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M1 Pacific Motorway extension to Raymond Terrace

Environmental impact statement – Chapter 10: Hydrology and flooding

Transport for NSW | July 2021

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Contents

List of figures

List of tables

10. Hydrology and flooding

This chapter describes the potential hydrology and flooding impacts that may be generated by the construction and operation of the project and presents the approach to the management of these impacts.

The desired performance outcomes for the project relating to flooding, hydrology and climate change, as outlined in the SEARs, are:

- Flooding:
  - Minimise adverse impacts on existing flooding characteristics
  - Avoid, or minimise the risk of, adverse impacts from infrastructure flooding, flooding hazards, or dam failure during construction and operation of the project.
- Water: Hydrology:
  - Minimise long term impacts on surface water and groundwater hydrology, including drawdown, flow rates and volumes
  - Maintain (where values are achieved) or improve and maintain (where values are not achieved) the environmental values of nearby connected and affected water sources, groundwater and dependent ecological systems, including estuarine and marine water
  - Provide for the sustainable use of water resources.
- Climate change:
  - Ensure the project is designed, constructed and operated to be resilient to the future impacts of climate change.

Table 10-1 outlines the SEARs that relate to hydrology and flooding and identifies where they are addressed in this EIS. The full assessment of hydrology and flooding impacts is provided in the Hydrology and Flooding Working Paper (**Appendix J**).

Table 10-1 SEARs (flooding, hydrology and climate change)

Secretary's requirement	Where addressed in this report
5. Flooding	
1. Identification of potential impacts and benefits of the proposal on existing flood regimes, consistent with the Floodplain Development Manual (Department of Natural Resources 2005), with an assessment of the potential changes to flooding behaviour (levels, velocities, storage and direction) and impacts on bed and bank stability, through flood modelling (using a validated model), including:	Potential impacts and benefits of the construction of the project on existing flood regimes is discussed in **Section 10.5.3**. Potential impacts and benefits of the operation of the project on existing flood regimes is discussed in **Section 10.6.3**.
(a) detailed description, justification and assessment of the flood management objectives, and other design objectives and design (including bridge, culvert and embankment design);	The flood management objectives are discussed in **Section 10.2.3**. The other design objectives and design are discussed in **Section 10.2.4**.

Secretary's requirement	Where addressed in this report
(b) flood assessment and modelling undertaken for a range of flood events, including (as a minimum) the 1 in 10 year, 1 in 100 year flood events and the probable maximum flood, or an equivalent extreme event. The assessment is to demonstrate how the assessment, including the use of the modelled events listed above, provides consideration of blockage, climate change and impacts of land use change on flood hydrology, noting below;	The modelling methodology is outlined in **Section 10.2**. Results of the assessment of blockage of hydraulic structures and climate change are detailed in **Section 10.6.3**. Results of the assessment with consideration of changes in land use on flood hydrology are detailed in **Section 10.5.3** for construction and **Section 10.6.3** for operation.
(c) modelling of the effect of the proposal (including fill) on current and future flood behaviour for the range of design events identified above, with use of the 1 in 200 year and 1 in 500 year flood events as proxies for assessing sensitivity to an increase in rainfall intensity due to climate change;	The effect of the project on current and future flood behaviour has been modelled with consideration of the identified design events and increased rainfall sensitivity as described in **Section 10.2**. Construction impacts are detailed in **Section 10.5.3** and operational impacts are discussed in **Section 10.6.3**.
(d) an assessment of afflux and flood duration (inundation period) on land, infrastructure, property and business operations (including agricultural land and stock movement to flood refuges and evacuation routes), hazard, evacuation and emergency service provision within the affected area, and future development potential of upstream and access affected land;	Construction impacts to afflux and flood duration are detailed in **Section 10.5.3** and operational impacts are discussed in **Section 10.6.3**.
(e) an assessment of impacts associated with the Hunter Valley Flood Mitigation Scheme;	Construction impacts on the Hunter Valley Flood Mitigation Scheme are detailed in **Section 10.5.3** and operational impacts are discussed in **Section 10.6.3.**
(f) an assessment of flooding during construction of the proposal;	An assessment of flooding during construction of the project is provided in **Section 10.5.3.**
(g) a cumulative flood assessment of the impact of other major projects recently completed, approved or preparing for construction; and	A cumulative flooding assessment is provided in **Chapter 23** (cumulative impacts).
(h) an assessment of emergency management, evacuation and access, and contingency measures for the development considering the full range of flood risk (based upon the probable maximum flood or an equivalent extreme flood event).	Flood risks to emergency management and access during construction and operation are detailed in **Section 10.5.3** and **Section 10.6.3** respectively.
7. Water – Hydrology	
1. The Proponent must describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users and for ecological purposes) likely to be impacted by the project, including stream orders, as per the Framework for Biodiversity Assessment (FBA).	Surface water resources, including the existing hydrological regime as described and mapped by the FBA are discussed in **Section 10.3.2**. Groundwater resources, including the existing hydrological regime as described and mapped by the FBA are discussed in **Section 10.3.4**. Mapping of existing surface water and groundwater resources is found in **Figure 10-5** and **Figure 10-6**. The biodiversity impacts of the project are assessed in accordance with the FBA in **Section 9.4.2** and **Section 9.4.3** and Chapter 8 of the Biodiversity Assessment Report (**Appendix I**).

Secretary’s requirement	Where addressed in this report
2. The Proponent must prepare a detailed water balance for ground and surface water including the proposed intake and discharge locations, volume, frequency and duration.	The construction site water balance is detailed in **Section 10.5.5**. The operational site water balance is detailed in **Section 10.6.5.**
3. The Proponent must assess (and model if appropriate) the impact of the construction and operation of the project and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including:	Impacts to surface water and groundwater hydrology during construction and operation are detailed in **Section 10.5** and **Section 10.6** respectively.
(a) natural processes within rivers, wetlands, estuaries, marine waters and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity and access to habitat for spawning and refuge;	The impact of the project on existing surface water processes and health during construction and operation is discussed in **Section 10.5.1** and **Section 10.6.1** respectively. This includes consideration of modified discharge volumes, durations and velocities. Impacts from the project to riparian vegetation, aquatic connectivity and access to aquatic habitats for spawning and refuge are assessed in **Section 9.4.2** and **Section 9.4.3** and Chapter 8 of the Biodiversity Assessment Report (**Appendix I**).
(b) impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species, groundwater users and the potential for settlement;	Impacts to groundwater flow during construction and operation are assessed in **Section 10.5.2** and **Section 10.6.2** respectively.
(c) impacts on regional hydrology, in particular the Tomago Sandbeds Catchment Area drinking water supply;	Impacts to regional hydrology, including impacts to the Tomago Sandbeds Catchment Area, during construction and operation are detailed in **Section 10.5** and **Section 10.6** respectively.
(d) changes to environmental water availability and flows, both regulated/licensed and unregulated/rules-based sources;	Changes to environmental water availability and flows as a result of construction and operation are detailed in **Section 10.5** and **Section 10.6** respectively.
(e) direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses;	Changes to erosion and siltation as a result of construction and operation are detailed in **Section 10.5** and **Section 10.6** respectively. Impacts from the project to riparian vegetation are assessed in **Section 9.4.2** and **Section 9.4.3** and Chapter 8 of the Biodiversity Assessment Report (**Appendix I**).
(f) minimising the effects of proposed stormwater and wastewater management during construction and operation on natural hydrological attributes (such as volumes, flow rates, management methods and re-use options) and on the conveyance capacity of existing stormwater systems where discharges are proposed through such systems; and	Impacts of stormwater during construction and operation are detailed in **Section 10.5** and **Section 10.6** respectively. Wastewater management is assessed in **Chapter 19** (waste).
(g) water take (direct or passive) from all surface and groundwater sources with estimates of annual volumes during construction and operation.	Water take during construction and operation is detailed in **Section 10.5.1** and **Section 10.6.1** respectively.

Secretary’s requirement	Where addressed in this report
4. The Proponent must identify any requirements for baseline monitoring of hydrological attributes.	Requirements for baseline monitoring of hydrological attributes are identified in Appendix K and Appendix L of the Hydrology and Flooding Working Paper (**Appendix J**).
5. The assessment must include details of proposed surface and groundwater monitoring.	Proposed surface water and groundwater monitoring is outlined in Appendix K and Appendix L of the Hydrology and Flooding Working Paper (**Appendix J**) and **Chapter 11** (surface water and groundwater quality).

10.1 Policy and planning setting

The hydrology and flooding assessment has been prepared to assess the potential impacts of the project in accordance with the following relevant legislation, policy and guidelines:

- Legislation:
  - Environment Protection and Biodiversity Conservation Act 1999
  - Environmental Planning and Assessment Act 1979
  - Water Management Act 2000 and Water Act 1912
  - Biodiversity Conservation Act 2016
  - Hunter Water Act 1991
  - Environmental Planning and Assessment Regulation 2000.
- Plans and policies:
  - NSW Aquifer Interference Policy (DPI 2012)
  - NSW Wetlands Policy (DECCW 2010c)
  - NSW Floodplain Development Manual and Flood Prone Land Policy (NSW Government 2005)
  - NSW Climate Change Policy Framework (OEH 2016)
  - Williamtown Salt Ash Floodplain Risk Management Study and Plan (BMT WBM 2017) for Port Stephens Council
  - Newcastle City Wide Floodplain Risk Management Study and Plan (BMT WBM 2012a) for Newcastle City Council
  - Hunter River Floodplain Risk Management Study and Plan (WMAwater 2015) for Maitland City Council
  - City of Newcastle Flood Emergency Sub Plan (SES 2013a)
  - Port Stephens Flood Emergency Sub Plan (SES 2013b).
- Guidelines:
  - Australian Groundwater Modelling Guidelines (Barnett et al 2012)
  - Guidelines for Controlled Activities on Waterfront Land (NSW Department of Industry 2018)
  - Australian Rainfall and Runoff (Ball et al. 2019)
  - Practical Consideration of Climate Change (DECC 2007b)
  - Floodplain Risk Management Guide: Incorporating sea level rise benchmarks in flood risk assessments (DECCW 2010d)
  - NSW Water Quality and River Flow Objectives (DECCW 2006)
  - NSW Blue Book requirements (DECC 2008).

Further detail on the above and how they apply to the project is provided in the Hydrology and Flooding Working Paper (**Appendix J**).

10.2 Assessment methodology

Assessment of the hydrology and flooding impacts involved the following key steps:

- Desktop review and analysis: carried out to characterise the existing environment within the respective study areas (refer to **Section 10.2.1**)
- Site visits, which included:
  - Visual assessment of the hydrological conditions and previous flood levels of waterways at 21 water monitoring sites (also used for water quality as discussed in **Chapter 11** (surface water and groundwater quality)) to support and enhance the findings of the desktop analysis and refine the understanding of potential issues
  - Groundwater survey to establish groundwater levels (refer to **Section 10.2.2**).
- Identification of sensitive receiving environments (SREs)
- Development of quantitative numerical modelling: carried out to assess the potential impacts of the project on flooding and groundwater quantity, comprising:
  - Groundwater modelling: Three-dimensional numerical groundwater modelling carried out using MODFLOW-NWT and applied to predict water level responses due to soft sediment consolidation, groundwater inflow and drawdown in relation to excavations for water quality basins and the Purgatory Creek drainage adjustment
  - Flood modelling: Two-dimensional flood hydraulic modelling of the Lower Hunter River carried out using TUFLOW, independently verified against historic flooding events and validated against existing flood studies
  - Stormwater discharge modelling: Hydrologic modelling of existing and operational phase drainage conditions carried out using DRAINS in accordance with Ball et al. 2019 (Refer to **Section 10.2.4**).
- Meetings with flood focus group (consisting of representatives from the community, local businesses, local councils, State government agencies, Transport and an independent reviewer) (refer to **Chapter 6**): aimed at gathering relevant information and keeping the community and stakeholders informed on the assessment process
- Consultation with landowners near to the main alignment (refer to **Chapter 6**): to gain an understanding of the drainage and flooding behaviour of recent flooding events on their properties and to verify the flood model performance
- Consideration of the following criteria during the impact assessment process:
  - Surface water: NSW river flow objectives (from DECCW 2006) and NSW Blue Book requirements (DECC 2008)
  - Groundwater quantity: NSW Aquifer Interference Policy (AIP) (DPI 2012) minimal impact considerations for groundwater level
  - Flooding from the project: Flood design criteria and flood management design objectives (refer to **Section 10.2.3**) established based on policies, planning controls and guidelines as relevant and similar infrastructure projects in NSW.
- Consideration of climate change impacts on operational flooding (refer to **Section 10.2.5**)
- Development of site water balance (refer to **Section 10.6.5**): to capture project water uses or demands as well as the key sources of water that are available to the project during construction and their water quality constraints
  - Water balance was divided into south and north of the Hunter River
  - Operational water balance was not assessed as project operation is not anticipated to have any ongoing water demand or water take.
- Identification of appropriate environmental management measures to mitigate the potential impacts to hydrology and flooding resulting from construction and operation of the project (refer to **Section 10.7**)

- Development of surface water and groundwater monitoring regime: to be carried out pre-construction, during construction and through operation (refer to **Chapter 11** (surface water and groundwater quality) and the Surface Water and Groundwater Quality Working Paper (**Appendix K**)).

A detailed description of the assessment methodology is provided in the Hydrology and Flooding Working Paper (**Appendix J**).

10.2.1 Study areas

Three different study areas are applicable for the hydrology and flooding assessment:

- **Surface water study area**: A 500 metre buffer around the construction footprint, chosen to encapsulate the inferred area that may be affected (directly or indirectly) by the project (refer to **Figure 10-1**)
- **Groundwater study area:** A two kilometre buffer around the construction footprint, chosen to encapsulate surrounding registered groundwater bores (refer to **Figure 10-1**)
- **Flooding study area:** Floodplain areas of the Hunter River, Williams River and Tilligerry Creek that surround the project (refer to **Figure 10-2**). This study area extends:
  - North of the project along the Hunter River and Williams River to the junction of the two rivers at Raymond Terrace
  - South of the project along the Hunter River to the City of Newcastle and the river's outlet to the Tasman Sea
  - East of the project over Fullerton Cove onto the Tilligerry Creek floodplain to the Tilligerry Creek outlet into Port Stephens.

10.2.2 Groundwater survey

The groundwater survey to establish groundwater levels included:

- Pore pressure dissipation tests via cone penetrometer testing (CPT)
- Establishment of a groundwater monitoring network including 20 piezometers at 13 locations, comprising six single and seven paired (deep and shallow) installations
- Hydraulic testing at selected project piezometers
- Installation of 12 groundwater level data loggers at selected piezometers
- Groundwater level monitoring at the project piezometers
  - Carried out over five rounds between September 2016 and July 2017, which is considered representative of current groundwater levels.
  - Included manual dip gauging of groundwater level and download of groundwater level data loggers at a six-hourly data recording frequency.

Groundwater quality sampling was also carried out as part of the field assessment as discussed in the Surface Water and Groundwater Quality Working Paper (**Appendix K**).

Figure 10-1 Surface water and groundwater study areas

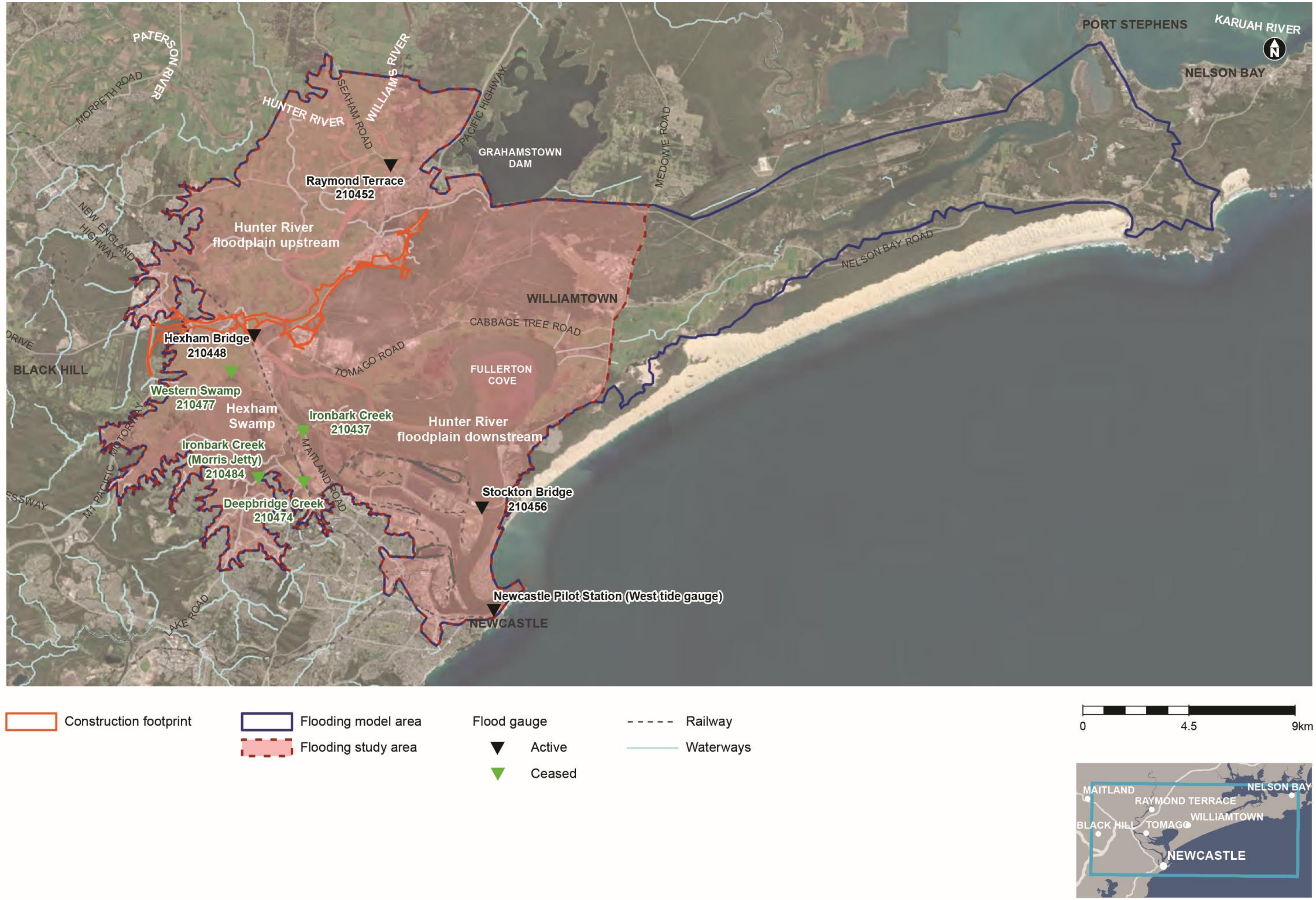

Figure 10-2 Flooding study area

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10.2.3 Flood design criteria and objectives

Flood design criteria

The relevant design criteria are outlined below:

- Flood immunity requirement
- At the main alignment, a minimum 5% annual exceedance probability (AEP) Hunter River flood (approximate equivalent 1 in 20 Average Recurrence Interval (ARI)). Achieved through design of proposed road embankments and culverts
- Underside of all bridges above the 1% AEP (1 in 100 ARI) Hunter River flood plus 0.5 metres freeboard
- Transverse culverts are generally designed for 1% AEP event (local catchment flooding), and 5% AEP in the floodplain to ensure 5% AEP flood immunity is provided to the carriageway edge line
- Minimise any increase in flood levels/depths, velocity, hazard and duration of inundation due to temporary and permanent infrastructure where reasonable and feasible during flood events up to and including the 1% AEP event
- Dedicated evacuation routes not to be adversely impacted in flood events up to and including the probable maximum flood.

Flood management design objectives

The objectives that have been adopted as the project's quantitative design limits are detailed in **Table 10-2**. These objectives apply outside the construction footprint, for events up to and including the 1% AEP flood event. These have been established based on relevant policies, planning controls and guidelines and benchmarked against similar infrastructure projects in NSW.

Adoption of these objectives would minimise the risk to public safety, buildings, existing highways and roads, existing rail lines and land uses.

Table 10-2 Quantitative flood management objectives

Parameter	Location or land use	Quantitative design objective	Justification / description
Afflux i.e. increase in flood level resulting from implementation of the project	Above floor flooding of habitable floors [1]	50mm	For the project, the increase in flood level (afflux) should be minimal. A target maximum afflux of 50mm has been adopted for habitable floors where there is above floor flooding. This target is unlikely to result in a significant impact to land use and hazard. A 50mm afflux threshold is considered reasonable in relation to the magnitude of flooding in the Hunter River and the overall susceptibility of urban development in the floodplain (large majority is above the 1% AEP event levels and most of the impacted area is rural). For the remaining areas a target of 100mm afflux outside the project has been generally adopted.
	Below floor flooding at habitable buildings	100mm	
	Other urban and recreational areas	100mm	
	Sensitive infrastructure, assumed to include: • Emergency services (e.g. hospitals, ambulance, fire, police stations) • Electricity substations • Water treatment plants.	50mm	
	Rural and forest land	100mm	

Parameter	Location or land use	Quantitative design objective	Justification / description
	Named roads and railways	Less than 100mm. Less than 10 per cent change in length of overtopping.	Target has been adopted to minimise impacts to transport routes
Flood hazard i.e. increase in flood hazard resulting from implementation of the project	All areas outside the project	Minimise changes based on an assessment of risk with a focus on land use and flood sensitive receptors	Minimising increases in flood hazard is important for public safety. Avoiding widespread increases in flood hazard would lead to minimal to no changes to hydraulic characteristics of the floodplain including floodways and flood storages. The project has been developed with a target of minimising increases in flood hazard.
Flood duration i.e. increase in duration of inundation resulting from implementation of the project	All areas outside the project	Less than 10 per cent change in duration of inundation for flood depths above 0.5m	Minimising increases in flood inundation duration would mitigate potential impacts to residents isolated within houses or may have evacuated and wish to return. Minimising flood inundation duration is also important in minimising impacts to rural and forested lands including agricultural activities. The project has been developed with a target of minimising increases in duration of flood inundation.

[1] The definition of habitable floors/rooms is consistent with the use of this term in the NSW Floodplain Development Manual (NSW Government 2005). In a residential setting this comprises a living or working area such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. In an industrial, commercial or other building, this comprises an area used for an office or to store valuable possessions, goods or equipment susceptible to flood damage in the event of a flood

Flood hazard

Flood preparedness, flood hazard and emergency management guidelines are detailed in Australian Disaster Resilience Handbook 7, Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (Australian Institute for Disaster Resilience 2017). The flood hazard classification from the guidelines which describe the varying flood hazard ratings according to flood depth and flow velocity are as follows:

- H1: Generally safe for people, vehicles and buildings
- H2: Unsafe for small vehicles
- H3: Unsafe for vehicles, children and the elderly
- H4: Unsafe for people and vehicles
- H5: Unsafe for people and vehicles. Buildings require special engineering design and construction
- H6: Unsafe for people or vehicles. All buildings types considered vulnerable to failure.

These guidelines were considered in defining existing flood hazard for the full range of flood events for the project. To provide a consistent and simplified commentary on impacts of the project on flood hazard, flood hazard categories H1 and H2 are referred to as “low” hazard and flood hazard categories H3 to H6 are referred to as “high” hazard.

10.2.4 Technical modelling assessment

Quantitative numerical modelling has been completed for the assessment of existing flooding, stormwater discharge and groundwater quantity conditions. A summary of the modelling carried out is provided below with further details in the Hydrology and Flooding Working Paper (**Appendix J**).

Groundwater modelling

Three-dimensional numerical groundwater modelling was carried out using MODFLOW-NWT, an industry standard saturated groundwater flow model code. The objectives of the groundwater model were to:

- Match historical groundwater levels
- Predict change in groundwater level due to the project
- Predict change in groundwater contribution to proximate surface watercourse and wetlands due to the project.

The groundwater model was applied to predict water level responses due to soft sediment consolidation, groundwater inflow and drawdown in relation to excavations for water quality basins and the Purgatory Creek adjustment. Dewatering requirements for smaller scale excavations (such as for bridge pier foundations) were assessed analytically due to limitations of the groundwater model resolution.

Flood modelling

Detailed flood modelling was carried out in a TUFLOW two-dimensional flood hydraulic model of the Lower Hunter River. The model extended five kilometres upstream on the Hunter River and four kilometres upstream on the Williams River from its junction with the Hunter River at Raymond Terrace, and includes the floodplains of these rivers. The model extends downstream to the Hunter River's outlet into the Tasman Sea. The model also covers the adjacent floodplain areas including swamp areas and Coastal wetlands within Hexham Swamp Nature Reserve, the Fullerton Cove overflow onto the Tilligerry Creek floodplain and the Tilligerry Creek outlet to Port Stephens.

Some of the key tasks carried out for the flood modelling were:

- Collection and review of existing flood studies and flood models
- Review, update and refinement of existing hydrology and hydraulic flood models for the Williamtown, Salt Ash, Purgatory Creek and Tomago areas
- Update and refinement of the TUFLOW model in key locations based on additional topographic survey and site reconnaissance, including improved representation of Hunter Valley Flood Mitigation Scheme
- Verification of the updated TUFLOW model for the most recent local, large flood events for which data is available, being the April 2015 and January 2016 flood events
- Modelling assessment of a range of design flood events including the 20% (1 in 5 ARI), 10% (1 in 10 ARI), 5%, 2% and 1% AEP and probable maximum flood events for the existing case
- Modelling assessment of a range of design flood events including the 20%, 10% and 5% AEP flood events for the construction phase
- Modelling assessment of a range of design flood events including the 20%, 10%, 5%, 2% and 1% AEP and probable maximum flood events for the operational phase, representing the change in land use, drainage conditions and hydraulic obstructions potentially affecting flood hydrology
- Assessment of cumulative flooding impacts due to the project and other approved projects
- Independent verification reviews of the flood modelling carried out by third parties.

Limitations identified in the flood model include:

- The extent of identified flooding impacts is in some cases limited by the extent of the available flood modelling. Impacts may extend further than the model domain
- The flood model is based on a 20 metre resolution model grid and estimates of localised impacts due to small scale features are considered indicative
- The absolute accuracy of the flood model is generally limited by vertical accuracy of LiDAR data (typically +/- 0.15 metres to one standard deviation), horizontal resolution of the model grid (20 metres), accuracy of bathymetric survey, the dynamic nature of the river bathymetry and other factors such as temporal variability of vegetation. Given these factors, the accuracy of the flood model is likely to be +/- 0.1 to 0.2 metres, with the accuracy of the LiDAR being a significant influence on the model accuracy. Other technical factors, including the numerical precision of the modelling computation scheme, also contribute to accuracy limits on all flood models. As a result, ARR 2019 guidelines (Ball et al. 2019) state that it is appropriate the modelling results (flood levels) are not reported to the nearest millimetre, and impacts less than 0.01 metre (i.e. 10 millimetres) are not reported, as they are considered to be within the precision of the numerical model and data.

Construction access tracks and ancillary facilities

During construction, the flood modelling assumed that the temporary access roads, are generally raised by 0.5 to one metres, and up to 2.5 metres above natural ground level. These are similar to other existing rural property access roads on the floodplain. Similarly, the flood modelling assumed that the ancillary facilities within low lying areas would be filled to provide 20% AEP flood immunity (typically raised by 0.5 to one metres, and up to 2.5 metres, above natural ground level).

During operation, the flood modelling assumed that the ancillary facilities and associated elevated hardstand areas would be removed, however access tracks across the flood plain to and along the viaduct have been assessed as retained for operational maintenance purposes.

Stormwater discharge modelling

The assessment of stormwater and flood discharges from the project was carried out based on DRAINS hydrologic modelling of existing and operational phase drainage conditions. The design rainfall data for the modelling was obtained from the Heatherbrae Bureau of Meteorology (BOM) site. Modelling was carried out using the RAFTS storage routing hydrology within DRAINS. Flows were quantified at the downstream model boundary, being the area immediately downstream of project stormwater discharges to receiving waterways and drainage lines. The model output was used to assess potential impacts to downstream drainage systems and natural areas and is considered indicative only of conditions immediately downstream of the assessed discharge location.

10.2.5 Climate change assessment

The potential impacts of climate change on flood behaviour were investigated through assessment of a number of combinations of increased catchment flooding, from increased rainfall intensity, and sea level rise scenarios.

The 0.5% (1 in 200 ARI) and 0.2% (1 in 500 ARI) AEP flood events were adopted as proxies for increased rainfall intensity and river flood flows due to climate change on the current day 1% AEP flood event. The 0.5% AEP flood event represents a 17 per cent increase in the Hunter River peak flow from the current day 1% AEP flood event. The 0.2% AEP flood event represents a 45 per cent increase in the Hunter River peak flow from the current day 1% AEP flood event. The sea level rise scenarios assessed included a 0.4 metre rise in sea level from current levels for the year 2050, and 0.9 metre rise for the year 2100. These projections are based on research by the Intergovernmental Panel on Climate Change (IPCC) and were refined for the Australian region.

10.3 Existing environment

10.3.1 Catchment overview

The project is located in the lower portion of the Hunter River catchment on a low-lying, gently undulating floodplain environment – the Lower Hunter River Floodplain. The eastern section of the project is within the Tomago Sandbeds Catchment Area, classified as a Special Area under the *Hunter Water Act 1991* and protected as a drinking water supply.

The project is located within the following water sources and water sharing plans (**Figure 10-3**):

- Newcastle Water Source of the Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009 (NSW Government 2009) (applicable for groundwater and surface water)
- Sydney Basin–North Coast Groundwater Source of the Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016 (NSW Government 2016b) (applicable for groundwater)
- Tomago Groundwater Source of the Water Sharing Plan for the North Coast Coastal Sands Groundwater Sources 2016 (NSW Government 2016c) (applicable for groundwater).

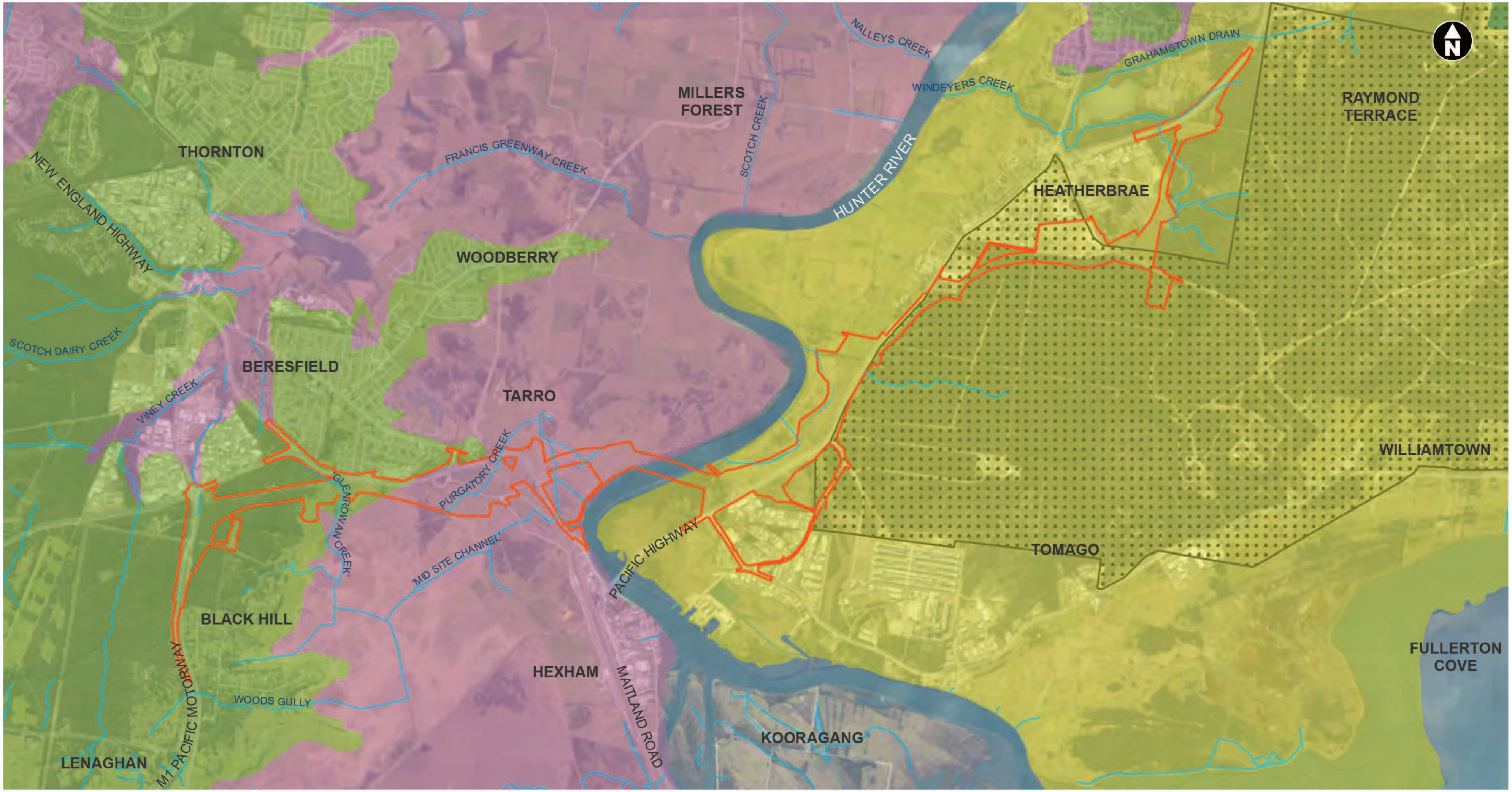
The catchment area surrounding the project is comprised of a range of land uses including agricultural, industrial, commercial, residential and environmental conservation in wetlands and national parks.

Three main geological units occur within the project area, Permian Tomago Coal Measures, Quaternary aged sediments associated with the Hunter River and Quaternary Coastal Sands, and Permian Mulbring Siltstone and the Muree Sandstone of the Maitland Group. The project and surrounding area traverse eight soil landscapes. These are detailed in **Chapter 16** (soils and contamination).

The climate of the Lower Hunter River catchment is warm and temperate, generally experiencing mild to hot summers and cool to mild winters. A review of the BOM rainfall and temperature data for the Raymond Terrace observation station indicated that the mean annual rainfall is about 1041 millimetres. Monthly rainfall is moderately seasonally distributed with a wetter period from December through June and a drier period from July through November. Median monthly rainfall is the lowest in August at about 40.8 millimetres and highest in March at about 102.1 millimetres. Average maximum temperature approaches 30 degrees Celsius in January and about 18 degrees Celsius in July (Australian Bureau of Meteorology 2020b).

The catchment area is generally characterised as a low-lying, gently undulating floodplain environment (refer to **Figure 10-4**). The elevation varies along the project construction footprint with three distinct areas:

- Western portion (between Tarro and Black Hill): comprising gently sloping ground between reduced level (RL) four metres Australian Height Datum (AHD) and RL 30 metres AHD (with a ridgeline oriented north to south)
- Central portion (between Tomago and Tarro): comprising low lying, gently undulating floodplains at below RL three metres AHD
- Eastern portion (between Raymond Terrace and Heatherbrae): comprising mildly undulating terrain between RL two metres AHD and 10 metres AHD.



Construction footprint

Tomago Sandbeds Catchment Area

Waterways

Water sharing plans

Sydney Basin–North Coast Groundwater Source of the *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* (groundwater)

Newcastle Water Source of the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009* (groundwater and surface water)

Tomago Groundwater Source of the *Water Sharing Plan for the North Coast Coastal Sands Groundwater Sources 2016* (groundwater)

0 1.5 3 km

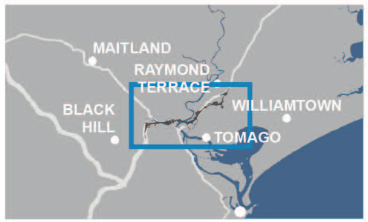


Figure 10-3 Water sharing plans

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Figure 10-4 Elevation

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10.3.2 Sensitive receiving environments

The following SREs relevant to flooding and hydrology have been identified within the flooding study area:

- Tomago Sandbeds Catchment Area: a strategically important ongoing and backup drinking water supply
- All groundwater bores within the project construction footprint (refer to **Section 10.3.4**)
- Coastal Wetlands (Coastal Management SEPP), the Hunter River wetland and the Hunter Estuary Wetlands Ramsar site
- All groundwater dependent ecosystems (GDEs) in the study area (refer to **Section 10.3.4**).

10.3.3 Surface water hydrology

Waterways and wetlands

The surface water study area contains a number of waterways and wetlands, as shown in **Figure 10-5**. The construction footprint would be located within the Hunter River and its floodplain, a ninth order major waterway which forms a tidally influenced estuarine system in its lower reaches. The Hunter River branches into the North Channel and South Channel around Kooragang Island and re-joins between Tighes Hill and Stockton, flowing adjacent to the Newcastle city centre, before discharging into the Tasman Sea through the Port of Newcastle breakwalls.

The following waterways and wetlands are located within the construction footprint:

- Viney Creek: ephemeral, fourth order stream that flows in a north-easterly direction into Woodbury Swamp, which is listed as a Coastal Wetland under the Coastal Management SEPP
- Glenrowan Creek: ephemeral, first order stream which drains a predominantly agricultural catchment but also receives runoff from New England Highway and urban runoff from Tarro
- Purgatory Creek: second order stream which is ephemeral in its upper reaches then becomes perennial about 1.5 kilometres upstream of its confluence with the Hunter River
- Windeyers Creek: second order stream situated between the southern urban area of Raymond Terrace and the northern part of Heatherbrae. It is largely ephemeral until its downstream reach where it is tidal
- Tributary of Windeyers Creek: first order tributary upstream of the project
- Grahamstown Drain: an artificial drainage channel which flows in a south-westerly direction from Grahamstown Dam to the Hunter River via Windeyers Creek
- Unnamed coastal wetland west of the Hunter River, which is an estuarine waterbody also defined as a Coastal Wetland under the Coastal Management SEPP
- Unnamed coastal wetland east of the Hunter River which is an estuarine waterbody also defined as a Coastal Wetland under the Coastal Management SEPP
- Unnamed coastal wetland south of the existing New England Highway which is a freshwater waterbody also defined as a Coastal Wetland under the Coastal Management SEPP
- Hunter River wetland: first order, ephemeral freshwater waterbody which is densely vegetated with instream macrophytes and riparian vegetation on the banks; located next to the Hunter Region Botanic Gardens (HRBG) between Tomago and Heatherbrae. It is considered an important wetland environment due to presence of aquatic and wetland habitat features on site.

The above waterways and wetlands have relatively small catchment areas and low gradients. The smaller waterways are ephemeral and typically only flow after rainfall events, giving rise to a series of semi-permanent ponds and waterholes. The above waterways and wetlands generally drain into the Hunter River and its floodplain, which is a ninth order major waterway which forms a tidally influenced estuarine system in its lower reaches. The Hunter River branches into the North Channel and South Channel around Kooragang Island and re-joins between Tighes Hill and Stockton, running adjacent to the Newcastle city centre before discharging into the Tasman Sea through the Port of Newcastle breakwalls.

Dramatic or intensive changes over a short period of time could result in adverse impacts to waterways. The geomorphic assessment of waterways within the surface water study area indicates that the waterways are typically stable, low energy, and show little evidence for lateral migration. As such, they are considered low risk from stormwater discharges from the project. The main surface water resource within and near to the surface water study area consists of Grahamstown Dam. There are a number of small farm dams on private rural and rural residential properties, mainly on the western floodplain of the Hunter River upstream of the project and surrounding Hexham Swamp, in the suburbs of Black Hill and Lenaghan. Ponds are located in Beresfield Golf Course and Pasadena Crescent soccer fields in Beresfield which are likely to be used for irrigation of these golf courses and sports fields.

A detailed description including geomorphology for each waterway and wetland within the surface water study area is provided in the Hydrology and Flooding Working Paper (**Appendix J**).

