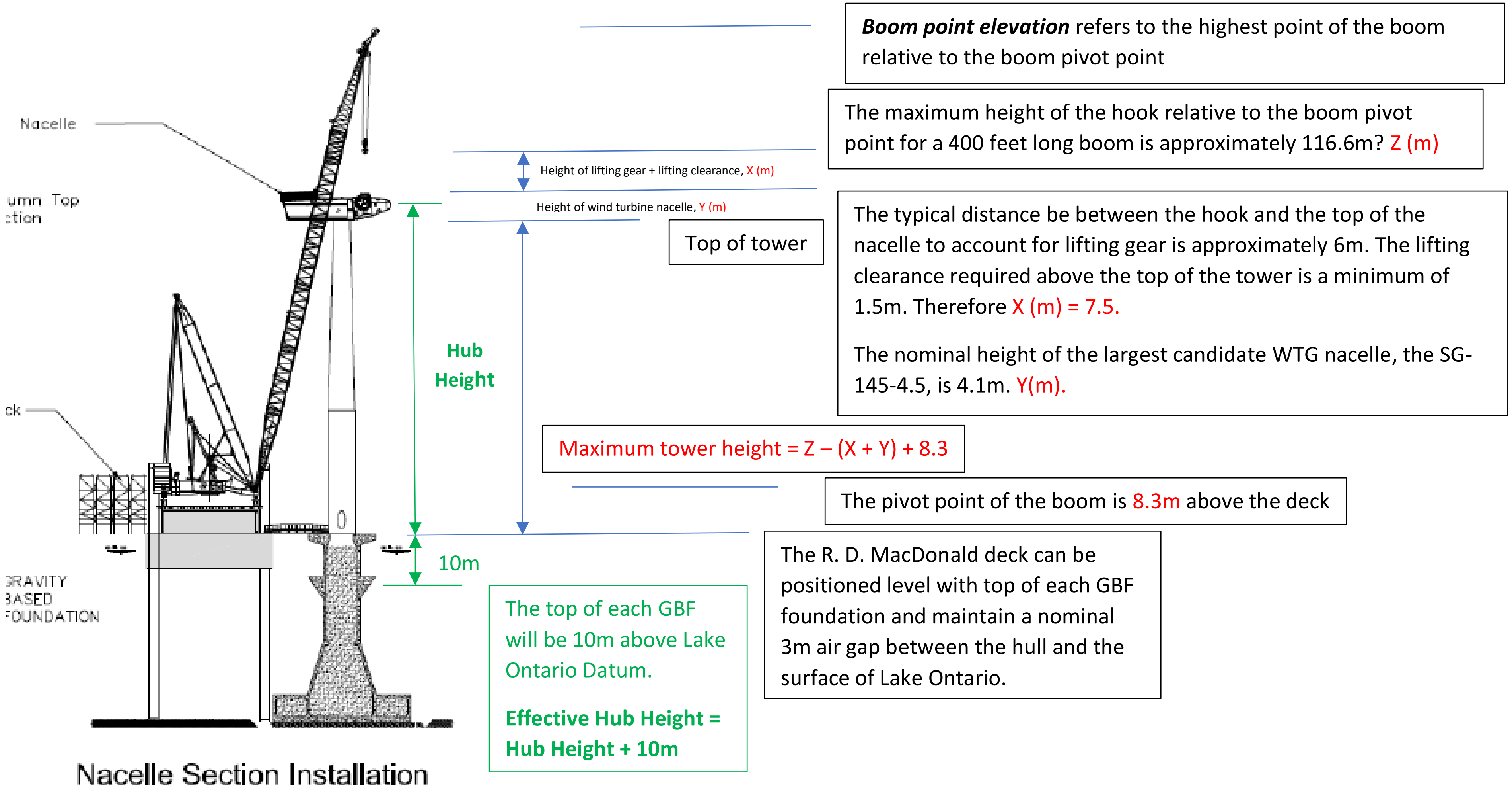

Figure 7 – Maximum Lifting Height of the R.D. MacDonald

Appendix C: Approximate Capital Costs of WIS layouts

Approximate capital costs were derived from the 4C report ***A Review of the Capital Costs of Wolfe Island Shoals P/20/1440 Revision C3***, an extract from which is reproduced below.

	2014 ($m)	Inflated to $m 2020	2020 Updated Costs ($m)	Delta ($m) 2020 - 2014	
DEVELOPMENT COSTS					
Preliminary desktop studies, EIA, preliminary designs	11.23	12.30	12.30		
Site Investigation					
Geophysical Surveys	1.4	1.53	1.53		
Geotechnical Surveys	7.99	8.75	8.75		
Met Mast	4.48	4.91	4.91		
TA costs for FEED studies and contractor procurement					
FEED	0.94	1.03	1.03		
Procurement	2.74	3.00	3.00		
Permitting & Environmental Studies					
Permitting	5.49	6.01	6.01		
Environmental Studies	7.92	8.68	8.68		
Legal fees	2.04	2.24	2.24		
	44.23	**48.46**	**48.46**		
SUPPLY COSTS					
Foundations					
Detailed Design	3.02	3.31	3.31		
Supply Costs	321.56	352.30	317.74	-34.6	-9.8%
WTG	483.86	530.12	297	-233.1	-44.0%
OHVS					
Detailed Design	2.35	2.57	2.57		
Supply Costs	42.65	46.73	46.73		
Array cables	26.17	28.67	31.61	2.9	10.3%
Export Cables	10.31	11.30	33.04	21.7	192.5%
	889.92	**975.00**	**732.01**		
INSTALLATION COSTS					
Foundations	50.8	55.66	47.97	-7.7	-13.8%
WTG	91.94	100.73	59.4	-41.3	-41.0%
OHVS	9.06	9.92	9.92		
Array Cables	21.35	23.39	39.78	16.4	70.1%
Export Cables	8.6	9.42	4.63	-4.8	-50.9%
	181.74	**199.11**	**161.70**		
ONSHORE INTERCONNECTION					
Substation	43.22	47.35	47.35		
Cabling	1.57	1.72	0.00		
	44.79	**49.07**	**47.35**	-1.7	-3.5%
TOTAL SUPPLY & INSTALLATION COSTS	1116.45	**1223.18**	**941.05**		
OWNER MANAGEMENT COSTS	12.35	**13.53**	**13.53**		
CONTINGENCY					
Rate	10%	10%	10%		
Amount	112.88	123.67	95.46	-28.2	-22.8%
TOTAL CAPEX	1285.91	**1408.84**	**1098.50**	-310.3	-22.0%

Appendix D: Approximate Operational Costs of WIS Layout

Approximate operational costs were derived from the Sprogø Offshore Wind Farm Information Memorandum dated 22 September 2017, an extract from which is reproduced below.

Historical O&M costs 2010 – 2017H1

Annual costs DKKt nom.	2010	2011	2012	2013	2014	2015	2016	2017 H1
WTG*	7,601	8,107	8,169	8,580	8,346	4,972	5,055	2,443
Foundation and cranes	-	204	499	47	40	98	36	-
Scheduled service	-	-	-	-	-	-	-	-
Unscheduled service	-	188	404	11	-	58	-	-
Cranes	-	16	95	36	40	40	36	-
Transmisssion assets and systems	-	-	-	-	-	-	-	-
Scheduled service	-	-	-	-	-	-	-	-
Unscheduled service	-	-	-	-	-	-	-	-
Technicial resources	1,220	1,077	1,172	1,220	1,152	1,278	1,541	767
Technicians**	1,141	1,077	1,160	1,192	1,145	1,276	1,528	764
Tools	79	1	12	28	7	2	13	3
Administration & back-office	228	521	519	465	421	345	686	258
Back office support	228	521	519	465	421	345	686	258
Environmental and safety related costs	4	31	34	93	-	2	-	-
Environmental related costs	-	31	-	-	-	2	-	-
Safety related costs	4	-	34	93	-	-	-	-
Logistics	1,436	1,177	1,272	1,308	1,308	1,282	1,268	595
Crew Vessels	1,436	1,177	1,272	1,308	1,223	1,246	1,241	579
Fuel costs	-	-	-	-	86	35	27	16
Onshore facilities	32	121	10	18	-	-	1	-
Facilities	32	121	10	18	-	-	1	-
Insurance	417	448	448	450	453	453	453	227
Property damage and liability insurance	417	448	448	450	453	453	453	227
Taxes & Fees	2,069	1,169	1,301	1,217	1,178	1,003	874	460
Balancing costs	1,686	837	907	869	802	575	382	260
TSO Feed-in fee	255	199	260	223	241	298	382	140
Trading costs	127	133	134	124	134	130	110	61
Total	**13,006**	**12,854**	**13,424**	**13,398**	**12,898**	**9,433**	**9,914**	**4,749**

TAB 9

Two Dogs Projects Ltd.

Windstream Energy Inc.

Wolfe Island Shoals
Offshore Wind Farm
Capital & Operational Expenditure
Sensitivity Analysis

18 February 2022

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Glossary

Abbreviation or Term	Definition
AEP	Annual energy production.
ASP	Average Selling Price
Baird	A consultancy that specialises in coastal and river engineering solutions.
BVG Associates	A consultancy providing strategic advice regarding renewable energy.
Capex	Capital expenditure associated with construction of WIS.
COD	Commercial Operation Date: The date at which all commissioning tests have been passed and the offshore wind farm begins to generate electricity and earn revenue.
COWI	A consultancy with extensive experience in the design, construction and deployment of offshore wind foundations, including GBFs.
CSP	Capex Spend Profile: The monthly Capital Expenditure require to progress a project from the beginning of the development phase to commercial operation.
ECN	Energy research centre of the Netherlands is the largest energy research institute in the Netherlands. ECN develops new technology and conducts pioneering research in various ways into innovative solutions to facilitate the transition to sustainable energy management.
Financial Close	Financial close occurs when all the Project and financing agreements have been signed and all conditions on those agreements have been met, allowing Windstream to start drawing down the financing to begin work on the Project.
4C	4C Offshore is a leading consultancy and market research organisation targeting the offshore energy markets.
GBF	Gravity base foundation.
IEA	International Energy Agency
km	Kilometre
kV	Kilovolt
LIDAR	**Li**ght **D**etection **a**nd **R**anging.
MECP	Ministry of Environment, Conservation and Parks
MNR	Ministry of Natural Resources
Opex	Operational expenditure associated with operating WIS.
Project Finance	Project finance is the financing of long-term industrial projects, such as an offshore wind farm, using a non-recourse or limited recourse financial structure. The debt and equity used to finance the project are paid back from the cash flow generated by the project.

Abbreviation or Term	Definition
SGRE	Siemens Gamesa Renewable Energy.
Ventolines	Ventolines is an organisation that supports the development, construction and management of renewable energy projects, including offshore wind.
Weeks	Weeks Marine.
WIS	Wolfe Island Shoals Offshore Wind Farm
Wood	The wind energy consultancy Wood.
WTG	Wind turbine generator.

1 Introduction

As an employee of SgurrEnergy (now Wood plc), I previously conducted studies for Windstream Energy Inc. (Windstream) filed in arbitration proceedings under the North American Free Trade Agreement in respect of the Wolf Island Shoals (WIS) offshore wind farm (referred to in this report as NAFTA 1).

The studies commissioned by Windstream in relation to NAFTA1 were to assess the technical feasibility of WIS. Based on the data provided by Windstream and SgurrEnergy's extensive knowledge of the then state-of-the-art of offshore wind industry practices, WIS was technically feasible. That is, WIS could be constructed and be operational within the required deadlines.

I understand that, on 18 February 2020, the Ontario Government notified Windstream that the power purchase agreement (feed-in tariff contract) issued for the Project had been cancelled by them. In response, Windstream submitted a Notice of Intent (February 2020) and a Notice of Arbitration (November 2020), as the initial steps in a second round of NAFTA arbitration proceedings (referred to in this report as NAFTA2).

In support of NAFTA2, Two Dogs Projects Limited was asked to estimate a range of Capital Expenditure (Capex) and Operational Expenditure (Opex) figures pertaining to the construction and operation of WIS. This exercise considers a Capex report prepared by 4C Offshore[1], the wider wind energy sector experience individuals and organisations supporting Windstream for NAFTA2 and recent studies relating to offshore wind Opex and provides an opinion on a range of Capex and Opex, figures referenced to February 2020[2], should the Project have been allowed to proceed in February 2020 in the absence of ("but for") restrictions imposed by various government agencies (outlined below).

Windstream has asked me to assume that the Ontario Government did not adopt an indefinite-term moratorium on offshore wind development on February 11, 2011. Instead, Windstream has asked me to assume that the following would have occurred by 18 February 2020:

a) Ministry of Environment, Conservation and parks (MECP, formerly MOE) would have confirmed its proposed regulatory amendment to include a five-kilometre setback or confirmed that it would not proceed with any regulatory amendment (such that setbacks for offshore wind projects would continue to be assessed on a site-specific basis).

b) Ministry of Natural Resources (MNR) would have fulfilled its commitment to discuss the reconfiguration of Windstream's applications for Crown land for the Project (if a five-kilometre setback was confirmed) and would have thereafter fulfilled its commitment to "move as quickly as possible through the remainder of the application review process so that the Project may obtain Applicant of Record status in a timely manner."

[1] **CER-4C Offshore 3,** A Review of the Capital Costs of Wolfe Island Shoals P/20/1440 Revision C3.

[2] **C-2290,** XE Currency Table https://www.xe.com/currencytables/?from=CAD&date=2020-02-18.

c) MECP and MNR would have fulfilled their commitment to process the Project's application for a Renewable Energy Approval (REA) within the six-month service guarantee.

d) MNR would have permitted Windstream to proceed through MNR's Crown land application process and granted Windstream site release.

e) the Ontario Government would have dealt with Windstream in good faith and not have subjected the Project to unreasonable regulatory delays; and

f) the FIT Contract was not cancelled.

The report has been prepared to produce a range of costs associated with the development, construction and operation of Wolfe Island Shoals Offshore Wind Farm (WIS). All values presented in this report are in Canadian funds ($CAD) unless otherwise indicated.

Section 2 of this report provides a summary of the relevant experience and expertise of the author of this report and Two Dogs Projects Limited.

Section 3 of this report reviews the 4C report: *A Review of the Capital Costs of Wolfe Island Shoals P/20/1440 Revision C3*, an extract from which is reproduced in Appendix A. This report is based on the supply and installation of 66 x SG 4.5-145 wind turbine generators (WTGs). Each of these Capex items (with some additional Capex items that I have identified) is considered in turn with the objective of adjusting the central estimate of Capex to reflect the collective market intelligence of the Windstream team and to establish an upper and lower bound to each item of Capex.

Section 4 of this report reviews Opex and the detail of which was derived from: *BVG Associates, IEA Task 26 Reports and Sprogø Offshore Wind Farm Information Memorandum dated 22 September 2017*[3], an extract from which is reproduced in Appendix B. The objective of the comparison was to establish an upper and lower bound to each item of Opex.

Section 5 of this report summarises and presents the results derived in Sections 3 and 4.

Section 6 of this report presents and describes an estimated monthly Capital Expenditure Profile for WIS that covers the development and construction phases of the Project.

[3] **C-2120,** Sprogø Offshore Wind Farm Information Memorandum - September 22, 2017 – ESP Consulting http://gphandlahdpffmccakmbngmbjnjiiahp/https://sundogbaelt.dk/wp-content/uploads/2017/09/170922-sprogoe-owf-information-memorandum-announcement.pdf.

2 Relevant Experience and Expertise

2.1 Ian Irvine and Two Dogs Projects

I have been at the forefront of the development of the renewable energy industry for over 30 years. My career in the renewable energy industry has included senior management roles in the UK electricity utility ScottishPower and subsequently the engineering consultancy Ingenco, which included establishing ScottishPower's internal renewable energy technical team in the early 1990s, generating business and internal management of resources, leading a team of 25 staff as the Development Group Manager for Ingenco supporting the development of fossil fuel plant, CHP, biomass, hydro-energy and wind projects and electrical infrastructure developments.

I established SgurrEnergy, an engineering consultancy focussed on the renewable energy industry, in 2002. I led, directed and grew the company from a team of two to over 300 dedicated professionals working on several hundred renewable energy projects worldwide. SgurrEnergy became a leader and innovator within the renewable energy industry. In 2016, I sold SgurrEnergy to Wood Group. I exited the business in 2017 and now work as an independent consultant, offering engineering consulting services through Two Dogs Projects.

I have been on the board of Point and Sandwick Power Limited, the UK's largest community owned wind farm, since 2017. Since 2019 I have been on the board of Clir Renewables Inc., a rapidly growing software start up, developing a world leading cloud-based *renewable* energy asset management and reporting software tool that optimises the performance of wind and solar assets.

2.2 Relevant Experience

I have been involved in offshore wind since undertaking technical due diligence on the world's first project financed offshore wind farm, the 120MW Princess Amalia wind farm (Q7), located off the coast of the Netherlands. I have continued to provide expert technical advice on GWs of offshore wind farms to developers and financiers regarding offshore wind measurement campaigns, WTG selection, wind farm design, WTG performance assessment, WTG enhancement and monitoring, technical due diligence and operation and maintenance.

I played a central and critical role in two major offshore wind studies for the Chinese Government during 2007 and 2009 (part-funded by the World Bank and EU respectively). I have also advised on numerous offshore wind farms throughout the UK, Europe, Asia and North America, exposing me to most of the offshore wind turbine technologies currently in operation. These include, but are not limited to, East Anglia, Burbo Bank, Humber Gateway, Beatrice, Neart na Gaoithe, Veja Mate, Galloper, London Array, MEG 1, Westermost Rough, Cape Wind, Nordsee Ost and North Hoyle.

I was Project Director on a major offshore wind R&D project involving the deployment of three scanning lidar units on 5MW Areva turbines in the Alpha Ventus offshore wind farm, between 2012 and 2014, an R&D programme sponsored by Areva, Mitsubishi and SSE, known as the Efficient Offshore Wind Project (EWOP). This programme investigated wind inflow conditions to large scale wind turbines and the behaviour and structure of wind turbine wakes, revealing the true characteristics and complexity of the wind and the resulting response of wind turbines.

3 Capital Expenditure

3.1 Capital Expenditure Items

Appendix A lists Capex items considered by 4C. I have also identified two additional Capex items to be considered:

- Construction of the gravity-based foundation (GBF) manufacturing facility.
- Construction insurance

The comprehensive list of Capex items to be considered are set out in Table 1. These Capex items are discussed in turn in the following sections.

Item #	Description	Comments
1	Development costs	This cost captures all costs up to Financial Close.
2	GBF Foundation Design	
3	GBF Manufacturing Facility	This includes design and construction of the GBF manufacturing facility. COWI has provided a bottom-up cost for this item.
4	GBF Supply	COWI has provided a bottom-up cost for this item.
5	WTG Supply	
6	Offshore Substation Design	
7	Offshore Substation Supply	
8	Array Cable Supply	
9	Export Cable Supply	
10	GBF Foundation Installation	
11	WTG Installation	
12	Offshore Substation Installation	
13	Array Cable Installation	
14	Export Cable Installation	
15	Onshore Substation Supply & Installation	This includes the design cost.
16	Onshore Substation Cable Supply	
17	Construction Insurance	
18	Project Management Costs	
19	Contingency	

Table 1 – List of Capital Expenditure Items

3.2 Development Costs

The development costs associated with WIS in 4C's report allow for:

- Preliminary desktop studies including a preliminary environmental impact assessment and preliminary designs of WIS and associated infrastructure.
- Site Investigation including geophysical surveys, geotechnical surveys and assessment of the wind resource using an offshore meteorological mast (if deemed necessary).
- Technical advisory costs associated with front-end engineering design studies and contractor procurement.
- Permitting and environmental studies required to progress construction of WIS.
- All legal fees associated with development of WIS.

4C benchmarked the WIS development cost estimate against a number of industry studies undertaken in 2019 and 2020 that looked at the combined development costs and post-financial close project management costs. The range of costs in this exercise ranged from being 7.1% lower than 4C's WIS estimate to 8.4% higher. The range of development costs is given in Table 2.

4C further noted that development costs allowed for wind regime assessment that would typically be undertaken using floating LIDAR at a cost of between \$1.79m and \$3.59m which could result in savings between \$1.32m and \$3.12m if the existing Windstream wind data from Long Point[4] could be used rather than undertaking further wind regime assessment.

Although the Long Point wind data adequately characterises the wind regime at WIS, rather than deducting the cost of a wind regime assessment using floating LIDAR from the development costs, this cost of a floating LIDAR wind regime assessment has been left in the development costs. Including the cost of a floating LIDAR assessment supports a conservative approach to estimating Capex and provides an allowance in the Capex estimate for conducting a floating LIDAR wind regime assessment should this be considered necessary as the Project is developed.

Capex Item	Low Estimate (\$CADm)	Central Estimate (\$CADm)	High Estimate (\$CADm)
Development Costs	45.02	48.46	52.53

Table 2 – Range of Development Costs

If the cost of a floating LIDAR wind regime assessment were to be deducted from the development costs, an estimate of such a cost is required. Assuming the wide range of 4C's floating LIDAR survey costs discussed above, related to the deployment location, with the higher LIDAR cost reflecting a more challenging environment (farther from shore, higher mean wave height, deeper water) and the lower cost a less challenging environment (closer to shore, lower mean wave height, shallower water), as WIS is in a fresh water, inland lake, it is reasonable to estimate the cost of a floating LIDAR wind regime assessment at WIS will align with the bottom of this range, namely \$1.32m.

[4] Windstream installed an 80m meteorological mast on the Long Point peninsula, approximately 10km from the centre of the WIS wind farm layout. Data were collected for several years from this location and are considered suitable for characterising the wind regime at WIS. However, site specific wind data could be collected from the centre of the WIS layout using floating LIDAR to further reduce the uncertainty in the predicted wind regime if required.

3.3 GBF Foundation Design

4C has allowed $3.31m for the detailed design of the GBFs. However, COWI has provided a figure of $3.02m (2020 USD) in its Opinion of Probable Costs report dated February 2022 for this work. Based on the same exchange rate as that used by 4C[5], this converts to $4.01m CAD. As the COWI estimate is more project specific $4.01m ±5% will be set across the range of GBF detailed design costs as per Table 3.

Capex Item	Low Estimate ($CADm)	Central Estimate ($CADm)	High Estimate ($CADm)
GBF Detailed Design	3.81	4.01	4.21

Table 3 – Range of GBF Detailed Design Costs

3.4 GBF Manufacturing Facility

4C does not detail the cost of the GBF manufacturing facility in its report as the primary reference does not provide this level of detail although it is recognised that a provision is made in the GBF cost build up for upgrading of port facilities to facilitate GBF manufacture.

COWI has provided a figure of $71.96m (2020 USD) in its Opinion of Probable Costs report dated February 2022 for this facility. Based on the same exchange rate as that used by 4C[6], this converts to $95.39m CAD. $95.39m ±11% will be set across the range of GBF manufacturing facility costs as per Table 4.

Capex Item	Low Estimate ($CADm)	Central Estimate ($CADm)	High Estimate ($CADm)
GBF Manufacturing Facility	84.80	95.39	105.98

Table 4 – Range of GBF Manufacturing Facility Costs

3.5 GBF Supply

4C estimates the GBF supply cost at $317.74m. However, as noted in Section 3.4, this estimate includes a provision for upgrading port facilities to facilitate GBF manufacture. 4C considers the range of water depths at WIS, 10m to 30m, and acknowledges that this will reduce the overall cost of GBFs compared to the ECN reference project due to the reduced weight of foundations, noting that the relative weight of the WIS GBFs is 800t/MW.

The cost attributed to upgrade port facilities in the ECN reference project is not known. 4C inflated the ECN GBF cost by 20% to account for relative scale disadvantage and facility investments necessary at WIS. Removing this 20% uplift would make the base ECN cost $264.8m, which also includes an element of cost for upgrading port facilities.

COWI has developed a bottom-up cost for a GBF in 25m of water and a methodology for scaling this cost for the range of water depths in WIS in its Opinion of Probable Costs report

[5] **C-2290,** XE Currency Table https://www.xe.com/currencytables/?from=CAD&date=2020-02-18.

[6] **C-2290,** XE Currency Table https://www.xe.com/currencytables/?from=CAD&date=2020-02-18.

dated February 2022. COWI's cost estimate was based on 2015 ice design loads. In 2021, Windstream commissioned Baird to undertake a new ice load study, which showed that the ice design loads previously established for the GBFs were conservative and could be reduced though further analysis as the Project progressed. This would offer a potential reduction in the GBF Capex figures in Table 5.

Wood has produced a WIS layout and provided the water depth at each WTG location[7], which was used to calculate a site-specific cost for the GBFs of $210.1m CAD, based on COWI's scaling methodology.

If all the WIS GBFs were installed in 25m of water the cost would be $224.3m CAD. Therefore, the cost reduction achieved by accounting for the variation in water depth at WIS from 10m to 30m is 6.3%. If this cost reduction is made to the adjusted ENC reference project base cost, it equates to $248.0m. However, there remains an unknown element included in this cost for upgrading port facilities.

Wood has estimated the supply cost of GBFs for WIS as ranging between $201m and $244.5m.

It is considered reasonable to use a range of costs with the COWI estimate of $210.13m at the low end and Wood's $244.5m at the high end, with the central estimate being the average of these, as shown in Table 5.

Capex Item	Low Estimate ($CADm)	Central Estimate ($CADm)	High Estimate ($CADm)
GBF Supply	210.13	227.32	244.50

Table 5 – Range of GBF Supply Costs

The combined cost of the GBF construction facility and GBF supply can be obtained by adding the figures from Tables 4 and 5, which gives a range of costs between $295m and $350m. The 4C GBF supply cost of $318m, which includes the construction of the GBF facility, lies between the combined costs from Tables 4 and 5 and is close to the combined central estimate of $323m.

3.6 WTG Supply

4C estimates the WTG supply cost at $1m/MW, which is based on Siemens Gamesa Renewable Energy (SGRE) average selling price (ASP) in 2020. The ASP is influenced by multiple factors including the WTG model and rating, the WTG hub height, the destination country, foreign exchange rates and contract scope, with the larger rated turbines typically having a lower $/MW price. For example, SGRE's onshore ASP in 2020 is lower due to a larger contribution from higher rated turbines plus narrower contract scopes. SGRE's contract scopes in the US normally exclude installation and commissioning whereas in Europe and Latin America these tasks are commonly within scope. This gives a WTG Supply cost of 297MW x $1m/MW = $297m, which is at the upper end of the range of the

[7] **C-2500,** Energy Yield Assessment Summary – Layout v3 – Simple Bathymetry (undated) Layout_v3_bathymetry.xlsx.

WTG supply cost for WIS, as WIS WTGs will be supply only (installation done by a third party) and use the shortest standard 90m hub height towers.

Wood has advised that SG 4.5-145s supplied to North America could be supplied on a WTG only basis at a cost of between \$3.6m and \$4.1m/WTG. Most of the projects that have employed the SG 4.5-145 are supplied with a hub height of 107.5m or higher, compared to the 90m hub height tower planned for WIS (100 m effective hub height). Very approximately, a tower for a 90m hub height WTG will be 84% of the cost of a tower for a 107.5m hub height WTG. Therefore, the cost of the WTGs for WIS may be closer to the bottom of the range suggested by Wood. However, I have employed a conservative approach and used the average of the range of figures suggested by Wood.

The average of the WTG cost range provided by Wood gives a WTG price of \$3.85m/WTG (\$0.86m/MW) and a total WTG supply only price of \$257.4m, which be used as the lower end of the range of the WTG supply cost.

The \$277m WTG supply cost central estimate in Table 6 is the average of the Wood and 4C figures and is equivalent to \$0.93m/MW.

Capex Item	Low Estimate (\$CADm)	Central Estimate (\$CADm)	High Estimate (\$CADm)
WTG Supply	257.40	277.20	297.00

Table 6 – Range of WTG Supply Costs

3.7 Offshore Substation Design

4C has estimated \$2.57m for the detailed design of the offshore substation, which is considered robust, with limited scope for reducing or increasing. Therefore, \$2.57m ±3% will be set across the range of detailed design costs as per Table 7.

Capex Item	Low Estimate (\$CADm)	Central Estimate (\$CADm)	High Estimate (\$CADm)
Offshore Substation Detailed Design	2.49	2.57	2.65

Table 7 – Range of Offshore Substation Detailed Design Costs

3.8 Offshore Substation Supply

4C estimates the cost of the offshore substation at $46.73m, which is robust as it is based on actual offshore substation supply and installation contracts. The actual project costs used to derive the average cost of an offshore wind farm substation by 4C varies by approximately +/- 40% from the average cost, reflecting the wide range of environments these substations were being deployed in. Given the reduced complexity and more benign environment that the WIS substation will be deployed in, a nominal ±10% has been applied to the central estimate to generate the range of costs in Table 8.

Capex Item	Low Estimate ($CADm)	Central Estimate ($CADm)	High Estimate ($CADm)
Offshore Substation Supply Cost	42.06	46.73	51.40

Table 8 – Range of Offshore Substation Supply Costs

3.9 Array Cable Supply

4C estimates the array cable supply cost to be $31.61m which is based on a detailed analysis of sub 8MW offshore wind farm array cable lengths and market rates for 33kV cable. The estimate also includes a 20% allowance to account for the offshore substation being deployed on Pigeon Island, which increases array cable costs as it is not optimally located within WIS. The estimate is considered accurate to within ±10%, which is used to determine the range of array cable supply prices.

Capex Item	Low Estimate ($CADm)	Central Estimate ($CADm)	High Estimate ($CADm)
Array Cable Supply	28.45	31.61	34.77

Table 9 – Range of Array Cable Supply Prices

3.10 Export Cable Supply

4C estimates the export cable supply cost to be $33.04m which is based on supply of 29km of 230kV cable to connect between Pigeon Island and the grid connection point and a detailed analysis of high voltage cable supply contracts awarded since 2015. The estimate is considered accurate to within ±10%, which is used to determine the range of export cable supply prices.

Capex Item	Low Estimate ($CADm)	Central Estimate ($CADm)	High Estimate ($CADm)
Export Cable Supply	29.74	33.04	36.34

Table 10 – Range of Export Cable Supply Prices

3.11 GBF Installation

4C estimated GBF installation at $47.97m based on a 2019 GBF cost report by ECN[8]. Wood estimated GBF installation in the offshore environment has been between $81m and $99m based on data from previous projects. GBF installation in Lake Ontario would present less risk than the offshore environment reflected in Wood's previous project data and offer a longer installation window compared to offshore. It is therefore highly probable that the actual installation costs would be significantly less than the lower end of the range reflected in the previous project data, which reflects projects undertaken in less benign conditions.

To arrive at a reasonable central estimate of GBF installation costs, the average of the 4C and lower end of the Wood range has been used in Table 11. The range of GBF costs in Table11 is based on a nominal ±10% uncertainty.

Capex Item	Low Estimate ($CADm)	Central Estimate ($CADm)	High Estimate ($CADm)
GBF Installation	58.04	64.49	70.94

Table 11 – Range of GBF Installation Costs

3.12 WTG Installation

4C estimated WTG installation at $59.4m, which is based on a per turbine installation cost of $0.9m/WTG. The SG 145-4.5 nacelle will be installed in two sections, adding to the installation cost. 4C's range of reference costs for WTG installation was between $0.78m and $1.00m per turbine and it is considered prudent to base the central estimate on the higher end of this range, giving an WTG installation cost of $66m. The range of costs presented in 4C's estimate is +/-11% of the average WTG installation cost. This figure. +/-11%, has been used to derive the range of WTG installation costs in Table 12.

Capex Item	Low Estimate ($CADm)	Central Estimate ($CADm)	High Estimate ($CADm)
WTG Installation	58.74	66.00	73.26

Table 12 – Range of WTG Installation Costs

It is worth noting that Ventolines, that previously worked on the offshore wind demonstration project, Project Icebreaker[9] on Lake Erie, proposed using a standard mobile crane fixed to a barge as the WTG installation vessel. This offers the prospect of reducing WTG installation costs compared to those in Table 12 as the Project progresses.

[8] **C-2206,** ECN-TNO Innovation for Life report entitled "Integrated Project Logistics and Costs Calculations for Gravity Based Structure" (January 17, 2019) ECN Report: Integrated project logistics and cost calculations for gravity-based structure. EERA Deepwind 2019, Trondheim.

[9] **C-2431,** Website (LEEDCo), The Project: Ice Breaker Wind (February 2022) http://www.leedco.org/index.php/about-icebreaker.

3.13 Offshore Substation Installation

4C estimates the cost of the offshore substation installation at $9.92m, which is robust as it is based on actual supply and installation contract prices, although considered high with respect to WIS as the offshore substation will be installed on Pigeon Island rather than on an offshore foundation. The actual project costs used to derive the average cost of an offshore wind farm substation by 4C varies by approximately +/- 40% from the average cost, reflecting the wide range of environments in which these substations were deployed. Given the reduced complexity and more benign environment that the WIS substation will be deployed in, a nominal ±10% has been applied to the central estimate to generate the range of costs in Table 13.

Capex Item	Low Estimate ($CADm)	Central Estimate ($CADm)	High Estimate ($CADm)
Offshore Substation Installation Cost	8.93	9.92	10.91

Table 13 – Range of Offshore Substation Installation Costs

3.14 Array Cable Installation

4C estimates the array cable installation cost to be $39.78m which is based on a detailed analysis of sub 8MW offshore wind farm array cable installation contracts rates for 33kV cable. The 4C costs estimate considers that the array cables at WIS will not be buried after being laid between the turbines. Laying high voltage power cables on the lakebed is common practice in Ontario with the 230kV underwater electrical connection between an existing wind farm on Wolfe Island to the mainland near Kingston a relevant local example. The range of array cable supply prices in Table 14 reflects the 4C estimate as the central estimate, ±10%.

Capex Item	Low Estimate ($CADm)	Central Estimate ($CADm)	High Estimate ($CADm)
Array Cable Installation	35.80	39.78	43.76

Table 14 – Range of Array Cable Installation Costs

3.15 Export Cable Installation

4C estimates the export cable installation cost to be $4.63m which is based on installation of 29km of 230kV cable to connect between Pigeon Island and the grid connection point as well as a detailed analysis of high voltage cable supply contracts awarded since 2015. The 4C costs estimate considers that the export cable at WIS will not be buried after being laid except for where it comes on shore near the grid connection point. This installation method is identical to the existing 230kV underwater cable installed between Wolfe Island and the mainland. The range of export cable supply prices in Table 15 reflects the 4C estimate as the central estimate, ±10%.

Capex Item	Low Estimate ($CADm)	Central Estimate ($CADm)	High Estimate ($CADm)
Export Cable Supply	4.17	4.63	5.09

Table 15 – Range of Export Cable Installation Costs

3.16 Onshore Substation Supply & Installation

4C estimates the cost of supply and installation of the onshore substation at $47.35m. Based on the range of costs used to derive the average cost of an offshore wind farm substation the range of substation supply costs will be ±10%.

Capex Item	Low Estimate ($CADm)	Central Estimate ($CADm)	High Estimate ($CADm)
Onshore Substation Supply & Installation Cost	42.62	47.35	52.09

Table 16 – Range of Onshore Substation Supply and Installation Costs

3.17 Onshore Substation Cable Supply

This cost is included in the export cable supply costs described in Section 3.10.

3.18 Construction Insurance

4C did not estimate a cost for construction insurance. Therefore, an estimate of construction insurance was requested from providers of insurance to the offshore wind market. To facilitate this request, the value of what was required to be insured must be determined.

With reference to the central estimates provided in Table 24, construction insurance is not required for the following items:

- Development costs $48.46m
- GBF Detailed Design: $4.01m
- Offshore Substation Detailed Design: $2.57m
- Construction insurance: $25.69m
- Project Management costs $13.53m

TOTAL **$94.26m**

Consequently, $94.26m needs to be deducted from central estimate of total Capex to determine the amount of insurance cover required. This gives $1136.64m CAD – $94.26m CAD = $1042.38m CAD.

A recent offshore wind insurance market appraisal, conducted with reputable insurance brokers, provided a range of $22.84m – $26.44m CAD for a $1b CAD construction project. Prorating this range to reflect a $1.042b CAD project (increasing by 4.2%) gives a range of $23.81m to $27.56m as shown in Table 17. The central estimate in Table 17 is the average of this range.

Capex Item	Low Estimate ($CADm)	Central Estimate ($CADm)	High Estimate ($CADm)
Construction Insurance	23.81	25.69	27.56

Table 17 – Range of Construction Insurance Costs

3.19 Project Management Costs

4C estimated the WIS project management cost at $13.53m and benchmarked this estimate against a number of industry studies undertaken in 2019 and 2020 that looked at the combined development costs and post-financial close project management costs. The range of costs in this exercise ranged from being 7.1% lower than 4C's WIS estimate to 8.4% higher, which has been used to generate the cost range is Table 18.

Capex Item	Low Estimate ($CADm)	Central Estimate ($CADm)	High Estimate ($CADm)
Project Management Costs	12.57	13.53	14.67

Table 18 – Range of Project Management Costs

3.20 Contingency

4C estimated contingency at 10% of Capex and notes that a range of contingency levels widely used in the offshore sector is between 7% and 12%. Development costs discussed in Section 3.2 are excluded from the calculation of contingency.

As the scope for cost increase is higher for the low estimate compared to the high estimate, 12% contingency is applied to the low estimate, 10% to the central estimate and 7% to the high estimate in Table 19.

Capex Item	Low Estimate ($CADm)	Central Estimate ($CADm)	High Estimate ($CADm)
Contingency	108.43	98.93	75.26

Table 19 - Range of Contingency Cost

4 Operational Expenditure

This operational expenditure (Opex) analysis is focused on the Technical Opex components which can vary over the lifetime of the offshore wind farm, increasing with the age of the WTG. The individual technical cost components depend on many site-specific parameters. These include the WTG rating (the rated MW capacity of the WTG), the distance the offshore wind farm is from the service port, the sea state and the water depth.

Non-technical Opex expenses include but are not limited to:

- Prevailing legislation regarding transmission charges
- Lakebed lease fees
- Operating insurance
- Community funds or taxes

These non-technical Opex costs are considered by others in the detailed financial modelling analysis of the Project and thus are not addressed in this report, beyond aligning each of the Opex references to reflect, as far is as practicable, the same Opex elements.

The references used to estimate Opex costs are from BVG Associates, IEA Task 26 and an information memorandum regarding the sale of Sprogo Offshore Wind Farm and these are described in Sections 4.1, 4.2 and 4.3 respectively below.

4.1 Operational Expenditure: BVG Associates

BVG Associates[10] has produced operational costs for a notional offshore wind farm which is considered typical of an upcoming UK offshore wind project. The BVG Associates cost is an average Opex costs over the lifetime of the wind farm. The wind farm is based on the following:

- Wind farm rating: 1000MW
- Wind turbine rating: 10MW
- Water depth at site: 30m
- Annual mean wind speed at 100m height: 10m/s
- Distance to shore, grid, port: 60km
- Date of financial investment decision to proceed: 2019
- First operation date: 2022

Table 20 lists the operational costs associated with this development.

[10] **C-2203,** Guide to Offshore Wind Farm – Wind Fam Costs – BVGA (2019) https://guidetoanoffshorewindfarm.com/wind-farm-costs.

Opex Item	Opex Cost (£/MW/Annum)
Training	500
Onshore logistics	450
Offshore logistics	1,600
Health and safety inspections	400
Other (insurance, environmental studies and compensation payments)	22,000
Turbine maintenance and service	33,000
Balance of plant maintenance and service	18,000
Total Opex	**75,950**

Table 20 – BVG Associates Operational Costs

As noted above, *Other* costs of £22,000/MW will be considered by others, therefore this reduces the Total Technical Opex to £53,950/MW which would equate to £16,023,150/annum for WIS or **$27.6m CAD/annum**.

There are several aspects of the Project that could lower this Opex cost. First, the Project is closer to a port and on Lake Ontario, a more benign environment than comparators. As a result, the cost of offshore logistics will be lower. The turbine maintenance cost is for a 10MW WTG which will be lower on a per MW basis compared to the WIS 4.5MW WTG. On balance, the BVG Associates Opex cost is a reasonable and conservative figure on which to base the central estimate of Technical Opex costs for WIS.

4.2 Operational Expenditure: IEA Task 26

Table 21 is reproduced from the IEA Wind Task 26 Offshore Wind Farm Baseline Documentation dated June 2016. It is a bottom-up estimate of Opex costs that is based on the output from two operation and maintenance (O&M) models (NOWIcob and ECN O&M Tool) and the collective experience of the IEA Task 26 group. This study estimates the average Opex over the life of a wind farm.

The O&M strategy begins with the first annual WTG service on 01 April and aims to undertake most services during the summer months, targeting 25% Spring, 50% Summer and 25% Fall[11]. This aligns well with the ice-free window applicable to WIS on Lake Ontario.

[11] **C-2031,** IEA Wind Task 26 – Offshore Wind Farm Baseline Documentation (June 2016) Table C-7, IEA Wind Task 26 Offshore Wind Farm Baseline Documentation, Technical Report NREL/TP-6A20-66262, June 2016.

Level	Category	Baseline Value	Baseline Value
		(€ millions/yr.)	(€/kW/yr)
1	OpEx	39.2	97.9
2	Maintenance	27.1	67.7
3	Offshore maintenance	26.9	67.2
4	Technicians	2.7	6.6
4	Spare parts	7.9	19.6
4	Vessels	16.4	40.8
3	Onshore electric maintenance	0.2	0.5
2	Operations	12.2	30.4
3	Operation, Management and General Administration	1.1	2.8
4	Project management and administration	0.3	0.8
4	Marine management	0.5	1.2
4	Weather forecasting	0.0	0.1
4	Condition monitoring	0.3	0.8
3	Operating facilities	0.5	1.3
3	Environmental, Health, and Safety Monitoring	0.2	0.5
3	Insurance	8.4	21.0
3	Annual Leases and Fees	1.9	4.8
4	Submerge land-lease costs	1.9	4.8
4	Transmission charges/rights	Not estimated	Not estimated
4	Community benefit fund	Not estimated	Not estimated

Table 21 – Baseline O&M Costs[12]

The jack-up vessel required in support of some operational activities, specifically major component replacements, is assumed to have a wind speed limit of 11m/s[13], which would rule out its use for much of the winter period in the IEA study, which aligns with the period that Lake Ontario may be ice bound and WIS would be similarly unable to effect major component repairs. It should be noted that, if required, it will be possible to access the WIS WTGs when Lake Ontario is icebound, either by helicopter or more novel means such as hovercraft.

The baseline costs in Table 21 include insurance and annual lease fees that would need to be deducted from the Technical Opex cost to align the Opex references.

The IEA Task 26 group updated its O&M analysis in October 2018[14] to account for increased competition in turbine supply, reduced demand from oil and gas projects for vessels leading to lower vessel rates and reduced time spent on major turbine repairs. This led to an adjustment of Opex as presented in Table 22.

[12] **C-2031,** IEA Wind Task 26 – Offshore Wind Farm Baseline Documentation (June 2016) Table C-14, IEA Wind Task 26 Offshore Wind Farm Baseline Documentation, Technical Report NREL/TP-6A20-66262, June 2016.

[13] **C-2031,** IEA Wind Task 26 – Offshore Wind Farm Baseline Documentation (June 2016) Table C-2, IEA Wind Task 26 Offshore Wind Farm Baseline Documentation, Technical Report NREL/TP-6A20-66262, June 2016.

[14] **C-2178,** IEA Wind TCP Task 26 – Offshore Wind Energy International Comparative Analysis (October 2018) IEA Wind TCP Task 26: Offshore Wind Energy International Comparative Analysis Technical Report NREL/TP-6A20-71558 October 2018.

Description	2016 Baseline €/kW	2017 Baseline €/kW
Fixed operating costs	30.4	28.3
Variable costs	67.5	48.6
Total Operation and Maintenance (Preventive and Corrective)	97.9	76.9

Table 22 – IEA Task 26 Updated Opex Costs[15]

Table 23 provides more detail on the figures presented in Table 22, the average of all results in Table 23, and presents the detail for each country considered in the IEA analysis.

Valuation Model Inputs Summary - Cost	2017 Baseline	Netherlands	UK	Belgium	Denmark	USA	Germany	Japan
OPEX Inputs Summary	**€/kW**	**€/kW**	**€/kW**	**€/kW**	**€/kW**	**€/kW**	**€/kW**	**€/kW**
Major repairs	31	29	24	25	20	22	26	58
Minor repairs	13	13	14	14	14	14	14	14
Preventive maintenance	5	5	5	5	5	4	5	5
Fixed operating costs	11	4	4	5	5	4	5	16
Operating insurance	17	17	17	17	17	17	17	17
Total Annual OPEX	**77**	**69**	**64**	**66**	**60**	**61**	**67**	**110**

Table 23 – IEA Task 26 OPEX Comparison for All Countries in the 2018 Study[16]

The most comparable geographical region set out above is the USA, as this is closest to the Project, with a total annual Opex of €61/kW. From this figure, the operating insurance element must be deducted, leaving €44/kW. This translates to $49.7 USD/kW (using the average exchange rate for 2017 of 1.13 USD/EUR). Converting to Canadian dollars and adjusting for inflation to 2020 leads to a value of $72 CAD/kW ($49.7 x (1.03)^3 = $54.3 USD/kW, converted to 2020 $CAD $54.3 x 1.3254). Using this figure for the 297MW WIS project results in $21,378,216 CAD/annum or **$21.4m CAD/annum**.

It is also worth noting that the USA model assumes 6MW WTGs, whereas WIS will employ 4.5MW WTGs. Consequently, the Opex cost on a per kW basis for the lower rated WTG is likely to be somewhat higher. The Netherlands project is rated at 600MW, nominally double that of WIS and is therefore likely to benefit from economies of scale compared to the 297MW WIS. However, the Netherlands site is 78km from the O&M port versus 30km for the USA project, nominally the same as the Project. The cost of major turbine repairs is estimated to be between the Netherlands and USA figures, and it is thus considered prudent

[15] **C-2178,** IEA Wind TCP Task 26 – Offshore Wind Energy International Comparative Analysis (October 2018) Table 2, IEA Wind TCP Task 26: Offshore Wind Energy International Comparative Analysis Technical Report NREL/TP-6A20-71558 October 2018.

[16] **C-2178,** IEA Wind TCP Task 26 – Offshore Wind Energy International Comparative Analysis (October 2018) Table 14, IEA Wind TCP Task 26: Offshore Wind Energy International Comparative Analysis Technical Report NREL/TP-6A20-71558 October 2018.

to use the midpoint or €65/kW, a 6.6% increase, resulting in an estimated Opex for the Project of **$22.8m CAD/annum**, which will be the basis for the low estimate of Opex for WIS.

4.3 Operational Costs: Sprogo Offshore Wind Farm Information Memorandum

Appendix B lists Opex items considered in an information memorandum relating to the sale of Sprogo Offshore wind farm in Denmark in 2017. The information memorandum presents actual Opex for seven years of operation for seven 3MW WTGs. Adjustments were made to these figures to account for the larger WIS WTGs (4.5 MW) and the fact that that the Project is farther from a port than Sprogo. Further to these adjustments the Sprogo reference estimates Opex at **$28.5m CAD/annum**.

The Sprogo information memorandum advises that the Opex costs for Sprogo are high and that there is significant scope for reducing Opex costs. Being an information memorandum associated with the sale of an operational wind farm, it may be optimistic. However, with only seven WTGs the Opex costs are likely to be higher when compared to a project that would benefit from the economies of scale of the Project, with 66 WTGs. Additionally, the Sprogo costs are based on the first seven years of operation and not necessarily representative of the average Opex costs over the life of Sprogo offshore wind farm. On balance, it is considered reasonable to use the Sprogo derived Total Technical Opex figure as the high estimate of Technical Opex.

4.4 Discussion

The Technical Opex Costs in Sections 4.1. 4.2 and 4.3 are based on data from the UK, USA and Denmark, respectively. The data from Table 23 allows these costs to be normalised to USA costs, as the Total Technical Opex for the UK is €47/kW, the USA €44/kW and Denmark €43/kW.

The normalised results are:

- BVG Associates: (44/47*$27.6m CAD) $25.8m CAD/annum
- IEA: $22.8m CAD/annum
- Sprogo: (44/43*$28.5m CAD) $29.2m CAD/annum

These results are considered to represent a reasonable range of Technical Opex costs for WIS. In addition, we have applied a $3m CAD/annum premium to the range of Opex figures above to reflect additional costs associated with major component replacement on the WIS WTGs because the Project is considered remote from the locus of offshore wind development activities in the USA, and so may not benefit from the reduced costs associated with proximity to these sites. This results in the following Technical Opex costs:

- **$25.8m CAD/annum** (IEA)
- **$28.8m CAD/annum** (BVG Associates)
- **$32.2m CAD/annum** (Sprogo)

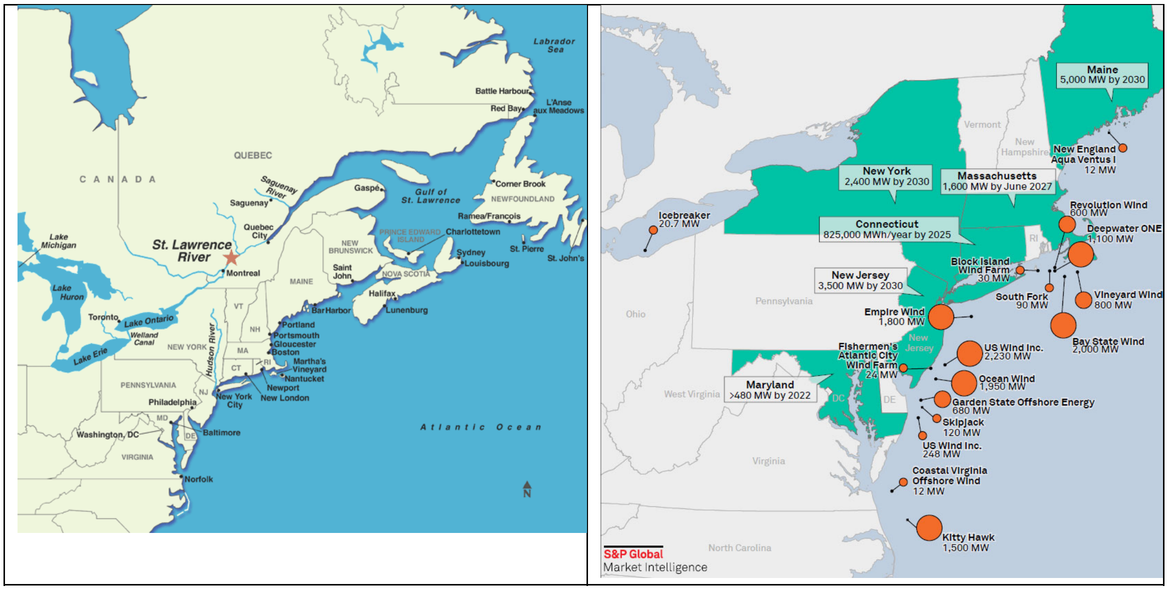

Figure 1 – Lake Ontario Relative to Offshore Wind Projects in the USA[17, 18]

[17] https://www.vacationstogo.com/cruise_port/St._Lawrence_Seaway.cfm.

[18] https://www.spglobal.com/marketintelligence/en/news-insights/research/offshore-wind-ready-to-take-off-in-the-united-states.

5 Summary of Results

5.1 Capital Expenditure Results

The range of total Capex costs is listed in Table 25, the costs are 2020 $CAD[19].

Capex Item	Low Estimate ($CADm)	Central Estimate ($CADm)	High Estimate ($CADm)
Development Costs	45.0	48.5	52.5
GBF Detailed Design	3.8	4.0	4.2
GBF Manufacturing Facility	84.8	95.4	106.0
GBF Supply	210.1	227.3	244.5
WTG Supply	257.4	277.2	297.0
Offshore Substation Detailed Design	2.5	2.6	2.6
Offshore Substation Supply Cost	42.1	46.7	51.4
Array Cable Supply	28.4	31.6	34.8
Export Cable Supply	29.7	33.0	36.3
GBF Installation	58.0	64.5	70.9
WTG Installation	58.7	66.0	73.3
Offshore Substation Installation Cost	8.9	9.9	10.9
Array Cable Installation	35.8	39.8	43.8
Export Cable Supply	4.2	4.6	5.1
Onshore Substation Supply & Installation Cost	42.6	47.4	52.1
Construction Insurance	23.8	25.7	27.6
Project Management Costs	12.6	13.5	14.7
Contingency	108.4	98.9	75.3
Total Capex	**1057.0**	**1136.6**	**1202.9**

Table 24 – Range of Capex Costs

[19] **C-2290,** XE Currency Table https://www.xe.com/currencytables/?from=CAD&date=2020-02-18.

5.2 Operational Expenditure Results

The range of Total Technical Opex costs is listed in Table 26, the costs are 2020 $CAD[20].

WIS Opex	Low Estimate ($CADm/annum)	Central Estimate ($CADm/annum)	High Estimate ($CADm/annum)
Total Opex Costs (related to mechanical operation)	25.8	28.8	32.2

Table 25 – Range of Opex Costs

5.3 Conclusions

The range of Capex and Opex costs for WIS is considered to provide a reasonable range of estimates for use in financial modelling. As with all large capital-intensive projects, these estimates can be refined using more site-specific information as the design of the Project advances.

6 Capital Expenditure Spend Profile

The Project will draw down Capex throughout the development and construction phases and until commercial operation is achieved, the commercial operation date or COD.

Windstream will finance the development phase, up to Financial Close, from February 2020 to February 2023 (37 months), after which Project Finance will be used to construct the Project to achieve its COD during December 2024 (22 months). During the development and construction phases monthly Capex will vary considerably, being relatively low during the development phase and ramping up considerably at Financial Close. An estimate of this Capex Spend Profile (CSP) is presented in Figure 2.

Figure 2 maps the Capex items described in Section 3 of this report onto the WIS development and construction schedule produced by Wood[21]. The mapping exercise draws on my experience of project delivery and makes a number of assumptions to simplify the CSP. The assumptions are detailed in the spreadsheet referenced in Appendix C.

[20] **C-2290,** XE Currency Table https://www.xe.com/currencytables/?from=CAD&date=2020-02-18.

[21] **CER-Wood,** Wood Report: Wolfe Island Shoals Offshore Wind Farm Technical Expert Report 20 January 2022 6.20.247560.CAN.R.001 2.

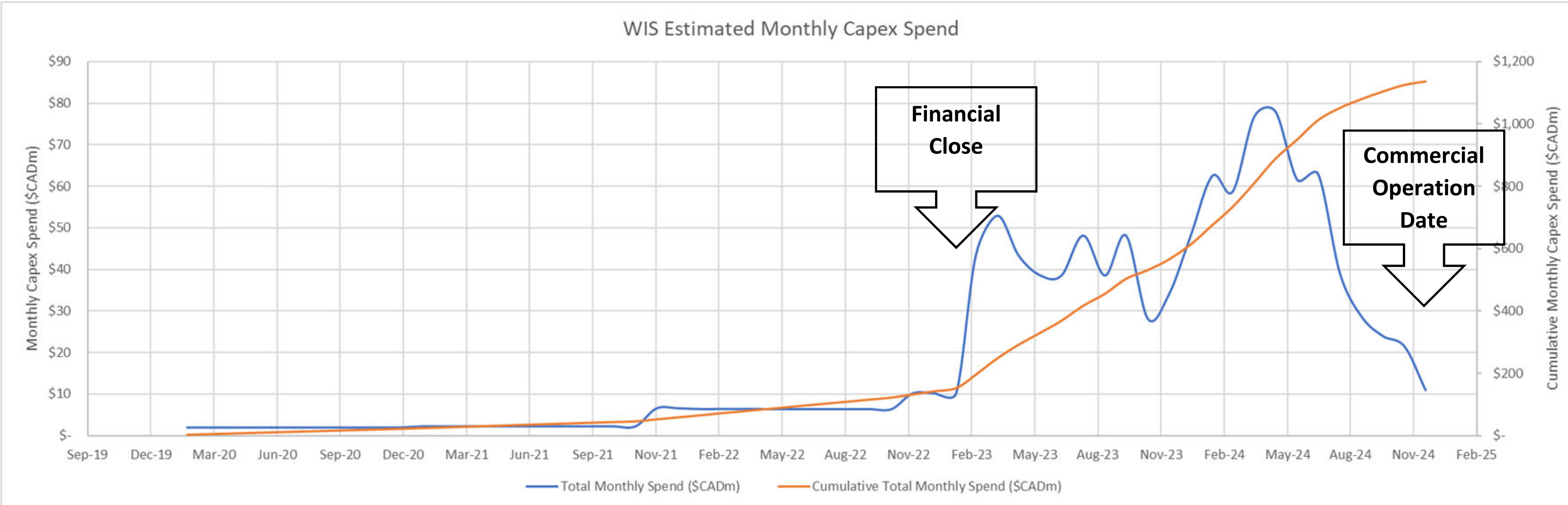

Figure 2 – WIS Capex Spend Profile

Appendix A: Approximate 4C Capital Costs

Approximate capital costs were derived from the 4C report ***A Review of the Capital Costs of Wolfe Island Shoals P/20/1440*** dated March 12, 2021, which is based on 66 x SG 4.5-145 WTGs. An extract from this report is reproduced below.

