Appendix E3

Stantec Receiving Water Study Effluent Treatment Plant Replacement

NORTHERN PULP
NOVA SCOTIA CORPORATION
A PAPER EXCELLENCE COMPANY

DILLON
CONSULTING

Environmental Assessment Registration Document
Replacement Effluent Treatment Facility
January 2019

Preliminary Receiving Water Study for Northern Pulp Effluent Treatment Plant Replacement, Pictou Harbour, Nova Scotia

FINAL REPORT

Prepared for:
KSH Solutions Inc.
3400, boul. de Maisonneuve Ouest,
Bureau 1600
Montréal, QC H3Z 3B8

Prepared by:
Stantec Consulting Ltd.
102-40 Highfield Park Drive
Dartmouth, NS B3A 0A3
Tel: (902) 468-7777

Stantec File No. 121414584

August 11, 2017

Sign-off Sheet

This document entitled Preliminary Receiving Water Study for Northern Pulp Effluent Treatment Plant Replacement, Pictou Harbour, Nova Scotia was prepared by Stantec Consulting Ltd. (“Stantec”) for the account of KSH Solutions Inc. (the “Client”). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec’s professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Reviewed by ____

(signature)

Don Carey, M.Sc., P.Eng.

Sam Salley

Approved by ____

(signature)

Sam Salley, M.Sc., Project Manager

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Executive Summary

Stantec Consulting Ltd. (Stantec) was retained by KSH Solutions Inc. (KSH) to undertake a preliminary receiving water study in Pictou Harbour, Nova Scotia to address the requirement of a new effluent pipeline and marine outfall for a wastewater treatment plant for Northern Pulp Nova Scotia Corporation (NPNS).

The dispersion characteristics of the effluent discharged from four alternative locations (Alt-A, Alt-B, Alt-C and Alt-D) were investigated by two-dimensional (2D) hydrodynamic modelling. The discharge locations Alt-A and Alt-B located inside Pictou Harbour were not retained for further analysis because the dispersed plume was in proximity to sensitive environmental and socio-economic areas. Also, because of the narrow entrance to Pictou Harbour a large portion of the discharged effluent from either the Alt-A or Alt-B outfall locations would be retained within the harbour. This retention of the discharged effluent within the harbour is anticipated to potentially result in the cumulative increase of effluent concentrations in the harbour on the longer term.

The Alt-C outfall location in the Northumberland Strait provided sufficient dilution of the discharged effluent and achieved the regulatory water quality guidelines within the prescribed mixing zone. However, there was some dispersion of effluent to ‘backwash’ into Boat Harbour and to affect the shorelines in the Northumberland Strait. This led to an additional location being identified, Alt-D, which was situated 0.5 km northeast from Alt-C to minimize the potential flow and dispersion of treated effluent into Boat Harbour. The 2D hydrodynamic modelling showed that Alt-D is the preferred alternative, which is located sufficiently into the Northumberland Strait to have minimal impact on water quality in Pictou Harbour, Boat Harbour and the near-shore areas.

Mixing and dilution at the Alt-D outfall location is driven by water depth at the outfall, tides and currents. Similar mixing and dilution is expected in close proximity to Alt-D (i.e. in a 100 m radius) assuming the depth of the outfall is the same or larger than in Alt-D. Outfall depth is a bigger driver than exact position in the Pictou Road Area.

The near-field mixing and dilution of the effluent within 200 m of the outfall was performed using a 3D CORMIX model. The CORMIX model was built for the Alt-C and Alt-D locations and where 1-port, 3-port and 6-port diffusers for the discharge of the effluent at the outfall were modelled and evaluated. Diffuser variables were iteratively adjusted during the design process to obtain maximum predicted dilution of the treated effluent. The preferred diffuser design was six ports, with each port having a 0.2 m opening, horizontal angle of 45˚ and vertical angle of 20˚. The recommended spacing between ports is 25 m.

The mixing zone for the discharged effluent was defined as the 100-m distance from the outfall pipe as per the Canadian Council of Ministers of the Environment (CCME) guidelines. The plume from the diffuser with six ports at Alt-D reaches the surface water at about 90 m from the diffuser.

The dilution ratio in the receiving environment at Alt-D is 36 times at 5 m from the port and 109 times at the end of the mixing zone (i.e., at 100 m). The conservative proposed discharge at the maximum daily effluent flow rate and exaggerated quality for adsorbable organic halides (AOX), total nitrogen (TN), total phosphorus (TP), colour, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), water temperature, dissolved oxygen (DO) and pH are anticipated to meet compliance at the end of the mixing zone for applicable federal water quality guidelines.

The selection of the preferred outfall option (i.e., the Alt-D discharge location in the Northumberland Strait) and for the effluent pipeline will require geotechnical information related to existing harbour soils, civil engineering related to hydraulics and conveyance of the wastewater treatment plant effluent flows to the point of discharge, and marine civil engineering support in the identification of measures to be employed for pipe stabilizations. Preliminary engineering considerations for the outfall pipe and diffuser are presented in this study. The hydraulics and pipe characteristics for the conveyance of the effluent to the Alt-D outfall location were also investigated.

Abbreviations

AOX	Adsorbable Organic Halides
AST	Atlantic Standard Time
BOD	Biochemical Oxygen Demand
CCME	Canadian Council of Ministers of the Environment
CD	chart datum
CHS	Canadian Hydrographic Services
COD	Chemical Oxygen Demand
CORMIX	Cornell Mixing Zone Expert System
DFO	Fisheries and Oceans Canada
DO	Dissolved Oxygen
ECCC	Environment and Climate Change Canada
GD	geodetic datum
HD	Hydrodynamic module
HHWLT	higher high water large tide
LAT	lowest astronomical tide
LNT	lowest normal tide
LLWLT	lower low water large tide
MWL	mean water level
NAD	North American Datum
psu	practical salinity unit
PT	Particle Tracking module
RWQO	Receiving Water Quality Objective
TCU	True Colour Units
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorus
TS	Temperature/Salinity module
TSS	Total Suspended Solids
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
WQG	Water Quality Guideline

1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

Northern Pulp Nova Scotia (NPNS)'s kraft mill located on Abercrombie Point in the town of New Glasgow, Nova Scotia has been in operation since 1967. The mill produces bleached kraft market pulp at a rate of 280,000 to 300,000 air-dry tonnes per year (ADt/y).

The mill's process effluent is treated currently in the wastewater treatment plant located in the western portion of an area known as Boat Harbour, about 3.5 km east of the mill across the East River. The treatment system consists of constructed sedimentation basins and a natural basin equipped with baffle curtains. A large, natural final polishing/stabilization basin follows prior to release to the Northumberland Strait through a weir in Boat Harbour.

As a result of the *Boat Harbour Act* that came into effect on May 11, 2015, the use of the present Boat Harbour treatment facility will be prohibited after January 30, 2020. This will require the mill to install a new wastewater treatment plant, including a new effluent outfall, prior to this deadline.

KSH Solution Inc. (KSH) has been mandated by NPNS, with the collaboration of the Nova Scotia Department of Transportation and Infrastructure Renewal, to evaluate the various processes available to treat the mill's effluent, assess the optimum organic and hydraulic loading, select an optimal effluent treatment process, and provide recommendations of the optimum outfall routing and point of discharge, using hydrodynamic modelling and to undertake a receiving water study.

Stantec Consulting Ltd. (Stantec) was retained by KSH Solution Inc. (KSH) to conduct hydrodynamic modelling and a preliminary receiving water study for Pictou Harbour to address the requirements of the new outfall pipeline. Four preliminary effluent discharge points were identified by KSH as:

- approximately 500 m from the mill and Causeway Outlet
- between 1 and 2 km from the mill towards the centre of Pictou Harbour
- approximately 6 km from the mill within Pictou Harbour
- approximately 9 km from the mill into the Northumberland Strait

It is possible that alternate discharge locations may be proposed, based on the results during the progress of this study.

This led to four alternative effluent discharge locations being retained and investigated based on preliminary assessments and discussions with KSH:

- Alt-A, located approximately 1 km from the mill and Causeway Outlet

- Alt-B, located approximately 3 km from the mill towards the centre of Pictou Harbour
- Alt-C, located approximately 9.5 km from the mill into the Northumberland Strait
- Alt-D, located approximately 10.0 km from the mill into the Northumberland Strait

1.2 OBJECTIVES

The key objective of the present receiving water study is to determine the optimum location among the identified options for the mill's outfall to discharge the effluent. The specific objectives of the study include:

- Conduct far-field hydrodynamic modelling using a MIKE 21 Coupled Model developed by the Danish Hydraulic Institute and provide recommendations for the preferred outfall location. MIKE 21 has capabilities to model the regional and local effluent dispersion characteristics in a tidal environment.
- Conduct near-field mixing modelling using a CORMIX (Cornell Mixing Zone Expert System) model to provide recommendations on preferred outfall design, including diffuser configuration and orientation, and to model water quality within the mixing zone.
- Provide a brief and preliminary description of the construction methodology for the effluent pipeline as well as to provide:
    - a civil engineering opinion related to hydraulics and conveyance of the wastewater treatment plant effluent flows to the point of discharge;
    - an opinion on the geotechnical information related to existing harbour soils; and
    - structural engineering support in the identification of measures to be employed for pipe stabilizations including bedding and anchoring systems and for pipe protection from ice, waves and vessel navigation.

1.3 STUDY AREA

The study area encompasses Pictou Harbour and a part of the Northumberland Strait with complex ocean currents, tides, winds and river flows. The study area corresponds to the hydrodynamic model domain and it was selected large enough to eliminate model boundary effects. The size of the study area was based on:

- The geographic extent of available bathymetry data sources;
- Location of available oceanographic information including the observed tides, currents, and winds; and
- The extent of potential hydrodynamic influences on hydrodynamics and effluent dispersion.

The study area (***Figure 1-1***) comprised an area of 46 km x 42.5 km (***Table 1-1***), encompassing the surrounding waters of the estuary of East River, Pictou Harbour, Pictou Road, Boat Harbour, and offshore into the Northumberland Strait.

Boat Harbour is currently separated from Pictou Road by a dam. However, for modelling purposes, a future scenario for Boat Harbour that is re-introduced to tidal influence was incorporated and for the assessment of the potential discharge locations. In this future scenario, Boat Harbour was assumed connected to Pictou Road through a navigation channel as proposed by Jacques Whitford Environment Limited (JWEL, 2005). As per the proposed channel with bridge design for Highway 348 and Boat Harbour returned to a tidal estuary, the navigation channel was assumed to be 2.55 m deep with a bottom width of 10 m and side slopes of 3H:1V.

Table 1-1 Coordinates of the Study Area

Vertex	Coordinates (UTM NAD83 Zone 20)	
	Easting (m)	Northing (m)
Southwest (SW)	519000	5052000
Northwest (NW)	519000	5094500
Northeast (NE)	565000	5094500
Southeast (SE)	565000	5052000

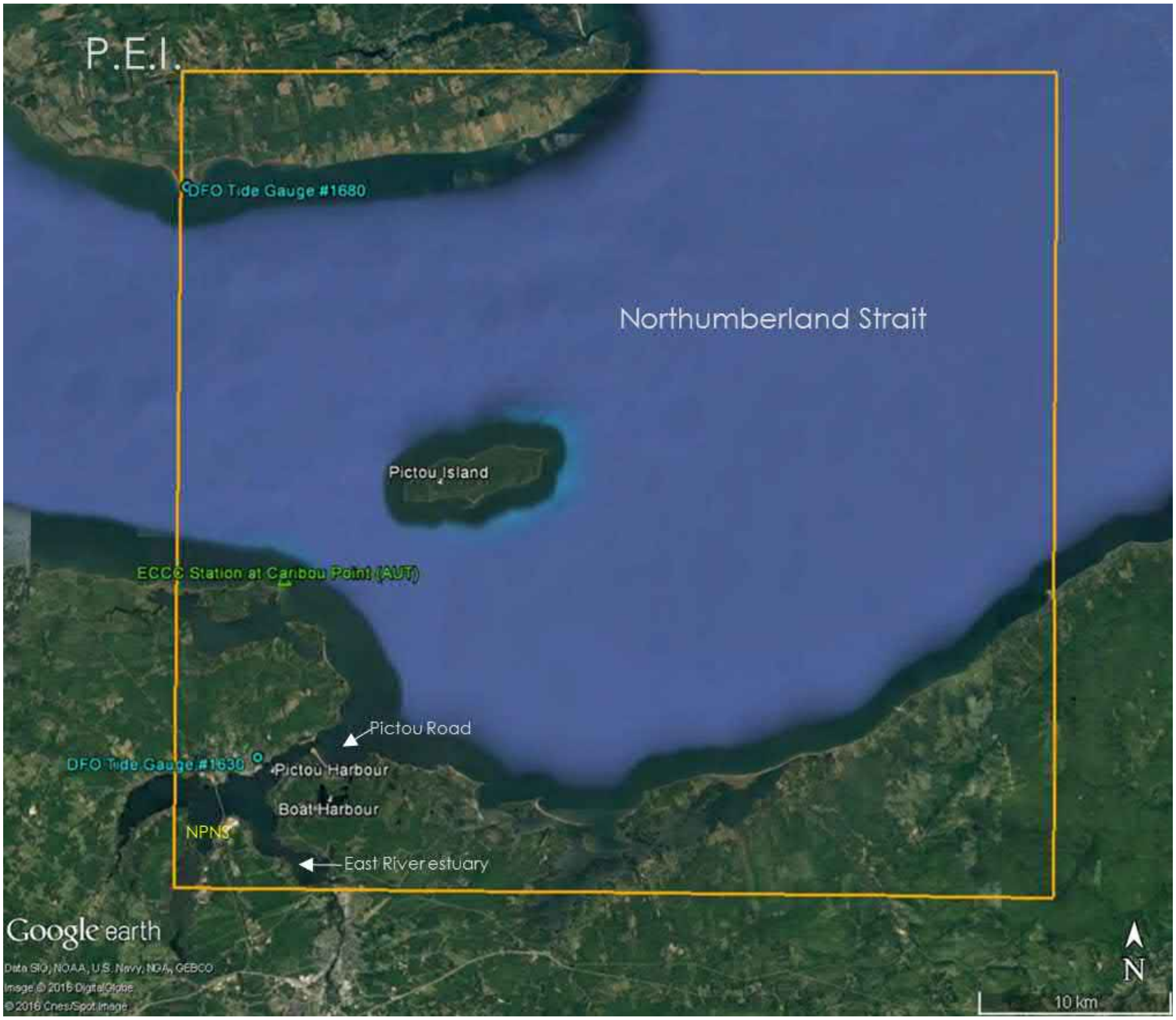


Figure 1-1 **Study Area**

2.0 FAR-FIELD MODELLING

2.1 BACKGROUND

As part of the modelling work, a two-dimensional (2D) model was used to simulate far-field effluent dispersion at the potential discharge locations Alt-A, Alt-B, Alt-C and Alt-D and to provide indications of the potential cumulative effects on sensitive marine habitat and areas of important socio-economic value.

A recommended modelling practice for receiving water studies is to simulate the dispersion behavior in the coastal hydrodynamic environments using a combined modelling approach of a 2D coastal hydrodynamic model for far-field mixing and a CORMIX model for near-field mixing. Based on Stantec's experience associated with marine water quality modelling and Environmental Impact Assessment (EIA) studies, a suitable 2D modelling tool for meeting the objectives of this study is the MIKE 21 model, which is a globally-recognized modelling tool for coastal and estuarine environmental processes.

2.1.1 MIKE 21 Coupled Model

The Danish Hydraulic Institute MIKE 21 Coupled Model was applied to simulate various aspects of the integrated hydrodynamic processes of tidal circulations, wind climates, river discharges, outfall discharge, and density currents to predict the changes of key water quality parameters in Pictou Harbour. The MIKE 21 Coupled Model consists of a Hydrodynamic Module (HD), a Temperature/Salinity Module (TS), and a Particle Tracking Module (PT). Descriptions of these computational modules used in the current study are provided below.

- The MIKE 21 Hydrodynamic Module (HD) — simulates unsteady flow taking into account density variations, bathymetry, and external forcings in rivers, lakes, estuaries and coastal areas. The model solves the continuity, momentum, temperature, salinity, and density equations. Water density varies with temperature and salinity. The HD Module is the basic computational component of the modelling system. The HD module was used to simulate reciprocal interactions among currents and effluent dispersion by coupling with the other modules.
- The MIKE 21 Temperature and Salinity (TS) Module — invoked in the HD Module via specification of the density. The TS module activates additional transport equations for temperature and salinity. The calculated temperature and salinity are fed back to the hydrodynamic equations through buoyancy forcing induced by density gradients.
- The MIKE 21 Particle Tracking (PT) Module — simulates transport and fate of dissolved and suspended substances.

The MIKE 21 Coupled Model is implemented using a flexible mesh, which divides the aquatic domain into discrete cells of finite volume, within which flow and transport equations are independently calculated. Specifically, in the horizontal plane, an unstructured grid is used, comprised of triangular and quadrilateral elements. A domain flexible mesh system was generated with horizontal mesh sizes varying from kilometres to metres wide. Mesh size reflected the shoreline, water depth variation (bathymetry), and harbour infrastructure configuration features. Generally, finer mesh sizes were used in the more complex nearshore areas.

The model was firstly calibrated using available hydrographic data from historical field measurements of water levels and currents in the study area, and then applied to the effluent discharge scenarios. Key objectives of this 2D modelling include:

- to understand the hydrodynamics and current circulation patterns in the study area;
- to characterize the dispersion patterns, extent and dilution factors of the discharged effluent;
- to compare effluent dispersion from the four proposed outfall locations; and
- to provide hydrodynamic information required for CORMIX near-field dispersion modelling.

2.1.2 Physical Oceanography

2.1.2.1 Data Sources

Physical oceanographic and hydrometric data were collected, reviewed, and processed to provide inputs to and calibrate the hydrodynamic model. The existing available data sources are identified in ***Table 2-1*** and their locations are shown in ***Figure 1-1***. The modelling simulations were conducted in a time domain using time-series data records with overlapping periods of time, and sufficient resolution and quality to meet the model requirements.

Even though some oceanographic and hydrometric data are 20 to 30 years old, it is reasonable to believe that the amplitude and direction of tides and currents did not appreciably change to affect the results of this study. Similarly, ocean water temperature and salinity are relatively constant characteristics and are unlikely to have significantly changed over the past 30 years. Since catchment areas and hydraulic regime of the East and Middle Rivers were not substantially changed in the last 20 years, it is expected that the average flow rates derived by ENSR (1999) are still relevant and can be used in this study.

Table 2-1 Existing Available Oceanographic and Hydrometric Data

Parameter	Data Sources
Seabed bathymetry	• Canadian Hydrographic Services (CHS) bathymetric survey in 2015 – 2016 (provided by DFO) • CHS nautical charts (4404, 4437, 4443 and 4445) • Boat Harbour bathymetric survey conducted by Canadian Seabed Research Ltd. in June 2006 • Bathymetric and topographic survey in the East River conducted by Canadian Seabed Research Ltd. in 2009
Tides and currents	• DFO Canadian Tides and Water Levels Data Archive (DFO no date (n.d.)) • Historical current measurements conducted by DFO for the period from February 22 to May 2, 1990 (DFO Ocean Data Inventory and Coastal Time Series database (DFO n.d.)
Winds	• Environment and Climate Change Canada (ECCC) Climate Archive for station Caribou Point (AUT), NS
Marine water temperature and salinity	• Previous studies (ENSR, 1999)
River discharge	• Previous studies (ENSR, 1999)

2.1.2.2 Bathymetry

The seabed elevations for the study area were obtained from various data sources as summarized in ***Table 2-1***. A combined bathymetry, with horizontal resolutions varying from 5 to 10 m in Pictou Harbour and Pictou Road areas, to 50 m in offshore open water in the Northumberland Strait, was developed for use for the present hydrodynamic modelling study.

At the present time, Boat Harbour is separated from Pictou Road by a dam. However, for the purposes of modelling the future scenario when Boat Harbour is connected to Pictou Road and returned to a tidal estuary, a navigation channel was incorporated. The bathymetry of the navigation channel connecting Boat Harbour and the Pictou Road area of the Northumberland Strait was generated in the model using the conceptual channel and bridge design for Highway 348 design proposed by Jacques Whitford Environment Limited (JWEL, 2005). The connecting channel was assumed to be 2.55 m deep with a bottom width of 10 m and side slopes of 3H:1V. These dimensions were assumed to accommodate the navigation of a Cape Island-style fishing vessel with a draft of 1.5 m.

Figure 2-1 presents the extent of bathymetry information used in the model which includes nautical charts, bathymetric surveys and the proposed channel from Boat Harbour to Pictou Road.

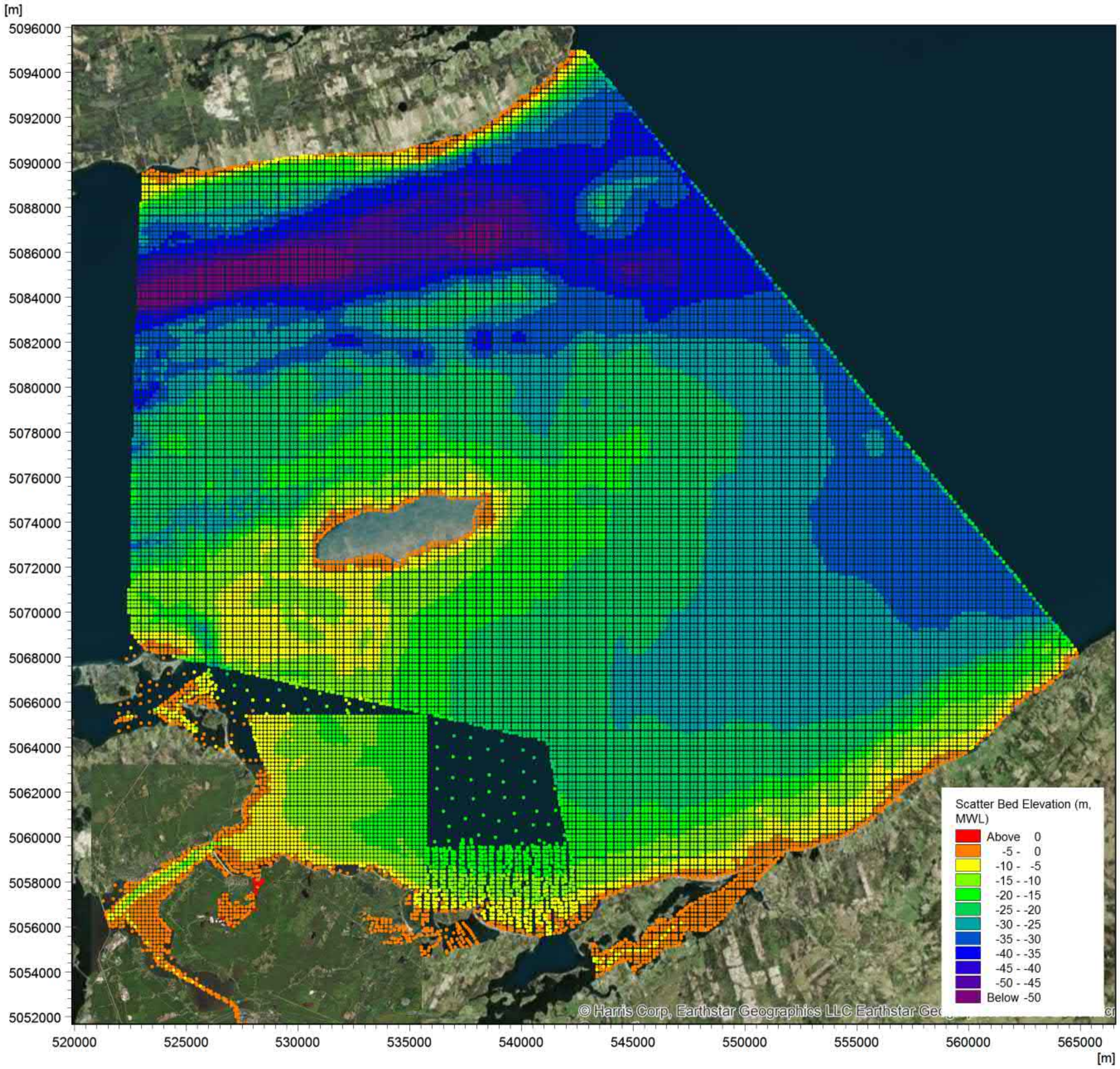


Figure 2-1 Available Bathymetric Data and Extent Covering the Study Area

2.1.2.3 Water Levels

Tides in the Pictou Harbour area are mixed by two dominant tidal components; a semi-diurnal (twice daily) component and a diurnal (daily) component (ENSR, 1999). The combination of semi-diurnal and diurnal tidal components results in the "mixed" tides in which relatively larger and smaller tides occur alternatively over time with successive highs and lows of unequal heights. The tides also have a bi-weekly spring-neap tide cycle in which the spring tidal ranges are about double those of neap tides.

Water levels due to astronomical tides are available from the Canadian Hydrographic Service (CHS), Fisheries and Ocean Canada (DFO). The tidal levels at Pictou Harbour are summarized in ***Table 2-2***. The tidal range is 2.11 m between the Highest Astronomical Tide (HAT) and the Lowest Astronomical Tide (LAT). Chart Datum (CD), defined as the Lowest Normal Tide (LNT), is 1.19 m below the Mean Water Level (MWL).

Table 2-2 Tide Levels at Pictou Harbour

Tides	Water Level above Chart Datum (m, CD)	Water Level above Mean Water Level (m, MWL)
Highest Astronomical Tide (HAT)	2.10	0.91
Higher High Water, Large Tide (HHWLT)	2.06	0.87
Higher High Water, Mean Tide (HHWMT)	1.72	0.53
Mean Water Level (MWL)	1.19	0.00
Lower Low Water, Mean Tide (LLWMT)	0.50	-0.69
Lower Low Water, Large Tide (LLWLT)	0.06	-1.13
Lowest Astronomical Tide (LAT)	-0.01	-1.20

The CHS maintains tidal stations and publishes historical water-level measurements (DFO website http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/twl-mne/inventory-inventaire/index-eng.htm). ***Table 2-3*** presents the available tidal data at the CHS stations located within the Project study area (***Figure 1-1***). The data were used for tidal analysis, prediction of tidal levels at the boundaries of the hydrodynamic models, and model calibration.

Table 2-3 CHS Stations and Available Tidal Records in the Study Area

Station Name	Station #	Coordinates		Available Data Records
		Easting (m)	Northing (m)	
Pictou Harbour, NS	1630	523361.00	5058908.00	1957/01/01 to 1996/03/11
Wood Islands, PEI	1680	519375.51	5088522.56	2004/03/ 01 to 2006/12/31

2.1.2.4 Wind Climate

Wind data near the Project site were available from the National Climate Data and Information Archive, Environment and Climate Change Canada (ECCC). The Caribou Point (AUT) climate station of ECCC is located approximately 10 km north of Pictou Harbour (***Figure 1-1***) with the available wind data records shown in ***Table 2-4***. This station was selected because it has a long period of wind records and located within the model domain. The hourly wind rose plot within the record period from 1994 to 2016 is presented in ***Figure 2-2***, which indicates that the wind climate in the study area is dominated by winds from the northwest and west. The recorded maximum wind speed was 95 km/hr (26.4 m/s) on March 7, 1997, with a wind direction from the northwest (320°). ***Figure 2-3*** illustrates a typical yearly wind variation pattern; stormy during the winter season and calm during the summer season.

Table 2-4 Environment and Climate Change Canada Climate Station and Available Wind Records in the Vicinity of Pictou Harbour, NS

Station Name	Station ID	Coordinates		Available Data Records (hourly)
		Easting (m)	Northing (m)	
Caribou Point (AUT)	8200774	524623.09	5068171.84	from 1994/01 to 2016/12 (measured elevation: 2.4m)

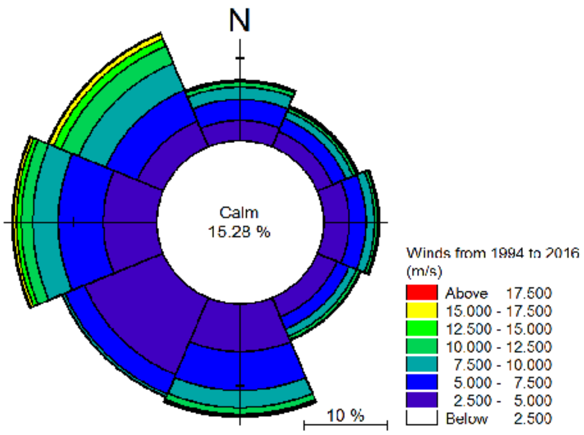


Figure 2-2 Wind Rose Plot at ECCC Station Caribou Point (AUT) for the Period from 1994/01 to 2016/12

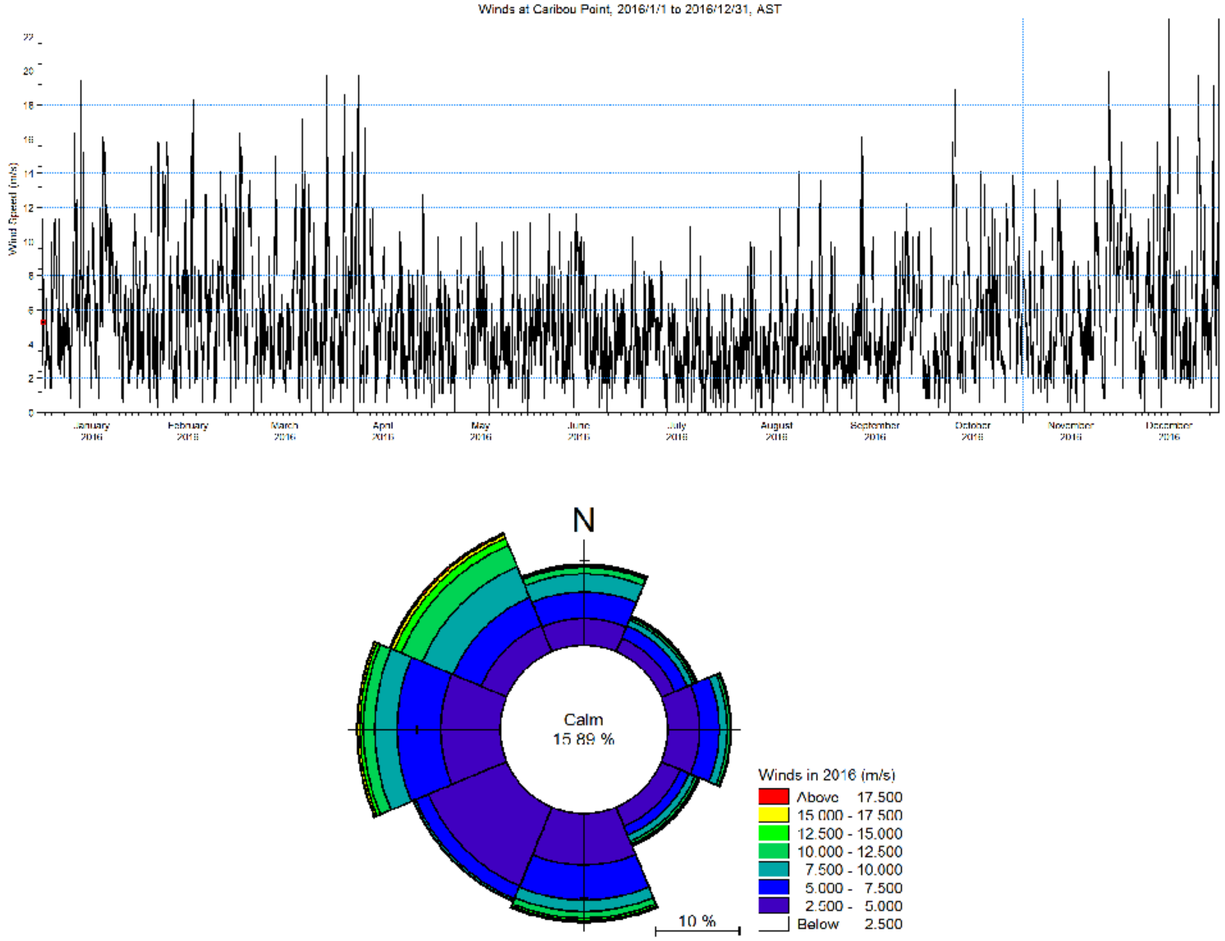


Figure 2-3 **Hourly Wind Records at ECCC Station Caribou Point (AUT) in 2016**

2.1.2.5 Currents

Aanderaa current meters were deployed by DFO in Pictou Harbour to measure the circulation currents (***Table 2-5***) for a period from February 22 to May 2, 1990. Current speeds and current directions in a 15-minute interval were provided by DFO (Ocean Data Inventory and Coastal Time Series database). ***Figure 2-4*** provides an example of the measured currents at Pictou Current #1 location in the harbour, where the currents moved predominantly towards the northeast and southwest directions. The water current statistics indicate that the minimum, mean, and maximum current speeds during the recording period were 0.01, 0.09, and 0.26 m/s respectively, and for about 30% of time the current speeds were less than 0.05 m/s. Currents at the Pictou Current #2 station, located also in Pictou Harbour but more northeast to station #1, were similar in direction but generally higher in magnitude during the same recording period with a minimum, mean, and maximum current speeds of 0.01, 0.19, and 0.63 m/s, respectively.

These above-noted data sets for bathymetry, water level, wind, and currents were used to calibrate the hydrodynamic model.

Table 2-5 DFO Current Measurements in Pictou Harbour

Deployment [1]	**Approx. Location**		**Approx. Depth** [2] (m)	**Period of Measurement** [3]
	Easting (m)	Northing (m)		
Pictou Current #1	522807.72	5057113.90	19	1990/02/22 to 1990/04/26
Pictou Current #2	525604.19	5059013.49	9.5	1990/03/06 to 1990/05/02

NOTES:

[1] Current meter locations are shown in ***Figure 2-7***

[2] Vertical reference is unknown

[3] Date and time in original data provided are in Coordinated Universal Time (UTC)

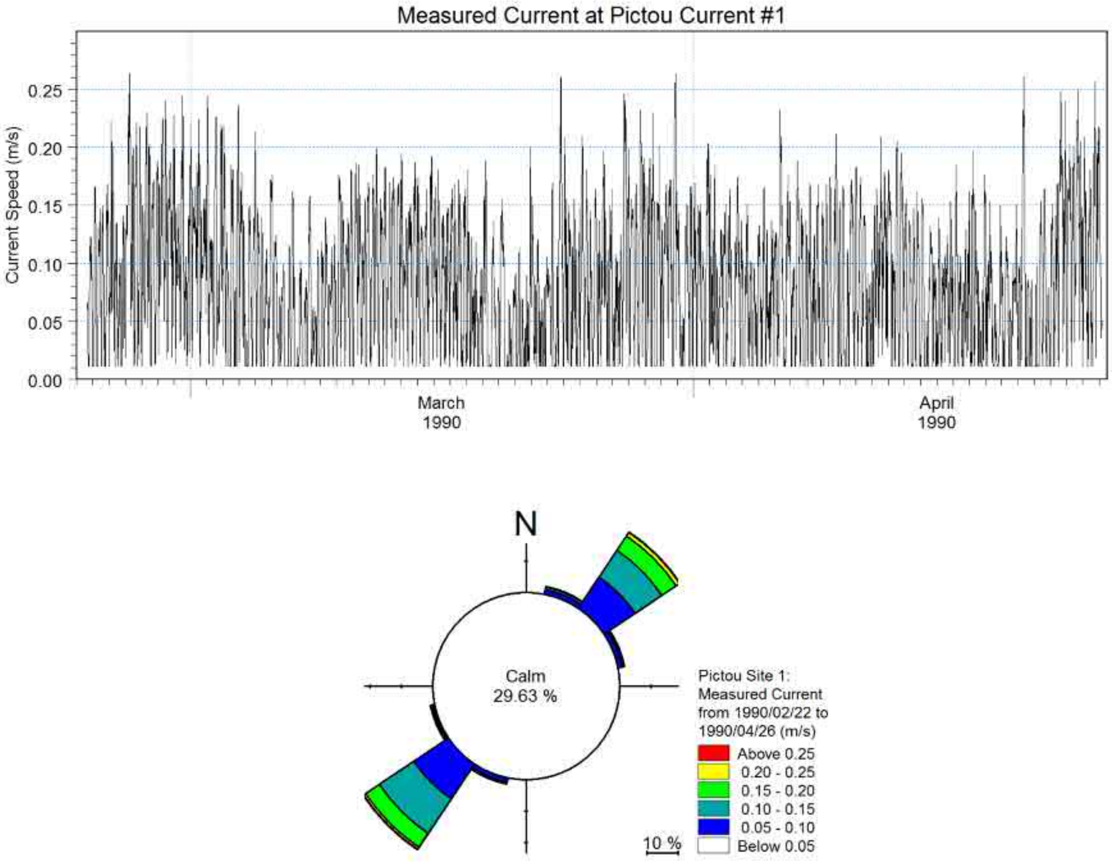


Figure 2-4 Measured Currents by DFO at Pictou Current #1 Location in Pictou Harbour (1990/02/22 to 1990/04/26)

2.1.2.6 Temperature and Salinity

ENSR (1999) conducted a detailed review on the water quality parameters in Pictou Harbour and surrounding areas, based on previous investigations and studies. The characteristics of water temperature and salinity are summarized below from the ENSR (1999) report as well as other sources as follows:

- Pictou Road
    - Salinity and temperature were measured in Pictou Road in July 1995 (JWEL, 1996). In the study area in Pictou Road off of Boat Harbour, salinity ranged from 23.7 practical salinity units (psu) at the surface to 31.2 psu at the bottom, and temperature was 14.0°C at the surface and 13.5°C at the bottom.
    - Salinity and temperature were measured in Pictou Road in December 1998 (ENSR, 1999). Salinity ranged from 25.5 psu to 27.5 psu, and temperature ranged from 2°C to 4°C. Salinity and temperature in Pictou Road was relatively uniform both vertically and spatially with little variation throughout the tidal cycle.
- Pictou Harbour
    - Surface water salinity in the harbour from the JWEL 1996 study generally was greater than 25 psu, but it varies with the tidal cycle. Peak salinity of 28 to 29 psu was recorded at high tide while lower salinity values were observed during low tides.
    - Salinity and temperature were measured in Pictou Harbour in December 1998 (ENSR, 1999). Salinity ranged from 23.5 psu to 27.5 psu, and water temperature ranged from 1°C to 3.5°C. Typically, during ebb and flood tides, the water column was not stratified, and during some slack water events the water column was slightly stratified.
- East River near Trenton
    - Depending on the degree of freshwater flow, salinity at the surface in the East River varied from 20 psu at low freshwater flow to 5 psu at high freshwater flow (ENSR, 1999).

2.1.2.7 East River Discharge

The East River does not have a hydrometric station or hydrological gauge to measure water levels and flows. A common practice to find a flow in ungauged catchments is to transpose flows (using catchment areas and exponential relationships) from the neighbouring gauged catchments. This technique was used in ENSR (1999) and RV Anderson (2015) to derive flows in the lower portion of the East River and Middle River, respectively, based on flows measured at the ECCC hydrometric station 01DP004 on the Middle River of Pictou at Rocklin (approximately 14.5 km southwest of New Glasgow). ENSR (1999), therefore, estimated the East River inflow based on the measured flows in the Middle River (at the Rocklin hydrometric station). The estimated average monthly flows in the East River for 1998 indicated that the flow rate was high in spring (15.47 m^3/s in March) and low in summer (1.64 m^3/s in July).

The Middle River and West River are separated from Pictou Harbour by a causeway. The tides do not have an impact on the flows in the Middle and West Rivers. Relatively low river flow passes through the spillway structure of the causeway on Highway 106; this flow does not substantially affect the hydrodynamic regime of Pictou Harbour, which is mostly governed by tides. As a conservative assumption and for modelling purposes, the causeway was assumed a no-flow boundary and flow from the Middle and West Rivers was not incorporated into the MIKE 21 model.

2.1.3 Effluent Characteristics

Characteristics of the expected treated effluent from the NPNS mill from the new wastewater treatment plant were provided by KSH (KSH, 2016) as summarized in ***Table 2-6***. The total dissolved solids (TDS) concentration for the effluent was estimated to be in the conservative range of 1,000 mg/L to 4,000 mg/L (KSH, pers. comm. 2017). Six effluent samples analyzed by Maxxam in May of 2017 showed that TDS in the effluent varied from 1,200 to 1,500 mg/L. A conservative TDS concentration of 4,000 mg/L was used for modeling purposes. TDS was used to estimate effluent density.

Table 2-6 Expected Treated Effluent Quality

Item	Unit	Parameter Value	
		Monthly average	Daily maximum
Adsorbable Organic Halides (AOX)	mg/L	3.9	7.8
Total Nitrogen (TN)	mg/L	3.0	3.0
Total Phosphorus (TP)	mg/L	1.5	1.5
Colour	TCU	750	750
Chemical Oxygen Demand (COD)	mg/L	480	725
Biochemical Oxygen Demand (BOD_5)	mg/L	24	48
Total Suspended Solids (TSS)	mg/L	24	48
Dissolved Oxygen	mg/L	Greater than 1.5	
pH	-	7.0 to 8.5	
Flow Rate	m^3/d	62,000 (annual average) 85,000 (daily maximum)	
Temperature	°C	25 (winter) to 37 (summer)	

2.2 MODELLING AND CALIBRATION

2.2.1 Approach and Model Setup

Water levels and currents with environmental forcings of tides, winds, and river discharges in the model domain of the study area were simulated using the integrated MIKE 21 hydrodynamic model. A model mesh system was developed using a range of mesh sizes, varying from coarse mesh offshore to fine resolution of elements in the Pictou Harbour areas. The model was calibrated using historical measurements to allow for appropriate offshore boundary conditions and domain forcings that established the modelling basis of the effluent transport from the locations of the outfall discharges investigated.

In the following modelling, the datum and time references were standardized for consistency. Horizontal datum is referenced to North America Datum of 1983 (NAD83) UTM Zone 20. Vertical datum is referenced to Mean Water Level (MWL). Time is Referenced to Atlantic Standard Time (AST; AST = Coordinated Universal Time (UTC) – 4).

Figure 1-1 illustrates the defined model domain, which covers 46 km ranging from 519,000 m to 565,000 m in the easting and 42.5 km ranging from 5,052,000 m to 5,094,500 m in the northing, including the Northumberland Strait, Pictou Road, Boat Harbour, Pictou Harbour and the East River estuary. The portion of Pictou Harbour west of the causeway on Highway 106 was not included in the model domain as the causeway is practically a no-flow boundary. Only little flow passes through the spillway structure in the causeway, which is not likely to impact the hydrodynamic regime of Pictou Harbour that is governed mostly by the tides.

A well-structured model bathymetry and generated mesh system is essential for obtaining reliable modelling results, especially in the shallower waters near the coast and in the Pictou Harbour areas. The elevation scatter points from CHS digital charts and field bathymetric surveys, together with a high-resolution aerial photo, were used to develop the seabed bathymetry and shoreline features. ***Figure 2-5*** presents the generated flexible mesh system (which contains 8,616 nodes and 15,872 elements) and seabed bathymetry. The mesh density of the computational domain generally increases from offshore to near-shore, and finer mesh was produced in the vicinity of the estuary, shorelines, channels, and harbour areas.

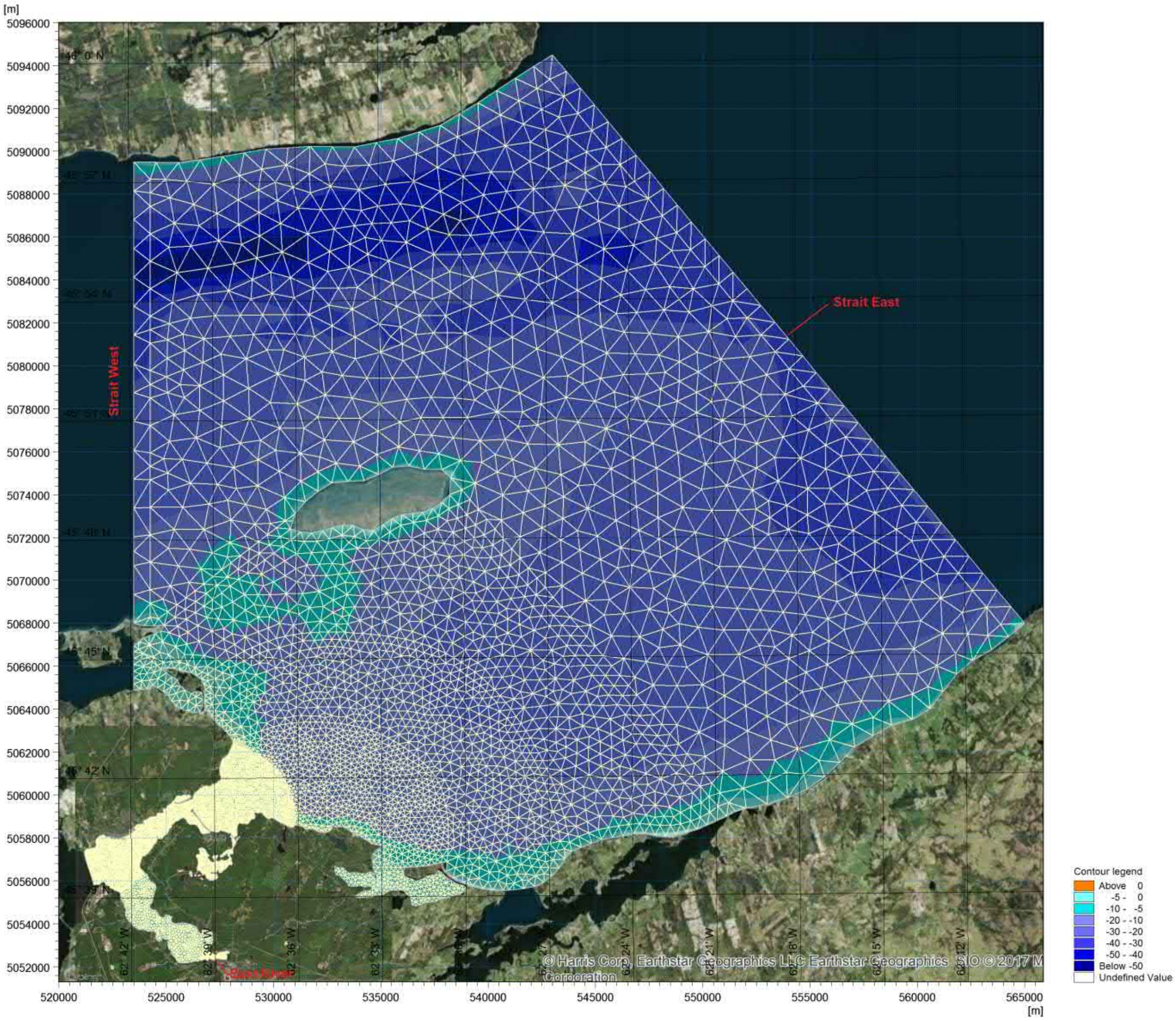


Figure 2-5 Computational Domain, Mesh System, and Boundaries

The model domain was established with the following open boundaries:

- Coastal Shoreline Boundary - the shoreline boundary was defined as solid, with no water current transmission.
- Offshore the Northumberland Strait Boundaries - these boundaries were set to allow for sufficient space for water current circulation between the Northumberland Strait and the Pictou Harbour water bodies. The boundary conditions were predicted tide levels, and the water temperature and salinity assumed were based on a literature review. All these parameters were applied as constant values along the model boundary and varied in time.
- East River Boundary - this boundary was set at the furthest extent of the available bathymetric data at the river mouth. The boundary conditions were given by assumed river discharges, water temperature and salinity.

Forcings over the model domain are defined as follows:

- Wind forcing - hourly wind records (wind speed and direction) at the ECCC Caribou Point (AUT) station were used. Wind parameters were applied as constant values in the domain and varied in time.
- Bed resistance - Manning's roughness, related to seabed roughness, is applied and varied in the domain. The roughness was a calibration parameter.
- Water density - water density is applied as a function of temperature and salinity and calculated in the Temperature/Salinity (TS) Module, varying in time and domain.
- Coriolis forcing - Coriolis forcing is included in the modelling and varied in the domain.

2.2.2 Tide Constituents

To provide appropriate tide level prediction at the model offshore boundaries in the Northumberland Strait, a tidal constituent analysis was conducted. This analysis was based on the historical tide gauge measurements at DFO's Wood Islands station (***Table 2-3***) from which the hourly data for a five-month period from 2004/04/01 to 2004/09/01 were used.

These observation data were originally recorded hourly in the AST time zone and with a vertical datum (CD). To compare with the tidal predictions, measured water levels were converted from CD to MWL. Verification plots of measured versus predicted water levels are presented in ***Figure 2-6***, and their statistics are provided in ***Table 2-7***. Good agreement between the measured and predicted water levels are achieved in terms of both the magnitude and phase of tidal cycles including all the spring and neap tides, noting that slight discrepancies may be attributed to measurement errors, meteorological effects not included in the tide prediction or not including minor tidal constituents. The analyzed major tide constituents (***Table 2-8***) are used for the prediction of tidal levels in the following hydrodynamic modelling.

