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Appendix E Marina Design

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1. Introduction

This Appendix provides the design methodology for expanding and reconfiguring the Royal Vancouver Yacht Club (RVYC) marina in Coal Harbour, Vancouver, BC.

The information in this Appendix expands on the notes on Drawing CV-203.

2. Project Description

The full project description is provided in the companion document “Coal Harbour Marina Expansion: Project Description”.

The marina expansion utilizes 9,040 m^2 (0.904 hectares or 2.234 acres) of additional water lot area as shown on Drawing CV-201, which is accomplished by extending the east and west corners of the water lot by 34.3 m and 36.4 m, respectively, as shown on Drawing CV-203. The extensions were provided by the Vancouver Fraser Port Authority (port authority) on November 9, 2018, and then in digital format to UTM coordinates on June 10, 2019 in the file “Channel - Coal Harbour - Final - 2019.dwg”.

3. Level of Design

The level of design conducted to date is considered preliminary, and a conservative approach is followed. The focus at this stage of design is on developing a marina that takes advantage of the additional water lot area, and places the larger boats along the outside of the marina where they do not have to navigate fairways, and where they provide protection to the smaller boats and fairways in the interior of the marina.

A geotechnical investigation is recommended for the next stage of design to refine pile sizes and lengths. The pile sizes and lengths shown on Drawing CV-304 have been developed using the pile fixity method in “Design of Marine Facilities for the Berthing, Mooring and Repair of Vessels”, 2nd edition, by J.W. Gaythwaite, 2004. A conservative assumption of medium dense sand was used, whereas stiffer soils, underlain by soft surface sediments, is expected in some area based on past pile driving experience, and which may result in shorter piles.

4. Design Criteria

4.1. Surveys

The existing property and lease lines are from the port authority, drawing "Lease Plan No. 2003-087", Dated October 7, 2003. The port authority provided a digital map of the navigation channel in UTM coordinates on June 10, 2019 in the file “Channel - Coal Harbour - Final - 2019.dwg”.

Seabed bathymetry is based on two surveys:

- Bathymetry in the area of the marina expansion and reconfiguration is provided in Figure 3, dated February 2018, in the report entitled "Marine Seismic Refraction, Bathymetry and Sub-Bottom Acoustic Profiling Survey Report, RVYC Coal Harbour Marina Reconfiguration, Vancouver, BC", March 2, 2018, by Frontier Geosciences Inc.
- Bathymetry north of N and M floats and east of B float is from Westmar Consultants Ltd. drawing "Pre-Dredge Survey Conditions", Project No. 02853, 2005.

The depth to bedrock is provided in Figure 4 of the Frontier Geosciences Inc. report of March 2, 2018, and it is noted in their report that the depth is interpretive and is accurate to plus or minus 15% and may not pick up boulders and narrow canyons in the bedrock. Areas of varying compressional (P) sonic wave velocity in the sediments overlying bedrock, from 1680 m/s to 1900 m/s are provided in Figure 6 to 12. The slower velocity of 1680 m/s is present over the middle of the survey area, with higher velocities of 1900 m/s observed on the southeast, south and northwest edge of the survey area. Higher velocities are indicative of an increase in compaction or density of the sediments.

A series of boreholes or test piles would better define where glacial till and softer sediments will be encountered when driving piles, and areas where drilling into bedrock may be required. Pile driving experience indicates that soils vary from bedrock, possibly including coal seams, where drilling is required, and glacial till where hard driving is encountered, will likely be experienced in the marina, and so a Geotechnical investigation is recommended for detailed design to better define conditions and costs.

4.2. Marina Layout

The marina layout is performed using various guidelines including "Marinas and Small Craft Harbors", 2nd edition, by B.O. Tobiasson and R.C. Kollmeyer (T&K), 2000.

Boat sizes including length, beam, draft and average profile height from T&K are provided in the notes on Drawing CV-203, along with shed dimension, for calculating wind loads.

