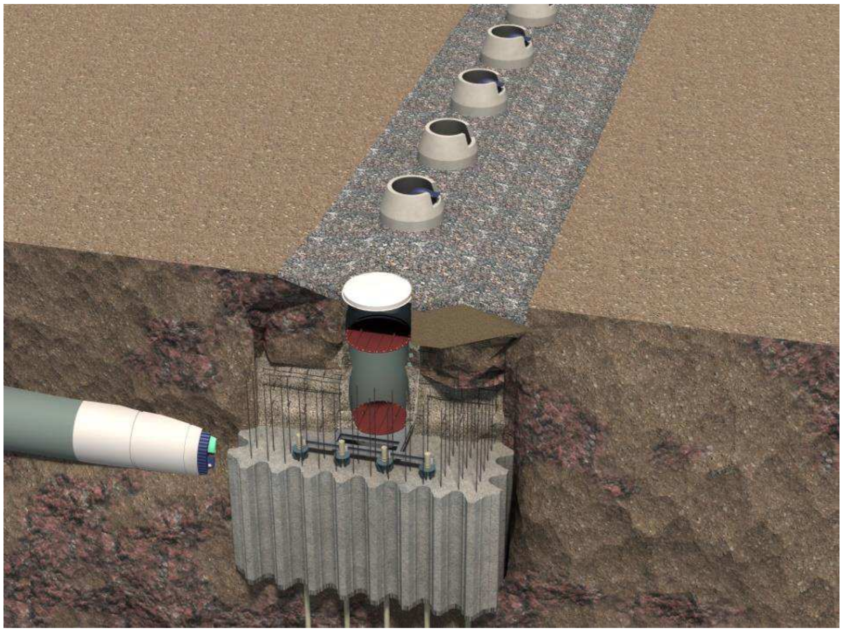
APPENDIX F
NAVIGATION STUDIES

F.2: Navigation Impact Assessment

Annacis Island WWTP New Outfall System

Vancouver Fraser Port Authority
Project and Environmental Review Application



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Navigation Impact Assessment

Annacis Island WWTP
New Outfall System

CDM Smith Canada ULC

Prepared for:

metrovancouver
SERVICES AND SOLUTIONS FOR
A LIVABLE REGION

December 22, 2017

CDM Smith

A Report Prepared for:

Metro Vancouver
Liquid Waste Services
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Burnaby, BC V5H 4G8

Navigation Impact Assessment
Annacis Island WWTP
New Outfall System

December 22, 2017

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Section 1

Introduction

This navigation impact assessment addresses potential navigation impacts and their mitigation related to construction and operation of a new outfall system the Annacis Island Waste Water Treatment Plant (AIWWTP), including:

- Navigation authority and regulation.
- River conditions including the navigation channel, physical conditions, water lots and existing facilities, and navigability.
- Anticipated in-river construction activities and completed outfall configuration.
- Potential marine impacts and obstructions either within the navigation channel or marine safety channel boundaries.
- Mitigation measures to address risks during the construction phase and ongoing operation and maintenance of the outfall.

Activities completed during project design in support of marine navigation assessment include:

- Several meetings with the Vancouver Fraser Port Authority (the port authority) held starting in March 2016 to discuss the project's objectives, constraints, design elements, construction methods, and operating conditions. A meeting on October 13, 2017 focused on marine navigation and was attended by Transport Canada (TC) representatives.

- Presented an overview of the project and planned public outreach at a regular meeting of the Port Community Liaison Committee - Delta on March 7, 2017.

- Conducted an information session and workshop with marine users on May 11, 2017 to provide an overview of the project and gather information about their marine operations. The meeting was attended by representative for the port authority and TC, water lot owners, Fraser River Pilots, Council of Marine Carriers, barge and tug operators, and marine contractors.

- Conduct a simulation manoeuvring assessment of Seaspan's barge manoeuvring operations at the Southern Rail Terminal on July 17 and 18, 2017. The simulation was performed by Lantec Marine at British Columbia Institute of Technology Marine Campus in conjunction with Seaspan Marine's (Seaspan) Port Captain and Tug Masters.

- Held a meeting with Souther Railway of British Columbia (SRY) and Seaspan to discuss results of the manoeuvring simulation and identified mitigation measures that would minimize risk created by any of their manoeuvring operations near the construction site.

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Section 2

Regulatory Authorities and Acts

2.1 Transport Canada

Transport Canada serves the public interest through the promotion of a safe and secure, efficient and environmentally responsible transportation system in Canada. Vessel operations in Canadian waters is regulated under several federal acts administered by Transport Canada, including the Canada Shipping Act; Canada Marine Act; Navigable Waters Protection Act; and the Pilotage Act.

Administered by the Navigable Waters Protection Program, a division of Transport Canada, the Navigable Waters Protection Act protects the public right of navigation in all Canadian waters, and regulates the construction of works that have the potential to infringe this right. It states, "No work shall be built or placed in, on, over, under, through or across any navigable water unless it is approved by the Minister." The Navigable Waters Protection Act requires that formal approval from Transport Canada be obtained prior to the construction of structures built or placed in, on, over or under navigable waters.

A permit for the project will be required under the Navigable Waters Protection Act. The process entails completing a Navigation Protection Plan (NPP) Notice of Works Form, along with any attachments and other supporting information required for review of the work. TC indicated that the Notice of Works Form can also serve as "Application for Approval". During the assessment phase of the review, the NPP may develop project-specific requirements for mitigating the potential impacts to navigation. This may include terms and conditions that would be attached to any approval or permission issued for the work. Possible compliance requirements may be identified, such as written confirmation of compliance from the owner or on-site inspections by TC staff during or after the construction of the work. TC indicated that final approval may be contingent on the contractor's Navigation Protection Plan submitted after Notice to Proceed with construction by Metro Vancouver.

2.2 Canadian Coast Guard

Under the Canada Shipping Act, the primary legislation governing marine transport, pollution and safety, the Canadian Coast Guard is responsible for, among others, the screening of vessel traffic to prevent the entry of unsafe vessels into Canadian waters, and regulating, monitoring, and managing of vessel traffic for marine risk reduction. The Canadian Coast Guard, through the Marine Communications and Traffic Services (MCTS) program, supports economic activities by optimizing vessel traffic movement and facilitating industry ship/shore communications on the Fraser River.

The Canadian Coast Guard's AVADEPTH website contains the latest information on water depths surveyed regularly by the port authority, tidal predictions and real-time information on water levels and currents throughout the river.

2.3 Pacific Pilotage Authority

The Pacific Pilotage Authority was created as a Crown corporation under the Pilotage Act. The principal mandate of the Pacific Pilotage Authority is to provide safe, reliable and efficient marine pilotage and related services in the Coastal waters of B.C., including the Fraser River.

Under the Pilotage Act every deep-sea commercial vessel over 350 gross registered tonnes is required to utilize the services of a qualified and licensed marine Pilot when entering British Columbia waters. In British Columbia, there are two groups of marine Pilots supplying this service, both acting independently as “commercial” enterprises: the B.C. Coast Pilots Ltd. (the Coast Pilots) and the Fraser River Pilots. The Fraser River Pilots are responsible for piloting vessel traffic in the Fraser River environment. Pilots board vessels at the river mouth (Sand Heads) for Fraser River vessels.

2.4 Vancouver Fraser Port Authority

Vancouver Fraser Port Authority (the port authority) is a non-shareholder, for-profit corporate entity, established in January 2008, pursuant to the Canada Marine Act, subject to provisions of the act. The Canada Marine Act is "an Act for making the system of Canadian ports competitive, efficient and commercially oriented”. The port authority’s mandate under the Canada Marine Act is to facilitate trade for the benefit of Canada, and to take steps to ensure that such trade is carried out in a safe and prudent manner. The port authority is accountable to the federal Minister of Transport, Infrastructure and Communities.

The South Arm of the Fraser River falls is under jurisdiction of the port authority which is responsible for safe, efficient and reliable movement of marine traffic and cargo. In conjunction with a broad range of municipal, provincial and federal stakeholders located along the river, the port authority coordinates harbour operations, developments, and facilities. This includes the Port Community Liaison Committee in Delta which brings together community, municipal, First Nation, business, industry and port authority representatives to better understand and address port-related issues in Delta where the project is located.

The port authority’s Harbour Master Office is responsible for the administration of all marine traffic and activities, including river patrol, to ensure that marine transport regulations are being observed. The port authority also operates a twenty-four-hour, seven-day Operations Centre which monitors and facilitates marine safety and environmental protection, supply chain efficiency and reliability, port security, and emergency management.

The project is in managed federal lands and waters within the port authority’s jurisdiction. A permit is required under the port authority’s Project Environmental Assessment Procedure (PEAP) to ensure the project meets applicable standards and minimizes environmental and community impacts. Application submission requirements for the Project & Environmental Review (PER) application were prepared by the port authority for this project based on meetings held with the port authority and other stakeholders. In addition to project and environmental requirements, the port authority review includes review of this marine navigation impact assessment.

Section 3

River Conditions

3.1 Navigation Channel and Safety Boundary

The new outfall system will discharge treated effluent into the Fraser River just north of the Deep-Sea Shipping Channel (the navigation channel) within the Fraser River South Arm (see **Figure 3-1**). The navigation channel extends from the mouth of the river at Sand Heads (kilometre mark 0) to the Fraser Surrey Docks at New Westminster (kilometre marker 35). The navigation channel is divided into several reaches for the purposes of defining navigation characteristics and for assigning dredging contract limits. The project site is located within the City Reach of the Fraser River South Arm at kilometre mark 29 (see **Figure 3-2**). The channel of the river passing on the south side of Annacis Island is termed the “Annieville Channel”.

The navigation channel width within the river bend (St. Mungo’s Bend) is 260 m. A single lane channel for the design vessel (270 m LOA by 32.3 m beam) requires a channel width of 170 m. For larger vessels (294 m LOA by 44 m beam), the channel width required is 223 m. If ship traffic is limited to a single direction in the south portion of the navigation channel, there would be between 37 and 90 m between the channel required for vessel maneuvers and the north channel boundary as shown north of orange shaded band on **Figure 3-2**.

The port authority maintains a 60-metre-wide “Safety Boundary” outside the navigation channel limits where permanent facilities are limited and water lot leases are excluded. This zone was established by the port authority to provide additional clearance between moving vessels and the closest fixed object along the shore, and to identify potential intrusions from development projects. The new outfall system’s relationship to the navigation channel and safety boundary is shown on **Figure 3-3** along with other nearby features (further described in **Section 3**).

Water depths within the navigation channel are referenced to Low Water Datum (LWD) or Chart Datum (CD). The port authority’s charted depth of the navigation channel is -10.9 metres (CD) at the location of the new outfall system. When maintenance dredging is performed, the dredging subgrade is set at -12.85 metres (CD). The port authority manages the channel by monitoring the available water depths and setting dredging priorities by first making sure there is a narrower but continuous deep central channel prior to deepening the channel across the full width.

3.2 Hydraulic Conditions

3.2.1 River Flow

The Fraser River headwaters lie in the Rocky Mountains 1,370 km from the mouth of the river. The drainage basin of the river accounts for 25% of the land area in British Columbia. Discharge in the Fraser River varies considerably from year to year and from season to season. Snow-melt, which contributes approximately two-thirds of the total runoff, begins in April and increases to a maximum in late May and early June. This period is known as the freshet. By late August, the flows have diminished, and the lowest flows of the year generally occur in winter (January-February).

Daily stream flow records are not available for the Annieville Channel; however, long-term daily flow records since 1912 are available for the Fraser River at Hope about 130 km upstream. The minimum and maximum flows by month recorded at Hope are shown in **Figure 3-4** along with the recorded monthly flows for 2017. Also shown on this figure is the Fisheries and Oceans Canada (DFO) marine/estuarine timing window for the protection of fish and fish habitat from June 16th to February 28th (Fisheries Closure) and DFO's recommended extended period from through November 1st that could require additional mitigation to limit impacts to fish and fish habitat due to higher-risk in-water works.

The flow at Hope is used as a reference for most correlations between flow and water levels on the Fraser River and are similarly referenced in this report. Actual flow rates in the Annieville Channel differ from the flow at Hope, primarily due to:

- Inflows to the Fraser River between Hope and Annacis Island that add to the total flow, even during low flow conditions at Hope. The average flow addition is estimated to ranging from 11% in May to as high as 41% in December.
- Approximately seventy-eight percent (78%) of the river flow passes through the Annieville Channel, the main arm of the river downstream of the trifurcation above Annacis Island.

3.2.2 Tides

Canadian Hydrographic Service, Department of Fisheries and Oceans maintains a record of tidal water surface elevations at New Westminster about 6.5 km upstream of the project. Hourly observations are available from 1970-2017, with the reported water surface elevation as height in metres above CD. Tidal datum values for the New Westminster tidal station are presented in **Table 3-1**.

Table 3-1. Tidal Datums for New Westminster Tidal Station (No. 7654)

Datum	Elevation (m)	Description
EHHW	4.66	Historical Extreme High Water (10 June 1948)
MHHW	3.25	Mean Higher High Water
CVD28GVRD2005 [1]	1.42	Geodetic Datum, 2005 GVRD Adjustment
CGVD28/GSC	1.32	Geodetic Datum, 1977 HT97 Geoid Adjustment
MLLW	0.10	Mean Lower Low Water
Chart Datum	0.00	Tidal Station Datum
ELLW	(0.42)	Historical Extreme Low Water (03 February 1989)

1) CVD28GVRD2005 based on Benchmark 13J (GCM No. 995682) Survey confirmation date 03/23/2005
2) CGVD28/GSC based on Benchmark 13J (GCM No. 995682) Survey confirmation date 03/01/1979

Figure 3-5 presents water surface observations at New Westminster for the 2013 calendar year. The tide signal exhibits a mixed semidiurnal tide with two high tides and two low tides occurring each day, but the twice daily high and low tides have different and irregular amplitudes. The year cycle also indicates the influence of the river flows on the tidal signal. During the freshet and high flow summer months, the low tide observations are almost 2 m higher than during low flow periods. Daily water surface excursions during low flow conditions are generally 2.5-3.5 m, yet during high flows, these daily excursions are reduced to approximately 1 m.

Water Survey of Canada (WSC) maintains a hydrometric station in the Fraser River South Arm about 10.7 km downstream of the outfall close to the Deas Island Tunnel (No. 08MH053). At high tide, when water levels are more controlled by the downstream tidal levels, the river levels at the New Westminster and Deas Island tidal stations are similar. At low tide, the New Westminster river levels are higher, due to the water levels being more controlled by the downstream flow in the river and the river bed level and slope in the 17.2 km between the gauge locations. High and low water surface elevations and times can be approximated at the new outfall system location by interpolation between the two tidal stations.

Estimated tidal datums at the new outfall system location are presented in **Table 3-2**.

Table 3-2. Estimated Tidal Datums for New Outfall System Site

Datum	Elevation (m)		Description
	AIWTTP Plant Datum [1]	Chart Datum [2]	
DRS w/ SLR [3]	104.18	5.90	Design River Stage w/ Sea Level Rise
DRS [3]	103.18	4.90	Design River Stage, 200-yr peak winter flood level
HW	101.86	3.58	High Water at Alex Fraser Bridge
CVD28GVRD2005 [4]	100.00	1.72	Geodetic Datum, 2005 GVRD Adjustment
CGVD28/GSC	99.86	1.58	Geodetic Datum, 1977 HT97 Geoid Adjustment
LW	98.28	0.00	Chart Datum at Outfall Location
Low River	96.78	(1.50)	River Low Elevation at Outfall Location (B&V; 99.5 Percentile)
Outfall Depth	89.70	(8.58)	Top of Diffuser Protective Covers
Dredge Grade	87.38	(10.90)	Navigation Channel Dredging Grade (+/- 0.01 m)
Dredge Subgrade	85.43	(12.85)	Navigation Channel Dredging Subgrade (+/- 0.16 m)

1) AIWWTP Datum Elevation = CVD28GVRD2005 Elevation + 100 metres.
2) Chart Datum = Low Water Datum based on CGVD28/GSC.
3) Design River Stage Elevations provided by Metro Vancouver.
4) CVD28GVRD2005 Elevation = CGVD28/GSC Elevation - 0.143 m. Estimated based on 2005 GVRD Regional Refresh for Benchmark 80333 (GCM No. 87H3501) along outfall alignment.

3.2.3 Currents

During the low flow months (September through April), the tides create alternating flood and ebb flows in the lower reach of the Fraser River. During freshet, currents are controlled by fresh water flows and are predominantly down river, but are reduced or even reversed by the high flood tides.

River current data is available from buoy in the Gravesend Reach of the Fraser River South Arm about 6.8 km downstream of the new outfall system location. Current speed and current direction are measured at one metre below the water surface and hourly data accessed for this report begins in April 2008 and ends in mid-December 2014 with some periods of missing data. Current velocity for this period in the river direction is shown on **Figure 3-6** (downstream positive).

According to correspondence with Environment Canada, the current meter at the Gravesend Reach buoy was removed between January 2015 and October 2016 when a new Buoy was deployed.

The current data for the Gravesend Reach buoy were filtered and limited to 2 m/s based on what appears to be meter drift or periods of instrument maintenance. The buoy data quality appears somewhat questionable (no QA review by Environment Canada was completed). However, measurements from the buoy provide a reasonable analog to a similar current behavior at the new outfall system location. **Figure 3-7** though **Figure 3-9** show current direction and velocity during flood tides in comparison to Fraser River flow at Hope and water surface elevations at the New Westminster tidal station. These figures present this data for three months of the 2013 calendar year that cover the duration of the fish work windows for construction. When bidirectional flow occurs, the upstream flow period is typically less than 5 hours and often only associated with the highest high tide of the day. Some days, however, experience two periods of reversing tide.

River current and direction were measured for this project at 1-meter above the river bottom during the month-long measurement period in 2017. Current measurements collected during low flow conditions showed that at least once per tidal cycle, the flow direction reversed through the water column to flow upriver. When tidal asymmetry was not as strong (diurnal inequality was minimal), the flow reversal occurred twice each cycle, during both flood tides. Mean current speeds were between 0.48 to 0.71 m/s and reached maximum values of 1.4 to 2.12 m/s through the water column from the bottom to surface, respectively. Speed and direction were relatively uniform through the water column, with speeds slightly higher near the surface and decreasing with depth. Current direction through the water column became stratified for a few salt wedge intrusion events, and current speed was slower near the bottom where the salt wedge was present.

In summary, the available data indicates that current velocity at the project site can be expected to reach 1.5 to 2.0 m/s (2.9 to 3.9 knots) downstream during ebb tides and 0.75 to 1.0 m/s (1.5 to 1.9 knots) upstream during flood tides.

3.3 Other Environmental Conditions

3.3.1 Visibility

Although heavy precipitation and pollution can reduce visibility, fog is the primary visibility concern for navigation along the lower Fraser River. Fog is caused by relatively warm moist air blown over the colder land mass during the cooler months (i.e., September to March). On average visibility is reduced to 1 km as often as 60 days per year in certain areas of the Fraser River delta (Fisheries and Oceans Canada 2006). Although fog can persist throughout the day during colder weather periods, it typically dissipates during the warmer daytime. There is no stated limitation on visibility for making a transit in the Fraser River by Vancouver Fraser Port Authority.

3.3.2 Ice and Snow

The waters near the mouth of the Fraser River are not subject to freezing and remain open all year round. Loose pieces of ice occasionally are transported down the Fraser River, but are small enough in size to be of consequence only to small craft.

The mild climate of the British Columbia coast typically causes any snow fall to melt relatively quickly thereby limiting the amount and duration of snow accumulation.

3.3.3 Wind and Waves

Winds at the river mouth regularly exceed 13 m/s (25 knots), and on occasion gust at 20+ m/s (40+ knots). However, wind velocities upriver from Steveston (kilometre 12) rarely exceed 15 m/s (30 knots). Three years of wind speed and direction data (April 2008 - April 2011) from the Gravesend Reach buoy on the Fraser River indicates that southeast, south, and east winds predominate. The maximum wind speed observed was less than 10 m/s (20 knots). There is no stated limitation on wind velocity for making a transit in the Fraser River by Vancouver Fraser Port Authority.

Due to the very sheltered nature of Annacis Island, observed wave heights near the Southern Railway’s Railcar Barge Terminal rarely exceed 30 centimetres and are fetch-limited. For all practical purposes it can be stated that their effect on manoeuvring is nominal for most vessel operations.

3.3.4 Salinity and Water Density

Saline intrusion from the ocean consists of waters that are denser than the freshwater flows discharging from the river. This results in a “salt-wedge” which migrates up and down the river depending on tidal fluctuations and river discharge.

The salt wedge position is mainly controlled by tidal fluctuations and will migrate upstream during flood tides and downstream during ebb tides. It reaches the new outfall system location and extends further upstream, but probably short of New Westminster. When river flows at Hope are greater than 2,000 m^3/s, the salt wedge does not appear to reach the outfall site. Based on recent monitoring for the project, the salt wedge is predicted to be present less than 5 percent of the time for flows between 1,500 and 2,000 m^3/s, 20 percent of the time when flows are between 800 and 1,500 m^3/s, and less than 40 percent of the time during lower flows. Rarely does the salt wedge persist during low tide.

3.3.5 Sedimentation and Dredging

The Fraser River experiences significant sediment transport throughout the year, with the greatest amount occurring during the freshet. Sediment accumulates in portions of the channel and water depths are routinely monitored by the Canadian Coast Guard and the port authority. When sediment accumulation reaches the design grade, dredging is required to maintain the design depths in the channel. Maintenance dredging operations are usually completed in February. Sediment transport along the channel bottom in this new outfall system area is characterized as medium to coarse sands moving along the river bed in 'sand waves'. These sand waves are analogous to sand dunes which migrate laterally due to erosion on the windward side and deposition on the lee side. At the actual location of the new outfall system, relatively little sediment accumulates as it seems to be naturally self-scoured by currents and eddies. The port authority maintains project depths with minimal maintenance dredging. However, on the inside of St. Mungo's Bend immediately downstream of the planned outfall location, the sand waves do not reach dynamic equilibrium and continue to grow in height, building up to several metres over a period of one to two years. The port authority is required to regularly perform maintenance dredging to maintain the navigation channel depth.

3.4 River Navigation

3.4.1 Vessel Traffic

Current vessel traffic on the Fraser River consists of deep sea vessels, tugs and tows, barges (aggregate, chip, log, crane), dredges, ferries, tour boats, fishing vessels, pleasure craft, and log operations. Each year thousands of vessels including approximately 600 to 700 ocean-going vessels transit along the South Arm of Fraser River to deliver a variety of cargoes. In 2016, 136 million tonnes of cargo moved through the port, which include general cargo, aggregate, logs, wood chips, hog fuel, paper, steel, cement and automobiles. The port authority distributes a "Port Information Guide" created pursuant to Section 56 of the Canada Marine Act and aligned with the standards of the International Harbour Masters Association. It contains a set of localized practices and procedures designed to promote safe and efficient navigation within the waters of the port and support efforts to protect the marine environment.

3.4.2 Aids to Navigation

The navigation channel between Sand Heads and New Westminster is marked with fixed and floating navigation aids established by the Canadian Coast Guard. Range lights with leading beacons help mariners identify the channel centre line. The use of navigation marks and buoys is in accordance with the International Conventions on Buoyage. The Canadian Hydrographic Service regularly publishes hydrographic charts that clearly indicate channel fairways and navigational aids. The southwest part of Gravesend Reach leading up to the Fraser Surrey Docks marine terminal is marked by lights.

3.5 Existing Water Lots, Faculties and Obstructions

3.5.1 Water Lots

Three federal water lots in the project area, shown on **Figure 3-3**, are utilized as follows:

- **Turning Point Brewery**: There is a dock and small pier with dolphins located in this water lot. Representatives did not attend the marine users meeting and it does not appear that the pier and dock are regularly utilized for commercial purposes other than occasional mooring of small water craft.

- **Southern Railway**: The primary use of the water lot is for loading and unloading of railcar barges at their railcar barge terminal. Seaspan is responsible for the barge operations in coordination with Southern Railway. They tow in and park very large, 300-foot barges three to four times per week. Coordination with the new outfall system in-river construction activities was identified as having potentially significant marine navigation impacts during the marine users meeting. The simulation assessment of Seaspan's barge manoeuvring operations was performed to assess the impact and develop mitigation measures, as described in **Section 5**.

- **Delta Cedar Products**: Their current operations require a similar barge manoeuvres to Seaspan's, though further east from the planned construction work area. They usually tow in two 66-foot barges (one behind the other) once per day, with the timing based on tide levels. Installation of the upstream leg of the new outfall diffuser could affect their operations and they may have to do their manoeuvres further up current and closer to the Alex Fraser Bridge, possibly require assistance from a stand-by tug.

3.5.2 Existing Facilities and Obstructions

Other features in the project area, shown on **Figure 3-3**, may have limited impact on marine navigation, as follows:

- **Alex Fraser Bridge Pier Protection Fill**: Sand fill with armor rock protection was placed in the Fraser River to protect the two main bridge towers bridge pier foundations for the Alex Fraser Bridge. These sand islands project into the Fraser River flow forming short guide banks. The south sand island is located on the outside of a gentle bend and creates a prominent back eddy and zone of flow separation downstream of the bridge along the southern third of the channel. The north sand island is more sheltered and has less impact on the approach flows, but still contributes to increased currents, eddy's, and sediment erosion.

