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PORT OF HASTINGS DEVELOPMENT PROJECT



DESIGN AND ENGINEERING
Concept Channel Design & Channel
Development Strategy

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Document Ref: AGH-CEP0-EG-REP-0012

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 requested that preliminary and draft reports previously commissioned for the development project be reissued to form 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

Concept Channel Design & Channel Development Strategy

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Client: Infrastructure Victoria

ABN: 44 128 890 975

Prepared by the AECOM + GHD Joint Venture

AECOM Australia Pty Ltd

Level 9, 8 Exhibition Street, Melbourne VIC 3000, Australia
T +61 3 9653 1234 F +61 3 9654 7117 www.aecom.com

+

GHD Pty Ltd

Level 8, 180 Lonsdale Street, Melbourne VIC 3000, Australia
T +61 3 8687 8000 F +61 3 8687 8111 www.ghd.com

JV ABN: 57 194 323 595

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Quality Information

Project Port of Hastings Development Project – Design and Engineering

Document Concept Channel Design & Channel Development Strategy

DRAFT

Ref AGH-CEP0-EG-REP-0012

Date 28-Feb-17

Prepared by B. Gray

Reviewed by A. Kennedy & R. Clarke

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
A	3-Nov-14	Draft for Discussion	Richard Clarke Port Planning Workstream Manager	* Richard Clarke
B	7-Nov-14	Draft with channel plans	Richard Clarke Port Planning Workstream Manager	* Richard Clarke
0	13-Mar-15	Final Working Draft	Richard Clarke Port Planning Workstream Manager	* Richard Clarke
1	28-Feb-17	Final Working Draft – Infrastructure Victoria Release	Austin Kennedy	* Austin Kennedy

Port of Hastings Development Project – Design and Engineering
Concept Channel Design & Channel Development Strategy

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28-Feb-17



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1.0 Introduction

This paper outlines the concept channel design and the proposed strategy to refine the depth, width and alignment to develop options for the integrated options assessment and preliminary design.

2.0 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.

3.0 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.

4.0 Initial Concept Design to PIANC

4.1 Design Vessels

The design vessels selected for the channel design are outlined in Table 1. The terminology of the design vessel corresponds to the naming of the demand forecast scenarios and this is discussed along with the rationale for the choice of design container vessel in AGH-CEP0-EG-MEM-0011 and additional work on the maximum ship size particulars for the referral design.

Table 1. Design Vessels

Vessel Designation	Length (LOA) (m)	Beam (m)
Constrained Container	300	42.9
Unconstrained Container	400	59
Tanker	250	44

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4.2 Channel Widths

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 current, 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 in Appendix B. For each design container vessel 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 2 summarises the required widths and the calculations and rationale are included in Appendix B.

Table 2. Concept Design Channel Widths (m)

Segment	Existing	Constrained Vessel		Unconstrained Vessel	
		One-Way	Two-Way	One-Way	Two-Way
Western Channel 1	400	169	432	212	519
Bend of Western Channel 1 and 2	560	192	476	243	581
Western Channel 2	536	147	389	183	460
Bend of Western Channel 2 and 3	592	174	441	220	534
Western Channel 3	536	150	383	183	448
Bend of Western Channel 3 and 4	1112	181	442	227	536
Western Channel 4	183*	185	-	230	-
Bend of Western Channel 4 and North Arm 1	183	212	-	267	-
North Arm 1	183	172	-	212	-
Bend of North Arm 1 and 2	605	194	-	243	-
North Arm 2	250	172	-	212	-

Red text indicates that the required dimensions 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*

Channel concept plans outlining the channel alignment for each of the scenarios in Table 2 are in Appendix A. Where the required widths are less than existing the channel dimensions have not been reduced. This has been done to determine the locations where dredging is required to see if it is possible for the existing width to be maintained without the need for additional dredging. Additionally there will be a discussion with the Harbour Master and pilots to determine if a narrower channel is acceptable.

Widening of the existing channel is required at the following locations under the following scenarios:

- Constrained container vessel for a two-way transit at the seaward end of Western Channel 1. The channel has been widened by moving the toelines to the north as shown in Figure 1.

