Cacouna Energy

Gros-Cacouna, Quebec

LNG Receiving Terminal

Metocean Summary

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142829

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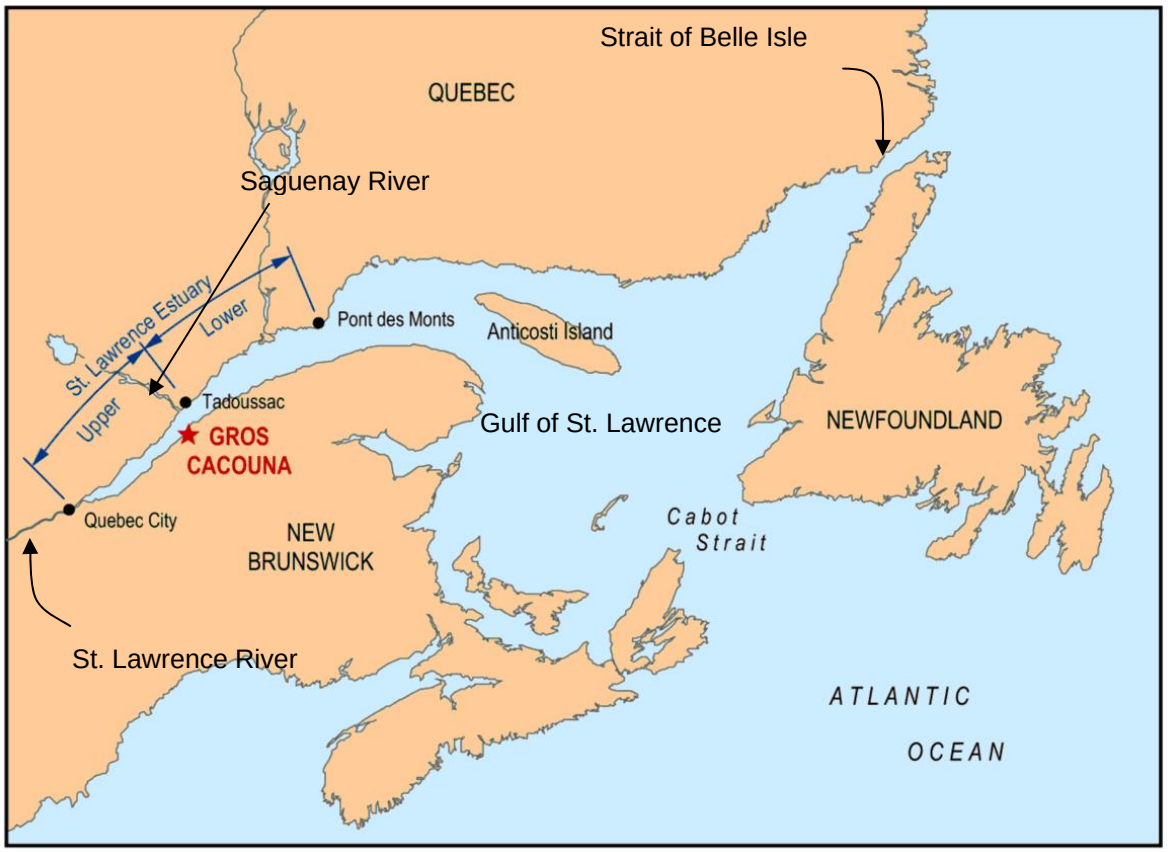
1 General

Cacouna Energy, a joint venture between TransCanada and Petro Canada is planning to build and operate a Liquefied Natural Gas (LNG) receiving terminal at Gros-Cacouna on the south shore of the Saint Lawrence River in Quebec as shown in Figure 1-1.

Figure 1-1 Gros-Cacouna Site Location



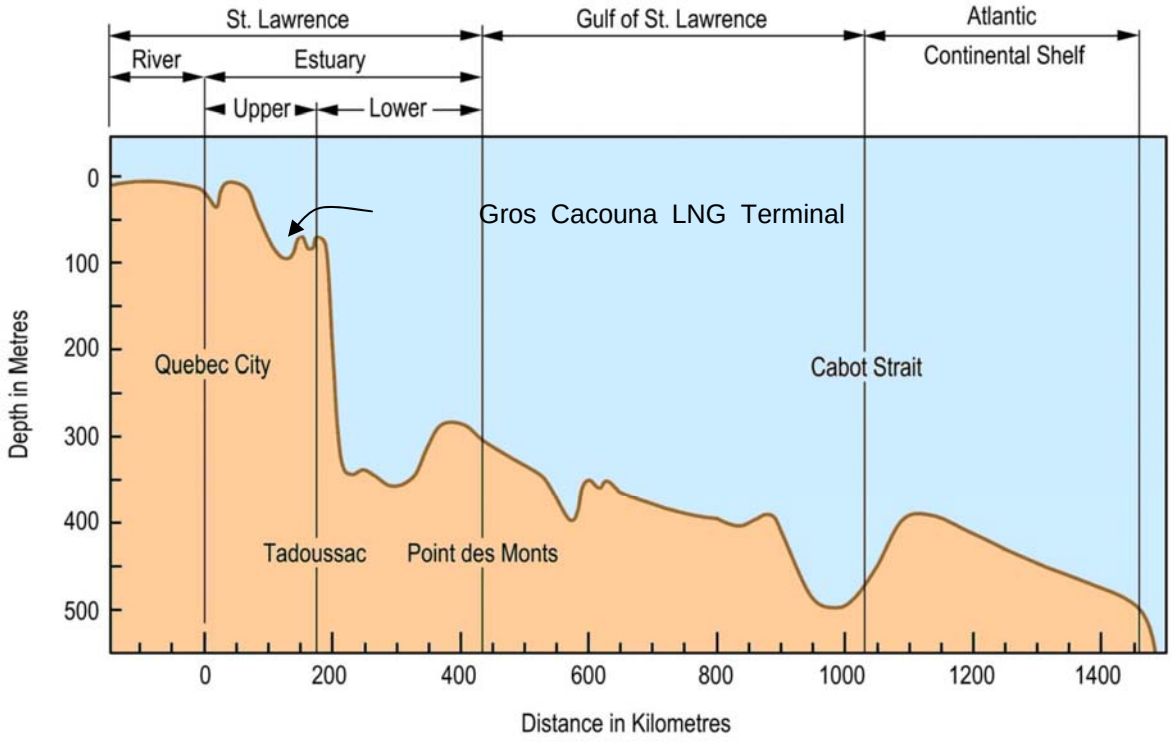
This report discusses the meteorological and oceanographic (metocean) conditions influencing the operation of LNG carriers on the St. Lawrence estuary in the vicinity of Gros-Cacouna.

It is conventional to divide the St. Lawrence waterway into sections based upon its principal oceanographic features. Figure 1-2 shows the limits of the river, estuary and gulf sections at Quebec City and Pont des Monts, respectively. The estuary is further sub-divided into an upper and lower section at Tadoussac.

According to this naming convention, the Cacouna Energy LNG terminal at Gros-Cacouna is located within the Upper St. Lawrence estuary. Gros-Cacouna is also located upstream of the confluence of the Saguenay River with the St. Lawrence estuary.

Figure 1-2 shows a section along the St. Lawrence indicating the depth profile. The abrupt change in depth near Tadoussac is of particular importance in understanding the oceanography of the St. Lawrence near Gros-Cacouna. As indicated on Figure 1-2 Gros-Cacouna is located upstream from the Tadoussac 'step'.

Figure 1-2 Cross-Section along the St. Lawrence



2 Oceanographic Setting

Most of the outflow of Gulf waters into the North Atlantic occurs through the Cabot Strait on the Cape Breton side, while saltier oceanic water flows into the Gulf on the eastern side of the Strait. Relatively fresh water from the St. Lawrence estuary travels along the surface to a depth of 10 to 30 m, while denser oceanic seawater runs from a depth of approximately 125 m to the seabed. The deep waters of the Laurentian Channel are made up of a mixture of waters from the Labrador Current and North Atlantic waters. The thickness of these water layers vary with seasonal stratification according to both temperature and salinity. During the summer, a cold intermediate layer is formed between the surface and the deep layers. This intermediate layer is assimilated into the surface layer during the fall and winter.

The seasonal influx of fresh water in the St. Lawrence estuary is the driving force for a current that extends into the Gulf. The spatial structure of the circulation is largely controlled by rotation and the pronounced bathymetry of the region. There is a general counterclockwise circulation in the eastern interior basin of the Gulf, proceeding north along the Newfoundland coast and west along the north shore of Québec.

Another dominant feature is the Gaspé current, which is a strong surface current flowing eastward from the St. Lawrence estuary along the north shore of the Gaspé Peninsula. This flow continues as a slower drift in the counter-clockwise direction across the Magdalene Shallows and eventually to the Cabot Strait. The current speeds in the Gulf are highly variable; the highest speeds are found in the outflow through Cabot Strait, reaching values of 30 to 50 cm/sec.

The semi-diurnal (two high tides daily) and diurnal (one high tide daily) tides from the North Atlantic Ocean enter Cabot Strait and the Strait of Belle Isle and propagate counterclockwise around the Gulf of St. Lawrence. The range of tides throughout the Gulf is less than 2.4 m. Off the coast of Îles de la Madeleine, the range of semi-diurnal tides is about 0.2 m, and along the north coast of Prince Edward Island it is 0.3 m. In Cabot Strait and in the northern and eastern parts of the Gulf, the range is 0.9 m.

In addition to tidal influences, pronounced increases in water levels along ocean coasts may be associated with the passage of storms. Pronounced decreases in water levels may be associated with offshore winds and high-pressure systems.

Throughout the open areas in the Gulf, tidal currents seldom exceed 30 cm/s, with the exception of the St. Lawrence estuary, the Cabot Strait, the Northumberland Strait, the Strait of Belle Isle, and other locally confined regions. The tidal streams through Cabot Strait are typically 30 cm/s.

Tides in the St. Lawrence are semi-diurnal. The crest of the tide takes about one hour to travel to the mouth of the Saguenay River (Sept Îles) and about five hours to travel to the vicinity of Quebec City. The range of the tide increases from about 2.1 m at Sept Îles to about 4.2 m in the vicinity of Quebec City, upstream of which the tide starts to diminish.

The tidal curve in the St. Lawrence River exhibits various peculiarities attributable to the narrowing and the slope of the river bed, as well as increasing friction, especially above Quebec City. One of these peculiarities is that the tide, as in many other river estuaries, rises faster than it falls, i.e., the time from low water to high water is much shorter than the time from high water to low water. The river profile approaching a high tide maintains almost the same absolute height, while the river profile approaching a low tide shows a considerable slope downstream.

2.1 Tides

Tidal data for the vicinity of Gros-Cacouna is shown in Table 2-1.

Table 2-1 Tidal Data for Gros-Cacouna

Locality	Gros-Cacouna		
Reference Port	Pointe-Au-Pére		
CHS Chart No.	1234,1235		
Type of Tide	Semi-diurnal		
Range	Mean Tide		3.7 m
	Large Tide		5.3 m
Height	Higher High Water	Mean Tide	4.5 m
		Highest Tide	5.5 m
	Lower Low Water	Mean Tide	0.8 m
		Lowest Tide	0.2 m
Extremes Recorded	Extreme High Water		5.9 m
	Extreme Low Water		-0.8 m
Mean Water Level			2.6 m

All heights are calculated in reference to chart datum.

2.1.1 Sea-Level Rise at Gros-Cacouna

Sea-level rise due to global warming is a part of the overall design water level used for the Gros-Cacouna project. Gros-Cacouna is located in the St. Lawrence Estuary, over 150 km downstream from the end of the St. Lawrence River at Quebec. Near Gros-Cacouna the Estuary is approximately 20 km wide with water depths up to 300 m. As a result, Gros-Cacouna water levels are expected to be controlled by ocean effects and only minimally influenced by river effects.

