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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Memorandum

To	Matthew Primmer
CC	Peter Fountain, Ian Cookson, Richard Clarke, Richard Hill
Subject	Channel Design for Construction – Stage 1 Preliminary Recommendations for Dredging Tolerances and Batter Slopes
From	Stephen Martin
File/Ref No.	AGH- CEP0-EG-MEM-0017 Date 3-Dec-14

Final Working Draft

1.0 Background

This Stage 1 assessment is intended to assist with preliminary estimates of dredge volumes which will be completed as part of the Dredge and Reclamation Work Package. The concept channel location, design depth, alignment and width have been determined as part of the Concept Channel Design for Navigation Work Package providing a theoretical channel footprint. The total dredge volume associated with the channel design for navigation will include additional volumes associated with batter slopes, an allowance for future siltation that guarantees that the declared depth is maintained between maintenance dredging campaigns, and an allowance for overdredging.

This memo provides preliminary recommendations for overdredging allowances and batter slopes to be used in the calculation of dredge volumes.

2.0 Channel Design for Navigation

The likely concept design depths given in Table 1 have been determined as part of the Concept Channel Design for Navigation Work Package.

Table 1 – Concept Design Depth

Channel Section	Concept Design Depth (mCD)
Western Channel 1	- 17.0
Western Channel 2	- 16.5
North Arm	-16.0
Port Area	-15.6

3.0 Overdredging Allowance

The preliminary dredging allowance to be adopted for channel design for construction is given in Table 2 and has been provided by Hadyn Pike of Baggerman Associates (30 October 2014).

Table 2 – Overdredging Allowance

Allowance		Comments
Vertical	0.5m	Applicable to all areas
Horizontal	3.0m	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

The overdredging allowances are expected to be refined as the dredging work methods are developed. For example if a trailer dredger is expected to be dredging in stiff to very stiff clay then the vertical overdredging allowance could increase to 1.0 metre and the horizontal overdredging allowance to 5.0 metres.

The vertical and horizontal overdredging allowances of 0.5m and 3.0m are generally in accordance with the recommendations given in BS6349-5 – Maritime Structures – *Code of Practice for dredging and land reclamation*. Tables 3 and 4 provide typical working vertical and horizontal accuracy for a range of dredging plant and soil types under various site conditions as given in BS6349-5, where adjustments for site conditions are added to the 'Bed Material' figures. For example the vertical accuracy for a standard trailer dredging soft clay using large plant in sheltered water with a strong current is 250mm + 75mm + 100mm = 425mm. A similar vertical overdredging allowance is given in the 2014 PIANC publication - *Harbour Approach Channels Design Guideline* which states that a typical vertical overdredging allowance is 0.2 to 0.5 m, depending on bottom and dredger.

Table 3 -Typical working vertical accuracy from BS6349-5

	Standard Trailer	Cutter Suction	Backhoe
Bed Material	**(mm)**	**(mm)**	**(mm)**
Loose silt	200	200	150
Cohesive silt	300	150	150
Fine sand	200	150	150
Medium sand	200	150	150
Soft clay	250	150	150
Medium clay	300	150	150
Stiff clay	250	150	150
Adjustments for site conditions			
Sheltered Water – Large Plant	75	100	75
Exposed Water Large Plant	200	300	250
Current – Moderate (0.5m/s)	0	0	0
Current – Strong (1.0m/s)	100	50	0

Table 4 -Typical working horizontal accuracy from BS6349-5

	Standard Trailer	Cutter Suction	Backhoe
Bed Material	**(mm)**	**(mm)**	**(mm)**
Loose silt	2500	500	250
Cohesive silt	2500	500	250
Fine sand	2500	500	250
Medium sand	2500	500	250
Soft clay	2500	500	250

Medium clay	2500	500	250
Stiff clay	2500	500	250
Adjustments for site conditions			
Sheltered Water – Large Plant	500	500	300
Exposed Water Large Plant	1500	1000	700
Current – Moderate (0.5m/s)	1000	500	200
Current – Strong (1.0m/s)	2500	1500	700

