PORT OF HASTINGS DEVELOPMENT PROJECT

DESIGN AND ENGINEERING

Channel Design for Navigation Report

Document Ref: AGH-CEP0-EG-REP-0024

INFRASTRUCTURE VICTORIA

In May 2016 the Special Minister of State asked Infrastructure Victoria to provide advice on the future capacity of Victoria's commercial ports. Specifically, the Minister has asked for advice on when the need for a second container port is likely to arise and which variables may alter this timeline. The Minister has also asked for advice on where a second container port would ideally be located and under what conditions, including the suitability of, and barriers to investing in, sites at the Port of Hastings and the Bay West location.

In undertaking this task, Infrastructure Victoria reviewed work that was completed as part of the Port of Hastings development project before it was cancelled in 2014. This document forms part of the initial work undertaken for the proposed port development at Hastings. Infrastructure Victoria considers that much of the previous Hastings work, although preliminary in nature, is relevant and suitable for informing a strategic assessment. Therefore, Infrastructure Victoria has made the reports previously commissioned for the development project part of the evidence base on which Infrastructure Victoria will use in providing the Minister with advice.

The opinions, conclusions and any recommendations in this document are based on conditions encountered and information reviewed at the date of preparation of the document and for the purposes of the Port of Hastings Development Project.

Infrastructure Victoria and its consultants have used the information contained in these reports as an input but have not wholly relied on all the information presented in these reports.

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Port of Hastings Development Project – Design and Engineering

Channel Design for Navigation Report

Client: Port of Hastings Development Authority

ABN: 33 737 350 749

Prepared by the AECOM + GHD Joint Venture

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Quality Information

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Executive Summary

The Port of Hastings Development Authority was set up by the Government of Victoria in 2012 to investigate the feasibility of establishing a container port at Hastings. This port will provide additional capacity to the Port of Melbourne and will also be able to handle larger ships that are unable to access the Port of Melbourne.

This report outlines the channel design works undertaken to date and recommendations on the preferred width, depth and alignment of the approach channel, swing basin and berth pocket.

Scope

The existing channel system that connects the Port of Hastings to deep water was assessed to determine the additional width and depth required to provide adequate capacity, accessibility and safety.

The scope of works included the selection of the design vessel, concept design in accordance with PIANC 2014, consultations with the Port Phillip Sea Pilots and the Harbourmaster, underkeel clearance (UKC) analysis, real time navigation simulations and design of navigational aids.

Works not undertaken that were part of the original brief included the channel capacity and depth modelling through discrete event simulations and further real time navigation simulations to further optimise the layout.

While this report is limited to the channel design for navigation, dredge volumes have been calculated based on assumptions documented in this report in order to illustrate the relationship between channel accessibility and dredge volumes.

Design Vessel

The Commercial and Economic workstream developed two demand forecast scenarios for international containers along with a forecast fleet spectrum for each scenario (Commercial and Economic, PoH Draft Forecast Demand Scenarios, 5 December 2014). The scenarios have a start date of 2031 and within six to eight years of the port opening, vessels with an LOA of about 400m and a beam of 56m are forecast to visit the port. Ships with an overall length of 400m and a beam of 59m are expected to call at the port within nine to eleven years of opening.

For the channel design, the timespan between the opening of the port and the arrival for the 400m LOA vessels is too short to consider two separate dredging campaigns. As such the 400m LOA, 59m beam vessel is adopted as the design vessel for the Stage 1 development and for subsequent development stages.

Channel Design Benchmark and Performance Criteria

The criteria used to assess the adequacy of the channel were:

- Channel Availability – In lieu of a discrete event simulation, channel availability has been used to assess the depth of the channel. To provide an illustration on channel depths and dredge quantities, based on the studies undertaken to date, it is proposed that a maximum average channel delay of three hours is used for the design vessel at its predicted running draught. This will allow for the majority of the channel closures to be less than four hours which will normally allow for a vessel to adjust its steaming speed to compensate.
- Environmental Limitations:
  - 30 knot wind speed – occurs less than 0.1% of the time based on records from weather stations at Long Island Point and Stony Points between 2000-2013, although it is reported that the actual winds speeds in the channel are higher than the wind speeds recorded at these stations.
  - Horizontal visibility of 0.5 nm or 1,000m – lower visibility occurs 1.1% of the time based on recordings between August 1972 and February 1983.
- Safety – The issues raised by the Port Phillip Sea Pilots and the Harbourmaster were addressed as part of the real time simulation studies or through the navigation aid design.

- Existing Operations – The existing facilities at Stony Point, Crib Point, Long Island Point Jetty and the BlueScope general purpose berth (Stage 1 development only) are assumed to remain operational.

Channel Alignment and Width

Based on the concept design requirements outlined in PIANC 2014 the existing channel required widening from the existing width of between 400m and 546m to 517m in Western Channel 1 (two-way traffic) and from 183m to 212m in North Arm 1. To avoid high spots at the intersection of Western Channel 1 and 2 near McHaffie's Reef at Ventnor on Phillip Island, the intersection has been moved 300m to the west and the angle at this corner increased by 2 degrees. In the port area the concept design had a swing basin width of 1.75 x LOA (700m) and berth pocket width of 2 x beam (120m). A drag back width of 400m (incl the berth pocket) and a basin width of 450m were adopted based on a review of worldwide ports that cater for the design container vessel.

Following the real time navigation simulations the following changes have been made to the channel and swing basin layout and are shown in Figures 1-3.

- The width of North Arm 1 between buoys 19/20 and 23/24 has been increased from 212m to the same width as North Arm 2 (250m)
- The angle into and out of North Arm 1 has been reduced by 2 degrees by keeping buoys 19 and 24 in the same place and moving buoys 20 and 23 to achieve the required width.
- The angle between North Arm 1 and 2 (at buoys 23/24) has been further reduced by straightening the toelines between buoys 23 and 25, and 24 and 26.
- The toeline from buoy 30 runs up to a point that is 30m south and 100m east of the southernmost end of the berths. This location has been chosen so that the toeline does not extend through the berth pocket for the Long Island Point Jetty.
- The berth pocket width has been reduced to 1.5 times the vessel beam.
- Stage 1 Development Swing Basin – reduced the width of the swing basin by 40m in order to maintain a beam width (60m) between the vessel and the toelines based on the vessel track plots for the navigation simulations.
- Along the Shore Alignment Swing Basin – the reduction in the width of the Stage 1 Development swing basin by 40m has been extended up to the start of the drag back area which has resulted in the corner between the swing basins along the southern berths and the drag back area moving by 270m to the southwest.
- Basin Alignment Swing Basin - The reduction in the width of the Stage 1 Development swing basin by 40m has been extended up to the toeline at the edge of the swing basin at the entrance to the basin.

The alignment of the approach channel and Stage 1 Development are outlined in Figure 1. The Along the Shore Alignment is in Figure 2 and the Basin Alignment is in Figure 3.

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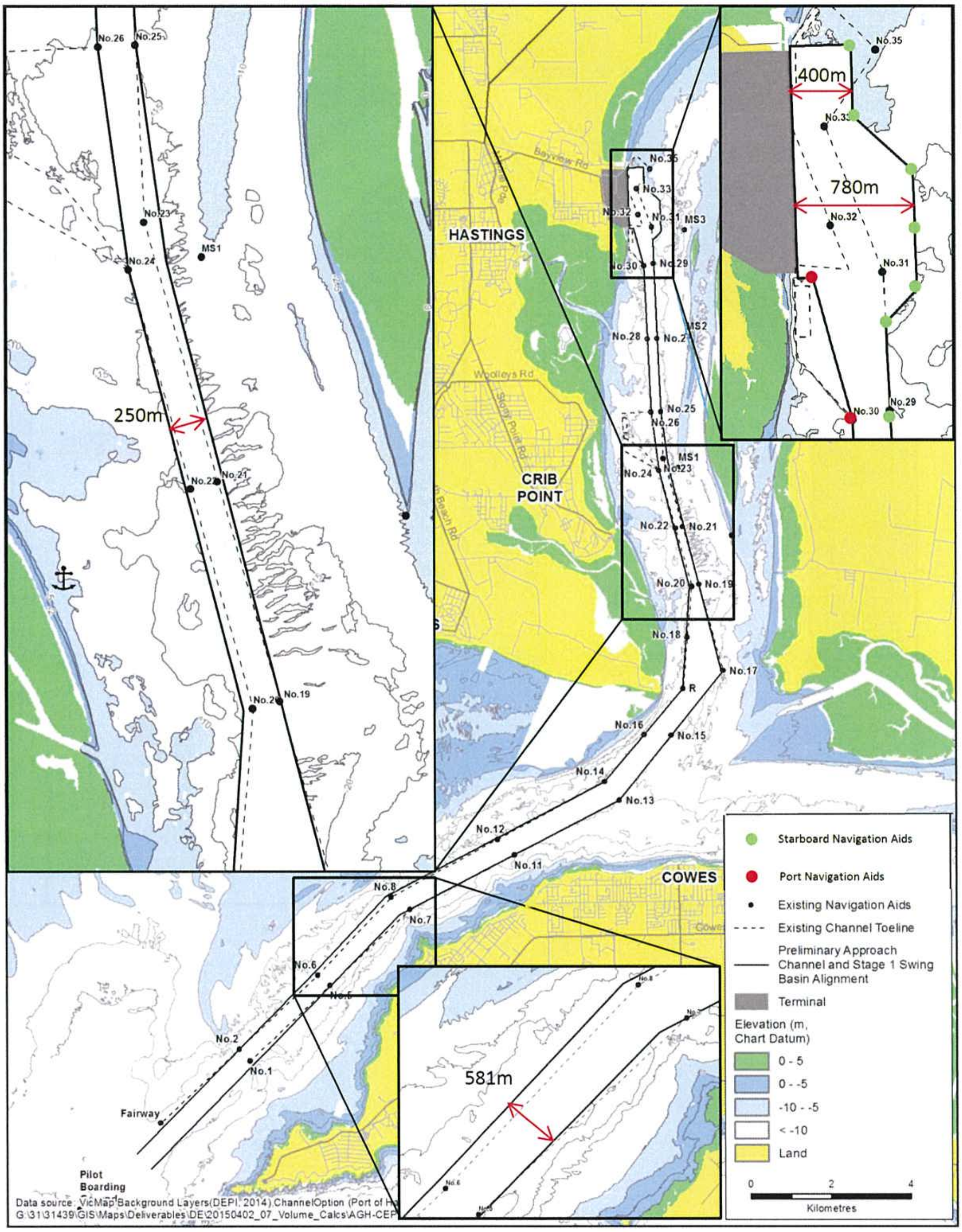

Figure 1. Channel and Stage 1 Development Alignment

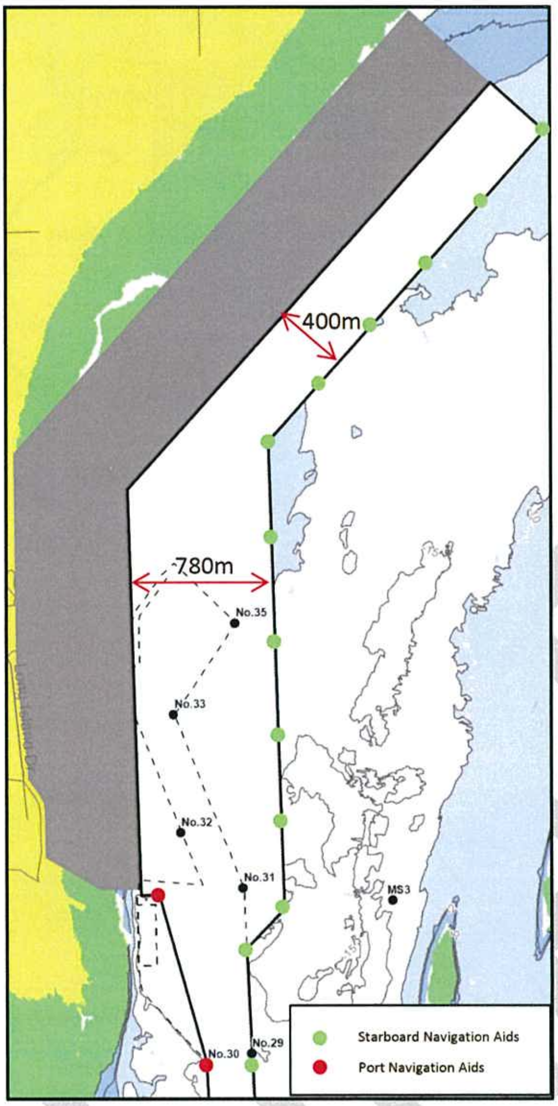

Figure 2. Along the Shore Alignment

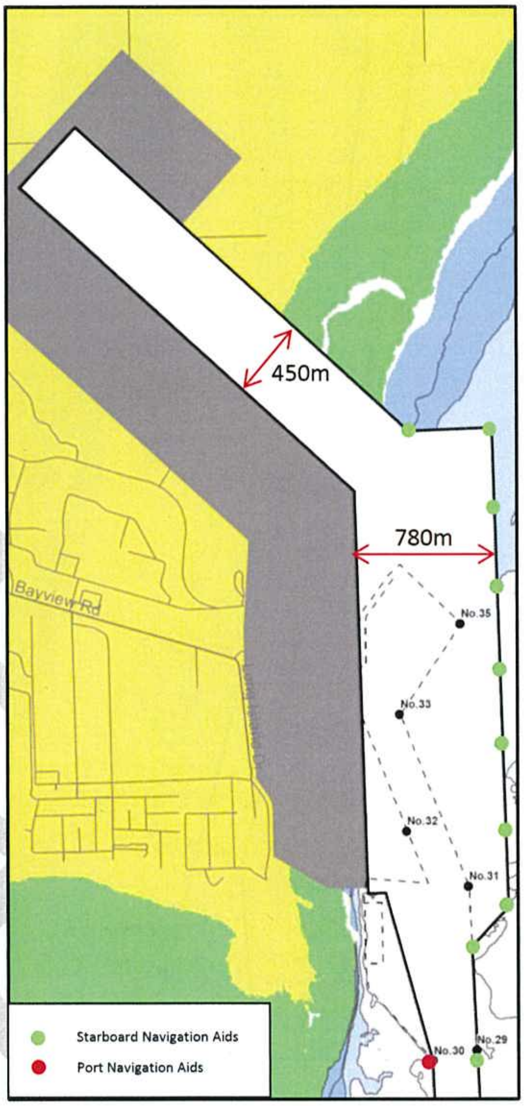

Figure 3. Basin Alignment

Channel Depth and Dredge Volumes

The following two depth scenarios were developed:

- Scenario A – Average channel closure below three hours (equates to a channel accessibility of about 80%) for a 15.0m draught vessel. Channel accessibility of just under 95% for a vessel with a draught of 14.5m
- Scenario B – Average channel closure below three hours (equates to a channel accessibility of about 80%) for a vessel with a draught of 14.5m

The channel, swing basin and berth pocket dimensions, declared depth and dredge volumes are summarised in Table 1 for Scenario A and Table 2 for scenario B. All volumes are in situ volumes.

Table 1. Summary of Dimensions, Depth and Dredge Volume for Scenario A

Segment	Dimensions	Declared Depth	Dredge Volume (m3 in situ)		
			To Dredge Clearance Level	Allowance for Overdredge	Total Incl Allowance for Overdredge
APPROACH CHANNEL					
Western Channel 1	519m	17.5	55,000	59,000	114,000
Western Channel 2	577m	17.0	18,000	10,000	28,000
Western Channel 3	500-577m	17.0	95,000	29,000	124,000
Western Channel 4	250-1,057m	17.0	173,000	52,000	225,000
North Arm 1	250m	16.3	659,000	207,000	866,000
North Arm 2	250m	16.2	909,000	313,000	1,222,000
Channel Total			**1,909,000**	**670,000**	**2,579,000**
PORT AREA					
Stage 1 Development	690m – Swing basin width 310m – drag back area width 450m – basin width 90m – berth pocket width	16.2 - Swing Basin 16.5 - Berth Pocket	4,700,000	400,000	5,100,000
Along the Shore Alignment			23,600,000	1,000,000	24,600,000
Basin Alignment			21,800,000	800,000	22,500,000
APPROACH CHANNEL & PORT AREA					
Stage 1 Development			**6,609,000**	**1,070,000**	**7,679,000**
Along the Shore Alignment[1]			**25,509,000**	**1,670,000**	**27,179,000**
Basin Alignment[1 & 2]			**23,709,000**	**1,470,000**	**25,079,000**

Notes

1. The Along the Shore and Basin Alignment quantities are for the entire development and including the Stage 1 development quantities.
2. Does not include the volume of material to be excavated beyond the approximate edge of foreshore vegetation at 2-3m CD. Removal of material within the basin landward of this line was considered by Haskoning to be carried out by excavation methods (i.e. behind a bund to prevent flooding of the basin during excavation) and this volume was estimated by Haskoning as 34.3M m3 (HAS-CEP0-HY-REP-0032-0).

Table 2. Summary of Dimensions, Depth and Dredge Volume for Scenario B

Segment	Dimensions	Declared Depth	Dredge Volume (m3 in situ)		
			To Dredge Clearance Level	Allowance for Overdredge	Total Incl Allowance for Overdredge
APPROACH CHANNEL					
Western Channel 1	519m	17.0	11,000	19,000	30,000
Western Channel 2	577m	16.5	7,000	6,000	13,000
Western Channel 3	500-577m	16.5	54,000	23,000	77,000
Western Channel 4	250-1,057m	16.5	105,000	38,000	143,000
North Arm 1	250m	15.7	324,000	152,000	476,000
North Arm 2	250m	15.7	435,000	212,000	647,000
Channel Total			**936,000**	**450,000**	**1,386,000**
PORT AREA					
Stage 1 Development	690m – Swing basin width 310m – drag back area width 450m – basin width 90m – berth pocket width	15.7 - Swing Basin 16.0 - Berth Pocket	4,200,000	400,000	4,500,000
Along the Shore Alignment			22,100,000	1,000,000	23,000,000
Basin Alignment			20,500,000	800,000	21,300,000
APPROACH CHANNEL & PORT AREA					
Stage 1 Development			**5,136,000**	**850,000**	**5,886,000**
Along the Shore Alignment[1]			**23,036,000**	**1,450,000**	**24,386,000**
Basin Alignment[1 & 2]			**21,436,000**	**1,250,000**	**22,686,000**

Notes

1. The Along the Shore and Basin Alignment quantities are for the entire development and including the Stage 1 development quantities.
2. Does not include the volume of material to be excavated beyond the approximate edge of foreshore vegetation at 2-3m CD. Removal of material within the basin landward of this line was considered by Haskoning to be carried out by excavation methods (i.e. behind a bund to prevent flooding of the basin during excavation) and this volume was estimated by Haskoning as 34.3M m3 (HAS-CEPO-HY-REP-0032-0).

Navigation Aid Layout

Along the approach channel the existing number and location of lateral navigation marks was deemed adequate during the real time navigation simulations with the exception of the North Arm 2. In the North Arm 2 it was recommended that an additional set of lateral navigation marks be included.

It is recommended to have markers along the toeline of the swing basin at intervals of 500 metres. Leading lights/markers, in some form, should be allowed for in the proposed basin alignment. This will not only aid the visual lateral positioning during the stern transit into the basin but also act as a reference during the turn in the swinging basin.

Conclusions

The following conclusions are drawn from the work undertaken to date. It is noted that the navigation design process has not been completed so all findings are subject to verification:

- The Port Phillip Bay Sea Pilots raised concerns about strong cross currents on the ebb tide at McHaffie Reef. The simulations showed this effect and demonstrated that the combination of vessel speed and channel width at this point allowed all vessels to negotiate this part of the channel safely.
- The PIANC guidelines for the concept design of the channel width appear to under estimate the width required for the container ships with large windage areas. It has been demonstrated that there is a need to widen the North Arm compared to the concept design recommendations. The North Arm channel will require a width of approximately 250m.
- Both the Basin and the Along the Shore layouts are feasible for combinations of peak spring tidal currents and wind speeds up to 30 knots, although a 30 knot wind speed may require additional tug capacity for certain manoeuvres.
- For operations in a 30 knot wind, three 80t tugs are required and in some circumstances a fourth tug may be needed.
- For the Basin layout the currents across the entrance are not an issue for swinging the vessel or transiting into or out of the basin.
- A swing basin with a length of 3xLOA (1,200m) is adequate for the Stage 1 Development and the width can be reduced below 1.75xLOA (700m). It is estimated that the width can probably be reduced to 1.65xLOA (660m).
- The construction of the berths between Long Island Point Jetty and the BlueScope berths has no significant impact on the berthing/unberthing of vessels at the Long Island Point Jetty.
- The volume of dredge material to provide an average channel closure of less than three hours per event (equates to a channel accessibility of about 80%) for a 14.5m draught vessel is 5.9M m^3 for the Stage 1 development, 23.9M m^3 for the entire Along the Shore Alignment and 22.4M m^3 for the entire Basin Alignment (excluding excavation beyond the approximate edge of foreshore vegetation at 2-3m CD).
- The volume of dredge material to provide an average channel closure of less than three hours per event (equates to a channel accessibility of about 80%) for a 15.0m draught vessel is 7.6M m^3 for the Stage 1 development, 26.6M m^3 for the entire Along the Shore Alignment and 24.9M m^3 for the entire Basin Alignment (excluding excavation beyond the approximate edge of foreshore vegetation at 2-3m CD).
- The depth of the berth pocket would need to be lower than the -17.0m CD level used in the structural quay options assessment. This is to allow for the 1% of the time that the water level in the Port Area is below 0m CD (lowest is approximately -0.5m CD).

Further Work

To define the optimal channel depth a discrete event simulation should be undertaken using the UKC data. The model would include the operational berths, together with the harbour and channel operations, tidal restrictions and operating procedures. The model would generate shipping for projected container and liquid bulk exports and imports and will process the movement of ships from arrival, berthing, loading/unloading and departure, subject to tidal and current constraints, port operating rules and harbour master requirements for tugs and pilots.

By varying the depth of the channel the delays to the shipping lines can be assessed. Additionally the model can assess delays to the existing operations within the Port of Hastings.

Further navigation simulation works would include the following:

- Use of a 3D flow model to input 3D currents into the simulations to investigate the effects of the complex flow patterns, especially at the basin entrance.

- Undertake more extensive simulations with a number of different pilots to confirm the widths of the channels, size of the swing basin, limits of safe navigation, aid to navigation requirements and tug requirements.
- Assess the Western Channel for two way operations.
- Assess the effect of passing vessels on vessels moored at the Long Island Point Jetty and the container berths to define what limitations are required.

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1.0 Introduction

1.1 Background Information

The Port of Hastings Development Authority was set up by the Government of Victoria in 2012 to investigate the feasibility of establishing a container port at Hastings. This port will provide additional capacity to the Port of Melbourne and will also be able to handle larger ships that are unable to access the Port of Melbourne.

As part of this port development the approach channel will need to be upgraded to cater for container vessels. This includes an assessment of the width and depth requirements of the channel, swing basin and berth pocket.

1.2 Purpose of this Report

This report outlines the channel design works undertaken to date and recommendations on the preferred width, depth and alignment of the approach channel, swing basin and berth pocket.

1.3 Objectives

The key objectives for the channel design are:

- Commercial - To ensure the channel design is commercially acceptable to shipping lines by providing sufficient accessibility to meet their KPIs for transit times and delays.
- Economic - Minimise project capex and scale of development by minimising the capital dredge volumes overall, optimising the channel alignment to avoid potential dredging of rock and maximising the use of the existing channel area.
- Safety - Ensure the design meets all safety requirements and is designed to relevant Australian and international standards.

1.4 Scope and Limitations

The existing channel system that connects the Port of Hastings to deep water is assessed for the vessels that will potentially visit the port to determine the suitability of the current alignment and configuration and where necessary the additional width and depth required to provide adequate capacity, accessibility and safety.

The scope of works undertaken includes the following:

- Determine the design vessel.
- Concept design of the approach channel, swing basin and berth pocket.
- Consultations with the Port Phillip Sea Pilots and the Harbourmaster.
- Underkeel clearance (UKC) analysis.
- Real time navigation simulations to assess the feasibility of potential layouts.
- Design of navigational aids.

Works not undertaken that were part of the original brief include the following:

- Channel capacity and depth modelling through discrete event simulations.
- Further real time navigation simulations to further optimise the layout.

While this report is limited to the channel design for navigation, dredge volumes have been calculated based on assumptions documented in this report in order to illustrate the relationship between channel accessibility and dredge volumes.

1.5 Project Team

The channel design was undertaken with specialist input from:

- HR Wallingford Pty Ltd – vessel simulations
- OMC International Pty Ltd – UKC analysis
- David Shennan of North & Trew Pty Ltd – marine operations

1.6 Reference Documents

Key reference documents used for the channel design for navigation are:

- AGH-CEPO-EG-MEM-0015 - Vessel Clearances and Safety Zones at LIP
- AGH- CEPO-EG-MEM-0016 - Initial Berth Alignments and Terminal Footprint
- HAS-CEPO-HY-REP-0016-B - Preliminary Siltation Analysis
- AGH-CEPO-EG-MEM-0017 - Channel Design for Construction – Stage 1 Preliminary Recommendations for Dredging Tolerances and Batter Slopes
- AGH- CEPO-EG-REP-0023 - UKC Vessel Analysis Report
- AGH-CEPO-EG-REP-0022 - Real Time Navigation Simulation Report
- HAS-CEPO-HY-REP-0012-A - Early Hydrodynamic Modelling for Port of Hastings Development Project
- HY-WP-27 - Hydrodynamic input for 2D Vessel Simulations
- HAS-CEPO-HY-REP-0032-0 - Port of Hastings Development Project, Dredging and Reclamation Options Report
- Port of Hastings Development Project (CE-WP-025 / 2150) Container Demand Assessment Findings, Final Working Draft Report (Rev 0), 27 February 2015
- Maximum Ship Size Particulars for Referral Design, 15 May 2014 prepared by the Commercial and Economic workstream.
- Port of Hastings Operating Handbook & Harbour Master's Directions, December 2013 Edition

1.7 Glossary

The acronyms and terminology used in this document are further defined in Table 1-1.

