Appendix G.18
Hatch Report – Pacific NorthWest LNG
Lelu Island
LNG Potential Impacts of the Marine Structures on the Hydrodynamics and Sedimentation Patterns

HATCH™

Project Memo

H345670

December 11, 2014

To: Capt. David Kyle
From: O. Sayao/L. Absalonsen

Pacific Northwest LNG
Lelu Island LNG

Potential Impacts of the Marine Terminal Structures on the Hydrodynamics and Sedimentation Patterns

1. Introduction

Hatch was commissioned to evaluate the potential project related effects of the PNW LNG marine terminal structures on Flora, Agnew and Horsey Banks and the vicinity of the LNG terminal.

The trestle, the southwest (SW) Anchor Block and the southwest (SW) Tower to be located on the subtidal area bordering Flora Bank and Agnew Bank, that connect Lelu Island to the LNG berths, are the primary focus of this study. This marine terminal infrastructure may result in changes to existing hydrodynamic circulation and sedimentation patterns in the project area.

2. Marine Terminal Structures

The PNW LNG marine terminal structures are shown in Figure 2-1 and consist of a trestle, constructed on piles, the SW Anchor Block and the SW Tower. The last two structures are structures designed to support the suspension bridge.

The suspension bridge from Lelu Island to the trestle was not included in this preliminary study since it was designed to minimize the potential impacts on Flora Bank, being one of the mitigation alternatives.

The bridge marine structures, SW Anchor Block and SW Tower are located adjacent to Flora Blank at northing easting coordinates 6005549.89, 413922.09 (WP15) and 6005799.42, 414221.82 (WP14) respectively, and are used to support the suspension bridge.

The bridge SW Tower is composed of a cast-in-place concrete tower; a concrete pile cap; and 28 concrete filled steel pipe piles for the foundation connected to the sea floor. The pile cap will have the most important influence on the flow and its preliminary design dimensions are 36.4 m long, 20.2 m wide and 4 m tall. According to Infinity Engineering Group, the bridge designers, the base of pile cap is assumed to be located at an elevation of -0.35 m CD (local seabed elevation).

The SW Anchor Block is composed of a concrete anchor block and 64 concrete filled steel piles for the foundation. The anchor block will have the most important influence changing the flow and its dimensions are 45 m long, 44 m wide and 21.3 m tall. According to Infinity Engineering Group, the pile cap base is assumed to be located at an elevation of -0.73 m CD (local seabed elevation). Details of these structures are addressed in Hatch's November 26, 2014 Report [3].

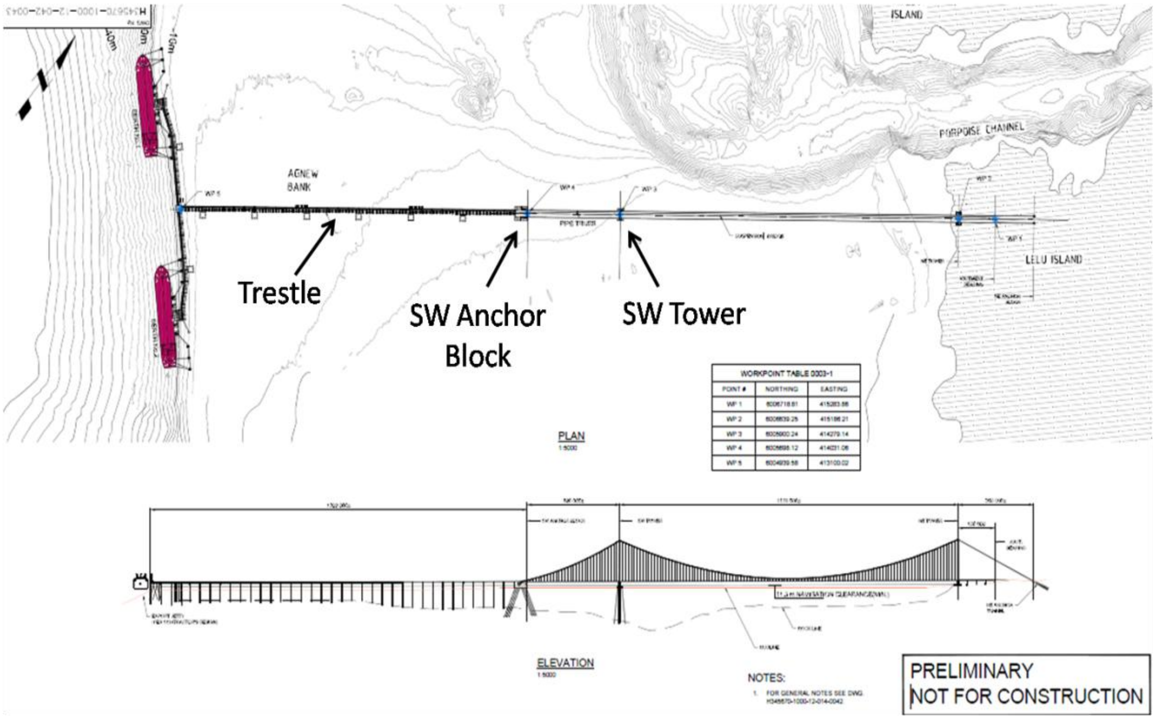

Figure 2-1: Location of the Marine Terminal Structures (modified from H345670-1000-12-042-0043)

3. Methodology

The study of the impacts of the marine terminal structures on the hydrodynamic circulation and sediment depositional patterns was conducted using numerical models (described below in Section 3.1) during four different periods (Freshet, Storm, Post Freshet and Fall). The same input conditions were used to run the simulations without the marine terminal structures and then including the marine terminal structures. Therefore, the marine structures were the only difference between the simulations.

The four periods used to characterize different meteorological and oceanographic conditions observed along the year were: Freshet, Storm, Post Freshet and Fall.

The Freshet represents the period with maximum discharge on Skeena River and Nass River and when the largest Total Suspended Solids concentrations are observed in the area.

The Storm period characterize the conditions when the winds and current velocities are stronger and when more sediments can be naturally suspended on the shallower waters (e.g. Agnew Bank and Flora Bank) if the critical bed shear stresses are exceeded. The critical bed shear stress for erosion and deposition may be calibrated with field investigation. The other two periods (Post Freshet and Fall) are transitional conditions.

The differences between the two simulations, without and with the marine structures, represent the potential influence that the marine terminal structures may have on the area of the terminal, including Flora Bank.

3.1 Description and Model Calibration

The hydrodynamic modeling was conducted using CMS Flow developed by the U.S. Army Corps of Engineers (USACE), which is a 2D depth-integrated model for simulating hydrodynamics (currents and water level oscillations), sediment transport and morphological changes. The model includes physical processes such as wetting and drying areas (during low and high tidal cycles), river discharges, tides, wind effects and atmospheric pressure. The current velocities obtained with this model are the average current velocities along the water column.

The hydrodynamic simulation included the Skeena River and Nass River discharges. Both rivers have a long time series of river discharge data available on the Canadian Hydrological Database, going back to 1928 (Skeena River – Usk Station) and 1929 (Nass River). The wind measured data was obtained from the Environment Canada Holland Rock wind station, located at 51.17°N, 130.36°W, which has been providing hourly wind data since 1994.

The water level results from the model were calibrated with water level data from Prince Rupert station (54.32°N, 130.32°W), which has measured data from January 1909 to November 2014. Two examples showing the comparison between modeled and measured water level and depth averaged current velocity magnitude are presented on Figure 3-1 and Figure 3-2, respectively. Details about the model calibration are presented on Hatch's April 25, 2014 Project Memo [2].

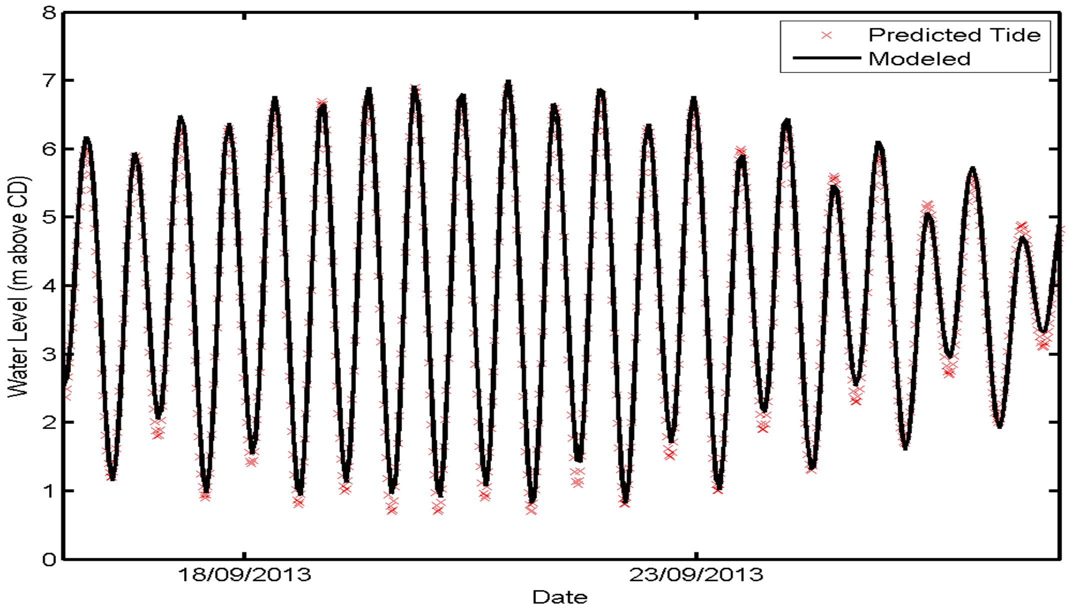

Figure 3-1: Comparison between the water level obtained from CMS Flow model and the predicted tides at Prince Rupert

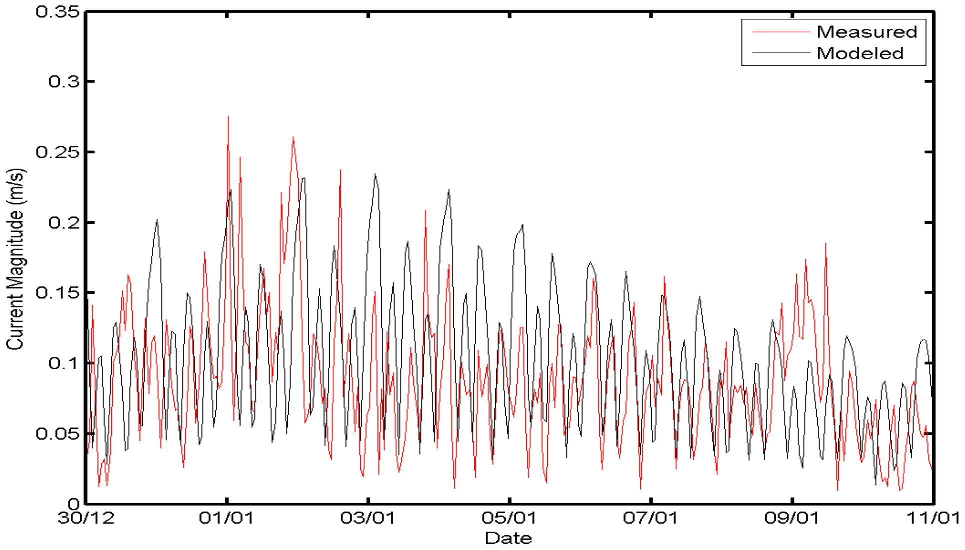

Figure 3-2: Comparison between CMS Flow depth averaged modeled currents and depth averaged currents measured by the buoy

The currents were calibrated using the buoy data located offshore of Flora Bank (54.19°N, 130.34°W) deployed by PNW specifically for this study and further verified with the currents measured by the ADCP inside Porpoise Channel (54.20°N, 130.30°W).

A sedimentation study was conducted using the Particle Tracking Model (PTM), developed by the USACE. PTM investigates the sediment pathways and fate after sediments are eroded or transported by the currents. After the sediments are suspended, the particles are transported by the local hydrodynamic conditions predicted with CMS Flow hydrodynamic simulations. The combined results of these two models indicate the potential areas where the sediments can be suspended, transported or accumulated, driven by the local currents.

3.2 Sediment Transport

The sediment grain sizes and composition are spatially variable along Agnew Bank and the north borders of Flora Bank, with different percentages of sand, silt and clay. Sediment samples collected by Stantec [6] and boreholes collected by Fugro [1] in the area showed median grain sizes (D_{50}) of the bottom sediment ranging from 0.025 mm to 0.085 mm.

The same current velocity that can suspend sediments with one particular D_{50}, may not be capable to suspend sediments with a different D_{50}. Similarly for the deposition, small changes in current velocities may create new areas of deposition.

The Hjulstrom diagram (Figure 3-3) [5] shows the relation between the current velocities and sediment grain sizes, indicating threshold current velocities for different grain sizes. Using a median grain size of 0.038 mm as an example, Hjulstrom diagram [5] shows that current velocities above 0.28 m/s are capable to suspend the sediments at the bottom. The sediments will only deposit during very low current velocities (below 0.003 m/s); the current velocities between these values are capable to transport the sediments already in suspension, but are not capable to resuspend sediments from the bottom.

Figure 3-3 indicates the current velocities capable of suspending sediments considering the range of sediments observed on the site.

