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NSW GOVERNMENT

M1 Pacific Motorway extension to Raymond Terrace

Environmental impact statement – Chapter 7: Traffic and transport

Transport for NSW | July 2021



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7. Traffic and transport

This chapter describes the potential traffic and transport 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 traffic and transport, as outlined in the SEARs, are:

- Network connectivity, safety and efficiency of the transport system in the vicinity of the project are managed to minimise impacts
- The safety of transport system customers is maintained
- Impacts on network capacity and the level of service are effectively managed
- Works are compatible with existing and planned infrastructure and future transport corridors.

Table 7-1 outlines the SEARs that relate to traffic and transport and identifies where they are addressed in this EIS. The full assessment of traffic and transport impacts is provided in the Traffic and Transport Working Paper (**Appendix G**).

Table 7-1 SEARs (traffic and transport)

Secretary's requirement	Where addressed
1. Transport and traffic	
1. The Proponent must assess construction transport and traffic (vehicle, pedestrian and cyclists) impacts, including, but not necessarily limited to:	
(a) the identification of transport routes and scheduling of movements, particularly outside standard construction hours;	**Section 7.4.1** provides consideration of construction traffic movements, including activities outside of standard construction hours. **Section 5.4.13** presents proposed working hours (including out-of-hours work). Information on the location of construction ancillary facilities and haulage routes is provided in **Section 5.4.3** and **Section 5.4.12** respectively.
(b) the indicative number, frequency and size of construction related vehicles (passenger, commercial and heavy vehicles, including spoil management movements);	**Section 7.4.1** provides information of the number, frequency and size of construction related vehicles.
(c) indicative construction worker parking	**Section 7.4.1** describes construction worker parking.
(d) the nature of existing traffic (types and number of movements) on construction access routes (including consideration of peak traffic times, land uses, in particular sensitive receivers, and parking arrangements);	**Section 7.3** presents the existing traffic and land uses surrounding the project. **Section 7.4** discusses the impacts of construction traffic on impacted land uses, existing parking arrangements and sensitive receivers, including residences, pedestrians and cyclists.
(e) access constraints and impacts on public transport, pedestrians and cyclists;	**Section 7.4.3** assesses impacts on public transport, pedestrians and cyclists.
(f) impacts to the operation of rail lines in the Lower Hunter, including the Main Northern Rail Line and rail infrastructure in Hexham;	**Section 7.4.3** assesses impacts on rail infrastructure.
(g) the need to close, divert or otherwise reconfigure elements of the road and cycle network associated with construction of the project; and	**Section 7.4** provides details of the need to close, divert or reconfigure the road network, including the cycle network.

Secretary's requirement	Where addressed
(h) the cumulative traffic impacts of other major development projects preparing for or commencing construction in the vicinity of the proposal.	**Section 7.3.9** outlines future growth and future land use relevant to the Emerging Black Hill Precinct. **Section 7.6** and **Chapter 23** (cumulative impacts) discuss the cumulative traffic impact of constructing this project with other projects.
2. The Proponent must assess (and model) the operational transport impacts of the project including, but not necessarily limited to:	
(a) forecast travel demand and traffic volumes for the project and the surrounding road, cycle and public transport network;	**Section 7.3.3** analyses traffic growth trends in the study area. **Section 7.2.3** describes how future traffic demand was determined.
(b) travel time analysis;	**Section 7.3.3** and the Traffic and Transport Working Paper (**Appendix G**) present a travel time analysis of the existing road network. **Section 7.5.2** discusses the travel time impacts that occur as a result of the project.
(c) performance of key interchanges and intersections by undertaking a level of service analysis at key locations;	**Section 7.3.3** presents the existing Level of Service of key intersections in the network. **Section 7.5.4** and **Section 7.5.5** present the performance outcomes of key intersections and interchanges during operation.
(d) wider transport interactions and modifications (local and regional roads, cycling, public and freight transport);	**Section 7.5** details the project's impact on local roads within the study area. No regional roads are located within the study area. **Section 7.5.9** summarises the project's impact on public transport infrastructure including rail and bus services. **Section 7.5.6** discusses impacts on freight. **Section 7.5.7** discusses the impact on regional connectivity. **Section 7.5.9** discusses the impact on the cycle network.
(e) access to identified and future development areas, such as the Beresfield and Tomago industrial areas;	**Section 7.5** discusses access to future development areas that have been identified within the study area.
(f) transport connectivity to and from existing communities and centres (such as Newcastle, Raymond Terrace, the Lower Hunter and Port of Newcastle),	**Section 7.5.7** summarises the impact to transport connectivity for communities within and surrounding the study area.
(g) impacts on Newcastle Airport and Williamtown RAAF Base, maritime traffic on the Hunter River, Port of Newcastle and rail infrastructure;	**Section 7.5.9** discusses impacts to the Newcastle Airport, Williamtown RAAF Base, the Hunter River, the Port of Newcastle and rail infrastructure.
(h) impacts on cyclists and pedestrian access and safety; and	**Section 7.5.9** discusses the impacts on cyclists and the impacts on pedestrians. **Section 7.5.8** discusses the improvements to safety as a result of the project.
(i) opportunities to integrate cycling and pedestrian elements with surrounding networks (existing and proposed) and within the project.	**Section 7.5.9** and **Chapter 5** discuss the integration of the project's cycling infrastructure with existing and proposed cycling infrastructure and discusses the proposed improvements to the pedestrian network in association with the existing pedestrian network.

7.1 Policy and planning setting

The project will provide benefits for road users at the local, regional and state level and will contribute towards achieving some of the goals identified in the following strategic plans:

- Infrastructure Priority List 2020 (Infrastructure Australia 2021)
- Future Transport Strategy 2056 (Transport for NSW 2018a)
- Regional NSW Services and Infrastructure Plan (NSW Government 2018)
- NSW Freight and Ports Plan (Transport for NSW 2018b)
- Moving More with Less 2018 (Transport for NSW 2018c)
- Greater Newcastle Metropolitan Plan 2036 (DPE 2018)
- Greater Newcastle Future Transport Plan (Transport for NSW 2018e)
- Hunter Regional Plan 2036 (DPE 2016).

Further detail on the above strategic plans, and how they apply to the project, is provided in **Chapter 3**.

The traffic and transport assessment was prepared to assess the potential impacts of the project in accordance with the following guidelines:

- Guide to Traffic Management Part 3: Traffic Studies and Analysis (Austroads 2017a)
- Guide to Traffic Generating Developments (RTA 2002)
- Motorway design guide: Capacity and flow analysis (Roads and Maritime Services 2017b)
- Highway Capacity Manual 2016 (Transportation Research Board 2016)
- Traffic Modelling Guidelines (Roads and Maritime Services 2013a)
- Cycling aspects of Austroads guides (Austroads 2017b)
- NSW Bicycle Guidelines v 1.2 (RTA 2005b)
- Planning Guidelines for Walking and Cycling (DIPNR 2004).

7.2 Assessment methodology

7.2.1 Overview

Assessment of the transport and traffic impacts involved the following key steps to identify project impacts during construction and operation:

- Review of the existing environment including existing traffic survey data, existing and future land use, crash data and public transport information
- Development, validation and calibration of a traffic model including:
  - Consideration of forecasts for population and employment growth and inter-regional traffic growth for 2028 (year of opening), 2038 (10 years after opening) and 2048 (20 years after opening)
  - A ‘without’ project assessment for the years 2028, 2038 and 2048 to provide a ‘without project’ baseline
  - Development of a future traffic model for 2028, 2038 and 2048 that includes the project
  - Development of sensitivity scenarios to quantify impacts from the Emerging Black Hill Precinct.
- Identification of construction impacts, including construction traffic and impacts on pedestrians, cyclists, maritime traffic and local access
- Assessment of operational traffic benefits and impacts on transport services, both quantitatively from the traffic modelling outputs and qualitatively

- Assessment of cumulative impacts as a result of project construction and operation, both quantitatively through the use of the traffic model and qualitatively based on the most recent and public available information.

A detailed description of the assessment methodology is presented in the Traffic and Transport Working Paper (**Appendix G**).

7.2.2 Study area

The project is located within the City of Newcastle and Port Stephens Council local government areas (LGAs) in the Hunter Region, north of Newcastle NSW. The study area for the transport and traffic assessment of the project covers the area displayed in **Figure 7-1** and includes:

- Major roads of state importance, including the M1 Pacific Motorway, the Pacific Highway, the New England Highway, John Renshaw Drive, the Hunter Expressway (via John Renshaw Drive), Tomago Road and Weakleys Drive
- The residential areas of Black Hill, Beresfield, Tarro, Heatherbrae and Raymond Terrace
- The semi-rural and urban areas of Black Hill, Tarro and Heatherbrae
- The light industrial, heavy industrial and commercial areas of Beresfield, Hexham, Tomago and Heatherbrae.

While the study area includes relevant roads and areas that would be impacted by the project, the traffic model used in this assessment was developed across a broader area than the study area to also capture potential improvements to the Pacific Highway at Hexham, which is located outside the study area.

7.2.3 Traffic model development

Traffic modelling was carried out in accordance with the Traffic Modelling Guidelines (Roads and Maritime Services 2013a) and as described in the Traffic and Transport Working Paper (**Appendix G**). A VISSIM microsimulation traffic model was used to simulate the movement of individual vehicles based on car-following, lane changing and gap acceptance algorithms. These vehicle-to-vehicle interactions provided the basis for calculating delays. The scenarios modelled are described in **Table 7-2**.

Table 7-2 Modelled scenarios

Scenario Name	Year	With the project	Without project	Description
Base	2017	N	N	This scenario reflects the transport network as it was in 2017 with no new projects or upgrades. The year 2017 was adopted as the existing year, as traffic counts were carried out at this time[1].
Without project	2028	N	Y	These scenarios include the listed network changes without the project and provide a model for comparative purposes. Network changes assumed for these scenarios are described in Traffic and Transport Working Paper (**Appendix G**).
Without project	2038	N	Y	
Without project	2048	N	Y	
With project	2028	Y	Y	These scenarios include the listed network changes with the project and have been compared against the future year 'without project' models to determine the impact of the project.
With project	2038	Y	Y	
With project	2048	Y	Y	

(1) Planned traffic counts were not carried out in 2020 as the COVID-19 pandemic resulted in substantial changes to traffic volumes and were not considered to be representative of an average year.

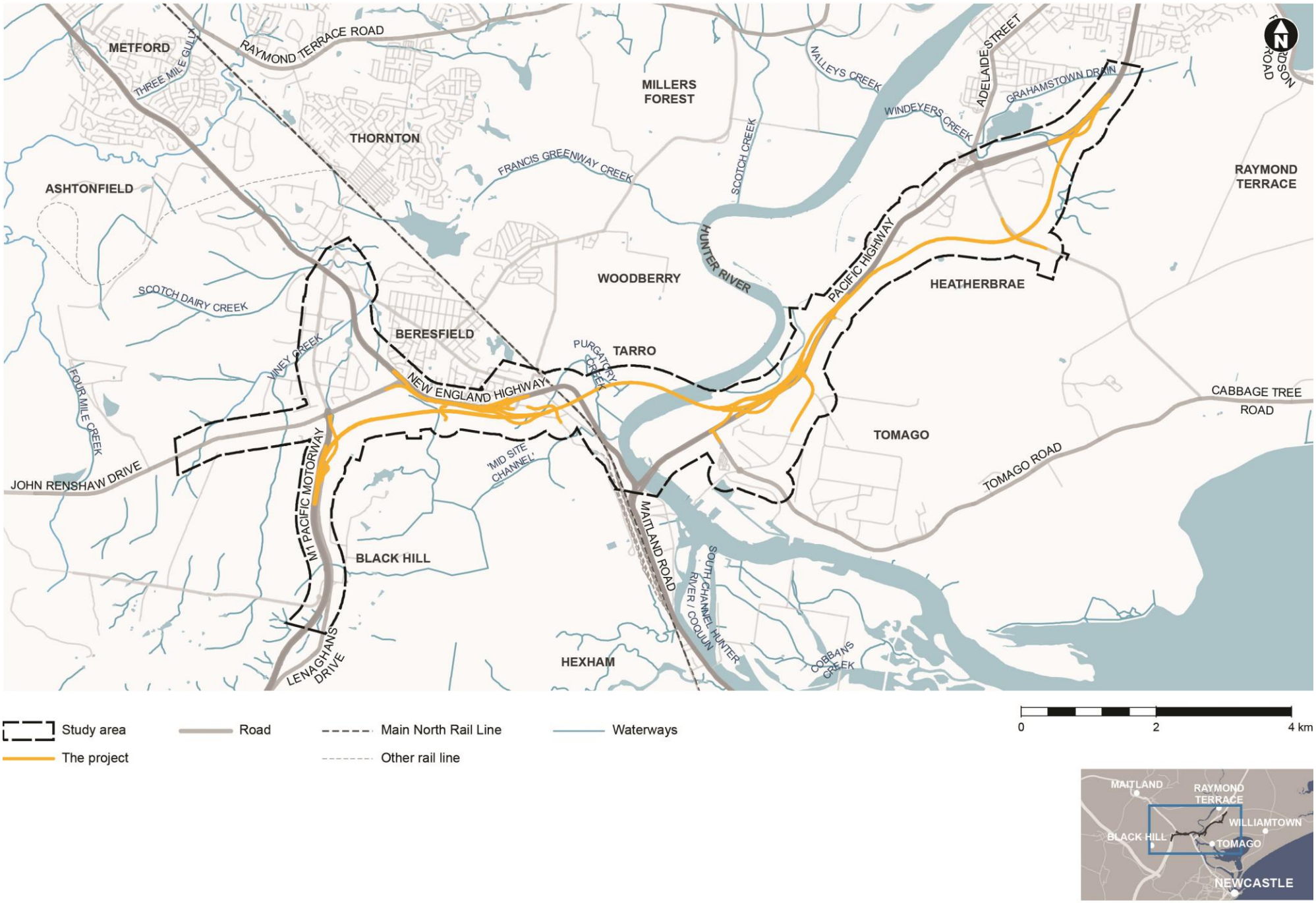


Figure 7-1 Traffic and transport study area

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The Sydney Traffic Forecasting Model (STFM) was used originally to develop the future growth across the network. The STFM modelling results were analysed and found to overestimate the future growth compared to historical growth rates. As such a 1.5 per cent per annum growth rate was adopted which aligns with historic growth in the region and represents a reasonable growth rate for future horizons. The Emerging Black Hill Precinct (refer to Section 4.10 of the Traffic and Transport Working Paper (**Appendix G**)) was not included in the future growth of the STFM. Therefore, a specific assessment and inclusion of future growth for this proposed development precinct, which is anticipated to be a major traffic generating development precinct, was included in addition to the yearly growth rate.

7.2.4 Sensitivity modelling

To quantify the impact of the Emerging Black Hill Precinct, sensitivity testing was carried out for peak periods in 2038. Two modelling scenarios were tested as follows:

- Scenario 1: Incorporating on and off ramps at the Black Hill Road interchange with the M1 Pacific Motorway to allow for direct connection to the Emerging Black Hill Precinct from the south
- Scenario 2: No traffic generated from the Emerging Black Hill Precinct.

7.2.5 Assessment criteria

The performance of operational traffic was modelled to provide an overview of the road network at a network level and at a single point level to compare the performance of each modelled scenario.

Network-wide statistics used for the assessment included:

- At a network level:
  - Road network performance can be assessed with network-wide statistics. These statistics are extracted from the traffic model for the morning and evening peak periods and include average speed, vehicle throughput and total time travelled within the modelled network.
- At a single point:
  - The performance of an intersection and its LoS is determined by the average delay per vehicle
  - At an interchange level, which is calculated from the density of traffic and the capacity of the entry ramp.

At individual locations, level of service (LoS) is used to determine the performance of intersections and interchanges, and ranges from A to F (refer to **Table 7-3**). Intersection LoS is determined by the average delay per vehicle. Interchange LoS is determined by vehicle interactions (including merges, diverges and weaving) that occur within 450 metres of the interchange. LoS A generally described free flowing traffic that is unaffected by other road users in comparison to LoS F, which described a road environment where, in the context of traffic signals and roundabouts, traffic approaching an intersection is unable to pass, resulting in queuing.

LoS D is the target performance level generally accepted. If the performance of an intersection, interchange or midblock segment falls below LoS D, investigations should be initiated to determine if suitable remediation can be provided. However, limited road capacity and high demand mean that LoS E and LoS F are regularly experienced by motorists, particularly during peak periods.

Table 7-3 LoS criteria

LOS	Average vehicles delay (s)	Traffic signals and roundabouts
A	d ≤ 10	Free flowing traffic virtually unaffected by other road users
B	10 < d ≤ 20	Steady flow of traffic allowing manoeuvrability
C	20 < d ≤ 35	Stable flow of traffic restricting manoeuvrability
D	35 < d ≤ 50	Limited stable flow and all drivers restricted in movement
E	50 < d ≤ 70	Operating at capacity with unstable traffic flow
F	70 < d	Traffic approaching the intersection exceeds ability for traffic to pass resulting in queueing

7.3 Existing environment

7.3.1 Road network

Transport uses a hierarchal system that designates the road network into state, regional and local roads based on the predominant function of a road. State roads comprise of major arterial roads and motorways, regional roads perform a sub-arterial function and local roads are the remaining council controlled roads.

The study area also includes roads that form part of the National Land Transport Network (NLTN). The NLTN is a network of nationally important road and rail infrastructure links and their intermodal connections.

The functional hierarchy of the existing road network within and surrounding the study area is presented in **Figure 7-2**.

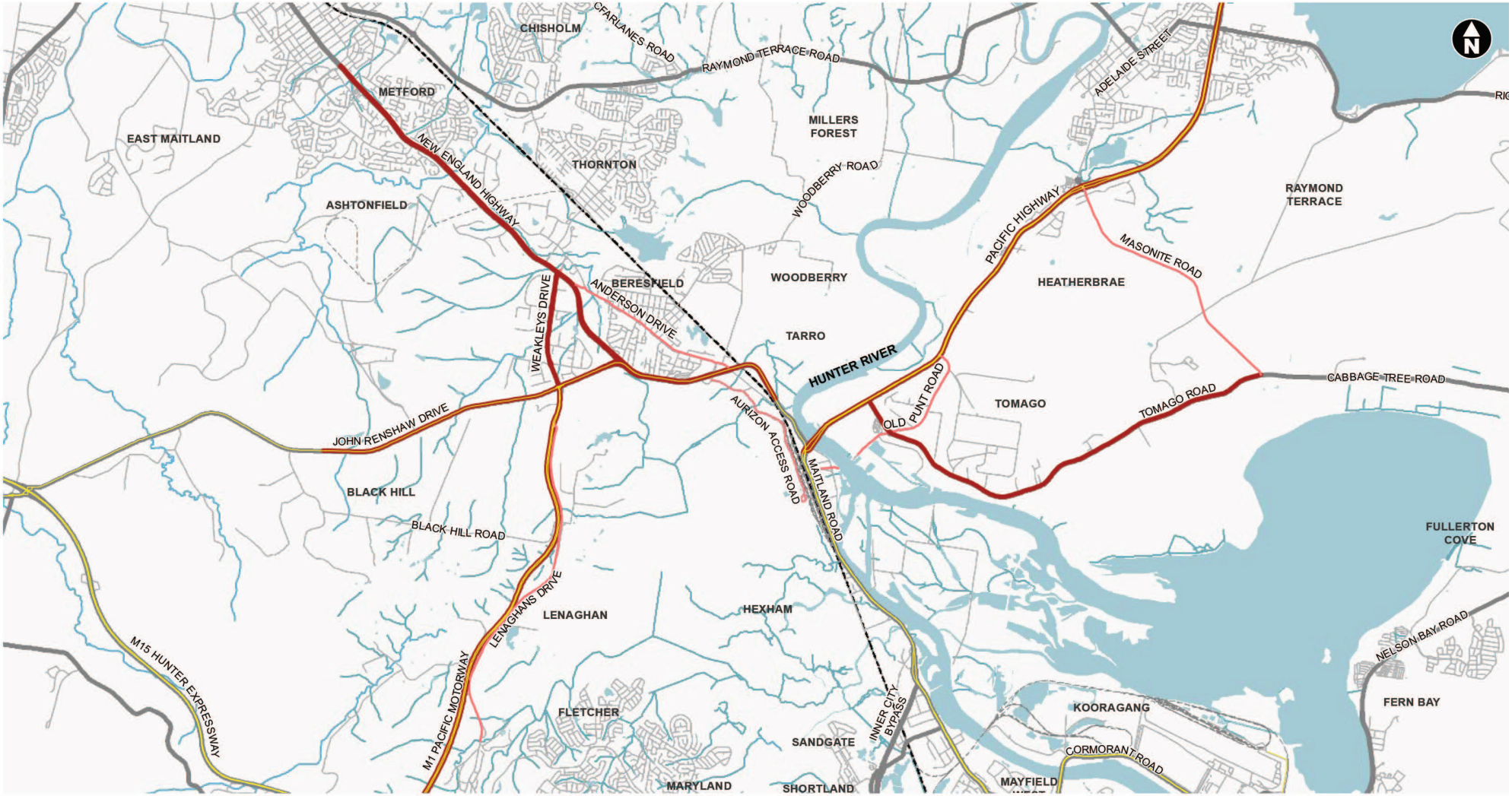


Figure 7-2 Existing road network

Table 7-4 describes the existing traffic conditions for state roads in the study area from traffic surveys carried out in 2017. No regional roads were identified within the study area.

Local roads within the study area include Old Punt Road, Masonite Road, Anderson Drive and the Aurizon access road. Further information on these roads is presented in the Traffic and Transport Working Paper (**Appendix G**).

Table 7-4 Existing traffic conditions for state roads in the study area

Road	Configuration	Average speed limit (km/h)	Existing average vehicles	Description
M1 Pacific Motorway	Dual carriageway with two lanes in each direction	110	About 40,600 per weekday (20 per cent heavy vehicles)	Key north-south corridor linking Sydney to the Central Coast, Newcastle and Hunter region that forms NLTN, a defined national network of important road and rail infrastructure links and their intermodal connections.
Pacific Highway	Dual carriageway with two lanes in each direction	80	About 51,800 vehicles per weekday north of Hexham Bridge (18 per cent heavy vehicles)	The intersection of Pacific Highway and Tomago Road provides key connections to employment areas in Tomago, Newcastle Airport and the Williamtown Royal Australian Air Force (RAAF) Base.
New England Highway	Dual carriageway road with two lanes in each direction	90 (west of Tarro) 80 (East of Tarro)	About 42,200 vehicles per weekday through Thornton (23 per cent heavy vehicles) About 61,000 vehicles per weekday north of the Pacific Highway (22 per cent heavy vehicles)	Key east-west link between Newcastle and the Lower Hunter, forming part of the NLTN and providing access to the Port of Newcastle.
John Renshaw Drive	Single carriageway with one lane in each direction (west of the M1 Pacific Motorway) Single carriageway with two lanes in each direction (east of the M1 Pacific Motorway)	100 (west of the M1 Pacific Motorway) 80 (east of the M1 Pacific Motorway)	About 32,000 vehicles per weekday west of Weakleys Drive (13 per cent heavy vehicles)	Key east-west corridor linking the M15 Hunter Expressway and the towns of Kurri Kurri and Cessnock with the M1 Pacific Motorway and New England Highway, forming part of the NLTN.
Tomago Road	One lane of travel in each direction along the majority of its length, with flaring at intersections to provide increased capacity	60	About 14,200 vehicles per weekday east of Pacific Highway (9 per cent heavy vehicles)	Connects Nelson Bay Road to the east and the Pacific Highway to the west. The intersection with the Pacific Highway is a T-intersection controlled by traffic signals, with right turns from Tomago Road onto the Pacific Highway prohibited.
Weakleys Drive	Single carriageway with one to two lanes in each direction	60	About 20,900 vehicles per weekday north of John Renshaw Drive (19 per cent heavy vehicles)	North-south connection between the M1 Pacific Motorway and New England Highway and serves the adjoining light industrial land uses.

7.3.2 Land use

The study area includes a mix of land uses, including rural and agricultural uses, environmental and water resources, manufacturing and industrial uses, services and utilities, and residential uses of varying densities. Key commercial centres within the study area include Black Hill, Tarro, Beresfield, Tomago, Heatherbrae and Raymond Terrace. Key manufacturing and industrial centres close to the project include Beresfield, Hexham, Tomago, and Heatherbrae. Heatherbrae is located south of Raymond Terrace and has been identified as an 'enterprise corridor' and destination for bulky goods retail.

The Port of Newcastle is a major seaport located in the City of Newcastle and is a major driver of commercial activity in the region. The Port of Newcastle is over 15 kilometres south-east of the project.

One designated rest area is located at the Beresfield Service Centre on John Renshaw Drive. This rest area provides for both light and heavy vehicles.

Most formal parking areas are associated with businesses and industrial developments, with limited formal parking or demand on the state roads in the study area. Informal public parking in the study area is generally limited to verges and local roads.

Newcastle Airport is located in Williamtown around 17 kilometres by road east of the Pacific Highway/ Tomago Road intersection and around 13 kilometres by road east of the Pacific Highway/Masonite Road intersection. The airport is owned by City of Newcastle Council and Port Stephens Council on land leased from the Australian Department of Defence. The airport runway is shared with Williamtown RAAF Base, which is located north of the runway and west of Medowie Road. Tomago Road provides the most direct route to and from the airport and is currently most commonly used as an access route to the airport.

Further detail on existing land use is presented in **Chapter 14** (land use and property).

7.3.3 Existing road performance

Traffic volumes and growth

Traffic surveys were carried out between 10 October 2017 and 23 October 2017 at various locations in the study area to gain an understanding of daily traffic volumes and traffic composition. The average daily traffic volumes observed on key routes throughout the study area are presented in **Figure 7-3**.

When considering daily and seasonal variation in traffic volumes, weekday traffic volumes are higher than weekend traffic volumes, and school holiday volumes are higher than weekend volumes but lower than weekday volumes. Further, seasonal fluctuations in traffic volumes have peaks which coincide with the Christmas/New Year period and Easter.

A review of the average annual daily traffic counts between 2006 and 2017 indicate that traffic in the study area has increased by about two to three per cent each year. Traffic growth has reduced since 2015, with the rate of increase reducing to about one per cent growth per year. Planned traffic counts were not carried out in 2020 as the COVID-19 pandemic resulted in substantial changes to traffic volumes and were not considered to be representative of an average year.

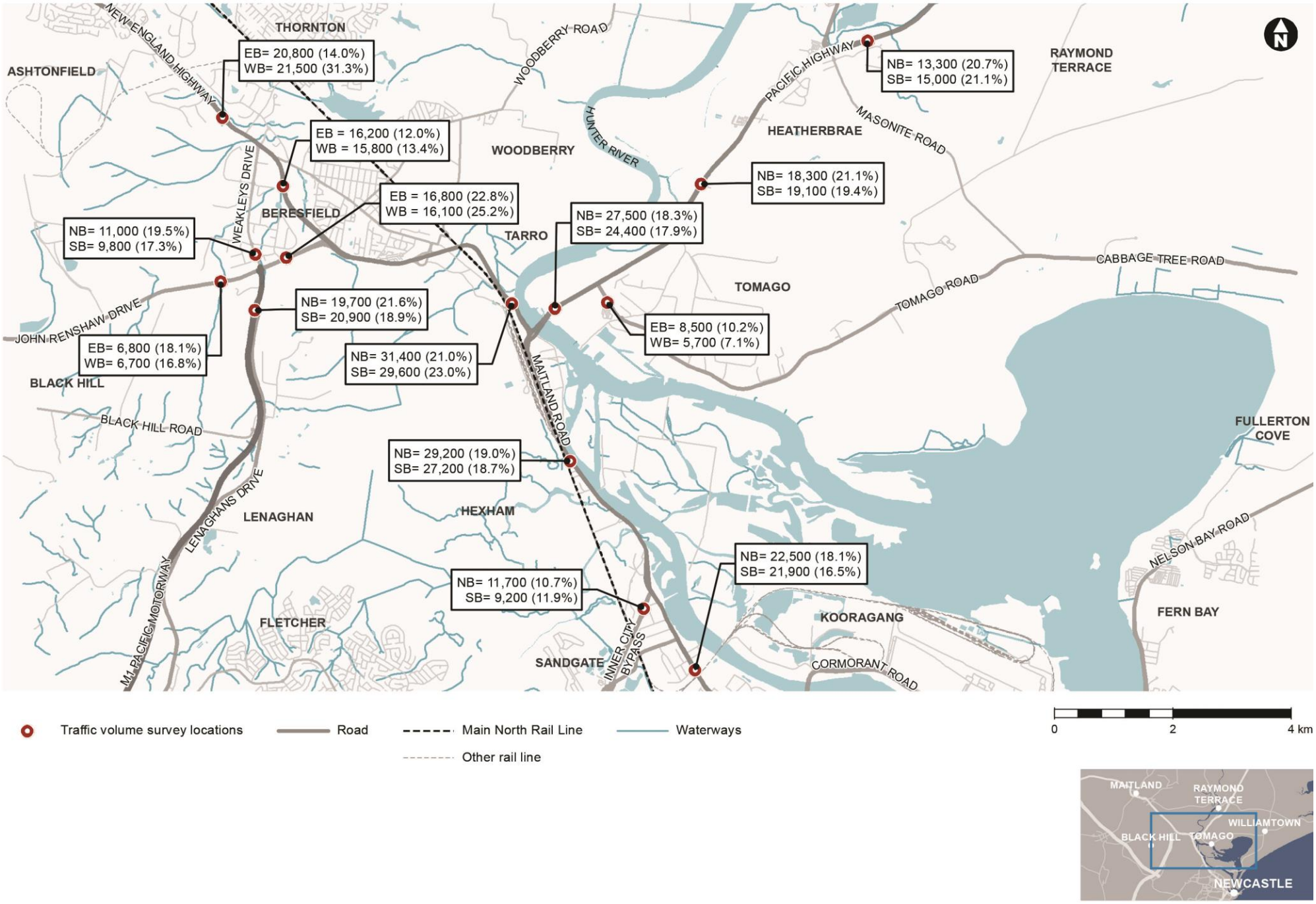


Figure 7-3 Daily traffic volumes of key routes in the study area

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Travel time

Travel times between the five key locations shown on **Figure 7-4**. **Table 7-5** displays the recorded travel times for the morning and evening peak periods. Overall, average travel speeds range between 66 to 76 kilometres per hour for north-eastbound traffic and 56 to 66 kilometres per hour for south-westbound traffic.

Table 7-5 Existing travel time

From	To	Distance (km)	Observed travel time (min:sec)	Travel speed (km/h)
Morning peak period (8–9am)				
New England Highway	Maitland Road	12.5	14:55	50
	Pacific Highway	16.3	13:26	73
M1 Pacific Motorway		20.7	16:52	74
John Renshaw Drive		18.0	15:13	71
Pacific Highway	New England Highway	16.6	16:26	61
	M1 Pacific Motorway	20.9	19:31	64
	John Renshaw Drive	18.2	17:24	63
	Maitland Road	13.2	14:06	56
Maitland Road	Pacific Highway	13.3	13:25	59
	New England Highway	12.6	12:24	61
Evening peak period (5–6pm)				
New England Highway	Maitland Road	12.5	11:59	63
	Pacific Highway	16.3	13:26	73
M1 Pacific Motorway		20.7	16:52	74
John Renshaw Drive		18.0	15:13	71
Pacific Highway	New England Highway	16.6	16:26	61
	M1 Pacific Motorway	20.9	19:31	64
	John Renshaw Drive	18.2	17:24	63
	Maitland Road	13.2	13:46	57
Maitland Road	Pacific Highway	13.3	14:45	54
	New England Highway	12.6	13:11	57

On the Pacific Highway, travel times for north-eastbound traffic are shorter than travel times for south-westbound traffic. This can be attributed to the following additional delays experienced by south-westbound traffic at signalised intersections along the Pacific Highway:

- Uncontrolled left-turn movement onto the New England Highway/Pacific Highway intersection
- Movements to and from Tomago Road at the Pacific Highway/Tomago Road intersection
- Traffic signal phasing at the Pacific Highway/Old Punt Road intersection.

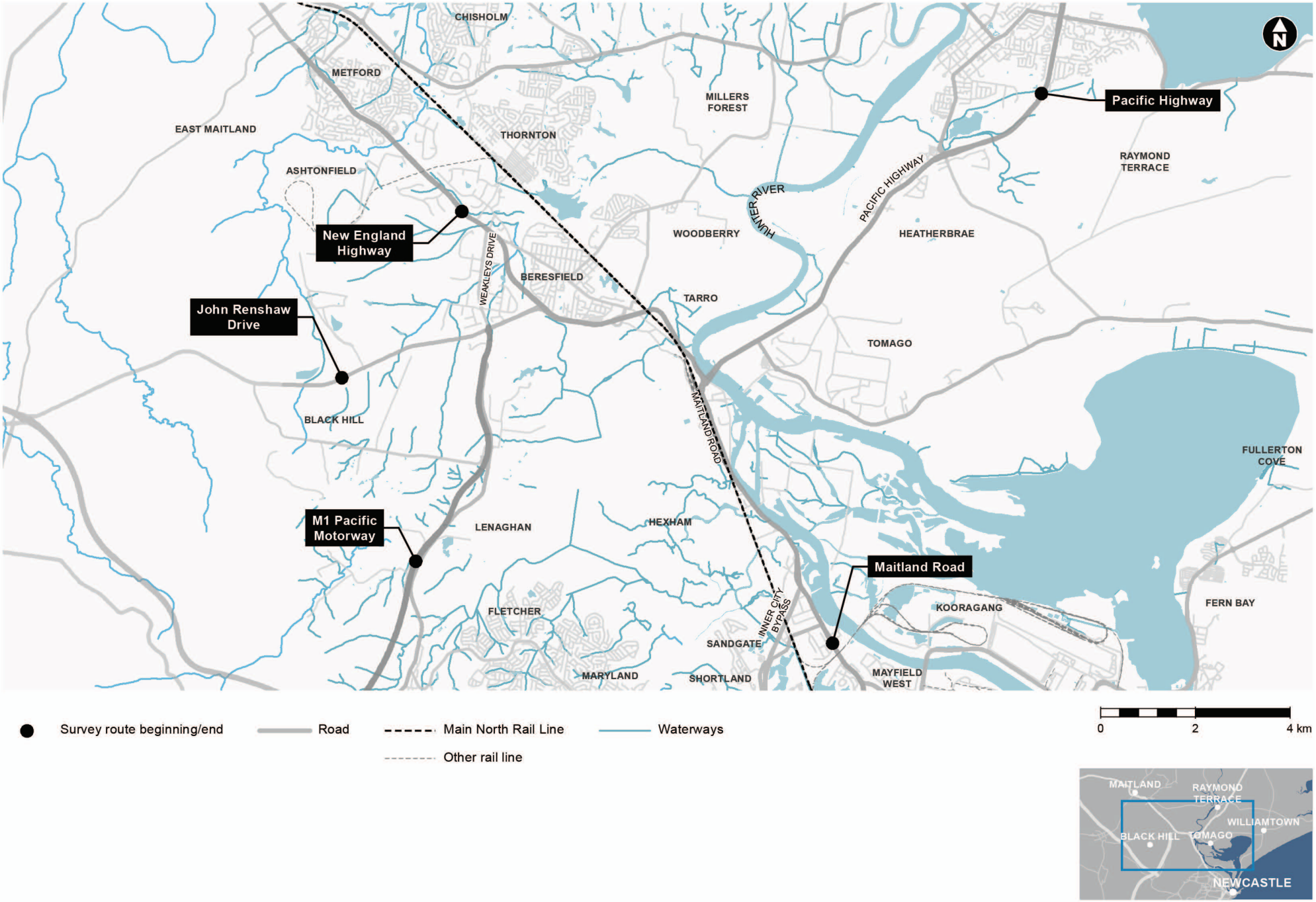


Figure 7-4 Travel time survey routes

Origin-destination surveys

Origin-destination surveys within the study area were completed as part of the Outer Newcastle Study in 2017.

The following morning peak observations were made:

- For trips entering the study area at M1 Pacific Motorway, Black Hill, Weakleys Drive, Beresfield was the most common destination accounting for 41 per cent of recorded vehicles. The Pacific Highway, Heatherbrae was the next most common destination accounting for 12 per cent of trips. Tomago Road, Tomago was also a common destination and attracted nine per cent of trips
- The largest movement recorded during the morning peak was the southbound movement from the New England Highway into Newcastle, 47 per cent of trips entering the study area at the New England Highway travelled to the Pacific Highway in Sandgate. Trips from the New England Highway to Tomago or Heatherbrae were also common, with a total of 13 per cent of trips travelling in this direction
- The most frequent destination (15 per cent) for trips entering the study area from Pacific Highway, Heatherbrae was to M1 Pacific Motorway
- The largest heavy vehicle movement in the morning peak was the southbound movement from Weakleys Drive to the M1 Pacific Motorway. Other common heavy vehicle routes were from Pacific Highway in Sandgate to both the New England Highway and the M1 Pacific Motorway.

The following evening peak observations were made:

- For trips entering the study area at M1 Pacific Motorway, Black Hill, Weakleys Drive, Beresfield was the most common destination accounting for 46 per cent of recorded vehicles. The Pacific Highway, Heatherbrae was the next most common destination accounting for 17 per cent of trips. Tomago Road, Tomago was also a common destination and attracted seven per cent of trips
- The largest movement recorded during the evening peak was the northbound movement from Newcastle to the New England Highway
- The most frequent destination (33 per cent) for trips entering the study area from Pacific Highway, Heatherbrae was to M1 Pacific Motorway
- The largest heavy vehicle movement in the evening peak was both southbound and northbound, between Weakleys Drive and the M1 Pacific Motorway.

An earlier origin-destination survey carried out for Heatherbrae traffic in 2016 determined that in the northbound direction there was almost an even split between through trips and local trips. In the southbound direction, a greater proportion (69 per cent) of trips were local trips. From these results, it can be expected the provision of a bypass would substantially reduce traffic travelling through Heatherbrae as vehicles would have an alternative faster route.

Intersection performance

The traffic modelling results from the calibrated and validated 2017 base model were extracted to gain an understanding of current performance for the intersections presented in **Figure 7-5**. Intersection delays and LoS for these intersections for the morning and afternoon peak periods is provided in **Table 7-6**, with intersection performance of LoS D or worse shaded in pink.

The M1 Pacific Motorway/Weakleys Drive/John Renshaw Drive intersection during the evening peak hour operates at a LoS E. At the time of the traffic data collection exercise and the construction of the base model, this intersection was a roundabout. It has since been upgraded to a signalised intersection. The performance of the M1 Pacific Motorway/Weakleys Drive/John Renshaw Drive intersection is likely to have improved as a result of the intersection upgrade to traffic signals.

Overall, the model results indicate the evening peak is more congested than the morning peak as vehicles experience longer delays at the assessed intersection. However, the existing intersection delay and LoS for the majority of intersections in the study area were operating at a satisfactory LoS (D or better) in 2017.

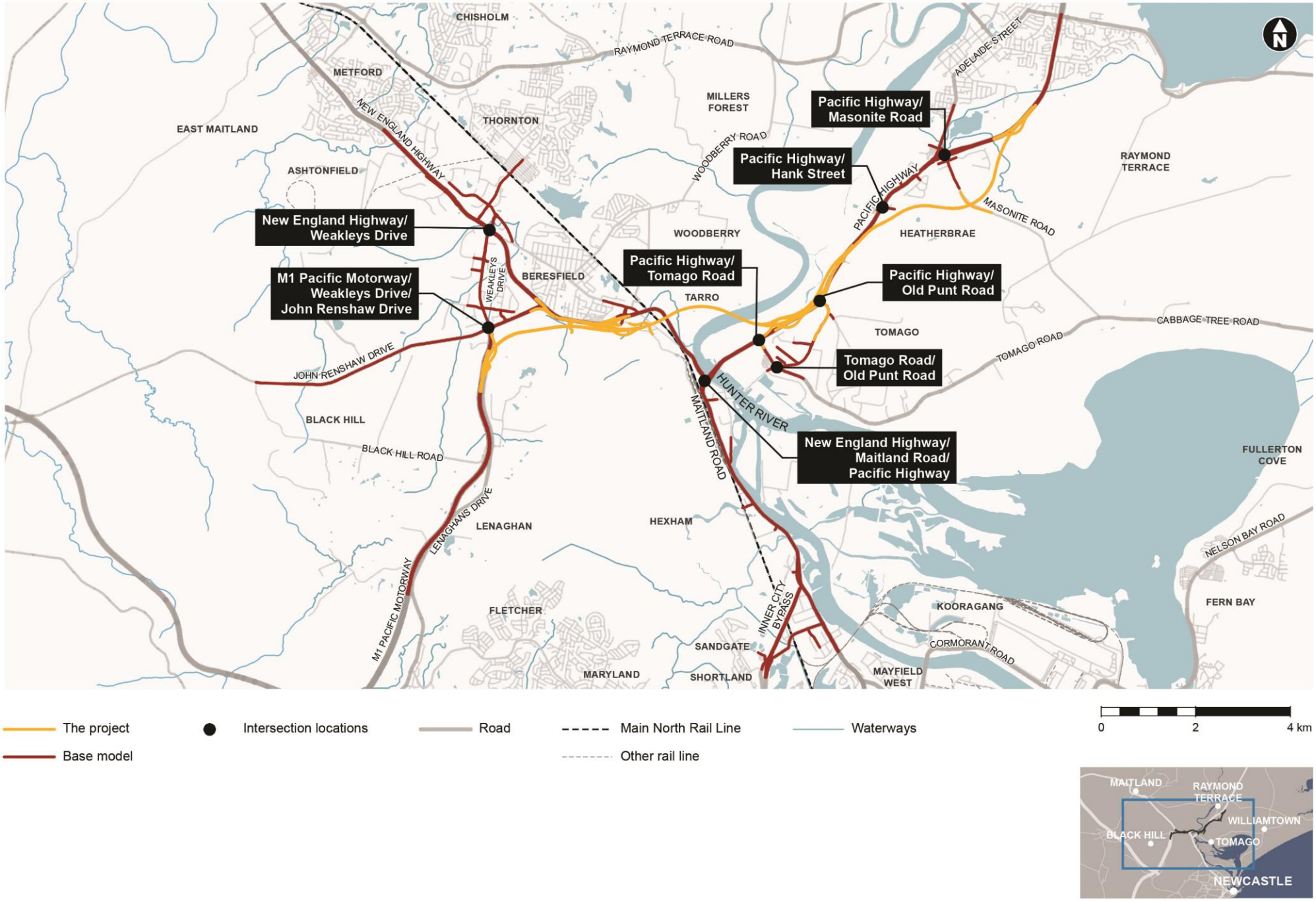


Figure 7-5 Locations of intersections assessed

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Table 7-6 Performance of modelled intersections in 2017

Intersection	Type	Morning (8–9am)		Evening (5–6pm)	
		Avg delay (sec)	LoS	Avg delay (sec)	LoS
M1 Pacific Motorway/Weakleys Drive/John Renshaw Drive, Black Hill	Roundabout*	27	C	63	E
New England Highway/Weakleys Drive, Beresfield	Signalised	11	B	18	B
New England Highway/Maitland Road/Pacific Highway	Signalised	19	B	19	B
Pacific Highway/Tomago Road, Tomago	Signalised	15	B	11	B
Pacific Highway/Old Punt Road, Tomago	Signalised	18	B	10	B
Old Punt Road/Tomago Road, Tomago	Roundabout	4	A	1	A
Pacific Highway/Hank Street, Heatherbrae	Signalised	11	B	10	A
Pacific Highway/Masonite Road, Heatherbrae	Roundabout	10	B	10	A

* At the time of the traffic data collection exercise and the construction of the base model, the M1 Pacific Motorway/Weakleys Drive/John Renshaw Drive intersection was a roundabout. This has since been upgraded to a signalised intersection, which has been used in the traffic modelling.

7.3.4 Road safety and crash history

Crashes on roads in the study area for the five-year period from October 2014 to September 2019 are shown in **Table 7-7**. In summary, a total of 289 crashes were recorded, of which six were fatal. The New England Highway and Pacific Highway recorded the highest number of crashes. Combined, these highways form the longest length of road in the study area and carry the highest traffic volumes. Further information of crash rates in the study area, expressed as crashes per 100 million vehicle kilometres travelled (VKT), are provided in the Traffic and Transport Working Paper (**Appendix G**).

Table 7-7 Total crashes on roads in the study area between October 2014 and September 2019

Road	Section	No. of fatal crashes	No. of injury crashes	No. of non-casualty (tow-away) crashes	Total
John Renshaw Drive	500m west of M1 Pacific Motorway to New England Highway	1	3	4	8
M1 Pacific Motorway	North of Black Hill to John Renshaw Drive	1	24	23	48
New England Highway	West of Thornton Rd to Old Maitland Road	1	70	50	121
Old Punt Road	Tomago Road to Pacific Highway	0	2	1	3
Pacific Highway	New England Highway to Richardson Road	2	55	36	93
Tomago Road	500m west of Tomago Aluminium to Pacific Highway	0	5	2	7

Road	Section	No. of fatal crashes	No. of injury crashes	No. of non-casualty (tow-away) crashes	Total
Weakleys Drive	John Renshaw Drive to New England Highway	1	4	4	9
Total		**6**	**163**	**120**	**289**

7.3.5 Public transport

Bus network and coach services

Ten local buses operate in the study area providing connections to Newcastle, Raymond Terrace, Newcastle Airport, Nelson Bay and Maitland. Most bus routes in the study area use the lower order road network, with the exception of:

- Route 140 that operates on Pacific Highway and Maitland Road
- Routes 145, 181 and 182 that operate on the A4 New England Highway west of Weakleys Drive.

Most routes operate at 30 to 60 minute frequencies on weekdays, 60 minute frequencies on Saturdays and 120 minute frequencies on Sundays. **Figure 7-6** shows the bus routes in the study area.

Long-distance coach services pass through the study area to provide inter-regional connections to Port Macquarie, Kempsey, Coffs Harbour, Grafton Ballina, Byron Bay, Gold Coast and Brisbane (operated by Greyhound and Premier Motor Service via the Pacific Highway) and to Tamworth, Armidale, Glen Innes, Tenterfield, Stanthorpe, Warwick and Brisbane (operated by Greyhound via the New England Highway). There are a total of four services in each direction per day.

Rail network

The rail network in the study area consists of the Main North Rail Line, with four tracks that broadly run parallel to the New England Highway and Pacific Highway, and primarily serves freight traffic from the Hunter Valley mining industry. Railway stations close to the project are located at Thornton, Beresfield, Tarro, Hexham and Sandgate as shown in **Figure 7-7**. These stations are serviced by the Hunter Line, which is an intercity line operated by NSW TrainLink and connects Hamilton (Newcastle) with Maitland, Scone and Dungog.

The average morning peak hour service frequency at Thornton and Beresfield towards Hamilton (Newcastle) is 10 to 20 minutes, compared to 60 minutes at Tarro, Hexham and Sandgate. Similarly, in the evening peak hour, the average service frequency at Thornton and Beresfield towards Scone/Dungog is 10 to 20 minutes, compared to 30 to 60 minutes at Tarro, Hexham and Sandgate.

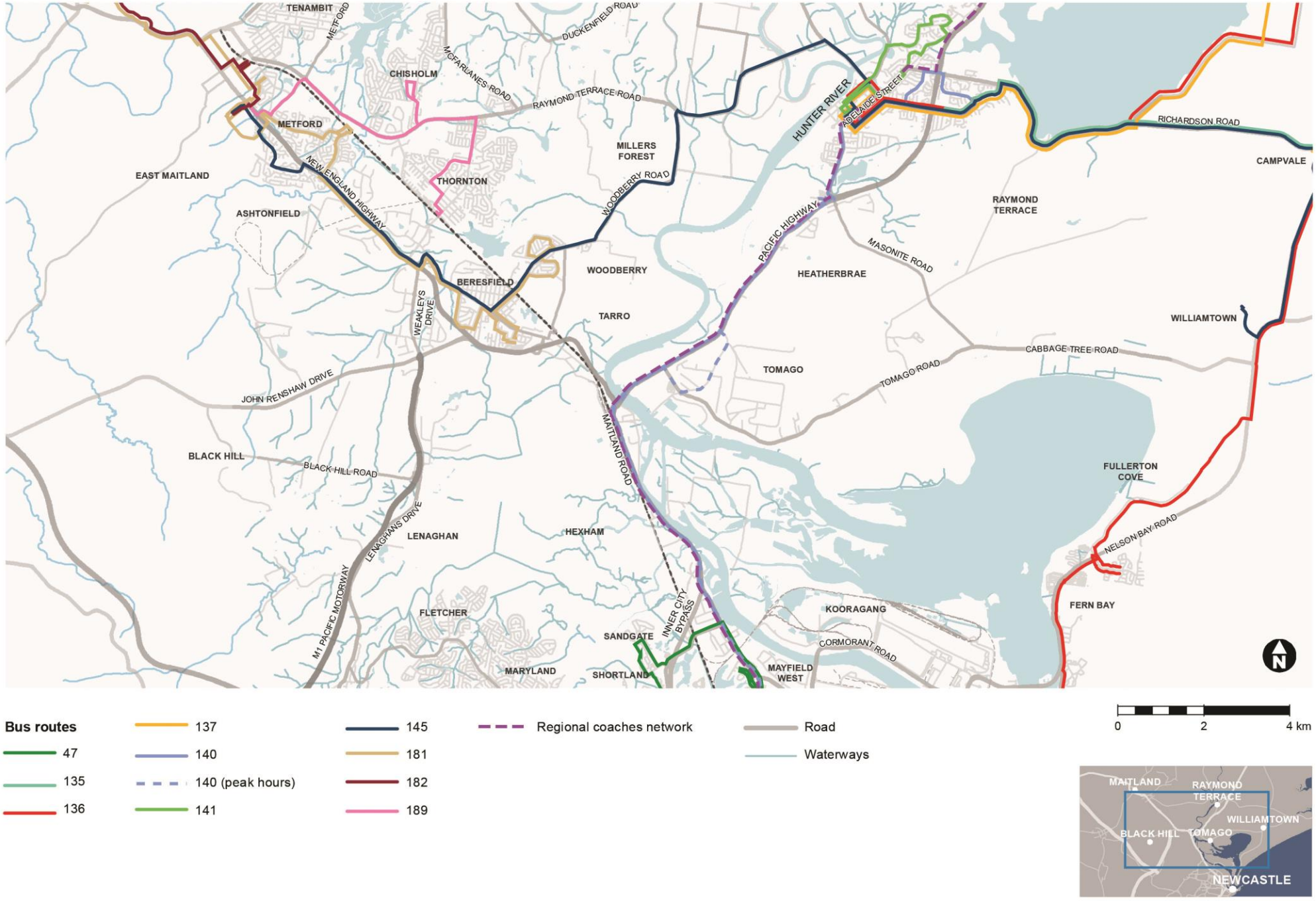


Figure 7-6 Operating bus services

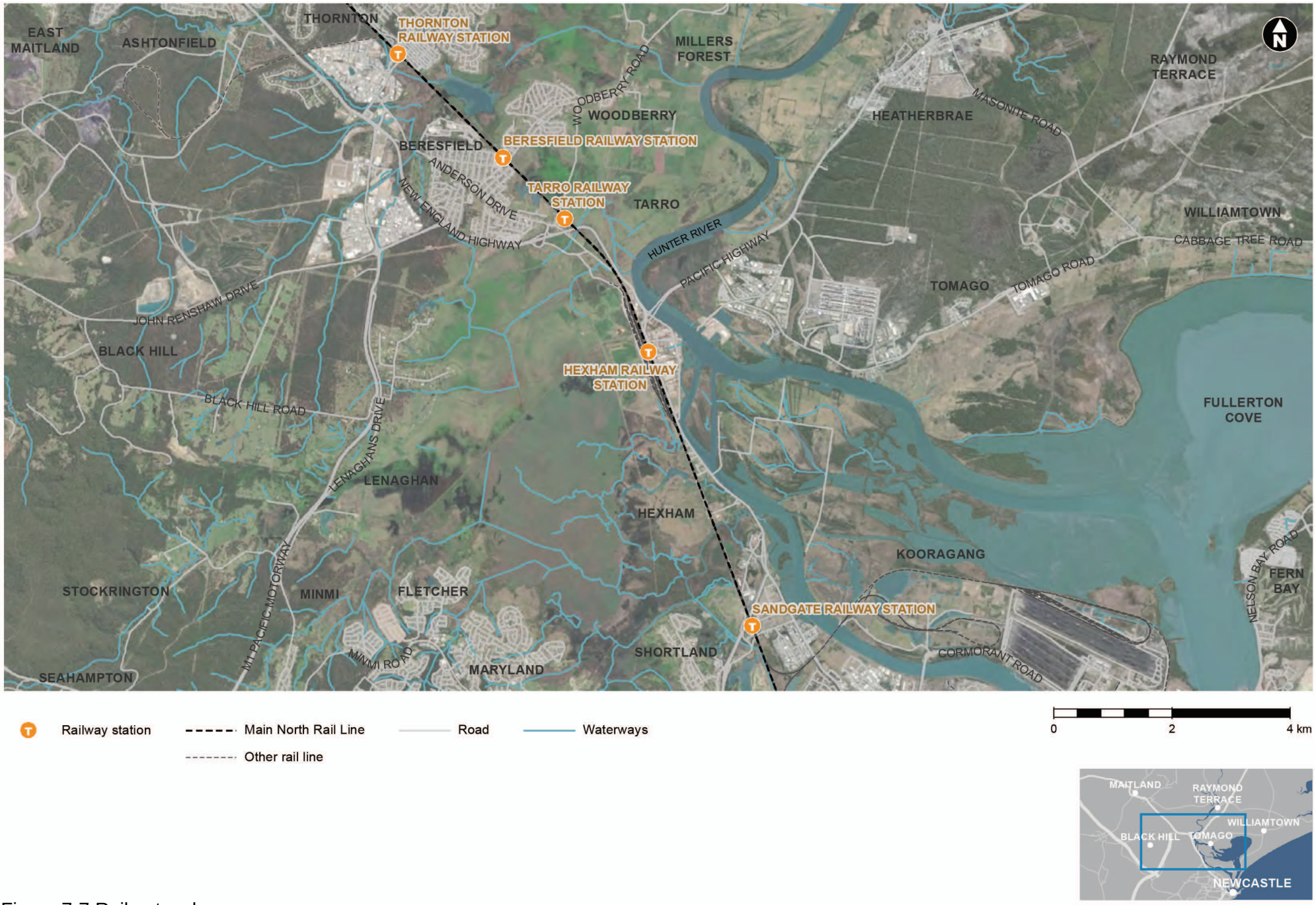


Figure 7-7 Rail network

7.3.6 Freight

Heavy vehicles and freight

The M1 Pacific Motorway, New England Highway and Pacific Highway provide a substantial north-south freight route. Major freight activity precincts near the study area include the Beresfield industrial area and Tomago industrial area, as shown in **Figure 7-8**. Other freight activity precincts include Newcastle, Port of Newcastle, Newcastle Airport and Williamtown RAAF Base. **Figure 7-8** displays the approved B-Double routes within and surrounding the study area.

Heavy vehicles contribute up to 26 per cent of daily traffic volumes, and there are higher percentages south of the project from the M1 Pacific Motorway to the Pacific Highway at Hexham (**Figure 7-3**).

The southbound Hexham Bridge is restricted from access by oversize overmass (OSOM) vehicles larger than 6.5 metres wide and/or 5.2 metres high due to the nature of the bridge design. The southbound bridge also has a load limitation which does not allow for vehicles over 68 tonnes. As a result, the southbound bridge does not provide access for higher productivity vehicles (PBS Class 2B vehicles up to 30 metres long and 90.5 tonnes in mass), as well as some OSOM vehicles from the adjacent Tomago industrial area and areas further away. A permit to travel contraflow over the northbound bridge at Hexham may be required for OSOM vehicles.

The New England Highway between Hexham Bridge and Weakleys Drive has restrictions on vehicles exceeding 3.2 metres wide or 22.0 metres long, they are not permitted to travel between 7:00am and 9:00am and 4:00pm and 6:00pm Monday to Friday. The Pacific Highway between Hexham and Raymond Terrace also has numerous restrictions on OSOM vehicles. Vehicle combinations exceeding 3.2 metres wide or 22.0 metres long must contact the Transport Pacific Highway Coordinator at least 48 hours prior to travel to gain access to the road network.

Freight rail

The Main North Rail Line supports the haulage of coal between 35 coal mines located in the Hunter Valley and the Port of Newcastle for export, known as the Hunter Valley Coal Chain. This infrastructure is owned by RailCorp and managed by the Australian Rail Track Corporation (ARTC). Collectively the Hunter Valley Coal Chain facilitates about 22,000 train movements per year, which equates to 60 train movements per day. In the study area, freight trains run on two dedicated tracks (one towards and one away from the Port of Newcastle). Coal trains are separated from passenger trains, while general cargo/container trains share tracks with passenger trains.

The Hexham Train Support Facility servicing Aurizon coal trains is located to the west of the Main North Rail Line, partially within the study area. The Hexham Train Support Facility is consistent with the ARTC strategy of continuous improvement associated within the Hunter Valley Corridor Capacity Strategy which would reduce reliance on the existing and future road network.

7.3.7 Walking and cycling

Limited pedestrian infrastructure exists within the operational footprint. Existing infrastructure includes footpaths on some local roads and signalised pedestrian crossings at the Pacific Highway and Tomago Road intersection.