	2014 ($m)	Inflated to $m 2020	2020 Updated Costs ($m)	Delta ($m) 2020 - 2014	
DEVELOPMENT COSTS					
Preliminary desktop studies, EIA, preliminary designs	11.23	12.30	12.30		
Site Investigation					
Geophysical Surveys	1.4	1.53	1.53		
Geotechnical Surveys	7.99	8.75	8.75		
Met Mast	4.48	4.91	4.91		
TA costs for FEED studies and contractor procurement					
FEED	0.94	1.03	1.03		
Procurement	2.74	3.00	3.00		
Permitting & Environmental Studies					
Permitting	5.49	6.01	6.01		
Environmental Studies	7.92	8.68	8.68		
Legal fees	2.04	2.24	2.24		
	44.23	**48.46**	**48.46**		
SUPPLY COSTS					
Foundations					
Detailed Design	3.02	3.31	3.31		
Supply Costs	321.56	352.30	317.74	-34.6	-9.8%
WTG	483.86	530.12	297	-233.1	-44.0%
OHVS					
Detailed Design	2.35	2.57	2.57		
Supply Costs	42.65	46.73	46.73		
Array cables	26.17	28.67	31.61	2.9	10.3%
Export Cables	10.31	11.30	33.04	21.7	192.5%
	889.92	**975.00**	**732.01**		
INSTALLATION COSTS					
Foundations	50.8	55.66	47.97	-7.7	-13.8%
WTG	91.94	100.73	59.4	-41.3	-41.0%
OHVS	9.05	9.92	9.92		
Array Cables	21.35	23.39	39.78	16.4	70.1%
Export Cables	8.6	9.42	4.63	-4.8	-50.9%
	181.74	**199.11**	**161.70**		
ONSHORE INTERCONNECTION					
Substation	43.22	47.35	47.35		
Cabling	1.57	1.72	0.00		
	44.79	**49.07**	**47.35**	-1.7	-3.5%
TOTAL SUPPLY & INSTALLATION COSTS	1116.45	**1223.18**	**941.05**		
OWNER MANAGEMENT COSTS	12.35	**13.53**	**13.53**		
CONTINGENCY					
Rate	10%	10%	10%		
Amount	112.88	123.67	95.46	-28.2	-22.8%
TOTAL CAPEX	1285.91	**1408.84**	**1098.50**	-310.3	-22.0%

Appendix B: Extract from Sprogo Information Memorandum

Approximate operational costs for WIS were derived from the Sprogø Offshore Wind Farm Information Memorandum dated 22 September 2017[22], an extract from which is reproduced below.

Historical O&M costs 2010 – 2017H1

Annual costs DKKt nom.	2010	2011	2012	2013	2014	2015	2016	2017 H1
WTG*	7,601	8,107	8,169	8,580	8,346	4,972	5,055	2,443
Foundation and cranes	-	204	499	47	40	98	36	-
Scheduled service	-	-	-	-	-	-	-	-
Unscheduled service	-	188	404	11	-	58	-	-
Cranes	-	16	95	36	40	40	36	-
Transmisssion assets and systems	-	-	-	-	-	-	-	-
Scheduled service	-	-	-	-	-	-	-	-
Unscheduled service	-	-	-	-	-	-	-	-
Technicial resources	1,220	1,077	1,172	1,220	1,152	1,278	1,541	767
Technicians**	1,141	1,077	1,160	1,192	1,145	1,276	1,528	764
Tools	79	1	12	28	7	2	13	3
Administration & back-office	228	521	519	465	421	345	686	258
Back office support	228	521	519	465	421	345	686	258
Environmental and safety related costs	4	31	34	93	-	2	-	-
Environmental related costs	-	31	-	-	-	2	-	-
Safety related costs	4	-	34	93	-	-	-	-
Logistics	1,436	1,177	1,272	1,308	1,308	1,282	1,268	595
Crew Vessels	1,436	1,177	1,272	1,308	1,223	1,246	1,241	579
Fuel costs	-	-	-	-	86	35	27	16
Onshore facilities	32	121	10	18	-	-	1	-
Facilities	32	121	10	18	-	-	1	-
Insurance	417	448	448	450	453	453	453	227
Property damage and liability insurance	417	448	448	450	453	453	453	227
Taxes & Fees	2,069	1,169	1,301	1,217	1,178	1,003	874	460
Balancing costs	1,686	837	907	869	802	575	382	260
TSO Feed-in fee	255	199	260	223	241	298	382	140
Trading costs	127	133	134	124	134	130	110	61
Total	13,006	12,854	13,424	13,398	12,898	9,433	9,914	4,749

[22] **C-2120,** Sprogø Offshore Wind Farm Information Memorandum - September 22, 2017 – ESP Consulting http://gphandlahdpffmccakmbngmbjnjiiahp/https://sundogbaelt.dk/wp-content/uploads/2017/09/170922-sprogoe-owf-information-memorandum-announcement.pdf.

Appendix C: WIS Estimated Monthly Capex Spend Profile

WIS Estimated Monthly Capex Spend Profile

Capex Item	Central Estimate ($CADm)	Check		Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22
			Total Monthly Spend ($CADm)	$ 1.9	$ 1.9	$ 1.9	$ 1.9	$ 1.9	$ 1.9	$ 1.9	$ 1.9	$ 1.9	$ 1.9	$ 1.9	$ 2.2	$ 2.2	$ 2.2	$ 2.2	$ 2.2	$ 2.2	$ 2.2	$ 2.2	$ 2.2	$ 2.2	$ 2.2	$ 6.5	$ 6.5
			Cumulative Total Monthly Spend ($CADm)	$ 2	$ 4	$ 6	$ 8	$ 10	$ 11	$ 13	$ 15	$ 17	$ 19	$ 21	$ 23	$ 25	$ 28	$ 30	$ 32	$ 34	$ 36	$ 38	$ 41	$ 43	$ 45	$ 52	$ 58
Development Costs	48.5	48.5		1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31
GBF Detailed Design	4.0	4.0		0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
GBF Manufacturing Facility	95.4	95.4																									
Design				0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43		
Construction																										4.77	4.77
GBF Supply	227.3	227.3																									
Total cost of GBF	**326.7**	**326.7**	**0**	**0.60**	**0.60**	**0.60**	**0.60**	**0.60**	**0.60**	**0.60**	**0.60**	**0.60**	**0.60**	**0.60**	**0.60**	**0.60**	**0.60**	**0.60**	**0.60**	**0.60**	**0.60**	**0.60**	**0.60**	**0.60**	**0.60**	**4.94**	**4.94**
WTG Supply	277.2	277.2																									
Selection, TSA & Design																											
Procurement																											
Built Slot Deposit (Manufacture - 9 Months)																											
Manufacture (Delivery - 1 Month)																											
Installation Port Works																											
Transportation/Delivery																											
Commissioning/Taking-Over Certs																											
Total Cost of WTG	**277.2**	**277.2**	**0**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Offshore Substation Detailed Design	2.57	2.57													0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Offshore Substation Supply Cost	46.7	46.7																									
Pigeon Island Foundation Procurement																											
Pigeon Island Foundation Construction Campaign 1																											
Pigeon Island Foundation Construction Campaign 2																											
Equipment Procurement 1 & 2																											
Prefabrication																											
Total Cost of OVHS	**49.3**	**49.3**	**0**	-	-	-	-	-	-	-	-	-	-	-	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**

Capex Item													Financial Close	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22		
	Feb-22	Mar-22	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24		Spend Profile Notes
Total Monthly Spend ($CADm)	$ 6.3	$ 6.3	$ 6.3	$ 6.3	$ 6.3	$ 6.3	$ 6.3	$ 6.3	$ 6.3	$ 6.3	$ 10.1	$ 10.1	$ 10.2	$ 43.4	$ 52.9	$ 43.3	$ 38.5	$ 38.5	$ 48.1	$ 38.5	$ 48.1	$ 28.1	$ 33.9	$ 48.0	$ 62.4	$ 58.7	$ 76.8	$ 78.0	$ 61.5	$ 62.8	$ 38.9	$ 28.5	$ 23.9	$ 21.4	$ 10.9		
Cumulative Total Monthly Spend ($CADm)	$ 64	$ 71	$ 77	$ 83	$ 90	$ 96	$ 102	$ 109	$ 115	$ 121	$ 131	$ 142	$ 152	$ 195	$ 248	$ 291	$ 330	$ 368	$ 416	$ 455	$ 503	$ 531	$ 565	$ 613	$ 675	$ 734	$ 811	$ 889	$ 950	$1,013	$1,052	$1,080	$1,104	$1,126	**$1,137**		
Development Costs	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31																								It is assumed that the development costs will be spread equally over the development period and will cease at Financial Close.
GBF Detailed Design																																					It is assumed that the GBF Detailed Design costs will be spread equally over the design period.
GBF Manufacturing Facility																																					
Design																																					Assume that 10% of the GBF Manufacturing Facility cost will be used for Logistics, GI & Design and will be spread equally over the respective period.
Construction	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77																					Assume that 90% of the GBF Manufacturing Facility cost will be used for construction and will be spread equally over the respective period. The key issue here is placing the order for the Elevator Platform as this will put spike on monthly capex. However, this will be offset by very low initial GBF Facility construction costs at the start of the build, for example site preparation. This can be refined if required.
GBF Supply											3.79	3.79	3.79		13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50							Assume that 5% of the GBF construction cost will go on the reusable formwork and 95% on GBF manufacturing. Both costs will be spread equally over the respective periods.
Total cost of GBF	**4.77**	**4.77**	**4.77**	**4.77**	**4.77**	**4.77**	**4.77**	**4.77**	**4.77**	**4.77**	**8.56**	**8.56**	**8.56**	**4.77**	**18.27**	**18.27**	**13.50**	**13.50**	**13.50**	**13.50**	**13.50**	**13.50**	**13.50**	**13.50**	**13.50**	**13.50**	**13.50**	**13.50**	**13.50**	**13.50**	-	-	-	-	-	#	
WTG Supply																																					
Selection, TSA & Design																																					Assume that these costs are already captured in the overall development costs
Procurement																																					Assume that these costs are already captured in the overall development costs
Built Slot Deposit (Manufacture - 9 Months)														10.395	10.395	10.395	10.395	10.395	10.395	10.395	10.395																
Manufacture (Delivery - 1 Month)																							10.395	10.395	10.395	10.395	10.395	10.395	10.395	10.395							
Installation Port Works																																					
Transportation/Delivery																								10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40						Assume that 30% of the WTG capex is paid on delivery to Lake Ontario port and this is spread equally over the delivery period.
Commissioning/Taking-Over Certs																														4.62	4.62	4.62	4.62	4.62	4.62		Assume that 10% of WTG Capex is paid on receipt of taking-over certificate and this is spread equally over the corresponding period.
Total Cost of WTG	-	-	-	-	-	-	-	-	-	-	-	-	-	**10.40**	**10.40**	**10.40**	**10.40**	**10.40**	**10.40**	**10.40**	**10.40**	-	**10.40**	**20.79**	**20.79**	**20.79**	**20.79**	**20.79**	**20.79**	**25.41**	**15.02**	**4.62**	**4.62**	**4.62**	**4.62**		
Offshore Substation Detailed Design	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10																								Assume that the offshore substation design cost is spread equally over the respective period.
Offshore Substation Supply Cost																																					
Pigeon Island Foundation Procurement													0.06	0.06																							Assume that offshore substation island construction procurement is 0.25% of total capex and spread over the first two months of the procurement period. Assume that offshore substation island capex is 49.75% of total capex and spread equally over the island construction period.
Pigeon Island Foundation Construction Campaign 1															2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11														
Pigeon Island Foundation Construction Campaign 2																											2.11	2.11									
Equipment Procurement 1 & 2								0.02	0.02	0.02	0.02	0.02	0.02	5.81										5.81	5.81			5.81									Assume that offshore substation equipment procurement is 0.25% of total capex and spread equally over the procurement period. Assume that offshore substation equipment capex is 49.75% of total capex and transferred in 24.75% payments on placing order, on product manufacture, on delivery and on installation & commissioning.
Prefabrication																																					
Total Cost of OVHS	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.12**	**0.12**	**0.12**	**0.12**	**0.12**	**0.18**	**5.87**	**2.11**	**2.11**	**2.11**	**2.11**	**2.11**	**2.11**	**2.11**	**2.11**	**2.11**	**5.81**	**5.81**	-	**2.11**	**7.93**	-	-	-	-	-	-	-		

WIS Estimated Monthly Capex Spend Profile

Capex Item	Central Estimate ($CADm)	Check		Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20
Array Cable Supply	31.6	31.6												
Design														
Procurement														
Fabrication														
Delivery & Commissioning														
Export Cable Supply	33.0	33.0												
Design														
Procurement														
Fabrication														
Delivery & Commissioning														
Total Cost of Array and Export cables	**64.7**	**64.7**	**0**	-	-	-	-	-	-	-	-	-	-	-
GBF Installation	64.5	64.5												
Season 1 Mobilisation														
Season 1 GBF Installation														
Season 1 Demobilisation														
Season 2 Mobilisation														
Season 2 GBF Installation														
Season 2 Demobilisation														
WTG Installation	66.0	66.0												
Offshore Substation Installation Cost	9.9	9.9												
Array Cable Installation	39.8	39.8												
Export Cable Installation	4.6	4.6												
Total Cost of Installations	**184.8**	**184.8**	**0**	-	-	-	-	-	-	-	-	-	-	-

Capex Item	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21
Array Cable Supply												
Design	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Procurement												
Fabrication												
Delivery & Commissioning												
Export Cable Supply												
Design	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Procurement												
Fabrication												
Delivery & Commissioning												
Total Cost of Array and Export cables	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
GBF Installation												
Season 1 Mobilisation												
Season 1 GBF Installation												
Season 1 Demobilisation												
Season 2 Mobilisation												
Season 2 GBF Installation												
Season 2 Demobilisation												
WTG Installation												
Offshore Substation Installation Cost												
Array Cable Installation												
Export Cable Installation												
Total Cost of Installations	-	-	-	-	-	-	-	-	-	-	-	-

Capex Item	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23
Array Cable Supply														
Design	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Procurement														
Fabrication														
Delivery & Commissioning														
Export Cable Supply														
Design	0.05	0.05	0.05	0.05	0.05									
Procurement														0.02
Fabrication														
Delivery & Commissioning														
Total Cost of Array and Export cables	0.08	0.08	0.08	0.08	0.08	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.05
GBF Installation														
Season 1 Mobilisation														
Season 1 GBF Installation														
Season 1 Demobilisation														
Season 2 Mobilisation														
Season 2 GBF Installation														
Season 2 Demobilisation														
WTG Installation														
Offshore Substation Installation Cost														
Array Cable Installation														
Export Cable Installation														
Total Cost of Installations	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Financial Close

Capex Item	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Array Cable Supply																						
Design																						
Procurement	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01													
Fabrication	9.19											9.19										
Delivery & Commissioning													9.19								3.16	
Export Cable Supply																						
Design																						
Procurement	0.02	0.02	0.02	0.02																		
Fabrication		9.61				9.61																
Delivery & Commissioning								9.61								3.30						
Total Cost of Array and Export cables	9.22	9.63	0.03	0.03	0.01	9.62	0.01	9.62	0.01	-	-	9.19	9.19	-	-	3.30	-	-	-	-	3.16	-
GBF Installation																						
Season 1 Mobilisation																						
Season 1 GBF Installation		4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61													
Season 1 Demobilisation														4.61	4.61	4.61	4.61	4.61	4.61			
Season 2 Mobilisation																						
Season 2 GBF Installation																						
Season 2 Demobilisation																						
WTG Installation													7.33	7.33	7.33	7.33	7.33	7.33	7.33	7.33	7.33	
Offshore Substation Installation Cost														4.96	4.96							
Array Cable Installation														5.68	5.68	5.68	5.68	5.68	5.68	5.68		
Export Cable Installation														4.6								
Total Cost of Installations	-	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	-	-	-	7.33	27.21	22.58	17.62	17.62	17.62	17.62	13.02	7.33	-

Capex Item	Spend Profile Notes
Array Cable Supply	
Design	Assume detailed design of the array cable layout and specification of the cable is 2.5% of the supply capex and spread equally over the design period. I assume such a high cost as I would expect detailed surveys of the lakebed along proposed cable routes would need to be conducted, a detailed map of the lakebed developed and an installation methodology derived.
Procurement	Assume that procurement is 0.25% of the cable supply capex and spread over the procurement period.
Fabrication	Assume that offshore array cable capex is 97.25% of total capex and transferred in four payments: on placing order, on product manufacture, on delivery with 10% paid on cable commissioning.
Delivery & Commissioning	
Export Cable Supply	
Design	Assume detailed design of the export cable layout and specification of the cable is 2.5% of the supply capex and spread equally over the design period. Same reason as array cable design cost.
Procurement	Assume that procurement is 0.25% of the cable supply capex and spread over the procurement period.
Fabrication	Assume that offshore array cable capex is 94.75% of total capex and transferred in four payments: on placing order, on product manufacture, on delivery with 10% paid on cable commissioning.
Delivery & Commissioning	
Total Cost of Array and Export cables	
GBF Installation	
Season 1 Mobilisation	
Season 1 GBF Installation	There are a lot of activities under GBF installation that will utilise different vessels. So this element can certainly be refined to reflect a more representative spend profile. To keep it simple the GBF installation will be spread equally over the installation period and no weighting given to mobilisation/demobilisation costs at the moment.
Season 1 Demobilisation	Costs are assumed to be representative of a two season installation period.
Season 2 Mobilisation	
Season 2 GBF Installation	
Season 2 Demobilisation	
WTG Installation	There are a mixture of activities here. For simplicity an average cost will be assumed over each month.
Offshore Substation Installation Cost	
Array Cable Installation	This capex item is averaged over the installation period.
Export Cable Installation	
Total Cost of Installations	

WIS Estimated Monthly Capex Spend Profile																																								Financial Close	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
Capex Item	Central Estimate ($CADm)	Check		Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24	Spend Profile Notes
Onshore Substation Supply & Installation Cost	47.4	47.4																																																													Assume that onshore substation design is 5% of total capex and spread equally over the design period.
Design															0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09																							
Procurement & Manufacture																																		0.02	0.02	0.02	0.02	0.02	0.02	0.02	5.30											5.30		5.30	5.30								Assume that onshore substation procurement is 0.25% of total capex and spread equally over the procurement period. It is assumed that offshore substation equipment capex is 44.75% of total capex and transferred in 24.75% payments on placing order, on product manufacture, on delivery and on installation & commissioning.
Installation																																									1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58								Assume that offshore substation construction capex is 50% of total capex and spread equally over the construction period.
Total Cost of Onshore Interconnection	**47.4**	**47.4**	**0**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**0.09**	**0.09**	**0.09**	**0.09**	**0.09**	**0.09**	**0.09**	**0.09**	**0.09**	**0.09**	**0.09**	**0.09**	**0.09**	**0.09**	**0.09**	**0.09**	**0.09**	**0.09**	**0.09**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**6.88**	**1.58**	**1.58**	**1.58**	**1.58**	**1.58**	**1.58**	**1.58**	**1.58**	**1.58**	**1.58**	**6.88**	**1.58**	**6.88**	**6.88**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	
Construction Insurance	25.7	25.7																																							1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	Assume that this can be spread equally over the construction period.
Project Management Costs	13.5	13.5																																							0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	Assume that Project Management costs start at Financial Close and end at handover. Earlier Project Management costs are assumed to be captured in the overall development costs.
Contingency	98.9	98.9																																							4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	Contingency is spread it equally across the construction phase from Financial Close.
Total Capex	**1136.7**	**1136.7**																																																													

TAB 10

FEBRUARY, 2022
WINDSTREAM ENERGY, INC.

WOLFE ISLAND SHOALS, NAFTA 2

WIND TURBINE GRAVITY BASE FOUNDATION DESIGN

EXPERT WITNESS REPORT

COWI

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FEBRUARY, 2022
WINDSTREAM ENERGY, INC.

WOLFE ISLAND SHOALS, NAFTA 2

WIND TURBINE GRAVITY BASE FOUNDATION DESIGN

EXPERT WITNESS REPORT

PROJECT NO.	DOCUMENT NO.
A221714	A221714-01-01

VERSION	DATE OF ISSUE	DESCRIPTION	PREPARED	CHECKED	APPROVED
1.0	February 18, 2022	Report	EMCH	CLWL	BRCO

1 Executive Summary

Windstream is planning to develop the approximately 300 MW Wolfe Island Shoals (WIS) Offshore Wind Farm on the Canadian side of the eastern end of Lake Ontario. It is COWI's understanding that in February 18, 2020, the government notified Windstream that the power purchase agreement issued for the Project has been cancelled. In response, Windstream submitted a Notice of Intent (February 2020) and Notice of Arbitration (November 2020), as the initial steps in a second round of NAFTA arbitration proceedings (referred to in this report as NAFTA2).

COWI was retained by Windstream to review the technical documentation with regard to the turbines' gravity base foundation and affirm or update the foundation concept design, fabrication plan and fabrication schedule and to prepare the fabrication Opinion of Probable Cost assuming the development of WIS would have been restarted in 2020. The scope of technical works completed during the first NAFTA Arbitration (NAFTA1) is largely still applicable to NAFTA2, excepting the advancement of turbine technology has allowed the use of a higher capacity turbine on a similar gravity base foundation, resulting in schedule savings as compared to NAFTA1. COWI considers the information, calculation procedures and results of the NAFTA1 foundation design and foundation fabrication plan as in accordance with typical industry practices at the time this report was produced. This report provides COWI's corporate qualifications as offshore wind turbine foundation designer, the industry track record of gravity base foundations and incremental modifications to the gravity base foundation as compared to NAFTA1.

CONTENTS

2 Introduction to Wolfe Island Shoals (WIS) Offshore Wind Farm

2.1 Wolfe Island Shoals Offshore Wind Farm

Windstream is planning to develop the approximately 300 MW Wolfe Island Shoals Offshore Wind Farm, on the Canadian side of the eastern end of Lake Ontario. COWI was retained by Windstream to prepare the design and fabrication plan for the semi-floating concrete gravity base foundations (GBF) that will be used to support the offshore wind turbine generators.

2.2 WIS Offshore Infrastructure

Wolfe Island Shoals is located in Lake Ontario southwest of Wolfe Island. The planned facility consists of sixty-six (66) SG 4.5-145 wind turbine generators (WTG) supported by semi-floating concrete gravity base foundations. A 230kV submarine electrical cable approximately 28km long will run along the lakebed, coming to shore and connecting at the Lennox TS.

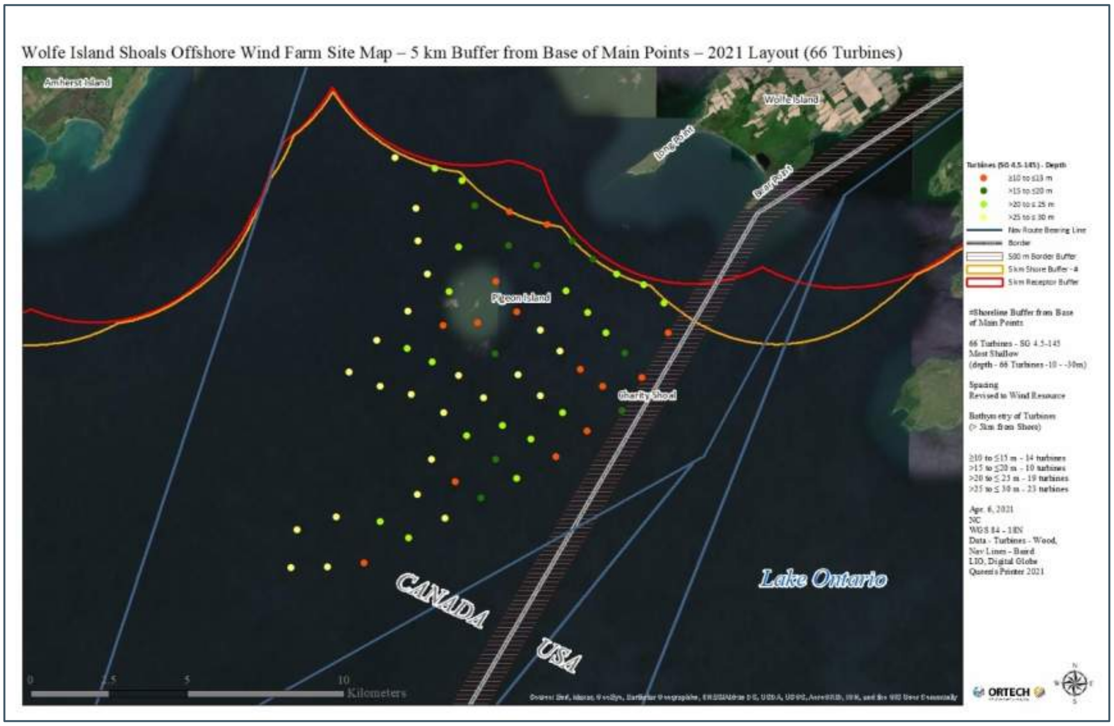


Figure 2-1: WIS 2021 Layout (66 turbines)

2.3 Development Status

COWI previously conducted studies for Windstream Energy Inc. (Windstream) in support of the NAFTA arbitration proceedings held in 2014-2016 (NAFTA1) related to the Wolfe Island Shoals (WIS) offshore wind farm (the Project). These previous studies are identified in Section 4.1 of this report for convenience. These previous studies have been recently reviewed and COWI considers the information, calculation procedures and results of the NAFTA1 foundation design as in accordance with modern industry best practices.

It is COWI's understanding that on February 18, 2020, the government notified Windstream that the power purchase agreement (Feed-in-Tariff contract) issued for the Project has been cancelled. In response, Windstream submitted a Notice of Intent (February 2020) and Notice of Arbitration (November 2020), as the initial steps in a second round of NAFTA arbitration proceedings (referred to in this report as NAFTA2).

In support of NAFTA2, COWI has reviewed our previously completed works and provided this update to our previous report with a detailed review of the key conclusions related to the feasibility of the Project from a technical, scheduling and financial perspective. This report considers recent information and experience obtained since NAFTA1 and provides an opinion on the feasibility of the Project should it have been allowed to re-start the development process in February 2020. The objective of this current study is to assess the feasibility of the Project should it have been allowed to progress in the absence of ("but for") restrictions imposed and uncertainty created by various government agencies.

In constructing a "but for" scenario, COWI has been asked to assume that the Ontario Government did not adopt an indefinite-term moratorium on offshore wind development on February 11, 2011. Instead, COWI has been asked to assume that the following would have occurred by **February 18, 2020**:

1 Ministry of Environment, Conservation and Parks (MECP) (formerly Ministry of Environment, MOE) would have confirmed its proposed regulatory amendment to include a five-kilometer setback, or confirmed that it would not proceed with any regulatory amendment (such that setbacks for offshore wind projects would continue to be assessed on a site-specific basis);

2 Ministry of Natural Resources (MNR) would have fulfilled its commitment to discuss the reconfiguration of Windstream's applications for Crown land for the Project (if a five-kilometer setback was confirmed), and would have thereafter fulfilled its commitment to "move as quickly as possible through the remainder of the application review process so that the Project may obtain Applicant of Record status in a timely manner.";

3 MECP and MNR would have fulfilled their commitment to process the Project's application for a Renewable Energy Approval (REA) within the six-month service guarantee;

4 MNR would have permitted Windstream to proceed through MNR's Crown land application process and granted Windstream site release;

5 the Ontario Government would have dealt with Windstream in good faith and not have subjected the Project to unreasonable regulatory delays; and

6 the FIT Contract was not cancelled.

Given the project program information conveyed to COWI, the available site characterization data and the engineering associated with the GBF foundation fabrication, transportation and installation plan, it is COWI's opinion that the GBFs proposed for WIS are a technically viable and constructible solution for Wolfe Island Shoals.

3 COWI Corporate and Personnel Qualifications

COWI is a leading consulting group that provides state-of-the-art, multidisciplinary engineering services with due consideration for the environment and society. Globally, COWI stands strong on the shoulders of our nearly 7,400 staff operating from more than 35 international offices. In North America, COWI is a prominent and award-winning specialty marine and coastal engineering firm with more than 240 technical staff in eight (8) North American offices.

COWI has extensive experience within design services related to the design of offshore wind turbine farms, including the design of wind turbine foundations, offshore substations, electrical systems and Offshore Wind (OSW) staging ports. COWI has been involved in large-scale offshore wind farm (OWF) and port infrastructure projects in the U.S. and all over the world. COWI has been involved with over 800 wind power projects in 68 countries. COWI has completed the detailed designs of more than 850 offshore foundations which, as installed, support 4,000 MW of nameplate capacity; we have been responsible for the ongoing detailed and preliminary designs for an additional 5,000 MW of capacity. Our expertise as an offshore wind designer means that we have a detailed understanding of the offshore and onshore construction methods and infrastructure required to successfully and efficiently complete projects.

Figure 3-1 (Left) Kårehamn OWF completed 2013 (Courtesy of Baltic Offshore)
Figure 3-2 (Right) Kårehamn OWF under construction 2012 (Courtesy of Baltic Offshore)

In North America, COWI has been involved with multiple offshore wind projects, including some of the projects being developed by Equinor, Ørsted, Vineyard Wind, Atlantic Shores, Ocean Winds, Mayflower Wind, Santee Cooper, LEEDCo, Diamond Generating Corporation, Trillium Windpower and more. Additionally, COWI has prepared a number of port(s) and infrastructure studies for a range of public and private clients.

3.1 COWI Project Experience

COWI has prepared the detailed design of 184 gravity base foundations, installed in four (4) distinct offshore wind farms; these foundations are fully commissioned and operational. COWI has completed significant design tasks for an additional five (5) distinct projects consisting of an additional approximately 260 foundations. A list of these projects can be seen in

Figure 3-5 (Left) Empire Wind rendering – GBF transportation (Courtesy of Equinor)
Figure 3-6 (Right) Empire Wind rendering – installed OWF (Courtesy of Equinor)

Table 3-1.

Figure 3-3 (Left) Thornton Bank Offshore Wind Farm GBF under construction, Feb. 2008
Figure 3-4 (Right) Thornton Bank Offshore Wind Farm GBFs under construction, Feb. 2008

Figure 3-5 (Left) Empire Wind rendering – GBF transportation (Courtesy of Equinor)
Figure 3-6 (Right) Empire Wind rendering – installed OWF (Courtesy of Equinor)

Table 3-1: COWI GBF Designs

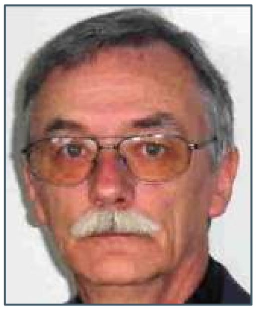
Project	Design Level / Project Status	Details
Thornton Bank Phase 1 OWF	Detailed Design / Installed	Belgium, (2006-2009): Detailed design, 6 GBF of the conical type for Repower 5 MW turbines. Water depth 21-27 m LAT.
Kårehamn OWF,	Detailed Design / Installed	Kårehamn Offshore Wind Farm, Sweden (2012-2013): Detailed design, 16 GBF for Vestas 3 MW turbines at 8m -21 m MSL water depth in the Baltic Sea near Øland in Sweden.
Nysted OWF	Detailed Design / Installed	Denmark (2001-2002): Detailed design, 72 GBF for Siemens 2.3 MW turbines and 1 OSS foundation Water depth 5 – 13 m MSL.
Rødsand 2 OWF	Detailed Design / Installed	Denmark (2001-2002): Detailed design, 90 GBF for Siemens 2.3 MW turbines and 1 Offshore Substation foundation. Water depth 5 – 13 m MSL.
Empire Wind	Pre-FEED	New York, USA (2018): One of four teams selected to prepare conceptual design of GBF for Equinor's Empire Wind I project. Empire Wind will provide 816 MW to New York generated from 10-15 MW turbines.
Lillebaelt Syd OWF	Concept Design	Denmark (2018): Concept design of two variants, 20 x 8.0 MW GBF and 40 x 4.0 MW GBF. Water depth 9 to 22m MSL.
Freshwater Wind	Technology Advancement Project	New York, USA: Design of holistic foundation, fabrication facility, transportation and installation program for semi-floating GBF, GBF with skirt, and GBF with integrated tower variants. All foundation types subject to fresh water (Lake Erie) ice loading.
Palmetto Wind / SEA WIND	Conceptual Design	South Carolina, USA: Concept design, 10-20 foundations for 3.6-4.0 MW turbines. Water depth 24-60 ft MLLW.
Fecamp Tender Design	Tender Design	France (2013): Tender design 83 GBF for Alstom (GE) 6 WM turbines. Water depth varies -27 to -33m LAT.

3.2 COWI Key Staff

Brent Cooper – Project Manager

Mr. Cooper has over 14 years' experience providing engineering solutions to offshore wind and marine terminal infrastructure projects, especially as they relate to the design of wind turbine foundations, substation foundations, and fabrication and staging port facilities. Brent and his team provide services through the full Lifecycle of a project, including planning, analysis, engineering, construction, structural condition monitoring and assessment, rehabilitation, and decommissioning. He has relevant recent experience with numerous similar gravity base foundation design studies for other offshore wind stakeholders and firsthand engineering experience that is directly applicable to Wolfe Island Shoals.

Jørn Thomsen – Chief Technical Specialist



Jørn Mr. Thomsen has more than 35 years of experience within planning, design and project management of marine works, notably offshore wind turbine foundations, port planning and harbor construction as well as pipeline engineering. Over more than a decade, the prime focus has been on offshore wind turbine foundations as project manager and key expert.

Jørgen Bang Cramwikt – Senior Technical Specialist

Mr. Cramwikt has a theoretical background in hydraulic engineering combined with geotechnical and structural engineering. He has acted as design manager and discipline lead for offshore wind GBF projects as well as ports and terminal projects. As specialist, his main experience is with finite element modelling of marine concrete structures like gravity base foundations for offshore wind farms and concrete caissons for ports. Within offshore wind farm design, he has undertaken concept studies with COWI's proprietary MS spreadsheet and 3D parametric finite element modelling using COWI's in-house FEM program IBDAS. Moreover, he has experience with numerical programs for assessment of environmental loads, such as waves, current, ice, and design of scour protection, numerical wave and current simulation.

Carly Wilmott – Technical Specialist

Ms. Willmott is a Marine Engineer specializing in structural engineering and design of waterfront facilities. Her experience also includes large scale land-based construction. She has extensive experience working in a collaborative team environment and communicating across the boundaries of different subject matters.

Emma Chick – Technical Specialist

Ms. Chick is a Marine Designer at COWI with a background in marine structure analysis and design. Her design experience consists of structural analysis of existing marine structures and design of new and rehabilitated marine structures such as piers, bulkheads, seawalls, revetments, and marinas.

4 Offshore Wind Farm Foundations

4.1 Traditional Offshore Wind Foundation Types

Offshore turbines are typically supported by either gravity base foundations, monopiles, jackets, suction buckets, tripods or a variant of the aforementioned types. Floating offshore wind foundations are not considered for WIS due to seasonal ice loading and relatively shallow water depths.

4.1.1 Gravity Base Foundation

Gravity base foundations are large concrete, steel or hybrid structures which are fabricated onshore and transported to the offshore site. GBFs rely on their own massive weight to support the structure and resist sliding, bearing capacity pressures and overturning. Large variations of design exist for this type of foundation, and the overall weights and dimensions are typically governed by the geotechnical capacity of the structure. GBFs are built onshore then transported to site and lowered into place, where seabed preparation is first typically required. The advantages of GBFs as they apply to WIS are further described in Section 4.2.

Figure 4-1 (Left): Thornton Bank Offshore Wind Farm GBFs under construction, Feb. 2008
Figure 4-2 (Right): GBF rendering (J. Mar. Sci. Eng. 2019, 7, 64)

4.1.2 Monopiles

Monopiles are currently the most common foundation type used in offshore wind turbine construction. Monopile foundations typically consist of hollow, steel cylinders with diameters between 3 and 8 m and varying lengths. A transition piece is attached at the top of the pile for turbine connection. The piles are driven into the seabed and typically suited to shallower depths due to their load resistance capabilities.

Figure 4-3 (Left): Typical monopile design (Courtesy of Geosea Nv)

Figure 4-4 (Left): London Array Offshore Wind Farm (Courtesy of London Array Ltd.)

4.1.3 Jacket

Jacket foundations, initially based on similar structures used in the oil and gas industry, consist of lattice framework with three or four seabed anchoring points, increasing the level of stability of the structure and making them more suitable for installation in deeper water. These foundations typically consist of four (4) main sub-systems including a transition piece, work platform and boat landing, jacket support structure with structural steel tubes, and suction anchors or pile sleeve foundations. The transition piece transfers the turbine loads to the jacket support structure and ultimately to the ground.

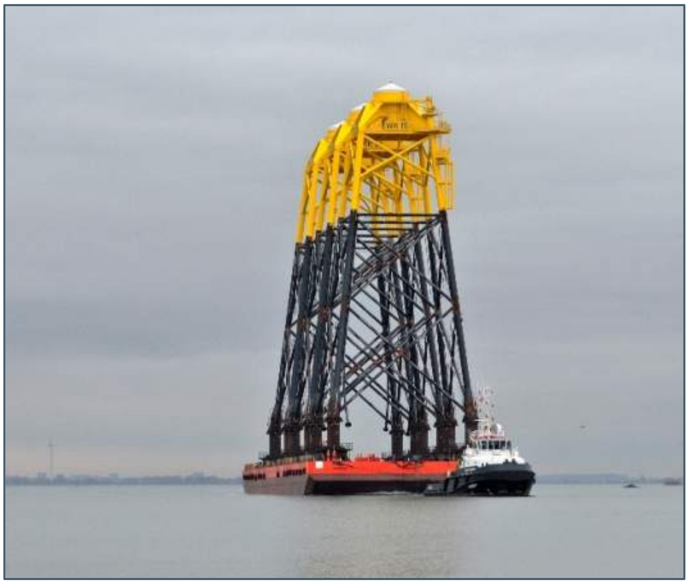


Figure 4-5 (Left): Wikinger OWF jacket foundations, Nov. 2016 (Courtesy of Bladt)
Figure 4-6 (Right): Jacket foundation rendering

4.1.4 Suction

Suction-installed foundations are normally constructed of steel or concrete and are referred to as suction buckets, suction caissons, suction piles or suction anchors. This foundation type is set apart by its means of installation: the caisson is allowed to settle into the seabed, then a pump (bucket) is attached at the head. Once attached, the pump applies suction to the caisson, creating a pressure difference between the inside of the bucket and the water surrounding it, causing the caisson to be pulled deeper into the seabed without application of mechanical force.

Figure 4-7 (Left): Borkum Riffgrund 1 suction foundation (Courtesy of Ørsted)
Figure 4-8 (Right): Suction foundation rendering (Courtesy of Universal Foundation)

4.1.5 Tripod

Tripod foundations consist of a turbine tower resting on a steel pile (like in a monopile foundation). A steel frame including three piles in a tripod formation is connected to the pile, distributing the loads from the tower pile to the tripod piles (similar to transfer in the jacket foundations). The three-legged foundation provides more anchor points and a wider base to stabilize the structure against lateral loads and overturning. Like jacket foundations, tripod foundations are typically more suited to sites with deeper waters due to their additional stabilizing capabilities against loads associated with deeper water conditions.

Figure 4-9 (Left): Global Tech 1 OWF tripod foundation (Courtesy of Global Tech 1)
Figure 4-10 (Right): Tripod foundation rendering (Courtesy of Cathwell)

4.2 Gravity Base Foundations for Wolfe Island Shoals

Gravity base foundations are particularly well suited to project locations with hard sea floor (i.e. geotechnical) conditions, such as exposed bedrock, very dense sands or over-consolidated clay similar to those expected for WIS. The semi-floating GBF design was chosen for the Wolfe Island Shoals project based on these site conditions, as well as a ready supply of raw materials and a supply chain experienced with concrete construction. The foundation installation plan assumes the GBF will be floated to site, assisted by two independent sets of four (4) low-cost, supplemental floatation barges, which are small vessels that can be re-purposed from an existing fleet or built in any small to medium size shipyard or steel fabrication facility with water access. This presents the potential for a significant cost and schedule advantage for the Wolfe Island Shoals project. The installation contractor may use additional sets of supplemental flotation barges to achieve an even faster foundation installation rate. Another distinct advantage is that multiple sets of supplemental floatation barges provide redundancy and schedule certainty, something not available to a project reliant on a single heavy lift vessel.

GBF are particularly well suited for installation at WIS. The materials and technology required to fabricate GBF are readily available, the foundation design is particularly well suited for the water depth, geotechnical conditions and ice found on Lake Ontario and similar designs are being studied or are in process of being developed at other locations in the Great Lakes.

Concrete cast-in-place and pre-stress post-tensioned technology is proven and readily available in Ontario. Local limestone quarries and cement manufacturing facilities are located nearby, ensuring a cost effective, reliable source of raw materials for manufacturing foundations. The construction techniques proposed for WIS are already in use in Ontario for other large civil infrastructure foundations (bridges, onshore wind, industrial).

Figure 4-11 Rødsand 2 OWF construction (Courtesy of GS Seacon)

The water depth for the proposed WIS project ranges from approximately 10m to 30m. Concrete GBF are readily adaptable to changes in water depth. The height of individual elements within the foundation, such as the buoyancy chamber, conical frustrum or cylindrical stem can all be modified without the need to also modify the diameter of each element. Concrete foundations are larger, more robust structures than their steel monopile and jacket counterparts, meaning they are less susceptible to changes in the frequency response of the integrated turbine and foundation system.

Figure 4-12 Blyth OWF (Courtesy of Ban Infra)

Geophysical investigations completed for WIS indicate that shallow bedrock is present over the majority of the project site. For additional discussion on the geophysical and geotechnical characterization of the WIS project site, see section 5.3. GBF are typically more economical than piled foundation in these conditions. Where necessary, surficial sediments will be removed and the underlying rock is leveled with a gravel mat. The GBF design assumes an average removal of 1.5m of sediment, though is generally applicable for the soil characteristics identified in the 2021 Turbine Layout Geological Assessment prepared by CSR (see further detail in section 5.3). The gravel mat also assists with load distribution, helping to ensure that horizontal and vertical loads are transferred evenly to the bedrock below. After the gravel mat is prepared, GBF are lowered in place onto the mat and ballasted with sand. By eliminating the need to drive piling (or more likely drilled-in pile foundations at the WIS project site due to shallow bedrock), GBF are able to reduce the overall installation risk and therefore reduce installation cost, as compared to other foundation types.

Figure 4-13 Sprogø OWF (Courtesy of Windpower Monthly)

GBF are relatively easily adapted to withstand the ice loading conditions that occur in Lake Ontario. Ice cones, either downward and/or upward breaking structures are slanted cones that are fitted to the stem of the GBF at the waterline. They break the sheet ice in flexure (bending) rather than in compression, where the strength of the ice would be much greater. The large mass of the GBF is able to resist the raft ice loading.

A number of wind farms have been built in Northern Europe that are subject to regular salt and freshwater ice loading conditions, including: Vindpark Vanern[1], Pori[2], and Nysted. Additional projects under development in this area facing similar conditions include the 100-MW Rewind Vanern (Stenkalles grund) offshore wind project, whose 16-turbine construction is anticipated to begin this year[3]. Projects have been proposed on the U.S. side of the Great Lakes that are also considering ice loading, including the Lake Erie Energy Development Corporation (LEEDCo) Project Icebreaker, the New York Power Authority Great Lakes Offshore Wind Project (Canceled 2011), and others.

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[1] **C-1827**, 4C Offshore, Vindpark Vanern
[2] **C-1588**, Eranti, E., et al (2011), A Novel Offshore Windmill Foundation for Heavy Ice Conditions
[3] 4C Offshore, Stenkalles grund

Figure 4-14 Nysted OWF, 2002

Figure 4-15 (Left) Nysted OWF installation, 2001

Figure 4-16 (Right) Nysted OWF installation, 2001

4.3 GBF Track Record

Gravity base foundations have been used for approximately forty (40) offshore wind projects in varying phases of project development. GBF support approximately 736 MW of installed capacity, which accounts for approximately 2% of total installed capacity as of February 2021. Offshore wind farms using GBF are provided in Table 4-1.

Figure 4-17 Lillgrund OWF (constructed with GFB) (Courtesy of Vattenfall)

Table 4-1: Gravity Base Foundation Record (Courtesy of 4C Offshore)

OWF Name	**Developer / Owner / Operator**	**Location (Region/Country)**	**Project Capacity (Max MW)**	**Qty Turbines/ Turbine Capacity (Max)**	**Development Status**
Avedøre Holme	Ørsted A/S (formerly DONG Energy AS) / Ørsted (66.6%), Hvidovre vindmøllelaug (33.3%) / Ørsted A/S (formerly DONG Energy AS)	Hovedstaden/Denmark	10.8	3/3.6 MW	Fully Commissioned
Blyth Offshore Demonstrator Project - Array 2	EDF Energy Renewables / EDF /	England, North East/United Kingdom	41.5	5/8.3 MW	Fully Commissioned
Breitling	Nordex Energy AG,WIND-projekt GmbH / WPD / WIND-projekt GmbH	12nm zone (Mecklenburg Vorpommern)/Germany	2.5	1/2.5 MW	Fully Commissioned
Choshi	Tokyo Electric Power Company, Inc (TEPCO) ,New Energy and Industrial Technology Development Organisation (NEDO) / New Energy and Industrial Technology Development Organisation (66.67%), TEPCO (33.33%) / Tokyo Electric Power Company, Inc (TEPCO)	Chiba Prefecture/Japan	2.4	1/2.4 MW	Fully Commissioned
Dafeng (Shanghai Electric) Intertidal Demonstration Turbine	China Power New Energy Development Company Limited / SPIC (50%), B.I. Energia (50%) /	Jiangsu, Yancheng, Dafeng/China	2	1/2 MW	Fully Commissioned
ELISA/ELICAN - Mario Luis Romero Torrent (PLOCAN site)	ESTEYCO / ESTEYCO /	Islas Canarias/Spain	5	1/5 MW	Fully Commissioned
Kårehamn	E.ON Vind Sverige AB / RWE / E.ON Vind Sverige AB,RWE Renewables	Borgholm Kommun/Sweden	48	16/3 MW	Fully Commissioned
Lillgrund	Vattenfall Europe Windkraft GmbH / Vattenfall / Vattenfall Europe Windkraft GmbH	Malmö Kommun/Sweden	110.4	48/2.3 MW	Fully Commissioned
Middelgrunden	Ørsted A/S (formerly DONG Energy AS) / Middelgrundens Vindmollelaug (50%), HOFOR Hovedstadsområdets Forsyningsselskab (50%) / Middelgrundens Vindmollelaug,HOFOR	Hovedstaden/Denmark	40	20/2 MW	Fully Commissioned
Nysted	Energi E2 / PensionDanmark (50%), Ørsted (42.75%), Stadtwerke Lübeck (7.25%) / Energi E2	Sjælland/Denmark	165.6	72/2.3 MW	Fully Commissioned
Reposaaren tuulipuisto	Suomen Hyötytuuli Oy / Suomen Hyötytuuli / Suomen Hyötytuuli Oy	Länsi-Suomi/Finland	2.3	1/2.3 MW	Fully Commissioned
Rødsand 2	E.ON Vind Sverige AB / SEAS-NVE (80%), RWE (20%) / RWE Renewables	Sjælland/Denmark	207	90/2.3 MW	Fully Commissioned
Sprogø	Sund & Baelt Holding A/S / European Energy / NorSea Group	Sjælland/Denmark	21	7/3 MW	Fully Commissioned

OWF Name	Developer / Owner / Operator	Location (Region/Country)	Project Capacity (Max MW)	Qty Turbines/ Turbine Capacity (Max)	Development Status
Tahkoluoto Offshore Wind Power Project	Suomen Hyötytuuli Oy / Suomen Hyötytuuli /	Länsi-Suomi/Finland	42	10/4 MW	Fully Commissioned
Thornton Bank phase I	C-Power nv / RWE (26.73%), Nuhma (20.8%), DEME Offshore (11.67%), Socofe (11.26%), Societe Regionale d'Investissement de Wallonie (11.26%), EDF (9.15%), Marguerite Fund (9.13%) / C-Power nv	Vlaanderen/Belgium	30	6/5.075 MW	Fully Commissioned
Tunø Knob	Ørsted A/S (formerly DONG Energy AS) / SE Blue Renewables / SE Blue Renewables	Midtjylland/Denmark	5	10/0.5 MW	Fully Commissioned
Parc éolien en mer de Fécamp	Eolien Maritime France / EDF (35%), WPD (30%), Enbridge (17.9%), CPPIB (17.1%) /	Normandie/France	498	71/7 MW	Pre-Construction
Havsul I	/ Vestavind Kraft /	Møre og Romsdal/Norway	350	40/10 MW	Consent Authorised
Storgrundet	Storgrundet Offshore AB / WPD /	Gävleborg/Sweden	1200	83/25 MW	Consent Authorised
Empire Wind	Equinor Wind US LLC / Equinor (50%), BP United States (50%) /	New York/United States	816	60-80 turbines at 10-14 MW ea.	Consent Application Submitted
Aflandshage	Københavns Kommune,HOFOR / HOFOR Hovedstadsområdets Forsyningsselskab /	Hovedstaden/Denmark	250	63/10 MW	Concept/Early Planning
Hiiumaa	Hiiumaa Offshore Tuulepark OU / Eesti Energia /	Hiiu/Estonia	1100	200/12 MW	Concept/Early Planning
Liivi laht	Eesti Energia AS / Eesti Energia /	Pärnu/Estonia	960	100/20 MW	Concept/Early Planning
Nordre Flint	HOFOR,Københavns Kommune / HOFOR Hovedstadsområdets Forsyningsselskab /	Hovedstaden/Denmark	160	40/10 MW	Concept/Early Planning
Oriel (Relevant Project)	Oriel Windfarm Limited / Parkwind (65%), ESB (35%) /	Louth/Ireland	330	55/6 MW	Concept/Early Planning
Sunly SW1	Sunly OÜ / Sunly /	Hiiu/Estonia	84	7/15 MW	Concept/Early Planning
Sunly SW2	Sunly OÜ / Sunly /	Hiiu/Estonia	144	12/15 MW	Concept/Early Planning
Sunly SW3	Sunly OÜ / Sunly /	Hiiu/Estonia	144	12/15 MW	Concept/Early Planning
Sunly SW4	Sunly OÜ / Sunly /	Hiiu/Estonia	132	11/15 MW	Concept/Early Planning
Tahkoluoto Extension	Suomen Hyötytuuli Oy / Suomen Hyötytuuli /	Tahkoluoto/Finland	720	45/16 MW	Concept/Early Planning
Vindeby	SEAS-NVE Energy Group / Ørsted / Ørsted A/S (formerly DONG Energy AS)	Sjælland/Denmark	4.95	11/0.45 MW	Decommissioned

OWF Name	Developer / Owner / Operator	Location (Region/Country)	Project Capacity (Max MW)	Qty Turbines/ Turbine Capacity (Max)	Development Status
Burgeo Banks	Beothuk Energy Inc.,COPENHAGEN OFFSHORE PARTNERS / ACOD /	Newfoundland and Labrador/Canada	1000	/ MW	Dormant
Dr. Techn. Olav Olsen and Seawind Systems Demonstator - Metcentre	Dr techn Olav Olsen,Seawind Systems AS / Dr techn Olav Olsen, Seawind Systems, ENZEN GLOBAL /	Rogaland/Norway	6.2	1/6.2 MW	Dormant
Global Renewable Solutions - Power Platform	Global Renewable Solutions(formerly Marine Power Technologies Pty Ltd) / Global Renewable Solutions /	South Australia/Australia	7	1/3 MW	Dormant
Kotka	/ Kotkan Energia /	Kymenlaakso/Finland	3	1/3 MW	Dormant
New Brunswick	Beothuk Energy Inc.,COPENHAGEN OFFSHORE PARTNERS / ACOD /	New Brunswick/Canada	500	500/ MW	Dormant
Prince Edward Island	Beothuk Energy Inc.,COPENHAGEN OFFSHORE PARTNERS / ACOD /	Prince Edward Island/Canada	200	/ MW	Dormant
St Ann's Bay	Beothuk Energy Inc.,COPENHAGEN OFFSHORE PARTNERS / ACOD /	Nova Scotia/Canada	500	/ MW	Dormant
St George's Bay	Beothuk Energy Inc.,COPENHAGEN OFFSHORE PARTNERS / ACOD /	Newfoundland and Labrador/Canada	180	30/8 MW	Dormant
Yarmouth	Beothuk Energy Inc.,COPENHAGEN OFFSHORE PARTNERS / Beothunk Energy, PensionDanmark /	Nova Scotia/Canada	1000	/ MW	Dormant

5 WIS GBF Design

5.1 NAFTA 1 Reports

COWI prepared a series of memos and technical reports in support of Windstream's NAFTA 1 arbitration with regard to the site characterization parameters affecting the foundation design, the geo-structural design of the gravity base foundation and the design of the facility used to fabricate the foundations. The NAFAT1 scenario considered the design, fabrication and installation of 130 turbine foundations. COWI considers the information, calculation procedures and results of the NAFTA1 foundation design in accordance with typical up-to-date industry practices. The foundation fabrication plan is also in accordance with typical industry practices, excepting the benefit of incremental cost savings as compared to NAFTA1 by reducing the quantity of foundations from 130 to 66. The technical documents developed for NAFTA1 are set out in Table 5-1.

Table 5-1: NAFTA1 Technical documents developed by COWI

Report No.	Report Title	Latest Version and Date	# Pages
214011.0-1	NAFTA 1 Basis of Design	V1.0 February 7, 2014	9
214011.0-1	NAFTA 1 GBF Design and Install Report	V1.0 March 20, 2014	30
214011.0-3A	NAFTA 1 Schedule Memo	V1.0 March 4, 2015	7
214011.0-3B	NAFTA 1 GBF Summary	V1.0 June 11, 2015	8

5.2 Foundation Updates for NAFTA 2

As compared to NAFTA1, Windstream has proposed limited technical updates to reflect development starting in 2020 and construction starting in 2023, as opposed to construction starting in 2014, as was presented in the most recent documentation prepared in support of NAFTA1.

