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June 12, 2023

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Re: **Lynn Creek Estuary Offset Project to Support the B2 FAA Preliminary Project Sedimentation Assessment Final, Rev. 3**

1 Introduction

This document presents the preliminary assessment of potential sedimentation at the Lynn Creek Estuary (LCE) Offset Project, as well as potential changes to sediment transport at the mouth of Lynn Creek as a result of the proposed Project. The purpose of this report is to assess the risk of infilling and sediment deposition on the constructed offset that would reduce its viability and productivity as an effective, functioning habitat. In addition, NHC examined possible changes to the quantities and patterns of sediment deposited at the mouth of the creek as a result of the proposed Project. The proposed site for the offset project is located at the creek mouth, adjacent to Lynnterm terminals, at the edge of Burrard Inlet. The site is being proposed as a fish habitat offset related to the project effects and resulting *FAA* for the B2 Project at the Neptune Terminal on Burrard Inlet.

Northwest Hydraulic Consultants Ltd. (NHC) has been contracted by Neptune Bulk Terminals Ltd. (Neptune) to develop a habitat offset design that will create intertidal and subtidal habitat (red polygon in Figure 1.1) which includes the physical work of constructing a rock and boulder reef at the seaward extent of the estuary. The engineering design basis and drawings related to these works are provided in separate documentation (NHC, 2023), which also contains background information on Lynn Creek and the estuary. Field investigations and initial modelling were undertaken in preliminary design.

As stated in NHC (2023), the assessed risk of sedimentation at the project site is believed to be low. This is because, under the current conditions, the velocities appear high enough to mobilize fine sediments and prevent infilling. In addition to effects of sedimentation on the offset design, it is also incumbent to assess whether the proposed design will impact sedimentation, scour, and erosion on adjacent areas. Similarly, there is no increased risk of sedimentation and deposition at the Lynn Creek delta due to the proposed Project. This is due to the limited extent of changed hydraulic conditions directly related to the proposed Project. Changes in modelled water depth and velocities were not observed to change markedly beyond the physical Project footprint.

This report is based on further assessments of the project site, examination of surficial materials and shallow test pits, review of channel forms and processes in the estuary, and hydraulic modelling at the Lynn Creek estuary with the proposed design to better inform the local hydraulics and sediment transport processes over the project footprint and adjacent areas of the estuary.

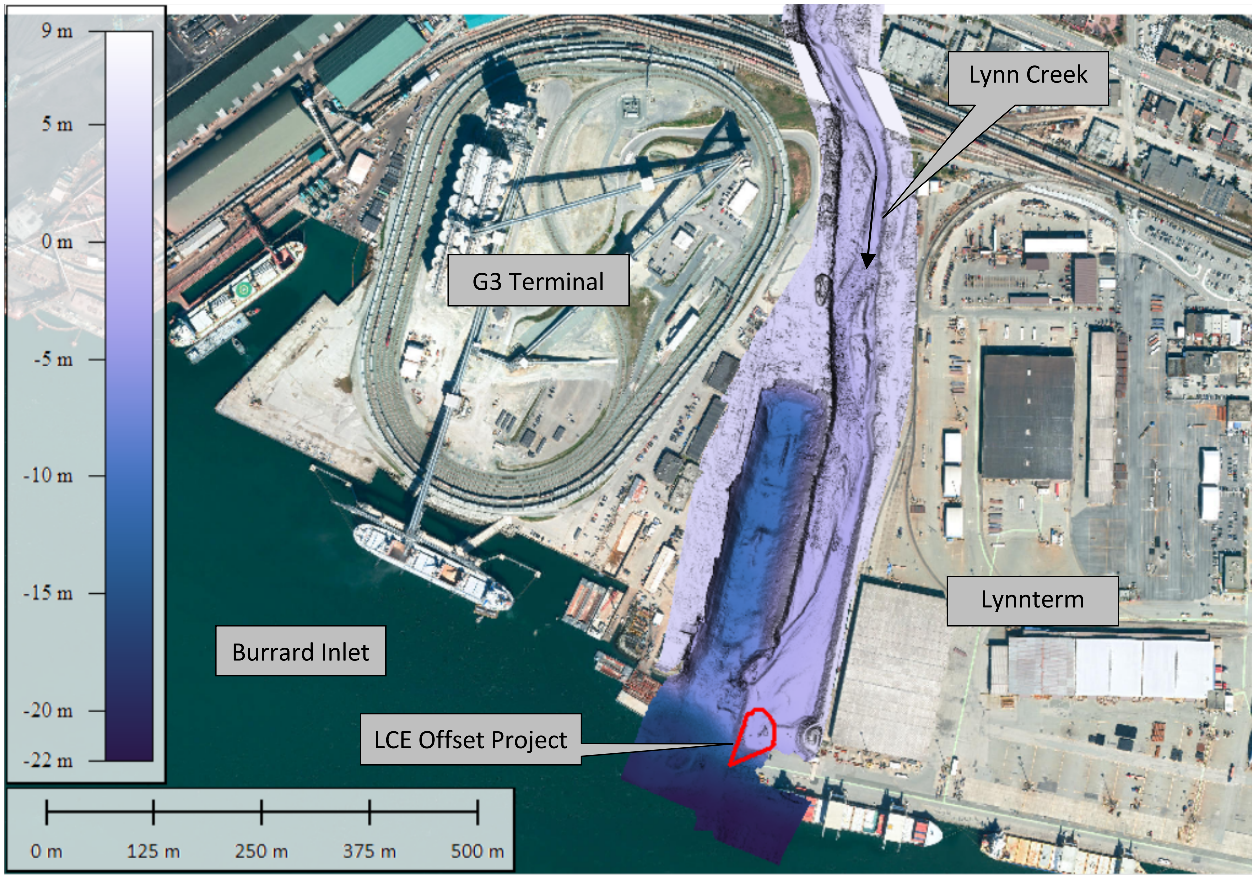

Figure 1.1 Proposed Lynn Creek Estuary Offset Project.