There are no existing dedicated cycle paths within the within the operational footprint, therefore cyclists use the shoulders of the existing road network. Inter-regional movement is facilitated on road shoulders on the M1 Pacific Motorway, New England Highway/Maitland Road and Pacific Highway and are classified by the Cycleway Finder V3 (Transport for NSW 2020b) as high difficulty routes. Weakleys Drive, John Renshaw

Drive and Tomago Road are also designated as high difficulty on-road routes. Anderson Drive through Beresfield and Tarro is designated as a low difficulty on-road route.

Dedicated shared paths are provided at the following locations:

- North of the existing bridge over the Hunter River (eastern side), Tomago to the intersection of Maitland Road/Old Maitland Road, Hexham (about 840 metres continuous length)
- Anderson Drive west of Byron Street, Beresfield to Glenwood Drive east of Thornton Road, Thornton (about 1.4 kilometres continuous length)
- Pacific Highway north of Motto Lane, Heatherbrae to Swan Street south of Sturgeon Street, Raymond Terrace (about 2.5 kilometres continuous length).

A marked cycle lane is provided on New England Highway in the southbound direction between the exit-ramp to the existing bridge over the Hunter River and the intersection with the Pacific Highway. The recent upgrade to the M1 Pacific Motorway and Weakleys Drive intersection provides painted shoulders for cyclists and designates crossing locations.

Cyclists use the existing road shoulders and traffic lanes to travel through the area. These include connections along:

- The M1 Pacific Motorway
- The New England Highway
- Weakleys Drive
- Anderson Road
- John Renshaw Drive
- Shortland to Tarro shared path
- Hexham to Kurri Kurri.

The following dedicated off road cycleways are proposed by the City of Newcastle (2020):

- Richmond Vale Rail Trail
- Shortland to Tarro shared path: ultimately providing links to Minmi and the proposed Richmond Vale Rail Trail.

The current cycle network in the study area is predominantly on high difficulty on-road routes. The current cycle network in the study area is further described in the Traffic and Transport Working Paper (**Appendix G**).

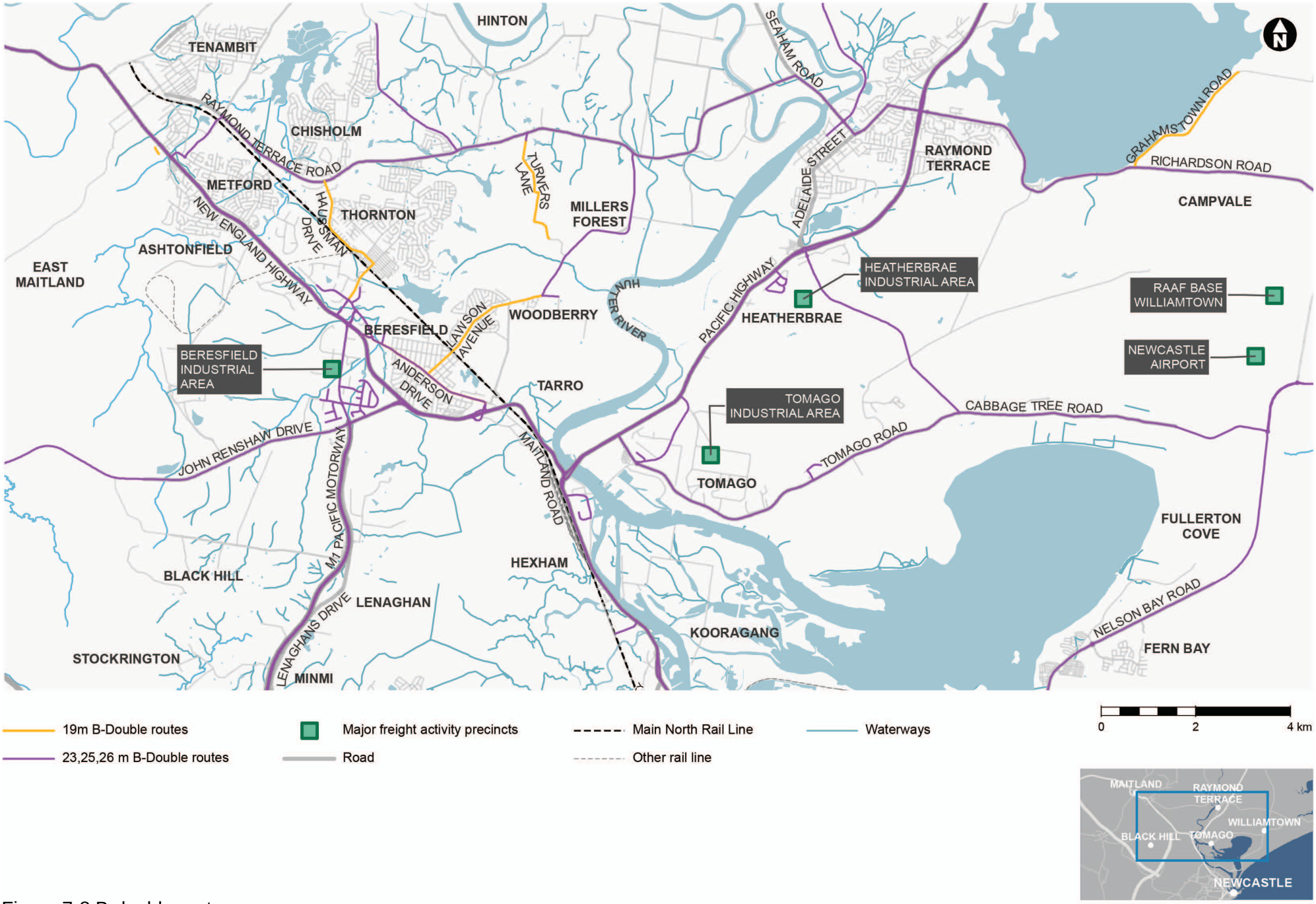


Figure 7-8 B-double routes

7.3.8 Maritime traffic

The Hunter River is a major river in NSW running between Newcastle and Liverpool Range in NSW. Within the study area is a navigable channel used by both commercial and recreational users.

The Hexham Bridge (northbound and southbound) passes over the Hunter River within the study area. The old Hexham Bridge carries southbound traffic and is a steel truss bridge with a central lifting span. While down it has a clearance height of 4.7 metres. The newer northbound bridge which carries northbound traffic has a fixed 10 metre clearance height. About eight trawlers regularly use the area, larger vessels can be booked for the bridge to be lifted providing greater clearance. The bridge is raised about 120 times per year and is also closed for bi-annual maintenance. When the bridge is raised, southbound traffic over the bridge is temporary stopped for approximately five minutes.

7.3.9 Traffic growth and future land use

Traffic volumes were extracted from Transport's traffic volume viewer for four traffic counting stations within the study area to complement the count data and the average annual daily traffic (AADT) for each year. The results indicate that historically traffic has experienced an increase of about two to three per cent each year. However, the data displays a reduction in traffic growth since 2015, with the rate of increase reducing to about one per cent AADT growth.

As described in **Section 3.1**, the study area is covered by the Hunter Regional Plan 2036 (DPE 2016) and Greater Newcastle Metropolitan Plan 2036 (DPE 2018), which outlines the future land use vision for the Hunter and Greater Newcastle areas.

Beresfield and Black Hill are proposed to be a freight and logistics hub, with complementary manufacturing and light industrial activity. Three precincts are identified within this location, including:

- Beresfield Precinct, which will support freight and logistics, manufacturing and other light industrial uses
- Emerging Black Hill Precinct, located west of the M1 Pacific Motorway, which is proposed to be the subject of a master plan that considers freight and logistic uses, the adjoining former mine site and road access to John Renshaw Drive
- Thornton Precinct, which is proposed to support expanded business and light industrial uses.

Tomago is proposed to be an advanced manufacturing and industrial area. Local planning for the Tomago Industrial Precinct would look to enable the efficient movement of goods by protecting freight routes connecting Tomago to Newcastle Airport and Port of Newcastle. The Tomago Shipbuilding Precinct located next to the Hunter River is identified as a location to promote the development of shipbuilding industries that maximise opportunities to secure defence contracts.

The Emerging Black Hill Precinct would be a major traffic generating development within the study area and is located south of John Renshaw Drive and west of M1 Pacific Motorway. The development is about 300 hectares of net development area, which is expected to generate substantial traffic volumes onto the adjacent road network. The Emerging Black Hill Precinct has been included in the traffic modelling for future horizon years (2028, 2038 and 2048). The development is a key generator of traffic in the region for future horizon and accounts for about 11 per cent of all trips in the study area by 2038 and 12 per cent by 2048.

7.4 Assessment of potential construction impacts

This section describes the construction traffic impacts that would result from the construction activities, indicative program and ancillary facilities described in **Chapter 5**.

7.4.1 Construction traffic

Construction of the project is expected to begin in 2023 and end in 2028, with work occurring across the full length of the construction footprint during this period.

Construction workforce travel

The size and composition of the construction workforce would vary over the duration of construction depending on the activities carried out and the construction program and staging. The workforce is expected to peak at about 1050 workers per year, including construction workers and professional and administrative staff. Multiple work crews may construct the project at any one time.

Construction staff would have parking available at the main compound with 200 spaces and satellite compounds with 40 spaces. Personnel would be advised of suitable parking arrangements as part of the compulsory project induction and would be encouraged to carpool.

It is expected that all construction workers would park within the construction footprint and therefore not impact on existing parking arrangements within the study area.

Construction work hours

The recommended standard hours for construction as noted in the Interim Construction Noise Guideline (DECC 2009a) are:

- 7am–6pm Monday to Friday
- 8am–1pm on Saturdays
- No work on Sundays.

There are some situations where construction may need to be carried out outside of the recommended standard construction hours. As the majority of work would be away from residences and sensitive receivers (particularly north of Tarro), Transport is seeking approval for standard construction hours plus:

- An extra hour at the start and end of each day Monday to Friday
- An extra five hours on a Saturday
- Work on Sunday and public holiday from 7am–5pm.

This is referred to as ‘extended construction hours’ and would apply across the project. Transport would carry out targeted consultation with affected residents before work starts.

Transport aims to achieve a balance between amenity and more efficient delivery of major infrastructure upgrades. As a result, Transport is investigating opportunities for ensuring delivery of the benefits of the project as soon as possible. Early completion of construction would provide considerable benefits to the community and road users. In particular, extended working hours would:

- Reduce the volume of traffic on roads during peak hours due to construction staff and construction vehicles travelling to and from the construction site outside of peak traffic periods
- Time benefits, including potentially bringing forward the opening date for the project by increasing the allowable construction hours

- Cause less disruption to sensitive receivers, the community, local business, motorists, pedestrians and cyclists as work would be completed earlier than compared to adopting standard work hours
- Enable greater flexibility in project scheduling. This would enable the contractor to make allowances for adverse weather and potential flooding events.

The proposed extended construction hours would only apply to normal construction activities. If required, blasting would only be carried out Monday to Friday between 9am–5pm and Saturday between 9am–1pm.

Out-of-hours work

The Interim Construction Noise Guideline (DECC 2009a) also recognises there are some situations where specific construction work may need to be carried out outside the recommended standard hours.

In addition to standard working hours and extended construction hours, some construction activities would need to be carried out during evening and night time periods (referred to as 'out-of-hours work'). The activities that may need to be carried out out-of-hours include:

- Delivery of plant and materials that is required outside construction work hours as requested by police or other authorities for safety reasons (e.g. oversized deliveries)
- Installation of traffic controls, such as concrete barriers
- Traffic switches between each construction phase
- Operation of concrete and asphalt batching plants within ancillary facilities
- Resurfacing of asphalt pavement on existing roads and concrete and asphalt pouring
- Construction work interfacing with the M1 Pacific Motorway, New England Highway and the Pacific Highway, including construction of overbridge piers for the M1 Pacific Motorway entry and exit ramps and ramp tie-ins with the M1 Pacific Motorway, cross drainage below existing roads, pavement, surfacing, line markings, kerbs and traffic islands, traffic signs and signals
- Short-term traffic diversions along the existing road network (M1 Pacific Motorway, New England Highway, John Renshaw Drive, Masonite Road, and the Pacific Highway)
- Bridge construction work over the Main North Rail Line and existing roads including the New England Highway, Pacific Highway and Old Punt Road traffic along existing road networks (including establishing temporary protection work, installation of girders, sealing of joints, establishing temporary screens to enable construction to continue on the deck, and removal of temporary work)
- Utility modifications, relocations or protection measures work
- Removal of existing static signage and installation of new signs
- Removal of existing traffic barriers and installation of temporary and permanent traffic barriers
- Removal of existing lane marking and application of new lane marking on existing roads
- Any work that does not cause noise emissions to be audible at any sensitive receiver
- Emergency work to avoid the loss of lives, property and/or to prevent environmental harm.

Out-of-hours construction activities would be supported by out-of-hours operation of temporary ancillary facilities.

The exact timing of out-of-hours work would depend on construction activities, construction techniques and constraints imposed by the affected communities or the relevant authorities (utility authorities or road/motorway operators) and would be subject to the requirements of the construction contractor.

The potential construction noise and vibration impacts are presented in **Chapter 8** (noise and vibration). Extended and out-of-hours work would be managed through the implementation of a Construction Noise and Vibration Management Plan which would include feasible and reasonable mitigation measures to minimise the potential for adverse impact on the local community.

Haulage routes and use of the existing road network

The majority of the project would be constructed from the existing road network, with many of the construction traffic movements not anticipated to impact traffic on existing roads, except at access points. **Figure 5-25** shows the haulage routes that would be used during construction.

Where construction traffic movements are unable to be confined to the construction footprint, the existing road network would be used. Where possible, heavy vehicle movements would primarily use state roads including the M1 Pacific Motorway, Pacific Highway and New England Highway, however there may be other roads that could be used by the project, including:

- Medowie Road
- Masonite Road
- Old Punt Road
- Anderson Drive
- Aurizon access road
- Woodlands Drive
- Woodbury Road
- Adelaide Street
- Seaham Road.

Impacts of construction activities and movements on pedestrians and cyclists are discussed in the section below. Further, extended and out-of-hours work would be managed through the implementation of a Traffic Management Plan and a Construction Noise and Vibration Management Plan which would include feasible and reasonable mitigation measures to minimise the potential for adverse impact on the local community.

Ancillary facilities

Twenty-one ancillary facilities have been identified along the length of the project (**Figure 5-1**) and potential functions (including accesses and indicative construction worker parking locations) are discussed in the Traffic and Transport Working Paper (**Appendix G**). For the purposes of this assessment, it is assumed that all ancillary facilities would be used for construction purposes. This assessment is expected to be conservative as not all sites would necessarily be used for construction, and not all sites would be functioning at all times over the construction period. It is expected that all construction workers would park within the construction footprint and therefore not impact on existing parking arrangements within the study area.

Access points at each of the ancillary facilities frontages would be provided with adequate sight distances relating to the posted speed limit. This would allow vehicles on the road network to see vehicles exiting from the ancillary facilities and would allow sufficient room to slow down and stop if necessary. This approach would also provide vehicles waiting to exit from the ancillary facilities with adequate sight distance to see approaching vehicles and determine acceptable gaps. It should be noted that ancillary facilities are generally connected, which would mean that construction traffic movements may fluctuate as they move between sites internally.

Construction traffic movements

The most substantial contribution to additional vehicle movements on the existing road network would occur at access points to the ancillary facilities and at roads being used for haulage. As shown in **Table 7-8**, about 2,800 daily vehicle movements are anticipated to support construction, comprising about 1,300 daily heavy vehicle movements and about 1,500 light vehicle movements. While no construction vehicle movements have been estimated for construction activities outside standard construction hours, they are anticipated to be below the peak hour movement numbers listed in **Table 7-8**.

Table 7-8 Daily construction traffic movement numbers (in and out)

Ancillary facility	Heavy vehicles		Light vehicles		Total vehicles	Peak hour total vehicles
	Daily	Peak	Daily	Peak		
AS1	26	3	46	4	72	7
AS2	64	6	46	5	110	11
AS3	210	21	154	15	364	36
AS4	42	4	10	1	52	5
AS5	54	5	46	5	100	10
AS6	0	0	46	5	46	5
AS7	128	13	154	15	282	28
AS8	0	0	46	5	46	5
AS9	90	9	46	5	136	14
AS10	108	11	154	15	262	26
AS11	50	5	46	5	96	10
AS12	70	7	46	5	116	12
AS13	156	16	46	4	202	20
AS14	24	2	46	5	70	7
AS15	38	4	10	1	48	5
AS16	128	13	154	15	282	28
AS17	12	1	154	16	166	17
AS18	34	3	10	1	44	4
AS19	18	2	154	15	172	17
AS20	40	4	10	1	50	5
AS21	26	3	46	4	72	7
Total	**1,318**	**132**	**1470**	**147**	**2788**	**279**

Construction traffic on the existing road network

The majority of the access points at each of the ancillary facilities are left in/left out arrangements with dedicated deceleration and acceleration lanes. The exceptions are AS8, which uses an existing u-turn lane on Maitland Road, and AS4 and AS5, which connect to low volume roads (Quarter Sessions Road and Aurizon access road respectively).

While the majority of construction traffic movements would occur within the construction footprint, away from existing roads, construction traffic on the existing road network is expected to be mainly from transportation of fill, delivery of pre-cast elements and materials to on-site batch plants as well as concrete and asphalt from on-site or nearby batch plants. Construction traffic would also include trucking contaminated material or dewatering discharge offsite. Vehicles delivering pre-cast concrete elements for the main viaduct, interchanges and bridges could be oversize, overmass, or both. Oversize and overmass

vehicles are likely to be escorted and travel at slower speeds than other vehicles on the existing road network.

Based on the existing traffic volumes on roads within the study area (refer to **Table 7-4**), the low number of peak hour construction traffic movements (on average 132 heavy vehicles and 147 light vehicles) and that the majority of the ancillary facilities are accessed via dedicated left in/left out arrangements, minimal delays and queuing to the surrounding network are anticipated as a result of construction traffic accessing ancillary facilities.

Temporary changes to the road network during construction

To accommodate construction activities and delivery of materials to various sites across the project, the following temporary traffic intersections are proposed at the following locations:

- New England Highway eastbound exit ramp at Tarro
- Aurizon access road at Tarro
- Anderson Drive at Tarro
- Tomago Road intersection with the Pacific Highway at Tomago
- Old Punt Road intersection with the Pacific Highway at Tomago
- Masonite Road
- Temporary turn provisions (possibly including acceleration and deceleration lanes) for entry and exit to ancillary facilities across the entire project.

The temporary intersections would improve direct access and connectivity for construction activities while reducing delays to general traffic by removing unnecessary heavy vehicle movements. These temporary traffic intersections would be subject to final design, construction staging and contractor usage of ancillary facilities.

Generally, during construction, traffic switches would occur within adjacent carriageways between each stage. However, construction also involves changes to traffic conditions such as alternate-flows which may pose a risk to motorists if appropriate controls such as temporary signage and line markings are not properly implemented. Temporary short-term diversions, road closures and temporary traffic intersections may be required to support construction. Additionally, where temporary pavement is required to be constructed close to existing traffic lanes, construction is likely to impact existing traffic including speed limit reductions, lane closures, traffic switches and temporary lane configurations. To minimise disruptions, some sections of temporary pavement could be constructed out-of-hours**.** Where possible, shoulders would be temporarily narrowed to provide adequate working width for the work, which may result in a reduction in speed limits.

Key impacts associated with the use of temporary pavements are expected to be associated with the tie ins with the existing road network. Depending on sight distance, clearances and pavement geometry, speed limits may need to be reduced in the vicinity of the temporary pavement. These speed limit reductions may result in temporary and localised traffic delays.

7.4.2 Impact on property access

During construction, access to properties near to construction work would be maintained although temporary changes may be required for some properties at Black Hill, Hexham, Tarro, Tomago, Heatherbrae and Raymond Terrace. This includes required adjustments to existing tracks and trails for utility infrastructure and associated easements.

These properties may require alternate access strategies during construction. Where the project severs existing access tracks, (including fire trails) turnaround facilities would be provided on access tracks to allow vehicles to turn around or alternate access to the road network would be provided. Access tracks and driveway adjustments would be confirmed during detailed design and consultation with property owners.

Access to all existing and proposed infrastructure for maintenance purposes would be provided by maintaining existing access and easement arrangements where possible or developing alternative maintenance access arrangements where required.

Access to roads and properties being impacted and managed during construction include:

- Aurizon access road, serving multiple properties
- Access to TransGrid easement in Black Hill and Tomago
- Access to Hunter Water Corporation utilities and property at Tarro and Heatherbrae
- Private property at Tarro, west of the new Tarro interchange
- Access across the future Newcastle Power Station proposed by AGL at Tomago
- Access to the Hunter Region Botanic Gardens
- Access to the existing forestry plantation north of Masonite Road.

The above changes to access would be managed throughout construction and become permanent changes once the project is completed.

Further information on property access impacts during construction are discussed in the Traffic and Transport Working Paper (**Appendix G**).

Permanent access changes that would continue during operation of the project are further discussed in **Section 7.5.7**.

7.4.3 Other transport modes

Public transport

As described in **Chapter 5**, three bus stops on the Pacific Highway would be temporarily relocated during construction. No bus routes would be impacted by the construction of the project, as bus routes travelling within the construction footprint would travel on temporary diversions as necessary in consultation with affected bus operators.

Pedestrians

As described in **Chapter 5**, pedestrian volumes within the construction footprint are anticipated to be very low given the lack of pedestrian infrastructure (refer to **Section 7.3**). No separated walking and cycling paths would be impacted as a result of the project. Pedestrian traffic management will be implemented as part of the Traffic Management Plan and associated traffic control plans. As a result, impacts to pedestrians during construction of the project are considered to be minor.

Cyclists

No existing cycle routes would be impacted by construction of the project. The proposed Shortland to Tarro shared path would be intersected by the project with a possible diversion to the realigned Aurizon access road. Where practical, minimum two metre shoulders have been adopted during construction to minimise disruption to cyclists. However, shoulders would be reduced at the Tarro interchange. Measures to maintain cyclist access (including communication, signage and alternative routes) will be implemented as part of the Traffic Management Plan and associated traffic control plans.

Rail

The viaduct (B05) would be constructed over the Main North Rail Line. Track possessions would be used to establish temporary protection work and to install the precast bridge girders over the rail line. Pre-defined periods of track work would be used for such activities to minimise the impact on the rail network. There would be minimal impact to rail infrastructure at Hexham as the construction contractor would likely work in and around ARTC shutdowns to construct over the rail. Impact to rail operations from project construction are expected to be negligible.

Maritime traffic

While it is not anticipated that large scale dredging of the Hunter River would be required, localised dredging may be necessary within the construction footprint at the temporary wharf locations, to support viaduct construction and/or to provide sufficient draft for the barges at localised low areas of the Hunter River.

The construction contractor would manage barge movements to ensure that the impacts on inbound and outbound marine traffic are minimised. In addition, a navigational channel would be kept open during construction. As such, impacts on maritime traffic during construction are anticipated to be low and manageable.

Given the Port of Newcastle is over 15 kilometres south east of the project, there would also be no impact on the functionality of the port during construction.

7.5 Assessment of potential operation impacts

7.5.1 Road network performance

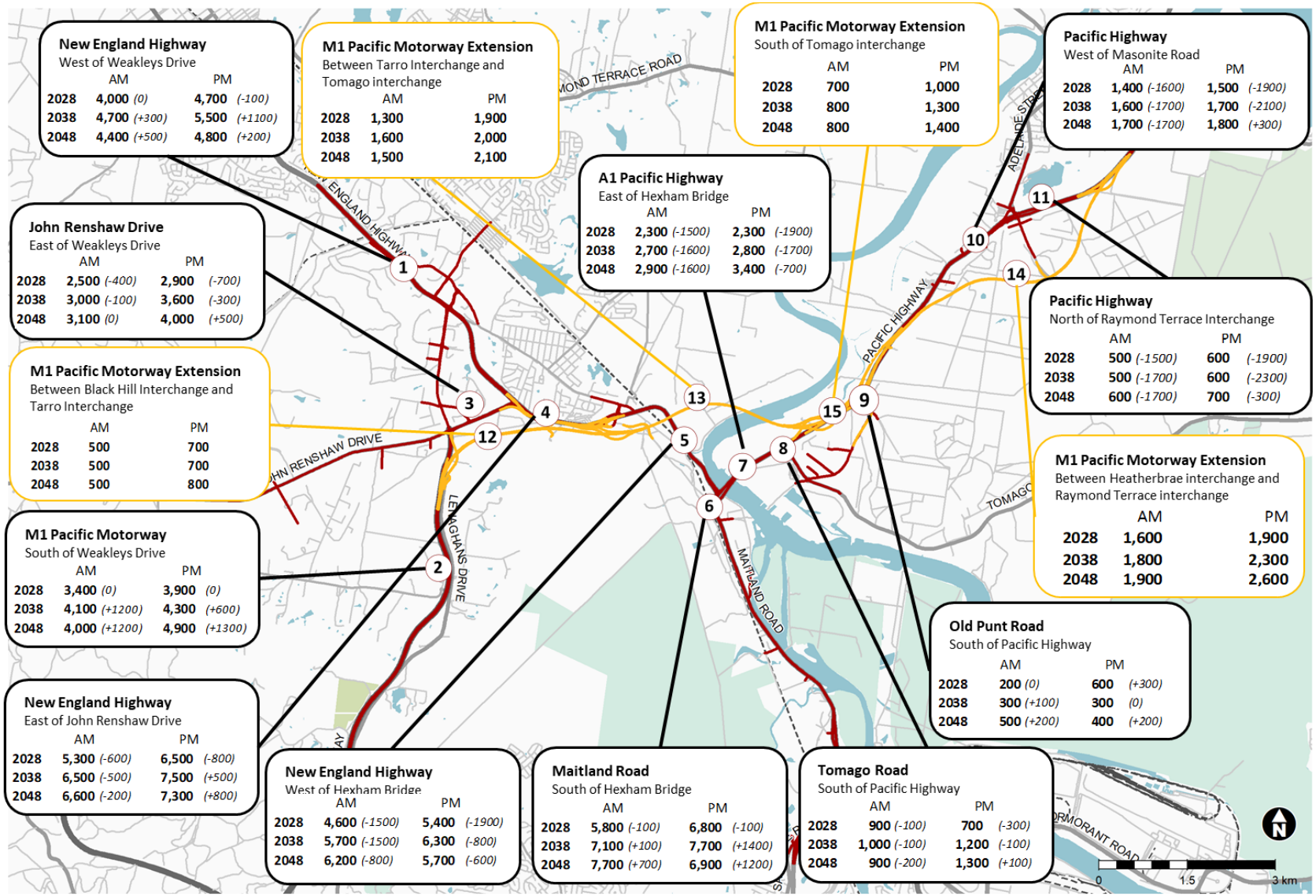
Traffic volumes

Modelled peak hour and daily 'with project' traffic volumes for 2028, 2038 and 2048 are presented in **Figure 7-9** and **Figure 7-10**. The figures display the peak hour traffic volumes in bold and the change in traffic volume from the 'without project' model is provided in brackets.

Analysis of the modelled traffic flows in 2028, the anticipated year of opening the project, in the 'with project' scenario shows the following key differences throughout the network:

- The New England Highway to the west and the Pacific Highway to the east of the existing Hexham Bridge would likely see substantially reduced traffic flow as a result of the project. These locations are expected to experience a reduction in traffic flow between about 20 to 45 per cent
- Substantial reductions in traffic flows are likely on John Renshaw Drive east of Weakleys Drive, with a reduction of up to 13 per cent in the morning peak (8-9am) and 19 per cent in the evening peak (5-6pm)
- The largest reduction in traffic is expected to occur on Pacific Highway west of Masonite Road, which is likely to experience about a 50 per cent reduction in traffic flow in both peak periods. The project would result in a shift in traffic flow from the Pacific Highway to the project, reducing traffic through Heatherbrae
- The volume of traffic travelling on Old Punt Road would increase in the evening peak period (about a 109 per cent increase) as a result of the project. As shown in **Table 7-12** to **Table 7-14**, the project would result in an improvement in level of service for the intersections along Old Punt Road. This outcome would be expected to occur due to the improved connectivity to the project. This increase in traffic on Old Punt Road correlates with a decrease in traffic travelling on Tomago Road, as the improved connectivity from Old Punt Road provides an alternative route for vehicles.

Analysis of the 2038 and 2048 volumes show a similar pattern with a reduction in daily traffic on John Renshaw Drive, New England Highway and Pacific Highway, as well as an increase in traffic on the existing M1 Pacific Motorway south of Weakleys Drive. This increase is expected as the project provides greater capacity for north and southbound traffic which reduces the unreleased trips (trips where vehicles which are unable to enter the modelled network due to congestion) that occur in the 'without project' traffic model.



Legend

Count location

Year **With Project modelled volume** (Change in volume from 'without project' model)

Figure 7-9 Modelled peak period traffic volumes (8–9am and 5pm–6pm)

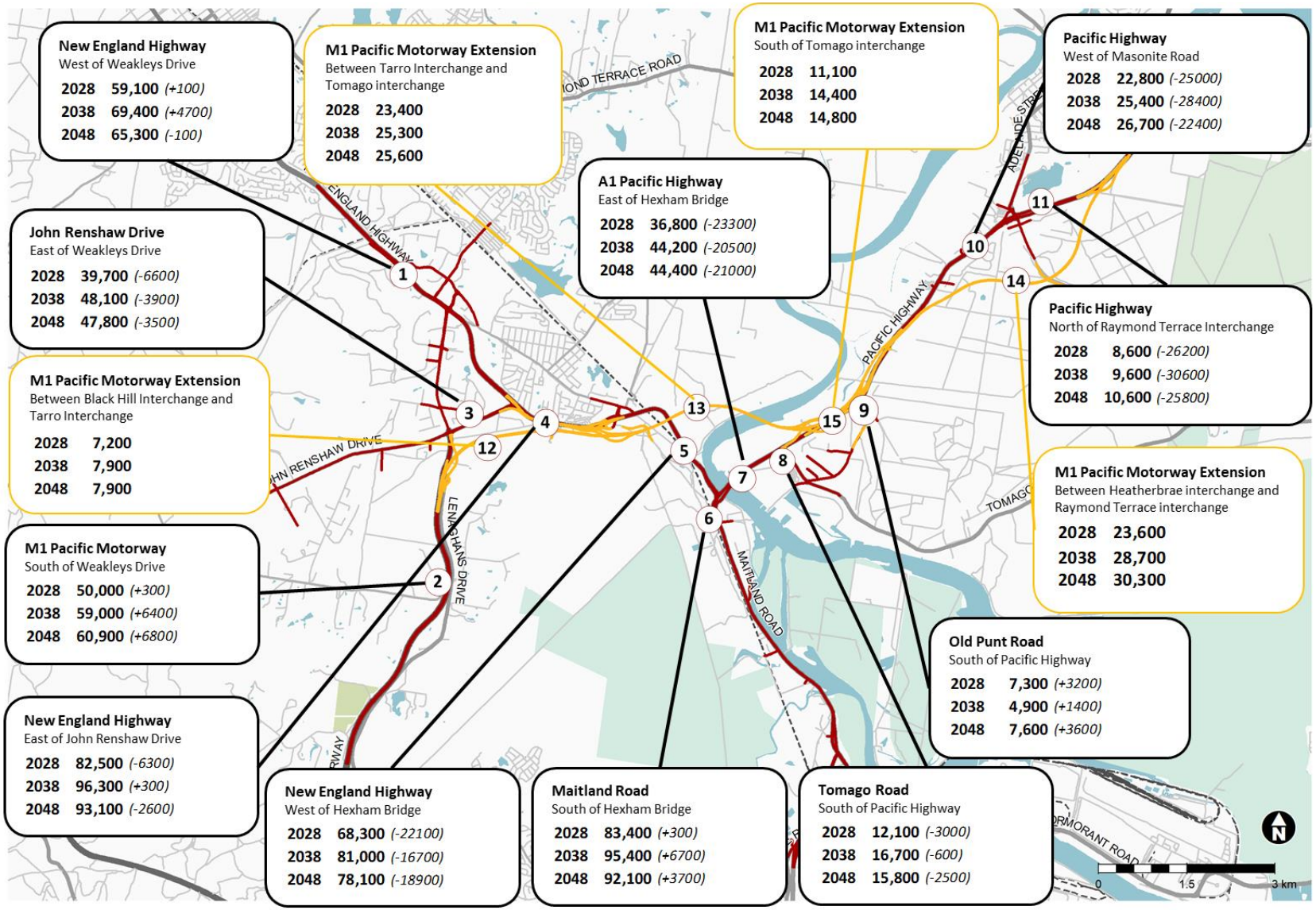


Figure 7-10 Estimated daily traffic volumes

7.5.2 Travel time performance

A comparison between the travel times modelled in the 'without project' and 'with project' indicates that the project substantially improves overall travel times for both the morning and evening peaks across all future modelled years. Travel time improvements on key routes are shown in **Table 7-9** and **Table 7-10**.

Table 7-9 Travel time improvements for key routes across the project (morning peak)

Origin	Destination	2028			2048		
		Travel time without project	Travel time with project	Time saved	Travel time without project	Travel time with project	Time saved
M1 Pacific Motorway	Pacific Highway	20:35	11:32	9:03	55:53	17:41	38:12
	Maitland Road	21:11	16:34	4:37	59:07	33:24	25:43
Pacific Highway	M1 Pacific Motorway	19:05	11:34	7:31	31:13	11:40	19:33
	New England Highway	15:52	10:10	5:42	24:03	10:20	13:43
	Maitland Road	17:24	14:00	3:24	24:35	19:55	4:40
Maitland Road	Pacific Highway	16:37	13:55	2:42	18:03	15:00	3:03

Table 7-10 Travel time improvements for key routes across the project (evening peak)

Origin	Destination	2028			2048		
		Travel time without project	Travel time with project	Time saved	Travel time without project	Travel time with project	Time saved
M1 Pacific Motorway	Pacific Highway	21:17	11:32	9:45	37:53	19:50	18:03
	Maitland Road	20:26	16:49	3:37	44:23	29:22	15:01
Pacific Highway	M1 Pacific Motorway	21:04	11:29	9:35	1:08:50	30:21	38:29
	New England Highway	17:58	10:16	7:42	1:07:05	38:09	28:56
	Maitland Road	16:07	13:37	2:30	1:06:21	30:11	36:10
Maitland Road	Pacific Highway	16:21	14:27	1:54	47:20	26:43	29:37

During the morning peak, travel times for most origin and destination combinations would likely reduce as a result of the project when compared with the 'without project' scenarios. Key morning peak hour outcomes include:

- Travel times along the road corridor between Black Hill and Raymond Terrace would reduce by about 39 to 74 per cent. In 2048, this improvement in travel time equates to a saving of about 30 minutes per vehicle
- The project would result in a reduction of about 35 to 60 per cent in travel times from the New England Highway at the western edge of the study area to Pacific Highway at the eastern edge of the study area. These improvements equate to a travel time saving of about 15 minutes per vehicle in 2048
- Travel times from the Pacific Highway to the New England Highway and the M1 Pacific Motorway would reduce by at least 36 per cent in 2028 and by about 60 per cent in 2048. In 2048, this improvement in travel time equates to a saving of 15 to 20 minutes per vehicle
- Improved travel times to and from Maitland Road, as travel times from and to key locations would be reduced by greater than 22 per cent in each of the future horizon years.

The evening peak hour results indicate travel times for most origin and destination combinations are likely to decrease as a result of the project when compared with the 'without project' scenarios. This is consistent for all the future years modelled. Key evening peak hour outcomes include:

- Travel times along the road corridor between Black Hill and Raymond Terrace would reduce by about 46 to 72 per cent. In 2048, this improvement in travel time equates to a saving of about 35 minutes per vehicle
- The project would result in about a 28 to 64 per cent reduction in travel times from the New England Highway at the western edge of the study area to Pacific Highway at the eastern edge of the network. These improvements equate to a travel time saving of about 15 minutes per vehicle in 2048
- Travel times from the Pacific Highway to the New England Highway and the M1 Pacific Motorway would reduce by at least 45 per cent in 2028 and about 42 per cent in 2048. In 2048, this improvement in travel time equates to a saving of 30 minutes per vehicle
- The project also improves travel times between Maitland and key locations with a reduction by greater than 12 per cent in each of the future horizon years.

When sensitivity modelling was carried out for the scenarios noted in **Section 7.2.4** for the Emerging Black Hill Precinct with an alternate access or with no traffic generated from the future proposed site, delays across the road network were reduced, which would correlate to improved travel times across the network.

These improvements would substantially reduce travel times between Newcastle, Raymond Terrace, Maitland and other regional industrial areas. Furthermore, the project would provide key infrastructure for movements along the eastern coast of Australia, improving travel time and travel time reliability between Brisbane in the north and Melbourne and Sydney. It is anticipated that travel times in off peak periods and holiday periods between Maitland and Raymond Terrace, and between Black Hill and Raymond Terrace would also markedly improve as vehicles can travel less distance at consistently higher speeds without the traffic signals interrupting traffic flow.

Further comparison between the travel times from 'without project' and 'with project' scenarios is presented in the Traffic and Transport Working Paper (**Appendix G**).

7.5.3 Network statistics

A comparison of network statistics between the 'without project' and 'with project' scenarios for horizon years (2028, 2038 and 2048) are provided in **Table 7-11**. Comparison of the 'without project' and 'with project' scenarios for the horizon years indicates that:

- In 2028, there is a substantial increase in average network speed, particularly during the evening peak period with the forecast average network speed is likely to increase by 10 per cent. This is accompanied by a slight increase in vehicle throughput
- In 2038, a substantial improvement in the operational performance of the road network is likely. Up to an additional nine per cent of vehicles can complete their trips within the modelled period. The forecasted average network speed is likely to increase by 17 per cent in the morning peak and 31 per cent in the evening peak
- In 2048, substantial improvement in the operational performance of the road network is likely, particularly during the evening peak period. Forecast average network speed is likely to increase by 22 per cent in each of the peak periods.

Overall, the key network statistics demonstrate the project would provide positive outcomes for the performance of the road network in each of the modelled scenarios. The project results in a more efficient road network, that can cater to a higher volume of vehicles, while also maintaining faster travelling speeds for motorists. More detailed network statistic outputs are provided in the Traffic and Transport Working Paper (**Appendix G**).

Table 7-11 Network speed for horizon years (2025, 2038, 2048)

Year	Network statistic	Morning peak		Evening peak	
		Without project	With project	Without project	With project
2028	Total throughput (vehicles)	42,801	42,927	47,787	48,048
	Network speed (km/h)	59	64	55	61
2038	Total throughput (vehicles)	48,673	50,362	50,993	55,620
	Network speed (km/h)	45	53	37	49
2048	Total throughput (vehicles)	50,361	53,037	51,081	56,924
	Network speed (km/h)	35	43	29	37

7.5.4 Intersection performance

The operational performance at key intersections within the network is presented in **Table 7-12** to **Table 7-14**. LoS D is generally the accepted target performance level. Cells with pink shading represent intersections where performance is worse than LoS D.

Analysis of the modelled intersections shows that the project would result in the following key differences in intersection performance at the following locations:

- **New England Highway/ Pacific Highway/Maitland Road intersection**: The project would substantially improve the performance of this intersection during the evening period as vehicles travelling on the New England Highway between Tarro and Tomago would reroute to the project. This is most evident in the 2038 evening model, under 'without project' conditions, as the intersection operates

at a LoS E. When modelled with the project, the intersection operates as a satisfactory LoS D. The project markedly reduces the traffic demand for the right turn movement from the Pacific Highway to the New England Highway. This substantially reduces the overall demand at the intersection and would enable the reallocation of green time to other movements at the intersection, ultimately improving the performance of the intersection

- **Pacific Highway/Masonite Road**: The project provides a bypass of Heatherbrae, which substantially reduces the traffic demand and throughput at the Pacific Highway/Masonite Road roundabout. The reduction in demand is evidenced in the evening peak in both 2038 and 2048, as the intersection improves from operating at LoS E (in 2038) and LoS F (in 2048) to LoS A in both years as a result of the project
- **M1 Pacific Motorway/Weakleys Drive/John Renshaw Drive intersection**: The project would improve the performance of this intersection, as traffic travelling to or from the east of the model extent would reroute to use the project in 2028. However, the intersection is expected to perform at LoS E from 2038 onwards
- **Intersections along the Pacific Highway between Maitland Road and Masonite Road** would improve in performance. This is particularly noticeable in the 2038 and 2048 horizon years when flows on the Pacific Highway are forecast to exceed the capacity of these intersections. Removal of the east-west movements along this section of the Pacific Highway improves the performance of the Maitland Road and Masonite Road intersections with Pacific Highway and reduces volumes to within the road's capacity.

The high volume of vehicles generated from the Emerging Black Hill Precinct contributes substantially to the poor performance of the M1 Pacific Motorway/Weakleys Drive/John Renshaw Drive intersection at Black Hill in future years. The sensitivity modelling results where the Emerging Black Hill Precinct is not constructed show the operation of the M1 Pacific Motorway/Weakleys Drive/John Renshaw Drive intersection is substantially improved. Vehicle delays at the intersection were almost halved and operating LoS improved from LoS F in both peak periods to a LoS D in the morning peak and LoS E in the evening peak.

Table 7-12 Performance of modelled intersections in 2028

Intersection	Type	2028 'without project'				2028 'with project'			
		8-9am		5-6pm		8-9am		5-6pm	
		Avg delay (sec)	LoS	Avg delay (sec)	LoS	Avg delay (sec)	LoS	Avg delay (sec)	LoS
M1 Pacific Motorway/ Weakleys Drive/ John Renshaw Drive, Black Hill	Signalised	83	F	93	F	60	E	62	E
New England Highway/ Weakleys Drive, Beresfield	Signalised	18	B	20	B	28	C	33	C
New England Highway/ Maitland Road/ Pacific Highway	Signalised	18	B	48	D	23	C	30	C
Pacific Highway/ Tomago Road, Tomago	Signalised	18	B	18	B	17	B	15	B
Pacific Highway/ Old Punt Road, Tomago	Signalised	10	A	9	A	5	A	5	A

Intersection	Type	2028 'without project'				2028 'with project'			
		8-9am		5-6pm		8-9am		5-6pm	
		Avg delay (sec)	LoS	Avg delay (sec)	LoS	Avg delay (sec)	LoS	Avg delay (sec)	LoS
Old Punt Road/ Tomago Road, Tomago	Roundabout	4	A	3	A	3	A	5	A
Pacific Highway/ Hank Street, Heatherbrae	Signalised	12	B	10	B	11	B	9	A
Pacific Highway/ Masonite Road, Heatherbrae	Roundabout	8	A	17	B	3	A	4	A

* Cells with pink shading represent intersections where performance is worse than LoS D

Table 7-13 Performance of modelled intersections in 2038

Intersection	Type	2038 'without project'				2038 'with project'			
		8-9am		5-6pm		8-9am		5-6pm	
		Avg delay (sec)	LoS	Avg delay (sec)	LoS	Avg delay (sec)	LoS	Avg delay (sec)	LoS
M1 Pacific Motorway/ Weakleys Drive/ John Renshaw Drive, Black Hill	Signalised	180	F	120	F	124	F	151	F
New England Highway/ Weakleys Drive, Beresfield	Signalised	58	E	104	F	28	C	41	D
New England Highway/ Maitland Road/ Pacific Highway	Signalised	25	C	83	F	36	D	38	D
Pacific Highway/ Tomago Road, Tomago	Signalised	19	B	101	F	18	B	15	B
Pacific Highway/ Old Punt Road, Tomago	Signalised	10	A	86	F	5	A	5	A
Old Punt Road/ Tomago Road, Tomago	Roundabout	4	A	114	F	4	A	10	A
Pacific Highway/ Hank Street, Heatherbrae	Signalised	14	B	49	D	12	B	9	A
Pacific Highway/ Masonite Road, Heatherbrae	Roundabout	9	A	62	E	4	A	5	A

* Cells with pink shading represent intersections where performance is worse than LoS D

Table 7-14 Performance of modelled intersections in 2048

Intersection	Type	2048 'without project'				2048 'with project'			
		8-9am		5-6pm		8-9am		5-6pm	
		Avg delay (sec)	LoS	Avg delay (sec)	LoS	Avg delay (sec)	LoS	Avg delay (sec)	LoS
M1 Pacific Motorway/ Weakleys Drive/ John Renshaw Drive, Black Hill	Signalised	181	F	131	F	142	F	136	F
New England Highway/ Weakleys Drive, Beresfield	Signalised	91	F	91	F	62	E	96	F
New England Highway/ Maitland Road/ Pacific Highway	Signalised	76	E	83	F	38	D	70	E
Pacific Highway/ Tomago Road, Tomago	Signalised	41	D	89	F	31	C	120	F
Pacific Highway/ Old Punt Road, Tomago	Signalised	22	C	143	F	6	A	48	D
Old Punt Road/ Tomago Road, Tomago	Roundabout	4	A	153	F	6	A	139	F
Pacific Highway/ Hank Street, Heatherbrae	Signalised	15	B	73	E	13	B	10	B
Pacific Highway/ Masonite Road, Heatherbrae	Roundabout	15	B	>200	F	4	A	5	A

* Cells with pink shading represent intersections where performance is worse than LoS D

7.5.5 Interchange analysis

A merge and diverge analysis was carried out at each proposed motorway entry and exit ramps for the project's interchanges to determine the performance of the ramp-motorway junction (merge/diverge influence area). **Table 7-15** presents the level of service in the modelled future horizon years for the proposed interchanges. In some instances, an interchange assessment could not be conducted due to nearby signalised intersections. In these cases, these assessments are represented by N/A.

Table 7-15 LoS performance of modelled interchanges

Intersection	2028		2038		2048	
	Morning peak	Evening peak	Morning peak	Evening peak	Morning peak	Evening peak
Black Hill interchange – Northbound Diverge*	N/A	N/A	N/A	N/A	N/A	N/A
Black Hill interchange – Southbound Merge	B	F	B	F	B	F

Intersection	2028		2038		2048	
	Morning peak	Evening peak	Morning peak	Evening peak	Morning peak	Evening peak
Tarro interchange – Eastbound Merge	B	B	B	B	B	B
Tarro interchange – Westbound Diverge	A	A	A	A	A	N/A*
Tomago interchange – Eastbound Merge	A	B	B	B	A	B
Tomago interchange – Westbound Diverge 1	A	A	A	A	A	A
Tomago interchange – Westbound Diverge 2	B	A	B	B	B	B
Tomago interchange – Eastbound Diverge	A	A	A	A	A	A
Tomago Interchange – Westbound Merge	A	B	A	A	A	B
Raymond Terrace interchange – Eastbound Merge	A	B	B	B	B	B
Raymond Terrace interchange – Westbound Diverge	B	B	B	B	B	B

* Due to a nearby signalised intersection or queueing upstream an interchange assessment could not be conducted at the Black Hill interchange – Northbound Diverge and Tarro interchange – Westbound Diverge
* Cells with pink shading represent intersections where performance is worse than LoS D

The Black Hill interchange southbound merge between Weakleys Drive and the M1 Pacific Motorway operates at LoS F during each of the assessed evening peak periods. This is due to the demand on the entry ramp exceeding its capacity during the assessed 15-minute peak period. The excess demand results in queueing on Weakleys Drive which extends to the M1 Pacific Motorway/Weakleys Drive/John Renshaw Drive intersection. This queueing impacts all southbound movements at the intersection and results in extensive queuing in 2038 onwards for the northern, eastern and western approaches. In 2048, the extensive queueing from the eastern approach increases in the evening peak to reach as far as the Tarro Interchange – Westbound Diverge.

Queuing from the south approach of the M1 Pacific Motorway/Weakleys Drive/John Renshaw Drive intersection does not create problems on the M1 Pacific Motorway which operates at LoS C. The M1 Pacific Motorway would continue to operate without major disruptions as the demand on the motorway is within the capacity and it is the motorway entry ramp that is constrained.

All other merges assessed across the project operate at an acceptable LoS C or better in each of the modelled scenarios, indicating that the project would experience a minimal decrease in performance due to merge points.

All diverge points assessed operate at LoS C or better in each of the modelled future horizon years. However, the Weakleys Drive northbound diverge cannot be assessed due to the influence of the downstream M1 Pacific Motorway/Weakleys Drive/John Renshaw Drive intersection. Queueing at the southern approach to this intersection extends to the northbound Weakleys Drive diverge point, causing a negative impact on the operation of the junction.

Overall, the interchange assessment shows the project would operate at LoS C or better across the modelled merge and diverge points for each of the scenarios.

Sensitivity testing

The traffic assessment carried out included the assumption that the Emerging Black Hill Precinct would be progressively developed, and the subsequent impacts of that development were included in the future operation of the road network. As a result, modelling was carried out as described in **Section 7.2.4** for two sensitivity scenarios for 2038 to quantify the impact of the Emerging Black Hill Precinct on the road network, particularly in relation to impacts to the Black Hill interchange southbound ramp to the M1 Pacific Motorway.

By 2038, it was assumed that 75 per cent of the Emerging Black Hill Precinct would be constructed. The development located south-west of the John Renshaw/Weakleys Drive intersection was found to be a major driver of traffic demand in the traffic model accounting for about 11 per cent of all traffic demand in 2038. While both scenarios modelled resulted in improvements to the performance of the road network, the sensitivity modelling identified the following under each scenario:

- Scenario 1: Black Hill Road interchange. The provision of south-facing ramps connecting Black Hill Road to the M1 Pacific Motorway was found to improve the performance of the road network, particularly during the evening peak. Improvements were evident at the M1 Pacific Motorway/Weakleys Drive/John Renshaw Drive and Black Hill interchange southbound merge, in the vicinity of the Emerging Black Hill Precinct These improvements are a result of more direct access to the site from the south, which reduces the distance travelled by vehicles accessing and departing the site. This consequently reduces the number of vehicles travelling the network surrounding the Emerging Black Hill Precinct and improved the southbound M1 Pacific Motorway ramp operation to LoS B
- Scenario 2: Sensitivity results. The sensitivity testing shows the removal of all Black Hill traffic from the 2038 road network would improve performance outcomes across the entire modelled network. There would be substantial improvements to the key network statistics along with intersection and interchange LoS improvements, with the M1 Pacific Motorway southbound ramp performance improving to LoS B. The improved outcomes are a result of less traffic demand which limits the build-up of queues and delays.

Further detail on interchange analyses, including sensitivity modelling results, is presented in the Traffic and Transport Working Paper (**Appendix G**).

7.5.6 Freight

As stated in **Section 7.3.6**, the current network has constraints for OSOM vehicles at both the southbound Hexham Bridge and at the New England Highway crossing of the Main North Rail Line. The project would provide an alternative route offering improved freight connectivity and allow free movement at these locations without the requirement for a permit.

Future land releases surrounding the study area are anticipated to substantially increase the generation of new freight movements in future years. This would be driven predominately by the Emerging Black Hill Precinct and developments around Tomago and Heatherbrae. Modelling indicates that without the project, there would be substantial congestion in the network, lengthy delays and increased travel times apply for all vehicles including freight.

Routes from the Pacific Highway (Sandgate) to both the New England Highway (Beresfield) and the M1 Pacific Motorway (Black Hill) carry a large volume of heavy vehicles (refer to **Figure 7-3**). Although vehicles travelling on these routes would not use the project, the redistribution of other traffic to the project would reduce congestion on other roads within the study area resulting in a reduction in travel times for all vehicles, including freight traffic by greater than 22 per cent during the peak hours.

Other routes between industrial areas such as Tomago, Black Hill, Beresfield and Raymond Terrace that carry a substantial volume of heavy vehicles would experience substantial reductions in delays and travel times as a result of the project. Furthermore, the project would also result in freer flowing traffic and greater efficiency of heavy vehicle operations.

The project would provide a free flowing high standard, access-controlled motorway that integrates with the NLTN. The project would contribute towards connecting Melbourne, Sydney and Brisbane via a high standard duplicated motorway and improve connectivity for state and national freight. The cumulative impact of projects on freight is discussed in **Chapter 23** (cumulative impacts).

7.5.7 Regional and local community connectivity

Regional connectivity

The M1 Pacific Motorway, New England Highway, Pacific Highway and John Renshaw Drive form part of the NLTN and are a key component of the Sydney to Brisbane road link. In addition to facilitating substantial interstate freight movements between Victoria, NSW and Queensland, these roads provide the primary access to the City of Newcastle, Port of Newcastle, Newcastle Airport, Upper Hunter Valley mining developments, Maitland and other major employment and commercial centres in the Hunter Region. The reduction in delays, reduction in travel time and improved travel time reliability that occur as a result of the project, would provide enhanced connectivity to communities and activity centres in the Lower Hunter and Newcastle regions, including Newcastle, Raymond Terrace, the Port of Newcastle and Newcastle Airport. The additional capacity provided by the project would also ensure the long term reliability and functionality of the NLTN, state roads and local roads.

These benefits would enable the project to support future land use and development within the study area and the surrounding region, improving access and connectivity to current and future employment and growth areas to and from the M1 Pacific Motorway and Pacific Highway. The project would support:

- Future employment and population growth at Raymond Terrace, which is identified as a strategic centre within the Hunter Region
- Growth and development of employment precincts at Tomago and Thornton, Beresfield and Black Hill.

The project would provide enhanced access to the Beresfield and Tomago industrial areas by providing new entry and exit points, delivered through the Tarro and Tomago interchange. The project would also provide more efficient access to facilitate economic growth for the Lower Hunter and key regional employment areas, such as the Port of Newcastle, Newcastle Airport, Raymond Terrace and Black Hill.

Property access

The project would be constructed to full motorway standard with no direct access to properties from the main alignment. During operation, 23 lots would have the existing property access affected by the project. Where existing property accesses would be permanently affected by the project, access would be provided either from existing roads or new access provided as part of the project. Transport will continue to liaise with landowners during detailed design to confirm access arrangements.

Further information on property access impacts during operation are discussed in **Chapter 14** (land use and property).

7.5.8 Road safety

As described in **Chapter 4**, one of the key objectives of the project is to improve road safety. The project would have a positive impact on road safety in the study area by addressing the following issues:

- Rear end, multi-vehicle crashes are the most common type of crash occurring within the study area. Many of these crashes occur on the New England Highway and Pacific Highway and are caused by traffic congestion. The project would reduce congestion on the New England Highway and Pacific Highway and is anticipated to result in a reduction in rear-end type crashes
- Lane changes are the second most frequent type of crash in the study area with 66 per cent of these crashes occurring on the New England Highway. The project would reduce the number of vehicles travelling on the New England Highway which would reduce the risk of lane change crashes
- Access to and from the project is to be provided via grade-separated interchanges. This would reduce potential points of conflict between vehicles. Providing grade-separated interchanges would also result in free-flow conditions along the project, minimising the risk of congestion-related incidents
- Off road and off bend crashes are a common cause of fatal and serious injury crashes in the study area. The project provides improved road alignment, wider lanes and shoulders with barriers, and would minimise the risk and impact of any off-road crashes.

The project would deliver improved pedestrian access at HRBG and Masonite Road and improved access to cyclist connectivity and crossing points. These infrastructure changes coupled with a reduction of traffic volumes on the existing road network would reduce the interaction between vehicles, pedestrians and cyclists, resulting in improve safety outcomes in the study area.

7.5.9 Other transport modes

Public transport

There would be no impact to the function of the Main North Rail Line and Hexham Train Support Facility during project operation. Access to Thornton, Beresfield, Tarro and Hexham railway stations, and ARTC assets via Tarro interchange would remain.

The project would not impact any current bus routes. Two bus stops would be included at the HRBG access along the Pacific Highway. The project would improve bus travel time reliability as a result of reduced traffic volumes on the existing road network. Decreased congestion and improved intersection performance would also benefit bus travel times.

Three bus stops would be relocated as described in **Chapter 5**. The relocated bus stops would be located as close as possible to the original bus stop locations, and pathways would be provided to maintain access to relocated bus stops. Consultation would be carried out with the affected bus operators during detailed design. Further information on operational impacts to public transport is presented in the Traffic and Transport Working Paper (**Appendix G**).

Pedestrians

The study area is predominantly comprised of industrial land uses which leads to very low volumes of pedestrians. The project would result in fewer traffic movements on the existing road network as traffic reroutes to the M1 Pacific Motorway.

The project would provide a shared path about 900 metres long along the southbound lane of the realigned Masonite Road in order to provide safer pedestrian access and to accommodate future development in the surrounding area. No shared path would be provided along the main alignment.

The proposed signalised intersection at the HRBG would provide a signalised pedestrian crossing which will provide access to the bus stop located on the eastern side of the Pacific Highway. It will also offer

improved pedestrian access to the HRBG. Further information on operational impacts to pedestrians is presented in the Traffic and Transport Working Paper (**Appendix G**).

Cyclists

The existing and proposed cycling network is shown in **Figure 5-1**. Cyclists would be able to use the 2.5 metre to three metre wide shoulders provided on the motorway and two metre to 2.5 metre wide sealed shoulders provided on ramps. This would improve cycle connectivity through the study area.