4.0 Geotechnical Conditions

Ground conditions are described in the Geotechnical Interpretative Report (AGH-CEP0-EG-REP-0009). A summary of the ground conditions relevant to dredged batter slopes is given below. Boreholes have been drilled on a wide grid, typically at 500m spacing in the Port Area and up to 2000m spacing in the Western Channel and North Arm. Materials within the dredge depth are interbedded and exhibit both vertical and lateral variability across the proposed dredge area. There is also potential for additional variability of materials between boreholes which has not been identified however the available information is considered adequate for the current study phase and it is recognized that further investigations will be undertaken as part of future design stages.

Western Channel

Two boreholes were drilled in the Western Channel as part of the 2013/2014 marine geotechnical investigation. Borehole WC3 encountered loose Quaternary marine deposits at seabed for 0.6 m overlying stiff silty clay and medium dense to very dense silty sand and borehole WC4 encountered basalt from seabed which was highly weathered and very low strength at surface.

The geophysical survey shows significant variation in elevation of the rock reflector in the Western Channel ranging from at or just below seabed to elevations of around -45 mCD. The 1974 seabed investigation in the Western Channel also encountered variation in rock elevation with only nine of the 27 boreholes in the Western Channel encountering rock at elevations ranging from approximately -16.5mCD to 22.5mCD.

Localised dredging and removal of high spots in the Western Channel is expected to encounter weathered basalt rock. For dredged batter stability analysis seabed materials have been assumed to comprise stiff clay or medium dense sand.

North Arm

Recent Quaternary marine deposits are present from seabed and typically comprise very loose to loose sand and clayey sands, typically to depths of up to 0.5 m below seabed. Baxter Formation is present below the Quaternary deposits to depths of up to 8m below seabed and typically present to below the proposed channel dredge depth. These materials typically comprise stiff to hard clay and silty clay, and medium dense to very dense sand.

Port Area

Ground conditions in the Port Area typically comprise Quaternary marine and undifferentiated Quaternary deposits from seabed overlying Baxter Formation which overlies Sherwood Formation.

Materials encountered from seabed comprise a surficial layer of low strength Quaternary marine deposits typically very loose and loose sand, and soft and very soft silty clay and sandy silt to depths typically less than 1.5 m below seabed.

The Quaternary deposits overlie the Baxter Formation which includes clayey sand, sandy clay, silty sand and silty clay. This unit is typically relatively competent comprising clay and silt materials of stiff to very stiff consistency and medium dense to dense sand materials.

The Baxter Formation also includes layers of very loose and loose silty and clayey sands. The average thickness of these layers is around 1.5 m but can be as great as 5 m as seen in borehole R3 which encountered very loose to loose silty sand from 6 to 11 m below seabed (approximately -11 mCD to -16 mCD). Infrequent soft to firm layers are also present within the Baxter Formation.

Underwater dredged slopes along the proposed channel and basin edges are expected to be in Quaternary deposits and Baxter Formation.

5.0 Existing Underwater Slopes

A summary of existing underwater slopes is given in Table 5 for slopes in the Port Area, and in Attachment A for slopes in the Western Channel and North Arm. These slopes are based on available bathymetric data and provide an indication of the long term batter angles which can be achieved in these materials.

Slopes given in Table 5 and Attachment B are based on inspection of bathymetric contours at individual slopes and are assumed to include natural and dredged slopes. These slopes are assumed to be in the Baxter Formation however due to the interbedded nature of these materials it is not possible to determine whether they are predominantly in clayey or sandy materials. Slopes given in Attachment A for the Western Channel and North Arm are provided at 1km intervals and have been averaged over a 20m channel width, and are thought to typically represent natural slopes.