Table 1-1. Glossary of Terms

Acronym / Term	Definition
Along the Shore Alignment	A port alignment that generally followings the contours of the Westernport Bay north of Long Island Point Jetty.
Approach Channel	The defined navigation channel from the open sea to the port area.
Basin Alignment	A port alignment that includes a 2,500m long basin after the Stage 1 development.
Beam (B)	Maximum width of a vessel.
Berth Pocket	Dredged area along each side of the Wharf, with depth sufficient to accommodate the design vessel at all states of the tide.
Bottom Clearance	The clearance between the lowest point of the vessel and the highest point of the channel under any part of the vessel.
Channel Availability	The percentage of time over the period of a year that the channel is open for a vessel of a given draught.
Declared Depth	The minimum depth guaranteed available to vessels as declared by the Harbourmaster.
Dredge Clearance Depth	The minimum level to be achieved by the dredging Contractor.

Acronym / Term	Definition
Ebb tide	The period between high tide and low tide during which water flows away from the shore.
Flood tide	The incoming or rising tide, occurring between low tide and high tide.
Inertia Heel	Rotation of a vessel about its longitudinal axis during a turn.
LOA	Length Over All or the maximum length of a vessel.
Manoeuvrability Margin	The term used to define the time-averaged clearance under a vessel. Vessel manoeuvrability may be defined as the vessel's ability to perform the manoeuvres intended by the pilot/master without the assistance of tugs. The ability of a vessel to manoeuvre at its design speed will decrease when the clearance between the channel bottom and the ship's keel is reduced and may become insufficient if it is less than a certain critical value that maintains sufficient flow under and around the ship.
Maximum Design Draught (T_{Design})	The maximum draught at which the vessel can safely sail with respect to classification rules and load line regulations. The draught is measured vertically from the lowest point on the hull to the water level when at the maximum permissible summer load line. This is sometimes referred to as the scantling draught.
North Arm	The navigation channel between the existing buoys 19 & 20 to buoys 29 & 30.
North Arm 1 (NA1)	The straight segment of the channel between buoys 19 & 20 and 23 & 24.
North Arm 2 (NA2)	The straight segment of the channel between buoys 23 & 24 and 29 & 30.
Over Dredge Allowance	The maximum vertical allowance below the Dredge Clearance Depth available to the Contractor to ensure that the Dredge Clearance Depth is achieved.
PIANC	Permanent International Association for Navigation Congresses.
Port Area	The area north of existing buoys 29 & 30 that encompasses the port including the swing basin and berth pockets.
Sailing Draught (T)	The draught of the vessel at arrival or departure from a port when it is at rest. Typically this is measured at the bow, amidships and stern prior to departure to confirm that the vessel can leave the port and enter the next port safely. This is sometimes referred to as the running draught.
Squat	The steady downward displacement consisting of a translation and rotation due to the flow of water past the moving hull.
Stage 1 Development	A port development with a berth length of 1,450m between the existing Long Island Point Jetty and the BlueScope general purpose wharf
Static Draught	Equal to the sailing draught.
Swing Basin	Designated area for turning vessels prior to berthing or following unberthing.
TEU	Twenty-Foot Equivalent Unit.
UKC	Underkeel clearance is the depth requirement between the bottom of the keel of the vessel and the channel bed level.
UKC calculation point or MP	Points along the channel where the UKC analysis has been undertaken.
Wave Response	The response of the vessel in the six degrees of freedom due to wave actions on the vessel.
Western Channel	The navigation channel from the exsting buoys 1 & 2 to buoys 19 & 20.
Western Channel 1 (WC1)	The straight segment of the channel between buoys 1 & 2 and 7 & 8.
Western Channel 2 (WC2)	The straight segment of the channel between buoys No. 7 & 8 and 13 & 14.
Western Channel 3 (WC3)	The straight segment of the channel between buoys 13 & 14 and 17 & R.
Western Channel 4 (WC4)	The straight segment of the channel between buoys 17 & R and 19 & 20.
Wind Heel	Rotation of a vessel due to the action of wind against the vessel.

2.0 Channel Design Process

2.1 Existing Channel

Hastings is a natural deep water port. The existing navigation channel along the North Arm of Western Port extends from the Western Channel south of Sandy Point, to the northern end of the existing BlueScope facility where it terminates, refer Figure 2-1 and Figure 2-2.

The channel is maintained to a depth of -14.8mCD along the Western Channel, reducing to -14.2mCD north of Sandy Point. The maintained depth of -14.2mCD extends all the way to Long Island Point, only reducing further to -9.1mCD at the northern end of the Long Island Jetty for the remainder of the channel. Actual water depths along the Western Channel are significantly greater than the maintained depths indicated on the charts.

According to the Port of Hastings Handbook the approach channel, with a maintained depth of -14.2mCD, may be used by vessels drawing 13m draught unassisted by tide or vessels up to 15.2m draught with tide assistance allowing for a gross under-keel clearance of 1.3m.

In the channel between the Long Island Point Jetty and BlueScope Steel Wharves with maintained depth of -9.1mCD, the handbook states that this channel may be used by vessels drawing 8.5m draught unassisted by tide or by vessels up to 10.7m draught with tide assistance allowing for a gross under-keel clearance of 0.6m.

The Western Channel has a width of between 400m and 560m and caters for 2-way traffic. The North Arm between Hanns Inlet (south of Stony Point) and Crib Point is 183m wide for 1-way traffic. The channel along the North Arm between Crib Point and Long Island Point is 250m wide and is also limited to 1-way traffic. Departing deep draught vessels have priority, with incoming vessels typically waiting in the East Arm anchorage until outbound deep draught vessels have departed. Further north the channel reduces to 200m between the Long Island Point Jetty and BlueScope wharves and is 1-way, with departing vessels also taking priority.

Table 2-1 summaries, the width, length and depth of each segment of the existing approach channel.

Table 2-1 Existing Channel Segment Dimensions

Channel Segment	Approximate Length (km)	Approximate Orientation (°N)	Angle of bend into Segment (°)	Min Width (m)	1-Way /2-Way	Declared Depth[1]	Description
Western Channel 1	8.0	046-226	-	400	2	14.8	Fairway Buoy to Buoys 7 & 8
Western Channel 2	5.8	061-241	15	500	2	14.8	Buoys Nos.7 & 8 to 13 & 14
Western Channel 3	3.6	040-220	21	500	2	14.2	Buoys Nos. 13 & 14 to 17 & R
Western Channel 4	2.4	359-179	41	183	1/2	14.2	Buoys Nos. 17 & R to 19 & 20 Buoys
North Arm 1	3.4	345-165	14	183	1	14.2	Buoys Nos.19 & 20 to 23 & 24
North Arm 2	4.8	358-178	13	250	1	14.2	Buoys Nos. 23 & 24 to 29 & 30

1. Maintained depth source Chart AUS 150 – Western Port (Edition No. 2 dated 4 Jun 2010)

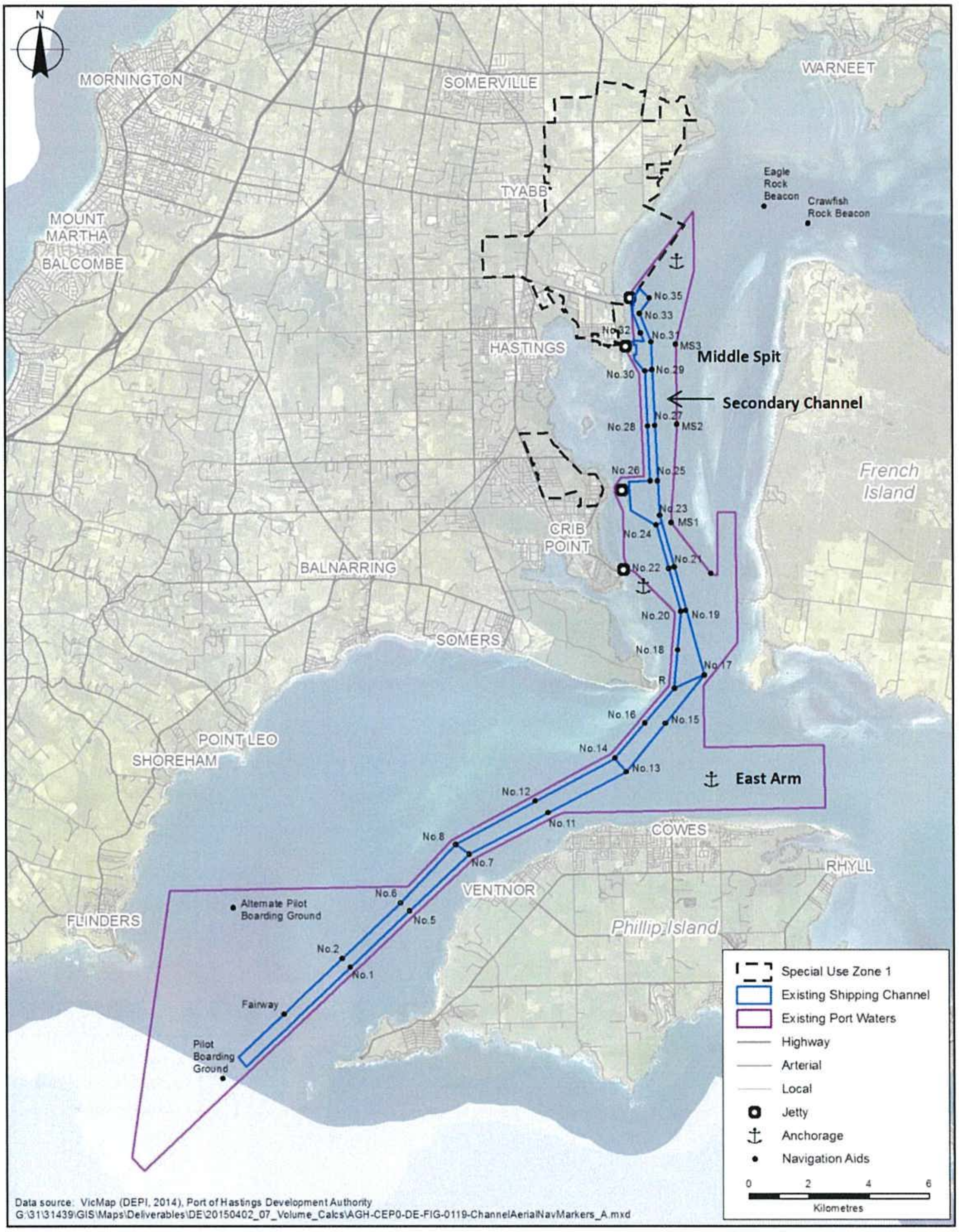

Figure 2-1. Existing Port of Hastings Approach Channel

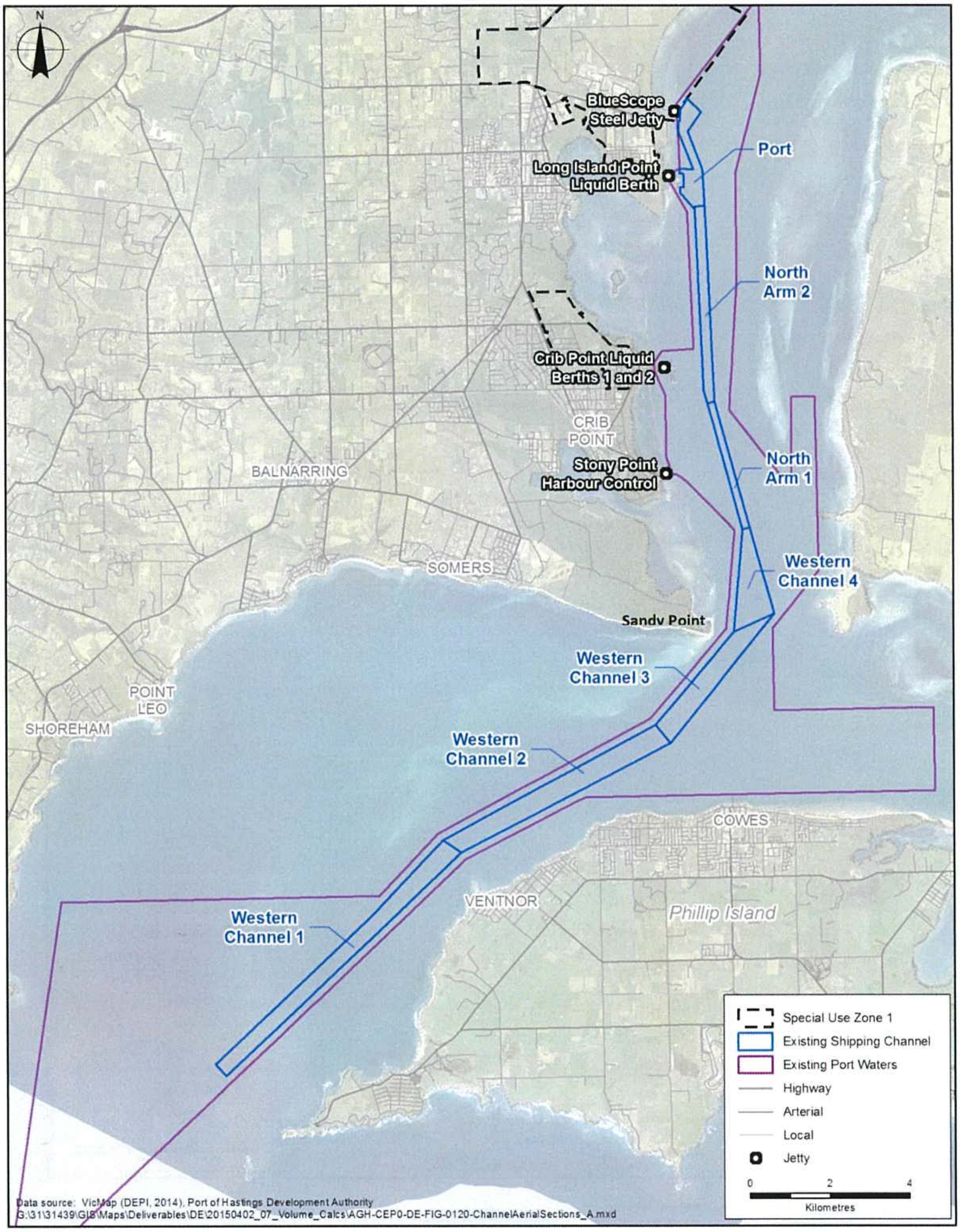

Figure 2-2. Port of Hastings Channel Segments

The Port of Hasting approach channel provides access to the Esso and BlueScope facilities at the Long Island Point precinct and to Crib Point Oil Terminal Jetty and Stony Point to the south.

The 1-way channels in the North Arm are supplemented with the Secondary Channel which has a minimum depth of -10mCD and is located on the east side of the North Arm bounded by the -10mCD contour marked by piles along the Middle Spit. This provides space for passing vessels when deeper draught vessels are occupying

the North Arm. The Secondary Channel may be used by vessels drawing 8.7m draught unassisted by tide or vessels up to 10.9m draught with tide assistance. Tide assistance of up to 2.2m is allowed in the Port of Hastings Handbook based on the neap tidal range. In addition vessels of up to 6m draught and 100m overall length are able to utilize the water space within 200m of the west side of the North Arm providing additional means for passing vessels. Vessels approaching the BlueScope steel wharves from the Secondary Channel pass between Buoy Nos. 35 and MS4 with a limiting draught of 9.9m with tide assistance.

In accordance with the Port of Hastings Operating Handbook and the Harbourmaster's Directions the passage of a vessel greater than 30m in length through Western Port is to be piloted. Such vessels are navigated under the direction of pilots provided by Port Phillip Sea Pilots. Pilots board arriving vessels 3 miles outside the entrance to Western Port or go aboard departing vessels at the berth. The pilots for Western Port are based at Flinders and the pilot boat is kept on a mooring to the north of Flinders pier.

Up to two tugs with a rated bollard pull capacity of 52 tonnes are provided to escort vessels through the channel and to assist in the berthing and unberthing operations. Tugs are operated by Svitzer Australasia and are stationed at Stony Point. Tugs meet incoming vessels at Buoy No. 19, approximately 1 mile southeast of Stony Point.

Vessel transits are controlled by the Harbour Master through the Harbour Control Office at Stony Point. Vessel transits are dealt with in sequence according to a pre-scheduled transit arranged at least 3.5hours in advance. There are no speed restrictions within the port and the passage from the pilot boarding point to Long Island Point is around 2hours.

2.2 Design Process and PIANC Design Methodology

The design of the channel is being undertaken in accordance with PIANC Design Guidelines for Harbour Approach Channels 2014 (PIANC 2014). PIANC 2014 describes two stages in the design development:

- Concept Design involves preliminary design using a series of empirical rules derived from experience of similar conditions to determine the width, depth and alignment.
- Detailed Design involves numerical models, physical models and/or simulations to validate, develop and refine the concept design.

PIANC 2014 also recommends the involvement of experienced users (pilots, mariners, etc.) in the design process.

The concept design is based on the alignment of the existing channel and it has been adjusted and widened as per the PIANC 2014 concept design guidelines. The concept design has then been adjusted and refined based on the outcome of further studies on underkeel clearance and navigation simulations.

What is termed the detailed design stage in PIANC 2014 has been termed preliminary design to avoid confusion with later design stages and to correspond to the level of design development undertaken to date.

2.3 Concept Design

The concept design has been undertaken using the PIANC Guidelines. PIANC sets out empirical rules, developed from a world-wide review of existing channels, which enable the width and depth of the channel to be estimated.

2.4 Pilot and Harbourmaster Discussions

A workshop was held to incorporate practical knowledge of the port and access channels from the Port Phillip Sea Pilots and the Hastings Harbourmaster into the channel design. This includes pilotage practices particular to Victoria and general guidance on how pilots navigate the Port of Hastings approach channels. This workshop also included a Master Mariner representative from North and Trew (David Shennan).

2.5 Preliminary Design

Following concept design and the discussions with the pilots and harbourmaster the following works were undertaken to further develop the channel design, including:

- Under keel clearance (UKC) analysis to assess the depth required for the design vessels.
- Real time navigation simulations to assess the feasibility of potential layouts and the width required.
- Design of navigation aid locations.

Works not undertaken that were part of the original brief includes the following:

- Channel capacity and accessibility optimisation through discrete event simulations (DES).
- Further real time navigation simulations to optimise the preferred layout and refine the approach channel and swing basin dimensions.

2.5.1 UKC Modelling

The UKC modelling has been undertaken by OMC International using their DUKC methodology, in accordance with PIANC 2014 to define the appropriate channel depths for a range of vessel draughts and accessibility. The DUKC model quantified wave response, squat and inertial heel for a synthesised shipping schedule for each channel section based on a year of hydrodynamic data. Additionally wind heel using meteorological data from the same time period was calculated manually.

2.5.2 Real Time Navigation Simulations

The real time navigation simulations were undertaken to assess the feasibility of the layouts and to undertake initial refinement of the horizontal dimensions of the channel and manoeuvring area. The navigation simulations used realistic design vessel performance characteristics, tug operations and metocean conditions to create an overlay of vessel track plots. These track plots have been analysed to identify areas where the conceptual channel design has been overly conservative (hence dredge volumes can be reduced), or where geometry or operational design needs to be reconsidered.

The simulations were only preliminary and involved a single run for each scenario under extreme conditions. To obtain a full envelope of vessel tracks plots for detailed design, a much more extensive set of simulations will be required.

2.5.3 Design of Navigational Aids

The type and location of the navigational aids has been developed utilising the experience of David Shennan from North and Trew, discussions with the pilots and harbourmaster and from information from the real time navigation simulations.

3.0 Vessel Spectrum and Design Vessels

3.1 Vessel Spectrum

3.1.1 International Container Vessels

The Commercial and Economic workstream has developed two demand forecast scenarios for international containers along with a forecast fleet spectrum for each scenario (Commercial and Economic, PoH Draft Forecast Demand Scenarios, 5 December 2014). The scenarios have a start date of 2031 and the bases of the two scenarios are as follows:

1. The Port of Hastings handles overflow from the Port of Melbourne and there are no limits on the size of vessel that can visit the Port of Hastings, refer to Figure 3-1.
2. One of the stevedores in Swanson Dock transfers to the Port of Hastings in 2034 with Swanson Dock remaining at 110% capacity, refer to Figure 3-2.

Although the demand scenarios state that there are no limits, a limit of 19,000 TEU capacity container vessels has been set for the determination of the number of vessel calls required. This corresponds to the largest container vessels currently in service.

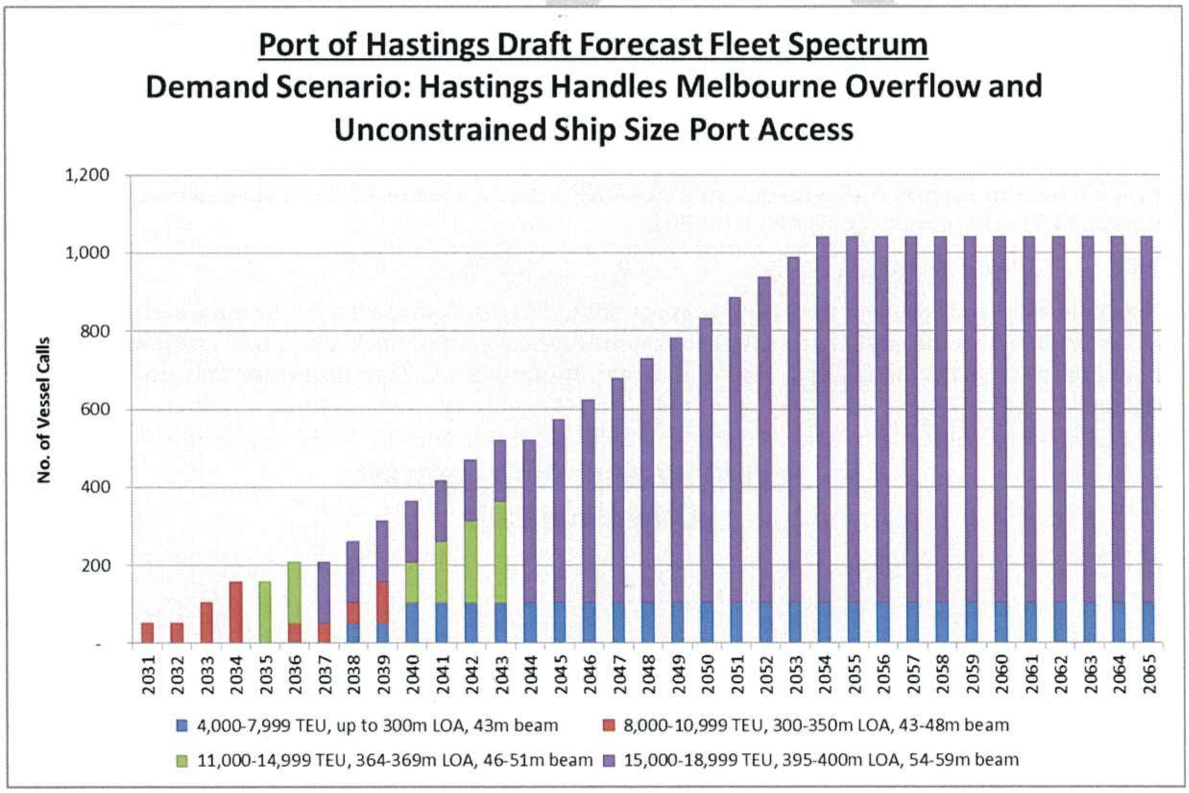

Figure 3-1. Port of Hasting Draft Forecast Fleet Spectrum, Demand Scenario Hastings Handles Melbourne Overflow and Unconstrained Ship Size Port Access (5 Dec 2014)

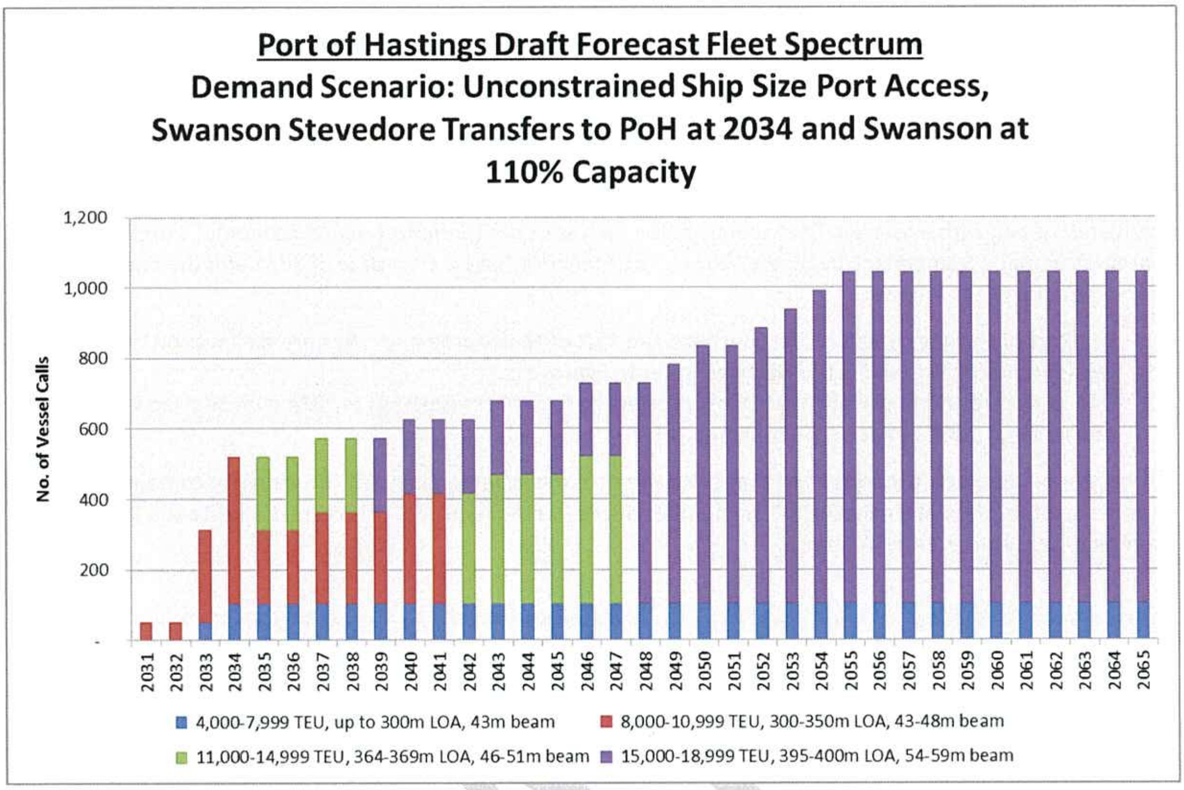

Figure 3-2. Port of Hasting Draft Forecast Fleet Spectrum, Unconstrained Ship Size Port Access, Swanson Stevedore Transfers to Port of Hastings at 2034 and Swanson at 110% Capacity (5 Dec 2014)

3.1.2 Other Vessels

The Commercial and Economic workstream has developed forecast fleet spectra for the other vessels based on the assumption that the cargo parcel sizes and ship sizes currently used remain the same with the assumed trade growth served by increasing number of ship calls. The resultant forecast fleet vessel calls are outlined in Figure 3-3.