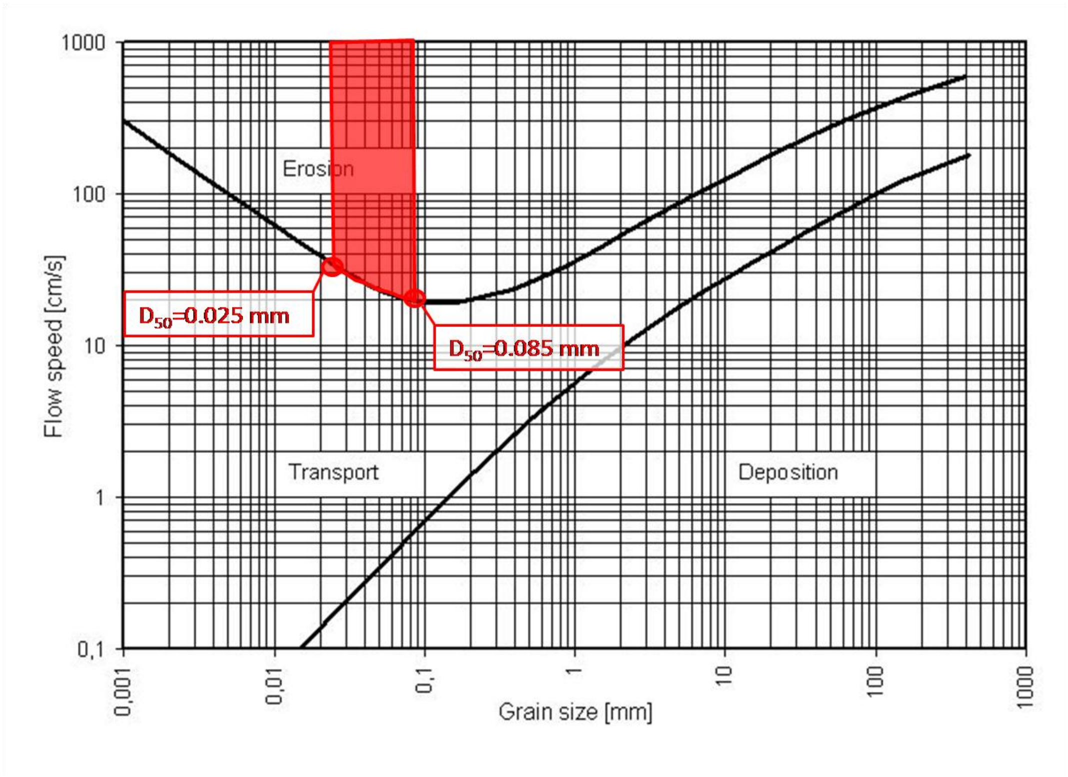

Figure 3-3: Hjulstrom Diagram highlighting the flow velocities capable of suspending sediments around the LNG terminal

3.3 Considerations and Assumptions

The sedimentation study conducted during the Freshet simulation (Hatch's November 26, 2014 Project Memo – [4]) showed that the majority of the sediments carried by the Skeena River are transported and deposited towards south east of the Kennedy Island, inside the main body of Skeena River and about 17 km away from Lelu Island and the project area (Flora, Agnew and Horsey Banks).

Only a small fraction of fine sediments are transported inside Inverness Passage and are still in suspension in the surrounding area of Flora Bank and Agnew Bank. This study indicated that the sediments from Skeena River are not a major source of sediments in the area around the terminal, therefore the marine terminal will not change this pattern.

The simulations including the marine terminal structures assumed that the piles on the trestle, SW Anchor Block and SW Tower were already protected to avoid local scour around them. This is described in Hatch's November 26, 2014 Report [3].

4. Hydrodynamic Circulation

An overview of the hydrodynamic circulation is presented in this section, showing general characteristics of the depth averaged current velocities during ebb, flood, low and high tides. The hydrodynamic simulation included the trestle, SW Anchor Block, SW tower (last two are the structures on the water supporting the suspension bridge) and the dredged area for the Materials Offloading Facility (MOF). These structures can change the currents in the area and create new depositional areas.

Four different conditions are presented to characterize the hydrodynamic circulation. An ebb tide condition during spring tide (Figure 4-1), where the strongest currents are located on the east and west sides of Lelu Island (Porpoise Channel and Inverness Passage) driven by the narrower areas in the channels. The currents can also be high on the shallow areas above Flora Bank and decrease their velocities offshore.

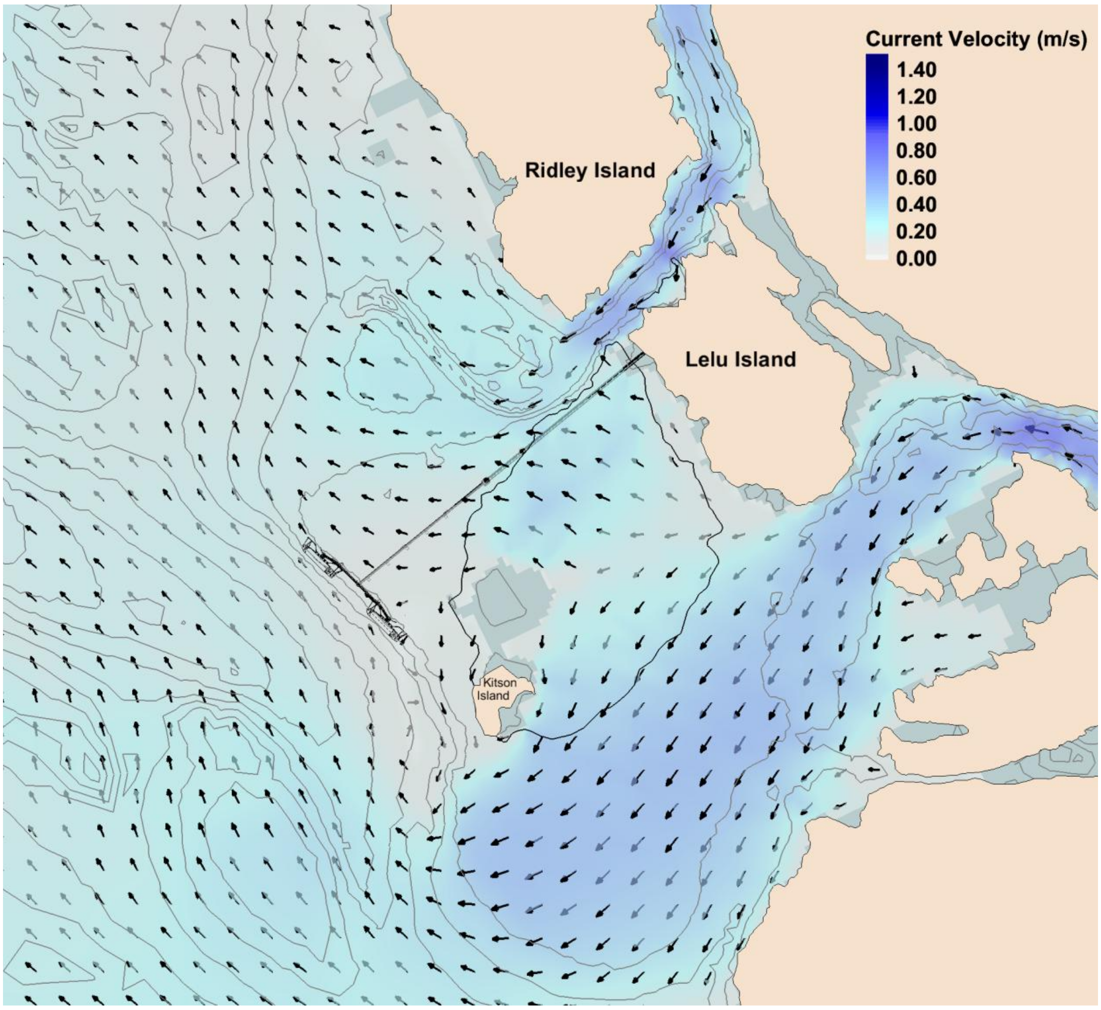

Figure 4-1: Characteristics of the hydrodynamic circulation during ebb tide conditions

The currents during a flood tide condition also accelerate at the entrance of the Porpoise Channel and Inverness Passage. The MOF dredged area has a localized effect on the currents, however the currents at Porpoise Channel are still strong during flood tides (Figure 4-2).

Figure 4-3 shows the currents during a low tide, when Flora Bank is entirely above water. The currents are weak when compared with the other two situations (ebb and flood tides), since this is a transitional phase between flood and ebb tides and the currents are expected to be weak.

The depth averaged current velocities are generally weak in the LNG terminal area during high tides, this is another transition between flood and ebb tides. Flora Bank is underwater during spring tides and the currents are slightly stronger above it, since the depths are relatively shallow (Figure 4-4).

Figure 4-1 to Figure 4-4 are general characterizations of the average currents along the water column inside the modeled area during one tidal cycle. However, this is a dynamic system where it is expected to observe some changes in the water level and depth averaged current velocities according to different meteorological and oceanographic conditions.

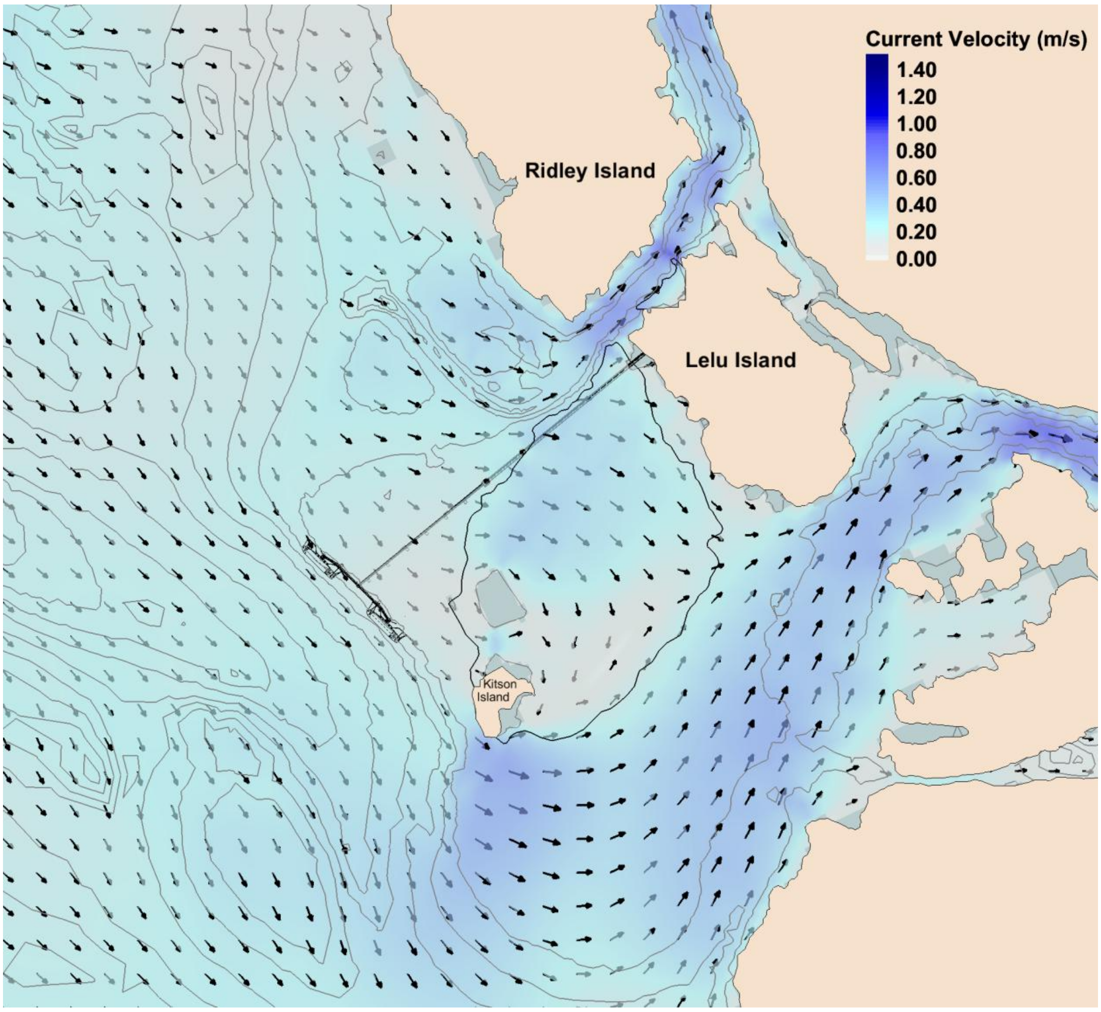

Figure 4-2: Characteristics of the hydrodynamic circulation during flood conditions