The UN Intergovernmental Panel on Climate Change (IPCC) has estimated the potential sea level rise based on various possible scenarios. All estimates are quite similar at 2050 with sea level rise near 20 cm. Based on the 30-year design lifetime of the Gros-Cacouna facility; 20 cm would appear to be a reasonable and conservative estimate of sea level rise for design purposes.

Although government studies have suggested that water levels in the Great Lakes could fall by 0.5 to 1 m or more on average and that the amount of water flowing out of the St. Lawrence River could be reduced by up to 20% within the next 30 years, this effect would not be significant below Quebec due to the hydraulics of the controlled outlet from Lake Ontario and those of the St. Lawrence River. In effect, the Great Lakes changes would have no effect on the water level at Gros-Cacouna which is located well within the Estuary.

The assumed sea-level rise is combined with the maximum (extreme) wave and the highest astronomical tide (HAT) to derive the design water level. This combination of maximum cases is assumed to be quite conservative due to the low probability of coincident extreme waves and HAT. The sea-level rise is a systematic addition to these water level components but of relatively small overall magnitude.

2.2 Currents

The currents in the St. Lawrence estuary near Gros-Cacouna are complicated due to a combination of tidal influences, the inflow from the Saguenay River, and the islands Ile aux Lievres upstream and Ile Verte downstream. As a result, Gros-Cacouna is subject to a rather complicated, spatially varying, tidal current pattern.

Detailed current modelling, performed operationally for the St. Lawrence in the vicinity of Gros-Cacouna, has been consulted as a general guide to current patterns.

Figure 2-1 shows a typical surface current pattern from this modelling during ebb. Figure 2-2 shows a corresponding typical surface current pattern during the flood. Both are seen to involve a complicated spatial interaction with the Saguenay River outflow particularly over the central part of the St. Lawrence River. The current direction and magnitude vary significantly over relatively short distances. Closer to Gros-Cacouna, and presumably in the region protected by Ile aux Lievres and Ile Verte, the current velocity is much smaller than in the main channel and the direction of flow deviates much less from parallel to the general shoreline trend.

Figure 2-1 Typical Surface Current Pattern In The Vicinity of the Saguenay River and Gros-Cacouna during Ebb

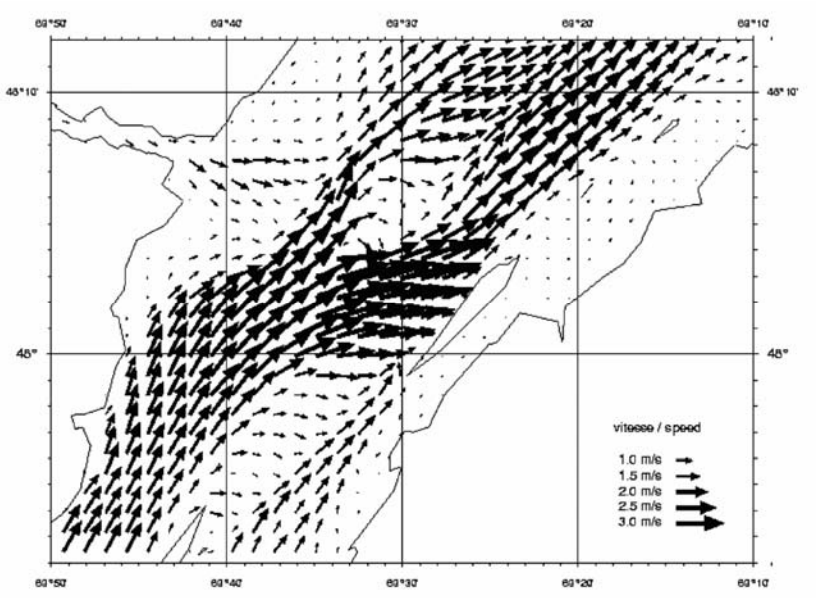
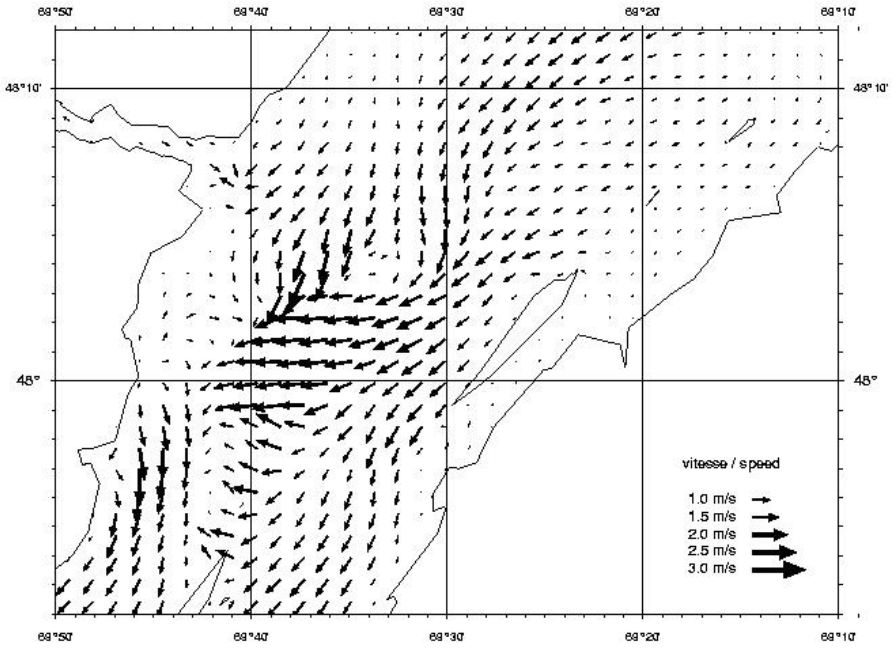


Figure 2-2 Typical Surface Current Pattern during Flood



An ADCP monitoring program (Ref. 1) during 2005 has provided direct measurement of currents in the vicinity of the proposed terminal. Figure 2-3 shows the location of the ADCP and the polar distribution of mean and maximum current speed and direction. The alignment of currents is approximately parallel to the local depth contours and agrees closely with the proposed berth alignment. The tidal current is somewhat stronger during ebb than during flood.

Figure 2-4 shows the seasonal variation of near surface current measured by the ADCP. The surface current pattern varied relatively little throughout the year. The alignment of the main current action is similar at all times with no evidence of a strong influence of varying river flows. Figure 2-5 shows the variation of current speed, particularly the mean and maximum, throughout the year. The maximum current speed observed is approximately 160 cm/s.

Detailed current scatter diagrams are shown in Table 2-3,

Table 2-2 and Table 2-4 for the near surface, mid depth and near bottom cases, respectively.

Figure 2-3 Current Distribution at the Gros-Cacouna Berth

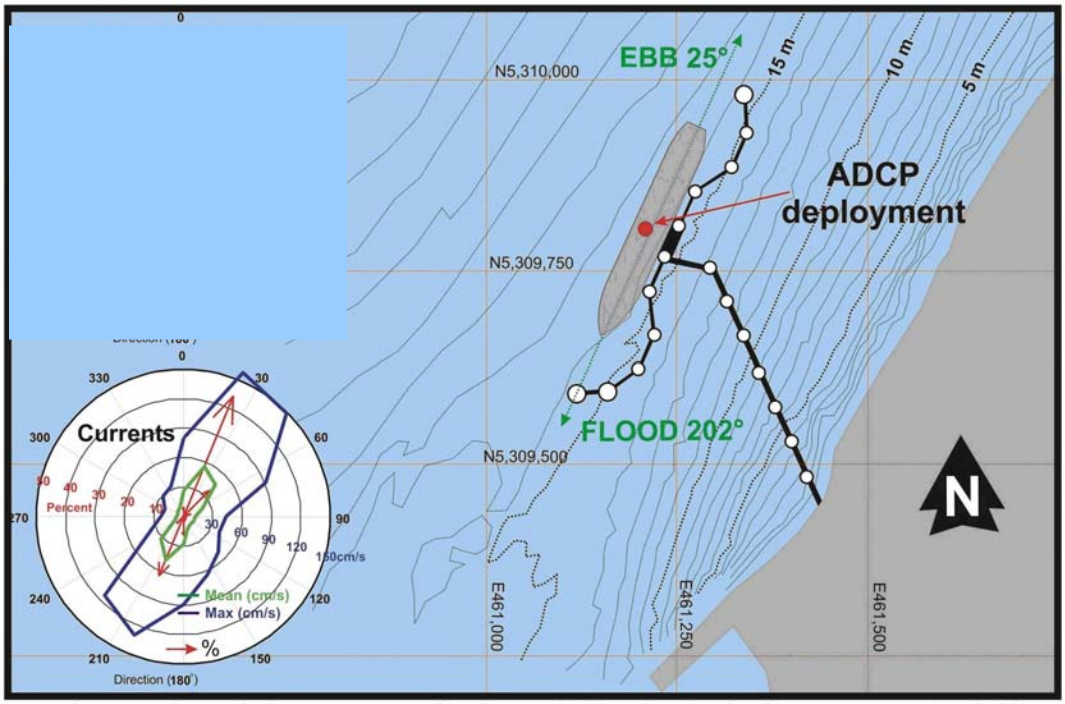


Figure 2-4 Seasonal Polar Plots of Near-Surface Current Obtained With ADCP

C.1 Seasonal Compass Plots

Near-Surface

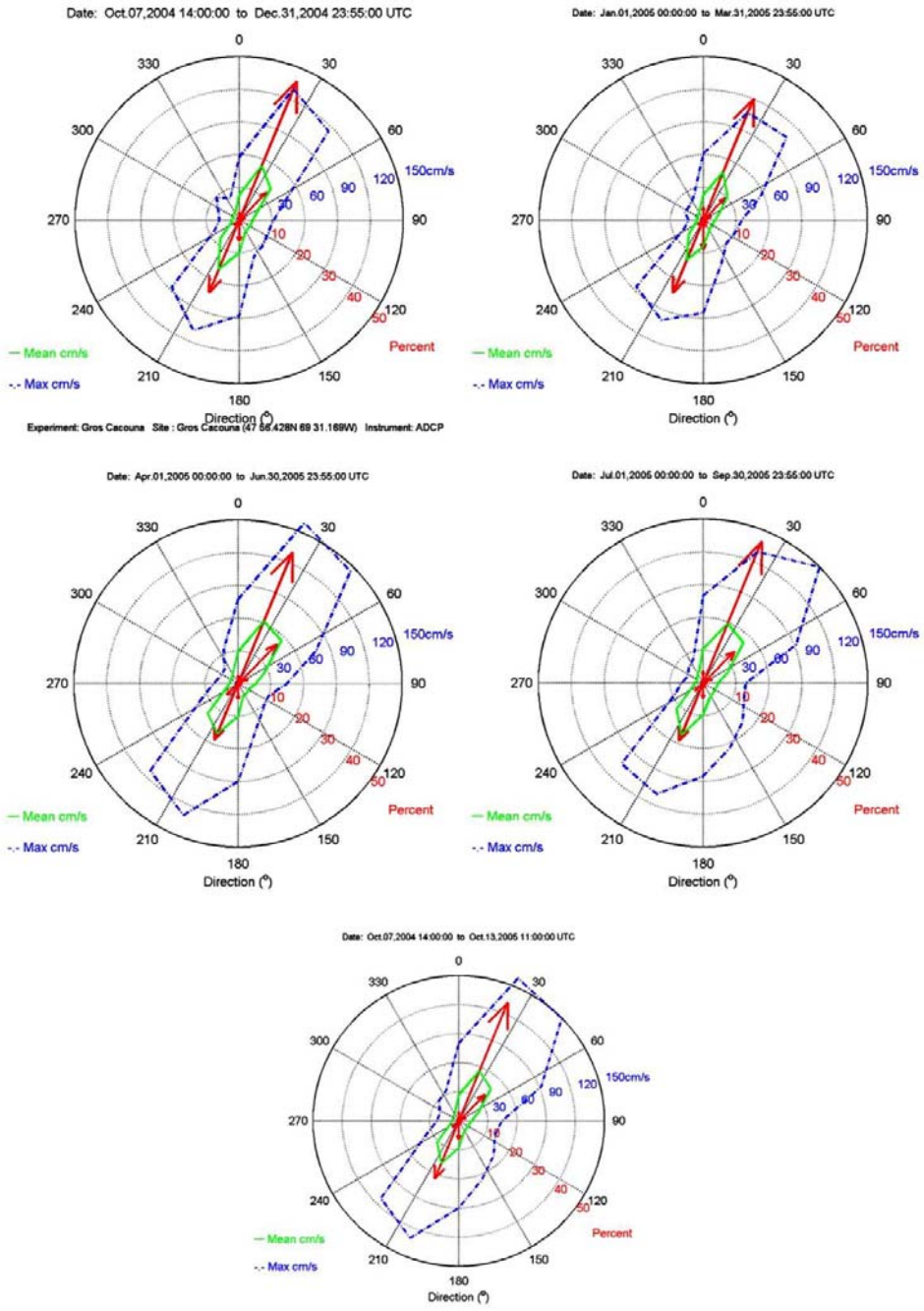


Figure 2-5 Seasonal Variation of Near- Surface Major Component Current Speed at Gros-Cacouna Measured with ADCP