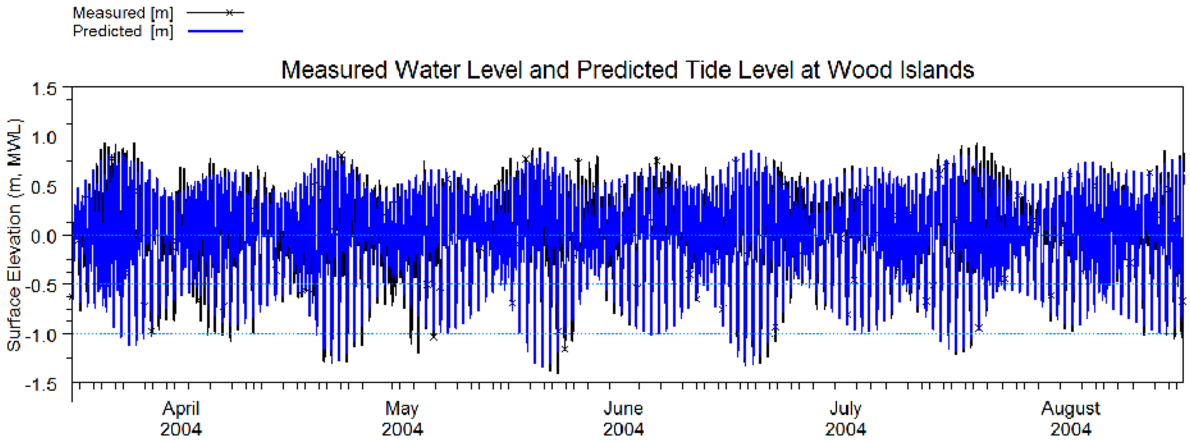


Figure 2-6 Comparison of Measured and Predicted Water Levels at DFO's Wood Islands Station

Table 2-7 Summary Statistics of Tide Levels (m, MWL) at DFO's Wood Islands Station

	Minimum	Maximum	Mean	Standard Dev.
Measured	-1.415	0.935	0.001	0.475
Simulated	-1.345	0.854	0.000	0.460

Table 2-8 Analyzed Tide Constituents at Wood Islands, PEI

Constituents	Amplitude (m)	Phase (deg.)
M2	0.5325	-75.94
S2	0.1265	-17.95
K1	0.2234	-100.72
O1	0.2038	-127.43
F4	0.0502	99.35
F6	0.0302	0.59

2.2.3 Model Calibration

The hydrodynamic components required for calibration are tide levels and currents. Using the historical records described in ***Table 2-3*** for water levels and in ***Table 2-5*** for currents, and considering available overlapped data with minimum data gaps, a one-month simulation period in April 1990 was selected as the calibration and validation scenario for tide and current circulation modelling. Key parameters in the hydrodynamic model were calibrated through a systematic process:

- The time step for the simulation typically needs to be selected to satisfy the criterion for numerical stability ($Cn < 1$, where Cn is Courant number). The simulation time depends not only on the number of nodes in the mesh but also the resulting Courant numbers. Sensitivity model runs were conducted with various time steps from 30 to 1200 seconds to determine the effect on model stability and accuracy. A time step of 60 seconds was then chosen for all model runs.
- The bed resistance value was varied from 20 to 50 $m^{1/3}/s$ in the model domain.
- The eddy viscosity value can be from 0.28 to 1.00 m^2/s. The default setting for the eddy viscosity is a coefficient of 0.28 and no adjustments to the default value were required to obtain agreement between predicted and field measurements.
- Simulated water levels were compared with DFO tide gauge measurements at Pictou station (#1630) (refer to ***Figure 2-7*** for tide measurement location).
- Simulated currents were compared with DFO current measurements in Pictou Harbour (refer to ***Figure 2-7*** for current measurement locations).
- Due to lack of the simultaneous records of wind and river discharge during the period of model calibration in April 1990, wind forcing in the domain and river inflows from the East River were not included in the model calibration exercise. Absence of these data did not impact the calibration, the results are still satisfactory. Wind forcing was incorporated into the model for simulation the mixing zones for Alt-A, Alt-B, Alt-C and Alt-D.

Verification plots of measured water levels at the DFO Pictou station (#1630) and simulated water levels for April 1990 are presented in ***Figure 2-8***, with their statistics summarized in ***Table 2-9***. Good agreement between measured and modelled simulation for water level is achieved in terms of both the magnitude and phase of tidal cycles including all the spring and neap tides, noting that slight discrepancies may be attributed to measuring accurracy, or some effects of minor tidal constituents, wind forcing and river discharge that were not included in the modelling.

Comparisons of measured and simulated current speeds in April 1990 at current measurement locations #1 and #2 are shown in ***Figure 2-9*** and in ***Table 2-10***. The simulated current values are depth-averaged as the result of the 2D model, but the information on the measured depths of the current meter deployments are not preciesly known. In general, simulated current magnitudes and phases captured well the variation of measured values through the tidal cycles from neap tide to spring tide. In general, good agreement is achieved between simulated and measured currents. Differences between the simulated and measured currents is considered to be due to the nature of stratified currents through the water column from surface to the seabed, as well as the difference in bathymetry between the existing condition and that in 1990. Even though the measured tides and currents are older than 20 years, it is reasonable to believe that the amplitude and direction of tides and currents influenced by primarily gravitational forces of the Sun and Moon are not likely to have appreciably changed if compared to more recent measurments and to affect the results for the model calibration. Therefore the measured 1990 data are still relevant for use in this study.

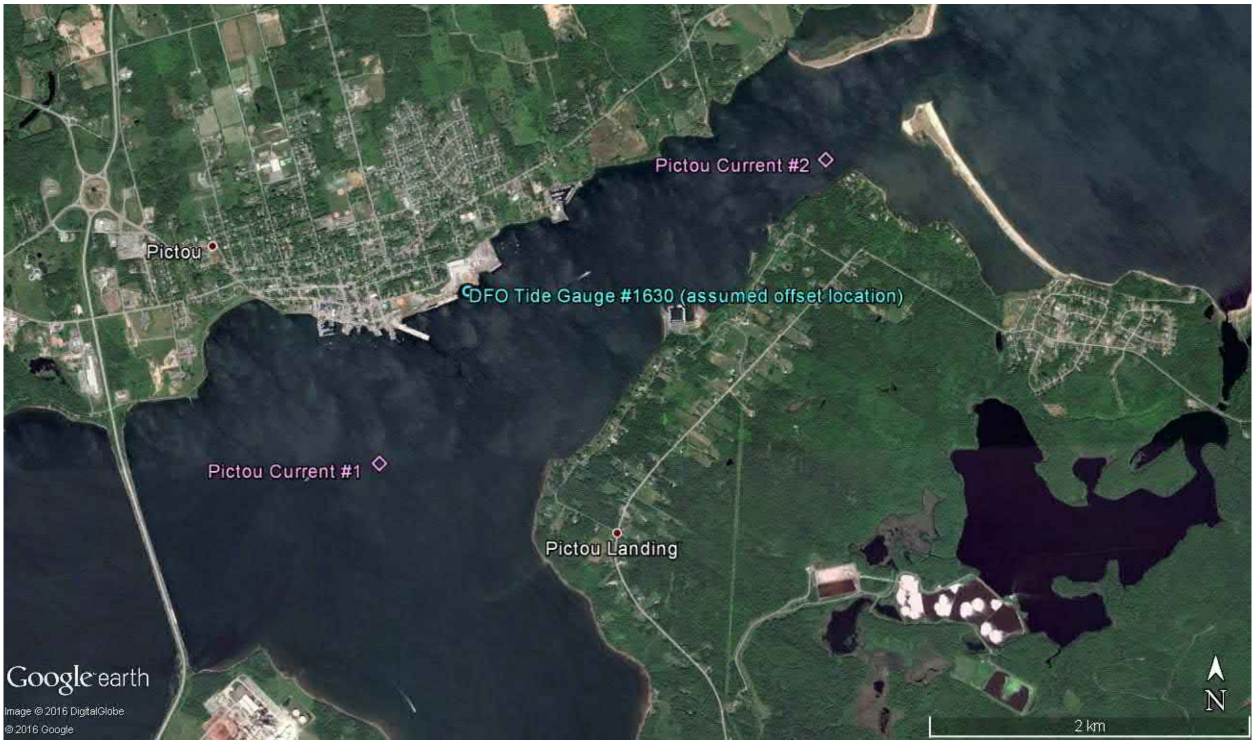


Figure 2-7 **Location Map of Historical DFO Water Level and Current Measurements in Pictou Harbour**

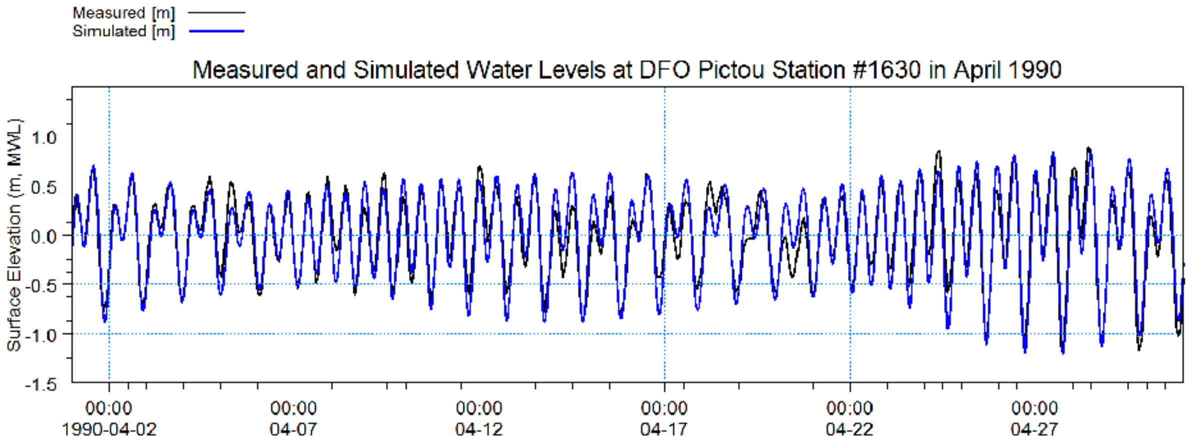


Figure 2-8 Measured and Simulated Water Levels at DFO Pictou Station (#1630)

Table 2-9 Statistics of Tide Levels (m, MWL) in April 1990 at DFO Pictou Station (#1630)

	Minimum	Maximum	Mean	Standard Dev.
Measured	-1.181	0.889	0.000	0.413
Simulated	-1.202	0.843	0.000	0.431

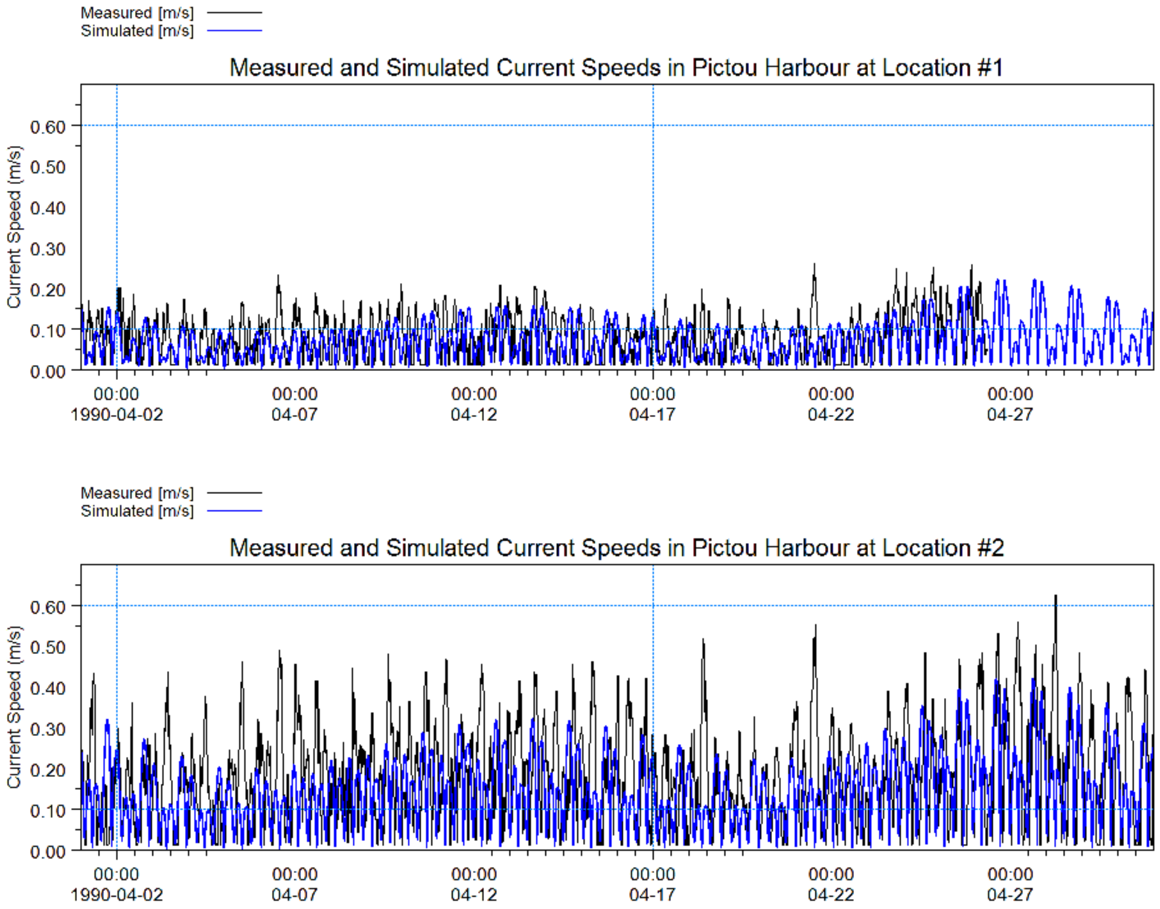


Figure 2-9 Measured and Simulated Current Speeds in April 1990 in Pictou Harbour

Table 2-10 Statistics of Current Speeds (m/s) in April 1990 in Pictou Harbour

Location		Minimum	Maximum	Mean	Standard Dev.
#1	Measured	0.011	0.261	0.082	0.054
	Simulated	0.004	0.254	0.084	0.050
#2	Measured	0.011	0.626	0.191	0.119
	Simulated	0.005	0.527	0.188	0.106

2.2.4 Modelling Conditions

2.2.4.1 Approaches

As presented previously, the objective for 2D modelling is to understand the hydrodynamic and effluent dispersion conditions in Pictou Harbour and surrounding areas, and to identify a preferred end-of-pipe outfall location from the proposed four options. This is to be achieved through further integrating a particle tracking (PT) module into the calibrated circulation (HD) module and carrying out the fully coupled hydrodynamic model for a one-month period of simulation time to characterize the circulation patterns, and indications of effluent transport in the harbour. The following approach and steps were undertaken:

- incorporating proposed outfall locations into the model;
- defining modelling scenarios and conditions;
- developing a fully coupled hydrodynamic model of currents (HD), temperature/salinity (TS) and particle tracking (PT) modules; and
- applying the model to the defined scenarios to investigate the dispersion features of the effluent at the alternative outfall discharge locations.

2.2.4.2 Alternative Outfall Locations

Proposed outfall locations are based on the following considerations:

- The outfall locations should not be located within or in the proximity of habitat sensitive areas as shown on the fishery sensitivity map in ***Figure 2-10*** and on the bird and shoreline sensitivity map in ***Figure 2-11***, or in proximity to socio-economic sensitivities identified on ***Figure 2-12***.
- The outfall locations should be located in a water depth of 10 m MWL or deeper to provide allowance for ship navigation and outfall pipe/diffuser structures.

The characterization of potential sensitivities of the discharge locations with respect to the environment (e.g., commercial, recreational and Aboriginal fishery species, fish migration species, spawning and nursery areas, species at risk and their habitats, and important wildlife areas) and socio-economics (e.g., recreational beaches, vessel navigation, commercial, recreational and Aboriginal fishing grounds, commercial harbours, marinas, and sewage marine outfalls) were either based on previous environmental impact assessments (EIAs) conducted for Boat Harbour (JWEL 1994, 2005), environmental effects monitoring investigations that describe resources for the area (Stantec, 2004; Ecometrix 2007, 2016), or obtained for this study. The latter included information on CHS Chart #4437 that was used to supplement socio-economic sensitivities (e.g., shipwrecks, navigation buoys and range lines, and submarine cables).

The environmental and socio-economic information on ***Figures 2-10*** to ***2-12*** guided the assessment and constraints analysis for the alternative options of the new effluent outfall location and pipeline routing in Pictou Harbour. Four alternative outfall locations inside and outside of Pictou Harbour were proposed (***Figure 2-13***) for effluent dispersion modelling and analysis.

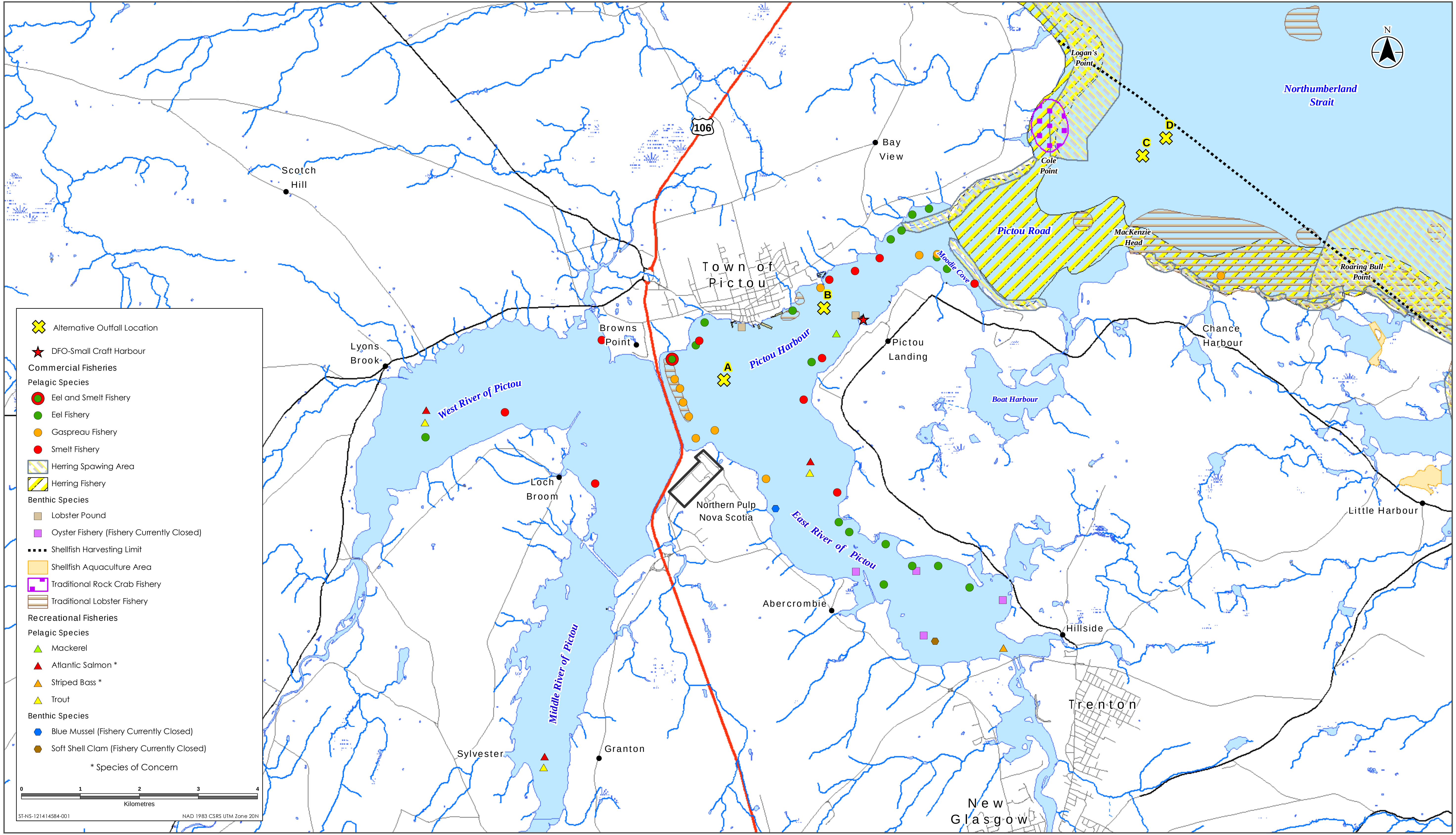
Alternative A (Alt-A):	Easting 522300 m, Northing 5057000 m, water depth 11.2 m MWL
Alternative B (Alt-B):	Easting 524000 m, Northing 5058220 m, water depth 10.8 m MWL
Alternative C (Alt-C):	Easting 529400 m, Northing 5060800 m, water depth 10.0 m MWL
Alternative D (Alt-D):	Easting 529800 m, Northing 5061100 m, water depth 11.3 m MWL

The alternative outfall locations Alt-A, Alt-B and Alt-C were identified before the modelling work was undertaken and using the criteria noted above for selecting these outfall locations. The location for the Alt-D outfall was identified during this study to improve on the effluent dispersion and after the modelling results for Alt-C were obtained. The criteria for selecting an outfall location were also used for Alt-D.

The potential outfall location initially proposed by KSH at approximately 500 m from the mill and outlet of the Pictou Causeway (HWY 106) was not considered further in this study for the following reasons:

- It was located in a shallow water in the range of 3 to 4 m. This depth range did not meet the criteria for preferred water depth for a discharge point for the effluent, including a likely reduced capacity for effluent mixing in the receiving environment at these depths.
- The presence of environmental sensitivities in the general vicinity of this location. These sensitivities include gaspereau fisheries and migratory bird habitat particularly in the winter (***Figures 2-10*** and ***2-11***), as well as recreational use.
- Relatively close in proximity to other wastewater discharges, such as the Town of Pictou wastewater treatment plant outfall.

V:\1214\active\121414584\03_data\gis_cad\geomatics\mapping\mxd\report\ST_NS-121414584-001_All_Fisheries.mxd krozalska



Sources: Government of Nova Scotia, Jacques Whitford and Stantec Consulting Ltd.

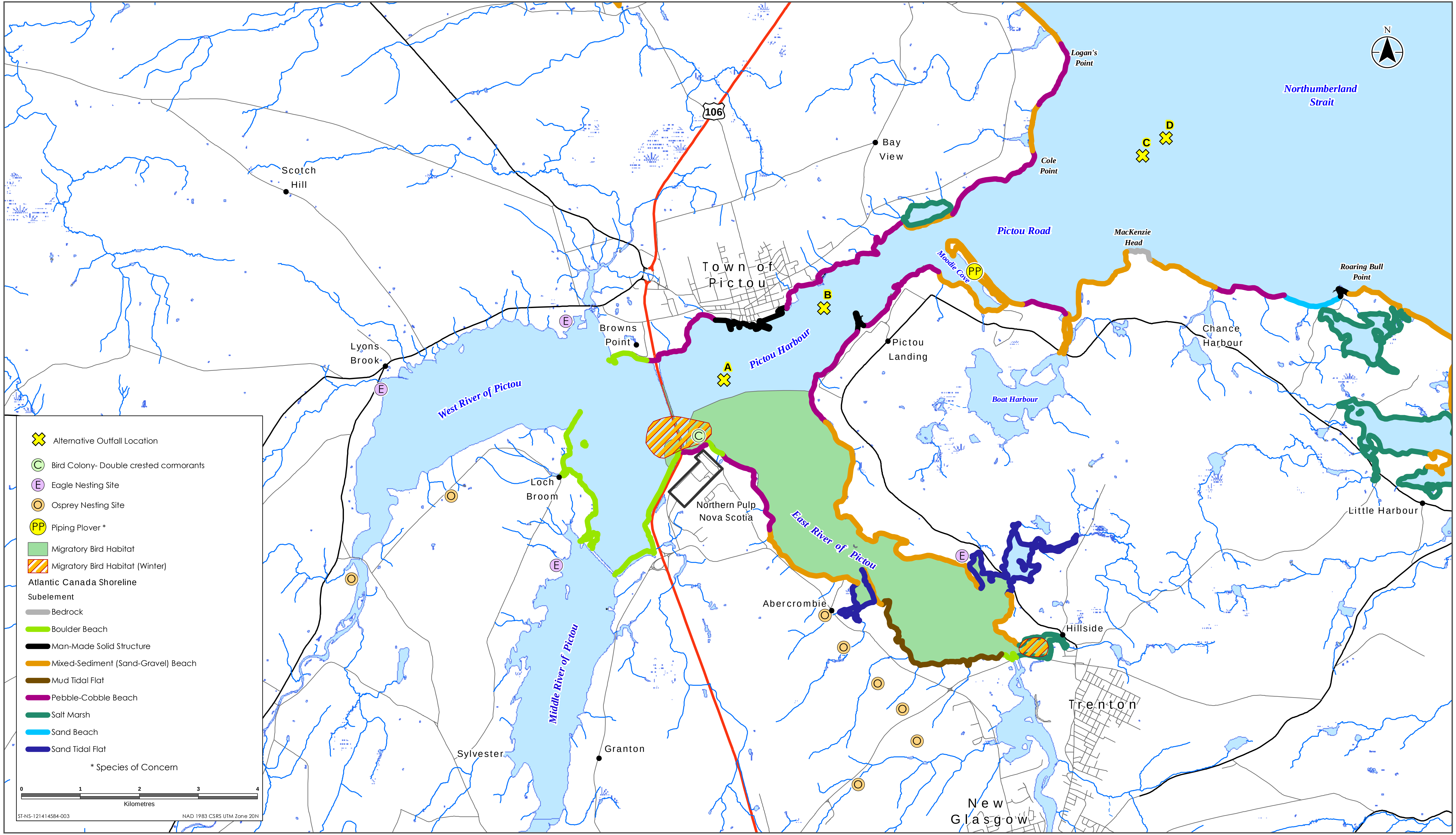
Commercial, Recreational, and Aboriginal Fishery Sensitivities

Stantec

PRELIMINARY RECEIVING WATER STUDY – PICTOU HARBOUR, NOVA SCOTIA

Figure 2-10

V:\1214\active\121414584\03_data\gis_cad\geomatics\mapping\mxd\report\ST_NS-121414584-003_Birds_Shoreline.mxd krozalska



Sources: Government of Nova Scotia, Jacques Whitford and Stantec Consulting Ltd.

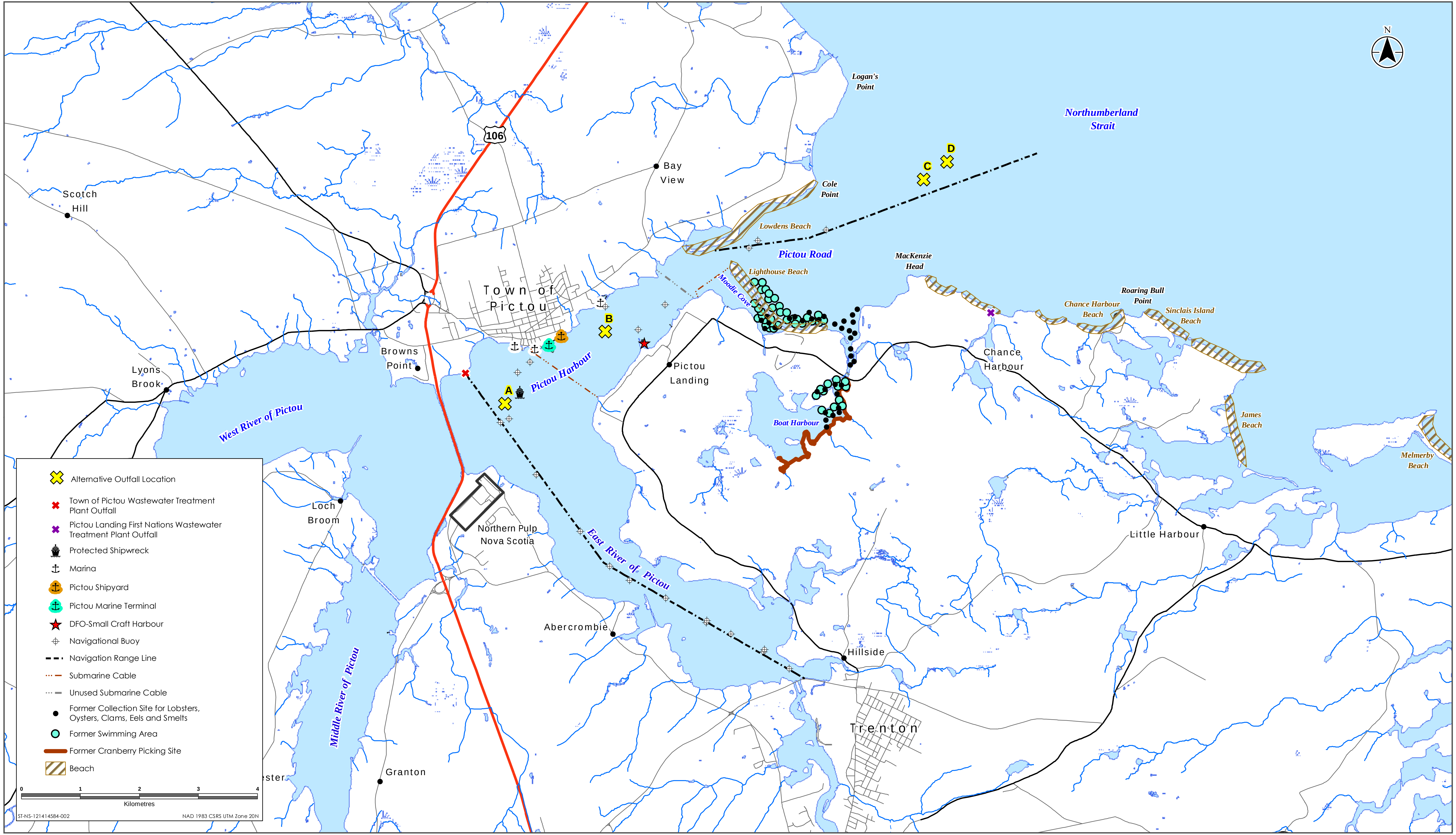
Disclaimer: This map is for illustrative purposes to support this Stantec project; questions can be directed to the issuing agency.

Bird and Shoreline Sensitivities

PRELIMINARY RECEIVING WATER STUDY – PICTOU HARBOUR, NOVA SCOTIA

Figure 2-11

V:\1214\active\121414584\03_data\gis_cad\geomatics\mapping\mxd\report\ST_NS-121414584-002_Socio_Ec_Sensitivities.mxd krozalska



Sources: Government of Nova Scotia, Jacques Whitford and Stantec Consulting Ltd.

Disclaimer: This map is for illustrative purposes to support this Stantec project; questions can be directed to the issuing agency.

Other Socio-economic Sensitivities

Stantec

PRELIMINARY RECEIVING WATER STUDY – PICTOU HARBOUR, NOVA SCOTIA

Figure 2-12

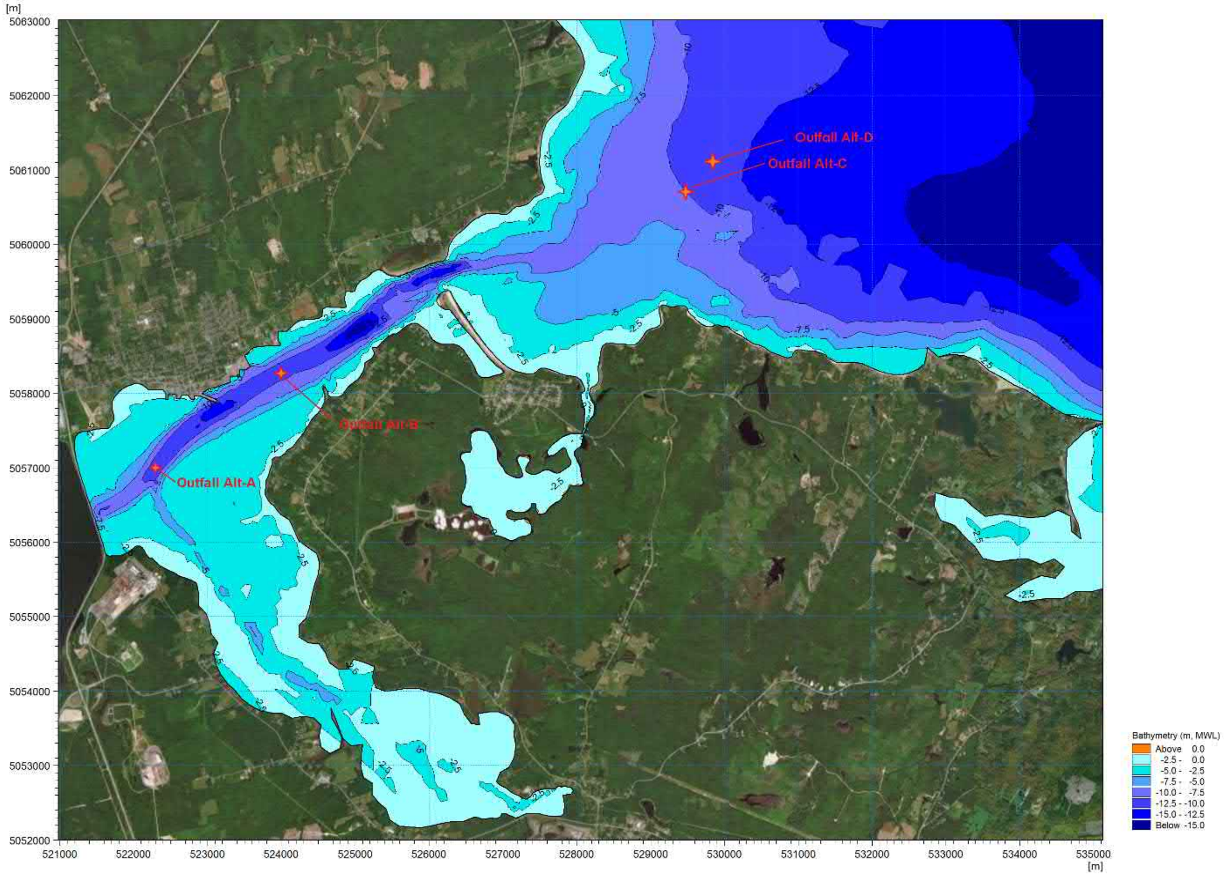


Figure 2-13 Selected Alternative Outfall Locations and Bathymetry in the Study Area

2.2.4.3 Modelling Scenario and Conditions

A modelling scenario was defined for the following key factors:

- a one-month simulation period with continuous hydrometric and environmental data records required to provide sufficient representative inputs for modelling
- typical tidal cycles, including spring tides and neap tides
- typical wind climate, including calm and storm events and seasonal variations
- field measurement records on ambient water temperature and salinity
- seasonal river discharges.

The 2016 July dataset provided the best coverage that represents conservative environmental conditions in terms of less magnitude of tidal range, calm wind, warm water and less river discharge that would not be as conducive for effluent mixing in the receiving environment.

Therefore, July 2016 was selected as the simulation period to reproduce physical oceanographic and hydrodynamic environments as the site baseline (conservative) conditions.

The general conditions and assumptions applied in the modelling are summarized in ***Table 2-11***. The assumptions include no decay of effluent quality, which is a conservative modelling approach that would represent an exaggerated condition and where normally some decay is anticipated to occur.

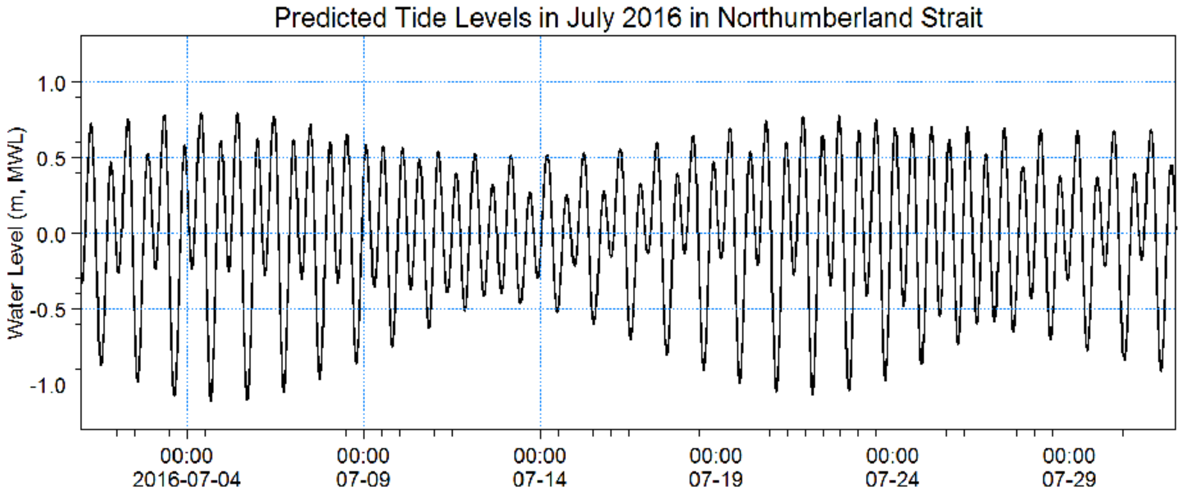


Figure 2-14 Predicted Tides in July 2016 in Northumberland Strait

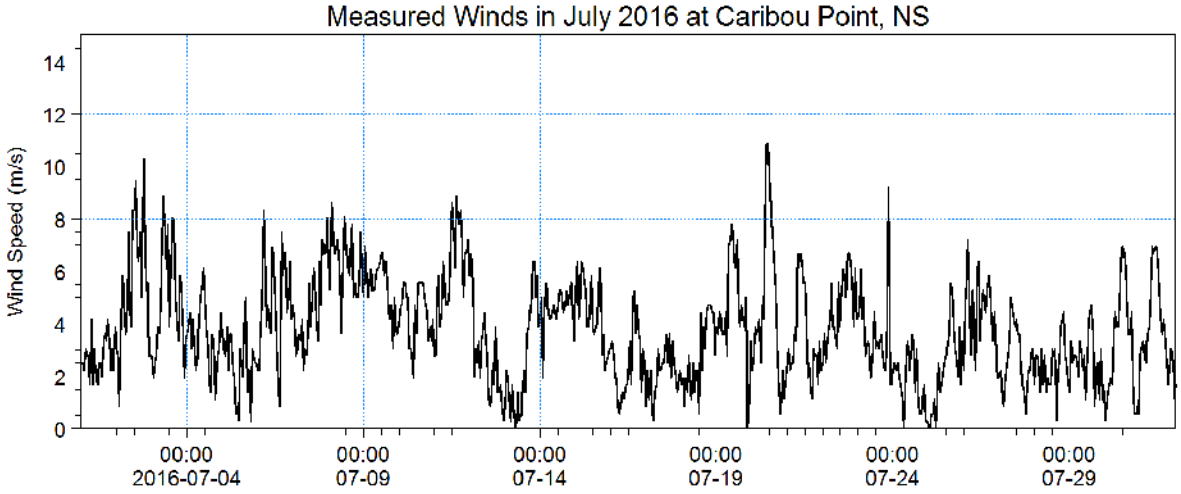


Figure 2-15 Measured Winds in July 2016 at ECCC Station Caribou Point (AUT), NS

Table 2-11 Summary of Conditions and Assumptions Used in the Hydrodynamic and Particle Tracking 2D Modelling

Feature	Characteristics	Comments
General Model Settings		
Model Domain	8616 nodes and 15872 elements	
Coupled Modules	Hydrodynamic (HD), Temperature/Salinity (TS), and Particle Tracking (PT)	
Simulation Period	A full month from July 1 to 31, 2016	
Simulation Time Step	60 seconds	
Assumptions	no decay and no dispersion in the Particle Tracking module	most conservative approach
Outfall Discharge Location		
Alternative A (Alt-A)	Easting 522300 m, Northing 5057000 m	at a water depth 11.2 m MWL
Alternative B (Alt-B)	Easting 524000 m, Northing 5058220 m	at a water depth 10.8 m MWL
Alternative C (Alt-C)	Easting 529400 m, Northing 5060800 m	at a water depth 10.0 m MWL
Alternative D (Alt-D)	Easting 529800 m, Northing 5061100 m	at a water depth 11.3 m MWL
Effluent Properties		
Discharge Rate	0.984 m^3/s	daily max provided by KSH
Parameter	Temperature: 35 °C	assumed maximum for July summer condition, based on information provided by KSH
	TDS: 4,000 mg/L	based on information provided by KSH a range is 1,000 to 4,000 mg/L. A conservative concentration was used
	Arbitrary parameter concentration in effluent: 100 mg/L	assumed arbitrary concentration at discharge for calculation of dilution ratios and easy visualization of the plume
Boundary and Ambient Conditions		
Predicted Tides	Tidal range 1.91 m (from -1.11 m to 0.8 m) including spring and neap tides (***Figure 2-14***)	This tidal range is less than the normal tidal range of 2.11 m in the Pictou Harbour area
Measured Winds	Peak and mean wind speeds in July 2016 are 10.83 m/s and 3.75 m/s respectively (***Figure 2-15***)	Based on wind records at Caribou Point (AUT), NS
River Discharge	1.64 m^3/s	based on ENSR 1999 study
Ambient Water	Temperature: 14 °C	based on ENSR 1999 study
	Salinity: 27.5 practical salinity unit (psu)	based on ENSR 1999 study

2.3 RESULTS AND DISCUSSION

2.3.1.1 Currents Circulation

Current flows in coastal areas depend strongly on tidal circulation, nearshore bathymetry, and shoreline topographic features. Current velocity is the predominant factor causing effluent transport and dispersion.

A time-series plot of current speeds at four alternative outfall locations to generally represent the study area is presented in ***Figure 2-16*** over the simulation period for July 2016. ***Figure 2-17*** presents the rose plots of current speed and current direction (towards) at the locations. The simulated maximum current speeds are:

- At Alt-A location, the hydrodynamic circulation pattern indicates flood currents are typically stronger than ebb currents flowing towards the southwest. The maximum and mean current speeds during the simulation period are 0.13 m/s and 0.05 m/s, respectively.
- At Alt-B location, the predominant currents are flowing through the navigation channel towards both the southwest and northeast directions, while flood currents are slightly smaller than ebb currents. The maximum and mean current speeds during the simulation period are 0.26 m/s and 0.11 m/s, respectively.
- At Alt-C location in the Northumberland Strait, the predominant currents are towards both the southwest and northeast directions with the same order of magnitude for flood and ebb currents. The maximum and mean current speeds during the simulation period are 0.14 m/s and 0.06 m/s, respectively.
- At Alt-D location in the Northumberland Strait, the predominant currents are the same as in Alt-C, the maximum and mean current speeds during the simulation period are 0.13 m/s and 0.05 m/s, respectively.

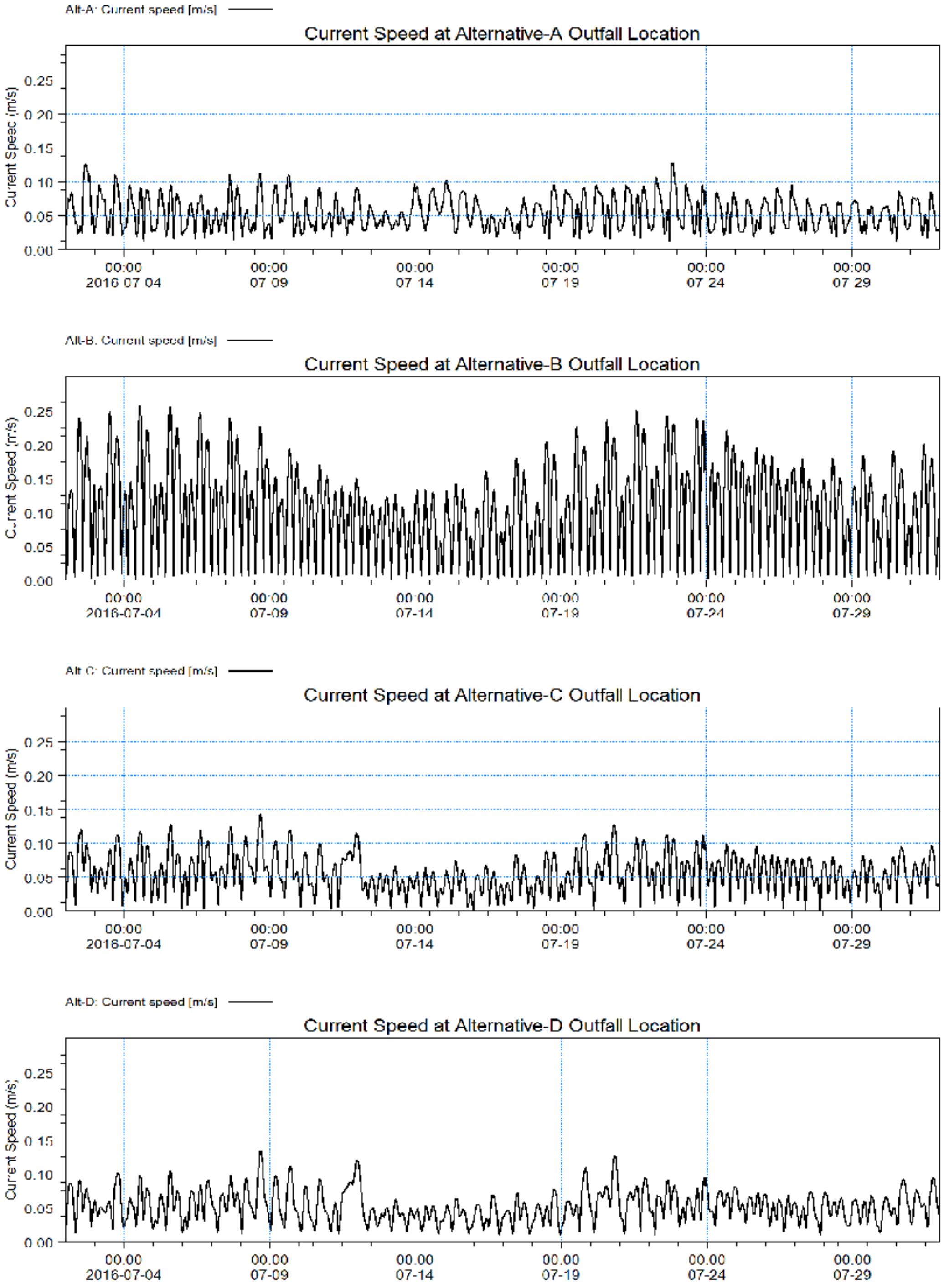


Figure 2-16 Time Series of Current Speed at Four Alternative Outfall Locations for July 2016

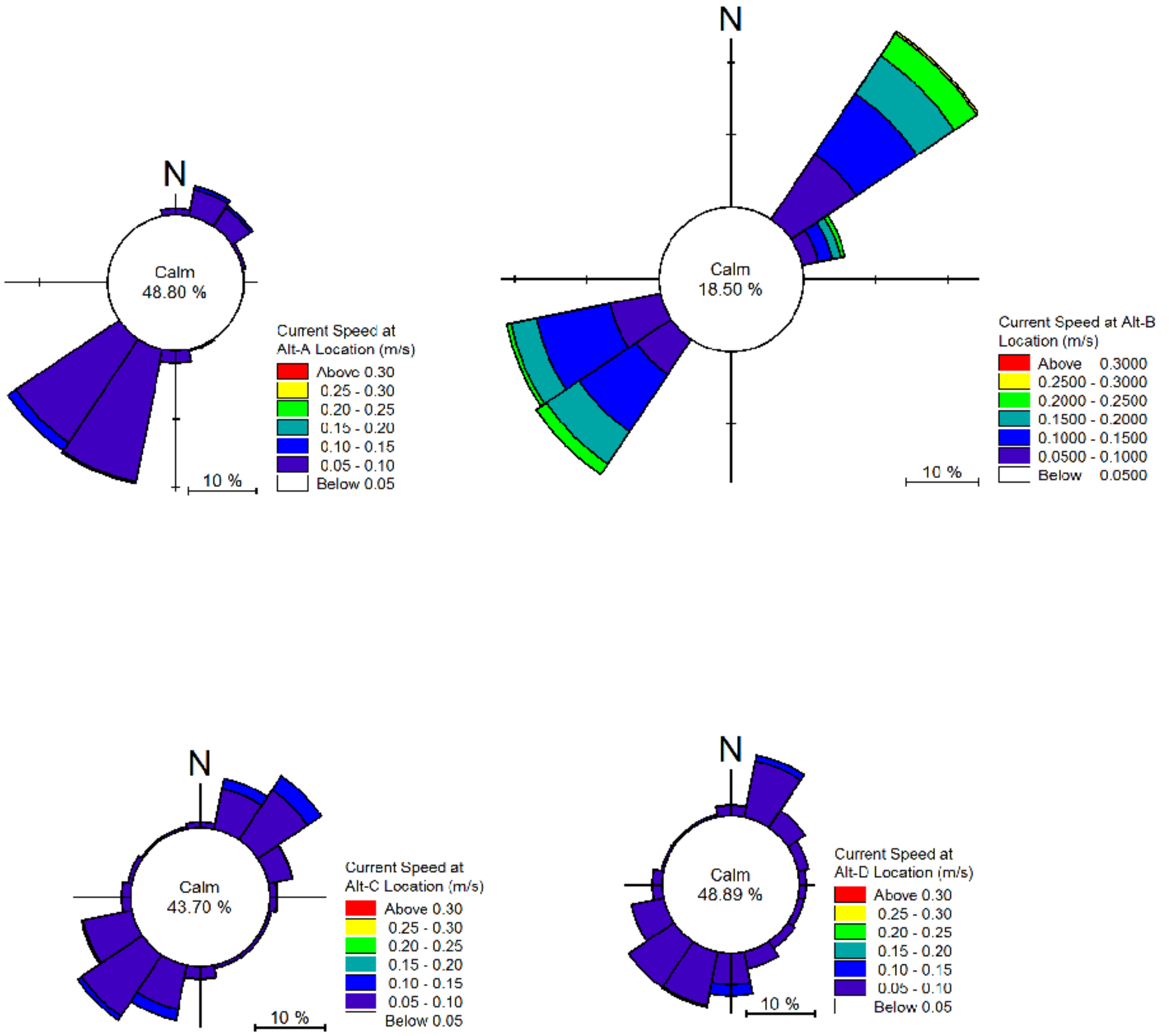


Figure 2-17 Rose Plots of Current Speed and Direction at Four Alternative Outfall Locations for July 2016

2.3.2 Effluent Dispersion

An arbitrary effluent parameter was assumed to be discharged at a single point discharge from the end-of-pipe outfall location and at a constant arbitrary concentration of 100 mg/L. Effluent transport was simulated in the PT module which was dynamically coupled with the circulation module (HD). Results are presented in time series of effluent concentrations, snapshots of spatial effluent plume for various stages of neap and spring tides, and accumulative effects with time by the end of the simulation period. No degradation or decay of the arbitrary effluent parameter was taken into consideration in the model.

2.3.2.1 Discharge at Alt-A Location

The simulated spatial distributions of the effluent plume at various stages of a typical neap tide cycle on July 13 are illustrated in ***Figures A-1*** to ***Figure A-4*** in **Appendix A**. The simulated spatial distribution of the effluent plume at various stages of a typical spring tide cycle on July 21 and July 22 are presented in ***Figures A-5*** to ***Figure A-8*** in **Appendix A**. Current vectors and circulation patterns are presented in the plots as well to provide supporting information of the current-driven forcing on effluent transport.

The effluent plume moves along the navigation channel southwesterly during the flood tides and northeasterly during the ebb tides. The effluent movement patterns corresponding to the advection of tidal and wind-driven currents are dominated by the tidal conditions. The simulated results indicate that the effluent plume is drifted to a larger extent during spring tides. In responses to current magnitudes and circulation patterns influenced by the seabed bathymetric and shoreline topographic features, the effluent plume is normally transported to and accumulated in areas with lower circulation velocities and eddies. When the effluent plume is drifted out of Pictou Harbour through the narrow opening at Lighthouse Beach, the plume typically moves back and forth along the south shoreline in the vicinity of the Boat Harbour entrance, and eventually part of the plume is trapped into Boat Harbour and the rest moves northeasterly towards Mackenzie Head and further out into the Northumberland Strait open water along the south coast (e.g., ***Figure A-5*** in **Appendix A**).

Figure 2-18 presents the predicted spatial distribution of the effluent dilution factors over the one-month simulation period in July. The results indicate that lower dilution factors, suggesting the potential presence of higher effluent concentrations in the receiving environment, occur in areas of Pictou Harbour, nearshore of the Boat Harbour entrance, as well as in Boat Harbour.

