Appendix D

Hydraulic assessment

A part of BMT in Energy and Environment

Burrill Bridge Upgrade Design Impact Assessment

Final Report
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Burrill Bridge Upgrade
Design Impact Assessment

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Synopsis : This report documents the hydraulic assessment of proposed upgrade to the Burrill Lake Bridge and Causeway of the Princes Highway

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1 INTRODUCTION

1.1 Background and Purpose

The Roads and Maritime Services, NSW (RMS) undertook investigations into options for the long-term future of the Burrill Lake Bridge. Options investigated included various maintenance activities and complete replacement of the bridge. The bridge replacement option has been identified as the preferred option with the current design being the subject of this assessment.

The Princes Highway Causeway which traverses the inlet channel was originally constructed in the 1880's. The level of the causeway was raised in the 1960's to reduce the frequency of inundation and highway closure. The current level of the Causeway however remains relatively low at 1.6m AHD. The span of the causeway across the inlet channel is approximately 200m, with the waterway opening (provided at the southern end) is limited to approximately 45m.

Burrill Lake is a large and relatively deep water body with a surface area of some 4km^2 and is connected to the ocean by Burrill Inlet, a 3km long meandering channel. The Burrill inlet channel is relatively shallow, with typical depths less than 3m, and potentially as shallow as 1m in some locations under low tide conditions. The topography of the Burrill Inlet and location of the existing Causeway is shown in Figure 1-1.

This study provides for an assessment of the impacts of the proposed upgrade on the flow conditions with the Burrill Inlet and broader estuary.

1.2 Previous Studies

There are number of previous studies with specific relevance to undertaking the flood impact assessment as summarised below.

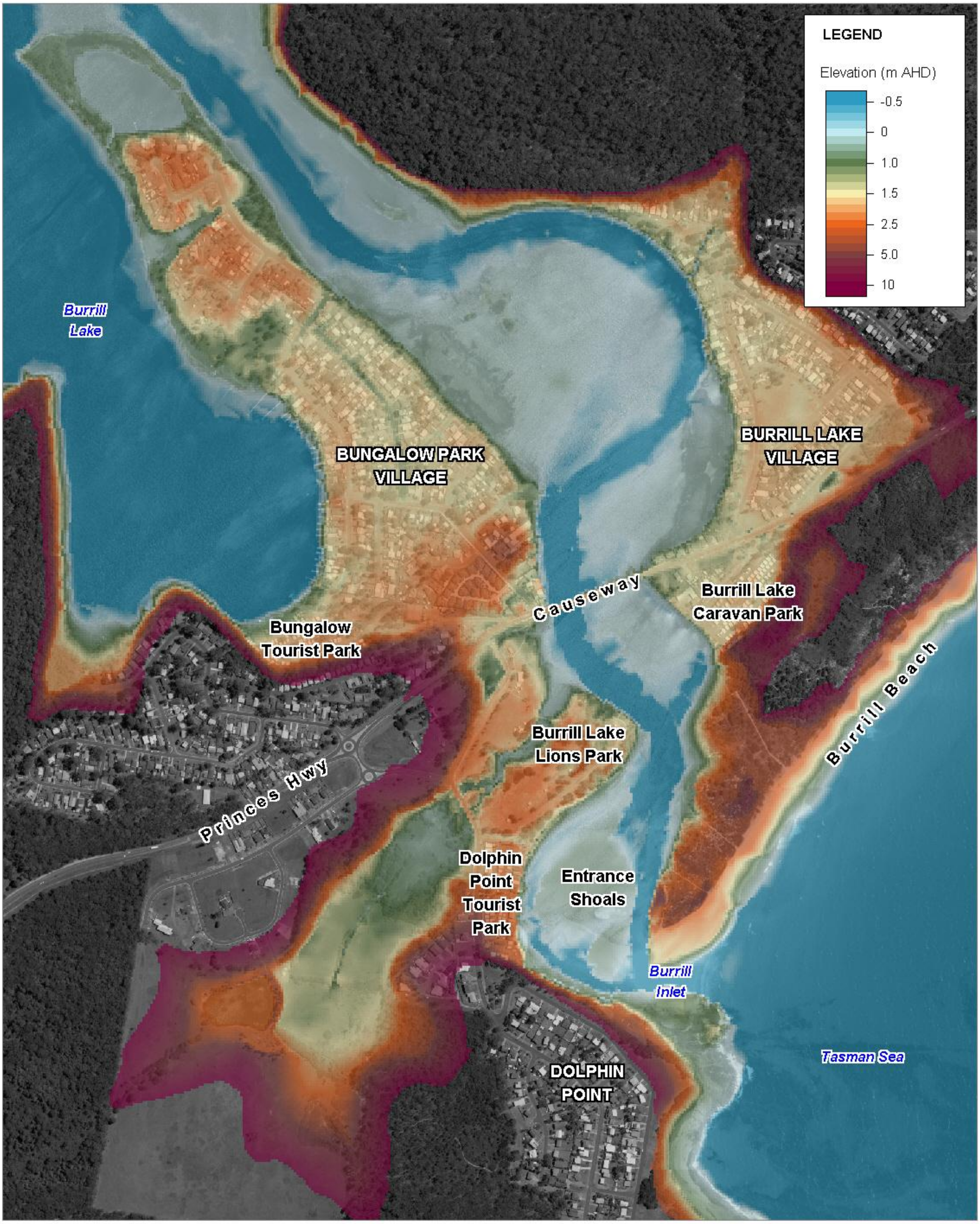
- Burrill Lake Flood Study (BMT WBM, 2007) – a detailed flood study of the Burrill Lake catchment was undertaken on behalf of Shoalhaven City Council. Central to this study was the development of appropriate hydrological and hydraulic models of the catchment flood behaviour to establish design flood conditions. The models originally developed in this study have been applied in the current investigations.

- Burrill Lake Floodplain Risk Management Study and Plan (BMT WBM, 2013) - the outcomes of this study provide the basis for the Floodplain Risk Management Plan, containing an appropriate mix of management measures and strategies, to help direct and coordinate the responsibilities of Government and the community in undertaking immediate and future flood management works and initiatives. Recommendations of the Plan include investigation of raising the Princes Highway to provide for appropriate flood access.

- Burrill Inlet Causeway Options Study (WBM Oceanics, 2001) – a detailed modelling study was undertaken to assess the impact of the existing bridge and causeway on tidal hydrodynamics and sediment transport and investigate the merit of modifications to the causeway configuration and dredging options. The study found that removal of the causeway had relatively minor effect on inlet processes. The impact on flood conditions was not assesses which is addressed in the current study.

- Strategic Concept and Options Study Burrill Lake Bridge (Aurecon, 2010) – this report provides an evaluation of potential upgrade options to the existing Burrill Bridge and Causeway. The concept designs included in the report provided the basis for the options investigation (BMT WBM, 2013)

- Burrill Bridge Upgrade Options Investigation (BMT WBM, 2013) - This study provides for an assessment of the impacts of the concept designs on the flow conditions with the Burrill Inlet and broader estuary.



Title:

Local Topography of Burrill inlet

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Approx. Scale

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2 PROPOSED BRIDGE UPGRADE DESIGN

The Strategic Concept and Options Study Burrill Lake Bridge (Aurecon, 2010) identified a number of bridge rehabilitation options summarised below:

- Option 1 – Do nothing;
- Option 2 – Concrete casing of the existing piles above bed level;
- Option 3 – Installation of new piles and three variations for headstock strengthening;
- Option 4A – Replacement of the current bridge, maintaining the existing causeway and alignment. This option replicates the current six-span arrangement with a seven-span bridge, reducing the causeway length by about 9m; and
- Option 4B – Construction of a new bridge off alignment. The bridge comprises a 200m long structure across the lake.

Option 4B in principle has been adopted as the preferred option. The current upgrade proposal represented by designs provided by RMS is the subject of this report with respect to the potential impact on the local flooding and hydraulic regimes within the Burrill Lake entrance channel. The following sections provide a summary of the key characteristics of the existing and proposed configurations and representation in the hydraulic model.

2.1 Existing Bridge and Causeway

The existing bridge comprises 6 spans with an overall length of approximately 55 metres. The general configuration of the bridge is shown in Figure 2-1. The effective waterway area through the bridge structure is marginally decreased due the presence of the piers. The existing hydraulic model provides for the effective clear span waterway area and provision for additional losses associated with the piers.

The bridge soffit level is at approximately 1.5m AHD with a centreline road level of approximately 2.1m AHD. Reinforced concrete safety barriers are provided on each side of the bridge, thereby further increases the level at which the bridge structure is overtopped.

The causeway provides for a total obstruction to flow within the Burrill Lake entrance channel. The crest level of the causeway varies between 1.5 – 2.0m AHD. The level of the causeway is such that under major flood conditions, significant overtopping of the causeway would occur.

2.2 New Bridge

The proposed option provides for complete replacement of the existing bridge and causeway on a modified alignment to the existing road as shown in Figure 2-1. The new alignment is proposed some 20m to the downstream side and parallel to the existing bridge and causeway.

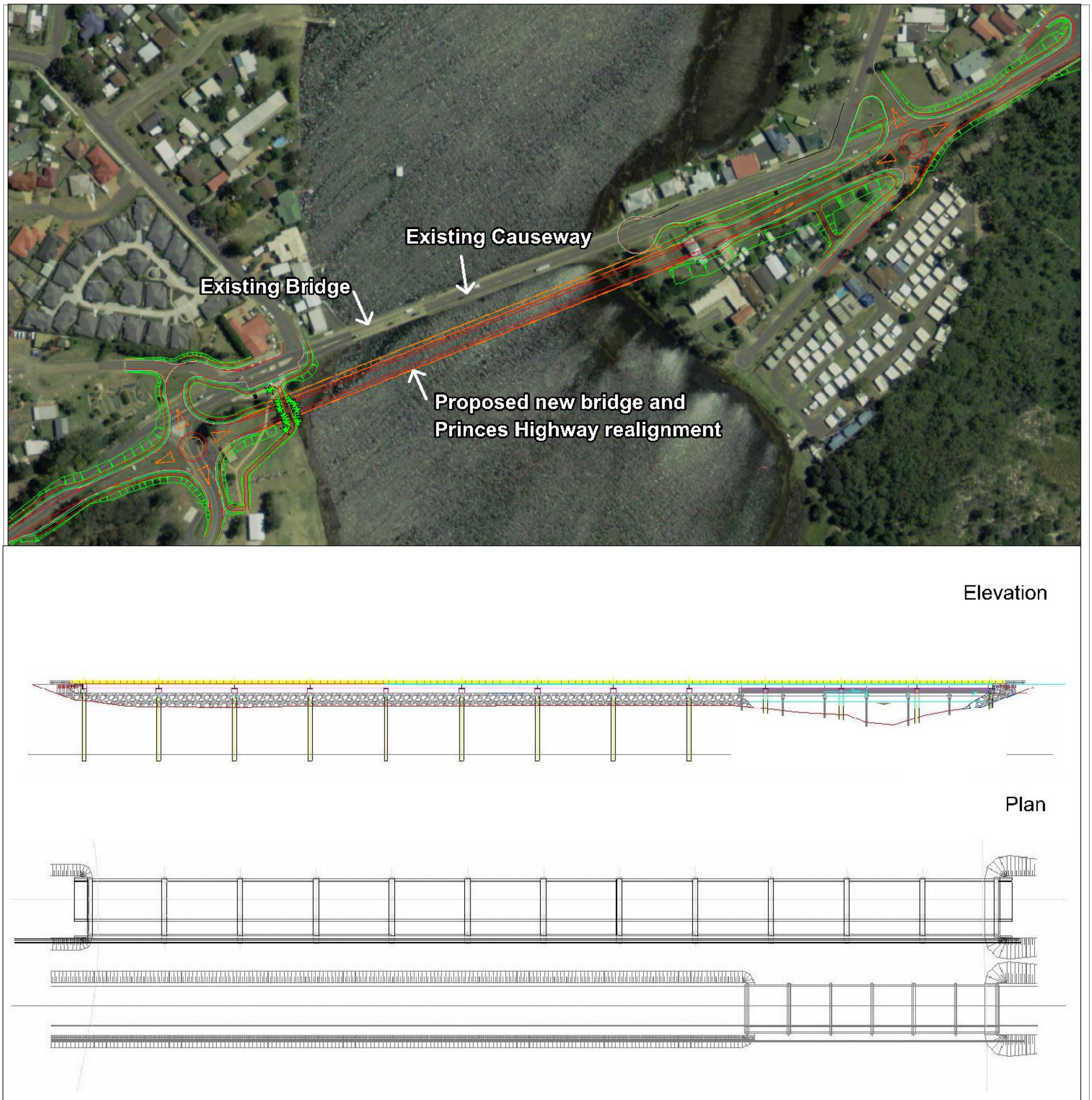
The new bridge structure would span some 200m across the full width of the Burrill Lake waterway, thereby providing minimal waterway encroachment. The loss in waterway area associated with the pier/headstock configuration is small in comparison to the total waterway area.