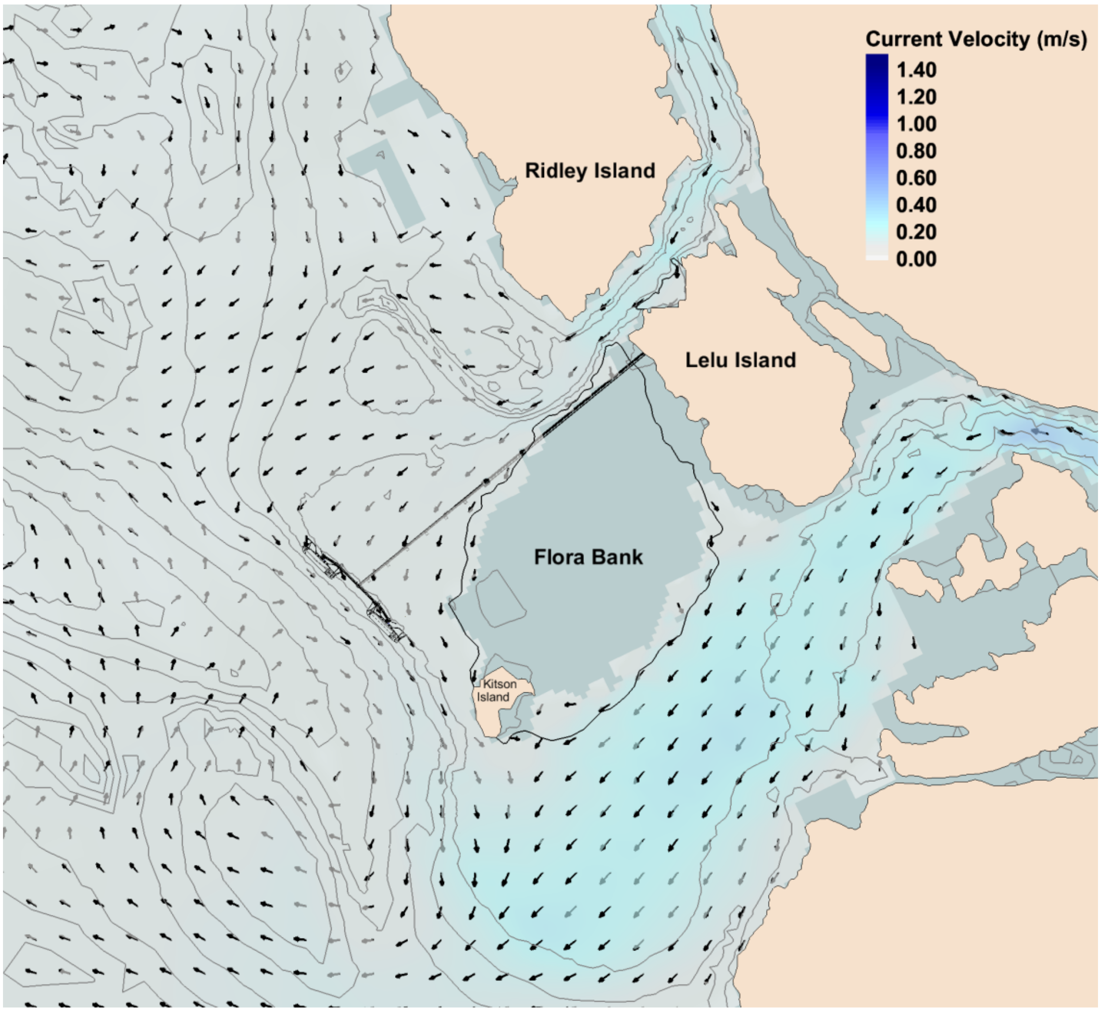

Figure 4-3: Characteristics of the hydrodynamic circulation during low tides

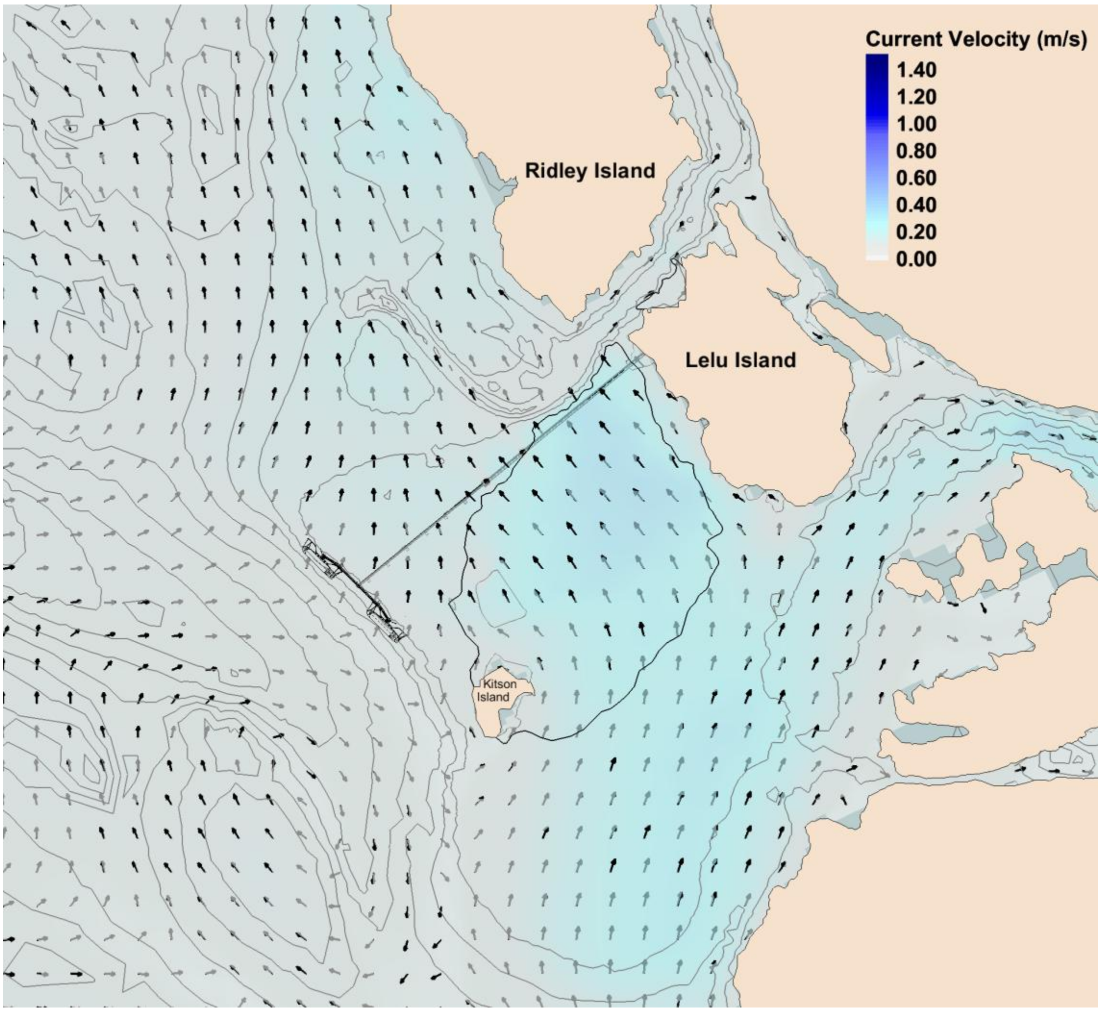

Figure 4-4: Characteristics of the hydrodynamic circulation during high tides

5. Potential Impacts of the Marine Terminal Structures on the Hydrodynamics

The comparison between the results from the simulations without and with marine structures is presented for the four periods mentioned in Section 3. These four different periods of simulations were used to represent seasonal changes that occur on Flora Bank, Agnew Bank and the terminal area.

The average current velocity along the water column was obtained at six locations around the marine terminal structures (Figure 5-1) and they were used to demonstrate the impacts of the marine terminal structures on the current velocities. These points are located approximately 125 m away from the marine structures, along both the northwest and southeast sides of the trestle and SW Anchor Block.

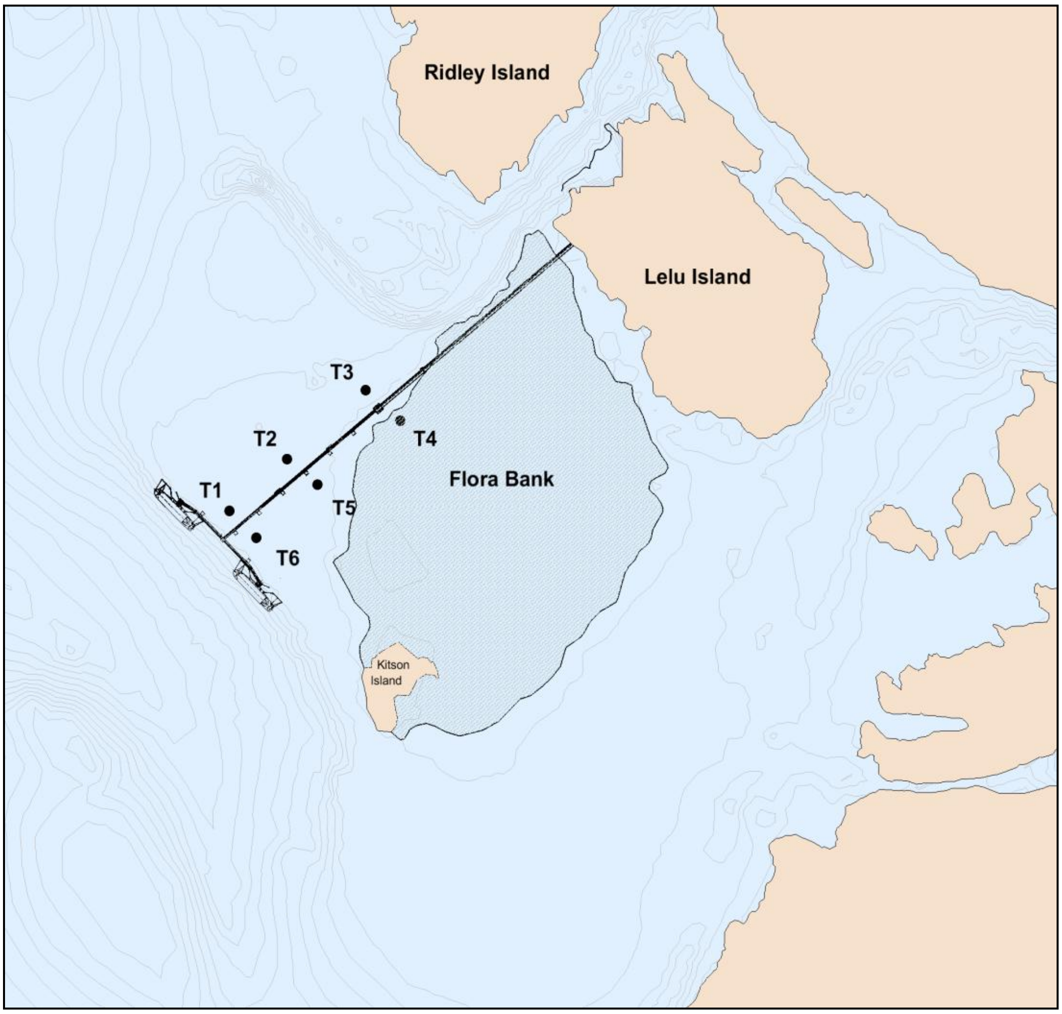

Figure 5-1: Locations where the results from the hydrodynamic simulations were extracted for the four periods

The results are presented in two different ways: a time series comparing the current velocities without and with marine terminal structures: and, snapshots showing the plan area affected by the marine structures during the four periods of simulations (Winter Storm, Freshet, Post Freshet and Fall).

5.1 Temporal Impacts of the Marine Terminal Structures

The comparisons between the average current velocity along the water column for the simulations without and with marine terminal structures are presented in Figure 5-2 to Figure 5-5. Each figure presents the results of eight days of simulations for each of the four periods used to characterize different metocean conditions observed throughout the year.

T3 and T4 were the locations where major changes were observed comparing the current velocities without and with marine terminal structures. These points are located on both sides of the SW Anchor Block, which is the structure with larger dimensions and consequently most likely to generate significant change in its vicinity. T3 and T4 were also the locations where the strongest currents were observed, when compared with the other locations from which the model results were extracted.

The maximum difference in the current magnitude was observed during the Storm simulation at T3. This difference was 0.17 m/s (February 10th) indicating that the SW Anchor Block has the largest potential to decrease the current velocities in the area. The maximum current velocities were observed at T4 also during the Storm simulation on February 10th, current magnitudes of 0.61 m/s and 0.52 m/s, without and with marine terminal structures, respectively.

The current velocities at T1 and T6 (located closer to the marine terminal and in deeper waters) are less strong than the currents at T3 and T4. The velocities at T1 and T6 are mostly influenced by the Trestle, which is the marine structure causing smaller changes to the local currents (when compared with the SW Anchor Block and SW Tower).

The currents at T2 and T5, on both sides of the Trestle, were the locations with weaker currents and less impact after the construction of the marine terminal structures. It is expected that changes to the current velocities due to the marine terminal structures will be smaller in places where the currents are already weak.

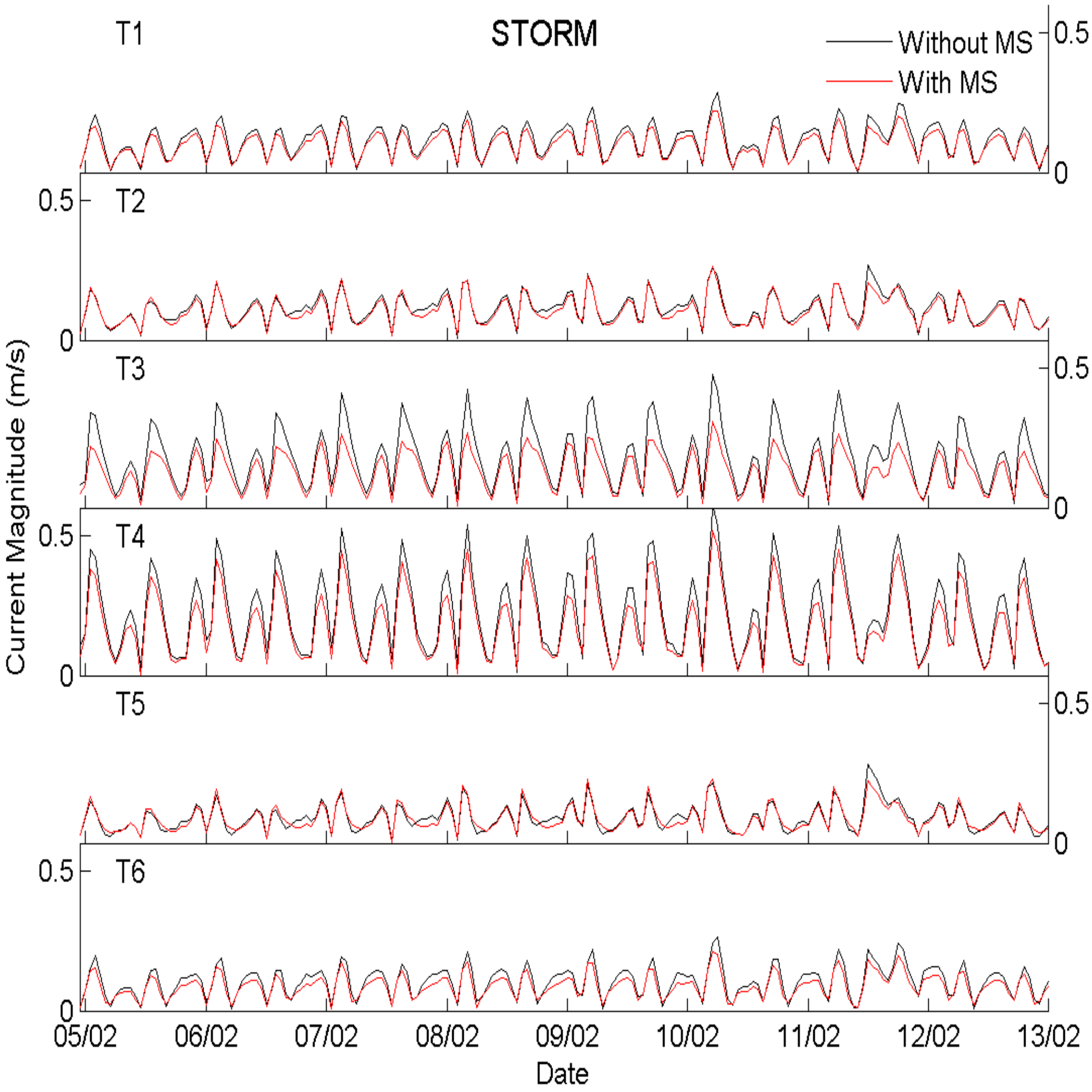

Figure 5-2: Depth averaged current magnitude without and with the Marine terminal Structures (MS) during the Storm simulation

