Physical Oceanography Setting for the Hebron Nearshore and Offshore Project Areas

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1.0 NEARSHORE

As related study for the Hebron Project Comprehensive Study Report, and oil production activities on the Grand Banks of Newfoundland, AMEC Earth & Environmental, a Division of AMEC Americas Limited (AMEC) has prepared a description of the physical oceanography settings for the Project Areas nearshore, in Bull Arm, Trinity Bay, Newfoundland, and offshore, at the Hebron Field on the Grand Banks. Additional details of the Hebron Project are presented in the *Hebron Project Description* (ExxonMobil Canada Properties, 2009).

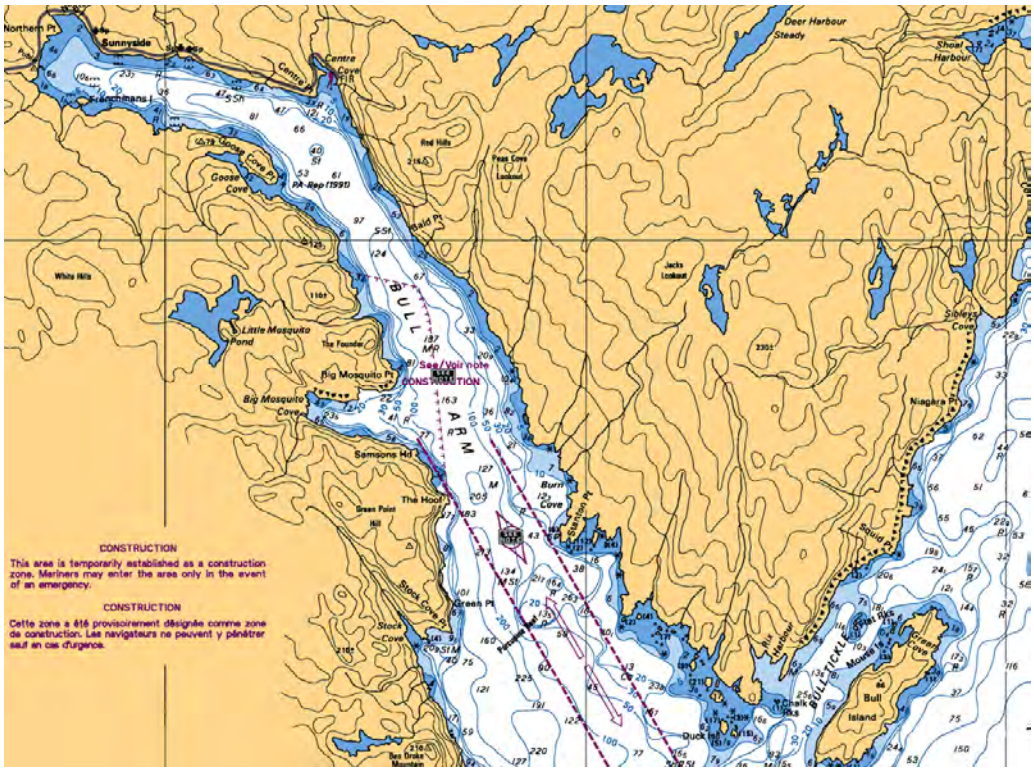
1.1 Bathymetry

Bull Arm is approximately 16 km in length, with an average width of 1.6 km, located at the northwest end of the head of Trinity Bay at the isthmus that connects the Avalon Peninsula with the main body of the Island of Newfoundland. Trinity Bay is a large bay on the northeastern coast of Newfoundland with a length of approximately 100 km, orientated towards the northeast.

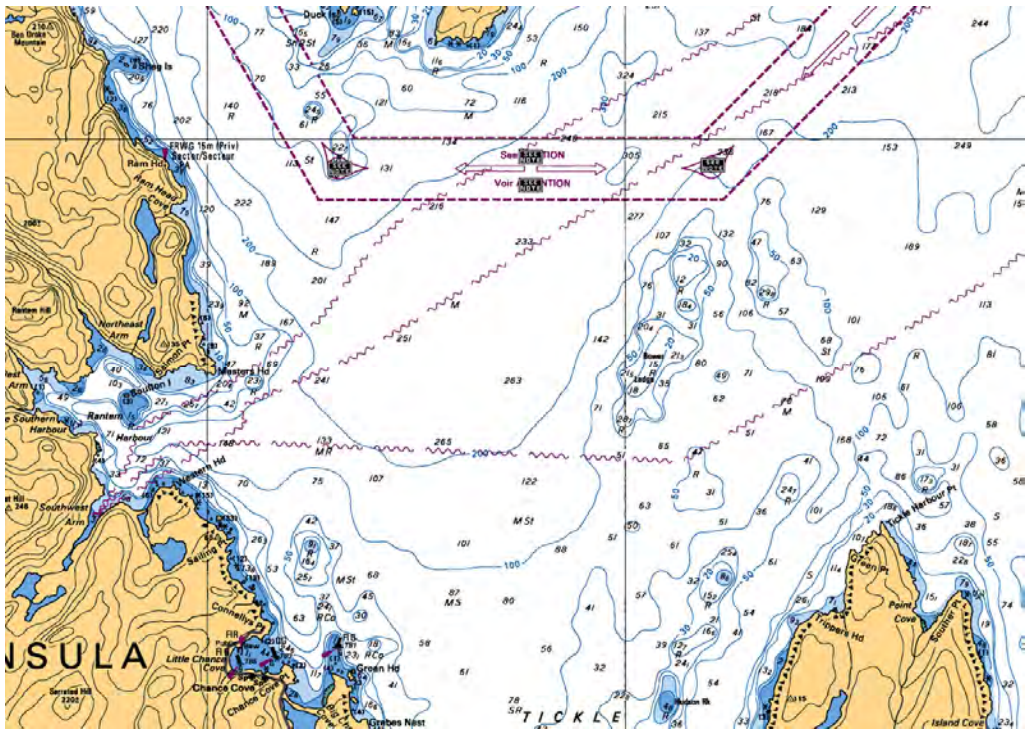
The Bull Arm Construction Site is located at Bull Arm; the Hibernia GBS was constructed at this site. This site was chosen due to its natural deep channel to Trinity Bay and its calm waters. This site has been proposed for construction of the Hebron GBS for similar reasons.

The study area encompasses the entire arm and extends seaward to just past Chance Cove across to Tickle Harbour point and straight back to the mouth of the arm. The bathymetry within the Study Area (from Canadian Hydrographic Services Chart #485101 (Canadian Hydrographic Services, 1997)) is illustrated in Figure 1-1. The range of depths within this area is from 1 to 2 m near shore to between 260 and 300 m at the head of Trinity Bay. Bull Arm has a deep centre channel reaching depths of over 200 m where it merges into Trinity Bay.

A



B



Note: Depths are in metres, Scale 1:60,000.
Source: Canadian Hydrographic Services, 1997, Chart #485101.

Figure 1-1 Bull Arm (A) and head of Trinity Bay (B), Newfoundland

1.1.1 Waves

Characterization of the wave climate in the offshore Newfoundland and Labrador area has been made using the long-standing Meteorological Service of Canada (MSC) 50-year Wind and Wave Climatology (MSC50) (an update of the Atmospheric Environment Service (AES) 40-year) of North Atlantic Wind and Wave Climatology (Swail *et al.*, 1998; Swail *et al.*, 2006; Meteorological Service of Canada, 1999; Meteorological Service of Canada, 2006; Oceanweather Inc., 2001). The hindcast was developed at Oceanweather with support from Climate Research Branch of Environment Canada (Oceanweather Inc., 2001). The hindcast involved the kinematic reanalysis of all significant tropical and extra-tropical storms in the North Atlantic for the continuous period 1958 to 1998. Oceanweather's 3rd generation wave model (OWI3G) was adopted onto a 0.625 by 0.833 degree grid. Wind and wave fields were archived at all active model Grid Points. The AES40 methodology and validation has been extensively documented and presented in peer-reviewed journals and conferences (Swail *et al.*, 1998). In 2005, the AES40 hindcast in Canadian waters was improved by a shallow-water version of the OWI3G on a 0.1 degree grid covering much of the Canadian Maritimes. The North Atlantic basin model was similarly upgraded and run at a 0.5 degree resolution. The MSC50 also extended the time-series to include the 52 years 1954 to 2005 (Swail *et al.*, 2006).

The MSC50 Grid Point M6012874 (47.7^{o}N, 53.8^{o}W) located near the Bull Arm site at 140.9 m water depth (Figure 1-2) is relevant for the Nearshore Project Area. Wave roses (representing direction "to") for MSC50 Grid Point M6012874 are presented in Figures 1-3 to 1-5. The wave height statistics are shown in Figures 1-3 to 1-5 and Tables 1-1 and 1-2. Wave parameters include significant wave height (Hs) and spectral peak wave period (Tp)[1]. The Hs is derived as the average height of the one-third largest waves. The Tp is the period of the waves with the largest energy levels (which approximate the period of the one-third highest waves). The Hs ranges from approximately 0.001 to 2.0 m, with maximum waves occurring in January and December. The greatest occurrence of Hs (38%) was between 0 and 0.3 m. During the summer months, waves propagate most frequently toward the north-northeast. By fall, the waves most frequently propagate eastward into the area. Peak wave period ranges from 0.1 to 25 s, with the greatest occurrence (81%) between 2 and 4 s.

The Hibernia Development Project Environmental Specifications report presents the 100 year extreme waves for two deep water sites in Bull Arm, which were near the construction site for the Hibernia GBS (47°49'23"N, 53°52'37"W and 47°48'42"N, 53°52'37"W) (Topside Engineering, 1992). Results are shown in Table 1-3. The extreme wave conditions show a maximum Hs of 2.6 m, which compares reasonably well with the maximum from the MSC50 Grid Point near Bull Arm of 1.9 m. However, the extreme peak periods reported in Bull Arm are significantly lower (three to four times) than the maximum calculated from the Grid Point near Bull Arm.

[1] MSC50 parameters include wind speed, wind direction, Hs, Tp (several estimates), wave direction, wave spread and spectral moments.

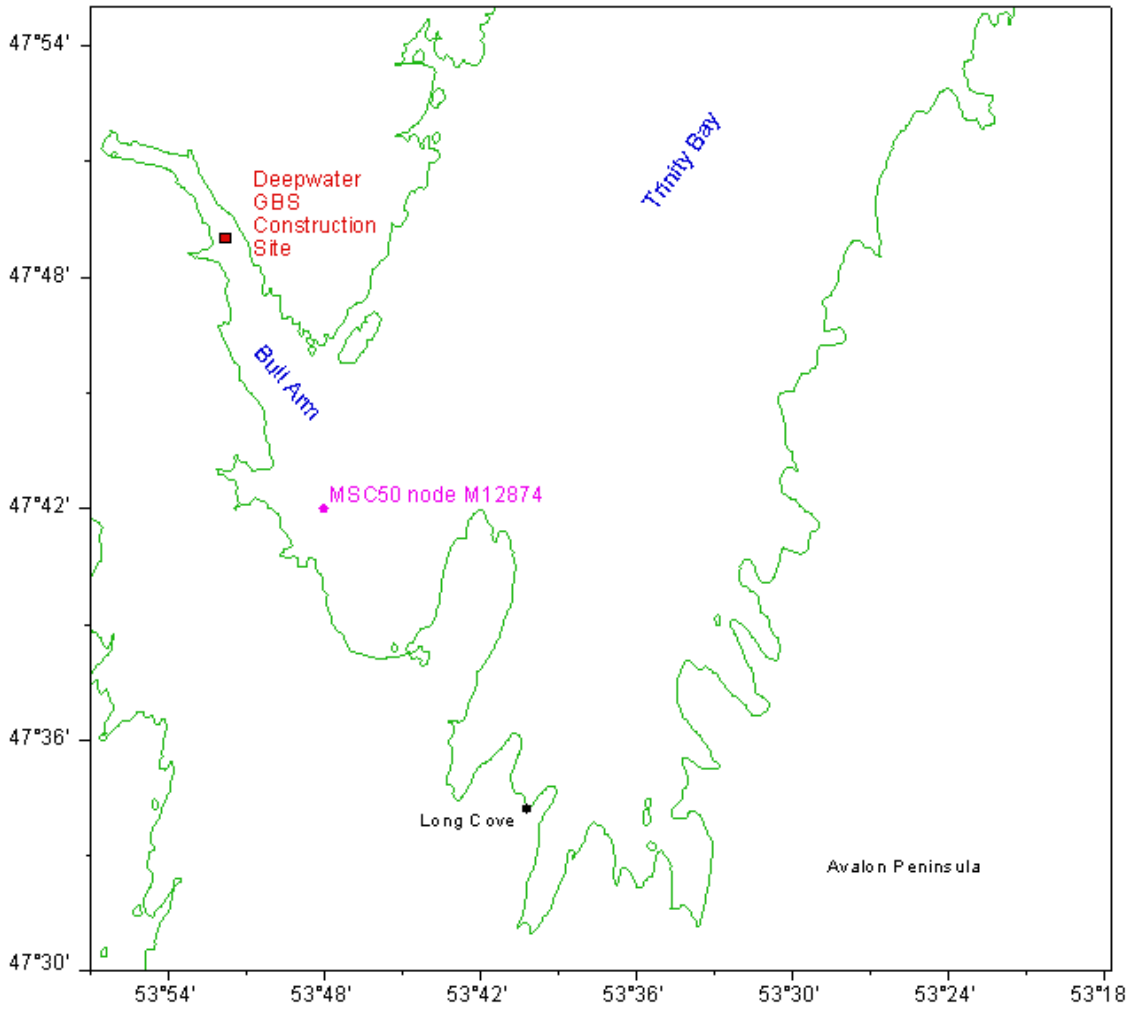


Figure 1-2 MSC50 Climatology Grid Point, M6012874 (47.7°N, 53.8°W) near Bull Arm, Newfoundland

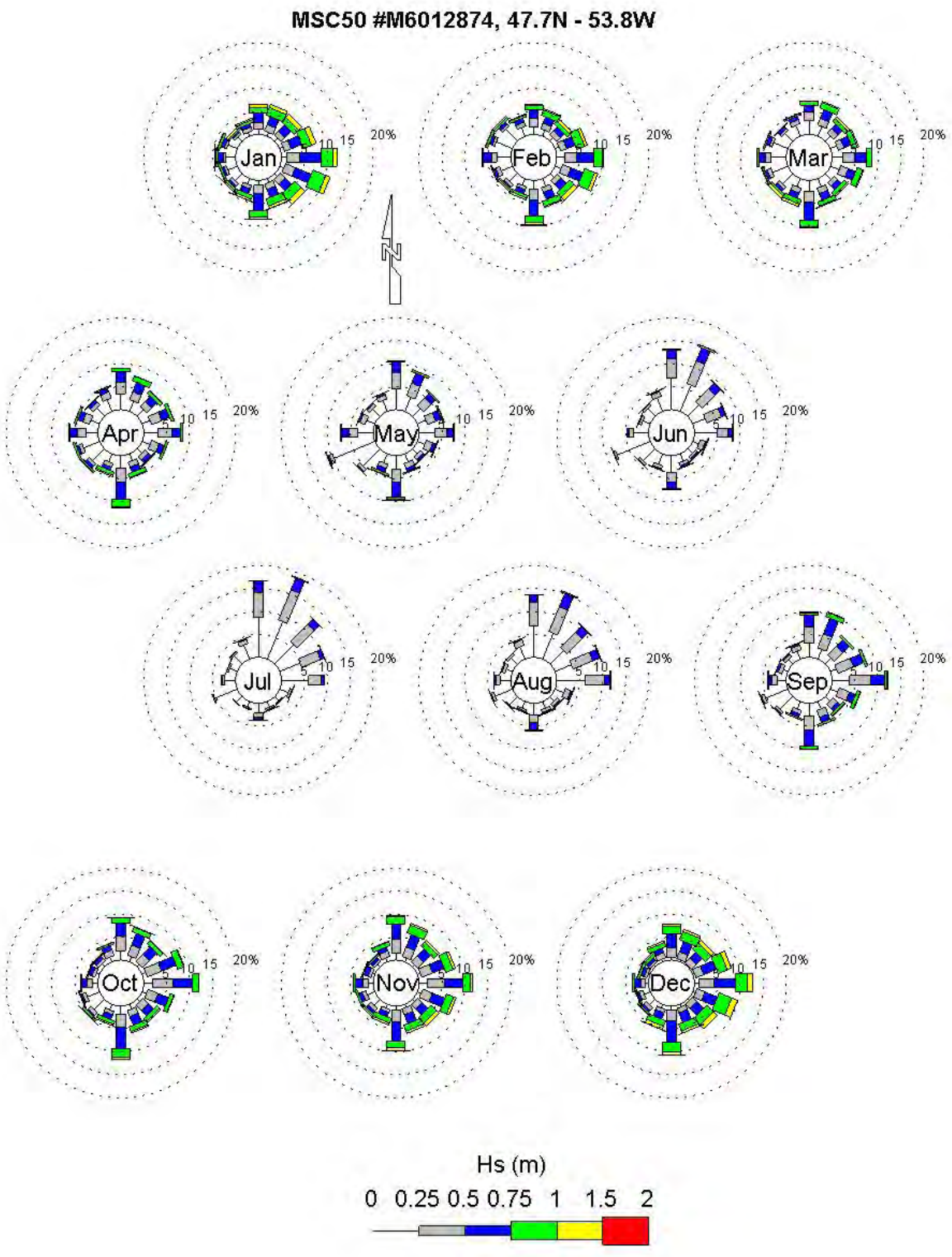


Figure 1-3 Monthly Frequency of Significant Wave Height Occurrence by Direction (to) for the MSC50 Grid Point M6012874 near Bull Arm

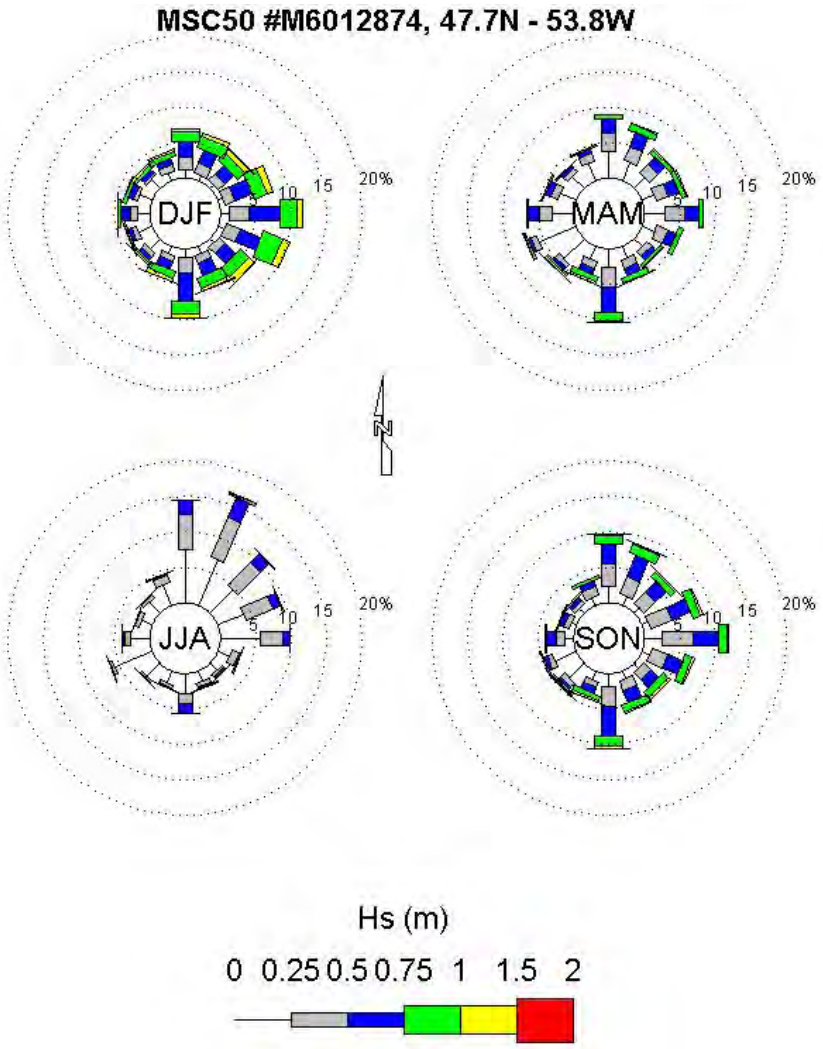


Figure 1-4 Seasonal Frequency of Significant Wave Height Occurrence by Direction (to) for the MSC50 Grid Point M6012874 near Bull Arm

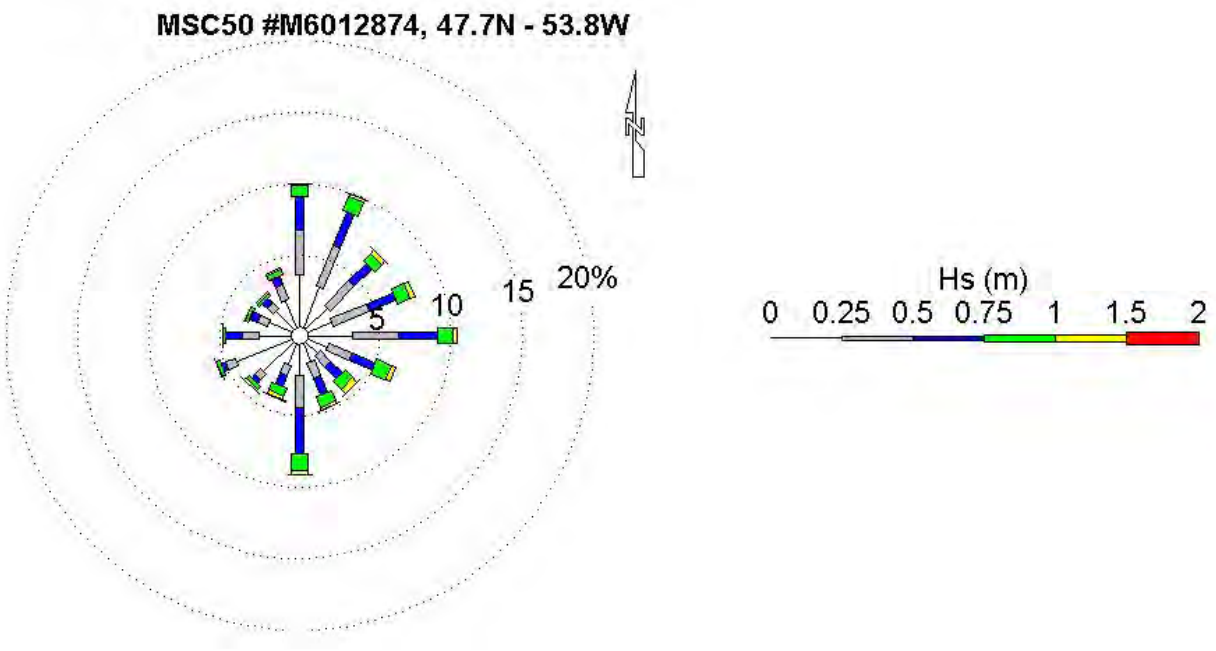


Figure 1-5 Annual Frequency of Significant Wave Height Occurrence by Direction (to) for the MSC50 Grid Point M6012874 near Bull Arm

Table 1-1 Monthly Significant Wave Height and Peak Period Statistics from MSC50 Grid Point M6012874 near Bull Arm

	Significant Wave Height (m)			Peak Period (s)		
Month	**Mean**	**Maximum**	**Most Frequent Direction (to)**	**Minimum**	**Mean**	**Maximum**
Jan	0.64	1.9	E	0.5	5	17.5
Feb	0.57	1.5	E	0.2	4.2	19.1
Mar	0.52	1.7	S	0.1	3.9	23.2
Apr	0.41	1.5	S	0.2	4.2	19.1
May	0.29	1.5	WSW	0.1	5.1	20.8
Jun	0.23	1.3	NNE	0.1	4.5	24.5
Jul	0.21	1.2	NNE	0.1	3.7	24.5
Aug	0.25	1.2	NNE	0.1	3.8	21.8
Sep	0.36	1.4	E	0.1	4.8	24.5
Oct	0.47	1.6	E	0.3	5	17.6
Nov	0.55	1.5	E	0.3	4.8	17.5
Dec	0.62	1.9	E	0.4	5.1	17.6
Year	0.42	1.92	E	0.1	4.5	24.5

Table 1-2 Annual Significant Wave Height versus Peak Period, from MSC50 Grid Point M6012874 near Bull Arm

	Significant Wave Height (m)							
Peak Period (s)	**0-0.3**	**0.3-0.6**	**0.6-1**	**1-1.3**	**1.3-1.6**	**1.6-2**	**Total**	**% Total**
0-2	0	0	0	0	0	0	0	0
2-4	116008	135321	94270	187	0	0	345786	80.8
4-6	9	0	10033	12814	1216	15	24087	5.6
6-8	13	0	0	0	0	0	13	0
8-10	1	0	0	0	0	0	1	0
10-15	37852	2390	1550	255	104	12	42163	9.8
15-20	8525	3567	2895	648	232	31	15898	3.7
20-25	164	0	0	0	0	0	164	0
Total	162572	141278	108748	13904	1552	58	428112	100
% Exceed	62	29	3.6	0.4	0	0	0	0

Table 1-3 100-Year Extreme Wave Heights at the Deepwater Sites (Hibernia GBS construction site), Bull Arm

	Location: 47°49'23"N 53°52'37"W		Location: 47°48'42"N 53°52'37"W	
	October to February	March	October to February	March
Extreme Height (m)	4.8	3.9	4.5	3.7
Associated Crest to Crest Period (s)	6.5	6.0	6.2	5.8
Significant Height (m)	2.6	2.1	2.4	2.0
Peak Period (s)	6.5	6.0	6.2	5.8
Zero Crossing Period (s)	5.1	4.7	4.8	4.5
Mean Period (s)	5.4	5.0	5.2	4.8
Source: Topside Engineering 1992.				

1.1.2 Tsunamis

Tsunamis are long-period gravity waves generated in a body of water by an impulsive disturbance that vertically displaces the water column. Earthquakes, landslides, volcanic eruptions and even explosions or the impact of cosmic bodies such as meteorites can generate tsunamis. The resulting wave energy spreads outwards across the ocean at high speed. Tsunami occurrences in Canada are rare, with the Pacific Coast at greatest risk due to the high occurrence of earthquake and landslide activity in the Pacific Ocean. Their occurrence can result in major damage and loss of life.

Tsunamis generated by earthquakes generally originate from what is referred to as far-field sources; they are sometimes called teletsunamis. Tsunamis resulting from the deformation of the sea floor caused by an earthquake can travel far, while tsunamis generated by other mechanisms generally dissipate quickly, only affecting areas close to the source. Not all earthquakes generate tsunamis (Fisheries and Oceans Canada 2008).

For Newfoundland and the Grand Banks, the most relevant far-field sources are the Azores-Gibraltar Ridge zone, the Mid-Atlantic Ridge and the north side of the Caribbean Arc. Tsunamis generated by other mechanisms generally originate from near-field sources such as the Laurentian Channel, origin of the 1929 Grand Banks tsunami.

A potential near-field source for the construction site would be a significant landslide in Bull Arm or Trinity Bay. However, there is only one known report of a landslide in the area (Natural Resources, 2009), which occurred May 9, 2003, in Southport and did not generate a tsunami.

There are four instances of probable or confirmed tsunamis in Newfoundland:

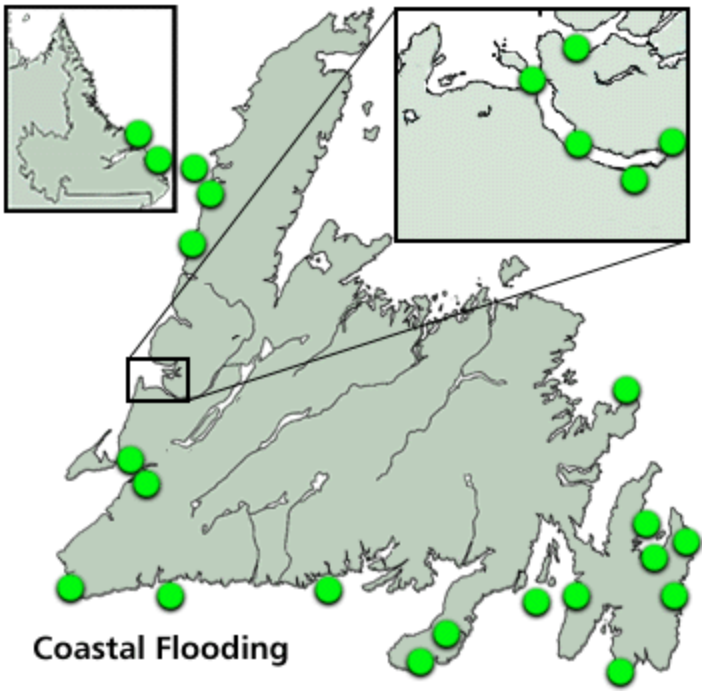
- Probable tsunami: November 1, 1755. "*Probable result of Lisbon earthquake. Emptied Bonavista harbour and 10 minutes later water returned and overflowed parts of the community.*" (Newfoundland and Labrador Heritage, 2000).

- Probable tsunami: September 24, 1848. "*Teletsunami from unknown source location. The tsunami was observed in southern Labrador from Fishing Ships Harbour to St. John's. No earthquake was recorded on that day, so it is likely that this was a landslide-induced tsunami, or possibly from an offshore earthquake, although none was recorded.*" (National Geophysical Data Center, 2009).

- Probable tsunami: June 27, 1864. "*An earthquake off the southwestern coast of the Avalon Peninsula caused a local tsunami at Saint Shotts.*" (National Geophysical Data Center, 2009).

- Confirmed tsunami: November 18, 1929. An earthquake of magnitude 7.2 occurred approximately 250 km south of Newfoundland along the southern edge of the Grand Banks, at 5:02 PM local time. "*The earthquake triggered a large submarine slump (an estimated volume of 200 cubic km of material was moved on the Laurentian slope) which ruptured 12 transatlantic cables in multiple places, and generated a tsunami. The tsunami was recorded along the eastern seaboard as far south as South Carolina and across the Atlantic Ocean in Portugal.*" Approximately 2.5 hours after the earthquake, tsunami waves struck the Burin in three main pulses, causing the local sea level to rise between 2 and 7 m, with waters as high as 13 m in some bays on the Burin. The tsunami claimed 28 lives and destroyed or moved many buildings. Effects on Trinity Bay are not documented but: "*The tsunami refracted counterclockwise around the Avalon Peninsula to arrive in the Bonavista area about 1:30 am N.S.T.*" on November 20. "*It appears that the water in Bonavista Harbour drained out completely, and then overflowed part of the community upon its return.*" (Natural Resources Canada, 2008; National Geophysical Data Center, 2009).