- **Existing Annacis Island WWTP Outfall**: The existing outfall for the AIWWTP extends from the shore to the edge of the navigation channel. It consists of three buried pipes, each with seven sets of vertical risers (total 27 risers) projecting above the river bed over a 60-m length of the outfall between the navigation channel and the safety boundary. The top of the riser pipes is more than 7 m below Chart Datum. Following construction of the Alex Fraser Bridge, rock scour protection was placed over the river bed along the riser portion.

- **South Surrey Interceptor**: This sewer interceptor conveys raw sewage to the AIWWTP in three parallel pipelines buried below the river bed. Following construction of the Alex Fraser Bridge, rock scour protection was placed over the South Surry Interceptor to protect it from being exposed by erosion. The top of the scour protection is more than 11 m below Chart Datum.

Section 4

Project Description

4.1 Overview

4.1.1 Work Summary

The proposed construction includes the following work:

- **On-land construction at the Annacis Island WWTP**: This construction work includes vertical shafts from which tunnels will be driven, tunneling within the plant and between the plant and river (which does not intersect the river bed), and modifications within the plant to the Chlorine Contact Tanks and Level Control Structure.
- **In-river construction within the Fraser River**: This construction work (see **Figure 4-1**) includes installation of a river riser structure within a cofferdam to provide a connection between the tunnel under the river and a diffuser pipe buried in the river bottom, installation of the diffuser pipe in a dredged and backfilled trench in the river bed, and final connection of the tunnel to the diffuser pipe through the riser near the completion of the construction. After the completion of the new outfall system, the existing outfall will be retrofitted with 'duckbill' valves at the top of its riser pipes so it can continue to serve as an emergency influent bypass.

4.2.1 Anticipated Schedule

The actual activities and sequence of the work will depend on the contractor's selected means and methods. Contractual requirements related to the in-river work windows, environmental management, and the permanent facilities constrain the contractor's options. **Figure 4-2** presents a bar chart schedule showing the anticipated relationship and duration of construction activities based on a start of construction date in January 2019. The in-river construction activities are shown on this bar chart in purple.

In describing the work activity schedule for the first two in-river activities, it has been assumed that the construction activities will require the full in-water work window to complete. This is a worst case with respect to the higher risk period identified by DFO within the full in-water work window. It is in the contractor's interest to complete the work over a shorter overall duration with the start of work beginning later in the summer or early fall when river flows are the lowest.

- The first two in-river seasons (river riser and diffuser construction) will be restricted to the June 16th to February 28th, fish window – the period defined as Least Risk to Fish.
- The second two in-river seasons/activities (diffuser connection and existing outfall rehabilitation) only require short-term, temporary anchoring of spud barges. Although it would be preferable to perform these activities later in the fish window when river flows are lowest, the contractor will be allowed to perform these activities outside the in-river work window as necessary to limit the overall duration and impact of the construction work.

4.2 In-River Construction Details

4.2.1 Construction Access

All access for the in-river construction will be on the Fraser River with labor, equipment, and materials mobilized from locations along the river selected by the contractor. There are no provisions for access from the nearby shore of Annacis Island. Marine navigation requirements will be the same as for all other commercial navigation on the river.

4.2.2 River Riser Construction – Season 1

River riser construction involves mobilization, installation of a cofferdam, excavation of a shaft within the cofferdam, installation of piles within the cofferdam at the base of the shaft, backfilling the shaft and installing the riser pipe, removal of the cofferdam and demobilization. The cofferdam is expected to be approximately 12 m by 20 m in plan dimension.

- **Equipment**: Equipment during all activities will include a crane spud-barge or jack-up barge, a support barge, material delivery barges, and worker/diver transport launches.
- **Materials**: Steel pipe piles and formed steel sheet piles, internal steel bracing, excavated sand, steel pipe foundation piles, self-consolidating concrete backfill, steel riser pipe assembly.
- **Construction Methods**: In-river mobilization, vibratory driving of piles and sheeting, excavation using clamshell bucket, pile driving of piles within the cofferdam, placement of rebar and concrete within the cofferdam, installation of the pre-cast fabricated riser pipe, and vibratory removal of cofferdam piles and sheets.

4.2.3 Diffuser Construction – Season 2

Diffuser construction involves mobilization, followed by installation of the diffuser pipe in sections. For the purposes of this report, it is assumed the contractor will elect to install the diffuser in four sections (two on each leg extending out from the river riser). Each leg of the 2.5 m diameter diffuser pipe is about 120 m long. The diffuser pipe will be installed by dredging a trench, placing pipe bedding material, installing the pipe, and backfilling with native river sand. Following pipe installation, protective caps and the flexible risers will be installed, armor rock will be placed over the entire diffuser, and construction demobilized.

- **Equipment**: Equipment during all activities will include a crane spud-barge or jack-up barges for pipe installation, a dredge barges, excavated material and backfill material barges, and worker/diver transport launches.
- **Materials**: Temporary steel sheeting, excavated sand, pipe bedding material, pre-assembled steel diffuser pipe sections, sand backfill, foundation rock and pre-cast concrete protective covers, armor rock, and flexible rubber risers.
- **Construction Methods**: In-river mobilization, vibratory pile driving, clamshell bucket dredging, pipe installation via slings, backfill and foundation rock placement via clamshell bucket or skip, placement of protective caps with crane, armor rock placement via clamshell bucket or skip, and multi-beam and sonar surveys of installed diffuser final location.

4.2.4 Diffuser Connection – Season 3

Diffuser connection involves removal of the internal bulkheads in the 3.8 m diameter riser pipe that isolate the tunnel from the diffuser pipe when the on-land work is completed to the point that the tunnel is flooded. The work is anticipated to take only a week or two to complete. The nature of the work will include:

- **Equipment**: Crane barge for bulkhead removal, worker / diver transport launches.
- **Materials**: None.
- **Construction Methods**: Remove riser cap, remove bulkheads, replace riser cap.

4.2.5 Existing Outfall Rehabilitation – Season 3 or 4

Rehabilitation of the exiting outfall involves installation of new flexible valves on the top of the existing 21 vertical steel riser pipes extending above the river bed over about a 60-m diffuser length perpendicular to the navigation channel. The work is anticipated to take a few weeks to complete. Then nature of the work will include:

- **Equipment**: Work barge, material delivery barge, worker / diver transport launches.
- **Materials**: Flexible rubber risers with steel connection flanges.
- **Construction Methods**: Diver installation of new risers.

4.3 Operational Phase

Once the new outfall system is completed, activities in the Fraser River will be limited to inspection, maintenance, and repair consisting of:

- Routine annual or more frequent diving and/or sonar inspection.
- Repair of damaged risers, if necessary.
- Coordination with Navigation Channel maintenance dredging.
- Installation of additional risers for future plant flow expansion.
- Remotely Operated Vehicle (ROV) inspection access in case of seismic event, etc.
- Riser replacement (30+/- years).

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Section 5

Marine Navigation Impacts and Mitigation

5.1 Fraser River Navigation

5.1.1 Impacts

During construction of the new outfall system, increased vessel traffic for transport of labour, equipment, and materials to the in-river construction site is expected to be minimal (less than about 10 vessel trips per day).

5.1.2 Mitigation

The contractor will be required to prepare a project specific Navigation Protection Plan (NPP) (see **Section 6**) addressing all anticipated marine navigation activities between barge or vessel loading sites along the Fraser River and the new outfall system project site. These activities will also be subject to the other requirements for the work described in **Section 6**.

5.2 Manoeuvring Analysis

5.2.1 Simulation Assessment

The new outfall system in-river construction activities were identified as having potentially significant marine navigation impacts to railcar barge operations performed by Seaspan at Southern Railway's Railcar Barge Terminal. A simulation assessment of Seaspan's barge manoeuvring operations was performed to assess the impact and develop mitigation measures. A Summary Report of Manoeuvring Analysis is included as an **Attachment** to this report.

The objectives of the analysis were to:

- Determine if the position of the cofferdam would encroach on the manoeuvring space used by Seaspan towing when making daily arrivals and departures with tugs and rail barges;
- Ascertain if certain portions of the tidal cycle and associated river current flow presented either preferred or complex manoeuvring conditions that could be directly associated with a lower or higher degree of risk of collision or close encounter with the cofferdam structure;
- Provide procedural recommendations to Seaspan Towing that would serve as risk mitigation measures for all barge movements to and from Southern rail during the riser installation period; and
- Develop a list of considerations and proposed procedures for use by the Marine Contractor to minimize risk created by any manoeuvring operations near the construction site.

Details of the simulation assessment are provided in the **Attachment**.

5.2.2 Mitigation Measures

Recommendations for procedures to mitigate risks associated with the railcar barge movements are detailed in the attached report and modified somewhat in follow up meetings with Southern Railway and Seaspan. These mitigation measures will be required by the contract specifications and are summarized as follows:

- **Coordination of Barge Movements**: In conjunction with required meetings with other marine users (see **Section 6.2.1**), or as otherwise agreed between the marine contractor, Southern Railway, and Seaspan, establish a procedure to share and coordinate a minimum two-week look-ahead schedule of all planned barge manoeuvres by Seaspan and all movements of major construction equipment by the contractor.
- **Protection of Contractor Personnel**: As a risk mitigation measure, remove personnel working in the cofferdam at least 15 minutes prior to scheduled barge moves.
- **Stand-by Tug**: Have a stand-by tug present during work hours throughout the river riser construction season and diffuser installation activities to provide response/assistance to the marine users if their operations pose a potential risk to the construction work.
- **Tethering of Seaspan Assist Tug**: For the duration of the cofferdam construction, and riser installation process, conduct all barge moves to and from Southern Rail using two tugs, both of which are tethered. The preferred position for the “Assist Tug” is tethered at or near midships on the river side of the barge.
- **Flood Tide Restrictions**: For the duration of the cofferdam construction, do not perform barge arrivals and departures from the Railcar Barge Terminal when upriver flood tide currents are present. This restriction would typically not exceed more than two, 3-hour windows on any given day.
- **Defined Approach Corridors**: Reach agreement between the Marine Contractor and Southern Rail/ Seaspan on a rail barge transit exclusion zone (see **Section 5.3**) that will be kept free during barge manoeuvres from any floating apparatuses, construction barges, cranes or other devices that are required as part of the construction. Also, simultaneous manoeuvres at Southern Rail and the construction site should be avoided. The practice of conducting movements at Southern Rail on the ebb tide, and at the construction site on the flood tide will facilitate this procedure.
- **Simulation of Final Operational Procedures**: Prior to commencing construction operations, convene a two to three-day simulation session with participation from the Marine Contractor, Seaspan Towing, Southern Rail, and any other identified vested interest group to practice the proposed procedures and to conduct any procedural refinement that might be deemed necessary prior to commencing live operations.

5.3 In-River Construction Work Areas

Figure 5-1 to **Figure 5-4** show the in-river work areas for each of the construction seasons described in **Section 4**. The work areas are differentiated as follows:

- **Area A**: Contractor exclusive work areas where work will be undertaken in deep water (i.e., generally greater than 10 m below Chart Datum) within the area between navigational channel and safety boundary using equipment and machinery located on a spud-anchored or jack-up barges. Construction activities within Area A are expected to have little or no interference on deep-sea navigation, which is restricted to the navigation channel. Mitigation measures identified in the manouvering analysis generally apply to all construction activities in Area A, particularly during the river riser construction.

- **Area A'**: This is the rail barge transit exclusion zone identified in the manouvering analysis Mitigation to be kept clear of any floating apparatuses, construction barges, cranes or other devices that are required as part of the construction during railcar barge operations. The contractor may occupy this area between the navigation channel and safety boundary at other times.

- **Area B**: Contractor staging area within the area between navigational channel and safety boundary where equipment and material may be staged during construction. Construction activities within Area B are expected to have little or no interference on deep-sea navigation, which is restricted to the navigation channel. Mitigation measures identified in the manouvering analysis generally do not apply to construction activities in Area B.

- **Area C**: Contractor temporary work area within Navigation Channel. The contractor may temporarily occupy a 37 m to 90 m wide (depending on vessel size) within the defined navigation channel. During these times, large vessel ship traffic would need to be restricted to a single direction past the construction site. Fraser River Pilots would need to be consulted to determine if addition tug assist would be required to avoid the area occupied by the contractor.

  The balance of the navigation channel would need to be clear of any equipment when ships are transiting past as well as 15 minutes (TBD) before a ship's ETA to the project site. An approved communication plan and protocol would need to be developed in consultation with marine industry as described in **Section 6**.

- **Area C'**: Contractor temporary work areas subject to further restrictions as defined for Area A' to provide a rail barge transit exclusion zone.

Additional restrictions on work areas may need to be negotiated between the marine contractor and Delta Cedar Products related to their barge activities during the Diffuser Installation season and during the Existing Outfall Rehabilitation.

5.4 Operational Phase

Figure 5-5 and **Figure 5-6** show the permanent new outfall system facilities as the planned diffuser plan and profile and the diffuser cross section, respectfully. All permanent portions of the new outfall system will be located within the area between the navigation channel and the safety boundary and be more than 8.7 m below Chart Datum. Since deep-sea vessels do not operates in this area, no impacts to navigation are anticipated.

As detailed in Section 6, the marine contractor is required to perform a high density hydrographic survey and/or side scan survey to clearly demonstrate elevation of completed diffusers above the mud-line. This will be submitted to Transport Canada for inclusion in future updates to navigation charts and references.

Inspection, maintenance, and repair activities during the operation of the new outfall system are anticipated to primarily occur between the edge of the navigation channel and safety boundary and not likely to have a significant impact on marine navigation. These activities will generally require an activity specific permit from the port authority. An exception is routine maintenance dredging activities performed by the port authority which are subject to a “Protocol for Dredging & Other Activities by External Parties near Metro Vancouver's Marine/River Crossings & Facilities” between Metro Vancouver and the port authority.

Section 6

Contractor Requirements

6.1 Navigation Plan

The project specifications require the selected contractor to prepare a project specific Navigation Protection Plan (NPP) addressing all navigation requirements associated with the contractor's means and method of performing the construction work. The NPP must meet all rules and regulations in force such as the Canada Marine Act, Navigation Protection Act, Marine and Transportation Security Regulations, as well as all guidance issued by the port authority. The contractor is required to submit the NPP to Transport Canada and the port authority, as well as the marine users work group. The NPP is required to be revised as necessary based on their input and approved prior to the start of work in the river.

6.2 Requirements during Work

6.2.1 Meetings with Marine Users

Contractor will work with Metro Vancouver to establish a Annacis Island WWTP New Outfall System Marine Users Work Group and hold work group meetings on a regular basis to discuss upcoming work, provide schedule updates, discuss navigation concerns, address access issues and coordinate overall communications. Meeting frequency will be monthly or as deemed necessary by the Marine Users Work Group. Meeting Agenda's and Minutes are to be prepared by the marine contractor and reviewed by Metro Vancouver. They will be emailed to the Marine Users Work Group prior to each meeting.

The work group should include but not limited to:

- Metro Vancouver Public Relations
- VFPA Operations Department
- Transport Canada - Navigable Waters Protection Division
- Fraser River Pilots
- Council Marine Carriers
- Seaspan
- Delta Cedar Products
- Harken Towing
- Catherwood Towing
- Pacific Custom Log Sort
- Forrest Marine
- First Nations

6.2.2 Marine Communications Plan

The contractor will prepare and submit for review a Marine Communication Plan to include, but not limited, to the following:

1) Detailed Project Description
2) High level timeline/schedule identifying key tasks
3) List of Marine Equipment
    a) Type of equipment (marine derrick, dredge, barge/scow, survey boat, etc.)
    b) Name of equipment
    c) Crewing information (deckhand, deck engineer, operator, etc.)
4) Conflicts and/or potential conflicts with Marine Traffic
5) Anticipated channel closure(s) and alternate routes with limitations
6) Identification and contact information of assist vessel(s) available onsite
7) Radio Communications protocol
    a) To be continuously monitored during construction work
    b) Identification of VHF standby channel
    c) Name of vessel expected to handle radio communications
8) Notification protocol, procedure and contacts for unscheduled or unplanned marine related incidents that either impede or could impede safe navigation
9) Copy of proposed Notice to Mariners regarding the construction work
10) Sample copy of proposed weekly Notice to Shipping advisories

6.2.3 Temporary Notice to Mariners

The Contractor will issue a Temporary Notice to Mariners publication that informs mariners of important navigational safety matters affecting Canadian Water. If a temporary change in conditions affecting navigation exists and if the change will be effective for a period of over three (3) months, then the Temporary Notice must be published through the Canadian Coast Guard.

The notice should include a summary version of the information required for the Marine Communications Plan including, but not limited to, the following:

- Duration of the work and work hours.
- Weekly advisories to be emailed directly to key stakeholders and through CCG's Notice to Shipping service. Also, weekly advisories are to be posted on the project's website.
- Ability for Mariners to contact construction crews and the contractor's stand-by tug on VHF channel 74 or 06 for further transit information or if tug assist is deemed necessary by the mariner.

6.2.4 Weekly Notice to Shipping Advisories

The Contractor will issue weekly advisories to advise mariners of the short-term work anticipated for the upcoming week and should list any expected impediments to navigation

These notices should include:

1) Period covered by notice
2) Description of activity
3) Vessels and equipment involved
4) Contact information
5) Radio communications
6) Special requests / additional information
7) Applicable drawings / sketches
8) Summary / table of impacts to navigation channels and working passages

Weekly notices are to be:

- Emailed to key stakeholders/users including VFPA.
- Sent to CCG for posting on the active Notice to Shipping web site.
- Posted on a project website.

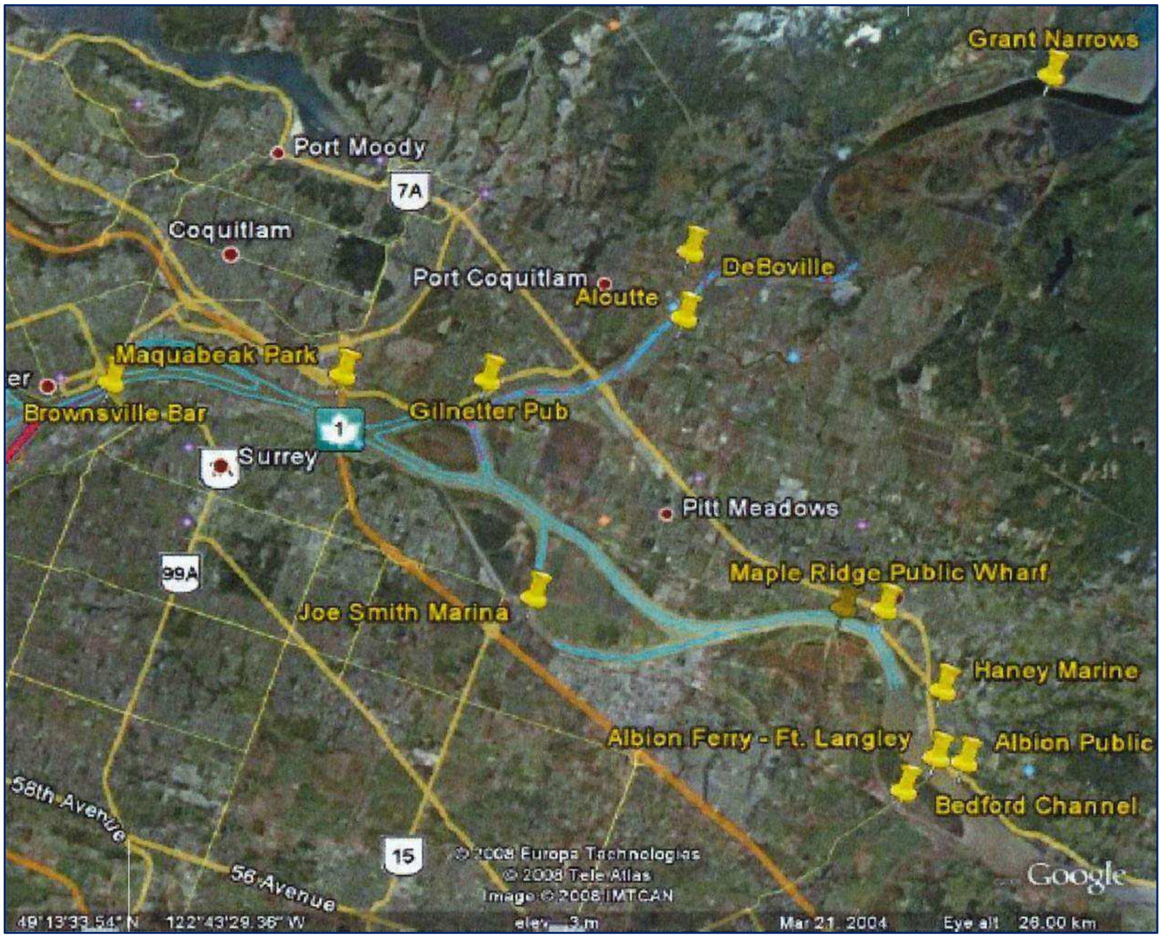
6.2.5 Public Notice

The Contractor will post and log work notices at the following Public access locations:

Table 6-1: Public Notice Locations

Location	Municipality	Number of Notices
Alouette River-Marina	Pitt Meadows	4
DeBoville Slough - Marina	Coquitlam	4
Grant Narrows - Boat Launch	Pitt Meadows	3
Gilnetter Pub - Float	Port Coquitlam	4
Maquabeak Park - Boat Launch	Coquitlam	2
Brownsville Bar - Boat Launch	Surrey	2
Derby Reach - Boat Launch	Langley	3
Bedford Channel - Boat Launch	Fort Langley	2
Joe Smith - Marina	Parsons Channel	2
Albion Ferry - Public Float	Ft Langley	2
Albion Ferry - Public Float	Maple Ridge	3
Haney Marine Float	Maple Ridge	4
Maple Ridge - Public Wharf	Maple Ridge	2

Suggested posting options include: Bulletin Boards, Marina Office, Top of Gangways, and Vehicle Entrance Gate.



Public Notice Locations

6.2.6 Stand-by Tug

The Contractor will provide a stand-by tug(s) of adequate size and power to accommodate the typical vessel and tow that frequently transits this part of the Fraser River, (i.e. log tows, chip barges, rock scows). The vessel must have current and appropriate certification to provide tug assistance and be operated by Mariners with Fraser River towing experience and appropriate certification. Communication information is to be supplied by the Contractor will include:

1) Standby times
2) VHF channel
3) Contact information (contact name, company, phone number)

6.2.7 Hydrographic Survey

The Contractor will perform a high density hydrographic survey and/or side scan survey to clearly demonstrate elevation of completed diffusers above the mud-line.

6.2.8 Permanent Notice with Chart Correction

Following completion of construction, the Contractor will be required to issue a Permanent Notice to Mariners, including:

1) Describing the work completed
2) As-built drawing of outfall diffuser:
    a) Plan View
        i) Horizontal coordinate system - UTM NAD 83
        ii) Diffuser alignment and port location
        iii) Relation to navigation channel and dimensions
    b) Profile View
        i) Vertical coordinate system - Geodetic (metres)
        ii) Diffuser ports
        iii) Navigation Envelope and dimensions
3) As-built drawing will include a table of tide and datum elevations
4) Adobe PDF versions of the drawings are required

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Section 7

References

7.1 Communications

Hart, Dave. 2014. Dredging Specialist, Operations, Vancouver Fraser Port Authority. Email communications to Metro Vancouver regarding Channel Lines and Tenure Boundary’s, Conversion from Geodetic to Chart Datum, Dredge Grade & Sub-Grade, and Navigation Channel Width in St. Mungo’s Bend, October 15, 2014.