Table 5 – Existing slope profiles in the Port Area

ID	Location	Slope	Dredged/Natural
1	Port Area – Northern end of swing basin	1V:4.3H	Dredged
2	Port Area – Northern end of swing basin	1V:2.6H	Dredged
3	Port Area – Northern end of swing basin	1V:2.4H	Dredged
4	Port Area – South of BlueScope Wharf – west of channel	1V:4.25H	Dredged?
5	Port Area – South of BlueScope Wharf – west of channel	1V:3.2H	Natural?
6	Port Area – South of BlueScope Wharf – west of channel	1V:3.2H	Natural?
7	Port Area – South of BlueScope Wharf – west of channel	1V:12H	Natural
8	Port Area – Crib Point – North of jetty	1V:3.9H	Dredged
9	Port Area – Crib Point – South of jetty	1V:3.0H	Dredged
10	Port Area – South of Crib Point	1V:14H	Dredged
11	North Arm	1V:5.3H	Dredged?
12	North Arm	1V:8.5H	Dredged?

6.0 Slope Stability Analysis of Underwater Slopes

Slope heights used for stability analysis are given in Table 6. A nominal siltation allowance of 0.5m has been adopted for the purposes of stability assessment. Changes to the siltation allowance and the overall slope height are not expected to have a significant effect on overall stability.

Table 6 – Slope details for geotechnical stability analysis

Channel Section	Declared Depth (mCD)	Overdredge allowance (m)	Siltation Allowance (m)	Existing Seabed RL (mCD)	Maximum slope height (m)	Comment
Western	- 16.5	0.5	0.5	-16	1.5	-

Channel						
North Arm	-16.0	0.5	0.5	-14.0	3.0	-
Port Area 1	-15.6	0.5	0.5	-4.0	12.6	At northern end of channel (Along the shore option)
Port Area 2	-15.6	0.5	0.5	-11.0	5.6	Average along channel (Along the shore option)
Port Area 3*	-15.6	0.5	0.5	+4.0	20.6	For Basin Option - landward of groyne structure. Includes underwater and above water slopes

Note: *Batter slopes for this area are to be confirmed in future stages of this work package when basin geometry has been confirmed.

The long term geotechnical stability of dredged slopes has been assessed using 2D limit equilibrium software (Rocscience Slide Version 6.0) and adopting a minimum factor of safety of 1.5 for normal conditions. Soil parameters have been based on the recommendations given in the Draft Geotechnical Interpretative Report (AGH-CEP0-EG-REP-0009).

Slope stability analysis has assumed Quaternary materials comprise very soft clay with an assigned friction angle of 17 degrees or an undrained shear strength of 2.0 +1.5z kPa (z = depth in metres below seabed) which is expected to govern stability compared to very loose sands which have a friction angle of 25 degrees. For dredged slopes in Baxter Formation analysis has been completed for both medium dense sand and stiff clay materials which are typical for this geological unit. The effect of layers of low strength materials in the Baxter Formation on overall slope stability has also been assessed. An example output from the slope stability analysis for the Port Area is given in Figure 1 for a 1V:3H slope in medium dense sand and a 1V:5H slope in the upper very soft clay which is assumed to be 1.0m thick. Figure 2 shows shallow surfaces with a factor of safety of less than 1.5 which may be expected where layers of very loose and/or loose sand are present in a 1V:3H slope, and Figure 3 shows shallow surfaces with a low factor of safety which may be expected in Quaternary deposits where they are dredged at a 1V:3H slope.

Figure 1 – Typical Slide output with factor of safety >1.5

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
2_MD Sand		18	Mohr-Coulomb	0	30	Water Surface	Custom	1
5_VS Clay		14	Mohr-Coulomb	0	17	Water Surface	Custom	1

