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Hexham Train Support Facility Flood Impact Assessment

Final Report

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Hexham Train Support Facility
Flood Impact Assessment
Final Report

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Title :	Hexham Train Support Facility Flood Impact Assessment
Author :	Daniel Williams
Synopsis :	Report for the Hexham Train Support Facility detailing the existing flood conditions of the proposed development and the assessment of potential cumulative flood impacts with other planned developments in the vicinity of the site. Flood mitigation is also considered to reduce the magnitude of flood impacts.

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1 INTRODUCTION

1.1 Purpose of this Report

This report has been commissioned by ADW Johnson on behalf of QR National for the purposes of identifying potential impacts of the proposed Hexham Train Support Facility, in conjunction with other planned developments in the vicinity of the site. The current report builds on a previous Flood Impact Assessment for the proposed development (WorleyParsons, 2011). The flood impact assessment of this report considers the cumulative impacts of the QR National Train Support Facility, ARTC Hexham Relief Roads and the access road alignment from the Tarro interchange (referred to as the 'proposed works'). The cumulative impacts of the proposed works and the RMS Pacific Highway upgrade from the F3 to Heatherbrae are also assessed.

The assessment includes a detailed flood impact investigation using an existing TUFLOW flood model to define existing flood conditions and quantify flooding impacts related to the proposed developments. The existing flood model was initially developed for the Williams River Flood Study, completed by BMT WBM in 2009 on behalf of Port Stephens Council (Council) and was further developed as part of the Williamtown / Salt Ash Flood Study Review (BMT WBM, 2011). Council has kindly given permission to use the existing model in the current flood impact assessment.

The flood impact assessment presented in this document details the nature of the proposed development and the analysis undertaken to quantify potential flood impact.

1.2 Site Location

The proposed site of the Train Support Facility is located within the Lower Hunter Valley, near Hexham and is presented in Figure 1-1.

1.3 Computer Modelling Tool

A detailed two dimensional computer model of the Lower Hunter floodplain was developed by BMT WBM as part of the Williams River Flood Study (BMT WBM, 2009), on behalf of Port Stephens Council and Dungog Shire Council. The model used a regular 40 by 40 m grid, covering an area of some 120 square kilometres.

There is considerable interaction between flooding in the lower parts of the Williams River and the Hunter River, requiring a model linking the two floodplains. The Hunter River model was developed as part of a project for the Roads and Traffic Authority (RTA) investigating a new Pacific Highway crossing of the Hunter River.

The hydraulic model was calibrated to the February 1990, March 1978 and May 2001 flood events. In terms of the Lower Hunter reach relevant to the subject proposed development site, the February 1990 flood event was the principal event used to calibrate the lower section of the Williams River model and the lower Hunter River model, being the largest Hunter River flows (coincident with a Williams River flood).

Title:

Study Locality

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The hydraulic model was further developed for the Williamtown / Salt Ash Flood Study Review (BMT WBM, 2011) which extended the modelled floodplain from Fullerton Cove through to Port Stephens. The interaction of the Hunter River with the Williamtown / Salt Ash floodplain is important for assessing large magnitude flood events in the Lower Hunter, particularly when considering potential climate change impacts. The combined design flood flows from the Hunter River and Williams River match the flood frequency analysis at Raymond Terrace from the Lower Hunter River Flood Study (PWD, 1994)

The same computer model that was developed for these studies has been used for the investigations described in this report.

2 EXISTING FLOOD BEHAVIOUR

2.1 Flooding Mechanisms

The Hunter River catchment covers an area of the order of 22,000km^2 which flows into the Tasman Sea through the Port of Newcastle. The lower reaches of the Hunter system are tidal and forms the Hunter River estuary. Three major rivers discharge into the estuary, namely the Hunter River, the Paterson River and the Williams River. The confluence of the Williams River and Hunter River is at Raymond Terrace approximately 30 km upstream of the estuary mouth (i.e. Newcastle Harbour). The Paterson River joins the Hunter River between Morpeth and Hinton some 15 km upstream of Raymond Terrace. The estuary extends a further 20 km along the Hunter River to the tidal limit at Oakhampton, near Maitland.

The proposed development site is located on the reach of the Hunter River that lies in the vicinity of Hexham Bridge (approximately 20km upstream of the mouth). Immediately upstream of Hexham Bridge, the Hunter River changes from a general south-westerly flow direction to a south-easterly flow direction. Downstream of Hexham Bridge the Hunter River main channel splits into two arms, the North Arm and the South Arm, separated by Kooragang Island. To the south-west of this location is Hexham Swamp, a large wetland area that would have been frequently inundated by the Hunter River prior to modern infrastructure development. The topography of the Hunter River floodplain in the region of the proposed development is shown in Figure 2-1.

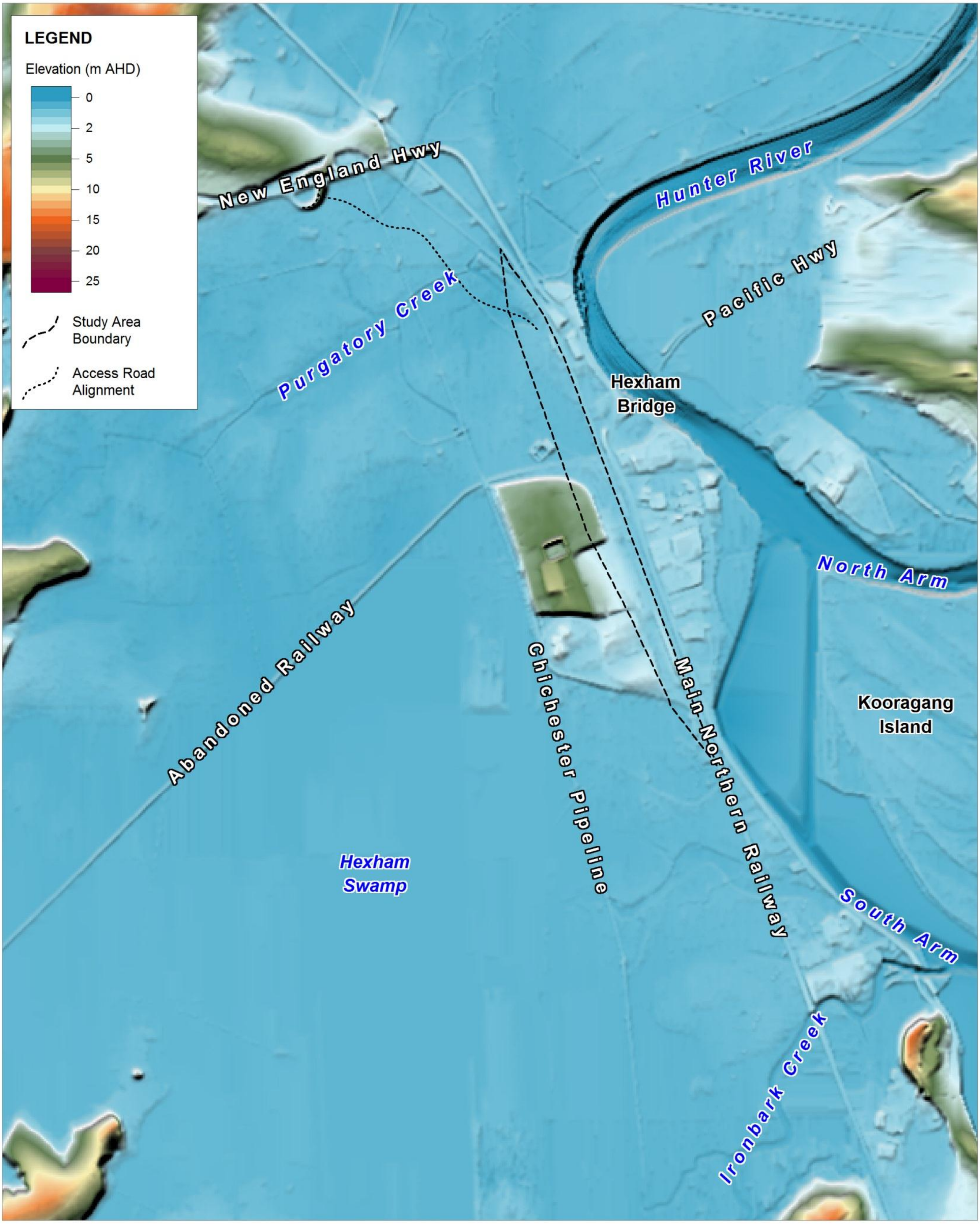
The Hunter River has experienced many floods during its recorded history. The largest flood on record was in 1955. After this event, which claimed 14 lives, the Hunter Valley Flood mitigation Scheme was established, which has subsequently instigated some 160km of levees, 3.8km of spillways, 40km of control banks, 245 floodgates and 120km of drainage canals.

Within the Lower Hunter Estuary, the 1955 flood caused extensive overbank inundation, with flood depths of up to three metres across the Kooragang Island wetlands. This flood has been estimated at approximately a 1 in 100yr event (PWD, 1994).

When the floodwaters reach Hexham Bridge overtopping of the New England Highway will occur, filling the available flood storage of Hexham Swamp. Flood flows will then return to the Hunter River South Arm in the vicinity of Ironbark Creek, the principal natural drainage channel of the swamp. The progression of flood flows through Hexham Swamp is controlled by a number of topographical features, including an abandoned railway and the Chichester Pipeline.

There is a set of eight flood gates located on Ironbark Creek, near the confluence with the Hunter River South Arm. These gates control flows in and out of Hexham Swamp through Ironbark Creek for lower order flood events, but are overtopped for events above the 5% AEP. The model configuration is representative of the current operation, where three of the gates have been raised open to enable flow into the swamp, while all eight gates are flapped to enable flow out of the swamp.

Ocean water levels, influenced by storm surge and the tide, have an effect on flood levels within the lower estuary, up to Green Rocks (approx. 8km upstream of the Williams River / Hunter River confluence).



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Local Floodplain Topography

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In higher frequency low discharge floods, the flow is contained within the rivers banks and levees. As flood magnitude increases, floodwaters overtop the natural and man-made levees and flow across the floodplain.

The proposed development site itself is situated within the broader floodplain area of Hexham Swamp. This floodplain receives flow spilling over the New England Highway and in major flood events will be subject to significant inundation. Major catchment flooding of the Hunter River system is accordingly the dominant flooding mechanism.

2.2 Hunter River Flood Hydrology

The hydrological inputs to the TUFLOW model are based on those that were adopted for the Williams River Flood Study. A critical storm duration of 48 hours was used to derive design inflows for the Williams River. For the PMF event a 36-hour Generalised Tropical Storm Method (GTSM) storm was used. The design inflow to the Hunter River was based on the recorded hydrograph from the 1955 historical flood event, which is the most significant Hunter River flood of modern times and was of the order of a 1% AEP design event. The inflow hydrographs were derived by scaling the 1955 flood hydrograph shape to match the estimated peak design flows for each event, based on a flood frequency analysis of peak water levels at Raymond Terrace. This approach is consistent with the Lower Hunter River Flood Study (PWD, 1994). The Hunter River inflow hydrograph for the PMF event is approximately four times the peak flow of the 1% AEP event and almost seven times the volume.

Being a large catchment of some 22,000km^2, the Hunter River at Hexham will typically have a significant warning time of any floods that are moving down the catchment. Depending on the specific rainfall distributions in a given event, it is likely that significant flooding of Hexham Swamp will typically not occur until a couple of days after a major rainfall event. Flood warnings issued by the Bureau of Meteorology (BoM) and the State Emergency Service (SES) are given 24 hours in advance for Singleton and Maitland. This provides sufficient warning a day in advance of when Hexham Swamp is likely to be inundated by Hunter River flood waters. However, once the flood level in the Hunter River rises above the New England Highway at Hexham, the Swamp can fill to a level of over 2m AHD within a few hours, inundating the study site.

The periods of inundation are dependent on the design hydrographs adopted. As discussed, the design hydrographs for the Hunter River are based on a scaling of the recorded 1955 flood hydrograph shape to estimated design peak flow magnitudes. Event hydrograph shapes would vary considerably dependent on the spatial and temporal distribution of rainfall across the extensive catchment area. However, the 1955 hydrograph shape as a representative condition for a major flood event in the catchment provides a useful indication of potential inundation periods for the study site.

For events up to the 2% AEP, inundation of the existing rail lines will not occur, or at worst be very localised. However, for flood events of a larger magnitude the existing rail infrastructure at the study site will become inundated. At a 1% AEP magnitude event the site may be inundated for a period of three to four days. At a PMF event magnitude the site is likely to be inundated for a full week.

2.3 Design Flood Conditions

The existing Williams River/Hunter River 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 2-1 summarises the simulated peak flood levels at the proposed development site for a range of design event magnitudes. There is a general flood water level gradient from north to south across the site, such that the peak water levels presented in Table 2-1 represent the maximums at the northern (ch.3000) and southern (ch.500) site locations.

Table 2-1 Design Flood Levels for Proposed Development Site (m AHD)

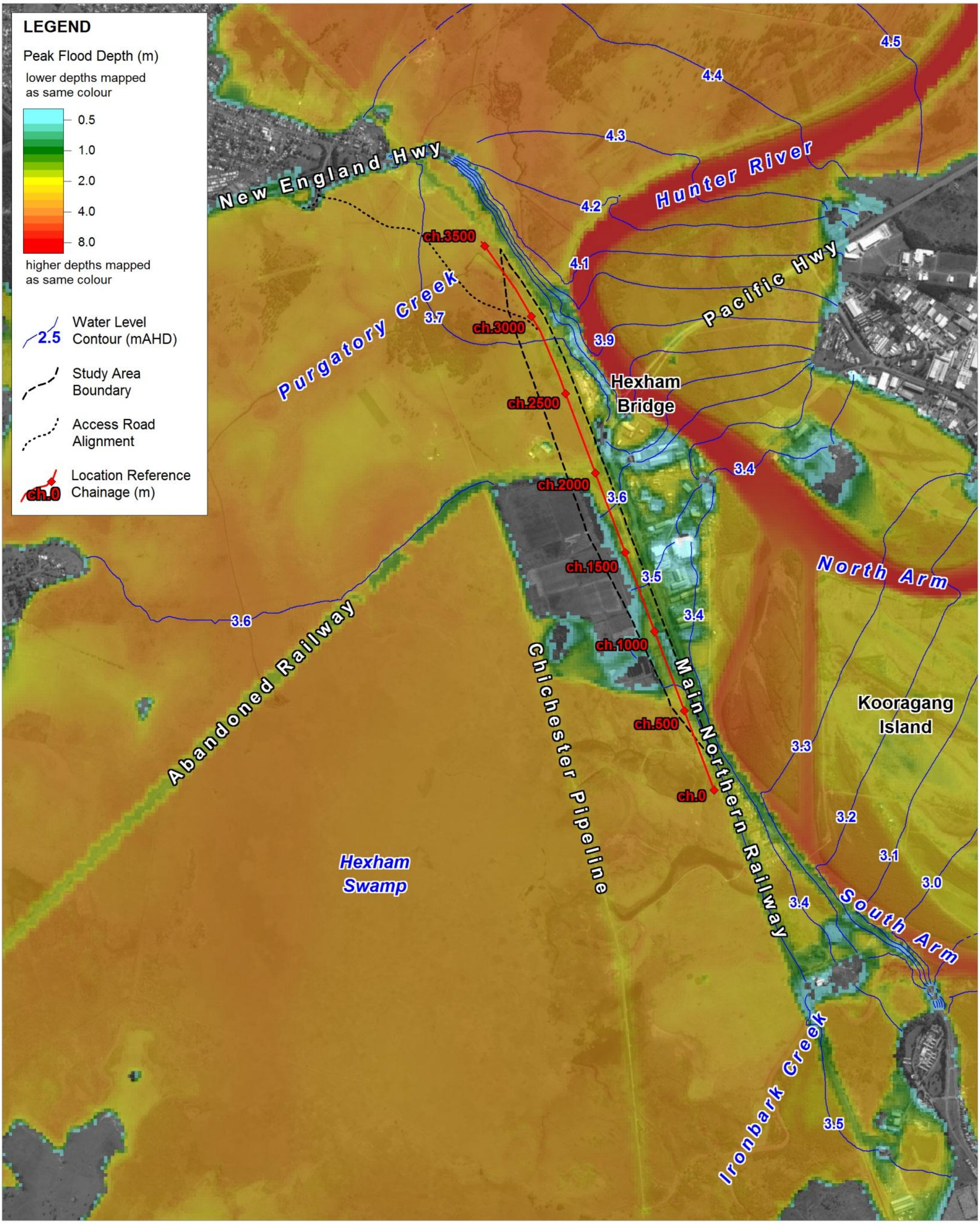
Design Flood Magnitude	Northern End of Site	Southern End of Site
10% AEP	1.0	0.8
5% AEP	1.2	1.0
2% AEP	2.2	2.1
1% AEP	3.7	3.5
PMF	8.3	7.7

The nature of flooding across the proposed development site is similar for a range of design event magnitudes. This principally originates from floodwaters spilling over the New England Highway from the Hunter River into Hexham Swamp. At the 20% AEP (Annual Exceedance Probability) event the Hunter River remains principally in-bank and has therefore not been modelled. At the 10% AEP, 5% AEP and 2% AEP event magnitudes, flood waters spill over the New England Highway into Hexham Swamp. Hexham Swamp is also filled from the southern end by flow from the Hunter River South Arm through Ironbark Creek.

The general flood extent and behaviour is similar for each event, albeit with the severity of flood depths and velocities increasing with event magnitude. At the 1% AEP event the Hexham Swamp floodplain becomes fully connected, with flood waters entering over the New England Highway and flowing back to the Hunter River between Hexham Bridge and Ironbark Creek.

The 5% AEP event is only just over the required level for overtopping the New England Highway, with less than 4% of the Hunter River flows spilling into Hexham Swamp at the peak of the flood. Small increases in peak flow and corresponding flood levels upstream of Hexham Bridge result in a significant increase in peak flood levels within Hexham Swamp. This is evidenced by the large increases in flood levels for the 2% AEP and 1% AEP events in Table 2-1, where around 13% and 34% of the peak flood flow is spilling into Hexham Swamp respectively. For events at and above the 1% AEP, the floodplain is fully connected and the sensitivity of flood waters spilling over the New England Highway and into Hexham Swamp is reduced.

The 1% AEP design flood event is typically used as the flood planning event for development control. The design flood conditions for the 1% AEP event representing peak flood level and depth, peak flood velocity and peak flow-rate per unit area, or unit flow (q), are presented in Figure 2-2 to Figure 2-4. Additional design flood mapping for the 10% AEP, 5% AEP, 2% AEP and PMF events is included in Appendix A. A chainage reference for the proposed works is included in the results presentation and is referred to in the discussion of the results.



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1% AEP Peak Flood Depths and Levels - Existing Conditions

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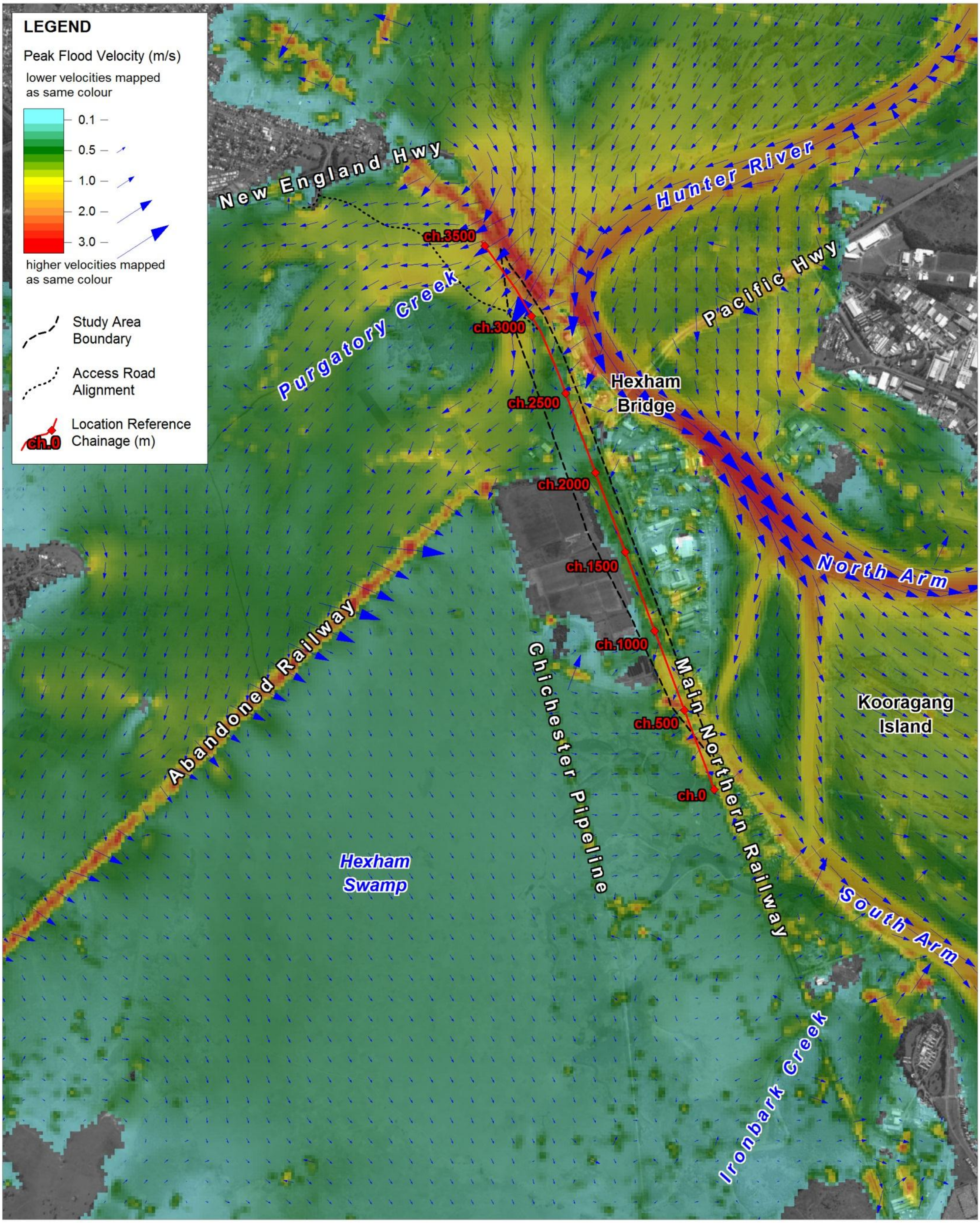

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1% AEP Peak Flood Velocities - Existing Conditions

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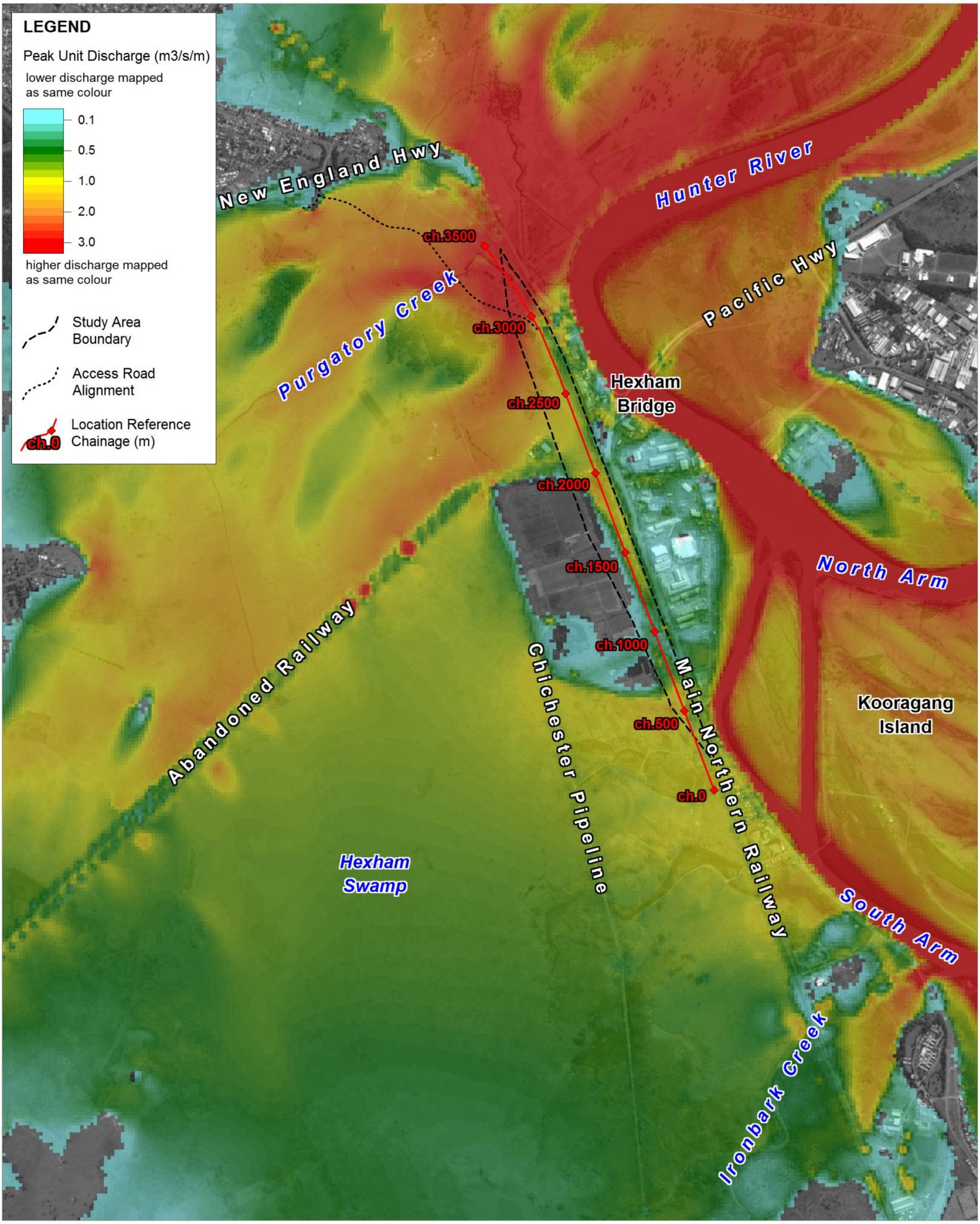

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1% AEP Peak Unit Discharge - Existing Conditions

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Typical inundation depths across the proposed rail development site for the 1% AEP event are of the order of 1.5 – 3.0m and 3 – 4m along the access road alignment. Peak flood velocities are typically less than 0.5 m/s, but are locally much higher near to the New England Highway, where the initial spilling from the Hunter River occurs. The floodplain flow distribution shows that the major area of conveyance is through the area to the north of Hexham Swamp. The northern end of the works site (ch.3000 to ch.3500) is located in this flowpath, whereas the majority of the site downstream of Hexham Bridge is sheltered to some degree by the surrounding areas of higher land and is not a principal flood flow path (ch.700 to ch.2300).