While the 1755 and 1929 tsunamis were observed to affect Bonavista and the 1848 event affected locations northwest and southeast of Trinity Bay, it is not clear that the construction site in Bull Arm is at risk. First, construction will take place over approximately four years, while the observed tsunamis seem to indicate a return period on the order of 50 to 100 years for Newfoundland, likely longer for Bull Arm and even longer for a destructive tsunami such as the 1929 event. Also, Bull Arm is very sheltered from the open ocean, although tsunami waves can in theory refract around shorelines. Given the complex shape and bathymetry of Bull Arm and Trinity Bay, numerical modelling would be required to evaluate the potential water elevation change and currents if a tsunami was to affect Eastern Newfoundland. The recorded coastal flooding events in Newfoundland and Labrador from 1755 to 1992 are shown in Figure 1-6 and show no flooding in Trinity Bay.



Source: Newfoundland and Labrador Heritage, 2000.

Figure 1-6 Locations of All Recorded Coastal Flooding in Newfoundland and Labrador from 1755 to 1992

1.1.3 Currents

Ocean current studies and data are limited for Bull Arm. Data were collected in the late 1980s and early 1990s to support the Hibernia Development Project. Studies have also been conducted in Trinity Bay, mostly related to the commercial fisheries in the area. Both Seaconsult Marine Reseach Ltd. and Oceans Ltd. conducted oceanographic data collection programs in support of the Hibernia Development Project. The Seaconsult data report is reviewed herein; however, the data from Oceans Ltd. were not made available at this time.

The study completed by Seaconsult (1991) reports current data for 5 to 75 m depths from February 9, 1991, to March 13, 1991, near the construction site for the Hibernia GBS (47°49’N, 53°53'W). Current data are presented in Table 1-4. The maximum mean current of 0.074 m/s occurred at the surface; however, the overall maximum current of 0.399 m/s was observed at 47 m. The most frequent direction is northwest at all depths except at the surface, where the flow can be moderated by local wind forcing.

The report completed by Topside Engineering (1992) presents the environmental design criteria for the Hibernia Development Project. The 100-year extreme current profiles for deepwater sites in Bull Arm are shown in Table 1-5. As expected, the estimated extreme currents are all higher than the measured currents reported by Seaconsult (1991) (and range from 1 m/s for depths from 5 to 80 m to 0.4 m/s at the surface).

Table 1-4 Currents for 5 to 75 m from February 9, 1991, to March 13, 1991, Near the Construction Site for the Hibernia Gravity-base Structure

Depth (m)	Mean (m/s)	Maximum (m/s)	St. Dev.	Most Frequent Direction (to)
5	0.074	0.313	0.054	S (150-165)
15	0.039	0.216	0.03	NW (330-345)
25	0.03	0.188	0.022	NW (330-345)
36	0.029	0.178	0.031	NW (300-315)
47	0.037	0.399	0.042	NW (300-315)
55	0.033	0.192	0.031	NW, N (330-345)
66	0.037	0.245	0.032	NW (315-330)
76	0.032	0.211	0.034	NW (330-345)
Source: Seaconsult 1991.				

Table 1-5 Hibernia Development Project Environmental Specifications 100- and 120-Year Extreme Current Profiles for Deepwater Sites, Bull Arm

	Probable Maximum Current in Downwind Direction (m/s)	
Depth (m)	Location: 47°49'23"N 53°52'37"W	Location: 47°48'42"N 53°52'24"W
Surface	0.6	0.4
5	1.0	0.8
10	1.0	0.8
20	1.0	0.8
30	1.0	0.8
40	1.0	0.8
50	1.0	0.8
60	1.0	0.8
70	1.0	0.8
80	1.0	0.7
90	0.9	0.7
100	0.9	0.5
Source: Topside Engineering 1992.		

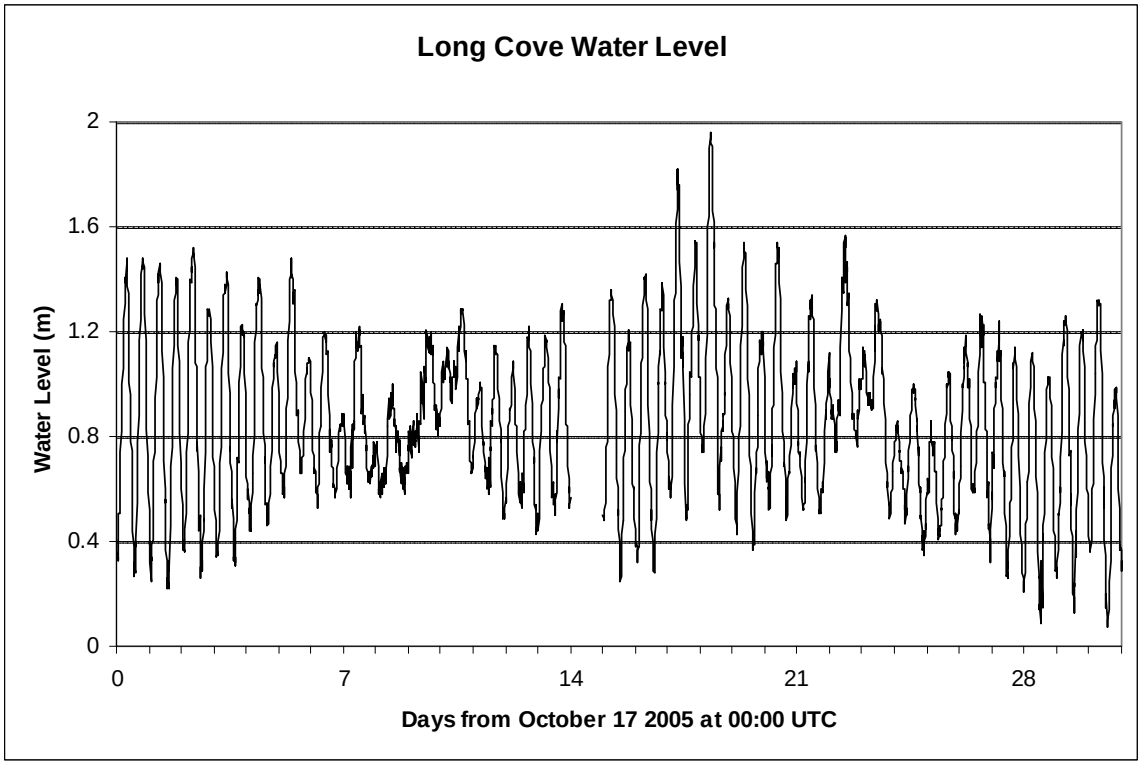
The current studies for Trinity Bay are summarized by Dalley *et al.* (2002), wherein they cite several studies as follows. Bailey (1958) concluded that mean currents from the inshore branch of the Labrador Current entered the Bay on the northwest side and exited on the southeast side. Bailey's data also suggested the existence of two weak gyres within the Bay. Yao (1986) subsequently confirmed the direction of these mean currents and showed that predominant southwesterly winds caused displacement of the mixed surface layers, along the axis of the Bay, from southwest to northeast. Yao (1986) found that surface currents flowing out of the bay as a result of the predominant winds along the axis produced an upwelling of colder water along the bay's northwest side and downwelling along its southeast side. Yao (1986) also found that incoming currents in the northwest corner are at times stronger than outflowing surface currents, produced by the prevailing southwesterly winds blowing out of the Bay, so despite prolonged offshore wind events, a net current into the bay may prevail as a result of the Labrador Current. The numerical hydrodynamic model of Davidson *et al.* (2001) was applied to Trinity Bay and residence times of 50 to 60 days were estimated near the head of Trinity Bay.

1.1.4 Tides and Storm Surges

The tidal levels in Trinity Bay have been reported by several sources for different locations. Forecast tides for Heart's Content and Clarenville show a tidal range of about 1.2 m (Canadian Hydrographic Service, 2008).

Observations at Long Cove (47.57°N, 53.67°W at the southern end of Trinity Bay) for a month (recorded every 15 minutes from October 17 to November 17, 2005) showed a water level variation from 0.07 to 1.96 m (Figure 1-7). Two peaks on November 3 and 4, 2005, are not of tidal origin and were likely caused by storm surge. Without the peaks, the tidal range in Long Cove is approximately 1.6 m (Fisheries and Oceans Canada, 2009a).

The DFO WebTide model (Dupont et al., 2002) was employed by AMEC (2009) at a location in the south end of Trinity Bay (47°42' 00"N, 53°48' 00"W) for the period 2000-2009, and the resulting tidal range was found to be approximately 1.26 m (variation from 0.067 m to 1.33 m).



Note: Observations were made every 15 minutes from October 17 to November 17, 2005.
Source: Fisheries and Oceans Canada, 2009a.

Figure 1-7 Observations at Long Cove (47.57°N, 53.67° W at the southern end of Trinity Bay) for a Month

Marex (1992) conducted a study on water levels in Bull Arm using data collected from January to August 1991. The measurements were conducted using a tide gauge at

location GULL, a site adjacent to the GULL survey monument located on a rocky headland on the southern shore of Great Mosquito Cove. This study identified the mean water level (MWL), the range of water levels associated with astronomical tides, as well as estimates of probable extreme surges (Table 1-6). Furthermore, this study provided estimates of the extreme maximum and extreme minimum still water levels in Bull Arm by combining the tide and estimated surge levels. The estimates of extreme water level for the 100 year condition in Table 1-6 include a contingency allowance to the 95% confidence limits. The estimated maximum extreme water level is +1.52 m relative to the MWL, which includes the standard deviation of the MWL, the tide (including the mean higher high water and the mean lower low water levels), the 50 year surge and the standard deviation on the 50 year surge. The minimum extreme water level is -1.2 m relative to the MWL which includes the same parameter levels as the maximum.

The best estimate for the tidal range (difference between highest and lowest astronomical tide levels) in Bull Arm was found to be 1.71 m. This range is relatively higher than those reported at other locations in Trinity Bay, but it is consistent with the constrained geometry of Bull Arm relative to the wider area of Trinity Bay.

Table 1-6 Mean and Extreme Tide and Surge Levels, Bull Arm

	Level (m)
Highest Astronomical Tide	0.80
Mean Water Level	0.00
Lowest Astronomical Tide	-0.91
Extreme Maximum Still Water Level (100-Year Total Level)	1.52
Extreme Minimum Still Water Level (100-Year Total Level)	-1.20
Mean Positive Surge Amplitude (100-Year Surge)	0.88
Mean Negative Surge Amplitude (100-Year Surge)	-0.54
Note: GULL benchmark, Bull Arm, Trinity Bay is located 3.2 m above CHS chart datum and 2.24 m above mean water level Source: Marex, 1992	

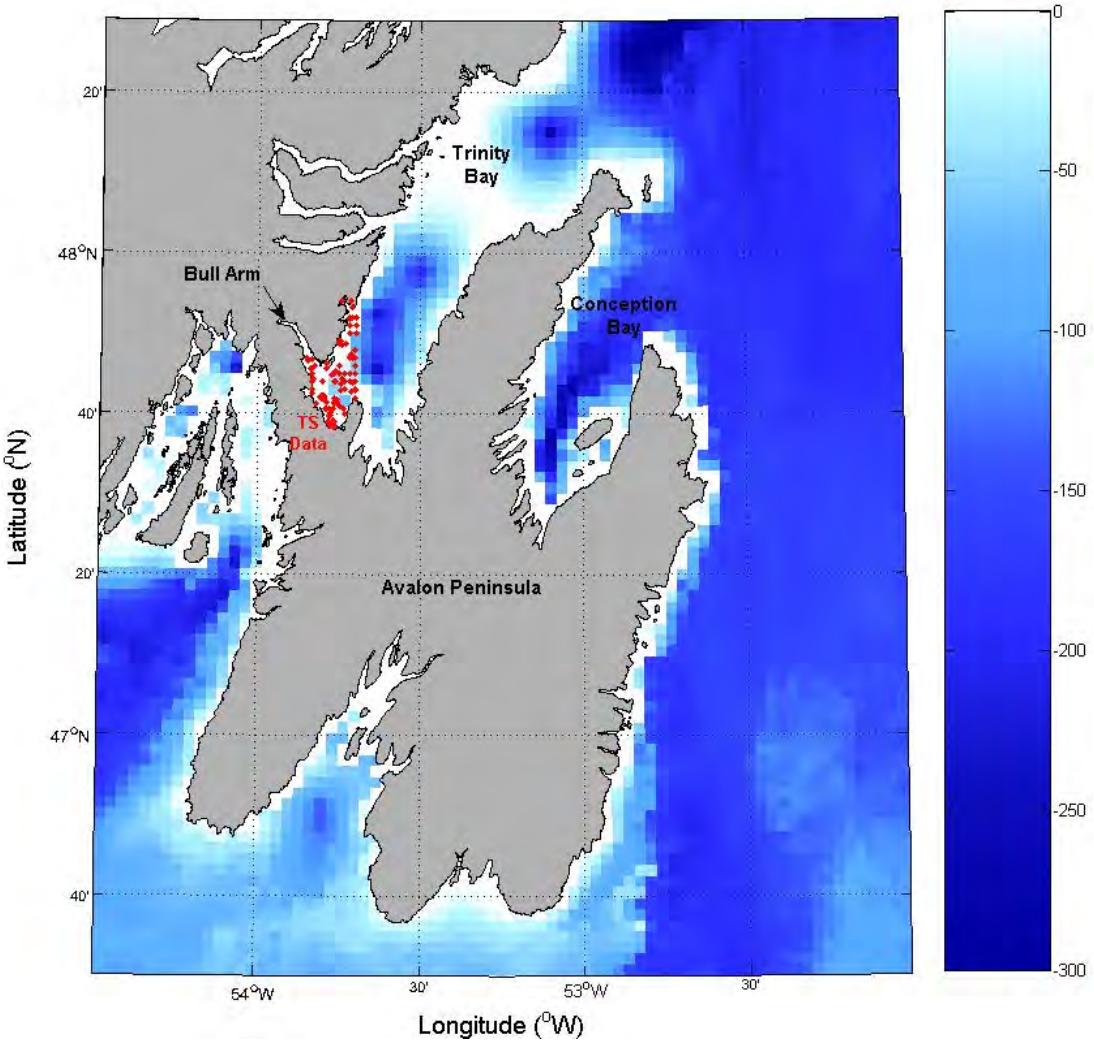
1.1.5 Physical and Chemical Properties

Temperature and salinity data were extracted from the Fisheries and Oceans Canada (DFO) hydrographic database (Fisheries and Oceans Canada, 2009b). This database is a collection of temperature and salinity measurements for the area approximately defined by 35°N to 80°N and 42°W to 100°W. The data come from a variety of sources, including hydrographic bottles casts, CTD casts, spatially and temporally averaged Batfish tows and expendable digital or mechanical bathythermographs. Near real-time data are in the form of IGOSS (Integrated Global Ocean Services System) Bathy or Tesac messages (codes for oceanographic data). The database currently consists of approximately 782,000 profiles and 35 million individual observations from 1910 to the present.

The geographic limits used for this study are 47.6°N, 48°N, 53.85°W and 53.7°W. Approximately 4,074 measurements are available within this area from the DFO database. These were averaged by depth with bin depth of 2 m for 0 to 20 m every 5 m

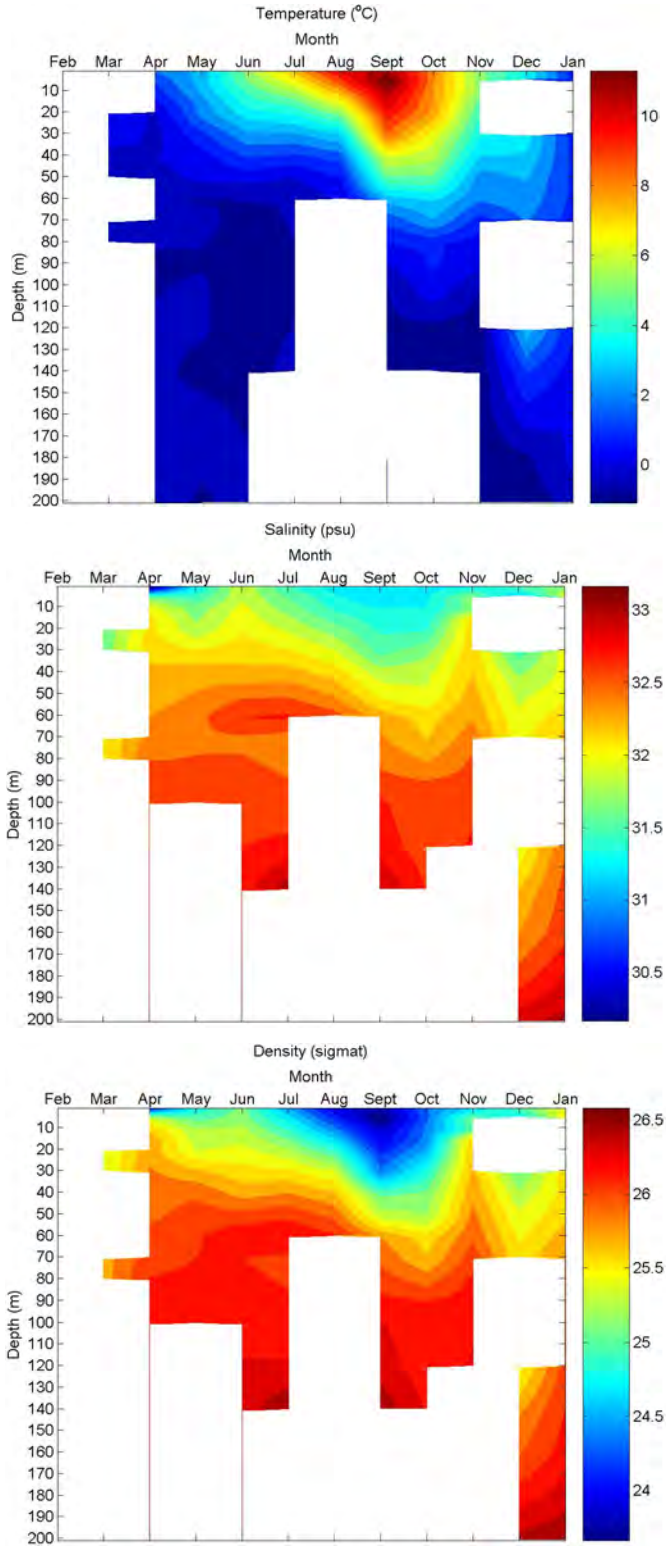
and bin depth 5 m from 30 to 100 m every 10 m and from 120 to 200 m every 20 m. The locations of the measurements are presented in Figure 1-8 and the results in Figure 1-9. The monthly statistics are presented in Appendix 1, while the summary of monthly statistics is provided in Table 1-7 and Table 1-8. There are no data for February, and data in March are sparse.

In summer, the system becomes thermally stratified with the development of a distinct surface layer to about 60 m, with average temperatures reaching between 14°C and 15°C and average salinities between 31.3 and 32 psu. By November, the system returns to one nearly homogeneous layer, which is colder and saltier than the conditions in the summer. In fall, the average temperatures range from 5.3°C (November) for the surface layer to -0.8°C (December) and the average salinities range from 31.4 psu at the surface to 32.7 psu near bottom. In the deeper layer, below 60 m, average temperatures range between -0.32°C and 1°C and average salinities between 32 and 33 psu.



Bathymetry Source: National Oceanic and Atmospheric Administration, 2009.

Figure 1-8 Temperature and Salinity measurement locations for Bull Arm



Source: Fisheries and Oceans Canada, 2009.

Figure 1-9 Contours of Temperature, Salinity and Density

Table 1-7 Temperature and Salinity Statistics

Depth (m)	Temperature (°C)					Salinity (psu)				
	Min	**Max**	**Mean**	**Std Dev**	**Total Count**	**Min**	**Max**	**Mean**	**Std Dev**	**Total Count**
January										
0	0.42	1.73	1.05	0.49	8	31.51	31.97	31.75	0.16	8
20	-0.38	2.57	1.20	0.85	13	31.61	32.26	32.01	0.19	10
50	0.38	2.01	1.26	0.52	18	31.76	32.33	32.07	0.22	15
100	-0.05	1.22	0.96	0.42	8	32.20	32.59	32.46	0.14	6
200	-0.32	-0.32	-0.32	0.00	1	33.07	33.07	33.07	0.00	1
February - No Data										
March										
0	0.00	0.71	0.23	0.33	4	31.67	31.67	31.67	0.00	1
20	0.70	0.70	0.70	0.00	1	31.69	31.69	31.69	0.00	1
50	-0.50	0.26	-0.12	0.54	2	31.89	31.89	31.89	0.00	1
100	-0.31	-0.31	-0.31	0.00	1	32.36	32.36	32.36	0.00	1
200	-	-	-	-	-	32.95	32.95	32.95	0.00	1
April										
0	0.40	3.25	2.10	1.02	12	29.30	31.87	30.16	1.48	3
20	-0.42	0.71	0.03	0.39	7	31.90	32.43	32.15	0.24	5
50	-0.97	1.10	-0.07	0.62	10	32.07	32.45	32.33	0.15	5
100	-1.00	0.00	-0.53	0.43	4	32.62	32.80	32.69	0.09	3
200	-0.64	0.90	0.13	1.09	2	33.12	33.12	33.12	0.00	1
May										
0	-0.10	5.60	2.83	1.84	17	30.53	31.63	31.32	0.53	4
20	-0.74	5.06	2.23	1.54	12	31.46	32.63	31.86	0.52	4
50	-0.92	2.49	0.27	1.16	13	32.24	32.70	32.43	0.19	5
100	-1.36	1.29	-0.33	0.94	7	32.66	32.66	32.66	0.00	1
200	-0.66	-0.66	-0.66	0.00	1	-	-	-	-	-
June										
0	-0.60	9.73	5.48	2.51	60	30.75	33.06	31.94	0.58	48
20	-1.07	9.96	3.55	2.85	73	31.34	32.78	32.10	0.39	60
50	-1.37	5.83	0.31	1.87	71	31.77	32.87	32.54	0.27	60
100	-1.36	-0.40	-1.08	0.31	9	32.61	32.71	32.66	0.07	2
200	-0.47	0.36	-0.03	0.42	3	33.31	33.31	33.31	0.00	2
July										
0	-0.10	12.90	7.75	2.82	148	29.80	33.69	31.52	0.77	131
20	-0.73	10.79	3.94	2.63	166	31.09	32.78	31.95	0.39	150
50	-1.25	5.71	0.11	1.17	159	31.88	32.84	32.55	0.17	145
100	-0.80	-0.38	-0.55	0.19	4	32.56	32.69	32.63	0.07	3
140	0.04	0.04	0.04	0.00	1	33.12	33.12	33.12	0.00	1

Table 1-8 Temperature and Salinity Statistics (continued)

Depth (m)	Temperature (°C)					Salinity (psu)				
	Min	Max	Avg	Std Dev	Total Count	Min	Max	Avg	Std Dev	Total Count
August										
0	0.88	14.77	10.23	3.10	110	29.81	33.12	31.29	0.64	108
20	-0.85	12.51	5.32	3.57	122	30.45	32.47	31.75	0.52	120
50	-1.19	3.95	0.74	1.47	119	31.67	32.88	32.41	0.24	117
100	-	-	-	-	-	-	-	-	-	-
200	-	-	-	-	-	-	-	-	-	-
September										
0	9.25	14.10	11.00	1.55	27	30.96	31.58	31.29	0.19	18
20	3.05	14.03	9.72	2.87	24	30.97	32.57	31.49	0.33	22
50	-0.23	9.20	4.92	2.85	30	31.67	32.48	32.06	0.28	22
100	-1.11	0.25	-0.49	0.41	11	32.57	32.88	32.75	0.10	9
200	-0.15	0.00	-0.08	0.11	2	33.37	33.37	33.37	0.00	1
October										
0	7.15	11.80	8.42	1.69	27	31.08	31.43	31.30	0.11	21
20	6.23	11.74	8.06	1.84	20	31.12	31.78	31.49	0.18	16
50	1.86	11.37	4.97	3.07	12	31.16	32.30	31.99	0.43	7
100	-1.04	3.10	0.67	1.76	4	32.40	32.72	32.56	0.23	2
140	-0.41	-0.41	-0.41	0.00	1	32.71	32.71	32.71	0.00	1
November										
0	2.89	7.17	5.27	2.01	6	30.55	32.25	31.35	0.85	3
20	1.65	7.85	4.48	2.58	7	32.12	32.27	32.20	0.11	2
50	1.07	3.52	2.26	1.18	5	32.32	32.33	32.33	0.01	2
100	-0.89	0.60	-0.45	0.70	4	32.68	32.68	32.68	0.00	1
200	-0.82	-0.82	-0.82	0.00	1	-	-	-	-	-
December										
0	3.40	4.07	3.74	0.47	2	31.58	31.58	31.58	0.00	1
20	-	-	-	-	-	-	-	-	-	-
50	2.66	2.66	2.66	0.00	1	31.92	31.92	31.92	0.00	1
100	-	-	-	-	-	-	-	-	-	-
200	-0.78	-0.78	-0.78	0.00	1	32.96	32.96	32.96	0.00	1

Source: Fisheries and Oceans Canada, 2009b.

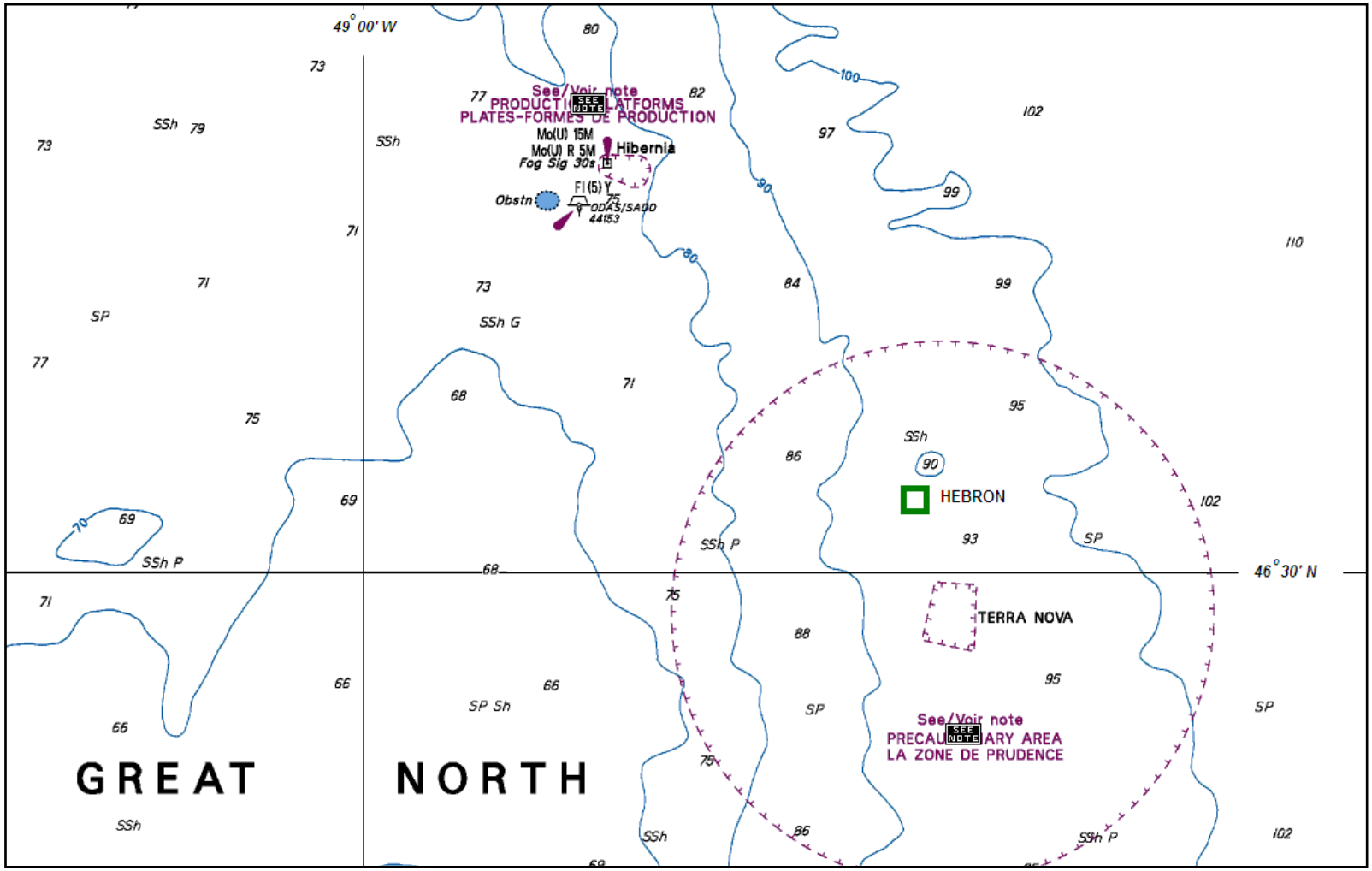
2.0 OFFSHORE

2.1 Bathymetry

The Grand Banks extends almost 500 km offshore and covers an area of approximately 270,000 km^2. The bank is relatively flat, with typical water depths of 100 m or less. East of the bank is the Flemish Pass, which separates the Grand Banks from the Flemish Cap. The Flemish Pass reaches depths of over 1000 m, while the Flemish Cap is of radius approximately 200 km and depths as shallow as about 140 m. East and south of the Flemish Pass is the slope of the Newfoundland Shelf and the Atlantic Basin at depths exceeding 3000 m. Hebron is located on the eastern section of the Grand Banks, 9 km north of the Terra Nova Site, in approximately 95 m of water.

The Offshore Study Area encompasses the eastern portion of the Grand Banks from just north of the tail to the South at about 43°N, and north to 48°N, just south of the nose. The western portion extends in over the Grand Banks about 100 km to the west.

The Offshore Project Area is situated between the Hibernia, White Rose, and Terra Nova development areas, and encompasses the Hebron, West Ben Nevis, and Ben Nevis SDL in a region approximately 30 km (east-west) by 15 km (north-south) on the eastern edge of the Grand Banks near the 100 m bathymetry contour (see Figure 2-1. In this area the depth ranges from about 88m in the west to 102 m in the east (ExxonMobil Canada Properties, 2009).



Depths are in metres, scale 1:400,000.
Source: Canadian Hydrographic Services, 1995, Chart #404901. Approximate Hebron location has been annotated with a green square.

