REPORT

Southwold Harbour Investment Plan

Assessment of Dredging Option

Client: East Suffolk Council

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1 Introduction

A high bank of sediment has built up close to the Southwold Harbour entrance channel, which restricts navigation and mooring at the North Wall, as shown in Figure 1-1below. Following discussions during the stakeholder meetings held in March and September, the Harbour Management Committee (HMC) is keen to explore whether it would be possible to dredge this sediment, with the aim of enabling increased mooring at the North Wall.

This report sets out the assessment that has been undertaken in order to develop a better understanding of the benefits and constraints of the proposed dredging, including:

1. The impact of removing the sediment on tidal flows at the North Wall and in the entrance channel;
2. The impact on wave conditions at the North Wall and further upstream;
3. Whether the proposed dredging could be undertaken as maintenance operations or would be considered to be capital works;
4. Whether ongoing maintenance dredging is likely to be needed;
5. Potential beneficial uses of any dredged material;
6. Any licence requirements for the proposed dredging; and
7. Any impacts on or from the dredging proposals due to other options proposed for the Southwold Harbour entrance, e.g. the proposed 'narrow channel' option.

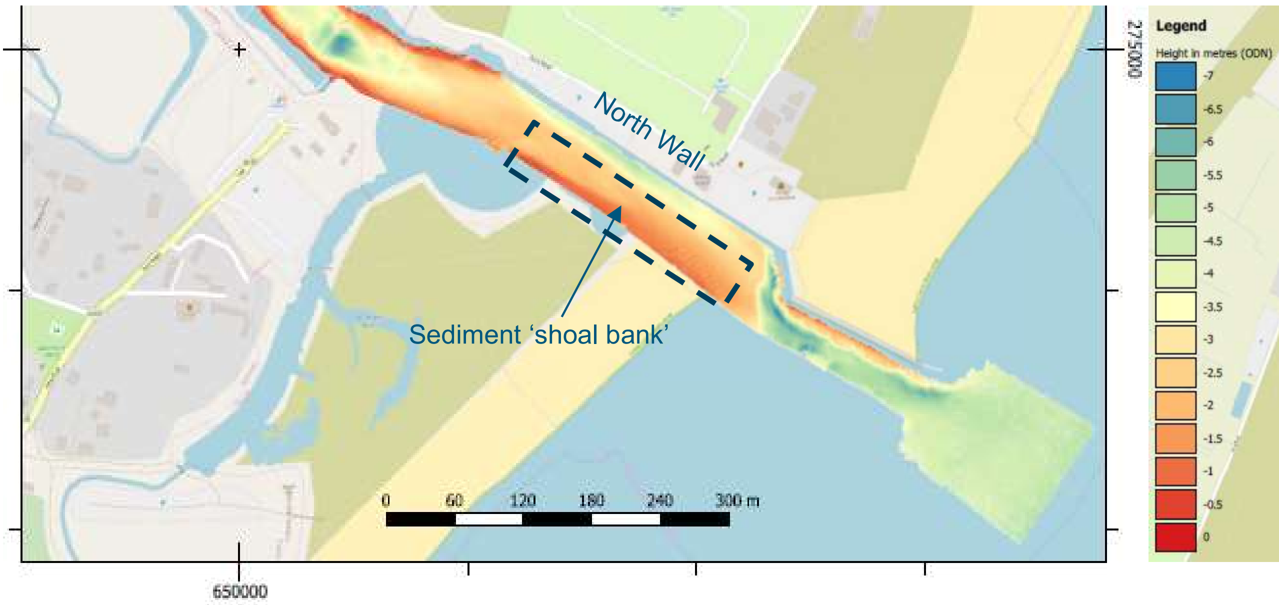

Figure 1-1 – Bathymetry of Southwold Harbour entrance (2020)

2 Approach

To review the benefits and constraints of dredging the shoal bank opposite the North Wall, we have undertaken the following activities:

a. Initial review of expected benefits and constraints of dredging the shoal bank, and preparation of a benefits and constraints note, issued to stakeholders for comment.
b. Review of historic evidence of shoal bank development.

c. Review of existing wave and tidal modelling results in the context of the dredging proposals.
d. Carry out additional Mike21 tidal modelling for a modified channel bed to represent the proposed dredging.
e. Review and update the sediment transport assessment, to include geomorphological review of potential future sedimentation of the outer harbour area, with and without dredging, and an assessment of whether the shoal bank is likely to re-establish in the future.
f. Review the requirements for consents / licences and comment on delivery programme.
g. Present and discuss the findings of the additional modelling and analysis at a stakeholder meeting.
h. Prepare a Technical Note to summarise the findings of the additional modelling, analysis and consultation. Update the main project report to include the findings of this additional work.

3 Dredging Option

3.1 Historic Evidence of Shoal Bank Development

There is a long history of issues with sediment blocking the entrance to Southwold Harbour, which has resulted in many changes to the location of the mouth of the River Blyth and the harbour entrance, with records dating back to medieval times[1]. Historically, several attempts were made to find a sediment 'free' entrance by trial-and-error relocation of the river mouth. The first seawards projecting pier was built in 1750, most likely with the aim of reducing shingle infill, and was largely successful. The North and South Piers push the harbour entrance into deeper water, partly restricting the alongshore sediment transport pathway. The Piers also confine the ebb tidal flow, causing it to exit more rapidly than if it were the natural river outfall. The high flow speeds act to flush the entrance of sediment.

However, blockages of the harbour entrance have continued with the piers in place. Records showing that the harbour mouth was dredged 13 times 1805 and 1818. Sediment deposition in the early 19th century may have been aggravated by the reclamation of $12km^2$ of saltmarsh which reduced the tidal prism and associated tidal flow velocities. The 1971 article by Robert Simper, titled 'The Southwold Saga', states:

"The trouble is that on an on-shore N.E. gale, shingle is piled up across the harbour mouth and there is not a current strong enough to scour it away."

The sediment accumulation that developed on both the north and south sides of the harbour entrance in 1987 is shown in **Figure 3-1** and **Figure 3-2**. No similar issues have occurred in the last 20 years, which suggests that tidal flow speeds are usually sufficient to keep the entrance channel clear.

The sediment bank shown in **Figure 3-2** is the area of interest for this assessment. It is located opposite the North Wall, immediately upstream of the Knuckle, extending along the southern side of the channel towards the Dunwich Creek entrance. Often referred to as the 'shoal bank', whilst it is not currently as large as in this photo, it is still present. The shoal bank is reported by harbour users to affect the local hydrodynamic behaviour, with swell waves building over this shallow area. The high sediment bank can also cause incoming waves to break in this area.

[1] Ref: The history of Southwold, by John Winter and George Bumstead, BBC, Suffolk, 24.10.2014: (http://www.bbc.co.uk/suffolk/content/articles/2005/07/05/coast05_walks_john_winter_feature.shtml), and Ref: "The Southwold Saga" by Robert Simper, 22 January 1971 (incomplete reference).

Anecdotal evidence varies around how the shoal bank formed:

- change in tidal flow velocities and directions following construction of the Knuckle, resulting in an area of lower flow velocity opposite the Knuckle, and the deposition of shingle;
- flow from the Dunwich Creek combining with flow in the main river channel, resulting in disturbed flow patterns immediately downstream and an increase in the potential for sediment deposition;
- a one-off release of sediment from the Dunwich Creek entrance, possibly when the timber piling was installed in this area;
- ongoing deposition of sediment carried by flows from the Dunwich Creek; and
- material from offshore shingle banks driven into the harbour entrance during north-easterly storms.

It is likely that all of these scenarios have contributed to the establishment of the shoal bank. Once a build-up of sediment has begun it supports its own growth as wave heights and flow velocities decrease in the reduced water depths.

The presence of this bank of sediment means that the navigation channel into the inner harbour is forced to the north, close to the North Wall. This means that there is relatively limited space available for boats to berth at the North Wall, as it would restrict access for other vessels.

Figure 3-1: Sediment accumulation, north side of harbour, 1987

Figure 3-2: Sediment accumulation, south side of harbour, 1987

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3.2 Review of Harbour Bathymetry

The local bathymetry within the harbour, as recorded by the February 2020 hydrographic survey, is shown in **Figure 3-3**. Furthermore, **Figure 3-4** compares the 2020 survey with a previous survey undertaken in 2013 by the Environment Agency.

A comparison of the 2013 and 2020 bathymetric surveys shows that there has been relatively little change to the channel bed in the harbour entrance, and in the vicinity of the North Wall, during this 7-year period. The areas where the bed level is relatively lower or higher have not moved, including the area of the shoal bank. This is confirmed by anecdotal evidence from harbour users, so there is good confidence in both survey datasets.

A brief discussion is provided below of the comparison of the two surveys, for the outer part of the harbour (locations i. to vii. as indicated on **Figure 3-4**).

i. The North Pier is currently long enough to retain most beach material and sediment moving alongshore from north to south. Without the pier, sediment would move into the channel, as is known to have happened when the North Pier was shorter.

ii. At the mouth of the harbour, erosion of up to 1.5m (depth) has occurred.

iii. The channel bed level immediately adjacent to the seaward section of the South Pier (170m length) is 5.5m ODN. There has been up to 0.5m of erosion along the centre of the harbour entrance channel over the full length of the entrance since 2013.

iv. The channel bed level immediately adjacent to the landward section of the South Pier (100m length) is -2.0m ODN. In the centre of the channel where the North Pier meets the Knuckle, a small area of erosion of >2m is indicated. However, review of both surveys suggests that this is more likely to be due to errors in the 2013 survey, which did not record data over the full channel width in this area.

v. Sediment deposition of up to 0.5m is shown upstream of the Knuckle on both sides of the channel. The bank of sediment located on the southern side of the channel extends from opposite the Knuckle towards the Dunwich Creek entrance.

vi. Erosion of up to 1m is shown over the full channel width adjacent to the North Wall. This may indicate an ongoing trend of erosion of 0.1-0.2m/year, but further monitoring would be needed to confirm this.

vii. Seaward of the Walberswick Ferry, there may be ongoing erosion of up to 0.5m.

In reviewing the survey data, we have considered the significance of any changes. In general, only change of the order of +/-0.5m or greater is likely to indicate an ongoing trend in the sedimentation within the harbour area. The main area of change is from the harbour entrance to the north end of the North Wall, in the centre of the channel. For this area, an ongoing trend of erosion of 0.1-0.2m per year is indicated, but this would need to be confirmed by future monitoring.

In terms of the shoal bank opposite the North Wall, comparison of the bathymetric surveys in **Figure 3-4** indicates that this could be gradually extending or migrating to the south, towards the entrance channel, although with a reduction in the crest level of the bank of about 0.5m since 2013.

This potential change in the shoal bank has been considered further by reviewing the change in the bed level for three cross sections in this area, based on survey data from 2013, 2015 and 2020. This comparison is provided as **Figure 3-5**, and confirms the 0.5m reduction in bed level since 2013. The cross sections in **Figure 3-5** show that the width of the bank can vary (e.g. 1-2m increase in width between 2013 and 2015), although in 2020 the bank width was comparable to that recorded in 2013. This data does not indicate any noticeable southerly movement of the shoal bank.

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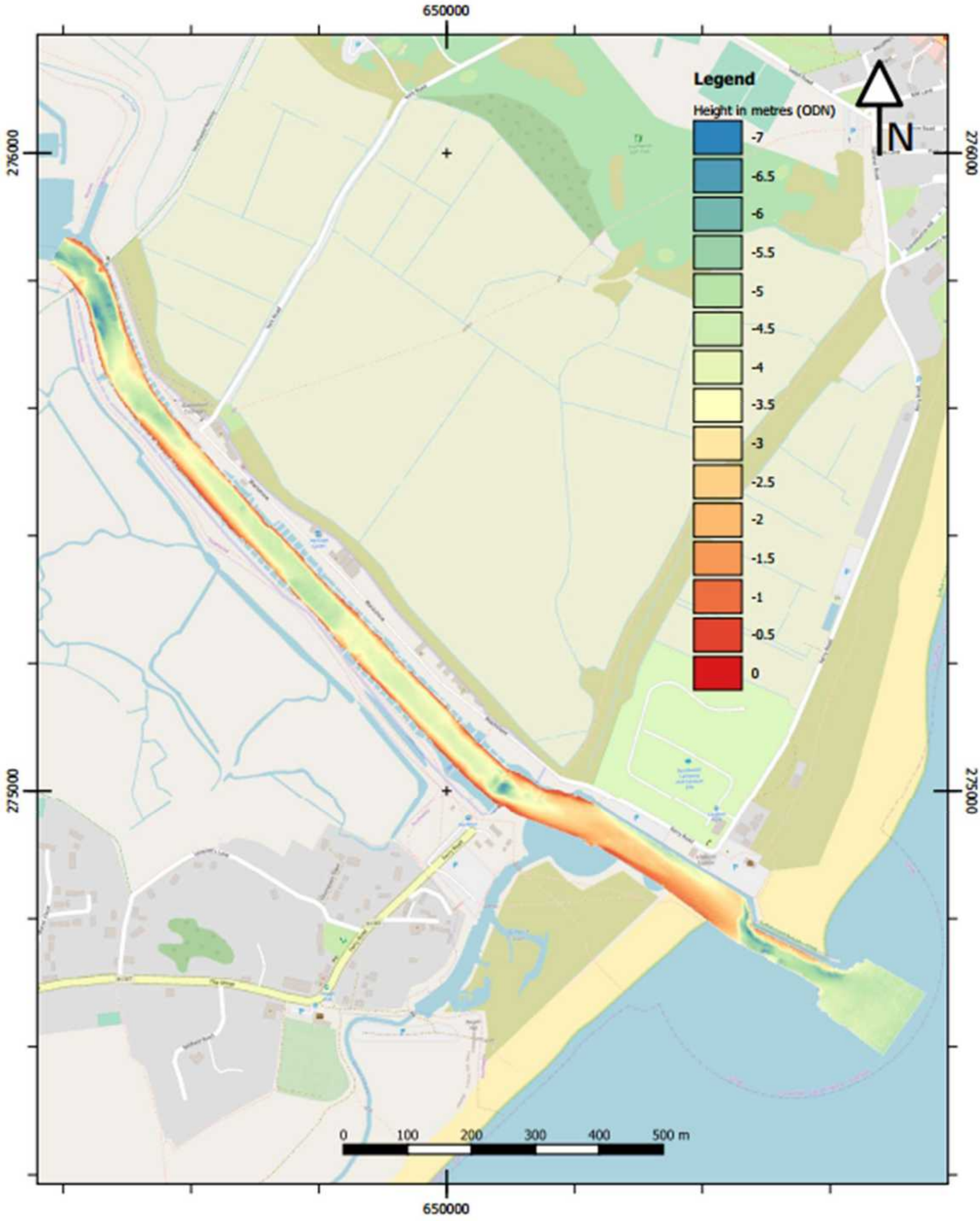