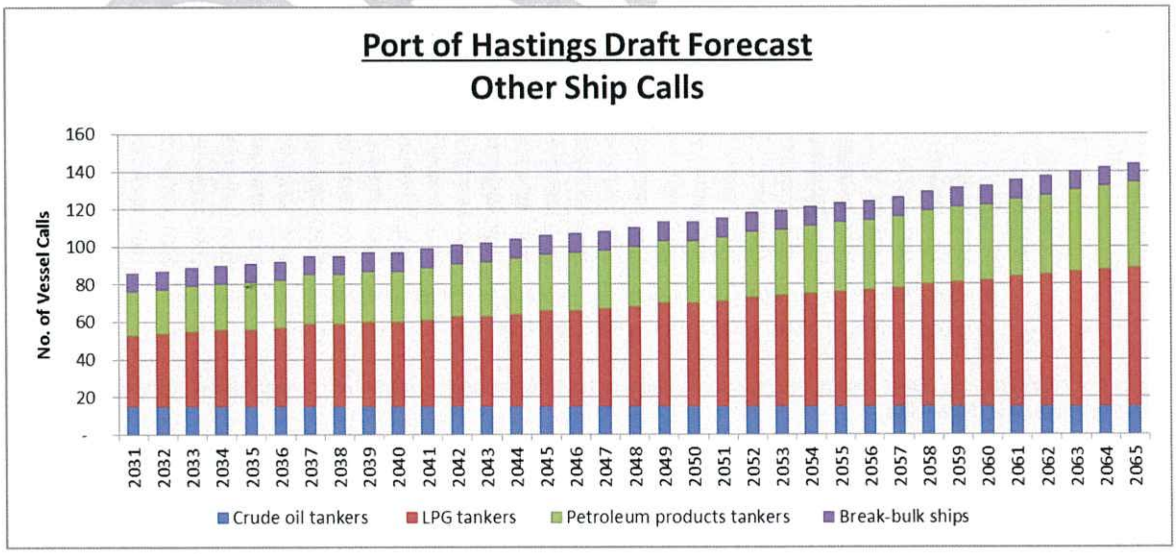

Figure 3-3. Port of Hasting Draft Forecast Other Ship Calls (7 Oct 2014)

3.2 Design Container Vessel

3.2.1 Vessel Dimensions

In the forecast fleet spectrum the largest container vessel has a LOA of 400m and a beam of 59m with a capacity of between 18,000-18,999 TEUs.

In the Melbourne Overflow scenario this vessel is forecast to arrive in 2040 or nine years after the port will open for container vessels. Container vessels of 398m LOA, 56m Beam, 15,000-15,999 TEUs are forecast to arrive in 2037 or six years after the port will open for container vessels.

In the scenario where one of the Swanson Stevedore transfers to Port of Hastings the 400m LOA, 59m beam, 18,000-18,999 TEU container vessels are forecast to arrive in 2042 or eleven years after the port opens for container vessels. Container vessels of 398m LOA, 56m Beam, 15,000-15,999 TEUs are forecast to arrive in 2039 or eight years after the port will open for container vessels.

This means that within six to eight years of the port opening, vessels with an LOA of about 400m and a beam of 56m are forecast to visit the port, with the beam increasing to 59m within nine to eleven years.

For the channel design, the timespan between the opening of the port to arrival for the 400m LOA vessels is too short to consider two separate dredging campaigns. As such the 400m LOA, 59m beam vessel is adopted as the design vessel for the Stage 1 development for subsequent development stages.

3.2.2 Sailing Draughts

The draught of a particular vessel most often quoted is the maximum design draught. The maximum design draught is the maximum draught at which the vessel can safely sail with respect to classification rules and load line regulations. The draught is measured vertically from the lowest point on the hull to the water level when at the maximum permissible summer load line. This is sometimes referred to the scantling draught.

Container vessels rarely sail at the maximum design draught due to the number and weight of containers (including empties), distribution of these containers on the vessel, the unloading and loading that occurs at each port of call and the consumption of fuel between ports.

For the 400m LOA vessels the maximum design draught is typically 16.0m. The Commercial and Economic workstream has undertaken a review of sailing draughts based on data from the Ports of Botany (Sydney), Brisbane and Singapore (Container Demand Assessment Findings, CE-WP-025 / 2150, Rev 0, 27 February 2015). The key findings of this analysis are quoted below:

- Following current shipping patterns, the Port of Hasting is unlikely to be either the first or last Australian port of call for the majority of services – this implies that the 95+% of maximum summer draught experienced by Singapore as a typical last port of call (westbound) and 90+% for typical first port of call (eastbound) is unlikely to be repeated for Hastings
- Melbourne's current estimated percentage of maximum summer draught for 4,000-6,500 TEU ships of 80-90% appears to be a realistic "indicative"* percentage for large (8,000+ TEU) ships calling at Hastings in the future
- Based on a conservative 90% of maximum summer draught, this would imply "indicative"* average running draughts at Hastings of 14.4 metres for 14,000-19,000 TEU ships given a typical 16 metres maximum summer (scantling) draught
- If 95% or 100% of maximum summer draught was ever required as running draught for 14,000+ TEU ships calling Hastings as first or last port then this would imply an "indicative"* extra 0.8-1.6 metres of tidal assistance given 14.4 metres of ship draught all-tides access

(*) Note: The analysis noted that actual running or operational draughts and the actual % of maximum summer draught are specific to each ship design and the cargo, fuel and supplies carried per ship voyage, but given the high-level scope of this analysis, the findings can be considered typical for Hastings.

The sailing draughts analysis for twelve months (Nov 2013 to Oct 2014) of data at the Port of Singapore found that for 8,000-18,000+ TEU containerships travelling westbound 18% of the vessels had a sailing draught

greater than 15.0m and 15% of the vessels had a sailing draught of between 14.5m and 15m. For the 14,000+ TEU capacity vessels the average sailing draught was 15.5m (30 calls) or 97% of the maximum sailing draught.

On the eastbound voyage 5% of the vessels had a sailing draught greater than 15.0m and further 5% of the vessels had a sailing draught between 14m and 14.5m. For the 15,000-15,999 TEU capacity vessels the average sailing draught was 14.7m (5 calls) while for the 18,000-18,499 TEU capacity vessels it was 14.5m (9 calls) or 90% of the maximum sailing draught.

The westbound voyages out of Singapore are typically fully loaded with full containers and the vessels have been refuelled in Singapore. The very high sailing draughts would not apply at Hastings as fuel would be used in transit and full containers taken off at other ports. The maximum range of sailing draughts at the Port of Hastings is likely to be in the 14.5-15.0m range, with some vessels that call first at Hastings having a draught higher than 15m.

3.3 Other Vessels

In addition to international container trades the Port of Hastings must continue to cater for the current trades that utilise the port. These include:

- crude oil tankers to the Long Island Point Jetty
- LPG tankers to the Long Island Point Jetty
- petroleum products tankers to the Crib Point Jetty, Berth 1
- breakbulk vessels that currently utilise the BlueScope general purpose berths and will transfer to another general cargo berth once the container berths extend past the BlueScope berths.

A review of the expected maximum bulk liquid vessel sizes undertaken by the Commercial and Economic workstream (Maximum Ship Size Particulars for Referral Design dated 15 May 2014) identified the following design vessels:

- Crude Oil Tankers – Currently the Aframax class (115,000 deadweight tonnages, 250m LOA, 44m beam and a maximum design draught of 15.5m) of crude oil tankers call at the Port of Hastings. The next size class of crude oil tankers operating globally, but not currently calling at the Port of Hastings, is Suezmax with average deadweight of 155,000, LOA of 274 metres, beam of 48 metres, and maximum summer draught of 16.7 metres. Given that currently the tankers are typically departing with a part load (conclusion based on tonnes loaded data as a percentage of vessel deadweight) and the next largest size in the global fleet (Suezmax) is significantly larger, it was concluded that the Aframax tanker is representative of the maximum size of tanker calling at Hastings in the future.
- LPG Tankers - The largest size class of LPG tankers operating globally is currently calling at the Port of Hastings and have been adopted as the LPG tanker design vessel (58,000 deadweight tonnage, 230m LOA, 37m beam, 12.6m maximum design draught).
- Petroleum Products Tankers - The 45-50,000 deadweight tonne petroleum products tankers currently calling at the Port of Hastings are not the largest size of petroleum products tankers in the global fleet, but are the most common (around 55% in deadweight terms). The next size of vessel is Panamax (18% of the global fleet in deadweight terms) with the largest size being Aframax/Suezmax. Given the recent refinery closures in Australia and the potential for more in the future along with the growth in petroleum products, it was concluded that Panamax size petroleum products tankers (72,000 deadweight tonnage, 227m LOA, 32m beam and maximum design draught of 13.9 metres) could be potentially calling in the future at the Port of Hastings.

The breakbulk vessels that currently visit the Port of Hastings are generally quite small and to allow for potential growth in bulk trades in the port an 115,000 deadweight tonne, 225m LOA, 43m beam and a maximum sailing draught of 14.5m bulk vessel has been included. This size of vessel was chosen as it is the largest that can transit the current Hastings approach channel.

3.4 Design Vessel Summary

The design vessel particulars are summarised in Table 3-1. It is expected that the tankers would be close to their maximum design draught during either their arrival or departure depending on the trade they are serving. For the container vessels the actual sailing draught would be lower than the maximum design draught as discussed in Section 3.2.2.

Table 3-1. Design Vessel Particulars

Vessel Type	Deadweight Tonnage (DWT)	Length Overall (m)	Beam (m)	Sailing Draught (m)
Container Vessel	195,000	400	59	14.5-15.0
Crude Oil Tankers	115,000	250	44	15.5
LPG Tankers	58,000	230	37	12.6
Petroleum Products Tanker	72,000	227	32	13.9
Dry Bulk Vessel – Future	115,000	225	43	14.5

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4.0 Channel Design Benchmark and Performance Criteria

4.1 Channel Availability

One of the main criteria that shipping lines use when choosing between competing ports is the total time for a ship to leave the steaming route, discharge and load cargo and then return to the steaming route. The distance from the steaming route to the port is usually termed the deviation distance. Hastings already has an advantage over the Port of Melbourne in that the deviation distance from a line joining Anderson Light and Cape Otway is approximately 37 miles less, implying a saving of approximately 5 hours for a ship call. Once at the port, the time to get alongside at Hastings is comparable to Webb Dock at the Port of Melbourne. If the ship is going to Swanson Dock in Melbourne, it will need a further 30 minutes each way to negotiate the Yarra River. With modern equipment at both ports, it is reasonable to assume that both ports could handle a cargo in the same time alongside. As the discrete event simulation has been removed from the work programme, an assessment of channel accessibility has been undertaken by considering the percentage of time that the channel is available and the average and maximum delay times until the channel becomes available.

If a vessel knows sufficiently far in advance that the channel will not be available at her planned time of arrival, her master can adjust her planned arrival time by either speeding up or slowing down. Using a higher steaming speed carries a fuel penalty so the tendency is to slow the vessel so that she arrives as the channel reopens. This strategy also protects the ship against a lower than expected tide or severe wave action causing further delays. To make use of adjusted steaming speeds to mitigate the effect of channel windows of closure, the port must have a modern VTS system that monitors the position of ships at least 12 hours out (usually by AIS live services) and integrates information on tides, waves and weather. These procedures are standard in modern deep sea ports. In practice, adjusting steaming speeds can be used to adjust arrival times by up to four hours.

The maximum number of annual vessel calls as reported in the Port of Hastings Draft Forecast Fleet Spectrum dated 5 December 2014 is 1,042 calls per year which occurs from 2054/55. It is very unlikely that this number of ship calls will require a two way channel although the natural bathymetry south of Sandy Point means that a 4-500m wide channel can be provided without dredging. This means that the dominant restriction on the use of the Hastings channel will be water depths. With an extreme tidal range of 3.3m (LAT to HAT) and even neap tides having high water some 2.0m above Chart Datum in Western Port there is the potential to use part of the tidal window to reduce charted channel depths and hence the dredge volumes.

If a channel is being proposed that does not offer 100% availability for a particular ship, to obtain the true access percentage for a ship, it is necessary to consider the percentage of time that the channel is actually in use. Normally this would be done using a discrete event simulation but, as this has been deleted from the work programme, a simplified approach must be used. If the channel is considered one-way from the Port Limits to the Port, and only one vessel allowed to be under way in the channel at a time (a conservative approach), then the channel occupancy will reach a maximum of 42% based on the Port of Hastings Draft Forecast Fleet Spectrum dated 5 December 2014. For a channel availability of 90% this equates to an availability to the shipping lines of 94% since there would be no shipping requirement for the remaining time.

To provide an illustration on channel depths and dredge quantities based on the studies undertaken to date, it is proposed that a maximum average channel delay of three hours is used for the design vessel at its predicted running draught. This will allow for the majority of the channel closures to be less than four hours which will normally allow a vessel to adjust its steaming speed to compensate.

4.2 Limiting Environmental Conditions

4.2.1 Wind

Limiting wind conditions would apply to the channel operations, berthing/unberthing operations and the wind heel allowance in the depth of the channel for the maximum draught vessels.

Table 4-1 outlines the percentage of time that the wind speed exceeds 20, 25 and 30 knots for each of the 16 cardinal directions from measurements at Stony Point and Long Island Point between 2000-2013. These wind stations are subject to shielding, particularly from the west to southwest sectors and it would be expected that the percentage exceedance values in this table would be higher than reported for these wind directions.

Table 4-1. Wind Speed and Direction – Percentage Occurrence

Weather Station	Stony Point			Long Island Point		
% of time exceeding	> 20knts	> 25knts	> 30knts	> 20knts	> 25knts	> 30knts
N	0.13	0.01	0	0.19	0.01	0
NNE	0.15	0.03	0.01	0.11	0.01	0
NE	0.15	0.02	0.01	0.07	0	0
ENE	0.03	0	0	0.14	0	0
E	0.01	0	0	0.10	0.01	0
ESE	0.12	0.02	0	0.14	0	0
SE	0.30	0.04	0	0.13	0	0
SSE	0.16	0.01	0	0.12	0	0
S	0.19	0.03	0	0.15	0.02	0
SSW	0.11	0.01	0	0.40	0.04	0
SW	0.07	0	0	0.49	0.06	0.01
WSW	0.07	0.01	0	0.34	0.04	0.01
WSW	0.10	0	0	0.24	0.03	0
WNW	0.11	0	0	0.25	0.01	0
NW	0.25	0.01	0	0.13	0	0
NNW	0.74	0.09	0.02	0.51	0.04	0
TOTAL	**2.77**	**0.37**	**0.07**	**3.60**	**0.33**	**0.05**

The limiting wind speed for berthing and unberthing operations at Swanson Dock is a 30 knot steady state wind or a wind gusting to 35 knots. This was selected as an appropriate limit for berthing and unberthing operations in the Port of Hastings and, given that there is no anchorage between the North Arm and the berth it is considered that this limit would also apply to the approach channels. Based on the wind data at Stony Point and Long Island Point this wind speed would occur less than 0.1% of the time or less than 8 hours in a given year on average. Anecdotal observations by the Port Phillip Sea Pilots suggest that the wind measurements from Stony Point and Long Island Point are lower than the wind speeds in the middle of the channel. The percentage of channel downtime due to wind will have to be re-evaluated when better meteorological data is available. Even if the channel closure due to strong winds doubled to 0.2%, this would still not be significant.

4.2.2 Sea Conditions

The Port Phillip Sea Pilots have reported that the limitation on boarding a vessel at Port Phillip Heads are due to the breaking waves that prevent the pilot launches coming alongside the vessel. WesternPort Bay does not have this issue as the pilot boarding area does not have the overfalls experienced at the Heads. The current location of Flinders pilot boat launching facility is ideal in terms of proximity to the boarding ground, however it is still exposed to considerable wave action meaning that the pilot boat has to be taken off station. If shipping into Western Port is increased, some form of wave attenuation (e.g. breakwater) and alongside launch moorings, supported by an adjacent maintenance workshop, amenities and refuelling arrangements will be required to ensure that the pilot boat can be deployed when required.

It is assumed that the Flinders pilot boat launching facility would be upgraded as part of the development of the port and therefore this would not limit the availability of the approach channel.

The limitations of the sea conditions on the use of the channel for the design vessels are a function of the channel depth and are covered further in Section 6.0.

4.2.3 Visibility

Poor visibility due to fog can also limit the operation of the channel. Horizontal visibility records for Stony Point for the distance range of 0-5,000m are shown in Table 4-2. The percentage occurrence for each of the visibility ranges is based on AM and PM visibility recordings taken at Stony Point weather station between 1 August 1972 and 28 February 1983. Anecdotal evidence indicates that typically the fog occurs in the early morning and usually dissipates by the mid-morning or the early afternoon, suggesting that delays of up to 4 hours could occur.

Table 4-2. Horizontal Visibility Recording for Stony Point up to 5 km

Horizontal Visibility (m)	Percentage Occurrence	Number of Hours / Year	
		No.	Cumulative No.
0 – 1,000	1.14%	100	100
1,000 – 2,000	0.23%	20	120
2,000 – 5,000	1.37%	120	240

Visibility is not usually an issue in the pilot boarding and berthing operations but it may dictate whether the channel is safe to use. A normal figure in place for many ports worldwide is that movement of vessels is restricted when visibility is reduced to or below 0.5nm or 1000m in the approach channels and 0.3 nm or 600m in the swing basin. It is possible for vessels to transit the channel in zero visibility using additional aids such as ECDIS, Radar, AIS, VTS Assistance etc., however, due to the low frequency of fog in Port Phillip Bay, the pilots may not all be comfortable working in these conditions.

As an example the Port of Felixstowe has procedures for one-way traffic and additional requirements for gaining permission to proceed when there is minimal to zero visibility. It is understood that recently, for reasons associated with the towage requirement, movements of such vessels has stopped when visibility was reduced below 0.3nm or 600m. Many vessel masters were reluctant to allow movement of these vessels even when the visibility was at this level.

Public safety of recreational boating needs to also be considered when setting a limit on horizontal visibility.

For the purposes of the channel availability assessment, a limiting horizontal visibility of 0.5 nm or 1,000m has been used, which corresponds to a percentage occurrence of 1.14%.

4.3 Safety

A formal navigation risk assessment is outside the scope of the current studies, however it will need to be undertaken before the design can be completed. The approach undertaken for this stage of the project to ensure that the design meets all safety requirements, is to incorporate comments and feedback from experienced users (pilots, mariners, harbourmaster etc) into the design through:

- Issues raised during the discussions with the Port Phillip Sea Pilots and the Harbourmaster have been incorporated into the real time navigation simulation program.
- Outputs and comments from the real time navigation simulation pilot have been incorporated into the latest design.
- Advice on marine operations from David Shennan of North & Trew Pty Ltd.

Additionally the design is to meet the requirements of PIANC Guidelines for Harbour Approach Channels (PIANC 2014) including minimum manoeuvrability margin and bottom clearance under a vessel.

4.4 Existing Operations

The following berths are to remain operational as part of the expanded port:

- Stony Point
- Crib Point
- Long Island Point Jetty
- BlueScope general purpose berth for the Stage 1 development only

The shipping numbers at these berths are very small at present and if they increase significantly a discrete event simulation exercise will have to be undertaken to check that delay times do not become excessive.

5.0 Channel Width and Layout

5.1 Concept Design

5.1.1 Approach Channel

The required width of the of the channel using the concept design method in PIANC 2014 is based on multiples of the design vessel beam taking into account vessel speed, prevailing cross wind, cross and longitudinal currents, waves, aids to navigation, bottom surface and the depth of the waterway.

The existing channel has been broken into segments by each straight length of channel as outlined in Figure 2-2. Two scenarios have been considered, a one-way channel all the way and a two-way channel up to Sandy Point then a one-way channel to the port area at Long Island Point. The second scenario is the same as the present pattern of operations. Table 5-1 summarises the required widths given by PIANC 2014, the calculations and rationale are included in Appendix A.

Table 5-1. Concept Design Channel Widths (m)

Segment	Existing Width (m)	Concept Design Width (m)			
		Container Vessel		Crude Oil Tanker	
		One-Way	Two-Way	One-Way	Two-Way
Western Channel 1	400	212	519	169	422
Bend of Western Channel 1 and 2	560	243	581	192	468
Western Channel 2	536	183	460	147	378
Bend of Western Channel 2 and 3	592	220	534	174	432
Western Channel 3	536	183	448	150	374
Bend of Western Channel 3 and 4	1112	227	536	181	437
Western Channel 4	183*	230	-	185	-
Bend of Western Channel 4 and North Arm 1	183	267	-	212	-
North Arm 1	183	212	-	172	-
Bend of North Arm 1 and 2	605	243	-	194	
North Arm 2	250	212	-	172	

Red text indicates that the required dimension is larger than the existing width

** This segment is trapezoidal in shape and the dimension corresponds to the minimum width and is located at the junction with North Arm 1*

Where the required widths are less than those existing, the channel dimensions have not been reduced. This has been done to determine if it is possible for the existing width to be maintained without the need for additional dredging. Widening or realignment of the existing channel is required at the following locations:

- For a two-way transit along the full length of Western Channel 1 and the bend of Western Channel Segments 1 and 2. High spots are located near the bend of Western Channel 1 and 2 near McHaffie's Reef at Ventnor on Phillip Island and along the north of the channel at the southern entrance to Western Channel 1. To avoid these high spots the intersection of Western Channel 1 and 2 has been moved 300m to the west and the angle at this corner increased by 2 degrees as outlined in Figure 5-1. This results in a marginally tighter approach into the first bend along the Western Channel.

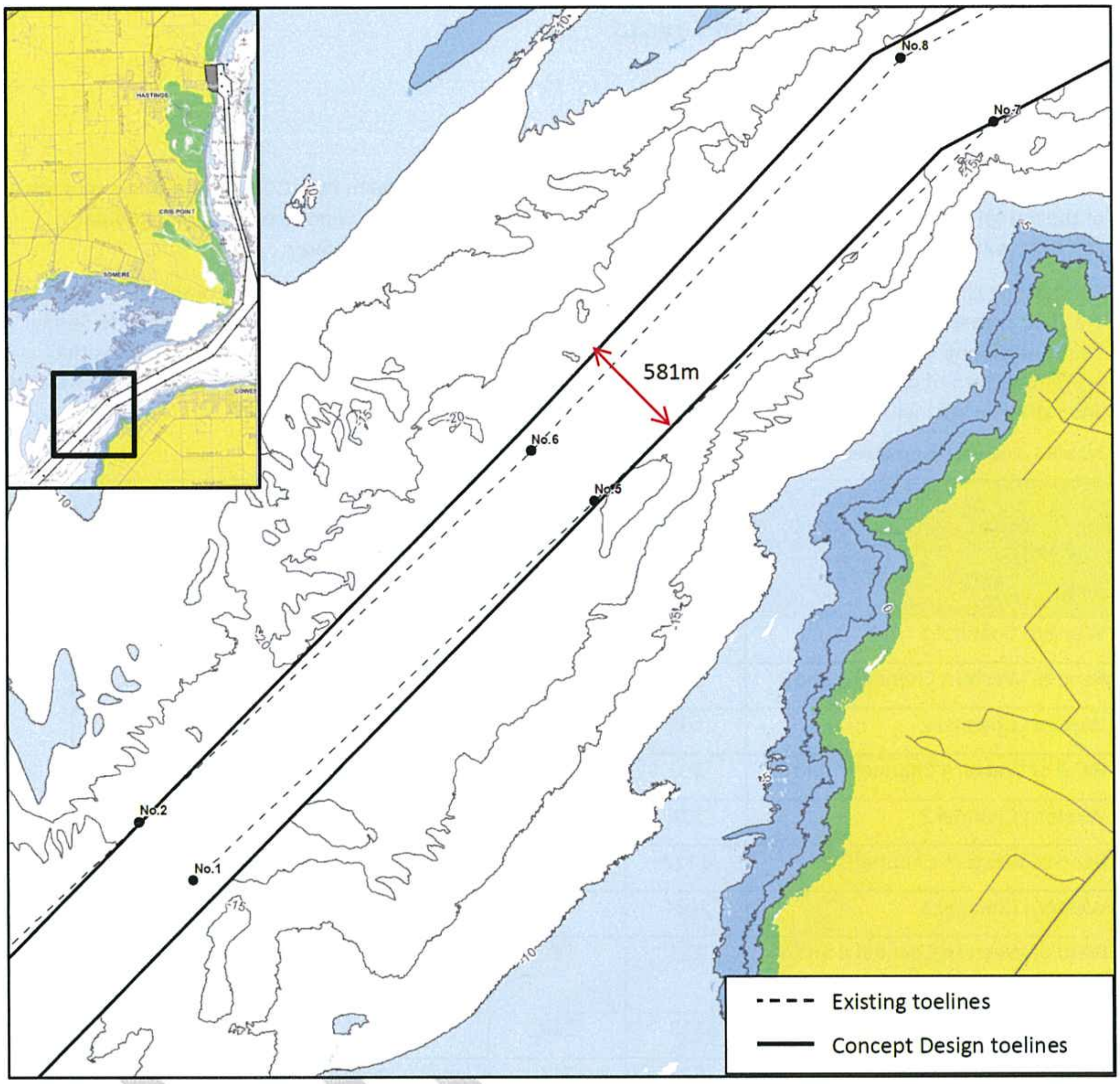

Figure 5-1. Western Channel 1 Alignment Concept Design

- At the entrance to the North Arm (the northern end of the Western Channel). At this location Beacon No. 19 has been moved eastward to accommodate the additional width. The eastern side was selected for adjustment because it is slightly deeper resulting in a lower dredge volume, however the operational impacts of this change will need to be confirmed in the simulation studies. The alignment is outlined Figure 5-2.

