Section 3.6: Special Underkeel Clearance Survey

TERMPOL Surveys and Studies

ENBRIDGE NORTHERN GATEWAY PROJECT

FINAL - REV. 0

Prepared for:
Northern Gateway Pipelines Inc.

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1 Objectives

In accordance with the TERMPOL Code, Enbridge has completed a review of the water depths within the navigation routes leading to the proposed Enbridge Northern Gateway Pipelines Terminal (Kitimat Terminal). The objective of the study is to consider all relevant factors which may affect underkeel clearance and to ensure that adequate water depths are available for a safe transit of the design vessel.

The study is based exclusively on the draught of the largest vessel that is expected to call on the Terminal, namely a Very Large Crude Carrier (VLCC), with a maximum design draught of 23.1 m.

1.1 Definitions and Context

Underkeel clearance is defined as the least distance between the underside of the vessel and the bottom of the channel, after taking into account the effects of tides, accuracy of charts, vessel trim, vessel motions due to waves, the dynamic effect of the ship moving through the water, sagging and hogging the vessel, draft and trim changes caused by salinity variations, and other factors.

The vessel's draught is a measure of the submerged portion of the vessel from the waterline to the bottom of the ship's keel. The maximum loaded draught of the vessels that have called on existing facilities in Kitimat Harbour to date is on the order of 11.5 m.

Enbridge's proposal introduces a new class of deeper draught vessels to the area. The largest proposed vessel that will call on the Enbridge Northern Gateway Pipelines Terminal (Kitimat Terminal) is a Very Large Crude Carrier (VLCC) class tanker, with a loaded draught of 23.1 m. Although the proposed routes comprise fjord-like channels that provide natural deep water routes in most areas, an important component of the marine review of Enbridge's proposal is to examine the hydrographic data that is available for the region, identify those areas where water depth may be limited for navigation of these deep draught VLCC's, and confirm suitability of the routes into and away from the terminal.

Although the Project includes a range of vessel sizes, the current study will be restricted to a review of limiting water depths and characteristics of the deepest draught proposed vessel, or VLCC.

2 Charted Depths for Proposed Routes

2.1 History of Nautical Surveying on Canada's West Coast

The CHS is tasked with the responsibility of preparing and updating nautical charts for Canadian waters. The west coast of British Columbia represents over 20,000 km of coastline and is represented by over 180 nautical charts.

The survey data in support of the nautical charts were collected by various methods over the span of many years. Surveying of the west coast of Canada began in the late 1800's and accelerated through the mid 1900's. These early surveys were conducted by measuring water depths with lead-lines and recording vessel positions either by relation to shore markings when close to shore, or by quadrant or sextant measurements when offshore.

As technological advances were made, survey methods became more reliable. For example, in the 1950's, lead-line methods were replaced by underwater single beam sonar; and, offshore position recording by manual geometrical calculations was replaced using an electronic positioning system known as two-range Decca technology – now replaced by the modern Global Positioning System (GPS). Much of the existing offshore survey data for the waters around the Haida Gwaii, including Hecate Strait and Dixon Entrance, was collected during the Decca surveys carried out from 1957 to 1964.

Today, state-of-the-art Hydrographic Survey equipment includes:

- Multi-beam Sonar technology that is able to map the complete coverage of the seabed compared to discrete points along the traverse of the survey vessel.
- Differential GPS, which can identify the geographical location of collected data to within a few centimetres.
- Seismic Sub-bottom Profilers can determine the general composition of the seabed without having to collect physical samples or core samples.

Hydrographic surveying of the seabed is an on-going exercise to ensure that the best available information is presented on nautical charts and is available to mariners. Due to the size and complexity of the western Canadian coastline and because of the harsh weather conditions that exist there for much of the year, the process of revising older, outdated survey data is slow.

In response to the recent interest in large-scale marine development projects on the north coast and in particular in the Kitimat area, the CHS has prioritized their objectives and their available resources to revise the nautical charts in the region. The planned revisions will meet several objectives, as follows:

- Revise the nautical charts that comprise the north and central coasts. The current proposal by the CHS is to develop 24 new charts for the region. The new charts are to be on the NAD83 horizontal datum, with bilingual notation, in metric units, and available in raster and vector electronic nautical chart formats.

- On-going collection of Multi-beam Hydrographic data in areas considered to be critical for navigation, narrow sections and for new terminal facilities. In 2006, data was collected in Caamaño Sound, Browning Entrance and Principe Channel.
- On-going digitization of existing field sheet data for all other areas.

Appendix B presents a summary of the current progress by CHS with respect to updating the hydrographic charts along the north coast of British Columbia.

2.2 Available Data Sources for Current Project

The review of the charted depths for the proposed routes for the current project was based on data from various sources, including CHS published nautical charts (Reference 1) and nautical publications (Reference 2 to Reference 4), as well as digital bathymetric data representation of the existing field sheet data that was prepared by the CHS for use by Enbridge during a concurrent marine simulation modeling program.

The accuracy of hydrographic survey data is dependent on the methods used to collect the data in the first place. As discussed above, various methods have been employed over the years to collect hydrographic data along Canada’s west coast.

The latest surveys of the rugged north coast, including Dixon Entrance and Hecate Strait were done in the late 1950s, early 1960s, known as the Great Decca Surveys. This program was documented in a research paper titled “The Great West Coast Decca Survey: SeaMap Past Meets Present” (Reference 5). These surveys were considered to be state-of–the-art at the time that they were completed; however, due to the rugged terrain and challenging climate, the data is known to have certain limitations. The need for an updated survey has been identified and its implementation is currently planned by the CHS.

2.3 Chart Datum

The vertical datum that is referenced on Canadian nautical charts and publications relates to the Lowest Normal Tide (LNT). LNT is synonymous with Lower Low Water Large Tide (LLWLT), which is defined as the average of the lowest low waters, one from each of 19 years of predictions.

2.4 Proposed Routes

The proposed routes as discussed in TERMPOL Study 3.5 are shown on Figure 2-1. The routes are considered feasible for VLCC transit based on a review of the CHS nautical charts and nautical publications; current navigation studies[1]; and discussions with the Pacific Pilotage Authority (PPA), the British Columbia Coast Pilots Ltd. (BCCP) and the Canadian Coast Guard (CCG), and are described as follows:

- The North Route navigates Dixon Entrance to Triple Island Pilot Station, Hecate Strait to Browning Entrance, Principe Channel, Otter Channel, Lewis Passage, Wright Sound, and Douglas Channel to the Kitimat Terminal. The approximate distance of marine transit from Triple Islands is 160 nautical miles and requires approximately 13 hours to transit by ship.

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[1] Fast-time computer simulations and real-time Full Mission Bridge navigation simulations were carried out by Force Technologies (Copenhagen) 2006, 2008 and 2009.

- The South Route via Caamaño Sound navigates from Cape Beale Pilot Station through Hecate Strait to Caamaño Sound, Squally Channel, Lewis Passage, Wright Sound, and Douglas Channel to the Kitimat Terminal. The approximate distance of marine transit from Caamaño Sound is 100 nautical miles and requires approximately eight to nine hours to transit by ship.
- The South Route via Browning Entrance can be used during severe weather, since Caamaño Sound may on occasion be inaccessible to vessels on approach from the South. In these cases, vessels may proceed further north through Hecate Strait to Browning Entrance and then follow the same route as the North Route. The approximate distance of marine transit from Caamaño Sound is 190 nautical miles and requires approximately 17 hours to transit by ship.

The proposed routes generally comprise deep and wide channels that are characteristic of northern British Columbia's coastal fjords. Water depths along the proposed routes are generally in excess of 365 m (200 fathoms). The shallowest areas of the routes are at the following locations:

- In Dixon Entrance, situated north of the Haida Gwaii, with shoaling depths of 36 m (20 fathoms) and less, that can be avoided by using the deep water channels to the North or South of Learmonth Bank, as shown in Figure 2-2.
- Within the delineated approach channel from Dixon Entrance to Triple Island Pilot Boarding Area and in the Northern Hecate Strait, from Triple Islands to Cape George, (Porcher Island) where charted water depth is more than 36 m (20 fathoms), as shown in Figure 2-3.
- Within the delineated approach channel to Browning Entrance, with a minimum charted depth of 42 m (23 fathoms) located in position Lat.52°42'N Long.130°34.5'W, as shown in Figure 2-4.
- Within the delineated deep-water channel in Principe Channel, near Dixon Island with depths of approximately 88 m (48 fathoms) mid channel and from 56 to 91 m (31 to 50 fathoms) on two significant sub-sea ledges on the NE side of the channel. On one of these ledges in position Latitude 53°33.06'N Longitude 130°09.82'W there is a 35 m (19 fathoms) patch, as shown in Figure 2-5. This shoal patch can easily be avoided by using the deeper portions of the navigational channel that run adjacent to the shoal patch.
- Within the delineated deep-water channel in Principe Channel, near Sewell Islet with depths of 62 to 91 m (34 to 50 fathoms) on two significant sub-sea ledges on the NE side of the channel, as shown in Figure 2-6.
- In Caamaño Sound, for the preferred route with shoaling depths outside of the deep-water channel, near the entrance of 36 m (20 fathoms) and less. Whilst within the delineated channels the least depth is charted as 42 m (23 fathoms) located in position Latitude 52°54.5N Longitude 129°42.4'W, as shown in Figure 2-7.
- In Caamaño Sound, for the first alternate route south of Ness Rock which also has shoals within the delineated channel, the least depth of which is charted as 38.4m (21 fathoms). Although this depth exceeds the required underkeel clearance depth, the viability of this alternate route is subject to confirmation by the current CHS hydrographic charting update programme.

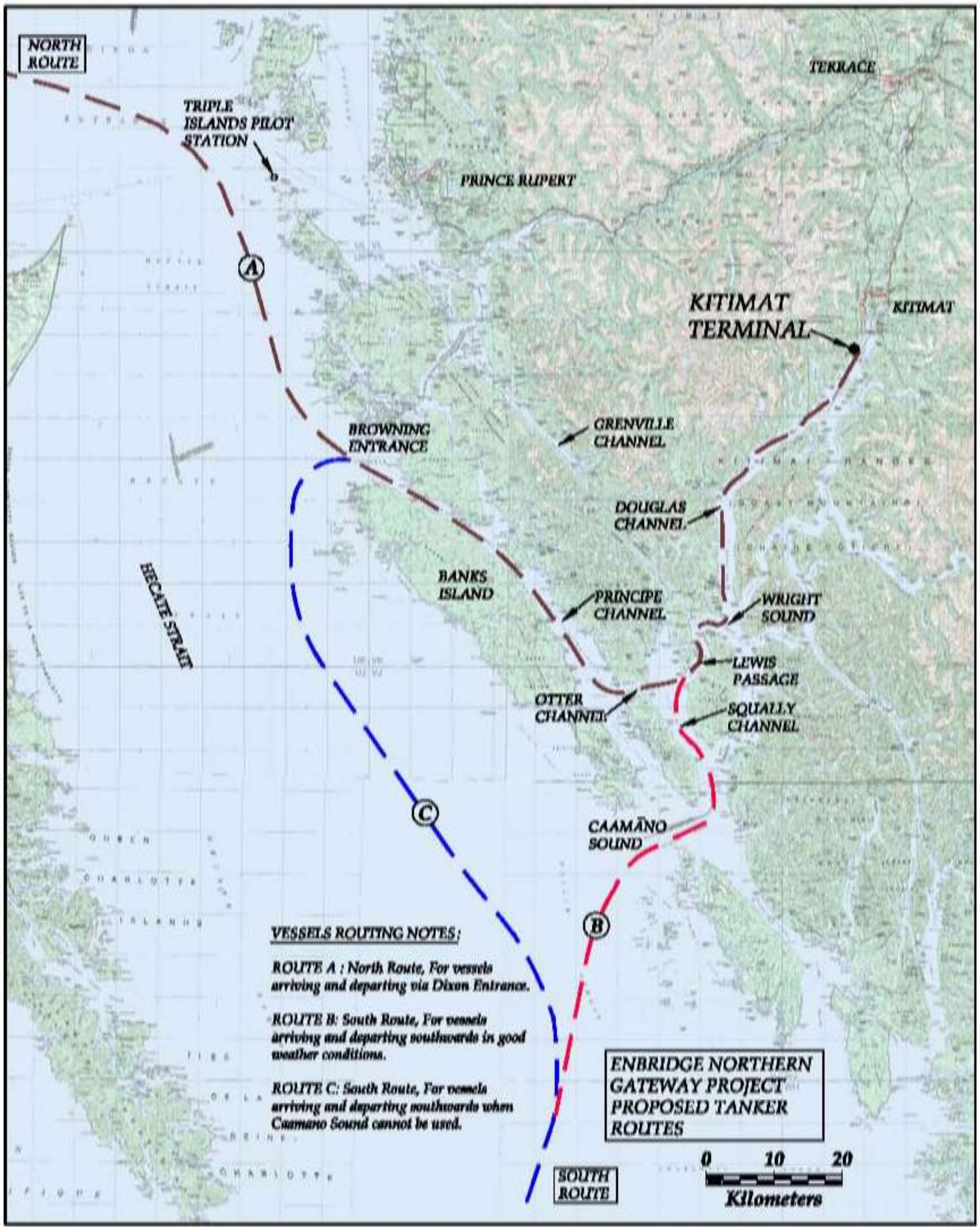

Figure 2-1 Proposed Tanker Navigation Routes

(Source: Moffatt & Nichol, adapted from National Topographic System Maps published by Natural Resources Canada)

While the North Route is considered to be navigable for most of the year, the South Route via Caamaño Sound will be limited to fair weather use due to cross-seas and swell that are set up across Caamaño Sound's approaches, during severe weather.