2.3.2.2 Discharge at Alt-B Location

The simulated spatial distributions of current circulation and effluent plume at various stages of a neap tide on July 13 are presented in ***Figures A-9*** to ***A-12*** in **Appendix A**, and in ***Figures A-13*** to ***A-16*** during a spring tide on July 21 and July 22. The accumulative dilution factors at the end of the one-month simulation period are presented in ***Figure 2-19***.

Compared to the effluent discharge from the Alt-A location, the predicted results from the Alt-B discharge location demonstrate similar effluent dispersion patterns, and similar order of magnitude and extent of effluent concentrations distributed over Pictou Harbour and the surrounding areas.

These results indicate that, if an outfall is located within Pictou Harbour, the discharged effluent will not be readily flushed out by tidal circulation into the Northumberland Strait open water. This is attributed to the effect of the narrow harbour opening and constriction at Lighthouse Beach, and as a result, the effluent concentration will likely increase cumulatively within Pictou Harbour for a longer-term discharge.

2.3.2.3 Discharge at Alt-C Location

The simulated spatial distributions of current circulation and effluent plume at various stages of a neap tide on July 13 are presented in ***Figures A-17*** to ***A-20*** in **Appendix A**, and in ***Figures A-21*** to ***A-24*** during a spring tide on July 21 and July 22. The accumulative dilution factors at the end of the one-month simulation period are presented in ***Figure 2-20***.

Compared to the discharges from Alt-A and Alt-B, the Alt-C location has much higher dilution factors in Pictou Harbour, Boat Harbour, and particularly in the nearshore fishery and socio-economic sensitive areas. In addition, the extent of effluent flow into Pictou Harbour and Boat Harbour is greatly reduced at the Alt-C discharge location. However, there still exist areas where the concentration is accumulated in Boat Harbour with lower dilution factors in the range of 20 to 30.

2.3.2.4 Discharge at Alt-D Location

The simulated spatial distributions of current circulation and effluent plume at various stages of a neap tide on July 13 are presented in ***Figures A-25*** to ***A-28*** in **Appendix A**, and in ***Figures A-29*** to ***A-32*** during a spring tide on July 21 and July 22. The accumulative dilution factors at the end of the one-month simulation period are presented in ***Figure 2-21***.

Alt-D is located in deeper water than Alt-C and 0.5 km further offshore from Alt-C. Alt-D further reduces the potential impact of the effluent on Boat Harbour and near the shorelines in the Northumberland Strait

Dispersion modelling results from Alt-D discharge indicate that the potential effluent impact on Boat Harbour is small when the outfall is located towards deeper water in the Northumberland Strait.

The cumulative effects by the end of the one-month simulation period indicate that the lowest dilution factor achieved in Boat Harbour is 79 (***Figure 2-21***), which is a much higher dilution when compared to the discharge from the Alt-C location where the lowest dilution factor in Boat Harbour was 29 (***Figure 2-20***). In addition, the extent of effluent flow into Pictou Harbour and Boat Harbour is reduced compared to that for the discharge from the Alt-C outfall location, and where generally the dilution in the Northumberland Strait is improved for effluent discharged from Alt-D.

Compared to the alternative outfall locations of Alt-A, Alt-B and Alt-C, the Alt-D location provides more dilution and much less potential negative effects on the fishery and socio-economic environments, and therefore is considered the better outfall location for the discharge of the treated wastewater from the mill.

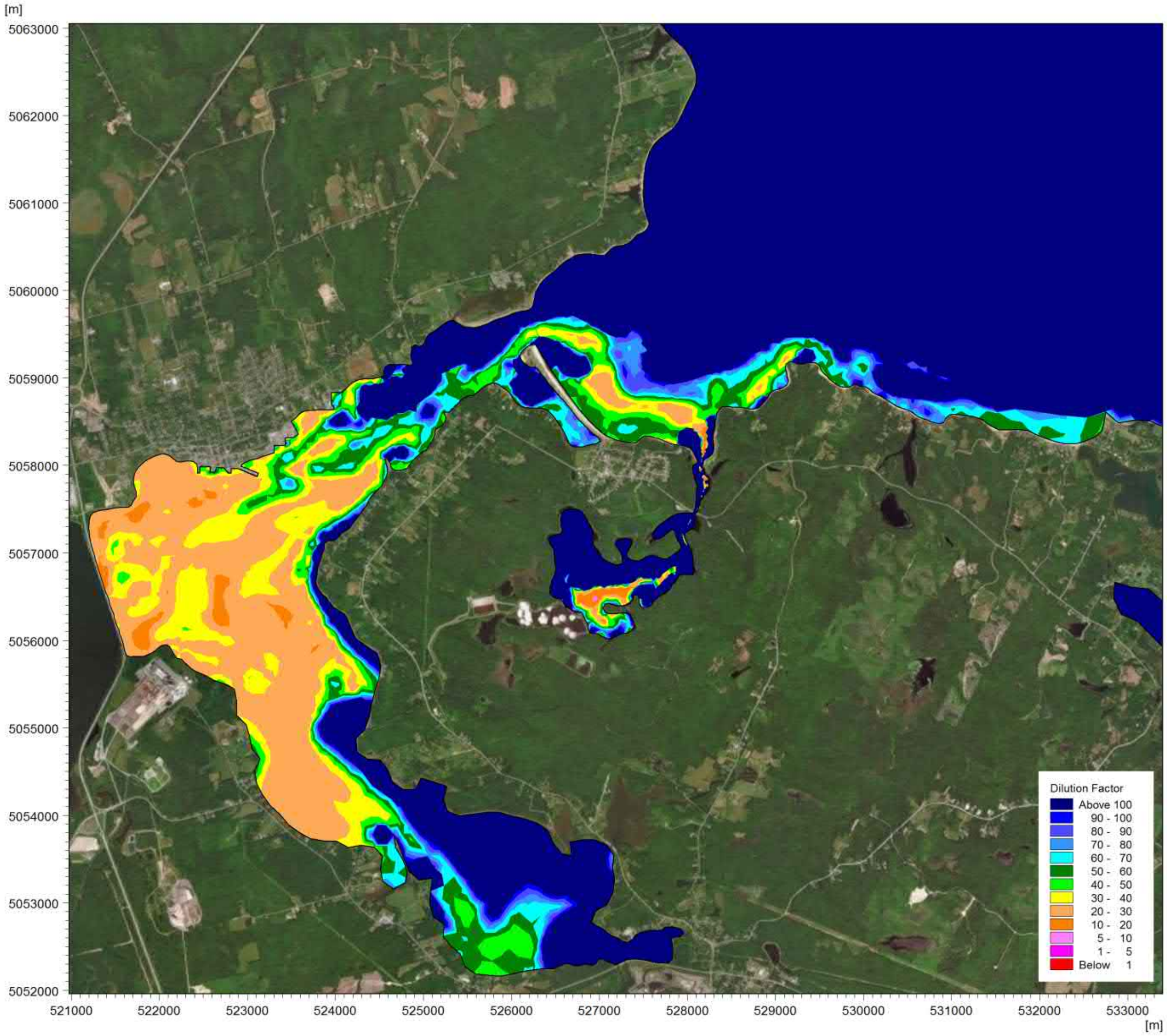


Figure 2-18 Alt-A Discharge: Spatial Distribution of Simulated Effluent Dilution Factor at the End of a One-Month Simulation Period (assuming no particle degradation over the simulation period)

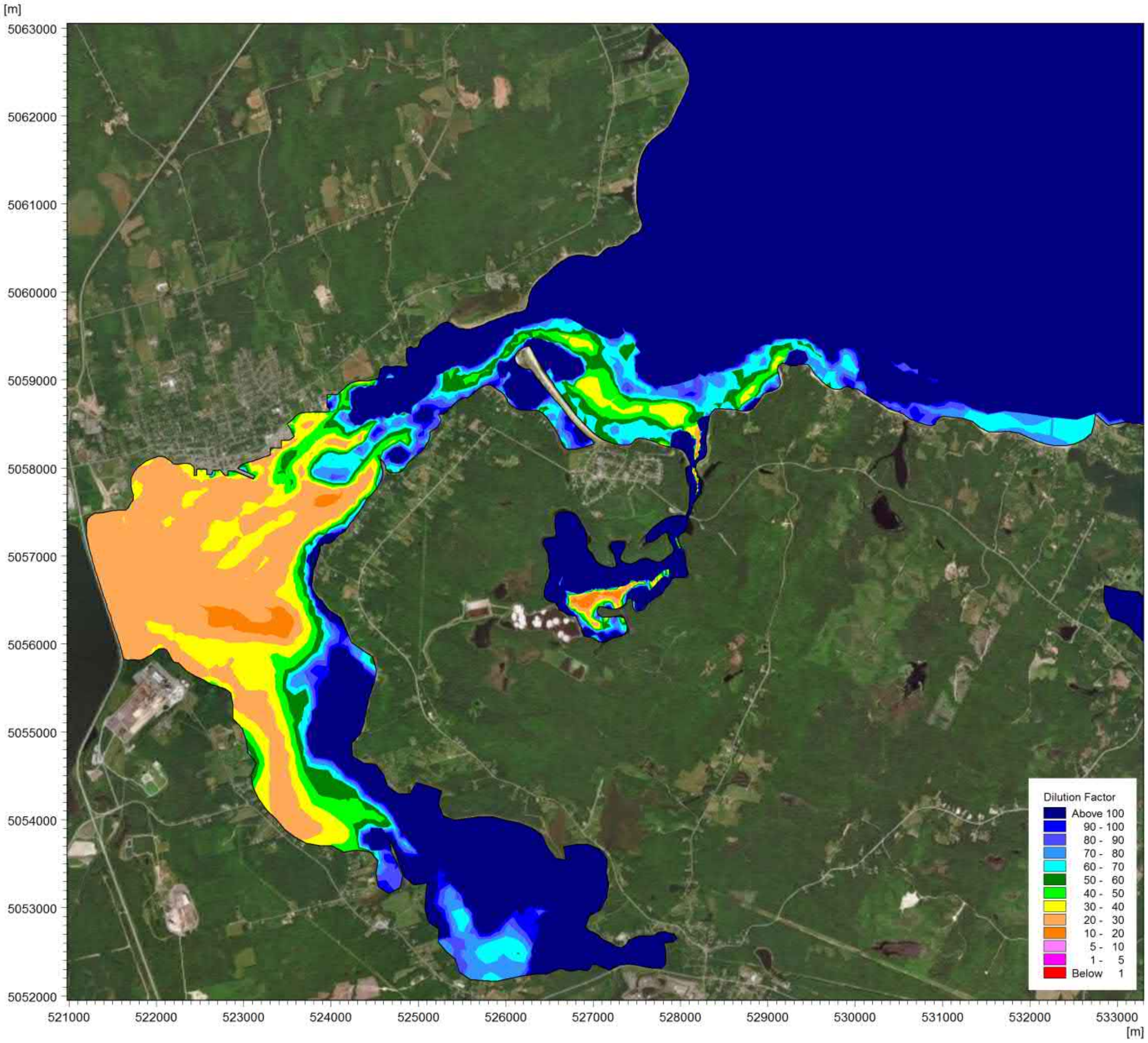


Figure 2-19 **Alt-B Discharge: Spatial Distribution of Simulated Effluent Dilution Factor at End of a One-Month Simulation Period (assuming no particle degradation over the simulation period)**

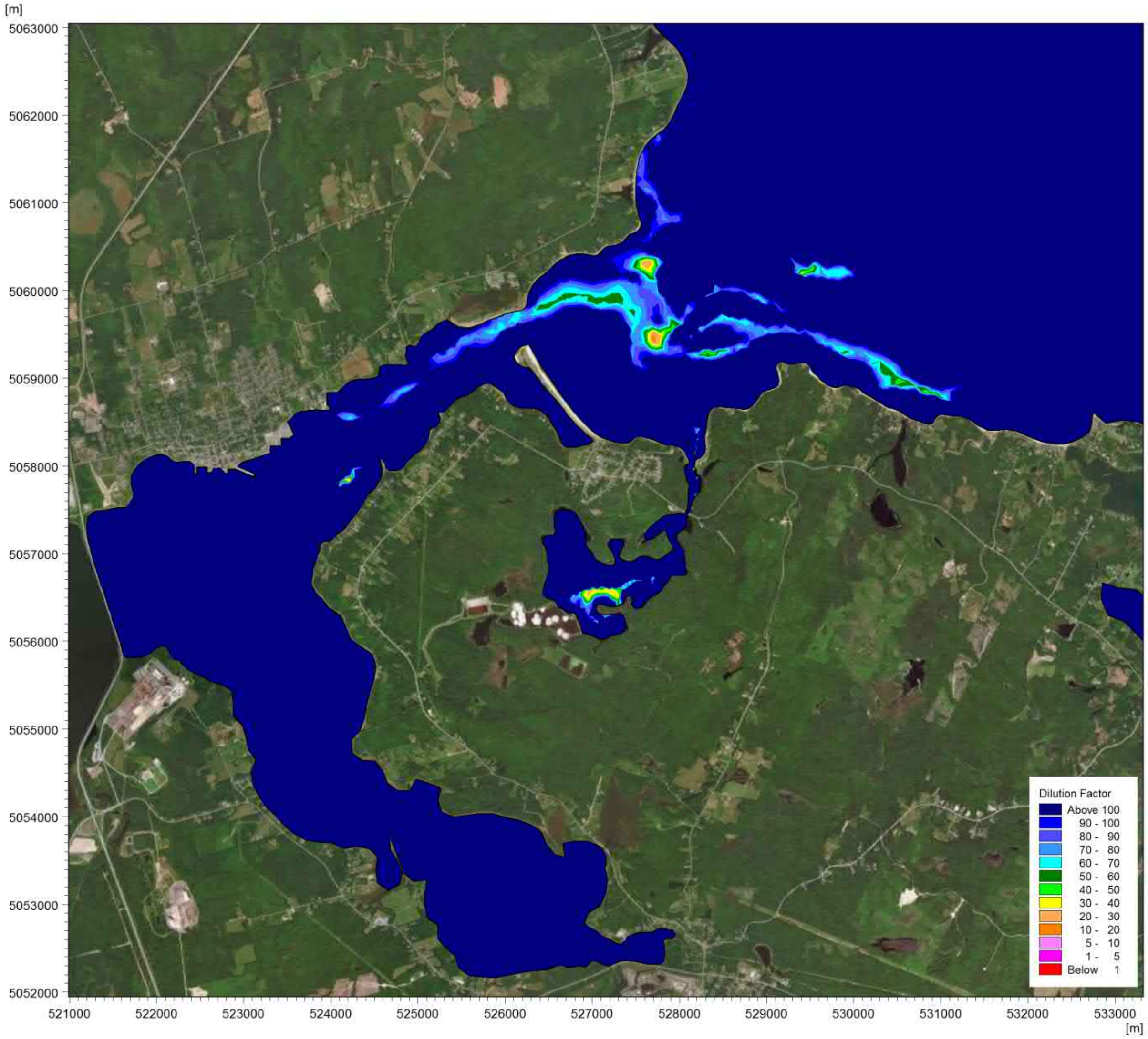


Figure 2-20 **Alt-C Discharge: Spatial Distribution of Simulated Effluent Dilution Factor at the End of a One-Month Simulation Period (assuming no particle degradation over the simulation period)**

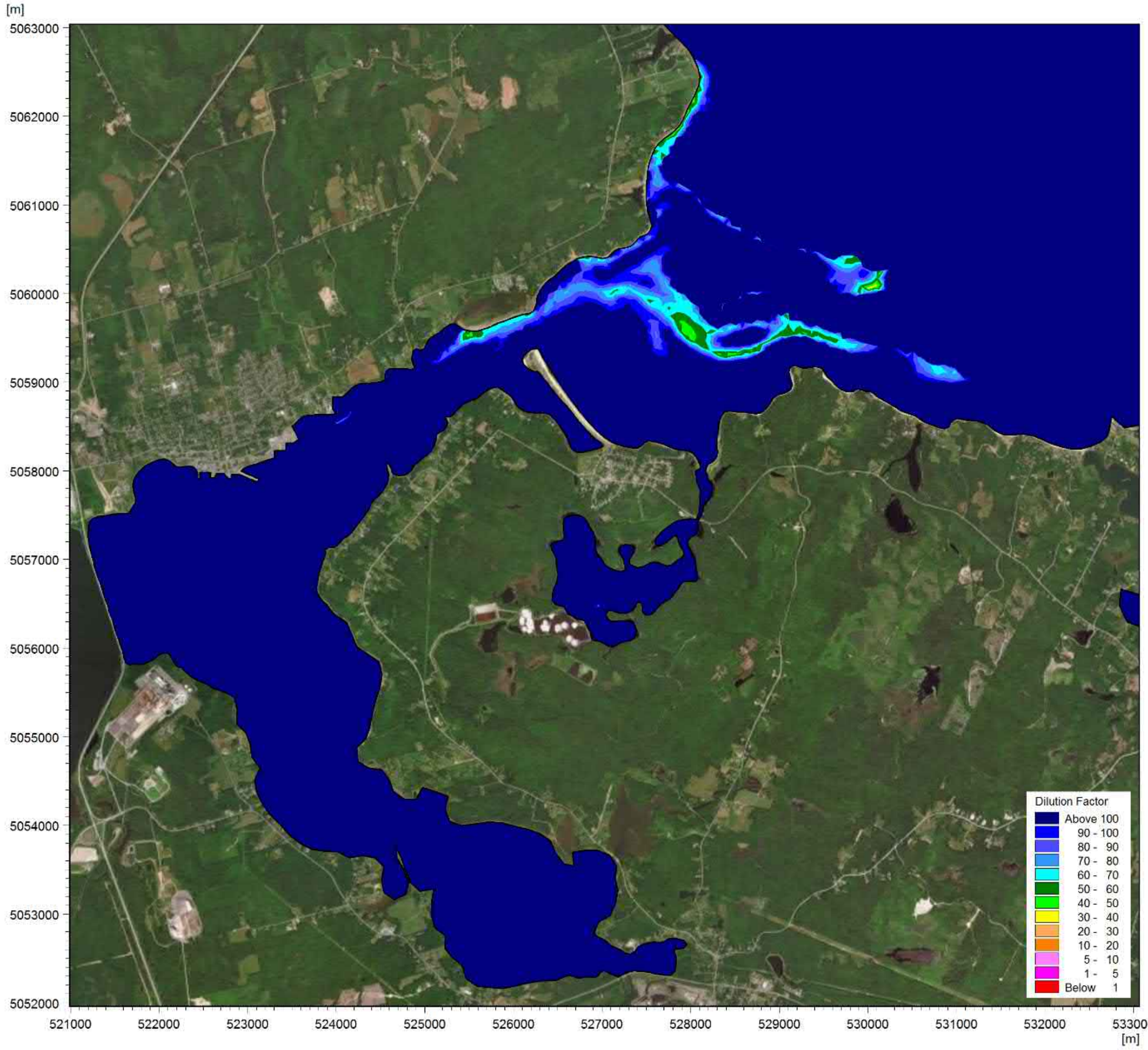


Figure 2-21 Alt-D Discharge: Spatial Distribution of Simulated Effluent Dilution Factor at the End of a One-Month Simulation Period (assuming no particle degradation over the simulation period)

2.4 CONCLUSIONS

A 2D numerical model (MIKE 21 Coupled Model) was developed to assist in the selection of a potential outfall location for the proposed treated wastewater discharge from the NPNS kraft mill. The model simulated the integrated hydrodynamics with tidal currents, wind forcing, river discharges, density flows, and effluent discharge in Pictou Harbour and the surrounding areas. Four alternative outfall locations within and outside of Pictou Harbour were selected to simulate the hydrodynamic process of tidal currents (at different tidal cycles) and effluent dispersion (transport), and to investigate the cumulative characteristics of effluent concentrations and dilution factors in a spatial domain that included Pictou Harbour, Boat Harbour and the Northumberland Strait. The modelled simulations were conducted in a time domain over an entire month in July 2016 for a single point discharge and no diffuser at the outfall. The physical oceanographic conditions during this summer simulation period were considered to be a conservative scenario within typical annual seasonal conditions based on calmer winds, warmer ambient waters and less river discharges during summer. In addition, a smaller magnitude for the tidal range was also selected for the simulation period and where no decay or particle degradation of the effluent was assumed to exaggerate further the conservative scenario. Other considerations for the MIKE 21 modelling included:

- Physical oceanographic and hydrometric data were collected, reviewed, and analyzed to characterize the physical environments in Pictou Harbour and surrounding areas.
- Tide constituents in the Northumberland Strait were analyzed for use for tide prediction.
- Coupled hydrodynamic models of tidal circulation, density flow and particle tracking were implemented with the objective of simulating water currents and effluent movements that are primarily affected by tidal variation, wind forcing, river discharges, effluent properties, water temperature, and salinity. The models were calibrated to the historical records of DFO tide gauge water levels and DFO current measurements. The calibrated model was then applied to predict effluent dispersion for the defined modelling scenarios.

The key conclusions based on the effluent dispersion modelling results indicate:

- Effluents discharged from an outfall located within Pictou Harbour (e.g., Alt-A and Alt-B) would experience difficulty in being flushed out of the harbour. This is attributed to the effect of the constriction and narrow opening of the Pictou Harbour entrance at Lighthouse Beach such that a large portion of discharged effluents would be retained within Pictou Harbour. The resulting effect is the potential cumulative increase of effluent concentrations in the harbour.
- Outside of Pictou Harbour beyond Lighthouse Beach and in the Pictou Road area, there exists circulation eddies nearshore of the south shoreline and Boat Harbour entrance. Effluent drifting out of Pictou Harbour moves dynamically westerly by flood currents and easterly by ebb currents. Eventually, part of the effluent would be transported by flood currents into

Boat Harbour, and the other part of the effluent would be transported by ebb currents northeasterly towards Mackenzie Head and further out into the open water of the Northumberland Strait along the south coast.

- The transport of effluent discharged at the Alt-C and Alt-D locations is predicted predominantly in areas offshore of Pictou Harbour and Boat Harbour. When the outfall is located towards deeper water from Alt-C to Alt-D in the Northumberland Strait, the potential effluent impact on Boat Harbour is reduced. The cumulative effects by the end of the one-month simulation period indicate that the lowest dilution factor achieved in Boat Harbour is 79 (***Figure 2-21***), which is a much higher dilution when compared to the discharge from the Alt-C location where the lowest dilution factor in Boat Harbour was 29 (***Figure 2-20***). In addition, the extent of effluent flow into Pictou Harbour and Boat Harbour is reduced compared to that for the discharge from the Alt-C outfall location, and where generally the dilution in the Northumberland Strait is improved for effluent discharged from Alt-D.
- Among the four potential outfall locations discussed in this study for the discharge of the effluent, the Alt-D outfall location provides the smallest potential long-term cumulative effects on the fishery and socio-economic environments, and therefore is considered the better outfall location for the discharge of the treated wastewater from the mill. It should be noted that this is for a single point discharge with no diffuser at the outfall. Further assessment and confirmation using near-field mixing and modelling analysis with the application of various diffuser designs is completed in Section 3.
- Key assumptions in this modelling study are no decay and no dispersion defined in the Particle Tracking module of MIKE 21; therefore, the modelling results are considered conservative.
- The 2D modelling results provide the hydrodynamic information (water levels and current velocities) required for the CORMIX near-field dispersion modelling presented in Section 3.
- MIKE21 uses inputs of flows, winds, tides, temperature and arbitrary water quality concentration in the effluent and presents results for far-field mixing. Near-field mixing, specific water quality parameters and detailed water quality modeling was done using CORMIX.

3.0 NEAR-FIELD MODELLING

The objective of near-field modelling is to undertake effluent dispersion analysis of the treated wastewater from the mill under conservative ambient conditions. Near-field modelling was conducted for a variety of submerged diffuser orientations and configurations to obtain a preliminary conceptual diffuser design that is well-suited to the receiving water body. The scale of the near-field modelling is on the order of several metres to a few hundred metres, which allows for a detailed prediction of the effluent plume discharging from the diffuser.

The near-field modelling was performed to determine the acceptability of expected daily maximum effluent water quality for a number of parameters. The acceptability was defined as compliance with applicable federal water quality guidelines at the end of the mixing zone in the receiving environment.

Near-field modelling was conducted for Alt-C and Alt-D, which are suitable discharge locations with respect to dilution potential of the effluent among the four assessed locations as determined by the results of MIKE 21 modelling. Even though the Alt-D location was assessed in Section 2 as being the preferred outfall location for the discharge of the treated wastewater from the mill, near-field modelling for the Alt-C location was also investigated to determine if with a diffuser the effluent water quality could meet applicable water quality guidelines at the edge of the mixing zone in the receiving environment.

3.1 BACKGROUND

3.1.1 CORMIX

The Cornell Mixing Zone Expert System (CORMIX, Version 10.0) was used to analyze and assess near-field mixing (conditions at and near the initial mixing zone). CORMIX is a software system for the analysis, prediction, and design of aqueous toxic or conventional pollutant discharges into diverse water bodies. The major emphasis is on the geometry and dilution characteristics of the initial mixing zone, but the system can also predict the behavior of the discharge plume at larger distances. CORMIX is a three-dimensional (3D) model which can be run in steady-state and tidal ambient conditions.

The CORMIX model was run through several iterations to identify the optimal end-of-pipe outfall configuration to reduce impact of treated effluent on water quality in the mixing zone. The modelling results were compared to applicable regulations and water quality guidelines, if available, or environmental quality objectives.

3.1.2 Site-specific Guidelines

A framework for developing site-specific guidelines for wastewater discharge to receiving waters is described in CCME (2003). Point-source discharges are based on the site-specific receiving water quality objectives (RWQOs) or the water quality guidelines (WQGs), if available. The RWQOs are based on protecting one or more designated uses of the receiving water body (e.g., sensitive environmental and socio-economic areas). The WQGs are often based on applicable CCME guidelines. CCME (2003) defines the mixing zone as “an area contiguous with a point source (effluent) where the effluent mixes with ambient water and where concentrations of some substances may not comply with water quality guidelines or objectives”.

The modelling of the near-field dilution mixing is aimed to confirm that the ambient water quality concentrations or the established WQGs are met at the edge of the mixing zone.

The distance from the outfall pipe to the boundary of the mixing zone applied in this study is limited to 100 m, which is the standard mixing zone distance accepted by the Council of Canadian Ministers of the Environment (CCME 2009). In addition, the Atlantic Canada Wastewater Guidelines Manual (EC 2006) indicates that the surface water quality objectives must be achieved at all points beyond a 100-m radius from the effluent outfall. Both above-mentioned documents are applicable for municipal effluent; however, they were used in this study as guidance for the industrial discharge.

3.1.3 Ambient Conditions

Ambient conditions in the receiving environment are characterized by hydrodynamic factors (flows, tides, currents, etc.) and by background water quality.

3.1.3.1 Flows and Currents

Current flows in coastal areas depend strongly on tidal circulation, wind patterns, and nearshore bathymetry. Current velocity magnitude and direction is the predominant factor causing effluent transport and dispersion.

Four alternative outfall locations in this study were evaluated and modelled using MIKE 21, as reported in Section 2. The results indicate that both Alt-C and Alt-D are suitable locations for the discharge of treated wastewater from the mill, from dilution and mixing perspective. CORMIX modelling was performed for Alt-C and Alt-D.

Alt-C and Alt-D are located 500 m apart in the Northumberland Strait. The predominant currents alternate between the southwest and northeast directions and maintain the similar order of magnitude under both flood and ebb tide conditions.

Water depth at Alt-C is 10 m and the depth-averaged maximum and mean current velocities simulated by MIKE 21 are 0.14 m/s and 0.06 m/s, respectively. The average depth for the mixing zone was conservatively assumed to be 10 m

Water depth at Alt-D is 11.3 m and the depth-averaged maximum and mean current velocities simulated by MIKE 21 are 0.17 m/s and 0.05 m/s, respectively. Based on the bathymetry map, the average depth for the extent of the mixing zone in the area of Alt-D was conservatively assumed to be 12 m.

Velocities simulated with MIKE 21 are in line with velocities measured in Pictou Road during a 1994 survey. The 1994 data show that the observed mean tidal velocities were approximately 0.05 m/s. The peak velocities were 0.1 - 0.15 m/s which corresponded to times of peak ebb and flood tide velocities (ENSR 1999).

3.1.3.2 Background Water Quality

Limited background water quality data are available for Pictou Harbour and particularly the Pictou Road area for the parameters of concern (**Appendix B**). Background water quality data from Dalziel art al. (1993), JWEL (1994, 2005) and Ecometrix (2007, 2016) were used. A summary of ambient water quality is shown in ***Table 3-1***.

Table 3-1 Background Water Quality

Parameter	Unit	Number of Samples	Average Value
Adsorbable Organic Halides (AOX)	mg/L	n/a	n/a
Total Nitrogen (TN)	mg/L	13	0.24
Total Phosphorus (TP)	mg/L	16	0.35
Colour	TCU	2	11
Chemical Oxygen Demand (COD)	mg/L	n/a	n/a
Biochemical Oxygen Demand (BOD_5)	mg/L	n/a	n/a
Total Suspended Solids (TSS)	mg/L	11	8.5
Dissolved Oxygen (DO)	mg/L	6	7.2
pH	-	13	8.0
Temperature (summer)	°C	6	17.6
Temperature (winter)	°C	2	0.0

n/a – no data available

3.1.4 Effluent Characteristics

The mill is currently operated under the Industrial Approval # 2011-076657-A01 issued by Nova Scotia Environment. The approval became effective on March 9, 2015 and expires on January 30, 2020.

The wastewater treatment plant is sized to treat a maximum of 85,000 m^3/day or 0.98 m^3/s. The annual average flow rate is 62,000 m^3/day or 0.72 m^3/s (KSH, 2016). For the purpose of this study, the maximum effluent flow rate of 0.98 m^3/s was used in CORMIX modelling. An additional scenario for a flow rate of 75,000 m^3/day or 0.87 m^3/s (a 10,000 m^3/day reduction) was also evaluated, as requested by KSH. Density of the effluent for modelling purposes was assumed to be 996.32 kg/m^3. This density was estimated based on an effluent temperature of 37 °C (assumed daily maximum in August – September) and total dissolved solids (TDS) of 4,000 mg/L (KSH, pers. comm. 2017). The maximum effluent flow rate, temperature and TDS for modelling were selected to provide conservative results for effluent mixing in the near-field to the outfall. Because the effluent is less dense than the receiving water, the discharge plume is buoyant and will rise above the diffuser until the plume reaches the density of the receiving water body.

Expected daily maximum water quality characteristics of the treated effluent from the mill were provided by KSH (2016) and summarized in ***Table 3-2***.

Table 3-2 Daily Maximum Effluent Water Quality

Parameter	Unit	Value
Adsorbable Organic Halides (AOX)	mg/L	7.8
Total Nitrogen (TN)	mg/L	3.0
Total Phosphorus (TP)	mg/L	1.5
Colour	TCU	750
Chemical Oxygen Demand (COD)	mg/L	725
Biochemical Oxygen Demand (BOD_5)	mg/L	48
Total Suspended Solids (TSS)	mg/L	48
Dissolved Oxygen (DO)	mg/L	> 1.5
pH	-	7.0 to 8.5
Temperature	°C	25 (winter), 37 (summer)

3.2 MODELLING

The CORMIX model requires three sets of input parameters to describe: 1) ambient conditions or receiving water body characteristics; 2) effluent discharge characteristics; and 3) diffuser specifications. Receiving water body characteristics were selected based on available literature and results of MIKE 21. Effluent discharge characteristics were provided by KSH. CORMIX iterative solutions were used to refine diffuser specification with an objective of obtaining optimal effluent mixing in the receiving water body.

3.2.1 Input Parameters

The required model input for the ambient conditions includes harbour water density, flow velocity, and average and outfall water depths. These characteristics affect the near-field transport and shape of the resulting plume of the effluent discharge.

Results of MIKE 21 showed that circulation of water around Alt-C and Alt-D is complex with velocity vectors pointing almost in all directions during a tidal cycle. However, the dominant flow direction is towards the southwest and northeast - i.e., the same as the direction of flood and ebb currents. During the tidal cycle, the maximum, average and minimum velocities at Alt-C are 0.14 m/s, 0.06 m/s and 0.007 m/s, respectively. The maximum, average and minimum velocities at Alt-D are 0.17 m/s, 0.06 m/s and 0.005 m/s, respectively. CORMIX was run in a tidal mode, with a tidal cycle of 12.4 h. The results are presented for a time step corresponding to 1 hour before slack tide conditions.

The water column at Alt-C and Alt-D was assumed non-stratified as it is sufficiently remote from fresh water sources (i.e., the East, Middle and West Rivers) to avoid fresh/saltwater stratification. Ambient water density used in the model is 1,020.43 kg/m^3, which was calculated based on salinity and average summer water temperature.

Bottom sediments in the Northumberland Strait are affected by tidal currents, with muddy sediments deposited where currents are less than 0.25 m/s and sands and gravels occurring where maximum tidal currents are greater than 0.25 m/s (Seakem, 1990). In deeper water to the northeast and east of Pictou Harbour, sediments are predominantly sandy mud (5 - 50% sand) (Seakem, 1990). For modelling purposes the Manning's "n", which represents bottom roughness applied to the flow by the channel and dependent on the bottom substrate, was assumed to be 0.02 in the mixing zone.

Winds can affect the circulation, mixing and plume movement in Pictou Harbour. The dominant wind direction in the region is from the northwest and west. The mean wind speed is 5.3 m/s, which was calculated using the 2016 hourly data for the Caribou Point (Station ID 8200774).

To provide conservative estimates of water quality in the mixing zone, the decay (or removal) coefficient was not applied in CORMIX for all conservative and non-conservative parameters. The first-order decay option can be used in CORMIX for non-conservative parameters to characterize exponential removal of a contaminant due to sedimentation, bioaccumulation or element transformation, but which was not applied in this study.

For presentation purposes (Figures 3-2 to 3-7) the initial effluent concentration for an arbitrary parameter prior to discharge for all scenarios was arbitrary assumed 100 mg/L. Based on this concentration the dilution factors in the near field mixing zone were derived. Then, the dilution factors were applied to the studied water quality parameters to derive the proposed effluent limit.

3.2.2 Diffuser Configuration

Three outfall diffuser designs were modelled using CORMIX: one-port diffuser, three-port diffuser and six-port diffuser. Several diffuser variables were iteratively adjusted during the design process to increase predicted dilution of the treated effluent.

The ports were assumed to be located 1.0 m above the seabed (i.e., port height).

The diffuser axis of 45˚ (or 315˚ in CORMIX notation) to ambient flow was found optimal for tidal environments. This angle provides sufficient mixing and avoids a right-angle transition from the pipe to the diffuser (***Figure 3-1***).

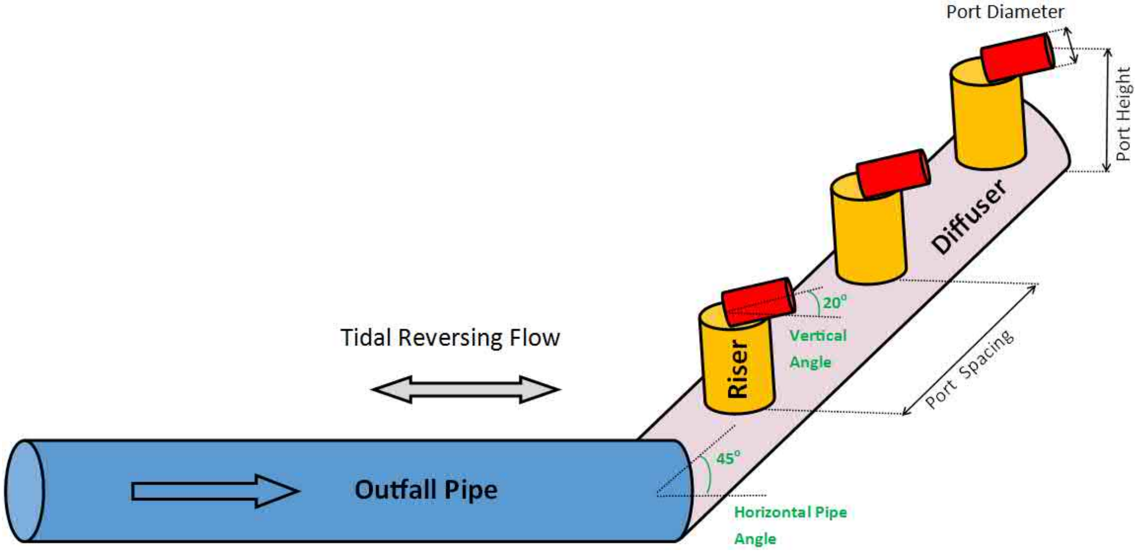


Figure 3-1 Schematic Representation of 3 Ports Diffuser

The port diameter for each diffuser design was back-calculated using CORMIX to achieve a jet velocity in the range of 4 to 7 m/s. This velocity range provides entrainment, fast initial mixing, and a stable plume formation. In the CORMIX model, a 0.4 m port opening was used in a single port diffuser, a 0.3 m port opening was used in a three-port diffuser, and a 0.2 m port opening was used in a six-port diffuser.

The number of ports on the diffuser is an important characteristic as it determines the flow rate from each port, port diameter, and ultimately the resulting plume dilution. Generally, more ports provide better dilution and mixing with the ambient environment. However, a very large number of ports may be expensive to build and maintain, and a larger number of ports may create an undesirable diffuser footprint in the receiving environment as well as not bringing any measurable benefits to the receiving water quality.

The discharge angle theta is the vertical angle of the discharge port relative to the seabed. An angle of 0° indicates that the diffuser jets discharge parallel to the seabed and 90° indicates an upward vertical discharge. Several vertical angles were modelled in CORMIX and compared. Generally, a smaller angle results in greater opportunity for mixing and dilution. However, angles less than 20° may scour and suspend bottom sediments and were not considered. An optimal horizontal angle of 20° which provides better mixing was used in this study.

Port spacing is an important consideration for 3- and 6-ports diffuser modelling. Several port spacing options were modelled in CORMIX. Generally, the bigger spacing the better dilution and the smaller the mixing zone. During preliminary design, consideration was given to a) avoid individual port plume overlapping when it breaks the surface, and b) have sufficient dilution before plumes from adjacent ports merge. An optimal spacing of 25 m between the ports was used. The same spacing was found to be optimal in the ENSR (1999) study.

Table 3-3 summarizes the results of the CORMIX model input data for Alt-C and Alt-D outfall locations for various diffuser designs, including a scenario for a reduced effluent flow rate using the six ports diffuser for Alt-C.

Table 3-3 CORMIX Input Data for the Various Diffuser Designs and Scenarios

Input Parameter	**Alt-C**				**Alt-D**	
Diffuser Design	**1 Port**	**3 Ports**	**6 Ports**	**6 Ports Reduced Flow**	**3 Ports**	**6 Ports**
Scenario, No.	**1**	**2**	**3**	**4**	**5**	**6**
Port Opening, m^2	0.4	0.3	0.2	0.2	0.3	0.2
Number of Ports	1	3	6	6	3	6
Vertical Pipe Angle (theta), deg.	20					
Horizontal Pipe Angle (sigma), deg.	315					
Alignment Angle (gamma), deg.	45					
Relative Orientation Angle (beta), deg.	n/a	90	90	90	90	90
Port Height Above Seabed, m	1.0					
Wastewater Flow Rate, m^3/s	0.98	0.98	0.98	0.87	0.98	0.98
Water Depth at Outfall, m	10	10	10	10	11.3	11.3
Average Depth in Mixing Zone, m	10	10	10	10	12	12
Maximum Ambient Velocity at Tidal Conditions, m/s	0.14	0.14	0.14	0.14	0.17	0.17
Average Ambient Velocity at Tidal Conditions, m/s	0.06	0.06	0.06	0.06	0.053	0.053
Minimum Ambient Velocity at Tidal Conditions, m/s	0.007	0.007	0.007	0.007	0.009	0.009
Manning's n	0.02					
Ambient Water Density, kg/m^3	1020.43					
Effluent Density, kg/m^3	996.32					
Average Wind Speed, m/s	5.3					

3.3 RESULTS AND DISCUSSION

3.3.1 Effluent Dilution and Mixing

The results for Scenario 1 (single port discharge at Alt-C) are presented in ***Figure 3-2***. A single port discharge characterizes the most conservative mixing conditions because load is concentrated at one point. The plume from the single port reaches the surface water at about 11 m from the diffuser.

Because effluent concentration reduces exponentially with distance from the port, the results are presented in dilution isolines or dilution ratios (***Figure 3-2***). The effluent dilution ratio is 4 times at 5 m from the port and 23 times at the end of the mixing zone (i.e., at 100 m). Dilution is noticeably smaller along the centerline of the plume than radially away from the centerline. Turbulent energy associated with the diffuser jet is the dominant process in the model because the ambient flow velocity is very low. ***Figure 3-2*** presents the plan and side view of the plume, as well as the dilution isolines for the single port diffuser.

The results for Scenario 2 (three ports diffuser at Alt-C) are presented in ***Figure 3-3***. The three ports diffuser scenario shows substantial improvement in near-field dilution and mixing in comparison with Scenario 1. The plume from three ports reaches the surface water at about 60 m from the diffuser. The dilution ratio is 12 times at 5 m from the port and 49 times at the end of the mixing zone (i.e., at 100 m). ***Figure 3-3*** presents the plan and side view of the plume, as well as the dilution isolines for the three ports diffuser.

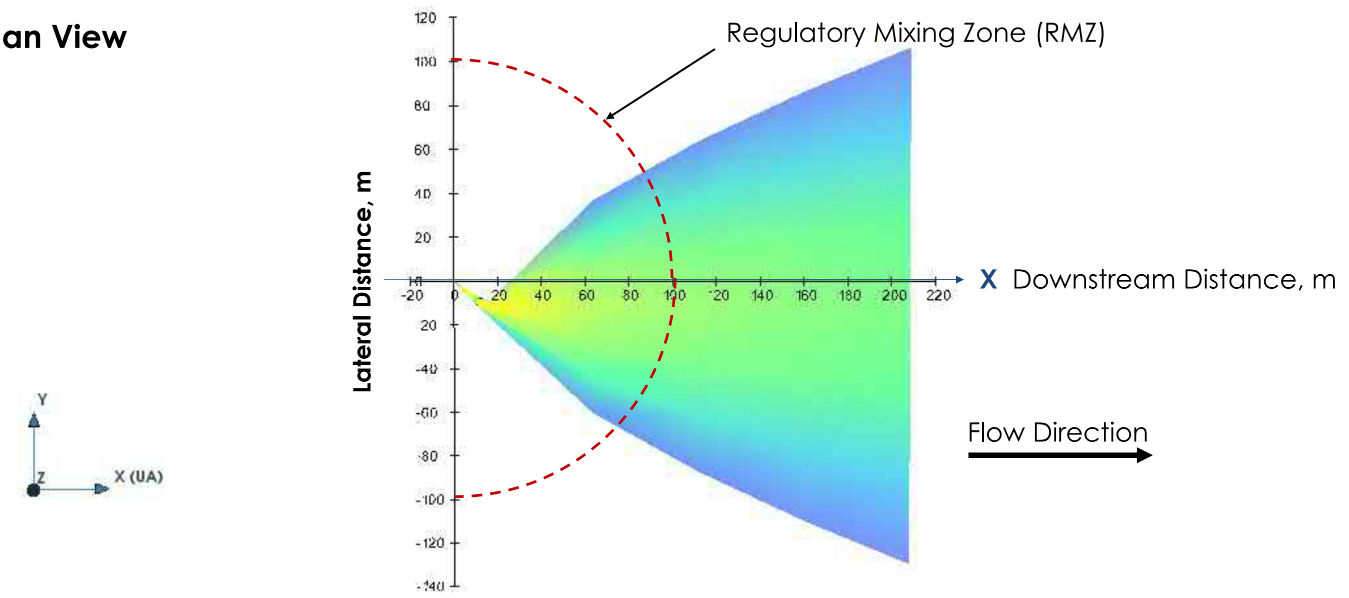
The results for Scenario 3 (six ports diffuser at Alt-C) are presented in ***Figure 3-4***. The six ports scenario shows substantial improvement in near-field dilution and mixing in comparison with Scenario 2. The plume from six ports reaches the surface water at about 80 m from the diffuser. The dilution ratio is 30 times at 5 m from the port and 86 times at the end of the mixing zone (i.e., at 100 m). ***Figure 3-4*** presents the plan and side view of the plume, as well as dilution isolines for the six ports diffuser.

As requested by KSH, an additional modelling scenario was run with the effluent flow rate reduced by 10,000 m^3/day. Scenario 4 (six port diffuser at Alt-C with reduced effluent flow) is presented in ***Figure 3-5***. The plume from six ports reaches the surface water at about 93 m from the diffuser. The dilution ratio is 32 times at 5 m from the port and 96 times at the end of the mixing zone (i.e., at 100 m). ***Figure 3-5*** presents the plan and side view of the plume, as well as dilution isolines for the six ports diffuser with the reduced effluent flow rate. Therefore, reduced flow, as expected, provided more favorable results.