The boats that berth on the channel side of K float are likely to have higher wind loaded areas, possibly more in line with motoryacht and megayacht profiles provided in Figure 10-7 of T&K, and the piles along K float are sized for wind loads on these vessels, particularly for winds from the west and north-west that come in across Lost Lagoon. High wind from these directions have done considerable damage to the trees in Stanley Park in the recent past, and so the piles along K float are designed for high winds from that direction, acting on the megayacht size boats. The benefit of having large vessel on the outside of K float is that they will shelter the boats on the inside of the marina in extreme winds from the west; and similarly, F float, which has covered moorage for the 27.4 m (90') long boats, shelters boats on the inside in extreme east wind and wave conditions.

Sheltering factors provided in T&K and in the National Building Code of Canada (NBCC) are used in calculating overall loads on piles that hold the floats and boats in place.

4.3. Winds and Waves

Wind speeds are one-hour averages and are at a height of 10 m above the water surface.

Wind records from 1976 to 1988 are available from a recording station on Deadman's Island entitled "Vancouver Harbour" by Atmospheric Environment Service, Environment Canada. Figure E1 presents a wind rose prepared with Vancouver Harbour data.

The Vancouver Harbour wind speeds are used primarily for indicating wind direction, while the wind speeds are scaled up as described in the flowing sub-sections.

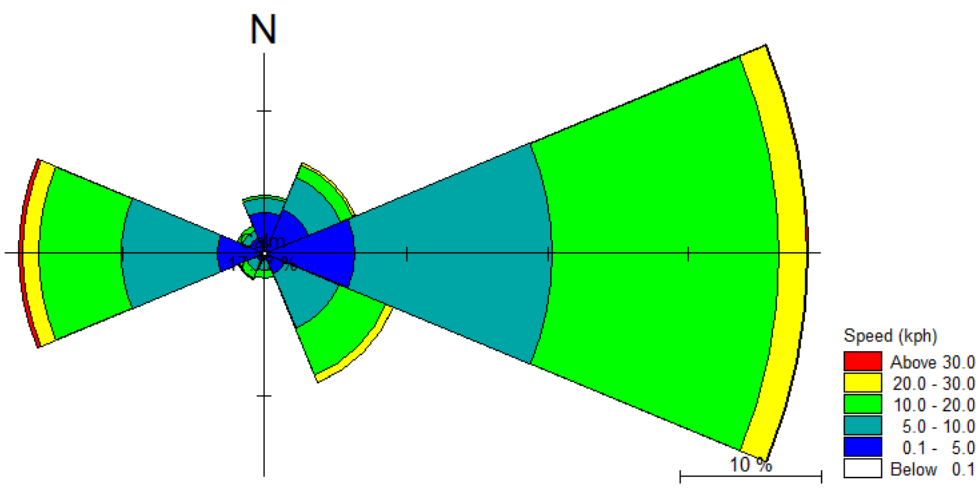

Figure E1. Wind rose of Vancouver Harbour wind data from an anemometer on Deadman's Island

4.3.1. National Building Code of Canada Wind Speeds

The National Building Code of Canada (NBCC) provides the 1-in-50-year wind pressure for Vancouver as 0.45 kpa, which converts to a wind speed of 95 kph for all directions.

4.3.2. 1-in-50-Year Winds and Waves from the East

The 1-in-50-year wind speed for generating waves over the open water fetch to the east of the site is 86 kph, which is determined by scaling up the Vancouver Harbour wind speeds to match the NBCC value of 95 kph for all directions.

The 1-in-50-year wind waves generated by the east direction winds has a significant wave height (H_s) of about 1.0 m at the south east corner of the marina and a peak spectral wave period (T_p) of 4.2 seconds.

H_S is defined as the average of the highest 33% of the waves, where the wave height is the vertical distance from the trough to the crest of the waves. T_p is defined as the period of the most energetic waves in the sea state, where wave period is the time between successive wave crests at a stationary point.

Wave heights and periods are calculated using the professional computer program Mike 21 SW developed by DHI. H_s and T_p simulated for the 1-in-50-year storm are shown in Figure E2 and E3 respectively.