Channel widths are generally several kilometres wide, with the narrowest parts located in Principe Channel near Dixon and Wheeler Islands (1,430 m) and in Douglas Channel near Emilia Island (1,450 m). Current TERMPOL guidelines recommend a minimum channel width for two-way traffic of seven times the breadth of the vessel, which results in approximately 490 m for the largest VLCC. The narrowest parts of the routes are at least 20 times the beam of the largest design vessel and are approximately three times wider than the minimum requirements under TERMPOL guidelines.

2.5 Dixon Entrance

From seaward, vessels making a north approach from the Pacific Ocean make landfall in Dixon Entrance, just north of Graham Island. The west side of Dixon Entrance is approximately 25 nautical miles wide. Learmonth Bank comprises charted shoals situated near the middle of western Dixon Entrance with limiting depths of 36 m (20 fathoms) or less. The water depths over the bank are described as uneven and the bottom comprises sand, rock and gravel (PAC 206). Mariners are cautioned about the possibility of shallower depths than charted on Learmonth Bank due to the accuracy of the existing survey, which was last carried out in 1964.

Vessels navigating Dixon Entrance must navigate the natural deep water channels situated either to the north or to the south of Learmonth Bank, as shown in Figure 2-2. The channel to the north is a minimum of 14.6 km wide between the 183m (100 fathom) bathymetric contours and the one to the south is a minimum of 11.5 km wide between the same contours. The mid-channel water depths within these deep water channels are generally in excess of 365 m (200 fathoms).

Once past Learmonth Bank, Dixon Entrance is generally a wide and deep fairway that approaches coastal British Columbia. Near the east end of Dixon Entrance, there is another group of shoals which include Celestial Reef, situated in the fairway but to the North of the shipping channel, approximately 35 km west of Dundas Island. The deep water channel to the south of the shoals is some 19 km wide and provides a route for deep draught vessels, with water depths in excess of 183 m (100 fathoms). Figure 2-3 illustrates eastern Dixon Entrance.

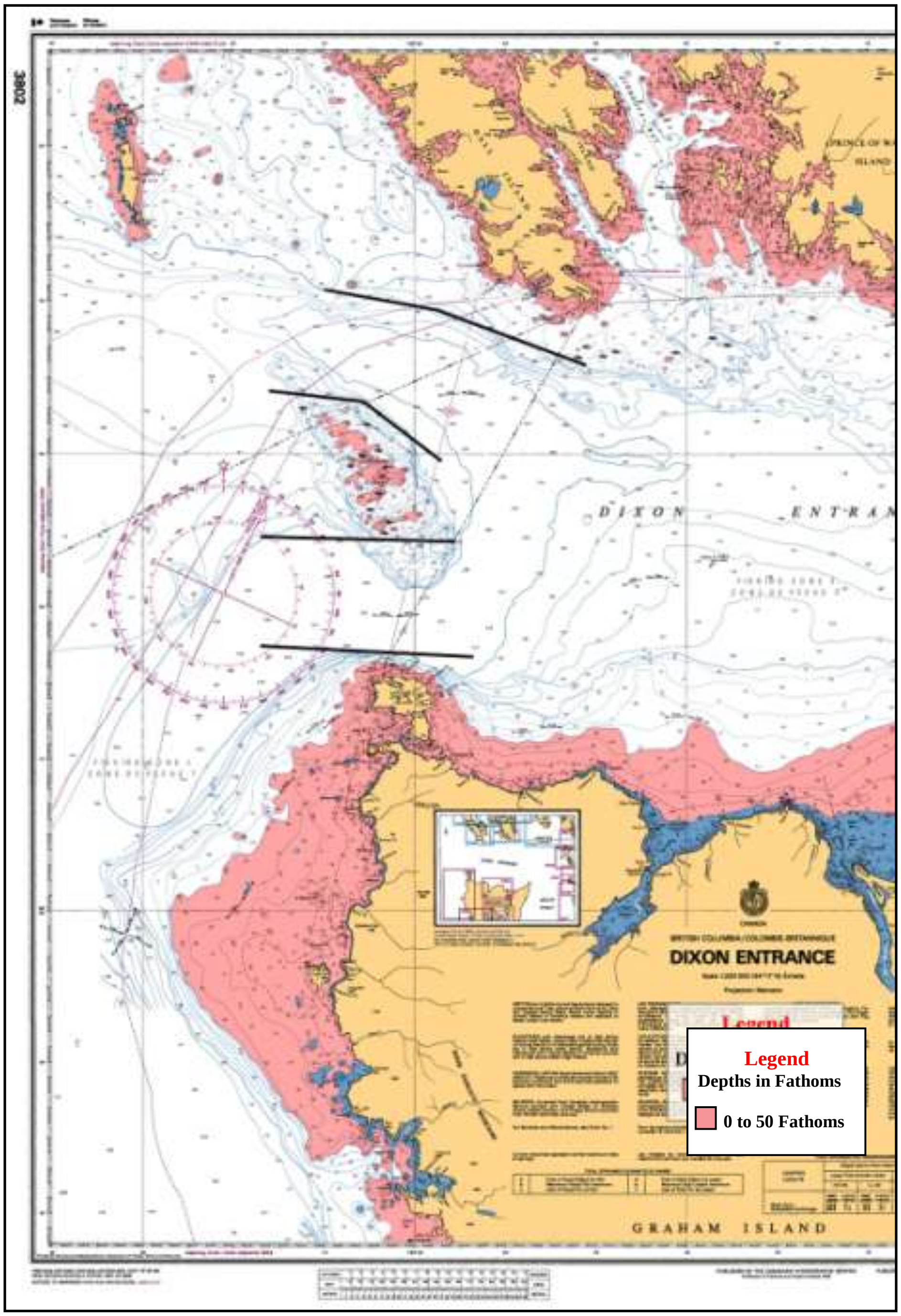

Figure 2-2 Deep Water Routes around Learmonth Bank in Dixon Entrance

(Source: CHS Chart 3802)[2]

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[2] Chart images in this document are copyright protected and reproduced with the permission of the Canadian Hydrographic Service. Not to be used for navigation.

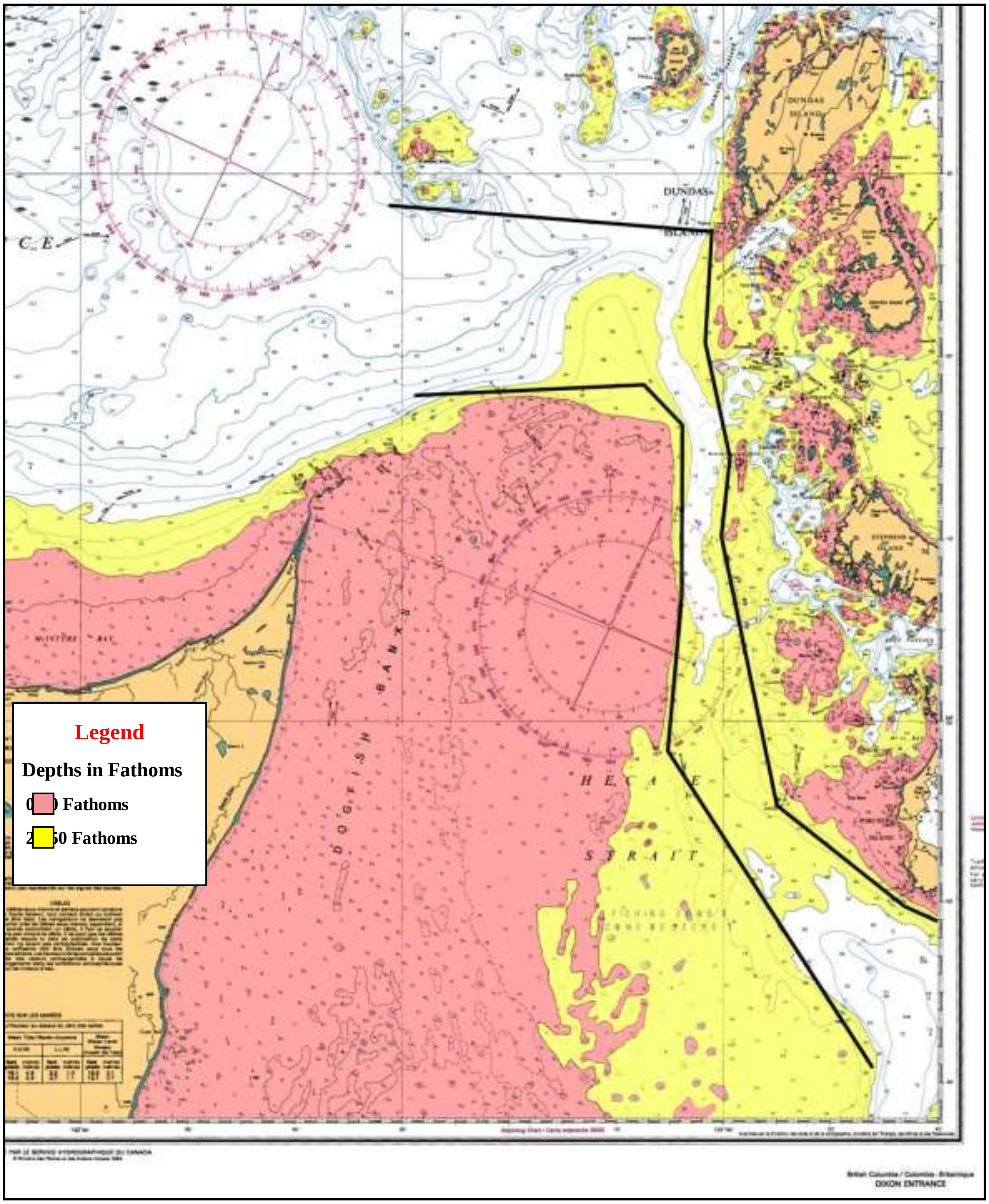

Figure 2-3 **Eastern Dixon Entrance and Northern Hecate Strait**

(Source: CHS Chart 3802)

The Triple Island Pilot Boarding Station for Prince Rupert traffic is situated in Brown Passage, just east of the north-south deep water route shown extending into Hecate Strait. This is the area where the BCCP will embark and disembark pilots required for navigation within coastal waters. The waters in direct vicinity of Triple Islands have extensive shoaling and are not accessible by deep draught vessels. BCCP have indicated that deep draught vessels will be met by a pilot boat, or by alternate means suitable for safe embarkation or disembarkation of marine pilots, in the deep water channels.

Navigation by deep draught vessels in northern Hecate Strait is limited to the deep-water channel shown in Figure 2-3. The route runs adjacent to Rose Spit on the north-eastern corner of Graham Island, with water depths generally exceeding 73 m (40 fathoms). The narrowest part of the navigable channel is 5.3 km in width.

2.6 Browning Entrance

The northern entrance into the coastal waterways from seaward is through Browning Entrance, in northern Hecate Strait. Figure 2-4 illustrates the charted water depths at Browning Entrance.

The south side of Browning Entrance has shoals with charted depths of 36 m (20 fathoms) extending north of Banks Island. The deep-water route delineated in Figure 2-4 represents a least water depth of 42 m (23 fathoms).

Browning Entrance represents one of the areas where the CHS focussed survey efforts during the summer of 2006. Multi-beam survey data were collected, and based on preliminary discussions with CHS there were two notable findings, as follows:

- An uncharted shoal was discovered near the southern portion of Browning Entrance. The location and depth of the shoal is shown on Figure 2-4.
- A shipwreck was discovered in Browning Entrance, in approximately 80 m (44 fathoms) water depth. The wreck is described in the Notice to Mariners (October, 2006) as a ‘non-dangerous wreck, depth unknown”. The approximate location of the shipwreck is shown on Figure 2-4.

These findings do not suggest a condition that will interfere with safe passage of the design vessel within the proposed deep water route shown below. Final published results of the survey have been incorporated into the latest navigational charts.

In addition, these findings illustrate the importance of updating available bathymetric data to take advantage of new technologies that provide a more reliable data set. In addition, on-going surveys are required to identify changes of the sea bottom.