Figure 2-1 Offshore Project Area Bathymetry near Hebron (depths shown in metres)

2.1.1 Waves

Characterizations of normal and extreme wave conditions are available from three primary sources: the multi-year MSC50 wave hindcast, design criteria prepared for the Hebron Project, and wave measurements from nearby Grand Banks oil production sites. The MSC50 Grid Point M10834 is located at 46.6°N, 48.5°W, at a water depth of 93.4 m, approximately 5.7 km north of the Hebron site (see Figure 2-2). MSC50 hindcast model data were extracted for this Grid Point from which to derive the wave climate summary plots and statistics presented below.

Wave parameters in the MSC50 hindcast include significant wave height[2], Hs, and peak wave period[3], Tp. Monthly and annual wave height statistics are shown in Table 2-1. Table 2-2 presents a bivariate statistics table of annual wave height versus peak wave period. Mean Hs values range from 1.7 m in July to 3.9 m in December and January. The annual mean Hs is 2.8 m. Hs is greatest at 13.7 m in February and 13.5 m in December. During the summer the maximum Hs ranges from 6.2 m in July to 8.5 m in August and 10.8 m in September. In winter (December through February), Hs is less than 2 m for 7% of the time, is between 2 and 4 m for 55% of the time, and is greater than 6 m for 9% of the time. By contrast, in summer (June through August), Hs is less than 2 m for 71% of the time, is between 2 and 4 m for 27% of the time, and is greater than 6 m for 0.4% of the time. Annually, 49% of waves have a significant wave height between 2 and 4 m.

Monthly, seasonal, and annual wave roses for MSC50 Grid Point M10834 are presented in Figure 2-3 to Figure 2-5. During the summer, waves propagate most frequently to the northeast, for 55% of the time. In the fall, winds switch around to the northwest, and by winter, waves are now travelling to the northeast 28% of the time and to the the east through south-southeast 36% of the time (15% in summer). In spring, the pattern reverses and while southwest winds are still the most frequent, there is no strongly predominant wind direction: each of the 16 wind directions occur from about 4 to 12% of the time.

[2] wave height is the vertical distance from trough to crest of a wave. Significant wave height, commonly abbreviated as Hs, is a descriptive wave height measure defined as the average height of the highest one-third of the waves. Significant wave height can also be estimated from a measured or hindcast wave spectrum as $4\sqrt{mo}$, where mo is the variance of the wave spectrum. The MSC50 employs this latter definition for Hs,

[3] the period of waves with the most energy (i.e., 1/fp, where fp is the peak frequency of the wave spectrum)

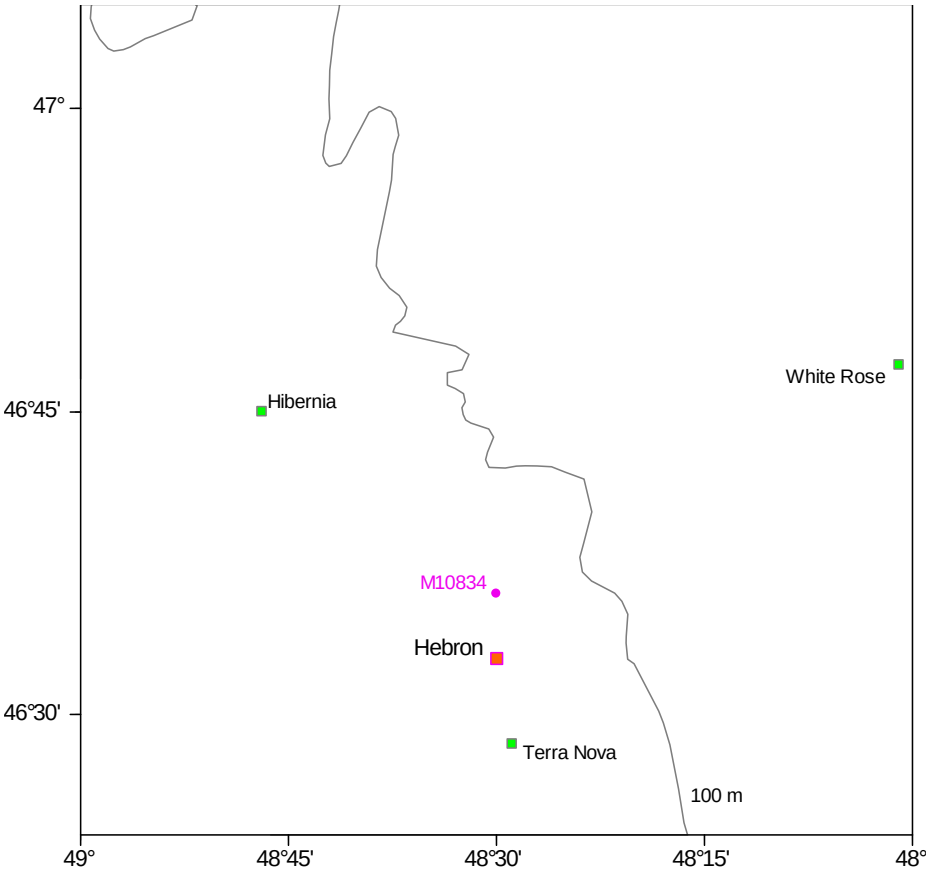


Figure 2-2 MSC50 Climatology Grid Point (M6010834) on the Grand Banks

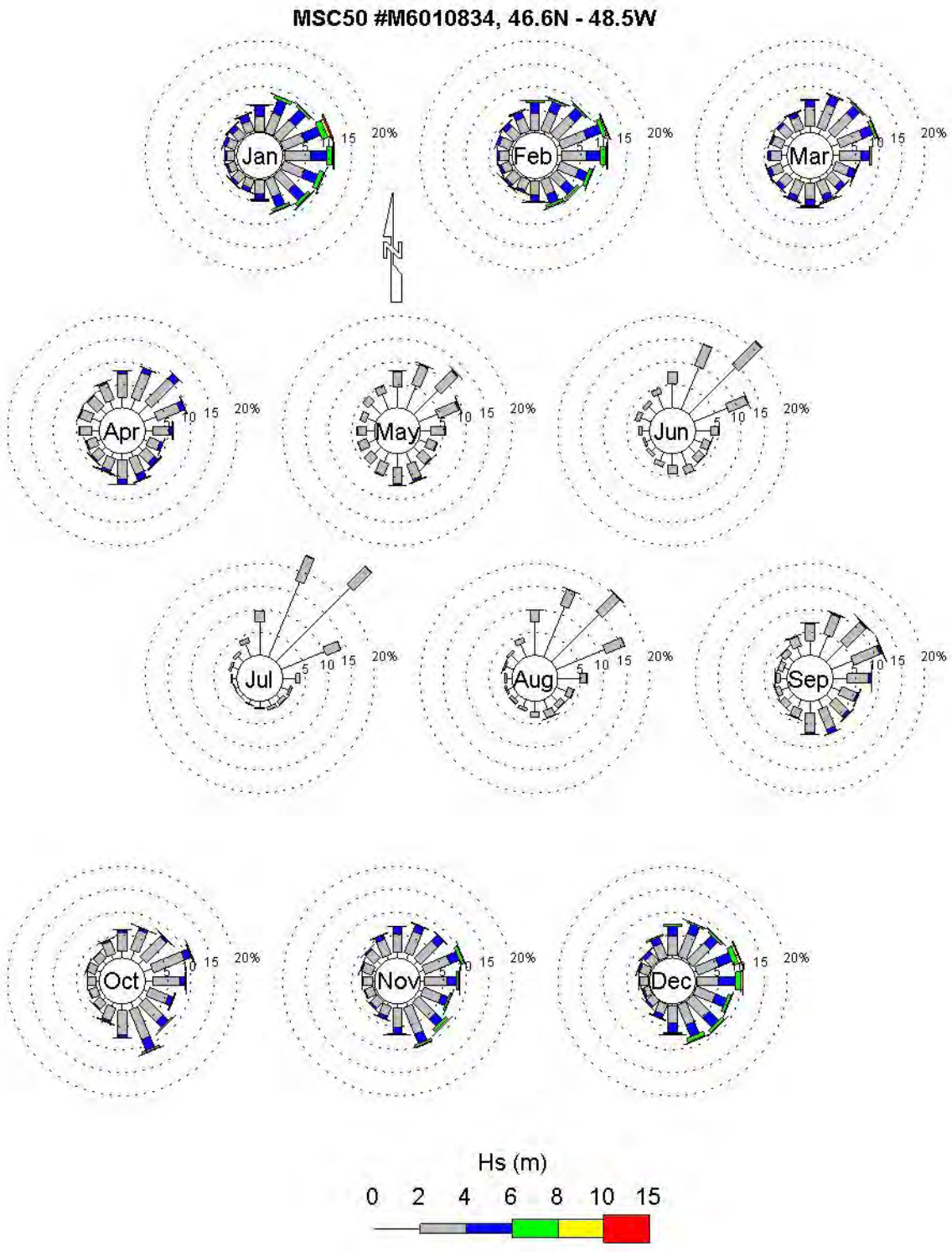


Figure 2-3 Monthly Frequency of Significant Wave Height Occurrence by Direction (to) for the MSC50 Gridpoint M6010834 near Hebron

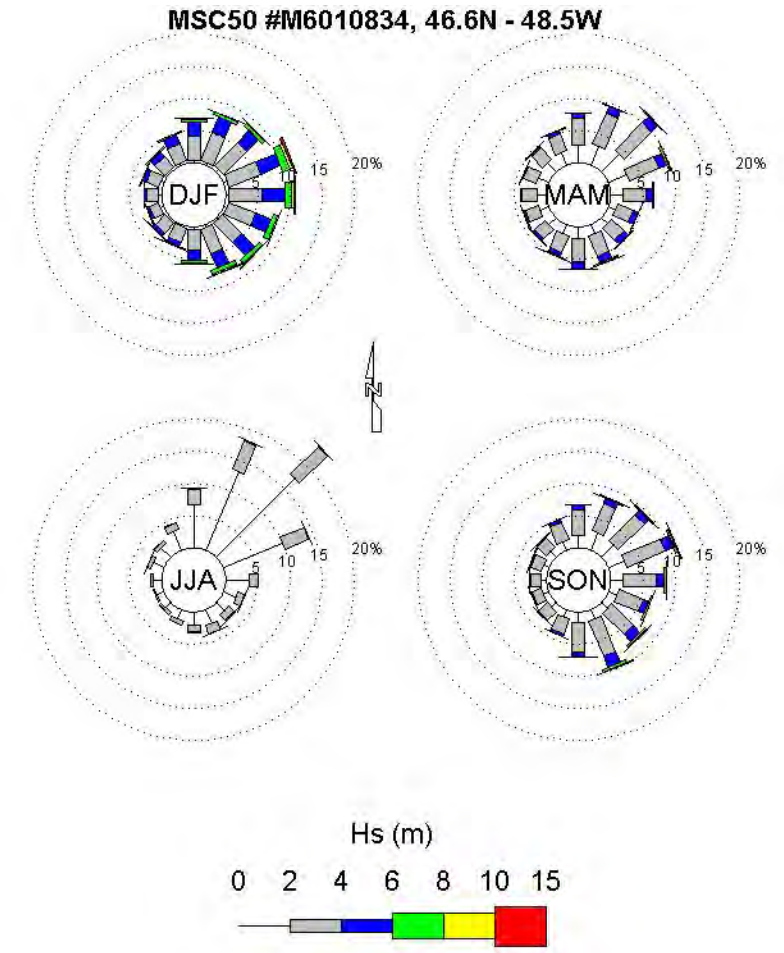


Figure 2-4 Seasonal Frequency of Significant Wave Height Occurrence by Direction (to) for the MSC50 Gridpoint M6010834 near Hebron

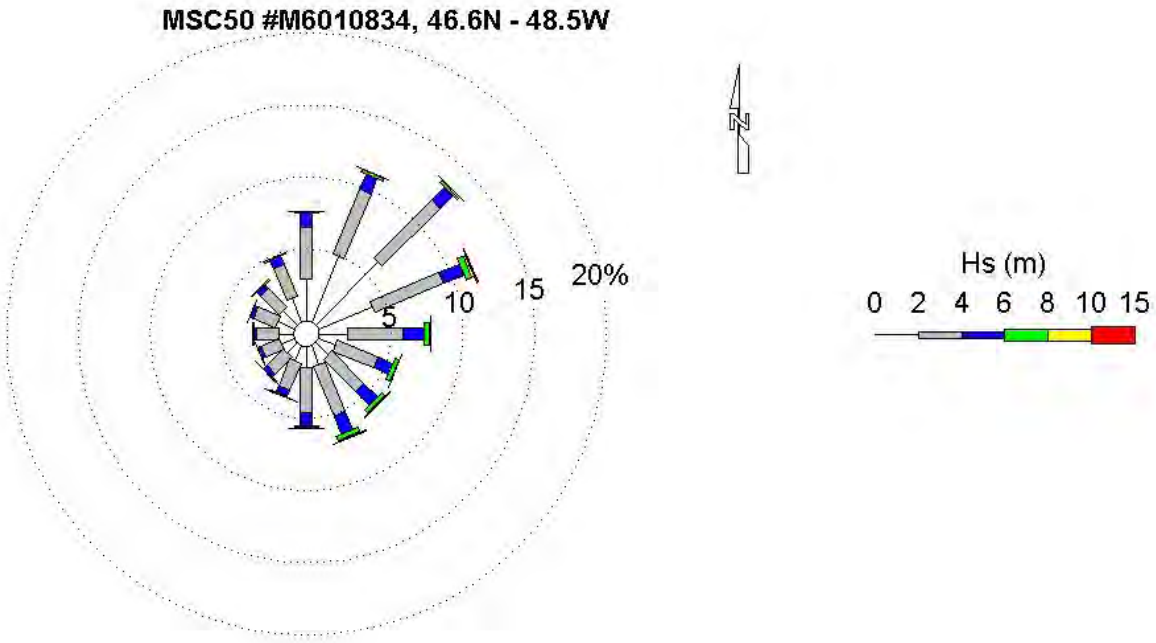


Figure 2-5 Annual Frequency of Significant Wave Height Occurrence by Direction (to) for the MSC50 Gridpoint M6010834 near Hebron

Table 2-1 Monthly and Annual Significant Wave Height and Peak Wave Period Statistics, from MSC50 Grid Point M10834 near Hebron

Month	Significant Wave Height (m)				Peak Wave Period (s)		
	Minimum[1]	Mean	Maximum	Most Frequent Direction (to)	Minimum[1]	Mean	Maximum
Jan	-	3.9	12.9	ENE	-	10.2	17.3
Feb	-	3.7	13.7	ENE	-	10.0	17.0
Mar	-	3.2	11.2	ENE	-	9.2	17.7
Apr	-	2.7	10.7	NE	-	9.0	17.1
May	-	2.2	9.9	NE	-	8.6	17.3
Jun	0.5	1.9	9.7	NE	3.4	7.9	14.4
Jul	0.6	1.7	6.2	NE	3.6	7.6	17.2
Aug	0.6	1.8	8.5	NE	3.6	7.7	16.1
Sep	0.7	2.4	10.8	ENE	3.6	8.9	17.3
Oct	0.9	2.9	11.8	SSE	3.7	9.4	17.6
Nov	0.6	3.3	11.2	ENE	3.7	9.8	16.0
Dec	1.1	3.9	13.5	ENE	4.2	10.3	16.0
Year	-	2.8	13.7	NE	-	9.0	17.7

Note: [1] historical minimum wave conditions in winter/spring are zero due to the possible presence of ice

Table 2-2 Annual Significant Wave Height vs. Peak Wave Period, from MSC50 Grid Point M10834 near Hebron

Peak Period (s)	Significant Wave Height (m)							
	0-2	2-4	4-6	6-8	8-10	10-14	Total	% Total
2-4	4950	0	0	0	0	0	4950	1.1
4-6	17563	2892	1	0	0	0	20456	4.5
6-8	62894	55559	875	0	0	0	119328	26.2
8-10	57420	86395	24925	325	0	0	169065	37.1
10-12	9561	60338	24795	7981	664	0	103339	22.7
12-14	2756	14021	9220	3068	2561	557	32183	7.1
14-16	433	2634	2452	403	108	290	6320	1.4
16-18	78	76	36	1	0	0	191	0.04
Total	155655	221915	62304	11778	3333	847	455832	100
% Exceed	65.9	17.2	3.5	0.9	0.2	0	0	0

ExxonMobil Upstream Research Company (URC) has prepared a Metocean Criteria for Hebron including operational[4] and extreme wave conditions based on the MSC50 hindcast at the same grid point M10834 (ExxonMobil Upstream Research Company 2009). In that work, the peaks-over-threshold approach was applied to fit storm peak wave values to a Weibull probability distribution from which long return value, or extreme, estimates could be made. The Hs values were first calibrated to Hibernia measurements.

Table 2-3 reports 95% and 99% upper limit, or non-exceedance, values, together with 1 to 100 year return period estimates. In addition to Hs, the table reports peak wave period, Tp, the maximum individual wave height, Hmax, calculated as 1.88 times Hs, the wave period associated with Hmax, THmax, and the associated wind speed. Further details of the data and methods employed to derive these values are provided by URC (ExxonMobil Upstream Research Company 2009). From these statistics, one may estimate that 5% of waves at Hebron have a significant wave height of 5.3 m or above, and corresponding maximum wave heights of 10 m or greater. For a 50-year return period, a significant wave height of 14.3 m and corresponding maximum individual wave height of 26.9 m could be expected.

[4] annual and monthly tables of wave height vs. wave direction, wave height vs. wave period, exceedance of wave height (monthly only), and wave roses

Table 2-3 Extreme Wave Statistics

Return Period	Hs (m)	Tp (s) (± 10% range)	Hmax (m)	THmax (s) (± 10% range)	1-h associated wind speed at 10 m (m/s)
95% upper limit	5.3	9.3 – 11.4	10.0	8.5 – 10.4	17.6
99% upper limit	7.8	10.7 – 13.0	14.7	9.7 – 11.8	21.7
1-year	10.5	12.1 – 14.8	19.7	11.0 – 13.5	26.2
5-year	12.2	13.1 – 16.0	22.9	11.9 – 14.6	29.0
10-year	12.9	13.5 – 16.5	24.3	12.3 – 15.0	30.1
25-year	13.7	13.9 – 17.0	25.8	12.6 – 15.5	31.4
50-year	14.3	14.2 – 17.4	26.9	12.9 – 15.8	32.4
100-year	14.8	14.5 – 17.7	27.8	13.2 – 16.1	33.2
Source: ExxonMobil Upstream Research Company 2009					

URC also provides directional scale factors for extreme waves. Due to the relatively shallow depths of the continental shelf and sloping bathymetry near Hebron long period waves feel the sea bottom with a resultant change in amplitude and direction. As a result, waves propagating to the south and west get reduced in amplitude whereas for other directions there is less effect. Table 2-4 presents directional factors: the extreme wave estimates may be scaled by the directional factor for consideration of waves propagating to a particular direction.

Table 2-4 Wave Height Directional Weighting Factors

Wave Direction (to)	S	SW	W	NW	N	NE	E	SE
Wave Height Scale Factor	0.95	0.75	0.70	0.70	0.90	1.0	0.95	0.95
Source: ExxonMobil Upstream Research Company 2009								

Physical monitoring data from offshore production activities on the Jeanne d'Arc Basin have been collected for more than 10 years. There are presently three oil-producing fields in the North Atlantic: Hibernia; Terra Nova; and White Rose (e.g., Figure 2-2). Water depths range from approximately 85 m at Hibernia to 95 m at Terra Nova to 120 m at White Rose. The Hebron Field is located in the Jeanne d'Arc Basin, approximately 9 km north of Terra Nova and approximately 35 km southeast of Hibernia.

Comparison of the monthly MSC50 hindcast statistics with the wave observations at Terra Nova (1999 to 2007) and White Rose (2003 to 2007) (AMEC Earth & Environmental 2003 to 2007; Fisheries and Oceans Canada 2009c) are presented in (Table 2-5, Table 2-6, Table 2-7, and Figure 2-6).

Table 2-5 Monthly and Annual Significant Wave Height and Peak Period Statistics at Terra Nova for 1999 to 2007

Month	Significant Wave Height (m)			Peak Wave Period (s)		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Jan	1.5	3.9	11.4	4.8	10.1	18.2
Feb	1.0	3.7	10.4	4.8	9.9	14.3
Mar	1.0	3.4	7.8	4.5	9.8	16.7
Apr	0.8	2.6	7.1	3.7	9.2	14.3
May	0.8	2.2	5.6	3.7	8.6	12.5
Jun	0.6	1.7	6.5	3.0	7.7	14.3
Jul	0.7	1.5	4.1	3.2	7.6	12.5
Aug	0.6	1.8	7.8	3.5	8.1	14.3
Sep	0.7	2.4	10.4	2.8	9.3	18.2
Oct	0.8	3.1	10.4	3.9	9.8	18.2
Nov	1.0	3.0	8.3	4.0	9.8	18.2
Dec	1.4	3.7	11.7	4.5	9.9	14.3
Year	0.6	2.8	11.7	2.8	9.3	18.2
Source: Fisheries and Oceans Canada 2009c						

Table 2-6 Annual Significant Wave Height vs. Peak Wave Period, from Terra Nova Observations

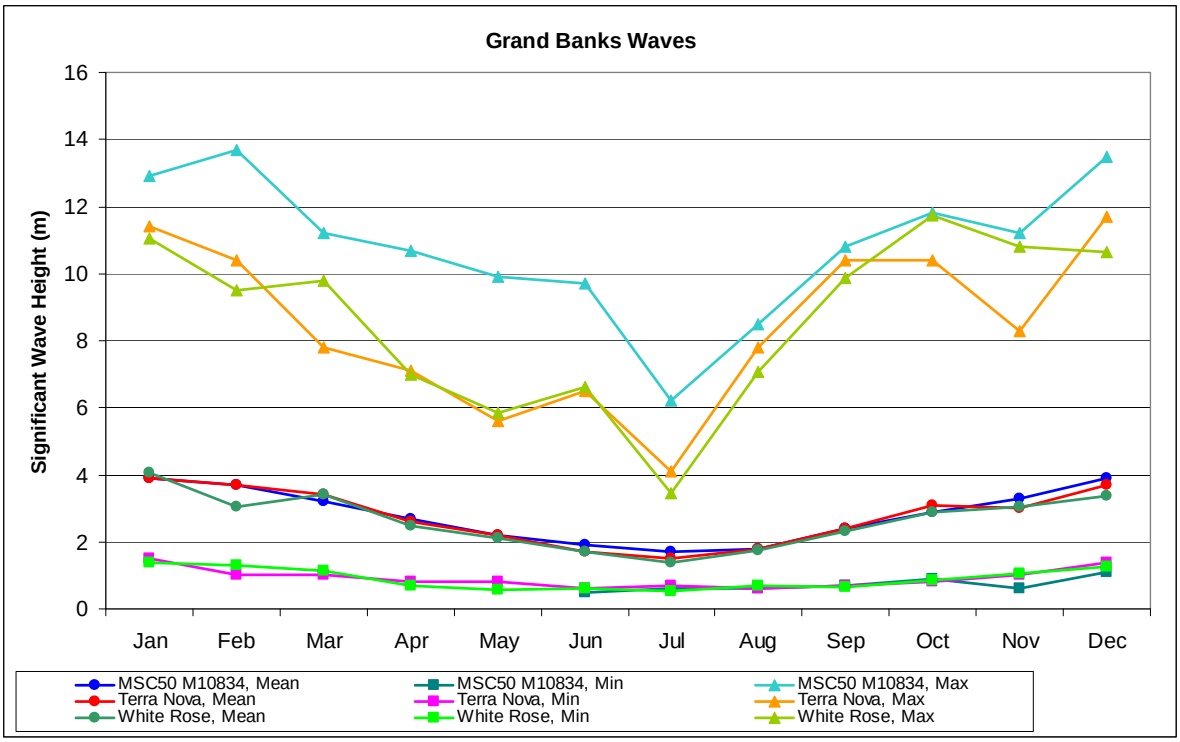
Peak Period (s)	Significant Wave Height (m)							
	0-2	2-4	4-6	6-8	8-10	10-12	Total	% Total
2-4	84	0	0	0	0	0	84	0.1
4-6	3073	859	0	0	0	0	3932	4.3
6-8	11074	8484	517	1	0	0	20076	21.9
8-10	12673	25953	6812	710	54	1	46203	50.3
10-12	1506	8554	3912	819	163	13	14967	16.3
12-14	287	2376	1475	203	52	7	4400	4.8
14-16	243	941	598	211	55	2	2050	2.2
16+	0	49	10	6	3	0	68	0.1
Total	28940	47216	13324	1950	327	23	91780	100
% Exceed	68.5	17.0	2.5	0.4	0.03	0	0	0
Source: Fisheries and Oceans Canada 2009c								

Table 2-7 Monthly and Annual Significant Wave Height and Peak Wave Period Statistics at White Rose for October 2003 to August 2007

Month	Significant Wave Height (m)			Peak Wave Period (s)[1]		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Jan	1.4	4.1	11.0	5.7	10.7	17.4
Feb	1.3	3.0	9.5	5.3	10.2	15.5
Mar	1.1	3.4	9.8	5.1	11.0	17.8
Apr	0.7	2.5	7.0	4.2	9.8	15.9
May	0.6	2.1	5.8	3.5	9.3	14.4
Jun	0.6	1.7	6.6	3.9	8.2	16.7
Jul	0.5	1.4	3.5	3.6	7.9	14.6
Aug	0.7	1.7	7.1	4.1	8.6	17.1
Sep	0.6	2.3	9.9	4.7	9.9	15.8
Oct	0.8	2.9	11.8	4.9	10.5	17.9
Nov	1.1	3.0	10.8	5.3	10.9	17.1
Dec	1.3	3.4	10.7	5.3	10.3	17.8
Year	0.5	2.6	11.8	3.5	9.7	17.8

Source: AMEC Earth & Environmental 2003 to 2007

[1] Tp5, TRIAXYS wave buoy peak period as computed by the Read method



Source: AMEC Earth & Environmental 2003 to 2007 (White Rose); Meteorological Service of Canada 2006; Fisheries and Oceans Canada 2009c (Terra Nova)

Figure 2-6 Comparison of Significant Wave Height Statistics between MSC50 grid point M6010834, White Rose, and Terra Nova Observations

2.1.2 Tsunamis

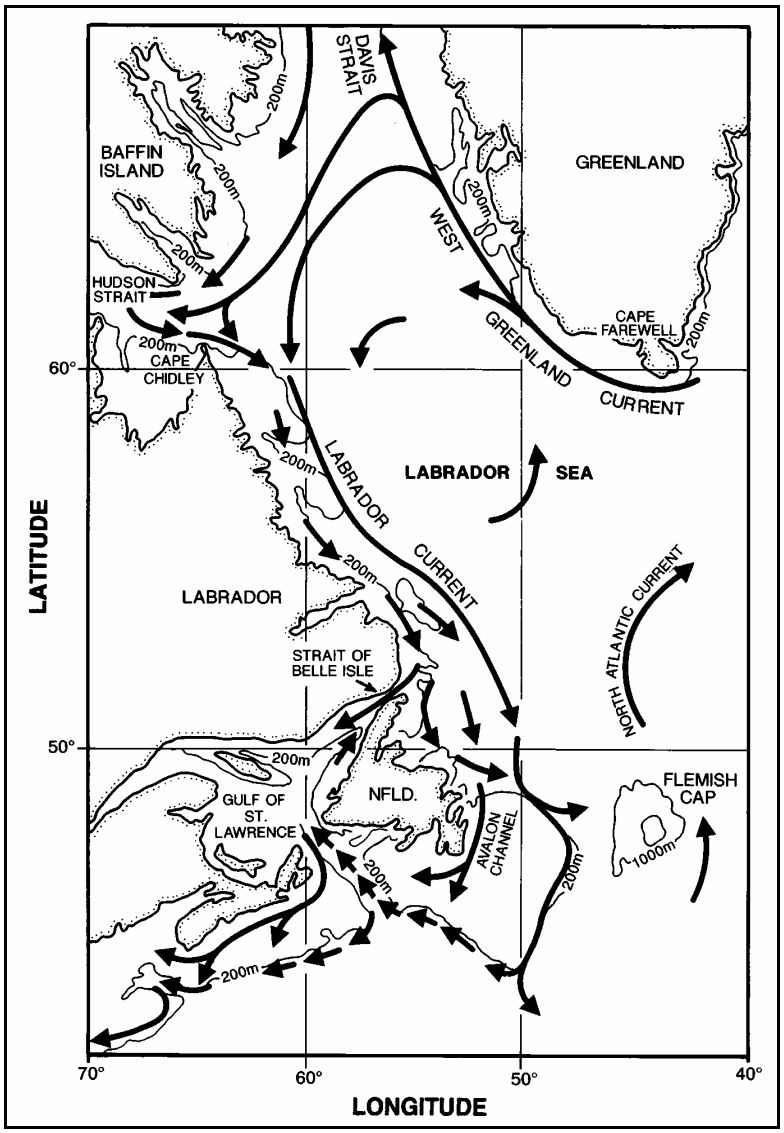
As described in the nearshore Section, Tsunamis are long-period gravity waves generated in a body of water by an impulsive disturbance that vertically displaces the water column. The most relevant far field sources effecting Newfoundland and the Grand Banks are the Azores-Gibraltar Ridge zone, the Mid-Atlantic Ridge and the north side of the Caribbean Arc. Tsunamis generated by other mechanisms generally originate from near-field sources such as the Laurentian Channel, the origin of the 1929 Grand Banks tsunami.

Over the open ocean, tsunamis generally have amplitudes below 1 m, wavelengths of 10 to 500 km and periods of five minutes to one hour. Being shallow water waves, tsunamis slow down when moving over shallower water such as the Grand Banks. As energy is conserved, shoaling leads to increased wave height; however, a rapid bathymetry change can lead to partial reflection of the wave energy and height (Fisheries and Oceans Canada, 2008).

While an unlikely event, an estimation of tsunami effect for the Hebron location can be obtained from the Physical Environmental Data report for Production Systems at [nearby] Terra Nova (Seaconsult Ltd., 1988). This study estimated a maximum theoretical tsunami amplitude of 2 m for Terra Nova, with expected amplitude of 0.7 to 1.2 m over a 100-year return period. Tsunami waves induce currents of nearly uniform speed from bottom to surface. The expected current speed is 35 cm/s over a 100-year return period, with maximum velocity of 70 cm/s for a 2 m tsunami wave (Seaconsult Ltd., 1988).

