Final report

Wallis Lake Dredging Assessment

28 June 2011 30011016

Great Lakes COUNCIL

Project Name:	Wallis Lake Dredging Assessment
Project Number:	30011016
Report for:	Great Lakes Council

PREPARATION, REVIEW AND AUTHORISATION

Revision #	Date	Prepared by	Reviewed by	Approved for Issue by
A	8 June 2011	Takehiko Nose	Evan Watterson	Evan Watterson
B	**24 June 2011**	**Evan Watterson**	**Evan Watterson**	**Dan Messiter**

ISSUE REGISTER

Distribution List	Date Issued	Number of Copies
Great Lakes Council:	28 June 2011	2
SMEC staff:		
Associates:		
Newcastle Office Library (SMEC office location):		
SMEC Project File:		

SMEC COMPANY DETAILS

SMEC Ports and Marine
74 Hunter Street, Newcastle, NSW 2300

Tel: (02) 4925 9631

Fax: (02) 4925 9666

Email: evan.watterson@smec.com

www.smec.com

TABLE OF CONTENTS

1 INTRODUCTION

SMEC has been engaged by Great Lakes Council to undertake an assessment of the impact of proposed dredging works on the hydrodynamics and sediment transport processes in the lower Wallis Lake estuary.

The investigation aims to quantify the impacts and facilitate a better understanding of the effectiveness of dredging in the lower estuary. The investigation primarily involves the application and interpretation of a calibrated numerical modelling system previously developed for the Wallis Lake estuary (WorleyParsons, 2011a).

1.1 Study Area

The study area comprises the lower Wallis Lake estuary (refer to **Figure 1**). Wallis Lake estuary is one of the largest coastal lakes in Eastern Australia. It is a complex system comprising a main lake, large rivers and entrance area with interconnecting channels that separate the coastal towns of Tuncurry and Forster. The estuary has a waterway area of approximately 73 km^2 and is connected to the ocean by a narrow trained entrance channel.

Figure 1 provides an overview of the study area and includes proposed dredge areas, oyster lease areas and the locations of model outputs referred to in this report.

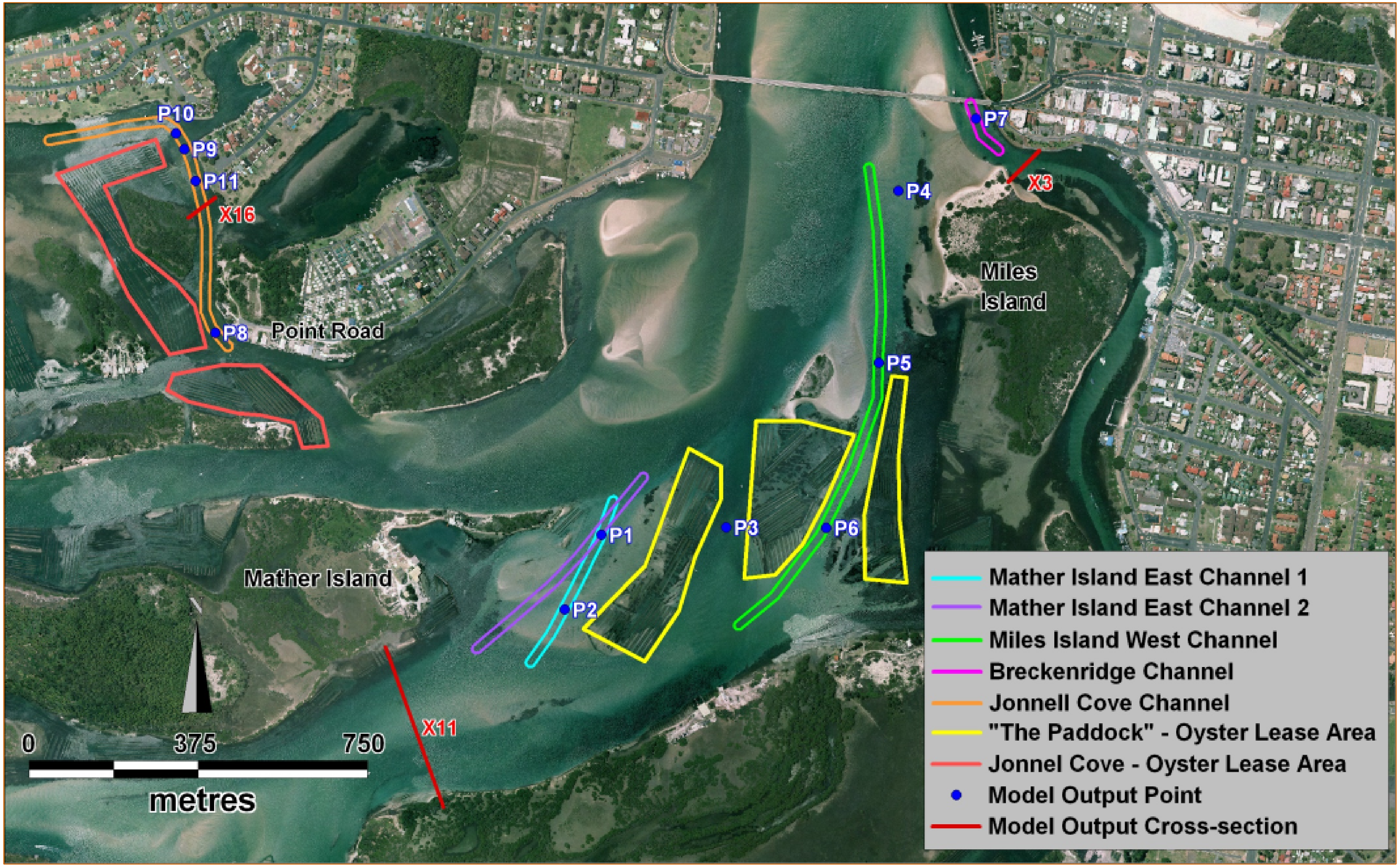


Figure 1 Study area and key study locations

2 BACKGROUND INFORMATION

2.1 Previous Studies

Previously proposed dredging works at 'The Step' and three other locations in the lower estuary have recently been the subject of environmental assessment studies (WorleyParsons, 2011a, 2011b and 2011c). As part of these studies a calibrated hydrodynamic and sediment transport model of Wallis Lake was established in MIKE 21 (a two-dimensional coastal modelling system developed by the Danish Hydraulics Institute (DHI, 2008)). In addition to developing this numerical model, the coastal processes investigation compiled all existing relevant data, including tidal gauging and hydrographical surveys, and collected additional tidal data. WorleyParsons (2011a) documents the numerical model and estuarine data and should be referred to if additional detail on these aspects is required.

2.2 Potential Dredging Areas

This study assesses five additional areas identified by Council where dredging is required for a variety of reasons, including navigation and maintaining oyster leases. The location and key features of these proposed works are summarised in **Figure 1** and **Table 1**. Council has specified that all areas would be dredged to a bottom-width of 20 m (i.e. this does not include batter slopes).

Table 1 Summary of potential dredging areas

Proposed Dredge Area	Proposed dredge level (m AHD)	Length (m)	Dredge area (m^2)	Dredge volumes (m^3)
Mather Island East Channel (Opt1)	2.5	420	7,600	9,850
Mather Island East Channel (Opt2)	2.5	550	9,700	13,140
Miles Island West Channel	2.5	1,140	19,400	13,570
Breckenridge Channel	2.5	150	2,600	1,820
Jonnell Cove Channel	2.5	820	12,900	6,450
"The Paddock' Oyster Leases	1.5	na	3,980	19,900

2.3 Site Visit

A site visit was conducted by members of the SMEC study team, Council and representatives of the Wallis Lake Oyster industry on the 28 April 2011. Each of the proposed dredge sites were visited aboard Graeme Barkley's the *Barkley Oysters'* vessel. The purpose of this site visit was to experience the local environment at each site first-hand and gain an appreciation of the individual issues associated with each site.

This vessel is one of the larger vessels that is permanently moored in the Lake and was suitable to experience the difficulty that can be encountered when attempting to navigate the shallow channels within the lower estuary.

This site visit was attended by:

- Gerard Tuckerman and David Hopper (Great Lakes Council)
- Graeme Barkley, Anthony Sciacca, Stephen Verdich, and John Ravell (local oyster growers)
- Don Sheffield (local community representative)
- Evan Watterson and Takehiko Nose (SMEC)

3 EXISTING CONDITIONS

3.1 Existing condition in each of the dredging areas

The local hydrodynamic and sediment transport conditions at each of the five potential dredge areas has been examined. A brief description of the key features associated with the existing environment (water depth, tidal range, current speed and sediment transport rate) in each area is summarised in **Table 2.**

Table 2 Summary of existing conditions at each site

Proposed Dredge Area	Water depth (m) (below AHD)	Mean Spring Tidal Range (m)[1]	Maximum Current Speed (m/s)	Sediment transport rate (x10^{-6} $m^3/s/m$)
Mather Island East Channel	0.4 – 2.5	0.6	0.6	13.2
Miles Island West Channel	1.4 – 3.0	0.7	0.5	3.1
Breckenridge Channel	1.6 – 2.7	0.7	0.6	14.4
Jonnell Cove Channel	1.3 – 2.7	0.4	0.4	0.2
'The Paddock' Oyster Leases	0.6 – 3.0	0.7	0.5	3.1

Note:

1. Based on model output at relevant locations shown on **Figure 1**.

3.1.2 Flow patterns

Figures A1 to **A3** (refer to **Appendix A**) provide plots of the peak ebb and flood flow patterns (both current speeds and water depth, and velocity vectors) based on the numerical modelling outputs for three key areas:

- 'The Paddock' – contains the Mather Island East Channel, Miles Island East Channel and 'The Paddock' oyster leases.
- Breckenridge Channel – the northern entrance of this channel where dredging is proposed.
- Jonnell Cove Channel.

The following section provides a short description of the nature of the modelled flow patterns across these areas.

'The Paddock'

The area around 'The Paddock' oyster leases provides for exchange between the entrance area and the upstream tidal prisms of Wallis Lake and the Coolongolook River via 'The Step' and 'The Western Step' (these are the names given to the marine delta drop overs). The main flow conveyance is through the relatively deep channel between the main oyster leases areas. Conveyance is also provided via the two shallow areas of Mather Island East Channel and Miles Island East Channel where dredging is proposed.

Flood and ebb flow patterns are quite different in terms of the flow velocity patterns (refer to **Figures A-1a** to **A-1d**).

Figure 2 shows a comparison of hydrographic surveys taken 12 years apart, areas shaded green are areas of deposition while areas shaded blue are areas of erosion. It is observed that the main flow channel through 'The Paddock' area has generally tended to scour while the two areas identified for dredging have generally shoaled or maintained depths. However, the northern end of Mather Island East Channel seems to have scoured. It should be noted that the survey data on which this comparison is may vary in resolution and comparison is only made where sufficient data allows (1998 survey points shown in red and 2010 survey points shown in black).