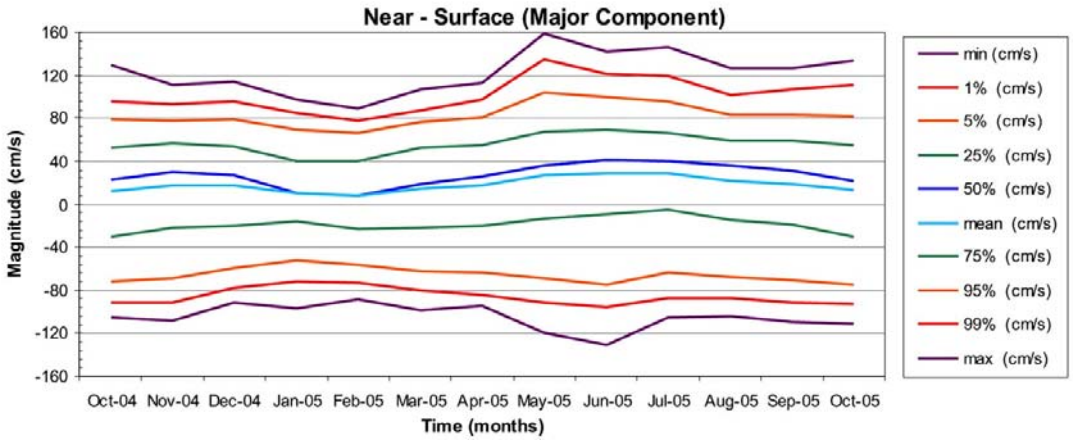


Table 2-2 Current Scatter Diagram at Mid Depth

Location: Gros Cacouna (47 56.428N 69 31.169W) at site Gros Cacouna
Instrument: ADCP
For period: Oct.07,2004 14:00:00 to Oct.13,2005 11:00:00 UTC Sample Interval: 5 min

		Speed (cm/s)																
Direction (deg)		0 to 10	10 to 20	20 to 30	30 to 40	40 to 50	50 to 60	60 to 70	70 to 80	80 to 90	90 to 100	100 to 110	110 to 120	120 to 130	130 to 140	140 to 150	150 to 160	Row Total (%)
11.25	33.75 NNE	0.61	2.48	5.20	6.73	6.25	4.32	2.51	1.12	0.44	0.14	0.04						29.85
33.75	56.25 NE	0.61	1.72	3.43	5.52	5.62	3.21	1.13	0.38	0.04	0.00							21.68
56.25	78.75 ENE	0.44	0.93	0.93	0.36	0.09	0.00											2.75
78.75	101.25 E	0.38	0.72	0.27	0.01													1.38
101.25	123.75 ESE	0.37	0.62	0.12	0.00													1.12
123.75	146.25 SE	0.37	0.71	0.16	0.00													1.25
146.25	168.75 SSE	0.42	0.91	0.52	0.05	0.00												1.90
168.75	191.25 S	0.48	1.27	1.72	1.44	0.77	0.27	0.11	0.04	0.00								6.09
191.25	213.75 SSW	0.58	1.76	2.84	3.92	4.19	4.34	3.67	2.33	1.31	0.54	0.13	0.01	0.00				25.63
213.75	236.25 SW	0.51	0.79	0.55	0.36	0.16	0.07	0.07	0.06	0.01	0.01	0.00	0.00					2.60
236.25	258.75 WSW	0.36	0.20	0.01														0.56
258.75	281.25 W	0.27	0.05	0.00														0.32
281.25	303.75 WNW	0.26	0.05															0.30
303.75	326.25 NW	0.29	0.05															0.34
326.25	348.75 NNW	0.41	0.24	0.03	0.00													0.69
348.75	11.25 N	0.54	1.20	1.11	0.45	0.15	0.07	0.02	0.00									3.55
Column Total (%)		6.90	13.70	16.91	18.85	17.23	12.29	7.52	3.92	1.81	0.69	0.18	0.01	0.00	0.00	0.00	0.00	

No. of Non-Flagged Records: 106232 No. of Flagged Recs: 581
Max. Speed : 121 cm/s Filename: gc_mid_all_5min_spd_ed1.dat
Mean Speed : 37.9 cm/s
Vector-averaged Speed: 7.79 cm/s at 58.0 deg

Table 2-3 Current Scatter Diagram near Surface

Location: Gros Cacouna (47 56.428 N 69 31.169 W) at site Gros Cacouna
Instrument: ADCP
For period: Oct.07,2004 14:00:00 to Oct.13,2005 11:00:00 UTC Sample Interval: 5 min

	Speed (cm/s)																
Direction (deg)	0 to 10	10 to 20	20 to 30	30 to 40	40 to 50	50 to 60	60 to 70	70 to 80	80 to 90	90 to 100	100 to 110	110 to 120	120 to 130	130 to 140	140 to 150	150 to 160	Row Total (%)
11.25 33.75 NNE	0.66	2.06	3.09	4.83	6.88	8.07	7.72	5.53	2.68	1.32	0.65	0.30	0.15	0.06	0.04	0.01	44.06
33.75 56.25 NE	0.67	1.59	1.88	1.85	1.75	1.42	1.00	0.82	0.64	0.52	0.31	0.15	0.10	0.03	0.02		12.76
56.25 78.75 ENE	0.56	0.79	0.70	0.28	0.11	0.07	0.04	0.02	0.00	0.00							2.56
78.75 101.3 E	0.49	0.47	0.20	0.03	0.00												1.19
101.3 123.8 ESE	0.46	0.33	0.09	0.01													0.88
123.8 146.3 SE	0.52	0.38	0.07	0.01	0.00	0.00											0.99
146.3 168.8 SSE	0.63	0.62	0.20	0.03	0.01	0.00	0.00										1.50
168.8 191.3 S	0.68	1.74	1.59	0.98	0.62	0.47	0.18	0.05	0.01								6.32
191.3 213.8 SSW	0.66	1.96	2.95	3.17	3.26	3.15	2.73	1.79	1.12	0.56	0.14	0.02	0.01	0.00			21.53
213.8 236.3 SW	0.46	0.78	0.63	0.36	0.25	0.19	0.12	0.11	0.09	0.06	0.02	0.01					3.06
236.3 258.8 WSW	0.34	0.22	0.02	0.00													0.58
258.8 281.3 W	0.27	0.05	0.00														0.32
281.3 303.8 WNW	0.24	0.05	0.00														0.29
303.8 326.3 NW	0.26	0.06	0.00														0.33
326.3 348.8 NNW	0.34	0.24	0.03	0.00													0.61
348.8 11.25 N	0.50	0.71	0.59	0.55	0.41	0.16	0.07	0.03	0.00								3.03
Column Total (%)	7.74	12.04	12.03	12.11	13.29	13.55	11.87	8.34	4.54	2.46	1.12	0.48	0.27	0.09	0.06	0.01	

No. of Non-Flagged F 1E+05 No. of Flagged Record 581
Max. Speed : 159.1 cm/s Filename: gc_ns_all_5min_ed2.dat
Mean Speed : 45.34 cm/s
Vector-averaged Spee 18.68 cm/s at 33.3 deg

Table 2-4 Current Scatter Diagram near Bottom

Location: Gros Cacouna (47 56.428 N 69 31.169 W) at site Gros Cacouna
Instrument: ADCP
For period: Oct.07,2004 14:00:00 to Oct.13,2005 11:00:00 UTC Sample Interval: 5 min

	Speed (cm/s)																
Direction (deg)	0 to 10	10 to 20	20 to 30	30 to 40	40 to 50	50 to 60	60 to 70	70 to 80	80 to 90	90 to 100	100 to 110	110 to 120	120 to 130	130 to 140	140 to 150	150 to 160	Row Total (%)
11.25 33.75 NNE	1.13	2.72	2.81	2.63	2.06	1.17	0.3	0.05	0								12.88
33.75 56.25 NE	0.94	2.88	4.67	5.36	3.3	1.21	0.23	0.01	0								18.59
56.25 78.75 ENE	0.67	1.43	1.86	1.35	0.53	0.03											5.86
78.75 101.25 E	0.52	0.77	0.64	0.17	0.02												2.12
101.25 123.75 ESE	0.4	0.67	0.43	0.05	0												1.54
123.75 146.25 SE	0.37	0.73	0.55	0.05	0												1.69
146.25 168.75 SSE	0.42	0.78	1.1	0.46	0.07	0											2.84
168.75 191.25 S	0.48	0.95	1.69	2.11	1.78	0.97	0.3	0.04									8.32
191.25 213.75 SSW	0.62	1.41	2.27	3.53	4.44	4.35	3.15	1.23	0.41	0.06	0						21.49
213.75 236.25 SW	0.82	1.74	1.7	1.32	1.06	0.65	0.37	0.13	0.05	0							7.83
236.25 258.75 WSW	0.84	0.98	0.34	0.07	0.01												2.24
258.75 281.25 W	0.81	0.63	0.09	0.01													1.53
281.25 303.75 WNW	0.82	0.61	0.1	0													1.53
303.75 326.25 NW	0.85	0.82	0.25	0.06	0												1.98
326.25 348.75 NNW	1.03	1.62	0.71	0.21	0.03	0.01											3.61
348.75 11.25 N	1.07	2.12	1.66	0.81	0.24	0.05											5.95
Column Total (%)	11.79	20.85	20.86	18.21	13.53	8.43	4.35	1.46	0.46	0.07	0	0	0	0	0	0	

No. of Non-Flagged Records: 105232 No. of Flagged Reco 581
Max. Speed : 101.1 cm/s Filename: gc_ab_all_5min_ed2.dat
Mean Speed : 30.39 cm/s
Vector-averaged Speed: 4.69 cm/s at 160.8 deg

2.3 Salinity

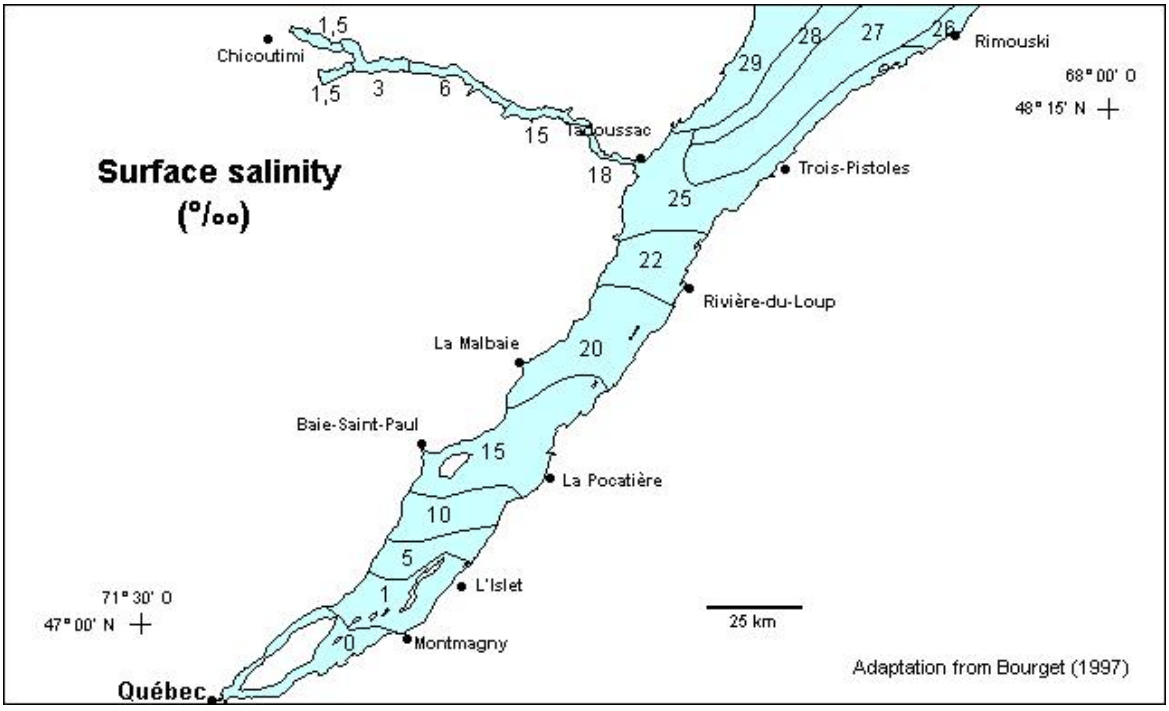
The salinity of the St. Lawrence River is governed by the mixing of saline sea water with fresh water contributions from the entire St. Lawrence watershed.