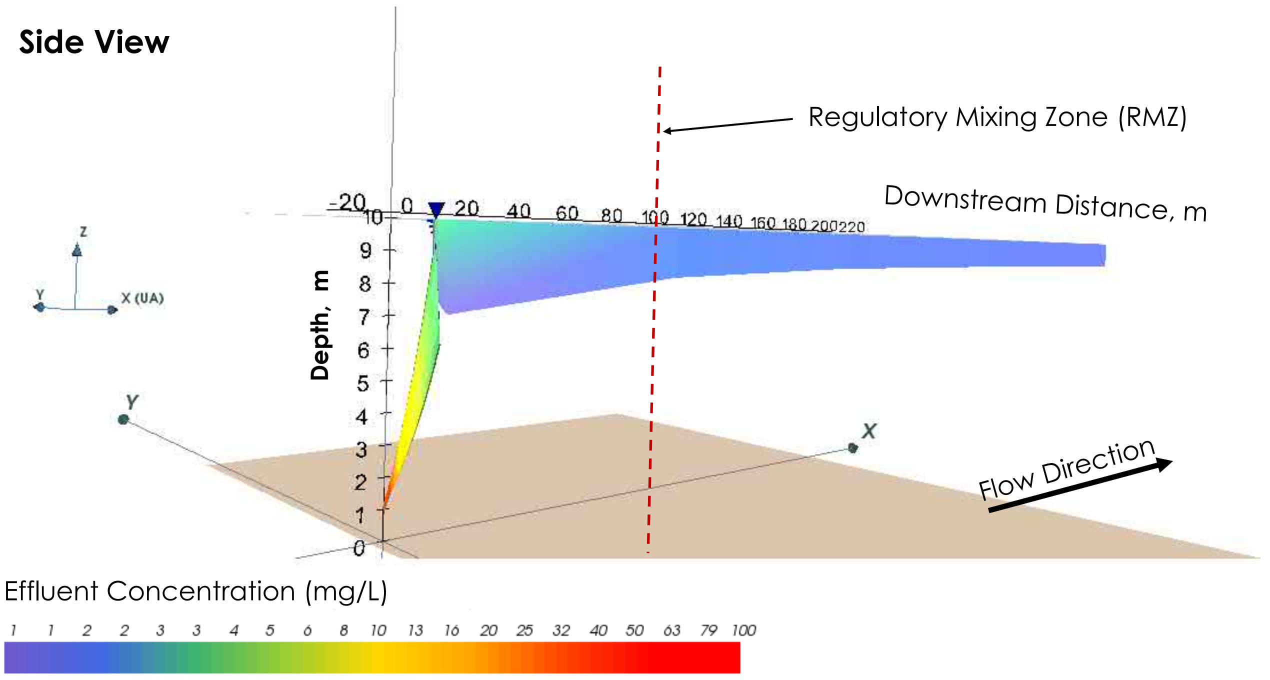
The results for Scenario 5 (three port diffuser at Alt-D) are presented in ***Figure 3-6***. The three-port diffuser scenario for the Alt-D outfall location indicates improvement in near-field dilution and mixing in comparison with the Alt-C location (Scenario 2). The plume at Alt-D reaches the

Figure 3-2. Effluent Plume Scenario 1 - Single Port Diffuser at Alt-C

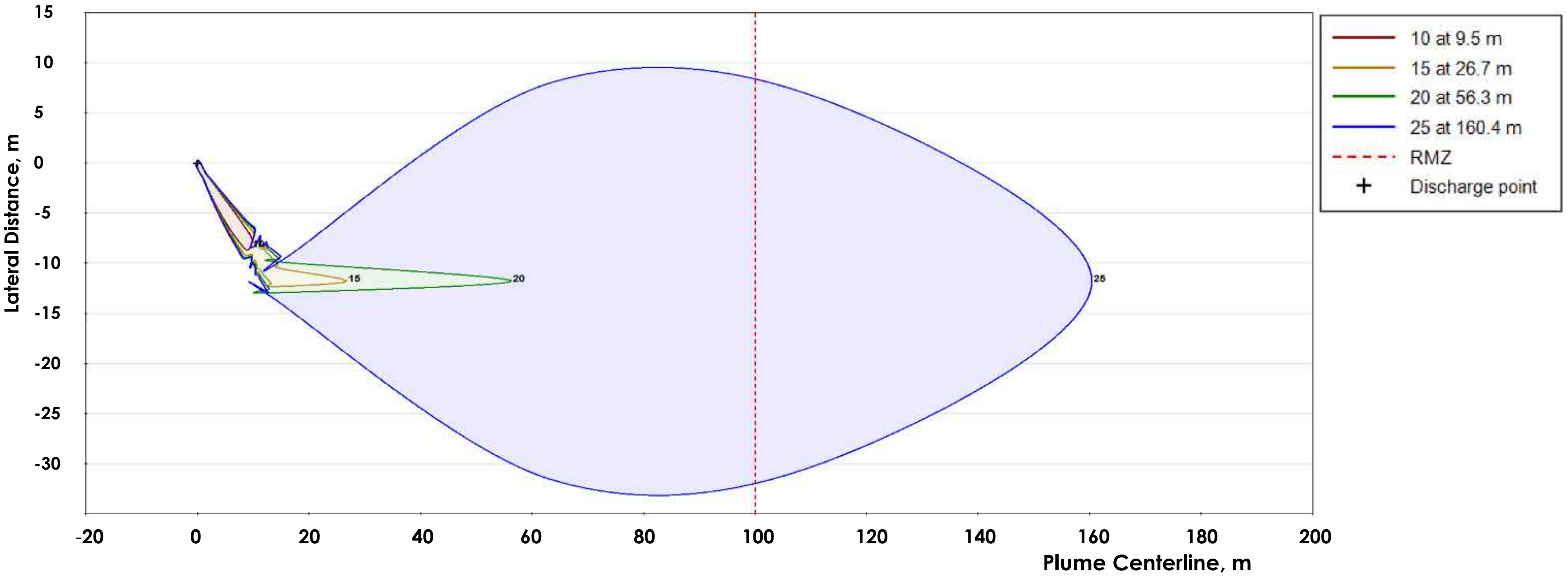
Plan View



Side View



Dilution Isolines



Dilution vs Downstream Distance

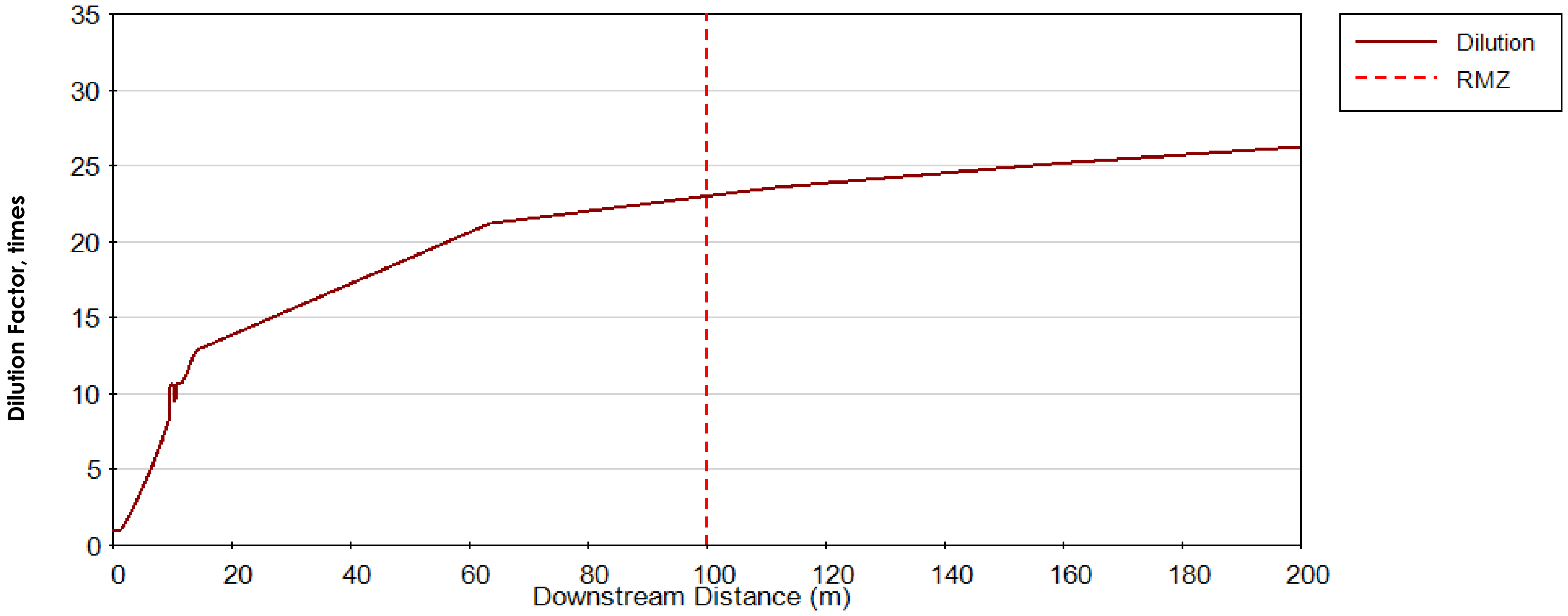
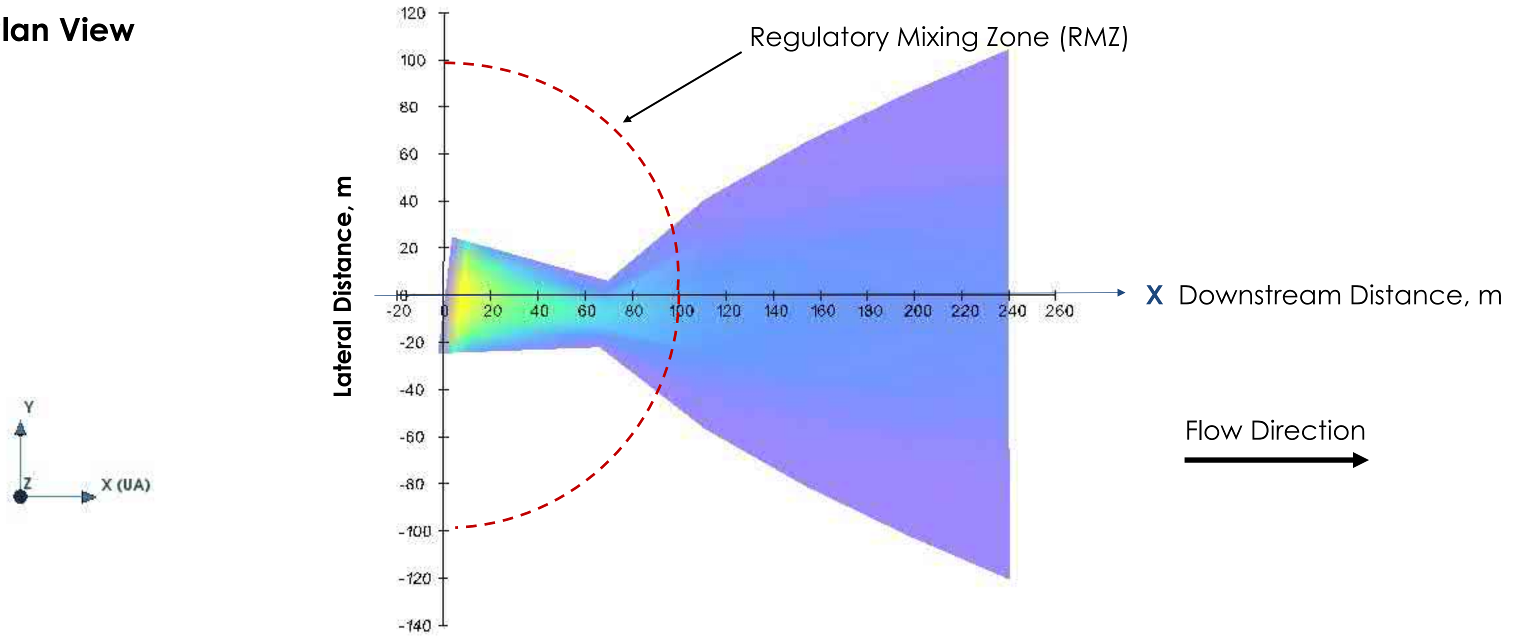
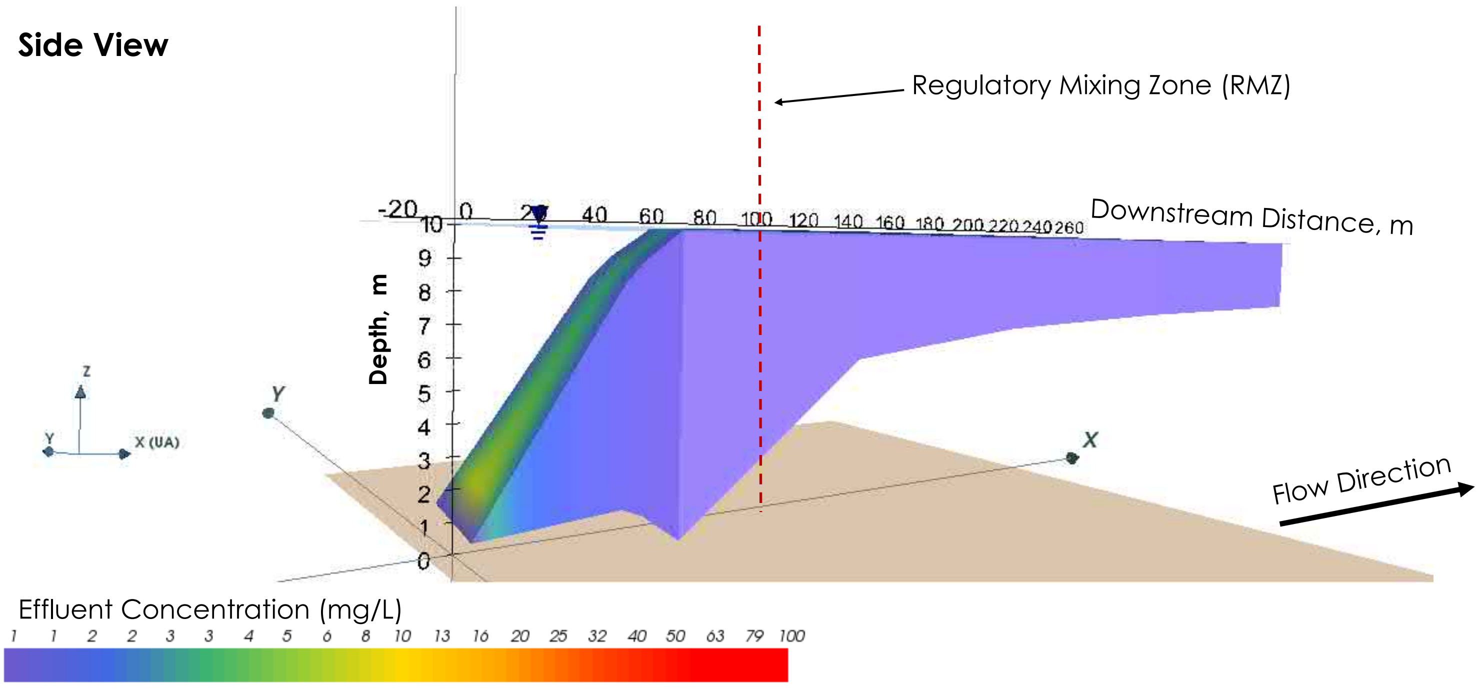


Figure 3-3. Effluent Plume Scenario 2 - Three Ports Diffuser at Alt-C

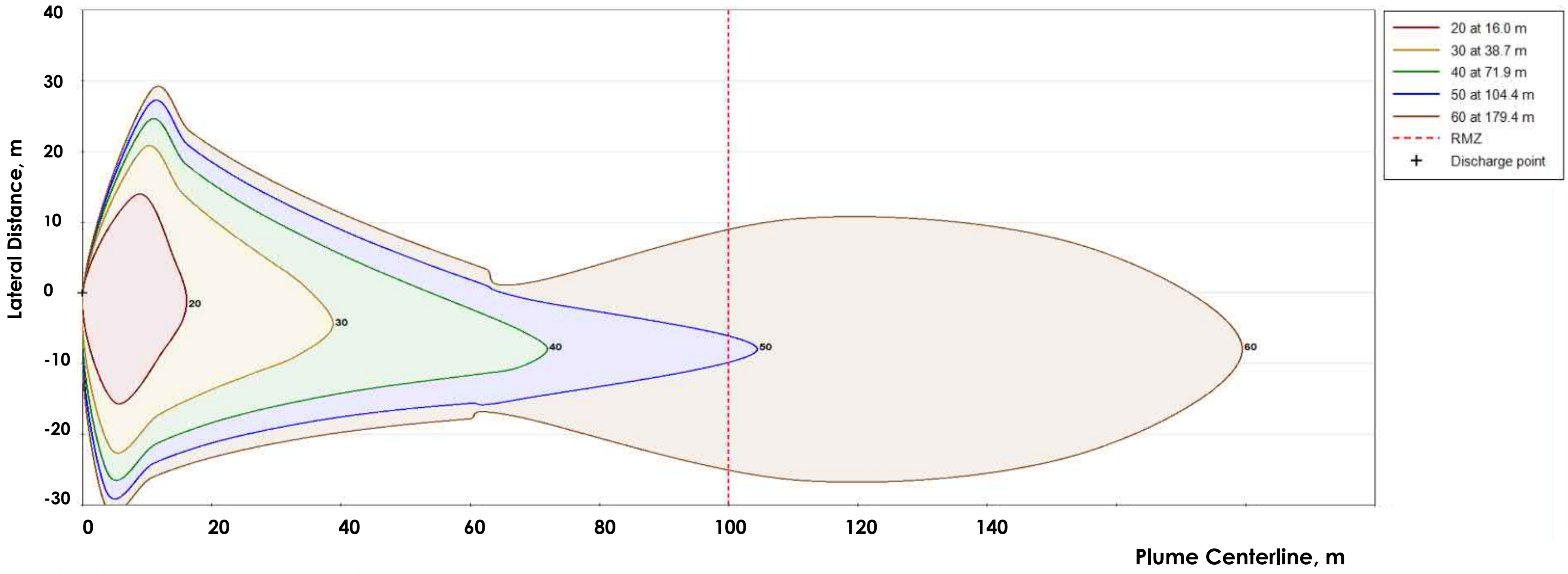
Plan View



Side View



Dilution Isolines



Dilution vs Downstream Distance

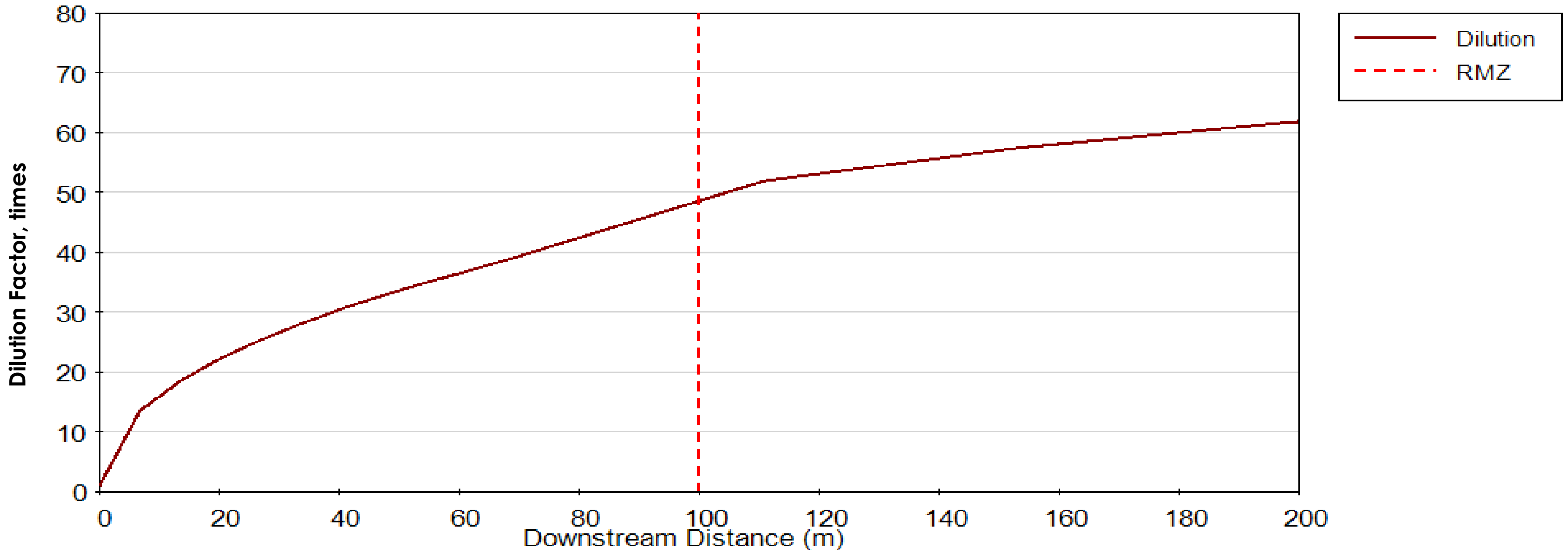
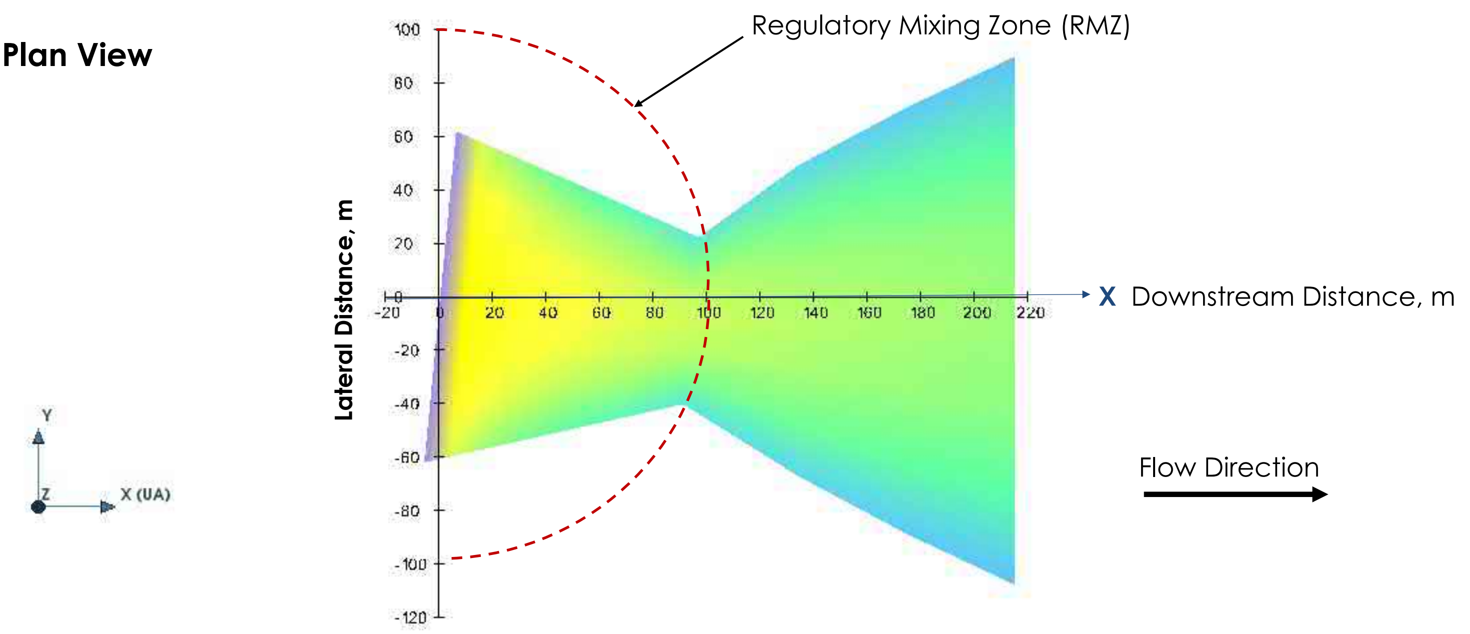
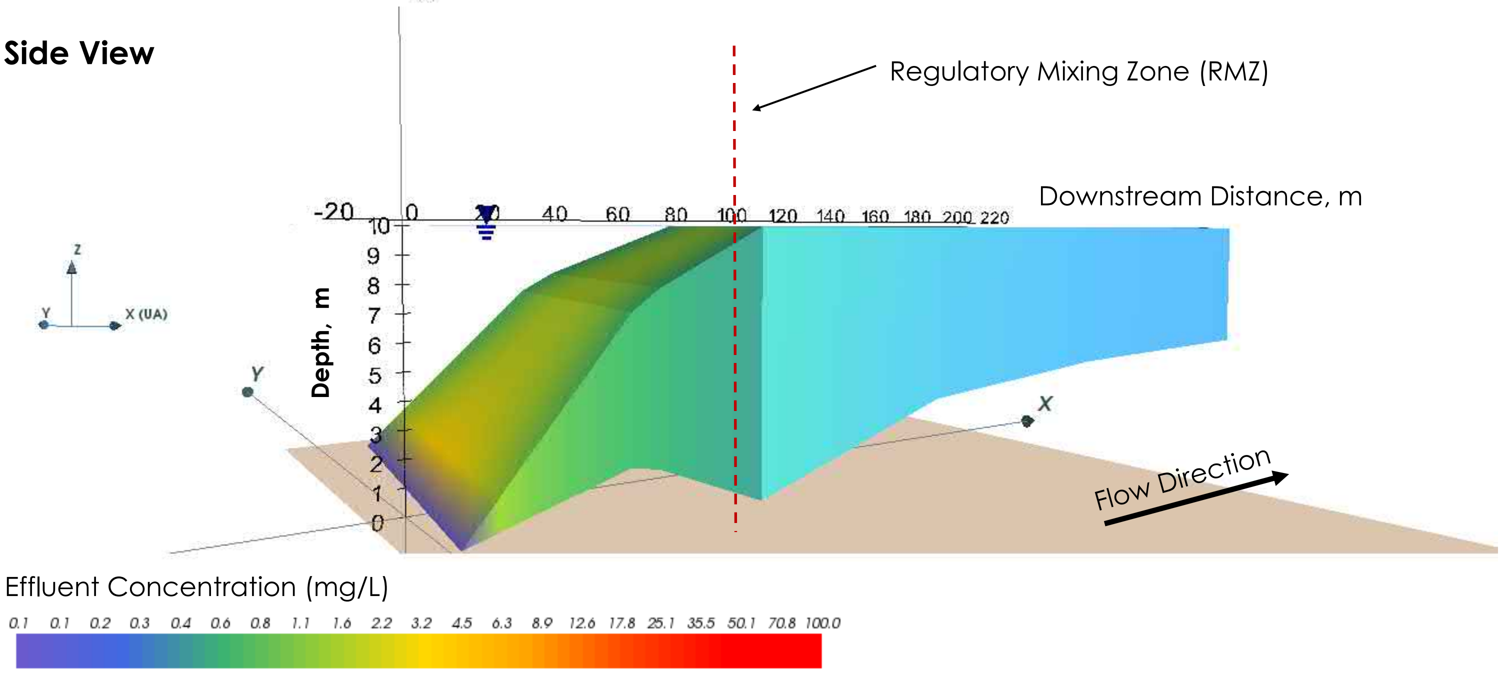


Figure 3-4. Effluent Plume Scenario 3 - Six Ports Diffuser at Alt-C

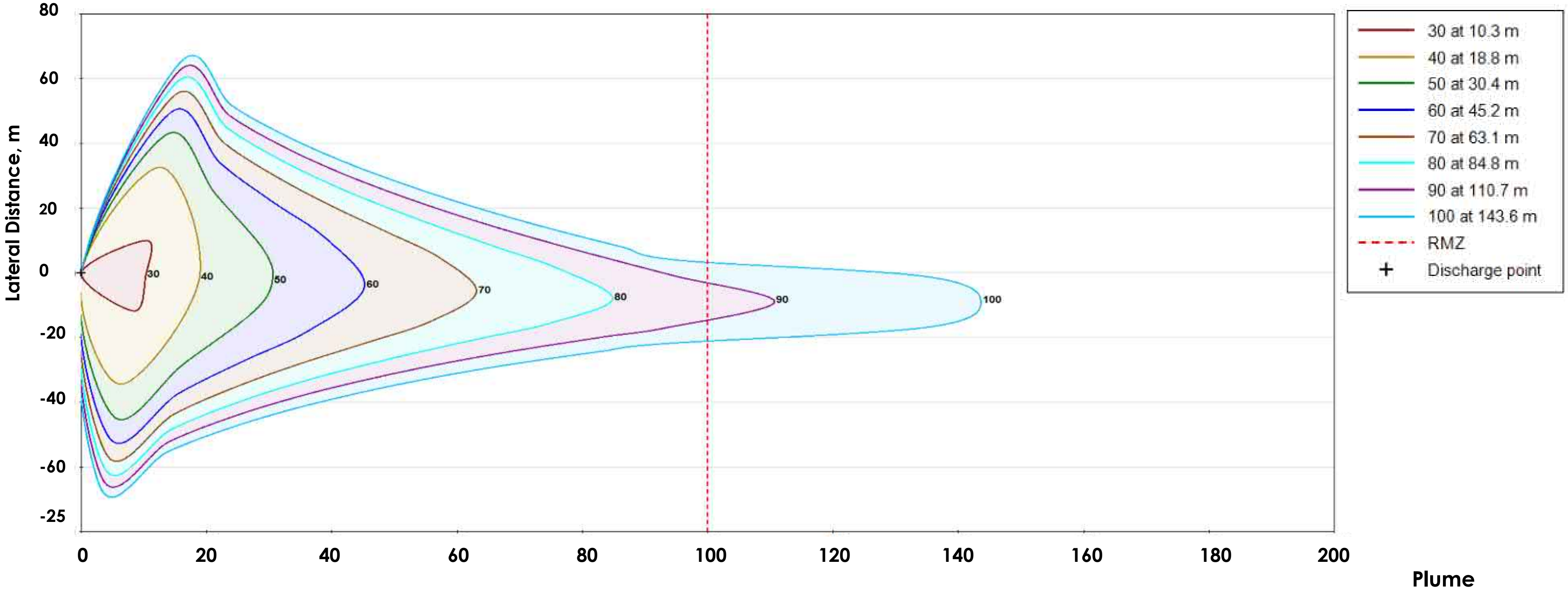
Plan View



Side View



Dilution Isolines



Dilution vs Downstream Distance

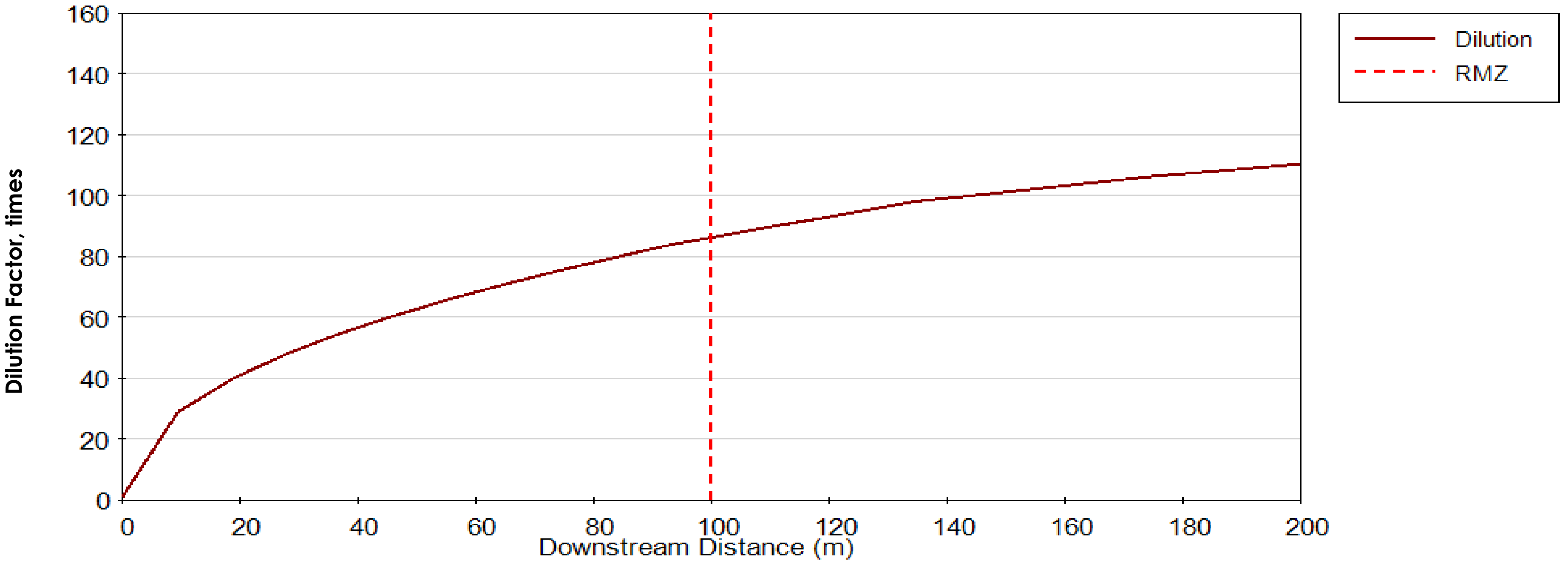
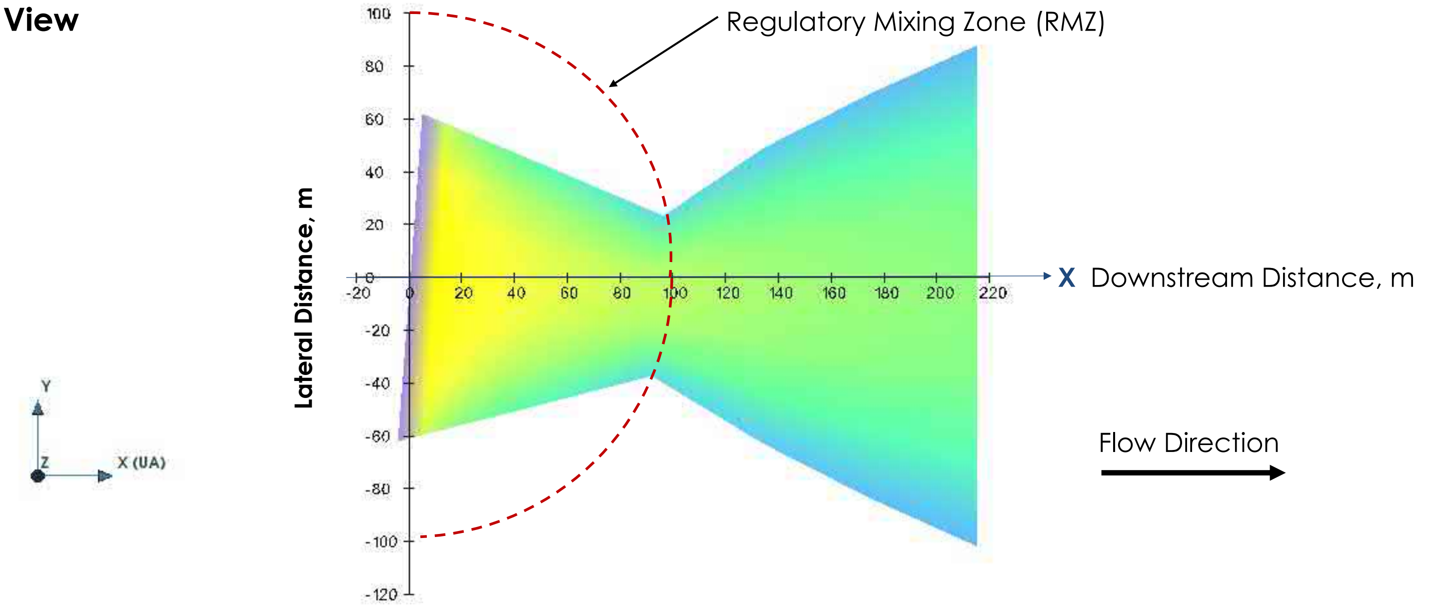
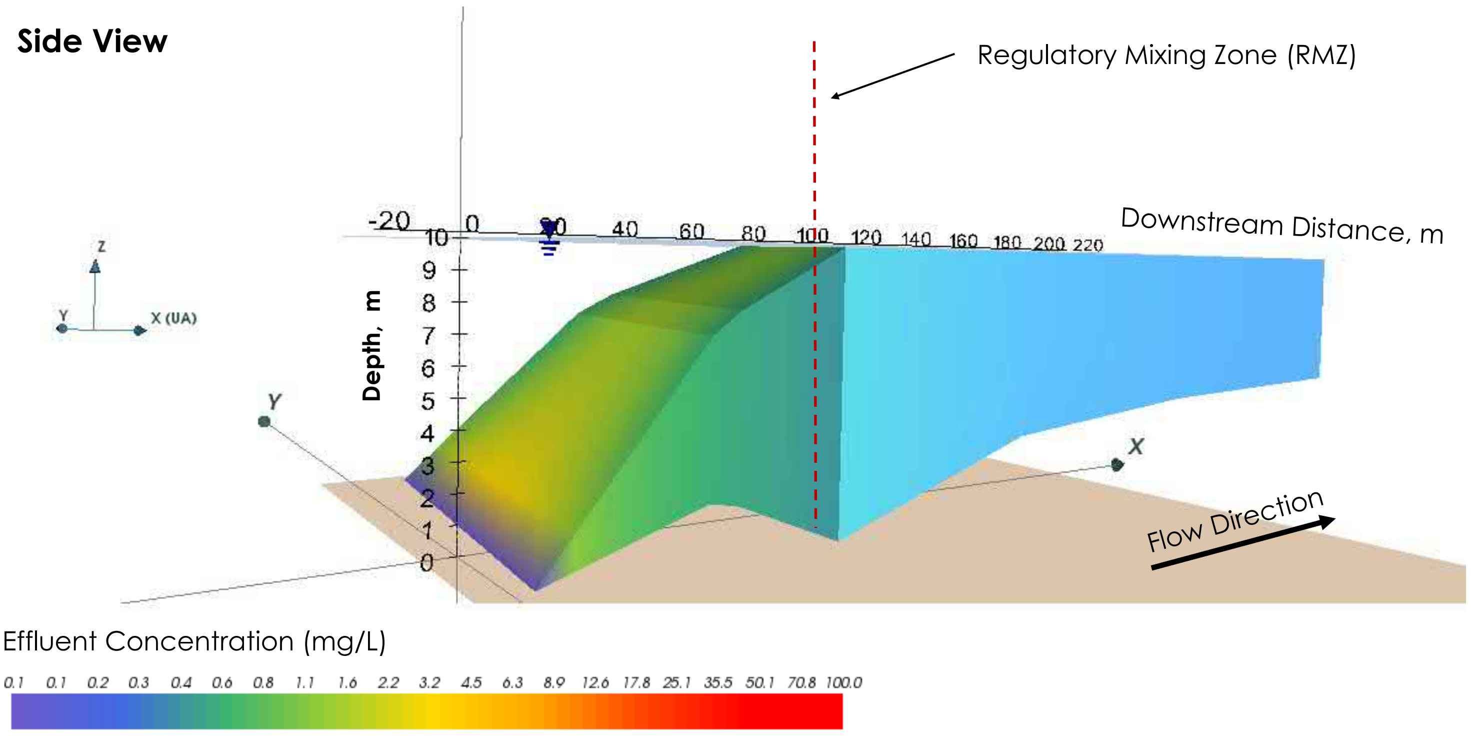


Figure 3-5. Effluent Plume Scenario 4 - Six Ports Diffuser with Reduced Effluent Flow (0.868 m³/s) at Alt-C

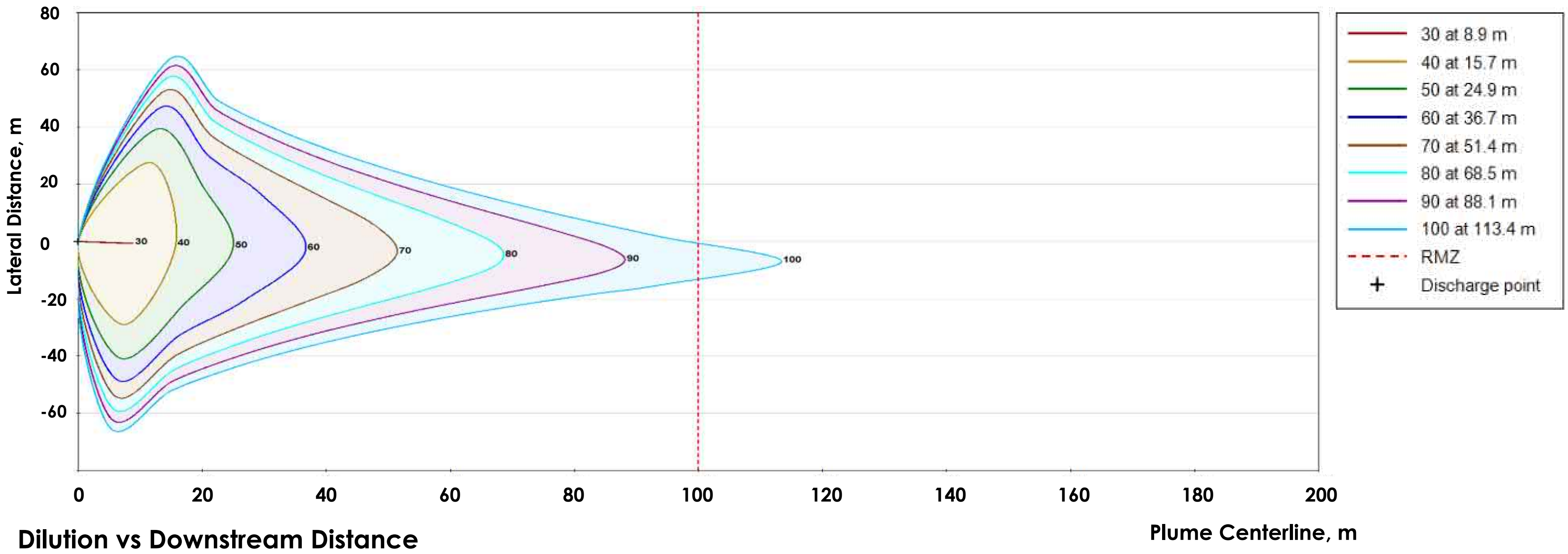
Plan View



Side View



Dilution Isolines



Dilution vs Downstream Distance

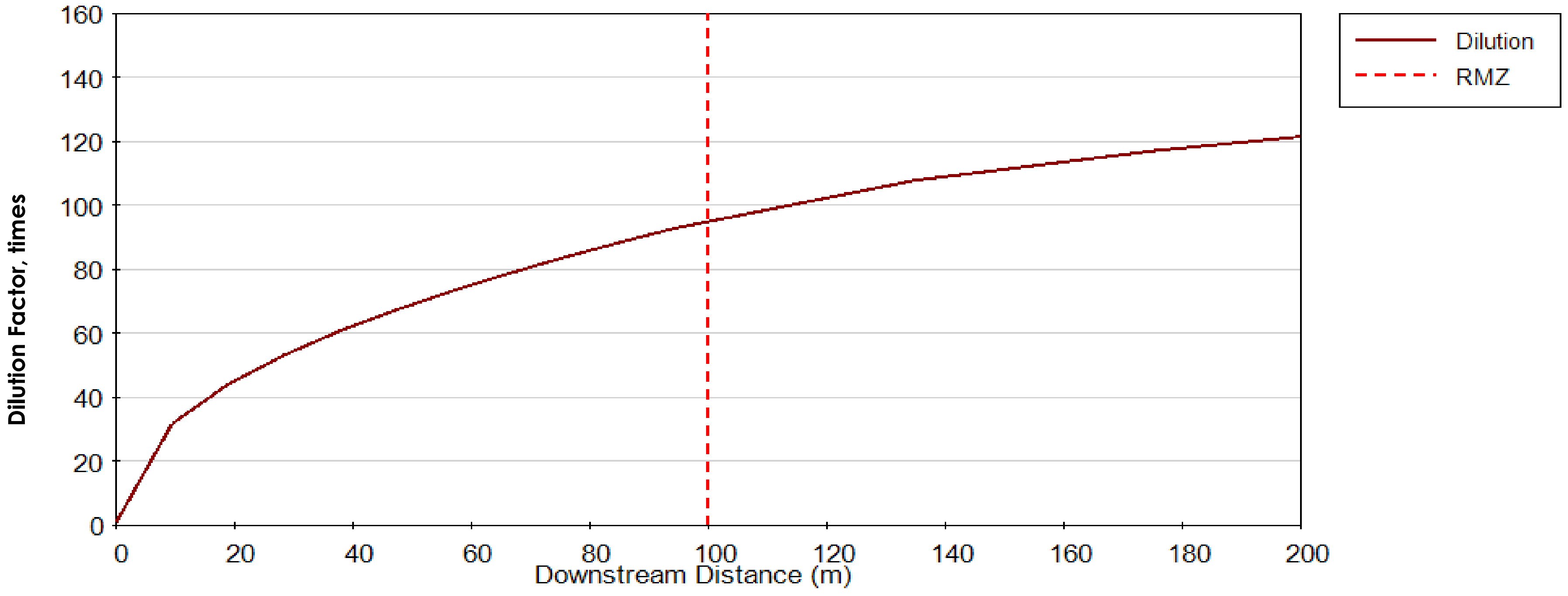
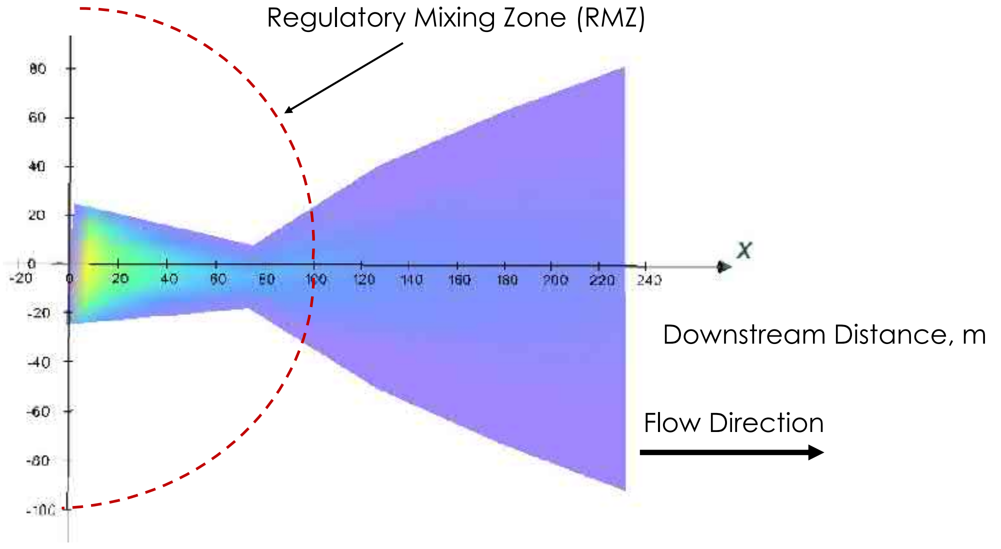
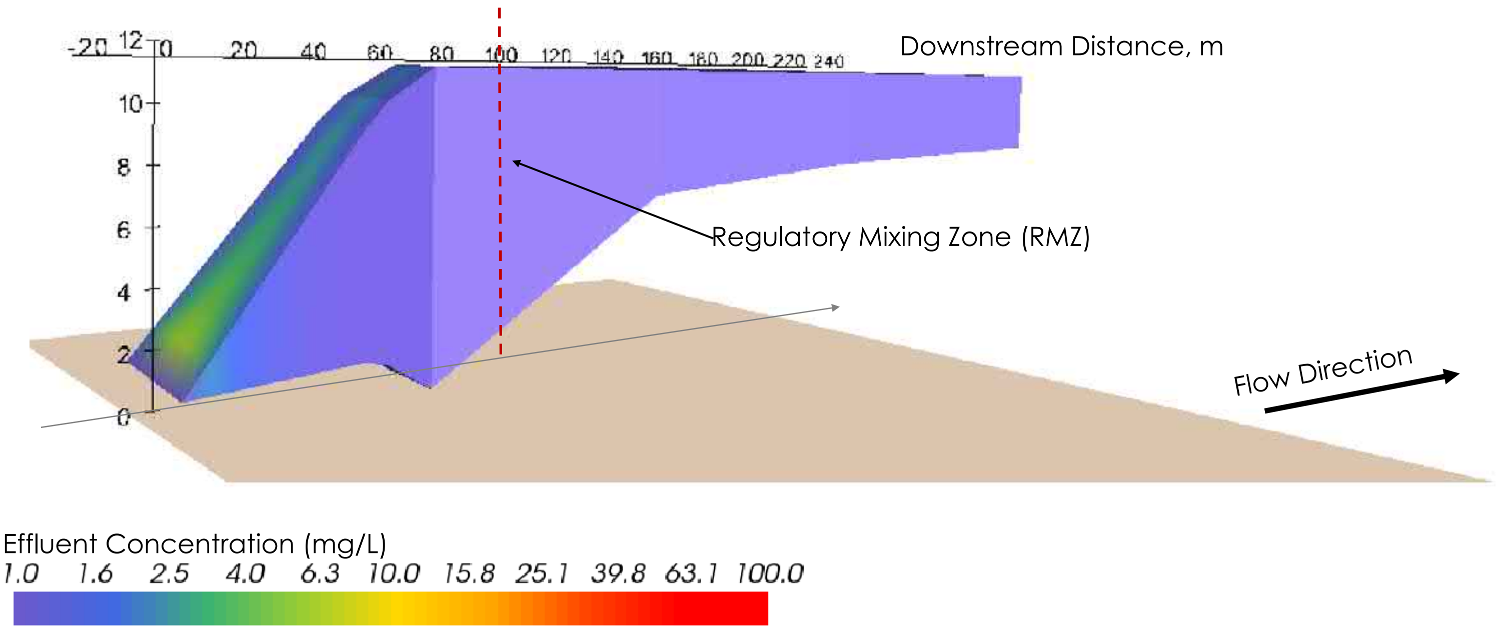


Figure 3-6. Effluent Plume Scenario 5 - Three Ports Diffuser at Alt-D

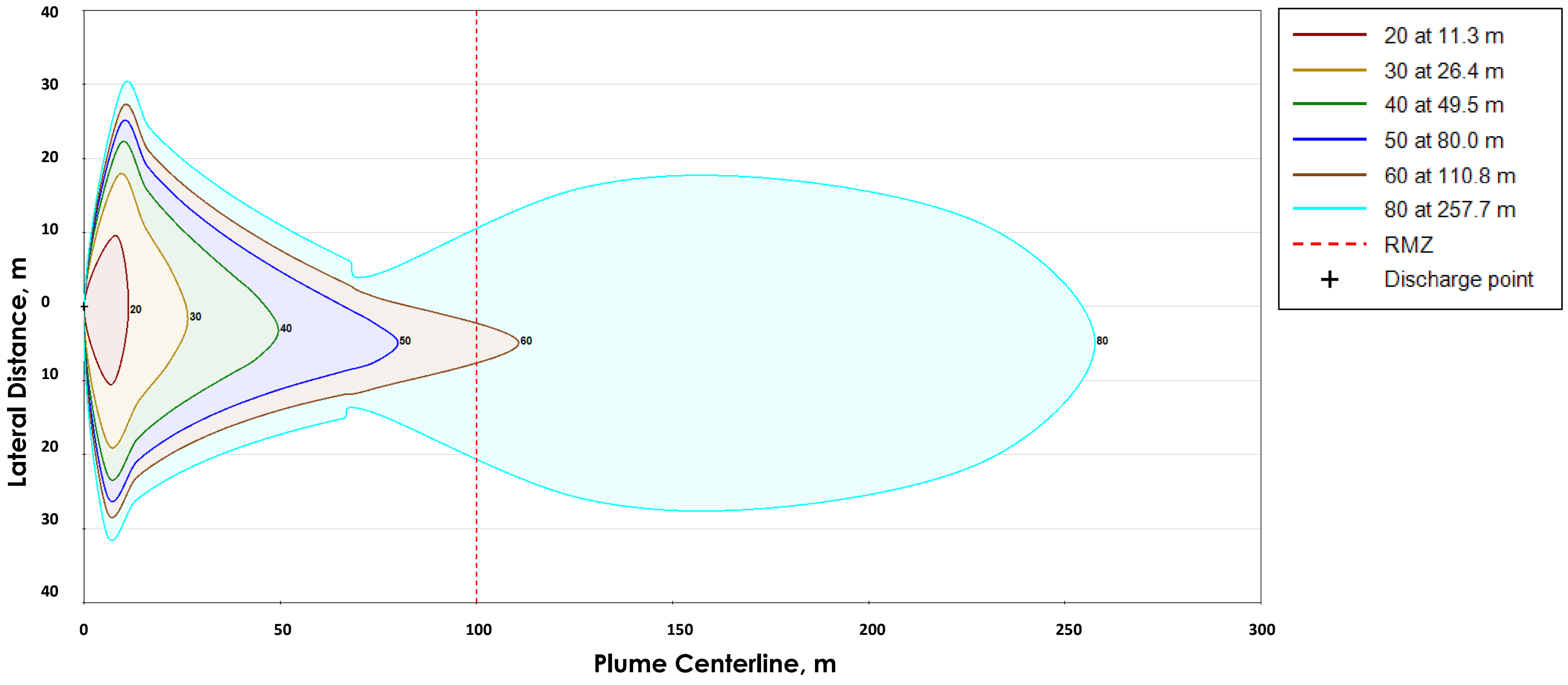
Plan View



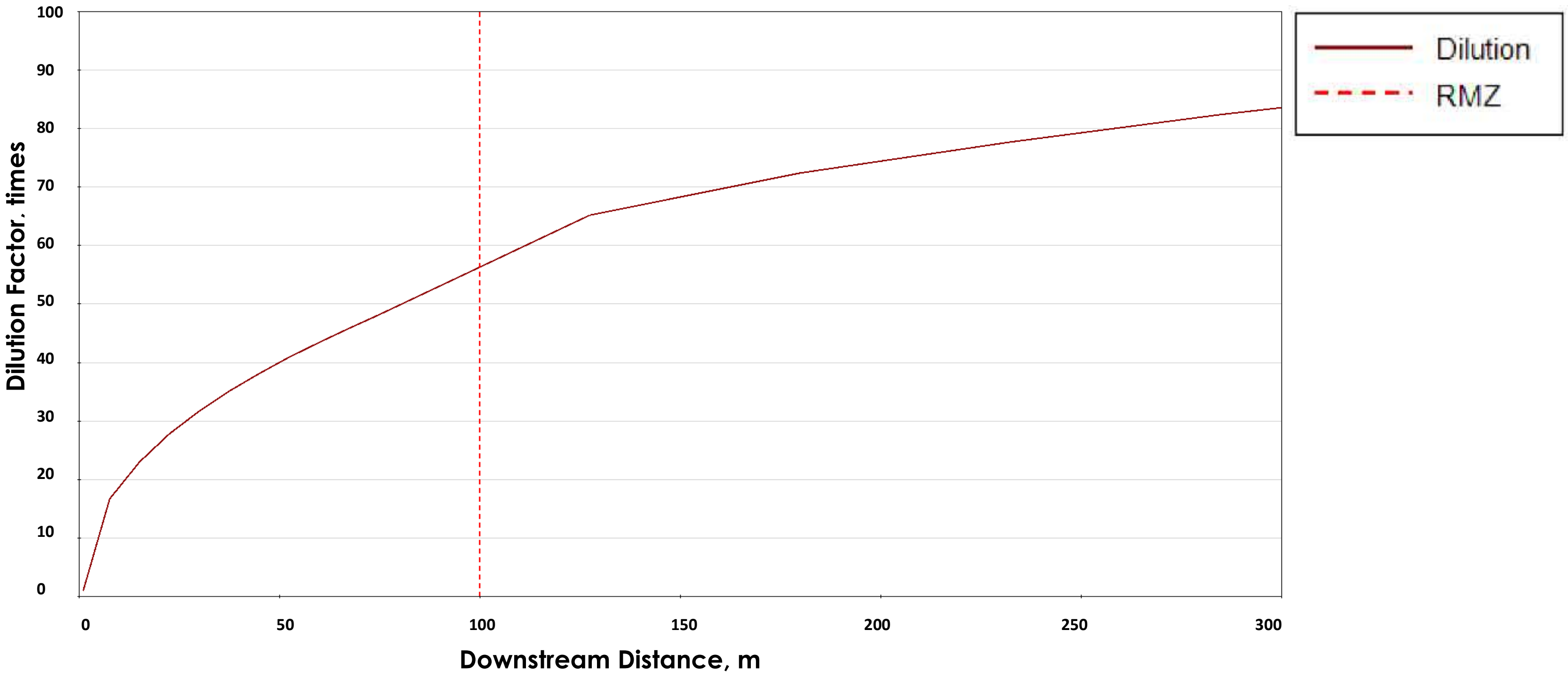
Side View



Dilution Isolines



Dilution vs Downstream Distance



surface at about 70 m from the diffuser in comparison to 60 m for Alt-C with a three port diffuser. The dilution ratio is 18 times at 5 m from the ports and 58 times at the end of the mixing zone (i.e., at 100 m) for Alt-D, compared to a dilution ratio of 12 times at 5 m from the ports and 49 times at the end of the mixing zone for Alt-C (Scenario 2). ***Figure 3-6*** presents the plan and side view of the effluent plume for Alt-D, as well as the dilution isolines for the three port diffuser.

