Appendix C – Final Report Marine Requirements for Little Tracadie Causeway/Bridge No. 2 (L695) Odilon Replacement - Mark MacNeil (March 28, 2013)

FINAL REPORT

Marine Requirements
for
Little Tracadie Causeway/Bridge
No 2 (L695)
Odilon
Replacement

Submitted to

New Brunswick Transportation and Infrastructure

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Executive Summary

Little Tracadie Bridge No 2 and causeway is located on the Route 365 crossing of Little Tracadie River near Odilon in the upper reaches of Tracadie Estuary on the gulf shore of New Brunswick. The existing 46 m long wood stringer bridge has come to the end of its serviceable life and needs to be replaced. This study was undertaken on behalf of New Brunswick Department of Transportation and Infrastructure as a part of its design and planning effort to ensure that the new structure will provide tidal flushing and exchange and minimize any negative environmental impacts in the marine system.

The study includes an analysis of tidal measurements, sounding survey data as well as water and sediment samples. Observations and modelling show that the tide at the study site is reduced compared to the coast tide due to restriction occurring in passages in the coastal barrier beach system at Val Comeau and North Tracadie Gully. Numerical models have been developed to simulate flows in the bridge channel and in the river/estuary near the bridge that simulate the existing tides and a hypothetical coastal tide unimpeded by the passages in the barrier beach. In addition to the existing bridge/causeway configuration, a 'no causeway' and minimum bridge gap width options were investigated.

The analysis of field data clearly shows that the existing bridge channel does not restrict the tide in Little Tracadie River. Modelling shows that the existing gap would also admit the coast tide if it were to become established in Tracadie Bay. Due to the presence of fine sediments, the existing channel has become scoured at the bridge producing a relatively uniform current from downstream through the bridge gap to upstream of the bridge. The local sediment regime appears to be in pseudo equilibrium with the current regime. If coastal tides were to become established a significant impact on the sediment regime could be expected. In order to continue to ensure ample cross section for flow and avoid disruption of the sediment regime we recommend that a new bridge be designed so as to span the existing scour channel.

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1 Introduction

The Tracadie Rivers/Estuaries system is a saline marine estuary with a surface area of 32.3 km^2 enclosed by a barrier beach system (Figure 1 shows the area with locations noted in the text). This beach system currently has two entrances: North Tracadie Gully – a natural overwash delta with channel about 80 m, and, Val Comeau Channel that is maintained with rock banks with a width of about 50 m. A second natural Gully, the Old Tracadie Gully, has filled in over recent years since construction of Two River Channel connecting Big Tracadie River to the south with Tracadie Bay and Little Tracadie River to the north. Two Rivers Channel is about 1000 m long with and about 30 m wide. The Little Tracadie Bridge/Causeway is located at Odilon 5 km upstream from the mouth of Little Tracadie River. The bridge gap is 40 m wide with an average depth of 3.5 m. The bridge is in need of replacement. In this study we assess the requirements for a new bridge channel in relation to the tides and other environmental processes in the area.

The study shows that the tidal range in Tracadie Bay is significantly reduced compared to the coastal tide in Northumberland Strait due to the constructions in the barrier beach system. The range of the tide in the bay is about 36% of the range of the coast tide during large tides. Taking range and duration of the tide into account, we estimate that the flushing rate of the bay is about 30% of the potential flushing by coast tides. While this is not the focus of the present study, we considered it necessary to ensure that not only does a replacement bridge at Odilon meet existing requirements for tidal passage but that it should also meet requirements in the case that the full coast tide becomes established in the bay. This could possibly occur due to natural forces or could be engineered with modifications to the entrance channels. In any case, two tidal scenarios are considered in this report to represent the existing situation and the situation that would result if coastal tides were to become established in Tracadie Bay.

Field data show that the existing reduced tide is easily admitted to the upper reaches of Little Tracadie River above the Little Tracadie Bridge. Modelling shows that this would remain the case even if the full coastal tide were to be restored in the bay. Modelling also shows that removal of the existing causeways would have a negligible effect on the tidal passage. In fact, a reduction in the width of the bridge crossing could be entertained with respect to tidal passage requirements. However, based on practice developed over several similar projects reflecting potential issues such as sedimentation, it is not advisable to alter the existing channel under the bridge. This channel has experienced significant scour since the construction of the existing bridge and provides a deep and wide passage for tidal currents. Our recommendation is that a new bridge should span the existing channel.

The remainer of this introduction presents brief background overviews of Holocene evolution of coastal estuaries along with a summary of rules of practise that have developed over several similar projects. Following this we consider the morphology near Little Tracadie Bridge. In the following sections of the report we present the results and analyses of field observations. Tidal records were obtained upstream and downstream of

Figure 1 Tracadie Estuary and River system with locations mentioned in the text.

the bridge. In addition, tides were measured for a day simultaneously at the Little Tracadie Bridge, Val Comeau Bridge and at a nearby coastal station at Upper Nequac. These latter measurements were made to assess the present tides before and after the Two River Channel project. Other field data included soundings, water and sediment sampling near the bridge.

The results of modelling efforts are presented in Section 3. Bathymetric models of the system are developed followed by hydraulic and hydrodynamic models of existing and hypothetical scenarios. The hydraulic model simply computed the rise and fall of the water levels upstream of the bridge and the associated flow velocity in the channel under the bridge. The hydrodynamic model is based on a 5 m resolution grid representing the area adjacent to the bridge and shows the pattern of currents to be expected for each scenario. Finally, a sediment transport model is employed in a simple fashion to determine the potential for transport of various fractions of material within the system.

1.1 Geological Overview

As in Little Buctouche report but with more on tidal asymmetry and transport – which is much more important in the case of Little Tracadie. Little Tracadie is an example of a strongly ‘flood-dominated’ system. Because the tide is restricted at the barrier beach it is very asymmetric with a fast rise during flood followed by a slow fall during ebb. Sediment is expected to be transported upstream if currents are strong enough to mobilize them.

Coastal geology and the morphological evolution of coast estuaries and associated water quality is a matter of world-wide concern. The reader can find good introductions to the important processes and overall issues at many sites on the world wide web (e.g. http://www.estuary-guide.net/index.asp (ABPmer and HR Wallingford, 2007. The Estuary-Guide: A website based overview of how to identify and predict morphological change within estuaries. Website prepared for the joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme. November 2007)

The coast along this section of the eastern shore of New Brunswick is an example of a transgressive system composed of soft, eroding bedrock cliffs and estuary complexes, each consisting of sandy barrier beaches with coastal dunes, protecting shallow, flood-dominant estuaries (Forbes et al, 2004). In the short term, sediments move along the shoreline in the littoral zone of this system. In geological terms, the coast can be considered to be an erosional front that is migrating landward in response to sea-level rise over the Holocene period since the last major ice age 10,000 years ago (notwithstanding, the extensive efforts to protect shoreline along several sections of this coast).

A simplified model of estuary evolution during the Holocene is depicted in Figure 2. The figure shows the typical evolution of drowned river valley. As sea level rises slowly, tides and other process strong enough to mobilize sediment from runoff and seaward inputs cause drowned river valleys to accumulate sediments until high banks rise above the level of mean water level on either side of a deep central channel. As infilling proceeds tidal currents advance more slowly over the shallow banks while ebb currents increase in a narrow drainage channel. The result is that once infill progresses sufficiently, the system can start to export sediment to balance the inputs from land and sea. This results in the typical modern drowned river valley comprised of a deep channel boarded by high banks of sediment reaching to or a little above the level of low tides. Of course, this is a simplified model and the actual balance depends on: sediment supply; the strength of mobilizing processes; and, the rate of sea level change. Current science suggests that sea level will continue to increase (AR4 report of the IPCC, 2007). Along the New Brunswick gulf coast mean sea level rise is expected to be about 0.8 m by 2100 (Shaw, et al.).

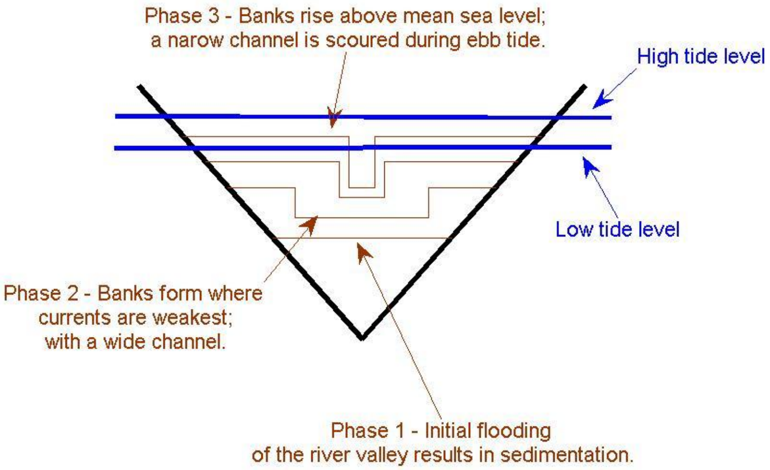

Figure 2 Schematic of infilling of a valley during the late Holocene.

In addition to the infilling of the estuary, the Little Tracadie system is bounded by a barrier beach that is created from along-shore sediment transport. Such systems can be semi-enclosed and open to the full tide from the Northumberland Strait, as at Buctouche, or can be essentially enclosed as is the case at Tracadie. In this case, channels form naturally in the barrier system to drain the enclosed bay. Whether the channels evolve to admit the tide or not will determine if the bay becomes a freshwater lagoon or a saline tidal estuary. In the case of Tracadie Bay data and modelling (see Section 2 and 3) show that the channels have developed so as to allow a portion of the tide. A larger demand for water (i.e. a larger bay area), or less sediment supply, or larger coastal tides would have the effect of scouring deeper and wider channels in which case the bay would become fully tidal. However, the present balance is for limited channel width and depth so that only about 1/3rd of the coastal tides enter the bay.

In addition, it will be shown, the reduced tide causes an asymmetry in the tides in the bay and hence upstream in the tidal river sections of the system. Flood currents are stronger and occur over a shorter period of time than ebb currents. This favours landward transport of mobile sediments within the tidal reaches of the river sections of the system. However, since the magnitude of the current is weak the actual transport volume may be small. Nevertheless, the asymmetry will tend to 'trap' any sediments that are swept into the upper reaches of the system. While land based sediment is still entering the system it is believed that a significant contribution occurred as a pulse of material during the period of deforestation that occurred in the 1700's and 1800's.

In summary, the Trcadie system appears to be naturally filling-in over recent geological time and this is compounded by large coastal sources that have resulted in semi-enclosure by a barrier beach system and asymmetric tides and trapping of land based sediments in the upper tidal reaches of the river sections including the pulse associated with deforestation.

1.2 Estuarine Bridge/Causeway Systems – an Overview

Modern considerations for river crossing go beyond traditional engineering requirements to provide drainage under extreme conditions. Crossings in tidal areas almost always experience the highest flows due to tides and surge and not just watershed drainage. In addition, the crossing can contribute to mixing, aeration and reduction of stagnation in some systems. In winter, they contribute to maintenance of an area of open water for wintering birds.

Many scientific models and investigations of estuaries focus on the natural processes that influence mixing and flushing and transport within the estuary and its connection to processes in the upland and seaward zones. Few studies, however, explicitly consider the effect of bridge/causeways on these systems despite the fact that a large proportion of estuaries are crossed by the man-made structures. The structures can play a significant role in estuary process by limiting the tidal range, creating turbulent jets that create residual circulation and tend to enhance vertically mixing, etc. An overall scientifically based approach on which to base policy does not appear to exist in the scientific literature. However, objective guidelines have evolved over the course of several similar studies (MacNeil, 1991-2013). These guidelines can be summarized in five general rules:

1. Ensure that new structures admit the tide.
2. Ensure that bridge openings are aligned with the natural river channel.
3. Do not encroach on the natural river channel.
4. Avoid creating a sill under the bridge.
5. Recognize that mixing can be enhanced by the jet formed at a bridge crossing.

Each of these ‘rules’ is discussed below.

1. Admit the tide.

In almost all cases where tidal range has been significantly reduced there have been adverse consequences for water quality. Early thinking that favoured creation of fresh water impoundments (systems controlled by a weir) resulted in unpopular results unless created well upstream where salt water intrusion is not possible. When impounded systems were created lower in the marine system salt water intrusion can occur during storm surges or even just from higher than normal tides. This can result in the formation of stagnant water which under the stress of high nutrient loading becomes eutrophic with depressed oxygen levels and foul odour. Therefore, unless the upstream shoreline includes valuable areas, we normally recommend that a new bridge channel is designed to admit the entire tidal range and thereby maximize the potential for flushing.

2. Align with the natural river channel.

In some cases, historical construction techniques for estuary crossings have involved construction of an almost complete causeway with excavation of a bridge channel at a convenient location near the shore. The new channel did not always align with the natural river channel. As a result the flow can be limited by depths over the river banks between the new bridge channel and the original river channel. This can result in the reduction of the tidal range and promotion of the growth of shellfish beds on the river banks near the ridge channel which further reduced tidal flows even if the bridge channel itself was wide and deep enough to sustain these flows. To avoid this, where possible, a new bridge/channel should be aligned with the natural channel.