Changes to the existing cycle network include:

- A signalised crossing at the M1 Pacific Motorway/John Renshaw Drive intersection with connectivity to the project to provide a safe crossing location for cyclists
- Relocating the existing cyclist crossing on the New England Highway, just east of John Renshaw Drive further west before the northbound entry ramp at the Tarro interchange
- Provision of a westbound cyclist crossing on the New England Highway across John Renshaw Drive
- Replacing the existing gore crossings at the Tarro interchange with new ramps which would create a link between the main alignment in both directions and the future Richmond Vale Rail Trail from Tarro to Shortland
- Provision for northbound cyclists on the Pacific Highway crossing to access Old Punt Road and for crossing from Old Punt to access the northbound Pacific Highway Carriageway
- Provision for northbound cyclists on Pacific Highway to access the main alignment at Tomago interchange and to connect to the traffic signals at Tomago Road
- Provision for northbound cyclists on Pacific Highway to access the HRBG
- Provision for a shared path over the realigned Masonite Road.

Overall, the project would provide additional cycling routes and enhanced safety for cyclists. Further information on operational impacts to cyclists is presented in the Traffic and Transport Working Paper (**Appendix G**).

A dedicated off-road cycleway is proposed between Tarro and Shortland by the City of Newcastle for a distance of about 900 metres. This proposed future route would intersect with the project requiring a diversion along the realigned Aurizon access road.

Regional airport

The project would have a positive impact on Newcastle Airport and Williamtown RAAF Base function once operational. It would reduce travel times and improve travel time reliability for trips to Newcastle Airport and Williamtown RAAF Base for traffic from Maitland, the M1 Pacific Motorway and areas west of the study area. The project would therefore result in improved access to the Newcastle Airport and Williamtown RAAF Base.

Maritime traffic

The new bridge structures associated with the project would have a clearance of about 11 metres and would be supported by six sets of piers within the river. This is greater than the existing Hexham Bridge downstream which was a fixed clearance height of 10 metres. The bridge design over the Hunter River would allow for the continued use of the river by maritime traffic once built.

The project would result in impact to prawn trawling areas due to the design and location of the viaduct over the Hunter River. The project would be designed to allow the passage of commercial fishing vessels along the Hunter River, although the placement of piers would limit the ability to trawl along the shoreline near the viaduct. The project would require changes to trawling practices near to the bridge, with trawling nets required to be pulled in to pass under the bridge.

No other impacts to maritime traffic are expected and there would also be no impact on the functionality of the Port of Newcastle when the project is operational.

7.6 Cumulative impacts

Cumulative traffic and transport impacts may arise from the interaction of construction and operation activities of the project, and other approved or proposed projects in the area. When considered in isolation, specific project impacts may be considered minor. These minor impacts may, however, be more substantial when the impact of multiple projects on the same receivers is considered.

As discussed in **Section 7.2.3**, this transport and traffic assessment has included a number of planned or proposed projects to estimate the future conditions on the transport network surrounding the project. In many instances, this is a high-level qualitative assessment, but future road projects have also been captured in the traffic modelling as part of the future traffic growth across the Hunter Region as described in **Table 7-16**.

Overall, the contribution of the project to the cumulative impact on traffic and transport in the area is minor, considering construction would be managed through the implementation of a range of environmental management measures. Cumulative impacts are further discussed in **Chapter 23** (cumulative impacts).

Table 7-16 Potential cumulative traffic impacts for relevant identified projects

Project (approval status)	Relevance in consideration of cumulative impact	Potential cumulative impact
Emerging Black Hill Precinct, which includes: • Black Hill Employment Lands (In planning) • Black Hill Hunter Business Park (In planning).	• Located south of John Renshaw Drive and west of M1 Pacific Motorway. • Likely to be some overlap in the construction program, meaning the likelihood of concurrent (simultaneous) construction and operation • Likely to be concurrent (simultaneous) operation.	The Emerging Black Hill Precinct is included in the traffic modelling for future horizon years. It has been assumed that 25 per cent of the development would be complete by 2028, 75 per cent by 2038 and 100 per cent by 2048. The development will be a key generator of traffic in the region for future scenarios and accounts for about 12 per cent of all trips in the study area by 2048. There is likely to be some overlap in construction, as it is located within the project's construction footprint, to the south of John Renshaw Drive and west of M1 Pacific Motorway. However, there is a low likelihood for disruptions, with construction access likely to come from John Renshaw Drive west of the Weakleys Drive intersection which is outside the construction footprint. It is possible construction traffic would use the M1 Pacific Motorway and New England Highway to access the Emerging Black Hill Precinct, which may result in construction vehicles additional to what the project would contribute. These construction vehicle volumes are not expected to exceed capacity (including heavy vehicle capacity) of these state roads. The impact of the Emerging Black Hill Precinct during project operation is captured throughout this report. Sensitivity testing of the development has been carried out as described in this chapter. In summary, the development substantially impacts the performance of the network in future horizon years due to the magnitude of traffic generated out of the development.
Kinross Industrial / Weathertex, Heatherbrae (Approved)	• Located within the project's construction footprint to the north of the project in Heatherbrae. • Potential to be consecutive (back to back) construction and concurrent (simultaneous) operation.	The timing for the Weathertex industrial development has not yet been announced, although some land has been cleared for the development to the north of the project. The industrial development is proposed on land identified for AS16. If the Weathertex industrial development is developed prior to or during construction this ancillary facilities would be unavailable to the project for use. Construction of the project and Weathertex industrial development have the potential to extend potential disruptions relating to amenity and traffic (including access and travel times). The Weathertex industrial development operational traffic impact is captured as part of the future traffic demand growth within the study area.
Newcastle Power Station (In planning)	• Located within the project's construction footprint at Tomago near Old Punt Road • Potential to be consecutive (back to back) construction and concurrent (simultaneous) operation.	AGL propose to construct a 250 megawatt gas fired power station at Tomago, with gas pipelines and electricity transmission lines. Construction of the power station is due to commence in 2021 with the power station expected to be operational in 2022. The site for the proposed power station is located between the Pacific Highway and Old Punt Road, north of the Tomago industrial area (AGL 2019). The power station would be located next to AS12 and AS13. The project has considered the AGL power station in its design. Cumulative traffic operational impacts are minimal, as the station would not generate large amounts of traffic as it would employ approximately 23 operational and maintenance people.

Project (approval status)	Relevance in consideration of cumulative impact	Potential cumulative impact
Hexham Straight (In planning)	• Located about one kilometre south of the project at Hexham • Potential to be consecutive (back to back) construction and concurrent (simultaneous) operation.	The Hexham Straight project has a funding commitment to proceed and the concept design and environmental assessment is currently being carried out. Transport plan to upgrade the Hexham Straight (Maitland Road) between Sandgate and the existing Hexham Bridge. The proposed scope of the Hexham Straight project involves the addition of an extra lane in both directions, replacement of the bridges at Ironbark Creek, adjustments to connecting roads as well as substantial utility relocation. The concept design and environmental assessment are currently being carried out for the Hexham Straight project. The construction of the project has the potential to overlap with the construction of Hexham Straight which would result in additional impact on traffic and road access within the study area. The Hexham Straight project has been captured in the traffic modelling as part of the 'without project' upgrades. The upgrades include an extra lane in each direction between Sandgate and the existing Hexham Bridge. For the 'without project' model, the lane configuration at the existing Hexham Bridge maintains the existing layout to ensure adequate operation. The operational impact of the existing Hexham Bridge is captured in the 'without project' and project traffic model. A comparison between the two modelling scenarios has identified the benefits originating from the project.
Lower Hunter Freight Corridor (in planning)	• The investigation area extends from Fassifern to Hexham and Tarro • The design of the project allows for the Lower Hunter Freight Corridor.	The Transport Lower Hunter Freight Corridor (LHFC) forms a part of the NSW Freight and Ports Strategy (Transport for NSW 2018b) and in 2018 preliminary investigations were being carried out to assess options for a dedicated freight rail line between Fassifern and Hexham.
Richmond Vale Rail Trail to Shortland, including Shortland to Tarro cycleway (In planning)	• Intersects the project at Tarro	This project is not expected to result in cumulative impact with the project. The Richmond Vale Rail Trail to Shortland would encourage additional pedestrian and cyclist use within the study area. The Shortland to Tarro Bike Trail would intersect with the project and provide an additional pedestrian and cyclist routes within the study area. Overall, it would have minimal impact on the traffic within the study area.

7.7 Environmental management measures

The environmental management measures that will be implemented to minimise the traffic and transport impacts of the project, along with the responsibility and timing for those measures, are presented in **Table 7-17**.

Table 7-17 Environmental management measures (traffic and transport)

Impact	Reference	Management measure	Responsibility	Timing
Management of traffic during construction	TT01	A Traffic Management Plan (TMP) will be prepared and implemented in accordance with the Traffic Control at Work Sites Manual (Roads and Maritime Services 2018b) and QA Specification G10 Control of Traffic. The TMP will include: • Confirmation of haulage routes, including minimisation of haulage movements during peak periods on routes where feasible • Access management plan to ensure access to properties can be maintained where it is safe and feasible during construction • Site specific traffic control measures (including signage) to manage and regulate traffic movement • Measures to manage temporary changes to the road network including use of barriers, lane occupancies or temporary road closures • Measures to maintain pedestrian and cyclist access (including communication, signage and alternative routes) • Requirements and methods to consult and inform the local community of impacts on the local road network (including for out of hours work) • Access to ancillary and construction sites including entry and exit locations and measures to prevent construction vehicles queuing on public roads • A response plan for any construction traffic incident • Consideration of other developments that may be under construction to minimise traffic conflict and congestion.	Contractor	Prior to construction/ construction
Property access	TT02	Existing accesses to properties and businesses will be maintained during construction. Where this is not feasible or reasonable, temporary alternative access arrangements will be provided following consultation with the affected property and business owners.	Transport / Contractor	Detailed design/ prior to construction/ construction

Impact	Reference	Management measure	Responsibility	Timing
	TT03	Access will be maintained to rail infrastructure facilities along Aurizon access road. Transport will liaise with Aurizon and ARTC during detail design and construction.	Transport / Contractor	Detailed design/ prior to construction/ construction
Impacts to bus services	TT04	Any changes to bus stops will be implemented in consultation with Transport, relevant councils, and relevant bus operators.	Contractor	Prior to construction/ construction
Emergency vehicle access	TT05	Where possible, access for emergency vehicles will be maintained at all times during construction. Any site-specific requirements will be determined in consultation with the relevant emergency services agency.	Contractor	Construction
Maritime impacts	TT06	A navigational channel would be provided during construction within the Hunter River	Contractor	Construction
Damage or impacts on local road infrastructure	TT07	A road dilapidation report will be prepared before impacts on local roads commence. The report will document the existing conditions of local roads. This report will be issued to councils and stakeholders as relevant.	Contractor	Prior to construction
Other relevant management measures				
Cumulative impacts	CI01	The construction contractor will review traffic impacts before the start of construction and as required during construction. Any changes to manage cumulative traffic impacts will be included in the TMP.	Contractor	Prior to construction/ construction
Business impacts	SE02	Signage will be provided in accordance with Transport signage policy to inform the travelling public about services in Beresfield and Heatherbrae.	Transport	Construction. Prior to operation
Property acquisition	LU02	Property adjustments will be completed in consultation with property owners/business managers.	Transport/ Contractor	Prior to construction/ construction

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Environmental impact statement – Chapter 8: Noise and vibration

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8. Noise and vibration

This chapter describes the potential noise and vibration 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 relating to noise and vibration, as outlined in the SEARs, are to:

- Minimise the adverse impacts of construction noise and vibration (including airborne noise, ground-borne noise and blasting) on acoustic amenity and the structural integrity of buildings and items including Aboriginal places and environmental heritage
- Manage increases in noise emissions affecting nearby properties and other sensitive receivers during operation of the project to protect the amenity and well-being of the community
- Manage increases in noise emissions and vibration affecting environmental heritage as defined in the *Heritage Act 1977* during operation of the project.

Table 8-1 outlines the SEARs that relate to noise and vibration and identifies where they are addressed in this EIS. The full assessment of noise and vibration impacts is provided in the Noise and Vibration Working Paper (**Appendix H**).

Table 8-1 SEARs (noise and vibration)

Secretary's requirement	Where addressed
2. Noise and Vibration – Amenity	
1. The Proponent must assess construction and operational noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must include consideration of impacts to sensitive receivers, and include consideration of sleep disturbance and, as relevant, the characteristics of noise and vibration.	Construction noise and vibration impacts are assessed in **Section 8.4**. Consideration of impacts to sensitive receivers including sleep disturbance during construction is detailed in **Section 8.4.3**. Operational road traffic noise is assessed in **Section 8.5**. The assessments were carried out in accordance with the relevant guidelines, as outlined in **Section 8.1**.
2. An assessment of construction noise and vibration impacts which must address:	
(a) the nature of construction activities (including transport, tonal or impulsive noise-generating works and the removal of operational noise barriers, as relevant);	The nature of construction activities, including construction scenarios and construction work hours, is addressed in **Section 8.2.3**. Construction noise and vibration impacts are assessed in **Section 8.4**. For annoying characteristics, such as tonal or impulsive noise, penalties have been included in the source noise levels for plant and equipment, which are detailed in Appendix C of the Noise and Vibration Working Paper (**Appendix H**).
(b) the intensity and duration of noise and vibration impacts (both air and ground borne);	The intensity and duration of noise and vibration impacts (both air and ground borne) are assessed in **Section 8.4.3**, **Section 8.4.4** and **Section 8.4.6**. The proposed construction hours and program are detailed in **Section 8.2.3**.
(c) the need to balance timely conclusion of noise and vibration-generating works with periods of receiver respite, and other factors that may influence the timing and duration of construction activities (such as traffic management);	The proposed construction hours and program is detailed in **Section 8.2.3**. The environmental management measures presented in **Section 8.6** recommend a Construction Noise Vibration Management Plan to be prepared, which would incorporate standard and additional mitigation measures from the relevant guidelines such as respite periods.

Secretary's requirement	Where addressed
(d) the potential for extended standard construction hours and/or works outside standard construction hours, including predicted levels, exceedances and number of potentially affected receivers and justification for the activity in terms of the Interim Construction Noise Guideline (DECCW, 2009);	The proposed construction hours and program, including extended construction hours and out-of-hours work, is detailed in **Section 8.2.3**. The impacts of the project during standard, extended, and out of hours work are assessed in **Section 8.4**.
(e) potential noise and vibration mitigation measures, including timing of implementation; and	Noise and vibration management measures, including timing of implementation, are provided in **Section 8.6**.
(f) a cumulative noise and vibration assessment inclusive of impacts from other major development projects preparing for or commencing construction in the vicinity of the proposal.	A cumulative assessment of road traffic noise has been carried out for the project. **Section 8.2.4** outlines the methodology used and results of the assessment are included in **Section 8.5.1** and **Section 8.5.2**. Further information on cumulative noise and vibration impacts is provided in **Chapter 23** (cumulative impacts) and Chapter 7 of the Noise and Vibration Working Paper (**Appendix H**).
3. The Proponent must demonstrate that blast impacts are capable of complying with the current guidelines, if blasting is required.	Blast impacts are assessed in **Section 8.4.7**. If required, blasting would be carried out in accordance with the guidelines outlined in **Section 8.1**.
3. Noise and Vibration – Structural	
1. The Proponent must assess construction and operation noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must include consideration of impacts to the structural integrity and heritage significance of items (including Aboriginal places and items of environmental heritage).	The noise and vibration assessment has been carried out in accordance with the relevant guidelines, as outlined in **Section 8.1**. An assessment of vibration impacts from operational traffic is provided in **Section 8.5**. An assessment of construction vibration impacts to nearby buildings and structures is provided in **Section 8.4.6** The assessment included consideration of Aboriginal places and items of environmental heritage.
2. The Proponent must demonstrate that blast impacts are capable of complying with the current guidelines, if blasting is required.	Blast impacts are assessed in **Section 8.4.7**. If required, blasting would be carried out in accordance with the guidelines outlined in **Section 8.1**.

8.1 Policy and planning setting

The following policies and documents were used to guide the development and implementation of the noise and vibration impact assessment:

- Construction noise and vibration:
  - Construction Noise and Vibration Guideline (CNVG) (Roads and Maritime Services 2016b)
  - Interim Construction Noise Guideline (ICNG) (DECC 2009a)
  - Assessing Vibration: a technical guideline (DECC 2006)
  - British Standard BS 7385: Part 2-1993 Evaluation and measurement for vibration in buildings Part 2: Guide to damage levels from groundborne vibration (BSI 1993)
  - German Standard DIN 4150-3 (2016) Vibration in buildings – Part 3: Effects on structures (DIN 2016)
  - Australian Standard AS 2187.2-2006 Explosives – Storage and use – Part 2 Use of explosives (Australian Standard 2006)
  - Technical Basis for Guidelines to Minimise Annoyance due to Blasting Overpressure and Ground Vibration (ANZECC 1990)
  - NSW Road Noise Policy (RNP) (DECCW 2011)
  - Noise Criteria Guideline (NCG) (Roads and Maritime Services 2015c)
  - Noise Policy for Industry (NSW Government 2017).
- Operational noise and vibration:
  - NSW RNP (DECCW 2011)
  - NCG (Roads and Maritime Services 2015c)
  - Application Notes – Noise Criteria Guideline (Roads and Maritime Services 2016c)
  - Noise Mitigation Guideline (NMG) (Roads and Maritime Services 2015d)
  - Noise Wall Design Guideline (Roads and Maritime Services 2016d)
  - At-Receiver Noise Treatment Guideline (Roads and Maritime Services 2017c)
  - Noise Model Validation Guideline (Roads and Maritime Services 2018c)
  - Environmental Noise Management Manual (ENMM) (RTA 2001)
  - Australian Standard AS2107:2016 Acoustics – Recommended design sound levels and reverberation times for building interiors.

Further detail on the above legislation, policies and guidelines, and how they apply to the project, is provided in the Noise and Vibration Working Paper (**Appendix H**).

8.2 Assessment methodology

Assessment of the noise and vibration impacts involved the following key steps to identify project impacts during construction and operation:

- Identification of sensitive receivers and noise catchment areas (NCAs) (refer to **Section 8.2.1**)
- Noise monitoring to establish the existing background and ambient noise environment and to capture existing traffic noise levels (refer to **Section 8.2.2**)
- Identification of relevant criteria to inform the construction and operational noise and vibration assessments (refer to **Section 8.2.3** and **Section 8.2.4**)
- Noise modelling of construction and operational noise impacts (refer to **Section 8.2.3** and **Section 8.2.4**)
- Assessing the expected construction and operational noise and vibration impacts of the project (refer to **Section 8.4** and **Section 8.5**)
- Identification of noise management measures to address operational traffic noise impacts (refer to **Section 8.6**).

The detailed assessment methodology is provided in the Noise and Vibration Working Paper (**Appendix H**).

8.2.1 Study areas and noise catchment areas

To assess the noise and vibration impacts of the project, separate study areas were defined for construction and operation as shown on **Figure 8-1**.

The construction study area, for the assessment of construction noise and vibration, has been defined as 940 metres either side of the construction footprint. This represents the distance from construction work where construction noise would not adversely impact sensitive receivers.

The operational study area, for the assessment of operational traffic noise, has been defined as 600 metres either side of the project roads (measured from the centreline of the outermost traffic lanes). This study area was developed in accordance with the RNP and NCG.

Based on the study areas defined for the project, NCAs were established in order to categorise sensitive receivers into areas of similar acoustic environments. Noise sensitive receivers applicable to the project and the NCAs in which they have been grouped are identified and described in **Section 8.3.1**.

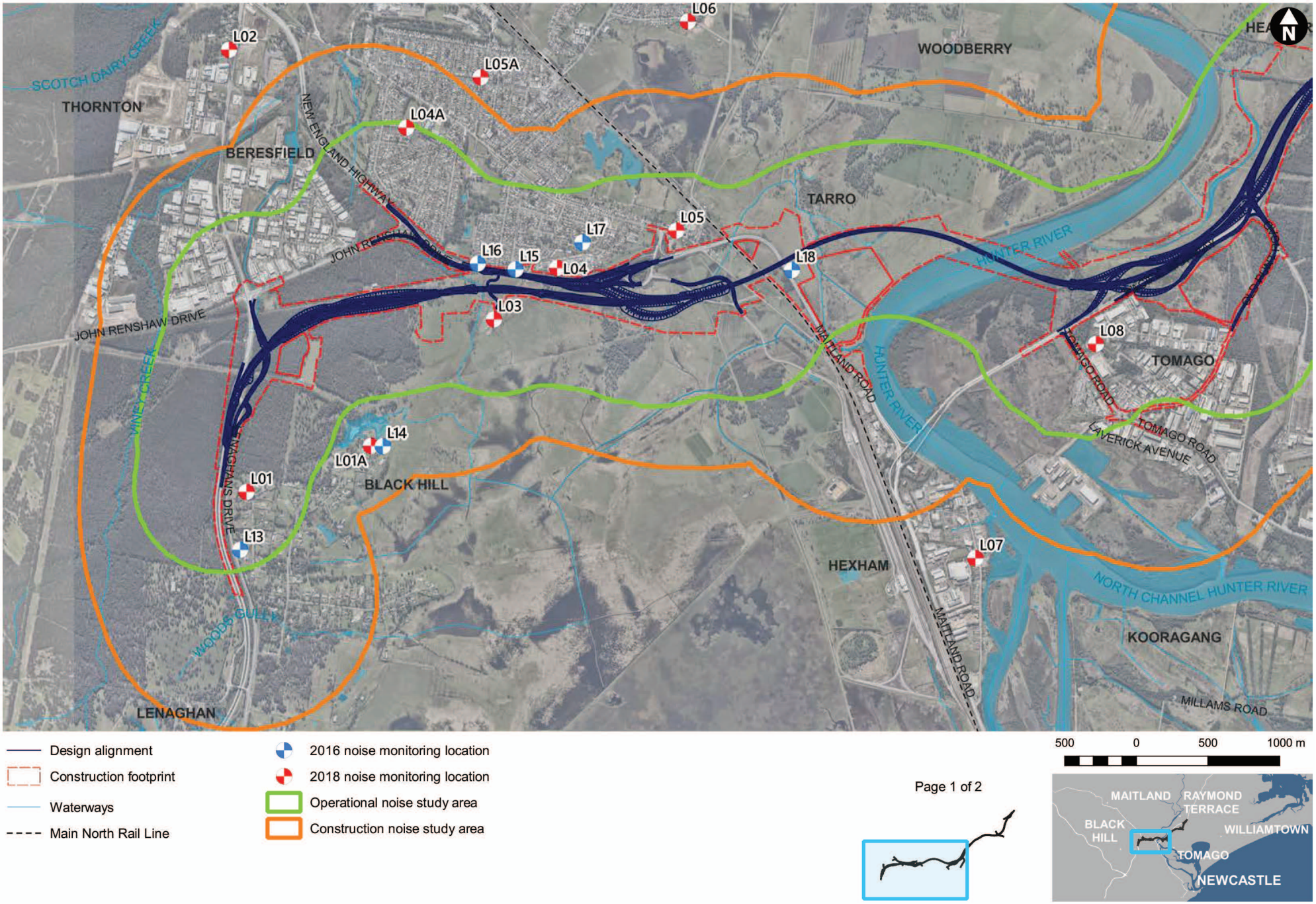


Figure 8-1 Study areas and noise monitoring locations (map 1 of 2)

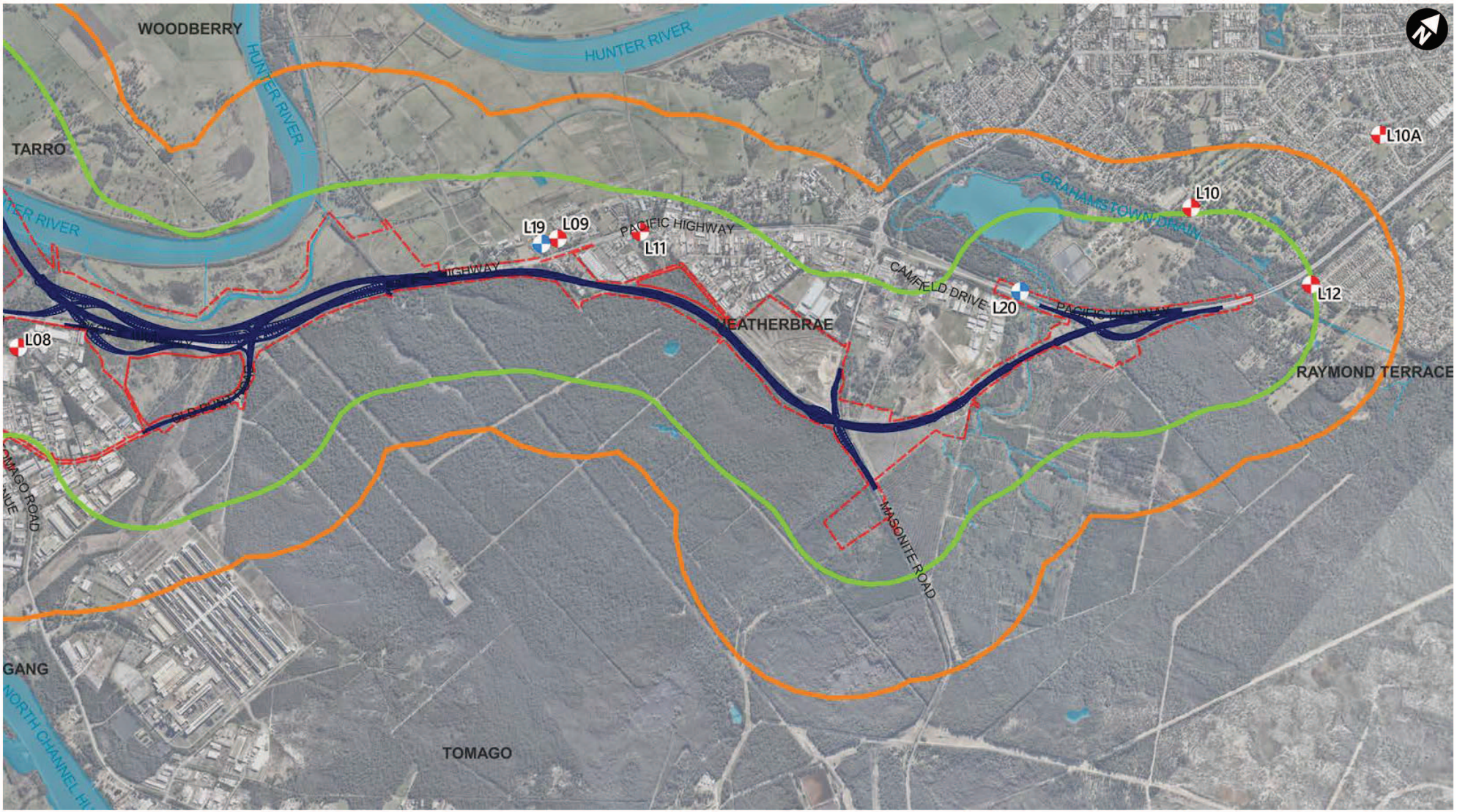


Figure 8-1 Study areas and noise monitoring locations (map 2 of 2)

8.2.2 Noise monitoring

To quantify the existing noise environment, noise monitoring was carried out in areas where receivers may potentially be affected by construction noise from the project. Noise monitoring was also carried out to determine the existing levels of road traffic noise along the project.

Long-term unattended noise monitoring was carried out at 11 locations within the construction study area between June and July 2018 to establish existing background and ambient noise levels. The long-term unattended background noise monitoring locations (L01 to L11) are shown on **Figure 8-1**.

In addition, long-term unattended noise monitoring of existing traffic noise levels was carried out in March 2016 at eight locations within the operational study area. Monitoring locations were selected based on their proximity to existing major roads to ensure that traffic noise was the main contributor to the noise levels measured. The 2016 data was included in the assessment given the Australian Government's travel restrictions in response to the declaration of the COVID-19 pandemic. The COVID-19 situation dramatically impacted traffic volumes, making it difficult to collect more recent traffic noise data for a "typical" period. Therefore, data from 2016 and 2018 was used to inform this assessment and is still considered representative of existing traffic and background noise levels respectively. The traffic noise monitoring locations (L13 to L20) are shown on **Figure 8-1**.

To determine correlations with the selected long-term measurement locations, short-term attended noise measurements were also collected concurrently with the long-term unattended noise monitoring. The short-term attended background noise measurement locations (L01A, L04A, L05A, L10A and L12) are shown on **Figure 8-1**.

Existing noise levels were measured in consistent 15-minute periods during the daytime, evening and night-time periods. Measurements affected by extraneous noise, wind (greater than five metres per second) or rain were excluded from the recorded data. The outcomes of noise monitoring carried out for the project are provided in **Section 8.3.2**.

8.2.3 Construction noise and vibration assessment methodology

Construction scenarios

To assess the likely impacts during project construction, 17 representative construction scenarios were developed. Construction scenarios for the assessment of noise impacts have been based on a 'realistic worst-case' scenario to determine the impacts from the noisiest 15-minute period that is likely to occur for each scenario, in accordance with the ICNG. The scenarios have been assessed as 'peak impact' or 'typical impact' work, where 'peak impact' work includes the use of noise intensive equipment like rock-breakers or concrete saws, and 'typical impact' work represents typical noise emissions from the project when noise intensive equipment is not in use. The 17 construction scenarios are shown in **Table 8-3**.

A full description of the construction activities comprising each construction scenarios is provided in the Noise and Vibration Working Paper (**Appendix H**).

Construction work hours

As described in **Section 5.4.13**, the standard hours for construction as noted in the ICNG are:

- Monday to Friday: 7am–6pm
- Saturday: 8am–1pm
- No work on Sunday or public holidays.

However, as the majority of construction work would be carried out away from residences and other sensitive receivers, extended construction work hours are proposed. Extended construction hours would reduce the volume of construction traffic on roads during peak hours, accelerate the construction program, reduce the longevity of impacts on receivers, and enable greater flexibility in project scheduling. The proposed extended construction work hours are:

- Monday to Friday: 6am–7pm
- Saturday: 7am–5pm
- Sunday and public holidays: 7am–5pm.

To ensure the health and safety of the public and construction crews, and to minimise disruption to existing traffic flows, some out-of-hours work would also be required during evening and night time periods, as described in **Section 5.4.13**. The activities that may need to be carried out during out-of-hours and relevant justifications, in accordance with the ICNG, are provided in **Table 8-2**.

Table 8-2 Justification for out-of-hours activities

Out-of-hours activity	Justification
Delivery of oversized plant and materials	Delivery of oversize and/or overmass equipment and materials to construction sites could occur after hours for safety reasons and to avoid disruptions and increase of heavy vehicles on the existing road network during peak volume. Such activities would be carried out in line with NSW Police, NSW Traffic Management Centre and Transport requirements.
Installation of traffic controls, such as concrete barriers	Some of these activities require works on or near major and local roads. As such, these activities would occur out-of-hours when traffic volumes are lower, to protect the health and safety of the public and construction crews and to minimise disruption to existing traffic flows. This work would be carried out in accordance with Transport for NSW and local council requirements. For utility works, where the utility authority only allows works to be carried out during a shutdown period, works would be coordinated with the utility authority and may occur out-of-hours.
Traffic switches between each construction phase	
Utility modifications, relocations or protection measures work	
Removal of existing static signage and installation of new signs	
Removal of existing traffic barriers and installation of temporary and permanent traffic barriers	
Removal of existing lane marking and application of new lane marking on existing roads	
Resurfacing of asphalt pavement on existing roads and concrete and asphalt pouring	
Operation of concrete and asphalt batching plants within ancillary facilities	Concrete and asphalt batching plants would be required to support out-of-hours works and project construction, particularly during construction of the viaduct.
Construction work interfacing with the M1 Pacific Motorway, New England Highway and the Pacific Highway, including construction of overbridge piers for the M1 Pacific Motorway entry and exit ramps and ramp tie-ins with the M1 Pacific Motorway, cross drainage below existing roads, pavement, surfacing, line markings, kerbs and traffic islands, traffic signs and signals	Completing or installing these items at night when traffic flows are low would minimise disruption to traffic and minimise any potential safety conflict between construction personnel and traffic. Such activities would be carried out in line with NSW Traffic Management Centre and Transport requirements.

Out-of-hours activity	Justification
Short-term traffic diversions along the existing road network (M1 Pacific Motorway, New England Highway, John Renshaw Drive, Masonite Road, and the Pacific Highway)	
Bridge construction work over the Main North Rail Line and existing roads including the New England Highway, Pacific Highway and Old Punt Road (including establishing temporary protection work, installation of girders, sealing of joints, establishing temporary screens to enable construction to continue on the deck, and removal of temporary work)	For bridge construction that can be carried out offline of the existing road network, construction can be carried out during normal working hours. Where bridge construction is required over the existing road network, activities would be carried out as out-of-hours work to ensure health and safety of public and construction workers, and to minimise disruption to motorists. Where bridge construction is required over the existing rail network, activities would be carried out during a rail shutdown, coordinated with the rail authority, and would require out-of-hours work. For the bridge over Hunter Region Botanic Gardens access road (B09), the access road would need to be closed for lifting of the girders. As the Hunter Region Botanic Gardens is only open during normal working hours, there is not expected to be any issues with closing the road out-of-hours. Any closures would be managed in consultation with Hunter Region Botanic Gardens.
Any work that does not cause noise emissions to be audible at any sensitive receiver	In locations where sensitive receivers are not susceptible to noise emissions, out-of-hours work would result in schedule benefits, flexibility in regard to programming of work around the various constraints of the project, such as capitalising on dry periods and thereby maximising construction on the flood plain, and reducing the impact to the existing road network by carrying out additional work during out-of-hours.
Emergency work to avoid the loss of lives, property and/or to prevent environmental harm.	To protect the health and safety of the public and construction crews any emergency work would be carried immediately which may include out-of-hours.

As outlined in **Chapter 5**, construction of the project is expected to start in 2023 with completion expected in 2028. Based on the proposed construction scenarios, construction work hours (standard, extended and out-of-hours) and construction program, indicative details of the construction work are presented in **Table 8-3**. In accordance with **Table 8-2**, out of hours work may also be carried out where that work does not cause noise emissions to be audible at any sensitive receiver. The indicative construction program based on the construction scenarios is presented in the Noise and Vibration Working Paper (**Appendix H**).

Table 8-3 Construction scenarios, indicative work durations and periods

ID	Scenario	Indicative duration (months)	Comments
1	Pre-construction and site establishment	20	Carried out during the day period and evening and night out of hours. Out of hours work includes infrequent Road Occupancy Licence (ROL) work for road connections
2	Ancillary facility (establishment)	13	As above
3	Ancillary facility (operation)	50	The operation of some ancillary facilities would be carried out during the day period and would also include evening and night out of hours work.

ID	Scenario	Indicative duration (months)	Comments
4	Batch plant operation	7	As above
5	Clearing, grubbing and demolition	21	Typically carried out during day period*, however some infrequent evening and night out of hours work would be required for work associated with the existing road network.
6	Utility work	40	Carried out during the day period with evening and night out of hours work limited to utility work associated with the existing road network and shutdowns for work on operational assets
7	Bulk earthwork (cuttings)	10	Typically carried out during day period
8	Blasting	10	Carried out during day period
9	Bulk earthwork (fill)	40	Typically carried out during day period
10	Concrete pavement (including pavement drainage)	24	Carried out during the day period with evening and night out of hours work limited to tie-in to existing road network or infrequent out of hours work periods for extended concrete pours
11	Asphalt pavement (including pavement drainage)	28	Carried out during the day period with evening and night out of hours work limited to widening and tie-in to existing road network or infrequent out of hours work periods for extended asphalt laying
12	Bridge work (excluding piling)	26	Carried out during the day period with evening and night out of hours work required for extended concrete pours, work near existing road and rail network, and where the work does not cause noise emissions to be audible at sensitive receivers.
13	Piling for bridges and bridge approaches	23	Carried out during the day period with evening and night out of hours work limited to work on existing road network
14	Roadside furniture and finishing work	28	Carried out during the day period with evening and night out of hours work limited to where work are required to be carried out on existing road network
15	Traffic management and control	26	Traffic management and control for all day period and out of hours work on existing road network
16	Landscaping	11	Typically carried out during day period
17	Cross drainage	17	Carried out during the day period with evening and night out of hours work limited to installation of cross drainage beneath the existing road network

* The ‘day period’ includes standard construction hours and daytime out-of-hours periods

Construction noise modelling

A noise model of the construction study area was used to predict noise levels from construction work to all surrounding receivers. Noise sources, receiver locations, buildings, structures and topographical features were digitised in the noise model to develop a three-dimensional representation of the construction study area and surrounding areas. The ICNG (DECC 2009a) is used to assess and manage impacts from construction noise on residences and 'other' sensitive land uses in NSW. The ICNG contains procedures for determining project specific noise management levels (NMLs) for sensitive receivers based on the existing background noise in the area.

Residential receivers

The NMLs for residential receivers, set in accordance with the ICNG are provided in **Table 8-4**. The NMLs are not mandatory limits, however where construction noise levels are predicted or measured to be above the NMLs, feasible and reasonable work practices to minimise noise emissions are to be investigated.

Construction noise impacts on residential receivers are assessed using these NMLs, set with reference to time of day and background noise (referred to as Rating Background Level (RBL)). NMLs developed for the project are provided in **Section 8.4.1**.

Table 8-4 Noise management levels for residential receivers in accordance with the ICNG

Time of day	NML
Recommended standard hours: • Monday to Friday: 7am–6pm • Saturday: 8am–1pm • No work on Sundays or public holidays	Noise affected: RBL + 10dB
	Highly noise affected: 75dB(A)
Outside recommended standard hours	Noise affected: RBL + 5dB

Non-residential receivers

NMLs for other noise-sensitive receiver locations located within the construction study area, including commercial and industrial premises, are provided in **Table 8-5**. These NMLs are absolute levels and are independent of the existing background and ambient noise environment, in accordance with the ICNG.

Table 8-5 NMLs at other noise sensitive land uses

Land use	NML
Classrooms at schools, and other educational institutions	Internal noise level 45 dB(A)[2]
Places of worship	Internal noise level 45 dB(A)[2]
Childcare centre	External noise level 50 dB(A)[6]
Active recreation areas (e.g. sports fields/activities which generate their own noise and are generally less sensitive to external noise)	External noise level 65 dB(A)
Passive recreation areas (e.g. area used for low intensity and low noise producing activities which could be impacted by external noise such as reading or meditation)	External noise level 60 dB(A)
Commercial premises (including offices and retail outlets)	External noise level 70 dB(A)[5]

Land use	NML
Industrial premises	External noise level 75 dB(A)[5]

1. NMLs apply when receiver areas are in use only
2. As per the ICNG and NPfI, it has been assumed that the difference between an internal noise level and the external noise level is 10 dB(A), assuming windows are open for adequate ventilation. An external NML would be defined on this basis.
3. Medical centres and similar are classified as commercial premises
4. Community centres have been assessed to an external noise level of 60 dB(A). Depending on the intended use of the centre, the noise management level may vary
5. The NML applies at the most affected occupied point on the premises
6. Specific criteria for childcare centres are not provided in the ICNG. The NML for childcare centres has been developed with consideration of Association of Australian Acoustical Consultants Guideline for Child Care Centre Acoustics Assessment (2013) and a conservative 10 dB(A) reduction from external to internal noise levels.

Sleep disturbance

A night-time sleep disturbance 'screening criterion' noise goal of the RBL +15 dB(A) is used to identify the receivers where there is potential for sleep disturbance. Where predicted maximum noise levels are above the screening level, more detailed analysis is required.

A sleep disturbance screening assessment has been carried out for the residential receivers within each NCA potentially impacted by the various construction scenarios and is provided in the Noise and Vibration Working Paper (**Appendix H**). Sleep disturbance impacts of the project are described in **Section 8.4.3**.

Construction road traffic noise

The construction road traffic noise calculations were carried out using the Calculation of Road Traffic Noise (CoRTN) (UK Department of Transport 1988) algorithms to predict the change in road traffic noise levels due to construction traffic.

Construction traffic movements along the proposed routes have been compared to the future traffic volumes during the peak construction period to determine if the additional traffic would increase noise levels by more than 2 dB(A) at residential receivers.

Where the predicted increase in traffic noise level is greater than 2 dB(A), further assessment is required using the NCG (Roads and Maritime Services 2015c), and all feasible and reasonable noise mitigation and management measures would be implemented. Where increases are 2 dB(A) or less then no further assessment is required.

When determining feasible and reasonable mitigation measures, consideration has been given to the actual noise levels associated with construction traffic and whether these levels comply with the following road traffic noise criteria from the RNP:

- 60 dB(A) $L_{Aeq(15\ hour)}$ day and 55 dB(A) $L_{Aeq(9\ hour)}$ night for freeway/arterial/sub-arterial roads
- 55 dB(A) $L_{Aeq(1\ hour)}$ day and 50 dB(A) $L_{Aeq(1\ hour)}$ night for local roads.

Ground-borne construction noise

Ground-borne or regenerated noise as a result of construction activities is usually associated with vibration generating equipment, such as rock hammers, operating near residential buildings.

Table 8-6 summarises the CNVG ground-borne construction noise objectives for residential receivers during the evening and night periods, which are consistent with the ICNG.

Table 8-6 Ground-borne noise objectives at residential premises

Period	Time	Internal $L_{Aeq(15\ minute)}$ ground-borne noise management level
Evening	6.00pm to 10.00pm	40 dB(A)
Night	10.00pm to 7.00am	35 dB(A)

Construction vibration

Construction vibration was assessed against three main types of impact:

- Disturbance to building occupants (human exposure)
- Potential damage to buildings (structural and cosmetic damage to buildings)
- Potential damage to buried utilities.

The CNVG provides recommended minimum working distances for typical vibration intensive plant and equipment, presented in **Table 8-7**. The minimum working distances are indicative only and potential vibration experienced by receivers would be dependent on separation distances, the intervening soil and rock strata, dominant frequencies of vibration and the receiver structure.

Table 8-7 Recommended minimum working distances for vibration intensive plant and equipment

Plant item	Rating/activity description	Recommended minimum working distances		
		Cosmetic damage		Human response [3]
		Structurally sound [1] (e.g. residential & light commercial)	Structurally unsound [2] (e.g. unsound heritage structures)	
Vibratory roller	< 50kN (typically 1-2t)	5m	11m	15m to 20m
	< 100kN (typically 2-4t)	6m	13m	20m
	< 200kN (typically 4-6t)	12m	15m	40m
	< 300kN (typically 7-13t)	15m	31m	100m
	> 300kN (typically 13-18t)	20m	40m	100m
	> 300kN (typically > 18t)	25m	50m	100m
Small hydraulic hammer	300kg – 5 to 12t excavator	2m	5m	7m
Medium hydraulic hammer	900kg – 12 to 18t excavator	7m	15m	23m
Large hydraulic hammer	1600kg – 18 to 34t excavator	22m	30m[4]	73m

Plant item	Rating/activity description	Recommended minimum working distances		
		Cosmetic damage		Human response [3]
		Structurally sound [1] (e.g. residential & light commercial)	Structurally unsound [2] (e.g. unsound heritage structures)	
Vibratory pile driver	Sheet piles	2m to 20m	5m to 30m	20m to 50m
Pile boring	≤ 800mm	2m	5m	5m
Jackhammer	Handheld	1m	3m	5m
Blasting operations[4]		Based on charge size – see Note 4		

1. Referenced from either the CNVG or against the criteria in the British Standard BS 7385 Part 2-1993 Evaluation and measurement for vibration in buildings Part 2
2. Criteria referenced from DIN 4150-3:2016 Vibration in buildings – Effects on structures (including heritage items)
3. Referenced from either the CNVG or the criteria referenced in the EPA's Assessing Vibration: a technical guideline (December 2006)
4. To be determined during test blasts to establish appropriate propagation characteristics for the site and increase the accuracy of blasting predictions.

Human exposure

Generally, if vibration levels are maintained so that they do not disturb building occupants, there is limited potential for structural damage to buildings. Criteria for human exposure are therefore more stringent than those to prevent structural damage.

In accordance with 'Assessing Vibration; a technical guideline' (DECC 2006), vibration impacts have been assessed as either:

- Continuous: Continued interruption for a defined period
- Impulsive: A rapid build-up to a peak followed by a damped decay that may or may not involve several cycles of vibration. It can also consist of a sudden application of several cycles at approximately the same amplitude, providing the duration is short
- Intermittent: interrupted periods of continuous or repeated periods of impulsive vibration that varies significantly in magnitude.

Further to the recommended minimum working distances for vibration intensive plant and equipment presented in **Table 8-7**, human exposure vibration impacts are assessed based on the type of building and the types of activities a building is designed for. The 'preferred' and 'maximum' vibration levels for maintaining human comfort in residences and other sensitive receivers for continuous, impulsive and intermittent vibration are provided in Section 3.5.1 of the Noise and Vibration Working Paper (**Appendix H**).

Structural and cosmetic damage to buildings and heritage items

Potential structural damage of buildings by vibration is typically managed by ensuring vibration impacting the structure does not exceed certain limits and standards. As outlined in the CNVG, guidance for cosmetic damage of structures is provided in the British Standard BS 7385: Part 2, while German Standard DIN 4150-3 has criteria of particular reference for heritage structures. There is no current Australian Standard for assessing structural building damage caused by vibration.

Heritage items are considered on a case by case basis, and care should be taken as these structures can be difficult to repair in the case of damage. Where a structure is found to have defects, or is structurally unsound following an inspection, maximum vibration criteria are to be established for that specific structure for construction work to not further damage the structure.

The recommended minimum working distances for vibration intensive plant and equipment provided in **Table 8-7** have been developed with consideration of the guidance provided in BS 7385 and DIN 4150-3 and have been used to assess the potential impacts of the project on structural and cosmetic damage (refer to **Section 8.4.6**). Vibratory guideline values for structural and cosmetic damage are further outlined in the Noise and Vibration Working Paper (**Appendix H**).

Damage to utilities

Section 5.3 of DIN 4150: Part 3 sets out guideline values for vibration velocity to be used when evaluating the effects of vibration on buried pipework. As part of detailed design, these vibration limits will be considered to minimise damage to any buried utilities potentially impacted by the construction work.

Recommended vibration goals for electrical cables and telecommunication utilities such as fibre optic cables range from 50mm/s to 100mm/s. Although cables may sustain these vibration levels, the utilities they are connected to, such as transformers and switch blocks, may not. If such equipment is encountered during the construction process, an individual vibration assessment will be carried out addressing impact on the utility, and consultation with the utility provider, to confirm specific vibration requirements.

Blasting

Australian Standard AS 2187.2-2006 Explosives – Storage and use – Part 2 Use of explosives has been adopted to assess overpressure and vibration impacts from blasting during construction. **Table 8-8** provides the recommended airblast limits for human comfort and damage to structures, as outlined in AS 2187.2-2006. **Table 8-9**, also reproduced from AS 2187.2-2006, provides the ground vibration limits for human comfort and damage to structures.

Table 8-8 Recommended airblast limits for human comfort and structural damage

Category	Type of blasting operations	Peak sound pressure level, dBL
Recommended airblast limits for human comfort (Table J5.4(A), AS 2187.2)		
Sensitive site[1]	Operations lasting longer than 12 months or more than 20 blasts	115 dBL for 95 per cent blasts per year. 120 dBL maximum unless agreement is reached with occupier that a higher limit may apply
Sensitive site[1]	Operations lasting for less than 12 months or less than 20 blasts	120 dBL for 95 per cent blasts. 125 dBL maximum unless agreement is reached with occupier that a higher limit may apply
Occupied non-sensitive sites, such as factories and commercial premises	All blasting	125 dBL maximum unless agreement is reached with the occupier that a higher limit may apply. For sites containing equipment sensitive to vibration, the vibration should be kept below manufacturer's specifications or levels that can be shown to adversely affect the equipment operation
Recommended airblast limits for control of damage to structures (Table J5.4(B), AS 2187.2)		
Structures that include masonry, plaster and plasterboard in their construction and also unoccupied structures of reinforced concrete or steel construction	All blasting	133 dBL maximum unless agreement is reached with the owner that a higher limit may apply

Category	Type of blasting operations	Peak sound pressure level, dBL
Service structures, such as pipelines, powerlines and cables located above the ground	All blasting	Limit to be determined by structural design methodology

1. A sensitive site includes houses and low rise residential buildings, theatres, schools, and other similar buildings occupied by people
2. The recommendations in Table J5.4(A) and Table J5.4(B) are intended to be informative and do not override statutory requirements with respect to human comfort limits set by various authorities. They should be read in conjunction with any such statutory requirements and with regard to their respective jurisdictions.

Table 8-9 Ground vibration limits for human comfort

Category	Type of blasting operations	Peak component particle velocity, mm/s
Ground vibration limits for human comfort (Table J4.5(A), AS 2187.2)		
Sensitive site[1]	Operations lasting longer than 12 months or more than 20 blasts	5mm/s for 95 per cent blasts per year 10mm/s maximum unless agreement is reached with the occupier that a higher limit may apply
Sensitive site[1]	Operations lasting for less than 12 months or less than 20 blasts	10mm/s maximum unless agreement is reached with occupier that a higher limit may apply
Occupied non-sensitive sites, such as factories and commercial premises	All blasting	25mm/s maximum unless agreement is reached with occupier that a higher limit may apply. For sites containing equipment sensitive to vibration, the vibration should be kept below manufacturer's specifications or levels that can be shown to adversely affect the equipment operation
Ground vibration limits for control of damage to structures (Table J4.5(B), AS 2187.2)		
Other structures or architectural elements that include masonry, plaster and plasterboard in their construction	All blasting	Frequency-dependent damage limit criteria Table J4.4.2.1
Unoccupied structures of reinforced concrete or steel construction	All blasting	100mm/s maximum unless agreement is reached with the owner that a higher limit may apply
Service structures, such as pipelines, powerlines and cables	All blasting	Limit to be determined by structural design methodology

1. A sensitive site includes houses and low rise residential buildings, theatres, schools, and other similar buildings occupied by people
2. The recommendations in Table J4.5(A) are intended to be informative and do not override statutory requirements with respect to human comfort limits set by various authorities. They should be read in conjunction with any such statutory requirements and with regard to their respective jurisdictions
3. The recommendations in Table J4.5(A) and Table J4.5(B) do not cover high-rise buildings, buildings with long-span floors, specialist structures such as reservoirs, dams and hospitals, or buildings housing scientific equipment sensitive to vibration. These require special considerations, which may necessitate taking additional measurements on the structure itself, to detect any magnification of ground vibrations that might occur within the structure. Particular attention should be given to the response of suspended floors.

For the assessment of vibration impact due to blasting on buried pipelines, the screening levels used to assess vibration impact from general construction activities on buried pipework (as outlined in DIN 4150-3) were adopted.

To assess the likelihood of damage to unsound heritage structures due to blasting, and in the absence of specific unsound structure limits or limits for structures with particular sensitivity to vibration impacts, the structural damage screening level from general construction vibration impacts on unsound heritage structures (as outlined in DIN4150-03) were adopted for vibration impacts due to blasting.

The potential blasting impacts of the project are assessed in **Section 8.4.7**.

8.2.4 Operational noise and vibration assessment methodology

Operational road traffic noise and vibration

As required by the RNP and NCG, operational traffic noise impacts were based on the following scenarios:

- 'No Build': the assessment scenario if the project were not to go ahead
- 'Build': the assessment scenario with the project constructed and operating.

The RNP and NCG require noise to be assessed at project opening and for a future design year, typically 10 years after opening. For this project, the opening year is 2028 and the design year is 2038.

Residences may be assigned new, redeveloped, transition zone or relative increase criteria depending on how the project would influence traffic noise levels. The most stringent applicable criteria would be used in the assessment for each facade of the residence.

For assessment purposes, a receiver building has been defined as a residential or non-residential building that has noise sensitive areas potentially impacted by operational road traffic noise. An individual receiver building is considered as a single receiver for the purposes of this assessment. For example, one double-storey residential building is represented by one receiver building.

Transition zones

The project consists of both redeveloped roads and new roads. A road is 'redeveloped' where the proposed alignment is in an existing road corridor and the existing road is not substantially realigned. A road is classified as being 'new' if the alignment is in an undeveloped corridor (e.g. a bypass) or is substantially realigned from the existing road.

The NCG requires transition zones to be applied at the point where road categories change from new to redeveloped, or vice versa, to provide a smooth transition in noise criteria. As such, the project contains the 'new road', 'redeveloped road' and 'transition zone' noise categories. The location of new, redeveloped roads and transition zones applicable to the project, as described above, are shown in Appendix D of the Noise and Vibration Working Paper (**Appendix H**).

Traffic noise criteria for residential receivers

A summary of the applicable traffic noise criteria in accordance with the NCG for residential receivers is presented in **Table 8-10**.

Table 8-10 NCG criteria for residential receivers

Road category	Type of project / land use	Assessment criteria, dB(A)	
		Daytime (7am–10pm)	Night time (10pm–7am)
Freeway / arterial / sub-arterial roads	Existing residences affected by noise from new freeway/arterial/sub-arterial road corridors	$L_{Aeq(15\ hour)}$ 55 (external)	$L_{Aeq(9\ hour)}$ 50 (external)
	Existing residences affected by noise from redevelopment of existing freeway/arterial/sub-arterial road corridors	$L_{Aeq(15\ hour)}$ 60 (external)	$L_{Aeq(9\ hour)}$ 55 (external)
	Existing residences affected by both new roads and the redevelopment of existing freeway/arterial/sub-arterial roads in a Transition Zone[1]	Between $L_{Aeq(15\ hour)}$ 55-60 (external)	Between $L_{Aeq(9\ hour)}$ 50-55 (external)
	Existing residences affected by increases in traffic noise of 12dB(A) or more from new freeway/arterial/sub-arterial roads[2]	Between $L_{Aeq(15\ hour)}$ 42-55 (external)	Between $L_{Aeq(9\ hour)}$ 42-50 (external)
	Existing residences affected by increases in traffic noise of 12dB(A) or more from redevelopment of existing freeway/arterial/sub-arterial roads[2]	Between $L_{Aeq(15\ hour)}$ 42-60 (external)	Between $L_{Aeq(9\ hour)}$ 42-55 (external)

1. The applicable noise criteria for a particular receiver would be dependent on its location relative to where the new road joins the redeveloped road (transition zone). Refer to Section 7.1 and Table 1 of the Transport for NSW 'Noise Criteria Guideline' for further information
2. The criteria at each facade are determined from the existing traffic noise level plus 12 dB(A)

Traffic noise criteria for non-residential receivers

A summary of the applicable traffic noise criteria for non-residential sensitive land uses receivers, in accordance with the NCG, is presented in **Table 8-11**. Further descriptions and considerations for each sensitive land use is provided in the Noise and Vibration Working Paper (**Appendix H**).

Table 8-11 NCG criteria for non-residential sensitive land uses

Existing sensitive land use	Assessment criteria, dB(A)	
	Daytime (7am–10pm)	Night time (10pm–7am)
School classrooms	$L_{Aeq(1\ hour)}$ 40 (internal) when in use	–
Places of worship	$L_{Aeq(1\ hour)}$ 40 (internal)	$L_{Aeq(1\ hour)}$ 40 (internal)
Open space (active use)	$L_{Aeq(15\ hour)}$ 60 (external) when in use	–
Open space (passive use)	$L_{Aeq(15\ hour)}$ 55 (external) when in use	–
Childcare facilities	Sleeping rooms LAeq(1 hour) 35 (internal) Indoor play areas LAeq(1 hour) 40 (internal) Outdoor lay areas LAeq(1 hour) 55 (external)	–

Maximum road traffic noise levels

Maximum noise levels generated by road traffic have the potential to cause disturbance to sleep. The purpose of a maximum noise level assessment is to determine where maximum noise levels are likely to change as a result of a project. Guidance for assessing maximum noise levels is provided in Practice Note iii of the ENMM (RTA 2001).

The assessment considers the extent to which the maximum noise levels for individual passing vehicles exceed the L_{Aeq} noise level for each hour of the night; where a maximum noise level event occurs when:

- L_{Amax} noise levels are greater than 65 dB(A)
- $L_{Amax} - L_{Aeq(1\ hour)} \geq 15$ dB(A).

Operational road traffic vibration

Vibration emissions from traffic travelling on roads typically occur where there are irregularities in the road surface (e.g. potholes). As the new and upgraded roads associated with the project would be designed and constructed to avoid road irregularities, operational ground-borne noise and tactile vibration impacts from operation traffic are not expected.

The potential for operational ground-borne noise and tactile vibration impacts on nearby sensitive receivers from traffic on project roads is presented in Appendix D of the Noise and Vibration Working Paper (**Appendix H**)). Vibration impacts from traffic travelling on the new and upgraded roads are considered negligible and are unlikely to result in ground-borne noise or tactile vibration impacts to sensitive receivers directly next to these roads, and as such, have not been assessed further.

Heritage buildings

There are no specific operational road traffic criteria for heritage buildings. The assessment of operational road traffic noise is based on the use of a receiver, rather than the classification of the receiver. For example, if a heritage building is used for residential purposes, then it is assessed as a residential receiver.

Therefore, heritage buildings identified in this study have been assessed accordingly for road traffic noise impacts based their use, where applicable.

Operational noise modelling

Operational road traffic noise impacts were assessed for the roads associated with the project. To conduct the road traffic noise assessment, a number of specific traffic scenarios were required to be modelled and compared. The assessment considers both the 'Build' (with the project) and 'No Build' (without the project) scenarios for the year of opening (assumed to be 2028) and 10 years after opening (2038) Descriptions of the scenarios modelled are provided in **Table 8-12**. Detailed noise modelling results for the scenarios and the assessment against the NCG requirements are provided in Appendix D of the Noise and Vibration Working Paper (**Appendix H**).

