Preliminary Mechanical Response Gap Analysis for the Enbridge Northern Gateway Project

Healthy Oceans. Healthy Communities.

Preliminary Mechanical Response Gap Analysis for the Enbridge Northern Gateway Project

Disclaimer

This report is based on the research of Katie Terhune, Energy Campaign Manager at Living Oceans Society. It is a preliminary response gap analysis which examines the frequency in which oil spill response would be impaired or impossible due to environmental conditions encountered in the proposed Enbridge Northern Gateway Project area. It is a basic analysis in that it is based solely on wave height observations and does not address the interplay between different environmental factors (e.g. wind, waves, temperature, etc.) in determining effective oil spill response capacity. It is strongly recommended that Enbridge Northern Gateway Pipelines commission a more comprehensive analysis to be conducted by a reputable consulting firm such as Nuka Research and Planning Group, LLC whose response operating limits were used in this preliminary analysis.

Acknowledgement

Living Oceans Society would like to thank Emma Point for her contributions in the writing of this report.

Healthy Oceans. Healthy Communities.

Living Oceans Society
Box 320 Sointula, BC V0N 3E0
Canada
250 973 6580
info@livingoceans.org
www.livingoceans.org

Terhune, K. (2011). *Preliminary Mechanical Response Gap Analysis for the Enbridge Northern Gateway Project*. Sointula, BC: Living Oceans Society.

Contents

Executive Summary

Enbridge Northern Gateway Pipelines (Enbridge) has proposed to build and operate dual pipelines running from Bruderheim, Alberta to a new marine terminal near Kitimat, British Columbia. One pipeline will carry petroleum for export. The other will import condensate. The pipelines will be serviced by oil tankers en route to and from markets in Asia and the United States. As with all oil pipeline and tanker projects, the potential for oil spills exists.

Enbridge's General Oil Spill Response Plan for the proposed Northern Gateway project includes the use of mechanical response methods (e.g. booms and skimmers) for oil collection activities in the event of a spill into the marine environment (Enbridge Northern Gateway Pipelines, 2011). However, Enbridge has provided no quantitative assessment of the expected efficacy of mechanical response in their application. An assessment of proposed oil spill response systems is crucial to adequately assess the risks posed by this project.

To address this inadequacy in Enbridge's application, a preliminary mechanical response gap analysis was performed and is described in this report. The analysis was based on mechanical response limits proposed by Nuka Research and Planning Group, LLC (Nuka Research, 2007) compared to wave height observations from weather buoys located in the proposed marine operating area.

The preliminary mechanical response gap analysis determined that booms and skimmers are likely to prove ineffective for much of the year in the proposed marine operating area based on wave height alone. This response gap does not include response limitations due to wind, visibility, temperature or currents and thus offers a very conservative response gap estimate. Response is impossible due to wave heights 30.37 percent of the time when averaged across all buoy locations. Response is either impaired or impossible due to wave heights 61.15 percent of the time across all buoy locations. The impairment of, or inability to use mechanical cleanup methods substantially increases the risk posed to marine ecosystems and coastal resources in the event of a spill.

Introduction

Weather and oceanographic conditions are key factors affecting the success of oil spill response. When certain environmental conditions are prevalent, such as high seas and strong winds, conventional oil spill response equipment (e.g. booms and skimmers) ceases to operate effectively. Beyond these conditions, a "response gap" exists because effective oil spill response becomes impaired or impossible. In other words, if an oil spill occurs during these weather and/or sea conditions, oil cannot be properly contained or cleaned up.

A mechanical response gap is calculated by analyzing historical weather data from a specific location (e.g. wind speed, wave height, temperature, etc. from a weather buoy) and comparing the results to the operational limits of different mechanical response techniques. The response gap is generally represented as the percentage of time when the efficacy of mechanical response equipment is compromised or when the equipment cannot be implemented at all due to logistical challenges. For example, if a response gap exists 50 percent of the time, it means that response would be impossible for 50 out of 100 days. It does not refer to the amount of oil that could be recovered.[1] A response gap analysis is critical to assess the risks of an oil spill from a specific project or location. If a response gap exists for an extended period of time, the risk posed to marine ecosystems and coastal resources would be substantially increased.

Enbridge's General Oil Spill Response Plan for the proposed Northern Gateway project (hereafter referred to as the proposed project) includes the use of mechanical response methods (e.g. booms and skimmers) for oil collection activities in the event of a spill into the marine environment (Enbridge Northern Gateway Pipelines, 2011). However, Enbridge has provided no quantitative assessment of the expected efficacy of mechanical response in their application. To address this inadequacy, this report was completed to provide a preliminary mechanical response gap analysis for the proposed project area. It is based on response operating limits defined by Nuka Research and Planning, LLC (hereafter referred to as Nuka Research) measured against weather conditions observed for the North and Central Coast of British Columbia. It is a preliminary analysis in that it assesses response operating limits for mechanical equipment compared to wave height observations only. A more comprehensive analysis should incorporate additional environmental conditions that can affect oil spill response (e.g. wind, temperature, visibility and currents).

Background

Mechanical Response Equipment

Mechanical response equipment includes components for containment and recovery of spilled oil. Booms, boom deployment vessels (e.g. tugs or modified fishing vessels), skimmers, storage barges and sorbents

[1] When response is possible, typically only 10 to 15 percent of the total volume of spilled oil might be recovered over the course of the entire response operation (based on estimates of open water recovery efficiencies for mechanical equipment) (Oceans North, 2011).

can all be used during a mechanical response operation. Floating booms are used to control and localize spilled oil and are viewed as the most effective method for containing spilled oil (Enbridge Northern Gateway Pipelines, 2011). A combination of techniques including skimmers and sorbents is generally used to recover contained oil.

Although all of the mechanical response components are required for successful response, each can be affected differently by environmental conditions encountered during response.

Environmental Conditions

Environmental conditions are key factors affecting the success of oil spill response. Response equipment is designed and built in different sizes and strengths to withstand different environmental conditions (Turner et al., 2010). However, all response equipment has operational limits. Environmental conditions above or below certain thresholds can impair or preclude effective response regardless of the size or strength of response equipment. Environmental conditions inhibiting response are briefly discussed below.

Sea State

Sea state is a function of wave height, wave period (the frequency of the waves) and wave steepness. Although each parameter interacts with the other, wave height is the parameter most often considered in response planning and used for the classification of oil spill response equipment (Nuka Research, 2007). For this analysis, only wave height was considered.[2]

Sea state can impair or inhibit response by causing boom failure, preventing a vessel from holding its station, creating an unsafe environment for response crews to work on deck, impeding equipment deployment and retrieval, causing spilled oil to become submerged, and making tracking oil difficult (Nuka Research, 2007).

Wind

Wind is a natural phenomenon which affects the marine environment. In terms of oil spill response, wind generally becomes an inhibiting factor as it alters the sea state. Generally, stronger winds create higher wave heights. However, wind alone can also impair or inhibit response by preventing a vessel from holding its station, creating an unsafe environment for response crews to work on deck, or impeding equipment deployment and retrieval (Nuka Research, 2007).

Response can be further impeded if there is difficulty in adequately predicting winds. For example, the rugged coastline of British Columbia modifies wind flow patterns and results in variability along the coast – light winds can be found in some areas whereas dangerously strong winds can be found in others at the same time (Environment Canada, 1990).

[2] This can sometimes be misleading. For example, response may be possible in 3 meter ocean swell yet not effective in 1 meter wind-generated chop (Nuka Research, 2007). Steepness and period can be used to help distinguish between swells and wind-generated waves. This study used the higher estimated values for wave height operating limits provided by Nuka Research (2007) in order to provide a more conservative response gap estimate.

Currents

Currents along the coast are caused by the periodic rise and fall of the tide, wind, and changes in atmospheric pressure. The velocity of water movement is variable and affected by the topography of the coastline and bathymetry of the seafloor. Currents can impede or inhibit response by causing containment boom failure, causing spilled oil to become submerged, or by preventing a vessel from maintaining its station (Nuka Research, 2007). Currents can also affect response by altering sea state (e.g. currents flowing against the predominant wave direction can cause waves to build in height and steepness).

Visibility

Decreased visibility can be caused by fog, precipitation in the form of rain or snow, low clouds and darkness. Response is generally not possible when visibility is restricted to less than one kilometer or at night (Turner et al., 2010). Decreased visibility can make directing oil spill response from the air impossible and tracking and recovering oil by vessels difficult, even with state of the art remote sensing equipment (Turner et al., 2010). It can also cause problems for navigation and a vessel's ability to hold its station (Nuka Research, 2007).

