Appendix B2

Dispersion Study –

NEAR-FIELD MODELLING STUDY OF EFFLUENT DISPERSION IN ARGENTIA HARBOUR

Effluent Dispersion Model Study

NEAR-FIELD MODELING STUDY OF EFFLUENT DISPERSION IN ARGENTIA HARBOUR

Submitted to

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List of Abbreviations

Abbreviations	**Definitions**
BIO	Bedford Institute of Oceanography
CCME	Canadian Council of Ministers of the Environment
CEQG	Canadian Environmental Quality Guidelines
CSAS	Canadian Science Advisory Secretariat
CTD	Conductivity Temperature Depth
DFO	Department of Fisheries and Oceans
FEL	Front End Loading study
NL	Newfoundland and Labrador
PSU	Practical Salinity Unit
SEM	Sikumiut Environmental Management
UTM	Universal Transverse Mercator

1.0 Introduction

The aim of this report is to execute a three-dimensional near-field modeling endeavor aimed at evaluating dilution patterns stemming from effluent discharge via a proposed marine outfall to support an Environmental Assessment registration. This investigation centers on near-field mixing phenomena, emphasizing conditions within and proximate to the initial mixing zone, while operating under typical summer and winter ambient seawater conditions. Utilizing the CORMIX model, water quality assessments were conducted concerning temperature and salinity alterations resulting from effluent dispersion. The primary objective of this study was to ascertain adherence to the ambient seawater quality standards as outlined by the Canadian Council of Ministers of the Environment (CCME) Canadian Environmental Quality Guidelines (CEQG) at the periphery of the mixing zone (CCME CEQG, 2003).

The report (dispersion study) delineates effluent characterization alongside ambient seawater conditions pertinent to the effluent discharge in Section 2. Subsequently, Sections 3 and 4 expound upon the model's configuration specifics and present the resultant modeling outcomes. Finally, Section 5 encapsulates the study's findings and draws pertinent conclusions.

2.0 Effluent and Ambient Characterizations

The effluent temperature at discharge is standardized at 25°C for summer and 15°C for winter scenarios. Additionally, the effluent, possessing a salinity akin to freshwater, is designated at 0.5 PSU. A consistent discharge rate of 688,800 liters per day is maintained, as detailed in Table B2-2.0-1.

Table B2-2.0-1 Effluent Discharge Rate and Characterization

Season	Discharge Rate (L/day)	Temperature (°C)	Salinity (PSU)
Summer	688,800	25	0.5
Winter	688,800	15	0.5

The discharge rate was estimated from the total import of water to the facility. During standard operations, the estimated effluent discharge rate will be lower than the one proposed in this report. However, during fire or storm, the effluent discharge rate could potentially reach the full effluent discharge rate proposed in the dispersion study.

Two potential discharge sites have been proposed: Coordinates from Marine Station 1 (MS1) and Marine Station 2 (MS2) are provided in Table B2-2.0-2. MS1 is situated at a water depth of approximately 37 meters (m) Chart Datum, while MS2 rests at approximately 14 m Chart Datum. The effluent discharge depth has been proposed at approximately 5 m below the surface of the water. Table B2-2.0-2 also provides the location of a station used for monitoring the temperature near MS1, which will be discussed in the following sections. Figure B2-2.0-1 depicts the geographical positions of MS1, MS2, and T1.

Table B2-2.0-2 Marine Stations and Temperatures Coordinates.

Station	Latitude	Longitude
Marine Station 1 (MS1)	47°18'33.4212"N	53°58'05.8227"W
Marine Station 2 (MS2)	47°18'23.9856"N	53°58'19.5690"W
Temperature Profiling (T1)	47°18'32.0976"N	53°58'01.9165"W
Station	**Easting**	**Northing**
Marine Station 1 (MS1)	275648.00	5243808.00
Marine Station 2 (MS2)	275342.00	5243528.00
Temperature Profiling (T1)	275728.45	5243764.02

UTM Zone 22N

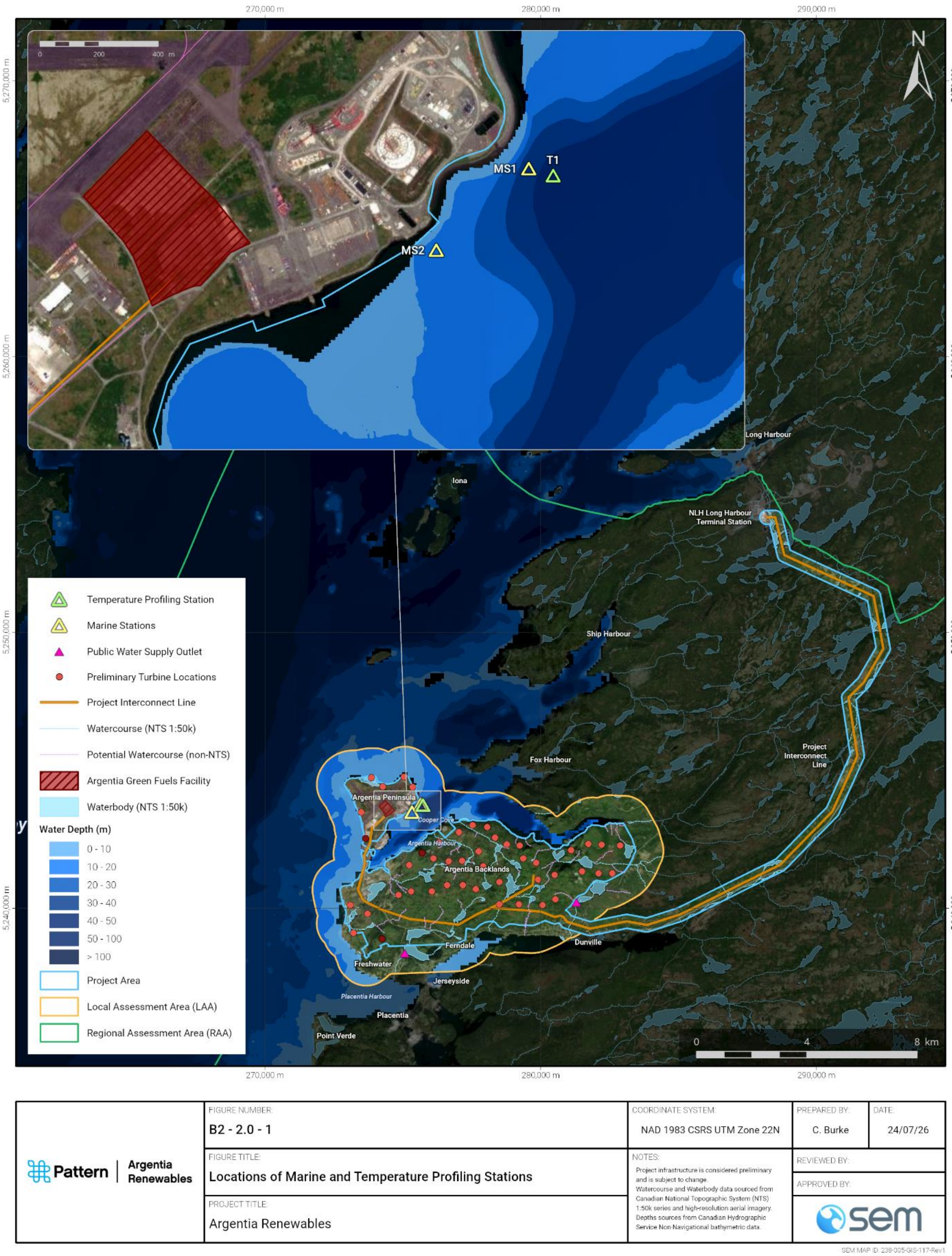


Figure B2-2.0-1 Locations of Marine and Temperature Profiling Stations.

2.1 CTD Measurement

On August 26, 2023, a single-day Conductivity, Temperature, and Depth (CTD) measurement was conducted at both MS1 and MS2. A summary of the ambient seawater condition from the CTD is provided in Table B2-2.1-1. The table also provides the conservative current speed of 5 cm/s, which was estimated based on historical data in proximity to the near-field study (section 2.2.3).

Table B2-2.1-1 Ambient Seawater Conditions

Season	Thermocline Depth (m)	Temperature (°C)		Salinity (PSU)		Current (cm/s)
		Top Layer	Bottom Layer	Top Layer	Bottom Layer	
Summer	13 to 18	17	6	31.2	32.0	5
Winter	N/A	0		32.0		5

Upon examination of the CTD observations at MS1 and MS2, alongside the temporal temperature profile from August to December 2023 at T1 (near MS1), it was determined that a thermocline persisted from August through late October, with a layer depth ranging between an approximate of 13 m and 18 m (Figures B2- 2.1-1 and B2- 2.1-2), which is also mentioned in the Aquatic Baseline Report (Section 6.0; Appendix B1). Notably, MS1 and MS2 exhibited analogous profiles above the 14 m depth, albeit MS1 displayed evidence of freshwater influence, characterized by fresher and lighter seawater within the upper approximately 2 m. Considering the dispersion study being proposed at a depth of 5 m, both marine stations are suitable for the interpretation of the model.

Measurements conducted with the CTD show a temperature value of approximately 17°C and a salinity of 31.2 PSU in the upper layer above the thermocline during summer, contrasting with a temperature of approximately 6°C and a salinity of 32.0 PSU at the bottom layer (Table B2-2.1-1). The temperature time series plot at T1, which was interpolated both temporally and spatially (Figure B2- 2.1-2), portrayed a consistent temperature near 4.5°C in December. Given the typical temperature decline to freezing point during winter along coastal regions of the study area (Cyr *et al.*, 2021), a conservative approach was adopted, designating 0°C as the representative winter temperature alongside a salinity of 32.0 PSU. Considering the effluent depth at 5 m, 17°C was designated as the representative summer temperature alongside a salinity of 31.2 PSU was adopted.