Table 8-12 Traffic noise modelling scenarios

Modelled scenario	Description
2028 Opening year	
'Do minimum 2028'	**'No Build'** opening year of the project but **WITHOUT** the project constructed and operating, including other network enhancements unrelated to the project that may already be committed or recognised as likely to be committed.
'With project 2028'	**'Build'** opening year of the project **WITH** the project constructed and operating, including other network enhancements unrelated to the project that may already be committed or recognised as likely to be committed.

Modelled scenario	Description
2038 Design year (10 years after opening)	
'Do minimum 2038'	**'No Build'** design year of the project but **WITHOUT** the project constructed and operating, including other network enhancements unrelated to the project that may already be committed or recognised as likely to be committed.
'With project 2038'	**'Build'** design year of the project **WITH** the project constructed and operating, including other network enhancements unrelated to the project that may already be committed or recognised as likely to be committed.

Operational traffic noise mitigation

The NMG provides three triggers where a receiver may qualify for consideration of additional noise mitigation. These are:

- Trigger 1: the predicted 'Build' noise level exceeds the NCG controlling criterion and the noise level increase due to the project is greater than 2.0 dB(A)
- Trigger 2: the predicted 'Build' noise level is 5.0 dB(A) or more above the NCG controlling criterion and the receiver is significantly influenced by project road noise, regardless of the incremental impact of the project
- Trigger 3: the noise level contribution from the road project is acute (daytime $L_{Aeq\ (15hour)}$ 65 dB(A) or higher, or night-time $L_{Aeq\ (9hour)}$ 60 dB(A) or higher) even if noise levels are dominated by a non-project road.

Potential noise mitigation measures are identified for receivers that qualify for consideration of noise mitigation measures, in the order of preference, are as follows:

1. Quieter pavement surfaces
2. Noise mounds
3. Noise walls
4. At property treatments.

Operational traffic noise management measures, and their applicability to the project, are further discussed in **Section 8.5.2** and **Section 8.6**.

8.3 Existing environment

Most of the project traverses large open land spaces with minimal nearby residential receivers. Semi-rural residential receivers are located in the Black Hill area at the southern end of the project. In the Tarro area, suburban residential receivers, including a caravan park and other sensitive receivers, are located north of the New England Highway. Towards the northern end of the project, in Heatherbrae and Raymond Terrace, suburban residential receivers including caravan parks and motels are located to the west of the existing Pacific Highway. The suburban residential areas in Heatherbrae and Raymond Terrace are located at large distances (greater than 800 metres) from the project, where noise impacts are unlikely to be substantial.

Concentrated areas of commercial and industrial receivers are located in Beresfield, Tomago and Heatherbrae. In Heatherbrae the commercial and industrial receiver buildings provide a buffer between the project and the nearest residential receivers.

The existing acoustic environment surrounding the project varies, with the acoustic environment in the residential areas mostly influenced by noise from:

- Roads: Predominantly the major arterial roads and motorway including the M1 Pacific Motorway, John Renshaw Drive, New England Highway and the Pacific Highway
- Local transport activities: Especially in commercial and industrial areas, where the noise generated by these activities can contribute to higher ambient noise levels which locally mask road traffic noise.

8.3.1 Noise sensitive receivers and noise catchment areas

To assess noise and vibration impacts, the project has been divided into 19 NCAs (including sub-NCAs) which collectively make up the construction study area. The NCAs were selected to group noise sensitive receivers into areas with similar acoustic environments. Various receiver types and land uses are located within each NCA. A description of each NCA is provided in **Table 8-13**. The location of each NCA is shown on **Figure 8-2**.

Noise and vibration sensitive receivers within each NCA are generally separated into the following major categories:

- Residential receivers (including caravan parks)
- Other sensitive (non-residential) receivers, including:
  - Schools
  - Places of worship
  - Childcare centres
  - Active recreation areas (e.g. sports fields/activities which generate their own noise and are generally less sensitive to external noise)
  - Passive recreation areas (e.g. areas used for low intensity and low noise producing activities which have the potential to be impacted by external noise, such as reading or meditation).
- Commercial premises (including offices and retail outlets)
- Industrial premises.

All sensitive receivers within the construction and operation study areas, based on the above major categories, are identified in the Noise and Vibration Working Paper (**Appendix H**).

Table 8-13 Noise catchment areas

NCA	Description
NCA01A	Located in Black Hill, directly to the west and east of the M1 Pacific Motorway and the project. Rural residential receivers and a single non-residential receiver are located within this NCA. The noise environment is typically dominated by traffic noise from the M1 Pacific Motorway.
NCA01B	Located in Black Hill, east of the M1 Pacific Motorway and south of the project. Rural residential receivers are located within this NCA. The noise environment includes distant traffic noise from the M1 Pacific Motorway.
NCA02	Located in Beresfield, north of John Renshaw Drive and the project. Commercial and industrial receivers and a single non-residential receiver are located within this NCA. The noise environment includes general industrial noise and traffic noise from John Renshaw Drive.
NCA03	Located in Beresfield, north of John Renshaw Drive and the project. Commercial and industrial receivers are located within this NCA. The noise environment includes general industrial noise and traffic noise from the New England Highway.

NCA	Description
NCA04A	Located in Beresfield and Tarro, directly to the north of the New England Highway and the project. Suburban residential receivers and two non-residential receivers are located within this NCA. The noise environment is typically dominated by traffic noise from the New England Highway.
NCA04B	Located in Beresfield and Tarro, north of the New England Highway and the project. Suburban residential receivers and two non-residential receivers are located within this NCA. The noise environment includes distant traffic noise from the New England Highway.
NCA05A	Located in Tarro, directly to the north of the New England Highway and the project. Suburban residential receivers and some industrial receivers are located within this NCA. The noise environment includes traffic noise from the New England Highway.
NCA05B	Located in Beresfield and Tarro, north of the New England Highway and the project. Suburban residential receivers and seven non-residential receivers are located within this NCA. The noise environment includes distant traffic noise from the New England Highway.
NCA06	Located in Woodberry, north and west of the New England Highway and the project. Suburban residential receivers and two non-residential receivers are located within this NCA. The noise environment includes distant traffic noise from the New England Highway.
NCA07	Located in Black Hill and Tarro, directly south of the New England Highway and the project. Two rural residential receivers and some industrial receivers are located within this NCA. The noise environment is dominated by traffic noise from the New England Highway.
NCA08	Located in Hexham, directly west of the New England Highway, east of the Pacific Highway and south of the project. Four residential receivers and numerous commercial and industrial receivers are located within this NCA. The noise environment is dominated by general industrial noise and traffic noise from the New England Highway and Pacific Highway.
NCA09	Located in Tomago, directly south of the Pacific Highway and the project. One residential receiver and a caravan park are located within this NCA. The noise environment is dominated by nearby industrial noise and traffic noise from the Pacific Highway.
NCA10	Located in Tomago, southeast of the Pacific Highway and the project. Commercial and industrial receivers are located within this NCA. The noise environment includes general industrial noise and traffic noise from the Pacific Highway.
NCA11	Located in Tomago, east of the Pacific Highway and the project. One non-residential receiver is located within this NCA. The noise environment is typically dominated by traffic noise from the Pacific Highway.
NCA12	Located in Heatherbrae, directly east of the Pacific Highway and west of the project. Residential receivers and commercial and industrial receivers are located within this NCA. The noise environment is dominated by general industrial noise and traffic noise from the Pacific Highway.
NCA13	Located in Raymond Terrace, directly east and west of the Pacific Highway and at the northern end of the project. Residential receivers and commercial and industrial receivers are located within this NCA. The noise environment includes traffic noise from the Pacific Highway.
NCA14A	Located in Heatherbrae, directly west of the Pacific Highway and the project. Residential receivers, two non-residential receivers and commercial and industrial receivers are located within this NCA. The noise environment is typically dominated by traffic noise from the Pacific Highway.
NCA14B	Located in Raymond Terrace, northeast of the Pacific Highway and the project. Suburban residential receivers and two non-residential receivers are located within this NCA. The noise environment includes traffic noise from the Pacific Highway.
NCA14C	Located in Raymond Terrace, east and west of the Pacific Highway and at the northern end of the project. Suburban residential receivers and one non-residential receiver are located within this NCA. The noise environment is typically dominated by traffic noise from the Pacific Highway.

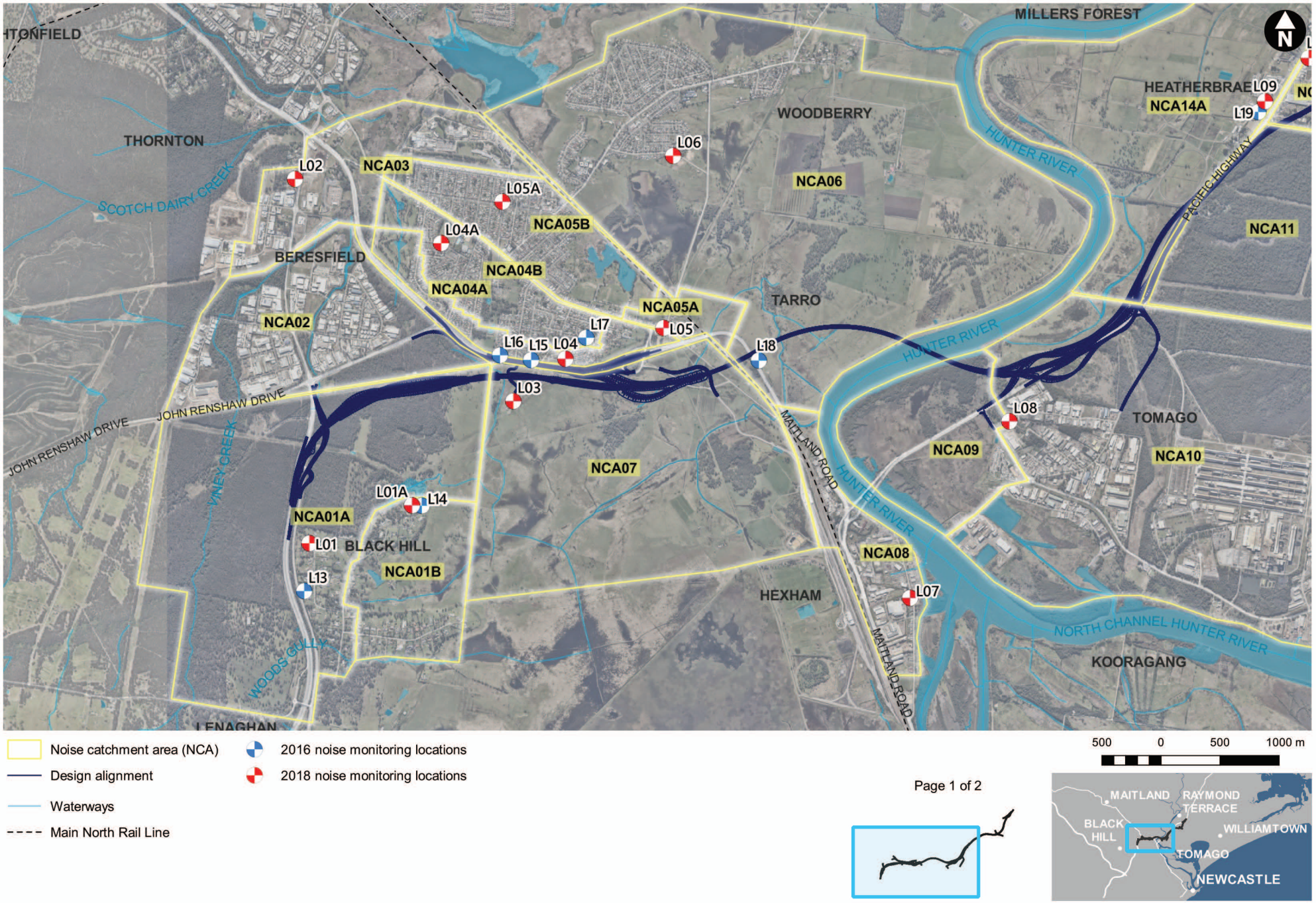


Figure 8-2 Noise catchment areas (map 1 of 2)

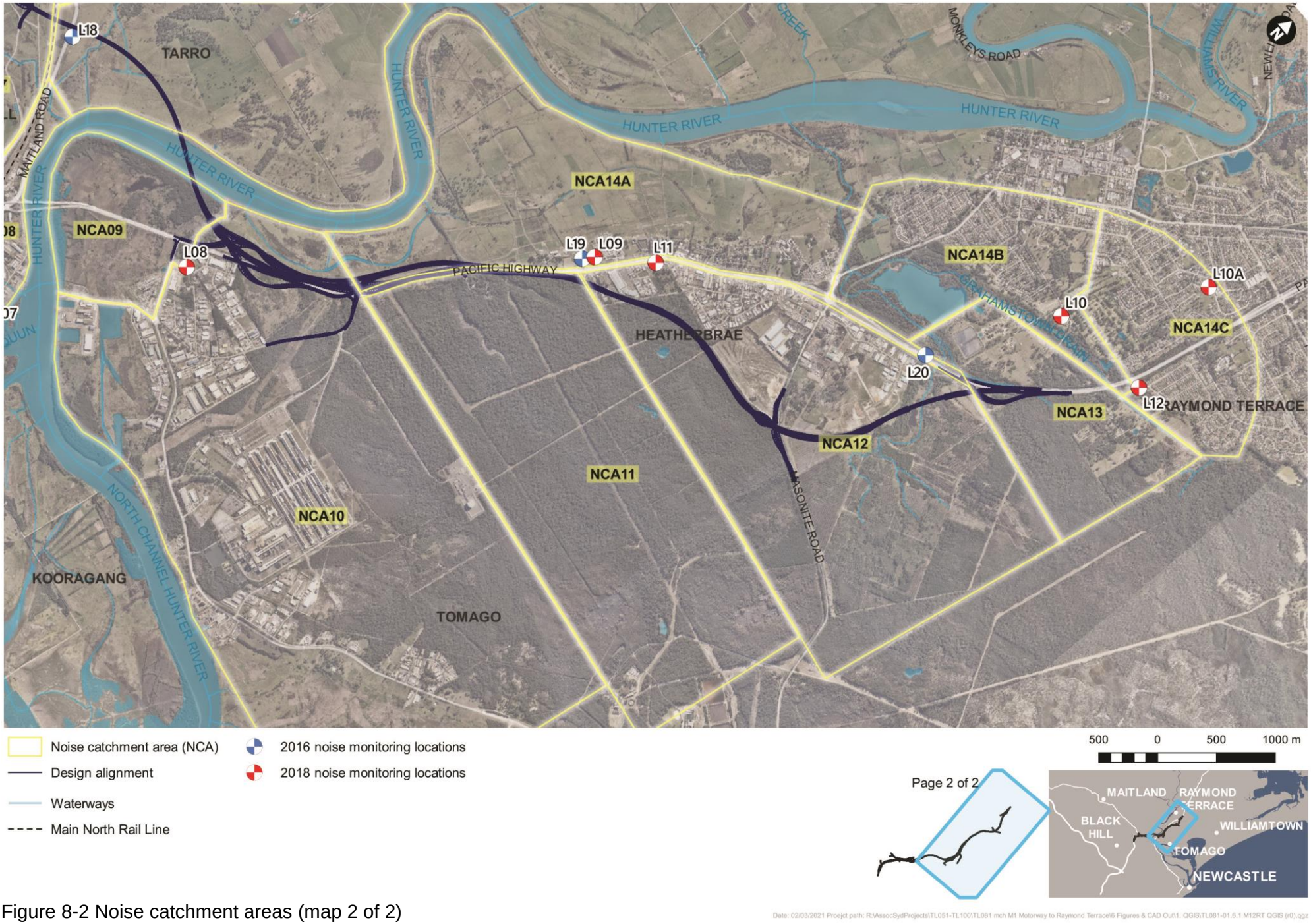


Figure 8-2 Noise catchment areas (map 2 of 2)

8.3.2 Existing noise levels

Existing background noise environment

As outlined in **Section 8.2.2**, noise monitoring was carried out along the project to quantify the existing noise environment. The results of background noise monitoring (locations shown on **Figure 8-1**) are summarised in **Table 8-14**.

Table 8-14 Summary of background noise monitoring results

ID	NCA	Address	Measured L_{A90} RBL[1], dB(A)				
			Morning shoulder[2]	Day[3]	Evening[4]	Evening shoulder[5]	Night[6]
L01	NCA01A	23 Cahill Close, Black Hill	56	54	53	56	45
L01A	NCA01B	24 Walter Parade, Black Hill	46	44	43	46	35
L02	NCA03	54 Weakleys Drive, Beresfield	37	37	40	40	37
L03	NCA07	51 New England Highway, Tarro	53	53	51	51	46
L04	NCA04A	1/15 Quarter Sessions Road, Tarro	59	57	54	57	46
L04A	NCA04B	22 Lenox Street, Beresfield	48	46	43	46	35
L05	NCA05A	11 Anderson Drive, Tarro	51	50	44	47	37
L05A	NCA05B	49 Beresford Avenue, Beresfield	44	43	37	40	30
L06	NCA06	61 Redbill Drive, Woodberry	44	38	40	42	38
L07	NCA08	179 Old Maitland Road, Hexham	45	41	43	41	44
L08	NCA09	838 Tomago Road, Tomago	56	53	52	55	47
L09	NCA14A	2213 Pacific Highway, Heatherbrae	52	53	49	52	41
L10	NCA14B	14 Elizabeth Avenue, Raymond Terrace	41	37	40	41	37
L10A	NCA14C	15 Brown Street, Raymond Terrace	46	42	45	46	42

ID	NCA	Address	Measured L_{A90} RBL[1], dB(A)				
			Morning shoulder[2]	Day[3]	Evening[4]	Evening shoulder[5]	Night[6]
L11	NCA12	2264 Pacific Highway, Heatherbrae	62	63	52	57	43
L12	NCA13	53 Martens Avenue, Raymond Terrace	46	42	45	47	42

1. RBL periods based on the extended construction work hours presented in **Section 8.2.3**
2. Morning shoulder: 6am–7am Monday to Friday
3. Day: 7am–6pm Monday to Saturday and 8am–6pm Sundays & Public Holidays
4. Evening: 6pm–10pm Monday to Sunday and Public Holidays
5. Evening shoulder: 6pm–7pm Monday to Friday
6. Night: 10pm–7am Monday to Saturday and 10pm–8am Sundays and Public Holidays
7. Background noise levels for locations L01A, L04A, L05A, L10A and L12 based on correlation with nominated long-term monitoring locations, as discussed in **Section 8.2.2**.

Existing traffic noise

As outlined in **Section 8.2.2**, noise monitoring of existing traffic noise levels was carried out within the operational study area to quantify existing traffic noise levels. The results of traffic noise monitoring are summarised in **Table 8-15**. Monitoring locations are shown on **Figure 8-1**.

Table 8-15 Monitored road traffic noise levels

ID	NCA	Address	Monitored traffic noise levels, dB(A)	
			$L_{Aeq(15\ hour)}$ Day (7am–10pm)	$L_{Aeq(9\ hour)}$ Night (10pm–7am)
L13	NCA01A	11 Cahill Close, Black Hill	56	53
L14	NCA01B	23 Walter Parade, Black Hill	50	45
L15	NCA04A	70 New England Highway, Tarro	74	72
L16	NCA04A	44 Sapphire Drive Beresfield	64	60
L17	NCA04B	11 Central Avenue, Tarro	57	51
L18	NCA06	Proposed interchange at Tarro	72	70
L19	NCA14A	2209 Pacific Highway, Beresfield	62	59
L20	NCA13	Pacific Highway (north of Raymond Terrace interchange)	75	72

8.4 Assessment of potential construction impacts

8.4.1 Noise management levels

In order to characterise potential construction noise impacts of the project, NMLs and sleep disturbance screening levels for each NCA (refer to **Section 8.3.1**) were established. NMLs were based on the results of background noise monitoring carried out for the project (refer to **Section 8.3.2**) and the CNVG criteria presented in **Table 8-4**. The NMLs for each NCA are presented in **Table 8-16**.

Residential receivers are considered 'noise affected' where construction noise levels are greater than the NMLs. The noise affected level represents the point above which there may be some community reaction to noise. If construction noise is equal to or above $L_{Aeq(15\ minute)}$ 75 dB(A) at any residence at any time, that residential receiver is considered to be highly noise affected. Where predicted and/or measured construction noise levels exceed NMLs, feasible and reasonable noise mitigation and/or management measures, as presented in the CNVG, would be considered in order to meet the NMLs.

Table 8-16 Construction NMLs and sleep disturbance screening levels for residential receivers

NCA[1, 2]	Monitoring location	$L_{Aeq(15\ minute)}$ NML, dB(A)						Sleep disturbance screening level (RBL + 15dB)[9]
		Standard hours (RBL + 10dB)	Extended / out of hours (RBL + 5dB)					
		Day[3]	Morning shoulder[4]	Day[5]	Evening[6]	Evening shoulder[7]	Night[8]	
NCA01A	L01	64	59	59	58	58	50	60
NCA01B	L01A	54	49	49	48	48	40	50
NCA03	L02	47	42	42	45	45	42	52
NCA04A	L04	67	62	62	59	59	51	61
NCA04B	L04A	56	51	51	48	48	40	50
NCA05A	L05	60	55	55	49	49	42	52
NCA05B	L05A	53	48	48	42	42	35	45
NCA06	L06	48	43	43	43	43	43	53
NCA07	L03	63	58	58	56	56	51	61
NCA08	L07	51	46	46	48	46	48	59
NCA09	L08	63	58	58	57	57	52	62
NCA12	L11	73	67	68	57	57	48	58
NCA13	L12	52	47	47	47	47	47	57
NCA14A	L09	63	58	58	54	54	46	56
NCA14B	L10	47	42	42	42	42	42	52

NCA[1, 2]	Monitoring location	$L_{Aeq(15\ minute)}$ NML, dB(A)						Sleep disturbance screening level (RBL + 15dB)[9]
		Standard hours (RBL + 10dB)	Extended / out of hours (RBL + 5dB)					
		Day[3]	Morning shoulder[4]	Day[5]	Evening[6]	Evening shoulder[7]	Night[8]	
NCA14C	L10A	52	47	47	47	47	47	57

1. Refer to **Section 8.3.1** and **Figure 8-2** for location of NCAs
2. NCA02, NCA10 and NCA11 comprise of commercial and industrial type receivers and are not presented in this table
3. Day standard construction hours: 7am–6pm Monday to Friday and 8am–1pm Saturday
4. Morning shoulder: 6am–7am Monday to Friday. Where morning shoulder RBL is higher than day RBL, the day RBL is adopted
5. Day out-of-hours: 7am–8am and 1pm–6pm Saturday, and 8am–6pm Sunday and public holidays
6. Evening: 6pm–10pm Monday to Sunday and Public Holidays. Where the evening RBL is higher than the day RBL, the day RBL is adopted
7. Evening shoulder: 6pm–7pm Monday to Friday. Where the evening shoulder RBL is higher than the evening RBL, the evening RBL is adopted
8. Night: 10pm–7am Monday to Saturday and 10pm–8am Sundays and Public Holidays. Where the night RBL is higher than the evening RBL, the evening RBL is adopted
9. Sleep disturbance assessed for night time period only
10. Caravan parks assessed as residential type receivers.

8.4.2 Predicted worst-case noise impacts

Due to the large number and size of work areas, and the variability of the types of construction activities associated with the project, the assessment of construction noise impacts is based on a ‘worst case’ construction scenario. However, the reality of construction noise impacts is that they would vary greatly depending on the location of the construction work within the work area, the distance between the noise sources and the nearby receivers, the noise intensity of the work, the time of day these specific activities take place, existing attenuation and the changing noise character with all these variables.

For the majority of work, the construction noise impacts would frequently be lower than predicted in the ‘worst-case’ scenario, which is typically only experienced for a short period of time when noisy equipment is in use. **Figure 8-3** shows the noise levels which would be experienced at a sensitive receiver near major construction work on a full day, and how construction noise levels would vary over the work period.

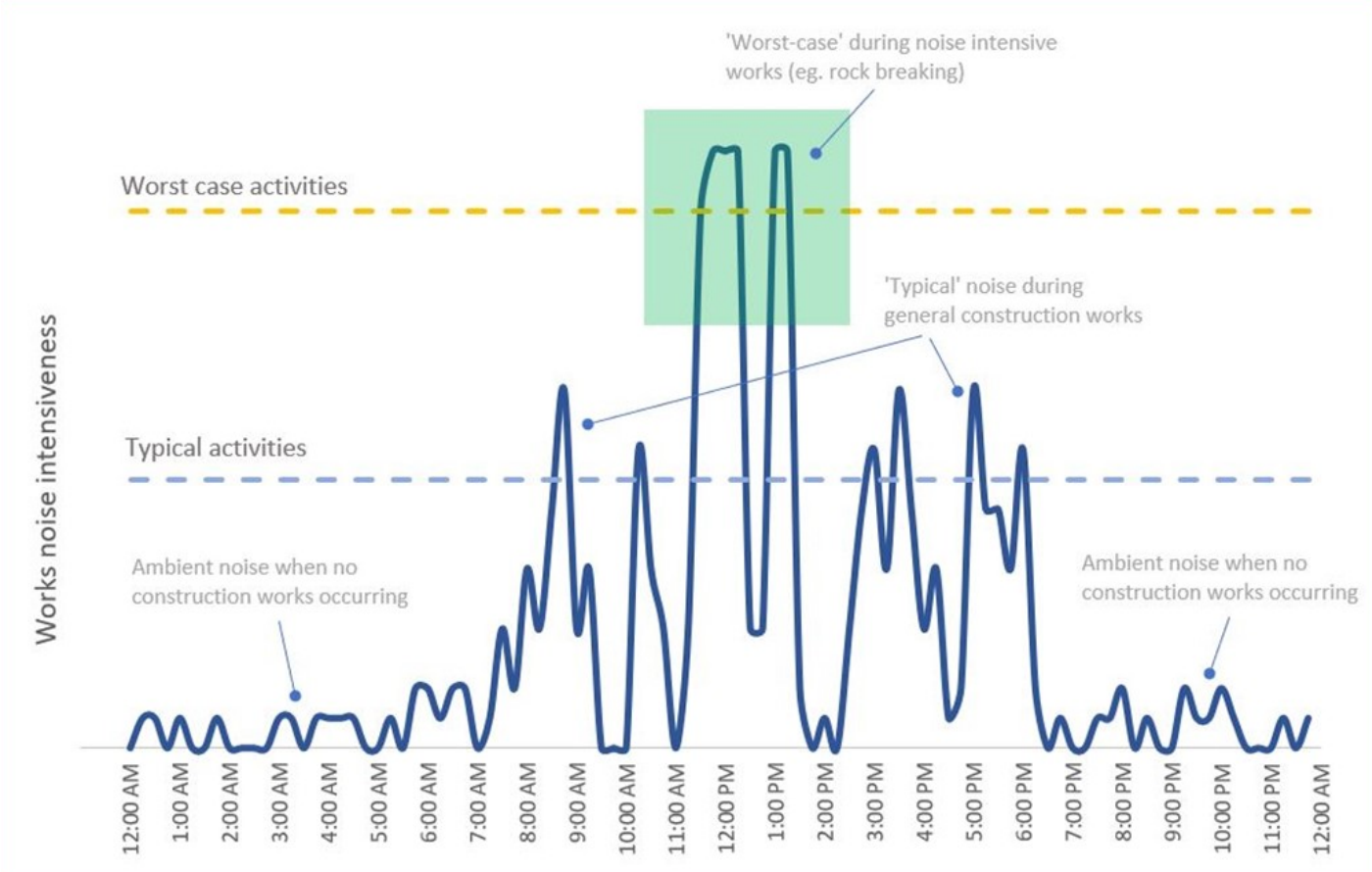


Figure 8-3 Example of indicative construction noise over a full day

The results in the following sections are based on the predicted noise impacts at the most affected receivers in each NCA and are representative of the worst-case (peak impact) and typical (typical impact) scenarios, as described in **Section 8.2.3** and shown on **Figure 8-3**. The worst-case (peak impact) scenario assumes that:

- All the equipment identified within a scenario would operate simultaneously, while in reality only some equipment would operate at the same time
- The equipment operates at its loudest (full load), in its worst case orientation without consideration of directivity, while in reality equipment would only operate at full load in rare instances and for short periods of time
- All plant are operating in one location, while in reality plant may be scattered around the work area
- All plant are at the closest location to each receiver, while in reality plant would move around the work area and noise levels would reduce as plant moves away from a receiver.

Predicted noise impacts are based on the exceedance of the NML, as per the exceedance bands presented in **Table 8-17**, and in accordance with the CNVG. The likely subjective perception from the community for each exceedance band is also shown on **Table 8-17**.

Table 8-17 NML exceedance bands and corresponding perception of impacts

Symbol	Perception	Exceedance of NML	
		Standard hours	Extended hours and out of hours
•	Noticeable	No exceedance	Less than 5 dB(A)
●	Clearly audible	1 dB(A) to 10 dB(A)	5 dB(A) to 15 dB(A)
◆	Moderately intrusive	11 dB(A) to 20 dB(A)	16 dB(A) to 25 dB(A)
■	Highly intrusive	Greater than 20 dB(A)	Greater than 25 dB(A)

* Based on Table C.1 of the CNVG

Predicted noise impacts in the following sections are based on a scenario where no noise and vibration management measures have been implemented. Therefore, once mitigated, the construction noise impacts would be reduced.

These results are considered conservative and noise levels during actual construction work are likely to be lower. The actual noise emissions from the work and resulting noise levels at nearby receivers would be influenced by:

- The location/distance of the plant/equipment with respect to the receiver
- The on/off time of the plant/equipment
- The intensity with which the plant/equipment is working.

In general, construction work would not occur continuously at a location and it is expected that there would be relatively long periods where construction noise levels are much lower than the worst-case levels presented in this assessment. There would also be many instances when no noisy work is occurring.

8.4.3 Construction airborne noise impacts

Residential receivers

The predicted construction noise impacts (with no noise mitigation) at residential receivers in each NCA are described in the following sections. Impacts are described for standard hours, extended hours and out-of-hours periods (as described in **Section 8.2.3**). Detailed noise level predictions and summaries of the number of receivers predicted to experience 'noticeable', 'clearly audible', 'moderately intrusive' and 'highly intrusive' unmitigated noise levels are provided in Appendix C of the Noise and Vibration Working Paper (**Appendix H**).

The predicted unmitigated construction noise impacts are presented for the most affected receivers within each NCA. Receivers which are further away and/or shielded from the work would have lower noise impacts. Where noise impacts are predicted, the methods for controlling the impacts through the use of construction noise management measures are discussed in more detail in **Section 8.6**.

Impacts during standard construction hours

Unmitigated construction noise impacts during standard construction hours and the likely community perceptions in each NCA are presented in **Table 8-18**. Impacts have been separated into the construction scenarios developed for this assessment, as outlined in **Section 8.2.3**.

Table 8-18 Predicted construction noise exceedances standard daytime – residential receivers

ID	Scenario	Activity	NCA01A	NCA01B	NCA03	NCA04A	NCA04B	NCA05A	NCA05B	NCA06	NCA07	NCA08	NCA09	NC012	NCA13	NCA14A	NCA14B	NCA14C
Key:	• Noticeable (no exceedance)		● Clearly audible (1 dB to 10 dB)					◆ Moderately intrusive (11 dB to 20 dB)						■ Highly intrusive (> 20 dB)				
1	Pre-construction and site establishment	Peak impact	•	•	•	◆	●	•	•	•	●	●	●	•	•	•	●	•
		Typical impact	•	•	•	◆	•	•	•	•	•	•	•	•	•	•	•	•
2	Ancillary facility – establishment	Peak impact	•	•	•	◆	●	●	•	•	●	◆	•	•	•	•	•	•
		Typical impact	•	•	•	●	•	•	•	•	●	◆	•	•	•	•	•	•
3	Ancillary facility – operation	Peak impact	•	•	•	●	•	•	•	•	●	◆	•	•	•	•	•	•
		Typical impact	•	•	•	●	•	•	•	•	•	◆	•	•	•	•	•	•
4A	Batch plant operation (concrete batch plant)	Peak impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
4B	Batch plant operation (asphalt batch plant)	Peak impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
5	Clearing, grubbing, and demolition	Peak impact	•	•	•	■	●	•	•	•	●	●	●	•	•	●	●	•
		Typical impact	•	•	•	◆	●	•	•	•	●	●	●	•	•	•	●	•
6	Utility work	Peak impact	•	•	•	■	●	•	•	•	●	●	●	•	•	●	●	•
		Typical impact	•	•	•	◆	●	•	•	•	●	●	●	•	•	•	●	•
7	Bulk earthwork – cuttings	Peak impact	•	•	•	•	●	•	•	•	•	•	•	•	•	●	●	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
9	Bulk earthwork – fill	Peak impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

ID	Scenario	Activity	NCA01A	NCA01B	NCA03	NCA04A	NCA04B	NCA05A	NCA05B	NCA06	NCA07	NCA08	NCA09	NC012	NCA13	NCA14A	NCA14B	NCA14C
10	Concrete pavement (including pavement drainage)	Peak impact	•	•	•	•	•	•	•	•	●	•	•	•	•	●	●	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
11	Asphalt pavement (including pavement drainage)	Peak impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
12	Bridge work (excluding piling)	Peak impact	•	•	•	◆	●	•	•	•	•	●	●	•	•	•	•	•
		Typical impact	•	•	•	◆	•	•	•	•	•	•	•	•	•	•	•	•
13	Piling for bridges and bridge approaches	Peak impact	•	•	•	■	●	•	•	•	•	●	●	•	•	•	●	•
		Typical impact	•	•	•	◆	•	•	•	•	•	•	●	•	•	•	•	•
14	Roadside furniture and finishing work	Peak impact	•	•	•	◆	●	•	•	•	•	•	●	•	•	•	•	•
		Typical impact	•	•	•	◆	•	•	•	•	•	•	•	•	•	•	•	•
15	Traffic management and control	Peak impact	•	•	•	●	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	●	•	•	•	•	•	•	•	•	•	•	•	•
16	Landscaping	Peak impact	•	•	•	◆	•	•	•	•	•	•	●	•	•	•	•	•
		Typical impact	•	•	•	●	•	•	•	•	•	•	•	•	•	•	•	•
17	Cross drainage	Peak impact	•	•	•	◆	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	◆	•	•	•	•	•	•	•	•	•	•	•	•

* NCA02, NCA10 and NCA11 comprise of commercial and industrial receivers and hence, are not included this table

From the results presented in **Table 8-18**, residential receivers are expected to experience the following key noise and vibration impacts during standard construction hours:

- The highest impacts are during ‘peak impact’ activities, which is due to all plant and equipment assessed as operating concurrently, including noise intensive equipment such as rock hammers or concrete saws. For most scenarios, the ‘peak impact’ activities would only occur for a relatively short period. Noise levels during the ‘typical impact’ activities would be lower, impact fewer receivers, and are more indicative of the typical construction noise impacts experienced by receivers
- The highest impacts at residential receivers are generally in catchments where receivers are located close to the construction footprint. This includes NCA04A and NCA08, which are directly to the north and west of the construction footprint, respectively. Receivers in NCA04A are within suburban areas and are densely distributed, resulting in a relatively large number of receivers being impacted by construction noise in this NCA
- ‘Highly intrusive’ noise levels (i.e. greater than 20 dB exceedance) are predicted in NCA04A during clearing, grubbing and demolition work, utility work and bridge piling work during ‘peak impact’ activities. This is due to residential receivers in NCA04A being close to the construction footprint at the Tarro Interchange
- Noise impacts from batch plant operations (concrete and asphalt), bulk earthwork (fill) and asphalt pavement work are not predicted to exceed the NMLs at any residential receiver during peak or typical impact activities. Noise impacts from bulk earthwork (cuttings) and concrete pavement work are not predicted to exceed the NMLs at any residential receivers during typical activities
- Clearing, grubbing and demolition work, and utility work generally impact the highest amount of residential receivers and have the highest exceedances. This is because this work would be carried out over the entire length of the project
- Construction noise impacts are predicted to be ‘Noticeable’ (i.e. no exceedance of NML) at all residential receivers in NCA01A, NCA03, NCA05B, NCA06, NCA12, NCA13 and NCA14C for all construction work scenarios during standard construction work hours.

Impacts during extended hours

Unmitigated construction noise impacts during extended hours and the likely community perceptions in each NCA are presented in **Table 8-19**, **Table 8-20** and **Table 8-21**. Noise impacts are presented for each of the construction scenarios during the morning shoulder, daytime out-of-hours and evening shoulder periods (as described in **Section 8.3.2**), respectively.

Table 8-19 Predicted construction noise exceedances morning shoulder – residential receivers

ID	Scenario	Activity	NCA01A	NCA01B	NCA03	NCA04A	NCA04B	NCA05A	NCA05B	NCA06	NCA07	NCA08	NCA09	NC012	NCA13	NCA14A	NCA14B	NCA14C
Key:	• Noticeable (< 5 dB)		● Clearly audible (5 dB to 15 dB)					◆ Moderately intrusive (16 dB to 25 dB)						■ Highly intrusive (> 25 dB)				
1	Pre-construction and site establishment	Peak impact	•	•	•	◆	●	•	•	•	●	●	●	•	•	●	●	•
		Typical impact	•	•	•	◆	•	•	•	•	•	•	•	•	•	•	•	•
2	Ancillary facility – establishment	Peak impact	•	•	•	◆	●	●	•	•	●	◆	•	•	•	•	•	•
		Typical impact	•	•	•	●	•	•	•	•	●	◆	•	•	•	•	•	•
3	Ancillary facility – operation	Peak impact	•	•	•	●	●	•	•	•	●	◆	•	•	•	•	•	•
		Typical impact	•	•	•	●	•	•	•	•	•	◆	•	•	•	•	•	•
4A	Batch plant operation (concrete batch plant)	Peak impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
4B	Batch plant operation (asphalt batch plant)	Peak impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
5	Clearing, grubbing, and demolition	Peak impact	•	•	•	■	●	●	•	•	●	●	●	•	●	●	●	•
		Typical impact	•	•	•	◆	●	•	•	•	●	●	●	•	•	●	●	•
6	Utility work	Peak impact	•	•	•	■	●	•	•	•	●	●	●	•	•	●	●	•
		Typical impact	•	•	•	◆	●	•	•	•	●	●	●	•	•	●	●	•
7	Bulk earthwork – cuttings	Peak impact	•	•	•	•	●	•	•	•	•	•	•	•	●	●	●	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
9	Bulk earthwork – fill	Peak impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

ID	Scenario	Activity	NCA01A	NCA01B	NCA03	NCA04A	NCA04B	NCA05A	NCA05B	NCA06	NCA07	NCA08	NCA09	NC012	NCA13	NCA14A	NCA14B	NCA14C
10	Concrete pavement (including pavement drainage)	Peak impact	•	•	•	•	●	•	•	•	●	•	•	•	●	●	●	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
11	Asphalt pavement (including pavement drainage)	Peak impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
12	Bridge work (excluding piling)	Peak impact	•	•	•	◆	●	•	•	•	•	●	●	•	•	•	•	•
		Typical impact	•	•	•	◆	•	•	•	•	•	•	●	•	•	•	•	•
13	Piling for bridges and bridge approaches	Peak impact	•	•	•	■	●	●	•	•	•	●	●	•	●	•	●	•
		Typical impact	•	•	•	◆	●	•	•	•	•	●	●	•	•	•	•	•
14	Roadside furniture and finishing work	Peak impact	•	•	•	◆	●	•	•	•	•	●	●	•	•	•	•	•
		Typical impact	•	•	•	◆	•	•	•	•	•	•	•	•	•	•	•	•
15	Traffic management and control	Peak impact	•	•	•	●	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	●	•	•	•	•	•	•	•	•	•	•	•	•
16	Landscaping	Peak impact	•	•	•	◆	●	•	•	•	•	●	●	•	•	•	•	•
		Typical impact	•	•	•	●	•	•	•	•	•	•	•	•	•	•	•	•
17	Cross drainage	Peak impact	•	•	•	◆	●	•	•	•	•	•	●	•	•	•	•	•
		Typical impact	•	•	•	◆	•	•	•	•	•	•	•	•	•	•	•	•

* NCA02, NCA10 and NCA11 comprise of commercial and industrial receivers and hence, are not included this table

Table 8-20 Predicted construction noise exceedances daytime out-of-hours – residential receivers

ID	Scenario	Activity	NCA01A	NCA01B	NCA03	NCA04A	NCA04B	NCA05A	NCA05B	NCA06	NCA07	NCA08	NCA09	NC012	NCA13	NCA14A	NCA14B	NCA14C
Key:	• Noticeable (< 5 dB)		● Clearly audible (5 dB to 15 dB)					◆ Moderately intrusive (16 dB to 25 dB)						■ Highly intrusive (> 25 dB)				
1	Pre-construction and site establishment	Peak impact	•	•	•	◆	●	•	•	•	●	●	●	•	•	●	●	•
		Typical impact	•	•	•	◆	•	•	•	•	•	•	•	•	•	•	•	•
2	Ancillary facility – establishment	Peak impact	•	•	•	◆	●	●	•	•	●	◆	•	•	•	•	•	•
		Typical impact	•	•	•	●	•	•	•	•	●	◆	•	•	•	•	•	•
3	Ancillary facility – operation	Peak impact	•	•	•	●	●	•	•	•	●	◆	•	•	•	•	•	•
		Typical impact	•	•	•	●	•	•	•	•	•	◆	•	•	•	•	•	•
4A	Batch plant operation (concrete batch plant)	Peak impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
4B	Batch plant operation (asphalt batch plant)	Peak impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
5	Clearing, grubbing, and demolition	Peak impact	•	•	•	■	●	●	•	•	●	●	●	•	●	●	●	•
		Typical impact	•	•	•	◆	●	•	•	•	●	●	●	•	•	●	●	•
6	Utility work	Peak impact	•	•	•	■	●	•	•	•	●	●	●	•	•	●	●	•
		Typical impact	•	•	•	◆	●	•	•	•	●	●	●	•	•	●	●	•
7	Bulk earthwork – cuttings	Peak impact	•	•	•	•	●	•	•	•	•	•	•	•	●	●	●	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
9	Bulk earthwork – fill	Peak impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

ID	Scenario	Activity	NCA01A	NCA01B	NCA03	NCA04A	NCA04B	NCA05A	NCA05B	NCA06	NCA07	NCA08	NCA09	NC012	NCA13	NCA14A	NCA14B	NCA14C
10	Concrete pavement (including pavement drainage)	Peak impact	•	•	•	•	●	•	•	•	●	•	•	•	●	●	●	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
11	Asphalt pavement (including pavement drainage)	Peak impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
12	Bridge work (excluding piling)	Peak impact	•	•	•	◆	●	•	•	•	•	●	●	•	•	•	•	•
		Typical impact	•	•	•	◆	•	•	•	•	•	•	●	•	•	•	•	•
13	Piling for bridges and bridge approaches	Peak impact	•	•	•	■	●	●	•	•	•	●	●	•	●	•	●	•
		Typical impact	•	•	•	◆	●	•	•	•	•	●	●	•	•	•	•	•
14	Roadside furniture and finishing work	Peak impact	•	•	•	◆	●	•	•	•	•	●	●	•	•	•	•	•
		Typical impact	•	•	•	◆	•	•	•	•	•	•	•	•	•	•	•	•
15	Traffic management and control	Peak impact	•	•	•	●	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	●	•	•	•	•	•	•	•	•	•	•	•	•
16	Landscaping	Peak impact	•	•	•	◆	●	•	•	•	•	●	●	•	•	•	•	•
		Typical impact	•	•	•	●	•	•	•	•	•	•	•	•	•	•	•	•
17	Cross drainage	Peak impact	•	•	•	◆	●	•	•	•	•	•	●	•	•	•	•	•
		Typical impact	•	•	•	◆	•	•	•	•	•	•	•	•	•	•	•	•

* NCA02, NCA10 and NCA11 comprise of commercial and industrial receivers and hence, are not included this table

Table 8-21 Predicted construction noise exceedances evening shoulder – residential receivers

ID	Scenario	Activity	NCA01A	NCA01B	NCA03	NCA04A	NCA04B	NCA05A	NCA05B	NCA06	NCA07	NCA08	NCA09	NC012	NCA13	NCA14A	NCA14B	NCA14C
Key:	• Noticeable (< 5 dB)		● Clearly audible (5 dB to 15 dB)					◆ Moderately intrusive (16 dB to 25 dB)						■ Highly intrusive (> 25 dB)				
1	Pre-construction and site establishment	Peak impact	•	•	•	■	●	●	●	•	●	●	●	•	•	●	●	•
		Typical impact	•	•	•	◆	●	•	•	•	•	•	•	•	•	•	•	•
2	Ancillary facility – establishment	Peak impact	•	•	•	◆	●	●	•	•	◆	◆	•	•	•	●	•	•
		Typical impact	•	•	•	●	●	●	•	•	●	●	•	•	•	•	•	•
3	Ancillary facility – operation	Peak impact	•	•	•	●	●	●	•	•	●	◆	•	•	•	•	•	•
		Typical impact	•	•	•	●	●	•	•	•	●	●	•	•	•	•	•	•
4A	Batch plant operation (concrete batch plant)	Peak impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
4B	Batch plant operation (asphalt batch plant)	Peak impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
5	Clearing, grubbing, and demolition	Peak impact	•	•	•	■	●	●	●	•	●	●	●	•	●	●	●	•
		Typical impact	•	•	•	■	●	●	●	•	●	●	●	•	•	●	●	•
6	Utility work	Peak impact	•	•	•	■	●	●	●	•	●	●	●	•	•	●	●	•
		Typical impact	•	•	•	■	●	●	●	•	●	●	●	•	•	●	●	•
7	Bulk earthwork – cuttings	Peak impact	•	•	•	●	●	•	●	•	•	•	•	•	●	●	●	•
		Typical impact	•	•	•	•	●	•	•	•	•	•	•	•	•	●	•	•
9	Bulk earthwork – fill	Peak impact	•	•	•	•	●	•	•	•	•	•	•	•	•	●	•	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	●	•	•

ID	Scenario	Activity	NCA01A	NCA01B	NCA03	NCA04A	NCA04B	NCA05A	NCA05B	NCA06	NCA07	NCA08	NCA09	NC012	NCA13	NCA14A	NCA14B	NCA14C
10	Concrete pavement (including pavement drainage)	Peak impact	•	•	•	•	●	●	●	•	●	•	•	•	●	●	●	•
		Typical impact	•	•	•	•	•	•	•	•	●	•	•	•	•	●	•	•
11	Asphalt pavement (including pavement drainage)	Peak impact	•	•	•	●	●	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	●	●	•	•	•	•	•	•	•	•	•	•	•
12	Bridge work (excluding piling)	Peak impact	•	•	•	◆	●	●	•	•	•	•	●	•	•	•	•	•
		Typical impact	•	•	•	◆	●	•	•	•	•	•	●	•	•	•	•	•
13	Piling for bridges and bridge approaches	Peak impact	•	•	•	■	●	●	●	•	•	●	●	•	●	•	●	•
		Typical impact	•	•	•	◆	●	●	•	•	•	•	●	•	•	•	•	•
14	Roadside furniture and finishing work	Peak impact	•	•	•	◆	●	●	•	•	•	•	●	•	•	●	•	•
		Typical impact	•	•	•	◆	•	•	•	•	•	•	•	•	•	•	•	•
15	Traffic management and control	Peak impact	•	•	•	●	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	●	•	•	•	•	•	•	•	•	•	•	•	•
16	Landscaping	Peak impact	•	•	•	◆	●	●	•	•	•	•	●	•	•	●	•	•
		Typical impact	•	•	•	◆	•	•	•	•	•	•	•	•	•	•	•	•
17	Cross drainage	Peak impact	•	•	•	◆	●	•	•	•	•	•	●	•	•	●	•	•
		Typical impact	•	•	•	◆	●	•	•	•	•	•	●	•	•	•	•	•

* NCA02, NCA10 and NCA11 comprise of commercial and industrial receivers and hence, are not included this table

Summarised from **Table 8-19**, **Table 8-20** and **Table 8-21**, residential receivers are expected to experience the following key noise and vibration impacts during extended construction hours:

- Similar to the impacts during standard working hours, the highest impacts are during the 'peak impact' activities, with 'peak impact' activities only occurring for a relatively short period. Noise levels during the 'typical impact' activities would be lower, impact fewer receivers, and are more indicative of the typical construction noise impacts experienced by receivers
- The highest impacts at residential receivers are generally in catchments where receivers are located close to the construction footprint. This includes NCA04A, NCA04B and NCA08, where receivers are located directly next to the New England Highway at Tarro and Hexham. In addition, receivers in NCA04A and NCA04B are located within densely populated suburban areas, resulting in relatively large number of receivers being impacted by construction noise
- During the morning shoulder and daytime out-of-hours periods, 'Highly intrusive' noise levels (i.e. greater than 25 dB exceedance of NML) are predicted in NCA04A during clearing, grubbing and demolition work, utility work and bridge piling work when 'peak impact' activities are being carried out
- Noise impacts during the morning shoulder and daytime out-of-hours periods from batch plant operations (concrete and asphalt), bulk earthwork (fill) and asphalt pavement work are predicted to be 'Noticeable' (i.e. less than 5 dB exceedance of NML) at all residential receivers in all NCAs during peak or typical impact activities. Noise impacts from bulk earthwork (cuttings) and concrete pavement work are predicted to be 'Noticeable' at all residential receivers during typical impact activities
- During the evening shoulder period, 'Highly intrusive' noise levels are predicted in NCA04A during the following scenarios:
  - Pre-construction and site establishment during peak activities
  - Clearing, grubbing and demolition work during peak and typical activities
  - Utility work during peak and typical activities
  - Bridge piling work during peak activities.
- Noise impacts from batch plant operations (concrete and asphalt) during the evening shoulder period are predicted to be 'Noticeable' at all residential receivers in all NCAs during peak or typical activities
- During extended construction hours, pre-construction site establishment work, clearing, grubbing and demolition work, utility work and bridge piling work generally impact the highest number of residential receivers and result in the highest exceedances. This is because this work would be carried out over the entire length of the project
- Construction noise impacts are predicted to be 'Noticeable' at all residential receivers in NCA01A, NCA03, NCA05B, NCA06, NCA12 and NCA14C for all construction work scenarios during the extended work hours. During the morning shoulder and daytime out-of-hours periods, all residential receivers in NCA05B also have 'Noticeable' noise impacts
- When compared to standard construction hours, the morning shoulder and daytime out-of-hours periods during the extended hours would typically have similar impacts at residential receivers. Some NCAs may experience additional construction noise impacts during the morning shoulder and daytime out-of-hours periods, however, the additional impacts are considered to be 'Noticeable' only. Therefore, noise impacts from the proposed construction work scenarios during the morning shoulder and daytime out-of-hours periods would be similar to the impacts during standard construction hours
- For the evening shoulder period, most construction work scenarios would have similar construction noise impacts as the standard construction hours period. Some NCAs may experience additional 'Noticeable' or 'Moderately intrusive' impacts during the evening shoulder period when compared to the standard construction hours period
- Additional 'Highly intrusive' construction noise impacts may be experienced at NCA04A during the evening shoulder period for pre-construction site establishment work (peak impact), clearing, grubbing and demolition work (typical impact) and utility work (typical impact), when compared to standard construction hours.

Impacts during out of hours work

Unmitigated construction noise impacts during extended hours and the likely community perceptions in each NCA are presented in **Table 8-22** and **Table 8-23**. These noise impacts are presented for each of the construction scenarios during the evening (7pm–10pm) and night time (10pm–6am) periods, respectively.

Table 8-22 Predicted construction noise exceedances evening – residential receivers

ID	Scenario	Activity	NCA01A	NCA01B	NCA03	NCA04A	NCA04B	NCA05A	NCA05B	NCA06	NCA07	NCA08	NCA09	NC012	NCA13	NCA14A	NCA14B	NCA14C
Key:	• Noticeable (< 5 dB)		● Clearly audible (5 dB to 15 dB)					◆ Moderately intrusive (16 dB to 25 dB)						■ Highly intrusive (> 25 dB)				
1	Pre-construction and site establishment	Peak impact	•	•	•	■	●	●	●	•	●	●	●	•	•	●	●	•
		Typical impact	•	•	•	◆	●	•	•	•	•	•	•	•	•	•	•	•
2	Ancillary facility – establishment	Peak impact	•	•	•	◆	●	●	•	•	◆	◆	•	•	•	●	•	•
		Typical impact	•	•	•	●	●	●	•	•	●	◆	•	•	•	•	•	•
3	Ancillary facility – operation	Peak impact	•	•	•	●	●	●	•	•	●	◆	•	•	•	•	•	•
		Typical impact	•	•	•	●	●	•	•	•	●	◆	•	•	•	•	•	•
4A	Batch plant operation (concrete batch plant)	Peak impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
4B	Batch plant operation (asphalt batch plant)	Peak impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
5	Clearing, grubbing, and demolition	Peak impact	•	•	•	■	●	●	●	•	●	●	●	•	●	●	●	•
		Typical impact	•	•	•	■	●	●	●	•	●	●	●	•	•	●	●	•
6	Utility work	Peak impact	•	•	•	■	●	●	●	•	●	●	●	•	•	●	●	•
		Typical impact	•	•	•	■	●	●	●	•	●	●	●	•	•	●	●	•
7	Bulk earthwork – cuttings	Peak impact	•	•	•	●	●	•	●	•	•	•	•	•	●	●	●	•
		Typical impact	•	•	•	•	●	•	•	•	•	•	•	•	•	●	•	•
9	Bulk earthwork – fill	Peak impact	•	•	•	•	●	•	•	•	•	•	•	•	•	●	•	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	●	•	•

ID	Scenario	Activity	NCA01A	NCA01B	NCA03	NCA04A	NCA04B	NCA05A	NCA05B	NCA06	NCA07	NCA08	NCA09	NC012	NCA13	NCA14A	NCA14B	NCA14C
10	Concrete pavement (including pavement drainage)	Peak impact	•	•	•	•	●	●	●	•	●	•	•	•	●	●	●	•
		Typical impact	•	•	•	•	•	•	•	•	●	•	•	•	•	●	•	•
11	Asphalt pavement (including pavement drainage)	Peak impact	•	•	•	●	●	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	●	●	•	•	•	•	•	•	•	•	•	•	•
12	Bridge work (excluding piling)	Peak impact	•	•	•	◆	●	●	•	•	•	●	●	•	•	•	•	•
		Typical impact	•	•	•	◆	●	•	•	•	•	•	●	•	•	•	•	•
13	Piling for bridges and bridge approaches	Peak impact	•	•	•	■	●	●	●	•	•	●	●	•	●	•	●	•
		Typical impact	•	•	•	◆	●	●	•	•	•	●	●	•	•	•	•	•
14	Roadside furniture and finishing work	Peak impact	•	•	•	◆	●	●	•	•	•	●	●	•	•	●	•	•
		Typical impact	•	•	•	◆	•	•	•	•	•	•	•	•	•	•	•	•
15	Traffic management and control	Peak impact	•	•	•	●	•	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	●	•	•	•	•	•	•	•	•	•	•	•	•
16	Landscaping	Peak impact	•	•	•	◆	●	●	•	•	•	●	●	•	•	●	•	•
		Typical impact	•	•	•	◆	•	•	•	•	•	•	•	•	•	•	•	•
17	Cross drainage	Peak impact	•	•	•	◆	●	•	•	•	•	•	●	•	•	●	•	•
		Typical impact	•	•	•	◆	●	•	•	•	•	•	●	•	•	•	•	•

* NCA02, NCA10 and NCA11 comprise of commercial and industrial receivers and hence, are not included this table

Table 8-23 Predicted construction noise exceedances night time – residential receivers

ID	Scenario	Activity	NCA01A	NCA01B	NCA03	NCA04A	NCA04B	NCA05A	NCA05B	NCA06	NCA07	NCA08	NCA09	NC012	NCA13	NCA14A	NCA14B	NCA14C
Key:	• Noticeable (< 5 dB)		● Clearly audible (5 dB to 15 dB)					◆ Moderately intrusive (16 dB to 25 dB)						■ Highly intrusive (> 25 dB)				
1	Pre-construction and site establishment	Peak impact	●	●	•	■	◆	◆	●	•	●	●	◆	•	•	◆	●	•
		Typical impact	•	•	•	■	●	●	●	•	●	•	●	•	•	●	•	•
2	Ancillary facility – establishment	Peak impact	•	●	•	■	◆	◆	●	•	◆	◆	●	•	•	●	•	•
		Typical impact	•	•	•	◆	●	●	•	•	●	●	•	•	•	●	•	•
3	Ancillary facility – operation	Peak impact	•	•	•	◆	◆	●	●	•	●	◆	•	•	•	●	•	•
		Typical impact	•	•	•	◆	●	●	•	•	●	●	•	•	•	●	•	•
4A	Batch plant operation (concrete batch plant)	Peak impact	•	•	•	•	●	●	●	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
4B	Batch plant operation (asphalt batch plant)	Peak impact	•	•	•	•	●	●	●	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
5	Clearing, grubbing, and demolition	Peak impact	●	●	•	■	◆	◆	◆	•	●	●	◆	•	●	◆	●	•
		Typical impact	●	●	•	■	◆	◆	●	•	●	●	◆	•	•	◆	●	•
6	Utility work	Peak impact	●	●	•	■	◆	◆	●	•	●	●	◆	•	•	◆	●	•
		Typical impact	●	●	•	■	◆	◆	●	•	●	●	◆	•	•	◆	●	•
7	Bulk earthwork – cuttings	Peak impact	●	●	•	●	◆	●	●	•	•	•	●	•	●	◆	●	•
		Typical impact	●	•	•	●	●	●	●	•	•	•	•	•	•	●	•	•
9	Bulk earthwork – fill	Peak impact	●	●	•	●	●	●	●	•	•	•	•	•	•	◆	•	•
		Typical impact	•	•	•	●	●	●	●	•	•	•	•	•	•	●	•	•

ID	Scenario	Activity	NCA01A	NCA01B	NCA03	NCA04A	NCA04B	NCA05A	NCA05B	NCA06	NCA07	NCA08	NCA09	NC012	NCA13	NCA14A	NCA14B	NCA14C
10	Concrete pavement (including pavement drainage)	Peak impact	•	•	•	●	◆	●	●	•	●	•	●	•	●	◆	●	•
		Typical impact	•	•	•	●	●	●	●	•	●	•	•	•	•	●	•	•
11	Asphalt pavement (including pavement drainage)	Peak impact	•	•	•	●	●	●	●	•	•	•	●	•	•	•	•	•
		Typical impact	•	•	•	●	●	●	●	•	•	•	•	•	•	•	•	•
12	Bridge work (excluding piling)	Peak impact	●	•	•	■	◆	●	●	•	•	•	●	•	•	●	•	•
		Typical impact	•	•	•	■	●	●	●	•	•	•	●	•	•	•	•	•
13	Piling for bridges and bridge approaches	Peak impact	●	●	•	■	◆	◆	◆	•	●	●	◆	•	●	●	●	•
		Typical impact	●	•	•	■	◆	●	●	•	•	•	●	•	•	•	•	•
14	Roadside furniture and finishing work	Peak impact	●	•	•	■	◆	●	●	•	●	•	●	•	•	●	•	•
		Typical impact	•	•	•	■	●	●	●	•	•	•	●	•	•	●	•	•
15	Traffic management and control	Peak impact	•	•	•	◆	●	•	•	•	•	•	•	•	•	•	•	•
		Typical impact	•	•	•	◆	●	•	•	•	•	•	•	•	•	•	•	•
16	Landscaping	Peak impact	●	•	•	■	◆	●	●	•	●	•	●	•	•	●	•	•
		Typical impact	•	•	•	■	●	●	•	•	•	•	●	•	•	●	•	•
17	Cross drainage	Peak impact	•	•	•	■	◆	●	●	•	●	•	●	•	•	●	•	•
		Typical impact	•	•	•	■	●	●	●	•	●	•	●	•	•	●	•	•

* NCA02, NCA10 and NCA11 comprise of commercial and industrial receivers and hence, are not included this table

From the results presented in **Table 8-22** and **Table 8-23**, residential receivers are expected to experience the following key noise and vibration impacts during out-of-hours construction work:

- Similar to impacts during 'standard working hours' and 'extended hours', the highest impacts are during the 'peak impact' activities, however for most scenarios, the 'peak impact' activities would only occur for a relatively short period. Noise levels during the 'typical impact' activities would be lower, impact fewer receivers, and are more indicative of the typical construction noise impacts experiences by receivers
- The highest impacts at residential receivers are generally in catchments where receivers are located close to the construction footprint. This includes NCA04A and NCA04B, which are directly to the north of the New England Highway at Tarro
- During the evening period, 'highly intrusive' noise levels (i.e. greater than 25 dB exceedance of NML) are predicted in NCA04A during the following scenarios:
  - Pre-construction and site establishment during 'peak impact' activities
  - Clearing, grubbing and demolition work during peak and typical impact activities
  - Utility work during peak and typical impact activities
  - Bridge piling work during 'peak impact' activities.
- During the night time period, 'Highly intrusive' noise levels are predicted in NCA04A during the following scenarios:
  - Pre-construction and site establishment during peak and typical impact activities
  - Ancillary facility establishment work during 'peak impact' activities
  - Clearing, grubbing and demolition work during peak and typical impact activities
  - Utility work during peak and typical impact activities
  - Bridge work (non-piling) during peak and typical impact activities
  - Bridge piling work during peak and typical impact activities
  - Roadside furniture and finishing work, landscaping work and cross drainage work during peak and typical impact activities.
- Noise impacts during the evening and night time periods from batch plant operations (concrete and asphalt) are predicted to be 'Noticeable' (i.e. less than 5 dB exceedance of NML) for all residential receivers during typical activities
- During out-of-hours, the following activities generally impact the highest number of residential receivers and with the highest exceedances; pre-construction site establishment work, ancillary facility establishment work, clearing, grubbing and demolition work, utility work, bridge work (non-piling), bridge piling work, roadside furniture and finishing work, landscaping work and cross drainage work
- Noise impacts during out-of-hours construction are predicted to be 'Noticeable' at all residential receivers in NCA03, NCA06, NCA12 and NCA14C for all construction work. All residential receivers in NCA01A would also experience 'Noticeable' noise impacts during the evening period.