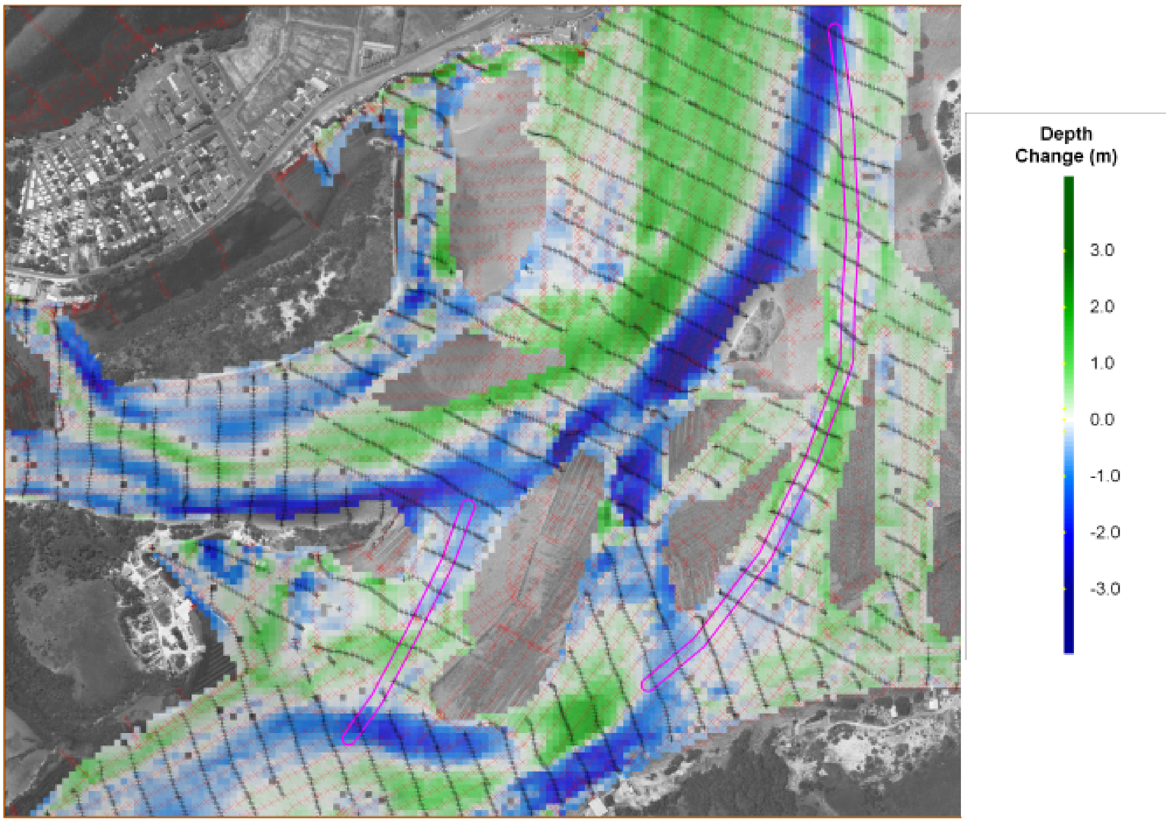
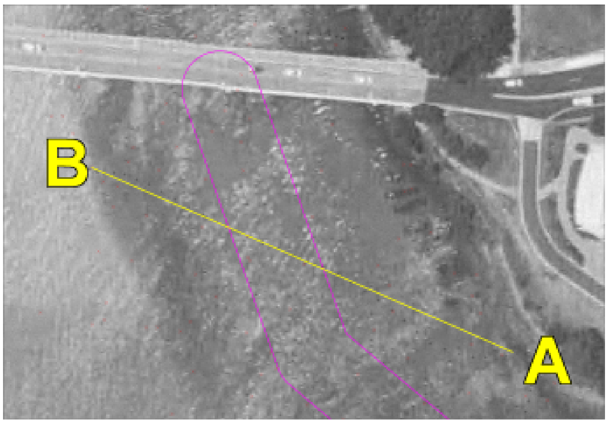


Figure 2 Hydrographic survey comparison at 'The Paddock'

Breckenridge Channel

Breckenridge Channel is a relatively narrow channel that, among others, connects the entrance area to Wallis Lake proper. It runs along the eastern foreshore of the estuary, along the Forster Township. Both flood and ebb flows change direction due to channel alignment as they enter or exit Breckenridge Channel at the northern end (refer to **Figures A-2a** to **A-2d**). It is also noted that flow patterns in this area are complicated by the Forster-Tuncurry Bridge structure, which is not represented in the model.

Based on comments made on the site visit, anecdotal evidence suggests that navigation in this area has become worse due to the growth of a sand lobe from the eastern bank. Where sufficient data allows comparison, hydrographic survey information supports this. **Figure 3** show a comparison of the bathymetric profiles available. It appears to suggest that a sand lobe has gradually increased in height, shoaling the channel (about 0.3 m over the 12 years). In addition a channel on the western side of this profile that was previously almost 2.5 m deep has infilled and is less than 2.0 m deep. This is likely due to the encroachment (or migration) of the large sand bar located on the western side of this profile.



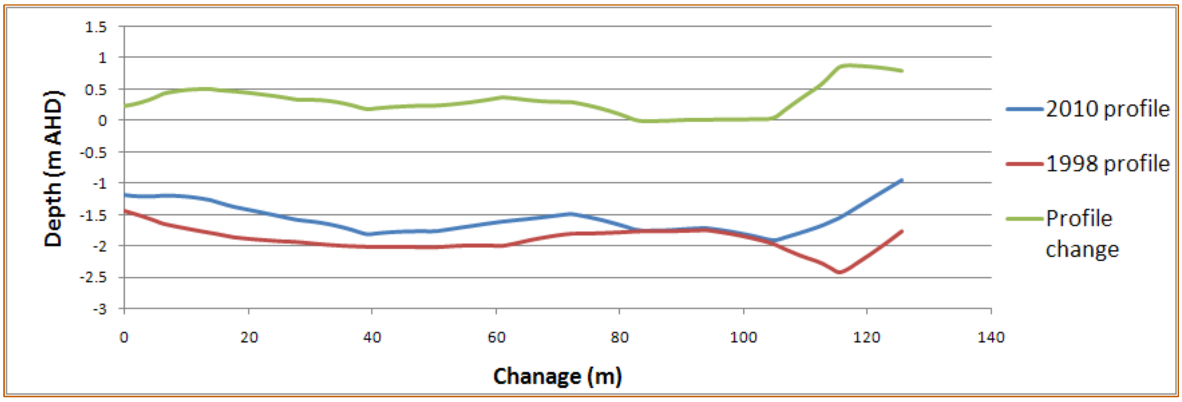


Figure 3 Breckenridge Channel bathymetry profiles (A-B) for 1998 and 2010 hydrographic surveys and the change

Jonnell Cove Channel

This channel provides one of the main flow paths for tidal and fluvial exchange to Wallamba River. Both flood and ebb current speeds are strong around the end of Point Road and between the island to the west and northern foreshore where the channel is narrow (refer to **Figures A-3a** to **A-3d**). The model predictions of relatively strong flows (current speeds of 0.6 m/s) through the oyster lease located opposite the western end of Point Road, particularly on the flood tide, may help to explain the observed scour of this lease (pers. comms. Stephen Verdich). There are concerns that dredging may impact on the flows through this oyster leases and enhance currently occurring scour.

The adjacent, broad and shallow area, largely occupied by oyster leases also provides a flow path through this area. There is also another flow path that is aligned east-west providing for tidal flows to Wallamba River.

Observed sedimentation patterns in this area are difficult to assess due to survey resolution. However, it appears that the Jonnell Cove Channel has generally maintained similar overall depths with some scour and shoaling as sand is redistributed within the channel.

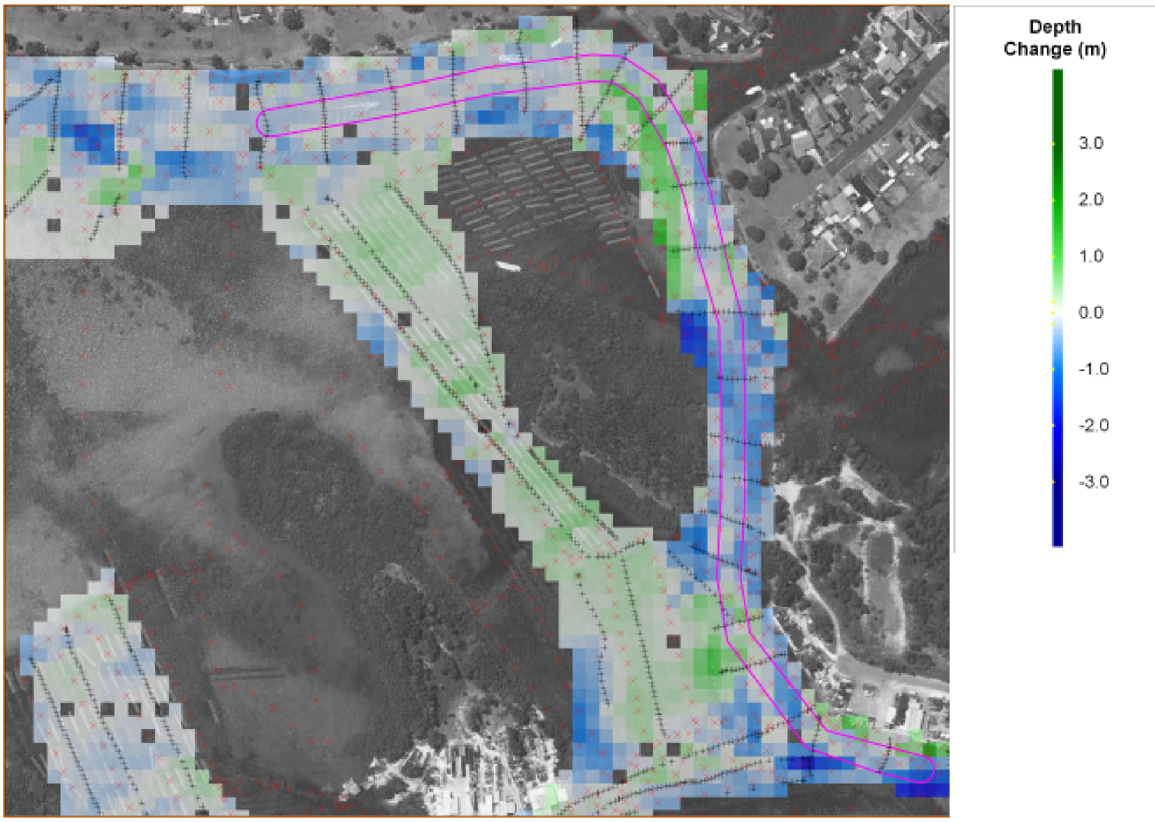


Figure 4 Hydrographic survey comparison at Jonnell Cove Channel

3.1.3 Sediments

Sediments in the lower Wallis Lake estuary are predominately composed of marine sands. A more detailed description of the sediment types observed in the estuary is provided in WorleyParsons 2011. For the purpose of this assessment the lower estuary is assumed to be composed of marine sand. More detailed sediment sampling in each of the dredge areas would be required prior to dredging works.