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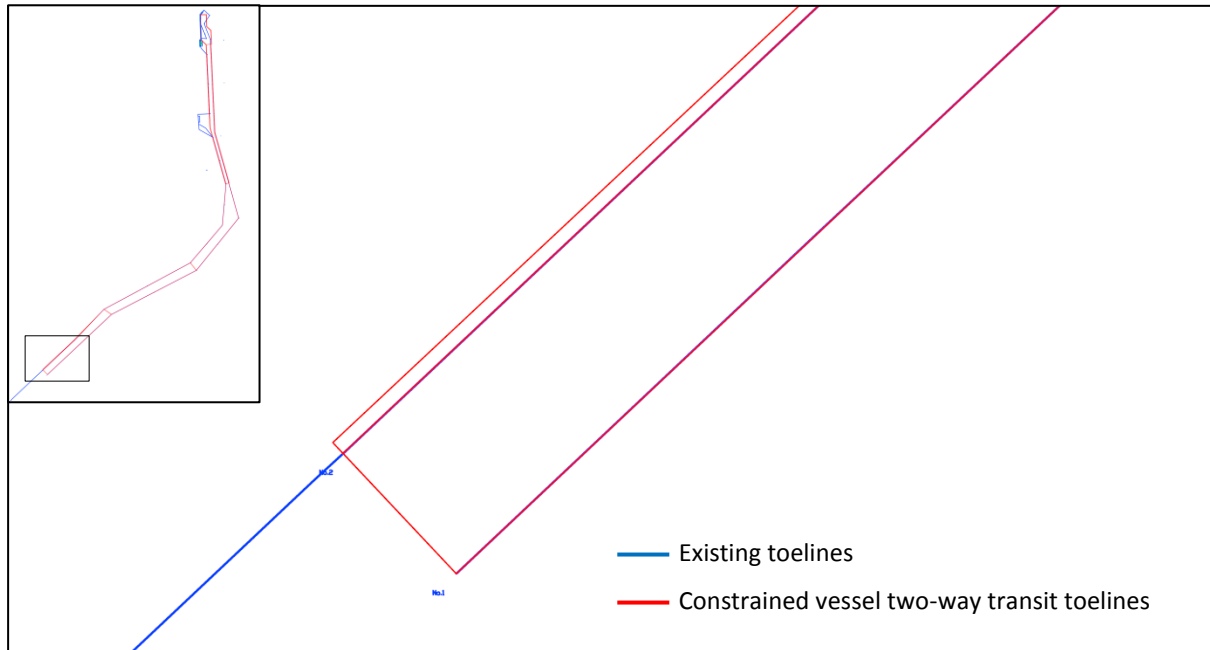


Figure 1. Western Channel 1 Alignment for a Constrained Vessel Two Way Transit

- Unconstrained container vessel for a two-way transit along the full length of Western Channel 1 and the bend of Western Channel sections 1 and 2. High spots are located near the bend of Western Channel 1 and 2 near McHaffie Point 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 move 300m to the west and the angle at this corner increased by 2 degrees as outlined in Figure 2 This results in a marginally tighter approach into the Western Channel and will need to be discussed with the pilots.

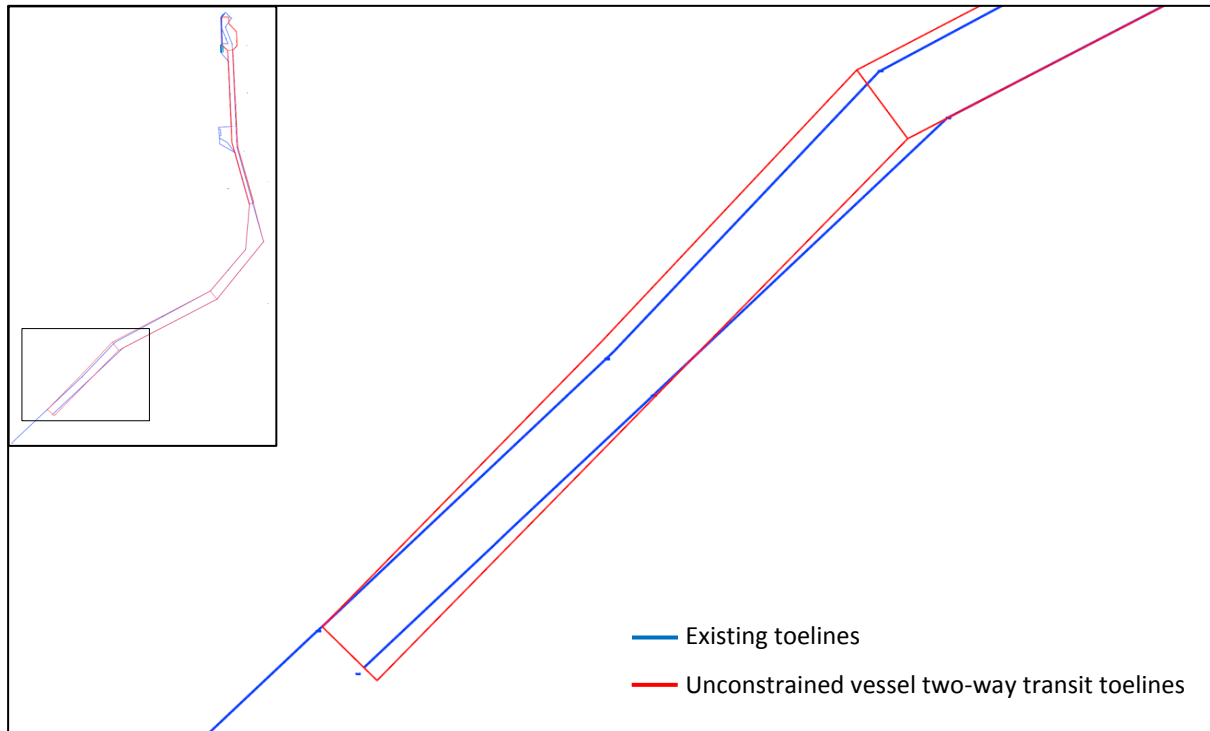


Figure 2. Western Channel 1 Alignment for a Constrained Vessel Two Way Transit

- For all scenarios at the entrance to the North Arm (the northern end of the Western Channel) for all vessels. At this location Beacon No. 19 has been moved to the east to accommodate the additional width. The east side was selected for adjustment because it is naturally deeper resulting in a lower dredge volume, however this will need to be confirmed in the simulation studies. The alignment for the unconstrained vessel is outlined in Figure 3.