Figure 3-3: Bathymetric survey of Southwold harbour, February 2020

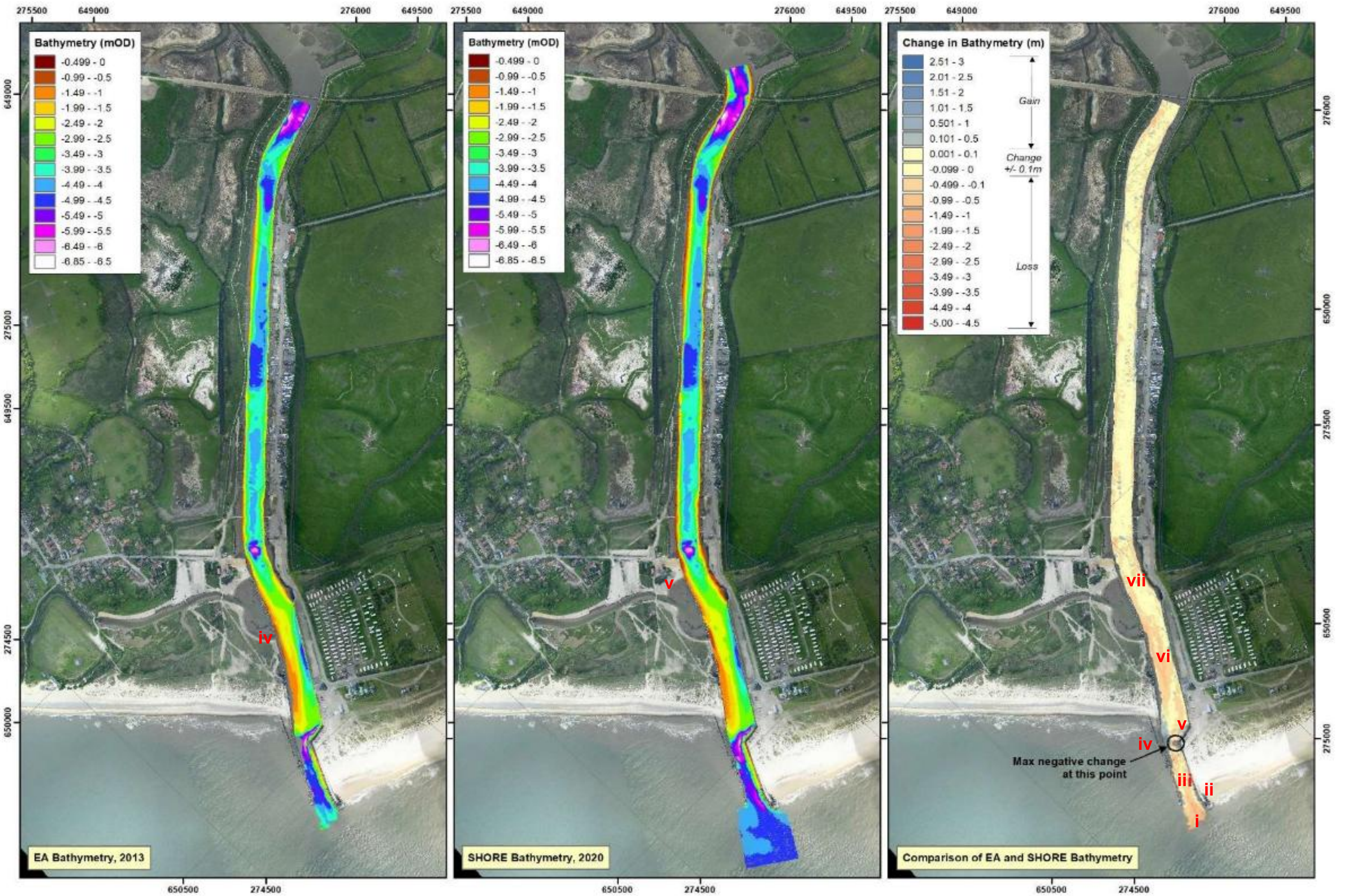

Figure 3-4: Comparison between the 2013 and 2020 bathymetric survey

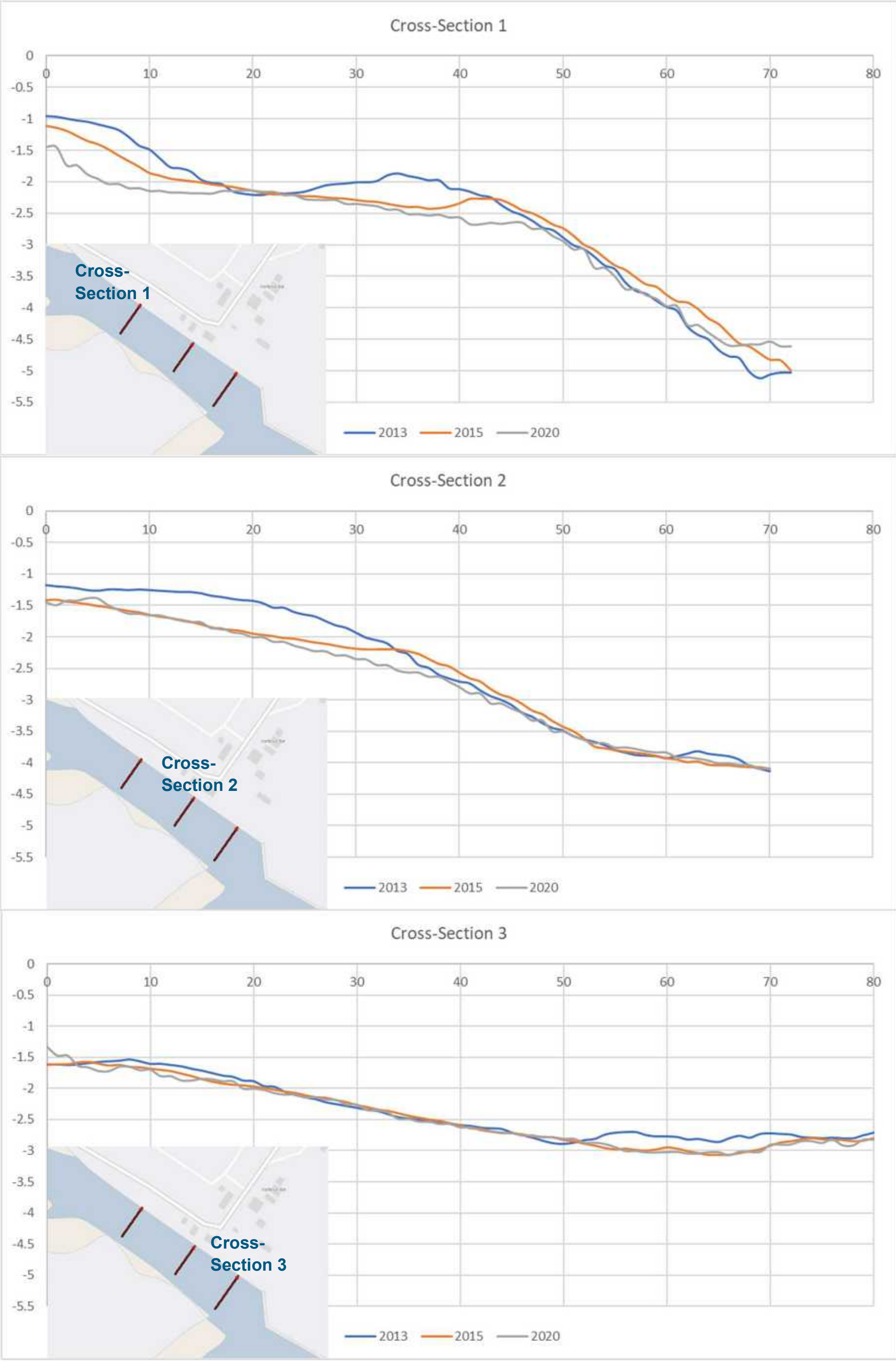

Figure 3-5: Comparison between 2013, 2015 and 2020, for 3 cross sections (see inset location plans)

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3.3 Summary of Dredging Proposals

The presence of the shoal bank opposite the North Wall has resulted in the navigation channel into Southwold Harbour running close to the wall, which restricts the space available for mooring vessels. Wave conditions at the North Wall would improve following construction of the proposed rock breakwater, and the HMC is keen to take this opportunity to increase mooring at the North Wall. Therefore, the HMC is keen to explore whether it would be possible to dredge or otherwise remove the shoal bank sediment.

A required depth of dredging has not been stated; however, it is expected that the channel bed level would be reduced over the full length of the North Wall to at least the current minimum depth of the navigation channel, which is -3.0mODN. For the purposes of the additional tidal modelling, a worst-case dredged channel level of -4.0mODN has been assumed.

The anecdotal evidence of areas of hard material within the channel bed should be recognised in the assessment of the dredging proposals. This material is thought to be concrete from historic construction works. The shoal bank is understood to be formed of compacted shingle, so could be difficult to remove.

3.4 Initial Review of Benefits and Constraints of Dredging

An initial review was undertaken of the potential benefits and constraints of the proposal to dredge the bank of sediment opposite the North Wall, which was included in a Technical Note (**Appendix A**) that issued to the Harbour Management Committee and the Project Stakeholder Group for comment. The initial assessment of benefits and constraints is provided in is provided in **Table 3-1**, whilst the stakeholder comments are summarised in **Table** 3-2.

Considering the stakeholder comments alongside the initial assessment of the benefits and constraints of the dredging proposals, the potential benefits and constraints of the proposals are recognised by the harbour users. The comments made by the stakeholders will be considered in this assessment.

Table 3-1: Initial review of benefits and constraints of dredging of shoal bank

Benefits	Constraints
Relatively low capital cost for initial dredging.	Capital cost of initial dredging.
Increased navigable width in outer harbour, improving access to inner harbour.	Shoal bank could rebuild, so ongoing maintenance dredging may be required.
Stability of shoal bank (2013-2020) suggests that maintenance dredging may not be necessary.	Licence may be required for capital and/or maintenance dredging, with associated requirements for environmental assessment (cost and time impacts).
More space at North Wall for vessel mooring.	Further works to North Wall may be required to enable safe mooring.
Flow rates could reduce at the North Wall due to the increase in channel cross section.	Changes to flow rates and directions at the North Wall could impact on navigation.
Dredged material could be reused in the works to replace the South Pier, or infill eroded areas behind South Training Arm.	Flow rates and directions may increase in the Entrance Channel, affecting navigation.
	Wave disturbance may increase in the inner harbour (upstream of the North Wall), as deeper water could maintain larger waves.
	Reports of very hard material being present within the channel bed, which could impact on cost of dredging and ease of disposal.

Table 3-2: Stakeholder comments on dredging proposals

Issue	Comment

Impact on wave and sediment conditions in harbour entrance	Need to understand how the dredging would affect other parts of the entrance in terms of sediment movement and swell.
Impact on navigation conditions	It would allow easier navigation into the harbour and allow us to carry out the additional works necessary to bring the North Wall into use for the mooring of larger vessels.
Dredged depth	What draft vessels are you hoping to assist – what will be the dredged depth?
Requirement for maintenance	Need to understand how likely it is that the dredging will need to be maintained.
Cost of dredging	On a day to day basis the harbour seems to work pretty well so is the (potentially ongoing cost) worth it?
Impact on Walberswick beach	How will this affect the protection to the Walberswick beach?

3.5 Review of Previous Wave Modelling

Additional wave modelling has not been undertaken as part of this assessment, so the previous wave modelling results have been considered against the proposals for dredging of the shoal bank.

The water depth within Southwold harbour is typically of the order of 5m. For this water depth, waves with a height of about 2m would not break. However, the water depth is much less over the shoal bank, where there is 2-3m water depth at Mean High Water Springs, so waves do break in this area. Anecdotal evidence also suggests that wave heights can build as they move over the shoal bank, particularly swell waves from the 90 to 120 degree direction sectors.

The wave modelling results for the present-day conditions show higher wave energy close to the shoal bank (red box in **Figure 3-6**) compared to elsewhere in the outer harbour. If the shoal bank was removed before works are undertaken to replace the South Pier, then wave heights would no longer build over the bank and break in the shallow water. Removing the shoal bank would increase the exposed height of the vertical structures on the south side of the channel, increasing wave reflection and therefore wave heights at the North Wall. The deeper water in the outer harbour would also be able to sustain larger waves.

If the South Pier was replaced with a rock breakwater, wave energy in the outer harbour and at the North Wall would reduce significantly, as shown in **Figure 3-6**. As such, the shoal bank would have much less influence on wave conditions in the harbour. With a rock breakwater in place, removal of the shoal bank would not be expected to affect the wave conditions in the harbour.

3.6 Review of Previous Tidal Modelling

The previous tidal modelling did not assess flow behaviours with the shoal bank removed. The tidal modelling results have therefore been reviewed in the context of the proposals for dredging the shoal bank.

Figure 3-7 shows the peak flow rates on the flood and ebb of a spring tide, recorded as part of the hydrographic survey in February 2020. This shows the lower flow velocities over the shoal bank, where the channel bed is higher. Over the bank, the flow directions are generally perpendicular to the channel, with the direction of flow being more variable closer to the North Wall, as flows are diverted around the shoal bank and the Knuckle. The highest flow velocities are observed in the deepest part of the channel.