1.1 Project Description

The location of the LCE Offset Project relative to Lynn Creek and Burrard Inlet is provided on the preliminary design drawings accompanying the design basis report on Sheet 2 and Sheet 3, portions which are provided in Figure 1.1 and Figure 1.2. The project site is exposed to discharge from Lynn Creek, currents during ebb (west) and flood (east), and wind waves from the southwest fetch.

In the preliminary design, a perimeter berm of larger rock material buttresses a rockfill pad with smaller rock clusters to provide holdfast sites for macroalgal growth and cover for juvenile migrant juvenile salmon smolts. The perimeter berm is approximately 1.5 m above the existing grade and 2.0 m wide at its crest. The rock clusters are interspersed on the slope above the perimeter berm and project approximately 1.0 m above existing grade. The design provides gaps and spaces between the placed rock to allow for flow through the reef structure.

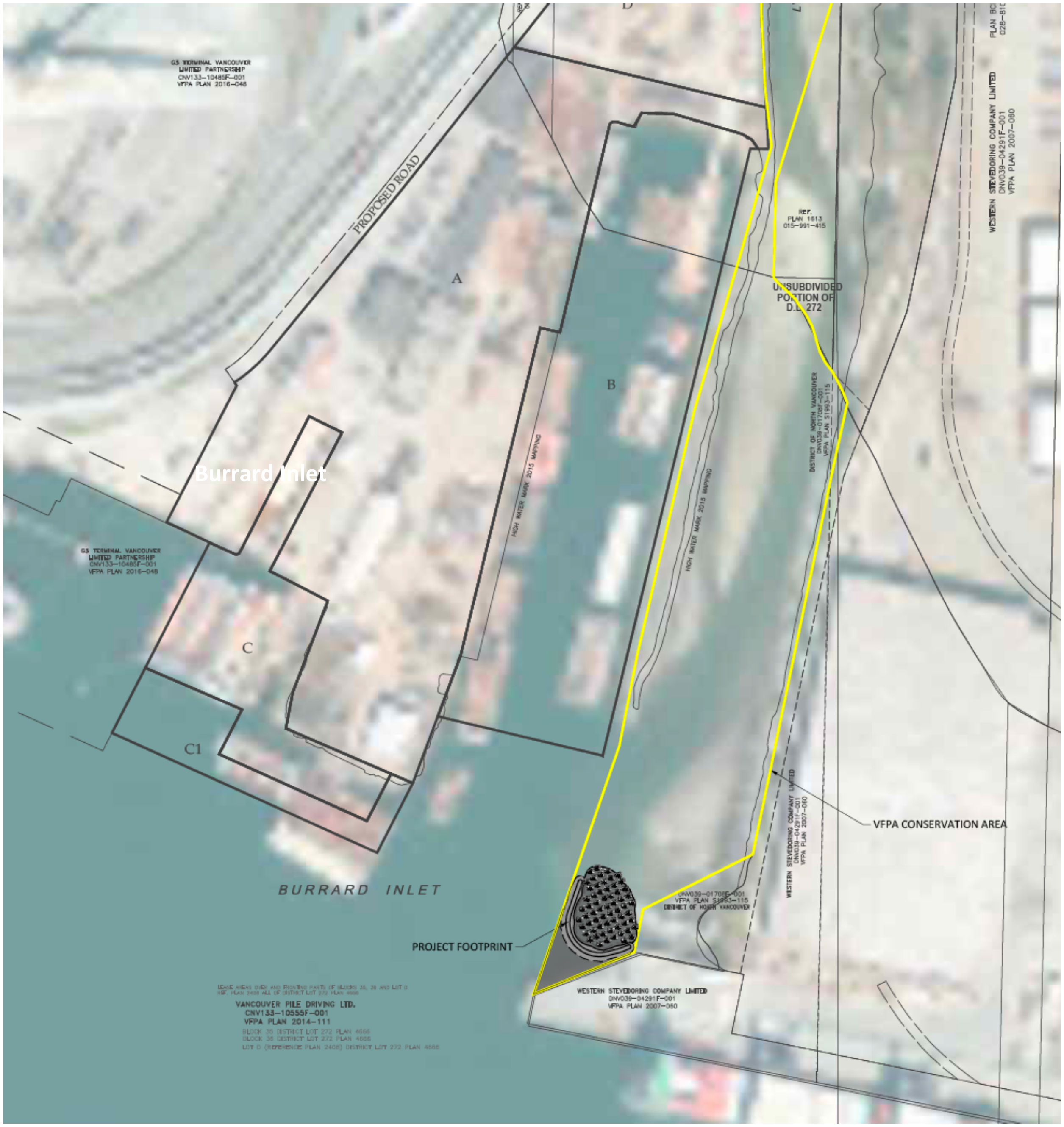

Figure 1.2 Proposed LCE Offset Project location and tenures (Sheet 2, NHC, 2023). The yellow polygon denotes the conservation area designated by Vancouver Fraser Port Authority (VFPA).