The Hunter Estuary Wetlands Ramsar site is part of the Hunter Wetlands National Park and is comprised of two parts (refer to **Figure 10-5**):

- Kooragang Nature Reserve, located a minimum distance of about 1.9 kilometres south-east of the project, about 5.1 kilometres directly downstream of the project
- The Hunter Wetlands Centre Australia in Shortland (south of Hexham Swamp Nature Reserve), located about 3.8 kilometres south of the construction footprint.

The Hunter Estuary Wetlands Ramsar site are downstream of the project and are identified as an SRE in this assessment as these wetlands have the potential to be impacted by changes in surface water and groundwater hydrology and flooding from the project.

Hydrological flow regimes

The Hunter River and the smaller waterways within the surface water study area are subject to tidal influence. The Hunter River flow is perennial with a strong baseflow component. Mean monthly flow is moderately seasonally distributed and typically greatest from February through March and June.

Upstream of the tidally influenced reach, flow in the Hunter River is partially regulated by the operation of the Water Sharing Plan for the Hunter Regulated River Water Source. The water sharing plan covers the river from Glenbawn and Glennies Creek Dams, and downstream to the tidal limit of the Hunter Estuary.

Where the waterways described above traverse the low-lying Hunter River floodplain a relatively permanent presence of water is found due to lack of streambed gradient, presence of floodgates and channel incision below the surrounding water table. Inflows from the upper catchment are likely to have long residence times resulting in prolonged inundation of the surrounding catchment after flood events.

Above the low-lying floodplain areas, the relatively small catchment areas of Viney Creek (to the west of the surface water study area) would typically only generate episodic flows. Stream flows recess relatively quickly and are restricted to periods during and immediately after rainfall events. Baseflow from Viney Creek is not expected to form a substantial proportion of the total discharge of this creek. Low channel gradients and channel geomorphology, however, result in prolonged storage of standing water within the channel that results in a series of semi-permanent ponds and waterholes.

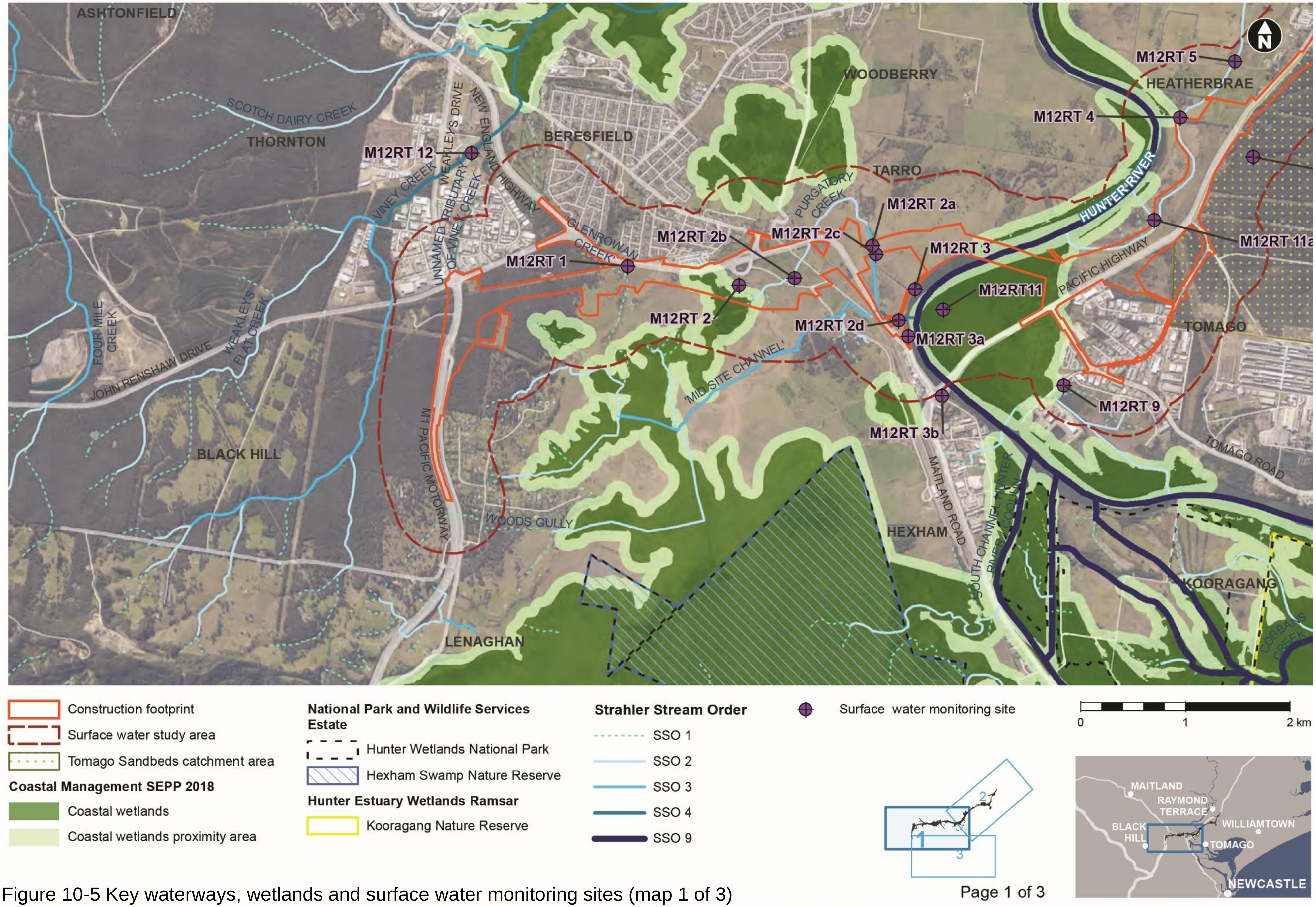

Figure 10-5 Key waterways, wetlands and surface water monitoring sites (map 1 of 3)

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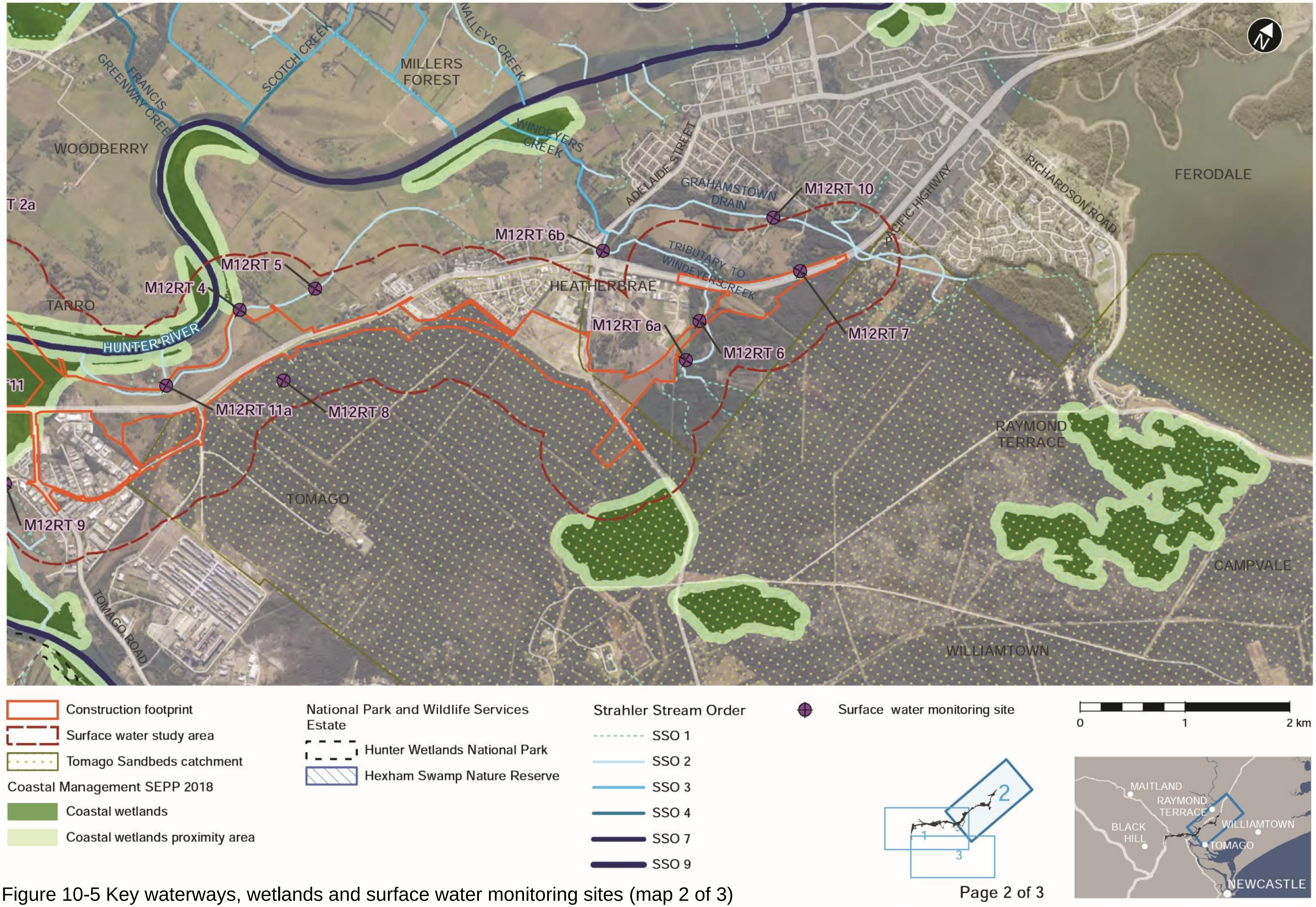

Figure 10-5 Key waterways, wetlands and surface water monitoring sites (map 2 of 3)

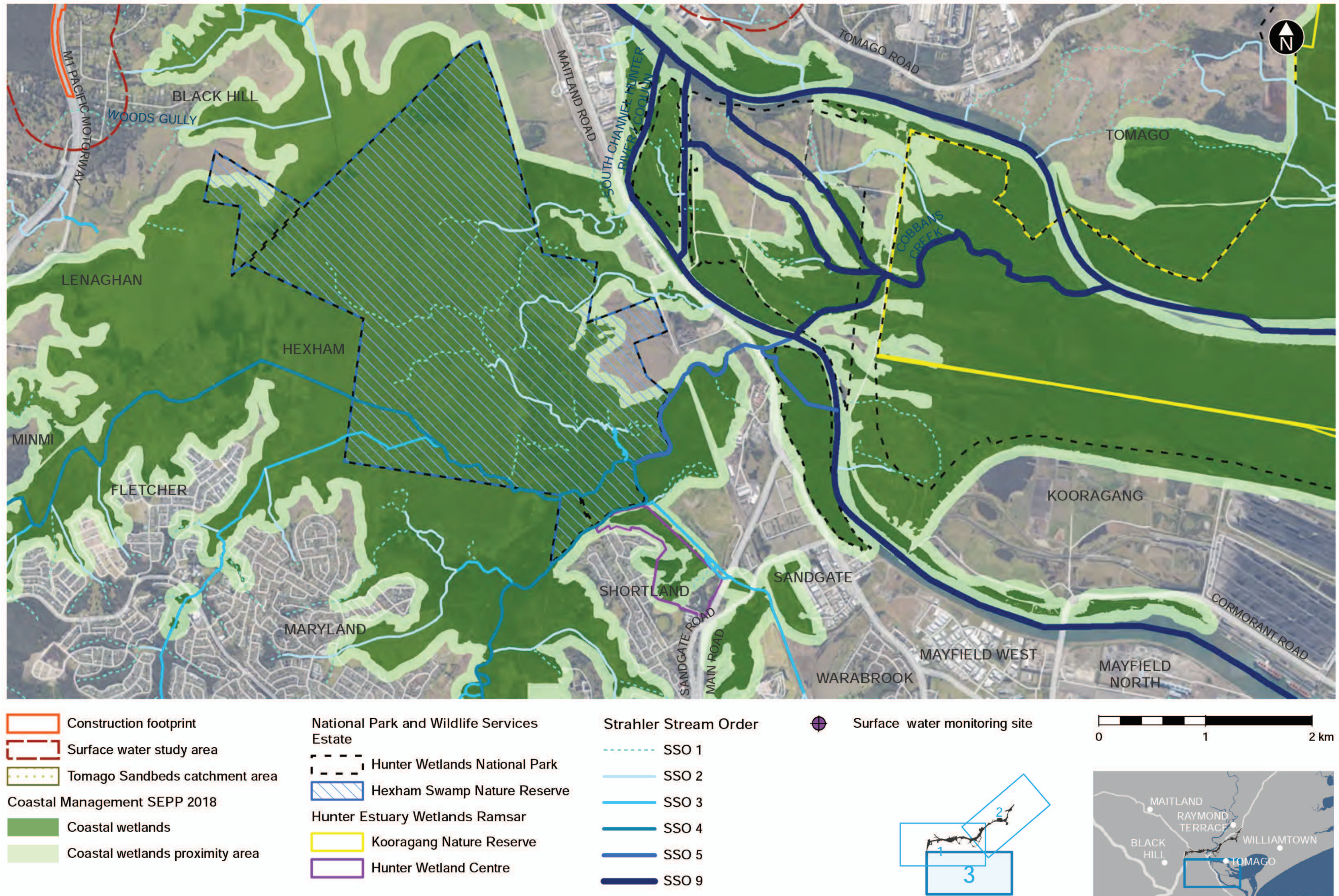

Figure 10-5 Key waterways, wetlands and surface water monitoring sites (map 3 of 3)

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10.3.4 Groundwater hydrology

Groundwater systems

Three main groundwater systems lie within the construction footprint (refer to **Figure 10-6**):

- Hunter Alluvium: Underlies the Hunter River floodplain and is comprised of Quaternary sedimentary deposits of clays, silts, sands and gravels. Key characteristics of this system include:
  - Groundwater largely flowing from the rocks of the Sydney Basin into the Quaternary alluvial deposits
  - Typically very shallow groundwater levels that often express at the surface, ranging from about 2.4 metres below ground level to 0.2 metres above ground level.
- Tomago Sandbeds: Located to the south-east of the project and is comprised of coastal sands associated with extensive inner barrier sand ridge deposits from the Pleistocene that are up to 30 metres thick. Key characteristics of this system include:
  - Occupies an area of 109 square kilometres which receives a relatively high percentage of recharge from rainfall runoff and infiltration
  - The catchment is designation as a 'Special Area' which is protected as a public drinking water supply under the *Hunter Water Act 1991*
  - Supplies about 20 per cent of the Lower Hunter's drinking water
  - Relatively shallow groundwater levels ranging from about 1.6 to 2.7 metres below ground level.
- Tomago Coal Measures: consists of a hard rock groundwater system associated with Permian deposits which outcrop in the western and central portions of the project. Key characteristics of this system include:
  - Typically relatively low permeability, particularly at depth with joints and fractures which provide pathways for groundwater flow
  - Lower permeability associated with interbedded sandstones and siltstones in comparison to the coal seams
  - Groundwater flow within the deeper hard rock formations is conceptualised to generally be controlled by bedding and fracture networks. A shallow unconfined aquifer can also exist in the weathering zone of the hard rock closer to the surface and is often associated with local drainage systems
  - Variable groundwater levels which are often a reflection of topography, ranging from about 6.3 to 16.8 metres below ground level in the area around Black Hill.

Groundwater flows

Groundwater in the study area flows from the high ground in the west associated with the Tomago Coal Measures that outcrops eastward towards the Hunter River floodplain. Groundwater flow from the Tomago Sandbeds within the study area is to the northwest, west, and south towards the Hunter River and Fullerton Cove.

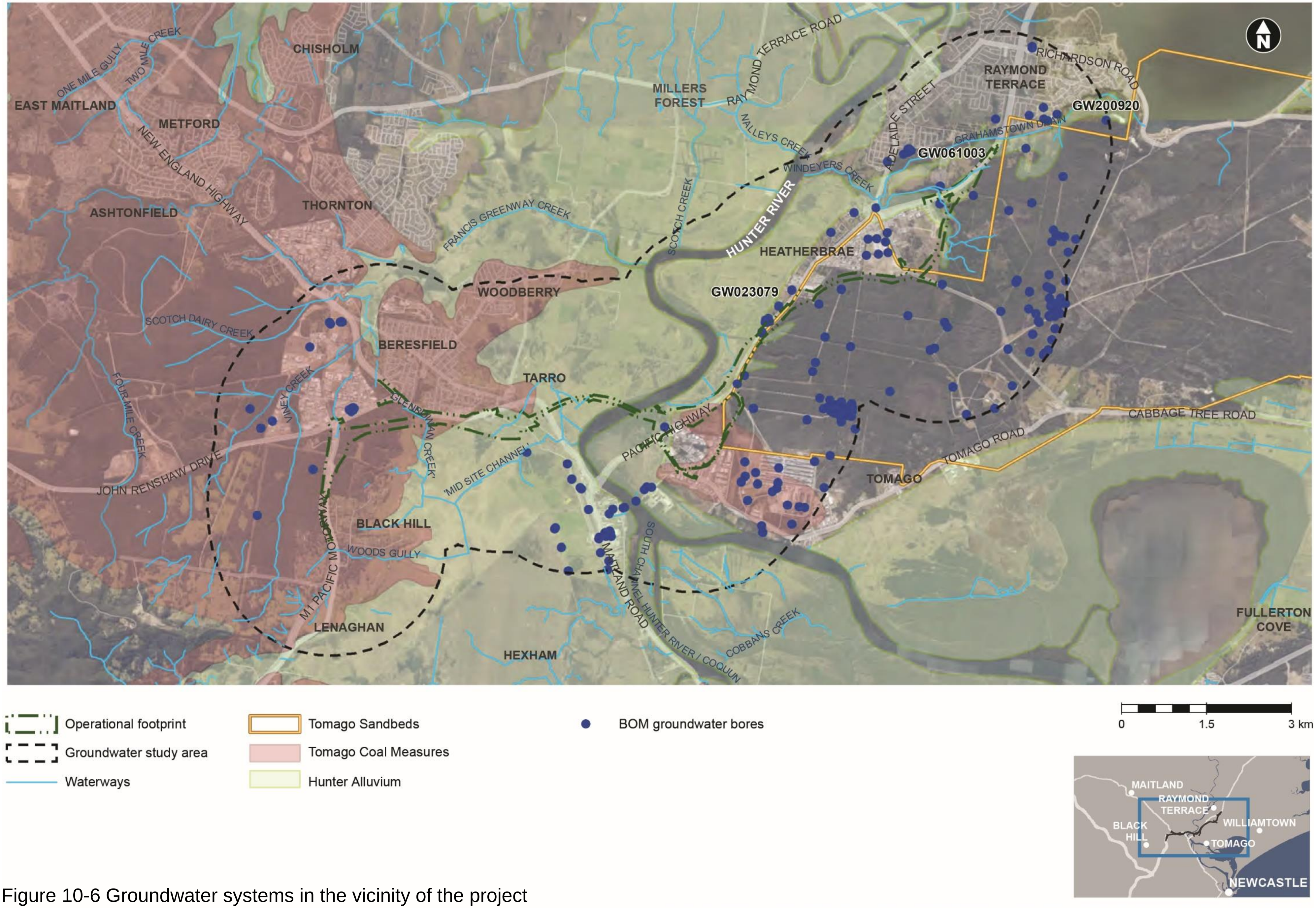

Figure 10-6 Groundwater systems in the vicinity of the project

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Groundwater levels

Groundwater levels in the Hunter River floodplain are typically below two metres AHD. Around Hexham, however, a localised groundwater mound occurs where the levels rise to about eight metres AHD. This mounding is associated with a historical coal tailings stockpile that was backfilled and rehabilitated in late 2015.

Groundwater levels along the main alignment range from 11 to 12 metres AHD in the west, declining to zero metres AHD around the Hunter River. East of the Hunter River groundwater elevations are typically two metres AHD, rising to four metres AHD in the area around Heatherbrae and declining to two metres AHD at Raymond Terrace.

Groundwater levels to the east of the study area are elevated. This is associated with enhanced infiltration and recharge at the Tomago Sandbeds, due to the relatively high percentage of recharge from rainfall runoff and infiltration

Groundwater dependent ecosystems

GDEs are considered to be ecosystems in which the species composition and natural ecological processes are wholly or partially determined by the availability of groundwater (Serov et al.,2012). **Section 9.3.4** details the aquatic and terrestrial GDEs within a landscape buffer area around the project. In addition, high priority GDEs within the groundwater study area as mapped within Water Sharing Plans (WSPs) (refer to **Figure 10-3**) are summarised below:

- WSP for the Hunter Unregulated and Alluvial Water Sources 2009 (NSW Government 2009):
  - Hexham Swamp, located near western area of project, south of Tarro
  - Woodberry Swamp, located near western area of project in Woodberry, about 700 metres north of construction footprint.
- WSP for the North Coast Fractured and Porous Rock Groundwater Sources 2016 (NSW Government 2016b):
  - Hexham Swamp and Woodberry Swamp
  - Wetland on boundary of groundwater study area, located about 1.8 kilometres north of the intersection of Masonite Road and Cabbage Tree Road, Tomago.
- WSP for the North Coast Coastal Sands Groundwater Sources 2016 (NSW Government 2016c):
  - Hexham Swamp and Woodberry Swamp
  - Wetland east of Tarro and south of Woodberry Swamp
  - Narrow (about 100 metres to 300 metres wide and up to 1.2 kilometres long) isolated pockets of ‘North Coast Coastal Sands GDEs’ adjacent to the western side of the Hunter River and relatively large pocket of ‘North Coast Coastal Sands GDEs’ adjacent to western side of Hunter River near Tomago, in the area where the project crosses the Hunter River
  - Two pockets of ‘North Coast Coastal Sands GDEs’ south west of Heatherbrae and at least 500 metres south west of the project’s construction footprint. Each pocket is about 300 to 400 metres in diameter.

These high priority GDEs generally coincide with areas formerly mapped as wetlands under the now repealed State Environmental Planning Policy No 14 – Coastal Wetlands. However, not all of the current Coastal Wetlands, as identified under the Coastal Management SEPP, in the groundwater study area are designated as high priority GDE by the relevant WSPs. The above wetlands are considered likely to be, in part, supported by groundwater discharge and as such are likely to be groundwater dependent ecosystems.

Groundwater users

Within the groundwater study area, 303 existing licensed bores were identified. Of these, five bores are located within the construction footprint (GW079605, GW200103, GW079447, GW079591 and GW200102). For all bores within the construction footprint except GW200102 (monitoring purpose), no specific use is recorded. Average and maximum bore depth was about nine and 54 metres respectively.

10.3.5 Flooding

Floodplain overview

Flooding on the Lower Hunter River floodplain is a result of both mainstream flooding from the Hunter River, and local catchment runoff. The Williams River joins the Hunter River just upstream of Raymond Terrace and the combined waters of these two rivers then flow in a south-westerly direction, traversing the Hunter River floodplain which varies in width. The floodplain is constricted at the following locations:

- On the western side of the river at a ridgeline that runs north-easterly to Woodberry from a high point in Beresfield
- Between Tarro and Tomago where a ridgeline restricts the floodplain to about 2.5 kilometres
- Just past the existing Hexham Bridge, where the floodplain is constricted to about 1.5 kilometres
- Fullerton Cove, connected to the North Channel of the Hunter River, is a shallow protected estuarine lagoon about three kilometres wide.

The floodplain within the flooding study area , varies in width from around seven kilometres between Heatherbrae and Thornton to 2.5 kilometres between Tarro and Tomago.

History of flooding

The Hunter River has experienced many floods during its recorded history, including in 1955, 1963, 1978, 1990, 2000, 2007, 2015 and 2016. The largest flood on record occurred in 1955 and was estimated to be about a 1% AEP flood event (Lawson and Treloar 1994) with flood depths of up to three metres across the Kooragang Island wetlands.

During the April 2015 floods, the gauge on the Hunter River at Hexham reached a peak water level of 1.88 metres AHD and 3.06 metres AHD at Williams River at Raymond Terrace (refer to **Figure 10-7**). It is generally the largest event experienced by many of the landowners in the area with the floodwaters extending onto the Hunter River floodplain. Based on peak flood levels and river flows at Raymond Terrace and Hexham, the flooding in April 2015 is estimated to be between a 20% AEP and 10% AEP flood event.

Following the 1955 flood event, which claimed 14 lives, the Hunter Valley Flood Mitigation Scheme was established by the NSW Government (refer to **Figure 10-8**). This has subsequently instigated 160 kilometres of levees, 3.8 kilometres of spillways, 40 kilometres of control banks, 245 floodgates and 120 kilometres of drainage canals (BMT WBM 2012b). The scheme provides flood protection to people, property and infrastructure across the Hunter River floodplain. While the scheme does not provide complete flood protection. It is designed to mitigate or reduce flood damage and provide minor flood protection for rural land and moderate flood protection for the Maitland, Lorn, Raymond Terrace, Singleton and Aberdeen areas.

Existing flooding behaviour

Flooding on the Hunter River floodplain is a result of both flooding from the Hunter River, and local catchment runoff. The 20%, 5%, 2%, 1% AEP and the probable maximum flood (PMF) flood events were simulated, mapped and analysed for existing catchment development conditions. Typical existing flood depths at Hexham Swamp and the Hunter River floodplain upstream of the project are shown in **Table 10-3**.

Table 10-4 presents the peak flood depths, flow velocities and duration of inundation for each of these events for Hexham Swamp and the Hunter River floodplain upstream and downstream of the project (refer to **Figure 10-2**). Existing flooding behaviour for the 5% and 1% AEP flood events are shown in **Figure 10-9** and **Figure 10-10**.

Table 10-3 Typical existing flood depths

Flood event	Hexham Swamp (metres)	Hunter River floodplain upstream of the project (metres)
20% AEP	0.5 to 1.0	0.3 to 0.5
10% AEP	0.7 to 1.5	1.5 to 2.3
5% AEP	1.0 to 3.0	2.0 to 2.5
2% AEP	2.0 to 3.5	2.5 to 3.5
1% AEP	3.0 to 4.0	3.0 to 4.5

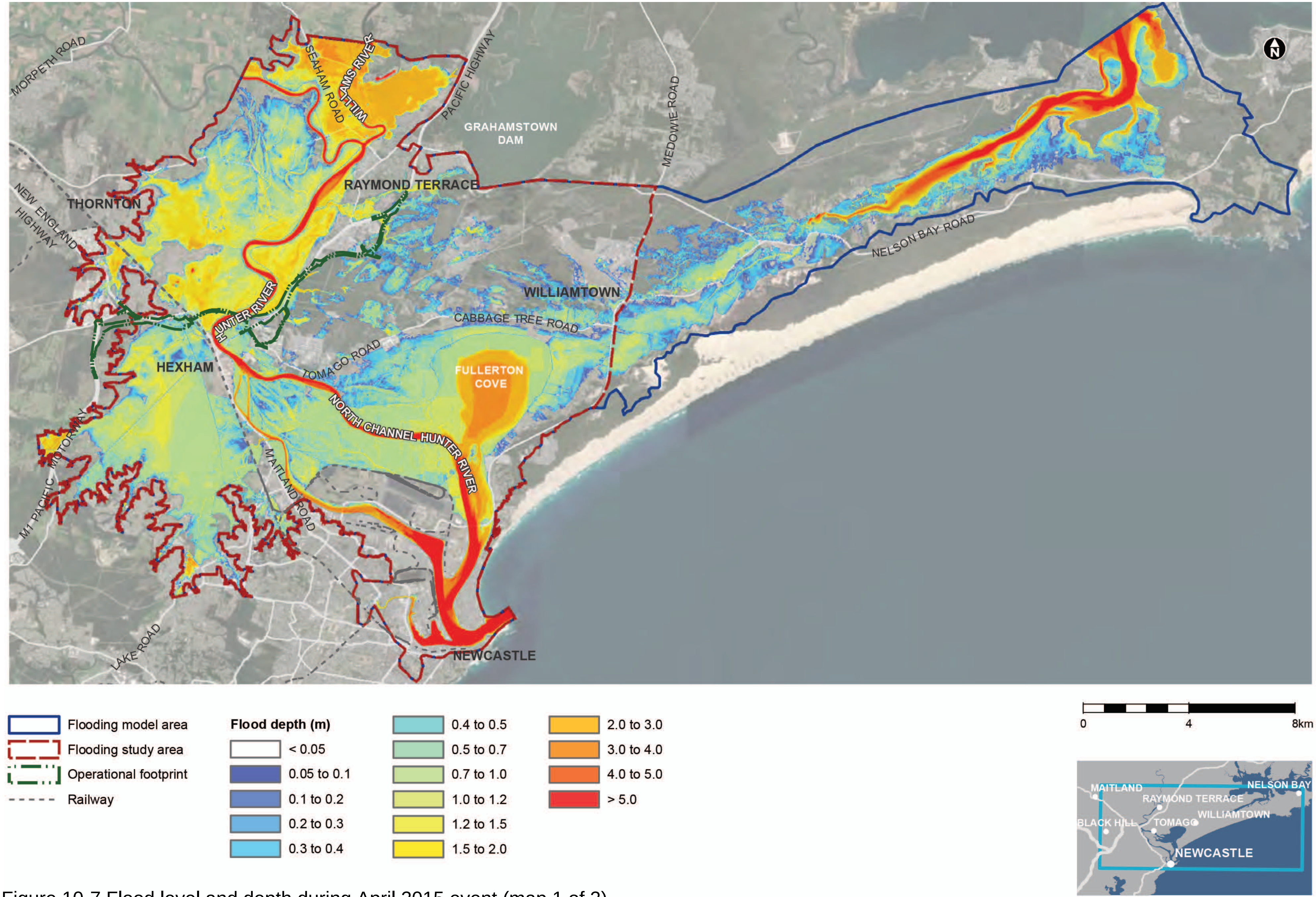
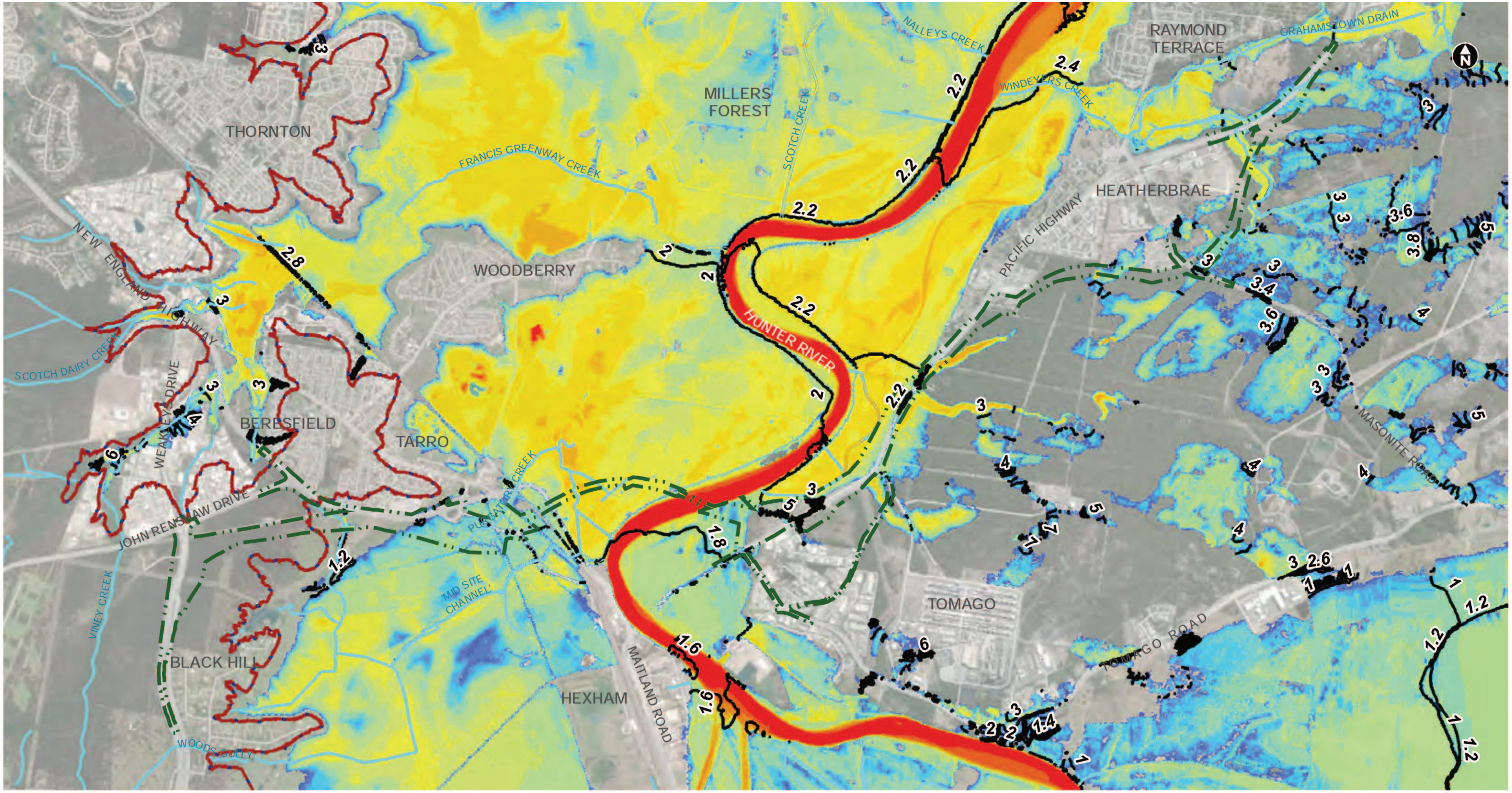


Figure 10-7 Flood level and depth during April 2015 event (map 1 of 2)



Flooding model area	
Flooding study area	
Operational footprint	
Flood level contour (0.2m AHD	

Flood depth (m)

- < 0.05
- 0.05 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.7
- 0.7 to 1.0
- 1.0 to 1.2
- 1.2 to 1.5
- 1.5 to 2.0
- 2.0 to 3.0
- 3.0 to 4.0
- 4.0 to 5.0
- \> 5.0

Note: zoomed project view

0 1 2km

Figure 10-7 Flood level and depth during April 2015 event (map 2 of 2)

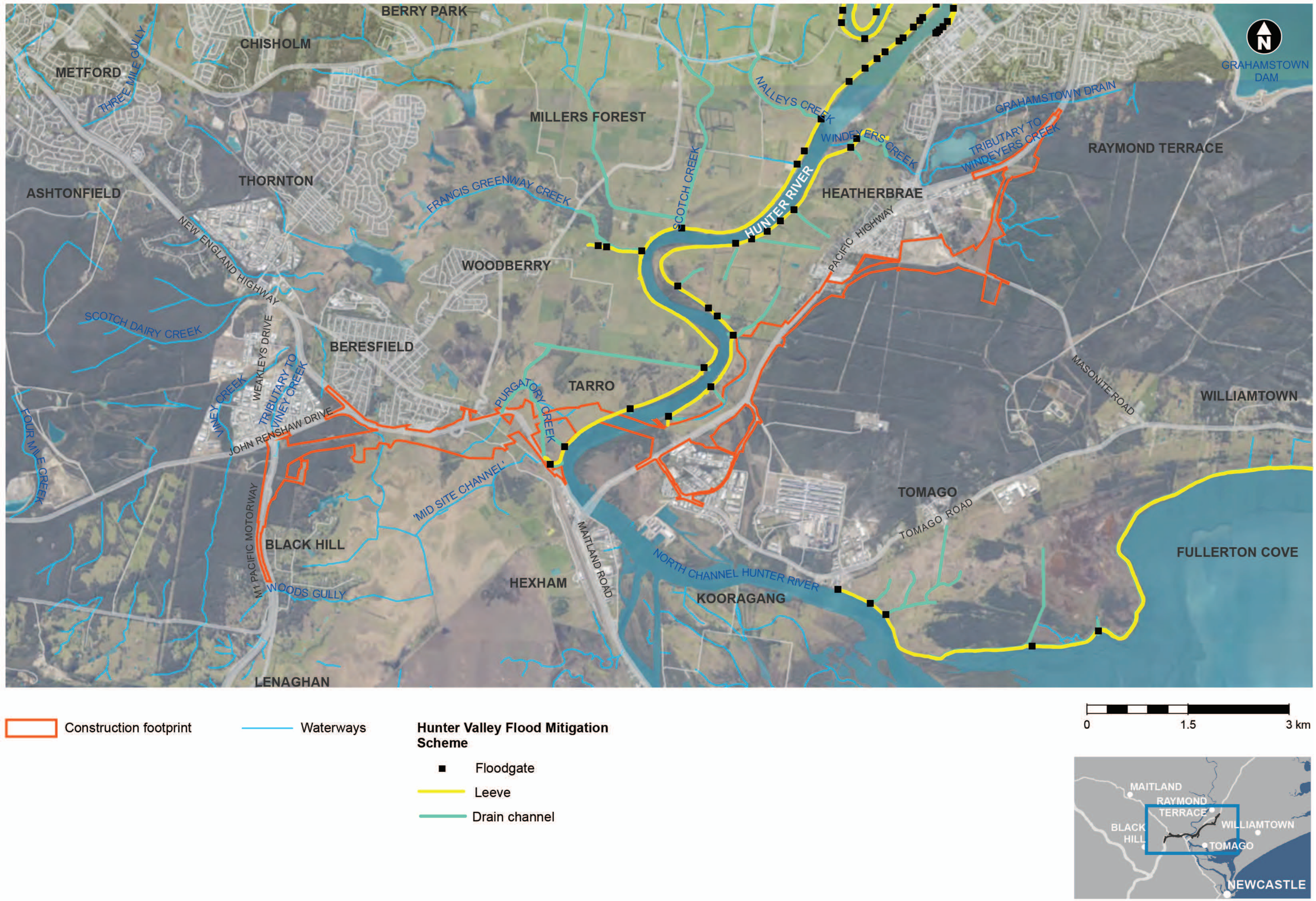


Figure 10-8 Hunter Valley Flood Mitigation Scheme

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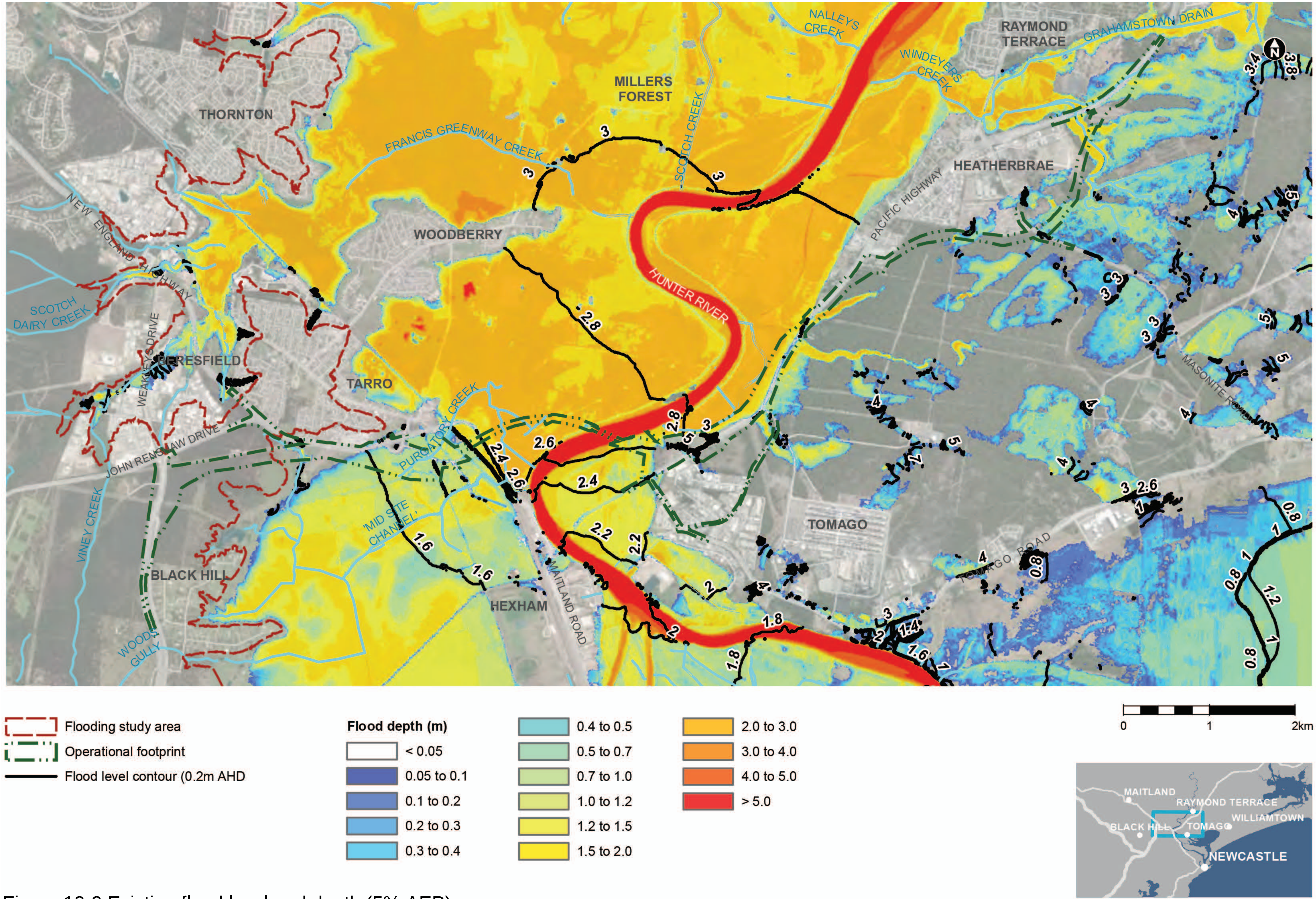