The design levels for the bridge have been set well above the design 100yr ARI flood condition to provide a flood free access route. With these levels, and with a 200m span, the proposed bridge structure will have minimal influence on hydraulic conditions in the estuary. However, this does represent a significant change from existing conditions.

In addition to the main bridge and approaches, there are minor changes to some of the local roads. On completion of construction of the new bridge, the existing causeway and bridge will be removed.

2.3 Temporary Works

One of the initial phases of construction involves the placement of working platforms in order to undertaking piling works for the new bridge structure. The proposed working platforms are fill embankments built to an approximate level of 1.2m AHD along the alignment of the proposed bridge structure. The temporary works consist of a northern and southern platform with a waterway opening between of approximately 20m width at the alignment of the existing bridge and main flow path.



Notes:
New bridge spanning full width of Burrill channel on new alignment downstream of existing bridge/causeway
New bridge soffit level above design 1% AEP flood level
Approach embankments constructed above existing floodplain level thereby limiting overtopping
Existing bridge and causeway removed

Title:
Proposed Bridge Configuration

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2-1

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3 EXISTING HYDRAULIC CONDITIONS

The design flood conditions for Burrill Lake have been estimated utilising the computer models developed as part of the Burrill Lake Catchment Flood Study (BMT WBM, 2007). These models were calibrated and tested utilising recorded flood data from the February 1971 and February 1992 flood events. The models have been subsequently utilised in the Burrill Lake Floodplain Risk Management Study (BMT WBM, 2013). Reference should be made to these previous studies for further detail on model development and calibration.

3.1 Flooding Mechanisms

Flooding around Burrill Lake can occur from three mechanisms (and combinations thereof):

- Catchment flooding, as a result of intense rainfall within the local catchments;
- Oceanic inundation, as a result of high ocean tides, storm surge, wave penetration; and
- Low-level persistent flooding, occurring through a gradual and prolonged rise in lake levels during periods of entrance closure.

Catchment flooding in Burrill Lake tends to emanate from major rainfall events within the catchment from falls of the order of hundreds of millimetres over 1-2 day periods. Given the size of the catchment and the storage of the Lake system itself, it is largely not prone to major flooding from shorter more intense rainfall.

The design catchment flood conditions for Burrill Lake, established as part of the Burrill Lake Catchment Flood Study (BMT WBM, 2007), were based on critical design storm duration of 18-hours. The design rainfall depths derived from standard Intensity-Frequency-Duration analysis as described in Australian Rainfall and Runoff (AR&R, 2007) are summarised in Table 3-1.

Table 3-1 Adopted Design Rainfall Totals

Design Event	Rainfall Depth (mm)
20% AEP (1 in 5)	187
10% AEP (1 in 10)	220
5% AEP (1 in 20)	259
2% AEP (1 in 50)	315
1% AEP (1 in 100)	335

The second flooding type that potentially affects Burrill Lake is inundation from elevated ocean water levels. In addition to normal astronomical tides, low air pressure causes ocean levels to increase (called inverse barometric set-up), while strong onshore winds can also 'pile-up' water against the coastline. These ocean storm conditions can cause elevated water levels considerably higher than normal tidal regimes.

Design ocean water levels adopted in the study are in accordance with the recommendations in the Draft Flood Risk Management Guide (DECCW, 2010). Peak ocean boundary water levels for various magnitude storm events are summarised in Table 3-2.

Table 3-2 Peak Design Ocean Flooding Boundary Condition

Design Event	Ocean Water Level (m AHD)
20% AEP (1 in 5)	1.9
10% AEP (1 in 10)	2.1
5% AEP (1 in 20)	2.25
2% AEP (1 in 50)	2.45
1% AEP (1 in 100)	2.6

The ocean derived events have been simulated with no coincident catchment inflows, simulating the attenuation of the tidal surge through the entrance channel and into the Lake system.

The entrance channel is subject to periodic closure dependent on the level of sand build up at the ocean entrance. These types of systems are classified as Intermittently Closed and Open Lakes and Lagoons (ICOLLs). During sustained periods of closure, water levels in the Lake can gradually rise and stay elevated. Given the presence of low-lying development around the Burrill Lake foreshore, an entrance management policy has been adopted for Burrill Lake to breach the entrance barrier when the water level reaches specified trigger levels, to relieve potential flooding of public roads and private properties. The current policy provides for breaching of the entrance channel when water levels measured at the Causeway gauge reach around 1.2m AHD.

The potential for climate change impacts is now a key consideration for floodplain management. Low-lying coastal areas, such as those surrounding Burrill Lake will be at increasingly high risk due to a range of predicted climate change impacts. The NSW Sea Level Rise Policy Statement (2009) advises that mean sea level could potentially rise, up to 0.4m by 2050, and up to 0.9m by 2100, relative to the 1990 levels. The NSW Government advises that these values be used for strategic planning and landuse management purposes.

Potential climate changes influences are likely to increase the frequency and severity of flooding around the Burrill Lake entrance through:

- Increases in design rainfall intensities;
- Elevated ocean levels and tidal conditions at the inlet; and
- Increases in the height of the entrance berm and general shoaling levels.

3.2 Design Flood Conditions

The existing flood model has been used to simulate design flood conditions for the development assessment. Model simulations for a range of design event magnitudes have been undertaken to establish existing flooding conditions across the site and to provide baseline conditions for assessing the impact of the proposed upgrade works on flooding.

Table 3-3 summarises the simulated peak flood levels upstream of the causeway for a range of design flood conditions incorporating both catchment and ocean derived flooding, and the potential impacts of climate change.

Table 3-3 Comparison of Peak Flood Conditions with Climate Change Scenarios

Event Conditions	Planning Horizon		
	Existing	2050	2100
5% AEP Catchment Event	2.2	2.5	2.8
5% AEP Ocean Event	1.5	2.0	2.6
1% AEP Catchment Event	2.4	2.7	3.0
1% AEP Ocean Event	1.8	2.4	3.0

The condition of the entrance, being closed, shoaled or open, has some impact on peak flood levels attained. For catchment flooding, a heavily shoaled or closed entrance at the onset of the event provides for worst case conditions in terms of flood levels. Conversely, greater penetration of ocean water through the entrance and into the body of the lake system is afforded by an open or unconstrained entrance. The peak flood water levels shown in Table 3-3 represent the worst-case scenarios for each flooding mechanism, i.e. a closed entrance for catchment events and open entrance for ocean events.

The adopted entrance condition for a closed entrance assumes a typical entrance berm elevation of around 1.0m AHD. For the open condition, the entrance channel is assumed scoured to a typical depth of -1.0m AHD. Given the dynamic nature of the entrance condition in response to coastal conditions and catchment rainfall, the entrance condition can vary considerably between the fully open and closed regimes. Typically, however the entrance is shoaled to some degree.

Simulations for catchment flooding scenarios were also undertaken assuming a fully open entrance condition. This provides for higher flow velocities in the channel compared with the closed entrance scenarios. Accordingly, discussion on peak velocities in subsequent sections are based on the higher velocity results of the open entrance scenario. The influence of the entrance condition on peak flood levels is summarised in Table 3-4.

Table 3-4 Comparison of Peak Flood Conditions with Closed or Open Entrance

Event Conditions	Entrance condition	
	Fully Open	Fully Closed
20% AEP Catchment Event	1.5	1.9
5% AEP Ocean Event	1.9	2.2
1% AEP Catchment Event	2.2	2.4

A change in entrance berm processes is likely to result from predicted sea level rise and changes to coastal storm intensity. From this change, a net upward shift in typical berm heights at the entrance may be expected commensurate with sea level rise estimates. Accordingly, a typical shoaled entrance at 1m AHD under existing conditions has been assumed to build to levels of 1.4m AHD and 1.9m AHD respectively for the adopted 2050 and 2100 sea level rise scenarios.

The dominant flooding condition in terms of peak flood level for the Causeway is the catchment derived flooding. The general flood extent and behaviour is similar for each event, albeit with the severity of flood depths and velocities increasing with event magnitude.

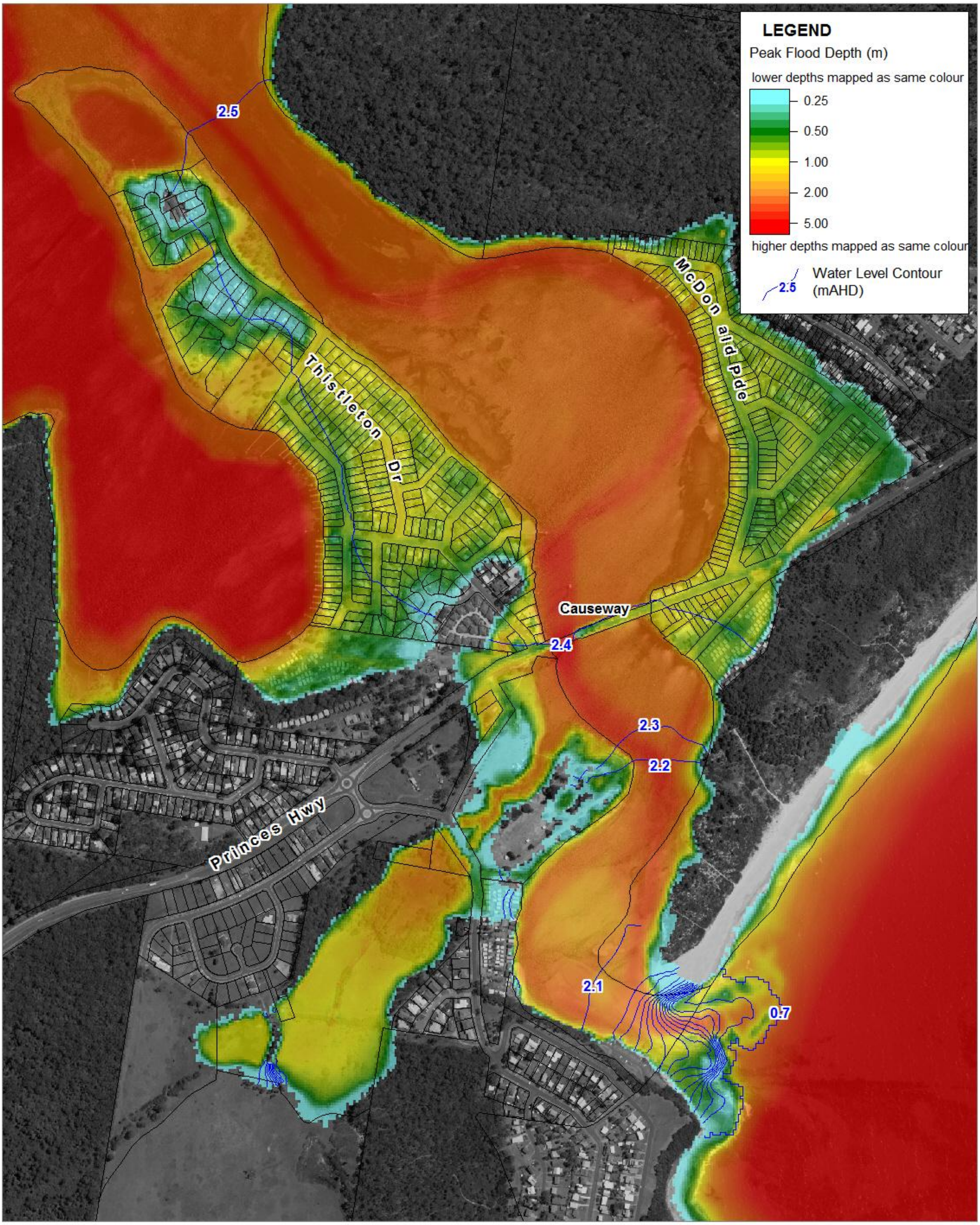
With existing Causeway levels as low as 1.5m AHD, inundation of the road would be expected in major flood events. The existing flood immunity of the road is relatively low with flood events of the order of the 20% AEP and 10% AEP potentially resulting in overtopping of the Causeway. For the 1% AEP design event, inundation depths of the order of 1m could be expected.

The design flood conditions for the 1% AEP event representing peak flood level and depth and peak flood velocity distribution are presented in Figure 3-1 and Figure 3-2. A flood event of this magnitude would result in an extensive inundation of existing property, particularly on the Bungalow Park Village peninsula and Burrill Lake Village (north Burrill Lake). Typical flood depths of the order of 0.5m – 1.0m would result in above floor flooding of a large number of properties.

In addition to extensive overtopping of the Burrill Bridge and Causeway, the approaches on the Princes Highway would also be subject to inundation for a considerable distance beyond the bridge. Given the susceptibility of large areas of existing urban development to flooding, the availability of suitable flood access routes is a significant issue. However, flood free access is limited given the low flood immunity of the existing Princes Highway crossing at Burrill Lake.