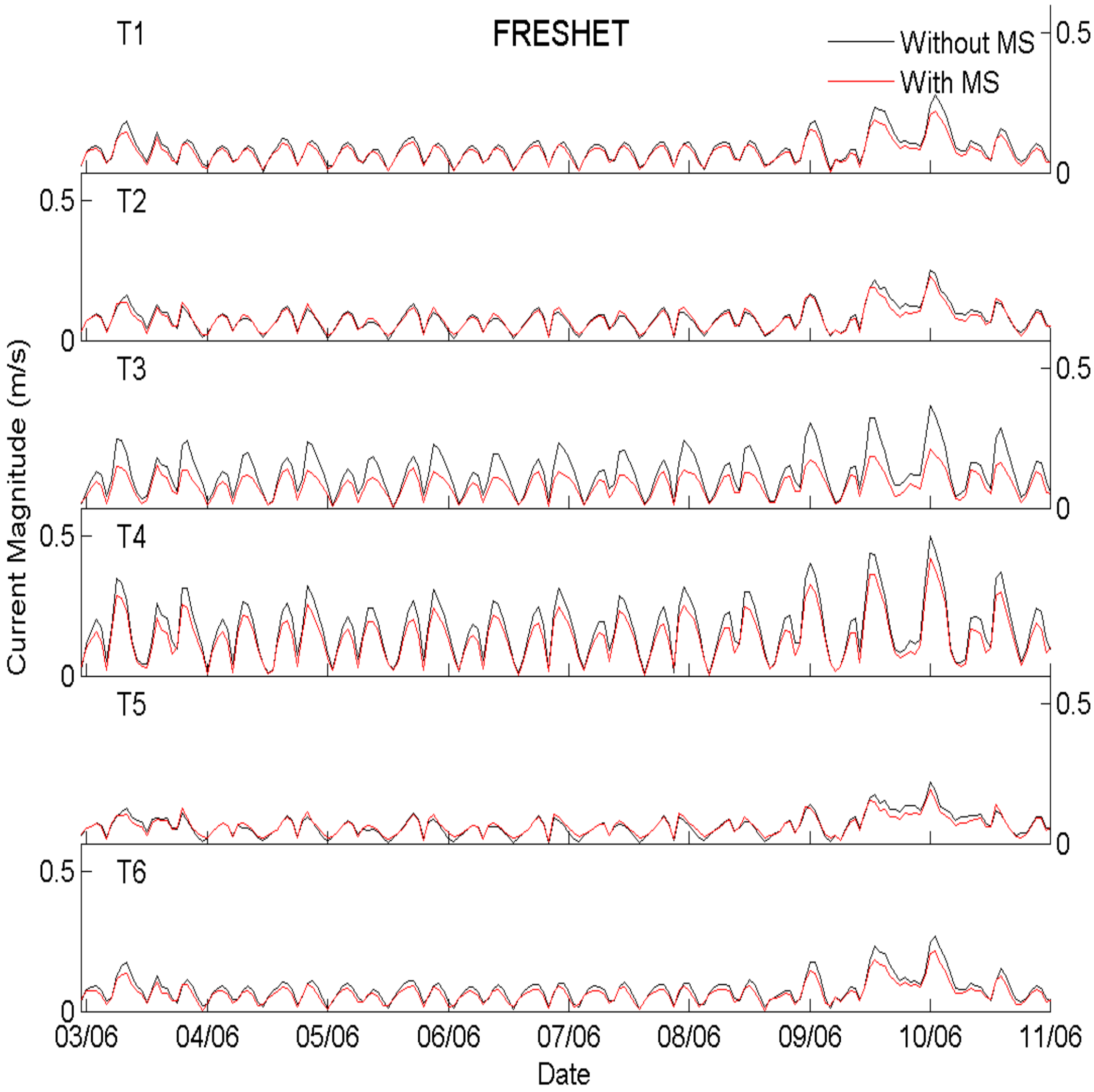

Figure 5-3: Depth averaged current magnitude without and with the Marine terminal Structures (MS) during the Freshet simulation

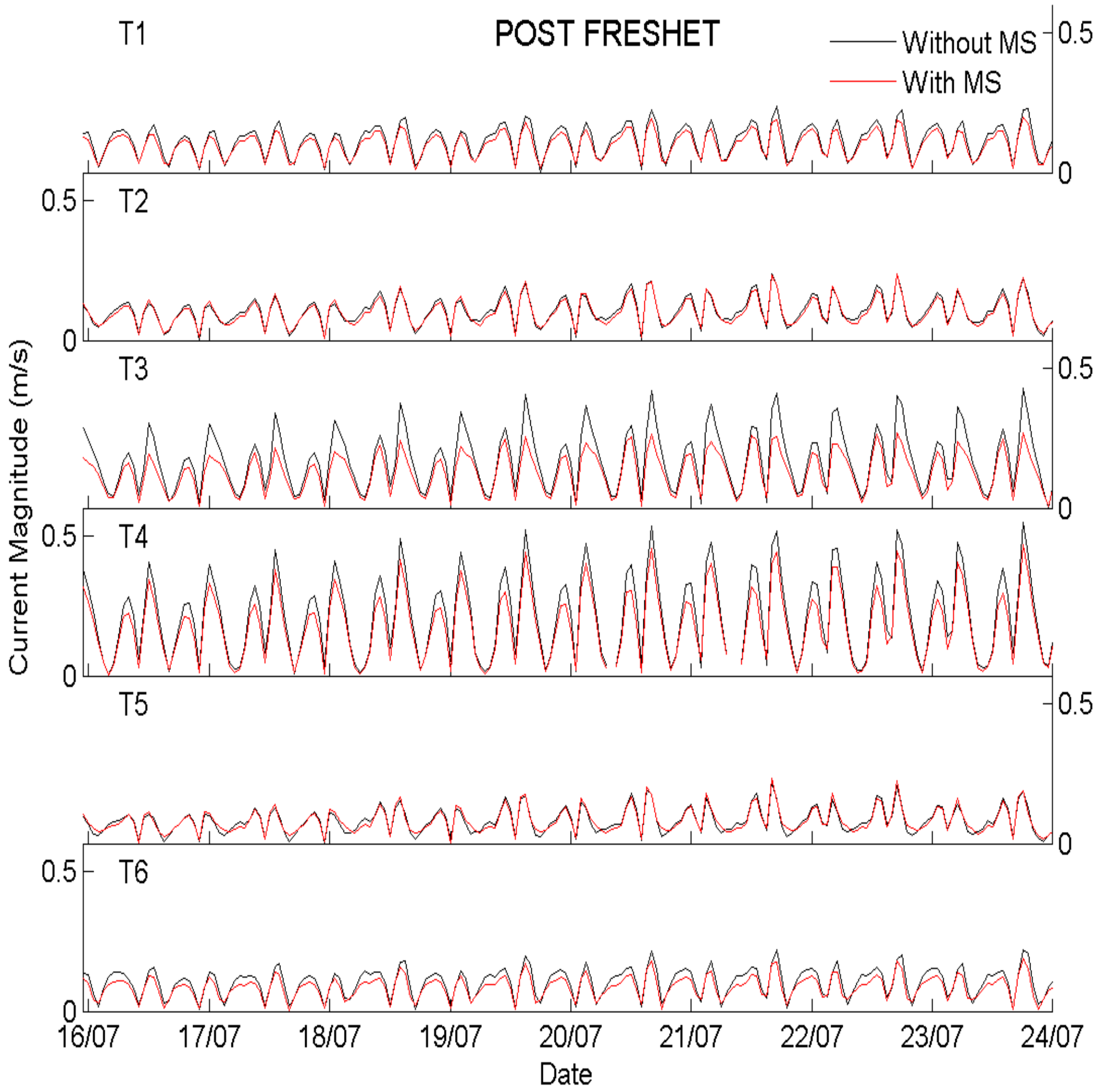

Figure 5-4: Depth averaged current magnitude without and with the Marine terminal Structures (MS) during the Post Freshet simulation

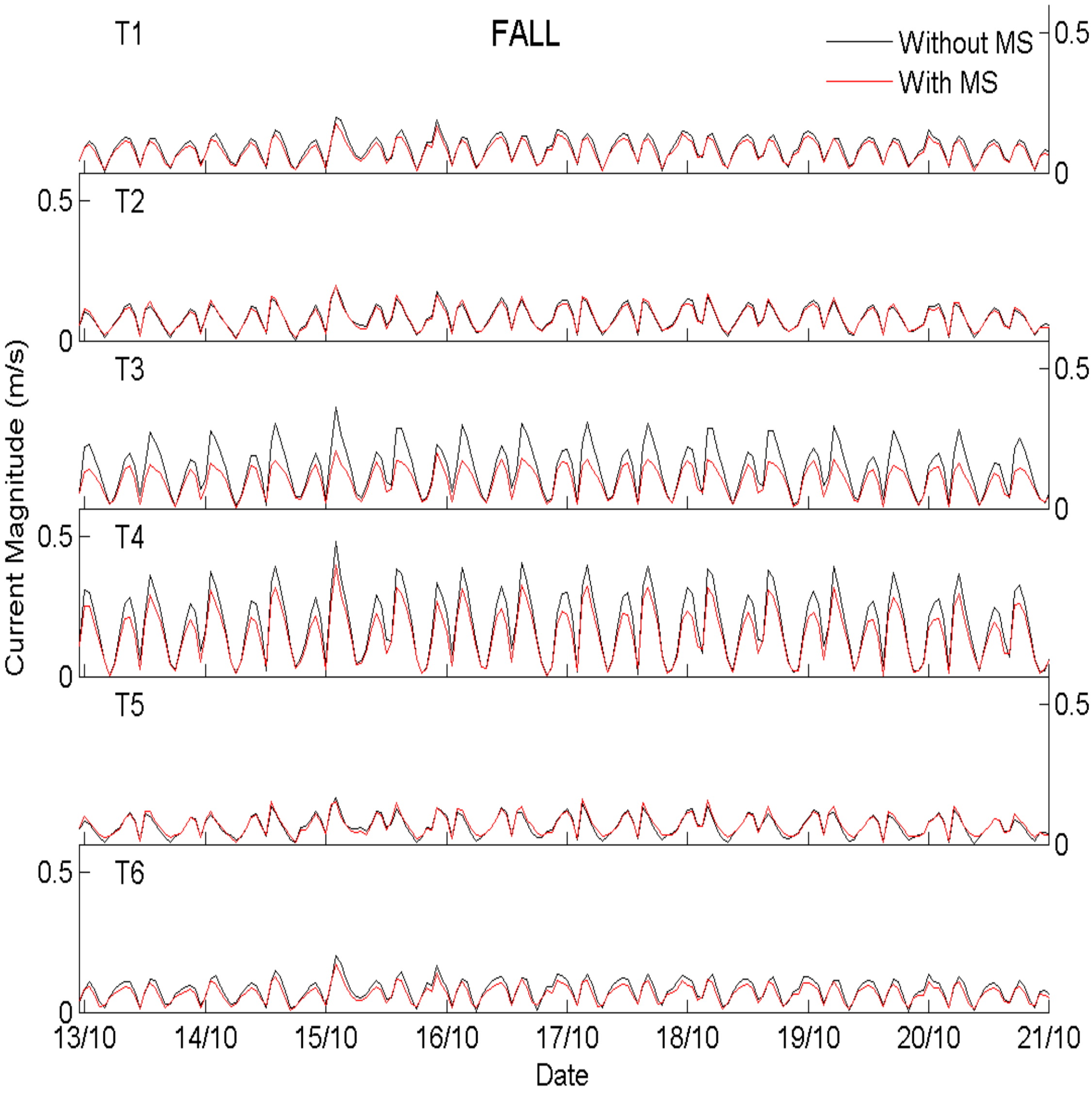

Figure 5-5: Depth averaged current magnitude without and with the Marine terminal Structures (MS) during the Fall simulation

In general, it was observed that the current velocities decreased around the project area with addition of the marine terminal structures. A summary with the average current velocity during these simulations, without and with marine terminal structures, is presented on Table 5-1, where all the averages were smaller or equal during the simulations including the marine structures. The average currents are low, because the calculations take into account the periods when the tides are changing from ebb to flood or vice versa. During these moments the current magnitude decreases to values close to zero, as it was demonstrated on Figure 4-3 and Figure 4-4.

The maximum current velocities were almost always greater in the simulations without marine terminal structures. The only exceptions were T2 during Fall and Post Freshet and T5 during Fall, when the maximum current velocity was the same without and with marine terminal structures (Table 5-2).

Table 5-1: Average current velocities during the simulations (four periods)

	Average Current Velocity (m/s)					
Periods	T1	T2	T3	T4	T5	T6
Without Marine Terminal Structures						
Storm	0.12	0.11	0.18	0.23	0.09	0.11
Freshet	0.8	0.08	0.13	0.17	0.06	0.08
Post Freshet	0.9	0.08	0.14	0.19	0.07	0.08
Fall	0.11	0.11	0.17	0.22	0.08	0.10
With Marine Terminal Structures						
Storm	0.10	0.11	0.13	0.19	0.09	0.09
Freshet	0.07	0.08	0.08	0.14	0.06	0.07
Post Freshet	0.08	0.08	0.10	0.15	0.07	0.07
Fall	0.10	0.10	0.13	0.18	0.08	0.09

Table 5-2: Maximum current velocities during the simulations (four periods)

	Maximum Current Velocity (m/s)					
Periods	T1	T2	T3	T4	T5	T6
Without Marine Terminal Structures						
Storm	0.28	0.27	0.48	0.61	0.28	0.26
Freshet	0.28	0.25	0.37	0.50	0.22	0.27
Post Freshet	0.20	0.20	0.36	0.48	0.17	0.20
Fall	0.24	0.24	0.43	0.55	0.22	0.22
With Marine Terminal Structures						
Storm	0.22	0.26	0.31	0.52	0.23	0.21
Freshet	0.22	0.23	0.21	0.42	0.19	0.22
Post Freshet	0.18	0.20	0.21	0.40	0.16	0.17
Fall	0.20	0.24	0.27	0.47	0.22	0.19

5.2 Spatial Impacts of the Marine Terminal Structures

The area affected by the marine terminal structures was also calculated using the differences in the depth averaged current velocities without the marine terminal structures and with the marine terminal structures for the four modeling periods mentioned above.

This analysis identified the main potential areas where the suspended sediments will deposit around the terminal after being carried by the local hydrodynamics. The results presented on Figure 5-6 to Figure 5-8 are snapshots in time, each representing one hour of simulations. They were selected because they are representative of extreme situations observed during ebb and flood conditions, used to define the potential affected area.

It is important to note that differences smaller than 0.05 m/s are not represented in these figures since these differences in current velocities are unlikely to change the depositional pattern.

Figure 5-6 shows the area in which the current velocities were affected by the marine terminal structures, in the situation when the maximum differences were observed during the Storm period. This snapshot was obtained during the ebb tide, therefore the most affected area is located on the northwest side of the marine structures. As it was described in Section 4.1, the SW Anchor Block and SW Tower are the structures that cause the main changes to the current pattern.