Figure 10-9 Existing flood level and depth (5% AEP)

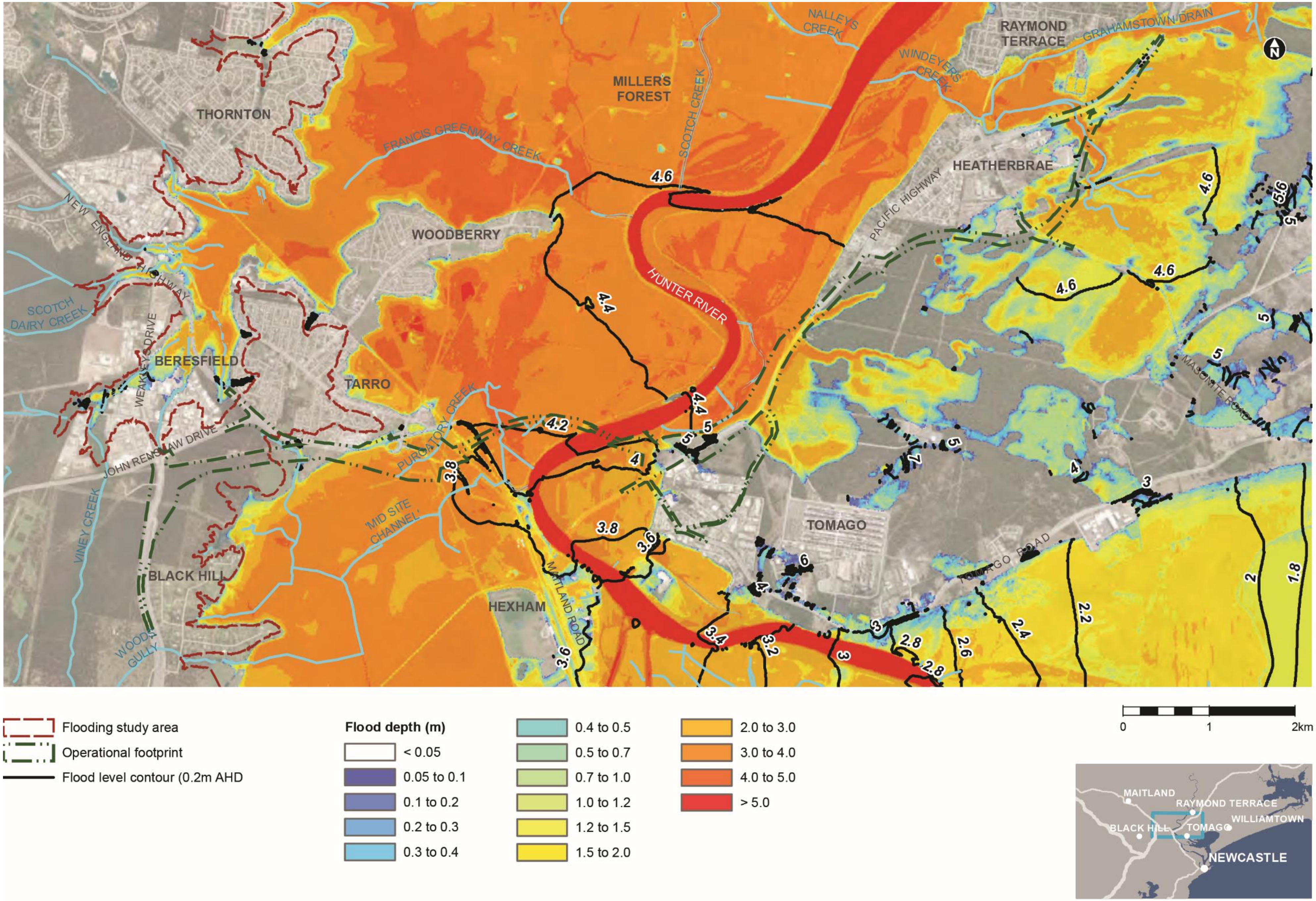

Figure 10-10 Existing flood level and depth (1% AEP)

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Table 10-4 Peak flood depths, flow velocities and duration of inundation at key parts of the study area

Key part of study area	Sub-sections of the study area	Peak flood depths (metres)				Flow velocities (metres per second)				Duration of inundation (hours)			
		20%	5%	1%	PMF	20%	5%	1%	PMF	20%	5%	1%	PMF
Hexham Swamp	Hexham Swamp	0.5-1	1-3	3-4	>7	0.1	0.1	0.6	0.5-1.5	40-90	70-90	80-90	>144
	Urban areas	1.5	1.5	1.8	-								
Hunter River floodplain upstream of the project	Rural and environmental conservation areas	0.3-0.5	2-2.5	3-4.5	7-8	0.1-0.5	0.5-0.8	0.6-1	0.7-2.7	20-70	65-80	75-90	>144
	Urban areas – Raymond Terrace	0.5	1-1.5	2-3	-								
	Minor waterways	0.5-2	1.5-2.5	2-4	-								
Hunter River floodplain downstream of the project	Hunter River floodplain	0.5-1	1-1.5	1.5-3	5-7	0.3-0.5	0.5	0.6-1.5	1-1.5	-	-	-	-
	Commercial and industrial – Tomago	0.2-0.4	0.2-0.4	0.2-0.4	-				-	-	-	-	-
	Commercial and industrial – Hexham and Sandgate	-	-	0.5-2	-	-	-		-	-	-	-	-

Existing inundation of infrastructure

Road

The existing major roads near the project that form the main evacuation and emergency access routes from areas that are flood prone are listed in **Table 10-5**. The conditions in which these roads would flood are also listed in the table. Further detail including the total lengths of each major road in the flooding study area affected by a flood hazard rating of H2 or higher, making the roads impassable for most vehicles, is listed in the Hydrology and Flooding Working Paper (**Appendix J**).

As described in **Section 3.2.8** and shown in **Table 10-5** and **Figure 10-11**, existing sections of the main thoroughfares in the vicinity of the project (the New England Highway and the Pacific Highway) are currently flooded during the 10% AEP event, and are unlikely to be trafficable in the 5% AEP event. The roads shown in **Table 10-5** and **Figure 10-11** also include evacuation and emergency access routes from flood prone areas.

Table 10-5 Flooding on existing major roads

Road	Comment
West of Hunter River	
M1 Pacific Motorway and John Renshaw Drive – Black Hill to Tarro	• Flood free except for in the PMF at Lenaghan, at crossing of an unnamed creek which drains to the north-western end of Hexham Swamp.
New England Highway – Thornton to Beresfield	• Flood free except for the PMF • Flooded during the PMF at Viney Creek.
New England Highway – Tarro	• Flooded in 2% AEP flood event, immediately west of Anderson Drive overpass.
Pacific Highway – Hexham	• Existing northbound bridge crossing the Hunter River (Hexham Bridge) is flood free in all events including the PMF • Existing southbound bridge is flood free in up to and including the 1% AEP event, and is flooded in the PMF.
New England Highway, Pacific Highway, Maitland Road – Hexham	• New England Highway heading north into Tarro flooded to 0.3m depth in 10% AEP flood event • Pacific Highway flooded in 10% AEP flood event affecting access to the south toward Hexham and Sandgate • Unlikely to be trafficable in 5% AEP flood event.
East of Hunter River	
Pacific Highway – Tomago	• Flooded to 0.1m depth in 20% AEP flood event, between Hexham Bridge and Tomago Road. Tomago Road also flooded at intersection. Unlikely to be trafficable in 10% AEP flood event due to depths over 0.4m • Minor flooding in 10% AEP flood event, just south of the HRBG.
Old Punt Road	• Flooded in 20% AEP flood event.
Tomago Road and Masonite Road	• Flooded to 1m depths in 20% AEP flood event, access cut-off.
Pacific Highway – Heatherbrae and Raymond Terrace	• Remains flood free up to the 5% AEP flood event • The Pacific Highway experiences depths of flooding over 0.5m during the 2% AEP flood event near Windeyers Creek, access cut-off over 1km length • Access cut-off at Grahamstown Drain in the PMF.

Road	Comment
Adelaide Street	• Access cut-off in 2% AEP flood event at Windeyers Creek and 450m section to the north.

An analysis of flooding of highways and major roads was carried out to estimate the total length on each major road in the study area affected by a flood hazard rating of H2 or higher, making the roads impassable for most vehicles. The results are summarised in **Table 10-6**, which shows the length of road that is flood-affected in each design flood event.

Table 10-6 Length of highways and major roads subject to H2 flood hazard in existing case

Road	Length (kilometres)					
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Blue Gum Road	0.4	0.4	0.4	0.4	0.5	0.5
Cabbage Tree Road	0.5	0.6	0.8	0.9	1.0	4.4
Cormorant Road	0.0	0.0	0.0	0.0	0.0	4.5
Hannell Street	0.1	0.1	0.1	0.1	0.1	2.1
Hunter Street	0.3	0.3	0.4	0.4	0.5	0.8
Industrial Drive	0.0	0.0	0.0	0.0	0.0	1.1
King Street	0.0	0.0	0.2	0.2	0.2	0.2
Lenaghans Drive	0.0	0.1	0.1	0.2	0.4	0.9
Maitland Road	0.0	0.3	0.6	4.5	5.1	6.1
Nelson Bay Road	0.0	0.0	0.0	0.0	0.0	6.3
New England Highway	0.2	0.5	0.8	0.9	1.8	4.5
Newcastle Road	0.4	0.5	0.5	0.6	0.6	0.7
Pacific Highway	0.1	1.2	1.9	4.4	5.8	11.9
Raymond Terrace Road	0.7	5.4	6.1	6.8	7.1	8.1
Sandgate Road	0.4	0.5	0.5	0.7	1.0	1.4
Seaham Road	3.3	3.6	3.9	3.9	4.0	4.4
Teal Street	0.0	0.0	0.0	0.0	0.0	1.0
Thomas Street	0.0	0.0	0.0	0.0	0.0	0.2
Tillie Street	0.0	0.0	0.0	0.0	0.0	0.1
Tomago Road	0.8	0.9	1.0	1.1	1.3	7.1
Tourle Street	0.2	0.2	0.2	0.2	0.2	0.7
Wilkinson Avenue	0.1	0.1	0.2	0.2	0.5	0.6
William Bailey Street	0.0	0.0	0.3	0.4	0.4	0.5

Construction footprint

Waterways

Flooded in event

10% AEP

5% AEP

2% AEP

1% AEP

PMF

0 1.5 3 km

Figure 10-11 Existing flooding on major roads

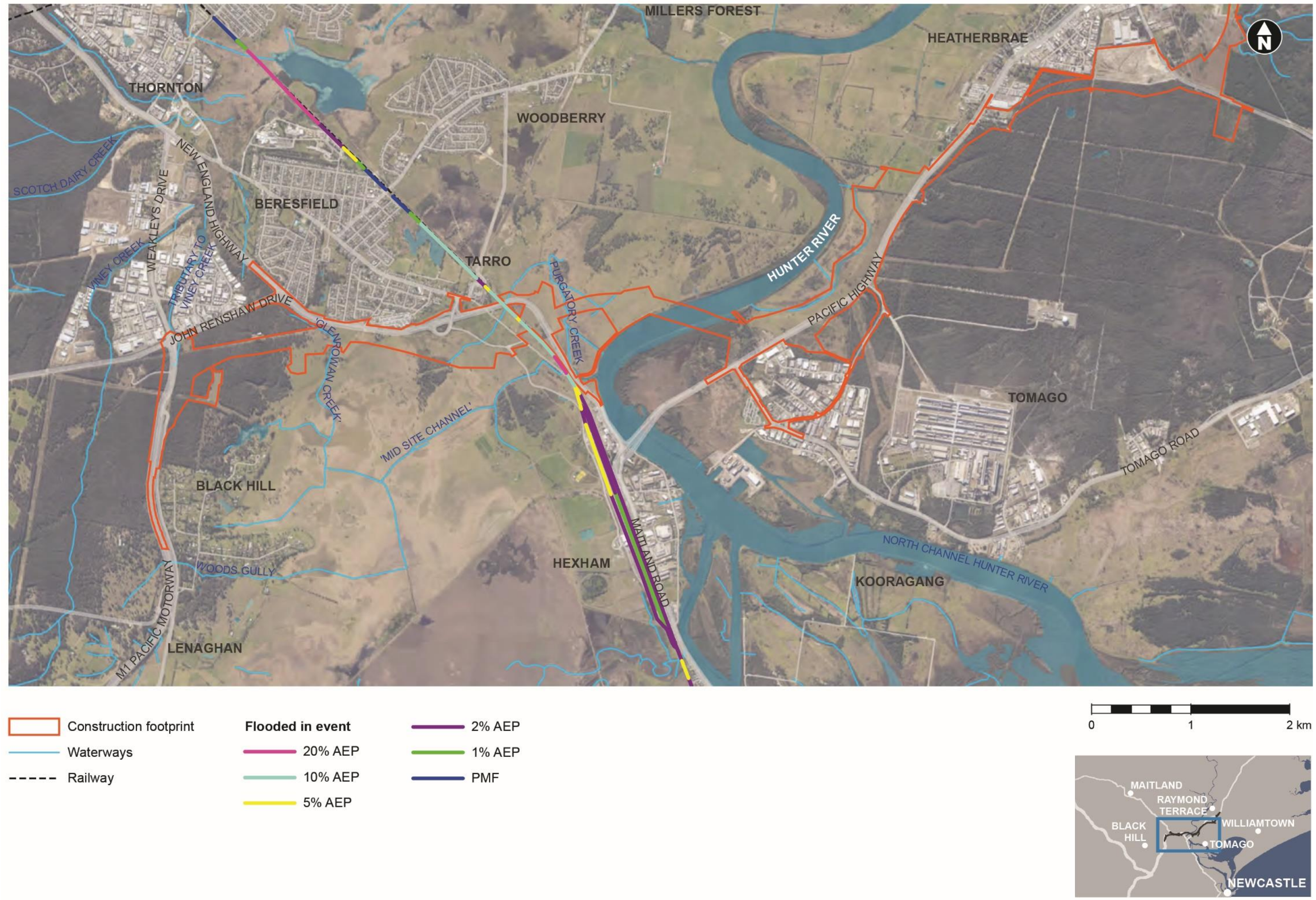


Figure 10-12 Existing flooding at railways

Rail

Sections of the Main North Rail Line are currently overtopped by flooding during various flood events as shown in **Table 10-7** and in **Figure 10-12**.

Table 10-7 Length of railway flooded in existing case

Road	Length (kilometres)					
	20% AEP	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**PMF**
Main North Rail Line	2.3	3.8	5.2	11.6	12.2	13.0
Other rail lines	1.0	2.1	2.4	2.7	3.3	27.3
Aurizon facility	0.4	0.4	0.6	2.0	2.1	2.1

The Aurizon Hexham Train Support Facility site, located east of Hexham Swamp, consists of several maintenance and administration buildings and a 1.6 kilometre long stabling yard for coal trains. The stabling yard is affected by localised flooding as described in **Table 10-7**. In the 1% AEP event the entire stabling yard is affected to depths of three metres.

The Hexham Relief Roads project supports the Aurizon Hexham Train Support Facility and is the main access road to the facility. The Hexham Relief Roads project also has some localised as described in **Table 10-7**. The road is fully inundated in the 5% AEP flood event.

Existing inundation of land uses

The number of existing lots within the flood study area affected by a flood of more than 0.05 metres during different flood events is shown in **Figure 10-13**.

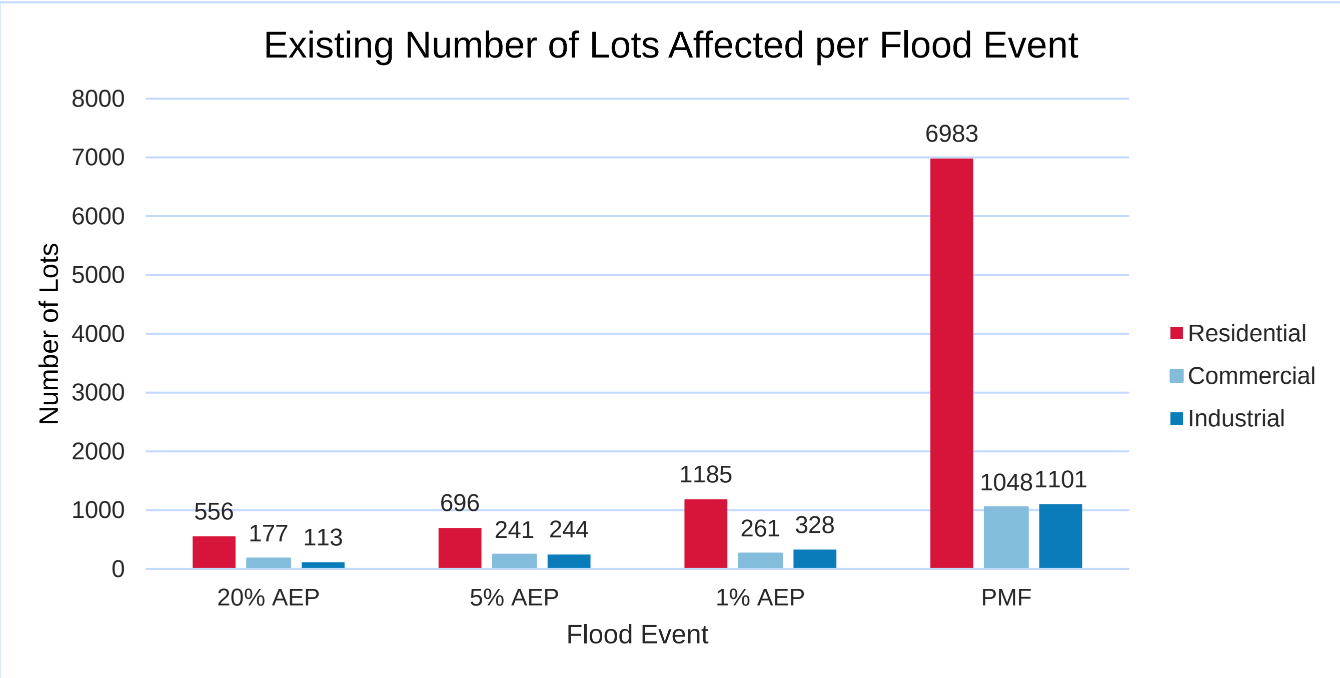


Figure 10-13 Number of existing lots affected

The number of lots and hectares of forestry and wetlands and national parks that are affected by high hazard flooding during the different flooding events are shown in **Figure 10-14** and **Figure 10-15** respectively.

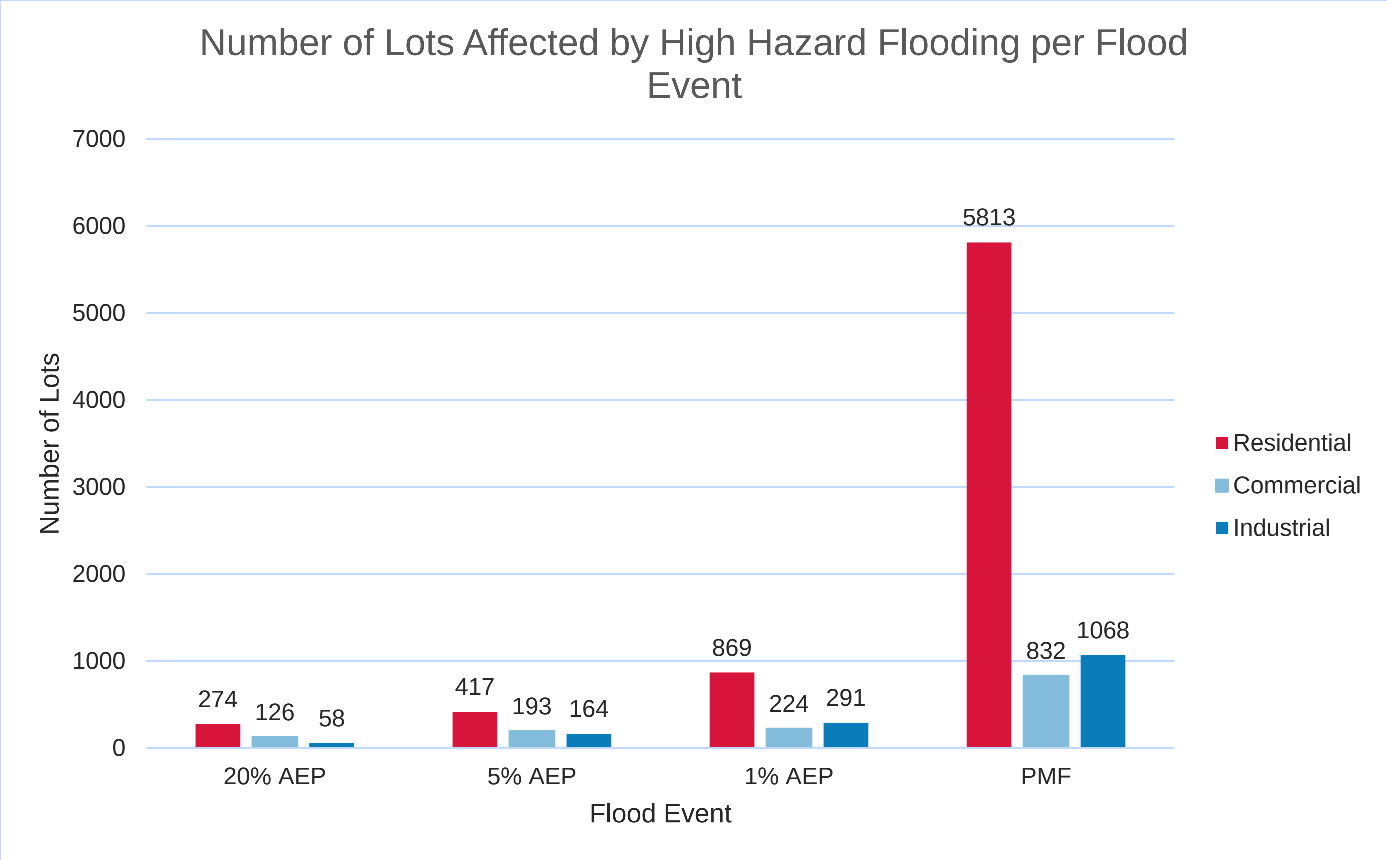


Figure 10-14 Number of lots affected by high hazard flooding

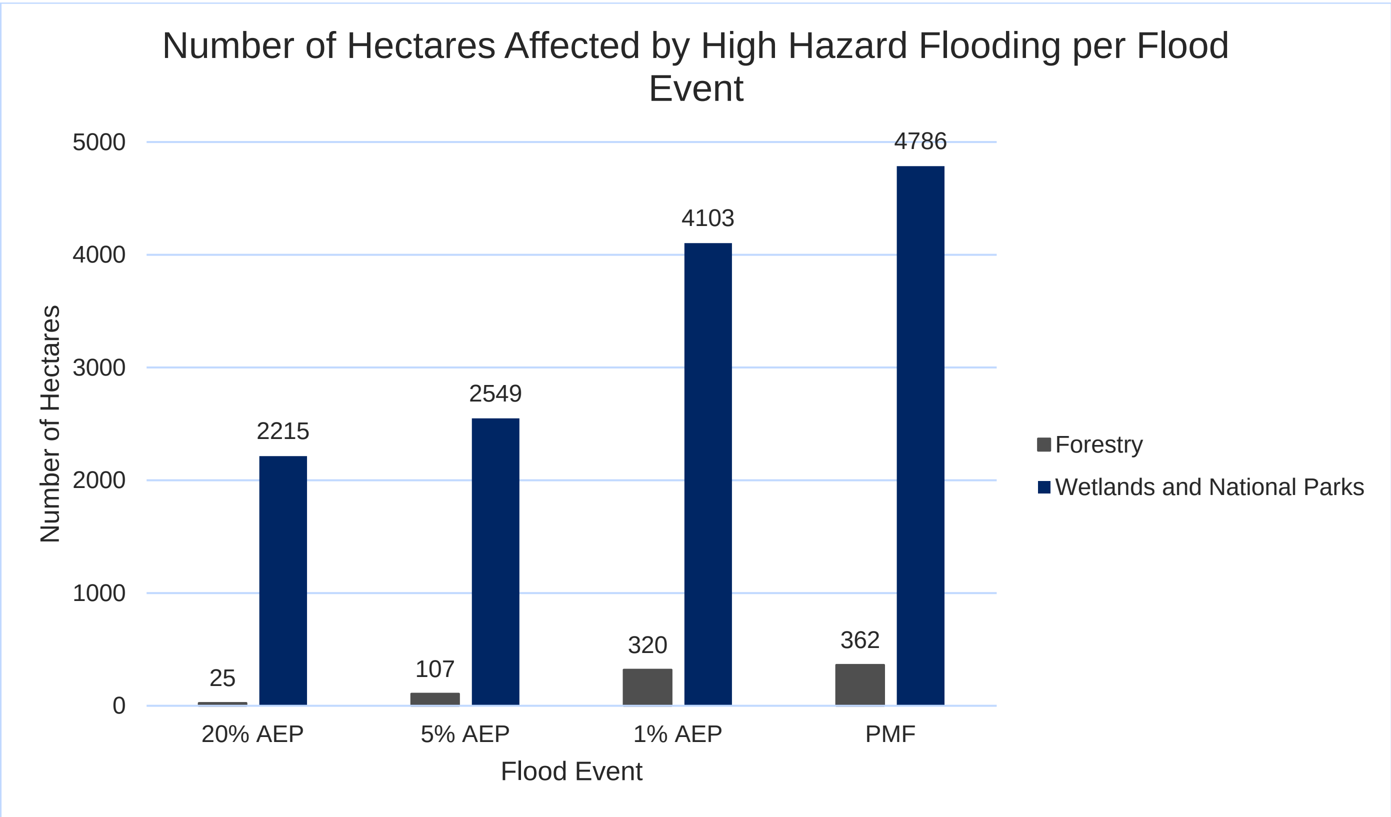


Figure 10-15 Hectares affected by high hazard flooding

Durations of inundation of up to 96 hours are typical for all land use types in the flooding study area in up to the 1% AEP flood event. Durations exceeding 96 hours are common in the PMF.

10.4 Impact avoidance

The project design as described in **Chapter 5** was developed using a multi-disciplinary process that identified and assessed routes against a range of engineering, environmental, social, land-use and economic criteria. This process (refer to **Chapter 4**) ultimately determined that the project alignment represented the best balance after a multi-criteria analysis of all known constraints and opportunities, including those related to hydrology and flooding.

As a result of project development, the alignment has been moved to be closer to the New England Highway and other existing infrastructure corridors, crossing the Hunter River 1.4 kilometres north of the original crossing. As a result of route optioneering and the design development, the project has substantially reduced:

- Upstream flooding impacts through design of a 2.6 kilometre viaduct instead of an embankment across the Hunter River floodplain
- Impacts to drainage capacity, flood storage and conveyance upstream in the swamp area in Hexham which would have resulted from an embankment on the floodplain
- Local afflux, by increasing culvert flow capacity in Tomago
- Groundwater impedance and level impacts from soft soil consolidation activities that would have resulted from an embankment across the floodplain
- Erosion and scour directly downstream of the project by providing rock riprap aprons downstream of all culverts.

In locations where impacts to hydrology and flooding were unable to be avoided, management measures have been identified to minimise impacts from the project (refer to **Section 10.7**).

10.5 Assessment of potential construction impacts

10.5.1 Surface water hydrology

Key construction activities that may impact the surface water hydrology include:

- Vegetation clearance
- Soil compaction and paving, leading to reduced infiltration
- Temporary dewatering of groundwater ingress to construction excavations
- Temporary and permanent alteration or impedance of existing drainage paths and waterways, in particular:
  - Construction of the bridges and the viaduct
  - Adjustment of Purgatory Creek and the tributary of Viney Creek
  - Temporary haulage road across Glenrowan Creek
  - Temporary and permanent culverts.
- Attenuated or delayed discharge of stormwater captured in temporary sediment basins
- Reuse of stormwater captured in temporary sediment basins.

NSW river flow objectives

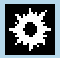
The potential construction impacts to waterways in the surface water study area in consideration of the NSW river flow objectives relevant to the project are detailed in **Table 10-8**. Construction is expected to result in some changes to the timing, rate and volume of stormwater discharge however these changes are only expected to moderately alter the existing flow regime.

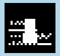
Impacts on waterways and wetlands

The project would involve the adjustment of smaller creeks and minor waterways, as well as the upgrade of existing drainage and construction of new drainage for the project. This includes adjustment of Purgatory Creek and the tributary of Viney Creek, to accommodate road embankments (refer to **Section 5.3.10**). In addition to the physical changes to these waterways, the associated construction activities have the potential to affect local hydrologic conditions.

The waterway adjustments and drainage structures have been designed to minimise impacts to drainage capacity and avoid redirection of flows.

Table 10-8 River flow objectives relevant to project construction impacts

NSW river flow objective	Description	Hunter River sub-catchment type				Project impacts
		Town water supply sub-catchments	Mainly forested areas	Waterways affected by urban development	Estuary	
	Maintain wetland and floodplain inundation	×	×	✓	✓	Construction of the project does not call for the damming of any waterway or extraction of surface water flows. Some changes to the depth and duration of floodplain inundation (refer to **Section 10.5.3**) are expected however these changes are not anticipated to substantially impact the existing regime.
	Mimic natural drying in temporary waterways (and wetlands)	×	×	✓	×	Continuous or prolonged releases of water to ephemeral receiving waterways are not planned or required by the project. However, some localised, minor changes are expected to the timing, frequency and duration of low flow events. These are expected to result from both temporary and permanent alteration of existing drainage paths during construction, changes to the extent of catchment imperviousness and discharge of stormwater via temporary sediment basins and permanent water quality basins.
	Maintain natural rates of change in water levels	×	×	✓	×	Some localised changes are anticipated to rates of rise and fall in water levels due to expected increases to rate of and volume of stormwater discharged during the construction phase. The changes are not expected to adversely impact existing environmental water availability and flows.
	Protect pools in dry times	×	✓	×	×	Surface water extraction from natural pools during the construction phase is not proposed.
	Protect natural low flows	×	✓	×	×	Surface water extraction from waterways during the construction phase is not proposed. Excavation dewatering during the construction phase is not considered to have a significant impact on surface water flows due to the small extraction volumes and short durations of dewatering at each location.
	Maintain natural flow variability	×	✓	✓	✓	Damming of waterways, surface water extraction (refer to **Section 10.5.5**) or prolonged discharge of water is not proposed for the construction phase of the project. Discharge of stormwater from the project would largely be coincident with existing flows in receiving waterways and is not expected to negatively impact existing flow variability.

NSW river flow objective	Description	Hunter River sub-catchment type				Project impacts
		Town water supply sub-catchments	Mainly forested areas	Waterways affected by urban development	Estuary	
	Manage groundwater for ecosystems	✓	✓	×	✓	Localised extraction of groundwater inflow will be required during construction. There would also be seepage to cuttings and water exuded from wick drains during the construction of embankments in soft soils. In addition, changes to the hydraulic properties of soft soils during construction can result in both increases and decreases in groundwater water levels. However, the total predicted change of groundwater contribution is not considered to be substantial, would be localised and would not materially impact on groundwater ecosystems.
	Minimise effects of weirs and other structures	×	✓	✓	✓	The project construction does not call for the use of weirs or any other permanent waterway blockage. Waterway crossings to be used during construction (including the viaduct access road) and minor realignments of Purgatory Creek and the tributary of Viney Creek may result in some minor temporary obstruction to flows however any impacts are likely to be minor, temporary and reversible.
	Maintain or rehabilitate estuarine processes and habitats	×	×	×	✓	The project does not call for the damming, permanent total blockage or interference of any estuarine waterway and the existing tidal flow regime would be maintained.

Changes to the existing flow regime

Receiving waterways potentially impacted by changes in flow regime from the project during construction are as follows:

- Tributary of Viney Creek
- Purgatory Creek
- Drainage line through coastal wetland to Hunter River
- Unnamed tributary of coastal wetland
- Hunter River Drain
- Tributary to Hunter River Drain
- Diffuse drainage lines that terminate into the Tomago Sandbeds Catchment Area
- Windeyers Creek.

Potential changes to the rates and volume of stormwater discharged during construction have not been assessed quantitatively, as there are no stream gauges relevant to the project site. Operational phase modelling in DRAINS (refer to **Section 10.6.1**) is considered to be representative of expected changes in stormwater discharge conditions during construction. The modelling indicates that the following potential changes are expected to the existing flow regime at or immediately downstream of discharge locations during construction:

- Minor reductions in baseflow and moderate increases to quickflow[1] contributions to total streamflow as a result of lowered rates of rainfall infiltration, increase in effective rainfall depth and installation of drains
- Minor to moderate increases to the rate of stormwater discharged from the project and subsequent inferred alteration (minor increases) to rates of water level rise and fall
- Minor increases to the duration and depth of inundation for overbank events
- Modelling results completed for the operation phase and applied to the construction phase indicate there would be a minor increase (less than 20 per cent) in the rate of stormwater at the following discharge points (refer to **Figure 10-16**):
  - Discharge point N1160B at the tributary of Viney Creek
  - Discharge point N8200C at the unnamed tributary of coastal wetland
  - Discharge point N9100C at the Hunter River Drain
  - Discharge point N9380C at the tributary to the Hunter River Drain.
- Modelling results completed for the operation phase and applied to the construction phase indicate there would be a moderate increase (more than 20 per cent) in the rate of stormwater at the following discharge points (refer to **Figure 10-16**):
  - Discharge point N3500C at Purgatory Creek
  - Discharge point N7300C at the drainage line through coastal wetland to the Hunter River
  - Discharge point N11920C that drains into diffuse drainage lines that feed into the Tomago Sandbeds Catchment Area
  - Discharge points N13020C and N12620C at Windeyers Creek.

Further detail of modelling results is presented in Tables J-1 to J-4 of the Hydrology and Flooding Working Paper (**Appendix J**). Construction of the project may also result in minor changes to the number, duration and magnitude of low flow events from the temporary sediment basins and changed rates of rainfall infiltration.

[1] The part of storm rainfall which moves quickly to a waterway via surface runoff or interflow and forms a flood wave in the waterway.

Changes in stormwater discharge, volume and velocity during construction are not expected to result in a material impact to the receiving environment as:

- The project design includes appropriate mitigation, including scour protection in the form of rock transition aprons and energy dissipation at culvert outlets
- Increased discharges of stormwater from the project and dewatering of temporary sediment basins would be largely consistent with existing variations. Increased discharges and dewatering would occur during or after naturally occurring flow events
- Potential changes to the number, timing and duration of flow events in the receiving environment are likely to be minor and not of a material impact
- Appropriate erosion and sediment control measures in accordance with the NSW Blue Book requirements (DECC 2008) will be implemented for temporary stormwater discharge locations.