3. Don’t encroach on the natural river channel.

As a rule, a new bridge should span a section of the system at least as wide as the original river channel – often indicated in aerial photos just upstream or downstream of the bridge/causeway. Encroaching on the natural river channel will cause higher currents near low water causing scour in the bridge channel. This may have the adverse consequence of causing a rapid siltation upstream and downstream of the scoured channel.

4. Avoid making a sill.

Circulation of water in an estuary is complex. In addition to tide there is a secondary component that tends to flow seaward near the surface and landward near the bottom of the water column. When construction results in a sill under a bridge there is a possibility that it will block the natural bottom flow. In this case the relatively deep waters upstream of the sill can become stagnant. High nutrient loading and high algal growth resulting in deposition of detritus into the stagnant layer invites the development of eutrophic conditions often resulting in low oxygen in the lower layers. Where possible, new construction should avoid trapping deep water upstream of the bridge channel.

5. Enhance mixing.

Perhaps the most controversial rule that has developed in relation to estuary crossings stems from a recognition that the mixing resulting from a jet and associated turbulence stemming from a constriction in a waterway can actually be a beneficial feature of an estuarine system. Mixing encourages aeration of the water column and forms an essential component of a healthy marine environment. Furthermore, by enhancing mixing the potential for stagnation is minimized and tidal flushing is more effective. This is not an option, of course, if it entails restriction of the tidal range or any other negative environmental consequences.

In our experience, these rules of thumb have had to be modified on a site by site basis to reflect specific valued components of the ecosystem and public concerns. However, they provide a good basis for evaluating design options.

1.3 Site Description and Historical Overview

An historical aerial photo of the Little Tracadie Bridge is shown in Figure 3. The figure shows several areas of sediment accumulation along Little Tracadie River and along Trout Stream and Seal Brook tributaries. The latter is also crossed by a bridge. Rough calculations show that this crossing admits the tide and no reduction in tidal range is expected in either tributary. The marshy areas of sediment accumulation are likely the result of high water levels and sediment loads associated with spring runoff over the past hundred years or more.

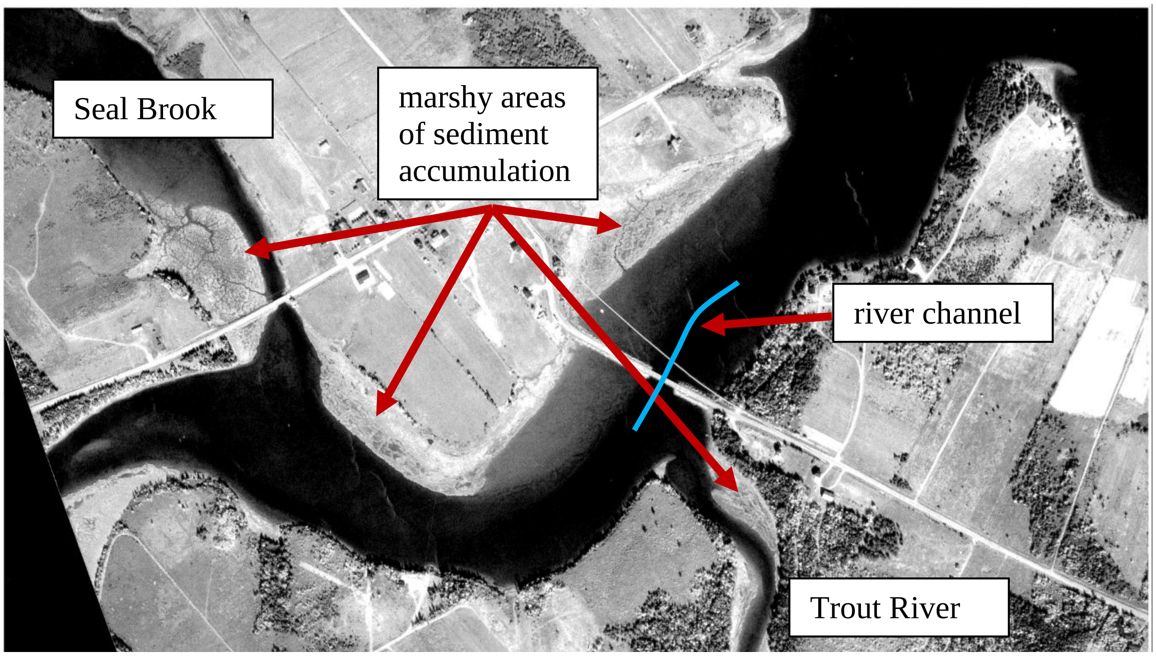

Figure 3 Aerial photo of LittleTtracadie Bridge showing the bridge located over the natural channel and marshy areas occurring throughout the system.

2 Field Program and Analyses

A field program was conducted over the summer months of 2012. The program included tidal observation upstream, and bathymetric survey and water and sediment sampling. The key results of the program are presented below.

2.1 Tides

Water levels were recorded every 5 minutes at site approximately 100 m upstream and downstream of the bridge. A subsample of the data showing results over a spring/neap cycle along with prediction based on Canadian Hydrographic Service tidal constituents for the coast near Old Tracadie Gully (CHS Blue Book) is shown in Figure 4. The data from upstream and downstream of the bridge are essentially indistinguishable on this plot indicating clearly that the bridge has no effect on the passage of the tidal range.

Both bridge records in Figure 4 are much less than the CHS predictions, however, indicating that there is some element of the system restricting tide between the bridge and the coast. Possible elements are the other two bridge structures crossing the Little Tracadie River at Route 11 and Rue Principale, or, the entrance channels at the coast in the barrier beach. A supplementary program to measure tides on the coast (Upper Nagac) and at Val Comeau Bridge and Little Tracadie Bridge along with subsequent modelling (presented in Section 3) show conclusively that the elements restricting the tide are the entrance channels in the barrier beach. The supplementary data are shown in Figure 5. Neither Little Tracadie Bridge, Route 11 Bridge or Rue Principale Bridge have any effect on the passage of tidal range.

In addition to reducing the tidal range the restrictions at the barrier beach have the effect of producing just one tide per day inside the bay during periods of large tides. As can be seen from either Figure 4 or Figure 5, due to the constrictions, the bay tide cannot rise as fast as the tide at the coast. As a result, the coast tide peaks and ebbs for some time before reaching the level in the bay. Only then does the level in the bay begin to fall, again, at a rate slower than that at the coast. In this way the smaller second tide of the day at the coast is not reflected in the bay. From the point of view of the bay, during the largest tides, the water level rises for about 8 hours and then falls more slowly for the following 16 hours.

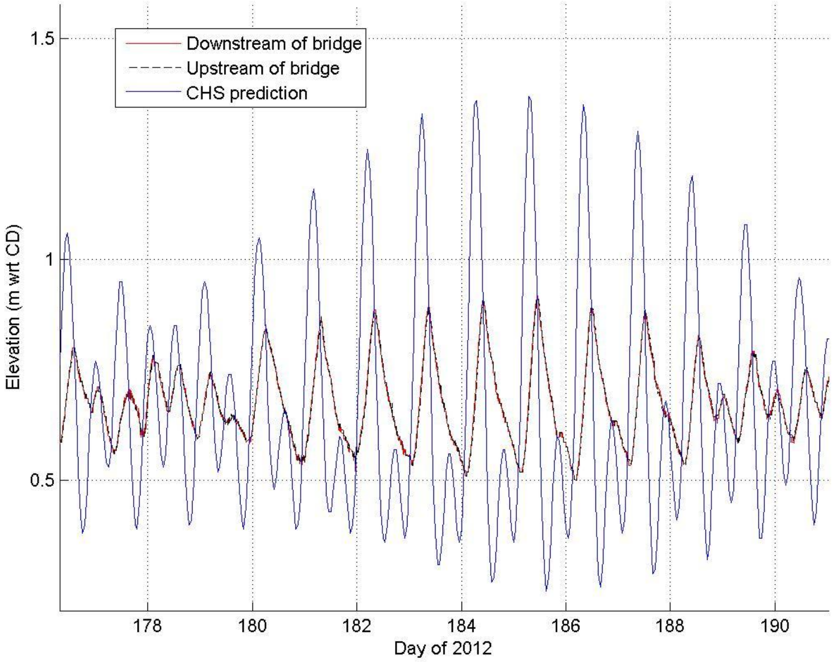

Figure 4 NBTI observations and 'Tracadie' CHS predictions – representative of the full time series of observations that extend from day xx to day xxx.

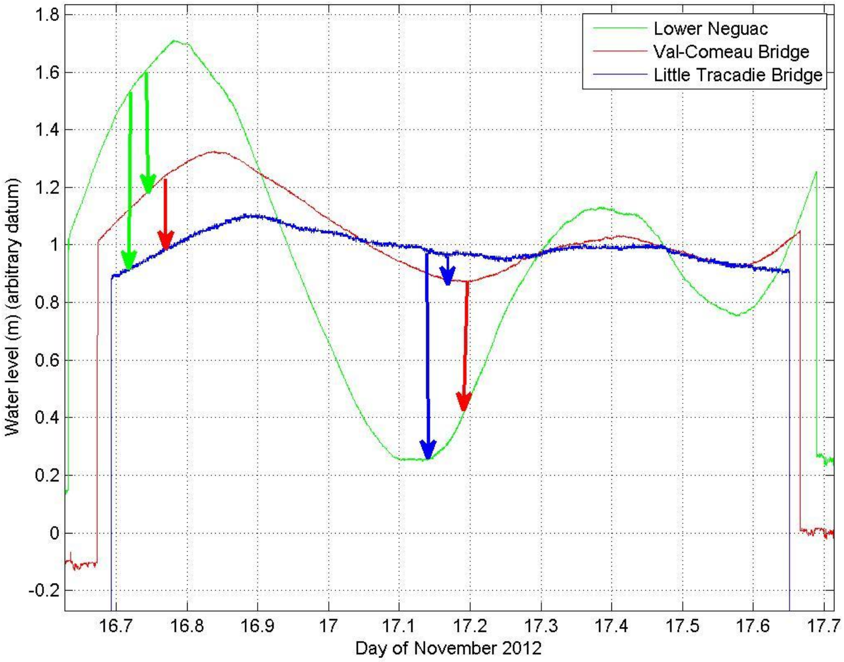

Figure 5 Supplementary one day tide observations. Note the difference in tides in both the Val Comeau section and the Tracadie section of the system compared to coastal (Upper Neguac) observations. Also note the complex pattern of flows that are indicated for the two entrances and the Two Rivers Channel.

2.2 Bathymetric Survey

A bathymetric survey was conducted in the vicinity of the bridge consisting of 1060 soundings. The results relative to geodetic datum are presented graphically in Figure 6. The data show a relatively deep depression at the bridge channel with depths of about 4.5 m. Downstream there is a well defined channel with a width similar to the bridge channel (i.e. 40 m) and depths of about 2.5 m. Upstream of the bridge the channel shoals to about 1.5 m.

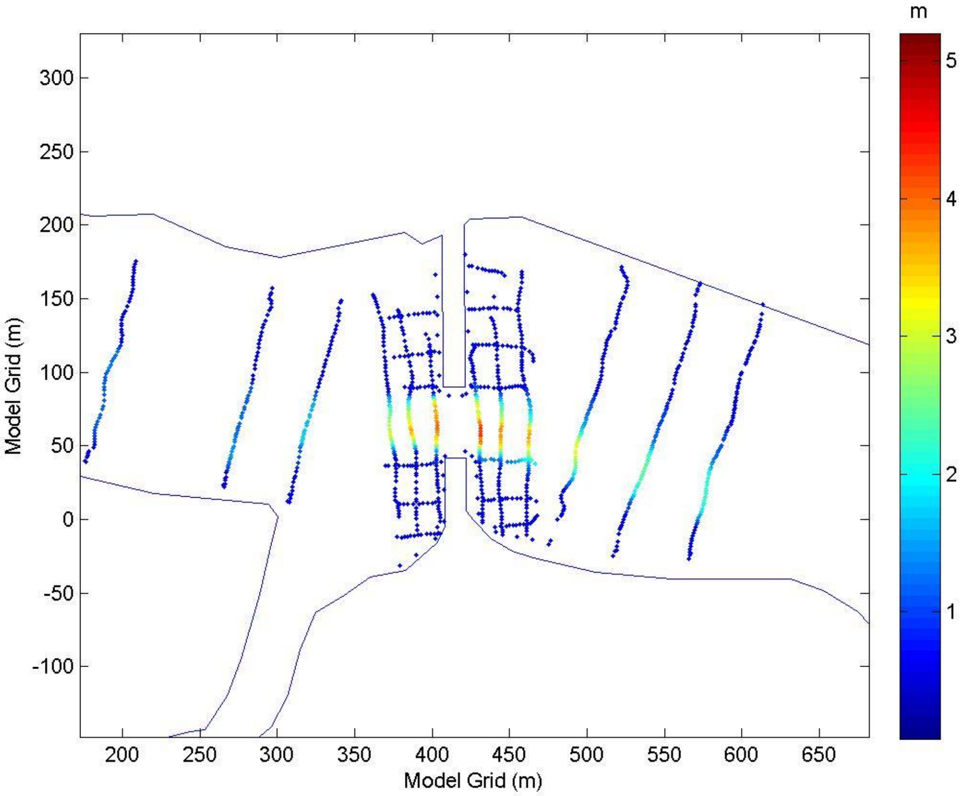

Figure 6 Results of bathymetic survey.