Temperature

Air temperature mainly impedes response when conditions are below freezing. Cold air temperatures can cause hypothermic situations which are unsafe for response crews and mechanical issues due to icing (Nuka Research, 2007). Cold temperatures and icing due to freezing sea spray are common in the proposed project area during winter months.

Local Conditions in the Project Area

Open Water Area

Winter storms are the main hazard in the Open Water Area (OWA), which encompasses Hecate Strait, Dixon Entrance and Queen Charlotte Sound (Figure 1). Storm force winds (48-55 knots[3]) and 8 to 10 meter seas are not uncommon in the winter months. Gusts up to 90 knots[4] are known to occur in Queen Charlotte Sound, and Hecate Strait is considered the fourth most dangerous body of water in the world because of the speed at which winds and sea state can change (Environment Canada, 1990).

Short, steep waves can develop quickly due to shallow water depths covering large areas of Hecate Strait and because of the interplay between waves and tidal currents throughout the OWA. Additionally, when waves approach the coastline and converge with a countering current, they can steepen and will often break. This greatly increases the risk of small vessels being swamped. Navigating along the coastline in high winds and low visibility are particularly hazardous (Environment Canada, 1990).

The poorest visibility in Hecate Strait occurs between September and February due to fog and snow. In Queen Charlotte Sound, ocean fog is prevalent from August to October. In Dixon Entrance, fog is most prevalent in the summer, when visibility can be reduced to below 2km. During the winter months however, cold arctic outbreaks from inlets on the mainland blow across the OWA to Dixon Entrance,

---

[3] Storm force winds are 48-55 knots, 89-102 km/hr or 24.5-28.4 m/sec.
[4] Gusts up to 90 knots are equivalent to 167 km/hr or 46.3 m/sec.

picking up moisture and often producing snow and freezing sea spray while reducing visibility (Environment Canada, 1990).

Confined Channel Assessment Area

The Confined Channel Assessment Area (CCAA) (Figure 1) also experiences the most extreme wind and wave conditions during the winter months. Arctic outbreaks can cause gale to storm force winds to blow through mainland inlets, including Douglas Channel (Environment Canada, 1990). Strong winds coupled with cold temperatures can produce rough seas and freezing sea spray which pose hazards to vessels. Many locations in the CCAA are sheltered by islands and do not experience strong winds, but others, such as Whale Channel, can experience gusty conditions when winds are funneled by local mountains. Additionally, when a storm approaches the B.C. coast, northeast winds blow down Douglas Channel and meet with southeast winds from Hecate Strait at Whale and Grenville Channels. This convergence can produce chaotic sea conditions. The southeast winds also funnel through Principe Channel causing high waves to build near Anger Island. Steep, breaking waves will also form on ebb tides in Otter Passage (Environment Canada, 1990).

Conditions are much calmer during the summer months when ocean breezes are the dominant factor controlling winds in the CCAA. Winds may rise to 25 knots[5] in the afternoon but are generally calm at night (Environment Canada, 1990).

The poorest visibility in the CCAA occurs from September to February due to snow and fog.

Methodology

Because a response gap analysis was not included by Enbridge in their proposed project application, this preliminary analysis was conducted. The methodology used involved the following four key steps:

1) Assemble datasets of environmental factors in the proposed Project area

Environmental datasets for the proposed project area were assembled from weather buoy data from Canada's Pacific coast. Environment Canada and Fisheries and Oceans Canada (DFO) maintain offshore weather buoys in the region. The buoys measure general weather data including air pressure, air temperature, sea surface temperature, wind observations and wave height. Data from buoys located near the proposed tanker routes – including Dixon Entrance, Queen Charlotte Sound, Hecate Straight and Douglas Channel – were obtained.[6] For the purpose of this preliminary analysis, only wave height data were used. The weather buoys used to assemble the datasets are summarized in Table 1. Locations of weather buoys are illustrated in Figure 1.

[5] Winds up to 25 knots are equivalent to 46 km/hr or 12.9 m/sec.

[6] Buoy data was downloaded from: http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/waves-vagues/search-recherche/list-liste/index-eng.asp?MedsID=C46&ID=&StnName=&Lat1=&Lat2=&Long1=&Long2=&sDate=&eDate=&typedisplay=HTML&Search=Get+Results

Table 1. Weather buoys along the proposed tanker routes for the Enbridge Northern Gateway Project

Buoy No.	Buoy Name	Latitude	Longitude	Data Collection Start Date	Data Collection End Date
C46145	Central Dixon Entrance	54.38	-132.43	4/16/1991	8/2/2011
C46147	South Moresby	51.82	-131.2	6/17/1993	8/2/2011
C46181	Nanakwa Shoal	53.82	-128.84	11/22/1988	8/2/2011
C46183	North Hecate Strait	53.57	-131.14	5/15/1991	8/2/2011
C46185	South Hecate Strait	52.42	-129.8	9/12/1991	8/2/2011
C46204	West Sea Otter	51.38	-128.74	9/7/1989	8/2/2011
C46205	West Dixon Entrance	54.17	-134.33	7/12/1990	8/2/2011
C46207	East Dellwood	50.86	-129.91	10/18/1989	8/2/2011

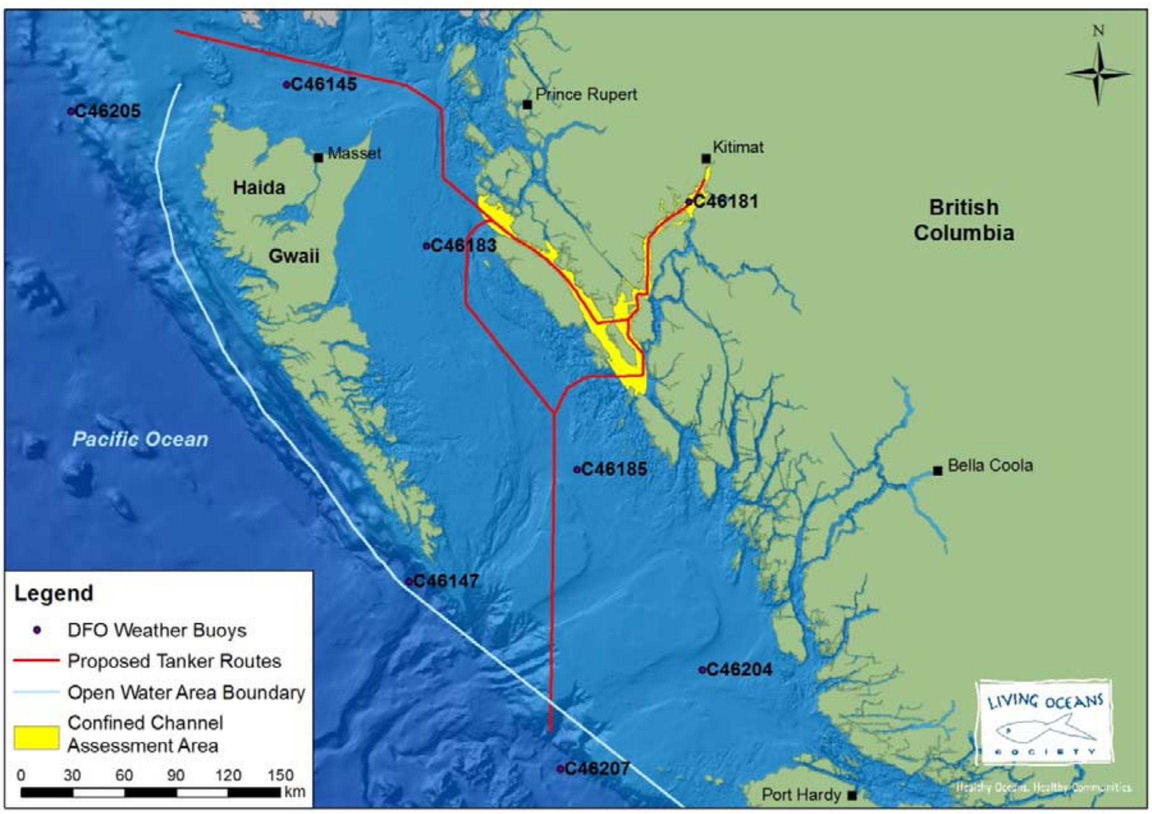

Figure 1. Weather buoy locations in the proposed project operating area, including Open Water Area and Confined Channel Assessment Area.

Environmental datasets for wave height were assembled in a spreadsheet and sorted according to month. To ensure only quality data were used, only readings with a rating of Good (quality control was performed, record appears correct) or Acceptable (quality control was performed, record appears inconsistent with other records) were included in the analysis.[7] Erroneous, doubtful or changed records were not included. Blank readings for wave heights were also filtered from the datasets.