The results for Scenario 6 (six-port diffuser at Alt-D) are presented in ***Figure 3-7***. The six-ports diffuser scenario shows substantial improvement in near-field dilution and mixing in comparison with Scenario 5. The plume from six ports reaches the surface at about 90 m from the diffuser. The dilution ratio is 36 times at 5 m from the port and 109 times at the end of the mixing zone (i.e., at 100 m). ***Figure 3-7*** presents the plan and side view of the plume for Alt-D, as well as the dilution isolines for the six-port diffuser.

Due to port configuration and effluent buoyancy, the plume does not interact to any appreciable extent with the seabed for all scenarios investigated; the plume does touch the seabed for the 3- and 6-port diffusers beyond the 100-m mixing zone where the effluent concentration reduces to less than the regulatory guidelines (i.e. CCME), and therefore not likely to result in potential adverse effects on the benthic environment.

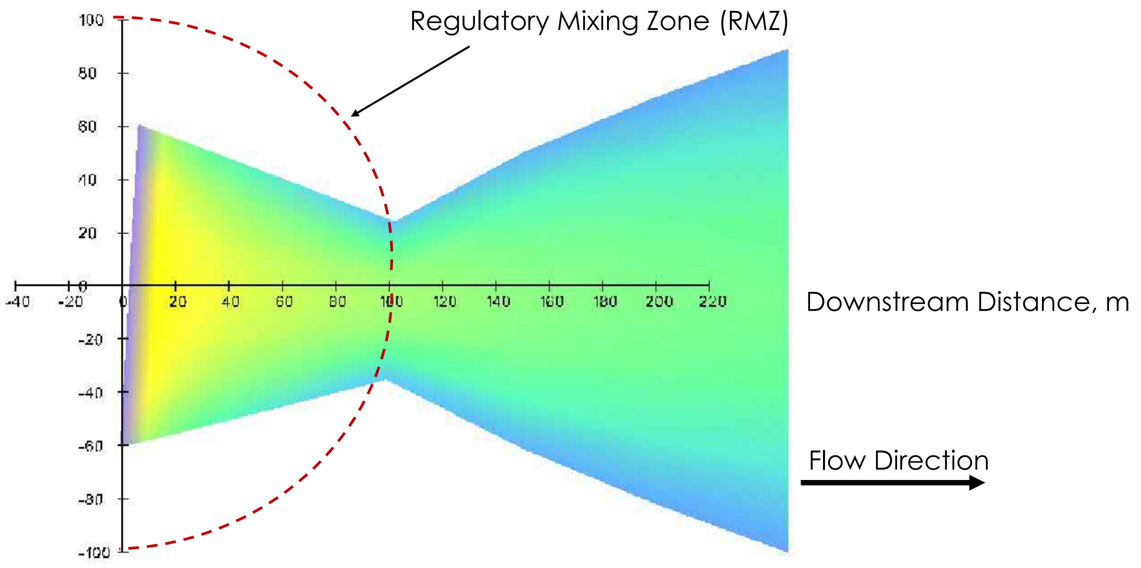
The summary of results for the effluent dilution ratios for the scenarios and diffuser designs is presented in ***Table 3-4***.

Table 3-4 Effluent Dilution Ratios for Various Scenarios

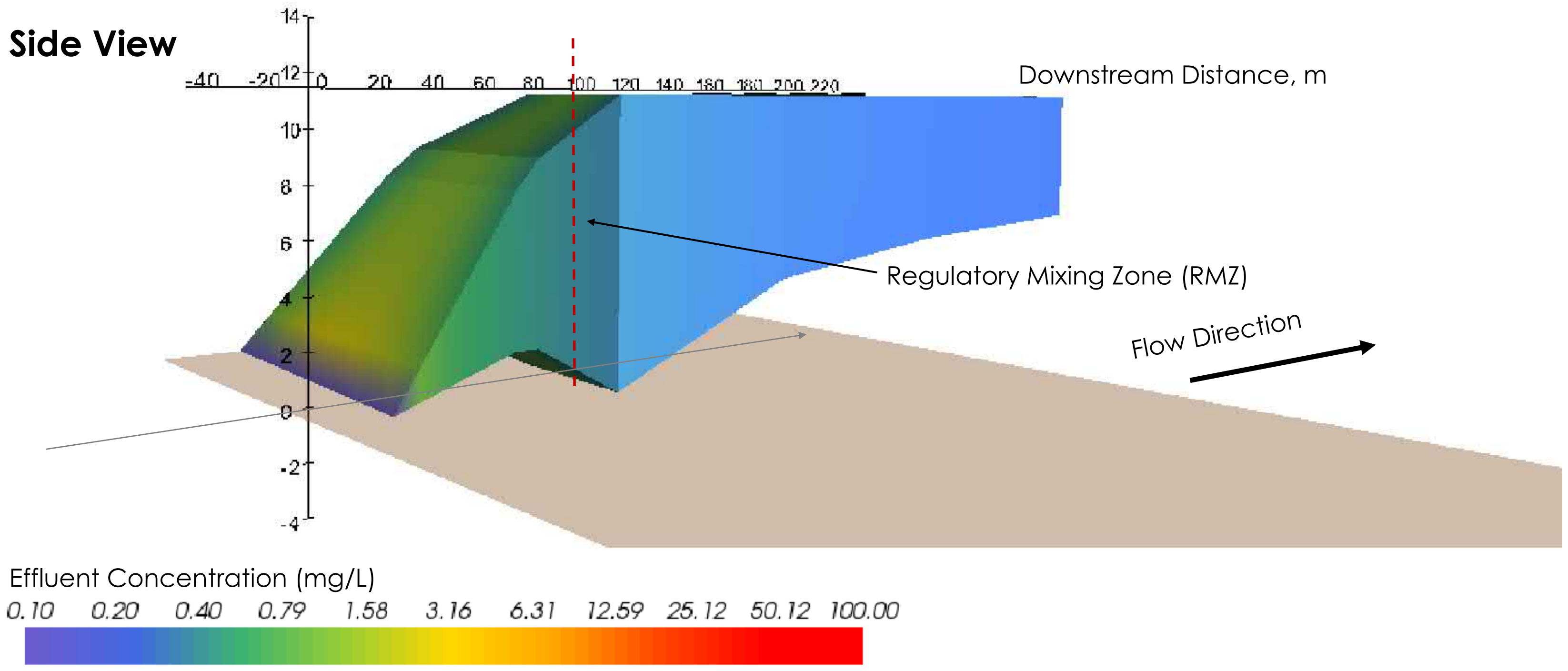
Scenario	**Distance from Diffuser and Dilution Ratio**					
	5 m	10 m	20 m	50 m	100 m	200 m
Scenario 1: Alt-C, Single Port Diffuser	4.1	8.9	14.1	19.0	23.5	25.9
Scenario 2: Alt-C, Three Ports Diffuser	12.3	14.9	19.8	32.8	49.0	64.0
Scenario 3: Alt-C, Six Ports Diffuser	29.6	33.5	41.1	61.4	86.0	110.9
Scenario 4: Alt-C, Six Ports Diffuser with Reduced Effluent Flow	32.5	36.8	45.1	67.5	96.3	122.1
Scenario 5: Alt-D, Three Ports Diffuser	18.1	20.8	25.8	39.5	57.6	75.9
Scenario 6: Alt-D, Six Ports Diffuser	36.3	41.3	50.9	76.7	109.3	135.8

Figure 3-7. Effluent Plume Scenario 6 - Six Ports Diffuser at Alt-D

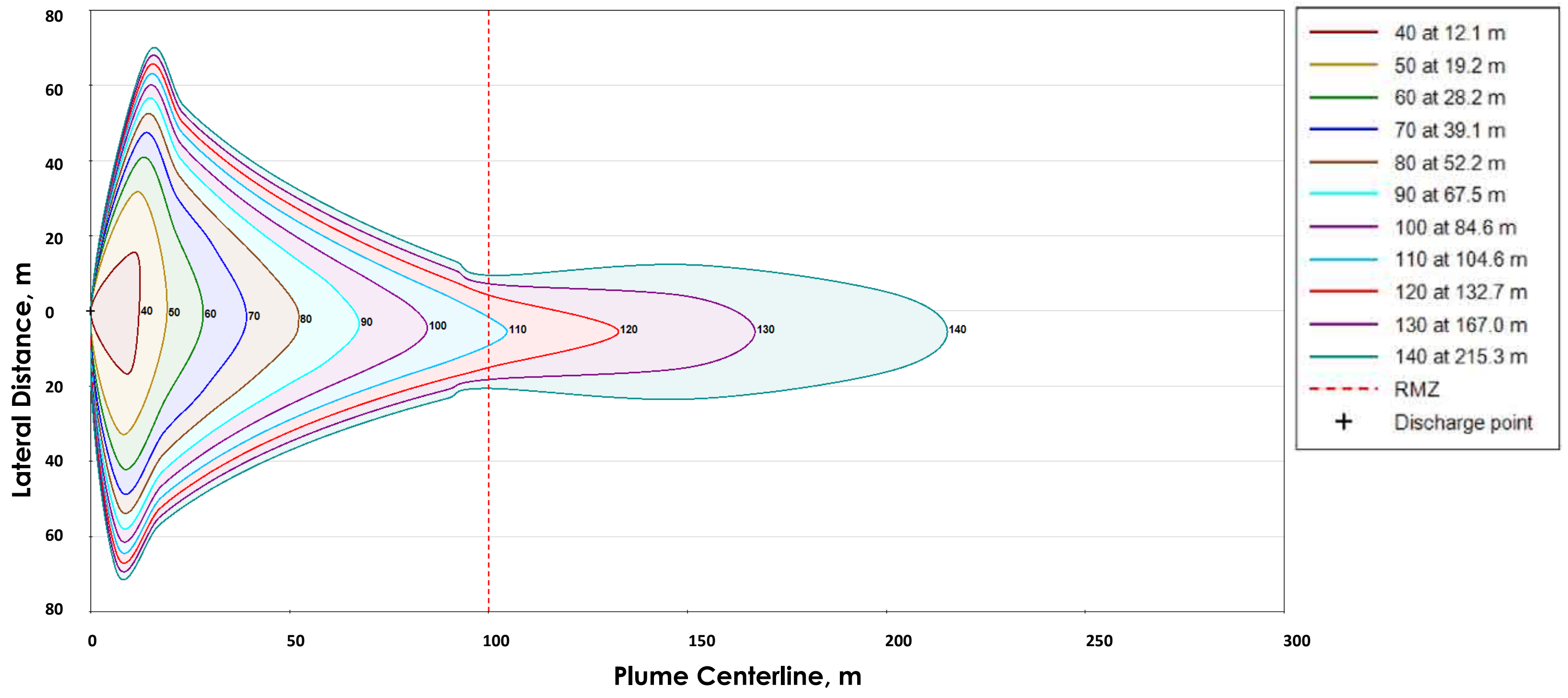
Plan View



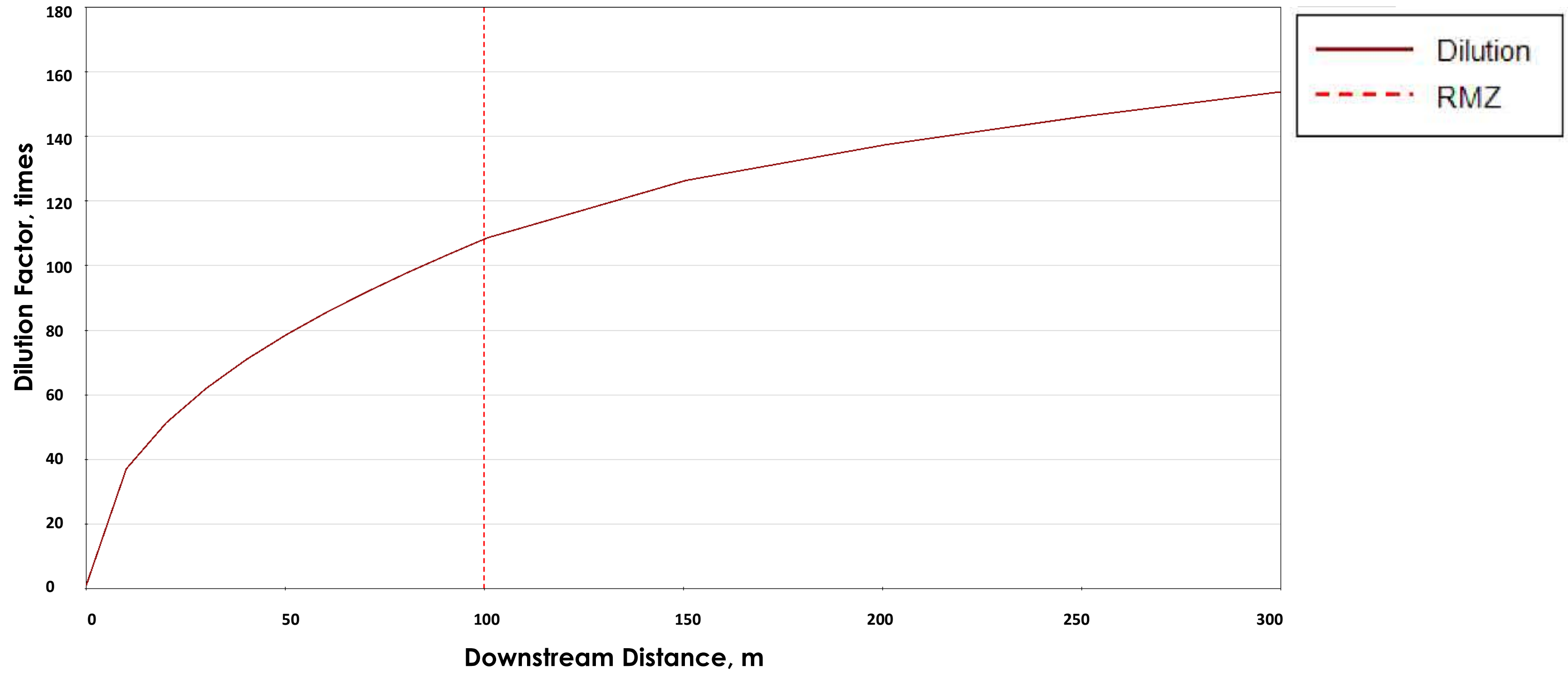
Side View



Dilution Isolines



Dilution vs Downstream Distance



3.3.2 Effluent Water Quality

A 6-port diffuser at Alt-D (Scenario 6) provides much better dilution and mixing of the treated effluent than the single or 3-port diffuser. Therefore, the 6-port diffuser at Alt-D with a daily maximum effluent flow rate of 0.98 m^3/s (85,000 m^3/day) was used to characterize water quality in the mixing zone which is presented in the sections below.

Water quality parameters studied in the mill treated effluent are adsorbable organic halides (AOX), total nitrogen (TN), total phosphorus (TP), colour, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), dissolved oxygen (DO), pH, and water temperature.

3.3.2.1 Adsorbable Organic Halides

Adsorbable organic halides (AOX) is a sum parameter for describing the organic halogen compound load in treated wastewater. AOX covers a large group of organic constituents from simple volatile substances such as chloroform, to complex organic molecules such as dioxins/furans. Most AOXs are chlorine-containing molecules. AOX compounds pose a potential concern for estuarine environment because they have long half-life periods. There are no CCME or provincial guidelines for AOX for marine or freshwater environments.

Data for AOX in Pictou Harbour are not available; however, it is expected that the AOX ambient concentrations are negligible. Proposed daily maximum AOX concentration in the effluent is 7.8 mg/L, which is substantially less than the World Bank guideline of 40 mg/L as the maximum limit for pulp mill effluents discharging into surface waters and slightly less than the 8 mg/L limit target objective for retrofit mills (World Bank 1998). For the NPNS mill effluent discharged through a 6-port diffuser at Alt-D, and conservatively assuming no decay, sedimentation or any other form of transformation of organic halides in the receiving environment, the resulting AOX concentration at the edge of the 100-m mixing zone is 0.07 mg/L.

This concentration of AOX is slightly more than the US EPA drinking water standard of 0.06 mg/L (USEPA 1994) at the 100 m boundary limit. However, drinking water guidelines are generally more stringent than marine water quality standards applicable to the outfall. Moreover, CCME guidelines are generally stricter for a freshwater environment when guidelines are also available in the marine environment for the same parameter (e.g. metals or some organochlorine pesticides) or chlorinated benzenes such as monochlorobenzene (e.g. fresh water limit is 1.2 µg/L, marine limit is 25 µg/L). Also, guidelines in some cases are available for freshwater environments but not for marine environments because of insufficient data to substantiate toxicity. An example for the latter includes guidelines for chlorinated organic compounds, which includes AOX, such as organic halogenated compounds (chloroethanes) or organic aromatic compounds (chlorinated phenols).

3.3.2.2 Total Nitrogen

Total nitrogen (TN) is a concern in the nearshore areas because abundance of this nutrient in the water can result in excessive algal growth that, in severe cases, can lead to anoxic conditions and obnoxious odours. Ambient concentrations of TN in Pictou Road vary between 0.025 mg/L and 0.969 mg/L with an average of 0.24 mg/L (**Appendix B**).

The CCME marine guideline for the protection of aquatic life for the nitrate ion is 45 mg/L (NO_3^- as N) for long term exposure and 339 mg/L (NO_3^- as N) for short term exposure.

Proposed daily maximum TN concentration in the effluent is 3.0 mg/L. At this concentration, TN is below the CCME marine guideline limit for the nitrate ion, which is a component and nitrogen form that contributes to the concentration of TN. A dilution ratio of 12.5 is required to reduce the effluent concentration of TN to background levels. This dilution ratio is achieved in the immediate vicinity (< 2 m) of the diffuser.

3.3.2.3 Total Phosphorus

Total phosphorus (TP) is a measure of both inorganic and organic forms of phosphorus. Both forms are essential nutrients for plant growth, however high concentrations of total phosphorus in the marine environment may result in excessive diatom algal growth followed by their settling and decay in sediments.

CCME has not established a guideline for total phosphorus in the marine environment because it is not considered a directly ‘toxic substance’, rather it has secondary effects such as eutrophication and oxygen depletion.

Ambient concentrations of TP in the Pictou Road area vary between 0.015 mg/L (½ the laboratory detection limit) to 1.45 mg/L, with an average of 0.35 mg/L (**Appendix B**).

Proposed daily maximum TP concentration in the effluent is 1.5 mg/L. A dilution ratio of 4 is required to reduce the effluent concentration to background levels. This dilution ratio is achieved in the immediate vicinity (< 2 m) of the diffuser.

3.3.2.4 Colour

The observed colour of water is the result of light scattered upward from the water after it has passed through water depth and undergone selective absorption. Colour and turbidity determine the depth to which light penetrates the water. The presence of decaying organic material or inorganic contaminants impact the colour. Colour is measured and reported in true colour units (TCU). A colour of 15 TCU can be detected in a glass of water by most people and it is the aesthetic objective of the Canadian drinking water guidelines (Health Canada, 1995).

CCME has not established a guideline for colour in the marine environment because in many cases colour is a site-specific parameter. Ambient concentrations of colour at a distance from Lighthouse Beach vary between 9.5 TCU and 12 TCU with an average of 10.8 TCU (**Appendix B**).

Proposed daily maximum colour concentration in the effluent is 750 TCU. A dilution ratio of 69 is required to reduce the effluent concentration to a background value of 10.8 TCU, which is lower than the detectable limit by the naked eye (i.e., 15 TCU). This dilution ratio is achieved about 40 m from the diffuser.

3.3.2.5 BOD

Biochemical oxygen demand (BOD) refers to the amount of oxygen that would be consumed if all organic material in one liter of a sample were oxidized. BOD directly affects the amount of dissolved oxygen in the mixing zone. Because organic matter needs varying time spans to be oxidized, a standard procedure is to use a 5-day incubation at 20°C which is referred to as BOD_5. There are no CCME or provincial guidelines for BOD. McNeeley et al. (1979) consider waters with BOD_5 less than 4 mg/L to be reasonably clean.

No data are available for BOD_5 in Pictou Harbour. Proposed daily maximum BOD_5 concentration in the effluent is 48 mg/L. Conservatively assuming no decay, sedimentation or any other form of transformation of organic matter, the resulting BOD_5 concentration at the edge of the 100-m mixing zone will be background or a concentration of 0.4 mg/L.

3.3.2.6 COD

Chemical oxygen demand (COD) is a measure of oxygen required to chemically oxidize organic matter and some inorganic materials. Based on communication with KSH, a conversion factor from BOD_5 to COD for the mill effluent is 21.74. A BOD/COD relationship is relatively constant in the effluent and often for wastewater treatment plants only the COD concentration is measured and then the BOD is calculated. COD is only measured because BOD analysis requires a 5-day incubation period and extensive sampling preparation. The COD analysis can be completed in 2 hours, which is critical for continuous effluent monitoring.

Data for COD in Pictou Harbour are not available. Proposed daily maximum COD concentration in the effluent is 725 mg/L. Conservatively assuming no decay, sedimentation or any other form of transformation of organic matter, the resulting COD concentration at the edge of the 100-m mixing zone will be 6.6 mg/L. Natural waters with concentrations of COD less than 20 mg/L are generally considered unpolluted (UNESCO 1996).

3.3.2.7 TSS

Total suspended solids (TSS) consists of silt, clay, fine particles of organic and inorganic matter, plankton, and other microscopic organisms. In estuarine waters a substantial proportion of suspended particles come from the resuspension of fine, unconsolidated sediments and detritus by wave action and currents.

The marine CCME limit for TSS for longer-term exposures (e.g., inputs lasting between 24 h and 30 d) is the maximum average increase of 5 mg/L from background levels. Ambient concentrations of TSS in the Pictou Road area and Lighthouse Beach site vary between 2.5 and 36 mg/L with an average of 8.5 mg/L (**Appendix B**).

Proposed daily maximum TSS concentration in the effluent is 48 mg/L. The water quality limit for a TSS concentration of 13.5 mg/L (background 8.5 mg/L + CCME threshold of 5 mg/L) is achieved in the immediate vicinity (< 2 m) of the diffuser.

3.3.2.8 Dissolved oxygen

Dissolved oxygen (DO) is essential for the respiration of most marine and estuarine organisms. The amount of oxygen in seawater depends on salinity, water temperature, atmospheric exchange, barometric pressure, currents, tides, ice cover, and biological processes (e.g., respiration and photosynthesis).

CCME recommends a minimum concentration of DO in marine and estuarine waters of 8.0 mg/L. When the natural DO level is less than the recommended guideline, the natural concentration becomes the site-specific guideline.

Ambient concentrations of DO in the Pictou Road area vary between 6.4 and 8.1 mg/L with an average of 7.2 mg/L (**Appendix B**).

Proposed daily maximum DO concentration in the effluent is > 1.5 mg/L. It is expected that due to the high jet velocity (4 to 6 m/s), dynamic ambient hydrodynamic conditions (agitation of water attributed to wind, tides, and waves) and substantial mass of ambient water (water depths are >11.3 m), the DO levels in the effluent will improve to background concentrations at the end of the mixing zone. This is also supported on the basis of substantial mixing achieved at the end of the mixing zone as described above.

3.3.2.9 pH

The pH of marine and estuarine waters should fall within the range of 7.0 to 8.7 units unless it can be demonstrated that such a pH is a result of natural processes (CCME, 2003). Within this range, pH should not vary by more than 0.2 pH units from the natural pH expected at that time.

Ambient concentrations of pH in the Pictou Road area vary between 7.9 and 8.1 mg/L with an average of 8.0 mg/L (**Appendix B**).

Proposed daily maximum pH in the effluent is in a range of 7 to 8.5. Due to substantial initial mixing after the effluent is discharged from the diffuser, the effluent pH is expected to reach ambient pH in the immediate vicinity of the diffuser (< 5 m).

3.3.2.10 Water temperature

Human activities should not cause changes in ambient temperature of marine and estuarine water to exceed ±1°C at any time, location, or depth (CCME 2003). The natural temperature cycle of the site should not be altered in amplitude or frequency by human activities (CCME 2003).

Ambient summer temperature in the Pictou Road area varies between 15.9 and 19.4°C (average 17.6°C) in summer and around 0 to 0.34 °C (average 0.16 °C) in winter (**Appendix B**). Maximum effluent temperature is 37°C in summer and 25°C in winter. Potential thermal impacts of the treated effluent on the thermal regime of Pictou Harbour were modelled using CORMIX. The results demonstrate that during winter conditions assuming conservative scenario, when effluent temperature is 25°C and ambient water temperature is 0°C, the CCME guideline limits (i.e., 1°C differential) are met within approximately 8 m of the diffuser. CORMIX shows that the heated effluent quickly mixes with ambient water and effluent temperature exponentially drops within several metres from the diffuser. After 8 m, the temperature drop decreases substantially and at 100 m the effluent plume temperature is 0.2 °C above background.

The effluent water temperature will meet the CCME guidelines within 8 m of the diffuser. As a result of the diffuser configuration and the warm temperature of the effluent, the plume will rise and the warm effluent will not come into contact with the seabed. Therefore, it is anticipated that thermal impacts are not likely to result in potential adverse effects on the benthic environment.

Table 3-5 summarizes water quality at the end of the mixing zone for the Alt-D location with a 6-port diffuser and for a maximum daily effluent flow rate of 85,000 m^3/day. For comparison purposes, the water quality at Alt-C for the same diffuser design and effluent flow rate is also provided in ***Table 3-5***. It can be observed in ***Table 3-5*** that most of the effluent water quality parameters have similar concentrations at the end of the 100-m mixing zone for both the Alt-C and Alt-D outfall locations, even though the dilution ratios with distance from the diffuser are higher for Alt-D (refer to ***Table 3-4***). However, based on the 2D modelling results, the longer-term far-field dispersion and dilution of the effluent is better at the Alt-D discharge location.

Table 3-5 Water Quality at the End of the Mixing Zone for a 6-port Diffuser at Alt-C and Alt-D

Parameter	Unit	Effluent Daily Maximum	CCME, Marine Guideline	Ambient Conditions	Alt-C End of Mixing Zone at 100 m from Diffuser	Alt-D End of Mixing Zone at 100 m from Diffuser
Adsorbable Organic Halides (AOX)	mg/L	7.8	n/a	n/a	0.09	0.07
Total Nitrogen (TN)	mg/L	3.0	45[1]	0.24	0.24	0.24
Total Phosphorus (TP)	mg/L	1.5	n/a	0.35	0.35	0.35
Colour	TCU	750	n/a	10.8	10.8	10.8
Chemical Oxygen Demand (COD)	mg/L	725	n/a	n/a	8.4	6.6
Biochemical Oxygen Demand (BOD$_5$)	mg/L	48	n/a	n/a	0.6	0.4
Total Suspended Solids (TSS)	mg/L	48	Narrative [2]	8.5	8.5	8.5
Dissolved Oxygen	mg/L	> 1.5	>8	7.2	7.2	7.2
pH	-	7.0 - 8.5	7.0 - 8.7	8.0	7.0 - 8.5	7.0 - 8.5
Temperature (summer)	°C	37	Narrative [3]	17.6 (Summer) 0 (Winter)	17.9 (Summer) 0.3 (Winter)	17.8 (Summer) 0.2 (Winter)

n/a – not available

[1] - CCME marine limit for NO_3^- as N

[2] - Maximum average increase of 5 mg/L from background levels for longer-term exposures (e.g., inputs lasting between 24 h and 30 d)

[3] - Human activities should not cause changes in ambient temperature of marine and estuarine water to exceed ±1°C at any time, location, or depth

3.4 CONCLUSIONS

Effluent dispersion analysis of the treated wastewater under conservative ambient conditions was undertaken using a 3D near-field hydrodynamic model at outfall locations Alt-C and Alt-D. Six scenarios with various submerged diffusers were modelled. The mixing zone was defined as the 100-m distance from the outfall pipe.

Diffuser variables were iteratively adjusted during the design process to obtain maximum predicted dilution of the treated effluent. The preferred diffuser design has six ports, with each port having a 0.2 m opening, horizontal angle of 45˚ and vertical angle of 20˚. Port height was assumed 1.0 m above the seabed to accommodate height of the riser and the preferred spacing between ports is 25 m.

Effluent dilution ratios for different diffuser design scenarios are presented in ***Table 3-4***. ***Figures 3-2*** to ***3-7*** present the plan and side view of the discharged plume, as well as dilution isolines for all modelled scenarios. The six-port diffuser scenario shows substantial improvement in near-field dilution and mixing in comparison with one- and three-port diffuser scenarios. Alt-D location showed better dilution and mixing than Alt-C.

The plume from the diffuser with six ports at Alt-D reaches the surface water at about 90 m from the diffuser. The dilution ratio at Alt-D is 36 times at 5 m from the port and 109 times at the end of the mixing zone (i.e., at 100 m). For comparison, using the same diffuser design and effluent flow rate, the dilution ratio is 30 times at 5 m from the ports and 86 times at the end of the mixing zone for the Alt-C outfall location.

The results of the near-field modelling and water quality at the end of the 100-m mixing zone at Alt-D for a 6-port diffuser are shown in ***Table 3-5***, based on maximum daily effluent discharge concentrations and flow rate of 85,000 m3/day. The proposed maximum effluent discharge concentrations for AOX, TN, TP, colour, BOD, COD, TSS, water temperature, DO and pH are expected to meet compliance at the end of the mixing zone for applicable federal water quality guidelines. The water quality at the end of the 100-m mixing zone for Alt-C are also likely to meet applicable water quality guidelines as shown in ***Table 3-5.*** However, based on the 2D modelling results, the longer-term far-field dispersion and dilution of the effluent is better at the Alt-D discharge location.

The recommended outfall is a six-port diffuser located at Alt-D.

Due to port configuration and effluent buoyancy, the plume does not interact to any appreciable extent with the seabed at Alt-D. The plume does touch the seabed for the 6-port diffuser beyond the 100-m mixing zone where the effluent concentration decreases to below the guidelines, and therefore not likely to result in potential adverse effects on the benthic environment.

The plume from six ports at Alt-D reaches the surface at about 90 m from the diffuser, where the dilution ratio of the effluent is 102 times. Therefore, when the effluent breaks the surface the effluent meets the applicable regulatory guidelines.

4.0 ENGINEERING CONSIDERATIONS

Stantec civil engineers have determined that the selection of the preferred outfall option (i.e., the Alt-D discharge location in the Northumberland Strait) and for the effluent pipeline will require geotechnical information related to existing harbour soils, civil engineering related to hydraulics and conveyance of the wastewater treatment plant effluent flows to the point of discharge, and marine civil engineering support in the identification of measures to be employed for pipe stabilization. The latter would include bedding and anchoring systems, and for pipe protection from ice, waves and vessel navigation. The following sections provide a preliminary and brief description of the engineering considerations and methodology that could be undertaken for the potential implementation of the Alt-D outfall option based on the effluent plume modelling and receiving water study results.

4.1 OUTFALL PIPE HYDRAULICS

The sizing of the outfall pipe is dependent on many variables including length of pipe, pipe wall friction, hydraulic head at discharge, inlet pressure and other factors. The following was considered in the preliminary calculations in determining the expected nominal pipe diameter required in Pictou Harbour to convey the plant effluent away from the shoreline:

- The outfall pipe will be approximately 10.0 km in length from the pumping source at the mill to the discharge diffuser at the Alt-D location in the Northumberland Strait.
- The pipe will be of high density polyethylene (HDPE) fabrication and fused on site to create suitable lengths for installation.
- Pipe lengths will be joined by couplings underwater, with no losses associated with the joints.
- The mean water level at the proposed diffuser location indicates that the discharge end of the pipe will be in approximately 11.3 m of water.
- High tide and storm surge conditions will add an additional maximum 3.5 m of head on the discharge diffuser.
- The maximum effluent daily flow from the pumping station is expected to be 0.984 m^3/s.
- The pipe diameter and flow conditions shall maintain a minimum cleansing velocity of 0.6 m/s within the outfall pipe length.

In addition to these physical hydraulic conditions considered, the design and selection of the pipe diameter shall consider that:

- HDPE piping has flexibility over long distances to bend, and as such it is not expected that mechanical or significant bends in the pipe will be required over the approximate 10 km length.
- Depending on the depth of the pumping station, bends may be required at the pumping station where the pipe enters Pictou Harbour.
- Proposed diffusers will consider ports that are placed on the upper side of the pipe and extend beyond the rock cover depth.
- Outfall pipe will sit on a rock mattress which follows the undulating ocean bottom profile.
- Effluent from the new wastewater treatment facility will require pumping.

The suggested pipeline routing in Pictou Harbour from the mill to the proposed outfall location beyond Pictou Road in the Northumberland Strait was considered on the basis of minimizing pipe bend and reducing potential interactions with environmental and socio-economic sensitivities, particularly achieving sufficient water depth, were possible, to minimize interference with navigation and/or potential ice keels. ***Figures 4-1*** to ***4-3*** present the environmental and socio-economic considerations with the conceptual pipeline route proposed to the Alt-D outfall location.

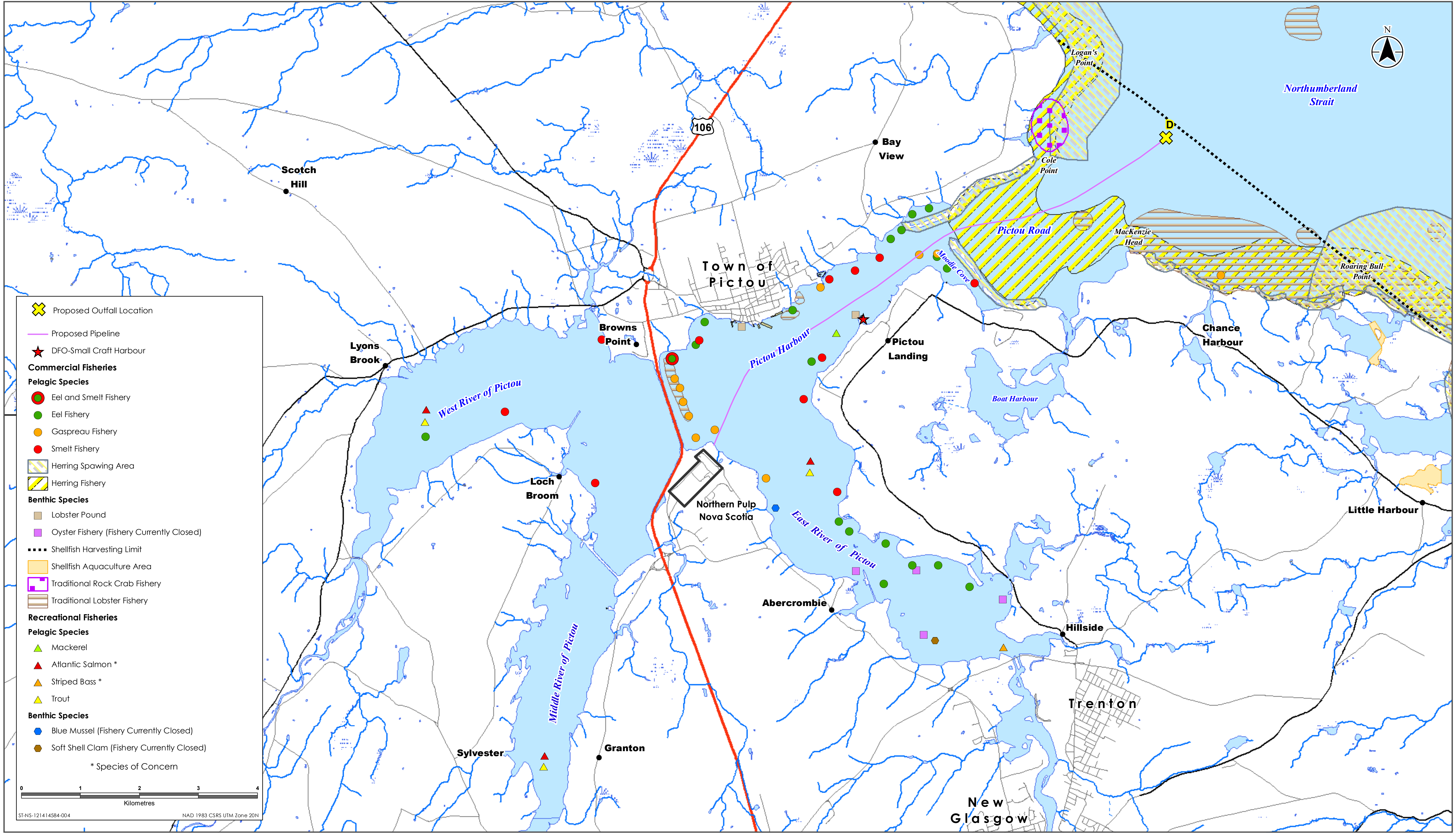
4.1.1 Preliminary Sizing Estimates

Preliminary calculations have considered the application of the Hazen Williams Equation for pressure pipe to determine pipe diameter, using the Bentley FlowMaster V8i computer software program. The equation considers the above-referenced conditions with an estimated elevation for the pumping station to be at 7.6 m above sea level (KSH, pers. comm. 2017). ***Figure 4-4*** indicates that a pipe size of 970 mm in diameter will be adequate to convey a flow rate of 0.984 m^3/s over a distance of 10.0 km with approximately 18.9 m of total head at the inlet (7.62 m elevation, plus 10 m of head provided by pump). This equates to a pipe slightly larger than 36 inches in diameter. At this stage in the design process the following is known:

- The outfall pipe will be between 36" and 42" in diameter (based on the difference in elevation between land at 7.62 m and the head at the discharge point at 10.0 km of minus (-) 11.3 m.
- Preliminary estimate of 20 m of pressure head at pipe inlet could be adequate for a 36 inch (900 mm) pipe diameter and elevation difference indicated.

If the mill's wastewater plant is situated at an elevation of approximately 7.6 m above sea level and it is to discharge under gravity conditions alone, a pipe diameter of 1250 mm would be required (refer to ***Figure 4-4***). This equates to a pipe slightly larger than 48 inches in diameter.

V:\1214\active\121414584\03_data\gis_cad\geomatics\mapping\mxd\report\ST_NS-121414584-004_Propsed_PL_All_Fisheries.mxd krozalska



Sources: Government of Nova Scotia, Jacques Whitford and Stantec Consulting Ltd.

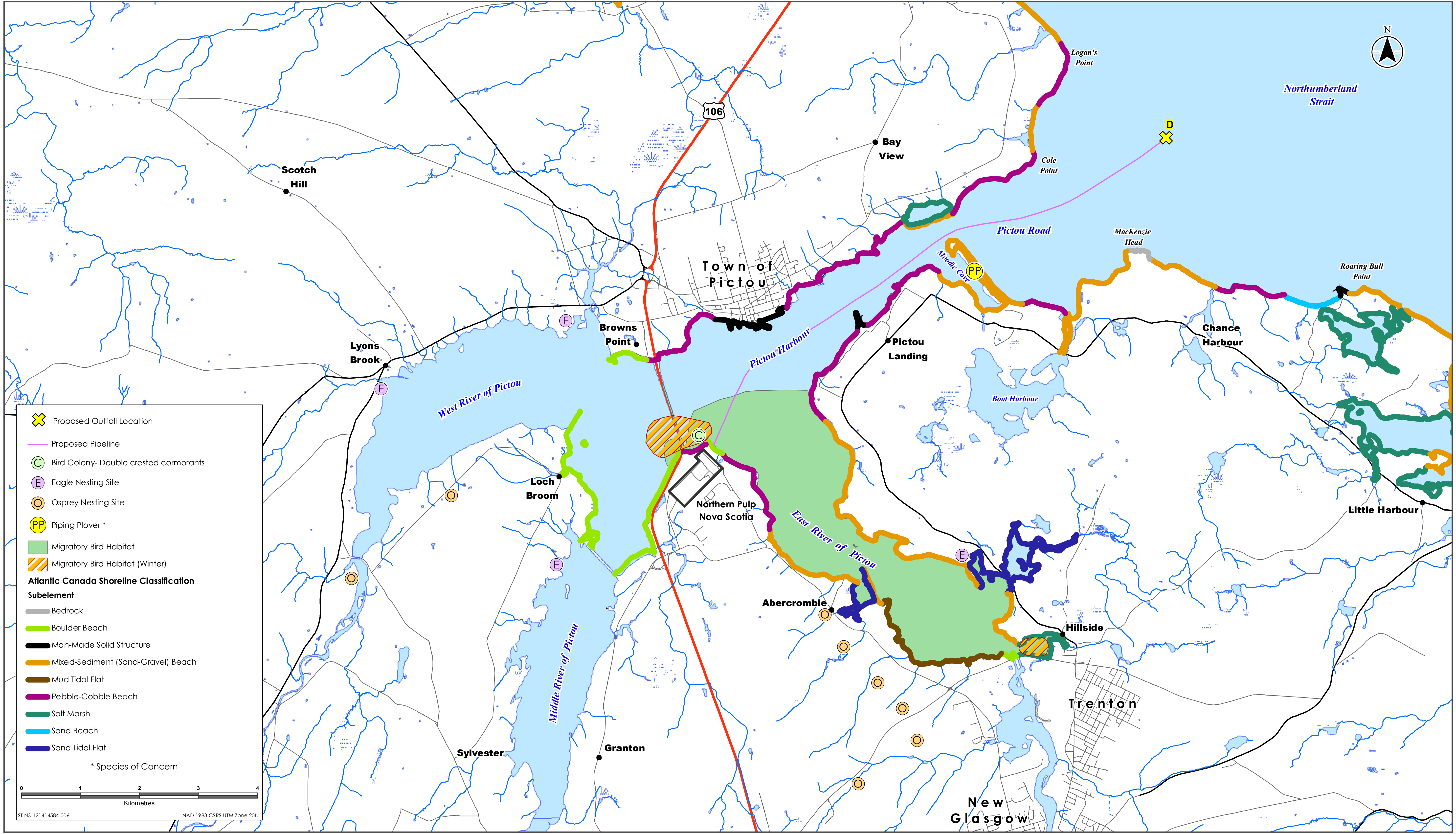
Disclaimer: This map is for illustrative purposes to support this Stantec project; questions can be directed to the issuing agency.

Proposed Pipeline Route and Commercial, Recreational, and Aboriginal Fishery Sensitivities in Pictou Harbour and Surrounding Areas

Stantec

Figure 4-1

V:\1214\active\121414584\03_data\gis_cad\geomatics\mapping\mxd\report\ST_NS-121414584-006_Propsed_PL_Birds_Shoreline.mxd krozalska



Sources: Government of Nova Scotia, Jacques Whitford and Stantec Consulting Ltd.

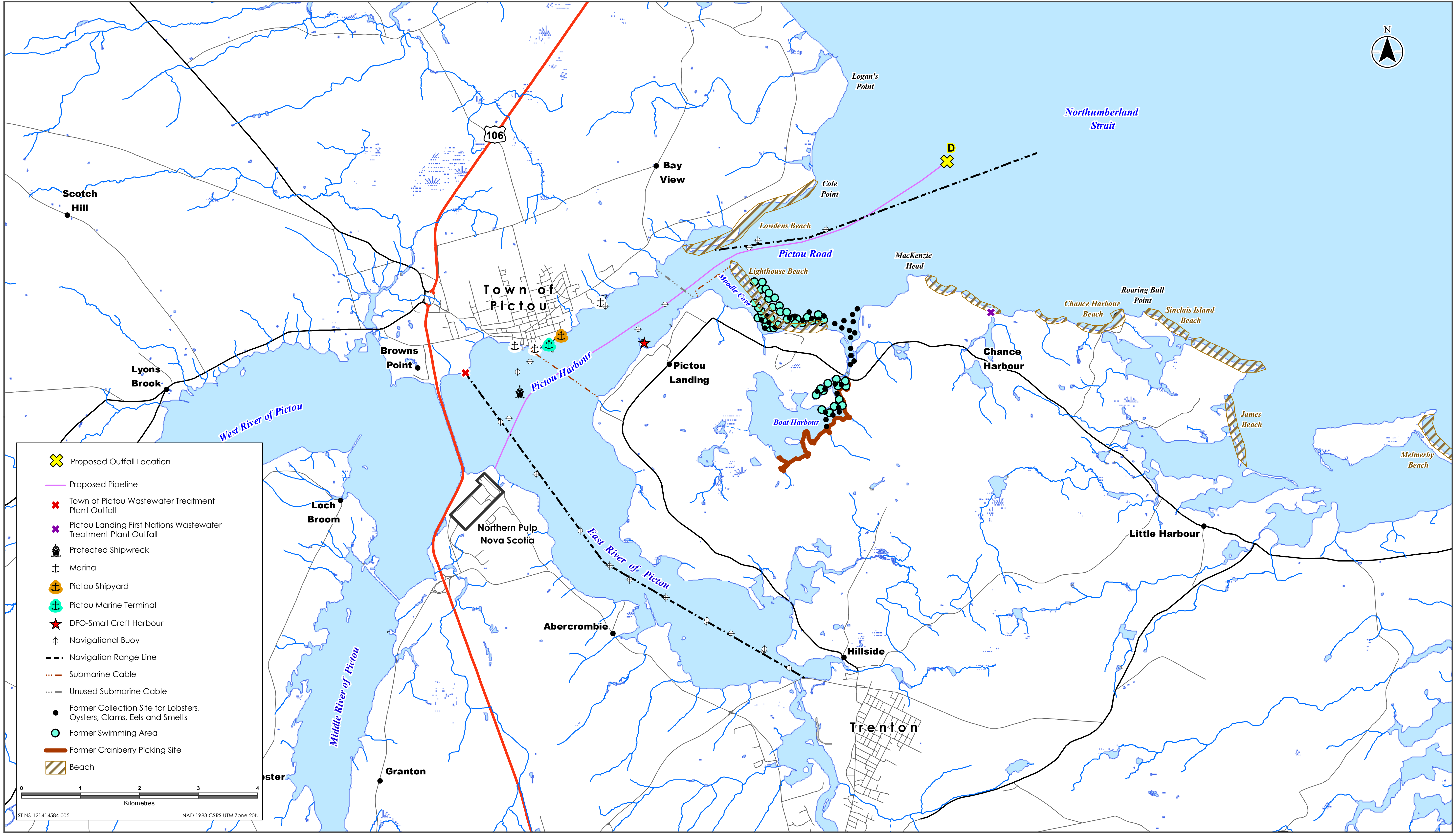
Disclaimer: This map is for illustrative purposes to support this Stantec project; questions can be directed to the issuing agency.

Proposed Pipeline Route and Bird and Shoreline Sensitivities in Pictou Harbour and Surrounding Areas

Stantec

Figure 4-2

V:\1214\active\121414584\03_data\gis_cad\geomatics\mapping\mxd\report\ST_NS-121414584-005_Proposed_PL_Socio_Ec_Sensitivities.mxd krozalska



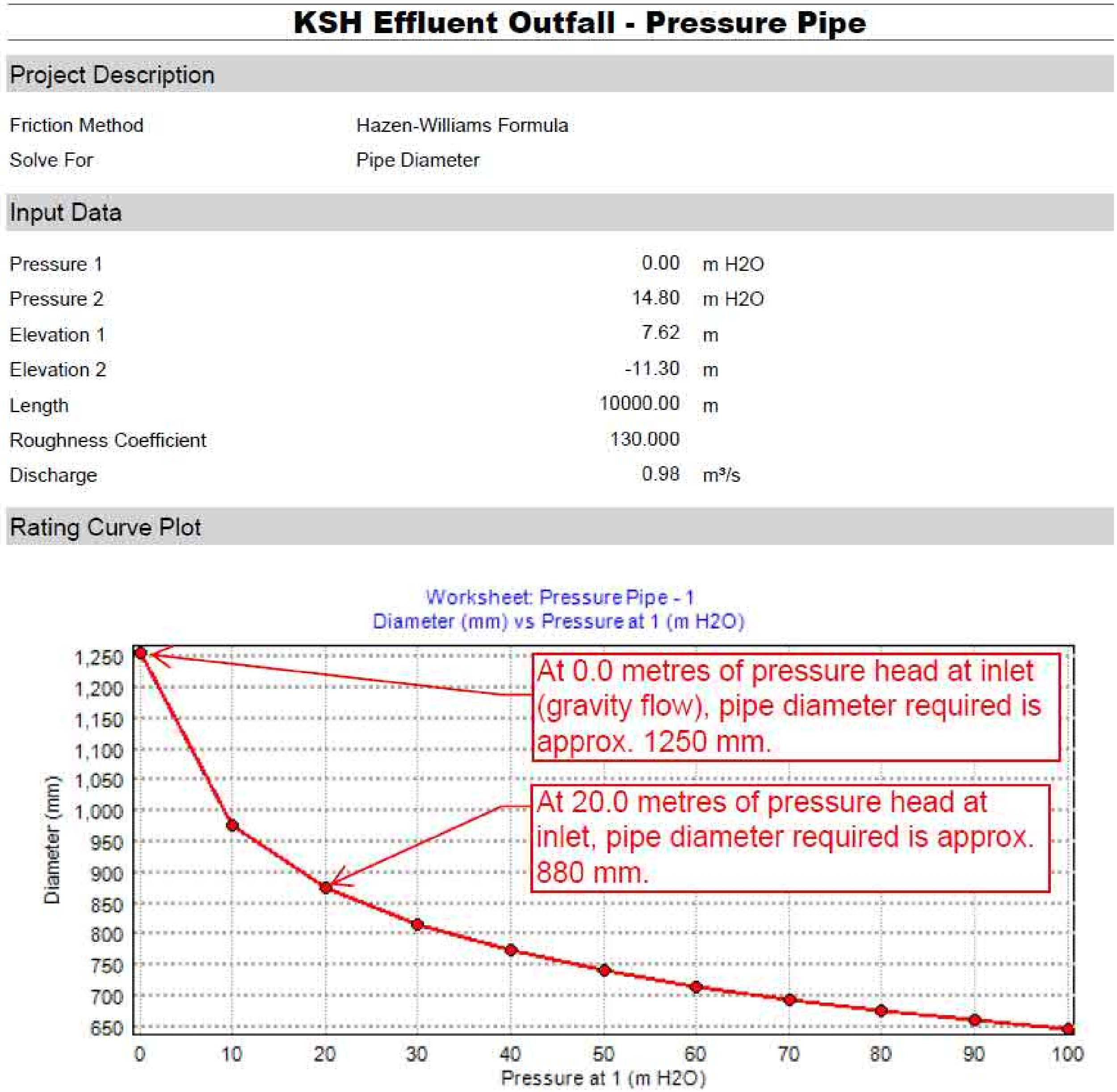
Sources: Government of Nova Scotia, Jacques Whitford and Stantec Consulting Ltd.