2.1.3 Currents

The general circulation on the Grand Banks is well understood based on geostrophic calculations, drifter data, current modelling and measurements. The dominant currents in the Northwestern Atlantic Ocean are the West Greenland, Baffin, Labrador and Nova Scotia currents. There are also two major deep basin currents, the warm Gulf Stream and the North Atlantic Current (Figure 2-7).



Source: adapted from Chapman and Beardsley, 1989.

Figure 2-7 General Circulation in the Northwest Atlantic Showing Major Current Systems

The Labrador Current is the major current that is closest to the eastern Grand Banks. The Labrador Current is divided into two streams: an inshore stream that flows along the coast and inside the Continental Slope; once it reaches the Grand Banks, it flows in the Avalon Channel along the coast or around the Banks, and may flow onto the Bank; and an offshore stream flows along the outer edge of the Banks, over the Continental Slope at water depths between 300 to 500 m and through the Flemish Pass. The flow in the offshore portion of the Labrador Current is stronger than the inshore portion. When it reaches Hamilton Bank, the inshore branch of the Labrador Current has average speeds of approximately 0.15 m/s, carrying approximately 15% of the total transport. The offshore Labrador Current (which remains bathymetrically trapped at the edge of the Continental Shelf) has average speeds of approximately 0.40 m/s, carrying approximately 85% of the total transport, mainly between the 400 and 1200 m isobaths (Lazier and Wright 1993).

Mean currents are generally weak (< 10 cm/s) and flowing southward, dominated by wind-induced and tidal current variability over those areas of the Grand Banks with water depths less than 100 m (Seaconsult, Ltd. 1988).

Specific characterizations of ocean current conditions are available from three primary sources: an archive database of Grand Banks current measurements which provides a regional picture, and for the Hebron location, current measurements from a Hebron exploration well drilled in 1999 and from the nearby Terra Nova location, and design criteria prepared for the Hebron Project.

Current statistics for all current meter data on the Grand Banks from the Bedford Institute of Oceanography (BIO) prior to 1996 are presented in Gregory *et al.* (1996) and these provide a good representation of the regional current regime. The current measurements were grouped into three water depths ranges: near-surface (<30 m); mid-depth (30 to 80 m); and near-bottom (>80 m). Maps of the mean annual and seasonal averages of current speed and direction for the Grand Banks are provided in Appendix 5. A seasonal summary of mean current speed and directions is presented in Table 2-8.

Table 2-8 Grand Banks Mean Currents

Water Depth	Winter	Spring	Summer	Fall
Surface 0 to 30 m	~0.10 m/s to the SE	<0.10 m/s to the SE or SW	~0.10 m/s to the SSE	0.10 to 0.20 m/s to the SE
Mid Depth 30 to 80 m	~0.15 m/s to the SSW	~0.10 m/s to the SSW	<0.10 m/s to the S	~0.10 m/s to the S
Deep 80 to bottom	0.05 to 0.10 m/s to the SE-SW	~0.05 to the E	~0.05 to the S	0.05 to 0.10 m/s to the S
Source: based on review of Gregory *et al.* 1996				

Gregory et al. (1996) also present monthly mean and maximum statistics for all months and all depths. From a review of the region 46°N and 47°N and 48°W and 49°W, which encompasses Hibernia, White Rose, Terra Nova, and Hebron, the largest mean and maximum currents and associated depths could be determined. The largest near-surface current speeds reached 0.25 m/s, with an associated maximum speed of 0.96 m/s in September at a depth of 18 m. At mid-depth, the largest mean currents reached 0.15 m/s in February (at 45 m) and the maximum speed was 0.96 m/s in December (at 47 m). Near-bottom, the mean current speed reached a maximum of 0.06 m/s in May and October at 101 and 98 m, respectively, and a maximum speed of 0.70 m/s was observed in November at 98 m. The strongest surface and mid-depth currents occur in the fall to winter: the strongest currents near-bottom occur in the spring and fall.

There are presently three oil-producing fields in the North Atlantic: Hibernia; Terra Nova; and White Rose (Figure 2-2). The Hebron Field is located in the Jeanne d'Arc

Basin, approximately 10 km north of Terra Nova and approximately 35 km southeast of Hibernia. Water depths range from approximately 85 m at Hibernia to 95 m at Terra Nova to 120 m at White Rose.

Current statistics for current meter data collected at Hebron by Oceans Ltd. from January 6 to April 23, 1999, are presented in Table 2-9 (Oceans Ltd. 1999). The maximum currents speeds are lower than those from the BIO data report (Gregory *et al.* 1996); however, summer and fall are not included in the Oceans Ltd. data, which is when the maximum speeds were measured in the BIO data. The mean speeds at mid and bottom depths are high compared to the BIO data.

Table 2-9 Currents Measured at the Hebron Site from January 6 to April 23, 1999

Instrument Depth	20 m	45 m	84 m
Period of record (1999)	Jan 6 to Feb 20	Jan 6 to Apr 23	Jan 6 to Apr 23
Location	46°35'00"N 48°29'56"N	46°34'54"N 48°29'58"N	46°34'54"N 48°29'58"N
Water Depth (m)	94	94	94
Mean Speed (m/s)	0.156	0.182	0.116
Maximum Speed (m/s)	0.503	0.537	0.320
Source: Oceans Ltd. 1999			

Extreme and operational[5] design criteria for currents for the Hebron Project are presented in the Hebron Metocean Criteria (ExxonMobil Upstream Research Company 2009). The data used to establish the criteria were taken from 10 years of current measurements at Terra Nova (July 1999 to October 2008). The measurements are 20-minute values and for three water depth bins near-surface (16-24 m); mid-depth (47-52 m); and near-bottom (84-89 m). Maximum values measured from the 10-year Terra Nova record are 0.94, 0.74, and 0.48 m/s for near-surface, mid-depth, and near-bottom respectively. Both annual and seasonal extremes were estimated. Table 2-10 presents annual non-exceedance levels or percent limits for current speeds at the three depths, e.g., near-surface speeds are 0.19 cm/s or less for 75% of the time.

Table 2-10 Extreme Current Speed Statistics

Statistic	Near-surface (m/s)	Mid-depth (m/s)	Near-bottom (m/s)
50% upper limit	0.13	0.09	0.09
75% upper limit	0.19	0.13	0.14
90% upper limit	0.26	0.19	0.18
95% upper limit	0.32	0.22	0.21
99% upper limit	0.44	0.32	0.28
Source: ExxonMobil Upstream Research Company 2009			

[5] annual and monthly tables of current speed vs. direction (near-surface, mid-depth, and near-bottom)

Annual and seasonal 1- to 100-year return period current speed estimates are presented in Table 2-11, together with Terra Nova current extreme estimates. Two seasons were selected by URC: a 'spring/summer' season during which the ocean is stratified due to solar heating of the surface and storm activity is reduced; and a 'fall/winter' season when due to the increased frequency and intensity of storms, the summer stratification is broken down and there is a much more uniform current response from the surface to the bottom. These seasons are considered to be from August to October (summer/spring) and from November to July (fall/winter) for the near-surface and correspondingly April to August, and September to March for mid-depth and near-bottom. The strongest near-surface current is in summer, while the strongest mid-depth and bottom currents occur in winter. For a 50-year return period, annual extreme current speeds of 1.01, 0.73, and 0.63 m/s for near-surface, mid-depth, and near-bottom respectively could be expected. These values are generally comparable to the maximum current speeds reported by Gregory *et al.* 1996 and noted above, although the mid-depth current there of 0.96 cm/s is larger than the 0.63 m/s 50-year estimate for Hebron.

Table 2-11 Extreme Current Speeds for 1 to 100 Year Return Periods for Hebron and Terra Nova

	Current Speed (m/s) (and direction towards) Return Period (Years)				
HEBRON [A]					
	Depth (m)	1	10	50	100
Surface *(Annual and Aug-Oct)*	20	0.64 (SW, W, NW)	0.91	1.01	1.16
Mid *(Annual and Sep-Mar)*	50	0.46 (SW)	0.66	0.73	0.79
Bottom *(Annual and Sep-Mar)*	85	0.42 (S)	0.55	0.63	0.66
Surface *(Nov-Jul)*	20	0.64 (SE)	0.91	1.01	0.7
Mid *(Apr-Aug)*	50	0.51 (N, NW)	0.56	0.6	0.62
Bottom *(Apr-Aug)*	85	0.46 (N,E,SW)	0.51	0.54	0.55
TERRA NOVA [B]					
Annual	Depth (m)	1	10	50	100
Surface	20	0.75 (W)	0.79	-	0.96
Mid	45	0.76 (SW)	0.87	-	0.99
Bottom	70	0.61 (SE)	0.74	-	0.87

Source:
[A] ExxonMobil Upstream Research Company 2009
[B] Petro-Canada et al., Terra Nova EIS, Table 3.2-7, p. 3-79.

An additional source of current information is the Canada-Newfoundland Operational Ocean Forecasting System (C-NOOFS), a pilot project operational ocean weather forecasting system for Canada (C-NOOFS, 2009). The ocean model runs on a daily basis, with wind forcing from the Environment Canada Canadian Meteorological Service GEM global wind prediction system that is run every 12 hours. The ocean model domain covers the Northwest Atlantic and Gulf of St. Lawrence at approximately 20 km resolution. Ocean surface current, wind, and sea temperature forecasts are available.

2.1.4 Tides and Storm Surges

From time-series of hourly water level measurement at Hibernia Drill Site 1 from April 20 to June 1, 1980. at 46.73°N; 48.82°W and Hibernia Drill Site 2 from July 27 to October 5, 1980 at 46.57°N; 48.73°W, two locations near Hibernia, the highest water level measured from the zero mark were 1 and 1.04 m, respectively (Fisheries and Oceans Canada, 2009a).

The report by Seaconsult, Ltd. (1988) summarizes tidal data from a study in December 1983 to April 1984 at 46°46.0'N and 48°50.9'W. The maximum tidal amplitude above the mean water level was 0.53 m and the minimum tidal amplitude below the mean water level was -0.51, resulting in a total range of 1.04 m. The report by Seaconsult, Ltd. (1988) also determined the storm surge for Terra Nova (Table 2-12).

Table 2-12 Extreme Storm Surge and Tide Levels at Terra Nova

Return Period (years)	Surge Levels (cm)			Tide Levels (cm)
	Mean Water Level above/below	Expected	95% Upper Limit	
1	above	50	64	53
	below	54	69	51
10	above	61	75	53
	below	66	81	51
25	above	66	79	53
	below	71	85	51
50	above	70	83	53
	below	75	89	51
100	above	73	86	53
	below	79	92	51

Source: Seaconsult, Ltd. 1988.

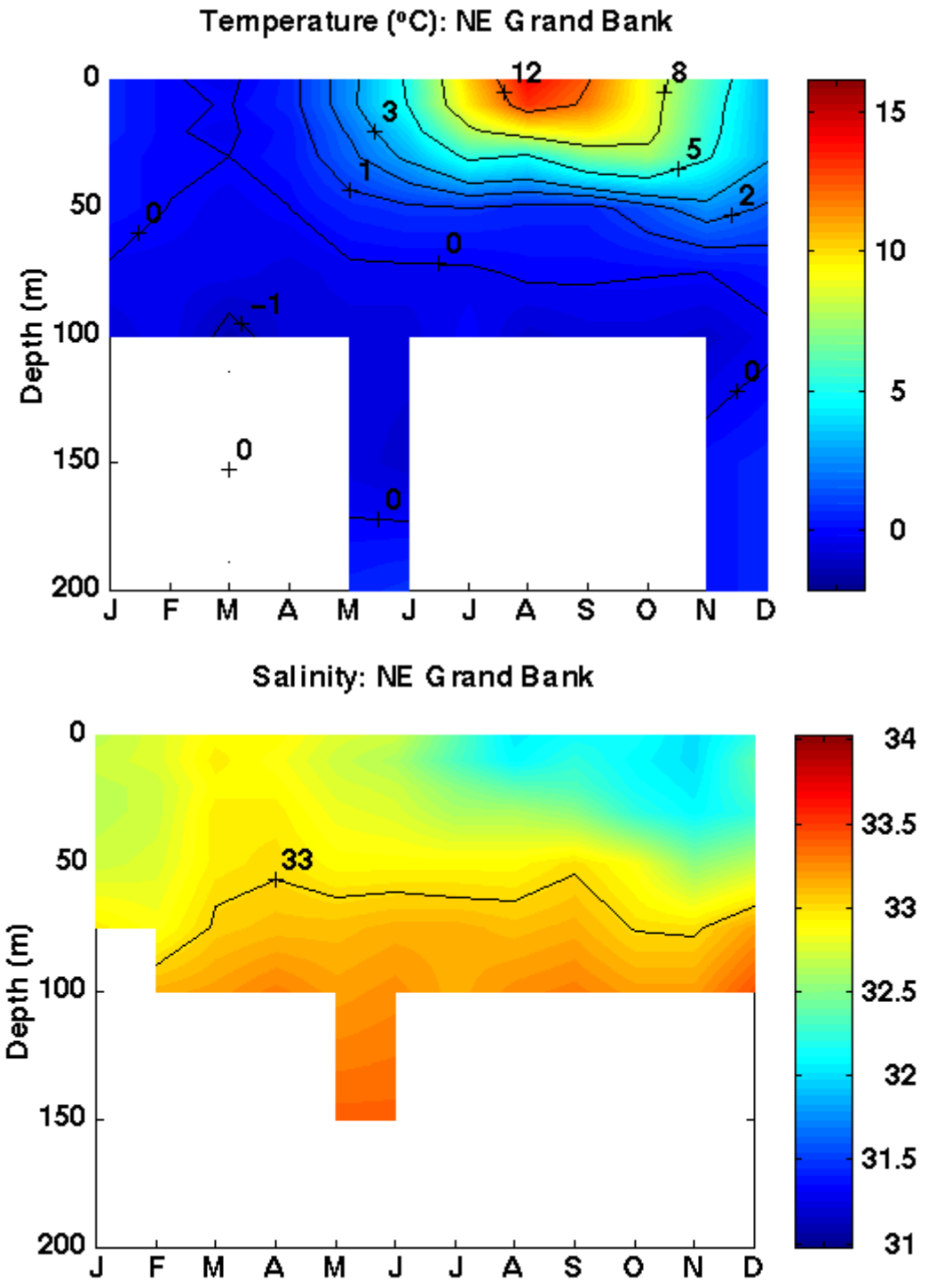
The Hebron Design Criteria prepared by URC estimates a maximum storm surge of 0.8 m, spring and neap tidal amplitudes of 0.5 and 0.3 m respectively, and a tidal amplitude of 1 m (ExxonMobil Upstream Research Company 2009). These estimates are in keeping with the Terra Nova values.

2.1.5 Physical and Chemical Properties

Sea temperature and salinity distributions are available from the Ocean and Ecosystem Science (OES) Branch (Fisheries and Oceans Canada, 2007). Hebron falls within the Hydrographic Database Subarea 46 for the Newfoundland Shelf. A monthly vertical

section for temperature and salinity is shown Figure 2-8; temperature and salinity statistics are presented in Table 2-13. Seasonal maps of surface and bottom temperature and salinity for the entire Hebron project area are shown in Figure 2-9 to Figure 2-12.

Records show a two-layer stratified system in summer and one homogeneous layer through fall and winter. The stratification degrades by October to one homogeneous layer, which is colder and saltier than the conditions in the summer. In summer, a surface layer develops down to approximately 50 m, with average temperatures reaching between 12˚C and 14°C and average salinities between 32 and 32.5 psu. In fall, average temperatures range from 8.9°C at the surface to -0.6°C near the bottom and average salinities range from 32 psu at the surface to 33.4 psu at 50 m. In the lower layer, below 60 m, average temperatures range between -1.38˚C and 1°C and average salinities between 32.66 and 33.25 psu throughout the year. In winter, temperatures range from 0.57°C at the surface to -1.38°C near bottom. This is consistent with the data presented in the *Drill Cuttings Deposition, and Produced Water and Storage Displacement Water Dispersion Modelling Study* (AMEC, 2010) which summarized temperature, salinity and density data obtained from the Fisheries and Oceans hydrographic database for the Hebron region. The results are reproduced here in Appendix 4.



Source: Fisheries and Oceans Canada, 2007 (Subarea 46).

Figure 2-8 Contours of Temperature and Salinity for North-Eastern Grand Banks

Table 2-13 Temperature and Salinity Statistics for North-Eastern Grand Banks

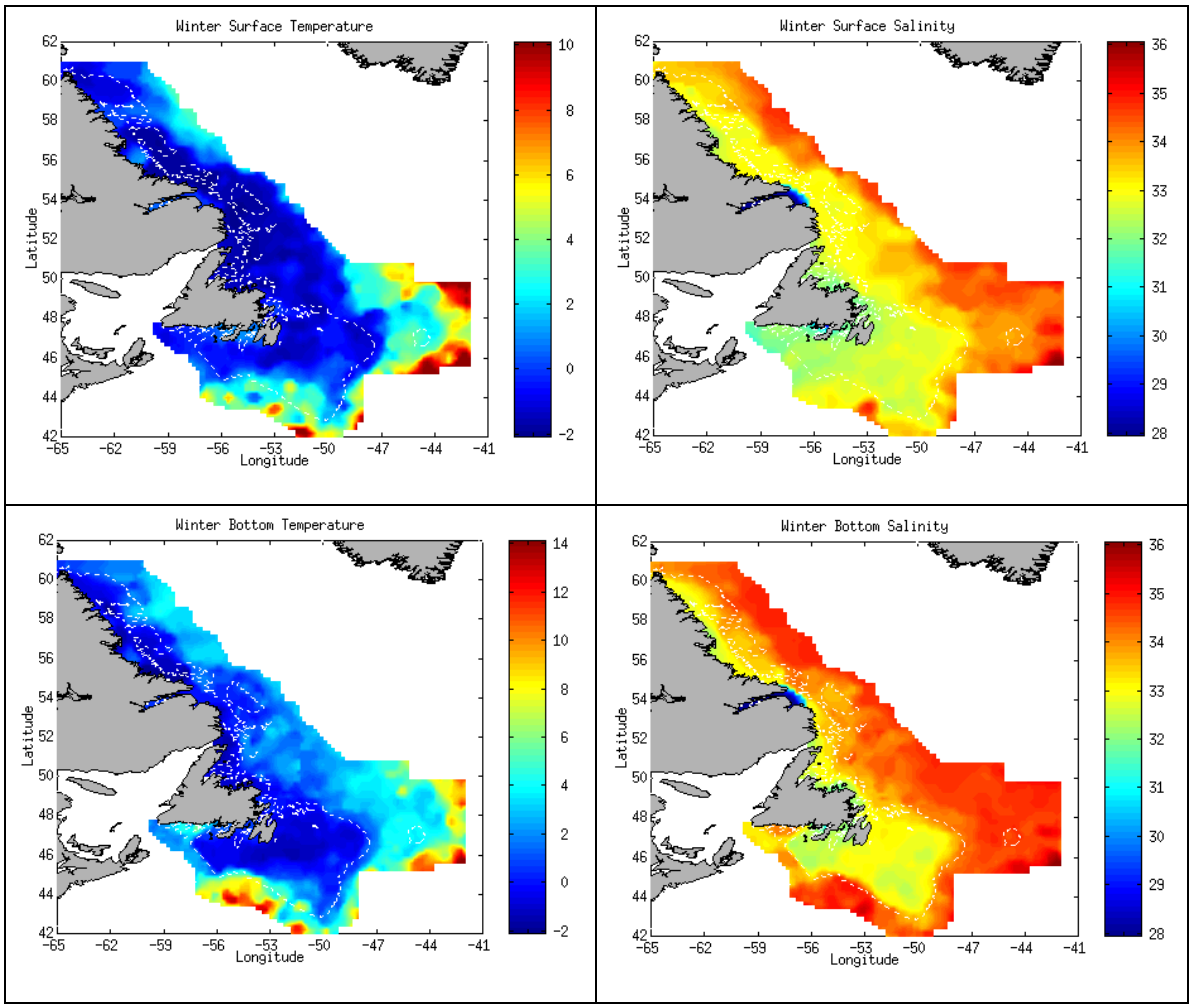
	Temperature (°C)			Salinity (psu)		
Depth (m)	Mean	Std Dev	Total Count	Mean	Std Dev	Total Count
January						
0	0.57	0.64	164	32.66	0.28	25
20	0.56	0.66	134	32.66	0.3	13
50	0.43	0.53	125	32.7	0.3	13
100	-0.57	0.67	13			
200						
February						
0	0.05	0.38	240	32.78	0.23	13
20	0.04	0.42	146	32.7	0.2	8
50	-0.02	0.43	151	32.77	0.23	10
100	-0.07	0.51	15	33.12		2
200						
March						
0	-0.14	0.91	141	32.89	0.17	58
20	-0.11	0.95	176	32.91	0.16	104
50	-0.23	0.88	157	32.96	0.18	94
100	-1.38	0.26	17	33.2		9
200	1.31		1			
April						
0	0.65	0.84	515	32.89	0.21	239
20	0.49	0.79	495	32.91	0.23	282
50	-0.01	0.68	698	32.97	0.21	377
100	-0.42	0.4	29	33.25	0.28	18
200	0.65	0.84	515			
May						
0	2.58	1.39	1145	32.77	0.24	387
20	2.1	1.24	1491	32.78	0.22	454
50	0.61	0.72	1509	32.92	0.18	550
100	-0.44	0.65	107	33.19	0.17	23
200	0.66	0.45	8			
June						
0	5.25	1.72	682	32.7	0.27	270
20	4.16	1.46	969	32.72	0.24	240
50	0.86	0.99	804	32.91	0.19	287
100	-0.36	0.62	52	33.21	0.15	15
200	0.92		1	33.72		1
July						
0	10.22	1.96	512	32.36	0.31	213
20	7.64	1.83	1423	32.53	0.24	290
50	1	1.08	664	32.88	0.16	296
100	-0.03	0.83	79	33.14	0.17	21
200						

Source: Fisheries and Oceans Canada, 2007 (Subarea 46).

Table 2-14 Temperature and Salinity Statistics for North-Eastern Grand Banks (continued)

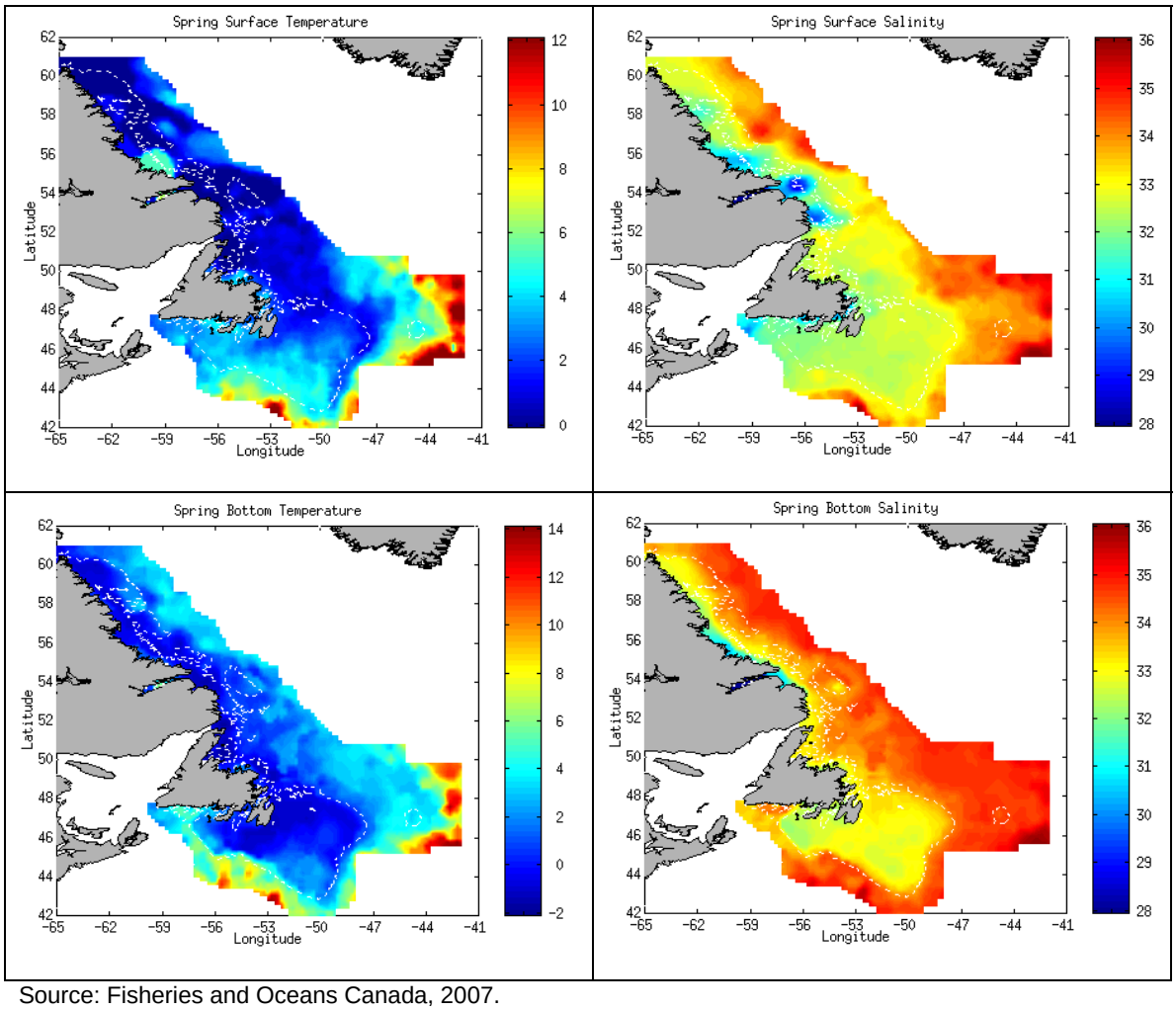
Depth (m)	Temperature (°C)			Salinity (psu)		
	Mean	Std Dev	Total Count	Mean	Std Dev	Total Count
August						
0	13.84	1.89	480	32.07	0.41	49
20	9.14	2.45	2088	32.37	0.27	132
50	0.68	1.12	645	32.9	0.16	105
100	-0.61	0.77	49	33.23	0.16	7
200						
September						
0	12.07	1.8	353	32.17	0.28	75
20	9.63	2.58	598	32.35	0.32	131
50	0.59	1.44	396	32.98	0.16	165
100	-0.41	1.09	32	33.27	0.07	9
200						
October						
0	8.91	1.82	374	32.13	0.17	77
20	8.55	2.25	441	32.14	0.16	189
50	1.59	1.59	1208	32.87	0.24	415
100	-0.55	0.57	34	33.19		1
200						
November						
0	6.08	1.61	568	32	0.17	109
20	5.55	1.5	471	32.04	0.13	78
50	2.63	1.37	1397	32.52	0.25	160
100	-0.61	0.5	70	33.17	0.12	6
200	0.47	3	0.61			
December						
0				32.24	0.22	22
20				32.35	0.11	14
50				32.66	0.22	44
100				33.41	0.07	7
200	0.33	3				

Source: Fisheries and Oceans Canada, 2007 (Subarea 46).



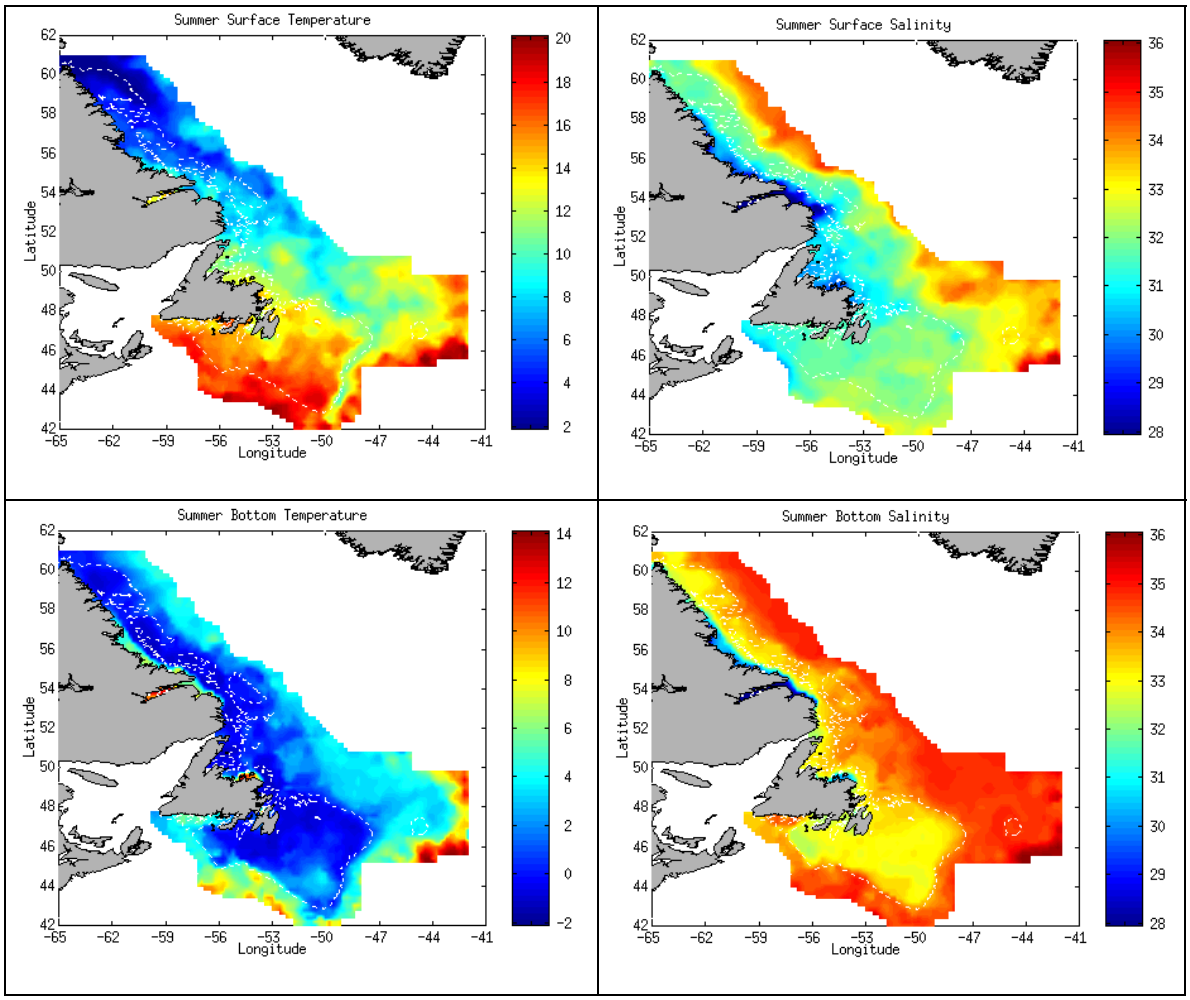
Source: Fisheries and Oceans Canada, 2007.