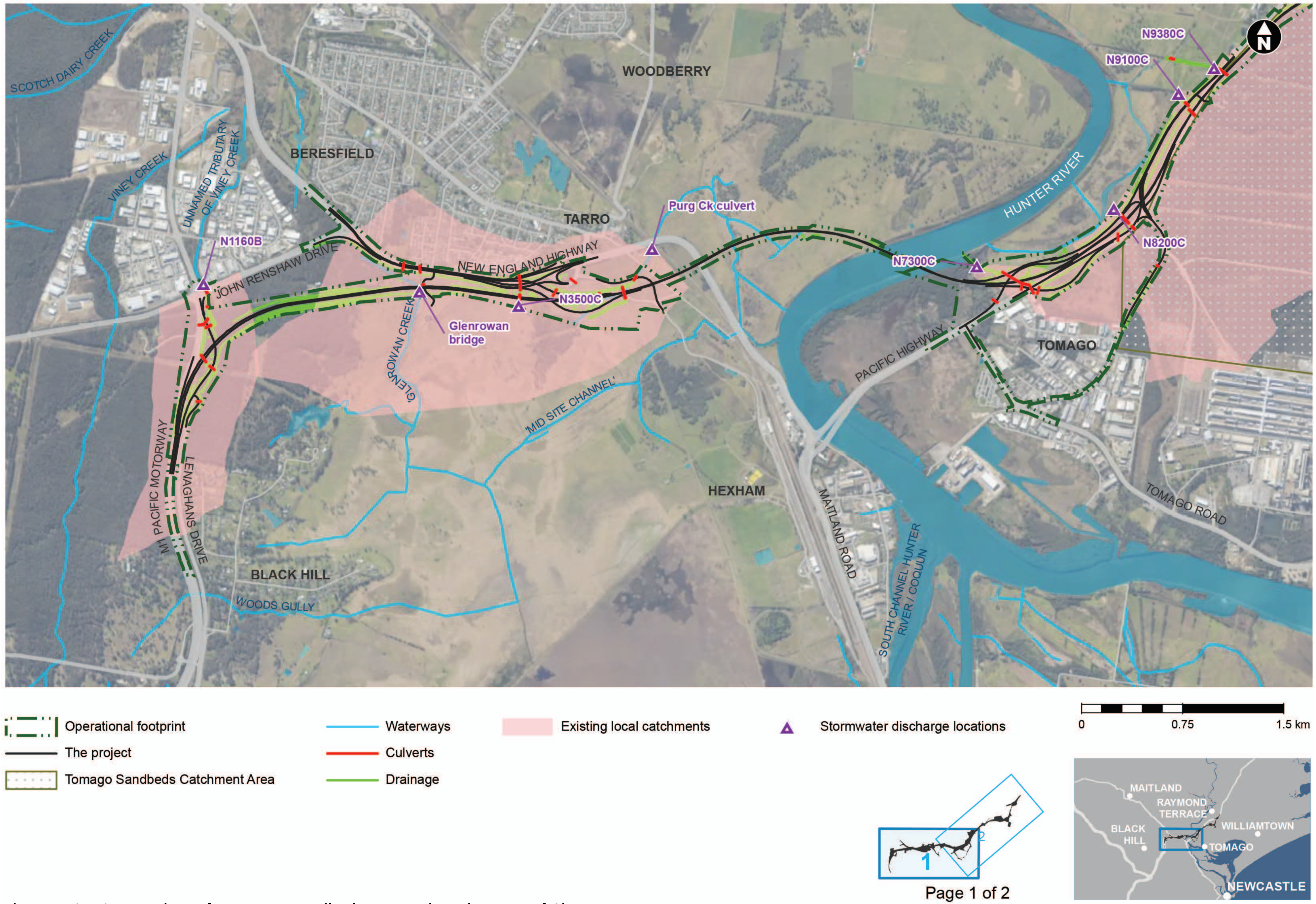


Figure 10-16 Location of stormwater discharge points (map 1 of 2)

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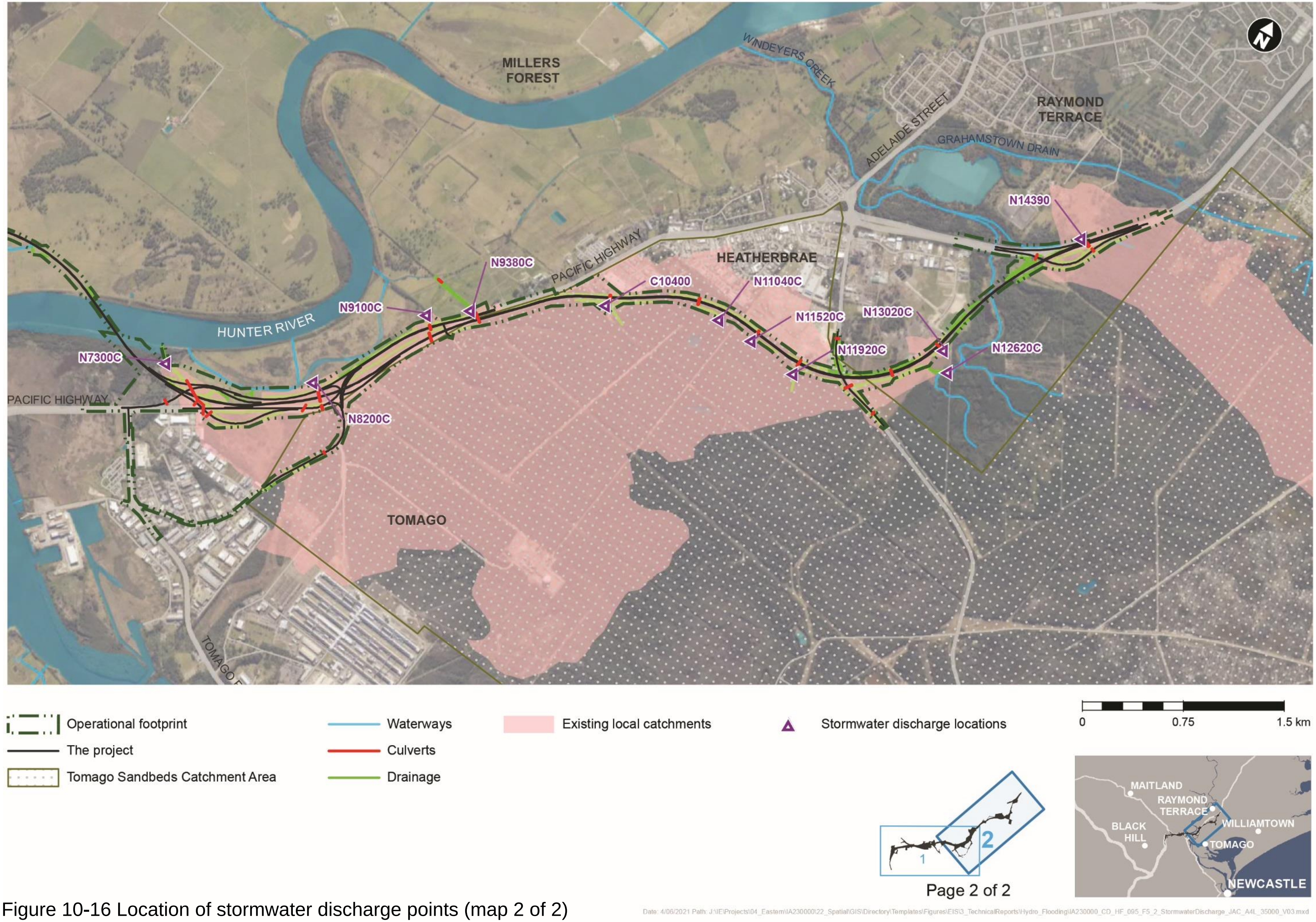


Figure 10-16 Location of stormwater discharge points (map 2 of 2)

Changes to environmental water availability and flows

Construction of the project is not expected to materially impact environmental water availability. The design of the project would generally allow the natural flow regimes to be maintained. No damming or permanent total blockage of major waterways is proposed, and extraction of surface water is not required. The proposed minor adjustment of Purgatory Creek and the tributary of Viney Creek would only have a minor impact to environmental water availability as downstream contributions to streamflow would largely be maintained during construction.

A small proportion of water captured in temporary sediment basins may be subject to opportunistic re-use within the construction footprint. Rates, volumes and velocities of stormwater discharged by the project are expected to increase as described in the section above and this is not expected to adversely impact existing environmental water availability and flows.

Changes to erosion, siltation, or stability of riverbanks or waterways

Geomorphic assessment of waterways within the project area indicate that waterways are typically stable, low energy, show little evidence for lateral migration and are hence considered low risk from stormwater discharges from the project. Some residual risk would still exist for the estimated changes to flow regimes to result in the following impacts to waterway health and instream processes during construction:

- Reduced bank stability: immediately downstream of project discharge locations as a result of increased streamflow discharge and velocities
- Increased rates of removal and transport of eroded bed and bank material: leading to downstream sedimentation and potential infilling of aquatic habitat features such as rocky holes or smothering of aquatic vegetation
- Increased water turbidity: due to suspended material and subsequent reduction in light infiltration potentially impacting sensitive aquatic vegetation
- Potential for fish passage obstruction: due to increased flow velocities, reduced water levels or physical obstructions.

The project seeks to minimise or avoid these impacts by adopting appropriate erosion and sediment controls (refer to **Chapter 11** (surface water and groundwater quality)), site-specific drainage design for the construction footprint and temporary and permanent erosion and scour protection and flow dissipation as described in **Chapter 5**.

Impacts on bed and bank stability

As discussed above, estimated changes to flood behaviour have the potential to result in the following impacts during construction:

- Reduced bank stability (scouring, undercutting, slumping, etc) immediately downstream of project discharge locations as a result of increased streamflow discharge and velocities
- Increased rates of removal and transport of eroded bed and bank material leading to downstream sedimentation and potential infilling of aquatic habitat features such as rocky holes or smothering of aquatic vegetation.

Water take

There would be no direct take of water from natural waterways during construction. Runoff from the construction footprint that accumulates in temporary sediment basins, however, may be used opportunistically for construction activities if it meets water quality criteria. Conservative estimates of 25 per cent of accumulated basin runoff being used for construction would result in surface water take over the duration of construction of about 10.45 megalitres or 3.5 megalitres per year.

Indirect surface water take due to groundwater drawdown and subsequent baseflow reduction at creeks is anticipated to be negligible. This is because construction dewatering periods would be short (typically about 10 days), maximum drawdowns would be small and lateral drawdown extents would be small and generally not near creeks or rivers.

Regional impacts on Hunter River catchment

The project would not result in the damming, permanent total blockage or extraction of water from any waterways in the surface water study area during construction. The construction of the project would therefore not impact on the regional hydrology of the Hunter River catchment. Adjustment of smaller creeks and minor waterways in addition to upgraded and new highway transverse drainage is proposed. While these creek adjustments have the potential to affect local hydrologic conditions, the design of the channel adjustments and hydraulic structures is adequately sized to minimise impacts to drainage capacity and avoid redirection of flows.

10.5.2 Groundwater hydrology

Impacts to groundwater flow have potential to occur where activities intersect the water table and require dewatering or alter the hydraulic characteristics of the sub-surface. Key activities with potential to alter groundwater levels and flow include:

- Temporary construction dewatering where excavations occur below the water table, including:
  - Excavation of temporary sediment basins and permanent water quality basins
  - Excavations for some culverts and utilities
  - Excavations for bridge piers
  - Excavations for the Purgatory Creek adjustment.
- Installation of temporary sediment basins below the water table
- Use of surcharge embankments to facilitate soft soil consolidation, due to a reduction in porosity of the sediment caused by consolidation, resulting in:
  - Water level mounding (rise in water level) upgradient of the consolidated area
  - Water level shadowing (lowering of water level) down-gradient of the consolidated area.

The adjustment of the tributary of Viney Creek, and shallow excavations for most culverts and utilities are not anticipated to intercept groundwater or require substantial dewatering.

Drawdowns may occur due to temporary dewatering during construction during:

- Installation of temporary sediment basins
- Dewatering for the construction of bridge pier foundations (on land)
- Diversion of Purgatory Creek.

Predicted groundwater level drawdown due to temporary construction dewatering is relative to the depth of excavation. The results of numerical groundwater modelling are included in the Hydrology and Flooding Working Paper (**Appendix J**).

These changes and impacts are discussed further in the sections below.

Impacts on groundwater systems

Based on the relatively short period of dewatering and drawdown, and limited drawdown propagation, changes to groundwater flow are not anticipated to materially affect baseflows or existing bores. All temporary sediment basins located within the Tomago Sandbeds Catchment Area will be lined and all runoff in the area captured in basins for treatment. As a result, groundwater flows, water levels and supply capacity of the Tomago Sandbeds Catchment Area drinking water supply will not be impacted by project construction.

Further details about temporary sediment basins, lining of basins and impacts to the Tomago Sandbeds Catchment Area are presented in **Chapter 11** (surface water and groundwater quality).

Impacts on groundwater flow and level

The results of numerical groundwater modelling for activities that might impact on groundwater are summarised below:

- At temporary sediment basins (the location of which are shown in **Figure 5-25**), results indicate a maximum drawdown of about 2.4 metres, and maximum drawdown distance from a basin to the 0.2 metre drawdown contour of about 500 metres. Results also indicate that:
  - At Tarro, drawdowns from temporary construction dewatering of temporary sediment basins are predicted to encroach on an area of high potential GDE (with a drawdown of up to 0.75 metres) and on an area of Coastal Wetlands (Coastal Management SEPP) (with drawdowns of up to two metres). The majority of the Coastal Wetlands predicted to be within the area of drawdown would be cleared by construction activities and embankment formation, with the remaining drawdown anticipated to be short term (less than 10 days) in duration. As a result, drawdown is not anticipated to materially affect GDEs
  - Dewatering at individual temporary sediment basins would typically be less than 10 days duration and there would be no substantial interference drawdown between adjacent water quality basins
  - At Tomago, a drawdown of up to 0.4 metres is predicted at temporary sediment basins and at Heatherbrae drawdowns between 0.6 to 0.8 metres are predicted at temporary sediment basins.
- During installation of the bridge pier foundations, drawdowns would be temporary, minimal and not expected to exceed 1.8 metres. Results also indicate that:
  - Anticipated drawdown distances would also be small and would be limited to about 40 metres from any excavation
  - A relatively short dewatering period of about 10 to 20 days is anticipated for any given excavation associated with the pier construction.
- During the adjustment of Purgatory Creek, results indicate a maximum drawdown magnitude of approximately 0.8 metres and maximum drawdown propagation (as indicated by the 0.2 metre drawdown contour) of about 100 metres
- During soft soil consolidation, results indicate that groundwater levels would rise in the Tarro interchange area of soft sediment consolidation by up to about 0.3 metres, reducing to an increase of about 0.05 metres at the margin of the area located to the south mapped as high priority GDE. At Tarro, the mounding is not considered to be substantia. Results also indicate that:
  - The magnitude of mounding of up to 0.3 metres is very localised, considered to be well within seasonal fluctuations and is in an area where there is frequent surface expression of groundwater
  - At the Old Punt Road intersection, near the HRBG, model results indicate a potential rise in groundwater levels of up to 0.2 metres predicted over most of the upstream area of soft sediment consolidation, increasing up to 0.8 metres in the central area
  - The mounding effect diminishes to about 0.05 metres within about 50 to 80 metres upgradient of the embankment

- Predicted mounding in the range 0.2 to 0.8 metres occurs beneath an area mapped as high potential GDE
- The greater magnitude of mounding predicted at the Old Punt Road intersection (at least two metres below ground surface) compared to the Tarro interchange is attributed to the larger through-flow of groundwater from the Tomago Sandbeds and is not expected to result in noticeable surface effects.

Modelled drawdown levels are considered to be conservative, as the model assumes that all basins would be dewatered concurrently and for a period of 30 days. In reality, basin excavation and dewatering would be staggered in timing and individual basin dewatering is expected to range from two to 10 days depending on the size of the basin. As such impacts are not anticipated to be as great as those modelled.

While construction of the project would result in some localised drawdown and mounding impacts, it is not anticipated to have any detrimental effect on the local groundwater hydrology regime, including GDEs and other groundwater users. During construction, the level one (acceptable) minimal impact considerations of the NSW AIP (DPI 2012) are met for groundwater level and pressure.

Groundwater produced during construction would be re-used where possible for dust suppression and fill conditioning. This would be a measure of sustainable use of the groundwater resource and to minimise, as far as practical, the need for the project to import water for construction activities.

The impacts of raised groundwater levels on soil salinity is discussed in **Section 11.4.3**.

Impacts on GDEs

As described above, at Tarro, drawdowns from temporary construction dewatering are predicted to encroach on an area of high potential GDE, with a drawdown of up to 0.75 metres, and Coastal Wetlands (Coastal Management SEPP), with drawdowns of up to 2.0 metres. It is noted, however, that the majority of the Coastal Wetlands (Coastal Management SEPP) predicted to be within the area of drawdown would be cleared by the construction activities and embankment formation, with the remaining drawdown anticipated to be short term (less than 10 days) in duration. As a result, drawdown is not anticipated to materially affect GDEs.

Groundwater modelling results indicate that groundwater levels are predicted to rise in response to soft soil consolidation while shadowing effects are negligible. Model results indicate groundwater levels would rise in the Tarro interchange area of soft sediment consolidation by up to about 0.3 metres, reducing to an increase of about 0.05 metres at the margin of the area located to the south mapped as High Priority GDE. Predicted mounding in the range 0.2 to 0.8 metres occurs beneath an area mapped as high potential GDE.

Based on the relatively short period of dewatering and drawdown, limited drawdown propagation and localised areas of mounding, changes to groundwater levels and flows are not anticipated to materially affect GDEs, including High Priority GDEs, baseflows, existing groundwater users or surrounding land due to settlement.

Impacts on groundwater users

Based on the relatively short period of dewatering and drawdown, and limited drawdown propagation, changes to groundwater flow are not anticipated to materially affect existing groundwater users or surrounding land due to settlement.

Water take

There would be direct water take from groundwater sources during construction due to temporary construction dewatering for basins, piers and Purgatory Creek adjustment works, and via wick drains in soft soil consolidation areas.

Most shallow excavations, such as for culverts and utilities, are not anticipated to require any substantial dewatering. The dewatering period for individual excavations is anticipated to be in the order of two to 10 days. The take associated with soft soil consolidation is anticipated to occur over a maximum period of about nine months, as dewatering would be more gradual during soft soil consolidation.

A summary of estimated groundwater take is provided in **Table 10-9**, with total groundwater take over 35 months for groundwater sources estimated as follows:

- Newcastle Water Source: 66.6 megalitres
- Sydney Basin-North Coast Groundwater Source: 5.6 megalitres
- Tomago Groundwater Source: 92.7 megalitres.

It is noted that Transport, as a Roads Authority, is exempt from the requirement to hold a Water Access License under Part 1, Schedule 4 of the Water Management (General) Regulation 2018.

Table 10-9 Estimated groundwater take during construction

Water source and WSP	Element	Estimated take (ML)	Calculation
Newcastle Water Source of the Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009 (NSW Government 2009)	Temporary construction dewatering for basins	5.86	• Temporary construction dewatering period of 10 days per basin • Groundwater model daily dewatering rate for 8 basins in this groundwater source was 0.586ML/d • 10 days x 0.586ML/d = 5.86ML
	Temporary construction dewatering for piers	31.52	• 10 to 20 days dewatering per excavation • Refer to **Section 10.5.5** for calculation
	Temporary construction dewatering for Purgatory Creek adjustment	0.71	• Temporary construction dewatering period of 10 days • Groundwater model daily dewatering rate of 0.071ML/d • 10 days x 0.071ML/d =0.71ML
	Soft soil consolidation	30.50	• Refer to **Section 10.5.5** for calculation
	Total	68.59	
Sydney Basin–North Coast Groundwater Source of the Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016 (NSW Government 2016b)	Temporary construction dewatering for basins	1.02	• Temporary construction dewatering period of 10 days • Groundwater model daily dewatering rate for 4 basins in this groundwater source was 0.102ML/d • 10 days x 0.102ML/d = 1.02ML
	Temporary construction dewatering for piers	4.54	• 10 days dewatering per excavation • Refer to **Section 10.5.5** for calculation
	Soft soil consolidation	N/A	• N/A
	Total	5.56	

Water source and WSP	Element	Estimated take (ML)	Calculation
Tomago Groundwater Source of the Water Sharing Plan for the North Coast Coastal Sands Groundwater Sources 2016 (NSW Government 2016c)	Temporary construction dewatering for basins	76.44	• Temporary construction dewatering period of 10 days • Groundwater model daily dewatering rate for 23 basins in this groundwater source was 7.644ML/d • 10 days x 7.644ML/d = 76.44ML
	Temporary construction dewatering for piers	1.92	• 10 days dewatering per excavation • Refer to **Section 10.5.5** for calculation
	Soft soil consolidation	14.37	• Refer to **Section 10.5.5** for calculation
	Total	92.73	
Total		**166.88**	**Total estimated water take**

10.5.3 Flooding

Potential impacts to flooding behaviour during construction within the flooding study area were assessed in TUFLOW for the 20%, 10% and 5% AEP flood events. The impacts to flooding are mapped in the Hydrology and Flooding Working Paper (**Appendix J**). Potential impacts may result due to construction and permanent works obstructing flood flows, change in drainage capacity for local catchments and loss of floodplain storage.

Due to the temporary nature of construction activities (as outlined in **Chapter 5**), the assessment should be read in context of the likelihood of a given AEP flood event occurring during construction. The chance of occurrence of a given AEP flood event during construction (i.e. about five years) is substantially lower than during operation (i.e. 100 years) of the project. The chance of occurrence of a 1% AEP flood event during construction and operation of the project are around 4.9 per cent and 63.4 per cent respectively, while the chance of occurrence of a 20% AEP flood event during construction and operation are approximately 67.2 per cent and 100 per cent respectively. Based on these probabilities it was considered appropriate to limit assessment to up to the 5% AEP flood event, as an equivalent extreme flood event to the PMF, during the short-term construction phase.

As described in **Section 10.2.4**, construction flood modelling has assumed ancillary facilities and temporary access tracks would be raised to provide flood immunity.

Potential changes to flooding behaviour

Flood levels

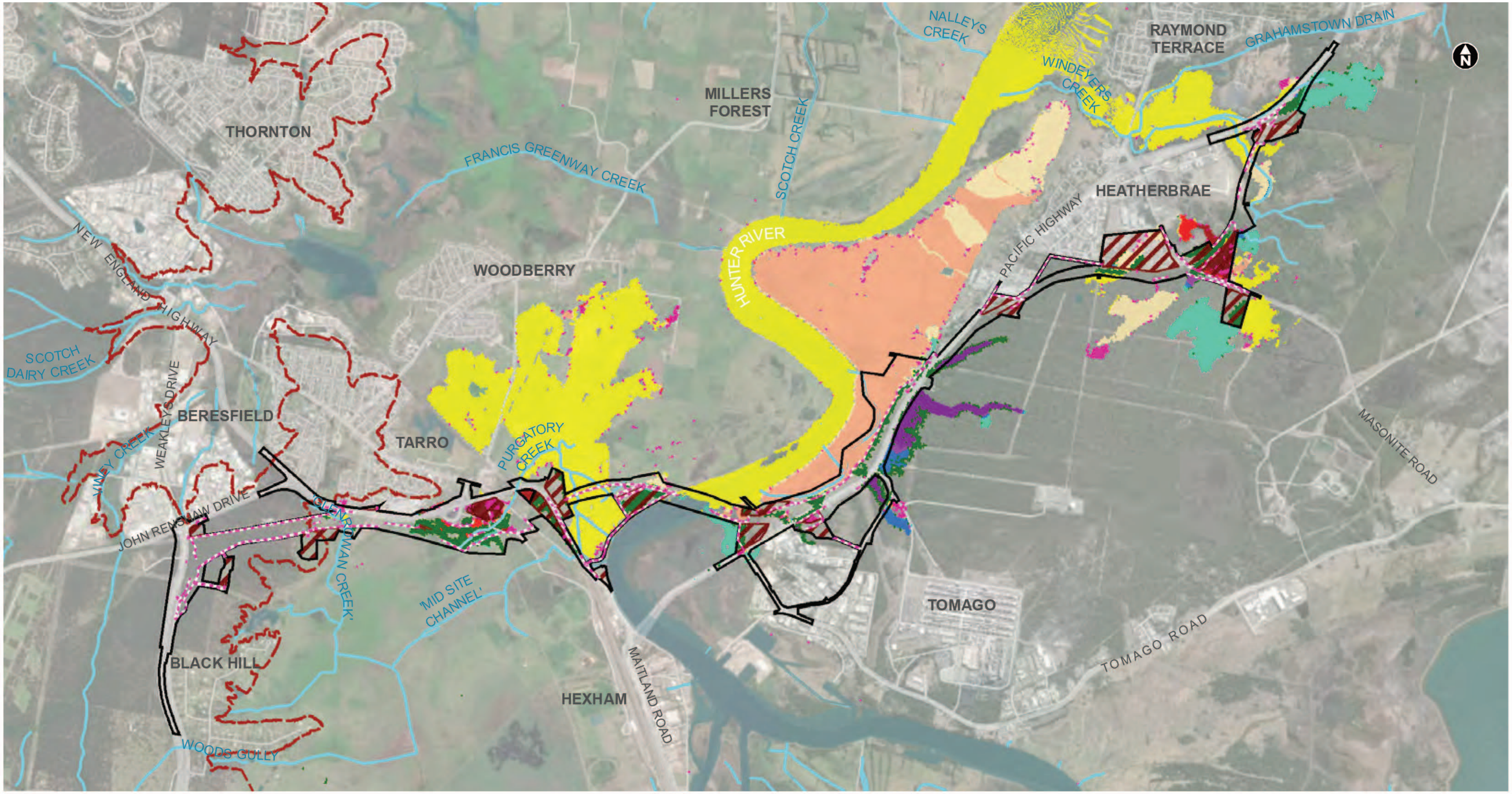
The potential changes in flood levels during the different modelled flood events would be:

- In the 20% AEP flood event (**Figure 10-17**):
  - Flood levels increase by up to 0.03 metres on the western bank of the Hunter River around Tarro, in the Hunter River itself upstream of the project and extending up past the Williams River junction, and in Windeyers Creek in Raymond Terrace
  - Flood levels increase by about 0.05 metres on the eastern bank of the river between the new viaduct crossing and Raymond Terrace
  - Localised increases in flood levels around a number of ancillary facilities along the project, with increase of over 0.4 metres near Tarro interchange and Masonite Road

  - Flood levels decrease by over 0.4 metres in local catchments on the eastern (upstream) side of the project and between the new viaduct and Heatherbrae as a result of increased cross drainage capacity
  - Reductions in flood levels would also be expected in localised areas around Masonite Road.
- In the 10% AEP flood event (**Figure 10-18**):
  - Flood levels increase by up to 0.08 metres on the western bank of the Hunter River around Tarro and Purgatory Creek, which are attributed to the access roads in this area
  - Flood level increases in Hexham Swamp of 0.01 to 0.02 metres as additional flows appear to overtop the railway and New England Highway and into Hexham Swamp
  - Reductions in flood levels of up to 0.05 metres downstream of the viaduct
  - Flood level increases of 0.03 to 0.04 metres extend along the western floodplain of the Hunter River up to the Williams River junction and Millers Forest, with these increases also occurring up Windeyers Creek and Grahamstown Drain
  - Localised increases in flood levels around a number of ancillary facilities along the project, with increase of over 0.4 metres near the western and eastern ends of the viaduct and at Masonite Road, and increases of up to 0.8 metres at Tarro interchange and 1.8 metres in wetland areas at Tarro interchange. This increase exceeds the adopted flood management criteria
  - Flood levels in local catchments on the eastern (upstream) side of the project and between the viaduct and Heatherbrae decrease by up to 0.8 metres as a result of increased cross drainage capacity.
- In the 5% AEP flood event (**Figure 10-19**):
  - Areas affected by 0.05 to 0.1 metre flood level are similar to those affected by the 10% AEP flood event, with a larger area of impact also including part of the eastern Hunter River bank
  - Increases of 0.08 metres affecting rural residential properties in Tarro, close to the western viaduct approach embankment. This incremental increase exceeds the adopted flood management criteria
  - Flood level increases in Hexham Swamp would also be higher, with increases around 0.06 metres
  - Flood levels in local catchments on the eastern (upstream) side of the project and between the viaduct and Heatherbrae experience increases of 0.02 metres, instead of reductions as in the 10% AEP flood event
  - Flood level increases in Windeyers Creek would also be slightly higher, at 0.03 metres, than the 10% AEP flood event (0.02 to 0.03 metres)
  - Localised increases in flood levels around a number of ancillary facilities along the project, with an increase of over 0.4 metres near the western and eastern ends of the viaduct and at Masonite Road, and increases of 0.6 metres at Tarro interchange and up to 1.4 metres in wetland areas near Tarro interchange. This incremental increase exceeds the adopted flood management criteria
  - Flood levels in the Hunter River downstream of the project would be reduced by 0.01 to 0.1 metres.

With the exception of the identified criteria exceedances, all potential changes to flood levels are predicted to be within the criteria identified in **Section 10.2.3**.

Temporary creek crossings (refer to **Section 5.4.9**) would be required at some of the creeks including Purgatory Creek and Windeyers Creek to enable bridge construction. However, with the installation of transverse drainage any impact on local and regional flooding is expected to be minimal.



Flooding study area	
Construction footprint	
Ancillary facility	
Access and haulage roads	

Change in flood level from existing case (m)

- < -0.4
- -0.4 - -0.25
- -0.25 - -0.1
- -0.1 - -0.01
- -0.01 - 0.01 (not shown)
- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.4
- > 0.4

Change - Wet and Dry

- Was Wet Now Dry
- Was Dry Now Wet

0 1 2km

Figure 10-17 Change in flood level during construction (20% AEP)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_025_D1_Change_in_Flood_Level_Construction_20_AEP_JAC_A4L_175000_V01.mxd

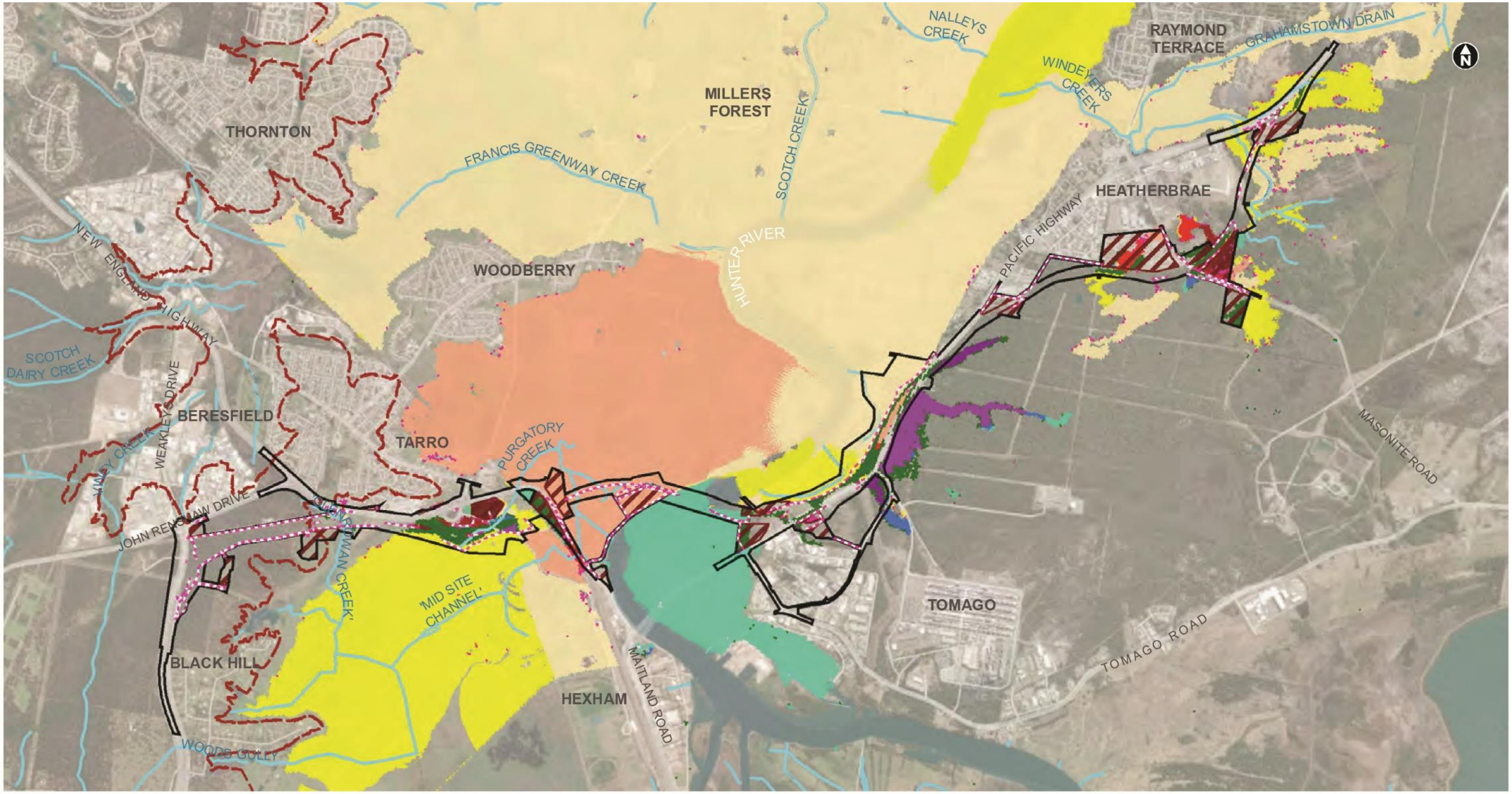


Figure 10-18 Change in flood level during construction (10% AEP)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_026_D2_Change_in_Flood_Level_Construction_10_AEP_JAC_A4L_175000_V01.mxd

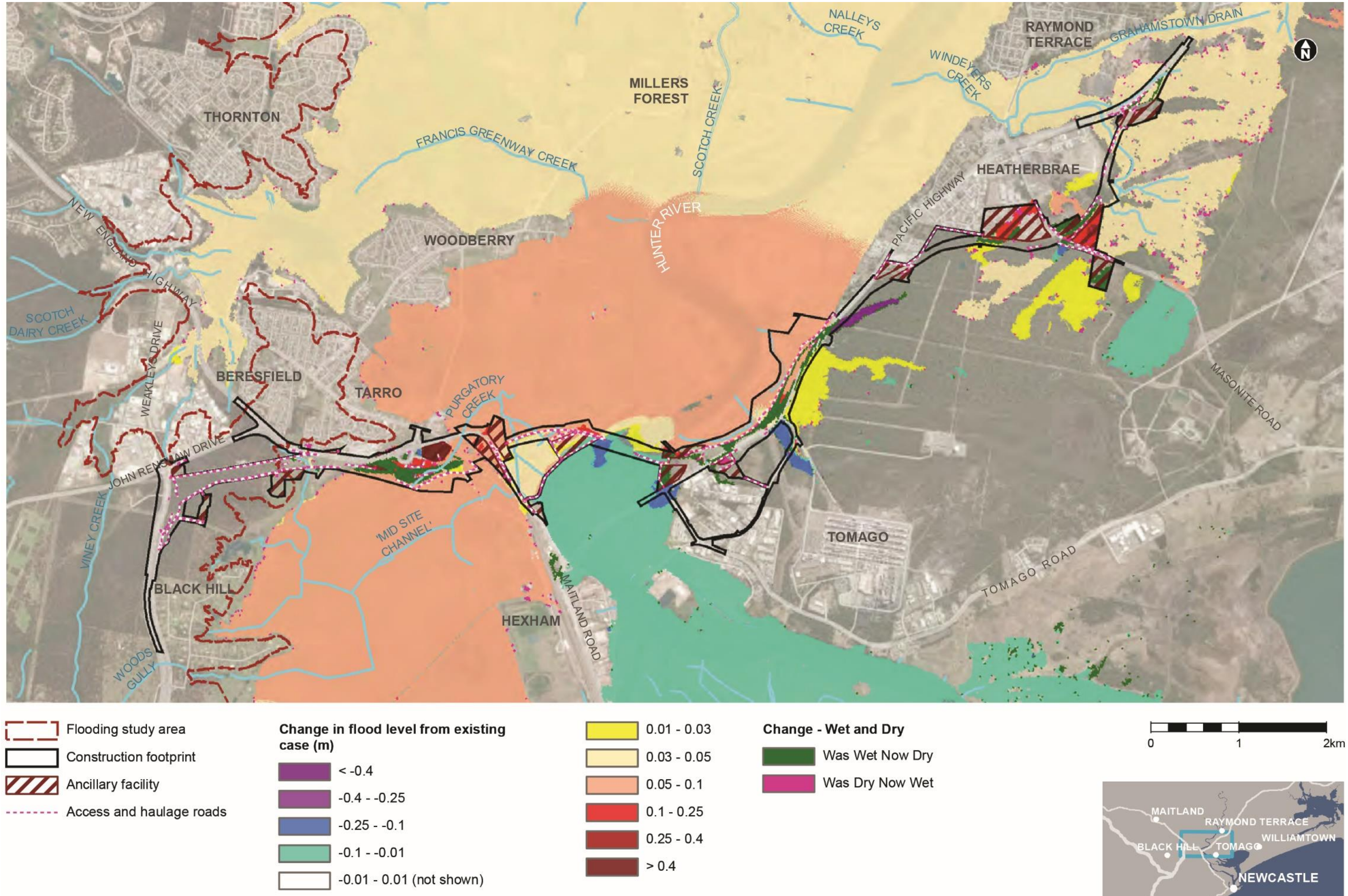


Figure 10-19 Change in flood level during construction (5% AEP)

Date: 4/01/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_027_D3_Change_in_Flood_Level_Construction_5_AEP_JAC_A4L_175000_V01.mxd

Flood velocities

There would be no large areas with substantial changes in velocities across the floodplain, with the majority of changes localised around the construction footprint. It is noted that due to the relatively coarse resolution (20 metre grid) of the TUFLOW model in comparison to small scale features of the project influencing flow velocities, the changes in flow velocities around these localised features are considered indicative only. The potential changes in flood velocities during construction for each flood event are listed below:

- In the 20% AEP flood event (refer to **Figure 10-20**), particularly evident on the eastern bank of the Hunter River, upstream of the viaduct crossing location:
  - Changes in velocities would generally be expected to be localised to areas around cross drainage and drainage channels downstream of the project and where filled formations associated with the project may partially impede existing flow patterns
  - Flow velocity increases would be expected downstream and upstream of the project construction footprint with increases of 0.3 to 0.5 metres per second being typical, with isolated increases over one metre per second
  - Changes would also be present around the proposed temporary wharves around the new viaduct construction site, with increases and decreases in velocities of 0.2 metres per second
  - There would be numerous locations within the construction footprint where velocity increases would be over one metre per second due to flows interacting with the ancillary facilities.
- In the 10% and 5% AEP flood events (refer to **Figure 10-21** and **Figure 10-22**):
  - Changes in velocities on the Hunter River eastern bank upstream of the viaduct crossing would be smaller than in the 20% AEP flood event, as the depth of flooding on the bank areas drowns out the impacts on the flow velocities
  - Changes in velocities would be more accentuated, with increases and decreases of up to 0.3 metres per second in the 10% AEP flood event and up to 0.5 metres per second in the 5% AEP event around the viaduct due to increased interaction of flood flows with access roads, temporary wharves and other features
  - Increased interaction with the New England Highway and ancillary facilities around the western end of the viaduct crossing with increased velocities of 1.5 metres per second. In the 5% AEP event, there would be increased velocities of up to two metres per second over the Main North Rail Line embankment due to increased overtopping depths of 0.1 metres.