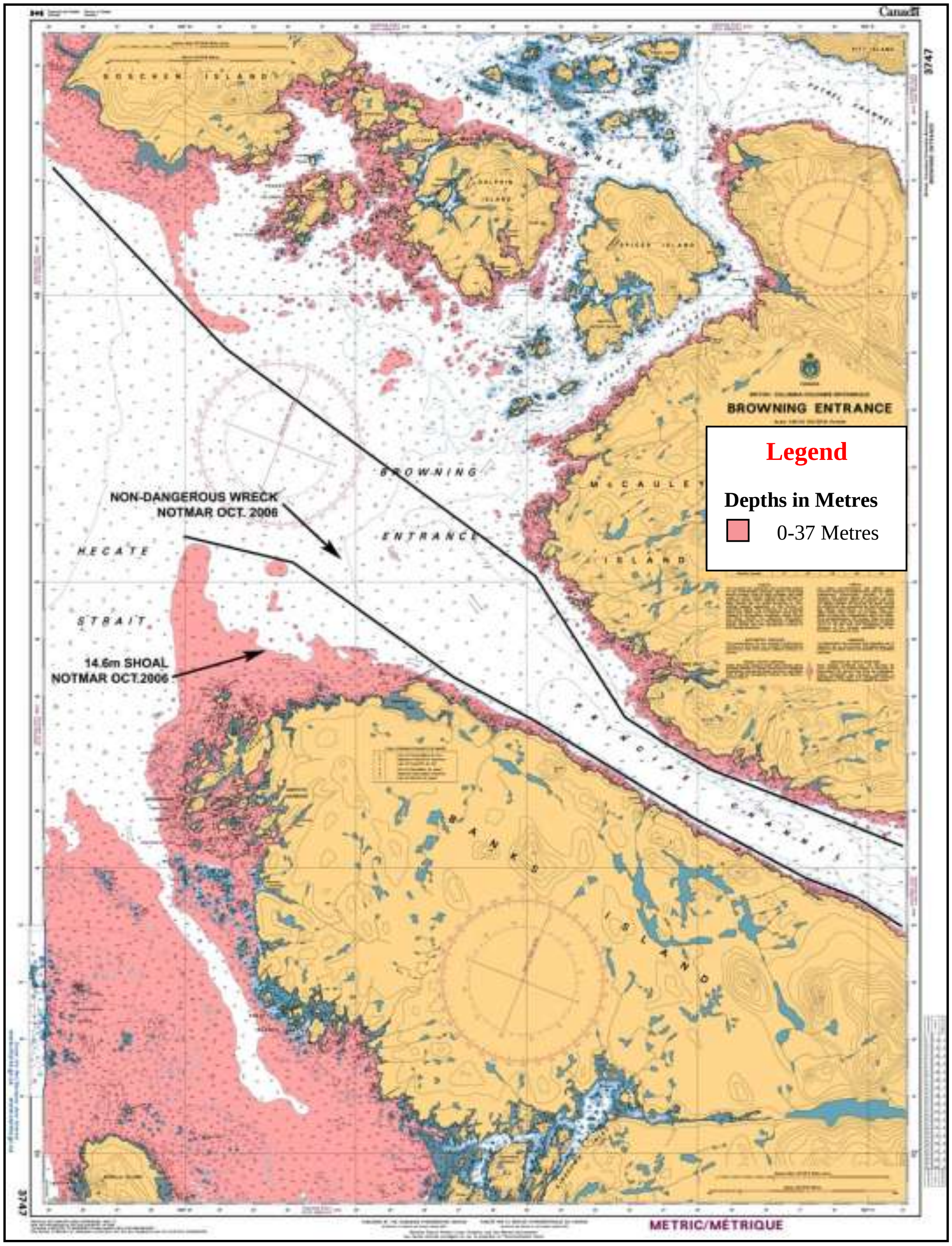

Figure 2-4 Deep Water Route in Browning Entrance

(Source: CHS Chart 3927)

2.7 Principe Channel

Principe Channel is a wide and deep channel, extending in an approximate northwest-southeast direction. The channel provides sheltering from inclement weather in the exposed conditions of Hecate Strait.

In general, the water depths in Principe Channel exceed 182 m (100 fathoms). However, there are two locations where the channel narrows as follows:

- Between Dixon and Wheeler Islands there exists several shallow shoal patches which limit the width of the navigable channel between these shoals to the north and Banks Island to the south, as shown on Figure 2-5, below. This area represents the narrowest part of the proposed routes, with a minimum navigable width in a water depth of more than 36 m of 1,430 m, or of 1,150 m in up to 91 m depth. The minimum water depth near the middle of the navigable channel exceeds 88 m (48 fathoms).

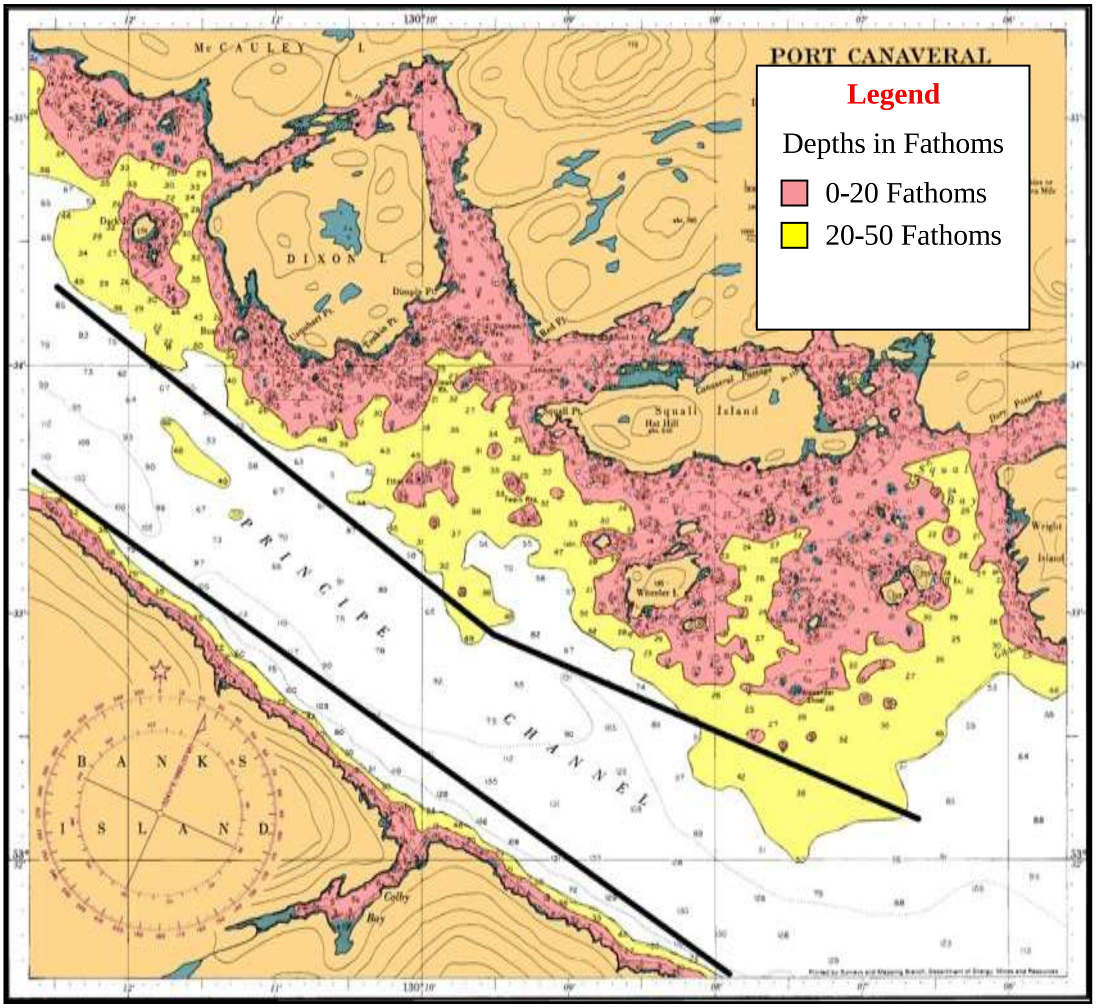

Figure 2-5 Northern Principe Channel

(Source: CHS Chart 3746)

- In Mink Trap Bay, situated off the main channel between Pitt Island to the north and Banks Island to the south, as shown on Figure 2-6, below are Sewell Islet and Nesbitt Rock. The water depths near the middle of the navigable channel between Banks Island and Sewell Islet or Nesbitt Rock generally exceed 182 m (100 fathoms).

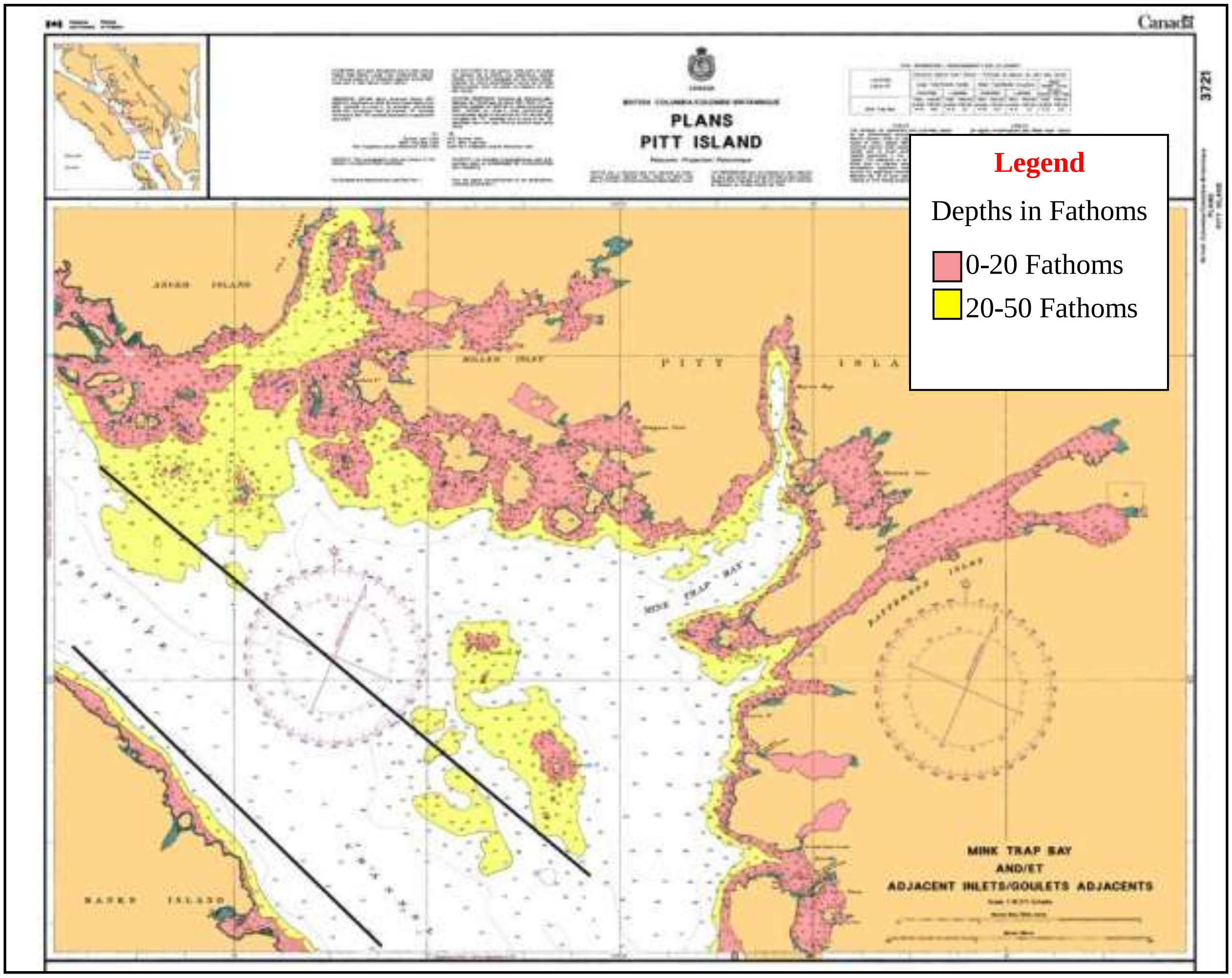

Figure 2-6 Central Principe Channel, at Mink Trap Bay

(Source: CHS Chart 3721)

Principe Channel represents another of the areas where the CHS has been focussing its surveying efforts. Multi-beam survey data were collected for this area in 2006 and have been incorporated into the latest navigational charts.

2.8 Caamaño Sound

The southern seaward entrance into the coastal waterways is through Caamaño Sound, in eastern Hecate Strait. This area is known to be fringed by banks, islets and reefs.

Vessels on approach to Caamaño Sound from seaward must navigate the deep water channels situated either to the north or to the south of Aranzazu Banks, as shown in Figure 2-7. The BCCP have noted in discussions that their navigational preference would be through the northern deep sea route because of its direct alignment. It may also be feasible to develop alternate routes to the south of Ness Rock if suitable navigation aids are constructed. The development of alternate routes will be done in consultation with the BCCP.