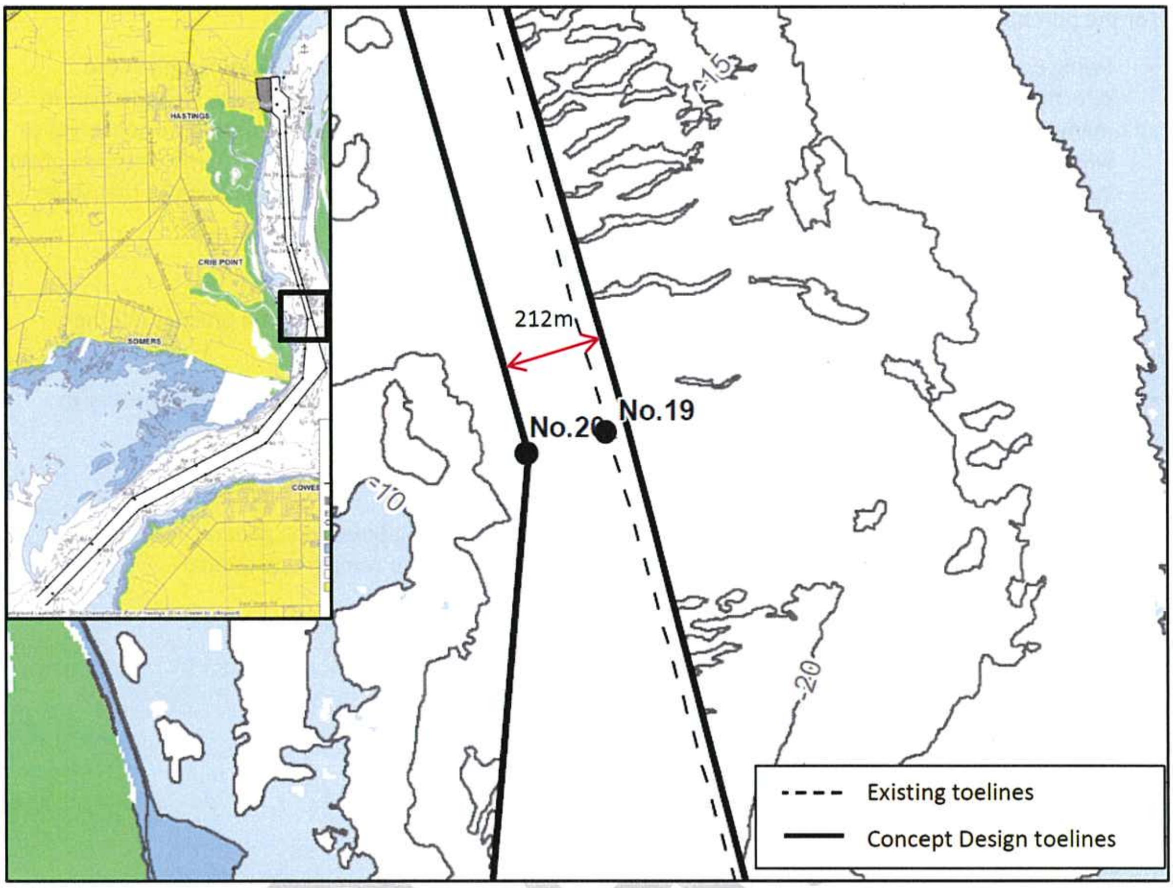

Figure 5-2. Entrance to the North Arm

5.1.2 Port Area

Within the port area two berth alignment options have been considered in the channel design. The rationale for the location and initial alignment of these options is outlined in AGH-CEPO-EG-MEM-0015 - Vessel Clearances and Safety Zones at LIP and AGH- CEPO-EG-MEM-0016 - Initial Berth Alignments and Terminal Footprint. The berth alignment options are:

- Along the Shore Option - berth line follows the general shape of the shoreline and bed level contours
- Basin Option - A basin is excavated in from the shore line with berths potentially located on both sides

Both alignments start at the same location which is 250m north of the centre point of the Long Island Point Jetty and are on the same alignment as the Long Island Point and BlueScope RoRo jetties.

The Stage 1 development is the same for both alignments and consists of 1,450m of berth length between the existing Long Island Point and BlueScope RoRo jetties. The Long Island Point Jetty and the BlueScope general purpose berth are to remain in operation while the BlueScope RoRo Jetty is to be demolished as part of the Stage 1 development. Refer to Figure 5-3.

The Along the Shore alignment is aligned with the existing Long Island Point Jetty and BlueScope RoRo wharf berth line over the first 2,200m. At this point the berth alignment changes by approximately 44 degrees to the east with a potential length of up to 3,000m which would bring the total berth length up to 5,200m. Refer to Figure 5-4.

The Basin alignment follows the same alignment as the Along the Shore alignment for the first 2,200m. At this point the berth alignment changes by approximately 46 degrees to the west and the length of the basin is 2,500m with an additional 800m of berths on the northern side of the basin. Refer to Figure 5-5.

For the port area the following dimensions have been considered:

- Swing Basin – PIANC 2014 recommends a width up to 2 x LOA and an additional vessel length in the direction of current flow. A width of less than 2 x LOA perpendicular to the current flow is used safely in many ports and this particular clause of the PIANC recommendations is generally considered conservative where there is a good tug fleet. A swing basin width of 1.75 x LOA has been adopted. In the direction of the current flow a width of 3 x LOA has been used for the concept design due to the unknowns at that stage about the impact of the current on the movement of vessels.
- Berth Pocket – a width of 2 x beam has been adopted
- Drag Area – a width of 282m (400m from the berth line) has been adopted based on practice in other ports.
- Basin – a width of 450m has been used based on a review of worldwide ports that cater for the design container vessel.

Figure 5-3 to Figure 5-5 show these dimensions on the Stage 1, Along the Shore and Basin alignments.

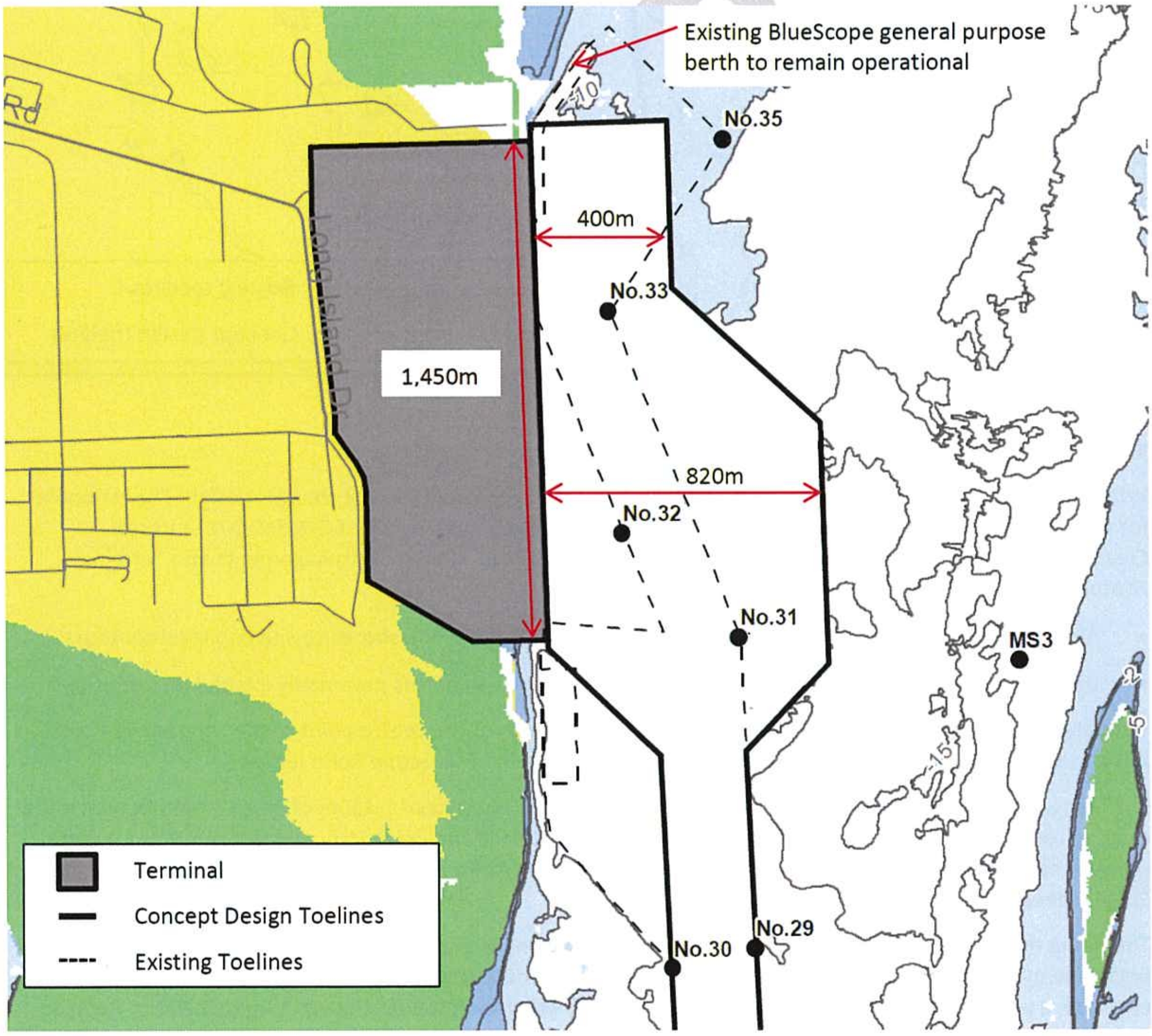

Figure 5-3. Concept Design Stage 1 Development Swing Basin Layout

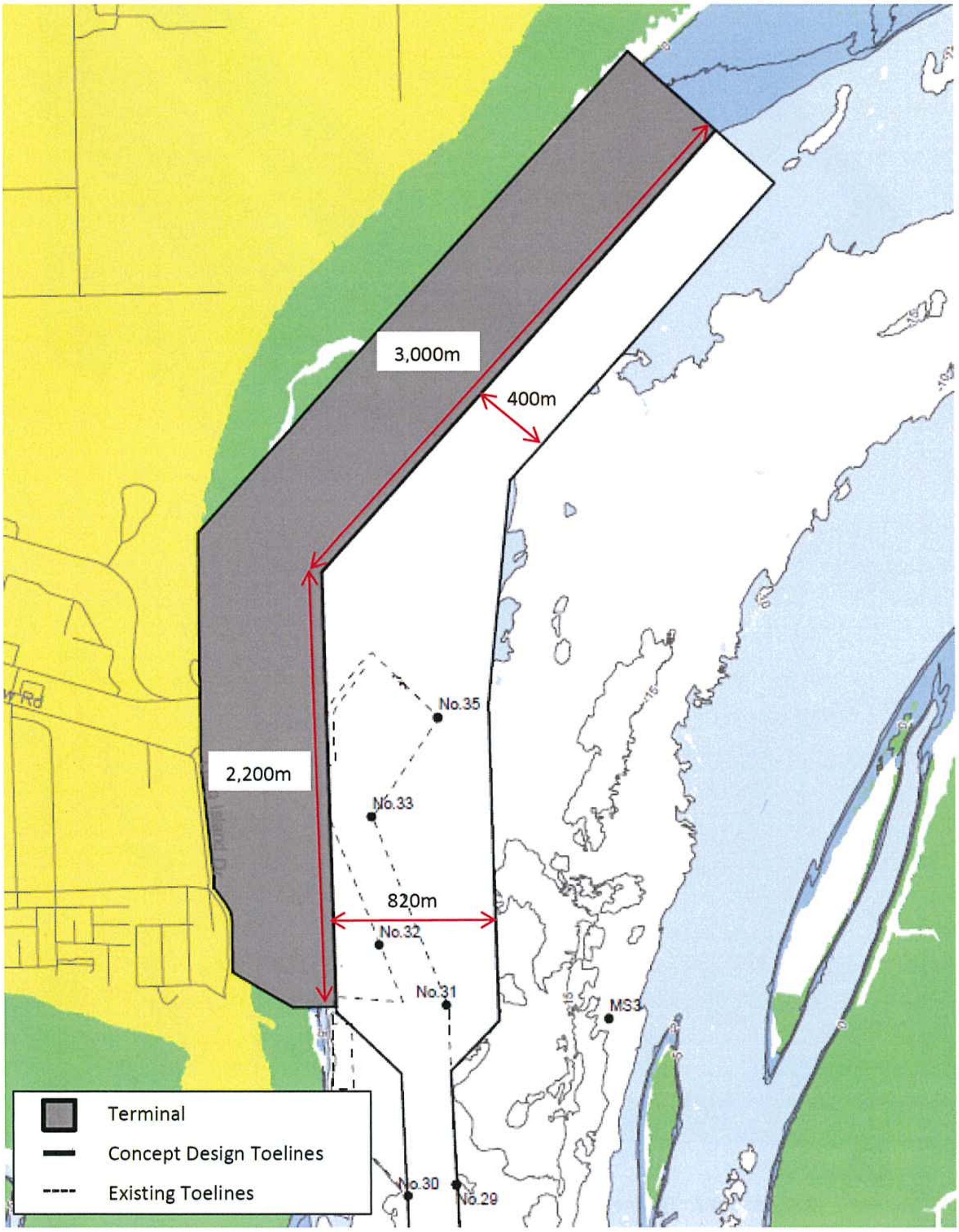

Figure 5-4. Concept Design Along the Shore Alignment Swing Basin Layout

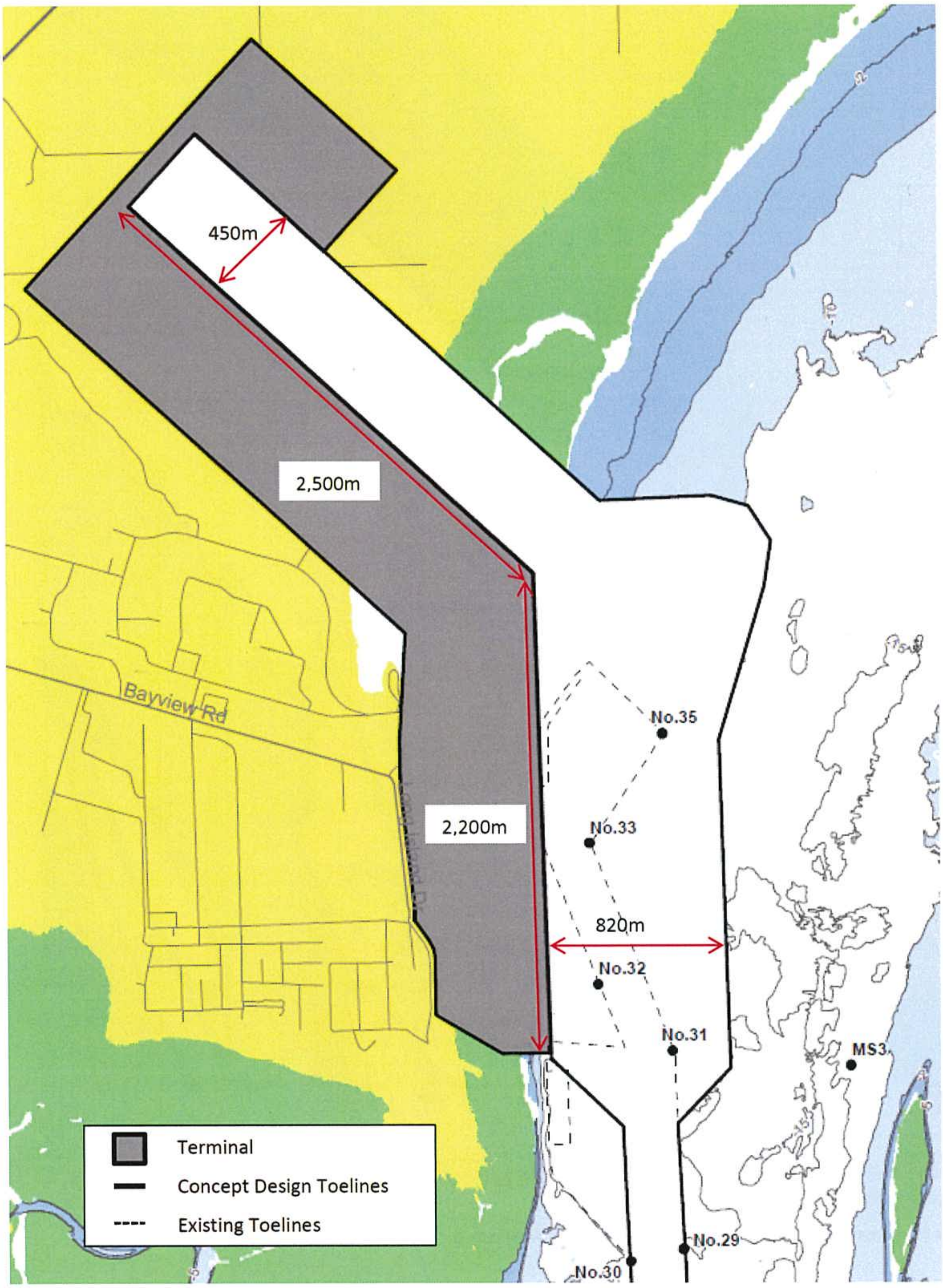

Figure 5-5. Concept Design Basin Alignment Swing Basin Layout

5.2 Pilot and Harbourmaster Discussions

Following the completion of the concept design a workshop was held with the Port of Hastings Harbourmaster and representatives from the Port Phillip Sea Pilots (PPSP). The Stage 1 and the Along the Shore Layouts were presented and the key outputs from this session were as follows:

- Points of difficulty when navigating the existing channel are:
  - McHaffie Reef can be a difficult turn on the ebb tide and an equipment failure could turn the vessel into the reef when inbound. The strong currents on the ebb tide produce a cross channel current pushing the ship out from the reef.
  - The turn at Sandy Point to enter the narrow section of the North Arm Channel.
- The different line of approach to the entrance to the approach channel along with the additional 2 degrees and repositioning of the first bend was not seen as an issue.
- The North Arm may potentially be too narrow for beam on winds such as easterlies.
- The length of the Stage 1 swing basin was considered to be too short, the pilots suggested that 1,200 to 1,500m would be required. The width appeared to be adequate.
- The navigation aids are adequate for the current port operations. Fog and rain are an issue occasionally and improved electronic navigation systems would assist. The pilots commented that buoys are not adequate for the expanded port.
- Existing facilities at Flinders are not adequate for the expanded port. Currently they have to take the boats away to a safer location in certain weather conditions. They would require a boat harbour, fuel supply and a similar facility to what exists at Point Lonsdale.
- At Port Phillip Heads the PSPP noted that there has never been an issue with not being able to board a vessel. The limitations are on breaking waves that restrict the launches from getting out to the vessel. Western Port does not have this issue.
- The harbourmaster would probably not allow anchorage of container vessels in the East Arm which is located between French and Phillip Islands, off Cowes, except in an emergency.

5.3 Navigation Simulations

5.3.1 Methodology

The real time navigation simulations were undertaken at HR Wallingford's facility in Fremantle. The simulation facility comprised wrap-around screens with a continuous visual angle of 280 degrees and a 42" TFT monitor for the astern view. A "look-around" facility is also incorporated that allows the pilots viewpoint to be moved from the centre of the bridge to either bridge wing and all around the ship. In addition, the pilot is able to look down the ship's side.

The simulations were undertaken by Captain Ian Simpson. Captain Simpson has considerable pilotage experience including bringing the first 400m LOA Container vessels into the Port of Felixstowe, United Kingdom. The Port of Felixstowe has some similarities to the Port of Hastings in that there is a run of tide along the face of the berths. The River Stour joins the River Orwell just opposite the main berths at Felixstowe, giving a complex pattern of tidal currents. Most vessels arriving at Felixstowe are turned in the current and then moved astern to reach their berths. Captain Simpson's experience therefore has direct relevance to Western Port.

Hydrodynamic data was prepared using a DELFT-3D model which has 2D (depth averaged) flow. The model comprised a 20m fine grid in the Port Area, North Arm and the Western Channel down to buoy No. 1 and 2. Beyond this the model comprises a 150m coarse grid that extends just past the port limits. A suitable tide period that closely matched a Spring Tide (i.e. levels of 2.84 m CD (MHWS) and 0.61 m CD (MLWS) (Cardno 2013)) was selected from the existing period of model validation (16/12/2012 to 16/01/2013).The closest 25 hour period of time to a Spring Tide was deemed to be the 19th December 2012 starting at 12:00 AM.

The hydrodynamics workstream are preparing an updated model with 3D flow validated through field measurements undertaken to date, however this was unavailable at the time of undertaking the simulations.

5.3.2 Vessels Characteristics for Simulation

The primary vessel for the real time simulations was the 400m (nominal length) LOA container vessel. The CSCL Globe model was chosen over the Maersk E Class model as it more closely represents the hull shape and fit out of the majority of the 400m LOA container vessels that are currently on order. For the bulk vessels a ship that closely represented the dimensions in Table 3-1 was selected.

The tugs used in the navigation simulations were centrally controlled. For the 400m LOA vessel, tugs with an 80 tonner bollard pull were used. For the existing layout the current tugs with a rated bollard pull capacity of 52 tonnes were downgraded to 40 tonnes as it is understood that they are not able to provide the rated capacity. The tugs were subject to realistic delays and loss of effectiveness due to speed and movement in waves.

Details of the vessels are outlined in Table 5-2 and further details are provided in the Real Time Navigation Simulation Report (AGH-CEPO-EG-REP-0022).

Table 5-2. Vessel Models

Vessel Name	LOA (m)	Beam (m)	Draught (m)	Comments
399m Container Ship	399	58.6	14.5	CSCL Globe verification model
250m Products Tanker	250	44	8.0	Ballast
250m Products Tanker	250	44	14.5	Laden
115,000 DWT Bulker	255	43	7.0 forward 8.0 aft	Ballast
115,000 DWT Bulker	255	43	13.2 forward 14.5 aft	Laden

5.3.3 Results

The following sections outline the results of the navigation simulation runs undertaken for each of the layouts that were assessed. Further details are provided in the Real Time Navigation Simulation Report (AGH-CEPO-EG-REP-0022)

5.3.3.1 Approach Channel

Table 5-3 outlines the summary of the findings from the runs undertaken in the approach channel. All runs were undertaken during the peak spring ebb or flood tide.

Table 5-3. Approach Channel Run Summary

Run	Direction & Transit	Current	Wind	Key Pilot Post Run Comments
01	IN - entire channel	Ebb	15knt Easterly	No issues in the Western Channel, the depth and width allows for speeds to be kept high. Entrance to North Arm (Buoy 19 and 20) is difficult, clearance to toelines about 20-30m.
02	IN – North Arm only	Ebb	30knt Westerly	Very difficult to assess the position of the vessel at the entrance to the North Arm (Buoy 19 and 20). Heading of vessel was always out of the channel in the North Arm with both buoys on the one side of the vessel.
03	IN – North Arm only	Flood	30knt Westerly	Entrance to North Arm (Buoy 19 and 20) was difficult.

Run	Direction & Transit	Current	Wind	Key Pilot Post Run Comments
04	IN – North Arm only	Flood	30knt Easterly	At the entrance to the North Arm (Buoy 19 and 20) the pilot tried to come through go past the buoys with the vessel parallel to the toelines and max clearance between buoys 19 and 20, however due to the tide the vessel drifted 10 degrees off the centrelines and he was relying on the instruments only.
05	IN – North Arm only	Ebb	30knt Easterly	Better than previous run but difficult to gauge what is having a bigger effect, wind or current. Once past buoy 19 and 20 at the entrance to the North Arm aimed for buoy 21 but went too far in order compensate for the wind and ended up close to buoy 22. Straight forward up North Arm 2 but still having to do regular changes to maintain course.
07	OUT – entire channel	Ebb	30knt Westerly	A cross current component was evident past McHaffie reef but the vessel speed and width of the channel meant that for these vessels this is not an issue. Went slow ahead though North Arm 2 as he was worried about having too much speed at the corner to North Arm 1. In the North Arm the difficulty is that the sligt lines are always out of the channel and the pilot has no visual reference that he is in the channel. Additional buoys will not necessarily help.

5.3.3.2 Stage 1 Layout

Table 5-4 outlines the summary of the findings from the runs undertaken from the end of the approach channel to and from the berth for the Stage 1 layout. All runs were undertaken during the peak spring ebb or flood tide unless otherwise noted.

Table 5-4. Stage 1 Layout Run Summary

Run	Direction	Current	Wind	Key Comments/Findings
01	IN	Ebb	15knt Easterly	No issues with the swing manoeuvre.
02	IN	Ebb	30knt Westerly	The speed passing through the end of the narrow channel influences where the swing basin occurs. To successfully transit past buoys 31 and 32 the pilot needed to maintain speed and was not able to initiate the turn until he had successfully passed these buoys. This and the direction of the current was why the turn was so high up in the swing basin. The vessel did not get to within 100m of the toelines between buoys 33 and 35 and the toelines between buoys 35 and 37.
03	IN	Flood	30knt Westerly	The pilot only stopped the engine to reduce the speed when he was satisfied that he could successfully enter into the swing basin. However the length of the swing basin was adequate despite the flood tide making it more difficult to slow the vessel down. The vessel did not get to within 150m of the toelines between buoys 33 and 35 and was about 100m from the toelines between buoys 35 and 37.