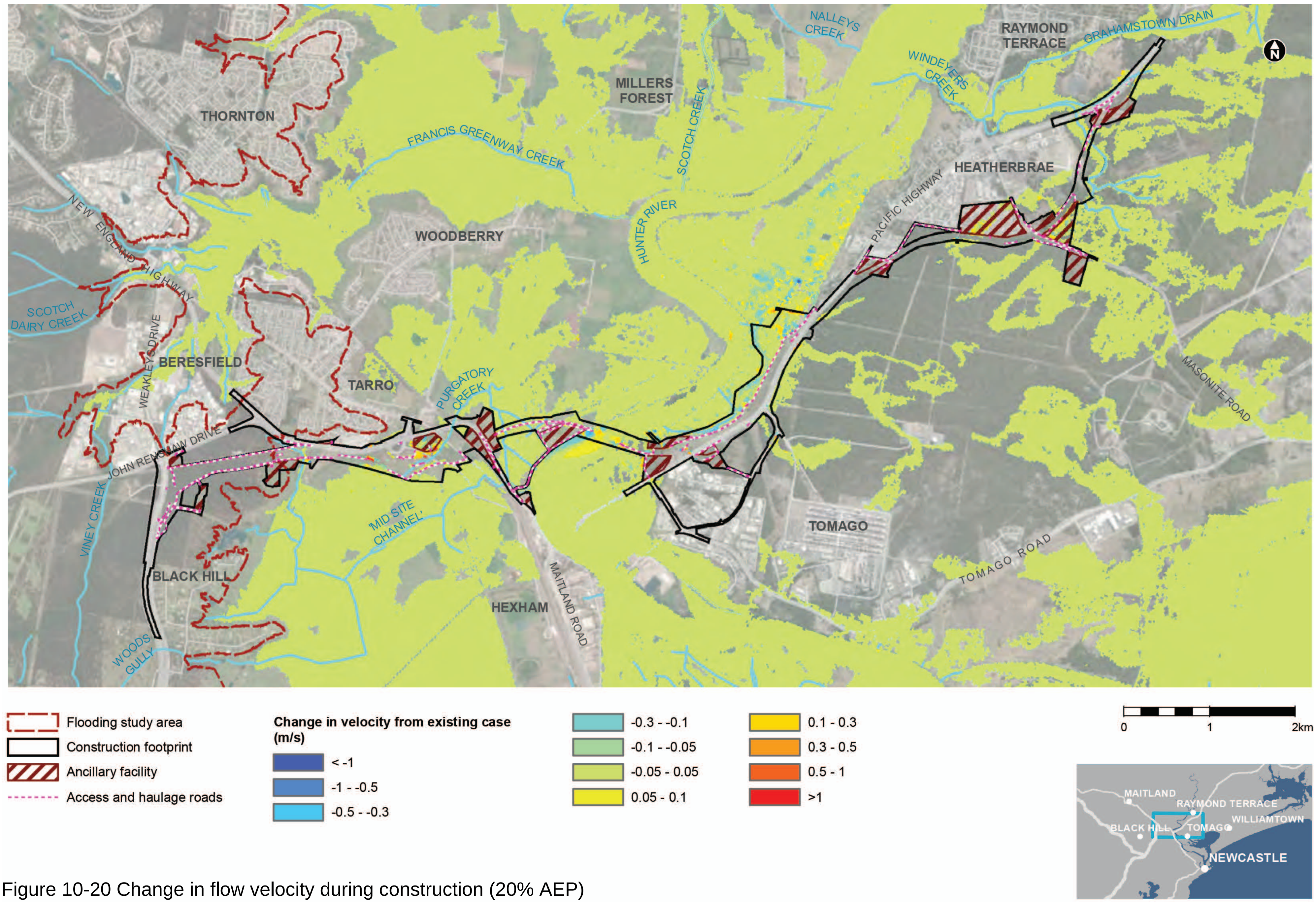


Figure 10-20 Change in flow velocity during construction (20% AEP)

Date: 11/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_028_D4_Change_in_FlowVelocity_Construction_20_AEP_JAC_A4L_175000_V01.mxd

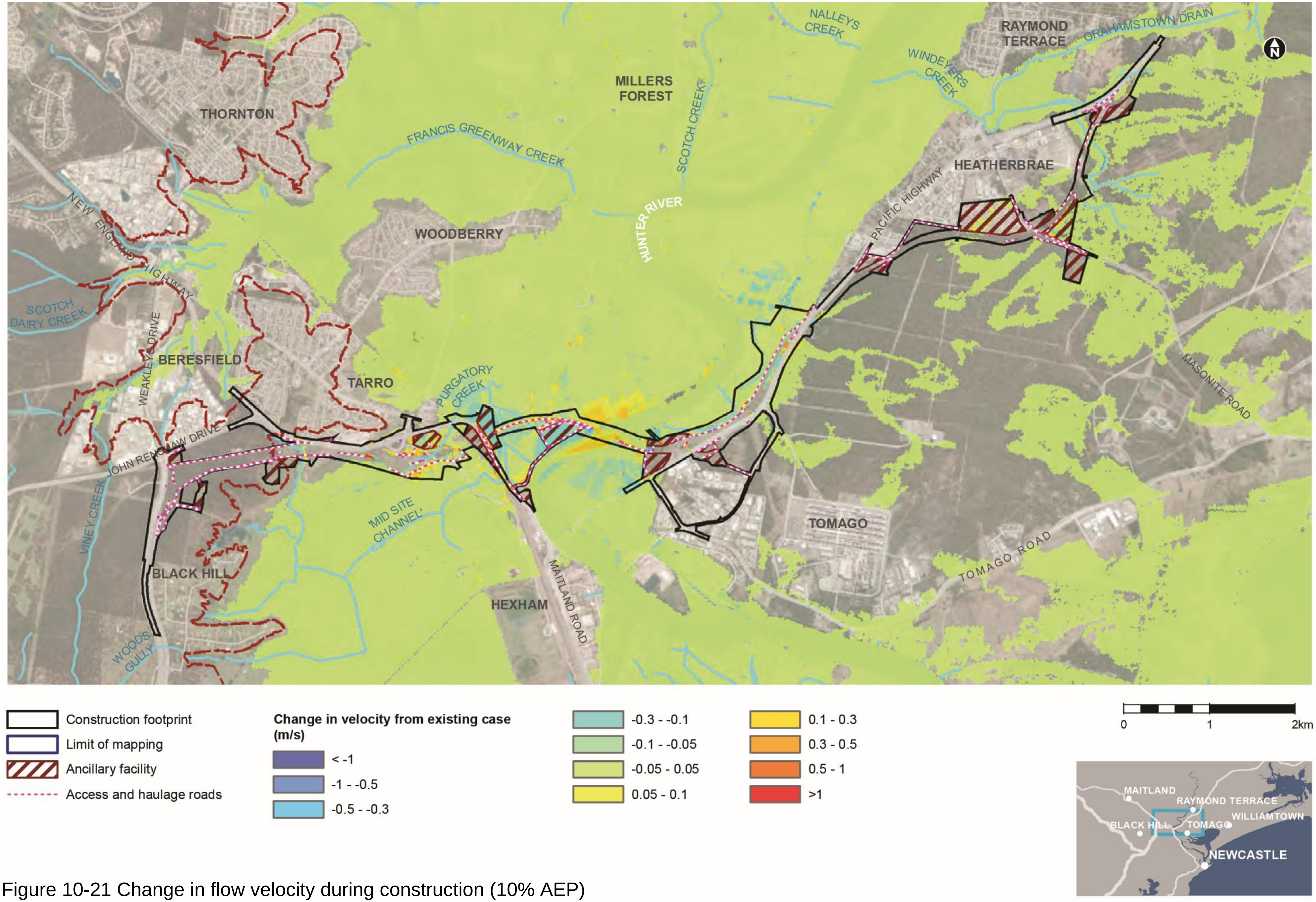


Figure 10-21 Change in flow velocity during construction (10% AEP)

Date: 11/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_029_D5_Change_in_FlowVelocity_Construction_10_AEP_JAC_A4L_175000_V01.mxd

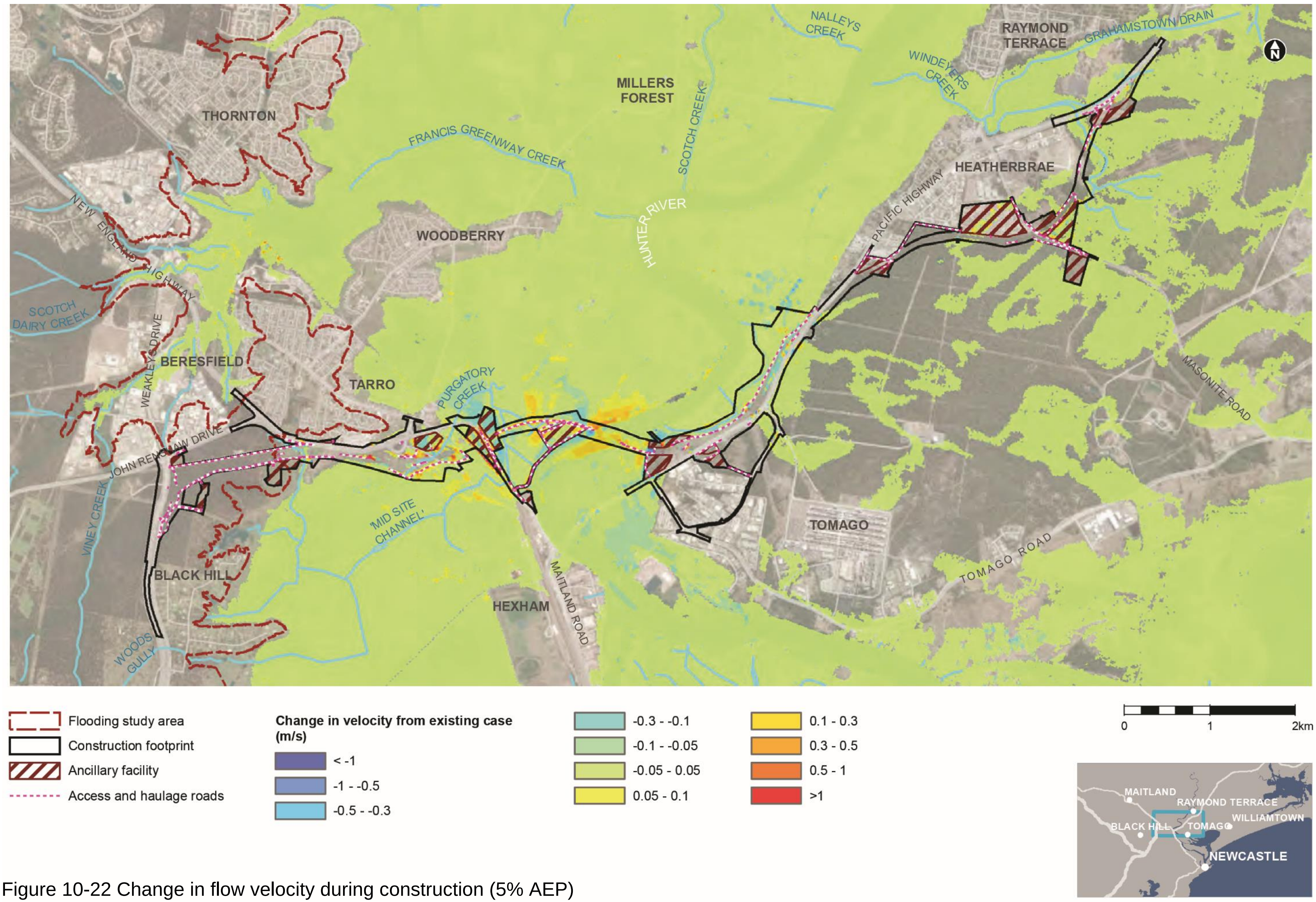


Figure 10-22 Change in flow velocity during construction (5% AEP)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_030_D6_Change_in_FlowVelocity_Construction_5_AEP_JAC_A4L_175000_V01.mxd

Flood hazard

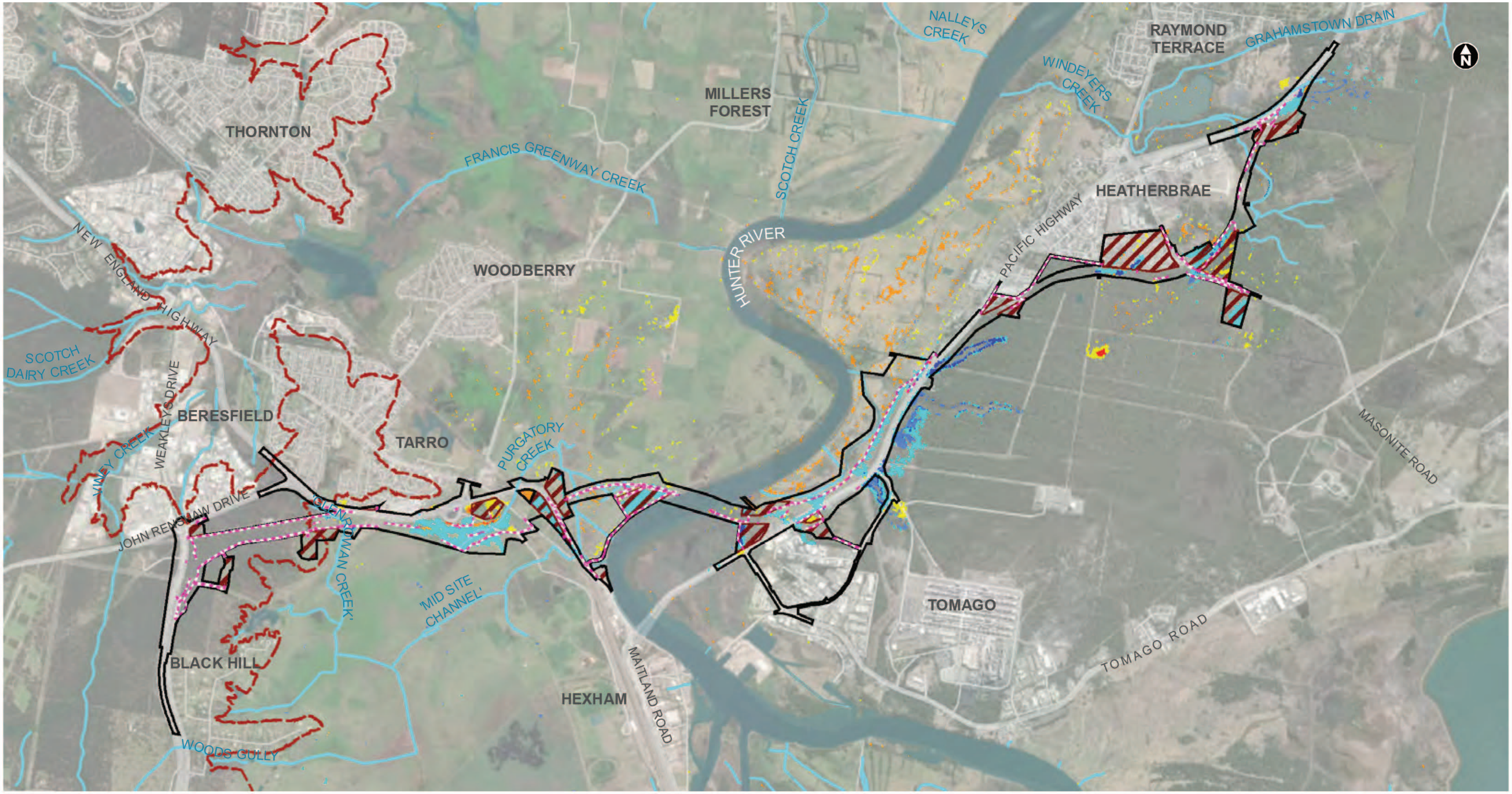
Overall, the change in flood hazard during construction would be localised and as such does not have adverse impacts on flood conveyance, floodways, flow direction and flood storage (refer to **Figure 10-23** to **Figure 10-25**). Project construction would result in the following changes to flood hazards:

- There would be no large increases in extent of the high hazard areas, which would indicate a new floodway or flow path being formed as a result of construction
- There would be reductions in flood hazard in local catchments on the eastern side of the project and between the new viaduct and Heatherbrae corresponding with decreases in flood levels in these areas
- In the 20% and 10% AEP flood events: There would be typically localised increases only in flood hazard on the floodplain on either side of the Hunter River upstream of the project crossing, corresponding to the increases in flood levels for those events
- In the 5% AEP flood event: There would be some larger areas of increased flood hazard in Hexham Swamp, corresponding to increases in flood levels, although these would also be relatively localised.

Flood duration

Project construction would result in the following changes to flood duration:

- In the 20% AEP flood event: Change in duration of inundation is typically within +/- five per cent from the existing case (up to 0.5 hour increase) in locations including in the Hunter River and Hexham Swamp, with the exception of the following increases:
  - Increases in the duration of inundation on the western bank of the Hunter River (in Purgatory Creek) and the eastern bank of the Hunter River upstream of the viaduct crossing of typically 10 to 20 per cent, with increases over 100 per cent on the fringes of the flooding extents (up to 10 hour increase)
  - On the eastern bank of the Hunter River the duration of inundation increase is attributed to the increase in flood levels of 0.05 metres over relatively shallow flood depths of 0.5 metres, due to increased cross drainage capacity that would be constructed as part of the project and would convey flood waters from the upstream western bank to the downstream eastern bank (up to 8 hour increase)
  - In Purgatory Creek the increase in duration of inundation is attributed to interaction of flooding with proposed access roads and reduced drainage capacity posed by proposed culverts under the access roads, and potential reduction in floodplain storage due to the ancillary facilities.
- In the 10% and 5% AEP flood events: Change in duration in inundation is relatively uniform in distribution and typically within +/- five per cent of existing conditions (up to one hour increase), with the exception of the following increases:
  - Localised increases in durations of 10 to 20 per cent (six to 15 hour increase) along the fringes of the flooding extent and along embankment areas, generally upstream of the viaduct crossing and in Hexham Swamp where increases in flood levels would be expected
  - Downstream of the bridge crossing there would be decreases in durations of 10 to 20 per cent (up to 0.5 hour decrease) where reductions in flood levels would be expected.



Flooding study area
Construction footprint
Ancillary facility
Access and haulage roads

Change in hazard from existing case

Was high, now dry
Was high, now low
Was low, now dry
Unchanged (not shown)
Was dry, now low
Was low, now high
Was dry, now high

0 1 2km

Figure 10-23 Change in flood hazard during construction (20% AEP)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_031_D7_Change_in_Floodhazard_Construction_20_AEP_JAC_A4L_175000_V01.mxd

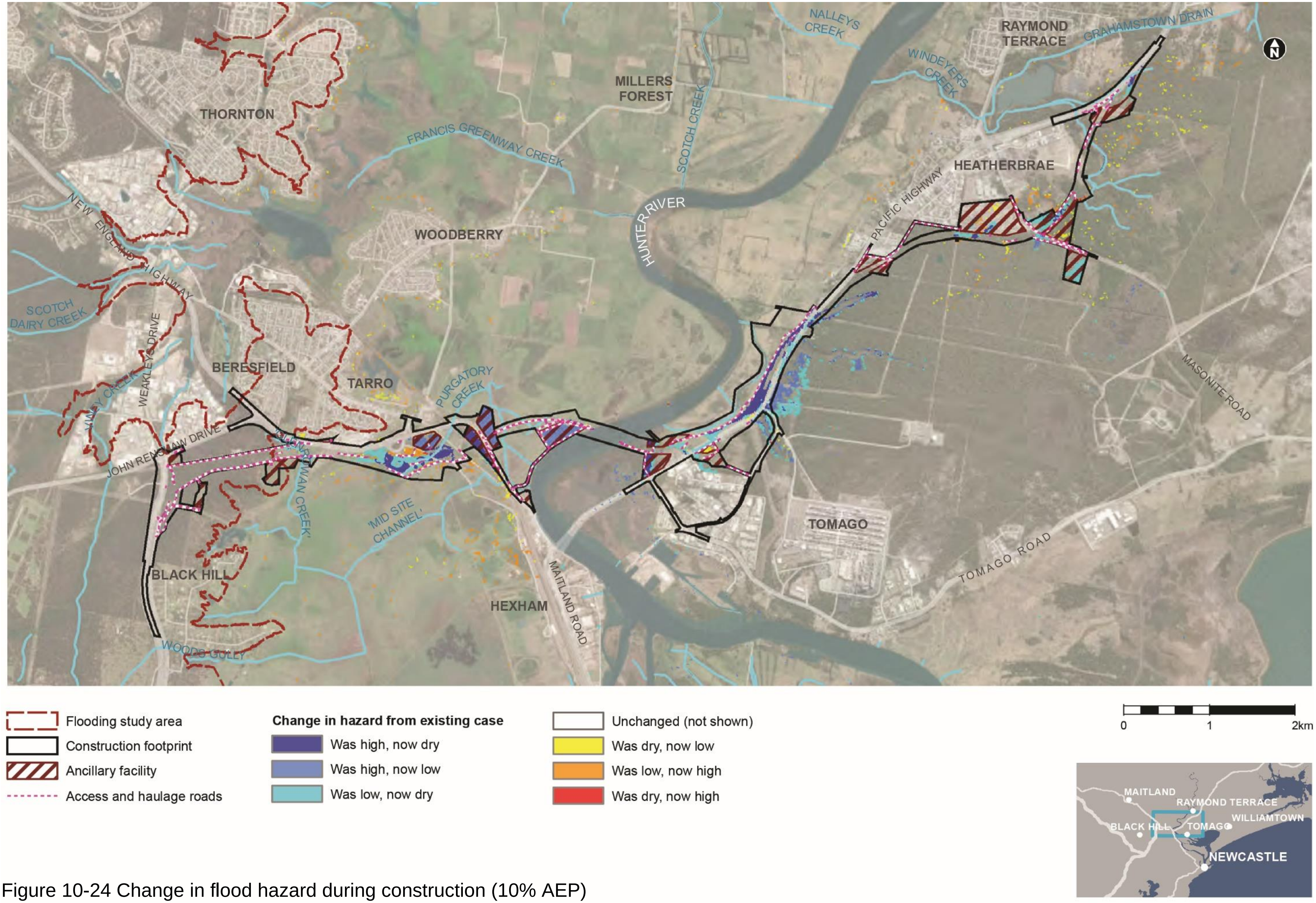


Figure 10-24 Change in flood hazard during construction (10% AEP)

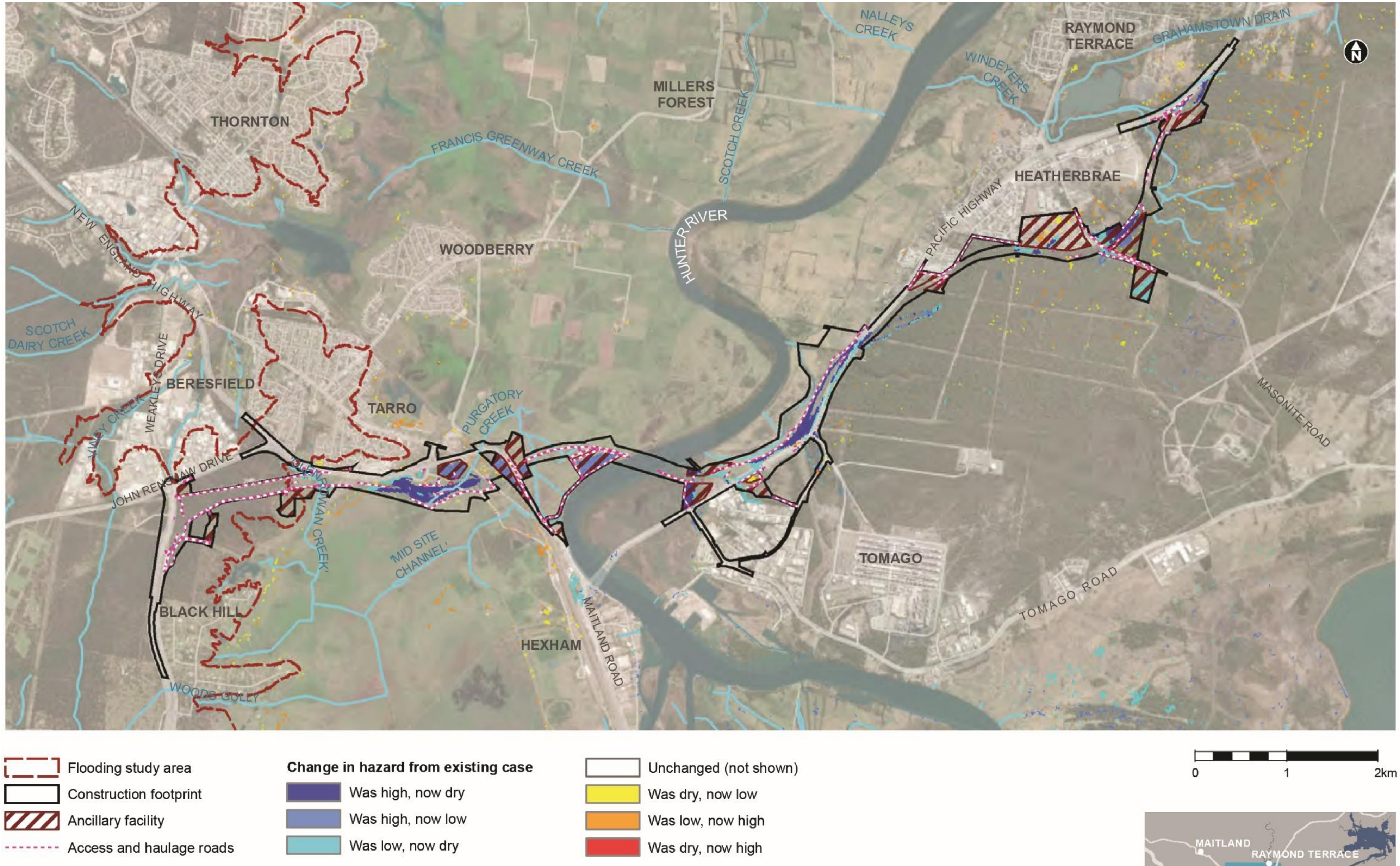


Figure 10-25 Change in flood hazard during construction (5% AEP)

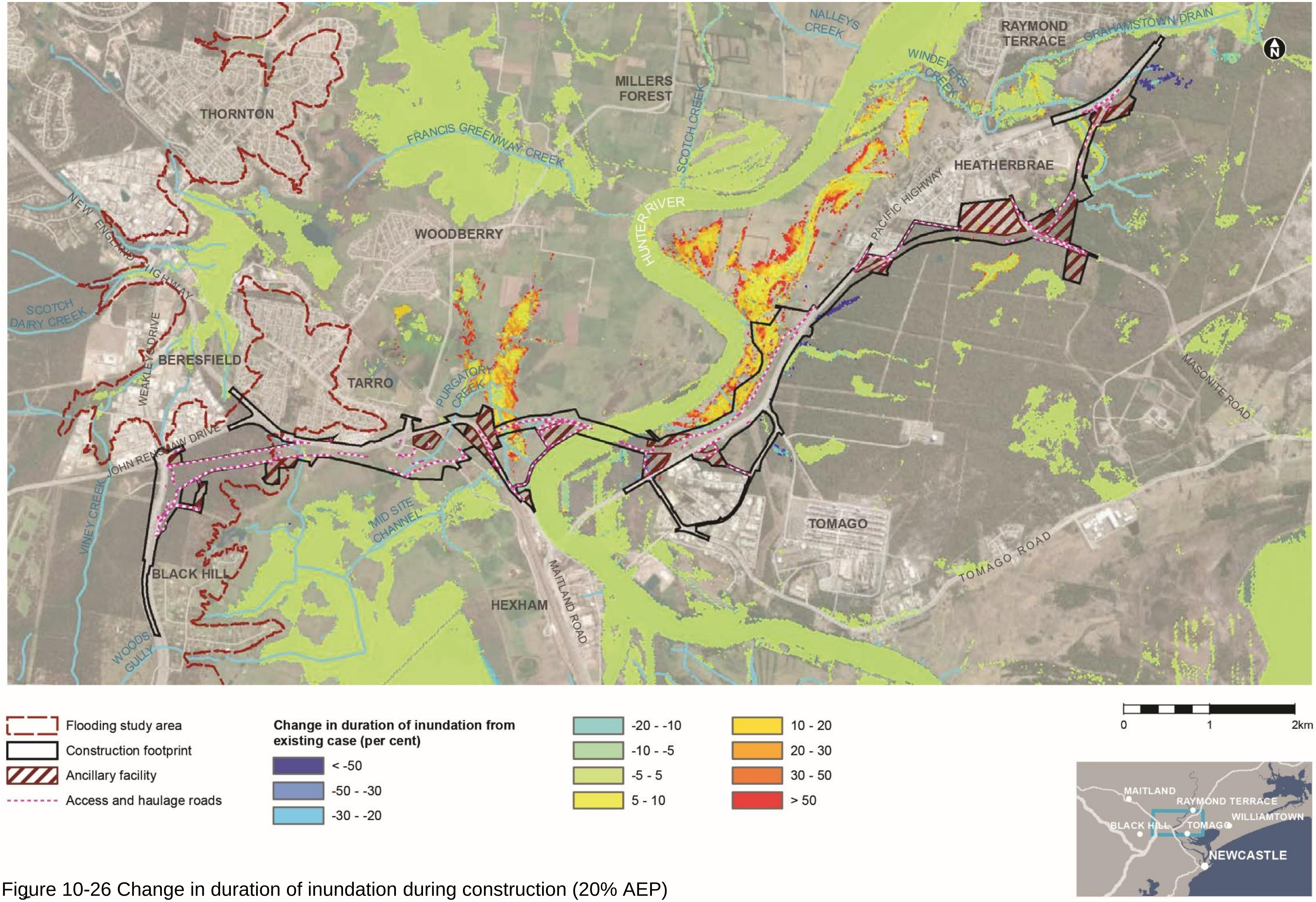
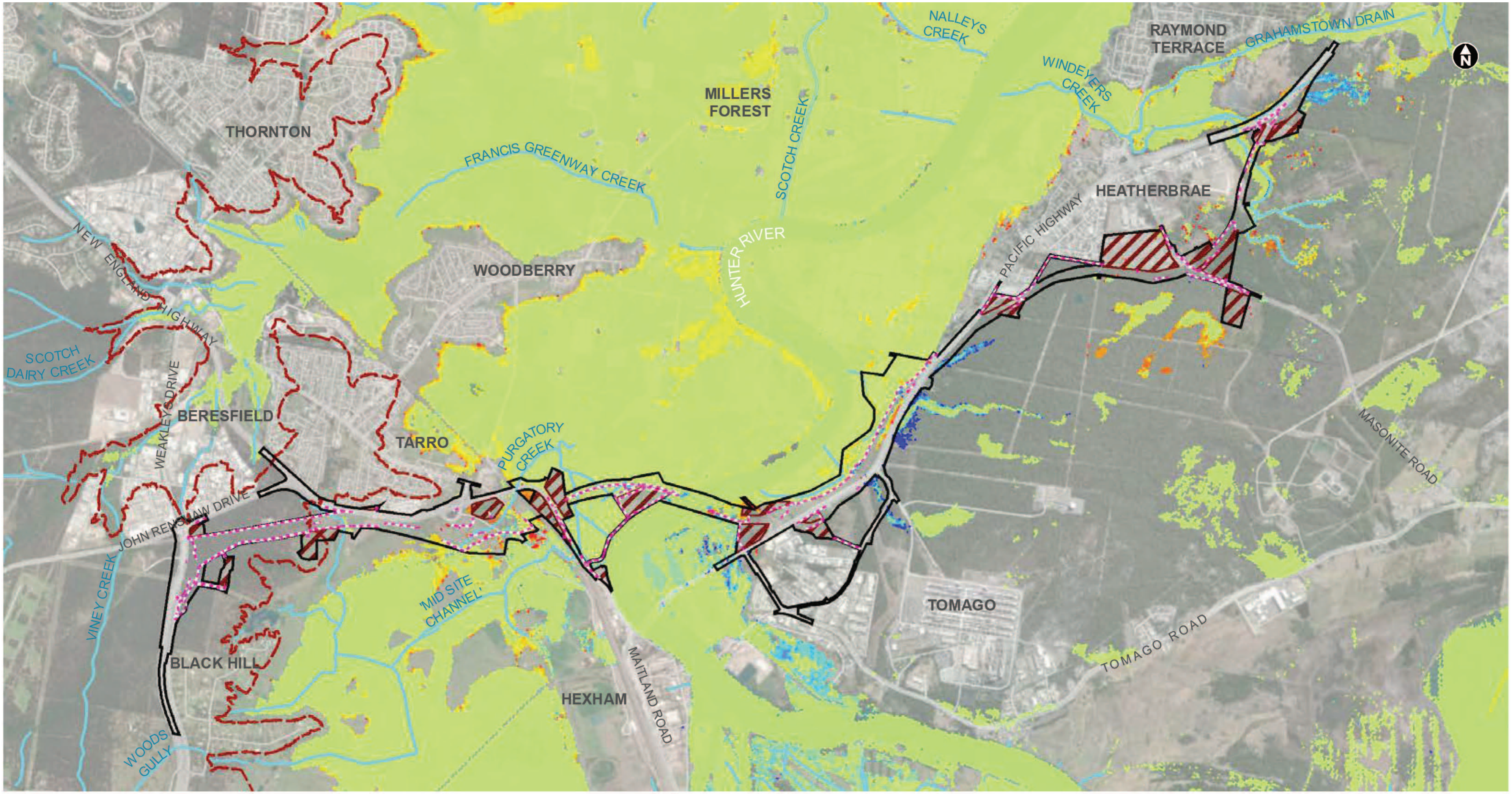


Figure 10-26 Change in duration of inundation during construction (20% AEP)



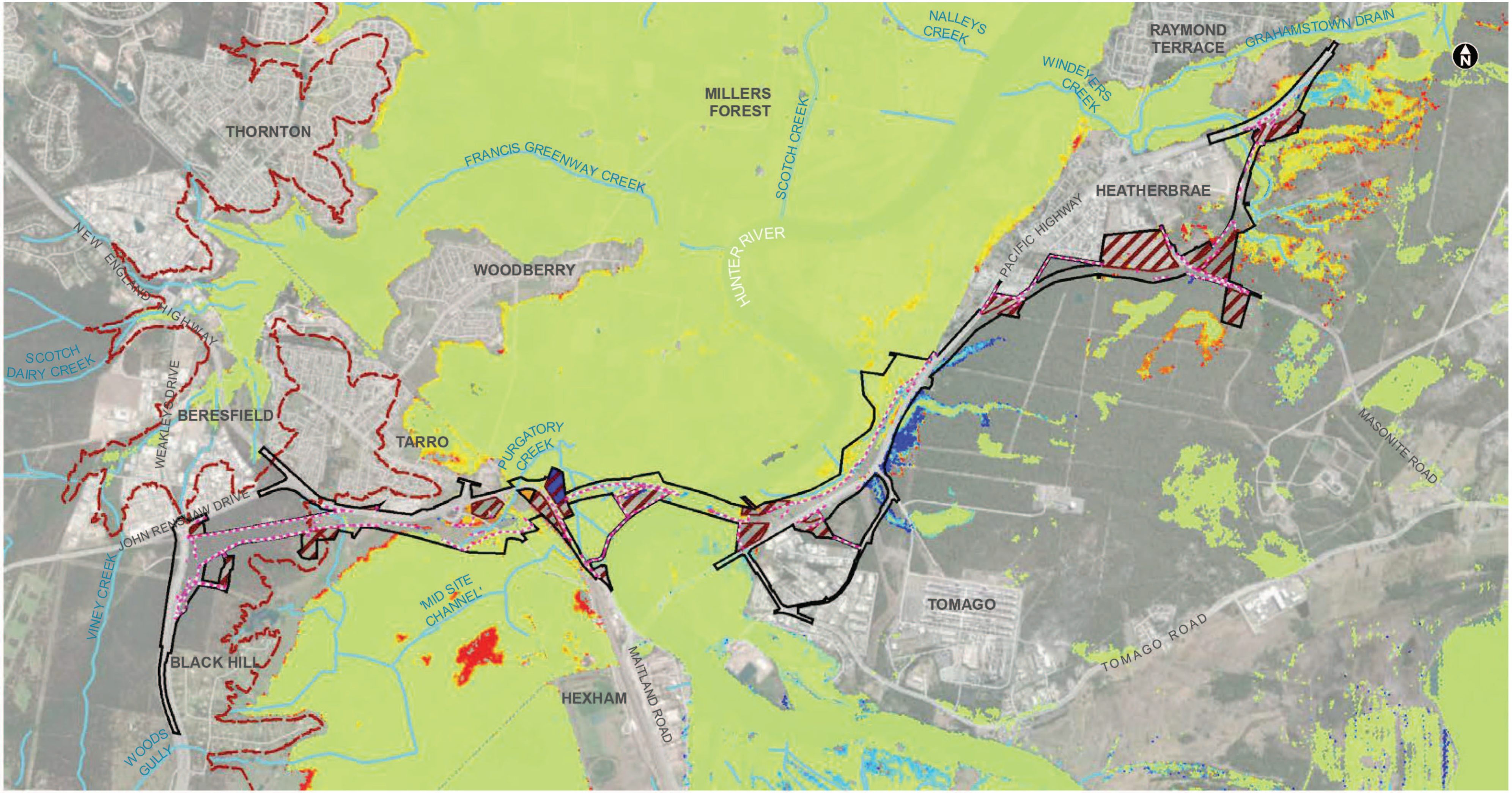
Flooding study area	
Construction footprint	
Ancillary facility	
Access and haulage roads	

Change in duration of inundation from existing case (per cent)

- < -50
- -50 - -30
- -30 - -20
- -20 - -10
- -10 - -5
- -5 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- > 50

0 1 2km

Figure 10-27 Change in duration of inundation during construction (10% AEP)



Flooding study area

Construction footprint

Ancillary facility

Access and haulage roads

Change in duration of inundation from existing case (per cent)

- < -50
- -50 - -30
- -30 - -20
- -20 - -10
- -10 - -5
- -5 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- > 50

Figure 10-28 Change in duration of inundation during construction (5% AEP)

Impacts on infrastructure

Road

Highways, major roads and other local roads were assessed for the total length of road affected by H2 flood hazard and higher during construction.

There would be no change in total length of road impacted for the majority of named roads within the study area. Where there would be a change in total length impacted when compared to the existing case, this is presented in **Table 10-10**. The results in **Table 10-10** reflect the change in trafficability of the roads from the existing case (refer to **Table 10-6**). H2 flood hazard and above indicates that the road is not trafficable due to flooding conditions as in accordance with the flood hazard classifications described in **Section 10.2.3**.

Table 10-10 Change in length of highways and major roads subject to H2 flood hazard, comparison of construction phase to existing case

Road	20% AEP (length change)	10% AEP (length change)	5% AEP (length change)
Maitland Road	-10% (<0.01km)	4% (0.01km)	-12% (-0.07km)
New England Highway	0%	23%* (0.11km)	6% (0.05km)
Pacific Highway	91%** (0.05km)	-6% (-0.07km)	-19% (-0.36km)
Raymond Terrace Road	2% (0.02km)	2% (0.09km)	0%
Seaham Road	1% (0.02km)	0%	0%

* Increase on the New England Highway is a minor extension of H2 flooding affecting a minor road on ramp and not the main alignment

** An increase of 91 per cent from existing inundated length is experienced on the Pacific Highway in the 20% AEP flood event, where the total length affected increases from 51 metres to 97 metres.

For highways and major roads, there would be no major increases in the total length of road affected by the H2 flood level hazard or higher. The 91 per cent increase in length of the Pacific Highway affected in the 20% AEP event translates to an increase of 46 metres, which is considered a minor increase. Some roads would experience a decrease in the total length of road affected by H2 flood hazard in comparison to existing conditions. Any increases in inundated length would occur at locations which are already subject to inundation.

Emergency management, evacuation and access

The highways and major roads in the study area are expected to form the main emergency access and flood evacuation routes. The minor change in the length of roads affected by H2 flood hazard, combined with a minor change in duration of inundation indicates that a new 46 metre section of the Pacific Highway at Tomago Road intersection would become cut-off in the 20% AEP event.

Physical works during construction including changed traffic conditions and roadworks could reduce the traffic capacity of existing evacuation routes. Management of construction impacts to evacuation route capacity would be included in the detailed construction planning phase.

Rail

Railways and railway facilities were assessed for the total length of rail overtopped by floodwater during construction. The per cent change in total length when compared to the existing case would remain the same for the Aurizon Hexham Train Support Facility and other rail lines. The Main North Rail Line would experience a 0.1 per cent increase in length of railway overtopped by floodwater compared to the existing case (**Table 10-7**).

Impacts on land uses

There would be minimal change in the duration of inundation on the overall floodplain. Higher increases would occur mainly on the edges of the existing flood plain where shallow areas of flooding with short inundation times (depths of less than 0.5 metres and inundation times of up to one day) are sensitive to increases in flood levels and durations of inundation. The large majority of flood-affected residential, commercial and industrial properties in the existing case experience negligible change in flood depth (+/- 0.01 metre change), hazard and time of inundation (+/- three hours) during construction.

Properties and buildings

Increases in flood depths of over 0.01 metres in the 5% AEP flood event (**Figure 10-19**) would affect up to[2]:

- 1.5 per cent of all residential lots within the study area
- 4.7 per cent of all commercial lots within the study area
- 6.9 per cent of all industrial lots within the study area.

Increase in flood depths of over 0.05 metres in the 5% AEP flood event would affect up to:

- 0.6 per cent of all residential lots within the study area
- 0.8 per cent of all industrial lots within the study area
- No commercial lots.

This includes a number of lots which are indicated to experience increases in maximum depths over 0.2 metres. The large majority of residential, commercial and industrial lots would experience no change in duration of inundation and flood hazard.

The results indicate that some properties may be subject to increases exceeding the adopted criteria in flood depth (greater than 0.1 metre increase), hazard and duration of inundation (greater than 3 hours increase), in addition to change in flood extent, in the 20% AEP or higher.

There would be 19 lots that may experience afflux exceeding the adopted criteria (greater than 0.1 metre increase) and five buildings that may experience afflux exceeding the adopted criteria (greater than 0.05 metre increase). No commercial or industrial lots would exceed the adopted criteria.

Refinement to the construction design would be considered for detailed design changes and any associated flood modelling. This would include refinement to temporary access roads to reduce flood afflux where reasonable and feasible. Transport would consult with landowners to discuss reasonable and feasible management measures to be implemented by the contractor in relation to impacts to individual properties from the project including those identified in this assessment (refer to **Section 10.7**).

Other land uses

The increased extent of inundation may increase the risk of damage and pasture die-off to agricultural and grazing land uses within a small section of the flood plain. As shown in **Figure 10-28**, the area affected by greater than 50 per cent increase in inundation duration in the 5% AEP flood is less than one per cent of the overall floodplain. Agricultural and grazing activities, including movement and evacuation of stock during flood events, are expected to be impacted by increases in flood levels during construction as follows:

- Up to 0.1 metres in the 5% AEP flood event on the Hunter River floodplain (refer to **Figure 10-19**) and in the coastal wetlands in Hexham, with lower impacts in the 20% and 10% AEP flood events (refer to **Figure 10-17** and **Figure 10-18**)
- In the 5% AEP flood event, the increased flood levels translate to a typical increase in the width of the flood extent by 10 to 20 metres in localised areas (refer to **Figure 10-19**)
- Minor changes (up to +/- five per cent) in the duration of inundation for flood depths over 0.5 metres.

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[2] Compared to 15,841 residential lots, 1,533 commercial lots and 1,315 industrial lots in the flooding study area.

The minor change in duration of inundation for flood depths over 0.5 metres (typically up to one hour increase), means that the duration of isolation of stock flood refuges would not be substantially impacted. It is expected that the time to drain the floodplains for water depths under 0.5 metres would be similar to existing conditions (maximum five per cent increase).

