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.

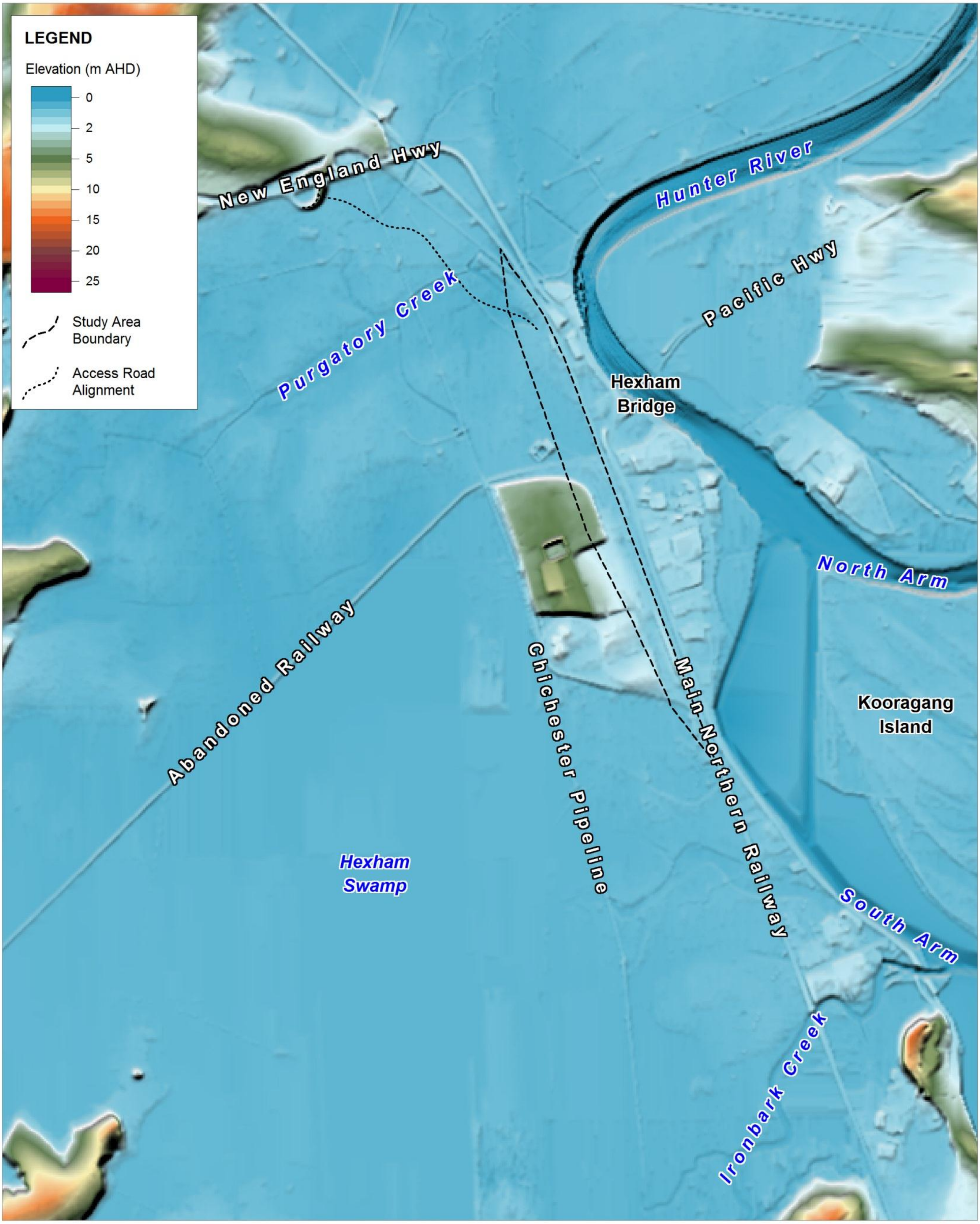
The Hunter River has experienced many floods during its recorded history. The largest flood on record was in 1955. After this event, which claimed 14 lives, the Hunter Valley Flood mitigation Scheme was established, which has subsequently instigated some 160km of levees, 3.8km of spillways, 40km of control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



Title:
Local Floodplain Topography

Figure: **2-1**

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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)

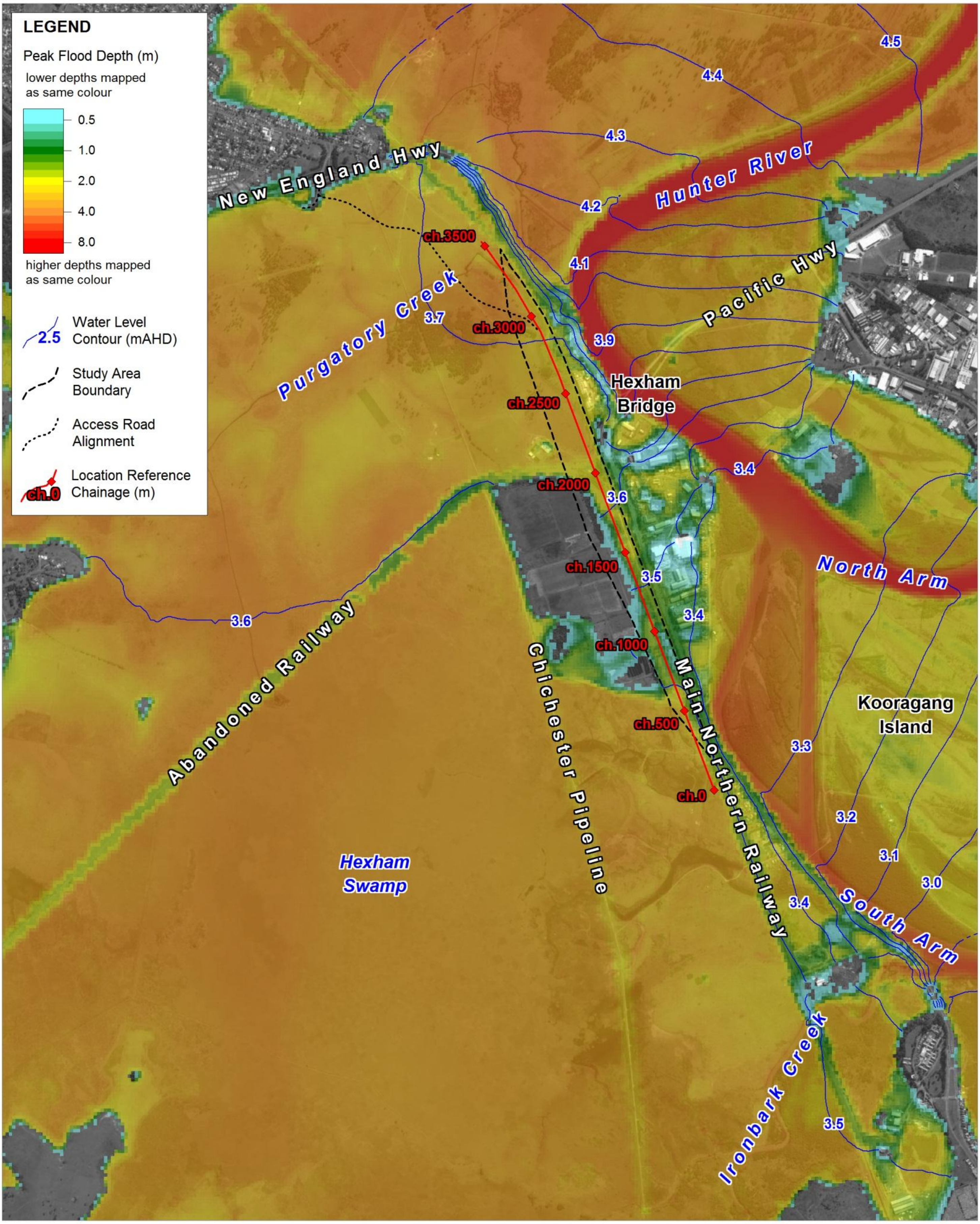
Design Flood Magnitude	Northern End of Site	Southern End of Site
10% AEP	1.0	0.8
5% AEP	1.2	1.0
2% AEP	2.2	2.1
1% AEP	3.7	3.5
PMF	8.3	7.7

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.