4 DREDGING IMPACT ASSESSMENT

4.1 Dredging Scenarios Used For Assessment

Dredging within Wallis Lake is likely to proceed on an 'as needed' basis when funds for required works become available. For the purposes of this assessment the following dredging scenarios have been considered:

- *Scenario A* – Dredging for navigation at Mather Island East Channel in isolation. Two alignments have been examined for *Scenario A*. Option1 presents a channel aligned more north-south and Option 2 presents a more east-west alignment (refer to **Figure 1**).
- *Scenario B* – Dredging for navigation at Miles Island West Channel in isolation.
- *Scenario C* – Dredging for navigation at Breckenridge Channel in isolation.
- *Scenario D* – Dredging for navigation at Jonnell Cove Channel in isolation.
- *Scenario E* – All of the above as shown on **Figure 1**.
- *Scenario F* – All navigation dredging and scraping of 'The Paddock' oyster leases.

The existing condition scenario (based on the 2010 condition) is also included for comparative purposes.

4.2 Assessment Methodology

The calibrated hydrodynamic and sediment transport model was used as a tool to assess the various dredging scenarios. The model system was used to simulate 29-days of typical tidal flow conditions, during the period 2 October 2010 to 1 November 2010. Sediment transport was included, as well as a morphological update of estuary bed levels based on the net sediment transport calculated by the model.

Each scenario was compared against the baseline scenario and against the other scenarios by assessing:

- changes to the local hydrodynamic and sediment transport conditions within the dredge areas;
- tidal regime change; and
- channel infilling (or sedimentation of the dredged channel).

4.3 Changed hydrodynamic and sediment transport conditions

Figure B1 to **B6** (refer to **Appendix B**) provide plots showing the difference in the peak flood and ebb patterns for the relevant areas (as defined above) under each of the dredging scenarios. It is noted that in these figures showing velocity change that the colour scale depicts relatively small changes.

The following provides a brief discussion of the results.

- *Scenario A* (Option 1 and Option 2) modelling indicates the impact on local flows is significant and can be generally described as an increase in the conveyance through the Mather Island East Channel and a subsequent decrease through the main flow channel in 'The Paddock'. Option 2 is a more effective dredge channel as it is more aligned to the existing flow patterns in the area, current speeds are predicted to increase by up to 0.1 m/s (or around 20%) through the dredged channel as more flow is captured. Decreases in current speed (in the order of 0.07 m/s or 10%) in flood and ebb currents upstream of 'The Paddock' area may result in minor shoaling of some areas. However, this is not expected to affect safe navigation in these areas. It is anticipated that the channels would eventually revert to their original configuration (i.e. with the main channel the preferred channel for tidal flows) and any shoaling would thus be short lived.

- *Scenario B* modelling indicates that the local flow impacts are confined to the Miles Island East Channel where an increase in current speed, as a result of additional conveyance through this channel, would assist in keeping the dredged channel open.
- *Scenario C* modelling indicates local flow patterns are not significantly affected. Local current speed decreases are due to the deeper dredged profile with no additional conveyance within Breckenridge Channel. *Scenario D* modelling indicates that most of the local flow impacts are confined to the dredge channel area with some minor impacts (current speed changes of <0.02 m/s, or less than 10%) on the shallow channel west of Jonnell Cove Channel, particularly in the ebb as additional flow goes through the Jonnell Cove Channel. In regard to concerns that the scour believed to be currently occurring in oyster leases opposite the western end of Point Road, dredging in Jonnell Cove Channel is not expected to significantly impact on this process and may actually improve the situation as more flow is directed to Jonnell Cove Channel.
- *Scenario E* modelling indicates that flows in the main channel through 'The Paddock' are reduced slightly (around 0.04 m/s, or 10%) particularly in the ebb as more flow passes through the dredged channels. The other areas show similar local impacts as the dredging in isolation cases (see *Scenarios C* and *D*).
- *Scenario F* modelling indicates similar results to *Scenario E*, however a greater decrease in tidal exchange is predicted to occur through the main channel in 'The Paddock' area, as more flow is conveyed within the dredged oyster leases. The other areas show similar local impacts as the dredging in isolation cases (see *Scenarios C* and *D*).

4.4 Tidal Regime

The impact on tidal hydraulics of the Wallis Lake estuary was examined for the various scenarios by comparing the tidal planes, tidal ranges and tidal prisms for each dredging scenario with existing conditions. The assessment was aimed at quantifying whether there were significant large scale changes to the tidal regime within the estuary, rather than the local impacts discussed above.

Table 3 presents the calculated spring tidal planes and ranges, based on the results of model simulations. It is noted that there are only minor changes to the existing tidal water levels simulated in the modelling. Where significant differences were found, they are shown in bold red text.

Generally, changes to tidal water levels as a result of the proposed dredging are not considered significant.

Table 3 Modelled spring tidal planes and tidal ranges for existing and dredge scenario conditions

Tidal plane or range		Dredging Scenarios					
	Existing Conditions	A	B	C	D	E	F
Wallis Lake							
MHWS (m AHD)	0.084	0.084	0.084	0.084	0.084	0.084	0.084
MLWS (m AHD)	-0.056	-0.057	-0.057	-0.056	-0.057	-0.058	-0.058
Mean spring range (m)	0.140	0.140	0.140	0.140	0.140	0.142	0.142
Entrance Wallamba River							
MHWS (m AHD)	0.161	0.161	0.161	0.161	0.162	0.162	0.162
MLWS (m AHD)	-0.135	-0.134	-0.135	-0.135	-0.136	-0.136	-0.136
Mean spring range (m)	0.296	0.295	0.295	0.296	0.298	0.298	0.298
Entrance Coolonglook River							
MHWS (m AHD)	0.083	0.083	0.083	0.083	0.083	0.083	0.083
MLWS (m AHD)	-0.051	-0.052	-0.052	-0.051	-0.051	-0.052	-0.053
Mean Spring Range (m)	0.134	0.135	0.135	0.134	0.135	0.135	0.136

Table 4 presents the calculated mean tidal prisms[1] based on the results of model simulations for the locations of model outputs referred to **Figure 1**.

In general, only minor changes (<5% difference) are expected in the mean tidal prisms in the lower estuary as a result of the potential dredging works.

Table 4 Modelled tidal prisms (x10^6 m^3) for existing and dredge scenario conditions

Tidal Prism (x10^6 m^3)	Existing Conditions	Dredging Scenarios A	B	C	D	E	F
Wallis Lake Entrance							
Flood (% difference to existing)	16.62	16.67 (0%)	16.67 (0%)	16.62 (0%)	16.63 (0%)	16.74 (+1%)	16.77 (+1%)
Ebb (% difference to existing)	-20.97	-21.03 (0%)	-21.03 (0%)	-20.98 (0%)	-20.98 (0%)	-21.11 (+1%)	-21.16 (+1%)
Boomers Channel (Site X11)							
Flood (% difference to existing)	10.58	10.63 (0%)	10.63 (0%)	10.59 (0%)	10.57 (0%)	10.73 (+1%)	10.80 (+2%)
Ebb (% difference to existing)	-8.37	-8.41 (0%)	-8.41 (0%)	-8.37 (0%)	-8.36 (0%)	-8.53 (+2%)	-8.58 (+3%)
Breckenridge Channel (Site X3)							
Flood (% difference to existing)	1.15	1.14 (-1%)	1.14 (-1%)	1.17 (+1%)	1.15 (0%)	1.15 (0%)	1.15 (0%)
Ebb (% difference to existing)	-1.43	-1.40 (-2%)	-1.40 (-2%)	-1.44 (+1%)	-1.43 (0%)	-1.42 (-1%)	-1.42 (-1%)
Jonnell Cove Channel (Site X16)							
Flood (% difference to existing)	0.82	0.82 (0%)	0.82 (0%)	0.82 (0%)	**0.91 (+11%)**	**0.90 (+10%)**	**0.90 (+10%)**
Ebb (% difference to existing)	-0.95	-0.96 (0%)	-0.96 (0%)	-0.96 (0%)	**-10.48 (+10%)**	**-10.46 (+10%)**	**-10.44 (+9%)**

[1] Tidal prism upstream of any location is the total volume of water exchange over a tidal cycle. It is calculated here by integrating the modelled discharge curve for each cross-section location.

4.5 Channel Infilling Estimates

The rate of channel infilling (or sedimentation) following proposed dredging was estimated based on results of the hydrodynamic and sediment transport models. The annual sedimentation depths and volumes derived are presented in **Table 5**.

Table 5 Annual sedimentation summary

Proposed dredge area	Dredging Scenarios					
	A	B	C	D	E	F
Mather Island East Channel (Opt 1)						
Average depth of siltation (m / yr)	**0.37**	-	-	-	**0.37**	**0.39**
Volume of siltation (m^3 / yr)	**2,830**	-	-	-	**2,789**	**2,981**
Estimated time to infill (years)	**3.5**	-	-	-	**3.5**	**3.3**
Mather Island East Channel (Opt 2)						
Average depth of siltation (m / yr)	**0.20**	-	-	-	-	-
Volume of siltation (m^3 / yr)	**1,840**	-	-	-	-	-
Estimated time to infill (years)	**7.1**	-	-	-	-	-
Miles Island West Channel						
Average depth of siltation (m / yr)	-	**0.10**	-	-	**0.10**	**0.11**
Volume of siltation (m^3 / yr)	-	**1,986**	-	-	**1,929**	**2,075**
Estimated time to infill (years)	-	**6.8**	-	-	**7**	**6.5**
Breckenridge Channel						
Average depth of siltation (m / yr)	-	-	**0.11**	-	**0.11**	**0.11**
Volume of siltation (m^3 / yr)	-	-	**291**	-	**289**	**292**
Estimated time to infill (years)	-	-	**6.3**	-	**6.3**	**6.2**
Jonnell Cove Channel						
Average depth of siltation (m / yr)	-	-	-	**0.05**	**0.05**	**0.05**
Volume of siltation (m^3 / yr)	-	-	-	**648**	**654**	**653**
Estimated time to infill (years)	-	-	-	**10**	**9.9**	**9.9**
The Paddock Oyster Leases						
Average depth of siltation (m / yr)	-	-	-	-	-	**0.03**
Volume of siltation (m^3 / yr)	-	-	-	-	-	**1,320**
Estimated time to infill (years)	-	-	-	-	-	**15.1**

Sediment infilling due to catchment inflows has not been considered in this assessment as it is expected that these rates would generally be low in the Wallis Lake estuary. However, intermittent flood flows can change the distribution of shoals within the lower estuary channels and thereby alter the flow regime. For example, a large flood in the Coolongolook River could scour Boomers Channel and, in particular, the build-up of sand around 'Hells Gate'. If a large flood was to occur, these estimates may need to be reassessed.