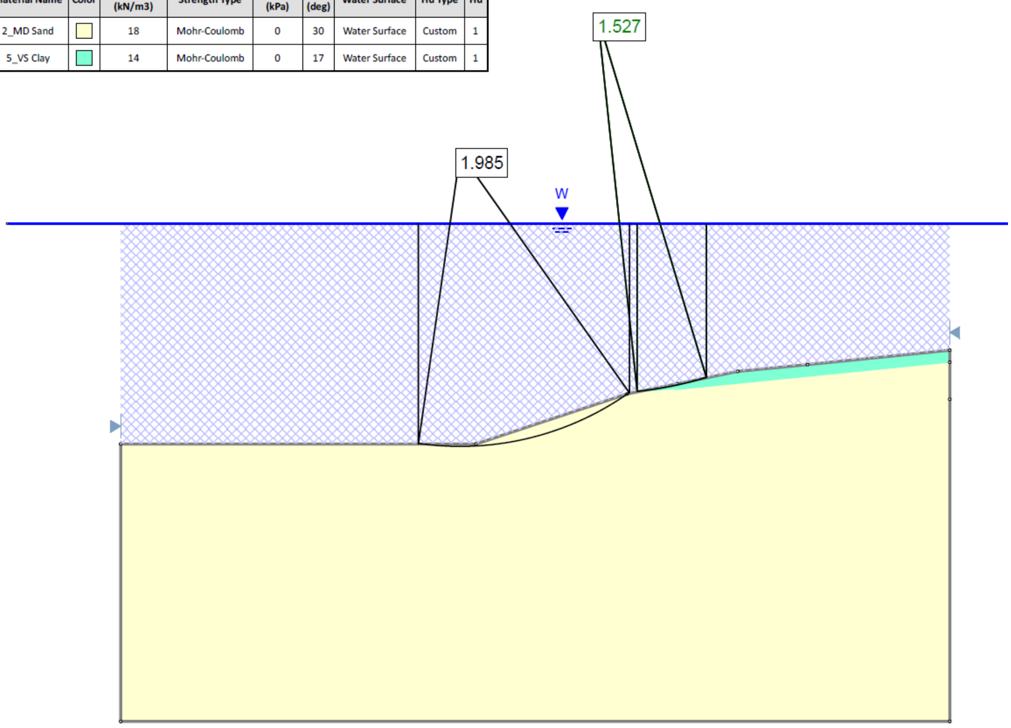

Figure 2- Shallow failure surfaces in very loose and loose sand layers (1V:3H Slope)

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
1_Stiff Clay		19	Mohr-Coulomb	5	26	Water Surface	Custom	1
2_MD Sand		18	Mohr-Coulomb	0	30	Water Surface	Custom	1
3_Firm Clay		18	Mohr-Coulomb	2	24	Water Surface	Custom	1
4_VLoose Sand		16	Mohr-Coulomb	0	25	Water Surface	Custom	1
5_VS Clay		14	Mohr-Coulomb	0	17	Water Surface	Custom	1
6_L Sand		17	Mohr-Coulomb	0	27	Water Surface	Custom	1
7_V Stiff Clay		19	Mohr-Coulomb	7.5	28	Water Surface	Custom	1