7.2 Regulations

Collision Regulations (C.R.C., c. 1416)

Marine Transportation Security Regulations (SOR/2004-144)

Pilotage Act (R.S.C., 1985, c. P-14)

Navigation Protection Act (R.S.C., 1985, c. N-22)

Canada Shipping Act, 2001 (S.C. 2001, c. 26)

Canada Marine Act (S.C. 1998, c. 10)

7.3 Online Documents

Canadian Coast Guard, Avadepth (available depths); http://www2.pac.dfo-mpo.gc.ca/index-eng.html

Environment Canada, Real-Time Hydrometric Data Graph for FRASER RIVER AT DEAS ISLAND TUNNEL (08MH053) [BC]; https://wateroffice.ec.gc.ca/report/real_time_e.html?stn=08MH053

Fisheries and Oceans Canada, Observed Water Levels NEW WESTMINSTER, B.C. (7654); http://www.pac.dfo-mpo.gc.ca/science/charts-cartes/obs-app/observed-eng.aspx?StationID=07654

Port of Vancouver, Port Information Guide; https://www.portvancouver.com/wp-content/uploads/2015/03/Port-of-Vancouver-Port-Information-Guide.pdf

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Figures

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Figure 3-1: Navigation Channels, Fraser and Pit Rivers (VFPA)

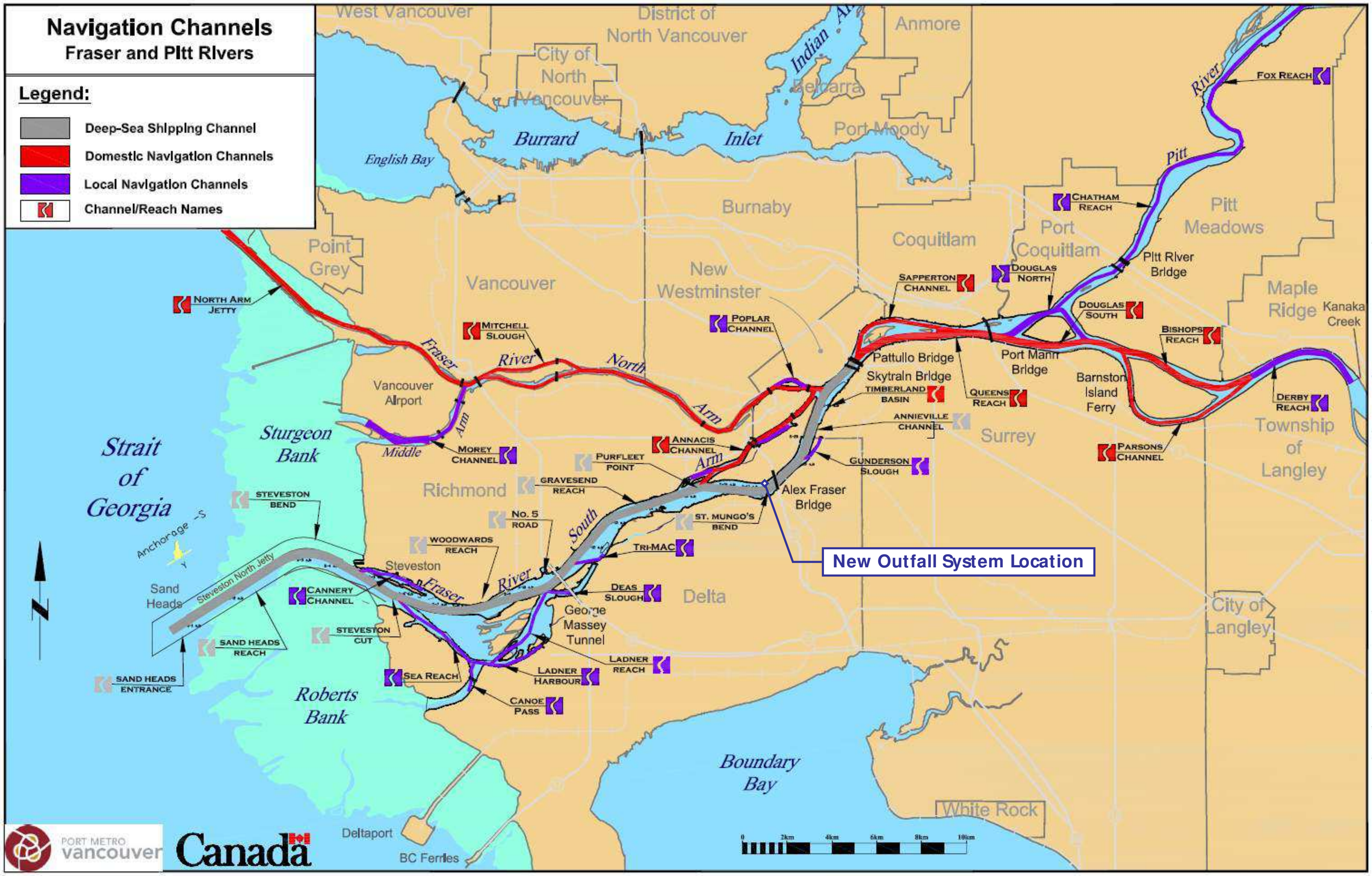


Figure 3-2: River Setting / Navigation Channel (VFPA)

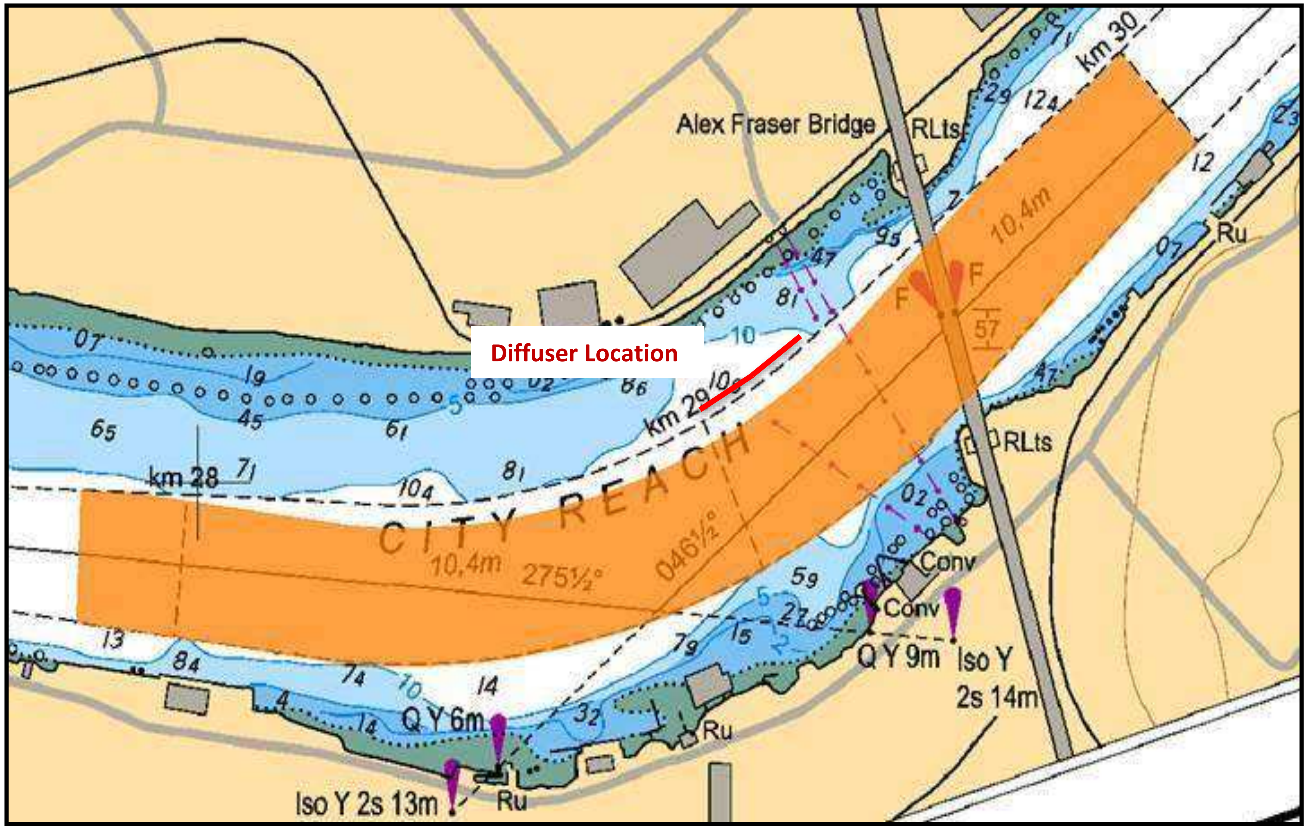


Figure 3-3: Outfall Location with Channel Boundaries

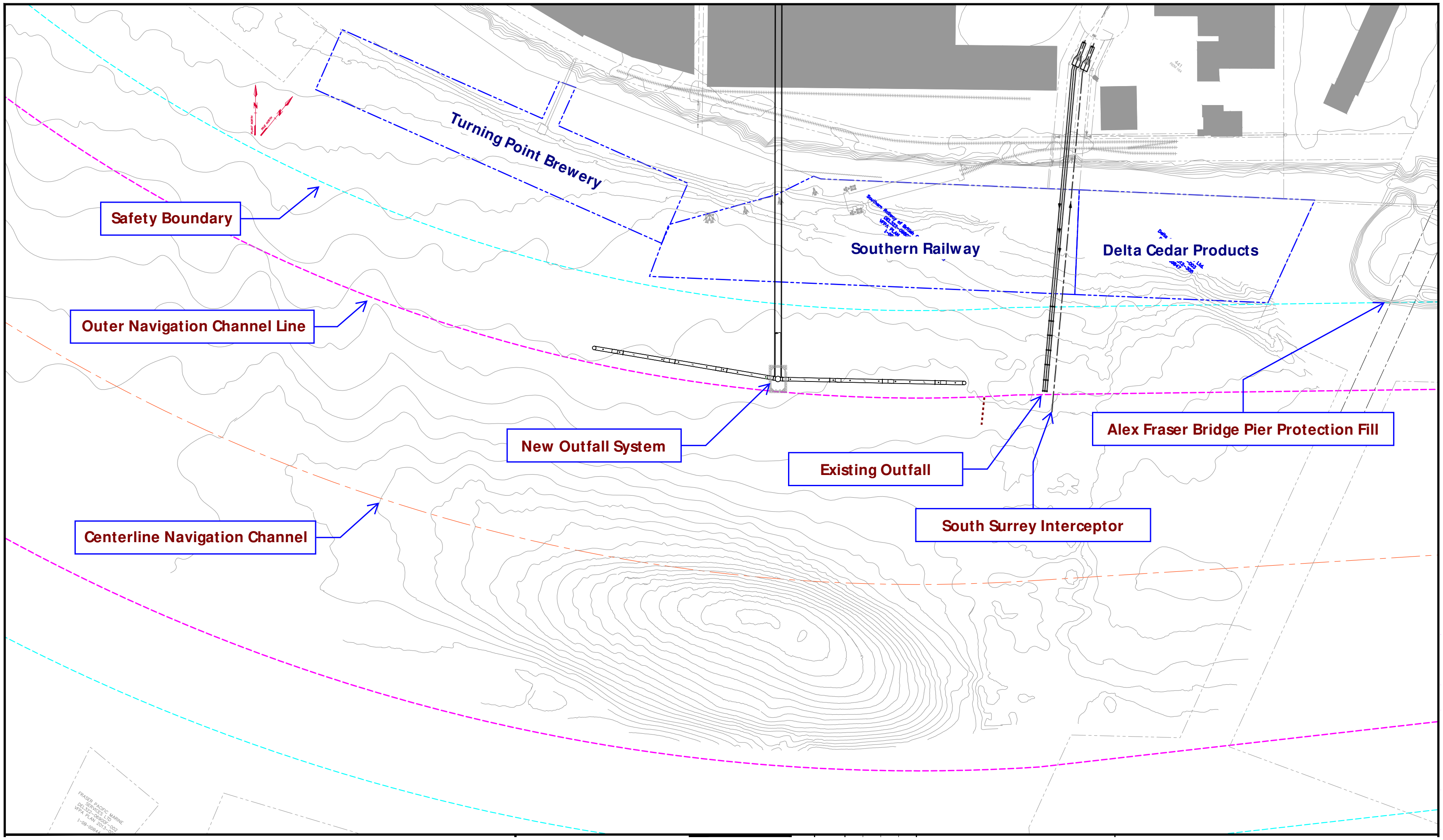


Figure 3-4: Fraser River Hydrograph at Hope (2017 to 2018, Avadepth)

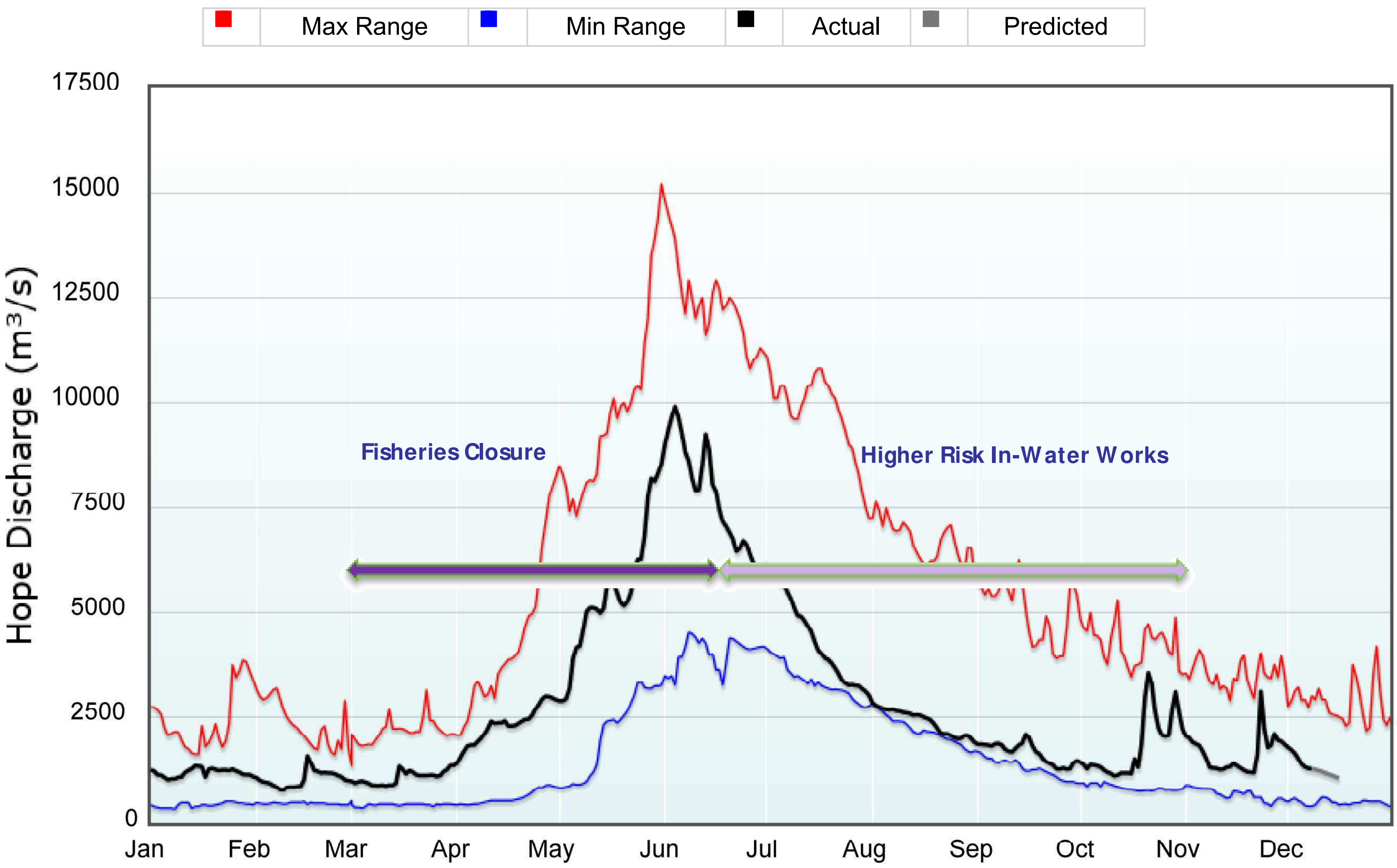


Figure 3-5: New Westminster Water Surface Elevations (2013)

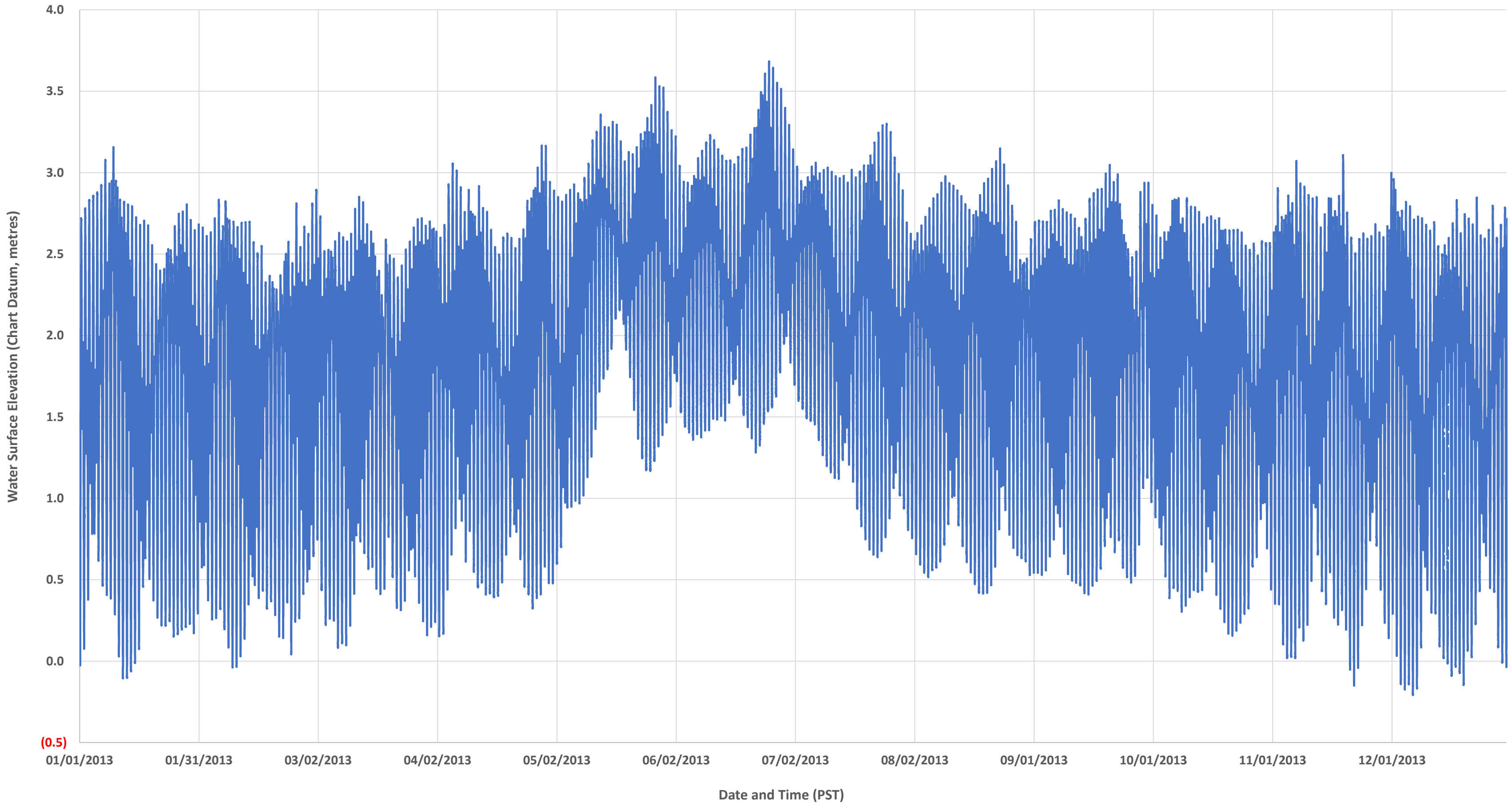


Figure 3-6: Gravesend Buoy Current Data (2008 - 2014)

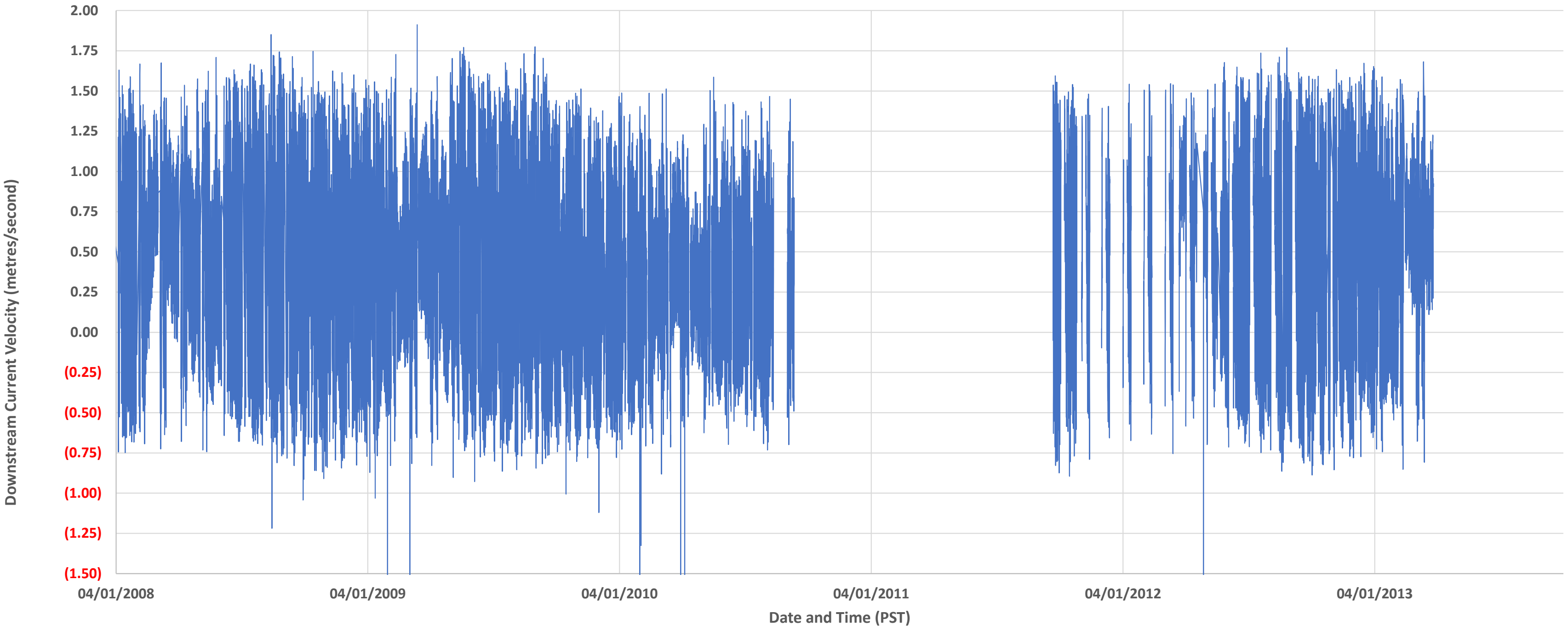
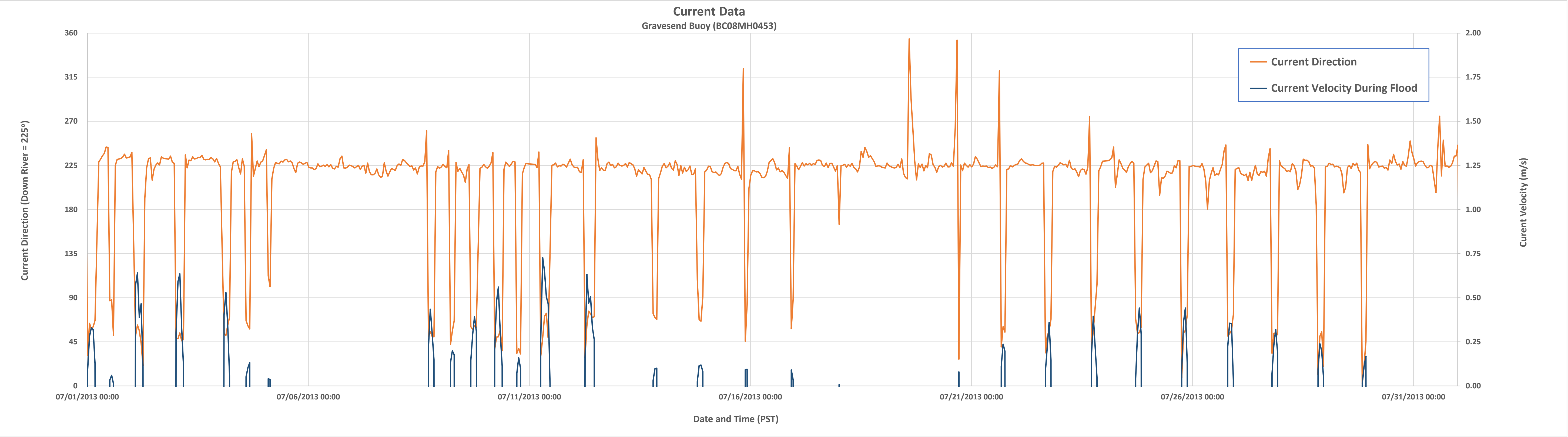