Title:

1% AEP Peak Flood Depths and Levels - Existing Conditions

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Approx. Scale

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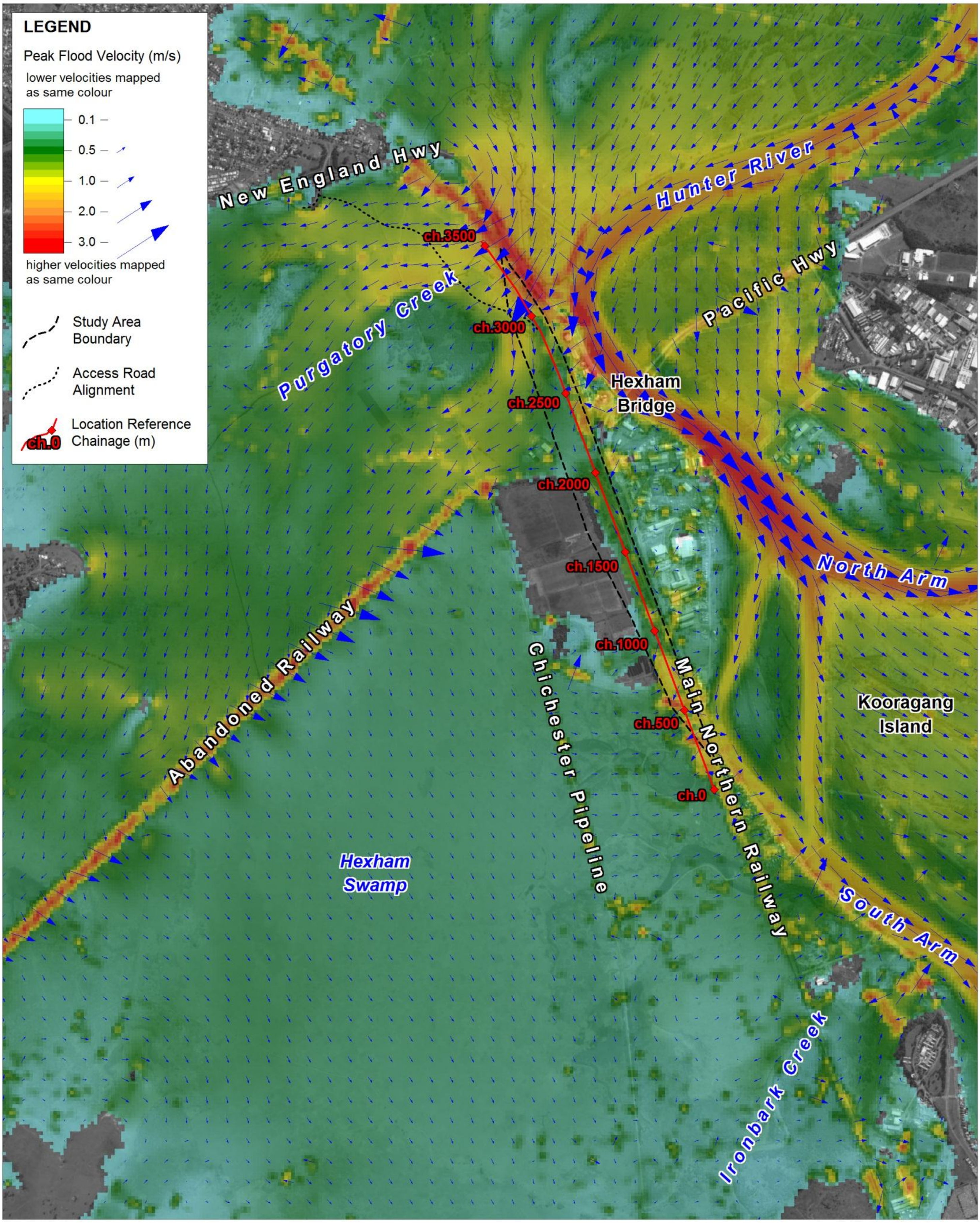

Title:

1% AEP Peak Flood Velocities - Existing Conditions

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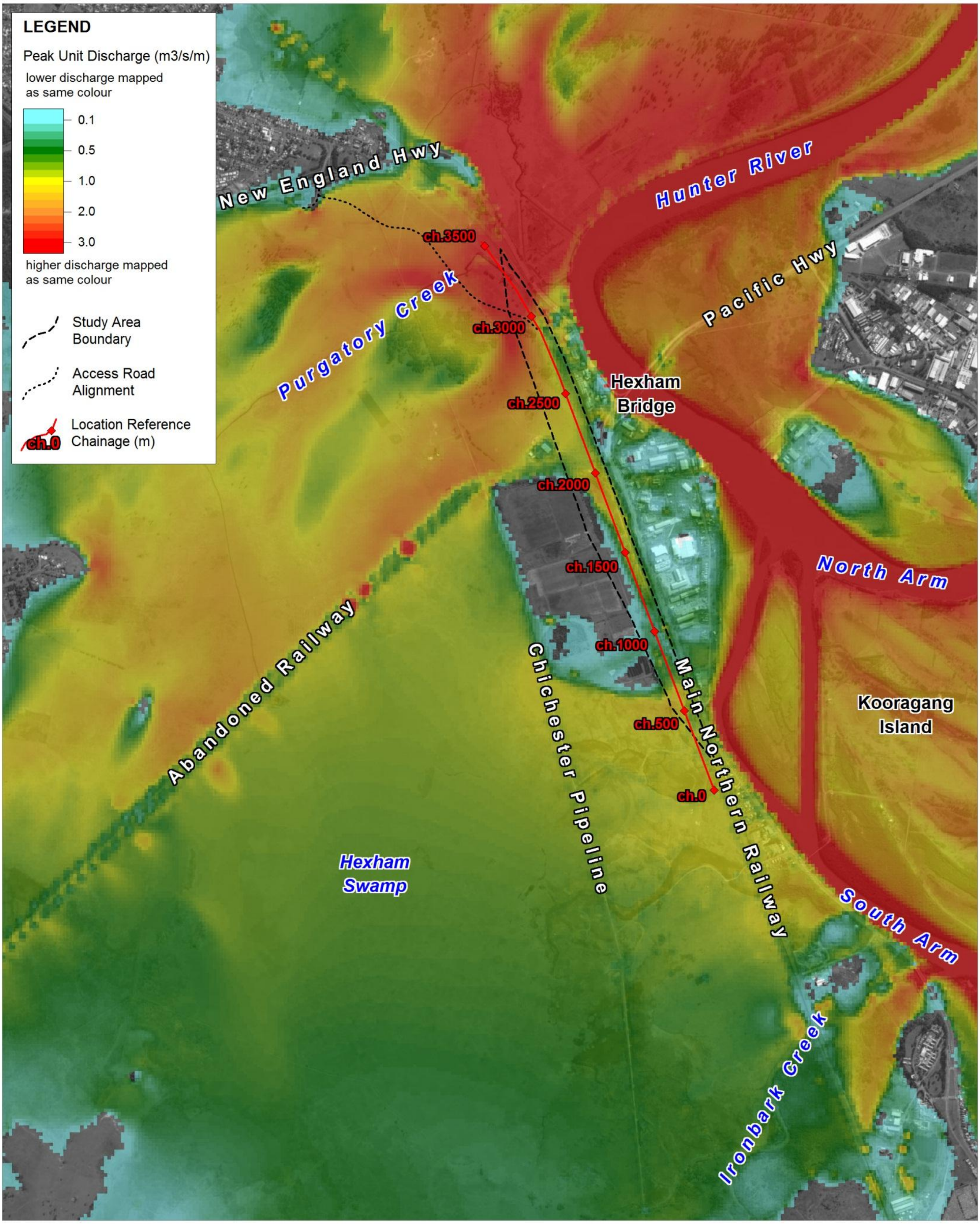