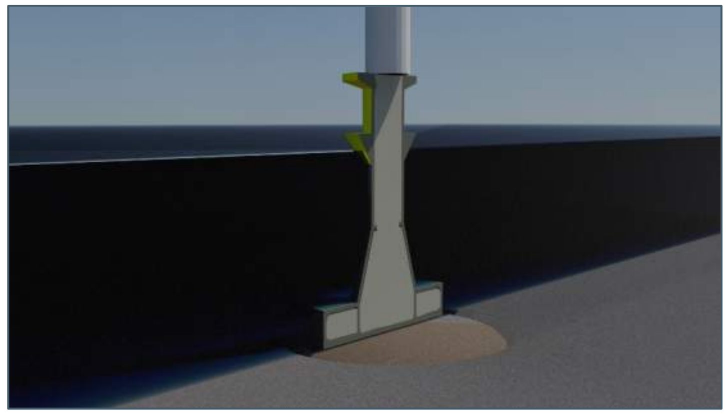


Figure 5-1 (Left) COWI render of fully-installed NAFTA1 design

Figure 5-2 (Right) COWI render of installed GBF section

Specifically, the main update as it affects the foundation design is the selection of 66 x 4.5 MW WTGs for NAFTA2 as opposed to 130 x 2.3 MW WTGs for NAFTA1. The primary impacts of foundation selection are the number of foundations and the load imparted to the foundations by the WTG. Critical foundation design parameters due to turbine loading are found in

Table 5-2.

Table 5-2: NAFTA1 vs NAFTA2 Turbine Characterization

Design Parameter	NAFTA1[(1)]	NAFTA2[(2)]
WTG Manufacturer and Model	Generic 2.3 to 3.6 MW	SG 4.5 - 145
Quantity of WTG	130	66
Rotor Diameter (m)	105	145
Hub Height (m CD)	92.5	100
Vertical Force from Turbine (kN)	4,100	(3)
Shear Force (kN)	1,400	1,184
Overturning Moment (kNm)	106,000	106,560
Interface Elevation (m CD)	10m	10

Design Parameter

(1) WTG loads from NAFTA1 were obtained from a database of loads anonymized from offshore wind projects installed and planned from 2010 to 2014.

(2) Loads for the SG 4.5 – 145 WTG were estimated by the Wood Group based on recent projects over the past three years with similar size WTG from multiple top tier WTG manufacturers. It should be noted that the loads are based on Wood's experience and knowledge with similar WTGs and actual loads may vary based on the variant of the selected WTG and should be confirmed by the WTG manufacturer in later phase of design.

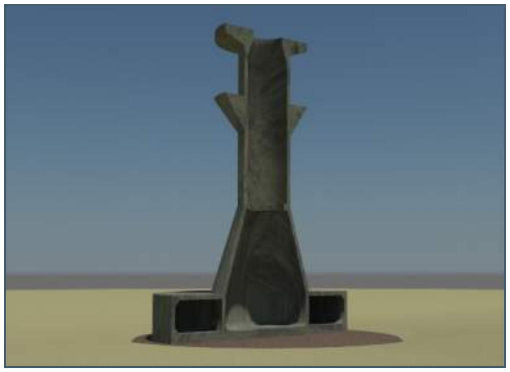
(3) Assumed similar to NAFTA1

Typical to normal wind energy design process, changing the turbine will result in another round of optimizing the foundation design to most efficiently/economically suit the updated loads; however, the changes proposed between NAFTA 1 and NAFTA 2 are within the bounds of the overall construction program. Specifically, the shear force is decreased by approximately 15% and the overturning moment is increased by approximately 0.53%. Therefore, despite the increase in nameplate capacity and rotor diameter, the overall foundation structure for NAFTA2 will be fundamentally similar as the foundation for NAFTA1.

Resulting from the updated WTG selection, some follow on updates to the foundation include:

- Larger WTG capacity – Customarily, a higher-capacity turbine will create a larger overturning moment, resulting in the need for a larger GBF. However, based on the negligible increase in overturning moment calculated above, the foundations developed during NAFTA1 would be capable of supporting the larger WTGs proposed for NAFTA2. Overall, fewer turbines will be required to generate the same project nameplate capacity. Therefore, fewer foundations will result in a considerable savings on the project cost and schedule.

- WTG Capacity Overturning Moment – The change in turbine selection produces a relatively insignificant increased overturning moment demand. The vendor-provided overturning moment value for the SG 4.5 – 145 is available only for a hub height of 107.5m. Therefore, to accurately determine the overturning moment for the project-selected hub height of 90m, the lateral load due to rotor diameter (vendor-provided) is interpolated by the distance from hub height to the interface elevation with the foundation. However, even with this conservative calculation, the increase in overturning moment is only 0.53%. Due to this small difference, the GBF design is expected to be similar to that detailed in NAFTA 1, with no significant geotechnical or structural changes.



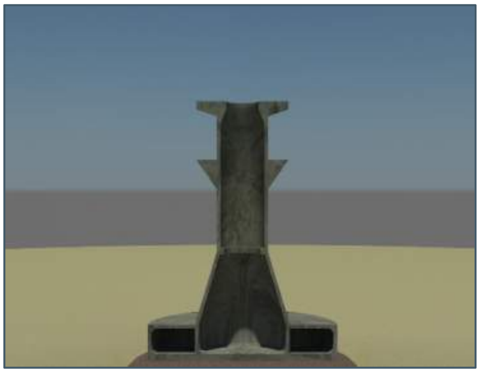


Figure 5-3 (Left) COWI render of NAFTA1 GBF section
Figure 5-4 (Right) COWI render of NAFTA1 GBF section

- Meteorological and oceanic characterizations for the GBF design are largely unaffected by the change in turbine selection. The following design parameters are considered in this characterization:

  - Wind Speed: Wind loads on the turbine act on the foundation through the Turbine Loads provided in

- Table 5-2, and wave loads are conservatively assumed to act on the full height of the foundation system. This design parameter remains unchanged.
- Bathymetry and Still Water Level: Turbine selection has no bearing on bathymetry nor still water level, the water depth at the selected turbine locations within in the study area has changed only slightly from the previous range of approximately 5 – 30 m to the current range of approximately 10 – 30 m.
- Waves: Turbine selection has no influence on wave height; therefore, this design parameter remains unchanged.
- Currents: Turbine selection has no bearing on current velocity; therefore, this design parameter remains unchanged.
- Ice characterization: Turbine selection has no influence on the ice cone geometry, or resulting horizontal and vertical ice loads, therefore this design parameter remains unchanged. The Ice Study (Baird, 2012) Ice Study was used as starting point to determine ice loading for the GBF in NAFTA1. As recommended in "Wolfe Island Shoals Wind Farm: Preliminary Assessment of Ice Design Criteria" (G. Comfort, 2021) ice loads on the GBF were increased from the Ice Study to account for a larger diameter GBF design, as compared to the base case loads. Therefore the loads input to the NAFTA1 GBF design are validated by the G. Comfort 2021 assessment.

5.3 Geophysical and Geotechnical Characterization

Geophysical investigations completed for WIS indicate that shallow bedrock is present over the majority of the project site. Depending on the specific turbine location, the bedrock may be exposed on the lakebed or may be overlaid by surficial sediments in varying thicknesses. The 2021 Turbine Layout Geological Assessment prepared by CSR indicates five (5) geological units in the vicinity of WIS, as seen in Figure 5-5.

Table 2.3.1 – WIS Sub-bottom Unit Summary

Wind Farm Sub-bottom Unit	Regional Lake Ontario Sub-bottom Unit
Unit 1	Post Glacial (Holocene) Sediments
Unit 2	Undifferentiated Post Glacial / Glacial Sediments
Unit 3a	Glaciolacustrine Sediments - Stratified Draped Unit
Unit 3b	Glacial Till - Basal Reflective Unit
Unit 4	Paleozoic Bedrock

Figure 5-5: WIS Sub-bottom Unit Summary (Excerpt Table 2.3.1 - from CSR, 2021)

While the GBF are optimally founded upon bedrock (Unit 4), the Glaciolacustrine Sediments (Unit 3a) and Glacial Till (Unit 3b) observed in the Great Lakes are typically also competent soils, capable of acting as a foundation layer for the GBF. Of the 66 WTG locations proposed for WIS, 61 of those locations are located with surficial sediments (combined Units 1 and 2) less than approximately five meters (5m) thick. For the remaining five (5) WTG foundations with greater surficial sediment thicknesses, there are a number of potential technical solutions, including further layout optimization, alternative GBF size/shape, and/or soil strengthening. In the course of a normal project, all 66 GBF proposed for the project would be further optimized following the collection of site-specific geotechnical investigations (e.g. borings and associated lab testing data); if additional technical solutions were necessary, they would be evaluated following the receipt of the geotechnical data.

5.4 GBF Fabrication Schedule

COWI assumes that a dedicated facility would be developed to fabricate the GBF for WIS. Based on experience with developing other marine terminals in North America, it is reasonable to assume that a facility could be constructed in 18-24 months. COWI Recommends using a value of 20 months for purposes of project scheduling.

Gravity Base Foundations for Thornton Bank (qty = 6, water depth 30m) were fabricated in approximately 135 days, each. This observation has been used as the baseline schedule assumption for the fabrication of foundations for WIS and is considered to be conservative. It is reasonable to assume a foundation fabrication duration of 110 to 135 days for planning purposes. COWI recommends a simplified assumption of 120 days per foundation is considered appropriate for the concept level of design

Further information regarding COWI's Opinion of Schedule is provided in COWI's NAFTA1 Task 3B Schedule Memo (see Table 5-1).

6 References

Reference	Latest Version and Date	# Pages
CER-COWI (OPC) Wolfe Island Shoals, NAFTA 2: Gravity Based Foundation Opinion of Probable Cost – COWI	February 18, 2022	18
CER-Wood Wood. Windstream Energy, Inc. Wolfe Island Shoals Offshore Wind Farm. Technical Expert Report	February 18, 2022	120
C-2485 CSR GeoSurveys Ltd., 2021 Turbine Layout Geological Assessment, Wolfe Island Shoals, Lake Ontario. Contract report prepared by CSR GeoSurveys Ltd. for Windstream Energy Inc., CSR Report # 2126-1.	July, 2021	43
C-2487 G. Comfort Ice Engineering, Ltd., Wolfe Island Shoals Wind Farm: Preliminary Assessment of Ice Design Criteria	February 2, 2022	18

TAB 11

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FEBRUARY, 2022
WINDSTREAM ENERGY

WOLFE ISLAND SHOALS, NAFTA 2

GRAVITY BASED FOUNDATION OPINION OF PROBABLE COST

CONTENTS

PROJECT NO.	DOCUMENT NO.
A221714	A221714-01-02

VERSION	DATE OF ISSUE	DESCRIPTION	PREPARED	CHECKED	APPROVED
1.0	February 18, 2022	Note	EMCH	BRCO	BRCO

1 Background and Project Description

1.1 Project Description

The project site is located on the Canadian side of the eastern end of Lake Ontario. Project water depths on site range from approximately 10m to 30M depth in the southern portion. Geotechnical investigations completed for WIS indicate that shallow bedrock is present over the majority of the project site. Depending on the specific turbine location, the bedrock may be exposed on the lake bed or may be overlaid by surficial sediments in varying thicknesses. The project site experiences significant icing from December through the end of March.

Gravity foundations have been selected as the most likely foundation type for the majority of the project due to a number of project site conditions including the proximity of bedrock and lack of overburden suitable for more typical monopile foundations. Additionally, the ready availability of aggregate and cement products in the immediate area as well as seasonal icing also influence this selection. Any foundation installed will be equipped with an ice cone.

For this analysis, it is assumed that 66 gravity based foundations (GBF) will be fabricated at a fabrication facility located on the shoreline of Lake Ontario. For the purposes of this opinion of probable cost (OPC), COWI and Windstream have identified the St. Mary's Cement facility in Bowmanville, Ontario as a representative of the potential facilities that could be used to fabricate the GBF. After being fabricated and launched into the Lake, GBF will be transported and installed using supplemental flotation barges (SFBs) and commonly available tugboats, in lieu of heavy lift construction vessels.

1.2 Scope of the Opinion of Probable Cost

COWI developed an engineer's Opinion of Probable Cost (OPC) for the foundation fabrication facility, design and fabrication of the semi-floating GBF proposed for WIS. The details of the GBF are found in "Offshore Works Plan: Foundation Conceptual Design and Installation Strategy" report (COWI, March 2014).

The activities captured within this OPC include:

- Cost to complete engineering design of the GBF [Front End Engineering Design (FEED), Basic and Detailed Design phases)
- Cost for construction of the fabrication facility, including:
  - Mobilization and Project Management during facility construction
  - Skidding rails (Quantity of Concrete and Reinforcement)
  - Elevator platform purchase and install
  - Dredging to install lift
- Cost (per foundation) to fabricate three different GBFs, representing three water depths (approx. 25m, 17m and 10m), including:
  - Mobilization and Project Management during GBF fabrication
  - Structural concrete elements of the GBF using a variety of traditional cast-in-place, post tensioned and slipform concrete methodologies as appropriate for each element
  - Ancillary support costs that includes forming systems, site equipment, etc.
  - Movement (skidding) of the foundations within the fabrication yard and onto the elevator platform.

This OPC includes skidding the GBF onto the elevator platform and lowering the platform into Lake Ontario. The OPC ends (does not include) at the point of attaching supplemental flotation units on the GBF.

COWI employed a scaling factor to the "base case" 25m water depth GBF quantities calculated in the Offshore Works Plan: Foundation Conceptual Design and Installation Strategy. The scaling factor, discussed further in Section 4, was used to account for variations in material quantities and costs for 17m and 10m water depth variants.

Major controlling assumptions for all OPC's include:

- 66 total GBF are fabricated continuously over approximately 16 months
- Fabrication of GBFs will progress year round

In order to complete the OPC, a number of assumptions have been made regarding the contractor's methods. These assumptions represent a level of analysis appropriate for a concept design level. This document represents the engineer's opinion as to probable means, methods, material, equipment and labor costs, crew sizes and productivity. It should be noted that limited design and site information is currently available. As such, the OPC was based primarily on experience with other similar projects, supplemented with material quotations, publicly available published cost data and engineering judgment. Due to the limited site specific and design information, OPCs should be considered "order of magnitude" or Class 5 according to AACE cost estimate classification system. This report documents the assumptions associated with OPCs.

1.3 Project Team

1.3.1 Windstream Energy, Inc.

Windstream Energy, Inc. (Windstream) is the project proponent and client for this study.

1.3.2 COWI

COWI North America, Inc. (COWI) was retained to develop the Offshore Works Construction Plan, Foundation Conceptual Design and Installation Strategy for the offshore components of the project. COWI was requested to develop an OPC of the GBF for NAFTA2.

1.3.3 Weeks Marine, Inc.

Windstream has retained Weeks Marine, Inc. (Weeks), as an internationally recognized offshore and marine contractor to support the development of the offshore works construction plan.

2 GBF Fabrication Facility

The design of fabrication yard components was based a model GBF 22m in diameter and weighing approximately 3,450 tonnes (3,800 tons). This presents a reasonable upper approximation of the GBF size and weight proposed for WIS.

During fabrication, the GBF is constructed in an "assembly line" style. As the GBF construction advances, the GBF is skidded along the assembly line rails and launched by an elevator platform system. Following fabrication, the GBF will be floated to the site and lowered into position by supplemental flotation pontoon and winch systems. The GBF design and installation process is further described in the "Offshore Works Plan: Foundation Conceptual Design and Installation Strategy" report (COWI, March, 2014).

2.1 Facility Location

For this study, the land adjacent to the St. Mary's cement facility in Bowmanville, Ontario was selected as the representative fabrication yard location. The site in Bowmanville was selected due to its proximity to the cement facility (as a potential material provider), available upland area, access to deep water, and existing pier. The site is intended to be indicative of the type of fabrication facilities that would have been available for Windstream's use.

2.2 Size

The Bowmanville Fabrication Facility size is determined by project scheduling constraints. The following constraints and assumptions were used in determining the size of the fabrication facility:

- GBF fabrication occurs continuously
- The yard must produce a total of 66 GBF over approximately 16 months
- Approximate duration to fabricate each GBF is approximately 120 days
- Multiple GBF being fabricated simultaneously, assembly line style

2.3 Facility Layout

The yard consists of a series of parallel fabrication assembly line rails, two transfer rails, access/launch rail, an elevator platform. Additional area is intended for use as staging and laydown areas, batch plant, site offices, and parking. The GBF begins on the assembly rail in the position furthest from the water. As fabrication reaches progressive levels of completion, the GBF is skidded from position to position toward the water and the elevator platform system. Once the GBFs are fabricated, they are skidded on the access/launch rail to the elevator platform. The access/launch rail extends from the upland site over the riprap slope to the south and to the elevator platform. The elevator platform lowers the GBFs into Lake Ontario where they can be connected to the supplemental flotation barge and towed to site by commonly available tug boats.

2.4 Primary Cost Drivers

2.4.1 Turbine Size

The optimum size of the fabrication yard may vary slightly depending on the nameplate capacity, and therefore number of foundations produced for WIS. In order to maintain the same total project nameplate capacity, fewer turbine foundations would be needed if a greater nameplate turbine (relative to baseline assumption 4.5MW) machine is selected. The existing facility layout is sufficient to fabricate and stage 66 foundations over approximately 16 months. Should a higher capacity turbine be selected, it may be possible to decrease the number of fabrication and staging positions, with the following effects:

- Decrease in overall fabrication facility size
- Reduced fabrication facility material quantities (e.g. concrete and steel)
- Decrease construction time

While larger turbines require larger and heavier GBF, thus potentially increasing the capacity in the skidding rails, the increase in rail size is anticipated to be relatively minimal as compared to the savings associated with fewer positions. The extents of the land available at the representative Bowmanville location, as well as other potential facilities in Lake Ontario are assumed to be able accommodate the required number of foundation fabrication and staging positions to support a turbine selection with a nameplate capacity of 2.3 to 6 MW per machine.

2.4.2 Production Schedule

This analysis assumes that all GBFs must be fabricated within sixteen (16) months. If the production and construction schedules can be extended, fabrication and staging positions can be re-used, reducing the number of fabrication and staging positions, as well as overall facility size required. The number of positions required affects the overall construction cost of the facility. In each case, because there is only one elevator platform, the cost of the elevator and pier system is considered fixed.

2.4.3 Regional Applicability

The GBF fabrication facility developed for WIS is anticipated to be applicable to offshore wind projects beyond WIS and throughout the Great Lakes. Numerous studies have demonstrated that the cost of energy to ratepayers can be reduced by developing regional facilities, rather than developing project specific support infrastructure. COWI has developed this OPC assuming the cost of developing the facility is carried by the WIS project alone. However, the cost of constructing the fabrication yard associated with the WIS project may be reduced by acknowledging the GBF casting facility as a regional asset available for use by other offshore wind projects and/or as a construction port for other regional heavy infrastructure projects.

3 GBF Fabrication Yard OPC

It is assumed the site is level and does not require significant grading.

3.1 Work Item 1 - Mobilization/Demobilization

Mobilization of a construction project includes the initial delivery of personnel, equipment and some materials to the project site.

3.2 Work Item 2 – Grade Beam

The grade beams are the structural elements that will be used as the skidding "rails". The concrete beams are cast-in-place and then topped with a low friction UHMW wearing surface.

3.2.1 Piles and Pile Driving

A geotechnical exploration was not included in the scope of this study. Based on aerial imagery (GoogleEarth, 2014), it appears that bedrock is shallow in this area. Piles are not anticipated to be necessary to support the grade beams. For the purposes of this OPC, the grade beams are assumed to be founded directly on bedrock and therefore piles and pile driving are not included.

3.2.2 Grade Beam

Based upon the appearance of shallow bedrock in the area, it is assumed that the concrete rails used to support the GBF during fabrication will be cast as grade beams.

This OPC provides for the excavation of soil, provision and installation of steel reinforcement, formwork and cast-in-place concrete. As per the Foundation Conceptual Design and Installation Strategy Report (COWI, March, 2014), grade beams are approximately 1.5m wide and 1.0m tall. Each GBF position will require two rails, each approximately 44m long to provide for one GBF diameter of clear space between GBFs.

In addition, two transfer rails are provided to allow GBF to be transferred between parallel fabrication rails. Each pair of rails is approximately 78m long.

3.2.3 UHMW

Each concrete rail consists of a pair of parallel concrete beams. The rails are covered with 10 cm thick UHMW pads to reduce friction during skidding.

3.2.4 Skidding Platform

During fabrication, GBFs are constructed on a steel skidding platform, which is moved along the concrete rails by large hydraulic jacks. This will allow the GBF to be fabricated assembly line style.

3.3 Work Item 3 – Dredging

This work item provides for dredging necessary to float the piers (Section 3.4) into place, as well as dredging below the elevator platform.

The work item also provides for the gravel leveling mat to be installed below the float-in-place caissons.

3.4 Work Item 4 –Launching Pier

The WIS concept design relies on an elevator platform system to launch the GBF from the upland staging area into the water, where they can rely on their integrated buoyancy chambers to reduce their effective transportation weight. This work item accounts for the solid fill piers on either side of the elevator platform.

For the Bowmanville location, COWI and Weeks Marine propose to use float-in concrete caissons. The caissons are fabricated on a barge, launched into the water, floated in place over a prepared bed, lowered into position and filled with stone or other ballasting material.

3.5 Work Item 5 – Elevator System

The WIS concept design relies on an elevator system to launch the GBF from the upland staging area into the water. This work item accounts for the elevator platform.

The marine elevator platform system, including the platform, winches and cables, command and control system is typically specified and provided as a manufactured product. Examples of such technology include the Rolls Royce Naval Marine, Inc. (RRNMI) Syncrolift® System. This concept design is not meant to imply a specific endorsement of the RRNMI system. Other organizations are capable of providing similar systems; however they have not been identified in this phase of design. The cost for the elevator platform is estimated based on previous project experience.

3.6 Work Item 6 – Surface Treatment

This concept calls for the casting yard to be surfaced with gravel that can be repaired readily by equipment on site.

3.7 Work Item 7 – Security

The OPC provides for the casting yard to be secured with a perimeter fence, closed circuit television cameras, facility lighting.

4 Gravity Based Foundation Design, Scaling, Quantities and Weights

The semi-floating GBF concept design was completed for installation in 25m water depth. The water depth at the WIS project site ranges from approximately 10m to 30m. In order to understand the effect of varying water depths on the project, COWI has also identified weights and material quantities associated with GBFs in 17m and 10m water depths. Weights of GBFs, as well as associated quantities of concrete and reinforcement, were determined by employing a scaling factor to the GBF quantities reported in the Conceptual Foundation Design and Installation Strategy (COWI, March, 2014). Scaling factors of 81% and 67% were used for GBF in 17m and 10m of water, respectively. The scaling factors were determined by plotting depth and dry weight relationships associated with a number of installed and designed GBFs and applying a best fit line, as seen in Figure 4-1. Depth and weight data was taken from public sources as well as internal databases. The depth and weight relationship shown in Figure 4-1, was validated based on the WIS 25m design weight.

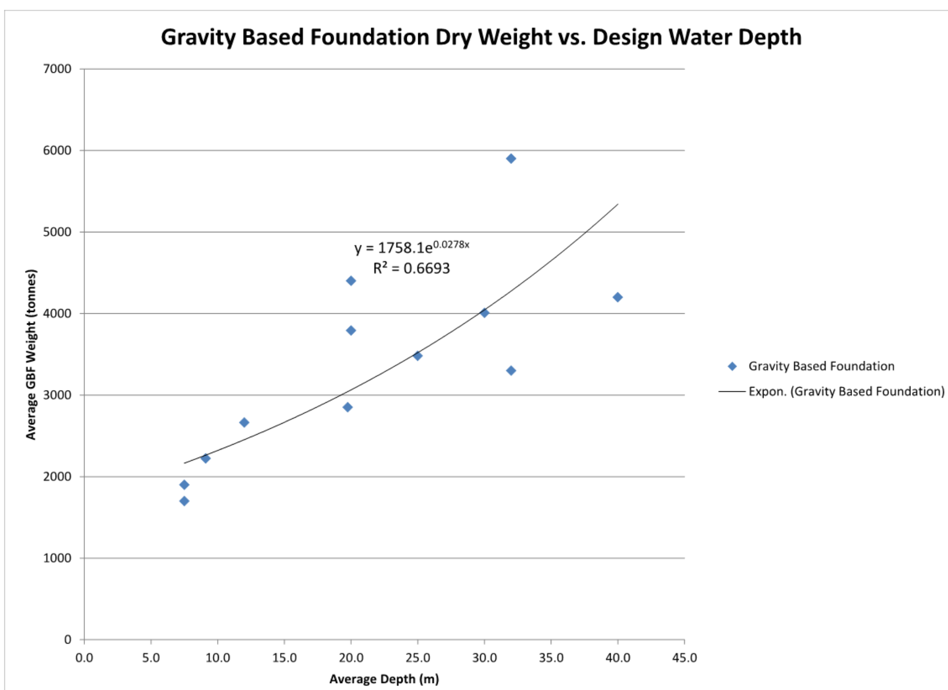

Figure 4-1: GBF Dry Weight vs. Design Water Depth

Equation 4-1:

$$Dry\ Weight = 1758.1 * e^{0.0278*Depth}$$

Using this factor, COWI identified the approximate material properties found in Table 4-1 for each noted water depth.

Table 4-1: GBF Parameters at Varying Depths

Design Water Depth (m)	25	17	10
GBF Scaling factor	100%	81%	67%
Service Platform Elevation (m)	10	10	10
Reinforced Concrete (weight in tonnes)	3480[1]	2820[2]	2331[2]
Reinforced Concrete (Volume in m^3)	1450[1]	1175[2]	967[2]
Grade 500 reinforcing steel (CIP) (weight in kg)	290000[3]	235023[3]	193462[3]
Grade 1860 (Post-tension) reinforcing steel (mass in kg)	29000	23502	19346

1 As designed during Conceptual Foundation Design and Installation Strategy (COWI, March, 2014)

2 Calculated by applying scaling factor.

3 See Section 5.4

5 Gravity Based Foundation OPC

Gravity based foundations are large, robust structures with no universal mode for construction. Therefore, following the completed design, there is a wide range of means and methods a fabrication contractor may select from to fabricate these structures. In order to complete the Opinion of Probable Cost, a number of assumptions have been made regarding the contractor's methods. These assumptions represent a level of analysis appropriate to the concept design level. This document represents the engineer's opinion as to probable means, methods, material, equipment and labor costs, crew sizes and productivity. This information has been obtained using a combination of publicly available published cost data, interviews with contractors, and actual proposals and quotations, where possible.

5.1 GBF Design

5.1.1 Front End Engineering Design

The OPC provides for the Front End Engineering Design or FEED. The FEED typically incorporates preparation of site-specific basis of design, identification of additional necessary site characterization parameters and conceptual foundation design for a limited number of load combinations.

5.1.2 Basic Design

The OPC provides for the Basic Design of the GBF. The Basic design typically incorporates receipt of previously missing site characterization data, additional load combinations and initial iterations with the turbine manufacturer. A representative range of water depths may be considered in the Basic Design; however, typically the Basic Design is not completed for each individual turbine location.

5.1.3 Detailed Design

The OPC provides for the Detailed Design of the GBF. Detailed design provides for geotechnical, structural and hydraulic design by evaluating the full suite of code-required load combinations, load iterations with the turbine manufacturer and specific design of each turbine installation. Since each turbine is detailed independently, this line item is provided per turbine, rather than per project.

5.2 Mobilization and Project Management

The Project Management work item provides for the professional staff that will be located on site full time during fabrication of the GBFs. This work item identifies personnel employed by the owner. Their roles are described in further detail, below. Project management personnel employed by the contractor are assumed to be included in the contractor's overhead.

5.2.1 Project Management:

The owner is likely to have four to five representatives assigned to the project and located on site full time. This OPC provides for the owner's project manager and a support staff of three engineers and two additional technical staff. The responsibilities of these staff are primarily in Quality Assurance, facilitating communication with the contractor, authorizing pay requests and ensuring the contractor is maintaining agreed upon production schedules.

5.2.2 Mobilization / Demobilization

Mobilization of a construction project typically includes the initial delivery of personnel, equipment and some materials to the project site. If necessary, mobilization may include the initial site preparations allowing the contractor to arrive on site. It may cover temporary accommodations for workers at remote sites.

In this case, initial site preparations have been completed as part of the construction of the fabrication facility, discussed in Section 3, above. It is typical for the contractor to provide field office provisions for representatives of the project owner. These costs are carried within the contractors overhead and therefore are not represented in this OPC.

Demobilization of a construction project typically includes the withdrawal of personnel and equipment from the project site.

5.3 Site Equipment

Large infrastructure projects such as the fabrication of concrete GBF require substantial equipment to complete the work efficiently. This Work Item provides for the major site equipment that is not otherwise associated with individual work crews. The two primary items noted here are the large site cranes and the movement of the GBFs along the skidding rail system. Smaller equipment, required on a continuous basis by individual work crews, such as smaller cranes, concrete pumps, small lifts and hoists, is accounted for within the individual work crew.

Specifically, this task assumes:

Three (3) Large cranes. The large cranes will be used between Position 4 and the transfer rail. Their primary purpose will be with work associated in the Position 4 and Final Assembly Work Items, including installation and removal of formwork, placement of concrete and installation of steel appurtenances. This OPC assumes that the cranes will be crawler cranes with a capacity greater than 200 tons, however the contractor may be elect to use fixed tower cranes instead.

Three (3) Medium cranes. The medium cranes will be used between positions 2, 3 and 4 and assist with the Work Items associated with those positions. This OPC assumes that the medium cranes will be crawler cranes with a capacity of approximately 150 tons.

Two (2) Sets of Skidding Equipment, including 16 skid shoes of 660 tons each, two power pack units, supervisors and riggers for 16 months.

5.4 GBF Prefabrication

A significant benefit of the assembly line system is the standardization of construction methodology and interchangeability of components between foundations. Accordingly, significant portions of the work can be completed prior to the fabrication on the assembly line. Prefabrication reduces the schedule and therefore associated costs.

The Prefabrication Work Item accounts for the assembly of re-usable formwork. The cost of forms and their initial assembly is considered in this Work Item. The costs of placing and removing forms that have been assembled is considered in the Work Item associated with that particular component.

This OPC assumes that forms will be made of steel/wood and will be re-used 10 times. As a lower boundary, there must be three complete sets of forms, one complete set of forms for each parallel assembly line.

Prefabrication of cast-in-place steel reinforcement is considered in this work item where possible. Costs associated with placing prefabricated reinforcement cages and tying rebar that is not prefabricated is considered in GBF Fabrication.

Prefabrication accounts for provision of slipforming equipment that will be used to construct the stem (taper and cylindrical sections). Materials and labor associated with construction of the stem is carried in the Fabrication section.

5.5 Fabrication of the GBF

The GBFs are fabricated in parallel assembly lines, beginning inshore and progressing offshore, towards the elevator platform. Fabrication work tasks are progressively completed as the GBF is moved into successive positions along each assembly line. Upon completion of final assembly, each GBF is moved to the elevator platform, where it is lowered into the water and transported to site using the supplemental flotation units and barges.

The concrete reinforcement was not detailed within the scope of this design. However, reinforcement ratios and pre-stress reinforcement ratios typical to other COWI gravity based foundations were applied to determine material quantities. Material costs were estimated as a function of the reinforcement ratio and volume of concrete. Labor costs were estimated using assumed crew sizes and production rates on a on a per kilogram basis.

Gravity Base Foundations for Thornton Bank (qty = 6, water depth approximately 30m) were fabricated in approximately 135 days, each. This observation has been used as comparative data point for the baseline schedule assumption and is considered to be conservative. Given the potential for economies of scale and improved rates of construction associated with the higher quantity of foundations, COWI recommends that the foundations for WIS may be fabricated within approximately 110-135 days each; a simplified assumption of 120 days per foundation is considered appropriate for the concept level of design. Based on the fabrication duration, required project schedule and number of available positions at the fabrication and staging yard, delays due to cold weather are not anticipated. The effects of cold weather on project schedule and concrete operations (cost) should be further evaluated in later phases of design.

5.5.1 Buoyancy Chamber

Fabrication of the GBF begins as elements of the buoyancy chamber are formed, reinforced and poured on the jacking truss. Buoyancy chamber elements include the baseplate, inner and outer circular vertical walls, vertical stiffeners and top plate.

It is assumed that the formwork and a portion of the reinforcement used in the baseplate and vertical walls is prefabricated to reduce the time required in this position. This work item considers that prefabricated forms are installed and removed for the baseplate. The work is completed at ground level using traditional methods. Work is assisted by small equipment associated with the individual work crews.

Upon completion of the vertical elements, the top plate of the buoyancy chamber is constructed. This work is completed using traditional forming methods, assisted by scaffolding and temporary shores inside the buoyancy chamber as necessary. The design of the GBF provides access for personnel to assemble and disassemble temporary formwork.

5.5.2 Stem

After the buoyancy chamber is completed, construction crews begin constructing the stem of the GBF. The taper and cylindrical sections are constructed using vertical slip forming. The forms are advanced using hydraulic jacks as the concrete is poured continuously up to the height of the service platform. Provisions for block outs, spacers and threaded inserts are placed into the concrete as necessary to allow for construction of ice cone after completion of the column. Scaffolding is an integral part of the formwork system and advances with the system. Construction is completed using the assistance of the medium and large cranes as necessary to lift construction materials and slipform components as the system moves higher. Reinforcement is typically prefabricated in small sections. Both taper and cylindrical sections of the stem are post tensioned following the curing of the concrete.

Appurtenances, such as the service vessel landing and handrails at the service platform are accounted for in this section. This OPC assumes that these components are substantially prefabricated prior to installation. The design of these components is assumed to be similar in nature to those components used on GBFs in the North Sea and will be completed in later phases of GBF design.

5.5.3 Ice Cone

Following slip forming of the stem, the concrete ice cones are added to the completed GBF columns. Reinforcement cages would be substantially prefabricated and installed into cut outs and threaded inserts left in the column (material and labor accounted for in this Work Item). The ice cones will be formed by re-usable gang forms. The gang forms will be lifted into place by the large cranes and supported from brackets, similar to those used in the bridge industry, attached to the completed column sections.

6 Standard Markups

6.1.1 General Conditions

A General Conditions markup of 5% is applied the work item subtotals. This is the value COWI typically applies to most OPCs.

6.1.2 Overhead

An Overhead markup of 10% is applied cumulatively to the work item subtotals and general conditions. This is the value COWI typically applies to most OPCs.

6.1.3 Profit

A Profit markup of 10% is applied cumulatively to the work item subtotals, general conditions and overhead. This value was selected due to the high volume associated with a production facility and therefore a modest markup for profit.

6.1.4 Inflation

The costs compiled for this OPC were reported in 2020 U.S. Dollars. Where the OPC relies on specific vendor provided quotations, those quotations were inflated to 2020 dollars using the USACE Civil Works Construction Cost Index System (CWCCIS) Engineering Manual (EM) 1110-2-1304 dated 30 September, 2019. The Ports and Harbors feature code was selected as the most representative code to estimate inflation.

A summary of the costs developed by this project and discussed above are presented in Table 7-1, below. The full OPC and details are found in Appendix 1.

6.1.5 Contingency

COWI understands the intent of this cost estimating project is to understand the most likely anticipated cost of the project, as opposed to a construction cost budget. Therefore, a design and construction contingency has not been included. COWI recommends that a contingency may be added to the values presented in the Opinion of Probable Cost, consistent with other elements of the project.

7 Summary Cost Table

A summary of the costs developed by this project and discussed above are presented in Table 7-1, below. The full OPC and details are found in Appendix 1.

Table 7-1: NAFTA2 Opinion of Probable Cost of Fabrication, per Gravity Base Foundation

	25m Water Depth	**17m Water Depth**	**10m Water Depth**
Foundation Fabrication OPC (ea.) (2020 U.S. Dollars)	$2,564,000	$2,112,000	$1,779,000

8 References

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C-1999, LORC Knowledge: List of Offshore Wind Farms. website: http://www.lorc.dk/offshore-wind-farms-map/list Accessed: April 16, 2014.

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C-1997, U.S. Army Corps of Engineers. Engineering Manual (EM) 1110-2-1304. Civil Works Construction Cost Index System (CWCCIS). dated March 31, 2017 Amendment #1, updated September 30, 2017. Department of the Army. Washington, DC 20314-1000 Available online: http://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-1304.pdf

C-1995, COWI Report entitled "Shallow Water Offshore Wind Optimization for the Great Lakes (DE-FOA-0000415) - Final Report: A Conceptual Design for Wind Energy in the Great Lakes" (February 28, 2014)

9 Appendices

Appendix A: Opinion of Probable Cost: Fabrication Yard and GBF Fabrication

Appendix A Opinion of Probable Cost: Fabrication Yard and GBF Fabrication

COWI

OPINION OF PROBABLE COSTS

COWI PROJECT NO: A221714 Windstream Wolfe Island Shoals NAFTA2
COWI PROJECT NAME: Wolfe Island Shoals, NAFTA2 OPC update (material costs only)
GBF Fabrication Cost Estimate
CLIENT: Windstream
SITE LOCATION: Southwest of Wolfe Island - Approx: 44°0'0" N, 76°34'0" W
Lake Ontario, Ontario, CA
PREPARED BY: EMCH
DATE: 18-Feb-22
CHECKED BY: BRCO

WORK ITEM DESCRIPTION	OPC PRICE (LUMP SUM - 2020 U.S. DOLLARS - $)
Fabrication Yard	
WORK ITEM 1 - MOBILIZATION AND DEMOBILIZATION	$1,461,000
WORK ITEM 2 - GRADE BEAM	$30,794,000
WORK ITEM 3 - DREDGING	$1,132,000
WORK ITEM 4 - FLOAT IN PLACE CAISSON PIERS	$12,821,000
WORK ITEM 5 - ELEVATOR PLATFORM	$24,906,000
WORK ITEM 6 - SURFACE TREATMENT	$551,000
WORK ITEM 7 - SECURITY	$293,000
FABRICATION YARD (TOTAL)	**$71,958,000**
GBF DESIGN	
GBF DESIGN	$3,024,000
GBF DESIGN (TOTAL)	**$3,024,000**

GBF Fabrication	25m Water Depth	17m Water Depth	10m Water Depth
MOBILIZATION AND PROJECT MANAGEMENT	$38,000	$38,000	$38,000
WORK ITEM 1 - SITE EQUIPMENT	$146,000	$146,000	$146,000
WORK ITEM 4 - GBF PREFABRICATION	$1,595,000	$1,292,000	$1,069,000
WORK ITEM 5 - GBF FABRICATION	$785,000	$636,000	$526,000
GBF FABRICATION TOTAL (Ea.)	**$2,564,000**	**$2,112,000**	**$1,779,000**

2020 OPC INCLUDE THE FOLLOWING MARK-UPS:
GENERAL CONDITIONS: 5%
OVERHEAD: 10%
PROFIT: 10%
CONTINGENCY: 0%

TAB 12

A Review of the Capital Costs of Wolfe Island Shoals

P/20/1440

Revision	Final
Date	18/02/2022
Prepared	Richard Aukland,

Checked and approved by Richard Aukland and Tugce Sahin

TABLE OF CONTENTS

1 Introduction

In 2014 Windstream Energy (Windstream) commissioned 4C Offshore to provide an estimate of the capital costs for the Wolfe Island Shoals (WIS) project in Lake Ontario (CER-4C Offshore: 4C Offshore, 2014). At that time the project design envisaged 130 x Siemens 2.3 MW turbines and a total installed capacity of 300 MW.

This report provides an update to the capital cost estimate, taking into account the 2020 market context, including any interim price movements. At the time of writing this report, the WIS project features the following changes to the 2014 design;

Parameter	2020 design	2014 design
Turbine Model	SGRE 4.5-145	Siemens 2.3 MW
Number of Turbines	66	130
Wind Farm Capacity	297	300
Water Depth	10-30m with distribution of turbines as follows: >10 to ≤ 15m : 11 units >15 to ≤ 20m : 9 units >20 to ≤ 25m : 21 units >25 to ≤ 30m : 25 units	Turbines distributed as follows: >5 to ≤ 10m : 4 units >10 to ≤ 14m : 27 units >17 to ≤ 25m : 58 units >25 to ≤ 30m : 41 units

Table 1. Changes between 2014 and 2020 design at WIS

Note: All references in this report to the 2014 costs are referring to the inflated costs as shown in Table 2. When estimating 2020 costs, all market data are inflated in the original currency to 2020 prices and then converted to CAD using the mid market rates from the Bank of Canada for 18th February 2020, available from https://www.xe.com/currencytables/?from=CAD&date=2020-02-18.

2 Executive Summary

The 2020 capital cost for WIS is estimated as $1.1 billion. This is a reduction of $310.3m (22%) in comparison to the inflated 2014 cost (Figure 1). Savings are primarily due to falling supply costs of wind turbines. The capital costs for WIS in 2014 and 2020 and the change in costs relative to the wider industry are shown in Figure 2, where it can be seen that although costs have fallen at WIS, the rate of fall is lower than the global trend. This is primarily due to the increasingly larger projects with higher rated turbines being developed globally.

A summary of changes is provided below. Additional details can be found in the report.

- **Development and Owner's Management Costs:** Costs are in line with current industry expectations and therefore have not been adjusted.
- **Foundation Supply and Installation:** There is recent industry evidence of the commercialisation of serial production of large (>3000t) gravity base foundations for offshore wind. Research suggests savings of $42.4m (10% net across supply and installation) compared to the price estimated in 2014.
- **Wind Turbine Supply and Installation:** The global energy transition towards renewable energy has stimulated a trend for increasingly price-competitive renewable energy auctions. Increasing turbine rating and downward price pressure have facilitated a 44% drop in supply price. Installation costs have also fallen by 41% as a result of the decrease in number of turbines.
- **Offshore High Voltage Substation (OHVS) Supply and Installation:** Costs findings for 2020 were similar to those identified in 2014. Therefore the 2014 cost estimates have been retained
- **Array Cable Supply and Installation:** Updated analysis shows that costs have increased by $ 19.3m, due to a combination of effects including exchange rates, price rises and high variance in the available data.

- **Export Cable Supply and Installation:** Updated analysis shows that costs have increased by $ 17m, due to a combination of effects including exchange rates, price rises and high variance in the available data. The onshore cable cost has also been moved into this section.
- **Onshore Interconnection:** Cost findings for 2020 were similar to those identified in 2014. Therefore the 2014 cost estimates have been retained. Onshore cable supply and installation is included with the export cable supply and installation.
- **Contingency:** Cost findings for 2020 were similar to those identified in 2014. Therefore the 2014 cost estimate (as a percentage of total CAPEX) has been retained.

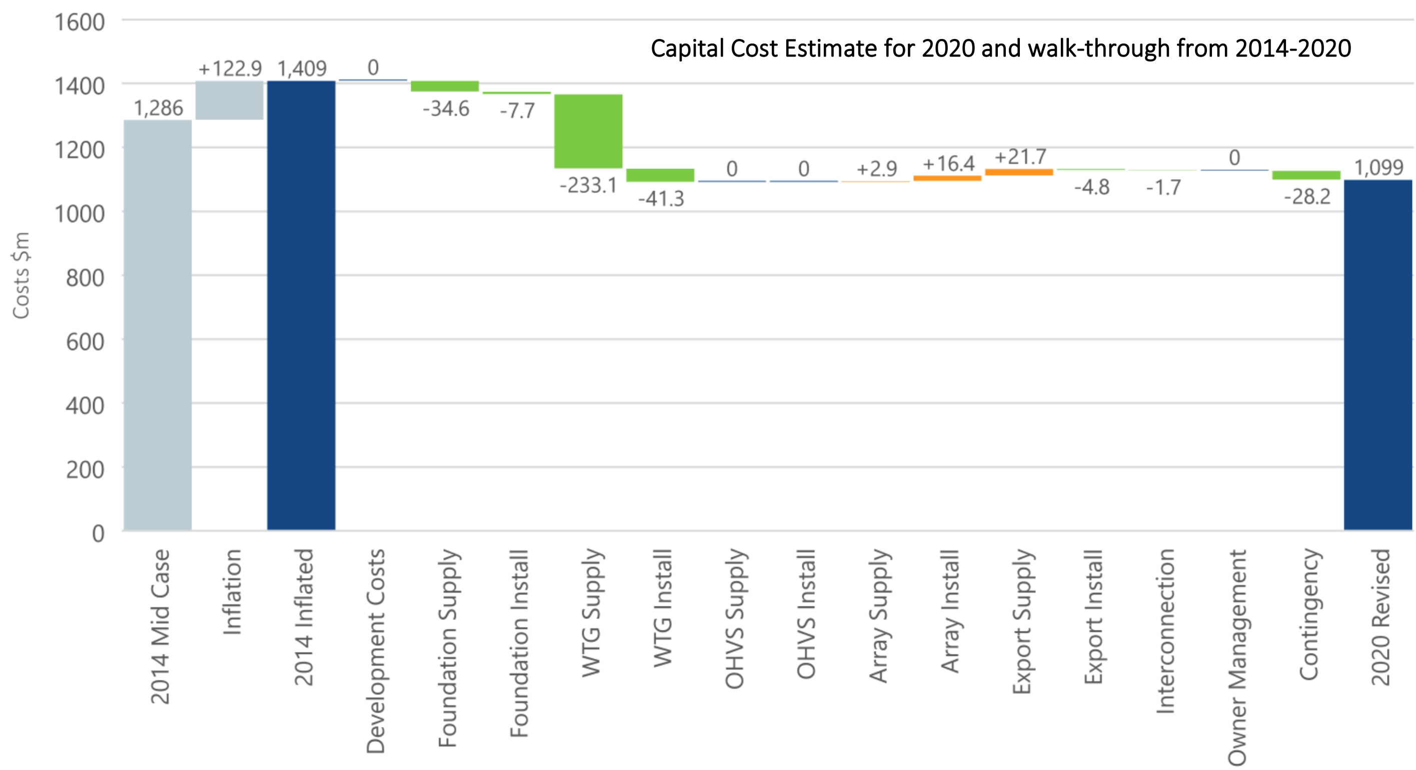


Figure 1. Cost change walk through, 2014-2020

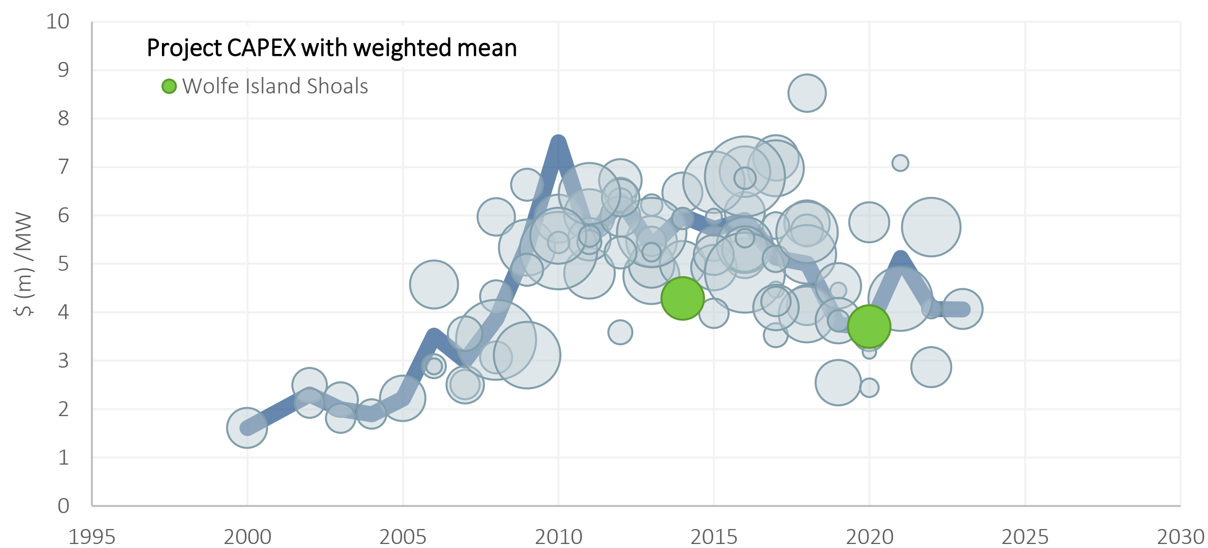


Figure 2. WIS project CAPEX in the context of European projects. Only showing projects >30 MW with bottom-fixed foundations that reached financial close prior to end-2020. Bubble size proportional to project capacity. In line with the dataset, WIS 2014 cost is not inflated to 2020.

	2014 ($m)	Inflated to $m 2020	2020 Updated Costs ($m)	Delta ($m) 2020 - 2014	
DEVELOPMENT COSTS					
Preliminary desktop studies, EIA, preliminary designs	11.23	12.30	12.30		
Site Investigation					
Geophysical Surveys	1.4	1.53	1.53		
Geotechnical Surveys	7.99	8.75	8.75		
Met Mast	4.48	4.91	4.91		
TA costs for FEED studies and contractor procurement					
FEED	0.94	1.03	1.03		
Procurement	2.74	3.00	3.00		
Permitting & Environmental Studies					
Permitting	5.49	6.01	6.01		
Environmental Studies	7.92	8.68	8.68		
Legal fees	2.04	2.24	2.24		
	44.23	**48.46**	**48.46**		
SUPPLY COSTS					
Foundations					
Detailed Design	3.02	3.31	3.31		
Supply Costs	321.56	352.30	317.74	-34.6	-9.8%
WTG	483.86	530.12	297	-233.1	-44.0%
OHVS					
Detailed Design	2.35	2.57	2.57		
Supply Costs	42.65	46.73	46.73		
Array cables	26.17	28.67	31.61	2.9	10.3%
Export Cables	10.31	11.30	33.04	21.7	192.5%
	889.92	**975.00**	**732.01**		
INSTALLATION COSTS					
Foundations	50.8	55.66	47.97	-7.7	-13.8%
WTG	91.94	100.73	59.4	-41.3	-41.0%
OHVS	9.05	9.92	9.92		
Array Cables	21.35	23.39	39.78	16.4	70.1%
Export Cables	8.6	9.42	4.63	-4.8	-50.9%
	181.74	**199.11**	**161.70**		
ONSHORE INTERCONNECTION					
Substation	43.22	47.35	47.35		
Cabling	1.57	1.72	0.00		
	44.79	**49.07**	**47.35**	-1.7	-3.5%
TOTAL SUPPLY & INSTALLATION COSTS	1116.45	**1223.18**	**941.05**		
OWNER MANAGEMENT COSTS	12.35	**13.53**	**13.53**		

CONTINGENCY					
Rate	10%	10%	10%		
Amount	112.88	123.67	95.46	-28.2	-22.8%
TOTAL CAPEX	1285.91	**1408.84**	**1098.50**	-310.3	-22.0%

Table 2. Table of capital cost findings; 2014, 2020 and the difference

3 Development & Owner Management Costs

Development cost categories are listed at the top of Table 2. Owner management costs are listed towards the bottom of the table. Owner management costs are interpreted as project management costs spent post financial close. This includes managing the contract interfaces between the main component contractors and managing issues during construction. Typically, owner's management costs are considered part of the late-stage development cost. Therefore, the development and owner's management costs are considered in aggregate here when comparing to industry benchmarks.

4C's 2014 analysis identified development costs of $48.5m and owner's management costs of $13.5m, a combined total of $62m.

Several 3rd party studies were reviewed to understand if development expenditure (DEVEX) had changed since the 2014 analysis. Table 3 shows the summary of the 3rd party DEVEX/MW results with a range of $ 192 - 224k/MW, including the owner management costs. The identified development costs are between $ 57.6-67.2 million for a 300MW project. **The 2014 development cost therefore sits centrally within the range of reported values, indicating they remain applicable in 2020.**

Source	Cost/MW as stated in the report	Cost CAD/MW	Development cost for a 300 MW project
Crown Estate BVGA, 2019	£120k/MW	$ 207k/MW	$ 62.1
Carbon Trust, 2020	£120k/MW	$ 207k/MW	$ 62.1
BEIS, 2020	£130k/MW	$ 224k/MW	$ 67.2
EirWind, 2020*	€134k/MW	$ 192k/MW	$ 57.6

Table 3. Industry estimates of development costs per MW. *Eirwind is an industry led collaborative research project, aimed at developing a blueprint for offshore wind development in Ireland.

Since 2014 the use of bottom-fixed met masts has become uncommon. Resource assessment is typically performed using a floating lidar. The cost of a floating lidar is between $1.79- 3.59m (C-2180: Carbon Trust, 2018). Whilst this provides the WIS project with potential savings of $1.32 - $3.12m, the costs in Table 3 assume lidar deployments so therefore no changes to the WIS cost have been made.

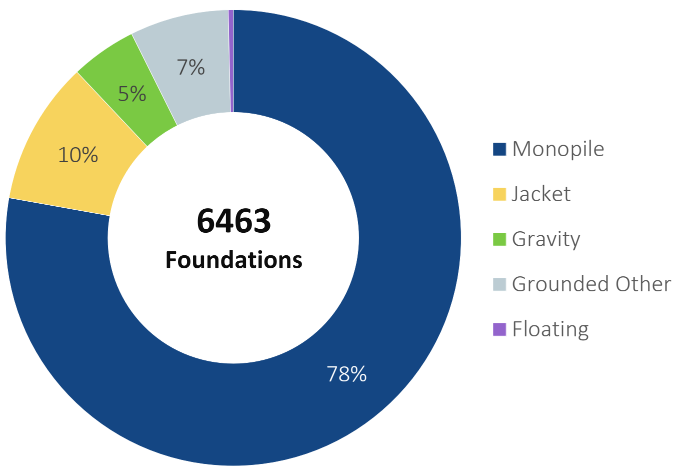
4 Foundations

A parametric study of foundation concepts (CER-SgurrEnergy: Sgurr Energy, 2014) concluded gravity-based foundations (GBF) as the most favourable solution for WIS. This decision was based on the avoidance of drilling operations given the site geology, the availability of raw materials and the potential for avoidance of heavy lift vessels if a floating or semi-floating design is employed.

4.1 Gravity Base Foundations

A total of 6463 offshore wind turbine foundations have been, or are currently being deployed globally (Figure 3). 302 of these, around 5%, are gravity-based foundations (GBF). Most GBFs have been installed in waters of 30m or less, with the exception being the Blyth Demonstrator project in the UK which deployed GBFs in up to 38m of water. There is a trend for GBFs to be deployed in deeper waters where they are being considered as an alternative to drilled and piled jackets in hard ground conditions.

Alongside the trend for deeper water, the increasing top head mass and overturning moments associated with larger nacelles and rotor diameters has led to an increase in substructure size and mass. GBFs deployed pre-2010 in the shallow Baltic Sea are characterised by having mass below 2000t and were installed by crane barge. The Blyth Demonstrator's GBFs, installed in 2017, weigh over 7500t and those to be deployed at Fécamp in 2022 will weigh over 5000t.