Figure 3-7: Tides and Currents – July 2013



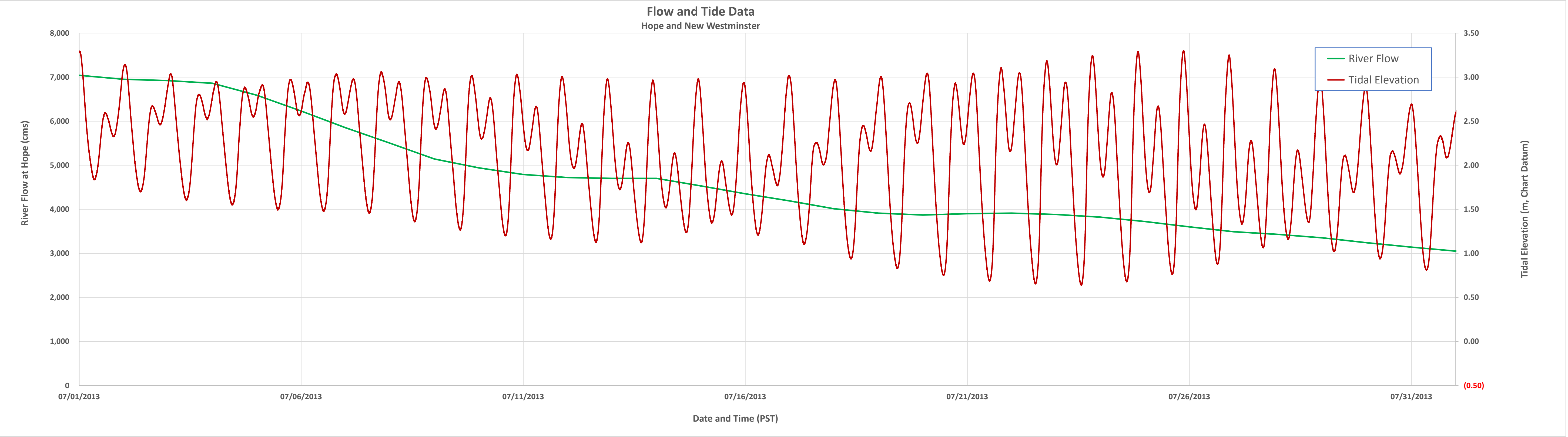
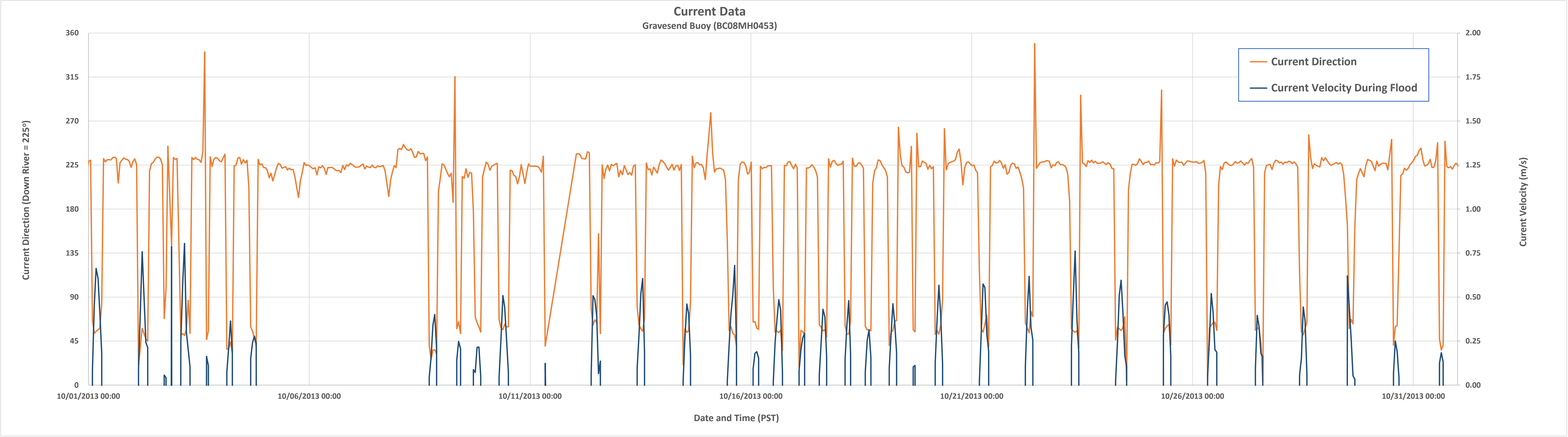
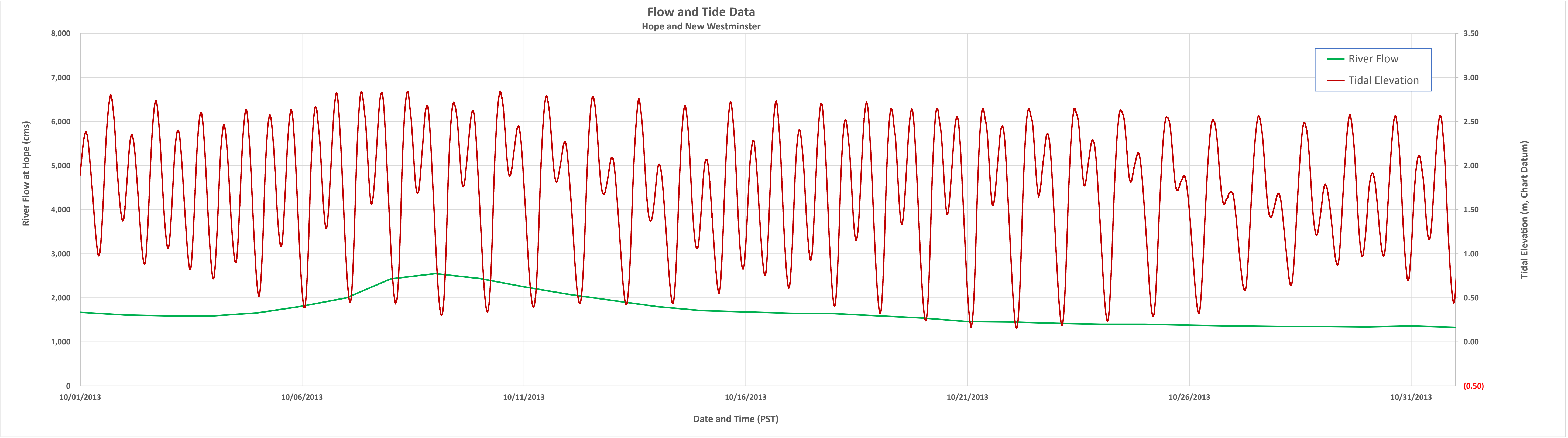


Figure 3-8: Tides and Currents – October 2013





CDM Smith

Figure 3-9: Tides and Currents – January 2014

Figure 4-1: In-River Work Elements

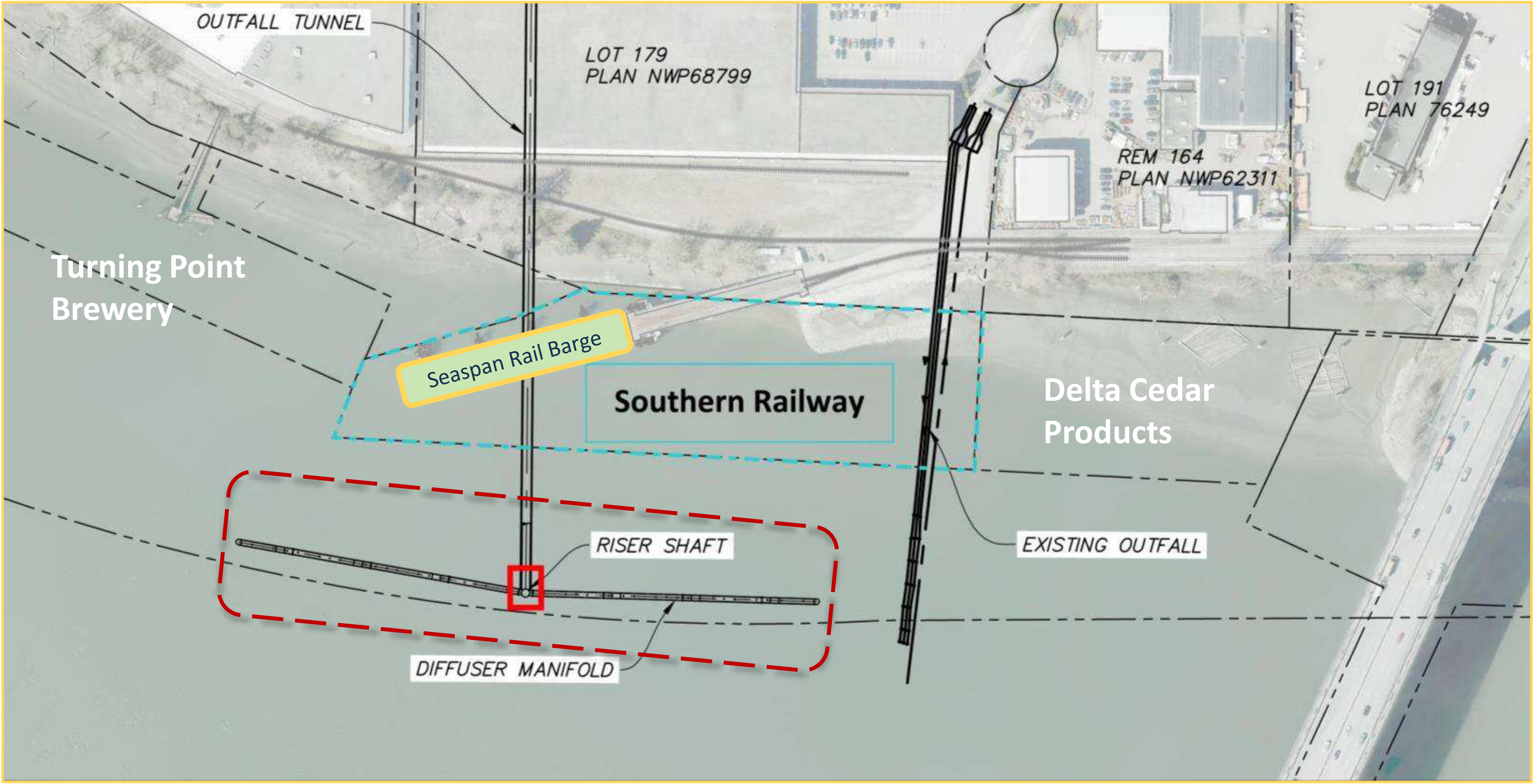


Figure 4-2: Overall Construction Schedule

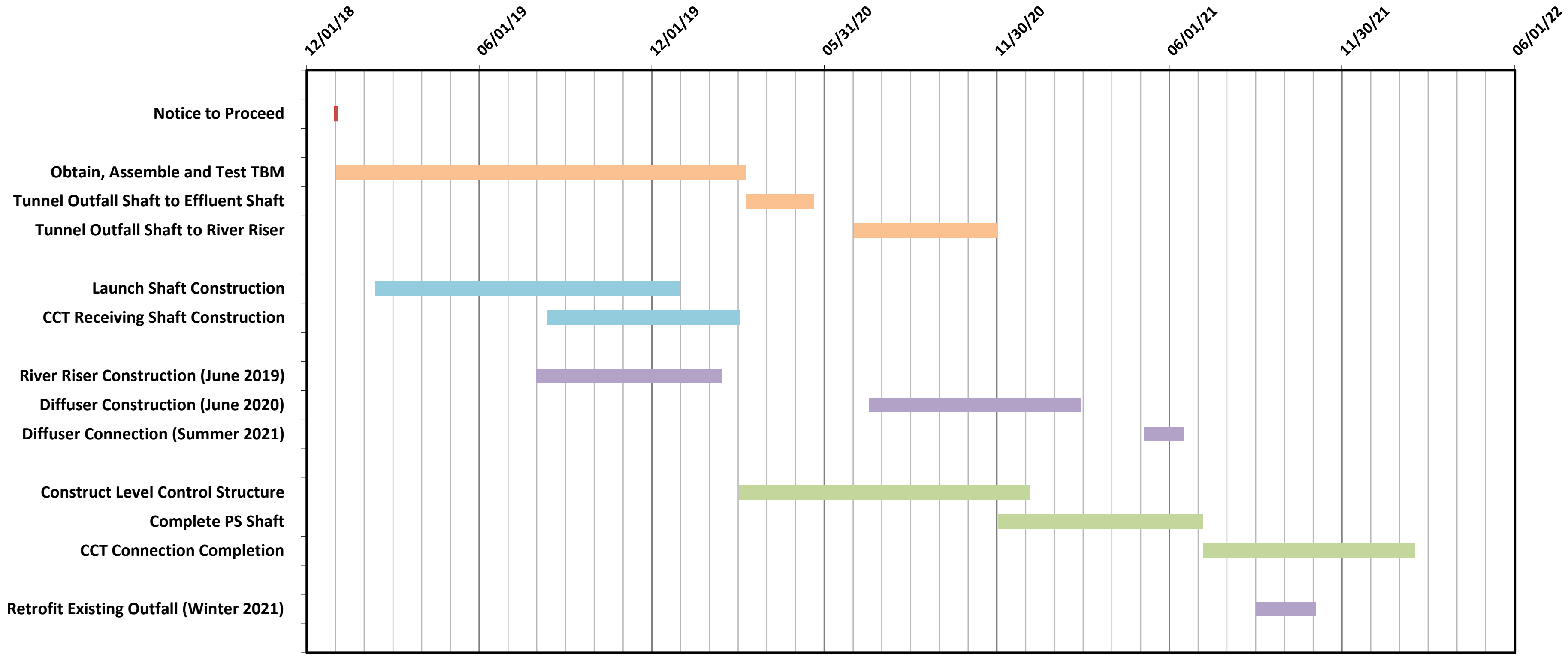


Figure 5-1: In-River Work Areas – River Riser

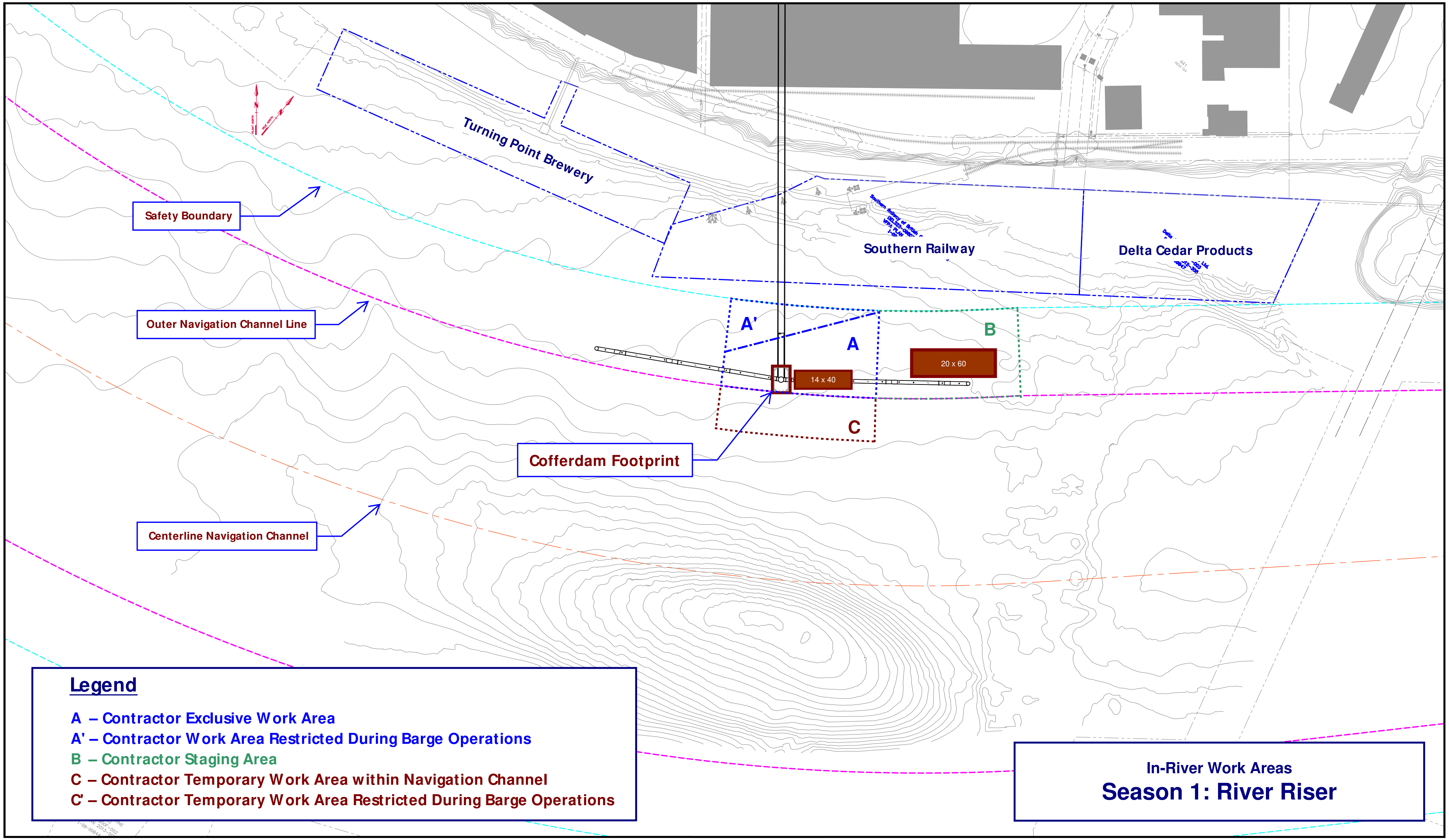
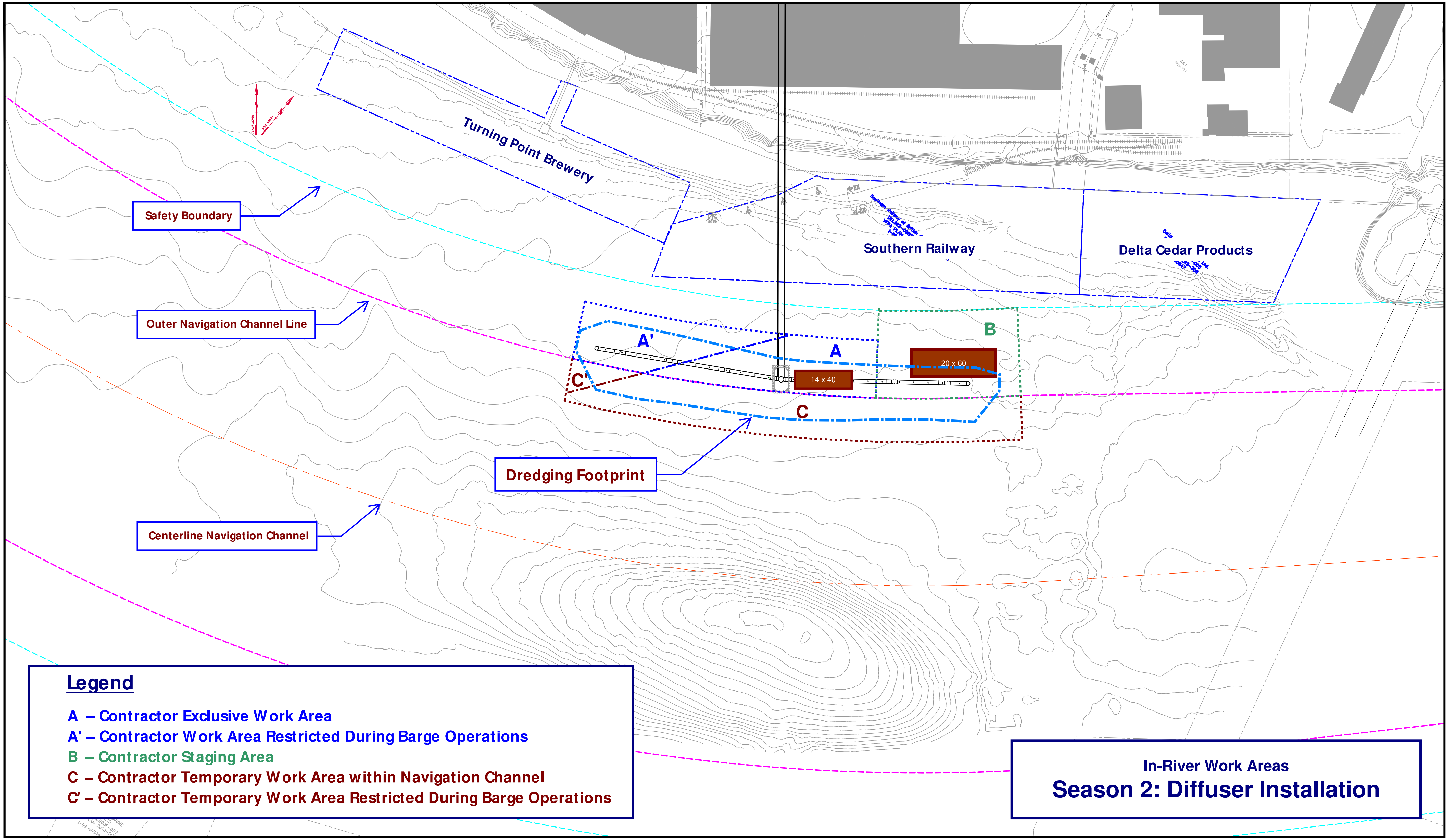


Figure 5-2: In-River Work Areas – Diffuser Construction



Legend

A – Contractor Exclusive Work Area
A' – Contractor Work Area Restricted During Barge Operations
B – Contractor Staging Area
C – Contractor Temporary Work Area within Navigation Channel
C' – Contractor Temporary Work Area Restricted During Barge Operations