2.3 Water Quality

Water and sediment samples were collected at four sites, two upstream of the bridge and two downstream as shown in Figure 6 on 25 July, 20 August and 19 September, 2012. Several parameters were measured but here we restrict or comments to salinity and nutrient levels as presented in Table 1. All sampling is assumed to be from surface waters.

Salinity levels at Little Tracadie Bridge indicate a brackish environment nearer fresh water 90 PSU) than typical coastal levels (typ. 28 PSU). A slight tendency to higher levels at the downstream sites is consistent with the expected increase toward open

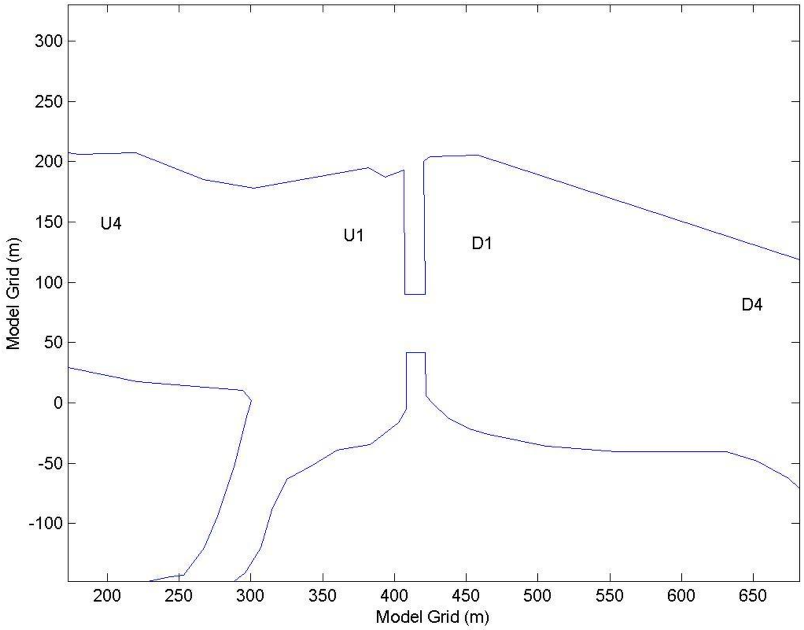

Figure 7 Water and sediment sampling sites.

waters of the Gulf of St Lawrence but the variation is small. Variation between sampling days is greater indicating the effect of variations in stream flow of tidal stage at the time of sampling. Levels of total nitrogen were generally less than the resolvable limit of the analytical technique used in all cases. However, that limit of 0.3 mg/L is high relative to water quality criteria. Eutrofication can occur at levels of about 0.7 mg/L but this can vary from system to system. The corresponding total phosphorus level from the Redfield ratio (Redfield, 1958) is about 0.1 mg/L. The data indicate that total phosphorus level are lower than this critical level. There does not appear to be a simple relation between nutrient levels and salinity though compared to another system sampled around the same time (Bouctouche) there appears to be higher nitrogen levels and lower phosphorus in this less saline site. Compared to systems we are familiar with (e.g. Raymond et al 2002; Meeuwig, 1999, Schmidt, 2012) it would appear that the system is under some eutrophic stress but it is not critical at the time of sampling.

Table 2 Key water quality parameters (25July/20Aug/19Sept (mean).

Site	Salinity (PSU)	Total P (mg/L)	Total N (mg/L)
U4	4/2/15 (7)	0.014/0.030/0.029 (0.024)	<.3/.3/<.3
U1	7/2/12 (7)	0.026/0.027/0.060 (0.038)	<.3/.5/<.3
D1	13/2/16 (10)	0.036/0.031/0.031 (0.033)	<.3/.5/.5
D4	8/3/16 (9)	0.017/0.055/0.036 (0.036)	<.3/.5/<.3

2.4 Sediments

Four sediment samples obtained at the sampling stations indicate a slight tendency toward finer sediments upstream with 54%, 60%, 48% and 17% passing a 75 micrometer screen at stations U4, U1, D1 and D4, respectively. This is consistent with the fact that the site is located in the fresher upper estuary. In comparison, samples obtained at about the same time in a more saline site in the Bouctouche estuary showed very little sediment passing the 75 micrometer screen. This suggests that the origins of the fine sediments are primarily land based rather than coast sources.

3 Modelling

Numerical modelling was employed to investigate the passage of the tide and the effect of various options including removal of the existing approach causeways, to increase cross section for flow, and, reducing the existing bridge channel, to determine the smallest opening that will admit the tidal.

The hydraulic model is based on a Bernoulli flow between the upstream and downstream water levels over a broad crested weir (Batchelor, 1967). The downstream level is input to the model as well as a description of the bridge gap. The hydraulic model computes the upstream levels flow at the bridge gap and the upstream surface area. Entrance and exit losses can be included in the model if necessary but this has not been necessary at the present site due to the depth of water ,weak flows and smooth transition through the bridge gap. The model is verified by reproduction of the observations for the existing conditions. The hydrodynamic model is a full non-linear representation of the depth averaged momentum and continuity equations implemented on a finite difference Richardson grid with a resolution of 5 meters. The hydrodynamic model is driven by the input tidal record at the downstream boundary. Outputs include water levels and currents in all 5m x 5m cells in the model grid. Reproduction of the observed water levels and hydraulic determined flow rates at the bridge gap are considered verification of the hydrodynamic model. The hydrodynamic model is used to investigate flood and ebb current patterns, mean tidal current patterns and the potential for sediment mobilization. All models have been developed in-house in the Matlab computing environment and have been verified in many previous studies.

3.1 Bathymetric Model

The bathymetic survey data were interpolated over a 5m x 5m grid as shown in Figure 8. Following this, cell depths adjacent to the approach causeways were translated to the causeway cells to make a 'no causeway' version of the grid as shown in Figure 9.

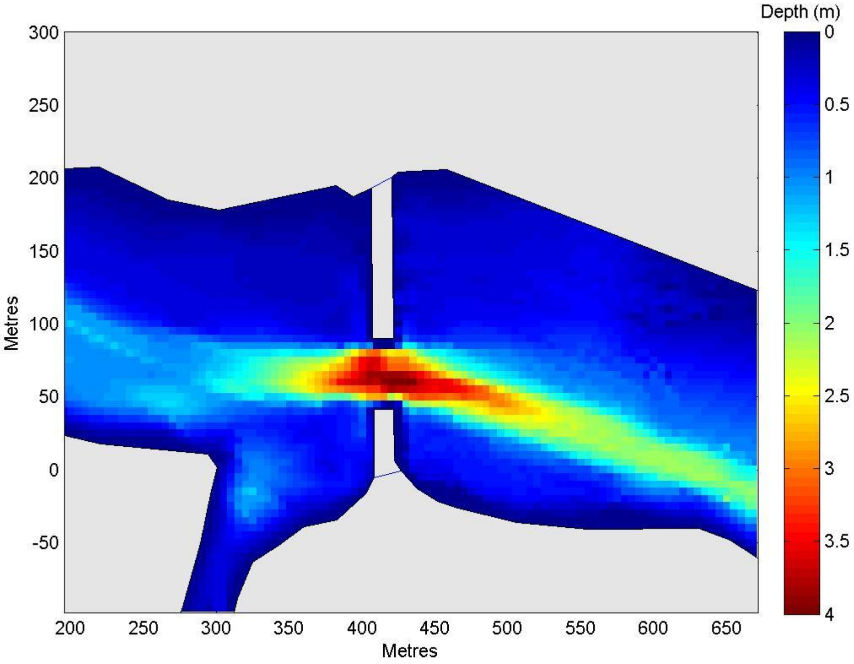

Figure 8 Bathymetric grid model of existing conditions - 5 m resolution.

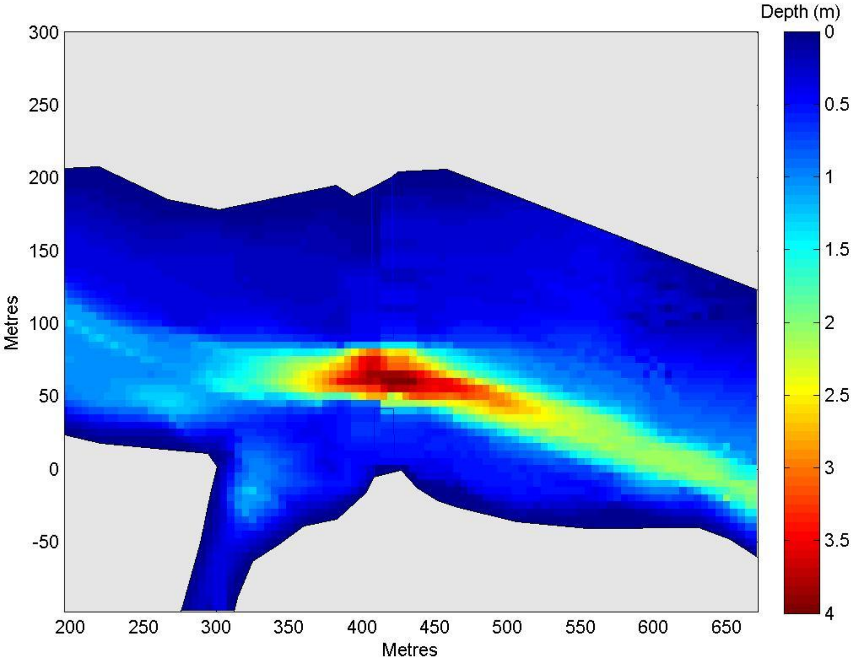

Figure 9 Bathymetric grid model with causeway removed - 5 m resolution.

3.2 Hydraulic Model Results

The hydraulic model was first used to investigate the passage of the coastal tide into Tracadie Bay. Follow this the model is used to investigate tidal passage at Little Tracadie Bridge assuming a large bay tide (day 184 of the observations) and also assuming the unrestricted coastal tide for that day. The unrestricted tide results indicate the behaviour of the system were the coastal tides to become established in the bay. The effect of removal of the approach causeway is then considered. Finally, we hypothetically reduce the width of the bridge gap until the tide becomes significantly affected and thereby determine roughly the minimum gap width that would admit the bay and coast tides.

3.2.1 Tide in Tracadie Bay

Tidal passage into Tracadie was simulated assuming a large coast tide cycle corresponding to day 184 in the field program (see Figure 4) with cross sections for the entrances at Val Comeau and North Tracadie. Widths for these entrances were determined from maps while depths were assumed based on reasonable estimates. A total cross section was comprised of a 3m x 30m gap representing Val Comeau Gully and the effect of Two River Channel and a second gap of 0.5m x 80m representing the North Tracadie Gully. These are obviously estimates but are sufficient to determine if the reduced tide in Tracadie Bay can be explained by the restrictions at the coast.

The results are presented in Figure 10. They show that even with these crude assumptions the reduction of tidal range in Tracadie Bay is obviously due to the limited flows through the entrance passages in the barrier beach system. since the modelled bay tide is essentially the same as that observed downstream of the bridge. This confirms that the two bridges downstream of Little Tracadie (Route 11 Bridge and Rue Principale Bridge) are not the cause of the tide reduction observed downstream of Little Tracadie Bridge.