2) Determine the operational limits of current oil spill response technology

The operational limits used in this analysis are based on a response gap analysis completed by Nuka Research (2007) for Prince William Sound. Nuka Research's proposed operational limits were based on an exhaustive literature review carried out to determine the performance of oil spill response techniques under varying weather and sea conditions. Limits were established by determining the environmental conditions that caused the response system to become inoperable.[8]
Table 2 contains the operational limits for wave height proposed by Nuka Research (2007) that were used in this analysis. Operational limits have been converted into metric measurements.

Table 2. Limits used for the preliminary response gap analysis based on limits from the Prince William Sound response gap analysis (2007).

Environmental Factor[9]	**Green: Response Possible**	**Yellow: Response Impaired**	**Red: Response Impossible**
Waves (m)[10]	≤ 1.2	> 1.2 to < 2.4	≥ 2.4

3) Calculate the frequency in which the operational limits are reached in the operating areas

The datasets of environmental factors were analyzed using basic queries in Microsoft Excel to determine how often the Green (Response Possible), Yellow (Response Impaired) and Red (Response Impossible) operating limits for wave height were reached at each of the specified buoy locations. Data were analyzed on a monthly basis.

---

[7] Environment Canada and DFO rate each reading in these datasets for quality control.
[8] It should be noted that establishing operational limits for a response gap analysis is a very subjective process. Nuka Research's literature review determined that quantitative guides for establishing operating limits for response techniques are generally not provided. Instead, data can be used to assess changes in mechanical response performance under certain weather conditions. Final operational limits are considered to be best estimates based on the authors' expertise. As such, the values used in this analysis are also not definitive. They offer a conservative estimate of the weather and sea conditions where the performance of mechanical response techniques is inhibited.

[9] Limits for wind, temperature and visibility were not used in this analysis. These limits, which were included in the original Prince William Sound analysis, would have provided a more comprehensive study but is currently beyond the capacity of this report.

[10] Sea state in the original report was measured in feet and included a wave steepness parameter. The wave steepness parameter was not included in this study. As such, the more conservative value in the original report was used. I.e. For a Green response, a value of ≤3 ft when the wave steepness parameter is greater than or equal to 0.0025, otherwise ≤4 ft feet was used. In this study ≤4 ft was used.

Since only wave height was considered in this analysis, the interplay between environmental factors (e.g. wind speed, visibility) to account for cumulative effects was not addressed. As a result, this analysis is considered a preliminary response gap analysis, and estimates are conservative. A cumulative analysis would likely demonstrate higher frequencies in which response was impaired or impossible at each of the buoy locations. For example, a situation may arise where the combination of a particular wave height and wind speed may present an operating limit even though each factor considered individually would not. Further analysis which addresses cumulative effects is required.

4) Define the response gap at each location

The estimated response gap at each location is based the on the percentage of wave height readings that fall within the Red (response impossible) parameters. The response gap at each buoy location can be used to help assess the increased risk of a potential oil spill in the operating area of the proposed project. Risk to the surrounding area is also significantly higher if response is Yellow (response impaired).

Results

The results of this analysis are based solely wave height data from weather buoys located in the proposed project's operation area, including Open Water Area and Confined Channel Assessment Area, compared to the operating limits outlined in Table 2.

Buoy C46145 – Central Dixon Entrance

Table 3 represents the results of applying the operational limits defined in Table 2 to the historical wave height data from buoy C46145, Central Dixon Entrance. When wave height was considered alone, operational limits were impaired or impossible for a substantial period of time. On average, response would be possible 41.27 percent of the year, impaired 40.24 percent of the year, and impossible 18.49 percent of the year. Response is impaired or impossible for 58.73 percent of the year on average.

The response gap reaches a maximum in December at 46.22 percent. When considered together, response is impaired or impossible 89.13 percent of the time in December.

Response is most effective in July when response would be possible 81.91 percent of the time.

Table 3. Relative frequency in which response is possible, impaired or impossible based on historical wave height observations at buoy C46145, Central Dixon Entrance.

		Response Possible		Response Impaired		Response Impossible	
Month	**Total weather observations**	**Wave height observations ≤1.2 m**	**Percent ≤1.2m**	**Wave height observations 1.2 to <2.4m**	**Percent 1.2 to <2.4 m**	**Wave height observations ≥2.4 m**	**Percent ≥2.4 m**
Jan	12334	2401	19.47	6511	52.79	3422	27.74
Feb	11666	2106	18.05	6163	52.83	3397	29.12
Mar	12651	3153	24.92	6450	50.98	3048	24.09
Apr	11116	4574	41.15	5166	46.47	1376	12.38
May	11984	7390	61.67	4040	33.71	554	4.62
Jun	13047	9646	73.93	3177	24.35	224	1.72
Jul	13591	11133	81.91	2409	17.72	49	0.36
Aug	13935	10574	75.88	3158	22.66	203	1.46
Sep	13530	6431	47.53	5660	41.83	1439	10.64
Oct	13286	3221	24.24	6475	48.74	3590	27.02
Nov	13118	2042	15.57	6282	47.89	4794	36.55
Dec	12963	1408	10.86	5563	42.91	5992	46.22
Averag**e**			**41.27**		**40.24**		**18.49**

Figure 2 is a graphic representation of the relative time response is possible, impaired or impossible based on the results in Table 3. In each month, total percentage of time equals 100 percent. Percentages represent the average rating for the specified month. There are significant periods of time when response is impaired or impossible based solely on wave height data. Response is most effective in the summer months. Response is least effective in the winter months.

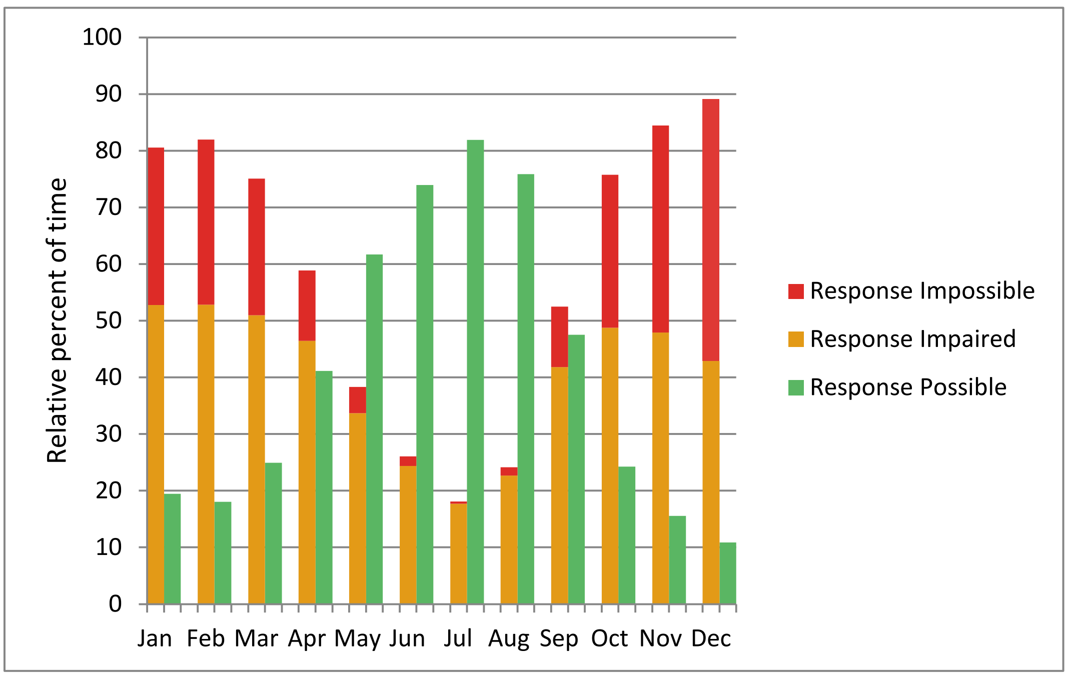

Figure 2. Relative percent of time response is possible, impaired or impossible based on historical wave height observations at buoy C46145, Central Dixon Entrance.

Buoy C46147 – South Moresby

Table 4 represents the results of applying the operational limits defined in Table 2 to the historical wave height data from buoy C46147, South Moresby. When wave height was considered alone, operational limits were impaired or impossible for a substantial period of time. On average, response would be possible 13.67 percent of the year, impaired 35.40 percent of the year, and impossible 50.92 percent of the year. Response is impaired or impossible for 86.32 percent of the year on average.

The response gap reaches a maximum in December at 81.35 percent. When considered together, response is impaired or impossible 98.33 percent of the time in December.