Figure 2-9 Winter Surface and Bottom Temperature and Salinity Contour Plots for North-Eastern Grand Banks



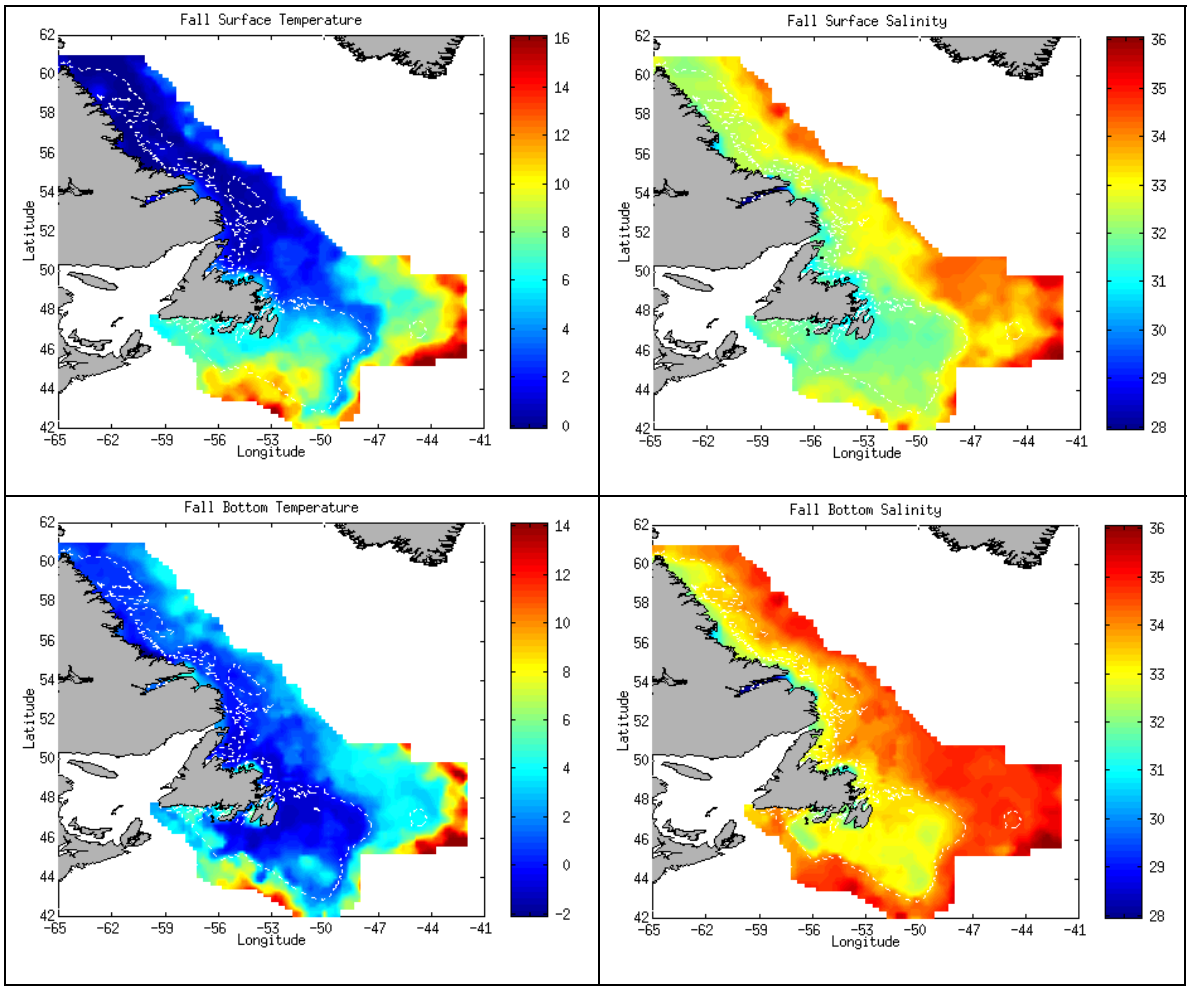
Source: Fisheries and Oceans Canada, 2007.

Figure 2-10 Spring Surface Temperature and Salinity Contour Plots for North-Eastern Grand Banks



Source: Fisheries and Oceans Canada, 2007.

Figure 2-11 Summer Surface Temperature and Salinity Contour Plots for North-Eastern Grand Banks



Source: Fisheries and Oceans Canada, 2007.

Figure 2-12 Fall Surface Temperature and Salinity Contour Plots for North-Eastern Grand Banks

2.1.6 Climate Change

Sea-Level Rise

It is generally accepted that global sea-level will rise in a warming world. This section discusses some of the literature on the subject and what effects there might be on the Grand Banks.

Kolker and Hameed (2007) examined meteorological drivers of the long-term trends in global sea level rise. They found that atmospheric indices like the North Atlantic Oscillation (NAO) explain a major fraction of the variability and trend at five Atlantic Ocean tide gauges since 1900. They state that "Debate has centered on the relative contribution of fresh water fluxes, thermal expansion and anomalies in Earth's rotation". They also note that variability in local mean sea level from year-to-year is one or two orders of magnitude greater than the long-term trend, with the cause of the variability

unknown. When they subtracted out factors such as the NOA from their analysis of the long-term rise, they found that the "residual" sea level rise was between 0.49+-0.25 mm per year, and 0.93+-0.39 mm per year. This residual rise could be due to rising global temperatures.

In 2007, the Intergovernmental Panel on Climate Control (IPCC) noted that "[G]lobal average sea level rose at an average rate of 1.8 [1.3 to 2.3] mm per year over 1961 to 2003. The rate was faster over 1993 to 2003: about 3.1 [2.4 to 3.8] mm per year. Whether the faster rate for 1993 to 2003 reflects decadal variability or an increase in the longer-term trend is unclear." The IPCC is predicting a worldwide increase of 18 to 58 cm by 2100.

A study by Aixue Hu from NCAR and Gerald Meehl in *Geophysical Research Letters* found that moderate to high rates of ice melt from Greenland could cause sea levels off the northeast coast of North America to rise by 30 to 51 cm more than other coastal areas. They also found that oceans will not rise uniformly as the world warms, since ocean dynamics would push water in different directions.

Scientists are generally cautious about predictions, in part because ice sheet dynamics are complex and not well understood. In addition, some studies indicate that global warming is not the dominant signal, but that most of the inter-annual variability could be due to long-term atmospheric states like the NAO. From the studies above, estimates of the rise globally over the next 50 years due to global warming alone are from 2.5 cm to as much as 15 cm. There has been an underlying trend upward over the last century, and this is expected to continue.

Waves

Waves are perhaps the most significant marine variable of interest to look at when examining climate change effects on the Grand Banks. A study by Wang and Swail (2001) looked at trends in extreme significant wave heights based on a 40-year hindcast. They found statistically significant trends only in the winter months, and these were found to be connected with the NAO. If the period of study is extended back 100 years, no significant trends were found. A later study by Swail *et al.* (2004) extended their results to an examination of wave heights in the North Atlantic under accepted climate change scenarios. They found that very significant increases in wave height were expected in the northeast North Atlantic (closer to Europe), but that negligible or negative increases were found in the vicinity of the Grand Banks.

Perrie *et al.* (2004) used high resolution modelling on a current data set of winter storms, and then produced simulations of storms based on a climate change scenario for the period 2041 to 2060. They found that while there were fewer total storms in the climate change scenario, there were more numerous strong storms with larger waves, and fewer weaker storms with associated lower wave heights (Perrie *et al.*, 2004). Another study by Lambert (2004) had very similar findings. While it did not explicitly examine wave heights, it found that while there were fewer cyclones in a warmer world, there were an

increased number of intense events. One could infer from this that there would also be associated higher significant wave heights. These results make sense, in that a warmer world would mean a decreased pole-equator temperature gradient, and less total energy available for storms. However, it is not clear what might be driving greater intensity of storms. One possibility would be more frequent tropical storms, since presumably there would be a larger pool of warm water available to support tropical systems.

It should be noted that the Grand Banks would be more susceptible to tropical storms in a warmer climate. Typically storms die out when hitting colder ocean water south of Nova Scotia. In a warmer climate, they would be able to maintain intensity farther northward, and would likely be more intense on average as they track over the Grand Banks. This would suggest higher associated peak wave heights. Since the tropical cyclone season lasts from June until November, with a peak in August and September, one would expect to see an increase in peak wave heights during the summer months and also in late fall.

Sea Surface Temperatures

It is generally accepted that sea surface temperatures will increase by 1°C to 2°C over the next several decades if global warming continues. However, this could be negated to some extent over the Grand Banks, since the Labrador Current flows through the area. With increased glacial melt from Greenland, the Labrador Current would tend to maintain an abundant flow of cold water into the region.

Summary

In general, the science is inclusive about what marine effects will be felt over the Grand Banks due to global warming. Climate simulations for the next century show almost no change in peak significant wave heights for the western North Atlantic, consistent with recent trends in observed data. Other studies show fewer storms in general, but more numerous strong storms with attendant increased peak significant wave heights. In a warmer world, more tropical storms can be expected to survive farther north, bringing with them higher waves during the tropical storm season. For sea level rise, there is good agreement that sea levels will continue to rise, but disagreement as to how much. Estimates range from less than 5 cm over the next 50 years to as much as 15 cm. Finally, there is considerable uncertainly as to the question of warming sea surface temperatures, since glacial melt north of Newfoundland would exert a cooling influence on the offshore waters.

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Appendix 1 Temperature and Salinity Statistics, Bull Arm

Depth (m)	Temperature (°C)					Salinity (psu)				
	Min	Max	Mean	Std Dev	Total Count	Min	Max	Mean	Std Dev	Total Count
January										
0	0.42	1.73	1.05	0.49	8	31.51	31.97	31.75	0.16	8
5	-0.42	2.34	1.15	0.85	14	31.68	32.24	31.96	0.17	11
10	0.67	2.37	1.39	0.60	11	31.72	32.24	31.99	0.18	8
15	-0.26	2.59	1.31	0.79	11	31.86	32.24	32.05	0.13	8
20	-0.38	2.57	1.20	0.85	13	31.61	32.26	32.01	0.19	10
30	-0.26	2.37	1.13	0.75	15	31.73	32.28	32.02	0.18	12
40	0.04	2.22	1.22	0.59	17	31.52	32.32	32.00	0.27	14
50	0.38	2.01	1.26	0.52	18	31.76	32.33	32.07	0.22	15
60	0.44	2.33	1.25	0.57	18	31.93	32.46	32.20	0.17	15
70	0.40	2.18	1.14	0.58	14	32.01	32.50	32.30	0.16	12
80	0.16	2.07	1.05	0.59	15	32.07	32.55	32.35	0.16	13
90	0.08	1.90	1.00	0.58	14	32.11	32.56	32.41	0.14	12
100	-0.05	1.22	0.96	0.42	8	32.20	32.59	32.46	0.14	6
120	0.62	1.15	0.87	0.21	7	32.48	32.58	32.54	0.04	6
140	0.29	0.76	0.50	0.21	5	32.58	32.62	32.60	0.02	4
160	-0.27	0.43	0.14	0.36	3	32.58	32.75	32.66	0.09	3
180	0.28	0.28	0.28	0.00	1	32.86	32.86	32.86	0.00	1
200	-0.32	-0.32	-0.32	0.00	1	33.07	33.07	33.07	0.00	1
February - No Data										
March										
0	0.00	0.71	0.23	0.33	4	31.67	31.67	31.67	0.00	1
5	-	-	-	-	-	-	-	-	-	-
10	0.69	0.69	0.69	0.00	1	31.65	31.65	31.65	0.00	1
15	-	-	-	-	-	-	-	-	-	-
20	0.70	0.70	0.70	0.00	1	31.69	31.69	31.69	0.00	1
30	0.80	0.80	0.80	0.00	1	31.69	31.69	31.69	0.00	1
40	-0.60	0.00	-0.35	0.31	3	-	-	-	-	-
50	-0.50	0.26	-0.12	0.54	2	31.89	31.89	31.89	0.00	1
60	-	-	-	-	-	-	-	-	-	-
70	-0.30	-0.30	-0.30	0.00	1	32.10	32.10	32.10	0.00	1
80	-0.30	-0.30	-0.30	0.00	1	32.10	32.10	32.10	0.00	1
90	-	-	-	-	-	-	-	-	-	-
100	-0.31	-0.31	-0.31	0.00	1	32.36	32.36	32.36	0.00	1
120	-	-	-	-	-	-	-	-	-	-
140	-	-	-	-	-	-	-	-	-	-
160	-	-	-	-	-	-	-	-	-	-
180	-	-	-	-	-	-	-	-	-	-
200	-	-	-	-	-	32.95	32.95	32.95	0.00	1

Depth (m)	Temperature (°C)					Salinity (psu)				
	Min	Max	Mean	Std Dev	Total Count	Min	Max	Mean	Std Dev	Total Count
April										
0	0.40	3.25	2.10	1.02	12	29.30	31.87	30.16	1.48	3
5	-0.01	2.60	1.44	1.00	7	31.01	32.38	31.73	0.73	4
10	0.00	3.00	1.06	0.99	9	31.73	32.38	32.03	0.31	5
15	-0.10	2.20	0.57	0.86	6	31.90	32.41	32.17	0.27	4
20	-0.42	0.71	0.03	0.39	7	31.90	32.43	32.15	0.24	5
30	-0.84	1.10	-0.05	0.63	9	31.92	32.43	32.23	0.20	5
40	-1.10	1.30	0.12	0.78	13	31.98	32.43	32.29	0.18	5
50	-0.97	1.10	-0.07	0.62	10	32.07	32.45	32.33	0.15	5
60	-0.86	0.30	-0.30	0.34	10	32.27	32.46	32.41	0.08	5
70	-0.85	0.05	-0.38	0.37	7	32.43	32.51	32.48	0.04	5
80	-0.87	0.05	-0.42	0.36	5	32.48	32.64	32.56	0.07	4
90	-1.00	0.00	-0.56	0.33	6	32.59	32.76	32.68	0.07	4
100	-1.00	0.00	-0.53	0.43	4	32.62	32.80	32.69	0.09	3
120	-0.50	0.00	-0.28	0.25	3	32.71	32.71	32.71	0.00	1
140	-0.84	0.20	-0.19	0.41	5	32.78	32.86	32.82	0.06	2
160	-0.82	0.30	-0.16	0.52	4	32.84	32.94	32.89	0.07	2
180	-0.22	0.53	0.16	0.53	2	32.94	32.94	32.94	0.00	1
200	-0.64	0.90	0.13	1.09	2	33.12	33.12	33.12	0.00	1
May										
0	-0.10	5.60	2.83	1.84	17	30.53	31.63	31.32	0.53	4
5	0.00	5.00	2.90	1.45	15	31.31	31.74	31.54	0.17	5
10	-0.84	5.81	2.70	1.81	14	31.45	32.45	31.72	0.41	5
15	-0.81	5.15	2.27	1.65	18	31.46	32.57	31.79	0.45	5
20	-0.74	5.06	2.23	1.54	12	31.46	32.63	31.86	0.52	4
30	-0.70	4.84	1.15	1.57	18	31.70	32.67	32.13	0.35	5
40	-0.87	3.60	0.50	1.29	18	31.98	32.70	32.35	0.29	5
50	-0.92	2.49	0.27	1.16	13	32.24	32.70	32.43	0.19	5
60	-1.03	-0.07	-0.53	0.31	11	32.26	32.70	32.51	0.18	4
70	-1.11	1.66	-0.15	1.01	11	32.29	32.67	32.54	0.17	4
80	-1.30	1.62	-0.43	0.85	11	32.37	32.65	32.57	0.13	4
90	-1.35	0.50	-0.54	0.66	9	32.42	32.67	32.58	0.14	3
100	-1.36	1.29	-0.33	0.94	7	32.66	32.66	32.66	0.00	1
120	-1.36	0.38	-0.34	0.75	4	-	-	-	-	-
140	-1.34	-0.22	-0.78	0.79	2	-	-	-	-	-
160	-1.32	0.50	-0.07	0.86	4	-	-	-	-	-
180	-1.08	0.40	-0.19	0.78	3	-	-	-	-	-
200	-0.66	-0.66	-0.66	0.00	1	-	-	-	-	-
June										
0	-0.60	9.73	5.48	2.51	60	30.75	33.06	31.94	0.58	48
5	-0.69	10.19	5.14	2.54	66	31.20	32.72	31.93	0.40	56
10	-0.87	10.13	4.56	2.54	72	31.37	32.74	32.01	0.38	58
15	-0.97	10.01	4.15	2.72	69	31.33	32.77	32.05	0.37	59
20	-1.07	9.96	3.55	2.85	73	31.34	32.78	32.10	0.39	60

Depth (m)	Temperature (°C)					Salinity (psu)				
	Min	Max	Mean	Std Dev	Total Count	Min	Max	Mean	Std Dev	Total Count
June (Cont.)										
30	-1.20	9.32	2.45	2.78	72	31.32	32.84	32.19	0.39	60
40	-1.30	9.17	1.46	2.52	69	31.55	32.81	32.31	0.34	60
50	-1.37	5.83	0.31	1.87	71	31.77	32.87	32.54	0.27	60
60	-1.26	3.09	-0.42	1.15	25	32.16	33.08	32.71	0.20	22
70	-1.40	-0.26	-0.93	0.34	10	32.50	32.58	32.53	0.04	3
80	-1.40	-0.26	-0.98	0.31	11	32.54	32.63	32.58	0.04	4
90	-1.13	-0.40	-0.82	0.31	4	32.59	32.67	32.63	0.06	2
100	-1.36	-0.40	-1.08	0.31	9	32.61	32.71	32.66	0.07	2
120	-1.34	-0.65	-1.01	0.27	6	32.68	32.74	32.71	0.04	2
140	-1.25	-0.64	-1.03	0.34	3	32.77	32.77	32.77	0.00	2
160	-0.80	-0.39	-0.63	0.21	3	32.87	32.87	32.87	0.00	2
180	-0.62	-0.05	-0.31	0.29	3	33.08	33.11	33.10	0.02	2
200	-0.47	0.36	-0.03	0.42	3	33.31	33.31	33.31	0.00	2
July										
0	-0.10	12.90	7.75	2.82	148	29.80	33.69	31.52	0.77	131
5	-0.28	11.56	6.72	2.84	163	30.56	32.86	31.66	0.50	145
10	-0.48	11.37	5.73	2.83	165	30.76	32.81	31.75	0.45	148
15	-0.62	11.29	4.74	2.76	165	30.99	32.80	31.85	0.43	148
20	-0.73	10.79	3.94	2.63	166	31.09	32.78	31.95	0.39	150
30	-1.04	8.60	2.46	2.23	166	31.21	32.75	32.14	0.33	150
40	-1.19	8.05	1.14	1.82	166	31.30	32.75	32.34	0.26	149
50	-1.25	5.71	0.11	1.17	159	31.88	32.84	32.55	0.17	145
60	-1.25	3.06	-0.39	0.79	43	32.37	33.31	32.74	0.22	41
70	-0.75	0.05	-0.35	0.28	6	32.43	32.55	32.48	0.05	6
80	-0.70	-0.34	-0.48	0.15	4	32.48	32.55	32.52	0.03	4
90	-0.74	-0.37	-0.54	0.17	4	32.52	32.60	32.57	0.04	3
100	-0.80	-0.38	-0.55	0.19	4	32.56	32.69	32.63	0.07	3
120	-0.65	-0.26	-0.43	0.20	3	32.65	32.81	32.75	0.09	3
140	0.04	0.04	0.04	0.00	1	33.12	33.12	33.12	0.00	1
160	-	-	-	-	-	-	-	-	-	-
180	-	-	-	-	-	-	-	-	-	-
200	-	-	-	-	-	-	-	-	-	-
August										
0	0.88	14.77	10.23	3.10	110	29.81	33.12	31.29	0.64	108
5	-0.08	14.29	9.16	3.62	116	30.50	32.51	31.40	0.50	115
10	-0.32	14.10	7.92	3.85	120	30.39	32.46	31.48	0.54	118
15	-0.60	13.15	6.59	3.84	122	30.56	32.45	31.61	0.52	120
20	-0.85	12.51	5.32	3.57	122	30.45	32.47	31.75	0.52	120
30	-0.98	10.30	3.13	2.56	122	30.81	32.57	31.99	0.42	120
40	-1.03	6.75	1.69	1.90	120	31.22	32.92	32.21	0.32	118
50	-1.19	3.95	0.74	1.47	119	31.67	32.88	32.41	0.24	117
60	-1.29	2.80	0.21	1.16	45	32.23	33.06	32.64	0.23	44
70	-	-	-	-	-	-	-	-	-	-

Depth (m)	Temperature (°C)					Salinity (psu)				
	Min	Max	Mean	Std Dev	Total Count	Min	Max	Mean	Std Dev	Total Count
August (Cont.)										
80	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-
100	-	-	-	-	-	-	-	-	-	-
120	-	-	-	-	-	-	-	-	-	-
140	-	-	-	-	-	-	-	-	-	-
160	-	-	-	-	-	-	-	-	-	-
180	-	-	-	-	-	-	-	-	-	-
200	-	-	-	-	-	-	-	-	-	-
September										
0	9.25	14.10	11.00	1.55	27	30.96	31.58	31.29	0.19	18
5	8.58	14.10	11.91	1.91	15	30.92	31.43	31.24	0.16	14
10	8.21	14.10	10.98	1.90	27	30.93	31.62	31.37	0.20	22
15	4.91	14.10	10.48	2.79	20	30.96	32.72	31.43	0.41	16
20	3.05	14.03	9.72	2.87	24	30.97	32.57	31.49	0.33	22
30	1.45	13.22	8.73	2.70	27	31.17	32.53	31.60	0.28	23
40	0.34	10.93	6.36	2.85	24	31.52	32.39	31.90	0.23	17
50	-0.23	9.20	4.92	2.85	30	31.67	32.48	32.06	0.28	22
60	-0.54	6.85	2.81	1.97	18	31.98	32.81	32.36	0.23	13
70	-0.79	3.26	1.46	1.05	18	32.32	32.57	32.44	0.08	13
80	-0.97	2.10	0.79	0.88	14	32.45	32.63	32.53	0.07	10
90	-1.05	1.15	0.09	0.72	11	32.48	32.75	32.62	0.10	8
100	-1.11	0.25	-0.49	0.41	11	32.57	32.88	32.75	0.10	9
120	-1.11	0.30	-0.59	0.63	4	32.66	32.91	32.80	0.13	3
140	-0.80	-0.68	-0.74	0.08	2	33.03	33.03	33.03	0.00	2
160	-	-	-	-	-	-	-	-	-	-
180	-0.50	-0.50	-0.50	0.00	1	-	-	-	-	-
200	-0.15	0.00	-0.08	0.11	2	33.37	33.37	33.37	0.00	1
October										
0	7.15	11.80	8.42	1.69	27	31.08	31.43	31.30	0.11	21
5	7.24	11.78	8.35	1.75	14	31.09	31.43	31.33	0.13	13
10	6.96	11.77	8.19	1.59	19	31.10	31.48	31.37	0.12	17
15	6.99	11.75	8.10	1.56	19	31.12	31.51	31.40	0.12	17
20	6.23	11.74	8.06	1.84	20	31.12	31.78	31.49	0.18	16
30	4.54	11.59	6.58	2.15	16	31.13	32.04	31.77	0.30	13
40	3.11	11.47	5.90	2.95	16	31.15	32.17	31.92	0.38	11
50	1.86	11.37	4.97	3.07	12	31.16	32.30	31.99	0.43	7
60	0.86	6.49	3.27	2.08	13	31.83	32.41	32.19	0.25	7
70	0.25	4.85	2.54	1.88	7	31.97	32.48	32.25	0.26	4
80	-0.51	3.08	0.89	1.38	5	32.12	32.61	32.40	0.23	4
90	-0.91	3.60	0.87	1.75	5	32.34	32.70	32.58	0.21	3
100	-1.04	3.10	0.67	1.76	4	32.40	32.72	32.56	0.23	2
120	-0.90	-0.46	-0.68	0.31	2	32.62	32.62	32.62	0.00	1
140	-0.41	-0.41	-0.41	0.00	1	32.71	32.71	32.71	0.00	1

Depth (m)	Temperature (°C)					Salinity (psu)				
	Min	Max	Mean	Std Dev	Total Count	Min	Max	Mean	Std Dev	Total Count
October (Cont.)										
160	-	-	-	-	-	-	-	-	-	-
180	-	-	-	-	-	-	-	-	-	-
200	-	-	-	-	-	-	-	-	-	-
November										
0	2.89	7.17	5.27	2.01	6	30.55	32.25	31.35	0.85	3
5	2.39	8.00	5.41	2.31	8	30.93	32.28	31.76	0.73	3
10	1.93	7.90	5.45	2.43	9	31.29	32.24	31.73	0.51	4
15	1.84	7.84	4.87	2.47	9	32.08	32.24	32.16	0.11	2
20	1.65	7.85	4.48	2.58	7	32.12	32.27	32.20	0.11	2
30	1.32	6.90	3.99	2.08	9	32.14	32.29	32.22	0.11	2
40	1.15	6.10	3.19	1.93	7	32.22	32.30	32.26	0.06	2
50	1.07	3.52	2.26	1.18	5	32.32	32.33	32.33	0.01	2
60	0.53	4.70	2.04	1.67	5	32.37	32.42	32.40	0.04	2
70	-0.23	3.40	1.03	1.40	5	32.45	32.54	32.50	0.06	2
80	-0.53	2.40	0.47	1.31	4	32.58	32.58	32.58	0.00	1
90	-0.70	1.60	0.30	1.13	5	32.61	32.61	32.61	0.00	1
100	-0.89	0.60	-0.45	0.70	4	32.68	32.68	32.68	0.00	1
120	-1.03	-0.10	-0.79	0.46	4	32.73	32.73	32.73	0.00	1
140	-1.10	-0.50	-0.89	0.34	3	-	-	-	-	-
160	-1.08	-0.40	-0.84	0.38	3	-	-	-	-	-
180	-1.01	-0.99	-1.00	0.01	2	-	-	-	-	-
200	-0.82	-0.82	-0.82	0.00	1	-	-	-	-	-
December										
0	3.40	4.07	3.74	0.47	2	31.58	31.58	31.58	0.00	1
5	3.82	3.82	3.82	0.00	1	31.14	31.14	31.14	0.00	1
10	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	-
30	3.30	3.70	3.50	0.28	2	31.57	31.57	31.57	0.00	1
40	3.18	3.18	3.18	0.00	1	31.79	31.79	31.79	0.00	1
50	2.66	2.66	2.66	0.00	1	31.92	31.92	31.92	0.00	1
60	2.27	2.58	2.43	0.22	2	31.99	31.99	31.99	0.00	1
70	2.02	2.02	2.02	0.00	1	32.04	32.04	32.04	0.00	1
80	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-
100	-	-	-	-	-	-	-	-	-	-
120	2.96	2.96	2.96	0.00	1	31.99	31.99	31.99	0.00	1
140	1.40	1.40	1.40	0.00	1	32.27	32.27	32.27	0.00	1
160	0.47	0.47	0.47	0.00	1	32.41	32.41	32.41	0.00	1
180	-0.59	-0.59	-0.59	0.00	1	32.63	32.63	32.63	0.00	1
200	-0.78	-0.78	-0.78	0.00	1	32.96	32.96	32.96	0.00	1

Appendix 2 Significant Wave Height versus Peak Period, Bull Arm, MSC50 Climatology Grid Point M6012874

Annual

Tp (s)	Hs (m) 0-0.3	0.3-0.6	0.6-1	1-1.3	1.3-1.6	1.6-2	Total	% Total
0-2	0	0	0	0	0	0	0	0.0
2-4	116008	135321	94270	187	0	0	345786	80.8
4-6	9	0	10033	12814	1216	15	24087	5.6
6-8	13	0	0	0	0	0	13	0.0
8-10	1	0	0	0	0	0	1	0.0
10-15	37852	2390	1550	255	104	12	42163	9.8
15-20	8525	3567	2895	648	232	31	15898	3.7
20-25	164	0	0	0	0	0	164	0.0
Total	162572	141278	108748	13904	1552	58	428112	100
% Exceed	62.0	29.0	3.6	0.4	0.0	0.0	0.0	0.0

January

Tp (s)	Hs (m) 0-0.3	0.3-0.6	0.6-1	1-1.3	1.3-1.6	1.6-2	Total	% Total
0-2	0	0	0	0	0	0	0	0.0
2-4	2747	9375	12563	49	0	0	24734	72.8
4-6	0	0	1648	3043	346	5	5042	14.8
6-8	0	0	0	0	0	0	0	0.0
8-10	0	0	0	0	0	0	0	0.0
10-15	1106	598	493	72	24	3	2296	6.8
15-20	484	691	574	104	38	21	1912	5.6
20-25	0	0	0	0	0	0	0	0.0
Total	4337	10664	15278	3268	408	29	33984	100
% Exceed	87.2	55.9	10.9	1.3	0.1	0.0	0.0	0.0

February

Tp (s)	Hs (m) 0-0.3	0.3-0.6	0.6-1	1-1.3	1.3-1.6	1.6-2	Total	% Total
0-2	0	0	0	0	0	0	0	0.0
2-4	4246	8933	9504	17	0	0	22700	81.5
4-6	2	0	1292	1635	195	0	3124	11.2
6-8	4	0	0	0	0	0	4	0.0
8-10	0	0	0	0	0	0	0	0.0
10-15	744	179	146	25	12	0	1106	4.0
15-20	218	266	283	109	53	0	929	3.3
20-25	0	0	0	0	0	0	0	0.0
Total	5214	9378	11225	1786	260	0	27863	100
% Exceed	81.3	47.6	7.3	0.9	0.0	0.0	0.0	0.0

March

Tp (s)	Hs (m) 0-0.3	0.3-0.6	0.6-1	1-1.3	1.3-1.6	1.6-2	Total	% Total
0-2	0	0	0	0	0	0	0	0.0
2-4	5995	10158	8725	20	0	0	24898	85.1
4-6	2	0	1219	1267	88	5	2581	8.8
6-8	7	0	0	0	0	0	7	0.0
8-10	1	0	0	0	0	0	1	0.0
10-15	928	163	132	30	37	4	1294	4.4
15-20	222	83	131	33	3	0	472	1.6
20-25	1	0	0	0	0	0	1	0.0
Total	7156	10404	10207	1350	128	9	29254	100
% Exceed	75.5	40.0	5.1	0.5	0.0	0.0	0.0	0.0