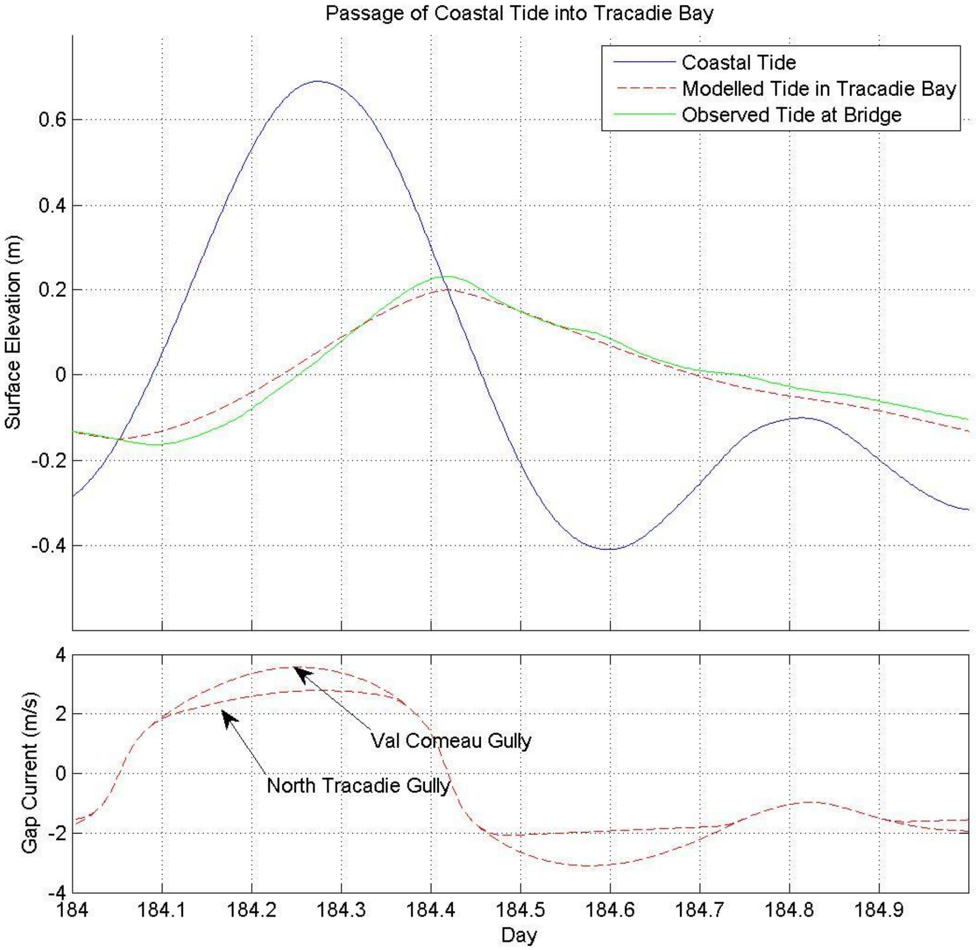

Figure 10 Hydraulic model passage of coastal tide in Tracadie Bay.

3.2.2 Existing Bridge - Bay and Coast Tide

Tidal passage through the existing bridge gap was modelled using the large bay tide observed on day 184 and the coast tide on the same day. The results are presented in Figure 11 and Figure 12. The results show that both the bay tide and the coast tide are passed by the existing bridge gap at Little Tracadie. The bay tide produces a maximum flood current of about 0.13 m/s while the coast tide produces a maximum flood current in the gap of about 0.4 m/s

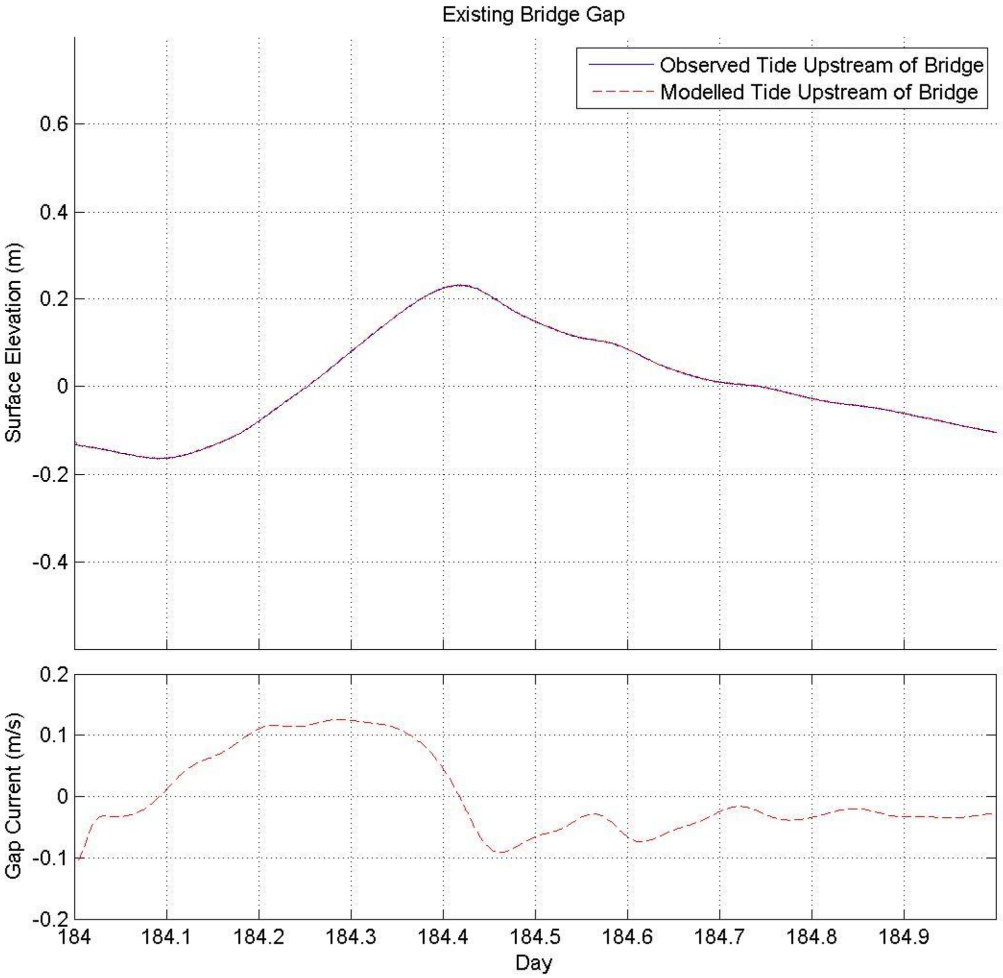

Figure 11 Observed and modelled water levels upstream and downstream of Little Tracadie Bridge and current strength in the bridge gap. Note the asymmetry with stronger currents during flood and weaker currents during ebb.

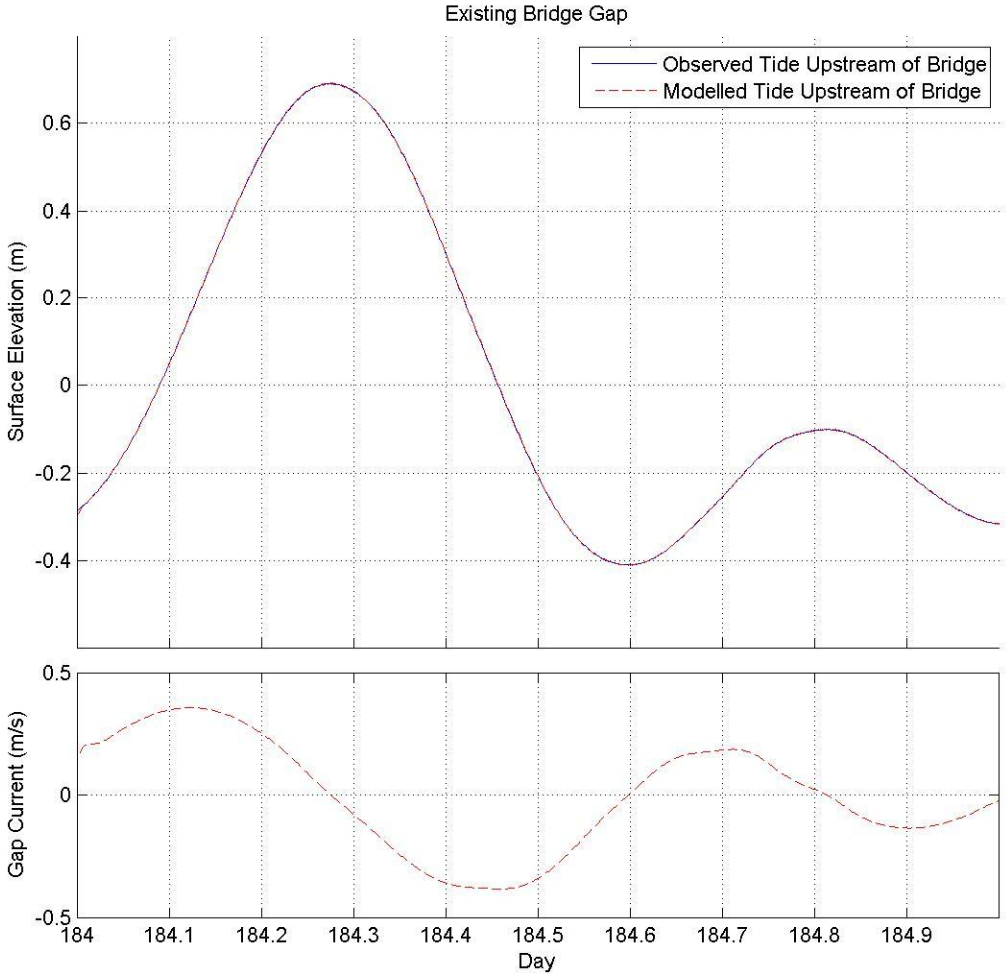

Figure 12 Modelled response of the existing Little Tracadie bridge channel to a hypothetical full coastal tide.

3.2.3 Causeways Removed

Based on the bathymetric models, removal of the approach causeway at Little Tracadie Bridge increases the cross section for flow from 119 m^2 to 165 m^2. This is a substantial increase but it has no effect on the passage of the tidal range, of course, since the range is already adequately passed by the existing configuration as shown in Figure 13 and Figure 14. The maximum currents in the bridge channel would be reduced by the larger cross section for flow in the absence of the causeways, however, from about 0.13 m/s to about 0.09 m/s for the existing bay tide, and from about 0.4 m/s to about 0.25 assuming the coast tide.

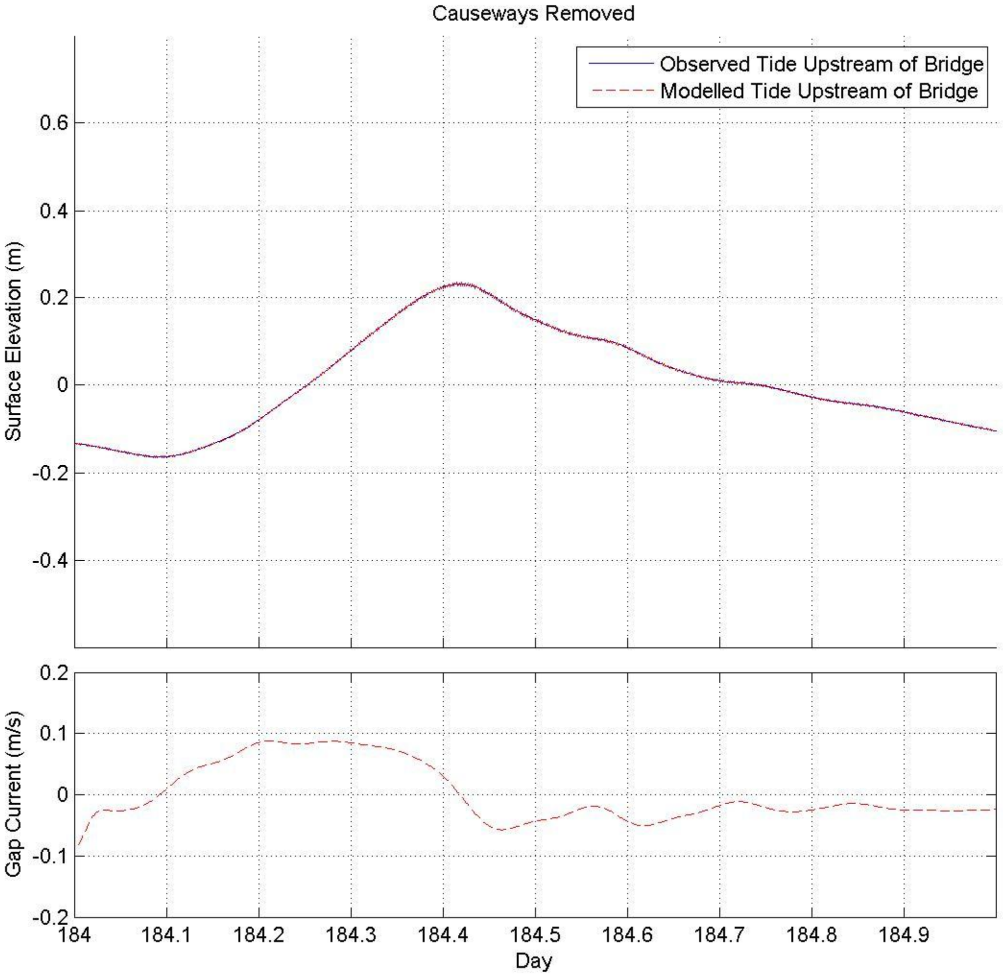

Figure 13 Modelled response assuming removal of the approach causeways.