These estimates do not include the influence of local wind-waves or ocean wave penetration at the estuary inlet. However, these processes are not expected to be a significantly contribution to sediment transport processes at the proposed dredging locations.

5 CONCLUSION AND RECOMMENDATIONS

Dredging of the four navigation channel examined as part of this study is considered a feasible option for improving navigation depths in Wallis Lake. The local sediment transport regime is moderately active. However, the proposed dredged channels are aligned with the prevailing direction of flow which assists to reduce sedimentation rates. Estimates of channel infilling indicate that maintenance dredging would be required at 6 to 15 year intervals for the different dredging areas.

The exception is the dredging of Mather Island East Channel where the originally proposed dredge channel (Option 1) is poorly aligned to the prevailing flow direction. The cross trench nature of the flow reduces the effectiveness of the dredged channel in this location with infilling predicted to be less than 4 years. In order to improve the effectiveness of dredging in this channel a second more east-west aligned channel (Option 2) was examined. This channel alignment improved the effectiveness of dredging with a time to infilling predicted as over 7 years.

In regard to concerns that the scour believed to be currently occurring in oyster leases opposite the western end of Point Road, dredging in Jonnell Cove Channel is not expected to significantly impact on this process and may actually improve the scour situation as more flow is directed to Jonnell Cove Channel.

Minimal impacts are expected on the overall tidal regime of the lower estuary from the dredging works assessed as part of this investigation.

6 REFRERENCES

DHI (2008). MIKE 21/3 Flow Model FM – Hydrodynamic Module – User Guide, Danish Hydraulic Institute

WorleyParsons (2011a) *Coastal Processes Report – Hydrodynamic and sediment transport assessment of Wallis Lake dredging*. Draft report prepared for Great Lakes Council.

WorleyParsons (2011b) *Wallis Lake – Dredging and Disposal Options.* Draft report prepared for Great Lakes Council.

WorleyParsons (2011c) *Review of Environmental Factors – Proposed dredging of 'The Step', Wallis Lake*. Report prepared for Great Lakes Council.

APPENDIX A – EXISTING CONDITIONS

Existing Condition – “The Paddock”

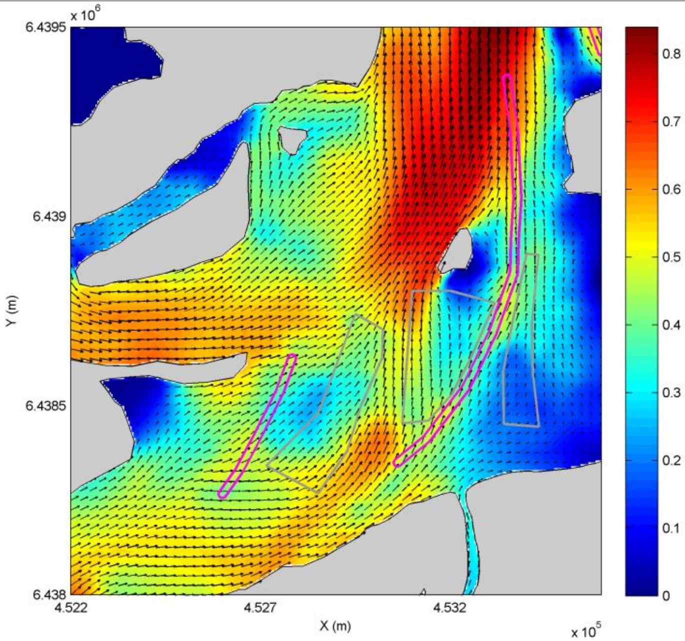


Figure A – 1a

Current speed (m/s) represented by color scale.

Current vectors represented by black arrows.

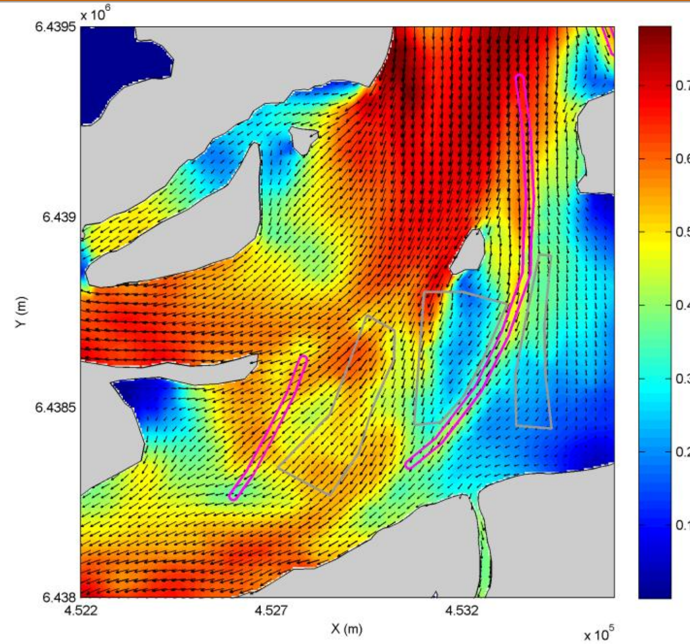


Figure A – 1b

Current speed (m/s) represented by color scale.

Current vectors represented by black arrows.

Current speed and direction for existing condition - ebb peak (left) and flood peak (right)

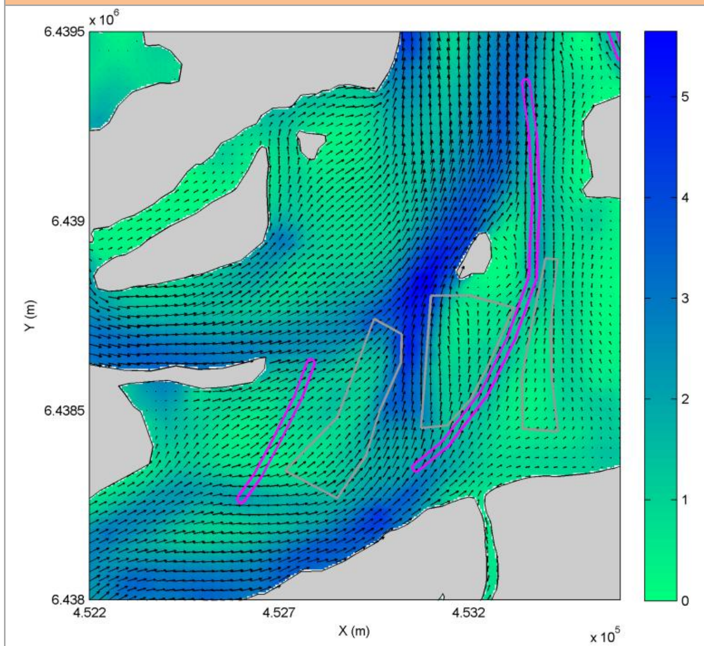


Figure A – 1c

Water depth (m) represented by color scale.

Current vectors represented by black arrows.

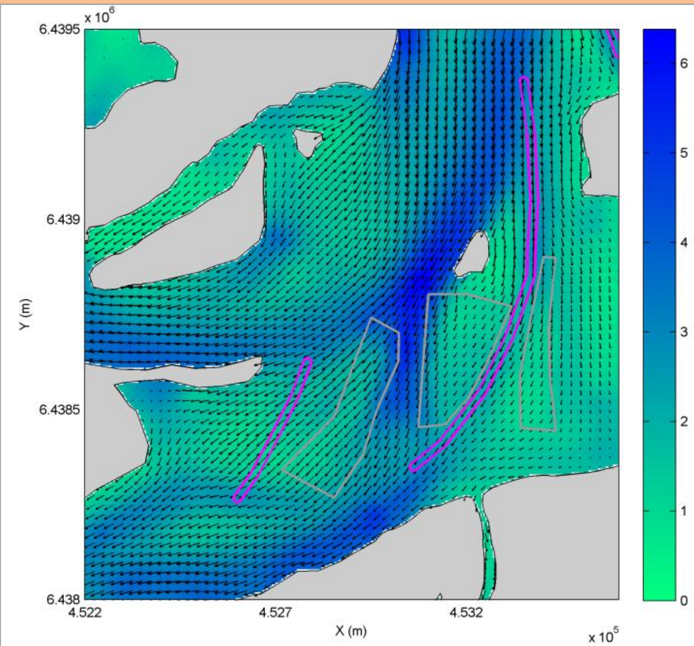


Figure A – 1d

Water depth (m) represented by color scale.

Current vectors represented by black arrows.

Water depth and current vectors for existing condition - ebb peak (left) and flood peak (right)

Existing Condition – Breckenridge Channel

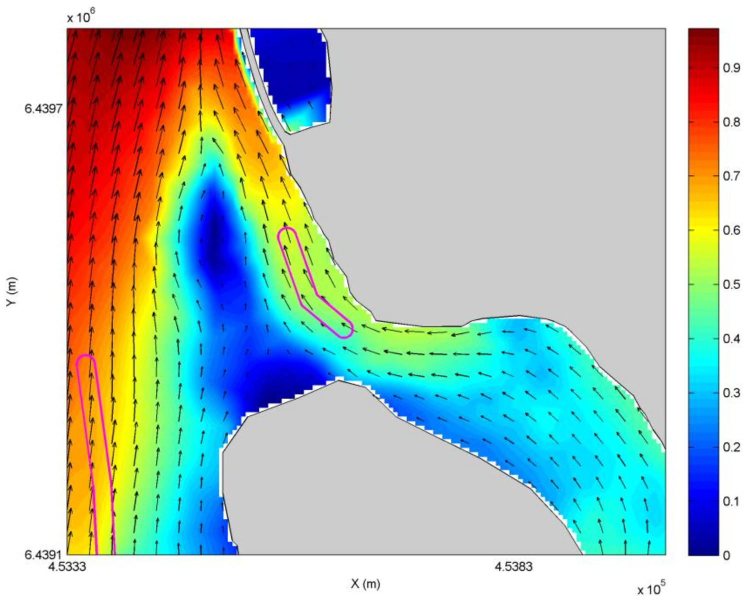


Figure A – 2a

Current speed (m/s) represented by color scale.

Current vectors represented by black arrows.

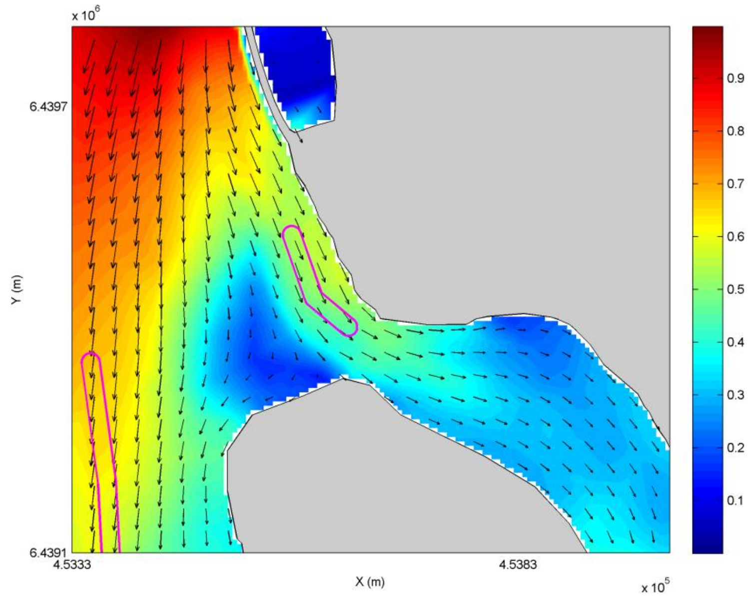


Figure A – 2b

Current speed (m/s) represented by color scale.