As with other oceanographic features of the St. Lawrence, a significant change in salinity occurs in the vicinity of the Saguenay River inflow and the abrupt depth change near Tadoussac. Further seasonal and inter-annual variations of salinity occur as a result of changing inflow to the St. Lawrence system.

The spatial variation of salinity is shown in Figure 2-6. Note that for the Lower St. Lawrence estuary the salinity varies spatially and temporally significantly more than for the upper estuary. For design purposes it is reasonable to assume a constant salinity of 22 $^{0/00}$ for Gros-Cacouna. Koutitonsky and Noel (1976) provide results for salinity in the St. Lawrence estuary and near Gros-Cacouna confirming these results.

The vertical variation of salinity over the typical draft depth of ships is not a concern at the Gros-Cacouna LNG terminal location.

Figure 2-6 Distribution of Surface Salinity along the St Lawrence

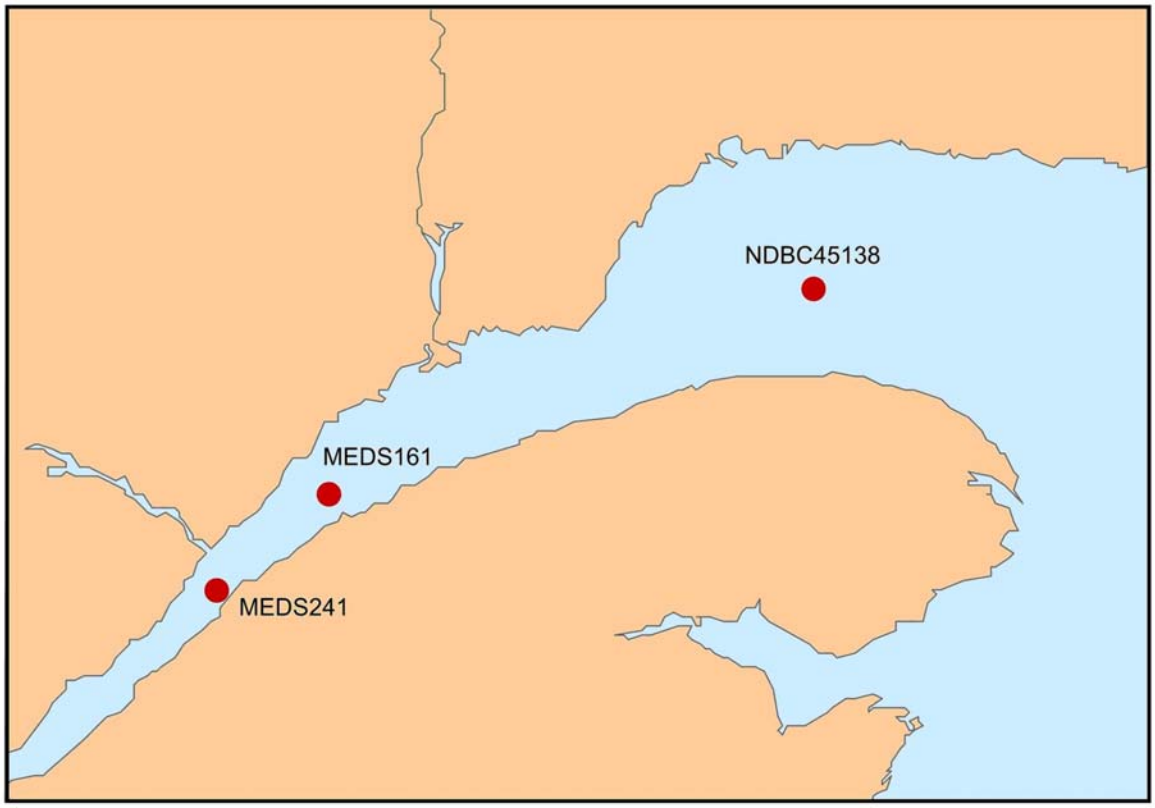


2.4 Waves

A relatively complete understanding of waves exists for the Gulf of St. Lawrence and adjoining regions of the Cabot Strait and Atlantic Ocean. In contrast, the data available for the St. Lawrence Estuary is quite sparse. Limited seasonal programs have been provided data for various locations along the St Lawrence. None of this data is sufficient to allow direct analysis of the operational or extreme wave climate for Gros-Cacouna.

Figure 2-7 shows the locations of three buoys (NDBC45138, MEDS161 and MEDS241) that provide wave data relevant to the approaches to Gros-Cacouna. The maximum significant wave heights decrease from about 6 m at NDBC45138 to about 3 to 4 m at MEDS161. At the MEDS241 buoy, the closest to Gros-Cacouna, the maximum waves are down to about 1.5 m, although it is possible that the buoy may be too sheltered to be really representative of the approaches to Gros-Cacouna.

Figure 2-7 Locations of Some Relevant Wave Buoys



Concurrent with the current measurement program, the ADCP measured wave height, period and direction (Ref. 1). Figure 2-8 shows the location of the ADCP and a polar distribution of wave height and direction. The predominant directions for large waves are from the N and NW.

Table 2-5 through Table 2-8 show seasonal scatter diagrams for significant wave height and mean wave direction. Table 2-9 through Table 2-12 show the corresponding seasonal scatter diagrams for significant height and peak period. Table 2-13 shows the annual scatter for these parameters. Figure 2-9 and Figure 2-10 show the monthly variation of significant wave height and peak period.

Figure 2-8 Current and Wave Polar Distribution with Proposed Gros-Cacouna Berth

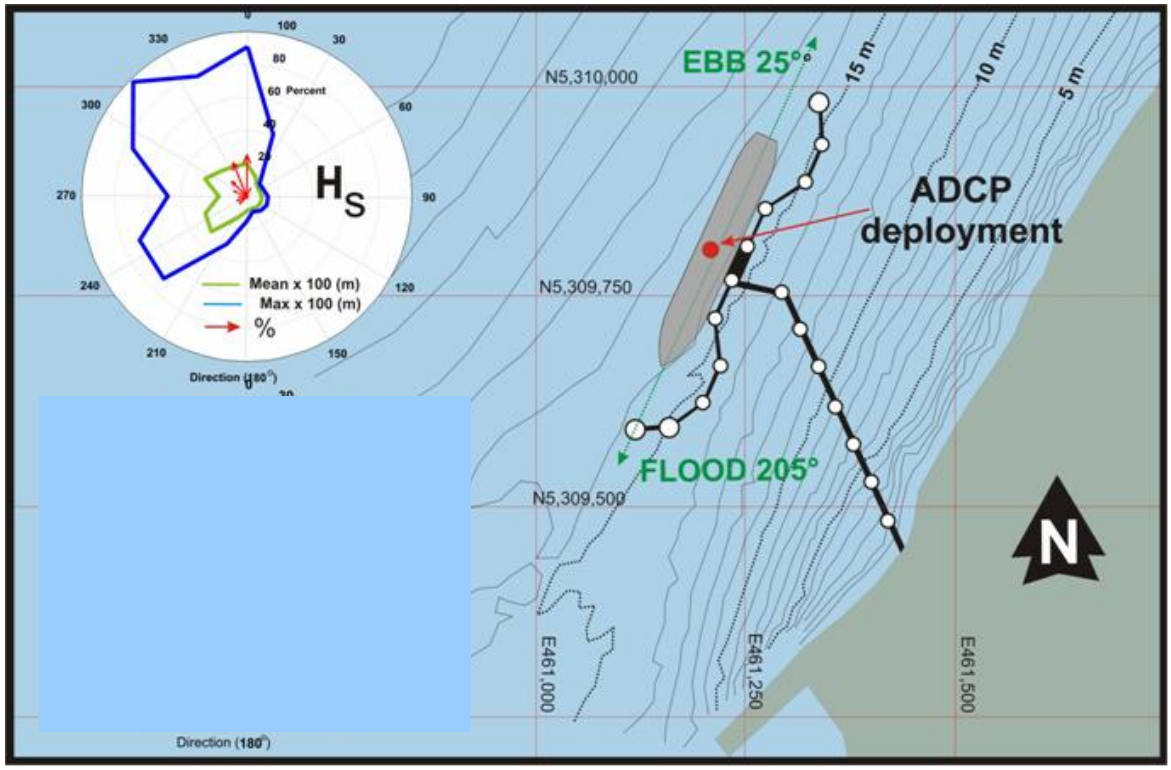


Table 2-5 Autumn Hs MWD Scatter Diagram

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP 2610
For period: Oct 07, 2004 15:00:00 to Dec 31, 2004 23:55:00 UTC Sample Interval: 5 min

		Hs (m)																
Direction (deg)		0 to 0.2	0.2 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1	1 to 1.2	1.2 to 1.4	1.4 to 1.6	1.6 to 1.8	1.8 to 2	2 to 2.2	2.2 to 2.4	2.4 to 2.6	2.6 to 2.8	2.8 to 3	3 to 3.2	Row Total (%)
11.25	33.75 NNE	2.36	0.46	0.07	0.02													2.92
33.75	56.25 NE	1.46	0.22	0.03														1.71
56.25	78.75 ENE	1.54	0.28	0.07	0.01													1.91
78.75	101.25 E	1.49	0.31	0.05	0.01													1.86
101.25	123.75 ESE	1.42	0.29	0.04	0.01													1.76
123.75	146.25 SE	1.30	0.23	0.04														1.57
146.25	168.75 SSE	1.76	0.27	0.04	0.01													2.08
168.75	191.25 S	1.72	0.34	0.05	0.01													2.13
191.25	213.75 SSW	1.85	0.59	0.06	0.01													2.52
213.75	236.25 SW	2.48	2.61	2.20	0.74	0.47	0.28	0.06	0.05	0.03								8.93
236.25	258.75 WSW	3.42	3.90	1.59	0.52	0.03	0.09	0.15	0.01									9.71
258.75	281.25 W	4.06	1.46	0.75	0.35	0.01	0.02	0.01										6.65
281.25	303.75 WNW	4.65	2.61	1.69	0.89	0.27	0.25	0.14	0.04	0.03								10.57
303.75	326.25 NW	5.55	2.76	2.59	1.53	0.82	0.11	0.06										13.42
326.25	348.75 NNW	9.70	5.22	2.57	1.28	0.41	0.32	0.11	0.13	0.15	0.07	0.03	0.03	0.03	0.03	0.03	0.01	20.10
348.75	11.25 N	6.24	3.38	1.11	0.59	0.36	0.12	0.27	0.02	0.02	0.05							12.16
Column Total (%)		51.00	24.94	12.96	5.98	2.37	1.19	0.81	0.26	0.22	0.12	0.03	0.03	0.03	0.03	0.03	0.01	