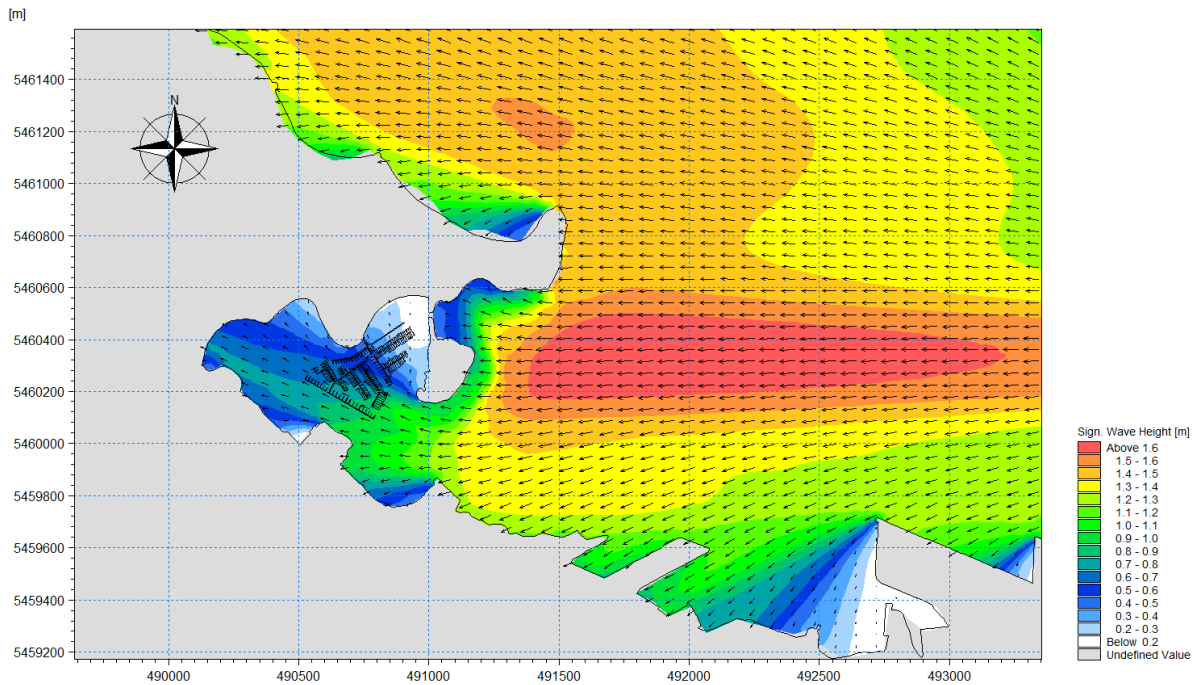

Figure E2. H_s for 1-in-50-year wind from the east, not including the dampening effect of F, K and other floats in the marina.