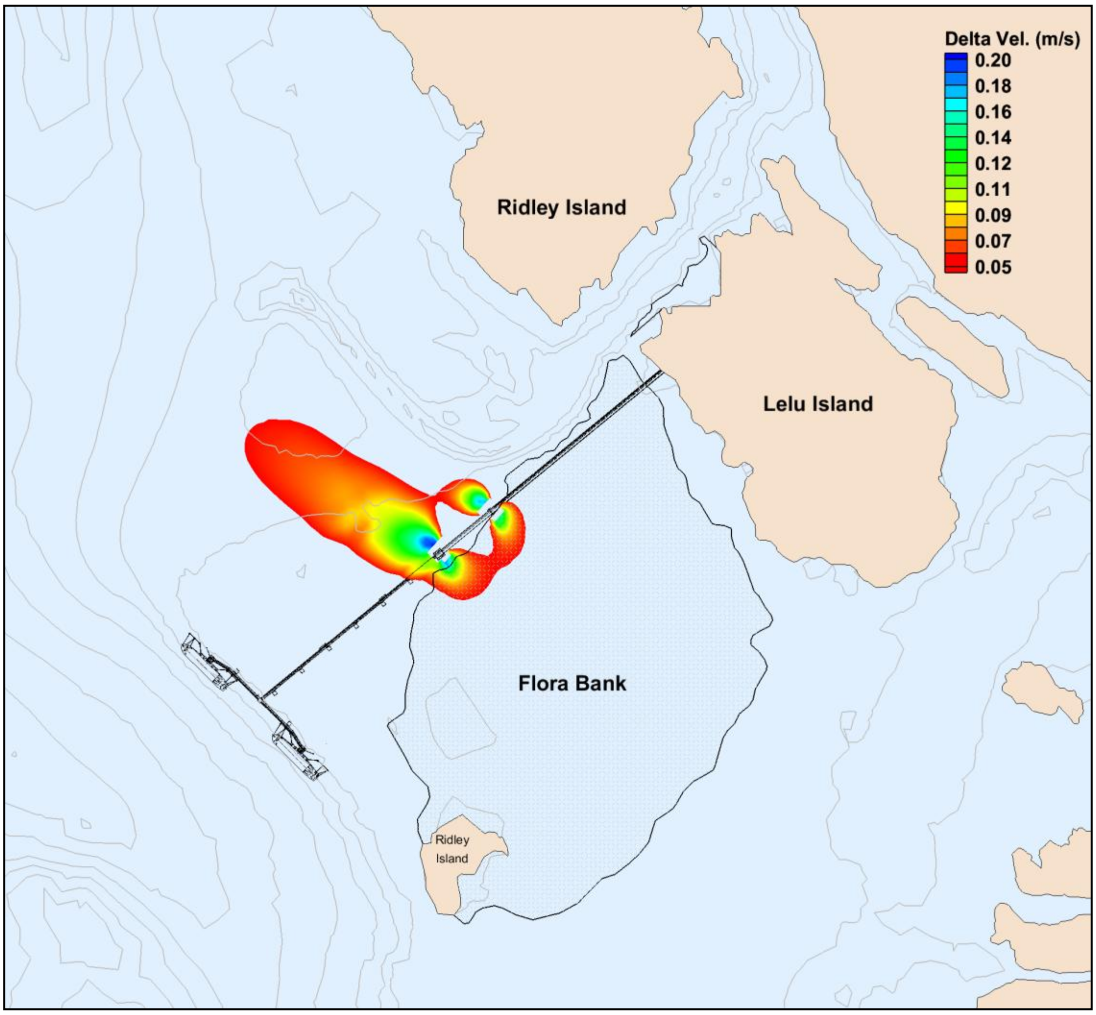

Figure 5-6: Differences between the current magnitude without and with the marine terminal structures (delta velocity plot) during the Storm simulation, ebb tide

However, the trestle is also capable of changing the currents during some tidal stages. Figure 5-7 shows one tidal stage (flood tide) when the currents are approximately parallel to the trestle, when the trestle effect is more noticeable and the currents are more affected by it.

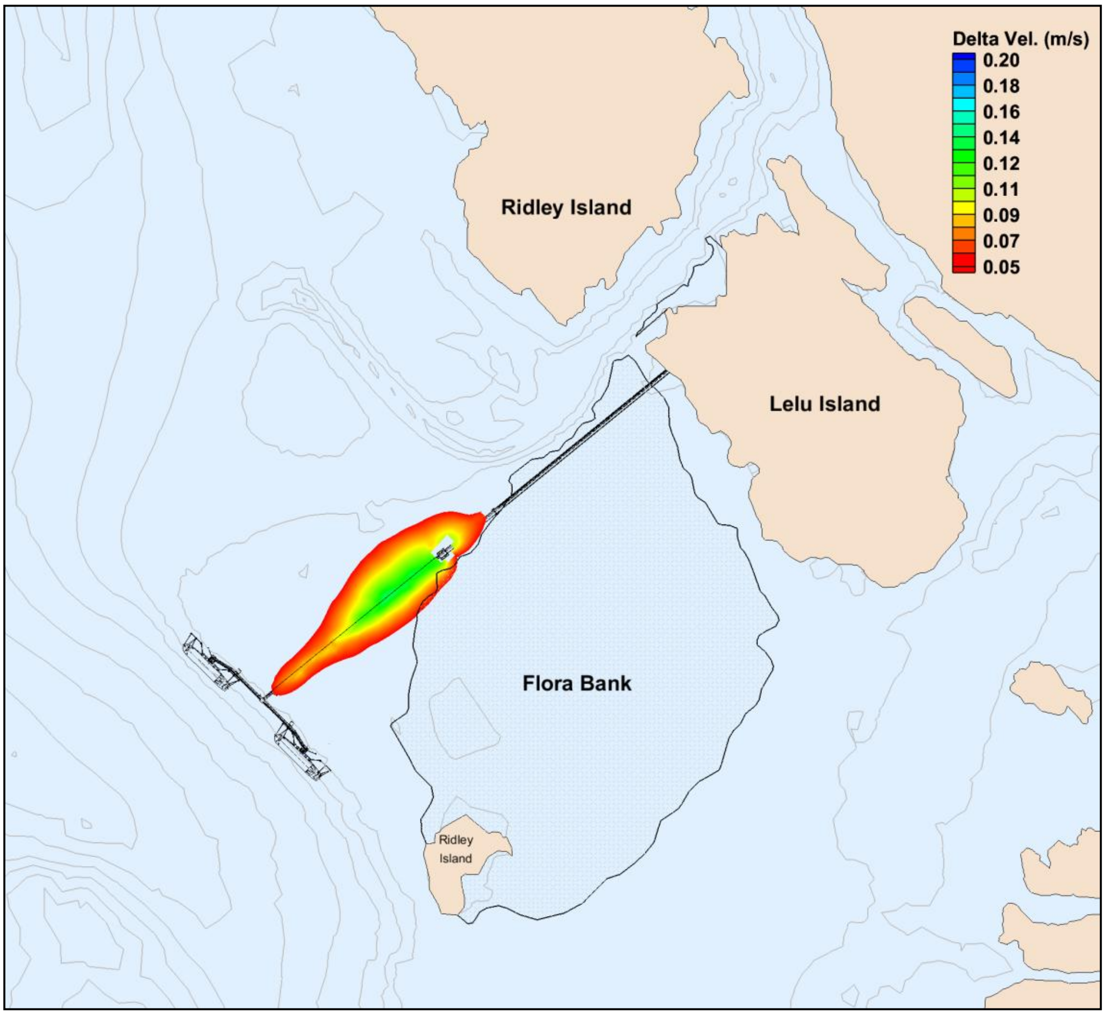

Figure 5-7: Differences between the current magnitude without and with the marine terminal structures (delta velocity plot) during the Storm simulation, flood tide, indicating the changes caused by the trestle

The results obtained during the Post Freshet simulation represent one situation when the currents are flowing from the marine terminal structures towards Flora Bank, during the flood tide (Figure 5-8). In this situation, the maximum difference was about 0.15 m/s (i.e., current velocities without the marine terminal structures are greater by about 0.15 m/s).

The results described above were used to characterize specific and extreme conditions in time. The snapshots only represent static presentation of simulated conditions to conclude averaged states. This is a dynamic simulation, where the area affected by the marine structures is constantly changing, according to physical environmental conditions, and at some moments the potential impacts are smaller than presented on Figure 5-6 to Figure 5-8.

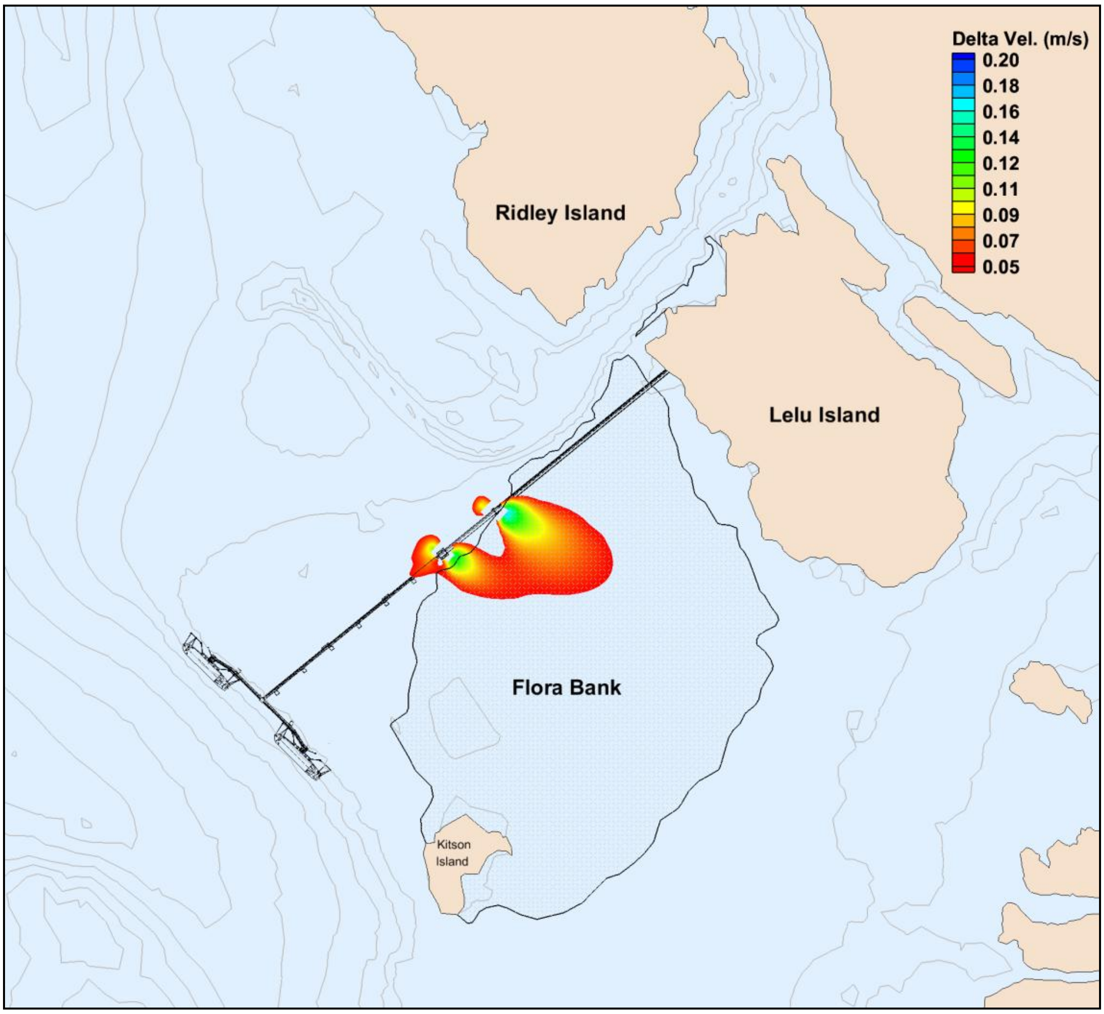

Figure 5-8: Difference between the current magnitude without and with the marine terminal structures (delta velocity plot) during the Post Freshet simulation, flood tide

6. Potential Depositional Pattern

Only a small fraction of the suspended sediments coming from Skeena River are capable of being transported towards the LNG terminal, therefore these sediments are not the main source of sediments for the PNW site (Hatch's November 26, 2014 Project Memo – [4]).

The sediments around the LNG terminal that are suspended in shallower areas are the main source of sediments that could be affected after the construction of the Trestle, SW Anchor Block and SW Tower.

The results obtained using the PTM helped identifying the predominant pathways observed in the area. During ebb tides (Figure 6-1), the sediments from shallow areas (e.g. Agnew Bank) are transported offshore of Flora Bank and sediments suspended in Porpoise Channel also move offshore.

The predominant sediment paths are in the opposite direction during flood tides (Figure 6-2). If the sediments are suspended on Agnew Bank, they will move towards Flora Blank and the sediments suspended in Porpoise Channel are transported further inland, since the current velocities at the channel are considerably higher.