Run	Direction	Current	Wind	Key Comments/Findings
04	IN	Flood	30knt Easterly	When entering the swing basin the pilot had to straighten up the vessel to miss buoy 32. This resulted in the vessel being in a worse position for the swing and very close to the berth (approx. 75m form the berth) during the swing. Without buoy 32 the stern could have been pushed out earlier and the swing would have been undertaken in a more central position. When the vessel was close to the berth the pilot was solely focused on moving it away from the berth and essentially stopped the swing.
05	IN	Ebb	30knt Easterly	No issues with the swing manoeuvre, however the pilot noted that three tugs would be required for berthing. The vessel did not get to within 150m of the toelines between buoys 33 and 35.
06	IN	Flood	30knt South westerly	Entered basin under control and swung to starboard because the pilot was unsure that he would have full control going in the other direction, however next time he would consider going bow into the berth. When backing up the current got on the wrong side (on the starboard side of the bow) and then to get control again he had to force the vessel around by having a tug on the bow with a bow thruster and then to put the ship engine ahead to keep away from the toelines between buoys 35 and 37. The vessel did not get to within 150m of the toelines between buoys 33 and 35.
07	OUT	Ebb	30knt Westerly	Entering the channel at buoys 31 and 32 was problematic. As soon as the pilot could see the buoy on the starboard he increased the speed to provide more control.

5.3.3.3 Along the Shore Layout

Table 5-5 outlines the summary of the findings from the runs undertaken from the end of the approach channel to and from the berth for the Along the Shore layout. All runs were undertaken during the peak spring ebb tide.

Table 5-5. Stage 1 Layout Run Summary

Run	Direction	Current	Wind	Key Comments/Findings
08	IN	Ebb	30knts Northerly	No issues. The pilot swung the vessel at buoy 35 and backed the vessel up away from the toeline between buoys 35 and 37 in order to assess if it was possible to assess the drag back area. The drag back area width was considered adequate. Clearance at the swing position to the toelines was 163m.
26	IN	Ebb	30knts Northwesterly	It was not possible to hold the vessel against this combination of tide and wind with three tugs which resulted in the vessel crossing the toelines at buoy 37.

5.3.3.4 Basin Layout

Table 5-6 outlines the summary of the findings from the runs undertaken from the end of the approach channel to and from the berth for the Basin layout. All runs were undertaken during the peak spring ebb or flood tide unless otherwise noted.

Table 5-6. Basin Layout Run Summary

Run	Direction	Current	Wind	Key Comments/Findings
09	IN	Ebb	10knt Northerly	No issues with the swing manoeuvre, adequate space and the area east of buoy 33 was not used. Vessel navigates stern first through the basin keep safe distances from the berth and training wall
10	IN	Ebb	30knt Northerly	Swing effected with adequate clearances. The stern first manoeuvre up the basin required more tug power in these conditions.
11	OUT	Ebb	30knt Northerly	Vessels successfully transited straight out of the basin without stopping to swing. Minimum clearance to the berth was 120m. Vessel entered the channel at buoy 30 under control but at high speed and it was difficult to control the speed in these conditions.
12	OUT	Flood	30knt South westerly	Vessels successfully transited straight out of the basin without stopping to swing. Minimum clearance to the berth was 100m. Stern tug used to control speed, however ground speeds was 6.5 knots when entering the channel.
13	IN	Flood	30knt South westerly	Swung the vessel further south due to the environmental conditions and the pilot was successfully able to position the vessel stern first for the transit up the basin with a minimum clearance of 120m from the berth.
14	OUT	Flood	30knt South westerly	Stern first exists from the basin. The swing manoeuvre was initiated too soon and as a result the vessels got to within 30m of buoy 39. More effective use of the available area is expected to give a better outcome.
15	IN	Ebb	30knt Northerly	Vessel swung and berthed about halfway along the southern berths. No problems identified on the ebb tide.
16	IN	Flood	30knt South westerly	Bulk vessel inbound swung at the entrance to the basin and transited stern first into the basin. Manoeuvre completed successfully maintain adequate clearance to port infrastructure.
17	OUT	Flood	30knt North Westerly	Bulk vessel outbound stern first out of the basin and swung successfully swung while maintaining adequate clearance to port infrastructure.
23	OUT	Ebb	30knt Northerly	Alternative strategy to that used in run 11 for the same conditions. The vessel speed was reduced when existing the basin with lateral control maintained by the tugs. swing completed successfully, however it was difficult to keep the speed low when entering the channel and the vessel was within 33m of buoy 29.

5.3.3.5 *Existing Operations at Long Island Point Jetty*

Table 5-7 outlines the summary of the findings from the runs undertaken to and from the Long Island Point Jetty. The runs where undertaken during a state of tide which was to replicate the current operations. Buoy 32 is considered to be a virtual navigation marker for container vessels only and was ignored for these runs.

Table 5-7. Long Island Point Jetty Run Summary

Run	Direction	Current	Wind	Key Comments/Findings
24	IN	Ebb	25knt Northwesterly	Routine berthing manoeuvre
25	OUT	Flood	25knt Southwesterly	This state of the tide is possibly the issue that the pilots have reported at this berth in that there is a flood current about 1-2 beams off the berth which reduces to nothing at the berth

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Run	Direction	Current	Wind	Key Comments/Findings
				and the ebb slowly moves out from the berth while there is still a flood tide in the middle of the swing area. Routine unberthing manoeuvre

5.3.4 Findings

The key findings from the navigation simulations are that the both the Along the Shore and Basin alignment options are feasible and that the width of the North Arm 1 (between buoys 19/20 and 23/24) needs to be increased. Furthermore a number of opportunities to reduce the width of the swing basin on all layouts have been identified. The findings from the navigation simulations undertaken are as follows:

- Approach Channel;
  - The Western Channel was found to be adequate, although two-way transits were not assessed
  - The bend east of Sandy Point was found to be adequate
  - The width of the North Arm 1 (212m between buoys 19/20 and 23/24) was found not to be adequate, however the width of the North Arm 2 (250m between buoys 23/24 and 29/30 was found to be adequate.
  - The deflection of the channel at buoy 23/24 is a significant navigational feature and consideration should be given to widening the channel and/or easing the bend in this area.
  - An additional set of lateral navigation marks was recommended for the North Arm 2 (between buoys 23/24 and 29/30).
  - The width of the channel at the entrance to the swing basin at 31/32 is inadequate. Widening the entrance to the swing basin will allow the vessel to slow down earlier while maintaining control. The vessel speeds in the navigation simulation past Long Island Point and on the entry to the swing basin were considered to be too high.
- Stage 1 Development Swing Basin;
  - The length of the swing basin is adequate
  - The width of the swing basin could be reduced as the closest a vessel was to the eastern toelines was approximately 100m.
  - The drag back area is adequate for vessels to manoeuvre stern-first.
- Along the Shore Alignment Swing Basin;
  - The manoeuvring area at the change in direction of the berths is more than adequate and the width could be reduced.
  - The drag back area is adequate for vessels to manoeuvre stern-first.
- Basin Alignment Swing Basin;
  - The manoeuvring area at the entrance of the basin is more than adequate and width could be reduced for both the Basin Short and Basin Long layouts. On the Basin Long layout the training wall does not adversely impact on the manoeuvres at the entrance to the basin or the southern berths.
  - The width of the basin is adequate for the entrance of vessels stern-first into the basin and the exit of vessels either stern or bow first from the basin.

One of the runs on the Along the Shore layout identified a scenario where the wind and current conditions were too strong to be safely controlled with the use of three 80 tonne tugs. This may result in some 30 knot wind conditions where either four tugs may be required or berthing/unberthing activities restricted.

Normally the PIANC 2014 guidelines are considered conservative but it is clear that in this case with a very large container ship operating in very strong cross winds, additional channel width is required because of the amount of lateral drift experienced. It is understood that PIANC are considering a revision to the guidelines to take account of these conditions.

The simulations were undertaken over a period of five days under a range of environmental conditions for a range of layouts and all simulations where undertaken using the same pilot. Typically this involved one run for each scenario and to be able to confirm the channel dimensions, multiple runs with different pilots would need to be undertaken. Additionally the simulations did not consider high swell conditions or poor visibility due to night or fog conditions. Notwithstanding the above there are a number of recommendations from these simulations which can be used to develop a preliminary design.

5.4 Preliminary Design

5.4.1 Approach Channel

Following the real time vessel navigation simulations and based on the findings outlined in Section 5.3.4 the following changes have been made to the approach channel layout.

- The width of North Arm 1 between buoys 19/20 and 23/24 has been increased to the same width as North Arm 2 (250m)
- The angle into and out of North Arm 1 has been reduced by 2 degrees by keeping buoy 19 and 24 in the same place and moving buoys 20 and 23 to achieve the required width.
- The angle between North Arm 1 and 2 (at buoys 23/24) has been further reduced by straightening the toelines between buoys 23 and 25, and 24 and 26.

These changes are outlined in Figure 5-6 and the preliminary design channel alignment plans are included in Appendix B.

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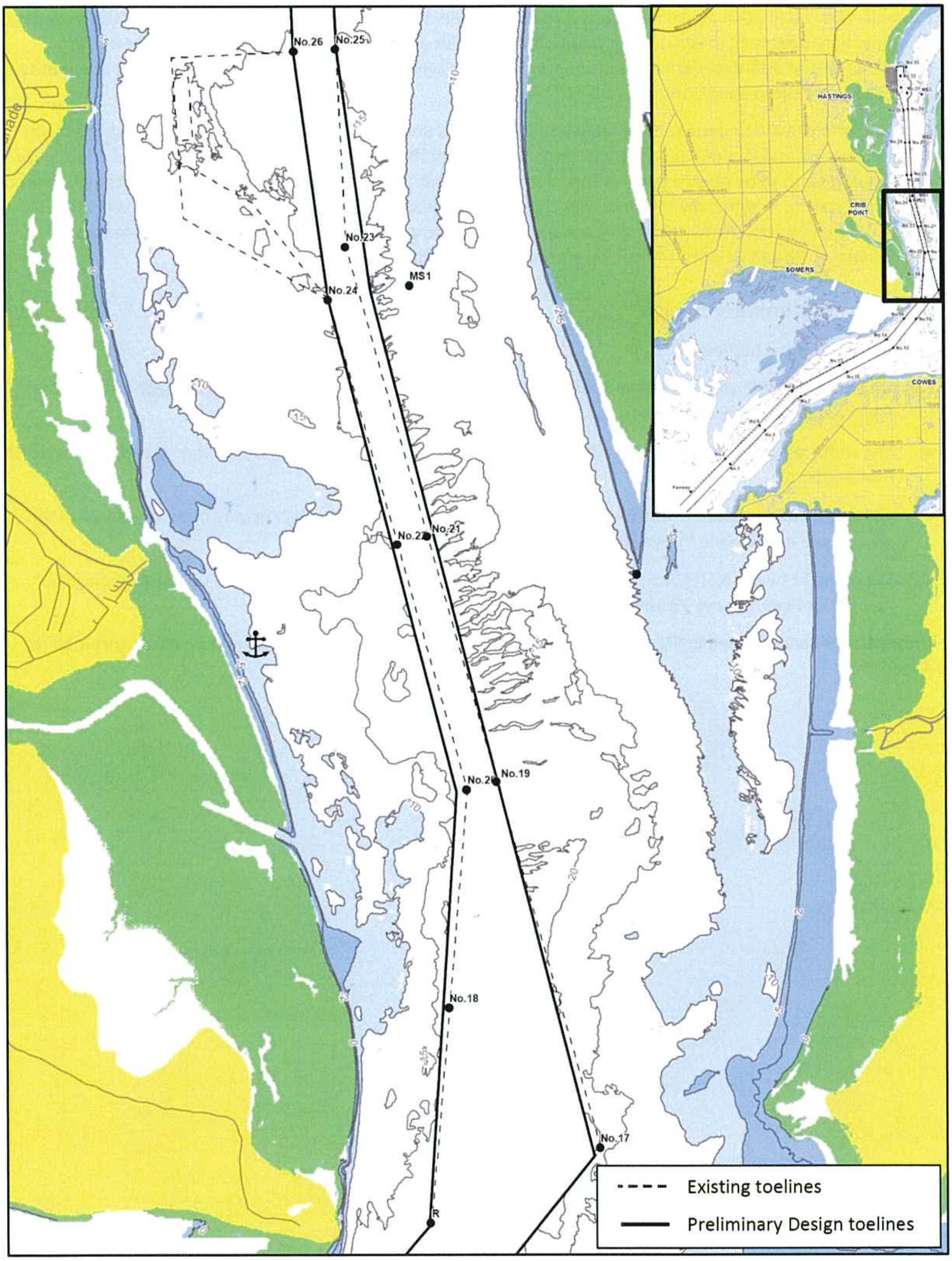

Figure 5-6. North Arm Preliminary Design

5.4.2 Port Area

Following the real time vessel navigation simulations and based on the findings outlined in Section 5.3.4 the following changes have been made to the port area layouts.

- All Layouts
  - Buoy 32 (virtual marker due to the presence of the adjacent Long Island Point Jetty) has been removed and the toeline from buoy 30 runs up to a point that is 30m south and 100m east of the southernmost end of the berths. This location has been chosen so that the toeline does not extend through the berth pocket for the Long Island Point Jetty. Refer to Figure 5-7 to Figure 5-9.
  - The berth pocket width has been reduced to 1.5 times the vessel beam.
- Stage 1 Development Swing Basin
  - Reduced the width of the swing basin by 40m in order to maintain a beam width (60m) gap between the vessel and the toelines based on the vessel track plots for the navigation simulations. Refer to Figure 5-7.
- Along the Shore Alignment Swing Basin
  - The reduction in the width of the Stage 1 Development swing basin by 40m has been extended up to the start of the drag back area which has resulted in the corner between the swing basins along the southern berths and the drag back area moving by 270m to the southwest. Refer to Figure 5-8.
- Basin Alignment Swing Basin
  - The reduction in the width of the Stage 1 Development swing basin by 40m has been extended up to the toeline at the edge of the swing basin at the entrance to the basin. Refer to Figure 5-9.

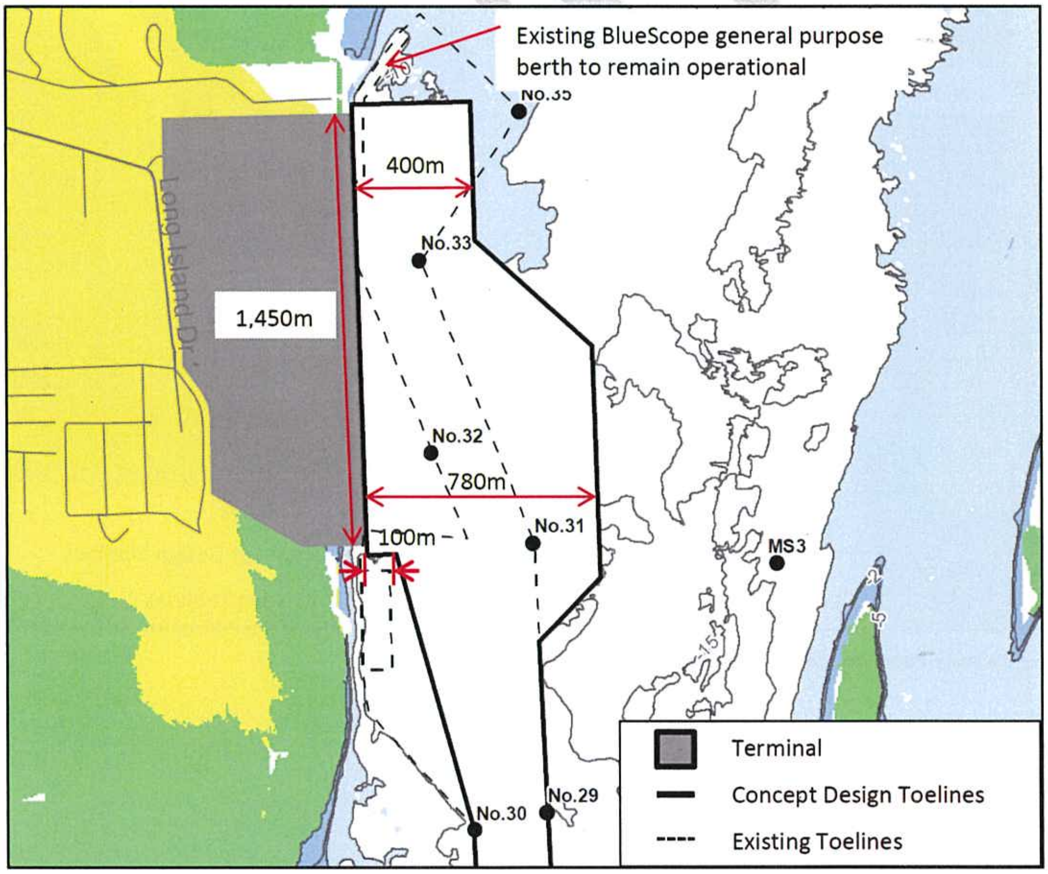

Figure 5-7. Stage 1 Development Preliminary Design Swing Basin Alignment

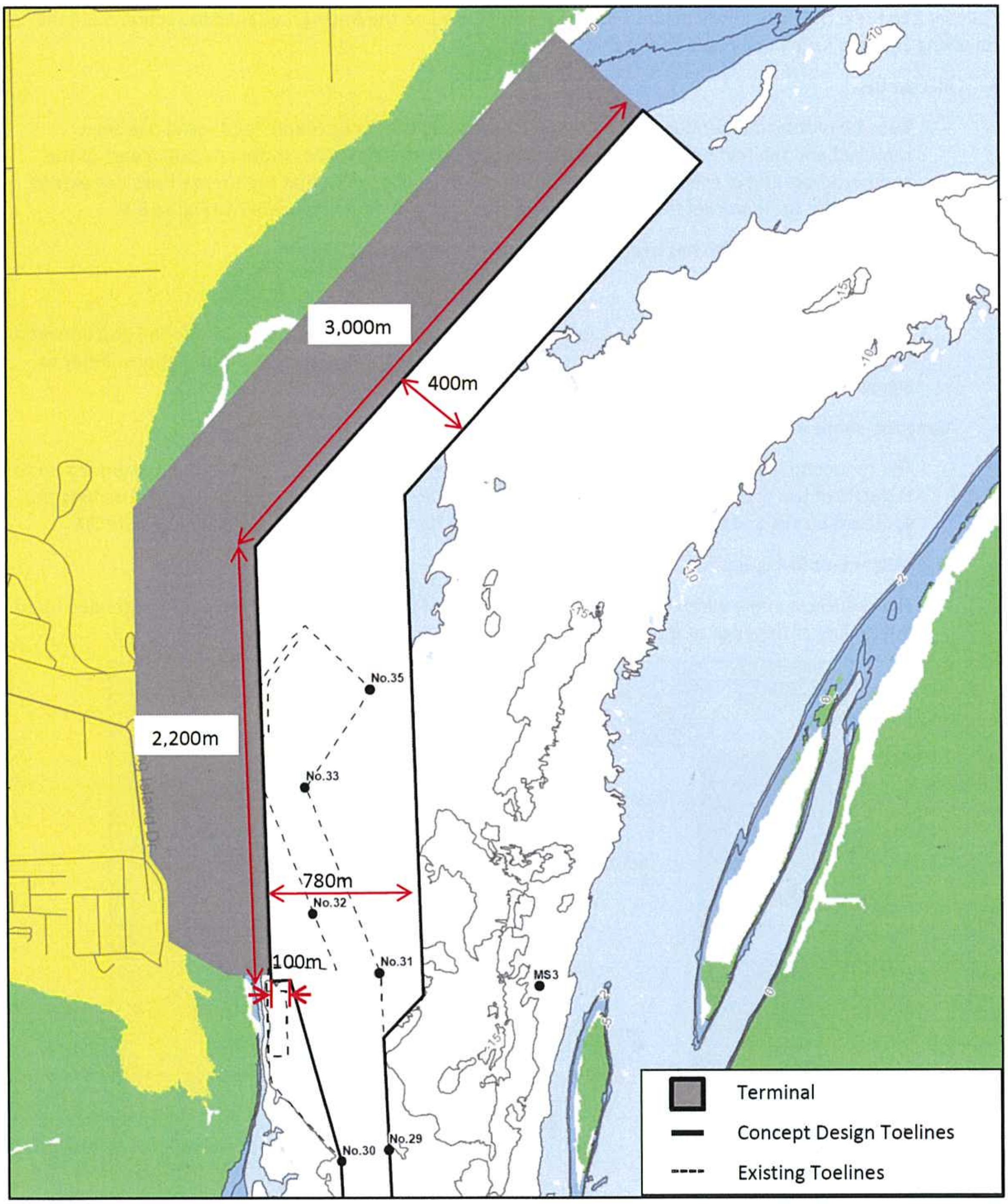

Figure 5-8. Along the Shore Preliminary Design Swing Basin Alignment

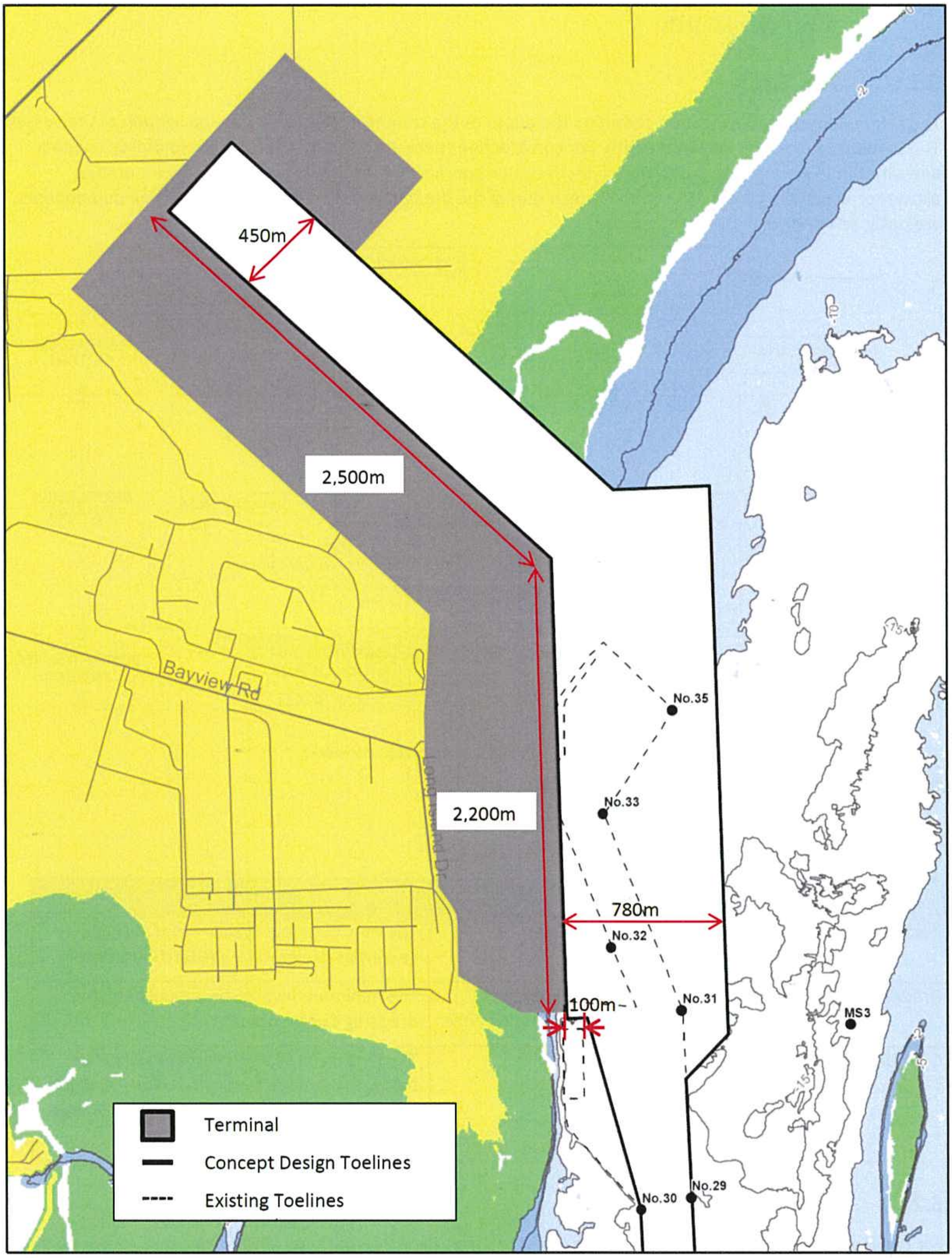

Figure 5-9. Basin Preliminary Design Swing Basin Alignment

6.0 Channel Depth

6.1 Key Terms

The channel design for navigation considers the depth of the channel required for safe navigation of the vessel. This is referred to as the declared depth. For construction there are additional factors for sounding accuracy and siltation to ensure that the declared depth can be guaranteed. Additionally there is an over dredge allowance which the contractor cannot exceed during the dredging works. These terms and their components are outlined in Figure 6-1 and Table 6-1.

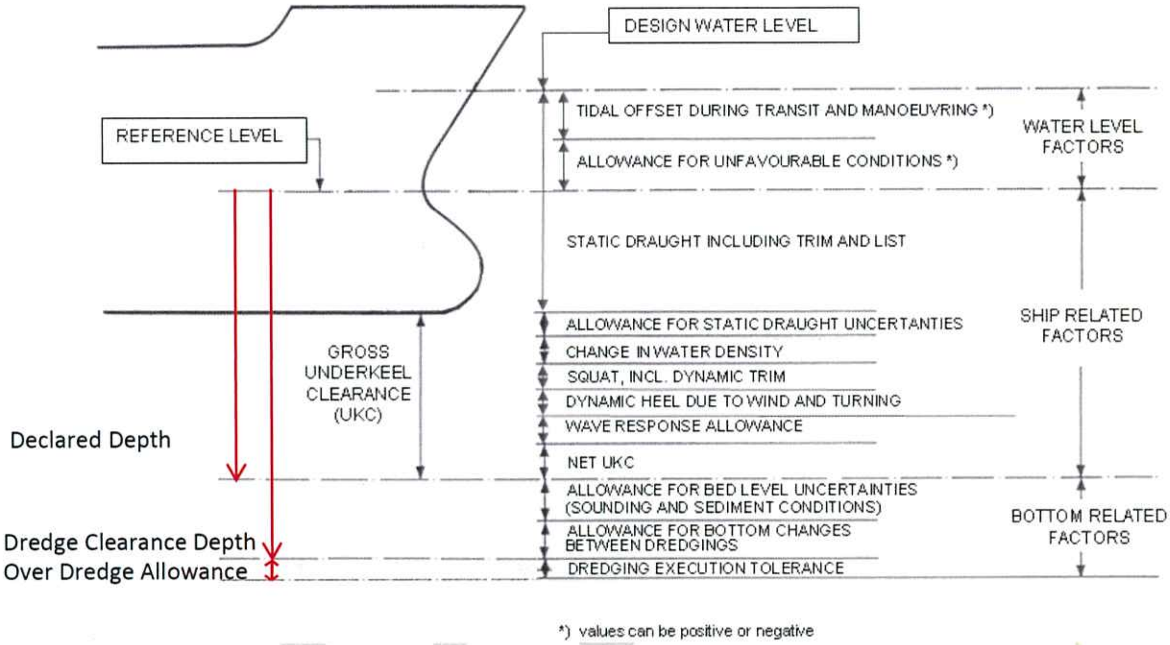

Figure 6-1. Channel Depth Factors (modified from PIANC 2014, Figure 2.1)

Table 6-1. Key Terms

Key Terms	Components	Definition
Declared Depth	Vessel Draught + UKC	The minimum level guaranteed available to vessels as declared by the Harbourmaster
Dredge Clearance Depth	Declared Depth + Survey Allowance + Siltation Allowance	The minimum level to be achieved by the dredging Contractor
Over Dredge Allowance	Over Dredge Allowance	The maximum allowed vertical allowance below the Dredge Clearance Depth available to the Contractor to ensure that the Dredge Clearance Depth is achieved.