The peak flow velocities for the 1% AEP catchment flood event shown in Figure 3-2 show the extensive overtopping of the Causeway with relatively high velocity generated across the embankment as the flow weirs over the top. In major flood conditions such as the 1% AEP event, the overtopping of the Causeway provides for a preferential flow path to the flood channel on the left bank downstream of the Causeway.

For comparison, the design flood conditions for the 20% AEP event representing peak flood level and depth and peak flood velocity distribution are presented in Figure 3-3 and Figure 3-4. The 20% AEP represents the approximate design flood immunity for the existing Causeway with peak flood levels of the order of 1.5m AHD, near the point of overtopping.



Title:

Existing 1% AEP Maximum Flood Depths and Water Levels

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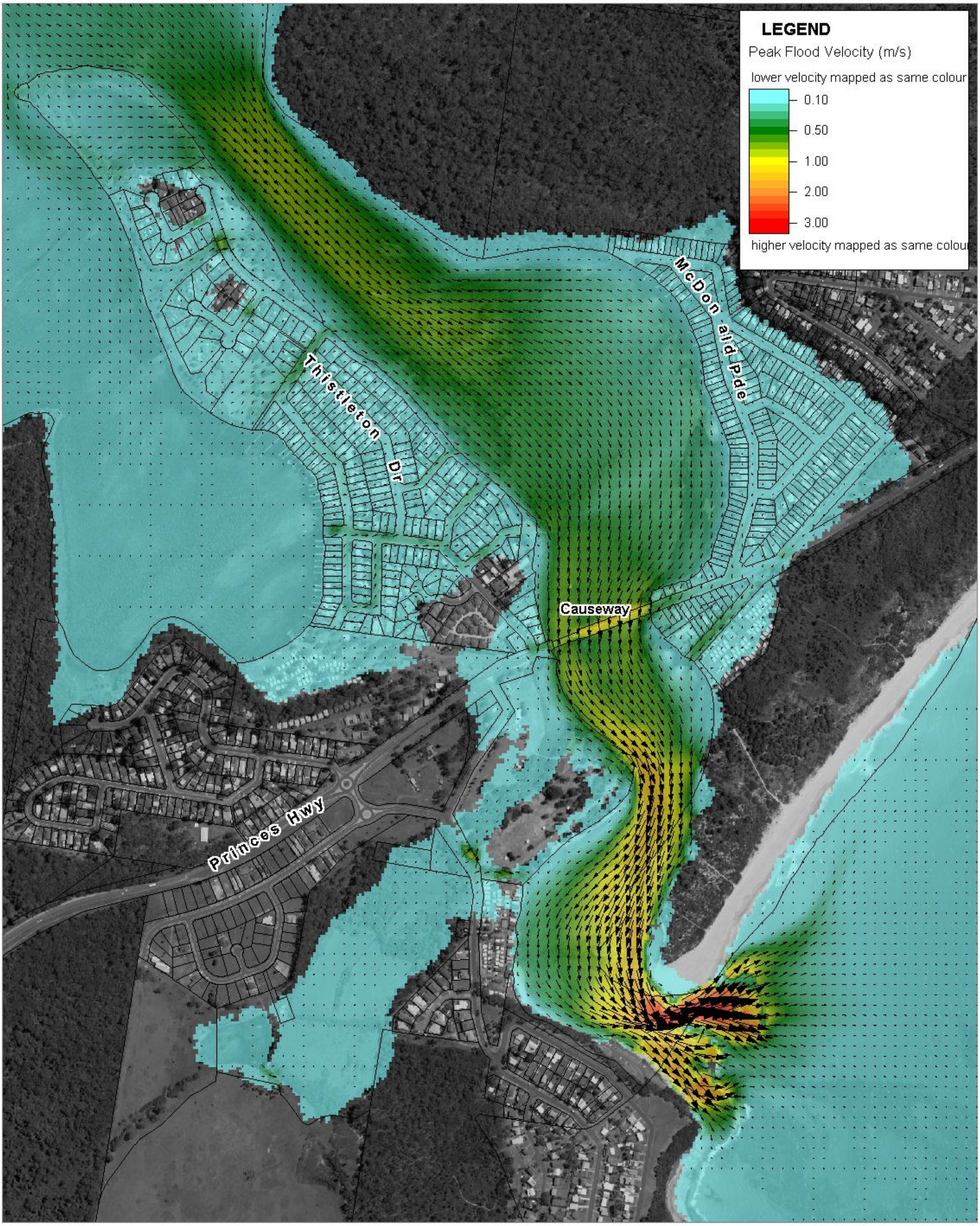

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Existing 1% AEP Maximum Flood Velocities

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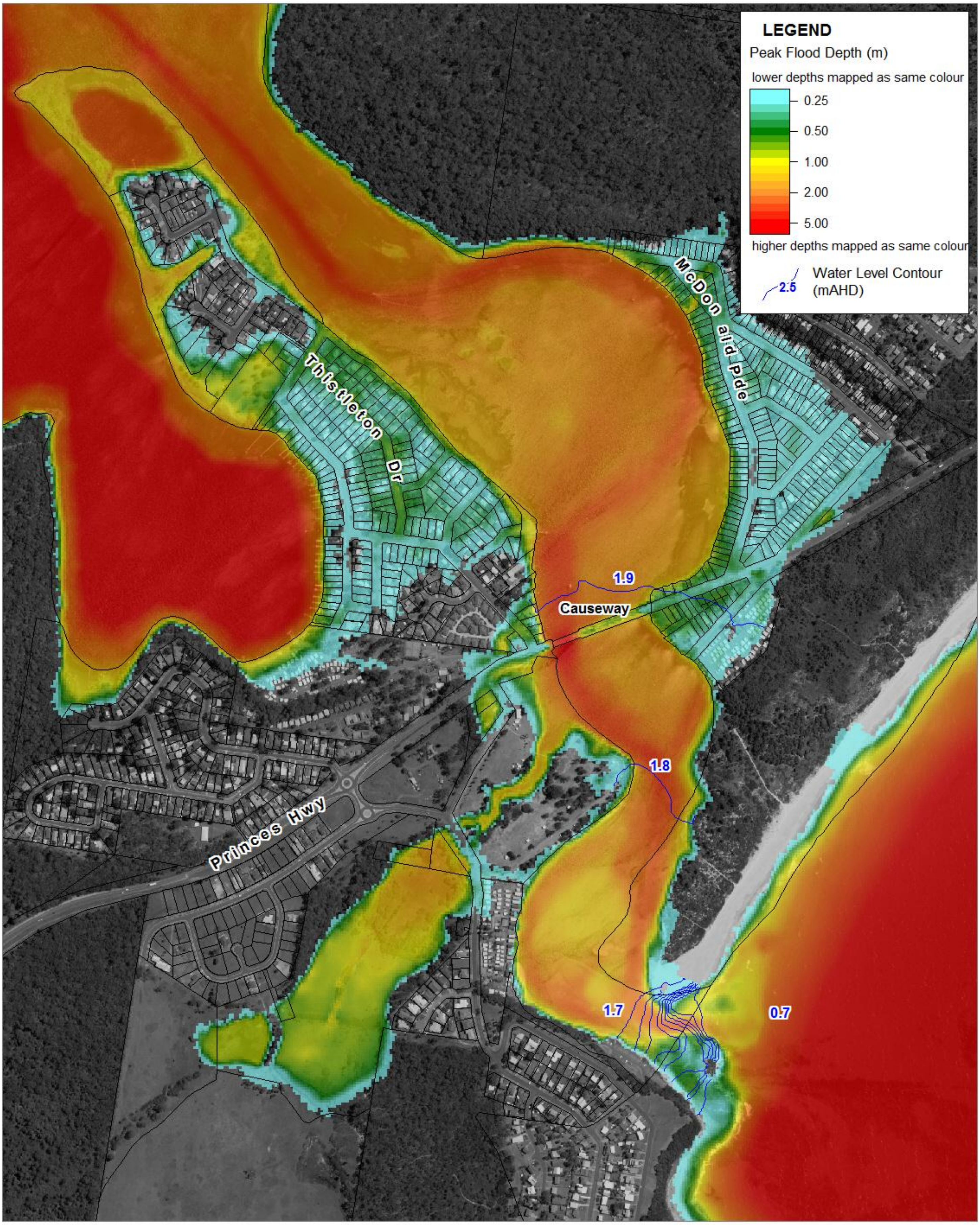

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Existing 20% AEP Maximum Flood Depths and Water Levels

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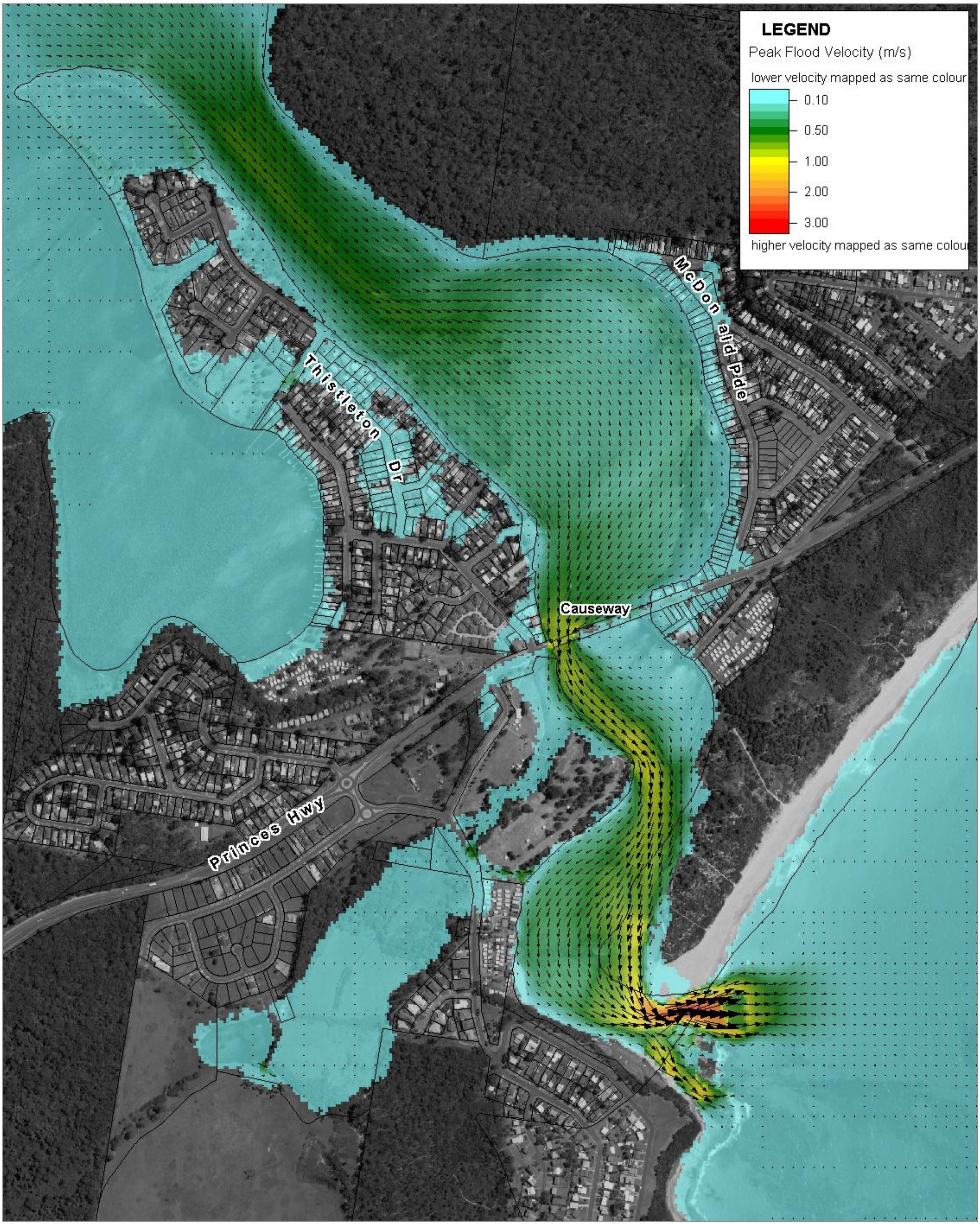

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Existing 20% AEP Maximum Flood Velocities

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The peak velocity distribution for the 20% AEP event is somewhat different to that of the 1% AEP event. Without extensive overtopping of the Causeway for the 20% AEP event, the majority of the flow is conveyed through the existing bridge. Given the narrowing of the channel through the bridge structure, there is a local acceleration of flow through the bridge opening. Downstream of the bridge, there is a rapid redistribution of flow to towards the left bank; this being the shortest flow path represents the main flood channel and again the preferential flow path in major flood events.

3.3 Tidal Flows

The tidal regimes in Burrill Lake are influenced by the degree of closure of the entrance. A fully open or scoured entrance will provide for a greater tidal exchange to the Lake, conversely a heavily shoaled entrance reduces the tidal flows in the Lake. Indicative tidal planes for Jervis Bay, indicative of the ocean entrance condition for Burrill Lake, are shown in Table 3-5.