As detailed in the Train Support Facility Flood Impact Assesment by WorleyParsons (2011), the site is located within a high hazard flood storage area. This has implications for personal safety, evacuation logistics and the structural integrity of buildings. However, the provisional hazard classification for the site can be reduced through the reduction of flood depths associated with the regrading of the site. The proposed site levels will be much closer to the 1% AEP flood level than the existing ground levels and will be largely flood free at the 2% AEP event. The access road from Tarro interchange is located in an area of high hazard floodway, corresponding to the high flow areas as shown in Figure 2-4.

2.4 Comparison with Previous Studies

In addition to the studies discussed in Section 1.3, from which the TUFLOW model of the Williams River and Lower Hunter has been developed, there have been a number of other flood investigations within the region. The principal of these is the Lower Hunter River Flood Study (PWD, 1994), which included the construction of a one-dimensional MIKE11 model and has been used as the basis for subsequent Floodplain Risk Management applications in the Lower Hunter. This model was further developed by DHI in 2009 to incorporate a two-dimensional representation of the Hexham Swamp floodplain area.

A two-dimensional RMA-2 model was developed by WorleyParsons in 2011 as part of the original Flood Impact Assessment for the Hexham Train Support Facility. It also covers the entire of the Lower Hunter River floodplain, from upstream of the Williams River confluence to Newcastle Harbour.

Table 2-2 shows modelled flood levels from the previous studies compared to the modelled flood levels from this study. The models generally show a good level of consistency, with peak flood levels being typically within 0.3m of each other for most locations. The most significant difference between the models occurs downstream of Hexham Bridge, where the water levels of the TUFLOW model deviate from those of the other two models, as evidenced by the levels at Kooragang Island.

The difference in modelled flood level at this location is most likely due to an improved representation of the floodplain between Kooragang Island and Fullerton Cove. This section of the DHI model is represented within the 1-D domain, whereas the TUFLOW model provides a fully 2D representation. It is also noted that several adjustments were made to the RMA-2 model to better fit with the existing model results (WorleyParsons, 2011), which may explain the consistency between the DHI and WorleyParsons models at Kooragang Island.

The flood levels in the study area are driven primarily by the Hunter River upstream of Hexham Bridge, where the models provide reasonably consistent results. The flow of flood waters through

Hexham Swamp is highly sensitive to the modelled geometry of the New England Highway and this is likely to explain the small differences in modelled flood levels at the development site.

Table 2-2 Comparison of the 1% AEP Peak Flood Levels (m AHD) Predicted by Previous Studies

Location	LHFS (1994) DHI (2009)	Worley Parsons (2011)	BMT WBM (2012)
Williams River confluence	5.0	4.9	4.9
d/s Raymond Terrace	4.5	4.7	4.7
Beresfield	4.1	4.5	4.5
Hexham Bridge	4.0	4.0	3.8
Development Site	**3.8**	**3.9**	**3.6**
Hexham Swamp	3.8	3.8	3.5
Kooragang Island	3.5	3.5	2.8

3 PROPOSED DEVELOPMENT

3.1 Description

The Train Support Facility covers an area of approximately 255ha in the vicinity of Hexham Bridge. The development of the site will involve the construction of a fill platform for a new Train Support Facility. The impacts of the ARTC Hexham Relief Roads have previously been assessed (BMT WBM, 2011). The focus of the current investigation is to assess the cumulative flood impacts of all the proposed works..

Details of the Hexham Relief Roads design were provided by Parsons Brinckerhoff as part of the Hexham Relief Roads Flood Impact Assessment as a Digital Terrain Model (DTM). Details of the Train Support Facility design were provided by the client. The final design may differ to that which has been modelled, but it is likely that the flood impacts would be similar in nature. This can be confirmed once the designs have been finalised. The topographic details of the design have been incorporated into the TUFLOW model to assess the cumulative impacts on regional Hunter River flooding. The northern end of the works include a crossing of Purgatory Creek (approximately ch.3300) and it has been assumed that the capacity of the culvert in this location will be maintained.

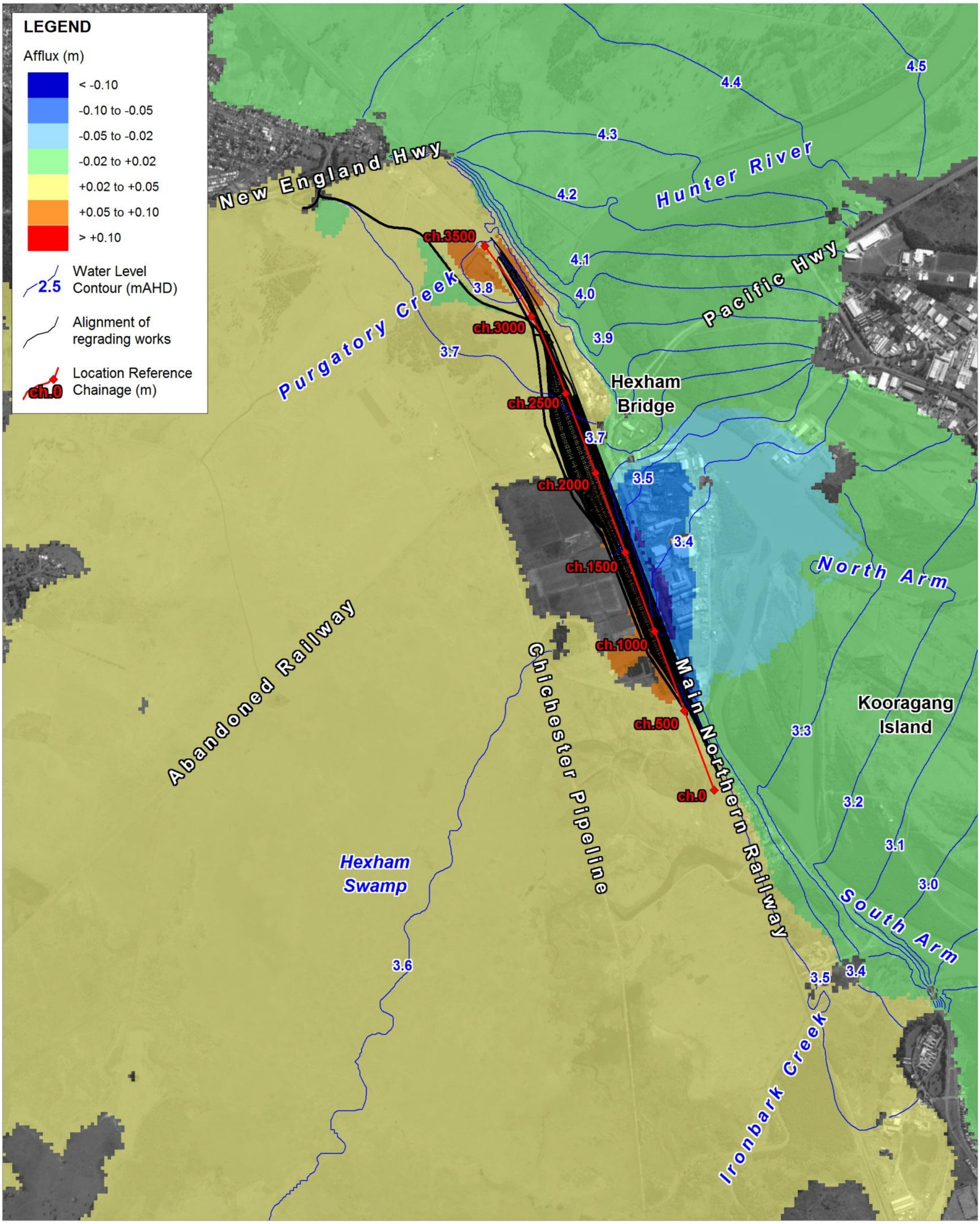
The details of the proposed access road from the Tarro interchange have also been supplied as a DTM. The access road is some 1.6km in length, with typical crest levels varying between 1.1m AHD and 2.2m AHD. The road alignment includes two creek crossings and it has been assumed that culverts will be constructed in these locations. The adopted culvert size is similar to the existing cross drainage structures through the railway and New England Highway (3x1.5m).

3.2 Cumulative Impacts

Of the proposed works it is the access road which has the most significant flood impact, with the impacts of the rail works being less substantial. At the 1% AEP event the proposed works were found to have a relatively minor impact on modelled peak water levels, as substantial overtopping of the proposed access road crest occurs. The road embankment becomes effectively drowned out, thereby limiting adverse flood impact. However, for lower order events such as the 5% AEP a significant increase (around 0.4m) in peak water levels was identified.

The existing flood level at the access road location for the 5% AEP event is around 1.2m AHD. The proposed access road has a crest elevation of between 1.1m AHD and 2.2m AHD, with an embankment approximately 1m in height obstructing the active floodplain of the Hunter River. The assumed cross drainage was a 3m by 1.5m box culvert at the two channel alignments (similar to the corresponding cross drainage provided through the New England Highway and existing rail embankment).

The reduced floodplain conveyance capacity through the access road alignment raised upstream peak flood levels by around 0.5m. Flood mitigation measures are therefore required to reduce the impact. Initial investigations indicated that a flow area of approximately 150m^2 was required to suitably reduce the peak flood level upstream of the access road. The flood mitigation is discussed in Section 4. The relative impacts on peak flood level without flood mitigation measures are presented in Figure 3-1 and Figure 3-2. More details of local flood impacts are provided in Section 4.2.



Title:

Impact on Peak 1% AEP Flood Level - Train Support Facility, Hexham Relief Roads & Access Road

Figure: **3-1**

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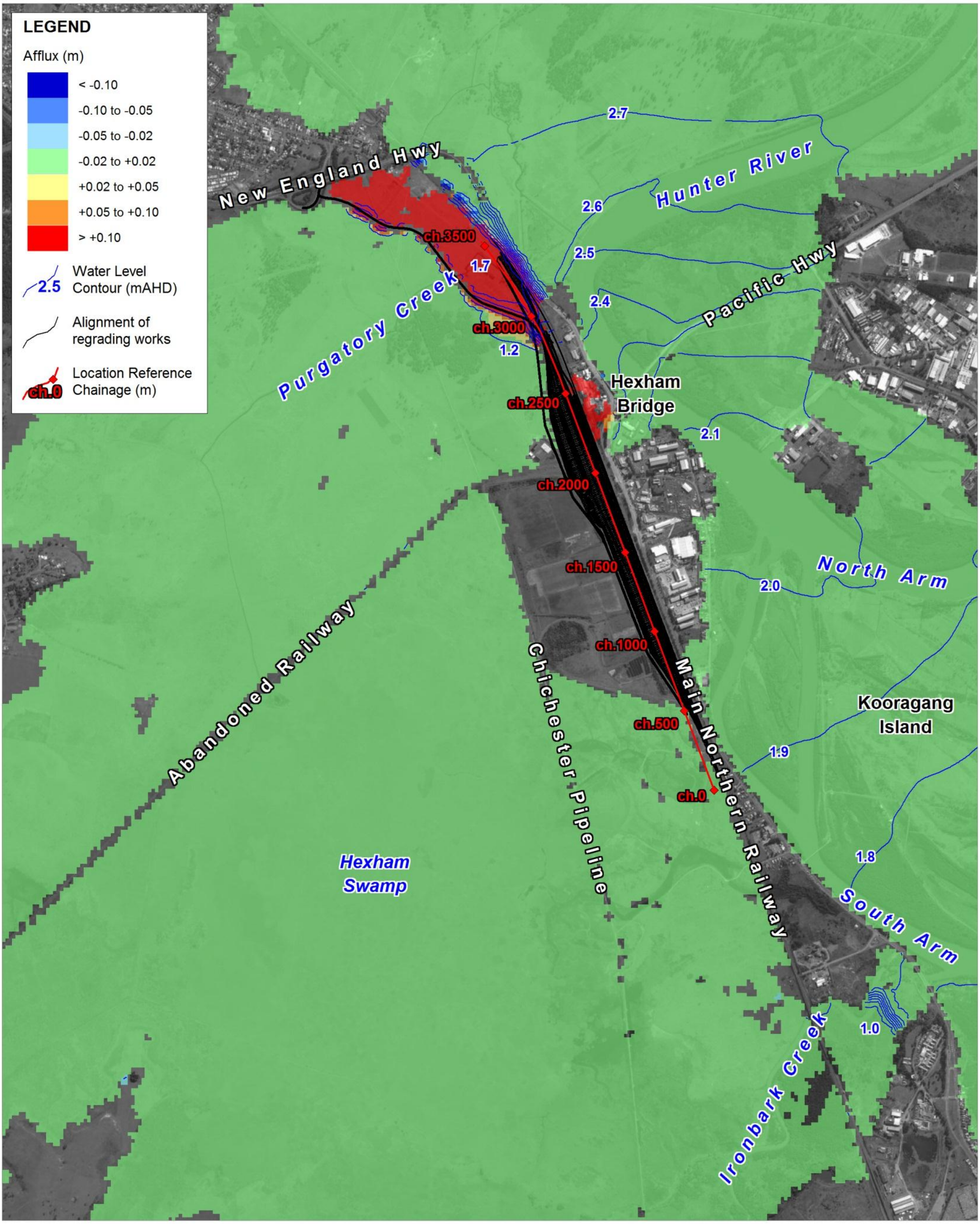

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Impact on Peak 5% AEP Flood Level - Train Support Facility, Hexham Relief Roads & Access Road

Figure: 3-2

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4 FLOOD MITIGATION

4.1 Description

As discussed in Section 3.2 additional cross drainage is required to mitigate the impact of the raised embankment of the proposed access road across the floodplain. For the assessment of flood mitigation options, a 9m by 1.5m crossing was provided at the two channel crossings, which is similar to the width of the channels. An additional 150m^2 of flow area was provided in the form of 300m width of flood relief culverts with a 0.5m height. The culverts were distributed across a 600m length of the access road, in the vicinity of Purgatory Creek, and is shown on Figure 4-1. This aligns with the existing area of floodplain flow concentration, as indicated on Figure 2-4. The culverts were situated at ground level within the broader area of high floodplain flow, generally located within the lower-lying land to improve conveyance for lower order events, such as the 5% AEP. The modelling assumes that the culverts are fully effective, with no allowance for potential blockages. Accordingly, future maintenance regimes should ensure that the culverts are kept free of blockages.

The ultimate configuration of flood relief measures may be refined during the detailed design stage but would need to provide a similar flow area through the access road embankment. This may be provided through an appropriate configuration of flood relief culverts, or potentially through the lowering of additional sections of the road elevation to beneath 1.2m AHD if feasible. Further flood impact reduction could be achieved through the provision of additional flood relief culverts, if required. The flood impact of the final design should then be re-assessed.

4.2 Mitigated Impacts

The cumulative impacts of the proposed works, in terms of changes in peak flood water level and peak flood velocity for the 1% AEP, 2% AEP, 5% AEP and 10% AEP events are shown in Figure 4-2 to Figure 4-9. Flood impacts for the PMF event are included in Appendix B. The impacts of the proposed works are restricted locally to the site and Hexham Swamp. The impact to the Hunter River floodplain beyond Hexham Swamp is negligible. The most significant impacts of the proposed developments are associated with the inclusion of the access road. The impacts from the rail developments are minor in comparison as the rail development is situated within an area of relatively low floodplain conveyance. Flood impacts associated with the rail development are localised, as presented in the Hexham Relief Roads Flood Impact Assessment (BMT WBM, 2011).

4.2.1 Impacts on Surrounding Land

When introducing a raised embankment across a major floodplain flow path there is always likely to be some level of flood impact. For the access road, flood impacts will be substantially reduced through the provision of additional cross drainage. However, some residual impact remains. The greatest impact on modelled flood behaviour is for the 2% AEP event, for which the peak flood level upstream of the road alignment is increased by just under 0.1m (typical flood depths increasing from approximately 1.5m to 1.6m). The floodplain flow peaks at around 560m^3/s, with 250m^3/s being conveyed through the cross drainage structures and the remainder flowing across the road embankment.

Elsewhere the impacts on peak flood levels are locally restricted to the east of the upgrade. Here water is spilling from the Hunter River to fill the available flood storage. With the regrading of the site, this water is becoming ‘trapped’ behind the rail tracks, raising the peak flood level, typically to the order of 0.2m. This occurs at three locations at about ch.600, ch.1200 and ch.2800 to ch.3300. However, no cross drainage infrastructure has been accounted for in the modelling. The provision of sufficient cross drainage structures in the affected locations would assist in mitigating the flood level increases. The flood impact between ch.2300 and ch.2800 is around 0.4m and is discussed further in Section 4.2.4

For the 1% AEP event the impacts are less than those of the 2% AEP event. The peak flood level impact upstream of the access road is reduced to around 0.05m (with typical flood depths being approximately 3m), as substantial overtopping of the road crest occurs. The road embankment becomes effectively drowned out, thereby limiting adverse flood impact.

Elsewhere the regrading of the rail corridor reduces the capacity to convey flood flows between the two areas of surrounding higher land. This results in a small redistribution of floodplain flows, pushing more water round to the west and through Hexham Swamp. However, the impact on flood levels in Hexham Swamp downstream of the access road alignment is relatively minor, at around 0.03m. There are locally higher increases in peak flood level of up to 0.1m, but these are restricted to the rail corridor immediately to the west (ch.500 to ch.2000). There is also a corresponding reduction in peak flood levels to the east of the site.

For the 5% AEP and 10% AEP events the flood impacts are relatively minor. Peak flood levels upstream of the access road are typically increased by around 0.04m, with some localised increase of up to 0.06m at the 10% AEP event. The impact at the 10% AEP event would be mitigated by the provision of stormwater cross drainage through the proposed access road.

The impacts on peak flood velocity for the 2% AEP event are of a similar order to those experienced at the 1% AEP event. The impact on peak velocity is minimal for both the 5% AEP and 10% AEP events.

The flood impacts for the PMF event show some localised redistribution of peak flood velocities and localised peak flood depth increases of around 0.03m.

4.2.2 Impacts on Local Infrastructure

The most significant impact on local infrastructure occurs at the 2% AEP event for a 1km stretch of the Pacific Highway immediately north of Hexham Bowling Club (ch.500 – ch.1500 on the flood impact mapping). The modelling shows peak flood level increases in the order of 0.1m – 0.2m at this location. As discussed in the previous section, this is due to a small volume of water spilling from the Hunter River and becoming ‘trapped’ behind the regraded rail corridor. The provision of local cross drainage structures for stormwater drainage should provide mitigation against these indicative modelled impacts. Flows extracted from the model results indicate that the flood waters spilling from the Hunter River between ch.500 and ch.1500 at the 2% AEP event from the simulated design hydrograph occur over around a ten hour period and have a peak flow of around $3m^3/s$. Adequate stormwater cross drainage provision through the Hexham Relief Roads and Train Support Facility in this vicinity would enable these flows to be conveyed through the regrading works and alleviate any potential impacts to the Pacific Highway.

At the 1% AEP event there is around a 0.05m modelled increase in peak flood level across the New England Highway to the North of Hexham Bridge (north of ch.3000 on the flood impact mapping). This impact is related to the redistribution of flood flows from the rail corridor to Hexham Swamp. There is a corresponding 0.1m modelled decrease in peak flood level across the New England Highway to the South of Hexham Bridge (between ch.500 and ch.2000 on the flood impact mapping).

The other local road infrastructure that is impacted by the proposed development works is Woodlands Close, which is situated between the rail corridor and the proposed access road alignment. Here modelled flood level increase are in the order of 0.08m at the 2% AEP event, 0.04m at the 1% AEP event and 0.03m at the 5% AEP event. Impacts in this location are related to both the local redistribution of flood flows and the proposed access road. There are no significant impacts to the local road infrastructure at the 10% AEP or PMF events.

The impact on peak flood levels at the existing rail infrastructure at the 2% AEP event are similar to those described in Section 4.2.1, being around 0.2m at ch.600, ch.1200 and ch.2800 to ch.3300 and around 0.4m between ch.2300 and ch.2800. It should be noted that at events of this magnitude (i.e. 2% AEP) the existing rail alignment is overtopped in this location under existing conditions. Flood impacts for other design event magnitudes are less significant.

The changes in peak velocities for the 1% AEP event as a result of the proposed development are typically less than 0.2m/s. There are two locations for which there is a greater modelled increase in peak flood velocity. There is substantial overtopping of the proposed access road for this event, resulting in increased velocities where the water spills across the road. This increase is in the order of 1m/s above the existing velocities of around 1m/s. Typical velocities across the access road will therefore be over 2m/s and locally higher. The access road would need to be designed to withstand high velocities in order to minimise damage from overtopping during a major flood event.

At the northern end of the rail upgrade (ch.2500) there is a localised increase in peak velocities of around 1m/s, where existing peak velocities are also in the order of 1m/s. This occurs at the onset of spilling from the Hunter River on to the floodplain. As the flood waters spill over the railway they are pushed around the northern end of the regrading works, locally increasing velocities. However, the scale of the regional modelling is not at a resolution to define precise local velocity distributions. Further investigation of this increase may be required to determine the need for any local protection works, if the increased velocities are of concern. This impacts on both the proposed rail development and the existing rail corridor.

4.2.3 Impacts on Local Housing

The flood impacts to local housing are predominantly associated with the access road. The most significant impact on local housing occurs at the 2% AEP event, where a 0.08m peak flood level increase is modelled at the property located on Woodlands Close. The impact on peak flood level at this location for the 1% AEP event is 0.04m and at the 5% AEP event it is 0.03m. These impacts are related to both the local redistribution of flood flows and the proposed access road.

Elsewhere, the only event indicating an impact on local housing is the 1% AEP event. There are three houses located on the New England Highway, to the north of Hexham Bridge (ch.2800) and another house situated within Hexham Swamp to the west of the development (around ch.2400). These four properties show a 0.03m increase in peak flood level at the 1% AEP event, related to the redistribution of flood flows from the rail corridor to Hexham Swamp. There is a corresponding reduction in peak flood levels of 0.03m indicated for the 30 or so properties located along Old Maitland Road (ch.500 to ch.1500).