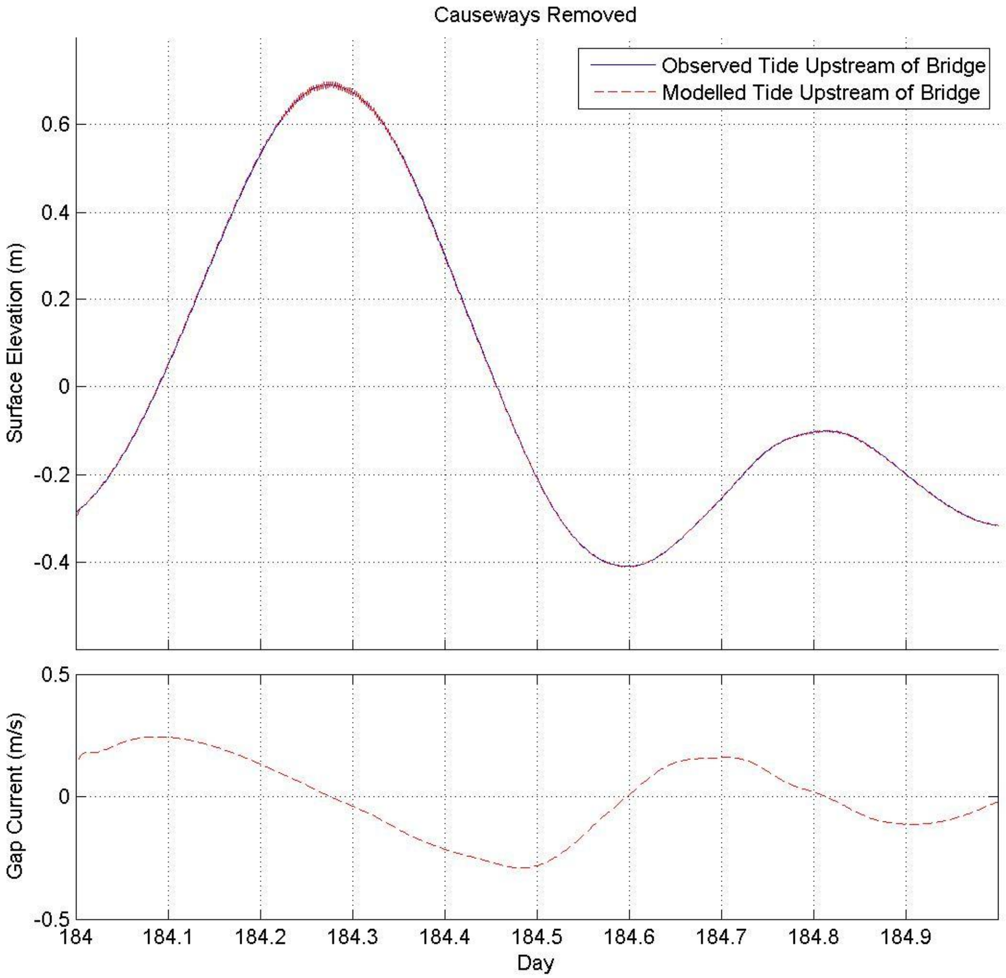

Figure 14 Modelled response assuming removal of approach causeways and a hypothetical full coastal tide.

3.2.4 Minimum Gap Analyses - Bay and Coast Tide

Since the tide is adequately passed by the existing bridge gap it is of interest to consider how much narrower the gap could be and still admit the tide. Often, in related studies the objective has been to identify the gap size that would admit the tide to an impounded or semi-impounded system. In those studies a bridge design follows identification of the minimum bridge gap that will serve with the exclusion of other issues. The results for Little Tracadie subject to bay tides are presented in Figure 15 and show that a bridge gap as small as 2 m would significantly reduce the tidal range; a gap of 5 m would be marginal; and a gap of 10 m would be satisfactory. Currents in the 10 m gap would be high however and might necessitate consideration of sediment dynamics. Thus, from the perspective of the passing the bay tide the existing gap with a width of 40 m is about four times as wide as would result from a study to open an similarly sized impoundment - barring sediment dynamic issues. Similar considerations based on the coast tide shown in Figure 16 suggest that a bridge gap with of 20 to 30 m would serve to open a similarly sized impoundment. Thus, the existing bridge gap appears to be significantly larger than necessary to simply admit either the bay or coast tide.

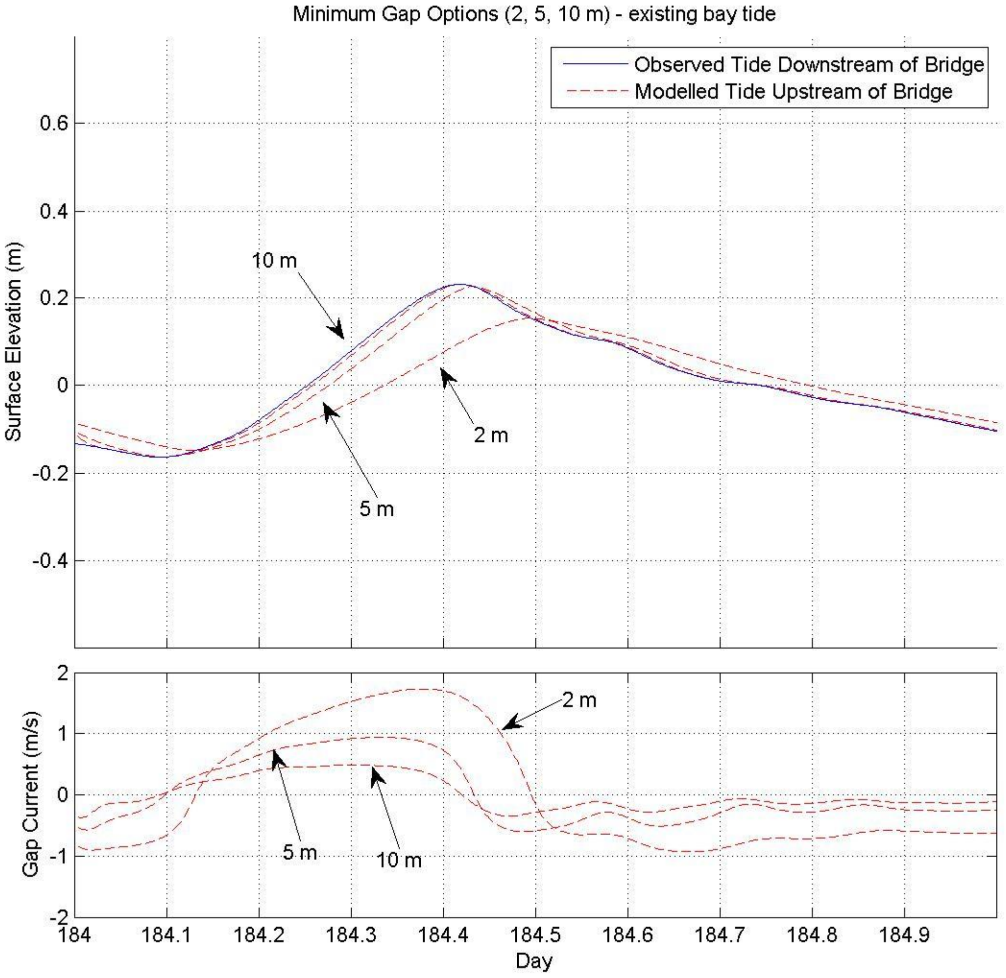

Figure 15 Modelled response to smaller bridge gaps.

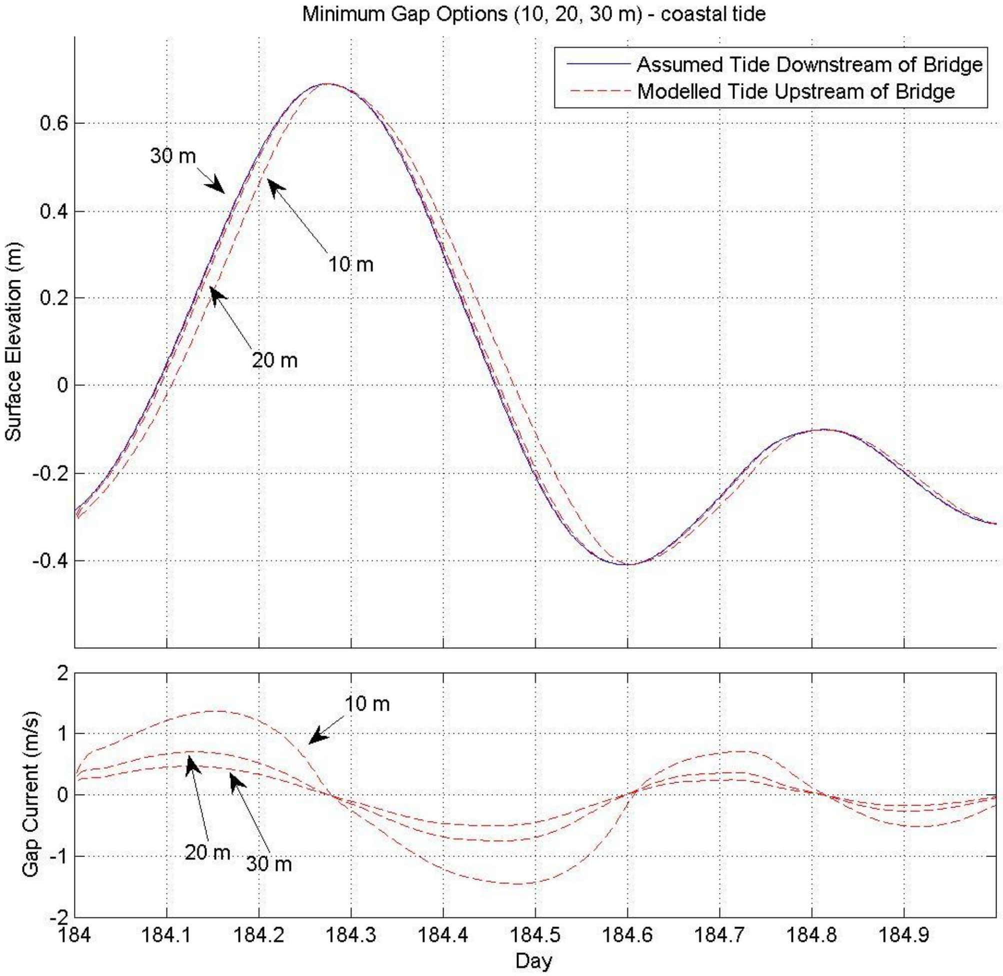

Figure 16 Modelled response to smaller bridge gaps and assuming a hypothetical coastal tide.

3.3 Hydrodynamic Model Results

Hydrodynamic model results corresponding to every 10 minutes of model time have been saved and can be made into a movie or other format for illustration. In this report we represent the results with typical saved images.

3.3.1 Ebb and Flood Tide Patterns

Ebb and flood current patterns for the existing bridge channel and with approach causeways removed assuming a bay tide and a coast tide are presented in Figures 17, 18, 19 and 20, respectively The results show that the tidal currents do not increase as the flow narrows through the existing bridge gap due to the increase depth under the bridge. Currents of about 15 cm/s extend upstream and downstream for the bridge. With the approach causeways removed the currents are actually weaker in the area of the crossing. This would probably lead to siltation in this area. If the coast tide was to become established the currents everywhere would increase significantly. Given the fine material present and as evidenced by the sediment sample collected during the field program and the fact that weaker currents have been sufficient to cause scour in the bridge gap, we feel that establishment of the coast tide would have profound impacts on the sediment regime in the study area. Whether these would be positive or negative is difficult to determine and, in any case, is outside the scope of the present study.

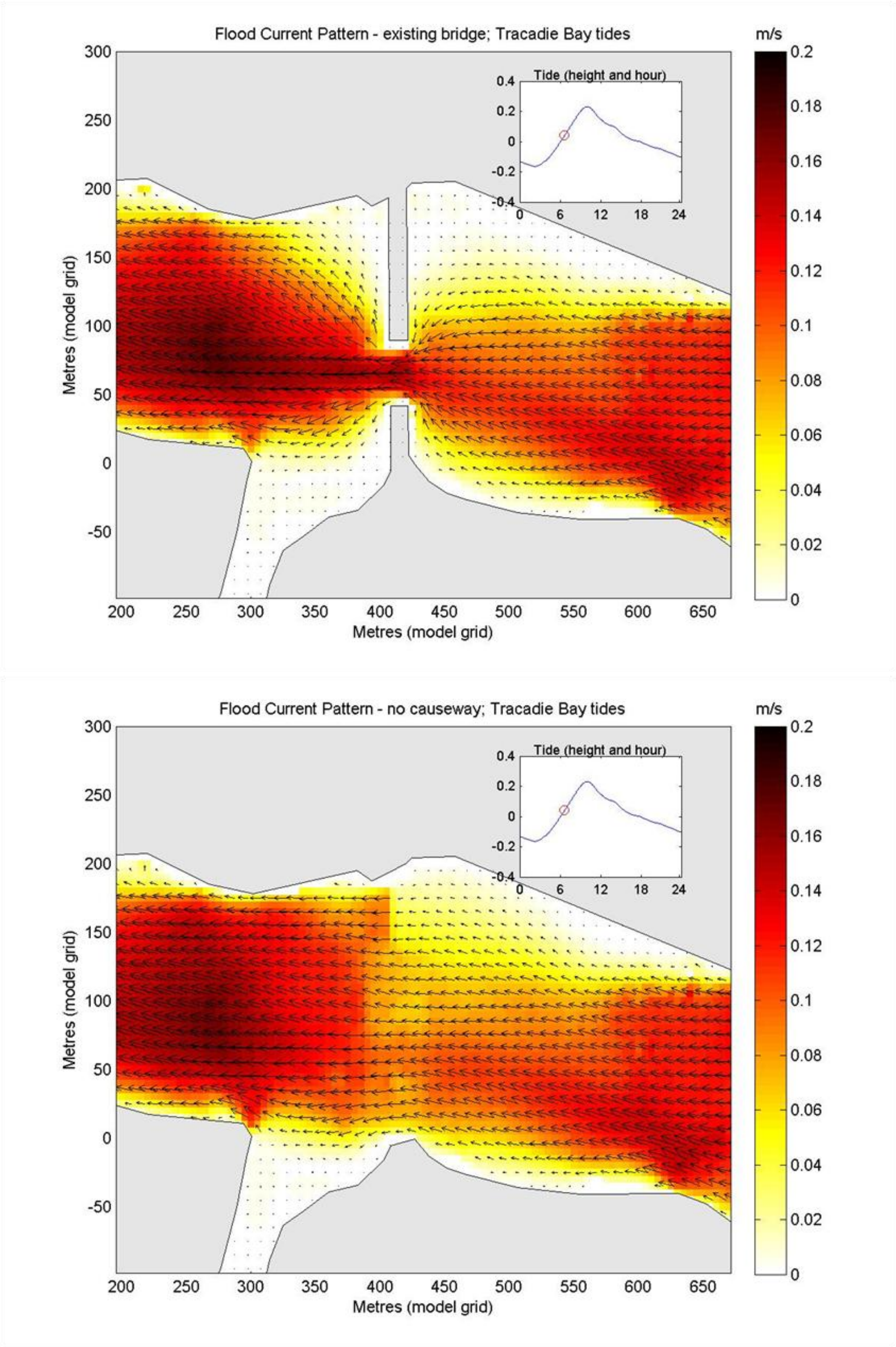

Figure 17 Typical flood current patterns for the existing bathymetric grid and with the approach causeways removed.