April

Tp (s)	Hs (m) 0-0.3	0.3-0.6	0.6-1	1-1.3	1.3-1.6	1.6-2	Total	% Total
0-2	0	0	0	0	0	0	0	0.0
2-4	9213	11183	7599	7	0	0	28002	85.2
4-6	4	0	707	582	36	0	1329	4.0
6-8	1	0	0	0	0	0	1	0.0
8-10	0	0	0	0	0	0	0	0.0
10-15	2532	161	72	2	0	0	2767	8.4
15-20	471	115	127	14	27	0	754	2.3
20-25	0	0	0	0	0	0	0	0.0
Total	12221	11459	8505	605	63	0	32853	100

% Exceed	62.8	27.9	2.0	0.2	0.0	0.0	0.0	0.0

May

	Hs (m)							
Tp (s)	0-0.3	0.3-0.6	0.6-1	1-1.3	1.3-1.6	1.6-2	Total	% Total
0-2	0	0	0	0	0	0	0	0.0
2-4	12839	11169	4750	4	0	0	28762	77.5
4-6	1	0	218	160	6	0	385	1.0
6-8	1	0	0	0	0	0	1	0.0
8-10	0	0	0	0	0	0	0	0.0
10-15	6894	70	5	7	5	0	6981	18.8
15-20	820	140	6	11	9	0	986	2.7
20-25	6	0	0	0	0	0	6	0.0
Total	20561	11379	4979	182	20	0	37121	100
% Exceed	44.6	14.0	0.5	0.1	0.0	0.0	0.0	0.0

June

	Hs (m)							
Tp (s)	0-0.3	0.3-0.6	0.6-1	1-1.3	1.3-1.6	1.6-2	Total	% Total
0-2	0	0	0	0	0	0	0	0.0
2-4	16648	10719	2758	0	0	0	30125	80.5
4-6	0	0	101	42	0	0	143	0.4
6-8	0	0	0	0	0	0	0	0.0
8-10	0	0	0	0	0	0	0	0.0
10-15	6197	11	3	0	0	0	6211	16.6
15-20	848	11	0	0	0	0	859	2.3
20-25	96	0	0	0	0	0	96	0.3
Total	23789	10741	2862	42	0	0	37434	100
% Exceed	36.5	7.8	0.1	0.0	0.0	0.0	0.0	0.0

July

	Hs (m)							
Tp (s)	0-0.3	0.3-0.6	0.6-1	1-1.3	1.3-1.6	1.6-2	Total	% Total
0-2	0	0	0	0	0	0	0	0.0
2-4	20643	11094	1731	0	0	0	33468	86.5
4-6	0	0	35	6	0	0	41	0.1
6-8	0	0	0	0	0	0	0	0.0
8-10	0	0	0	0	0	0	0	0.0
10-15	4322	6	0	0	0	0	4328	11.2
15-20	812	0	0	0	0	0	812	2.1
20-25	30	0	0	0	0	0	30	0.1
Total	25807	11100	1766	6	0	0	38679	100
% Exceed	33.3	4.6	0.0	0.0	0.0	0.0	0.0	0.0

August

	Hs (m)							
Tp (s)	0-0.3	0.3-0.6	0.6-1	1-1.3	1.3-1.6	1.6-2	Total	% Total
0-2	0	0	0	0	0	0	0	0.0
2-4	18106	12945	2830	1	0	0	33882	87.6
4-6	0	0	68	23	0	0	91	0.2
6-8	0	0	0	0	0	0	0	0.0
8-10	0	0	0	0	0	0	0	0.0
10-15	4025	5	0	0	0	0	4030	10.4
15-20	641	3	0	0	0	0	644	1.7
20-25	29	0	0	0	0	0	29	0.1
Total	22801	12953	2898	24	0	0	38676	100
% Exceed	41.0	7.6	0.1	0.0	0.0	0.0	0.0	0.0

September

	Hs (m)							
Tp (s)	0-0.3	0.3-0.6	0.6-1	1-1.3	1.3-1.6	1.6-2	Total	% Total
0-2	0	0	0	0	0	0	0	0.0
2-4	10438	13397	6642	4	0	0	30481	81.4
4-6	0	0	428	293	16	0	737	2.0
6-8	0	0	0	0	0	0	0	0.0
8-10	0	0	0	0	0	0	0	0.0
10-15	4582	33	0	0	0	0	4615	12.3
15-20	1165	298	130	4	0	0	1597	4.3

20-25	2	0	0	0	0	0	2	0.0
Total	16187	13728	7200	301	16	0	37432	100
% Exceed	56.8	20.1	0.8	0.0	0.0	0.0	0.0	0.0

October

	Hs (m)							
Tp (s)	0-0.3	0.3-0.6	0.6-1	1-1.3	1.3-1.6	1.6-2	Total	% Total
0-2	0	0	0	0	0	0	0	0.0
2-4	6641	13398	11102	13	0	0	31154	80.5
4-6	0	0	792	842	98	0	1732	4.5
6-8	0	0	0	0	0	0	0	0.0
8-10	0	0	0	0	0	0	0	0.0
10-15	3002	269	52	33	0	0	3356	8.7
15-20	1292	751	358	45	0	0	2446	6.3
20-25	0	0	0	0	0	0	0	0.0
Total	10935	14418	12304	933	98	0	38688	100
% Exceed	71.7	34.5	2.7	0.3	0.0	0.0	0.0	0.0

November

	Hs (m)							
Tp (s)	0-0.3	0.3-0.6	0.6-1	1-1.3	1.3-1.6	1.6-2	Total	% Total
0-2	0	0	0	0	0	0	0	0.0
2-4	5064	12237	12021	19	0	0	29341	78.4
4-6	0	0	1522	1943	111	0	3576	9.6
6-8	0	0	0	0	0	0	0	0.0
8-10	0	0	0	0	0	0	0	0.0
10-15	1863	390	217	33	24	0	2527	6.7
15-20	825	545	496	90	40	0	1996	5.3
20-25	0	0	0	0	0	0	0	0.0
Total	7752	13172	14256	2085	175	0	37440	100
% Exceed	79.3	44.1	6.0	0.5	0.0	0.0	0.0	0.0

December

	Hs (m)							
Tp (s)	0-0.3	0.3-0.6	0.6-1	1-1.3	1.3-1.6	1.6-2	Total	% Total
0-2	0	0	0	0	0	0	0	0.0
2-4	3428	10713	14045	53	0	0	28239	73.0
4-6	0	0	2003	2978	320	5	5306	13.7
6-8	0	0	0	0	0	0	0	0.0
8-10	0	0	0	0	0	0	0	0.0
10-15	1657	505	430	53	2	5	2652	6.9
15-20	727	664	790	238	62	10	2491	6.4
20-25	0	0	0	0	0	0	0	0.0
Total	5812	11882	17268	3322	384	20	38688	100
% Exceed	85.0	54.3	9.6	1.0	0.1	0.0	0.0	0.0

Appendix 3 Significant Wave Height versus Direction, Bull Arm, MSC50 Climatology Grid Point M6012874

Note: Wave direction for these Appendix 3 Tables are presented as Direction From

YEARLY STATISTICS

Direction from	Height m 0-0.25	0.25-0.5	0.5-0.75	0.75-1	1-1.25	1.25-1.5	1.5-1.75	1.75-2	Total	% Total
N	8723	10518	14743	5023	1041	253	43	4	40348	9.4
NNE	5728	3421	3799	2759	1062	240	34	11	17054	4.0
NE	11423	2541	1809	1106	641	198	10	0	17728	4.1
ENE	16719	3150	1761	1004	154	7	9	0	22804	5.3
E	7429	5359	5244	907	95	13	3	0	19050	4.5
ESE	4424	3355	2802	1134	162	11	0	0	11888	2.8
SE	5707	2413	2066	918	560	37	0	0	11701	2.7
SSE	7406	4976	3101	1537	425	45	0	0	17490	4.1
S	15105	14174	10670	3518	702	32	3	0	44204	10.3
SSW	12431	14018	11681	4744	890	91	4	0	43859	10.2
SW	8247	11159	7886	3303	1194	192	3	0	31984	7.5
WSW	7297	12293	9235	4502	1309	204	0	0	34840	8.1
W	12982	14894	12545	4808	976	216	0	0	46421	10.8
WNW	5545	8031	7892	5230	1405	208	0	0	28311	6.6
NW	4232	4631	5178	3577	1627	333	15	0	19593	4.6
NNW	5257	4968	5857	3703	810	207	35	0	20837	4.9
Total	138655	119901	106269	47773	13053	2287	159	15	428112	100
% Exceed	67.6	39.6	14.8	3.6	0.6	0.0	0	0	0	0

MONTHLY STATISTICS

January

Direction from	Height m 0-0.25	0.25-0.5	0.5-0.75	0.75-1	1-1.25	1.25-1.5	1.5-1.75	1.75-2	Total	% Total
N	243	722	1453	537	148	28	21	4	3156	9.3
NNE	275	316	438	323	147	31	10	3	1543	4.5
NE	543	226	218	143	113	24	2	0	1269	3.7
ENE	341	216	192	176	17	7	9	0	958	2.8
E	146	263	436	197	37	11	3	0	1093	3.2
ESE	119	199	309	209	41	1	0	0	878	2.6
SE	122	155	182	126	138	5	0	0	728	2.1
SSE	136	321	299	238	113	13	0	0	1120	3.3
S	225	571	801	461	242	16	0	0	2316	6.8
SSW	149	576	723	669	239	54	0	0	2410	7.1
SW	102	476	731	543	257	84	0	0	2193	6.5
WSW	114	569	969	741	331	97	0	0	2821	8.3
W	266	1085	1802	987	280	76	0	0	4496	13.2
WNW	173	907	1436	1181	334	57	0	0	4088	12.0
NW	145	531	820	712	376	77	12	0	2673	7.9
NNW	149	506	715	625	196	32	19	0	2242	6.6
Total	3248	7639	11524	7868	3009	613	76	7	33984	100
% Exceed	90.4	68.0	34.0	10.9	2.0	0.2	0	0	0	0

February

Direction from	Height m 0-0.25	0.25-0.5	0.5-0.75	0.75-1	1-1.25	1.25-1.5	1.5-1.75	1.75-2	Total	% Total
N	397	769	1224	562	119	51	4	0	3126	11.2
NNE	212	242	348	201	135	21	0	0	1159	4.2
NE	378	195	154	103	57	24	0	0	911	3.3
ENE	386	304	200	87	17	0	0	0	994	3.6
E	272	420	589	98	4	0	0	0	1383	5.0
ESE	137	203	251	170	31	3	0	0	795	2.9

SE	187	128	261	186	100	13	0	0	875	3.1
SSE	190	321	323	170	53	3	0	0	1060	3.8
S	354	616	667	348	51	4	0	0	2040	7.3
SSW	227	454	519	433	102	5	0	0	1740	6.2
SW	140	405	433	296	152	28	0	0	1454	5.2
WSW	147	500	695	661	186	32	0	0	2221	8.0
W	297	919	1343	615	102	28	0	0	3304	11.9
WNW	224	686	997	828	227	40	0	0	3002	10.8
NW	208	407	539	474	282	91	3	0	2004	7.2
NNW	308	387	593	429	51	27	0	0	1795	6.4
Total	4064	6956	9136	5661	1669	370	7	0	27863	100
% Exceed	85.4	60.5	27.7	7.3	1.4	0.0	0	0	0	0

March

Direction from	Height m 0-0.25	0.25-0.5	0.5-0.75	0.75-1	1-1.25	1.25-1.5	1.5-1.75	1.75-2	Total	% Total
N	511	964	1529	504	92	12	0	0	3612	12.4
NNE	271	427	473	396	189	35	0	0	1791	6.1
NE	513	245	258	208	147	88	5	0	1464	5.0
ENE	581	335	220	128	55	0	0	0	1319	4.5
E	276	473	538	132	15	0	0	0	1434	4.9
ESE	164	234	291	133	8	0	0	0	830	2.8
SE	240	196	209	69	47	1	0	0	762	2.6
SSE	302	378	293	121	42	3	0	0	1139	3.9
S	541	684	619	312	47	0	0	0	2203	7.5
SSW	361	589	790	490	103	2	0	0	2335	8.0
SW	237	504	537	315	126	14	0	0	1733	5.9
WSW	235	517	649	414	109	4	0	0	1928	6.6
W	538	973	1015	431	54	3	0	0	3014	10.3
WNW	352	677	662	485	98	2	0	0	2276	7.8
NW	258	421	415	336	90	10	0	0	1530	5.2
NNW	348	489	597	364	61	11	14	0	1884	6.4
Total	5728	8106	9095	4838	1283	185	19	0	29254	100
% Exceed	80.4	52.7	21.6	5.1	0.7	0.1	0	0	0	0

April

Direction from	Height m 0-0.25	0.25-0.5	0.5-0.75	0.75-1	1-1.25	1.25-1.5	1.5-1.75	1.75-2	Total	% Total
N	847	1158	1385	624	66	29	0	0	4109	12.5
NNE	484	331	287	279	92	17	0	0	1490	4.5
NE	1029	250	188	135	88	17	0	0	1707	5.2
ENE	1082	302	204	174	3	0	0	0	1765	5.4
E	686	730	628	91	6	0	0	0	2141	6.5
ESE	399	571	435	178	7	0	0	0	1590	4.8
SE	529	315	255	44	17	0	0	0	1160	3.5
SSE	594	534	341	93	5	0	0	0	1567	4.8
S	881	937	891	211	23	0	0	0	2943	9.0
SSW	580	685	815	414	32	0	0	0	2526	7.7
SW	432	584	582	243	49	0	0	0	1890	5.8
WSW	409	886	674	237	37	0	0	0	2243	6.8
W	920	1137	696	214	11	0	0	0	2978	9.1
WNW	488	666	452	182	14	0	0	0	1802	5.5
NW	385	339	312	89	71	8	0	0	1204	3.7
NNW	468	425	451	318	66	10	0	0	1738	5.3

Total	10213	9850	8596	3526	587	81	0	0	32853	100
% Exceed	68.9	38.9	12.8	2.0	0.3	0.0	0	0	0	0

May

	Height m									
Direction from	0-0.25	0.25-0.5	0.5-0.75	0.75-1	1-1.25	1.25-1.5	1.5-1.75	1.75-2	Total	% Total
N	1100	1091	1189	228	61	12	1	0	3682	9.9
NNE	688	379	352	183	20	11	3	0	1636	4.4
NE	1885	236	158	29	0	0	0	0	2308	6.2
ENE	3543	282	150	51	0	0	0	0	4026	10.9
E	1238	749	629	31	2	0	0	0	2649	7.1
ESE	692	460	175	16	2	0	0	0	1345	3.6
SE	820	240	129	8	7	0	0	0	1204	3.2
SSE	913	376	179	15	0	0	0	0	1483	4.0
S	1684	1348	851	92	1	0	0	0	3976	10.7
SSW	1208	1132	906	172	3	0	0	0	3421	9.2
SW	825	890	482	122	22	0	0	0	2341	6.3
WSW	659	748	506	108	31	0	0	0	2052	5.5
W	1261	1022	545	69	3	0	0	0	2900	7.8
WNW	613	587	283	81	0	0	0	0	1564	4.2
NW	508	304	201	23	9	0	0	0	1045	2.8
NNW	658	450	277	90	14	0	0	0	1489	4.0
Total	18295	10294	7012	1318	175	23	4	0	37121	100
% Exceed	50.7	23.0	4.1	0.5	0.1	0.0	0	0	0	0

June

Direction from	Height m 0-0.25	0.25-0.5	0.5-0.75	0.75-1	1-1.25	1.25-1.5	1.5-1.75	1.75-2	Total	% Total
N	1352	784	566	36	14	1	0	0	2753	7.3
NNE	907	269	114	5	12	0	0	0	1307	3.5
NE	1397	146	63	17	0	0	0	0	1623	4.3
ENE	2907	183	35	14	0	0	0	0	3139	8.4
E	1183	390	201	0	0	0	0	0	1774	4.7
ESE	645	204	65	12	0	0	0	0	926	2.5
SE	860	162	67	5	0	0	0	0	1094	2.9
SSE	1188	398	111	16	0	0	0	0	1713	4.6
S	2579	1559	719	60	2	0	0	0	4919	13.1
SSW	2308	2000	1149	175	2	0	0	0	5634	15.1
SW	1324	1458	613	70	1	0	0	0	3466	9.3
WSW	1102	1281	365	45	0	0	0	0	2793	7.5
W	1826	895	392	34	0	0	0	0	3147	8.4
WNW	522	444	112	57	0	0	0	0	1135	3.0
NW	499	224	134	39	0	0	0	0	896	2.4
NNW	644	260	170	31	6	4	0	0	1115	3.0
Total	21243	10657	4876	616	37	5	0	0	37434	100
% Exceed	43.3	14.8	1.8	0.1	0.0	0.0	0	0	0	0

July

Direction from	Height m 0-0.25	0.25-0.5	0.5-0.75	0.75-1	1-1.25	1.25-1.5	1.5-1.75	1.75-2	Total	% Total
N	851	331	250	30	0	0	0	0	1462	3.8
NNE	489	106	48	0	0	0	0	0	643	1.7
NE	684	44	5	0	0	0	0	0	733	1.9
ENE	2046	92	3	0	0	0	0	0	2141	5.5
E	898	245	99	0	0	0	0	0	1242	3.2
ESE	674	152	14	3	0	0	0	0	843	2.2
SE	941	142	53	0	0	0	0	0	1136	2.9
SSE	1279	355	117	5	0	0	0	0	1756	4.5
S	3375	2103	969	37	1	0	0	0	6485	16.8
SSW	3425	2746	1072	62	3	0	0	0	7308	18.9
SW	2283	2063	628	18	1	0	0	0	4993	12.9
WSW	1857	1714	343	14	1	0	0	0	3929	10.2
W	2287	1064	262	0	0	0	0	0	3613	9.3
WNW	781	200	49	11	0	0	0	0	1041	2.7
NW	487	72	39	6	0	0	0	0	604	1.6
NNW	509	137	65	39	0	0	0	0	750	1.9
Total	22866	11566	4016	225	6	0	0	0	38679	100
% Exceed	40.9	11.0	0.6	0.0	0.0	0.0	0	0	0	0

August

Direction from	Height m 0-0.25	0.25-0.5	0.5-0.75	0.75-1	1-1.25	1.25-1.5	1.5-1.75	1.75-2	Total	% Total
N	1012	616	612	56	12	0	0	0	2308	6.0
NNE	597	161	88	44	0	0	0	0	890	2.3
NE	950	116	30	14	0	0	0	0	1110	2.9
ENE	1576	242	51	19	0	0	0	0	1888	4.9
E	926	330	202	11	0	0	0	0	1469	3.8
ESE	545	277	94	6	0	0	0	0	922	2.4
SE	732	173	36	7	0	0	0	0	948	2.5
SSE	1113	483	119	12	0	0	0	0	1727	4.5
S	2688	1932	662	33	2	0	0	0	5317	13.8
SSW	2363	2254	1233	96	0	0	0	0	5946	15.4
SW	1627	1761	714	77	1	0	0	0	4180	10.8
WSW	1495	1791	649	58	3	0	0	0	3996	10.3
W	2357	1658	482	45	1	0	0	0	4543	11.8
WNW	793	485	162	44	0	0	0	0	1484	3.8
NW	527	238	146	18	0	0	0	0	929	2.4
NNW	603	254	91	66	5	0	0	0	1019	2.6
Total	19904	12771	5371	606	24	0	0	0	38676	100
% Exceed	48.5	15.5	1.6	0.1	0.0	0.0	0	0	0	0

September

Direction from	Height m 0-0.25	0.25-0.5	0.5-0.75	0.75-1	1-1.25	1.25-1.5	1.5-1.75	1.75-2	Total	% Total
N	1033	1180	1311	240	23	0	0	0	3787	10.1
NNE	661	306	283	124	10	0	0	0	1384	3.7
NE	1445	208	113	29	5	0	0	0	1800	4.8
ENE	1961	236	98	16	0	0	0	0	2311	6.2
E	763	376	312	35	0	0	0	0	1486	4.0
ESE	398	315	197	12	0	0	0	0	922	2.5
SE	525	225	103	16	7	0	0	0	876	2.3
SSE	692	384	166	31	9	0	0	0	1282	3.4
S	1169	1322	962	204	20	2	0	0	3679	9.8
SSW	848	1231	1386	376	41	3	0	0	3885	10.4
SW	690	956	733	194	29	5	0	0	2607	7.0
WSW	532	1371	890	199	14	8	0	0	3014	8.1
W	1431	1681	1182	213	22	2	0	0	4531	12.1
WNW	634	897	550	258	45	7	0	0	2391	6.4
NW	506	501	325	189	52	6	0	0	1579	4.2
NNW	649	605	460	177	7	0	0	0	1898	5.1
Total	13937	11794	9071	2313	284	33	0	0	37432	100
% Exceed	62.8	31.3	7.0	0.8	0.1	0.0	0	0	0	0

October

Direction from	Height m 0-0.25	0.25-0.5	0.5-0.75	0.75-1	1-1.25	1.25-1.5	1.5-1.75	1.75-2	Total	% Total
N	667	1090	1819	792	146	20	0	0	4534	11.7
NNE	501	298	442	294	97	26	6	0	1664	4.3
NE	1250	279	182	153	73	6	3	0	1946	5.0
ENE	1107	297	151	78	2	0	0	0	1635	4.2
E	437	476	471	32	10	0	0	0	1426	3.7
ESE	277	262	309	89	13	0	0	0	950	2.5
SE	333	262	239	82	30	2	0	0	948	2.5
SSE	436	497	411	150	20	2	0	0	1516	3.9
S	803	1191	1160	424	35	0	3	0	3616	9.3
SSW	466	916	1056	413	45	1	4	0	2901	7.5
SW	267	811	925	298	51	9	1	0	2362	6.1
WSW	338	1286	1321	537	63	7	0	0	3552	9.2
W	750	1756	1613	476	36	10	0	0	4641	12.0
WNW	399	911	957	321	45	5	0	0	2638	6.8
NW	310	609	669	326	120	9	0	0	2043	5.3
NNW	431	536	789	429	98	33	0	0	2316	6.0
Total	8772	11477	12514	4894	884	130	17	0	38688	100
% Exceed	77.3	47.7	15.3	2.7	0.4	0.0	0	0	0	0

November

Direction from	Height m 0-0.25	0.25-0.5	0.5-0.75	0.75-1	1-1.25	1.25-1.5	1.5-1.75	1.75-2	Total	% Total
N	360	906	1611	558	166	50	5	0	3656	9.8
NNE	324	254	386	399	144	20	0	0	1527	4.1
NE	691	306	224	142	86	31	0	0	1480	4.0
ENE	651	326	306	170	8	0	0	0	1461	3.9
E	352	506	612	130	5	2	0	0	1607	4.3
ESE	215	242	365	94	27	4	0	0	947	2.5
SE	249	196	258	143	67	2	0	0	915	2.4
SSE	331	479	339	325	51	0	0	0	1525	4.1
S	556	1133	1227	614	140	0	0	0	3670	9.8
SSW	334	831	1090	692	146	3	0	0	3096	8.3
SW	211	714	773	451	198	13	0	0	2360	6.3
WSW	252	935	1021	642	207	12	0	0	3069	8.2
W	654	1444	1433	683	129	19	0	0	4362	11.7
WNW	329	848	1096	626	193	25	0	0	3117	8.3
NW	229	498	712	627	274	41	0	0	2381	6.4
NNW	263	516	775	521	138	54	0	0	2267	6.1
Total	6001	10134	12228	6817	1979	276	5	0	37440	100
% Exceed	84.0	56.9	24.2	6.0	0.8	0.0	0	0	0	0

December

Direction from	Height m 0-0.25	0.25-0.5	0.5-0.75	0.75-1	1-1.25	1.25-1.5	1.5-1.75	1.75-2	Total	% Total
N	350	907	1794	856	194	50	12	0	4163	10.8
NNE	319	332	540	511	216	79	15	8	2020	5.2
NE	658	290	216	133	72	8	0	0	1377	3.6
ENE	538	335	151	91	52	0	0	0	1167	3.0
E	252	401	527	150	16	0	0	0	1346	3.5
ESE	159	236	297	212	33	3	0	0	940	2.4
SE	169	219	274	232	147	14	0	0	1055	2.7
SSE	232	450	403	361	132	24	0	0	1602	4.1
S	250	778	1142	722	138	10	0	0	3040	7.9
SSW	162	604	942	752	174	23	0	0	2657	6.9
SW	109	537	735	676	307	39	2	0	2405	6.2
WSW	157	695	1153	846	327	44	0	0	3222	8.3
W	395	1260	1780	1041	338	78	0	0	4892	12.6
WNW	237	723	1136	1156	449	72	0	0	3773	9.8
NW	170	487	866	738	353	91	0	0	2705	7.0
NNW	227	403	874	614	168	36	2	0	2324	6.0
Total	4384	8657	12830	9091	3116	571	31	8	38688	100
% Exceed	88.7	66.3	33.1	9.6	1.6	0.1	0	0	0	0

Appendix 4 Temperature and Salinity Statistics, Hebron Region

		Temperature (deg C)						Salinity (psu)						Sigmat					
Month	Depth (m)	Min	Max	Avg	Std Dev	Count	Total	Min	Max	Avg	Std Dev	Count	Total	Min	Max	Avg	Std Dev	Count	Total
Jan	0	-1.70	3.14	0.07	0.80	20	208	32.19	33.36	32.86	0.29	13	42	25.77	26.77	26.37	0.25	13	42
	10	-1.70	2.21	0.05	0.70	18	244	32.22	33.41	32.86	0.21	11	36	25.82	26.79	26.39	0.17	11	36
	20	-1.70	2.17	0.04	0.80	19	235	32.19	33.45	32.90	0.26	12	37	25.78	26.82	26.42	0.24	12	37
	30	-1.70	3.50	0.12	0.83	19	232	32.19	33.51	32.92	0.31	12	35	25.78	26.87	26.43	0.27	12	35
	40	-1.70	3.80	0.23	0.90	15	162	32.57	33.60	33.12	0.38	3	14	26.18	27.01	26.62	0.32	3	14
	50	-1.71	2.44	0.09	0.68	19	240	32.23	33.83	33.03	0.30	12	39	25.83	27.11	26.52	0.25	12	39
	60	-1.70	2.61	0.21	0.55	17	158	32.38	33.84	33.02	0.61	4	14	25.97	27.18	26.51	0.50	4	14
	70	-1.75	2.69	0.01	0.69	20	218	32.38	34.00	33.15	0.31	13	40	25.97	27.22	26.62	0.25	13	40
	80	-1.75	2.73	-0.10	0.67	20	213	32.69	34.00	33.17	0.29	12	43	26.28	27.22	26.64	0.23	12	43
	90	-1.70	2.73	-0.20	0.80	17	148	32.74	34.00	33.28	0.32	9	31	26.32	27.28	26.73	0.24	9	31
	100	-1.80	2.77	-0.09	0.87	20	167	32.93	34.08	33.43	0.30	13	40	26.47	27.32	26.84	0.22	13	40
Feb	0	-1.82	3.20	-0.53	0.67	27	331	32.36	33.43	32.99	0.20	14	44	25.98	26.87	26.51	0.16	14	44
	10	-1.83	3.30	-0.56	0.65	22	305	32.36	33.79	33.06	0.26	11	33	25.97	27.11	26.57	0.21	11	33
	20	-1.80	3.30	-0.50	0.64	23	266	32.36	33.88	32.99	0.23	11	35	25.97	27.17	26.51	0.20	11	35
	30	-1.80	3.30	-0.47	0.62	26	290	32.37	33.93	33.03	0.22	13	41	25.98	27.20	26.54	0.18	13	41
	40	-1.74	3.30	-0.37	0.58	19	184	32.88	33.95	33.18	0.28	6	15	26.39	27.21	26.65	0.23	6	15
	50	-1.80	3.30	-0.40	0.65	24	289	32.45	33.66	33.12	0.23	13	38	26.05	27.04	26.61	0.19	13	38
	60	-1.75	3.20	-0.28	0.55	22	194	32.75	33.99	33.21	0.31	7	11	26.28	27.24	26.67	0.25	7	11
	70	-1.82	3.40	-0.32	0.58	23	291	32.66	33.79	33.23	0.23	12	30	26.25	27.11	26.70	0.17	12	30
	80	-1.82	1.30	-0.34	0.60	23	250	32.57	34.09	33.24	0.27	13	41	26.17	27.30	26.71	0.20	13	41
	90	-1.79	2.50	-0.18	0.43	19	157	33.19	34.10	33.45	0.23	6	12	26.65	27.31	26.86	0.17	6	12
	100	-1.78	2.90	-0.13	0.71	21	187	32.68	34.15	33.36	0.28	13	37	26.27	27.34	26.79	0.20	13	37
Mar	0	-1.86	3.70	-0.38	0.89	35	246	32.28	33.93	33.05	0.24	22	92	25.97	27.12	26.55	0.18	22	92
	10	-1.86	3.70	-0.39	0.92	29	250	32.50	33.76	33.09	0.27	17	82	26.15	27.10	26.58	0.21	17	82
	20	-1.86	4.90	-0.41	0.94	34	260	32.57	34.04	33.10	0.25	21	102	26.20	27.15	26.58	0.19	21	102
	30	-1.80	4.90	-0.37	1.01	34	259	32.68	34.01	33.09	0.26	22	99	26.20	27.12	26.58	0.19	22	99
	40	-1.80	4.90	-0.11	1.17	25	192	32.70	33.81	33.14	0.33	9	52	26.21	27.02	26.60	0.24	9	52
	50	-1.80	4.90	-0.16	1.34	34	255	32.73	34.24	33.15	0.28	22	106	26.23	27.24	26.62	0.20	22	106
	60	-1.74	4.90	0.08	1.56	24	192	32.75	33.83	33.10	0.34	10	59	26.32	27.11	26.57	0.25	10	59
	70	-1.83	4.13	-0.19	1.09	32	240	32.76	34.44	33.28	0.34	19	96	26.32	27.41	26.72	0.24	19	96
	80	-1.80	4.13	-0.25	0.99	30	235	32.77	34.33	33.35	0.33	17	89	26.27	27.38	26.76	0.20	17	88
	90	-1.81	4.55	0.00	1.47	25	165	32.92	34.34	33.49	0.39	10	40	26.48	27.20	26.86	0.21	10	40
	100	-1.80	4.04	-0.03	1.21	31	203	33.00	34.54	33.57	0.37	19	72	26.45	27.52	26.93	0.24	19	72
Apr	0	-1.60	8.70	0.23	0.74	62	1151	31.47	34.11	32.92	0.21	59	853	25.28	27.31	26.42	0.17	59	850
	10	-1.50	8.70	0.15	0.80	43	1692	32.12	34.08	32.88	0.20	38	1391	25.81	27.23	26.40	0.16	38	1391
	20	-1.70	8.80	0.13	0.95	61	1677	32.19	34.11	32.98	0.25	58	1370	25.83	27.28	26.47	0.18	58	1365
	30	-1.80	8.90	0.00	0.79	62	1805	31.75	34.18	32.98	0.21	59	1473	25.49	27.32	26.48	0.16	59	1472
	40	-1.79	8.90	-0.06	0.99	50	1352	32.03	34.21	33.06	0.34	41	1080	25.72	27.35	26.54	0.25	41	1080
	50	-1.80	8.80	-0.35	0.66	62	1900	32.38	34.26	33.08	0.21	59	1557	25.91	27.36	26.57	0.16	59	1554
	60	-1.80	9.00	-0.27	0.92	50	1312	32.48	34.35	33.14	0.33	43	1052	26.00	27.39	26.61	0.24	43	1052
	70	-1.81	9.30	-0.37	0.95	61	1596	32.48	34.42	33.24	0.27	58	1306	26.00	27.41	26.70	0.18	58	1305
	80	-1.78	9.30	-0.51	0.79	63	1447	32.54	34.55	33.23	0.21	60	1174	26.17	27.47	26.70	0.15	60	1173
	90	-1.80	8.60	-0.14	1.12	50	815	32.56	34.22	33.37	0.31	45	626	26.19	27.31	26.79	0.20	45	626
	100	-1.79	7.70	-0.24	0.92	62	1081	32.68	34.52	33.45	0.26	57	855	26.28	27.53	26.86	0.18	57	851