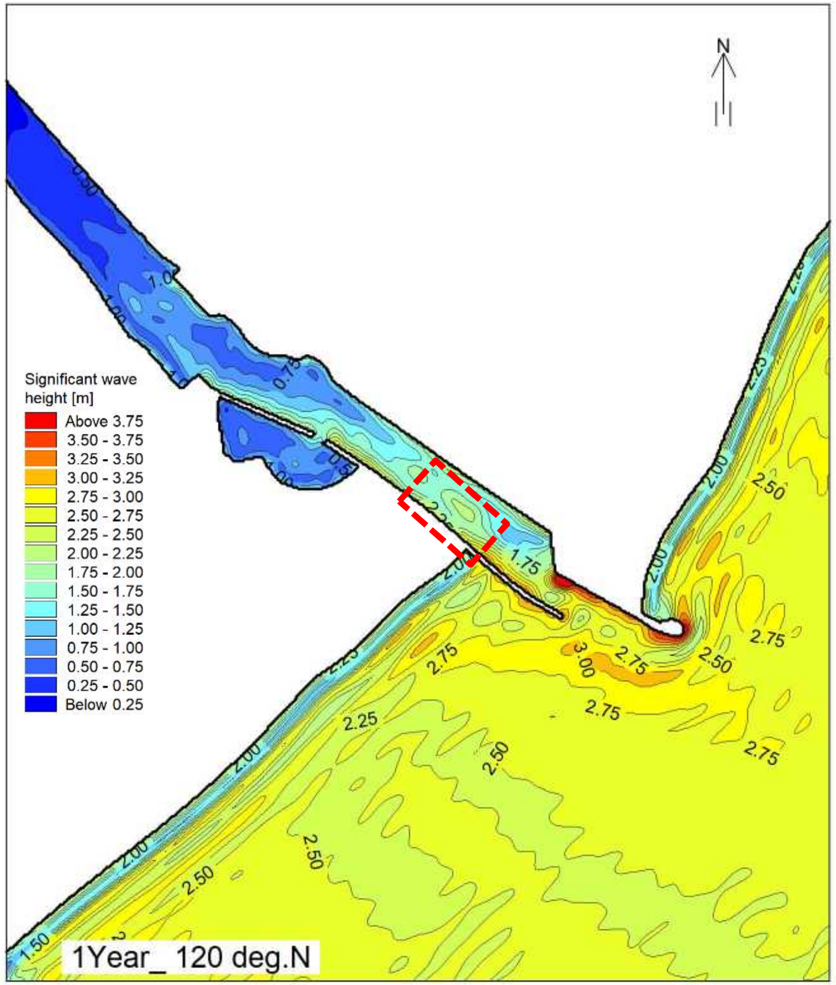
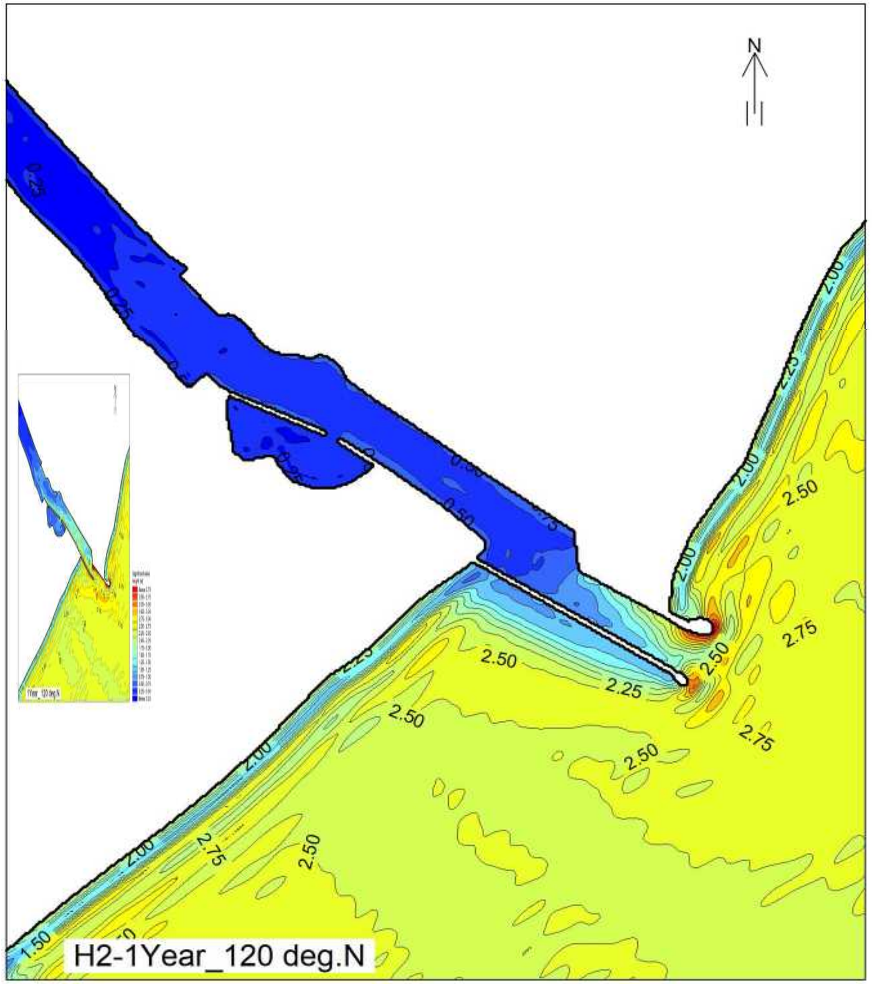
Present-day conditions, 1-year wave from 120 deg	Rock breakwater, 1-year wave from 120 deg
	

Figure 3-6: Example of wave modelling results for present-day harbour entrance structures and rock breakwater option

Peak flow on flood tide	Peak flow on ebb tide

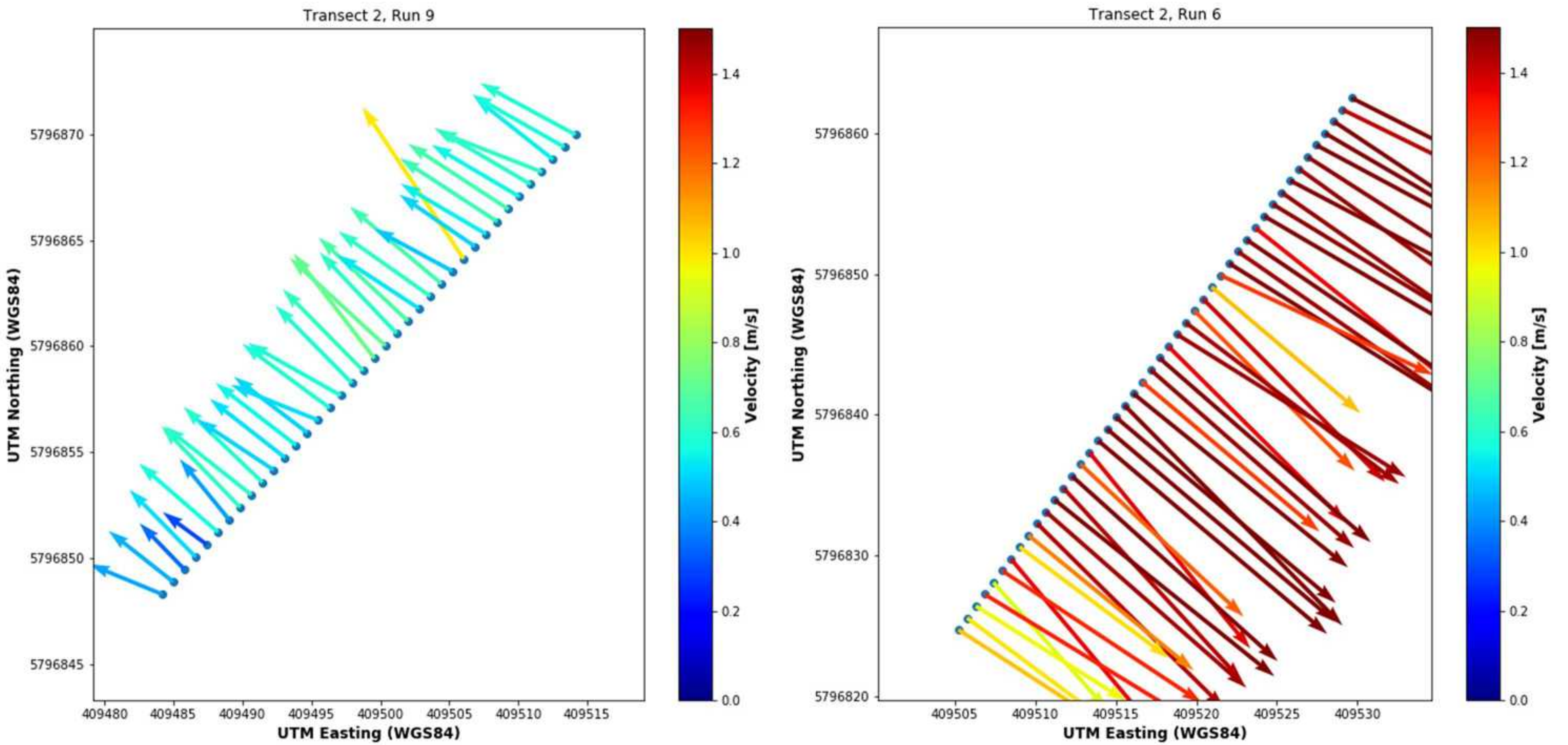


Figure 3-7: Peak flow rates (Spring tide) – Transect 2 (location of shoal bank)

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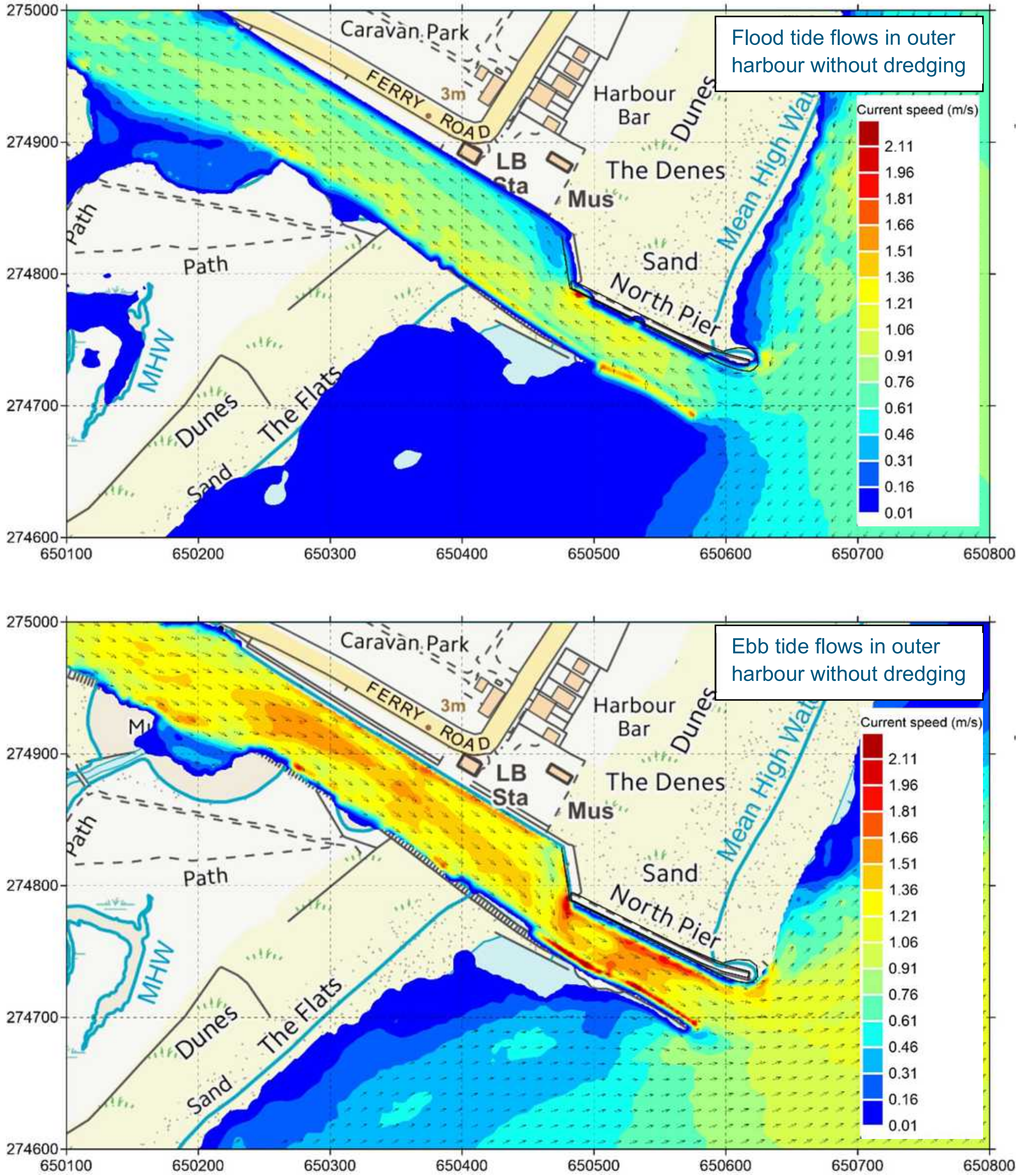

Figure 3-8: Peak flow velocity and direction for present-day defences without dredging, December 2013 conditions

Figure 3-8 shows the present-day peak flow velocities and directions in Southwold Harbour on a flood and ebb tide, for the February 2020 conditions. From this figure, it can be seen that the peak flow on the ebb tide is lower over the higher bed levels of the shoal bank, compared to flow velocities along the centre of the channel past the North Wall. **Figure 3-8** also shows how flow directions change as the channel widens at the Knuckle, and lower flow velocities near to Dunwich Creek as discharge from the creek disturbs flows in the main channel.

The predicted increase in peak flow velocity for the Do Nothing scenario (**Figure 3-9**) would be expected to increase the rate of erosion of the shoal bank. The changes in channel bathymetry discussed in **Section 3.2** show erosion of the shoal bank between 2013 and 2020, which could reflect an increasing tidal prism or increased storminess during that period. If the estuary defences were to be raised, peak flow rates would reduce during extreme conditions (**Figure 3-9**), which could result in growth of the shoal bank.

An initial assessment of the potential impacts of the removal of the shoal bank on tidal flow patterns was undertaken as part of the preparation of the draft project report, which can be summarised as follows:

- An area of lower flow rates would be expected where the shoal bank is currently located, due to flow around the Knuckle and outflows from Dunwich Creek.
- If the shoal bank was to be removed, the bathymetry would need to be monitored in case of future sediment accumulation, which could require maintenance.
- Further modelling was recommended to assess the impact of dredging on flow rates in the vicinity of the North Wall. This additional modelling has now been undertaken to inform the preparation of this report.