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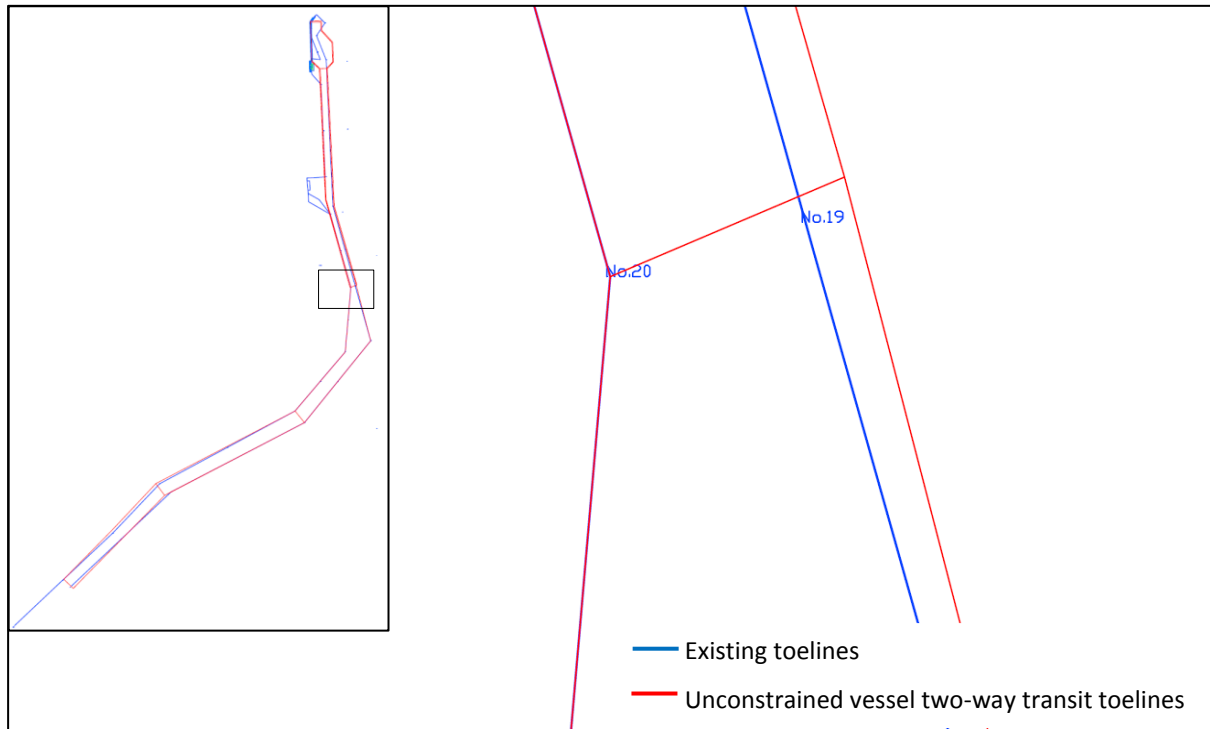


Figure 3. Entrance to the North Arm Alignment for an Unconstrained Vessel

For the berth 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 this 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 265m (350m from the berth line) for the constrained and 282m (400m from the berth line) for the unconstrained has been adopted. There is no guidance on this and the dimensions used reflect practice in other ports.

4.3 Channel Depths

To provide an early estimation of dredge locations and volumes, the likely channel depths were assessed. The PIANC 2014 concept design method is known to provide very conservative design depths and instead the initial UKC modelling undertaken by OMC International was used. This modelling was based on 30 days of metocean information and a transit speed of through the water of 16 knots for container vessels and 12 knots for tankers. This vessel speed is considered to be the highest speed practical and reductions in the speed to reduce squat will be considered in future studies. 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.

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A survey tolerance of 0.25m is assumed as well as the following over-dredge allowances:

- Vertical – 0.5 m
- Horizontal – 3.0 m through the toeline where appropriate

Batters are assumed to be 1 in 3 generally and 1 in 5 for the north edge of the port area. No allowances have been made for siltation in the channel based on preliminary advice from the Hydrodynamics workstream. A 0.3m siltation allowance was included for the port area.

For the constrained vessel a design draught of 14.0m sailing at LAT has been included as a comparison case which corresponds to the design draught for the Port of Melbourne. However due to the significant tidal range in Western Port Bay compared to Port Phillip Bay an alternative scenario of a design draught of 14.0m at +1.0m which roughly equates to MLWN (+1.06mCD) has been included. The resulting dredge depths are outlined in Table 3.

Table 3. Concept Channel Depths for the Constrained Vessel

Segment	WC1	WC2	WC3	WC4	NA1	NA2	Swing Basin
Static Draught (m)	14.0	14.0	14.0	14.0	14.0	14.0	14.0
UKC (m)	2.5	2.0	1.5	1.5	1.5	1.5	1.1
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
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 14m at LAT	-17.25	-16.75	-16.25	-16.25	-16.25	-16.25	-16.15
Over Dredge Depth for a sailing draught of 14m at MLWN (~+1.0mCD at Stony Point)	-16.25	-15.75	-15.25	-15.25	-15.25	-15.25	-15.15

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For the unconstrained vessel a design draught of 14.5m at LAT and MLWN has been included and the dredge depths are outlined in Table 4.