Highly noise affected residential receivers

As outlined in **Section 8.4.1**, residential receivers that are subject to noise levels of 75 dB(A) or more are considered to be highly noise affected. For the project, all highly noise affected residential receivers (up to 24 in total) are located within NCA04A, in Tarro, where construction work is closest to receivers.

The location of residential receivers likely to be highly noise affected, regardless of construction scenario or activity, are shown on **Figure 8-4**. However, in reality, the construction work would occur in isolated locations and the number of highly noise affected receivers during any single work scenario would be less than shown. The Noise and Vibration Working Paper (**Appendix H**) further identifies which residential receivers are predicted to potentially be highly noise affected during the different construction scenarios and activities.

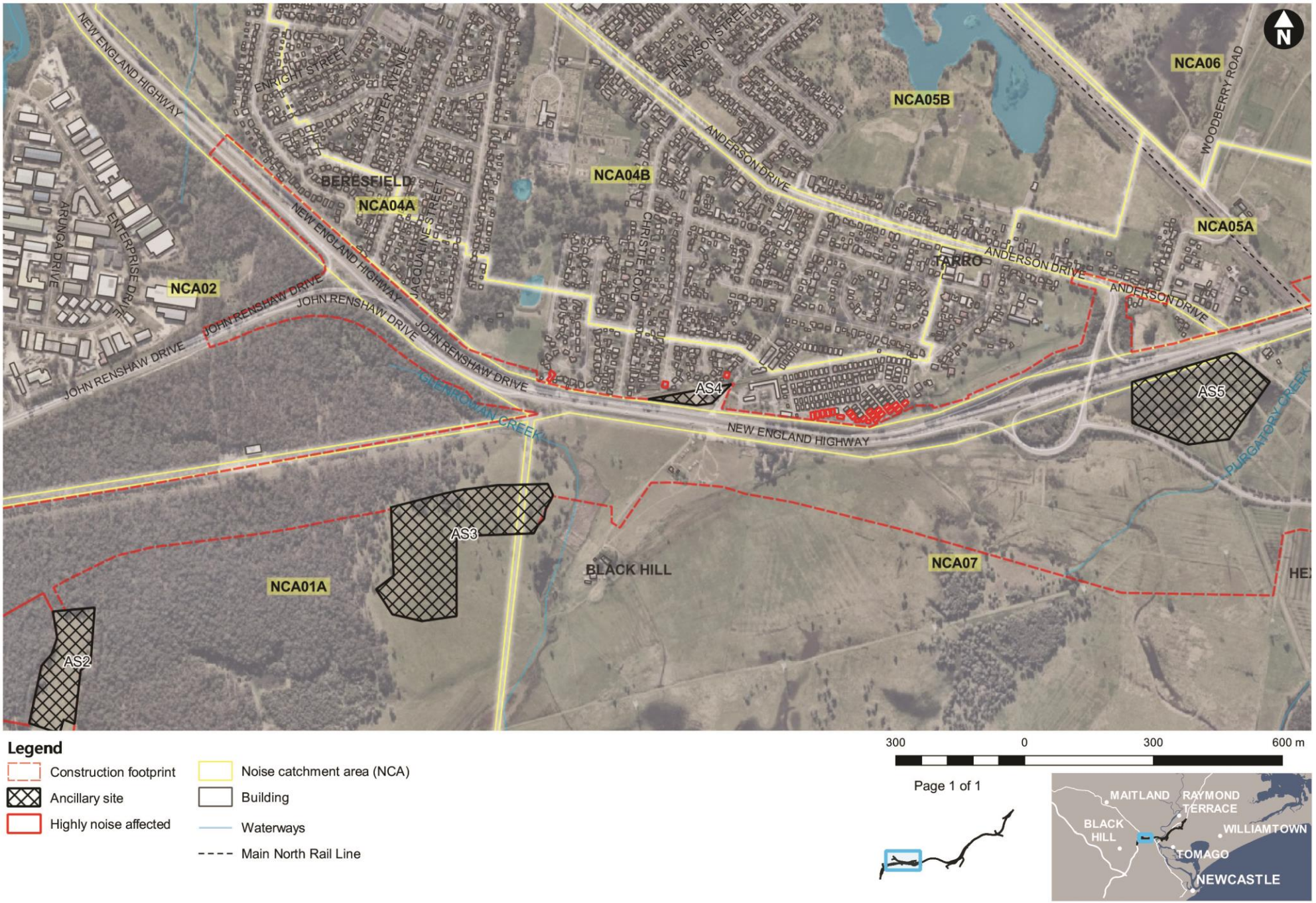


Figure 8-4 Predicted construction noise impacts – highly noise affected residential receivers

Other sensitive receivers

Twenty-one other sensitive receivers and associated buildings (such as classrooms, places of worship, childcare centres and recreation areas, refer to **Section 8.2.3**) would potentially be affected by construction noise from construction of the project. The locations of other sensitive receivers, and the number of other sensitive receivers predicted to exceed the relevant NML for each receiver type during each construction scenario, are provided in the Noise and Vibration Working Paper (**Appendix H**).

The receivers identified as exceeding the NML are:

- Tarro Public School (educational receiver), which consists of eight receiver buildings
- Pasadena Crescent Reserve Soccer Fields (active recreation receiver)
- Hunter Region Botanic Gardens (passive recreation receiver).

The key construction noise impacts associated with these other sensitive receivers are summarised as follows:

- Ancillary facility establishment and operation, batch plant operation (concrete and asphalt), and traffic management and control are not predicted to result in exceedances at any other sensitive receiver locations
- The majority of construction scenarios are predicted to result in exceedances of the NMLs at each of the receivers listed above, where 'Clearly audible' noise levels (i.e. 1 dB to 10 dB exceedance of NML) are typically predicted
- 'Moderately intrusive' noise levels (i.e. 11 dB to 20 dB exceedance of NML) are predicted at the Hunter Region Botanic Gardens during asphalt pavement work, pre-construction and site establishment work, clearing, grubbing and demolition work, utility work and bulk earthwork for cuttings
- The Hunter Region Botanic Gardens is predicted to experience 'Highly intrusive' noise levels (i.e. greater than 20 dB exceedance of NML) during peak and typical concrete pavement work.

Commercial and industrial receivers

Predicted construction noise impacts in each NCA for commercial and industrial receivers is further outlined in the Noise and Vibration Working Paper (**Appendix H**). The key noise impacts associated with commercial and industrial receivers are summarised as follows:

- Construction noise impacts in NCA04A are predicted to be 'Clearly audible' (i.e. 1 dB to 10 dB exceedance of NML) during pre-construction and site establishment work, clearing, grubbing and demolition work, utility work, bridge and viaduct superstructure work (including bridge piling work) and roadside furniture and finishing work
- Construction noise impacts in NCA10, NCA12 and NCA14A are predicted to be 'Clearly audible' and 'Moderately intrusive' (11 dB to 20 dB exceedance of NML) during different construction scenarios and activities
- 'Highly intrusive' noise levels are predicted in NCA10 and NCA12 during pre-construction and site establishment work, ancillary facility establishment and operation, clearing, grubbing and demolition work, and utility work. These impacts occur when peak and/or typical activities are carried out
- Other NCAs either have no commercial or industrial receivers, or the receivers are of sufficient distance from the construction footprint to prevent exceedances.

Sleep disturbance

The project has the potential for sleep disturbance impacts during construction, as outlined in **Section 8.2.3**. Sleep disturbance impacts on residential receivers affected by the project are discussed further in the Noise and Vibration Working Paper (**Appendix H**) and summarised as follows:

- NCA04A and NCA04B have the highest number of residential receivers that would exceed the sleep disturbance screening level. This is because NCA04A and NCA04B have the highest number of residential receivers located close to the construction footprint
- Residential receivers located within NCA05A and NCA05B are predicted to exceed the sleep disturbance screening level, however, fewer exceedances are expected due to the distance between the NCAs and construction activities
- NCA01A, NCA01B, NCA07, NCA08, NCA09 and NCA14A show low numbers of residential receivers exceeding the sleep disturbance screening level
- Utility work causes highest number of exceedances of the sleep disturbance screening level.

Sleep disturbance impacts are dependent on a number of factors, including the existing facade performance of affected residential receiver buildings. Noise mitigation measures that would be used to attenuate L_{Aeq} noise levels would also attenuate maximum (L_{Amax}) noise levels, resulting in compliance of the sleep disturbance screening levels at some residential receivers. The assessed sleep disturbance impacts of the project are therefore a conservative estimate and are likely to be less in reality.

8.4.4 Construction ground-borne noise

Construction can cause ground-borne noise impacts in nearby buildings when vibration-generating equipment is in use. Ground-borne noise impacts should be considered where the ground-borne noise levels are likely to be higher than airborne noise (i.e. noise transmitted through the air) in internal areas of the affected buildings. This may occur where a building near the construction footprint has high performing facades which sufficiently attenuate the airborne noise component.

The majority of receivers are sufficiently distant from the work for ground-borne noise impacts to be minimal. Where residential receivers are located near construction work, airborne noise levels would typically be dominant over the ground-borne noise component.

Ground-borne noise arising from the project is therefore not expected to impact on sensitive receivers and has not been assessed further.

8.4.5 Construction road traffic noise

As outlined in **Section 8.3**, the existing acoustic environment of the project is mostly influenced by noise from users of major arterial roads (including large numbers of light and heavy vehicles) and local transport activities, particularly in commercial and industrial areas.

Construction traffic has the potential to increase road traffic noise levels at receivers located near the construction traffic routes. Where feasible and reasonable, haulage routes associated with the construction of the project would use the existing motorway, and arterial and sub-arterial roads.

Construction traffic associated with the project is not expected to increase traffic noise levels by more than 2 dB(A) on most of the roads along the proposed construction traffic routes. However, increases of up to 5.9 dB(A) during the night time period have been predicted along Masonite Road in Heatherbrae when accessing AS16, AS17, AS18 and AS19. It is noted that only commercial and industrial premises are located along Masonite Road, with no residential or other sensitive receivers. Therefore, although an increase in traffic noise levels of more than 2 dB(A) is predicted, no sensitive receivers would be impacted by construction road traffic noise.

Predicted construction road traffic noise increases for day and night periods are identified in the Noise and Vibration Working Paper (**Appendix H**).

8.4.6 Construction vibration impacts

Residential and commercial / industrial structures

Based on the recommended minimum working distances presented in **Table 8-7**, an assessment of potential vibration impacts was carried out, with a summary of the results provided in **Table 8-24**. The assessment is relevant to all residential and commercial / industrial use buildings, and other similar type structures in the vicinity of construction.

Table 8-24 Potential vibration impacts for residential and commercial / industrial structures

NCA	Approx. distance to nearest buildings from work (metres)	Type of nearest sensitive buildings	Assessment on potential vibration impacts		
			Structural damage risk	Human disturbance	Vibration monitoring
NCA01A	160m – 180m	Residential	Very low risk of structural damage	Very low risk of adverse comment	Not required
NCA01B	590m – 610m	Residential	Very low risk of structural damage	Very low risk of adverse comment	Not required
NCA02	70m – 80m	Commercial / Industrial	Very low risk of structural damage	Very low risk of adverse comment	Not required
NCA03	1150m – 1200m	Commercial / Industrial	Very low risk of structural damage	Very low risk of adverse comment	Not required
NCA04A	10m – 15m	Residential	Medium risk of structural damage	High risk of adverse comment	Vibration monitoring may be considered
NCA04B	80m – 90m	Residential	Very low risk of structural damage	Low risk of adverse comment	Vibration monitoring may be considered
NCA05A	100m – 110m	Residential / Commercial / Industrial	Very low risk of structural damage	Very low risk of adverse comment	Not required
NCA05B	300m – 310m	Residential	Very low risk of structural damage	Very low risk of adverse comment	Not required
NCA06	1350m – 1400m	Residential	Very low risk of structural damage	Very low risk of adverse comment	Not required
NCA07	35m – 40m	Residential	Low risk of structural damage	Medium risk of adverse comment	Vibration monitoring may be considered
NCA08	40m – 45m	Residential	Low risk of structural damage	Medium risk of adverse comment	Vibration monitoring may be considered
NCA09	55m – 60m	Residential	Very low risk of structural damage	Low risk of adverse comment	Vibration monitoring may be considered

NCA	Approx. distance to nearest buildings from work (metres)	Type of nearest sensitive buildings	Assessment on potential vibration impacts		
			Structural damage risk	Human disturbance	Vibration monitoring
NCA10	5m – 10m	Industrial	Low risk of structural damage	Medium risk of adverse comment	Vibration monitoring may be considered
NCA11	70m – 80m	Recreational structure	Very low risk of structural damage	Low risk of adverse comment	Vibration monitoring may be considered
NCA12	10m – 15m	Industrial	Low risk of structural damage	Low risk of adverse comment	Vibration monitoring may be considered
NCA13	290m – 300m	Residential	Very low risk of structural damage	Very low risk of adverse comment	Not required
NCA14A	10m – 15m	Commercial	Low risk of structural damage	Low risk of adverse comment	Vibration monitoring may be considered
NCA14B	520m – 540m	Residential	Very low risk of structural damage	Very low risk of adverse comment	Not required
NCA14C	460m – 480m	Residential	Very low risk of structural damage	Very low risk of adverse comment	Not required

Buried water, sewer and gas pipelines

As outlined in **Chapter 5**, a number of buried water, sewer mains and the Hunter Water Corporation Chichester Trunk Gravity Main (CTGM) are located within the construction footprint at Black Hill, Tarro, Tomago, Heatherbrae and Raymond Terrace. Additionally, high and medium pressure gas mains are located within the construction footprint near the proposed Tomago interchange at the Pacific Highway and Old Punt Road. During construction, vibration intensive plant and equipment (including hydraulic rock breakers / hammers, vibratory pile drivers, bored piling rigs and vibratory rollers) could be used near the water and gas pipelines. However, in accordance with the vibratory level limits for metal flanged buried pipework (as outlined in DIN 4150-3), the vibration intensive plant and equipment likely to be used on site are not expected to impact on these utilities.

Electrical and telecommunication utilities

Numerous buried low and high voltage electrical lines, and optical fibre cables are located within the construction footprint. Based on the vibratory limits for buried electrical cables and telecommunication infrastructure outlined in **Section 8.2.3**, the vibration intensive plant and equipment likely to be used on site are not expected to impact on these utilities. Nevertheless, further assessment and consultation with utility providers would be carried out during detailed design.

For aboveground high voltage electrical transmission lines, vibration impacts to the associated structures such as the stanchions and associated footings are not referred to in the nominated standards, policies and guidelines. Nevertheless, the stanchions and associated footings would be significant as other impacts such as wind loads encountered by the stanchions would be a major factor in their design. Therefore, the vibration limits nominated for buildings would not be applicable for these structures and higher limits would likely be relevant. As a result, the vibration intensive plant and equipment likely to be used on site are not expected to cause adverse impacts to the stanchions and associated footings.

Heritage structures

Heritage within or near the construction footprint comprises Aboriginal and non-Aboriginal heritage (refer to **Chapter 12** (Aboriginal cultural heritage) and **Chapter 17** (non-Aboriginal heritage)). Non-Aboriginal heritage within the construction study area comprises above ground structures and below ground archaeological sites, while Aboriginal heritage within the construction study area comprises surface and subsurface (below ground) artefacts. Below ground archaeological sites (non-Aboriginal heritage) and both surface and subsurface artefacts (Aboriginal heritage) are not subject to potential vibration impacts and so are not considered further in this assessment.

Heritage items with the potential to be impacted by construction vibration are identified in **Table 8-25**.

All identified heritage items are typically located outside of the minimum working distances provided in **Table 8-7**. Given that the closest construction activities to the Hannell Family Vault comprise of ancillary facility activity at AS8 (where vibratory equipment is not expected to be used) vibration intensive plant and equipment associated with the proposed construction activities are not expected to cause cosmetic damage to the nearest affected heritage listed structures.

Table 8-25 Heritage items with the potential to be impacted by construction vibration

Heritage item[1]	Heritage item name	NCA	Location	Approx. distance to vibration intensive work[2]
Item 1	Hannell Family Vault (I179)	NCA08	398B Maitland Road, Hexham	Greater than 100m
Item 3	Glenrowan Homestead (residence)	NCA07	51 New England Highway, Black Hill	85m
Item 4	Residence (I548)	NCA04A	29 Eastern Avenue, Tarro	75m
Item 7	Tarro Substation (I546)	NCA04A	6A Anderson Drive, Tarro	100m
Item 8	Pumping Station (I550)	NCA05A	3 Woodberry Road, Tarro	Greater than 100m
Item 9	Newcastle Crematorium (I34)	NCA04B	176 Anderson Drive, Beresfield	Greater than 500m
Item 10	Our Lady of Lourdes Church (I547)	NCA04A	42 Anderson Drive, Tarro	Greater than 250m

1. Heritage item number specified in **Chapter 17** (non-Aboriginal heritage). Numbers in parenthesis represent listed heritage ID number on relevant local environment plan
2. Distances presented represent distance to construction work areas where vibration intensive plant and equipment would be operating

Based on the results presented in **Table 8-25**, heritage listed structures are unlikely to be impacted by vibration from the construction activities. However, heritage listed structures that are within 100 metres from vibration intensive work would be considered on a case by case basis and further investigation will be carried out during detailed design to confirm the structural integrity (i.e. structurally sound or unsound) of all potentially affected structures. Management measures for potential vibration impacts to heritage items are presented in **Section 8.6**.

8.4.7 Construction blasting noise and vibration

The overpressure and vibration levels generated by blasting are dependent on site specific factors, local ground conditions and the blast design. If required, blasting would occur during construction of the cutting in the Black Hill area, south of John Renshaw Drive, and likely impact on receivers within NCA01A, NCA01B, NCA02, NCA04A and NCA07. Potential construction blasting impacts on these NCAs are described in the Noise and Vibration Working Paper (**Appendix H**).

The need for blasting would be determined as part of the pre-construction and detailed design stages of the project. If blasting is required, site specific noise and vibration investigations would be carried out, which would consider charge and blast configuration design. Analyses would be carried out to identify actual buffer zones associated with the project, and assist in identifying appropriate measures to limit overpressure and vibration to acceptable levels at critical locations. Blast charge and blast configurations would be identified to ensure that the blast management levels are not exceeded.

If required, a Blast Management Plan would be developed before construction, as outlined in **Section 8.6**. The strategy will design appropriate blast charges and configurations in order to achieve compliance with the established management levels for blast overpressure and ground vibration, and comply with relevant guidelines.

8.5 Assessment of potential operational impacts

8.5.1 Operational road traffic noise predictions – impacts without mitigation

As outlined in **Section 8.2.4**, operational road traffic noise impacts have been assessed for the 'No Build' and 'Build' scenarios for both the opening and design years (2028 and 2038 respectively). These scenarios do not include any noise mitigation measures, other than the existing measures (e.g. existing noise barriers) and those that are incorporated into the road design.

The number of receiver buildings that have been predicted to exceed the NCG noise criteria levels for the 'No-Build' (without the project) and 'Build' (with the project) unmitigated scenarios for the opening year and design year are shown in **Table 8-26**. It is noted that if a receiver building is predicted to exceed the NCG noise criteria, it may not necessarily be eligible for additional noise mitigation. Eligibility for additional noise mitigation measures is subject to the processes and criteria discussed in **Section 8.2.4**.

Table 8-26 Number of receiver buildings exceeding the NCG noise criteria without mitigation

NCA	2028 'No-Build'		2028 'Build'		2038 'No-Build'		2038 'Build'	
	Day	Night	Day	Night	Day	Night	Day	Night
NCA01A	13	14	14	18	13	16	18	20
NCA01B	0	0	0	0	0	0	0	0
NCA02	1	1	1	1	1	1	1	1
NCA04A	249	249	280	258	279	275	323	321
NCA04B	19	27	52	59	29	41	81	101
NCA05A	30	27	30	30	30	30	30	30

NCA	2028 'No-Build'		2028 'Build'		2038 'No-Build'		2038 'Build'	
	Day	Night	Day	Night	Day	Night	Day	Night
NCA05B	10	0	10	1	10	1	11	7
NCA07	2	2	2	2	2	2	2	2
NCA09	1	1	1	1	1	1	1	1
NCA12	7	7	7	7	7	7	7	7
NCA13	2	6	4	5	2	6	6	6
NCA14A	104	115	115	131	112	123	137	156
NCA14B	0	5	3	7	2	6	7	22
NCA14C	56	85	60	79	70	101	81	114
Total	**494**	**539**	**579**	**599**	**558**	**610**	**705**	**788**

1. Includes residential and non-residential sensitive receivers
2. NCA03, NCA06 and NCA08 are located outside the operational study area for operational traffic noise and are not included in this table
3. No sensitive (residential and non-residential) receivers are located within NCA10 and NCA11 and are therefore not included this table

As shown in **Table 8-26**, receivers in NCA04A would experience the highest number of exceedances of the NCG noise criteria. This is expected given that the receivers in NCA04A are in a suburban setting and are located close to the project. A high number of receiver buildings in NCA14A, which is located next to the Pacific Highway in Heatherbrae, are also predicted to exceed the NCG noise criteria.

Change in traffic noise levels due to the project

The assessment identified that:

- Some receivers are predicted to experience a decrease in traffic noise levels when the project is operational, mainly due to traffic using the project and bypassing the existing roads near these receivers. On average, the project is predicted to result in reduced traffic noise for about 10 per cent of receivers
- The project is predicted to typically increase traffic noise levels by no more than 2 dB(A) at the majority of receivers surrounding the project, which is considered to be a minor impact. An average of about 82 per cent of receivers within the NCAs are predicted to experience traffic noise level increases of less than 2 dB(A), which is described by the RNP as a minor impact and is barely perceptible
- Some receivers may experience increases of more than 2 dB(A) in traffic noise levels due to traffic from the project moving closer to these residences or increasing the exposure to more traffic lanes. An average of about eight per cent of receiver buildings within the NCAs are predicted to experience increases in traffic noise of more than 2 dB(A) due to the project.

For the majority of receiver buildings within the operational study area (refer to **Figure 8-1**), there is either a reduction or relatively minor change in traffic noise levels due to the project. As such, any requirement for additional noise mitigation is likely to be a result of the existing high noise levels from road traffic.

Further information on the number of receivers in each NCA that are predicted to experience changes in traffic noise when comparing the 'No Build' and 'Build' scenarios is provided in the Noise and Vibration Working Paper (**Appendix H**).

Receivers triggered for consideration of additional noise mitigation

Where road traffic noise levels at receivers are predicted to be above the NCG criteria, the requirement for additional noise mitigation is determined using guidance from the NMG, as outlined in **Section 8.2.4**.

Receivers triggered as requiring consideration of additional noise mitigation for the 2038 design year ‘Build’ scenario are summarised in **Table 8-27**.

Table 8-27 Number of receiver buildings impacted due to the project for design year 2038

NCA [1]	Total Number of residences assessed	Day period – number of receiver buildings				Night period – number of receiver buildings				Requiring consideration of additional noise mitigation [6]
		Exceed NCG noise criteria level [2]	> 2 dB(A) Increase and exceed NCG criteria [3,4]	Exceed cumulative noise limit	Experience acute noise levels (≥ 65 dB(A))[5]	Exceed NCG noise criteria level [2]	> 2 dB(A) Increase and exceed NCG criteria [3,4]	Exceed cumulative noise limit	Experience acute noise levels (≥ 60 dB(A)) [5]	
NCA01A	42	8	6	2	0	8	1	2	0	8
NCA01B	29	0	0	0	0	0	0	0	0	0
NCA02	1	1	0	1	0	1	0	0	0	1
NCA04A	425	103	0	94	71	85	0	83	79	103
NCA04B	615	4	1	2	0	4	3	0	0	4
NCA05A	31	2	2	0	0	2	2	0	0	2
NCA05B	36	0	0	0	0	0	0	0	0	0
NCA07	2	1	0	1	0	1	1	1	1	1
NCA09	1	1	0	1	0	1	0	1	1	1
NCA12	7	6	2	6	0	6	2	6	0	6
NCA13	9	2	2	0	0	2	1	0	0	2
NCA14A	180	50	34	29	6	59	28	34	8	59
NCA14B	84	1	2	0	0	2	1	0	0	2
NCA14C	209	0	0	0	0	0	0	0	0	0
Total	**1671**	**179**	**49**	**136**	**77**	**171**	**39**	**127**	**89**	**189**

1. NCA03, NCA06 and NCA08 located outside the operational study area for operational traffic noise, and no sensitive (residential and non-residential) receivers in NCA10 and NCA11; hence, not included this table
2. NCG noise criteria level based on 'New Road', 'Redeveloped Road', 'Transition Zone' or 'Relative Increase' criteria as per RNP
3. Greater than 2 dB(A) increase based on comparison between 'Build' scenario and 'No-Build' scenario for the design year 2038
4. Exceedance of NCG noise criteria AND increase of more than 2 dB(A) are required to be eligible for noise mitigation
5. Acute noise levels due to contribution from the project only
6. A receiver building qualifies for noise mitigation if it falls under any of the three NMG noise mitigation triggers (i.e. greater than 2 dB(A) increase, exceed cumulative or acute noise) or a multiple of triggers
7. An individual receiver building is considered as a single receiver for the purposes of this assessment, i.e. one double-storey residential building = one receiver building.

As shown in **Table 8-27**, 189 receiver buildings (around 11 per cent of the 1671 assessed) are eligible for consideration of additional noise mitigation in accordance with the NMG requirements outlined in **Section 8.2.4**.

The 189 receiver buildings were identified based on the following assumptions:

- The predicted 'With project' (Build) traffic noise levels in the design year (2038) would exceed the NCG project road noise criteria and would also increase by more than 2 dB(A) as a result of the project at 49 and 39 receiver buildings during the day and night periods, respectively
- The cumulative limit (5 dB(A)) above the NCG project road criterion) would be exceeded at 136 and 127 receiver buildings during the day and night periods, respectively
- There are 77 and 89 receiver buildings predicted to experience acute day $L_{Aeq(15hour)}$ greater than or equal to 65 dB(A) or night $L_{Aeq(9hour)}$ greater than or equal to 60 dB(A)) noise levels due to the project during the day and night periods, respectively.

Some receiver buildings eligible for consideration for additional noise mitigation may fall into more than one of the NMG noise mitigation triggers and have multiple triggers. For example, an eligible receiver building may exceed the cumulative noise limit and also be exposed to acute noise levels.

Other sensitive receivers

Of the 189 receiver buildings identified as being eligible for consideration for additional noise mitigation, 21 receiver buildings are associated with the following other sensitive (non-residential) receivers:

- NCA02: Saint Mary & Saint George Coptic Orthodox Church (place of worship)
- NCA04A: Our Lady of Lourdes Primary School (educational)
- NCA04A: Our Lady of Lourdes Church (place of worship)
- NCA04A: Tarro Public School (educational)
- NCA04B: Newcastle Memorial Park (place of worship)
- NCA04B: Tarro Uniting Church of Australia (place of worship).

The above other sensitive receivers were identified based on the predicted traffic noise levels exceeding the cumulative limit and/or experiencing acute noise levels due to the project.

8.5.2 Operational road traffic noise predictions – impacts with mitigation

Operational noise impacts on noise sensitive receivers have been predicted with quieter pavement surfaces, noise barriers and at-property noise treatments, in accordance with the NMG criteria outlined in **Section 8.2.4**. The following sections describe the operational road traffic noise mitigation measures that have been assumed for the purposes of the assessment and the receivers triggered for consideration of additional noise mitigation. Final noise mitigation treatment would be carried out in accordance with Transport guidelines.

Quieter pavement surfaces

For the purpose of this assessment and in accordance with the NMG, the following quieter pavements have been considered as the first form of noise mitigation to be implemented:

- Open graded asphalt along the upgraded section of the New England Highway, which would achieve a 2 dB(A) noise reduction compared to dense graded asphalt
- Low noise diamond grinding of the concrete pavements along sections of the main carriageways of the project, which would reduce the noise from the concrete pavement equivalent to that of dense graded asphalt.

To investigate the potential benefits of implementing quieter pavements, a comparison of the number of receiver buildings with and without mitigation in the form of quieter pavements was carried out for design year 2038 traffic noise modelling scenarios.

By implementing the proposed quieter pavements, the number of receiver buildings eligible for consideration of additional noise mitigation reduces from 189 to 161 (about a 15 per cent reduction). In addition to the number of receiver buildings being reduced, quieter pavements would also provide an overall noise reduction at all receivers within the operational study area.

The final road pavement surface used for the project will be investigated further during detailed design and would be subject to various requirements besides acoustic benefits, including structural integrity, skid resistance, water dispersion, maintenance, safety and design life.

Noise barriers

The location of noise barriers proposed for the project, where barriers are considered to be a reasonable and feasible noise mitigation option, are shown on **Figure 8-5**. These noise barriers have undergone the NMG barrier analysis, with results of the analysis and recommended reasonable and feasible barrier heights for each location summarised in **Table 8-29**.

The barrier heights indicated in **Table 8-29** are based on the height above the local ground where the proposed barrier is to be located. Receiver counts presented in **Table 8-29** refer to receiver points, where a receiver point is representative of each habitable floor level of a residence. For example, a double storey residence would be represented by two receiver points.

Based on feasibility constraints (including integration with existing noise barriers, interactions with existing utilities, established landscaping and vegetation, heritage, landscape character, visual amenity and constructability), the project would adopt the assessed alternative height for barriers NB.02 (about 3.8 metres) and NB.03 (about four metres).

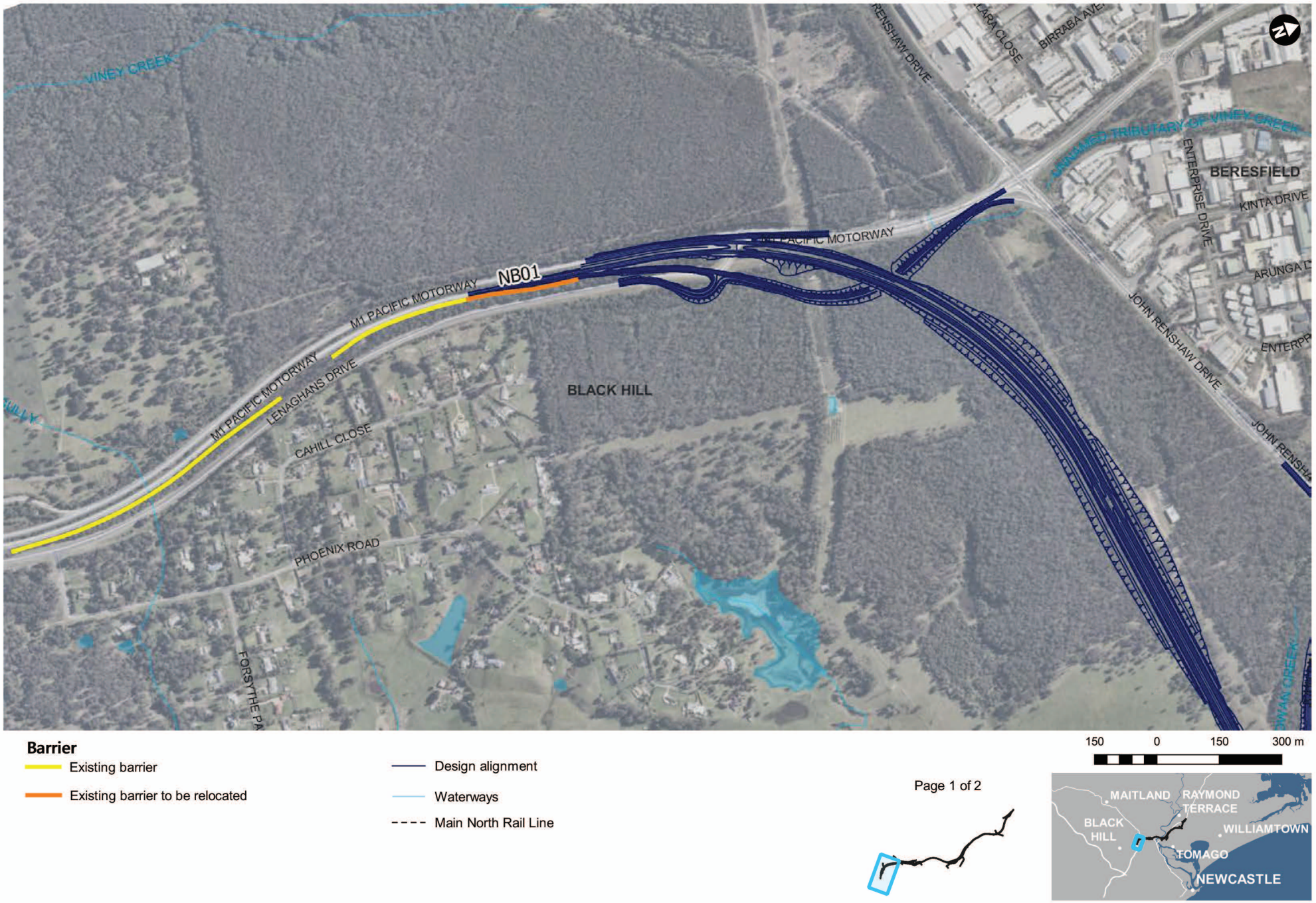


Figure 8-5 Proposed noise barriers considered for NMG analysis (map 1 of 2)

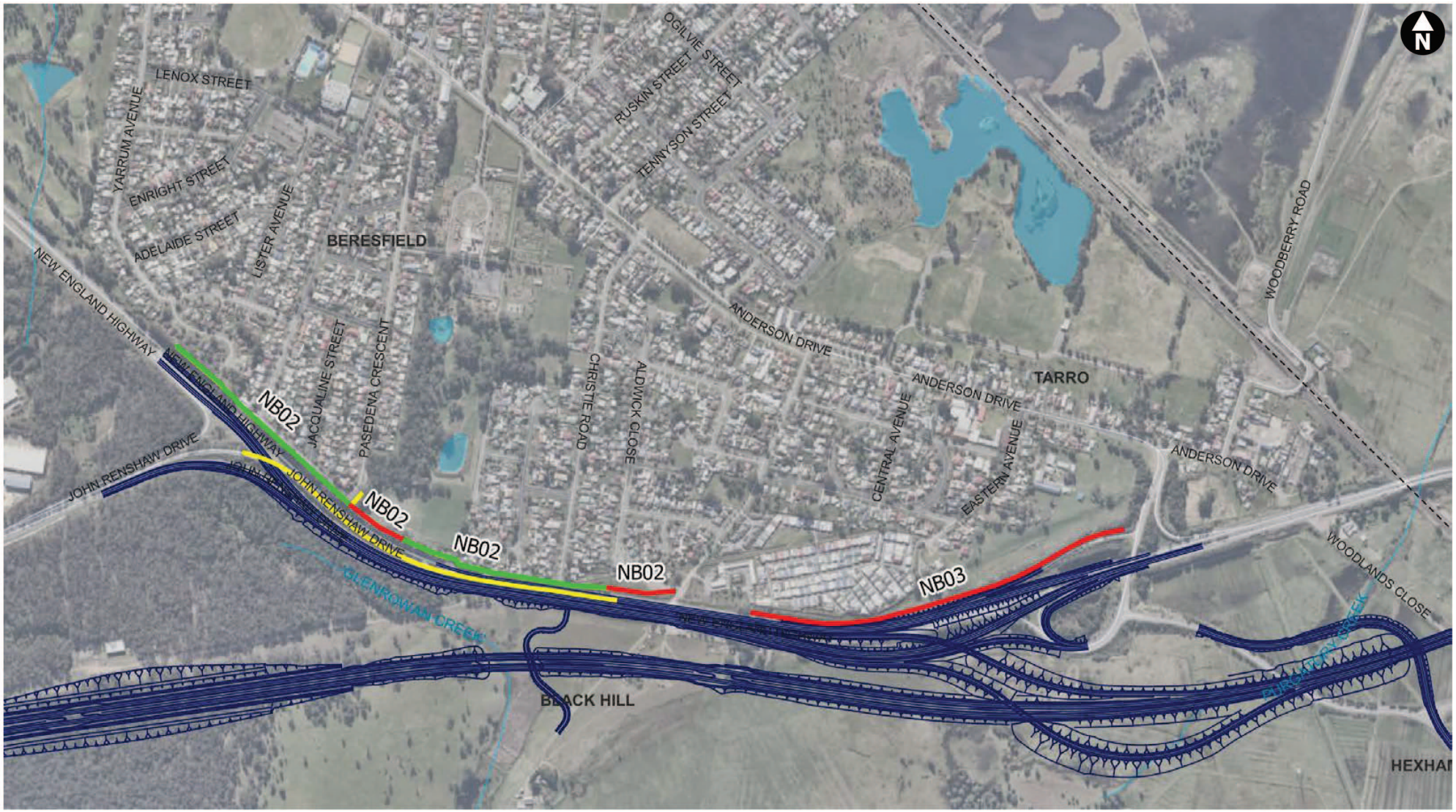


Figure 8-5 Proposed noise barriers considered for NMG analysis (map 2 of 2)

Table 8-28 Summary of NMG noise barrier analysis

Barrier ID	NMG noise barrier analysis						Alternative barrier height (metres) [2, 3]	Comments
	Barrier considered	Approx. length (metres)	Design height (metres) [1, 3]	Total number of benefitting receivers [4]	Triggered receivers with no barrier [4]	Remaining triggered receivers with design barrier [4]		
NB.01	Existing barrier (relocated)	265	-	5	3	3	Retain relocated existing noise barrier	A barrier in this location would not provide acoustic benefits to impacted receivers as the number of receivers identified for at-property treatment would not reduce by two thirds at any barrier height (i.e. no initial design barrier height). Therefore, the existing noise barrier with the same top of barrier height (2.5m) is to be relocated. Increasing the height of the relocated barrier in this location is not reasonable and feasible and is not recommended.
NB.02	Existing barriers (about 3.8m) + new barriers	1105	7	172	36	10	3.8m (consistent with existing barrier heights)	Design barrier height of 7m would provide more than 10 dB(A) insertion loss as required for barriers over 5m. Maintaining the same 3.8m barrier height as the existing barriers would provide more than 5 dB(A) insertion loss as required for barriers 5m and under. Although the design barrier height of 7m would achieve the insertion loss requirements, an alternative barrier height consistent with the lower existing noise barriers may be considered. Constraints affecting the feasibility of the barrier such as the integration with existing structures, removal of vegetation (e.g. well established urban/native trees) as well as urban design and visual amenity impacts would be further investigated during further design development. It is noted that this noise barrier consists of existing barriers and new barriers to fill in the gaps between the existing barriers.

Barrier ID	NMG noise barrier analysis						Alternative barrier height (metres) [2, 3]	Comments
	Barrier considered	Approx. length (metres)	Design height (metres) [1,3]	Total number of benefitting receivers [4]	Triggered receivers with no barrier [4]	Remaining triggered receivers with design barrier [4]		
NB.03	New	741	8	56	35	19	4	Design barrier height of 8m would provide more than 10 dB(A) insertion loss as required for barriers over 5m. The alternative barrier height of 4m achieves the required insertion loss of 5 dB(A) for barriers 5m and under. Therefore, the alternative barrier height of 4m has been considered and would provide a reasonable balance between addressing noise impacts and visual amenity impacts for nearby receivers. Constraints affecting the feasibility of the barrier such as removal of vegetation (e.g. well established urban/native trees) as well as urban design and visual amenity impacts would be further investigated during further design development.

1. Calculated noise barrier height following the process described in Section 8 of the NMG without considering urban design, visual impacts and/or engineering constraints
2. Alternative noise barrier height determined based on urban design, visual impacts and/or engineering constraints
3. Height of barrier based on the height above the local ground where the proposed barrier is to be located
4. Receiver counts based on receiver points, where a receiver point is representative of each habitable floor level of a residence. For example, a double storey residence would be represented by two receiver points.

Receiver buildings considered for at property noise treatment

Following the NMG noise barrier analysis, any residual residential and non-residential sensitive receivers triggered for additional noise mitigation and still exceeding the relevant NCG traffic noise criteria would be considered for at-property treatment. A summary of the number of receiver buildings identified as being eligible for consideration of at-property treatment based on the design barrier and alternative barrier heights is presented in **Table 8-29**.

Receiver buildings identified as potentially eligible for at-property treatment are presented in the Noise and Vibration Working Paper (**Appendix H**).

Table 8-29 Number of receiver buildings potentially eligible for at-property noise mitigation treatment

NCA	Design barrier height		'Alternative' barrier height	
	Number of residential receiver buildings[1, 2]	Number of non-residential receiver buildings[1, 2]	Number of residential receiver buildings[1, 3, 4]	Number of non-residential receiver buildings[1, 3, 4]
NCA01A	4	0	4	0
NCA01B	0	0	0	0
NCA02	0	1	0	1
NCA04A	44	18	85	18
NCA04B	0	2	0	2
NCA05A	1	0	1	0
NCA05B	0	0	0	0
NCA07	1	0	1	0
NCA09	1	0	1	0
NCA12	6	0	6	0
NCA13	2	0	2	0
NCA14A	38	0	38	0
NCA14B	1	0	1	0
NCA14C	0	0	0	0
Total	**98**	**21**	**139**	**21**

1. A receiver building represents the individual building outlines as shown in Appendix D of the Noise and Vibration Working Paper (**Appendix H**)
2. Based on the implementation of quieter pavements and the design barrier heights nominated in **Table 8-28**
3. Based on the implementation of quieter pavements and the alternative barrier heights nominated in **Table 8-28**
4. Only receiver buildings in NCA04A, NCA04B and NCA05A are protected by the 'alternative' barrier.

The number of receivers considered for at-property treatment would be confirmed during detailed design. Additional investigations to consider at-property noise treatments are outlined in **Section 8.6**.

Other sensitive receivers

From **Table 8-29** the non-residential receiver buildings identified as being eligible for consideration of at-property treatment are associated with the following other sensitive receivers:

- NCA02: Saint Mary & Saint George Coptic Orthodox Church (place of worship)
- NCA04A: Our Lady of Lourdes Primary School (educational)
- NCA04A: Our Lady of Lourdes Church (place of worship)
- NCA04A: Tarro Public School (educational)
- NCA04B: Newcastle Memorial Park (place of worship)
- NCA04B: Tarro Uniting Church of Australia (place of worship).

It is noted that the introduction of quieter pavements and noise barriers do not provide sufficient benefits to the above other sensitive receivers and associate receiver buildings to allow traffic noise impacts to comply with the corresponding NCG project road criterion. This is due to these receivers being located at distances greater than 100 metres from the traffic noise source, resulting in marginal noise mitigation benefits.

Furthermore, given that other sensitive receivers are assessed against internal noise criteria, further investigation during further design development would be required for non-residential receiver buildings considered for at-property treatment to confirm the extent of noise impact and eligibility for consideration of noise mitigation. This is because the difference in noise from outside to inside can increase to more than 30 dB(A) depending on the building construction type, location of the room within the building, window type and whether the use of the space requires the window to be fully opened, slightly opened or closed.

8.5.3 Maximum noise level assessment

Maximum noise levels across the project were assessed based on the results of noise monitoring carried out for the project (**Section 8.3.2**) and the methodology presented in **Section 8.2.4**.

Maximum noise levels range from 68 dB(A) and 87 dB(A), with the highest noise levels typically recorded at locations near or adjacent to the M1 Pacific Motorway, New England Highway and the Pacific Highway.

The project is predicted to potentially change maximum noise levels and events (refer to **Section 8.2.4**) at the following NCAs:

- NCA01A: receivers to the east of the M1 Pacific Motorway may experience an increase in maximum noise levels and the number of events compared to the existing situation. This is due to the widening of the M1 Pacific Motorway and the introduction of the Black Hill interchange moving traffic closer to receivers in this NCA. Receivers in the northern section of this NCA may also experience increases in maximum noise levels and number of events due to the introduction of new carriageways to the north
- NCAs 04A, 04B and 05A: receivers to the north of the New England Highway may experience a reduction in the number of maximum noise level events due to vehicles using the project's new carriageways, and the widening of the New England Highway toward the south. However, maximum noise levels would likely remain the same as the northern side of the New England Highway would remain the same as the existing
- NCAs 14A and 14B: receivers to the west of the Pacific Highway and the project may experience a reduction in the number of maximum noise level events due to vehicles travelling along the project east of the Heatherbrae industrial precinct.

For NCAs where maximum noise levels and the number of events would increase due to the project, the affected receivers may be considered for additional noise mitigation measures. With the implementation of noise mitigation measures, there would be an overall reduction in road traffic noise levels, including L_{Amax} noise levels.

8.6 Environmental management measures

The environmental management measures that will be implemented to minimise the noise and vibration impacts of the project, along with the responsibility and timing for those measures, are presented in **Table 8-30**.

Table 8-30 Management measures (noise and vibration)

Impact	Reference	Environmental management measure	Responsibility	Timing
General construction noise and vibration	NV01	A Construction Noise and Vibration Management Plan (CNVMP) would be prepared for the project to mitigate and manage noise and vibration impacts. The CNVMP would include: • All potential significant noise and vibration generating activities associated with the activity • Measures to be implemented during construction to minimise noise and vibration impacts, such as restrictions on working hours, respite periods, staging, placement and operation of ancillary facilities, temporary noise barriers, haul road maintenance, and controlling the location and use of vibration generating equipment • A monitoring program to assess performance against relevant noise and vibration criteria • Process for the implementation of respite periods to provide residents with respite from ongoing impact • Arrangements for consultation with affected receivers, including notification and complaint handling procedures • Contingency measures to be implemented in the event of noncompliance with noise and vibration criteria.	Contractor	Prior to construction/ construction
	NV02	Where reasonable and feasible, implementation of recommended operational noise mitigation would be carried out within 12 months of construction activities commencing.	Transport / Contractor	Prior to construction/ construction
Vibration impacts to residential and commercial structures	NV03	Where vibration generating activities will be carried out within minimum working distances for cosmetic damage, vibration monitoring will be carried out. Where monitoring indicates cosmetic damage criteria are exceeded, alternative low vibration work practices will be investigated and implemented.	Contractor	Construction
Vibration impacts to utilities	NV04	Where works are within 25m of utilities consultation will be carried out with the relevant utility authorities to establish site specific mitigation measures to manage potential vibration impacts.	Contractor	Construction

Impact	Reference	Environmental management measure	Responsibility	Timing
Vibration impacts to heritage structures	NV05	Heritage items within 100m of vibration intensive work are to be considered on a case by case basis and further investigation would be carried out during detailed design to confirm the structural integrity (i.e. structurally sound or unsound) of all potentially affected structures. Where items are considered sensitive to vibration, appropriate vibration criteria would be determined after detailed inspections have been completed.	Contractor	Prior to construction/ construction
Blasting	NV06	If blasting is to be included as part of the construction work, the CNVMP would include a Blast Management Plan (BMP). The BMP would be prepared in consultation with the EPA, demonstrating that all blasting and associated activities would be carried out in a manner that would not generate unacceptable noise and vibration impacts or pose a substantial risk impact to residences and sensitive receivers.	Contractor	Prior to construction/ construction
Operational road traffic noise impacts	NV07	Operational noise and vibration mitigation measures would be identified in an Operational Noise and Vibration Review (ONVR). Requirements for mitigation measures, including quieter noise pavements, noise barriers, and at-property treatments, would be reviewed as part of the ONVR and as the detailed design progresses. Detailed information on floorplans and facade construction for school classrooms, places of worship and childcare centres determined to exceed the applicable Noise Criteria Guideline (NCG) (Roads and Maritime Services 2015c) internal noise criteria will be obtained during design development. The implementation of treatments would be carried out in accordance with the Noise Mitigation Guideline (NMG) (Roads and Maritime Services 2015d).	Transport / Contractor	Detailed design/ construction/ prior to operation
Operational road traffic noise impacts	NV08	Within 12 months of starting project operation, actual operational noise performance would be compared to predicted operational noise performance to analyse the effectiveness of the operational road traffic noise mitigation measures. Additional reasonable and feasible mitigation would be considered where any additional receivers are identified as qualifying for consideration of noise mitigation under the NMG.	Transport / Contractor	Operation

Impact	Reference	Environmental management measure	Responsibility	Timing
Impacts from Out of Hours Works	NV09	An Out of Hours Work Procedure will be included as part of the CNVMP. The procedure will follow the approach in Roads and Maritime Services' Construction Noise and Vibration Guideline (Roads and Maritime Services 2016b) and include, but not be limited to: • Scheduling of noise intensive or high noise impact work to evening periods where feasible • Use of alternative plant and equipment and/or construction techniques to minimise noise • Notification and consultation requirements including preparation of a 'look ahead' program for likely out of hours work • Use of temporary noise barriers • Respite periods • Representative noise monitoring • Offers of reasonable and temporary alternative accommodation or an act of good will • Use of negotiated agreements.	Contractor	Construction

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M1 Pacific Motorway extension to Raymond Terrace

Environmental impact statement – Chapter 9: Biodiversity

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9. Biodiversity

This chapter describes the potential biodiversity 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 biodiversity, as outlined in the SEARs, are to:

- Consider all feasible measures to avoid and minimise impacts on terrestrial and aquatic biodiversity
- Offsets are equivalent to any remaining impacts from construction and operation of the project
- Assure the delivery of offsets and /or supplementary measures required for the project.

Table 9-1 outlines the SEARs that relate to biodiversity, including the Commonwealth assessment requirements under the EPBC Act, and identifies where they are addressed in this EIS. The full assessment of biodiversity impacts is provided in the Biodiversity Assessment Report (BAR) (**Appendix I**).

Table 9-1 SEARs (biodiversity)

Secretary's requirement	Where addressed
1. Environmental Impact Assessment Process	
2. The project will impact matters of national environmental significance (MNES) protected under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and will be assessed in accordance with the NSW Bilateral Agreement (2015). The Proponent must assess impacts to MNES protected under the EPBC Act. The assessment must be in accordance with the requirements listed in Attachment A.	Impacts of the project on MNES are assessed in **Section 9.4.2** and **Section 9.4.3**. Attachment A requirements of the SEARs are detailed below (within this table).
4. Biodiversity	
1. The Proponent must assess biodiversity impacts in accordance with the Framework for Biodiversity Assessment (FBA) and be carried out by a person accredited in accordance with section 142B(1)(c) of the *Threatened Species Conservation Act 1995*.	The biodiversity impacts of the project are assessed in **Section 9.4.2** and **Section 9.4.3**. Impacts have been assessed in accordance with the FBA, as outlined in **Section 9.1** and **Section 9.2**.
2. The Proponent must assess any impacts on biodiversity values not covered by the FBA, as specified in section 2.3, including but not limited to aquatic biodiversity values covered by the *Fisheries Management Act 1994*, relating to aquatic species, riparian and marine vegetation, instream macrophytes and habitat condition.	Other impacts not covered by the FBA, including impacts to aquatic habitat, are discussed in **Section 9.4.2** and **Section 9.4.3**.
3. The Proponent must survey and assess impacts on EECs, threatened species and/or populations and provide the information specified in section 9.2 of the FBA. Species specific surveys shall be undertaken for those species and in accordance with the survey requirements specified by the OEH.	Information relating to surveys is provided in **Section 9.2.3.** Potential impacts on EECs, threatened species and/or populations are identified in **Section 9.4.2** and **Section 9.4.3**.
4. The Proponent must identify whether the project as a whole, or any component of the project, would be classified as a Key Threatening Process (KTP) in accordance with the listings in the *Threatened Species Conservation Act 1995* (TSC Act), *Fisheries Management Act 1994* (FM Act) and *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).	Key threatening processes listed under legislation are discussed in **Section 9.4.2**.