Response is most effective in July when response would be possible 39.50 percent of the time.

Table 4. Relative frequency in which response is possible, impaired or impossible based on historical wave height observations at buoy C46147, South Moresby.

		Response Possible		Response Impaired		Response Impossible	
Month	**Total weather observations**	**Wave height observations ≤1.2 m**	**Percent ≤1.2m**	**Wave height observations 1.2 to <2.4m**	**Percent 1.2 to <2.4 m**	**Wave height observations ≥2.4 m**	**Percent ≥2.4 m**
Jan	11368	229	2.01	2295	20.19	8844	77.80
Feb	10391	243	2.34	2242	21.58	7906	76.09
Mar	11325	499	4.41	2639	23.30	8187	72.29
Apr	10477	780	7.44	3885	37.08	5812	55.47
May	11317	2272	20.08	5800	51.25	3245	28.67
Jun	11923	3510	29.44	6014	50.44	2399	20.12
Jul	12510	4491	35.90	7115	56.87	904	7.23
Aug	12597	4707	37.37	6401	50.81	1489	11.82
Sep	12162	1820	14.96	6246	51.36	4096	33.68
Oct	11727	701	5.98	2917	24.87	8109	69.15
Nov	11129	276	2.48	2239	20.12	8614	77.40
Dec	11858	198	1.67	2013	16.98	9647	81.35
Average			**13.67**		**35.40**		**50.92**

Figure 3 is a graphic representation of the relative time response is possible, impaired or impossible based on the results in Table 3. In each month, total percentage of time equals 100 percent. Percentages represent the average rating for the specified month. There are significant periods of time when response is impaired or impossible based solely on wave height data. Response is most effective in the summer months. Response is least effective in the winter months.

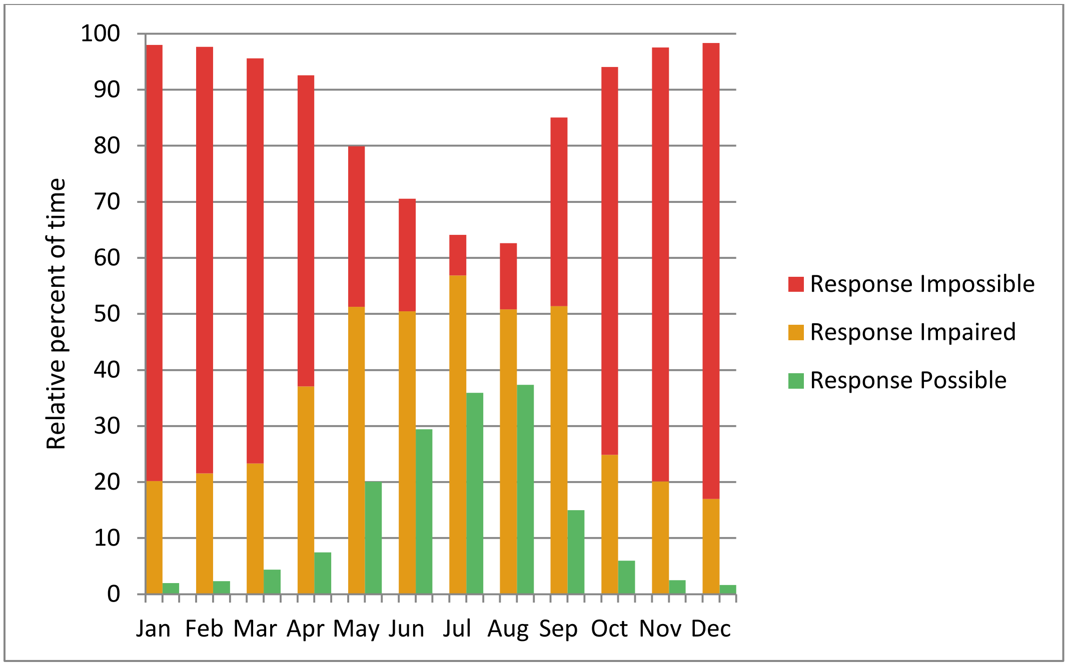

Figure 3. Relative percent of time response is possible, impaired or impossible based on historical wave height observations at buoy C46147, South Moresby.

Buoy C46181 – Nanakwa Shoal

Table 5 represents the results of applying the operational limits defined in Table 2 to the historical wave height data from buoy C46181, Nanakwa Shoal. When wave height was considered alone, operational limits were very rarely exceeded. On average, response would be possible 99.54 percent of the year, impaired 0.33 percent of the year, and impossible 0.12 percent of the year. Response is impaired or impossible for only 0.45 percent of the year on average.

The response gap reaches a maximum in January at 0.87 percent. When considered together, response is impaired or impossible 3.33 percent of the time in January.

Response is effective for most of the year when based exclusively on wave height observations.

Table 5. Relative frequency in which response is possible, impaired or impossible based on historical wave height observations at buoy C46181, Nanakwa Shoal.

		Response Possible		Response Impaired		Response Impossible	
Month	**Total weather observations**	**Wave height observations ≤1.2 m**	**Percent ≤1.2m**	**Wave height observations 1.2 to <2.4m**	**Percent 1.2 to <2.4 m**	**Wave height observations ≥2.4 m**	**Percent ≥2.4 m**
Jan	10575	10223	96.67	260	2.46	92	0.87
Feb	9076	9038	99.58	23	0.25	15	0.17
Mar	9713	9692	99.78	21	0.22	0	0.00
Apr	8782	8781	99.99	1	0.01	0	0.00
May	9444	9442	99.98	1	0.01	1	0.01
Jun	9126	9125	99.99	1	0.01	0	0.00
Jul	8719	8716	99.97	3	0.03	0	0.00
Aug	8810	8809	99.99	1	0.01	0	0.00
Sep	8785	8785	100.00	0	0.00	0	0.00
Oct	9594	9594	100.00	0	0.00	0	0.00
Nov	10051	10049	99.98	2	0.02	0	0.00
Dec	10801	10646	98.56	106	0.98	49	0.45
Averag**e**			**99.54**		**0.33**		**0.12**

Figure 4 is a graphic representation of the relative time response is possible, impaired or impossible based on the results in Table 3. In each month, total percentage of time equals 100 percent. Percentages represent the average rating for the specified month. There is little time when response would not be possible.

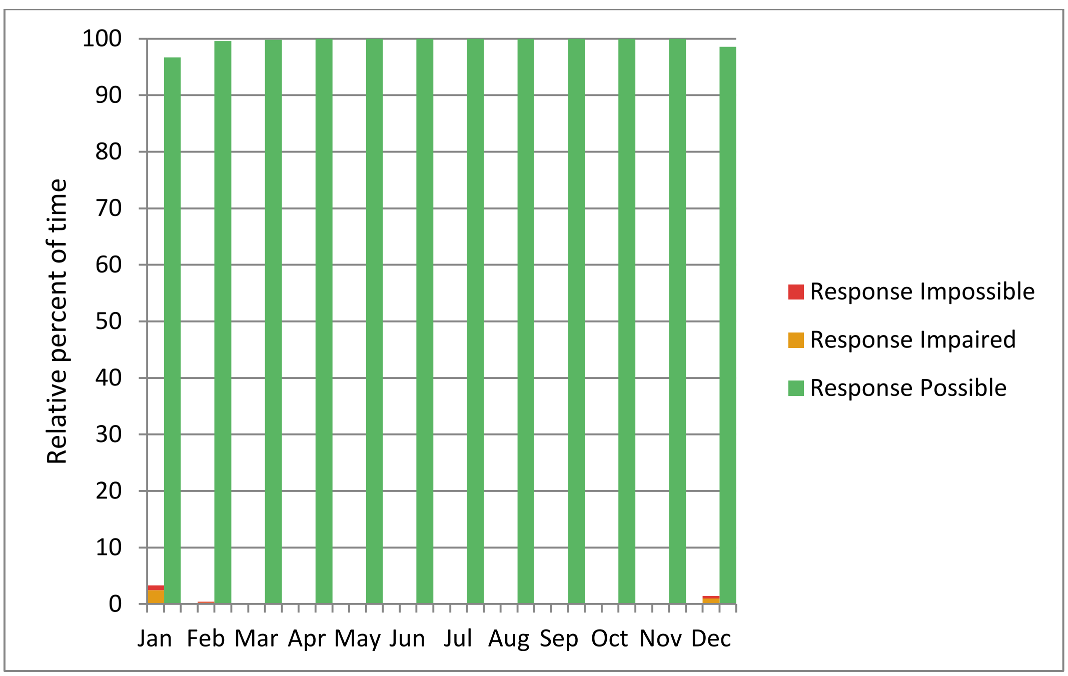

Figure 4. Relative percent of time response is possible, impaired or impossible based on historical wave height observations at buoy C46181, Nanakwa Shoal.