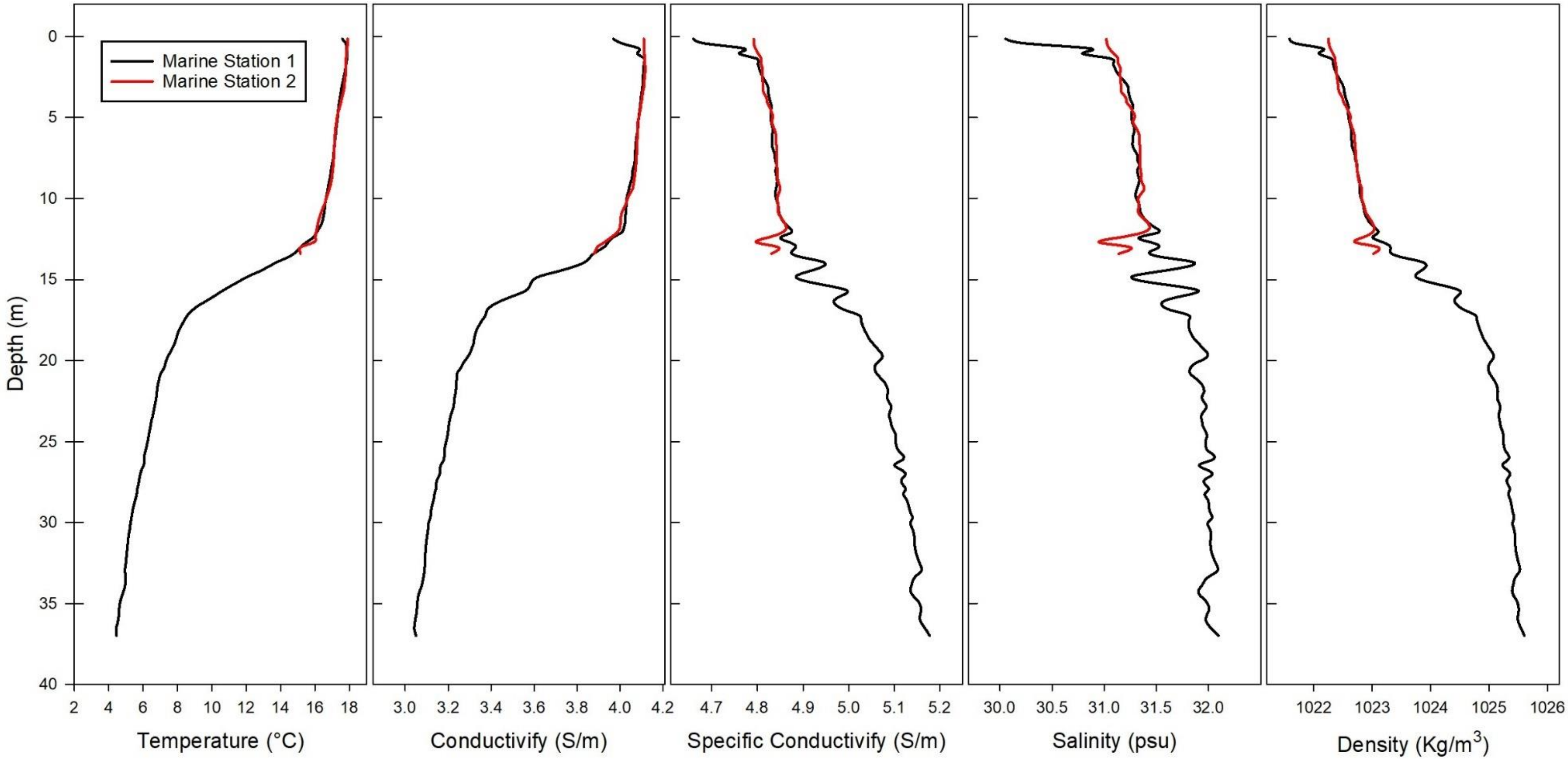


Figure B2-2.1-1 Combined Marine Station CTD Profiles, August 26, 2023 (Figure B1-6.3-1: Appendix B1).

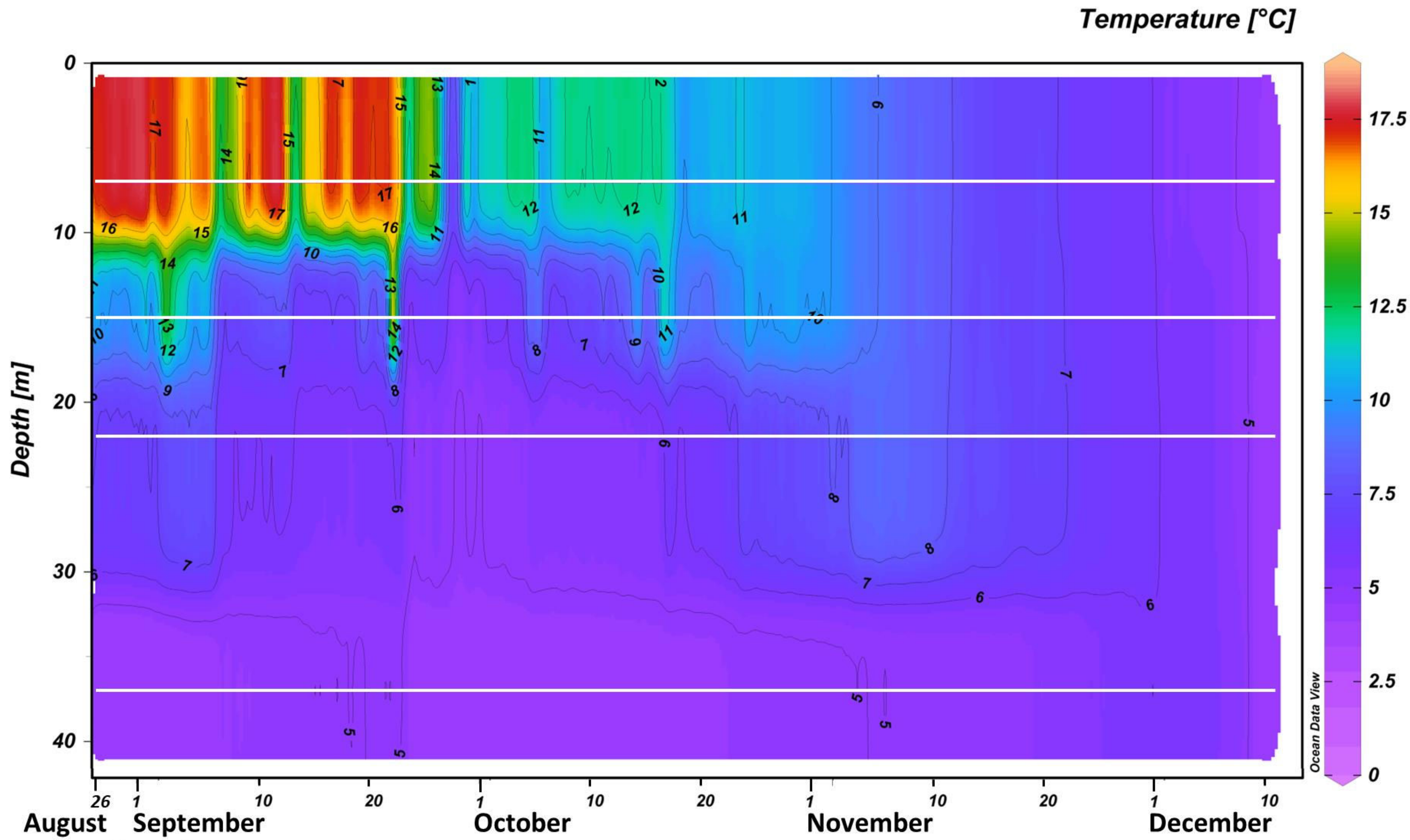


Figure B2-2.1-2 Temperature Profile Modeling at T1 in Argentia Harbour between August 26 and December 10, 2023. Horizontal white lines represent the depth of the four loggers (7, 15, 22, and 37 m) (Figure B1-6.4-2: Appendix B1).

2.2 Current Data

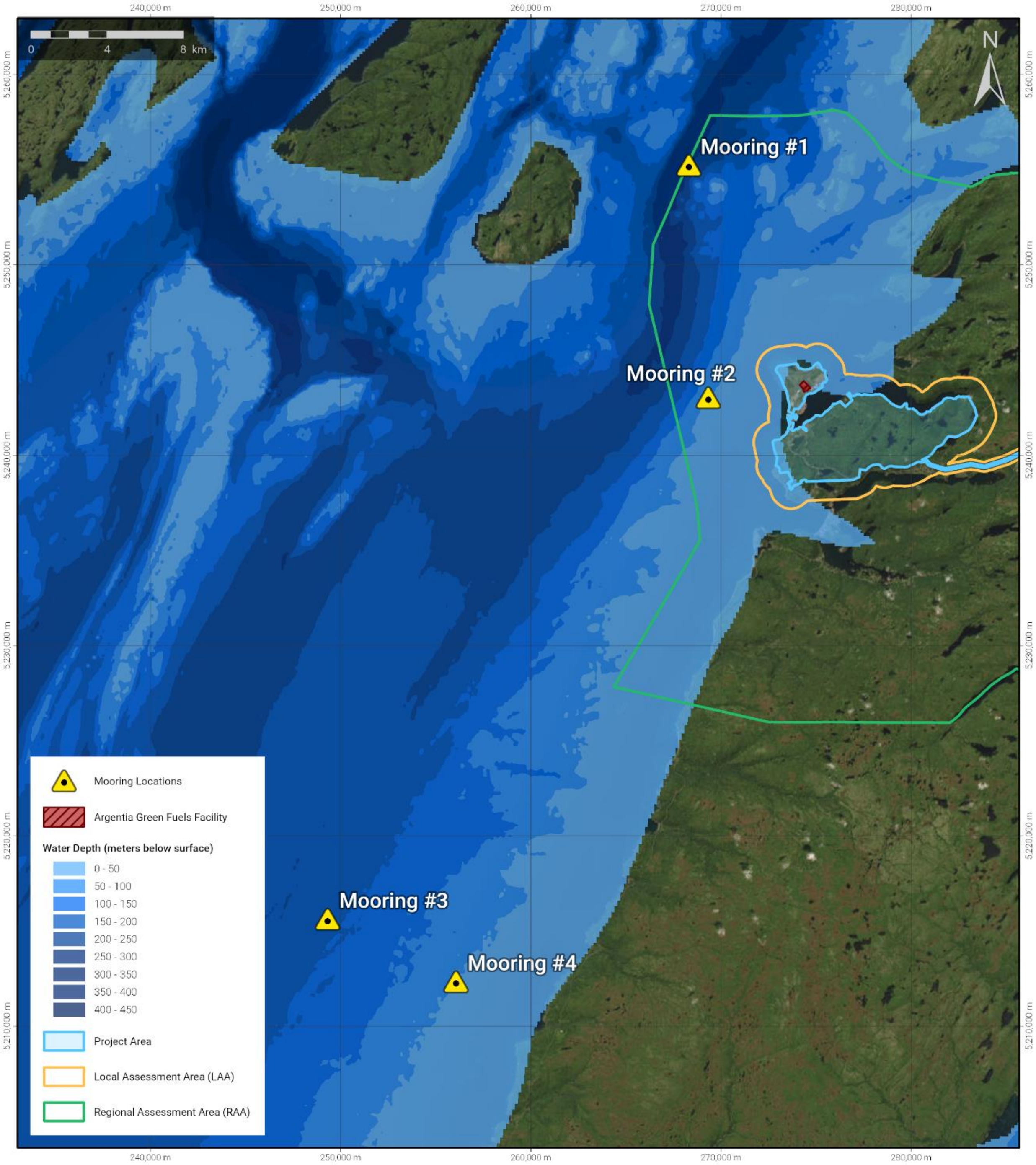
Current data in Placentia Bay was collected by Memorial University at 3 sites (Mooring #1, Mooring #3 and Mooring #4) during the spring of 1999 (Schillinger *et al.,* 2000) and by the Bedford Institute of Oceanography (BIO, 1988) in the fall of 1988 (Mooring #2; BIO, 1988). The locations, instrument depths and measurement periods are presented in Table B2-2.2.-1.

Table B2-2.2-1 Current Meter Moorings in Placentia Bay.

Mooring	Coordinates		Measurement depth (m)	Sampling Periods
1 (M6)	47°24’56” N	54°04’27” W	16	Apr. 19, 1999 – Jun. 27, 1999
1 (M6)	47°24’56” N	54°04’27” W	36	Apr. 19, 1999 – Jun. 27, 1999
1 (M6)	47°24’56” N	54°04’27” W	72	Apr. 18, 1999 – Jun. 27, 1999
1 (M6)	47°24’56” N	54°04’27” W	104	Apr. 18, 1999 – Jun. 27, 1999
2 (BIO)	47°18’00” N	54°03’08” W	23	Sep. 27, 1988 – Oct. 29, 1988
2 (BIO)	47°18’00” N	54°03’08” W	56	Sep. 27, 1988 – Oct. 29, 1988
3 (M3)	47°02’79” N	54°18’02” W	20	Apr. 18, 1999 – Jun. 25, 1999
4 (M4)	47°01’17” N	54°12’59” W	20	Apr. 17, 1999 – Jun. 25, 1999
4 (M4)	47°01’17” N	54°12’59” W	45	Apr. 17, 1999 – Jun. 25, 1999

UTM Zone 21N

The locations of the moorings are shown in Figure B2-2.2-1, along with the nautical chart of Placentia Bay. Mooring #3 and #4 are located south of the marine component of the Regional Assessment Area. Mooring #1 and #2 are comprised in the Regional Assessment Area. Mooring #2 is the closest to the Project area.