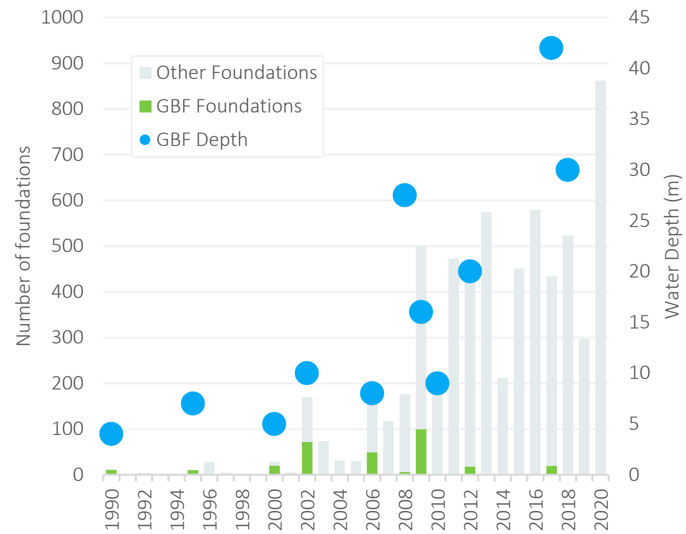


Figure 3. Global turbine foundations deployed, or currently in construction (excluding China)

4.2 Advancements in GBF deployments since 2014

4C's 2014 cost analysis of GBFs was based on known masses and costs associated with GBF project deployments for the period to 2012. Since the 2014 estimate there has been additional developments in GBF technology, three of which are discussed below. In addition, GBFs have been selected as the foundation option on the following projects;

Project Name	Country	Owners	Status	MW	Num Turbines	Installed
Blyth Offshore Demo	UK	EDF	Operational	41.5	5	2017
Tahkoluoto	Finland	Suomen Hyötytuuli	Operational	42	10	2017
Nissum Bredning Vind	Denmark	Nissum Brednings Vindmøllelaug (55%), Jysk Energi (45%)	Operational	28	4	2017
ELISA/ELICAN Demo	Canary Islands, Spain	ESTEYCO	Operational	5	1	2018
Fécamp	France	EDF (35%), WPD (30%), Enbridge (17.9%), CPPIB (17.1%)	GBF fabrication underway	498	71	2022
Empire Wind	USA	Equinor (50%), BP (50%)	PPA Secured (83.36 USD/MWh), Awaiting permits	816	80	2023
Havsul I	Norway	Vestavind Kraft	Procurement and business case development	350	40	Possibly 2023
GBFs are also under consideration at the following projects: Storgrundet (Sweden), Nodre Flint (Denmark), Oriel (Ireland)						Post 2023

Table 4. Projects deploying GBFs since 2014

4.2.1 Blyth Demonstrator Project, UK

EDF's 41.5 MW Blyth Offshore Wind Demonstrator Project, located 5.6km off the coast of Blyth in N.E. England, comprises five MHI Vestas V164-8.3 MW turbines, supported by GBFs in 38m of water. In 2016 EDF awarded two BAM companies, BAM Nuttal and BAM Infra a contract to design, fabricate and install the foundations. The project was is in part funded by a grant from the Dutch Ministry of Economic Affairs.

Foundations were constructed in a dry dock located at nearby Tyneside (C-2064: BAM, 2017). They were then filled with ~800m^3 concrete, floated out to site, sunk onto the preprepared site using water ballast to control the immersion process and then ballasted with sand and water to increase mass and stability. The process is known as 'float and submerge' installation. The total immersed mass of the ballasted foundation including transition piece is ~12-15,000 tonnes and comprises over 1,800m^3 of concrete (C-2064: BAM, 2017), (C-2106: EDF Energy, 2017).

Project Economics

Local production of the concrete structures brought local employment and economic value. Given only five units were produced, the process was not optimised. BAM report (C-2065: BAM Infra, 2017) that "If they have to be built in large numbers, BAM Offshore Wind will be using an industrialized production process to create a cost-efficient production method." There is no disclosed value for the contract, although an unverifiable value of £40 million has been reported in the media (C-2107: Construction Enquirer, 2017). Project CAPEX, also not disclosed, is estimated in this analysis as £178 m ($307 m, ~$7.4m/MW) from the project's balance sheet (C-2129: EDF Renewables, 2018).

The project has access to long term stable revenues through the UK's Renewable Obligation Certificate (ROC) scheme. It qualifies for 1.8 ROCs/MWh, estimated as being worth up to £137.8/MWh if using the 2019-20 ROC buy-out price of £48.78/ROC and assuming the long-term wholesale electricity price of £50/MWh.

4.2.2 Parc éolien en mer de Fécamp, France

EDF, Enbridge and wpd's 498 MW Fécamp project is located 13 km from the Haute-Normandie coast in N.W. France. Site depth ranges from 25-30m and the 71 x SWT-7-154 SGRE turbines will be supported by GBFs (C-2307: EDF Group, 2020).

Bouygues Construction, leading a consortium with Saipem and Boskalis is responsible for supply and installation of the 71 GBFs (Table 5). Each has an individual weight of 5,000t. Bouygues and Saipem are responsible for the design, construction and installation. Boskalis is tasked with the design and preparation of the seabed preparations prior to installation, scour protection and ballasting. Foundations are currently being constructed in the Bougainville maritime works yard in the Grand Port Maritime of Le Havre and will be transported by heavy crane barge Saipem 7000 to the site and installed during 2022. Manufacturing started in June 2020 for completion by end-2022. Full project commissioning is expected in 2023.

<table>
<tr><th>Company</th><th>Role</th><th>Value</th><th>Total</th></tr>
<tr><td>Bouygues Travaux Publics</td><td>Consortium Lead: design, construction and installation of 71 concrete gravity-based foundations</td><td>EUR 223.56m (40.5%)</td><td rowspan="3">EUR 552m (€1.1m/MW)</td></tr>
<tr><td>Saipem</td><td>Design, construction and installation of 71 concrete gravity-based foundations</td><td>EUR 223.56m (40.5%)</td></tr>
<tr><td>Boskalis</td><td>Design and preparation of the seabed rock foundation prior to installation. Scour protection and ballasting post installation.</td><td>EUR 104.88 million (19%)</td></tr>
</table>

Table 5. Roles and contract values for supplying and installing GBFs at Fécamp

Project Economics

Total project CAPEX for Fécamp is estimated as €2 billion ($2.87m, or $5.75m/MW) (C-2307: EDF Group, 2020). The turnkey supply and installation contract for the 71 GBFs is worth €552m ($791m), or $1.59m/MW.

The project has access to long term stable revenues through an award in France's first call for tenders in 2011. In June 2018 the PPA terms were revised in light of offshore wind cost reductions during the interim period. The project will now receive €150/MWh, down from a maximum allowed tender price of €175/MWh.

4.3 Industry Modelling Studies

The Energy research Centre of the Netherlands (ECN) sponsored a Joint Industry Project (JIP) investigating the 'Integrated project logistics and cost calculations for gravity-based structures'. Work, undertaken by a consortium of leading players (Marine, Deltares, Witteveen + Bos and Vuyk Engineering, DEME, Besix, Saipem, Jan de Nul, Statoil, Strukton, Bureau Veritas, ALP Maritime and

MonobaseWind) focused on increasing the understanding of the costs and risks associated with gravity base foundations with the aim of making them an economic alternative alongside jackets and monopile for deeper waters (C-2206: ECN, 2019).

ECN used details of the construction, transportation and installation of GBFs provided by the project partners as inputs into a cost of energy analysis. Some of the partners had been active on the Blyth Demonstrator Project (see above). The existing Borssele I and II project site in the Netherlands was the chosen as the model for the case study. The study assumed 60 x 10 MW turbines, supported by GBFs built at the Damen Verolme Rotterdam yard (105 km from the site) and turbines delivered from Port of Esbjerg. Three separate GBF designs were evaluated;

1. Floating design.
   Each foundation is 50m high, 38m diameter base and has a dry weight of 11200t.
   Constructed in batches of 20 within a dry dock, these structures are towed to site by tug then ballasted. Construction time is approximately 1 year per batch. Any delay in one of the GBFs will impact the whole batch and increase the total construction costs.
2. Non-floating (lifted) design.
   Each foundation is 50m high, has a 38m diameter base and a dry weight of 7240t.
   Constructed on the quay side there is no need for a batch process, and therefore no risk in one structure delaying the whole batch, but the construction period remains long (only 10% shorter than above). An expensive heavy lift vessel is required for installation.
3. Integrated design with pre-installed turbine (patented 'MonobaseWind' design).
   Each foundation is 12m high, 45.5m in diameter and has a dry weight of 12000t.
   Constructed in a dry dock, the design has a faster construction time and reduced offshore logistics (due to the turbine being installed onshore) but requires higher man hours and is more restricted by weather conditions during installation.

Results provided insight into the cost drivers for LCOE, logistics planning, required resources and weather restrictions. Installation was least affected by weather conditions between April and September, and a switch from loading out one to two structures at a time allowed all 60 foundations to be installed and commissioned within a year (excludes foundation construction which must be scheduled accordingly, with an appropriately sized dry-dock).

Project Economics

The floating design has manufacturing costs of approximately €370 million and installation costs of around €58m, giving a total of €428m (€ 0.714m/MW). The lifted design has manufacturing costs of approximately €320 million (€0.533 m/MW) and installation costs of around €137m giving a total of €457m (€0.762m/MW). The integrated design has manufacturing costs of approximately €415 million (€0.69 m/MW) and installation costs of around €29m giving a total of €444m (€0.740m/MW)

Compared to the monopile base case, LCOE was 5-7% higher for the gravity base solutions.

4.4 Wolfe Island Shoals Foundations

4.4.1 Foundation Manufacture

COWI and Weeks Marine (CER-SgurrEnergy: Weeks Marine, 2014) reviewed the potential GBF types and their associated installation methodologies and determined that a semi-floating gravity foundation was the most appropriate. The design can accommodate a 2.3 to 4.0MW turbine with a 100 to 113m diameter rotor and a water depth of 25m. The foundation has a maximum base diameter of 22m and an overall height of 35.5m. This design requires approximately 1450m³ of concrete and 319t of reinforcing steel per foundation. An ice cone is centred at the water line to break winter ice and force it downwards (CER-SgurrEnergy: Sgurr Energy, 2014). The conceptual design supposes a total weight of approximately 3800 tons at 25m depth (assuming a density of concrete as 2400 kg/m³ plus steel requirements).

Further studies in 2021 (Wood, 2021) concluded the foundation design is suitable for the proposed 4.5 MW turbine and park layout as detailed in Table 1. Foundations sited in shallow or deeper water depths will have a proportionally lower or higher mass. For example, a foundation sited in 30m has a mass of 4343 kg.

Windstream selected land adjacent to the St. Mary's cement facility in Bowmanville as the GBF fabrication facility. The site is adjacent to a cement facility, has access to deep water and is close to the site (175km). The facility is designed to support year-round serial construction and launch of the foundations; a set of rails facilitates construction and a foundation elevator platform is used for launching.

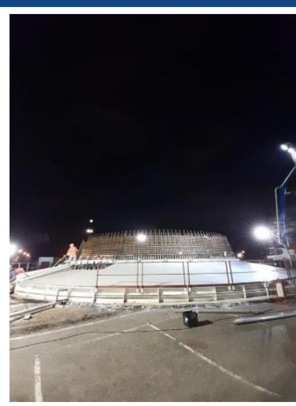
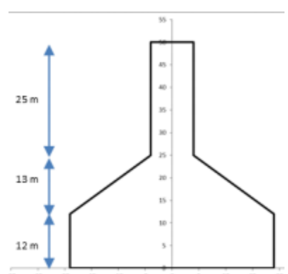
4.4.2 Foundation Installation

Site preparation involve removals through dredging and disposal of 1-2m of surface soil to expose the underlying bedrock which is then covered and levelled with bedding stone.

The foundation transportation and installation strategy for WIS is designed to reduce cost and risk by simplifying and shortening the offshore process, thereby minimising the vessel costs and exposure to weather delays (CER-SgurrEnergy: Sgurr Energy, 2014). Transportation of the semi-floating foundations from yard to site is facilitated through a supplementary foundation flotation system, consisting of barges, designed to lift the foundation from the elevator platform, transport it to site and install it. The supplemental floatation's jacking system, coupled with preliminary ballasting is used to lower the foundation into its final position. The system is then repeated for subsequent foundations. Finally, the foundation is filled with permanent sand ballast and protected from scour, using armour stone fixed around the perimeter of the base. It is likely that less scour protection would be needed than is typically deployed at oceanic offshore sites due to minimal wave and current action in Lake Ontario.

4.4.3 Foundation Supply and Installation Costs

The details for the three GBF case studies are summarized in Table 6 below.

	Blyth Demo	Fécamp	ECN Project	WIS
				
Turbines	5 x MVOW 8.3 MW (41.5 MW)	71 x SWT-7-154 (498 MW)	60 x 10 MW (600 MW)	66 x 4.5 MW (297 MW)
Depth Range	36 - 42m	24 - 31m	35m	10 - 30m
Construction	Dry dock batch construction followed by float and sink installation	Serial production on quayside. Heavy lift crane installation.	Dry dock batch construction followed by float and sink installation	Serial production at facility before launching and fixing onto floatation system and towing to site for sinking.
Dimensions	30m diameter x 60m height	50m height	38m diameter x 50m height	22m diameter x 35.5m height
Mass per unit	4300t concrete + 1100t steel (reinforcement + steel shaft) = 5400t. Ballast: 7000t	5000t + ballast Total: 355 ktons + ballast	11,200t + ballast Total: 672 ktons + ballast	~3800 tons + ballast Total: 237.8 ktons + ballast

Total Mass (ex. Ballast)	27 ktons	355 ktons	672 ktons	238 ktons, assuming the layout as defined in Table 1
t / MW (ex. ballast)	650t/MW	714t/MW	1120 t/MW	800 t/MW
Total Cost	Unavailable	€552m (€1.11m/MW) EPCI (design, supply, install)	€428m (€0.713m/MW) EPCI (design, supply, install)	
Cost / MW		€1.11m/MW	€0.713m/MW	
Cost / kt		€1.56m/kt	€0.637m/kt	

Table 6. Details of GBF case studies

A few observations relating to cost drivers can be made;

- The number of units for the WIS project is between the Fécamp and ECN projects, meaning the WIS project can be expected to obtain similar scale economies in production and installation.
- The majority of the WIS turbines (62%) are located in water depths of 25m or less. Because of the smaller turbines and shallower water, the total mass-per-unit is lowest at WIS.
- On a tonnes/MW basis the WIS project is in the mid-low part of the range.
- Installation conditions are most favourable at the WIS project

Metocean conditions in Lake Ontario are very unlike those of the North Sea and the English Channel, the location of the case studies, where installation is constrained by significant wave heights. For example, significant delays, accounting for 30% of installation time, are expected in the ECN study. These delays are mitigated through a costly doubling up of summer installation effort.

Figure 4. Saipem 7000 to be used for heavy lift installation at Fécamp (left) and float and sink installation by tug at Blyth (right)

The Saipem 7000 (Figure 4) being used to lift the Fécamp units is one of the world's most capable lift vessels and will have spot-market rates measured in hundreds of thousands of Euros per day. Because of the metocean environment and vessel spread, it is expected that installation costs will be significantly lower for WIS than in the ECN and Fécamp projects.

The WIS project is most similar to the ECN study in that it avoids the costs of heavy installation vessels. Therefore it is expected that the manufacturing and installation costs of the GBFs for WIS will be more similar to the ECN study than the Fécamp project. The WIS project is also endowed with locational characteristics that will help to further reduce costs. WIS is located in shallower water than ECN resulting in lighter foundations (800t/MW compared to 1120t/MW). It also has a longer available installation season of nine months compared to a six-month season at ECN, where significant delays are expected due to metocean impacts on the weather-sensitive installation process. The longer installation season and more benign conditions at WIS allow for a more compressed timetable and reduced vessel costs.

Conversely, the WIS project has other characteristics which are expected to increase relative costs at WIS compared to ECN. WIS has less opportunity to exploit scale economies in procurement and processes, having a total installed capacity of half the size of ECN. The windfarm site is also further from the manufacturing site (175km compared to 105km), eroding some of the metocean and seasonal installation advantages. WIS also requires additional investments in GBF fabrication and load out facilities at the Bowmanville site. These have been estimated by COWI as costing around $72m. It is expected that some of this cost will also be in the ECN study, which included dry-dock rent.

An additional 20% is added to the ECN study to account for the relative scale disadvantage and facility investments necessary at WIS. Therefore an estimated cost of €0.856/MW ($1.243m/MW in 2020 CAD) is used, giving a total $369m for detailed design, supply and installation of the 66 GBFs.

The detailed design cost is comparatively small and was deeply researched for the 2014 report so will remain unchanged. 13% of GBF costs are attributed to installation, below the ECN ratio of 18% to account for the differences in cost structure (relatively higher fabrication and lower installation costs at WIS).

This cost estimate assumes no material change in the design of the GBF foundation as detailed in the engineer's report (CER-SgurrEnergy: Sgurr Energy, 2014).

5 Turbine Supply and Installation

5.1 Turbine Supply

The global transition towards decarbonised power has increased the frequency and volume of competitively allocated wind power auctions. This has increased the competitiveness of wind as an energy source and placed demands on the supply chain to drive down prices. The number of turbine suppliers in offshore wind has consolidated around three; Siemens Gamesa Renewable Energy (SGRE), GE Renewable Energy (GE) and MHI Vestas Offshore Wind (MVOW).

Public domain details of offshore turbine prices remain scant, of variable scope and are too old to be of relevance. Public contracts are listed below in Table 7.

Project	Supplier	Year Announced	Scope	CAD $m	$m/MW
WindFloat Atlantic (WFA)	MHI Vestas	2018	Supply 3 x V164-8.4 MW turbines for floating offshore wind project	66.35	1.47
Merkur	GE Energy	2015	Supply of 66 x Haliade 150-6MW with long term O&M agreement	919.01	1.44
Dudgeon	SGRE	2014	Supply and install 67 x 6MW turbines plus 5-year service contract	982.80	1.51
Kentish Flats Extension	MHI Vestas	2013	Supply 15 x V112-3.3MW	85	1.52
Gemini	SGRE	2014	Supply and install 150 x 4MW turbines with a 15-year service agreement	2268.00	1.51
Butendiek	SGRE	2013	Supply and install 80 x 3.6MW turbines with a 10-year service agreement	1067.37	1.52

Table 7. Publicly available details of offshore wind turbine supply contracts

The BNEF turbine price index for 2010-2020 shows prices have fallen nearly 50% in the last decade (Figure 5, adapted from BNEF 2020).

The average selling prices (ASP) reported by SGRE for onshore and offshore wind turbines for the period 2017-2020 are shown in Figure 5. The ASP is influenced by multiple factors including turbine prices, geography mix, foreign exchange, contract scope and the turbine product mix within the reporting figures, with the larger rated turbines having a lower $/MW price. For example, SGRE's onshore ASP in 2020 is lower due to a larger contribution from higher rated turbines plus narrower contract scopes. SGRE's contract scopes in the US normally exclude installation and commissioning whereas in Europe and Latin America these tasks are within scope.

For SGRE the average turbine capacity in contracts for delivery has moved from over 3MW to over 4MW; 4MW or higher accounted for 45% of order intake, including 755 MW for the 5.X onshore platform. By Q1 2021 82% of the ASP is comprised of 4-5 MW machines. Orders for onshore turbines are roughly split one third each across APAC, Americas and AMEA. Servicing is reported separately and is not included in the ASP figures.

SGRE observes that following a period of steep price declines during 2016-2017, declines have since decelerated to <5% annually during 2020, "in line with the historical price trends and manufacturing productivity" (SGRE Annual Reports 2017-2020).

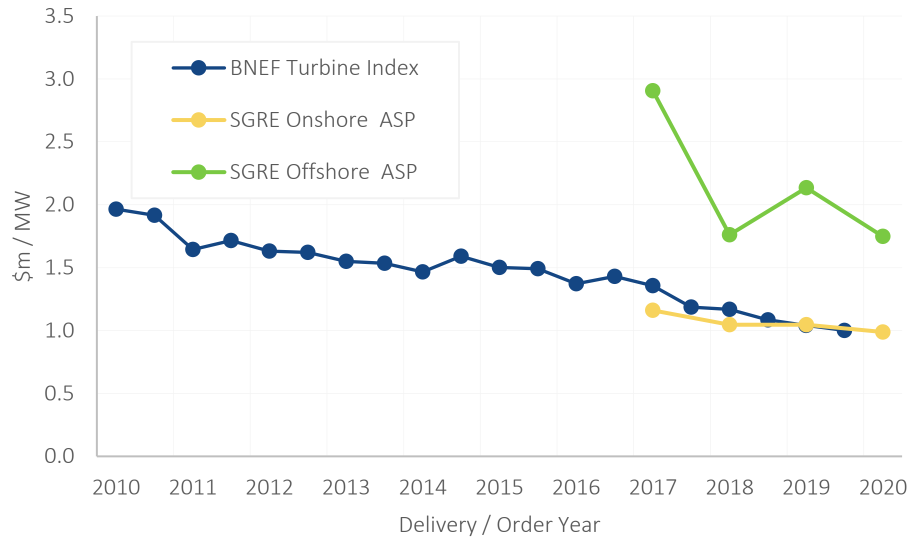


Figure 5. Turbine price trends 2010-2020

SGRE do not report the ASP for offshore turbines, but figures can be derived through the available order intake data (Figure 5). The offshore ASP varies considerably due to the geography and the relative proportion of contracts having installation within the scope, which is increasingly common.

During Fiscal Year 2020 SGRE sold 4139 MW of offshore turbines. Offshore turbines are significantly larger than for onshore. For example, the 2020 sales volume includes 140 units of the SG 11.0-200 DD offshore turbine to be deployed at HKZ I, II, III & IV from 2022. Similarly, among the 5.6 GW of conditional orders signed in FY20 were those for 4.3 GW of the new SG 14-222 DD Offshore turbine. The average rated SGRE turbine for the period entering construction in 2021 is over 8MW (4C 2021), corresponding with firm orders received during the period 2019-2020. Clearly SGRE offshore turbines sold in this period are significantly larger than those at Wolfe Island Shoals.

Wolfe Island Shoals is an inland, freshwater windfarm and will therefore deploy onshore turbines, specifically the SG 4.5-145. Consequently, it is appropriate to use the SGRE ASP for onshore turbines when assessing likely costs. The SGRE and BNEF data are closely aligned, providing additional confidence. **Therefore, a cost of $1.0m/MW for turbine supply is estimated.**

5.2 Turbine Installation at Wolfe Island Shoals

The nearby port of Ogdensurg has been selected as the staging port for WIS and will take delivery of components, and support preassembly and load out. Ogdensurg port has been a staging port for previous onshore wind projects in Ontario.

The original turbine installation plan envisaged engaging offshore contractor Weeks Marine, who would use its jack-up vessel RD MacDonald equipped with a 750t crane to conduct turbine installation operations. The jack-up, under construction at the time, was dependent on orders from the WIS and Cape Wind projects in order to finalize the build. These orders did not materialize. However, the vessel was completed and now serves the oil and gas market in the Gulf of Mexico.

Similar jack-ups to the RD MacDonald have installed turbines at the first offshore wind farms in Europe. A handful of these are also compliant with St Lawrence Seaway's 24m width restrictions. Only J/U WIND, operated by ZITON A/S is still active the sector, undertaking large component maintenance (e.g., blade repair, generator replacement) at European projects. Others have been redeployed to other sectors or retired. However, these vessels, or other oil and gas focused lift-boats based in the Gulf of Mexico could be fitted with an appropriately capable crane and made suitable for performing the installation. For example, Fred. Olsen Windcarrier signed a long-term time charter early in 2019 with Falcon Global for the lift boat Jill which is now in Europe performing large component replacement. Note that at 41m breadth, Jill is not Seawaymax compliant.

WIS features a 3.4 – 4.3 MW turbine in its optimized, 2020 design. Estimates for the 2014 design were centred around costs for the Siemens 3.6 MW turbine which was the most common at the time, with adjustments for the planned 2.3 MW turbine. For the original cost estimate, 4C engaged in discussions with leading installation contractors A2Sea, GeoSea and MPI Offshore, and cross referenced these against market information to obtain a range of $0.78-$1.00 million per turbine. This equates to $0.34-$0.43 million/MW for a 2.3 MW turbine.

Because turbines currently being installed are in the 8MW+ range, there are no contemporary market prices for installation of smaller machines offshore. It is estimated that a 1 GW park installing 100 x 10MW machines would expect to pay around $88k/MW, or around $0.88 million per turbine (C-2203: BVGA, 2019). In other words, since 2014 the cost of installing turbines on a per-MW basis has fallen by over 50% whilst the per-turbine costs have remained similar.

Because turbine rating in the optimized design is of similar scale to the original design, the WIS project will not obtain the same level of cost reduction. **A cost of $0.9m per turbine is assumed for installation.** Obtaining an appropriate Seawaymax compliant jack-up barge, or fitting an existing barge with a suitable crane is assumed here to not add significant cost.

6 Offshore Substation Supply and Installation

The offshore substation for WIS is land-based, built on a retained extension of the north end of Pigeon Island (Figure 6), potentially using spoils from the site preparation works. This approach has several advantages over the platform-based offshore substations more typical of far-shore projects where no island is available;

I. The land-based structure makes use of common construction practices employed throughout the Great Lakes for marine terminals and waterfronts (CER-SgurrEnergy: Sgurr Energy, 2014).
II. Platform-based substations typically require complex and costly jacket or gravity-jacket foundations in addition to a spatially-efficient topside containing specialist electrical equipment.
III. The jacket and topside also require a heavy-lift crane vessel for installation.
IV. The island has the potential to support operations and maintenance activities.

The substation design is conservatively assumed to require a 130m by 93m footprint and is configured with two main transformers, 35kV and 230KV switchgear, dis-connectors and capacitor banks (CER-SgurrEnergy: Sgurr Energy, 2014). The substation collects 35kV power generated by the turbines and steps the voltage up to 230kV for onward transmission via the submarine export cable. The cable makes land fall approximately 1 km from the Lennox Thermal Generating Station substation, where it is connected to the electrical grid.

Figure 6. Pigeon Island showing substation on northern extension.

6.1 Cost Estimate

In 4C's 2014 study, offshore substation costs were estimated on the assumption that the Pigeon Island solution is expected to be more expensive than a typical onshore substation due to the requirement for (i) marine-based construction in extending the island, and (ii) offshore transportation and installation of the components. Similarly, the cost is assumed to be lower than a platform-based offshore substations for the reasons outlined above.

The cost will therefore lie somewhere between costs of building a new onshore substation and the costs of an offshore substation. Onshore substation costs are reviewed in Section 9 and find costs in agreement with the 2014 estimation of $0.158m/MW. Offshore substation costs have been reviewed using the most recently available market and third-party data (Table 8). Findings suggest a supply and installation cost of $0.206m/MW, similar to costs identified for offshore wind substations in the 2014 study when accounting for inflation.

Because cost findings are similar for 2020 and 2014, the 2014 cost estimates for offshore substation supply and installation are retained for the 2020 estimate.

Project	Contractor	Cost $m	MW	Cost $m/MW
West of Duddon Sands	Windfang Consortium	93.0	389	0.239
Dudgeon	Siemens / Sembmarine	89.8	402	0.223
Gemini	FICG Consortium	64.2	300	0.214
East Anglia One	Navantia	95.8	714	0.134
Offshore Substation Supply & Install	BVGA	267.5	1000	0.267
Offshore Substation Capex Metrics 2011 – 2015 Low	Catapult			0.134
Offshore Substation Capex Metrics 2011 – 2015 High	Catapult			0.230
Wikinger	Navantia	103.9	350	0.297*
		Average (excluding Wikinger)		0.21

Table 8. Offshore Substation Supply and Installation Contracts. *Wikinger substation cost includes a second topside, with similar weight, acting as a switching station for a separate wind farm. Both topsides share the same jacket. Structure has been excluded when calculating the average.

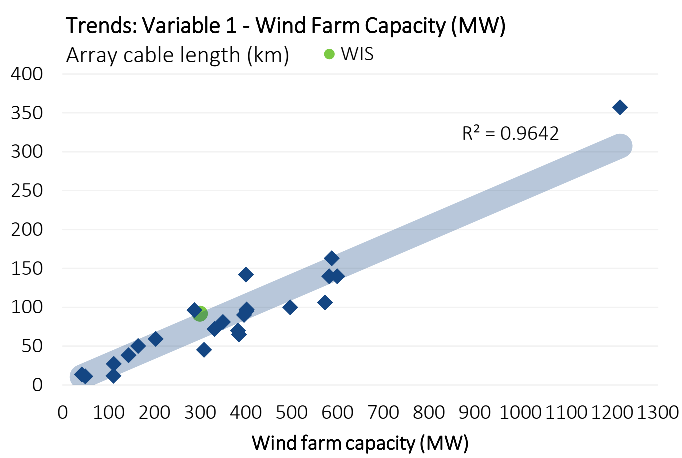
7 Array Cable Supply and Installation

The analysis performed in 2014 has been updated to capture changes in the required length and costs of array cabling.

7.1 Required Array Cable Length

The length of array cable required is estimated using market data from commissioned or under construction offshore wind projects. Suitable offshore projects, i.e., projects built since 2015, those not built over split geographical zones (which would require excess cabling), and those that have reached financial close, were examined carefully and array cable length information was obtained through direct communication with developers, press releases, and planning documents.

An array cable length model was formulated using a multivariate linear regression from the resulting dataset Figure 7. Two independent variables were considered: the total project capacity and the number of turbines. A specific model was built for projects with <=8 MW turbines, acknowledging the increased spacing required between larger turbines and to not overestimate array cable supply requirements for smaller turbines.



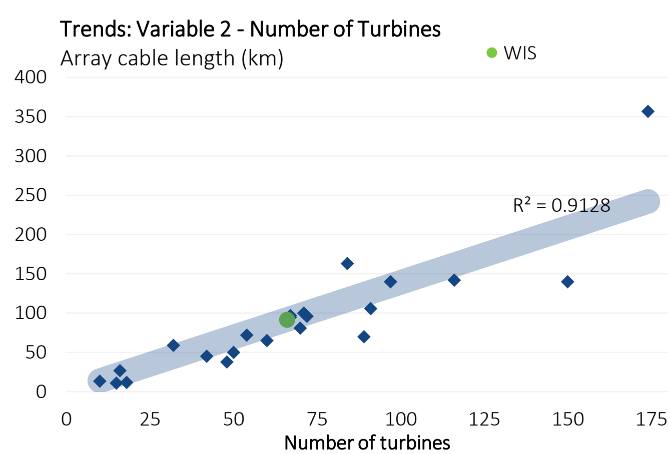


Figure 7. Multivariate array cable length model

The array cable length model is defined as: L= 0.2371c+ 0.089n

Where L is the total required array cable length (km), c is the project capacity (MW), and n is the number of turbines. For WIS the model suggests a required array cable length of 76.3km for 66 turbines.

However, the turbine layout at WIS is not fully optimised for array cable lengths. Typically a developer will have some freedom when deciding the location of the offshore substation location, and will position it such that the length of array cable needed is minimised, whilst also balancing other economic considerations. In the case of WIS the substation is positioned on Wolfe Island, within the north extreme of the site. Therefore it is expected that WIS may require more array cable than other projects. An additional 20% is added to the estimate above to account for this constraint, bringing the total to 91.6km. Figure 7 shows this to be within the variance of the dataset.

7.2 Array Cable Supply and Installation Costs

A cost model comprising primarily of contracts since 2015 has been created using available market data (Figure 8). Most data points were available for "engineering, procurement, construction, and installation" (EPCI) contracts, essentially where supply and installation of cable are combined into a single contract. The contractor would then either perform both tasks where capable, or subcontract either manufacturing or installation to a specialist partner.

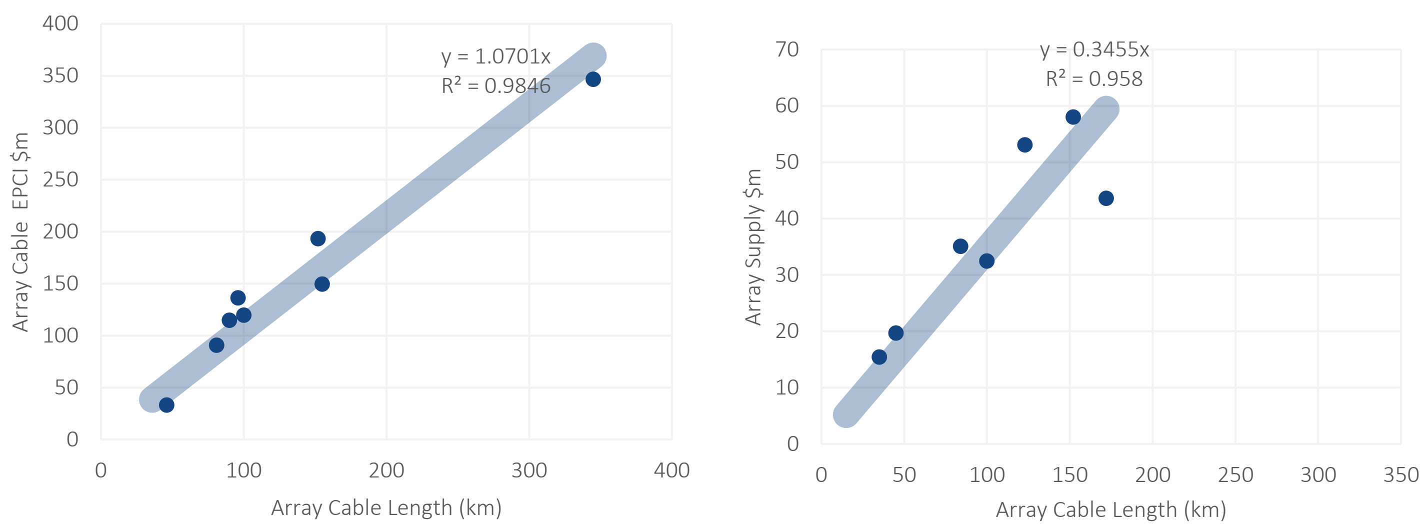


Figure 8. Cost model for array cabling

Using the above model, and the required length of 91.6km as identified in Section 7.1, combined array cable *supply and installation* costs are estimated as $97.9m. **Array supply is modelled separately using known *supply only* contracts as $31.6m.**

Only four data points are available for *installation only* contracts, yielding the relationship y=0.40x (R^2=0.87; chart not shown). Ordinarily it could be expected that the supply and installation costs, if estimated separately, should approach the EPCI contract price, with differences attributable to economic and contractual factors. However, because the datasets in each of the above array cable EPCI, supply and installation models are independent of each other, i.e., derived from different offshore wind farms which deploy different cables, differing lengths, different contractors and varying ground conditions, the sum of supply and installation falls short of the EPCI estimate.

Therefore, installation costs are estimated by subtracting the supply from the EPCI cost to give $66.3m. However, as identified in the 2014 report, the array cables at WIS will not be buried after being laid between the turbines. In the 2014 analysis 4C estimated this would reduce installation costs by around 65%. During 2020, 4C studied array cable installation rates at a sample of global projects, finding that cable pull-in is a significant driver of time spent installing array cables, in addition to cable burial and protection. 4C identified that when the same vessel was used for array cable lay, burial and pull-in, around 60% of the time is spent on lay and pull-in and 40% on burial. In this analysis 4C has therefore reduced the costs by 40% to account for surface laying.

This results in a final installation cost estimate of $39.8m for array cable installation.

8 Export Cable Supply and Installation

The 28km export cable at WIS will connect the offshore substation, situated on Pigeon Island, to shore, approximately 1km from the Lennox Thermal Generating Station substation, where it is connected to the electrical grid (CER-SgurrEnergy: Sgurr Energy, 2014).

In line with common contracting practices, for this 2020 estimation, the additional 1km of onshore cabling will be included in the offshore export cable contract. Therefore, a total of 29km of subsea 230kV cable is required. This cost estimate assumes a single export cable.

A study commissioned by Windstream and conducted by Genivar has demonstrated the need only to lay the export cable on the seabed, therefore omitting burial and its significant contribution to cable installation costs. The requirement to avoid burial of the cable is largely due to the surrounding environmental conditions and a proven track record of power transmission cables installed without burial in the Great Lakes.

A cost model comprising relevant high voltage contracts, the majority of which are 220kV and awarded since 2015 has been created using available market data (Figure 9). Most data points were available for cable supply contracts or EPCI contracts, where supply and installation of cable are combined into a single contract. The contractor would then either perform both tasks where capable, or subcontract either manufacturing or installation to a specialist partner. Only limited (four) market data points are available for installation contracts.

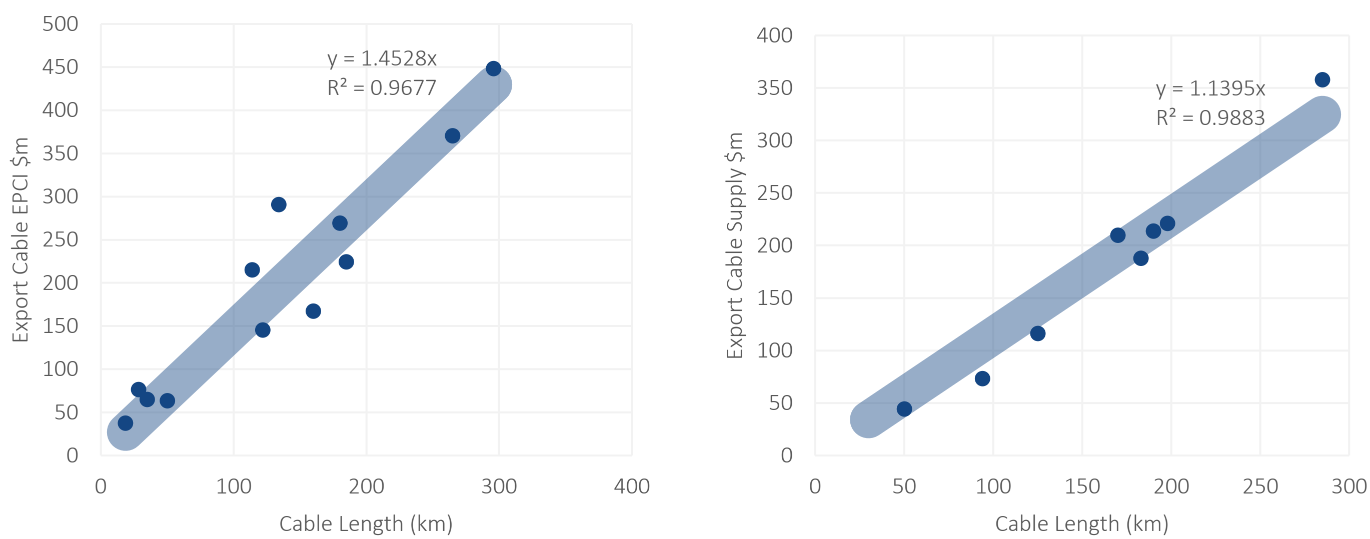


Figure 9. Cost model for export cabling

Using the above model, **supply of 29km of 230kV export cable is estimated as $33.04m**. Export cable installation can be estimated as EPCI (supply and installation) less supply, i.e. $42.11m – $33.04m = $9.07m.

However, the export cable will not be buried between Pigeon Island and the shore. In the 2014 analysis 4C estimated this would reduce costs by around 65%. During 2020 4C studied export cable installation rates at a sample of global projects, finding that cable pull-in was a significant driver of time spent installing, in addition to cable burial and protection. 4C identified that when the same vessel was used for export cable lay, burial and pull-in, around 40% of the time is spent on cable lay and pull-in, 60% on burial. 4C have therefore reduced the costs by 60% to remove the export cable burial component. This results in an export cable installation cost estimate of $3.63m. An additional correction needs to be made for burial of the onshore component of the cable, a provision of $1m is allocated allowing for the additional difficulties of onshore installation. **Total installation costs are therefore $4.63m.**

8.1 Cable Cost Increases

Supply costs for both export and array cables have increased on a per-km basis since the 2014 estimate. This is because

I. Estimates are dependent on a relatively small sample size of market contract data (< 10 contracts per estimate). There is inherent variability between projects, contracts and market context.
II. The export cable (29km including land component) is very short in comparison to other windfarms and therefore sits outside the range of known data, making the model less accurate.
III. Some of the 2014 market data point samples are now unrealistically low. They originate from early projects (pre-2010). Following well documented cable failures for early projects, it is possible there has been an upward pressure on some costs.
IV. In 2014 a decision was made not to force the regression through the chart origin. In 2020 it was considered more appropriate, given the shorter cable lengths of the WIS project relative to the sample, to force the model through the origin, with an upward result on costs.
V. Differences in EUR/CAD exchange rates between 2014 and 2020

9 Onshore Connection Costs

Onshore connections for offshore wind projects typically comprise of:

I. Transition joints between the offshore and onshore cabling, located in pits near the shoreline.
II. Onshore export cables running in a ducted and trenched system to an onshore substation.
III. An onshore substation adjacent to a substation owned by the system operator. Onshore substations require civil and enabling works and contain one or more transformers and auxiliary transformers, reactive compensation, switch gear, SCADA systems and ancillary equipment.

The WIS project connects to the grid at the Ontario Power Generation Lennox TS, situated only a short distance from the shore of Lake Ontario. The submarine export cable will transition from an underwater cable design to a standard cabling at transition joints housed within a junction station approximately 1km from the Lennox Station. The onshore cable will then run underground to the Lennox Switchyard and will be terminated at two 230KV breakers installed adjacent to lines X21 and X22 (CER-SgurrEnergy: Sgurr Energy, 2014).

4C's 2014 assessment of connection costs were based on experiences at offshore wind projects in Northern Europe. Information was collated from three sources; 3rd party research, actual contract awards and estimates based on OFTO transmission cost assessments made by OFGEM. Costs were then adjusted to account for key differences expected to have a material downward impact on costs, namely;

I. The WIS project has only one export cable, not two or more as is common.
II. WIS is exporting from Pigeon Island at 230kV, the grid voltage, and therefore there is no need for a step-up transformer and associated switchgear. Typically, two sets of transformers and switchgears are used onshore at European projects.
III. European projects require the use of more expensive compact technology including gas insulated switchgear (GIS) as opposed to oil or air insulation.

Taking into account these differences, in 2014 4C estimated a base-case of $47.3m ($0.158m/MW), excluding onshore cabling.

A review of additional information since then is shown below in Table 9.

Report	Title	Value
Catapult (High Case)	Review of 13 offshore wind onshore connections costs between 2011-2015	$0.268m / MW
Catapult (Low Case)	Review of 13 offshore wind onshore connections costs between 2011-2015	$0.153m / MW
BVGA	Guide to an offshore wind farm.	$0.095m / MW

Table 9. Additional onshore connect cost data since 2014

The 2014 estimate is similar to the low end of costs identified by Catapult (Table 9), even though the Catapult low estimate may still have a broader scope than is required for WIS. Specific details of connection requirements for the high and low-price trends are unavailable. The BVGA cost estimate is based on a 1 GW project and therefore benefits from economies of scale. The 2014 estimate for WIS is therefore retained as the estimate for 2020 on the basis that the WIS connection requirements are minimal.

10 Contingency

Research into current contingency budgets for offshore wind identified allowances for between 7 and 12% of CAPEX. The International Energy Agency used 9% for its calculation in its Wind TCP Task 26 report (C-2179: International Energy Agency, 2018). Sumitomo Mutsui Banking Corporation, a leading global project finance bank suggests a 7-12% contingency budget for Taiwanese offshore wind (C-2175: Sumitomo, 2018).

It is therefore concluded that the 10% contingency budget used in 2014 remains appropriate.

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TAB 13

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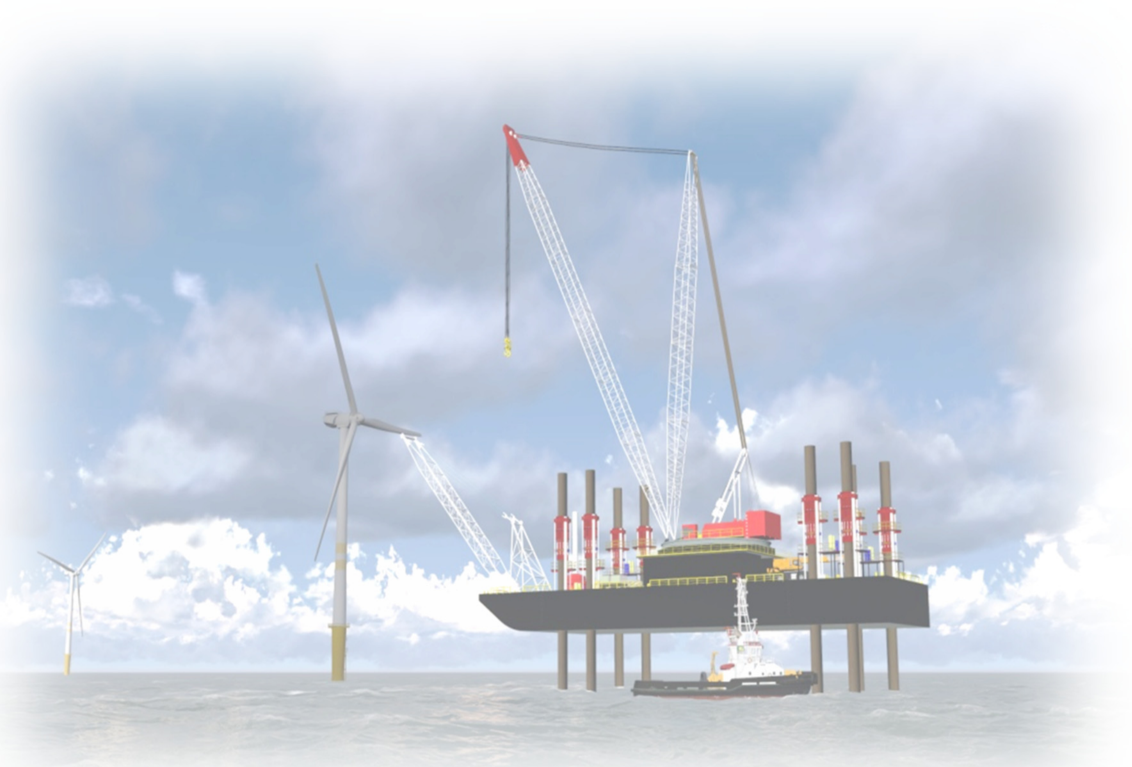
February 2022

Wolfe Island Shoals

Gravity Based Foundation and Wind Turbine Generator Installation Means and Methods



R.D. MacDonald Wind Turbine Installation Vessel (Rendering)

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Version:	Final
Issued:	February 18, 2022
Prepared By:	NEW
Reviewed By:	RPP

WEEKS

Contents

Drawing List

WIS – Weeks Marine – GBF Installation Method Summary Drawing Set

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WMI-0077-002	Jacking Assembly
WMI-0077-003	Jacking Assembly – Section Views
WMI-0077-004	Enlarged Jacking Beams
WMI-0077-005	Enlarged Lower Brackets
WMI-0077-008	Hydraulic Sand Ballast – Plan View
WMI-0077-009	Hydraulic Sand Ballast – Profile View
WMI-0077-010	Mechanical Sand Ballast – Plan View
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WIS – Weeks Marine – WTG Installation Method Summary Drawing Set

Includes:

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Table List

Preface

Weeks Marine previously prepared a Construction Methodology (Means & Methods) report for Windstream Energy Inc. (Windstream) in support of the NAFTA arbitration proceedings held in 2014-2016 (NAFTA1) related to the Wolfe Island Shoals (WIS) offshore wind farm (the Project). The previous report has been reviewed and we believe it presented a viable description of the work required to perform the on-water installation of the wind farm with the information known at the time of the report preparation.

It is our understanding that on February 18, 2020, the government notified Windstream that the power purchase agreement (Feed-in-Tariff contract) issued for the Project had been cancelled. In response, Windstream submitted a Notice of Intent (February 2020) and Notice of Arbitration (November 2020), as the initial steps in a second round of NAFTA arbitration proceedings (referred to in this report as NAFTA2).

In support of NAFTA2 and at the request of Windstream, Weeks Marine has updated our previous report where required based on a detailed review of the Project from a technical and scheduling perspective. This current report considers recent information and experience since NAFTA1 and confirms the feasibility of the Project should it have been allowed to re-start the development process in February 2020.

Following a detailed selection process, Windstream has chosen 66 Siemens-Gamessa (SG) 4.5 MW – 145 wind turbine generators which is the basis of this analysis. For the purposes of this current report, Weeks Marine has included the full installation (erection and commissioning) of the SG turbines in this Means and Methods analysis, whereas the previous NAFTA1 report assumed the erection and commissioning would be performed by others.

The objective of this current report is to confirm the constructability of the Project should it have been allowed to progress in the absence of (“but for”) restrictions imposed and uncertainty created by various government agencies.

Wolfe Island Shoals Offshore Wind Project

Foundation and WTG Installation – Means and Methods

1.0 Project Description and Background

The installation of the concrete Gravity Based Foundations (GBFs) and the erection of the Wind Turbine Generators (WTGs) for the Wolfe Island Shoals (WIS) project is logistically challenging and complex. This document is intended to describe the Offshore Installation Contractor's (OIC's) means and methods for installation of the GFBs and the erection of the WTGs.

The GBFs will be fabricated on land and skidded on concrete rails using large hydraulic jacks. The foundations will be skidding until over water and loaded on to an elevator platform. The elevator system will then lower the GBF into the water where the OIC will begin the transportation process.

1.1 Scope of Work

The Offshore Installation Contractor's scope of work includes providing supplemental flotation, towing to the site, site preparation (dredging and stone bedding) and lowering the GBF on to the stone bedding. The OIC is also responsible for providing the equipment and crews for the installation of the Wind Turbine Generator (WTG) components including the towers, nacelles and blades.

1.2 Weeks Marine, Inc. Introduction

Weeks Marine, Inc. (WMI) is a 103-year-old, privately owned company currently ranked 119th on the *Engineering News Record* 2021 "Top 400 Contractors" list and number one in Ports and Marine Facilities. The Construction Division specializes in international engineering and construction of marine facilities while the Dredging Division is one of the largest dredge operators in the U.S. Other WMI divisions include Stevedoring, Heavy Lift & Salvage, Towing and Equipment Charter.

The Construction Division, along with our wholly owned subsidiaries, Healy Tibbitts Builders, Inc. and McNally Construction Inc., have completed projects in Canada, the Caribbean Basin, Gulf of Mexico, Central and South America, the Central Pacific Islands of Micronesia, as well as along the coastlines and waterways of the United States.

Typical projects include design and construction of LNG berths, docks, piers, wharfs, offshore platforms, specialized ship mooring systems, breakwaters, submarine pipelines and cables, as well as the rehabilitation of similar facilities. WMI project managers, engineers, construction managers, estimators, superintendents, safety personnel and quality control personnel are dedicated and proven professionals.

The WMI inventory of owned marine construction vessels is one of the largest in the North America and includes crane barges with capacities to 700 tons, ABS cargo barges, dredges, utility barges of various types, tugboats, and extensive ancillary support equipment. A selective listing of WMI's marine vessels and barges is included in Attachment E.

Weeks Marine is committed to providing outstanding customer satisfaction, which includes focused safety and quality programs and good stewardship of the environment. Our company has the experience, qualified personnel, and equipment resources to safely and successfully complete the most challenging marine projects.

WMI was requested by Windstream to develop the offshore means and methods plans for the Wolfe Island Shoals Project. This selection was based on Weeks Marines resources the capabilities of their equipment resources and the marine experience of their personnel. This experience allows us, to develop the creative and innovative solutions required to construct projects like the Wolfe Island Shoals Offshore Wind Project.

Following the submission of the original NAFTA1 report, Weeks Marine successfully completed the installation of the Block Island Offshore Wind Foundations for Deepwater Wind (now Orsted) off the coast of Rhode Island, US in 2016 and has continued to support planning and development efforts for offshore wind along the east coast of the US to the present day.

2.0 Mobilization

Mobilization will consist of the normal mobilization of floating equipment including derrick cranes, barges and tugboats to the jobsite. The equipment will be towed from its east coast port up the Saint Lawrence River and into Lake Ontario. It will then proceed to the project staging area. For the purpose of developing the project installation plans, the St Mary's cement facility in Bowmanville, Ontario has been selected as the project staging and fabrication area.

In addition to the normal equipment mobilization, specialized barges and heavy lift devices will need to be fabricated. Conceptual plans for the specialized equipment are detailed herein.

Municipalities surrounding the Great Lakes provide many opportunities for the OIC contractor to develop relationships with local vendors and subcontractors. The OIC contractor will explore these potential relationships during the procurement process. Opportunities to use the local resources include, but are not limited to, dredging, barge rental, tugboat leasing, electrical subcontractors, steel fabrication, ballasting materials and scour protection stone.

2.1 Supplemental Flotation Barges

Supplemental Flotation Barges (SFB) will be used to provide the added flotation necessary for the semi-floating GBF. Each SFB will be assembled from four specialized modular barges. An SFB will consist of two barges that are approximately 32.61 m long (107 ft) by 9.75 m wide (32 feet) by 4.57 m deep (15 ft) and two barges that are approximately 13.11m long (43 Feet) by 9.75m wide (32 feet) by 4.57m deep (15 feet). They will be joined together to form a 32.61 m by 32.61m (107 ft x 107 ft) square barge with a 13.11m (43 ft) square opening in the center (See Drawing WMI-0077-001). The two longer barges will each have two, 2.5m diameter moon pools to facilitate the GBF lowering mechanism.

The SFB will have flanged connection points where pins can be inserted locking the modular barges together. This will enable the 4 modular barges to be joined together using a rigid connection to form a single 32.61m by 32.61m SFB. Two SFBs (eight modular barges in total) will be utilized for the GBF transport and installation.

The SFBs will be towed to the Bowmanville precast yard using tugboats from the fabrication location.

2.2 Jacking Devices

Jacking frames will be designed and fabricated using a combination of wide flange beams, stiffener plates and schedule 80 pipe. Four frames will be required, one for each of the four jacking locations. The base or lower member of the jacking frame is a steel plate girder that sits on the barge. The top member is also a steel plate girder and serves as the jacking member (WMI -0077-002). The jacking devices will be fabricated and delivered to the Bowmanville precast yard to be assembled on the SFB barges.

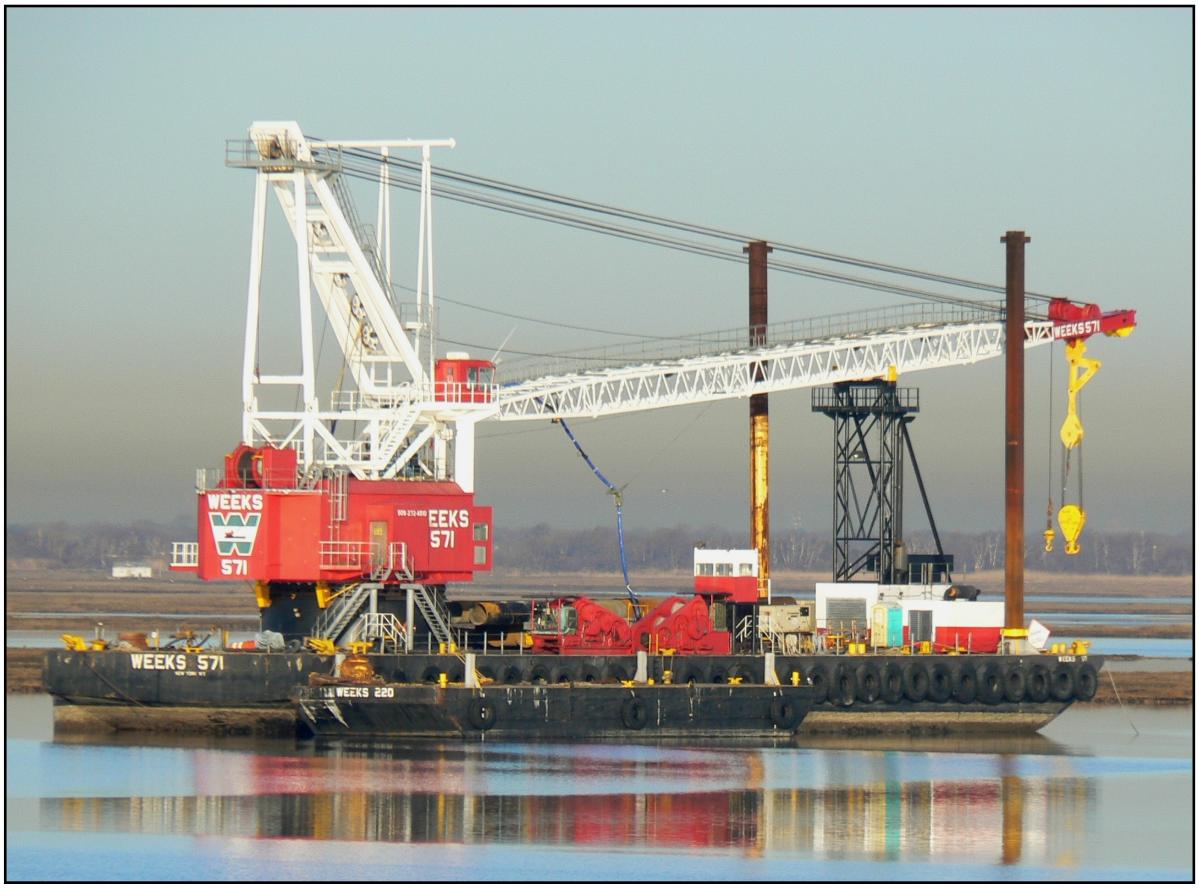
The SFB barge will then be outfitted with Global Positioning System (GPS) equipment. The GPS equipment will be used to ensure the GBF is installed in the proper location and within the specified construction tolerances.