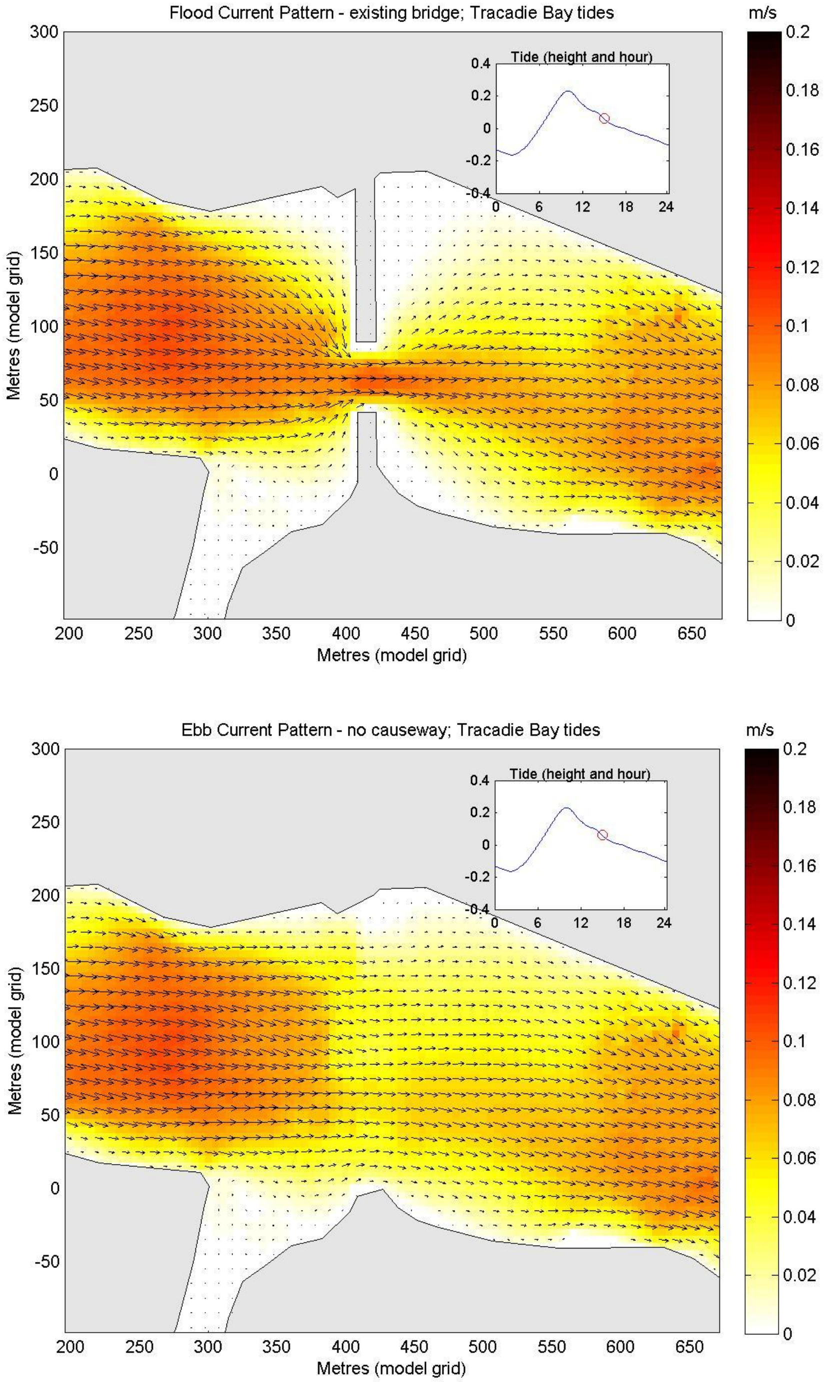

Figure 18 Typical ebb current patterns for the existing bathymetric grid and with the approach causeways removed.

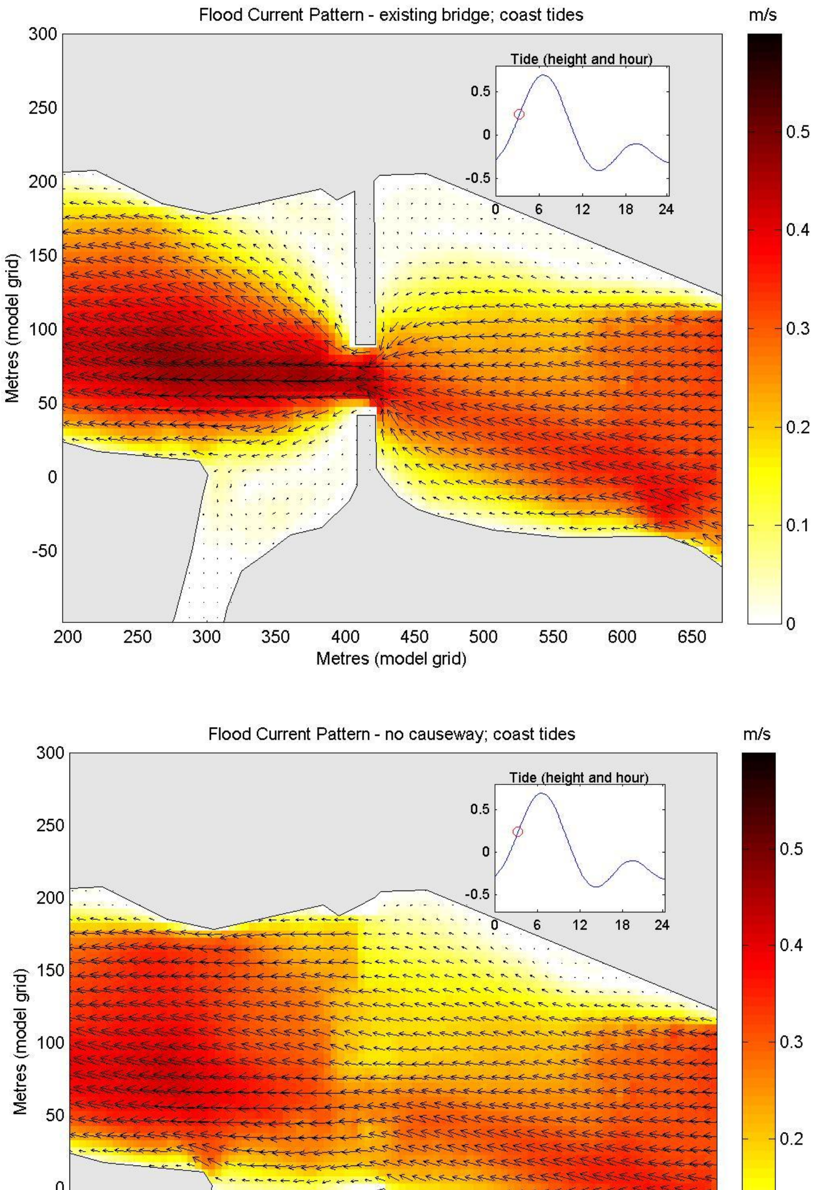

Figure 19 Typical flood current patterns for the existing bathymetric grid and with the approach causeways removed assuming a hypothetical coastal tide.

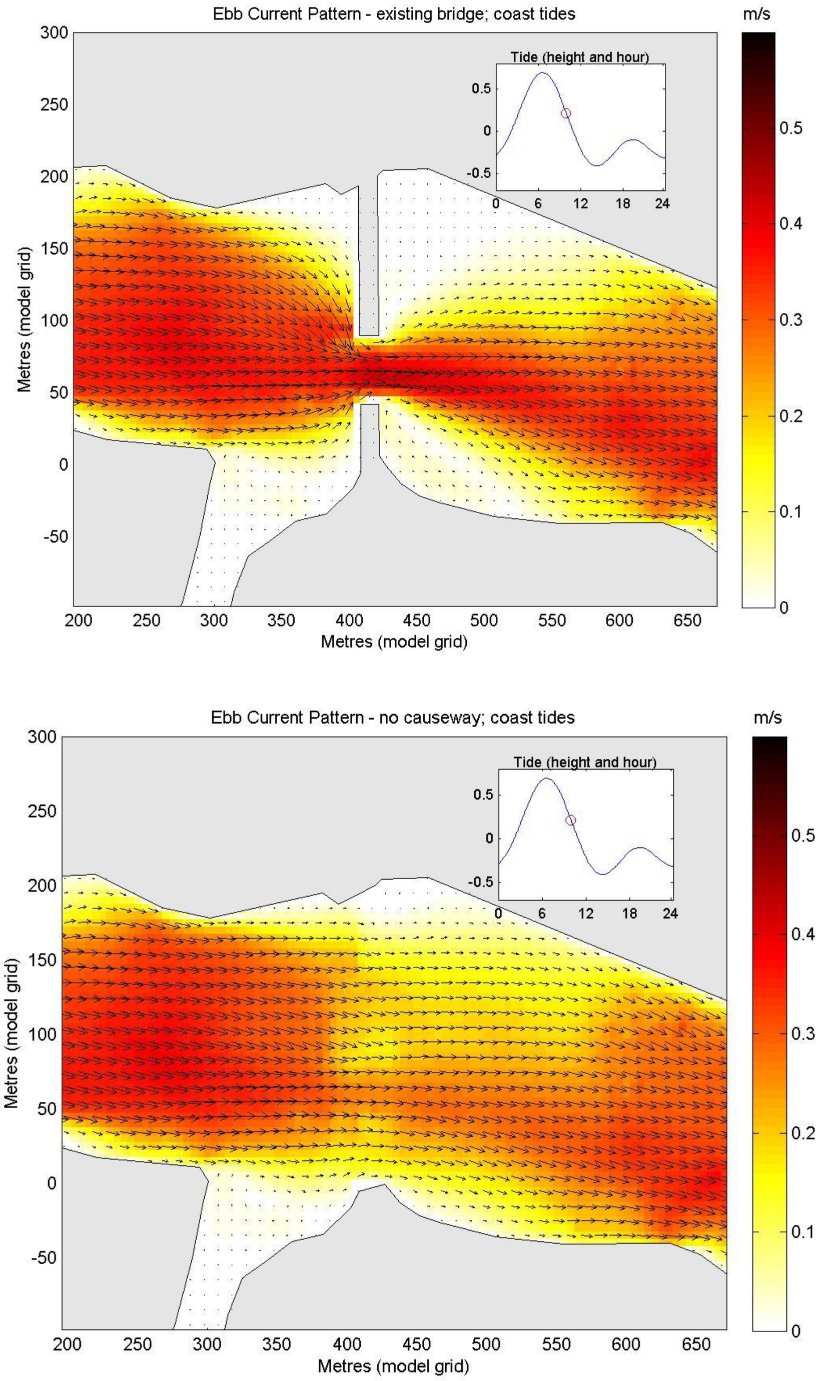

Figure 20 Typical ebb current patterns for the existing bathymetric grid and with the approach causeways removed assuming a hypothetical coastal tide.

3.3.2 Mean Tide Patterns

Mean tidal patterns are present in Figure 21 and Figure 22. The results show generally weak residual currents especially in the case where the approach causeways have been removed. The residuals are stronger in the case of coast tides.