In-River Work Areas
Season 2: Diffuser Installation

Figure 5-3: In-River Work Areas – Diffuser Connection

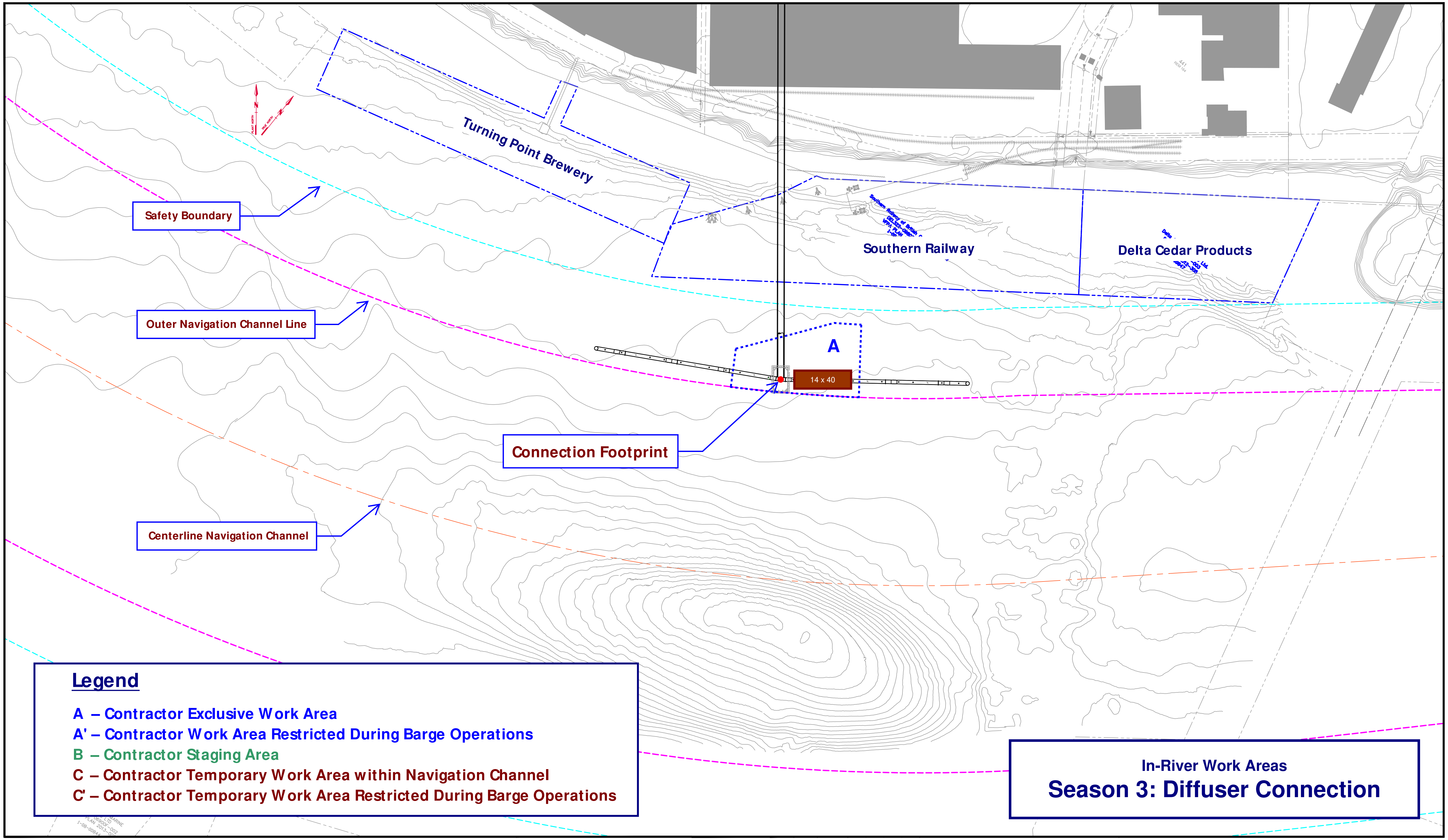


Figure 5-4: In-River Work Areas – Existing Outfall Rehabilitation

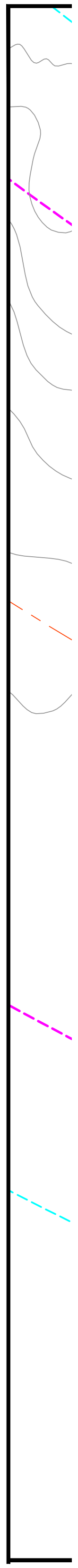


Figure 5-5: Diffuser Plan and Profile

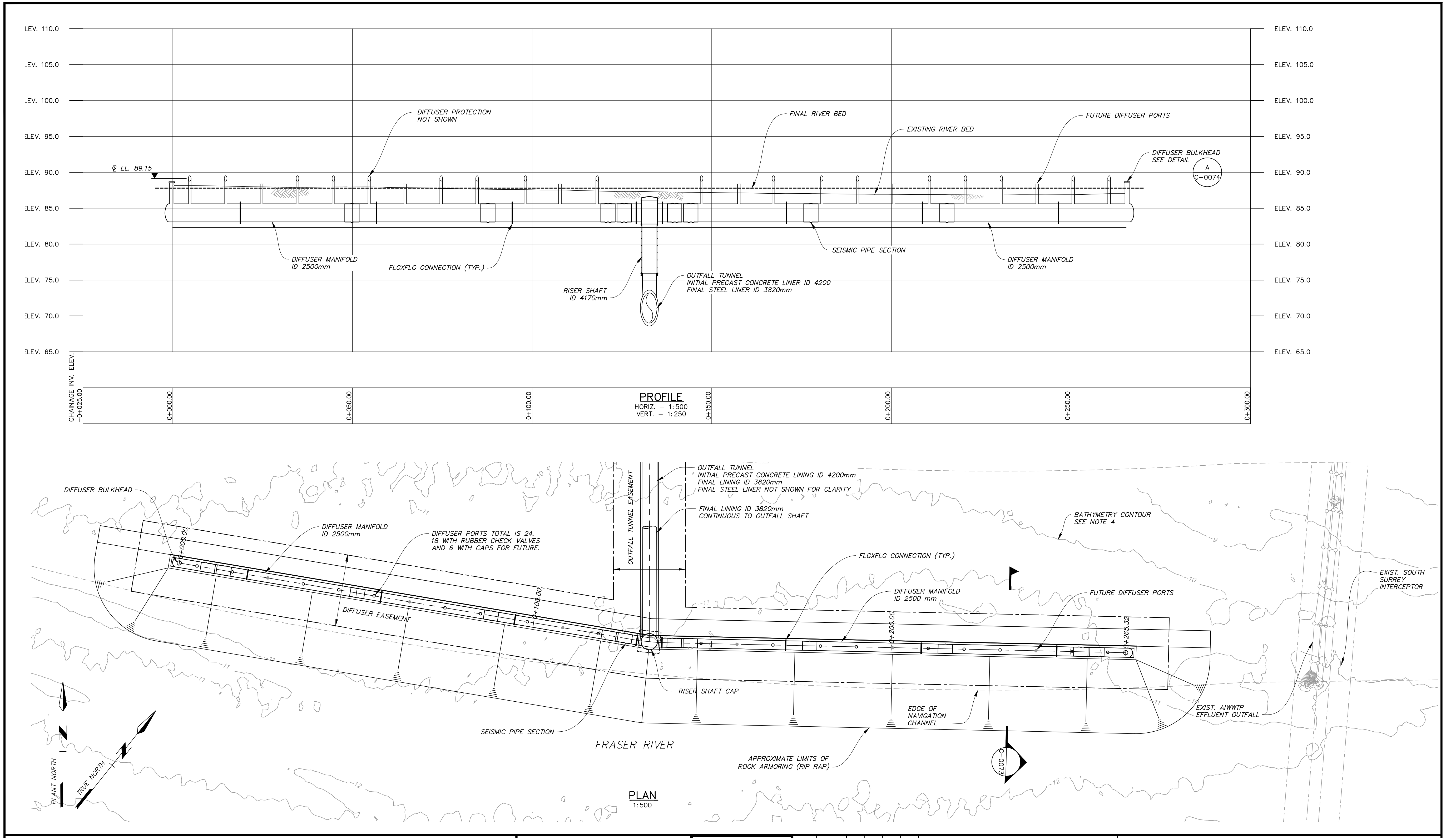
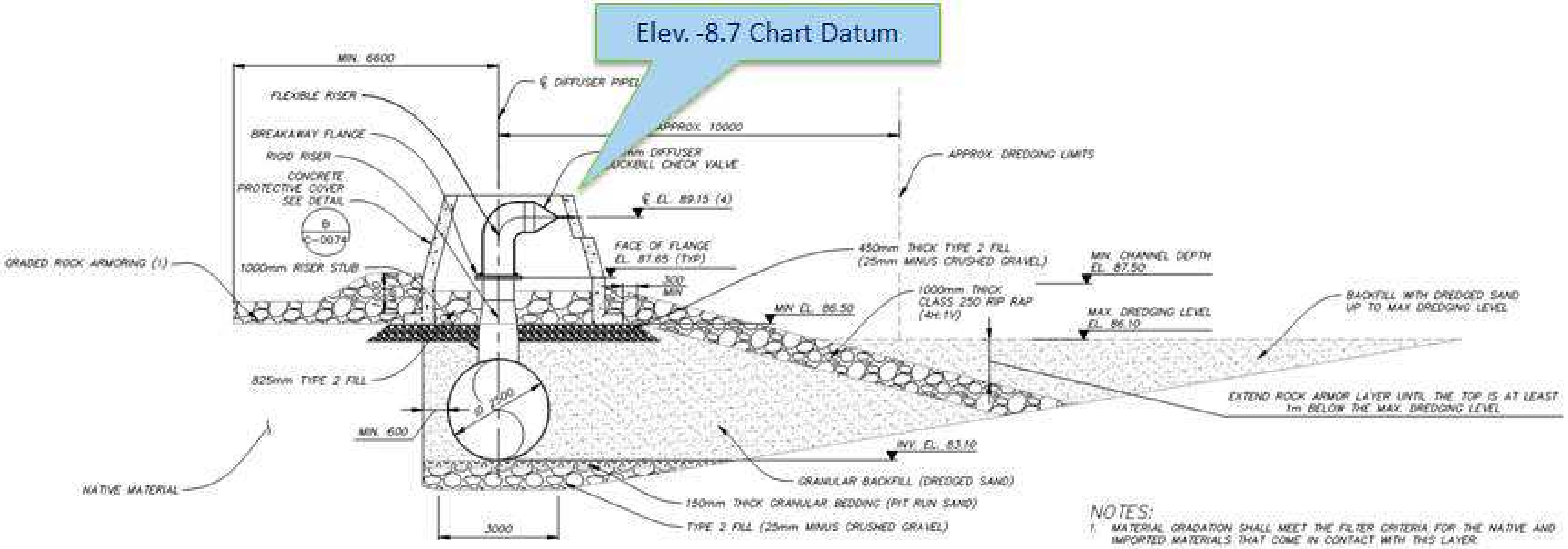


Figure 5-6: Diffuser Cross Section



DIFFUSER MANIFOLD SECTION – INSTALLED CONDITIONS

SECTION 2B
1:75 C-0052

NOTES:

1. MATERIAL GRADATION SHALL MEET THE FILTER CRITERIA FOR THE NATIVE AND IMPORTED MATERIALS THAT COME IN CONTACT WITH THIS LAYER.
2. NATIVE MATERIAL EXCAVATED IN THE TRENCH MEETING THE SPECIFICATIONS FOR GRANULAR SAND BACKFILL MAY BE ALLOWED.
3. TEMPORARY SHEET PILE SHORING MAY BE USED ON ONE OR BOTH SIDES OF THE DIFFUSER MANIFOLD PIPE TO REDUCE DREDGING VOLUME. SHEET PILES MUST BE REMOVED FOLLOWING INSTALLATION AND BACKFILL OF THE DIFFUSER MANIFOLD AND BEFORE PLACEMENT OF THE ARMOR ROCK AND PRE-CAST CONCRETE RINGS.
4. ALL DIFFUSER DUCKBILL CHECK VALVES SHALL BE INSTALLED TO THE SAME ELEVATION.

Attachment

Summary Report of Manoeuvring Analysis

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Summary Report of Manoeuvring Analysis

Metro Vancouver – CDM Smith

Annacis Island Sewer Outfall and Southern Rail Berth

28 August 2017
Prepared By:

LANTEC Marine

Executive Summary

Metro Vancouver has initiated a project to expand its sewage treatment operation located on Annacis Island in the Fraser River. Enhancements to the sewer treatment facility include the construction of a new (replacement) sewer outfall which will be sub-terrain with a riser ascending to the river bed to a diffuser manifold located approximately 150 metres from the river bank. The diffuser manifold will also be within 110 metres of the Southern Rail Berth where rail cars are loaded onto barges for transport along the Fraser River by Seaspan Towing. During the construction process, and specifically when installing the riser, a cofferdam structure will be temporarily placed in the river, directly above the final location of the riser connection to the diffuser manifold.

CDM Smith, the engineering lead for this project, after consultation with Seaspan Towing, commissioned the services of LANTEC Marine Incorporated to conduct a simulation manoeuvring assessment, namely to:

a. Determine if the position of the cofferdam would encroach on the manoeuvring space used by Seaspan towing when making daily arrivals and departures with tugs and rail barges;
b. Ascertain if certain portions of the tidal cycle and associated river current flow presented either preferred or complex manoeuvring conditions that could be directly associated with a lower or higher degree of risk of collision or close encounter with the cofferdam structure;
c. Provide procedural recommendations to Seaspan Towing that would serve as risk mitigation measures for all barge movements to and from Southern rail during the riser installation period; and
d. Develop a list of considerations and proposed procedures for use by the incumbent Marine Contractor that would minimise risk created by any manoeuvring operations near the construction site.

Annacis Island is located in the estuary portion of the Fraser River just downriver from the municipality of New Westminster. This section of the river is navigated by ocean going vessels up to PANAMAX size as well as extensively by tugs and barges, and other small commercial and pleasure craft. The tidal range at the river mouth is approximately 5 metres and it decreases by approximately 10 centimetres with each kilometre of upriver travel, still attaining heights of up to 3.5 metres at Annacis Island. Currents vary in speed seasonally from 2 to 6 knots, and the tidal stream reaches beyond New Westminster. As a consequence, when the river is at lower outflow levels (less than 2000 cubic metres per second) the direction of the resultant river flow at the construction site reverses and flows inwards for several hours per day. Prior to conducting the simulation analysis, a Vancouver firm, Tetra Tech that specialises in water-flow analysis was commissioned to develop two tidal cycle/ river current flow models to be used during the simulation analysis. One model represented a river volumetric flow rate of 2000 CMS and the other a rate of 1500 CMS. Both models encompassed a twenty-four hour period in order to support a comprehensive examination of the normal diurnal current flow variations that would occur for each of the river flow levels.

The manned simulation analysis was conducted 17 – 18 July at the BCIT Marine

Campus. Key simulation components included a highly detailed area model encompassing complete bathymetry of the South Arm of the Fraser River from the Alex Fraser Bridge to the western tip of Annacis Island, all physical aspects of the Southern Rail berth, and hydrodynamic models of a barge and the Seaspan River Tugs Venture and Tempest. The tugboats were operated by senior tug masters from Seaspan's Fraser River fleet. All towing lines/ bridle connection/ disconnections were performed as in real life on directions given from the tug master to the vessels' deckhands, (in this case the test director). The functions of connecting and disconnecting lines was affected from the simulator instructor control station by the test director.

A total of thirty-one simulated manoeuvres were conducted; 24 inbound barge arrivals and 7 outbound barge departures. Seventeen of these manoeuvres were conducted under a rising (flood) tide approaching high water where the river was actually flowing inwards towards New Westminster, and fourteen were conducted with the more common, and preferred manoeuvring condition of an outflow river current. Twelve manoeuvres were conducted with the river at the mid-level flow rate of 2000 CMS, and nineteen were at the low river flow rate of 1500 CMS. Also, to test that the overall level of control provided by the tugs afforded sufficient redundancy, the last six manoeuvres that were conducted included propulsion or steering failures in one of the two tugboats, such that a single tug needed to manoeuvre the barge to safety away from the cofferdam/ construction site. With the exception of one arrival manoeuvre, the barge and tugs maintained an acceptable distance from the cofferdam. The one mishap, surprisingly occurred under a relatively light tidal flow condition, and was attributed largely to the fact that the assist boat was not tethered to the barge, and was hence slow to respond when manoeuvring assistance was needed.

To conclude, the results of the simulation exercises showed that all types of barge manoeuvres could be conducted under the full range of anticipated river current flow conditions. The level of manoeuvring risk will always be somewhat higher for barge arrivals that occur on a flood tide, approaching high water, coupled with a low river level (inwards resultant current flow). In these circumstances, the approach to the dock must be made “upstream” of the cofferdam, and if a manoeuvring error is made, or if a tug loses power, the barge is naturally inclined to drift towards the cofferdam. This is not to imply that a normal flood tide arrival is an overly complex or risky manoeuvre, but merely to state that risk mitigation measures must be implemented in order to prevent a situation where a barge is in danger of drifting onto the cofferdam.

For project planning and implementation purposes, it is recommended that the procedures proposed below be considered, and that any planned protocols/ policies be practiced further through simulations prior to commencing the installation of the cofferdam. It is recommended that:

i) Southern Rail Terminal/ Seaspan Towing Dispatch establish a procedure whereby Metro Vancouver's Marine Contractor always receives at least twenty-four hours advanced notification of all planned barge manoeuvres;

ii) As a risk mitigation measure (considering that tugs and barges will routinely pass within 50 metres of the cofferdam), personnel working in the cofferdam should be removed at least 15 minutes prior to scheduled barge moves;

iii) The marine contractor should have a stand-by tug present throughout the riser placement/ construction process. This standby tug could provide response/ assistance not just for movements to and from Southern Rail, but also in the event of any other mishap that might occur upstream of the construction site (i.e. transiting tug and barge loses power, small craft loses power, large drifting debris, etc.). The stand-by tug as a matter of practice should stand by downstream from the cofferdam when there are no vessel moves near the construction site, and should be standing-by upstream of the cofferdam during anticipated vessel moves.

iv) For the duration of the cofferdam construction, and riser installation process, all barge moves to and from Southern Rail must be conducted by two tugs, both of which are tethered. The analysis has also shown that under most tidal conditions, the preferred position for the "Assist Tug" is tethered at or near midships on the river side of the barge such that in the event of a mishap, or manoeuvring control problem the assist tug can move (push or pull) the barge laterally away from the cofferdam structure;

v) This simulation analysis utilised the normal seasonal medium to low river flow rates of 2000 and 1500 CMS which is expected for most of the riser installation process. If during the actual construction period the river volumetric flow falls below 1500 CMS, it is recommended that arrival operations be ceased during periods of a rising tide when the tidal level exceeds 2.0 metres (New Westminster). During this stage of the rising tide, a strong inwards flow develops which tends to set in a direct line from the Annacis Barge Tie Up towards the cofferdam position. This proposed "blackout period" would typically not exceed more than two, 3-hour windows on any given day;

vi) The Marine Contractor and Southern Rail/ Seaspan should come to a mutual agreement with respect to establishing a rail barge transit exclusion zone that will be kept free during barge manoeuvres from any floating apparatuses, construction barges, cranes or other devices that are required as part of the cofferdam construction/ riser installation process. Based on the track plots of the thirty-one test manoeuvres, the prevailing current patterns, and the requirements to position floating construction equipment, the corridors as depicted in Figure 28 below is offered for consideration; and

vii) After contract award to the selected Marine Contractor, and prior to commencing construction operations, another two to three-day simulation session should be convened with participation from the Marine Contractor, Seaspan Towing, Southern Rail, and any other identified vested interest group to practise the proposed procedures and to conduct any procedural refinement that might be deemed necessary prior to commencing live operations.

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1 Overview of Simulation Study

This study was conducted as part of an initial manoeuvring feasibility/ construction site impact analysis associated with the installation of a sewer outfall riser in the bed of the Fraser River near the Southern Rail Barge Loading Ramp on Annacis Island. The primary focus of the study was to determine operational procedures and risk mitigation measures that would support the safe and efficient installation of the riser whilst having as little impact as possible on Seaspan's tug and barge manoeuvring operations at the Southern Rail Terminal. The simulation study was conducted 17 and 18 July 2017 using a Kongsberg Full Mission Tug Simulator located at the British Columbia Institute of Technology Marine Campus.

1.1 Simulation System

The study was conducted using the Kongsberg built, Class B and DNV approved, simulators located at the British Columbia Institute of Technology Marine Campus in North Vancouver. The system consists of a purpose design tug simulator with a 360° field of view and a second tug simulator with a 160° field of view. The barge that was being manoeuvred was also a complex hydrodynamic and towing model, and was assigned to another bridge cubicle with a 160° field of view to allow observers to have an overall view of the entire integrated operation. The tug models consisted of a purpose built model of a Seaspan Tempest Class river tug as well as a generic twin screw tug which is similar in characteristics to a Seaspan Coastal tug. Both models have a very high degree of accuracy, and have been proven to be very accurate over the course of their use for several years to support Seaspan's internal tug mate and master training programmes. All tug boat operations and manoeuvres performed during the analysis were conducted by senior tug masters from Seaspan's Fraser River Fleet.

1.2 Test Team

The test team conducting the simulation study consisted of the individuals listed in the following table:

Table 1: Simulation Study Test Team

Name	Role	Organisation
Mike Foulkes	Tug Master	Seaspan Towing
Sean Poole	Tug Master	Seaspan Towing
Chris Jensen	Tug Master/ Port Captain	Seaspan Towing
John Newby	Project Manager	CDM Smith
Nancy Bonham	Lead Senior Engineer	Metrovancouver
Garland Hardy	Test Director	LANTEC Marine Inc.

1.3 Study Goals

Goals for the study included a preliminary assessment of the following:

- Determine if the position of the temporary cofferdam structure would encroach on the manoeuvring space used by Seaspan towing when making daily arrivals and departures with tugs and rail barges during the period when the riser is being installed;
- Ascertain if certain portions of the tidal cycle and associated river current flow presented either preferred or complex manoeuvring conditions that could be directly associated with a lower or higher degree of risk of collision or close encounter with the cofferdam structure;
- Provide procedural recommendations to Seaspan Towing that would serve as risk mitigation measures for all barge movements to and from Southern rail during the riser installation period; and
- Develop a list of considerations and proposed procedures for use by the incumbent Marine Contractor that would minimise risk created by any manoeuvring operations near the construction site.

1.4 Ship Models

This study was conducted using existing proven models from the Kongsberg simulation model library. Twenty-five of the thirty–one manoeuvres conducted utilised custom built models of Seaspan's River tugs the Tempest and Venture. The remaining six runs used a combination of one Tempest Class and a generic model of a twin screw tug similar to a Seaspan Coastal Tug. Particulars of the vessels are listed in the following table:

Table 2: Vessel Particulars

Vessel Type	Vessel Name	Displacement (tonnes)	Length LOA (m)	Beam (m)	Draught Forward (m)	Draught Aft (m)
Tug40 River Tug	Seaspan Venture	188	19.5	7.0	3.2	3.2
Tug09 Coastal Tug	Cape May	668	32.7	9.0	3.7	4.6
Barge07 Inland Barge	N/A	3907	89.9	16.46	2.74	2.74

1.5 Area Model

A high-fidelity 3D geographical area model encompassing complete bathymetry of the South Arm of the Fraser River from the Alex Fraser Bridge to the western tip of Annacis Island, and all physical aspects of the Southern Rail berth was developed by Kongsberg Digital specifically for this project. Electronic Navigation Charts and CHS source data from December 2016 were used for geo-referencing all pertinent aspects of marine navigation: bathymetric contours (including drying areas), spot soundings, terrain elevation, coast line and man-made structures. Additional bathymetric information in 10- and 25-metre grid spacing was provided from Port of Vancouver sources. Satellite imagery and local photography were used to ensure that the visual scenery yielded an accurate area representation including non-charted fixtures commonly used by the tug masters.

2 Met-ocean Conditions for Annacis Island

Due to the very sheltered nature of Annacis Island, observed wave heights in the vicinity of the Southern Rail Terminal rarely exceed 30 centimetres and are fetch-limited. For all practical purposes it can be stated that their effect on manoeuvring is negligible during docking and undocking operations. Wind and Tidal/River Current conditions are described below.

2.1 Fraser River Overview

The Fraser River is a tidal estuary that is navigable by PANAMAX size, ocean going ships as far upriver as New Westminster with tug and barges transiting much further upriver. The tidal range at the river mouth is approximately 5 metres and it decreases by approximately 10 centimetres with each kilometre of upriver travel. Currents vary in speed seasonally from 2 to 6 knots, and the tidal stream reaches beyond New Westminster. Winds at the river mouth regularly exceed 25 knots, and on occasion gust at 40+ knots. The two prevailing wind directions are approximately 290º and 115º True. Wind upriver from Steveston rarely exceeds 30 knots.

The test area focused on the portion of the Fraser River from the Alex Fraser Bridge, downriver to the western end of Annacis Island.

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2.2 Tidal Cycles – River Levels and Resultant Current Flow

Due to the tidal estuary conditions described above, the prevailing river flow at Annacis Island is outwards, (i.e. from the direction of the Alex Fraser Bridge towards the Strait of Georgia), however when the river has a level of less than 2000 cubic metres per second (generally June to January) the resultant river flow reverses with each rising tide that exceeds approximately 1.4 metres in height; this condition then results in an inflow current. In order to conduct simulation tests that would reflect the range of possible conditions to be experienced during the riser construction period, EBD Tetra Tech was contracted to create 3-D current prediction models that could be used dynamically during the manoeuvring simulations. The resulting simulated water flow predictions were compiled to cover two unique 24-hour periods, one with a river volumetric outflow rate of 2000 CMS and one with a flow rate of 1500 CMS. Additionally, each of these conditions was modelled both with the cofferdam structure in place (causing a small diversion in water flow), and without the cofferdam. The simulation tidal stream/current model was dynamic and included the vertical height of tide, as well as current direction and velocity values at horizontal levels for depths of 0.3, 1.3, 2.8, and 8.8 metres. This provided a highly realistic representation of both the dynamic water levels (height of tide) and current/ tidal stream velocities at a grid spacing of 3, 10 and 25 metre.