3.0 Gravity Based Foundation Site Preparation

The installation site for each of the GBFs will require preparation prior to installing them on the lake floor. The overburden will be removed at each foundation site using a mechanical dredge method. Following the dredging operations, stone bedding will be installed over the GBF footprint for each site. All in-water construction activities will be performed on a 24 hour per day, 7 days per week schedule (no change from previous NAFTA1 report.)

3.1 Dredging

Prior to the installation of the bedding stone, the existing overburden will be removed to the required design depth. A clamshell bucket dredge – Weeks Derrick Barge 571 (W571) or a similar – will be used to perform this task. The dredge, two hopper barges and associated mechanical dredging equipment will be mobilized to the site. See Attachment A for the W571 General Arrangement drawing and Attachment B for the W571 capacity chart.



Weeks 571

A pre-dredging hydrographic survey will be performed to serve as a baseline for the dredging work. The survey results will be shared with the engineer of record as part of the final report to determine the required amount of stone bedding for each foundation location.

Tugboats will be used to transport and locate the W571 at each GBF site. Once on location the dredge will be moored via an anchor system. The anchors will be deployed using a tugboat and an anchor handling barge. Once the dredge is positioned an empty hopper barge will then be brought alongside. The dredge will then begin excavating the lake bottom using the boom mounted GPS and other integrated survey equipment to control the digging location and elevation. The clamshell bucket loads will be deposited on to the hopper barge.

When the hopper barge is filled, it will be removed and replaced with a second hopper barge to maximize the efficiency of the dredge. If the dredged material is deemed suitable to be used as ballast material in the GBF, it will be off loaded at the Bowmanville yard for storage until it can be reused. If the material is unsuitable for use as a ballast material it will be disposed of in accordance the applicable permits and contract documents.

When the dredging is completed a post dredge hydrographic survey will be performed. The results will be reviewed with the foundation designer to determine the amount of stone bedding required. If it is determined that additional dredging is necessary, the dredge and supporting equipment will return and remove the excess material identified by the hydrographic survey. When completed another survey will be performed to verify the dredging was performed in accordance with the contract requirements.

3.2 Bedding Stone Supply and Installation:

The stone bedding for the site will be provided from local quarries and transported to site via suitable barges. In advance of on-site work, the stone bedding barges will be outfitted with concrete wear decks and bin walls to prepare them for transporting the bedding stone. The stone will be transported by truck from local quarries to the designated waterfront facility and towed to the jobsite.

On site, a Material Handling (MH) crane barge, equipped with a clamshell bucket and skip pan, will be positioned at a WTG foundation site using GPS equipment. The MH barge will deploy its anchors with the assistance of tugboats and an anchor handling barge. A loaded cargo barge with bedding stone will be towed to and breasted against the material handling barge. Utilizing a clamshell bucket and/or a skip pan, the MH will unload the bedding stone from the cargo barge and place the material on the lake bottom.

Several barges will be employed to provide sufficient bedding stone to allow the material placement to proceed continuously. The rotation of the barges is important to maximize the efficiency of the material placement operation.

Utilizing a boom tip equipped with GPS, the crane operator will place stone in a grid pattern within the designed bedding stone footprint. When the MH crane barge has placed an appropriate quantity of stone, it will be graded to the proper elevation. The bedding stone will be leveled by employing a heavy beam or blade. The beam is lowered to the required elevation and dragged across the foundation bedding stone to level it to the specified elevation and slope.

Hydrographic surveys are performed and documented to ensure the stone has been placed in accordance with the foundation specifications. If holes or mounds are found in the survey, the MH crane barge will return to the location to add additional stone to fill the holes using a clamshell bucket. It will repeat the grading process for the bedding stone to remove the mounds. The hydrographic survey will then be performed again to verify the results. The process will be repeated until the results of the survey meet the project requirements. When the survey results are completed and approved, the site is ready for installation of the GBF.

4.0 Gravity Base Foundation Transportation and Positioning

4.1 Preparations for Transportation

The GFBs are lowered from the fabrication facility into the lake via the Syncrolift/ elevator platform where they are prepared for the tow to site. The four supplementary flotation barges are positioned over the GBF ballast tanks with the moon pools aligned with GBF connection points. When the four barges are properly aligned, they are interlocked with the installed flange to pin system. The assembled barge will be a 32.61m (107 feet) square barge with a 13.1m (43 foot) square opening centered on the 12.6m (41.33 foot) diameter GBF Caisson. (See Drawing WMI-0077-001 for assembled supplemental flotation barge)

Following the positioning and attachment of the barges, the lower jacking frame is installed over the moon pools in preparation for the attachment of the tie rods. (See drawing WMI-0077-003 for barge and jacking system layout) Once the lower jacking frame is positioned the Eight 1500-ton jacks are placed on the lower jacking frame. Two jacks are installed per frame located over the appropriate frame stiffener plates. The top jacking frame is then installed in alignment with the jacks and the lower frame to allow for installation of the tie rods.

Once the jacking equipment is properly positioned, 24 high strength rods (six at each moon pool) are lowered through the top jacking frame (See Drawing WMI-0077-004), the lower jacking frame (See Drawing WMI-0077-005), the moon pool and connected to the load transfer plate. As the rods are being lowered the high strength nuts and plate washers are threaded on to the rods; there is one nut and a double split plate washer above the top flange of the upper jacking frame and one above the top flange of the lower jacking frame. Drawing WMI-0077-002 illustrates the complete jacking system. The process is repeated until the assembled supplementary floatation barge all four sectional barges are in position and have the 24 tie rods installed with the nuts and plate washers.

The high strength rods will be attached to a large, gusseted plate which will be lowered through the moon pool and under the SFB barge. The bottom of the plate will then be attached to the GBF using a hydraulic pin release mechanism (See Attachment C).

The SFB barge will be secured to the GBF with mooring lines to limit movement during the jacking process. Neoprene bumper guards will be installed between the barge and the caisson for protection.

The eight 1500-ton jacks are powered by a power pack that also controls the jacks synchronizing the raising and lowering operation (See Drawing WMI-0077-004). The system monitors each jack to ensure that the load in each of the 8 jacks is equally balanced.

When activated the jacks will raise the top jacking frame and the GBF, the nuts on the rods are continually lowered as the high strength rods are jacked up. When the jacks reach their maximum throw, the nuts will be spun down on the top of the lower jacking frame until snug tight. The pressure on the jacks is released and the jacks return to their relaxed or closed state. The nuts on the top of the upper jacking frame are then lowered until snug on the top flange. The jacking process is repeated until the top of GBF ballast tank is in the transit position (almost touching the bottom of the SBF barge). The GBF is then ready for the tow to the site.

The GBF will be towed to site with zero ballast to minimize the weight of the tow. To ensure the GBF remains unballasted during the tow they will be monitored throughout the tow with pumps pre-installed in the GBF to insure positive buoyancy throughout the transit to site. A leap-frog method of GBF installation will be utilized. When the first GBF is deployed, the second set of SFBs will be used to repeat the process and maximize the efficiency of the installation equipment.

4.2 GBF Tow to Installation Site

The tow to the site will be performed by a 3000 HP tugboat and a 2000 HP assist tugboat. Both tugboats will be equipped with bow thrusters and GPS which are necessary to aide in the proper placement of the GBF.

The 3000 HP tug will be attached to the bow of the SFB barge using cables connected to the barge cleats. The 2000 HP tug will be attached to the stern of the SFB barge, again using cables attached to the cleats on the SFB barge. (See Table 1 for estimated cycle time)

4.3 Positioning and Lowering to Final Position

Upon arrival to the GBF installation location, the tugs will move from a towing configuration to a controlling configuration where both tugs are hipped up to opposite sides of the SFB barge. Using the tugs main engines and their bow thrusters the tugs will be able to locate and hold the barge in place during the lowering process using their on-board Global Positioning System (GPS). All in-water construction activities will be performed on a 24 hour per day, 7 days per week schedule (no change from previous NAFTA1 report.)

When the tugboats have the barge properly positioned over the installation site, the crews will begin lowering the GBF down to the lake floor. The crew will begin the process by jacking the GBF up to release the load on the 24 high strength nuts which held the load during the tow. When the load is relieved on the nuts, the crews will spin the nuts up on the high strength rods and the lowering process can begin. The pressure on the eight 1500-ton jacks will slowly be released allowing the GBF to move down through the water column. When the jack is fully retracted the crews will spin the bottom nuts down until snug on the lower jacking beam. The load is then transferred from the jacks to the lower nuts. The top nuts will then be spun up and the 1500 ton jacks will raise the top lifting frame using approximately 90 percent of the jack's stroke. The upper nuts will then be spun down until snug with the top flange of the upper frame. Using the balance of ten percent of the stroke, the jacks raise the upper frame transferring the load to the upper nuts and freeing the lower nuts which can then be spun up the rod. When the load is removed from the lower nuts the pressure on the jacks can again be slowly released until the jack is completely retracted. Assuming the jacks have approximately twelve inches of stroke, the process will then be repeated approximately 90 times, assuming the water depth is about 27 m (90 feet). (See Table 1 for estimated cycle time). The water depths for the 66 GBFs is estimated to range from 10 m (33 feet) to 30 m (98 feet) and average approximately 22 m (72 feet)[1]

As the GBF is lowered into the water, water will be pumped into the ballast tanks to counteract the increasing buoyancy of the GBF as it is lowered through the water column. Initial calculations for a foundation designed for a 25m depth indicate that the foundation become buoyant when submerged to a depth of approximately 23m (75 feet). The water provides the added weight needed to overcome the buoyancy for GBFs installed at depths greater than approximately 23 m (75 feet) until the permanent ballast can be installed.

Once resting on the lake floor and the load on the high strength rods is completely relieved, the hydraulic pin release mechanism is activated. (See Figure 1) The hydraulic pin is operated via remote release from the topside. When all four pins have been activated the GBF is free of the SFB barges. A Remote Operated Vehicle (ROV) will be used to confirm the pins released properly and the jacking system is used to raise the rods up to the bottom of the SBF barges.

Once the GBF is sitting on the previously place bed stone the location and the level verification will be confirmed. The location will be verified using GPS. The levelness

[1] **C-2350,** SG4.5-145 Layout and Water Depths (February 26, 2021)

will be verified across the top column flange in at least 2 directions. The verification results and as-built location will be submitted to the engineer of record.

When the GBF positioning is confirmed the SBF barges are disconnected and towed back to the Bowmanville yard in preparation of the next GBF float out.

Table 1 provides an estimated cycle time for the GBF installation for each set of SFBs (Note: two SFBs each comprised of four modular barges, along with supporting tugs will be used for the Project to transport and position the 66 GBFs) The GBF installation process is a 24 hr/day operation. The total duration of the GBF transportation and positioning process using two sets of SFBs is estimated to be 198 days (66 GBFs x 6 days/GBF/set of SFBs / 2 sets of SFBs).

Figure 1: Hydraulic Pin Release Mechanism

Table 1
GBF Installation Cycle Time per Set of SFBs

Activity	Assumptions	Calculation	Duration (Hours)
Assemble SFB around GBF	GBF is lowered on elevator and in water when SFB pontoons arrive	6 hours to assemble SFB 16 hours to attach jacks 8 hours to jack GBF tight with SFB and prepare for tow	30
Tow SFB/GBF to Site	Bowmanville Yard to Site	132 Miles @ 2 Knots avg.	58
GBF Positioning			2
Lowering/Jacking Operations	Assumes 12" of Jack throw and average 22 m (72 feet of Jacking Distance (represents average water depth across 66 GBFs)	72 x 12 min / Cycle / 60 min/hr	14
Check Positioning/Level and Adjust			4
Disconnect Jacking System			2
Raise Jacking System			4
Disassemble Barges			12
Tow SFB pontoons to Yard	Site to Bowmanville	132 Miles @ 6 Knots	19
		Total:	145 (Approx. 6 days per cycle)

5.0 Sand Ballasting and Scour Protection

5.1 Sand Ballasting

When the Gravity Based Foundation has been set and its location is verified, it will be ready for the installation of the sand ballast. The ballast tanks will be filled using a hydraulic method and the caisson will be filled using a clam shell bucket gravity fill method. All in-water construction activities will be performed on a 24 hour per day, 7 days per week schedule (no change from previous NAFTA1 report.)

A hopper barge will be loaded with sand and towed to the site where the Ballast Installation (BI) barge (Weeks 571 or similar) will be anchored adjacent to the GBF to be ballasted. The hopper barge will be moored to the BI barge and readied for the installation process to begin. The GBF ballast tanks will be filled first using the slurry pump method prior to filling of the central caisson. The caisson will be filled using mechanical methods.

The hydraulic sand fill in the ballast tanks will be placed before the central caisson is filled. To accomplish this, the crane on the BI barge will lower and suspend a Toyo (or similar) dredge pump in the hopper barge loaded with sand. As the pump is run and moved through the hopper, sand will be pumped through flexible pipelines into the GBF ballast cells. Opposing tanks will be filled simultaneously to prevent overloading the GBF on any one side. A discharge hose from each pump will be attached to the previously installed piping on the inside wall of the caisson leading to the respective tanks located on opposite sides of the GBF. The internal piping terminates at nozzles in each of the six ballast tanks. The discharge pipe is connected to the pump and the suction hose lowered into the hopper barge. The pump transfers the sand slurry from the hopper barge into the two opposing ballast tanks. When the ballast tanks are full, the pump is stopped, and a ROV is used to confirm the tanks are full via the tank vent. (See drawing WMI-0077-008 for plan view of hydraulic ballasting) When tank fill is confirmed the discharge hoses will be moved to the next two internal pipes corresponding to tanks on the opposing sides of the GBF. The slurry pumping will be repeated on both the second set and then final set of ballast tanks. (See drawing WMI-0077-009 for profile view of hydraulic ballasting)

When the ballast tank fill operation is complete and verified, the sand fill can be installed in the caisson. (See drawing WMI-0077-010 for plan view of mechanical ballasting) This process will be accomplished using a clamshell bucket, the BI barge's crane and a specially fabricated hopper. The hopper will sit on top of the GBF outside the GBF flange that connects the column to the GBF. The BI crane will dig sand from a loaded sand barge deposit the material into the hopper on the GBF. The sand will settle to the bottom of the foundation displacing the water in the caisson. The BI crane transfer ballast sand until the foundation caisson is filled to elevation +7.0. (See drawing WMI-0077-011 for plan view of mechanical ballasting)

The sand fill operations will then move on to the next GBF to perform the ballast sand fill operation.

5.2 Scour Protection

Scour protection will be installed at the base of the GBF from the top of the ballast cell to the perimeter limits provided by foundation designer. The scour protection prevents erosion of material around the base due to severe weather conditions.

The Material Handling (MH) barge (Weeks 571 or similar) will be anchored directly adjacent to the GBF. A deck barge loaded with rip rap (armor) stone will be moored to its side. (See drawing WMI-0077-012 for the vessel positioning)

The MH crane will load the clamshell bucket and/or skip pan with stone from the material barge moored to its side. With a loaded bucket, the derrick will swing the bucket to the designated grid illustrated on the cranes Hypac positioning system. The bucket will be lowered over the proper location where it will be opened or dumped placing the stone on the lake floor over the previously placed stone bed and filter stone. The Hypac Software records the stone placement location for tracking and documentation purposes. The process is repeated until the grid pattern indicated on the Hypac Software is completed and extends over the diameter specified by the final scour design. (See drawing WMI-0077-013 for a profile view of the Scour Protection Stone Installation)

When completed, the hydrographic survey of the GBF filter stone area will be performed to verify the filter stone was placed in accordance with the project specifications, prior to the W571 moving to the next GBF location where the process will be repeated.

6.0 WTG Installation:

6.1 WTG Delivery to the Site

The Wind Turbine Generator components will be delivered by feeder barges to the installation site. They will be installed using the Weeks Marine RD MacDonald (RDM) jack-up barge. All WTG erection activities will be performed on a 24 hour per day, 7 days per week schedule (no change from previous NAFTA1 report.)

The first two sets of WTG components will be loaded onboard the RDM at the WTG staging port. The components will be sea-fastened and the RDM, towed to the site using a 3000 HP tugboat and a 2000 HP assist tugboat. The RDM will remain on site once it has installed the first 2 sets of WTGs, and additional WTG components will be loaded on transport feeder barges at the staging port and towed to the site. The use of both the RDM and the feeder barges to transport WTG components will be optimized to maximize installation efficiency at the project site.

The installation sequence is graphically presented in the WTG Installation Method Summary Drawing Set included with this report.

6.2 Positioning the *R. D. MacDonald* (RDM)

The RDM is a jackup barge equipped with a Manitowoc 4600 ringer crane. The crane will be configured with 400 foot of boom with a lift capacity of 166 tons. Due to the hard bottom in Lake Ontario making anchoring barges difficult, the RDM jack-up is an ideal vessel for installing the WTG components. See **Attachment D** for details of the RD MacDonald and the Manitowoc crane.

RD MacDonald Rendering In Tow

The RDM will arrive at the WTG location via tug. It will carry the WTG components for the erection of 2 WTGs. The balance of the components will be delivered to their installation site via barge to maximize the efficiency of the RDM.

Two tugs will position the barge using GPS. When the RDM arrives at the site one leg is lowered to the sea floor, temporarily fixing position. Tugs orient the RDM to desired alignment and check positioning. If final position is achieved, the opposite leg is lowered to the sea floor. If final position is not achieved after setting one leg, the tugs have the ability to rotate the barge, pivoting on the lowered leg and "walk" the RDM into the correct location, lowering and raising legs as needed. Once the RDM is in the correct alignment and location, all legs are lowered to the sea floor. The legs will be pre-loaded using the RDM's self-weight to ensure sufficient bearing capacity before jacking to elevation. Tugs are then released from the barge. The jacks are engaged and lift the RDM out of the water to the intended height; the deck will roughly be at the same height as the top of the GBF.

6.3 RDM Sets WTG Components:

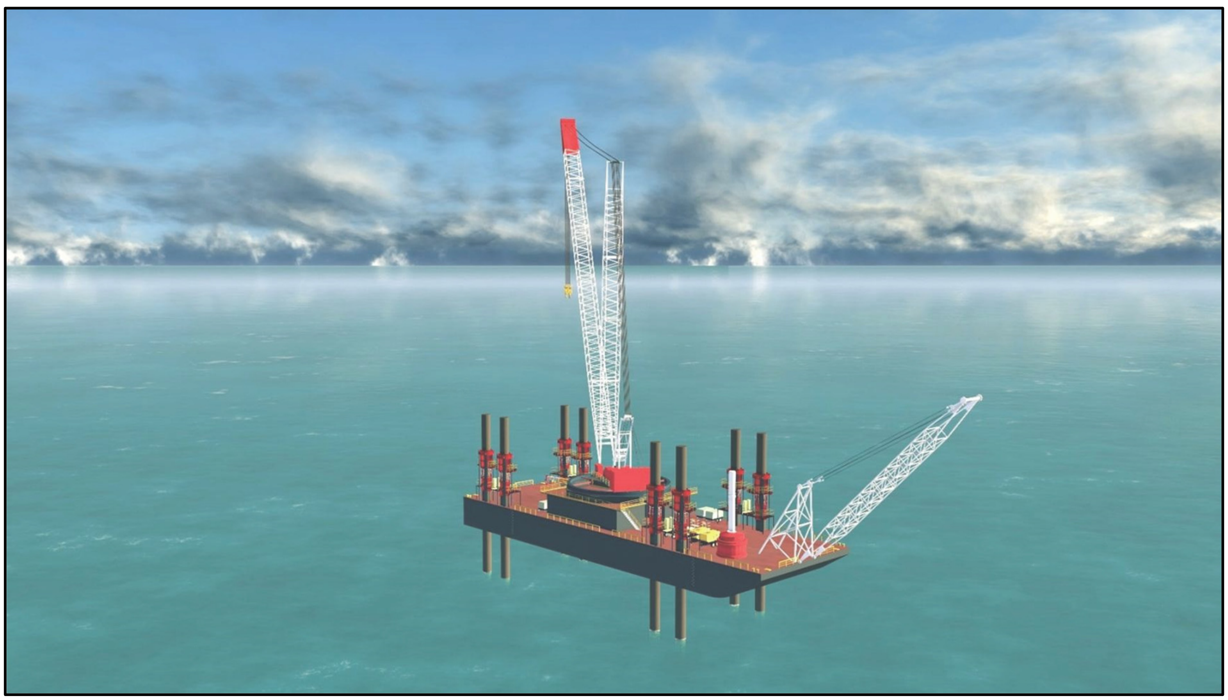
Weeks will provide marine operations support and craft personnel for the installation of the WTG components. Weeks will provide a jack-up barge and crane capable of hoisting the components to their installation location. Delivery barges and tugboat services will also be supplied by the Weeks.

6.4 Tower Installation:

Prior to and during tower installation, WMI personnel will determine if the current and forecast wind conditions are appropriate for such work by using the anemometer on the crane's boom tip and through other weather monitoring methods.

The tower installation cycle is executed in the following order:

- RDM picks rigging and workers ascend the lower tower section using internal ladders to attach rigging to top of lower tower section.
- Sea-fastening for lower tower section is released.
- RDM lifts the lower tower section and swings it into place over the top of the GBF, WMI craft personnel make the connection to the GBF and de-rig.



RD MacDonald Rendering - Jacked up to Full Height

- RDM will then swing to the top of the upper tower section; workers attach rigging to top of top tower section.
- Sea-fastening for upper tower section will be released.
- RDM crane lifts upper tower section and swings into place over top of the lower tower section.

- WMI personnel make final connection to lower tower section and release the rigging.

6.5 Nacelle Installation:

Prior to and during nacelle installation, WMI personnel will determine if the current and forecast wind conditions are appropriate for such work by using the anemometer on the crane's boom tip and through other weather monitoring methods.

The Nacelle installation cycle is executed in the following order breaking the nacelle into two separate picks including the nacelle body and the hub/generator:

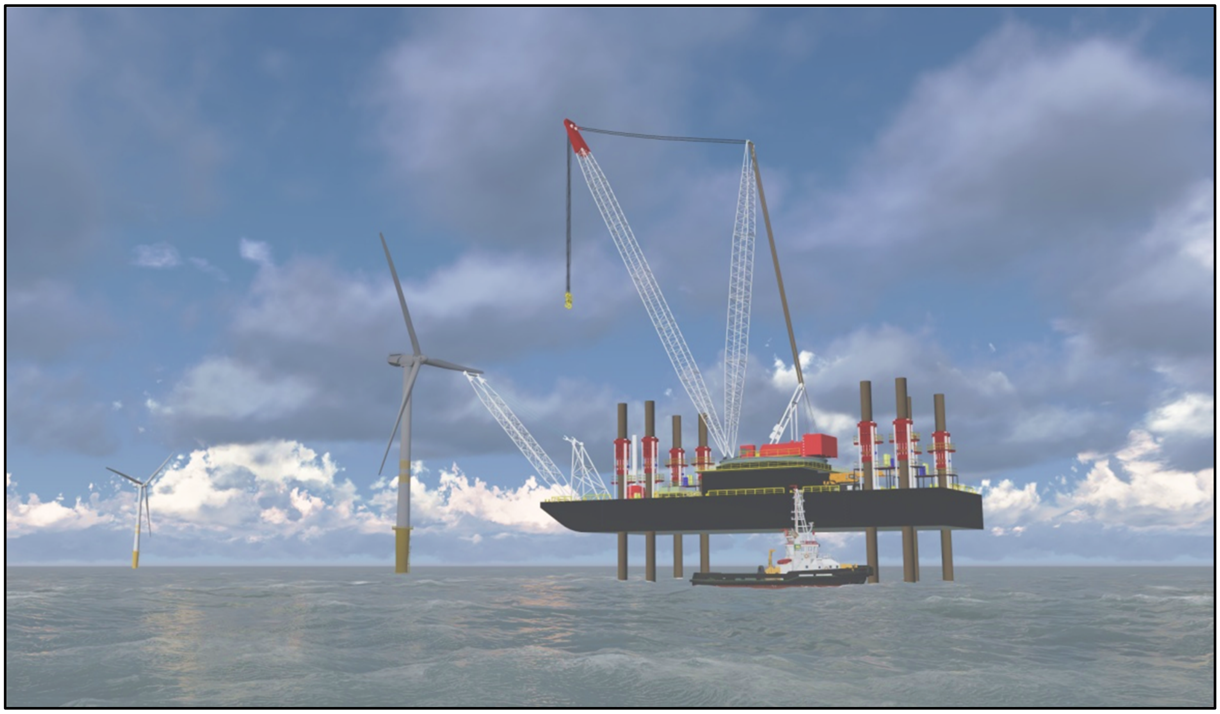
- The RDM picks nacelle rigging and workers attach rigging to the top area of the nacelle body.
- The Nacelle sea-fastening is removed.
- The Crane hoists the load up to the top of the upper tower where the craft personnel make connection between upper tower and nacelle body and the rigging is removed.
- The RDM picks hub rigging and workers attach rigging to the hub/generator.
- The hub/generator sea-fastening is removed.
- The Crane hoists the hub up to and places it in the nacelle body where the craft personnel will secure the hub/generator in place and the rigging is removed.

6.6 Blades Installation:

Prior to and during blade installation, WMI personnel will determine if the current and forecast wind conditions are appropriate for such work by using the anemometer on the crane's boom tip and through other weather monitoring methods.

The rotor assembly process is executed in the following order:

- The RDM picks the yoke rigging, the crew attaches the rigging to yoke, and RDM lifts yoke from yoke cradle.
- The RDM swings the yoke to marked locations on the first blade where the craft personnel attach yoke to blade using man-lifts for access.
- The RDM lifts the blade out of the blade rack, swings it into position at the nacelle hub where the WMI craft personnel make final connection to nacelle hub and the rigging is removed.
- The process is repeated until all three WTG blades are installed on the nacelle hub.



RD MacDonald Rendering - Blade Installation

6.7 Preparation for Transport Next WTG Site:

The Gangway to top of the GBF is removed and all materials are secured for transit. The RDM is jacked down until floating. Two tugs connect to the RDM with legs retracted, and tugs tow the RDM to the next WTG location. The process will be repeated until all WTGs are installed.

The WTG installation cycle time is summarized in Table 2. The WTG installation process is a 24 hr/day operation (no change from previous NAFTA1 report) which, on average, is estimated to require 2 days/WTG x 66 = 132 days.

Table 2
WTG Installation Cycle Time

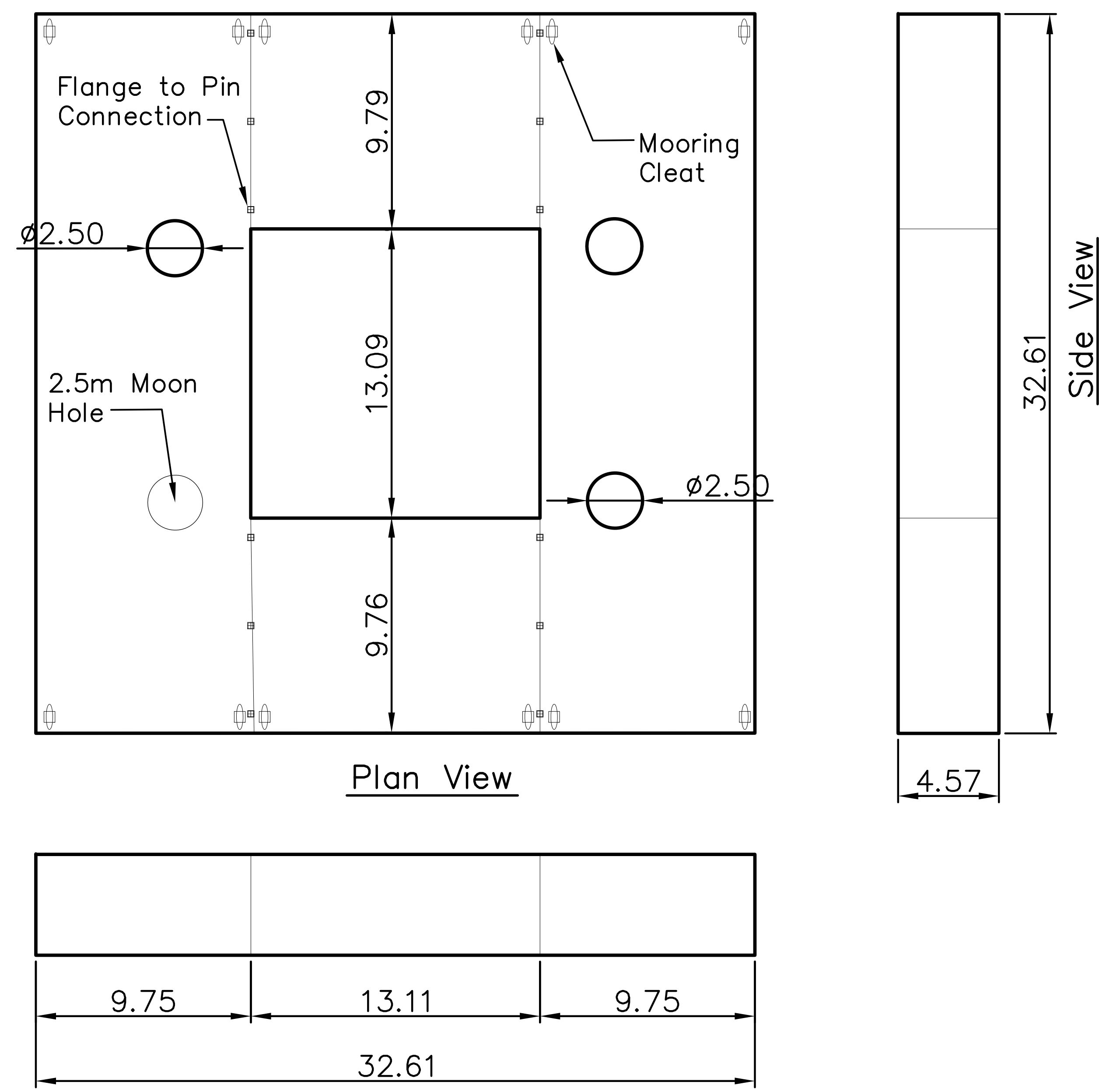
Activity	Duration (Hours)
Positioning at foundation	2
Align Feeder barge and Jackup at location	4
Jacking and preload	8
Release crane, release seafastenings, transfer personnel, transfer power and prepare for lifting	6
Lifting and installation of tower sections (2 each)	6
Lifting and installation of nacelle (2 parts)	8
Lifting and Installation of blades	8
Seafastening of crane, transfer of personnel and equipment	2
Jack down	2
Relocation to next turbine position	2
Total:	48 Hours (2 days)

7.0 Conclusion:

The means and methods provided herein describe a viable and comprehensive solution for the installation of the Wolfe Island Shoals Offshore Wind Project as currently scoped. Known geotechnical, bathymetric, and weather data were considered for the development of these means and methods. As progress towards the final design progresses, adjustments to the means and methods may be required to incorporate design revisions.

WIS – Weeks Marine – GBF Installation Method Summary Drawing Set

[11 Sheets]



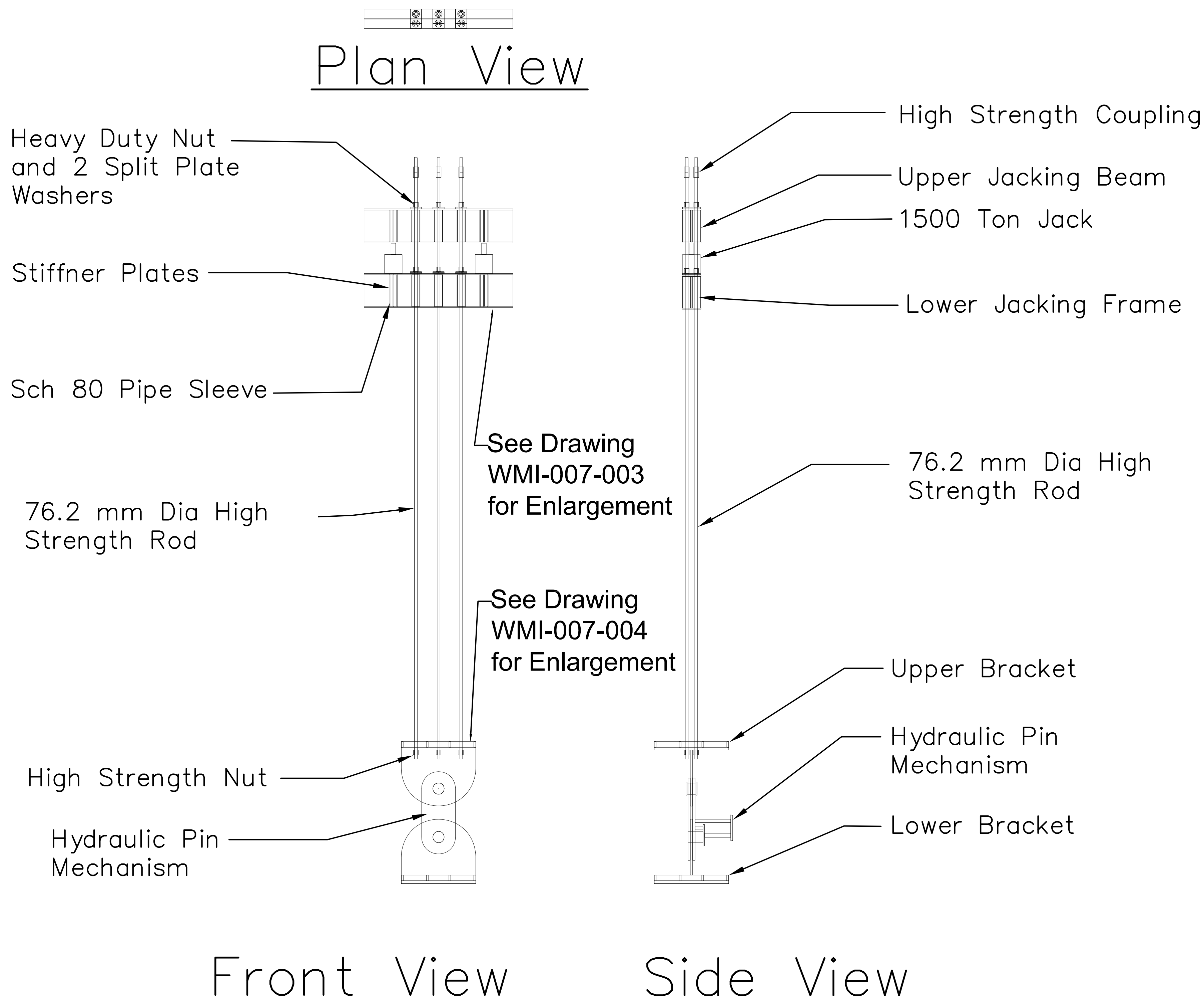
Front View

BARGE VIEWS

WEEKS		
DESIGNED BY:	DRAWN BY: NEW	CHECKED BY:

Gravity Base Foundation
SFB Configuration
Barge Views

SCALE AS NOTED	REVISION
DATE 03-12-14	
WMI-0077-001	

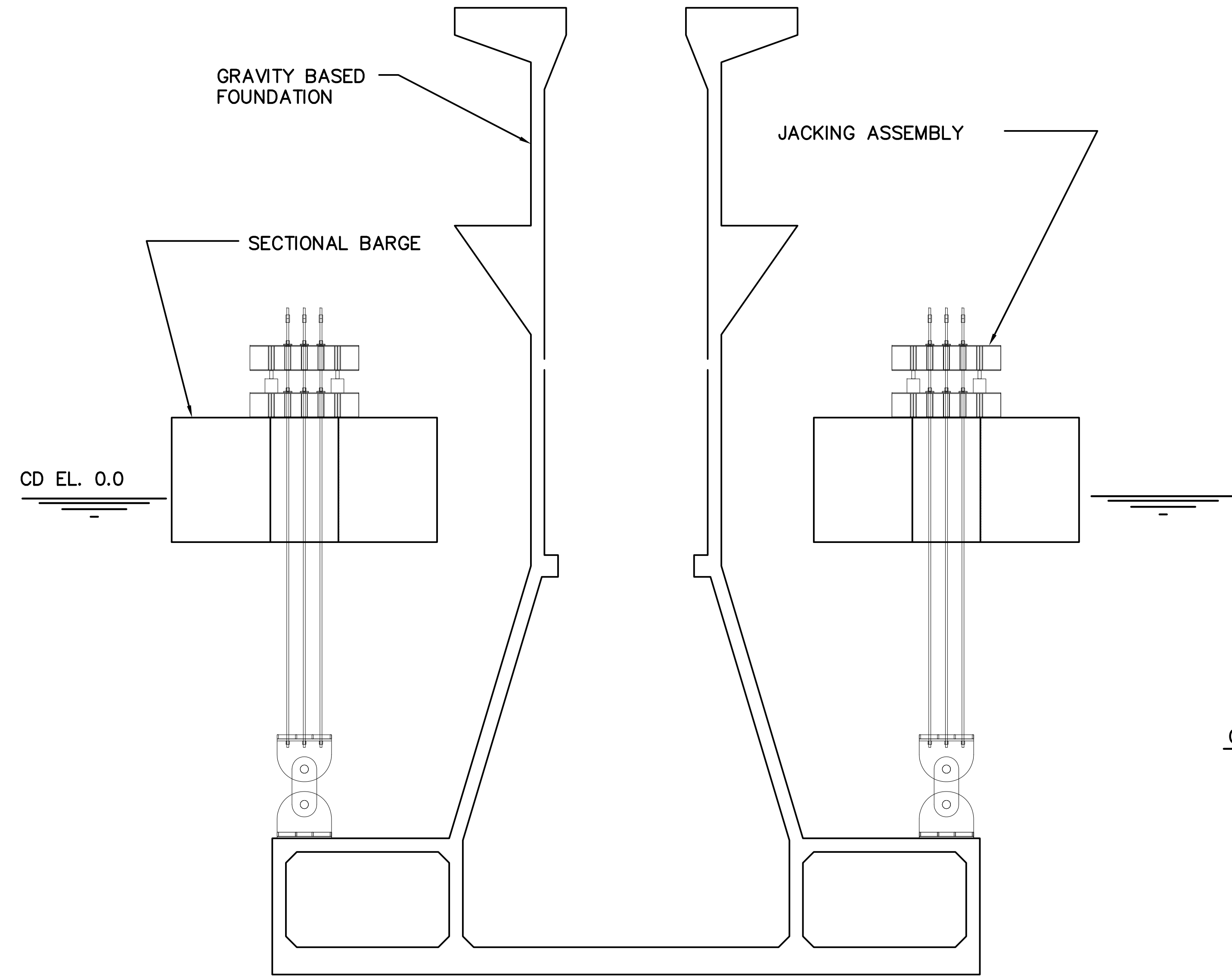


WEEKS

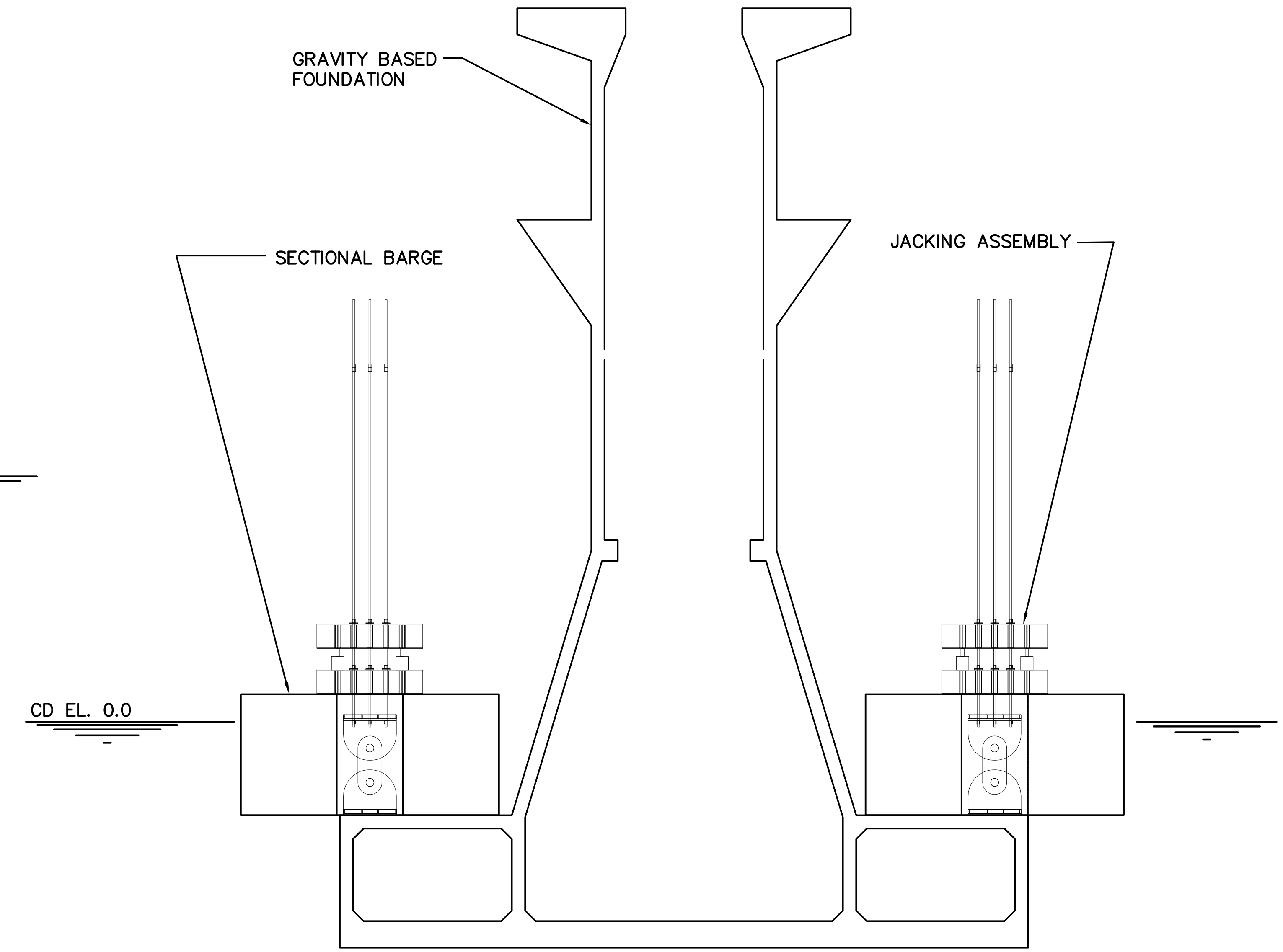
DESIGNED BY:	DRAWN BY: NEW	CHECKED BY:

Gravity Base Foundation
SFB Configuration
Jacking Assembly

SCALE AS NOTED	REVISION
DATE 03-12-14	
WMI-0077-002	



SECTION – BARGE & LIFT DEVICE



GBF & BARGE IN TOW CONFIGURATION

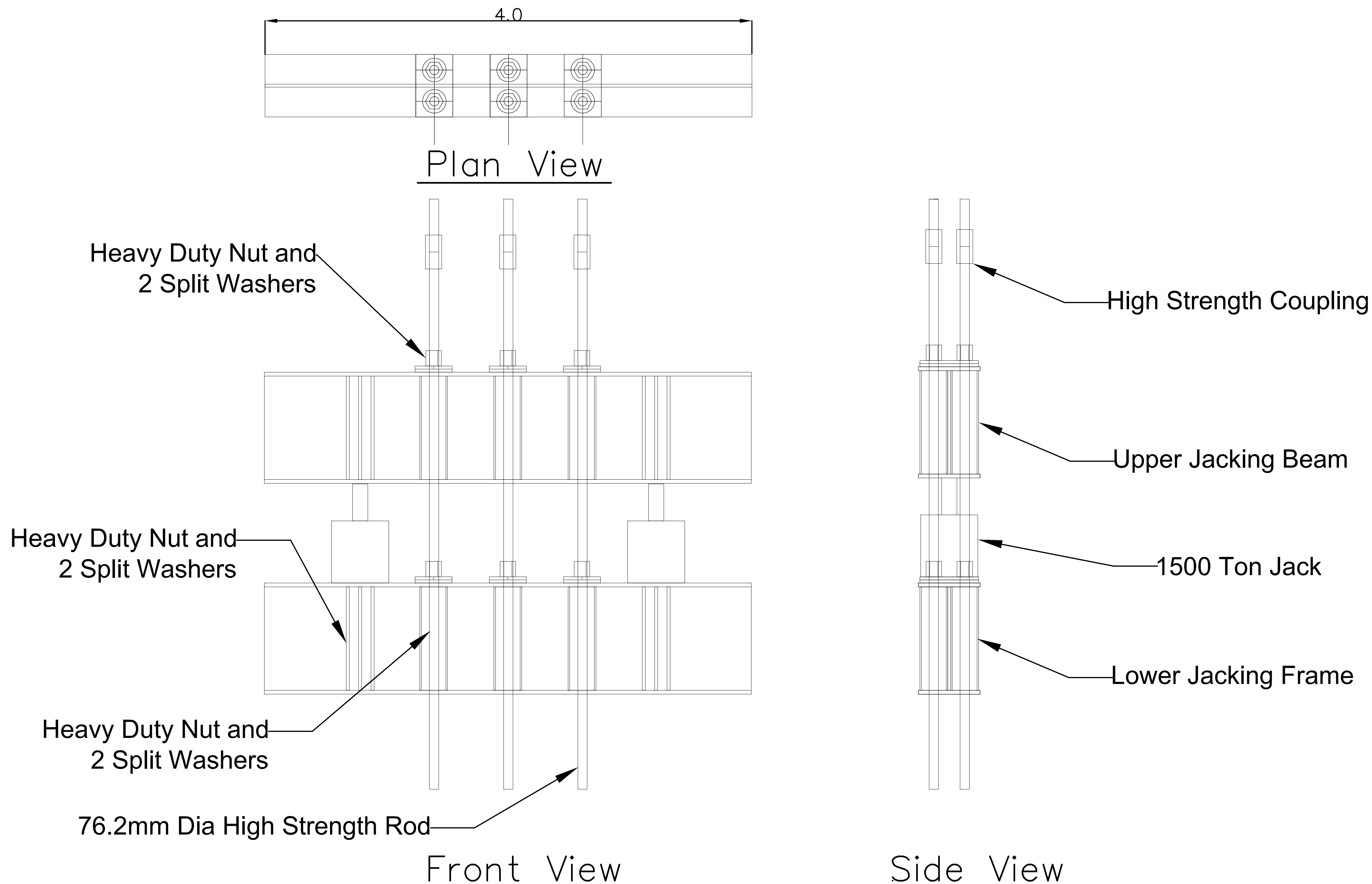
WEEKS

DESIGNED BY:	DRAWN BY: NEW	CHECKED BY:

Gravity Base Foundation
Sectional Barge Configuration
Section Views–GBF/Barge/Jack Assm

SCALE	REVISION
AS NOTED	
DATE	
03-12-14	

WMI–0077–003

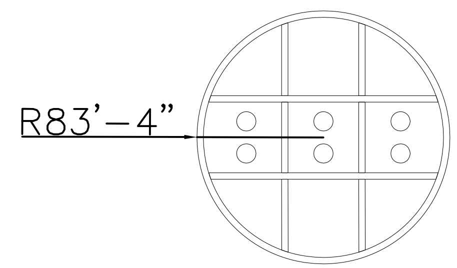


WEEKS

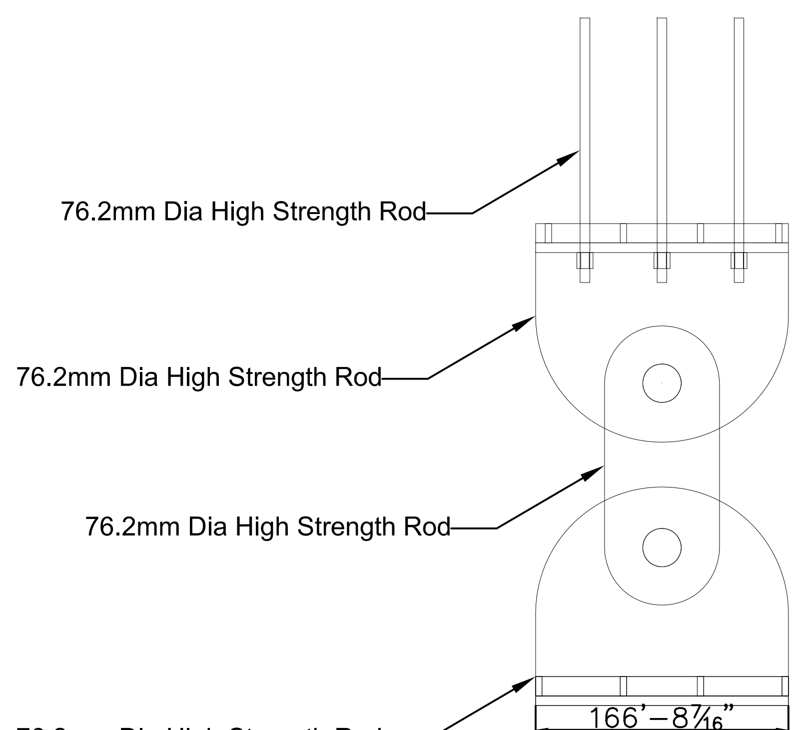
DESIGNED BY:
DRAWN BY: NEW
CHECKED BY:

Gravity Base Foundation
Jacking Assembly
Enlarge Jacking Beams

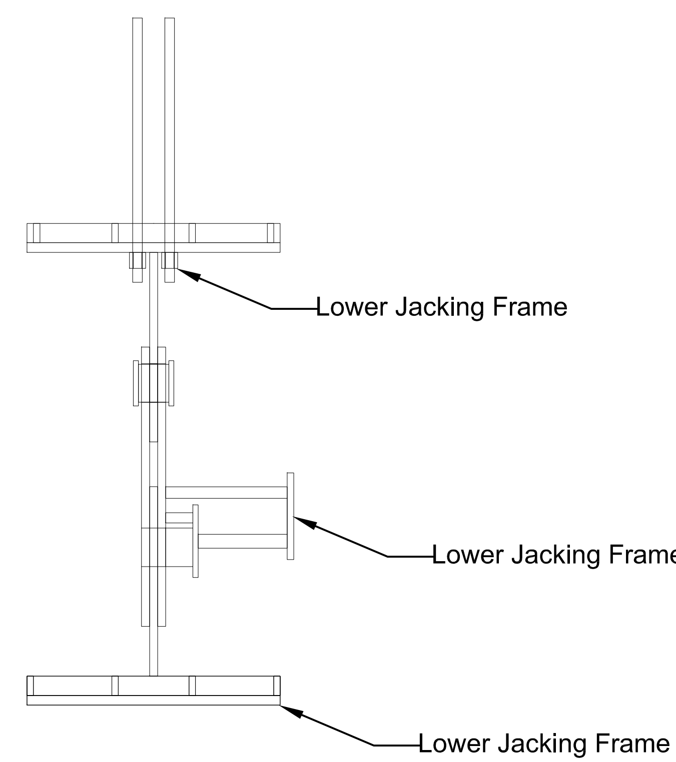
SCALE AS NOTED
DATE 03-12-14
REVISION
WMI-0077-004