The 0.03m peak flood level increase in Hexham Swamp for the 1% AEP event also has implications for properties fringing the swamp in suburbs such as Shortland, Birmingham Gardens, Jesmond and Wallsend. However, this is unlikely to have a significant impact on flooding to houses, more a small increase in peak flood levels to low-lying land that is already inundated.

4.2.4 Impacts on Local Businesses

The only local businesses to be impacted by the proposed development are those located on the former Oak Milk site. At the 5% AEP and 2% AEP events there is a local increase in peak flood levels of around 0.4m. This impact is due to the higher spill level of the proposed development restricting the progression of flood flows through the site. For the 1% AEP event and events of a greater magnitude the local flood impact is negligible as the entire site becomes fully connected with the wider floodplain and is substantially inundated.

At events of a 5% AEP magnitude the flow rate of flood waters spilling through the site is sufficiently small that they can be managed through the provision of local cross drainage infrastructure. However, for a narrow range of flood events of greater magnitude (e.g. the 2% AEP event), prior to the extensive inundation of the site (such as at the 1% AEP event), the flow rates are large enough to require alternative mitigation works. There are a number of options through which this impact can be mitigated and these are currently undergoing further investigation for incorporation into the detailed design phase.

4.2.5 On-site Flood Risk

The development includes regrading of site elevations up to a level of around 2.5m AHD. Rail and building infrastructure that is situated at or above this level will remain flood free in the 2% AEP event, which has a peak level of around 2.2m AHD. The development site did not previously flood at the 5% AEP event, but did so at the 2% AEP event. Under the developed conditions the site will be largely flood free at the 2% AEP event, but inundated during a 1% AEP design event. This reduction of flood inundation frequency is only local to the development site itself and does not impact on the flooding frequency of the broader Hexham Swamp system.

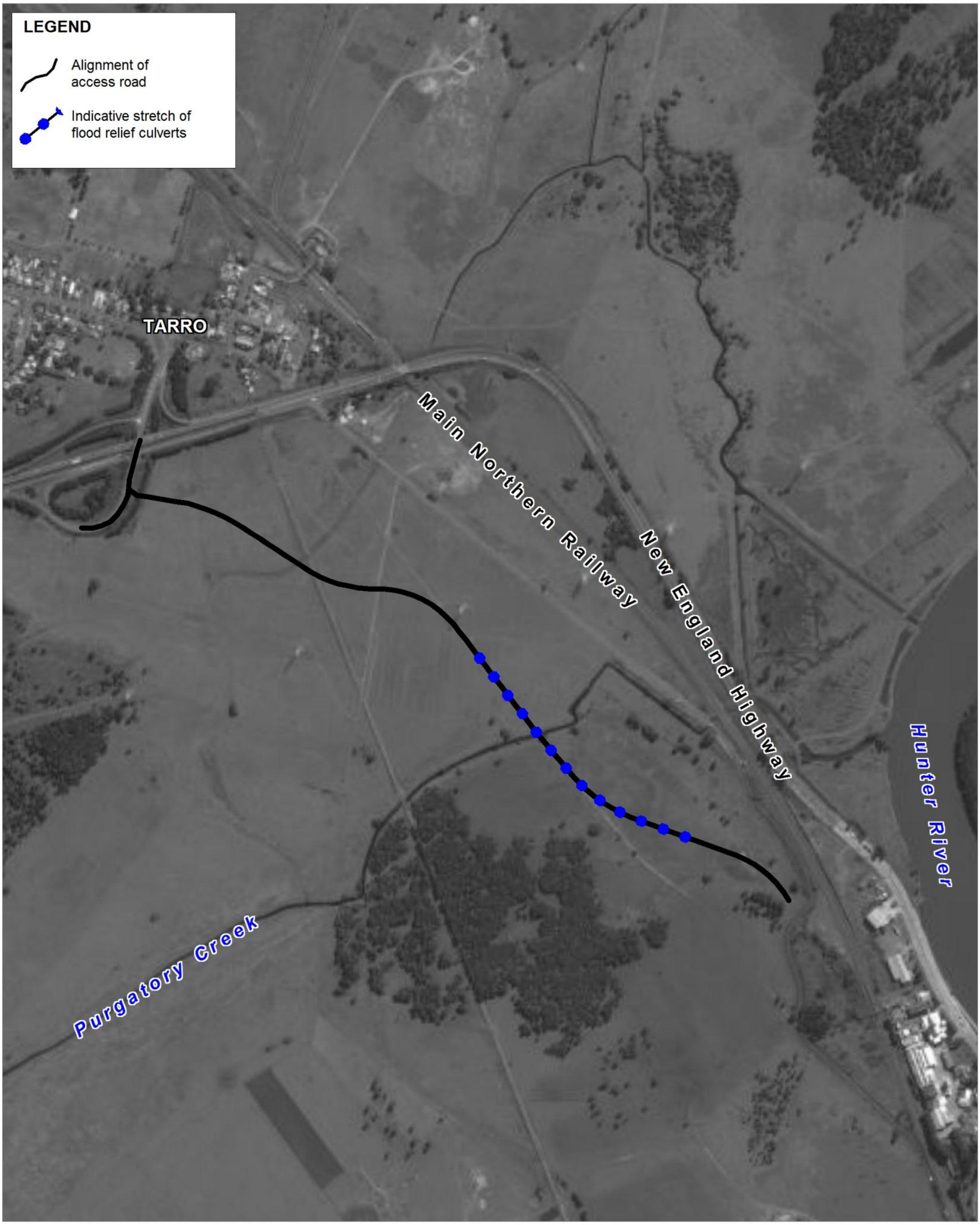
Although the highest parts of the site will be located above the 2% AEP flood level, there will be a residual on-site flood risk for larger magnitude events such as the 1% AEP and PMF events. The peak flood level at the 1% AEP event is around 3.7m AHD, which will correspond to a flood depth of over 1m across the development site. This has implications for the on-site rail and building infrastructure. It is recommended that critical infrastructure, such as electrical supply and equipment is elevated above the 1% AEP level and a suitable freeboard (typically 500mm), i.e. 4.2m AHD.

At the 1% AEP event the velocity depth product for the elevated on-site areas does not exceed 1.0 and is therefore suitable for light building constructions, as recommended by the NSW Floodplain Development Manual. Impacts on the velocity depth product remote from the development site are not significant.

At the PMF event flood waters would be over 5m deep, with a velocity depth product of around 2.0. An event of this magnitude would likely result in extensive damage to on-site infrastructure.

4.2.6 Impacts on Geomorphology

The proposed development has a negligible impact on the flood flows within the Hunter River channel and so will not impact on the Hunter River geomorphology. The impacts of the proposed development are predominantly within the partially disconnected floodplain of Hexham Swamp and are restricted to events of around a 5% AEP magnitude and greater. Due to the negligible impact on high frequency flood events no significant geomorphic impacts are anticipated. Within Purgatory Creek local peak flood velocities are increased to around 2m/s through the access road cross drainage. However, this impact can be mitigated through the inclusion of appropriate scour protection works in the vicinity of the access road crossing. Impacts to flood velocities in the local floodplain areas are typically less than 0.2m/s.



Title:

Location of Flood Relief Culverts Distribution

Figure: **4-1**

Rev: **A**

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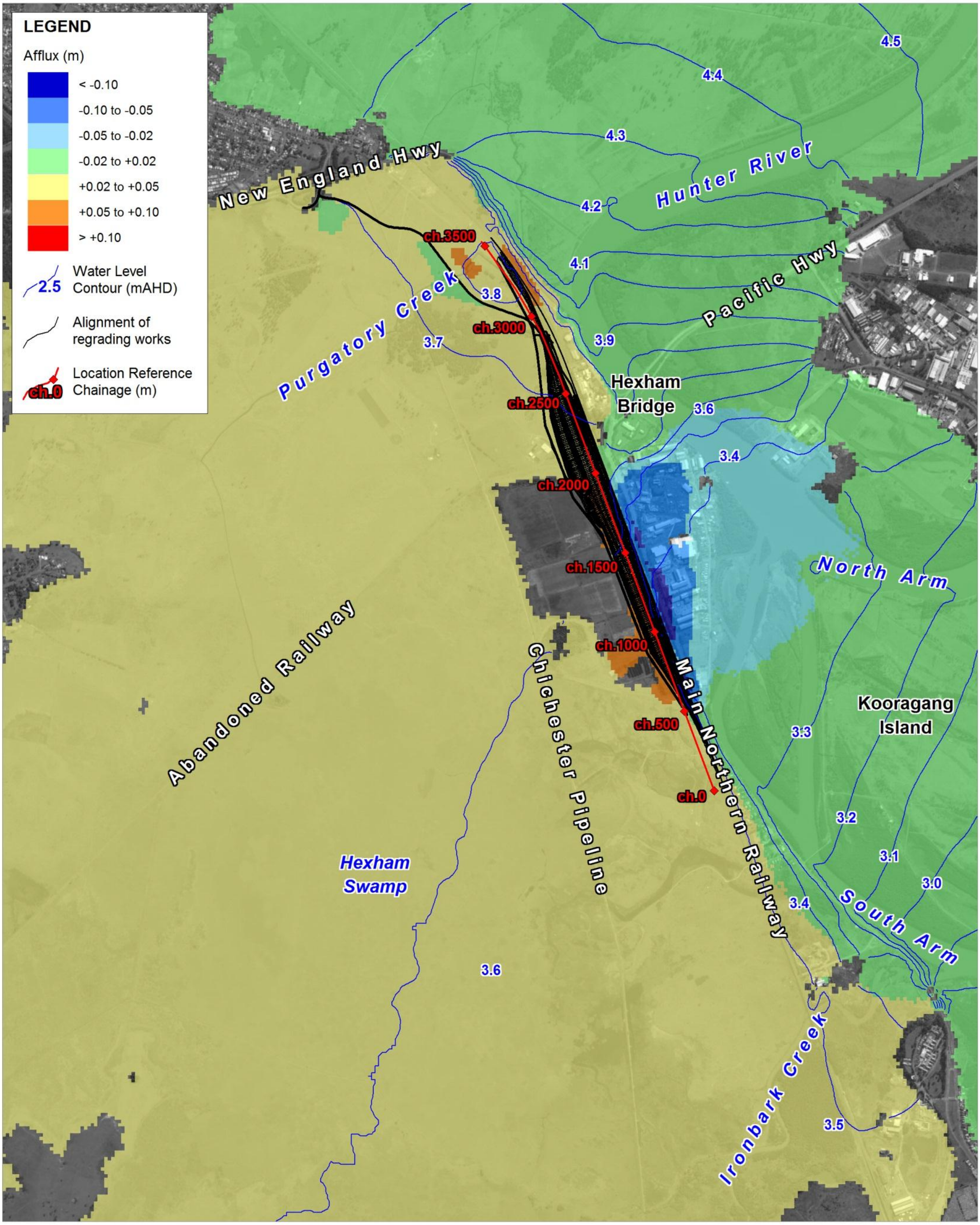

Title:

Impact on Peak 1% AEP Flood Level with Flood Mitigation - Train Support Facility, Hexham Relief Roads & Access Road

Figure: 4-2

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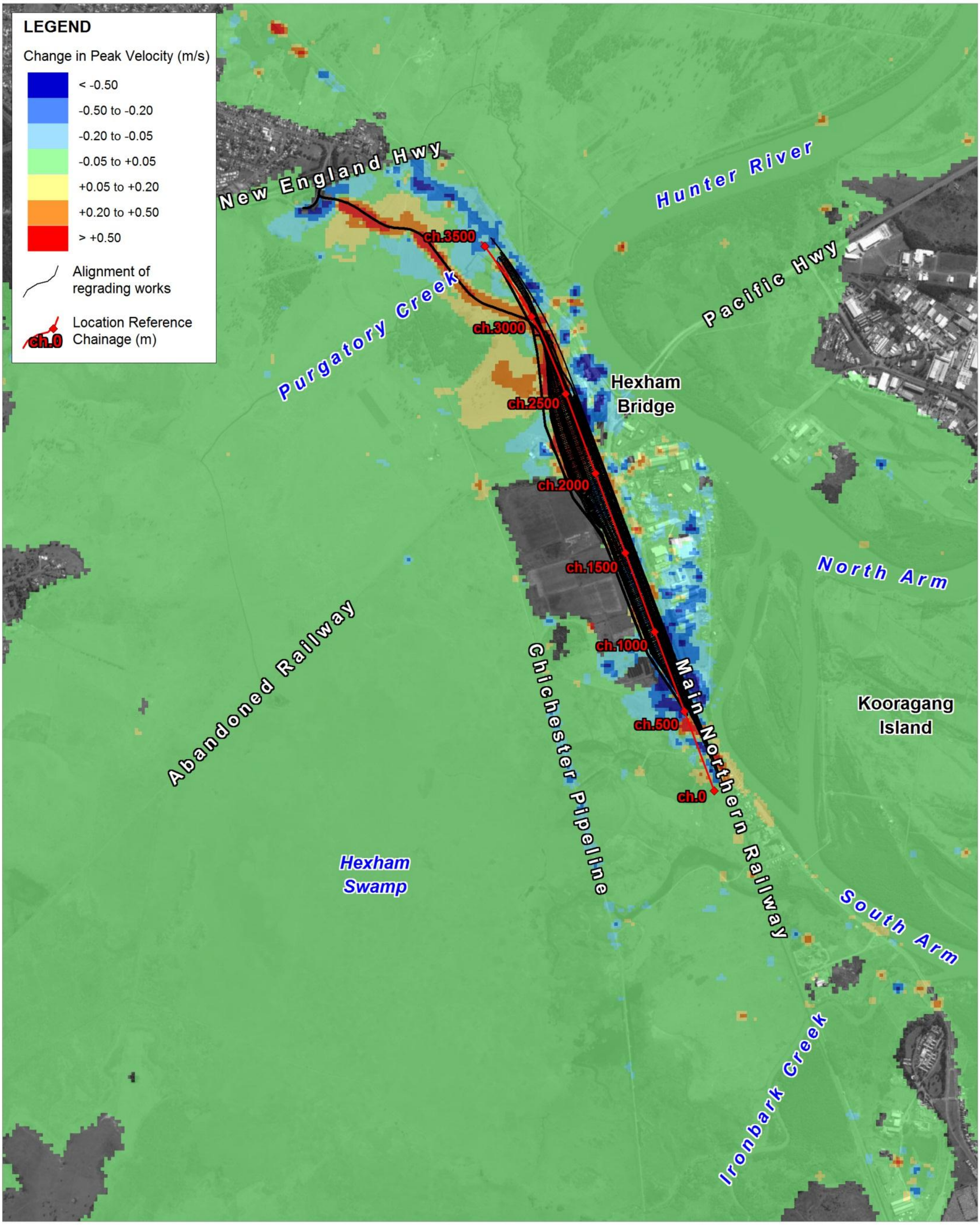

Title:
Impact on Peak 1% AEP Flood Velocity with Flood Mitigation - Train Support Facility, Hexham Relief Roads & Access Road

Figure: 4-3

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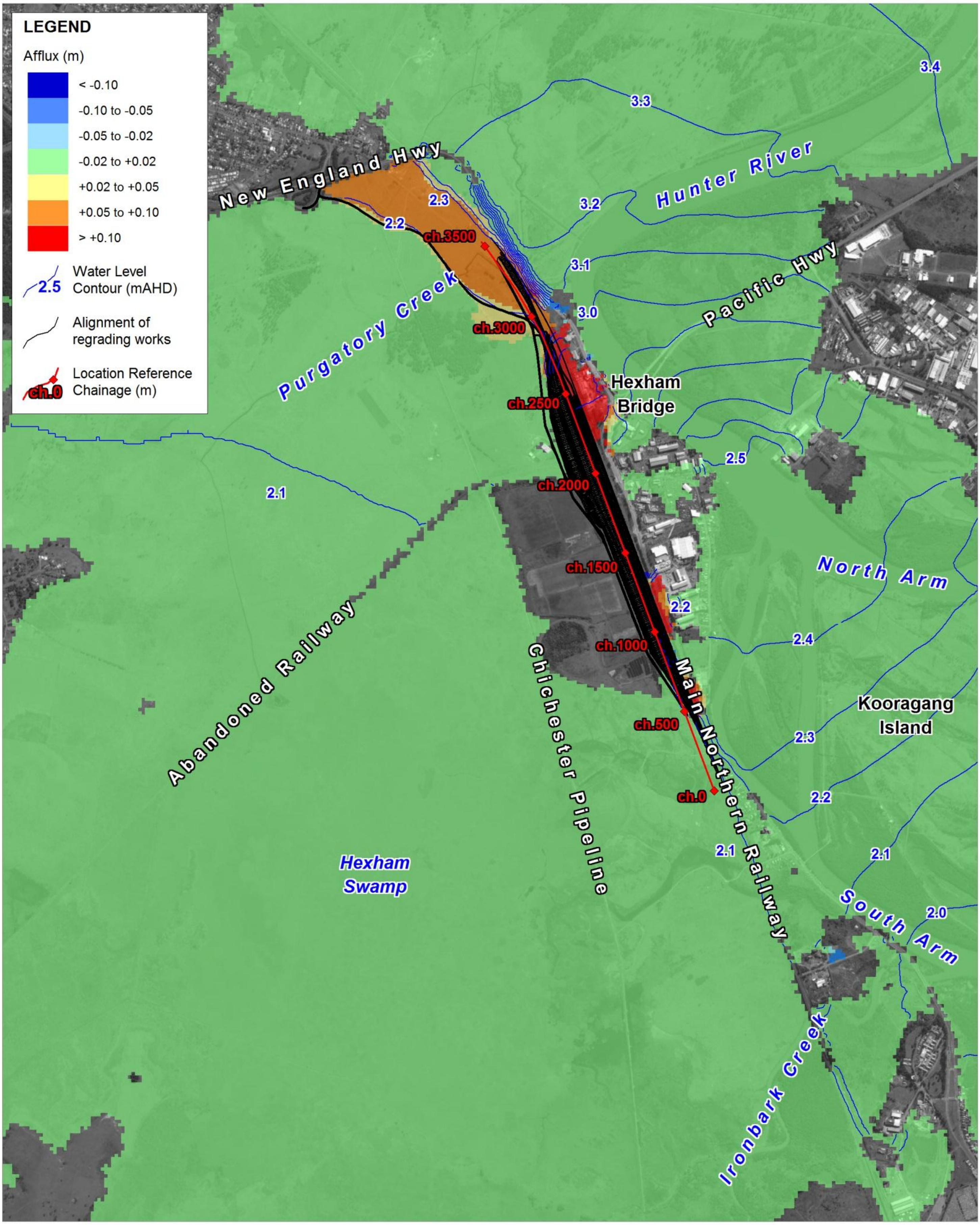

Title:

Impact on Peak 2% AEP Flood Level with Flood Mitigation - Train Support Facility, Hexham Relief Roads & Access Road

Figure: 4-4

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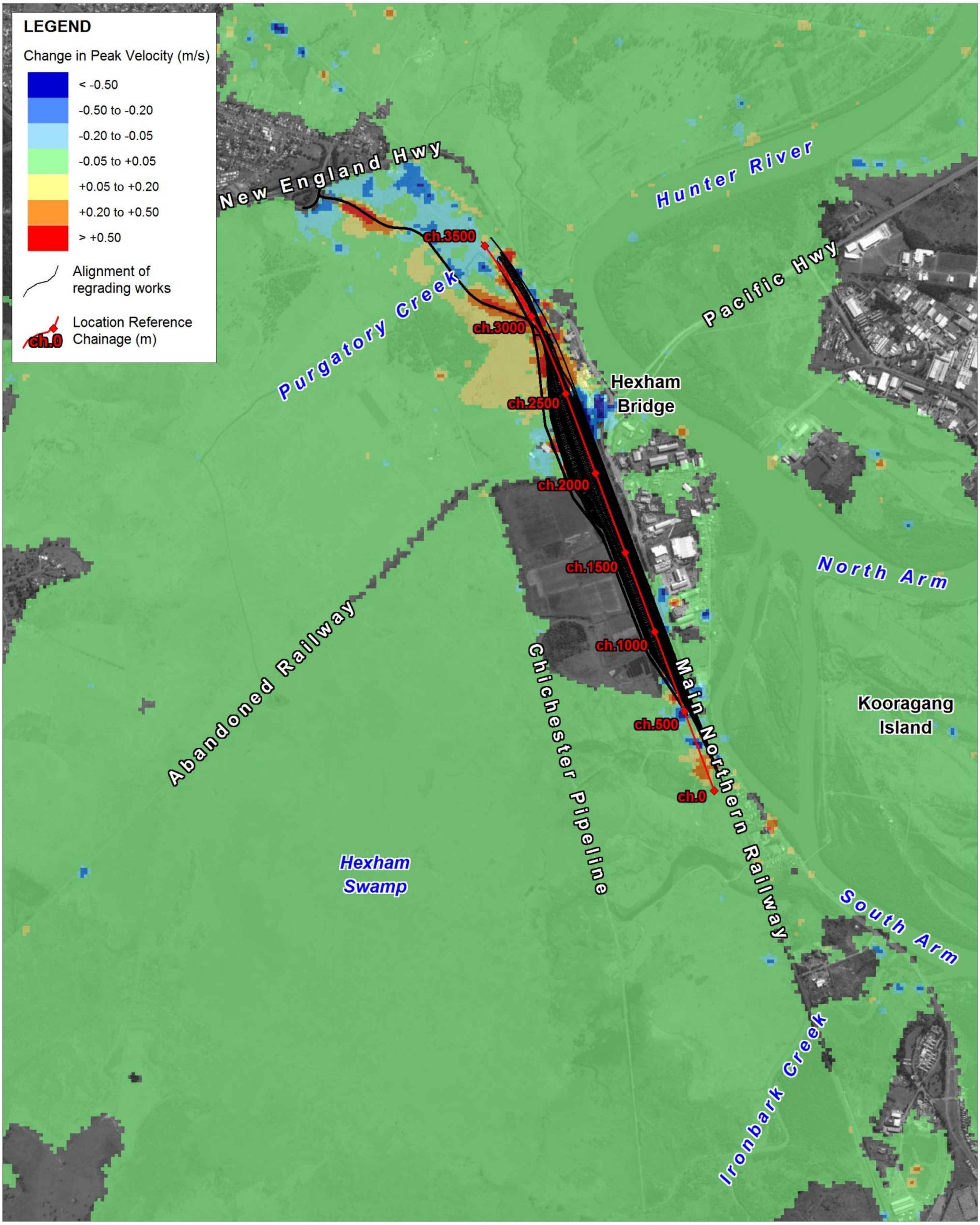

Title:

Impact on Peak 2% AEP Flood Velocity with Flood Mitigation - Train Support Facility, Hexham Relief Roads & Access Road