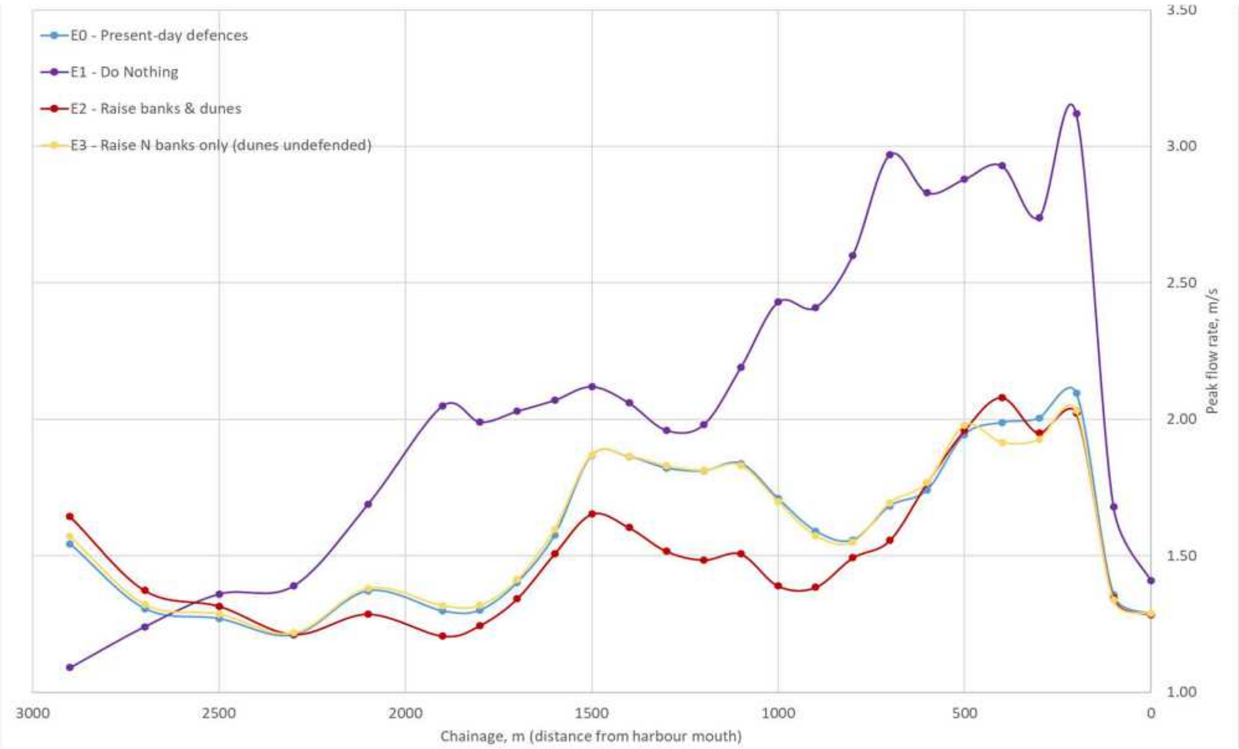

Figure 3-9: Change in peak flow rate along river channel, December 2013 conditions

4 Narrow Channel Option

4.1 Description of Narrow Channel Option

Following discussions with harbour users, an additional option has been assessed, where the river channel would be narrowed by constructing a short rock groyne on the south side of the channel. By extending the narrowed channel of the harbour entrance further upstream, the volume of water entering the estuary would be constrained, reducing peak water levels in the harbour. The rock groyne would also limit the penetration of swell waves into the inner harbour. This option could be combined with any of the other management options for the estuary defences and harbour structures.
This option is described further in Appendix E of the main report.

The Technical Note that was prepared for the stakeholder group (**Appendix A**) included details of the proposed narrow channel option. Four potential locations were proposed for the rock groyne to narrow the channel, as shown in **Figure 4-1,** with each location having different benefits or constraints. The initial assessment of benefits and constraints is included in **Section 4.2 Error! Reference source not found.**, as well as the stakeholder comments on the proposed option.

The previous wave and tidal modelling assessed a narrow channel option with a rock groyne located opposite the North Wall, near to the Lifeboat Station (approximately Location 2 in **Figure 4-1**), and the results of this modelling are discussed in **Sections 4.3 and 1.1.** The additional tidal modelling that has been completed to inform this assessment is discussed in **Section 6**.

4.2 Initial Assessment of Benefits and Constraints

An initial review was undertaken of the potential benefits and constraints of the proposal to extend the narrow channel further into the harbour. This assessment was provided in the Technical Note that was issued to the stakeholder group (**Appendix A**) and is provided in **Table 4-1**. The stakeholder comments on this option are summarised in **Table 4-2**.

Considering the stakeholder comments alongside the initial assessment of benefits and constraints shows that opinions are split about whether the channel should be narrowed. The review of the wave modelling and the additional tidal modelling will consider locations 1, 2 and 4 for the rock structure.

Table 4-1: Initial review of benefits and constraints of narrow channel option

Benefits	Constraints
Modelling shows that peak water levels would be lower in the inner harbour if a rock structure was constructed in the outer harbour (modelling undertaken for location 2).	Increased tidal flows around the rock structure, affecting navigation and with a risk of scour of the channel bed which could affect the foundations for the North Wall.
	Navigation impacts of narrowed channel.
Position of rock structure may help with vessel turning, particularly for locations 1 and 2.	Rock structure reduces the space available for mooring at the North Wall, particularly for locations 2 and 3.
The rock structure would limit the penetration of swell waves into the inner harbour by absorbing wave energy.	Access to lifeboat station restricted, particularly for location 2.
Sediment accumulation to either side of the rock structure could improve stability of both the rock structure and the adjacent South Training Arm.	Sediment may accumulate either side of the rock structure, which could further restrict navigation and require maintenance dredging.
Increased flow rates around the rock structure could limit any sediment accumulation.	

Table 4-2: Stakeholder comments on narrow channel option

Issue	Comment
Potential location of a rock groyne structure to extend the narrow channel	Position 1.5 seems optimum, i.e. half way between positions 1 and 2.
	Position 1 appears to provide the greatest length of dock wall with a lower wave height and would provide a lower surge flood level to the Fisherman's Compound, RNLI shed, Caravan Park and Ferry Road.
	Positions nearer the harbour entrance give the biggest potential benefit so position 1 seems best.
	I believe that the constraints outweigh the benefits and would consider the only possible location for a rock structure to be location 4, to bring the benefits to the inner harbour without restricting our longer term plans for the development of the harbour facility.

4.3 Review of Previous Wave Modelling

The previous wave modelling included an option with a rock groyne incorporated into the outer harbour to narrow the channel, located opposite the North Wall near to the Lifeboat Station. This option also assumed that a rock breakwater would be constructed to replace the South Pier. The model results for this option are provided in **Table 4-3**, compared with the results for the present-day conditions and for a rock breakwater without the narrowed channel, for three locations within Southwold Harbour. **Figure 4-2** provides an example of the wave modelling results for 1-year return period waves from the 150 degree direction sector.

These results show that the construction of a rock groyne to narrow the channel near to the Lifeboat Station would improve wave conditions in the harbour entrance, immediately upstream of the rock groyne (Dunwich Creek area) and at the upstream moorings, for waves from all direction sectors. If the channel was narrowed further upstream, e.g. north of Dunwich Creek (location 4 in **Figure 4-1**), then the rock groyne structure would be expected to have less influence on wave conditions downstream of the structure, i.e. at the harbour entrance and the Dunwich Creek area.

Table 4-3: Wave modelling results for narrow channel option (1-year wave conditions)

Layout	Layout	Hm0 (m) due to waves from Offshore Direction (deg.N)							
		0	**30**	**60**	**90**	**120**	**150**	**180**	**210**
Harbour entrance	H0: Present-day Baseline	0.7-1.0	0.8-1.2	0.6-1.0	0.6-1.4	1.0-2.2	1.0-2.6	1.5 -3.5	1.3-3.3
	H2: Rock Breakwater	0.5-0.6	0.6-0.8	0.4-0.6	0.4-0.7	0.4-0.7	0.4-0.8	0.6-0.8	0.4-0.6
	H6: Rock breakwater + narrow channel	0.4-0.6	0.5-0.8	0.3-0.5	0.3-0.6	0.3-0.6	0.4-0.7	0.5-0.8	0.3-0.6
Dunwich - Walberswick	H0: Present-day Baseline	0.5-1.5	0.6-1.8	0.5-1.4	0.5-1.3	0.7-1.8	0.7-2.0	1.0-2.3	0.7-2.1
	H2: Rock Breakwater	0.4-0.9	0.4-0.9	0.3-0.7	0.4-0.7	0.4-0.7	0.4-0.8	0.4-0.8	0.4-0.6
	H6: Rock breakwater + narrow channel	0.5-0.6	0.6-0.8	0.4-0.6	0.4-0.7	0.4-0.7	0.4-0.8	0.6-0.8	0.4-0.6
Upstream Moorings	H0: Present-day Baseline	0.3-0.5	0.3-0.6	0.3-0.7	0.3-0.6	0.3-0.7	0.3-0.7	0.6-0.9	0.4-0.7
	H2: Rock Breakwater	0.3-0.4	0.3-0.4	0.2-0.3	0.2-0.3	0.2-0.3	0.2-0.3	0.3-0.4	0.2-0.3
	H6: Rock breakwater + narrow channel	0.2-0.3	0.2-0.3	0.2-0.3	0.2-0.3	0.2-0.3	0.2-0.3	0.2-0.3	<0.25

Figure 4-1: Potential locations for rock structure to extend the narrow entrance channel

Present-day, 1-year wave from 150 deg	Rock Breakwater, 1-year wave from 150 deg	Rock breakwater + narrow channel, 1-year wave from 150 deg

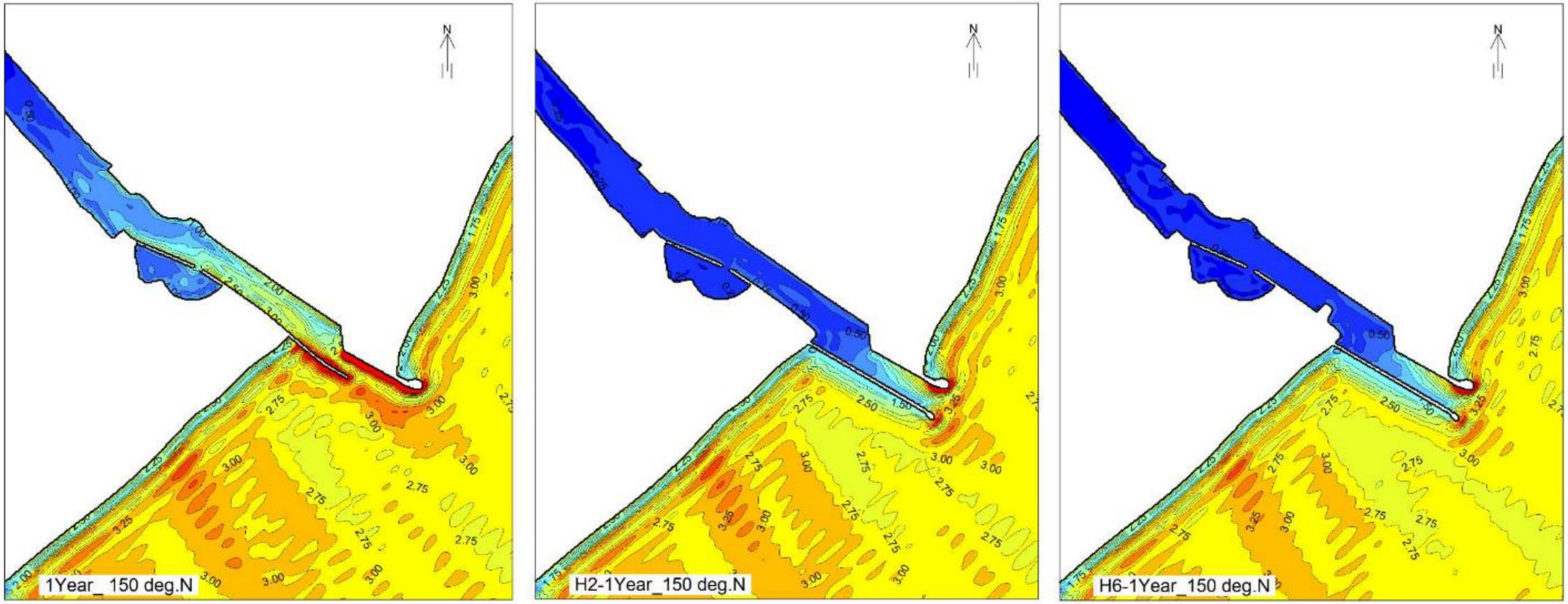

Figure 4-2: Comparison of wave modelling results showing benefits of narrowed channel option

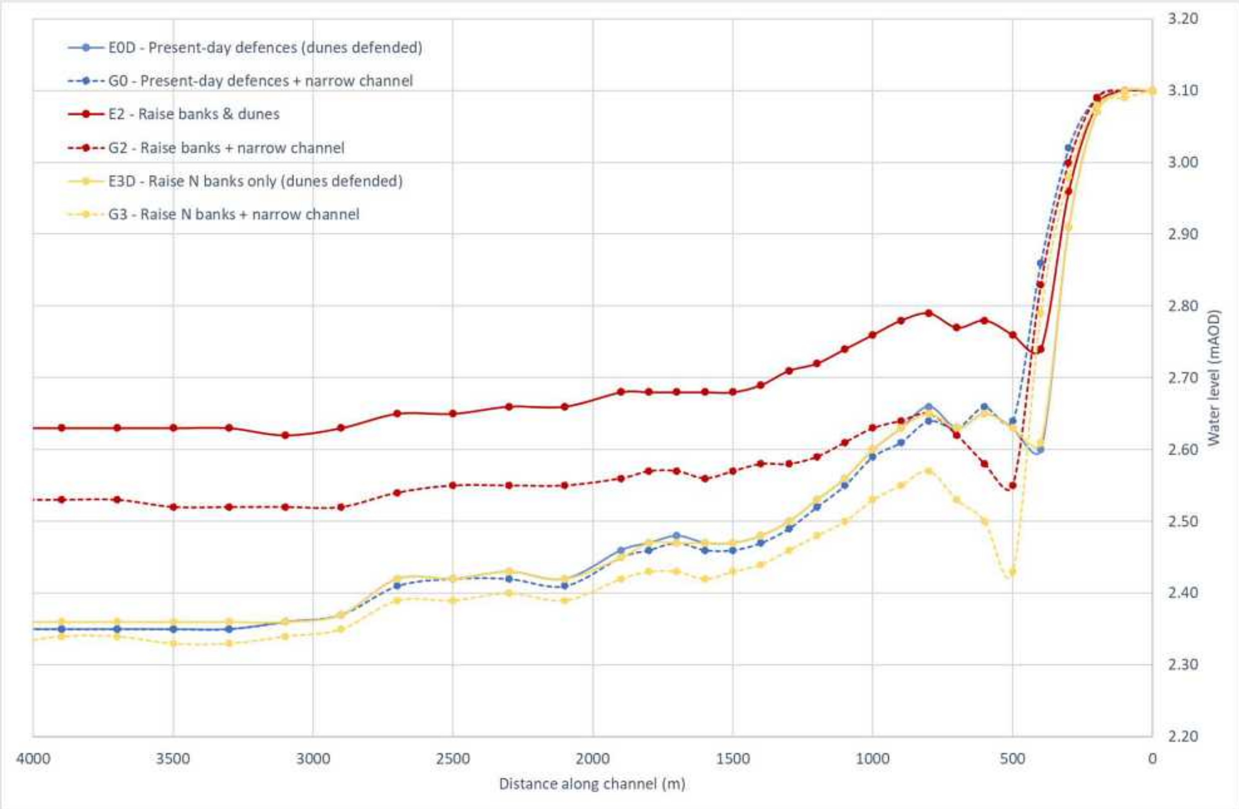

Figure 4-3: Change in peak water level along river channel with narrow channel, December 2013 conditions