Table 3-5 Tidal Planes

	Jervis Bay (chart datum)
Mean High Water Spring	1.6m
Mean High Water Neap	1.3m
Mean Sea Level	0.9m
Mean Low Water Neap	0.6m
Mean Low Water Spring	0.3m
Mean Spring Tidal Range	1.3m
Mean Tidal Range	1.0m
Mean Neap Tidal Range	0.7m

The hydraulic model has been used to simulate a representative spring tide condition in Burrill Lake. The adopted ocean boundary water level time series is shown in Figure 3-5 with the simulated water profiles upstream of the causeway and in the main body of the Lake shown for comparison. The ocean tide is highly attenuated through the entrance channel as a result of the friction losses that occur along the inlet. The reduction in tidal range to the causeway (1km upstream of the ocean entrance) and further into the Lake body (3km upstream of the ocean entrance) is significant shown in Figure 3-5.

The simulated peak flood and ebb tide velocity distributions for the representative spring tide are shown in Figure 3-6 and Figure 3-7 respectively. The tidal simulations assume no catchment inputs, with system flow derived purely from tidal flow.

Typically the flood tide provides for the highest flow velocities in the entrance channel. Peak velocities in the main channel through the existing bridge opening are of the order of 0.5-0.6m/s on the flood tide and 0.2–0.3m/s on the ebb tide. Lower velocities are evident in the shallower areas upstream and downstream of the Causeway.

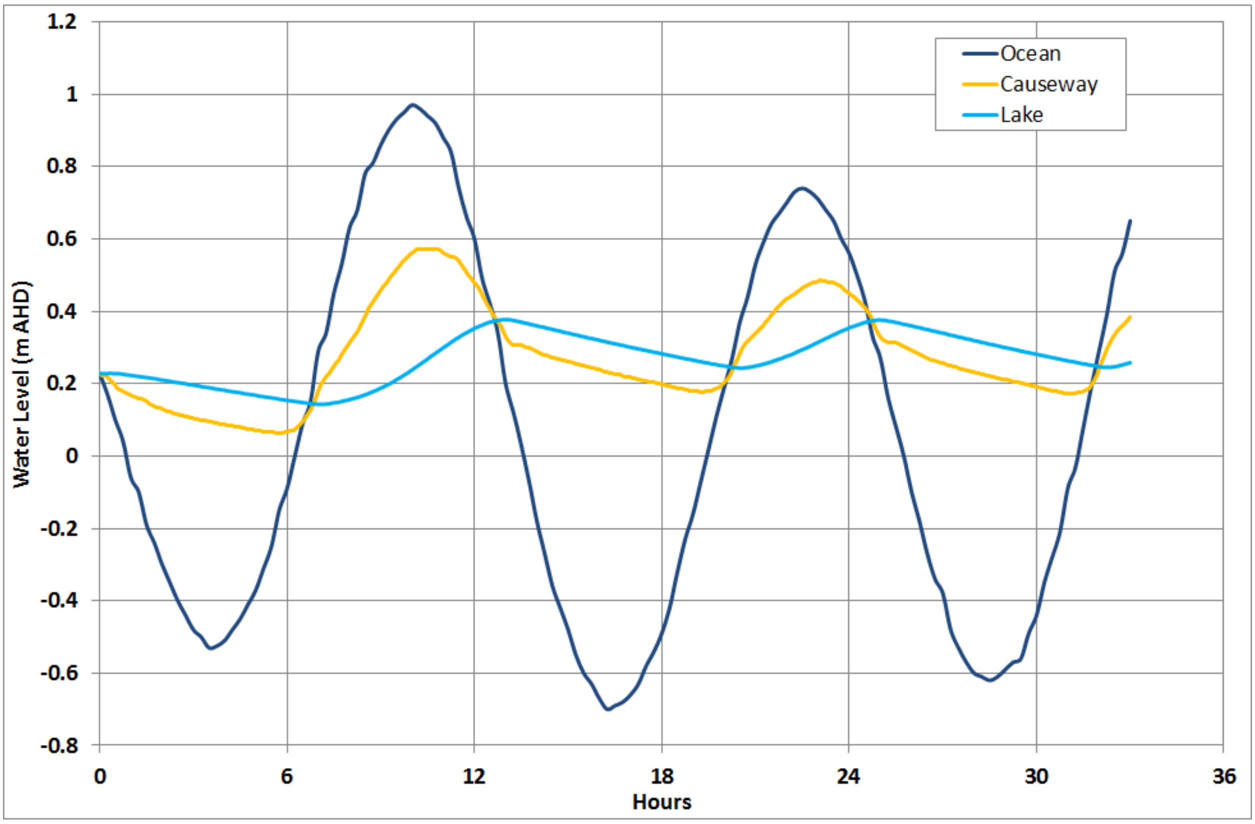
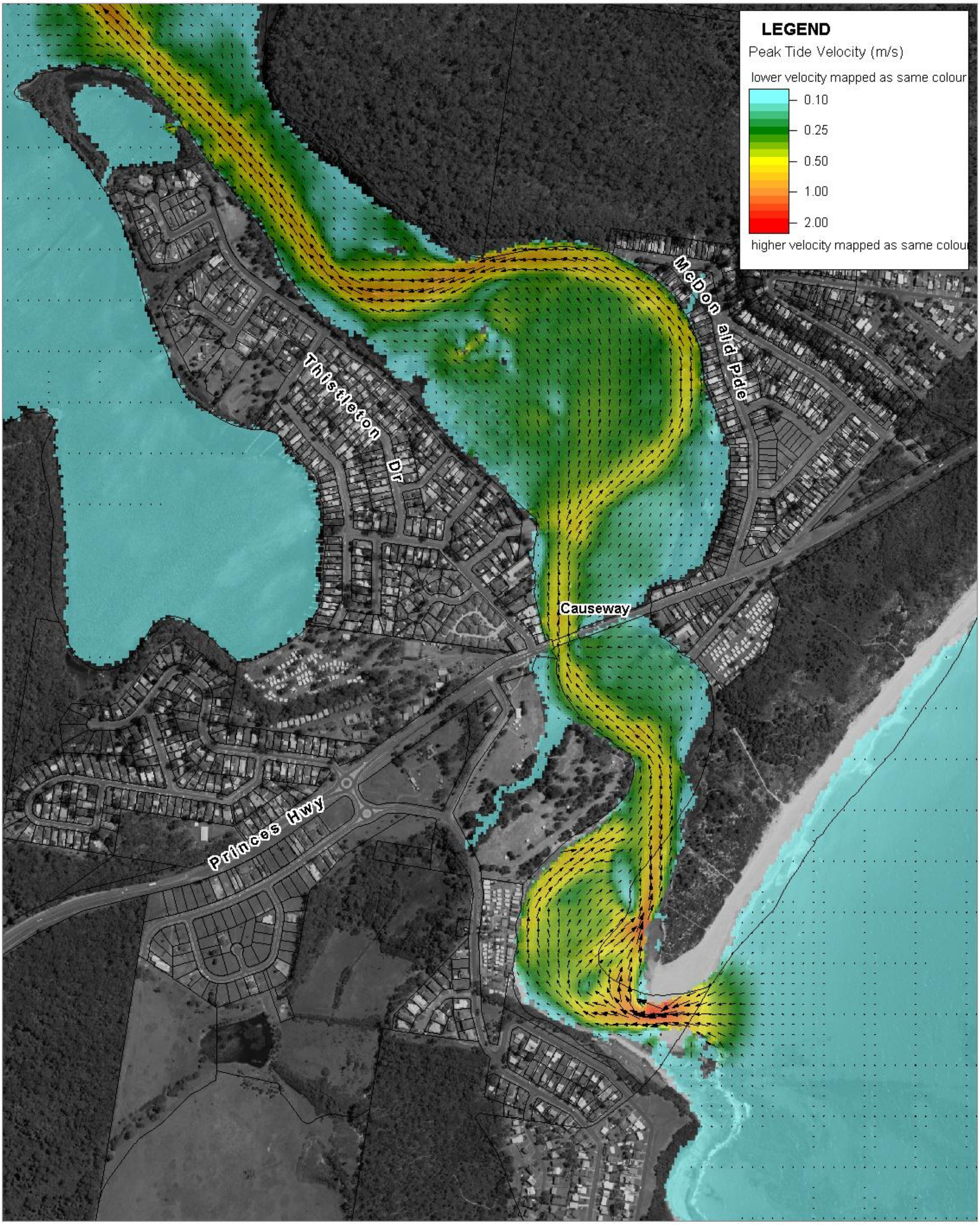


Figure 3-5 Comparison of Tidal Water Level Profiles



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Existing Peak Flood Tide Velocities

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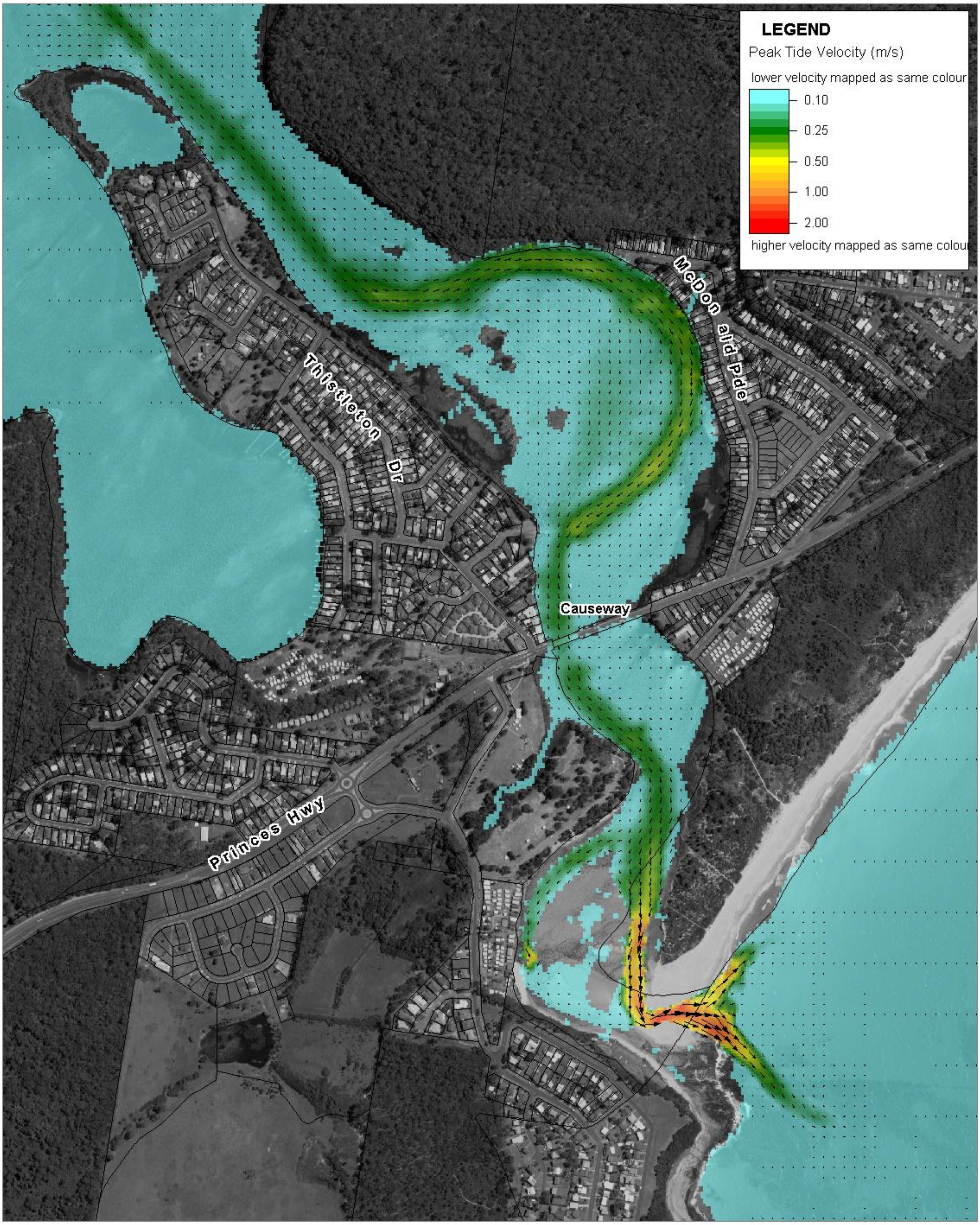

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Existing Peak Ebb Tide Velocities

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4 IMPACT ASSESSMENT

The proposed design option under consideration for the Burrill Lake Bridge and Causeway was presented in Section 2. The existing TUFLOW model was modified accordingly to represent the modified bridge and causeway arrangements. Model simulations for a range of design events were undertaken and compared to the results for existing conditions in order to establish the relative impact of the proposed option.