6.2 Concept Design

For concept design the initial UKC modelling undertaken by OMC international (OMC) was used rather than the PIANC 2014 concept design method as the PIANC approach is known to provide very conservative design depths.

The concept OMC modelling was based on 30 days of metocean information and a transit speed through the water of 16 knots for container vessels and 12 knots for tankers. The UKC depths were chosen based on 95%

channel accessibility at LAT. An additional scenario has been developed to consider the design vessel sailing at Mean Low Water Neaps (MLWN) which is at +1.06mCD.

A survey tolerance of 0.25m and an over dredge allowance of 0.5m were allowed based on preliminary advice from Hadyn Pike of Baggerman Associates (Dredge Material Management workstream). No allowances were made for siltation in the channel based on preliminary advice at the time from the Hydrodynamics workstream. A 0.3m siltation allowance was included for the port area.

For the 400m LOA container vessel a design draught of 14.5m at LAT and MLWN was assumed and the associated levels are outlined in Table 6-2.

Table 6-2. Concept Channel Depths for the 400m LOA container vessel

Segment	WC1	WC2	WC3	WC4	NA1	NA2	Swing Basin
Buoy Reference	1 & 2 to 7 & 8	7 & 8 to 13 & 14	13 & 14 to 17 & R	17 & R to 19 & 20	19 & 20 to 23 & 24	23 & 24 to 29 & 30	-
Static Draught (m)	14.5	14.5	14.5	14.5	14.5	14.5	14.5
UKC (m)	2.5	2	1.5	1.5	1.5	1.5	1.1
Declared Depth Level for a sailing draught of 14.5m at LAT (mCD)	**-17.0**	**-16.5**	**-16.0**	**-16.0**	**-16.0**	**-16.0**	**-15.6**
Declared Depth Level for a sailing draught of 14.5m at MLWN (mCD)	**-16.0**	**-15.5**	**-15.0**	**-15.0**	**-15.0**	**-15.0**	**-14.6**
Survey Tolerance (m)	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Siltation Allowance (m)	0	0	0	0	0	0	0.3
Dredge Clearance Level for a sailing draught of 14.5m at LAT (mCD)	**-17.3**	**-16.8**	**-16.3**	**-16.3**	**-16.3**	**-16.3**	**-16.2**
Dredge Clearance Level for a sailing draught of 14.5m at MLWN (mCD)	**-16.3**	**-15.8**	**-15.3**	**-15.3**	**-15.3**	**-15.3**	**-15.2**
Construction/Over Dredge (m)	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Over Dredge Depth for a sailing draught of 14.5m at LAT (mCD)	**-17.8**	**-17.3**	**-16.8**	**-16.8**	**-16.8**	**-16.8**	**-16.7**
Over Dredge Depth for a sailing draught of 14.5m at MLWN (mCD)	**-16.8**	**-16.3**	**-15.8**	**-15.8**	**-15.8**	**-15.8**	**-15.7**

6.3 Preliminary Design

6.3.1 Methodology

6.3.1.1 Underkeel Clearance

The required depth (vessel draught plus UKC) has been calculated for a years' worth of hydrodynamic and wind data at 33 locations (MP01-33 on Figure 6-3) along the channel for the scenarios outlined in Table 6-3. The UKC includes squat, wave response, inertial heel, wind heel and uses a water density of 1,025kg/m^3. The UKC calculations are based on satisfying either a bottom clearance of 0.25m where the wave response is greater than 0.65m (i.e. static draught + squat + inertia heel + wind heel + wave response + 0.25m) or a manoeuvrability margin of 0.9m (i.e. static draught + squat + inertia heel + wind heel + 0.9m).

The UKC analysis has been based on the model outputs from a years' worth of historical data as outlined in the report prepared by the Hydrodynamic workstream (HAS-CEPO-HY-REP-0012-A). The tide data is based on

historical records and includes tide residuals. This analysis was undertaken for the draughts and transit ground speeds outlined in Table 6-3, Figure 6-4 and Figure 6-5.

Figure 6-2 is a channel profile from the UKC Vessel Analysis Report (AGH-CEPO-EG-REP-0023) showing the required depth (draught plus UKC, excluding wind heel) for various accessibility levels for the 400m LOA, 59m beam, 14m draught Container vessel in the fast transit speed scenario. The red dots indicate the existing bed level at each of the UKC calculation points and provide an indication of where dredging could be required. In the outer parts of the channel (between the pilot boarding ground and halfway between the fairway buoy and the start of Western Channel 1) there is a significant difference in the required depth between the inbound and outbound transits. This is due to both the slightly faster transit speed in the outbound direction and the angle of incidence of the waves against vessel.

At the end of Western Channel 1 and the start of Western Channel 2 the inbound transit depth requirements are again much higher than the outbound transit depths. The vessel speed is the same at this point for both directions and it is the angle of incidence of the waves against the vessel on the inbound transits that results in a higher wave response. Beyond this point the different inbound and outbound depth requirements are largely due to the different vessel transit speeds.

Further information about the methodology and outputs are outlined in the UKC Vessel Analysis Report (AGH-CEPO-EG-REP-0023).

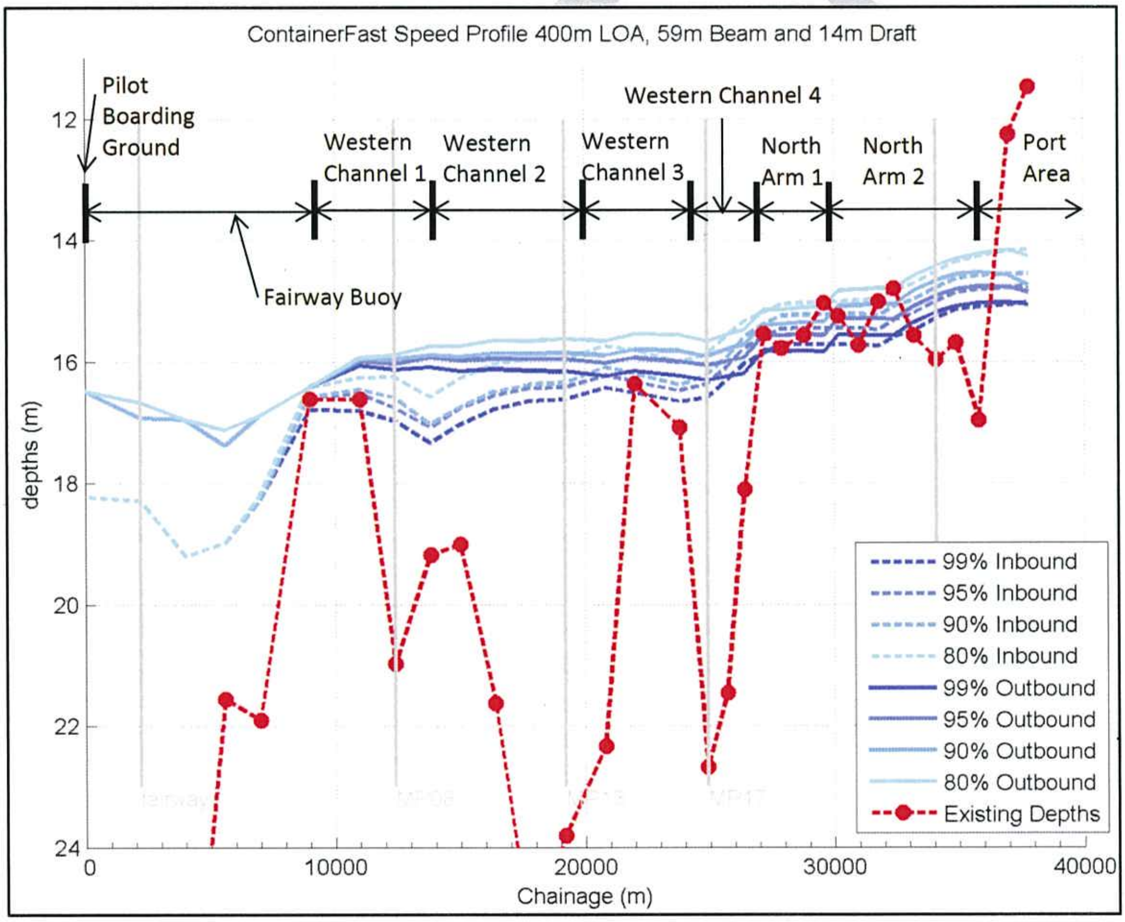

Figure 6-2. Channel profiles for Various Accessibilities – 400m LOA, 59m beam, 14m draught Container vessel, Fast Transit Speed Scenario

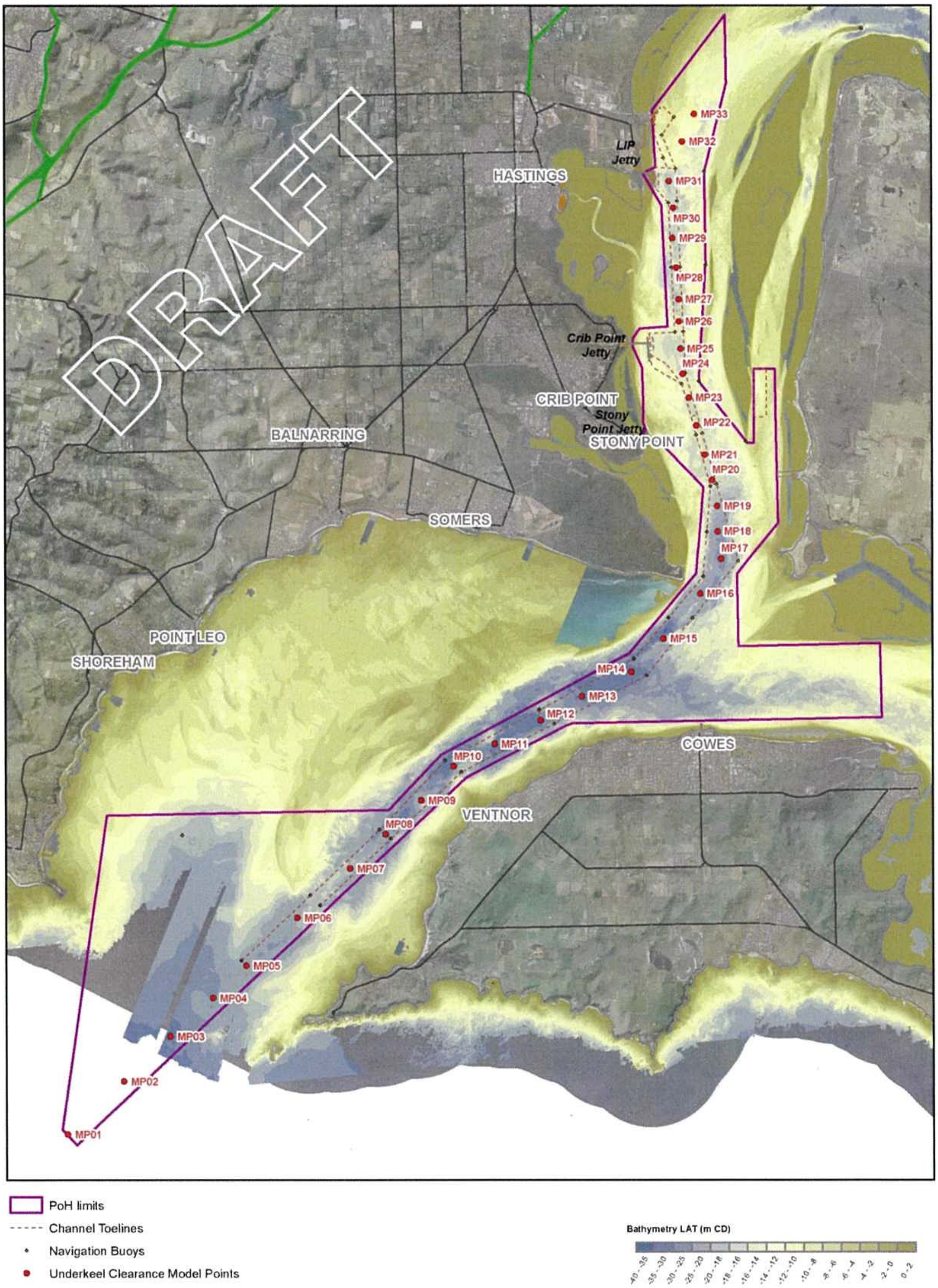

Figure 6-3. UKC Calculation Points

Table 6-3. UKC Scenarios

Scenario No.	Vessel	Draught (m)	Transit Speed Scenario (refer to Figure 6-4 and Figure 6-5)
1	300m LOA, 42.9m Beam Container Vessel	12	Container Fast
2		13	
3		14	
4		12	Container Slow
5		13	
6		14	
7	400m LOA, 59m Beam Container Vessel	14	Container Fast
8		15	
9		16	
10		14	Container Slow
11		15	
12		16	
13	115,000 DWT Afromax Crude Oil Tanker (250m LOA, 44m Beam)	14	Tanker
14		15	
15		16	

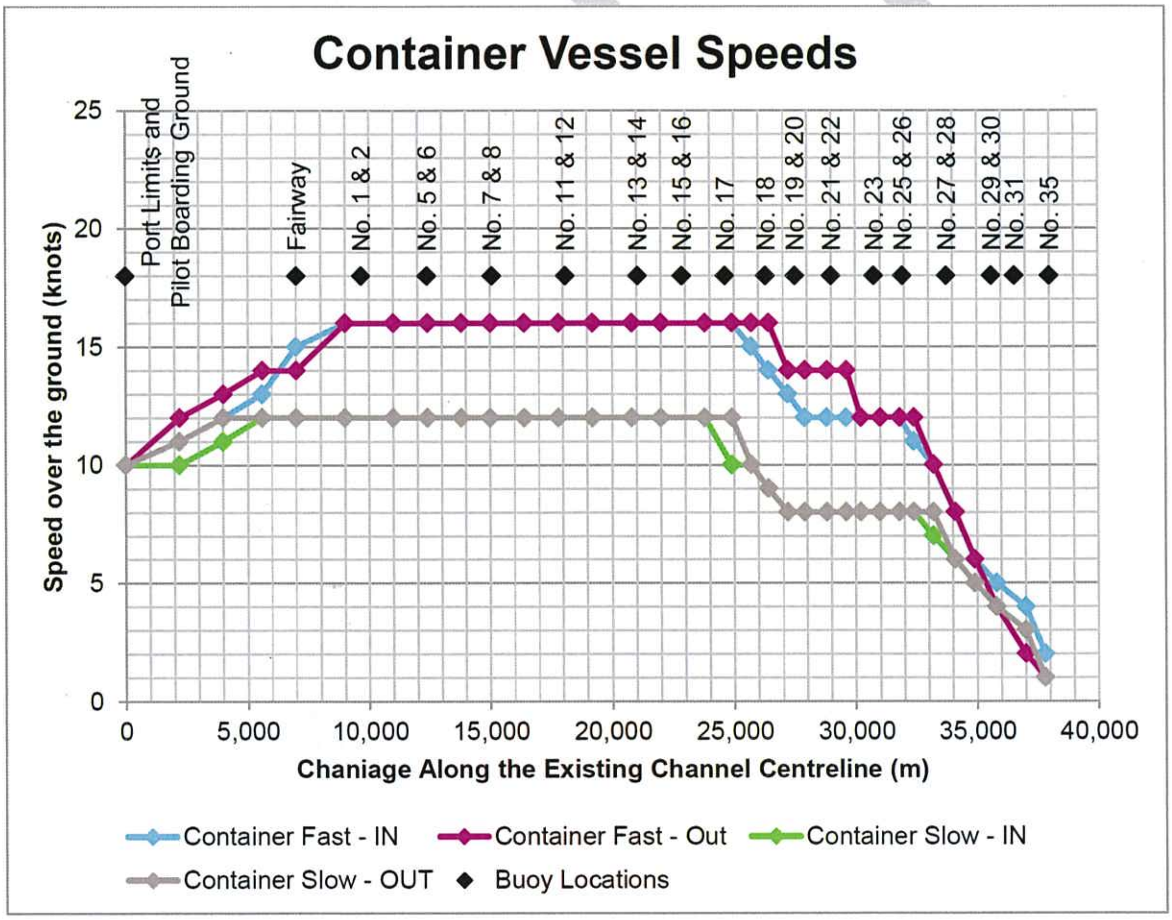

Figure 6-4. Container Transit Speed Scenarios

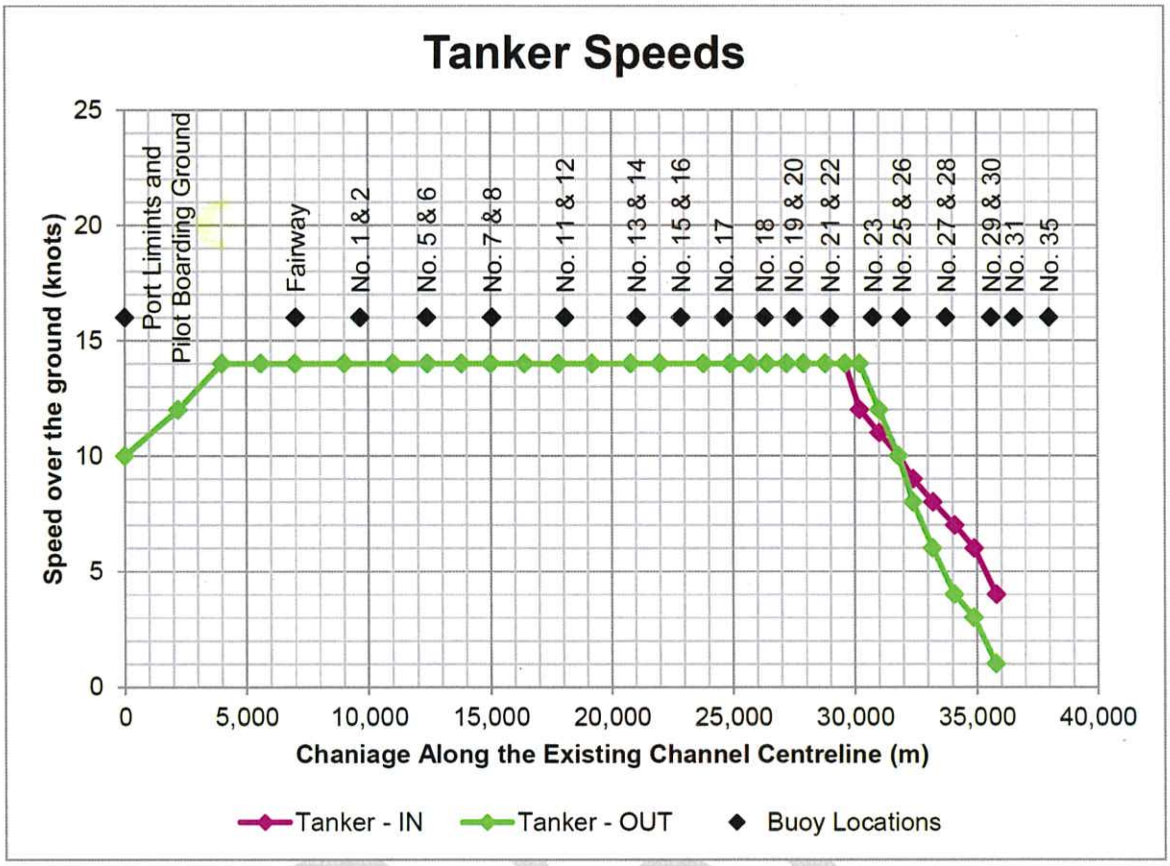

Figure 6-5. Tanker Transit Speed Scenarios

The wind heel calculations are based on wind data from the same period as the hydrodynamic data used by OMC International and have been added to OMC International's results. On average the wind heel contributed about 20mm to the overall required depth, although in high winds with winds perpendicular to the side of the vessel this increased to 300-400mm. A limit of 30 knots was set for when the channel would be closed as outlined in Section 4.2.1. A 30 knot wind speed was only recorded once in the data set (hourly winds over a year). There are two issues with the approach undertaken, these are:

- The wind speeds are taken from Stony Point and infilled with data from Cerberus. The pilots have reported that the winds in the channel are higher than the wind measurements from these stations. This is considered to be due to the shielding from the west to south-westerly winds at these locations.
- The angle of the wind against the side of the vessel does not account for any vessel drift angle in the channel. The navigation simulations identified that this could be as much as 10 degrees from the heading of the channel. If the angle between the vessel and the wind increases the amount of wind heel increases.

A sensitivity analysis was undertaken and it was found that a 50% increase in the wind speeds would essentially double the wind heel. A 10 degree increase in the angle of the wind against the side of the vessel would increase the wind heel by 5-18% depending on the channel segment. As it is currently not known what increase in the wind speed should be used, a 25% increase has been assumed. For the angle of the wind against the side of the vessel a 10 degree increase has been used. These increases result in an average increase of between 62-81% or 12-14mm as outlined in Table 6-4.

Table 6-4. Wind Heel Sensitivity Analysis

Case	Increase in Wind	Increase in Angle of Wind Against the Vessel (deg)	Average wind heel (m and % over base case) over the course of a year					
			WC1	WC2	WC3	WC4	NA1	NA2
Base	0	0	0.021	0.023	0.020	0.015	0.015	0.015
Angle of Wind Only	0	10	0.023	0.024	0.022	0.018	0.017	0.018
			7%	5%	8%	17%	18%	17%
Wind Speed Only	50%	0	0.041	0.045	0.039	0.031	0.030	0.031
			96%	97%	96%	100%	102%	100%
Both	50%	10	0.047	0.050	0.045	0.038	0.037	0.038
			122%	119%	124%	150%	153%	149%
Both	25%	10	0.035	0.037	0.033	0.028	0.027	0.028
			64%	62%	66%	81%	83%	81%

6.3.1.2 Depth for Navigation

As the discrete event simulation is not currently being undertaken a spreadsheet model was set up to determine channel availability. The model used the UKC outputs (required depths) from the analysis undertaken by OMC with the proposed declared depths along the channel and the vessel draught entered as input variables. The model only considered the 400m LOA container vessels.

The model assessed at hourly intervals if the vessel could transit along the channel. If the vessel was not able to transit at any point along the channel, then the channel would be considered to be closed for that vessel draught. The channel availability is then the percentage of time that the channel is open for the selected declared depths and vessel draught over the course of a year. A limit on wind speed of 30 knots and an additional 1% unavailability of the channel due to poor visibility have been included in the model.

For example if at 6am on 29 April a 14.5m draught, 400m LOA vessel was travelling at the fast transit speed scenario into the port where there was a declared depth of -16.5 mCD at MP10. If at this point of time the declared depth was higher (i.e. less negative) than the required depth (draught plus UKC for the environmental conditions at 6am on 29 April), then the channel would be considered closed. Using a channel with a vessel that is unable to transit the channel at all times requires the port to have a VTS system that is able to generate real time and predictive water depth data and relay that information to the vessel.

As outlined in Figure 6-4 there are two transit speed scenarios for the container vessels. A comparison was undertaken with the transit speeds from the navigation simulations and the results are presented in Figure 6-6.

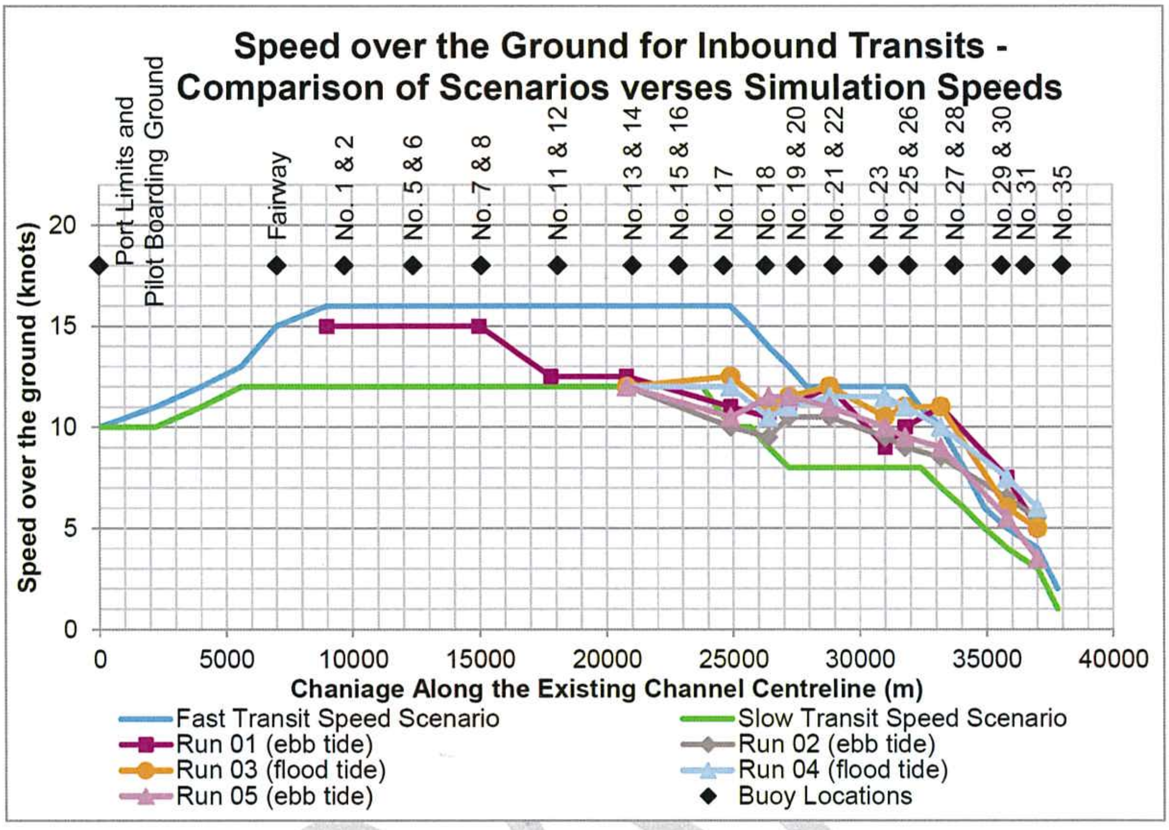

Figure 6-6. Comparison of Speed Scenarios verse Simulation Speeds (All speeds are over the ground)

Figure 6-6 shows that the simulation speeds were generally in between the two scenarios except at the end of the channel. This is due to the configuration of the channel which meant that the pilot needed to keep the speed high to maintain control until he had passed buoy No. 30 and 31. With the amendments made to the preliminary approach channel layout it is expected that the speeds in this area would be able to be reduced. The fast vessel speed scenario has been used in the channel availability model.