No. of Non-Flagged Records: 18710
Max. Hs : 3.04 m
Mean Hs : 0.29 m
Vector-averaged Speed: 0.18 m at 304.8 deg

No. of Flagged Records: 5878
Filename: gc_waveparm_year_5min_4_JFT.dat

Table 2-6 Winter Hs MWD Scatter Diagram

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP 2610
For period: Jan 01, 2005 00:00:00 to Mar 31, 2005 23:55:00 UTC Sample Interval: 5 min

		Hs (m)																
Direction (deg)		0 to 0.2	0.2 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1	1 to 1.2	1.2 to 1.4	1.4 to 1.6	1.6 to 1.8	1.8 to 2	2 to 2.2	2.2 to 2.4	2.4 to 2.6	2.6 to 2.8	2.8 to 3	3 to 3.2	Row Total (%)
11.25	33.75 NNE	0.57	1.37	0.15	0.05	0.05												2.19
33.75	56.25 NE	0.30	0.47	0.15	0.07	0.05												1.05
56.25	78.75 ENE	0.52	0.50	0.17	0.05	0.05												1.29
78.75	101.25 E	0.37	0.60	0.22	0.02	0.10												1.32
101.25	123.75 ESE	0.37	0.47	0.25	0.05	0.05												1.20
123.75	146.25 SE	0.30	0.47	0.27	0.05	0.05												1.15
146.25	168.75 SSE	0.42	0.55	0.20	0.05	0.05												1.27
168.75	191.25 S	0.35	0.47	0.22	0.07	0.05												1.17
191.25	213.75 SSW	0.35	1.27	0.35	0.10	0.02												2.09
213.75	236.25 SW	1.17	1.39	2.56	0.10	0.02												5.25
236.25	258.75 WSW	1.99	3.19	1.10	0.07	0.07												6.42
258.75	281.25 W	2.32	1.94	0.50	0.55	0.17												5.48
281.25	303.75 WNW	1.37	3.24	1.84	1.89	2.04	0.10	0.27										10.76
303.75	326.25 NW	2.91	8.24	7.27	5.38	6.15	2.24	2.34										34.54
326.25	348.75 NNW	2.19	4.93	2.59	2.22	1.39	0.85	2.02										16.19
348.75	11.25 N	0.90	4.01	2.27	1.15	0.32												8.64
Column Total (%)		16.41	33.12	20.12	11.88	10.66	3.19	4.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

No. of Non-Flagged Records: 4016
Max. Hs : 1.39 m
Mean Hs : 0.49 m
Vector-averaged Speed: 0.38 m at 315.1 deg

No. of Flagged Records: 21904
Filename: gc_waveparm_year_5min_4_JFT.dat

Table 2-7 Spring Hs MWD Scatter Diagram

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP 2610
For period: Apr 01, 2005 00:00:00 to Jun 30, 2005 23:55:00 UTC Sample Interval: 5 min

		Hs (m)																
Direction (deg)		0 to 0.2	0.2 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1	1 to 1.2	1.2 to 1.4	1.4 to 1.6	1.6 to 1.8	1.8 to 2	2 to 2.2	2.2 to 2.4	2.4 to 2.6	2.6 to 2.8	2.8 to 3	3 to 3.2	Row Total (%)
11.25	33.75 NNE	3.80	1.41	0.42	0.06	0.02	0.03	0.01		0.00								5.75
33.75	56.25 NE	1.89	0.32	0.21	0.07	0.03	0.04	0.00	0.00	0.00								2.58
56.25	78.75 ENE	1.68	0.32	0.21	0.06	0.02	0.04	0.00	0.00									2.35
78.75	101.25 E	1.77	0.33	0.22	0.08	0.04	0.04	0.01	0.01									2.52
101.25	123.75 ESE	1.75	0.30	0.21	0.06	0.05	0.03	0.01	0.01									2.42
123.75	146.25 SE	1.74	0.29	0.20	0.06	0.03	0.02	0.01										2.35
146.25	168.75 SSE	1.78	0.30	0.23	0.06	0.03	0.02	0.01	0.00									2.43
168.75	191.25 S	2.17	0.33	0.23	0.07	0.04	0.02	0.02	0.00									2.88
191.25	213.75 SSW	2.60	0.65	0.23	0.06	0.03	0.02	0.01	0.00									3.62
213.75	236.25 SW	4.18	3.67	1.60	0.34	0.06	0.02	0.01										9.88
236.25	258.75 WSW	4.26	2.86	0.80	0.21	0.08	0.02	0.01	0.00									8.25
258.75	281.25 W	3.87	0.87	0.24	0.10	0.04	0.02	0.01	0.00									5.15
281.25	303.75 WNW	4.33	1.15	0.47	0.07	0.04	0.02	0.01	0.00									6.08
303.75	326.25 NW	4.74	1.62	0.56	0.23	0.06	0.11	0.03										7.35
326.25	348.75 NNW	8.21	4.49	1.72	1.20	0.89	0.41	0.13	0.02	0.00								17.07
348.75	11.25 N	6.70	4.74	2.94	2.18	1.48	0.68	0.27	0.18	0.13	0.03							19.33
Column Total (%)		55.48	23.64	10.49	4.92	2.95	1.55	0.55	0.25	0.14	0.03	0.00	0.00	0.00	0.00	0.00	0.00	

No. of Non-Flagged Records: 24764 No. of Flagged Records: 1444
Max. Hs : 1.92 m Filename: gc_waveparm_year_Sm in_4_JFT.dat
Mean Hs : 0.27 m
Vector-averaged Speed: 0.13 m at 331.1 deg

Table 2-8 Summer Hs MWD Scatter Diagram

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP 2610
For period: Jul 01, 2005 00:00:00 to Sep 30, 2005 23:55:00 UTC Sample Interval: 5 min

		Hs (m)																
Direction (deg)		0 to 0.2	0.2 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1	1 to 1.2	1.2 to 1.4	1.4 to 1.6	1.6 to 1.8	1.8 to 2	2 to 2.2	2.2 to 2.4	2.4 to 2.6	2.6 to 2.8	2.8 to 3	3 to 3.2	Row Total (%)
11.25	33.75 NNE	3.55	0.03															3.58
33.75	56.25 NE	3.55	0.05															3.60
56.25	78.75 ENE	3.60	0.07															3.67
78.75	101.25 E	3.66	0.06															3.71
101.25	123.75 ESE	3.53	0.05															3.58
123.75	146.25 SE	3.59	0.04															3.63
146.25	168.75 SSE	3.77	0.05															3.82
168.75	191.25 S	4.79	0.06															4.85
191.25	213.75 SSW	5.08	0.49	0.01														5.58
213.75	236.25 SW	6.59	2.29	0.31	0.74	0.32	0.16	0.10	0.03	0.02								10.56
236.25	258.75 WSW	8.28	1.74	0.45	0.07	0.19				0.02								10.75
258.75	281.25 W	8.84	0.79	0.09														9.72
281.25	303.75 WNW	8.13	0.87	0.02														9.12
303.75	326.25 NW	8.18	0.55	0.03														8.76
326.25	348.75 NNW	8.08	1.32	0.23	0.25	0.08	0.05											10.02
348.75	11.25 N	3.44	0.70	0.34	0.32	0.06	0.00	0.10	0.05	0.03								5.05
Column Total (%)		87.28	8.65	1.48	1.37	0.65	0.21	0.20	0.08	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

No. of Non-Flagged Records: 26198 No. of Flagged Records: 298
Max. Hs : 1.79 m Filename: gc_waveparm_year_Sm in_4_JFT.dat
Mean Hs : 0.13 m
Vector-averaged Speed: 0.05 m at 271.9 deg

Table 2-9 Autumn Hs Tp Scatter Diagram

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP2610
For period: Oct.07,2004 15:00:00 to Dec.31,2004 23:55:00 UTC Sample Interval: 5 min

Hs (m)

Tp (s)		0 to 0.2	0.2 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1	1 to 1.2	1.2 to 1.4	1.4 to 1.6	1.6 to 1.8	1.8 to 2	2 to 2.2	2.2 to 2.4	2.4 to 2.6	2.6 to 2.8	2.8 to 3	3 to 3.2	Row Total (%)
0	1																	0.00
1	2																	0.00
2	3	19.85	2.93	0.43	0.01													23.21
3	4	22.45	14.75	7.11	2.18	0.22												46.70
4	5	3.38	3.70	3.34	2.17	1.11	0.34	0.17										14.21
5	6	2.39	2.02	1.53	0.87	0.50	0.51	0.33	0.11	0.05								8.31
6	7	1.12	0.97	0.21	0.32	0.16	0.02	0.03		0.01								2.83
7	8	0.64	0.25	0.14	0.27	0.09	0.03	0.03										1.44
8	9	0.84	0.17	0.10	0.06	0.09	0.07	0.19	0.03		0.01	0.01	0.02	0.01	0.03	0.03	0.01	1.67
9	10	0.28	0.09	0.10	0.10	0.05	0.12	0.05	0.10	0.03	0.03	0.02	0.02	0.02				0.99
10	11	0.06	0.05		0.01	0.11	0.09		0.01	0.05	0.07							0.44
11	12		0.01			0.04	0.02	0.02	0.01	0.08	0.01							0.19
Column Total (%)		51.00	24.94	12.96	5.98	2.37	1.19	0.81	0.26	0.22	0.12	0.03	0.03	0.03	0.03	0.03	0.01	

No. of Non-Flagged Rec 18710 No. of Flagged Records 5878
Max. Hs : 3.04 m File name : gc_wavepam_year_5min_4_JFT.dat
Mean Hs : 0.29 m

Table 2-10 Winter Hs Tp Scatter Diagram

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP2610
For period: Jan.01,2005 00:00:00 to Mar.31,2005 23:55:00 UTC Sample Interval: 5 min

Hs (m)

Tp (s)		0 to 0.2	0.2 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1	1 to 1.2	1.2 to 1.4	1.4 to 1.6	1.6 to 1.8	1.8 to 2	2 to 2.2	2.2 to 2.4	2.4 to 2.6	2.6 to 2.8	2.8 to 3	3 to 3.2	Row Total (%)
0	1																	0.00
1	2																	0.00
2	3	3.31	3.96	0.12	0.92													8.32
3	4	7.50	15.06	10.71	4.31	1.62	0.05											39.24
4	5	2.61	5.48	4.18	3.88	5.13	1.44	2.04										24.78
5	6	1.57	5.48	2.94	1.54	2.12	0.85	1.54										16.04
6	7	0.42	2.49	1.99	0.70	0.40		0.27										6.27
7	8	0.27	0.65	0.17	0.20	0.85	0.52	0.15										2.81
8	9	0.55			0.32	0.55	0.32	0.55										2.29
9	10	0.17						0.07										0.25
10	11																	
11	12																	
Column Total (%)		16.41	33.12	20.12	11.88	10.66	3.19	4.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

No. of Non-Flagged Rec 4016 No. of Flagged Records 21904
Max. Hs : 1.39 m File name : gc_wavepam_year_5min_4_JFT.dat
Mean Hs : 0.49 m

Table 2-11 Spring Hs Tp Scatter Diagram

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP2610
For period: Apr.01,2005 00:00:00 to Jun.30,2005 23:55:00 UTC Sample Interval: 5 min

Hs (m)