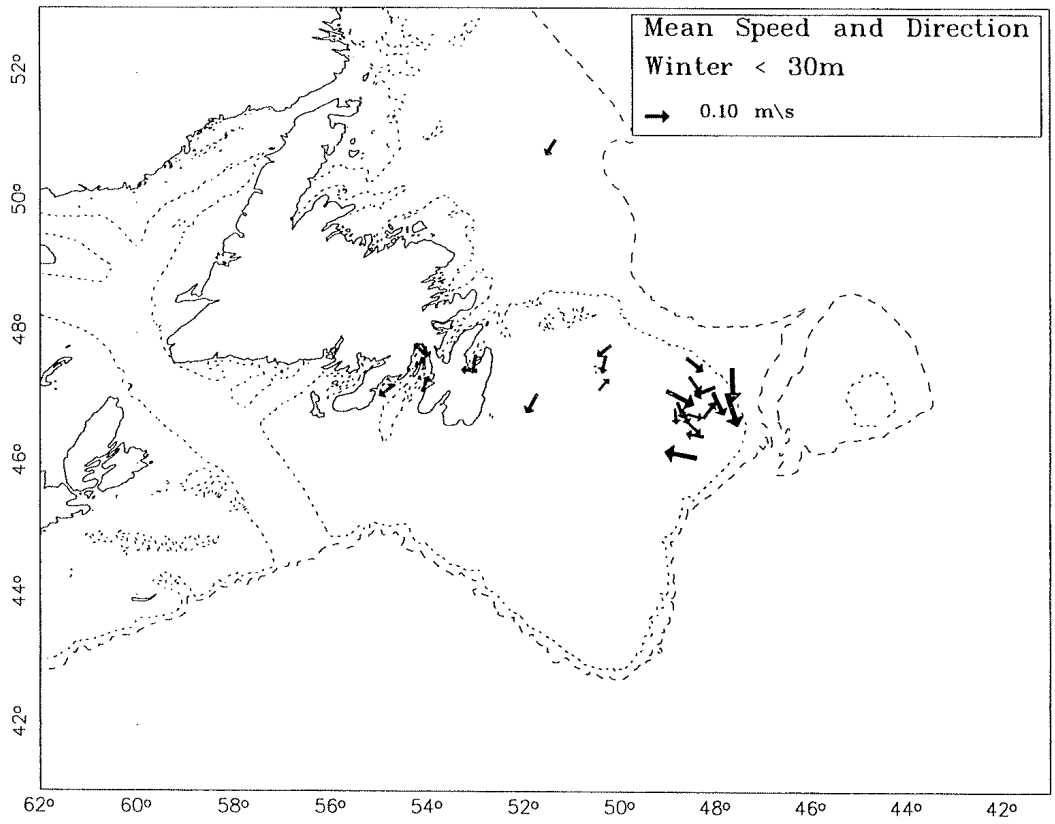
		Temperature (deg C)						Salinity (psu)						Sigmat					
Month	Depth (m)	Min	Max	Avg	Std Dev	Count	Total	Min	Max	Avg	Std Dev	Count	Total	Min	Max	Avg	Std Dev	Count	Total
May	0	-2.00	9.10	2.03	1.35	67	2165	31.84	34.66	32.84	0.23	62	1034	25.13	27.70	26.22	0.23	62	1034
	10	-1.40	8.70	2.01	1.34	45	3003	31.92	34.08	32.80	0.23	40	1429	25.13	27.01	26.19	0.22	40	1429
	20	-1.60	7.00	1.40	1.15	63	3632	31.37	34.48	32.88	0.24	61	1852	25.04	27.09	26.30	0.22	61	1847
	30	-1.80	6.80	1.06	1.01	64	3796	32.22	34.04	32.91	0.21	62	1883	25.59	27.10	26.35	0.17	62	1883
	40	-2.00	6.70	0.53	0.96	48	3010	32.27	34.05	32.90	0.20	31	1317	25.84	27.14	26.38	0.16	31	1317
	50	-2.00	7.04	0.15	0.88	65	3672	32.28	34.48	33.05	0.25	61	1936	25.80	27.42	26.52	0.18	61	1935
	60	-1.90	6.60	-0.03	1.07	51	2635	32.40	34.33	33.00	0.21	43	1298	26.00	27.42	26.50	0.18	43	1298
	70	-2.00	8.02	-0.35	0.96	64	2807	32.41	34.72	33.23	0.27	59	1470	26.01	27.36	26.69	0.18	59	1467
	80	-2.00	6.60	-0.46	1.11	62	2197	32.63	34.46	33.23	0.22	59	1120	26.22	27.44	26.70	0.16	59	1117
	90	-2.00	7.91	-0.17	1.76	55	1300	32.63	34.87	33.34	0.37	47	483	26.24	27.47	26.76	0.20	47	483
	100	-1.88	6.60	-0.29	1.07	63	1650	32.71	34.74	33.42	0.25	60	796	26.30	27.53	26.84	0.17	60	796
June	0	-0.60	14.36	4.53	1.55	68	3080	30.11	33.90	32.69	0.24	59	2457	23.73	26.72	25.88	0.29	59	2457
	10	-0.80	11.08	4.11	1.46	47	5101	31.60	33.36	32.61	0.21	37	4123	24.77	26.66	25.89	0.27	37	4123
	20	-1.70	12.05	3.12	1.25	67	5589	31.61	34.06	32.76	0.23	57	4423	24.77	26.95	26.08	0.24	57	4421
	30	-1.70	12.05	2.34	1.27	67	5774	31.61	34.06	32.80	0.20	56	4574	24.91	27.24	26.17	0.20	56	4570
	40	-1.76	6.90	1.02	1.21	44	5174	31.97	34.64	32.86	0.25	31	4122	25.42	27.63	26.32	0.25	31	4122
	50	-1.79	6.84	0.28	0.84	67	5375	32.17	34.45	33.02	0.26	57	4427	25.62	27.45	26.49	0.21	57	4427
	60	-1.80	4.20	0.02	0.86	48	4549	32.40	34.06	32.99	0.19	38	3762	25.97	27.17	26.48	0.17	38	3761
	70	-1.80	5.80	-0.34	0.72	64	3708	32.48	34.57	33.20	0.28	57	3004	25.99	27.51	26.67	0.21	57	3004
	80	-1.80	5.80	-0.51	0.60	63	2754	32.48	34.56	33.20	0.22	56	2138	25.99	27.47	26.68	0.17	56	2137
	90	-1.73	4.25	-0.19	0.95	51	1880	32.56	34.57	33.42	0.37	38	1366	26.17	27.42	26.84	0.25	38	1366
	100	-1.80	5.80	-0.23	0.79	65	1610	32.56	34.90	33.42	0.33	57	1146	26.17	27.93	26.84	0.24	57	1146
July	0	3.42	14.40	9.39	2.07	59	1080	30.95	33.28	32.31	0.27	53	622	23.47	26.03	24.89	0.40	53	618
	10	-0.70	13.90	8.73	1.93	46	2019	30.97	33.14	32.33	0.26	42	1091	23.50	26.01	24.95	0.39	42	1091
	20	-1.40	12.98	6.27	1.77	58	2450	31.59	33.93	32.53	0.23	52	1245	24.49	26.68	25.46	0.32	51	1244
	30	-1.60	11.40	3.92	1.77	58	2344	31.84	33.32	32.68	0.18	51	1283	24.72	26.69	25.90	0.28	51	1283
	40	-1.80	7.77	1.45	1.08	45	1931	31.96	34.07	32.82	0.24	19	1055	25.36	27.24	26.25	0.17	18	1054
	50	-1.80	7.26	0.27	0.93	57	1952	32.31	34.01	32.94	0.17	52	1265	25.33	27.32	26.42	0.15	51	1264
	60	-1.85	5.77	-0.02	1.15	45	1532	32.57	34.48	33.08	0.36	19	942	26.00	27.32	26.53	0.18	18	940
	70	-1.87	5.90	-0.43	0.82	56	1630	32.61	34.48	33.14	0.16	51	1074	25.91	27.36	26.62	0.12	50	1072
	80	-1.86	5.90	-0.46	0.78	53	1436	32.68	34.00	33.14	0.12	50	951	25.91	27.37	26.63	0.10	50	950
	90	-1.87	5.23	-0.31	0.97	49	1004	32.82	34.52	33.24	0.23	28	613	26.38	27.39	26.70	0.15	28	613
	100	-1.87	6.30	-0.44	0.85	53	1000	32.85	34.54	33.32	0.16	52	656	25.96	27.51	26.76	0.12	51	655
Aug	0	1.10	18.35	11.99	2.24	39	646	30.28	33.07	31.94	0.44	24	201	22.83	25.69	24.18	0.53	24	201
	10	-1.49	18.36	10.83	2.88	35	1971	30.63	33.12	32.05	0.40	21	1193	22.88	26.39	24.43	0.51	21	1193
	20	-1.90	18.23	6.88	3.84	36	2506	30.72	33.52	32.46	0.27	23	1330	23.04	26.55	25.30	0.59	23	1329
	30	-1.90	14.16	3.49	3.22	37	2419	31.29	34.12	32.70	0.26	24	1301	24.02	27.13	25.92	0.47	24	1299
	40	-1.80	9.71	0.96	2.09	32	1830	32.47	34.37	32.89	0.25	14	1009	25.40	27.38	26.36	0.25	14	1009
	50	-1.90	10.86	-0.16	1.22	37	1225	32.55	35.18	33.00	0.20	25	623	25.67	27.42	26.50	0.17	25	622
	60	-1.90	5.40	-0.39	1.06	32	835	32.69	34.40	33.04	0.26	13	399	26.12	27.43	26.54	0.19	13	399
	70	-2.00	4.90	-0.71	0.95	35	737	32.75	34.52	33.11	0.17	23	393	26.33	27.53	26.62	0.13	23	393
	80	-2.00	4.60	-0.81	0.99	33	622	32.75	34.52	33.17	0.18	23	351	26.33	27.53	26.67	0.14	23	351
	90	-2.00	4.40	-0.62	1.13	29	484	32.89	33.84	33.24	0.20	15	278	26.45	27.15	26.73	0.15	15	277
	100	-1.75	10.10	-0.55	1.03	33	566	32.89	35.17	33.28	0.18	24	380	26.45	27.56	26.75	0.13	24	377

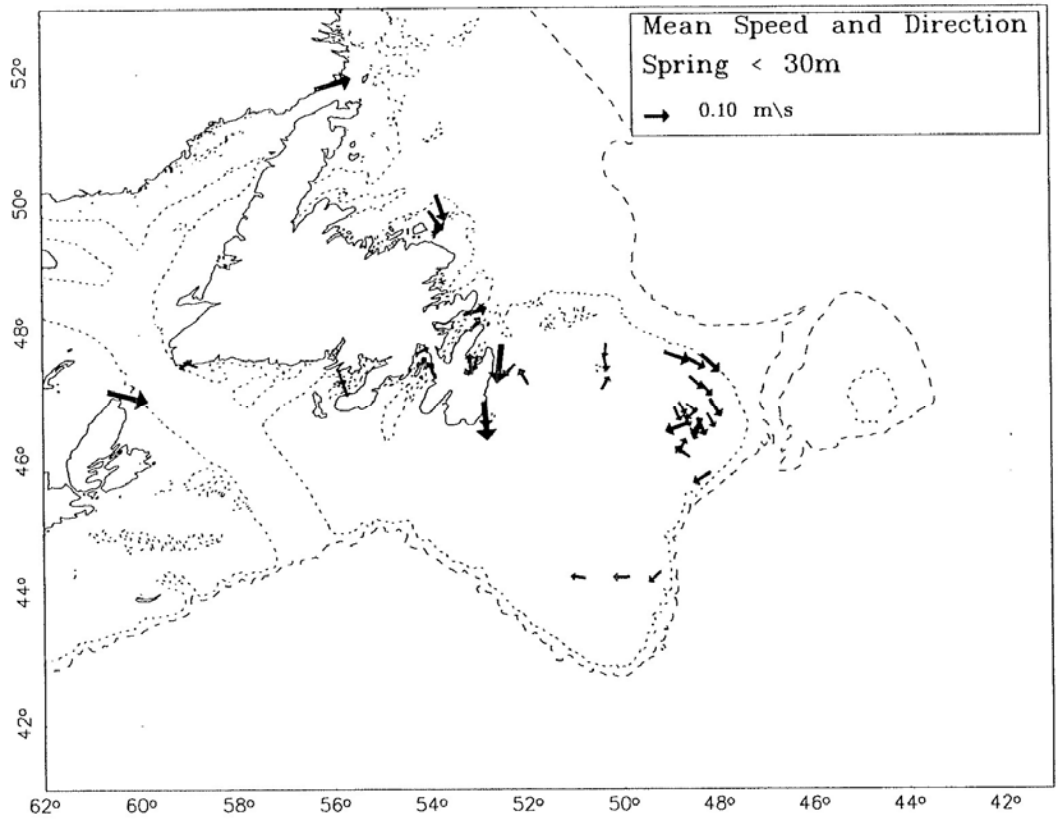
		Temperature (deg C)						Salinity (psu)						Sigmat					
Month	Depth (m)	Min	Max	Avg	Std Dev	Count	Total	Min	Max	Avg	Std Dev	Count	Total	Min	Max	Avg	Std Dev	Count	Total
Sept	0	0.57	18.20	11.26	2.65	38	630	31.16	33.65	32.08	0.34	21	266	23.19	25.92	24.38	0.68	21	266
	10	0.10	17.20	10.74	2.45	34	898	31.26	33.71	32.09	0.34	17	347	23.26	25.99	24.43	0.64	17	347
	20	-1.30	17.20	7.95	2.85	36	1161	31.48	33.76	32.37	0.26	19	356	23.45	26.50	25.07	0.49	19	356
	30	-1.65	16.40	4.63	2.67	36	1231	31.48	33.85	32.64	0.28	19	401	23.71	26.92	25.72	0.45	19	401
	40	-1.80	10.40	1.65	2.06	31	886	31.86	33.89	32.86	0.28	9	312	24.99	27.04	26.24	0.27	9	312
	50	-1.90	8.84	0.16	1.43	36	723	32.26	34.06	33.08	0.23	20	312	25.48	27.22	26.52	0.19	20	312
	60	-1.96	7.56	-0.21	1.26	28	533	32.52	34.06	33.07	0.21	8	220	25.98	27.11	26.53	0.09	8	220
	70	-1.96	7.30	-0.35	1.15	33	509	32.69	34.33	33.24	0.28	17	228	26.18	27.34	26.71	0.19	17	228
	80	-1.94	7.60	-0.34	1.12	33	415	32.76	34.20	33.24	0.23	17	182	26.31	27.34	26.72	0.17	17	182
	90	-1.74	7.60	-0.20	1.15	29	329	32.89	34.55	33.40	0.42	11	129	26.46	27.47	26.83	0.25	11	129
	100	-1.70	7.30	-0.17	1.11	33	326	32.92	34.42	33.41	0.23	18	133	26.48	27.48	26.85	0.16	18	133
Oct	0	2.90	14.90	8.03	2.09	34	927	30.28	33.86	32.27	0.38	23	480	22.98	26.48	25.13	0.50	23	480
	10	1.27	14.80	7.83	2.05	33	1995	31.30	33.87	32.28	0.39	22	1517	23.80	26.49	25.18	0.51	22	1517
	20	-1.33	14.10	7.12	2.05	34	2112	31.19	33.87	32.41	0.37	24	1497	23.80	26.60	25.39	0.50	24	1497
	30	-1.67	13.78	5.88	2.11	35	2625	31.06	34.43	32.59	0.35	24	1650	23.74	27.14	25.69	0.49	24	1650
	40	-1.70	12.60	3.09	2.37	31	2943	31.87	34.12	32.87	0.26	13	1708	24.46	27.25	26.18	0.34	13	1708
	50	-1.70	11.20	0.87	2.20	35	2698	31.99	34.40	33.05	0.19	25	1757	25.03	27.34	26.50	0.16	25	1756
	60	-1.73	9.40	0.26	2.11	30	2213	32.06	34.39	33.16	0.23	15	1607	25.25	27.42	26.62	0.17	15	1607
	70	-1.74	8.20	-0.04	1.80	34	1924	32.75	34.40	33.26	0.19	23	1418	26.23	27.43	26.72	0.14	23	1418
	80	-1.71	8.07	-0.07	1.77	31	1244	32.81	34.49	33.33	0.22	21	832	26.28	27.43	26.78	0.16	21	832
	90	-1.68	7.20	0.11	1.76	30	872	32.95	34.51	33.43	0.26	15	549	26.51	27.43	26.85	0.17	15	549
	100	-1.68	6.78	-0.25	1.08	29	843	32.93	34.54	33.50	0.26	23	539	26.49	27.50	26.91	0.17	23	539
Nov	0	0.19	11.10	4.77	1.38	36	1241	30.60	33.86	32.50	0.44	29	785	24.11	27.01	25.75	0.46	29	785
	10	-0.02	11.08	4.58	1.30	34	1803	31.62	33.86	32.54	0.41	25	1289	24.50	27.01	25.78	0.43	25	1289
	20	-0.40	11.05	4.24	1.24	36	1801	31.42	34.13	32.61	0.40	29	1226	24.42	27.19	25.88	0.41	29	1224
	30	-1.40	11.02	3.74	1.03	36	2008	31.08	34.46	32.69	0.41	28	1262	24.18	27.46	25.98	0.41	28	1261
	40	-1.40	11.00	2.69	0.97	33	2195	31.41	34.46	32.80	0.35	20	1268	24.39	27.50	26.12	0.32	20	1266
	50	-1.70	9.00	1.45	1.10	36	2284	31.73	34.35	33.01	0.30	29	1321	24.79	27.52	26.42	0.28	29	1319
	60	-1.80	7.52	0.49	1.00	33	1965	31.81	35.16	33.10	0.27	22	1281	24.91	28.26	26.55	0.24	22	1280
	70	-1.50	5.10	0.04	0.77	35	1639	32.11	35.16	33.29	0.28	28	1091	25.64	28.29	26.71	0.21	28	1091
	80	-1.50	5.30	-0.15	0.72	36	1374	32.68	34.18	33.35	0.22	28	944	26.21	27.33	26.76	0.14	28	944
	90	-1.60	4.40	-0.30	0.81	31	1132	32.76	34.37	33.39	0.17	19	832	26.23	27.45	26.81	0.10	19	832
	100	-1.62	5.09	-0.16	0.73	35	1106	32.86	34.45	33.52	0.24	29	827	26.35	27.51	26.91	0.15	29	827
Dec	0	-1.18	6.95	1.96	1.30	24	533	30.05	34.92	32.68	0.42	14	348	24.08	27.77	26.08	0.38	14	348
	10	-1.18	6.95	2.01	1.31	23	946	31.96	34.25	32.66	0.31	14	632	25.16	27.20	26.07	0.31	14	632
	20	-1.17	6.97	1.96	1.23	23	896	31.78	34.24	32.65	0.27	13	578	25.17	27.18	26.07	0.29	13	578
	30	-1.16	6.98	1.86	1.13	23	884	31.78	34.25	32.76	0.30	14	573	25.14	27.18	26.17	0.29	14	573
	40	-1.20	6.86	1.55	0.82	18	853	31.33	34.28	32.77	0.23	10	571	25.00	27.19	26.20	0.23	10	571
	50	-1.60	5.70	1.20	0.96	24	928	31.93	34.31	32.95	0.28	14	587	25.50	27.21	26.37	0.21	14	587
	60	-1.37	5.41	0.77	0.88	21	876	32.15	34.33	33.03	0.22	10	564	25.75	27.22	26.49	0.19	10	564
	70	-1.70	5.25	0.23	0.90	23	858	32.49	34.33	33.22	0.21	14	570	26.09	27.28	26.65	0.14	14	570
	80	-1.59	5.60	0.01	1.01	23	735	32.74	34.42	33.27	0.19	14	496	26.31	27.55	26.70	0.11	14	496
	90	-1.70	5.60	-0.01	1.21	21	425	32.92	34.56	33.38	0.33	14	281	26.46	27.43	26.77	0.20	14	281
	100	-1.80	5.60	0.13	1.76	21	344	33.06	34.65	33.48	0.31	13	225	26.59	27.53	26.86	0.16	13	225

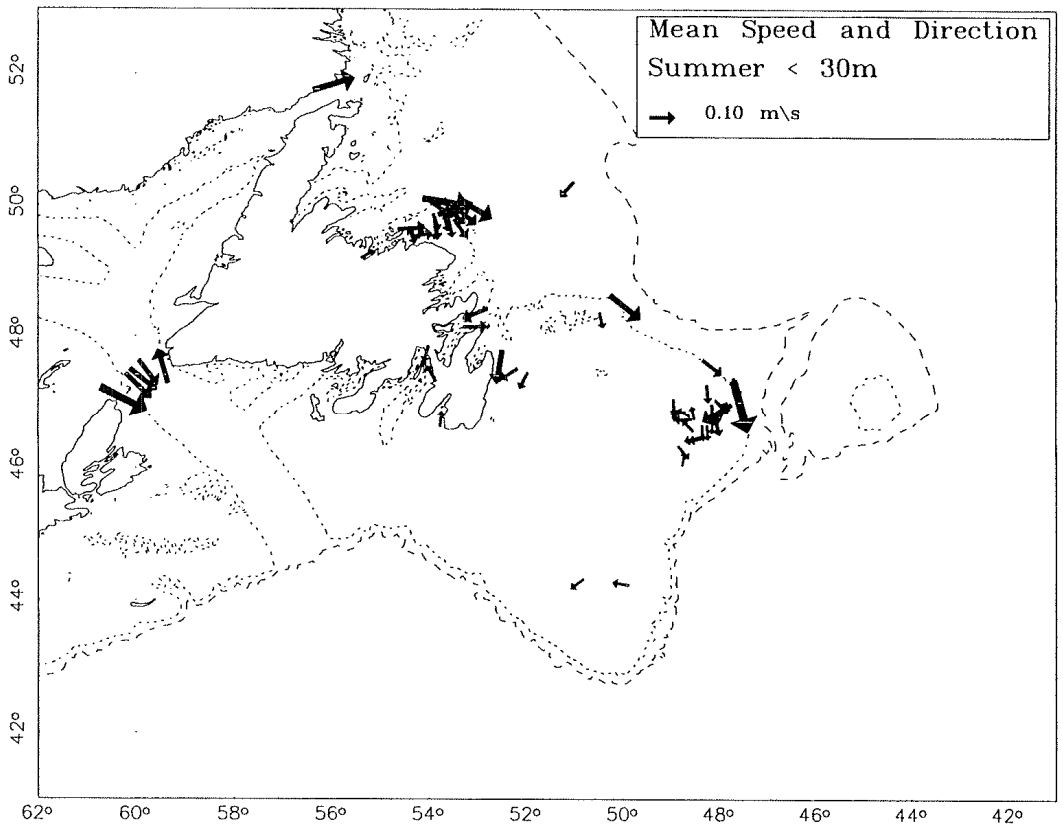
Appendix 5 Seasonal Mean Current Speed and Direction, Grand Banks

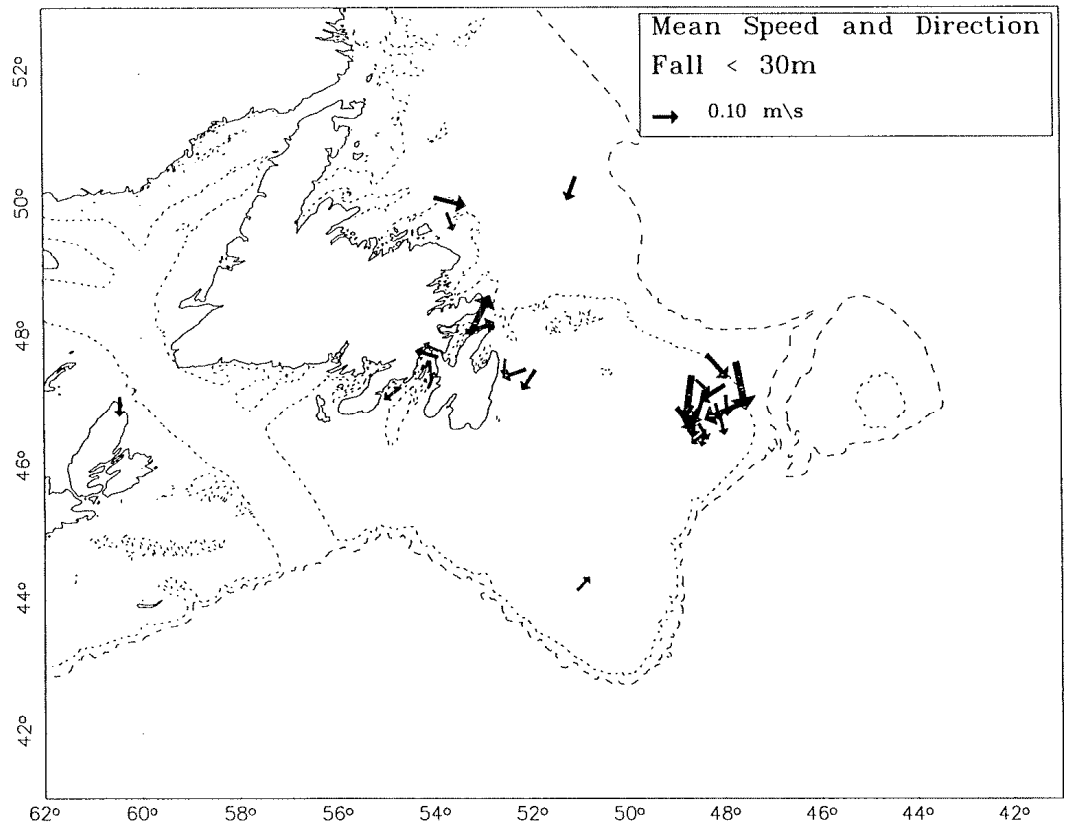
Seasons are defined as:
Winter: January to March,
Spring: April to June,
Summer: July September
Fall: October to December

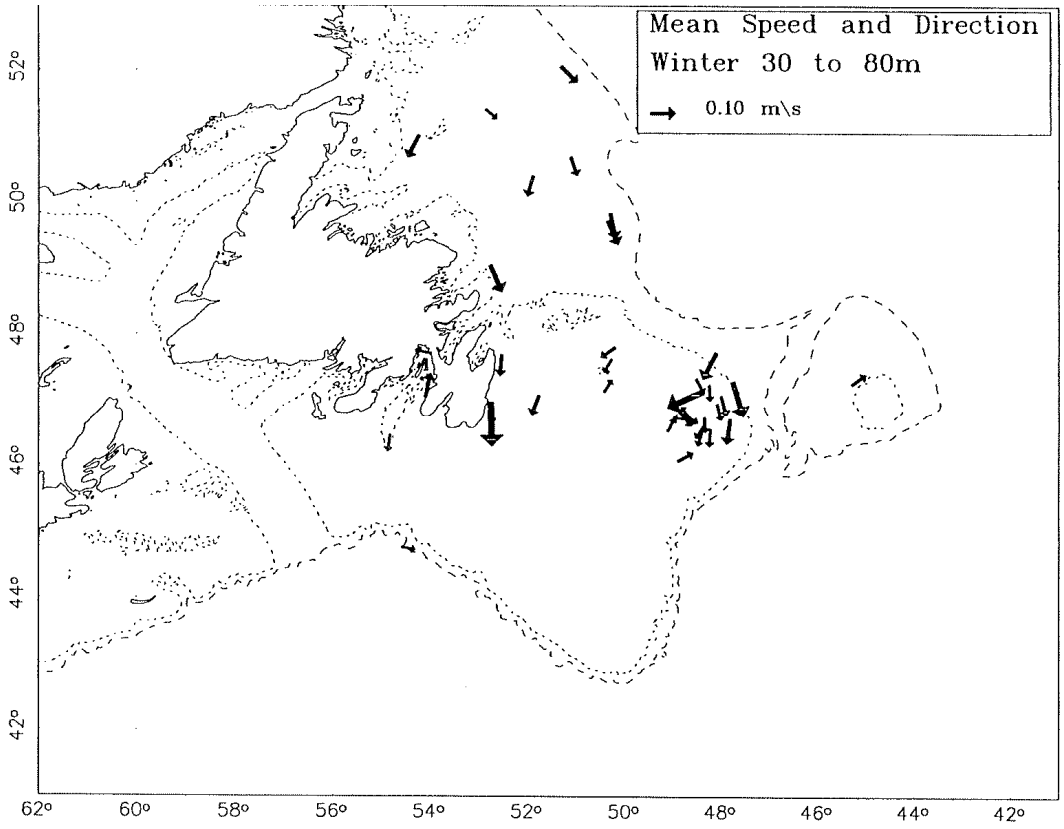
The 200 and 1000 m bathymetric contours are shown. Source: Gregory *et al.* 1996.