6.3.1.3 Dredging Volumes

In order to evaluate the declared depth in terms of dredge volumes, estimates of survey tolerance, siltation allowance and over dredge depths are required. To date minimal work has been undertaken on these aspects and assumptions have been made in order to calculate dredge quantities.

For the purpose of evaluating the different depth scenarios in Section 6.3.2 a simplified spreadsheet model has been used to estimate the dredge volumes. To estimate the dredge volume the spreadsheet model uses cross-sections of the channel at 200m intervals with depth readings at approximately 2m intervals along each of the cross-sections. This has been used to calculate volumes up to the end of the approach channel at buoy No. 29 and 30.

For the scenarios outlined in Section 6.3.3 the dredge volumes have been estimated using ArcGIS with bathymetry points at a horizontal resolution of about 1-2m. All volumes are in situ volumes.

For the Basin alignment the split between 'dredged' and 'excavated' volumes is defined by a line drawn along the approximate edge of foreshore vegetation at approximately 2-3m CD as per the Haskoning Dredging and Reclamation Options Report (HAS-CEPO-HY-REP-0032). This report noted the following *"Removal of material within the basin landward of this line was considered to be carried out by excavation methods (i.e. behind a bund to prevent flooding of the basin during excavation). Removal of material seaward of this line was considered to be carried out by dredging methods."* The volume of material to be excavated within the basin landward of this line has been estimated by Haskoning to be 34.3M m3.

6.3.1.3.1 *Survey Tolerance*

A survey tolerance of -0.25m/+0.0 has been used based on preliminary advice from Hadyn Pike of Baggerman Associates (Dredge Material Management workstream)

6.3.1.3.2 *Siltation Allowance*

The Preliminary Siltation Analysis Report (HAS-CEPO-HY-REP-0016-B) concluded that sedimentation rates in the North Arm and Port Area are unlikely to exceed 50mm/year. In the Western Channel sedimentation is expected to be insignificant as the actual water depths are much greater than the declared depths.

The preliminary siltation analysis report noted the following about the sand waves in the North Arm "...it is considered that sand waves in certain parts of the channel will regrow to a level above the proposed declared depth of -16.5mCD following capital dredging and will require ongoing dredging to maintain the declared depth. The ongoing dredging is likely to be required at a frequency in the order of years rather than months, but further analysis of this issue will be required."

Overdredging to a degree to provide a 'sink' should be in the strategy for the North Arm and the Port Area. Intervention by levelling or water injection periodically could be a strategy to manage siltation, especially for the sand waves. Monitoring and a reasonable time availability of the necessary plant is clearly a key factor. Alternatively levelling in combination a slit trap could be used, however more investigation is required on the suitability of this method. Assessment of this is outside the scope of this report and a siltation depth of 0.3m or 50mm/year by 6 years has been assumed for the purposes of estimating dredge volumes in the North Arm and the Port Area.

6.3.1.3.3 *Overdredge Depths*

As reported in Channel Design for Construction – Stage 1 Preliminary Recommendations for Dredging Tolerances and Batter Slopes (AGH- CEPO-EG-MEM-0017), Hadyn Pike of Baggerman Associates (Dredge Material Management workstream) provided the preliminary dredging allowances outlined in Table 6-5. For the purposes of estimating potential over dredge volumes an average depth of 0.3m and width of 1.8m has been assumed as outlined in Table 6-5.

Table 6-5 Overdredge Allowance

Over dredge Allowance		Allowance for Volume Estimates	Comments
Vertical	0.5m	0.3m	Applicable to all areas
Horizontal	3.0m	1.8m	Applicable through the toeline where appropriate (i.e. no allowance alongside berths etc.
Batters			Over dredging profile to parallel the design slope from the point of intersection of vertical and horizontal overdredging at the base of the batter

6.3.1.3.4 *Batters*

Table 6-6 outlines the batter slopes assumed based on the preliminary findings outlined in Channel Design for Construction – Stage 1 Preliminary Recommendations for Dredging Tolerances and Batter Slopes (AGH- CEPO-EG-MEM-0017).

Table 6-6. Batter Slopes

Location	Slope
Port Area (Baxter or Sherwood Formation)	1V:4H
Port Area (Baxter or Sherwood Formation) – At northern end of channel approximately perpendicular to direction of current	1V:5H
North Arm (Baxter Formation)	1V:4H
Western Channel (Residual Soil)	1V:3H

6.3.1.3.5 Summary

Table 6-7 outlines the additional depths added to the declared depths for the purposes of estimating the potential dredge volumes. For each scenario two volumes have been estimated, these are termed:

- To Dredge Clearance Level – The volume of material that is required to be removed to provide a navigable channel with a siltation allowance. Depending on the contractual arrangement this may also be the volume the Contractor is paid for.
- Incl Allowance for Overdredge – The potential total volume of material that will have to be dredged and taken to disposal. It should be noted that this value will vary depending on the exposure in the channel, dredging methodology and material type.

Table 6-7. Summary of Additional Depths for Dredge Volume Calculations

Segment	Western Channel 1	Western Channel 2	Western Channel 3	Western Channel 4	North Arm 1	North Arm 2	Swing Basin
Survey Tolerance (m)	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Siltation Allowance (m)	0	0	0	0	0.3	0.3	0.3
Additional Depth for the Dredge Clearance Level (m)	**0.25**	**0.25**	**0.25**	**0.25**	**0.55**	**0.55**	**0.55**
Construction/Over Dredge (m)	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Additional Depth for the Over Dredge Volumes (m)	**0.55**	**0.55**	**0.55**	**0.55**	**0.85**	**0.85**	**0.85**

6.3.2 Channel Sensitivity Analysis

A sensitivity assessment for the 400m LOA, 59m beam container vessels for a 14.5m draught vessel using the fast transit speed scenario has been undertaken to compare channel availability to potential dredge volumes in each segment of the channel. The dredge volumes are based on the nominated declared depth plus the additional depths outlined in Table 6-7. The results are presented in Table 6-8 to Table 6-13.

The inbound and outbound transits show different availabilities at the same depth because the ships are modelled as travelling at constant speed across the ground and the tidal currents produce different speeds through the water. This gives different amounts of squat. In addition, the ship's pitch response is different going into the waves compared with travelling with them and this can change the safe water depth required.

Table 6-8. Western Channel 1 Sensitivity Analysis Results

Declared Depth	Western Channel 1					Comment on inbound transits delays (excluding poor visibility delays)
	Channel Availability		Dredge Volume (m3 in situ)			
	Inbound	Outbound	To Dredge Clearance Level	Allowance for Overdredge	Total Incl Allowance for Overdredge	
18.0	98%	99%	204,022	113,251	317,272	1 closure every 5 days of 2.3hrs on average
17.5	95%	99%	81,281	66,006	147,287	1 closure every 2.5 days of 2.4hrs on average
17.3	92%	99%	50,807	49,923	100,730	1 closure every 1.4 days of 2.5hrs on average
17.0	85%	99%	22,148	28,659	50,807	1.2 closures per day of 2.8hrs on average
16.5	71%	96%	3,505	6,995	10,500	1.8 closures per day of 3.8hrs on average

Table 6-9. Western Channel 2 Sensitivity Analysis Results

Declared Depth	Western Channel 2					Comment on inbound transits delays (excluding poor visibility delays)
	Channel Availability		Dredge Volume (m3 in situ)			
	Inbound	Outbound	To Dredge Clearance Level	Allowance for Overdredge	Total Incl Allowance for Overdredge	
17.5	99%	99%	24,260	10,091	34,351	
17.3	98%	99%	18,549	9,221	27,770	1 closure every 10 days of 1.7hr on average
17.0	96%	99%	8,475	18,795	24,260	1 closure every 2.5 days of 1.7hr on average
16.5	85%	95%	670	4,708	5,378	1.3 closure per day of 2.6hrs on average

Table 6-10. Western Channel 3 Sensitivity Analysis Results

Declared Depth	Western Channel 3					Comment on inbound transits delays (excluding poor visibility delays)
	Channel Availability		Dredge Volume (m3 in situ)			
	Inbound	Outbound	To Dredge Clearance Level	Allowance for Overdredge	Total Incl Allowance for Overdredge	
17.0	96%	99%	86,082	30,843	116,925	1 closure every 2.5 days of 1.7hr on average
16.5	84%	95%	44,996	24,077	69,073	1.3 intervals per day of 2.7hrs on average
16.3	78%	90%	31,233	21,398	52,631	1.6 closures per day of 3.1hrs on average
16.0	68%	80%	15,470	15,792	31,262	1.9 closures per day of 3.9hrs on average

Table 6-11. Western Channel 4 Sensitivity Analysis Results

Declared Depth	Western Channel 4					Comment on inbound transits delays (excluding poor visibility delays)
	Channel Availability		Dredge Volume (m3 in situ)			
	Inbound	Outbound	To Dredge Clearance Level	Allowance for Overdredge	Total Incl Allowance for Overdredge	
17.0	97%	99%	99,654	51,426	151,081	1 closure every 3.3 days of 1.6hr on average
16.5	85%	93%	57,581	33,282	90,863	1.3 intervals per day of 2.6hrs on average
16.3	78%	89%	45,165	27,641	72,806	1.6 closures per day of 3.1hrs on average
16.0	68%	77%	31,585	19,675	51,260	1.9 closures per day of 3.9hrs on average

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Table 6-12. North Arm 1 Sensitivity Analysis Results

Declared Depth	North Arm 1					Comment on inbound transits delays (excluding poor visibility delays)
	Channel Availability		Dredge Volume (m3 in situ)			
	Inbound	Outbound	To Dredge Clearance Level	Allowance for Overdredge	Total Incl Allowance for Overdredge	
16.5	98%	98%	721,683	246,416	968,099	1 closure every 10 days of 1.5hr on average
16.3	97%	97%	599,083	225,122	824,205	1 closure every 3.3 days of 1.6hr on average
16.0	92%	92%	433,042	193,156	626,198	1 closure every 1.2 days of 2.1hr on average
15.7	83%	84%	292,046	159,540	451,586	1.4 closures per day of 2.8hrs on average
15.5	76%	76%	117,485	233,533	313,777	1.7 closures per day of 3.2hrs on average

Table 6-13. North Arm 2 Sensitivity Analysis Results

Declared Depth	North Arm 2					Comment on inbound transits delays (excluding poor visability)
	Channel Availability		Dredge Volume (m3 in situ)			
	Inbound	Outbound	To Dredge Clearance Level	Allowance for Overdredge	Total Incl Allowance for Overdredge	
16.5	99%	99%	979,394	343,464	1,322,858	1 closure every 10 days of 1.5hr on average
16.3	98%	99%	810,874	310,075	1,120,949	1 closure every 10 days of 1.5hr on average
16.2	97%	98%	734,287	291,442	1,025,729	1 closure every 3.3 days of 1.5hr on average
16.0	94%	97%	594,997	252,382	847,380	1 closure every 1.6 days of 1.8hrs on average
15.7	87%	92%	416,166	203,507	619,673	1.2 closures per day of 2.4hrs on average
15.5	81%	86%	313,777	176,764	490,541	1.5 closures per day of 2.9hrs on average

6.3.3 Channel Scenarios

Based on the results of the sensitivity analysis the two following scenarios have been developed:

- Scenario A – Average closure below three hours (equates to a channel accessibility of about 80%) for a 15.0m draught vessel. Channel accessibility of just under 95% for a vessel with a draught of 14.5m.
- Scenario B – Average closure below three hours (equates to a channel accessibility of about 80%) for a vessel with a draught of 14.5m.

As outlined in Section 6.3.2 the channel availability of the inbound and outbound transits varies. For each segment of the channel the inbound transit has the lower channel availability and hence the higher average closure time. Therefore the inbound transits have been used when calculating the average closure times.

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Table 6-14 outlines the channel availability and dredge volumes for each segment of the channel and Table 6-15 and Table 6-16 outlines the channel availability for draughts between 14m and 16m for Scenario A. For Scenario B this information is outlined in Table 6-17 to Table 6-19.

Table 6-14. Scenario A Results

Segment	Declared Depth	Channel Availability (400m LOA, 14.5m draught)		Dredge Volume (m3 in situ)			Comment on inbound transits delays (excluding poor visibility delays)
		Inbound	Outbound	To Dredge Clearance Level	Allowance for Overdredge	Total Incl Allowance for Overdredge	
WC1	17.5	95%	99%	55,044	58,995	114,039	1 closure every 2.5 days of 2.4hrs on average
WC2	17.0	96%	99%	18,104	10,025	28,129	1 closure every 2.5 days of 1.7hr on average
WC3	17.0	96%	99%	94,973	28,781	123,753	1 closure every 2.5 days of 1.7hr on average
WC4	17.0	97%	99%	172,706	52,661	225,366	1 closure every 3.3 days of 1.6hr on average
NA1	16.3	97%	97%	659,378	206,722	866,100	1 closure every 3.3 days of 1.6hr on average
NA2	16.2	97%	98%	909,324	312,536	1,221,860	1 closure every 3.3 days of 1.5hr on average
TOTAL		**93%**	**97%**	**1,909,529**	**669,719**	**2,579,248**	1 closure every 1.6 days of 2.3hrs on average

Table 6-15. Scenario A Channel Availability for Various Draughts – Inbound Transits

Channel Segment	Declared Depth	Availability (%) - Inbound				
		14m	14.5m	15m	15.5m	16m
Western Channel 1	17.5	97%	95%	86%	72%	57%
Western Channel 2	17.0	99%	96%	86%	70%	55%
Western Channel 3	17.0	99%	96%	85%	68%	54%
Western Channel 4	17.0	99%	97%	86%	68%	53%
North Arm 1	16.3	99%	97%	86%	69%	52%
North Arm 2	16.3	99%	98%	90%	74%	57%
Channel Availability		**97%**	**93%**	**80%**	**63%**	**48%**
Channel Unavailability Statistics (excluding visibility delays)						
Total Hours Per Year that the Channel is Unavailable	Hrs/Yr	139	517	1653	3136	4495
Total Number of Intervals Per Year that the Channel is Unavailable	No.	63	224	525	705	706
Average Number of Intervals Per Day that the Channel is Unavailable	No.	0.2	0.6	1.4	1.9	1.9
Average Duration of Each Channel Closure	Hours	2.2	2.3	3.1	4.4	6.4
Average Hours Per Day that the Channel is Closed	Hrs/Day	0.4	1.4	4.5	8.6	12.3
Maximum Duration of a Channel Closure during a Year	Hours	5	7	11	32	33

Table 6-16. Scenario A Channel Availability for Various Draughts – Outbound Transits

Channel Segment	Declared Depth	Availability (%) - Outbound				
		14m	14.5m	15m	15.5m	16m
Western Channel 1	17.5	99%	99%	99%	96%	79%
Western Channel 2	17.0	99%	99%	95%	80%	55%
Western Channel 3	17.0	99%	99%	95%	80%	56%
Western Channel 4	17.0	99%	99%	93%	78%	54%
North Arm 1	16.3	99%	97%	87%	67%	46%
North Arm 2	16.3	99%	99%	94%	79%	58%
Channel Availability		**99%**	**97%**	**87%**	**66%**	**45%**
Channel Unavailability Statistics (excluding visibility delays)						
Total Hours Per Year that the Channel is Unavailable	Hrs/Yr	17	146	1027	2862	4691
Total Number of Intervals Per Year that the Channel is Unavailable	No.	10	96	396	683	711
Average Number of Intervals Per Day that the Channel is Unavailable	No.	0.0	0.3	1.1	1.9	1.9
Average Duration of Each Channel Closure	Hours	1.7	1.5	2.6	4.2	6.6
Average Hours Per Day that the Channel is Closed	Hrs/Day	0.0	0.4	2.8	7.8	12.9
Maximum Duration of a Channel Closure during a Year	Hours	3	3	5	7	10

Table 6-17. Scenario B Results

Segment	Declared Depth	Channel Availability (400m LOA, 14.5m draught)		Dredge Volume (m3 in situ)			Comment on inbound transits delays (excluding poor visibility delays)
		Inbound	Outbound	To Dredge Clearance Level	Allowance for Overdredge	Total Incl Allowance for Overdredge	
WC1	17	85%	99%	10,543	19,799	30,342	1.2 closures per day of 2.8hrs on average
WC2	16.5	85%	95%	6,522	6,174	12,696	1.3 closure per day of 2.6hrs on average
WC3	16.5	85%	93%	53,992	23,488	77,480	1.3 intervals per day of 2.7hrs on average
WC4	16.5	85%	93%	105,227	37,670	142,897	1.3 intervals per day of 2.6hrs on average
NA1	15.7	83%	84%	323,963	152,507	476,470	1.4 closures per day of 2.8hrs on average
NA2	15.7	87%	92%	435,382	211,648	647,031	1.2 closures per day of 2.4hrs on average
TOTAL		**79%**	**84%**	**935,630**	**451,287**	**1,386,917**	

Table 6-18. Scenario B Channel Availability for Various Draughts – Inbound Transits

Channel Segment	Declared Depth	Availability (%) - Inbound				
		14m	14.5m	15m	15.5m	16m
Western Channel 1	17.0	94%	85%	71%	57%	43%
Western Channel 2	16.5	96%	85%	70%	55%	40%
Western Channel 3	16.5	96%	84%	68%	54%	39%
Western Channel 4	16.5	97%	85%	68%	52%	38%
North Arm 1	15.7	95%	83%	65%	49%	32%
North Arm 2	15.7	97%	87%	70%	53%	37%
Channel Availability		**92%**	**79%**	**61%**	**46%**	**29%**
Channel Unavailability Statistics (excluding visibility delays)						
Total Hours Per Year that the Channel is Unavailable	Hrs/Yr	593	1787	3293	4622	6110
Total Number of Intervals Per Year that the Channel is Unavailable	No.	254	556	707	706	661
Average Number of Intervals Per Day that the Channel is Unavailable	No.	0.7	1.5	1.9	1.9	1.8
Average Duration of Each Channel Closure	Hours	2.3	3.2	4.7	6.5	9.2
Average Hours Per Day that the Channel is Closed	Hrs/Day	1.6	4.9	9.0	12.7	16.7
Maximum Duration of a Channel Closure during a Year	Hours	7	11	32	33	48

Table 6-19. Scenario B Channel Availability for Various Draughts – Outbound Transits

Channel Segment	Declared Depth	Availability (%) - Outbound				
		14m	14.5m	15m	15.5m	16m
Western Channel 1	17.0	99%	99%	96%	79%	49%
Western Channel 2	16.5	99%	95%	80%	55%	32%
Western Channel 3	16.5	99%	95%	80%	56%	36%
Western Channel 4	16.5	99%	93%	78%	54%	33%
North Arm 1	15.7	96%	84%	62%	42%	18%
North Arm 2	15.7	98%	92%	75%	53%	34%
Channel Availability		**96%**	**84%**	**61%**	**41%**	**17%**
Channel Unavailability Statistics (excluding visibility delays)						
Total Hours Per Year that the Channel is Unavailable	Hrs/Yr	257	1329	3299	5040	7159
Total Number of Intervals Per Year that the Channel is Unavailable	No.	157	461	704	710	555
Average Number of Intervals Per Day that the Channel is Unavailable	No.	0.4	1.3	1.9	1.9	1.5
Average Duration of Each Channel Closure	Hours	1.6	2.9	4.7	7.1	12.9
Average Hours Per Day that the Channel is Closed	Hrs/Day	0.7	3.6	9.0	13.8	19.6
Maximum Duration of a Channel Closure during a Year	Hours	3	5	8	10	88

In Scenario A the channel availability for a 15.0m draught vessel is 80% with delays averaging 3.1 hours on three out of every four low tides. For higher draughts the delays are too frequent and the duration of the delays is too long for container vessel operations. This indicates that Scenario A could be suitable for regular calls by container vessels with a draught up to 15.0m. A draught of 15.0m is 94% of the maximum design draught of container vessels with a maximum design draught of 16.0m.

In Scenario B the channel availability for a 15.0m draught vessel is 62% with delays averaging almost five hours on every low tide. This indicates that Scenario B would only be suitable for regular calls by container vessels with a draught up to 14.5m. A draught of 14.5m is 90% of the maximum design draught of container vessels with a maximum design draught of 16.0m

Based on the analysis undertaken and the frequency and average duration of channel closures it is expected that Scenario A would be suitable for vessels with a sailing draught up to 15m while Scenario B would be suitable for vessels with a sailing draught of up to 14.5m. This is subject to confirmation through a discrete event simulation that this does not cause delays to the shipping lines that would make the Port of Hastings commercial unattractive.

6.3.4 Port Area

6.3.4.1 Swing Basin

There are no anchorages along the North Arm and if delays or high winds occur on an inbound transit, the swing basin is the only point of refuge. Therefore the swing basin will need to cater for all except the most extreme conditions. A transit speed of 6 knots has been considered in the swing basin, although for the Stage 1 development the entry speed into the swing basin may be only 4 knots. Table 6-20 outlines the availability in the swing basin for varying draughts and depths. Within the Port Area (MP31-33) about 1% of the time the water level is below LAT. Basing the analysis on a water level of 0mCD as the criteria for the swing basin then the required depth for Scenario A, which could regularly accommodate vessels up to about 15m draught, would be 16.2m. For Scenario B, which could regularly accommodate vessels up to about 14.5m draught, it would be 15.7m.

Table 6-20. Swing Basin Availability

Swing Basin Declared Depth	Swing Basin Availability for a Vessel Draught of				
	14m	14.5m	15m	15.5m	16m
16.2	99.8%	99.8%	99.0%	91.5%	75.7%
16.1	99.8%	99.8%	98.2%	88.9%	71.7%
16.0	99.8%	99.7%	97.0%	85.8%	67.9%
15.9	99.8%	99.6%	95.5%	82.7%	64.2%
15.8	99.8%	99.4%	93.7%	79.3%	60.8%
15.7	99.8%	99.0%	91.5%	75.7%	57.4%
15.6	99.8%	98.2%	88.9%	71.7%	53.5%
15.5	99.7%	97.0%	85.8%	67.9%	50.4%

6.3.4.2 Berth Pocket

The berth pocket would need to provide safe water to cater for all environmental conditions. As outlined in Section 6.3.4.1 within the Port Area (MP31-33) about 1% of the time series data had a water level of below LAT (at Stony Point) with the lowest tides being about -0.5 mCD. The normal maximum ship out of trim during loading is 1.5 degrees. This equated to a UKC of 0.7m, or 0.95m with a bottom clearance of 0.25m. A value of 1m has been adopted which will allow for a roll angle of 1.6 degrees in normal conditions and up to 2.1 degrees in extreme conditions.

Note that while the port can potentially accept deeper draught vessels, the draught of the vessel in Scenario A is restricted to 15.0m and the draught of the vessel in Scenario B is restricted to 14.5m for the purposes of defining a berth pocket depth. The results are presented in Table 6-21.

Table 6-21. Berth Pocket Depths

Parameter	Depth (m or mCD)	
	Scenario A	Scenario B
Tide Level and Residuals	-0.5m	-0.5m
Vessel Draught	15.0m	14.5m
UKC	1.0m	1.0m
Declared Depth	**-16.5 mCD**	**-16.0 mCD**
Survey Tolerance	0.25m	0.25m
Siltation Allowance	0.3m	0.3m
Dredge Clearance Level	**-17.05 mCD**	**-16.55 mCD**
Over dredge Allowance	0.5m	0.5m
Over Dredge Level	**-17.55 mCD**	**-17.05 mCD**

6.3.5 Summary

Scenario A could cater for vessels with a draught of up to 14.5m for 93% of the time, and with a draught of up to 15.0m for 80% of the time. Scenario B could cater for vessels with a draught of up to 14.5m for 79% of the time. The depth and dredge volume estimates are outlined in Table 6-22 for Scenario A and Table 6-23 for Scenario B. Since the channel is likely to operate at an occupancy level lower than 50%, the combined probability of channel availability is marginally higher than that indicated.

Table 6-22. Summary of Depth and Dredge Volume for Scenario A

Segment	Declared Depth	Dredge Volume (m3 in situ)		
		To Dredge Clearance Level	Allowance for Overdredge	Total Incl Allowance for Overdredge
APPROACH CHANNEL				
Western Channel 1	17.5	55,000	59,000	114,000
Western Channel 2	17.0	18,000	10,000	28,000
Western Channel 3	17.0	95,000	29,000	124,000
Western Channel 4	17.0	173,000	52,000	225,000
North Arm 1	16.3	659,000	207,000	866,000
North Arm 2	16.2	909,000	313,000	1,222,000
Channel Total		**1,909,000**	**670,000**	**2,579,000**
PORT AREA				
Stage 1 Development	16.2 - Swing Basin 16.5 - Berth Pocket	4,700,000	400,000	5,100,000
Along the Shore Alignment		23,600,000	1,000,000	24,600,000
Basin Alignment		21,800,000	800,000	22,500,000
APPROACH CHANNEL & PORT AREA				
Stage 1 Development		**6,609,000**	**1,070,000**	**7,679,000**
Along the Shore Alignment[1]		**25,509,000**	**1,670,000**	**27,179,000**
Basin Alignment[1 & 2]		**23,709,000**	**1,470,000**	**25,079,000**

Notes

1. The Along the Shore and Basin Alignment quantities are for the entire development and including the Stage 1 development quantities.
2. Does not include the 34.3M m3 of material to be excavated beyond the approximate edge of foreshore vegetation at 2-3m CD as estimated by Haskoning (HAS-CEPO-HY-REP-0032-0).