Disclaimer: This map is for illustrative purposes to support this Stantec project; questions can be directed to the issuing agency.

Proposed Pipeline Route and Socio-economic Sensitivities in Pictou Harbour and Surrounding Areas

Stantec

Figure 4-3



KSH Effluent Outfall - Pressure Pipe

Project Description

Friction Method	Hazen-Williams Formula
Solve For	Pipe Diameter

Input Data

Pressure 1	0.00	m H2O
Pressure 2	14.80	m H2O
Elevation 1	7.62	m
Elevation 2	-11.30	m
Length	10000.00	m
Roughness Coefficient	130.000	
Discharge	0.98	m³/s

Rating Curve Plot

Worksheet: Pressure Pipe - 1
Diameter (mm) vs Pressure at 1 (m H2O)

At 0.0 metres of pressure head at inlet (gravity flow), pipe diameter required is approx. 1250 mm.

At 20.0 metres of pressure head at inlet, pipe diameter required is approx. 880 mm.

Figure 4-4 Determination of Effluent Pipe Diameter for Alt-D Location Using the Hazen Williams Equation

4.2 MARINE CIVIL ENGINEERING

This section provides some considerations for the various marine civil engineering aspects that could affect the design and construction of the marine outfall including: climatic conditions (wind, waves, currents, ice, sea level rise), bathymetry, physical constraints, sub-surface conditions, and pipeline construction.

4.2.1 Climatic Conditions

Although an assessment of the metocean and climatic conditions are beyond the scope of this preliminary assignment as it applies to the pipeline, below are some general considerations on climate with some anecdotal information provided.

Information on wind climate is provided in Section 2.1.2.4. The predominant wind during winter months is NW to WNW which will influence wind-generated waves in the Northumberland Strait during winter months when ice is not present. The presence of ice in winter will not result in the formation of waves. The prevailing winds in the summer are from the SSE to ESE, which will have an effect on wind-generated waves in Pictou Harbour.

There is no readily available information on wave heights for the study area; however, information contained in Owens and Bowen (1977) for the Southern Gulf of St. Lawrence area is provided in ***Table 4-1***.

Table 4-1 Seasonal and Annual Significant Wave Heights for the Southern Gulf of St. Lawrence

Median Significant Wave Height (m) in Southern Gulf of St. Lawrence					
General Location	**June - Mid-September**	**Mid-September to October**	**November - December**	**Annual**	**Expected Significant Wave Height Once / year**
NW PEI	0.6	1.0	1.1	0.9	5.5
NE PEI	0.8	1.0	1.3	0.9	5.8
Cape Breton	1.2	1.7	3.2	1.4	7.6

There is some shielding of winds and reduced fetch from Prince Edward Island and therefore smaller waves are anticipated on the Nova Scotia shore of the Northumberland Strait in the Pictou area. Significant waves are still possible and there have been occasions when the Nova Scotia – PEI Ferry has been taken out of services because of wind and waves attributed to storms (e.g., http://www.huffingtonpost.ca/2011/10/05/ferries-cancelled-as-mari_n_995672.html).

Anecdotal evidence suggests that wave heights in Pictou Harbour can be in the order of 0.6 m with significant winds out of the southeast.

The currents in the study area are described in Sections 2.1.2.5 and 3.1.3.1. Although there is a general current in the Gulf of St. Lawrence from west to east, the magnitude is small and considered to be negligible at somewhere in the range of 0.06 to 0.11 m/s per day (CCG, 2012).

There is much written lately about sea level rise, resulting from the combined effect of an increased global mean sea level and the additional effect of regional subsidence of the Earth's crust, or glacial isostatic adjustment. According to information presented in the Province of Nova Scotia's 2009 *State of Nova Scotia's Coast: Technical Report* there are several numerical models regarding this subject. But it is noted in this report that a global mean sea level rise of up to 1.2 m for a strong warming scenario should not be ruled out.

Storm surge should also be acknowledged for pipe planning purposes and a minimum storm surge of 1.0 m should be considered.

4.2.2 Ice Conditions

The general information provided below was obtained from the Canadian Coast Guard on Ice Climatology and Environmental Conditions (CCG, 2012). Generally, or normally, the first ice formation in the Gulf of St. Lawrence occurs in the St. Lawrence River in early to mid-December and progressively moves to Saguenay River and then forms along the coast of New Brunswick and progressively moves eastward. In January, the ice concentrations have reached very close pack range in the Northumberland Strait. By the end of February, thin first-year ice may be found in the Northumberland Strait. It is emphasized, however, that ice conditions in the Northumberland Strait are highly variable and the ice cover varies considerably from year-to-year. There have been years when the entire Strait is frozen and totally ice-covered, while other years the Strait is relatively ice-free.

It is quite possible for drift ice to be blown into the shore with winds out of the north. There is also the possibility of some ice-rafting along Nova Scotia's Northumberland shore where ice sheets over-ride each other and stack-up along the shore.

Fast ice (ice which forms and remains fast along the coast) for most coastal regions in the Gulf has limited extents as it forms in smaller bays and inlets which might be more typical and expected in Pictou Harbour (ENSR 1999).

The 1999 ENSR report included a review of available ice data for the Pictou area including consultation with researchers and review of published literature. It was determined that quantitative data in Pictou Road and Pictou Harbour was unavailable, while ice in the Northumberland Strait has been measured and studied extensively. Of particular interest were the events of ice scouring as it is well known that pipelines, outfalls, diffusers, and submarine cables are at risk during ice scour events.

It was reported (in ENSR, 1999) that Maritime Telephone and Telegraph (MT&T) performed an ice evaluation in support of an optical communication cable deployment across the

Northumberland Strait. Based on MT&T's review, the estimated potential for damage to the cable from ice scour extended to water depths of 12 to 14 m. In 1991 their cable was trenched and buried to a selected depth (depth is unknown) and left on the surface of the sea bottom at greater depths. Unfortunately, the winter of 1991/1992 was severe and the cable was severed by ice keels at a water depth greater than 18 m towards the Woods Island, PEI side of the Northumberland Strait.

Based on the above, substantial ice pile-up should be expected near shore of the Northumberland Strait and ice scour is possible and should be anticipated anywhere in Pictou Road and the Northumberland Strait area. Although available information suggests that there is a potential for damage to the pipe, outfall, and diffusers in the areas of Pictou Road out into the Northumberland Strait, based on ENSR (1999) it appears unlikely that ice scour would occur in Pictou Harbour.

4.2.3 Bathymetry

Bathymetric information is provided in ***Figure 2-13***, showing the general shape of the bottom topography and water depths in metres referenced to Mean Water Level. A main channel is present along the longitudinal axis of Pictou Harbour that is generally 10 m in depth or greater in some areas. This channel decreases in depth to between 7.5 to 10 m in Pictou Road before the depths gradually increase in the Northumberland Strait and at the proposed Alt-D outfall location.

4.2.4 Physical Constraints

There are several physical constraints that may interact with the outfall pipe and which have been presented on ***Figure 4-3*** and described in general as socio-economic sensitivities in this report (e.g., Section 4.1). These include physical constraints such as submarine cables, navigation buoys and a sunken relic which could impact the final routing of the outfall pipe.

4.2.5 Subsurface Conditions

4.2.5.1 General Surficial Geology and Sub-Surface Conditions

The characteristics of the Southern Gulf of St. Lawrence has been described by Owens and Bowen (977) as:

a. Geological character - Predominantly un-resistant carboniferous sedimentary rocks with metasediments overlain by thin till deposits;
b. Backshore relief – Low, unrestrained cliffs (3 – 10 m);
c. Beach character – Great variety, ranging from barrier islands to multiple intertidal bars and narrow beaches;

d. Fetch and wave exposure - Generally less than 50 km; however, the area is somewhat sheltered from waves out of the northwest by Prince Edward Island. Also, when ice is present along the coast there is some protection to the Nova Scotia coastline from winter onshore winds;
e. Ice climate - 7 to 8 months ice-free season;
f. Mean tidal range - 1 to 2 m; and
g. Coastal erosion - Generally, in the order of 1 to 2 m per annum.

4.2.5.2 Site-Specific Information

Stantec has completed nearshore marine geotechnical investigations in the general vicinity of this pipeline in Pictou Harbour for various other clients. Based on the findings of these previous investigations, the thickness of soft compressible marine sediments ranges from 7 to 15 m. Beneath the marine sediments, a relatively thin layer of glacial till was encountered overlying mudstone or sandstone bedrock.

In addition, Stantec has reviewed the historical geotechnical information from 1965 that was provided by KSH (pers. comm. 2017). This information included both land and marine boreholes which encountered similar conditions to the boreholes Stantec has drilled in the area. It should be noted that the thickness of marine sediments encountered in the historical boreholes may have significantly changed due to natural currents and the construction of the adjacent causeway which was completed in 1968.

4.2.5.3 Geotechnical Considerations

The likely existence of the soft layer of marine sediments along the proposed outfall route will create a challenge for design and construction as it is anticipated that significant amounts of total and differential settlement and resulting pipe stresses will be experienced when a load is applied to this material.

To determine the properties of the marine sediments that will be encountered along the proposed outfall pipe alignment, it is recommended that a geophysical survey complimented with a marine geotechnical investigation be completed to determine the thickness of the marine sediments, time rates for consolidation to provide settlement estimates, and to obtain strength parameters of the marine sediment material.

4.2.6 Construction

4.2.6.1 Pipe Material

It is anticipated that the pipe for the outfall and diffuser will be high density polyethylene (HDPE) pressure class pipe to ASTM, AWWA and CSA Standards. The pipe is resistant to both internal and external chemical attack and is highly suited for conveying fluids of lower temperature (i.e., < 60°C). HDPE pipe does not degrade when exposed to ultraviolet light.

For long outfalls and diffusers, the pipe is typically assembled by joining individual lengths of pipe by either butt fusion welding or by joining with factory-made flanged joints. A long site next to the water's edge is desired for the outfall pipe fabrication and assembly yard. The pipe is then assembled on dry land to the required length and the ends are covered with blind flanges. As the fabricated pipe is launched into the water, concrete collars are added for ballast. The pipe, however, is very buoyant and does not sink with the concrete ballast. Riser pipes for the duckbill diffuser ports are added at the required locations. When the pipe is floating, and positioned over its final resting place, on the seafloor below, the pipe is slowly ballasted with sea water and the pipe gradually descends to the prepared rock mattress previously placed on the harbour bottom. A dive inspection would be conducted on the outfall pipe after it is positioned on the harbour bottom to ensure that the pipe is not damaged. Due to the excessive length of the pipeline of about 10 km to reach the Alt-D outfall location, the pipe may have to be fabricated and placed in manageable sections, say 1000 m long, and outfitted with bolted flanged connections and expansion joints.

4.2.6.2 Construction Approach

The actual assembly of the pipe is outlined above. The placement of the pipe would generally be as described below.

Near Shore Zone

The pipe installation in the Pictou Harbour near-shore zone to the mill would be installed in a pre-excavated trench, buried, and protected with armourstone. The armourstone would extend up the shore to a height that is sufficient to protect the pipe considering:

- high water level
- storm surge
- sea level rise
- wave height
- wave run-up.

For preliminary planning purposes, the armourstone would extend up the shore zone to about Elevation +4 m to +5 m above Chart Datum. The lower extents of the armourstone protection should extend into the near shore zone down to about Elevation -3.0 m Chart Datum.

The installation may require a temporary causeway as the water depth will likely be too shallow and insufficient for marine plant. The construction technique used for the 2009 East River crossing of the mill's effluent replacement pipe to Boat Harbour as depicted in ***Figures 4-5*** and ***4-6*** is a suitable example of the construction technique.

Source: http://www.mcnallycorp.com/projects/projects-details/northern-pulp-river-crossing

Figure 4-5 **East River Shore Construction of Mill's Effluent Pipeline Replacement in 2009**

Source: http://www.mcnallycorp.com/docs/default-source/Project-Specs/b70-northern-pulp-river-crossing-.pdf?sfvrsn=b17999df_2

Figure 4-6 Floating Effluent Pipeline on the East River in 2009

Bottom Laid Pipe – Pictou Harbour

It is anticipated that there will be relatively deep marine sediment deposits on the harbour bottom and this will have to be examined in more detail in a site-specific sub-surface investigation. The pipeline construction may require the placement of a thick blasted and crushed rock mattress on the harbour bottom in order to partially consolidate the silts and to prepare the bottom to receive the new pipe. The pipe with concrete collars would rest on the mattress and then would be backfilled with a crushed rock backfill to totally cover the outfall pipe and to afford the pipe some protection against accidental impact from vessels and protection against inadvertent anchorage of vessels.

Trenched and Covered Pipe, Outfall, and Diffusers – Pictou Road to Northumberland Strait

It appears that the pipe, outfall, and diffusers would likely extend out into the Northumberland Strait to a depth of approximately 11.3 m at the Alt-D location. The potential for ice scour and disturbance from waves should be investigated in more detail. As with the pipe in the near shore zone, it is recommended that a heavier armourstone be used from the main entrance of Pictou Harbour to the outer limits of the diffuser.

Diffuser ports should have riser pipe extensions to ensure that the discharge points are clearly above the top of the armourstone protection. Typically, the diffuser ports would be installed by divers after the stone protection is placed.

An access hatch should be provided at the end of the outfall pipe so that a remotely-operated vehicle (ROV) video inspection can be done after the protective rock layer is placed on the outfall pipe.

It is noted that the scour is possible and should be anticipated in Pictou Road and the Northumberland Strait and there is a potential for damage to the pipe, outfall, and diffusers. This requires further investigation.

4.3 SUMMARY AND RECOMMENDATIONS

Engineering considerations for the outfall pipe and diffuser were presented in this report. The selection of the preferred outfall option (i.e., the Alt-D discharge location in the Northumberland Strait) and for the effluent pipeline will require geotechnical information related to existing harbour soils, civil engineering related to hydraulics and conveyance of the wastewater treatment plant effluent flows to the point of discharge, and marine civil engineering support in the identification of measures to be employed for pipe stabilizations.

A preliminary sizing of the outfall pipe was estimated to be between 36” to 42” in diameter. This was based on the difference in elevation between land at 7.62 m and the head at the discharge point at 10.0 km of 11.3 m below mean sea level. Other dependent variables considered in this sizing of the pipe included a maximum flow rate of 0.984 m^3/s conveyance over the distance of 10 km with 18.9 m of pressure head at the inlet end, high tide and storm surge conditions that would add an additional 3.5 of head on the discharge diffuser, and the requirement to maintain a minimum cleansing velocity of 0.6 m/s within the outfall pipe length. Other factors to be considered included effluent pumping, placement of ports for the diffuser, and pipe bends and bedding on the seabed.

Marine civil engineering aspects considered that could affect the design and construction of the marine outfall included: climatic conditions (wind, waves, currents, ice, sea level rise), bathymetry, physical constraints, sub-surface conditions, and pipeline construction. It was determined that substantial ice pile-up should be expected near shore of the Northumberland Strait and ice scour is possible and should be anticipated anywhere in Pictou Road and the Northumberland Strait area. It appears unlikely, however, that ice scour would occur in Pictou Harbour. Physical constraints that may interact with the outfall pipe included submarine cables, navigation buoys and a sunken relic in Pictou Harbour which could impact the final routing of the outfall pipe.

Site-specific nearshore marine geotechnical investigations in the general vicinity of the proposed pipeline in Pictou Harbour suggest the thickness of soft compressible marine sediments are in the order of 7 to 15 m. The likely existence of this soft layer of marine sediments along the proposed outfall route will create a challenge for design and construction as it is anticipated that significant amounts of total and differential settlement and resulting pipe stresses will be experienced when a load is applied to this material. It is recommended that a geophysical survey complimented with a marine geotechnical investigation be completed to determine the thickness of the marine sediments, time rates for consolidation to provide settlement estimates, and to obtain strength parameters of the marine sediment material. This will enable the determination of the properties of the marine sediments that will be encountered along the proposed outfall pipe alignment.

An approach for the construction of the 10 km outfall pipe was proposed, where the pipe may have to be fabricated and placed in manageable sections of about 1000 m long, and outfitted with bolted flanged connections and expansion joints. The placement of the pipe would generally differ depending on whether it is in the near shore zone, in Pictou Harbour, or in Pictou Road to the Northumberland Strait. The pipe installation in the Pictou Harbour near-shore zone to the mill would be in a pre-excavated trench, buried, and protected with armourstone. The armourstone would extend up the shore to a height sufficient to protect the pipe from physical factors such as high water level, storm surge, sea level rise, wave height, and wave run-up. The construction technique for pipe installation in the near shore zone could be similar to the 2009 East River crossing of the mill's effluent replacement pipe to Boat Harbour. The anticipated relatively deep marine sediment deposits in Pictou Harbour may require the placement of a thick blasted and crushed rock mattress on the bottom in order to partially consolidate the silts and to prepare the bottom to receive the new pipe. The pipe fitted with concrete collars would rest on the mattress and then would be backfilled with a crushed rock backfill to totally cover the outfall pipe and to afford the pipe some protection against accidental impacts from vessels and protection against inadvertent anchorage of vessels.

The outfall pipe from Pictou Road to the Northumberland Strait to a depth of approximately 11.3 m at the Alt-D location may encounter the potential for ice scour and disturbance from waves, which should be investigated in more detail. As with the pipe in the near shore zone, it is recommended that a heavier armourstone be used from the main entrance of Pictou Harbour to the outer limits of the diffuser. Diffuser ports should have riser pipe extensions to ensure that the discharge points are clearly above the top of the armourstone protection. Typically, the diffuser ports would be installed by divers after the stone protection is placed. An access hatch should be provided at the end of the outfall pipe so that a remotely-operated vehicle (ROV) video inspection can be done after the protective rock layer is placed on the outfall pipe.

5.0 STUDY SUMMARY AND RECOMMENDATIONS

Effluent dispersion analysis was undertaken at the outfall locations Alt-A, Alt-B, Alt-C and Alt-D under conservative ambient conditions using a 2D far-field and a 3D near-field hydrodynamic models.

MIKE 21 modelling indicted that among the four potential outfall locations investigated, the Alt-D outfall location provides the smallest potential long-term cumulative effects on the fishery and socio-economic environments, and therefore is considered the better outfall location for the discharge of the treated wastewater from the mill.

The CORMIX model was used to analyze the mixing zone for outfall locations Alt-C and Alt-D under conservative ambient conditions for various outfall configurations. Modelling indicated that the preferred diffuser design has six ports, with each port having a 0.2 m opening, horizontal angle of 45˚, vertical angle of 20˚, port height of 1.0 m above the seabed, and 25 m spacing between the ports.

Effluent discharge from the Alt-D outfall location gave better dilution and mixing than for the Alt-C location. The plume from the diffuser with six ports at Alt-D reaches the surface water at about 90 m from the diffuser. The dilution ratio in the receiving environment at Alt-D is 36 times at 5 m from the port and 109 times at the end of the mixing zone (i.e., at 100 m). The water quality results at the end of the 100-m mixing zone for Alt-D are shown in ***Table 3-5***. The proposed maximum effluent discharge concentrations for AOX, TN, TP, colour, BOD, COD, TSS, water temperature, DO and pH are anticipated to meet compliance at the end of the mixing zone for applicable federal water quality guidelines.

Due to port configuration and effluent buoyancy, the plume does not interact to any appreciable extent with the seabed for the Alt-D discharge location. The plume does touch the seabed for the 6-port diffuser beyond the 100-m mixing zone where the effluent concertation decreases to below the regulatory guidelines, and therefore not likely to result in potential adverse effects on the benthic environment.

The plume from six ports at Alt-D reaches the surface at about 90 m from the diffuser, where the dilution ratio of the effluent is 102 times. Therefore, when the effluent reaches the surface the effluent will meet the applicable regulatory guidelines.

Mixing and dilution at the Alt-D outfall location is driven by water depth at the outfall, tides and currents. Similar mixing and dilution is expected in close proximity to Alt-D (i.e. a 100 m radius) assuming the depth of the outfall is the same or larger than in Alt-D. Outfall depth is a bigger driver than exact position in the Pictou Road Area.

6.0 REFERENCES

CCG (Canadian Coast Guard). 2012. Ice Climatology and Environmental Conditions. In: *Ice Navigation in Canadian Waters.* Revised August 2012 (Available from: http://www.ccg-gcc.gc.ca/folios/00913/docs/ice-navigation-dans-les-galces-eng.pdf).

CCME (Canadian Council of Ministers of the Environment). 2003. Canadian water quality guidelines for the protection of aquatic life: Guidance on the Site-Specific Application of Water Quality Guidelines in Canada: Procedures for Deriving Numerical Water Quality Objectives. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

CCME (Canadian Council of Ministers of the Environment). 2009. Canada-wide Strategy for the Management of Municipal Wastewater Effluent. Endorsed by CCME Council of Ministers, February 17, 2009.

Dalziel, J.A., Yeats, P.A. and D.H. Loring. 1993. Water chemistry and sediment core data from Pictou Harbour and the East River estuary. Bedford Institute of Oceanography, Department of Fisheries and Oceans Canada. Can. Tech. Rep. Fish. Aquat. Sci. 1917: 78 p.

Ecomtrix. 2007. EEM Cycle 4 Interpretive Report for the Neenah Paper (Pictou Mill) Facility at New Glasgow, Nova Scotia. Report prepared for Neenah Paper Inc. (Pictou Mill).

Ecomtrix. 2016. EEM Cycle 7 Interpretive Report for the Northern Pulp Nova Scotia Corp. Facility near Pictou, Nova Scotia. Report prepared for Northern Pulp Nova Scotia Corp.

Environment Canada (EC). 2006. Atlantic Canada Wastewater Guidelines Manual. 432 p.

Environment and Climate Change Canada (ECCC). N.D.a. Climate Archive. Available at: http://climate.weather.gc.ca/climate_data/hourly_data_e.html?hlyRange=1994-02-01%7C2017-02-22&dlyRange=1993-04-01%7C2017-02-22&mlyRange=2004-11-01%7C2007-07-01&StationID=8990&Prov=NS&urlExtension=_e.html&searchType=stnName&optLimit=yearRange&StartYear=1840&EndYear=2017&selRowPerPage=25&Line=0&searchMethod=contains&txtStationName=caribou+point+%28aut%29&timeframe=1&Year=2017&Month=1&Day=22. Accessed: February 2017.

ENSR. 1999. Preliminary Effluent Diffuser Study, Kimberly-Clark Nova Scotia.

Fisheries and Oceans Canada (DFO) Website: Tides, Currents, and Water Levels. Available at: http://www.isdm-gdsi.gc.ca/isdm-gdsi/twl-mne/index-eng.htm#s5. Accessed: February 2017.

Jacques Whitford Environment Limited (JWEL). 1994. Initial Environmental Assessment of a Pipeline and Diffuser Proposal for the Boat Harbour Treatment Facility. Report prepared for the Nova Scotia Department of Supply and Services.

Jacques Whitford Environment Limited (JWEL), 1996. First cycle EEM aquatic environmental effects monitoring program Boat Harbour waste water treatment facility. Report to Environment Canada on behalf of the Nova Scotia Department of Supply and Services, 65 p. appendices A - I.

Jacques Whitford Environment Limited (JWEL). 2005. Re-introduction of Tidal Influence to Boat Harbour, Pictou County, Nova Scotia.

Health Canada (HC). 1995. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Colour.

KSH Solutions Inc. (KSH). 2016. Receiving Water Study, Northern Pulp Nova Scotia, New Glasgow, NS, December 2016 (RFP 11 1112A-001).

KSH Solutions Inc. (KSH). 2017. Email communications with Stantec Consulting Ltd. on March 22, April 3 and May 8, 2017.

McNeely, R.N., Neimanis, V.P. and L. Dwyer. 1979. Dissolved Oxygen. In: Water Quality Sourcebook. A Guide to Water Quality Parameters. Water Quality Branch, Inland Waters Directorate, Environment Canada, Ottawa, Ont. pp. 33-34.

Owens, E.H. and A.J. Bowen. 1977. Coastal Environments of the Maritime Provinces. Marine Sediments, 13(1): 1-31.

Province of Nova Scotia. 2009. The 2009 State of Nova Scotia's Coast: Technical Report.

R.V. Anderson Associates. 2015. Middle River of Pictou Water Availability. Final Report. December 17, 2015.

Seakem Oceanography Limited (Seakem). 1990. Preliminary Environmental Profile - Pictou Harbour. A report to Environment Canada Conservation and Protection, 35p.

Stantec Consulting Ltd. (Stantec). 2004. Cycle 3 Environmental Effects Monitoring Interpretive Report for the Kimberly-Clark Nova Scotia Mill at New Glasgow, Nova Scotia. Report prepared for Kimberly-Clark Nova Scotia, New Glasgow, NS.

UNESCO. 1996. Water Quality Assessments - A Guide to Use of Biota, Sediments and Water in Environmental Monitoring - Second Edition. Edited by Deborah Chapman.

US Environmental Protection Agency (USEPA). 1994. Drinking Water Regulations and Health Advisories. Office of Water, Washington DC.

World Bank Group, Pollution Prevention and Abatement Handbook, World Bank Group, Effective July 1998.

APPENDIX A

SIMULATED CURRENTS CIRCULATION AND EFFLUENT CONCENTRATION FIGURES FOR TYPICAL TIDAL STAGES AT ALT-A, ALT-B, ALT-C AND ALT-D DISCHARGE LOCATIONS

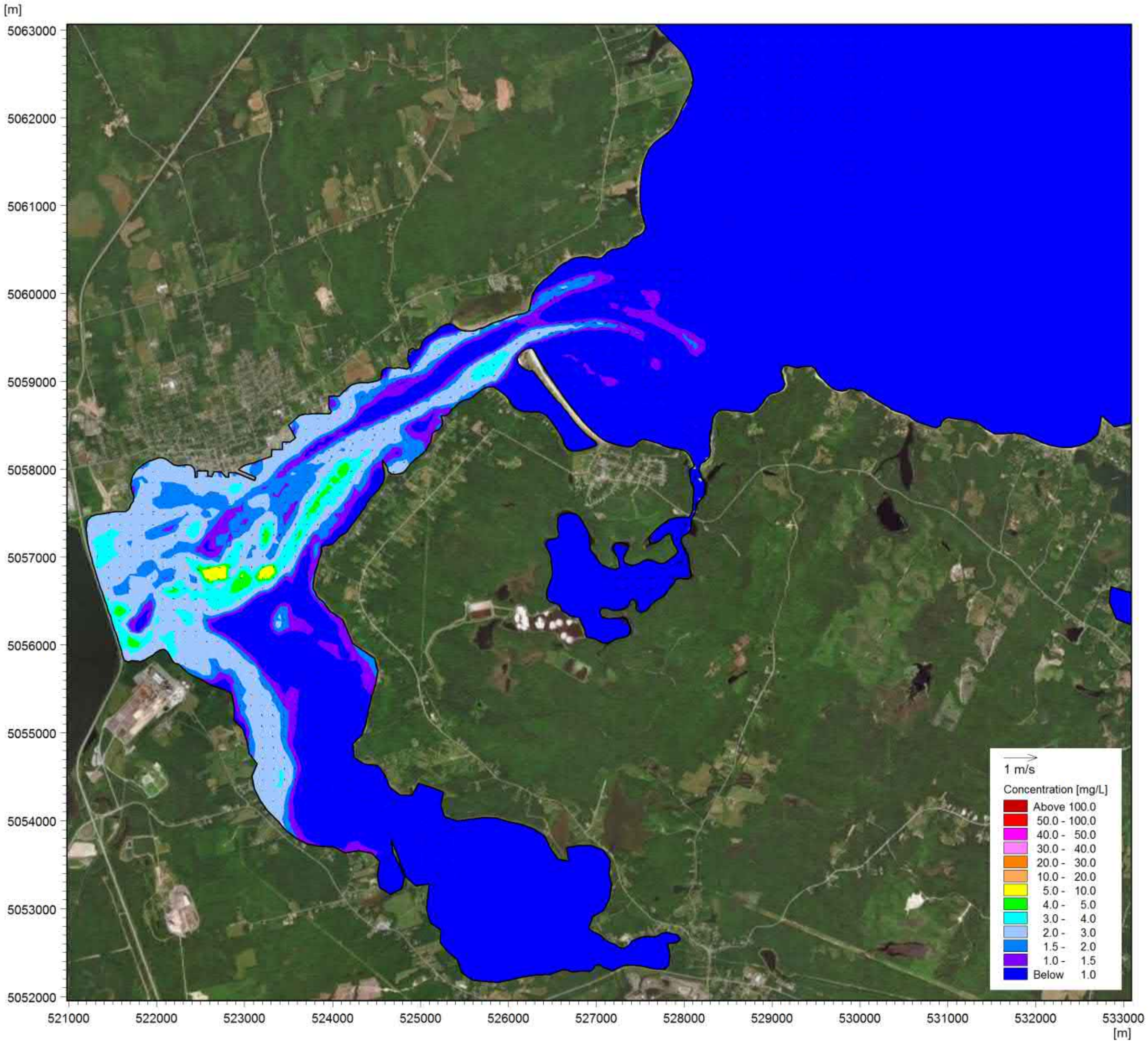


Figure A-1 Alt-A Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Neap Tide - Slack Low Tide at 10:00 hr, July 13

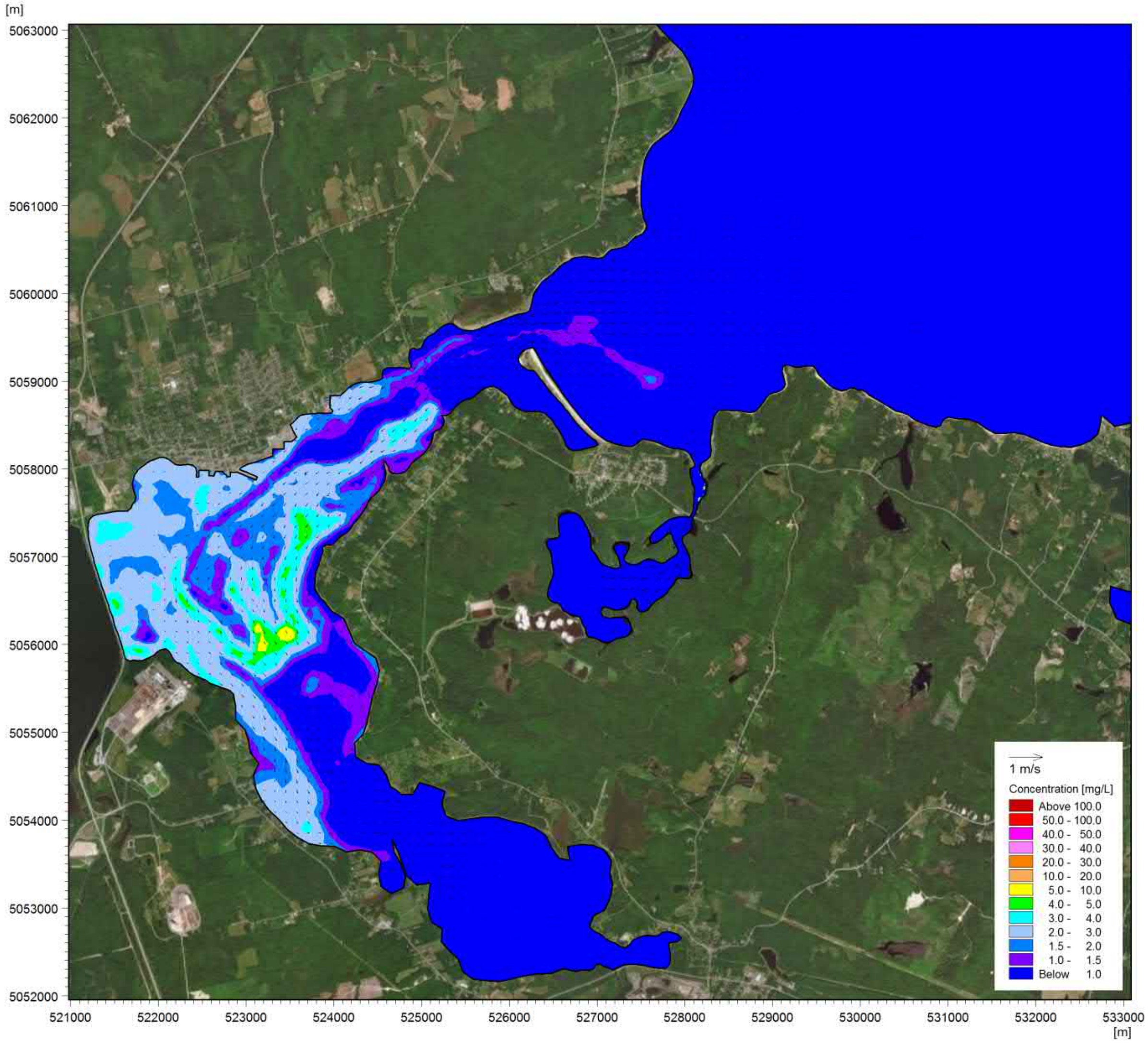


Figure A-2 Alt-A Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Neap Tide - Flood Tide at 14:00 hr, July 13

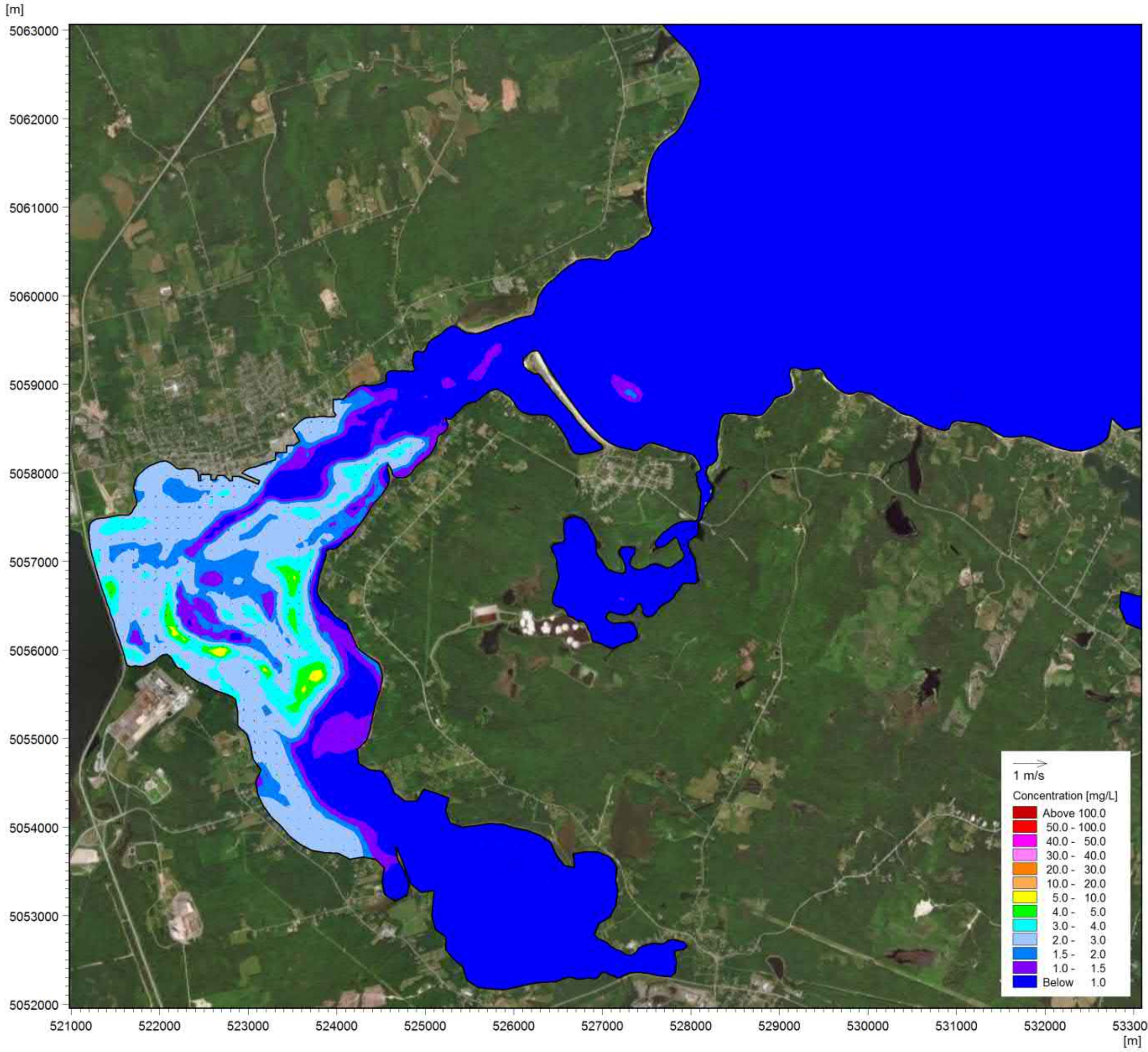


Figure A-3 Alt-A Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Neap Tide - Slack High Tide at 17:00 hr, July 13

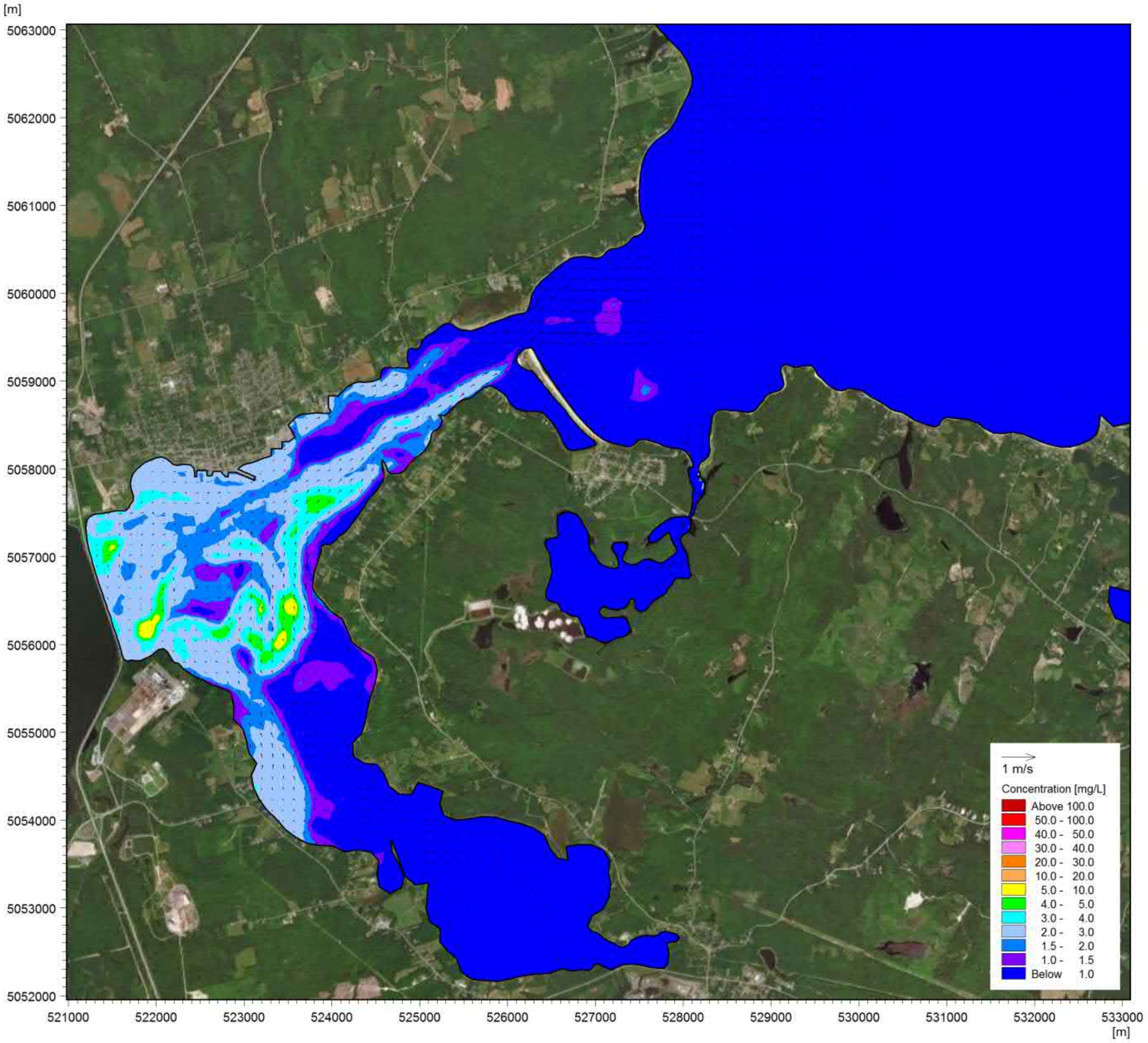


Figure A-4 Alt-A Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Neap Tide - Ebb Tide at 20:00 hr, July 13

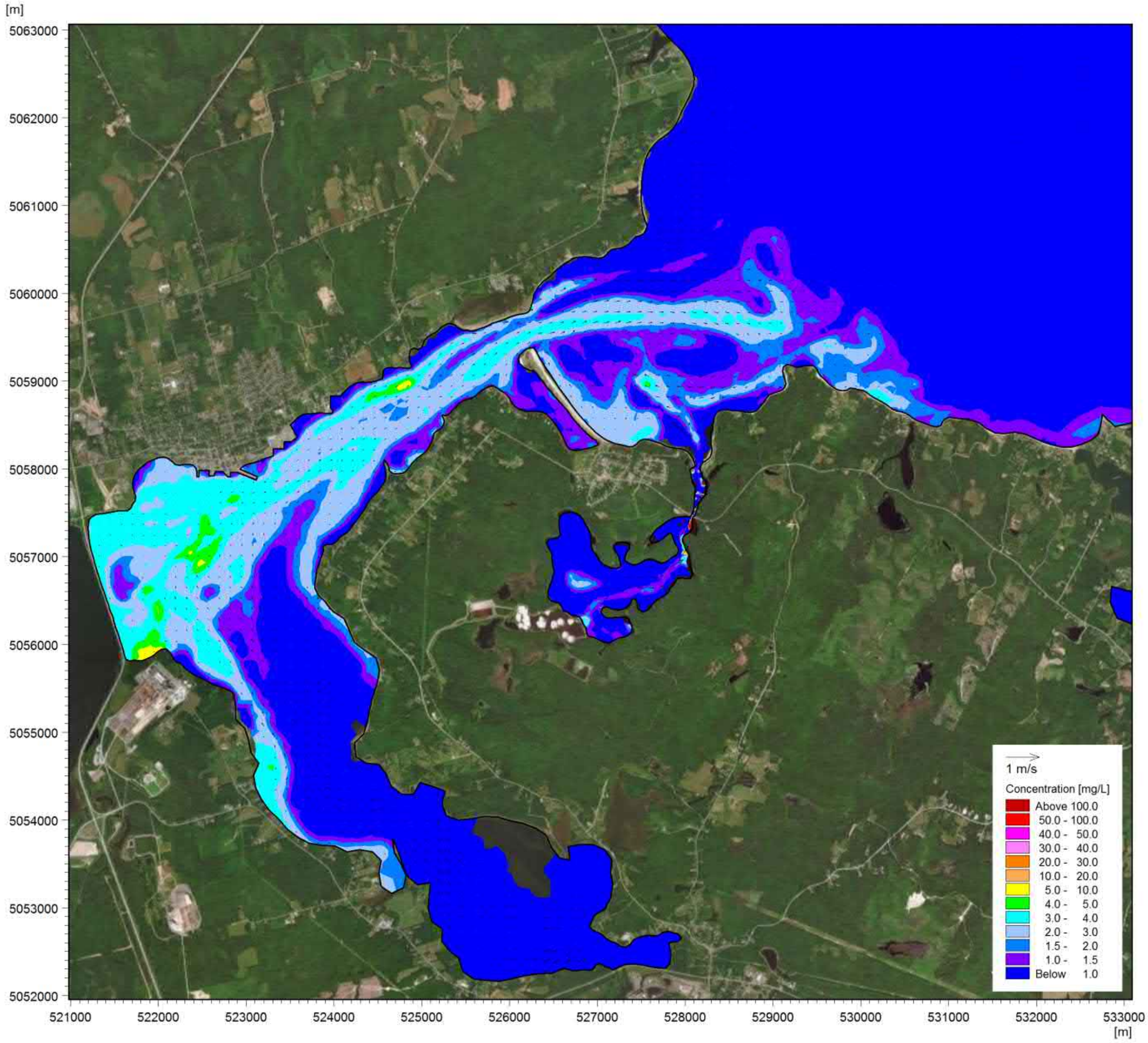


Figure A-5 Alt-A Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Spring Tide - Slack Low Tide at 17:00 hr, July 21

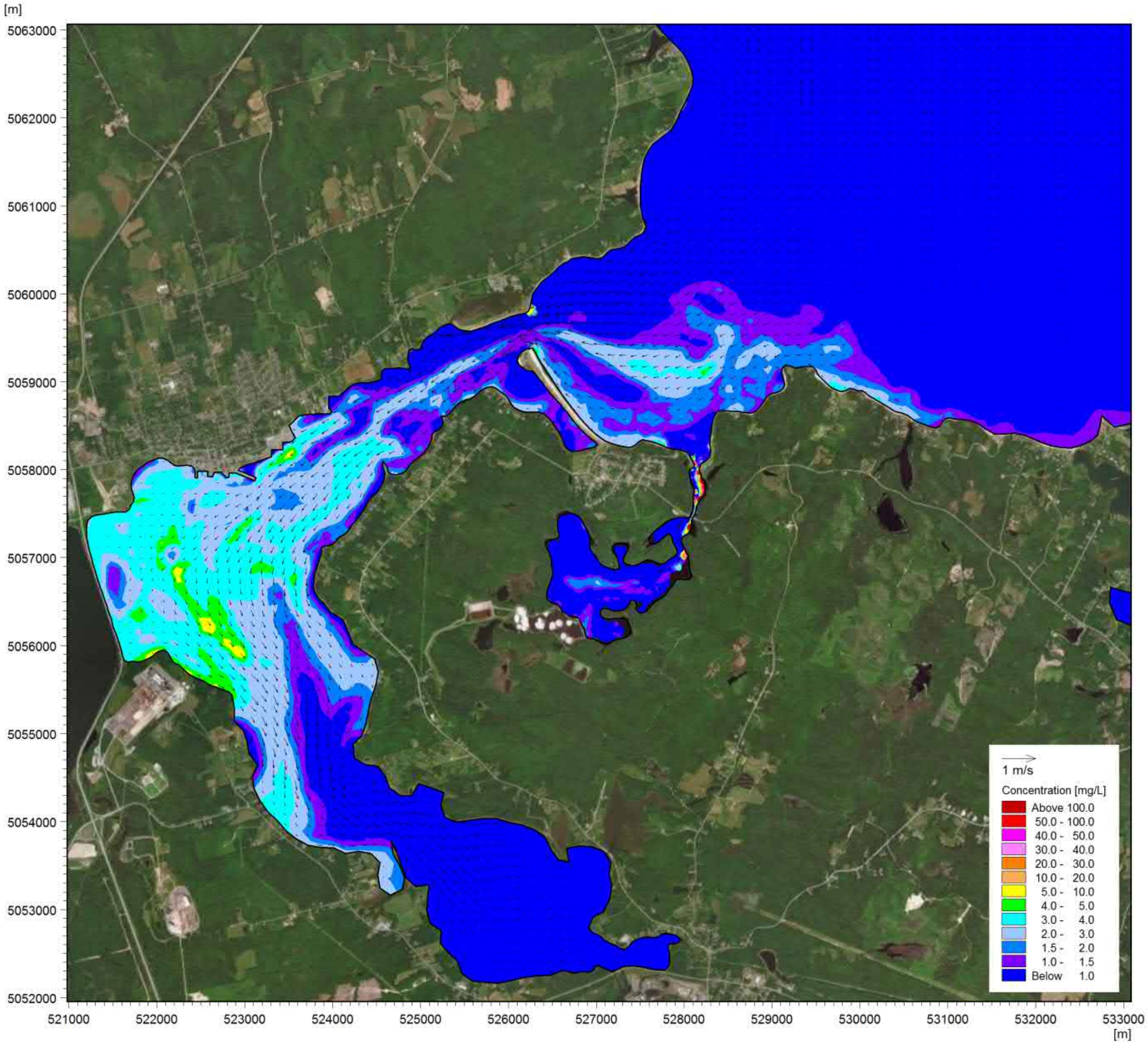


Figure A-6 Alt-A Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Spring Tide – Flood Tide at 21:00 hr, July 21

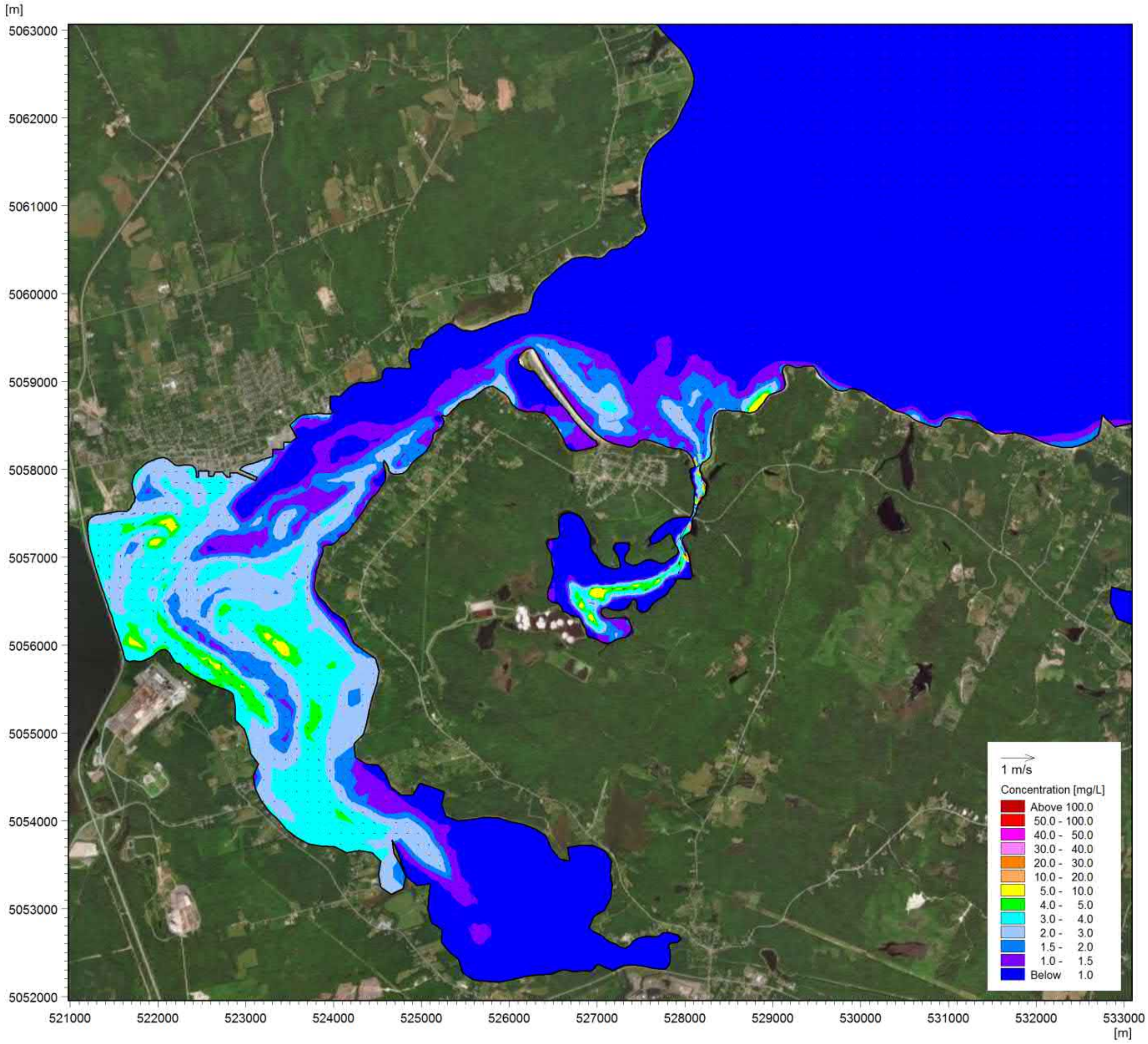


Figure A-7 Alt-A Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Spring Tide –Slack High Tide at 11:00 hr, July 22