Figure: 4-5

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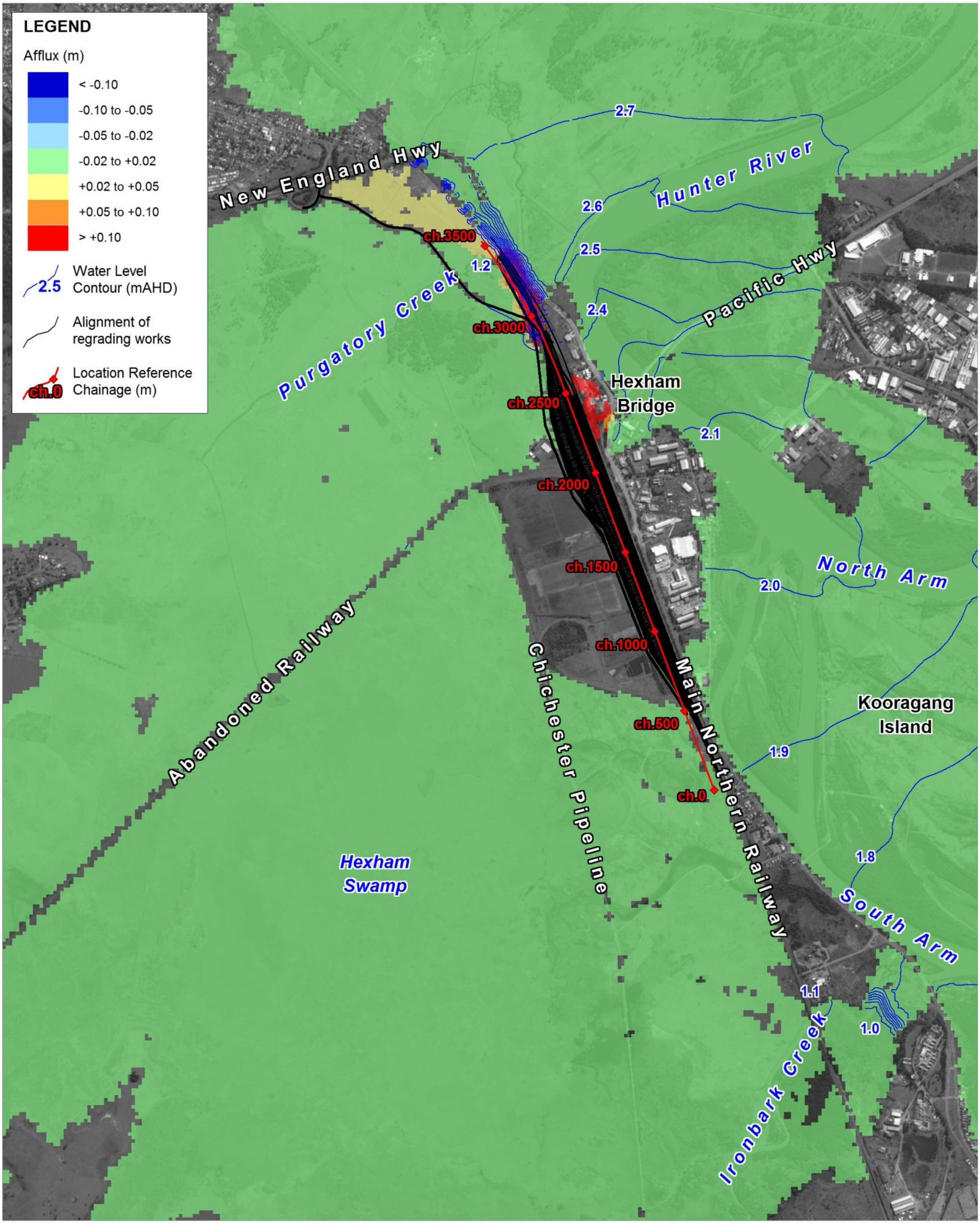

Title:

Impact on Peak 5% AEP Flood Level with Flood Mitigation - Train Support Facility, Hexham Relief Roads & Access Road

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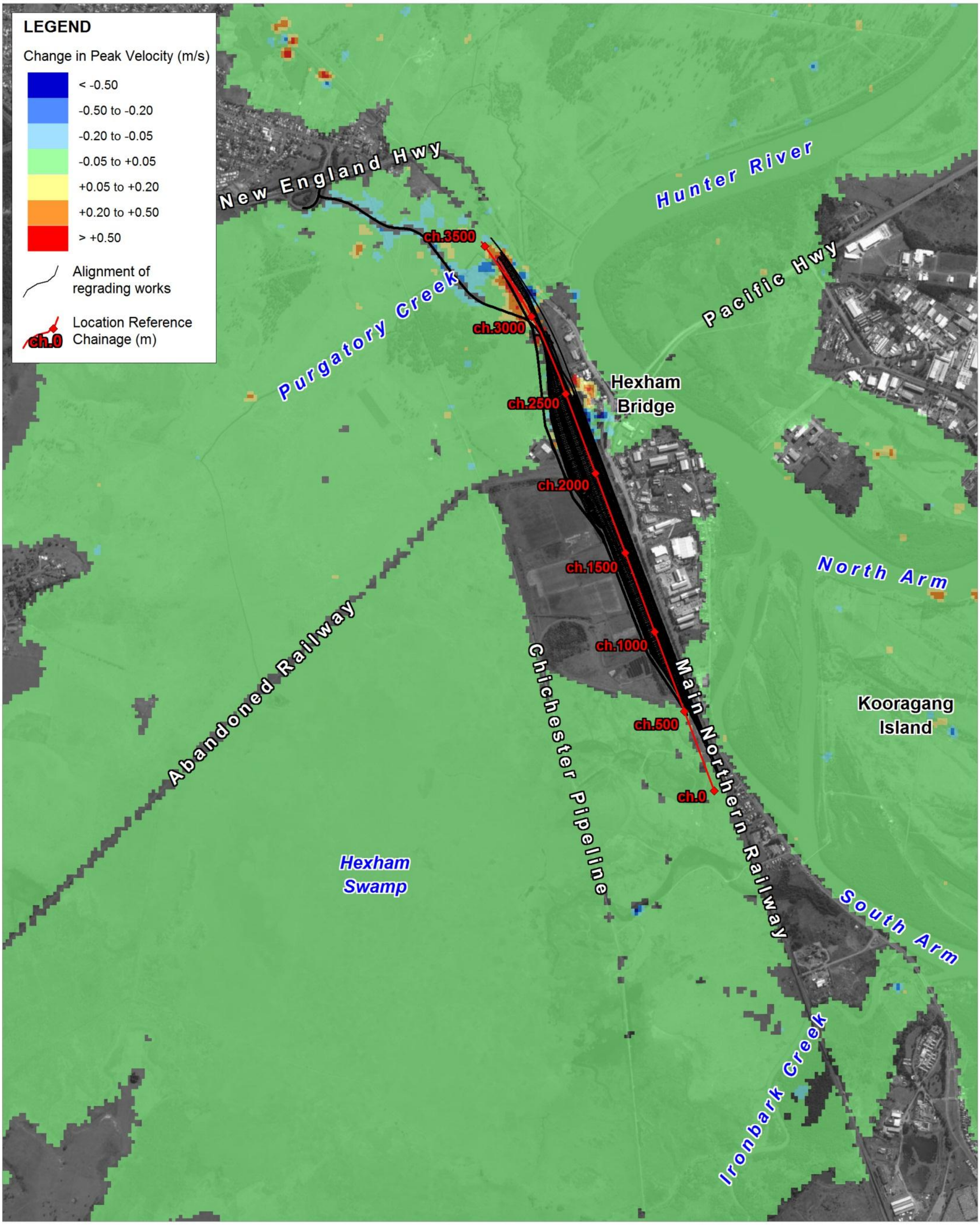

Title:

Impact on Peak 5% AEP Flood Velocity with Flood Mitigation Train Support Facility, Hexham Relief Roads & Access Road

Figure: 4-7

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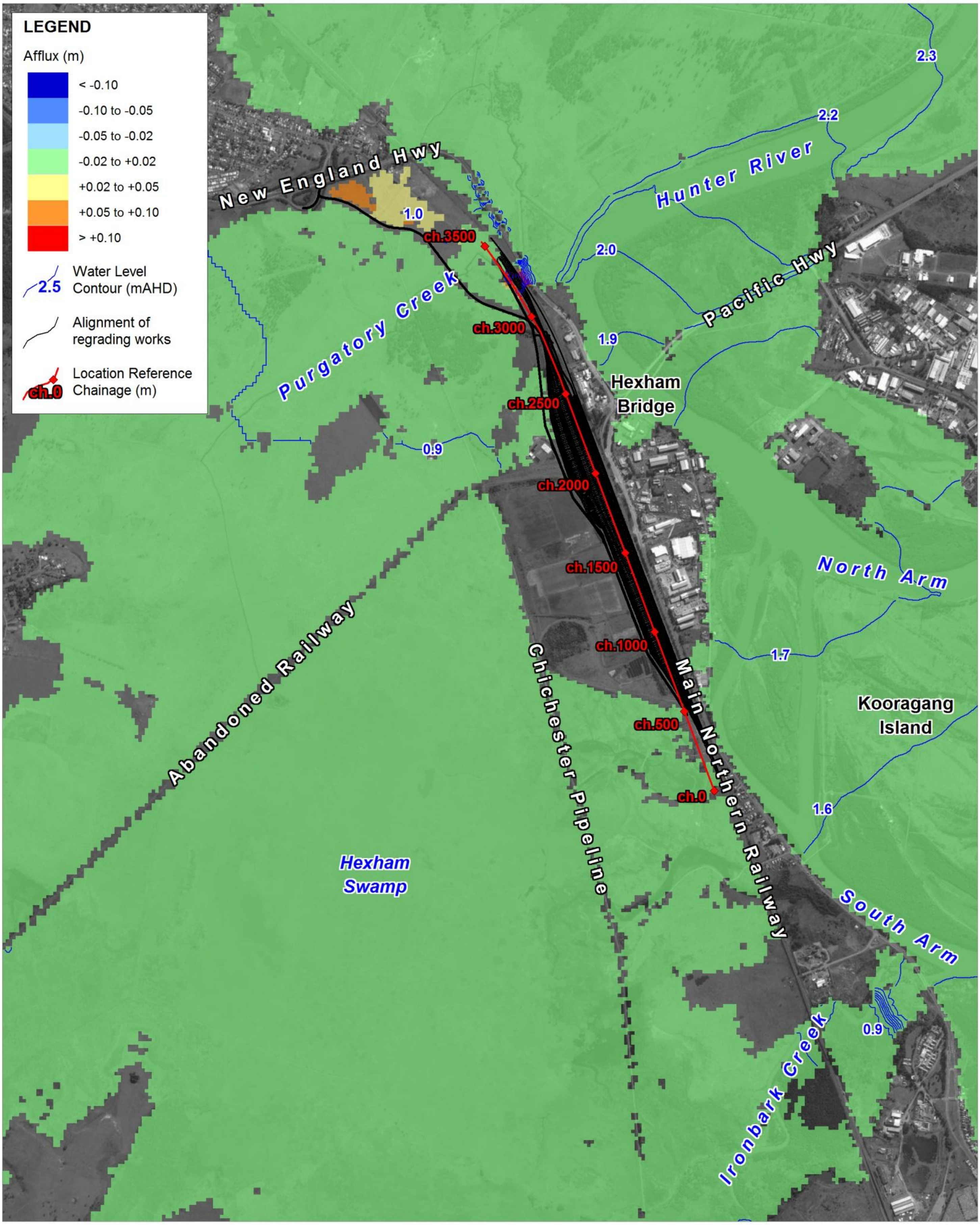

Title:

Impact on Peak 10% AEP Flood Level with Flood Mitigation - Train Support Facility, Hexham Relief Roads & Access Road

Figure: 4-8

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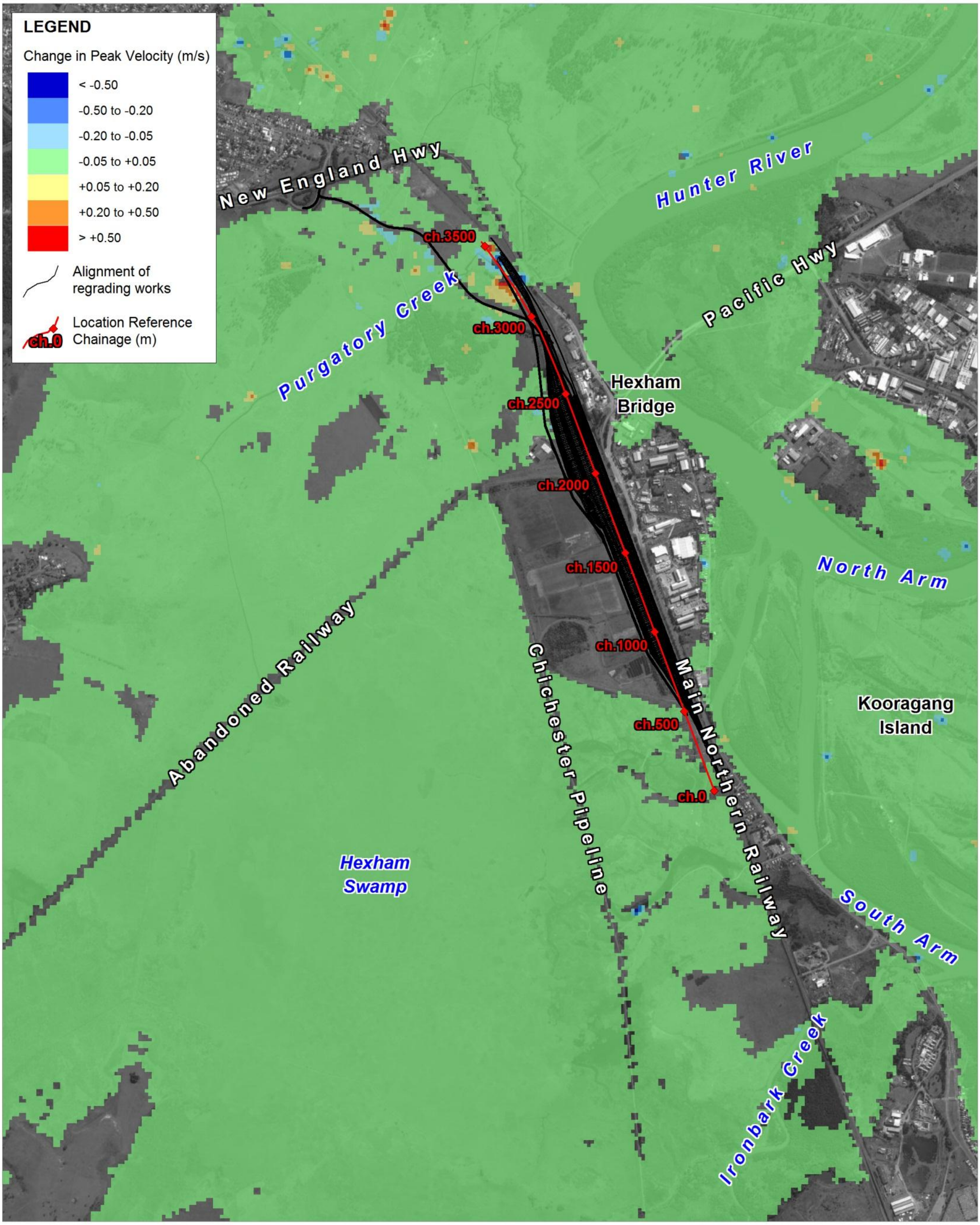

Title:

Impact on Peak 10% AEP Flood Velocity with Flood Mitigation Train Support Facility, Hexham Relief Roads & Access Road

Figure: **4-9**

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5 F3 UPGRADE

5.1 Description

The NSW Roads and Maritime Service (RMS) is proposing to upgrade the Pacific Highway from the F3 Freeway, south of John Renshaw Drive to the Raymond Terrace bypass, north of Heatherbrae. The freeway extension would be approximately 13 km long and follow a route that crosses the Hunter River and associated floodplain. A separate flood impact assessment has been undertaken by BMT WBM (2011) to determine the potential flood impacts associated with the proposed F3 upgrade. The focus of the current investigation is to assess the cumulative flood impacts of the Hexham Relief Roads, Train Support Facility, Tarro access road and F3 Upgrade.

The design details for the preferred route option of the road upgrade were incorporated into the TUFLOW model of the Lower Hunter as part of the study for the Roads and Traffic Authority in 2011. The road levels have been designed to be flood free in the 5% AEP event, with flood impacts at the 1% AEP event reduced to acceptable standards through the provision of adequate flood flow cross drainage. The details of the design that were incorporated into the TUFLOW model for the 2011 study have also been included in this study to assess the cumulative impacts on regional Hunter River flooding. This includes road crest elevations, bridge and culvert details.

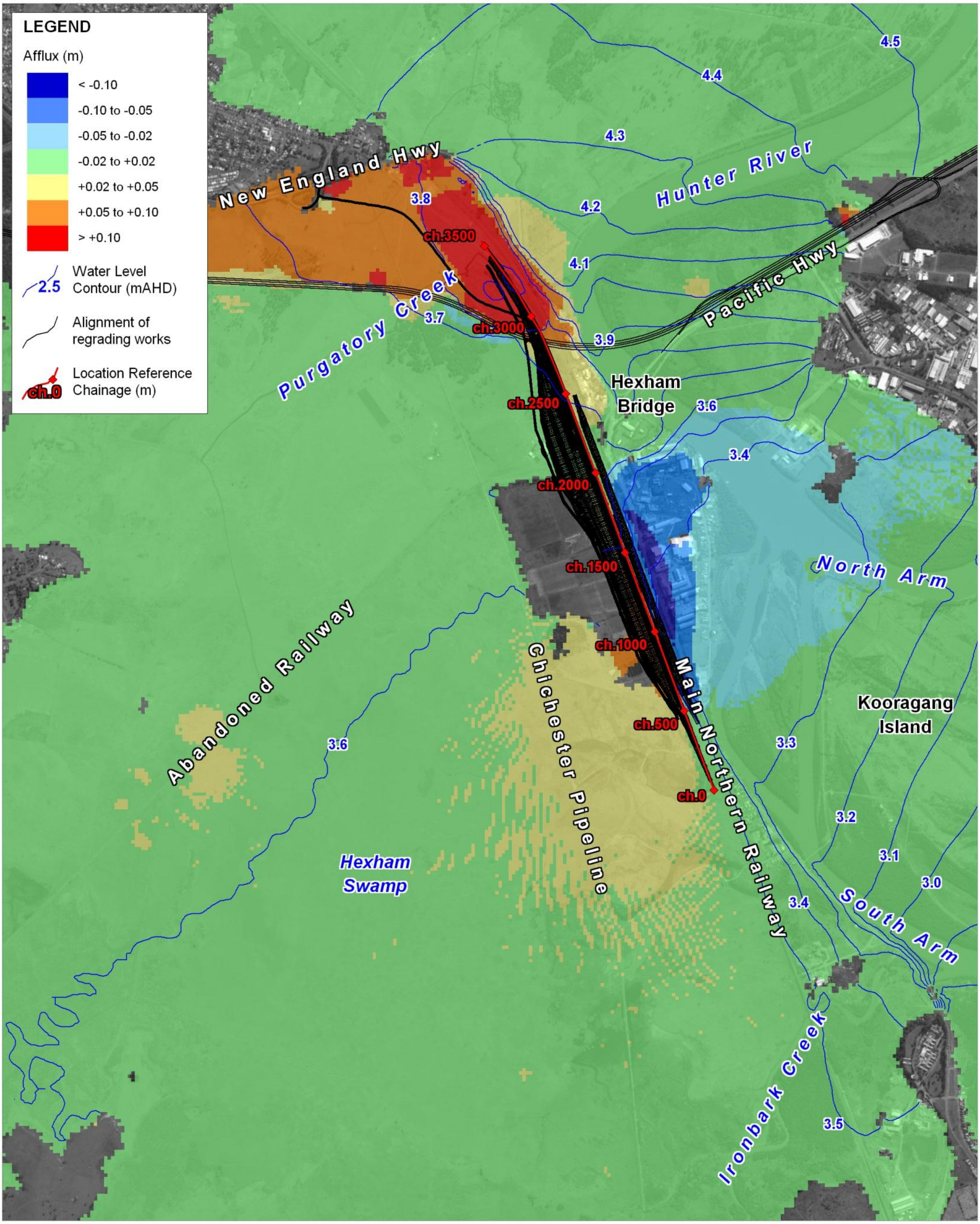
5.2 Cumulative Impacts

The cumulative flood impacts of the two proposed rail developments, access road and the F3 upgrade have been modelled for the 1% AEP event and 5% AEP event. The cumulative impacts on peak flood level and velocity are presented in Figure 5-1 to Figure 5-4.

For the 1% AEP event, the most significant area of impact is the area bounded by the upgrade to the south and the New England Highway to the north. In this area, peak flood level increases are typically 0.11m above the existing conditions. This is a similar order of magnitude to the impacts presented in the Pacific Highway Upgrade F3 to Heatherbrae: Flooding, Drainage and Water Quality Impact Assessment (BMT WBM, 2011). However, there is a small redistribution of the impacts as a result of the rail works and access road, being increased upstream of the access road alignment and decreased downstream. Overall there is no significant increased flood impact resulting from the cumulative consideration of the three proposed developments when compared to consideration of the developments in isolation.

For the 5% AEP event the cumulative impacts of the proposed developments are more pronounced. Upstream of the access road alignment the peak flood level increase is typically 0.16m, being around 0.1m above the impact of either proposed development in isolation. This is a result of the alignment of flood relief culverts through the access road conflicting to some extent with those through the F3 upgrade. Towards the eastern end of the proposed access road flood relief culvert distribution the current F3 upgrade configuration provides no cross drainage at a similar alignment. This reduces the effectiveness of the access road flood mitigation, increasing peak flood levels for the 5% AEP event. However, there would be scope for this cumulative impact to be reduced through a revision of the distribution of flood relief culverts through the F3 upgrade embankment, to provide consistency between the two proposed road developments.

The inclusion of the F3 upgrade results in changes to the peak velocities, corresponding to the redistribution of flood flows across the floodplain relative to the location of flood relief cross drainage structures and bridge openings. This may be an important consideration for the location at which the F3 upgrade would cross over the Train Support Facility works (approximately ch.2800). In this location the peak flood velocities are showing an increase of up to around 2m/s, which would raise local peak velocities to around 3m/s. However, the scale of the regional modelling is not at a resolution to define precise local velocity distributions. Further investigation of this increase may be required to determine the need for any local protection works, if the increased velocities are of concern.