Plan View



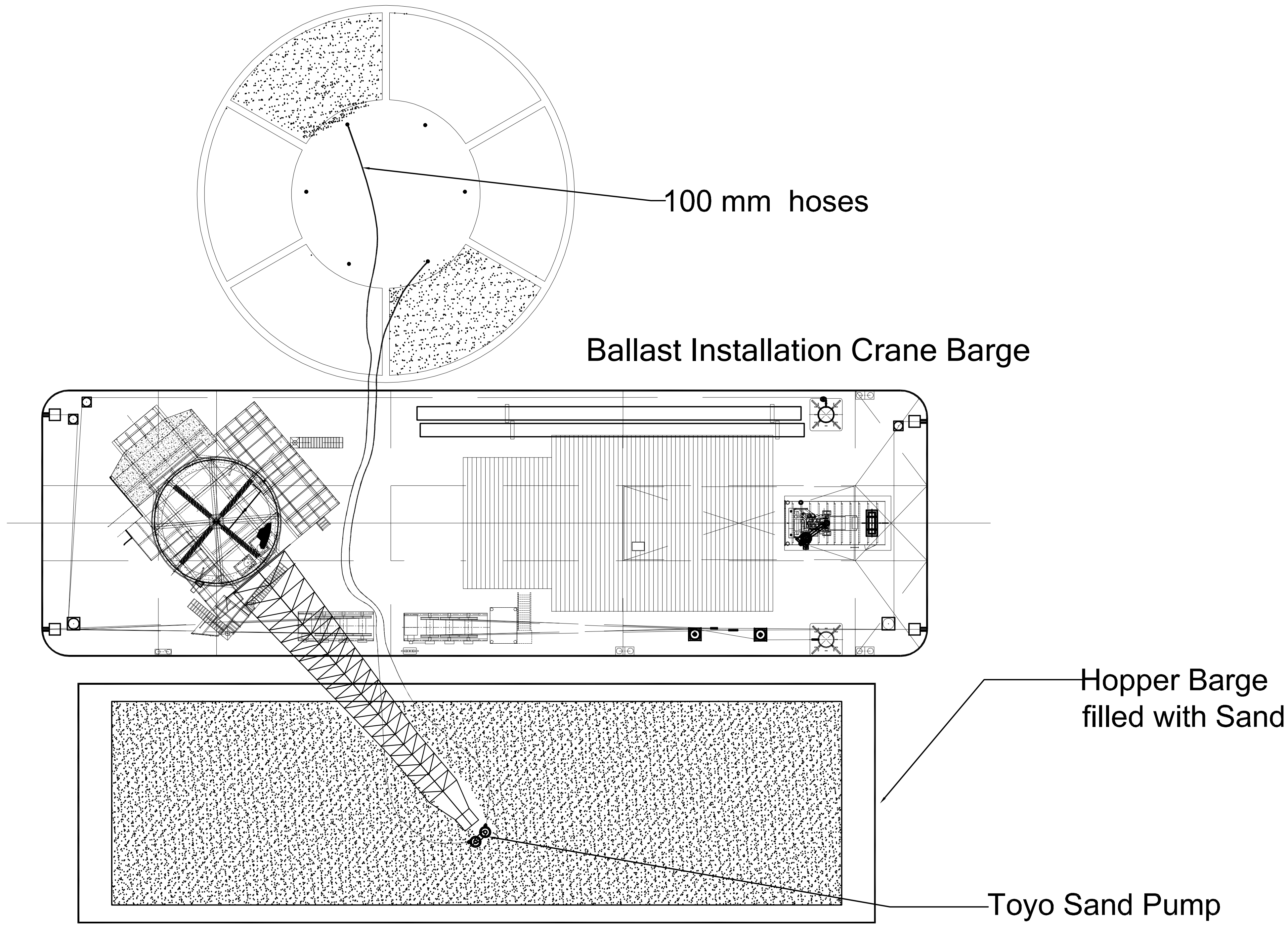
Front View



Side View

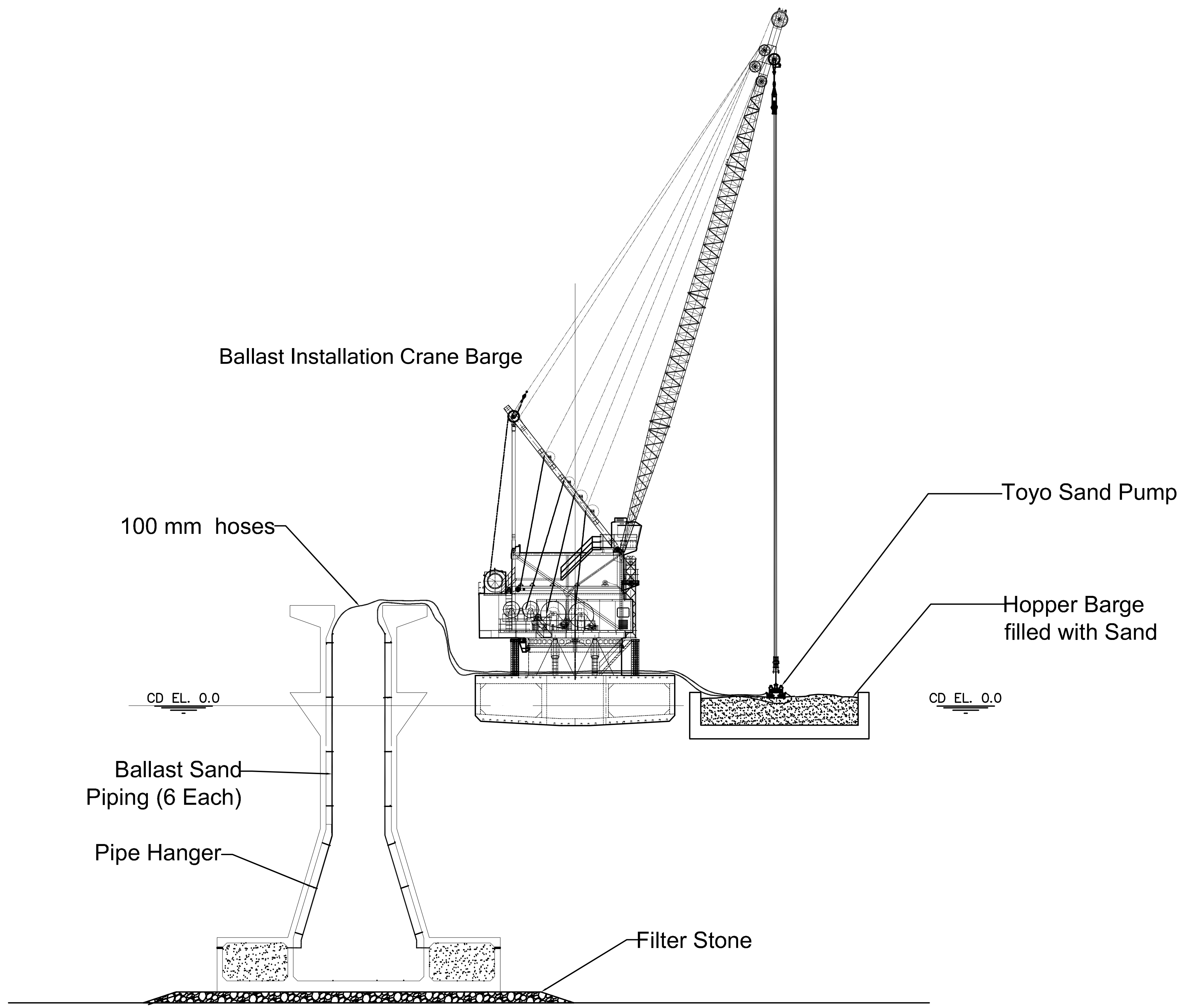
LOWER LIFTING BRACKETS

WEEKS				SCALE AS NOTED DATE 03–12–14	REVISION
DESIGNED BY:	DRAWN BY: NEW	CHECKED BY:	Gravity Base Foundation Jacking Assembly Enlarge Lower Brackets	WMI–0077–005	



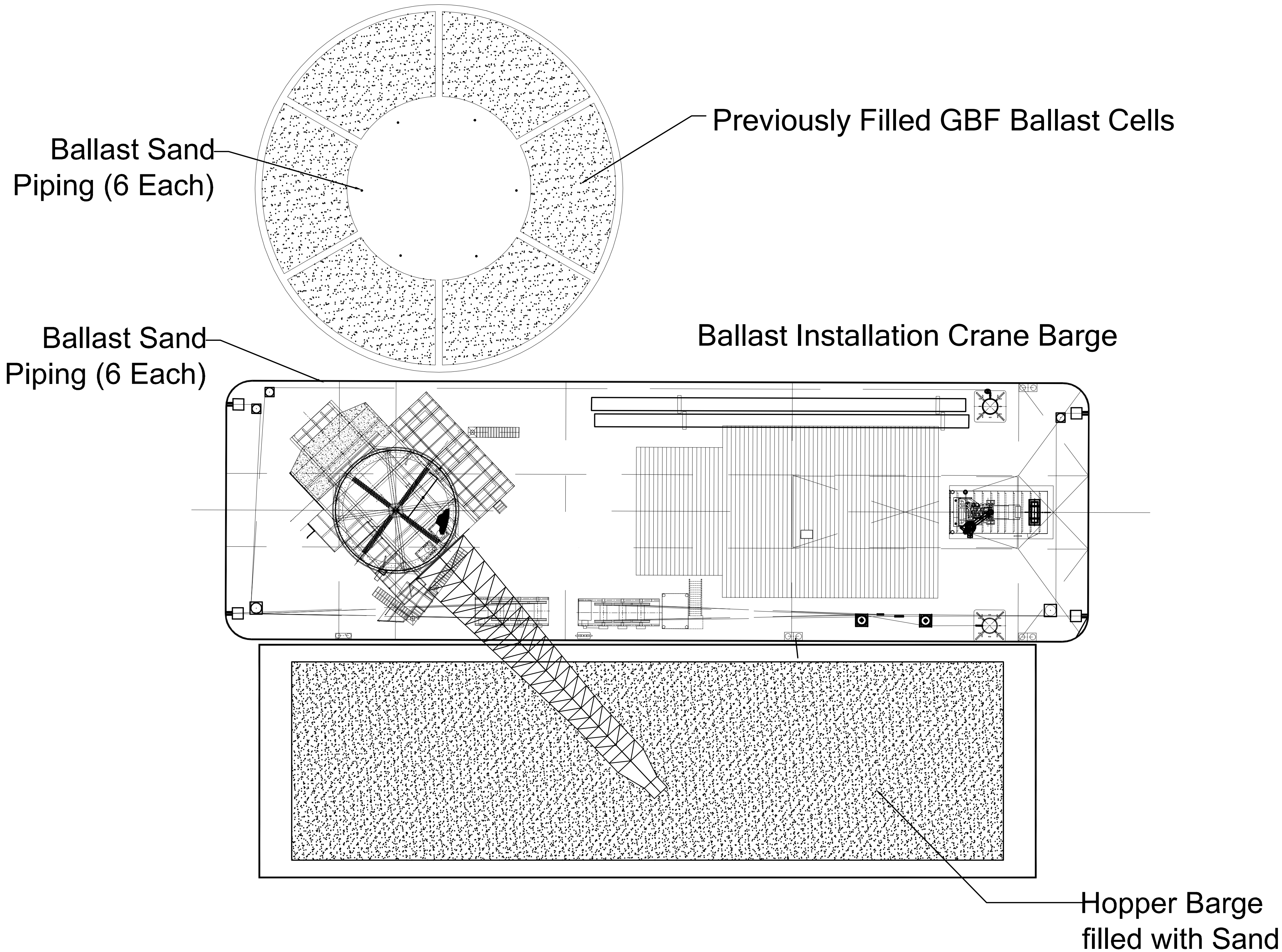
Plan View

WEEKS		SCALE AS NOTED DATE 03-26-014	REVISION
DESIGNED BY:	DRAWN BY: NEW	CHECKED BY:	
Sand Ballast Fill Hydraulic Sand Fill Plan View		WMI-0077-008	



Profile View

WEEKS				SCALE AS NOTED	REVISION
				DATE 03-26-014	
DESIGNED BY:	DRAWN BY: NEW	CHECKED BY:	Sand Ballast Fill Hydraulic Sand Fill Profile View	WMI-007-009	



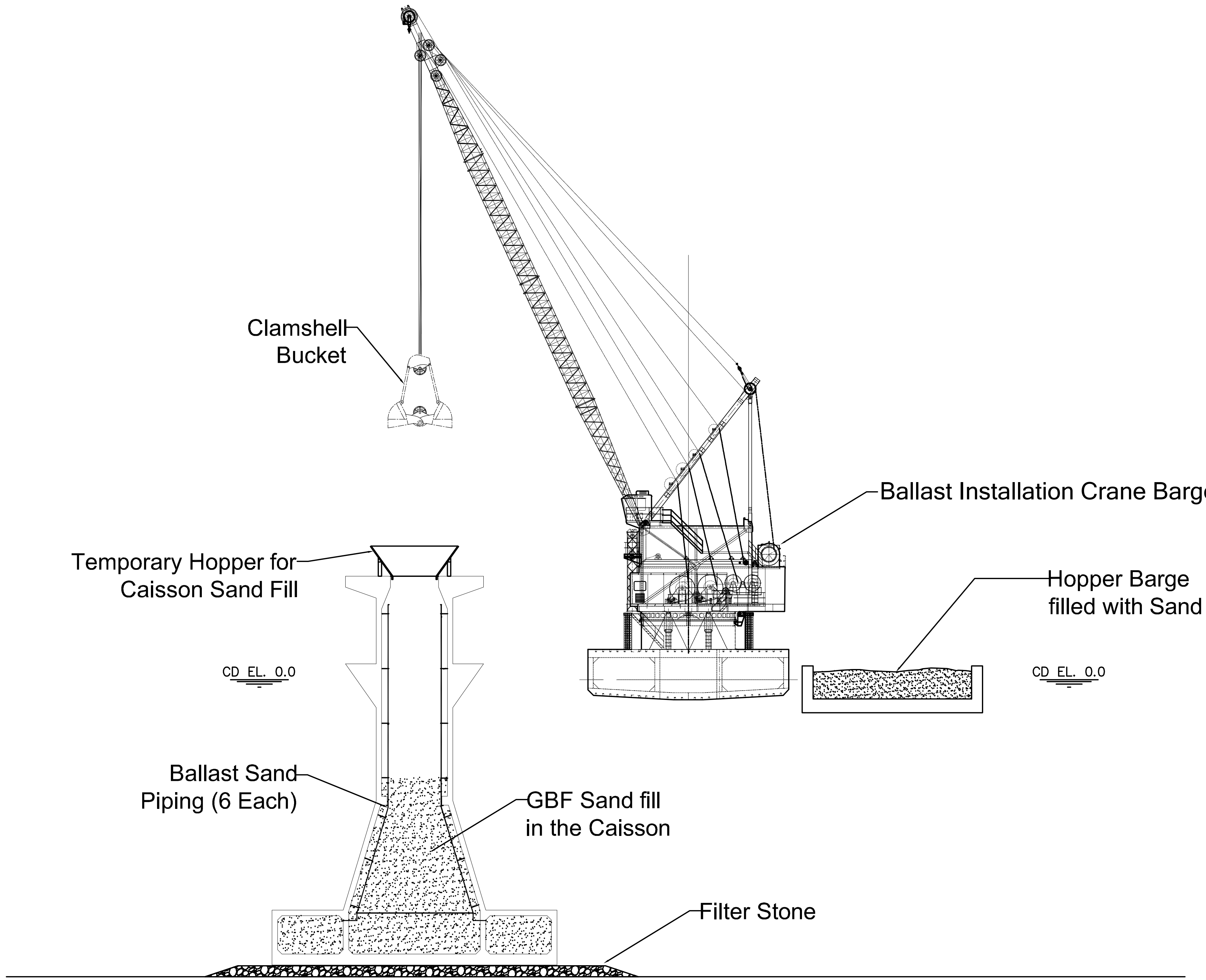
Plan View

WEEKS

DESIGNED BY: INITIAL	DRAWN BY: INITIAL	CHECKED BY: INITIAL

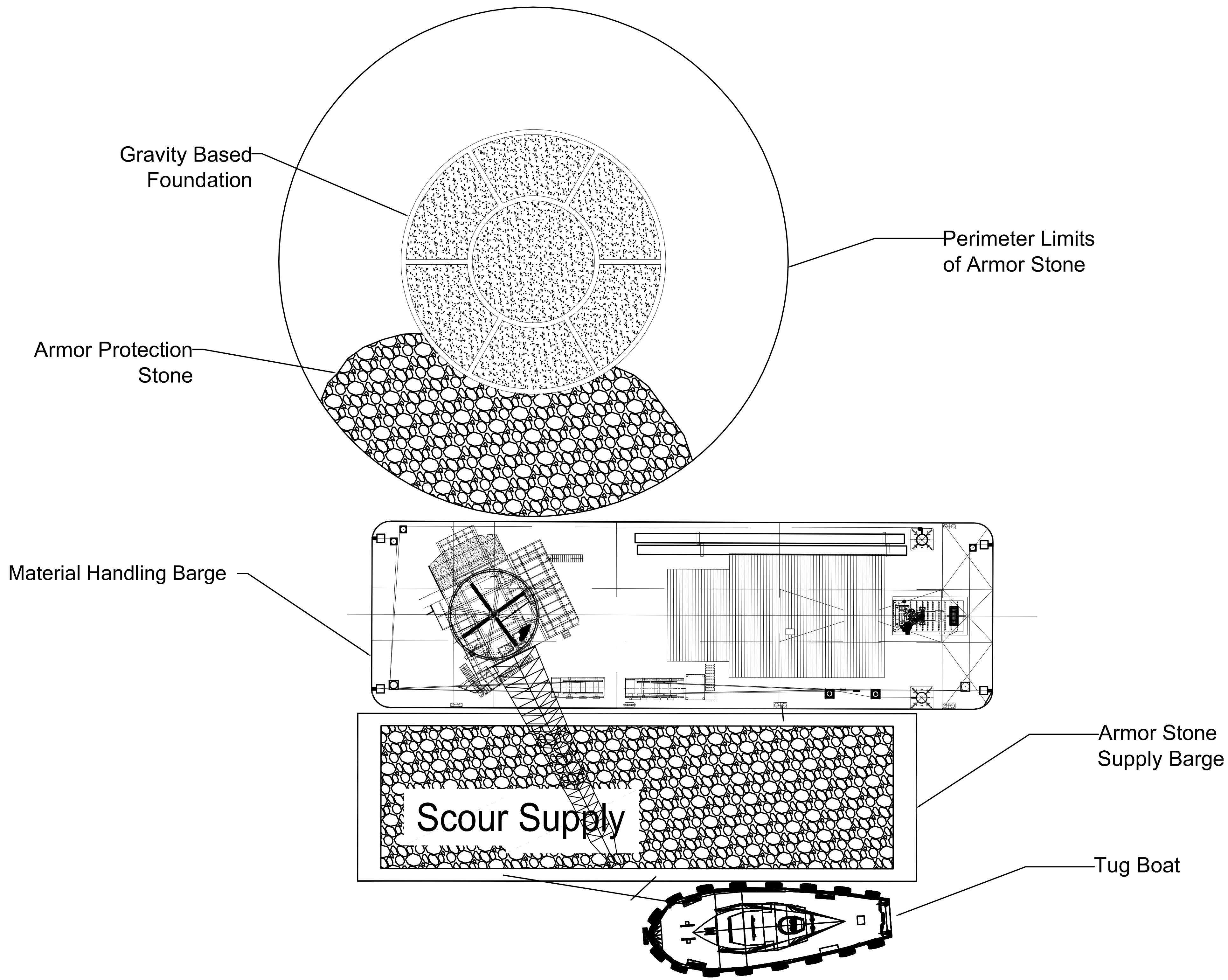
Sand Ballast Fill
Caisson Fill
Plan View

SCALE AS NOTED
DATE XX/XX/XX
REVISION
WMI-007-010



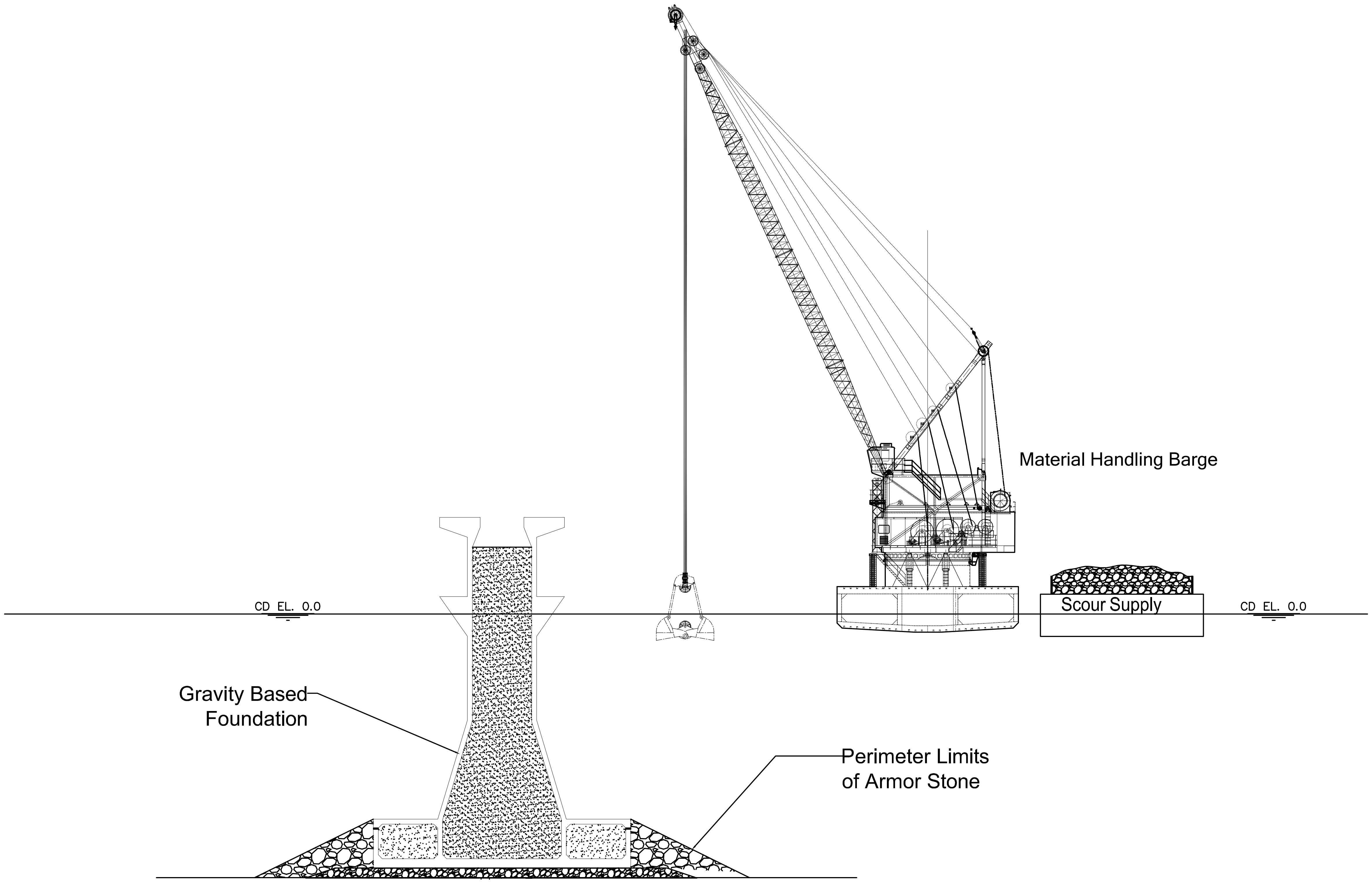
Profile View

WEEKS				SCALE AS NOTED	REVISION
				DATE 03-26-14	
DESIGNED BY:	DRAWN BY: NEW	CHECKED BY:	Sand Ballast Fill Caisson Fill Profile View	WMI-0077-011	



Plan View

WEEKS		SCALE AS NOTED DATE 03-26-14	REVISION
DESIGNED BY:	DRAWN BY: NEW	CHECKED BY:	Scour Protection Armor Stone Plan View	WMI-0077-012



Profile View

WEEKS

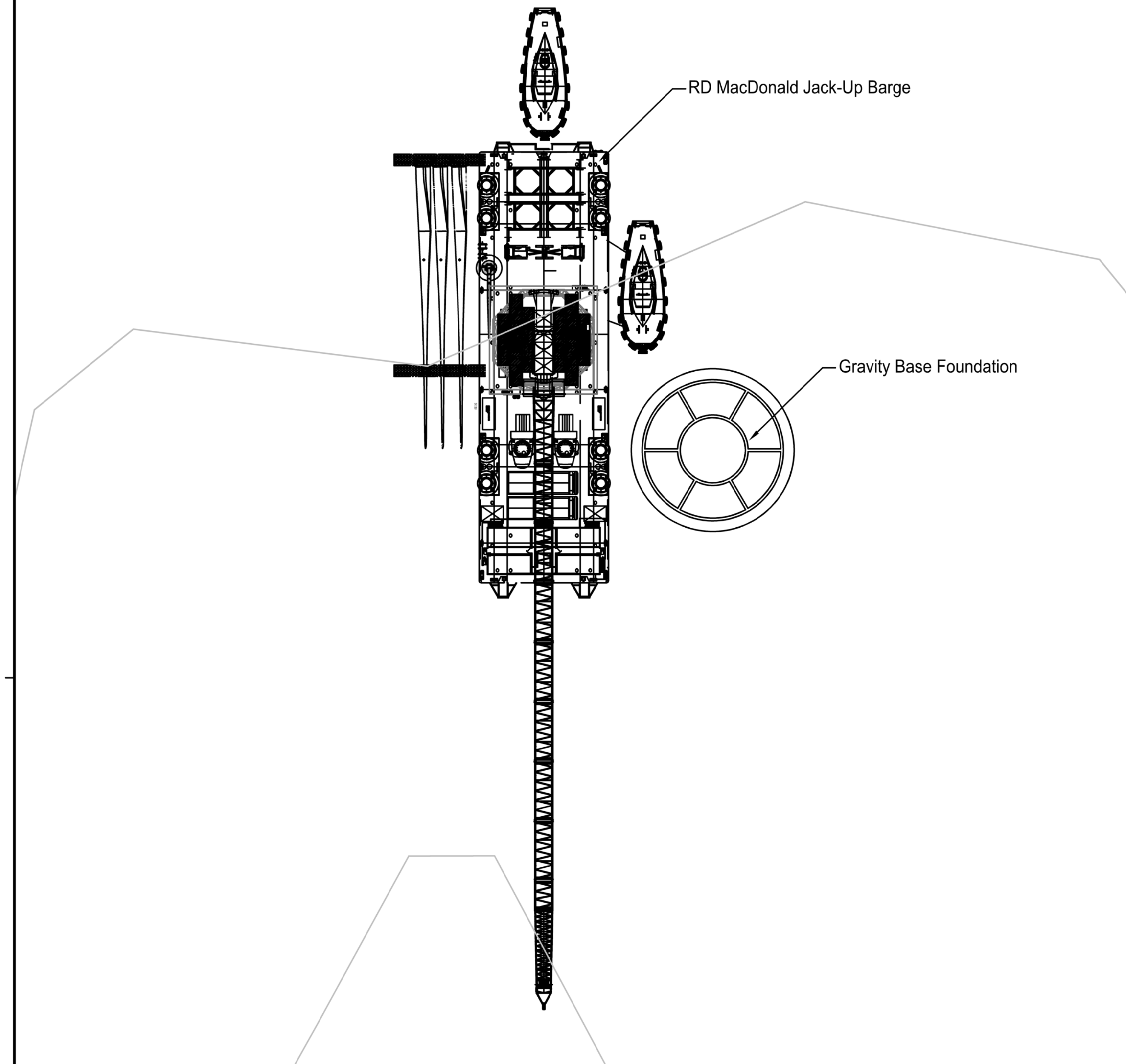
DESIGNED BY:	DRAWN BY: NEW	CHECKED BY:

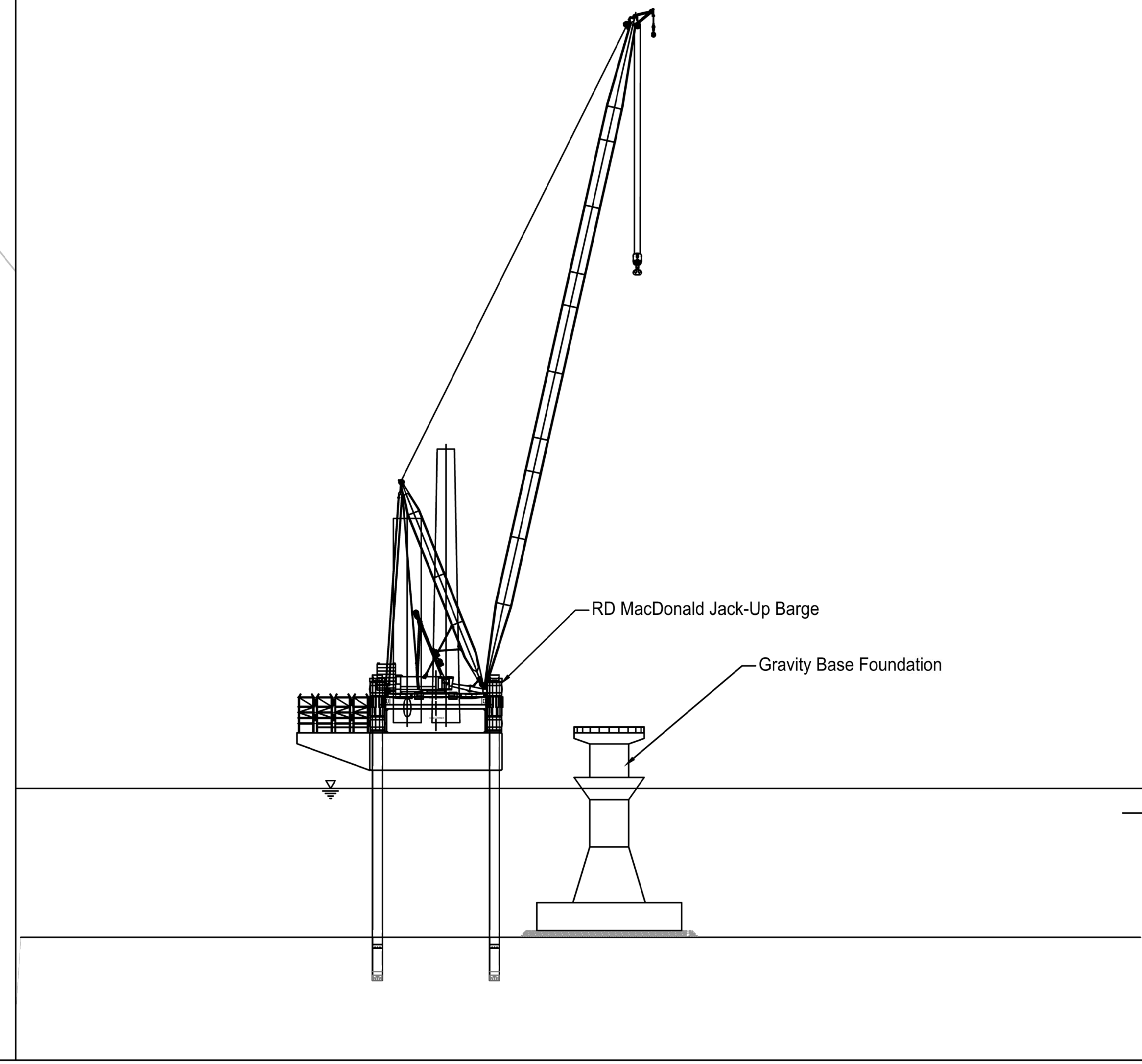
Scour Protection
Armor Stone
Profile View

SCALE AS NOTED
DATE 03-26-14
REVISION
WMI-0077-013

WIS – Weeks Marine – WTG Installation Method Summary Drawing Set

[7 Sheets]





Panel 1: RDM Crane in Position at WTG Foundation

a. RDM Arrives to WTG location via tug with WTG components on deck.
b. Two tugs position the barge using GPS.

Panel 2: RDM Crane Jack-Up at Intended Height

a. Jacks are engaged and lift the barge out of the water to intended elevation (Deck @ +10m).

REF. NO.	DWG. NO.	REV.	REFERENCES
5			
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BY	REV	REVISION	CHK	APP'D	DATE
RPP	0	ISSUED FOR REVIEW	RPP	RPP	03/23/21

Weeks Marine, Inc.

WOLFE ISLAND SHOALS - TURBINE INSTALLATION

	DRAFTED BY	DRAFTING CHECK	ORIGINATING ENGINEER	ENGINEERING CHECK	PROJECT MANAGER	CLIENT APPROVAL
BY	RPP	--	--	--	RPP	--
DATE	03/23/21	--	--	--	03/23/21	--

CLIENT JOB NO. --

WEEKS

WIND TURBINE GENERATOR
INSTALLATION METHOD SUMMARY
SHEET 1

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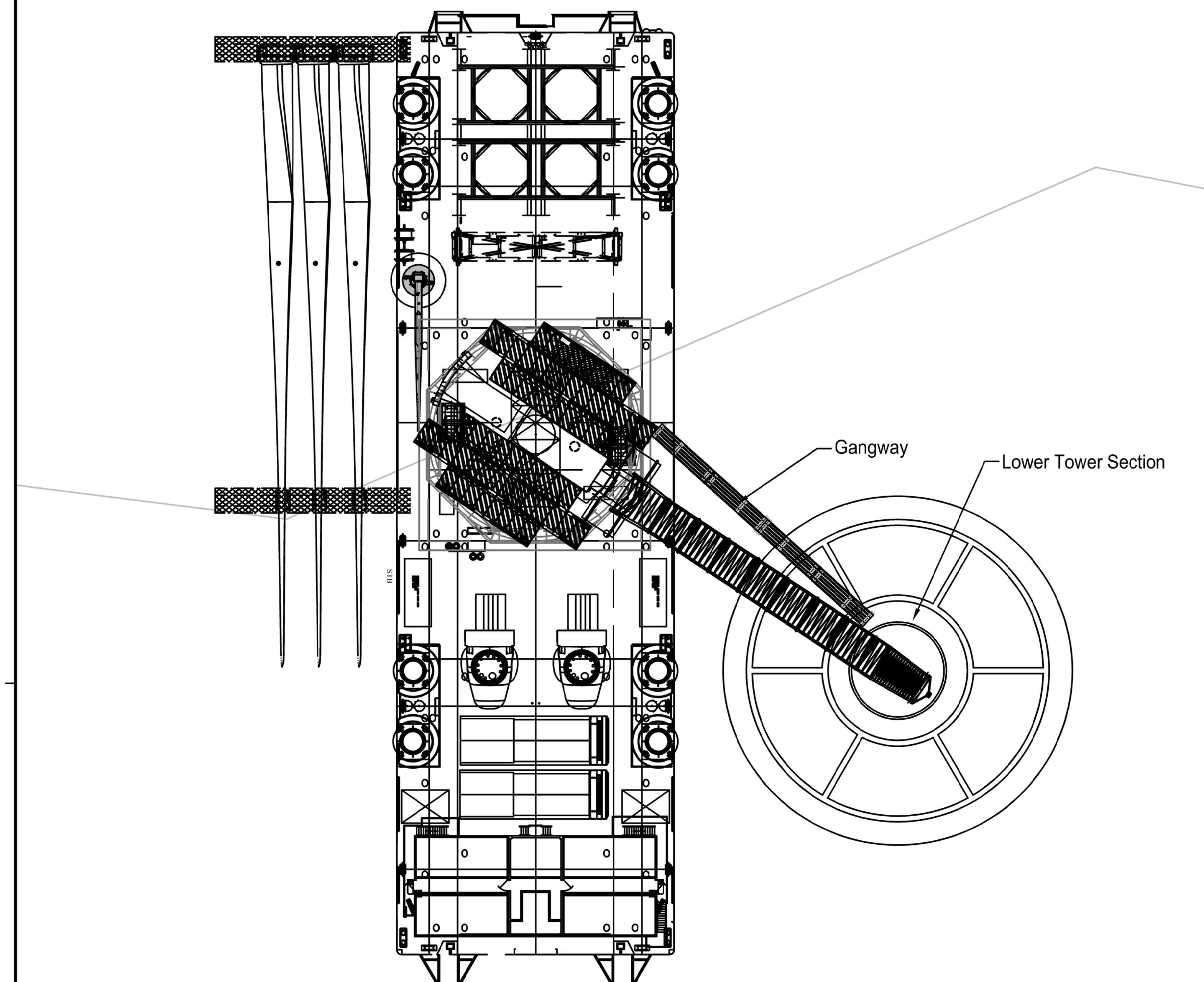

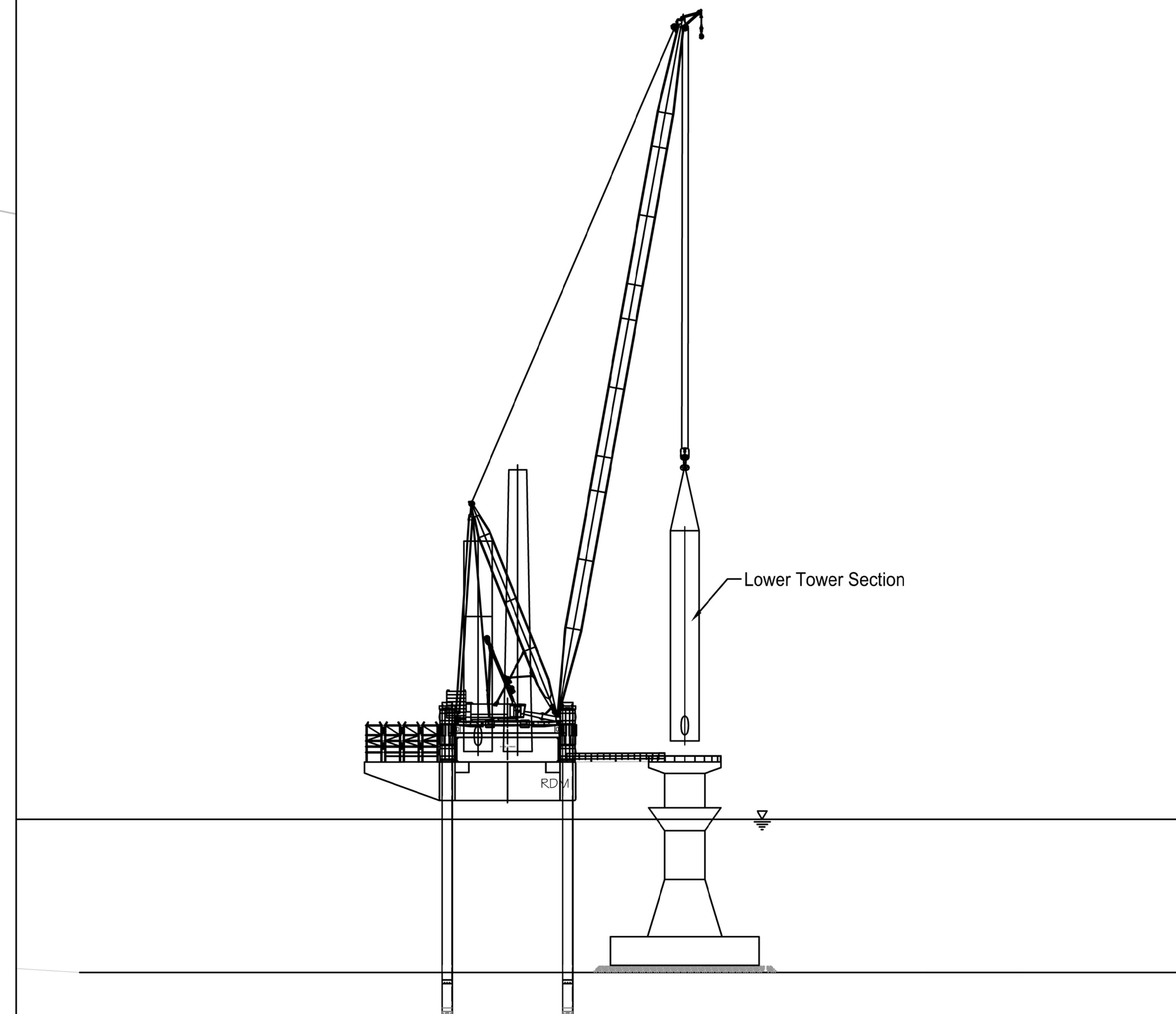

Panels: RDM Crane Installing Lower Tower Section

a. Sea-fastening for lower tower section is released.
b. RDM crane lifts lower tower section and swings into place over top of GBF.

REF. NO.	DWG. NO.	REV.	REFERENCES
5			
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BY	REV	REVISION	CHK	APP'D	DATE
RPP	0	ISSUED FOR REVIEW	RPP	RPP	03/23/21

Weeks Marine, Inc.

WOLFE ISLAND SHOALS - TURBINE INSTALLATION

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DATE	03/23/21	--	--	--	03/23/21	--

CLIENT JOB NO. --

WEEKS

WIND TURBINE GENERATOR
INSTALLATION METHOD SUMMARY
SHEET 2

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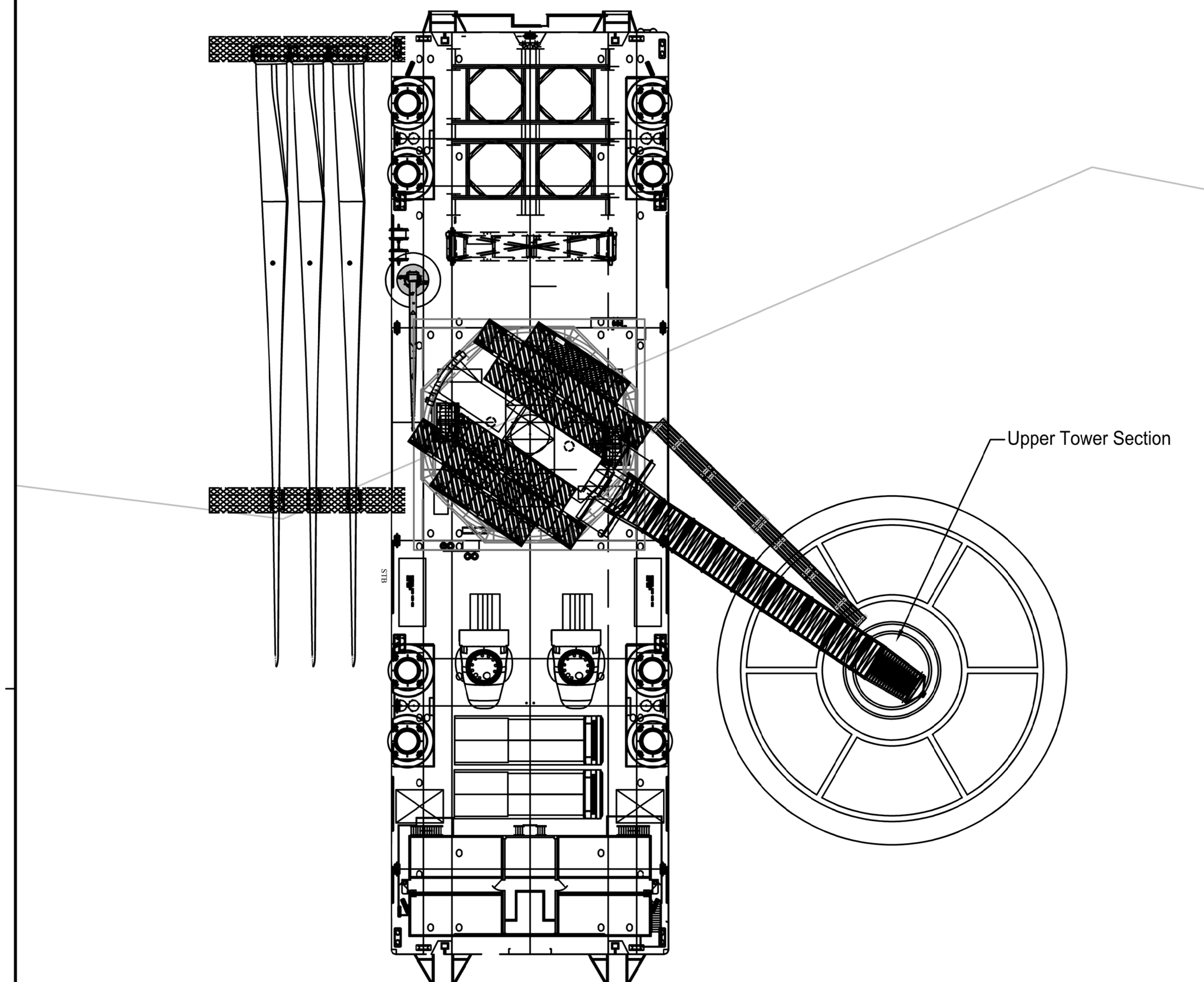

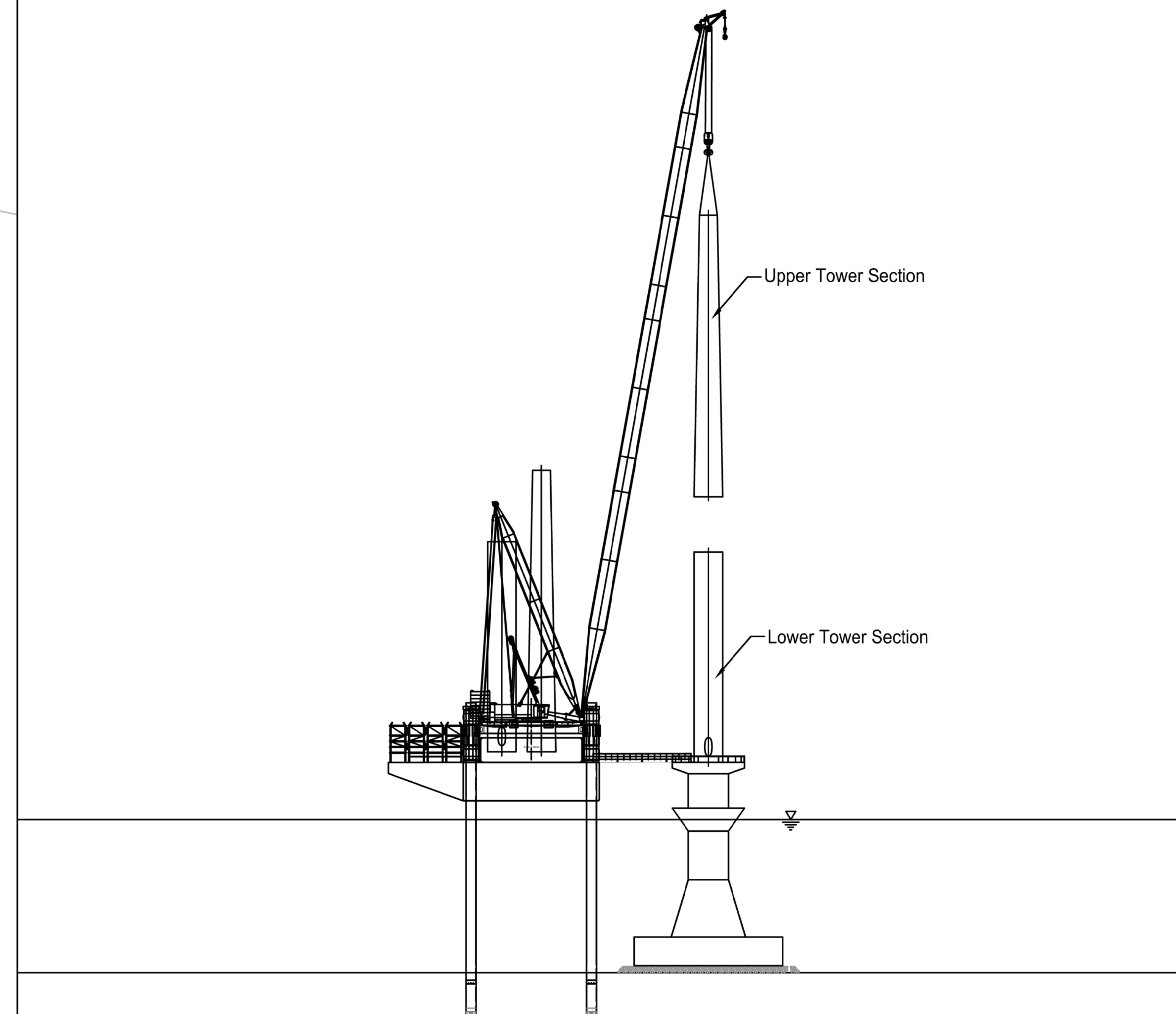

Panels: RDM Crane Installing Upper Tower Section

a. Sea-fastening for upper tower section is released.
b. RDM crane lifts upper tower section and swings into place over top of lower tower section.

REF. NO.	DWG. NO.	REV.	REFERENCES
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Weeks Marine, Inc.

WOLFE ISLAND SHOALS - TURBINE INSTALLATION

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CLIENT JOB NO. --

WEEKS

WIND TURBINE GENERATOR

INSTALLATION METHOD SUMMARY

SHEET 3

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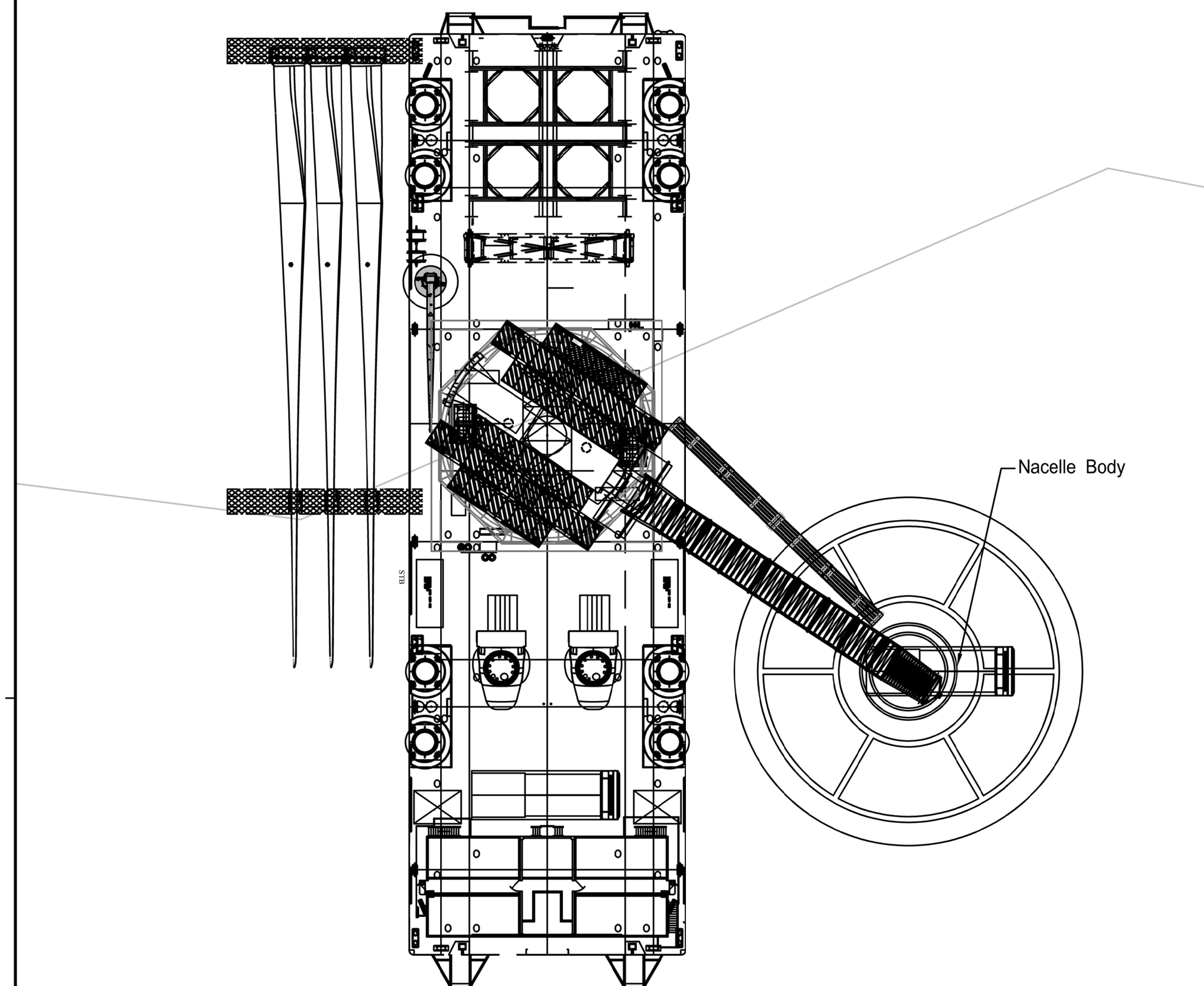

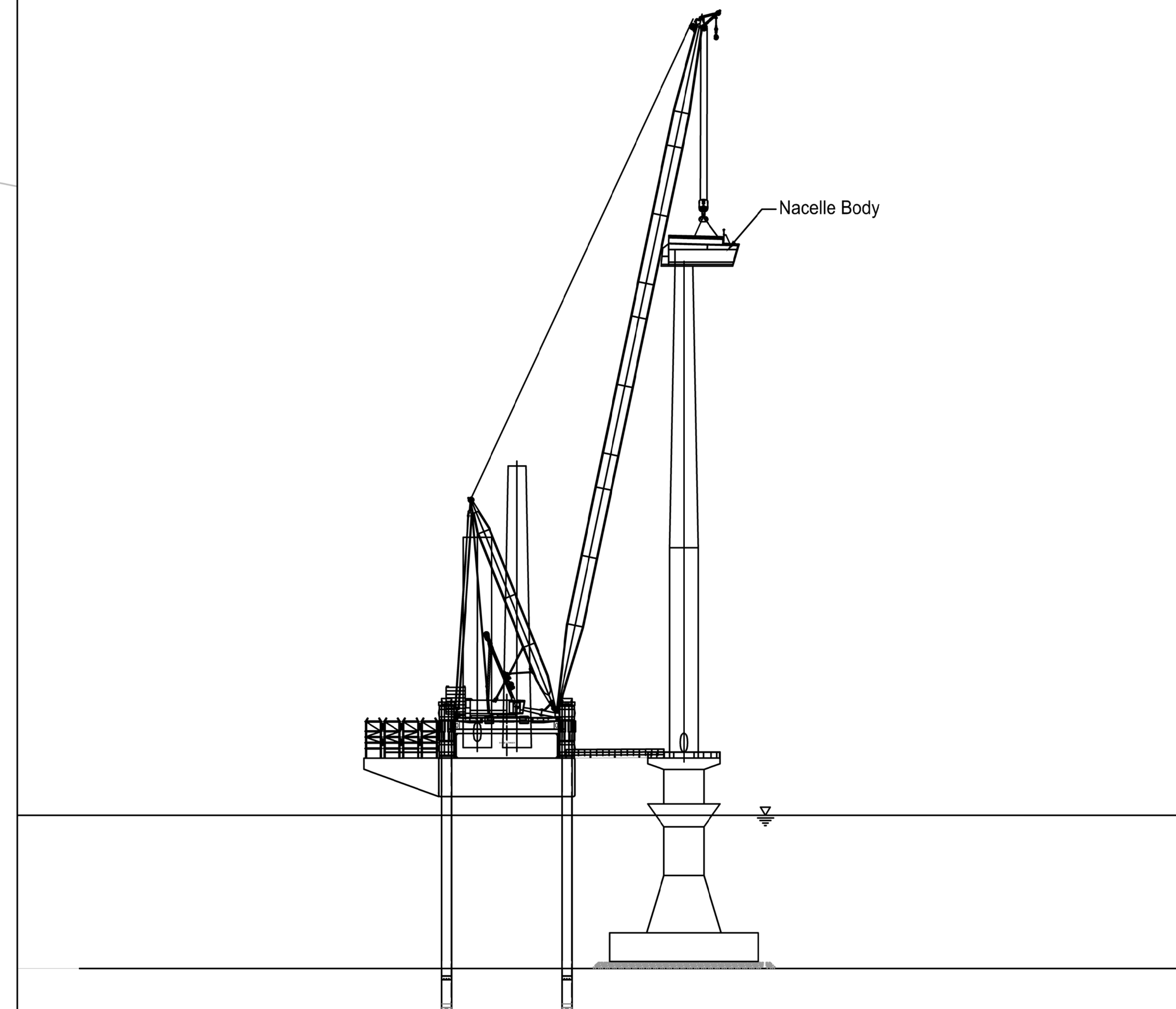

Panels: RDM Crane Installing Nacelle Body

a. Nacelle Body sea-fastening is released.
b. RDM crane lifts Nacelle Body and swings into place over top of Upper Tower Section. [Hub Elevation = +98 meters]

REF. NO.	DWG. NO.	REV.	REFERENCES
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Weeks Marine, Inc.