Increases in flood hazard occur where there are increases in flood depths and levels, while decreases in flood hazard occur where there are reductions in flood depths and levels. The potential impacts of flood hazard changes (refer to **Figure 10-23** to **Figure 10-25**) on land uses would be as follows:

- Flood hazard changes on grazing lands:
  - Increase in flood hazard on 0.6 to 0.8 per cent of the land in all flood events assessed
  - Decrease in flood hazard on 0.5 to 0.8 per cent of the land in all flood events assessed.
- Flood hazard changes on forestry lands:
  - Up to four per cent of the total forestry area would experience an increase in flood hazard
  - Up to four per cent of the total forestry area would experience a decrease in flood hazard.
- Flood hazard changes on wetland and national park areas:
  - Some portions of wetland and national park areas (up to 0.2 per cent of the total area) would experience an increase in flood hazard
  - Other portions of wetland and national park areas (also up to 0.2 per cent of the total area) would experience a decrease in flood hazard.

Impacts associated with the Hunter Valley Flood Mitigation Scheme

A number of ancillary facilities, in addition to temporary wharves and access roads, would be situated immediately adjacent to or on the levees, channels and drainage infrastructure which are part of the Hunter Valley Flood Mitigation Scheme. Access roads for the project would be constructed immediately next to Hunter Valley Flood Mitigation infrastructure, namely existing flood levees on the western Hunter River floodplain. While these access roads may affect the structure and maintenance of the levees, changes to levees are not expected to result in changes to existing flows or capacity, and as such are not expected to impact operation, function or structural integrity of the scheme (including the floodgates).

Transport would continue to consult with the operators of the scheme during detailed design to minimise potential impacts.

10.5.4 Sensitive receiving environments

The potential impacts on SREs during construction of the project are as follows:

- Drinking water supply aquifers: As described above, while the project would have some localised drawdown and mounding impacts it is not anticipated to have any detrimental effect on the local groundwater hydrology regime, including GDEs and other groundwater users. All temporary sediment basins would be lined within the Tomago Sandbeds Catchment Area. As a result, no impacts are expected to the nearby Tomago Sandbeds Catchment Area drinking water supply
- Groundwater users: Although the project would have some localised drawdown and mounding impacts, including within an area of high potential GDE at Tarro, it is not anticipated to have any detrimental effect on the local groundwater hydrology regime, including GDE and other groundwater users

- Wetlands, including:
  - **Coastal Wetlands (Coastal Management SEPP)**: At Tarro, drawdowns from temporary construction dewatering are predicted to encroach into Coastal Wetlands (Coastal Management SEPP), with drawdowns of up to 2.0 metres. It is noted that the majority of the Coastal Wetlands (Coastal Management SEPP) predicted to be within the area of drawdown would be cleared by the construction activities and embankment formation. As a result, drawdown is not anticipated to materially affect GDEs
  - **Hunter River wetland**: While not classified under the Coastal Management SEPP, the Hunter River wetland located within the Tomago Sandbeds Catchment Area, has also been considered an important wetland environment. As described above, no impacts are expected to the Tomago Sandbeds Catchment Area where the wetland is located
  - **Hunter Estuary Ramsar site**: The Hunter Estuary Ramsar site is located downstream of the Hunter River. As hydrological changes to the Hunter River are not anticipated to be significant, no impacts to the Hunter Estuary Ramsar site are predicted.
- GDEs: Based on the relatively short period of dewatering and drawdown, limited drawdown propagation and localised areas of mounding, changes to groundwater levels and flows are not anticipated to materially affect GDEs, including High Priority GDEs, baseflows, existing groundwater users or surrounding land due to settlement.

10.5.5 Site water balance

Key water demands during construction are outlined as follows:

- Earthworks: conditioning of bulk fill materials and pavement foundations
- Dust suppression: ancillary facilities, access roads and work areas
- Concrete batching: for pavements and bridges
- Landscaping: irrigation for revegetation and landscaping
- Potable water: for use at ancillary facility offices, crib rooms and ablutions.

For each water demand there is an upper limit to the acceptable water quality for project use. The different water quality classifications relevant to project water use include fresh, slightly brackish, brackish and saline. Due to health and quality assurance considerations all water required for potable supply and concrete batching would meet quality standards before use.

Key project water sources (intake locations) that are available for use are as follows:

- Temporary sediment basins
- Temporary construction dewatering
- Soft soil consolidation wick drains.

The project would operate with a net deficit of water even without considering the limitations on water use and availability. Key water balance outputs for the base case scenario were:

- Net water demand would exceed net supply by approximately 7.3 megalitres per month or 254 megalitres over the construction phase
- With consideration for limitations on water re-use and availability, the project would need to import approximately 10.6 megalitres per month or 370 megalitres of potable water over the construction phase
- Given the limited opportunity for re-use, the majority of runoff water captured in the temporary sediment basins (an average of 2.66 megalitres per month, and a total of about 93 megalitres) would be discharged

- The project is expected to produce a total volume of about 26 megalitres of saline water from temporary construction dewatering. Highly saline water would be reused in applications where there is minimal risk of harm to biodiversity, infrastructure, existing soils or entry into waterways (such as compaction of elevated formations, dust suppression etc) and where the salinity is commensurate with existing soil and groundwater conditions
- The production of saline and brackish water through dewatering and wick drain extrusion occurs predominantly on the low-lying floodplain areas
- The dry season water balance scenario results in a 29 per cent increase in makeup water demand and a 25 per cent reduction in discharge
- The wet season water balance results in a 30.5 per cent reduction in makeup water demand and 48 per cent increase in discharge.

The project aims for sustainable use of water resources, and as such re-use of water would be incorporated where possible. However, issues around timing and water quality constraints mean that re-use of produced or captured water may not always be possible. The water balance would be reviewed when the delivery and procurement strategy for the project is confirmed.

10.5.6 Summary of construction impacts

Summary of surface water construction impacts

The project would have the following impacts to surface water hydrology during construction:

- Increased runoff associated with vegetation clearance, soil compaction, paving of the new road corridor and construction of the temporary ancillary facilities, access roads and tracks
- Temporary and permanent alteration or impedance of existing drainage paths and waterways resulting from:
  - The construction of the viaduct, (i.e. temporary waterway structures and wharves and the permanent piers themselves)
  - Adjustment of Purgatory Creek and the tributary of Viney Creek as well as temporary and permanent culverts
  - Minor increase (less than 20 per cent increase) in the rate of stormwater at discharge from the project at the tributary of Viney Creek, the unnamed tributary of coastal wetland, the Hunter River Drain and the tributary to the Hunter River Drain
  - Moderate increase (more than 20 per cent increase) in the rate of stormwater at discharge from the project at Purgatory Creek, the drainage line through coastal wetland to the Hunter River, diffuse drainage lines that feed into the Tomago Sandbeds Catchment Area and Windeyers Creek
  - Siting and design of the ancillary facilities would seek to maintain existing drainage lines where feasible and reasonable however some redirection may be necessary.
- Changes to stormwater discharge is likely to result in the following additional changes to existing receiving environment flow regimes:
  - A minor reduction in baseflow and moderate increase to quickflow contributions
  - Minor increases to rates of water level rise and fall
  - Minor changes to the number, duration and magnitude of low flow events.
- Changes to existing flow regimes identified above may have the potential to result in the following impacts to local receiving waterway processes and health:
  - Reduced bank stability (scouring, undercutting, slumping, etc.) immediately downstream of project discharge locations
  - Possible increases to the rate of removal and transport of eroded bed and bank material during storm events

- Risk of increased water turbidity during and after storm events due to discharge of suspended material
- Minor increases to the duration and depth of inundation for overbank events.

Summary of groundwater construction impacts

The project is likely to intersect the groundwater table in some locations during the following construction activities:

- Excavation of temporary sediment basins and permanent water quality basins
- Excavations for bridge piers
- Excavations for the Purgatory Creek adjustment.

Temporary dewatering of basins and piers would be required during construction as some temporary sediment basins would have an invert lower than the surrounding groundwater level and they would infill. Groundwater modelling has shown that the predicted groundwater level drawdown would be proportionate with the depth of excavation and ranges between 0.4 metres to 2.4 metres. It is noted that the majority of the Coastal Wetlands (Coastal Management SEPP) predicted to be within the area of drawdown would be cleared by the construction activities and embankment formation. As a result, drawdown is not anticipated to materially affect GDEs. Impacts at basins and the diversion of Purgatory Creek would typically be less than 10 days, and between 10–20 days at the bridge piers.

Groundwater produced during project construction, through temporary construction dewatering or via wick drains, would be re-used where possible for dust suppression and fill conditioning as a measure of sustainable use of the groundwater resource. This approach would minimise, as far as practical, the need for the project to import water for construction activities. A total groundwater take of 164.9 megalitres (ML) across the three water sources and WSPs is anticipated.

The project would also likely result in soft soil consolidation in some areas that would potentially impact on groundwater levels and flow. This may result in water level mounding (rise in water level) on the upgradient margin of the consolidated area, and water level shadowing (lowering of water level) on the down-gradient margin of the consolidated area.

Although the project would have some localised drawdown and mounding impacts it is not anticipated to have any detrimental effect on the local groundwater hydrology regime, including groundwater dependent ecosystems and other groundwater users. No impacts are expected to the nearby Tomago Sandbeds Catchment Area drinking water supply.

Summary of flooding construction impacts

Flooding impacts during construction include flood level increases of generally 0.02 to 0.1 metres in the 5% AEP event. There are 19 lots and five habitable buildings identified as experiencing afflux exceeding the adopted criteria. Flood level increases of up to 0.02 metres reach Raymond Terrace and beyond the current flood model extent.

A new 46 metre section of the Pacific Highway within the construction footprint is affected by H2 flood hazard at Tomago Road intersection, but not Tomago Road itself, due to a change in the modelled road levels. Opportunities to adjust the design to minimise the flood impact to this localised section will be investigated at detailed design, although generally the design aims to match existing levels for local roads.

Access roads for the project would be constructed immediately next to Hunter Valley Flood Mitigation infrastructure, namely existing flood levees on the western Hunter River Floodplain. While these roads may modify the structure and maintenance of the levees, they are not expected to impact operation, function or structural integrity of the scheme (this includes the floodgates). Transport will continue to consult with the operators of the scheme during detailed design to minimise impacts on the scheme.

10.6 Assessment of potential operational impacts

10.6.1 Surface water hydrology

Key activities during project operation that may impact the nature (volume, rate, timing, duration, velocity, etc.) of stormwater discharges that may then impact on surface water hydrology include:

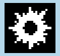
- Road paving and soil compaction leading to reduced or effectively eliminated rates of infiltration
- Alteration or restriction of existing drainage paths and catchments
- Attenuated or delayed discharge of stormwater captured in water quality basins which have been designed to meet the design criteria.

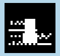
The project would have similar impacts to surface water hydrology during operation as those identified in construction.

NSW river flow objectives

The potential operational impacts to waterways in the surface water study area in consideration of the NSW river flow objectives relevant to the project are detailed in **Table 10-11**.

Table 10-11 River flow objectives relevant to project operation impacts

River flow objective	Description	Hunter River sub-catchment type				Project impacts
		Town water supply sub-catchments	Mainly forested areas	Waterways affected by urban development	Estuary	
	Maintain wetland and floodplain inundation	×	×	✓	✓	Project operation does not require waterway damming or extraction of surface water flows. Some changes to the depth and duration of floodplain inundation are expected however these changes are only expected to have a minor impact to the existing regime.
	Mimic natural drying in temporary waterways (and wetlands)	×	×	✓	×	Continuous or prolonged releases of water to ephemeral receiving waterways are not planned or required by the project. However, some localised, minor changes are expected to the timing, frequency and duration of low flow events. These are expected to result from the alteration of existing drainage paths, changes to the extent of catchment imperviousness and discharge of stormwater via permanent water quality basins.
	Maintain natural rates of change in water levels	×	×	✓	×	Some localised changes are anticipated to rates of rise and fall in water levels due to the expected increases to rate of and volume of stormwater discharged during the operational phase. Where required, bed and bank stability issues have been addressed through implementation of erosion and scour management measures such as rock transition aprons at culvert outlets, refer to **Section 10.7**.
	Protect pools in dry times	×	✓	×	×	Extraction of surface water is not proposed as part of the project and any impact to pools in dry times is expected to be minimal.
	Protect natural low flows	×	✓	×	×	Extraction of surface water is not proposed as part of the project and any impact to natural low flows is expected to be minimal.
	Maintain natural flow variability	×	✓	✓	✓	Damming of waterways, surface water extraction or prolonged discharge of water is not proposed during project operation. Discharge of stormwater from the project would largely be coincident with existing flows in receiving waterways and are not expected to negatively impact existing flow variability.

River flow objective	Description	Hunter River sub-catchment type				Project impacts
		Town water supply sub-catchments	Mainly forested areas	Waterways affected by urban development	Estuary	
	Manage groundwater for ecosystems	✓	✓	×	✓	The total predicted change of groundwater contribution to surface water features is not considered to be substantial and would not detrimentally impact on wetlands and waterways.
	Minimise effects of weirs and other structures	×	✓	✓	✓	Weirs or any other waterway obstruction are not proposed for the project. Minor adjustments of Purgatory Creek and the tributary of Viney Creek are not expected to impact flows once completed.
	Maintain or rehabilitate estuarine processes and habitats	×	×	×	✓	The project does not call for the damming, obstruction or interference of any estuarine waterway and the existing tidal flow regime would be maintained.

Impacts on waterways and wetlands

The project would impact on a number of existing waterways and wetlands due to features such as embankments and its location over existing waterways and drainage lines.

Potential changes to the Hunter River catchment and rate and volume of stormwater discharged during operation of the project are as follows:

- Total catchment areas are not proposed to substantially change, with a maximum increase of 3.2 per cent for the catchment draining to the culvert under the New England Highway and a maximum reduction of -2.2 per cent for the Glenrowan Creek catchment draining to bridge (B02) over the unnamed wetlands
- Progressive construction of the project would result in changes to the total amount of impervious areas (areas which impede infiltration of water into groundwater). While percentage changes within each catchment would vary from zero to 577.7 per cent, most changes would be in the order of 55.1 per cent or lower
- Discharge rates would generally increase as a result of the project which is consistent with the increase in impervious area within each catchment. The mean magnitude of the relative increase is greatest for the 50% AEP rainfall event (19 per cent) and lowest for the 1% AEP rainfall (13 per cent)
- Discharge volumes would increase as a result of the project with the mean relative increase being five per cent for the 50% AEP rainfall event and five per cent for the 1% AEP rainfall event
- Estimated flow velocities would also increase with the mean relative increase ranging from 54 per cent for the 50% AEP rainfall event to 89 per cent for the 5% AEP rainfall event. While the magnitude of relative increases is high, the estimated velocities for all proposed conditions and events remain below three metres per second.

The adjustment of Purgatory Creek would result in a beneficial impact to the drainage capacity at the upstream end of the creek.

The adjustment of the tributary of Viney Creek has been designed with a 1% AEP flood event flow capacity. Natural creeks typically have a capacity well below the 1% AEP flood event. Hence, no impact on flow capacity is expected on the tributary of Viney Creek.

Changes to the existing flow regime

Receiving waterways potentially impacted by discharges of stormwater from the project based on the result of the hydrology modelling and the activities listed above would be as follows:

- Tributary of Viney Creek
- Purgatory Creek
- Drainage line through coastal wetland to Hunter River
- Unnamed tributary of coastal wetland
- Hunter River Drain
- Tributary to Hunter River Drain
- Drainage lines that feed into the Tomago Sandbeds Catchment Area
- Windeyers Creek.

DRAINS hydraulic modelling has been completed for twelve locations immediately downstream of project stormwater discharge points to assess impacts to surface water hydrology during operation. The results indicate that the project operation may result in a moderate increase to the rate, volume and velocity of stormwater discharged.

In addition to the quantified changes to stormwater discharge, the project is likely to result in the following additional changes to existing receiving environment flow regimes:

- Minor reductions in baseflow and a moderate increase to quickflow contributions to total streamflow as a result of lowered rates of rainfall infiltration, increase in effective rainfall depth and formalisation of drainage conveyance

- Minor to moderate increases to the rate, volume and velocity of stormwater discharged from the project and subsequent inferred alteration (minor increases) to rates of water level rise and fall
- Minor increases to the duration and depth of inundation for overbank events
- A minor increase (less than 20 per cent) in the rate of stormwater at the following discharge points (refer to **Figure 10-16**):
  - Discharge point N1160B at tributary of Viney Creek
  - Discharge point N8200C at unnamed tributary of coastal wetland
  - Discharge point N9100C at the Hunter River Drain
  - Discharge point N9380C at the tributary to the Hunter River Drain.
- A moderate increase (more than 20 per cent) in the rate of stormwater at the following discharge points (refer to **Figure 10-16**):
  - Discharge point N3500C at Purgatory Creek
  - Discharge point N7300C at the drainage line through coastal wetland to the Hunter River
  - Discharge point N11920C drains into diffuse drainage lines that feed into the Tomago Sandbeds Catchment Area
  - Discharge points N13020C and N12620C at Windeyers Creek.

Changes to environmental water availability and flows

The project is not expected to materially impact environmental water availability. No damming, permanent total blockage or diversion of major waterways is proposed, and extraction of surface water is not required. While rates, volumes and velocities of stormwater discharged by the project are expected to increase, this is not expected to adversely impact existing environmental water availability and flows.

Changes to erosion, siltation, or stability of riverbanks or waterways

The estimated operational phase changes to flow regimes may result in the following impacts to waterway health and instream processes and may extend beyond the immediate discharge location:

- Reduced bank stability (scouring, undercutting, slumping, etc) as a result of increased streamflow discharge and velocities
- Increased removal and transport of eroded bed and bank material leading to downstream sedimentation and potential infilling of aquatic habitat features such as rocky holes or smothering of aquatic vegetation
- Increased water turbidity due to suspended material and subsequent reduction in light infiltration potentially impacting sensitive aquatic vegetation
- Potential for fish passage obstruction due to increased flow velocities or reduced water levels.

Impacts on bed and bank stability

Similar to the construction impacts, the estimated changes to flood behaviour as a result of project operation may result in the following impacts and may extend beyond the immediate discharge location:

- Reduced bank stability as a result of increased discharge and velocities
- Increased removal and transport of eroded bed and bank material.

Water take

There would be no direct or passive water take from any surface water sources during operation.

Regional impacts on Hunter River catchment

The project would not result in the damming, permanent total blockage or extraction of water of any waterways in the surface water study area during operation. Therefore, operation of the project would not impact on the regional hydrology of the Hunter River catchment.

10.6.2 Groundwater hydrology

Impacts on groundwater systems

Project operation would result in relatively small groundwater level increases and some localised groundwater mounding. Project changes to groundwater level or flow are not anticipated to materially affect baseflows or existing groundwater bores. As a result, operation of the project would not impact the Tomago Sandbeds Catchment Area drinking water supply due to reduced groundwater levels or flows.

All permanent water quality basins and grassed swales located within the Tomago Sandbeds Catchment Area will be lined and all runoff in the area captured in basins for treatment.

Further details about permanent water quality basins, lining of basins and grassed swales and impacts to the Tomago Sandbeds drinking water catchment are presented in **Chapter 11** (surface water and groundwater quality).

Impacts on groundwater flow and level

Groundwater dewatering would not be required during operational phase. Except for at areas of soft soils consolidation, there is negligible potential for the project to materially impact groundwater flow or levels during operation.

While there would be no further soft soil consolidation during operation, groundwater impacts, including mounding impacts and shadowing effects, would be similar to those predicted for soft soil consolidation during construction (as discussed in **Section 10.5.2**) due to the relatively rapid equilibration of groundwater levels. Negligible additional mounding, other than might be expected from seasonal fluctuation, is expected to occur during project operation.

During the operational phase, the acceptable minimal impact considerations of the NSW AIP (DPI 2012) are met with respect to groundwater level.

Impacts on GDEs

Based on the relatively small groundwater level increases and the localised areas of mounding, changes to groundwater level or flow are not anticipated to materially affect GDEs, including high priority GDEs.

Impacts on groundwater users

Changes to groundwater levels and flows from operation of the project would be negligible and localised. Potential changes are not anticipated to materially affect existing groundwater users.

Water take

There would be no direct or passive water take from any groundwater sources during operation. As described in **Chapter 11** (surface water and groundwater quality), no long term lowering of the water table is anticipated as a result of operation of the project. Once temporary dewatering activities are finished, recovery of the water table at individual dewatering locations is expected to occur within the same time frame for which dewatering was carried out (typically two to 10 days).

10.6.3 Flooding

The 20%, 10%, 5%, 2% and 1% AEP and PMF flood events were assessed in TUFLOW with flooding impact maps presented in the Hydrology and Flooding Working Paper (**Appendix J**). Potential impacts may result from permanent works obstructing flood flows, change in drainage capacity for local catchments and loss of flood storage. The modelled impacts during project operation are discussed below.

As discussed in **Section 10.2.4**, flood modelling has assumed the removal of all ancillary facilities and any associated elevated hardstand areas. The main influence on flooding impacts are the retention of raised maintenance access roads around the viaduct which obstruct floodplain flows and cause increases in flood levels upstream of the roads (as discussed in **Section 10.2.4**). These in turn result in increased flows into Hexham Swamp particularly in the 10% AEP event and larger. Further information is provided below.

Flood immunity of project infrastructure

The project would meet the 1% AEP local flood immunity criterion between Black Hill and Tomago, and most of Tomago to Raymond Terrace, with the exception of:

- A 46 metre section of the Pacific Highway at the Tomago Road intersection
- A 300 metre section of the main alignment halfway between Tomago Road and Old Punt Road in Tomago
- A 120 metre section of the main alignment south of the HRBG access road in Heatherbrae
- A 450 metre section of the main alignment to the east of Masonite Road at Heatherbrae.

The main alignment has been designed to achieve a minimum 5% AEP Hunter River flood immunity.

Impacts on flooding behaviour

Flood levels

Impacts to flood levels during the operational phase, including both increases and decreases, would generally be less than during construction for the 20% to 5% AEP events. The afflux resulting from the project extends to the upstream boundary of the flood model, with afflux at the upstream boundary below the criteria of 0.05 metres (refer to **Section 10.2.3**) The potential changes in flood levels during the different flood events modelled are:

- 20% AEP flood event (**Figure 10-29**):
  - Increase by up to 0.02 metres on the western bank of the Hunter River around Tarro and in Windeyers Creek in Raymond Terrace
  - Increase by about 0.05 metres on rural land on the eastern bank of the river between the viaduct crossing and Raymond Terrace
  - Decrease by over 0.4 metres at local catchments on the eastern (upstream) side of the project and between the viaduct and Heatherbrae as a result of increased cross drainage capacity
  - Reductions in flood levels in localised areas around Masonite Road.
- 10% and 5% AEP flood events (**Figure 10-30**):
  - Increase by up to 0.02 metres upstream of the project on both sides of the Hunter River, up to Raymond Terrace, including Windeyers Creek and Millers Forest
  - Increase of 0.03 metres on the western bank of the river, around Purgatory Creek
  - Increase of 0.02 to 0.03 metres in the northern part of Hexham Swamp, and 0.03 to 0.04 metres in the southern part of Hexham Swamp in the 5% AEP flood event
  - Increase of 0.05 metres affecting rural residential properties in Tarro, close to the western viaduct approach embankment
  - Minor decreases in flood levels in the 5% AEP flood event downstream of the project
  - Decrease by up to 0.8 metres in local catchments on the eastern side of the project and between the viaduct and Heatherbrae as a result of increased cross drainage capacity
  - Localised increases in flood levels at the Tarro interchange exceeding 0.4 metres and a localised increase in a wetland area near the Williams River of 0.16 metres.

- 2% and 1% AEP flood events (**Figure 10-31**):
  - Increase by up to 0.02 metres upstream of the project on both sides of the Hunter River, extending up the Williams and Hunter Rivers past Raymond Terrace, and also including Windeyers Creek and wetland areas around Masonite Road
  - Increase of 0.03 metres on the western bank of the river, around Purgatory Creek
  - Localised increases of 0.07 metres at the Tarro interchange
  - Change by up to +/- 0.1 metres in local catchments on the eastern side of the project and between the viaduct and Heatherbrae as a result of changed cross drainage capacity
  - Minor decreases of over 0.01 metres in the 1% AEP flood event in Hexham Swamp
  - Increase in the 2% and 1% AEP flood levels of about 0.04 metres in rural residential properties in Tarro, close to the western viaduct approach embankment.
- PMF (**Figure 10-32**):
  - Extensive flood level increases upstream of the project crossing of the Hunter River of 0.05 to 0.08 metres, which would extend up the Hunter River and Williams River upstream of the limit of mapping
  - Increases exceeding 0.1 metres around the viaduct
  - Decreases in flood levels downstream of the project crossing of the Hunter River and in Hexham Swamp of 0.01 to 0.03 metres.

The afflux resulting from the project extends to the upstream boundary of the flood model, with afflux at the upstream boundary below the acceptable threshold of 0.05 metres. From this it can be inferred that the afflux beyond the model boundary would also be acceptable since the afflux reduces with distance upstream as the floodplain elevations increase up the valley.

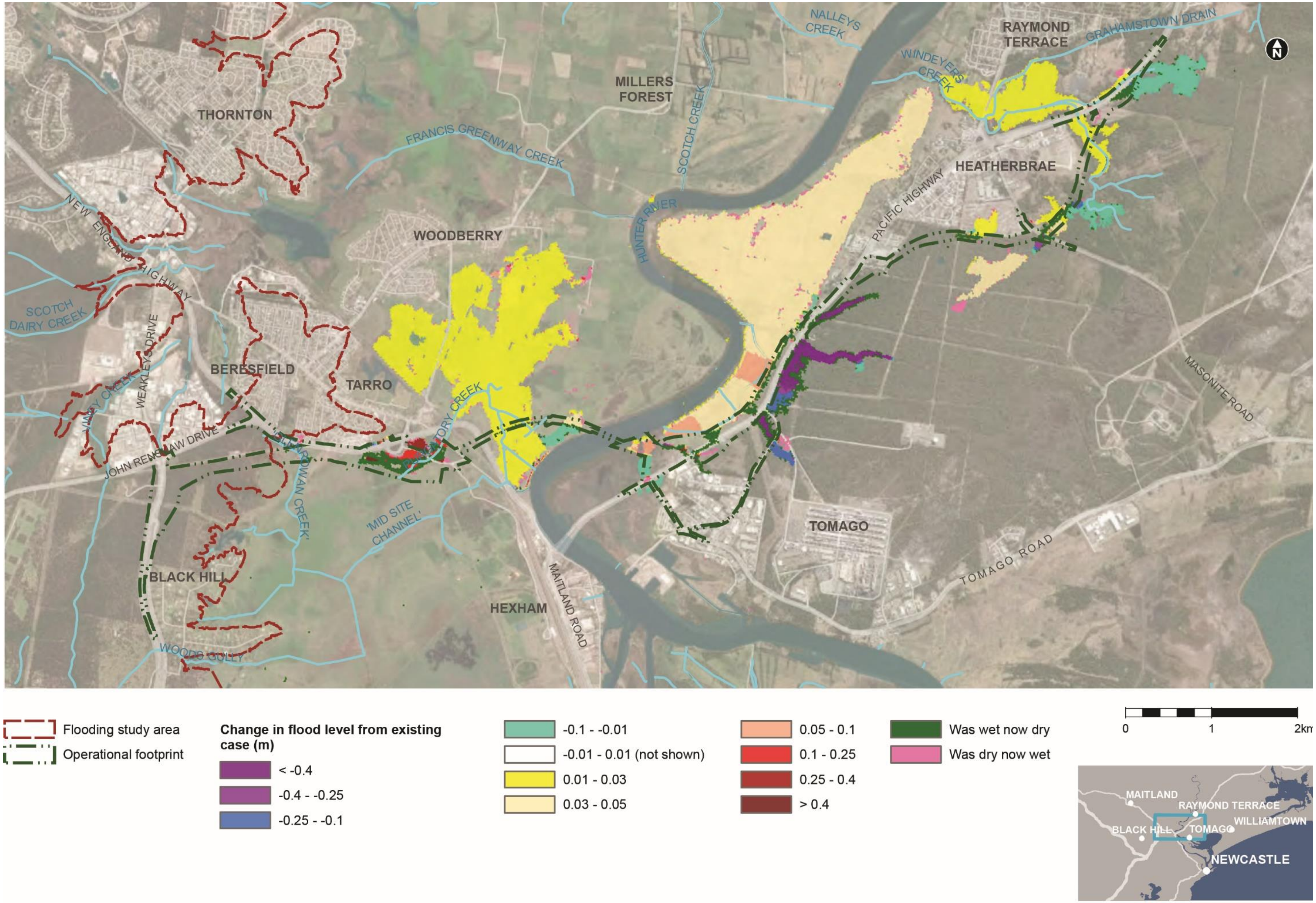


Figure 10-29 Change in flood level during operation (20% AEP)

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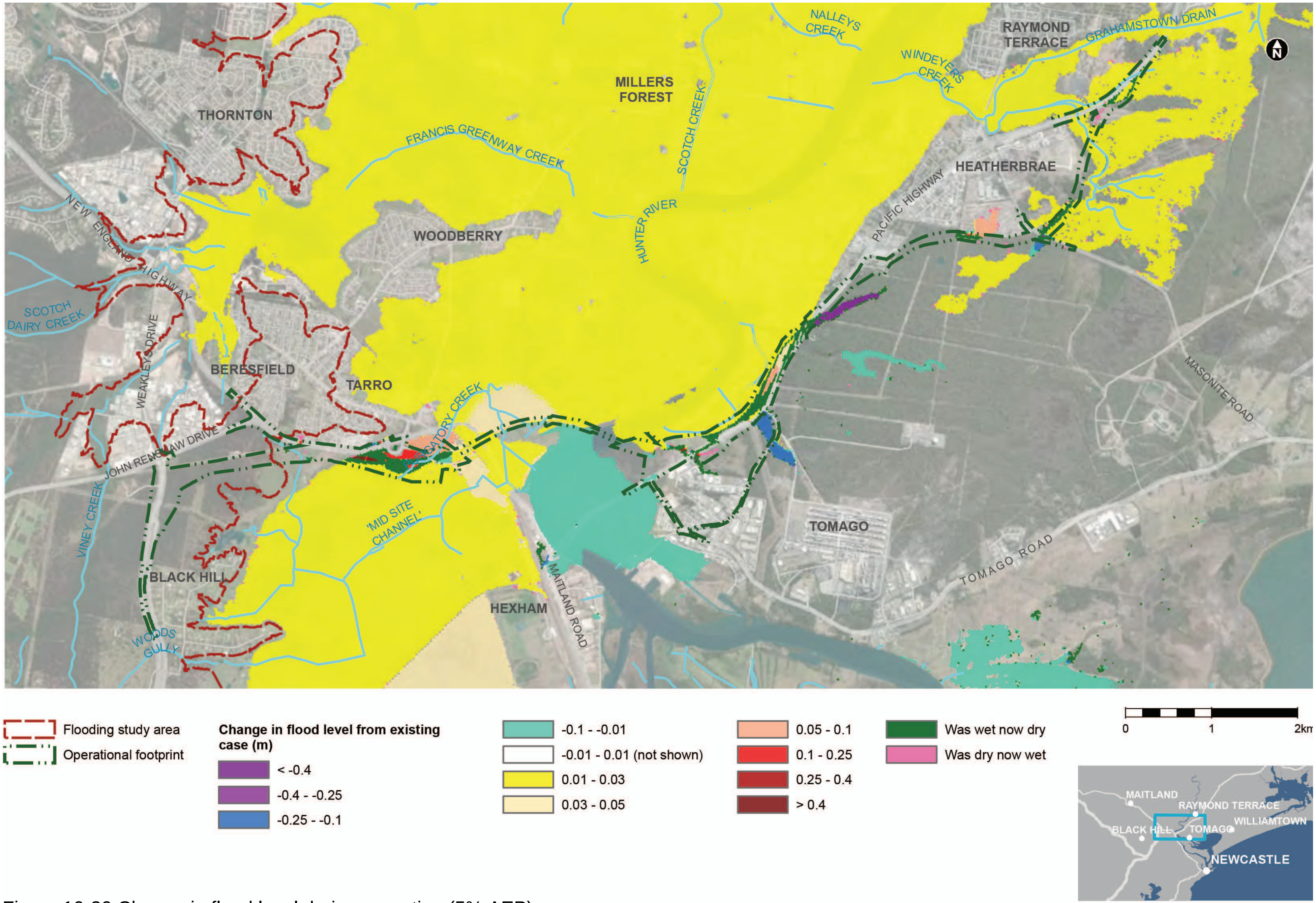

Figure 10-30 Change in flood level during operation (5% AEP)

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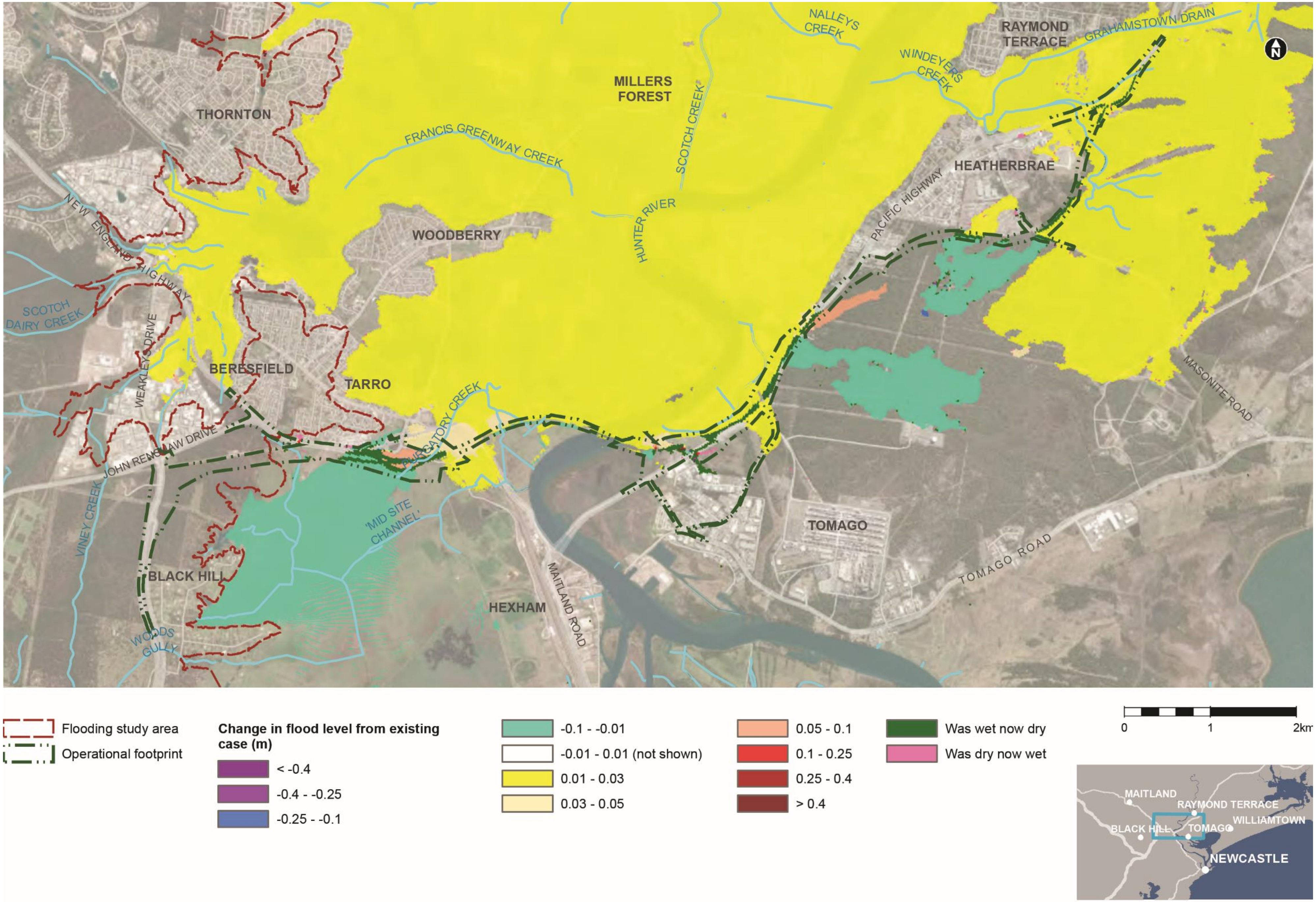

Figure 10-31 Change in flood level during operation (1% AEP)

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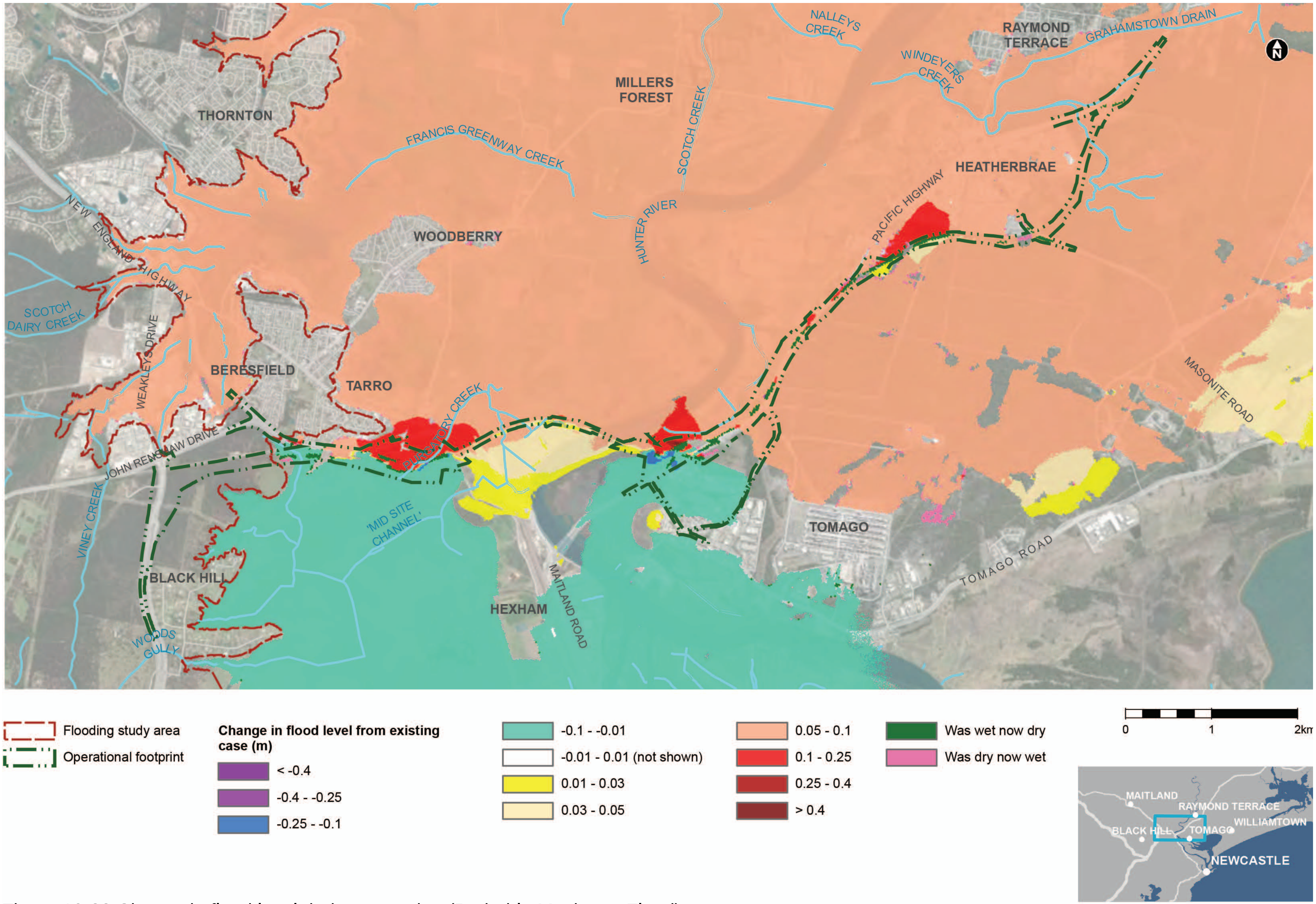
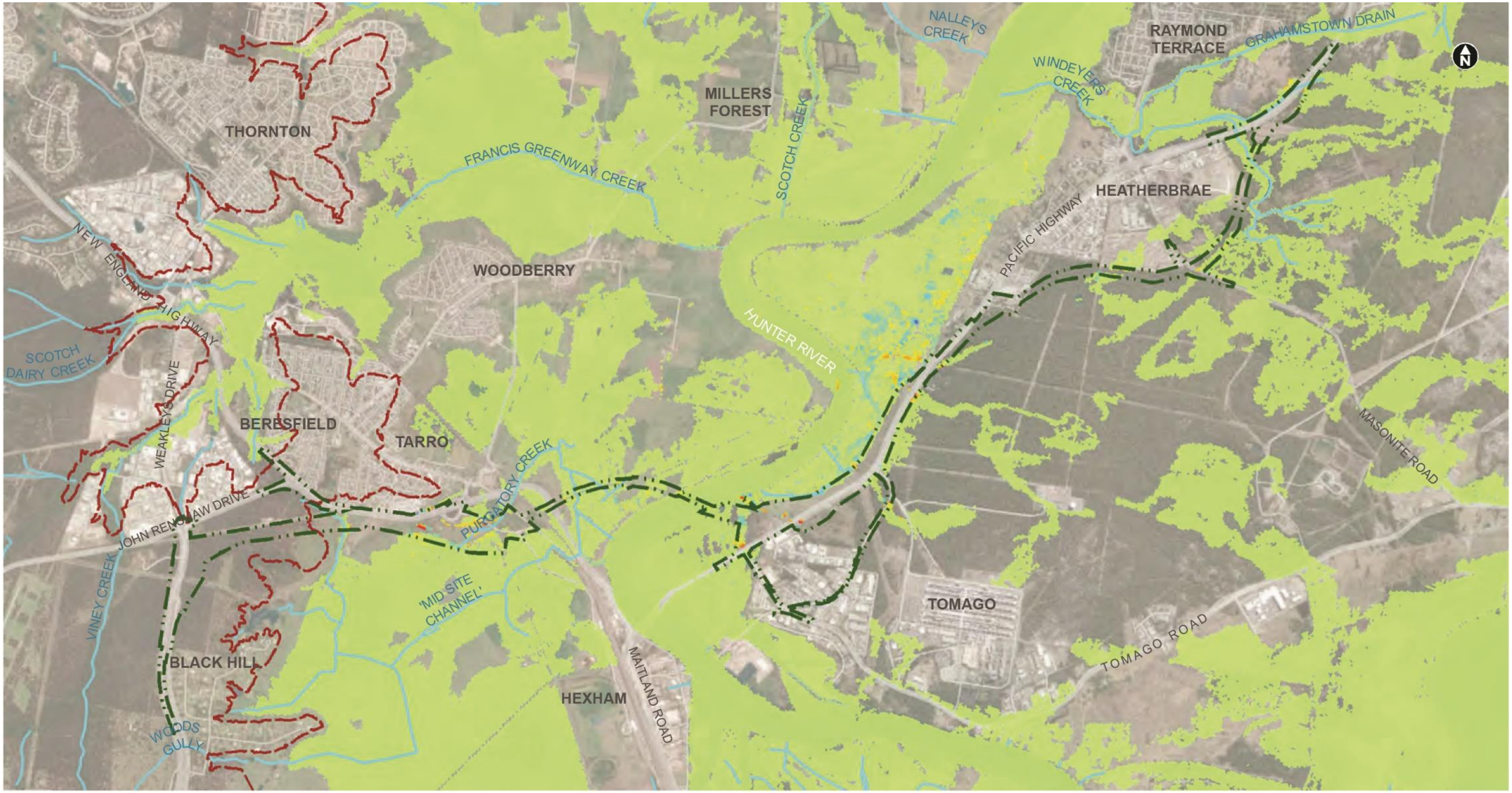


Figure 10-32 Change in flood level during operation (Probable Maximum Flood)

Flood velocities

There would be no large areas with significant changes in velocities across the floodplain, with the majority of changes localised around the operational footprint. The potential changes in flood velocities during operation for each flood event are:

- 20% AEP flood event (**Figure 10-33**):
  - Changes in velocities would be generally localised to areas around cross drainage and downstream drainage channels, and where filled formations associated with the project, including permanent access roads, may partially impede existing flow patterns
  - Changes would be expected, mainly upstream of the operational footprint, with both increases and decreases of up to 0.3 metres per second being typical, and with isolated increases of 0.5 to 1.0 metre per second
  - Increases in velocity of up to two metres per second within the operational footprint around the Tarro interchange and Tomago Road interchange.
- 10% and 5% AEP flood events (**Figure 10-34**):
  - Changes show similar trends to the 20% AEP flood event, with changes around the viaduct particularly on the western side of the river
  - Increases in velocity of up to 0.4 metres per second and decreases of up to 0.2 metres per second occur around the western side of the viaduct, due to the permanent access roads, and around the Tarro interchange.
- 2% and 1% AEP flood events (**Figure 10-35**):
  - Impacts similar to the 10% and 5% AEP flood events, there would be areas of increased velocity of 0.1 to 0.2 metres per second and decreased velocity of 0.1 metres per second in the far northern part of Hexham Swamp
  - Decreases of 0.2 metres per second around the New England Highway and Main North Rail Line near Purgatory Creek, in addition to decreases of 0.1 metres per second in local catchment waterways between Tomago and Heatherbrae
  - Both localised increases and decreases of typically up to 0.3 metres per second around the Pacific Highway interchange at Raymond Terrace, with isolated increases and decreases of 0.6 metres per second.
- In the PMF (**Figure 10-36**):
  - Numerous locations where flow velocities both increase and decrease, typically by up to 0.2 metres per second
  - Most prominent changes would be located around the Tarro interchange, downstream of the western and eastern sides of the Hunter River and floodplain viaduct and around the Masonite Road interchange; localised increases and decreases of one metre per second occur in these locations
  - Increases and decreases in velocities of up to 0.2 metres per second occur at the northern end of Hexham Swamp as a result of changed patterns of overflow into the swamp area
  - Localised increases in velocities of over one metre per second within the operational footprint.