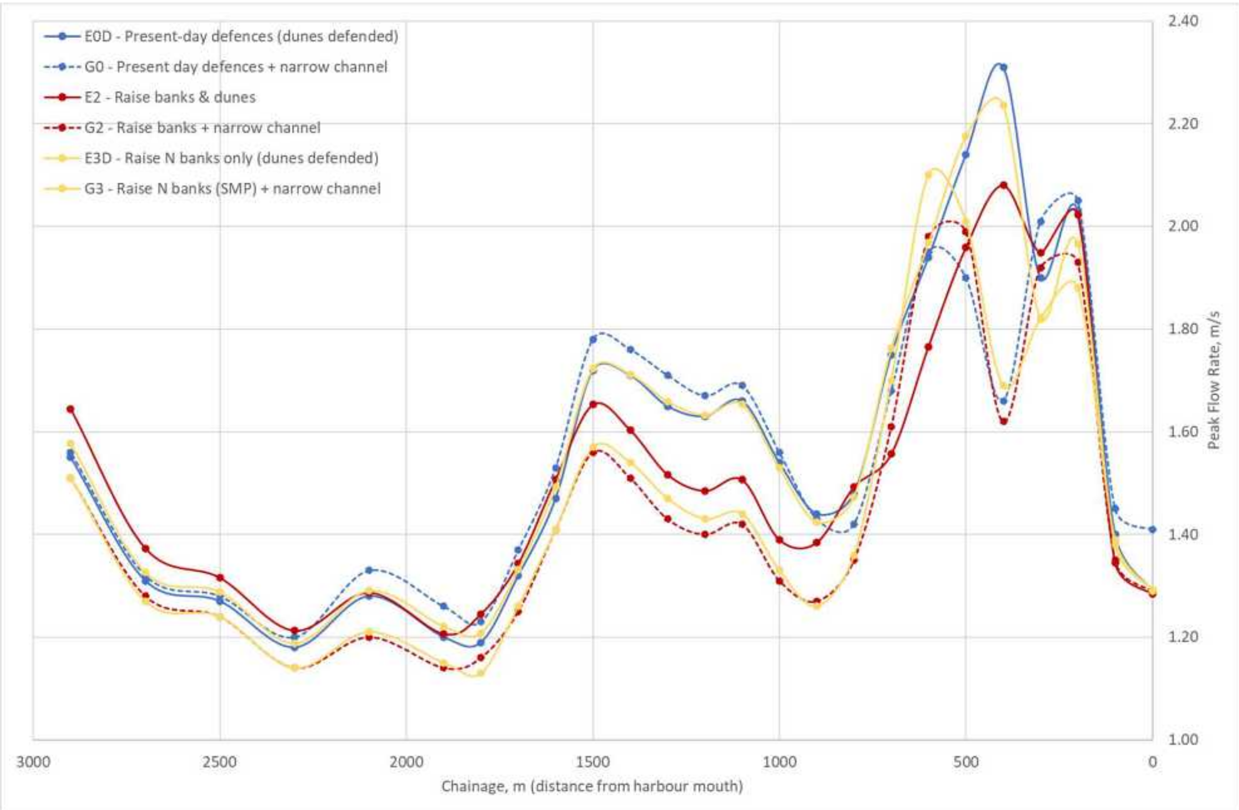

Figure 4-4: Change in peak velocity along river channel with narrow channel, December 2013 conditions

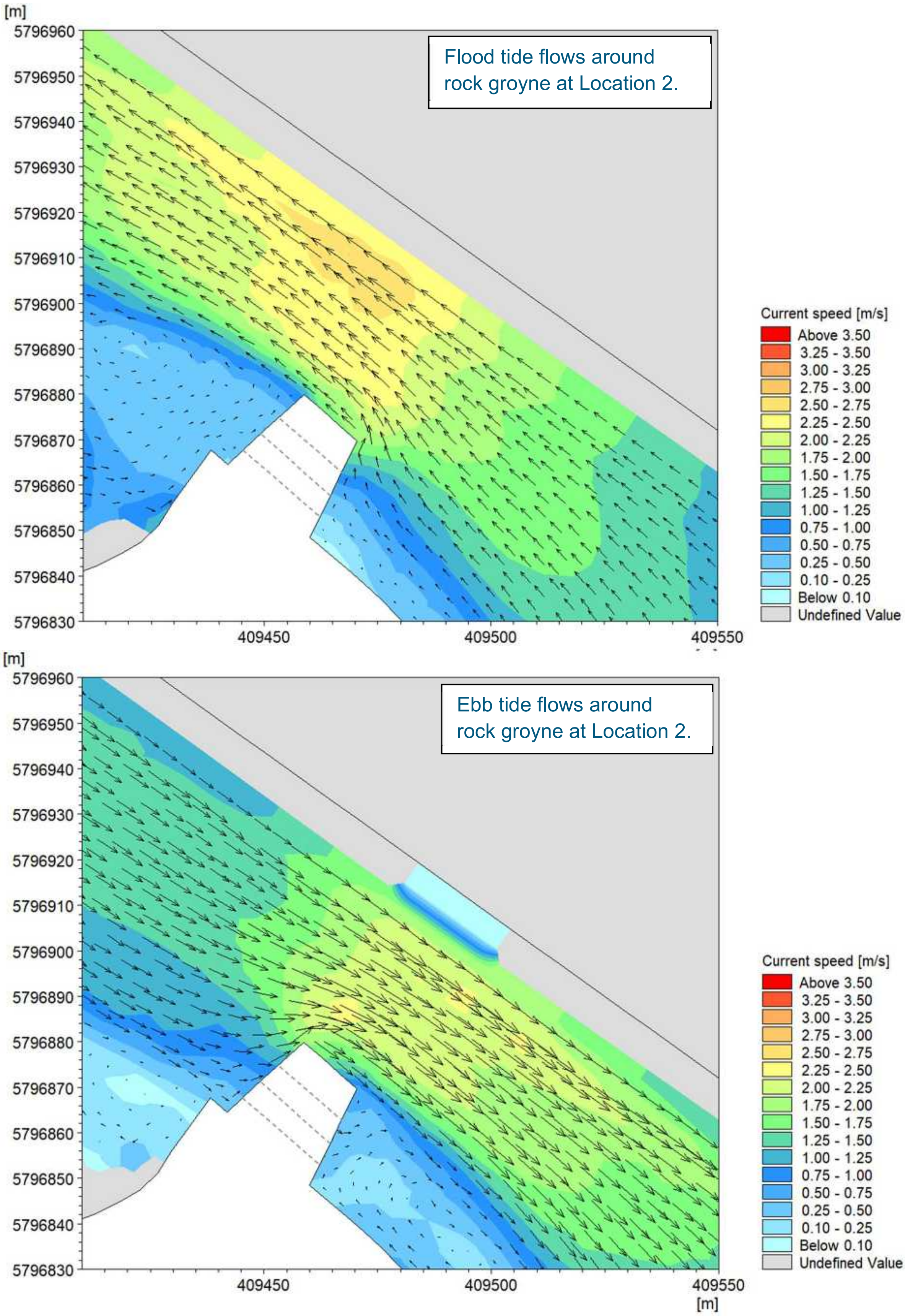

Figure 4-5: Peak flow velocity and direction around the rock groyne structure (narrow channel option), December 2013 conditions

Raised estuary defences, 2013 conditions	Raised estuary defences and narrowed channel, 2013 conditions

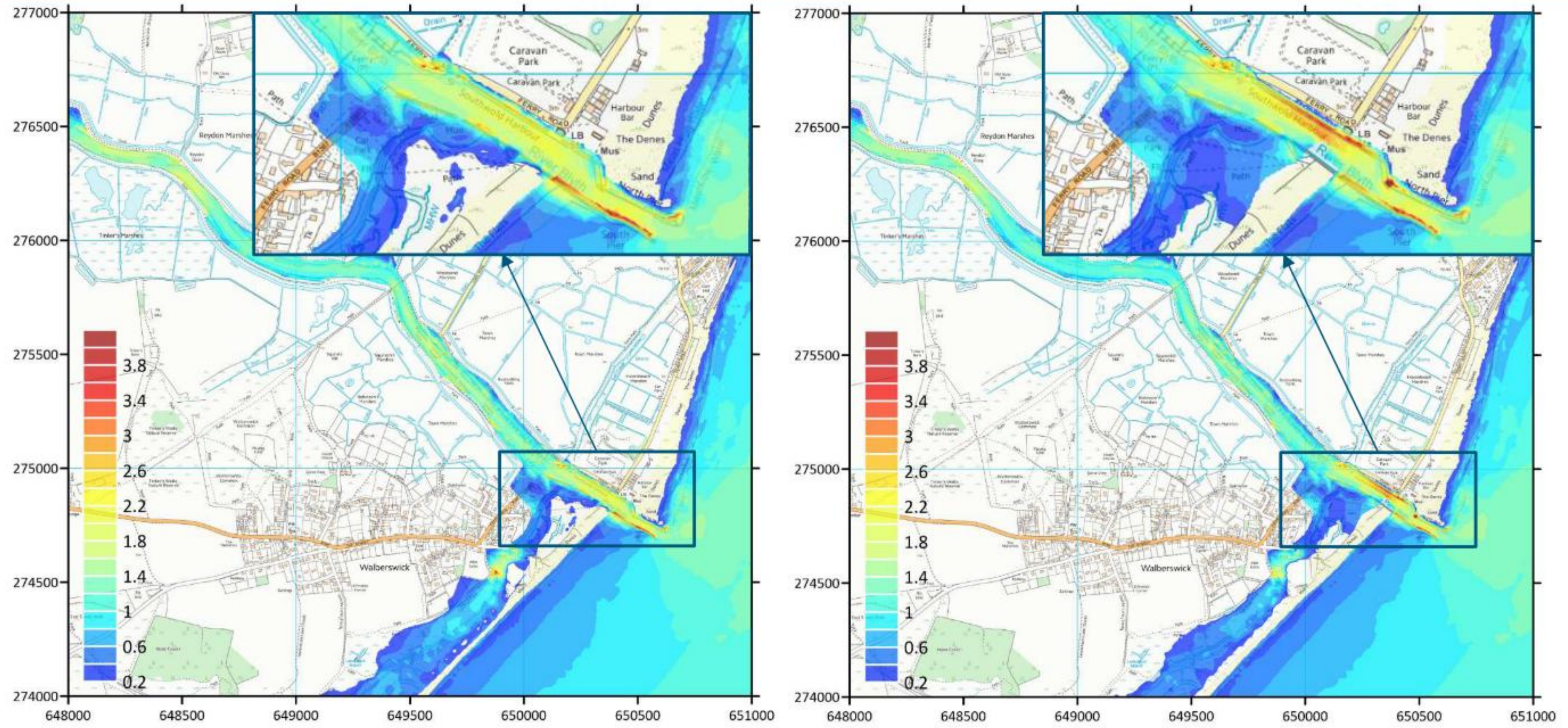

Figure 4-6: Peak flow velocity for raised estuary defences with/without narrow channel option, December 2013 conditions

4.4 Review of Previous Tidal Modelling

The previous tidal modelling included an option with a rock groyne incorporated into the outer harbour to narrow the channel, located opposite the North Wall near to the Lifeboat Station. The narrow channel option was modelled for the present day estuary defences, and for raised estuary embankments.

The modelling results (**Figure 4-3**) show that if the channel was to be narrowed opposite the North Wall, combined with raising the estuary defences, the peak flood levels at the Blackshore (chainage 1500m) for the December 2013 conditions would be reduced by 110mm compared to raising the defences alone. If the existing defences were unchanged (option E0), narrowing the channel would reduce peak flood levels by only 10mm.

In terms of peak flow velocities with the December 2013 conditions (**Figure 4-4** and **Figure 4-6**), if the embankments were raised and the channel narrowed opposite the North Wall, peak flow rates in the entrance channel would be reduced by about 0.1m/s compared to embankment raising alone. Peak flow rates further upstream are also reduced. The model results showed that peak flow velocities would increase in the vicinity of the rock structure with a narrowed channel (**Figure 4-5**).

5 Additional Tidal Modelling

5.1 Approach to Additional Modelling

Additional tidal modelling has been undertaken to assess the impact of the proposed dredging on tidal flows within the harbour entrance channel.

The tidal model was revised to set the channel bed level at -4mODN over the length of the North Wall, to represent the proposed dredging/removal of the shoal bank. Further model runs were also set up with various combinations of the potential management solutions for the harbour entrance structures and estuary defences, plus the narrow channel option (2 possible locations). **Table 5-1** summarises the model runs that have been undertaken, including relevant previous model runs that have been used for comparison.

Table 5-1: Tidal model runs completed to inform assessment of dredging proposals and narrow channel option

Option			**Model run ref.**	
			Tide level (mODN)	
Harbour entrance	Estuary defences	Dredging	1.49 (2020)	3.1 (2013 event)
Present-day defences	Present-day defences	No dredging	E0	E0
Present-day defences	Present-day defences	Dredged to -4mODN	**D1**	D2
Breakwater	Present-day defences	No dredging	F0	F0
Breakwater	Present-day defences	Dredged to -4mODN	**D3**	D4
Present-day defences + narrow channel (v1)	Present-day defences	No dredging	G0	G0
Breakwater + narrow channel (v1)	Present-day defences	Dredged to -4mODN	**D5**	D6
Breakwater + narrow channel (v2)	Present-day defences	No dredging	-	C2
Breakwater + narrow channel (v2)	Present-day defences	Dredged to -4mODN	-	C3

The tidal modelling results are provided in **Appendix B** (Peak Water Levels), **Appendix C** (Peak Flow Velocities), and **Figure 5-1** to **Figure 5-3** below.