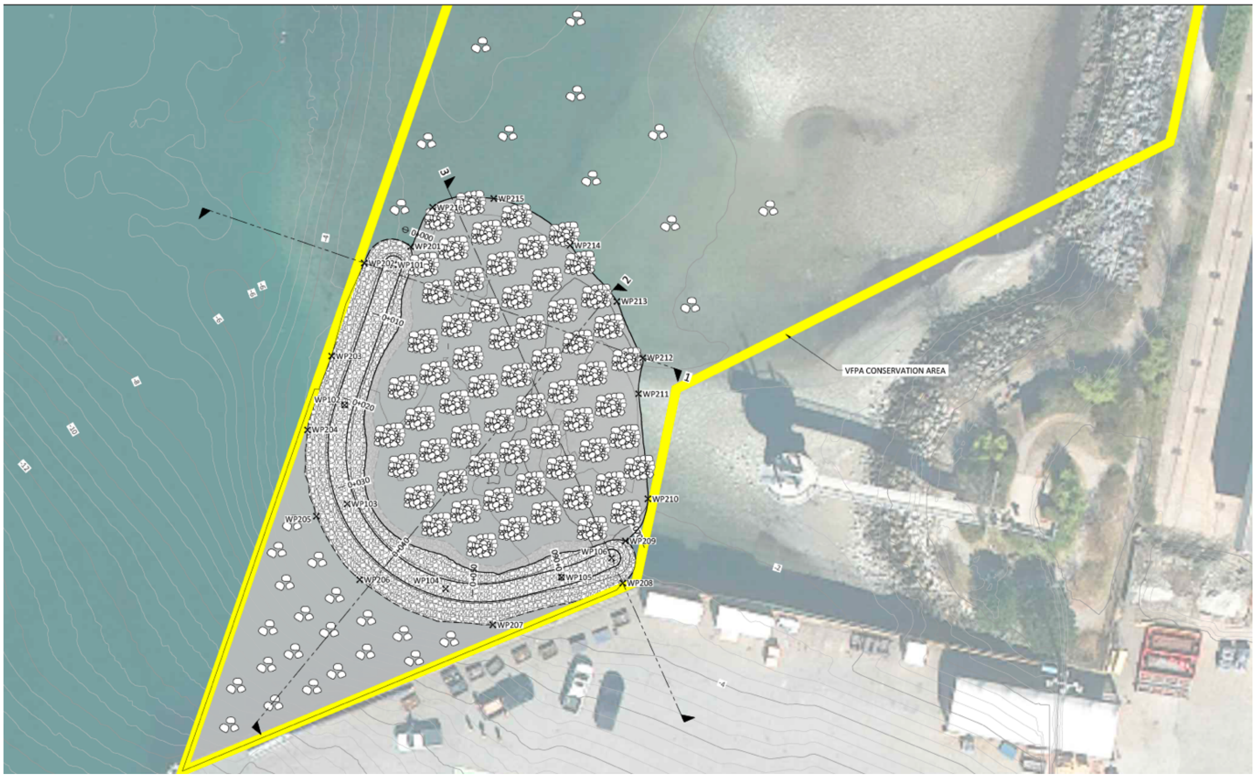

Figure 1.3 LCE Offset Project Preliminary Design (Sheet 3, NHC 2023).

2 Lynn Creek Estuary Site Observations

A site inspection was conducted by the NHC project team during the low tide on January 21, 2023, to investigate the current conditions. The low tide elevation reached about El. -3.0 m CGVD28 (0 m Chart Datum) at 23:38 PST.

Adjacent to the project site to the north along the eastern bank, the exposed intertidal area was gently sloping and composed of fine-grained sands and silts (Photo 2.1) with defined cobble benches on the upper slopes (Photo 2.1 and Photo 2.3). Closer to the project site, the benches and bar tops transitioned to gravels, sands, and sand bars. In contrast, further upstream and only partially affected by the tides, bar tops were heavily armoured with cobble with fine sediment only accruing behind wood, on the lee side of bars, or on the upper surface of the bars above high water.

Photo 2.1 LCE cobble and gravel bar forms (dashed line) with fine grained deposition on lower slope.

Photo 2.2 View of proposed offset site looking east towards observation tower on upper beach.

Photo 2.3 Gravel and Cobble sediments in the LCE (0.3 m Scale Bar).

Recent deposits of coarse sand formed lateral bars or lenses across the shoreline upstream and adjacent to the project site. These sands were coarse textured and had a different colour than the other fine textured sediments and were thinly deposited over gravel and cobble. NHC believes these to be recent deposits from large flood events on Lynn Creek in late 2022. At lower elevations, shallow surface excavations found that fine sands and silts were deposited in a layer up to 0.5 m thick before reaching a hard cobble and gravel surface.

Thicker deposits of finer gravels and sand were only observed near the HHW east of the observation tower and upstream along the east riprap slope. It appears that the deposition and retention of fine sediments occurs where velocities are low during both high tides and high flood flows from Lynn Creek, and there is limited exposure to wind waves. It is believed that fine sediments are likely mobilized within this area but are not readily transported off site by wave and tidal processes. Minor wave action was observed at the shoreline during the site inspection, and no sorting was observed within the fine sediments, indicating a low energy depositional area. Water depth and darkness limited the extent of the area surrounding the offset area that could be investigated. Despite areas of softness within the bar, the surface materials appeared competent.

NHC observed the hydraulics of the creek flow entering tidewater at the low tide, and this revealed an extended gravel bar leading out into area immediately south the VanPile lease area. The size and extent of the gravel bar indicated that significant bed load has likely deposited into the estuary area from the Fall 2022 flood events. This deposition is also unaffected by the presence of the proposed Project, which is located downstream and to the east of the Vanpile lease area.

3 Sediment Processes at Lynn Creek Estuary

The Lynn Creek estuary is influenced hydraulically by Lynn Creek outflows, the tidal currents, and wind and ship waves generated in Burrard inlet. It is suspected that coastal processes such as longshore drift and wave action do not contribute to significantly to the sediment influx in the estuary as wharf and dock development along the foreshore to the east and west reduces potential sources of sediments.

Currently, most sediments in the lower river are sourced by Lynn Creek as either suspended or bed load, generated by flood events. Suspended sediments, carried in the water column, deposit along the channel as surficial deposits or small bar forms in areas of reduced water velocity, and finer sediments are carried into Burrard Inlet as wash load. Bed load, transported largely along the riverbed interface, deposits at the terminus or end of the Lynn Creek channel as a prograding bed form composed of cobbles, gravels, and sands. Smaller bed load deposits are found on the edges and tops of bars upstream of the terminus, but they are relatively minor.

Tidal action likely influences how coarse sediments are pulled out in the marine confluence as a bed form, which progrades like a small delta. Historically this deltaic development would occur until it reached deep marine waters where its slope was unstable and beyond the angle of repose, it would ravel and sort, with finer sediments worked by tidal currents. Tides also may influence the overall sediment transport in the lower section of river channel below the railway bridge by altering the effective hydraulic slope of the reach with reduced shear (less slope) at high tide and increased shear at low tide (increased slope) in addition to the influence of creek discharge.