Title:

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.

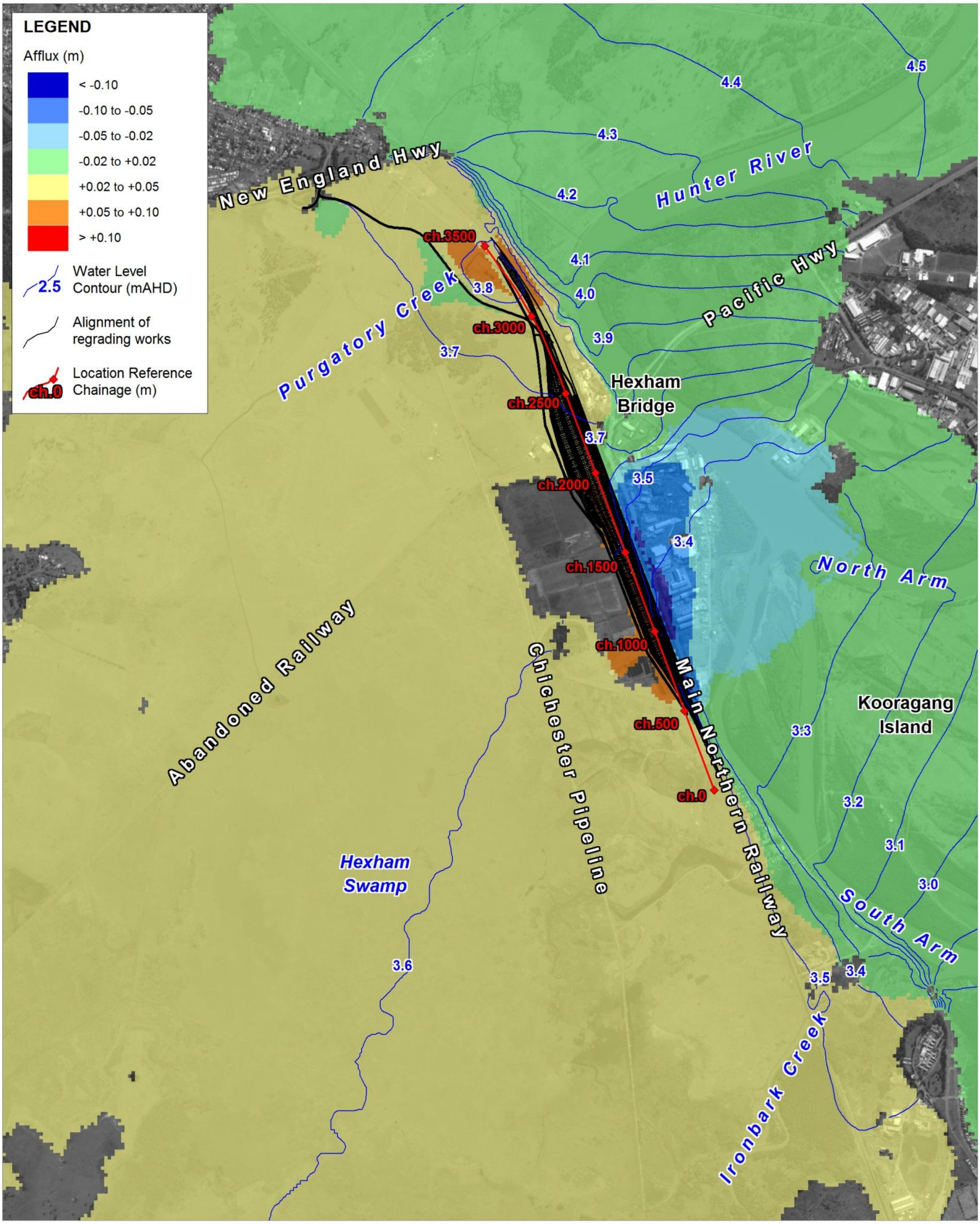
The details of the proposed access road from the Tarro interchange have also been supplied as a DTM. The access road is some 1.6km in length, with typical crest levels varying between 1.1m AHD and 2.2m AHD. The road alignment includes two creek crossings and it has been assumed that culverts will be 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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Approx. Scale

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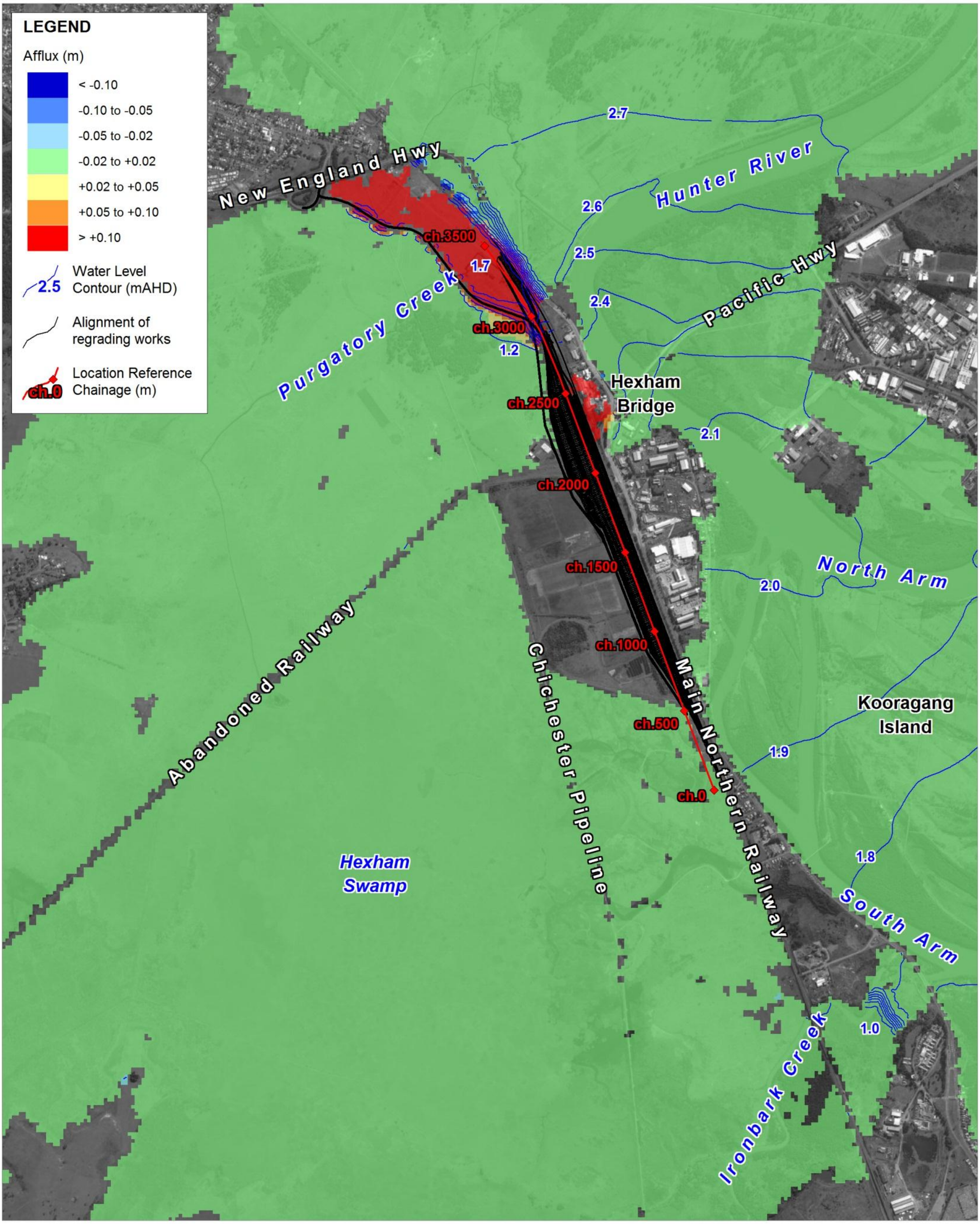