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5.2 Peak water levels

Figure 5-1 compares the peak water levels along the channel for the various options for the harbour entrance structures, with and without dredging. **Table 5-2** gives the peak water levels at key locations in the harbour and further upstream, and **Table 5-3**Table 5-3 compares these peak water levels with the present-day conditions for the December 2013 surge event.

Table 5-2: Summary of peak water levels for dredging options, December 2013 conditions

Option			Peak water level (m)				
Ref.	Harbour entrance structures	Dredging	Entrance channel (200m)	Lifeboat Station (400m)	Dunwich Creek (600m)	Blackshore Cottages (1500m)	Upstream of Bailey Bridge (2500m)
E0	Present-day defences	No dredging	3.07	2.60	2.65	2.47	2.42
D2	Present-day defences	Dredged to -4mODN	3.08	2.82	2.83	2.54	2.48
F0	Breakwater	No dredging	2.68	2.62	2.62	2.45	2.41
D4	Breakwater	Dredged to -4mODN	2.71	2.79	2.79	2.48	2.45
G0	Present-day defences + narrow channel (Location 2)	No dredging	3.09	2.86	2.66	2.46	2.42
D6	Breakwater + narrow channel (Location 2)	Dredged to -4mODN	2.87	2.92	2.66	2.47	2.40
C3	Breakwater + narrow channel (Location 4)	Dredged to -4mODN	2.80	2.77	2.79	2.38	2.35

Table 5-3: Comparison of peak water levels with present-day peak water levels, December 2013 conditions

Option			Change in peak water level (m)				
Ref.	Harbour entrance structures	Dredging	Entrance channel (200m)	Lifeboat Station (400m)	Dunwich Creek (600m)	Blackshore Cottages (1500m)	Upstream of Bailey Bridge (2500m)
D2	Present-day defences	Dredged to -4mODN	+0.01	+0.22	+0.18	+0.07	+0.06
F0	Breakwater	No dredging	-0.39	+0.02	-0.03	-0.02	-0.01
D4	Breakwater	Dredged to -4mODN	-0.36	+0.19	+0.14	+0.01	+0.03
G0	Present-day defences + narrow channel (Location 2)	No dredging	+0.02	+0.26	+0.01	-0.01	0.00
D6	Breakwater + narrow channel (Location 2)	Dredged to -4mODN	-0.20	+0.32	+0.01	0.00	-0.02
C3	Breakwater + narrow channel (Location 4)	Dredged to -4mODN	-0.27	+0.17	+0.14	-0.09	-0.07

For the existing South Pier and estuary defences, dredging the shoal bank would increase peak water levels by about 20cm in the outer harbour and by up to 10cm through the Blackshore for the December 2013 event conditions. The shoal bank currently acts to extend the narrowed channel upstream of the harbour entrance, so removal of this sediment would allow more water to flow into the estuary, raising peak water levels.

If the South Pier was replaced with a rock breakwater, peak water levels through the entrance channel are reduced by up to 40cm, because the rock breakwater constrains the entrance channel more than the existing South Pier (the additional flow through the windows in the pier would be removed). There is a slight reduction in peak water levels at the Blackshore and further upstream with a breakwater. Dredging of the shoal bank with a breakwater in place would increase peak water levels by about 20cm in the outer harbour, but only by a few centimetres further upstream compared to present-day peak water levels for the December 2013 event conditions. Including a narrowed channel as well as the breakwater and removal of the shoal bank increases peak water levels upstream of the narrowed section but reduces the peak water levels further upstream by about 5cm (option D6 compared to option D4).

Figure 5-2 compares the peak water levels for two alternative locations of a narrowed channel (Locations 2 and Location 4, **Figure 4-1),** which shows that Location 4 performs slightly better than Location 2 in terms of peak water levels further upstream, although the difference is less than 5cm.

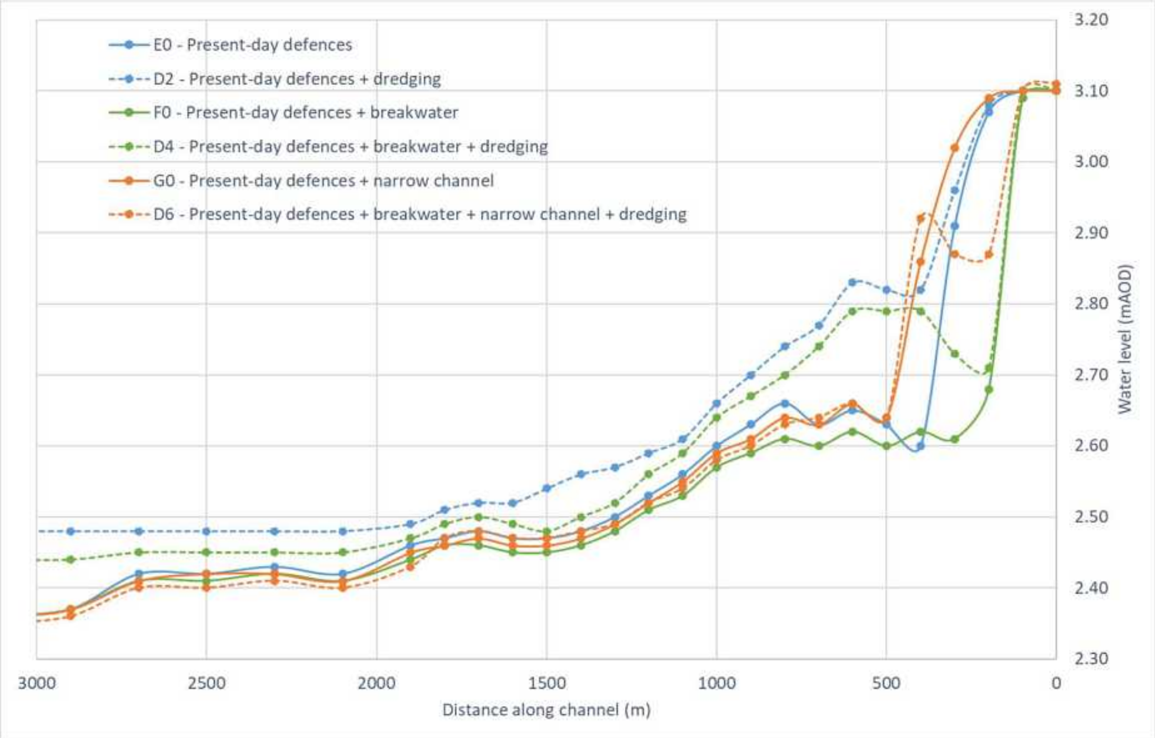

Figure 5-1: Peak water level with dredging, December 2013 conditions

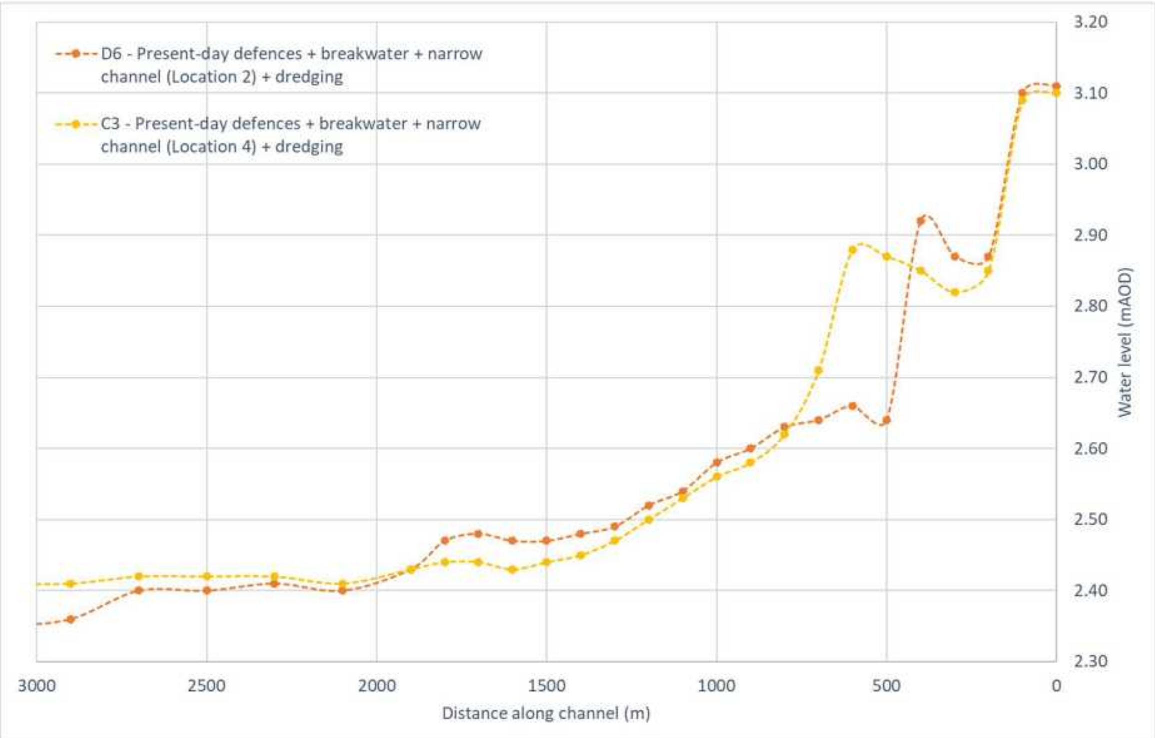

Figure 5-2: Peak water level for narrow channel options, December 2013 conditions

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5.3 Peak flow velocities

Figure 5-3 and **Figure 5-4** show that with the existing South Pier and estuary defences, dredging the shoal bank would decrease peak flow velocities through the outer harbour by up to 0.5m/s for the February 2020 conditions and by 0.4m/s for the December 2013 surge event conditions. This is due to the increased channel cross section with the removal of the shoal bank. Further upstream, peak flow velocities would increase due to the increase in the tidal prism, although the increase would be less than 0.1m/s for both water level conditions.

Replacing the South Pier with a rock breakwater would result in an increase in peak flow velocities within the entrance channel, because the breakwater constrains the surge tide flow more than the existing South Pier. Further upstream, peak flow velocities are reduced because the more constrained entrance channel reduces the amount of water flowing into the estuary, and therefore limits the peak flow velocities. The influence of the breakwater on peak flow velocities is much less for lower water levels.

If the shoal bank is dredged with a rock breakwater in place, peak flow velocities along the North Wall would be up to 0.6m/s lower than with the breakwater but without dredging, for both the February 2020 and December 2013 conditions. Upstream of the North Wall, peak flow velocities for the December 2013 event conditions would be up to 0.3m/s higher than with a breakwater but without dredging. For the February 2020 conditions, peak flow velocities would be about 0.1m/s higher.

Including a narrowed channel as well as the breakwater and removal of the shoal bank reduces peak flow velocities by up to 0.3m/s upstream and downstream of the narrowed section for the December 2013 conditions (option D6 compared to option D4). For this option with the February 2020 conditions, peak flow velocities in the outer harbour reduce by only 0.1m/s compared to the conditions without the narrow channel (option D5 vs option D3) .

Figure 5-5 to **Figure 5-7** show the spatial variation in peak flow velocity in the outer harbour on the flood and ebb tides for the various dredging options with the February 2020 conditions, which are representative of a 1-year return period event (worst-case operational conditions). The peak flow velocities on the ebb tide are also compared with the present-day conditions. These figures further demonstrate that dredging would have limited impact on flow conditions in the entrance channel, but reduces peak flow velocities along the North Wall.

The reduction in flow velocities in the outer harbour with dredging could result in an increased rate of sediment deposition compared to present day conditions.

5.4 Flow directions

Figure 3-8 shows the spatial variation and direction of the peak flow velocities for the present day conditions. Comparing this figure with **Figure 5-5** to **Figure 5-7** shows that the dredging proposals would not have a significant impact on flow directions. However, any change in flows could be more noticeable to harbour users, as with dredging, the flows will be more consistent over the full width of the channel, rather than the faster flows being concentrated in the existing narrow navigation channel close to the North Wall.