Tp (s)		0 to 0.2	0.2 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1	1 to 1.2	1.2 to 1.4	1.4 to 1.6	1.6 to 1.8	1.8 to 2	2 to 2.2	2.2 to 2.4	2.4 to 2.6	2.6 to 2.8	2.8 to 3	3 to 3.2	Row Total (%)
0	1																	0.00
1	2																	0.00
2	3	14.29	1.48	0.04			0.02	0.02										15.85
3	4	25.63	10.64	2.73	0.44	0.10	0.03	0.01										39.60
4	5	6.17	6.53	4.47	1.25	0.41	0.10	0.02										18.96
5	6	4.95	2.65	2.03	1.20	0.73	0.38	0.14	0.06	0.03	0.01							12.19
6	7	1.56	1.26	0.61	0.91	0.59	0.38	0.13	0.02	0.06								5.52
7	8	0.95	0.64	0.33	0.70	0.64	0.38	0.08	0.09	0.05	0.02							3.88
8	9	0.96	0.20	0.11	0.34	0.29	0.17	0.15	0.07	0.00								2.27
9	10	0.88	0.25	0.10	0.03	0.18	0.09	0.01	0.00									1.55
10	11	0.07		0.05	0.05													0.17
11	12																	
Column Total (%)		55.48	23.64	10.49	4.92	2.95	1.55	0.55	0.25	0.14	0.03	0.00	0.00	0.00	0.00	0.00	0.00	

No. of Non-Flagged Rec: 24764
Max. Hs : 1.92 m
Mean Hs : 0.27 m

No. of Flagged Records: 1444
File name: gc_waveparm_year_5min_4_JFT.dat

Table 2-12 Summer Hs Tp Scatter Diagram

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP2610
For period: Jul.01,2005 00:00:00 to Sep.30,2005 23:55:00 UTC Sample Interval: 5 min

Hs (m)

Tp (s)		0 to 0.2	0.2 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1	1 to 1.2	1.2 to 1.4	1.4 to 1.6	1.6 to 1.8	1.8 to 2	2 to 2.2	2.2 to 2.4	2.4 to 2.6	2.6 to 2.8	2.8 to 3	3 to 3.2	Row Total (%)
0	1																	0.00
1	2																	0.00
2	3	25.41	1.06	0.04														26.52
3	4	46.77	5.52	0.71	0.29	0.10												53.39
4	5	5.66	1.13	0.54	0.73	0.32	0.09	0.08	0.03	0.03								8.61
5	6	3.00	0.26	0.05	0.08	0.18	0.08	0.04										3.69
6	7	2.11	0.03	0.01	0.08			0.00	0.01									2.24
7	8	1.73	0.34	0.08	0.11	0.03	0.03	0.08	0.03	0.03								2.48
8	9	1.50	0.25	0.04	0.09	0.02	0.01		0.00									1.92
9	10	1.10	0.06															1.15
10	11																	
11	12																	
Column Total (%)		87.28	8.65	1.48	1.37	0.65	0.21	0.20	0.08	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

No. of Non-Flagged Rec: 26198
Max. Hs : 1.79 m
Mean Hs : 0.13 m

No. of Flagged Records: 298
File name: gc_waveparm_year_5min_4_JFT.dat

Table 2-13 Annual Hs Tp Scatter Diagram

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP2610
For period: Oct 07, 2004 15:00:00 to Oct 13, 2005 11:00:00 UTC Sample Interval: 5 min

Hs (m)

Tp (s)		0 to 0.2	0.2 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1	1 to 1.2	1.2 to 1.4	1.4 to 1.6	1.6 to 1.8	1.8 to 2	2 to 2.2	2.2 to 2.4	2.4 to 2.6	2.6 to 2.8	2.8 to 3	3 to 3.2	Row Total (%)
0	1																	0.00
1	2																	0.00
2	3	18.78	1.89	0.14	0.05		0.01	0.01										20.88
3	4	31.47	10.18	3.52	1.00	0.20	0.01	0.00										46.39
4	5	5.06	3.93	2.89	1.44	0.78	0.22	0.18	0.01	0.01								14.52
5	6	3.44	1.86	1.29	0.75	0.53	0.31	0.22	0.05	0.02	0.00							8.48
6	7	1.61	0.87	0.37	0.45	0.25	0.13	0.06	0.01	0.02								3.77
7	8	1.09	0.45	0.20	0.34	0.28	0.17	0.07	0.04	0.03	0.01							2.68
8	9	1.07	0.21	0.08	0.17	0.15	0.09	0.12	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	1.93
9	10	0.74	0.12	0.06	0.03	0.07	0.06	0.02	0.02	0.01	0.01	0.00	0.00	0.00				1.15
10	11	0.04	0.01	0.02	0.02	0.03	0.02		0.00	0.01	0.02							0.16
11	12		0.00			0.01	0.01	0.00	0.00	0.02	0.00							0.05
Column Total (%)		63.3	19.54	8.55	4.25	2.29	1.02	0.68	0.17	0.12	0.04	0.01	0.01	0.01	0.01	0.01	0	

No. of Non-Flagged Rec 77254
Max. Hs : 3.04 m
Mean Hs : 0.24 m

No. of Flagged Records 29547
File name : gc_waveparm_year_5min_4_JFT.dat

Figure 2-9 Monthly Variation of Peak Period

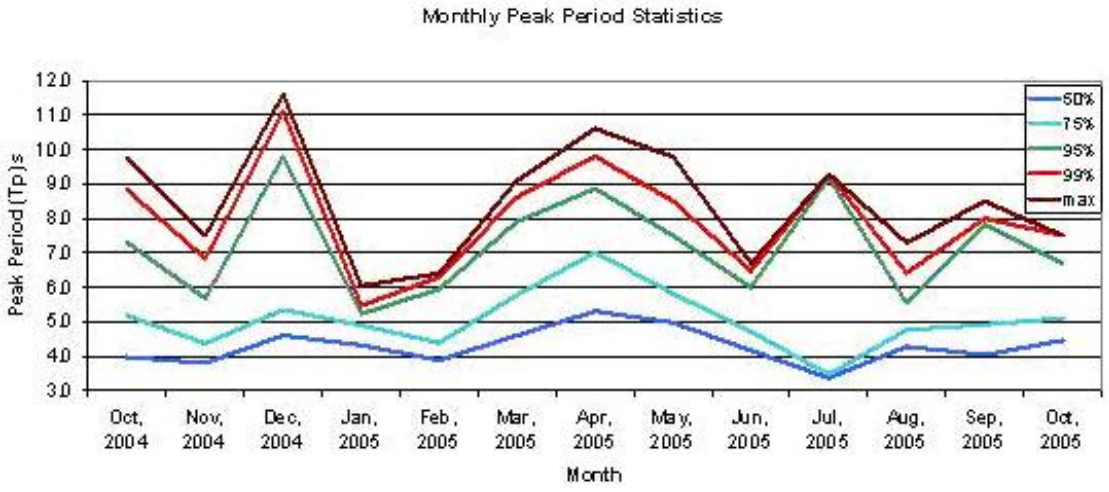
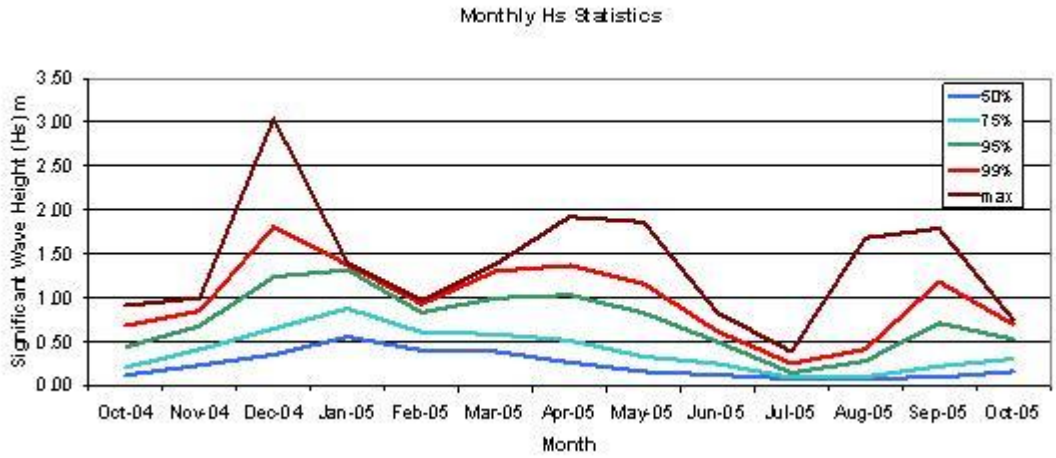


Figure 2-10 Monthly Variation of Hs



2.5 Extreme Wave

The determination of the extreme wave at Gros-Cacouna is complicated by the lack of a local long-term wave record. Some measurements have been made using buoys in the St Lawrence; however, these have been relatively short duration, typically one season after which ice forces removal. The data from these buoys remains useful for comparison and validation of some wave hindcasting results.

The determination of extreme waves must therefore be accomplished using wind records, for which a longer duration record exists, and wave hindcasting techniques. Initially this was done for Gros-Cacouna using wind records from nearby meteorological stations (e.g. Riviere du Loup, Pt au Pere etc.) for storm conditions. The SWAN hindcasting model was used to predict wave heights at Gros-Cacouna occurring under these conditions. The resulting maximum wave heights for each storm were then analyzed using conventional extreme value methods.

Where possible these records were also compared with the MED161 buoy data to ensure consistency. On the basis of these extreme wave height results for each storm an extreme wave estimate of Hs = 2.8m was made for Gros-Cacouna.

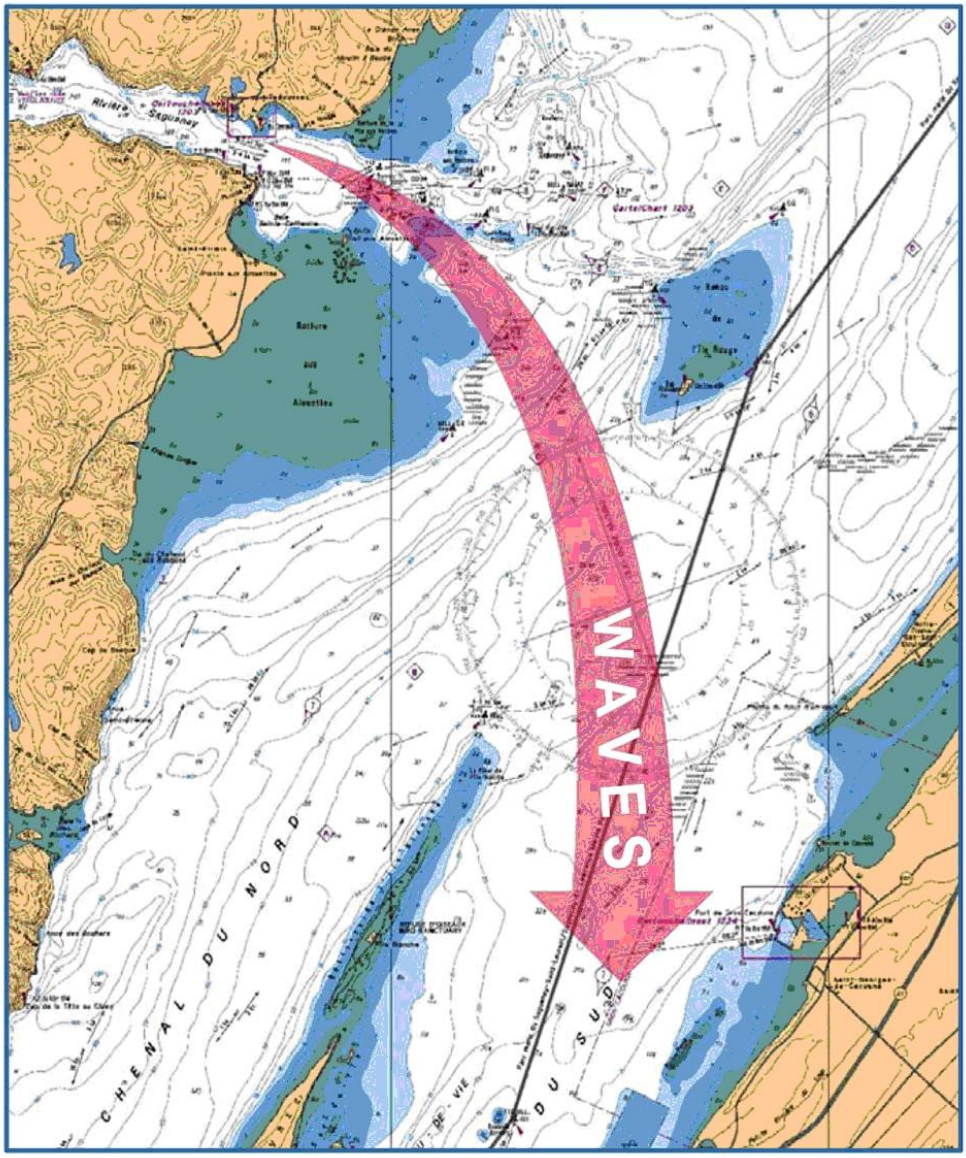
On December 12, 2004 the ADCP recorded a significant wave height of 3.1 m, somewhat larger than the 100-year wave height as estimated above. It became clear that the wave generation mechanisms in the vicinity of Gros-Cacouna were more complicated than the simple model originally applied. In particular, there are intense and highly localized areas of wind speed (Saguenay Cannon), strong tidal currents and complicated topography and bathymetry around nearby islands (Ile aux Lievres and Ile Verte).