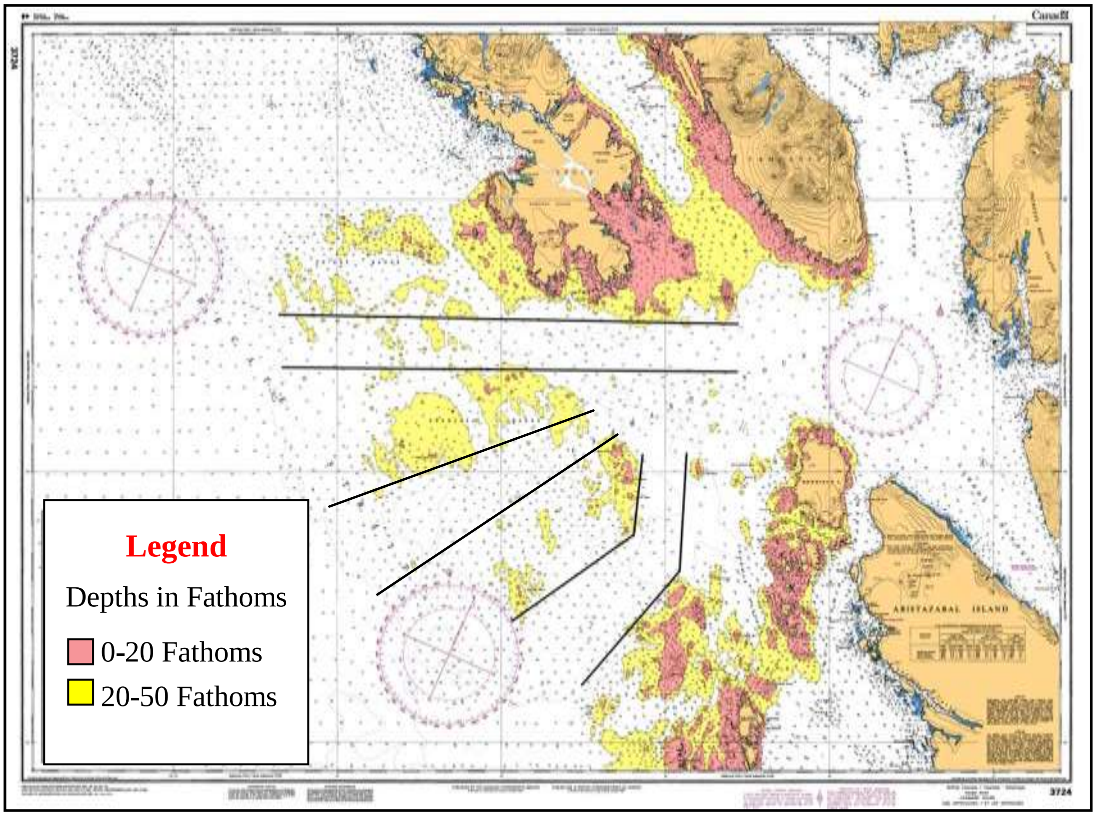

Figure 2-7 Caamaño Sound

(Source: CHS Chart 3724)

Caamaño Sound represents another of the areas where the CHS has been focussing its surveying efforts. Multibeam survey data was collected for this area during of 2006 and the findings have been incorporated into the latest navigational charts.

2.9 Remaining Portions of Navigation Routes

The remaining portions of the navigation routes to Kitimat Terminal include, Nepean Sound, Otter Channel, Squally Channel, Lewis Passage, Wright Sound and Douglas Channel. These routes are wide and deep with no underkeel clearance limitations. The reader is referred to the full-size set of CHS navigational charts for further information.

2.10 Berth Depth at the Terminal

Based on engineering efforts to date, including a detailed bathymetric survey of the seabed in the vicinity of the proposed tanker berths, it has been determined that limited dredging and/or rock blasting will be required to ensure underkeel clearances exceed the minimum requirements of 10 percent of the ship’s draught, as recommended in Appendix 3, Clauses 1.2 and 1.3 of the TERMPOL guidelines. Because the turning basin is directly adjacent to the berth, and considering the seabed consists of a rock bottom, it is recommended that a more conservative minimum underkeel clearance consisting of 15 percent of the ship’s draught as given in TERMPOL, Appendix 2, Clause 4.1 be used.

In accordance with the recommendations of the TERMPOL guidelines and with generally accepted engineering practise, the minimum water depths at the compressed fender line of the tanker berths is established as follows:

- Maximum draught of VLCC: 23.1 m
- Recommended Underkeel Clearance: 3.5 m (15 percent of draught)
- Contingency: 0.5 m
- Minimum Water Depth: 27.1 m

Drawings 002 and 007 in Appendix A present the local bathymetry at the terminal site. Note that these figures are considered conceptual only at this point. The exact structural configuration and location of the berths have not yet been finalized pending completion of the detailed engineering. For a more detailed description of the berth structures and other terminal facilities refer to TERMPOL Studies 3.10 and 3.11.

3 Tidal Variations

Tides are a result of the gravitational effects, or tidal forces, of the moon and, to a lesser extent the sun, acting on the earth. Tides affect large bodies of water, including the oceans and large lakes. Tidal variations are the result of the changing positions of the moon and sun relative to the earth and are unique to an area due to its geographical position and due to the local bathymetry of the sea bottom.

The observed tides on British Columbia's coast are resultant of diurnal and semi-diurnal tides, or approximately daily and twice-daily cycles, respectively. As a result, daily highs and lows, each occurring twice, are seldom of the same magnitude along the exposed coastlines of British Columbia. Due to regional geological characteristics, the semi-diurnal tide amplitude tends to increase in Hecate Strait and Dixon Entrance and, as a result, the tides in our region of interest exhibit a predominantly semi-diurnal pattern, that is to say, there is a less profound difference between successive highs and lows.

3.1 Tide Level Information

The CHS operate a number of tidal gauge stations that collect real-time tide readings. Currently, there are 13 such stations in operation on Canada's west coast (see Figure 3-1), and three of these are located on the north coast, at Queen Charlotte City, Prince Rupert and Bella Bella.

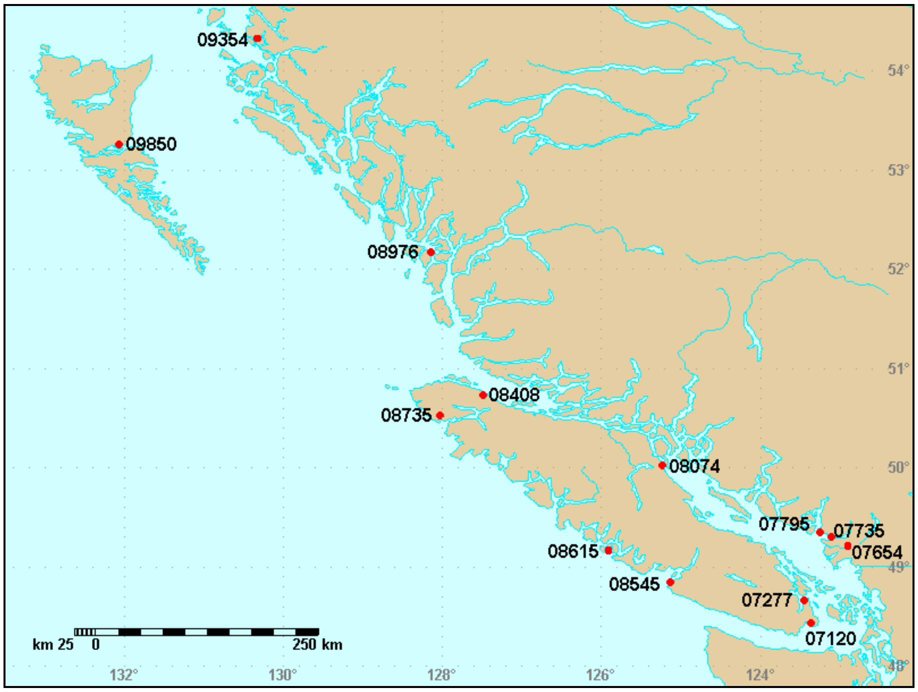

Figure 3-1 Tide Gauging Stations on Canada's West Coast

(Source: MEDS website http://www.meds-sdmm.dfo-mpo.gc.ca/)

Tidal predictions are also made for hundreds of other ports. Tidal information and predictions are available to mariners through the Vessel Traffic Services (VTS), as well as through the Canadian Tide and Current Tables, published annually by the Fisheries and Oceans Canada.

3.2 Vertical Tidal Variations

Tidal predictions for the region are published annually by the Department of Fisheries and Oceans Canada (DFO) in the Canadian Tide and Current Tables, Volume 7, Queen Charlotte Sound to Dixon Entrance (Reference 6). The tables provide predicted times and heights of successive highs and lows and are used by mariners to ensure adequate underkeel clearances in shallow water areas, for anchoring, and for planning of transits and beaching.

The tidal characteristics for various ports in the region are summarized in Table 3-1, below. All tidal measurements are in m above or below chart datum.

Table 3-1 Published Tidal Variations for Ports on British Columbia's North Coast

Description	Langara Point	Prince Rupert	Browning Entrance at Griffith Harbour	Caamaño Sound at Gillen Harbour	Hartley Bay	Kitimat
Extreme High	5.5	8.0	N/A	N/A	N/A	6.7
HHW, Large Tide	5.3	7.5	7.3	6.1	6.4	6.5
HHW, Mean Tide	4.4	6.2	6.0	4.9	5.2	5.3
Mean Water Level	2.8	3.8	3.7	3.1	3.2	3.3
LLW, Mean Tide	0.9	1.2	1.2	0.9	0.9	1.0
LLW, Large Tide	-0.1	-0.1	0.0	-0.1	-0.2	-0.1
Extreme Low	-0.1	-0.4	N/A	N/A	N/A	-0.2
Mean Tidal Range	3.5	5.0	4.8	4.0	4.2	4.3
Large Tidal Range	5.4	7.6	7.3	6.2	6.6	6.5

Source: Fisheries and Oceans Canada, Canadian Tide and Current Tables, Volume 7. Queen Charlotte Sound to Dixon Entrance, and Corresponding CHS Paper Charts.

Where the tide enters coastal waterways such as those leading to Kitimat, the tendency is for the tidal variations to increase towards the head of the inlet as compared to those near the entrance. Tidal ranges also increase as the tide moves northward. These effects are evident by comparing tide ranges for Caamaño Sound, Hartley Bay and Kitimat.

3.3 Tidal Currents

The available water depth underkeel of a vessel is directly affected by the vertical tidal variations. However, tides also produce lateral movement of water in the form of tidal currents which can be quite swift. The tidal currents have less of an effect on underkeel clearance in the deep water routes that generally comprise the region, but may add to the effects of vessel squat, which is speed dependent, in shallower areas. Squat is discussed in greater detail in Section 4 of this report.

3.4 Tidal Surges and Wind Set-up

Wind set-up, also known as a storm surge, results from strong winds that push the sea state either onshore (rise in sea level) or offshore (decrease in sea level). In areas where surface currents are also present, the effect of storm surges could create a cumulative effect that leads to exceptionally variant sea levels, as well as influence the predicted times for slack tides.

Storm surges have the greatest effect in shallow water and low-lying coastal areas such as the Mackenzie Delta of the Arctic Ocean. This is generally not the case along the British Columbia coast. Surge levels are usually greater along the eastern side of Hecate Strait than the western side (Reference 7).

4 Ship Motions

4.1 Dynamic Ship Motions

Dynamic ship motions can be estimated in accordance with empirical methods described in the International Association of Classification Societies (IACS) Joint Tanker Project (JTP) Rules that were recently brought into effect (Reference 8). The dynamic ship motions that are estimated using the prescribed methods yield 20-year return values that can be expected in open seas with wave heights of up to approximately 15 m. The results are also used for the structural assessment of oil tankers by IACS members.

The motions are estimated with simple, empirical formulae based on some of the basic dimensions and characteristic parameters of the ship and the speed of the vessel. A correction might have to be made to account for unique weather and wave conditions at specific sites.

The formulae for roll and pitch are as follows:

Roll (in radians)

$$\theta = \frac{50}{B+75}\left(1.25 - 0.025U_{roll}\right)f_{bk}$$

$$\mathrm{U}_{\mathrm{roll}} = \frac{2.30\mathrm{r}_{\mathrm{roll-gyr}}}{\sqrt{\mathrm{GM}}}$$

Where,

- B is the beam of the vessel, in m;
- f_{bk} is a dimensionless factor taken as 1.2 for ships without bilge keels;
- $r_{roll\text{-}gyr}$ is the roll radius of gyration estimated as 35 percent of the vessel’s beam, in m;
- GM is the metacentric height, estimated as 12 percent of the vessel’s beam, in m.

Pitch (in radians)

$$\varphi = 960\left(\frac{\mathrm{V}_1}{\mathrm{C}_\mathrm{b}}\right)^{0.25}\frac{1}{\mathrm{L}}\frac{\pi}{180}$$

Where,

- V_1 is the vessel’s cruising speed, estimated at 10 knots.
- C_b is the vessel’s block coefficient
- L is the length of the vessel, in m.

The predicted dynamic motions of the vessels as calculated by the previous formulae are as follows:

- Transverse roll motions of ± 17 degrees about the VLCC's centre of gravity equate to a vertical motion of ± 8.4 m from one side of the vessel to the other side;
- Longitudinal pitch motions of ± 5.4 degrees about the VLCC's centre of gravity equate to a vertical motion of ± 15.6 m from one end of the vessel to the other end.