Secretary's requirement	Where addressed
12. Socio-economic, land use and property	
5. The Proponent must undertake an assessment of biosecurity risks and management measures relating to the potential for spread of pests, disease or weeds, in accordance with the 'general biosecurity duty' under the *Biosecurity Act 2015*.	Existing weeds, pests and pathogens are discussed in **Section 9.3.8**. The potential risks of spread are discussed in **Section 9.4.2, Section 9.4.3** and **Section 14.4.2**.
17. Safety and risk	
2. The Proponent must assess the biosecurity risk of the project to minimise the inadvertent spread of disease and pathogens affecting agricultural activities, native vegetation and threatened fauna.	Impacts associated with the inadvertent spread of disease and pathogens on native vegetation and threatened fauna is discussed in **Section 9.4.2** and **Section 9.4.3**. Impacts to agricultural activities are discussed in **Chapter 22** (safety and risk).
Attachment A of the SEARs: Commonwealth (EPBC Act) General assessment requirements	
The EIS must address the matters outlined in Schedule 4 of the EPBC Act Regulations and the matters outlined below in relation to the controlling provisions. For each of the EPBC Act-listed species and ecological communities impacted by the proposed action, the EIS must provide:	The EIS has addressed the matters outlined in Schedule 4 of the EPBC Act Regulations (refer to **Appendix C**)
1. Survey results, including details of the scope, timing and methodology for studies or surveys used and how they are consistent with (or justification for divergence from) published Commonwealth guidelines and policy statements. For ecological communities, this includes any condition thresholds provided in the listing advice or approved conservation advice.	A summary of the surveys is presented in **Section 9.2.3**. Further details of surveys such as timing, scope and methodologies are provided in the BAR (**Appendix I**).
2. A description and quantification of habitat in the study area (including suitable breeding habitat, suitable foraging habitat, important populations and habitat critical for survival), with consideration of, and reference to, any relevant Commonwealth guidelines and policy statements including listing advices, conservation advices and recovery plans, threat abatement plans.	A description of habitat within the study area is provided in **Section 9.3.** Further details are provided in the BAR (**Appendix I**).
3. Maps displaying the above information (specific to EPBC matters) overlaid with the proposed action. It is acceptable, where possible, to use the mapping and assessment of Plant Community Types (PCTs) and the species surveys prescribed by the BAM as the basis for identifying EPBC Act-listed species and communities. The EIS must clearly identify which PCTs are considered to align with habitat for the relevant EPBC Act-listed species or community and provide individual maps for each species or community.	The PCTs and threatened ecological communities within the construction footprint have been mapped in **Figure 9-5** and **Figure 9-6** respectively. **Table 9-6** identifies the PCTs that align with the threatened ecological communities. **Section 9.3.5** identifies habitat for threatened species listed under the TSC Act and the EPBC Act. Threated species recorded within and adjacent to the construction footprint are displayed on **Figure 9-7**. Individual maps are provided in the BAR (**Appendix I**).
4. Description of the nature, geographic extent, magnitude, timing and duration of any likely direct, indirect and consequential impacts on any relevant EPBC Act-listed species and communities. It must clearly identify the location and quantify the extent of all impact areas to each relevant EPBC Act-listed species or community.	Impacts to EPBC Act listed species and migratory species are summarised in **Section 9.4.2** and **Section 9.4.3**. Further details are provided in the BAR (**Appendix I**).

Secretary's requirement	Where addressed
5. Information on proposed avoidance and mitigation measures to deal with the impacts of the action, and a description of the predicted effectiveness and outcomes that the avoidance and mitigation measures will achieve.	Design refinements that have avoided or minimised potential impacts of the project are outlined in **Section 9.4.1**. Environmental management measures identified to minimise the biodiversity impacts of the project are presented in **Section 9.5**.
6. Quantification of the offset liability for each species and community significantly impacted, and information on the proposed offset strategy, including discussion of the conservation benefit for each species and community, how offsets will be secured, and the timing of protection. It is a requirement that offsets directly contribute to the ongoing viability of the specific protected matter impacted by a proposed action i.e. 'like-for-like'. Like-for-like includes protection of native vegetation that is the same ecological community or habitat being impacted (preferably in the same region where the impact occurs), or funding to provide a direct benefit to the matter being impacted e.g. threat abatement, breeding and propagation programs or other relevant conservation measures.	Quantification of offset liability is provided in **Section 9.6**. A Biodiversity Offset Strategy (BOS) has been prepared for the project (Appendix I of the BAR (**Appendix I**)).

9.1 Policy and planning setting

The biodiversity assessment for the project was facilitated under Clause 28 of the Biodiversity Conservation (Savings and Transitional) Regulation 2017, which permits the proponent to submit the application in accordance with the former planning provisions. This approach was approved by DPIE (formerly Department of Planning and Environment) on 13 November 2017. As such, the former provisions of the TSC Act remain in force for this assessment, rather than the *Biodiversity Conservation Act 2016* (BC Act). This includes the listing of threatened species and ecological communities as per the TSC Act, instead of the BC Act.

Biodiversity impacts have been assessed through implementation of the FBA (OEH 2014a) and with reference to the NSW Biodiversity offsets policy for major projects (OEH 2014b). For aquatic biodiversity impacts, the FBA refers to the requirements guided by the Fisheries NSW Policy and guidelines for fish habitat conservation and management (DPI 2013a).

The biodiversity assessment has been prepared by a person accredited in accordance with s142B(1)(c) of the TSC Act (accreditation number 179).

As described in **Section 2.2.2**, the project is a controlled action (under section 75 of the EPBC Act) due to its potential for significant impacts on listed threatened species and communities (section 18 and 18A of the EPBC Act). As such, the project requires assessment and approval under the EPBC Act.

The biodiversity assessment was prepared in accordance with the following relevant legislation, policy and guidelines:

- Legislation:
  - Biodiversity Conservation (Savings and Transitional) Regulation 2017
  - *Threatened Species Conservation Act 1995* (TSC Act)
  - *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
  - *Biodiversity Conservation Act 2016* (BC Act)
  - Bilateral agreement made under section 45 of the EPBC Act relating to environmental assessment between Commonwealth of Australia and the State of New South Wales
  - *Fisheries Management Act 1994* (FM Act)
  - State Environmental Planning Policy (Coastal Management) 2018 (Coastal Management SEPP)
  - National Parks and Wildlife Regulation 2019.
- Guidelines:
  - Guideline for Biodiversity Offsets (Roads and Maritime Services 2016e)
  - Policy and guidelines for fish habitat conservation and management (DPI 2013a)
  - Aquatic Ecology in Environmental Impact Assessment – EIA guideline (Marcus Lincoln Smith 2003)
  - Threatened Biodiversity Survey and Assessment Guidelines for Developments and Activities – Working Draft 2004 (Department of Environment and Conservation 2004)
  - NSW Guide to Surveying Threatened Plants (OEH 2016a). This guideline has since been superseded by "Surveying threatened plants and their habitats – NSW survey guide for the Biodiversity Assessment Method" (DPIE 2020a). While flora surveys were completed before the updated guideline was published, the guidelines are considered to be generally consistent
  - Risk Assessment Guidelines for Groundwater Dependent Ecosystems (Kuginis et al. 2012)
  - Why do fish need to cross the road? Fish passage requirements for waterway crossings (Fairfull & Witheridge 2003)
  - NSW Biodiversity Offsets Policy for Major Projects (OEH 2014b)
  - Framework for Biodiversity Assessment (OEH 2014a)
  - Developments adjacent to NPWS: Guidelines for consent and planning authorities (NPWS 2020a). This guideline has superseded the "Guidelines for developments adjoining land and water managed by DECCW" (DECCW 2010b).

Further detail on the above legislation, policies and guidelines, and how they apply to the project, is provided in the BAR (**Appendix I**).

9.2 Assessment methodology

9.2.1 Study area

In accordance with the FBA, the study area for the biodiversity assessment is the area directly affected by the development and any additional areas likely to be affected, either directly or indirectly. For this assessment the study area is the construction footprint, as described in **Section 5.4.1**, and shown on **Figure 9-1**.

A wider study area was used to assess landscape values and native vegetation cover percentages. This wider study area comprised of a 550 metre buffer around the construction footprint, known as a 'landscape buffer' (**Figure 9-1**).

9.2.2 Desktop assessment

Background research

In July 2020, a default list of threatened flora and fauna species with the potential to occur within the study area (known as 'candidate species') was first identified using the assessment filtering tool in the BioBanking Credit Calculator (BBCC). A review was then conducted to identify possible additional candidate species using the following databases and literature sources:

- NSW BioNet Vegetation Classification database (DPIE 2020b)
- BioNet Atlas of NSW Wildlife
- BioNet Threatened Biodiversity Data Collection
- The federal Bureau of Meteorology's Atlas of Groundwater Dependent Ecosystems (GDE) (Australian Bureau of Meteorology 2020a)
- NSW Coastal Management State Environmental Planning Policy – interactive map viewer (DPIE 2020c)
- Soil Landscapes of the Newcastle 1:100,000 Sheet Map (Matthei 1995)
- Available regional vegetation mapping and previous biodiversity studies
- NSW Department of Primary Industries (DPI) Fisheries Spatial Data Portal
- The federal Department of Agriculture, Water and the Environment (formerly the Department of Environment) Protected Matters Search Tool (PMST)
- Department of Planning, Industry and Environment Area of Outstanding Biodiversity Value register
- Port Stephens Council Comprehensive Koala Plan of Management (CKPoM) (Port Stephens Council and Australian Koala Foundation 2002)
- Hunter Wetlands National Park: Plan of Management (NPWS 2020b).

Additionally, the following spatial databases (using a 10 kilometre radius around the construction footprint) were also consulted:

- Lower Hunter Koala Study (Eco Logical Australia 2013) mapping of key habitat areas for the koala in the lower Hunter
- Grey-headed Flying-fox management strategy for the Lower Hunter (GeoLink 2013)
- Swift Parrots and Regent Honeyeaters in the Lower Hunter Region of New South Wales: An assessment of status identification of high priority habitats and recommendations for conservation (Birdlife Australia 2013).

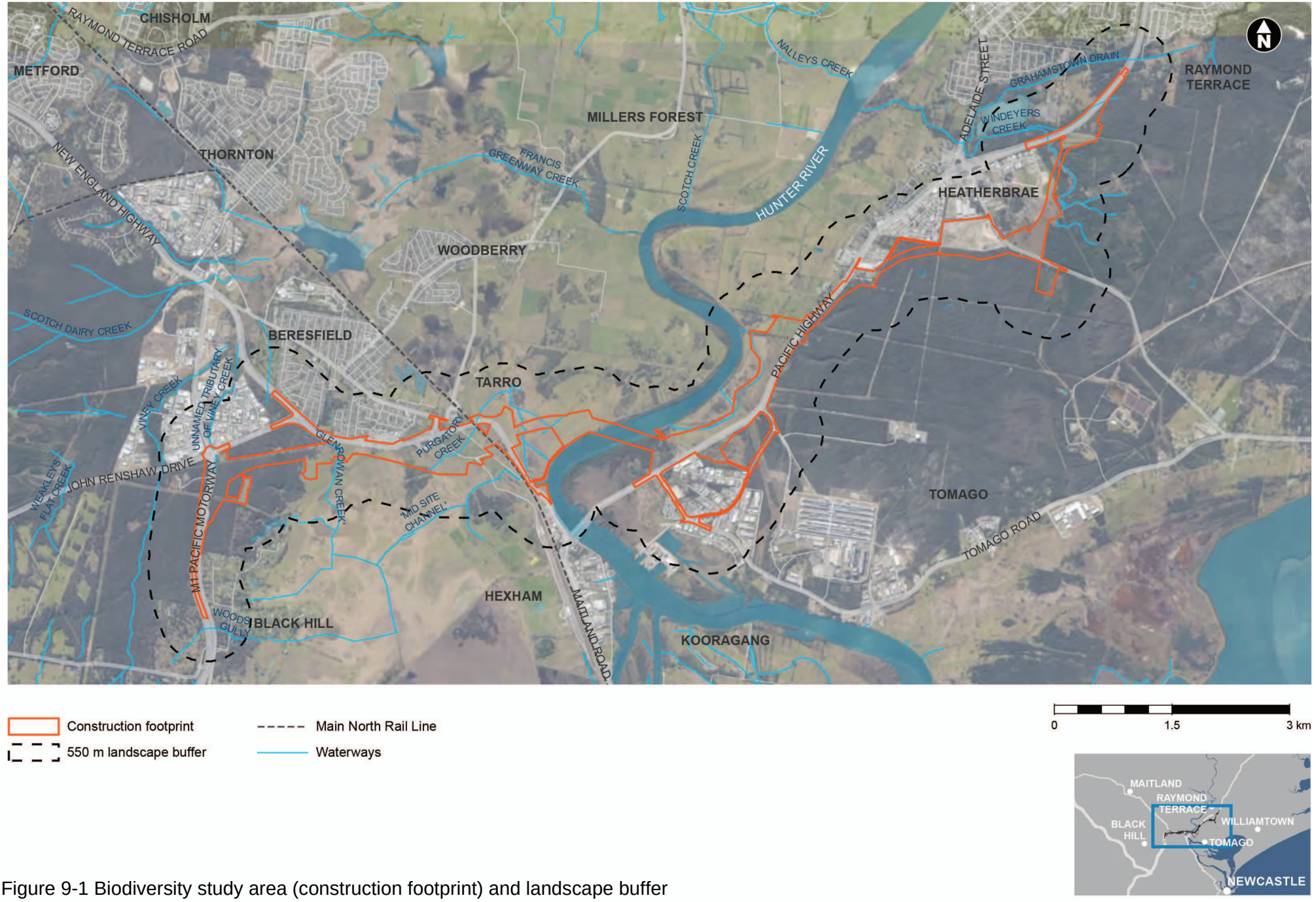


Figure 9-1 Biodiversity study area (construction footprint) and landscape buffer

Candidate species

Ecosystem credit species

The BBCC assessment tool identified 38 ecosystem credit species for consideration within the construction footprint. In assessing the likely presence of these species, the FBA allows an assessor to identify whether any of the habitat components for the predicted threatened species are present or not within the construction footprint.

The likelihood of occurrence for each species was then considered based on the presence of habitat components. The assessment identified 25 of the 38 ecosystem credit species initially identified by the BBCC with a likelihood to occur within the construction footprint. These species were targeted in field surveys discussed below.

Species credit species

The BBCC assessment tool identified, as a first filtering step, 24 species credit species to be assessed for potential presence, considering geographic and habitat constraints described for each species. From this, seven species were removed on the basis that specific habitat constraints were not present in the study area, and/or the species range occurred outside the study area. The remaining 17 species were considered in a second filtering step, by assessing the habitat present in the study area with the preferred habitat requirements of each species.

The BBCC identified an additional 19 species to be assessed in the second filtering step, due to known records of each species in a 10 kilometre radius of the study area, as determined by database searches and/or were identified in the SEARs.

The 36 identified species represent potential candidate species credits from the BBCC. A number of additional species credit species were not identified in the BBCC, although were identified from the background review of regional records and / or were identified in the SEARs (in correspondence with government agencies). Those species identified as having a moderate to high likelihood of occurring in the construction footprint were also considered candidate species and were targeted in field surveys.

9.2.3 Field surveys

Vegetation mapping

Field surveys were carried out within the construction footprint between 2014 and 2020 across multiple years, seasons and conditions, to identify and map vegetation communities and optimise candidate species (threatened species considered to have potential habitat present) surveys. Site value (i.e. vegetation condition) was assessed using data collected from 56 plots within the construction footprint, as shown on **Figure 9-5**. Surveys were carried out at an additional 10 plots in areas of non-native vegetation and vegetation outside of the construction footprint.

Targeted surveys

Targeted surveys were carried out between December 2014 and November 2018 for threatened flora and fauna species considered to have moderate to high likelihood of occurring within the construction footprint.

Targeted threatened flora

Targeted flora surveys for 20 candidate species were carried out and involved traversing parallel transects through potential habitat for target species within and around the construction footprint, in accordance with the relevant guidelines. Targeted threatened flora species are listed in **Table 9-2** and survey locations for threatened flora are provided in the BAR (**Appendix I**).

Table 9-2 Targeted threatened flora species

Scientific name	Common name	Conservation status	
		TSC Act	EPBC Act
Non-cryptic plant species			
Acacia bynoeana	Bynoe's Wattle	V	V
Asperula asthenes	Trailing Woodruff	V	V
Callistemon linearifolius	Netted Bottle Brush	V	-
Commersonia prostrata	Dwarf Kerrawang	E	E
Cynanchum elegans	White-flowered Wax Plant	E	E
Eucalyptus camfieldii	Camfield's Stringybark	V	V
Eucalyptus parramattensis subsp. decadens	Drooping Red Gum	V	V
Grevillea parviflora subsp. parviflora	Small-flower Grevillea	V	V
Maundia triglochinoides	-	V	-
Persicaria elatior	Tall Knotweed	V	-
Rhodamnia rubescens	Scrub Turpentine	CE	CE
Rhodomyrtus psidioides	Native Guava	CE	CE
Rutidosis heterogama	Heath Wrinklewort	V	V
Cryptic plant species			
Cryptostylis hunteriana	Leafless Tongue Orchid	V	V
Diuris arenaria	Sand Doubletail	V	-
Diuris pedunculata	Small Snake Orchid	E	E
Diuris praecox	Rough Doubletail	V	V
Corybas dowlingii	Red Helmet Orchid	V	-
Pterostylis chaetophora	-	V	-
Rhizanthella slateri	Eastern Underground Orchid	V	E

Note: V = Vulnerable, E = Endangered, CE = Critically Endangered.

Targeted threatened fauna

Based on the desktop review, targeted fauna surveys for 24 candidate species were carried out using the following survey methods:

- Arboreal (tree-based) Elliot traps
- Terrestrial (ground-based) Elliot traps
- Pitfall trapping
- Camera trapping
- Nest boxes
- Harp traps
- Bat call recording
- Time and area-based bird surveys
- Walked and vehicle spotlighting transects
- Area-based frog searches/spotlighting/call playback
- Koala Rapid Assessment Method (KRAM).

Targeted threatened fauna species are listed in **Table 9-3** and survey locations are shown in **Figure 9-2**.

Table 9-3 Targeted threatened fauna species

Scientific name	Common name	Conservation Status	
		TSC Act	EPBC Act
Amphibians			
Litoria aurea	Green and Golden Bell Frog	E	V
Litoria brevipalmata	Green-thighed Frog	V	-
Crinia tinnula	Wallum Froglet	V	-
Uperoleia mahonyi	Mahoney's Toadlet	E (BC Act)	-
Birds			
Anthochaera phrygia	Regent Honeyeater	CE	CE
Pandion haliaetus	Eastern Osprey	V	-
Haliaeetus leucogaster	White-bellied Sea-Eagle	V (BC Act)	M
Ixobrychus flavicollis	Black Bittern	V	-
Botaurus poiciloptilus	Australasian Bittern	E	E
Ephippiorhynchus asiaticus	Black-necked Stork	E	-
Irediparra gallinacea	Comb-crested Jacana	V	-
Xenus cinereus	Terek Sandpiper	V	M
Mammals			
Phascolarctos cinereus	Koala	V	V
Petaurus norfolcensis	Squirrel Glider	V	-
Phascogale tapoatafa	Brush-tailed Phascogale	V	-
Cercartetus nanus	Eastern Pygmy Possum	V	-

Scientific name	Common name	Conservation Status	
		TSC Act	EPBC Act
Planigale maculata	Common Planigale	V	-
Pseudomys novaehollandiae	New Holland Mouse	-	V
Chalinolobus dwyeri	Large-eared Pied Bat	V	V
Miniopterus australis	Little Bent-winged Bat	V	-
Miniopterus orianae oceanensis	Large Bent-winged Bat	V	-
Myotis macropus	Southern Myotis	V	-
Pteropus poliocephalus	Grey-headed flying fox	V	V
Reptiles			
Hoplocephalus bitorquatus	Pale-headed Snake	V	-

Note: M = Migratory, V = Vulnerable, E = Endangered, CE = Critically Endangered.

All surveys were carried out under the appropriate licences, including scientific licences as required under Clause 22 of the National Parks and Wildlife Regulation 2002 (now superseded by the National Parks and Wildlife Regulation 2019), Section 132C (now repealed) of the *National Parks and Wildlife Act 1974* (License Number: SL100044) and Animal Care and Ethics approval and animal research authority 15/681 from DPI. A change to scientific licence as a result of superseded legislation is granted under Part 2 of the BC Act.

Koala

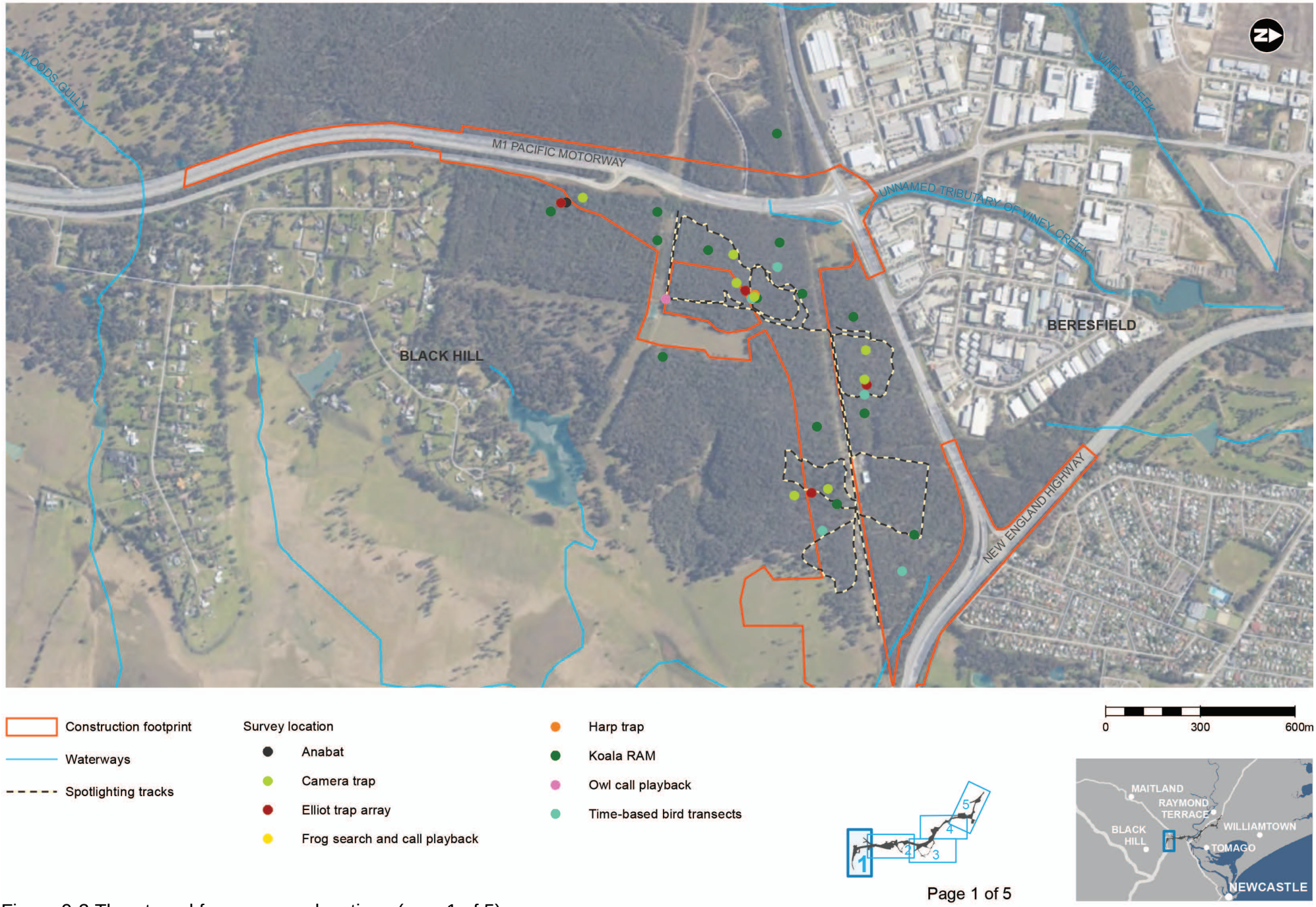
Surveys for the koala were carried out in 2016 and 2018. The key activities carried out were:

- Stratification of habitats by PCT with all forest habitats targeted
- Spotlighting including area based and transect surveys (walked and vehicle surveys)
- Call playback at the start of each spotlighting transect with the species call played for five minutes from a loud speaker
- Tracks, scats and scratches searches
- Identification of koala food tree species and densities.

Koala scat searches were conducted at 61 sites stratified across the construction footprint using the KRAM to target koalas and assess the quality of koala habitat. Surveys were carried out in 2016 and then each site was revisited again in 2018 (resulting in searches of 122 sites). Surveys involved sampling a radial plot randomly placed at the site and searching for scats, starting at a central tree and continuing until 20 trees were searched. Details of each tree species within the plot were recorded. Further information is provided in the BAR (**Appendix I**).

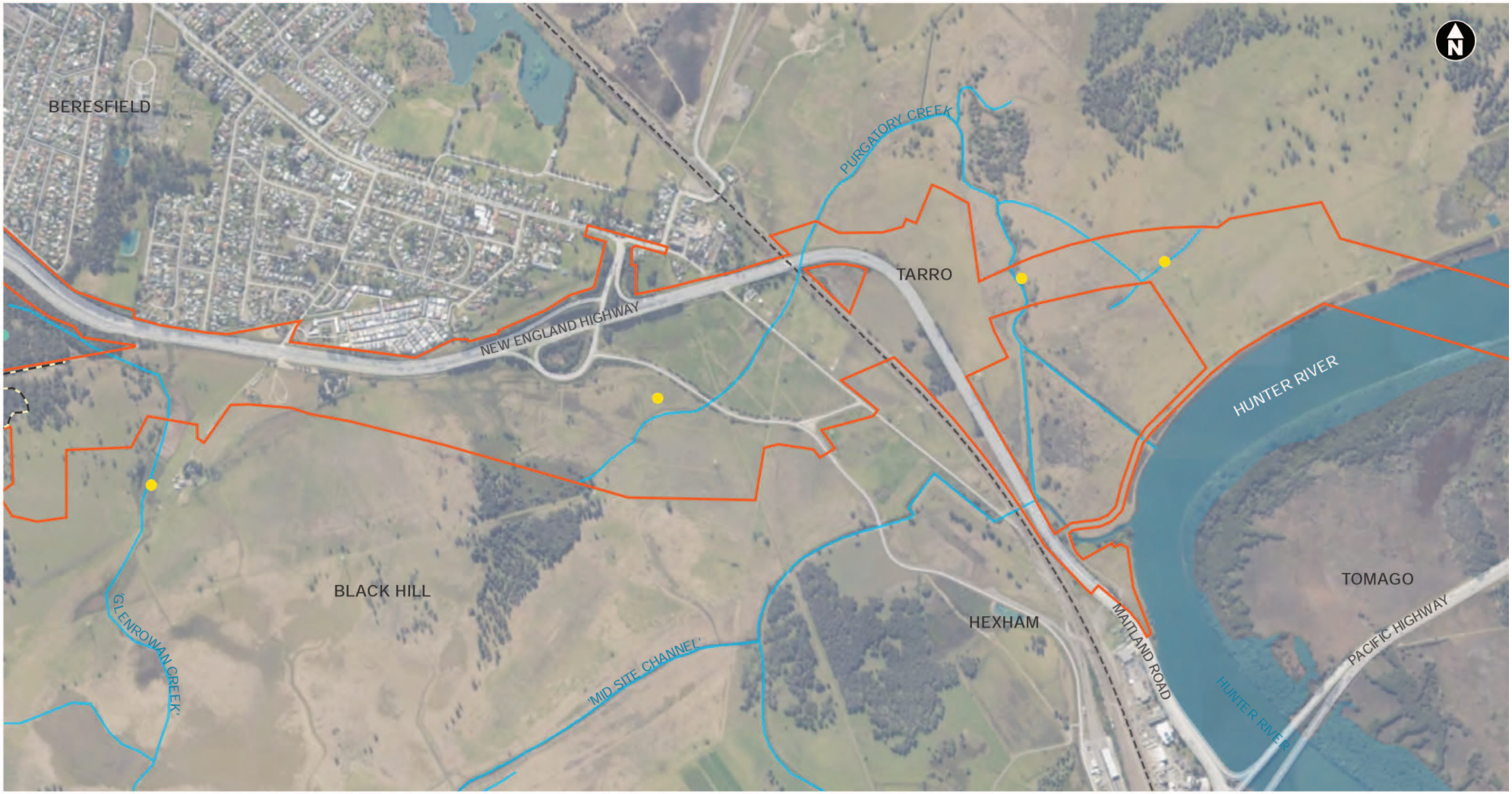
Aquatic surveys

The aquatic habitat assessment is based on aquatic assessments at monitoring sites, desktop review of available literature, threatened species distribution mapping (DPI 2016) and species sightings recorded in public databases. The location of aquatic monitoring sites is shown in **Figure 9-8**.



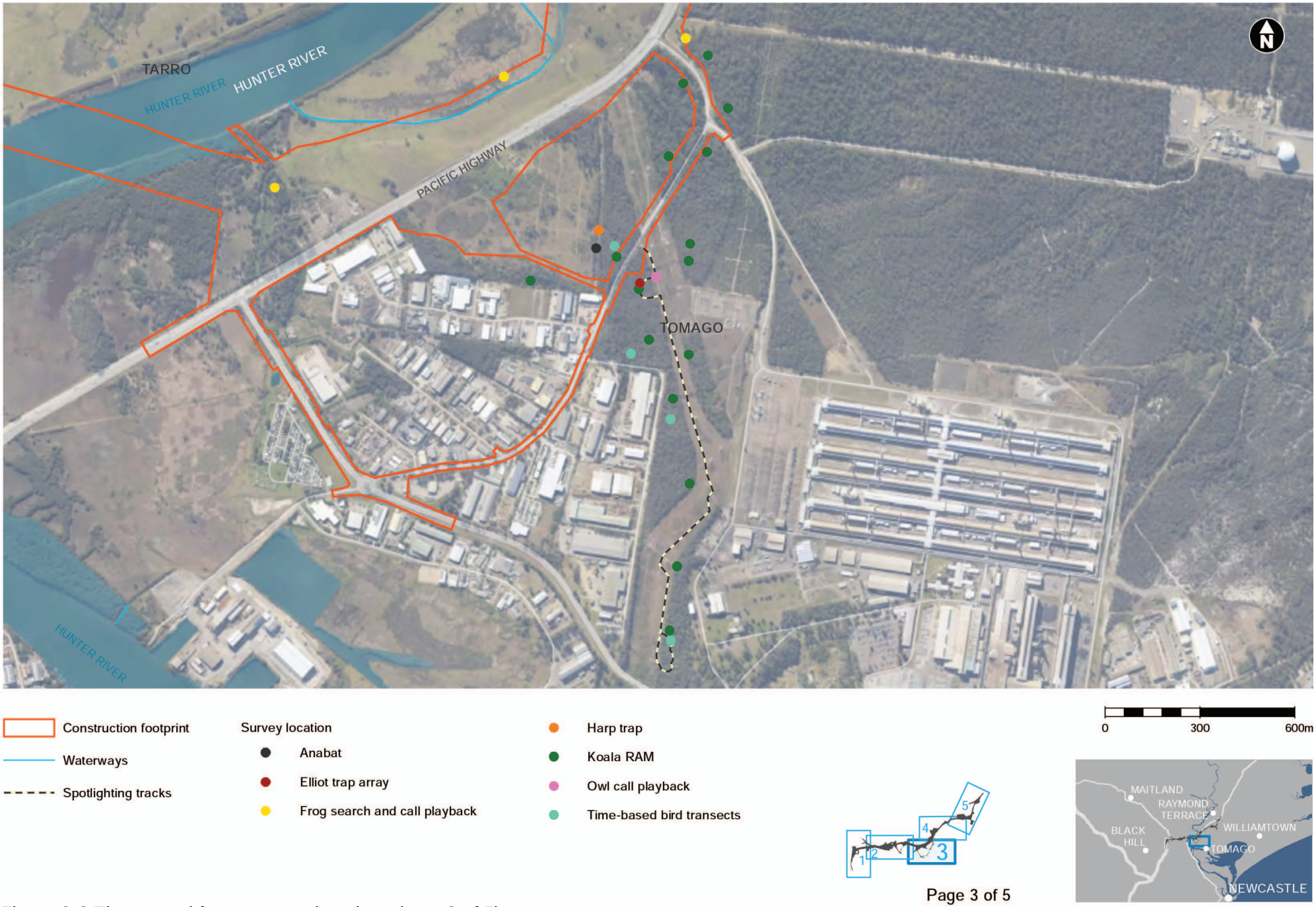
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Figure 9-2 Threatened fauna survey locations (map 1 of 5)



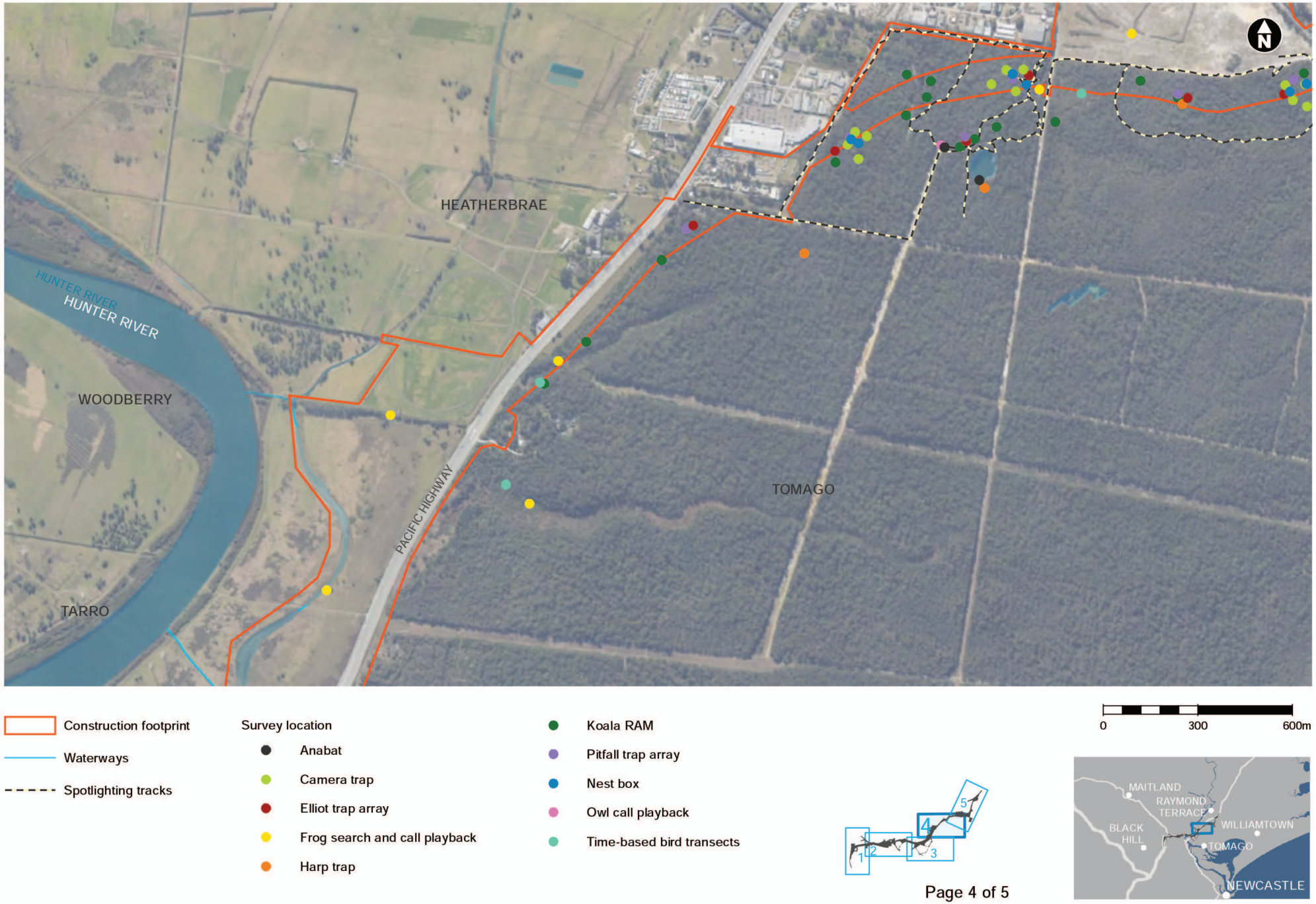
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Figure 9-2 Threatened fauna survey locations (map 2 of 5)



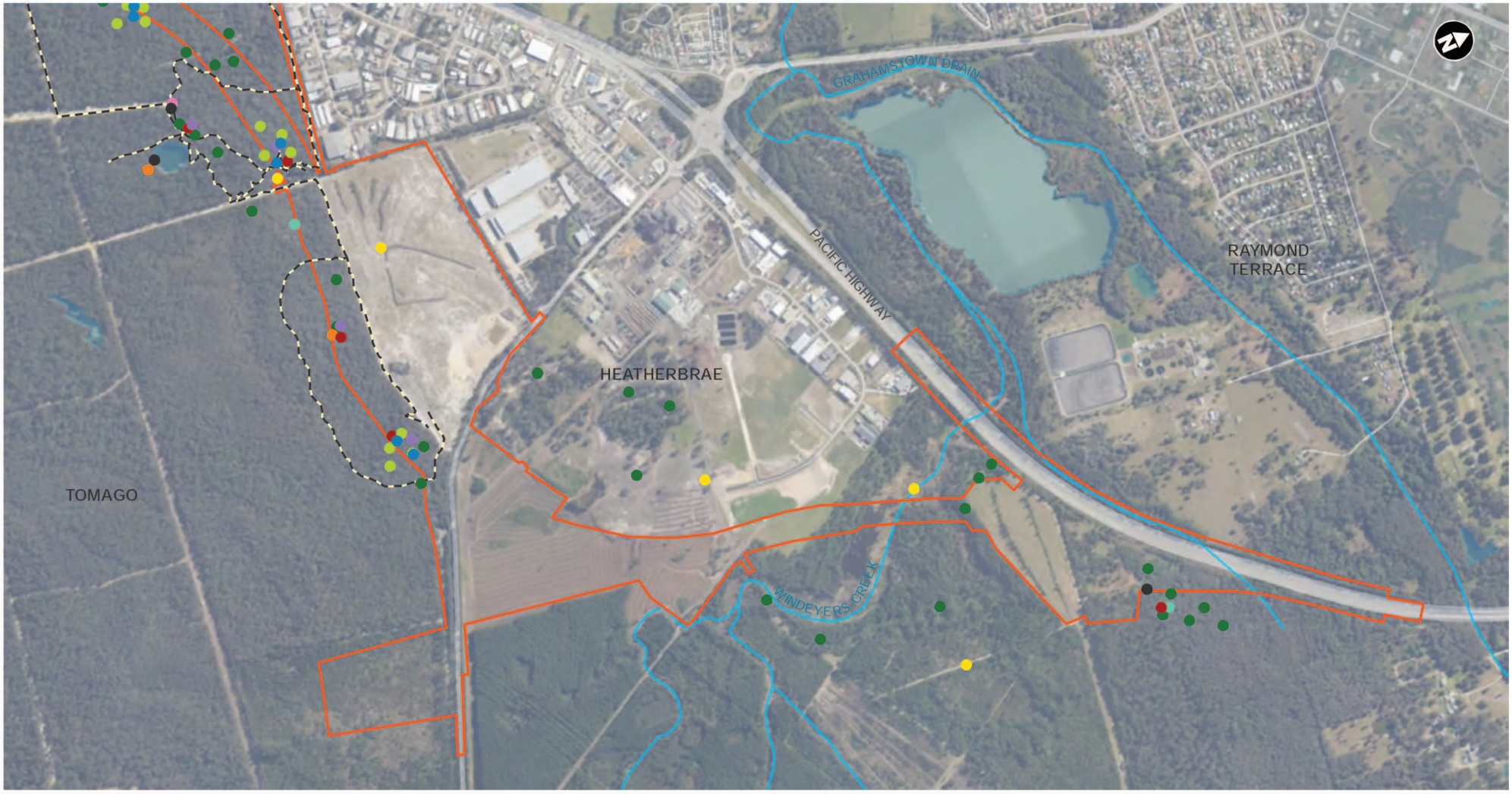
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Figure 9-2 Threatened fauna survey locations (map 3 of 5)



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Figure 9-2 Threatened fauna survey locations (map 4 of 5)



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Figure 9-2 Threatened fauna survey locations (map 5 of 5)

9.2.4 Key fish habitat

Habitat type and the waterway class were used to assess the functionality and determine the requirement to maintain long-term fish passage.

The Policy and Guidelines for Fish Habitat Conservation and Management (DPI 2013a) outlines the habitat types and sensitivity classes used for assessing potential impacts of certain activities and developments on key fish habitat types. These habitat types and waterway classifications are discussed in further detail in the BAR (**Appendix I**).

9.2.5 Biodiversity offsets

Under the FBA, residual impacts that cannot be avoided, minimised or mitigated, must be offset. The process for identifying the required offsets involved an accredited assessor using the BBCC with inputs from the field vegetation integrity assessment and area of confirmed habitat or number of individuals for threatened species impacted. Offsetting requirements under the FBA are discussed in **Section 9.6**.

9.3 Existing environment

9.3.1 Landscape features and values

The landscape features were determined in accordance with the requirements of the FBA. **Table 9-4** summarises the relevant biodiversity landscape features identified. Important wetlands, waterways and the existing BioBanking site are shown in **Figure 9-3**. Native vegetation extent and fauna corridors are shown in **Figure 9-4**.

Table 9-4 Biodiversity landscape features and values

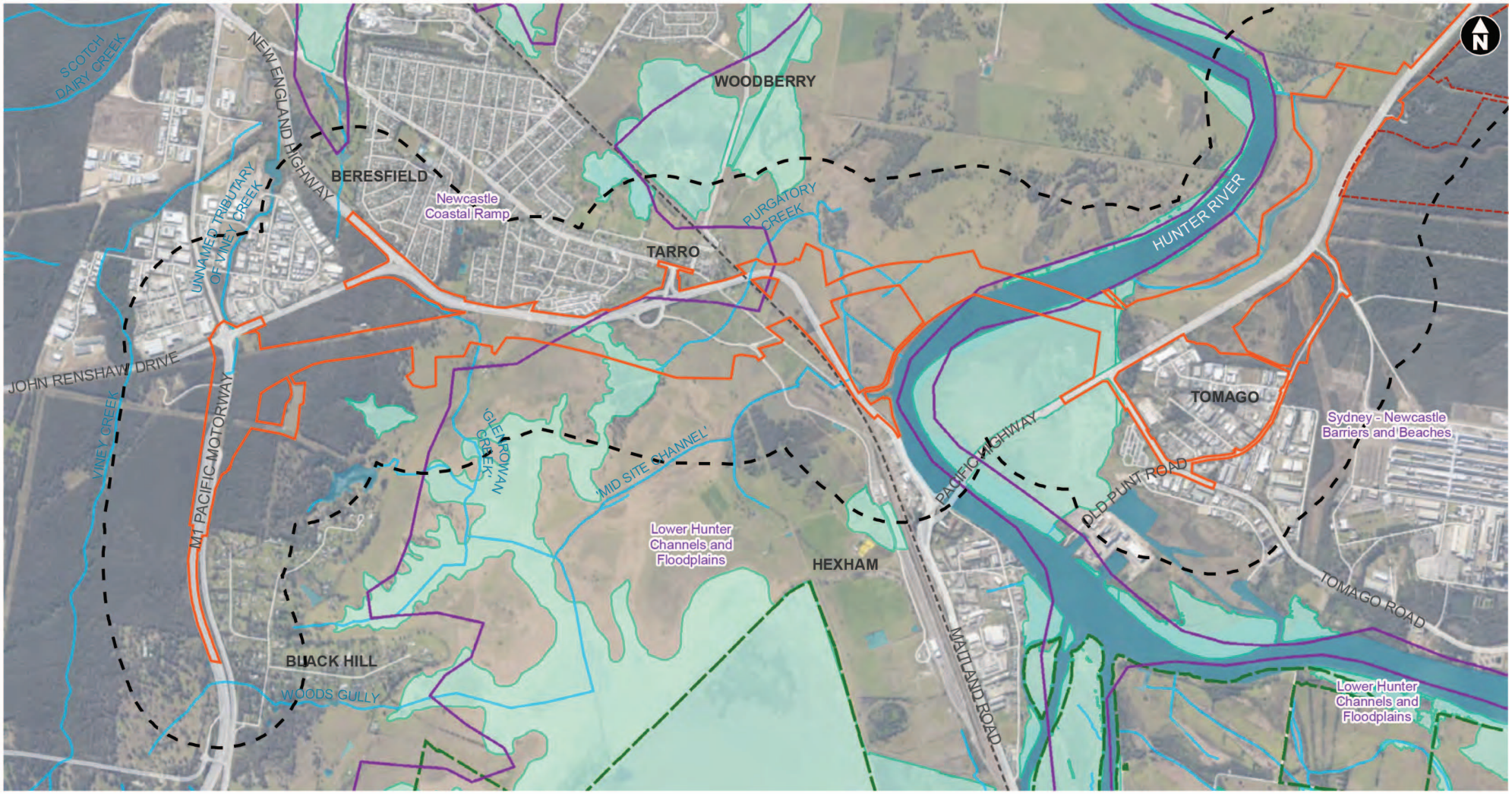
Landscape feature/value	Description
Landscape features	
Interim Biogeographic Rationalisation for Australia bioregions and subregions	• Sydney Basin Bioregion (Hunter subregion) from Black Hill to Tomago • NSW North Coast Bioregion from Tomago to Heatherbrae.
NSW landscape Regions (Mitchell landscapes)	• Newcastle Coastal Ramp • Lower Hunter Channels and Floodplains • Sydney – Newcastle Barriers and Beaches.
Rivers and streams	The construction footprint is located within the Hunter River catchment and would traverse the Hunter River and its floodplain. The Hunter River catchment covers an area of about 22,000km^2 and is a major river in NSW. The confluence of the Williams River and the Hunter River is at Raymond Terrace about 1km upstream of the construction footprint. In addition to the Hunter River, the project would cross several waterways including: • A tributary of Viney Creek • 'Glenrowan Creek' (Note: this is an unnamed local tributary of Mid Site Creek and is referred to as Glenrowan Creek for ease of interpretation only) • Purgatory Creek • Hunter River • Windeyers Creek.

Landscape feature/value	Description
Wetlands and aquatic habitat	Aquatic habitats within the landscape buffer area include mangroves and saltmarsh, freshwater wetlands, ephemeral streams and drainage channels that are located on the floodplains and flow toward the Hunter River. Three waterways have been identified as key fish habitat (KFH) within the construction footprint (discussed further in **Section 9.3.6**): • Purgatory Creek (downstream of floodgates at junction with Hunter River) (Type 1 KFH) • Hunter River (Type 1 KFH) • Unnamed wetland listed under Coastal Management SEPP (Type 1 KFH).
	Three wetlands listed under the Coastal Management SEPP are located within the construction footprint: • South of the existing New England Highway at Tarro • On the western banks of the Hunter River • The eastern bank of the Hunter River, north of the Pacific Highway. Other Coastal Management SEPP coastal wetlands within 500m of the construction footprint are shown in **Figure 9-3**. Although not classified under the Coastal Management SEPP or a protected wetland, a wetland (referred to as the Hunter River wetland, site M12RT8) is located adjacent to the Hunter Region Botanic Gardens on the north-eastern side of the Hunter River. This wetland is considered likely to be supported by groundwater discharge and is likely to be a groundwater dependent ecosystem. Hexham Swamp Nature Reserve forms part of the floodplain environment on the southern side of the Hunter River. The Hexham Swamp Nature Reserve, and the surrounding wetland area, is classified as Coastal Wetland under the Coastal Management SEPP. The boundary of the Hexham Swamp Nature Reserve is located about two kilometres south of the construction footprint.
	The Hunter Estuary Wetlands Ramsar site is located within 10km of the construction footprint, and is comprised of: • Kooragang Nature Reserve (as part of the Hunter Wetlands National Park). The Reserve is located about 1.9km to the south-east of the construction footprint at its nearest point at Tomago Road. The reserve is located about 5.1km downstream of the proposed crossing of the Hunter River • Hunter Wetlands Centre Australia in Shortland located about 3.8km south of the construction footprint.
State, regional, local biodiversity links and connectivity value	No plan detailing regionally significant biodiversity links approved by the EES Group Chief Executive exists for the landscape buffer area and there are no state significant or regionally significant biodiversity links intersected by the construction footprint. However, the following corridors have been identified within the landscape buffer area: • The construction footprint is wholly within the Watagan to Stockton Green Corridor as identified in the Lower Hunter Regional Strategy (NSW Department of Planning 2006) • The northern portion of the construction footprint is within the regional corridor referred to as Richardson Road (Scotts 2003), which provides a link from the Hexham Swamp Nature Reserve north and east across the Hunter River to Grahamstown Dam • The Newcastle and Karuah-Hunter coastal climate change corridors (i.e. Newcastle and Karuah-Hunter) join at the Hunter River (DECC 2007a) and identify a north-south regional link traversing to the west of Newcastle within the construction footprint • The riparian buffer of the Hunter River (as a 6th order stream or greater) located in the construction footprint supports Mangrove and Swamp Oak forests as well as Coastal Saltmarsh.
Existing BioBanking sites	The construction footprint impacts on about 0.6ha of a site with an existing BioBanking Agreement, located around the Hunter Region Botanic Gardens and east of the existing Pacific Highway. The entire BioBanking site is around 106ha in size.

Landscape feature/value	Description
Landscape values	
Native vegetation extent	The landscape buffer comprises a mix of remnant native vegetation, planted (exotic) vegetation and modified and cleared land used for agriculture. Existing native vegetation cover in the landscape buffer assessment area is estimated at 1,277ha (43.79 per cent).
Patch size	The average patch size score for the vegetation in the construction footprint is 11.7ha (the average of the patch scores for the three NSW (Mitchell) Landscapes).
Area to perimeter ratio	Linear projects are required to assess the change in area to perimeter ratio of vegetation patch size areas that are impacted by the project in accordance with the FBA. The BAR identified a proportional change in area to perimeter ratio of 14 per cent. The patch area to perimeter ratio increases after the development, caused by a reduction in the area of the patches, but an increase in perimeter as a result of fragmentation in some areas.

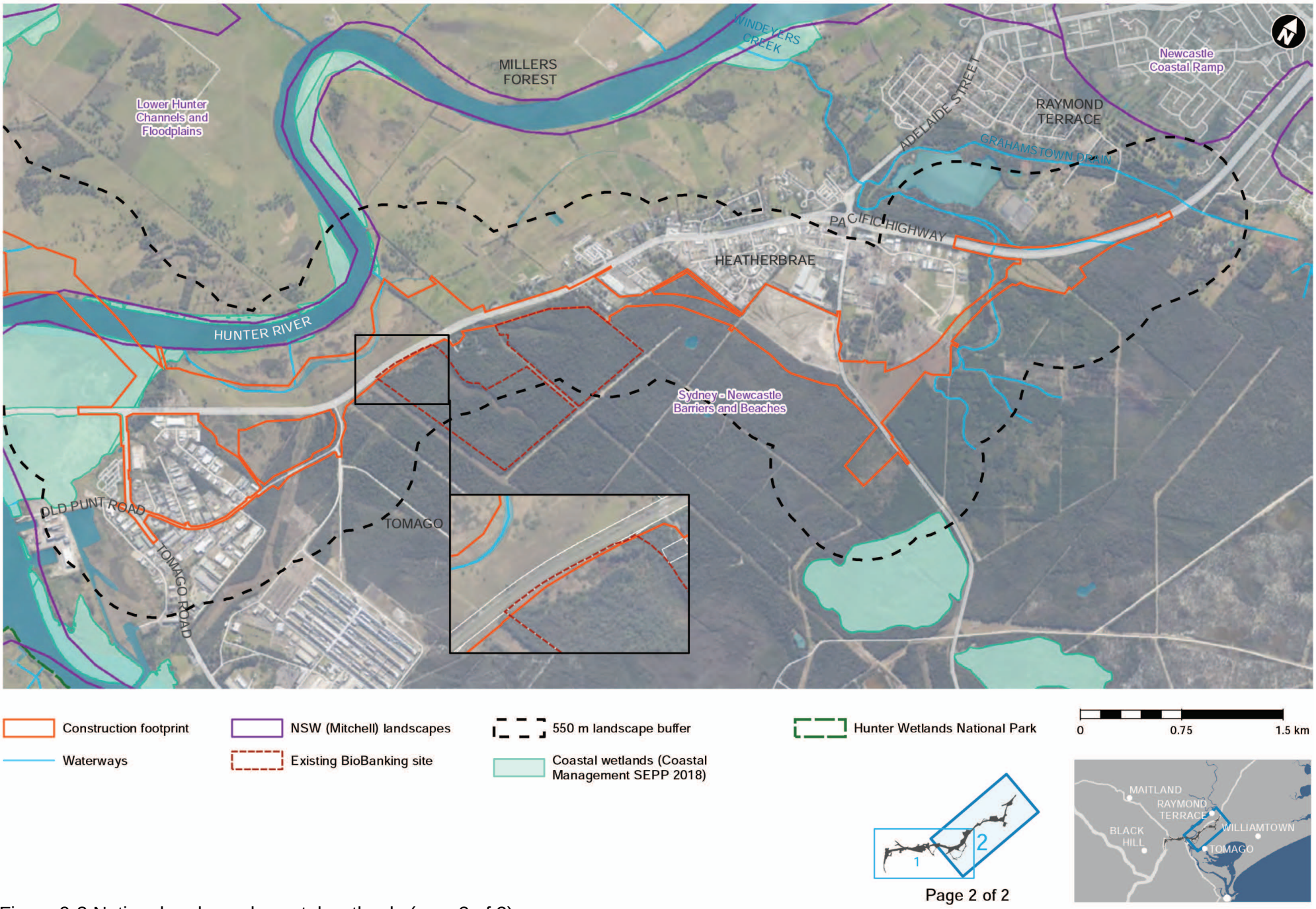
Hunter Valley Flood Mitigation Scheme

Hunter Valley Flood Mitigation Scheme provides flood protection to people, property and infrastructure across the Hunter floodplain. The scheme is managed by DPIE with support from Hunter Local Land Services and is subject to periodic maintenance and reviews. The scheme includes levees, spillways, control banks, floodgates on drainage channels and waterways directly connected to the Hunter River. The floodgates in the vicinity of the project are shown on **Figure 9-8**. The floodgates have significantly altered tidal processes including tidal flushing on the floodplain, movement of salt and freshwater between the Hunter River and its tributaries and has removed the ability for species migration upstream in the local waterways.



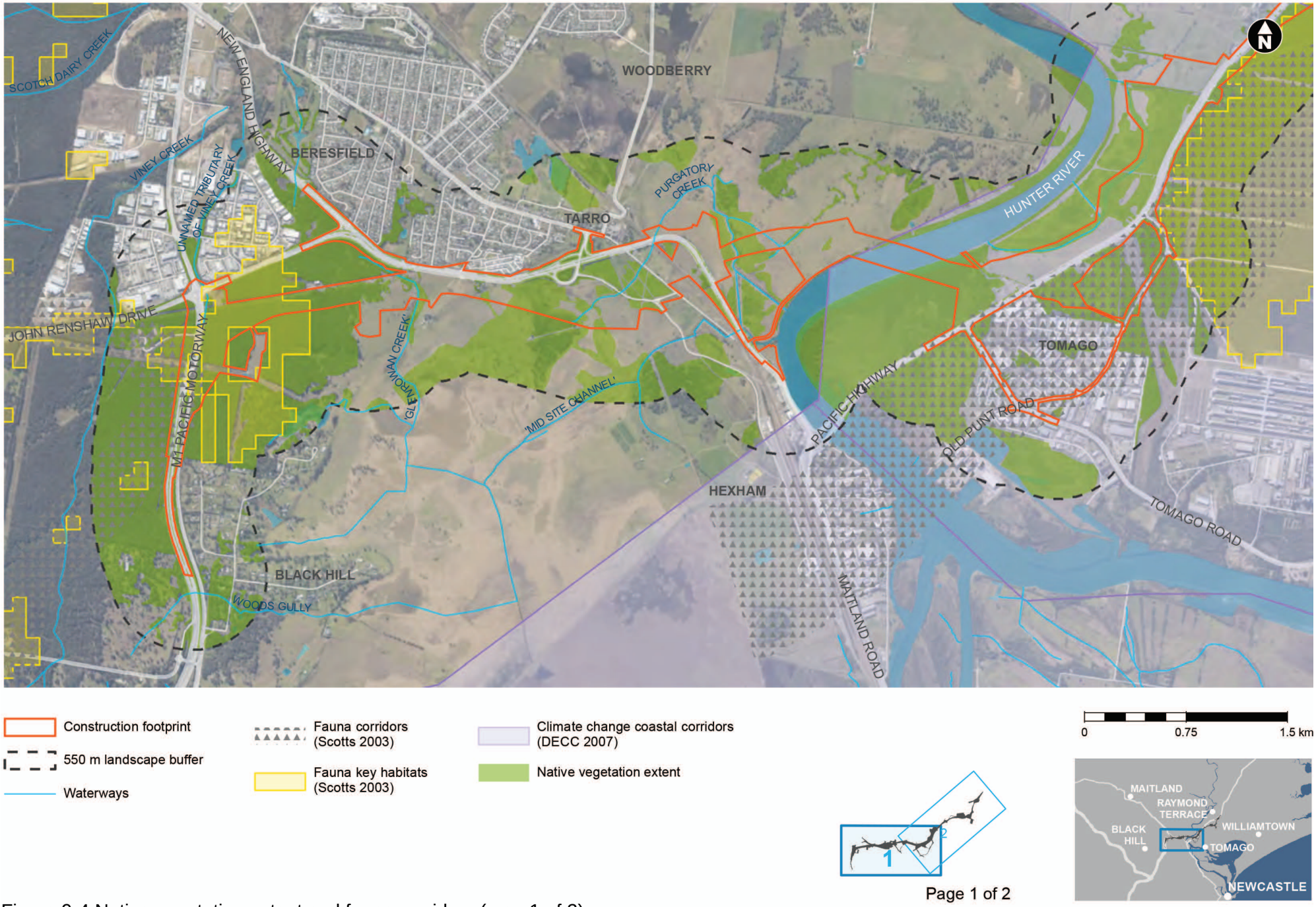
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Figure 9-3 National parks and coastal wetlands (map 1 of 2)



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Figure 9-3 National parks and coastal wetlands (map 2 of 2)



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Figure 9-4 Native vegetation extent and fauna corridors (map 1 of 2)

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Figure 9-4 Native vegetation extent and fauna corridors (map 2 of 2)

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9.3.2 Native vegetation

Following desktop review and detailed field surveys, 14 PCTs were identified within the construction footprint, that were then assigned into 21 vegetation zones according to their condition, consistent with the NSW BioNet Vegetation Classification Database.