Current vectors represented by black arrows.

Current speed and direction for existing condition - ebb peak (left) and flood peak (right)

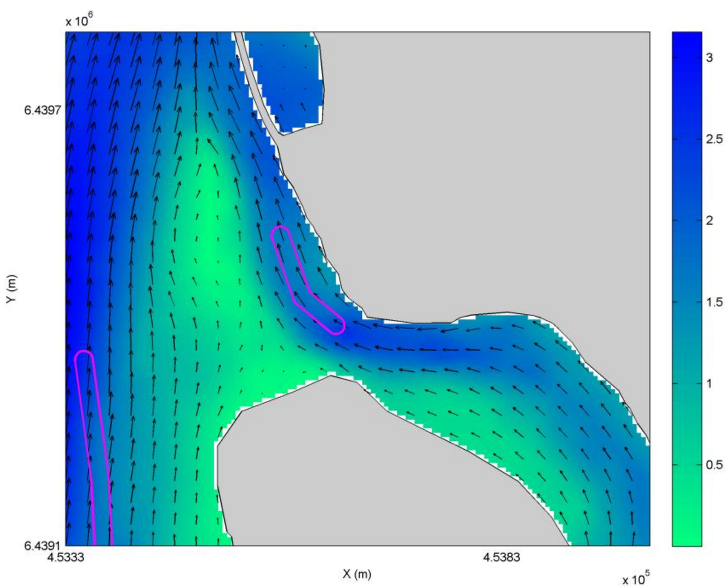


Figure A – 2c

Water depth (m) represented by color scale.

Current vectors represented by black arrows.

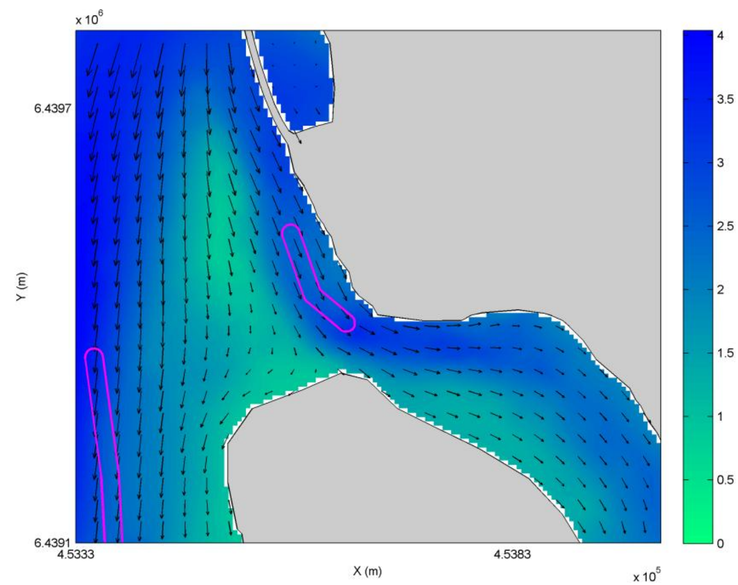


Figure A – 2d

Water depth (m) represented by color scale.

Current vectors represented by black arrows.

Water depth and current vectors for existing condition - ebb peak (left) and flood peak (right)

Existing Condition – Jonnell Cove Channel

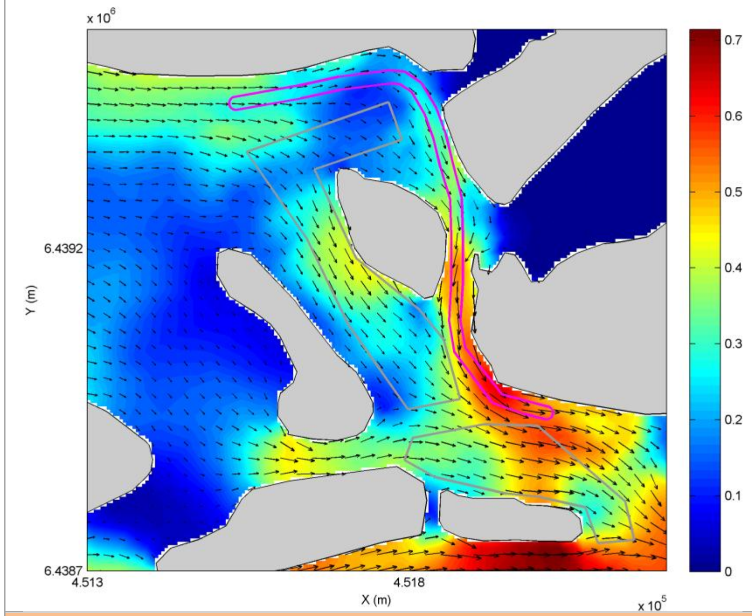


Figure A – 3a

Current speed (m/s) represented by color scale.

Current vectors represented by black arrows.

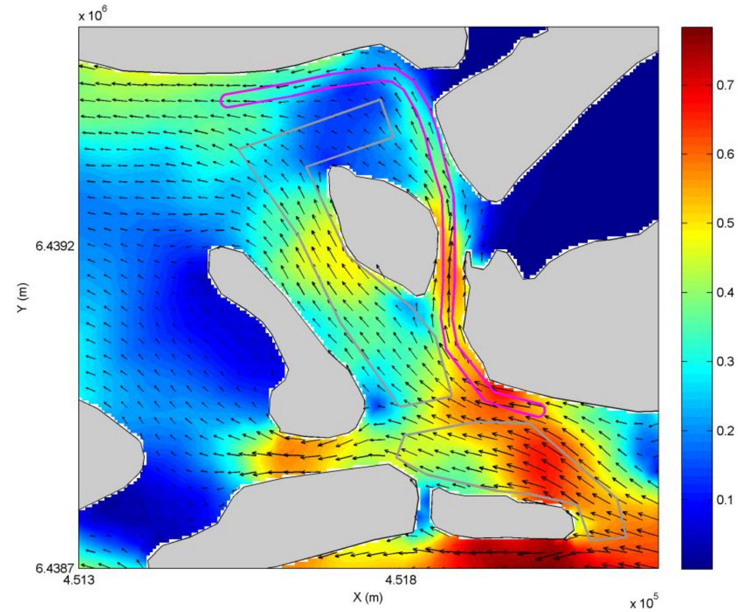


Figure A – 3b

Current speed (m/s) represented by color scale.

Current vectors represented by black arrows.

Current speed and direction for existing condition - ebb peak (left) and flood peak (right)

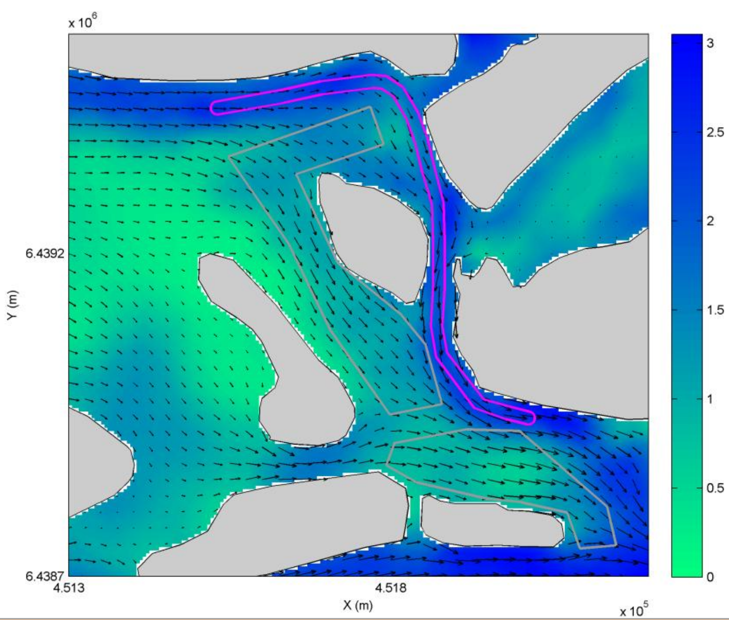


Figure A – 3c

Water depth (m) represented by color scale.

Current vectors represented by black arrows.

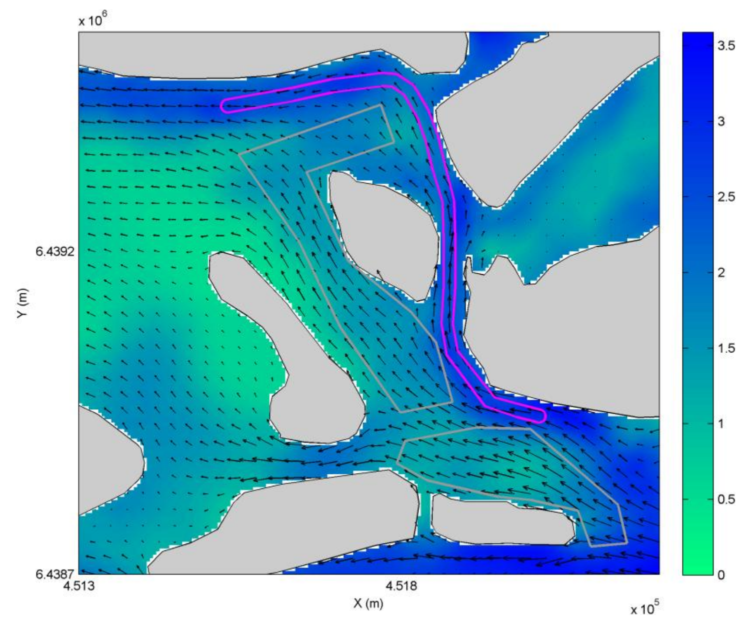


Figure A – 3d

Water depth (m) represented by color scale.

Current vectors represented by black arrows.