Table 6-23. Summary of Depth and Dredge Volume for Scenario B

Segment	Declared Depth	Dredge Volume (m3 in situ)		
		To Dredge Clearance Level	Allowance for Overdredge	Total Incl Allowance for Overdredge
APPROACH CHANNEL				
Western Channel 1	17.0	11,000	19,000	30,000
Western Channel 2	16.5	7,000	6,000	13,000
Western Channel 3	16.5	54,000	23,000	77,000
Western Channel 4	16.5	105,000	38,000	143,000
North Arm 1	15.7	324,000	152,000	476,000
North Arm 2	15.7	435,000	212,000	647,000
Channel Total		**936,000**	**450,000**	**1,386,000**
PORT AREA				
Stage 1 Development	15.7 - Swing Basin 16.0 - Berth Pocket	4,200,000	400,000	4,500,000
Along the Shore Alignment		22,100,000	1,000,000	23,000,000
Basin Alignment		20,500,000	800,000	21,300,000
APPROACH CHANNEL & PORT AREA				
Stage 1 Development		**5,136,000**	**850,000**	**5,886,000**
Along the Shore Alignment[1]		**23,036,000**	**1,450,000**	**24,386,000**
Basin Alignment[1 & 2]		**21,436,000**	**1,250,000**	**22,686,000**

Notes

1. The Along the Shore and Basin Alignment quantities are for the entire development and including the Stage 1 development quantities.
2. Does not include the 34.3M m3 of material to be excavated beyond the approximate edge of foreshore vegetation at 2-3m CD as estimated by Haskoning (HAS-CEPO-HY-REP-0032-0).

Figures showing the location and extent of the dredging are included in Appendix C. Note that these figures are A0 plots.

7.0 Navigation Aids

7.1 Navigational Aid Locations

Figure 7-1 outlines the proposed lateral navigation mark layout in the Hastings approach channel based on the findings of the navigation simulations and recommendations from David Shennan of North & Trew. The existing buoy numbering in the approach channel has been maintained to avoid confusion with the current buoy referenced. The exception to this is lateral navigation markers No. 29 and 30 which have been renumbered to No. 31 and 32 respectively due to the additional two lateral navigation markers in the North Arm 2.

The distance between swinging basin markers will be dependent on the manoeuvring visibility parameters set for operations, the size of the markers to be used and the electronic navigation systems available onboard. A risk-based approach will need to be taken, which will determine the likelihood of failure of ship and port systems and the consequence of an unsuccessful manoeuvre. If, for example, a modern large container vessel suffers a control system failure (which has occurred) it is necessary for the pilot to have an immediate indication of the proximity to the nearest danger. Contact with the channel edge with a ship's stern can have serious affects.

There are currently swinging area locations both at the Port of Geelong and off Station Pier, Port of Melbourne, where the limits of safe water are not well marked. However pilots take this into account and have a 'work around' at Station Pier to keep the vessel safe during the swing using leading lights.

Ensuring there is adequate spacing of markers/buoys along the toeline will ensure these problems don't exist in Hastings, and would therefore reduce the risk profile.

A poor visibility limit for channel transit has been suggested at 0.5 nm (926 metres), which could possibly be reduced to 0.3 nm (556 metres) in the North Arm and swinging area.

The PIANC Harbour Approach Channel Design Guidelines recommend that: *'A minimum requirement of channel marking is that at least one marker should always be visible (by eye or radar) on either side of the channel. With this rule and knowledge of visibility conditions in the area of interest, one can calculate maximum distances between markers. Maximum marker spacing is then less than minimum visibility required. The ship size, speed, bridge visibility and the use of electronic navigational aids may dictate that the minimum distance required is smaller than the minimum meteorological distance considered.'*

Additionally, *'If straight parts are longer than the maximum spacing allowed, there is always an option to place additional markers along the straight sidelines.'* Based on this it is recommended to have markers along the toeline at intervals of 500 metres. Leadings lights/markers, in some form, should be allowed for in the proposed basin alignment. This will not only aid the visual lateral positioning during the stern transit into the basin but also act as a reference during the turn in the swinging basin.

It is assumed that the BlueScope common user berth will remain operational as part of the Stage 1 development. This means that navigation aid No. 39 may need to be to a virtual marker. The suitability of a virtual navigation mark at this location will need to be assessed as part of future navigation simulation studies. The navigational aid layouts are outlined in the following figures.

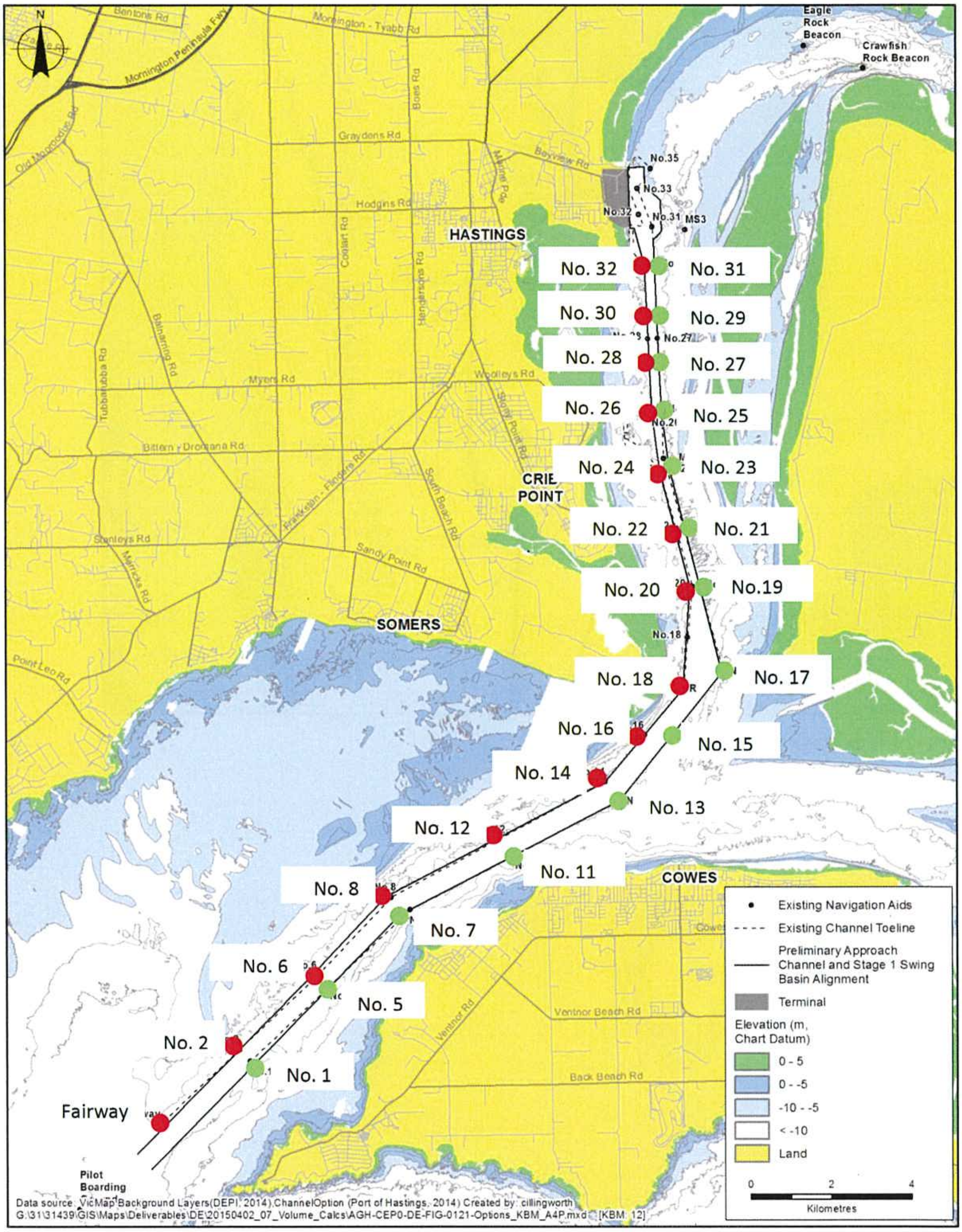

Figure 7-1. Approach Channel Navigation Aids Layout

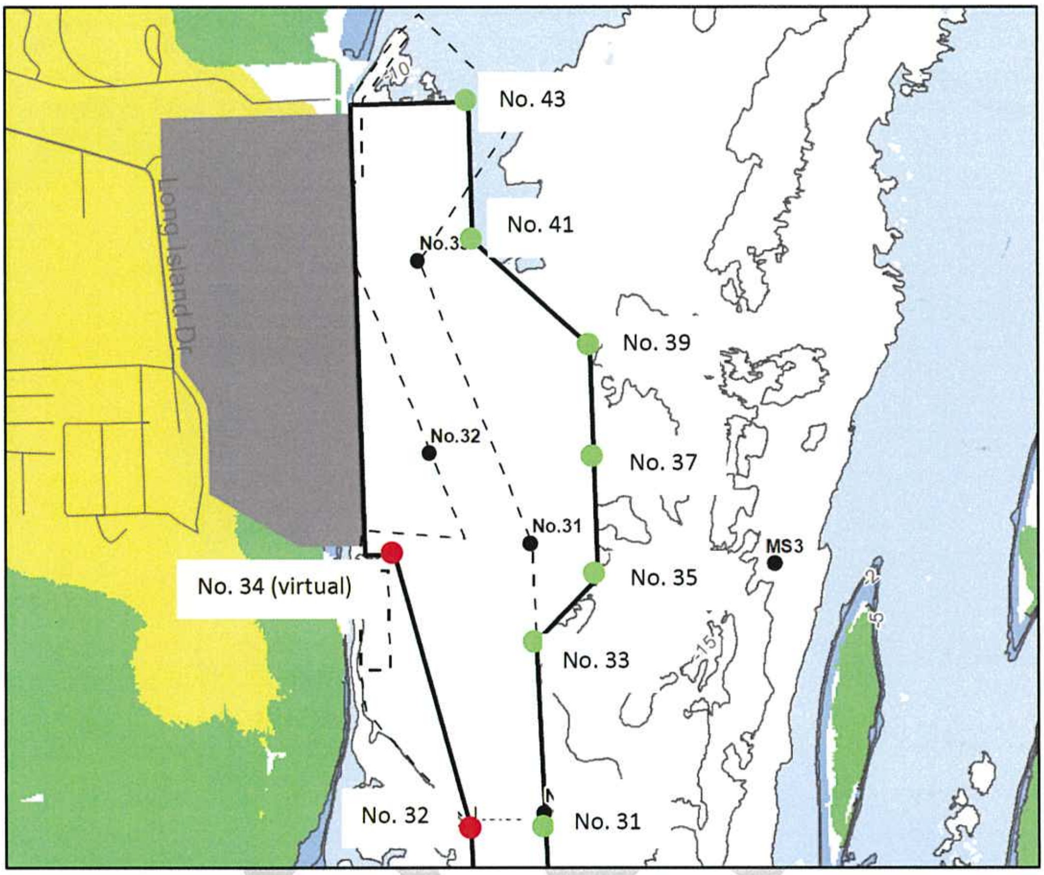

Figure 7-2. Stage 1 Development Navigation Aids Layout

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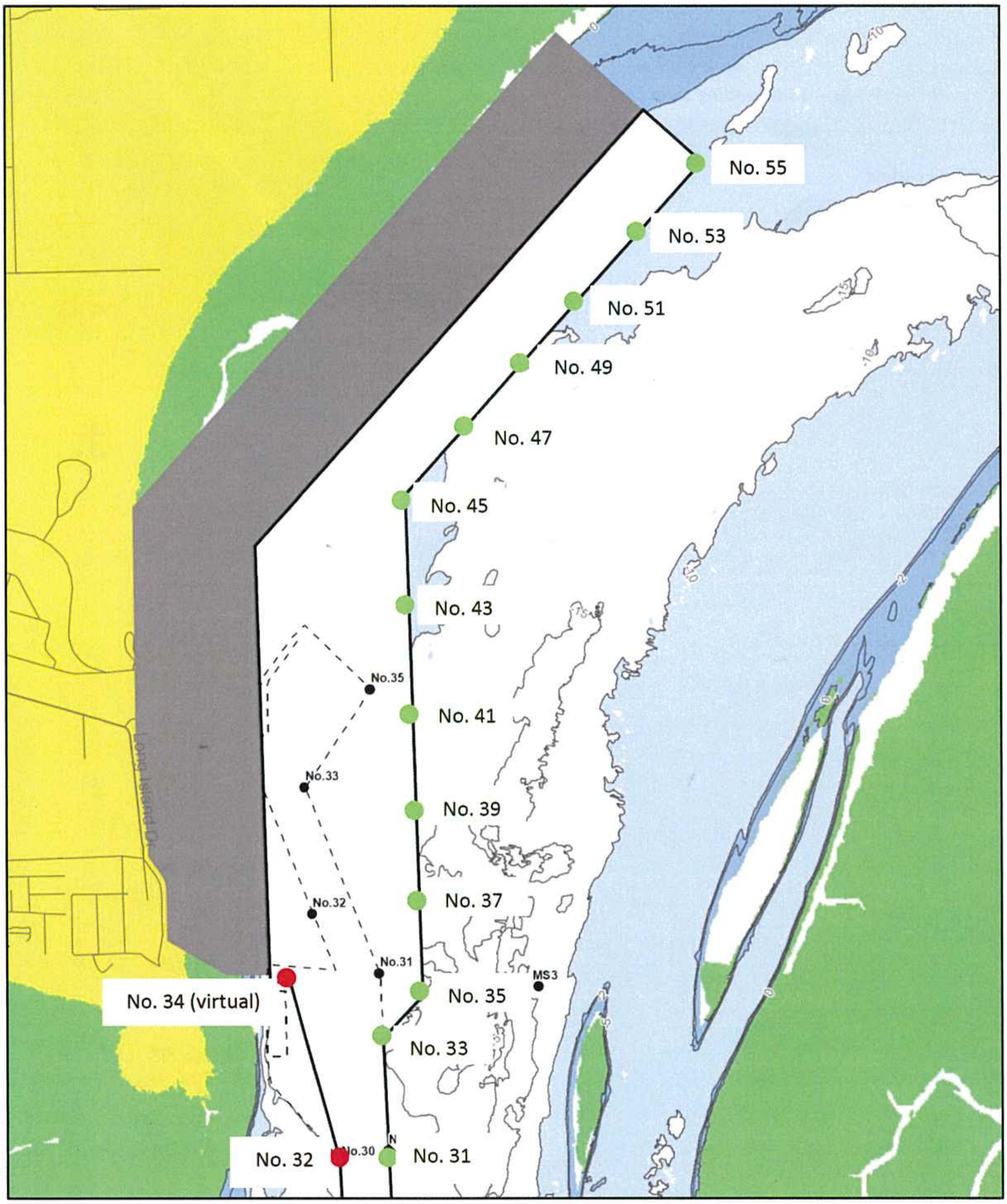

Figure 7-3. Along the Shore Alignment Navigation Aids Layout

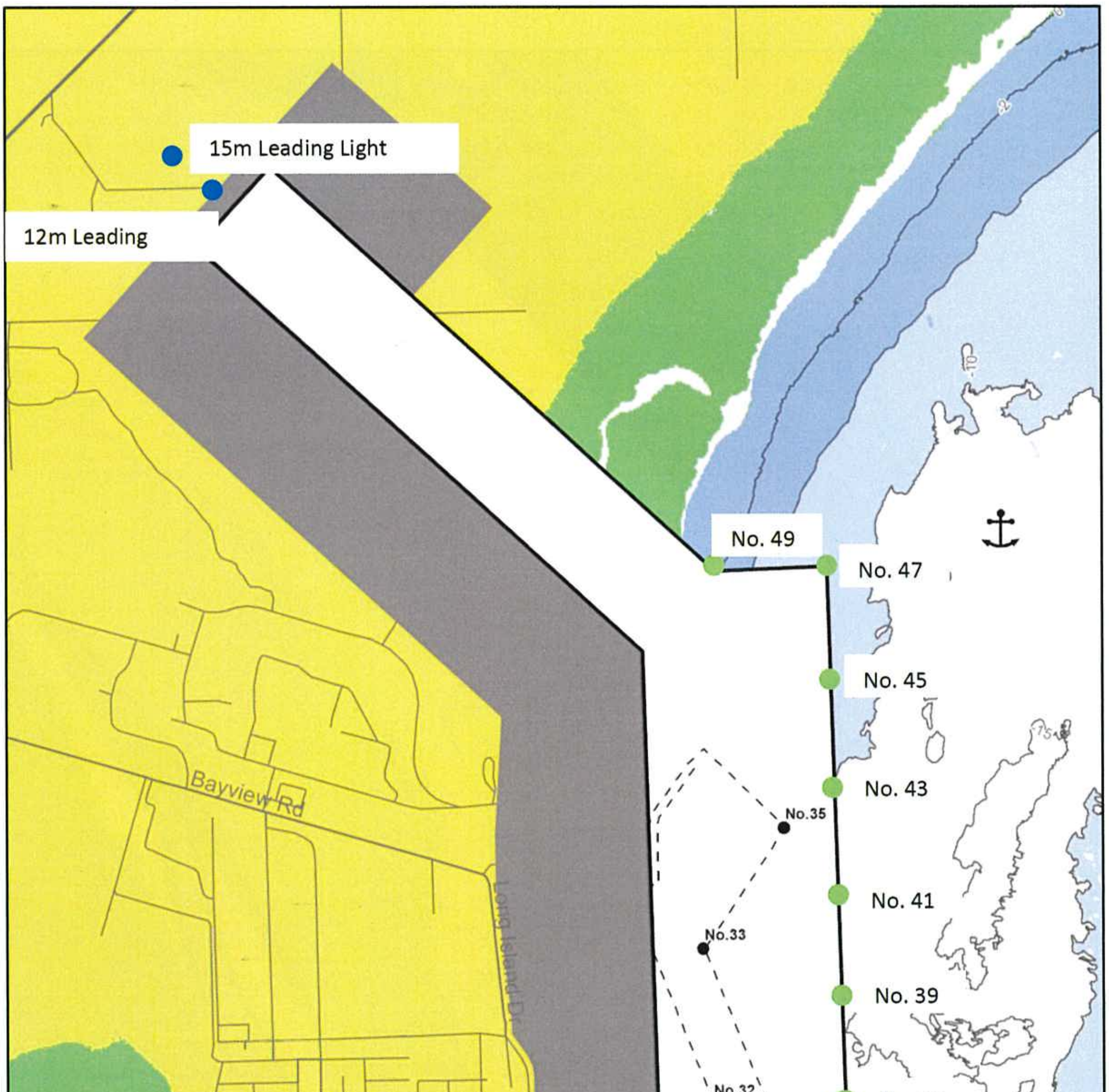

Figure 7-4. Basin Alignment Navigation Aids Layout

7.2 Navigational Aid Types

The decision to use beacons or buoys depends on a result of a number of considerations. Buoys are used where fixed aids (beacons) may be uneconomical or impractical due to the depth of water i.e. buoys 1 to 18. While the position of a beacon can be accurately verified and its positioned maintained, buoys cannot be relied on to maintain their charted position consistently.

The charted position of a buoy indicates the approximate position of the sinker which secures the buoy to the seabed, or the central position of the combined ground tackle if more than one sinker is used. The approximate position is used because of the practical limitations in keeping buoys in precise geographical locations. These limitations include the prevailing weather and sea conditions, tidal height, current and the scope of the mooring chain. Continuous monitoring of the buoy position by, for example, AIS or a Vessel Traffic Service, is required to give early warning of movement from its charted position. There is an additional risk of grounding on the channel edge if a buoy moves out of position.

Modern mooring arrangements using an encapsulated nylon tether can provide elasticity in the mooring which reduces the watch circle from a 3:1 (mooring length to depth of water), to a ratio of 2:1. This improves the position-keeping ability of the buoy.

Consideration has to be given to the routine on-station navigational aid maintenance requirement of both buoys and beacons. Beacons and their associated lighting equipment and instrumentation are more easily accessible. Buoys require a more involved maintenance regime. The buoy and ground tackle (sinker, chain and swivel or nylon tether) are raised and inspected and any cleaning, repairs or replacement carried out. The sinker then needs to be returned to the exact charted position using GPS positioning. Currently, maintenance frequencies have been extended to five years with modern mooring systems.

While the cost of beacons can be greater than that of buoys, it is possible to have a combination of the two types of markers. For example, beacons marking important turn or swinging points, with buoys being placed in the less critical channel positions. This combined approach might prove cheaper after a cost/benefit analysis of purchase/maintenance costs.

Beacons are more widely adopted in Port Phillip Bay than buoys. Experience has seen their use be supported and preferred by the local pilots. Port of Melbourne has moved away from the use of buoys due to the increasing OH&S issues associated with their maintenance. Globally, buoy systems are used much more widely than beacons.

7.3 Navigation Aid Design

All navigational aids are required to meet IALA Recommendations and Guidelines. Beacons in use within the Ports of Melbourne and Geelong channels provide an indication of the size, type and light arrangements that can be applied to the Port of Hastings if adopted. Beacons in Geelong are fitted with lights with a range of five nautical miles.

Examples of the buoys likely to be used in marking the channel and swinging area toeline would be similar to the SL-B1500 1500mm diameter navigation buoy, while the larger Poseidon-1750 1750mm diameter Ocean Buoy would be more suitable for the Western Channel and the larger Nautilus-2200 (refer to Figure) in the seaward approaches into the port. These buoys are supplied in Australia by Sealite.

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Figure 7-5. Navigation Beacon in Port Phillip Bay

Figure 7-6. SL-B1500 1500mm diameter navigation buoy (source Sealite)

Lighting for both buoys and beacons would be of the solar powered type as provided by Sealite with ranges of 2-3 nm, 3-5 nm and 6-9 nm. The SL-70, SL-C410 and SL-C600 are examples. Synchronisation with other channel markers can be achieved using short range RF or GPS synchronisation. By synchronising the buoys marking the toeline of straight channel sections, e.g. swinging area, there is a resulting improvement in the visual reference to the channel edge.

Remote monitoring of performance can be achieved with the GSM Cell-Phone monitoring and control system. An AIS solution can be fitted to buoys to give notification should the buoy move off-station.

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8.0 Conclusions and Further Work

8.1 Conclusions

The following conclusions are drawn from the work undertaken to date. It is noted that the navigation design process has not been completed so all findings are subject to verification:

- The Port Phillip Bay Sea Pilots raised concerns about strong cross currents on the ebb tide at McHaffie Reef. The simulations showed this effect and demonstrated that the combination of vessel speed and channel width at this point allowed all vessels to negotiate this part of the channel safely.
- The PIANC guidelines for the concept design of the channel width appear to under estimate the width required for the container ships with large windage areas. It has been demonstrated that there is a need to widen the North Arm compared to the concept design recommendations. The North Arm channel will require a width of approximately 250m.
- Both the Basin and the Along the Shore layouts are feasible for combinations of peak spring tidal currents and wind speeds up to 30 knots, although a 30 knot wind speed may require additional tug capacity for certain manoeuvres.
- For operations in a 30 knot wind, three 80t tugs are required and in some circumstances a fourth tug may be needed.
- For the Basin layout the currents across the entrance are not an issue for swinging the vessel or transiting into or out of the basin.
- A swing basin with a length of 3xLOA (1,200m) is adequate for the Stage 1 Development and the width can be reduced below 1.75xLOA (700m). It is estimated that the width can probably be reduced to 1.65xLOA (660m).
- The construction of the berths between Long Island Point Jetty and the BlueScope berths has no significant impact on the berthing/unberthing of vessels at the Long Island Point Jetty.
- The volume of dredge material to provide an average channel closure of less than three hours per event (equates to a channel accessibility of about 80%) for a 14.5m draught vessel is 5.9M m^3 for the Stage 1 development, 23.9M m^3 for the entire Along the Shore Alignment and 22.4M m^3 for the entire Basin Alignment (excluding excavation beyond the approximate edge of foreshore vegetation at 2-3m CD).
- The volume of dredge material to provide an average channel closure of less than three hours per event (equates to a channel accessibility of about 80%) for a 15.0m draught vessel is 7.6M m^3 for the Stage 1 development, 26.6M m^3 for the entire Along the Shore Alignment and 24.9M m^3 for the entire Basin Alignment (excluding excavation beyond the approximate edge of foreshore vegetation at 2-3m CD).
- The depth of the berth pocket would need to be lower than the -17.0m CD level used in the structural quay options assessment. This is to allow for the 1% of the time that the water level in the Port Area is below 0m CD (lowest is approximately -0.5m CD).

8.2 Further Work

To define the optimal channel depth a discrete event simulation should be undertaken using the UKC data. The model would include the operational berths, together with the harbour and channel operations, tidal restrictions and operating procedures. The model would generate shipping for projected container and liquid bulk exports and imports and will process the movement of ships from arrival, berthing, loading/unloading and departure, subject to tidal and current constraints, port operating rules and harbour master requirements for tugs and pilots.

By varying the depth of the channel the delays to the shipping lines can be assessed. Additionally the model can assess delays to the existing operations within the Port of Hastings.

Further navigation simulation works would include the following:

- Use of a 3D flow model to input 3D currents into the simulations to investigate the effects of the complex flow patterns, especially at the basin entrance.
- Undertake more extensive simulations with a number of different pilots to confirm the widths of the channels, size of the swing basin, limits of safe navigation, aid to navigation requirements and tug requirements.
- Assess the Western Channel for two way operations.
- Assess the effect of passing vessels on vessels moored at the Long Island Point Jetty and the container berths to define what limitations are required.

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