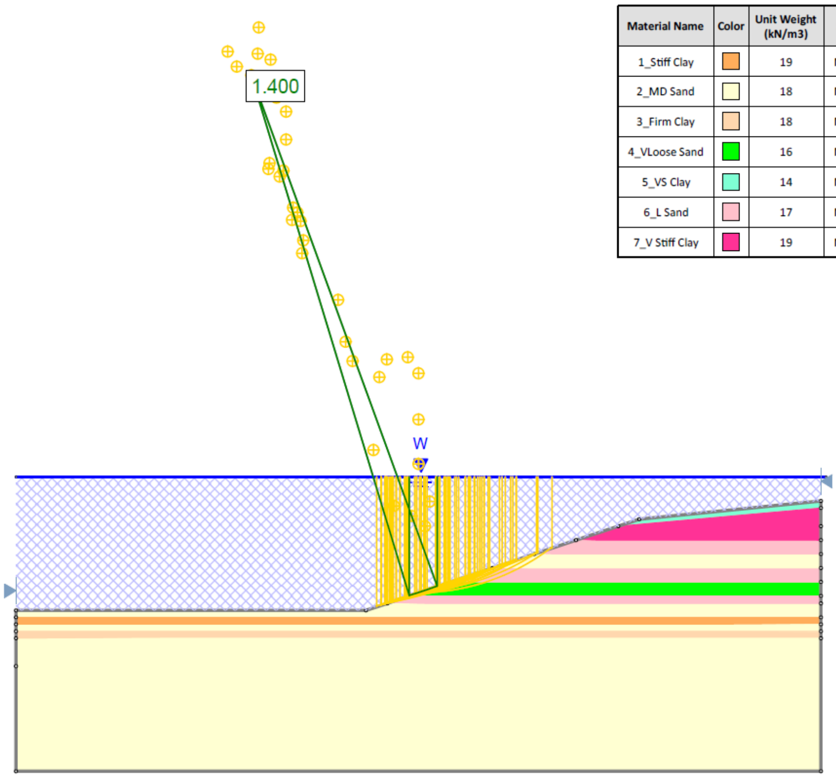

Figure 3 - Factor of Safety < 1 for very soft clay at 1V:3H slope

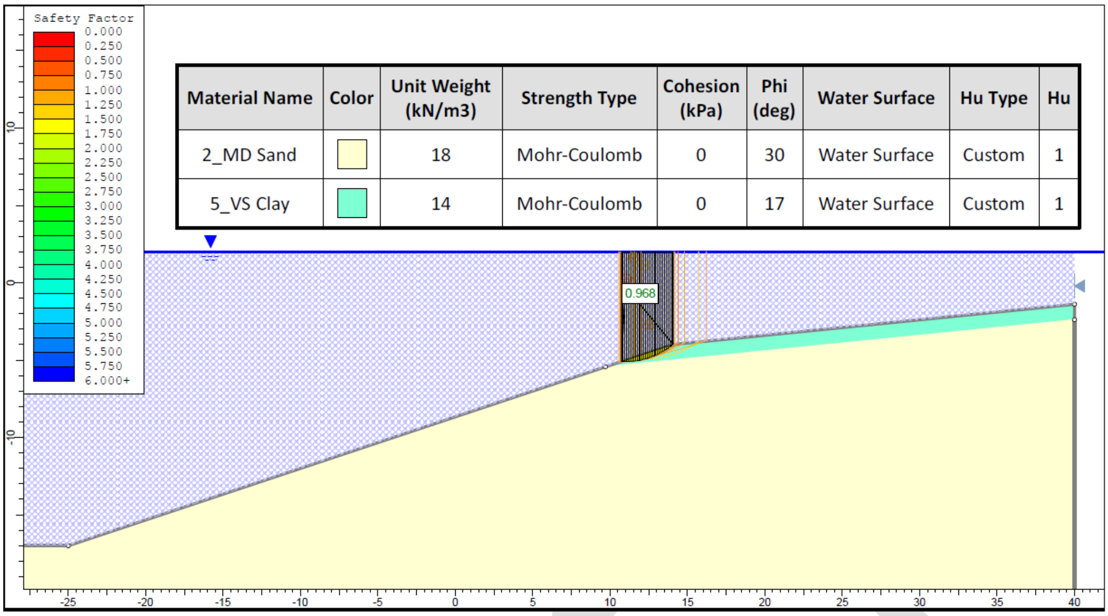

Table 7 provides a summary of dredged slope angles with a theoretical factor of safety greater than 1.5.

Table 7 –Slope profiles with a factor of safety > 1.5

Channel Section	Assumed Ground Conditions	Nominal Slope Angle
Western Channel	Quaternary deposits	1V:5H*
	Stiff Clay or Medium Dense Sand (or better)	1V:3H
North Arm	Quaternary deposits	1V:5H*
	Stiff Clay or Medium Dense Sand (or better)	1V:3H
Port Area	Quaternary deposits	1V:5H*
	Stiff Clay or Medium Dense Sand (or better)	1V:3H
	Stiff Clay or Medium Dense Sand with layers of loose to very loose sand – e.g. Borehole R3	1V:4H

Note: *Very soft normally consolidated and recently flocculated clays and silts may flow at very low angles

7.0 Hydrodynamic Effects on Slope Stability

The stability of underwater dredge slopes will be influenced by hydrodynamic effects associated with current and wave action and propeller wash acting on the slope. To account for these factors it is typical to adopt flatter slopes than those required for geotechnical stability. The recommendations given in BS 6349-1-3:2012 – *Maritime Works – General – Code of Practice for Geotechnical Design* for underwater slopes for both still and active water conditions are given in Table 8. Quaternary materials would fall into the mud and silt category and Baxter Formation materials are closest to the sandy clay and stiff clay soil types.