The following model configurations were assessed representing different scenarios through the construction sequence:

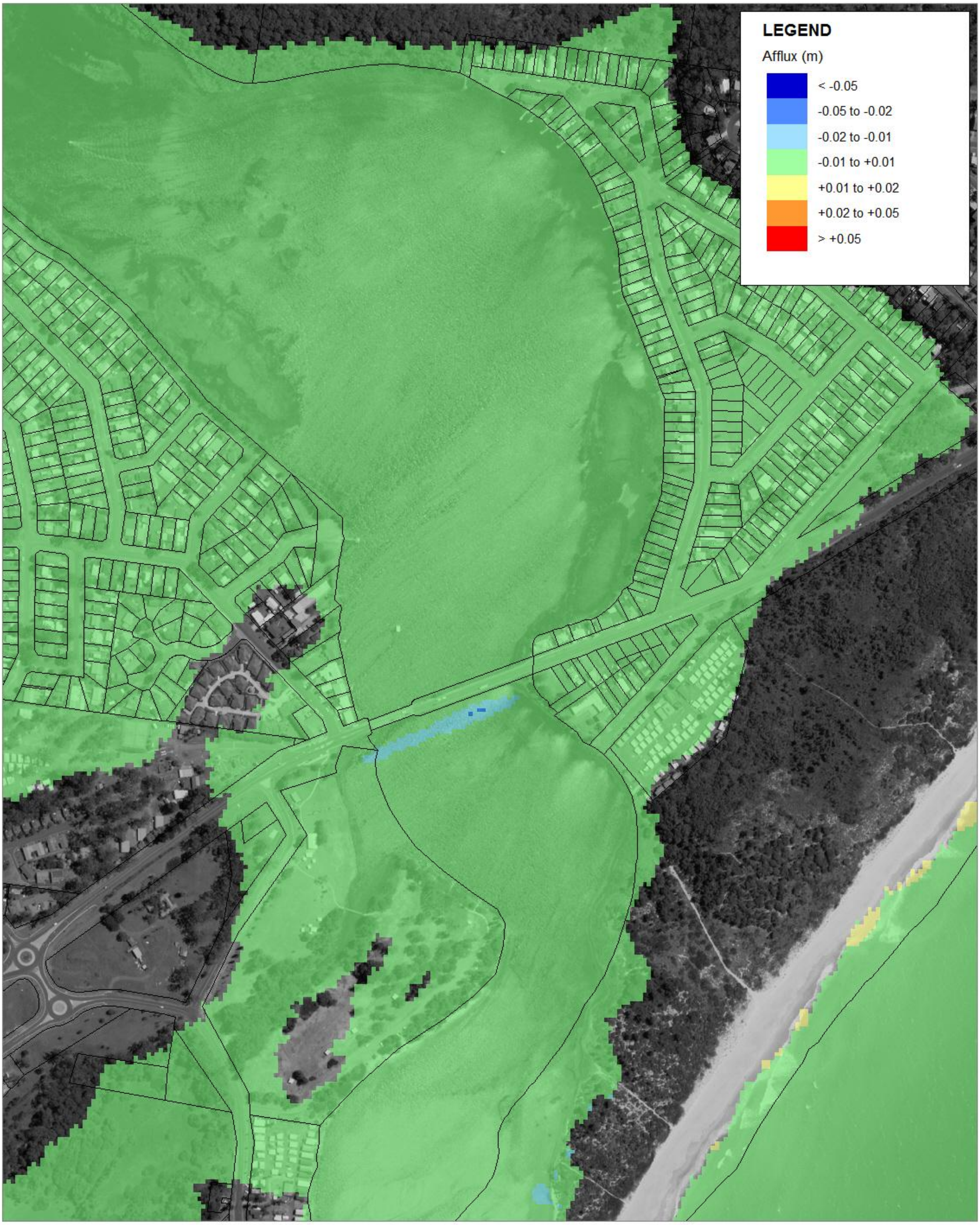
1. Working Platforms – represents a construction sequence with the working platforms in place with the existing bridge and causeway arrangement.
2. New Bridge and Existing Bridge/Causeway – represents an expected short term condition following completion of the new bridge construction, prior to removal of the existing bridge and causeway.
3. New Bridge – represents the finished project with new bridge and associated approaches and local roadwork's including removal of the existing bridge and causeway.

4.1 Design Flood Levels

The impact of the bridge upgrade on peak 1% AEP flood levels are shown in Figure 4-1 to Figure 4-3 for the construction sequences discussed above. The 1% AEP design flood event is typically used as the flood planning event for development control. All of the model configurations provide for limited change to the existing flood level conditions across the estuary as discussed below.

As shown in Figure 4-1, the development sequence with the working platforms in place has no significant impact on design peak flood levels. Despite including effectively a second embankment downstream of the existing causeway, peak 1% AEP flood levels effectively remain unchanged. This limited impact is due to the significant amount of overtopping of both the causeway and working platforms at flood levels of this magnitude. Accordingly, the embankments provide for little hydraulic control at this magnitude being heavily drowned out, and hence limited impact on peak flood level conditions. The peak 1% AEP flood level is of the order of 2.4m AHD, with the working platforms at 1.2m AHD.

The second model configuration providing for the completed bridge upgrade works with the existing causeway still in place also has a relatively minor impact on peak flood levels as shown in Figure 4-2. Across the broader estuary there is no significant change in peak flood level condition. There is small reduction in peak flood levels on the downstream side of the northern approach of the new bridge. This is a result of the raised approaches above existing conditions which provide for a local "shadow zone" behind the embankment at the edge of the floodplain. Under existing conditions this floodplain area is inundated at the 1% AEP level from flow across the existing causeway approach. With this effect is a corresponding minor increase (~1.5cm) in flood levels upstream of the proposed raised northern approach. This increase in flood level is limited in extent, however, does have some impact on existing property.



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Working Platforms + Existing Bridge/Causeway Impact on 1% AEP Flood Level

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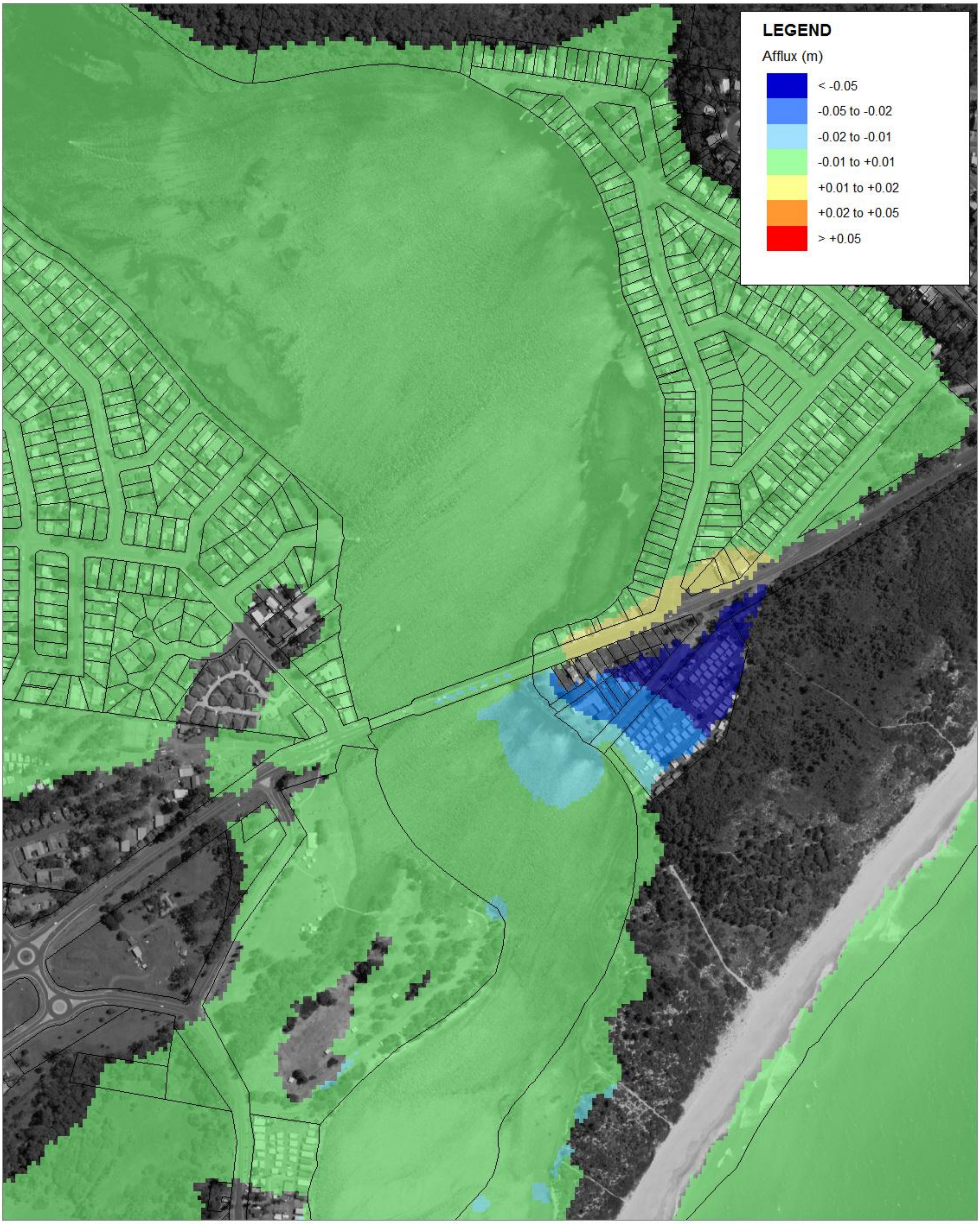

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New Bridge + Existing Bridge/Causeway Impact on 1% AEP Flood Level

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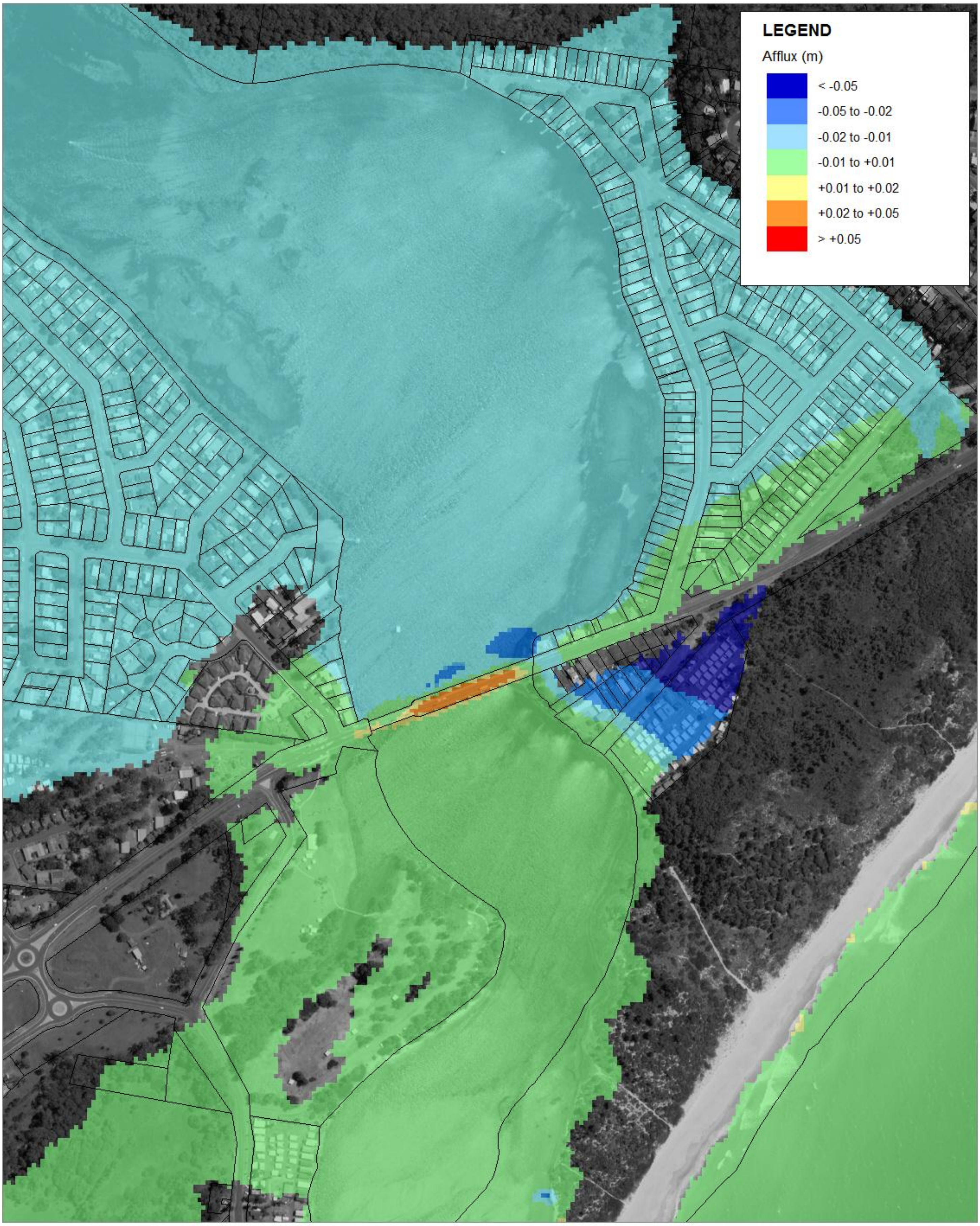

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New Bridge + Removal of Existing Bridge/Causeway Impact on 1% AEP Flood Level

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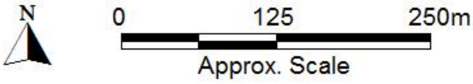

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The final bridge configuration with the existing causeway and bridge removed again has limited impact on the overall peak flood level condition as shown in Figure 4-3. There is a similar minor reduction in peak level downstream of the northern approach as discussed above in relation to the shadow zone provided by the proposed northern approach. However, it can be seen that the corresponding increase in flood levels on the upstream side are negated with the removal of the causeway.