Table 4. Concept Channel Depths for the Unconstrained Vessel

Segment	WC1	WC2	WC3	WC4	NA1	NA2	Swing Basin
Static Draught (m)	14.5	14.5	14.5	14.5	14.5	14.5	14.5
UKC (m)	2.5	2.0	1.5	1.5	1.5	1.5	1.1
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
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	-17.75	-17.25	-16.75	-16.75	-16.75	-16.75	-16.65
Over Dredge Depth for a sailing draught of 14.5m at MLWN (~+1.0mCD at Stony Point)	-16.75	-16.25	-15.75	-15.75	-15.75	-15.75	-15.65

It is clear that significant savings could be made to the dredged depths through optimising:

- Lowering the transit speeds resulting in reduced squat
- Lower design draughts that correspond to the actual sailing draughts expected
- Reduction in the over dredge tolerances
- Reduction in tidal window available to the largest draught vessels

4.4 Concept Plans and Dredge Volumes

Concept plans for the scenarios outlined in Table 5 are included in Appendix A and the dredge volumes for these scenarios are shown in Table 5. These calculations are based on the over dredge depth and do not consider if the bathymetry sounding is within the construction/over dredge allowance. In many areas along the Western Channel and North Arm the dredge depth is less than 1m. Where these depths are less than 0.5m they would not be dredged as they are below the survey tolerance of the declared depth. This would lead to lower dredge volumes than outlined in Table 5 for the Western Channel and the North Arm. There was insufficient time to undertake this additional analysis prior to the issue of this document.

Table 5. Scenario and Dredge Volumes

Scenario			Dredge Volume (M m ³)			
Vessel	1 or 2 way	Draught	Western Channel	North Arm	Port Area (Stage 1)	Total
Constrained (300m LOA, 42.9m Beam)	One-way	14.0m at LAT	55,600	617,200	3,026,700	3,699,500
		14.0m at MLWN	2,500	55,800	2,293,400	2,351,700
	2-way in Western Channel and 1-way in the North Arm	14.0m at LAT	57,500	617,700	3,024,800	3,700,000
		14.0m at MLWN	2,900	56,100	2,293,400	2,352,400
Unconstrained (400m LOA, 59m Beam)	One-way	14.5m at LAT	149,800	1,295,700	4,666,000	6,111,500
		14.5m at MLWN	16,100	292,400	3,608,500	3,917,000
	2-way in Western Channel and 1-way in the North Arm	14.5m at LAT	145,800	1,295,700	4,662,300	6,103,800
		14.5m at MLWN	15,900	292,400	3,605,300	3,913,600

5.0 Optimisation Opportunities and Costs

There are numerous opportunities for reducing the concept design channel dimensions, overall dredge volumes and resulting capex. These opportunities fall into two broad categories:

- better understanding of existing conditions (including metocean, geotech and bathymetric) and enabling more detailed modelling to reduce the conservative design elements suggested in the PIANC design guidelines
- imposing limiting constraints on operations that will either reduce the design vessel or limit accessibility in extreme conditions

The first optimisation category is relatively straight forward within the design process from concept to detailed design, and will impose no additional costs or constraints on the future port operations. The second category will by necessity have some commercial implications through increased delays to vessels or limitations on the class(es) of vessels that might call at the port.

Some potential operational limitations include:

- Tidal assistance. It may be possible to define the design draught for tide levels higher than LAT so long as the downtime due to tides being lower than this limit is minimised
- Additional tugs. This may provide opportunities for reducing the swing basin dimensions, however this will come with higher operational costs
- Speed management. Modern on-board DUKC systems can optimise transit speeds to reduce squat and/or maximise tidal assistance
- Maintenance dredge program optimisation
- Imposing higher preference for container vessels over tankers

6.0 Optimisation Methods and Tools

6.1 Underkeel Clearance Analysis

The UKC modelling will be undertaken by OMC International using their DUKC® methodology, in accordance with PIANC 121, to define the appropriate channel depths for a range of vessel draughts. The UKC analysis will be undertaken using a full year of hydrodynamic information. The UKC will be assessed at 33 locations along the channel for the design vessels and proposed draughts outlined in Table 6. At each location the vessel will be sailed hourly over a full year to provide a plot of channel depth (static draft plus UKC) against percentage accessibility.

Table 6. Initial UKC Scenarios

Vessel	Proposed Draughts (m)
Constrained	12.0, 13.0 and 14.0
Unconstrained	14.0, 15.0 and 16.0
Crude Oil Tanker	13.5, 14.5 and 15.5

6.2 Real Time Simulations

A real time vessel simulation will be undertaken to refine the horizontal dimensions of the channel design and manoeuvring area designs. Realistic design vessel performance characteristics, tug operations and metocean conditions will be used to create an overlay of vessel track plots. These track plots will be 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 scope and scenarios for the 2D simulations will be discussed when Mark McBride from HR Wallingford is in Hastings in late November.

Key areas to be assessed as part of the simulation studies include:

- Width of the swing basin perpendicular and parallel to the berth
- Width of the drag area
- Width required on the entry to the North Arm at Beacons No. 19 and 20
- Width around the first two bends for two container vessels passing and a container and tanker vessel passing (if allowed by the harbour master)
- Minimal width for the tankers if the existing channel width is to be narrowed

6.3 Discrete Event Simulation

It is proposed that the Discrete Event Simulation (DES) be undertaken in two parts.

- Initial DES to assess the need for a one, part one - part two way or full two way channel and determine the effect that a tide restricted port will have on vessel delay times.
- Detailed DES that includes metocean and UKC inputs to refine the need for a 1 way, part one - part two way or full two way channel and the depths required.