Unlike typical estuaries, Lynn Creek is largely confined such that there are no overbank flows or wide areas for sediment to deposit. With lateral transport of sediment effectively cut off, most sediments are carried to tidewater near the end of the channel. With the existing channel confinement and abbreviated channel terminus at tidewater, bed load is conveyed effectively to the same location and is not dispersed in multiple channels. Currently, the Lynn Creek channel deposits most bed load sediments west of the project site and south of the VanPile lease area in an open section entering Burrard Inlet. If these deposited sediments are excavated or removed, the fixed channel transports and deposits new sediments, and reforms the bed.

4 Numerical Modelling

Additional numerical modelling was completed to better investigate the hydraulics resulting from both the discharge of Lynn Creek and the tidal action within Burrard Inlet. The combination of both the creek discharge and ongoing tidal currents provide the likely drivers of sediment transport dynamics at the Project site and estuary. Numerical modelling analysis was conducted using the TELEMAC SYSTEM, a suite of finite element computer programs developed by the Laboratoire National d’Hydraulique et Environnement (LNHE), a department of Electricité de France’s Research and Development Division, to evaluate the hydraulics associated with the proposed design.

4.1 Model Implementation

The ocean boundary of the TELEMAC model mesh used for the study extends from Eagle Island at its northern boundary to Point Grey at the south boundary (Figure 4.1). The model includes the Burrard Inlet, Vancouver Harbour, Indian Arm, and extends eastward to Port Moody. The 3D model mesh contains approximately 72,000 nodes, 140,000 elements and 11 levels in the vertical dimension. The element lengths vary from approximately 200 m in the Burrard Inlet to about 0.5 m near LCE and the location of the proposed design.

The bathymetry for the model is derived from available bathymetric data from Vancouver Fraser Port Authority (VFPA) and from the National Centers for Environmental Information (NCEI) coastal digital elevation models (DEMs). The LCE bathymetry was derived from survey data collected by NHC in December 2022.

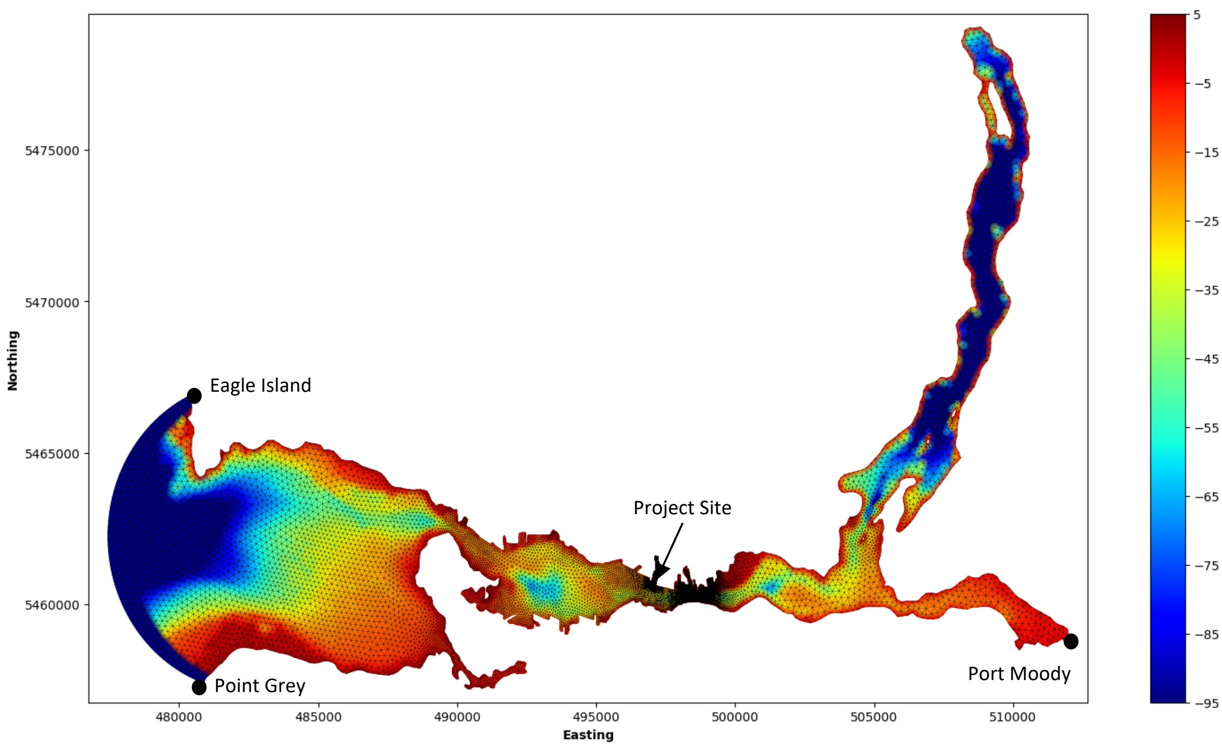

Figure 4.1 TELEMAC model domain.

For the analysis, the period of a large spring tide (December 21st to 26th, 2022) is chosen as it is anticipated to be the tidal conditions where mobilization of suspended sediment loads is expected. The tidal conditions at Point Atkinson for the simulation period is shown in Figure 4.2 .

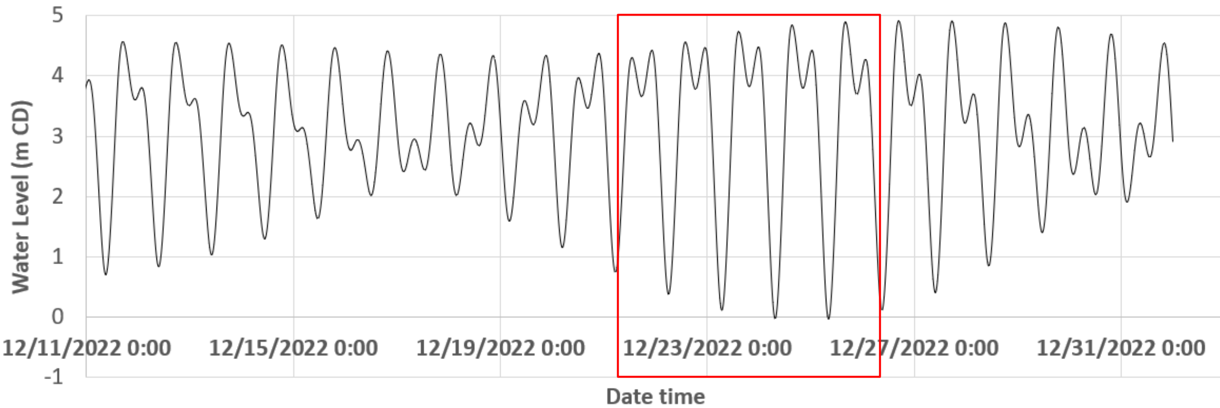

Figure 4.2 Water Levels recorded at Point Atkinson tidal gauge.