Title:

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.

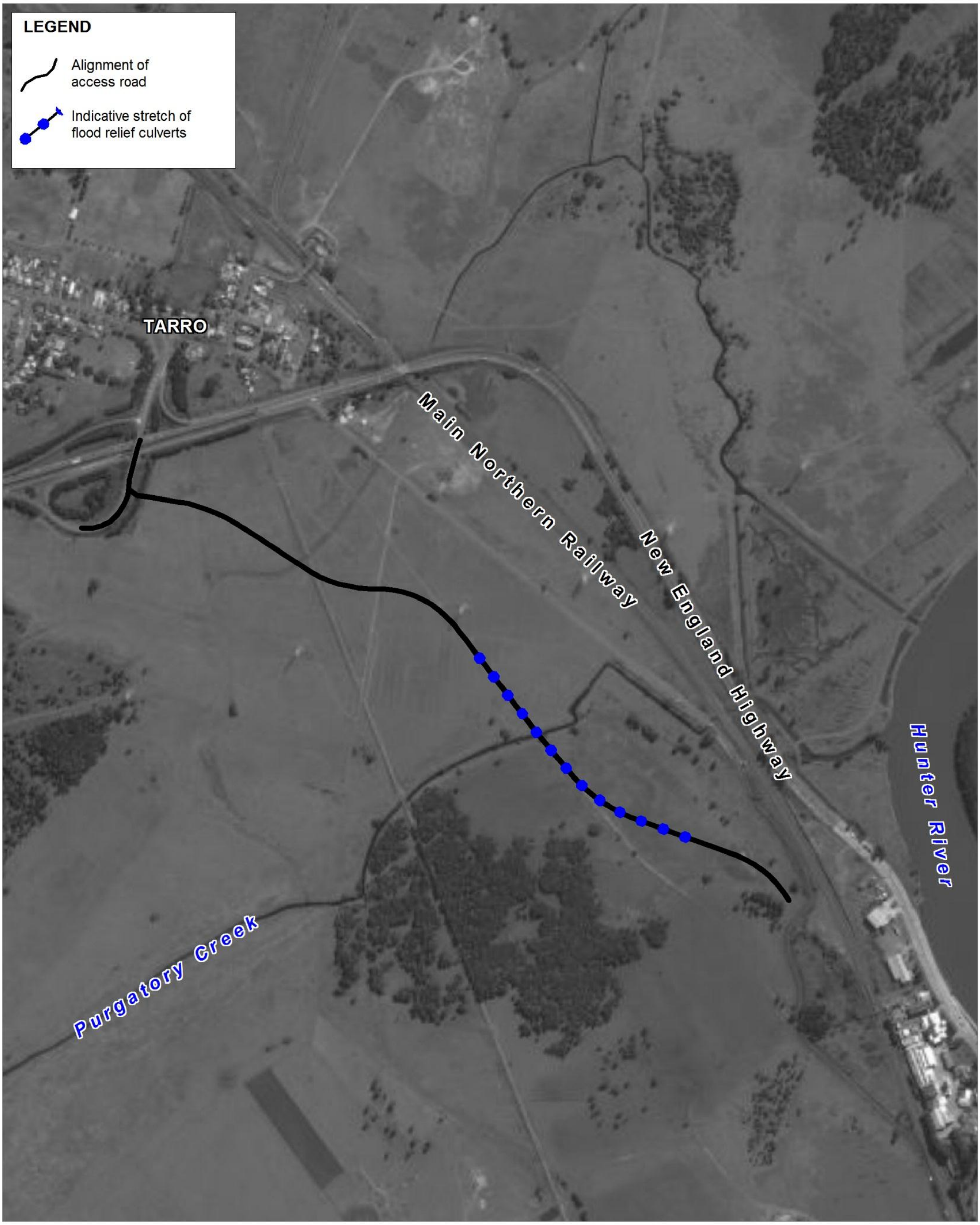
Although the highest parts of the site will be located above the 2% AEP flood level, there will be a residual on-site flood risk for larger magnitude events such as the 1% AEP and PMF events. The peak flood level at the 1% AEP event is around 3.7m AHD, which will correspond to a flood depth of over 1m 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**