Figure 1: Modelled tidal stream conditions for 1500 CMS River Flow

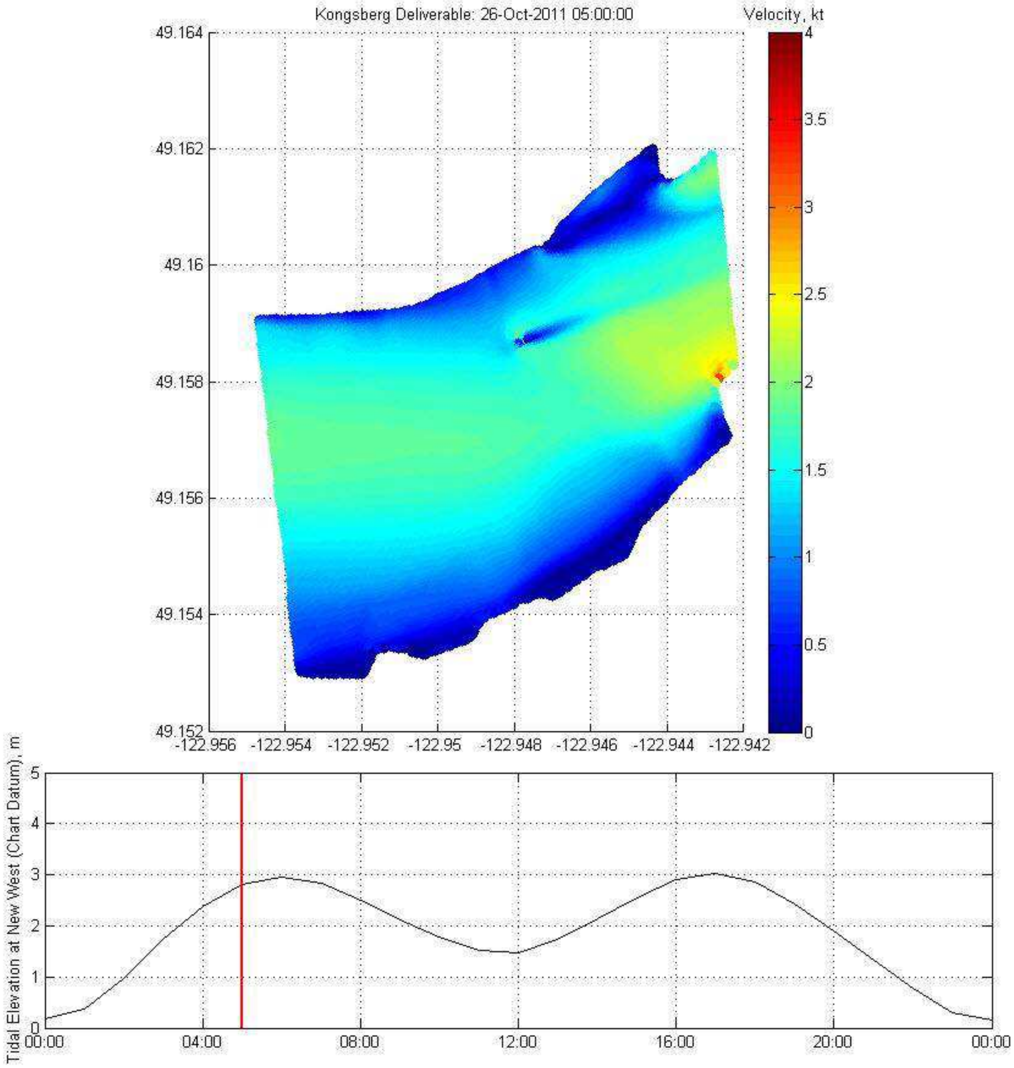


Figure 2: Modelled tidal stream conditions for 2000 CMS River Flow

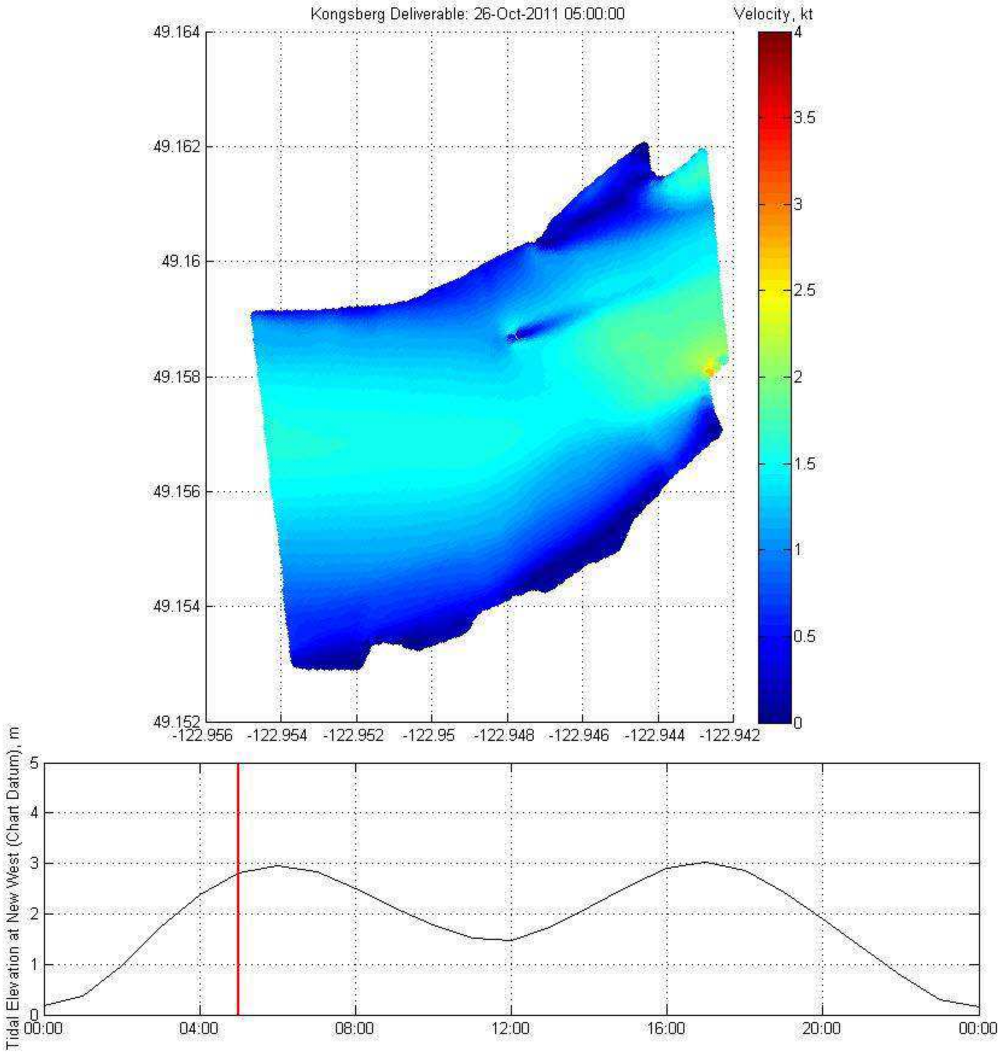
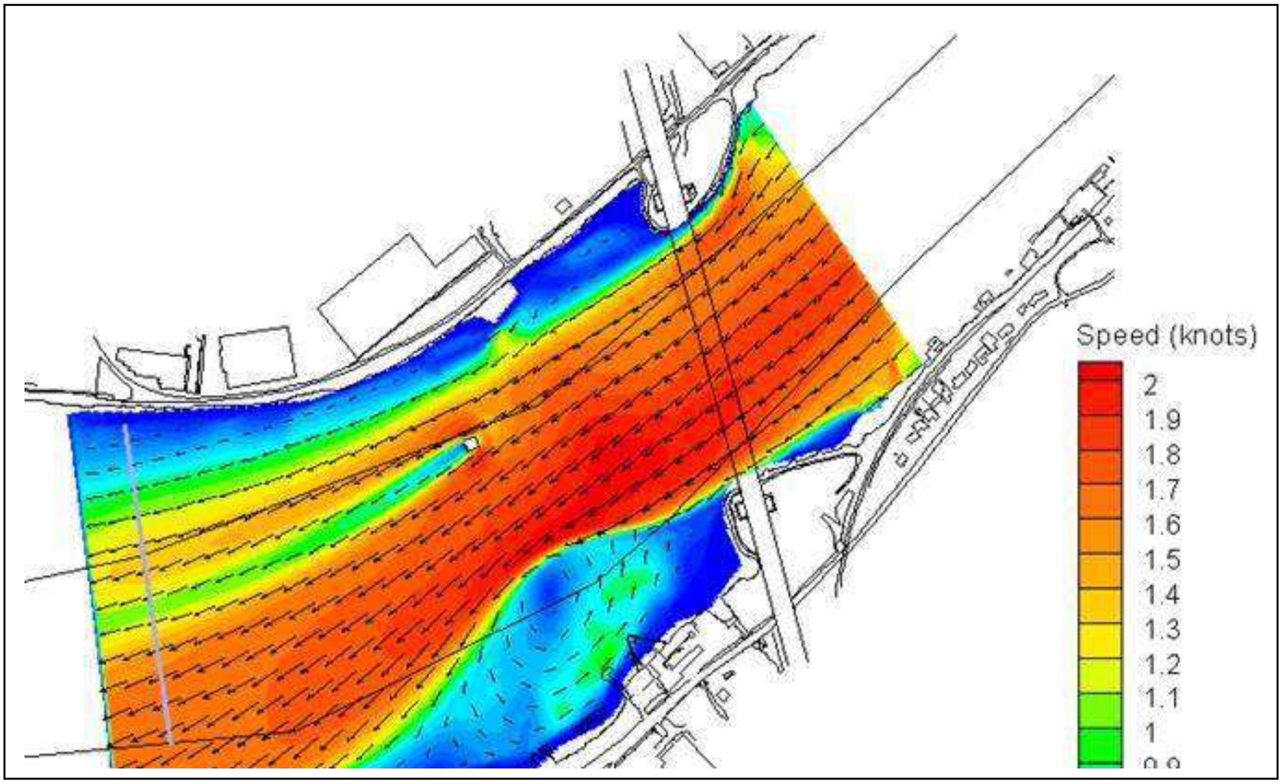


Figure 3: Fine Grid Model Surface Flow Conditions – Southern Rail Dock



3 Summary of Real Time Simulation Analysis

Seaspan Towing Captains have many years of experience manoeuvring barges to and from the Southern Rail Barge Ramp. Real world evidence has shown that the more complicated tidal conditions for these manoeuvres, particularly arrivals tends to be on the flood tidal stream (rising tide above 1.5 metres). Overall, the simulation analysis was consistent with anecdotal experience, and a larger portion of the study was dedicated to examining the more complicated flood tide manoeuvres.

3.1 Existing Operational Rules and Protocol

At present, there are no restrictions on when barge arrivals or departures can be conducted at Southern Rail. The majority of the arrival manoeuvres at Southern Rail consist of picking up the barge from the nearby Barge Tie Up, and then proceeding up river with the barge for approximately one kilometre and then landing the barge at the Southern Rail Ramp. Occasionally a coastal tug will arrive with a barge directly from Georgia Strait and drop it off at Southern Rail. The preferred tidal condition for both of these approaches is an ebb tide. Finally, on rare occasions, a barge is moved from the repair facility above the Alex Fraser Bridge down to southern Rail. The preferred tidal condition for this manoeuvre is a flood tide.

3.2 Employment of Assist tugs

All moves to and from Southern Rail are conducted with two tugs. For any operation, there is a primary tug (the towing tug) which typically is made up on a double bridle at the head (bow) of the barge. The second tug, referred to as the “Assist Tug” is there to assist with final stages of manoeuvring the barge to the ramp, or the early stages of the departure. At present, there is no established protocol, or even a de-facto method for the employment of the Assist Tug. The choice of whether to tether to the barge, to work at the stern, or near mid-ships, etc. is left to the discretion and judgement to the tug master.

3.3 Summary of Controlled Runs

One of the two tug masters, Captain Foulkes had extensive experience working in the simulator as an instructor and mentor, hence a short simulator familiarisation session was run for Captain Poole, and then the study proceeded directly to the controlled simulation runs. A summary of all controlled runs conducted 17 and 18 July 2017 are listed below:

Table 3: Southern Rail Berth Controlled Simulation Test Runs

Controlled Runs – River Flow Rate 1500 CMS			
Run	*Description*	*In/Out*	*Tidal Period*
1	Assessment of berthing under final stages of Flood – Big Rise	Inbound	06:00 – rising tide
2	Assessment of berthing under final stages of Flood – Big Rise	Inbound	06:00 – rising tide
3	Assessment of berthing under early ebb – Small Drop	Inbound	08:00 – falling tide
4	Assessment of berthing under late ebb – Small Drop	Inbound	10:00 – falling tide
5	Assessment of berthing under early stages of Flood – Small Rise	Inbound	13:00 – rising tide
6	Assessment of berthing under middle stages of Flood – Small Rise	Inbound	15:00 – rising tide
7	Assessment of berthing under late stages of Flood – Small Rise	Inbound	16:00 – rising tide
8	Assessment of berthing under early stage of Ebb – Big Drop	Inbound	18:00 – falling tide
9	Assessment of berthing under middle stage of Ebb – Big Drop	Inbound	21:00 – falling tide
10	Assessment of berthing under late stage of Ebb – Big Drop	Inbound	23:00 – falling tide
Controlled Runs – River Flow Rate 2000 CMS			
Run	*Description*	*In/Out*	*Tidal Period*
11	Assessment of berthing under early stages of Flood – Big Rise	Inbound	06:00 – rising tide
12	Assessment of berthing under middle stages of Flood – Small Rise	Inbound	15:00 - rising tide
13	Assessment of berthing under middle stages of Flood – Small Rise	Inbound	15:00 - rising tide
14	Assessment of berthing under early stage of Ebb – Big Drop	Inbound	18:00 – falling tide
15	Assessment of berthing under early stage of Ebb – Big Drop	Inbound	18:00 – falling tide

Controlled Runs – River Flow Rate 2000 CMS			
Run	*Description*	*In/Out*	*Tidal Period*
16	Assessment of berthing under middle stage of Ebb – Big Drop	Inbound	21:00 – falling tide
17	Assessment of berthing under middle stage of Ebb – Big Drop	Inbound	21:00 – falling tide
18	Assessment of berthing under middle stage of Ebb – Big Drop	Outbound	21:00 – falling tide
19	Assessment of berthing under early stage of Ebb – Big Drop	Outbound	18:00 – falling tide
Controlled Runs – River Flow Rate 1500 CMS			
Run	*Description*	*In/Out*	*Tidal Period*
20	Assessment of un-berthing under final stages of Flood – Big Rise	Outbound	06:00 – rising tide
21	Assessment of un-berthing under late stages of Flood – Big Rise	Outbound	04:00 – rising tide
22	Assessment of un-berthing under late stages of Flood – Big Rise	Outbound	04:00 – rising tide
Controlled Runs – River Flow Rate 2000 CMS			
Run	*Description*	*In/Out*	*Tidal Period*
23	Assessment of berthing under middle stage of Ebb – Big Drop	Inbound	21:00 – falling tide
Controlled Runs – River Flow Rate 1500 CMS			
Run	*Description*	*In/Out*	*Tidal Period*
24	Assessment of berthing under late stages of Flood – Big Rise	Inbound	04:00 – rising tide
25	Assessment of berthing under late stages of Flood – Big Rise	Inbound	04:00 – rising tide
26	Assessment of berthing under late stages of Flood – Big Rise Engine Failure in Lead Tug	Inbound	04:00 – rising tide
27	Assessment of berthing under late stages of Flood – Big Rise Engine Failure in Assist Tug	Inbound	04:00 – rising tide
28	Assessment of berthing under late stages of Flood – Big Rise Engine Failure in Lead Tug	Inbound	04:00 – rising tide
29	Assessment of berthing under late stages of Flood – Big Rise Engine Failure in Lead Tug	Inbound	04:00 – rising tide

Controlled Runs – River Flow Rate 2000 CMS			
Run	*Description*	*In/Out*	*Tidal Period*
30	Assessment of berthing under middle stage of Ebb – Big Drop Downriver landing	Inbound	21:00 – falling tide
31	Assessment of berthing under middle stage of Ebb – Big Drop Downriver landing	Inbound	21:00 – falling tide

4 Results and Findings

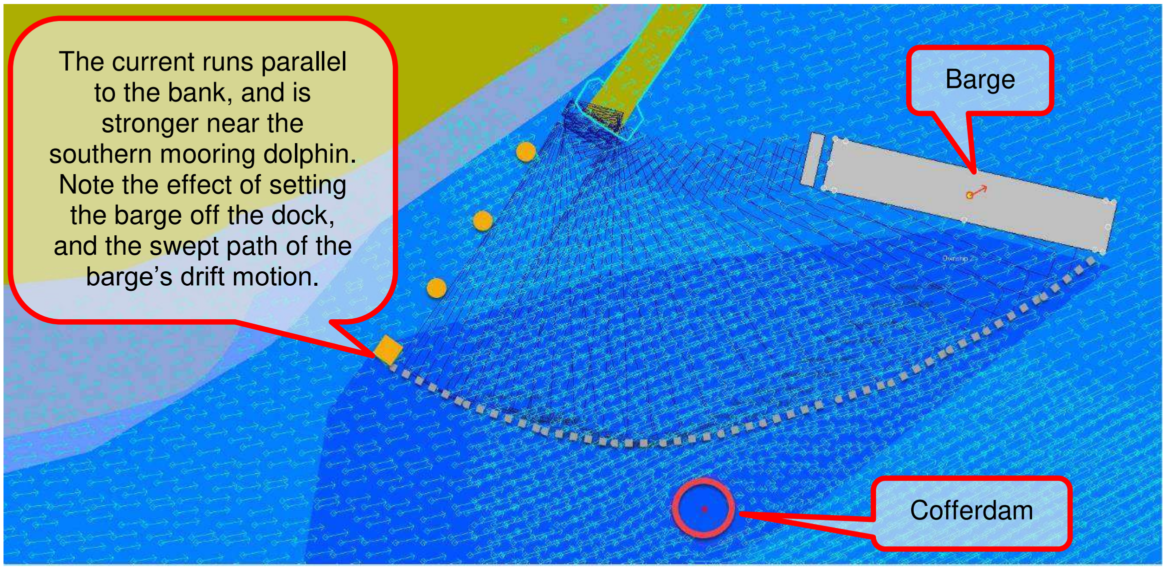
4.1 General Tidal Stream Effects - Manoeuvring Considerations

When manoeuvring barges, the flow of the current, and the resultant drift that it produces on the barge is critical. Even for routine operations at Southern Rail, where consideration for nearby construction does not need to be taken into account, the natural flow tendency of the ebb tidal stream, or outwards flowing river current presents a manoeuvring state that is preferred to the flood flow. Similarly, the direction of the river flow is an equally important consideration for tugs manoeuvring to and from the riser construction site, particularly if they are deliver materials by barge.

In order to establish mutually compatible, defined approach corridors for both the Southern Rail ramp, and the riser construction site, as well as workable staging areas for construction equipment, the effect of the prevailing river current flow must be a paramount consideration. It has been noted that the overall direction of the current flow is quite consistent through both the ebb and flood cycles; the velocity of the current changes considerably throughout the cycle, and then a near 180º change in directional flow at the end of each cycle. As such, we can examine the flow patterns of the flood current, and the ebb current, and then plan operations at both Southern Rail and the Riser Construction Site accordingly.

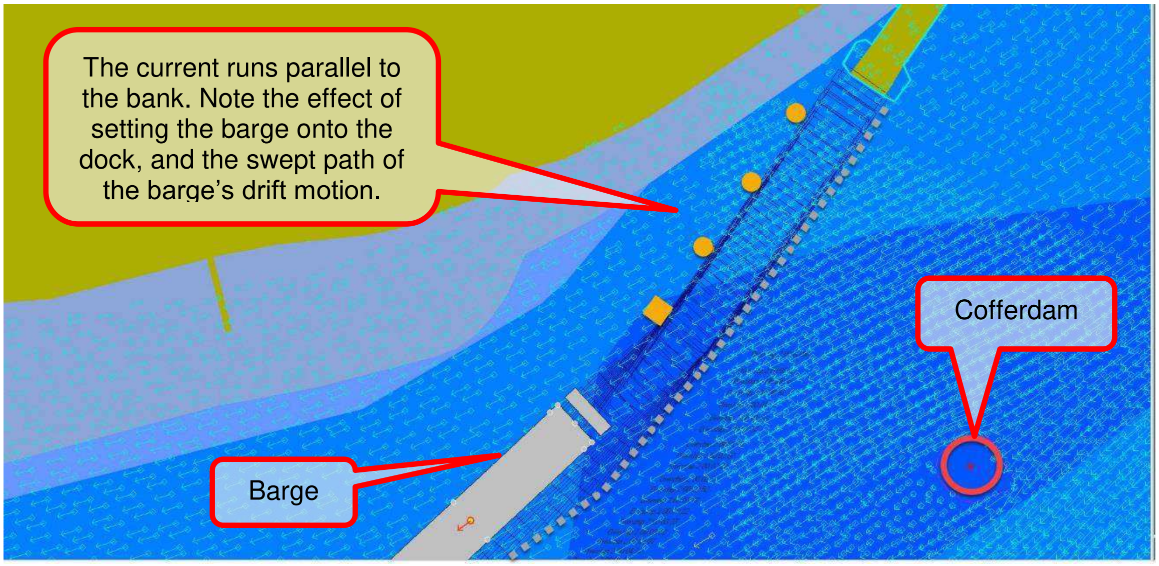
When the flood current is examined, it can be seen that in the vicinity of Southern Rail and the construction site, the current flow is near parallel to the river bank. Since the Southern Rail Ramp and mooring dolphins are at an angle of approximately 20º to the river bank, the flood current always tends to set a barge away from the Southern Rail ramp, and towards the Alex Fraser Bridge. The illustration in Figure 4 below shows how a barge adjacent to the ramp would drift with the flood current if it were left unattended. It should also be noted how the higher velocity current near the southern mooring dolphin causes the end of the barge to swing out in the river towards the cofferdam structure.

Figure 4: Current Drift Effects – Flood Tidal Stream (Rising Tide) - Barge



In a similar manner, the ebb current also parallels the riverbank, but in this case sets onto the ramp and the mooring pilings. If we look at the swept path of the unattended barge in Figure 5 below, we can see that in a "drift-off" situation, the barge rubs along the mooring dolphins and then drifts downriver away from the cofferdam structure.

Figure 5: Current Drift Effects – Ebb Tidal Stream (Falling Tide) - Barge



When considering risk mitigation measures for the riser/cofferdam construction site, it is recommended that a methodology similar to what is employed in the offshore oil and gas industry be used. For example, vessels approaching an offshore installation always approach from a "downstream" position such that if they experience loss of propulsion or manoeuvring control the natural tendency will be to drift away from the installation. The swept paths of a tug in a "drift-off" situation from the cofferdam, both during flood and ebb current flows are illustrated in Figures 6 and 7 below. It should also be noted, that as with an offshore installation, the stand-by tug while a mechanism to assist with collision prevention between another vessel and the cofferdam, also presents a perpetual collision risk. When other vessels are not in the proximity of the cofferdam/ construction site, and especially when personnel are in the cofferdam, the stand-by tug should remain downstream of the cofferdam. When other vessels are in the vicinity, the stand-by tug should remain between the cofferdam and any vessel that it may have to ward off.

Figure 6: Current Drift Effects – Flood Tidal Stream (Rising Tide) – Standby Tug

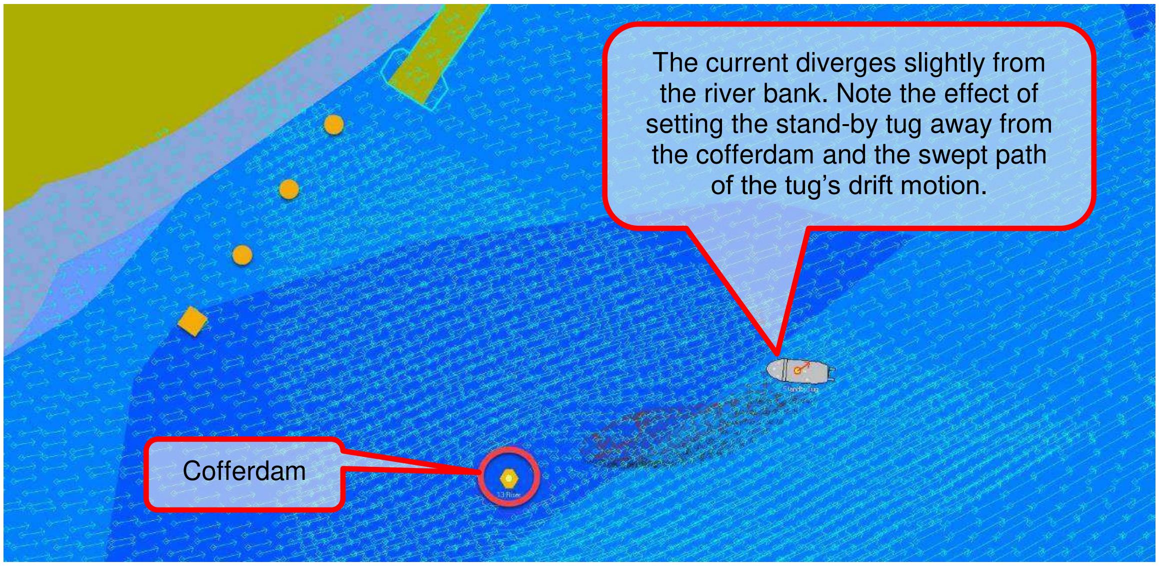
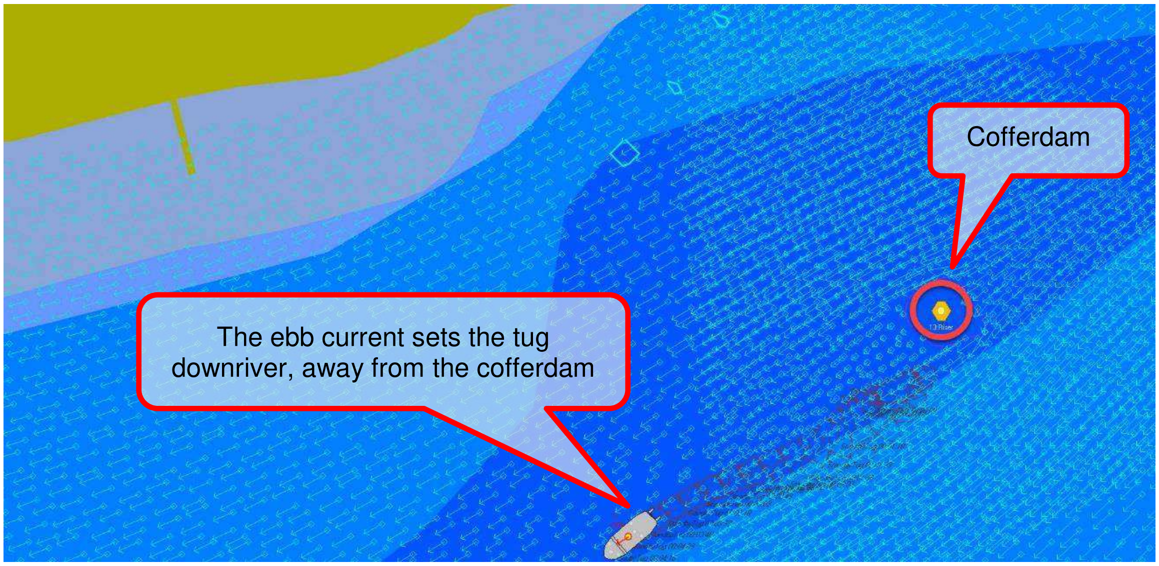
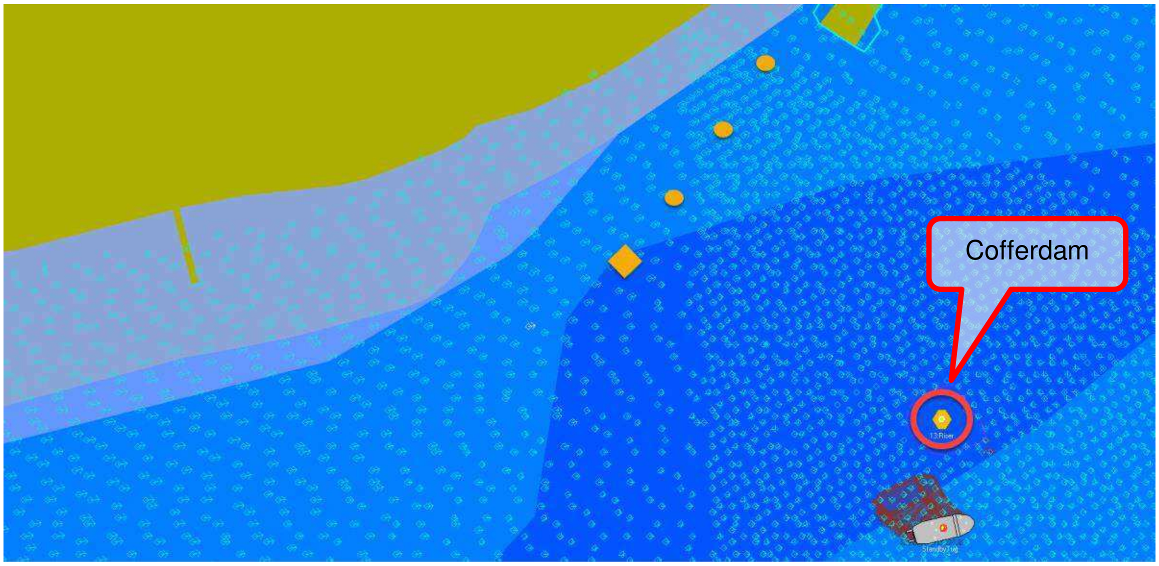


Figure 7: Current Drift Effects – Ebb Tidal Stream (Falling Tide) – Standby Tug



During the tidal transition, the drift-off effect for the stand-by tug will be quite light and variable. The swept paths of a tug in a "drift-off" situation from the cofferdam, during the transition from ebb to flood current flows is illustrated in Figure 8 below.