Title:

Impact on Peak 1% AEP Flood Level with Flood Mitigation - Rail Developments, Access Road and F3 Upgrade

Figure: 5-1

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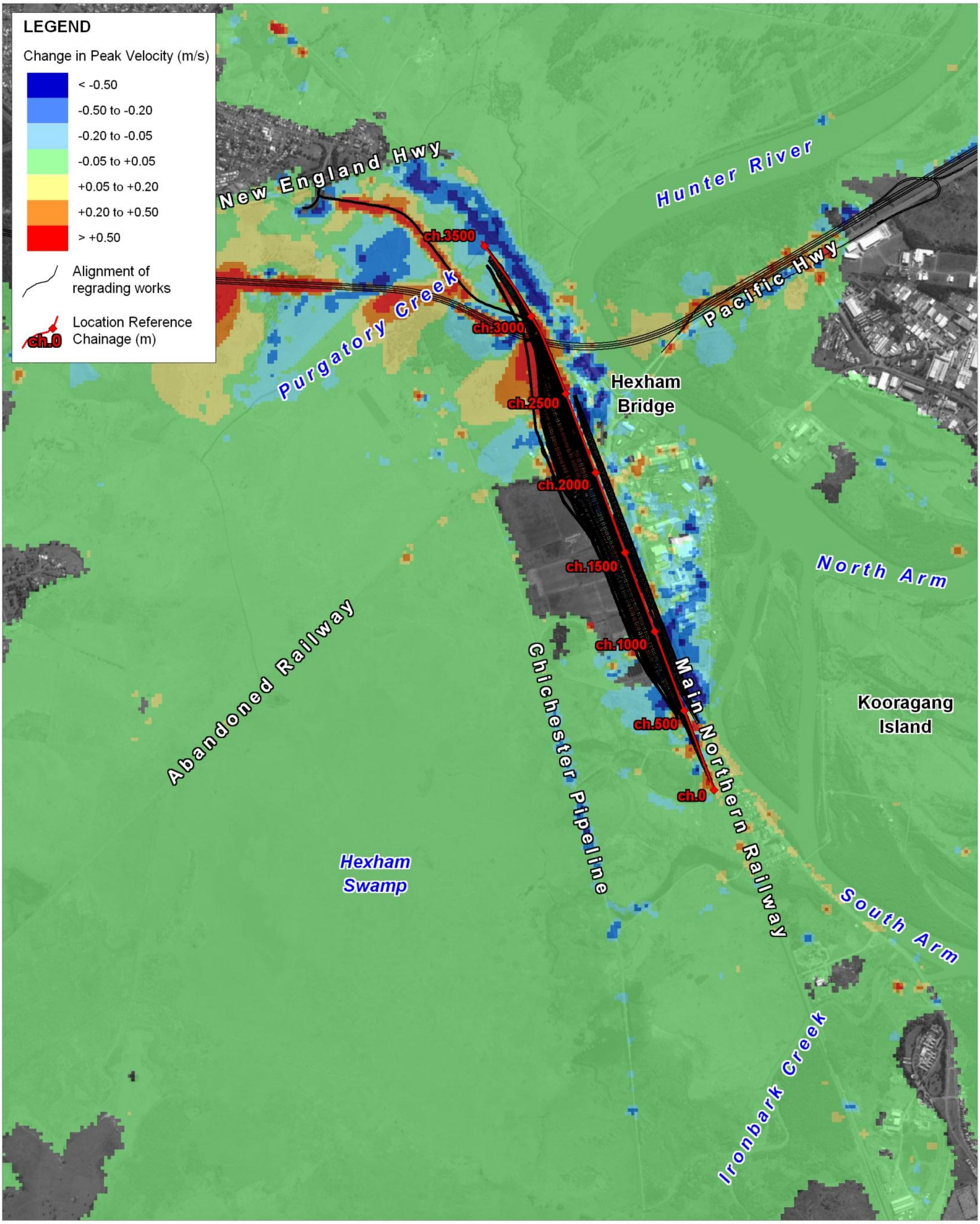

Title:

Impact on Peak 1% AEP Flood Velocity with Flood Mitigation - Rail Developments, Access Road and F3 Upgrade

Figure: 5-2

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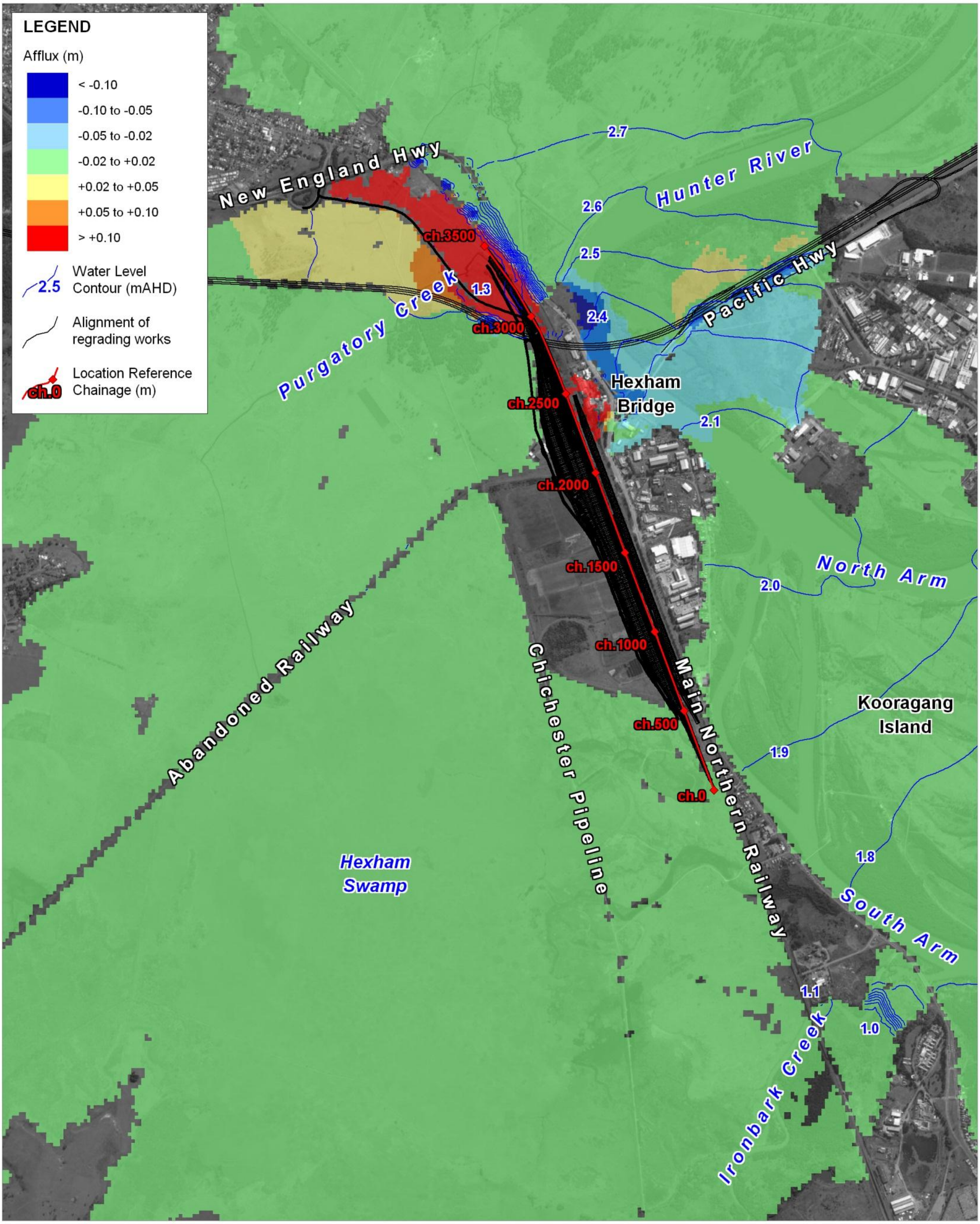

Title:

Impact on Peak 5% AEP Flood Level with Flood Mitigation - Rail Developments, Access Road and F3 Upgrade

Figure: **5-3**

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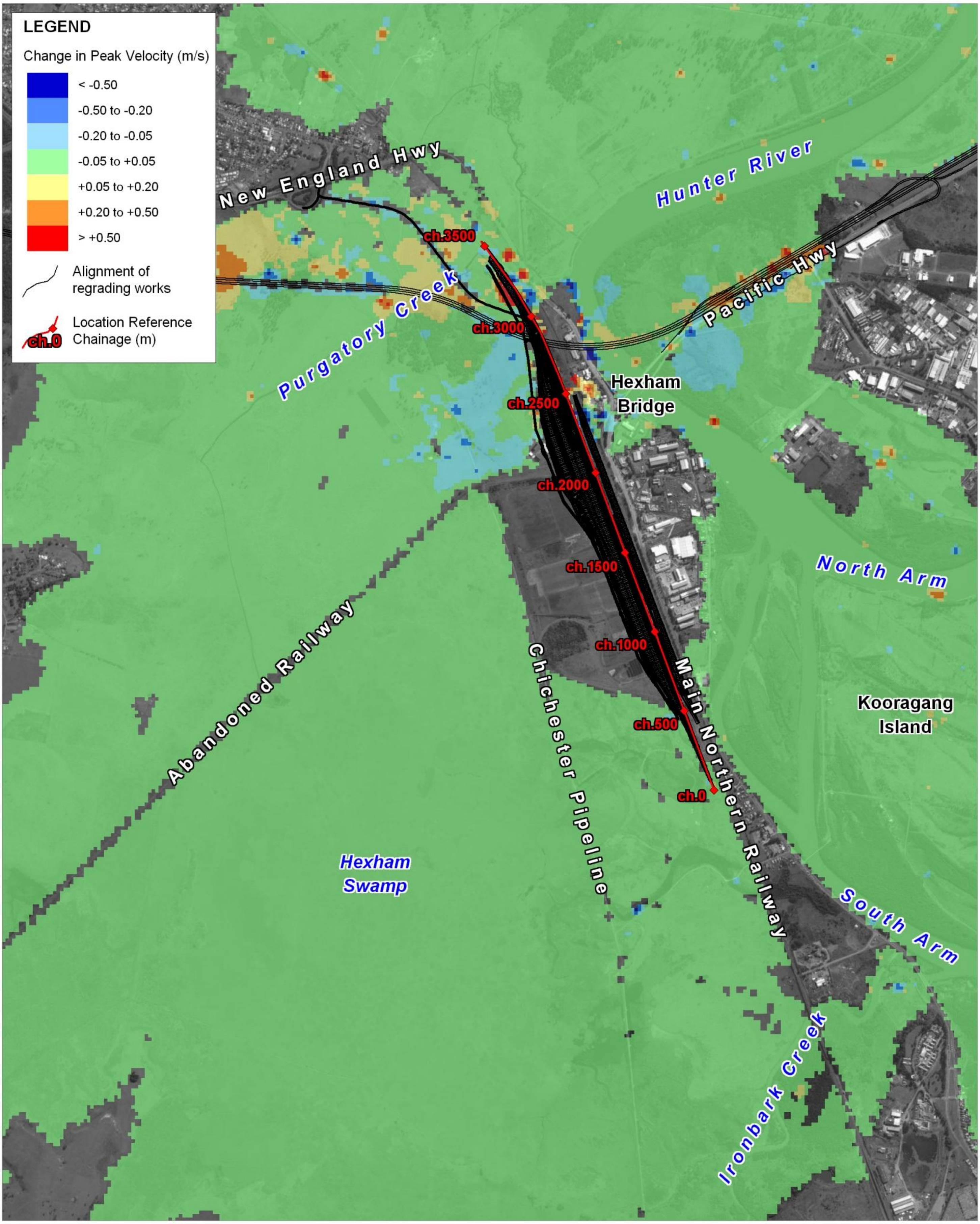

Title:

Impact on Peak 5% AEP Flood Velocity with Flood Mitigation - Rail Developments, Access Road and F3 Upgrade

Figure: 5-4

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6 CLIMATE CHANGE CONSIDERATIONS

The NSW Government recently adopted sea level rise planning benchmarks to ensure consistent consideration of sea level rise in coastal areas of NSW. These planning benchmarks are an increase above 1990 mean sea levels of 0.4m by 2050 and 0.9m by 2100.

To assess the impact these sea level rise scenarios have on the proposed development a sensitivity test on the 1% AEP design event has been undertaken incorporating a 0.9m increase in water level conditions at Newcastle Harbour (model boundary).

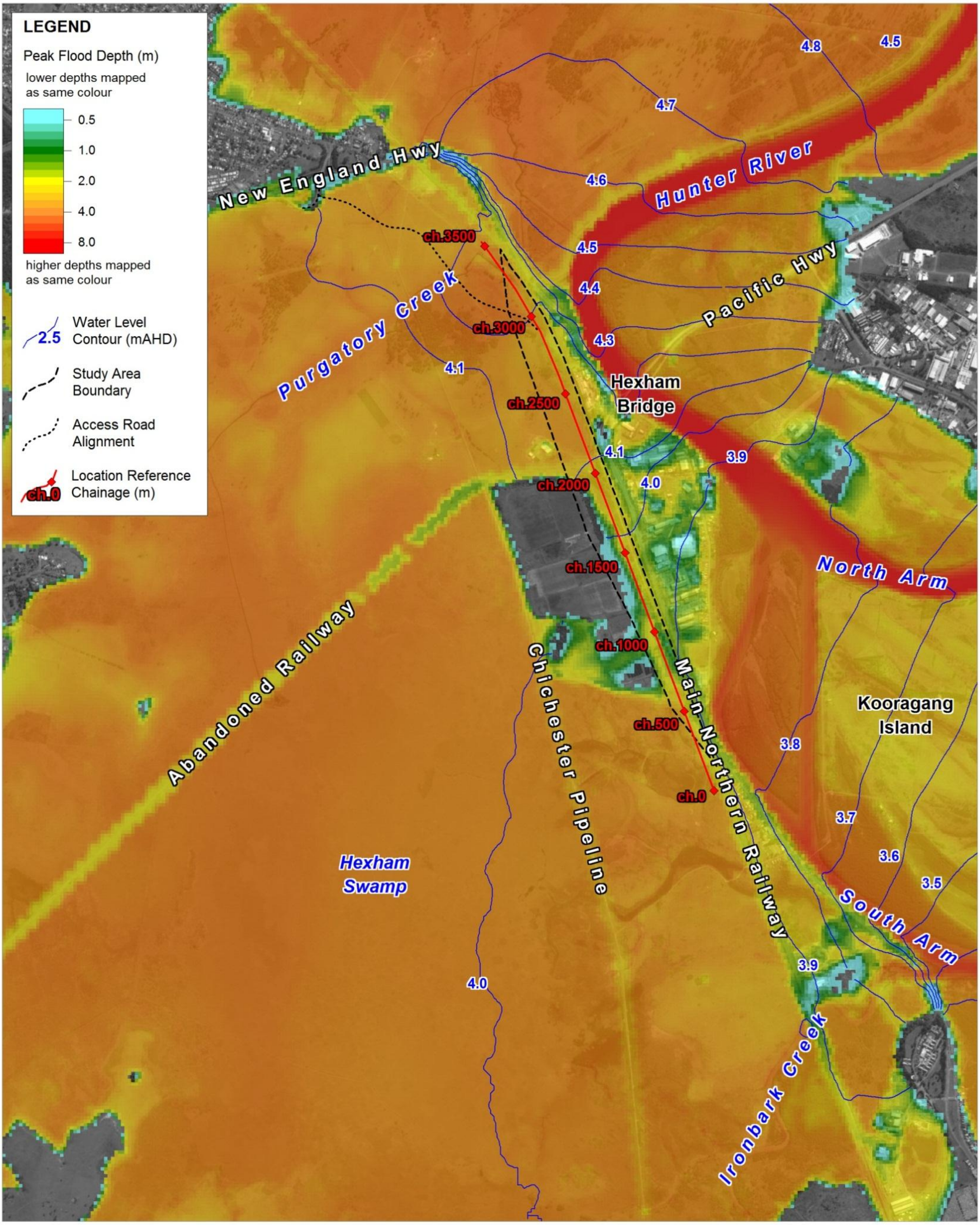
Typically climate change sensitivity tests also consider increases in design rainfall intensity of 10%, 20% or 30% in accordance with DECCW Practical Consideration of Climate Change Guideline for Floodplain Risk Management (2007). An increased rainfall intensity of 10% has been considered for this study, represented as direct increases to the inflow hydrographs, to assess the potential impacts on flood conditions at the development site.

The baseline flood condition at the 2100 planning horizon is shown in Figure 6-1. Typically the increase in peak flood level local to the development site is over 0.4m, raising peak flood levels to around 4.1m AHD.

The cumulative impacts of the proposed train support facility, the Hexham relief roads and the access road (including flood mitigation measures) were assessed under the future climate change conditions for the 2100 planning horizon. The cumulative impacts of the development are presented for peak flood levels in Figure 6-2 and velocities in Figure 6-3.

The cumulative impacts under climate change conditions have also been assessed with the inclusion of the proposed Pacific Highway upgrade from the F3 to Heatherbrae. These cumulative impacts are presented for peak flood levels in Figure 6-4 and velocities in Figure 6-5.

It can be seen from these figures that the flood impacts under future climate change conditions are similar to those modelled under current conditions for the cumulative rail development impacts (refer Figure 4-2 and Figure 4-3) and for the cumulative rail and F3 developments (refer Figure 5-1 and Figure 5-2). Under future climate change the impacts of the developments are typically reduced by around 0.01m to 0.02m throughout Hexham Swamp, but are increased by around 0.01m to 0.02m in the Hunter River upstream of Hexham Bridge.



Title:

1% AEP Peak Flood Depths and Levels - 0.9m Sea Level Rise to 2100 and 10% Increase in Design Rainfall

Figure: 6-1

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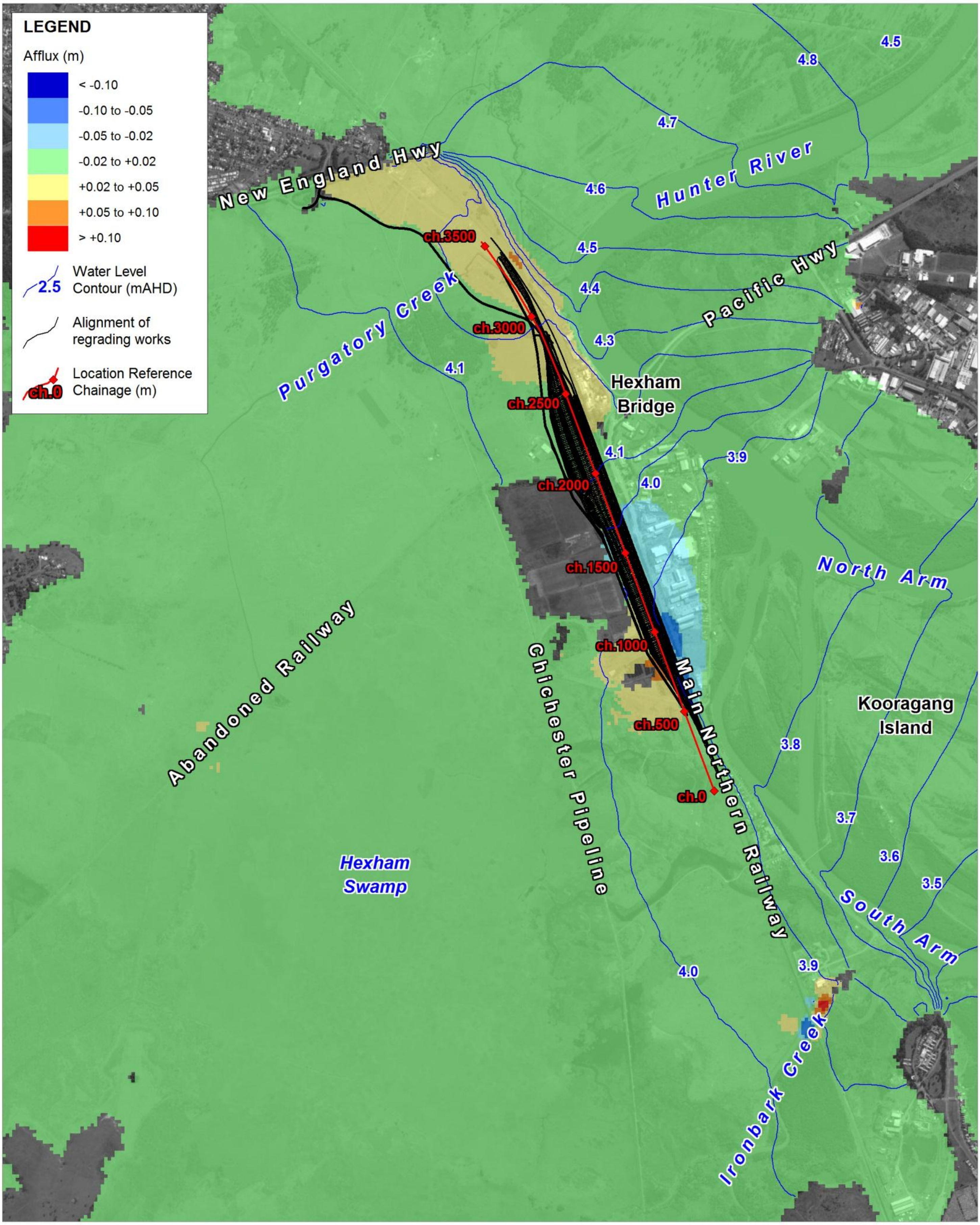

Title:

Impact on Peak 1% AEP Climate Change Flood Level - Rail Developments with Flood Mitigation

Figure: 6-2

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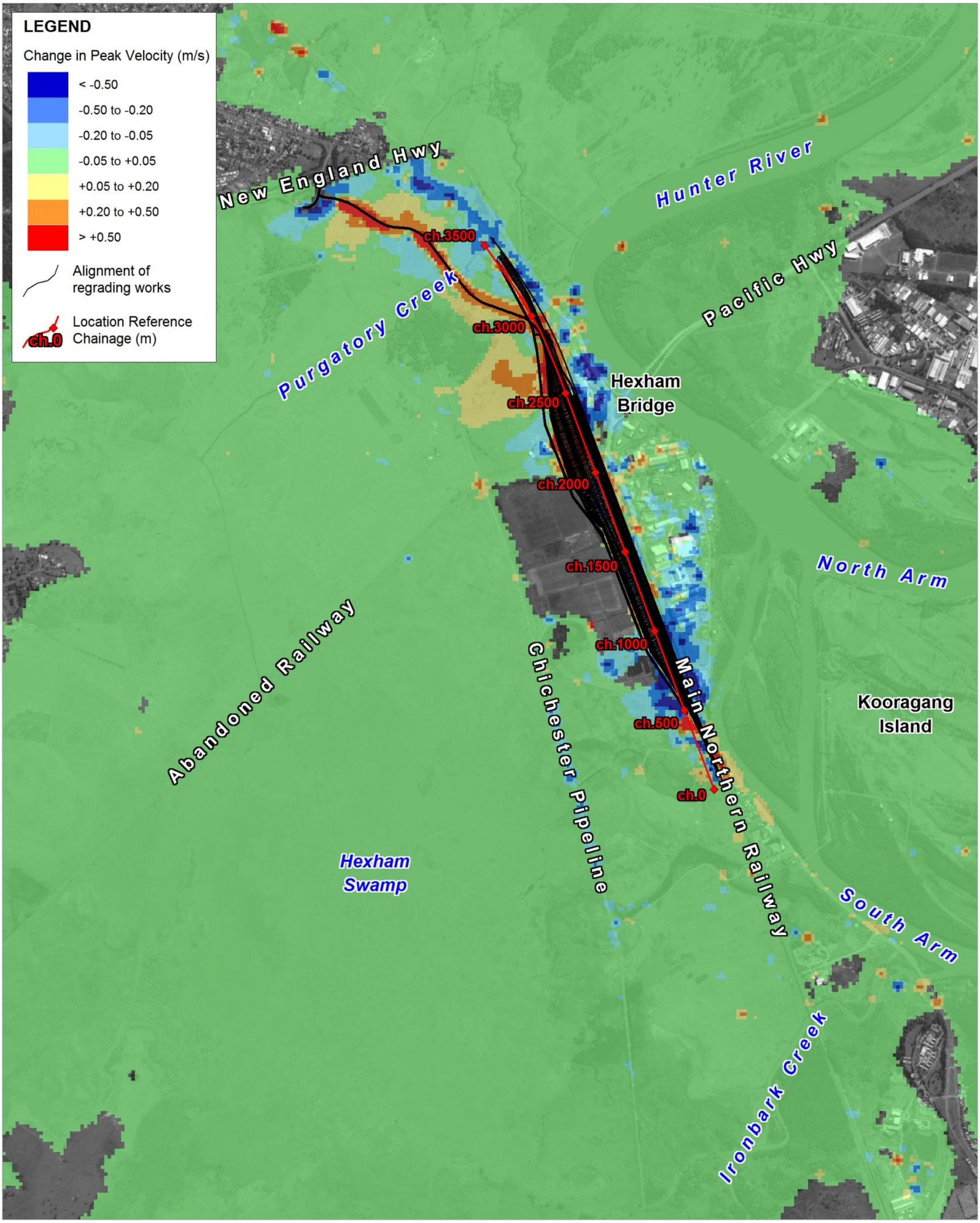

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Impact on Peak 1% AEP Climate Change Flood Velocity - Rail Developments with Flood Mitigation

Figure: 6-3

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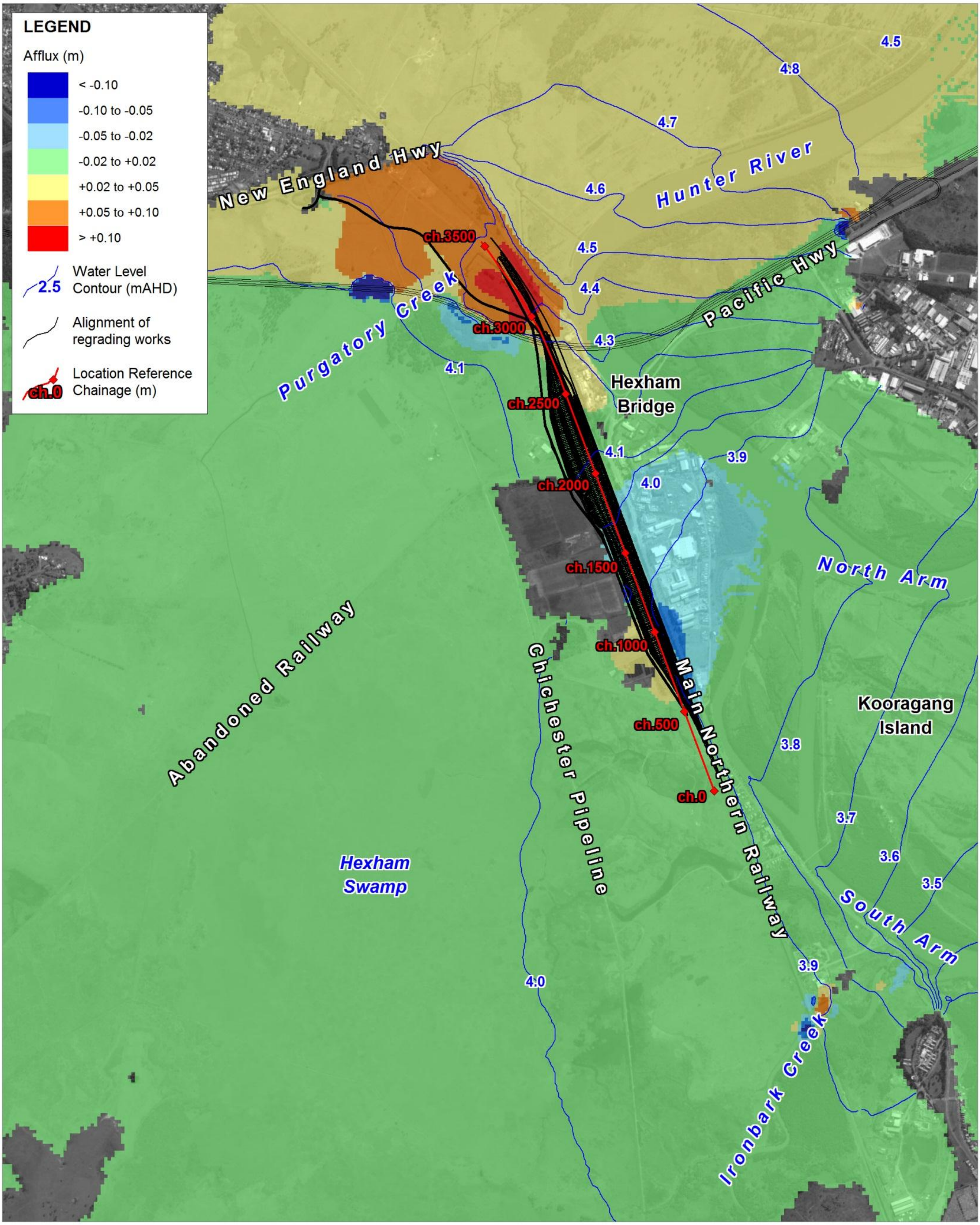