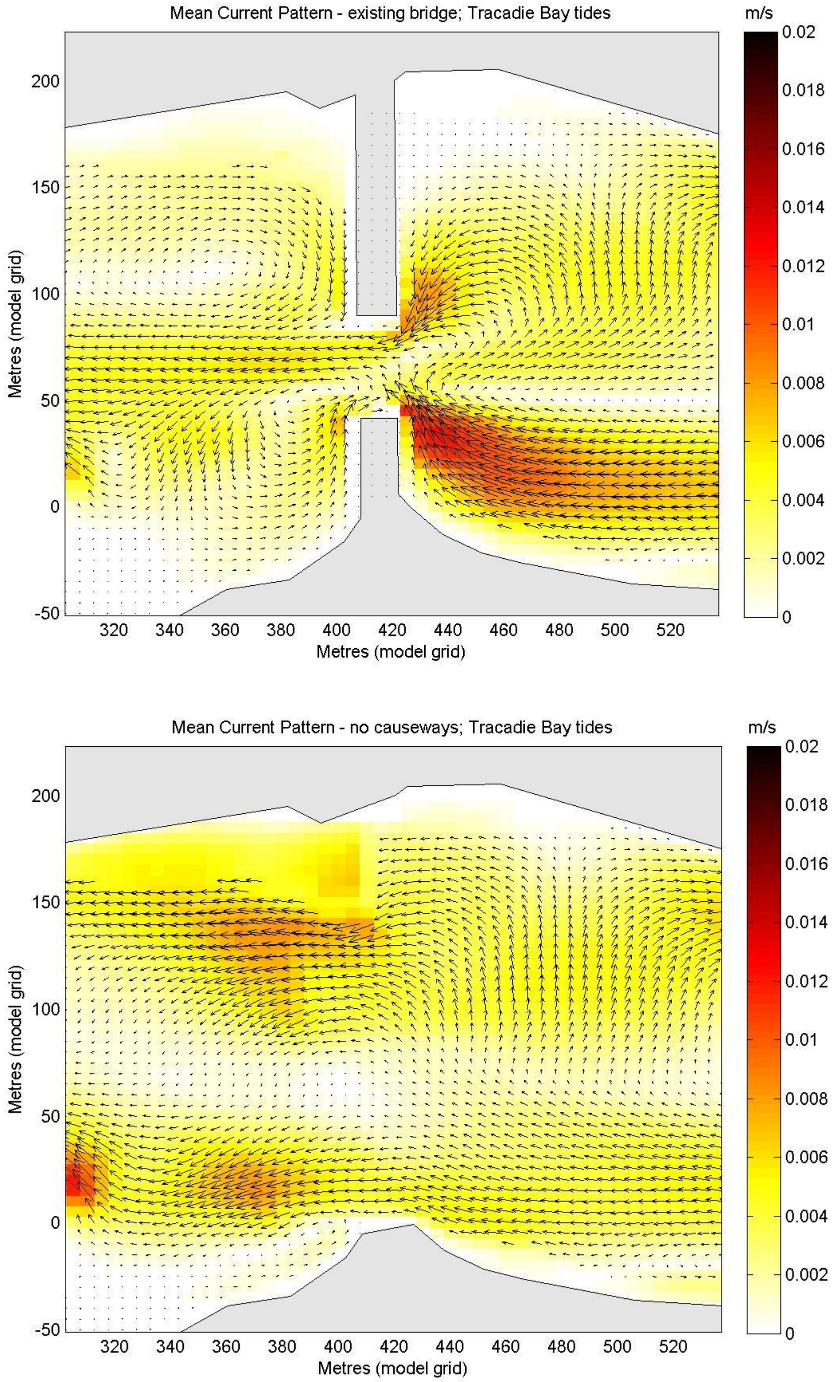

Figure 21 Mean tidal current patterns for the existing bathymetric grid and with the approach causeways removed.

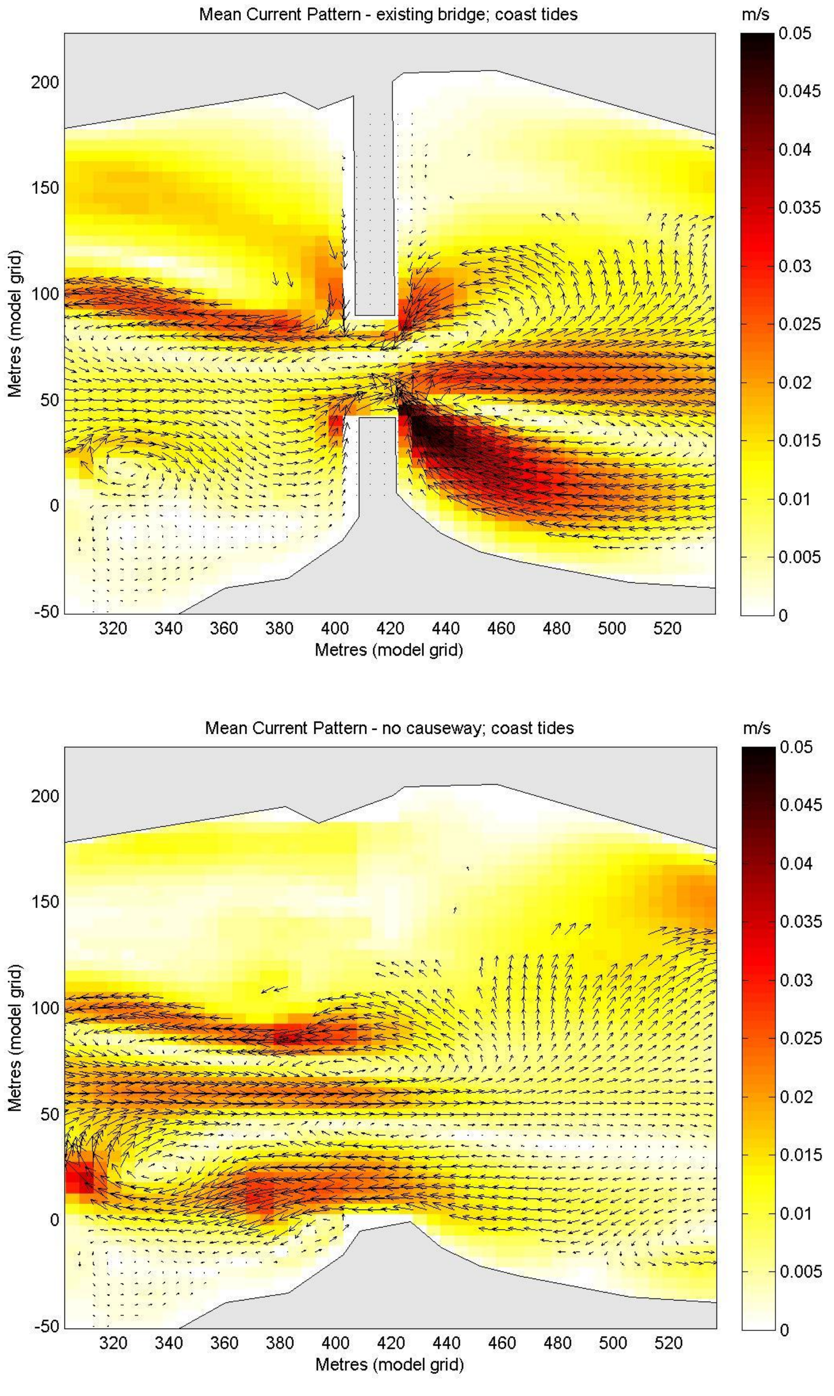

Figure 22 Mean tidal current patterns for the existing bathymetric grid and with the approach causeways removed assuming a hypothetical coastal tide.

3.3.3 Sediment Mobilization Potential

Sediment mobilization frequency results are shown for various unconsolidated grain size in Figures 23, 24, 25 and 26. The results show relatively weak potential for sediment mobilization for all but the smallest grain size for the existing bridge configuration and even less potential for the case where the approach causeways are removed. In the event of the coast tide becoming established in the bay the results show confirm that there would be ample potential for sediment transport and redistribution.

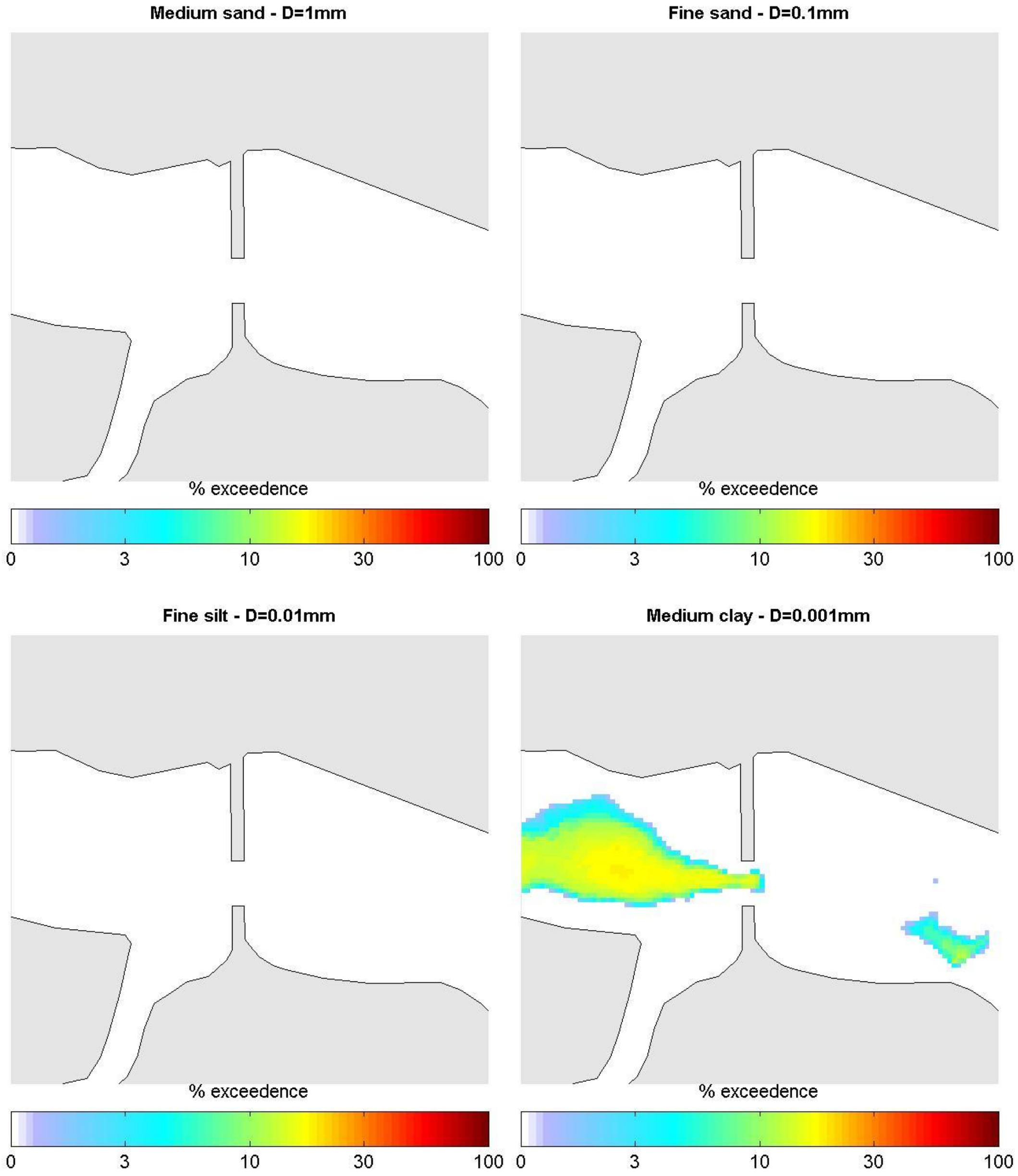

Figure 23 Potential mobility for various size fractions of unconsolidated sediments and existing tides.