When combining these two motions, the JTP Rules suggest the application of a 0.71 factor to both estimates to account for the combined probability of dynamic motions. The resulting correction in the draught of the ship is 17.0 meters, and assumes quartering seas to induce both pitch and roll.

The JTP Rules do not provide guidance on determining heave motions. Various other sources suggest that the Response Amplitude Operator (RAO)[3] for heave motions of a VLCC can be up to 1.5 for quartering seas with wavelengths in the proximity of the length of the ship. If we assume a wave height of 15.0 m as for the roll and pitch motions above, the estimated heave motion is approximately 22.5 m, peak to peak. Accordingly the reduction in underkeel clearance due to heave is 11.25 m. With application of the same 0.71 factor discussed above, heave could add an additional 8 m to the total motion of one extremity of the ship.

The total vertical displacement of one extremity of a VLCC due to dynamic ship motions is the sum of the three components, and is estimated as 25 m. It is important to note that these estimated dynamic ship motions are for a severe metocean climate that may be encountered in the open seas. Although this is a large motion, it is an estimate based on an extreme event with a recurrence interval of approximately 20 years. Based on discussions with BCCP, it is assumed that under severe weather conditions when such an event might occur, a tanker would not attempt an approach to Triple Island, Browning Entrance or Caamaño Sound, but rather would heave-to in open waters until the weather cleared.

The most critical point in the route would be while navigating between Browning Entrance and the vicinity of Triple Island since this is located at the junction of eastern Dixon Entrance and northern Hecate Straight, where severe wave conditions do occur and water depths along the proposed route are as low as 55 m (30 fathoms). Using the extreme motion as a conservative worst case scenario, the underkeel clearance would still exceed the required value by about 5 m.

Other points along the route to the Kitimat Terminal are in more protected waters where the combination of water depth and smaller waves result in reduced ship motions.

Historical wave statistics collected by the CHS at OCWS-P, located in the North Pacific Ocean more than 900 km west of the Queen Charlotte Islands in a water depth of 4,200 m, indicate maximum heights of 12 to 15 m in open sea conditions, although even at that location they are considered to be rare events, having been observed on seven occasions over a period of 13 years.

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[3] The RAO is a statistic used in the field of ship design to determine the likely behaviour of a ship when operating at sea. The ship motions are estimated by multiplying a known parameter by the RAO to estimate dynamic response.

As discussed in Section 3, mean wave heights near the north British Columbia coast are on the order of 3 to 4 m, with significant wave heights of 7 to 10 m. Wave measurements collected in Queen Charlotte Sound, Hecate Strait and Dixon Entrance indicate a wave climate that is similar to Hibernia, on the Grand Banks of Newfoundland and slightly more severe than the central North Sea (Reference 2). Since the effects of open sea waves and swells are diminished near the coast, the corresponding dynamic ship motions in the areas of Dixon Entrance, Hecate Strait and Caamaño Sound will likely be greatly reduced compared to the estimates presented for an open sea, 20 year return event described above. For the purposes of the present study, dynamic vessel motions in the open channel waterways of Dixon Entrance, Hecate Strait, and Caamaño Sound are estimated as one-third of the values calculated for the open sea, 20 year return event values, as follows:

- Estimated vertical displacement due to roll, 2.8 m;
- Estimated vertical displacement due to pitch, 5.2 m; and,
- Estimated vertical displacement due to heave, 3.8 m.

The combined dynamic ship motion within the coastal waterways is estimated as 8.4 using a factor of 0.71 for the combined probability or occurrence.

The effects of open sea waves and swells will be further diminished once inside the protected channels of the north British Columbia coast. In accordance with work completed by Enbridge in defining the Marine Physical Environment (Reference 7) and confirmed through discussions with the BCCP, steep, choppy wave conditions of 1-2 m height are common within the coastal waterways. The significant wave height for a 100 year event is estimated to be approximately 2.0m in the Douglas Channel system and the maximum wave period is estimated to be in the order of 2.5 to 5 seconds (Reference 7). Considering the relatively small wave height and short wave period, the effects of waves on large tankers should be minimal and hence the dynamic ship motions should be negligible within the confined channel areas. Table 4-1 summarizes the estimated dynamic ship motions for the various geographic areas.

Table 4-1 Estimated Dynamic Ship Motions

Ship Motion Causing Displacement	Vessel Vertical Displacements		
	Open Ocean	Coastal Areas	Confined Channels
Roll	8.4 m	2.8 m	Negligible
Pitch	15.6 m	5.2 m	Negligible
Heave	11.25 m	3.8 m	Negligible
Combined	25 m	8.4 m	Negligible

4.2 Vessel Squat

Squat is defined as the increase in draught, or reduction in underkeel clearance, between a vessel at rest and when underway caused by the flow of water past the moving ship. The relative velocity between the ship and the surrounding water produces a pressure change along the ship that in turn results in a downward vertical force and moment on the ship.

Squat is typically different along the length of the ship, with the maximum values at the bow.

Several formulations exist for predicting squat, and the formula presented by Eryuzlu et al. (1994) is chosen here since it is applicable to unrestricted channels and is also exclusively used by the CCG.

Their formula for bow squat, S_{bE2}, is defined as:

$$S_{bE2} = 0.298 \frac{h^2}{T} \left(\frac{Vs}{\sqrt{gT}} \right)^{2.289} \left(\frac{h}{T} \right)^{-2.972} K_b$$

Where,

- h is the channel depth, in m;
- T is the ship draught, in m;
- V_s is the ship speed, in m/s;
- g is the acceleration due to gravity, 9.81 $m/s^{2;}$
- K_b =

$$\begin{cases} \frac{3.1}{\sqrt{W/B}} & \frac{W}{B} < 9.61 \\ 1.0 & \frac{W}{B} \geq 9.61 \end{cases}$$

- B is the beam of the vessel, in m;
- W is the effective width of the channel, in m,
- = $(7.7 + 45(1\text{-CWP})^2)\cdot B$; and,
- CWP is the water plane coefficient, taken to be 0.95.

For a VLCC with a beam of 60 m, the predicted squat values for a range of water depths and ship speeds are presented in Table 4-2.

For a conservative operational evaluation, the estimated bow squat for a ship speed of 12 knots and a minimum water depth of 35 m is 0.66 m.

Table 4-2 Predicted Squat Values in Metres, as a Function of Water Depth and Vessel Speed

Water Depth(m)	Speed (Knots)												
					Range of Transit Speeds 8 to12 knots								
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
30	0.06	0.10	0.16	0.22	0.30	0.40	0.50	0.63	0.77	0.92	1.09	1.28	1.48
31	0.06	0.10	0.15	0.22	0.29	0.38	0.49	0.61	0.74	0.89	1.06	1.24	1.43
32	0.06	0.10	0.15	0.21	0.28	0.37	0.47	0.59	0.72	0.86	1.02	1.20	1.39
33	0.06	0.09	0.14	0.20	0.28	0.36	0.46	0.57	0.70	0.84	0.99	1.16	1.35
34	0.05	0.09	0.14	0.20	0.27	0.35	0.45	0.56	0.68	0.81	0.96	1.13	1.31
35	0.05	0.09	0.13	0.19	0.26	0.34	0.43	0.54	0.66	0.79	0.94	1.10	1.27
36	0.05	0.09	0.13	0.19	0.25	0.33	0.42	0.53	0.64	0.77	0.91	1.07	1.24
37	0.05	0.08	0.13	0.18	0.25	0.32	0.41	0.51	0.62	0.75	0.89	1.04	1.21
38	0.05	0.08	0.12	0.18	0.24	0.31	0.40	0.50	0.61	0.73	0.87	1.01	1.18
39	0.05	0.08	0.12	0.17	0.23	0.31	0.39	0.49	0.59	0.71	0.84	0.99	1.15
40	0.05	0.08	0.12	0.17	0.23	0.30	0.38	0.47	0.58	0.70	0.82	0.96	1.12
41	0.05	0.08	0.12	0.16	0.22	0.29	0.37	0.46	0.57	0.68	0.80	0.94	1.09
42	0.04	0.07	0.11	0.16	0.22	0.29	0.36	0.45	0.55	0.66	0.79	0.92	1.07
43	0.04	0.07	0.11	0.16	0.21	0.28	0.36	0.44	0.54	0.65	0.77	0.90	1.04
44	0.04	0.07	0.11	0.15	0.21	0.27	0.35	0.43	0.53	0.63	0.75	0.88	1.02
45	0.04	0.07	0.11	0.15	0.20	0.27	0.34	0.42	0.52	0.62	0.73	0.86	1.00
46	0.04	0.07	0.10	0.15	0.20	0.26	0.33	0.41	0.51	0.61	0.72	0.84	0.98
47	0.04	0.07	0.10	0.14	0.20	0.26	0.33	0.41	0.49	0.59	0.70	0.82	0.96
48	0.04	0.07	0.10	0.14	0.19	0.25	0.32	0.40	0.48	0.58	0.69	0.81	0.94
49	0.04	0.06	0.10	0.14	0.19	0.25	0.31	0.39	0.48	0.57	0.68	0.79	0.92
50	0.04	0.06	0.10	0.14	0.18	0.24	0.31	0.38	0.47	0.56	0.66	0.78	0.90

4.3 Vessel Sag and Hog

Since the weight and the buoyancy of the ship are not equally distributed along the length of the ship, there are net distributed loads acting on the hull girder. These loads, in addition to those induced by waves, result in bending moments along the length of the ship and a corresponding deflection in the vertical direction. As a result, the available underkeel clearance will be reduced. The JTP Rules define several parameters for determining a vessel's sagging and hogging deflections based on the design loads. The estimated deflections are based on load and strength parameters used to design the ship.

The still water bending moment, in units of kN-m, is given by:

$$M_{sw-min-sea-mid} = -0.05185 C_{wv} L^2 B (C_b + 0.7)$$

Where,

- $C_{wv} = 10.75$ for $300 < L \leq 350$;
- C_b, the block coefficient, is a measure of the how closely the hull approximates a rectangular block (for the design VLCC, taken to be 0.82); and,
- L and B are the length and breadth, respectively of the design vessel.

The wave bending moment, in units of kN-m, is given by:

$$M_{wv-sag} = -f_{prob} 0.11 f_{wv-v} C_{wv} L^2 B (C_b + 0.7)$$

Where,

- f_{prob} is a probability factor taken as 1.0 to correspond with a 10-8 level;
- f_{wv-v} is a distribution factor for the wave bending moment along the hull of the vessel. At mid-ships, where the maximum total moment occurs, f_{wv-v} is equal to 1.0.

The minimum required hull girder inertia based on the design bending moments, in units of m^4, is given by:

$$I_{v-min} = 2.7 C_{wv} L^3 B (C_b + 0.7) 10^{-8}$$

Where C_b is as defined above.

The resulting sag deflection is calculated as follows:

$$\Delta = \frac{M_{tot} L^3}{10 E I_{v-min}}$$

Where,

- $M_{tot} = M_{sw-min-sea-mid} + M_{wv-sag}$;
- E is the elastic modulus of steel taken as 200,000,000 kN/m^2.

The corresponding decrease in underkeel clearance due to sagging is estimated to be one-half of the calculated deflection, or 0.5 m for the design VLCC. Under calm conditions, there would not be a contribution due to wave loading, decreasing the calculated deflection to 0.2 m.

4.4 Vessel Trim

A fully loaded tanker in a departure condition will be the limiting condition for the underkeel clearance. A tanker in a full load departure condition is typically loaded at even keel with no trim, or slightly trimmed by the bow.

For the purpose of the underkeel clearance survey, a trim of 0.5 m by the bow or stern can be assumed when no ship-specific data is available. This small adjustment in the draught at the bow or stern will not limit the navigability of the vessel within the proposed deep water routes.

4.5 Summary of Cumulative Draught Effects due to Ship Motions

The required underkeel clearance for safe transit of the design vessel should be based on the loaded draught of the design vessel plus the cumulative increases due to the effects discussed above.

The maximum draught of the design VLCC for open ocean conditions is calculated as follows:

- Maximum loaded draught = 23.1 m
- Maximum estimated dynamic ship motions = 25.0 m
- Maximum estimated squat = 0.90 m
- Maximum estimated sag (static + wave) = 0.5 m
- Maximum estimated trim = 0.5 m
- Total Cumulative Draft = 50.0 m

The maximum draught of the design VLCC for coastal waters is calculated as follows:

- Maximum loaded draught = 23.1 m
- Maximum estimated dynamic ship motions = 8.4 m
- Maximum estimated squat = 0.66 m
- Maximum estimated sag (static + wave) = 0.5 m
- Maximum estimated trim = 0.5 m
- Total Cumulative Draft = 33.2 m

The maximum draught of the design VLCC for the confined channel area is calculated as follows:

- Maximum loaded draught = 23.1 m
- Maximum estimated dynamic ship motions = Minimal
- Maximum estimated squat = 0.66 m

- Maximum estimated sag (static only) = 0.2 m
- Maximum estimated trim = 0.5 m
- Total Cumulative Draft = 24.5 m → 27.1 m (TERMPOL Min.)