6.3.1 Model Development

The initial DES will have the following simplifications to allow the work to be done quickly:

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- Fixed time at berth based on the vessel size
- No consideration of tug, pilot or line boat availability
- Berth allocation will be based on LOA and up to 80% of the total berth length being occupied
- No anchorage or tankers
- Percentage allowance for downtime due to metocean conditions
- Limited number of snapshots throughout the demand forecast period
- Two vessel spectra corresponding to the constrained and unconstrained cases

The tidal cycle will be included to assess the effect on vessel delays from restricting access at the bottom of the tidal range. With a tidal range of about 2.5m at Stony Point there is the potential for significant savings in depth by limiting access at the bottom of the tidal range. However this needs to be balanced with the commercial need to limit the delays to container vessels.

The initial DES will assist in narrowing the scope for the 2D simulations by defining which of the one way, part one - part two way or full two way channel patterns are mostly likely for the constrained and unconstrained scenarios.

The detailed DES will be a more sophisticated model that will remove the limitations of the initial DES by including:

- rules for berth allocation,
- metocean conditions and UKC requirements,
- tankers and the anchorage,
- Bass Strait vessels along with a potential by-pass channel in the north arm, if required,
- Tugs, pilots and line boats to assess the number required.

The models will be developed to generate ships calls from the time they depart the preceding port. This will allow for slow steaming into the Port of Hastings and delays prior to arrival at the Port to be measured separately.

6.3.2 Outputs

The acceptability of the channel design will be determined by safety considerations and the average and maximum delays to ships.

The key performance indicators for the port will be developed by the Commercial & Economic workstream and may include the following:

- Maximum allowable waiting time to service time ratio
- Maximum allowable single delay (excluding severe weather events)
- Maximum average delay

Delays will be summarised by:

- Berth occupancy delay due to no available berths
- Channel delay due to extreme weather or poor visibility (includes the pilot not being able to board the vessel)
- Channel UKC delay due to insufficient UKC in the channel
- Channel occupancy delay due to congestion in the channel

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Scenarios that are proposed to be tested in the initial DES are outlined in Table 7. The detailed DES will be undertaken in two parts with a workshop after the initial scenarios have been run to review the results and agree on any additional scenarios to be tested. Scenarios that are proposed to be tested in the detailed DES are outlined in

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Table 8.

Table 7. Initial DES Scenarios

Variable	Options	Comment
Demand Forecast	Constrained Unconstrained	There are two constrained scenarios developed by Commercial & Economic (C&E) and it is proposed to test the Swanson stevedore transfers to Port of Hastings in 2034 scenario
Vessel Speed	Fixed	An appropriate speed based on input from the harbour master and pilots
Channel Configuration	One-way Part one – part two way Two-way	The part one – part two way alignment is two way in the Western channel and one-way in the North Arm The two-way channel will only be tested for the year of maximum vessel arrivals
Tidal Limitations	None (LAT) MLWS (+0.6m) MLWN (1.0m)	These will be review when the percentage of time that the tide is below this level is known.
Year	2045, 2055, 2065	These correspond with the maximum vessel calls
Time at Berth	Fixed	Fixed time at berth based on the vessel size
Arrival Distribution	As per current	As developed by C&E based on the current arrival patterns into the Port of Melbourne

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Table 8. Detailed DES Scenarios

Variable	Options	Comment
Demand Forecast	Constrained Melb Fully Opened Constrained Stevedore Move Unconstrained	Three forecast demand scenarios developed by C&E
Vessel Speed	Single Speed High Single Speed Low High speed in the Western Channel and Low speed in the North Arm	The speeds to be used will be determine following the workshop with the harbour master
Channel Configuration	One-way Part one – part two way Two-way	The part one – part two way alignment is two way in the Western channel and one-way in the North Arm The two-way channel will only be tested you the year of maximum vessel arrivals
Tidal Limitations	None (LAT) MLWS (+0.6m) MLWN (1.0m)	These will be review when the percentage of time that the tide is below this level is known.
Year	5 year intervals	
Time at Berth	Varies	Taken from the landside DES
Arrival Distribution	As per Current Variation	As developed by C&E based on the current arrival patterns into the Port of Melbourne. Due to the current low utilisation of Swanson Dock the container vessels have limited restrictions on when they can arrive into the Port of Melbourne. It is proposed that a variation in the arrival pattern is developed to smooth out the peaks on the basis that the shipping lines will adjust their schedule to suitable berth availability.

7.0 Channel Optimisation Work Plan

Below is a summary of the work plan for the channel design for navigation.

Stage 1 is currently underway and focuses developing initial layouts, meeting with key stakeholders and refining the scope for the stage 2 modelling.

Stage 2 involves numerical and simulation modelling to refine the alignment and develop the options for the integrated options assessment.

Stage 3 is the final proof of concept for the preferred options to be developed as part of the preliminary design.

- Stage 1
 - Concept Design – Current
 - Initial Discrete Event Simulation – Nov
 - Pilots and Harbour Master Workshop – Late Nov
 - Specifications and Scoping of UKC, DES and 2D Simulations – Late Nov – Early Dec
- Stage 2
 - UKC Analysis – Mid Dec – March
 - 2D Simulations – Mid Dec – March
 - Design of Navigation Aids – April
 - Discrete Event Simulation – Feb – May
 - Initial Channel Design Report – June
- Stage 3
 - 3D Real Time Simulations - Oct
 - Channel Design Report – Nov 2015



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Appendix A Concept Channel Plans

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Appendix B Concept Channel Design

Channel Arrangement

For the purposes of the concept design the approach channel has been divided into the following segments as outlined in Table 9 and presented in Figure 4.