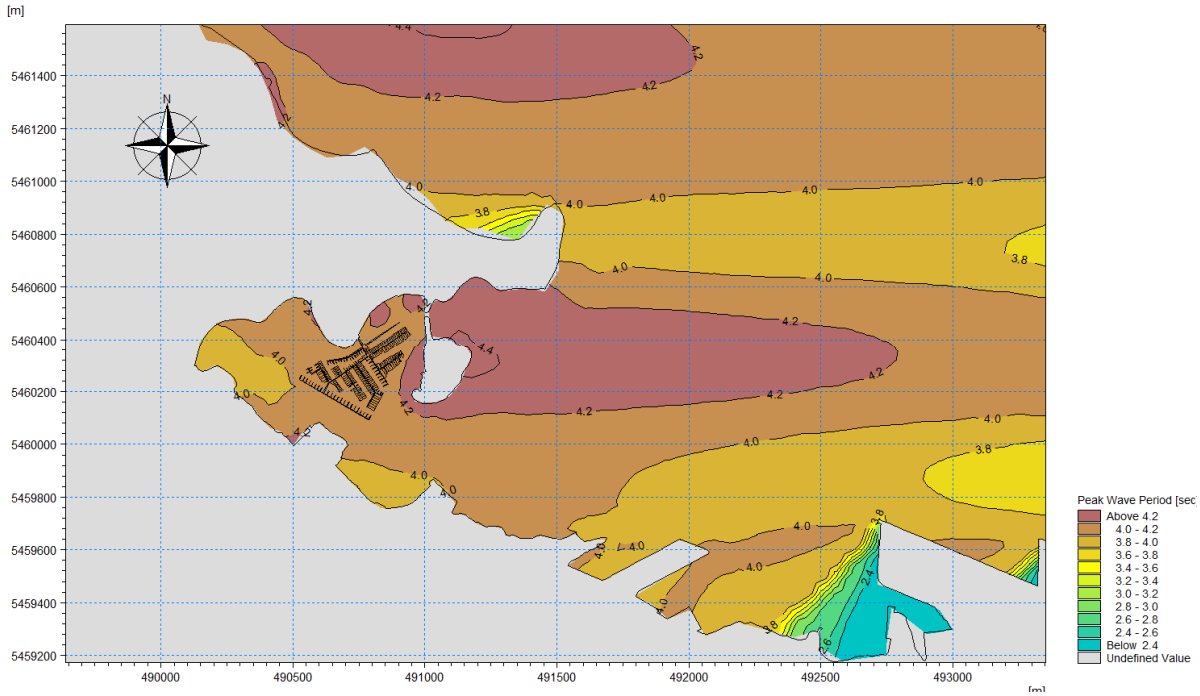

Figure E3. T_p for 1-in-50-year wind from the east

4.3.3. Extreme Winds from the West

The 1-in-50-year wind speed from the west and north-west, for applying to K float for winds from the direction of Lost Lagoon is 91 kph, which is determined by scaling up the Vancouver Harbour wind speeds to match the NBCC value of 95 kph for all directions.

4.3.4. Annual Winds and Waves

The annual wind speed from the east is about 50 kph, and the waves generated over the fetch extending to Second Narrows are shown in Figure E4, which does not include the dampening effect of F, K, and other floats. The waves in the marina will be improved from the existing configuration and will generally meet the criteria in “Guidelines of Harbour Accommodation” by Small Craft Harbours Directorate, Fisheries and Oceans Canada, 1985 when the dampening effect of F, K, and other floats is included.