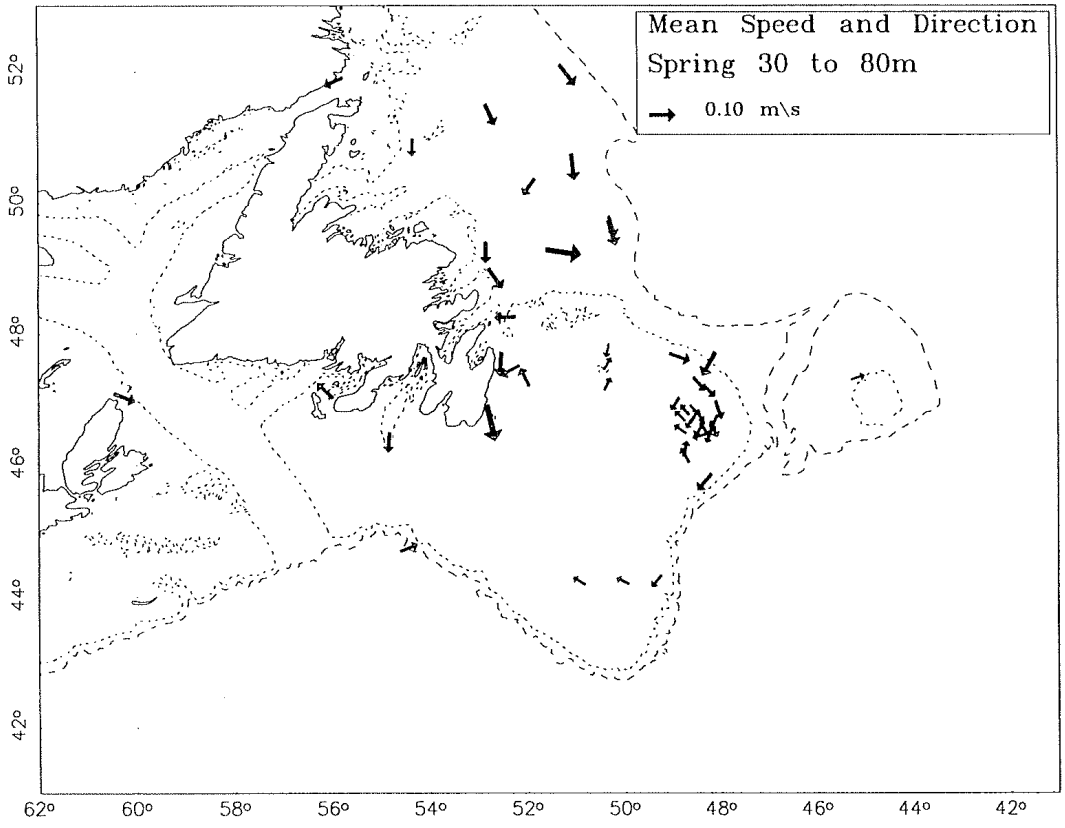

Mean Speed and Direction
Winter < 30m
0.10 m\s
52°
50°
48°
46°
44°
42°
62°
60°
58°
56°
54°
52°
50°
48°
46°
44°
42°

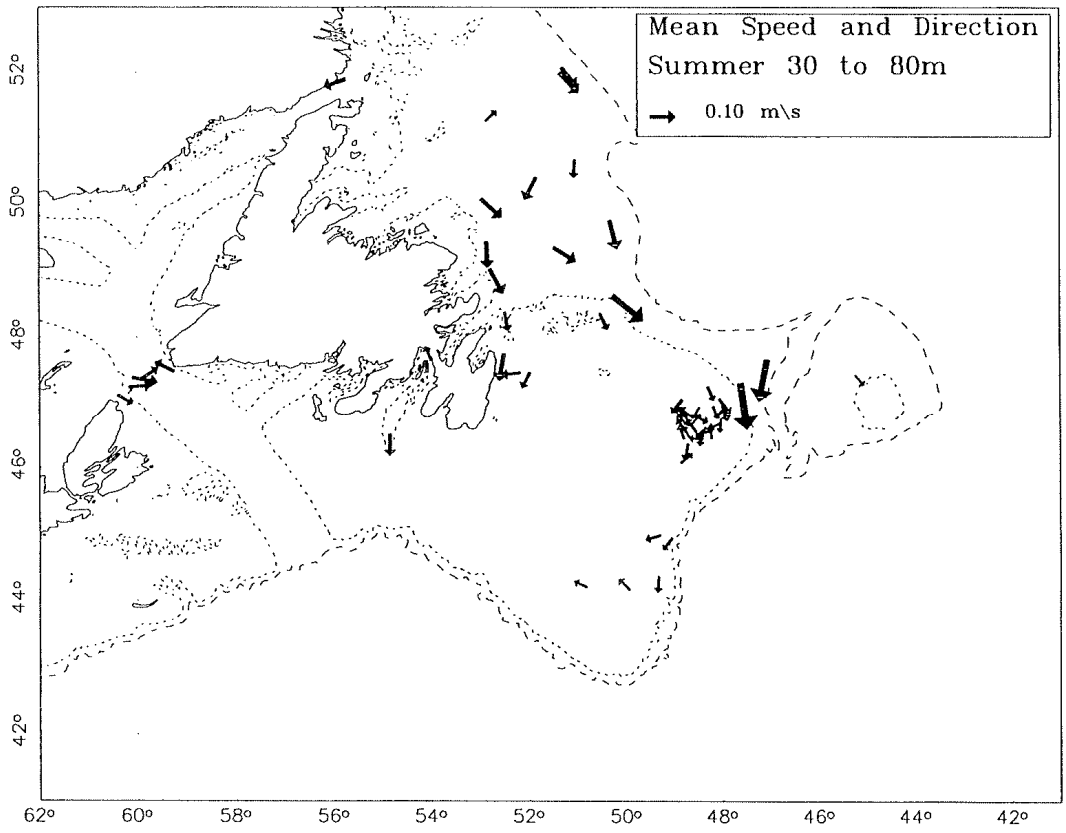

Mean Speed and Direction
Spring < 30m
0.10 m\s
52°
50°
48°
46°
44°
42°
62°
60°
58°
56°
54°
52°
50°
48°
46°
44°
42°

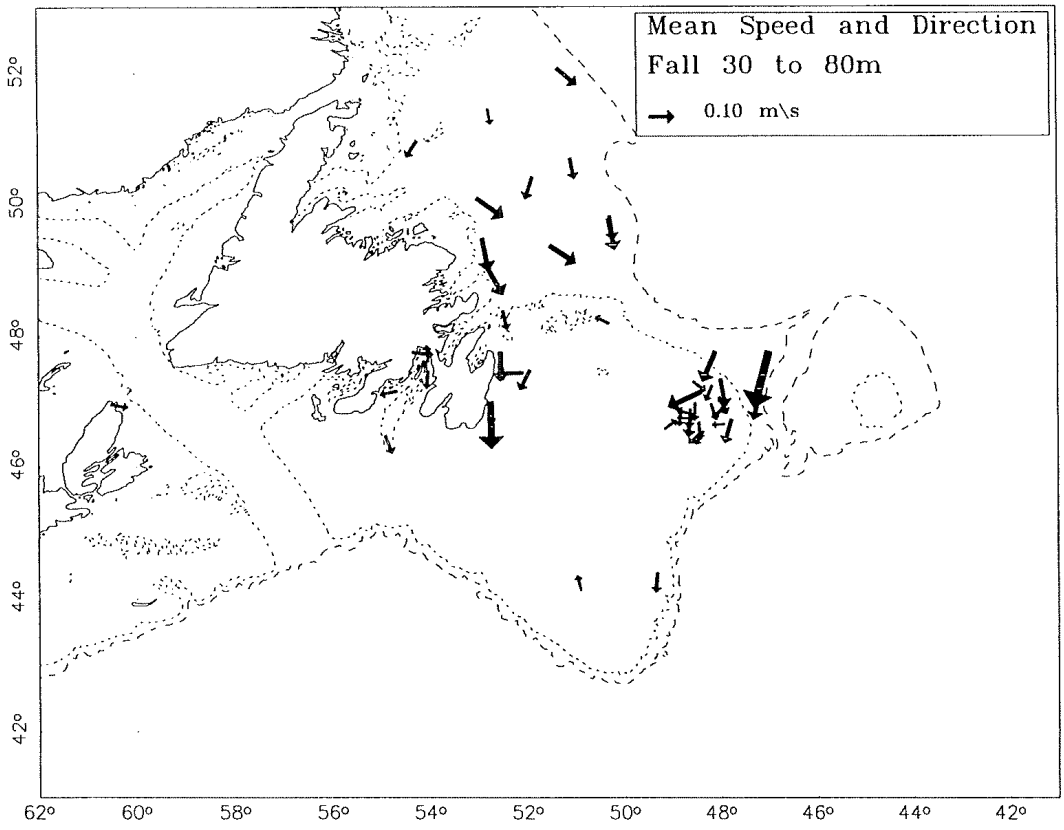

Mean Speed and Direction
Summer < 30m
0.10 m\s
52°
50°
48°
46°
44°
42°
62°
60°
58°
56°
54°
52°
50°
48°
46°
44°
42°

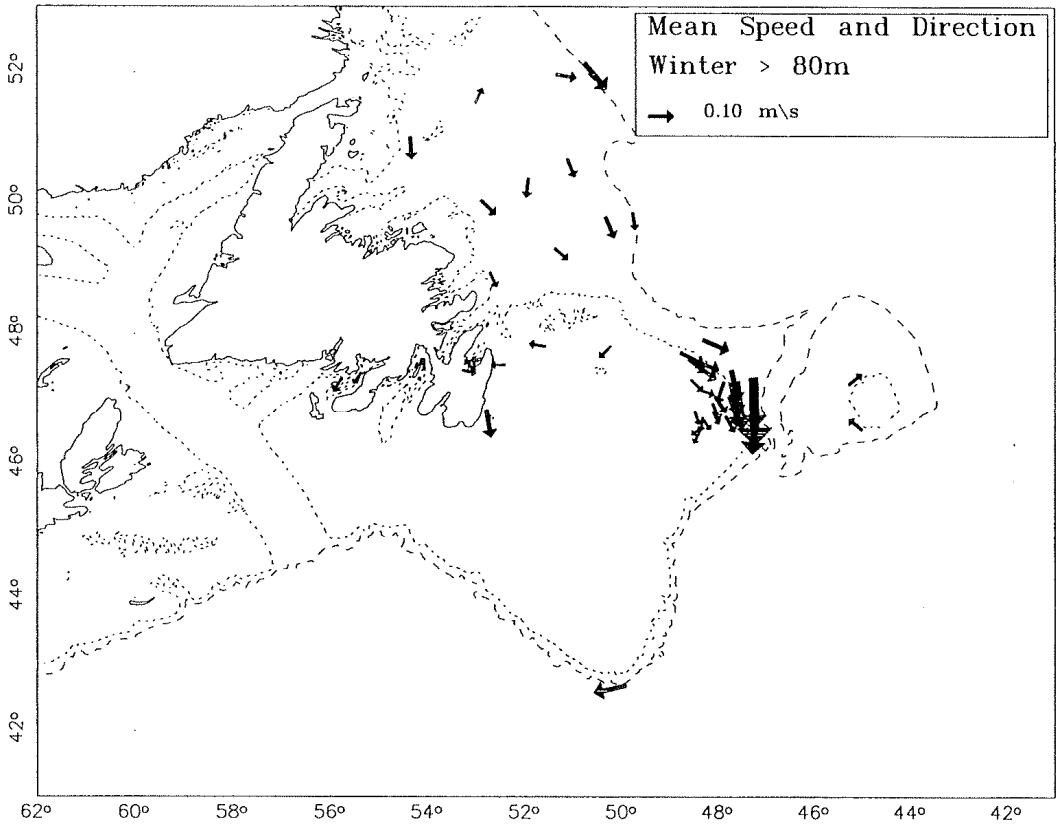

Mean Speed and Direction
Fall < 30m
0.10 m\s
52°
50°
48°
46°
44°
42°
62°
60°
58°
56°
54°
52°
50°
48°
46°
44°
42°

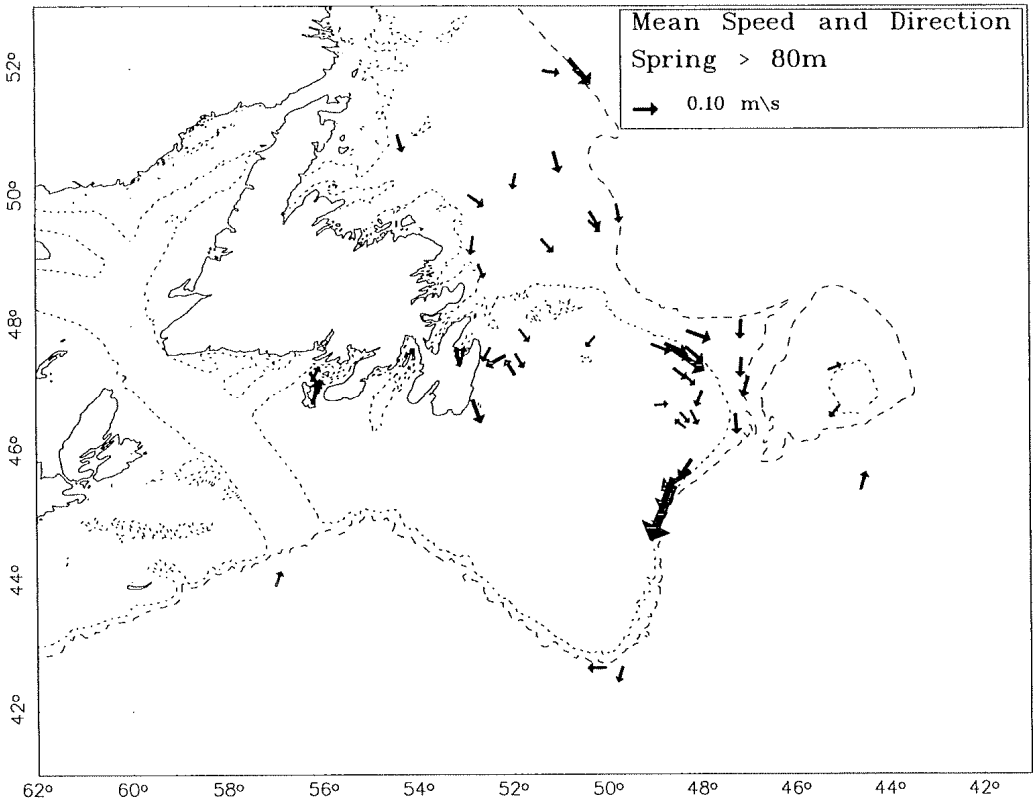

Mean Speed and Direction
Winter 30 to 80m
0.10 m\s
52°
50°
48°
46°
44°
42°
62°
60°
58°
56°
54°
52°
50°
48°
46°
44°
42°

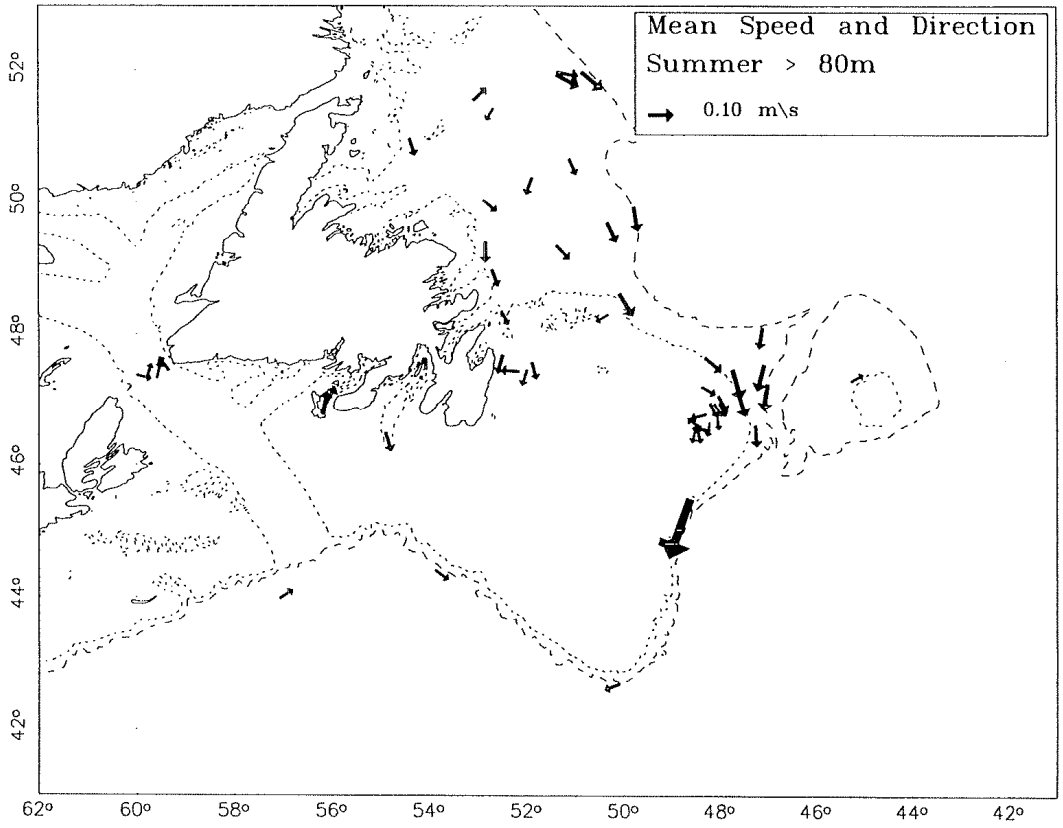

Mean Speed and Direction
Spring 30 to 80m
0.10 m\s
52°
50°
48°
46°
44°
42°
62°
60°
58°
56°
54°
52°
50°
48°
46°
44°
42°

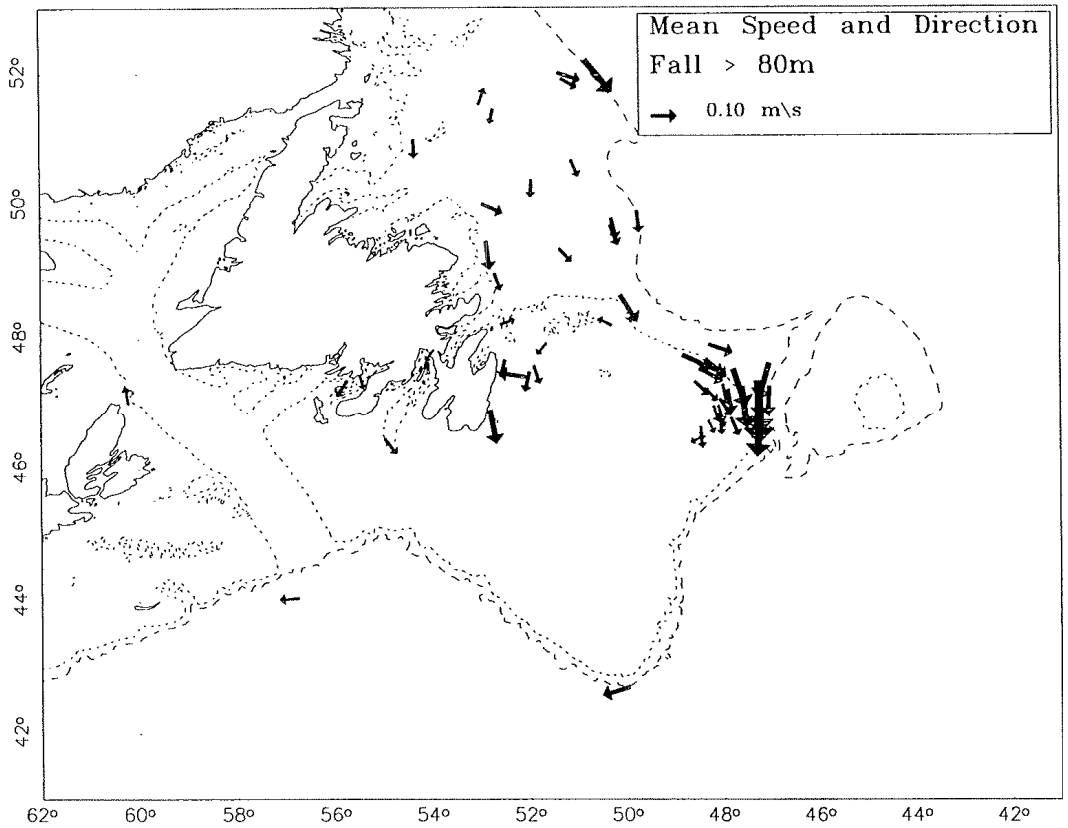

Mean Speed and Direction
Summer 30 to 80m
0.10 m\s
52°
50°
48°
46°
44°
42°
62°
60°
58°
56°
54°
52°
50°
48°
46°
44°
42°

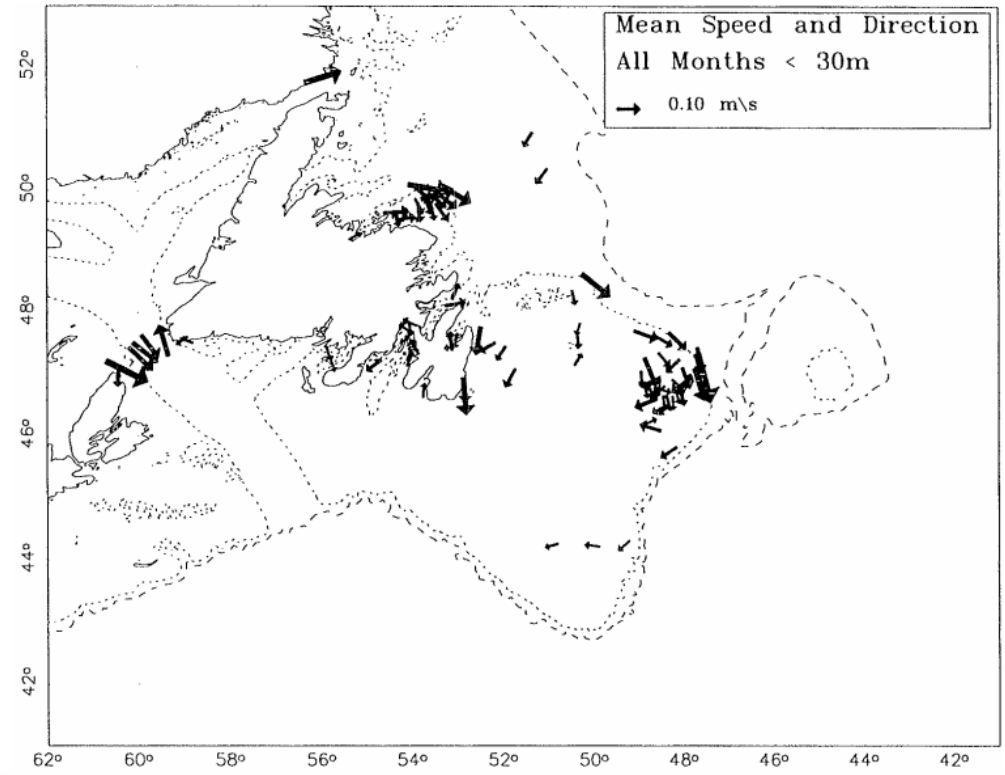

Mean Speed and Direction
Fall 30 to 80m
0.10 m\s
52°
50°
48°
46°
44°
42°
62°
60°
58°
56°
54°
52°
50°
48°
46°
44°
42°

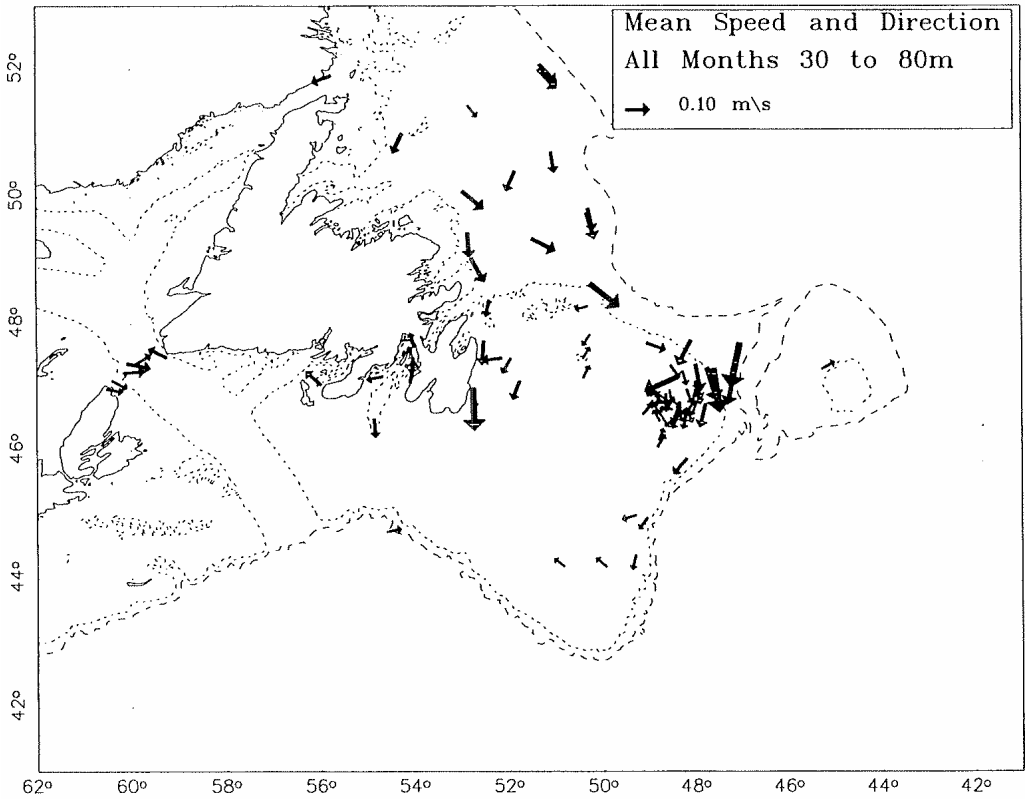

Mean Speed and Direction
Winter > 80m
0.10 m\s
52°
50°
48°
46°
44°
42°
62°
60°
58°
56°
54°
52°
50°
48°
46°
44°
42°

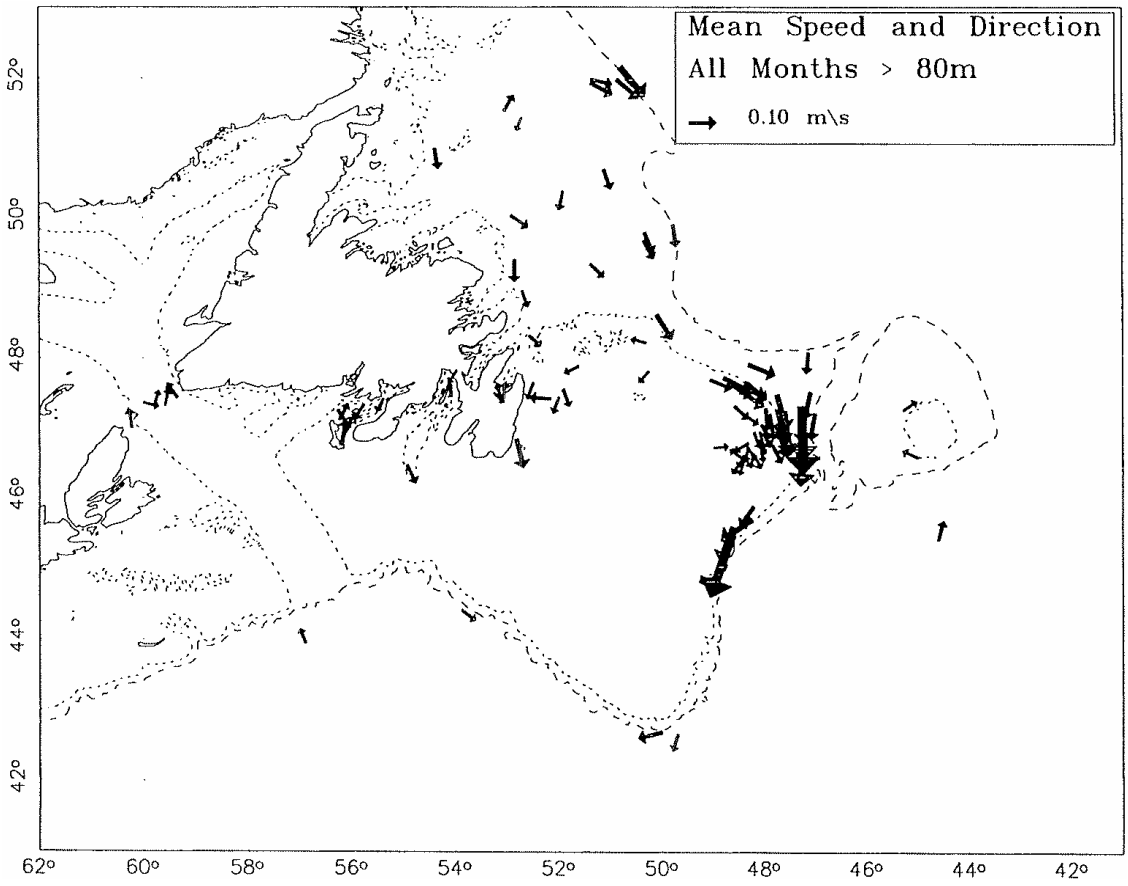

Mean Speed and Direction
Spring > 80m
0.10 m\s
52°
50°
48°
46°
44°
42°
62°
60°
58°
56°
54°
52°
50°
48°
46°
44°
42°


Mean Speed and Direction
Summer > 80m
0.10 m\s
52°
50°
48°
46°
44°
42°
62°
60°
58°
56°
54°
52°
50°
48°
46°
44°
42°


Mean Speed and Direction
Fall > 80m
0.10 m\s
52°
50°
48°
46°
44°
42°
62°
60°
58°
56°
54°
52°
50°
48°
46°
44°
42°


Mean Speed and Direction
All Months < 30m
0.10 m\s
52°
50°
48°
46°
44°
42°
62°
60°
58°
56°
54°
52°
50°
48°
46°
44°
42°


Mean Speed and Direction
All Months 30 to 80m
0.10 m\s
52°
50°
48°
46°
44°
42°
62°
60°
58°
56°
54°
52°
50°
48°
46°
44°
42°


Mean Speed and Direction
All Months > 80m
0.10 m\s
52°
50°
48°
46°
44°
42°
62°
60°
58°
56°
54°
52°
50°
48°
46°
44°
42°