Two Lynn Creek flow scenarios were considered to represent the estuary hydraulics during this tidal cycle:

1. Lynn Creek flow of 10 m^3/s – this value is the mean daily discharge over the months of April to August during the period of record. This flow condition is chosen as a typical flow discharge in Lynn Creek during large tide cycles where the tidal influence can be assessed with a relatively lower Lynn Creek discharge.
2. Lynn Creek flow of 97.1 m^3/s – this value is the 95^{th} percentile of mean annual flood (MAF) from October to February during period of record. This flow condition is chosen as it is anticipated to be a time when there would be a significant influx of both bedload and suspended sediment loads from the river.

4.2 Model Results

The model results for water depth and velocity near the project site during rising tide, slack water, and falling tide conditions are presented in the attached figures in Appendix A.

The model simulation results show that the largest velocities over the offset project footprint occur during high Lynn Creek discharge, which are downstream directed. Velocities peak near 1.5 m/s over the perimeter berm and boulder clusters (Figure 4.3, Appendix A). During low Lynn Creek flows, high velocities occur over the rock berm crest during rising tides, with flow speeds up to 0.5 m/s. Adjacent to the offset footprint where the main channel discharges to Burrard Inlet, velocities also remain similar regardless of Lynn Creek flow.

In order to assess the overall impact of the tidal current over the offset area and local estuary, the maximum velocities over the entire tidal cycle at Lynn Creek flows of 97 m^3/s and 10 m^3/s are shown in Figure 4.3.

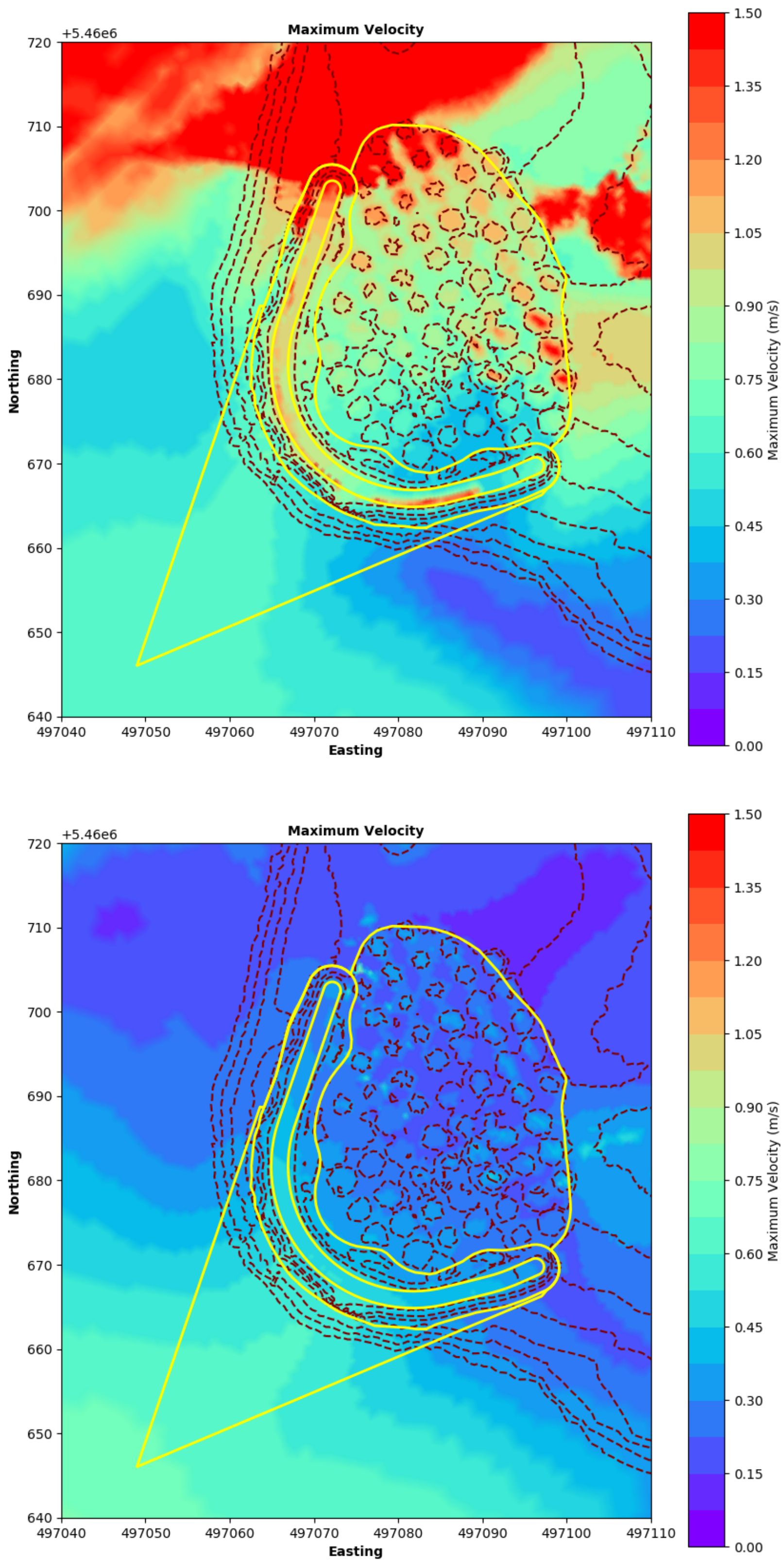

Figure 4.3 Maximum velocities through the tidal range during Lynn Creek flows of 97 m^3/s (top) and 10 m^3/s (bottom).