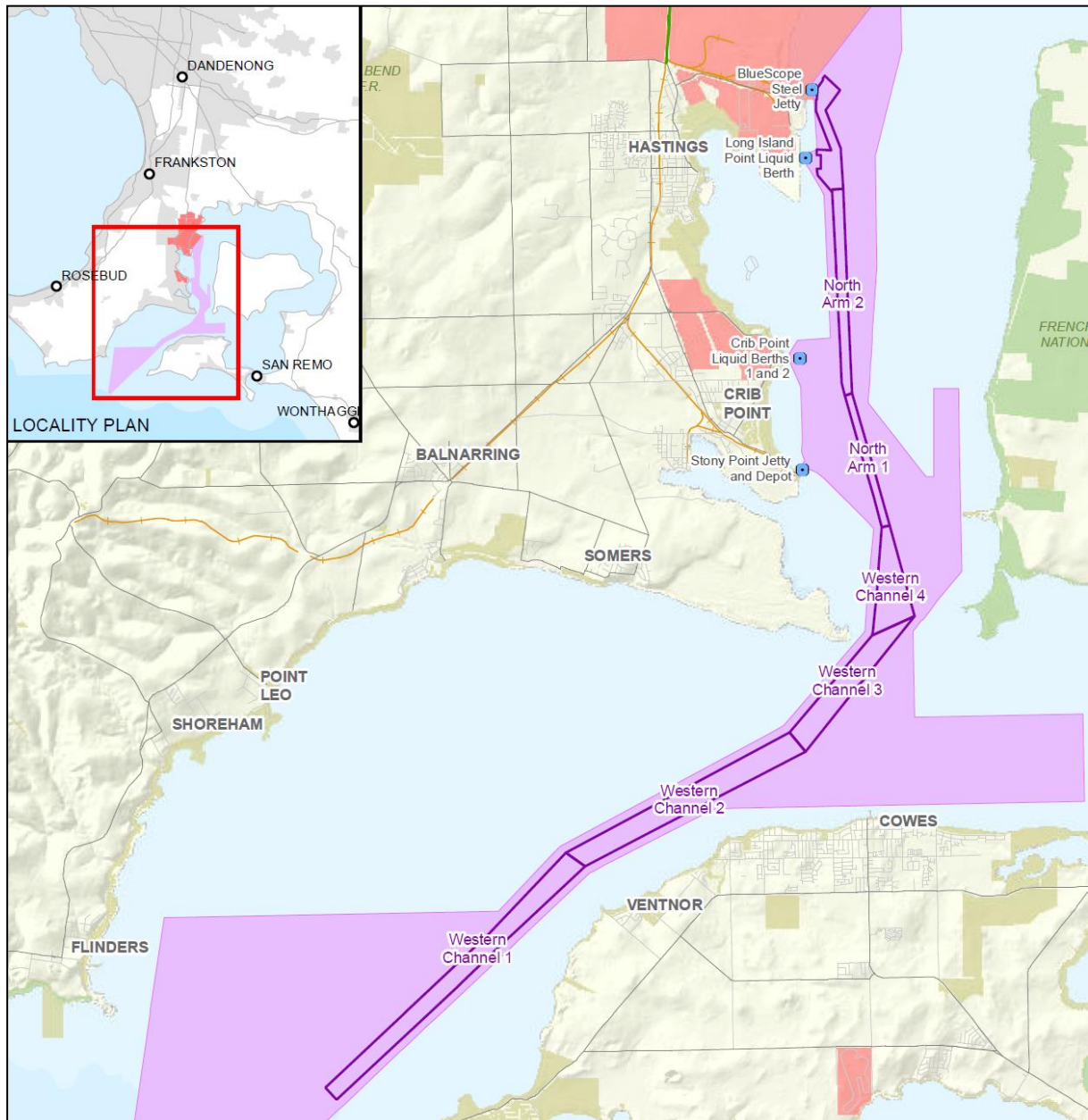


Figure 4. Channel Segments

Table 9. Channel Segments

Section No.	Section Name	Approx. Chainage (m)	Beacons
1	Western Channel 1	0 – 15,075	Port limits to No. 7/8
2	Western Channel 2	15,075 – 21,050	No. 7/8 to No. 13/14
3	Western Channel 3	21,050 – 24,650	No. 13/14 to No. 17
4	Western Channel 4	24,650 – 27,000	No. 17 to No. 19/20
5	North Arm 1	27,000 – 30,100	No. 19/20 to No. 23/24
6	North Arm 2	30,100 – Swing Basin	No. 23/24 to No. 35

Channel Width Factors

PIANC 2014 provides the following formula for determining the channel width for concept design:

- One-Way Channel Width (W) = $W_{BM} + 2\Sigma W_i + W_{Br} + W_{Bg}$
- Two-Way Channel Width (W) = $2W_{BM} + 2\Sigma W_i + W_{Br} + W_{Bg} + \Sigma W_p$

Where:

- W_{BM} is the width of basic manoeuvring lane as a multiple of the design ship's beam
- ΣW_i additional widths to allow for the effect of wind, current, waves etc
- W_{Br} , W_{Bg} is the bank clearance on the 'red' and 'green' sides of the channel
- ΣW_p is the passing distance, comprising the sum of a separation distance between both manoeuvring lanes and an additional distance for traffic density.