Flooding study area

Operational footprint

Change in velocity from existing case (m/s)

- < -1
- -1 - -0.5
- -0.5 - -0.3
- -0.3 - -0.1
- -0.1 - -0.05
- -0.05 - 0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- >1

0 1 2km

Figure 10-33 Change in flow velocity during operation (20% AEP)

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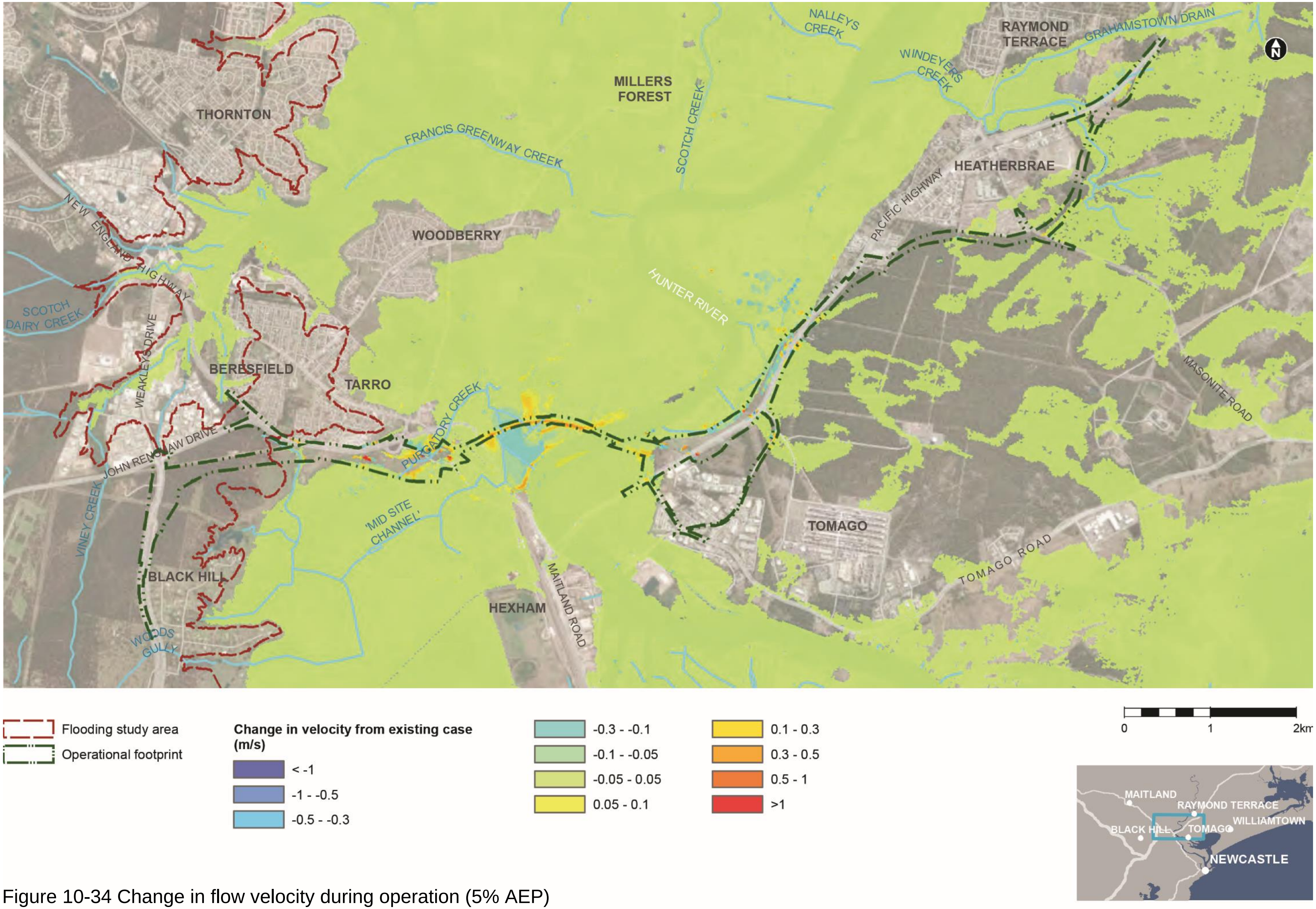

Figure 10-34 Change in flow velocity during operation (5% AEP)

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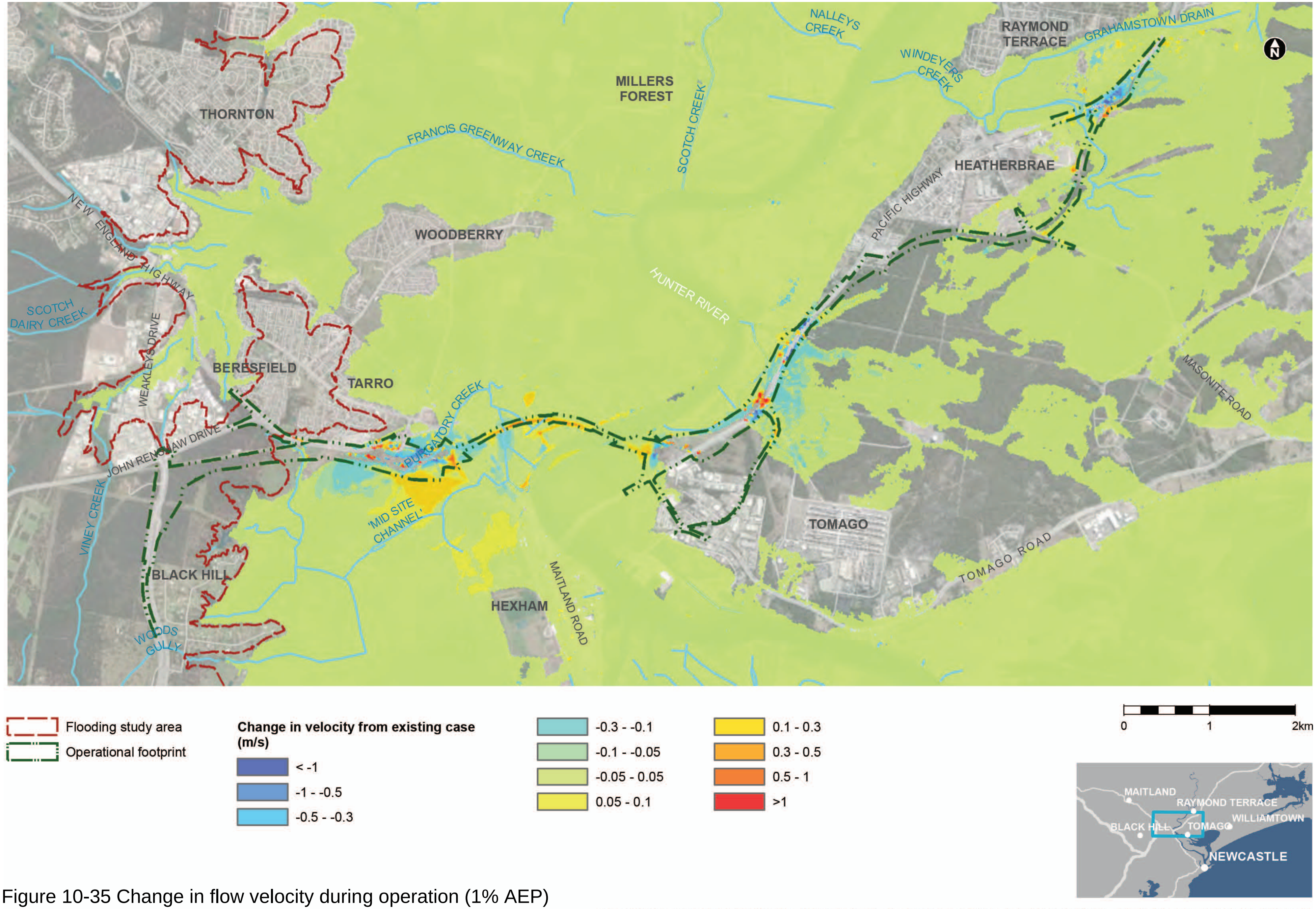

Figure 10-35 Change in flow velocity during operation (1% AEP)

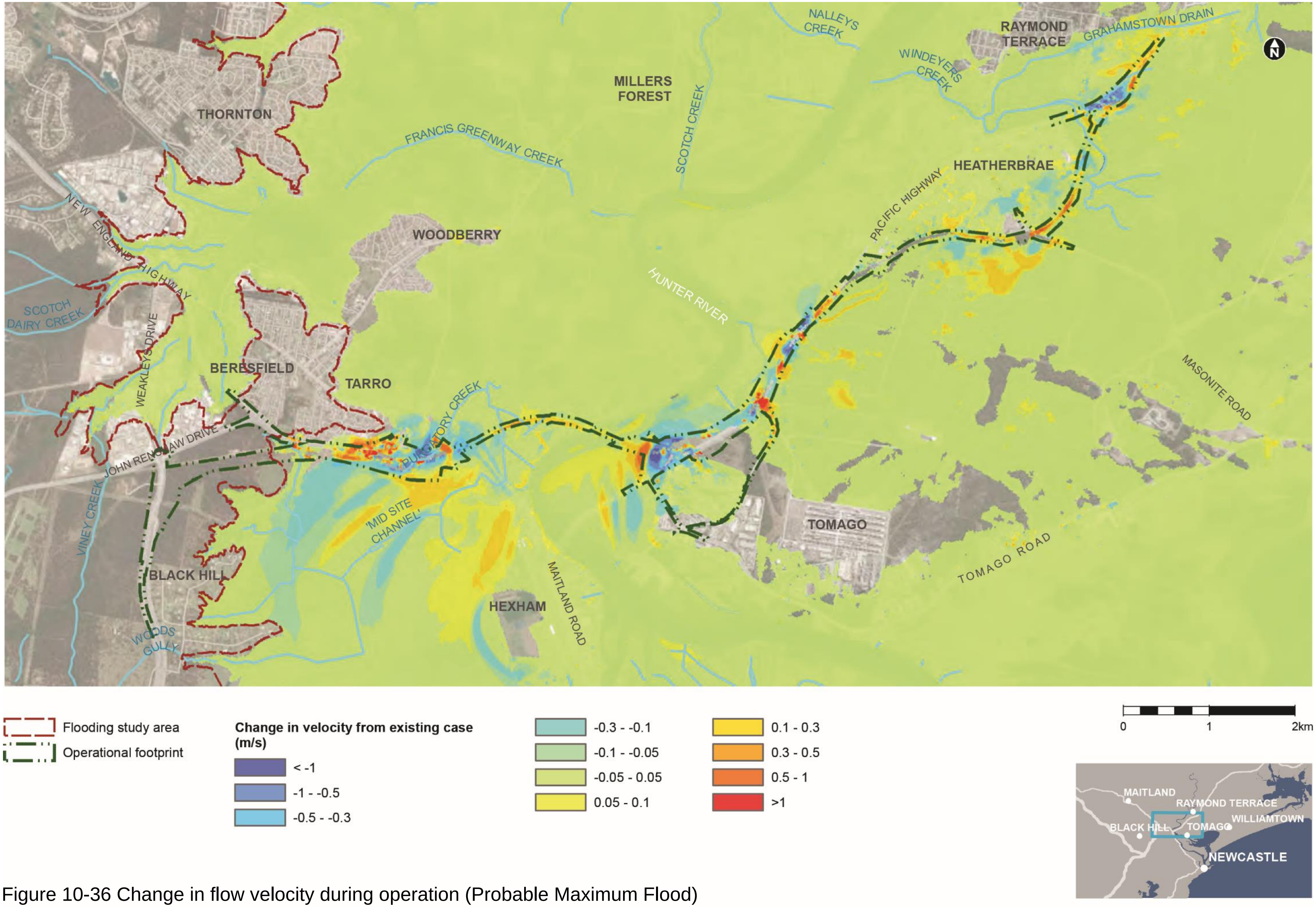

Figure 10-36 Change in flow velocity during operation (Probable Maximum Flood)

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Flood hazard

Changes to flood hazard would be generally minor and localised. Operation of the project would result in the following changes to flood hazards:

- Typically scattered increases in flood hazard due to minor increases in flood depths rather than increases in flow velocity
- In the 20% AEP flood event (refer to **Figure 10-37**): Increases on the floodplain on either side of the Hunter River upstream of the project crossing
- In the 10% and 5% AEP flood events (refer to **Figure 10-38**): Increases on the fringes of Hexham Swamp and on Tarro sports fields
- In up to the 1% AEP flood events (refer to **Figure 10-39**):
  - Increases in flood hazard in vegetated areas east of Heatherbrae and Raymond Terrace
  - Increases around the fringes of the flood extent, outside of developed areas, in Thornton, Tarro, Woodberry, Heatherbrae and Raymond Terrace
  - Reductions in flood hazard in local catchment areas between Tomago and Heatherbrae.
- In the probable maximum flood (refer to **Figure 10-40**): Localised increases in developed areas of Thornton, Beresfield, Tarro, Woodberry, Heatherbrae and Raymond Terrace in addition to vegetated areas to the east of Raymond Terrace
- No large increases in extent of the high hazard areas, which would indicate a new floodway or flow path being formed as a result of the operational phase.

Overall, the change in flood hazard during project operation is localised and as such does not have adverse impacts on flood conveyance, floodways, flow direction and flood storage.

In addition, project compatibility with the flood hazard of the land and the hydraulic functions of flow conveyance, floodways and flood storage has been considered throughout the design process to minimise flood impacts.

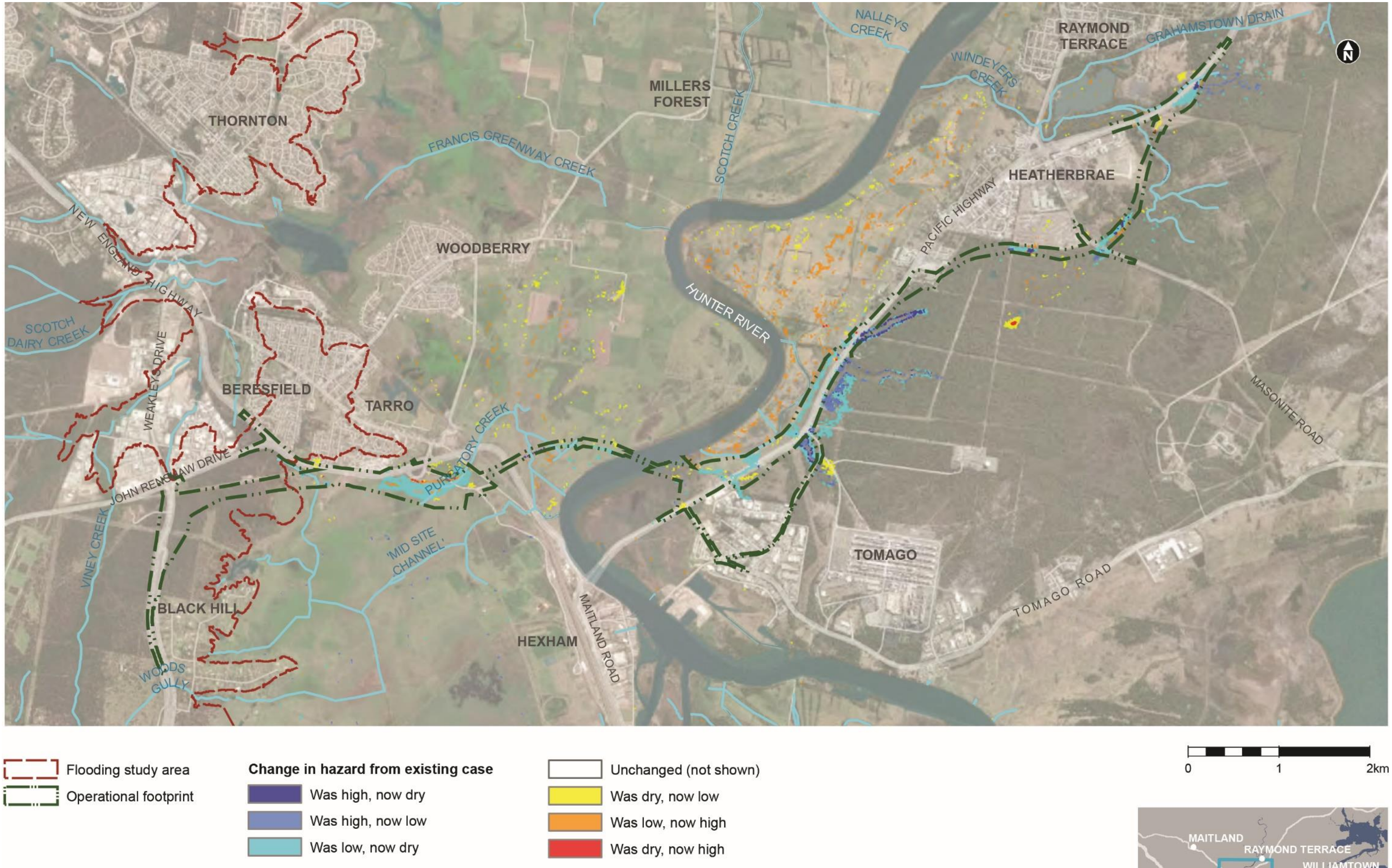

Figure 10-37 Change in flood hazard during operation (20% AEP)

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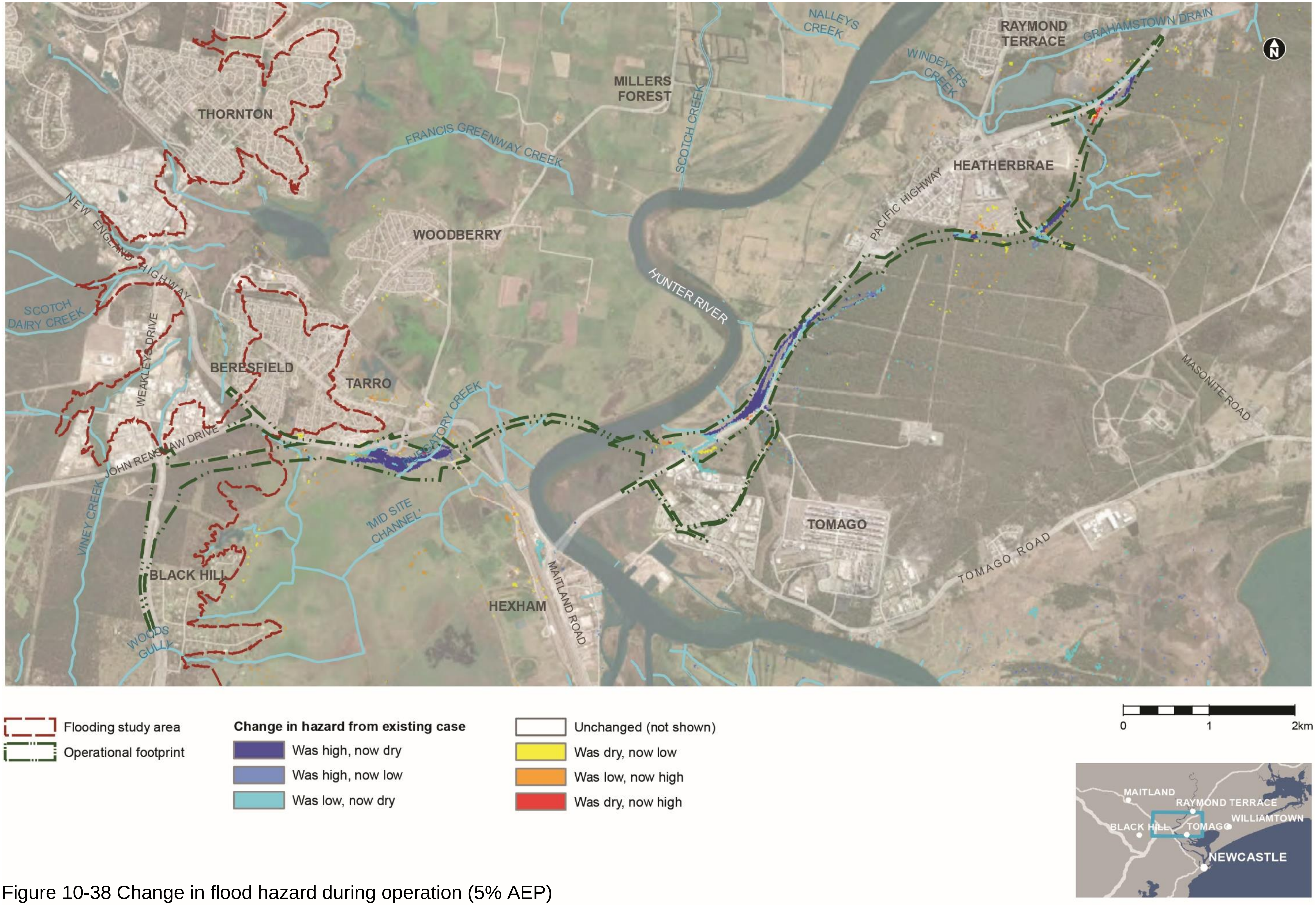

Figure 10-38 Change in flood hazard during operation (5% AEP)

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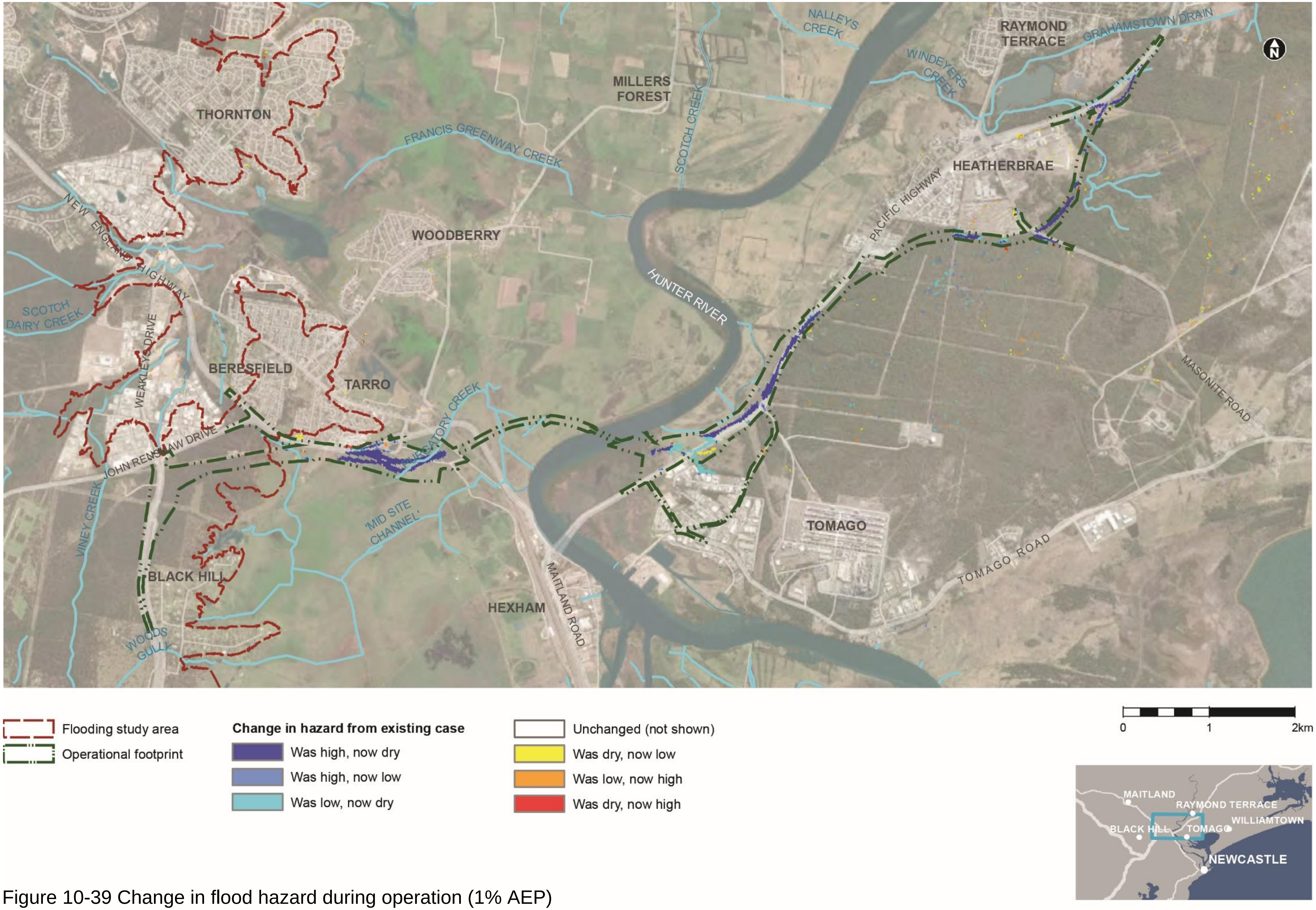

Figure 10-39 Change in flood hazard during operation (1% AEP)

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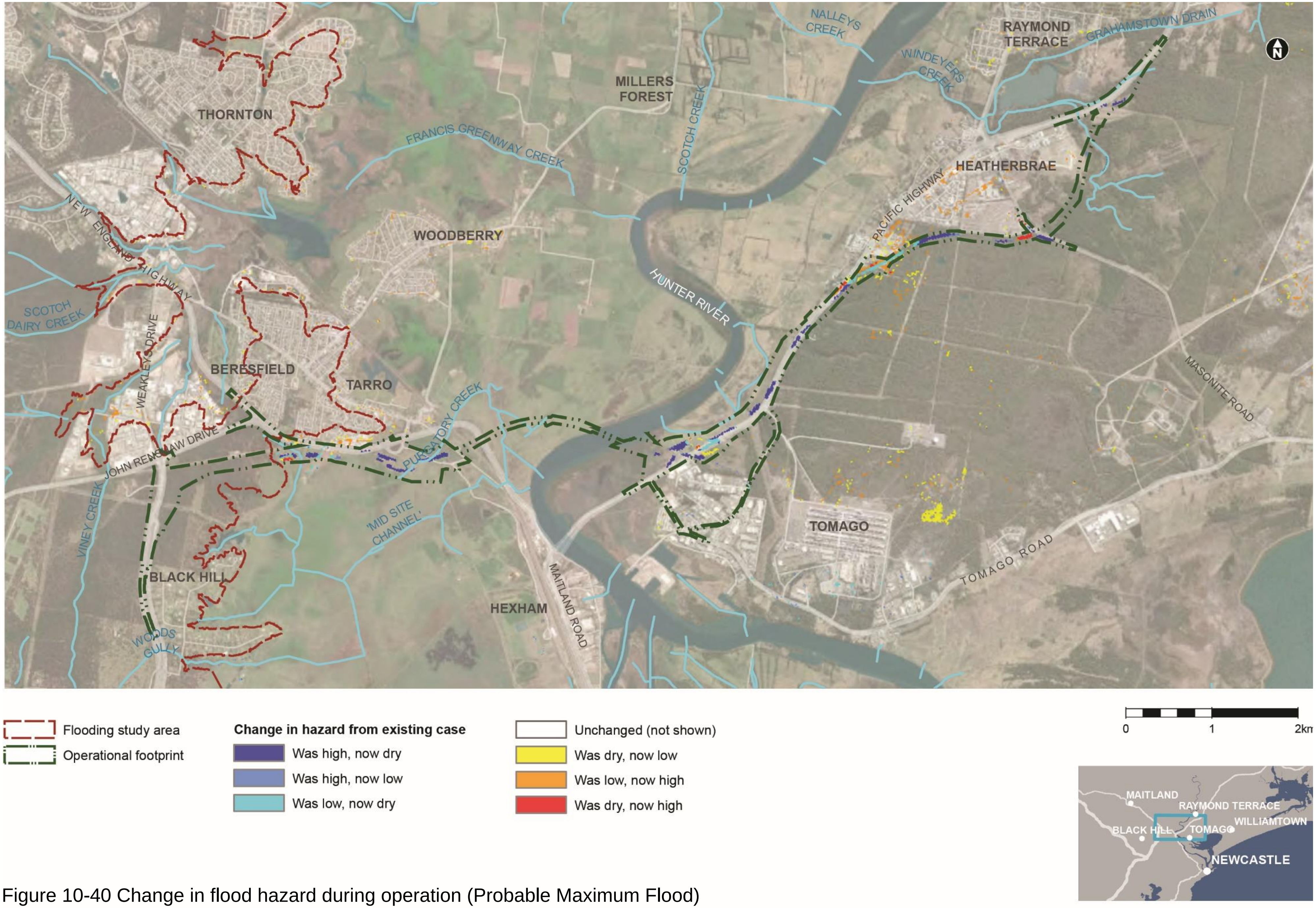


Flooding study area
Operational footprint

Change in hazard from existing case

- Was high, now dry
- Was high, now low
- Was low, now dry
- Unchanged (not shown)
- Was dry, now low
- Was low, now high
- Was dry, now high

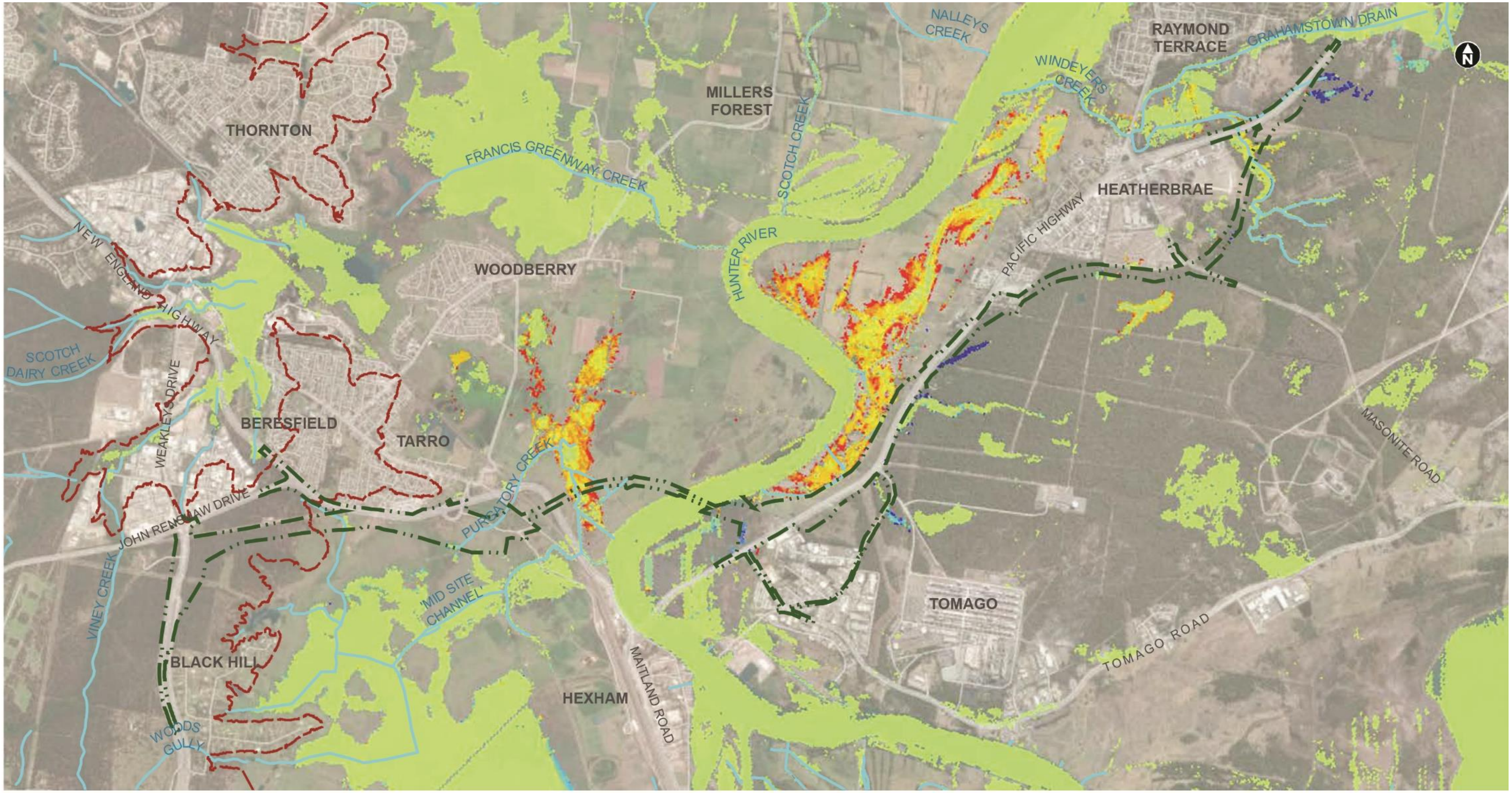
Figure 10-40 Change in flood hazard during operation (Probable Maximum Flood)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_054_E18_ChangeFloodHazard_ProbMax_Operational_JAC_A4L_175000_V02.mxd

Flood duration

Changes in duration of inundation as a result of project operation would be minor. The operation of the project would result in the following changes to flood duration:

- 20% AEP flood event (refer to **Figure 10-41**): Changes similar to those during construction, where the change in duration of inundation is typically within +/- five per cent from the existing case (up to 0.5 hour increase) in locations including in the Hunter River and Hexham Swamp, with the exception of the following increases:
  - Increases in the duration of inundation on the western bank of the Hunter River (in Purgatory Creek) and the eastern bank of the Hunter River upstream of the viaduct crossing of typically 10 to 20 per cent, with increases over 100 per cent on the fringes of the flooding extents (up to 10 hour increase)
  - On the eastern bank of the Hunter River the increase in duration of inundation is attributed to the increase in flood levels of 0.05 metres over relatively shallow flood depths of 0.5 metres, due to increased cross drainage capacity, discharging greater flow volumes into these areas (up to eight hour increase)
  - In Purgatory Creek the increase in duration of inundation is attributed to interaction of flooding with proposed access roads and reduced drainage capacity posed by proposed culverts under the access roads, and potential reduction in floodplain storage.
- 10% and 5% AEP flood events (refer to **Figure 10-42**): Change in duration of inundation is relatively uniform in distribution and typically within +/- five per cent of existing conditions (up to one hour increase), with the exception of the following increases:
  - Localised increases in durations of 10 to 20 per cent (six to 15 hour increase) along the fringes of the flooding extent and along embankment areas, generally upstream of the new viaduct crossing and in Hexham Swamp where increases in flood levels would be expected. Downstream of the viaduct crossing there would be localised decreases in durations of 10 to 20 per cent (up to 0.5 hour decrease) where reductions in flood levels would be expected
  - Reductions in duration of up to 50 per cent in the local catchment waterways between Tomago and Heatherbrae. There would also be areas of reductions in Windeyers Creek upstream of the project.
- 2% and 1% AEP flood events (refer to **Figure 10-43**):
  - Changes in duration of inundation would be similar to the 10% AEP and 5% AEP flood events, with prominent differences in the local catchment waterways between Tomago and Heatherbrae, where both increases and decreases in flood duration of +/- 20 per cent occur. Typical increases in duration are up to one hour. There are localised areas occupying less than one per cent of the floodplain where increases in duration exceed one hour, with maximum increases up to 12 hours.
- PMF (refer to **Figure 10-44**):
  - Change in duration of inundation is again typically within +/- five per cent from the existing case across the majority of the floodplain, with increases over 40 per cent around the fringes of the floodplain, most notably around Raymond Terrace, Heatherbrae and Tomago. Typical increases in duration are up to 0.5 hours. There are localised areas occupying less than one per cent of the floodplain where increases in duration exceed one hour, with maximum increases up to eight hours.