Buoy C46183 – North Hecate Strait

Table 6 represents the results of applying the operational limits defined in Table 2 to the historical wave height data from buoy C46183, North Hecate Strait. When wave height was considered alone, operational limits were impaired or impossible for a substantial period of time. On average, response would be possible 61.73 percent of the year, impaired 24.70 percent of the year, and impossible 13.57 percent of the year. Response is impaired or impossible for 38.27 percent of the year on average.

The response gap reaches a maximum in December at 26.76 percent. When considered together, response is impaired or impossible 61.28 percent of the time in December.

Response is most effective in July when response would be possible 85.51 percent of the time.

Table 6. Relative frequency in which response is possible, impaired or impossible based on historical wave height observations at buoy C46183, North Hecate Strait.

		Response Possible		Response Impaired		Response Impossible	
Month	**Total weather observations**	**Wave height observations ≤1.2 m**	**Percent ≤1.2m**	**Wave height observations 1.2 to <2.4m**	**Percent 1.2 to <2.4 m**	**Wave height observations ≥2.4 m**	**Percent ≥2.4 m**
Jan	12093	5054	41.79	4003	33.10	3036	25.11
Feb	11702	5868	50.15	3542	30.27	2292	19.59
Mar	12646	6369	50.36	3875	30.64	2402	18.99
Apr	11398	6930	60.80	3004	26.36	1464	12.84
May	11470	8629	75.23	2182	19.02	659	5.75
Jun	10963	8791	80.19	1860	16.97	312	2.85
Jul	11499	9833	85.51	1524	13.25	142	1.23
Aug	11362	9249	81.40	1636	14.40	477	4.20
Sep	11089	8447	76.17	1879	16.94	763	6.88
Oct	11975	6937	57.93	3108	25.95	1930	16.12
Nov	12393	5262	42.46	4341	35.03	2790	22.51
Dec	12071	4674	38.72	4167	34.52	3230	26.76
Average			**61.73**		**24.70**		**13.57**

Figure 5 is a graphic representation of the relative time response is possible, impaired or impossible based on the results in Table 3. In each month, total percentage of time equals 100 percent. Percentages represent the average rating for the specified month. There are significant periods of time when response is impaired or impossible based solely on wave height data. Response is most effective in the summer months. Response is least effective in the winter months.

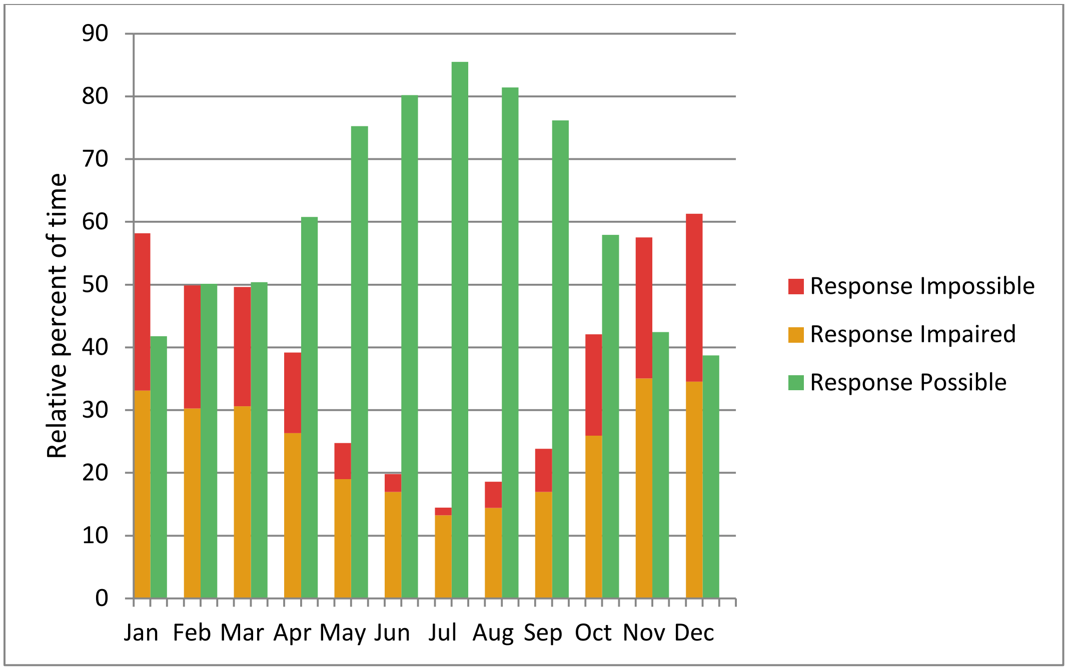

Figure 5. Relative percent of time response is possible, impaired or impossible based on historical wave height observations at buoy C46183, North Hecate Strait.

Buoy C46185 – South Hecate Strait

Table 7 represents the results of applying the operational limits defined in Table 2 to the historical wave height data from buoy C46185, South Hecate Strait. When wave height was considered alone, operational limits were impaired or impossible for a substantial period of time. On average, response would be possible 42.10 percent of the year, impaired 33.69 percent of the year, and impossible 24.22 percent of the year. Response is impaired or impossible for 57.91 percent of the year on average.

The response gap reaches a maximum in December at 47.80 percent. When considered together, response is impaired or impossible 86.05 percent of the time in December.

Response is most effective in July when response would be possible 76.09 percent of the time.

Table 7. Relative frequency in which response is possible, impaired or impossible based on historical wave height observations at buoy C46185, South Hecate Strait.

		Response Possible		Response Impaired		Response Impossible	
Month	**Total weather observations**	**Wave height observations ≤1.2 m**	**Percent ≤1.2m**	**Wave height observations 1.2 to <2.4m**	**Percent 1.2 to <2.4 m**	**Wave height observations ≥2.4 m**	**Percent ≥2.4 m**
Jan	12440	2336	18.78	4484	36.05	5620	45.18
Feb	11692	3389	28.99	4323	36.97	3980	34.04
Mar	12883	3243	25.17	5274	40.94	4366	33.89
Apr	10864	4097	37.71	4310	39.67	2457	22.62
May	10826	5812	53.69	3867	35.72	1147	10.59
Jun	11018	7512	68.18	2737	24.84	769	6.98
Jul	11282	8584	76.09	2295	20.34	403	3.57
Aug	10781	7772	72.09	2406	22.32	603	5.59
Sep	11162	6657	59.64	3376	30.25	1129	10.11
Oct	11959	3896	32.58	4767	39.86	3296	27.56
Nov	11447	2095	18.30	4471	39.06	4881	42.64
Dec	12468	1739	13.95	4769	38.25	5960	47.80
Average			**42.10**		**33.69**		**24.22**

Figure 6 is a graphic representation of the relative time response is possible, impaired or impossible based on the results in Table 3. In each month, total percentage of time equals 100 percent. Percentages represent the average rating for the specified month. There are significant periods of time when response is impaired or impossible based solely on wave height data. Response is most effective in the summer months. Response is least effective in the winter months.

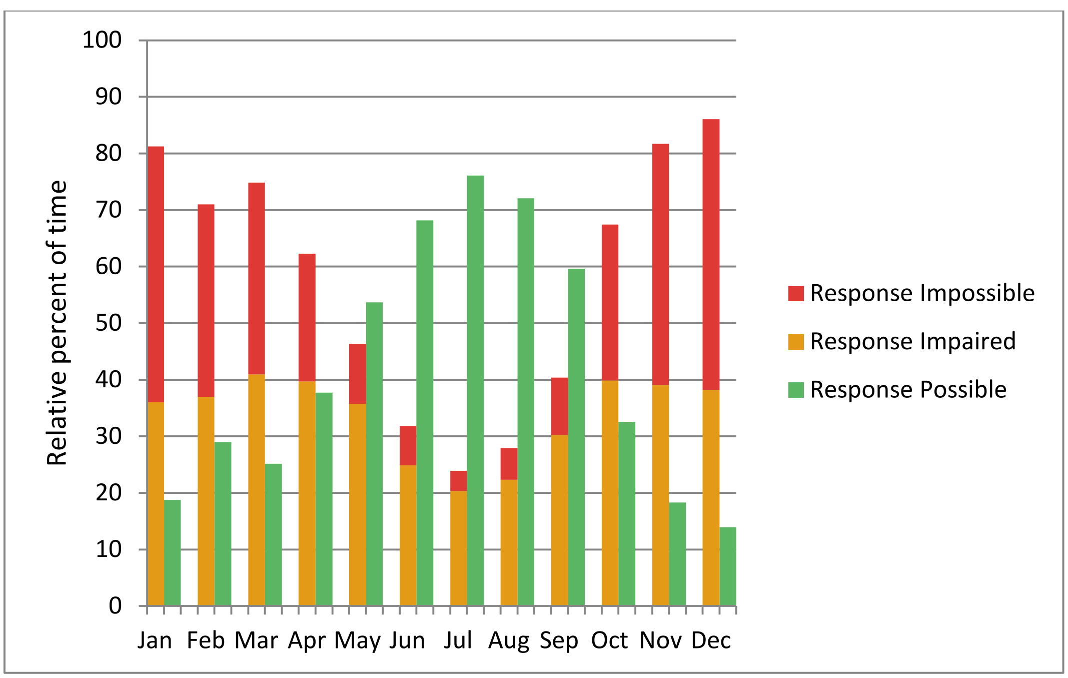

Figure 6. Relative percent of time response is possible, impaired or impossible based on historical wave height observations at buoy C46185, South Hecate Strait.