Pattern | Argentia Renewables	FIGURE NUMBER: B2 - 2.2 - 1	COORDINATE SYSTEM: NAD 1983 CSRS UTM Zone 22N	PREPARED BY: C. Burke	DATE: 5/9/2024
	FIGURE TITLE: Locations of Current Moorings in Placentia Bay	NOTES:	REVIEWED BY:	
			APPROVED BY:	
	PROJECT TITLE: Argentia Renewables		sem	

SEM MAP ID: 238 005 GIS 119 Rev0

Figure B2-2.2-1 Locations of Current Moorings in Placentia Bay.

2.2.1 Progressive Vectors

Published information by Bradbury *et al. (2000), Hart et al. (1999),* and Schillinger *et al*. (2000) show the existence of a cyclonic circulation pattern in Placentia Bay. On the eastern side of Placentia Bay, the currents flow into the bay, while on the western side, the currents are flowing out of the bay. Current data for the spring and summer of 1999 indicate a general counterclockwise circulation around Placentia Bay (Schillinger *et al*., 2000). Figures B2-2.2.1-1 through B2-2.2.1-5 provide progressive vector diagrams, which show the distance and direction a particle of water would travel if the flow was spatially uniform.

Mooring #1 progressive vector diagrams are provided in Figures B2-2.2.1-1 through B2-2.2.1-2. The current was in a northerly direction into the bay at a depth of 16 m. The progressive vector diagrams indicate that the flow was toward the northwest at 36 m but with a lot of variability. The variability was more pronounced at depths of 72 m and 104 m. At 72 m and 104 m, the flow has two preferred directions, northwest and southwest. The flow was towards the northwest in April, towards the southwest in May with one occasion when the flow was towards the northwest for several days, and then oscillating between north and southwest in June.

Mooring #2 progressive vector diagrams are provided in Figure B2-2.2.1-3. The current was in a northerly direction into the bay at a depth of 23 m but with a lot of variability. The progressive vector diagrams indicate that the flow was toward the southwest at 56 m, with a northeast flow at the end of October.

Mooring #3 progressive vector diagram is provided in Figure B2-2.2.1-4. The current was steady in a northeast direction into the bay at a depth of 20 m throughout April to June.

Mooring #4 progressive vector diagrams are provided in Figure B2-2.2.1-5. The currents were steady in a northeast direction into the bay at a depth of 20 m and 45 m throughout April to June.

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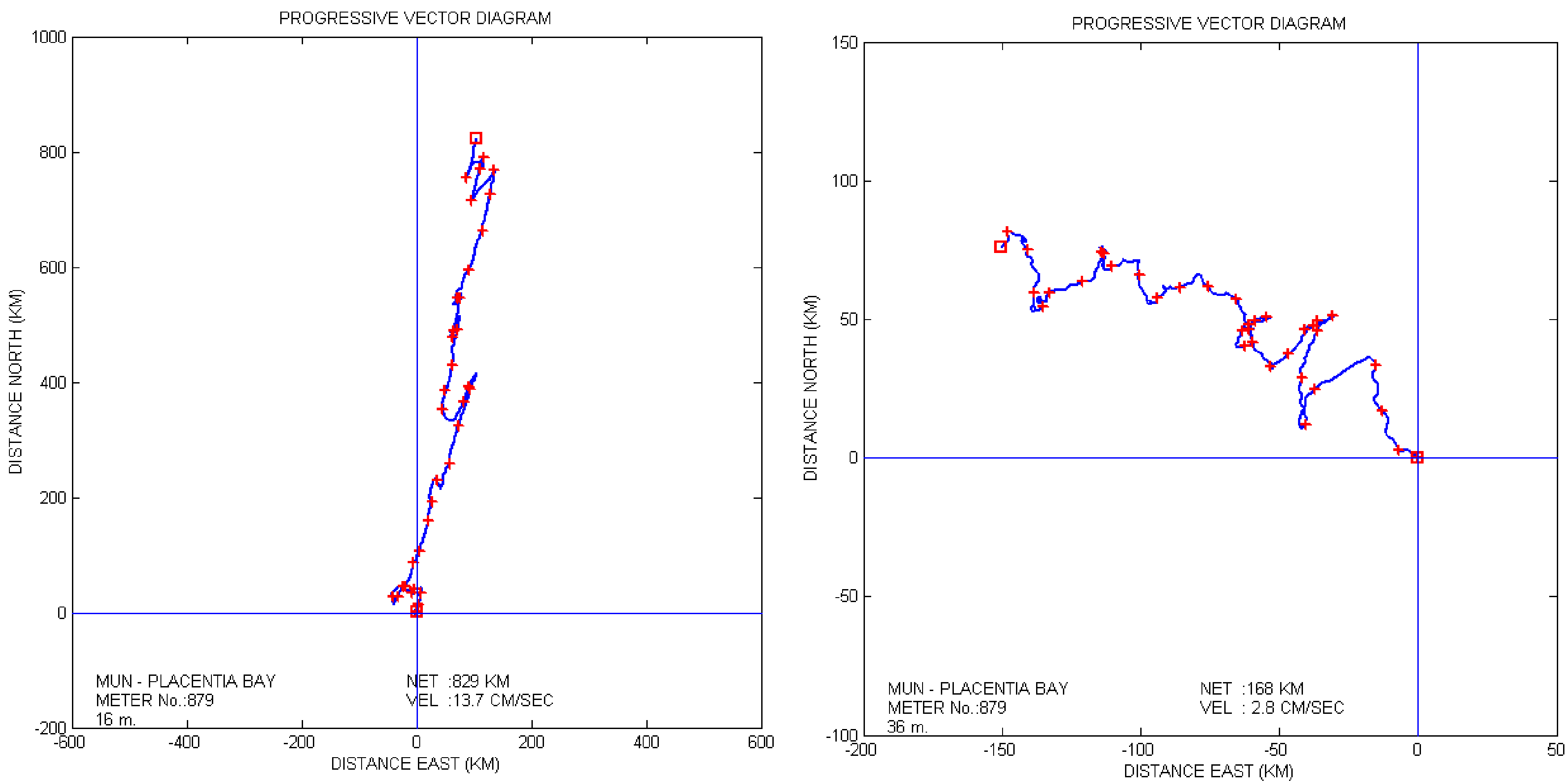


Figure B2-2.2.1-1 Progressive Vector Diagrams for Mooring #1 (16 m and 36 m Depth) in Placentia Bay.

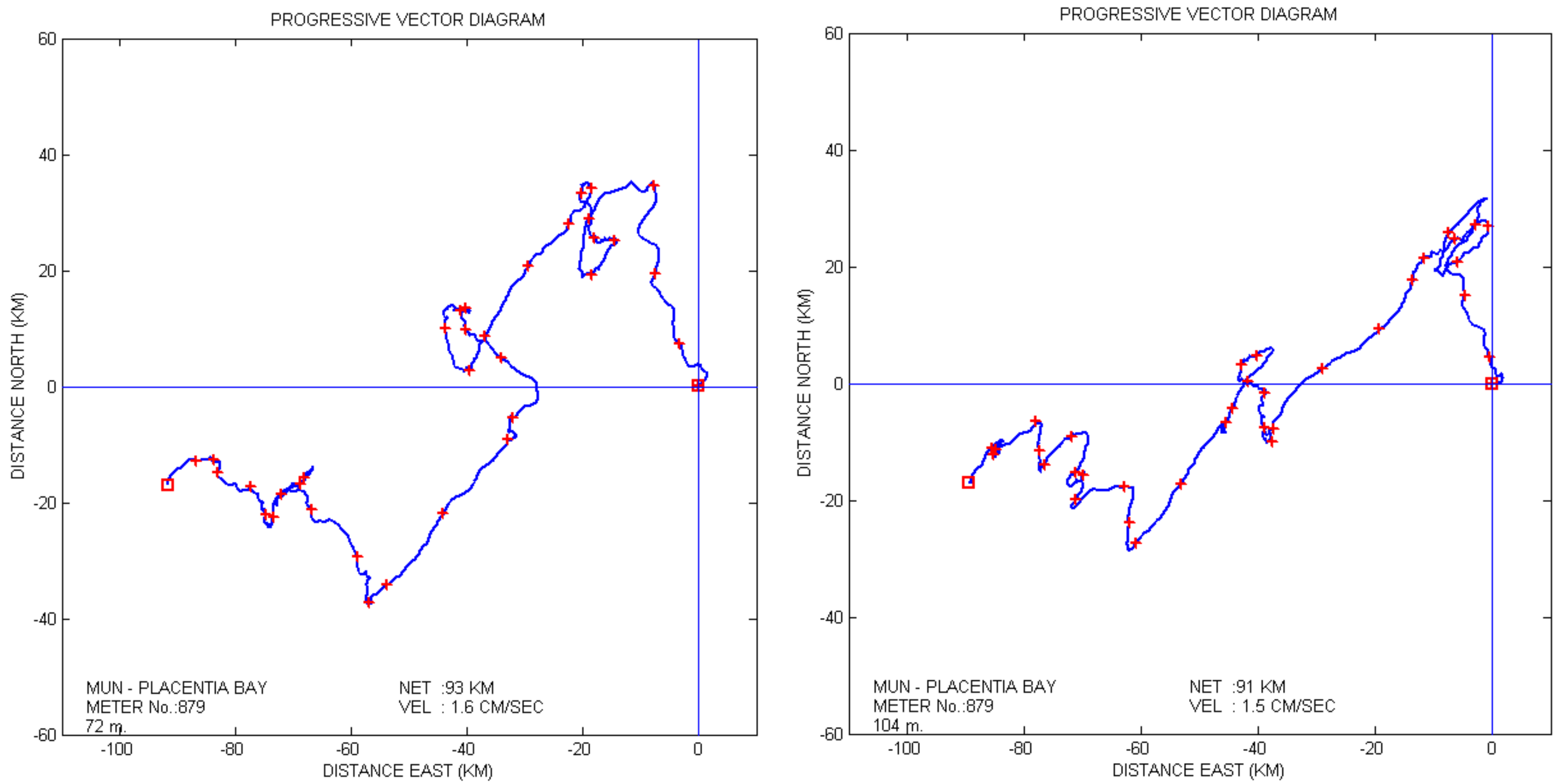
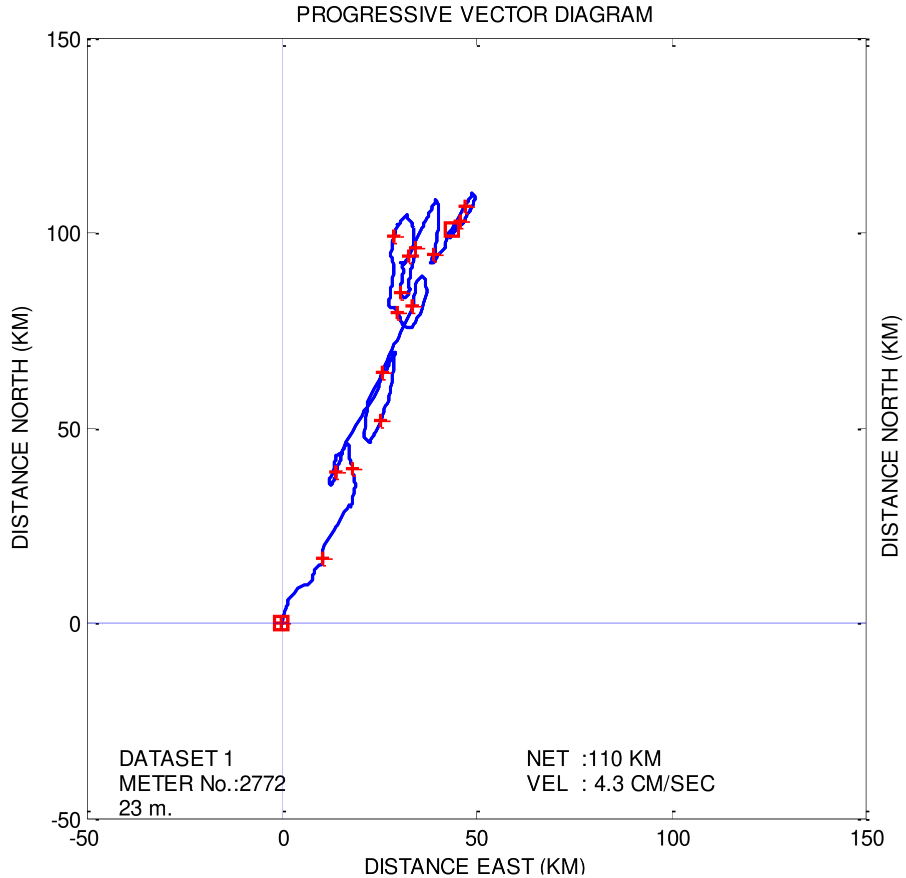