WOLFE ISLAND SHOALS - TURBINE INSTALLATION

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DATE	03/23/21	--	--	--	03/23/21	--

CLIENT JOB NO. --

WEEKS

WIND TURBINE GENERATOR
INSTALLATION METHOD SUMMARY
SHEET 4

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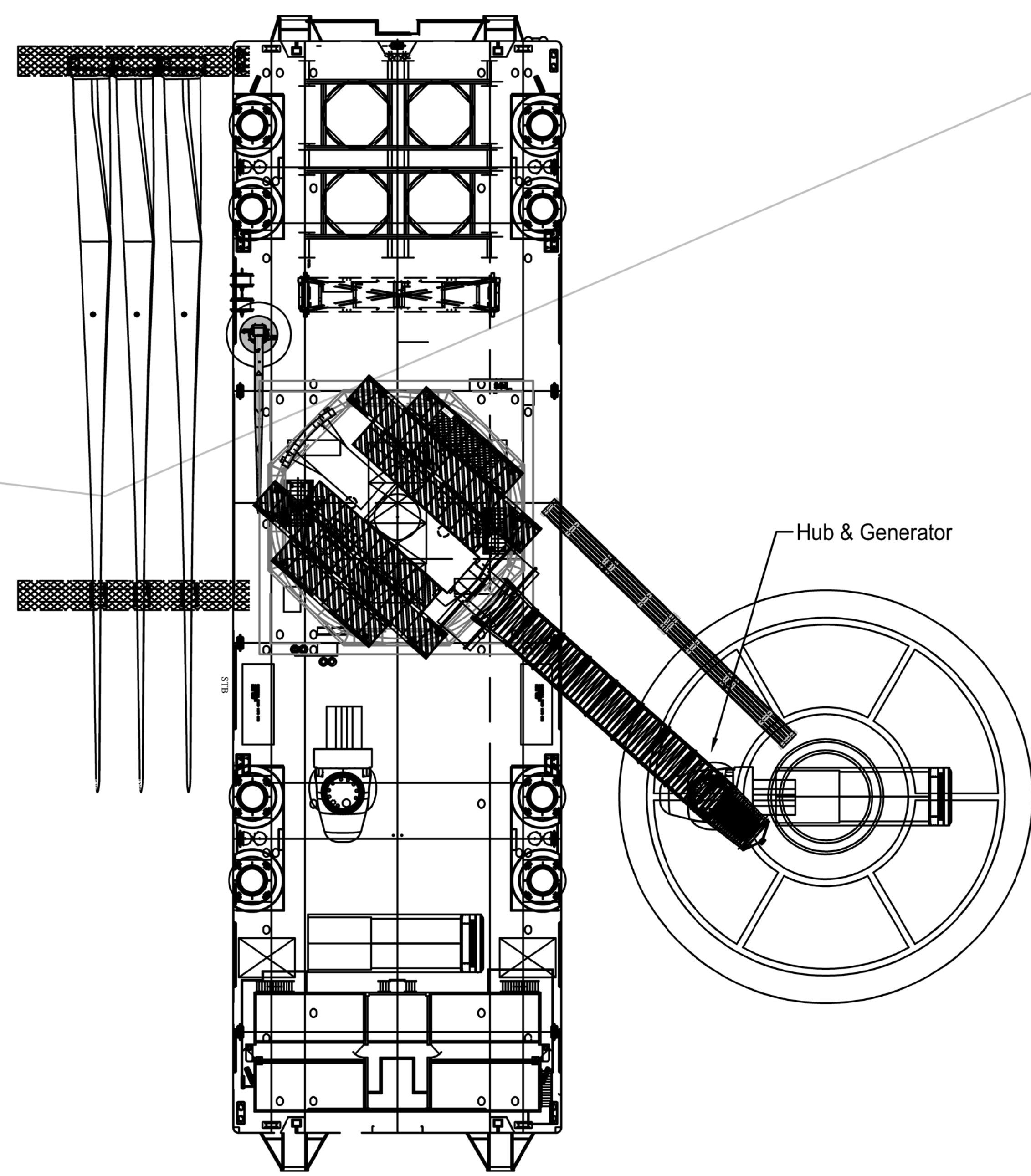

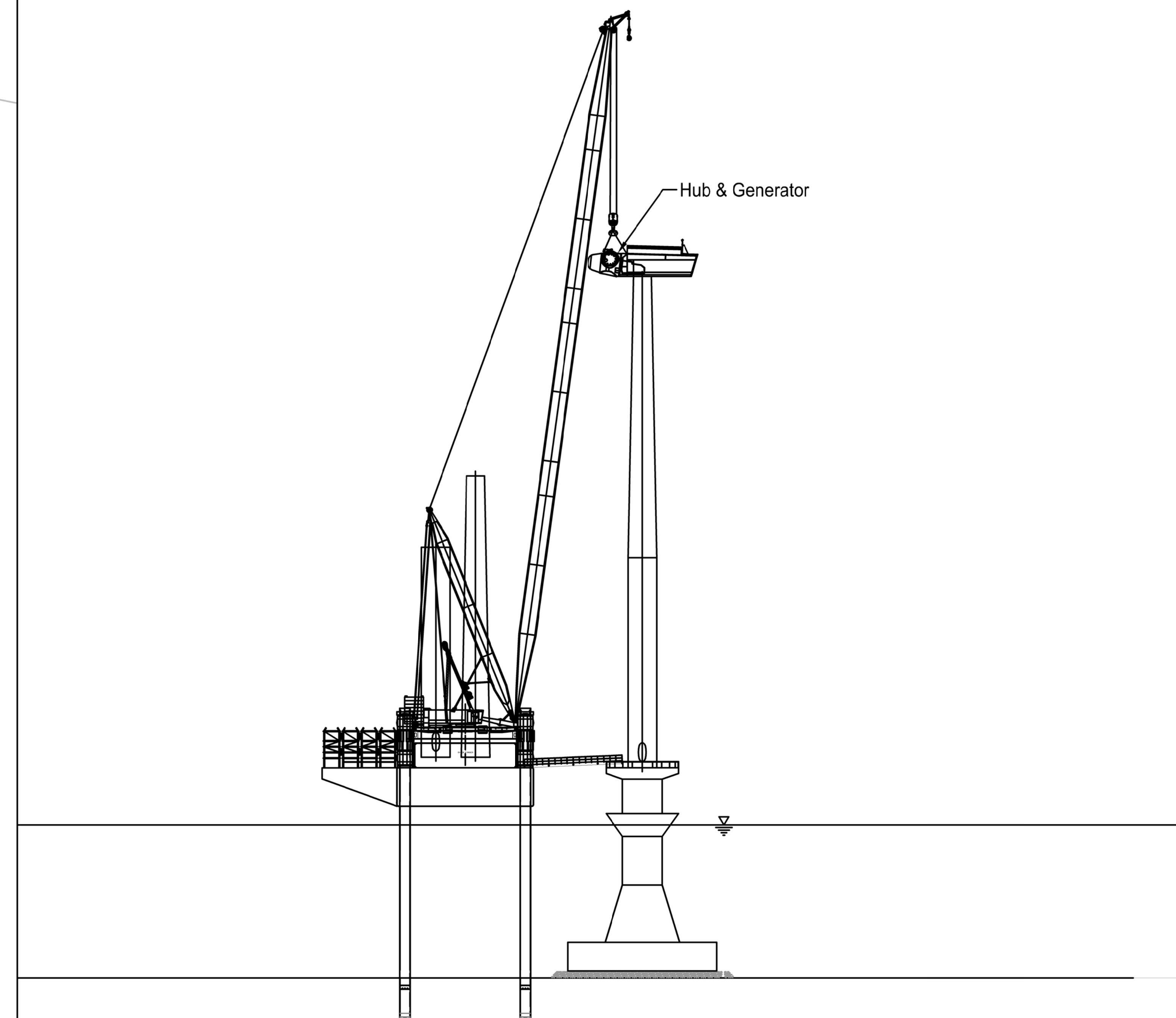

Panels: RDM Crane Installing Hub & Generator

a. Hub/Generator sea-fastening is released.
b. RDM crane lifts Hub/Generator and places it into the Nacelle Body. [Hub Elevation = +98 meters]

REF. NO.	DWG. NO.	REV.	REFERENCES
5			
4			
3			
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BY	REV	REVISION	CHK	APP'D	DATE
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Weeks Marine, Inc.

WOLFE ISLAND SHOALS - TURBINE INSTALLATION

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BY	RPP	--	--	--	RPP	--
DATE	03/23/21	--	--	--	03/23/21	--

CLIENT JOB NO. --

WEEKS

WIND TURBINE GENERATOR
INSTALLATION METHOD SUMMARY
SHEET 5

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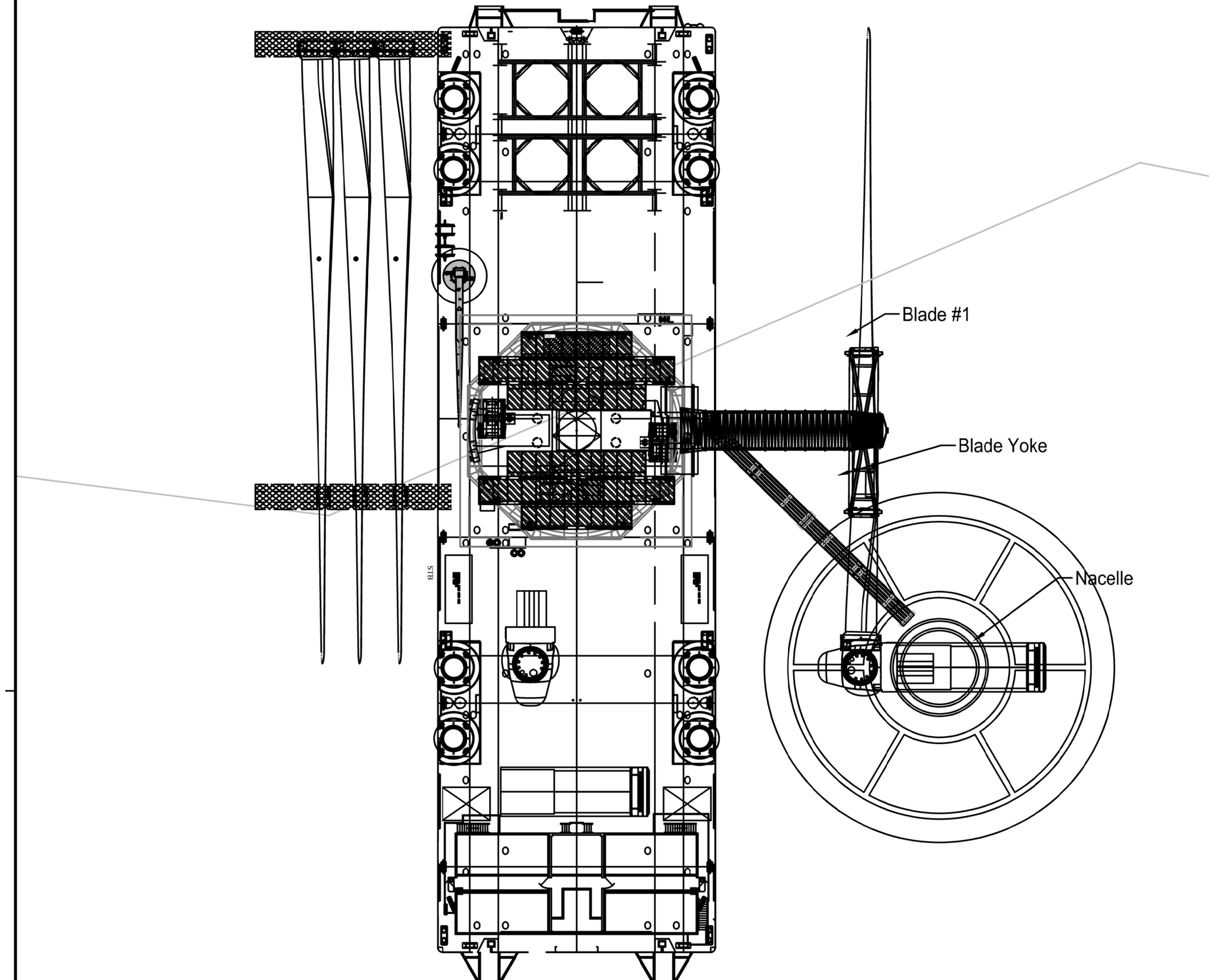
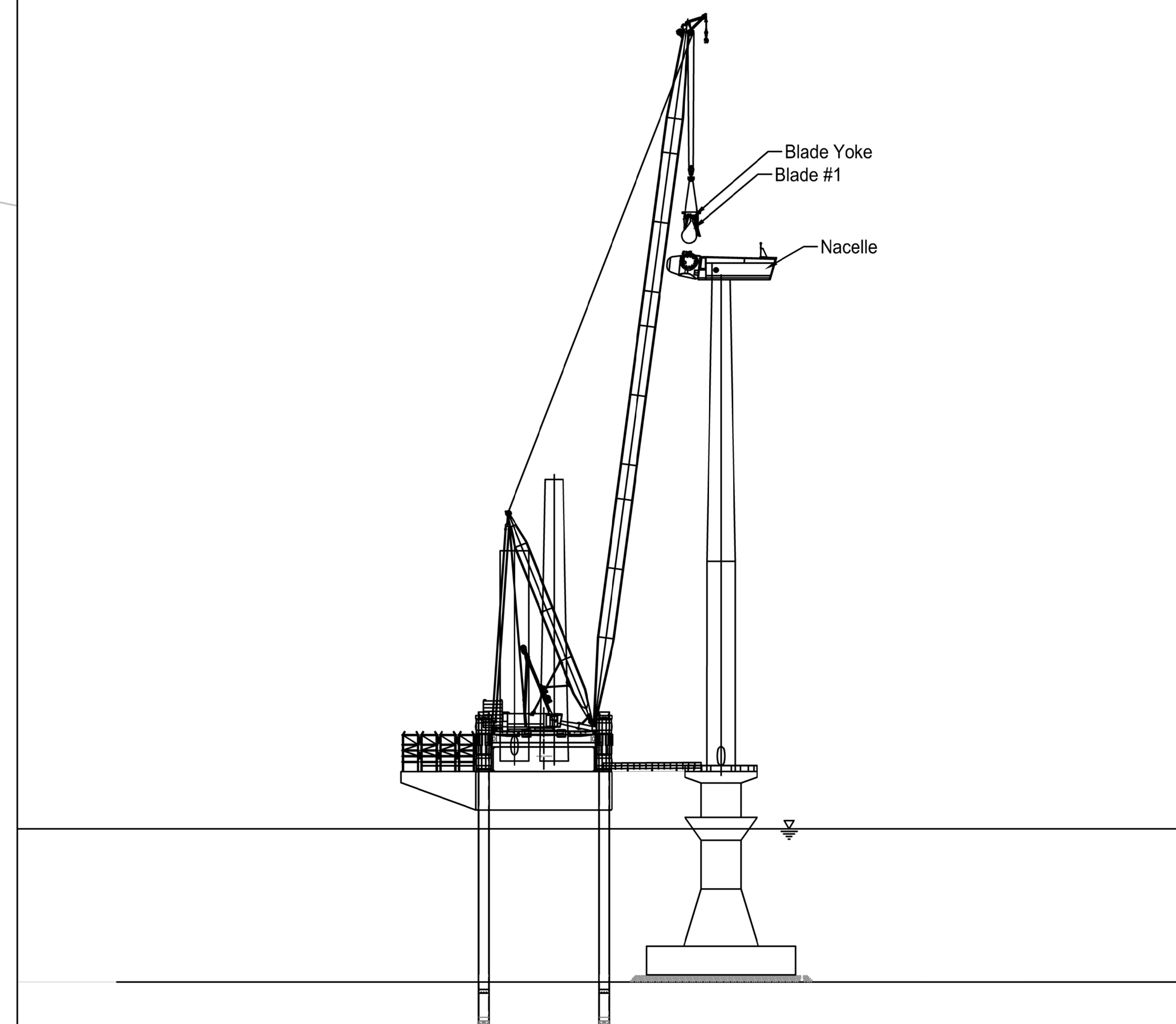
NTS	WIS - TE -CO - IM - F100 - 005	0





Panels: RDM Crane Installing Blade # 1

a. RDM picks yoke rigging.
b. RDM crane lifts blade out of the blade rack, swings it into position at the Nacelle Hub.

REF. NO.	DWG. NO.	REV.	REFERENCES
5			
4			
3			
2			
1			

BY	REV	REVISION	CHK	APP'D	DATE
RPP	0	ISSUED FOR REVIEW	RPP	RPP	03/23/21

Weeks Marine, Inc.

WOLFE ISLAND SHOALS - TURBINE INSTALLATION

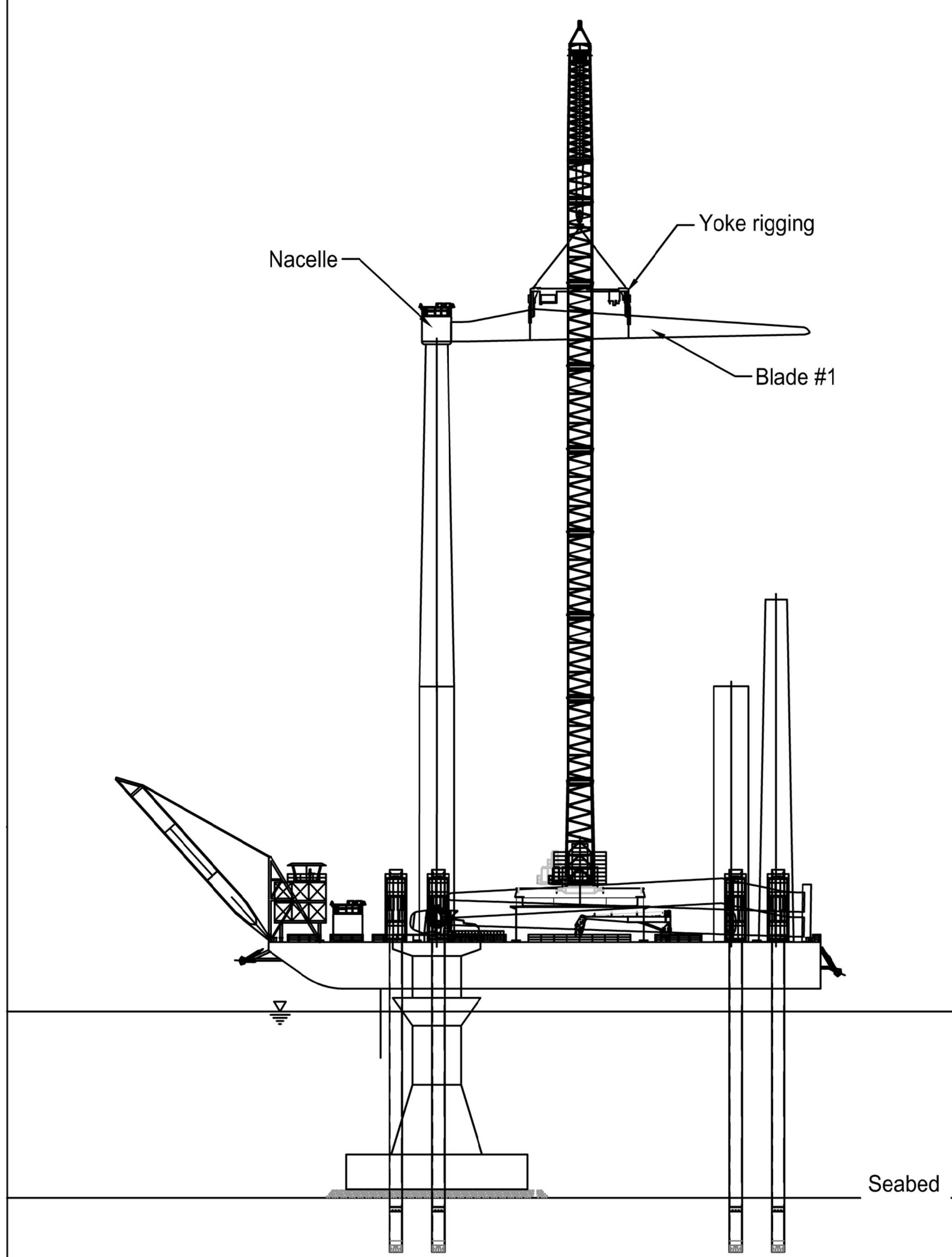
	DRAFTED BY	DRAFTING CHECK	ORIGINATING ENGINEER	ENGINEERING CHECK	PROJECT MANAGER	CLIENT APPROVAL
BY	RPP	--	--	--	RPP	--
DATE	03/23/21	--	--	--	03/23/21	--

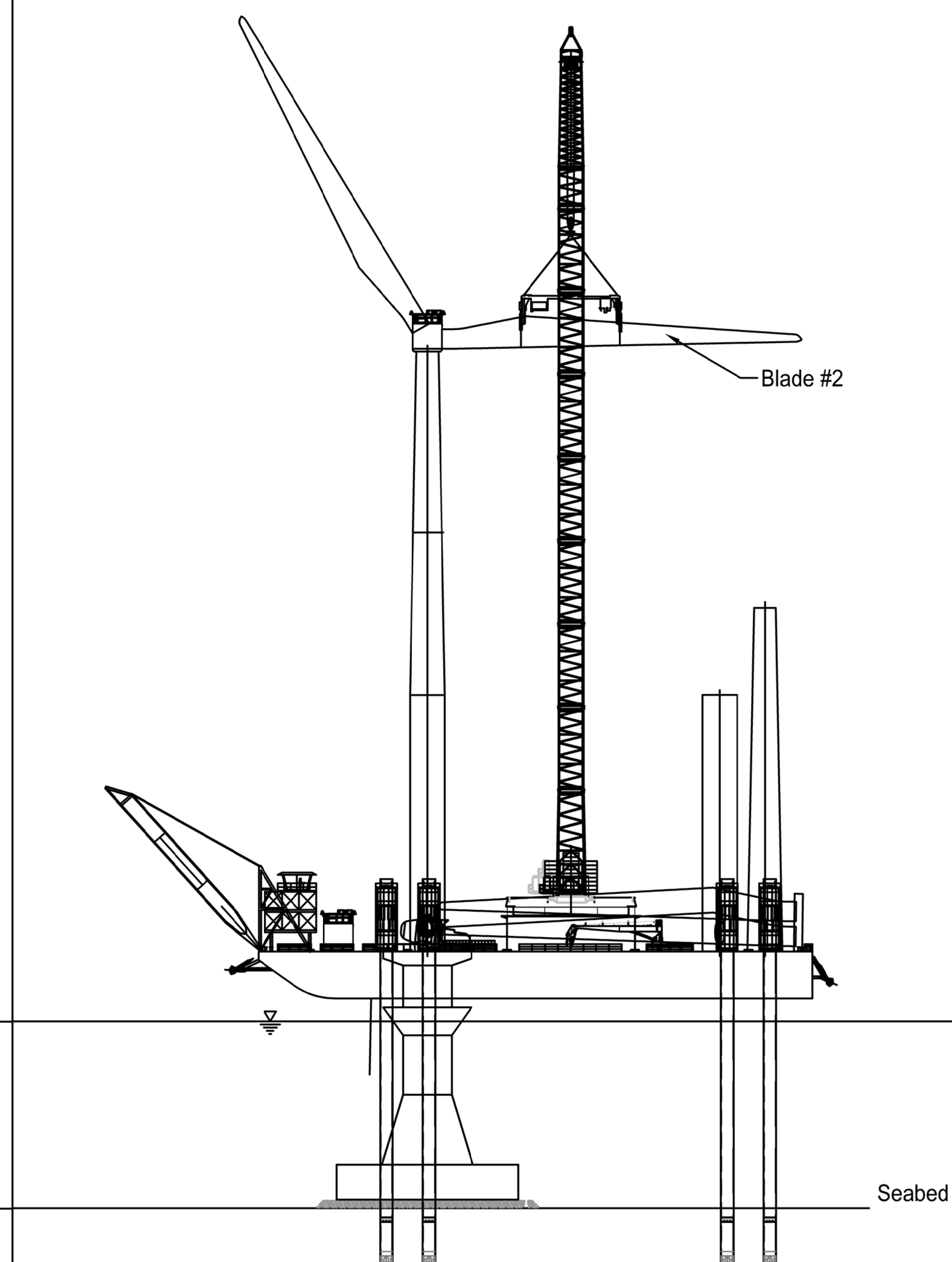
CLIENT JOB NO. --

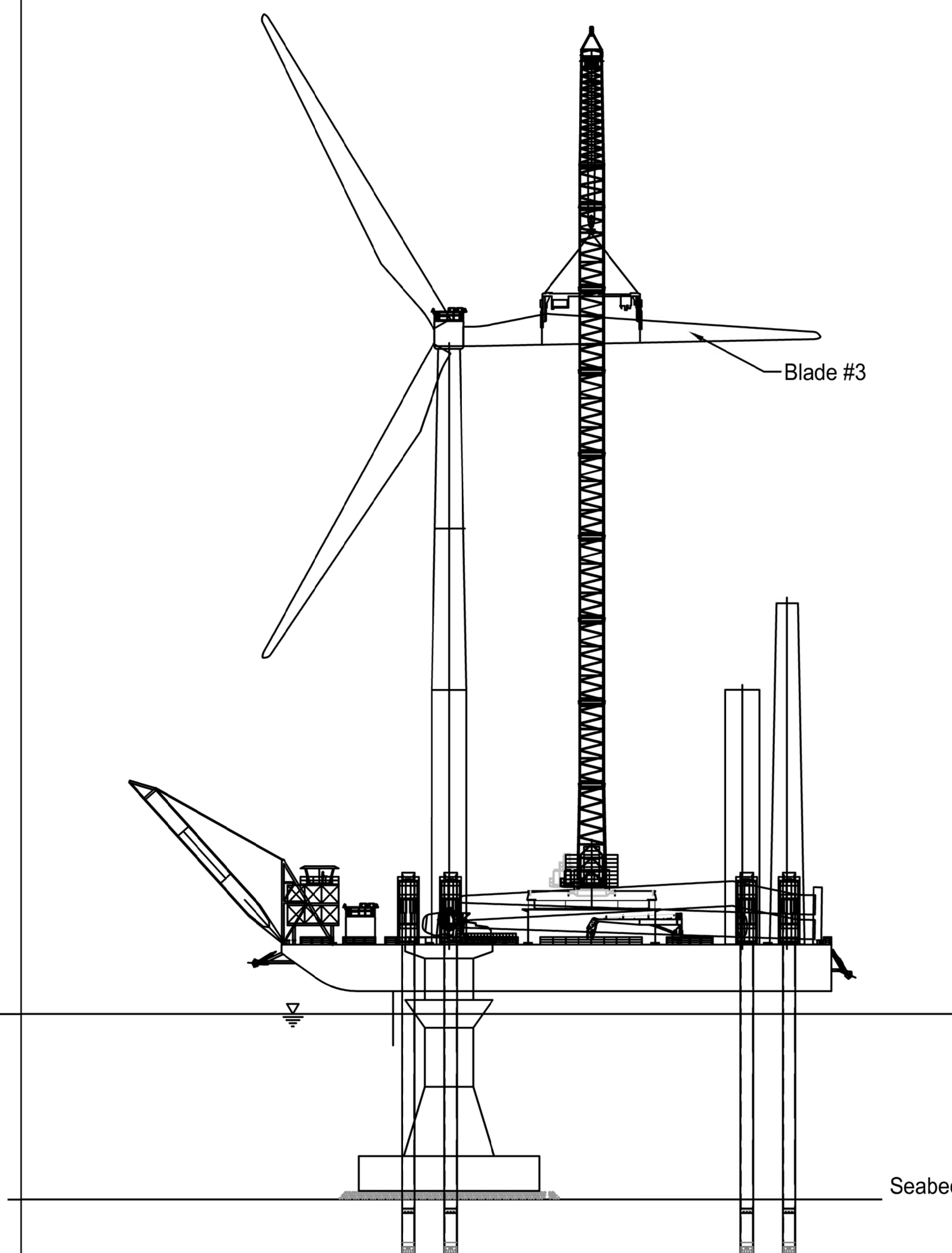
WEEKS

WIND TURBINE GENERATOR
INSTALLATION METHOD SUMMARY
SHEET 6

SCALE AT 11X17 SIZE:	DRAWING NO.	REV.
NTS	WIS - TE - CO - IM - F100 - 006	0







Panel 1: RDM Crane Installing Blade #1

a. RDM crane picks blade yoke.
b. RDM crane lifs blade #1 out of blade rack, swings into position at the Nacelle Hub.

Panel 2: RDM Crane Installing Blade #2

a. RDM crane lifts blade #2 out of blade rack, swings into position at the Nacelle Hub.

Panel 3: RDM Crane Installing Blade #3

a. RDM crane lifs blade #3 out of blade rack, swings into position at the Nacelle Hub.

REF. NO.	DWG. NO.	REV.	REFERENCES
5			
4			
3			
2			
1			

BY	REV	REVISION	CHK	APP'D	DATE
RPP					
RPP	0	ISSUED FOR REVIEW	RPP	RPP	03/23/21

Weeks Marine, Inc.

WOLFE ISLAND SHOALS - TURBINE INSTALLATION

	DRAFTED BY	DRAFTING CHECK	ORIGINATING ENGINEER	ENGINEERING CHECK	PROJECT MANAGER	CLIENT APPROVAL
BY	RPP	--	--	--	RPP	--
DATE	03/23/21	--	--	--	03/23/21	--

CLIENT JOB NO. --

WEEKS

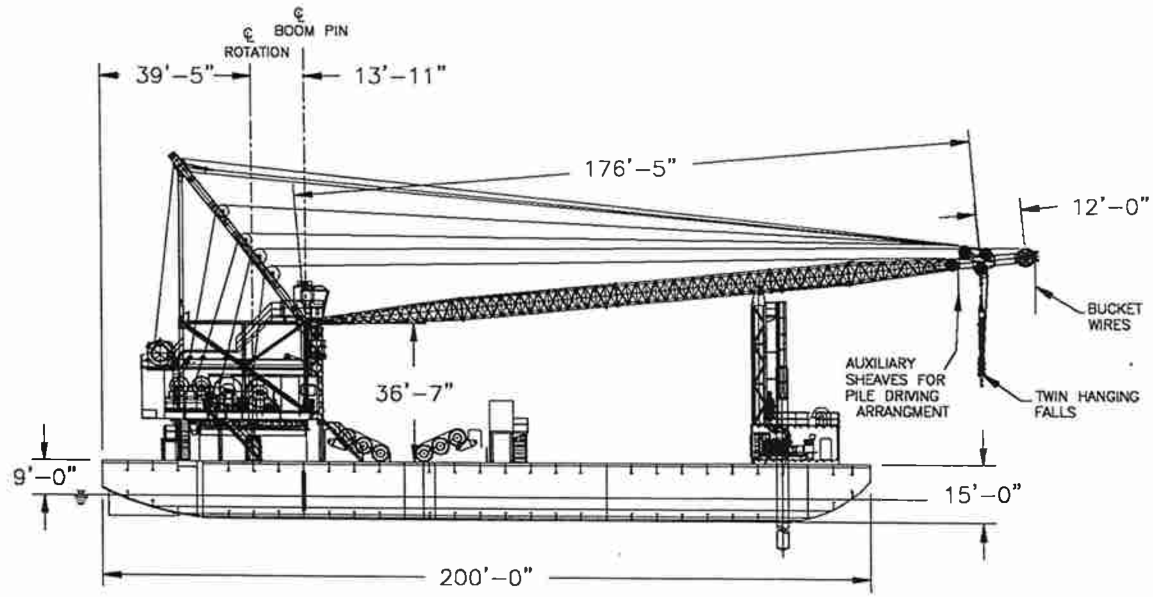
WIND TURBINE GENERATOR
INSTALLATION METHOD SUMMARY
SHEET 7

SCALE AT 11X17 SIZE:	DRAWING NO.	REV.
NTS	WIS - TE - CO - IM - F100 - 007	0

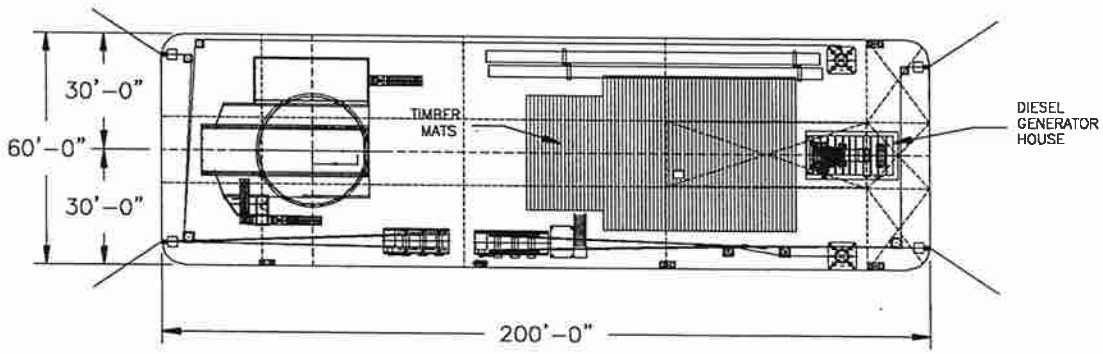
Attachment A

W571 General Arrangement Drawing

Attachment A



ELEVATION



PLAN

WMI 571 SUMMARY DESCRIPTION	
HULL	DIMENSIONS: 200'X60'X15' LOADED DRAFT: 9FT TIMBER MATS 12X12
MOORING SYSTEM	WEEKS EQUIPMENT: SKAGIT G130, W28390, 3 DRUM HYDRAULIC WINCH . WIRE 1½" DIA. SKAGIT RB 90W, W28139, 3 DRUMS, WIRE 1½" DIA.
FUEL CAPACITY	(U.S. Gal.) 65,000 GALS.
CRANE SPECIFICATION DATA	
CRANE MODEL	DRAVO 28 S/N-YD242 CRANE LOAD BLOCKS ARE 4 SHEAVE RATED FOR 110T EA. WIRE SIZES: TWIN FALLS – 1 1/8", WIRE BOOM HOIST – 1 1/4" 16 PARTS, BUCKET WIRES SHEAVES – 1 5/8", WIRE AUX. AND SHEAVES-1 3/4" WIRE
CURRENT BOOM	(1) ea. 49' -10" BOOM TIP (1) ea. 40'-11" BOOM BUTT (2) ea. 40'-4" MID SECTION (1) ea. 20'-4" MIDSECTION THE 176' -5" LENGTH BOOM IS TAKEN FROM THE CENTER OF THE BOOM PIN TO THE CENTER OF THE MAIN SHEAVE BLOCK.
SPUDS	(2) ea. 42" DIA. SPUDWELLS WITH (2) ea. 36" DIA. SPUDS, 86' 9" LONG
BALLAST – FRESH WATER (FULL)	1. 224,814 LBS 2. 17,904 LBS

WEEKS MARINE, INC.
4 COMMERCE DR. CRANFORD, NJ 07016-2497 (908) 272-4010

571 GENERAL ARRANGEMENT – GOOSE CREEK – 176'-5" BOOM

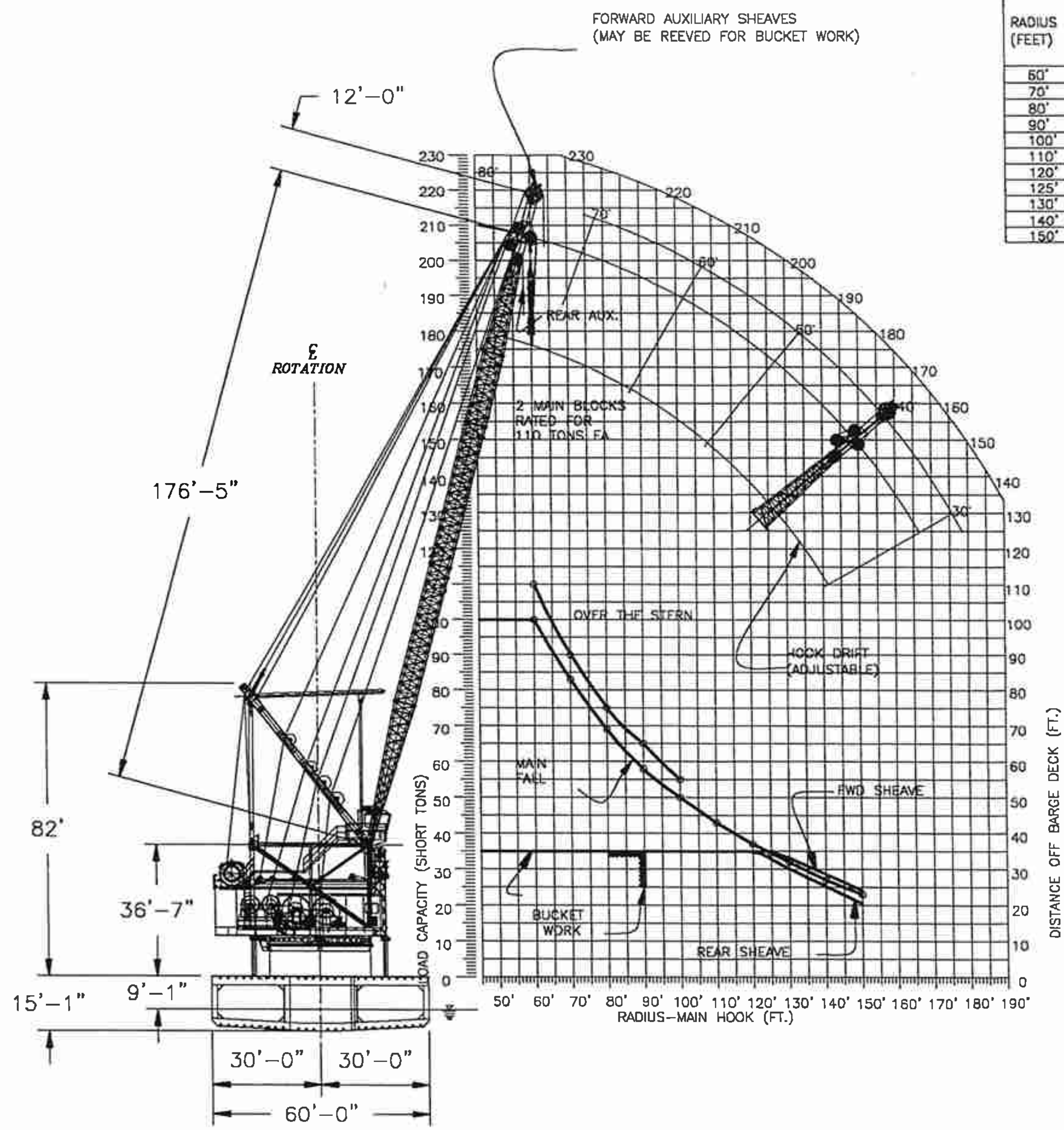
SCALE: 1"=50'

REF DRAWING: 091008_SAC_LOAD CAPCITY_571 _176'-5"

Attachment B

W571 Capacity Chart

Attachment B



WEEKS 571 CAPACITY CHART 175' BOOM								
RADIUS (FEET)	MAIN BLOCKS BOOM ANGLE(°)	MAIN BLOCKS FULL ROTATION (TONS)	OVER THE STERN NO LIST, NO SLEWING (TONS)	*BUCKET WORK (TONS)	REAR AUX. SHEAVE (TONS)	REAR AUX. BOOM ANGLE(°)	FORWARD AUX. SHEAVE (TONS)	FORWARD AUX. BOOM ANGLE(°)
60'	75.5	100	110	35	35	74.2	35	75.8
70'	72.1	83	90	35	35	70.6	35	72.7
80'	68.6	69	75	35	35	67.0	35	69.5
90'	65.1	58	65	35	35	63.2	35	66.2
100'	61.4	50	55		35	59.4	35	62.8
110'	57.6	43			35	55.3	35	59.3
120'	53.6	37			35	51.1	35	55.7
125'	51.6	34.5			33	48.9	35	53.9
130'	49.5	32			30.2	46.6	33.2	52.0
140'	45.0	27			25.3	41.7	28.7	48.0
150'	40.1	23			20.5	36.3	24.2	43.8

NOTES AND ADDITIONAL INFORMATION

1. CRANE MODEL: DRAVO 28 S/N–YD242
2. OVER STERN CRANE AT CENTER LINE BARGE
3. NOTE THAT CRANE LOAD BLOCKS ARE 4 SHEAVE RATED FOR 110T EA.
4. FOR CAPACITIES OVER 110T, 2 BLOCK PICK IS REQUIRED
5. BOOM 176'–5" CONSIST OF: BOOM TIP =49'–10", BOOM BUTT =40'–11", (2) MID SECTION = 40'–4", INSERT = 20'.
6. THE 176'–5" LENGTH BOOM IS TAKEN FROM THE CENTER OF THE BOOM PIN TO THE CENTER OF THE MAIN SHEAVE BLOCK.
7. WIRES SIZES: TWIN FALLS ARE 1 ⅛" WIRE, BOOM HOIST WIRES ARE 1 ¼" 16 PARTS OF LINE, BUCKET SHEAVES WIRES 1 ⅝", AUX. SHEAVES WIRES 1 ¾"
8. BARGE DIMENSIONS 200'X60'X15'
9. ALL PICKS ARE WITH SPUDS FREELY FLOATING
10. ALL CAPACITIES IN SHORT TONS
11. ALLOWABLE CRANE LIST = 3.5°
12. CRANESMART LOAD INDICATORS ON ALL 4 HOIST LINES EQUIPPED WITH AUDIBLE OVERLOAD ALARM
13. CRANESMART ANTI–2–BLOCK ON ALL 4 HOIST LINES EQUIPPED WITH AUDIBLE LIMIT ALARM
14. CRANESMART BOOM ANGLE INDICATOR WITH AUDIBLE LIMIT ALARM
15. LIST AND TRIM INCLINOMETERS INSTALLED IN OPERATORS CAB
16. BOOM ANGLES ARE FOR REFERENCE ONLY.
17. *BUCKET CAPACITY IS GROSS CAPACITY (MATERIAL & BUCKET WEIGHT)

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571 CAPACITY CHART – GOOSE CREEK – 176'–5" BOOM

SCALE: 1"=50'

REF DRAWING: 091008_SAC_ LOAD CAPCITY_571 _176'–5"

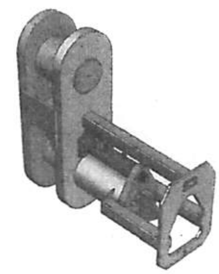
Attachment C

Hydraulic Pin Release Mechanism

Attachment C

PRM
Pin Release Mechanism

Pin release mechanisms are used in custom-made lifting applications.



Specifications

- Standard suitable for 500m water depth
- Custom made design
- Lifting capacities up to 2000t
- Certified and designed according Lloyds Lifting Appliances
- Available for purchase

Features

Specifically used for the connection between the crane and the gravity based foundation.

Projects

OWF

2011 Hornsea Meteorological Mast - UK

2008 Thorton Bank 1 - Belgium

WEEKS

Attachment D

RD MacDonald Jack-up Barge and Manitowoc 4600 Ringer

Crane Specifications_RevB_1

Attachment D

R.D. MacDonald

WMI #752

New York, NY

Jack-up Barge

Vessel Specifications

File Name: WMI 752 Vessel Specification Rev B_1 Weeks Marine

Prepared by: Engineering, Cranford

Prepared on: August 17, 2012

Rev.: B_1 (April 6, 2021) - for Wolfe Island Shoals Analysis

Weeks Marine Inc.
4 Commerce Drive
Cranford, NJ 07016

Table of Contents

1. Introduction

The objective of this project is to construct a jackup barge with a heavy lift crane capable of operating offshore and near shore conditions in the marine construction market. The primary objective is to commission the vessel as a Jones Act compliant US Flag American Bureau of Shipping classed +A1 Self Elevating Unit for the construction of Offshore Wind Farms in the Domestic and Foreign markets. Additional objectives are to have the vessel capable of pursuing general Marine Construction, Decommissioning, and Offshore wind in US and International markets, and meet necessary regulatory requirements to do so.

1.1 Vessel Official Data

Vessel Name:	R.D. MACDONALD
WMI Equipment No.:	752
USCG Official No.:	1240384
ABS ID No.:	11237747
Hailing Port:	New York, NY
Dimensions:	260' x 78' x 22'
Tonnage: (simplified)	3,747 GRT / 3,747 NRT (domestic)
Tonnage: (ITC)	TBD (international)
Builder:	BAE Systems Southeast Shipyards
Builder Hull No.:	4254
FCC Call Sign:	WDG4059
MMSI No.:	367532530

1.2 Design Basis

a. Use of existing Weeks Marine inventory of DeLong D-6-6 jacks, modified for modern performance and service. Maximum jacking and holding capacity at 8,064 and 16,128 s. tons respectively. Weeks has long term experience with the DeLong system on other vessels including the Weeks Jackup #751.

b. Main crane is Manitowoc 4600 S4 Ringer S3 ringer crane acquired by Weeks for use in 166 s. ton through 750 s. ton configurations with boom lengths 140 ft to 400 ft. Weeks has long term experience with Manitowoc crawler and ringer cranes in marine applications.

c. A barge and jacking system capable of supporting the cranes full capacity for 360 degree swing in the elevated condition.

d. Nominal deck capacity of 5000 psf to support high localized deck loads anticipated with carrying project components and support equipment for offshore wind project foundations, towers, and turbines.

e. Spacing of the legs far enough from the center pin of the crane to allow the crane to self install the legs and service the jacks, within the minimum allowable pick radius.

2. WMI 752 Specifications

2.1 Key Vessel Dimensions

a.	Hull Length	260 ft	(79.2 m)
b.	Hull Breadth	78 ft	(23.7 m)
c.	Hull Depth	22 ft	(6.7 m)
d.	Crane center pin to bow	150 ft	(45.7 m)
e.	Crane center pin to stern	110 ft	(33.5 m)
f.	Crane center pin to starboard	39 ft	(11.9 m)
g.	Crane center pin to port	39 ft	(11.9 m)
h.	Longitudinal Pair Leg Centers	160 ft	(48.7 m)
i.	Transverse Leg Centers	69 ft	(21.0 m)

2.2 Operating Conditions

The general operating parameters developed to date are listed below based on 160 ft and 180 ft. 160ft leg length has been fabricated to date due to bridge height restrictions anticipated on what was to be the first project. These parameters are based on ABS "unrestricted" service up to 100kt wind and associated waves (Category 2-3 hurricane). Weeks recognizes that it will be an advantage to instead obtain ABS "restricted" service designation (50kt – 70kt wind) as it should allow options for operating with longer leg length, higher air gap, or deeper water depth. The need to operate or maintain station in hurricane conditions is not necessary.

Typical project parameters are included below as desired performance goals. Use of spud cans has so far not been considered as near term projects are on sand, but may be addressed on future project specific soil conditions as needed.

2.2.1 Typical Project Parameters

a. Near Term Projects
   - a. Water Depth .... 40 -70 ft (12-22 m)
   - b. Hub Height .... 300-330 ft (90 – 100 m)
   - c. WTG Max Pick Weight* .... 250-342 s. ton (232-310 t)

b. Long Term Projects
   - a. Water Depth .... 70-100 ft (22-30 m)
   - b. Hub Height .... ±330 ft (±100 m)
   - c. WTG Max Pick Weight* .... 330-440 s. ton (300-400 t)

c. Far Term Projects
   - a. Water Depth .... 100-120 ft (30-37 m)
   - b. Hub Height .... ±360 ft (±110 m)
   - c. WTG Max Pick Weight* .... 500-660 s. ton (450-600 t)

*approx WTG weight for single lift; some nacelle models allow erection in sub-assemblies

2.2.2 Jacked-Up Configuration

a. Leg length (present) .... 160 ft (48.7 m)

b. Caisson Leg Outer Diameter .... 71 in (1828 mm)
c. Caisson Leg Wall Thickness .... 1-1/2 in (38.1 mm)
d. Spud Cans – Not Included – TBD based on future project needs
e. Wind Speed
    a. Working Conditions .... 70 kts (36 m/s)
    b. Storm Survival Conditions.................................. 100 kts (51 m/s)
f. Wave Height
    a. Working Conditions .... 17 ft (5.2 m)
    b. Storm Survival Conditions.................................. 26 ft (7.9 m)
g. Wave Period
    a. Working Conditions ....
    b. Storm Survival Conditions..................................
h. Air Gap Minimum (w/ 10 FT Leg Penetration)
    a. Working Conditions – 160 ft leg .... 18 ft (8.2 m)
    180 ft leg .... 21 ft (6.4 m)
    b. Storm Survival Conditions – 160 ft leg................ 27 ft (5.5 m)
    180 ft leg................ 27 ft (8.2 m)
i. Water Depth (w/ 10 FT Leg Penetration)
    a. Working Conditions– 160 ft leg .... 72 ft (21.9 m)
    180 ft leg .... 90 ft (27.4 m)
    b. Storm Survival Conditions -160 ft leg .... 63 ft (19.2 m)
    180 ft leg.................. 75 ft (22.8 m)

2.2.2 Floating Draft Configuration (approx)

a. Light (Barge, Deck House, Crane, Jacks)
    a. Draft .... 7.5 ft (2.29 m)
    b. Freeboard.. 14.5 ft (4.42 m)
b. Operating (Light condition plus full tanks)
    a. Draft .... 8.9 ft (2.71 m)
    b. Freeboard.. 13.1 ft (3.99 m)
c. Operating with Cargo
    a. Draft .... 14.6 ft (4.24 m)
    b. Freeboard.. 7.4 ft (2.47 m)
d. Maximum
    a. Draft .... 19.0 ft (5.79 m)
    b. Freeboard.. 3.0 ft (0.91 m)

2.3 Key Features

a. Variable Load Capacity
    a. Maximum Net Cargo Capacity (approx.) .... 2300 s. tons (2177243 kg)
    b. Deck Uniform Load Capacity............................... 5000 psf (24.4 m. ton/m^2)
    c. Deckhouse Roof Uniform Load Capacity .... 250 psf
b. Clear Deck Area
    a. Forward
        i. Area.. 6264 sq ft (581.9 m^2)

ii. Width .... 58 ft (17.7 m)
iii. Length .... 108 ft (32.9 m)

b. Aft
   i. Area... 4466 sq ft ($414.9\ m^2$)
   ii. Width .... 58 ft (17.7 m)
   iii. Length .... 77 ft (23.6 m)

2.4 Equipment

a. Main Crane - Manitowoc .... 4600 S4 Ringer S3 750 US ton
b. Jacking System .... 8ea x Delong modified
c. Marine davit crane - Manriding .... EBI C30-40
d. Marine davit crane – general service/safety .... TBD
e. Mooring Winches.. 2ea x American 350A 2 Drum
f. Generators .... ?ea CAT x ? kW Gen. Set
g. Fuel Oil System... 2ea x 2” electric
h. Potable Water System .... 2ea x 2” electric
i. Ballast / Bilge Pump – Centrifuge, Electric VFD .... 2 ea x 8” 1500gpm self-priming
j. Auxiliary Submersible Pumps-Electric .... 2 ea x 6” 1000gpm
k. Mobile 90 ton Hydraulic RT Crane .... 1 ea Grove 890E or equal

2.5 Elevating System

2.5.1 DeLong Air Grip Hydraulic Stroke Jacking System

Current system is designed around pairing (2) DeLong D-6-6 bowls together top and one set of hydraulic lift cylinders required per leg. A total of (16)ea Delong D-6-6 Jacks are required for the system, with (24)ea pneumatic grippers per leg. A total of (96)ea hydraulic cylinders with 5' stroke are required, or (12)ea per leg. Hydraulic, air, and electric lines are to run through the below deck utility trough from machinery located in the deckhouse to the jack locations at the four quadrants. Control

For service, individual jack units may be unpinned at the tiebars and removed over top of the leg.

System Lift Capacity: 8,064 s. tons

Hold Capacity: 16,128 s. tons

a. Elevating Capacity (8 EA) .... 2016 Kip/Leg (914442 kg/leg)
b. Maximum normal holding capacity (8 EA)........................ 4032 Kip/Leg (1828884 kg/leg)
c. Barge Jacking Weight - estimated.................................... 5700 s. ton (5170 t)
d. Jacking Speed - estimated... 2 ft/min (0.61 m/min)
e. Jacking Stroke .... 5 ft (1.52 m)

2.6 Storage Capacities

a. Fuel Oil (2 EA)... 39500 gal (149524 L)
b. Potable Water .... 43450 gal (164476 L)
c. Ballast.. Variable

2.7 Main Crane

2.7.1 Manitowoc 4600 Series 4 Ringer Series 3

The main crane is a Manitowoc 4600 S4 Ringer S3 owned by Weeks. It is a standard Manitowoc crawler crane with added ringer attachment package giving the machine a nominal maximum boom capacity of 750 US ton (680 ton). The main boom is lattice type and adjustable in length from 140ft to 400ft.

Weeks requires the ability to vary the boom length to suit project specific needs, from 140ft heavy lift configuration, in 20ft increments through 400 ft high reach configuration. A typical Offshore Wind Project will require 140-200ft boom for foundation installation and then extend to 260-300ft boom for tower and turbine erection. Therefore vessel stability, structure, and elevated operating envelope need to consider the loads and moments imparted by this boom range.

a. Serial Number (Base Crane).. 460085
b. Serial Number (Ringer Attachment) 10335
c. Year of Manufacture 1993

d. Engine .... 1ea Cummins VTA 28-C800 Diesel
e. No . 65 Boom .... 140—400 ft (42.7— 121.9m)

Sample boom capacities — Chart 7300-A1, 0 deg list

    a. 140 ft Boom Tip Capacity@ 70' radius................ 750 s. ton (681 t)
    b. 200 ft Boom Tip Capacity@ 70' radius................ 641 s. ton (582 t)
    c. 400 ft Boom Tip Capacity @95' Radius................ 166 s. ton (151 t)

f. No. 27 Mast .... 130 ft (39.6 m)
g. Boom Heel Pin Elev. above deck.................................... 26’-10”± (8.2 m)
h. Boom Point Elev. above deck (400ft @ 95ft radius)......... 421’- 8” (128.5 m)
i. Mast Tip Elev. above deck .... 149’-2” (45.5 m)
j. Ringer attachment diameter .... 60 ft (18.3 m)
k. Tail Swing Radius... 36’-3” (11.0 m)
l. Boom part reeving .... 18 Part
m. Boom pendants .... 8 x 1-3/8 in (8 x 34.9 mm)
n. Base Crane Counterweight .... 123 kips (55791 kg)
o. Auxiliary Ringer Counterweight...................................... 987.7 kips (448013 kg)
    a. 23 pieces .... 40–44 kips ea. (18143—19958 kg)

p. Load Line Specifications
    a. Maximum Load per Parts of Line for 1-5/8in Wire
        i. 1 Part .... 30 s. ton (27210 kg)
        ii. 5 Part .... 150 s. ton (136070 kg)
        iii. 10 Part .... 300 s. ton (262150 kg)
        iv. 15 Part .... 450 s. ton (408230 kg)
        v. 20 Part .... 600 s. ton (544310 kg)
        vi. 26 Part .... 750 s. ton (680380 kg)
    b.
q. Drum Specifications
    a. Front Drum (1 EA)
        i. Width .... 40 in (1016.0 mm)
        ii. Drum Diameter .... 28 in (711.2 mm)
        iii. Flange Diameter.................................... 63 in (1600.2 mm)
        iv. Spooling Capacity .... 1578 ft (478.2 m)
        v. Wire Rope Type .... 6 x 41 EIPS, IWRC
        vi. Wire Rope Diameter .... 1-5/8 in (41.3 mm)
        vii. Linepull.. 60,000 lb (27,215.5 kg)
    b. Rear Drum (1 EA)
        i. Width .... 43 in (1092.2 mm)
        ii. Drum Diameter .... 28 in (711.2 mm)
        iii. Flange Diameter.................................... 50-1/2 in (1282.7 mm)

iv. Spooling Capacity .... 598 ft (181.2 m)
v. Wire Rope Type .... 6 x 41 EIPS, IWRC
vi. Wire Rope Diameter .... 1-5/8 in (41.3 mm)
vii. Linepull...

c. Boom Hoist Drum (2 EA)
   i. Dimensions ....
   ii. Drum Capacity .... 1210 ft (368.8 m)
   iii. Wire Rope Diameter .... 1-1/8 in (28.6 mm)
   iv. Wire Rope Type .... 6x26 boom hoist rope
   v. Linepull...
d. New Main Drum (1 EA)
   i. Dimensions ....
   ii. Drum Capacity .... 6000 ft (1828.8 m)
   iii. Wire Rope Diameter .... 1-1/4 in (31.7 mm)
   iv. Linepull... 60,000 lb (27,215.5 kg)

r. Main Block (heavy lift configuration – short boom)
   Johnson Load Block with Top Mounted Tandem Block with Duplex Hook
   a. Capacity.. 750 s. ton (680 t)
   b. Wire Rope Dia. .... 1-5/8 in (41.3 mm)
   c. Sheave Dia... 47 in (1193.8 mm)
   d. Sheaves on Main Block 10
   e. Sheaves on Tandem 3
s. Twin Main Blocks (pile driver configuration – long boom)
   Tri-plate assembly with 2ea side by side Hanger Blocks and Hook Blocks
   a. Capacity per Block... 350 s. ton (318 t)
   b. Wire Rope Dia. .... TBD
   c. Sheave Dia... TBD
   d. Sheaves on Main Block .... TBD
   e.
t. Auxiliary Block, Boom Upper Point
   a. Single or Double Part .... (TBD)

2.8 Auxiliary Marine Davit Crane

2.8.1 Personnel Handling Crane (EBI Model# C30-40)

a. Serial Number ....

b. Year of Manufacture 2012

c. Regulatory

   i. API 2C Monogrammed

   ii. API Q1 assembled components

   iii. General compliance with ABS Guide for Certification of Cranes

b. Boom Type .... Fixed Box Tube

c. Picking Radius Range .... 10-40 ft (3.8 - 15.2 m)

d. Tail Swing @ 80 deg .... 7'-9" (2.4 m)

e. Onboard Load Line @ 40 ft .... 16,000 lbs (7,257 kg)

f. Personnel Capacity @ 40 ft... 5,320 lbs (2413 kg)

g. Wire Rope Diameter (19x17 EIPS IWRC).......................... 1 in (25.4 mm)

h. Wire Rope Capacity for Personnel .... 8,440 lbs (3,828 kg)

i. Wire Rope Capacity for Non-Personnel Applications .... 16,880 lbs (7,620 kg)

2.8.2 General Service or Safety Crane

a. Regulatory requirement or general need for additional safety or general service related davit crane(s) need to be established such as handling rescue boat, liferaft stations, or submersible pump for fire system water.