Over the entire winter tidal cycle simulated, the offset area becomes dry at the end of the ebb. Depths range from approximately 3.0 m at the peak of the flood tide to 0 m at the end of the ebb over central area of the offset. Velocities tend to peak during high Lynn Creek flows at the margins of the design footprint as the tide recedes and water depths are reduced until flows run off the rocky reef platform. During the falling tide, velocities are greatest over the northern half of the rock clusters with values of approximately 1.5 m/s. When the tide is rising velocities are reduced overall regardless of Lynn Creek discharge with values of 0.75 m/s over the south extent of the rock clusters (Appendix A).

A comparison of model results for the existing conditions versus the proposed design was conducted to quantify the extents of the hydraulic influence of the offset project. The pre and post project difference mapping are presented in Appendix B.

Changes in flow velocity were calculated across the LCE and show that implementing the offset design will cause local velocity changes during high Lynn Creek flows and low slack tidal conditions. Very few changes in the velocity field are noted at the modelled low Lynn Creek discharges sampled at three different timesteps in the tidal cycle which suggests the structure does not greatly influence the relatively low velocities during the tidal exchange. During the modelled high Lynn Creek discharge some areas of velocity change are noted with some areas varying approximately -0.5 to 0.5 m/s. Some changes appear to be simply the result of reduced conveyance during a time within the tidal cycle when the project area is within the water column (first frame; S153. and middle frame; S161). The middle frame during slack tide shows some complex interaction that may be a feature of the geometry extending out from the estuary where depth increases suddenly.

5 Discussion

During low Lynn Creek flows, both bed load and suspended sediment transport within the channel are expected to be minor compared to during flood flows. Since the offset footprint is located at the estuary terminus, tidal hydraulic processes are dominant during non-flood flow conditions and the velocity vector field (magnitude and direction) are relatively insensitive to Lynn Creek discharges.

The project does not appear to affect hydraulics outside of its relative footprint, hence hydraulics further from the project site are unaffected. There are no expected changes to the existing sedimentation patterns and quantities at the mouth of Lynn Creek where sediments currently accrue. As discussed earlier, larger bed load composed of cobble and gravel material will deposit on the channel bed and creating the prograding bed form west of the offset area. This process will continue and is unaffected by the offset geometry.

Based on the current site conditions, the project site is neither aggrading or degrading in terms of fine sediment accumulations and some quasi-equilibrium has established. Assuming that the coarse sediments observed – likely historical deposits – underlie the offset area, degradation is also unlikely. Fine sediments are most likely to accrue and settle in the project site due to:

- Episodic large flood discharges in Lynn Creek that suspend fine sediment into the water column, carried downstream and these settle in the offset area where velocities are reduced due to channel area expansion, and

- Fine sediments adjacent to the offset area that are eroded and re-distributed by tidal action and wave climate.

The numerical modelling illustrates how velocities change over the offset project as water levels fluctuate tidally by approximately 3.0 m. Bed shear stresses were estimated using the hydraulics over the offset area. Estimated bed shear stresses ranges from 58 N/m^2 at 1.5 m/s to 0.3 N/m^2 at 0.1 m/s during the end of the lowering tide. These hydraulic condition have the capability to mobilize sediments with size clasts from coarse gravel to fine silts (USGS, 2008). NHC expects that fine sediments that settle and deposit on the project site from Lynn Creek floods will be remobilized by shear generated by the tidally driven flows on both ebb and flood tides. The cyclic flow conditions of the tidal hydraulics has sufficient transport capacity to remove settled sediments.

Flows and velocities between individual large rocks or rock clusters cannot be modelled, but velocity tends increase as conveyance area is reduced. In order for accrued sediment to be mobilized and moved out of the project site with tidal action, smaller channels between the rock clusters will be included and these channels will be aligned with the direction of flow during both ebb and flood conditions. The perimeter berm will be gapped to accommodate these channels and allow sediment to flush from the habitat structure.

Implementing the offset design results in local velocity fluctuations near the offset footprint. Slower velocities are typically centred directly on the footprint due to the increased roughness and flow separation. The high flow low slack tidal scenario produces the most varied velocity distribution because the reef is fully dry and river flows are directed into the channel. The higher velocity regions are typically bounded by low velocity regions and do not extend across the entire channel width. The velocity changes may result in some localized sediment movement, but not large scale changes in sediment transport rates or shift in sediment deposition. These local changes are likely similar to adjustments that occur naturally in the estuary due to high Lynn Creek discharges and resulting sediment transport. The project itself is not likely to increase or decrease deposition rates substantially or influence sediment flux through the LCE through to the marine environment.

6 Summary

The following summarizes the assessment completed regarding sedimentation at the Lynn Creek estuary and proposed offset project:

1. Sediment deposition is expected to continue in the estuary following the general observations made during the site inspection on January 21, 2023. Fine sediments will continue to deposit during high flood flows on Lynn Creek and be redistributed locally during tidal cycles. Bed sediments are expected to continue to deposit in the current location immediately south of the VanPile lease area.
2. The offset has no influence on hydraulics outside of the project footprint; hydraulic effects are limited locally to the project site. The offset habitat does not influence Lynn Creek outflow hydraulics or sedimentation outside of project area.
3. Numerical model results indicate that velocities over the offset are typically elevated when the tide lowers and depths are reduced before the offset footprint is stranded. Sediments are not

expected to accrue on the proposed Project site to the degree where it buries the placed rocky substrate. This is similar to what was observed in the pilot study area.

4. Detailed design of the offset project – including arrangement and alignment of the rock and boulder materials – is critical to ensure sediments will flush from the offset area. Elevated velocities within the boulders and small interstitial channels will mobilize and flush fine sediments.
5. Refinement to the offset project will result in minor changes to these reported values, which were presented to provide conceptual level of future hydraulic conditions to support analysis of sediment transport and deposition in Lynn Creek estuary. Since no sediment sampling or turbidity measurements were collected as part of this study, the general level of variability and uncertainty should be considered when evaluating the presented values.
6. The hydraulic influence of implementing the offset project is expected to result in some localized sediment transport (deposition and scour) near the project footprint. No changes to large scale sediment transport processes are expected that would result in increases to the annual sediment load within the lower LCE. Implementing the offset design is not expected to result in increased sedimentation or dredging in neighboring tenures.