A number of the criteria are subjective and the following sections discuss the rationale behind the criteria that has been used.

Inner/Outer Channel

PIANC 2014 gives the following description for outer and inner channels:

- An outer channel in open water and exposed to waves that can produce significant vertical ship motions of heave, pitch, and roll.
- An inner channel that lies in relatively sheltered waters and is not subject to wave action of any significance to large ships.

A swell wave model setup by the Hydrodynamic work stream (HAS-CEP0-HY-REP-0001) found that once the swell waves reached Sandy Point the H_s is 0.2m and T_p is 7 seconds (refer to Figure 5). Within Western Channel 2 and 3, H_s is between 0.7-1.3m and T_p is between 7-11 seconds.

Long duration swell waves affect the heave, pitch and roll of vessels and Western Channel 1-3 are considered as Outer Channel while the remainder is considered as Inner Channel.

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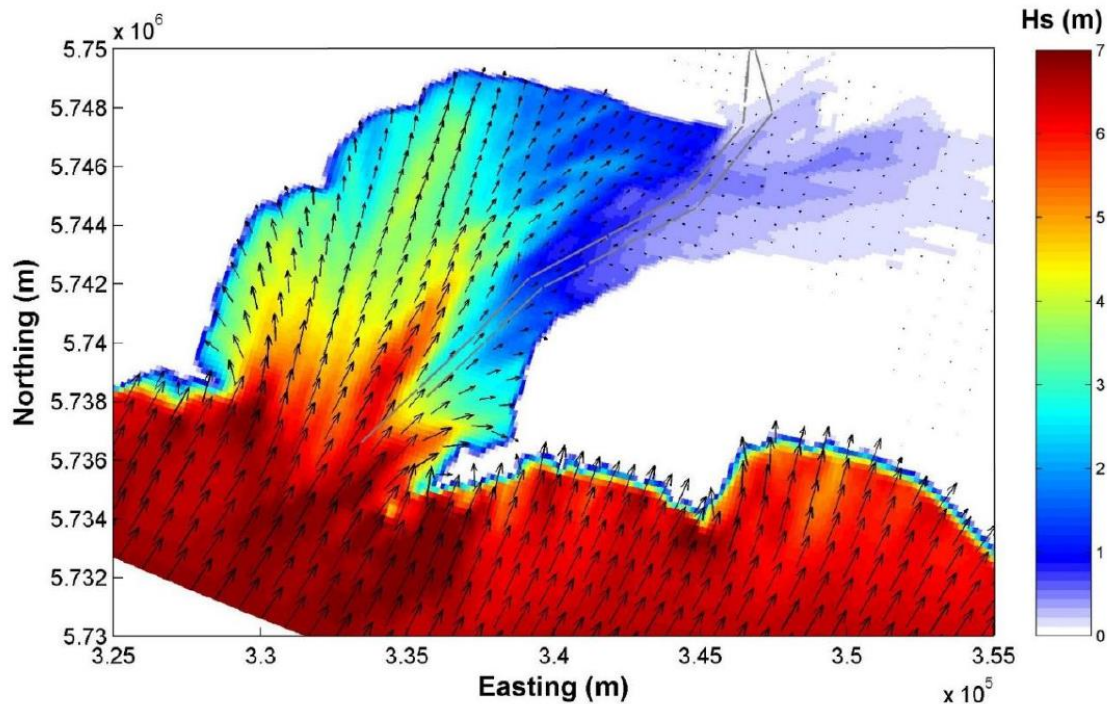


Figure 5. H_s and wave vectors for the largest wave height with a 0.01% probability of exceedance at waverider buoy Sweetwaves at Point Nepean (Figure 6 from HAS-CEP0-HY-REP-0001)

Basic Manoeuvring Lane

PIANC 2014 recommends moderate manoeuvring characteristics (1.5B) for container vessels and poor manoeuvring characteristics (1.8B) for container vessels.

Vessel Speed

PIANC characterises vessel speed into the following categories:

- Fast - $V_s \geq 12$ kts
- Moderate - $8 \text{ kts} \leq V_s < 12$ kts
- Slow - $5 \text{ kts} \leq V_s < 8$ kts

Faster speeds result in a narrower channel because the ship is more controllable, however this is offset by the need to have a deeper channel. For container vessels both fast and moderate vessel speeds have been considered while for tankers only moderate speed has been considered. It was found that the differences between the speeds are minimal (0-3m for one way and 0-18m for two way) and the larger dimensions have been used.

Prevailing Cross Wind

Table 10 outlines the PIANC wind categories and the percentage exceedance for a 10 minute duration wind at an industrial site near Hastings (HAS-CEP0-HY-REP-0001). A wind category of moderate has been used.

Table 10. PIANC Wind Categories and Percentage Exceedance for an Industrial Site Near Hastings

PIANC wind category	% Exceedance (10 min duration)
Mild - $V_{cw} < 15$ kts (< Beaufort 4)	20%
Moderate - $15 \text{ kts} \leq V_{cw} < 33$ kts (Beaufort 4 - Beaufort 7)	0.1%

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Strong - $33 \text{ kts} \leq V_{cw} < 48 \text{ kts}$ (Beaufort 7 - Beaufort 9)

>0.1%

Prevailing Cross Current

A 2-Dimensional depth-averaged hydrodynamic model of Western Port was run for a 30 day period by the Hydrodynamic workstream (HAS-CEP0-HY-REP-0001) and the modelled peak flood and ebb tides are outlined in Figure 5.