However using the minimum underkeel clearance recommendations from the TERMPOL Guidelines equal to 15 percent of the vessel’s draught when manoeuvring, the governing water depth for the confined channel area will be similar to that required at the terminal berths, namely 27.1 m.

The minimum water depth required to accommodate the cumulative draught effects in the coastal waters of Dixon Entrance, Hecate Strait, and Caamaño Sound is 33.2 m (18 fathoms) and for the confined channel area is 27.1 m (14.8 fathoms). Due to the steep shorelines, water depths generally reach 36.5 meters (20 fathoms) within short distances of the shoreline and exceed the minimum required depths by large margins near the centre of the navigable channels. For the purposes of determining the navigable channel widths, the minimum required water depth of 33.2m (18 fathoms) for the coastal water area was conservatively used for the entire length of the tanker routes.

5 Effects of Water Density Changes

The proposed routes are tidal saltwater waterways. However, freshwater tributaries drain into the channels and during the spring freshet many of the channels will include a surficial layer of freshwater run-off. Based on work completed by Enbridge in support of their Environmental Impact Assessment application to the National Energy Board, the maximum thickness of surface freshwater varies from just under one metre near the entrances to the coastal channels, approximately 5 m near Wright Sound and lower Douglas Channel and Kitimat Arm, to nearly 9 m in the middle of Douglas Channel. Figure 5-1, reproduced from Figure 3-8, in Enbridge's Freshwater Discharge and Temperature-Salinity Distributions report (Reference 9), summarizes the variations in freshwater depths in the region.

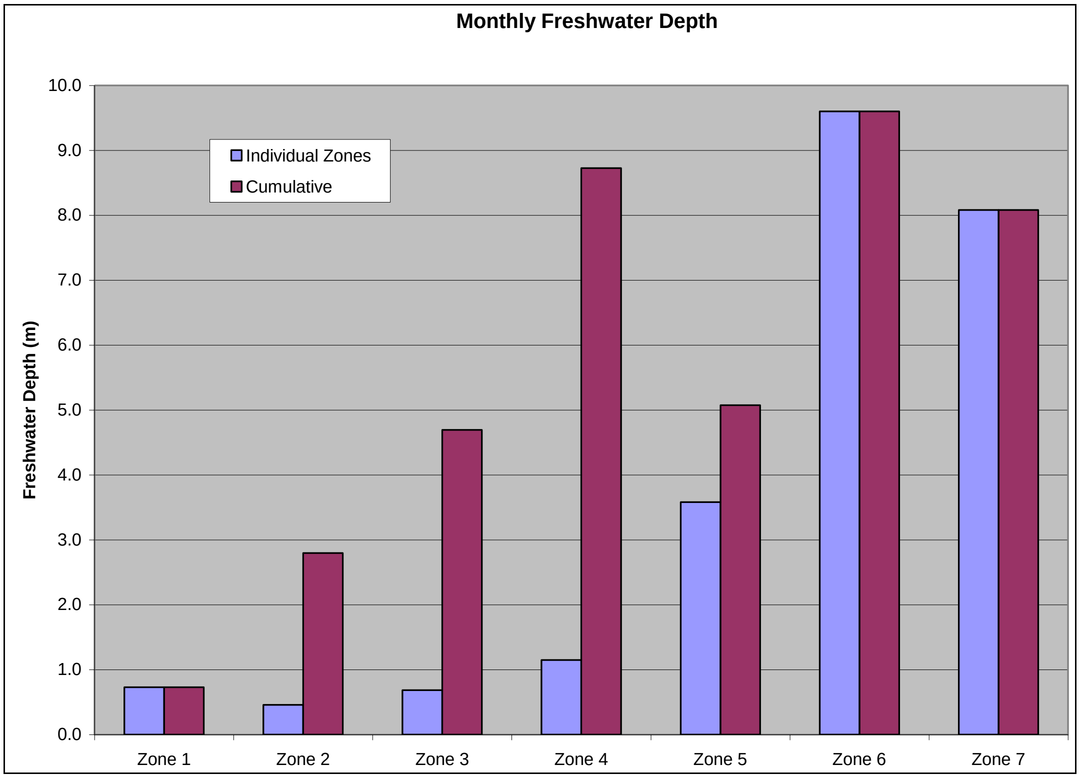

Figure 5-1 Equivalent Monthly Freshwater Depth

(Source: GEM Marine Physical Environment Tr-Asl-003; Freshwater Discharges and Temperature-Salinity Distributions)

The values shown in Figure 5-1 distinguish between the freshwater that flows directly into the watercourse from its tributaries (shown in blue) and the cumulative freshwater as the surface layer moves towards the open ocean. The zones are identified on the map shown in Figure 5-2.

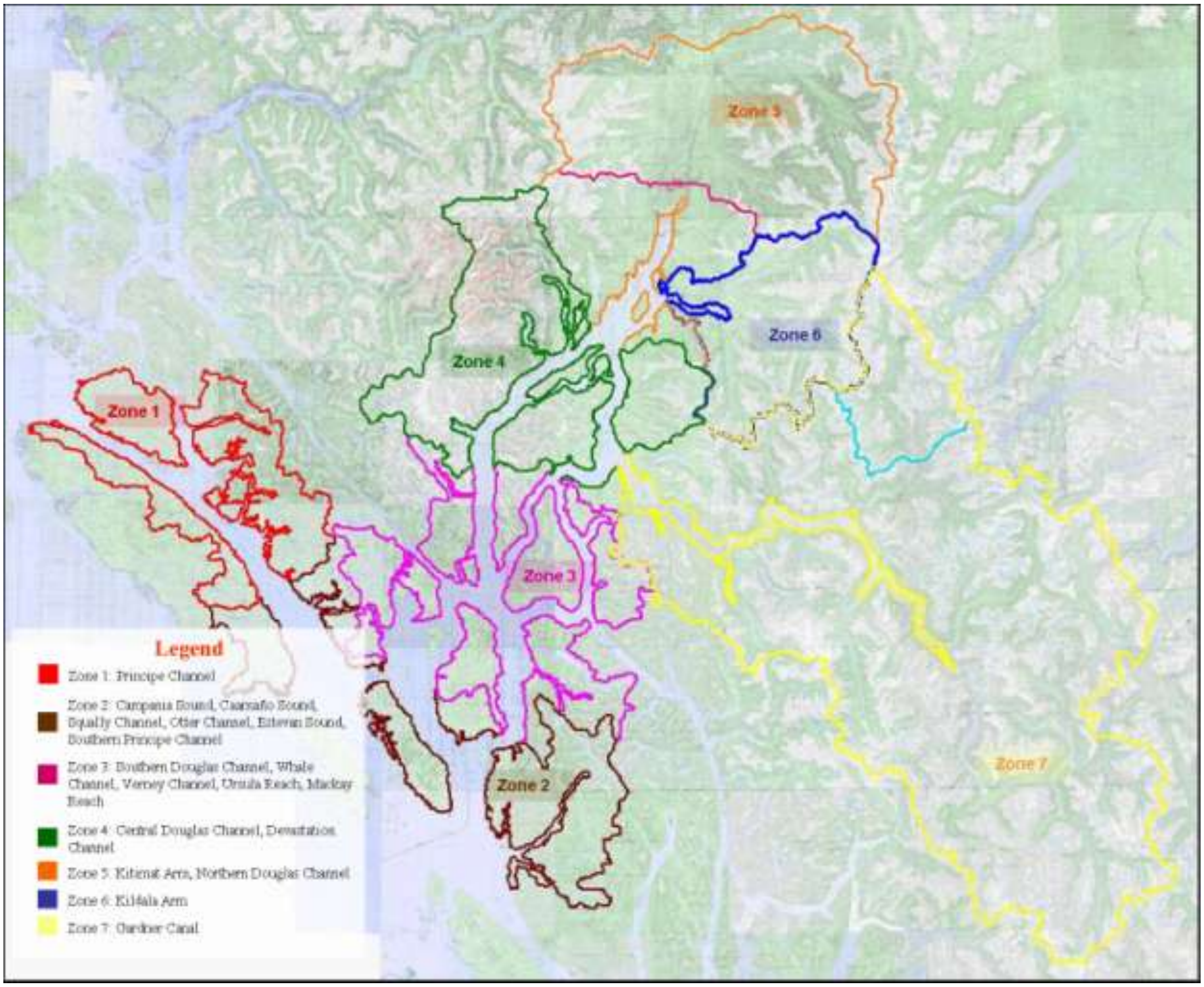

Figure 5-2 Freshwater Tributary Zones

(Source: GEM Marine Physical Environment TR-ASL-003; Freshwater Discharges and Temperature-Salinity Distributions)

Since an object displaces a volume of water equivalent to its own weight, a vessel will draw greater draught in a freshwater environment than a saltwater environment. As summarized in Table 5-1, below, the draught of a loaded VLCC would increase by approximately 575 mm in a body of pure freshwater. However, because the estimated depth of freshwater is considerably less than the loaded draught of the vessel, the draught of the vessel will increase by a proportionate margin. Table 5-2 summarizes the estimated draught increases over a range of freshwater depths.

Table 5-1 Effects of Water Salinity on Vessel Draught

Vessel Type	Displacement Tonnage, tonnes	LOA, m	Beam, m	Draught, m	Block Coefficient[a]
Saltwater Buoyancy					
Aframax	112,000	210	40	14.7	0.885
Suezmax	208,000	274	48	17	0.908
VLCC	400,000	343	58	23	0.853
Freshwater Buoyancy					
Vessel Type	**Displacement Tonnage, tonnes**	**LOA, m**	**Beam, m**	**Draught, m[b]**	**Block Coefficient**
Aframax	112,000	210	40	15.068	—
Suezmax	208,000	274	48	17.425	—
VLCC	400,000	343	58	23.575	—

Notes: [a] Based on specific gravity of saltwater = 1.025

[b] Based on Block Coefficients calculated above.

Table 5-2 Effects of Water Salinity on Vessel Draught

Depth of Surface Freshwater m	Effective Draught m	Approximate Draught Increase mm
0	23.000	0
1 (Zone 1)	23.024	24
2	23.048	48
3 (Zone 2)	23.072	72
4	23.096	96
5 (Zones 3 and 5)	23.120	120
6	23.144	144
7	23.168	168
8	23.192	192
9 (Zone 4)	23.216	216

Because of the limited depth of the surface run-off, water density changes will not have an appreciable effect on the buoyancy of the vessel. The maximum estimated draught increase is 216 mm, occurring in the centre portion of Douglas Channel where the channel is known to be very deep. In the coastal approaches, including Caamaño Sound and Principe Channel / Browning Entrance, the estimated draught increase is only 25 to 100 mm.

6 Other Sources of Depth Anomalies

6.1 Inconsistent Sounding Units

Existing CHS chart publications are based on a variety of measuring units, and adjacent charts may not use consistent units for sounding depths. Depending on the original publication date of a chart, depths may be given in fathoms, feet or m.

The CHS is presently working on chart improvements. Once complete, the new charts will consistently be in metric units. In the meantime, however, mariners must pay particular attention to units on adjacent charts.

6.2 Meteorological Conditions Affecting Water Depth

Published water depths and tidal variations are based on normal barometric pressure. However, barometric pressure changes and strong, prolonged wind events can influence the predicted water depths.

A change in barometric pressure of 30 mbar can result in a corresponding change in sea level of approximately 0.3 m.

Also, storm surges may result from strong winds that push the sea state either onshore (rise in sea level) or offshore (decrease in sea level). In areas where surface currents are also present, the effect of storm surges could create a cumulative effect that leads to exceptionally variant sea levels, as well as influence the predicted times for slack tides (Reference 7).

6.3 Sudden Depth Changes

Sudden changes in water depth may cause hydrological anomalies with water currents and may also cause pressure changes in vicinity of the vessel. In these cases, the vessel’s speed, its handling and manoeuvring characteristics, and consequently its trim and draught may be affected.

Based on the foregoing review, adequate deep channel navigational routes exist such that sudden depth changes of the seabed are not encountered by the vessel.

6.4 Drawdown (Tanker Wake Effects)

From a hydrodynamic point of view, flow near a moving ship is similar to flow around a fixed body such as bridge abutment. As the ship moves along the channel, there is water flow past the vessel hull opposite the direction of travel, known as the return current. The velocity head of the water flowing past the vessel causes the water level along the vessel’s length to fall to maintain the total head constant. The water level around the vessel is thus lowered. This water level depression is also sometimes referred to as primary wave, as illustrated in Figure 6-1.