Title:

Impact on Peak 1% AEP Climate Change Flood Level - Rail Developments and F3 Upgrade with Flood Mitigation

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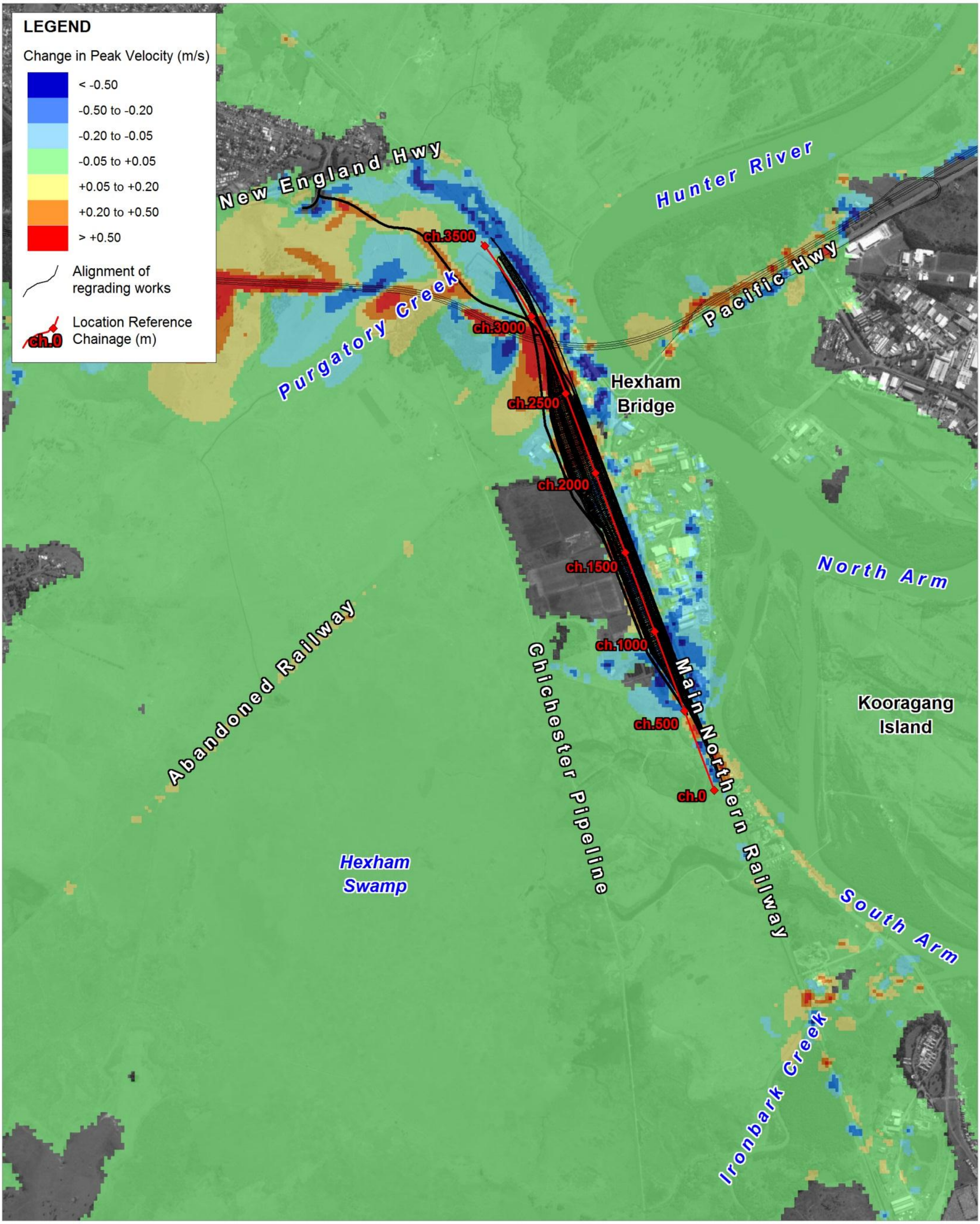

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Impact on Peak 1% AEP Climate Change Flood Velocity - Rail Developments and F3 Upgrade with Flood Mitigation

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7 FLOOD EMERGENCY RESPONSE MANAGEMENT

A Flood Emergency Response Strategy was prepared for the site as part of the original Flood Impact Assessment by WorleyParsons (2011). This strategy has been reproduced in this section. However, certain elements of the original strategy have been modified where appropriate, due to the revised nature of the development and to be consistent with other information presented within this report.

As outlined in the preceding sections, the site that QR National plans to develop at Hexham is located within the floodplain of the lower Hunter River. As a result, there is potential for floodwaters to inundate the QR National site and the surrounding land. In severe floods the depth of inundation across surrounding lands can be substantial. In addition, floodwaters could be at elevated levels for several days. Hence, there is potential for future employees of the Train Support Facility, to be exposed to an increased risk during times of major flooding.

Employee numbers at the Train Support Facility are expected to increase from 10 to around 30 once fully operational. Accordingly, there is a need to recognise that major flooding of the Lower Hunter River and severe floods like the 1955 flood, could present emergency management issues for QR National. Although these developments will be above the predicted peak level for the 2% AEP flood, provisions will need to be made to cater for rarer floods up to the Probable Maximum Flood (PMF). The PMF is the largest flood that could conceivably occur and is of the order of the 0.001% AEP event or greater.

One way of reducing the flood risk is to develop and implement a Flood Emergency Response Plan (FERP). The primary objective of a FERP is to reduce the threat that floods pose to the safety of people living and/or working on or adjacent to flood affected land.

A flood emergency response plan typically consists of the following distinct processes:

- Identification of areas at risk to flooding;
- Forecasting the time, arrival and height of the flood peak;
- Dissemination of warnings to flood prone property owners;
- Flood awareness and education of staff;
- Evacuation of people from areas at risk from flooding; and
- Recovery in the flood aftermath.

From a floodplain and river-wide perspective, these processes are the responsibility of local Councils, the State Emergency Services (SES) and the Bureau of Meteorology.

However, where new development is proposed in areas exposed to high hazard, local and state governments are encouraging individual developers to act independently to minimise their risks due to flooding. Accordingly, it is appropriate for QR National to consider the risks that future employees of the Train Support Facility could be exposed to and to ensure that a mechanism is in place to reduce that risk.

7.1 Background Information

7.1.1 Flood Behaviour in the Hexham Area

Contemporary flood behaviour in the Lower Hunter Valley is influenced by the levees and structures that form part of the Lower Hunter Valley Flood Mitigation Scheme. Higher frequency floods up to the 20% AEP event are generally contained within the river's banks and the levees that form the flood mitigation scheme. As flood severity increases, floodwaters overtop the natural and man-made levees, discharging into low lying storage areas (i.e. backwater swamps) via levee spillways and control banks. During floods larger than the 20% AEP event, floodwaters discharge to floodplain storage areas across spillways located within the levee system.

Hexham is situated on the southern banks of the Hunter River between the main river channel and Hexham Swamp (refer Figure 1-1). During the notorious 1955 flood, floodwaters entered the Swamp across the New England Highway (then Maitland Road) between Hexham Bridge and Tarro. Computer based flood modelling has since confirmed that this flowpath is a major floodway during large floods. The distribution of floodwaters in the Hexham area during a 1% AEP flood (i.e. a 1955 type flood) is shown in Figure 2-2.

Although the New England Highway in the Hexham area has been raised over the last 50 years or so, this floodway has been maintained. Newcastle City Council has dedicated this low lying land between Hexham and Tarro as a flood reserve, classified as floodway in Council's City-wide Floodplain Risk Management Study and Plan (2012)

Nonetheless, floodwaters that overtop the river's banks are not necessarily contained within the defined floodway. In large floods, floodwaters spill out across the floodplain filling Hexham Swamp. In these circumstances, Hexham Swamp, Kooragang Island and Longbight Swamp resemble an inland sea, and most of the existing development in the Hexham area is likely to be at least partly inundated.

In major floods water levels remain in the overbank areas for at least 72 hours. In February 1955, floodwaters reached depths of 4 metres over the floor of the Australian Co-operative Foods plant at Hexham (also known as the Oak Milk Factory), and the Hexham area remained isolated for several days (Hawke, 1958).

7.1.2 Flood Levels

7.1.2.1 Historical Floods

As discussed, the Lower Hunter River, and in particular, the Hexham area, has a long history of flooding. The major floods that have occurred in the Hunter over the last 50 years are listed in Table 7-1, along with the corresponding peak water level at Hexham, and the estimated annual exceedance probability for each event.

The largest flood at Hexham since completion of the Lower Hunter Flood Mitigation Scheme occurred in 1978. This flood reached a peak water level at Hexham of about 2.0m AHD.

Table 7-1 Characteristics of Historical Floods at Hexham

Year of Flood	Peak Water Level at Hexham (m AHD)	Approximate Flood Probability at Hexham
1955	3.8	1% AEP
1971	1.6	>10% AEP
1972	1.6	>10% AEP
1977	1.8	10% AEP
1978	2.0	>5% AEP
1985	1.6	>10% AEP
1990	1.6	>10% AEP
2007	1.7	>10% AEP

7.1.2.2 Design Floods

Peak flood levels at Hexham for floods of varying degrees of severity are listed in Table 7-2.

Table 7-2 Design Flood Levels for Hexham

Design Flood	Peak Flood Level at Hexham Bridge (m AHD)
PMF	8.0
1% AEP	3.8
2% AEP	2.9
5% AEP	2.3
10% AEP	1.9

7.1.3 Potential Flooding Mechanisms

7.1.3.1 Historical Floods

Based on the history of flooding in the Hexham area, there are two potential flooding mechanisms that could cause inundation of the QR National development site. These are:

- Overtopping of the banks of the Hunter River upstream of Hexham Bridge and discharge across the New England Highway and into Hexham Swamp; and
- Backwater flooding due to filling of Hexham Swamp by floodwaters overtopping the Pacific Highway downstream of Hexham Bridge.

7.1.3.2 Bank Overtopping During Mainstream Flooding

Flooding at Hexham would typically be due to mainstream Hunter River floods overtopping the river bank upstream of Hexham Bridge. As discussed above, floodwaters from the Hunter River flow in a south-westerly direction towards the New England Highway where they cross the floodplain between Tarro and Hexham.

Investigations into the impact of raising the level of the New England Highway between Tarro and Hexham established that the road, which is higher than the general level of the floodplain, controls the discharge of floodwaters south from the Hunter River into Hexham Swamp. The Main Northern Railway, which is located about 100 metres west of the New England Highway in this area, acts as a secondary control on floodwaters entering the Swamp.

Longitudinal profiles of the New England Highway between Hexham and Tarro indicate that the low point in the road is located about 900 metres north of Hexham Bridge (see Figure 7-1). Available RTA drawings indicate that the road crest at this low point is at an elevation of around 2.1 mAHD.

Therefore, the Hunter River immediately upstream of Hexham Bridge, would begin to overtop the New England Highway once floodwaters reached an elevation of about 2.1 mAHD (see Figure 7-1).

Based on the design flood levels listed in Table 7-2, a flood slightly more severe than the 10% AEP event at Hexham would be required to cause overtopping of this section of the New England Highway. Nonetheless, for the purposes of emergency response planning, it can be conservatively assumed that a 10% AEP flood is required before overtopping of the highway upstream of Hexham Bridge, would occur.

7.1.3.3 Backwater Overtopping During Mainstream Flooding

Hexham Swamp can also be flooded when the Pacific Highway south of Hexham Bridge is overtopped. This would require the swampland between the Pacific Highway and the Great Northern Railway to fill and floodwaters to 'back-up' upstream, leading to inundation of the Hexham area.

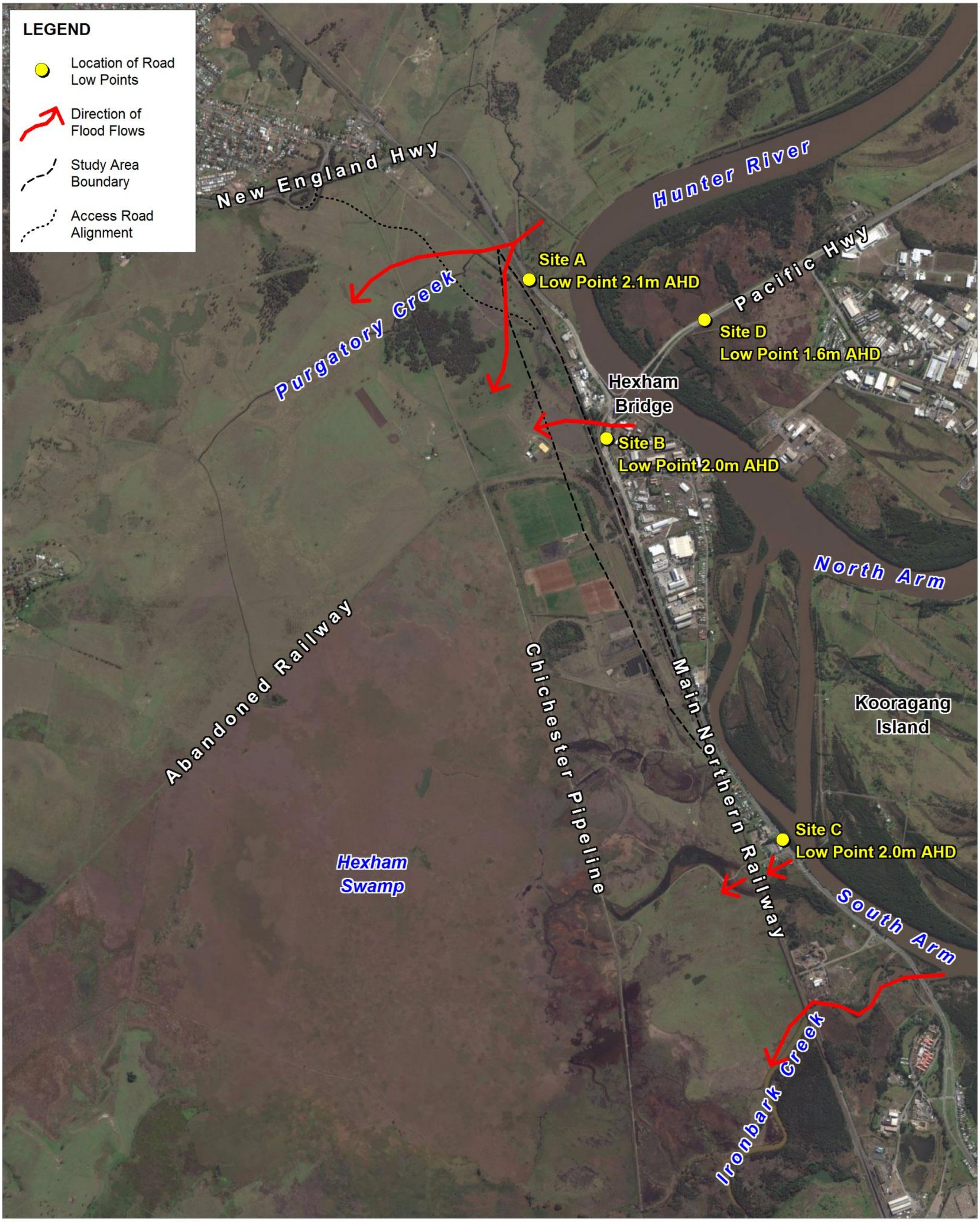
As shown in Figure 7-1 the Pacific Highway between Hexham Bridge and Sandgate forms a barrier between the South Arm of the Hunter River and Hexham Swamp. The road surface along this stretch of the highway is higher than most of Hexham Swamp. However, for drainage purposes, there are a number of low points along the road across which floodwaters can spill from the South Arm into the Swamp.

Available elevation information for this section of the highway indicate that low points occur at the locations listed in Table 7-3 and highlighted in Figure 7-1**.**

Table 7-3 Overtopping of the Pacific Highway Between Tarro and Sandgate

Low Point (see Fig 7-1)	Description of Low Point Location	Road Surface Level (m AHD)	Approximate Probability of Flood Required to Cause Overtopping
A	Along the New England Highway about 900m north of Hexham Bridge	2.1	10% AEP
B	Intersection of New England Highway & Pacific Highway (at Hexham Bridge)	2.0	5% AEP
C	Intersection of Pacific Highway & Shamrock Street	2.0	2% AEP

Based on this information, floodwaters would first overtop the Pacific Highway at Hexham Bridge (*i.e., Site B in* Figure 7-1). Floodwaters would need to reach a level of around 2.0 mAHD before overtopping would occur.



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Potential Flooding Mechanisms in the Vicinity of Hexham

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Computer modelling shows that a flood of around a 5% AEP event would be required to cause flooding to this level in the vicinity of Hexham Bridge.

Overtopping of the Pacific Highway would next occur near the intersection with Shamrock Street (*i.e., Site C in* Figure 7-1). The road surface at this location is around 2.0 mAHD. Computer modelling shows that a flood of almost a 2% AEP would be required to cause flooding to this level at this location.

7.1.3.4 Critical Flooding Mechanism

The data presented above shows that around a 10% AEP flood is required to cause overtopping of the New England Highway immediately north of Hexham. A flood of greater severity is required to cause overtopping of the Pacific Highway downstream of Hexham Bridge.

Therefore, overtopping of the New England Highway will occur first, and be the critical flooding mechanism that would lead to the onset of flooding across the QR National Site.

7.1.4 Flood Warning Times

The issuing of flood warnings in the Hexham region is the responsibility of the Lower Hunter Division of the State Emergency Services (*SES*). At present flood warnings and estimates of the time of arrival of the flood peak are based on floodwater levels at gauges located upstream at Maitland and Greta. Typically, water levels at these gauges are communicated to the Lower Hunter headquarters of the SES, where they are compared with stage hydrographs for recorded floods. There is no telemetered flood forecasting and warning system in existence for the downstream reaches of the Lower Hunter.

In order to determine indicative flood warning times for the Hexham area, the lag time between flood peaks at key locations across the Lower Valley were determined for a range of recorded and 'design' floods. The lag times were estimated using the MIKE 11 flood model that was developed for the 1994 Flood Study and are summarised in Table 7-4.

These flood warning times can be used to estimate the time of arrival of the peak of a flood at Hexham. As outlined in the *Newcastle Flood Plan,* the SES conveys flood information via Flood Bulletins that are distributed to local radio and television stations. These bulletins advise the general severity of flooding, as well as the current and expected peak flood level at key locations such as Maitland and Raymond Terrace. Unfortunately, the SES does not give flood level projections for areas downstream of Raymond Terrace due to the potential influence of the tide on peak flood levels.

The data contained in Table 7-4 can be used to understand approximate lag times for the arrival of the flood peak at Hexham. It can be seen that for large flood events a lag time of around 20 hours or more can be expected between the flood peak passing Maitland and arriving at Hexham. Flood warnings issued by the Bureau of Meteorology (BoM) and the State Emergency Service (SES) are given 24 hours in advance for Singleton and Maitland. This provides sufficient warning of more than a day in advance of when Hexham Swamp is likely to be inundated by Hunter River flood waters. However, it should be recognised that no two floods are the same, and therefore, any interpretation of the data contained in Table 7-4 to predict the arrival of the flood peak should be superseded by advice from the SES, when received.

Table 7-4 Lag Time Before Modelled Peak Flood Level Reaches Hexham

Location	Lag Time (hrs)				
	1% AEP Event	2% AEP Event	5% AEP Event	10% AEP Event	1955 Flood *
Maitland (Belmore Bridge)	29	21	20	18	20 (31)
Hinton (Paterson confluence)	11	13	12	16	6 (9)
Green Rocks	6	7	8	8	5 (5)
Raymond Terrace	3	2	3	5	2 (1)

* The bracketed values represent actual recorded lag time for the 1955 flood. This shows that the computer modelling only provides indicative estimates of lag times and that contemporary flood behaviour may differ to that experienced during actual floods.

7.2 Flood Evacuation

Given the length of flood warning time of one or two days available at the site, evacuation from the site during a flood event should not be a likely situation to occur. When a major flood warning for the Lower Hunter River is issued by BoM or the SES then Train Support Facility staff should be advised not to enter the site. This would prevent the staff from being placed at risk from any potential flooding of the site. However, in the event of flood warning information not being communicated to staff or other potential visitors to the Train Support Facility site, it is necessary to understand how the site should be evacuated during the onset of flooding.

Although flooding at Hexham is not serious until floodwaters rise to above the level of the 2% AEP event, many of the potential evacuation routes from the area could be cut before this level is reached. Therefore, it is important for any Flood Emergency Response Plan for the QR National Site to consider the potential evacuation routes for safe independent evacuation of employees and visitors.

7.2.1 Potential Evacuation Routes

During major floods there are three vehicular routes available for independent evacuation from the Hexham area (see Figure 7-2). These evacuation routes all connect Hexham to 'high ground' with an elevation of at least 10 mAHD, which is well above the peak flood level estimated for the PMF. Each potential evacuation route is listed in Table 7-5 on the following page along with the distance to 'high ground'.

Although Woodlands Close and the proposed access road will have a road crest level that is relatively low, floodwaters cannot overtop the New England Highway and discharge along the Hexham Swamp floodway and across these routes until peak river levels reach at least 2.0 mAHD. Therefore, the low points along Woodlands Close or the proposed access road are not the critical control for evacuation from the QR National Site. Floodwaters must firstly overtop the New England Highway or the Pacific Highway at one of the low points identified in Figure 7-1 before floodwaters can inundate either site access route.