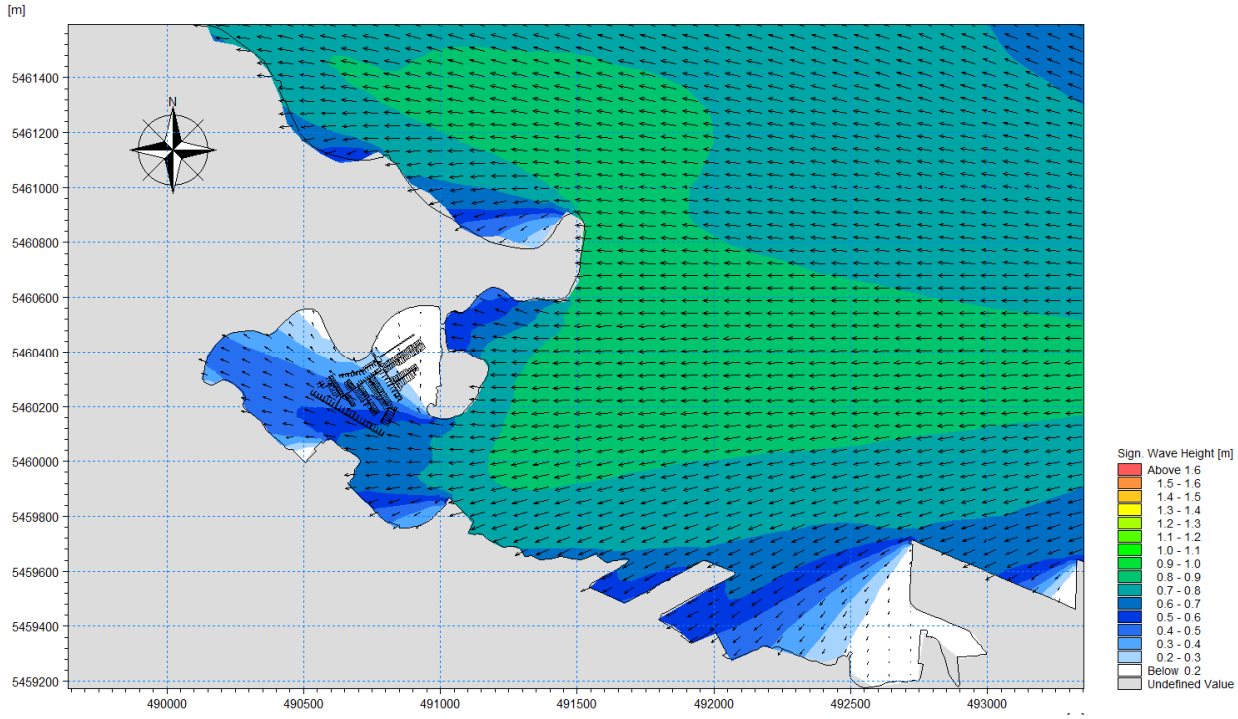

Figure E4. H_s distribution for annual winds, not including the dampening effect of F float, the float at the south-east end of K float, and other floats.

5. Marina Layout

5.1. Fairway width

Fairway widths are generally in the range of 1.25 to 1.75 times the length of the largest vessel that is moored on either side of the fairway. A fairway width factor of 1.25 factor is applied to the design of the Coal Harbour marina as the boats are generally well equipped and handled, and interior of the marina is generally relatively calm, with K float providing protection from the west direction winds, and with the south-east end of K float and the boat sheds for 27.5 m (90') boats on F float providing protection from the east direction winds and waves.

5.2. Number of new boat slips

There are a total of 47 new boat slips, and the largest boats are placed along the outside of K float. By placing the largest boats on the outside of K float and in F float boat sheds, the fairway widths in the interior of the marina are minimized.

All of the new boat slips are open, and the number of boats in sheds does not change in the reconfigured and expanded marina.

6. Water Levels

Tidal elevations are to Chart Datum (CD), defined as the lowest normal tide, using the Canadian Tide and Current tables, Canadian Hydrographic Services, 2019 edition, for Vancouver, are as follows:

Recorded Extreme High Water Level, (EHWL)	5.6 m CD
Higher High Water Level, Large Tide (HHWL)	5.0 m CD
High Water Level, Mean Tide (HWL)	4.5 m CD
Mean Water Level (MWL)	3.1 m CD
Low Water Level, Mean Tide (LWL)	1.2 m CD
Lower Low Water Level, Large Tide (LLWL)	0.1 m CD
Recorded Extreme Low Water Level, (ELWL)	-0.4 m CD

The increase in water levels by 2100 due to climate change is approximately 0.6 m using the average projected sea-level change for Representative Concentration Pathway (RCP) Scenario 8.5 (RCP 8.5) in James et al Geological Survey of Canada Open File 7942 Report "Tabulated Values of Relative Sea-level Projections in Canada and the Adjacent Mainland United States", 2015.

The projections for sea-level change due to West Antarctic ice sheet melting are for a further increase of 0.65 m by 2100 (James et al, 2015).

Pile cut-off elevations will include an additional 1.25 m for sea-level rise and will be above the float freeboard at EHWL plus a 0.3 m safety allowance.

High Water Level, Mean Tide (HWL) is used for combining with extreme storm conditions.

7. Wind Loads, Pile Sizes and Lengths

Wind loads are calculated using a one-minute steady wind speed as given in British Standard BS 6349-1:2000, "Maritime Structures, Part 1, Code of Practice for General Criteria", amended in 2003.

The one-minute wind speed is calculated as 1.25 times the one-hour average wind speed.

Required pile capacity is calculated using a load factor of 1.4 and wind pressure as per the NBCC and a steel resistance factor of 0.9 as per the Handbook of Steel Construction, Canadian institute of Steel Construction, latest edition.

Wind sheltering for boats is from Figure 15-4 of T&K.

Wind sheltering for boat sheds is from Figure I-32 of the NBCC.

Pile sizes and lengths are provided on Drawing CV-304. The piles will be sleeved with HDPE pipe and will be sealed at the top to prevent corrosion and provide for a much longer life cycle than for the present steel piles in the marina.

8. Summary and Recommendations

In summary, the marina has been laid out to optimize the addition water lot area and has resulted in 47 additional boats.

It is recommended that a Geotechnical investigation be conducted during detailed design to better define the costs.