2.9 Mooring System

a. Mooring system a 4 point anchor spread comprised of 2ea American 350A x2 drum winches mounted Port/Starboard inside the deckhouse. Wire is run down through the deck to a fleeting sheave inside the below deck utility trough, and run fore and aft to bergers which are recess mounted at the bow and stern respectively. Outboard anchor racks are planned below the bergers to catch and store the anchors so the crane is not required to deploy or retrieve.

   b. Winch – American 350 x 2 Drum .... 2 ea

      i. Pulling Capacity – nominal..................... 70,000 lbs (31750 kg)

      ii. Holding Capacity –nominal .... 200,000 lbs (90700 kg)

      iii. Drum Diameter .... 25 in (635 mm)

      iv. Drum Length .... 40 in (1016 mm)

      v. Drum Flange.. 57 in (1448 mm)

      vi. Drum Spool Capacity 1 ½" wire .... 2600 ft (790 m)

   c. Anchor- Delta Flipper type................................. 4ea x 6,600 lbs (3000 kg)

      i. Holding – Sand .... 143,000 lbs (64900 kg)

      ii. Holding – Soft Clay................................. 109,000 lbs (49700 kg)

   d. Wire – 6x19 EIP IWRC .... 1 ½" dia (38 mm)

      i. Wire Capacity - Ultimate......................... 228,000 lbs (103400 kg)

2.10 Ballast & Bilge System

a. Weeks Marine has investigated installation of a combined ballast and bilge system so as to allow maintaining level trim and list when mobilizing and demobilizing from a project site after offloading cargo (project material). The 8" pipe system is uses a pair of 8" x 1500 gpm self priming centrifugal pumps with electric VFD. The plan is based on a central pump room in compartment 5-CP with electric actuated valves to be run from a remote location, with valve stems for local manual control. Ballast Tanks include the wing tanks, exclusive of jack cases, and the centerline forepeak and afterpeak tanks. System will draw from a Seachest in compartment 5-CP or be back fed from 2 ea auxiliary 6" submersible pumps rated for 1000gpm to allow adjusting ballast while elevated, providing general service water, or fire water.

   b. Pipe 8" Scd 80 .... 2500 lf
   c. Valves – 8" Elec Actuated B.fly .... 39 ea
   d. Foot Valves .... 14 ea
   e. Deck General Service/Monitor Stems .... 4 ea
   f. Compartment Vent Checks .... 28 ea
   g. Main Pump - Centrifuge, Electric VFD .... 2 ea x 8" 1500gpm self-priming
   h. Auxiliary Submersible Pump -Electric .... 2 ea x 6" 1000gpm
   i. Seachest – 10" SCH 80 .... 1ea x 30" x 36"

2.11 Accommodations

a. Future projects may dictate the need for portable modular accommodation units. Requirements will be project specific.

2.12 Regulatory

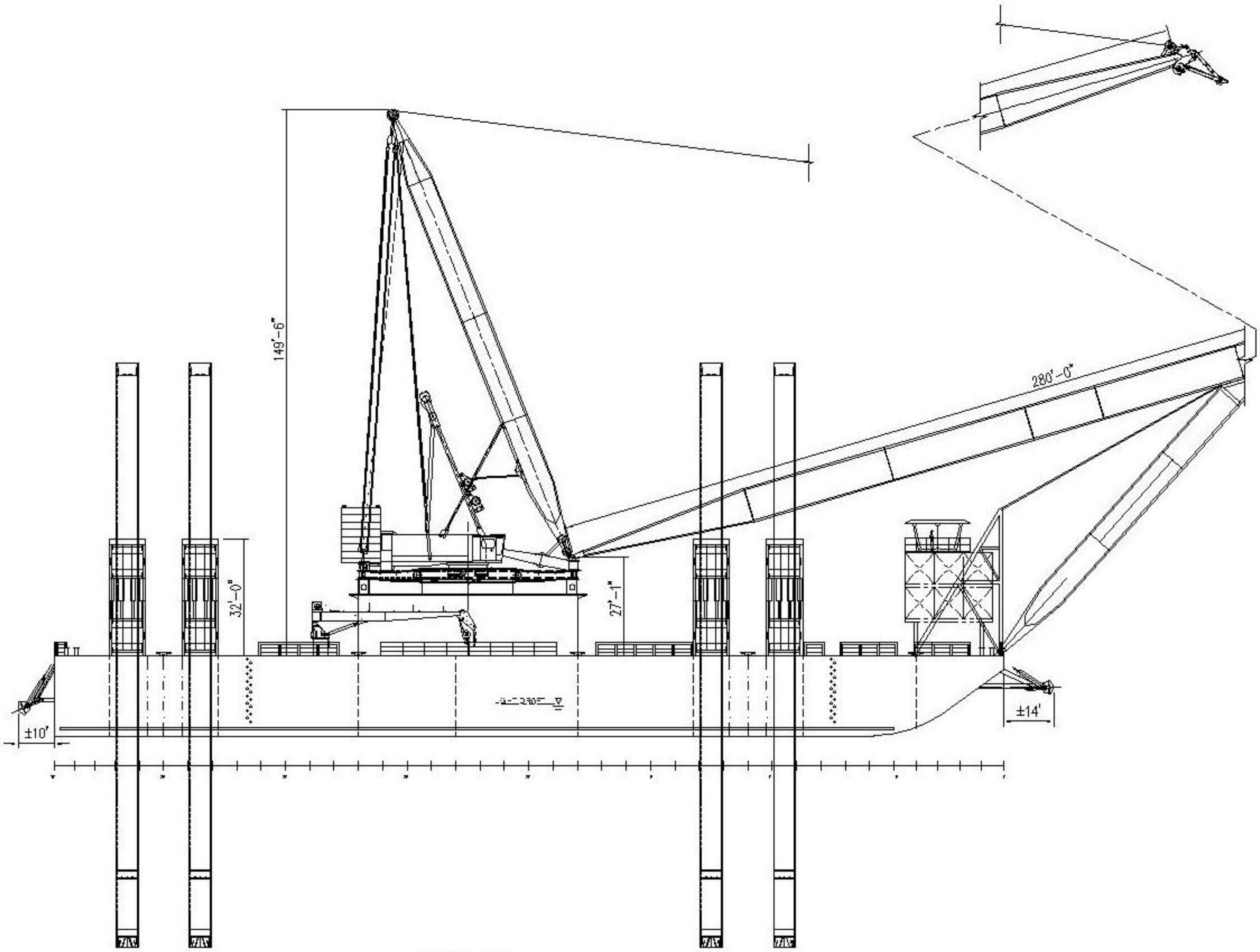
a. It is the desire of Weeks Marine that the vessel obtains full classification with American Bureau of shipping as: ABS +A1 SEU, Wind IMR, UWILD, with International Load Line.

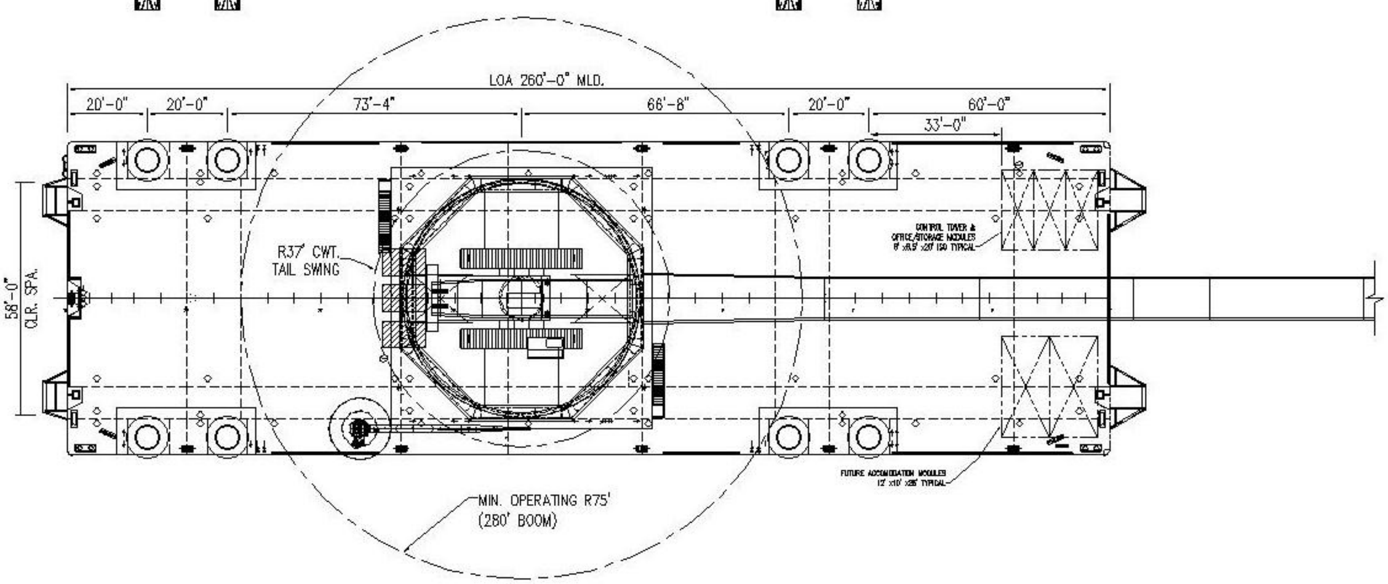
b. In order to satisfy Wind IMR class requirements any pedestal mounted cranes are required to be certified by ABS Guide for Certification of Lifting Appliances (CRC classed) or API Spec 2C for Offshore Pedestal Cranes as an equivalent. It is undetermined at this time if the Manitowoc S4 Ringer S3 will be considered mobile or permanent mounted by ABS. However, Weeks Marine recognizes there is an advantage to obtaining certification of the Manitowoc crane as it is likely to become a customer or project specific requirement in the Offshore Wind industry.

c. The table below lists all vessel certifications that have been identified to date which need to be in place for vessel operation:

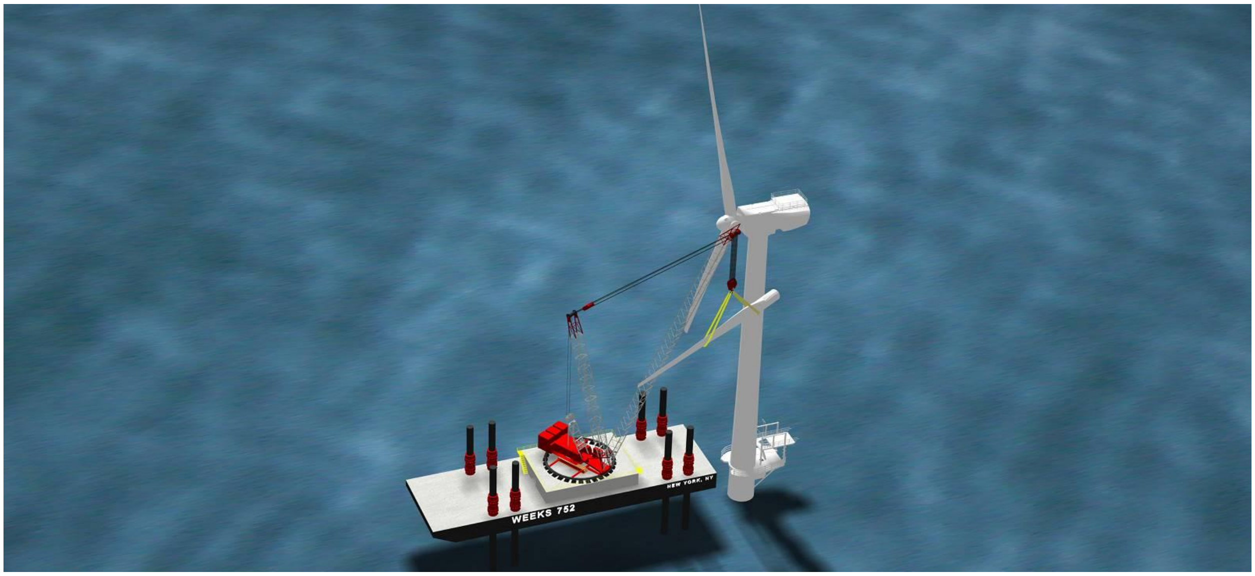
Agency	Certificate/Document	Designation	In Place
ABS	+A1 Self Elevating Unit	SEU	
ABS	Wind Turbine Install, Maintenance, and Repair	Wind IMR	
ABS	Under Water Inspection In Lieu of Drydocking	UWILD	
ABS	Cert. of Lifting Devices - Manitowoc 4600 Ringer	CRC	
API	API Specification 2C – Manitowoc 4600 Ringer	API Spec 2C	
API	API Specification 2C – EBI C30-40	API Spec 2C	Y
ABS	International Load Line	LL / LL11D	
USCG	Stability Letter	10-83	
ABS	International Tonnage	ITC	
USCG	Simplified Tonnage	CG-5397	Y
USCG	Certificate of Documentation	COD	Y
USCG	Certificate of Inspection	COI	
USCG	Certificate of Financial Responsibility	COFR	
USCG	International Oil Pollution Prevention	IOPP	
USCG	International Air Pollution Prevention	IAPP	
EPA	Engine International Air Pollution Prevention	EIAPP	
USCG	Shipboard Oil Pollution Emergency Plan	SOPEP	Y
USCG	Vessel Response Plan	VRP	
USCG	Vessel General Permit	VGP	
USCG	Vessel Security Plan	VSP	
FCC	Ship Radio License		Y
FCC	EPIRB Registration		

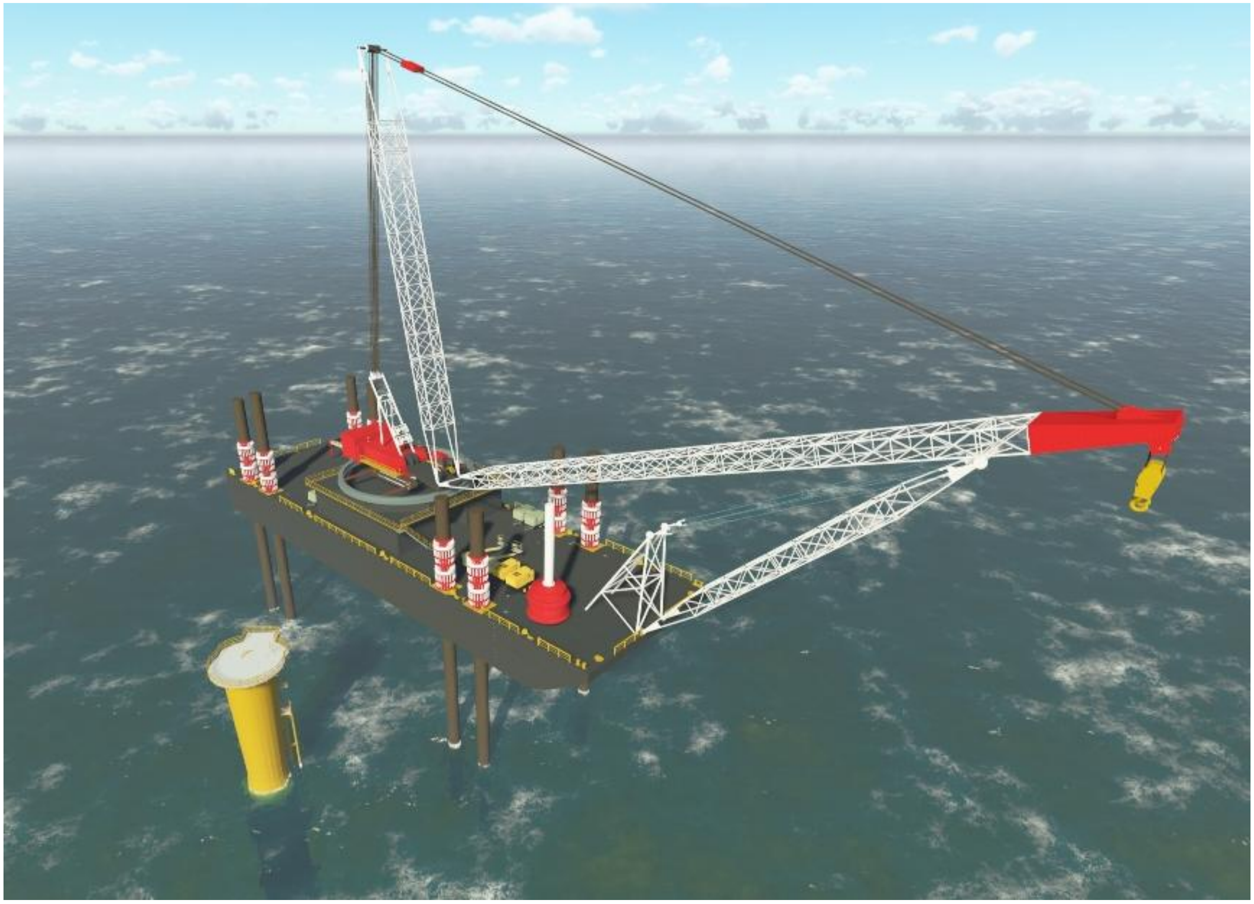
2.13 Starboard Outboard Profile and General Arrangement Views

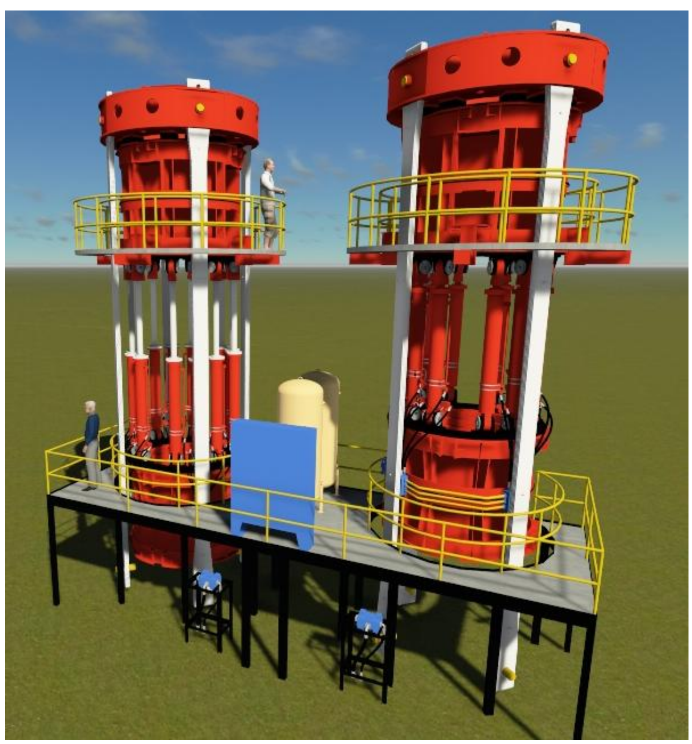




2.14 3D Rendering Isometric Views







MANITOWOC ENGINEERING CO.

Division of The Manitowoc Company, Inc. Manitowoc, Wisconsin 54220

LIFTCRANE CAPACITIES

MEETS ANSI B30.5 REQUIREMENTS

4600 SERIES 4
RINGER SERIES 3

BOOM NO. 65
60' RINGER ATTACHMENT ON BLOCKING OR PEDESTALS
123,000 LB. CRANE COUNTERWEIGHT
978,700 LB. AUXILIARY COUNTERWEIGHT
360 DEGREE RATING

CAPACITIES FOR VARIOUS BOOM LENGTHS AND OPERATING RADII ARE FOR FREELY SUSPENDED LOADS AND DO NOT EXCEED 75% OF A STATIC TIPPING LOAD. CAPACITIES BASED ON STRUCTURAL COMPETENCE ARE DENOTED BY AN ASTERISK (*).

UPPER BOOM POINT CAPACITIES FOR LIFTCRANE SERVICE WITH SINGLE PART WHIP LINE ARE 44,000 LBS. FOR 1-1/4" WIRE ROPE, 45,000 LBS. FOR 1-3/8" WIRE ROPE AND 50,000 LBS. FOR 1-1/2" OR 1-5/8" WIRE ROPE. CAPACITIES FOR TWO PART LINE ARE 88,000 LBS. FOR 1-1/4" WIRE ROPE, 90,000 LBS. FOR 1-3/8" WIRE ROPE AND 100,000 LBS. FOR 1-1/2" OR 1-5/8" WIRE ROPE. IN ALL CASES, UPPER BOOM POINT CAPACITIES CANNOT EXCEED THOSE LISTED FOR THE MAIN BOOM CAPACITY.

WEIGHT OF JIB, ALL LOAD BLOCKS, HOOKS, WEIGHT BALL, SLINGS, HOIST LINES, ETC., BENEATH BOOM AND JIB POINT SHEAVES, IS CONSIDERED PART OF THE MAIN BOOM LOAD. BOOM IS NOT TO BE LOWERED BEYOND RADII WHERE COMBINED WEIGHTS ARE GREATER THAN RATED CAPACITY. WHERE NO CAPACITY IS SHOWN, OPERATION IS NOT INTENDED OR APPROVED.

MACHINE TO OPERATE ON A FIRM UNIFORMLY SUPPORTING SURFACE WITH ROLLER PATH LEVEL WITHIN A TOLERANCE OF 1-1/4" IN 60' AND PROPERLY SUPPORTED. REFER TO RIGGING NO. 66184 AND WIRE ROPE SPECIFICATION CHART NO. 7307-A OR NO. 7357-A. CRANE OPERATOR JUDGMENT MUST BE USED TO ALLOW FOR DYNAMIC LOAD EFFECTS OF SWINGING, HOISTING OR LOWERING, WIND CONDITIONS, AS WELL AS ADVERSE OPERATING CONDITIONS AND PHYSICAL MACHINE DEPRECIATION.

OPERATING RADIUS IS THE HORIZONTAL DISTANCE FROM THE AXIS OF ROTATION TO THE CENTER OF VERTICAL HOIST LINE OR LOAD BLOCK. BOOM ANGLE IS THE ANGLE BETWEEN HORIZONTAL AND CENTERLINE OF BOOM BUTT AND INSERTS AND IS AN INDICATION OF OPERATING RADIUS. IN ALL CASES, OPERATING RADIUS SHALL GOVERN CAPACITY. BOOM POINT ELEVATION IS VERTICAL DISTANCE FROM GROUND LEVEL TO CENTERLINE OF BOOM POINT SHAFT.

MACHINE EQUIPPED WITH 60' RINGER ATTACHMENT, 30'5" CRAWLERS, 60" TREADS, 33' RETRACTABLE GANTRY, 130' MAST, 18 PART BOOM HOIST REEVING, EIGHT 1-3/8" BOOM PENDANTS, 123,000 LB. CRANE COUNTERWEIGHT (120,000 LBS. WITH COUNTERWEIGHT ASSEMBLY NO. 49667) AND 978,700 LB. AUXILIARY COUNTERWEIGHT.

MAXIMUM BOOM AND JIB LENGTHS LIFTED UNASSISTED		DEDUCT FROM CAPACITIES WHEN JIB IS ATTACHED	
BOOM LGTH.	JIB NO. 27AB	JIB LGTH.	JIB NO. 27AB
400'	---	80'	48,000 LBS.
380'	120'	100'	57,800 LBS.
LOAD BLOCK, HOOK AND WEIGHT BALL ON GROUND AT START.		120'	67,000 LBS.

WARNING: CHECK AMOUNT OF AUXILIARY COUNTERWEIGHT ON MACHINE BEFORE USE OF THIS CHART.

CONSULT JIB CHART FOR JIB CAPACITIES.

BOOM LGTH. FEET	OPER. RAD. FEET	BOOM ANG. DEG.	BOOM POINT ELEV. FEET	CAPACITY POUNDS
140	55	80.1	145.5	1,500,000*
	60	78.0	144.5	1,500,000*
	65	75.9	143.2	1,500,000*
	70	73.8	141.8	1,500,000*
	75	71.6	140.2	1,333,200
	80	69.5	138.3	1,198,700
	85	67.2	136.2	1,084,800*
	90	65.0	133.9	982,200*
	95	62.7	131.4	895,100*
	100	60.3	128.6	820,300*
	105	57.9	125.5	753,100*
	110	55.5	122.1	693,200*
	115	52.9	118.4	640,000*
	120	50.3	114.3	592,500*
	125	47.5	109.8	549,700*
	130	44.7	104.9	510,900*
	135	41.6	99.4	475,300*
	140	38.4	93.3	442,400*
	145	34.9	86.3	411,600*
	150	31.0	78.4	382,600*
	155	26.7	69.0	354,500*
	160	21.5	57.3	326,500*

BOOM LGTH. FEET	OPER. RAD. FEET	BOOM ANG. DEG.	BOOM POINT ELEV. FEET	CAPACITY POUNDS
180	60	80.7	185.2	1,500,000*
	65	79.1	184.3	1,500,000*
	70	77.5	183.2	1,492,700
	75	75.8	182.0	1,325,700
	80	74.2	180.6	1,191,200
	85	72.5	179.0	1,080,500
	90	70.8	177.3	988,000
	95	69.1	175.4	909,300
	100	67.4	173.3	841,700
	105	65.7	171.1	783,000
	110	63.9	168.7	731,400
	115	62.1	166.1	685,900
	120	60.3	163.2	645,300
	125	58.4	160.2	608,900
	130	56.5	156.9	576,200
	135	54.6	153.4	546,500
	140	52.6	149.6	513,600*
	145	50.5	145.6	483,200*
	150	48.4	141.2	455,300*
	155	46.2	136.5	429,600*
	160	43.9	131.4	405,700*
	165	41.6	125.8	382,300*
	170	39.1	119.8	359,400*
	175	36.4	113.2	337,900*
	180	33.6	105.9	317,400*
	185	30.6	97.7	297,900*
	190	27.2	88.4	278,900*
	195	23.4	77.5	260,100*
	200	18.8	64.2	241,000*

BOOM LGTH. FEET	OPER. RAD. FEET	BOOM ANG. DEG.	BOOM POINT ELEV. FEET	CAPACITY POUNDS
200	60	81.7	205.5	1,301,700*
	65	80.2	204.7	1,301,700*
	70	78.7	203.7	1,281,600*
	75	77.3	202.6	1,248,100*
	80	75.8	201.3	1,188,400
	85	74.3	199.9	1,077,800
	90	72.8	198.4	985,200
	95	71.3	196.7	906,500
	100	69.8	194.9	838,900
	105	68.2	192.9	780,200
	110	66.7	190.8	728,600
	115	65.1	188.5	683,100
	120	63.5	186.0	642,500
	125	61.9	183.4	606,100
	130	60.2	180.6	573,300
	135	58.6	177.5	543,600
	140	56.9	174.3	516,600
	145	55.1	170.9	491,900
	150	53.3	167.2	469,200
	155	51.5	163.2	448,300
	160	49.7	159.1	425,400*
	165	47.7	154.6	402,600*
	170	45.7	149.8	381,400*
	175	43.7	144.6	361,600*
	180	41.6	139.1	343,000*
	185	39.3	133.1	325,500*
	190	37.0	126.6	308,100*
	195	34.5	119.5	290,600*
	200	31.8	111.7	273,700*
	205	28.9	102.9	257,500*
	210	25.8	93.0	241,600*
	215	22.1	81.5	225,800*
	220	17.8	67.3	209,500*

SN: 10335

MANITOWOC ENGINEERING CO.

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Manitowoc

LIFTCRANE CAPACITIES

MEETS ANSI B30.5 REQUIREMENTS

4600 SERIES 4
RINGER SERIES 3

BOOM NO. 65
60' RINGER ATTACHMENT ON BLOCKING OR PEDESTALS
123,000 LB. CRANE COUNTERWEIGHT
978,700 LB. AUXILIARY COUNTERWEIGHT
360 DEGREE RATING

BOOM LGTH. FEET	OPER. RAD. FEET	BOOM ANG. DEG.	BOOM POINT ELEV. FEET	CAPACITY POUNDS
220	65	81.1	225.0	1,138,000*
	70	79.8	224.1	1,110,500*
	75	78.5	223.1	1,083,900*
	80	77.1	221.9	1,058,300*
	85	75.8	220.7	1,033,500*
	90	74.4	219.3	982,600
	95	73.1	217.8	904,000
	100	71.7	216.2	836,300
	105	70.3	214.4	777,600
	110	68.9	212.5	726,100
	115	67.5	210.4	680,500
	120	66.1	208.2	639,900
	125	64.6	205.9	603,500
	130	63.2	203.4	570,800
	135	61.7	200.7	541,100
	140	60.2	197.9	514,000
	145	58.7	194.9	489,300
	150	57.2	191.7	466,700
	155	55.6	188.3	445,800
	160	54.0	184.7	426,500
	165	52.3	180.9	408,600
	170	50.7	176.8	392,000
	175	48.9	172.5	376,500
	180	47.2	167.9	358,500*
	185	45.4	163.1	340,700*
	190	43.5	157.9	324,000*
	195	41.5	152.3	308,300*
	200	39.5	146.3	293,400*
	205	37.4	139.9	279,200*
	210	35.2	133.0	265,700*
	215	32.8	125.4	251,800*
	220	30.3	117.1	237,700*
	225	27.5	107.9	223,900*
	230	24.5	97.4	210,400*
	235	21.1	85.2	196,900*
	240	17.0	70.2	182,800*
240	65	81.9	245.2	1,009,900*
	70	80.6	244.4	992,400*
	75	79.4	243.5	975,000*
	80	78.2	242.4	957,700*
	85	77.0	241.3	940,700*
	90	75.8	240.0	924,000*
	95	74.5	238.7	901,500
	100	73.3	237.2	833,800
	105	72.0	235.6	775,100
	110	70.8	233.8	723,500
	115	69.5	232.0	678,000
	120	68.2	230.0	637,400
	125	66.9	227.9	601,000
	130	65.6	225.6	568,200
	135	64.3	223.2	538,500
	140	62.9	220.7	511,500
	145	61.6	218.0	486,800
	150	60.2	215.2	464,100
	155	58.8	212.2	443,200
	160	57.4	209.0	424,000
	165	56.0	205.7	406,100
	170	54.5	202.1	389,500
	175	53.0	198.4	374,000
	180	51.5	194.5	359,500
	185	49.9	190.3	346,000
	190	48.3	185.9	333,300
	195	46.7	181.3	320,000*
	200	45.0	176.3	305,000*
	205	43.3	171.1	290,700*
	210	41.5	165.5	277,200*
	215	39.7	159.6	264,400*
	220	37.7	153.3	252,200*
	225	35.7	146.4	240,500*
	230	33.6	139.1	229,300*
	235	31.4	131.1	218,300*
	240	28.9	122.3	206,300*
	245	26.3	112.5	194,600*
	250	23.4	101.5	182,900*
	255	20.1	88.7	171,200*
	260	16.2	73.1	158,900*
260	70	81.4	264.7	862,800*
	75	80.3	263.8	848,600*
	80	79.1	262.9	834,500*
	85	78.0	261.8	820,400*
	90	76.9	260.7	806,400*
	95	75.7	259.4	792,700*
	100	74.6	258.0	779,100*
	105	73.4	256.6	765,600*
	110	72.3	255.0	720,900
	115	71.1	253.3	675,300
	120	70.0	251.5	634,700
	125	68.8	249.6	598,400
	130	67.6	247.5	565,600
	135	66.4	245.3	535,900
	140	65.2	243.0	508,900
	145	63.9	240.6	484,200
	150	62.7	238.1	461,500
	155	61.5	235.4	440,600
	160	60.2	232.5	421,300
	165	58.9	229.5	403,400
	170	57.6	226.4	386,800
	175	56.3	223.1	371,300
	180	54.9	219.6	356,900
	185	53.6	215.9	343,400
	190	52.2	212.1	330,700
	195	50.8	208.0	318,700
	200	49.3	203.8	307,500
	205	47.8	199.3	296,900
	210	46.3	194.6	286,900
	215	44.8	189.6	274,400*
	220	43.2	184.3	262,100*
	225	41.5	178.8	250,300*
	230	39.8	172.8	239,200*
260	235	38.0	166.6	228,500*
	240	36.2	159.8	218,300*
	245	34.3	152.7	208,400*
	250	32.2	144.9	198,900*
	255	30.1	136.5	189,700*
	260	27.8	127.3	179,900*
	265	25.3	117.0	169,700*
	270	22.5	105.5	159,600*
	275	19.3	92.1	149,300*
	280	15.6	75.8	138,400*
280	70	82.0	284.9	759,800*
	75	81.0	284.1	748,200*
	80	79.9	283.2	736,500*
	85	78.9	282.3	724,700*
	90	77.8	281.2	713,000*
	95	76.8	280.0	701,300*
	100	75.7	278.8	689,700*
	105	74.7	277.4	678,200*
	110	73.6	276.0	666,800*
	115	72.5	274.4	655,500*
	120	71.4	272.7	632,000
	125	70.4	271.0	595,600
	130	69.3	269.1	562,900
	135	68.2	267.1	533,200
	140	67.1	265.0	506,100
	145	65.9	262.8	481,400
	150	64.8	260.4	458,700
	155	63.7	258.0	437,900
	160	62.5	255.4	418,600
	165	61.4	252.7	400,700
	170	60.2	249.8	384,100
	175	59.0	246.8	368,600
	180	57.8	243.7	354,200
	185	56.6	240.4	340,600
	190	55.3	237.0	327,900
	195	54.1	233.4	316,000
	200	52.8	229.6	304,800
	205	51.5	225.7	294,200
	210	50.1	221.6	284,200
	215	48.8	217.2	274,700
	220	47.4	212.7	265,700
	225	46.0	207.9	257,200
	230	44.5	202.9	247,200*
	235	43.0	197.6	236,500*
	240	41.5	192.0	226,200*
	245	39.9	186.1	216,400*
	250	38.3	179.9	206,900*
	255	36.6	173.2	197,900*
	260	34.8	166.2	189,200*
	265	33.0	158.6	180,800*
	270	31.0	150.5	172,600*
	275	28.9	141.7	164,700*
	280	26.7	132.0	156,700*
	285	24.3	121.4	147,700*
	290	21.6	109.3	138,800*
	295	18.6	95.4	129,600*

CHART NO. 7300-A, 10-19-89/GA

MANITOWOC ENGINEERING CO.
Division of The Manitowoc Company, Inc. Manitowoc, Wisconsin 54220

LIFTCRANE CAPACITIES — 4600 SERIES 4 RINGER SERIES 3

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BOOM NO. 65
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123,000 LB. CRANE COUNTERWEIGHT
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360 DEGREE RATING

BOOM LGTH. FEET	OPER. RAD. FEET	BOOM ANG. DEG.	BOOM POINT ELEV. FEET	CAPACITY POUNDS
300	75	81.6	304.4	653,500*
	80	80.6	303.6	643,900*
	85	79.6	302.6	634,100*
	90	78.7	301.7	624,200*
	95	77.7	300.6	614,300*
	100	76.7	299.4	604,400*
	105	75.7	298.1	594,600*
	110	74.7	296.8	584,800*
	115	73.7	295.3	575,000*
	120	72.7	293.8	565,300*
	125	71.7	292.1	555,700*
	130	70.7	290.4	546,200*
	135	69.7	288.6	530,100
	140	68.7	286.6	503,100
	145	67.6	284.6	478,400
	150	66.6	282.4	455,700
	155	65.5	280.2	434,800
	160	64.5	277.8	415,500
	165	63.4	275.3	397,600
	170	62.3	272.7	381,000
	175	61.3	270.0	365,600
	180	60.2	267.2	351,100
	185	59.1	264.2	337,600
	190	57.9	261.1	324,900
	195	56.8	257.8	313,000
	200	55.6	254.4	301,700
	205	54.5	250.9	291,100
	210	53.3	247.2	281,100
	215	52.1	243.3	271,600
	220	50.8	239.3	262,600
	225	49.6	235.0	254,100
	230	48.3	230.6	246,000
	235	47.0	226.0	238,300
	240	45.7	221.2	231,000
	245	44.3	216.1	222,500*
	250	42.9	210.8	213,000*
	255	41.5	205.2	203,900*
	260	40.0	199.3	195,200*
	265	38.5	193.1	186,900*
	270	36.9	186.6	178,800*
	275	35.3	179.6	171,000*
	280	33.6	172.2	163,500*
	285	31.8	164.3	156,200*
	290	29.9	155.8	149,200*
	295	27.9	146.7	142,200*
	300	25.8	136.6	135,400*
	305	23.5	125.5	127,700*
	310	20.9	113.0	119,800*
	315	18.0	98.5	111,600*
320	80	81.2	323.8	567,200*
	85	80.3	323.0	559,000*
	90	79.4	322.1	550,700*
	95	78.5	321.0	542,300*
	100	77.5	319.9	533,900*
	105	76.6	318.8	525,400*
	110	75.7	317.5	517,000*
	115	74.8	316.1	508,500*
	120	73.8	314.7	500,100*
	125	72.9	313.2	491,700*
	130	72.0	311.6	483,300*
	135	71.0	309.9	475,000*
	140	70.1	308.1	466,800*
	145	69.1	306.2	458,600*
	150	68.1	304.2	450,500*
	155	67.2	302.1	432,400
	160	66.2	299.9	413,100
	165	65.2	297.6	395,300
	170	64.2	295.2	378,600
	175	63.2	292.7	363,200
	180	62.2	290.1	348,700
	185	61.2	287.3	335,200
	190	60.2	284.5	322,500
	195	59.1	281.5	310,600
	200	58.1	278.4	299,300
	205	57.0	275.2	288,700
	210	55.9	271.8	278,700
	215	54.8	268.3	269,200
	220	53.7	264.7	260,300
	225	52.6	260.9	251,700
	230	51.4	256.9	243,600
	235	50.3	252.8	235,900
	240	49.1	248.5	228,600
	245	47.9	244.0	221,600
	250	46.7	239.4	214,900
	255	45.4	234.5	208,500
	260	44.1	229.4	201,100*
	265	42.8	224.0	192,700*
	270	41.5	218.4	184,600*
	275	40.1	212.6	176,800*
	280	38.7	206.4	169,300*
	285	37.2	199.9	162,100*
	290	35.7	193.1	155,100*
	295	34.1	185.8	148,400*
	300	32.5	178.1	141,800*
	305	30.8	169.9	135,400*
	310	28.9	161.0	129,200*
	315	27.0	151.5	123,100*
	320	24.9	141.0	117,100*
	325	22.7	129.5	110,600*
	330	20.2	116.6	103,400*
	335	17.4	101.6	96,100*
340	80	81.7	344.1	508,800*
	85	80.9	343.3	501,700*
	90	80.0	342.4	494,500*
	95	79.1	341.5	487,100*
	100	78.3	340.4	479,700*
	105	77.4	339.3	472,100*
	110	76.6	338.1	464,500*
	115	75.7	336.9	456,900*
	120	74.8	335.5	449,300*
	125	73.9	334.1	441,700*
	130	73.1	332.6	434,100*
	135	72.2	331.0	426,500*
	140	71.3	329.3	419,000*
	145	70.4	327.5	411,500*
	150	69.5	325.7	404,000*
	155	68.6	323.7	396,600*
	160	67.7	321.7	389,300*
	165	66.8	319.5	382,100*
	170	65.8	317.3	374,900*
	175	64.9	315.0	360,000
	180	64.0	312.6	345,600
	185	63.0	310.0	332,100
	190	62.1	307.4	319,400
	195	61.1	304.6	307,400
	200	60.1	301.8	296,200
	205	59.2	298.8	285,600
	210	58.2	295.7	275,600
	215	57.2	292.5	266,100
	220	56.2	289.2	257,100
	225	55.1	285.7	248,600
	230	54.1	282.1	240,500
	235	53.0	278.4	232,800
	240	52.0	274.5	225,500
	245	50.9	270.5	218,400
	250	49.8	266.3	211,800
	255	48.7	261.9	205,400
	260	47.5	257.4	199,200
	265	46.4	252.7	193,400
	270	45.2	247.8	187,800
	275	44.0	242.6	180,600*
	280	42.8	237.3	173,100*
	285	41.5	231.7	165,800*
	290	40.2	225.8	158,800*
	295	38.9	219.7	152,100*
	300	37.5	213.3	145,600*
	305	36.1	206.5	139,300*
	310	34.6	199.3	133,200*
	315	33.1	191.8	127,300*
	320	31.5	183.8	121,500*
	325	29.8	175.2	115,900*
	330	28.1	166.0	110,300*
	335	26.2	156.1	104,900*
	340	24.2	145.3	99,500*
	345	22.0	133.4	94,000*
	350	19.6	120.0	87,600*
	355	16.8	104.5	80,900*
360	90	80.6	362.7	434,300*
	95	79.8	361.8	428,000*
	100	78.9	360.9	421,700*
	105	78.1	359.8	415,200*
	110	77.3	358.7	408,700*
	115	76.5	357.5	402,100*
	120	75.7	356.2	395,400*
	125	74.9	354.9	388,800*
	130	74.0	353.5	382,100*
	135	73.2	352.0	375,400*
	140	72.4	350.4	368,800*
	145	71.5	348.7	362,100*
	150	70.7	347.0	355,500*
	155	69.8	345.2	348,800*
	160	69.0	343.2	341,800*
	165	68.1	341.2	334,900*
	170	67.3	339.2	328,100*
	175	66.4	337.0	321,300*
	180	65.5	334.7	314,600*
	185	64.6	332.4	308,000*
	190	63.8	329.9	301,400*
	195	62.9	327.4	294,900*
	200	62.0	324.7	288,500*
	205	61.1	322.0	282,100*
	210	60.1	319.1	273,100
	215	59.2	316.1	263,700
	220	58.3	313.1	254,700
	225	57.3	309.9	246,200
	230	56.4	306.6	238,100
	235	55.4	303.2	230,300
	240	54.4	299.6	223,000
	245	53.4	295.9	216,000
	250	52.4	292.1	209,300
	255	51.4	288.1	202,900
	260	50.4	284.0	196,800
	265	49.4	279.8	190,900
	270	48.3	275.4	185,300
	275	47.2	270.8	179,900
	280	46.1	266.0	174,800
	285	45.0	261.0	169,800
	290	43.9	255.9	162,800*
	295	42.7	250.5	156,000*
	300	41.5	244.9	149,500*
	305	40.3	239.1	143,100*
	310	39.0	233.0	137,000*
	315	37.7	226.6	131,200*
	320	36.4	219.9	125,400*
	325	35.0	212.8	119,900*
	330	33.6	205.4	114,500*
	335	32.1	197.6	107,900*
	340	30.6	189.3	95,900*
	345	28.9	180.4	84,100*
	350	27.2	170.9	72,300*
	355	25.4	160.7	60,700*

CHART NO. 7300-A, 10-19-89/GA

SN: 10335

MANITOWOC ENGINEERING CO.

Division of The Manitowoc Company, Inc. Manitowoc, Wisconsin 54220

LIFTCRANE CAPACITIES

MEETS ANSI B30.5 REQUIREMENTS

4600 SERIES 4
RINGER SERIES 3

BOOM NO. 65
60' RINGER ATTACHMENT ON BLOCKING OR PEDESTALS
123,000 LB. CRANE COUNTERWEIGHT
978,700 LB. AUXILIARY COUNTERWEIGHT
360 DEGREE RATING

BOOM LGTH. FEET	OPER. RAD. FEET	BOOM ANG. DEG.	BOOM POINT ELEV. FEET	CAPACITY POUNDS
380	95	80.3	382.1	385,100*
	100	79.5	381.2	379,500*
	105	78.8	380.2	373,700*
	110	78.0	379.2	367,800*
	115	77.2	378.1	361,800*
	120	76.4	376.9	355,800*
	125	75.7	375.6	349,700*
	130	74.9	374.3	343,600*
	135	74.1	372.8	337,400*
	140	73.3	371.3	331,300*
	145	72.5	369.8	325,100*
	150	71.7	368.1	318,800*
	155	70.9	366.4	312,500*
	160	70.1	364.6	306,200*
	165	69.3	362.8	299,900*
	170	68.5	360.8	293,600*
	175	67.7	358.8	287,200*
	180	66.9	356.6	281,000*
	185	66.1	354.4	274,700*
	190	65.2	352.1	268,600*
	195	64.4	349.7	262,400*
	200	63.6	347.3	256,300*
	205	62.7	344.7	250,100*
	210	61.9	342.0	244,100*
	215	61.0	339.3	238,100*
	220	60.1	336.4	232,300*
	225	59.3	333.5	226,400*
	230	58.4	330.4	220,700*
	235	57.5	327.2	215,000*
	240	56.6	324.0	209,300*
	245	55.7	320.6	203,600*
	250	54.7	317.0	198,000*
	255	53.8	313.4	192,500*
	260	52.9	309.6	187,100*
	265	51.9	305.8	181,700*
	270	50.9	301.7	176,400*
	275	50.0	297.6	171,100*
	280	49.0	293.2	166,000*
	285	48.0	288.8	160,800*
	290	46.9	284.1	155,700*
	295	45.9	279.3	150,700*
	300	44.8	274.3	145,700*
	305	43.7	269.1	140,700*
	310	42.6	263.7	133,100*
	315	41.5	258.1	121,800*
	320	40.3	252.3	110,600*
	325	39.1	246.2	99,600*
	330	37.9	239.9	88,600*
	335	36.7	233.2	77,800*
	340	35.4	226.3	67,100*
	345	34.0	219.0	56,500*

BOOM LGTH. FEET	OPER. RAD. FEET	BOOM ANG. DEG.	BOOM POINT ELEV. FEET	CAPACITY POUNDS
400	95	80.8	402.4	333,800*
	100	80.1	401.6	329,100*
	105	79.3	400.6	324,300*
	110	78.6	399.6	319,300*
	115	77.9	398.6	314,000*
	120	77.1	397.4	308,400*
	125	76.4	396.2	302,700*
	130	75.7	395.0	296,900*
	135	74.9	393.6	291,200*
	140	74.2	392.2	285,400*
	145	73.4	390.7	279,600*
	150	72.7	389.2	273,800*
	155	71.9	387.6	268,000*
	160	71.2	385.9	262,200*
	165	70.4	384.1	256,400*
	170	69.6	382.2	250,600*
	175	68.9	380.3	244,800*
	180	68.1	378.3	239,000*
	185	67.3	376.2	233,300*
	190	66.6	374.1	227,700*
	195	65.8	371.8	222,000*
	200	65.0	369.5	216,300*
	205	64.2	367.1	210,800*
	210	63.4	364.6	205,200*
	215	62.6	362.0	199,800*
	220	61.8	359.4	194,400*
	225	60.9	356.6	189,100*
	230	60.1	353.8	183,800*
	235	59.3	350.8	178,500*
	240	58.5	347.7	173,300*
	245	57.6	344.6	168,200*
	250	56.7	341.3	163,100*
	255	55.9	338.0	158,100*
	260	55.0	334.5	153,100*
	265	54.1	330.9	148,200*
	270	53.2	327.2	143,400*
	275	52.3	323.3	138,600*
	280	51.4	319.4	133,900*
	285	50.5	315.3	129,200*
	290	49.6	311.0	124,600*
	295	48.6	306.7	120,100*
	300	47.6	302.1	113,700*
	305	46.7	297.4	103,600*
	310	45.7	292.6	93,700*
	315	44.6	287.6	83,800*
	320	43.6	282.4	74,100*
	325	42.6	277.0	64,400*
	330	41.5	271.4	54,800*

Attachment E

Weeks Marine and McNally Construction – Selective Marine

Equipment listing

ATTACHMENT E

REPRESENTATIVE LIST OF MAJOR MARINE EQUIPMENT

VESSEL NO.	HULL DIMENSIONS (FEET)	CAPACITY	BOOM	DESCRIPTION
		DERRICK / CRANE BARGES (TYPICAL OF 34)		
508	120 x 60 x 10	100T @ 50'	148'	Diesel Dravo 28 w/36" spuds
521	100 x 50 x 7.5	60T @ 60'	140'	Diesel American Whirley
510, 511	100 x 52 x 9.5	80T @ 35'	120'	Clyde Model 24 Diesel w/hydraulic anchor winch & fairleads
547	240 x 72 x 16.4	100T @ 70'	150'	American R30 w/ 6 point mooring
541	200.5 x 59.6 x 13	110T @ 45'	163'	Clyde Model 32 Diesel w/ winches 7 4 point mooring 36" spuds
524, 529, 535, 536	250 x 64 x 12	155T @ 43'	120'	Clyde Model 28 Diesel Gantry
526	292.5 x 80 x 19	350T @ 80'	220'	American M40 w/ 4 two-drum RB-97 winches and fairleads
532	300 x 90 x 19	350T @ 80'	220'	American M40 w/ 3 two-drum RB-90 winches and fairleads 150 man crew quarters
533	300 x 90 x 22	500T @ 70'	210/290'	Clyde Model 52-DE w/ 2 ea. 3 drum & 1 ea. 2 drum RB-90 winches and fairleads, 3 spuds
566, 568, 569	140 x 70 x 12.5'	100T @ 80'	up to 200'	Diesel Dravo 36 w/36" spuds
545	160 x 52 x 12.0	70T @ 60'	110'	Clyde Model 32 w/36" spuds
		JACK-UP BARGES		
750	139.5 x 80 x 10	2600T Jack Cap. 200T @ 50’	200'	4100-W Ringer Crane Varco hydraulic jacks w/ 4-6” ɸ x 120’ legs, 4 drum anchor winch, loadline
751	130 x 58 x 10	2000T Jack Cap. 80T @ 50’	148'	Diesel Dravo 28 Delong pneumatic jacks w/ 4 ea. - 71"ɸ x 120' legs; 4 point anchor spread w/ winches and fairleads

Revised: 05/16/2021

REPRESENTATIVE LIST OF
MAJOR MARINE EQUIPMENT

VESSEL NO.	HULL DIMENSIONS (FEET)	CAPACITY	BOOM	DESCRIPTION
		ABS LOADLINE BARGES (TYPICAL OF 24)		
262	160 x 50 x 7.6	1100 S.T. @ 6.6’		Flat, step deck raked bow, square stern 3 spuds, 4 point anchor spread
240	165 x 42.5 x 11	1450 S.T. @ 9.25’		Flat deck, double raked w/ skegs, matted deck, wood rails
241	166 x 42.5 x 11	1450 S.T. @ 9.25’		Flat deck, double raked w/ skegs, matted deck, wood rails
266	160 x 54 x 12.5	1600 S.T. @ 8.25’		Flat deck, double raked w/ skegs and stanchions
267	161 x 54 x 12.5	1600 S.T. @ 8.25’		Flat deck, double raked w/ skegs and stanchions
244	150 x 54.3 x 13	1850 S.T. @ 10.5’		Flat deck, double raked, armor plate sides
290	180 x 54 x 14	2770 S.T. @ 11.5’		Flat deck, raked bow, square stern w/ stanchions
291	181 x 54 x 14	2770 S.T. @ 11.5’		Flat deck, raked bow, square stern w/ stanchions
294	182 x 54 x 14	2770 S.T. @ 11.5’		Flat deck, raked bow, square stern w/ stanchions
298	183 x 54 x 14	2770 S.T. @ 11.5’		Flat deck, raked bow, square stern w/ stanchions
246	250 x 75 x 16	5500 S.T. @ 12.6’		Flat deck, double raked w/ skegs and stanchions Launch barge construction
297	250 x 75 x 16	5500 S.T. @ 12.6’		Flat deck, double raked w/ skegs and stanchions Launch barge construction
2701	340 x 78 x 19	8400 S.T.		Long stern bow, stern rake, w/ skegs large wave break bulkhead forward 7’ high bin wall w/ removable side and stern sections, 5/8” steel wear deck
2702	340 x 78 x 19	8400 S.T.		Long stern bow, stern rake, w/ skegs

Revised: 05/16/2021

REPRESENTATIVE LIST OF
MAJOR MARINE EQUIPMENT

VESSEL NO.	HULL DIMENSIONS (FEET)	CAPACITY	BOOM	DESCRIPTION
TUGS AND WORK BOATS (TYPICAL OF 66)				
410	Elizabeth 83 x 26 x 10.8			Tug - Twin Screw 1800 HP
412	Alexandra 126 x 34 x 14.6			Tug -·Twin Screw 4000 HP
413	Thomas 126 x 34 x 14.6			Tug - Twin Screw 4000 HP
414	Katherine 105 x 32.0 x 15.3			Tug - Twin Screw 3000 HP
433	Marty C 43.7 x 16 x 7.6			Tug - Twin Screw 500 HP
416	Gerard D 60.2 x 23 x 8.9			Tug - Twin Screw 800 HP
418	Kathleen 62.0 x 24.0 x 9.1			Tug - Twin Screw 1000 HP
424	Olivia 52.3 x 15.5 x 7.1			Crew Boat - Twin Screw
SMALL DECK BARGES (TYPICAL OF 98)				
165	165 x 38.4 x 9			w/ spuds
237	133.3 x 40 x 10.7			w/ rails
272	330 x 40 x 11.5			Carfloat w/ spuds
SPLIT HULL DUMP SCOWS (TYPICAL OF 9)				
260, 261	198.6 x 45 x 16	2000 CY		Dump scow
254, 255	234 x 53 x 23	4000 CY		Dump scow
257, 264	286 x 62 x 27.5	6600 CY		Dump scow

REPRESENTATIVE LIST OF
MAJOR MARINE EQUIPMENT

VESSEL NO.	HULL DIMENSIONS (FEET)	CAPACITY	BOOM	DESCRIPTION
HOPPER BARGES (TYPICAL OF 20)				
285	145 x 38 x 17.5	2000 Tons		Hopper barge; single side
286	146 x 38 x 17.5	2000 Tons		Hopper barge; double side
284	200 x 40 x 17.4	3000 Tons		Hopper barge; single side
100	260 x 52.5 x 12	3000 Tons		Hopper barge; double side
PUMP OUT BARGES				
110	300 x 62 x 23	7800 CY		Hopper barge w/ slope sheets, loadline
111	300 x 62 x 23	7800 CY		Hopper barge w/ slope sheets, loadline
112	300 x 62 x 23	7800 CY		Hopper barge w/ slope sheets, loadline
113	300 x 62 x 23	7800 CY		Hopper barge w/ slope sheets, loadline
HYDRAULIC DREDGES (TYPICAL OF 10)				
302	160 x 41 x 10	30"		*Weeks Venture*
308	280 x 65 x 17.5	30"		*R.S. Weeks*
310	156.1 x 42.6 x 9.7	24"		*Borinquen*
BTD 100	186 x 48 x 12	30"		*Capt. Frank*
BTD 110	186 x 48 x 12	30"		*G.D. Morgan*
SELF PROPELLED HOPPER DREDGES				
450	294 x 54 x 22.3	4000 CY		*R. N. Weeks*
456	294 x 55 x 22.3	4000 CY		*B. E. Lindholm*

Revised: 05/16/2021

Weeks Marine, Inc.

REPRESENTATIVE LIST OF

MAJOR MARINE EQUIPMENT

VESSEL NO.	HULL DIMENSIONS (FEET)	CAPACITY	BOOM	DESCRIPTION
BUCKET DREDGES				
500	120 x 54 x 10	15 CY		Diesel Clyde 6 w/ drum hydraulic winch and 6 fairleads, 2 ea. 36" round spuds
506	158.6 x 60 x 11.5	32 CY		Marion 195 w/ 3 ea. 48" sq pinup spuds, w/ winches and scow winch, loadline
544	160 x 65 x 12	15 CY		Clyde Model 32 Diesel 4 point mooring system, loadline
549	130 x 50 x 10	14 CY		Clyde Model 28 w/ 3 ea. 36" sq spuds, side spuds are pinup, w/ winches and scow winch
550	155 x 60 x 11.8	26 CY		w/ 3 ea. 48" sq pinup spuds w/ winches and scow winch
551	155 x 60 x 11.8	26 CY		w/ 3 ea. 48" sq pinup spuds w/ winches and scow winch

Revised: 05/16/2021

Weeks Marine, Inc.