Table 7-5 Primary Vehicular Evacuation Routes

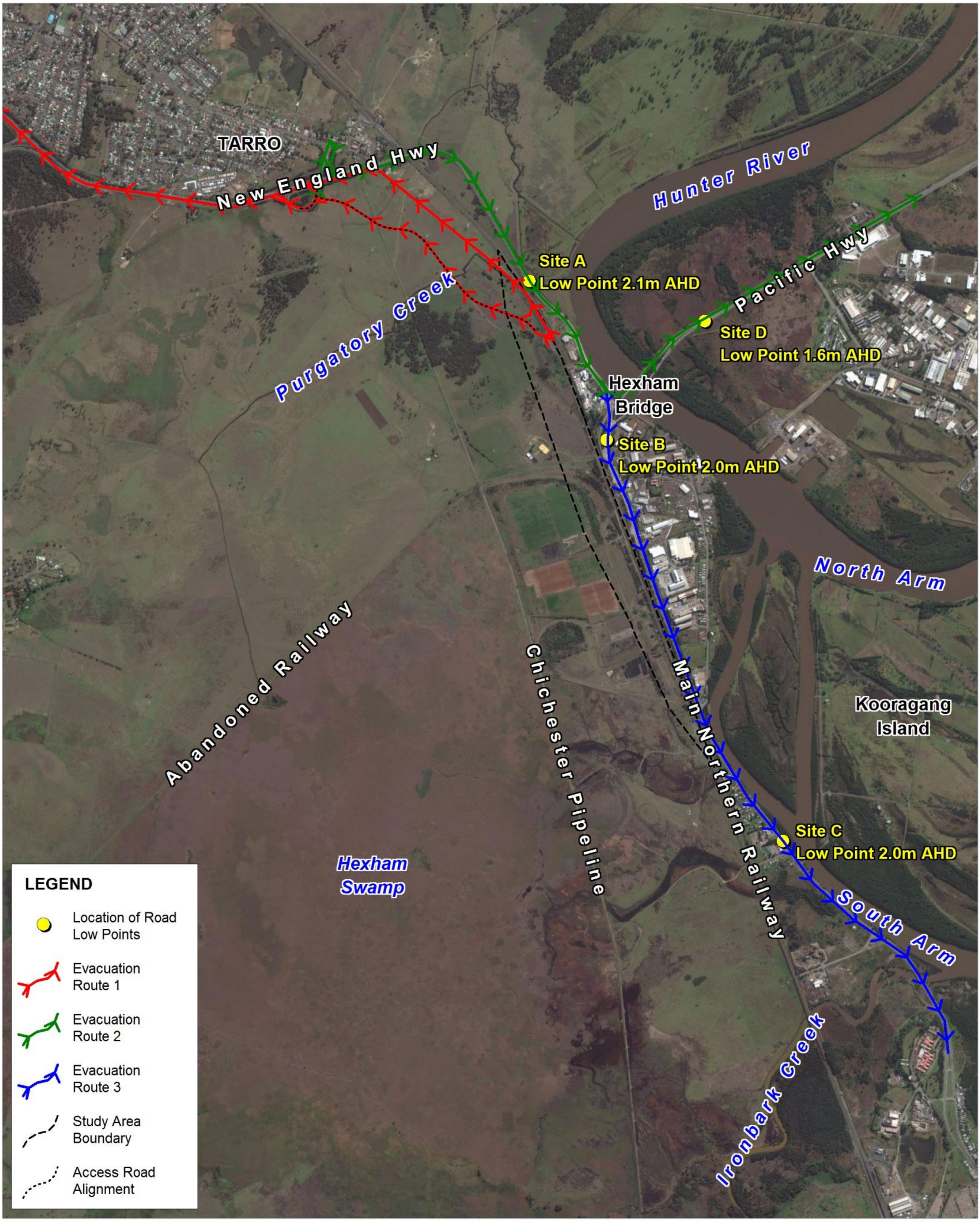
Route	Evacuation Route Description	Distance to 'High Ground' (km)	Lowest Point Along Route (m AHD)
1	Along Woodlands Close or the proposed access road to Tarro and then north-west along the New England Highway toward Thornton	3.5	1.1 (Woodlands Close or proposed access road)
2	Along Woodlands Close or the proposed access road to Tarro and then south along the New England Highway to Hexham and then along the Pacific Highway to Sandgate	9.0	1.1 (Woodlands Close or proposed access road) 2.0 (Pacific Highway)
3	Along Woodlands Close or the proposed access road to Tarro, then south along the New England Highway to Hexham, across the Hexham Bridge and then north-east along the Pacific Highway to Tomago	6.5	1.1 (Woodlands Close or proposed access road) 1.6 (Pacific Highway)

In a 10% AEP event floodwaters would largely not overtop the highways or would be at a shallow depth at each of Sites A, B and C (see Figure 7-1 and Figure 7-2) and would not impede vehicular traffic. In floods of 5% AEP, the water depths at sites A and B would be about 0.5m and 0.1m, respectively. Floodwaters are considered unsafe for vehicular traffic to negotiate once the product of the velocity (*v*) and depth (*d*) of floodwaters exceeds about 0.4. Computer modelling shows that floodwaters would be safe for vehicular traffic at site B, but unsafe for vehicular traffic at point A.

The Pacific Highway north-east of Hexham Bridge (*low point Site D*) would be covered by floodwaters to a depth of 0.4 metres in a 10% AEP flood. Computer modelling shows that when the river breaks its banks upstream of Hexham Bridge on the Tomago (*northern*) side, a portion of the flow travels overland and across the Pacific Highway between the northern bridge abutment and the high ground at Tomago. This evacuation route is therefore considered unsafe for evacuation once flood levels in the Hexham area reach 2m AHD and major flooding of Hexham Swamp begins.

7.2.2 Evacuation Timing

As discussed previously, at least a day or more of warning time should be available before the onset of flooding to the proposed development site. It is therefore unlikely that the situation should arise where an urgent emergency evacuation of the site is required. However, once the flood level in the Hunter River rises above the New England Highway at Hexham, the Swamp can fill to a level of over 2m AHD within a few hours and begin inundating the study site. It is therefore essential that if people are on the site at the onset of flooding to Hexham Swamp, that they begin evacuation immediately.



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Potential Evacuation Routes from Hexham

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7.3 Suggested Emergency Response Measures

7.3.1 Procedures to Facilitate Evacuation

The response of the flood affected community to flood warnings is probably the single-most important factor that determines the effectiveness of a 'flood emergency response system' (*Australian Water Resources Council, 1992*). The successful implementation of emergency response measures is highly dependent on the flood awareness of the community resident in the floodplain and the local work force, and on their knowledge of the protocols that need to be followed during a major flood.

The information presented in the preceding sections indicates that there is sufficient time for the Train Support Facility workforce to relocate to higher ground or allocated flood refuge centres during the onset of a major flood.

Flood education and emergency response training will need to be undertaken for the Train Support Facility workforce. This should include the identification of flood wardens and staff responsible for relocating stock and equipment so that it is not damaged during a major Hunter River flood. Flood awareness workshops for employees should also be held at regular 6 month intervals to allow for staff turnover.

The key to ensuring the safety of the workforce in times of major flooding will be the dissemination of flood intelligence during the onset of a major flood so that they can take advantage of the warning time that is available. This can occur through interpretation of Bureau of Meteorology Flood Bulletins and SES flood warnings.

7.4 Procedures for Reducing Impacts and Potential Flood Damages on Development

The Train Support Facility will comprise buildings that are to be constructed with floor levels that are approximately equivalent to the predicted peak 2% AEP flood level. Accordingly, it is recognised that the Facility could be inundated during a major flood of the order of the 1955 flood and that there is potential for flooding of this magnitude to cause damage to components of the Facility.

However, as outlined in 4.2.5 of this report, velocity depth products across the Hexham floodplain during major flood events are typically low and are therefore, unlikely to result in structural damage to components of the Facility infrastructure. Furthermore, QR National plans to construct the Facility using flood compatible materials in accordance with the guidelines outlined in the NSW Government's *'Floodplain Development Manual'* (*2005*). This would include the siting of power facilities at a suitable freeboard above the design 1% AEP flood.

In addition, the analysis documented in the preceding sections indicates that a flood warning time of around one to two days is available. Accordingly, there would be ample time for Train Support Facility staff to relocate stock and equipment to areas above the predicted peak level of the oncoming flood. There would also be opportunity for rolling stock to be relocated to higher ground further up the valley.

8 CONCLUSIONS

The objective of the study was to undertake a detailed flood impact assessment of the proposed cumulative development on Hunter River flood conditions. Central to this was the application of a two-dimensional hydraulic model of the Hunter River floodplain developed as part of the Williams River Flood Study (BMT WBM, 2009) and updated for the Williamtown / Salt Ash Flood Study Review (BMT WBM, 2011) for Port Stephens Council.

Specifically the modelling undertaken for the proposed cumulative development aimed to:

- Confirm existing flooding conditions across the site including flood levels, flows and velocities to establish baseline conditions for impact assessment;
- Identify the potential flood impacts of the proposed cumulative developments of the Hexham Train Support Facility, Relief Roads and access road for a range of design flood magnitudes; and
- Consider the potential cumulative flood impacts of development with the RMS Pacific Highway upgrade from the F3 to Heatherbrae.

The results of the modelling and flood impact assessment have confirmed:

- Peak 1% AEP flood levels for existing conditions are estimated to vary from 3.7m AHD at the northern end of the site to 3.5m AHD at the southern end;
- The majority of the proposed development would be subject to significant inundation in major flood events where typical 1% AEP flood depths across the site are of the order of 1.5 – 3.0m;
- Corresponding peak flow velocities for the 1% AEP event under existing conditions are typically of the order 0.5m/s, but locally higher;
- The site is located within an area of high hazard flood storage, which has implications for safety considerations;
- The site is to be raised to a level above that of the 2% AEP flood level but largely below the 1% AEP flood level;
- Local increases in peak flood level of up to 0.1m upstream of the proposed access road alignment are simulated for the 2% AEP event with peak flood level increases of less than 0.05m being typical for other design events;
- Elsewhere localised increases in peak flood level can be addressed through adequately designed cross drainage infrastructure and additional mitigation works;
- Localised increases in peak flood velocity at the northern end of the rail developments and along the access road may require consideration in terms of protecting the infrastructure from potential flood damage;
- The cumulative impacts of the proposed rail developments and access road with the proposed F3 upgrade upgrade show no significant additional flood impacts to those when considering the developments in isolation for the 1% AEP event; and
- The cumulative assessment of the proposed access road and F3 upgrade show an increased flood impact for the 5% AEP event. However, there is scope to reduce this by considering the distribution of flood relief culverts for the two developments together, rather than in isolation.

9 REFERENCES

BMT WBM (2009) *Williams River Flood Study*

BMt WBM (2011) *Hexham Relief Roads Flood Impact Assessment*

BMT WBM (2011) *Pacific Highway Upgrade – F3 to Heatherbrae: Flooding, Drainage and Water Quality Impact Assessment*

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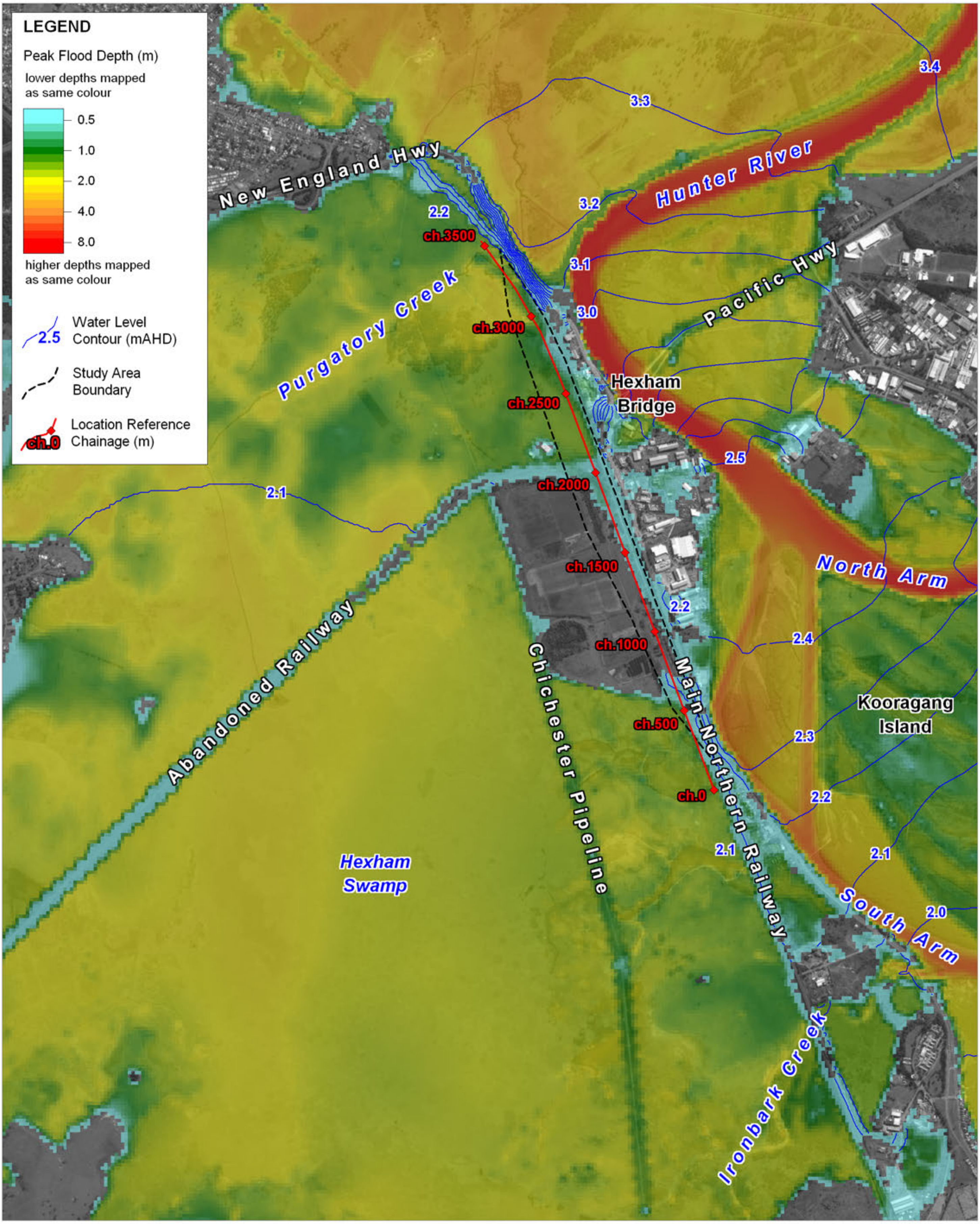
PWD (1994) *Lower Hunter River Flood Study – Green Rocks to Newcastle*

WorleyParsons (2011) *Hexham Redevelopment Project Incorporating a Train Support Facility, Industrial Subdivision and Intermodal Facility – Flood Impact Assessment*

APPENDIX A: FLOOD MAPS FOR EXISTING CONDITIONS



Title:

2% AEP Peak Flood Depths and Levels - Existing Conditions

Figure: **A-1**

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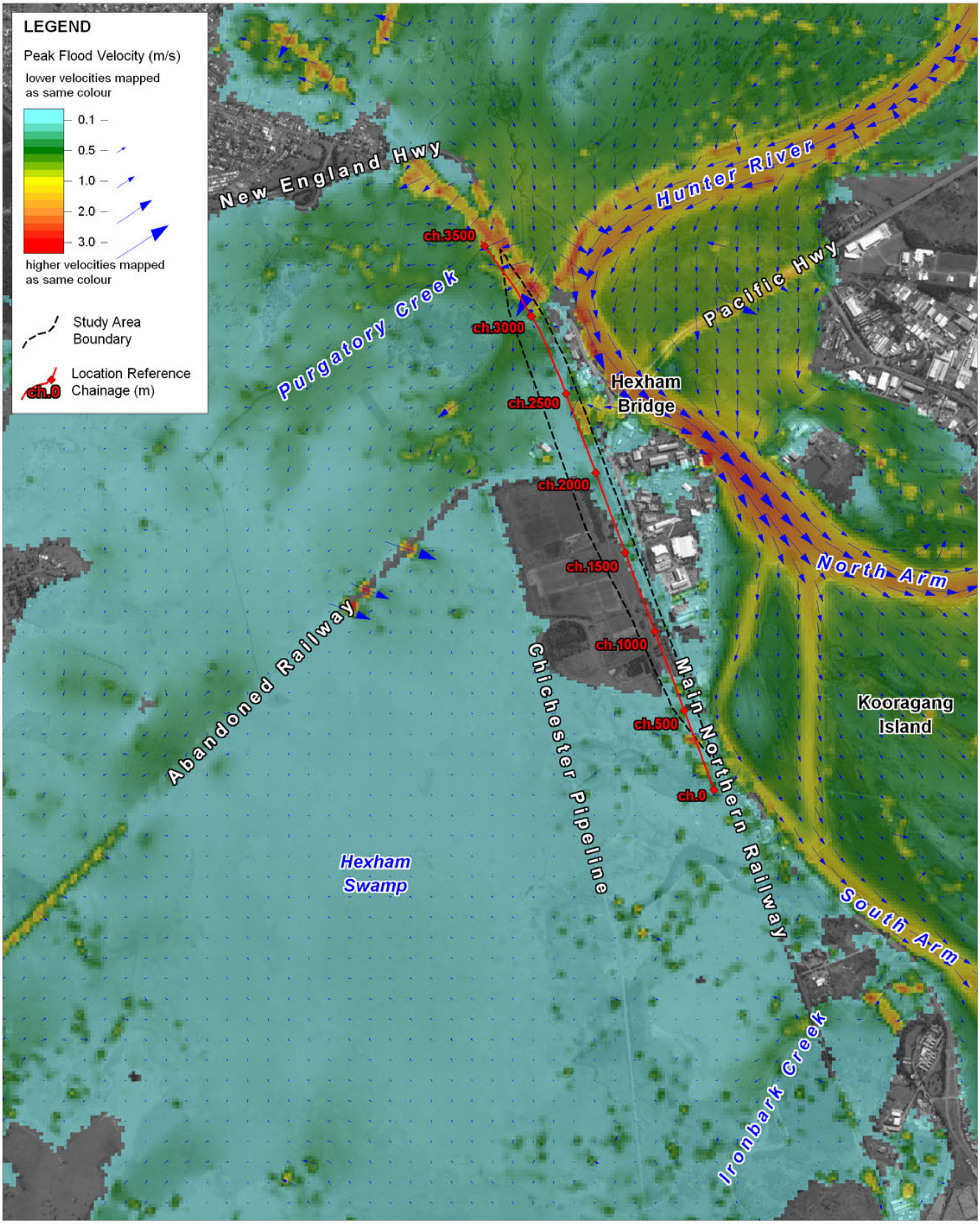

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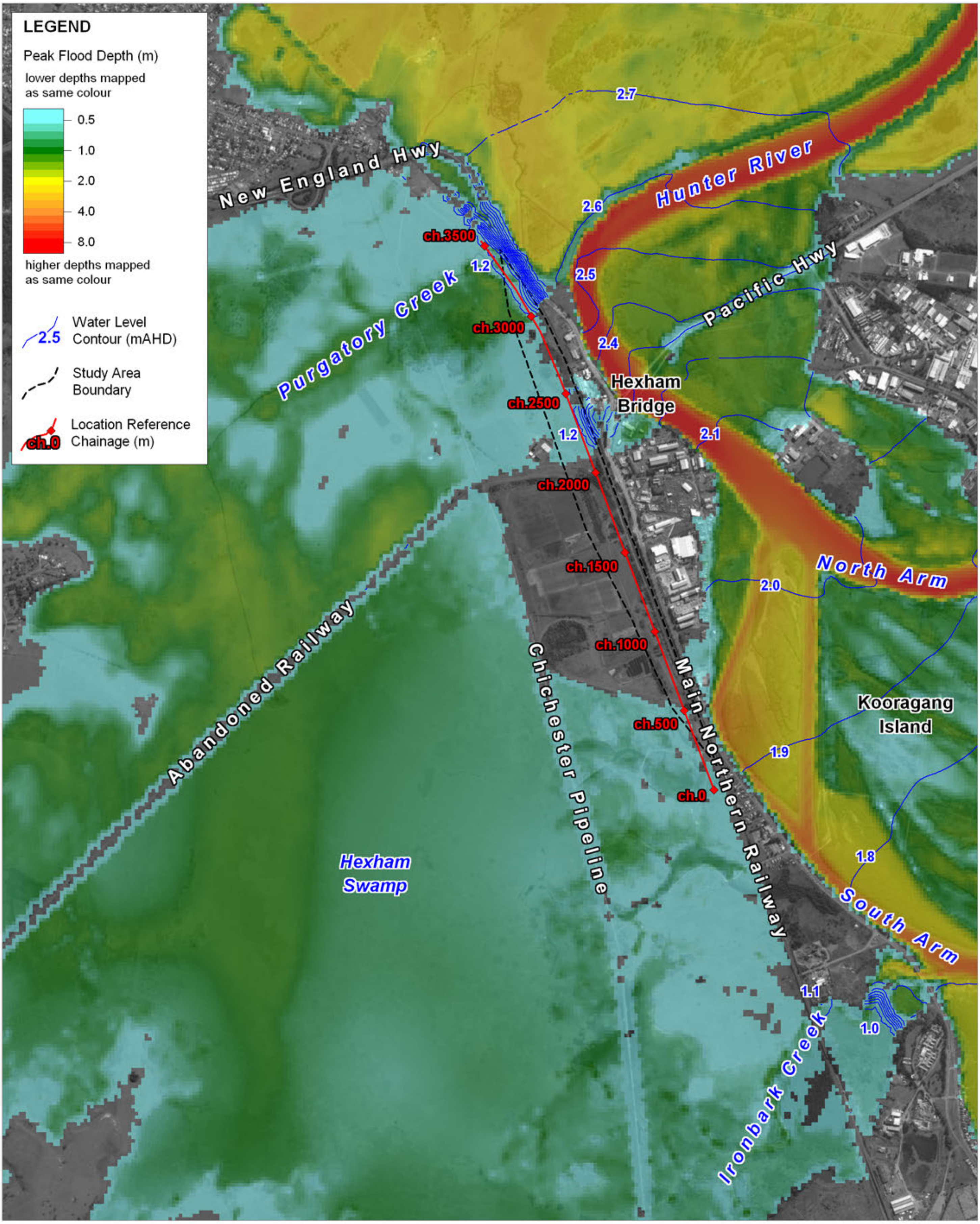

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5% AEP Peak Flood Depths and Levels - Existing Conditions

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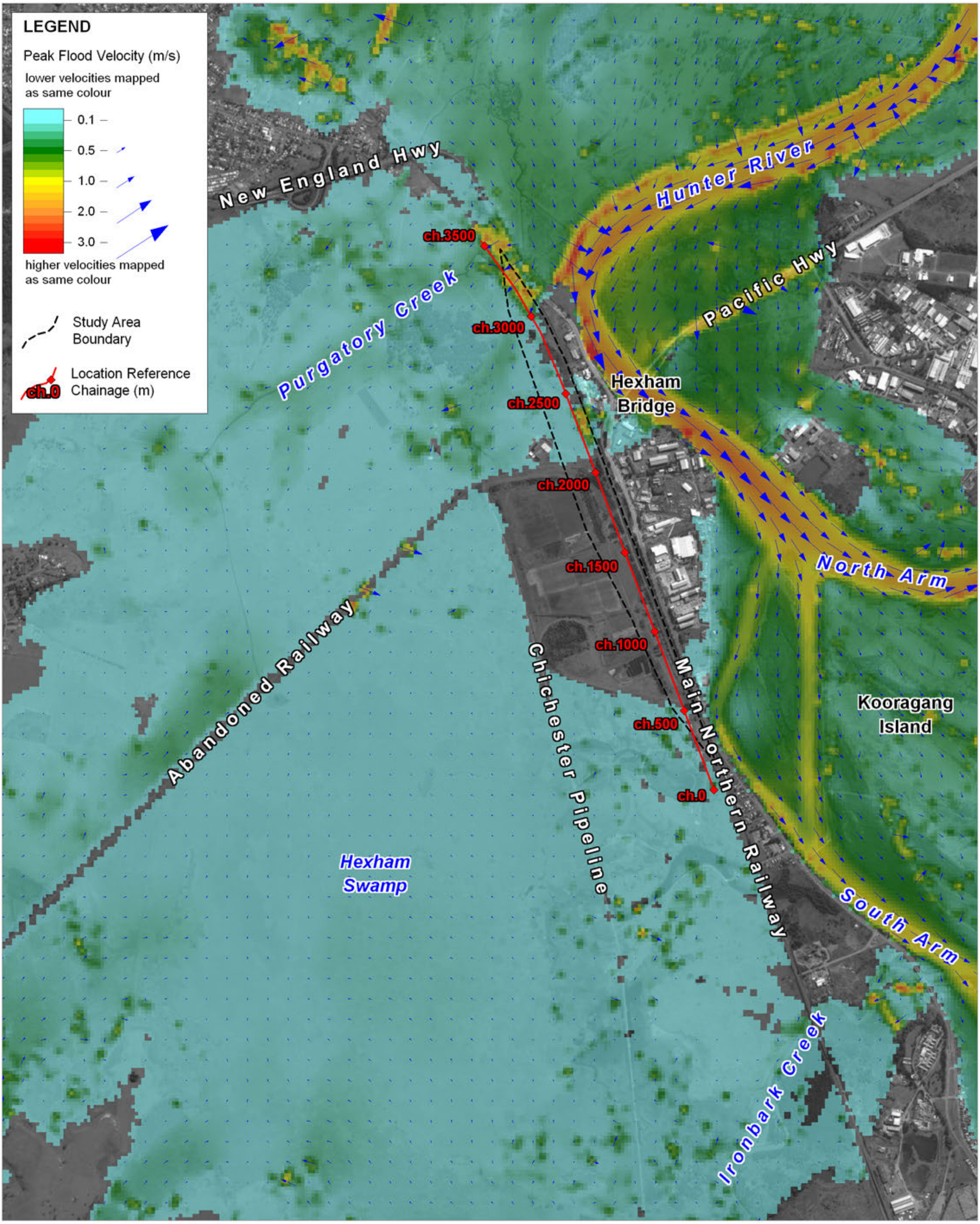