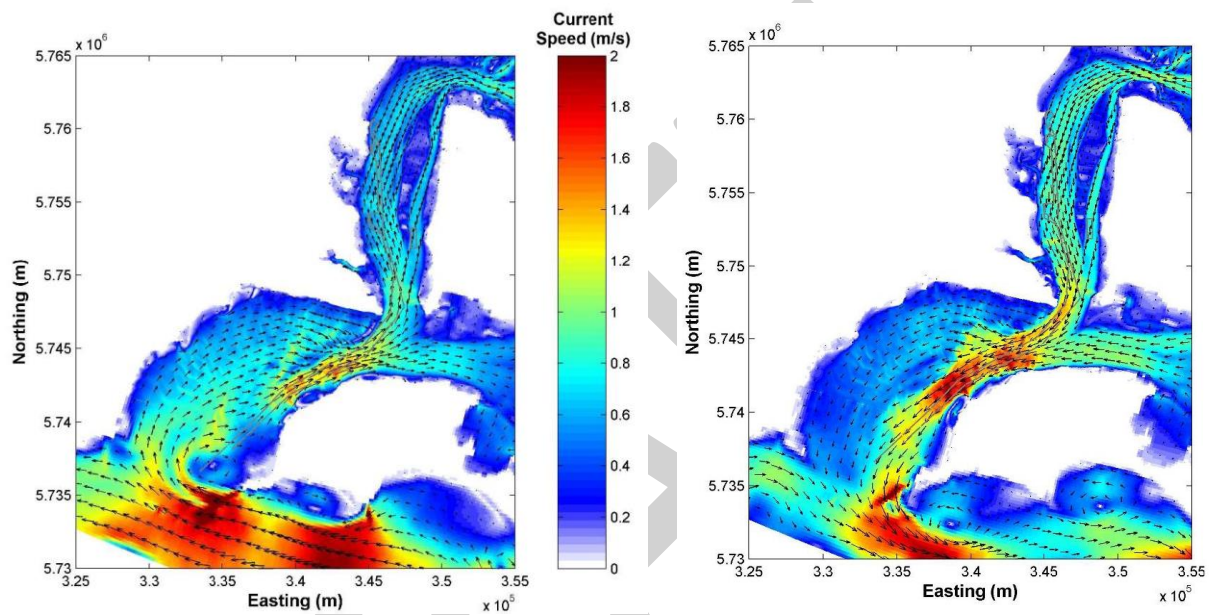


Figure 5. Modelled Peak Flood and Ebb Tides

PIANC categories the prevailing cross current as follows:

- Negligible $V_{cc} < 0.2 \text{ kts}$
- Low $0.2 \text{ kts} \leq V_{cc} < 0.5 \text{ kts}$
- Moderate $0.5 \text{ kts} \leq V_{cc} < 1.5 \text{ kts}$
- Strong $1.5 \text{ kts} \leq V_{cc} < 2.0 \text{ kts}$

The tide largely follows the path of the channel and the prevailing cross current has been considered the be Low.

Prevailing Longitudinal Current

PIANC categories the prevailing longitudinal current as follows:

- Low $V_{lc} < 1.5 \text{ kts}$
- Moderate $1.5 \text{ kts} \leq V_{lc} < 3 \text{ kts}$
- Strong $V_{lc} \geq 3 \text{ kts}$

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Figure 5 shows that the maximum current in the Western Channel is about 2kts whereas in the North Arm Channel the maximum current does not appear to exceed 1.5kts. Therefore the Western Channel has been categorised as Moderate and the North Arm has been categorised as Low

Beam and Stern Quartering Wave Height

PIANC categories the beam and stern quartering wave height as follows:

- $H_s \leq 1$ m
- $1 \text{ m} < H_s < 3$ m
- $H_s \geq 3$ m

Figure 5 outlines that waves with a H_s of up to 3m can occur in Western Channel 1, however they tend to be on the bow or stern based on the initial modelling undertaken. Given the exposure to waves within Western Channel 1 the largest wave category has been considered. Once past the first bend in the channel the waves have a significant wave height of less than 3m and the middle categories was considered for the remainder of the Western Channel.

Within the port near wind driven waves with a 1 year ARI was found to produce a significant wave height (H_s) of up to 1m with a period (T_p) of 3.5 seconds. A significant wave height of less than 1m was considered for the North Arm and Port Area.

Aids to Navigation

Excellent corresponds to paired lit buoys with radar reflectors, lit leading lights and VTS along with the availability of pilots, DGPS and ECDIS. It is assumed that this level of aids to navigation will be provided.

Depth of Waterway

In the Western Channel the depth is generally between 1.25-1.5T, however in some sections it is much deeper.

In the North Arm the depth will generally be $< 1.15T$

Width for Bank Clearance

Slopes in Western Channel segments C1-3 are generally much wider and deeper than required with slopes less than 1:10.

In Western channel segment 4 and up to the port area the slopes are around 1:5, however they are steeper in some sections, dredged slopes are likely to be around 1:3.

Traffic Density

For the constrained scenarios there will be on average more than 3 vessels per day from 2042 in the constrained Melbourne fully open scenario and from 2037 in the constrained stevedore move scenario. For the unconstrained scenario the maximum annual average is less than 3 vessels per day throughout the forecast period.