Table 8 – BS 6349-1-3 - Recommended underwater slope profiles in still and active water

Soil Type	Side Slope			
	Still Water		Active Water	
Rock	Nearly Vertical		Nearly Vertical	
Stiff Clay	45°	1V:1H	45°	1V:1H
Firm Clay	40°	1V:1.9H	35°	1V:4.3H
Sandy Clay	25°	1V:2.1H	15°	1V:3.7H
Coarse Sand	20°	1V:2.75H	10°	1V:5.7H
Fine Sand	15°	1V:3.7H	5°	1V:11.4H
Mud and Silt	10° -1°	1V:5.7H to 1V:57H	5° or less	<1V:11.4H

Slopes in active water are typically 5-10 degrees flatter compared to those in still water however the definition of active water is not given in BS6349-1-3. Based on preliminary discussions with the Hydrodynamics team it is suggested that the channels should be considered as 'Active Water' for this preliminary stage of the assessment. The results of hydrodynamic modelling and the influence of hydrodynamic effects on underwater dredge slopes will be considered in future stages of this work package.

8.0 Recommended Slope Profiles

The recommended slope profiles for use in the preliminary assessment of dredge volumes are given in Table 9 and have been based on the requirements for geotechnical stability considering the variability of ground conditions across the site, the likely hydrodynamic effects associated with waves, current and vessels, and considering existing dredge and natural slope profiles along the channel.

Table 9 – Recommended underwater slope profiles for calculation of dredge volumes

Location	Slope
Port Area – Quaternary Materials	1V:10H*
Port Area – Clay and Sand Materials (Baxter or Sherwood Formation)	1V:4H
Port Area – Clay and Sand Materials (Baxter or Sherwood Formation) – At northern end of channel approximately perpendicular to direction of current	1V:5H
North Arm – Quaternary Materials	1V:10H*
North Arm – Baxter Formation	1V:4H
Western Channel – Quaternary Materials	1V:10H*
Western Channel – Residual Soil	1V:3H

Note: *Very soft normally consolidated and recently flocculated clays and silts may flow at very low angles flatter than 1V:10H and could be as low as 1 degree. This is applicable to surficial deposits which are typically less than 1.5m thick. Potential flow of these materials will also be dependent on the local bathymetry. Where there is potential for these materials to flow into the channel they may need to be removed by additional dredging or included as part of the siltation allowance.

It is assumed that for the basin option a training structure or groyne will be constructed along the northern side of the channel to minimise siltation of the channel. The stability of batter slopes landward of the groyne (between the end of the terminal area and the start of the groyne), which includes above water and underwater slopes will be completed as part of future stages of this work package when basin geometry has been confirmed.

9.0 Further Work

The following works are to be completed as part of future stages of this work package:

- Review siltation rates from the Hydrodynamics team and assessment of siltation volumes for a range of maintenance dredging frequencies and associated siltation allowance. This may include dredge scenario modelling to compare the frequency of maintenance dredging, siltation volumes and dredge equipment and methods.
- Assessment of options for siltation management – e.g. the use of silt traps to reduce the frequency of maintenance dredging.
- Undertake a detailed review of proposed dredge technology requirements, production rates and geotechnical data to review and update the proposed overdredge allowance.
- Review and update channel batter slope design to include all dredge areas including batter slopes associated with the basin option. This will also include further consideration of hydrodynamic effects based on the results of the hydrodynamic modelling by the Hydrodynamics team.