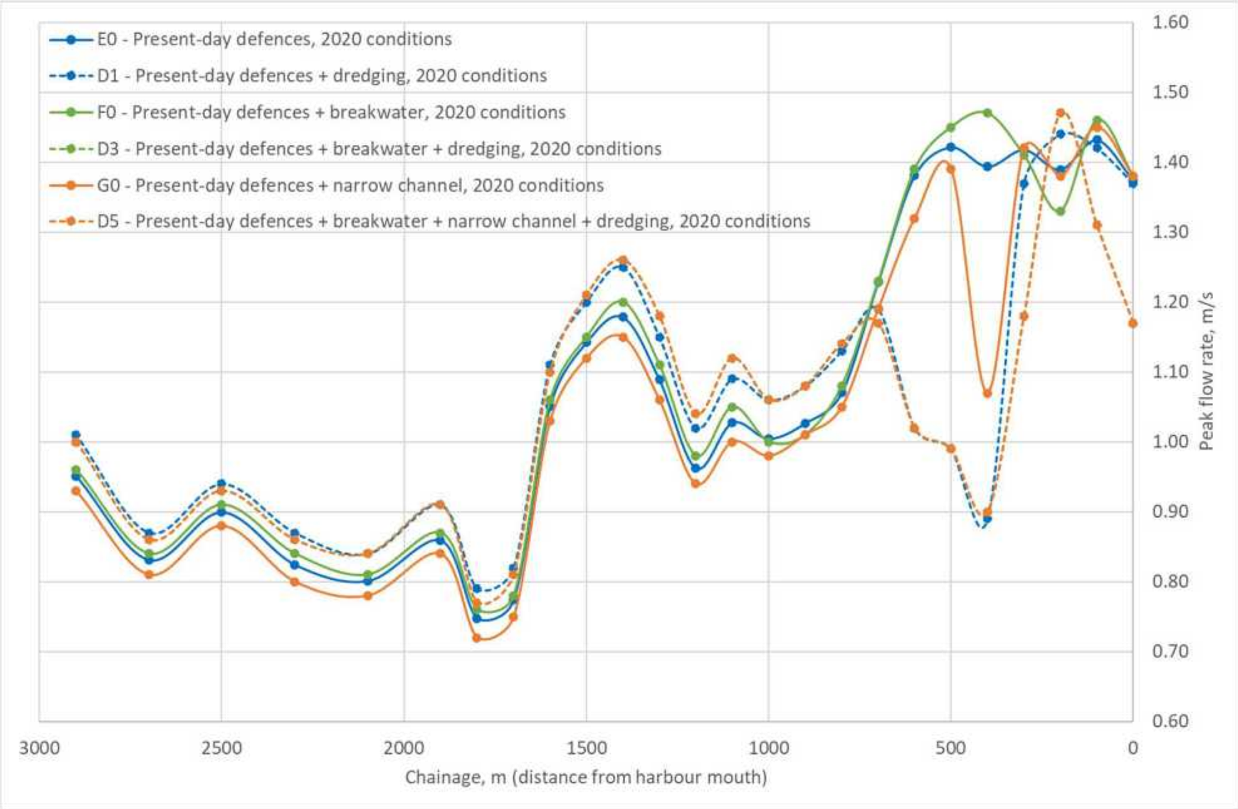

Figure 5-3: Peak flow velocities with dredging, February 2020 conditions

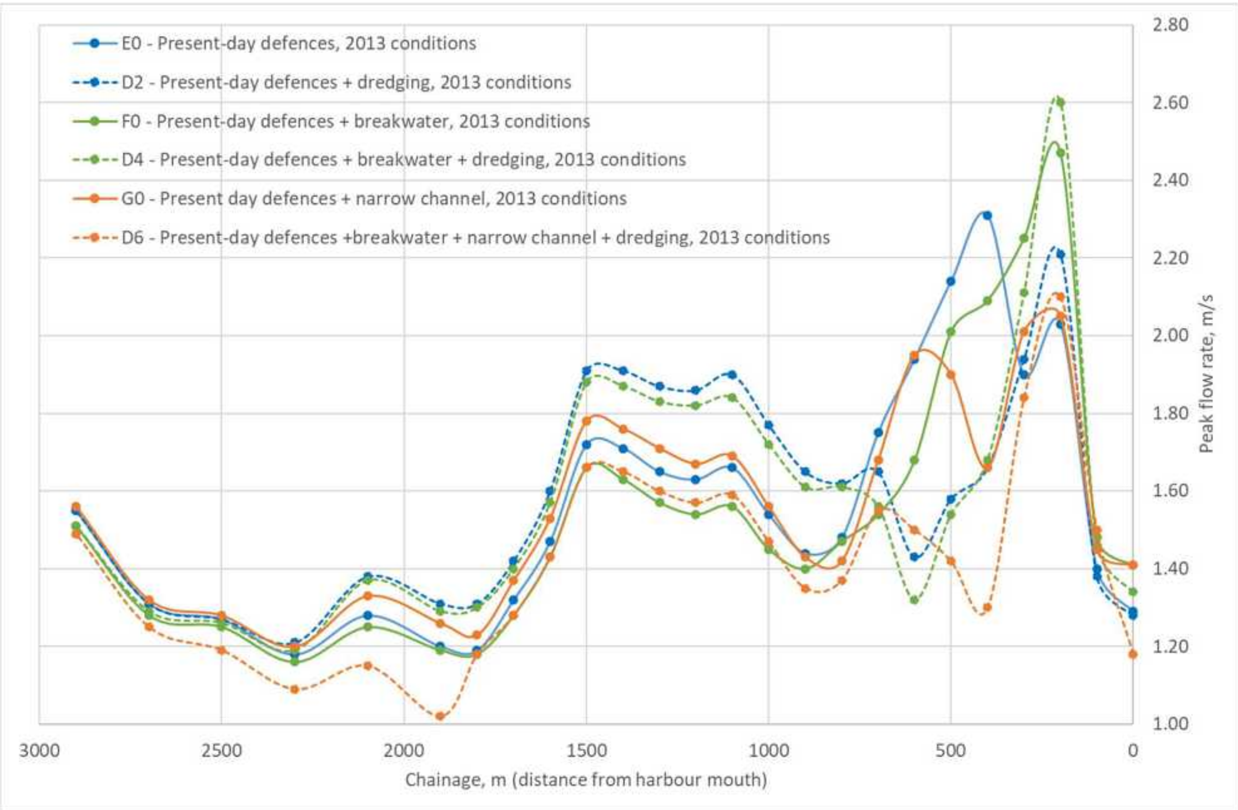

Figure 5-4: Peak flow velocities with dredging, December 2013 conditions

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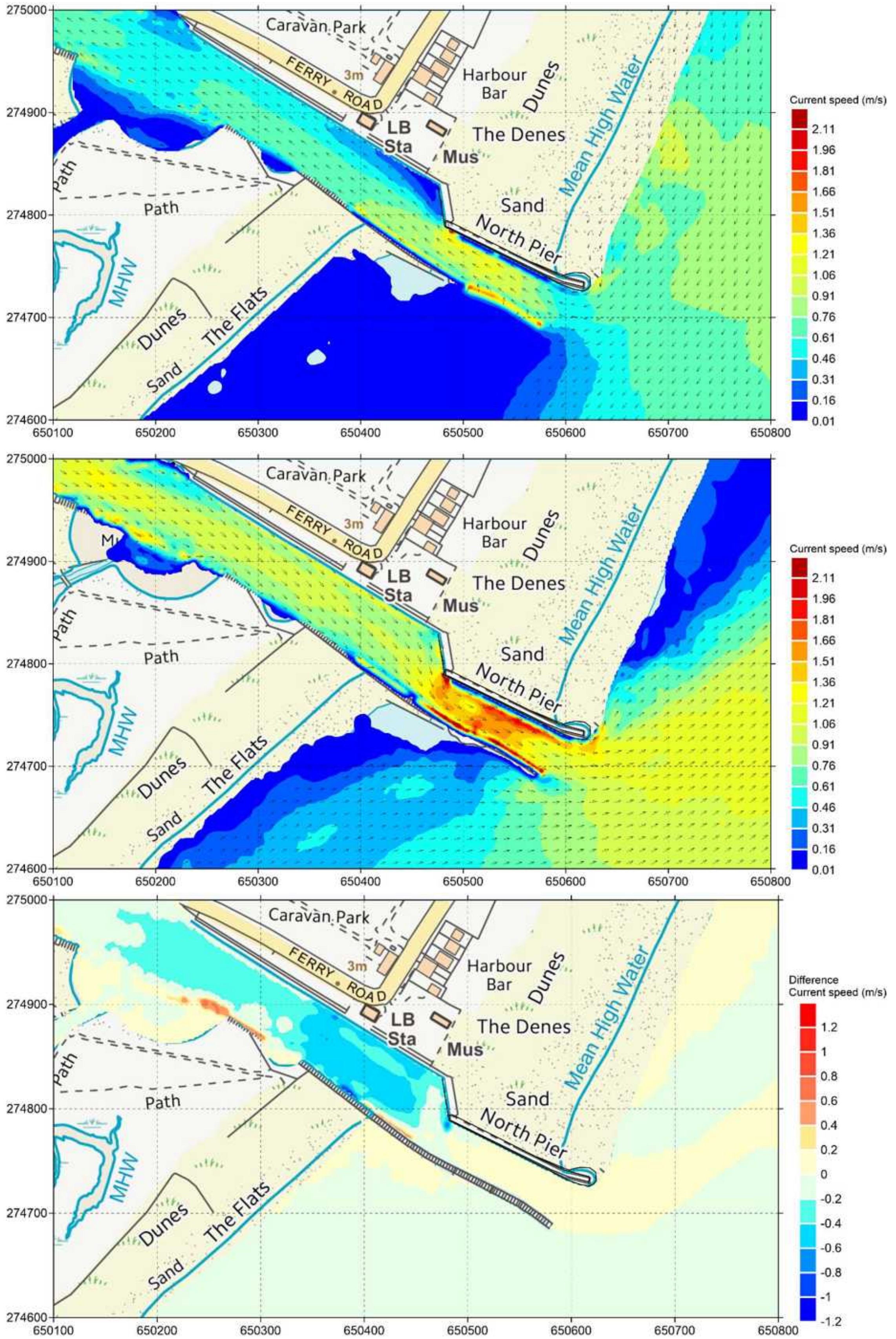

Figure 5-5: Spatial variation and direction of peak flows, Present-day defences with dredging, February 2020 conditions

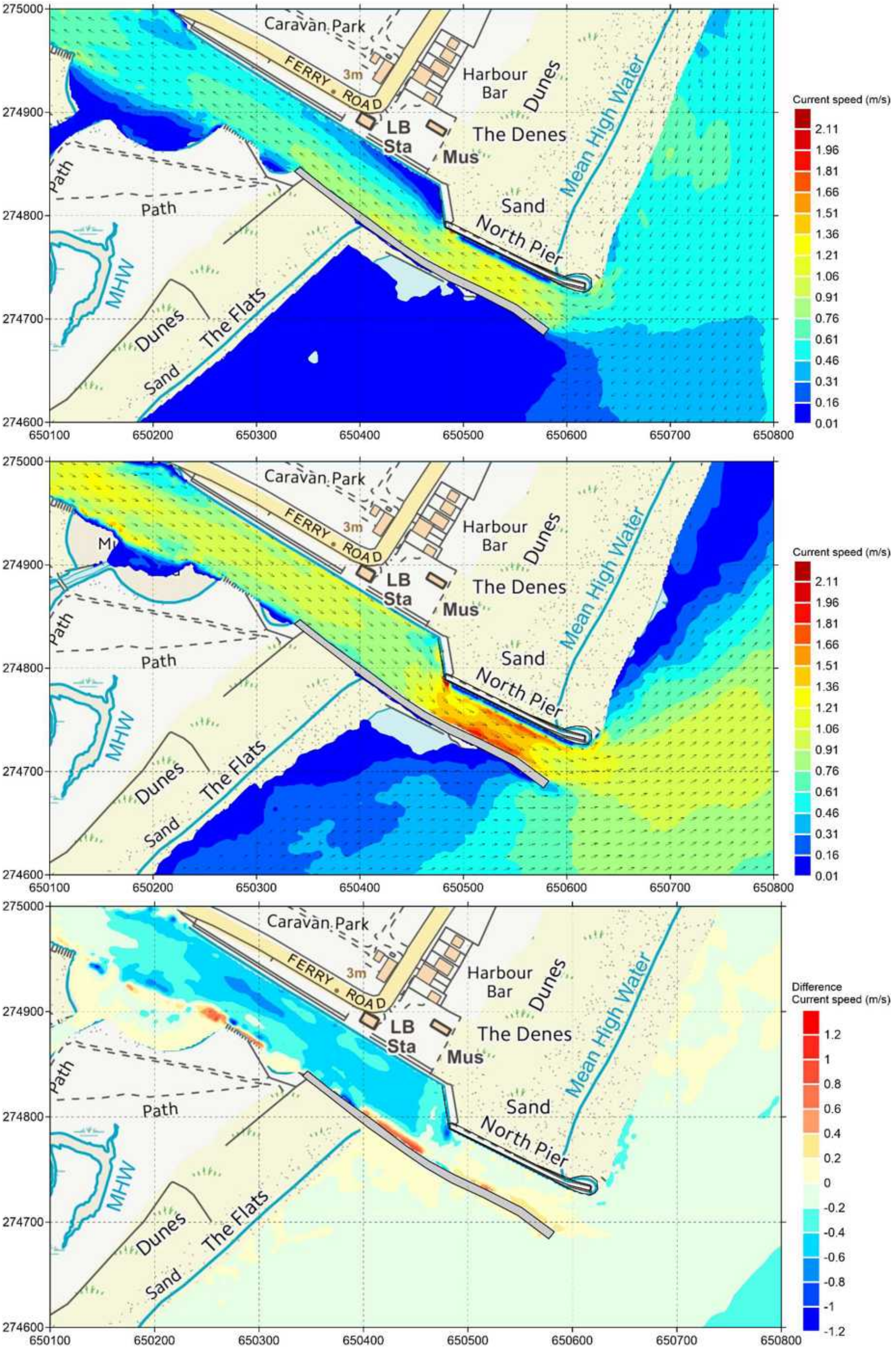

Figure 5-6: Spatial variation and direction of peak flows, breakwater with dredging, February 2020 conditions

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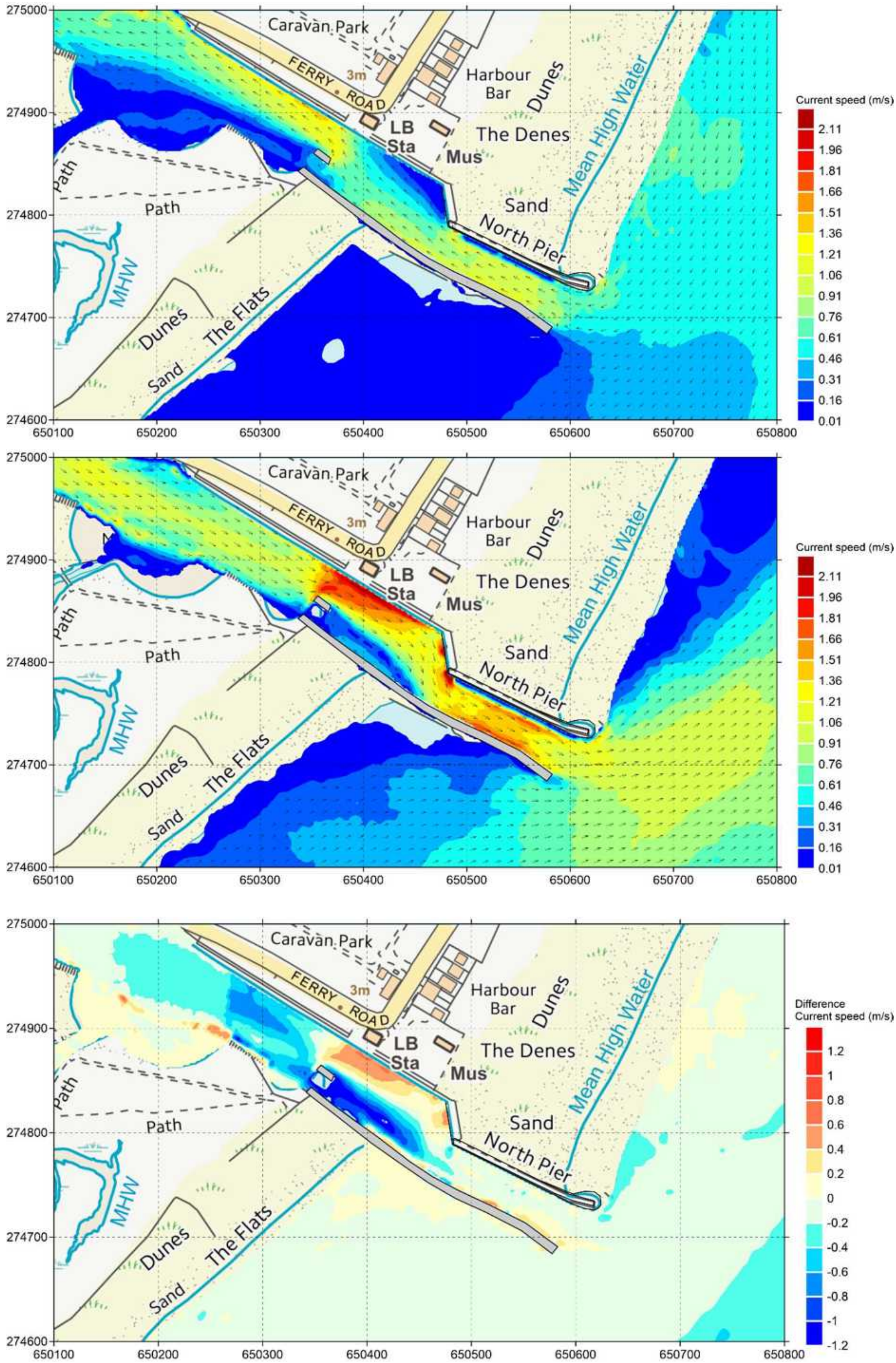