Water depth and current vectors for existing condition - ebb peak (left) and flood peak (right)

APPENDIX B - DREDGING IMPACTS ON HYDRODYNAMICS

Scenario A – "The Paddock"

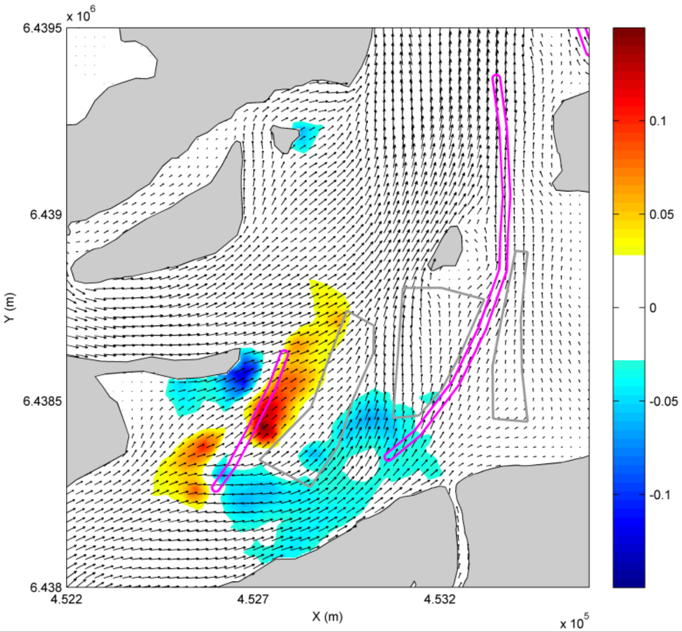


Figure B – 1a

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows.

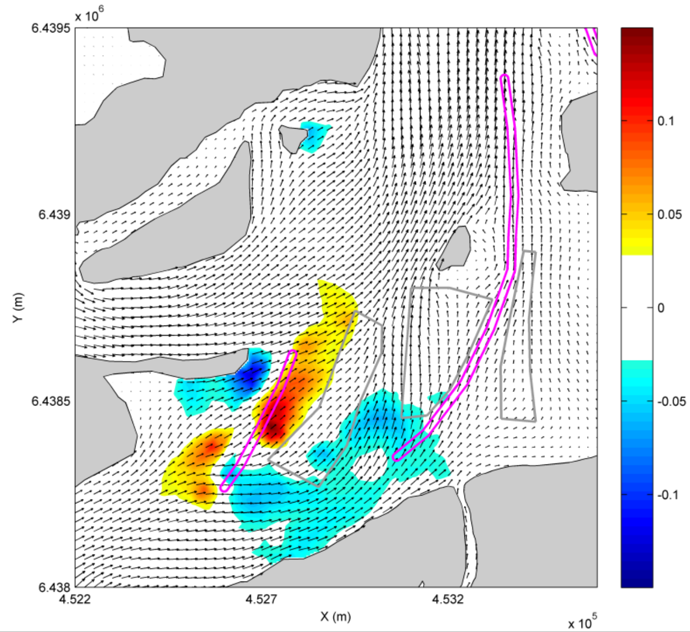


Figure B – 1b

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows.

Current speed difference between Scenario A (Option 1) and existing condition – ebb peak difference (left) and flood peak difference (right)

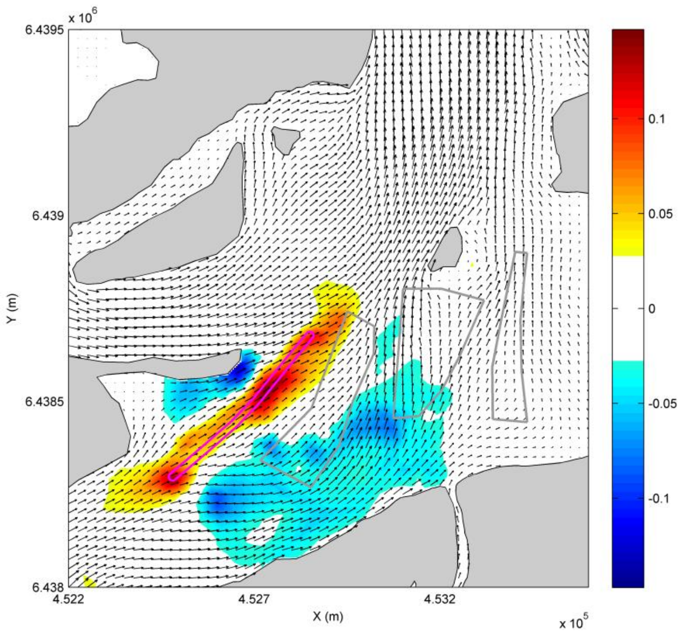


Figure B – 1c

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows

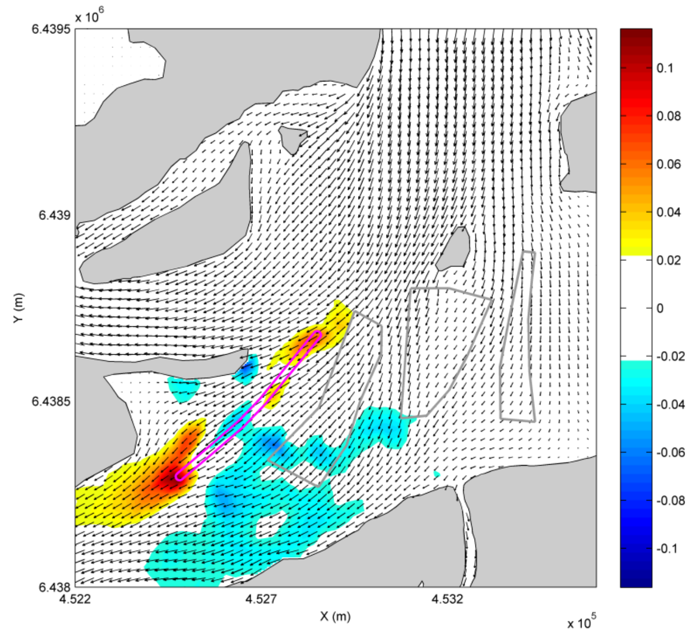


Figure B – 1d

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows

Current speed difference between Scenario A (Option 2) and existing condition – ebb peak difference (left) and flood peak difference (right)

Scenario B – "The Paddock"

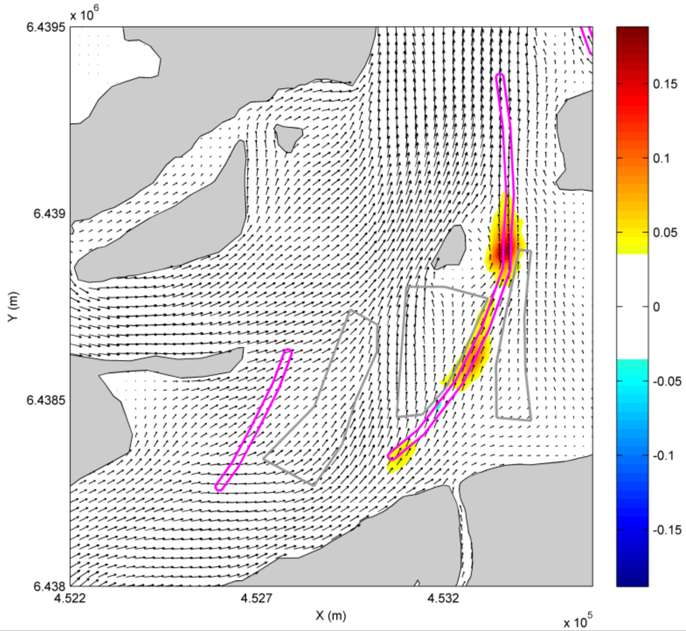


Figure B – 2a

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows.

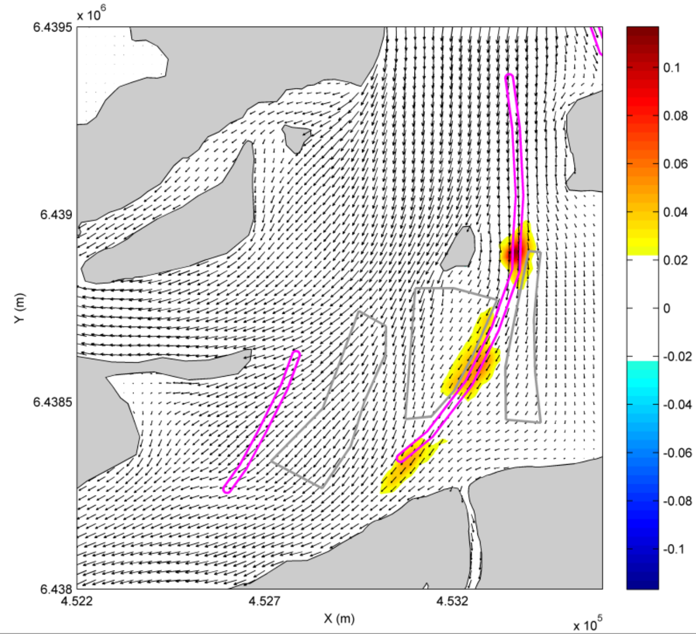


Figure B – 2b

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows.

Current speed difference between Scenario B and existing condition – ebb peak difference (left) and flood peak difference (right)

Scenario C – Breckenridge Channel

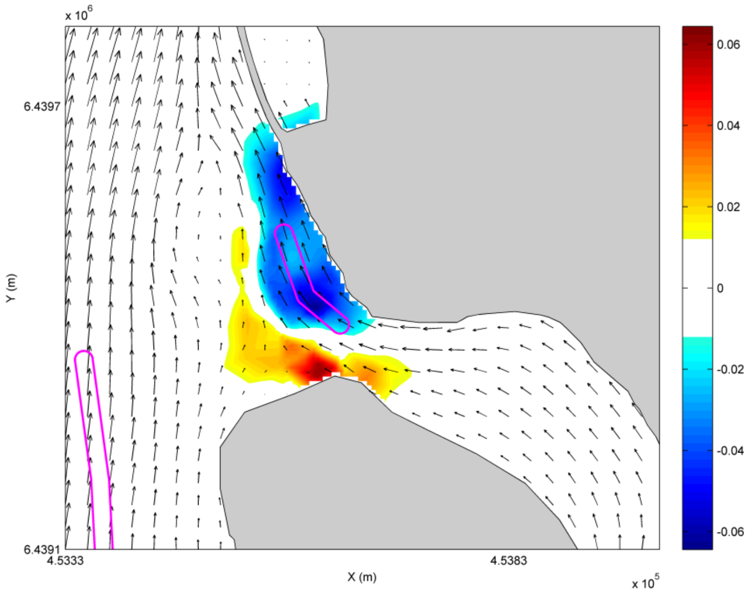


Figure B – 3a

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows.