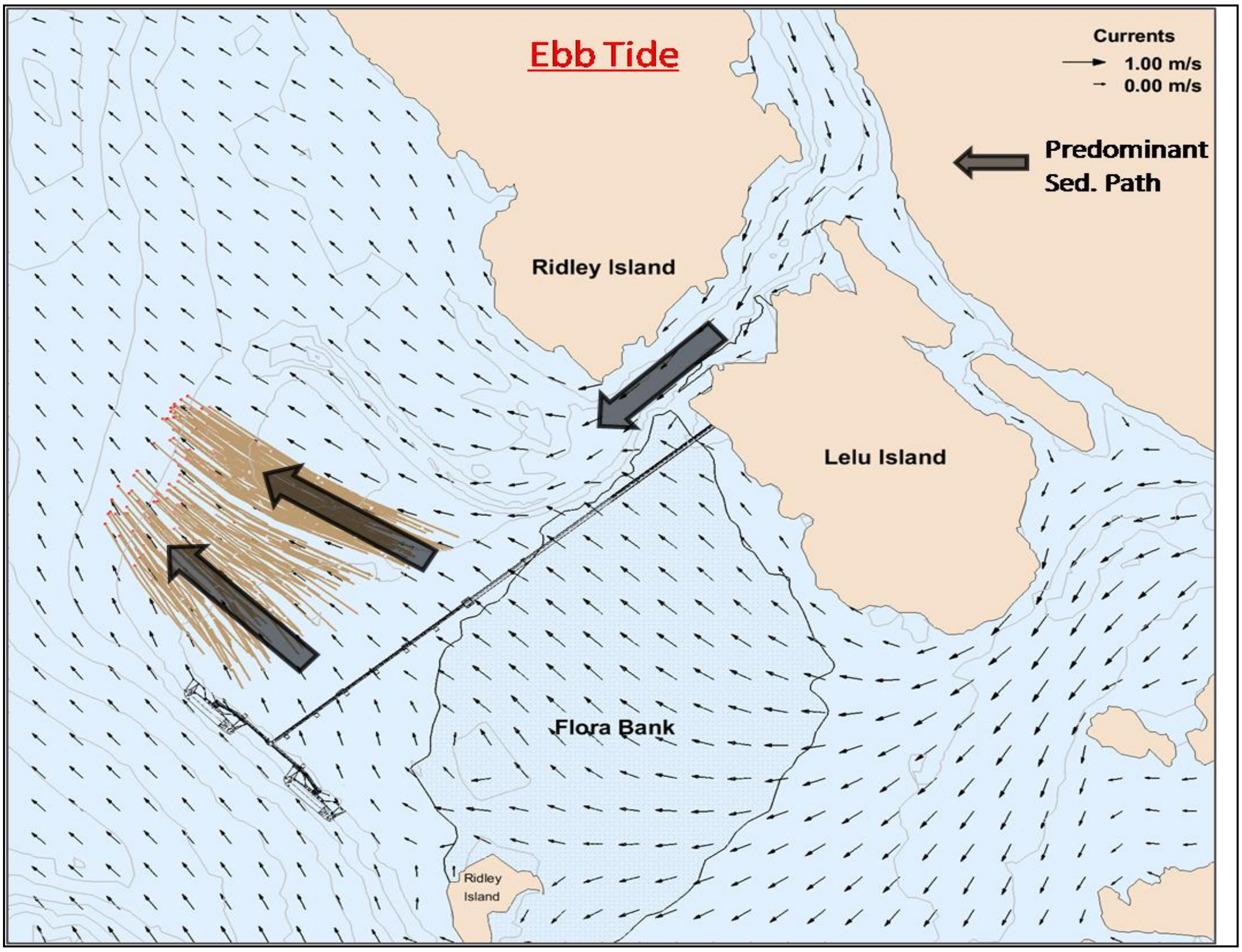

Figure 6-1: Predominant sediment path observed during ebb tides. Brown lines indicate individual sediment paths and the larger arrows the predominant sediment paths

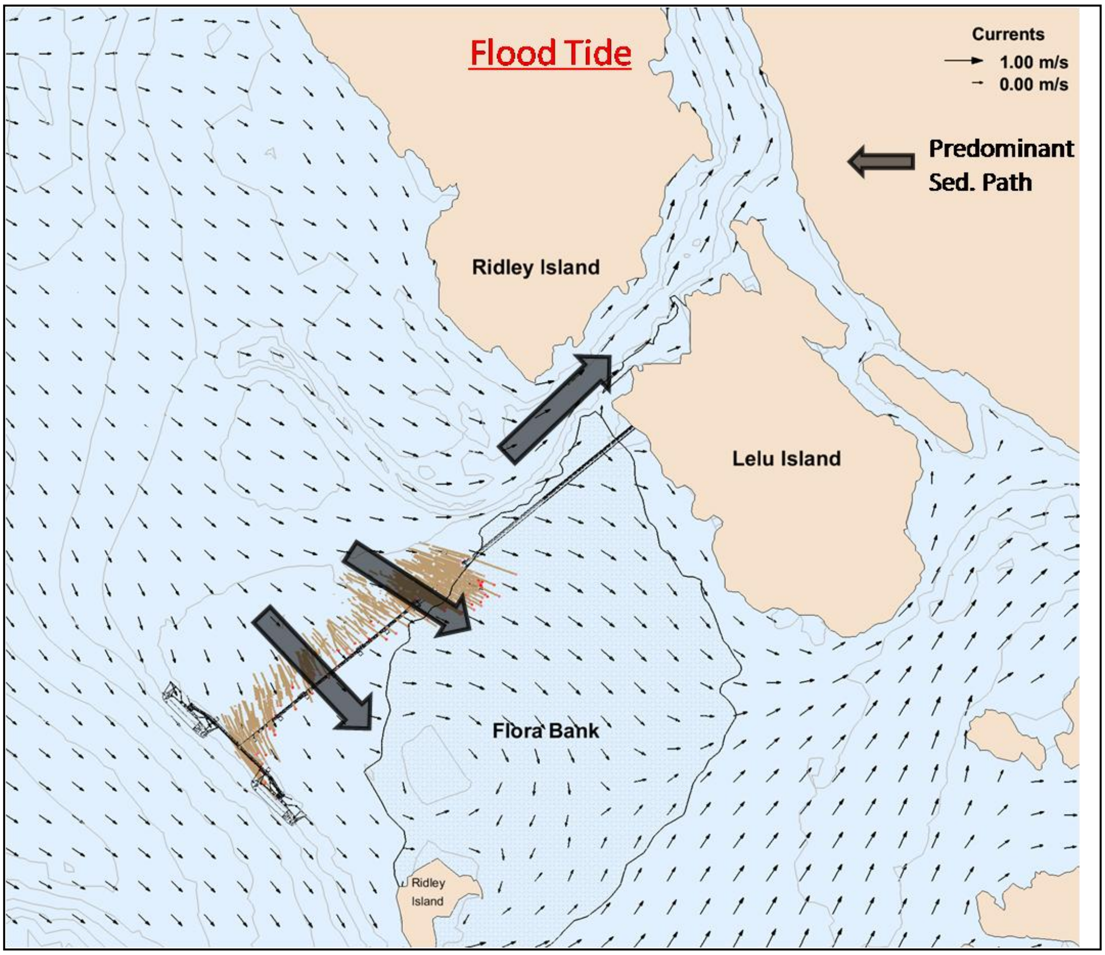

Figure 6-2: Predominant Sediment Path observed during flood tides. Brown lines indicate individual sediment paths and the larger arrows the predominant sediment paths

The preliminary results of expected depositional patterns after the construction of the marine terminal structures were obtained by combining the results from all hydrodynamic simulations without and with the marine structures and the predominant sediment pathways. Due to the nature of hydrodynamic simulations, some variation is expected to the predicted sediment rates in the order of 5cm/yr. This study will be further verified with a comprehensive three dimensional model using the software Delft 3D. This additional work is currently underway by Hatch.

These results indicate that the areas around the SW Anchor Block and SW Tower are locations where the currents are especially affected by the structures and where most sediments may deposit (Figure 6-3). The preliminary results showed a deposition rate between 5 cm/yr and 10 cm/yr. The deposition is more pronounced during the winter months, outside the eelgrass growing season, when the current velocities are stronger and combined with wave action, more sediments are resuspended in the water column.

The Trestle effects are smaller when compared with the areas around the SW Anchor Block and SW Tower, however a deposition rate less than 5 cm/yr may be expected around piles and pile groups. This area of influence is outlined on Figure 6-3. The predicted sedimentation patterns and estimates can be corroborated with further field investigation and modeling (testing the sediment erodibility potential).

The area on Flora Bank that might be affected by the deposition induced by the marine terminal structures can be observed in more detail on Figure 6-4. The dense patched of eelgrass are concentrated predominantly on the north east edge bank Flora Bank [7] adjacent to Lelu Island. The area where more deposition is expected, near the Flora Bank NW borders, is not covered by dense eelgrass patches. Additional areas of stable sediment may be created or enhanced though areas of sedimentation near the NW borders of Flora Bank.

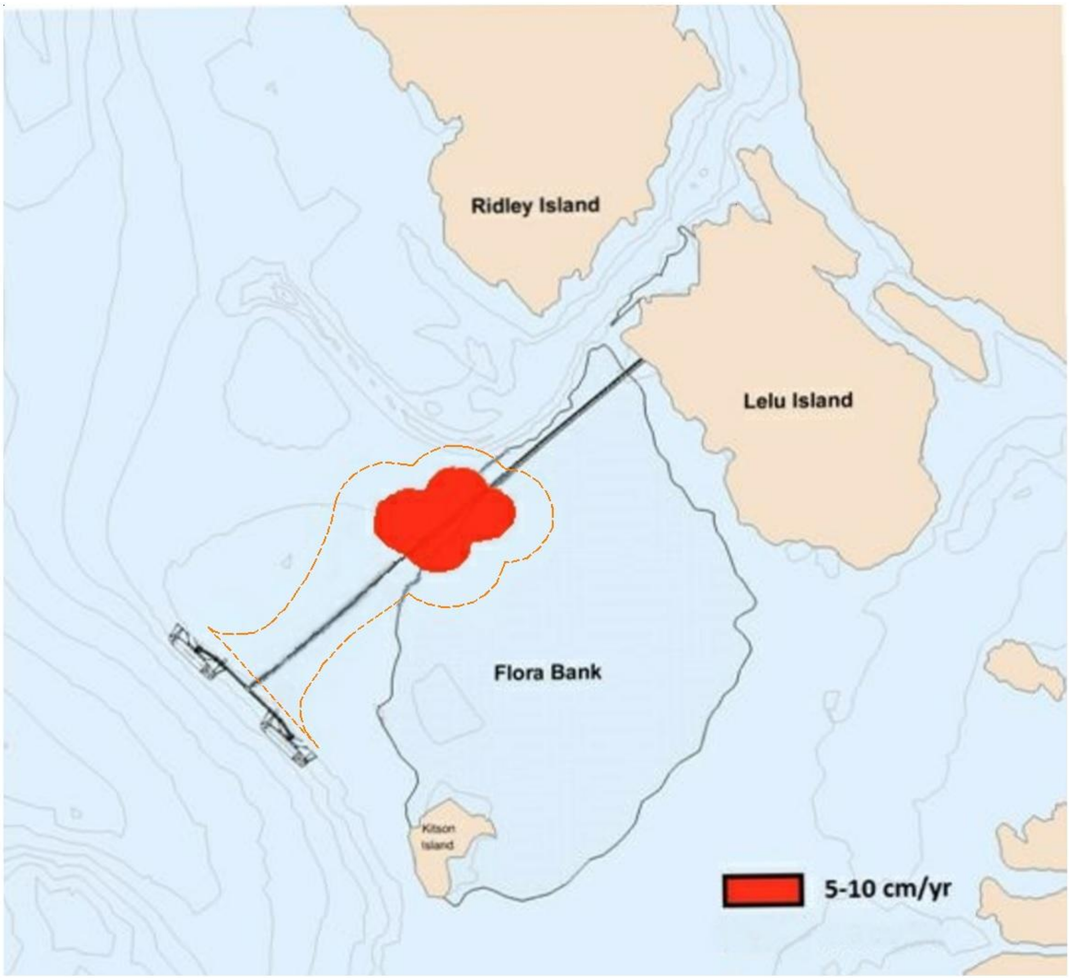

Figure 6-3: Depositional Pattern expected after the construction of the marine terminal structures

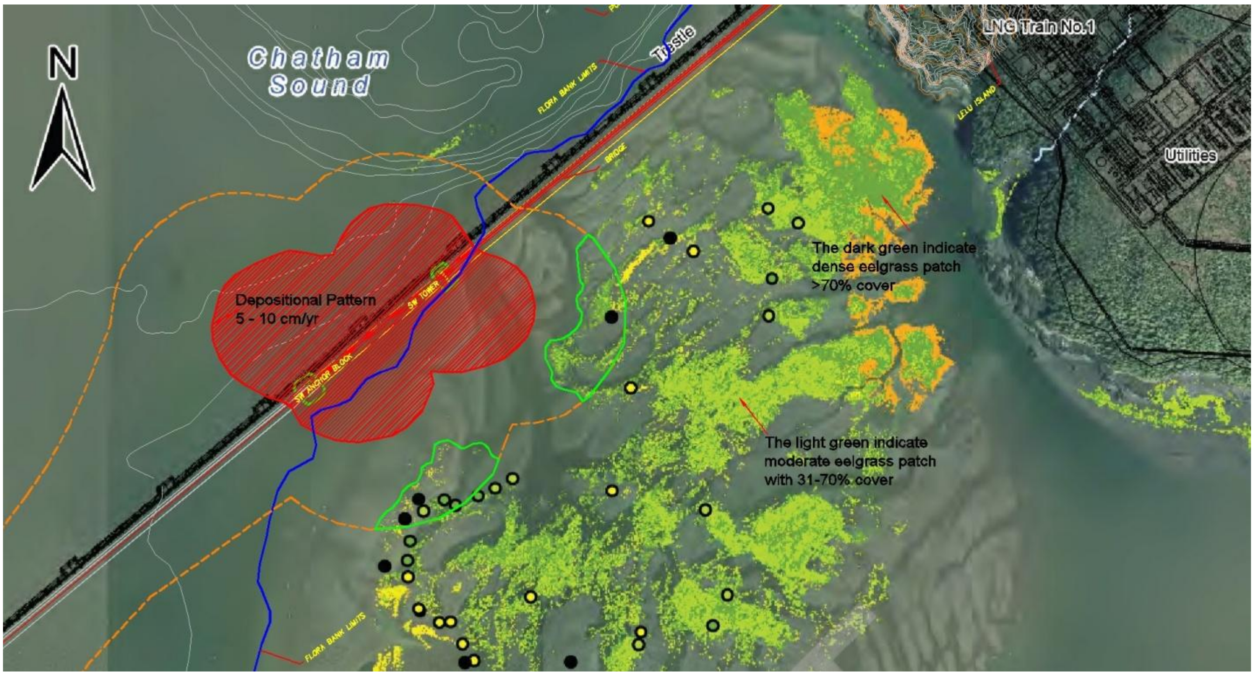

Figure 6-4: Deposition pattern expected with the marine terminal structures (Figure with Flora Bank eelgrass obtained from Stantec report [7])

7. References

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5. Hjulstrom, F., 1935. Studies of the morphological activity of rivers as illustrated by River Fyris. Bulletin of the Geological Institute University of Uppsala, 25,221-527. 1935.

6. Stantec Consulting Ltd., 2014. “Technical Data Report – Marine Sediment and Water Quality – Appendix L”. Report issued February 07, 2014.

7. Stantec, 2013. PACIFIC NORTHWEST LNG Technical Data Report – Marine Draft Rev. A. September 2013.

Appendix A

A.1 Hydrodynamic Modelling Runs

A.1.1 Model Description

The hydrodynamic modelling task was conducted using CMS Flow developed by the U.S. Army Corps of Engineers (USACE) which is a 2D depth-integrated model for simulating hydrodynamics (currents and water level oscillations), sediment transport and morphologic changes. The model includes physical processes such as wetting and drying areas, river discharges, tides, wind effects and atmospheric pressure.

A.1.2 Model Calibration

The hydrodynamic model was calibrated and validated using measured data collected around Lelu Island by two different companies. This is an important part of the study since it determines the model reliability and allows its use for different situations and for simulating different scenarios.