Further detailed analysis of the December 12, 2004 event indicated that the effect of current was particularly important in transporting waves that initially develop in the vicinity of Ile Rouge into the area around Gros-Cacouna. The mechanism appears to be as follows: northerly flows generate intense localized winds down the Saguenay River Valley issuing into the St. Lawrence near Ile Rouge as the so-called 'Saguenay Cannon'; the high wind speed leads to a rapid initial rate of growth of waves; since the outflow conditions typically continue for 12-24 hour there will be at least one high tide and a corresponding flood tide current during this period; this current transports the wave initially generated near Ile Rouge into the Gros-Cacouna area; the rate of growth diminishes away from the high wind speed area; however, the overall height is greater than what would be suggested by a simple wave generation mechanism without the effect of currents.

Figure 2-11 shows a schematic diagram of this mechanism.

On the basis of this analysis the 100 year return period significant wave height is more realistically estimated to be 3.5 m.

Figure 2-11 Propagation of Waves into the Gros-Cacouna Region from the Ile Rouge Region under the Influence of Strong Flood Tide Currents



3 Meteorological Setting

3.1 Winds

A relatively complete picture of winds in the vicinity of Gros-Cacouna can be assembled from wind measurements made at the proposed terminal location and the concurrent and historical wind measurements at nearby Riviere du Loup. Koutitonsky and Noel (1976) includes an analysis of the relationship between data obtained at Gros-Cacouna and Riviere du Loup, generally supporting the use of meteorological data obtained at the latter where the record is much more extensive. The field work undertaken in 2005 by Enviromet (Ref. 2) further supports this approach.

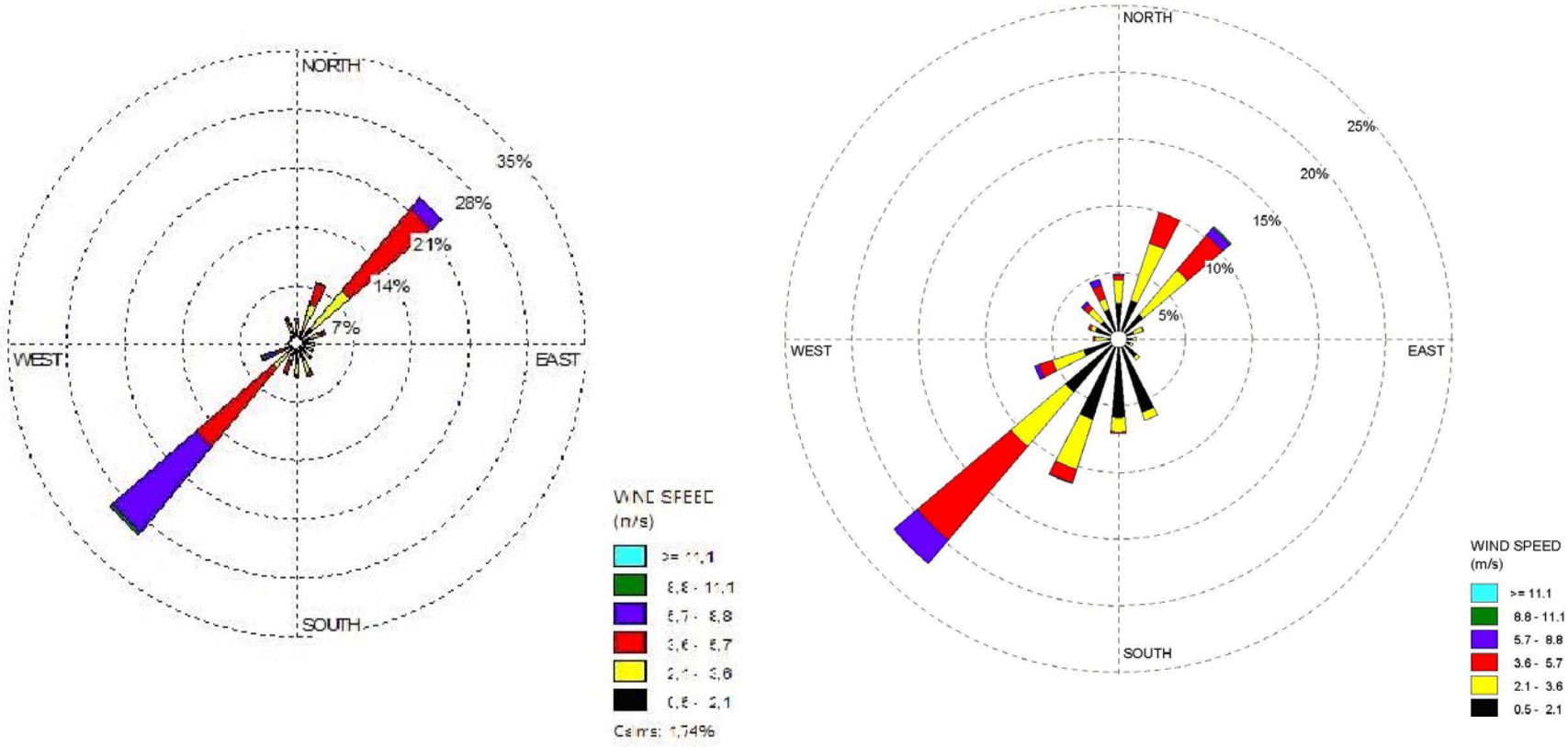
In the broader parts of the St. Lawrence River below Quebec City and east to Anticosti Island easterly to northeast winds are common, particularly during the spring and summer. Such winds will also accompany the passage of the low pressure areas south of the river at all seasons. During the summer, southwest winds will be fairly frequent and will often bring warm moist air, producing extensive fog. In autumn, northwest winds become more common as cold air flows off the plateau to the north. Late in the fall these northwest winds may be accompanied by snow squalls.

Winds along the Saguenay River take their direction almost entirely from the relative difference in pressure between the upper portion of the river at Lake St. John and the mouth of the river. Winds will blow from high to low pressure, and have been known to be opposite to that prevailing along the St. Lawrence River itself.

In any part of the St. Lawrence River strong winds seldom veer sharply from one quarter of the compass to another, though rare instances of a shift from strong easterly to strong southwest winds in the lower St. Lawrence have occurred. Wind shifts from southwest to stronger westerly winds may take place with the influx of fresh cold air to the river valley; almost never will northwest winds veer through north to easterly.

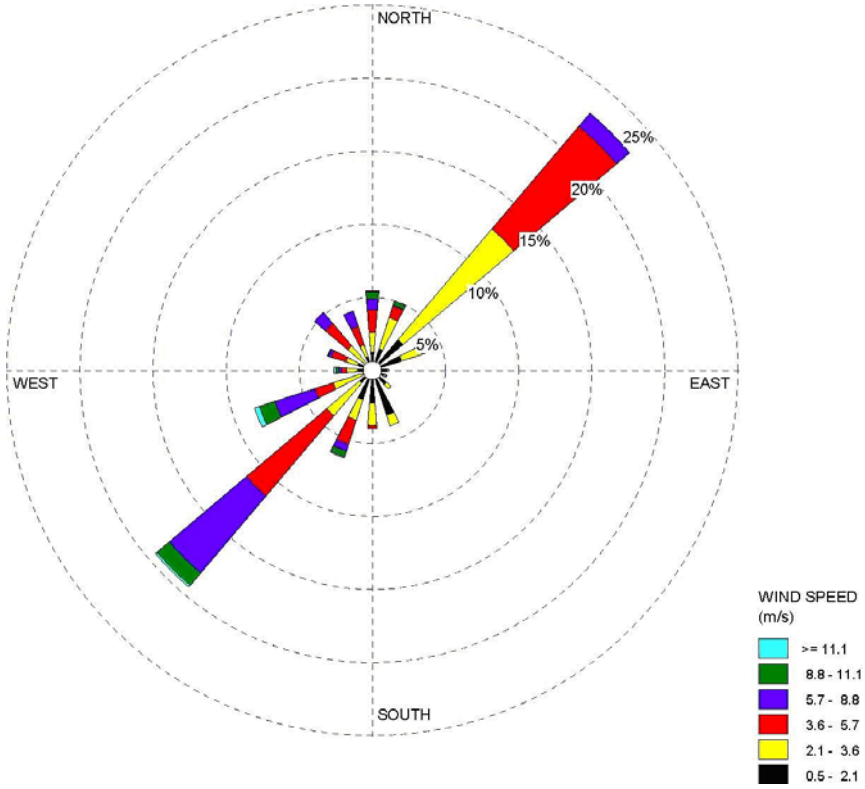
Figure 3-1 shows selected wind roses for the GC2 station based on 2005 measurements. The wind roses show the strong bias in wind direction imposed by the topography and surface roughness features of the St. Lawrence Valley.

Figure 3-1 Wind Roses for GC2 Station at Gros-Cacouna (Ref. 2)

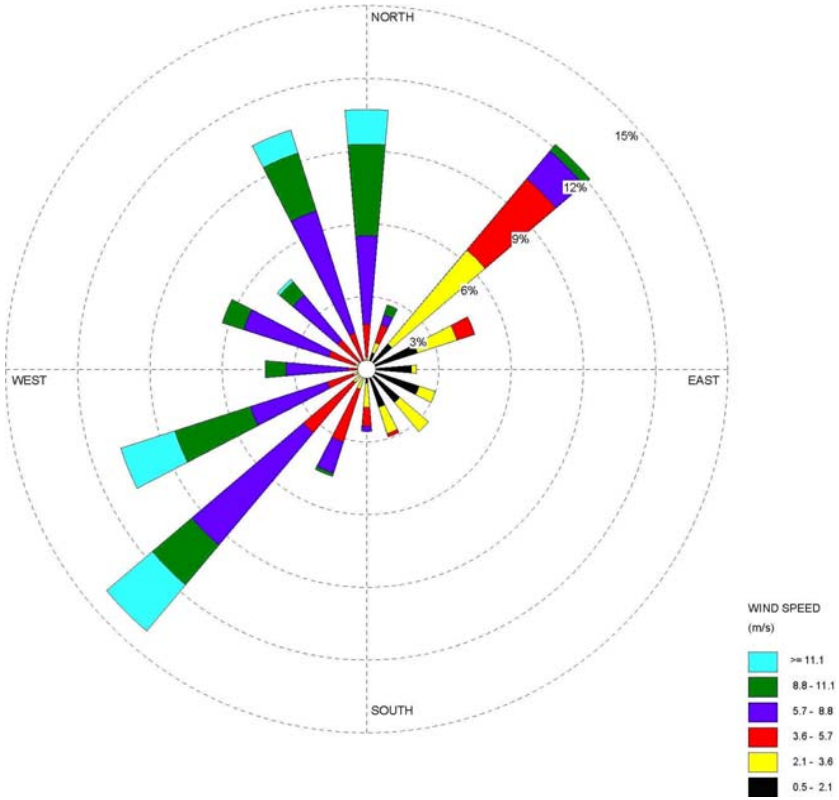


June 2005 **July to August 2005**

Figure 3-1 Wind Roses for GC2 Station at Gros-Cacouna (Ref. 2) (cont.)