Figure 5-7: Spatial variation and direction of peak flows, breakwater and narrow channel with dredging, February 2020 conditions

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6 Consent Requirements

Section 75 of the Marine and Coastal Access Act 2009, as amended, provides exemptions to a marine licence for certain dredging activities where:

a) the activity is undertaken by or on behalf of a harbour authority, and
b) the activity is authorised by, and carried out in accordance with, any legislation listed below:
    a. any local Act,
    b. any order under section 14 or 16 of the Harbours Act 1964 (c. 40),
    c. any order under section 1 of the Harbours Act (Northern Ireland) 1970 (c. 1 (N.I.)), or
    d. section 10(3) of that Act.

The following conditions also need to be met:

a) the activity involves the relocation of sediments inside surface waters;
b) the activity is for the purpose of:
    a. managing waters or waterways;
    b. preventing floods;
    c. mitigating the effects of floods or droughts; or
    d. land reclamation; and
c) it is proved to the satisfaction of the appropriate licensing authority for the area in which the activity is to be undertaken that the sediments are not hazardous waste.

Whether East Suffolk Council, as Statutory Harbour Authority for the lower section of the tidal River Blyth, is exempt from requiring a marine licence will depend upon whether they have existing powers to do so. Should powers exist, sediment sampling will still be required to prove to the satisfaction of the appropriate licensing authority (the Marine Management Organisation (MMO)) that the sediments are not hazardous. Where powers do not exist, a marine licence will be required for dredging and/or disposal.

It is understood that dredging has not been carried out at Southwold within the past 10 years and therefore, based on guidance from the Marine Management Organisation[1], any dredging proposed for navigational purposes or channel clearance would be defined as capital dredging works.

The application process for a marine licence is defined in the Marine pages of www.gov.uk[2]. An environmental assessment should be undertaken to consider the potential effects of the proposed dredging and disposal activities on the marine environment.

For the proposed dredging works, it may be possible to re-use the sediment within the harbour, so that disposal offshore is not required. For example, the dredged shingle could be used to infill areas of erosion, such as on the landward side of the South Training Arm, or to fill areas of scour in the channel (e.g. near to the Walberswick Ferry or the Bailey Bridge). Whilst beneficial use is preferred over offshore disposal, this these activities still require approval.

A further option would be to undertake the dredging alongside the construction of the proposed rock breakwater, using the material as fill material to the proposed rock breakwater, or placing it against the toe of the structure to reduce erosion risk. In this case dredging and disposal would be related to a construction project and therefore the Environmental Impact Assessment (EIA) Regulations will apply.

Sediment sampling and analysis will be needed to inform the nvironmental assessment. The hydrographic survey completed in 2020 included suspended sediment sampling, plus samples of sea-bed sediments taken from various locations within the harbour, but no samples were taken from the shoal bank. Samples

[1] Dredging - GOV.UK (www.gov.uk)
[2] The marine licence application timeline - GOV.UK (www.gov.uk)

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will need to be collected throughout the dredge depth. The number and location of samples and analysis would need to be undertaken in accordance with the requirements of the MMO.

7 Assessment of Potential Impacts of Proposals

Table 7.1 summarises the benefits and constraints of the proposals to dredge the shoal bank opposite the North Wall, and to narrow the channel in the outer harbour, considering the various key issues for both scenarios. The conclusions and recommendations based on this assessment are set out in **Sections 8 and 9** respectively.

8 Conclusions

The removal of the shoal bank would have a minor benefit for wave conditions in the vicinity of the North Wall if the South Pier was not replaced. If the South Pier is replaced with a rock breakwater, then the bathymetry in the outer harbour, including any changes to the shoal bank, would have limited influence on wave conditions, because wave energy will be dissipated by the rock breakwater. Narrowing the channel would further reduce wave penetration into the inner harbour.

The presence of the shoal bank influences peak water levels upstream, as the shoal bank acts to narrow the channel and limit the volume of water that flowing into the estuary. If the shoal bank was to be removed, peak water levels in the outer harbour would be approx. 20cm higher on an extreme event similar to 2013. At the Blackshore, peak water levels would be less than 10cm higher. Narrowing the channel with the construction of a rock groyne would replicate the effect that the shoal bank currently has on upstream water levels, reducing peak water levels upstream.

Flow velocities over the shoal bank are less than in the deeper part of the channel at present due to the reduced water depth and the shape of the Knuckle which influences the direction and speed of flow. The influence of the Knuckle on flow directions and velocities would continue with removal of the shoal bank, but this would be less pronounced as flows would no longer be ‘squeezed’ past the bank. Removing the shoal bank would result in a reduction in peak flow velocities past the North Wall, but a slight increase in peak flow velocities further upstream. With a narrow channel, flow velocities upstream are slightly reduced.

Construction of a rock groyne structure to narrow the channel immediately upstream of Dunwich Creek (Location 4 in **Figure 4-1**) would have fewer constraints for navigation than a rock groyne positioned at Location 2 and would achieve slightly lower peak water levels. Due to increased flow velocities around the structure, there would be a risk of scour of the channel bed in this area. Sediment would be expected to accumulate to either side of the structure, which could partially mitigate the scour risk.

If the shoal bank was removed, some deposition of sediment in the vicinity of the existing shoal bank would be expected in the future, as flow velocities and directions would continue to be influenced by the shape of the channel at the Knuckle. The future rate of sediment deposition is difficult to quantify, as it depends on the frequency of storm events from the North East, and the volume of sediment discharged from Dunwich Creek, which is hard to measure as the shallow depth of the Dunwich Creek channel restricts access for hydrographic survey

A Marine Licence would be required in order to undertake the proposed dredging, as maintenance dredging has not been undertaken to the harbour within the past 10 years. This would require environmental assessment, supported by sediment sampling and analysis for samples taken from the shoal bank. Based on current assessment timescales for Marine Licence applications by the MMO, this process could take 6 months to 1 year.

9 Recommendations

Removing the shoal bank located opposite the North Wall would improve conditions for navigation in the outer harbour and increase space for mooring at the North Wall. Dredging would not change conditions in the entrance channel. Flow velocities in the outer harbour would be reduced, and the impact on upstream flow velocities would be limited. However, there would be negative impacts on water levels further upstream.

If dredging was to be undertaken, construction of a rock groyne to narrow the channel would mitigate the impacts on peak water levels. A location upstream of Dunwich Creek is preferred for the narrowed channel, however, further discussion with stakeholders is required regarding any constraints associated with the construction of a rock groyne at this location.

A marine licence application, supported by an environmental assessment and sediment sample analysis, would need to be completed to enable the shoal bank to be removed.

Regular bathymetric surveys would be needed to monitor future channel depths and any requirement for maintenance dredging.

Table 7.1: Assessment of benefits and constraints of proposed dredging and narrow channel options

Issue	Benefits	Constraints	Assessment
Wave conditions	With a rock breakwater, any changes to the shoal bank would have limited influence on wave conditions, because wave energy would have been dissipated by the rock armour. Narrowing the channel, with or without dredging, would reduce wave penetration into the inner harbour.	If the shoal bank was removed before the South Pier is replaced, wave heights would no longer build or break in the shallow water. More wave energy could progress into the inner harbour if waves do not break over the shoal bank. Removing the shoal bank could increase wave reflection from the south side of the channel, causing higher waves at the North Wall. The deeper water in the outer harbour would be able to sustain larger waves.	Removal of the shoal bank is expected to increase wave heights in the outer harbour if dredging is undertaken before the South Pier is replaced. After replacement of the South Pier with a rock breakwater, dredging the shoal bank would have minimal impact on wave disturbance in the outer harbour and entrance channel, because wave energy would be dissipated by the breakwater.
Peak water levels	Removal of the shoal bank would allow more water to flow into the estuary, raising peak water levels by about 20cm in the outer harbour and by up to 10cm through the Blackshore for the December 2013 event conditions. Upstream water levels are less with a rock breakwater in place but would be a few centimetres higher than present day conditions.	Narrowing the channel in the outer harbour as well as dredging the shoal bank reduces peak water levels upstream by about 5cm compared to the option with a breakwater + dredging, Peak water levels at the Blackshore would be comparable with present-day conditions.	The shoal bank currently acts to extend the narrowed channel upstream of the harbour entrance, so removal of this sediment would allow more water to flow into the estuary, raising peak water levels in the outer harbour and further upstream. Narrowing the channel in the outer harbour would replicate the effect that the shoal bank has on constraining flows, so peak water levels upstream would be comparable with the present day conditions. A rock groyne at Location 4 is slightly better for peak water levels compared to Location 2.
Peak flow velocities	**D**redging the shoal bank would decrease peak flow velocities through the outer harbour by up to 0.6m/s due to the increase in channel cross section. Dredging has limited impact on flow velocities in the entrance channel. Including a narrowed channel as well as the breakwater and removal of the shoal bank	Through the Blackshore and further upstream, peak flow velocities would increase by up to 0.3m/s compared to the present day with a rock breakwater plus dredging of the shoal bank. With a rock breakwater in place, dredging would increase peak flow velocities upstream of the North Wall by up to 0.3m/s for the December 2013 event conditions. For the	Dredging the shoal bank would reduce peak flow velocities in the outer harbour for all options. Peak flow velocities would increase further upstream as the tidal prism would increase, unless the channel is narrowed by a rock groyne.

Issue	Benefits	Constraints	Assessment
	reduces peak flow velocities by up to 0.3m/s upstream and downstream of the narrowed section (December 2013 conditions). Peak flow velocities in the outer harbour reduce by 0.1m/s for the February 2020 conditions.	February 2020 (operational) conditions, peak flow velocities would be only 0.1m/s higher.	
Flow directions	The dredging proposals are not expected to have a significant impact on flow directions.	Any change in flows could be more noticeable to harbour users, as with dredging the flows will be more consistent over the full width of the channel, rather than the faster flows being concentrated in the navigation channel close to the North Wall.	Whilst a change in flow patterns would be experienced by harbour users following removal of the shoal bank, this is not expected to be significant.
Channel bed erosion and/or sediment deposition	The dredging proposals would not have a significant impact on erosion of the channel bed in the entrance channel. Sediment accumulation to either side of a rock groyne to narrow the channel could improve stability of both the rock groyne and the adjacent South Training Arm.	The reduction in flow velocities in the outer harbour with dredging could result in an increased rate of sediment deposition. Therefore, the shoal bank could re-establish in the future. It is difficult to predict the rate of sediment deposition as this would also depends on the frequency of storm events that could drive sediment into the harbour, and discharge from Dunwich Creek. For a narrowed channel, the increased flow velocities around the structure could result in scour of this part of the channel, with a risk of undermining the foundations to the North Wall. Sediment would also be deposited on either side of the structure which may need to be removed in future.	The shoal bank could re-establish in the future and could require maintenance dredging. Channel bed levels should be monitored to determine the requirement for maintenance dredging, or scour around a narrow channel structure.
Navigation and mooring	The navigable width of the outer harbour would be increased, improving access to inner harbour and creating more space at North Wall for vessel mooring. A rock groyne at Location 2 may help with vessel turning.	If a rock groyne is installed to narrow the channel, this would restrict navigation, which could be more difficult due to faster flows around the structure. Access to the Lifeboat Station could be restricted, particularly for a rock groyne at Location 2. Without a narrowed channel, there could be increased wave disturbance in the inner harbour. Further works to North Wall may be required to enable safe mooring.	Removing the shoal bank would increase space for mooring at the North Wall, and the width of the navigation channel, assuming the shoal bank does not re-establish. A narrowed channel would increase navigation constraints. Narrowing the channel at Location 4 would be preferable to Location 2 in terms of minimising the constraints on navigation and mooring.

Issue	Benefits	Constraints	Assessment
Consent requirements	A marine licence is unlikely to be required for any future maintenance dredging, but this would need to be confirmed with the MMO.	The proposed dredging is likely to be defined as capital dredging works because dredging has not been carried out at Southwold within the past 10 years. Therefore, a marine licence will be required, supported by an environmental assessment to consider the potential effects of the proposed dredging and disposal activities on the marine environment. Sediment sampling and analysis in accordance with the requirements of the MMO will be needed to inform the environmental assessment.	A Marine Licence is likely to be required to enable the proposed dredging. The application and assessment process for a licence could take 6 months to 1 year.
Undertaking the proposed dredging	The capital cost for initial dredging would be relatively low. Dredged material could be reused in the works to replace the South Pier, or infill eroded areas behind South Training Arm, although an environmental assessment would be required for this.	Hard material may be present within the channel bed, which could impact on cost of dredging and ease of disposal.	Subject to obtaining the relevant consents for undertaking the proposed dredging, these works should be straightforward. Sediment samples will be required to inform the Marine Licence application, which would provide useful information for planning the works.

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