Figure B2-2.2.1-2 Progressive Vector Diagrams for Mooring #1 (72 m and 104 m Depth) in Placentia Bay



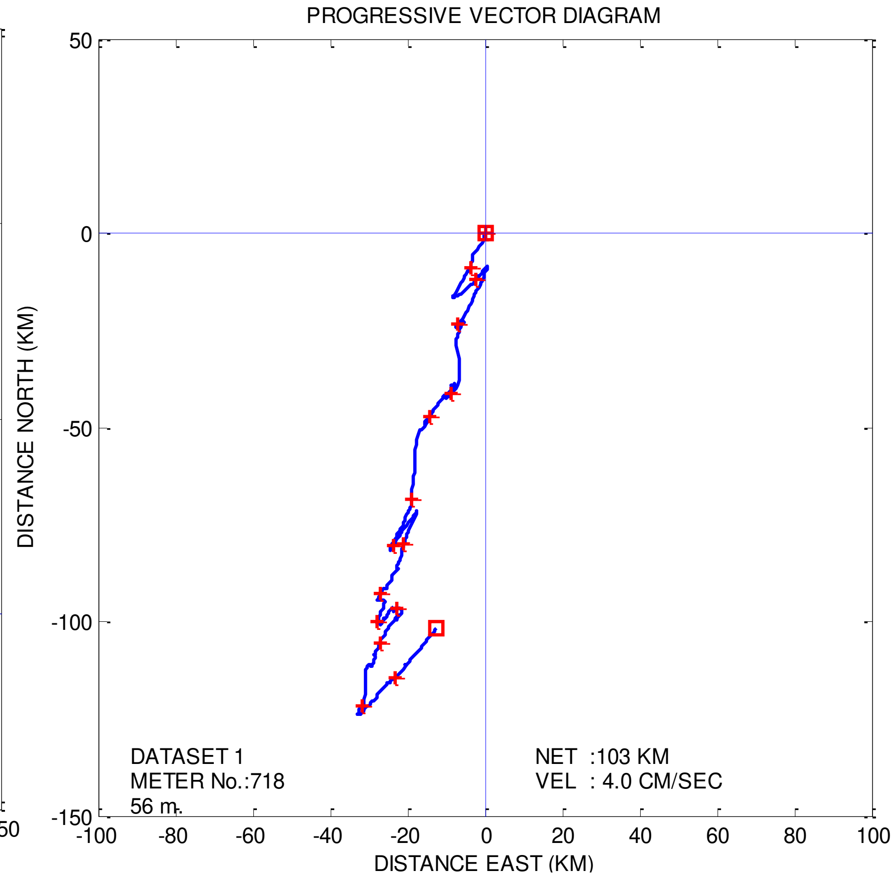


Figure B2-2.2.1-3 Progressive Vector Diagrams for Mooring #2 (56 m and 23 m Depth) in Placentia Bay

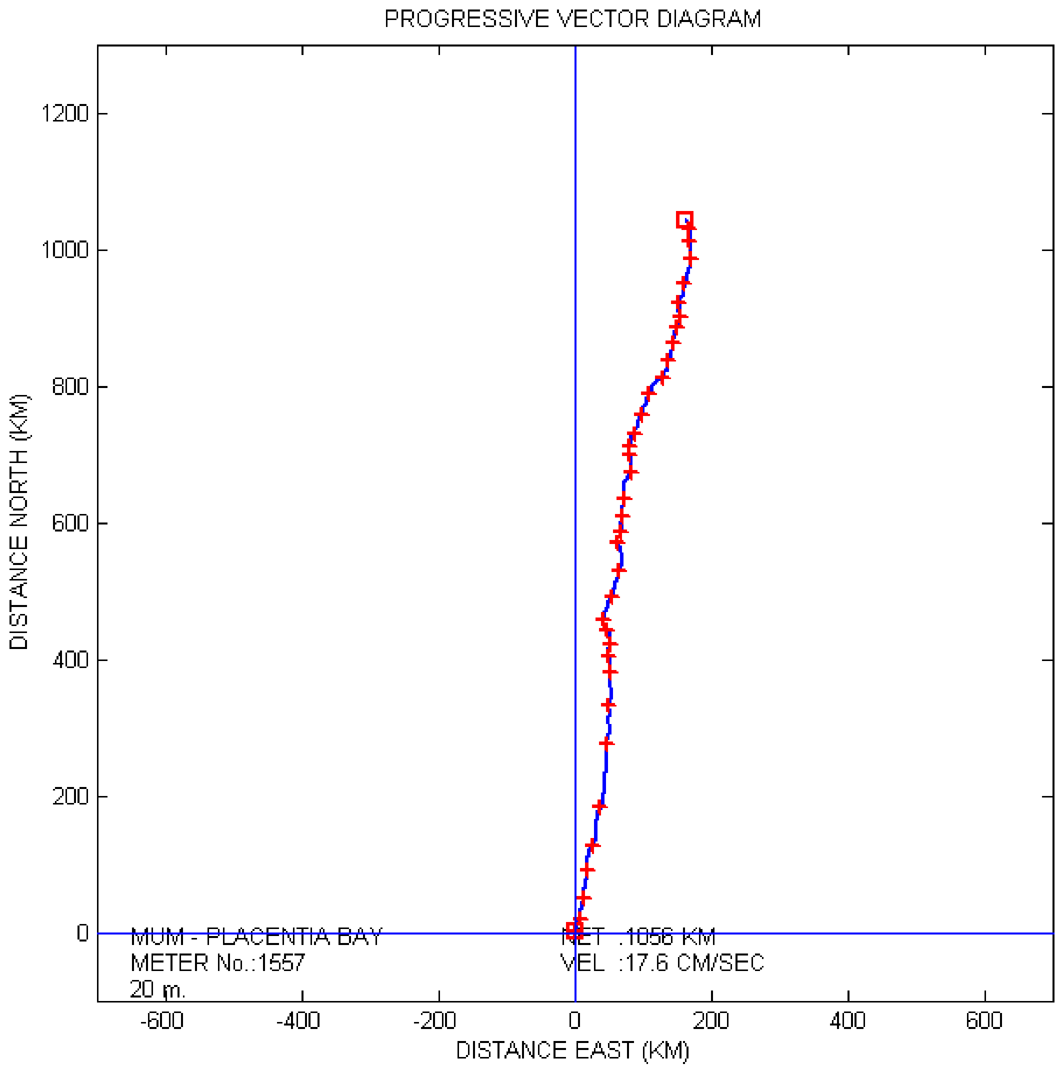


Figure B2-2.2.1-4 Progressive Vector Diagrams for Mooring #3 (20 m Depth) in Placentia Bay

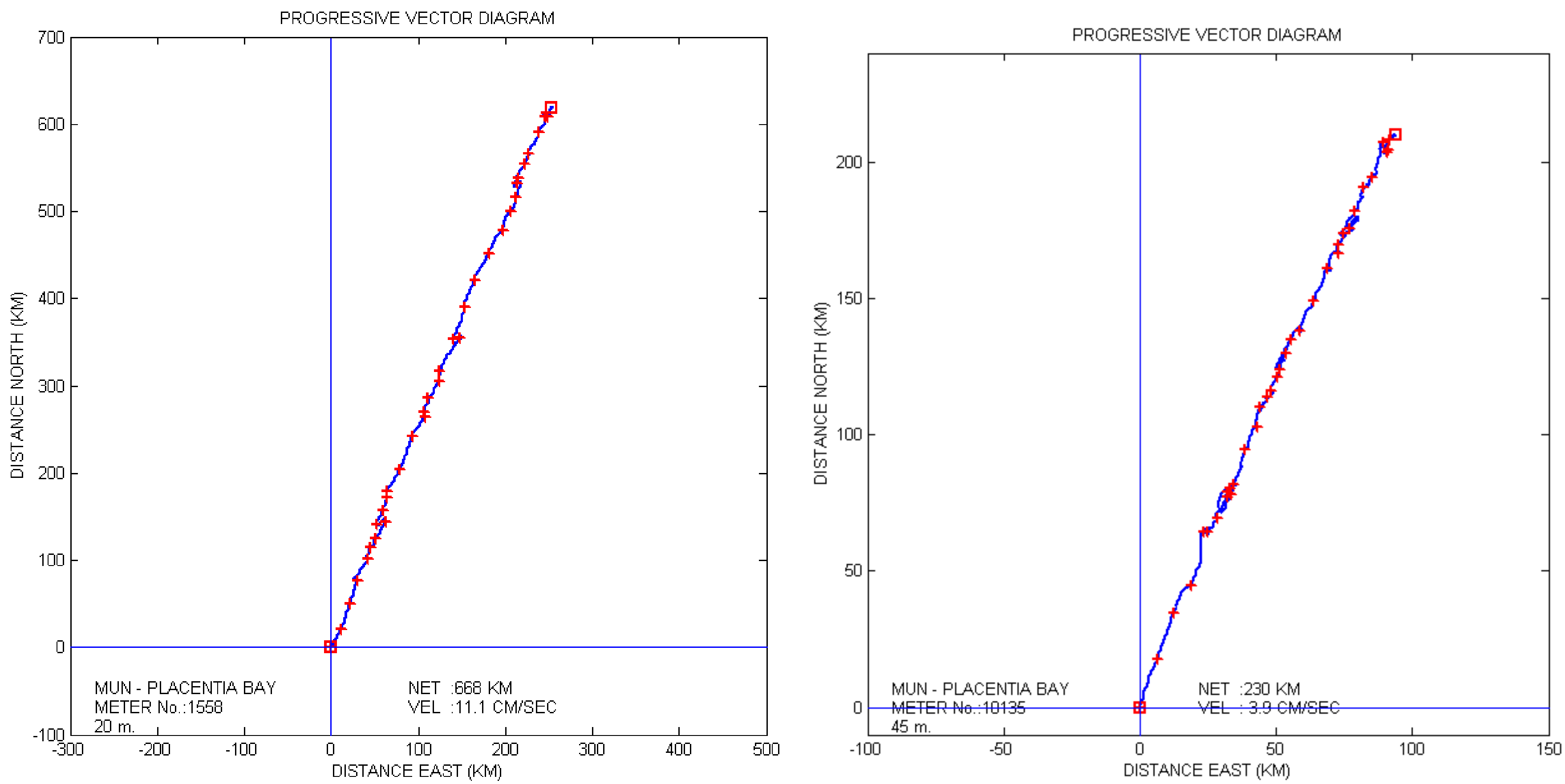


Figure B2-2.2.1-5 Progressive Vector Diagrams for Mooring #4 (20 m and 45 m Depth) in Placentia Bay

2.2.2 Rose Plots

Rose plots of Mooring #1, #2, #3 and #4, which visually display the distribution of ocean current speed and directions over a specific time period, are provided in Figure B2-2.2.2-1 through Figure B2-2.2.2-4, respectively.

The rose plots of Mooring #1 show that the dominant currents flow towards the north-northeast at 16 m depth with a maximum estimated speed greater than 55 cm/s. Deeper currents flow mostly toward the southwest at lesser speeds. Variability in current speeds and directions at 36 m, 72 m, and 104 m depth are also indicated in Figure B2-2.2.2-1.