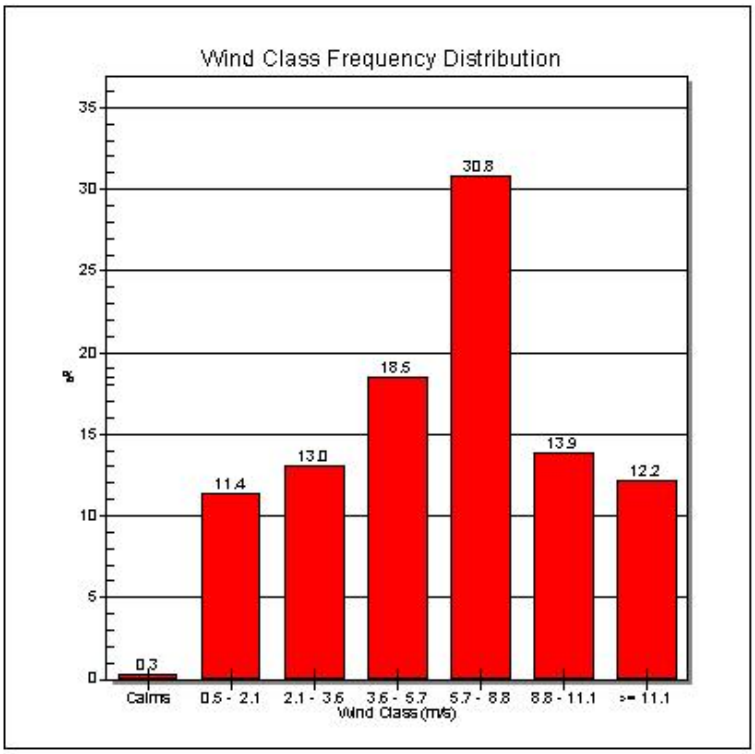
September to October 2005



November to December 2005

Figure 3-2 shows the wind speed class distribution for the GC2 station at Gros Cacouna.

Figure 3-2 Wind Class Frequency Distribution for GC2 Station at Gros-Cacouna



The data obtained from the GC2 station at Gros-Cacouna and the data available from the Environment Canada station at Riviere du Loup have been used to derive a transformation for both velocity and direction between the two stations. This allows the long term record at Riviere du Loup to be transformed and applied to Gros-Cacouna. Figure 3-3 shows the wind rose for Gros-Cacouna based on transformed Riviere du Loup data for 2005.

The transformation between Riviere du Loup was also investigated using the MM5 mesoscale numerical model. The results confirm the relationship established on the basis of the measured winds at the two sites.

Figure 3-3 Gros Cacouna Long Term Wind Rose Based on Transformed Riviere Du Loup Record

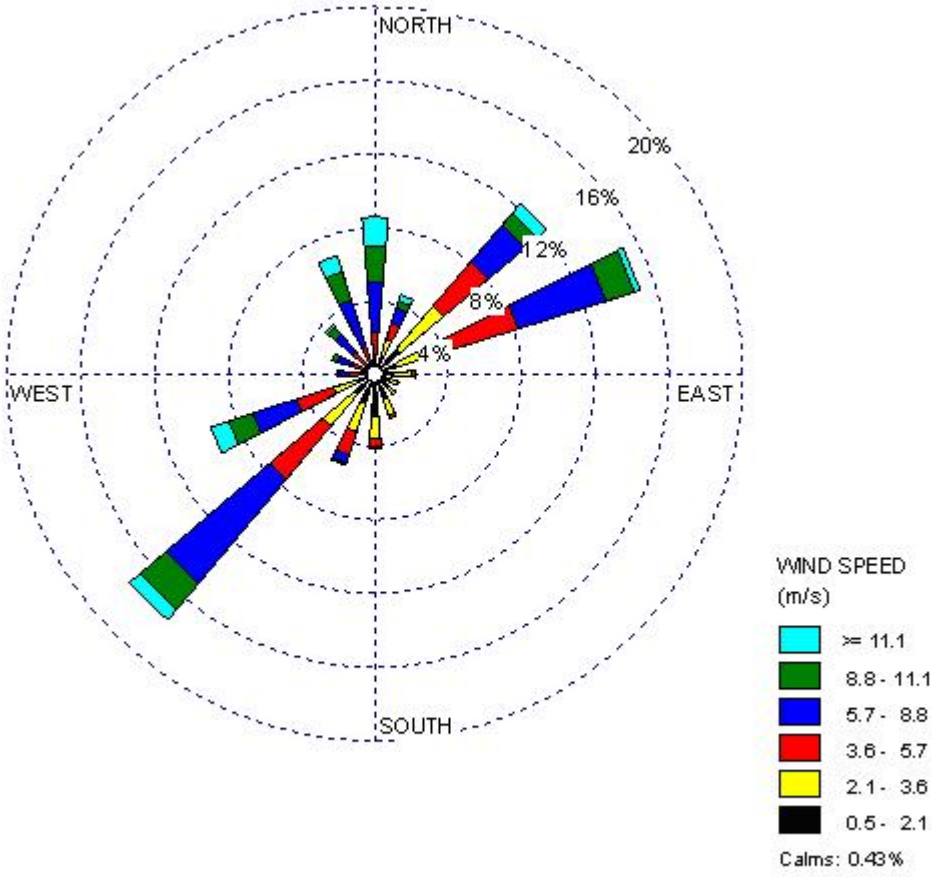
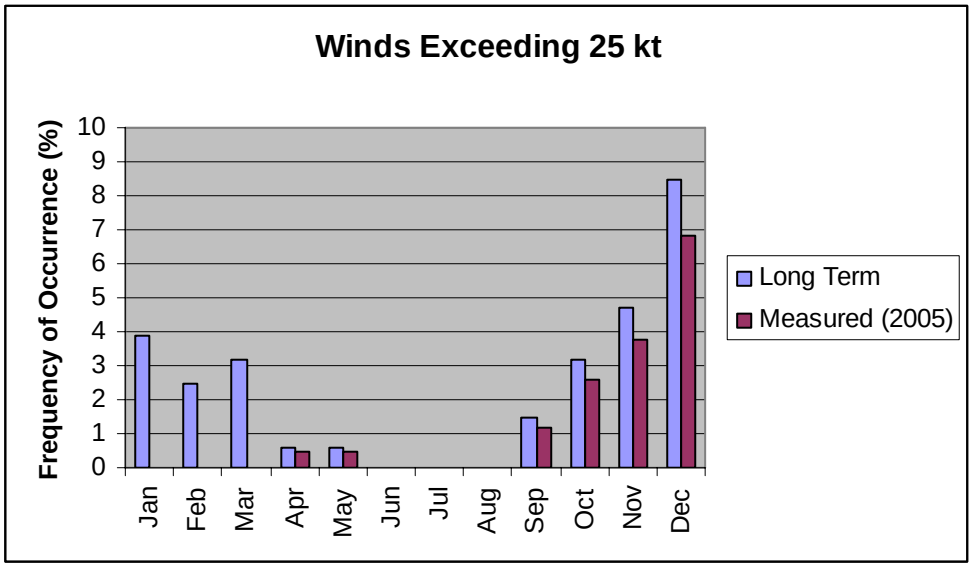


Figure 3-4 shows the occurrence of winds exceeding 25 knots at Gros-Cacouna based on the 2005 measured data and on the long term record transformed from Riviere du Loup. Gros-Cacouna measurements were not available for January through March.

Figure 3-4 Monthly Distribution of Winds Exceeding 25 Knots at Gros-Cacouna



3.2 Visibility

Fog is frequent in the summer months in the lower part of the river because of the relative coolness of the water surface. The effect is intensified, and the fog thicker and more persistent, with flows of warm moist air from the southwest. This type of fog may persist even with moderate winds.

Table 3-1 shows monthly visibility measurements obtained at the GC1 site at Gros-Cacouna from January to December in 2005.

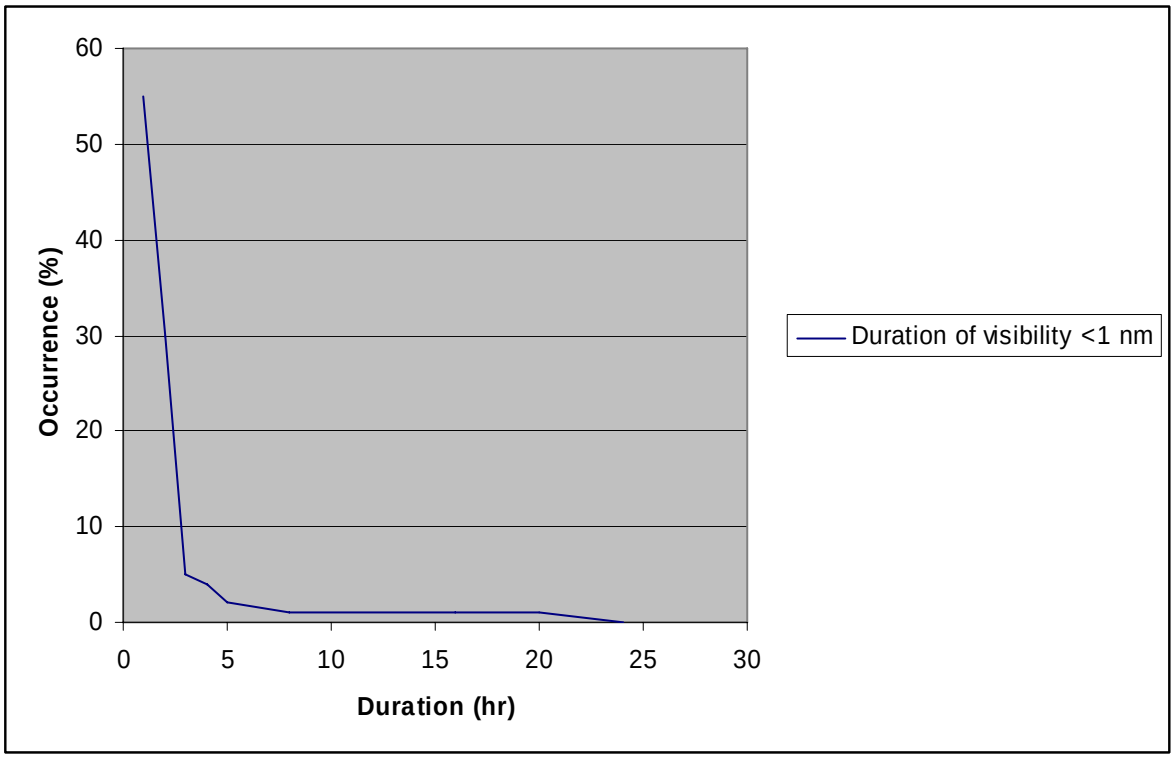
Visibility observations at Baie Cameau and Mount Joli have also been checked to ensure that the Gros-Cacouna measurements are broadly consistent with other observations.

The persistence of limited visibility conditions has been analyzed to determine the duration of individual visibility events. Figure 3-5 shows the probability of duration for visibility events with less than 1 nm visibility. The probability of directions greater than approximately four hours is very small.

Table 3-1 Occurrence of Visibility < 1nm in 2005 at Gros-Cacouna (Ref. 2)

Month	Visibility < 1nm
January	9.4%
February	12.1%
March	17.7%
April	6.5%
May	1.7%
June	2.5%
July	0.0%
August	3.1%
September	7.2%
October	3.0%
November	3.5%
December	2.4%

Figure 3-5 Persistence of Visibility Events



4 References

1. “Currents, Waves and Water Levels, October 2004 to October 2005, St. Lawrence River at Gros-Cacouna”, ASL Environmental Sciences Inc., December 2005

2. “Meteorological Study for a Proposed LNG Import Terminal at Gros-Cacouna, Monthly Operation and Reporting, January to December 2005”, Enviromet International Inc., 2005