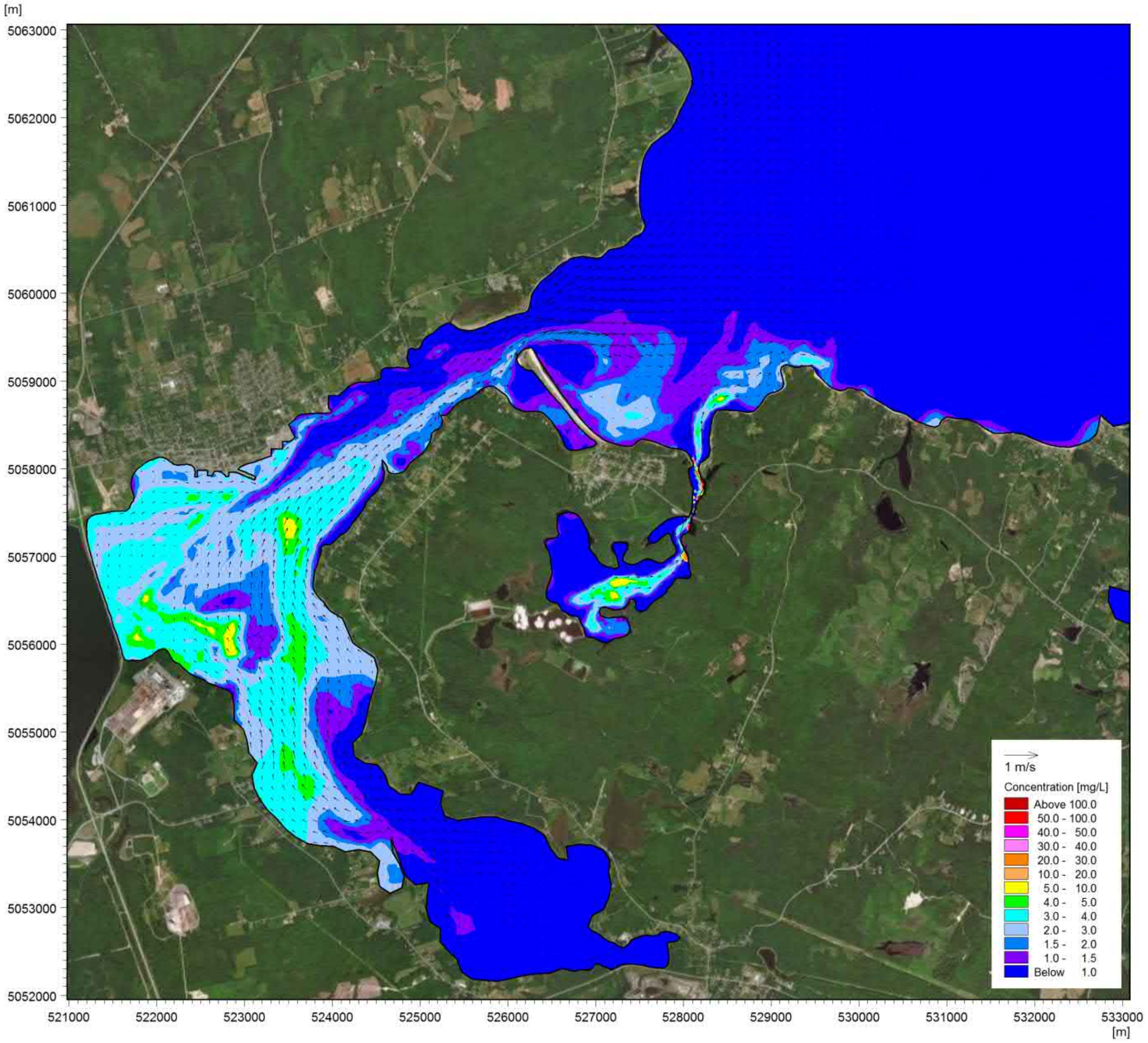


Figure A-8 Alt-A Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Spring Tide – Ebb Tide at 14:00 hr, July 22

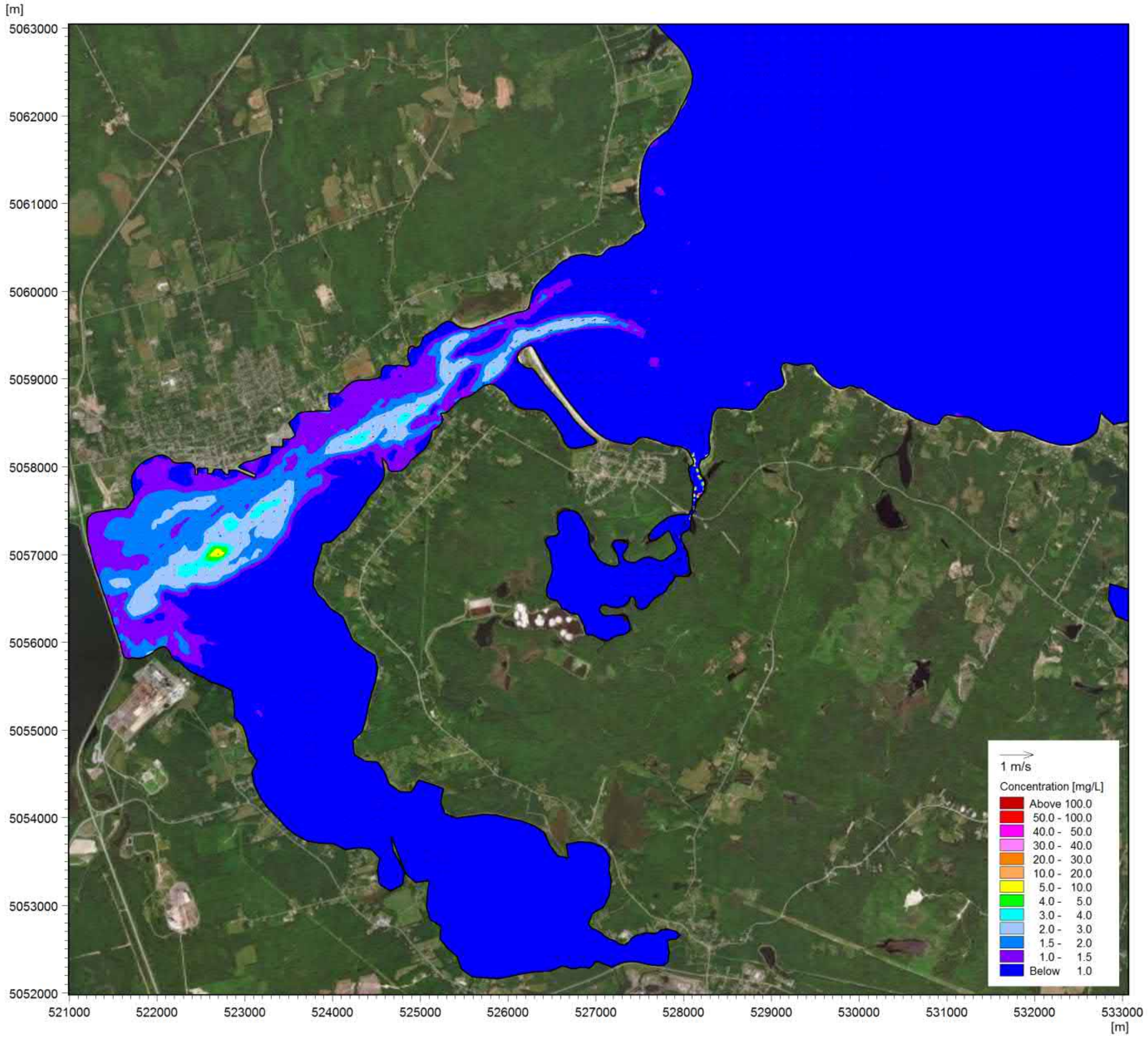


Figure A-9 Alt-B Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Neap Tide - Slack Low Tide at 10:00 hr, July 13

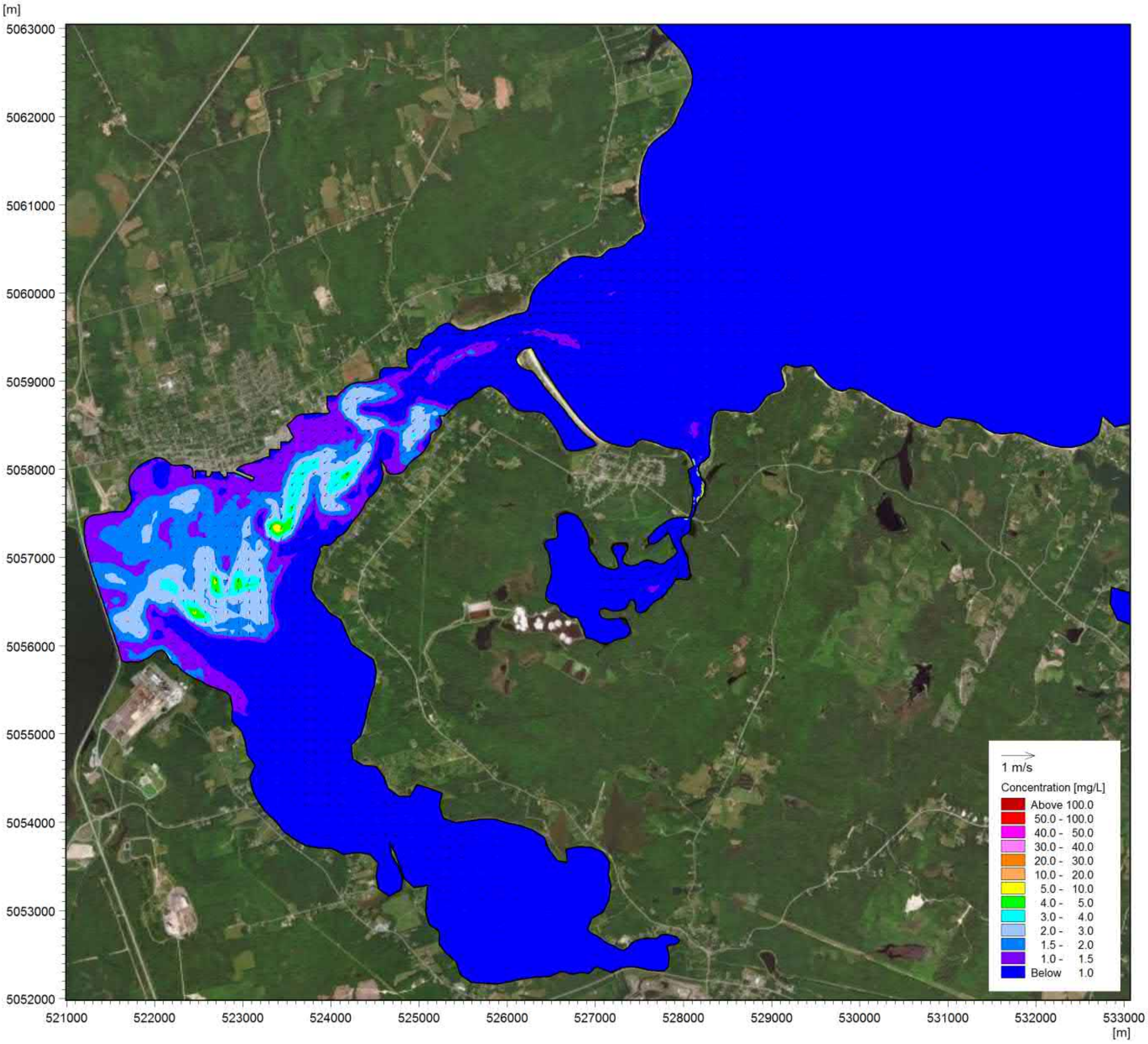


Figure A-10 **Alt-B Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Neap Tide - Flood Tide at 14:00 hr, July 13**

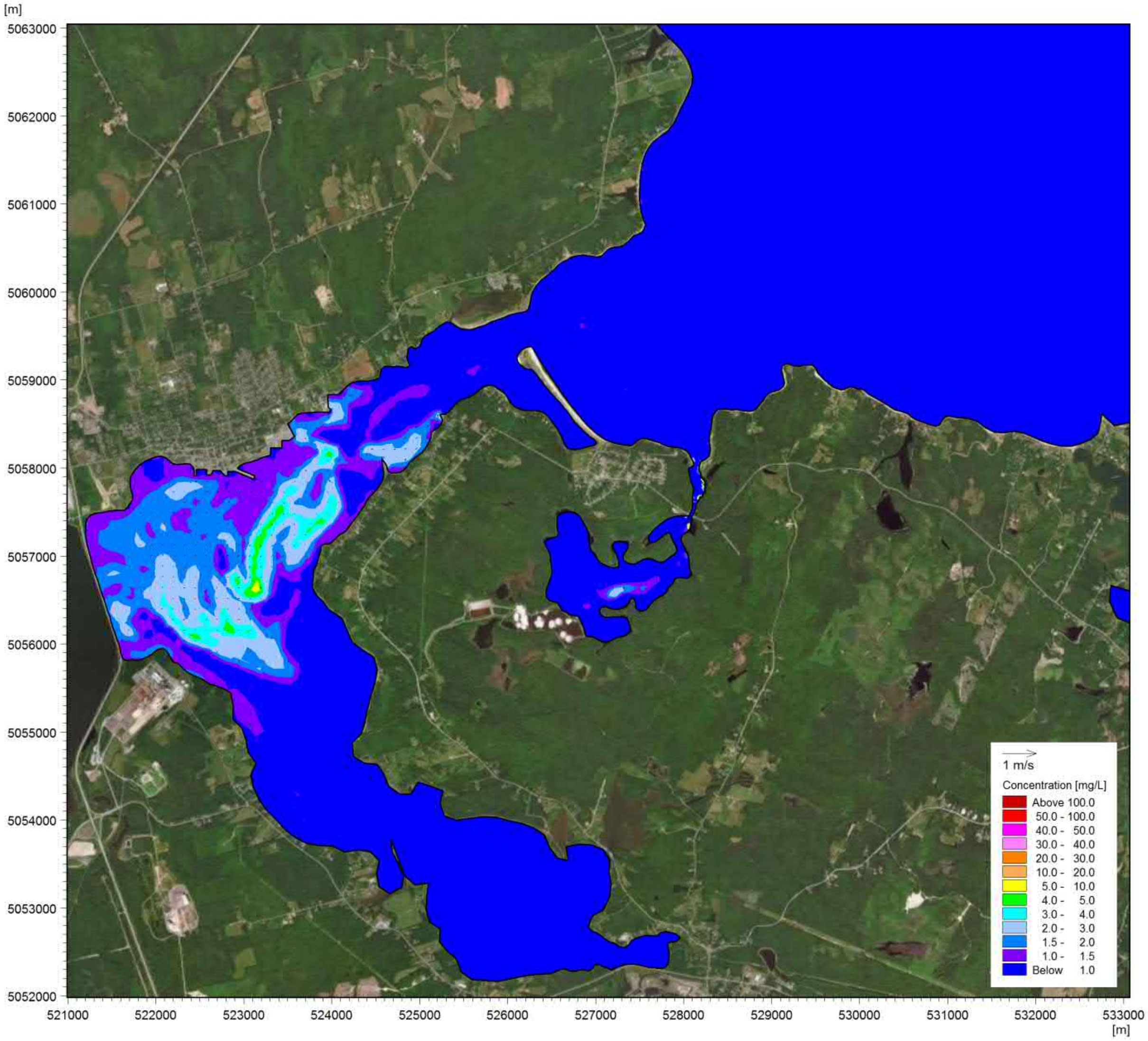


Figure A-11 Alt-B Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Neap Tide - Slack High Tide at 17:00 hr, July 13

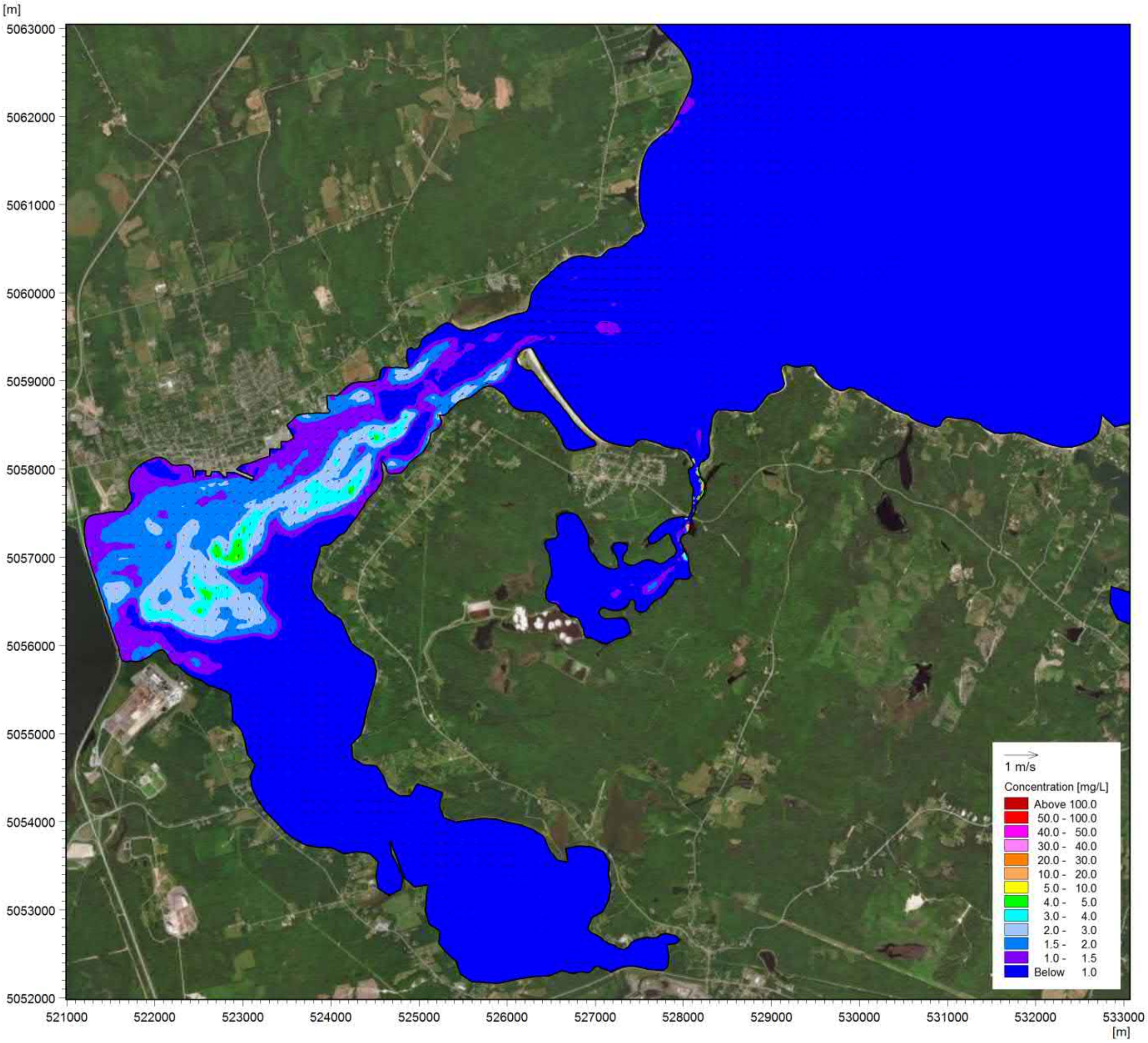


Figure A-12 Alt-B Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Neap Tide - Ebb Tide at 20:00 hr, July 13

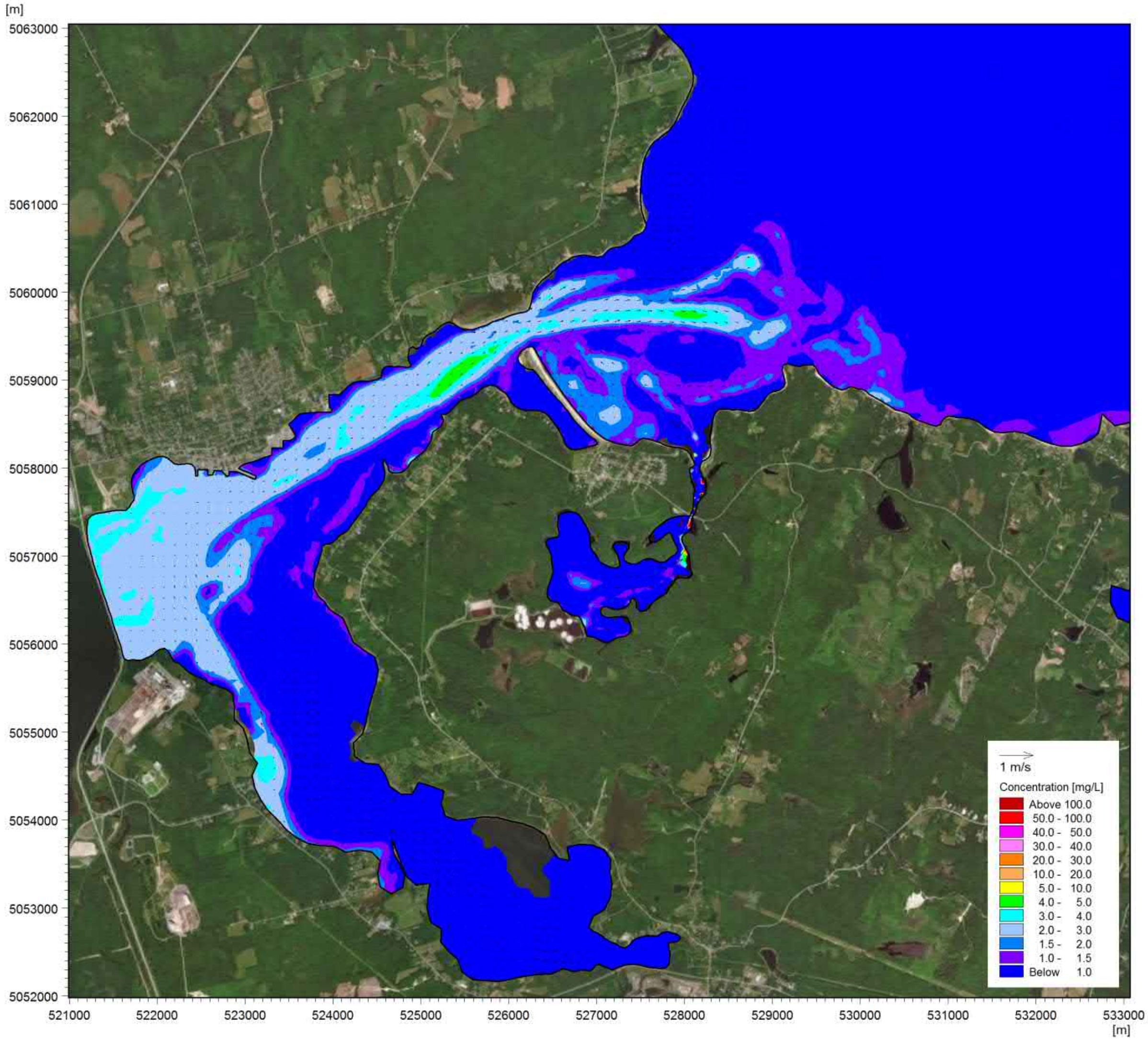


Figure A-13 **Alt-B Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Spring Tide - Slack Low Tide at 17:00 hr, July 21**

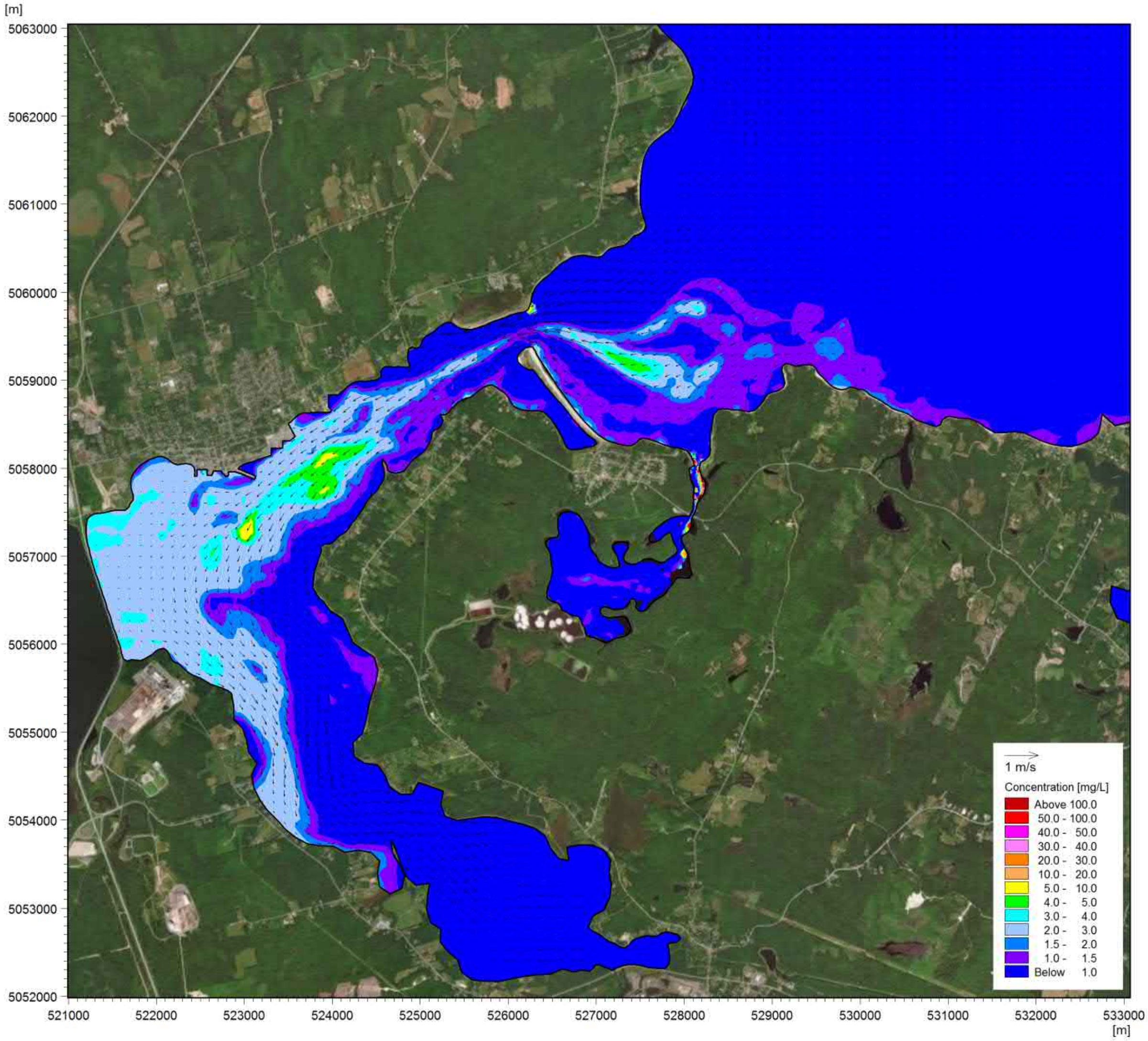


Figure A-14 Alt-B Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Spring Tide – Flood Tide at 21:00 hr, July 21

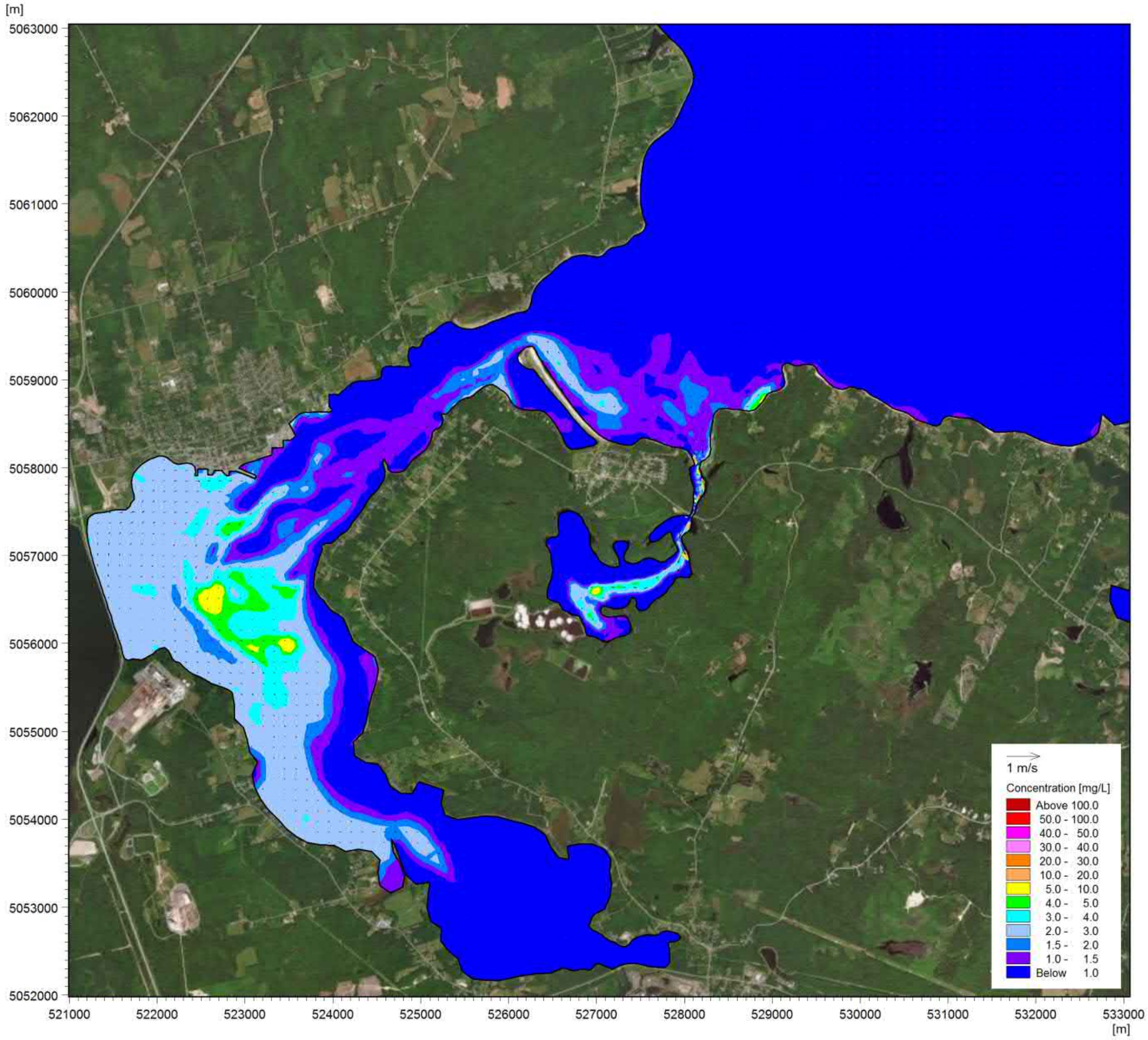


Figure A-15 Alt-B Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Spring Tide –Slack High Tide at 11:00 hr, July 22

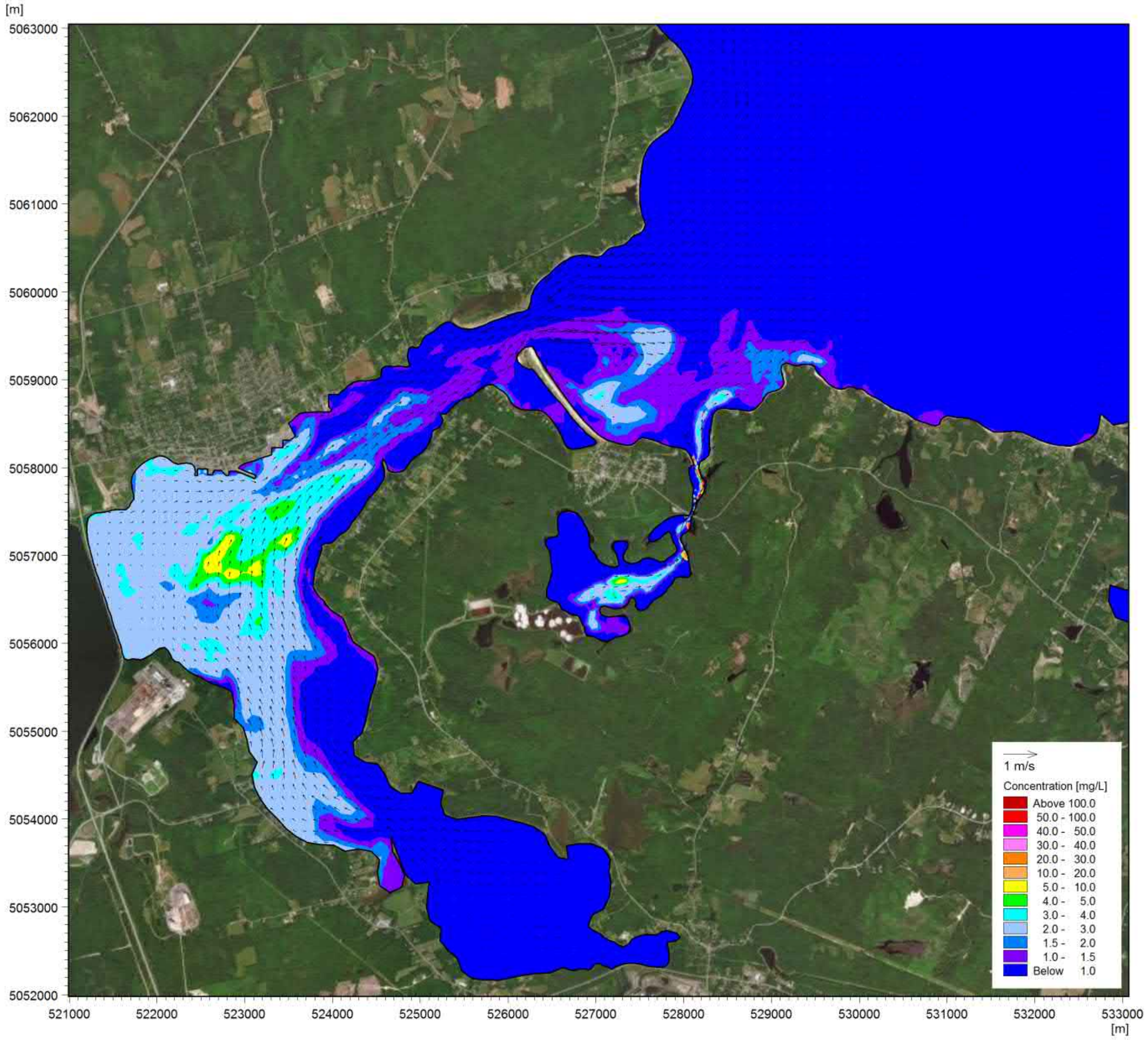


Figure A-16 Alt-B Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Spring Tide – Ebb Tide at 14:00 hr, July 22

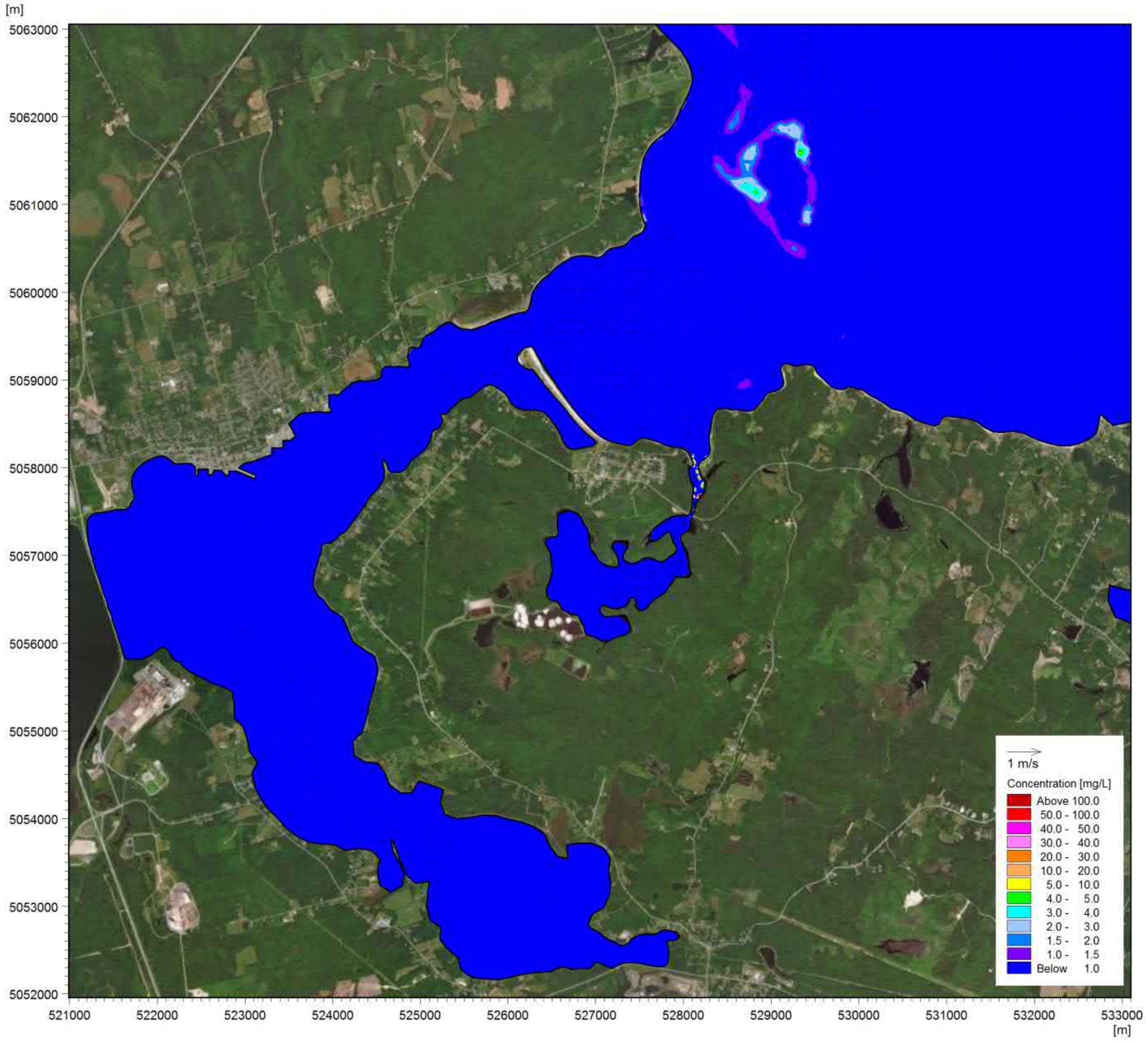


Figure A-17 Alt-C Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Neap Tide - Slack Low Tide at 10:00 hr, July 13

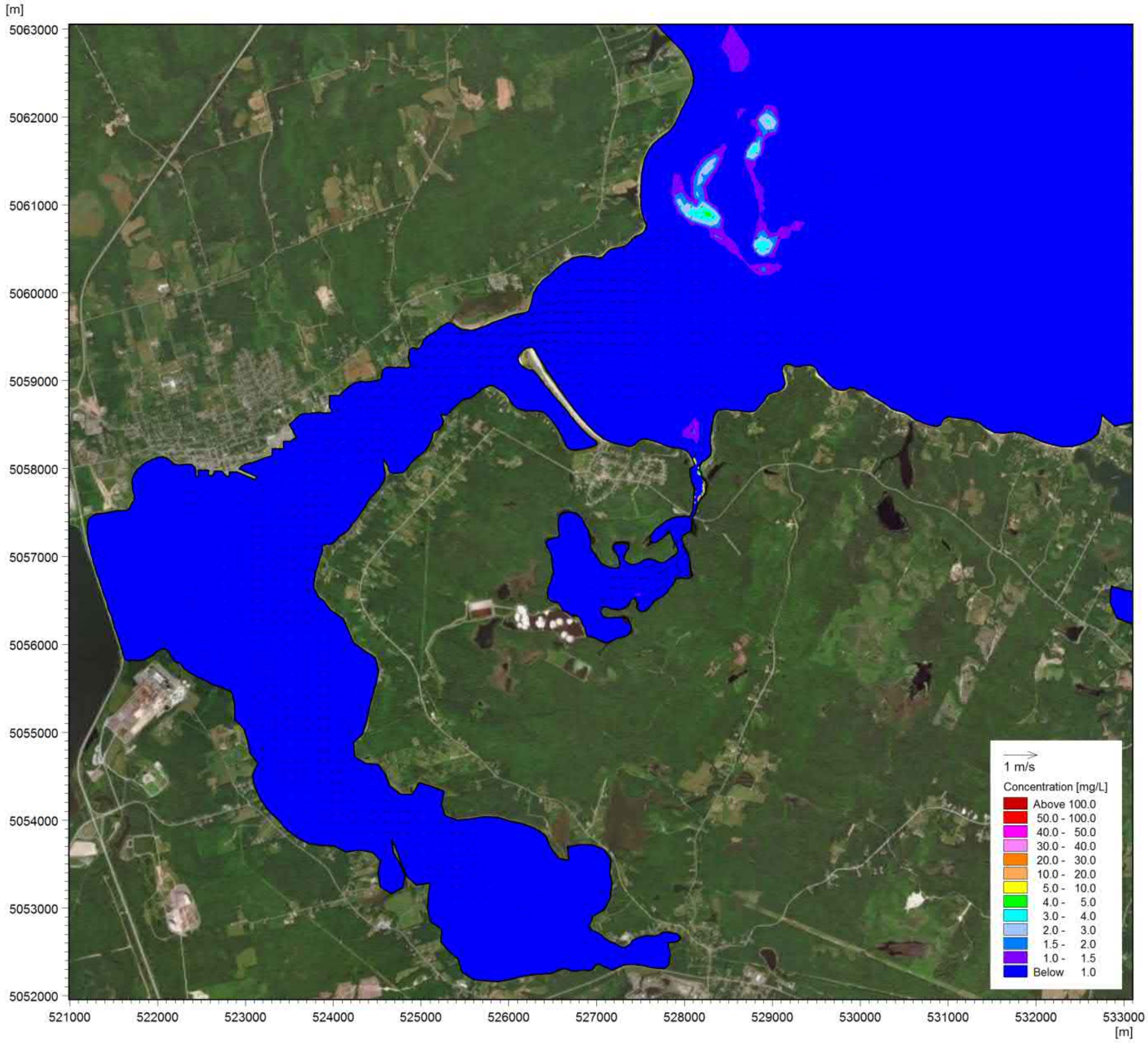


Figure A-18 Alt-C Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Neap Tide - Flood Tide at 14:00 hr, July 13

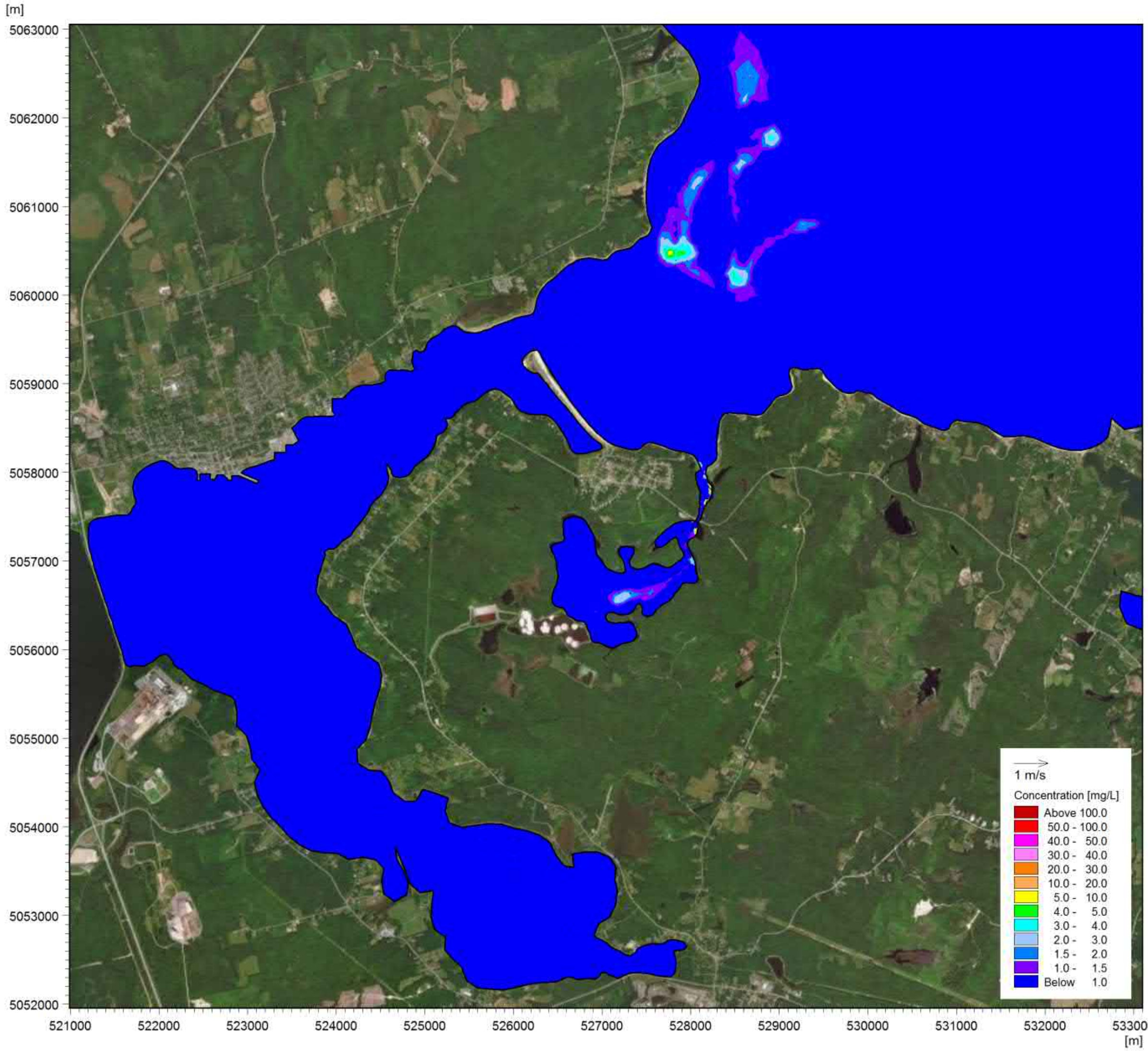


Figure A-19 **Alt-C Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Neap Tide - Slack High Tide at 17:00 hr, July 13**

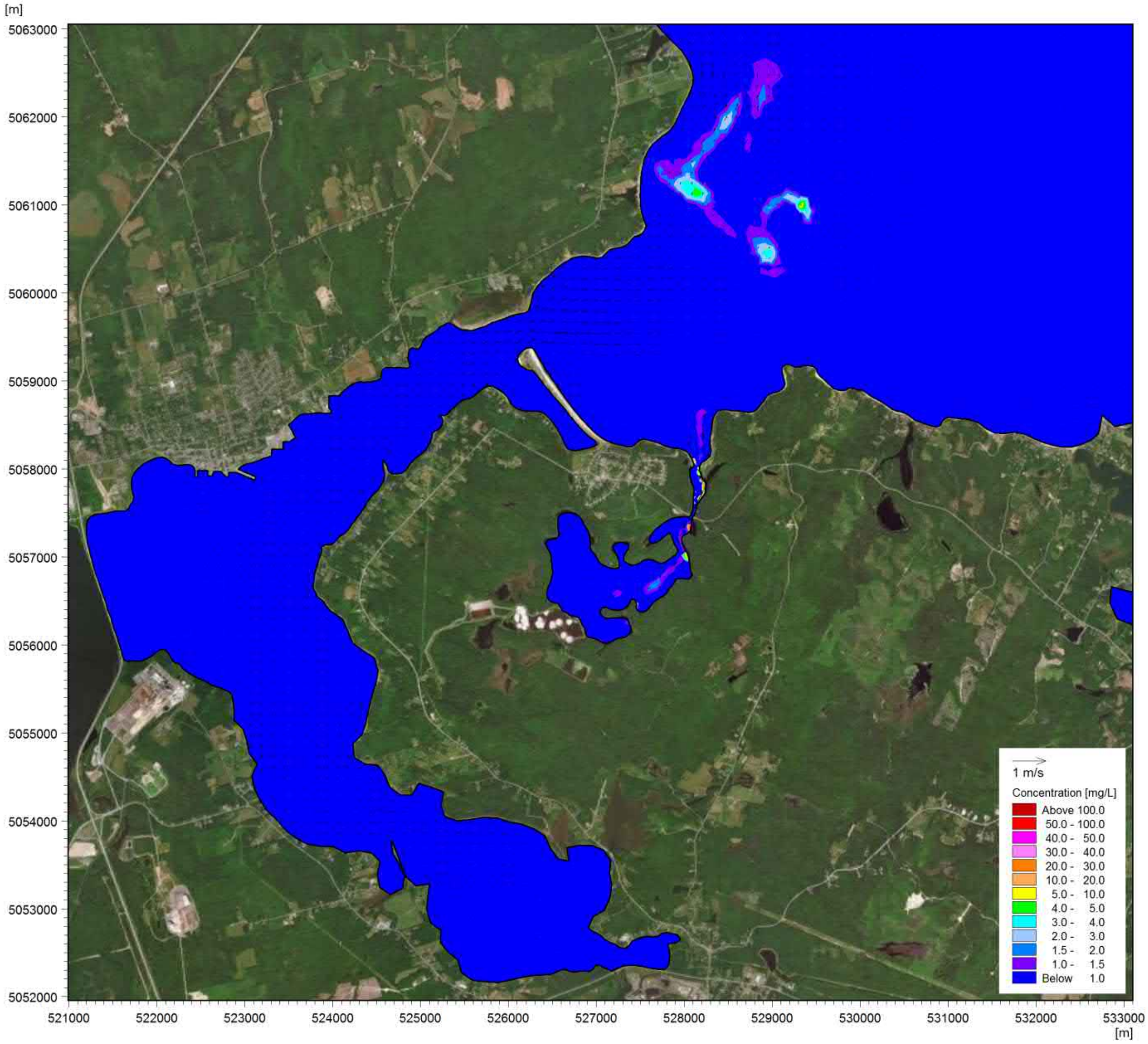


Figure A-20 Alt-C Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Neap Tide - Ebb Tide at 20:00 hr, July 13