Table 9-5 provides a summary of the PCTs and vegetation zones identified within the construction footprint (shown on **Figure 9-5**). The corresponding Biometric Vegetation Type code (BVT) is also provided for consistency with the BioBanking Credit Calculator (BBCC). The area of non-native vegetation within the construction footprint is also presented in the table below. Full details on the floristic and structural condition of each vegetation zone are provided in the BAR (**Appendix I**).

Table 9-5 PCTs identified within the construction footprint

PCT No.	Plant community type (PCT) (BVT)	Vegetation zone	Area within construction footprint (ha)
1590	Spotted Gum – Broad-leaved Mahogany – Red Ironbark shrubby open forest of the Lower Hunter (HU804)	1. Good	25.16
		2. Moderate	8.35
		3. Regenerating	8.37
1588	Grey Ironbark – Broad-leaved Mahogany – Forest Red Gum shrubby open forest on Coastal (HU802)	4. Moderate	6.78
		5. Regenerating	0.82
1646	Smooth-barked Apple – Blackbutt – Old Man Banksia woodland on coastal sands of the Central and Lower North Coast (HU860)	6. Good	20.76
		7. Poor	7.83
1649	Smooth-barked Apple – Red Mahogany – Swamp Mahogany – *Melaleuca sieberi* heathy swamp woodland of coastal lowlands (HU863)	8. Good	1.36
1598	Forest Red Gum grassy open forest on floodplains of the lower Hunter (HU812)	9. Poor	0.45
1716	Prickly-leaved Paperbark forest on coastal lowlands of the Central Coast and Lower North Coast (HU930)	10. Good	1.82
1717	Broad-leaved Paperbark – Swamp Mahogany – Swamp Oak – Saw Sedge swamp forest of the Central Coast and Lower North Coast (HU931)	11. Good	3.85
		12. Poor	6.64
1724	Broad-leaved Paperbark – Swamp Oak – Saw Sedge swamp forest on coastal lowlands of the Central Coast and Lower North Coast (HU938)	13. Good	1.61
1727	Swamp Oak – Sea Rush – *Baumea juncea* swamp forest on coastal lowlands of the Central Coast and Lower North Coast (HU941)	14. Moderate	8.76
1736	Water Couch – Tall Spike Rush freshwater wetland of the Central Coast and lower Hunter (HU950)	15. Good	33.23
		16. Moderate	25.81
1742	Jointed Twig-rush sedgeland (HU956)	17. Good	1.45
1071	*Phragmites australis* and *Typha orientalis* coastal freshwater wetlands of the Sydney Basin Bioregion (HU673)	18. Good	7.71

PCT No.	Plant community type (PCT) (BVT)	Vegetation zone	Area within construction footprint (ha)
1746	Saltmarsh Estuarine Complex (HU960)	19. Good	1.26
1747	Grey Mangrove low closed forest (HU961)	20. Good	2.04
		21. Moderate	0.23
Subtotal			**174.29**
N/A	Planted native vegetation	N/A	13.04
N/A	Pine plantation	N/A	25.87
N/A	Exotic vegetation	N/A	1.86
Total			**215.06**

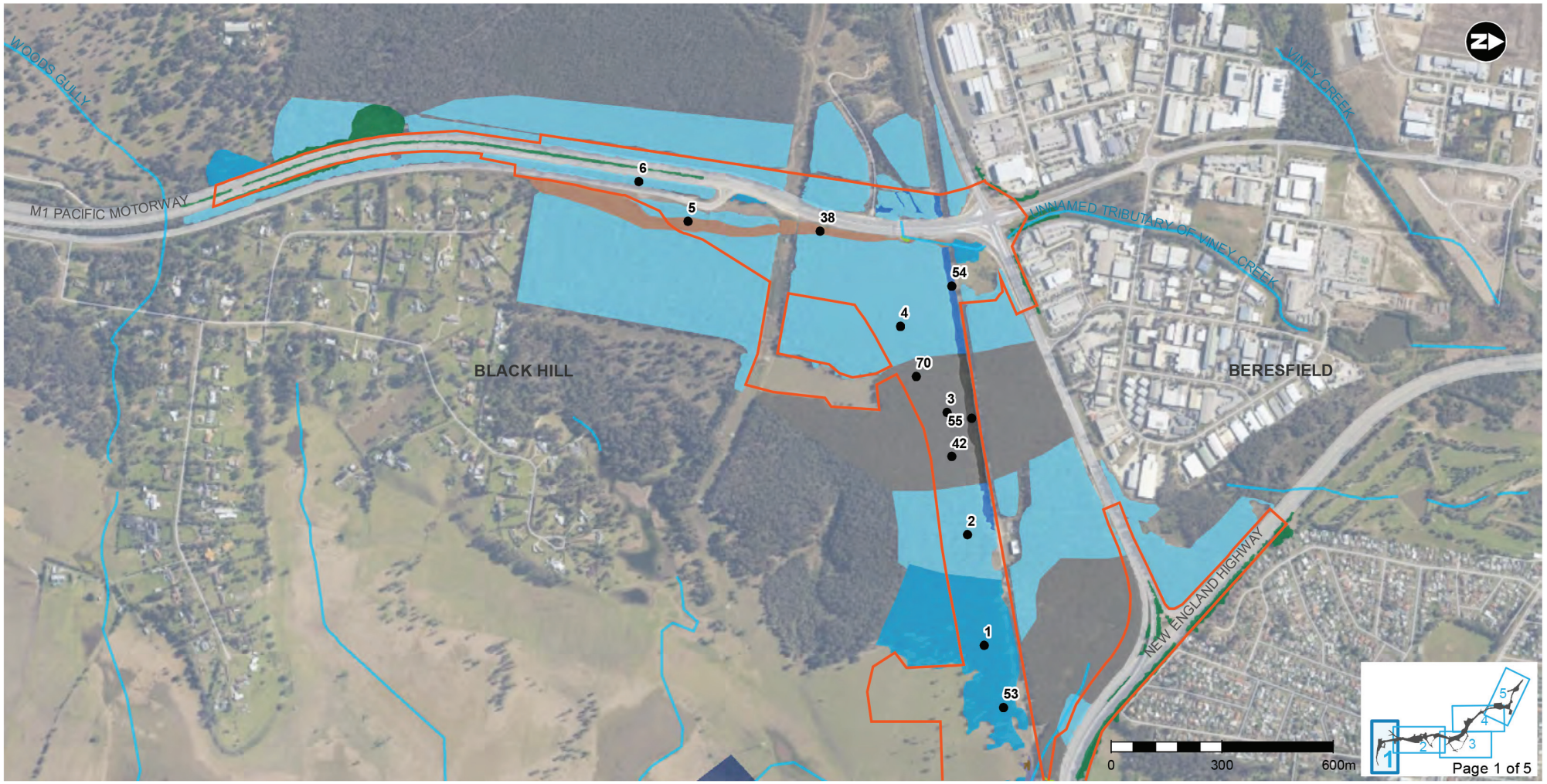


Figure 9-5 Plant Community Types, condition and vegetation survey locations (map 1 of 5)

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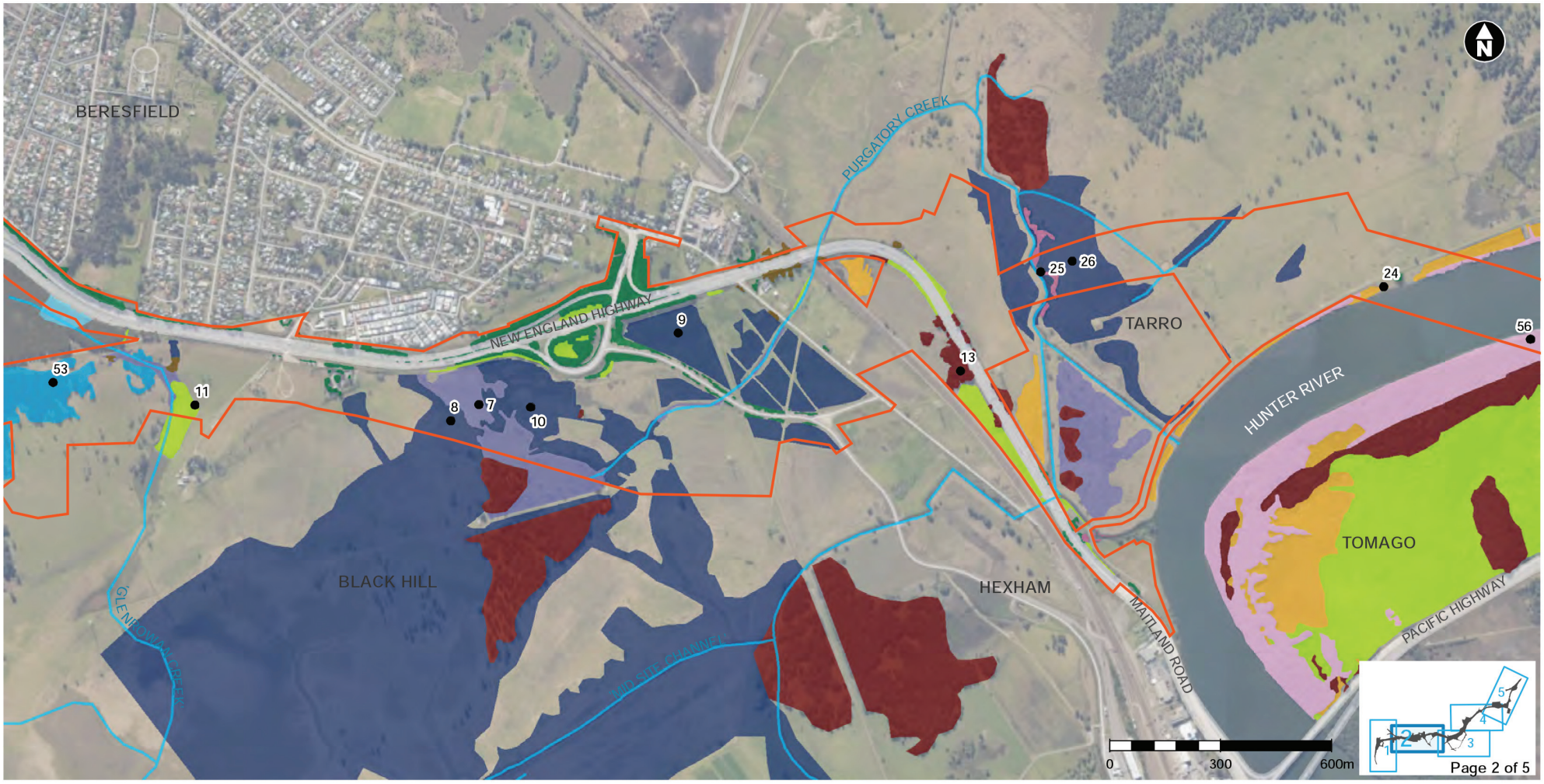


Figure 9-5 Plant Community Types, condition and vegetation survey locations (map 2 of 5)

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Construction footprint
Waterways
Plots
Broad-leaved Paperbark - Swamp Mahogany - Swamp Oak - Saw Sedge swamp forest of the Central Coast and Lower North Coast (1717). Good - zone 11
Broad-leaved Paperbark - Swamp Oak - Saw Sedge swamp forest on coastal lowlands of the Central Coast and Lower North Coast (1724). Good - zone 13
Forest Red Gum grassy open forest on floodplains of the lower Hunter (1598). Good
Forest Red Gum grassy open forest on floodplains of the lower Hunter (1598). Moderate - zone 9
Grey Ironbark - Broad-leaved Mahogany - Forest Red Gum shrubby open forest on Coastal Lowlands of the Central Coast (1588). Moderate - zone 4
Grey Mangrove low closed forest (1747). Good - zone 20
Grey Mangrove low closed forest (1747). Moderate - zone 21
Phragmites australis and Typha orientalis coastal freshwater wetlands of the Sydney Basin Bioregion (1071). Good - zone 18
Planted native vegetation
Saltmarsh Estuarine Complex (1746). Good - zone 19
Smooth-barked Apple - Blackbutt - Old Man Banksia woodland on coastal sands of the Central and Lower North Coast (1646). Good - zone 6
Spotted Gum - Broad-leaved Mahogany - Red Ironbark shrubby open forest (1590). Good - zone 1
Spotted Gum - Broad-leaved Mahogany - Red Ironbark shrubby open forest (1590). Moderate - zone 2
Spotted Gum - Broad-leaved Mahogany - Red Ironbark shrubby open forest (1590). Regenerating - zone 3
Swamp Oak - Sea Rush - Baumea juncea swamp forest on coastal lowlands of the Central Coast and Lower North Coast (1727). Moderate - zone 14
Water Couch - Tall Spike Rush freshwater wetland of the Central Coast and lower Hunter (1736). Good - zone 15
Water Couch - Tall Spike Rush freshwater wetland of the Central Coast and lower Hunter (1736). Moderate - zone 16

Note: Areas within the construction footprint that are not mapped have been cleared and at the time of survey did not constitute native vegetation

Figure 9-5 Plant Community Types, condition and vegetation survey locations (map 3 of 5)

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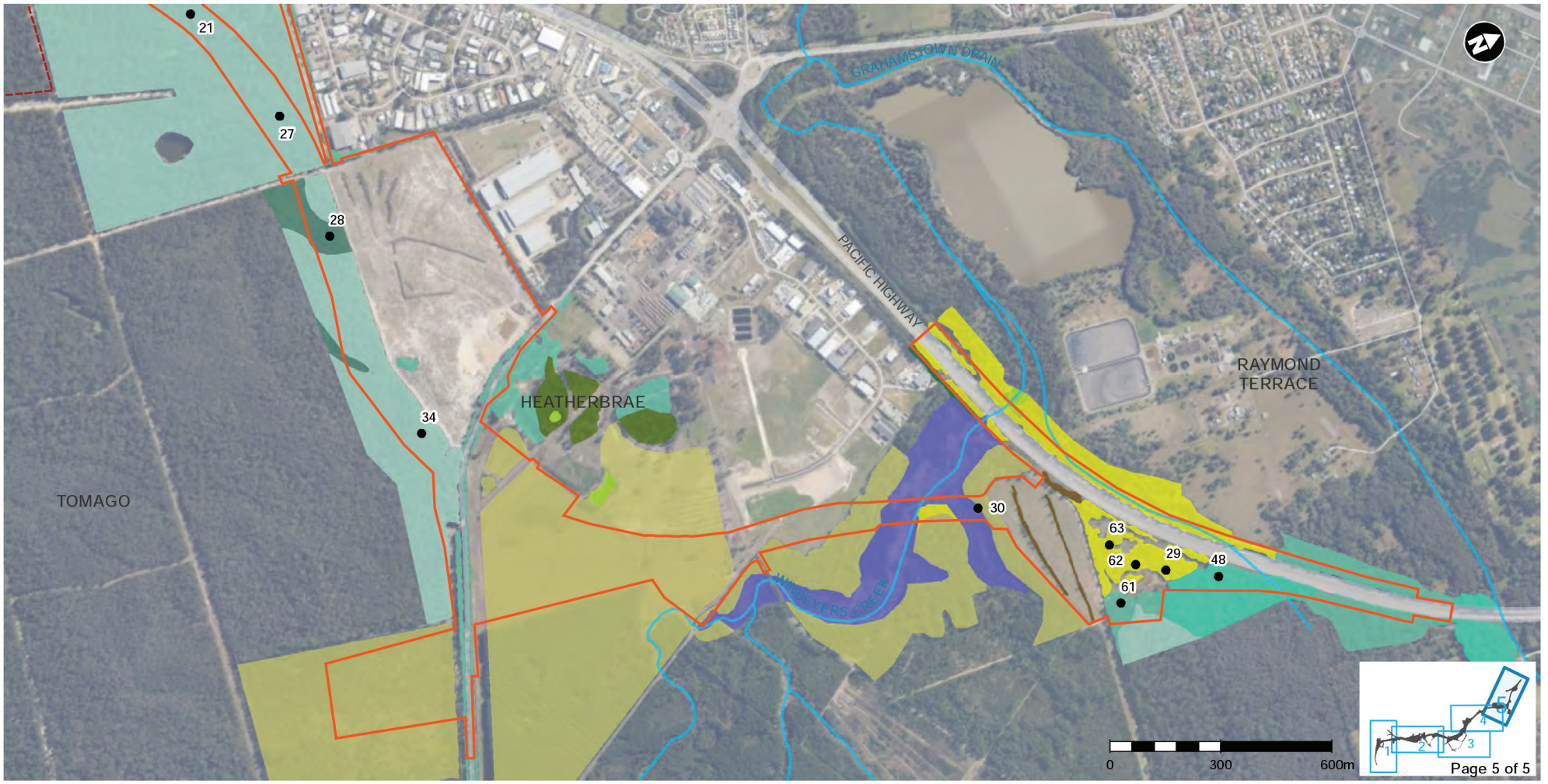


Construction footprint
Existing BioBanking Site
Waterways
Plots
Broad-leaved Paperbark - Swamp Mahogany - Swamp Oak - Saw Sedge swamp forest of the Central Coast and Lower North Coast (1717). Good - zone 11
Non-native woody vegetation
Forest Red Gum grassy open forest on floodplains of the lower Hunter (1598). Moderate - zone 9
Jointed Twig-rush sedgeland (1742). Good - zone 17
Phragmites australis and Typha orientalis coastal freshwater wetlands of the Sydney Basin Bioregion (1071). Good - zone 18
Planted native vegetation
Saltmarsh Estuarine Complex (1746). Good - zone 19
Smooth-barked Apple - Blackbutt - Old Man Banksia woodland on coastal sands of the Central and Lower North Coast (1646). Good - zone 6
Smooth-barked Apple - Blackbutt - Old Man Banksia woodland on coastal sands of the Central and Lower North Coast (1646). Poor - zone 7
Smooth-barked Apple - Red Mahogany - Swamp Mahogany - Melaleuca sieberi heathy swamp woodland of coastal lowlands (1649). Good - zone 8
Swamp Oak - Sea Rush - Baumea juncea swamp forest on coastal lowlands of the Central Coast and Lower North Coast (1727). Moderate - zone 14
Water Couch - Tall Spike Rush freshwater wetland of the Central Coast and lower Hunter (1736). Good - zone 15
Water Couch - Tall Spike Rush freshwater wetland of the Central Coast and lower Hunter (1736). Moderate - zone 16

Note: Areas within the construction footprint that are not mapped have been cleared and at the time of survey did not constitute native vegetation.

Figure 9-5 Plant Community Types, condition and vegetation survey locations (map 4 of 5)

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Construction footprint
Existing BioBanking Site
Waterways
Plots
Broad-leaved Paperbark - Swamp Mahogany - Swamp Oak - Saw Sedge swamp forest of the Central Coast and Lower North Coast (1717). Good - zone 11
Broad-leaved Paperbark - Swamp Mahogany - Swamp Oak - Saw Sedge swamp forest of the Central Coast and Lower North Coast (1717). Poor - zone 12
Non-native woody vegetation
Forest Red Gum grassy open forest on floodplains of the lower Hunter (1598). Disturbed
Jointed Twig-rush sedgeland (1742). Good - zone 17
Phragmites australis and Typha orientalis coastal freshwater wetlands of the Sydney Basin Bioregion (1071). Good - zone 18
Pine plantation
Planted native vegetation
Smooth-barked Apple - Blackbutt - Old Man Banksia woodland on coastal sands of the Central and Lower North Coast (1646). Good - zone 6
Smooth-barked Apple - Blackbutt - Old Man Banksia woodland on coastal sands of the Central and Lower North Coast (1646). Poor - zone 7
Smooth-barked Apple - Red Mahogany - Swamp Mahogany - Melaleuca sieberi heathy swamp woodland of coastal lowlands (1649). Good - zone 8

Note: Areas within the construction footprint that are not mapped have been cleared and at the time of survey did not constitute native vegetation.

Figure 9-5 Plant Community Types, condition and vegetation survey locations (map 5 of 5)

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9.3.3 Threatened ecological communities

Eleven of the 14 PCTs identified within the construction footprint correspond with six Threatened Ecological Communities (TECs) listed under the TSC Act. **Table 9-6** summarises the corresponding PCTs for each TEC listed under the TSC Act and provides the area within the construction footprint.

In addition, 0.55 hectares of PCT 1746 (Saltmarsh Estuarine Complex) is also consistent with the listed Subtropical and Temperate Coastal Saltmarsh community, listed as vulnerable under the EPBC Act. This is described further in **Table 9-11**.

The location and distribution of TECs is shown in **Figure 9-6**. A description of each TEC is provided in the BAR (**Appendix I**).

Table 9-6 TECs present within the construction footprint

TEC	TSC Act Status	Corresponding PCT	Area within construction footprint (ha)
Coastal Saltmarsh in the New South Wales North Coast, Sydney Basin and South East Corner Bioregion	Endangered	1746	1.26
Freshwater Wetlands on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	Endangered	1742, 1071, 1736	68.18
Hunter Lowland Redgum Forest in the Sydney Basin and New South Wales North Coast Bioregions	Endangered	1598	0.45
Lower Hunter Spotted Gum Ironbark Forest in the Sydney Basin and NSW North Coast Bioregions	Endangered	1590	41.88
Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	Endangered	1727	8.76
Swamp Sclerophyll Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	Endangered	1649, 1716, 1717, 1724	15.28
Total			**136**

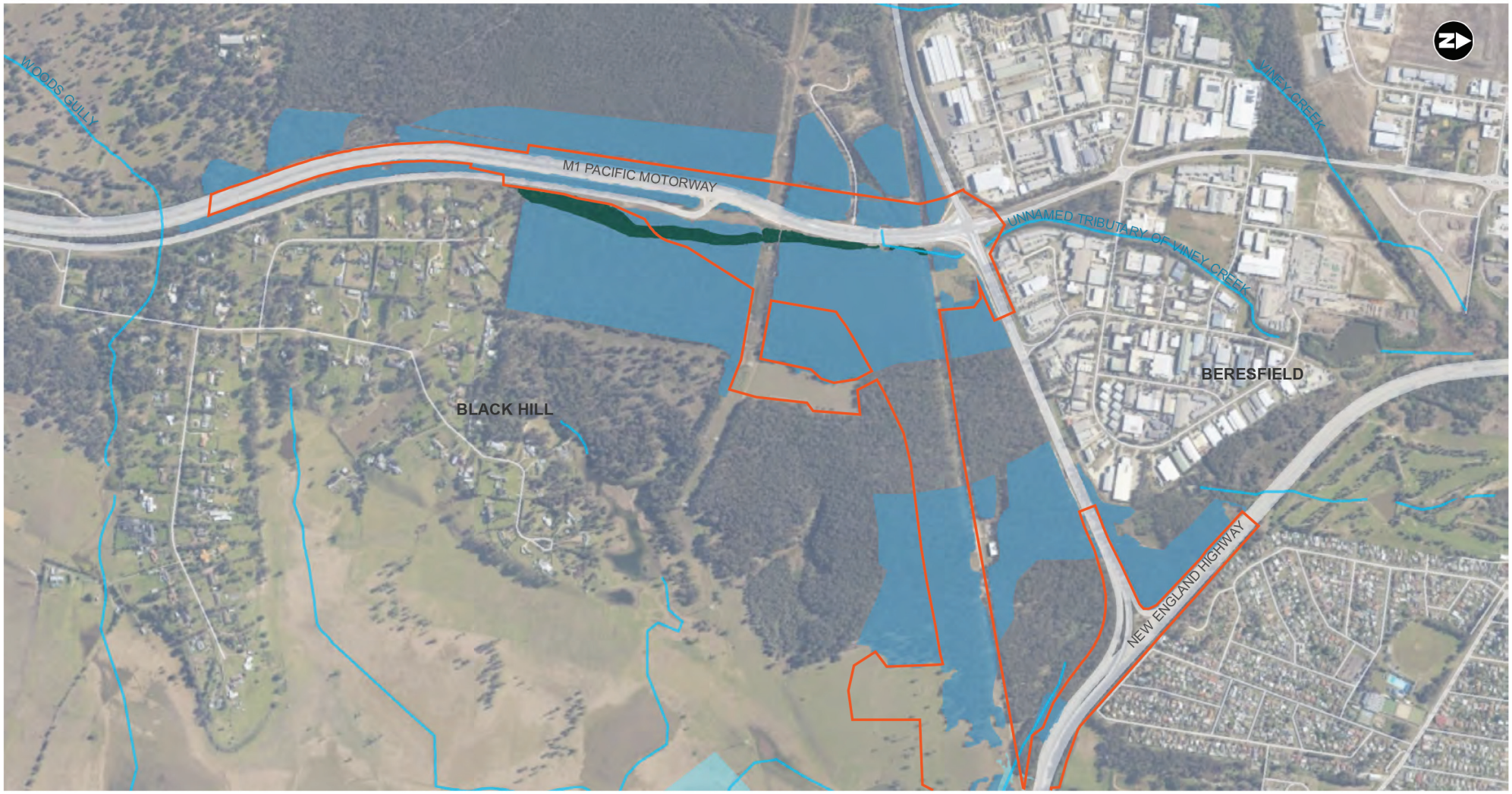


Figure 9-6 Threatened ecological communities identified within the construction footprint (map 1 of 5)

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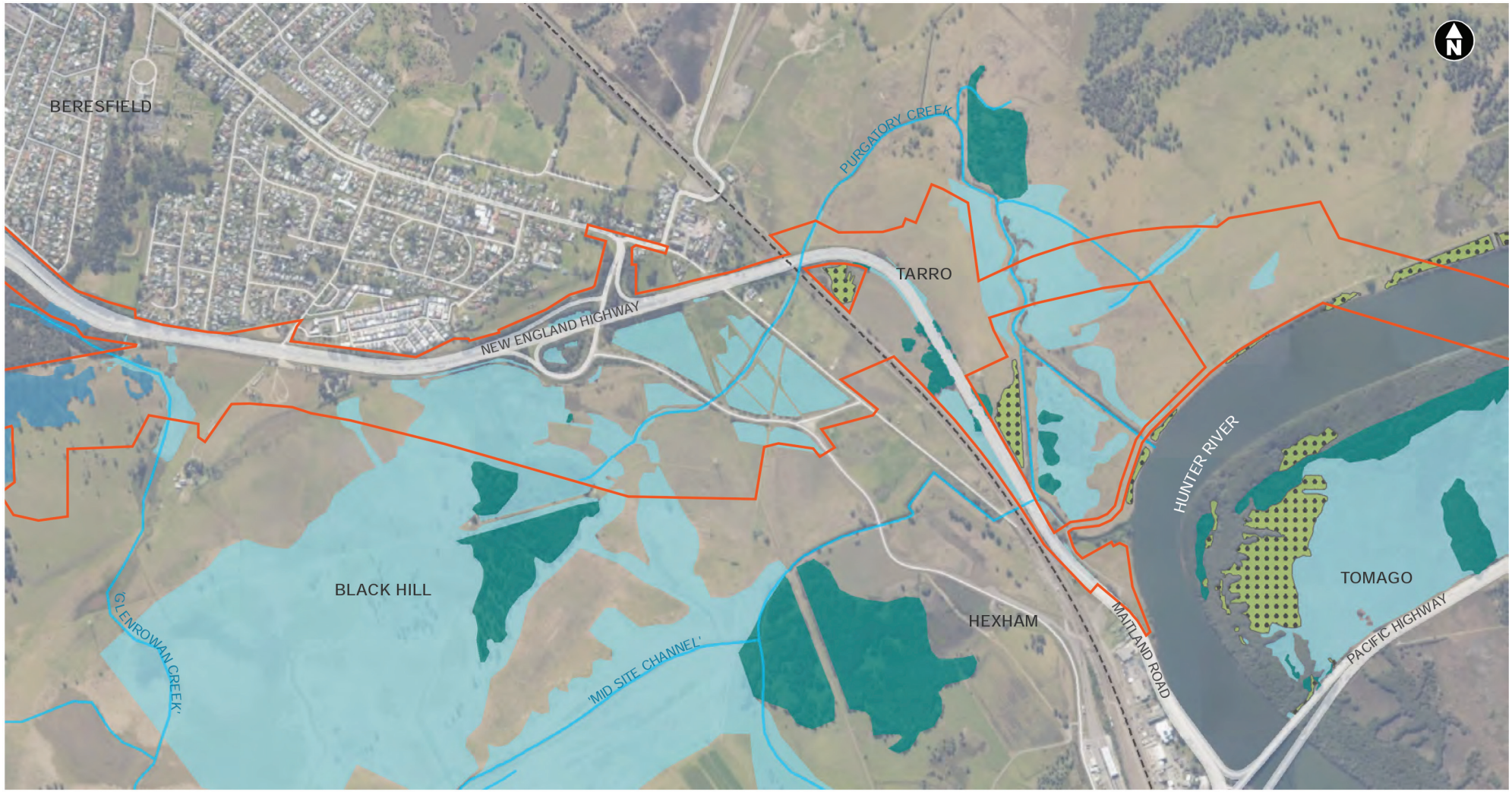


Figure 9-6 Threatened ecological communities identified within the construction footprint (map 2 of 5)

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Figure 9-6 Threatened ecological communities identified within the construction footprint (map 3 of 5)

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Figure 9-6 Threatened ecological communities identified within the construction footprint (map 4 of 5)

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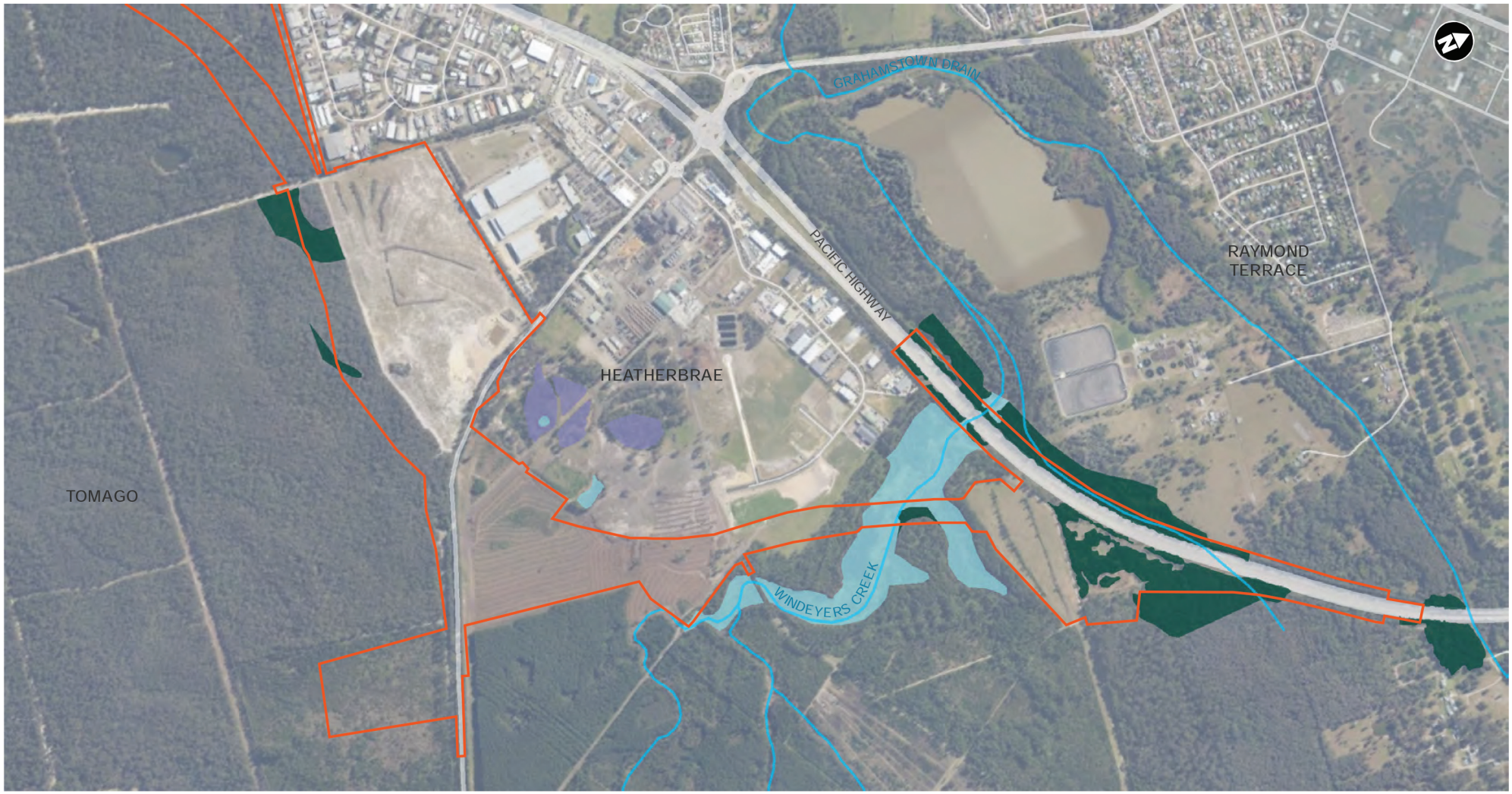


Figure 9-6 Threatened ecological communities identified within the construction footprint (map 5 of 5)

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9.3.4 Groundwater dependent ecosystems

Based on the PCTs identified in the construction footprint during field surveys and a review of Bell and Driscoll (2006), Kuginis et al. (2012) and the GDE Atlas, it is likely that some of the PCTs present in the construction footprint would have a degree of groundwater dependence (refer to **Table 9-7**), and include:

- Known aquatic GDEs:
  - Floodplain wetlands (Hexham Swamp Nature Reserve and surrounding wetlands, Hunter Wetlands National Park)
  - Hunter River.
- Potential terrestrial GDEs:
  - Coastal Floodplain Wetlands on the floodplain of the Hunter River (Tarro, Hexham and Tomago)
  - Mangrove Swamps on margins of the Hunter River
  - Coastal Dune Dry Sclerophyll Forests on the Tomago Sandbeds (Tomago and Heatherbrae)
  - Freshwater wetlands adjacent to the floodplain such as sedgeland plant communities.

The PCTs identified in **Table 9-7** are not obligate GDEs (i.e. they are not entirely dependent on groundwater) and are likely to be opportunistic GDEs that may depend on the subsurface presence of groundwater during excessive dry periods. The PCTs that are likely to have the most dependence on groundwater are those located in low-lying areas in the Hunter River floodplain and Tomago Sandbeds. Based on the distribution of each PCT, a possible corresponding groundwater system has also been assigned. Groundwater systems are described in further detail in **Chapter 10** (hydrology and flooding).

Table 9-7 Potential terrestrial groundwater dependent ecosystems present within the construction footprint

PCT ID	Plant community type	Possible corresponding groundwater system	Area within construction footprint (ha)
1071	*Phragmites australis* and *Typha orientalis* coastal freshwater wetlands of the Sydney Basin Bioregion	Hunter Alluvium system	7.71
1590	Spotted Gum – Broad-leaved Mahogany – Red Ironbark shrubby open forest	Tomago Sandbeds (excluding Black Hill occurrence)	41.88
1598	Forest Red Gum grassy open forest on floodplains of the lower Hunter	Tomago Sandbeds	0.45
1646	Smooth-barked Apple – Blackbutt – Old Man Banksia woodland on coastal sands of the Central and Lower North Coast	Tomago Sandbeds	28.59
1649	Smooth-barked Apple – Red Mahogany – Swamp Mahogany – *Melaleuca sieberi* heathy swamp woodland of coastal lowlands	Tomago Sandbeds	1.36
1716	Prickly-leaved Paperbark forest on coastal lowlands of the Central Coast and Lower North Coast	Hunter Alluvium system (in part)	1.82
1717	Broad-leaved Paperbark – Swamp Mahogany – Swamp Oak – Saw Sedge swamp forest of the Central Coast and Lower North Coast	Tomago Sandbeds	10.49
1724	Broad-leaved Paperbark – Swamp Oak – Saw Sedge swamp forest on coastal lowlands of the Central Coast and Lower North Coast	Tomago Sandbeds	1.61

PCT ID	Plant community type	Possible corresponding groundwater system	Area within construction footprint (ha)
1727	Swamp Oak – Sea Rush – *Baumea juncea* swamp forest on coastal lowlands of the Central Coast and Lower North Coast	Hunter Alluvium system (in part)	8.76
1736	Water Couch – Tall Spike Rush freshwater wetland of the Central Coast and lower Hunter	Hunter Alluvium system (in part)	59.04
1742	Jointed Twig-rush sedgeland	Tomago Sandbeds	1.45
1746	Saltmarsh Estuarine Complex	Hunter Alluvium system	1.26
1747	Grey Mangrove low closed forest	Hunter Alluvium system	2.27
Total			**166.70**

9.3.5 Threatened species

Threatened flora species

Four of the targeted threatened flora species (refer to **Table 9-2**) were recorded within the construction footprint during the field surveys and are presented in **Table 9-8**.

Table 9-8 Recorded threatened flora within the construction footprint

Flora species	Conservation Status		Presence in the construction footprint
	TSC Act	EPBC Act	
Drooping Red Gum (*Eucalyptus parramattensis* subsp. *decadens*)	V	V	34 plants
Sand Doubletail (*Diuris arenaria)*	V	-	161 plants
Netted Bottlebrush (*Callistemon linearifolius)*	V	-	157 plants
Tall knotweed (*Persicaria elatior)*	V	V	3 plants

Two additional threatened flora species were also recorded near the construction footprint:

- Small-flower Grevillea (*Grevillea parviflora* subsp. *parviflora*) – listed as vulnerable under the TSC Act and EPBC Act)
- *Maundia triglochinoides* – listed as vulnerable under the TSC Act.

The recorded location of the above threatened flora species are shown on **Figure 9-7**.

Threatened terrestrial fauna species

Ten threatened fauna species (refer to **Table 9-3**) were recorded during the field surveys, and three additional credit species have been assumed to be present on the basis that there are associated PCTs present, stable habitat and reliable and recent records of these species in the locality.

Two species, the White-bellied Sea-Eagle (*Haliaeetus leucogaster*) and Mahony's Toadlet (*Uperoleia mahonyi*) were listed under the BC Act in 2016 and 2018 respectively. These species have not been added

to the BioBanking calculator assessed for this project, however impacts have been included and assessed in order the meet the SEARs. Mahony's Toadlet (*Uperoleia mahonyi*) was assumed to be present.

In addition, four species listed as migratory under the EPBC Act were recorded during the targeted bird surveys and opportunistically in the construction footprint during surveys, listed in **Table 9-9**. The recorded locations of threatened fauna species are shown on **Figure 9-7**. Migratory species that were observed are not presented in the figure as the assessment focused on whether important habitat for migratory species was present or not, rather than the location of individuals. Further, migratory species were typically observed in degraded grazing paddocks and flying over the site, not on the ground surface.

Table 9-9 Listed threatened and migratory fauna species confirmed by surveys or assumed present within the construction footprint

Fauna species	Conservation Status		Presence in the construction footprint
	TSC Act	EPBC Act	
Wallum Froglet (*Crinia tinnula*)	V	-	Recorded
Squirrel Glider (*Petaurus norfolcensis*)	V	-	Recorded
Grey-crowned Babbler (*Pomatostomus temporalis temporalis*)	V	-	Recorded
Varied Sittella (*Daphoenositta chrysoptera*)	V	-	Recorded
Little Bent-winged Bat (*Miniopterus australis*)	V	-	Recorded
Grey-headed Flying-fox (*Pteropus poliocephalus*)	V	V	Recorded
Masked Owl (*Tyto novaehollandiae*)	V	-	Recorded
White-bellied Sea-Eagle (*Haliaeetus leucogaster*)	V (BC Act)	M	Recorded
Eastern False Pipistrelle (*Falsistrellus tasmaniensis*)	V	-	Recorded
Eastern Coastal Free-tailed Bat (*Micronomus norfolkensis*)	V	-	Recorded
Koala (*Phascolarctos cinereus*)	V	V	Assumed present
Australasian Bittern (*Botaurus poiciloptilus*)	E	E	Assumed present
Black Bittern (*Ixobrychus flavicollis*)	V	-	Assumed present
Mahony's Toadlet (*Uperoleia mahonyi*)	E (BC Act)	-	Assumed present
Latham's Snipe (*Gallinago hardwickii*)	-	M	Recorded
Satin flycatcher (*Myiagra cyanoleuca*)	-	M	Recorded
Rufous Fantail (*Rhipidura rufifrons*)	-	M	Recorded

Note: M = Migratory V = Vulnerable, E = Endangered

Koala

The northern portion of the construction footprint occurs within the Port Stephens Council LGA within an area mapped as known koala habitat by CKPoM (Port Stephens Council and Australian Koala Foundation 2002). The construction footprint has also been identified in the Lower Hunter Koala Study as containing moderate and high value koala habitats and a very small area of very high value koala habitat (Eco Logical Australia 2013). The majority of recorded koala sightings in the locality are relatively old, however, there have been infrequent koala sightings recorded outside the northern extent of the construction footprint every year since 2011. The most recent records are from 2018 with one recorded sighting located about two kilometres north of the construction footprint. The consistent but relatively low number of sightings each year between Tomago, Raymond Terrace/Ferodale and Williamtown demonstrate the presence of a low density population accessing habitat close the construction footprint on the eastern side.

The more recent targeted survey and assessment work for the project, carried out over several years, identified no evidence of koalas within the construction footprint. There were no observations of koalas during targeted and opportunistic surveys and no evidence of koala activity identified within the potential habitat areas within the construction footprint.

Some primary and secondary koala feed trees are present within the construction footprint. North of the Hunter River three primary feed tree species are present, Swamp Mahogany (*Eucalyptus robusta*), Forest Red Gum (*E. tereticornis*) and Drooping Red Gum (E. parramattensis subsp. decadens). These trees were recorded from 21 of the 61 plots (34.4 per cent). Two secondary koala feed tree species are also present in this area, Grey Gum (*E. punctata*) and Red Mahogany (*E. resinifera*). These species were present in six plots (9.8 per cent). The remaining 34 plots (55.7 per cent) did not contain koala feed tree species. While koala habitat is mapped in parts of the construction footprint from desktop data, the field survey data for the project assessment indicates an absence of the species in these specific areas along the construction footprint.

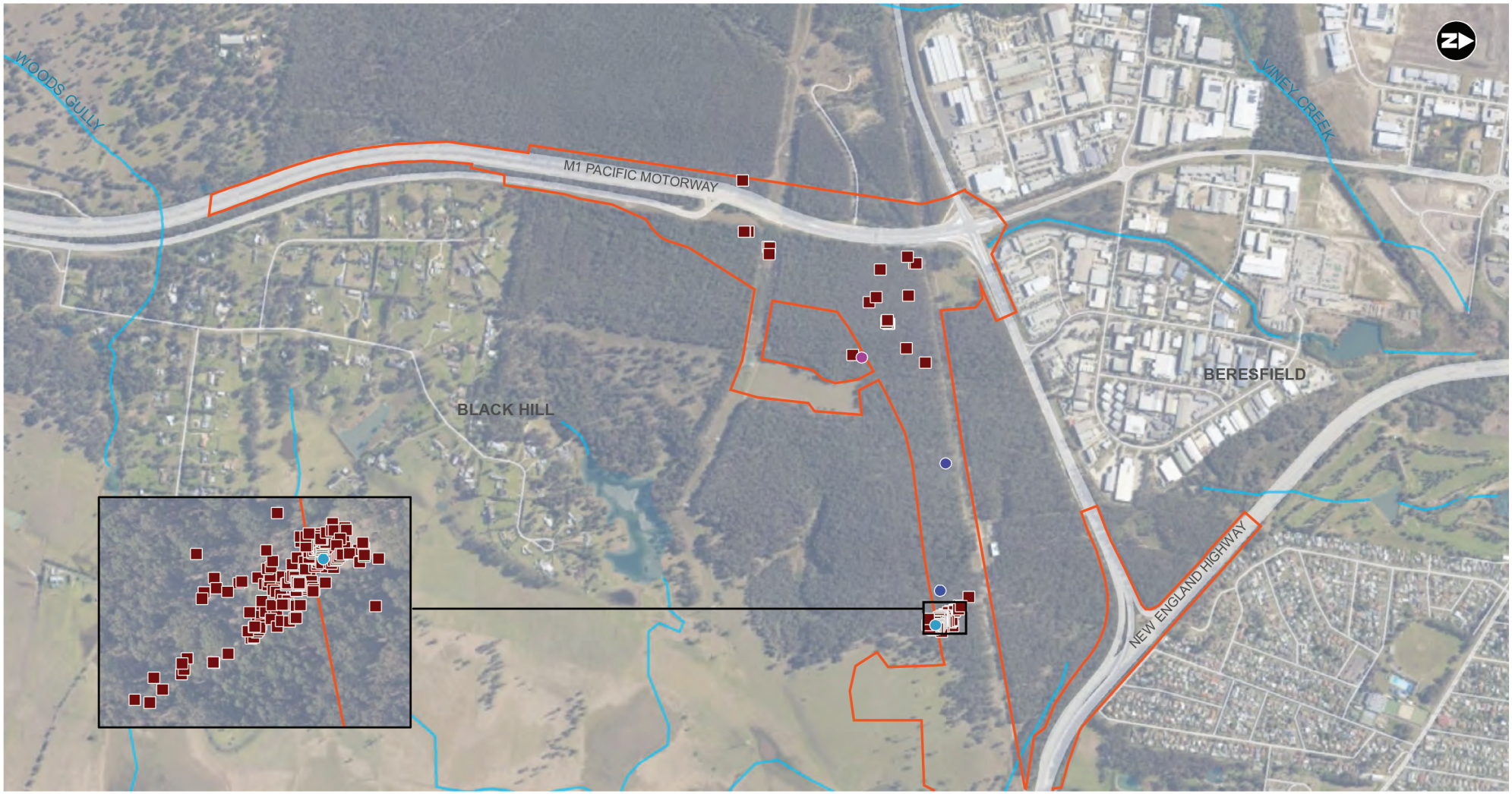
While koala feed tree species also occur at the south western end of the project around Black Hill (i.e. the primary feed tree *Eucalyptus tereticornis* and secondary feed trees *E. agglomerata* and *E. eugenioides*) there are no historic records at Black Hill east of the M1 Pacific Motorway and the scat surveys suggest no evidence of koala presence in this portion of the construction footprint.

Threatened aquatic fauna species

Database review of threatened fish species habitat and distribution identified three species with potential to occur in the construction footprint:

- Purple Spotted Gudgeon (*Mogurnda adspersa*) – listed as endangered under FM Act
- Black Rock Cod (*Epinephelus daemelii*) – listed as vulnerable under the FM Act and EPBC Act
- Green Sawfish (*Pristis zijsron*) – listed as vulnerable under EPBC Act, though presumed extinct in NSW.

Due to the highly disturbed and largely saline conditions of the Hunter River and tributaries, it is considered unlikely that the Purple Spotted Gudgeon or the Black Rock Cod inhabit waterways within the construction footprint. The Green Sawfish is presumed extinct in NSW (last observed in 1972 in the Clarence River). Therefore, no protected or threatened fish species are expected to occur within the construction footprint.



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Figure 9-7 Recorded threatened species (map 1 of 5)

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Figure 9-7 Recorded threatened species (map 2 of 5)

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Figure 9-7 Recorded threatened species (map 3 of 5)

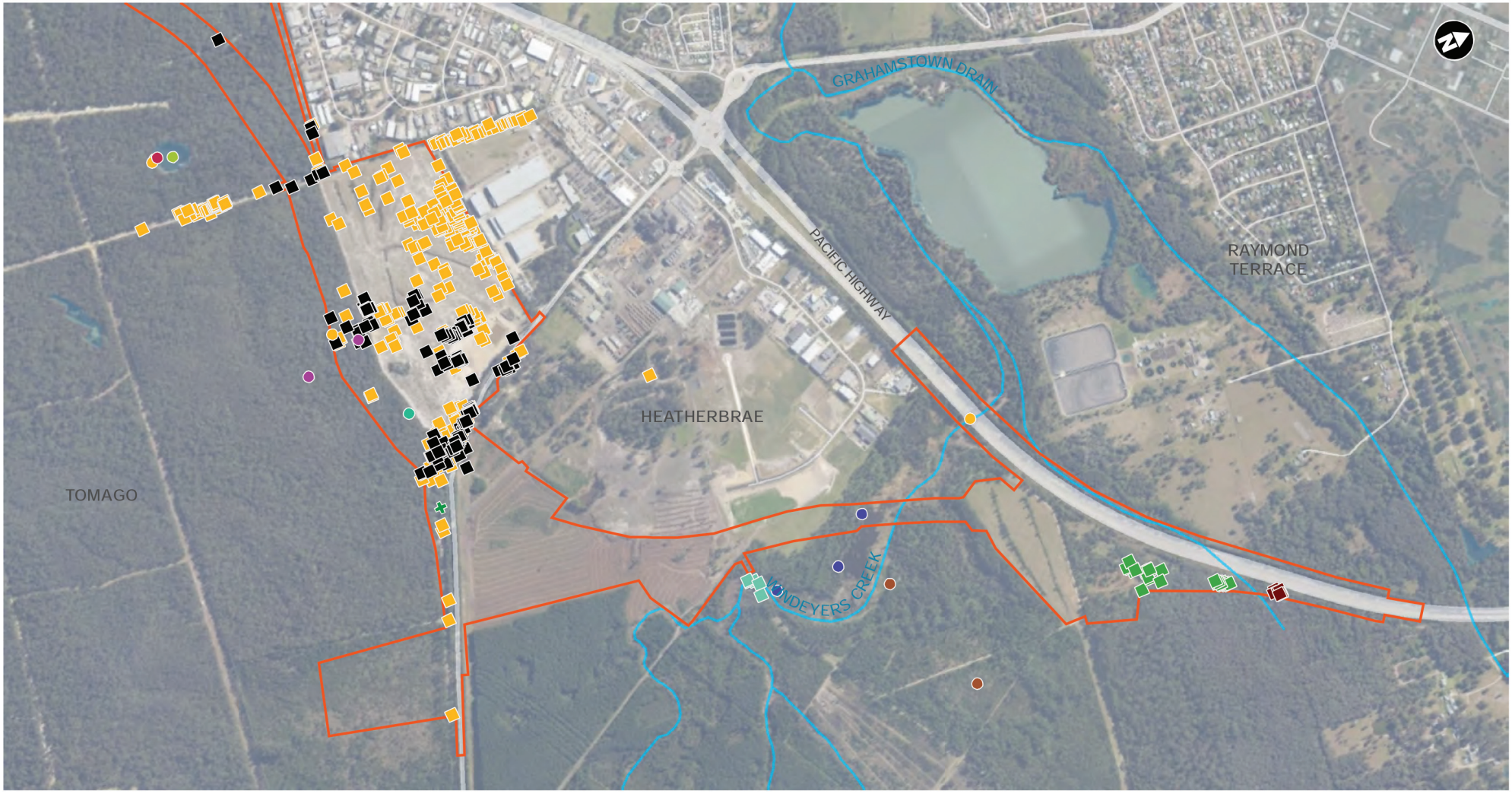
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Figure 9-7 Recorded threatened species (map 4 of 5)

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Figure 9-7 Recorded threatened species (map 5 of 5)

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9.3.6 Aquatic habitat

The Hunter River is a ninth order major river which originates in the Liverpool Range and flows generally in a south-easterly direction, reaching the Tasman Sea at Newcastle. In general, the benthic habitats of the Hunter River estuary are considered disturbed from the surrounding land use and history, though still provide important habitat. No threatened invertebrates have been recorded in the area.

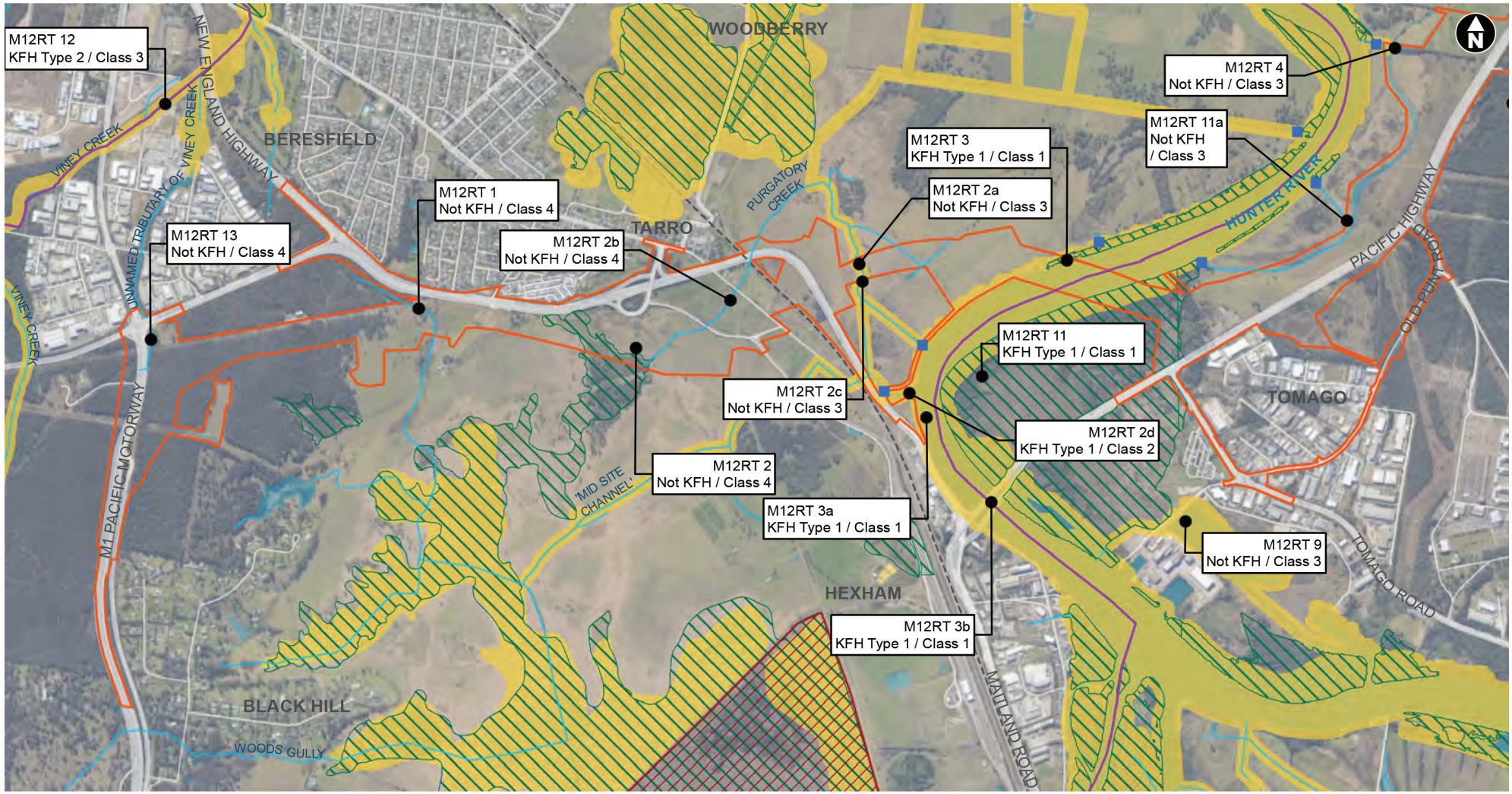
Seagrass beds are not known to occur in the lower Hunter River estuary and therefore the fish assemblages are different to those of other nearby NSW estuaries which are dominated by seagrasses (DPI 2000).

Table 9-10 lists the waterways within the construction footprint identified as KFH in accordance with the definitions in the Policy and Guidelines for Fish Habitat Conservation and Management (DPI 2013a) and that have been mapped by DPI Water (DPI 2007).

Table 9-10 Waterways identified as KFH within the construction footprint

Waterway name	KFH type (DPI 2013a)	Waterway classification (Fairfull and Witheridge 2003)
Purgatory Creek downstream of floodgates at junction with Hunter River	Type 1 – Highly sensitive Key Fish Habitat	Class 2 – Moderate fish habitat
Hunter River estuary – at proposed Hunter River crossing	Type 1 – Highly sensitive Key Fish Habitat	Class 1 – Major fish habitat
Unnamed wetland listed under the Coastal Management SEPP	Type 1 – Highly sensitive Key Fish Habitat	Class 1 – Major fish habitat

The location of KFH is provided in **Figure 9-8**.