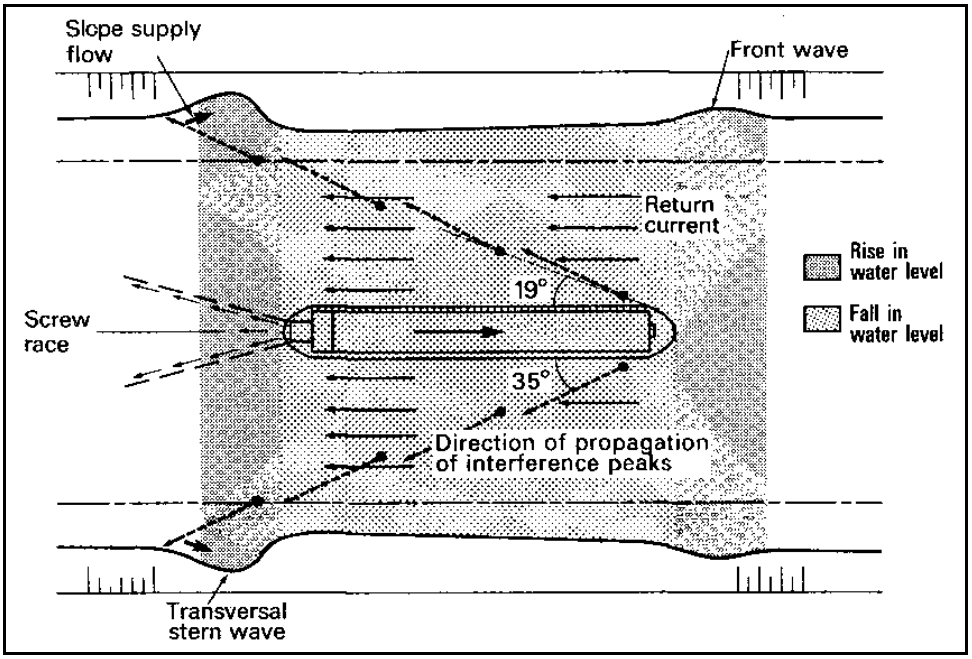

Figure 6-1 Primary Wave Components of Ship Induced Water Motions

(Source: PIANC 1987)

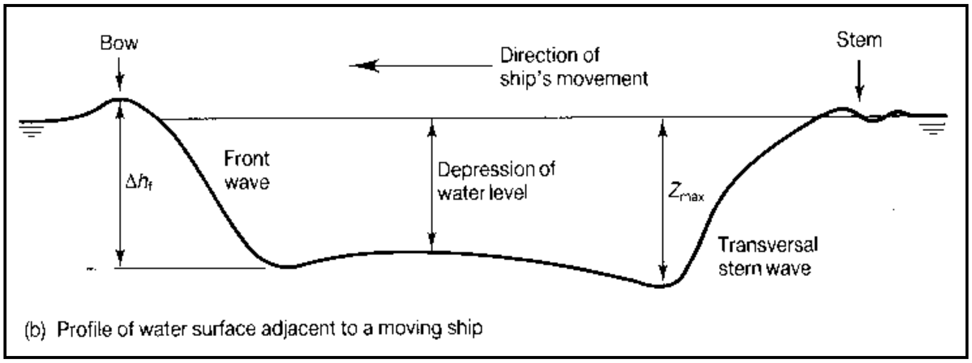

Figure 6-2 Primary Wave Components of Ship Induced Water Motions

(Source: PIANC 1987)

The transition between the undisturbed water level in front of the vessel and the water level depression take the form of sloping water surface referred to as the front wave. The water surface immediately ahead of the vessel is elevated by the approaching ship and so the total height of the front wave is slightly greater than the water level depression.

The transversal stern wave is the transition between the water level depression and the normal water level behind the ship.

The combination of water level depression, front wave and transversal stern wave will hereafter be referred to as drawdown. Drawdown behaves like a long solitary wave with a length similar to that of the ship. Therefore, drawdown is generally not easily observed in the field, other than in the case of relatively large vessels sailing in confined channels. Drawdown does not “break” at the shoreline as “normal” waves do. It is more like a tidal “pulse”, slowly rising and falling as the vessel passes.

Calculations show that the primary wave height or drawdown of a VLCC transiting the confined channel area will be in the order of 0.025 m (Reference 10 to Reference 15). The drawdown is relatively small because of the much larger size of the various channel cross-sectional areas as compared to the ship cross-sectional area. Therefore drawdown effects are not significant.

6.5 Seasonal Effects

The following discussion about seasonal effects on water levels is a summary of the information prepared by the Gateway Environmental Management Team, in the Technical Data Report titled Marine Physical Environment TR-ASL-004: Water Levels and Waves (Reference 7).

During winter, the northerly movement of water due to prevailing southerly winds combined with the rightward deflection, due to Coriolis Effect, results in an average 10-20 cm rise in the coastal sea level along the central British Columbia coast. The opposite happens in summer with a corresponding, but smaller, drop in the coastal sea level.

The El Niño-Southern Oscillation (ENSO) cycle can cause further fluctuations in water levels on a scale of several years. During an intense El Niño the northerly surge of warm water reaches Queen Charlotte Sound, causing water levels to increase by almost 40 cm, as shown in Figure 6-3.

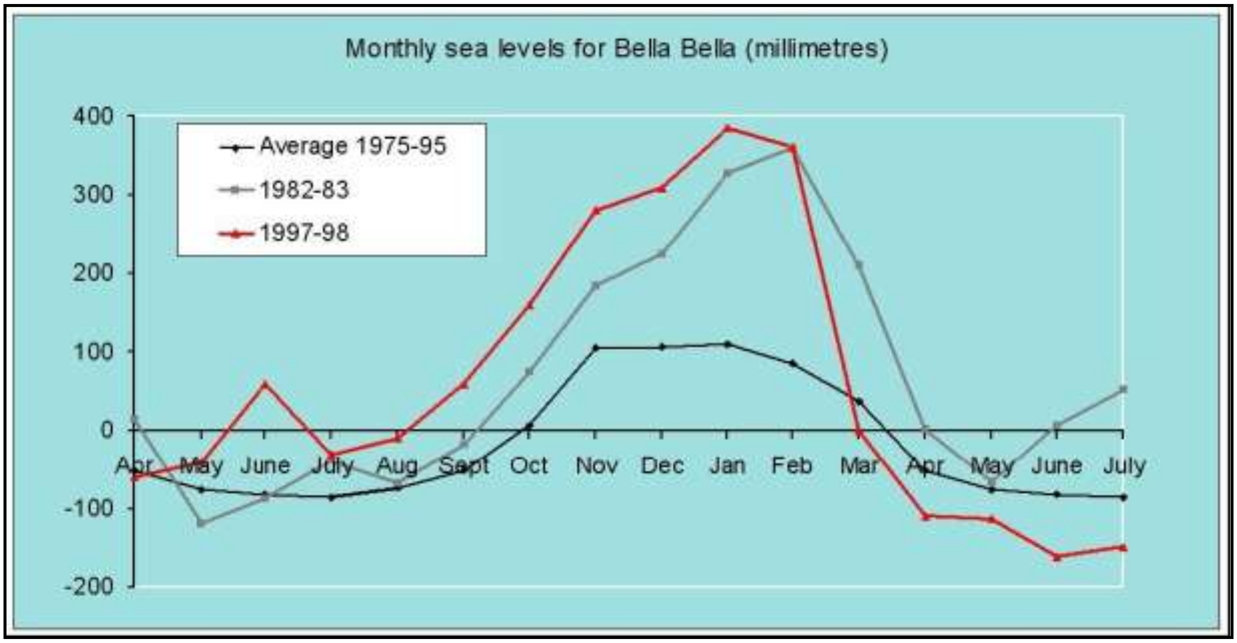

Figure 6-3 Monthly Sea Levels at Bella Bella, 20-year Average and El Niño's of1982 to 1983 and 1997 to 1998

(Source: Gateway Environmental Management Team. February 2006. Marine Physical Environment TR-ASL-004: Water Levels and Waves)

The channels comprising the routes between seaward and the Project site are not subjected to a measurable degree of siltation and therefore capital or maintenance dredging is not a project requirement.

The Project site is situated in Douglas Channel, approximately 5.4 nautical miles from the head of the Channel at Kitimat. At the proposed location, the mid-channel depth is in excess of 182 m (100 fathoms) and the shoreline comprises a steep, rocky embankment.

7 Conclusions

Underkeel clearance is affected by various natural phenomenon including seabed bathymetry, tidal variations, metocean conditions created by wind, waves and currents, salinity and meteorological conditions. The draught of a vessel may also vary as a result of loading conditions, dynamic effects due to sea-state and hydrodynamic effects due to movement through water.

The routes within the study area are generally characterised by wide and deep watercourses, with water depths often well in excess of 183 m (100 fathoms). Due to the steep topography within the area, water depths increase rapidly from the shoreline.

Localized shoaling within the proposed routes has been charted by the Canadian Hydrographic Service (CHS) in a number of areas including Dixon Entrance, Northern Hecate Strait, Browning Entrance, Principe Channel and Caamaño Sound, but this review concludes that navigable deep water routes can be charted to avoid the shoals.

In accordance with the TERMPOL Guidelines, a minimum underkeel clearance of 15 percent of the ship's loaded draught is recommended. For the design VLCC, with a loaded draught of 23.1 m, this translates into a recommended clearance of 3.5 m. Including a contingency of 0.5m, the minimum required water depth at the terminal berth and for manoeuvring in the confined channel area is 27.1 m (15 fathoms). This however does not take into account additional clearance required due to dynamic ship motions caused by wind, waves, and ocean swell (see Section 4 of this document).

The estimated minimum underkeel clearance for a VLCC navigating at a speed of 10 to 12 knots within the coastal areas is 10.1 m. This is based on subtracting the maximum VLCC draught of 23.1m from the corresponding minimum water depth of 33.2 m (18 fathoms). The conclusions of the study indicate that the proposed routes meet and exceed the underkeel clearance requirements as indicated in Table 7-1.

Table 7-1 Required Water Depths and Underkeel Clearances

Area	Water Depths		Underkeel Clearances	
	Minimum Required Water Depth	Minimum Available Water Depth	Minimum Required Underkeel Clearance	Minimum Available Underkeel Clearance
Open Ocean	50 m (27 fathoms)	55 m (30 fathoms)	26.9 m	31.9 m
Coastal Areas including Hecate Strait, Dixon Entrance, and Caamaño Sound	33.2 m (18 fathoms)	36.5 m (20 fathoms)	10.1 m	13.4 m
Confined Channels	27.1 m (15 fathoms)	35 m (19 fathoms)	4.0 m	11.9 m
Terminal Berth	27.1 m (15 fathoms)	30 m (16.5 fathoms)	4.0 m	6.9 m

Based on a review of the available navigation charts, it appears that there is ample water depth to accommodate the largest design vessel over the entire proposed tanker routes. In some areas, particularly Hecate Strait, the published charts are based on decades-old surveys that have a limited level of detail and accuracy compared to modern standards. It is understood that the CHS has embarked on a program of re-surveying these areas and is in the process of updating these navigation charts. It is recommended that the proposed navigation routes be re-visited once the new charts are available, and/or that project specific surveys be commissioned along the critical portions of the routes to verify that there are no dangerous uncharted shoals in these areas.

8 References

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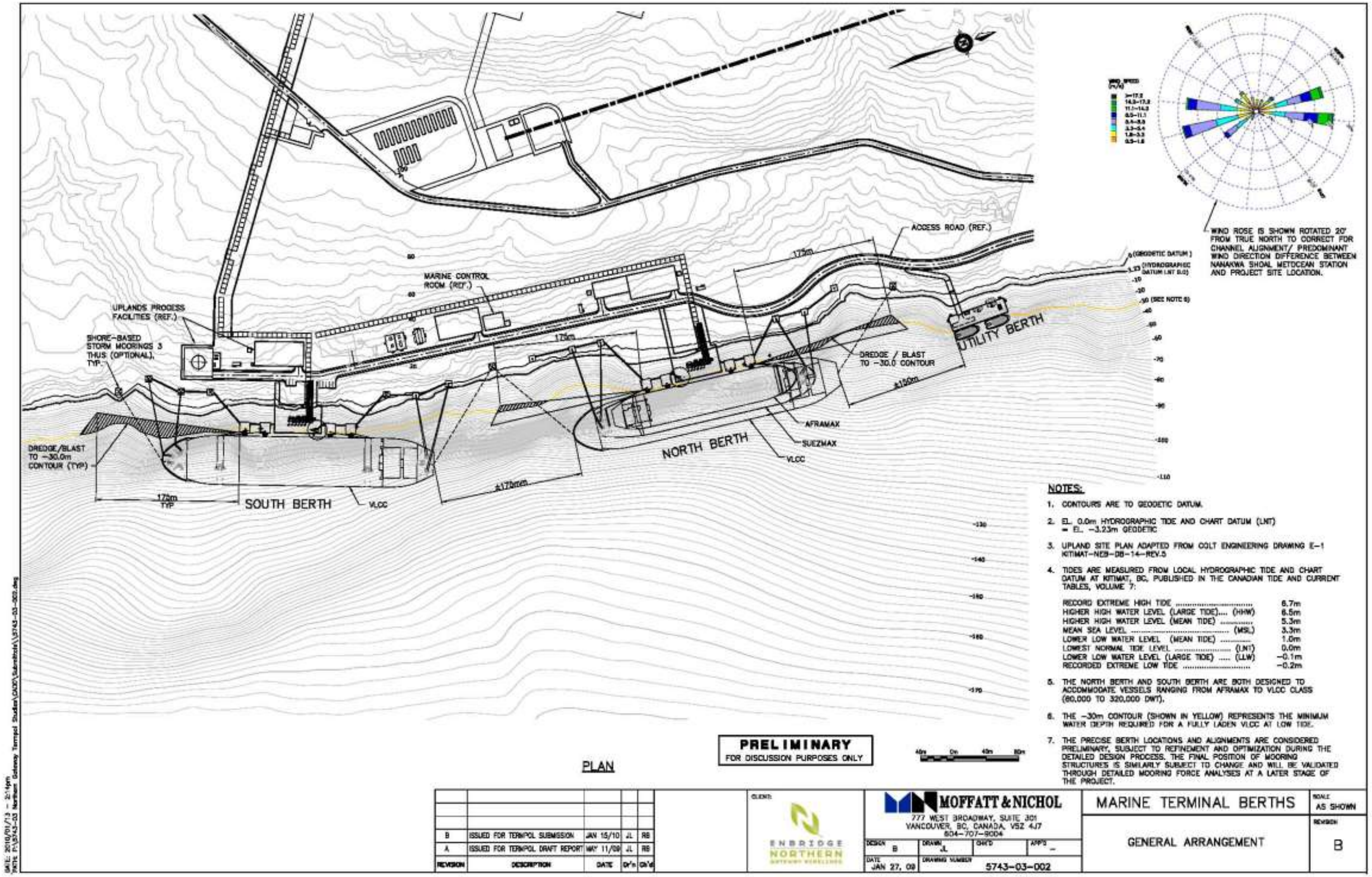
Appendix A Marine Terminal Drawings