7 Closure

Report prepared by:

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Hydrotechnical Engineer

Report reviewed by

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
B. M. CHILIBECK
EGBC P2P 1003221 12 June 2023

Barry Chilibeck, P.Eng.
Principal

DISCLAIMER

This report has been prepared by Northwest Hydraulic Consultants Ltd. for the benefit of Neptune Bulk (Canada) Terminals Ltd. for specific application to the Lynn Creek Estuary Offset Project to Support the B2 FAA. The information and data contained herein represent Northwest Hydraulic Consultants Ltd. best professional judgment in light of the knowledge and information available to Northwest Hydraulic Consultants Ltd. at the time of preparation and was prepared in accordance with generally accepted engineering and geoscience practices.

Except as required by law, this report and the information and data contained herein are to be treated as confidential and may be used and relied upon only by Neptune Bulk (Canada) Terminals Ltd. , its officers and employees. Northwest Hydraulic Consultants Ltd. denies any liability whatsoever to other parties who may obtain access to this report for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this report or any of its contents.

EGBC Permit to Practice Number: 1003221

8 References

NHC (2023). *Lynn Creek Estuary Offset Project to Support the B2 FAA. Design Basis Report Final, Rev. 2*. Report prepared by Northwest Hydraulic Consultants Ltd. for Neptune Bulk (Canada) Terminals Ltd. 13 pp.

USGS (2008). *Simulation of Flow, Sediment Transport, and Sediment Mobility of the Lower Coeur d'Alene River, Idaho* (2008–5093). Scientific Investigations Report. Prepared in cooperation with the Idaho Department of Environmental Quality, Basin Environmental Improvement Commission, and the U.S. Environmental Protection Agency, Virginia. 164 pp.

APPENDIX A

NEAR-FIELD MODEL SIMULATION OUTPUT

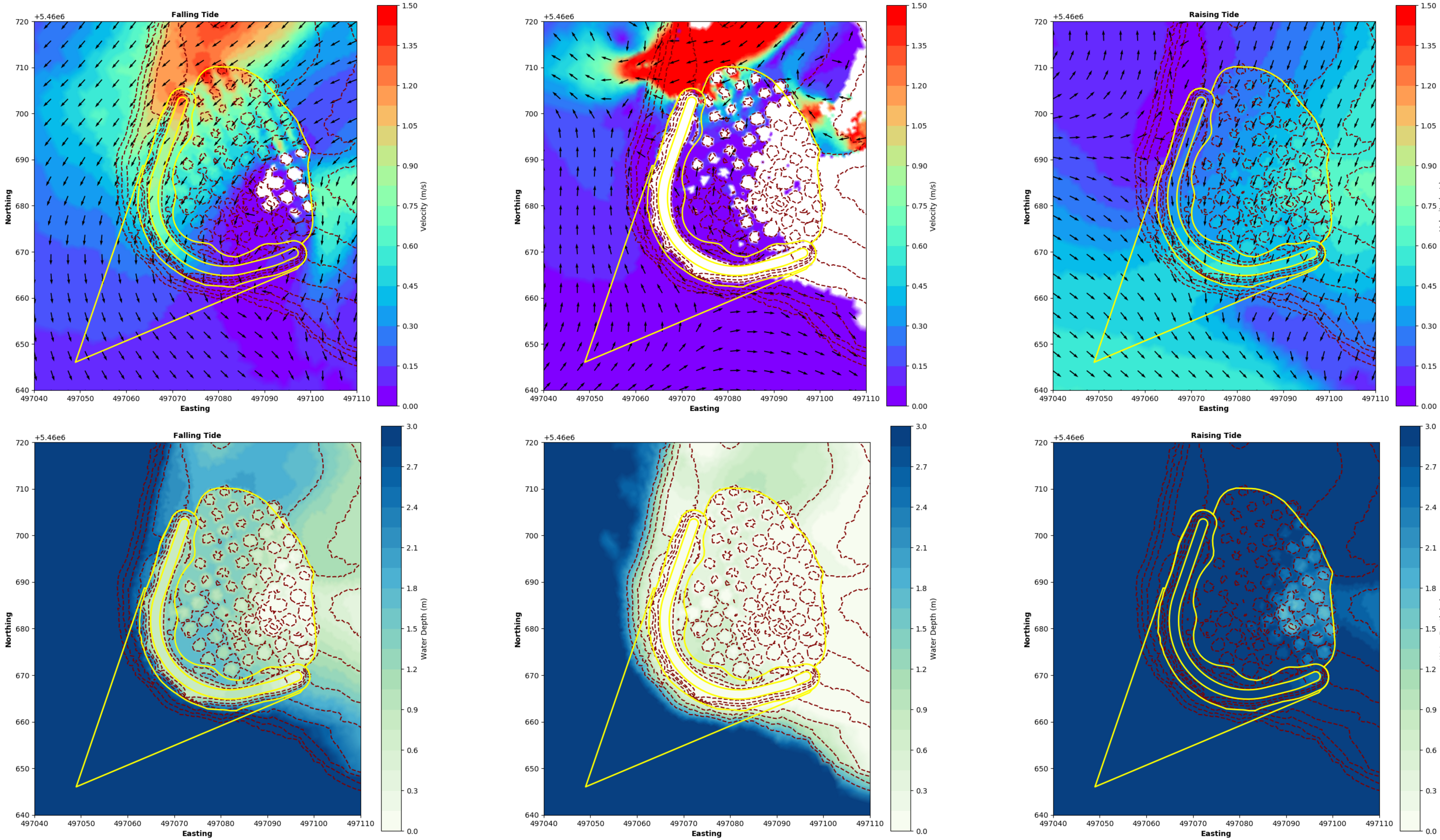

Figure A1 Velocity and depth over the offset footprint during high Lynn Creek discharge