The rose plots of Mooring #2 (Figure B2-2.2.2-2) show that the dominant currents flow towards the north-northeast at 23 m depth with a maximum estimated speed between 55 to 60 cm/s and the south-southwest at 56 m depth with a maximum estimated speed of approximately 35 cm/s.

The rose plot of Mooring #3 (Figure B2-2.2.2-3) shows that the dominant currents flow towards the north at 20 m depth with a maximum estimated speed of approximately 55 cm/s.

Rose plots of Mooring #4 (Figure B2-2.2.2-4) show that the dominant currents flow towards the north-northeast at 20 m depth with a maximum estimated speed of approximately 40 cm/s. At 45 m depth, the maximum estimated speed was approximately 25 cm/s.

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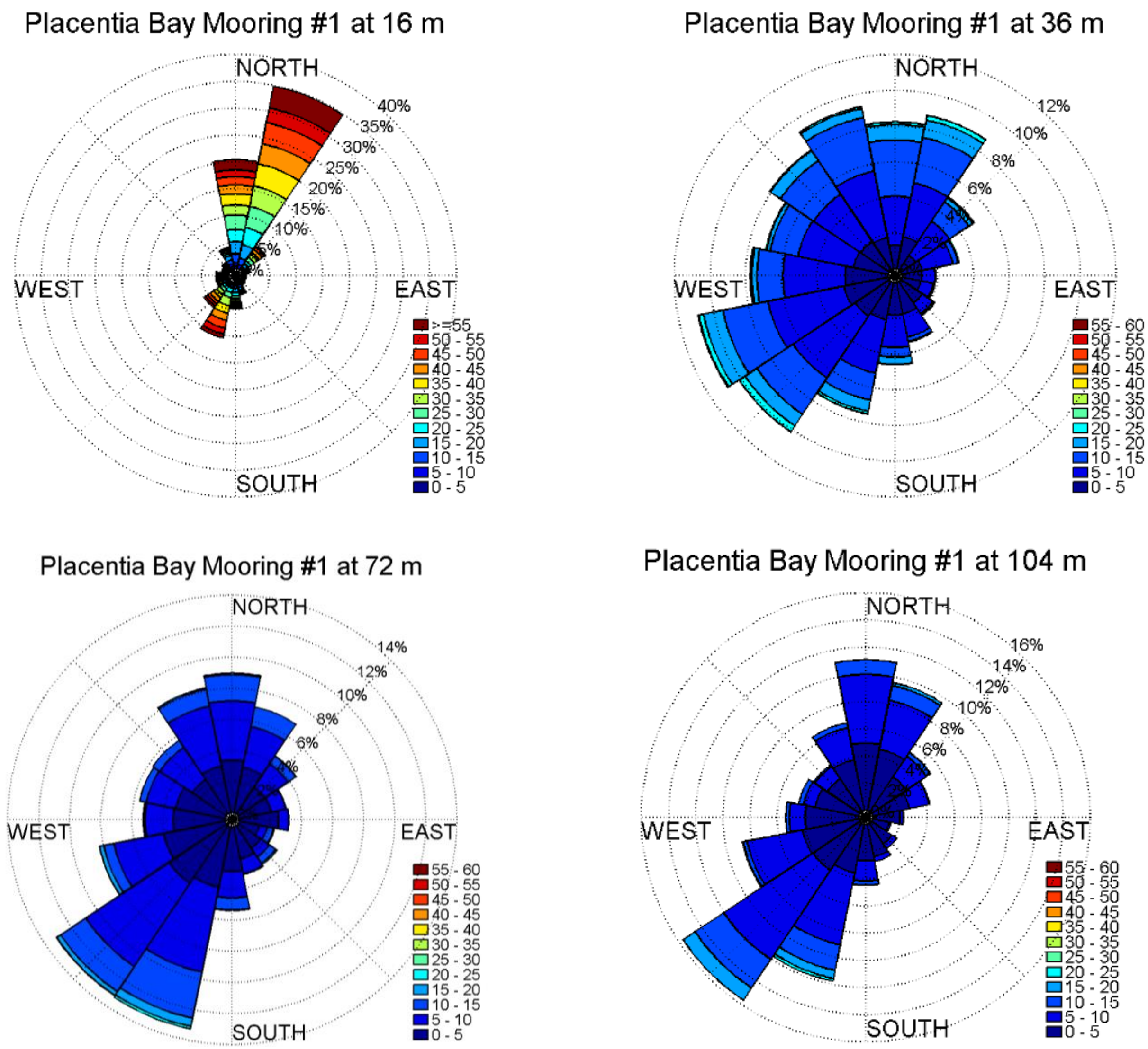


Figure B2-2.2.2-1 Rose Plots of Current Speed (cm/s) for Mooring #1 in Placentia Bay

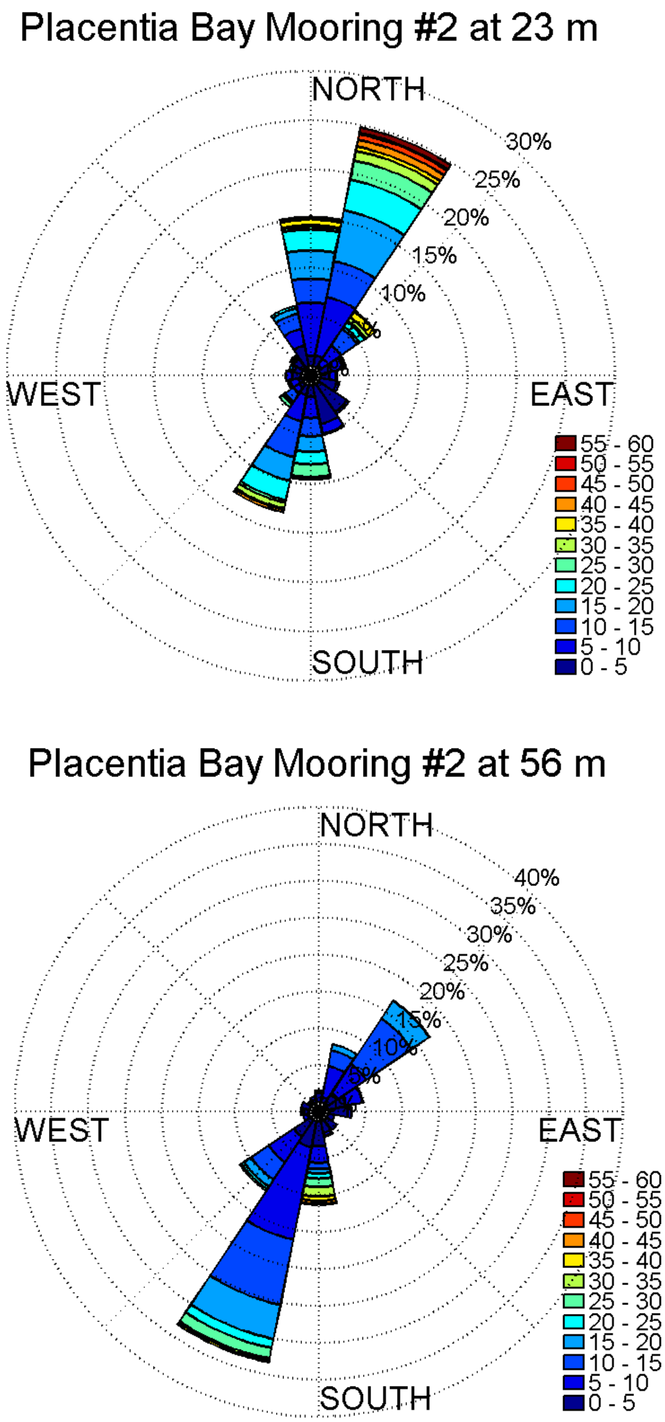


Figure B2-2.2.2-2 Rose Plots of Current Speed (cm/s) for Mooring #2 in Placentia Bay

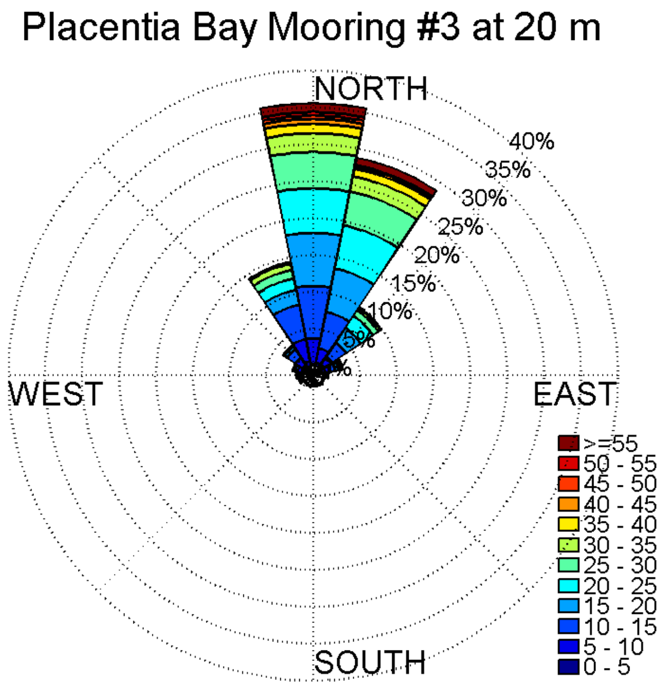
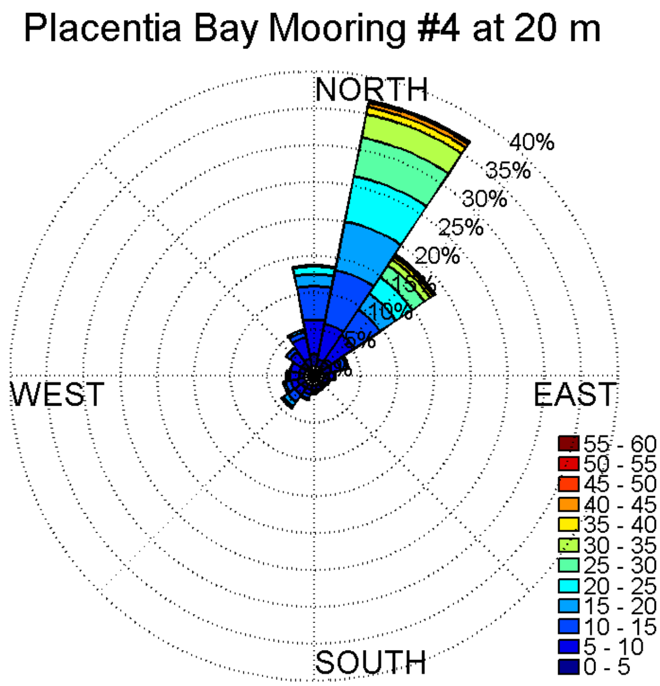


Figure B2-2.2.2-3 Rose Plots of Current Speed (cm/s) for Mooring #3 in Placentia Bay



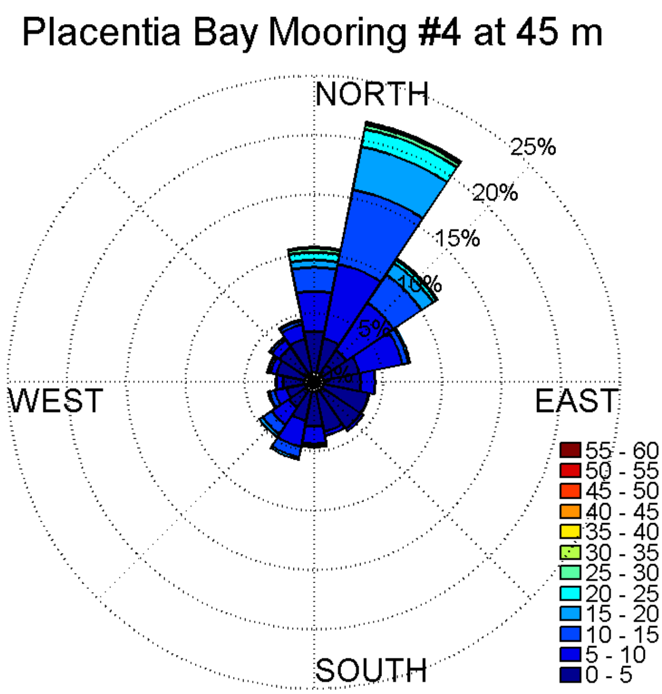


Figure B2-2.2.2-4 Rose Plots of Current Speed (cm/s) for Mooring #4 in Placentia Bay

2.2.3 Current Speed Statistics

Table B2-2.2.3-1 provides the current speed statistics for Mooring #1. The progressive vector diagrams (Figures B2-2.2.1-1 and B2-2.2.1-2) and rose plots (Figure B2-2.2.2-1) were graphically shown in sections 2.2.1 and 2.2.2.