N

0 0.5 1km
Approx. Scale

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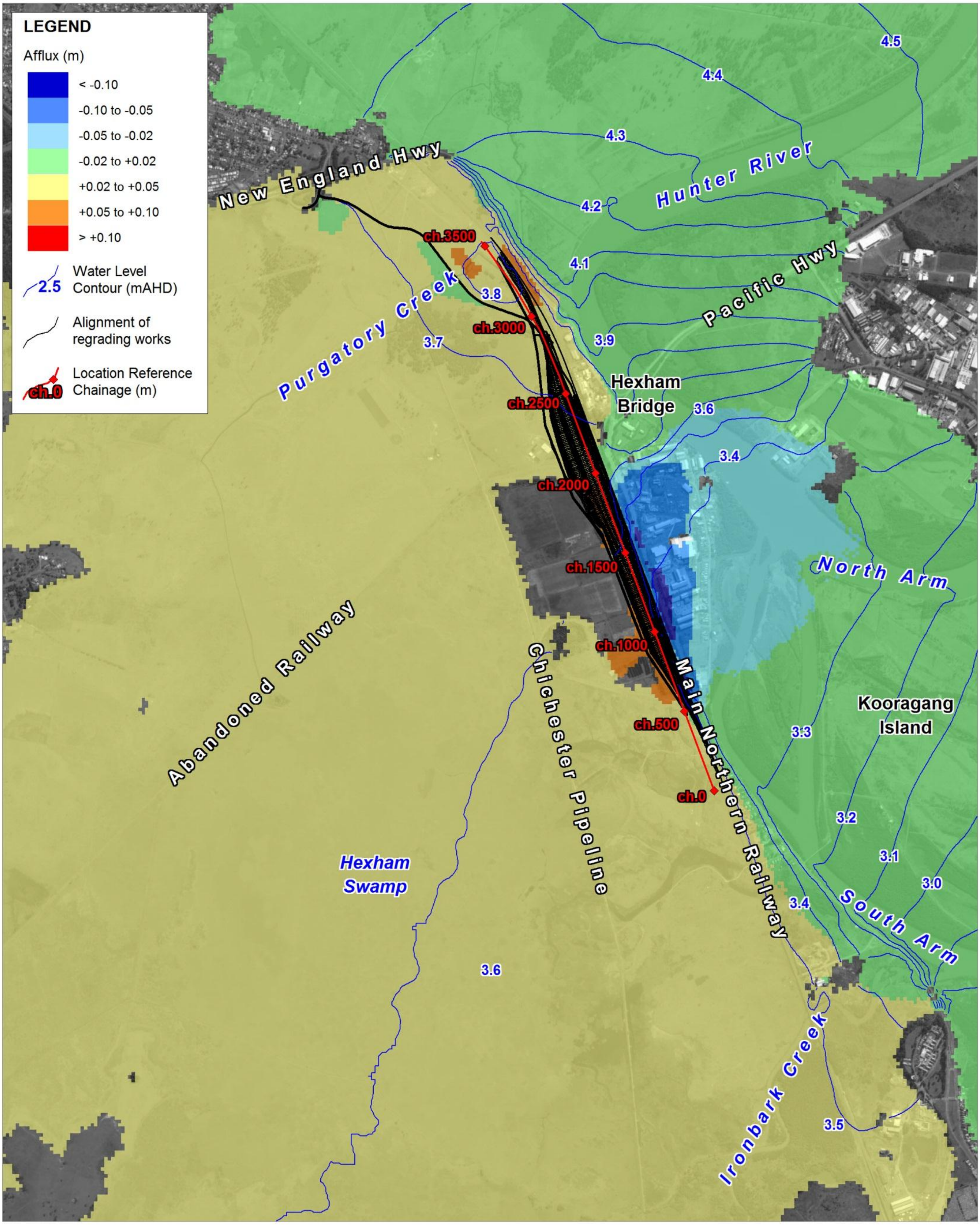

Title:

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

Figure: **4-2**

Rev: **A**

N

0 0.5 1km

Approx. Scale

BMT WBM

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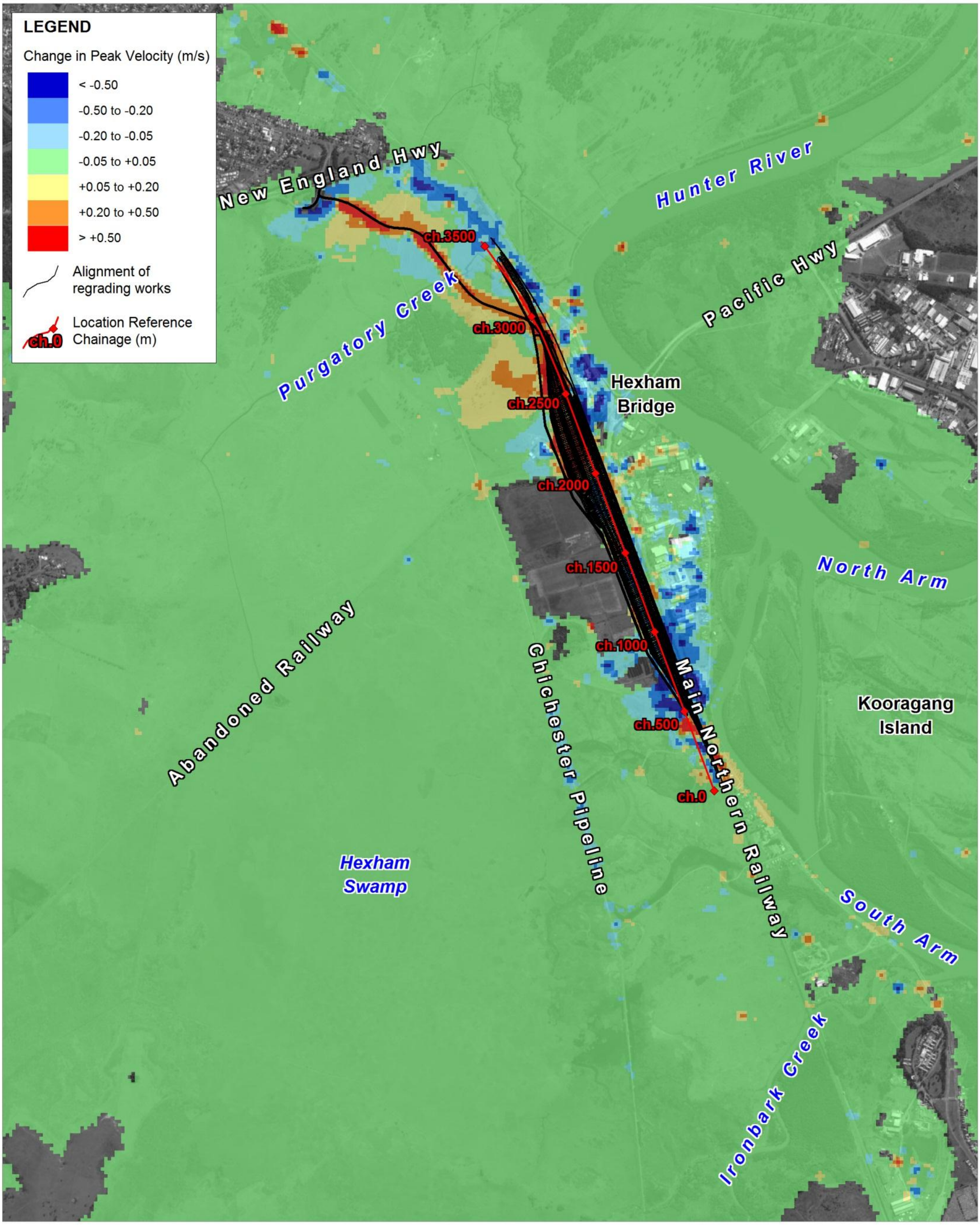

Title:

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

Figure: **4-3**

Rev: **A**

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0 0.5 1km

Approx. Scale

BMT WBM

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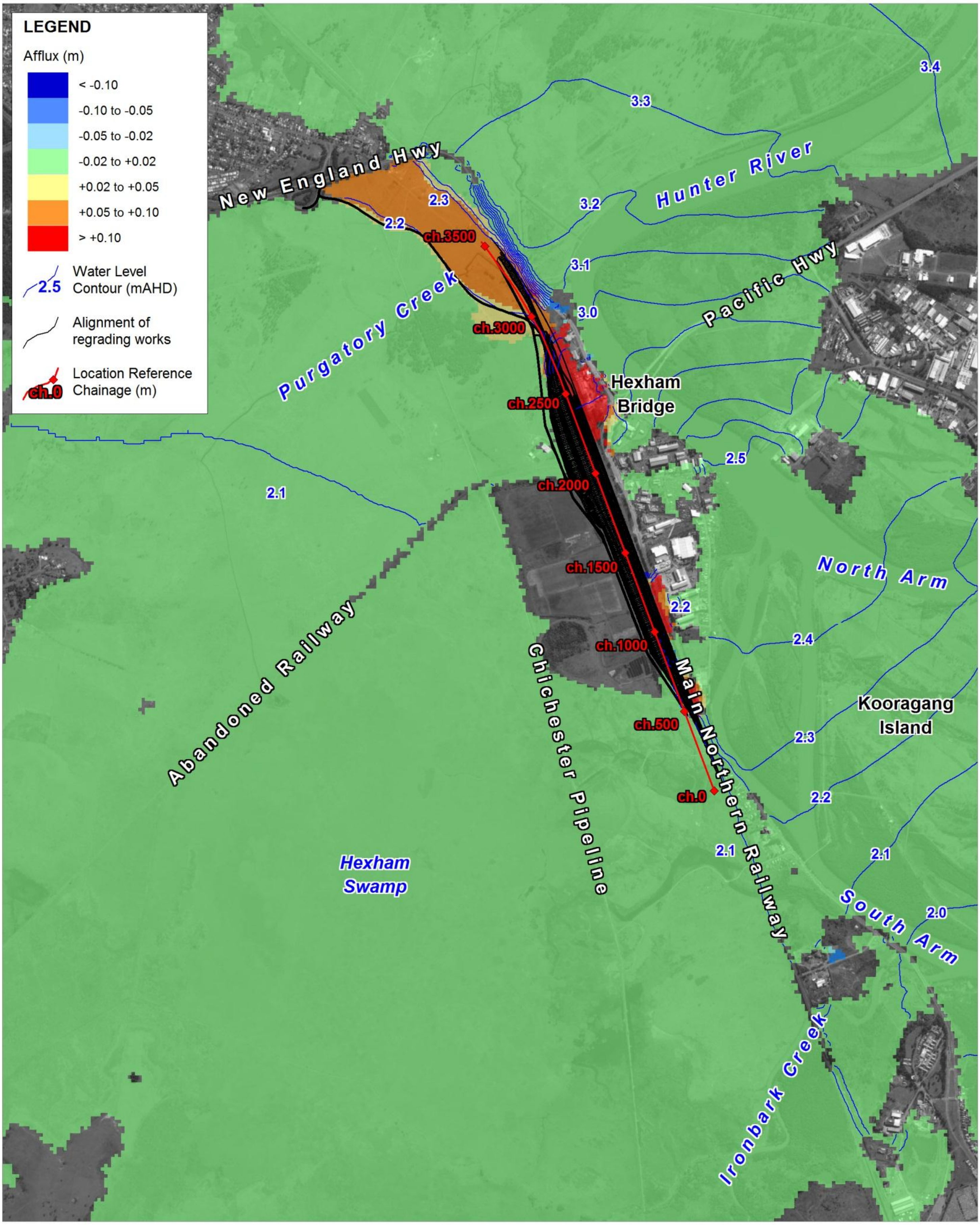

Title:

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

Figure: 4-4

Rev: A

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0 0.5 1km

Approx. Scale

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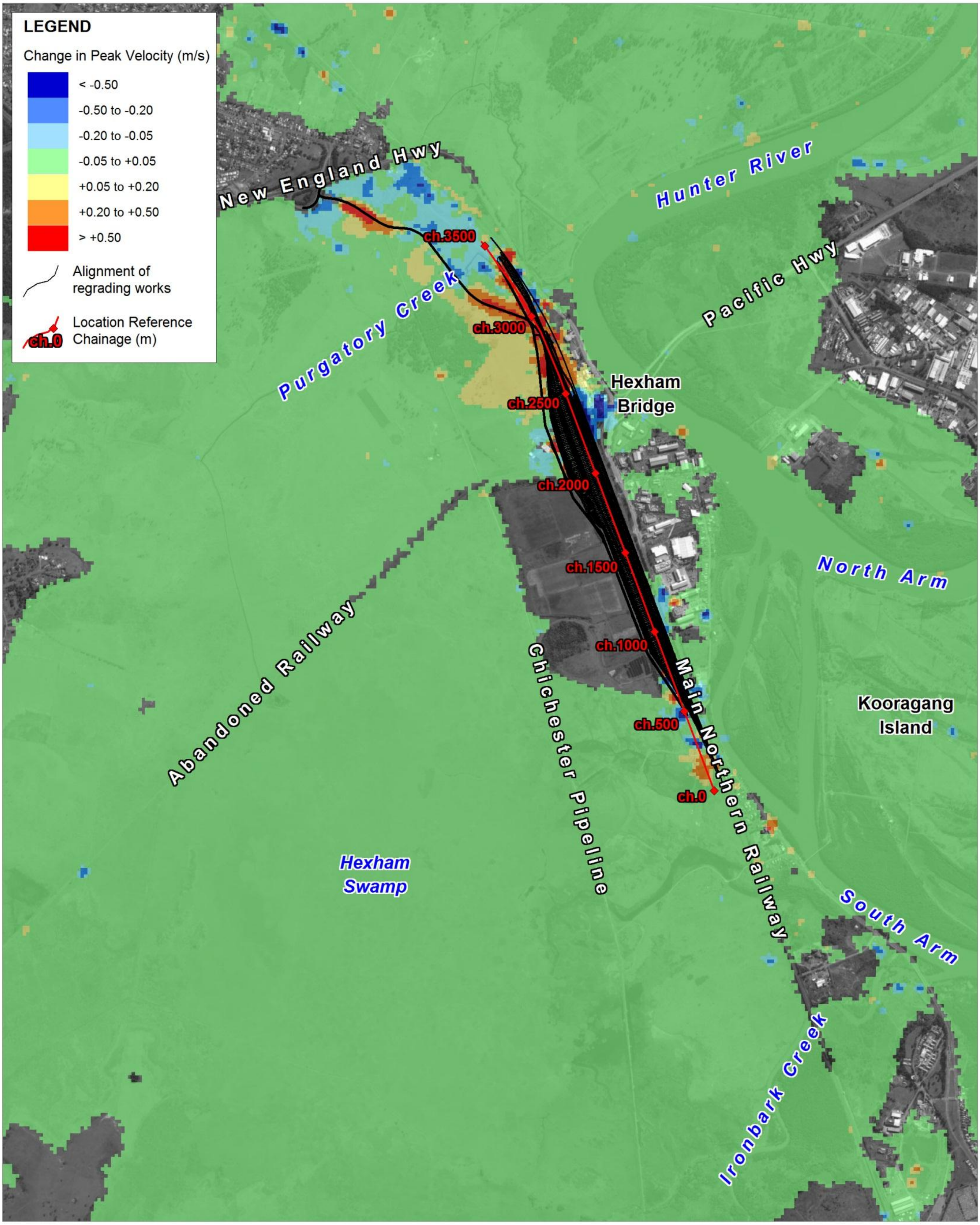

Title:

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

Figure: 4-5

Rev: A

N

0 0.5 1km

Approx. Scale

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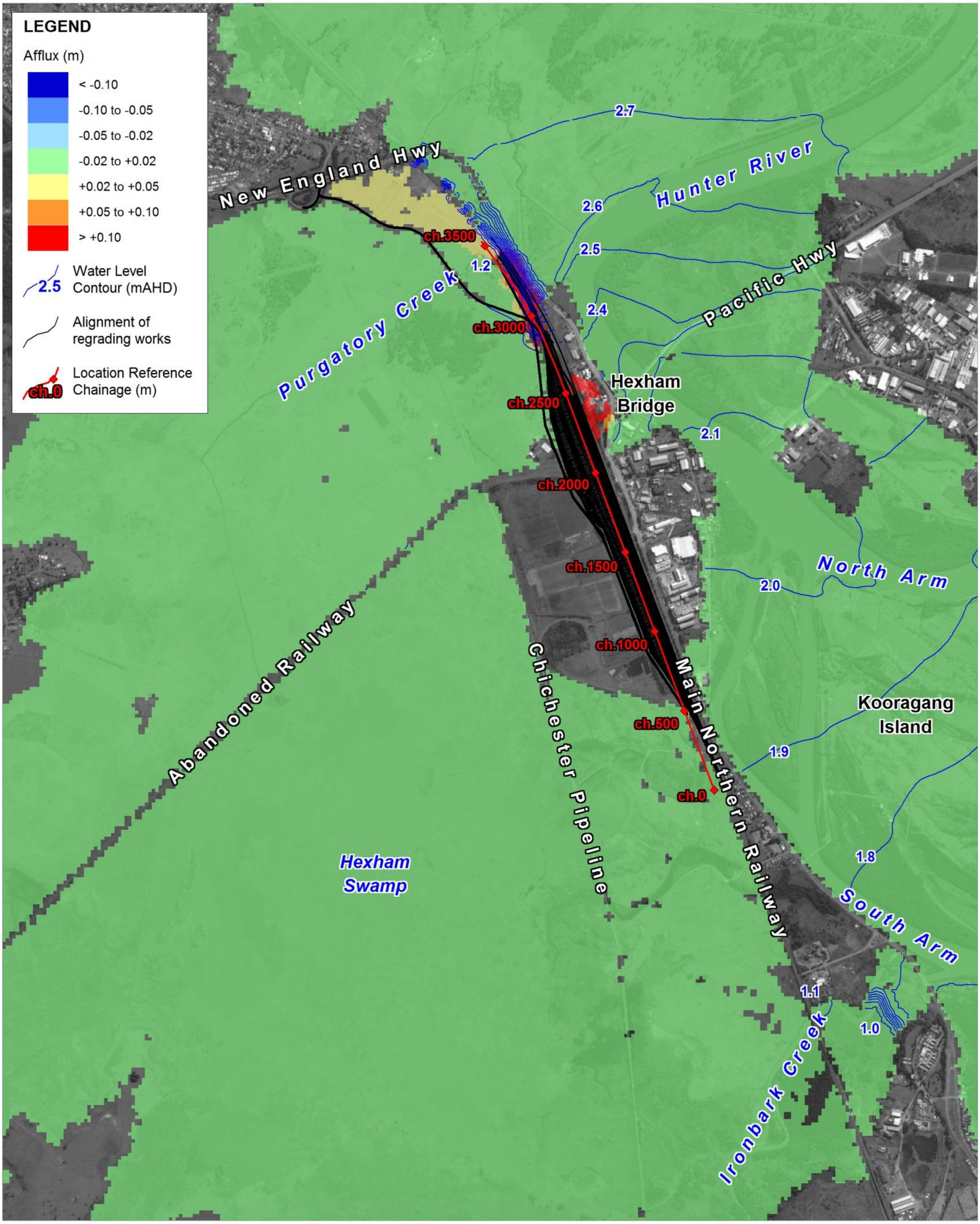

Title:

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

Figure: **4-6**

Rev: **A**

N

0 0.5 1km

Approx. Scale

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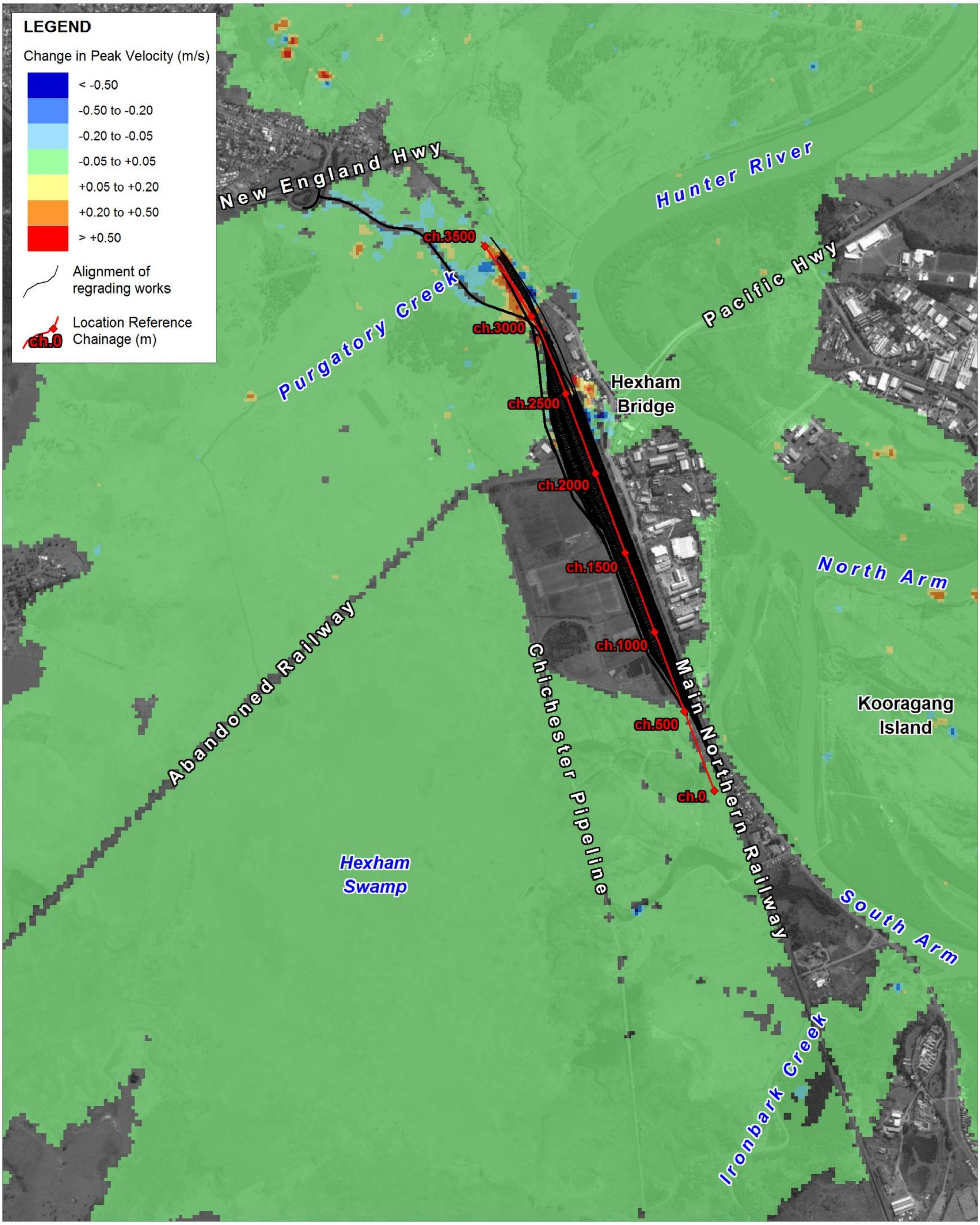

Title:

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

Figure: 4-7

Rev: A

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Approx. Scale

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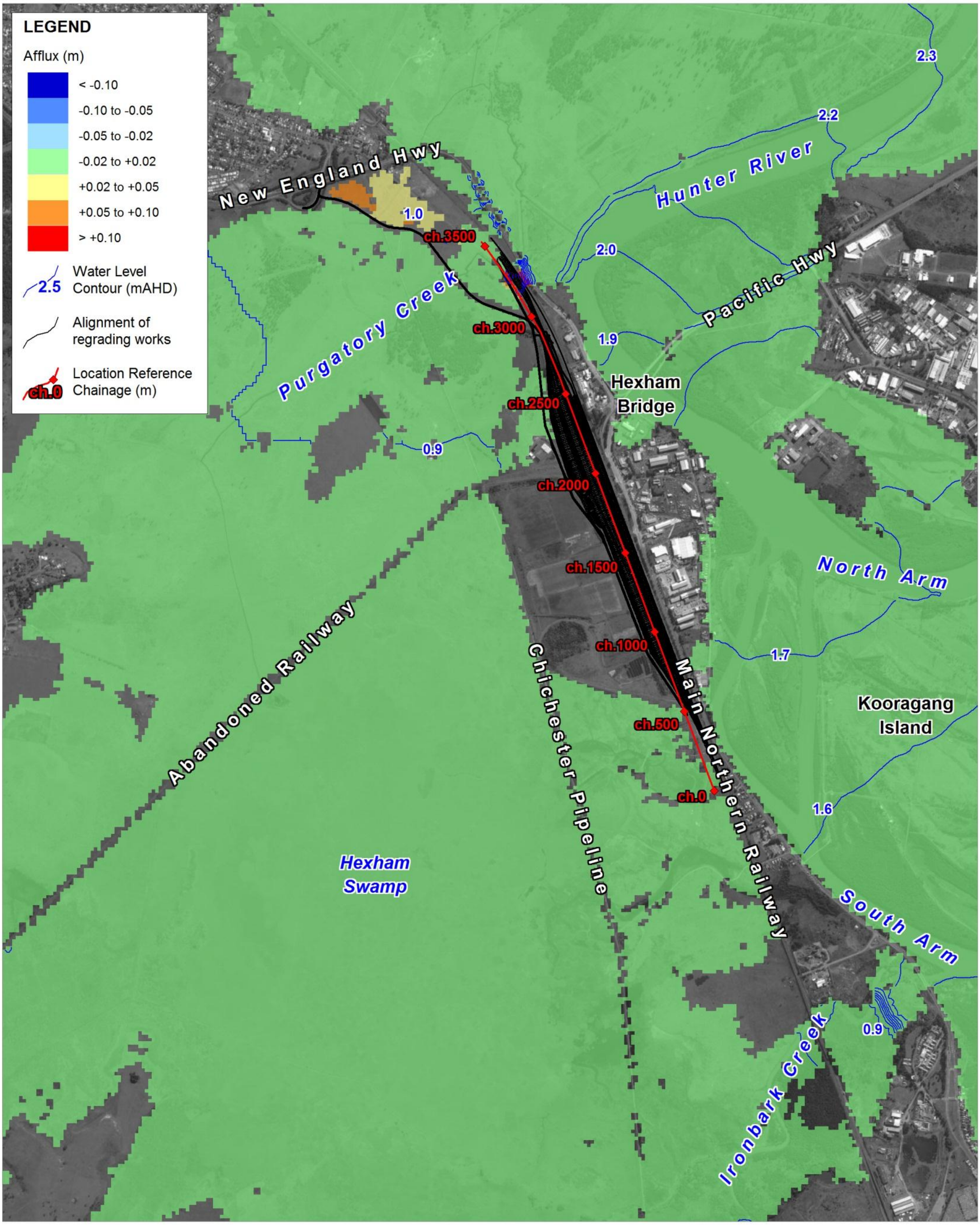

Title:

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

Figure: 4-8

Rev: A

N

0 0.5 1km

Approx. Scale

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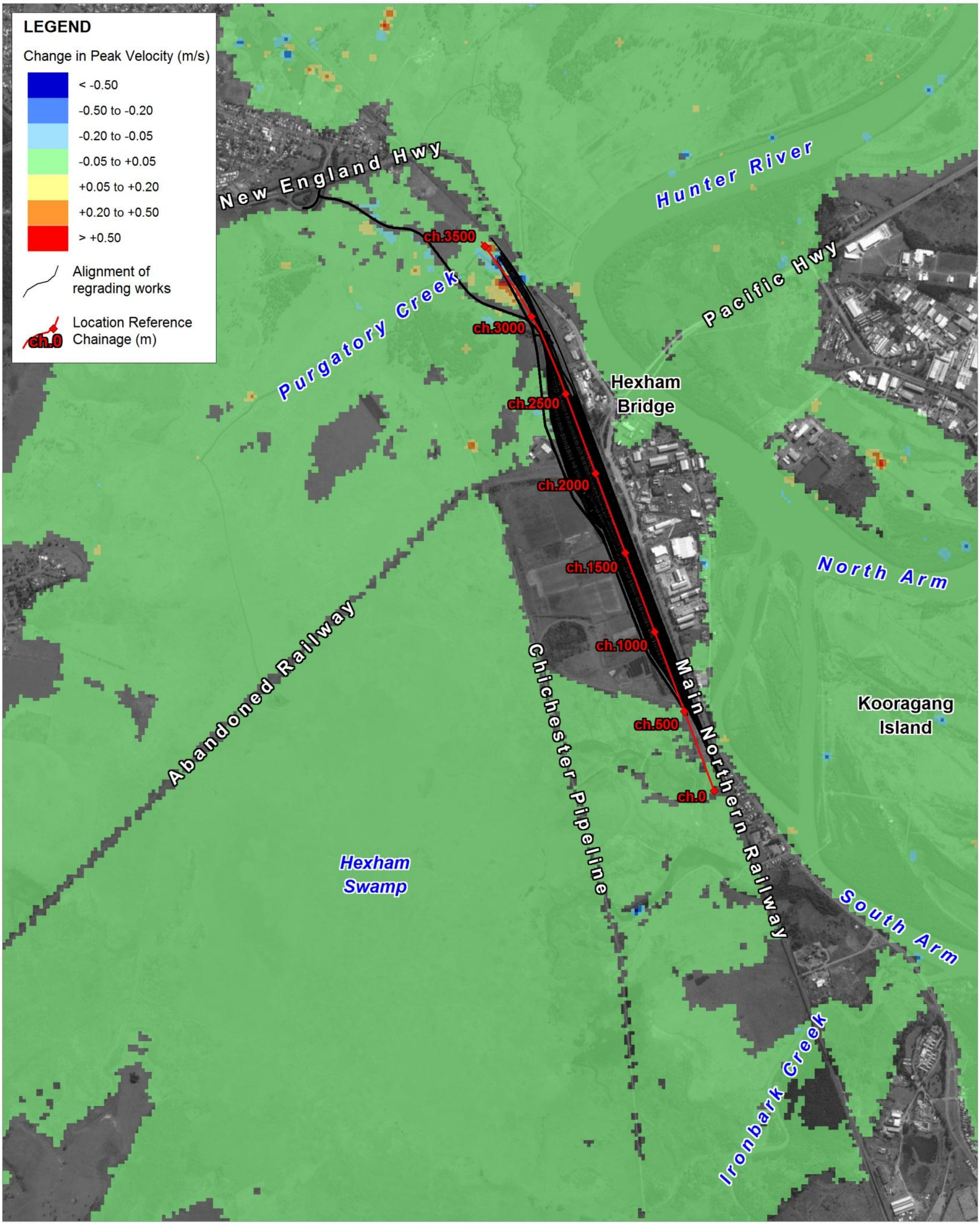

Title:

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

Figure: **4-9**

Rev: **A**

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0 0.5 1km

Approx. Scale

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