Flooding study area

Operational footprint

Change in duration of inundation from existing case (per cent)

< -50	-20 - -10
-50 - -30	-10 - -5
-30 - -20	-5 - 5
	5 - 10
	10 - 20
	20 - 30
	30 - 50
	> 50

0 1 2km

Figure 10-41 Change in duration of inundation during operation (20% AEP)

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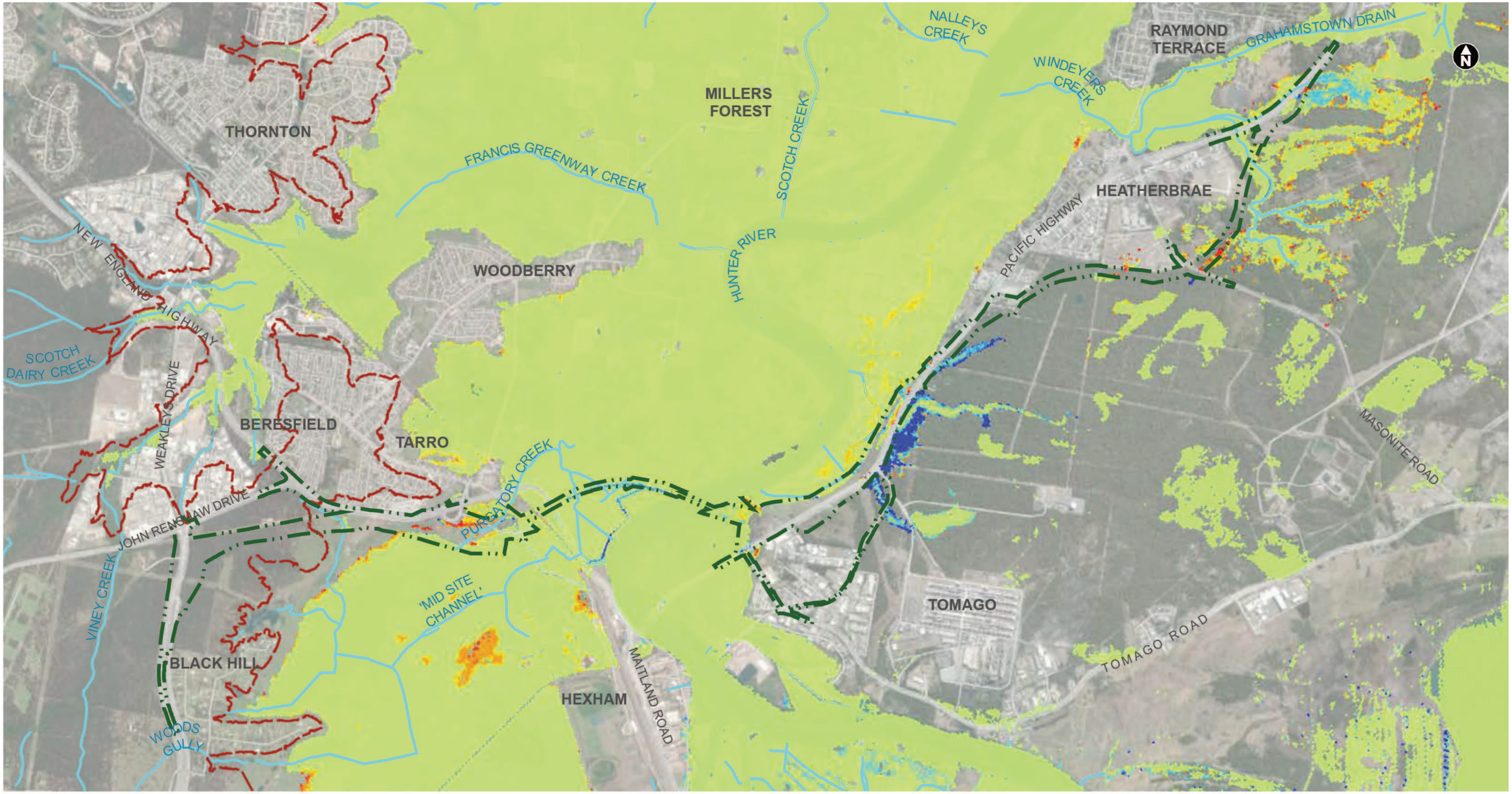

Flooding study area

Operational footprint

Change in duration of inundation from existing case (per cent)

- < -50
- -50 - -30
- -30 - -20
- -20 - -10
- -10 - -5
- -5 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- > 50

0 1 2km

Figure 10-42 Change in duration of inundation during operation (5% AEP)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_057_E21_ChangeDurationInundation5Operational_JAC_A4L_175000_V02.mxd

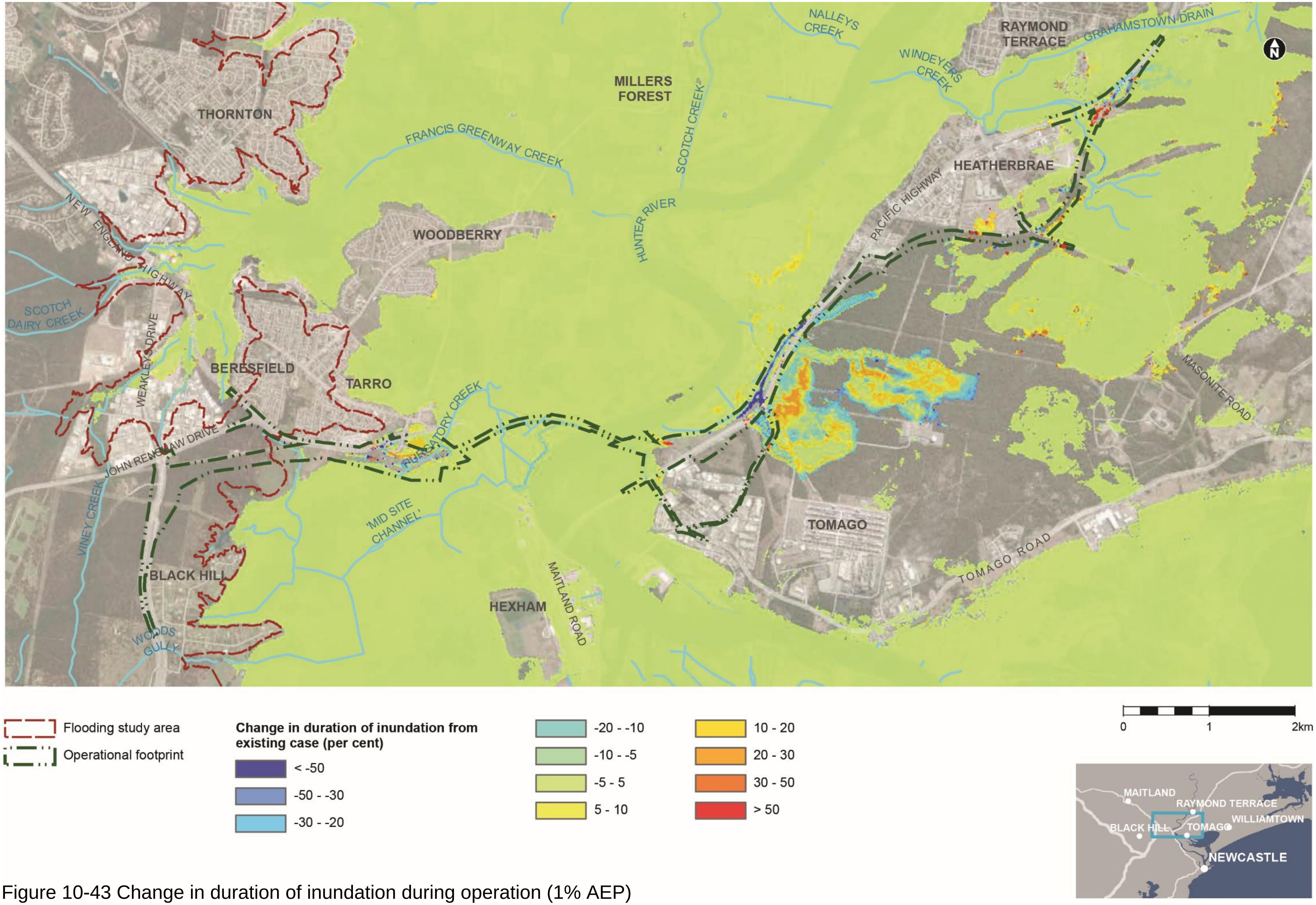

Figure 10-43 Change in duration of inundation during operation (1% AEP)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_059_E23_ChangeDurationInundation1Operational_JAC_A4L_175000_V02.mxd

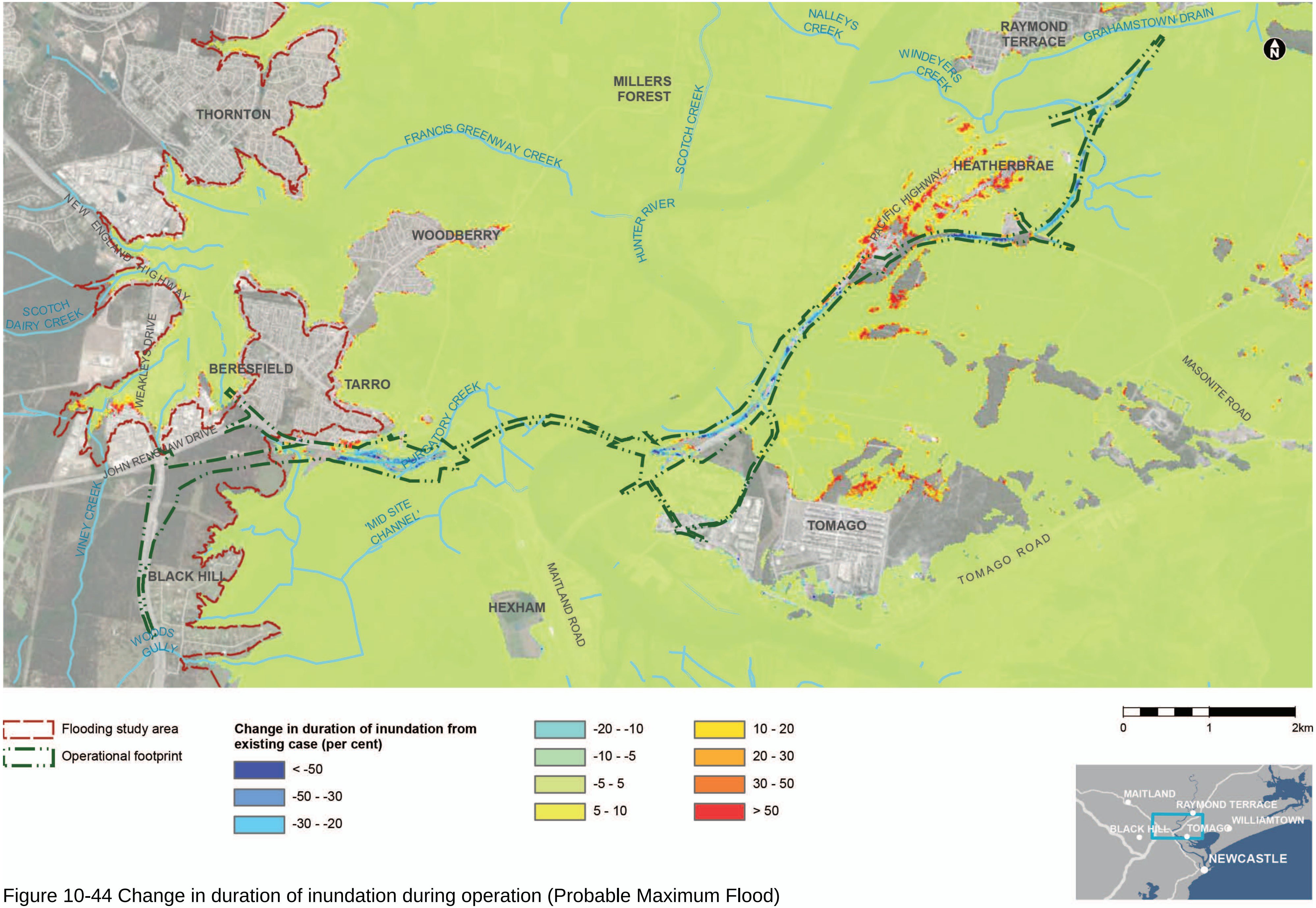

Figure 10-44 Change in duration of inundation during operation (Probable Maximum Flood)

Impacts on infrastructure

Road

Highways, major roads and other named roads were assessed for the total length of road affected by H2 flood hazard and higher during operation. There would be no change in total length of road impacted for the majority of named roads within the study area. Where there would be a change in total length impacted compared to the existing case (refer to **Table 10-6**), this is presented in **Table 10-12**. The results in the tables reflect the change in trafficability of the roads from the existing case (**Table 10-6**). H2 flood hazard and above indicates that the road is not trafficable due to flooding conditions.

Table 10-12 Change in length of highways and major roads subject to H2 flood hazard, comparison of operational phase to existing case

Road	20% AEP (length change)	10% AEP (length change)	5% AEP (length change)	2% AEP (length change)	1% AEP (length change)	PMF (length change)
Maitland Road	0%	4% (0.01km)	-6% (-0.03km)	0%	0%	0%
New England Highway	0%	8% (0.04km)	3% (0.02km)	0%	-19% (-0.34km)	1% (0.04km)
Pacific Highway	91%* (0.05km)	-3% (-0.03km)	-17% (-0.32km)	-27% (-1.20km)	-19% (-1.11km)	-2% (-0.26km)
Raymond Terrace Road	2% (0.02km)	2% (0.09km)	0%	0%	0%	0%
Sandgate Road	0%	0%	0%	0%	-1% (-0.01km)	0%
Tomago Road	-4 (-0.03km)	0%	0%	0%	0%	0%

* An increase of 91 per cent from existing inundated length is experienced on the Pacific Highway in the 20% AEP event, where the total length affected increases from 51 metres to 97 metres.

Similar to the construction phase, there would be no major increases in the total length of road affected by H2 flood level hazard or higher for highways and major roads. The 91 per cent increase in length of the Pacific Highway affected in the 20% AEP event translates to an increase of 46 metres, which is considered to be a minor increase. Some roads would experience a decrease in the total length of road affected by H2 flood hazard in comparison to existing conditions. Any increases in inundated length would occur at locations which are already subject to inundation. Overall, there is a negligible to minor impact from project operation to flooding of major roads.

Emergency management, evacuation and access

Flooding would have a negligible impact on emergency access and evacuation routes in all flooding events up to the PMF during project operation. This is due to the low or nil change in the length of roads affected by H2 flood hazard, combined with minor changes in duration of inundation.

The project would provide some improvements to the trafficability of the Pacific Highway and New England Highway during operation, particularly in the 10% AEP event and below. The project itself would provide a new access route between Black Hill and Raymond Terrace with flood immunity up to the 5% AEP Hunter River flood event.

Rail

Project operation would have a negligible impact on railways, with less than 0.1 per cent increase in affected length on the Main North Rail Line.

The Aurizon access road would be affected by less than a 0.01 metre change in flood level in the 20% and 10% AEP flood events (refer to **Figure 10-29**), up to a 0.03 metre increase in flood level in the 5% AEP flood event (refer to **Figure 10-30**) and a 0.02 metre increase in flood level in the 1% AEP flood event (refer to **Figure 10-31**). The whole road is overtopped in the existing case for both the 5% and 1% AEP events.

Impacts on land uses

The large majority of flood-affected residential, commercial and industrial properties in the existing case experience negligible change in flood depth (+/- 0.01 metres change), hazard and duration of inundation (+/- three hours) during operation of the project.

Properties and buildings

The project achieves the flood management objectives and criteria at properties and buildings. There would be increases in flood depths of over 0.01 metres during the 1% AEP (**Figure 10-31**) at some properties, including[3]:

- 2.4 per cent of all residential lots within the study area
- 5.5 per cent of all commercial lots within the study area
- 9 per cent of all industrial lots within the study area.

Increases in flood depths of over 0.05 metres in the 1% AEP would affect less than 0.5 per cent of all residential, commercial and industrial lots within the study area.

Flood hazard during the 1% AEP event would be increased at:

- Up to eight residential lots
- No commercial lots
- No industrial lots.

There would be 17 lots comprised of residential and industrial uses which would be newly flooded in the 1% AEP flood event, to depths of 0.05 metres and up to 0.3 metres. Ten lots would experience afflux exceeding the adopted criteria during the 20% AEP or higher, and one building would experience afflux exceeding the adopted criteria.

There is minimal change in the duration of inundation on the overall floodplain. Larger inundation time increases would occur mainly on the edges of the existing floodplain where shallow areas of flooding with short inundation time (depths of less than 0.5 metres and inundation times of up to one day) would be sensitive to increases in flood levels and durations of inundation. An increase in duration of inundation greater than three hours would affect up to five residential lots and no commercial and industrial lots during the 1% AEP event.

Other land uses

The flood hazard on the main rural land uses including grazing, forestry and wetlands/national park areas does not change from existing for the large majority of these land use areas.

Agricultural and grazing activities, including movement and evacuation of stock during flood events, would be expected to experience minor impacts in the 20%, 10%, 5%, 2% and 1% AEP flood events due to increases in flood depths of up to 0.02 to 0.04 metres during project operation. These activities may also be impacted by the die-off of pastures due to increased inundation durations.

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[3] Compared to 15,841 residential lots, 1,533 commercial lots and 1,315 industrial lots in the flooding study area.

The negligible change in duration of inundation for flood depths over 0.5 metres (typically less than one hour increase) means that the duration of isolation of stock flood refuges would not be substantially impacted. It is expected that the time to drain the floodplains for water depths under 0.5 metres would be similar to existing (maximum five per cent increase in duration).

On grazing land, the increase in flood hazard occurs on less than 0.5 per cent of land. For all other main rural land uses, for all flood events assessed, there would be an increase in flood hazard of up to two per cent of the land and a decrease in flood hazard on up to one per cent of the land.

Future development potential of affected land

The majority of the future residential growth areas around the project lie outside of the PMF. Growth areas which are within the 1% AEP flood event extent (refer to **Figure 10-31**) include:

- Wallsend: Future residential growth area includes the Maryland Creek floodplain. Not affected by increases in flood level as a result of the project in up to the 1% AEP flood event. Minor reduction in probable maximum flood level of 0.03 metres at this location
- North-west of Raymond Terrace adjacent to Newline Road: A small portion of the growth area would be affected by 0.02 metre increase in 1% AEP flood level and 0.07 metre increase in PMF level.

It is considered that there would be negligible impact on the development potential of the future residential growth areas.

It is also expected there would be negligible impact on the development potential for the large majority of other areas on the floodplain, given minor (typically 0.02 to 0.03 metre) increases in 1% AEP flood level and a negligible increase in duration of inundation. Further, access to these areas would not be affected given negligible flooding impacts to roads and rail infrastructure.

Impacts associated with the Hunter Valley Flood Mitigation Scheme

Impacts on the Hunter Valley Flood Mitigation Scheme during operation would be similar to those identified during construction of the project.

The structure and maintenance of the scheme may be affected by project features such as permanent embankments and/or access roads immediately next to or on levees, channels and drainage infrastructure related to the scheme. The project design would, however, ensure the existing scheme culverts and floodgates located in the flood levees would not be impeded by the project and there would be no impacts to the scheme’s structural integrity, function or flow capacity from project operation.

The drainage channels which are a part of the scheme would also potentially be affected by increased storm flow rates discharged from the project. This is a result of some existing cross drainage being upsized for the project, which may affect the drainage ability of the channels. This potential impact is most likely during frequent storm and flood events, which indicates increased flood levels on the eastern floodplain of the Hunter River upstream of the project.

Transport would continue to consult with the operators during detailed design to minimise impacts on the scheme.

Assessment of blockage of hydraulic structures

The sensitivity of flooding to blockage of hydraulic structures related to the project was assessed for the 20%, 5% and 1% AEP events. Blockage conditions were represented on transverse drainage structures with the blockage factors selected based on the guidance in ARR 2019. Blockage factors of between 10 per cent and 100 per cent were applied in the sensitivity modelling depending on the culvert size. The effect of blockage conditions was then compared to the design flood modelling which incorporated zero blockage.

Changes in flood behaviour due to blockage of hydraulic structures would be most prominent in the northern section of the project between Tomago and Raymond Terrace. Culvert blockage would not result in overtopping of the main alignment of the project but overtopping of the HRBG access road underpass and minor carriageways at Tomago interchange would occur. The following changes in flood levels would result due to blockage of hydraulic structures:

- Increases in flood levels in the 20% AEP flood event would be 0.7 to two metres, 0.4 to two metres in the 5% AEP flood event and up to 0.4 metres in the 1% AEP flood event due to full blockage conditions of cross drainage culverts near Old Punt Road and the HRBG and partial blockage at other culverts
- Increases in flood levels of up to 0.4 metres also occur upstream of culverts at Old Punt Road and Masonite Road, and up to 0.05 metres at Raymond Terrace interchange, in the 20% and 5% AEP flood events
- At Tarro, there would be increases in flood levels of 0.01 to 0.03 metres as a result of culvert blockage in the 5% and 1% AEP flood events, which affect adjacent residential properties
- Reductions in flood levels on the eastern Hunter River floodplain upstream of the project in the 20% AEP flood event as a result of reduced flows being discharged to the floodplain area. The partial blockage of culverts reduces the backflow of Hunter River flooding to the areas upstream of the culverts
- Reductions in flood levels occur in the 1% AEP flood event as a result of partial blockage of culverts in a number of locations in Tomago and Heatherbrae.

Black Hill is located on higher ground above the Hunter River floodplain and blockage of culverts was not analysed in the flood model for this area. The areas upstream of the proposed culverts in Black Hill are forested or rural, and any flood level increases due to culvert blockage would be expected to have negligible impact.

Climate change assessment

The impact of climate change on flooding at the project was assessed to determine the changes to flooding behaviour affecting the project. A number of combinations of increased catchment flooding (resulting from increased rainfall intensity due to climate change) and sea level rise were assessed. The 0.5% AEP (200 year ARI) and 0.2% AEP (500 year ARI) flood events were adopted as a proxy for increased rainfall intensity and river flood flows due to climate change on the current day 1% AEP flood event. The 0.5% AEP represents a 17 per cent increase in the Hunter River peak flow from the current day 1% AEP flood event, and the 0.2% AEP represents a 45 per cent increase in the Hunter River peak flow from the current day 1% AEP flood event. The sea level rise scenarios assessed included a 0.4 metre rise in sea level from current levels for the year 2050, and 0.9 metre rise for the year 2100 in assessing the impact of climate change on flooding. These projections are based on research by the IPCC and were refined for the Australian region. The results of the assessment, including the predicted change in flood level at the project and areas where the project would be overtopped, are presented in **Table 10-13**.

Table 10-13 Climate change scenarios and change in flooding at the project

Scenario	Catchment flooding	Sea level rise	Change in flood level at the project due to climate change	Areas where project is overtopped
1	Current day 5% AEP	0.9m sea level rise (year 2100)	Compared to current day 5% AEP event • West of Main North Rail Line: increase of 0.6 to 0.7m. Hexham Swamp flooding influenced by sea level rise • East of Main North Rail Line to Heatherbrae: increase of 0.15 to 0.17m • Masonite Road to eastern end of project: increase of 0.12m.	Minor carriageway[1] only, Tomago interchange

Scenario	Catchment flooding	Sea level rise	Change in flood level at the project due to climate change	Areas where project is overtopped
2	Current day 1% AEP	0.4m sea level rise (year 2050)	Compared to current day 1% AEP event • West of Main North Rail Line: increase of 0.06m • East of Main North Rail Line to Heatherbrae: increase of 0.03 to 0.05m • Heatherbrae to eastern end of project: increase of 0.03 to 0.04m.	• New England Highway, Tarro interchange • Main alignment and minor carriageways, Tomago interchange • Masonite Road • Main alignment, Raymond Terrace interchange.
3	Current day 1% AEP	0.9m sea level rise (year 2100)	Compared to current day 1% AEP event • West of Main North Rail Line: increase of 0.17m • East of Main North Rail Line to Heatherbrae: increase of 0.1 to 0.13m • Heatherbrae to eastern end of project: increase of 0.09 to 0.13m.	• New England Highway and minor carriageways, Tarro interchange • Main alignment and minor carriageways, Tomago interchange • Main alignment and Masonite Road • Main alignment, Raymond Terrace interchange.
4	Current day 0.5% AEP	Nil sea level rise	Compared to current day 1% AEP event • West of Main North Rail Line: increase of 0.45m • East of Main North Rail Line to Heatherbrae: increase of 0.45m • Heatherbrae to eastern end of project: increase of 0.46 to 0.48m.	• New England Highway and minor carriageways, Tarro interchange • Main alignment and minor carriageways, Tomago interchange • Main alignment and Masonite Road • Main alignment, Raymond Terrace interchange.
5	Current day 0.5% AEP	0.4m sea level rise (year 2050)	Compared to current day 1% AEP event • West of Main North Rail Line: increase of 0.48m • East of Main North Rail Line to Heatherbrae: increase of 0.45 to 0.48m • Heatherbrae to eastern end of project: increase of 0.48 to 0.58m.	• Main alignment, New England Highway and minor carriageways, Tarro interchange • Main alignment and minor carriageways, Tomago interchange • Main alignment and Masonite Road • Main alignment, Raymond Terrace interchange.
6	Current day 0.5% AEP	0.9m sea level rise (year 2100)	Compared to current day 1% AEP event • West of Main North Rail Line: increase of 0.58m • East of Main North Rail Line to Heatherbrae: increase of 0.5 to 0.54m • Heatherbrae to eastern end of project: increase of 0.55 to 0.65m.	• New England Highway and minor carriageways, Tarro interchange • Main alignment and minor carriageways, Tomago interchange • Main alignment and Masonite Road • Main alignment, Raymond Terrace interchange.

Scenario	Catchment flooding	Sea level rise	Change in flood level at the project due to climate change	Areas where project is overtopped
7	Current day 0.2% AEP	Nil sea level rise	Compared to current day 1% AEP event • West of Main North Rail Line: increase of 1.04 to 1.09m • East of Main North Rail Line to Heatherbrae: increase of 0.97 to 1.05m • Heatherbrae to eastern end of project: increase of 1.08 to 1.2m.	• Main alignment, New England Highway and minor carriageways, Tarro interchange • Main alignment and minor carriageways, Tomago interchange • Main alignment and Masonite Road • Main alignment, Raymond Terrace interchange.
8	Current day 0.2% AEP	0.4m sea level rise (year 2050)	Compared to current day 1% AEP event • West of Main North Rail Line: increase of 1.07 to 1.1m • East of Main North Rail Line to Heatherbrae: increase of 1.02 to 1.07m • Heatherbrae to eastern end of project: increase of 1.09 to 1.22m.	• Main alignment, New England Highway and minor carriageways, Tarro interchange • Main alignment and minor carriageways, Tomago interchange • Main alignment and Masonite Road • Main alignment, Raymond Terrace interchange.
9	Current day 0.2% AEP	0.9m sea level rise (year 2100)	Compared to current day 1% AEP event • West of Main North Rail Line: increase 1.15m • East of Main North Rail Line to Heatherbrae: increase of 1.1 to 1.12m • Heatherbrae to eastern end of project: increase of 1.14 to 1.28m.	• Main alignment, New England Highway and minor carriageways, Tarro interchange • Main alignment and minor carriageways, Tomago interchange • Main alignment and Masonite Road • Main alignment, Raymond Terrace interchange.

[1]Minor carriageway refers to adjustments to existing roads and new ramps

Table 10-13 shows that the project would be overtopped in some modelled flood events. This indicates that the road flood immunity would be reduced as a result of climate change. Raising the proposed project road levels is not considered practical to achieve increased flood immunity in the climate change scenarios as raised road levels would exacerbate the potential flooding impacts resulting from the project. Raising of the proposed road levels would also result in increased project footprint, increased resources for construction and operation, and increased property and environmental impacts in many locations along the project alignment.

The environmental management measures identified in **Table 10-14**, including further investigation and refinement during detailed design, would be implemented to seek to minimise these expected climate change impacts.

10.6.4 Sensitive receiving environments

The operation of the project would have the potential to impact on SREs as follows:

- Drinking water supply aquifers: As described above, during the operational phase, the project would not impact the Tomago Sandbeds Catchment Area drinking water supply due to reduced groundwater levels or flows, and the lining of permanent water quality basins in the Tomago Sandbeds Catchment Area. Potential groundwater quality impacts are covered in **Chapter 11** (surface water and groundwater quality)
- Groundwater users: Based on the relatively small groundwater level increases and the localised area of mounding, changes to groundwater level or flow are not anticipated to materially affect GDEs, including high priority GDEs, baseflows or existing groundwater users
- Wetlands, including:
  - **Coastal Wetlands (Coastal Management SEPP):** There would be a minor increase in the rate of stormwater discharge at the unnamed tributary of the unnamed coastal wetland. Given that impacts to groundwater levels during operation would be negligible and localised to the vicinity of the project, no drawdown impacts are anticipated at any Coastal Wetlands (Coastal Management SEPP)
  - **Hunter River wetland:** Wetland areas in local catchments upstream of the project and within the HRBG may be affected by modified cross drainage arrangements. The proposed culverts under the upgraded highway are designed to be 0.2 metres higher than the existing culverts under the current highway. This may translate to increased permanent water levels in the wetlands of 0.2 metres. However, this is not expected to have any material impact on the wetland community. As the proposed road drainage would discharge on the downstream side of the highway embankments, it is not expected that there would be impacts from increased road runoff to the wetlands. Inundation depths in the wetlands during flood events is expected to be reduced as a result of the project by 0.5 to one metre in the 20% AEP flood event as a result of upgraded transverse culvert capacity, an improvement compared to existing
  - **Hunter Estuary Ramsar site:** The Hunter Estuary Ramsar site is located downstream of the Hunter River. As operation of the project is not expected to have any impact on the flow regime of the Hunter River and no regional hydrology impacts are predicted, no impacts to the Hunter Estuary Ramsar site are predicted.
- All GDEs in the study area: As described above, based on the relatively small groundwater level increases and the localised areas of mounding, changes to groundwater level or flow are not anticipated to materially affect GDEs, including high priority GDEs.

10.6.5 Site water balance

As project operation is not anticipated to have any ongoing water demand or water take, an operational water balance is not required.

10.6.6 Summary of operational impacts

Summary of surface water operation impacts

The project would have similar impacts to surface water hydrology during operation as those identified in construction, refer to **Section 10.5.6**.

Summary of groundwater operation impacts

Ongoing interaction with groundwater during operation would occur due to the operation of permanent water quality basins below the water table and through the interruption to groundwater flow caused by soft soil consolidation. Potential impacts to groundwater quality are discussed in **Chapter 11** (surface water and groundwater quality).

The soft soil consolidation is not anticipated to have any material impact and overall the project is not anticipated to have any detrimental effect on the local groundwater hydrology regime, including GDEs and other groundwater users during operation and this includes to the nearby Tomago Sandbeds Catchment Area drinking water supply.

Summary of flooding operation impacts

During operation, flood level increases of generally 0.02 to 0.04 metres in the 5% and 1% AEP event are expected to occur. A dwelling near the Tarro interchange experiences an increase of up to 0.06 metres, which exceeds the afflux design objective criterion during a 5% AEP flood event. The afflux criterion is exceeded for the 5% AEP event. Flood levels in vegetated local catchments on the eastern side of the project and between the viaduct and Heatherbrae change by up to +/- 0.1 metres as a result of changed transverse drainage capacity. Flood levels in the probable maximum flood generally increase by up to 0.08 metres across the Hunter River floodplain during operation.

Localised increases in flow velocities, flood hazard and duration of inundation are expected, with overall negligible to minor impacts. The absence of widespread increases in flood hazard indicate there is negligible change to flood hydraulic characteristics, including floodways and flood storages.

Broadly, the project achieves the flood management objectives and criteria discussed in **Section 10.2.3**, including for afflux, flood hazard and flood duration. The large majority of existing flood-affected residential, commercial and industrial properties experience at most a negligible in flood depth (defined as 0.01 metres change), hazard and time of inundation (defined as a change of up to three hours) during operation of the project. There would be 17 lots that would be newly flooded in the 1% AEP flood event, with 10 lots and one habitable building identified as experiencing afflux exceeding the adopted criteria. Flood level increases of up to 0.02 metres reach Raymond Terrace and beyond the current flood model extent.

There are negligible impacts to existing roads and rail infrastructure. There are negligible to minor impacts expected to agricultural and grazing activities, emergency services (including evacuation routes) and future development potential of affected lands.

Access roads for the project would be constructed immediately next to Hunter Valley Flood Mitigation infrastructure, namely existing flood levees on the western Hunter River Floodplain. These roads may affect the structure and maintenance of the levees, however there would be no impacts to the operation, function or structural integrity of the scheme (including the floodgates). Transport will continue to consult with the operators of the scheme during detailed design to minimise impacts on the scheme.

Summary of climate change impacts on operation flooding

The impact of climate change on flooding at the project was assessed to determine the changes to flooding behaviour affecting the project. A number of combinations of increased catchment flooding (resulting from increased rainfall intensity due to climate change) and sea level rise were assessed. The 0.5% AEP and 0.2% AEP flood events were adopted as a proxy for increased rainfall intensity and river flood flows due to climate change on the current day 1% AEP flood event. The 0.5% AEP represents a 17 per cent increase in the Hunter River peak flow from the current day 1% AEP flood event, and the 0.2% AEP represents a 45 per cent increase in the Hunter River peak flow from the current day 1% AEP flood event. The sea level rise scenarios assessed included a 0.4 metre rise in sea level from current levels for the year 2050, and 0.9 metre rise for the year 2100 in assessing the impact of climate change on flooding. These projections are based on research by the IPCC and were refined for the Australian region.

The assessment indicates:

- Increases in peak flood levels due to sea level rise (in conjunction with current day 5% and 1% AEP catchment flooding) are generally up to 0.17 metres, with the exception of west of Main North Rail Line where increases of up to 0.7 metres are expected in the 5% AEP event due to sensitivity of flood conditions in Hexham Swamp
- Increases in peak flood levels with a 0.5% AEP catchment flood for all sea level rise scenarios are in the range of 0.45 to 0.65 metres
- Increases in peak flood levels with a 0.2% AEP catchment flood for all sea level rise scenarios are in the range of 0.97 to 1.28 metres.

While there will be a reduction in the flood immunity of the project due to climate change, the main alignment of the project would remain flood-free in the 5% AEP flood (existing climate) with a year 2100 sea level rise of 0.9 metres (i.e. climate change scenario 1). Hence the project would continue to meet the key design criterion of an existing climate 5% AEP Hunter River flood immunity.

Raising the proposed project road levels to address the climate change impact on project flood immunity is not considered practical, as raised road levels would exacerbate the potential flooding impacts resulting from the project. Raising of the proposed road levels would also result in increased project footprint, increased resources for construction and operation, and increased property and environmental impacts in many locations along the project alignment.

10.7 Environmental management measures

The environmental management measures that will be implemented to minimise the hydrology and flooding impacts of the project, along with the responsibility and timing for those measures, are presented in **Table 10-14**.

Table 10-14 Environmental management measures (hydrology and flooding)

Impact	Reference	Management measure	Responsibility	Timing
Flooding impacts during construction	FH01	A Flood Management Plan (FMP) will be prepared for the project and will detail the processes for flood preparedness, materials management, weather monitoring, site management and flood incident management. The FMP will also address procedures and responsibilities for flood response (preparation of site upon receipt of flood warning, evacuation of site personnel) during and recovery following a flood event. The FMP will also include: • Consideration of temporary traffic arrangements to minimise impact on flood evacuation route traffic capacity. • Appropriate measures to manage potential flood impact associated with temporary ancillary facilities subject to flooding within 20% AEP flood level • Where feasible, the size of the ancillary facilities and the height and extent of temporary access tracks will be reduced to minimise flood impacts • Ancillary facilities will also be designed to provide for conveyance of flood flows in order to minimise flooding impacts to adjacent properties and environment	Transport/ Contractor	Prior to construction
Potential changes to flood impacts resulting from detailed design	FH02	Any changes to the design described in this EIS would be further investigated during detailed design, including further flood investigations and hydrological and hydraulic modelling to ensure the flood immunity objectives and performance criteria for the project are met. The detailed design will consider refinement to temporary and permanent access roads to further reduce flood afflux with impacts to drainage capacity, where reasonable and feasible.	Transport / Contractor	Detailed design
Flooding impacts on property	FH03	Consultation will be carried out with landowners impacted by flood affects from the project which exceed the flood management objectives (afflux, change in flood hazard, change in time of inundation) about reasonable and feasible management measures. Further modelling may be carried out at detailed design to assess impacts to property.	Transport/ Contractor	Detailed design

Impact	Reference	Management measure	Responsibility	Timing
Impacts on existing drainage systems	FH04	Existing hydraulic capacity of drainage systems will be maintained during construction where practicable.	Contractor	Construction
	FH05	The requirement to provide further upgrades to existing drainage systems will be considered at detailed design where there is: • An increase of more than 20 per cent in the peak discharge rate during operation • An increase in drainage system capacity within the project footprint but where downstream infrastructure has not been upgraded.	Contractor	Detailed design
Impacts to flood mitigation schemes	FH06	The design of temporary and permanent works will ensure there is minimal impact to the function and flow capacity of the Hunter Valley Flood Mitigation Scheme or as otherwise agreed during consultation with operators of the scheme.	Transport/ Contractor	Detailed design
Impacts to river banks immediately downstream of project discharge locations during construction	FH07	Monitoring of temporary construction phase stormwater discharge locations to minimise downstream geomorphological impacts from the project will be included in the Construction Soils and Water Management Plan.	Contractor	Construction
Impacts to river banks immediately downstream of project discharge locations during operation	FH08	The project design aims to ensure that stormwater discharge velocities are controlled at the project outlet to ensure minimal downstream impacts occur immediately downstream of the project. A geomorphological survey will be completed of the waterways downstream of the discharge points where there is greater than 20 per cent increase in stormwater discharge from the project. Waterways (channels and banks) immediately downstream of these project discharge locations will be monitored for a minimum period of twelve months or until establishment and stabilisation. Monitoring will look for evidence of initiation of erosion and scour and, if required, carry out appropriate remediation measures.	Transport/ Contractor	Operation
Impact to surface water and groundwater hydrology	FH09	Baseline monitoring of hydrological attributes would be carried out prior to the commencement of construction, with ongoing monitoring during construction and the initial stages of operation (refer to Hydrology and Flooding Working Paper (**Appendix J**)).	Transport/ Contractor	Prior to construction / Construction/ operation

Impact	Reference	Management measure	Responsibility	Timing
Other relevant management measures				
Flood Risk	CC01	Hydrological and hydraulic assessments would be carried out for any design changes during detailed design and would consider the climate change related flood risks to the project and flood impacts from the project.	Contractor	Detailed design