Table B2-2.2.3-1 Current Speed Statistics for Mooring #1 in Placentia Bay for April 1999 – June 1999.

April 1999 - June 1999 Current Speed Statistics						
Month	16 m Depth			36 m Depth		
	Mean (cm/s)	STD (cm/s)	Max (cm/s)	Mean (cm/s)	STD (cm/s)	Max (cm/s)
April	19.36	10.71	50	11.29	4.64	23.3
May	31.97	14.31	73.3	6.33	3.71	21.7
June	37.21	15.83	78.7	9.34	4.88	30.7
Overall	**31.95**	**15.63**	**78.7**	**8.31**	**4.75**	**30.7**
Month	72 m Depth			104 m Depth		
	Mean (cm/s)	STD (cm/s)	Max (cm/s)	Mean (cm/s)	STD (cm/s)	Max (cm/s)
April	8.29	3.68	21.1	7.45	3.66	19.6
May	5.71	3.61	23.5	5.39	3.59	23.5
June	5.39	3.15	16	5.11	3.14	19
Overall	**6.01**	**3.59**	**23.5**	**5.62**	**3.56**	**23.5**

The mean current speed at Mooring #1 was approximately 32.0 cm/s at 16 m, 8.3 cm/s at 36 m, 6.0 cm/s at 72 m, and 5.6 cm/s at 104 m. The maximum current speeds occurred in June at 16 m and 36 m with speeds of 78.7 cm/s and 30.7 cm/s, respectively. At 72 m and 104 m, the maximum speed occurred in May with a value of 23.5 cm/s at both depths (Table B2-2.2.3-1).

At Mooring #2, the flow was into the bay at a depth of 23 m and out of the bay at a depth of 56 m as shown by the progressive vector diagrams and rose plots in Figures B2-2.2.1-3 and B2-2.2.2-2, respectively. The mean overall current speed was approximately 13.4 cm/s at 23 m and 10.3 cm/s at 56 m. The maximum overall speed was approximately 57.0 cm/s at 23 m and 45.1 cm/s at 56 m (Table B2-2.2.3-2).

Table B2-2.2.3-2 Current Speed Statistics for Mooring #2 in Placentia Bay for September 1988 – October 1988.

September 1988 - October 1988 Current Speed Statistics						
Month	23 m Depth			56 m Depth		
	Mean (cm/s)	STD (cm/s)	Max (cm/s)	Mean (cm/s)	STD (cm/s)	Max (cm/s)
September	16.21	6.92	36.51	8.43	5.50	21.02
October	13.20	10.27	56.95	10.35	7.35	45.08
Overall	13.35	10.14	56.95	10.26	7.27	45.08

Table B2-2.2.3-3 provides the Current Speed Statistics for Mooring #3 and #4. The progressive vectors diagrams (Figures B2-2.2.1-4 and B2-2.2.1-5) and rose plots (Figures B-2.2.2-3 and B2-2.2.2-4), were graphically shown in sections 2.2.1 and 2.2.2.

Table B2-2.2.3-3 Current Speed Statistics for Moorings #3 and #4 in Placentia Bay for April 1999 – June 1999

April 1999 - June 1999 Current Speed Statistics			
Month	20 m Depth (Mooring #3)		
	Mean (cm/s)	STD (cm/s)	Max (cm/s)
April	29.96	15.34	75
May	17.09	8.37	43
June	16.84	8.08	43.5
Overall	19.51	11.27	75

Month	20 m Depth (Mooring #4)			45 m Depth (Mooring #4)		
	Mean (cm/s)	STD (cm/s)	Max (cm/s)	Mean (cm/s)	STD (cm/s)	Max (cm/s)
April	15.52	8.93	52.8	9.28	6.72	41.2
May	14.91	9.81	58.9	7.03	5.22	37.42
June	13.03	8.96	42	7	5.42	43.82
Overall	14.36	9.4	58.9	7.46	5.68	43.82

At Mooring #3, the flow was towards the north at 20 m with little variability in direction as shown by the progressive vector diagrams (Figure B2-2.2.1-4) and rose plots (Figure B2-2.2.2-3). The mean overall current speed was approximately 19.5 cm/s and the maximum current speed occurred in April with a value of 75.0 cm/s.

Mooring #4 was located slightly inshore of Mooring #3. The currents were measured at depths of 20 m and 45 m. The progressive vector diagrams (Figure B2-2.2.1-5) and rose plots (Figure B2-2.2.2-4) show that the current flowed towards the northeast with little variability at both depths. At 20 m, the mean overall speed was approximately 14.4 cm/s and the maximum speed occurred in May with a value of 58.9 cm/s. At 45 m, the mean overall speed was approximately 7.5 cm/s and the maximum current speed occurred in June with a value of approximately 43.8 cm/s (Table B2-2.2.3-3).

2.3 Tidal Height

The tidal heights for various stations in Placentia Bay are presented in Table B2-2.3-1 and have been taken from the Canadian Tide and Current Tables (DFO, 2018). The tidal heights are in reference to each location's respective chart datum.

Table B2-2.3-1 Placentia Bay Tidal Data

Port	Mean Water Level	Range (m)		High Water (m)		Low Water (m)		Recorded Extremes (m)	
		Mean Tide	Large Tide	Mean Tide	Large Tide	Mean Tide	Large Tide	Highest High Water	Lowest Low Water
Argentia	1.4	1.6	2.4	2.3	2.6	0.7	0.2	3.4	-0.4
Burin	1.2	1.5	2.2	2.4	2.7	0.6	0	-	-
South East Bight	1.2	1.3	2.1	2.5	3	0.5	0.2	-	-
Tacks Beach	1.1	1.6	2.4	2.5	2.8	0.8	0.4	-	-
Woody Island	1.2	1.6	2.5	2.4	2.7	0.7	0.3	-	-
North Harbour	1.4	1.7	2.5	2.1	2.5	0.6	0.1	-	-
Come by Chance	1.4	1.6	2.5	2.2	2.5	0.5	0.1	-	-
Arnold's Cove	1.4	1.7	2.5	2.1	2.5	0.6	0.1	-	-
Long Harbour	1.5	1.7	2.7	2	2.3	0.5	0.1	-	-
St. Bride's	1.2	1.6	2.5	2.4	2.7	0.8	0.4	-	-
Great St. Lawrence	-	-	-	-	-	-	-	3.1	-0.2

Water level recorders have been installed at both Argentia and Great St. Lawrence. Measurements from these stations were analyzed for events in which the recorded water levels exceeded 3.0 m (DFO, 2018a). There were eleven individual events recorded at Argentia between February 12, 1971, and March 29, 2018 (Table B2-2.3-2).

Table B2-2.3-2 Events Where the Maximum Water Level Recorded at the Argentia Tidal Station Exceeded 3.0 Metres (Feb 12, 1971, to March 29, 2018)

Date	Time (24 h)	Tidal Heights (m)
Dec 22, 1983	1100	3.2
Dec 25, 1983	1200	3.2
Jan 10, 1982	1000	3.15
Dec 15, 2016	2200	3.14
Jan 05, 1989	0600	3.13
Dec 04, 2013	0900	3.11
Dec 25, 1991	1200	3.08
Jan 03, 2010	1100	3.05
Dec 13, 2016	0700	3.04
Jan 10, 1974	0900	3.03
Jan 30, 1975	1000	3.01

3.0 Model Approach

Typically, the current direction in shallow waters tends to conform to bathymetric features, often following isolines. Positioned along the topographic slope extending from the shoreline, MS1 and MS2 are anticipated to experience currents predominantly driven by tides, aligning with isolines parallel to the shoreline. Consequently, the ambient current's impact on effluent dispersion is presumed to be favorable when the discharge direction is perpendicular to the shoreline. Information regarding the outfall and diffuser specifications was partially obtained through Argentia Renewables FEL 1 Study (Feasibility Study Report) (SNC-Lavalin, 2023), client's communication and assumptions.

Assessable historical current data (Section 2.2) indicated that the minimum average current speed in Placentia Bay is 5.11 cm/s at Mooring #1 at a depth of 104 m. (Table B2-2.2.3-1). To adopt a conservative approach, a relatively modest current speed of 5 cm/s was selected to mitigate the ambient current's influence on effluent dispersion (Table B2-2.1-1). The model will also be conducted without the effect of current speed, reflecting a stationary ambient flow at the location of effluent.

Moreover, the timescale for current reversal induced by tides (i.e., hours) is significantly longer than the transient timescale for effluent dispersion to meet the CCME regulatory requirements (i.e., minutes). Hence, the reversal of the current direction is not factored into the simulations.

Furthermore, as outlined in the CORMIX User Manual (Doneker and Jurka, 2021), the wind is deemed inconsequential for near-field mixing, exerting critical influence solely on plume behavior in the far field. Therefore, wind effects were disregarded in this study.

In summary, the representative ambient seawater conditions for this near-field modeling endeavor are tabulated in Table B2- 2.1-1 for both the summer and winter seasons. The effluent discharge rate and characterization are tabulated in Table B2-2.0-1 for both summer and winter seasons.

4.0 3D-Near Field Modeling

The objective of the near-field dilution mixing modeling is to verify compliance with the ambient seawater quality concentrations, particularly those outlined in the Canadian Council of Ministers of the Environment (CCME) Canadian Environmental Quality Guidelines (CEQG), at the periphery of the mixing zone. As defined by CCME (2003), the mixing zone denotes an area contiguous with a point source (i.e., effluent discharge), where the effluent blends with ambient water, potentially leading to concentrations of certain substances that may not align with water quality guidelines or objectives.

Newfoundland and Labrador, as a signatory to the CCME, has endorsed the establishment of CCME CEQGs, including those aimed at safeguarding marine aquatic life. In this study, CCME marine water quality guidelines pertaining to temperature and salinity were employed.

CCME's water quality guidelines for the protection of aquatic life regarding temperature advocate for the prevention of human activities inducing changes in the ambient temperature of marine and estuarine waters beyond ±1°C at any given time, location, or depth.

Similarly, CCME's water quality guidelines for the protection of aquatic life regarding salinity advocate for human activities to avoid causing fluctuations in the salinity (expressed as parts per thousand, ppt, or g/kg) of marine and estuarine waters exceeding 10% of the natural level anticipated at that specific time and depth.

4.1 CORMIX Model

CORMIX was employed to conduct an in-depth analysis and evaluation of near-field mixing, focusing on conditions within and proximate to the initial mixing zone. CORMIX stands as a sophisticated software system designed for the comprehensive analysis, prediction, and design of discharges of aqueous toxic or conventional pollutants into various water bodies. Its primary emphasis lies in assessing the geometry and dilution characteristics of the initial mixing zone, although the system is also capable of forecasting the behavior of the discharge plume at greater distances. CORMIX operates as a three-dimensional (3D) model that can be executed under steady-state, unsteady-state, and tidal ambient conditions, thus offering a versatile tool for modeling diverse scenarios of pollutant dispersion.