Figure 8: Current Drift Effects – Transition from Ebb to Flood – Standby Tug



4.2 Berthing and Un-berthing Manoeuvres Flood Tidal Stream

Consistent with the tug masters' experience handling barges at Southern Rail, and as discussed in Section 4.1 above, the flood tidal stream/ river flow in the vicinity of the Southern Rail berth presented a more difficult manoeuvring situation than that of the more dominate ebb or outflow current. All approaches to and departures from Southern Rail on the flood tide were made safely, with adequate clearance from the proposed cofferdam construction area. The first flood tide approach was made in a rather conventional fashion, making a "sweeping turn" into the ramp. It was found that the turning moment of the barge, coupled with the flood tide, caused the stern of the barge to swing towards the cofferdam, and both tugs had to push hard to prevent the barge from being set onto the construction site. In order to mitigate the more adverse effects of the current, on subsequent runs, the tug master in the lead tug followed an approach track close to the north bank of the river passing close to the outer most mooring dolphin at the Southern Rail berth. The assist tug was then used to push against the barge and to keep it close to mooring dolphins and to prevent it from being set onto the construction site. Even when an engine failure was experienced in one of the tugs, the other tug was still able to control the barge and keep it from being set onto the cofferdam.

For departure manoeuvres the flow of the current facilitates a lateral departure with the barge, followed by a turn to starboard between the cofferdam and the Alex Fraser Bridge. It was also found to be quite feasible to push the barge against the mooring dolphins, and to slide the barge downriver and then rotate it to the west of the cofferdam.

It should be noted, that the flood tide approaches in particular, always required considerably more tug power than those conducted on the ebb tide, and that the margin for manoeuvring error is considerably less than that of the ebb tidal condition. See Figures 9 to 17 below:

Figure 9: Run 1 Track Plot – Flood Tide Arrival

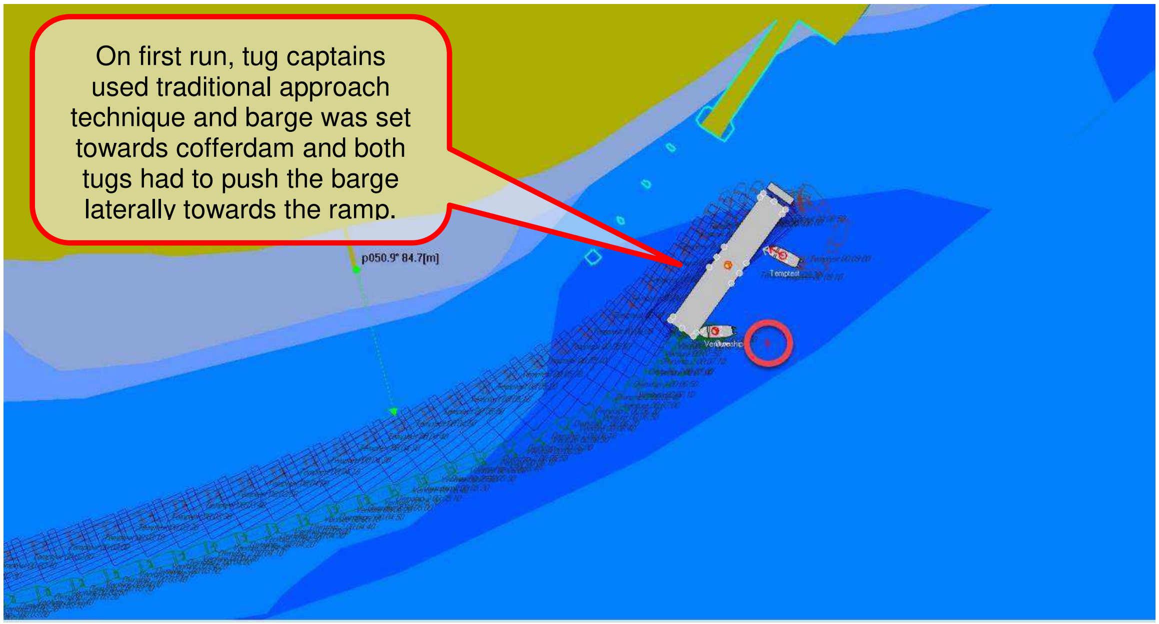

On first run, tug captains used traditional approach technique and barge was set towards cofferdam and both tugs had to push the barge laterally towards the ramp.

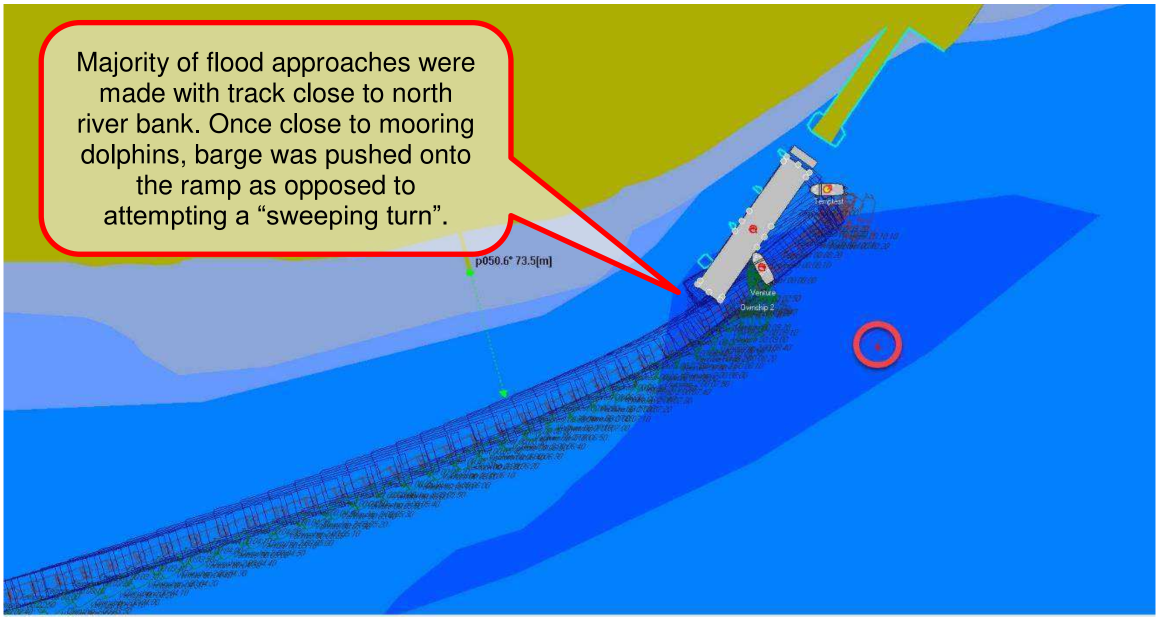
Figure 10: Lead Tug Engine Power Graph – Simulation Run 1


Lead tug used a lot of power to push the barge onto the ramp against the flood current.

Figure 11: Assist Tug Engine Power Graph – Simulation Run 1

Assist tug used a moderate of power to push the barge onto the ramp against the flood

Figure 12: Run 13 Track Plot – Flood Tide Arrival



Majority of flood approaches were made with track close to north river bank. Once close to mooring dolphins, barge was pushed onto the ramp as opposed to attempting a "sweeping turn".

Figure 13: Lead Tug Engine Power Graph – Simulation Run 1


Lead tug used only light power on the approach, and then moderate power to push the barge against the ramp.

Figure 14: Assist Tug Engine Power Graph – Simulation Run 13

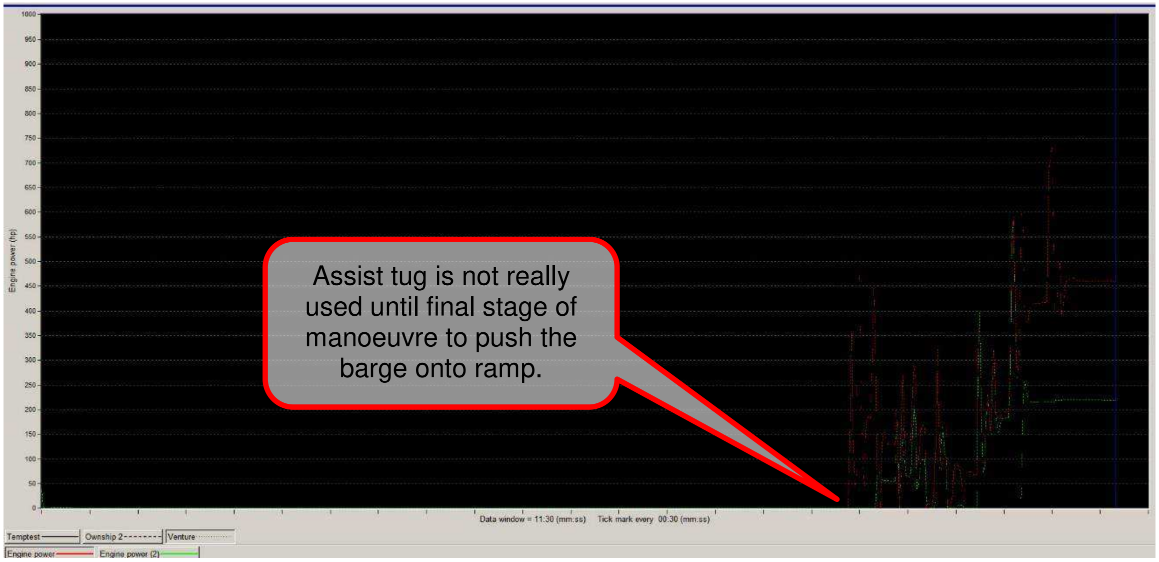
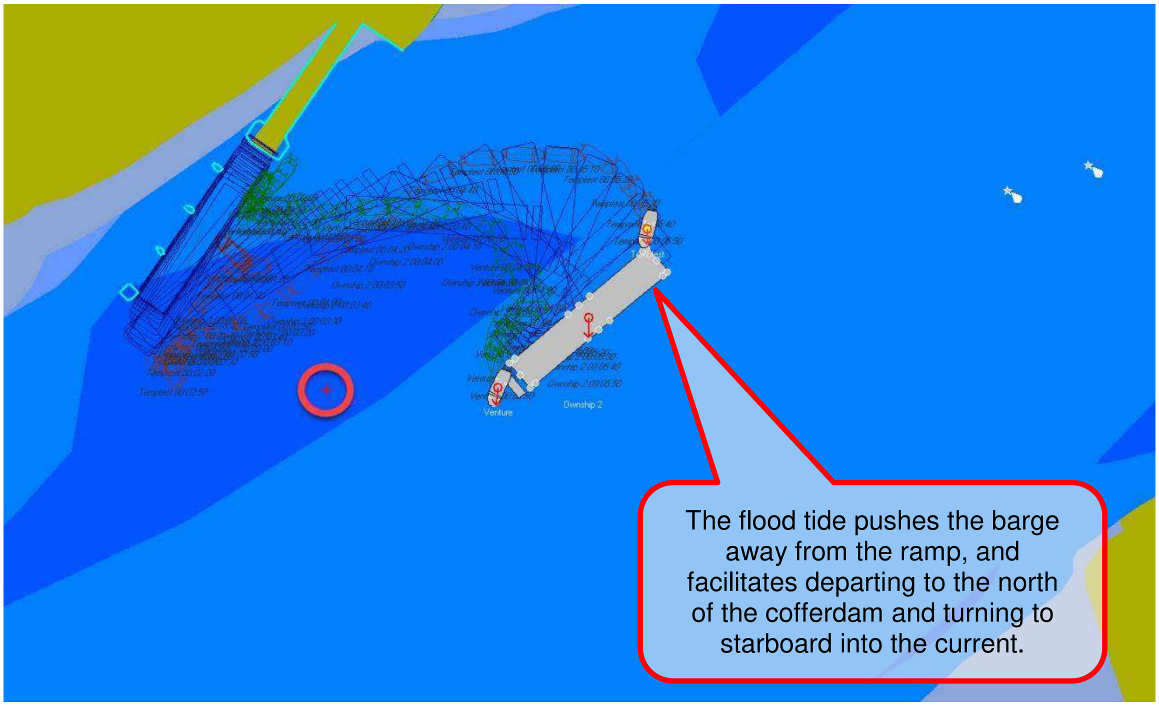
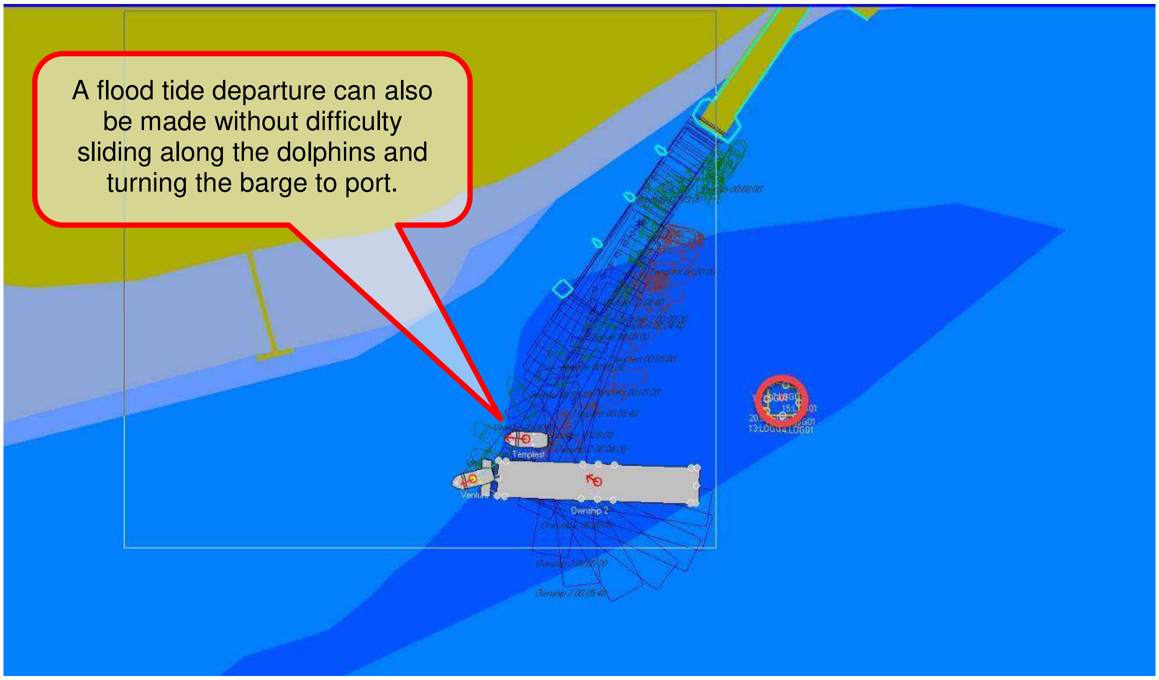

Assist tug is not really used until final stage of manoeuvre to push the barge onto ramp.

Figure 15: Run 21 Track Plot – Flood Tide Departure



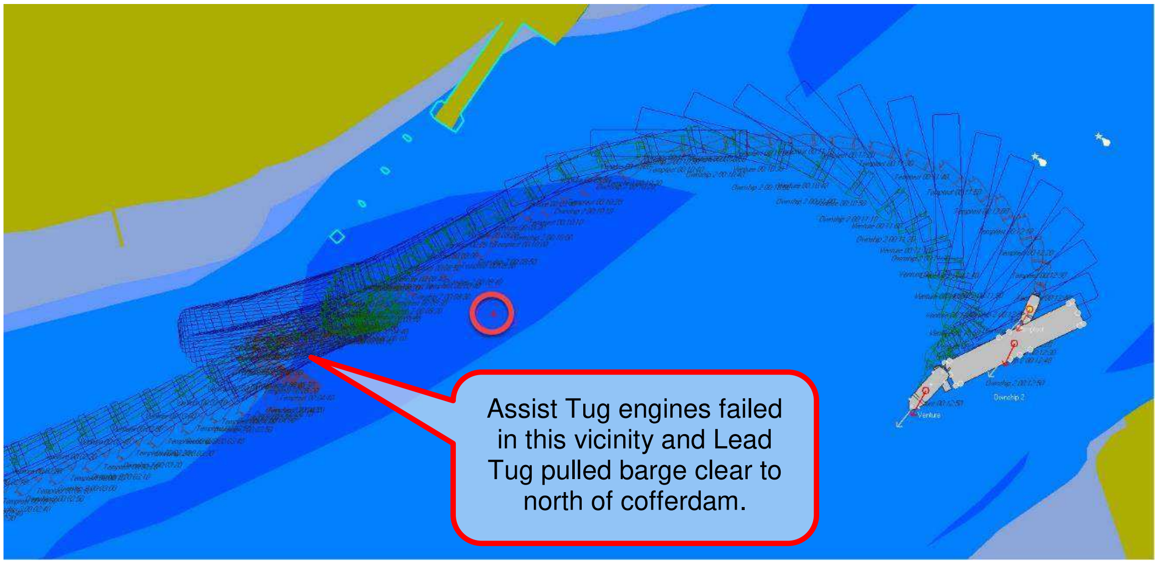
The flood tide pushes the barge away from the ramp, and facilitates departing to the north of the cofferdam and turning to starboard into the current.

Figure 16: Run 22 Track Plot – Flood Tide Departure



A flood tide departure can also be made without difficulty sliding along the dolphins and turning the barge to port.

Figure 17: Run 27 Track Plot – Flood Tide Arrival with Assist Tug Engine Failure

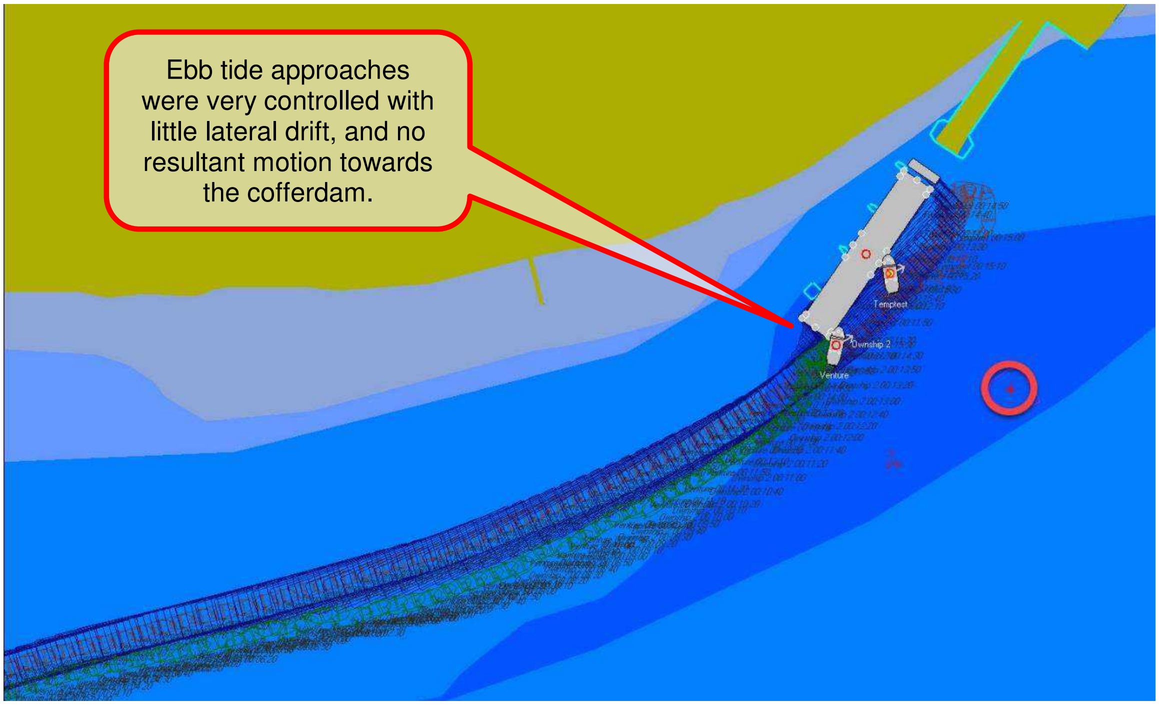


Assist Tug engines failed in this vicinity and Lead Tug pulled barge clear to north of cofferdam.

4.3 Berthing and Un-berthing Manoeuvres Ebb Tidal Stream

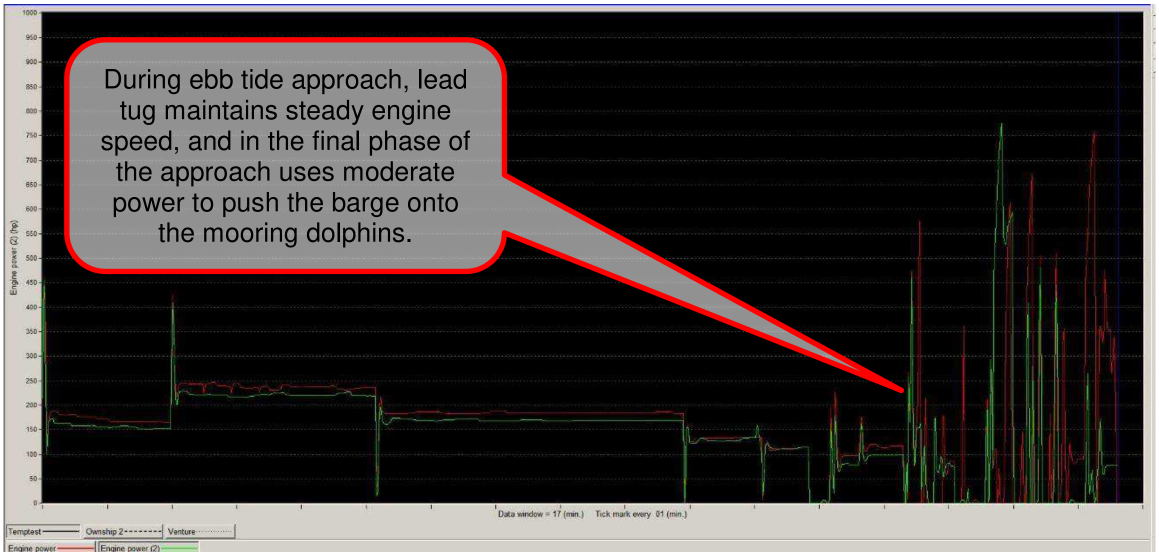
As discussed in Section 4.1, the Ebb tidal stream flow provides a higher overall degree of manoeuvring control for the tug masters as the opposing river current naturally slows the ground speed of the barge, providing more time to judge vessel motion, and to fine tune positional control of the barge. Ironically, the only mishap involving contact between the barge and the cofferdam was on a very light ebb tide. This however was a function of approaching with a much faster ground speed than earlier runs, due to light counter-current effect, and not having the assist boat tethered due to the “relatively benign conditions (This is discussed further in Section 4.4). In all other cases, approaches were made with a high level of control, and relatively light tug power. Similarly ebb tide departures were easily achieved with the assistance of the current naturally taking the barge downstream. See illustrations in Figures 18 to 22:

Figure 18: Run 4 Track Plot – Ebb Tide Arrival



Ebb tide approaches were very controlled with little lateral drift, and no resultant motion towards the cofferdam.

Figure 19: Lead Tug Engine Power Graph – Simulation Run 4

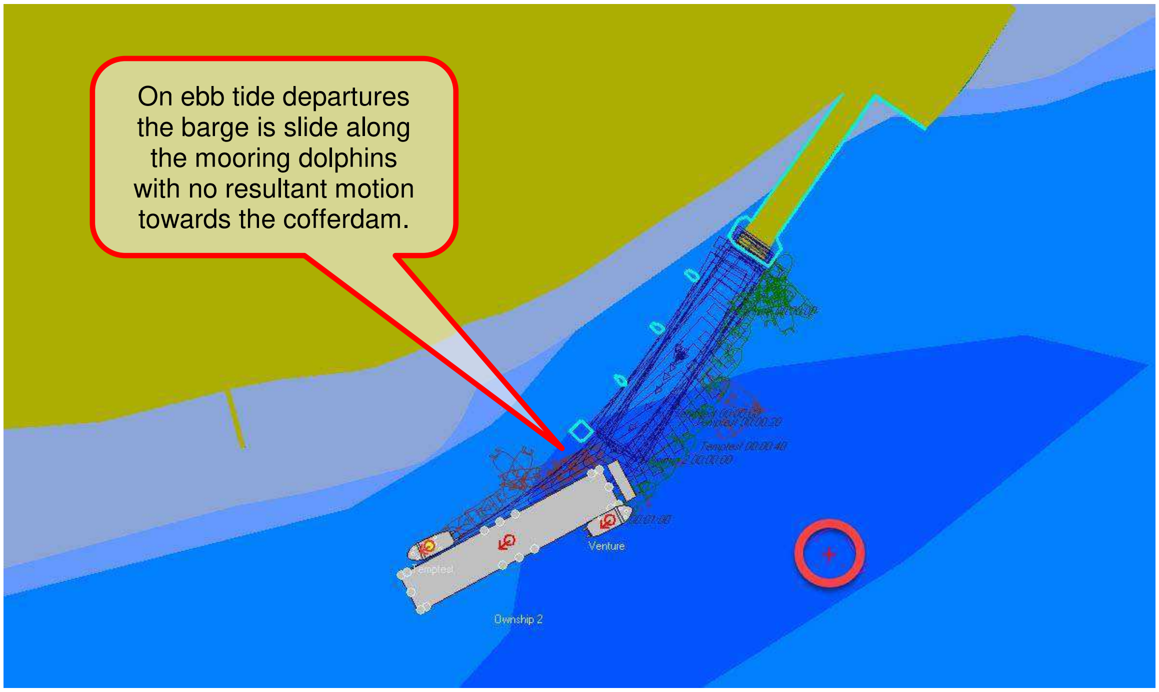


During ebb tide approach, lead tug maintains steady engine speed, and in the final phase of the approach uses moderate power to push the barge onto the mooring dolphins.