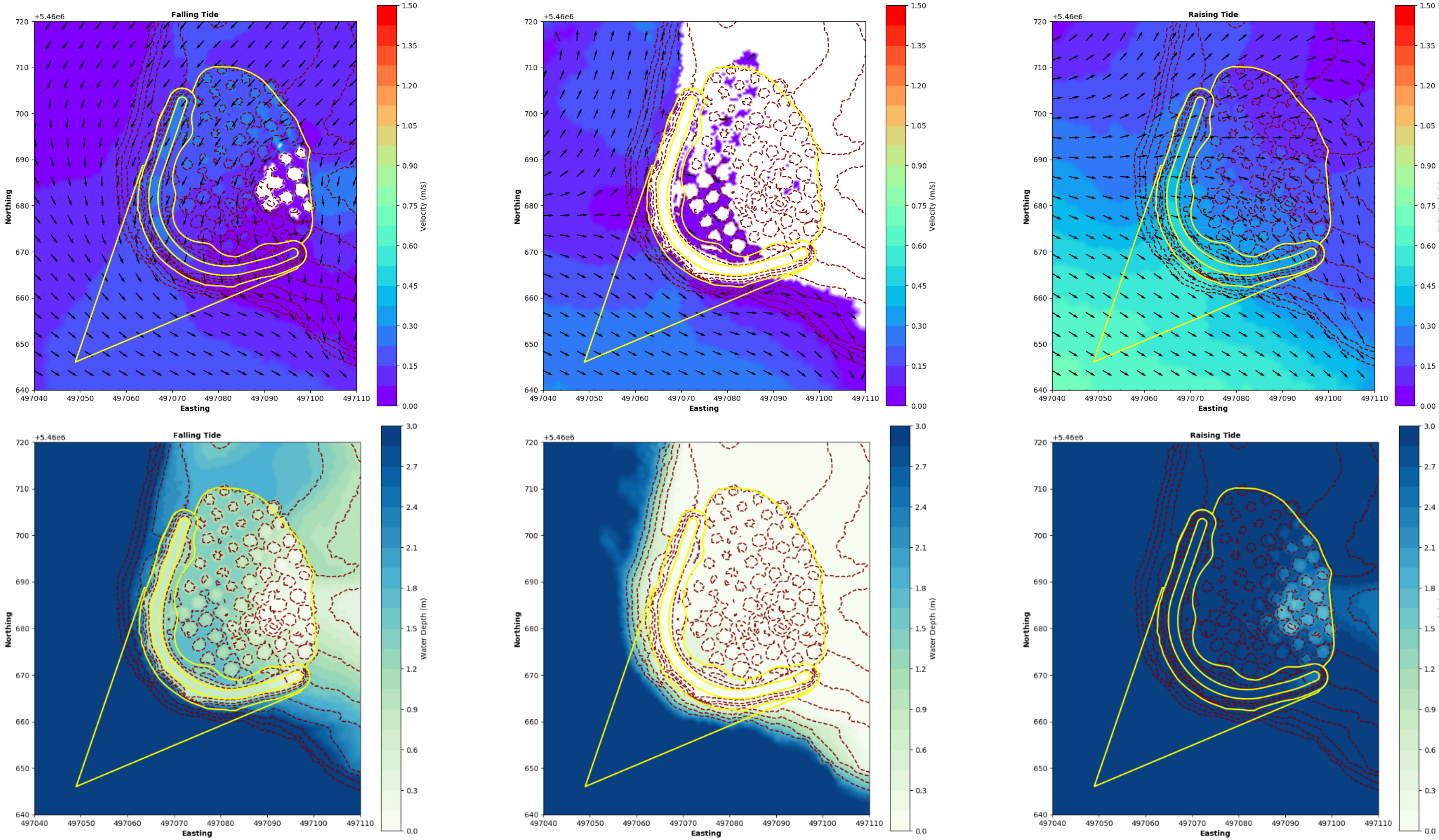

Figure A2 Velocity and depth over the offset footprint during low Lynn Creek discharge

APPENDIX B

FAR-FIELD MODEL SIMULATION OUTPUT

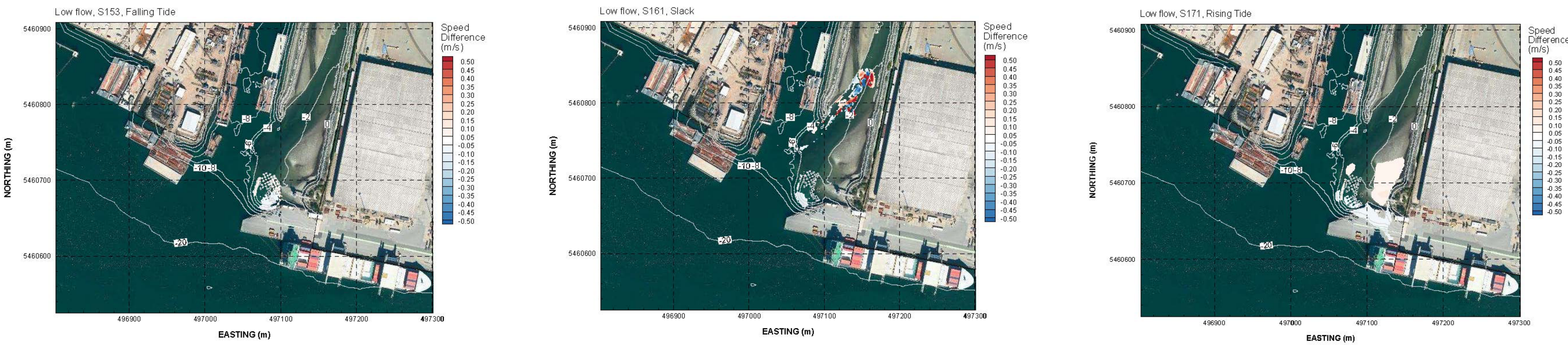

Figure B1 Velocity difference between the existing conditions and proposed design the offset footprint during low Lynn Creek discharge

Figure B2 Velocity difference between the existing conditions and proposed design the offset footprint during high Lynn Creek discharge