Buoy C46204 – West Sea Otter

Table 8 represents the results of applying the operational limits defined in Table 2 to the historical wave height data from buoy C46204, West Sea Otter. When wave height was considered alone, operational limits were impaired or impossible for a substantial period of time. On average, response would be possible 24.15 percent of the year, impaired 38.86 percent of the year, and impossible 36.98 percent of the year. Response is impaired or impossible for 75.84 percent of the year on average.

The response gap reaches a maximum in December at 69.74 percent. When considered together, response is impaired or impossible 96.61 percent of the time in December.

Response is most effective in July when response would be possible 58.57 percent of the time.

Table 8. Relative frequency in which response is possible, impaired or impossible based on historical wave height observations at buoy C46204, West Sea Otter.

		Response Possible		Response Impaired		Response Impossible	
Month	**Total weather observations**	**Wave height observations ≤1.2 m**	**Percent ≤1.2m**	**Wave height observations 1.2 to <2.4m**	**Percent 1.2 to <2.4 m**	**Wave height observations ≥2.4 m**	**Percent ≥2.4 m**
Jan	11822	784	6.63	3434	29.05	7604	64.32
Feb	10466	594	5.68	4673	44.65	5199	49.68
Mar	12011	1041	8.67	4405	36.67	6565	54.66
Apr	11734	2049	17.46	5200	44.32	4485	38.22
May	10316	3912	37.92	4954	48.02	1450	14.06
Jun	9353	4230	45.23	4137	44.23	986	10.54
Jul	9764	5719	58.57	3698	37.87	347	3.55
Aug	9813	5614	57.21	3749	38.20	450	4.59
Sep	10237	3352	32.74	5064	49.47	1821	17.79
Oct	11435	1321	11.55	4504	39.39	5610	49.06
Nov	10515	504	4.79	2904	27.62	7107	67.59
Dec	11885	403	3.39	3193	26.87	8289	69.74
Average			**24.15**		**38.86**		**36.98**

Figure 7 is a graphic representation of the relative time response is possible, impaired or impossible based on the results in Table 3. In each month, total percentage of time equals 100 percent. Percentages represent the average rating for the specified month. There are significant periods of time when response is impaired or impossible based solely on wave height data. Response is most effective in the summer months. Response is least effective in the winter months.

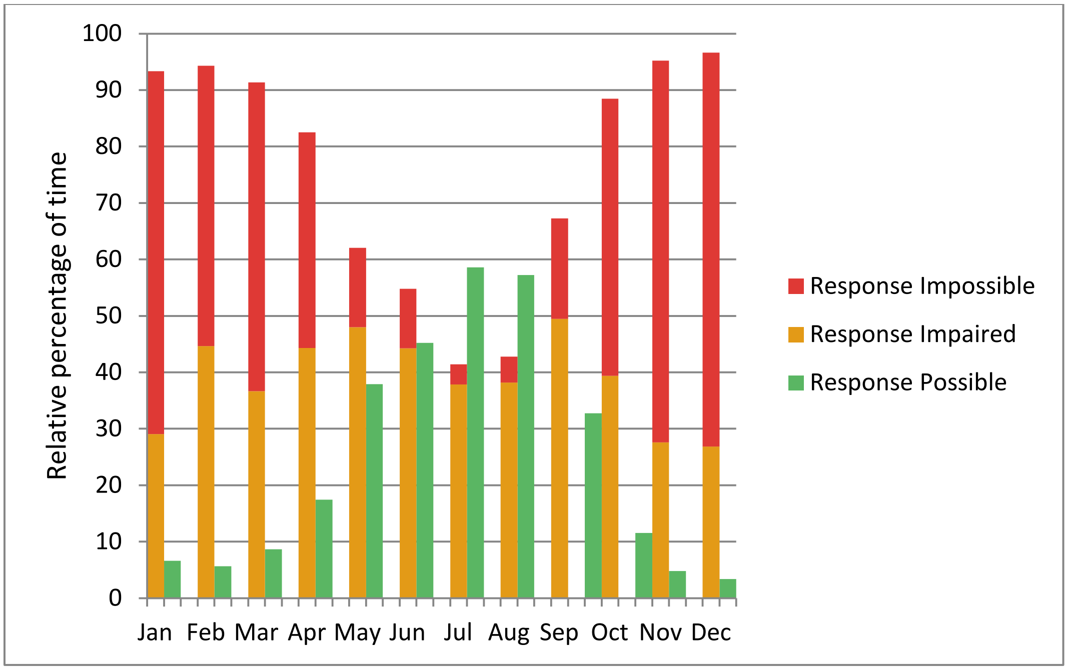

Figure 7. Relative percent of time response is possible, impaired or impossible based on historical wave height observations at buoy C46204, West Sea Otter.

Buoy C46205 – West Dixon Entrance

Table 9 represents the results of applying the operational limits defined in Table 2 to the historical wave height data from buoy C46205, West Dixon Entrance. When wave height was considered alone, operational limits were impaired or impossible for a substantial period of time. On average, response would be possible 15.25 percent of the year, impaired 36.43 percent of the year, and impossible 48.32 percent of the year. Response is impaired or impossible for 84.75 percent of the year on average.

The response gap reaches a maximum in December at 81.40 percent. When considered together, response is impaired or impossible 98.32 percent of the time in December.

Response is most effective in July when response would be possible 39.50 percent of the time.

Table 9. Relative frequency in which response is possible, impaired or impossible based on historical wave height observations at buoy C46205, West Dixon Entrance.

		Response Possible		Response Impaired		Response Impossible	
Month	**Total weather observations**	**Wave height observations ≤1.2 m**	**Percent ≤1.2m**	**Wave height observations 1.2 to <2.4m**	**Percent 1.2 to <2.4 m**	**Wave height observations ≥2.4 m**	**Percent ≥2.4 m**
Jan	9137	219	2.40	2078	22.74	6840	74.86
Feb	8779	191	2.18	2492	28.39	6096	69.44
Mar	11132	488	4.38	3073	27.61	7571	68.01
Apr	10975	837	7.63	4804	43.77	5334	48.60
May	10702	2635	24.62	5241	48.97	2826	26.41
Jun	10764	3572	33.18	5598	52.01	1594	14.81
Jul	10956	4892	44.65	5408	49.36	656	5.99
Aug	10734	4156	38.72	5301	49.39	1277	11.90
Sep	9862	1637	16.60	4695	47.61	3530	35.79
Oct	11137	625	5.61	3248	29.16	7264	65.22
Nov	10373	136	1.31	2209	21.30	8028	77.39
Dec	10714	180	1.68	1813	16.92	8721	81.40
Average			**15.25**		**36.43**		**48.32**

Figure 8 is a graphic representation of the relative time response is possible, impaired or impossible based on the results in Table 3. In each month, total percentage of time equals 100 percent. Percentages represent the average rating for the specified month. There are significant periods of time when response is impaired or impossible based solely on wave height data. Response is most effective in the summer months. Response is least effective in the winter months.