4.2 Discharge Configuration

The CORMIX model necessitates three distinct sets of input parameters for comprehensive characterization:

1) *Ambient Conditions or Receiving Water Body Characteristics:*
   - Describes the ambient conditions prevailing within the receiving water body.
   - Presented in Section 2, encompassing parameters are delineated in Table B2- 2.1-1.

2) *Effluent Discharge Characteristics:*
   - Pertains to the specific attributes of the effluent discharge.
   - Detailed in Section 2 and tabulated in Table B2-2.0-1.

3) *Outfall and Diffuser Specifications:*
   - Specifies the outfall structure and any associated diffuser configuration with the present understanding of the project description shared by SEM.
   - The outfall pipeline features an 8" (20.32 cm) diameter and is situated 5 m below the water surface, located either at MS1 or MS2.
   - Positioned perpendicular to the shoreline, the outfall discharges effluent horizontally (parallel to the seabed) into the receiving water body.
   - No diffuser is incorporated into the study.

Model simulations encompassed four distinct scenarios:

- Representative summer ambient conditions without current.
- Representative summer ambient conditions with current.
- Representative winter ambient conditions without current.
- Representative winter ambient conditions with current.

It's notable that the near-field modeling outcomes were found to be independent of the outfall location, as elaborated upon in subsequent sections. Thus, whether the discharge outfall is situated at MS1 or MS2, comparable dilution results can be achieved.

4.3 Near Field Results

The CORMIX model was employed to conduct dilution-mixing simulations for both summer and winter scenarios, utilizing conservative ambient and effluent conditions. By considering the specified effluent and ambient parameters, the resultant water temperature within the near-field mixing zone was determined. The temperature outcomes for both winter and summer scenarios are tabulated in Table B2-4.3-1.

Additionally, salinity results within the mixing zone for both summer and winter scenarios are presented in Table B2-4.3-2. These tables (B2-4.3-1 and B2-4.3-2) provide a comprehensive overview of the temperature and salinity characteristics prevailing within the near-field mixing zone under varying conditions.

Table B2-4.3-1 Temperature Results in the Mixing Zone for Summer and Winter Scenarios

Scenario	Effluent Temperature (ºC)	Ambient Temperature (ºC)	CCME Guideline [1] (ºC)	Temperature at Various Distances from Outfall (ºC)				
				1 m	2 m	3 m	4 m	5 m
Summer, No Current	25	17	<18	18.1	17.52	17.3	17.2	17.15
Summer, with Current	25	17	<18	17.62	17.27	17.14	17.09	17.06
Winter, No Current	15	0	<1	2.02	0.94	0.58	0.39	0.28
Winter, with Current	15	0	<1	1.14	0.49	0.26	0.17	0.12
Note: [1] change of 1 ºC from ambient temperature.								

Table B2-4.3-2 Salinity Results in the Mixing Zone for Summer and Winter Scenarios

Scenario	Effluent Salinity (PSU)	Ambient Salinity (PSU)	CCME Guideline [1] (PSU)	Salinity at Various Distances from Outfall (PSU)				
				1 m	2 m	3 m	4 m	5 m
Summer, No Current	0.5	31.2	>28.08	26.98	29.22	30.05	30.41	30.61
Summer, with Current	0.5	31.2	>28.08	28.81	30.17	30.66	30.85	30.96
Winter, No Current	0.5	32	>28.80	27.76	30.02	30.78	31.18	31.42
Winter, with Current	0.5	32	>28.80	29.6	30.97	31.45	31.65	31.75
Note: [1] change of 10% from ambient salinity.								

Figures B2-4.3-1 and B2-4.3-2 provide a schematic illustration of the plume boundary and centerline originating from the outfall during both summer and winter seasons in the absence of current influence, respectively. The proposed direction for the outfall x-plane was set perpendicular to the shoreline. The upper left panel and upper right panel indicate the centerline in the x-y plane and x-z plane, respectively. The lower panel shows the dilution factor as a function of distance from the source. Notably, the plume boundary and centerline remained consistent between summer and winter scenarios, owing to identical discharge flow speeds and the absence of ambient current. However, differences in mixed temperature and salinity were observed between the two seasons.

In Figures B2-4.3-3 and B2-4.3-4, the schematic representation depicts the plume under the influence of ambient current during both summer and winter seasons, with a current, respectively. Like the previous scenario, the proposed direction for the outfall x-plane was set perpendicular to the shoreline. The centerline in the x-y plane and the x-z plane are presented in the upper left panel and upper right panel, respectively. The dilution factor as a function of distance from the source was shown in the lower panel. It was observed for all scenarios that the effluent, being buoyant, ascended to the surface shortly after discharge. Moreover, the ambient current augmented the mixing processes, facilitating the attainment of regulatory guidelines at an expedited pace and over a shorter distance from the discharge source.

Furthermore, all figures include the corresponding mean dilution factor plotted as a function of distance from the discharge source, providing insight into the dispersion characteristics of the effluent plume. The dilution factor reaches 50 at the distance of 5 m from the discharge source for the scenarios without current, while it reaches a value of 140 for the scenarios with current, demonstrating that a relatively weak current can significantly enhance the dispersion process.

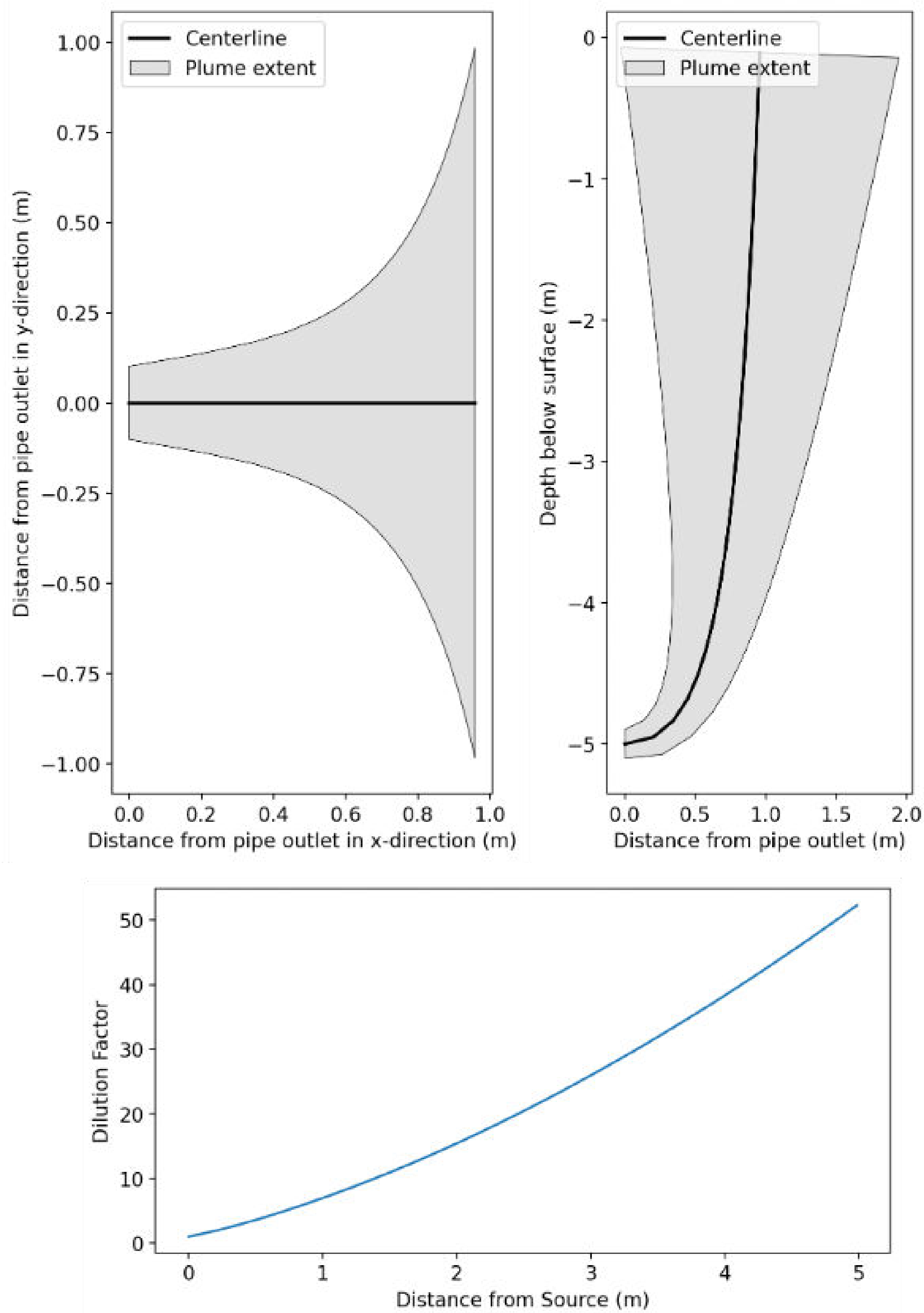


Figure B2-4.3-1 Schematic Representation of Plume Boundary in Summer without Current.

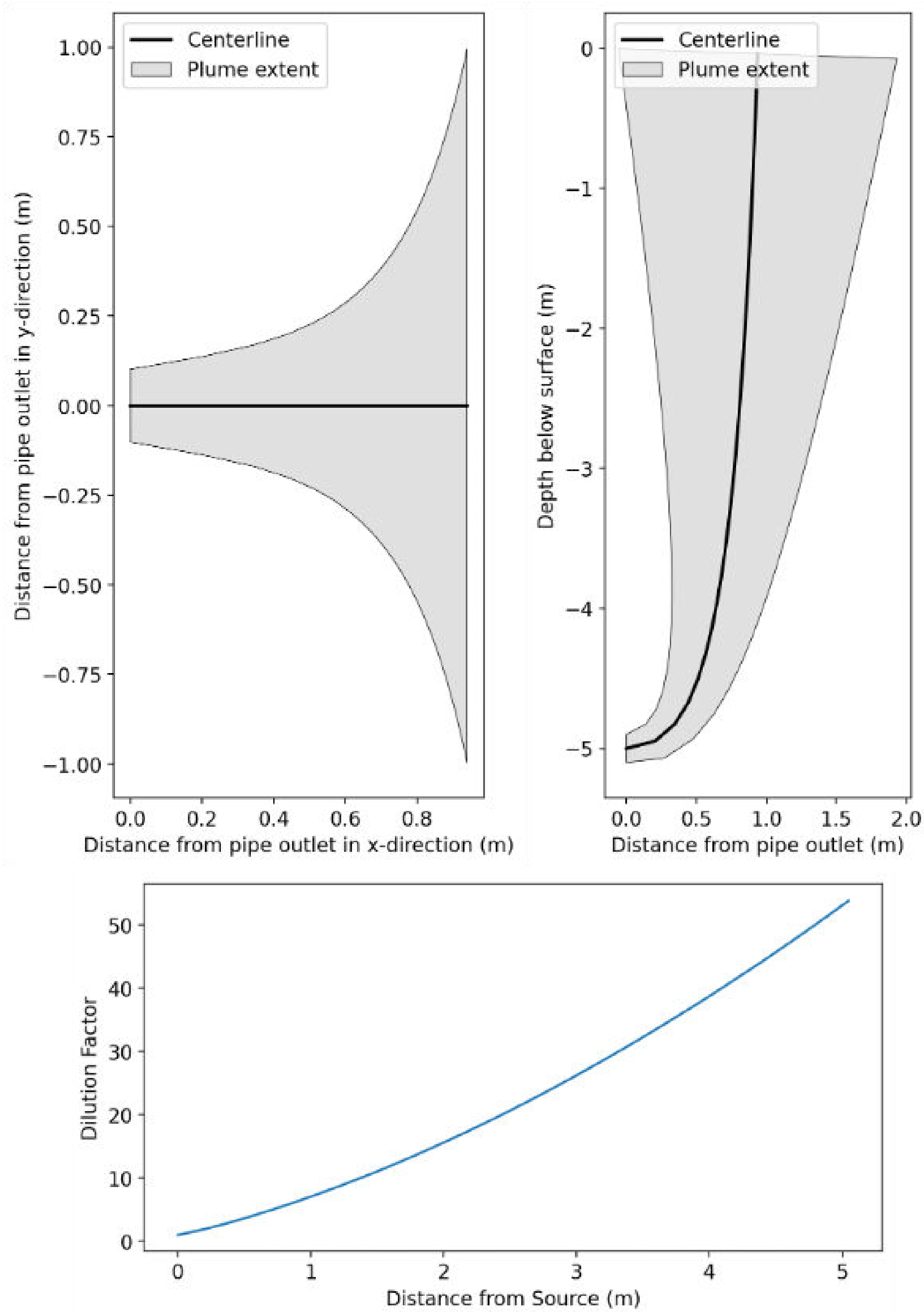


Figure B2-4.3-2 Schematic Representation of Plume Boundary in Winter without Current