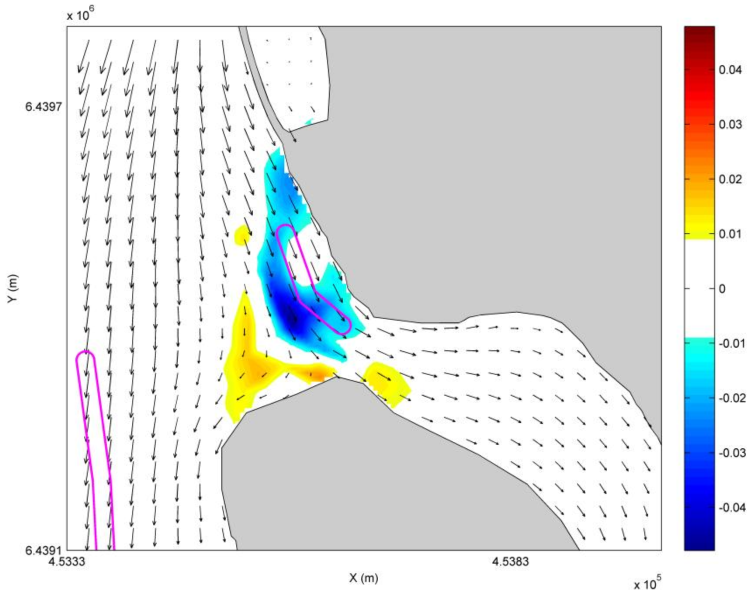


Figure B – 3b

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows.

Current speed difference between Scenario C and existing condition – ebb peak difference (left) and flood peak difference (right)

Scenario D – Jonnell Cove Channel

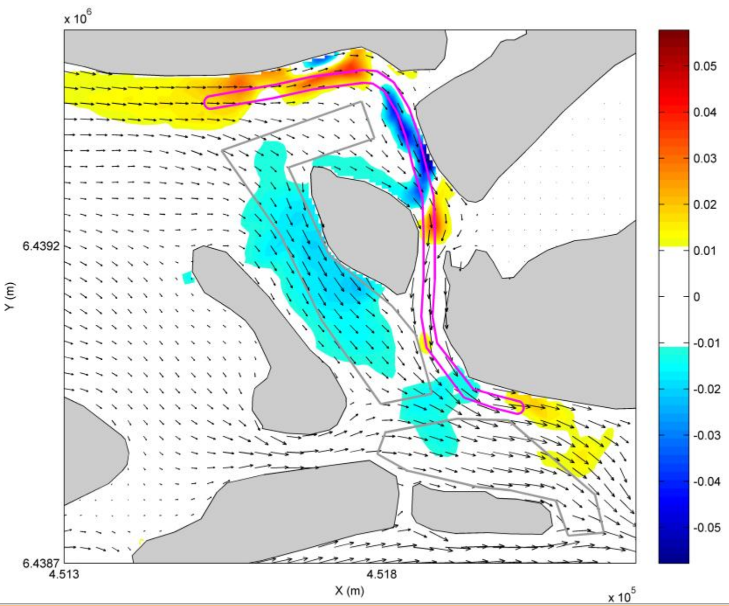


Figure B – 4a

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows.

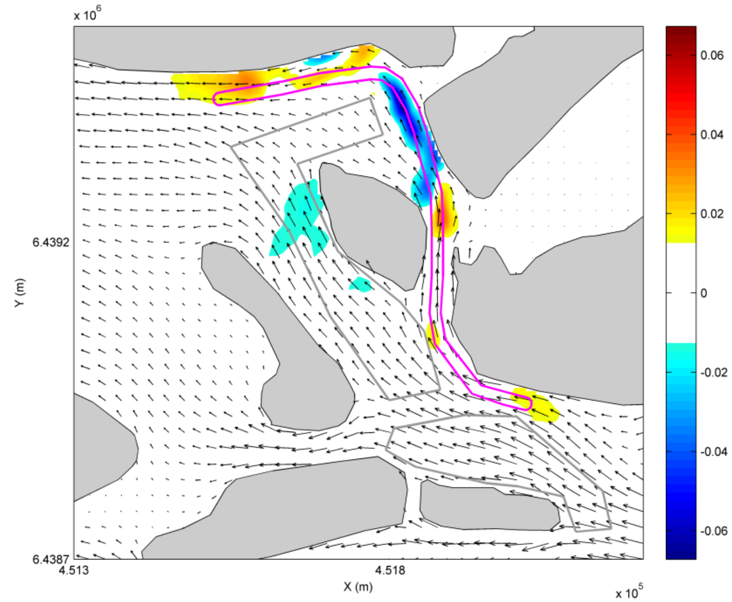


Figure B – 4b

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows.

Current speed difference between Scenario D and existing condition – ebb peak difference (left) and flood peak difference (right)

Scenario E – “The Paddock”

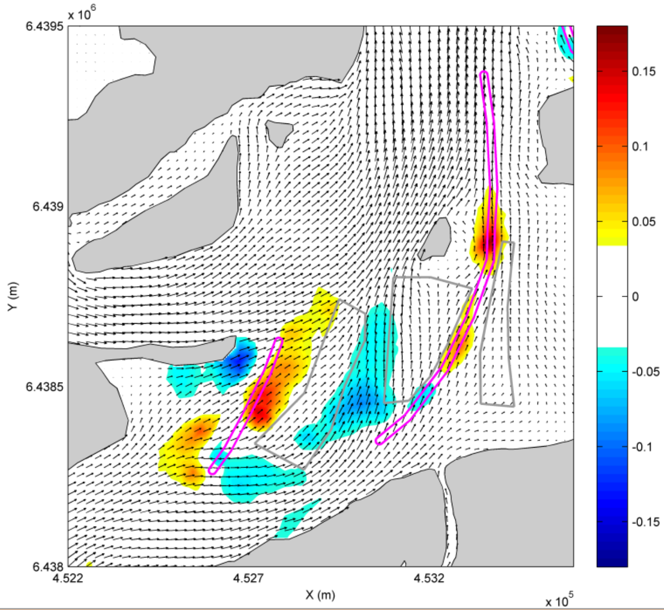


Figure B – 5a

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows.

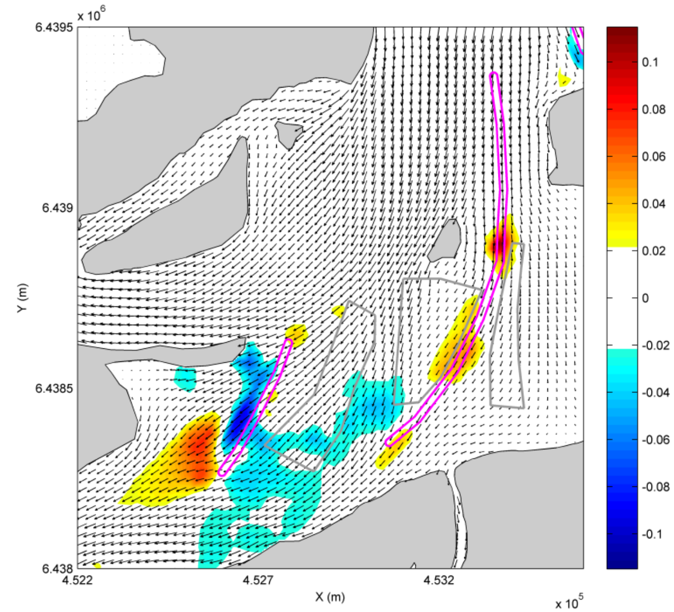


Figure B – 5b

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows.

Current speed difference between Scenario E and existing condition – ebb peak difference (left) and flood peak difference (right)

Breckenridge Channel

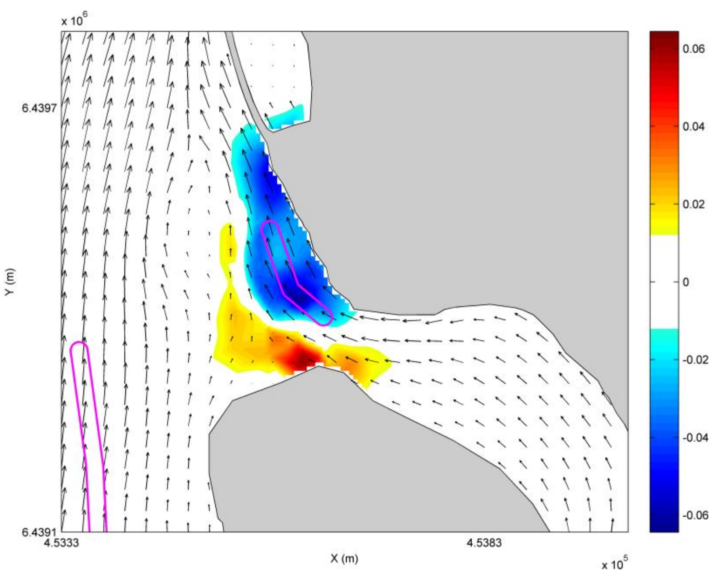


Figure B – 5c

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows.

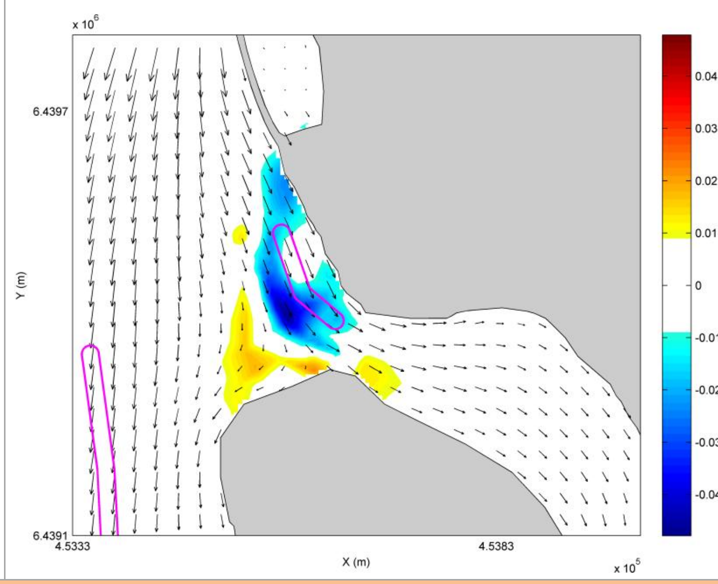


Figure B – 5d

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows.

Current speed difference between Scenario E and existing condition – ebb peak difference (left) and flood peak difference (right)

Jonnell Cove Channel

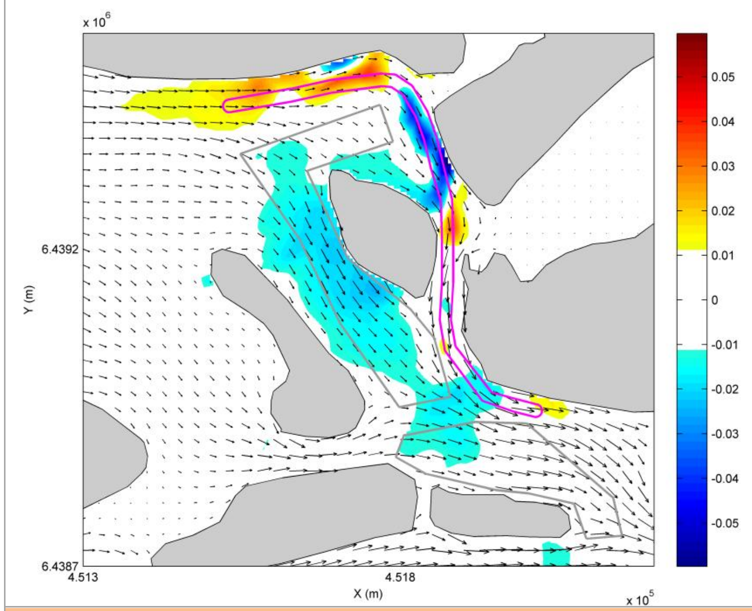


Figure B – 5e

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows.