The causeway removal is also shown to provide for a minor decrease (~1cm) in flood level across the broader Lake system upstream. This impact is due to the improved flow efficiency through the largely open new bridge in comparison to the existing condition where the causeway is overtopped.

A minor increase in flood level can also be seen along the alignment of the existing causeway within the waterway area. This reflects a minor change in the flow distribution associated with removal of the existing causeway.

The minor impact of the proposed bridge configuration on existing flow conditions can be appreciated further by consideration of the relative waterway area provided at the peak 1% AEP flood level. Figure 4-4 shows the representative cross section of Burrill Lake across the alignment of the Princes Highway, along with the profile of the existing causeway and proposed bridge. The fill area of the existing causeway embankments and proposed bridge approaches are shown. Provided for reference is the estimated 1% AEP flood level (~2.4m AHD).

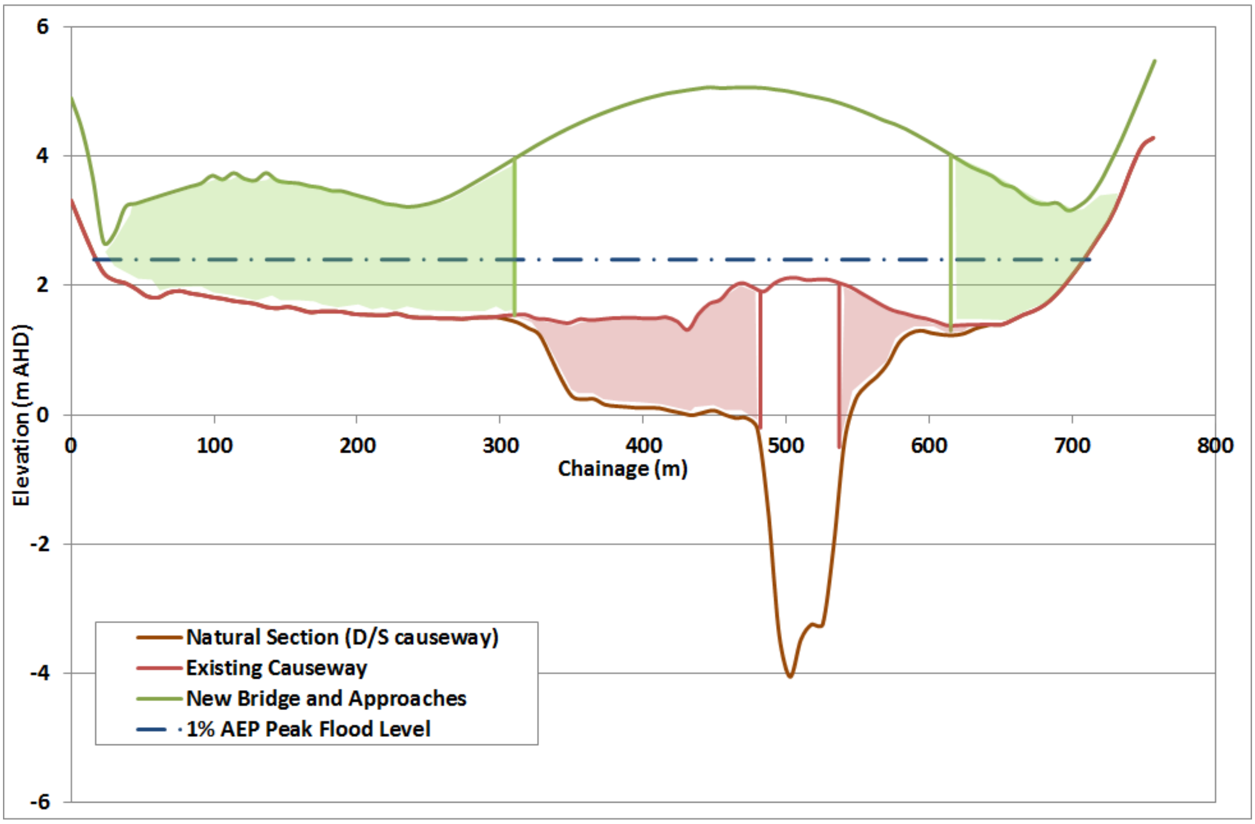


Figure 4-4 Comparison of Waterway Area

The total waterway area below the 1% AEP flood level is approximately the same for existing case and the design condition (assuming causeway removal). The waterway area encroachment of the existing causeway is approximately equal to that of the new approach embankments. Accordingly, the loss in waterway area as a result of the raised approaches of the proposed bridge is offset by the removal of the causeway.

It is also noted that velocities in the overbank areas are significantly lower than the waterway. Accordingly, the waterway areas blocked out by the raised bridge approaches in the proposed design are lower convective flow areas. Conversely, the existing embankment provides for a major reduction in flow area within the main waterway. The large span of the proposed bridge across the majority of the waterway provides for a more efficient flow in comparison to the existing causeway and bridge arrangement.

For lower flood levels, the proposed approach embankment encroachment would also be less than the existing causeway providing a greater and more efficient waterway area also.

As shown in Figure 4-1 and Figure 4-3, the proposed bridge construction would provide for some change to existing flood conditions through redistribution of flow, however, the magnitude and extents of the changes are somewhat limited. The relatively minor change to existing 1% AEP peak flood level conditions and minimal adverse impacts can be attributed to:

- Proposed designs providing for similar waterway area to existing conditions at the major flood levels;
- Improvement in flood conveyance and flow efficiency within the main waterway area; and
- The hydraulic control associated with the natural flow constriction downstream of the existing causeway which limits the influence of changes to the existing bridge configurations.

4.2 Flow Velocity

The impact of the proposed bridge upgrade on peak 20% AEP velocity distribution are shown in Figure 4-5 to Figure 4-7 for the various construction sequences . A design flood event of the order of a 20% AEP event has been simulated to demonstrate the impacts as it represents a flood with peak level nearer to the causeway level such that extensive overtopping of the causeway is limited. Accordingly, the existing flow is concentrated through the bridge such that the impacts of changes in the waterway configuration are potentially greater.

As shown in Figure 4-5, the working platforms have a localised impact on peak 20%AEP flood velocity distribution. The main impact is a general increase in velocity across the working platforms themselves, in comparison to the existing conditions along the platform alignments. Further downstream of the working platforms, the velocities are slightly higher within the main deep channel with a corresponding small reduction in peak velocities in the adjacent waterway area. This minor impact is a result of the working platforms confining the main flow to within the narrow channel further downstream of the existing bridge opening, and accordingly the redistribution of flow across the broader waterway area occurs further downstream than under existing conditions. There are small local variations in peak velocity as a result of the changes to the waterway configuration, however these changes only represent a small change from existing conditions. Any changes are very localised, with the broader flow distribution in the estuary unaffected.

As expected, the scenario with the new bridge constructed and the existing bridge and causeway still in place, has little impact on the velocity distribution as shown Figure 4-6. Given the effective clear span of the proposed new bridge, with waterway encroachment limited to minor losses associated with the piers, the new bridge provides no significant change to the existing velocity distributed which is a function of the existing bridge and causeway arrangement.

The change in peak 20%AEP velocity distribution for the proposed bridge, including removal of the existing bridge and causeway, is shown in Figure 4-7. This configuration provides for the most significant change in the flow distribution through removal of the flow constriction provided by the existing bridge and causeway. With the full width of the channel being bridged, the flow distribution is more even across the channel. Accordingly, Figure 4-7 shows a significant reduction in peak flow velocity in the vicinity of the existing bridge opening on the right bank, and a corresponding increase in velocity along the left bank across the alignment of the existing causeway.

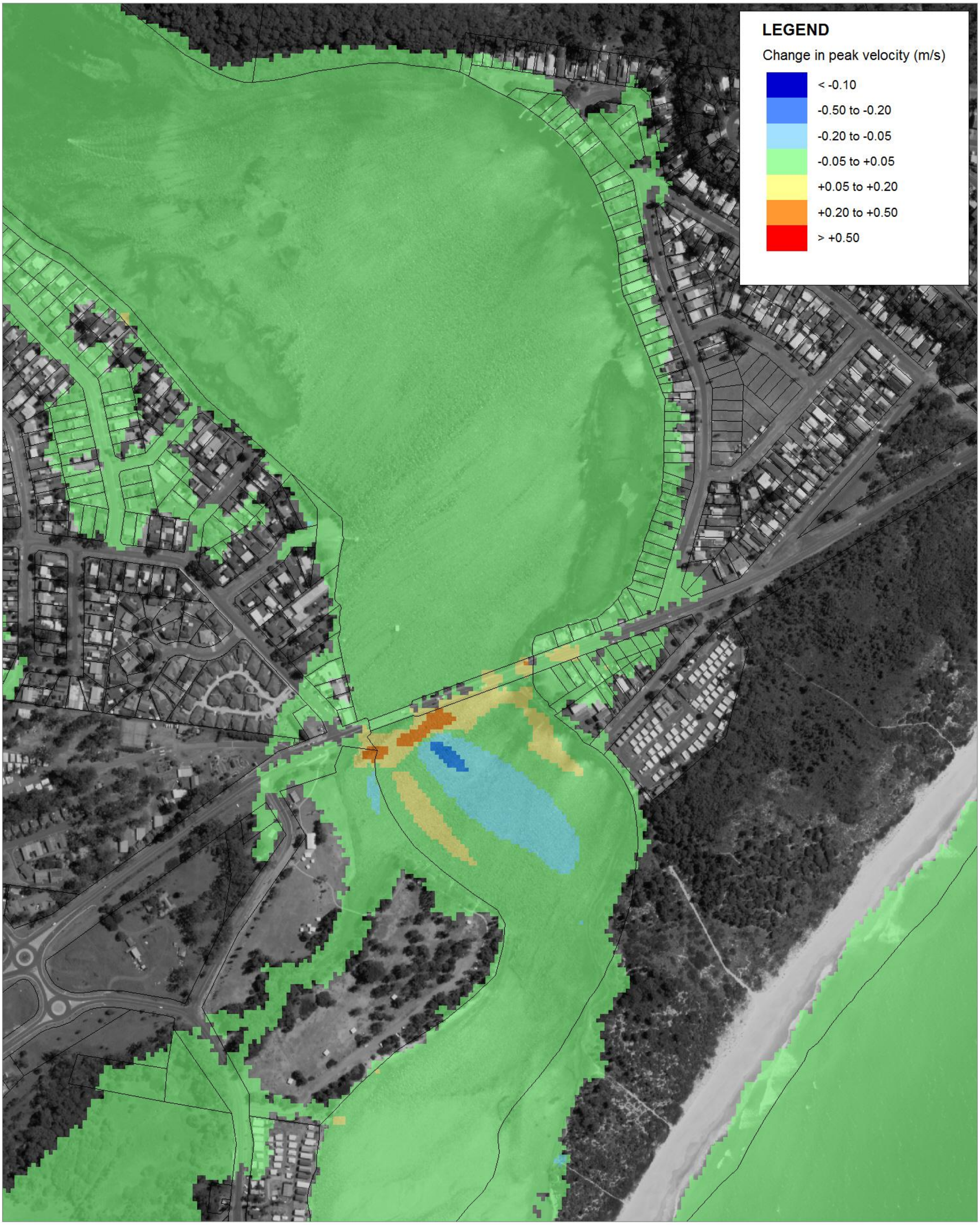
The maximum increase in 20% AEP flood velocity is of the order of 0.4 – 0.5m/s, however, this is a localised impact near the existing causeway. This impact represents the change from largely a backwater condition (on the lee side of the Causeway) to a convective flow area through the open bridge section as proposed. Typically, the change in peak velocity is less than 0.4m/s over the main area of influence. The zone of influence in terms of the changed velocity distribution remains limited to within 100 metres or so of the bridge.

4.3 Road Flood Immunity

The existing Burrill Bridge and Causeway has flood immunity of the order of a 20% AEP flood magnitude. This flood immunity would be expected to decrease gradually with climate change influences such as progressive sea level rise.