Figure 20: Assist Tug Engine Power Graph – Simulation Run 4

Assist tug maintains position on the stern of the barge and is barely needed to assist with routine landings.

Figure 21: Run 19 Track Plot – Ebb Tide Departure



On ebb tide departures the barge is slide along the mooring dolphins with no resultant motion towards the cofferdam.

4.4 Assist Tug Employment and Tethering

During normal operations at Southern Rail, the primary role of the assist tug is to supplement the manoeuvres of the lead tug, and mainly to assist with controlling the stern of the barge. There is no firmly defined scope of its manoeuvring role, and it varies considerably from flood to ebb tidal conditions (i.e. apply lateral forces on the stern of the barge, braking forces, etc.). When manoeuvring near a construction site, as per the simulation analysis, the role of the assist tug should be more firmly defined. Most importantly, the assist tug has an important safety role, in that it is the tug that can be most effectively employed to move the barge laterally away from the cofferdam in the event that the barge is experiencing set. Secondly, in the event of a steering or propulsion failure in the lead tug, the assist tug must be able to either push or pull the barge as required to ensure that it is kept clear of the cofferdam.

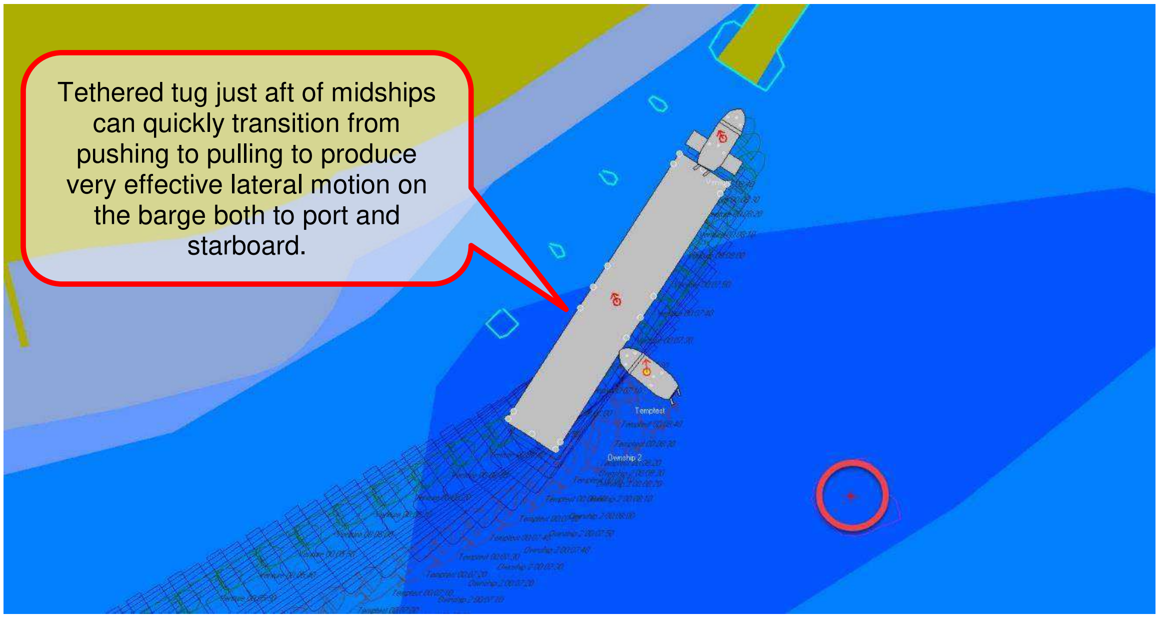
Throughout the simulation runs, particularly during the flood tidal cycle, but even on the ebb, it was observed that the assist tug was best able to apply lateral forces (i.e. move the entire barge sideways, or hold it against the current, if it were tethered just aft of the midships position. It was also noted that its ability to respond to unexpected events, both during routine and emergency manoeuvres was far better when it was tethered on a headline. The one mishap involving contact with the cofferdam occurred under very light ebb tide conditions, and was largely attributed to the fact that the assist tug was on the upstream side of the barge, and untethered. The lead tug conducted a sweeping turn, with little opposing current, the barge swung wide to starboard, and the assist tug took too long to manoeuvre to the (starboard) downstream side of the barge in order to push. See illustration in Figure 22 on the page below.

The benefit of tethering the tug just aft of midships was demonstrated on numerous runs as it allowed the assist tug to easily move the barge laterally to either port or starboard. With a headline made up, the transition from pushing to pulling forces was affected without delay. This is illustrated in Figures 23 and 24 in the pages that follow:

Figure 22: Run 14 Track Plot – Ebb Tide Arrival and Loss of Barge Control

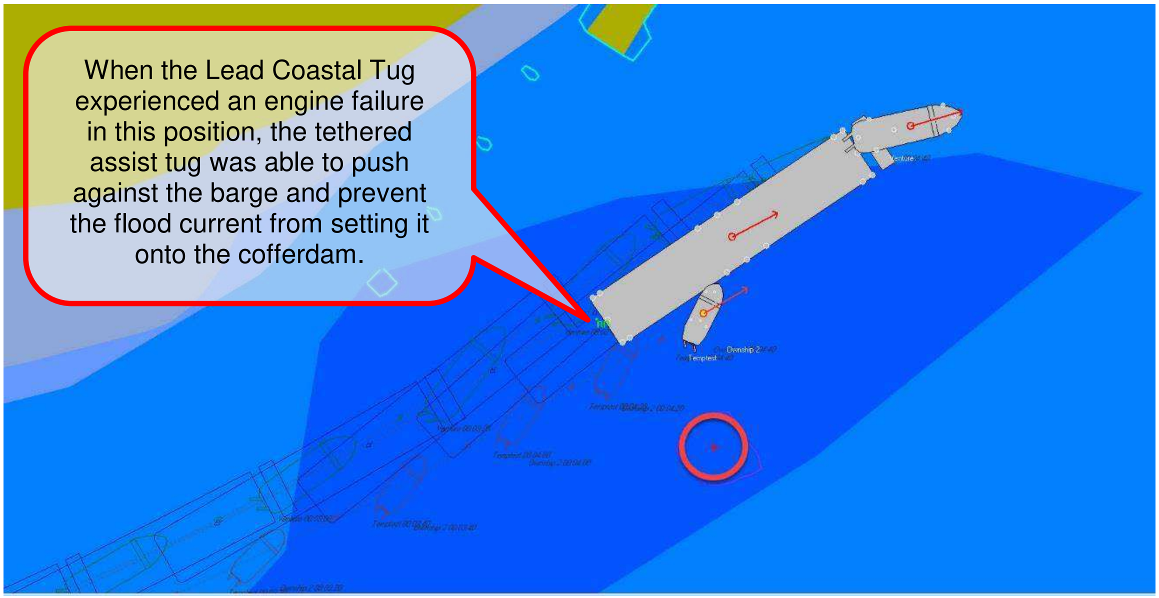
Untethered tug was following on port quarter of barge and could not get into position fast enough to push and prevent barge from swinging into cofferdam.

Figure 23: Preferred Assist Tug Tethering Position – Track Plot Run 16



Tethered tug just aft of midships can quickly transition from pushing to pulling to produce very effective lateral motion on the barge both to port and starboard.

Figure 24: Preferred Assist Tug Tethering Position – Track Plot Run 26 Engine Failure in Lead Tug



4.5 Observations on River Level and Resulting Current Effects

Two river flow rates of 1500 Cubic Metres per Second (CMS) versus 2000 Cubic Metres per Second were tested. From an overall level of manoeuvring difficulty and risk mitigation standpoint, the observed differences in the two flow rates were not significant. As expected, the velocity of the ebb tidal flow is greater at the 2000 CMS and the velocity of the flood is greater at the 1500 CMS rate. In all cases, there was sufficient manoeuvring power and control redundancy provided with both the use of the two river tugs, or one river tug and one coastal tug.

4.6 Considerations for Floating Construction Equipment

This analysis was the first step in identifying key manoeuvring and operational parameters that need to be factored into the development of a comprehensive vessel movement plan for the cofferdam construction phase. At the time of testing, the only confirmed parameter was the position of the riser and cofferdam structure. As such, manoeuvres were conducted without consideration for other floating equipment simply to determine the manoeuvring corridors that would be preferred under various tidal conditions for movements to and from Southern Rail. In determining the best location for floating construction equipment, (including a semi-permanent barge that would likely be pinned to the river bed) and the regular movement of materials and personnel to and from the construction site, the following variables must be considered:

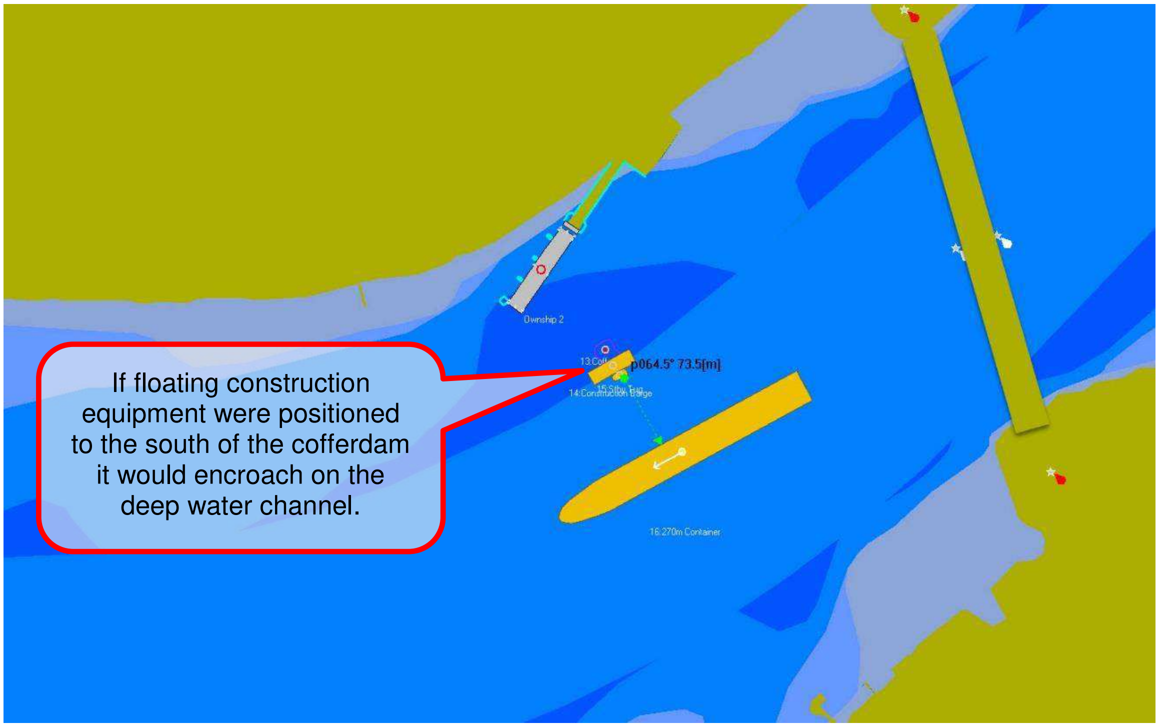
a) The location of the manoeuvring corridors used for Southern rail;
b) The effects of the river flow and vessel/ object drift tendencies as described in Section 4.1;

c) The proximity to the main river channel, particularly the deeper section which is used by ocean going vessels; and

d) With consideration for items a) through c), the preferred approach channel for construction equipment staging and movements that minimises manoeuvring risk to construction equipment and personnel, but does not adversely affect routine river navigation.

Positioning of a construction barge to the south of the cofferdam location would be conductive both to ease of tender/ standby tug movements and emergency vessel drift-off, however it is deemed that it would present too much of an obstruction to the deep river channel which is less than 250 metres in width. This would result in large vessels passing within 75 metres of the construction equipment. See Figure 25 below:

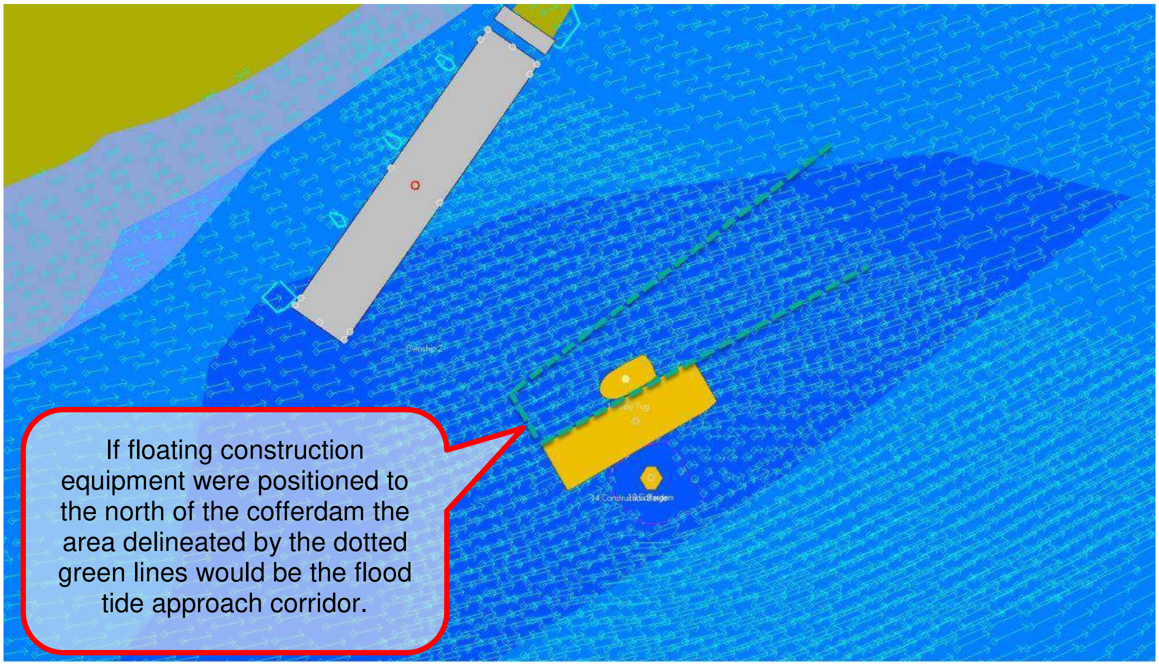
Figure 25: Construction Equipment on South Side of Cofferdam



If floating construction equipment were positioned to the south of the cofferdam it would encroach on the deep water channel.

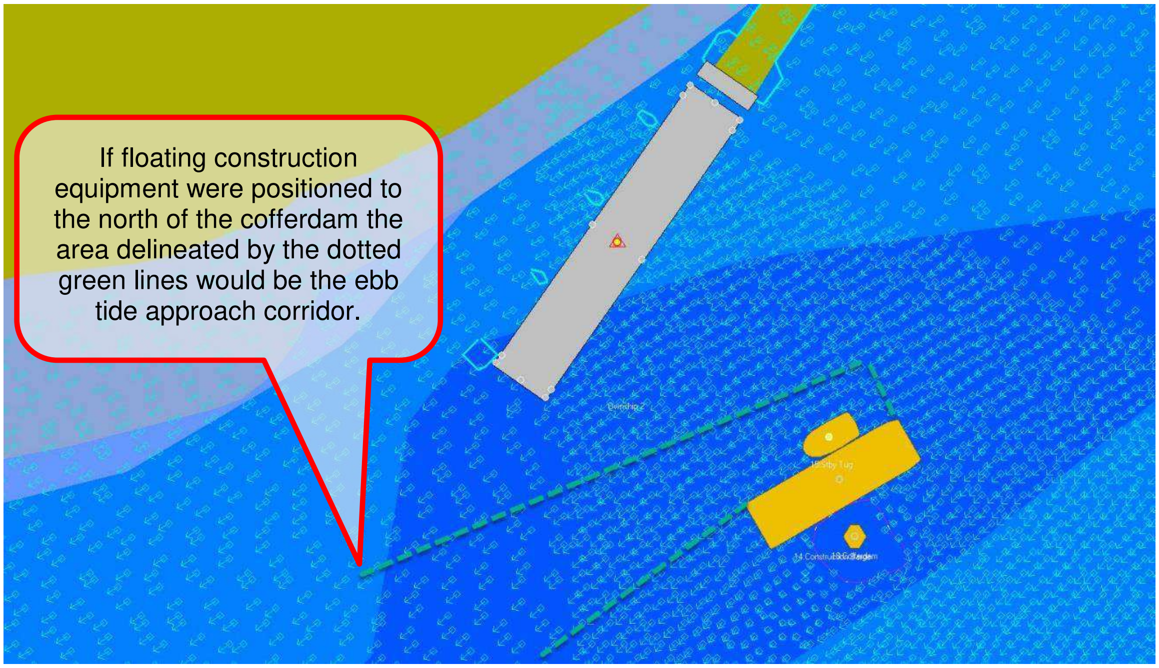
With consideration of all relevant factors, it is assessed that the best position for floating equipment is to the north of the cofferdam at an angle of approximately 240º/ 060º. This would allow movements of equipment to be made outside of the deep navigation channel, and the approach corridor to the construction barge would only have a small overlap with the approaches to Southern Rail. See Figures 26 and 27 on the next page:

Figure 26: Construction Equipment on North Side of Cofferdam – Flood Tide



If floating construction equipment were positioned to the north of the cofferdam the area delineated by the dotted green lines would be the flood tide approach corridor.

Figure 27: Construction Equipment on North Side of Cofferdam – Ebb Tide

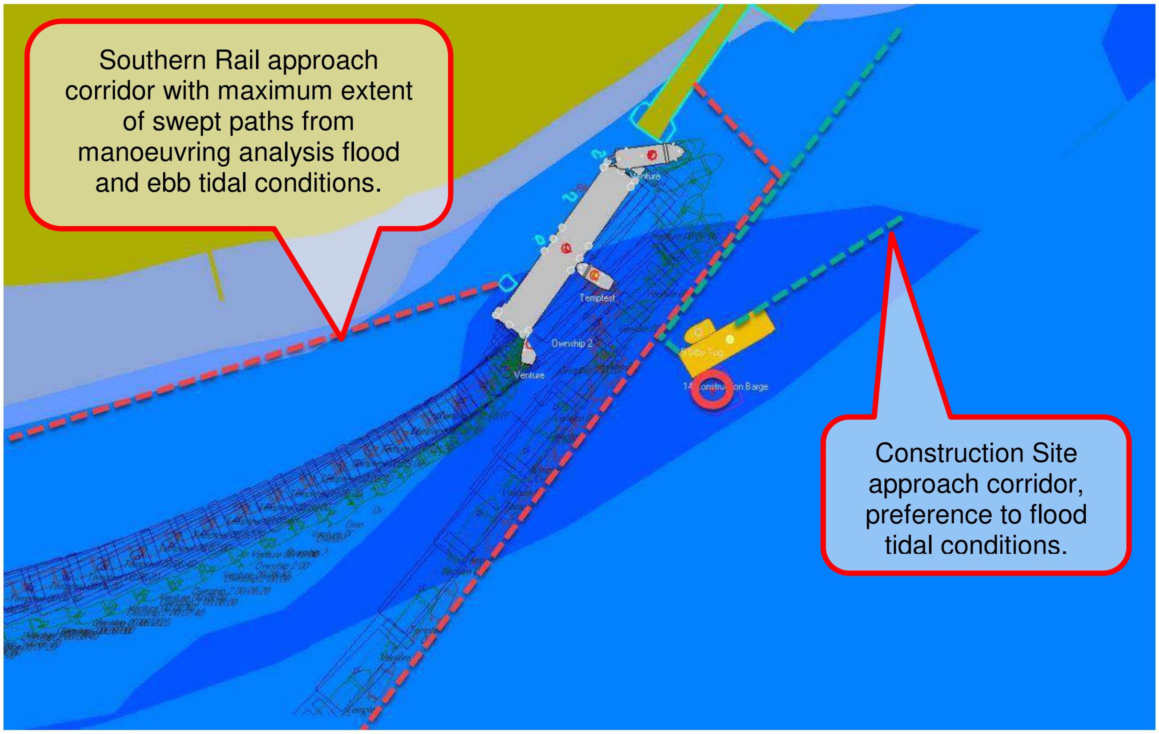


If floating construction equipment were positioned to the north of the cofferdam the area delineated by the dotted green lines would be the ebb tide approach corridor.

4.7 Preferred Approach Corridor – Southern Rail

Although several departures, and one arrival were made from the north side of the cofferdam to the Southern Rail Terminal, it was the overall finding of this analysis that the safest and simplest manoeuvres to and from the terminal were made from the downriver side of the dock/ cofferdam. Also, from a risk mitigation standpoint, the ebb tidal condition is preferred for both arrivals and departures, and this also corresponds to utilising a down river corridor. When the position of construction equipment to the north of the cofferdam is also considered, then barge movements upriver of the ramp should not be considered as a viable option. On this premise, unique preferred approach corridors could be established for both Southern Rail and construction equipment movements whereby barge movements to southern Rail would be conducted on the ebb tide, and equipment movements to the construction site on the flood tide. See Figure 28 below:

Figure 28: Preferred Approach Corridors – Southern Rail and Construction Site



Southern Rail approach corridor with maximum extent of swept paths from manoeuvring analysis flood and ebb tidal conditions.

Construction Site approach corridor, preference to flood tidal conditions.

5 Recommendations

Based on the findings described above, for project planning and implementation purposes, it is recommended that the procedures proposed below be considered:

5.1 Coordination of Barge Movements

It is recommended that Southern Rail Terminal/ Seaspan Towing Dispatch establish a procedure whereby Metro Vancouver’s Marine Contractor always receives at least twenty-four hours advanced notification of all planned barge manoeuvres. Similarly, if the marine contractor is planning movements other than by the tender/ stand-by tug, he should provide twenty-four hour advanced notice to Southern Rail/ Seaspan.

5.2 Personnel in Cofferdam

As a risk mitigation measure (considering that tugs and barges will routinely pass within 50 metres of the cofferdam), personnel working in the cofferdam should be removed at least 15 minutes prior to scheduled barge moves.

5.3 Stand-by Tug Requirements

The marine contractor should have a stand-by tug present throughout the riser placement/ construction process. This standby tug could provide response/ assistance not just for movements to and from Southern Rail, but also in the event of any other mishap that might occur upstream of the construction site (i.e. transiting tug and barge loses power, small craft loses power, large drifting debris, etc.). For reasons as outlined in Section 4.1 of this report, the stand-by tug as a matter of practice should remain downstream from the cofferdam when there are no vessel moves near the construction site, and should be standing-by upstream of the cofferdam during anticipated vessel moves.

5.4 Tethering of Assist Tug

For the duration of the cofferdam construction, and riser installation process, all barge moves to and from Southern Rail must be conducted by two tugs, both of which are tethered. The analysis has also shown that under most tidal conditions, the preferred position for the “Assist Tug” is tethered at or near midships on the river side of the barge (as described in Section 4.4 of this report) such that in the event of a mishap, or manoeuvring control problem the assist tug can move (push or pull) the barge laterally away from the cofferdam structure.

5.5 Flood Tide Restrictions – Barge Arrivals Southern Rail

This simulation analysis utilised the normal seasonal medium to low river flow rates of 2000 and 1500 CMS which is expected for most of the riser installation process. If during the actual construction period the river volumetric flow falls below 1500 CMS, it is recommended that arrival operations be ceased during periods of a rising tide when the tidal level exceeds 2.0 metres (New Westminster). During this stage of the rising tide, a strong inwards flow develops which tends to set in a direct line from the Annacis Barge Tie Up towards the cofferdam position. This proposed “blackout period” would typically not exceed more than two, 3-hour windows on any given day.

It should also be noted that it is the assessment of this analysis that the degree of risk with flood tide manoeuvres, while manageable, is always more elevated than that of ebb tide manoeuvres. If all efforts are taken to mitigate risk, then flood tide manoeuvres would be avoided during the entire period when the cofferdam is in place.

5.6 Defined Approach Corridors

The Marine Contractor and Southern Rail/ Seaspan should come to a mutual agreement with respect to establishing a rail barge transit exclusion zone that will be kept free during barge manoeuvres from any floating apparatuses, construction barges, cranes or other devices that are required as part of the cofferdam construction/ riser installation process. Based on the track plots of the thirty-one test manoeuvres, the prevailing current patterns, and other factors discussed in Sections 4.6 and 4.7 approach corridors as depicted in Figure 28 are offered for consideration.

It should also be noted that consistent with the proposed exclusive corridors, simultaneous manoeuvres at Southern Rail and the construction site should be avoided. The practice of conducting movements at Southern Rail on the ebb tide, and at the construction site on the flood tide would also facilitate this procedure.

5.7 Simulation of Final Operational Procedures

After contract award to the selected Marine Contractor, and prior to commencing construction operations, another two to three-day simulation session should be convened with participation from the Marine Contractor, Seaspan Towing, Southern Rail, and any other identified vested interest group to practise the proposed procedures and to conduct any procedural refinement that might be deemed necessary prior to commencing live operations. These simulations would also provide an opportunity to ensure that all tug masters conducting movements to either Southern Rail or the construction site are completely familiar with the established operational protocols.

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