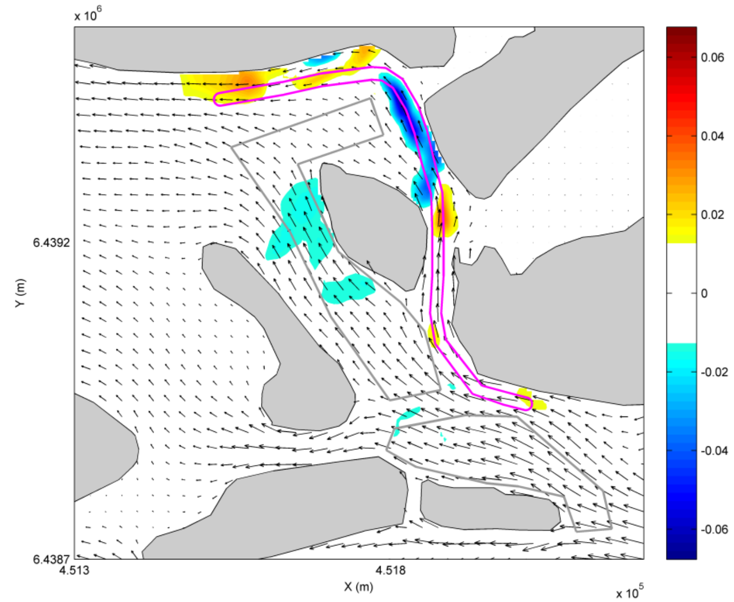


Figure B – 5f

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows.

Current speed difference between Scenario E and existing condition – ebb peak difference (left) and flood peak difference (right)

Scenario F – "The Paddock"

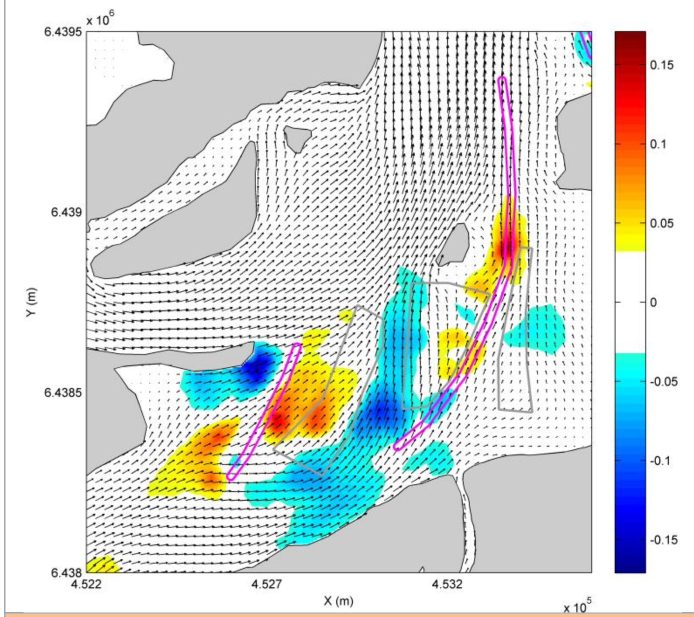


Figure B – 6a

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows.

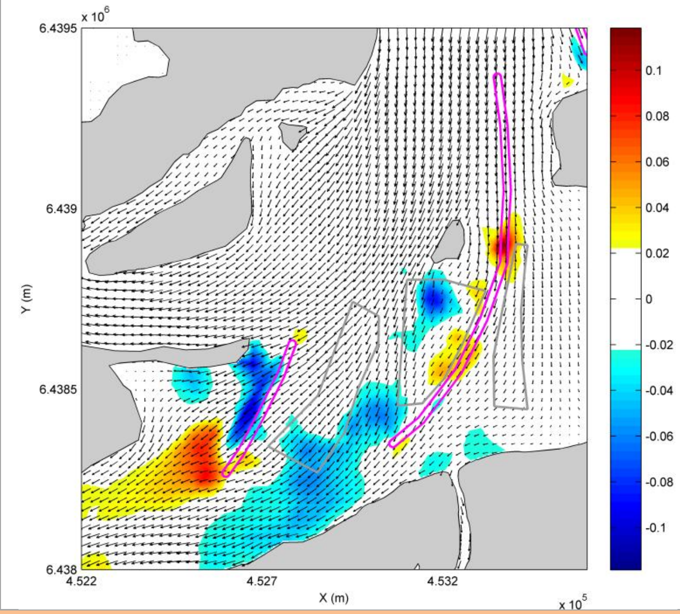


Figure B – 6b

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows.

Current speed difference between Scenario F and existing condition – ebb peak difference (left) and flood peak difference (right)

Breckenridge Channel

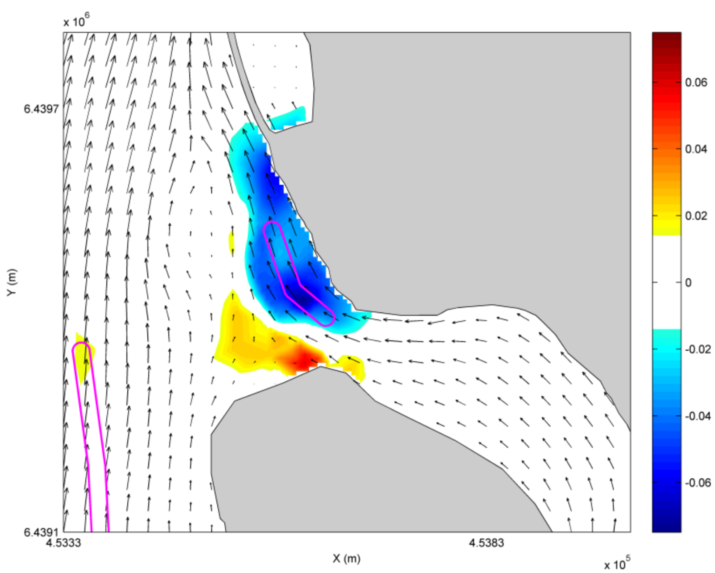


Figure B – 6c

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows.

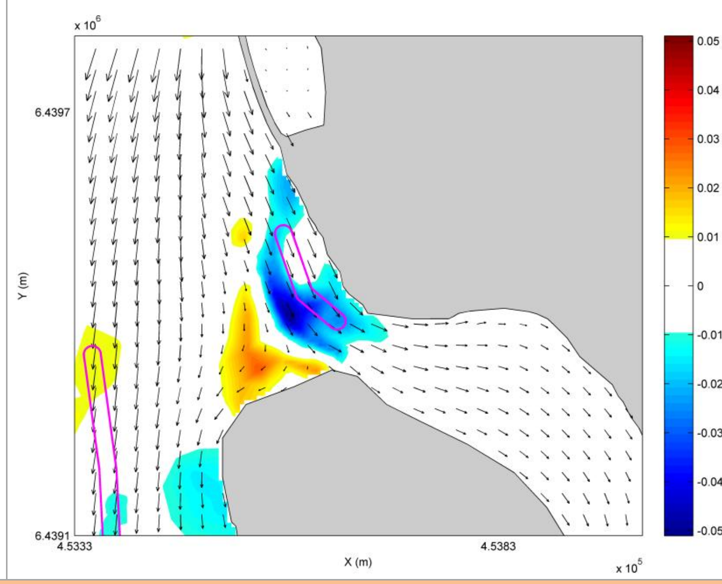


Figure B – 6d

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows.

Current speed difference between Scenario F and existing condition – ebb peak difference (left) and flood peak difference (right)

Jonnell Cove Channel

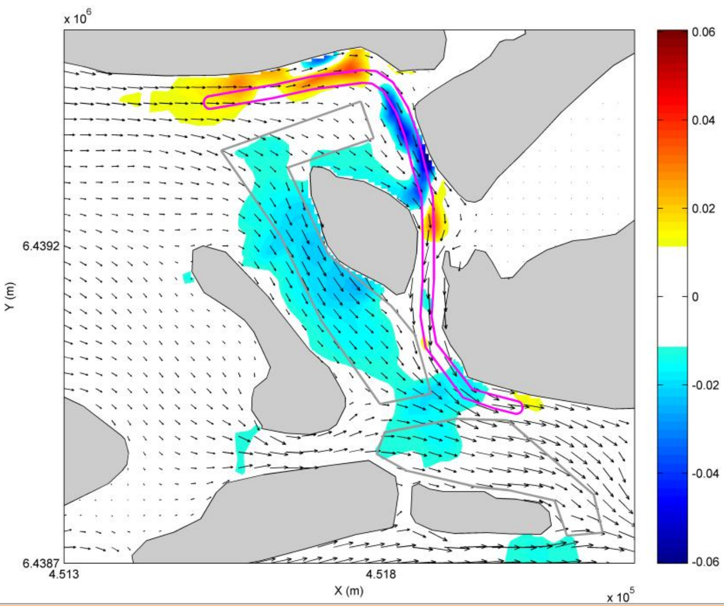


Figure B – 6e

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows.

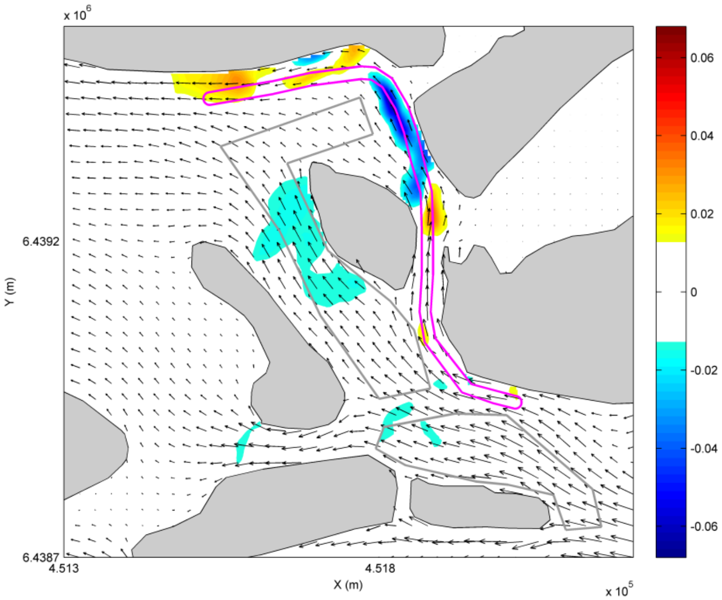


Figure B – 6f

Current speed difference (m/s) represented by color scale.

Current vectors represented by black arrows.

Current speed difference between Scenario F and existing condition – ebb peak difference (left) and flood peak difference (right)