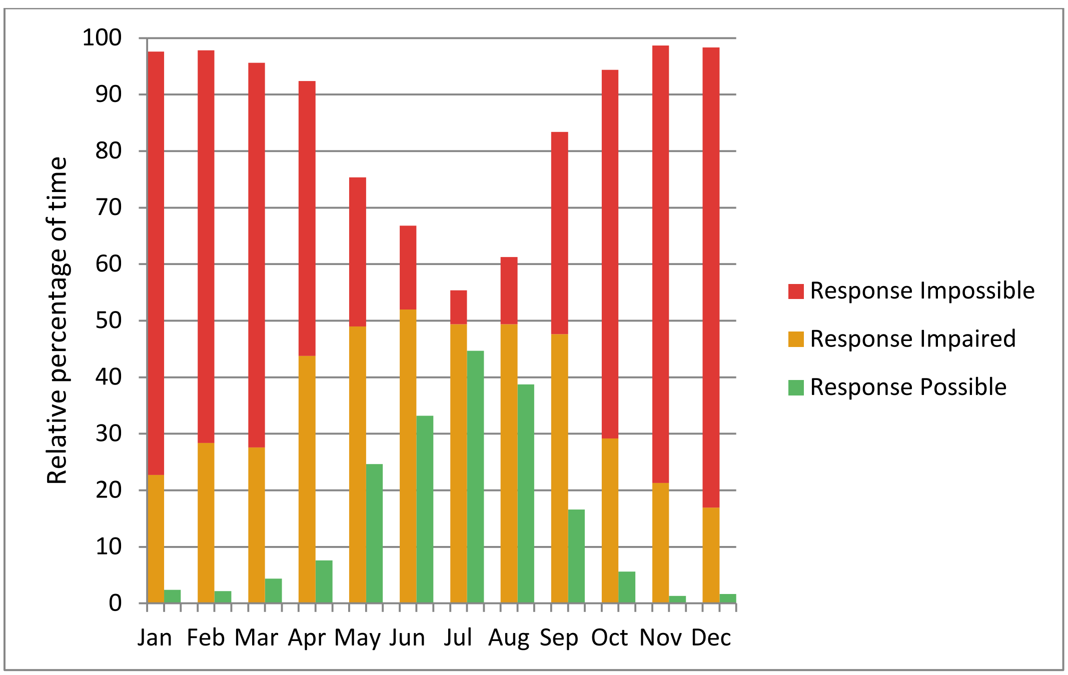

Figure 8. Relative percent of time response is possible, impaired or impossible based on historical wave height observations at buoy C46205, West Dixon Entrance.

Buoy C46207 – East Dellwood

Table 10 represents the results of applying the operational limits defined in Table 2 to the historical wave height data from buoy C46207, East Dellwood. When wave height was considered alone, operational limits were impaired or impossible for a substantial period of time. On average, response would be possible 13.04 percent of the year, impaired 36.65 percent of the year, and impossible 50.30 percent of the year. Response is impaired or impossible for 86.95 percent of the year on average.

The response gap reaches a maximum in December at 86.25 percent. When considered together, response is impaired or impossible 99.12 percent of the time in December.

Response is most effective in July and August when response would be possible 34.93 percent of the time.

Table 10. Relative frequency in which response is possible, impaired or impossible based on historical wave height observations at buoy C46207, East Dellwood.

		Response Possible		Response Impaired		Response Impossible	
Month	**Total weather observations**	**Wave height observations ≤1.2 m**	**Percent ≤1.2m**	**Wave height observations 1.2 to <2.4m**	**Percent 1.2 to <2.4 m**	**Wave height observations ≥2.4 m**	**Percent ≥2.4 m**
Jan	11806	181	1.53	2175	18.42	9450	80.04
Feb	11561	164	1.42	2833	24.50	8564	74.08
Mar	12485	421	3.37	3077	24.65	8987	71.98
Apr	11150	754	6.76	4635	41.57	5761	51.67
May	10952	2248	20.53	5756	52.56	2948	26.92
Jun	11108	3276	29.49	5993	53.95	1839	16.56
Jul	11506	4019	34.93	6667	57.94	820	7.13
Aug	11601	4052	34.93	6170	53.19	1379	11.89
Sep	11835	1897	16.03	6236	52.69	3702	31.28
Oct	12978	649	5.00	3848	29.65	8481	65.35
Nov	12371	205	1.66	2208	17.85	9958	80.49
Dec	12645	112	0.89	1627	12.87	10906	86.25
Average			**13.04**		**36.65**		**50.30**

Figure 9 is a graphic representation of the relative time response is possible, impaired or impossible based on the results in Table 3. In each month, total percentage of time equals 100 percent. Percentages represent the average rating for the specified month. There are significant periods of time when response is impaired or impossible based solely on wave height data. Response is most effective in the summer months. Response is least effective in the winter months.

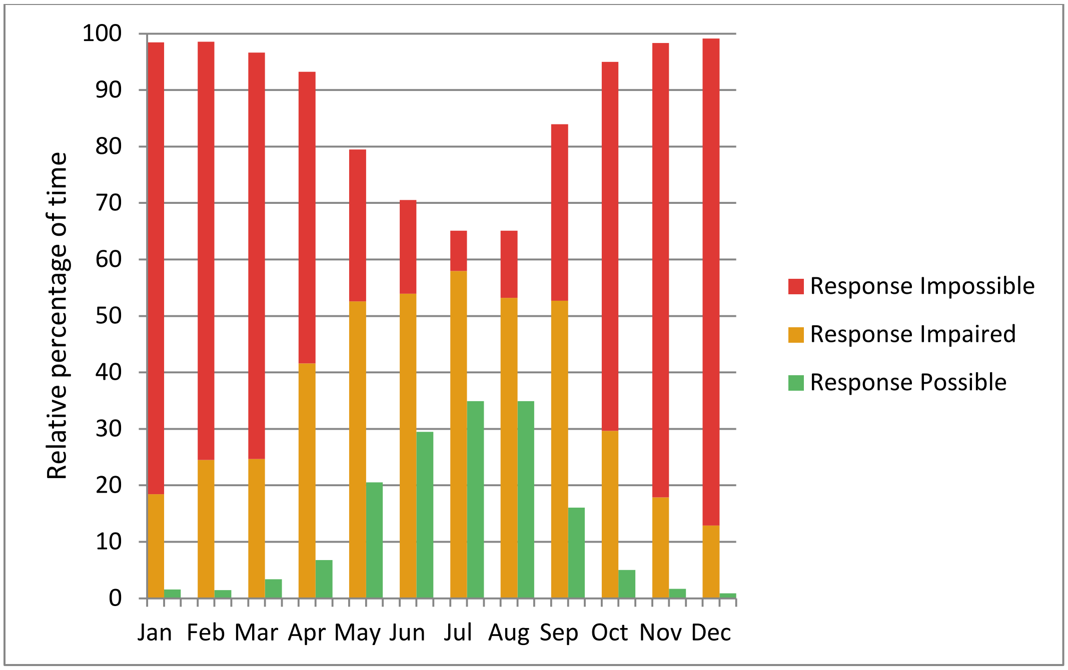

Figure 9. Relative percent of time response is possible, impaired or impossible based on historical wave height observations at buoy C46207, East Dellwood.

All buoy locations

Table 11 represents the average yearly response gap at each buoy location. The greatest response gap exists at South Moresby; on average, response would not be possible 50.92 percent of the time. The response gap is least significant at Nanakwa Shoal; on average, response would not be possible 0.12 percent of the time. When all buoy locations are considered collectively, a response gap exists 30.37 percent of the time on average in the proposed project area.

Table 11. Average yearly response gap (response is impossible) at all buoy locations.

Buoy No.	Buoy Name	Response Gap Minimum		Response Gap Maximum		Response Gap Yearly Average (%)
		Month	Percent	Month	Percent	
C46145	Central Dixon Entrance	Jul	0.36	Dec	46.22	18.49
C46147	South Moresby	Jul	7.23	Dec	81.35	50.92
C46181	Nanakwa Shoal	Jun-Nov	0	Jan	0.87	0.12
C46183	North Hecate Strait	Jul	1.23	Dec	26.76	13.57
C46185	South Hecate Strait	Jul	3.57	Dec	47.8	24.22
C46204	West Sea Otter	Jul	3.55	Dec	69.74	36.98
C46205	West Dixon Entrance	Jul	5.99	Dec	81.4	48.32
C46207	East Dellwood	Jul	7.13	Dec	86.25	50.30
	Average		**3.63**		**55.05**	**30.37**

Table 12 represents the average yearly frequency in which response would be impaired or impossible at each buoy location. Response is impaired or impossible for the greatest period of time at South Moresby; on average, response is impaired or impossible 86.32 percent of the time. Response is impaired or impossible for the least significant period of time at Nanakwa Shoal; on average, response is impaired or impossible 0.45 percent of the time. When all buoy locations are considered collectively, a response gap exists 61.15 percent of the time on average in the proposed project area.