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5% AEP Peak Flood Velocities - Existing Conditions

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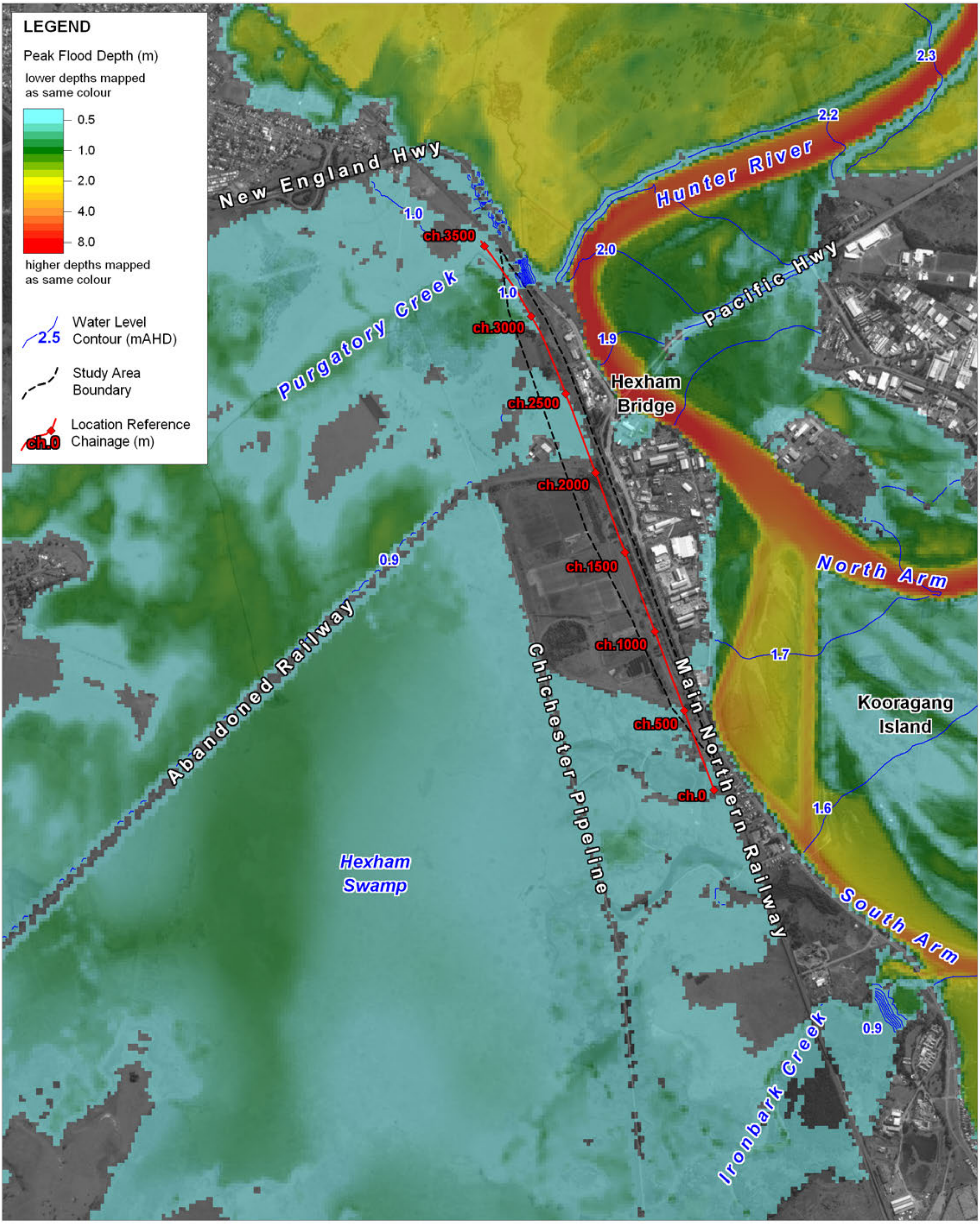

Title:

10% AEP Peak Flood Depths and Levels - Existing Conditions

Figure: A-5

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 0.5 1km

Approx. Scale

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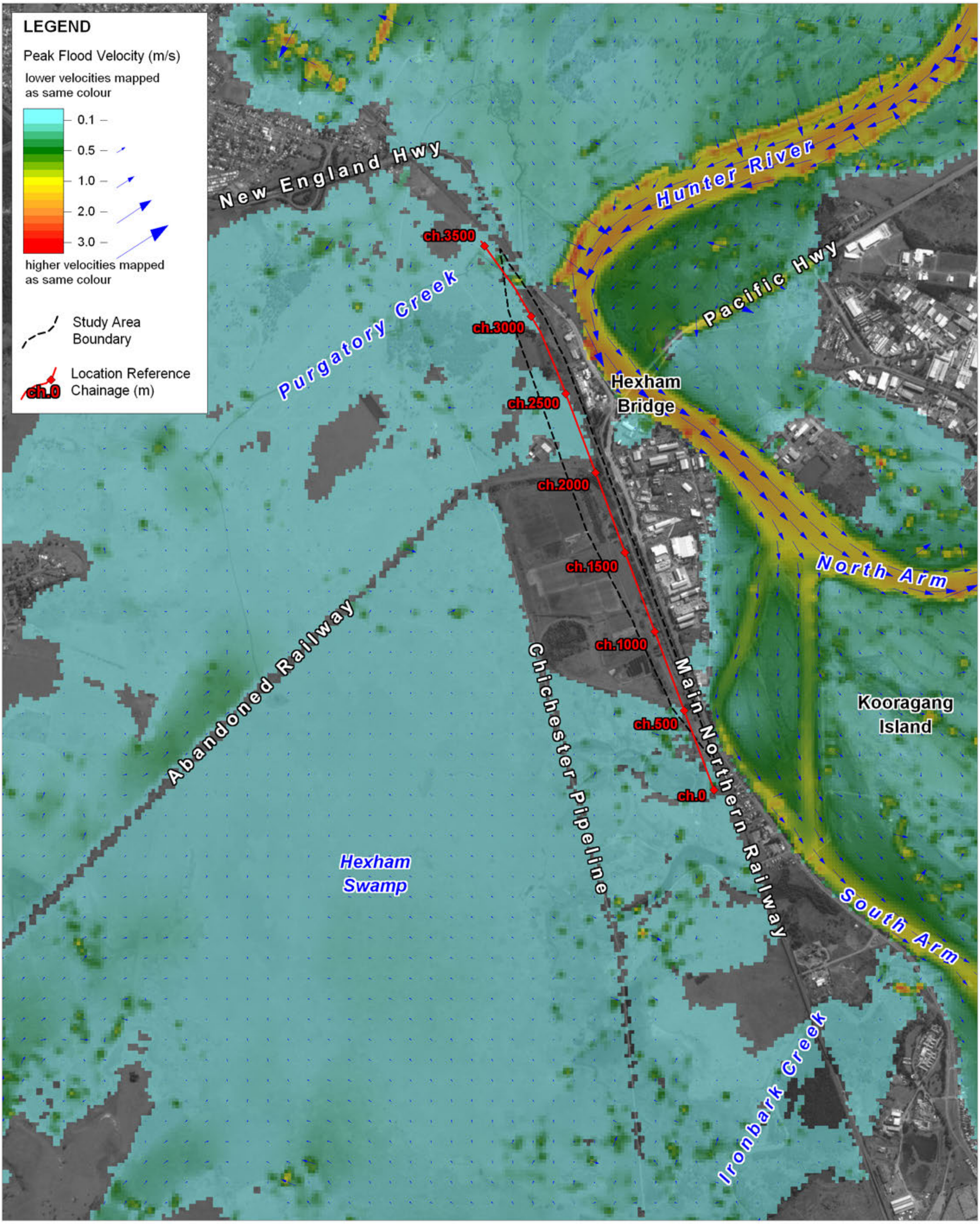
Filepath : K:\N2197_Hexham_Rail_Development\MapInfo\Workspaces\DRG_006_120228_10%AEP_Depths.WOR



Title:

10% AEP Peak Flood Velocities - Existing Conditions

Figure: **A-6**

Rev: **A**

N

0 0.5 1km
Approx. Scale

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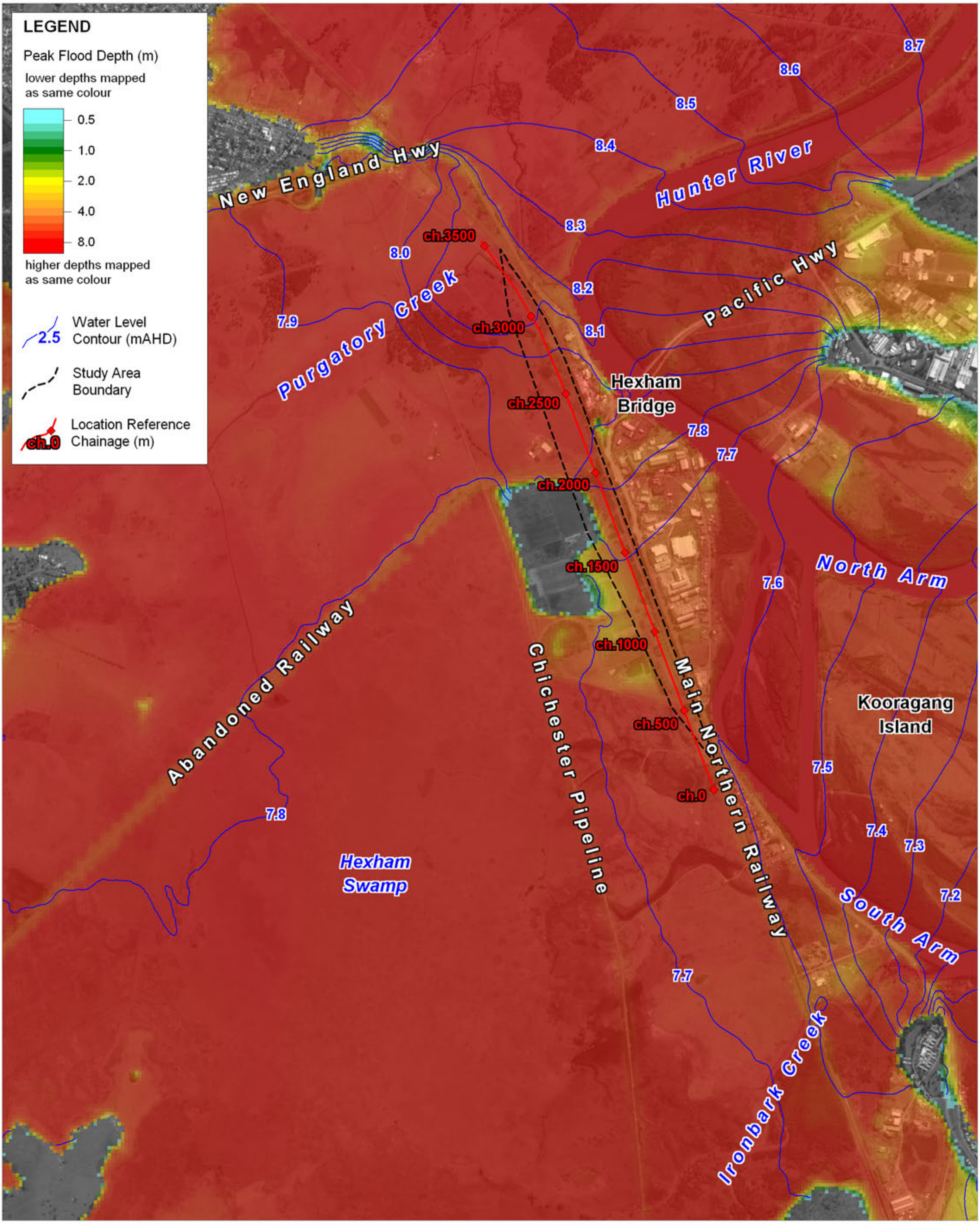
Filepath : K:\N2197_Hexham_Rail_Development\MapInfo\Workspaces\DRG_010_120228_10%AEP_Velocities.WOR



Title:

PMF Peak Flood Depths and Levels - Existing Conditions

Figure: **A-7**

Rev: **A**

N

0 0.5 1km

Approx. Scale

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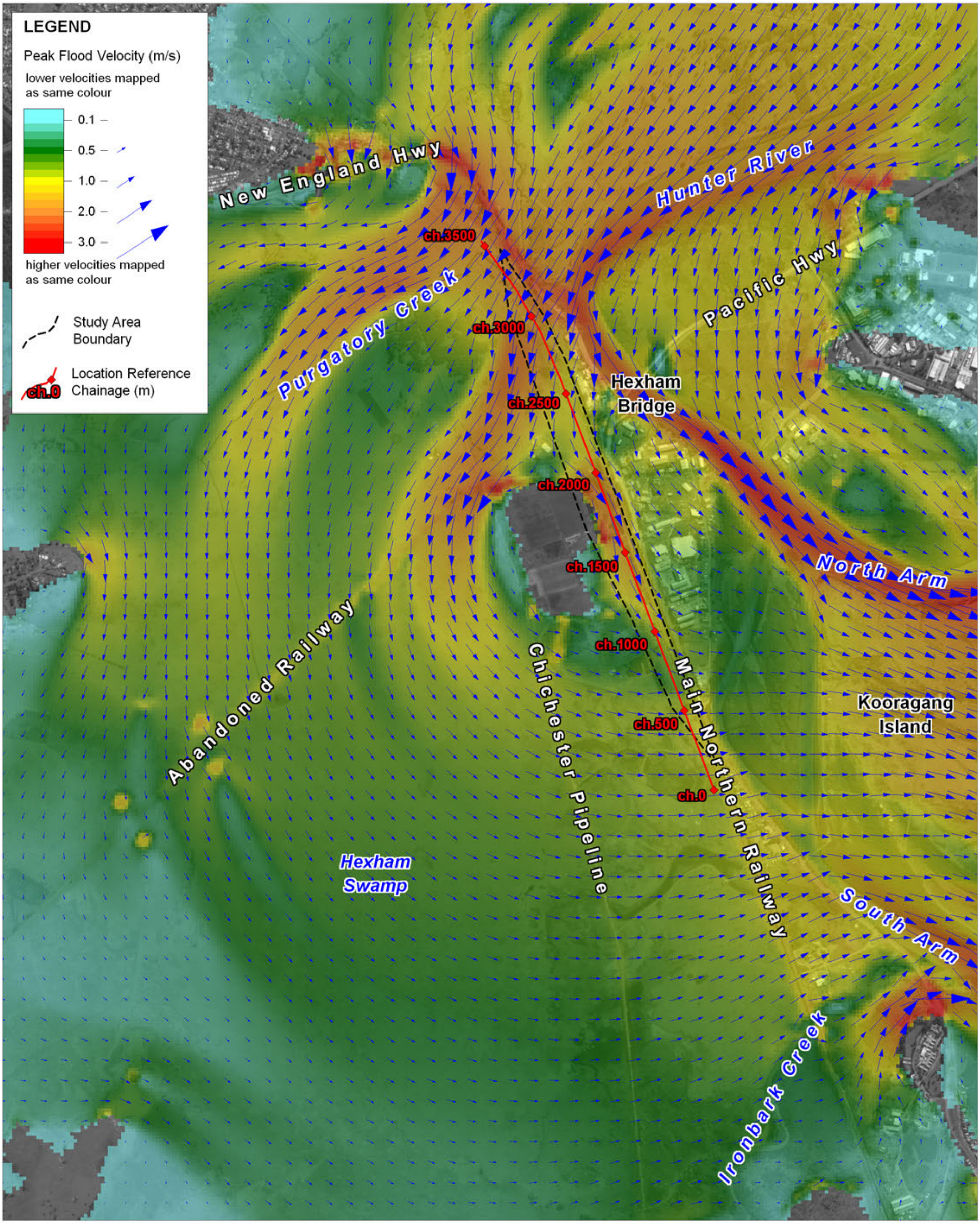

Title:

PMF Peak Flood Velocities - Existing Conditions

Figure: A-8

Rev: A

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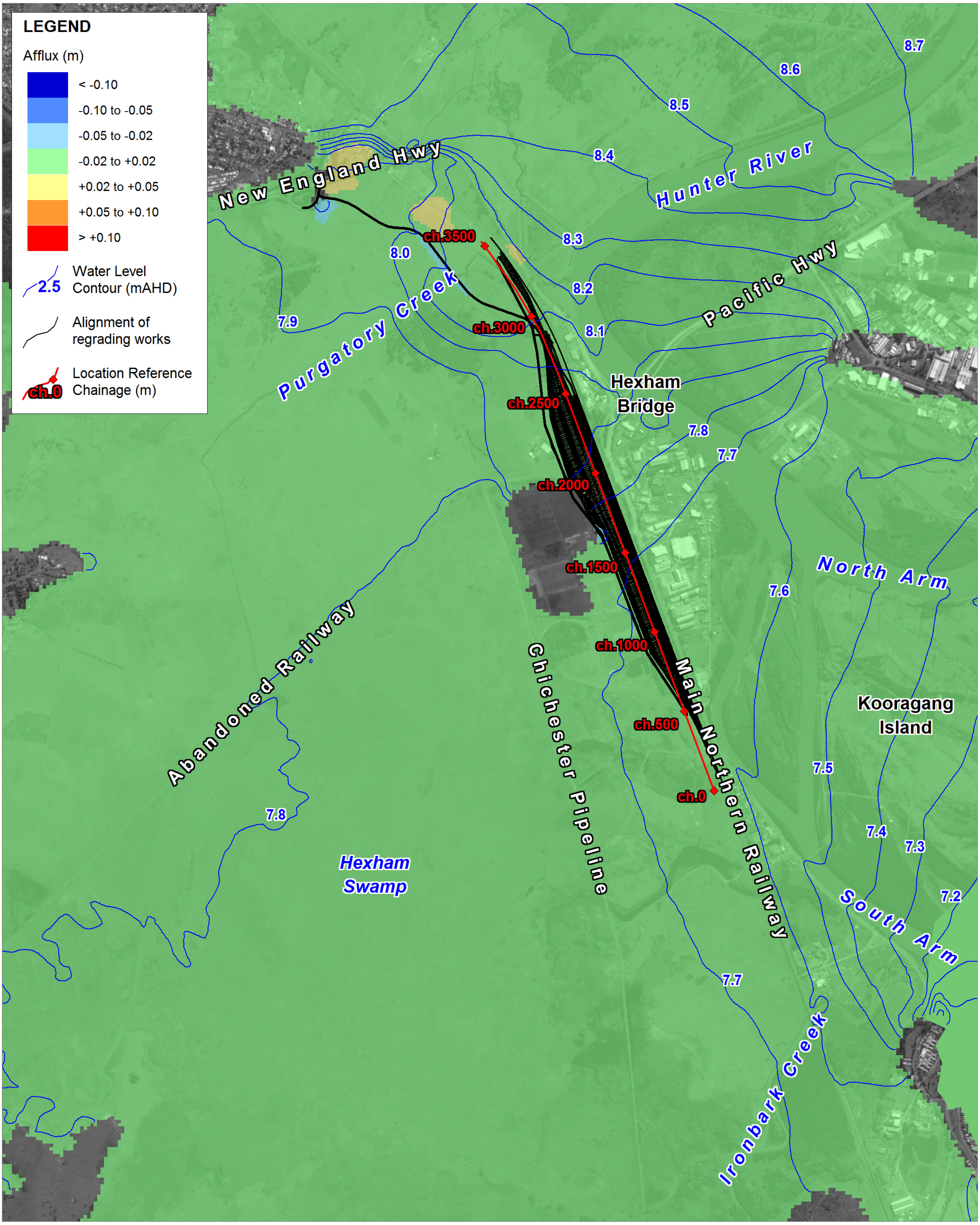
Filepath : K:\N2197_Hexham_Rail_Development\MapInfo\Workspaces\DRG_041_120320_PMF_Velocities.WOR

APPENDIX B: FLOOD IMPACTS FOR THE PMF EVENT



Title:

Impact on Peak PMF Flood Level with Flood Mitigation - Train Support Facility, Hexham Relief Roads & Access Road

Figure: **B-1**

Rev: **A**

N

0 0.5 1km

Approx. Scale

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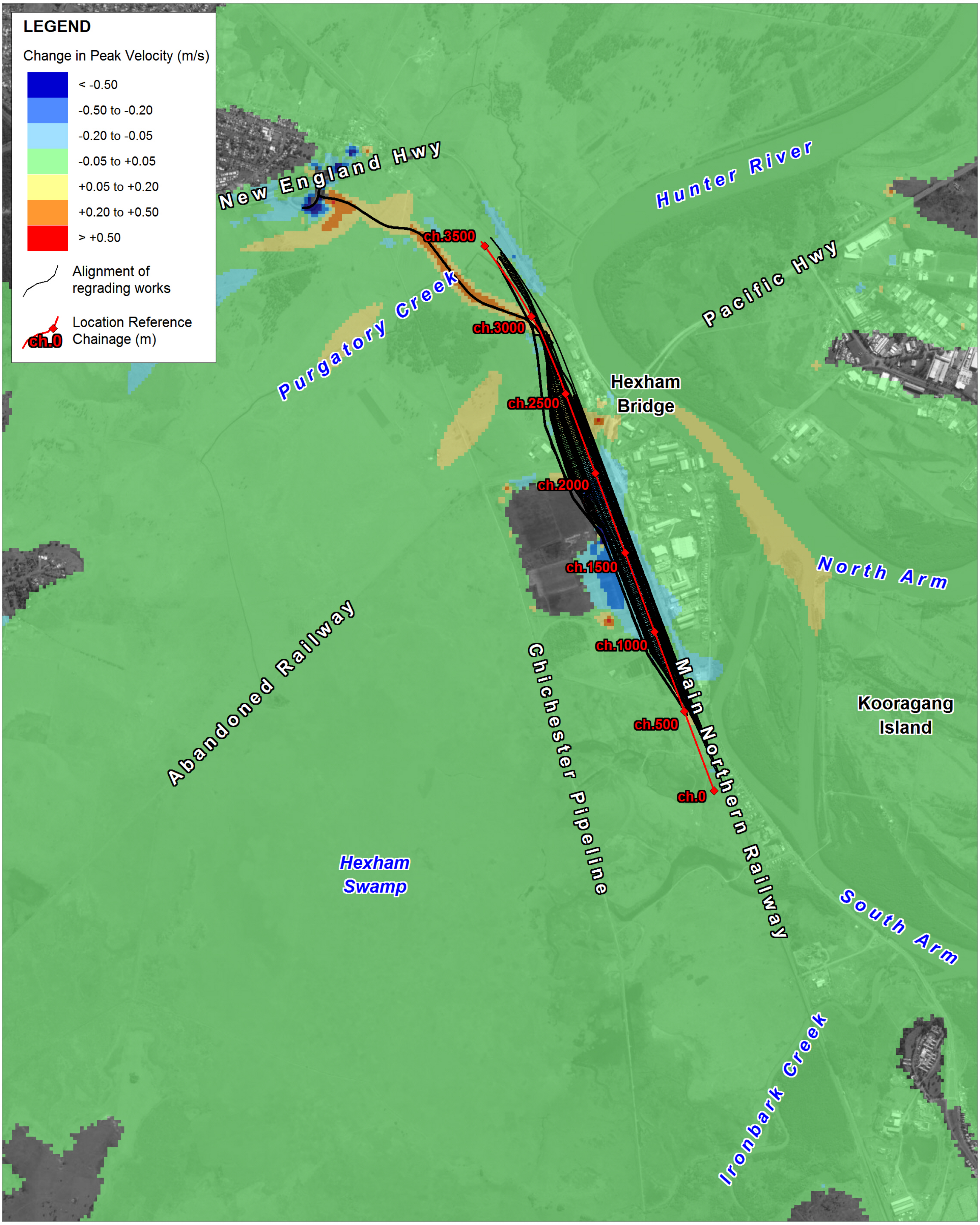
Filepath : K:\N2335_QR_Hexham_Train_Support_Facility\MapInfo\Workspaces\DRG_016_120525_PMF_RRQRARFR_Impact_h.WOR



Title:

Impact on Peak PMF Flood Velocity with Flood Mitigation - Train Support Facility, Hexham Relief Roads & Access Road

Figure: **B-2**

Rev: **A**

N

0 0.5 1km

Approx. Scale

BMT WBM

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Filepath : K:\N2335_QR_Hexham_Train_Support_Facility\MapInfo\Workspaces\DRG_017_120525_PMF_RRQRARFR_Impact_v.WOR

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