As well as being a significant regional route, the Princes Highway represents in important route for emergency response in times of major flooding. Locally within Burrill Lake, in excess of 300 properties have been identified as subject to potential inundation at the 1% AEP flood level representing a substantial flood risk. This flood risk is exacerbated given the lack of suitable of flood free access providing for evacuation routes and access for emergency services. Local roads, including the principal Princes Highway at Burrill Lake, are inundated at relatively low levels (much lower than the 1% AEP flood level) with access likely to be cut well before the peak of the flood event.

The provision of suitable flood emergency access routes, including raising of the Princes Highway, is a key recommendation of the Burrill Lake Floodplain Risk Management Study and Plan (BMT WBM, 2013). The proposed bridge design provides for a higher design flood immunity standard above the 1% AEP level, consistent with this recommendation.



Title:

Working Platforms + Existing Bridge/Causeway Impact on 20% AEP Flow Velocity

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4-5

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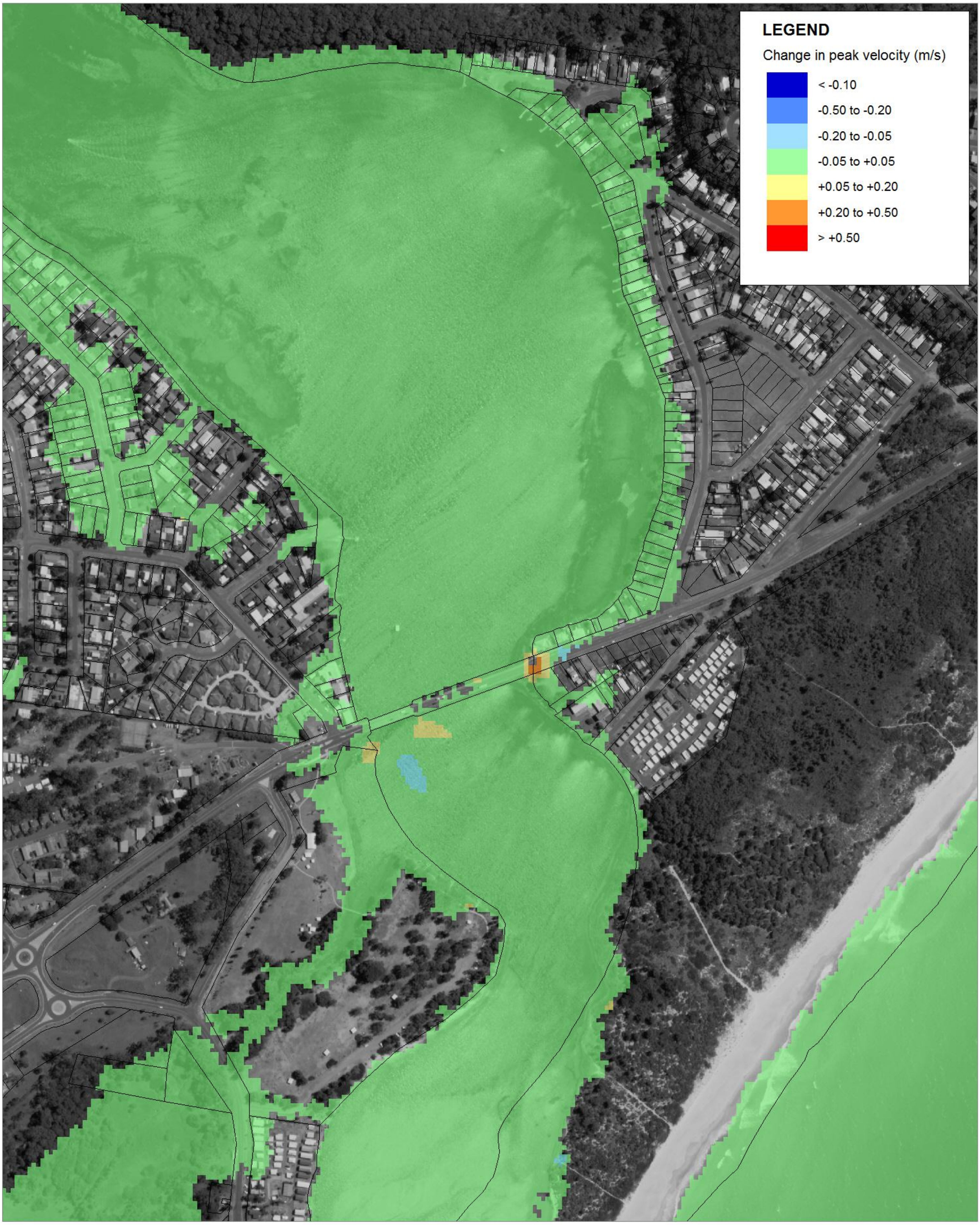

Title:

New Bridge + Existing Bridge/Causeway Impact on 20% AEP Flow Velocity

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Approx. Scale

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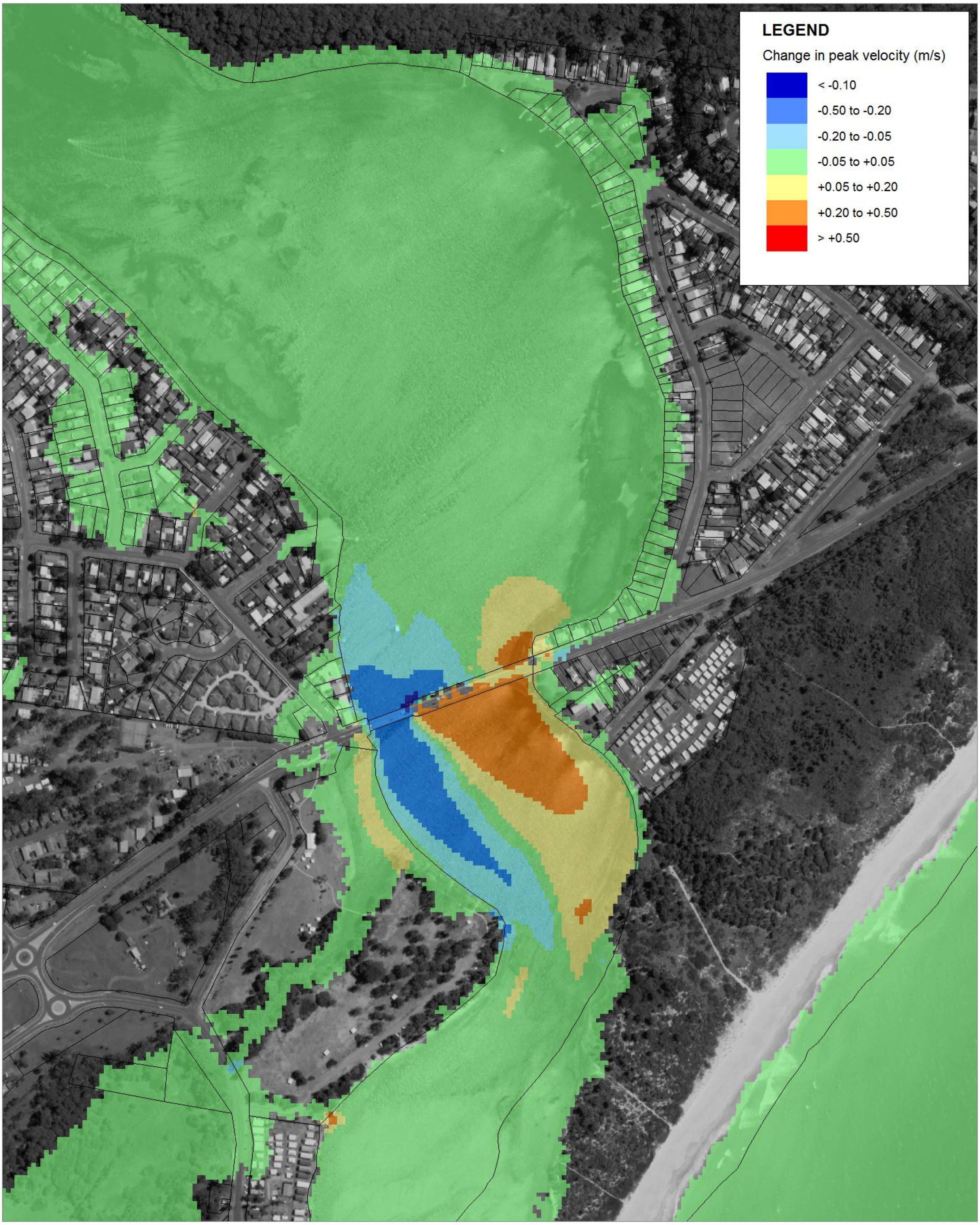

Title:

New Bridge + Removal of Existing Bridge/Causeway Impact on 20% AEP Flow Velocity

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4.4 Tidal Flows

A representative spring tide condition as discussed in Section 3.3 has been simulated to investigate the impact of the proposed upgrade option on tidal flows. Figure 4-8 shows the simulated total flow across the bridge/causeway section for existing conditions and the proposed bridge upgrade.

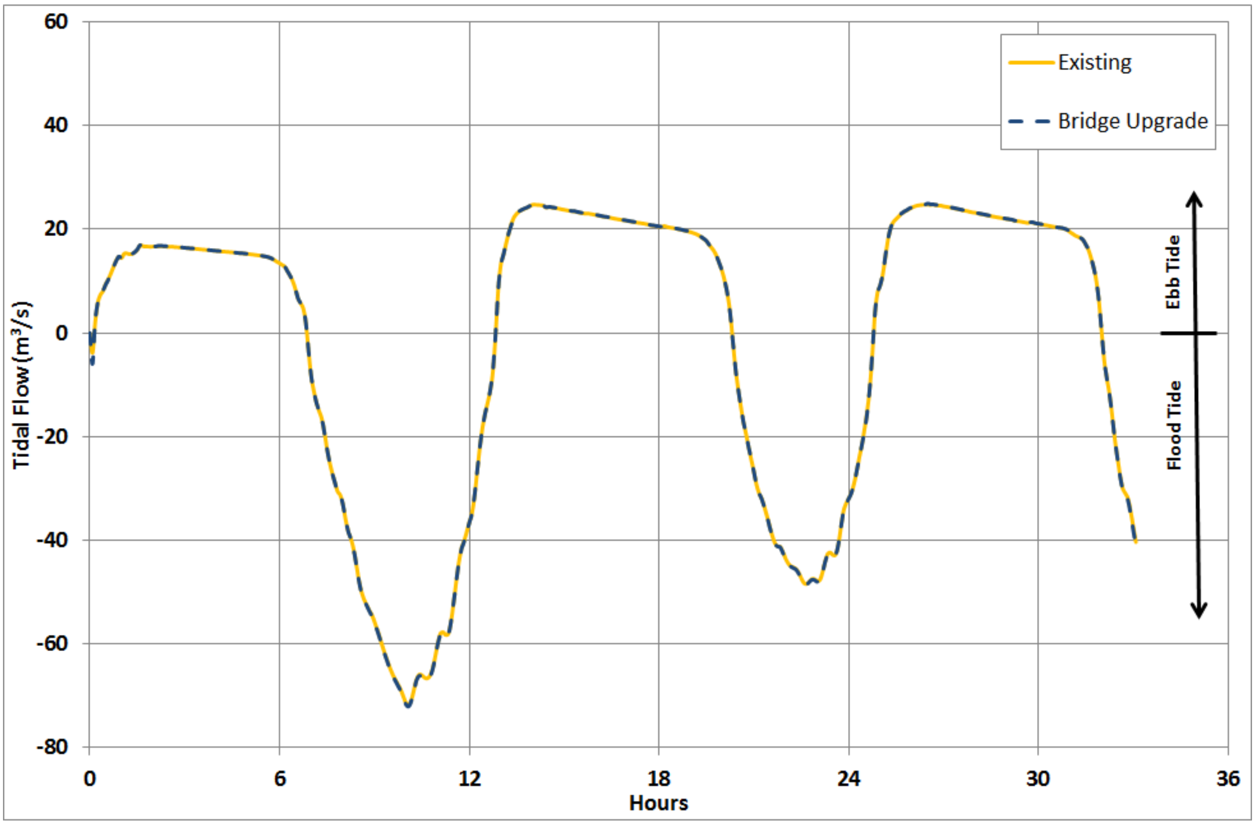


Figure 4-8 Comparison of Simulated Tidal Flow

The result indicates that the bridge upgrade has no significant impact on the existing tidal flow exchange in Burrill Lake. The relative impact on the flows of changes to the bridge/causeway configuration is largely insignificant in relation to the overall frictional losses along the length of the entrance channel and the resulting attenuation of the flow. Even with complete removal of the existing causeway and a largely unimpeded flow area through the new bridge, there is no insignificant impact on the broader tidal regime of the Lake system.

The limited impact of the Causeway on tidal regimes as demonstrated by the modelling undertaken in this study is consistent with the findings of previous studies including PWD (1992) and BMT WBM (2001). Each of these studies has provided for independent assessment of the Burrill Lake system including the application of different modelling software and approaches.