Table 12. Average yearly frequency in which response is impaired or impossible at all buoy locations

Buoy No.	Buoy Name	Response Impaired or Impossible Minimum		Response Impaired or Impossible Maximum		Response Impaired or Impossible Yearly Average (%)
		Month	Percent	Month	Percent	
C46145	Central Dixon Entrance	Jul	18.08	Dec	89.13	58.73
C46147	South Moresby	Jul	64.1	Dec	98.33	86.32
C46181	Nanakwa Shoal	Jun-Nov	0.7	Jan	3.33	0.45
C46183	North Hecate Strait	Jul	14.48	Dec	61.28	38.27
C46185	South Hecate Strait	Jul	23.91	Dec	86.05	57.91
C46204	West Sea Otter	Jul	41.42	Dec	96.61	75.84
C46205	West Dixon Entrance	Jul	55.35	Dec	98.32	84.75
C46207	East Dellwood	Jul	65.07	Dec	99.12	86.95
	Average		**35.39**		**79.02**	**61.15**

Discussion

In analyzing historical wave height observations from buoys located within the proposed project area, it becomes evident that there are substantial periods of time when a response gap exists for mechanical oil spill equipment. During these periods, environmental conditions preclude the effective operation of mechanical response equipment, and containment and cleanup of an oil spill would not be possible. On average, this occurs approximately 30 percent of the year in the proposed project area. Coastal resources and marine ecosystems could be severely impacted during this time.

Because only wave height was considered in this analysis, and the interplay between other environmental factors to account for cumulative effects was not addressed, the response gaps values identified in this analysis are highly conservative. A cumulative analysis would likely demonstrate higher values at each buoy location. For instance, a situation may arise where the combination of wave height and wind speed may present a response gap even though each factor considered individually would not. The resulting value from taking both environmental factors into consideration would be greater than if each factor was considered individually.

Likewise, including hours without daylight in the analysis would result in a larger response gap. Despite state of the art remote sensing techniques, it is not possible to conduct response operations at night, and it extremely difficult when visibility is less than one kilometer even during the day (Turner et al., 2010). On the summer solstice, Kitimat – the location of the pipeline terminus and marine terminal – receives approximately 19 hours of daylight including civic twilight; on the winter solstice, Kitimat only receives approximately 9 hours of daylight including civic twilight (NRDC, 2011). On this day, response would not be possible for upwards of 15 hours simply due to darkness. Fog and precipitation, whether in the form of rain or snow, are prevalent in the proposed project area, only acting to further reduce visibility during the day and night.

The addition of currents would further increase the response gap. Conventional oil spill containment booms fail at a current of 0.5 m/sec (1 knot) regardless of boom design or other environmental conditions merely due to hydrodynamic limitations of the equipment (Fingas, 2004). In Otter Passage, alongside the proposed oil tanker route, the current reaches 6 knots (CHS, 1982); portions of Douglas Channel reach 1.5 knots (CHS, 1977), and currents in Principe Channel reach 3 knots (CHS, 1954).

Calculating the frequency in which response is either impaired or impossible may also present a more accurate representation of response success. Even though response may not be "impossible," it will still be less than effective if it has been rated "impaired." During the best of weather conditions, responding to an oil spill is challenging. Generally only 10 to 15 percent of spilled oil is recovered, based on typical estimates for open water recovery efficiencies for mechanical equipment (Oceans North, 2011). If response is "impaired," this value may be even less. Within the proposed project area, response is either "impaired" or "impossible" approximately 61 percent of the year on average. This is a substantial amount of time when response may be less than adequate, and the marine environment is at risk.

The portion of time that mechanical response is impaired or impossible is substantially higher in the Open Water Area (OWA) of the proposed project area than the Confined Channel Assessment Area (CCAA).

This is to be expected. The waters in the OWA are more exposed to the open Pacific Ocean and approaching storms. In terms of wave height – the only environmental factor assessed in this analysis – fetch (the distance wave-generating wind travels over open water) and wind strength in the OWA are much greater. Thus, the wave heights, and in turn the mechanical response gap, are greater than in the CCAA.

Similarly, areas within the OWA have higher response gaps than others. South Moresby, West Dixon Entrance and East Dixon Entrance all have average yearly response gaps around 50 percent. Maximum response gaps in these areas occur in December when response would be impossible greater than 80 percent of the time at each location. The smallest response gap occurs at North Hecate when response would still be impossible 13 percent of the year on average. These values are not insignificant. Most structural failures of oil tankers occur in open waters in heavy weather (Devanney, 2006). If an oil spill were to occur in the winter months, the environmental impacts could be devastating.

The response gap for the CCAA may not accurately represent the entire CCAA. Nanakwa Shoal is the only DFO weather buoy located within the CCAA. Other areas within the CCAA would likely exhibit different outcomes due to differences in topography, orientation and exposure. For example, Whale Channel can experience gusty conditions when winds are funneled through the surrounding mountains. Likewise, southeast winds funnel through Principe Channel and can cause steep waves to build near Anger Island. Additional weather collection sites are needed throughout the CCAA to determine a more accurate response gap for the entire CCAA.

Regardless of weather conditions, many other variables come into play when assessing the effectiveness of response. The size of the spill, the product spilled, the response time (i.e. how long it takes response crews to arrive on site), availability of response equipment (both the amount available and models), length of oiled shorelines, amount of oiled wildlife, and availability of trained responders, among many other factors, can all influence response (Turner et al., 2010).

As oil spills around the world have demonstrated, spill response is challenging at the best of times. The likelihood of having favourable wind and waves, good visibility, daylight hours and slack currents at the time of a spill and for days afterward is not just improbable, it is nonexistent. As this preliminary response gap analysis reveals, ineffective response is guaranteed for much of the year if an oil spill occurs within the proposed project area. The spilled oil would not be contained or cleaned up during these periods. Coastal resources and marine ecosystems would be severely impacted.

Recommendations

Because this report is a preliminary response gap analysis which considers only wave height observations and does not address the interplay between different environmental factors (i.e. wind, temperature, currents and visibility) in determining effective oil spill response capacity, it is strongly recommended that Enbridge Northern Gateway Pipelines commission a more comprehensive analysis to be conducted by a reputable consulting firm such as Nuka Research and Planning Group, LLC.

Literature Cited

Canadian Hydrographic Service (CHS). (1954). *3747 Browning Entrance* [chart]. 1: 39,058. Ottawa: CHS.

Canadian Hydrographic Service (CHS). (1977). *3743 Douglas Channel* [chart]. 1: 73,032. Ottawa: CHS.

Canadian Hydrographic Service (CHS). (1982). 3742 *Otter Pass to/à McKay Reach* [chart]. 1:70,920. Ottawa: CHS.

Devanney, J. (2006). *The Tankship Tromedy: the Impending Disasters in Tankers*. Tavernier : CTX Press.

Environment Canada, Atmospheric Environment Service. (1990). *Marine Weather Hazards Manual – a guide to local forecasts and conditions 2nd edition* (Catalogue No. En 56-74/1990E). Ottawa: Minister of Supply and Services.

Fingas, M. (2004). *Weather Windows for Oil Spill Countermeasures*. Retrieved from: http://www.pwsrcac.org/docs/d0002500.pdf

Fisheries and Oceans Canada. (2011). *Observed Wave Data Search Results*. Retrieved from http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/waves-vagues/search-recherche/list-liste/index-eng.asp?MedsID=C46&ID=&StnName=&Lat1=&Lat2=&Long1=&Long2=&sDate=&eDate=&typedisplay=HTML&Search=Get+Results

Natural Resources Council Canada. (2011). *Sunrise/Sunset/Sun Angle Calculator*. Retrieved from http://www.nrc-cnrc.gc.ca/eng/services/hia/sunrise-sunset/angle-calculator.html

Enbridge Northern Gateway Pipelines. (2011). *General Oil Spill Response Plan*. Retrieved from https://www.neb-one.gc.ca/ll-eng/livelink.exe/fetch/2000/90464/90552/384192/620327/624798/679120/B21-2_-_General_Oil_Spill_Response_Plan_-_Enbridge_Northern_Gateway_%28March_2011%29_-_A1Y3Y8.pdf?nodeid=679124&vernum=0

Nuka Research and Planning Group, LLC. (2007). *Response Gap Estimates for Two Operating Areas in Prince William Sound; Report to Prince William Sounds Regional Citizens' Advisory Council*. Retrieved from http://www.pwsrcac.org/docs/d0034200.pdf

Oceans North. (2011). *Response Gap*. Retrieved from http://www.oceansnorth.org/response-gap

Turner, M., Skinner, J., Roberts, J., Harvey, R., & S.L Ross Environmental Research Ltd. (2010). *Review of Offshore Oil-spill Prevention and Remediation Requirements and Practices in Newfoundland and Labrador.* St. John's: Government of Newfoundland and Labrador.