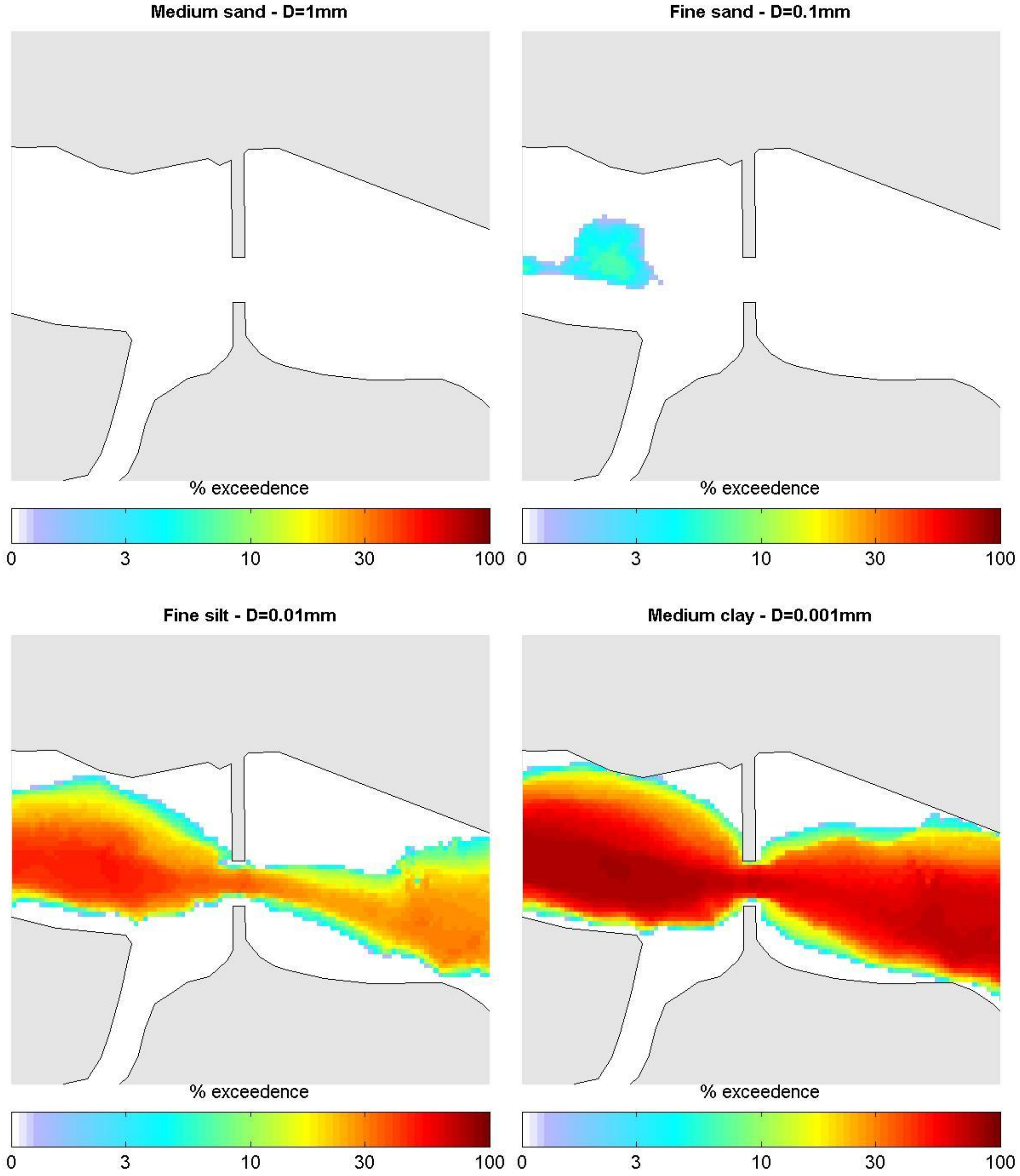

Figure 24 Potential mobility for various size fractions of unconsolidated sediments and a hypothetical coastal tide.

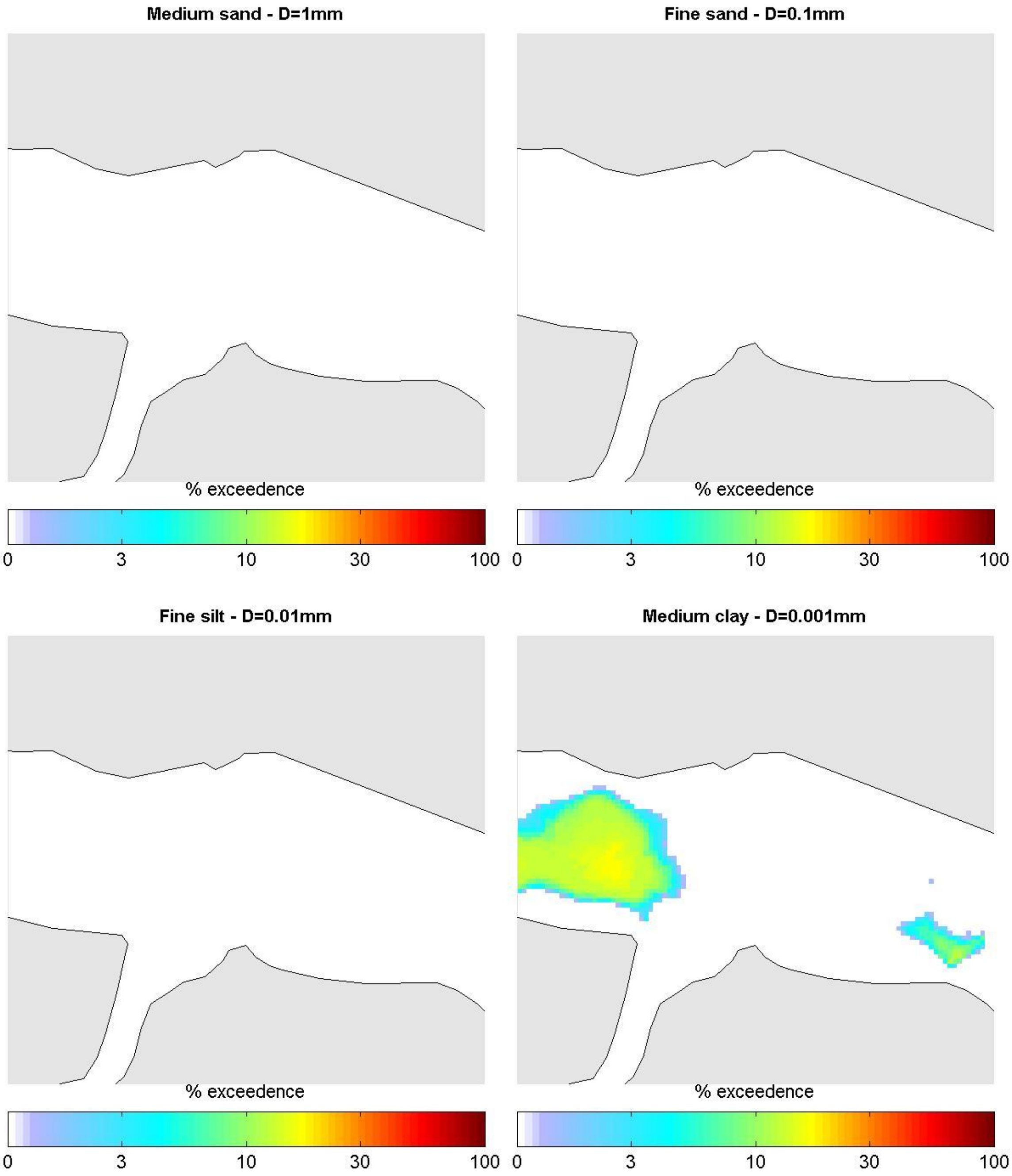

Figure 25 Potential mobility for various size fractions of unconsolidated sediments and existing tides with approach causeways removed.

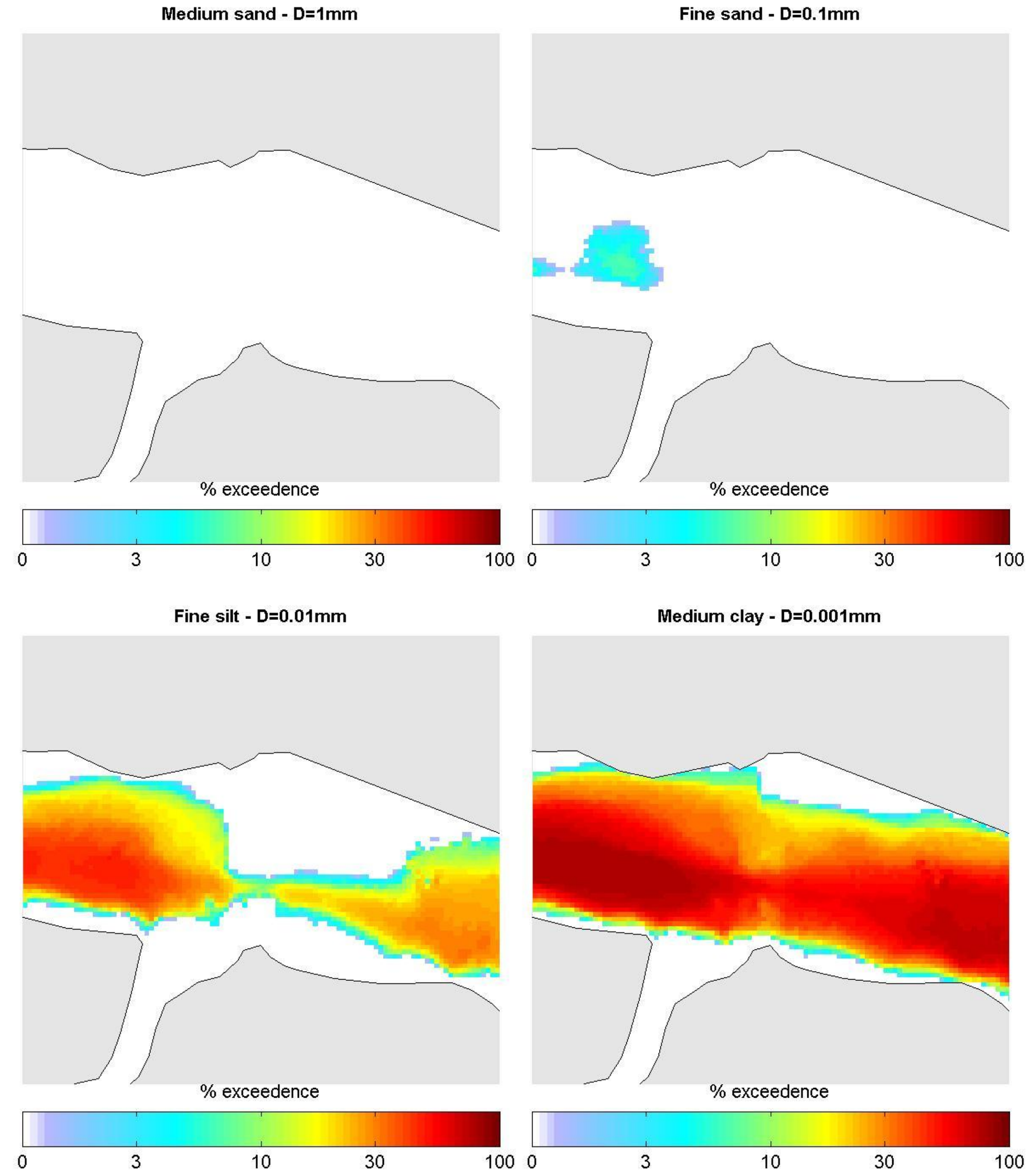

Figure 26 Potential mobility for various size fractions of unconsolidated sediments and a hypothetical coastal tide with approach causeways removed.

4 Discussion and Recommendations

The tidal range in the Little Tracadie system is significantly less than that of the Gulf of St Lawrence. An NBTI field program undertaken in 2012 shows that, while reduced, the tide is not restricted by the bridge gap. These data were augmented with a single day record that included records at Upper Naguac and Val Comeau Bridge. Together with a hydraulic model of the system the data show that the restriction to the tides is due to the constrictions at Val Comeau Channel and Tracadie Gully. These channels have a combined effective hydraulic cross-section (including the effect of the Two Rivers Channel) of about 130 m^2 and cannot supply the $3x10^7$ m^3 of tidal water that would constitute a full tide. On average they allow only about a third of this amount or about $1x10^7$ m^3 of renewal waters per day. In comparison, the Little Tracadie Bridge channel with a cross-sectional area almost the same as the entrance channels combined (120 m^2) needs only supply $2x10^5$ m^3 of tidal flux upstream of its location. That is, the same cross section is providing a flow that is only 1/50'th of the combined flow through the barrier beach channels into Tracadie Bay. Hydraulic and hydrodynamic modelling has shown that the Little Tracadie Bridge channel is more than adequate to admit the existing tide and also the full coastal tide in the event that natural or man-made modifications were take place at the existing coastal entrances.

The Little Tracadie Bridge site is characterized by low salinity and fine grained sediments. The asymmetry of the tide at this location and proximity to fresh water flows together with the existence of several areas of marshy build up are all consistent with the location of the study site in the upper part of the estuary. Not surprisingly, the area of the bridge channel has been scoured even though the currents are weak. This appears to have progressed to a depth that results in an increase in cross section so that currents are relatively constant from downstream of the bridge through the gap and into the area upstream. Modelling has shown that the tidal range could be passed by a more narrow bridge gap it would be at the expense of higher currents in the gap and possibly more scour. While higher currents are not necessary a negative feature of such systems since they tend to enhance mixing and aeration, a more narrow gap cannot be recommended due to the possibility of disrupting local sediment dynamics.

Both data and modelling have shown that the existing bridge gap is amply wide and deep to admit the existing reduced tides from Tracadie Bay and also that it is large enough to admit the full coastal tides should they ever become established in the bay. Our recommendation is that a new bridge structure should continue to essentially cross the existing scoured channel. By this we mean to allow, that since the existing cross section is more than ample, some allowance for abutment design is reasonable so long as it does not extend far into the scour channel (i.e. a sloped wall reinforcing new abutment could extend several meters from the edge of the existing abutments).

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