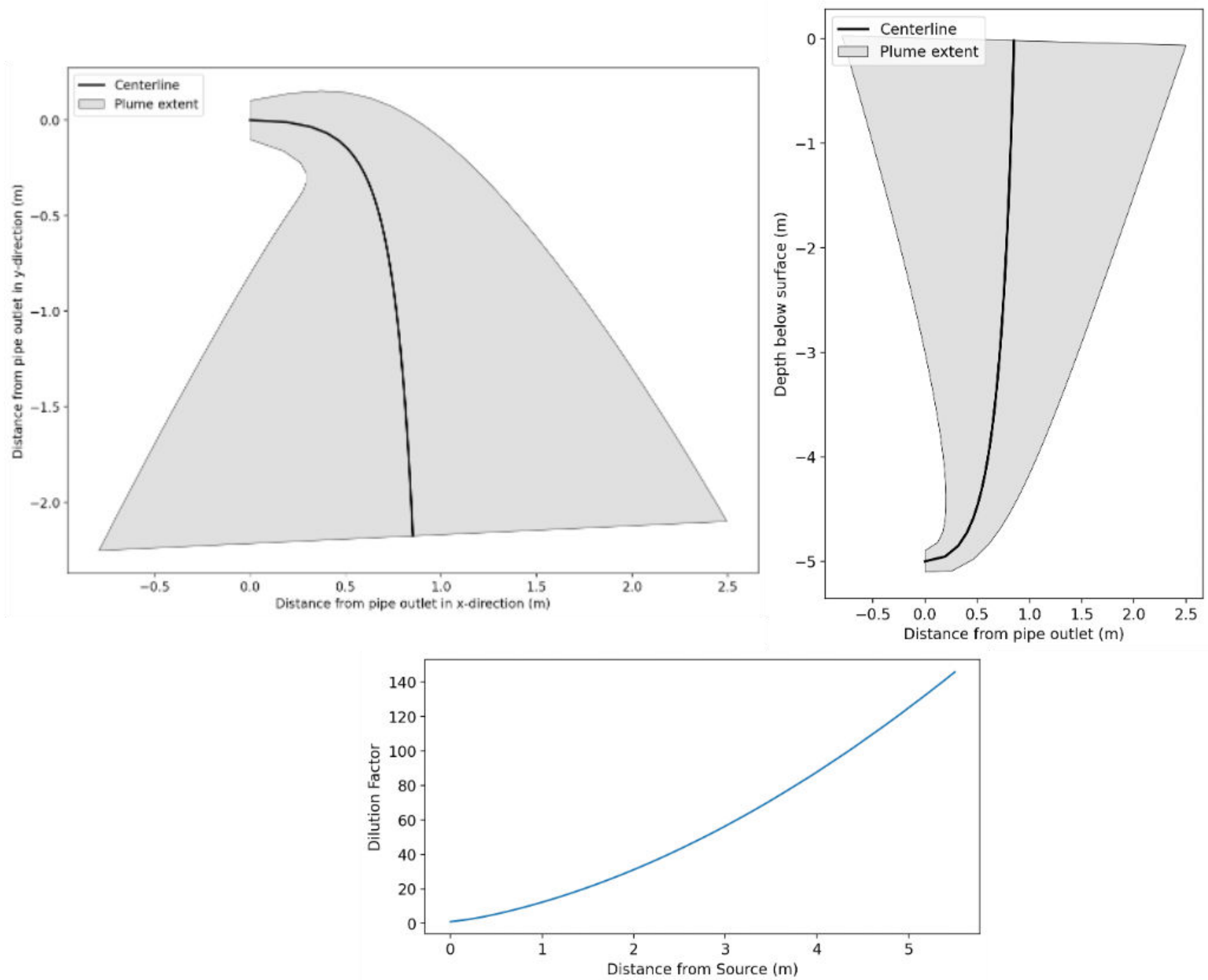


Figure B2-4.3-3 Schematic Representation of Plume Boundary in Summer with Current.

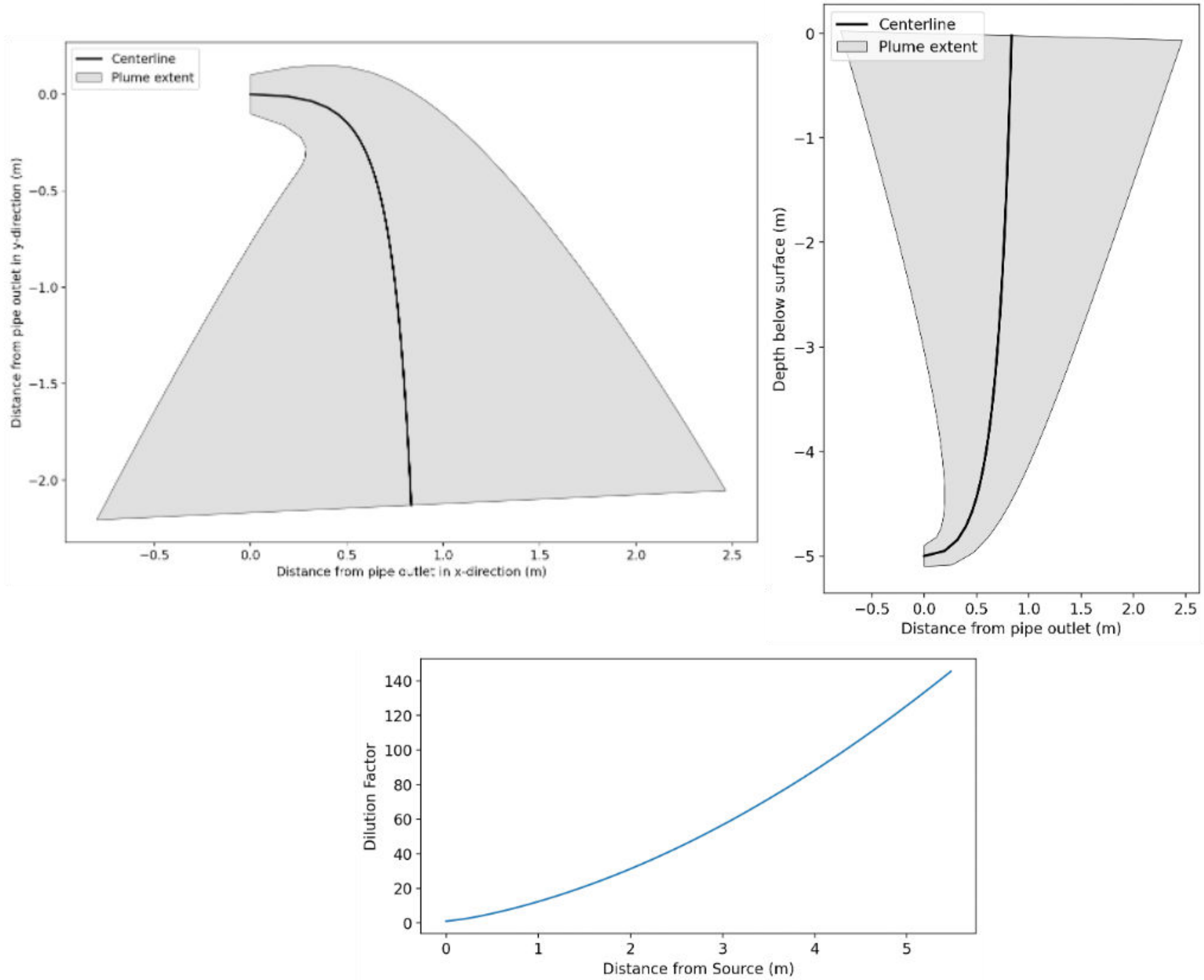


Figure B2-4.3-4 Schematic Representation of Plume Boundary in Winter with Current.

4.4 Key Findings

The key findings from the simulations are summarized as follows:

1) *Summer Scenario without Current:*

- Temperature change reduced to below 1°C within 7 seconds, at a distance of 1.20 m from the source.
- Salinity change reduced to below 10% of the ambient value (31.2 PSU) within 9 seconds, at a distance of 1.53 m from the source.
- Upon surfacing, ambient temperature and salinity changes were 0.15°C and 0.59 PSU, respectively, equivalent to 1.88% of the ambient salinity.

2) *Summer Scenario with Current:*

- Temperature change reduced to below 1°C within 5 seconds, at a distance of 0.77 m from the source.
- Salinity change reduced to below 10% of the ambient value (31.2 PSU) within 6 seconds, at a distance of 0.90 m from the source.
- Upon surfacing, ambient temperature and salinity changes were 0.05°C and 0.21 PSU, respectively, equivalent to 0.68% of the ambient salinity.

3) *Winter Scenario without Current:*

- Temperature change reduced to below 1°C within 12 seconds, at a distance of 2.04 m from the source.
- Salinity change reduced to below 10% of the ambient value (32.0 PSU) within 8 seconds, at a distance of 1.39 m from the source.
- Upon surfacing, ambient temperature and salinity changes were 0.28°C and 0.58 PSU, respectively, equivalent to 1.83% of the ambient salinity.

4) *Winter Scenario with Current:*

- Temperature change reduced to below 1°C within 8 seconds, at a distance of 1.19 m from the source.
- Salinity change reduced to below 10% of the ambient value (32.0 PSU) within 6 seconds, at a distance of 0.91 m from the source.
- Upon surfacing, ambient temperature and salinity changes were 0.10°C and 0.22 PSU, respectively, equivalent to 0.68% of the ambient salinity.

5.0 Conclusions

In this study, the CORMIX model was utilized to investigate the near-field mixing and dispersion of effluent discharge from an outfall in Argentia Harbour. Model simulations were conducted for both winter and summer conditions, focusing on water temperature and salinity. The resulting modeling outcomes were subsequently compared against the marine water quality guidelines outlined by CCME.

The primary conclusions drawn from the study are summarized as follows:

1) *Compliance with CCME Guidelines:*

- The marine water quality guidelines established by CCME for temperature and salinity were consistently met at close proximity to the discharge source across all examined scenarios.
- The scenario presents the greatest challenge for mixing and dispersion occurred under winter ambient conditions without current, where the temperature guideline was met at a distance of 2.04 m from the source, and the salinity guideline was met at 1.39 m from the source.

2) *Impact of Thermocline:*

- The presence of a thermocline was found to have negligible influence on the mixing and dispersion results, as the simulated discharge remained well above the thermocline (i.e., 5 m below the surface).
- It is anticipated that discharges originating from below the thermocline or bottom would also effortlessly adhere to CCME regulatory guidelines, given the buoyancy of the effluent plume, which ascends through the thermocline upon discharge.

3) *Outfall Location Suitability:*

- Both Marine Station 1 (MS1) and Marine Station 2 (MS2) were determined to be suitable locations for the design of a marine outfall, yielding comparable mixing and dispersion results, as the two locations are in close proximity and have comparable ambient conditions.

4) *Effect of Freshwater Layer at MS1:*

- The thin layer of freshwater observed at MS1 was deemed to exert minimal impact on effluent dispersion, as regulatory guidelines were consistently met prior to effluent surfacing, facilitated by a relatively large dilution factor.

6.0 References

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