The initial simulation runs were defined with the same intervals as presented in the SNC-Lavalin Inc. (SLI) hydrodynamic study, for comparison purposes. Once the results compared well with field data and with SLI results, other relevant scenarios and different comparisons were carried out in our numerical model simulations.

A.1.2.1 CMS Flow Calibration Simulation 1

The first simulation occurred between September 14th 2013 and September 27th 2013 and included the river discharges from Skeena River and Nass River. The water level oscillation obtained with the model was compared with the predicted tides at Prince Rupert (Figure 3-1). The first 48 hours of simulations were not included since this is the ramp period, when the model is still stabilizing the initial conditions.

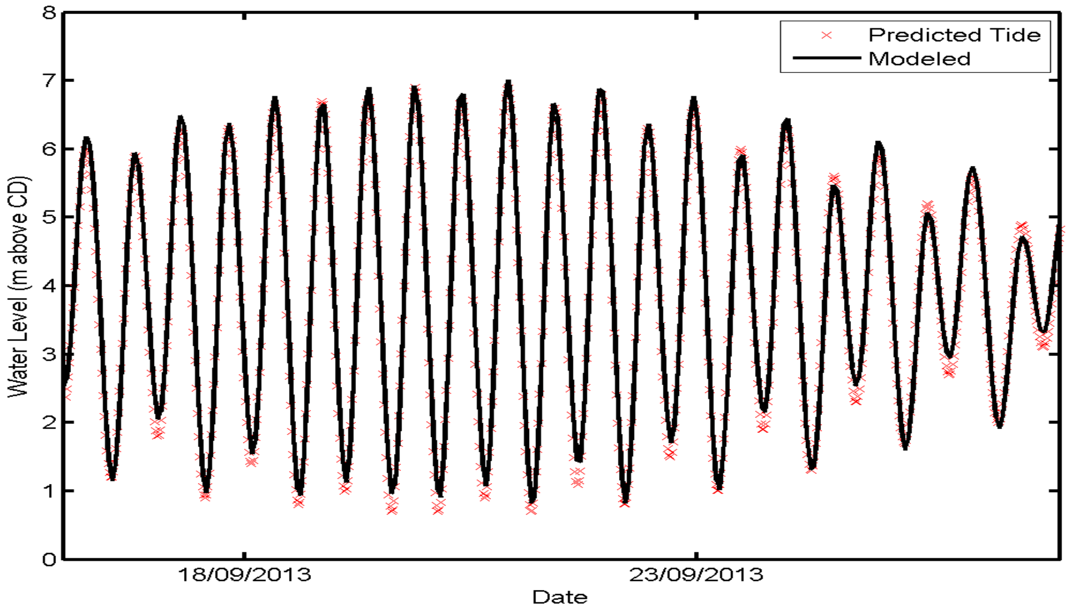

Figure 0-1: Comparison between the water level obtained from CMS Flow results and the predicted tides at Prince Rupert.

The current velocities obtained from the CMS Flow model during the calibration period were compared with the velocities measured by ASL Environmental Sciences on their field campaign between September 19th and September 21st 2013 (614887-1000-41ER-0001D_PB_Appendix D; Field Program Report.pdf).

Figure 0-2 presents the comparison between measured data and model results at the Porpoise Channel. The model represented well the current velocity pattern, increasing inside the channel, due to the area restriction.

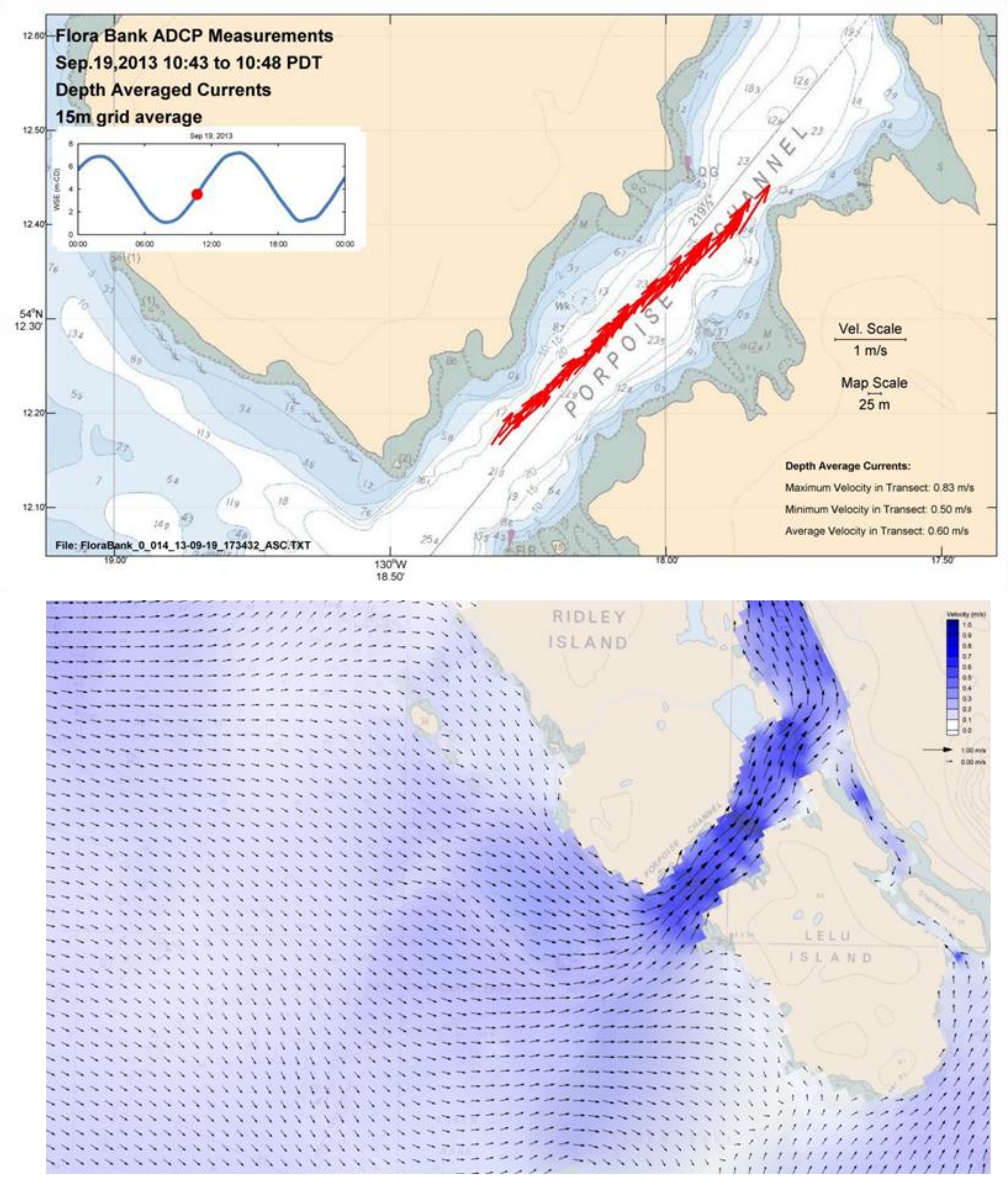

Figure 0-2: Comparison between measured currents (ASL, 2013) at the Porpoise Channel (top) and the currents modeled with CMS Flow (bottom).

The currents measured offshore of Agnew Bank also presented a good agreement with the currents obtained from the hydrodynamic model (Figure 0-3), where the depth averaged current velocities were low on both of them.

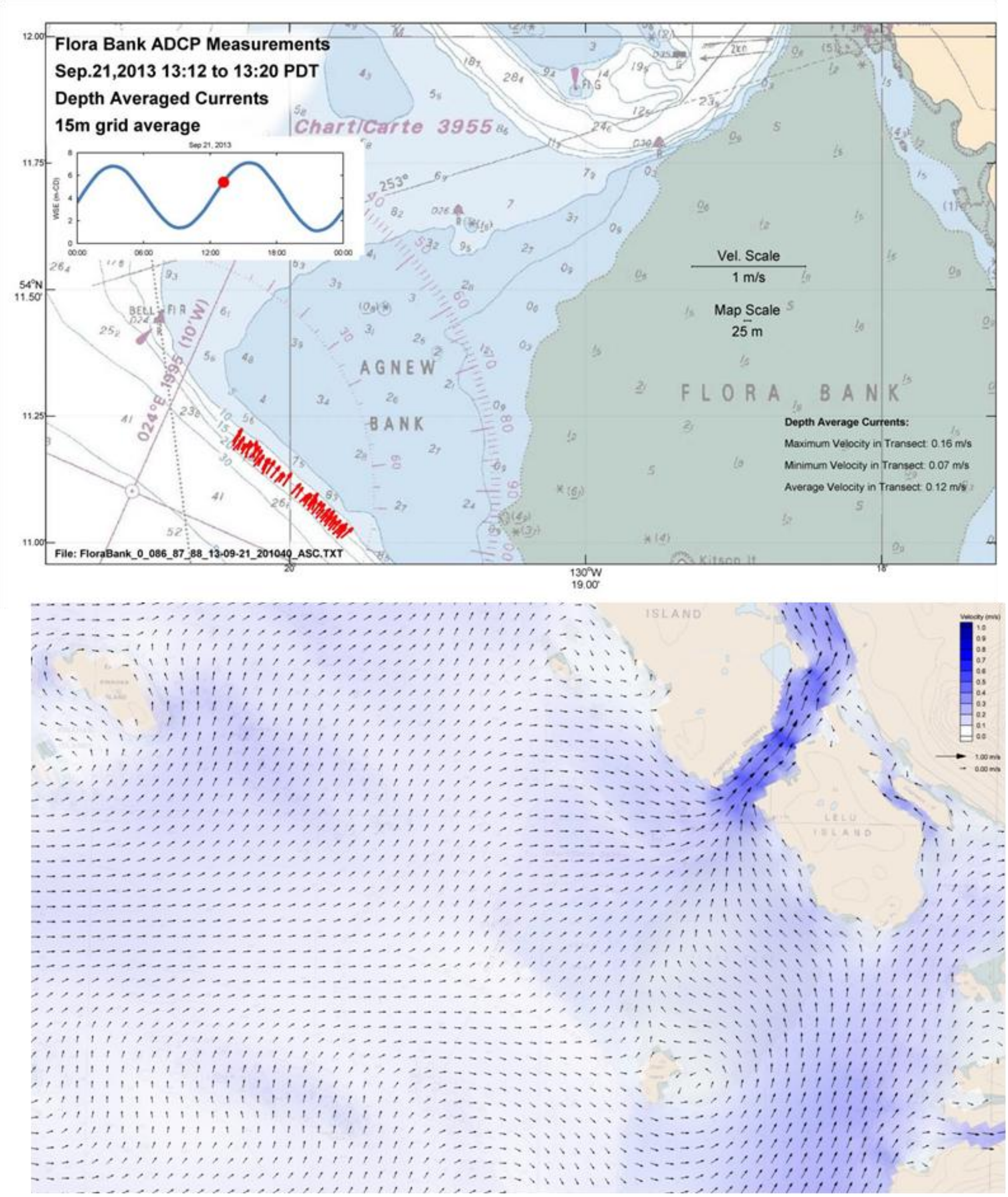

Figure 0-3: Comparison between measured currents (ASL, 2013) offshore of Agnew Bank (top) and the currents modeled with CMS Flow (bottom).

A.1.2.2 CMS Flow Calibration Simulation 2

The second period used to calibrate the numerical model was the period when the WatchMate^{TM} Buoy was deployed by Axys Technologies Ltd. (for PNW LNG) in 18 m (CD) of water to the West of Flora Bank (54°12'N and 130°20'W). Two weeks, from December 30th 2013 to January 11th 2014, was chosen for the calibration, since large spring tides were measured at Prince Rupert during this period.

The comparison between the CMS water level modeled results and the predicted tide at Prince Rupert presented a good correlation (Figure 0-4). The large water level oscillations during the spring tide were well represented by the hydrodynamic model.

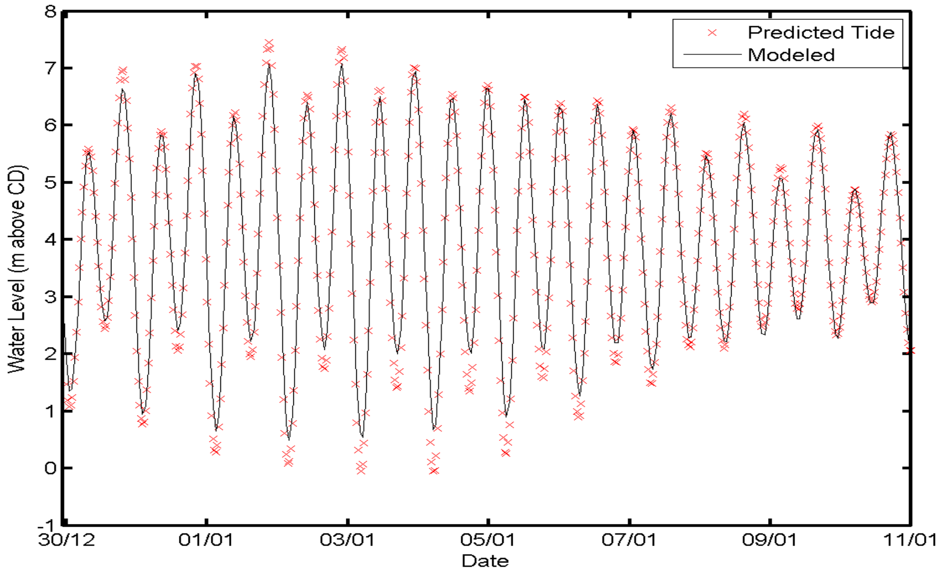

Figure 0-4: Comparison between modeled water level oscillation and predicted tide at Prince Rupert.

The WatchMate^{TM} Buoy wasn´t collecting water level information, therefore the current velocities were corrected according to the water level data collected at Prince Rupert. This correction is important since the tidal range can be greater than 7 m and the water column is constantly changing its depth.

Depth averaged current velocities measured by the WatchMate^{TM} Buoy during these period are presented on Figure 0-5.