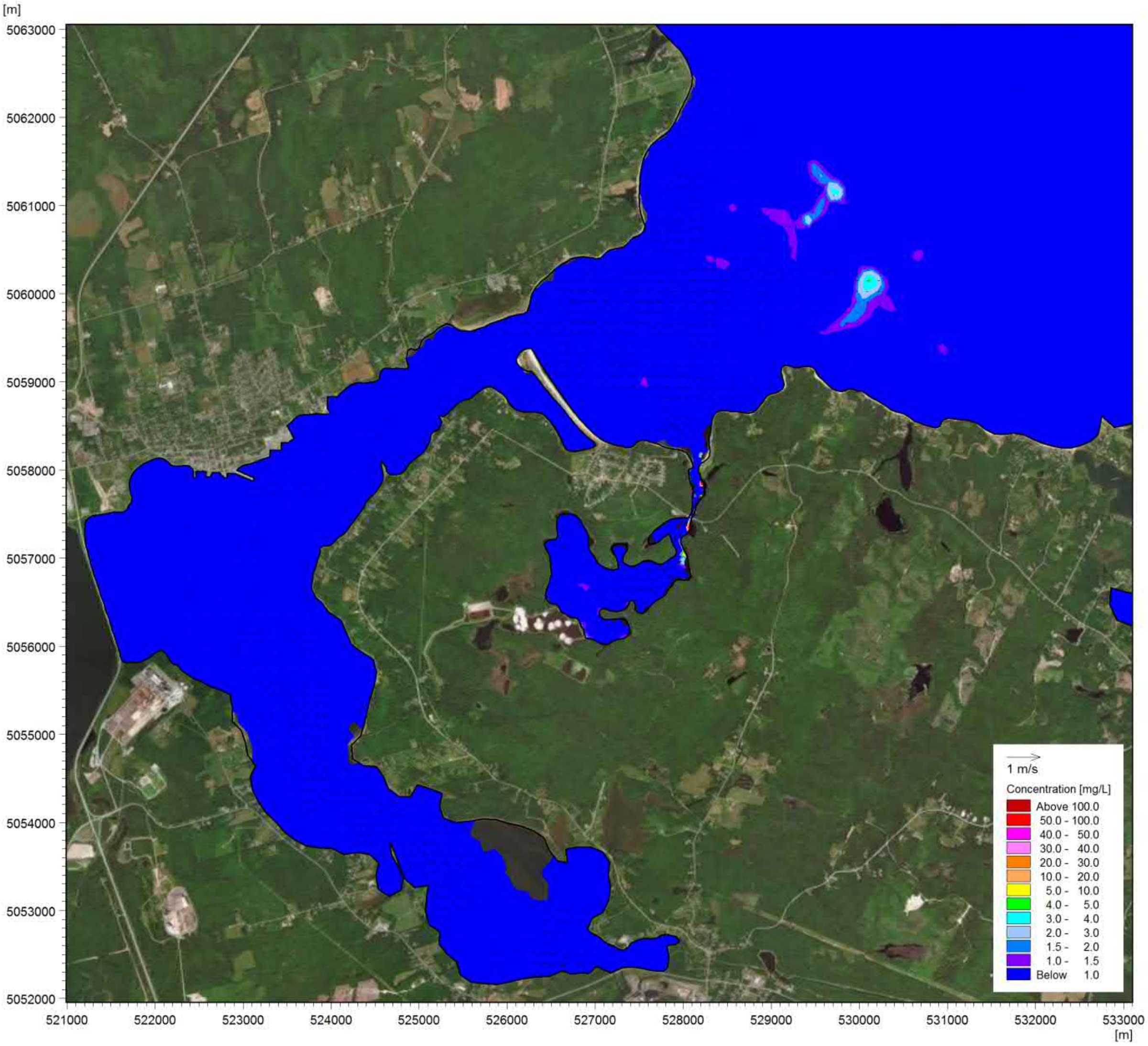


Figure A-21 Alt-C Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Spring Tide - Slack Low Tide at 17:00 hr, July 21

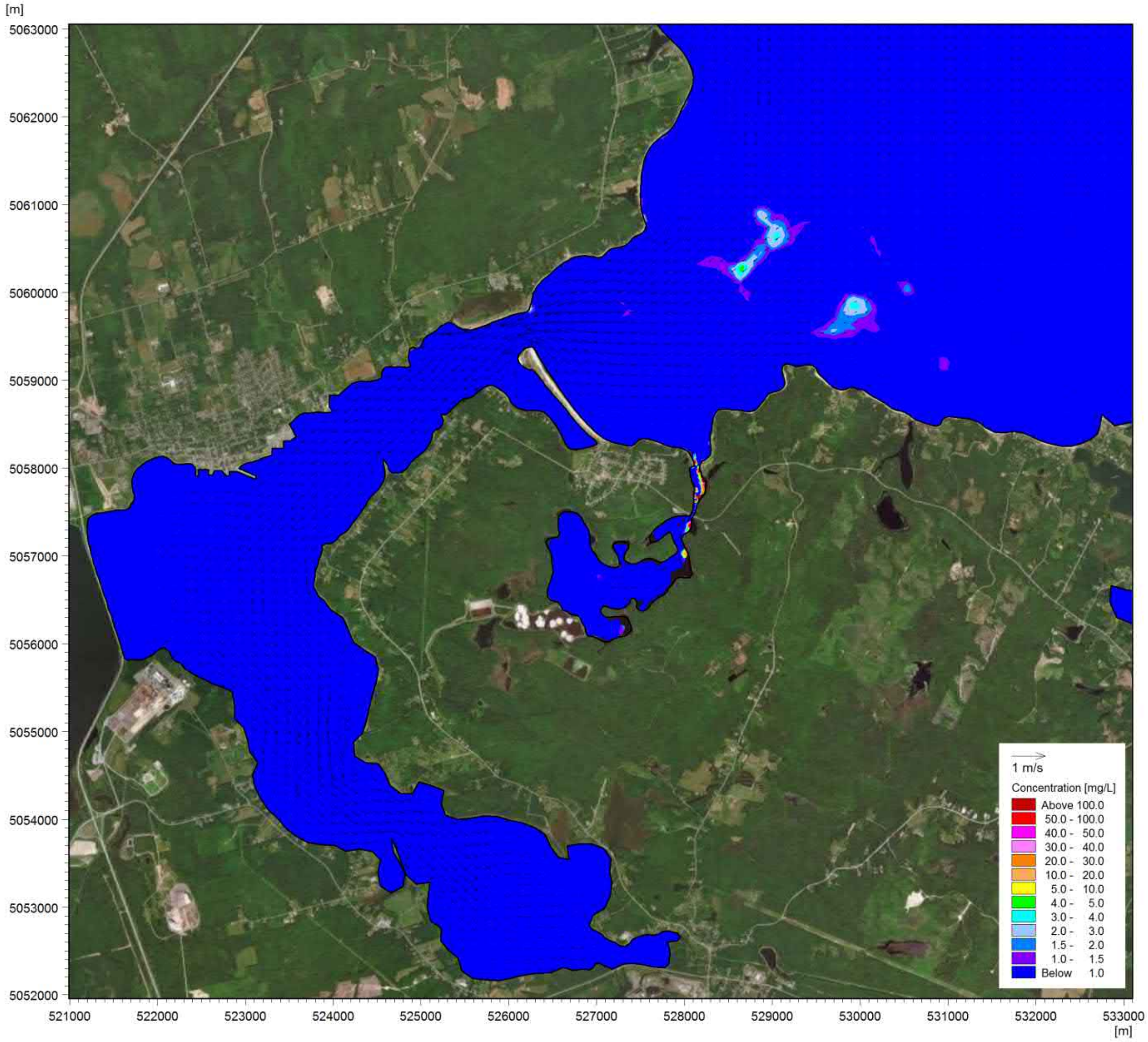


Figure A-22 Alt-C Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Spring Tide – Flood Tide at 21:00 hr, July 21

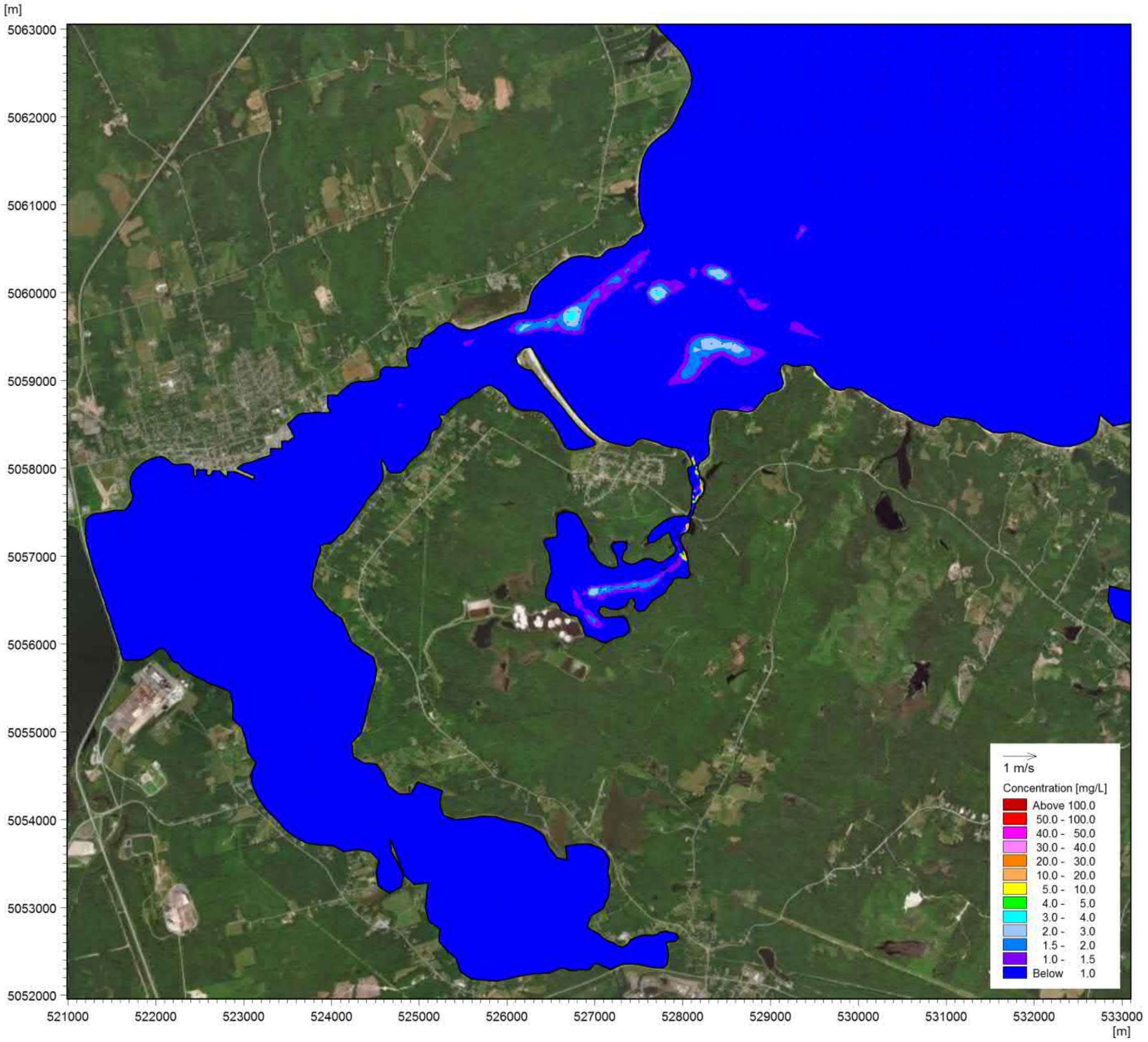


Figure A-23 Alt-C Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Spring Tide –Slack High Tide at 11:00 hr, July 22

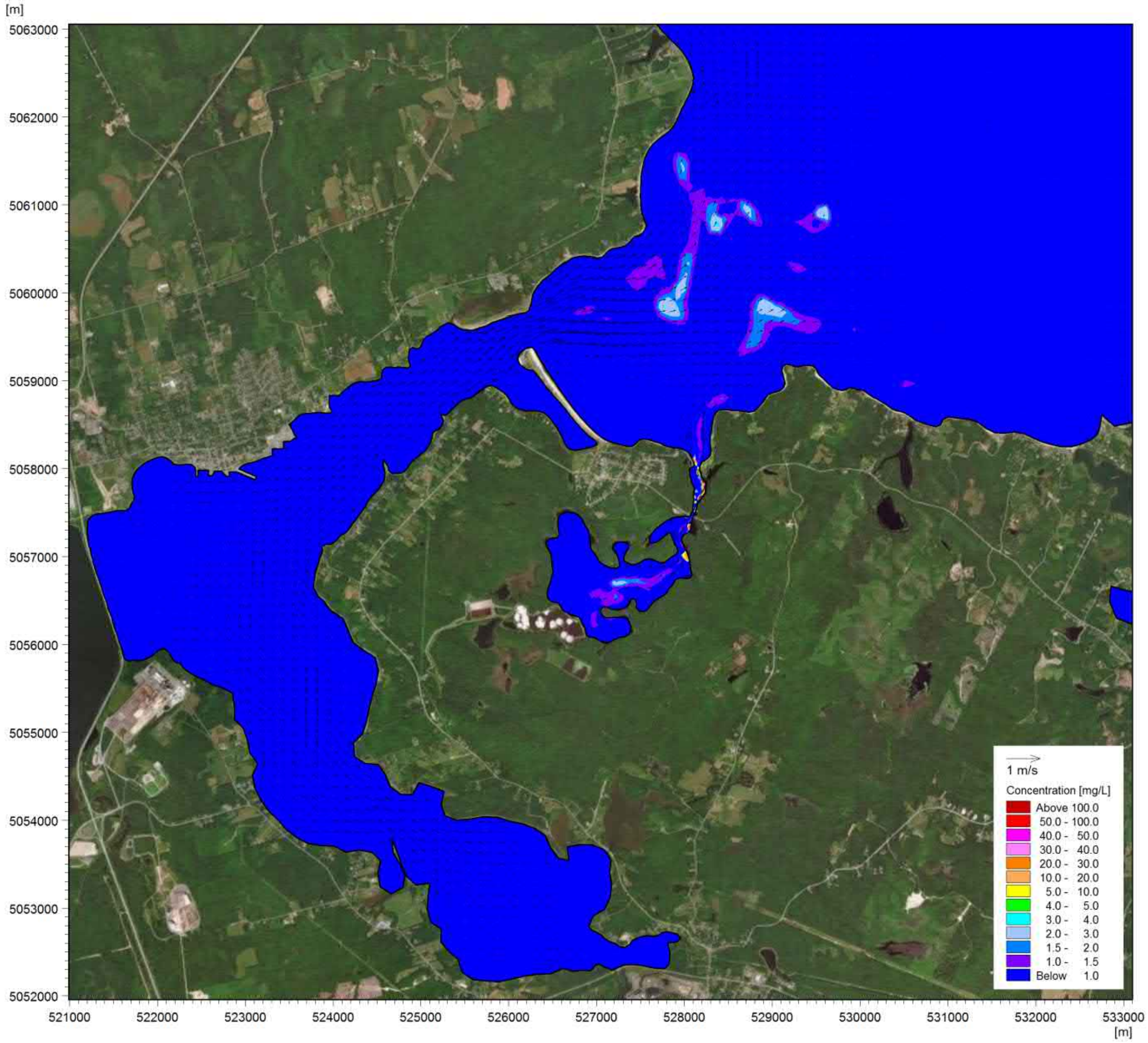


Figure A-24 Alt-C Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Spring Tide – Ebb Tide at 14:00 hr, July 22

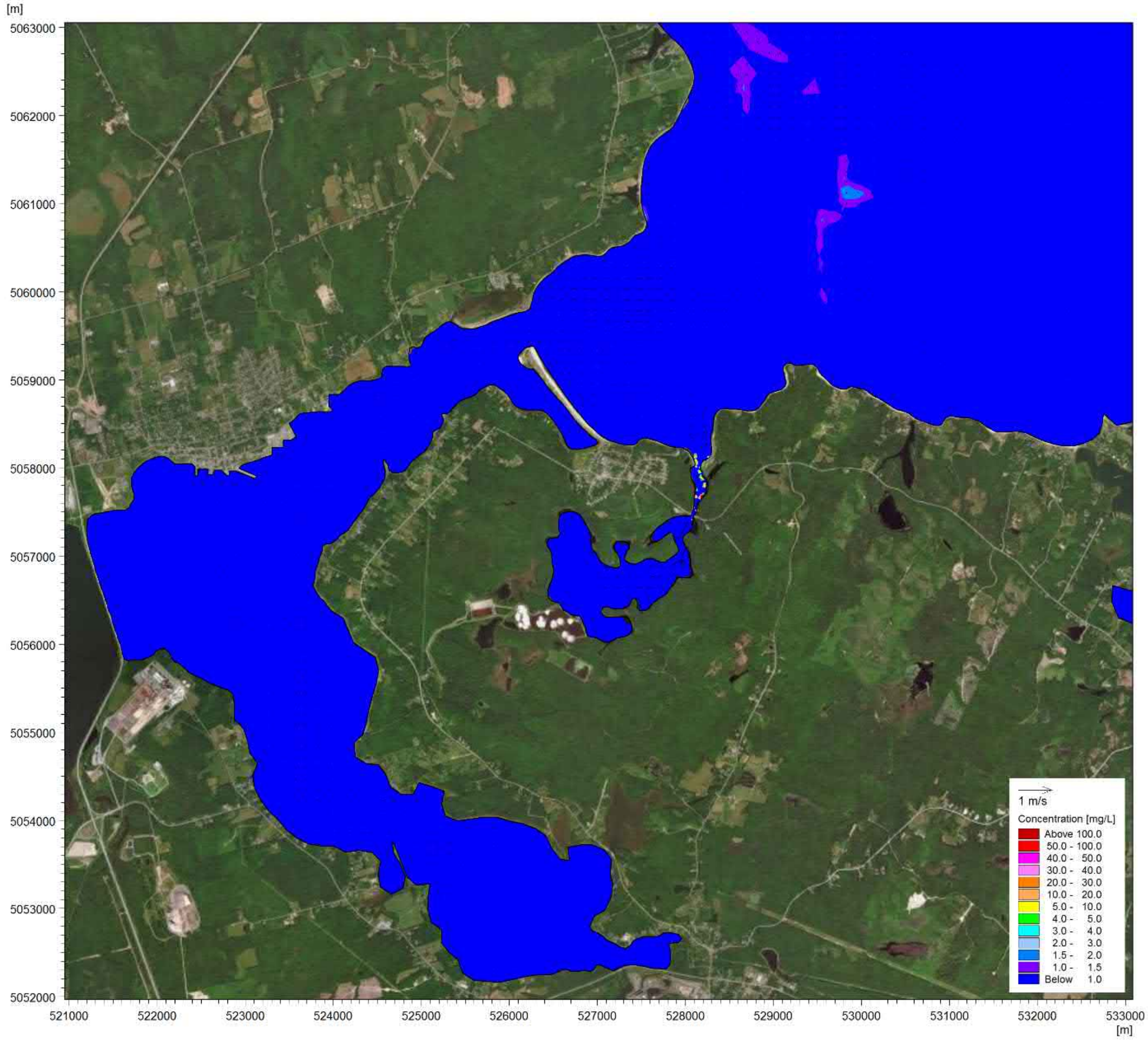


Figure A-25 Alt-D Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Neap Tide - Slack Low Tide at 10:00 hr, July 13

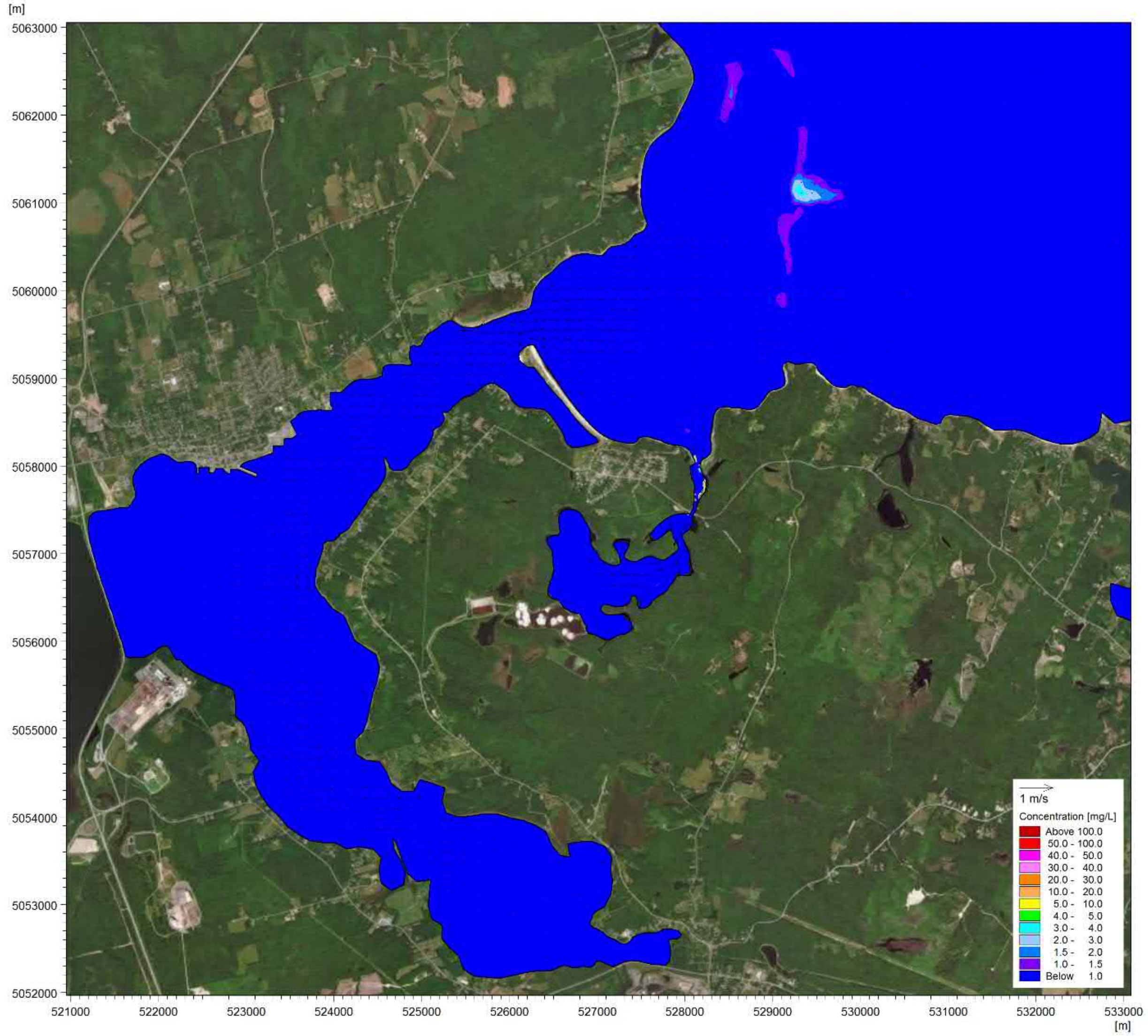


Figure A-26 Alt-D Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Neap Tide - Flood Tide at 14:00 hr, July 13

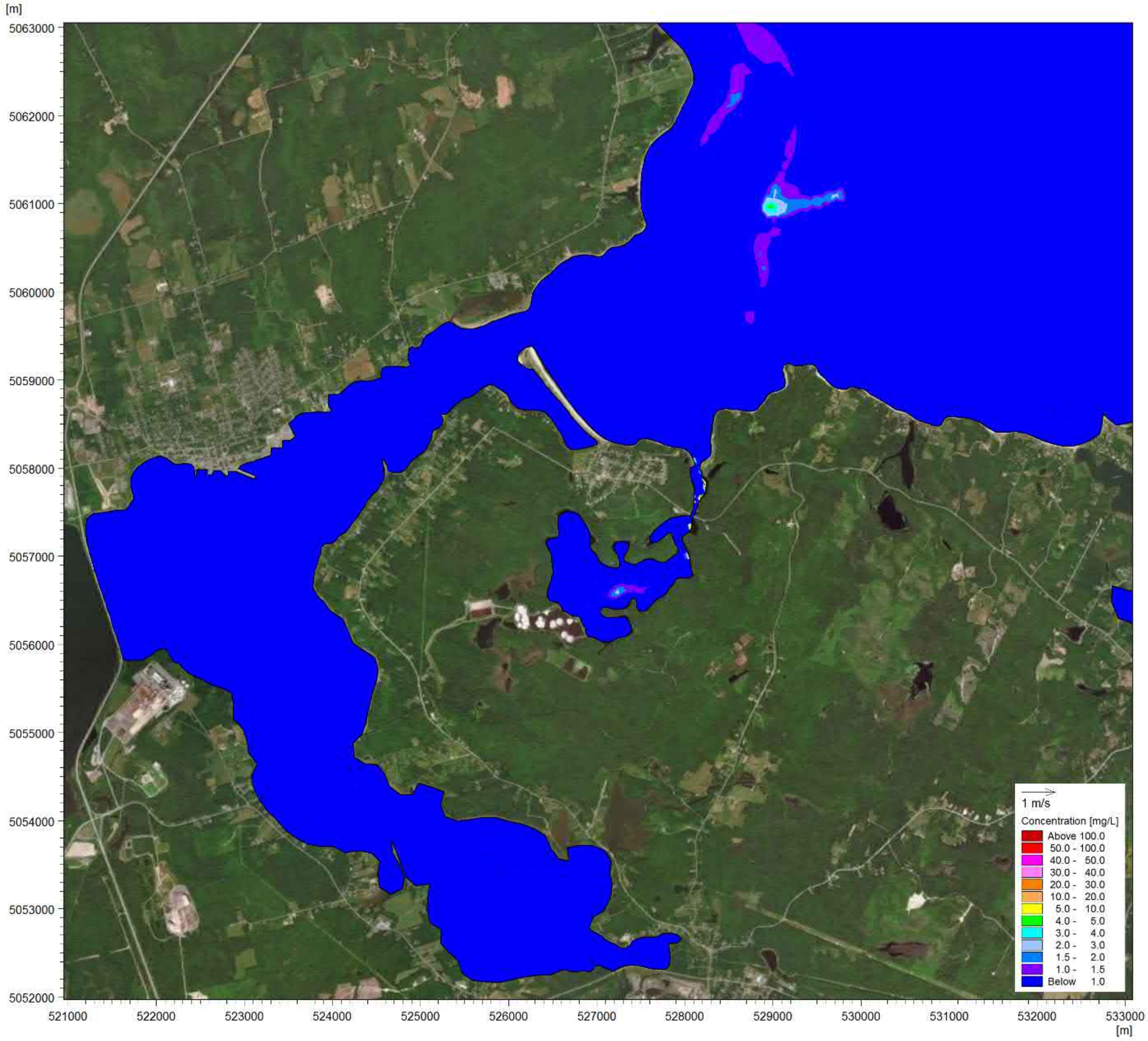


Figure A-27 Alt-D Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Neap Tide - Slack High Tide at 17:00 hr, July 13

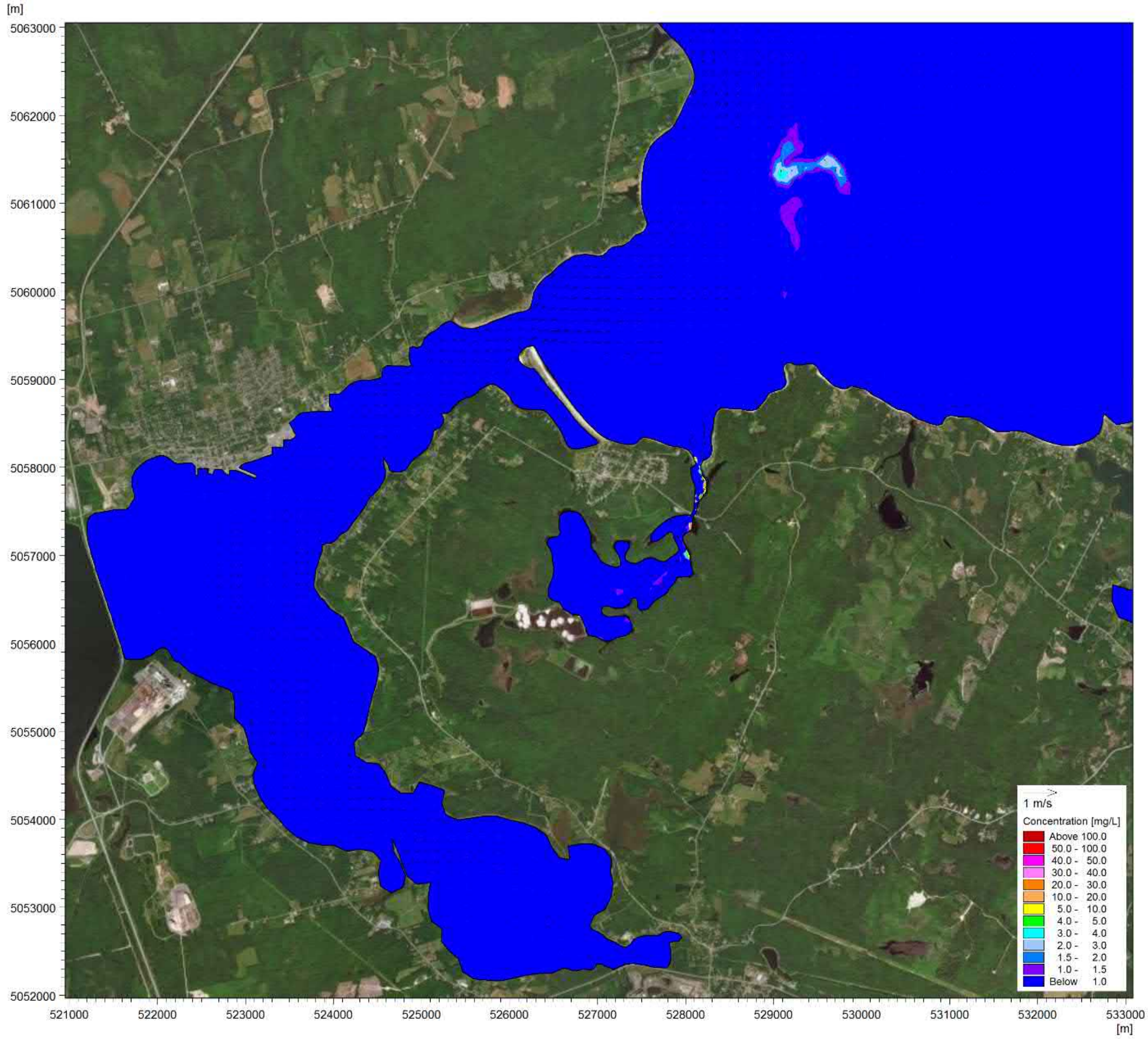


Figure A-28 Alt-D Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Neap Tide - Ebb Tide at 20:00 hr, July 13

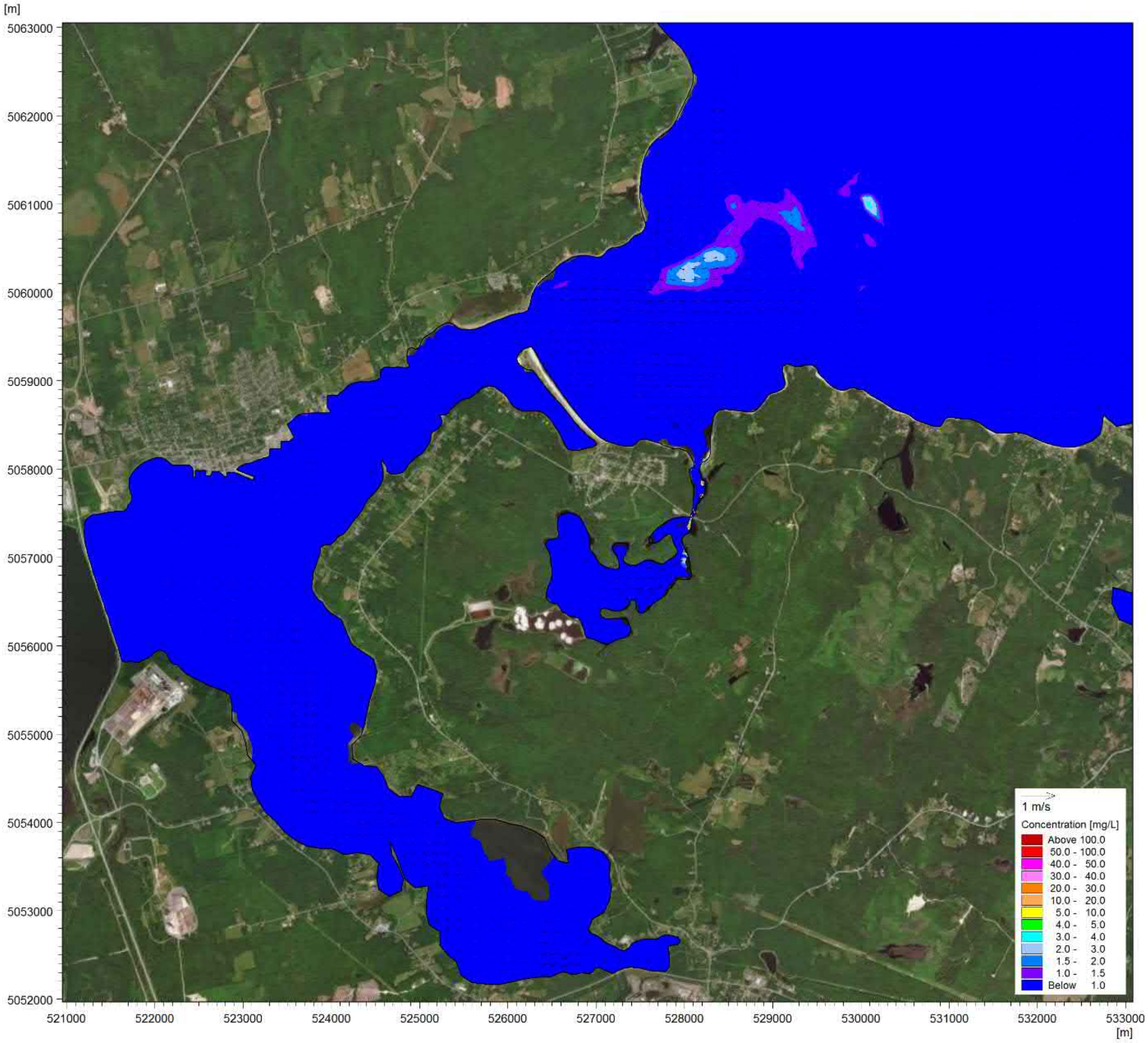


Figure A-29 Alt-D Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Spring Tide - Slack Low Tide at 17:00 hr, July 21

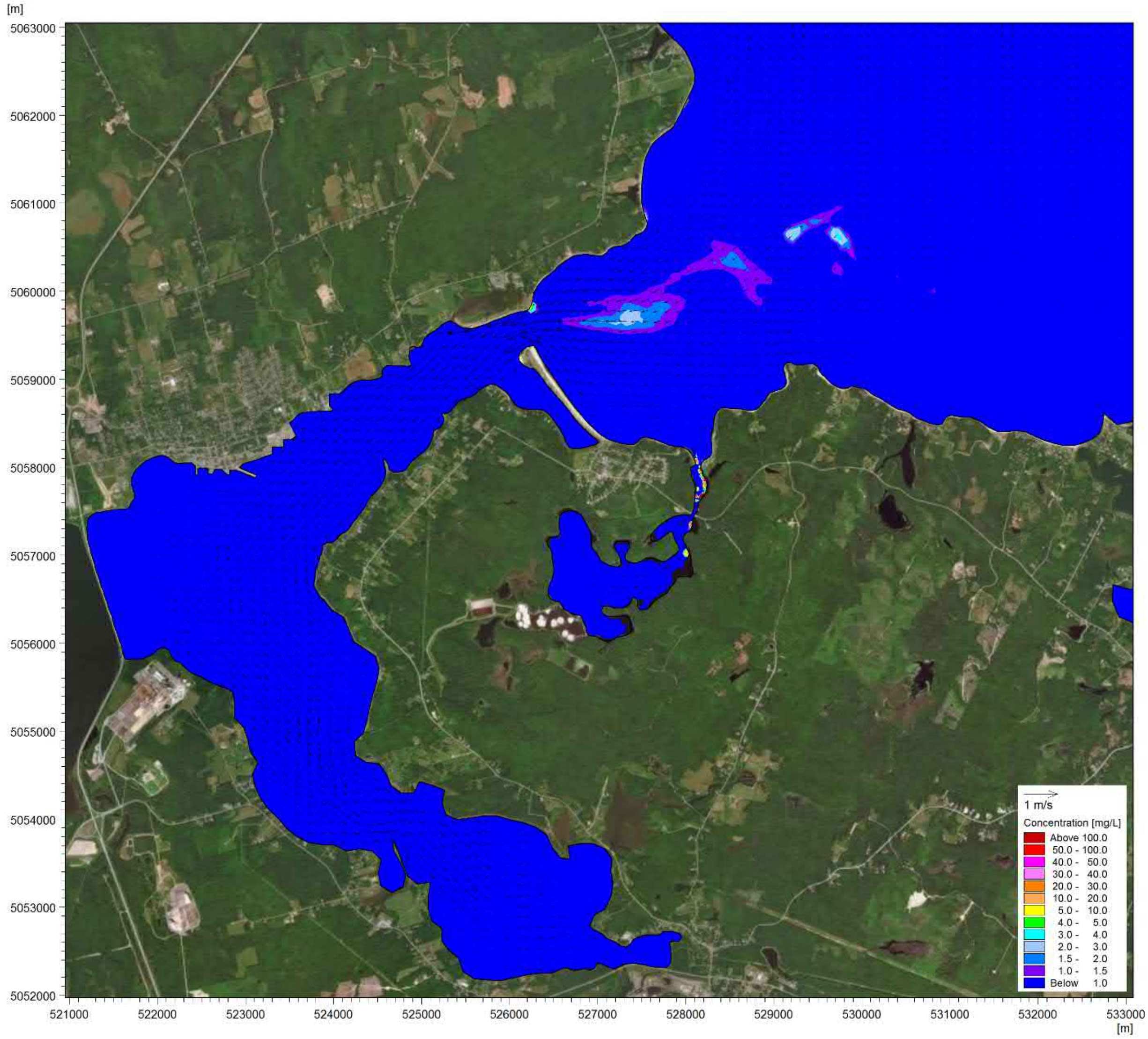


Figure A-30 **Alt-D Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Spring Tide – Flood Tide at 21:00 hr, July 21**

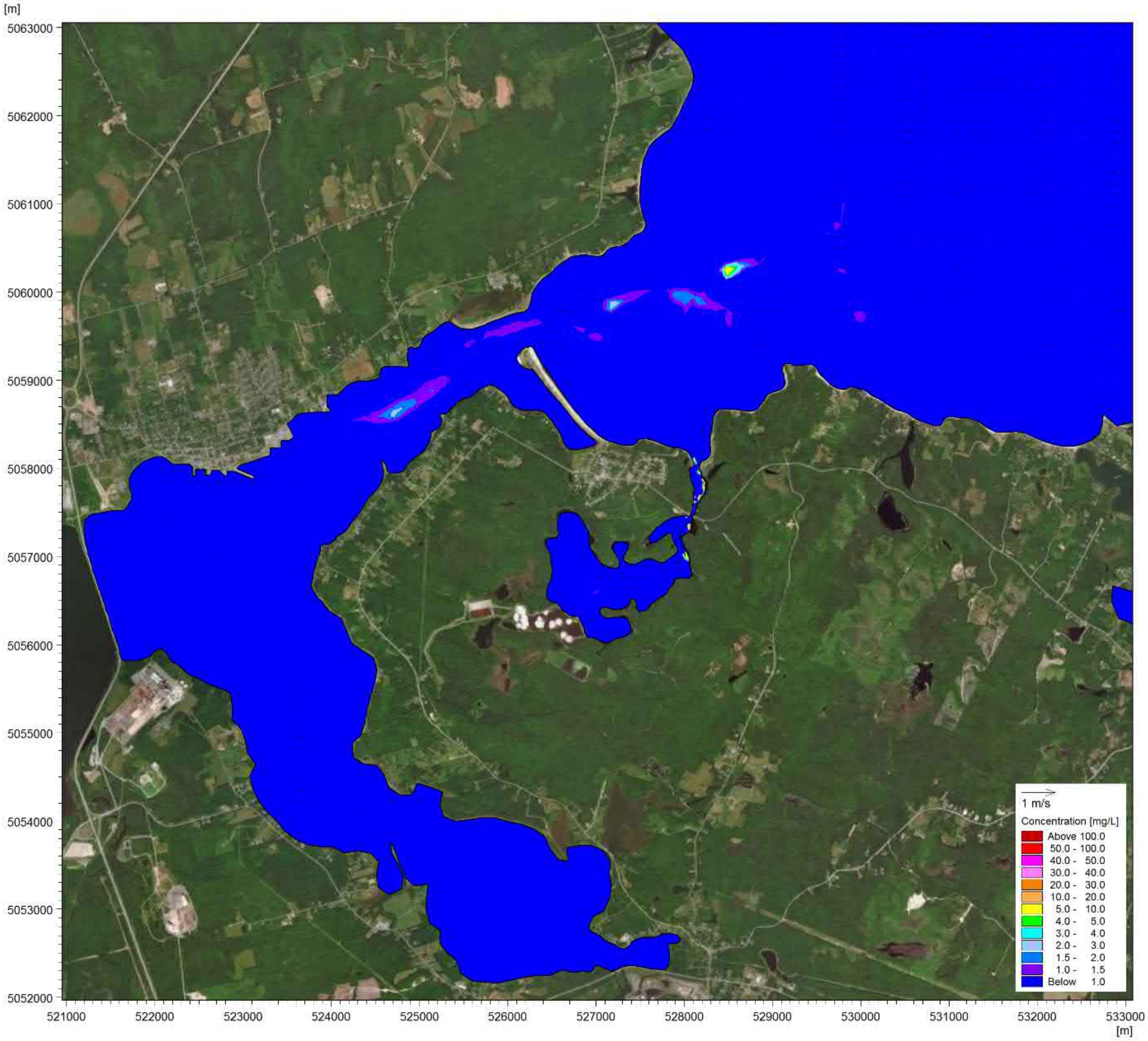


Figure A-31 **Alt-D Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Spring Tide – Slack High Tide at 11:00 hr, July 22**

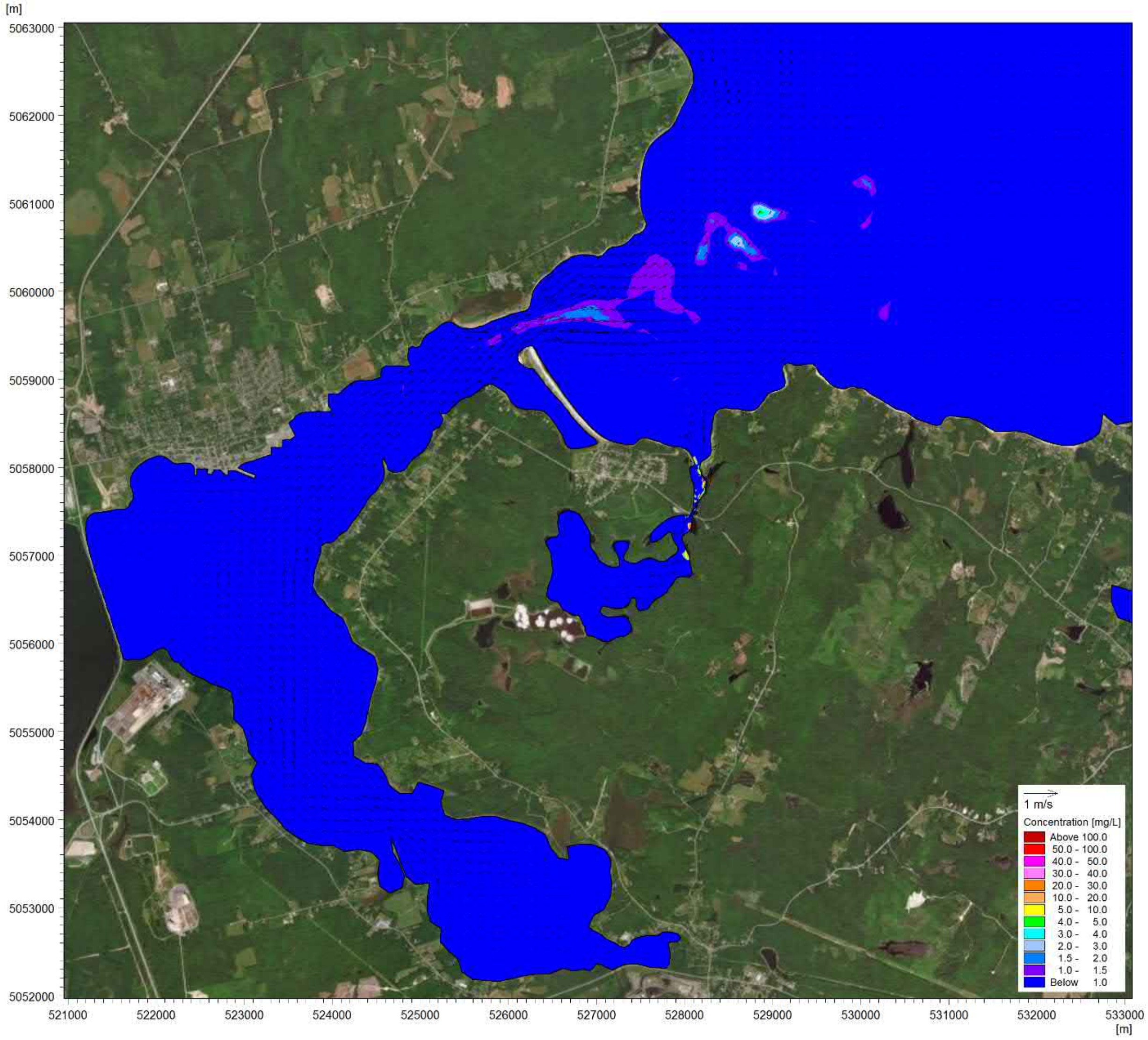


Figure A-32 Alt-D Discharge: Simulated Currents Circulation and Effluent Concentrations for Typical Spring Tide – Ebb Tide at 14:00 hr, July 22

APPENDIX B

BACKGROUND WATER QUALITY IN THE PICTOU ROAD AREA, NS

Appendix B - Background Water Quality in the Pictou Road Area, NS

Location	Date	Parameter								
		Total Nitrogen (mg/L)	**Total Phosphorus (mg/L)**	**TSS (mg/L)**	**Dissolved Oxygen (mg/L)**	**pH**	**Temperature (°C)**	**Salinity (psu)**	**Colour (TCU)**	**Source**
Outer Harbour	6-Mar-1990 to 2-May-1990						0.34	28.75		DFO Current Database
Outer Harbour	6-Mar-1990 to 2-May-1990						-0.01	30.37		DFO Current Database
Lighthouse Beach Site 1	23-Jun-89			36					670[B]	JWEL. 1994. Project #9768
Lighthouse Beach Site 2	23-Jun-89			26					420[B]	JWEL. 1994. Project #9768
Lighthouse Beach Site 3	23-Jun-89			4.5					9.5	JWEL. 1994. Project #9768
Lighthouse Beach Site 4	23-Jun-89			4					12	JWEL. 1994. Project #9768
Pictou Road Area	2002	0.025	0.04	4.5		8.1				JWEL 2005. Reintroduction to tidal influence.
Pictou Road Area	2002	0.025	0.08	3		8				JWEL 2005. Reintroduction to tidal influence.
Pictou Road Area	2002	0.025	0.07	3.5		8.1				JWEL 2005. Reintroduction to tidal influence.
Pictou Road Area	2002	0.025	0.005	3.2		8.1				JWEL 2005. Reintroduction to tidal influence.
Pictou Road Area	2002	0.025	0.02	3.2		7.9				JWEL 2005. Reintroduction to tidal influence.
Pictou Road Area	2002	0.025	0.005	3		8				JWEL 2005. Reintroduction to tidal influence.
Pictou Road Area	2002	0.025	0.005	2.5		8				JWEL 2005. Reintroduction to tidal influence.
Pictou Road Nearfield	Sep-06		0.04		6.4	8	16.1	26.5		Ecometrix.2007. EEM Cycle 4
Pictou Road Farfield	Sep-06		0.015[A]		6.5	8.1	15.9	27		Ecometrix.2007. EEM Cycle 4
Pictou Road Far-farfield	Sep-06		0.015[A]		6.4	8	16.3	27		Ecometrix.2007. EEM Cycle 4
Pictou Road Nearfield (surface)	Aug-14				7.8	7.9	18.8	24		Ecometrix.2016. EEM Cycle 7
Pictou Road Farfield (surface)	Aug-14				8.1	7.9	19.4	23		Ecometrix.2016. EEM Cycle 7
Pictou Road Far-farfield (surface)	Aug-14				8.1	8	19.2	23		Ecometrix.2016. EEM Cycle 7
Pictou Road	Sep-90	0.101	0.8							Dalziel et al. 1993. Water Chem Pictou harbour
Pictou Road	Sep-90	0.867	0.711							Dalziel et al. 1993. Water Chem Pictou harbour
Pictou Road	Sep-90	0.789	0.64							Dalziel et al. 1993. Water Chem Pictou harbour
Pictou Road	Sep-90	0.969	0.84							Dalziel et al. 1993. Water Chem Pictou harbour
Pictou Road	Sep-90	0.148	1.451							Dalziel et al. 1993. Water Chem Pictou harbour
Pictou Road	Sep-90	0.105	0.918							Dalziel et al. 1993. Water Chem Pictou harbour

No. of Samples		13	16	11	6	13	8	8	2	
MEDIAN		0.025	0.055	3.5	7.2	8.0	16.2	26.8	11	
AVERAGE		0.243	0.353	8.5	7.2	8.0	13.3	26.2	10.8	
MIN		0.025	0.005	2.5	6.4	7.9	0.0	23.0	10	
MAX		0.969	1.451	36.0	8.1	8.1	19.4	30.4	12	

Notes:

[A] Value below the laboratory reportable detection limit < 0.03 mg/L, therefore half the detection limit was used (i.e., 0.015 mg/L).

[B] high colour values at Sites 1 and 2 are disregarded as these are close to Boat Harbour discharge.