WIND ROSE IS SHOWN ROTATED 20° FROM TRUE NORTH TO CORRECT FOR CHANNEL ALIGNMENT/ PREDOMINANT WIND DIRECTION DIFFERENCE BETWEEN NANAKWA SHOAL METOCEAN STATION AND PROJECT SITE LOCATION.

PRELIMINARY
FOR DISCUSSION PURPOSES ONLY

NOTES:

1. CONTOURS ARE TO GEODETIC DATUM.
2. EL. 0.0m HYDROGRAPHIC TIDE AND CHART DATUM (LNT) = EL. −3.23m GEODETIC
3. UPLAND SITE PLAN ADAPTED FROM COLT ENGINEERING DRAWING E-1 KITIMAT-NEB-DB-14-REV.5
4. TIDES ARE MEASURED FROM LOCAL HYDROGRAPHIC TIDE AND CHART DATUM AT KITIMAT, BC, PUBLISHED IN THE CANADIAN TIDE AND CURRENT TABLES, VOLUME 7:

RECORD EXTREME HIGH TIDE	6.7m
HIGHER HIGH WATER LEVEL (LARGE TIDE).... (HHW)	6.5m
HIGHER HIGH WATER LEVEL (MEAN TIDE)	5.3m
MEAN SEA LEVEL .... (MSL)	3.3m
LOWER LOW WATER LEVEL (MEAN TIDE)	1.0m
LOWEST NORMAL TIDE LEVEL .... (LNT)	0.0m
LOWER LOW WATER LEVEL (LARGE TIDE) ..... (LLW)	−0.1m
RECORDED EXTREME LOW TIDE	−0.2m

5. THE NORTH BERTH AND SOUTH BERTH ARE BOTH DESIGNED TO ACCOMMODATE VESSELS RANGING FROM AFRAMAX TO VLCC CLASS (80,000 TO 320,000 DWT).
6. THE −30m CONTOUR (SHOWN IN YELLOW) REPRESENTS THE MINIMUM WATER DEPTH REQUIRED FOR A FULLY LADEN VLCC AT LOW TIDE.
7. THE PRECISE BERTH LOCATIONS AND ALIGNMENTS ARE CONSIDERED PRELIMINARY, SUBJECT TO REFINEMENT AND OPTIMIZATION DURING THE DETAILED DESIGN PROCESS. THE FINAL POSITION OF MOORING STRUCTURES IS SIMILARLY SUBJECT TO CHANGE AND WILL BE VALIDATED THROUGH DETAILED MOORING FORCE ANALYSES AT A LATER STAGE OF THE PROJECT.

REVISION	DESCRIPTION	DATE	Dr'n	Ch'd
B	ISSUED FOR TERMPOL SUBMISSION	JAN 15/10	JL	RB
A	ISSUED FOR TERMPOL DRAFT REPORT	MAY 11/09	JL	RB

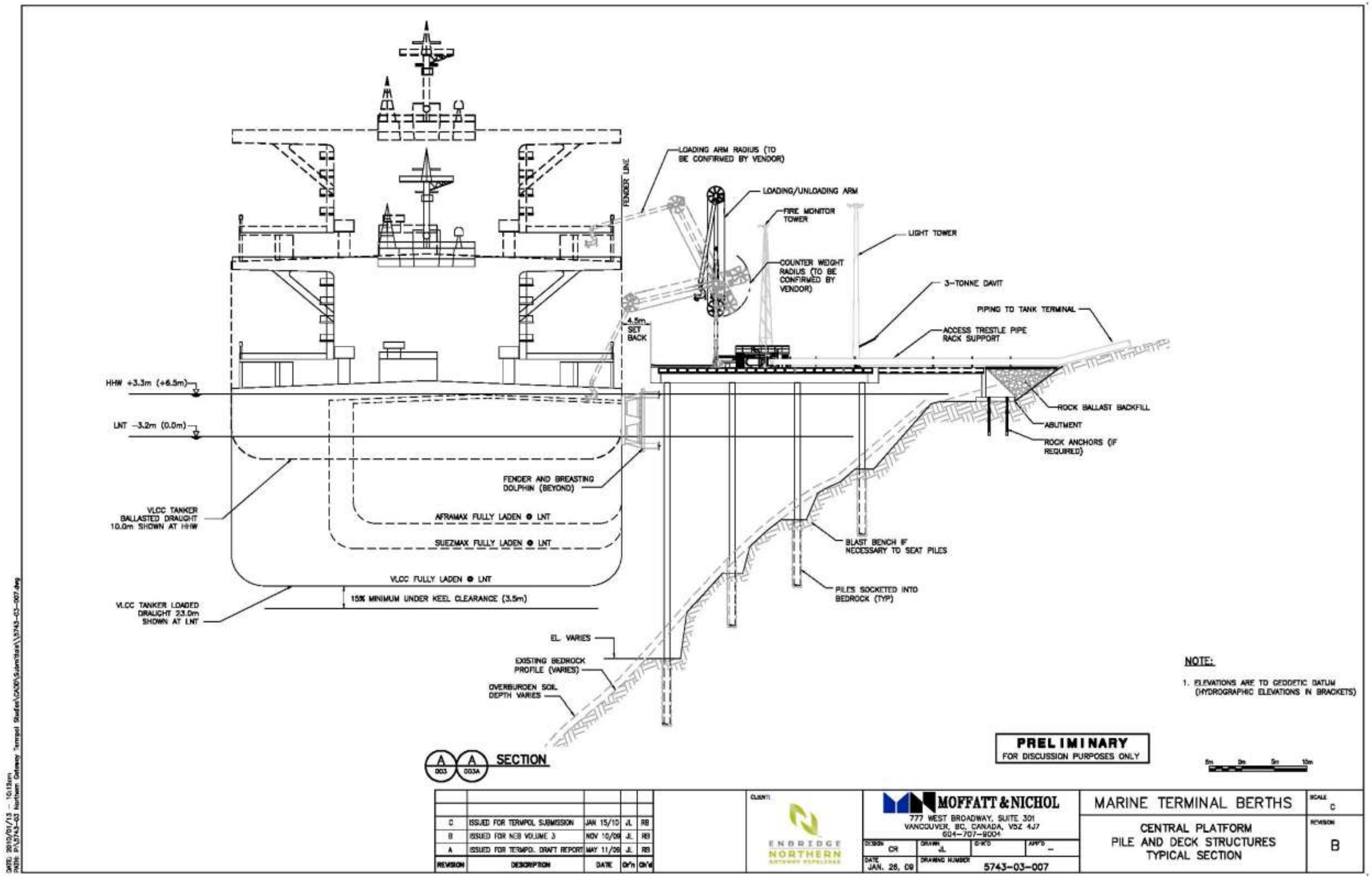
CLIENT: ENBRIDGE NORTHERN GATEWAY PIPELINES

MOFFATT & NICHOL
777 WEST BROADWAY, SUITE 301
VANCOUVER, BC, CANADA, V5Z 4J7
604-707-9004

DESIGN: B
DRAWN: JL
CHK'D:
APP'D: –
DATE: JAN 27, 09
DRAWING NUMBER: 5743-03-002

MARINE TERMINAL BERTHS
GENERAL ARRANGEMENT

SCALE: AS SHOWN
REVISION: B


LOADING ARM RADIUS (TO BE CONFIRMED BY VENDOR)
FENDER LINE
LOADING/UNLOADING ARM
FIRE MONITOR TOWER
LIGHT TOWER
COUNTER WEIGHT RADIUS (TO BE CONFIRMED BY VENDOR)
3-TONNE DAVIT
PIPING TO TANK TERMINAL
ACCESS TRESTLE PIPE RACK SUPPORT
4.5m SET BACK
HHW +3.3m (+6.5m)
LNT -3.2m (0.0m)
ROCK BALLAST BACKFILL
ABUTMENT
ROCK ANCHORS (IF REQUIRED)
FENDER AND BREASTING DOLPHIN (BEYOND)
VLCC TANKER BALLASTED DRAUGHT 10.0m SHOWN AT HHW
AFRAMAX FULLY LADEN @ LNT
SUEZMAX FULLY LADEN @ LNT
BLAST BENCH IF NECESSARY TO SEAT PILES
VLCC FULLY LADEN @ LNT
15% MINIMUM UNDER KEEL CLEARANCE (3.5m)
PILES SOCKETED INTO BEDROCK (TYP)
VLCC TANKER LOADED DRAUGHT 23.0m SHOWN AT LNT
EL. VARIES
EXISTING BEDROCK PROFILE (VARIES)
OVERBURDEN SOIL DEPTH VARIES
NOTE:
1. ELEVATIONS ARE TO GEODETIC DATUM (HYDROGRAPHIC ELEVATIONS IN BRACKETS)
PRELIMINARY
FOR DISCUSSION PURPOSES ONLY
5m 0m 5m 10m
A 003 A 003A SECTION
DATE: 2010/01/13 - 10:12am
PATH: P:\5743-03 Northern Gateway Termpol Studies\CADD\Submittals\\5743-03-007.dwg
C ISSUED FOR TERMPOL SUBMISSION JAN 15/10 JL RB
B ISSUED FOR NEB VOLUME 3 NOV 10/09 JL RB
A ISSUED FOR TERMPOL DRAFT REPORT MAY 11/09 JL RB
REVISION DESCRIPTION DATE Dr'n Ch'd
CLIENT:
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604-707-9004
DESIGN CR
DRAWN JL
CHK'D
APP'D –
DATE JAN. 26, 09
DRAWING NUMBER 5743-03-007
MARINE TERMINAL BERTHS
CENTRAL PLATFORM
PILE AND DECK STRUCTURES
TYPICAL SECTION
SCALE C
REVISION B

Appendix B CHS Gateway Charting Project

B.1 Nautical Chart Updates

CHS is currently (Spring 2009) in the midst of a comprehensive program of re-surveying the navigation routes in the region. This program includes a total of 24 new charts and is expected to be largely completed by 2012. The program will include updates (new editions) of most of the existing charts, as well as few new charts covering some key areas in more detail. The new and updated charts will be issued both in electronic form (vector and raster format) suitable for electronic navigation systems, as well as paper versions. The charts encompass the area from Seaforth Channel to Chatham Sound including charts up Douglas Channel to Kitimat. The charts will be issued at various scales from large scale plan charts to 1:80,000 overview charts.

To date the CHS has issued new versions of six charts, which mostly cover the inside passage. Plans are in place to release six others by the end of 2009 which will complete the inside passage and part of the outside passage. Over the next two to three years, the CHS plans to complete the remaining 12 charts covering the main navigation routes to Kitimat. Estimated completion dates for the each chart are given in Table B-1 below.

Table B-1 CHS Gateway Charting Project

Areas	Chart Numbers	Estimated Completion Date
Inside Passage	3941,3942,3943,3944,3946 and 3948	Completed
Inside Passage / Outside Passage	3912,3945,3947,3984,3985 and 3987	End of 2009
Outside Passage, Browning Entrance, and Bella Coola	3910, 3911, 3986 and 3974	End of 2010
Outside Passage and Kitimat Harbour	3980, 3981,3982,3983 and 3908	End of 2011
Outside Passage and Douglas Channel	3975,3976 and 3977	End of 2012

Future plans will address small scale charting needs through Hecate Strait, Queen Charlotte Sound and down to Cape Scott. CHS also hopes to update some of the older Haida Gwaii charts. There are no firm dates for the completion of these projects, however.