Whilst having minimal impact on the overall tidal exchange between the ocean and Burrill Lake, the proposed new bridge configuration does have some localised impact on tidal velocity distributions as shown in Figure 4-9.

The removal of the causeway would provide for a change in the flow distribution increasing the flow conveyed through the eastern side of the inlet, currently in the lee of the causeway, and a corresponding reduction in flow in the vicinity of the existing bridge opening and main channel alignment. Increases in peak flood tide velocities of the order of 0.2m/s may be anticipated in the vicinity of the existing causeway, but typically increases over a wider region would be less than 0.1m/s. Similar orders in a reduction of velocity are simulated in the vicinity of the existing bridge opening. Whilst changing the local velocity distribution in the immediate vicinity of the causeway, it is noted that the extent of the impacts are somewhat limited to within a distance of a 100m or so from the existing road alignment. Beyond this vicinity, the proposed upgrade provides for no discernible change in existing flow distribution and thus has limited impact on the tidal regimes within the broader estuary.

4.5 Geomorphological Impacts

A concern in regard to changes in hydraulic regimes associated with the upgrade option is the potential for long term change in the erosion and sedimentation processes within the entrance channel. The proposed upgrade providing for removal of the causeway represents a significant change from existing conditions in terms of both flood and tidal flow distributions. The modelling has indicated that the impacts are however confined to the near vicinity of the causeway. The principal hydraulic impacts of the causeway removal are the:

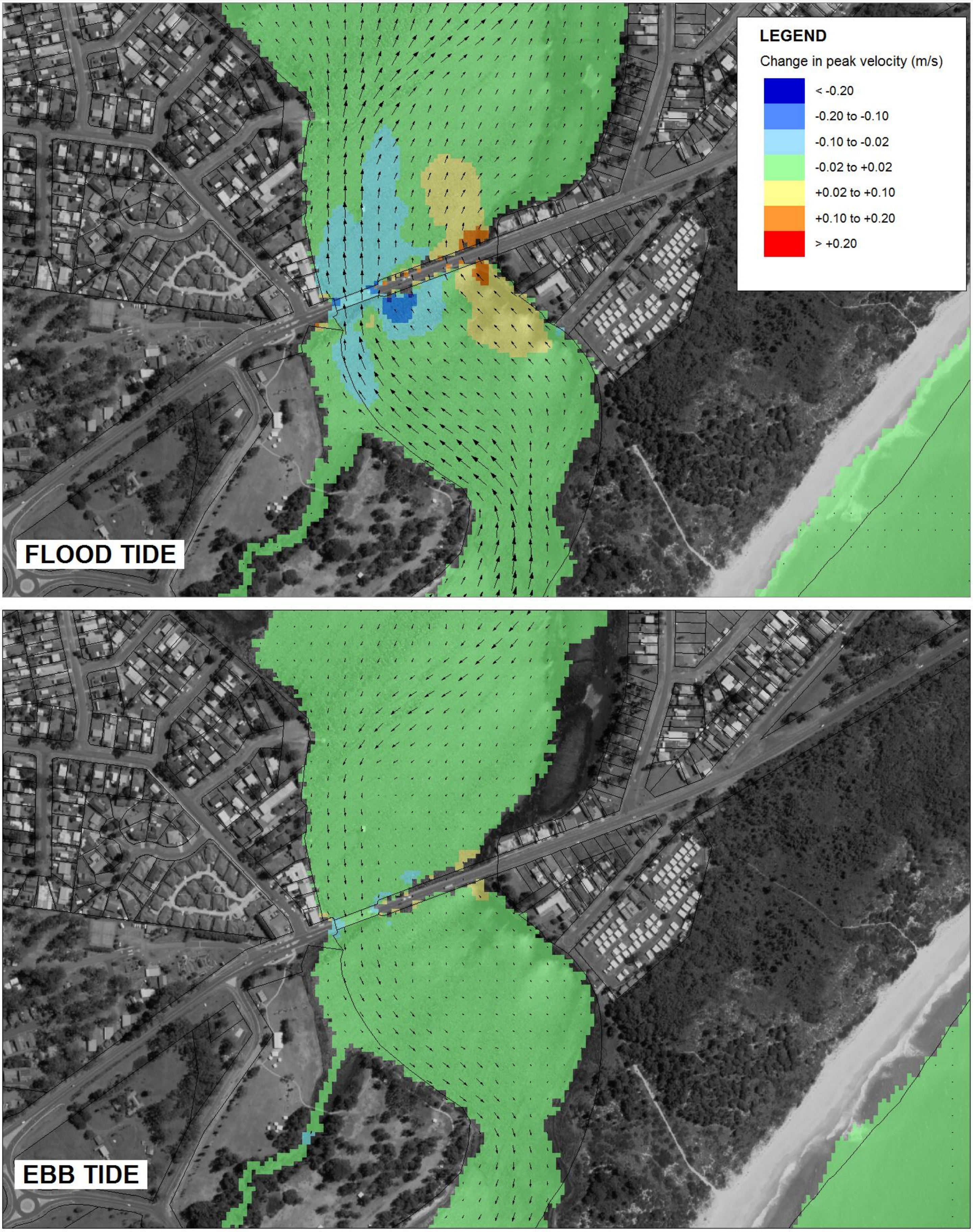
- Decrease in flow through the existing bridge opening and main channel alignment; and
- Increased current speeds on the eastern side of the channel upstream and downstream of the causeway.

The potential for long-term geomorphological change in the entrance channel as a result of the causeway removal is predominantly related to:

- A decrease or increase in the flow and sand transport within the main channel (being the principal area of sediment flux);
- Any changes to the overall tidal regime that may increase or inhibit the net flow of sand through the entrance; and
- Whether or not the flow over the shoals introduced by the causeway removal is sufficient to mobilise sediments in these areas.

The Burrill Inlet Causeway Options Study (WBM Oceanics, 2001) investigated in detail the hydrodynamic, sedimentation and ecological processes of the Burrill Inlet incorporating modelling of various causeway upgrade options. The current study provides for similar impacts in terms of the hydrodynamics for the causeway removal and reinforces the findings in regards to potential changes in erosion and sedimentation regimes as summarised below:

- the causeway removal would have limited influence on broader shoaling patterns within the entrance channel with limited movement of marine sand beyond the immediate vicinity of the entrance;
- the changes in main channel velocities and hence sediment transport potential are relatively minor, particularly given the variability and range of existing velocities experienced under typical tidal and flooding regimes;



Title:

New Bridge + Removal of Existing Bridge/Causeway Impact on Peak Flood and Ebb Tide Flow Velocity

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Approx. Scale

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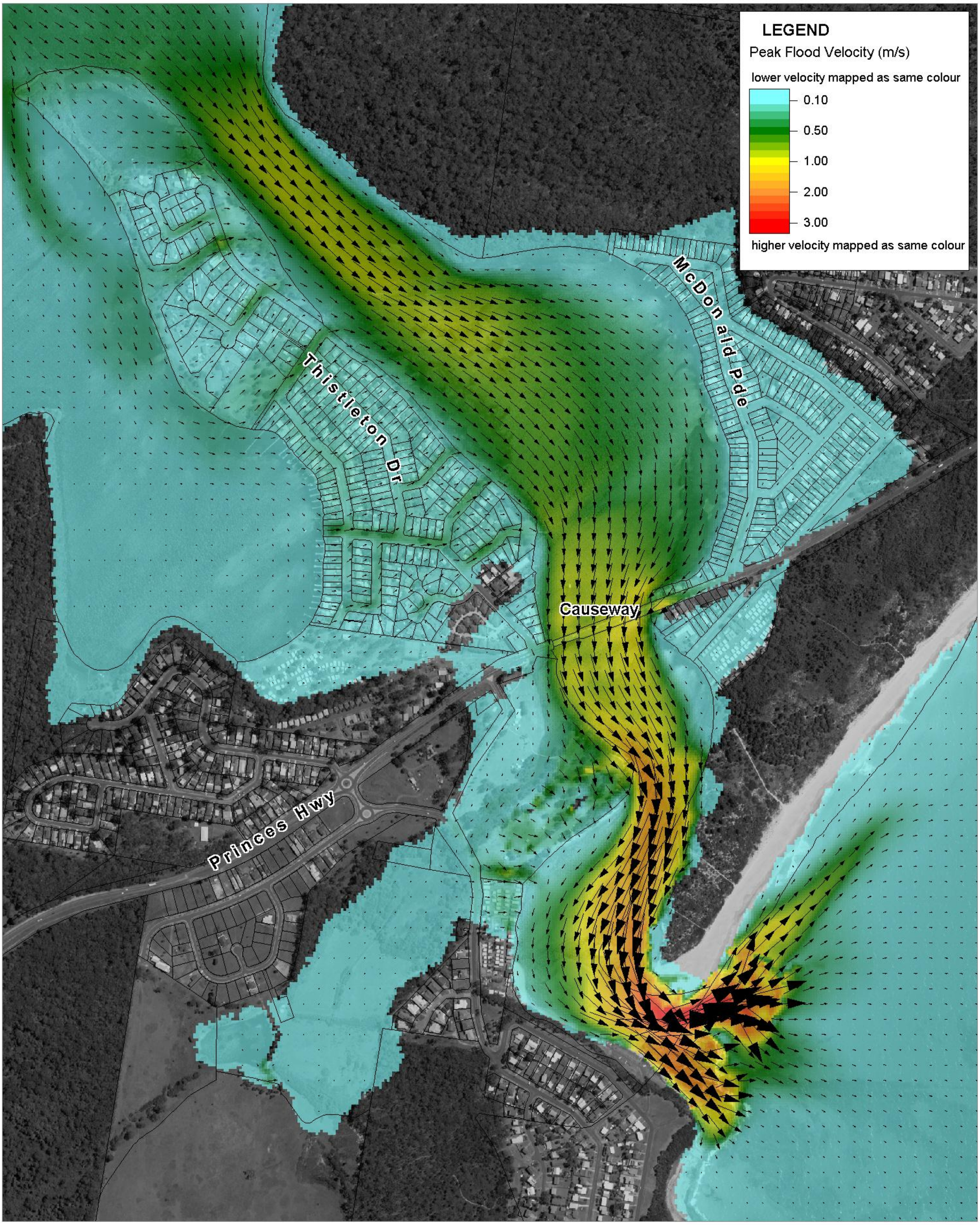
- the causeway removal has been demonstrated have no impact on the net tidal exchange between the ocean and the Lake which is predominantly controlled by than entrance conditions rather than the Causeway;
- the reduced velocities in the lee of the existing causeway would tend to increase the rate of accumulation of fine sediments in the shoals immediately upstream and downstream of the causeway (perhaps indicated by reed and sedge growth in these zones). Removal of the causeway providing for increases in velocity over these shoals may provide potential for scour some of this finer siltation as the channel adjusts to a new equilibrium. This affect would be local to the causeway alignment and not affect broader areas along the inlet foreshore.

4.6 Limit State Design

Design flood conditions for the 0.05% AEP (1in 2000yr ARI) have been simulated to provide further information in regard limit state design conditions for the bridge design. Peak flood levels at the bridge crossing are approximately 2.7m AHD for this design flood condition with peak velocities of the order of 1m/s. The peak flood velocity distribution for the 0.05% AEP event is shown in Figure 4-10.



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New Bridge Maximum 0.05% AEP Flood Velocities

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5 SUMMARY

Hydrodynamic modelling has been undertaken to determine the relative impact of the proposed upgrade of the Burrill Bridge and Causeway on the hydrodynamic and sediment transport regimes under tidal and flooding conditions. The principal findings of the study are summarised below.

- The proposed option provides for removal of the existing bridge and causeway and replacement with a full bridging of the entrance channel at a higher elevation. The option effectively provides for no obstruction to flows across the full width of the inlet.
- The impact of the proposed option of flood conditions is limited. Minor changes in peak flood level conditions may be realised through changes in the flow distribution. The removal of the existing causeway would limit potential increases in peak flood levels on existing properties.
- There is a significant change in the velocity distribution in the vicinity of the causeway as a result of the removal of the causeway flow obstruction. Increases in flow and velocity over the shoals adjacent to the existing Causeway may mobilise sediments in these areas. The impacts of the changed flow distribution are limited to the local vicinity of the causeway.
- There is no discernible change on tidal flow exchange between the ocean and the Lake and accordingly unlikely to impact on the broader distribution of shoals within the entrance channel.
- As with the flooding regimes, the proposed upgrade provides for changes in the tidal velocity distribution by reducing velocities in the existing main channel and increasing velocities through the area currently in the lee of the existing causeway.). Increases in velocity over the shoals near the causeway may provide potential scour of this finer siltation as the channel adjusts to a new equilibrium. This affect would be local to the causeway alignment and not affect broader areas along the inlet foreshore.
- The proposed upgrade provides for improved road flood immunity. Significantly, the proposal provides for flood immunity above the 1% AEP flood level (incorporating also potential increases associated with climate change) and would appropriately address recommendations in the Burrill Lake FRMS.

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