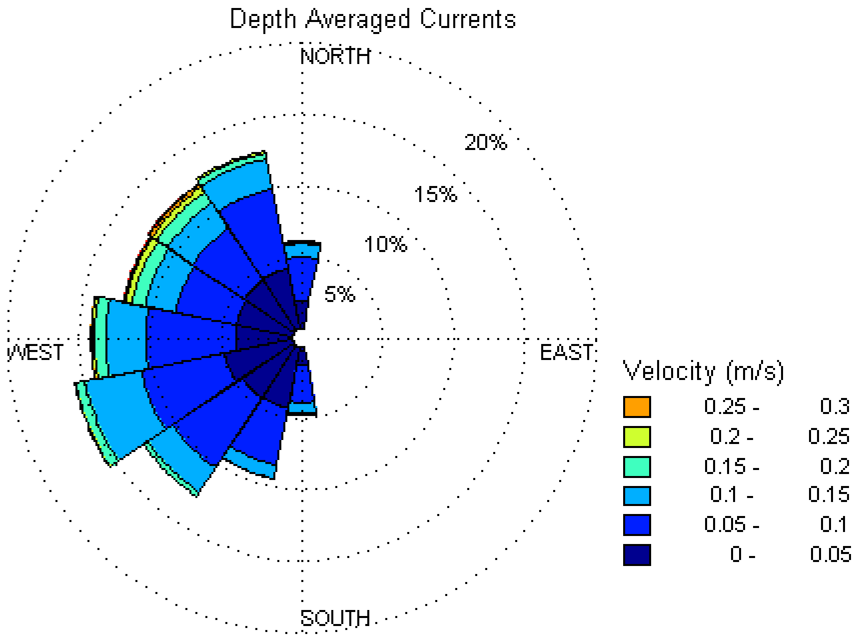

Figure 0-5: Depth averaged currents from December 30th 2013 to January 11th 2014.

The average current velocity measured by the WatchMate™ Buoy and corrected with Prince Rupert water level data was compared with the results extracted from the hydrodynamic model at the buoy location. The results from December 30th 2013 to February 15th 2014 are presented on Figure 3-2.

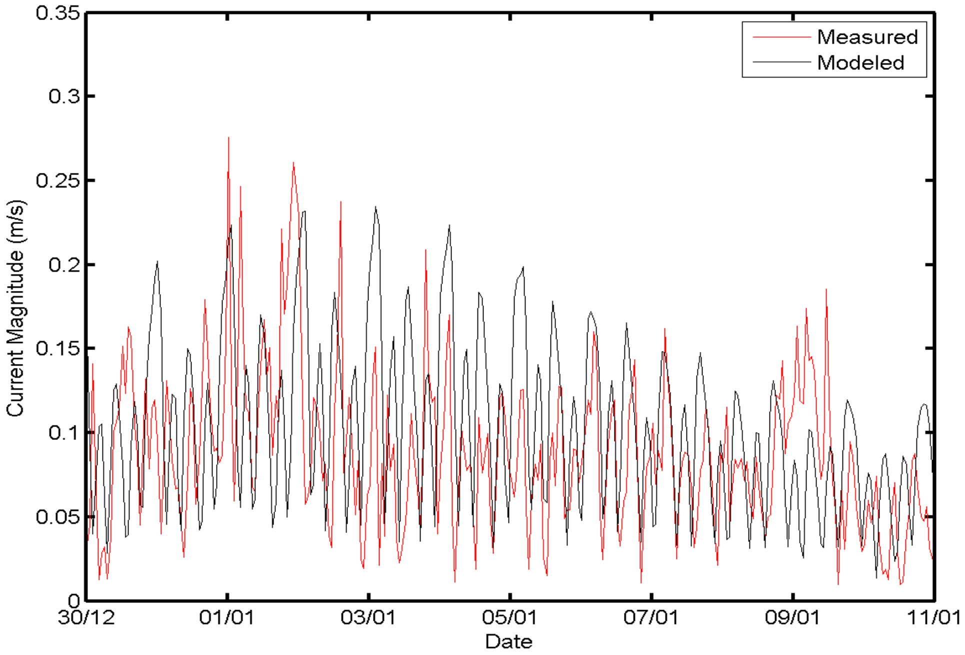

Figure 0-6: Comparison between CMS modeled currents and depth averaged currents measured by the buoy.

A.1.3 *Large Spring Tide Simulation*

A longer period with large spring tides was simulated to observe the hydrodynamic circulation characteristics around Flora Bank during a large spring tide event. This period was between January 1st and February 26th 2013, a total of 56 days.

The comparison between the water level obtained by the hydrodynamic model and the predicted tide at Prince Rupert during this period is presented on Figure 0-7, indicating a good correlation between modeled and predicted tides.

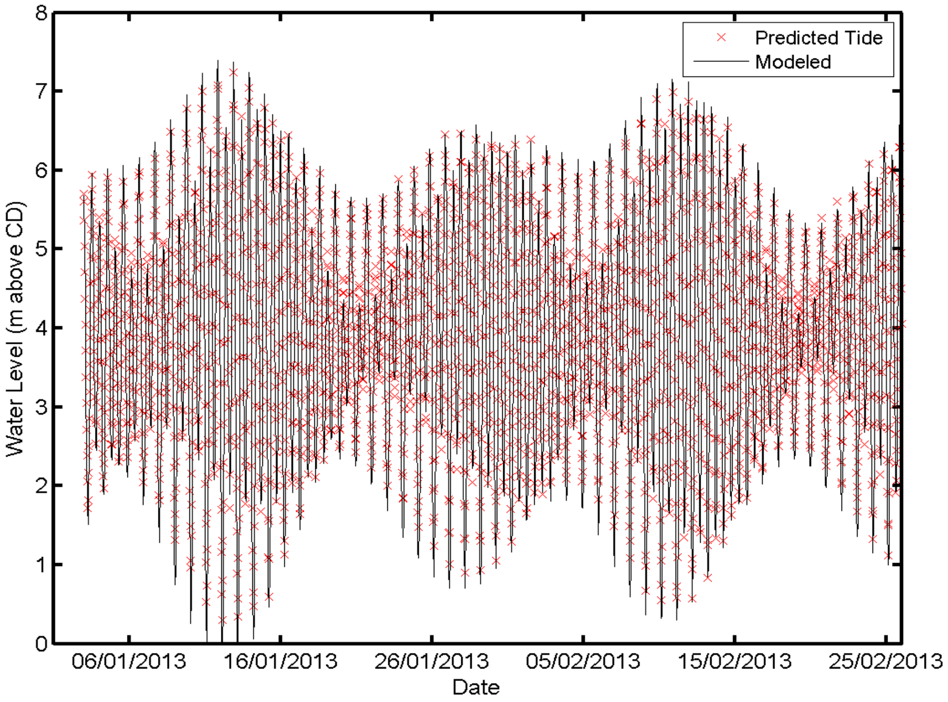

Figure 0-7: Comparison between the water level obtained from CMS Flow results and the predicted tides at Prince Rupert between January 1st 2013 and February 26th 2013.

The current characteristics around Flora Bank were extracted from the model representing one tidal cycle in February 11th 2013. Figure 0-8 shows the results every hour for the six hours prior to the high water (HW). This is the flood tidal stage, when the currents are moving towards the shore and Flora Bank becomes submerged. Figure 0-9 shows six hours after the HW mark, where in general the currents change their direction.

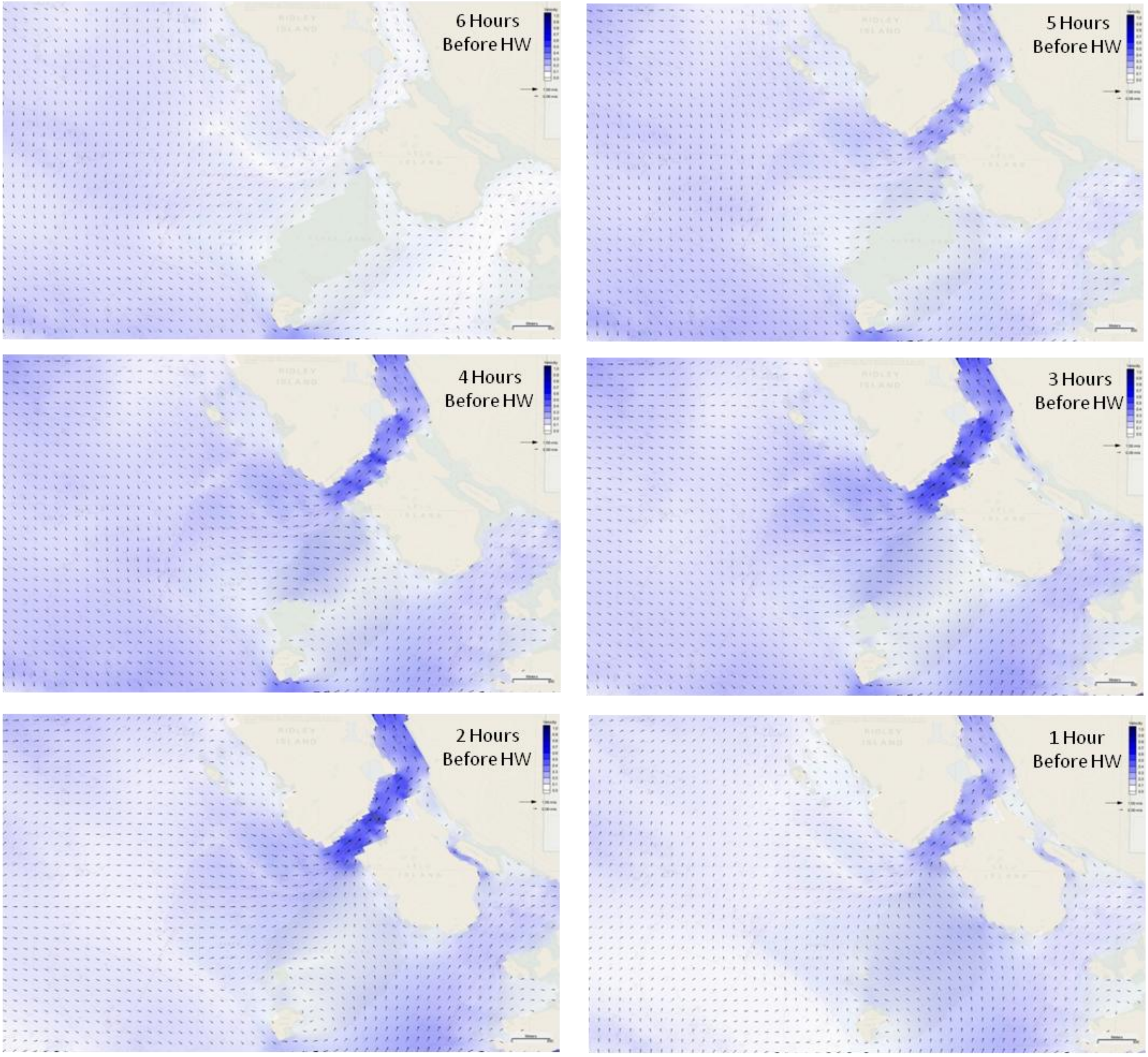

Figure 0-8: Current characteristics six hours before February 11th 2013 high water.

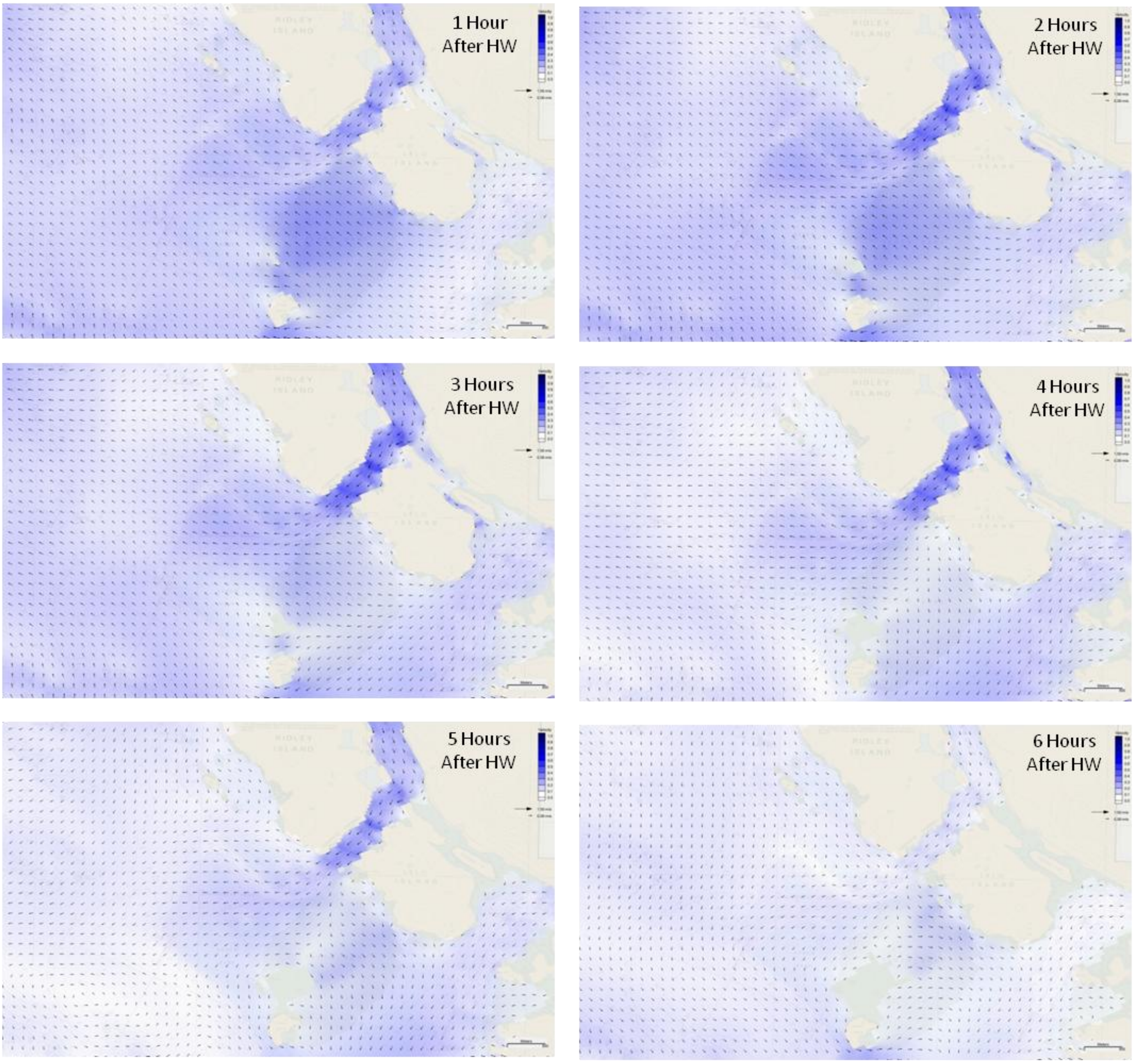

Figure 0-9: Current characteristics six hours after February 11th 2013 high water.