Construction footprint

Main North Rail Line

Coastal wetlands (Coastal Management SEPP 2018)

Key Fish Habitat DPI 2007

Hexham Swamp Nature Reserve

Southern Purple Spotted Gudgeon (current predicted distribution DPI 2015)

Monitoring site

Floodgates

0 0.5 1 km

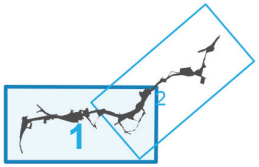
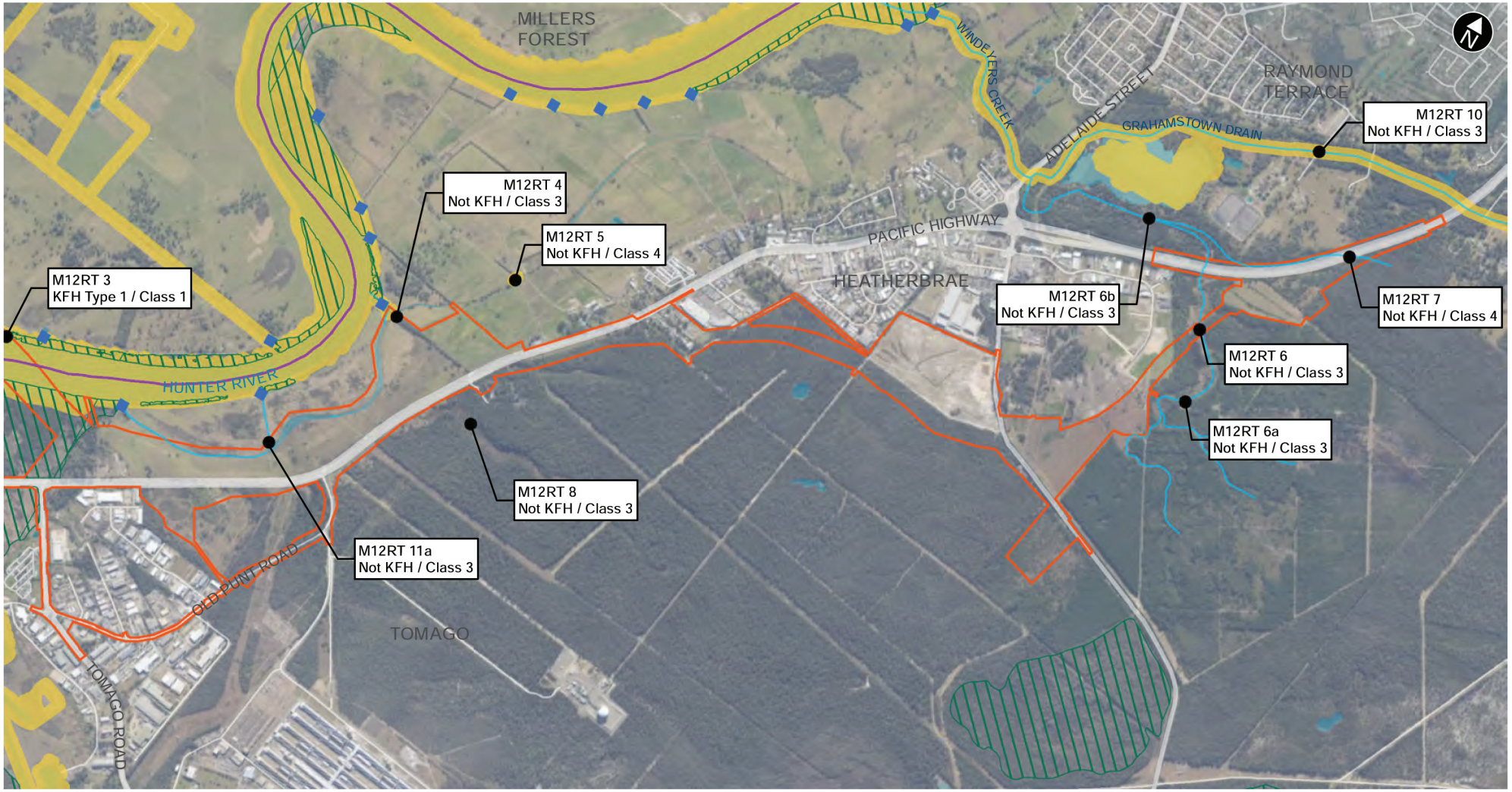




Figure 9-8 Aquatic habitat and key fish habitat assessment sites (map 1 of 2)

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Construction footprint

Coastal wetlands (Coastal Management SEPP 2018)

Key Fish Habitat DPI 2007

Southern Purple Spotted Gudgeon (current predicted distribution DPI 2015)

Monitoring site

Floodgates

0 0.5 1 km

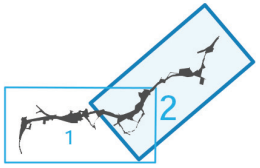




Figure 9-8 Aquatic habitat and key fish habitat assessment sites (map 2 of 2)

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9.3.7 Matters of national environmental significance

Desktop review and field survey results indicated the presence of Matters of National Environmental Significance (MNES) within the construction footprint including threatened species and communities listed under the EPBC Act as described in **Table 9-11**.

Table 9-11 MNES applicable to the project

MNES factor	Applicability to the project
Wetlands of international importance (Ramsar wetlands)	As described in **Table 9-4**, the Hunter Estuary Wetlands Ramsar site is located within 10km of the construction footprint, and is comprised of: • Kooragang Nature Reserve about 1.9km to the south-east of the construction footprint and about 5.1km downstream of the proposed crossing of the Hunter River • Hunter Wetlands Centre Australia in Shortland located about 3.8km south of the construction footprint. Hunter Wetlands National Park and Kooragang Nature Reserve contains mangroves, saltmarsh, paperbark and Swamp Oak swamp forest, brackish swamps, mudflats and sandy beaches. The Ramsar site receives surface water flows that pass through the project. The Hunter Wetlands Centre Australia is in a hydraulically separate subcatchment from the project. Given the distance from the construction footprint and the nature of the subcatchment, the Hunter Wetlands Centre Australia is not considered to be subject to potential impacts as a result of the project.
Listed ecological communities	Five nationally listed TECs listed under the EPBC Act were identified from the desktop assessment. Detailed field surveys confirmed that vegetation types consistent with two TECs were potentially present within the construction footprint based on the occurrence of corresponding PCTs: • Subtropical and Temperate Coastal Saltmarsh – listed as Vulnerable • Coastal Swamp Oak (*Casuarina glauca*) Forest of New South Wales and South East Queensland ecological community – listed as Endangered. Based on condition thresholds about 0.55 hectares of the saltmarsh community (PCT 1746) in the construction footprint is consistent with Subtropical and Temperate Coastal Saltmarsh TEC. None of the occurrences of PCT 1727 within the construction footprint are of sufficient size or condition to meet the eligibility for the listed Coastal Swamp Oak (*Casuarina glauca*) Forest of New South Wales and South East Queensland ecological community.
Listed threatened flora species	Eleven threatened flora species listed under the EPBC Act were considered to have a moderate to high likelihood of occurring in the construction footprint. The targeted field surveys confirmed two nationally listed threatened flora species in the construction footprint: • *Eucalyptus parramattensis* subsp. *decadens* (listed as vulnerable) • *Persicaria elatior* (listed as vulnerable).
Listed threatened fauna species	Nine nationally listed fauna species listed under the EPBC Act were identified as having a moderate to high likelihood of occurring within the construction footprint: • Regent honeyeater (*Anthochaera Phrygia*) • Australasian Bittern (*Botaurus poiciloptilus)* • Swift parrot (*Lathamus discolor)* • Australasian painted snipe (*Rostratula australis)* • Spotted tail quoll (*Dasyurus maculatus)* • Koala (*Phascolarctos cinereus)* • New Holland mouse (*Pseudomys novaehollandiae)* • Grey-headed Flying-fox (*Pteropus poliocephalus*) • Green and golden bell frog (*Litoria aurea).* The Grey-headed Flying-fox (*Pteropus poliocephalus*) (listed as vulnerable) was the only one of these species to be observed within the construction footprint (refer to **Table 9-9**).

MNES factor	Applicability to the project
Listed migratory species	The desktop assessment identified 16 listed migratory species listed under the EPBC Act with a moderate to high likelihood of occurring within the construction footprint: • 10 migratory wetland species • 6 migratory forest species. Of these species, White-bellied Sea-Eagle, Latham's Snipe, Satin Flycatcher and Rufous Fantail were observed within the construction footprint (refer to **Table 9-9**).

9.3.8 Weeds, pests and pathogens

A total of 32 high-threat exotic weed species (associated with the Biodiversity Assessment Methodology (BAM)), were identified in the construction footprint during surveys. Five of these species are listed as Weeds of National Significance and include *Alternanthera philoxeroides* (Alligator weed), *Asparagus aethiopicus* (Asparagus weed), *Lantana camera* (Lantana), *Rubus fruticosus agg.* (Blackberry) and *Senecio madagascariensis* (Fireweed). The classification and legal requirements associated with weed species identified in the construction footprint is provided in **Table 9-18**.

The construction footprint is currently habitat for a range of pest species including rabbits, cats, foxes, and Plague Minnow.

Pathogens were not observed in the construction footprint.

9.4 Assessment of potential impacts

9.4.1 Avoidance and minimisation of impacts

As described in **Chapter 4**, the project development has been an iterative process. The environmental focus of the route selection for the project was to align the construction footprint with existing development and infrastructure and thereby avoid biodiversity impacts where possible. This has resulted in a construction footprint that has minimal impact to vegetation connectivity at a landscape scale since the route follows the edge of existing vegetation, particularly north of Tomago Road. For this reason, potential impacts to large areas of koala habitat between Tomago and Raymond Terrace have been avoided and the project is not expected to impact on the movements of koala.

The following key refinements were made to the project design to avoid potential impacts on biodiversity:

- Aligning the western section of the operational footprint with existing development to limit the interface with the wetlands
- Locating the northern section of the operational footprint to reflect the existing development corridor so as to limit impacts to habitat and limit habitat fragmentation (inclusive of koala habitat)
- Design of a viaduct crossing the Hunter River and floodplain, in contrast to a built formation option that has resulted in avoiding a lengthy direct impact to floodplain wetlands and associated biodiversity and maintained connectivity for fauna associated with floodplain habitats
- Moving the previously proposed viaduct crossing the Hunter River further upstream, which has resulted in avoiding impacts to the Coastal Management SEPP coastal wetland on the western bank of the Hunter River and reducing the extent of impacts on Saltmarsh TEC and Freshwater Wetland TEC
- Moving the main alignment closer to the New England Highway has reduced the area of land to be fragmented which may provide suitable habitat for some migratory and wetland species
- Reduced impacts to the Coastal Wetland directly south of the Tarro interchange

- Reconsideration of the scope and functionality of project elements, such as the removal of a previously considered link road at Tomago, which has avoided impacts to remnant vegetation, potential habitat for threatened species, connectivity impacts and a population of 150 Grevillea parviflora subsp. parviflora individuals
- The locations of ancillary facilities have been positioned, where possible, to avoid impacts to biodiversity by placing them within previously cleared and disturbed land such that there would be minimal vegetation disturbance required.

Where it was not possible to avoid all impacts by the preferred corridor location, the project was designed to minimise impacts as far as possible, including:

- Raymond Terrace: Removal of the northbound exit ramp. This design change allowed the project to minimise impacts on native vegetation in this area
- Locating the northern abutment of the Hunter River bridge across former industrial site that is a known contamination site, resulting in minimising vegetation loss and removing the contamination source to limit future ongoing contamination risk
- Inclusion and design of fauna fencing and fauna crossing opportunities designed to minimise impacts to localised movements of fauna.

9.4.2 Assessment of potential construction impacts

Removal of native vegetation

Vegetation clearance and habitat loss are likely to be the largest detrimental impacts for terrestrial biodiversity that may arise from the project. The impact may be direct in the form of vegetation and habitat removal, or indirect in the form of fragmentation of habitat and edge effects to retained areas of vegetation.

This assessment has assumed that there would be complete vegetation clearance within the construction footprint. This precautionary approach has been applied to the assessment of the impacts of the concept design to ensure all potential 'worst case' impacts are assessed. If approved, the project would undergo a detailed design phase, during which impacts will be further reviewed and minimised as far as practicable.

The project would result in the removal of about 174.3 hectares of native vegetation from 14 different PCTs within the construction footprint (refer to **Figure 9-5**), representing 13.6 per cent of the native vegetation within the landscape buffer.

The impacts identified in **Table 9-12** include the impact on 0.6 hectares (0.5 per cent) of the existing 106 hectare BioBanking site. Transport will acquire this impacted land and offset the impacts to the existing BioBanking site.

The native vegetation to be removed includes 136 hectares of TEC listed under the TSC Act and 0.55 hectares of TEC listed under the EPBC Act. For all TECs listed under the TSC Act, with the exception of Hunter Lowland Redgum Forest in the Sydney Basin and New South Wales North Coast Bioregions, vegetation clearance is listed as a key threatening process (KTP), however, the proportional impact of the project is relatively low.

Management measures designed to reduce the impact of vegetation removal are provided in **Section 9.5**. Impacts on TECs listed under EPBC Act are discussed below.

Table 9-12 Impacts to PCTs and TECs listed under the TSC Act and EPBC Act

Vegetation zone	Plant Community Type	Threatened Ecological Community		Impact (ha)
		TSC Act	EPBC Act	
1. 1590 – Good	Spotted Gum – Broad-leaved Mahogany – Red Ironbark shrubby open forest (1590) (HU804)	Lower Hunter Spotted Gum Ironbark Forest in the Sydney Basin and NSW North Coast Bioregions (Endangered)	-	25.16
2. 1590 – Moderate				8.35
3.1590 – Regenerating				8.37
4.1588 – Moderate	Grey Ironbark – Broad-leaved Mahogany – Forest Red Gum shrubby open forest on Coastal Lowlands of the Central Coast (1588) (HU802)	-	-	6.78
5.1588 – Regenerating				0.82
6. 1646 – Good	Smooth-barked Apple – Blackbutt – Old Man Banksia woodland on coastal sands of the Central and Lower North Coast (1646) (HU860)	-	-	20.76
7.1646 – Poor				7.83
8.1649 – Good	Smooth-barked Apple – Red Mahogany – Swamp Mahogany – *Melaleuca sieberi* heathy swamp woodland of coastal lowlands (1649) (HU863)	Swamp Sclerophyll Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (Endangered)	-	1.36
9.1598 – Poor	Forest Red Gum grassy open forest on floodplains of the lower Hunter (1598) (HU812)	Hunter Lowland Redgum Forest in the Sydney Basin and New South Wales North Coast Bioregions (Endangered)	-	0.45
10.1716 – Good	Prickly-leaved Paperbark forest on coastal lowlands of the Central Coast and Lower North Coast (1716) (HU930)	Swamp Sclerophyll Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (Endangered)	-	1.82
11.1717 – Good	Broad-leaved Paperbark – Swamp Mahogany – Swamp Oak – Saw Sedge swamp forest of the Central Coast and Lower North Coast (1717) (HU931)	Swamp Sclerophyll Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (Endangered)		3.85
12.1717 – Poor				6.64
13.1724 – Good	Broad-leaved Paperbark – Swamp Oak – Saw Sedge swamp forest on coastal lowlands of the Central Coast and Lower North Coast (1724) (HU938)	Swamp Sclerophyll Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (Endangered)	-	1.61

Vegetation zone	Plant Community Type	Threatened Ecological Community		Impact (ha)
		TSC Act	EPBC Act	
14.1727 – Moderate	Swamp Oak – Sea Rush – *Baumea juncea* swamp forest on coastal lowlands of the Central Coast and Lower North Coast (1727) (HU941)	Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (Endangered)	Does not meet size or condition criteria for a listed community under EPBC Act	8.76
15.1736 – Good	Water Couch – Tall Spike Rush freshwater wetland of the Central Coast and lower Hunter (1736) (HU950)	Freshwater Wetlands on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	-	33.23
16.1736 – Moderate				25.81
17.1742 – Good	Jointed Twig-rush sedgeland (1742) (HU956)	Freshwater Wetlands on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	-	1.45
18.1071 – Good	*Phragmites australis* and *Typha orientalis* coastal freshwater wetlands of the Sydney Basin Bioregion (1071) (HU673)	Freshwater Wetlands on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (Endangered – in part 7.67ha)	-	7.71
19.1746 – Good	Saltmarsh Estuarine Complex (1746) (HU960)	Coastal Saltmarsh in the New South Wales North Coast, Sydney Basin and South East Corner Bioregion (Endangered)	Subtropical and Temperate Coastal Saltmarsh (vulnerable – in part 0.55ha meets condition criteria)	1.26
20.1747 – Good	Grey Mangrove low closed forest (1747) (HU961)	-	-	2.04
21.1747 – Moderate				0.23
Total area of clearing		**136ha**	**0.55ha**	**174.29**

Threatened flora

The project would directly impact four threatened flora species, as summarised in **Table 9-13**.

Table 9-13 Impacts to threatened flora

Threatened flora species	TSC Act	EPBC Act	Individuals impacted	Significance to local population
Eucalyptus parramattensis subsp. *decadens*	V	V	34 plants	Given the condition and location of the habitat where these trees are located on the edge of the Pacific Highway, the loss of 34 trees from the broader Tomago Sandbeds population is unlikely to lead to the decline of the local population and is not considered to be a significant impact.

Threatened flora species	TSC Act	EPBC Act	Individuals impacted	Significance to local population
Diuris arenaria	V	-	161 plants	A small number of plants will remain outside the construction footprint however the cumulative loss from this project and an adjacent approved development represents a significant loss of plants from this local population.
Callistemon linearifolius	V	-	157 plants	The loss of plants from the southern end of the construction footprint (considering only known individuals) is likely a large portion of the known population around the footprint east of the M1 Pacific Motorway. The remaining plants at the southern end of the population would be subject to indirect impacts through edge effects, with many located on the edge of the new road, suggesting the long-term viability of the remainder of this local population would also be impacted. Other populations and suitable habitat occur to the west of the project.
Persicaria elatior	V	V	3 plants	The direct impact on these three individuals represents a small number of plants that form a small isolated population. The habitat where these plants were identified is considered to be poor quality habitat for the species, due to impacts from ongoing cattle grazing and weed invasion. The three individuals likely represents a small isolated population that have dispersed from nearby large areas of swamp forest and wetlands to the east. Given this, the habitat that would be impacted by the project is not considered likely to be habitat critical to the survival of the species.

Threatened fauna species habitat and habitat features

The project would result in loss of about 174.3 hectares of habitat for threatened fauna species. The loss of habitat is a KTP listed under the TSC Act and is described as land clearance under the EPBC Act. Habitat loss would be made up of:

- Dry sclerophyll forests with a shrub and grass understorey: 49.49 hectares (about 28.4 per cent)
- Dry sclerophyll forests with a shrubby understorey: 28.59 hectares (about 16.4 per cent)
- Freshwater wetland habitat: 68.2 hectares (about 39.1 per cent)
- Forested wetlands: 24.49 hectares (about 14.1 per cent)
- Saline wetlands: 3.53 hectares (about two per cent).

The project would also remove about 13.04 hectares of planted native vegetation, which provide a foraging resource for a range of mobile nectivorous bird and bat species.

The removal of this native vegetation would result in the loss of fauna habitat features known to support locally occurring threatened fauna species. This includes potential breeding and sheltering habitats in the form of hollow-bearing trees, riparian vegetation, dead and dying wood and wetland vegetation, as well as foraging habitat and resources such as foliage, nectar and sap exudates. Additionally, a number of threatened fauna species require winter flowering food resources, which are present within the construction footprint, to supply food when there are resource shortages, or to coincide with migratory movements.

A summary of the potential impacts on threatened fauna species is provided in **Table 9-14**.

Table 9-14 Summary of threatened fauna species impacts

Threatened species	Credit type	TSC Act	EPBC Act	Habitat or individuals in construction footprint (direct impact)	Potential habitat in the landscape buffer area
Wallum Froglet (*Crinia tinnula*)	Species	V	-	3.21ha of confirmed habitat based on a 40m buffer around the waterways where this species was identified.	About 73ha
Squirrel Glider (*Petaurus norfolcensis*)	Ecosystem	V	-	93.36ha of potential habitat, populations recorded at Black Hill and Heatherbrae.	About 396ha, very large areas of contiguous habitat for this species extend east to Tomago, Williamtown and Tilligerry.
Grey-crowned Babbler (*Pomatostomus temporalis temporalis*)	Ecosystem	V	-	70.47ha of potential habitat based on associated PCTs, prefer dry sclerophyll forest with grassy/shrubby understorey.	Extent of population and occurrence not known, although up to 511ha of potential habitat present.
Varied Sittella (*Daphoenositta chrysoptera*)	Ecosystem	V	-	100.96ha of potential habitat based on associated PCTs, prefer dry sclerophyll forest with grassy/shrubby understorey. Consistently recorded at Black Hill at western end of the construction footprint	Up to 511ha of potential habitat within landscape buffer.
Little Bent-winged Bat (*Miniopterus australis*)	Ecosystem and Species	V	-	82.78ha of potential foraging habitat impacted. No roosting habitat identified in the construction footprint. Roosting habitat identified at Windeyers Creek bridge, which is outside the construction footprint and would not be impacted.	This species may forage over all forested and open habitats including cleared and modified lands, urban and industrial areas. Over 1000ha of forest habitat present plus very large areas of contiguous habitat for this species extend east to Tomago, Williamtown and Tilligerry.
Grey-headed Flying-fox (*Pteropus poliocephalus*)	Ecosystem	V	V	85.05ha of potential foraging habitat based on associated PCTs and habitat modelling data for the locality.	Over 1000ha of potential foraging habitat present. Very large areas of contiguous habitat for this species extend east to Tomago, Williamtown and Tilligerry.
Masked Owl (*Tyto novaehollandiae*)	Ecosystem	V	-	70.47ha of potential habitat. The species was confirmed at Black Hill and Heatherbrae and is likely to comprise separate individuals and home range area. No nesting trees identified, although suitable large tree hollows are present in the landscape at Heatherbrae and there is potential to remove trees used for nesting.	About 396ha of potential habitat present, very large areas of contiguous habitat for this species extend east to Tomago, Williamtown and Tilligerry

Threatened species	Credit type	TSC Act	EPBC Act	Habitat or individuals in construction footprint (direct impact)	Potential habitat in the landscape buffer area
Eastern False Pipistrelle (*Falsistrellus tasmaniensis*)	Ecosystem	V	-	82.78ha of potential habitat based on associated PCTs. This includes all forested habitats of the construction footprint.	This species occupies a diversity of forest habitat with tree hollows for roosting, may forage over all forested and open habitats. Over 1000ha of forest habitat present plus very large areas of contiguous habitat for this species extend east to Tomago, Williamtown and Tilligerry.
Eastern Coastal Free-tailed Bat (*Micronomus norfolkensis*)	Ecosystem	V	-	82.78ha of potential habitat based on associated PCTs. This includes all forested habitats of the construction footprint.	This species occupies a diversity of forest habitat with tree hollows for roosting, may forage over all forested and open habitats. Over 1000ha of forest habitat available plus very large areas of contiguous habitat for this species extend east to Tomago, Williamtown and Tilligerry.
Koala (*Phascolarctos cinereus*)	Species	V	V	Impacts to about 51.12ha from Tomago to Heatherbrae, predominantly impacts on edge habitats and fragmented habitat, no impacts to koala movements anticipated. Up to 5.3ha of potential habitat would be isolated at Heatherbrae, however this is on the edge of the existing industrial area, and no evidence of koala use was recorded.	Large areas of potential habitat across the Tomago Sandbeds through to Williamtown and north to Grahamstown Dam. About 670ha mapped within the landscape buffer.
Australian Bittern (*Botaurus poiciloptilus*)	Species	V	-	43.64ha of potential habitat based on associated PCTs. Historical record from Windeyers Creek.	Known from Hunter Wetlands National Park and Hexham Swamp Nature Reserve. Up to 160ha of potential habitat occurs.
Black Bittern (*Ixobrychus flavicollis*)	Species	V	-	61.95ha of potential habitat based on associated PCTs could occur in freshwater and saline wetlands.	Known from Hunter Wetlands National Park. Up to 233ha of potential habitat mapped within the landscape buffer. High quality habitat occurs to the east in the Hunter Region Botanic Gardens and to the south at Black Hill. These areas are outside of the construction footprint and would not be impacted.

Threatened species	Credit type	TSC Act	EPBC Act	Habitat or individuals in construction footprint (direct impact)	Potential habitat in the landscape buffer area
Mahony's Toadlet (*Uperoleia mahonyi*)	Newly listed species – Not listed under the TSC Act or included in the BBCC	E (BC Act)	-	3.21ha of confirmed habitat based on a 40m buffer around the waterways where this species was identified. The extent of the population in the construction footprint is unknown, but is considered to be a minor proportion of the broader local population.	About 73ha. Similar type habitats are widespread and very large, particularly in Hunter Water Corporation owned lands in Heatherbrae and to the east of Raymond Terrace within the Tomago Sandbeds region.
White-bellied Sea- Eagle (*Haliaeetus leucogaster*)	Newly listed species – Not listed under the TSC Act or included in the in BBCC	V (BC Act)	M	174.3ha of potential foraging habitat, largely associated with vegetation surrounding the Hunter River and small tributaries. No nest sites identified in the construction footprint during surveys.	May forage over all forested and open habitats including cleared and modified lands. Over 1000ha of forest habitat present plus very large areas of contiguous habitat for this species extend east to Tomago, Williamtown and Tilligerry.

Note: M = Migratory, V = Vulnerable, E = Endangered

Koala

The project has been designed to minimise the loss of mature forest by selecting an alignment as close as possible to the existing Pacific Highway from Tomago to Heatherbrae, along the edge of the known koala habitat within Port Stephens Council LGA. While no evidence of koalas was recorded during targeted field surveys, construction of the project would remove about 51.12 hectares of potential koala habitat. This area of impact has been calculated based on the area of PCTs associated with koala habitat within the Tomago to Heatherbrae section of the project. As there is no known koala population within the Black Hill area west of the M1 Pacific Motorway and PCTs within this area have not formed part of the koala habitat impact area.

The 51.12 hectares impacted is predominantly comprised of edge habitats and fragmented habitat with no impacts to koala movements anticipated. Up to 5.3 hectares of potential habitat would be isolated at Heatherbrae, however this is on the edge of the existing industrial area, and no evidence of koala use was recorded during field survey.

As part of the assessment process under the EPBC Act, the Koala habitat assessment tool (DoE 2013a) was used to identify the extent and importance of the impact to koala habitat. The assessment tool uses a scoring system based on known occurrence, presence of feed trees, habitat connectivity, existing threats and recovery value. Even though survey results identified no recent koala activity within the construction footprint, based on the habitat present and previous records in the local area, the construction footprint was identified as having habitat critical to the survival of the koala in accordance with the assessment tool guidelines.

As the project was considered likely to adversely affect habitat critical to the survival of the koala, an assessment of significance was required under the EPBC Act referral guidelines (DoE 2014). The key outcomes from the assessment of significance are:

- No evidence of koala activity was confirmed within the construction footprint during surveys
- The small area of habitat to be lost along the edge of the existing Pacific Highway between Tomago and Heatherbrae is unlikely to result in a long-term decrease in the size of the Port Stephens koala population
- The small loss of habitat area (in comparison to the large areas of very high and high quality habitat to the east and north of the construction footprint) is considered unlikely to reduce the area of occupancy for the koala
- While the project would isolate two small patches of habitat considered to be of low value, the project is not expected to fragment habitat for an important koala population and would not sever an important link between areas of core koala habitat
- The project is unlikely to impact habitat critical to the survival of the species
- The project has the potential to disrupt the breeding cycle of a small number of animals, however, this impact would be minor relative to the extent of the Port Stephens koala population
- Management measures such as fencing would prevent koalas from accessing the road. Connectivity measures were not considered necessary as the project would not isolate an important area of habitat or sever an important link.
- The project would not be directly responsible for introducing disease known to affect koala populations such as Chlamydia
- The project would not interfere with any of the objectives identified in the National Recovery Plan for the Koala
- The project would have minimal impact to koala habitat in terms of absolute habitat loss and impacts to the movement of koalas, due to the location of the proposed action being at the outer extent of koala habitat.

Given the position of the project, the findings from the background review, spatial review and field surveys, and the outcomes of the Assessment of Significance, the proposed action is not expected to significantly impact on the koala.

Removal of migratory species habitat

The project would result in impacts associated with the removal of habitat for wetland and terrestrial migratory species listed under the EPBC Act, including:

- 16.4 hectares of habitat for Latham's snipe (wetland species)
- 70.47 hectares of habitat for Rufous Fantail and Satin Flycatcher (terrestrial species).

The project would remove around 174.3 hectares of potential hunting, perching, and nesting habitat used by White-bellied Sea-Eagle during construction. However, this is not expected to impact on the ability of the species to forage and hunt along riverine / estuarine habitats within the construction footprint.

The Rufous Fantail and Satin Flycatcher were recorded at Black Hill near the proposed M1 Pacific Motorway interchange within the adjacent Spotted-Gum – Ironbark Forest with a paperbark understorey. Rufous Fantail was also recorded in the sandy Blackbutt dominated forest at the northern end of the project. Suitable habitat for these species is widespread across the construction footprint and wider area. The impact to these species would be minimal and affect non-breeding habitat.

Since habitat for migratory species within the construction footprint is not classed as 'important habitat' as defined under the EPBC Act Policy Statement 1.1 Significant Impact Guidelines (DoE 2013b), is it unlikely that the project would have a significant impact on these species.

Landscape features and values

Impacts on landscape features and values that are considered to be complicated or severe, that were subject to further consideration in accordance with the requirements of the FBA, include the following, which are discussed below:

- Impacts on vegetation in the riparian buffer zone bordering rivers and streams 4th order or greater
- Impacts on important wetlands and their buffers
- Impacts on biodiversity links
- Impacts in the buffer zone along estuaries.

Impacts on riparian buffer of important rivers, streams and estuaries

The project would directly impact on vegetation in the riparian buffer zone where it is proposed to cross the Hunter River. Specifically, the project would result in the removal of vegetation at:

- The western bank (immediate western edge):
  - Mangrove forest (PCT 1747) about 0.18 hectares
  - Saltmarsh complex (PCT1746) about 0.48 hectares.
- The eastern bank (floodplain between Hunter River and existing highway):
  - Mangrove forest (PCT 1747) about 1.86 hectares
  - Swamp Oak forest (PCT 1727) about 6.28 hectares
  - Swamp Mahogany – Flax-leaved Paperbark swamp forest (PCT 1717) about 0.36 hectares
  - *Phragmites australis* and *Typha orientalis* freshwater wetlands (PCT 1071) about 3.39 hectares.

Impacts on important wetlands

Important wetlands in the construction footprint include wetlands listed under the Coastal Management SEPP. The project has the potential to impact on important wetlands in the construction footprint by:

- Partial clearance of areas classified as coastal wetland
- Removal of vegetation within wetlands

- Changes to hydrological regimes (i.e. flooding) resulting in:
  - Changes in species assemblages
  - Reduction in water quality
  - Weed invasion.
- Establishment and spread of new and existing exotic flora species.

Hexham Swamp Nature Reserve is located about two kilometres from the construction footprint, therefore construction activities would not directly impact or discharge directly into the reserve. Indirect water quality impacts from the project are also not expected because surface water flow from the construction footprint would not reach Hexham Swamp Nature Reserve, except during a 20% or greater annual exceedance probability (AEP) flood event when the northern and southern floodplain at Hexham become hydrologically connected due to culvert flow (refer to **Chapter 11** (hydrology and flooding) for further details). During these events, any water quality impacts which are associated with the project would be negligible due to flooding from the greater catchment which would provide dilution to any runoff from the project. Therefore any observable changes to water quality in Hexham Swamp Nature Reserve, during and following a flood event, would be representative of the broader catchment pollutant loads and not directly attributable to the project.

The project would directly impact around 16.4 hectares of Coastal Management SEPP coastal wetlands, concentrated around three areas:

- Riparian vegetation on the eastern bank of the Hunter River (about 11.9 hectares): includes Mangrove forest (PCT 1747), Swamp Oak forest (PCT 1727), Swamp Mahogany – Flax-leaved Paperbark swamp forest (PCT 1717) and *Phragmites australis* and *Typha orientalis* wetlands (PCT 1071)
- A thin strip of riparian vegetation on the western bank of the Hunter River (about 0.66 hectares), which includes Mangroves (PCT 1747) and Saltmarsh (PCT 1746)
- An area of wetland (about 4.95 hectares), which consists of vegetation identified as Water Couch – Tall Spike Rush freshwater wetland (PCT 1736). The area of PCT 1736 in this area covers a larger area than mapped coastal wetlands.

Mapped important wetlands associated with the Hunter River floodplain in this location have a long history of impacts from development. These impacts are associated with clearing and modification for past agricultural land use. This included flood mitigation and this has resulted in altered surface hydrology, reduced cover of macrophytes and corresponding reduced wetland health.

The potential for downstream impacts to occur outside of the construction footprint, such as sedimentation resulting in a reduction in water quality or a change in the hydrological regime resulting in changes in species assemblages or water quality, is considered to be low in both the short-term and long-term. These short-term impacts can be mitigated using effective management measures. Management measures proposed to mitigate impacts on wetlands are described in **Section 9.5**.

Biodiversity links and connectivity

The project would not impact on any State biodiversity links.

The regional landscape corridors identified in **Table 9-4** are only important for large and mobile fauna species and the project structures and operation would not impact on the movements of these species. On a local scale, a connectivity strategy was developed to provide effective mitigation in areas of the construction footprint that may become fragmented and therefore impact on the movements of fauna species. Further information regarding proposed connectivity features is provided in **Section 9.5.1**.

Impacts on Matters of National Environmental Significance

As discussed in **Section 2.2.2**, the project was determined to be a controlled action based on its potential to impact on MNES. As part of the referral, assessments of significance under the MNES Significant impact guidelines 1.1 (DoE 2013b) were completed for the TECs and species identified through desktop assessment and field surveys.

Based on assessment of the referral, DoAWE determined that significant impacts would be unlikely for Earp's Gum (*Eucalyptus parramattensis* subsp. *decadens*), Small-flowered Grevillea (*Grevillea parviflora* subsp. *parviflora*), Tall Knotweed (*Persicaria elatior*), Australasian Bittern (*Botaurus poiciloptilus*), Australian Painted Snipe (*Rostratula australis*), Spotted-tailed Quoll (*Dasyurus maculatus*), New Holland Mouse (*Pseudomys novaehollandiae*) and Green and Golden Bell Frog (*Litoria aurea*).

Since the referral, the biodiversity assessment has identified one new impacted species (*Persicaria elatior*) and increased impacts on five threatened species (*Eucalyptus parramattensis* subsp. *decadens*, Australasian Bittern, Australian Painted Snipe, Spotted-tailed Quoll and New Holland Mouse).

Assessments of Significance have concluded that a significant impact to any of the species and TECs listed within the original referral or identified as having an increased and changed impact is considered unlikely. A detailed assessment against the EPBC Act significant assessment criteria is provided in the BAR (**Appendix I**).

Six nationally listed TECs under the EPBC Act were identified from the PMST and desktop assessment for consideration in the construction footprint:

1. Subtropical and Temperate Coastal Saltmarsh (vulnerable)
2. Coastal Swamp Oak (*Casuarina glauca*) Forest of New South Wales and South East Queensland ecological community (endangered)
3. Central Hunter Valley eucalypt forest and woodland ecological community (critically endangered)
4. Lowland Rainforest of Subtropical Australia (critically endangered)
5. Posidonia australis seagrass meadows of the Manning-Hawkesbury ecoregion (endangered)
6. River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria.

Assessment confirmed the presence of only Subtropical and Temperate Coastal Saltmarsh and Coastal Swamp Oak (*Casuarina glauca*) Forest of New South Wales and South East Queensland.

Coastal Swamp Oak (*Casuarina glauca*) Forest of New South Wales and South East Queensland ecological community (endangered under the EPBC Act) was discussed in the referral as having potential to occur, however as described in **Table 9-11** none of the occurrences of Coastal Swamp Oak (PCT 1727) within the construction footprint are considered of sufficient size, condition and connectivity to meet the condition thresholds and eligibility for the listed community.

Of the 1.26 hectares of the PCT Saltmarsh Estuarine Complex (PCT 1746) present within the construction footprint, about 0.55 hectares is consistent with the listed Subtropical and Temperate Coastal Saltmarsh community listed as vulnerable under the EPBC Act. As this community is listed as vulnerable, and not endangered, under the EPBC, an Assessment of Significance is not required as it is not a MNES for the purposes of Part 3 of the EPBC Act (requirements for environmental approval).

The project would result in a loss of habitat for some migratory species listed under the EPBC Act that frequent the Hunter region, including:

- 16.4 hectares of habitat for Latham’s snipe
- 70.47 hectares for Rufous Fantail and Satin Flycatcher.

The project would remove around 174.3 hectares of potential hunting, perching, and nesting habitat used by White-bellied Sea-Eagle during construction. However, this is not expected to impact on the ability of the species to forage and hunt along riverine / estuarine habitats within the construction footprint.

The Assessment of Significance concluded that the loss of habitat would be unlikely to result in a significant impact on these threatened migratory species.

The impact of the project on MNES has been assessed in further detail in the BAR (**Appendix I**).

Aquatic impacts and changes to hydrology

Construction activities associated with the project have the potential to impact aquatic ecosystems and result in changes to existing hydrology. Aquatic impacts could occur due to changes in water quality, habitat loss, temporary instream barriers and potential impacts to KFH. Impacts to these environmental values and KFH have been considered in this section.

The potential aquatic impacts associated with construction activities is discussed in the sections below.

Bridge crossings over waterways and near wetlands

The project involves three bridge crossings over waterways or wetlands including:

- A 2.6 kilometre viaduct (B05) over the Hunter River floodplains, Hunter River and areas classified as Coastal Wetland (Coastal Management SEPP) on either side of Hunter River
- A single bridge (B11) over Windeyers Creek
- Twin bridges (B02) over Glenrowan Creek and in proximity to a Coastal Wetland (Coastal Management SEPP), located south of the existing New England Highway.

Potential impacts associated with bridge construction over waterways and adjacent to wetlands are described in **Table 9-15**.

Table 9-15 Potential impacts associated with proposed bridge construction

Proposed bridge crossing	Construction activities	Potential impact
Viaduct over the Hunter River (B05)	Aquatic risks are primarily associated with the bridge construction activities, such as: • Vegetation clearing in the riparian zones of the Hunter River which would directly remove a section of dense mangrove vegetation located on the eastern bank of the river inside the construction footprint. There are no mangroves on the western bank of the river at the bridge site, however small areas of saltmarsh would be directly impacted • Piling for installation of instream and floodplain bridge foundations and substructures (including piles, abutments and piers) • Dredging of a limited area of the riverbed to allow shallow water access for barges during construction • Installation of temporary instream structures which may include rock platforms with sheet piled retaining walls (or similar) that would be built out from the banks at each side of the river, two wharf structures which would be built out from the banks at each side of the river, floating barge platforms (that would be anchored and docked at the wharf structures or mid channel) and silt curtains around piling and dredging locations • Movement and use of heavy vehicles and machinery over water and on the banks of the river • Construction of in situ steel reinforced concrete piers and bridge structure above water. This may also include the installation of offsite prefabricated pier and bridge components • Extraction of surplus spoil and construction waste and transfer from waterway to land for management. Wastewater may also be transferred to land for management • Removal of temporary construction structures and material from the ricer channel and riparian areas.	• The loss of aquatic habitat features such as mangrove forest and associated woody debris and other riparian vegetation • A reduction in local water quality associated with mobilisation of riparian sediments or existing contaminates • Exposure of acid sulfate soils (ASS) to the air after extracted from the waterway (either on barges or on land) • Impacts to local river bank morphology due to destabilisation/erosion as a result of clearing of existing riparian vegetation or removal of imported riparian armouring materials • Introduction of invasive aquatic species to the local environment from the construction vessels and equipment • A reduction in local water quality associated with the uncontrolled release of concrete dust, concrete slurries or waste water associated with work overwater. • A reduction in local water quality values associated unplanned release of hydrocarbons (i.e. fuel for plant equipment and vessels on barges) as a result of accidental spills or leaks • A reduction in local water quality associated with the unplanned loss of solid waste and construction materials (e.g. litter and equipment) within the river and surrounding wetland habitats. Following the implementation of appropriate management measures and erosion and sediment controls, the risk of impacts to aquatic biodiversity within the Hunter River are considered to be low and any residual impacts that are expected would be localised and minor. In the location where the proposed viaduct crosses the Hunter River, and dredging would occur, this area does not support gravel beds, snags or other fish spawning areas. There are also no significant areas of instream vegetation in the deep section of channel. Specific management measures related to dredging activities are planned to avoid or minimise potential direct and indirect impacts to estuarine fauna and mangrove areas within the Hunter River.

Proposed bridge crossing	Construction activities	Potential impact
Glenrowan Creek (B02) and Windeyers Creek (B11) bridge crossings	Construction activities which have potential to cause temporary impacts to these waterways include: • Vegetation clearing in the riparian zone of creeks • Preparation of instream bridge work areas including, piling and crane pads, as well as construction of site access roads • Temporary instream access tracks to allow haulage of material across waterways. Temporary access tracks may remain in place for up to two years • Associated civil works for the bridges, including cut and fill earthworks, as well as movement and use of heavy vehicles and machinery within and on the banks of the waterway • Dewatering of pile locations (if water is present) and temporary sediment basins.	• Mortality or a reduction in range of aquatic fauna due to habitat loss • Impacts to aquatic flora due to reduced light penetration from increased suspended sediments from instream civil works • Physiological impact on aquatic fauna (e.g. ingestion of contaminants from suspended sediments) • Reduction in local water quality due to increased suspended sediment and unplanned release of contaminants • A reduction in local water quality associated with the uncontrolled release of concrete dust, concrete slurries or waste water associated with work overwater • A reduction in local water quality values associated with unplanned release of hydrocarbons (i.e. fuel for plant equipment and vessels on barges) as a result of accidental spills or leaks • A reduction in local water quality associated with the unplanned loss of solid waste and construction materials (e.g. litter and equipment) within the river and surrounding wetland habitats • A reduction in local water quality associated with the discharge of water downstream. Construction of the project has aimed to minimise disturbance to the creeks and wetland environments by implementing appropriate management measures and erosion and sediment controls. Any residual impacts that may occur are likely to be highly localised and temporary. As such, it is expected that there would be minimal impacts to aquatic biodiversity as a result of bridge crossings at Glenrowan Creek or Windeyers Creek. Accidental spills would be managed in accordance with the Construction Soils and Water Management Plan (CSWMP) prepared for the project (refer to **Chapter 11** (surface water and groundwater quality)).

Potential impacts to aquatic ecosystems

Construction of the project has potential to impact aquatic ecosystems. In general, impacts to waterways may include:

- Barriers to fish passage
- Displacement or removal of existing large wood debris or snags
- Clearing of mangroves and riparian vegetation
- Interaction with equipment and machinery
- Changes to water quality resulting from, but not limited to:
  - Mobilisation of sediment-laden or contaminated water associated with construction activities
  - Water discharges from temporary sediment basins
  - Untreated ASS drainage
  - Tannin-laden runoff from stockpiled vegetation.
- Removal of instream macrophytes and habitat features
- Unplanned introduction and establishment of aquatic pest species and/or weeds.

Although several waterways in the area are ephemeral or modified drainage channels and disconnected from the Hunter River estuary as part of the flood mitigation scheme, the central portion of the construction footprint is a floodplain that contains patches of terrestrial and wetland features. These areas are mapped as Coastal Wetland under the Coastal Management SEPP (2018) and are potential habitat for dragonfly species and aquatic macroinvertebrates. Infrequent flushing of these areas results in very long residence times for contaminants, therefore, changes to water quality, aquatic habitat and natural flow regimes due to the project could result in the degradation of the wetlands and may reduce the available habitat for these aquatic species.

The above risks to aquatic ecosystems are discussed in the context of the project in **Table 9-16**.

Potential impacts to key fish habitat

As described in **Section 9.3.6**, the project crosses mapped KFH (as identified by DPI and based on field observations) (refer to **Figure 9-8**).

The most sensitive fish habitats (Type 1) within the construction footprint are associated within the Hunter River estuary, including the Hunter River itself, the Coastal Wetland (Coastal Management SEPP) on the eastern side of the Hunter River, and Purgatory Creek (downstream of the floodgate) as these environments consist of mangrove forests or have mangrove and saltmarsh vegetation along the banks and in the intertidal zone.

All other waterways within the construction footprint have been identified as Minimal (Type 3) or Unlikely (Type 4) fish habitat as they are generally disconnected from the Hunter River due to the managed environment (i.e. the Hunter River Flood Mitigation Scheme) and therefore currently do not exhibit aquatic habitat features that would support KFH.

The potential construction impacts to KFH are the same as those identified for the general aquatic environment as addressed in **Table 9-16**. Where potential impacts are specifically relevant to KFH this has been noted in **Table 9-16**.

Table 9-16 Potential impacts to aquatic ecosystems during construction of the project

Type of impact	Associated construction activities	Potential impact
Barriers to fish passage	Installation of instream bridge structures	The construction of the proposed viaduct (B05) over the Hunter River is unlikely to result in barriers to fish passage due to the following: • The floating silt curtains would be limited to installations around individual piling locations and dredging sites and installed in a manner that facilitates fish movement through the river channel • The barges are floating platforms, anchored to the riverbed via cables, therefore no physical barriers to fish passage are anticipated • The rock platforms and wharf structures would result in some obstruction of the waterway; however, they are anticipated to be built from / connected to the riverbank (to a distance of about 20m) and therefore would not significantly obstruct fish movement within the waterway.
Barriers to fish passage	Temporary waterway crossings	There will be no impact to fish passage in the short or medium term as flow conditions at temporary crossings will be maintained.
Removal of large woody debris or snags	In-stream works	The removal of large woody debris or snags is listed under Schedule 6 of the FM Act as a KTP. Woody debris plays an important role in freshwater and marine ecosystems by providing essential habitat for aquatic organisms and stabilising stream beds and banks. Visual assessment during field investigations revealed that large woody debris was not a significant component of the aquatic habitat along waterways traversed by the project. However, there is potential for large woody debris to be submerged and therefore not recorded, or to become deposited prior to construction. As such, large woody debris may be present within the Hunter River, Purgatory Creek, the tributary of Viney Creek, Glenrowan Creek, and Windeyers Creek. To minimise any impacts to aquatic environments due to removal of instream large woody debris, any large woody debris that is identified within the construction footprint prior to construction would be preserved and re-established at the site following construction or relocated downstream in consultation with a qualified ecologist.

Type of impact	Associated construction activities	Potential impact
Clearing of mangrove and riparian vegetation	Vegetation clearing for project components	The project would require clearance of some patches of mangrove vegetation on the eastern side of the Hunter River within the area classified as unnamed Coastal Wetland (Coastal Management SEPP), as well as an area of native riparian vegetation around Windeyers Creek. The eastern side of the Hunter River and unnamed Coastal Wetland are both KFH. Riparian vegetation on the banks of waterways and mangroves that are established in the intertidal zone, banks and floodplain areas of estuaries are structurally important for stabilising stream beds and riverbanks and can be utilised as shelter or refuge habitat for aquatic species or provide nursery habitat. The extent of mangroves in the lower Hunter River estuary is widespread and in the areas adjacent to the project, there are substantial patches of mature Grey Mangrove low closed forest present. Clearance of a portion of the mangroves on the eastern side of Hunter River is required to facilitate the installation of the temporary wharf structure, as well as other temporary assets which will be used to construct the viaduct over Hunter River (B05) and bridge abutments in the area. Additionally, there may be a limited clearance of mangroves associated with the remediation of the former mineral sands processing facility from the eastern bank of the Hunter River. Clearance of portions of the riparian zone around Windeyers Creek is required to facilitate the road and bridge footprint and provide access during construction. To minimise impacts to aquatic environments due to clearance of riparian vegetation and mangroves, temporary riparian and instream construction equipment would be removed, and disturbed areas would be stablilised and rehabilitated progressively or prior to demobilisation. Where practicable, site rehabilitation would include re-planting appropriate vegetation types in the disturbed areas. As such, removal of riparian vegetation and mangroves within the construction footprint is expected to be localised and is considered unlikely to result in a long term impact on the associated aquatic habitat.
Interaction with equipment and machinery	In-stream works	There is potential for fish and other aquatic species to be harmed through interaction with equipment and machinery that would be utilised for instream works. For the proposed viaduct (B05), aquatic species could be harmed as a result of direct interaction with equipment in close proximity to piling locations. However, through minimising the impact area and the use of typical exclusion controls as well as by employing standard mitigation measures for underwater piling these potential impacts are considered minor. For other waterways where temporary and permanent crossing structures would be installed, aquatic species may be harmed (where water is present) if they are in proximity of the instream construction areas. However, this would be avoided as fauna salvage would be carried out prior to water being pumped out of the waterway as per pre-clearing survey requirements.

Type of impact	Associated construction activities	Potential impact
Changes to water quality	• Instream works • Construction activities that mobilise sediment-laden or contaminated water into waterways	Mobilisation of sediments and contaminated water have the potential to reduce water quality within waterways and KFH and consequently directly or indirectly harm native species that are unable to tolerate changes to water quality and favour aquatic pest species, such as the Plague Minnow, which predate on native species. Predation by the Plague Minnow is listed as a KTP under the TSC Act. With the implementation of erosion and water quality control measures during construction the risk of changes to water quality would be minimised therefore aquatic flora and fauna, including KFH, are not expected to be significantly impacted. Contaminated material may enter waterways through disturbance of contaminated sites and/or acid sulfate soils (ASS), spills of fuels and oils, discharge of saline water and leaching of tannins. Any contamination of a waterway would impact the overall ecological health and biological functioning of the waterway and result in a decrease in the likelihood of meeting the relevant NSW Water Quality Objectives. The CSWMP prepared for the project would outline procedures for the management of high-risk activities such as stockpiling, excavation and treatment of ASS, disturbance of soft soils and saline soils, dewatering, discharging water from temporary sediment basins, emergency spill response and unexpected contaminated finds, including asbestos. The plan would also further detail water quality monitoring during construction for both surface water and groundwater quality at nominated monitoring sites. Following the implementation of recommended management measures (refer to **Chapter 11** (surface water and groundwater quality) and **Chapter 16** (soils and contamination)), the project is expected to have only minor to negligible impacts on existing water quality during the construction phase.
Changes to water quality	Discharge from temporary sediment basins	Treated construction runoff is proposed to be discharged (controlled discharge) from temporary sediment basins and other minor locations. Waterways, including those which have been deemed KFH, would receive controlled discharges. Adverse impacts to these aquatic ecosystems are not expected from controlled discharges because temporary sediment basins would capture and treat runoff prior to being released downstream, (refer to **Chapter 11** (surface water and groundwater quality)). The treated discharges would have similar water quality to the existing surface water quality of these receiving environments. The existing water quality of non KFH waterways is indicated to be highly variable, generally poor and currently not meeting the relevant NSW Water Quality Objectives (refer to **Chapter 11** (surface water and groundwater quality)), therefore the limited biodiversity present in the waterways are likely to be habituated to poor water quality conditions. As such, the water quality that would be discharged from temporary sediment basins is expected to be similar to or better than existing water quality of the receiving environment and therefore aquatic ecosystems are likely to remain unchanged. In the event of extreme rainfall events (greater than 38.9mm) however, temporary sediment basins are anticipated to overflow and untreated runoff would be discharged to downstream waterways. These overflows are considered to be partially controlled as the temporary sediment basins would still be able to contain and treat the volume of runoff they have been sized for. This risk is considered low (based on historic rainfall data for the region) as the frequency of these events is likely to be minimal (about seven occurrences per year). As such, it is expected that any changes to water quality caused by releases during partially controlled discharges are likely to be temporary and would settle or become diluted within the surrounding environment in a relatively short

Type of impact	Associated construction activities	Potential impact
		timeframe. Aquatic biodiversity within these waterways is therefore expected to be able to tolerate the changes in the short term (further detail is provided in the Surface Water and Groundwater Quality Working Paper (**Appendix K**). As such, it is expected that any changes to water quality caused by releases during partially controlled discharges are likely to be temporary and would settle or become diluted by the surrounding environment within a relatively short timeframe. Aquatic biodiversity within these waterways are therefore expected to be able to tolerate the changes in the short term. Further information on discharge of temporary sediment basins is provided in **Chapter 11** (surface water and groundwater quality).
Removal of habitat	Purgatory creek adjustment	As described in **Section 5.3.10**, Purgatory Creek would need to be permanently realigned over a distance of 320m to accommodate the Tarro interchange. The creek is proposed to be realigned 90m to the south of its current location and would have a similar capacity to the existing creek channel. Potential impacts to aquatic biodiversity in Purgatory Creek as a result of this activity may include removal of instream aquatic macrophytes and other habitat features such as large woody debris (if present) and potential disruption of aquatic species which may utilise these features. These temporary impacts to the localised habitat are not expected to have a significant impact on aquatic biodiversity because the location is a substantial distance from downstream sections of the waterway that have been identified as KFH, and aquatic fauna that may be present would typically be mobile due to the ephemeral character of the waterway therefore would be able to relocate to similar upstream/downstream habitat during the temporary instream works. Further, large woody debris, if present, would be preserved and relocated downstream at an appropriate location. Following the creek adjustment, the project landscaping of the impacted area is anticipated to generally replicate the existing vegetated form.
Removal of habitat	Tributary of Viney Creek adjustment	As described in **Section 5.3.10**, about 150m of an artificial drainage channel that flows to Viney Creek is proposed to be permanently realigned up to 70m to the east. The section of tributary was modified during the construction of the existing motorway and presents as an ephemeral, partially rock armoured drainage line that flows through culverts under the motorway and later under John Renshaw Drive before flowing through an industrial area with a water level that is controlled by several constructed weirs. Temporary damming and bypassing of the existing drainage channel may be required during construction if water is present. The waterway is ephemeral, has minimal channel definition and is likely to be the product of a stormwater drainage path established by the initial construction of the M1 Pacific Motorway rather than a natural creek at this location. Water quality (when water is present) would reflect the modified catchment and aquatic species are highly unlikely to inhabit the waterway. Further, it is largely isolated from downstream environments due to the presence of several culverts and weirs, therefore upstream migration by aquatic fauna to this area is considered unlikely.

Type of impact	Associated construction activities	Potential impact
		As the drainage channel is highly disturbed and isolated from downstream waterways due to instream barriers, the permanent loss of the existing localised ephemeral features is unlikely to have a significant impact on the downstream aquatic environment of Viney Creek. Furthermore, following the installation of the new drainage channel, the project landscaping of the impacted area is anticipated to generally replicate the existing vegetated form. While risk to aquatic ecology in the tributary of Viney Creek and Viney Creek downstream is considered unlikely to be significant, the project has aimed to protect the downstream receiving environment (i.e. Viney Creek) by minimising disturbance to the waterway by implementing appropriate management measures (as outlined in **Section 9.5**).
Unplanned introduction and establishment of marine pest species in Hunter River	Instream works including barge movements	Instream works and discharges to aquatic environments may create the potential for the introduction and/or spread of aquatic biosecurity hazards. Due to the disconnection between the minor local creeks and wetlands and the Hunter River (and therefore likely sources of vectors of aquatic pests) the notable aquatic biosecurity risk is related to the Hunter River itself. The Hunter River is a shallow-water, nutrient rich, estuarine habitat which may be conducive to the establishment of invasive species. Further, the Hunter River estuary has a heightened risk to biosecurity as it hosts an active prawn fishery which extends from the river mouth to about 30km upstream to Raymond Terrace, and an established oyster farm which is located about 13km downstream of the project. Project activities that present the highest risk to aquatic biosecurity within the Hunter River include the movement and use of the instream floating barge platforms and other vessels required for instream works due to the potential for biofouling organisms on the external surfaces of vessels and/or within the vessel's ballast water, to be introduced into the Hunter River by the vessels. Marine pest species include non-native bivalve molluscs, seaweed and sea snails and slugs. Potential marine pests include seaweeds (*Caulerpa taxifolia* and *Undaria pinnatifida*), crustaceans (*Carcinus maenas*), polychaetes (*Sabella spallanzanii*), gastropods (*Maoricolpus roseus*), bivalve molluscs (*Musculista senhousia* and *Perna viridis*) and fish (*Tridentiger trigonocephalus*, *Oreochromis mossambicus* and *Acanthogobius flavimanus*). Other instream activities including piling, installation and use of temporary crossing structures, as well as in situ concrete pouring and installation of precast concrete structures also present a minor risk to aquatic biosecurity should equipment and/or materials be contaminated. Overall, potential direct and indirect impacts to aquatic ecosystems from introduction of pest species are considered minor and manageable with the application of recommended management measures (outlined in **Section 9.5**).

Changes to hydrology

As described in **Chapter 10** (hydrology and flooding), construction of the project has the potential to change surface water hydrology as it would involve creek adjustments at Purgatory Creek and a tributary of Viney Creek, bridge/viaduct construction over waterways and a wetland and the upgrade of existing and new highway cross drainage. Potential changes during construction include moderate increases to the rate, volume and velocity of stormwater discharged, changes to the existing flow regime at or immediately downstream of stormwater discharge locations, as well as changes to drainage. These changes may result in indirect impacts to aquatic biodiversity and aquatic ecosystems due to:

- Increased streamflow discharge and velocities may lead to reduced bank stability (e.g. scouring, undercutting, slumping), which could cause riverbank and streambed erosion and downstream sedimentation that may lead to infilling aquatic habitat features or smothering of aquatic vegetation
- Increased water turbidity due to suspended material may lead to clogging fish gills or smothering aquatic vegetation. Increased turbidity could also reduce light penetration through the water column which may impact growth of sensitive aquatic vegetation
- Increased flow velocities, reduced water levels or physical obstructions may result in obstruction to fish passage.

Minor changes to the hydrological regime of ephemeral waterways that are not KFH during construction of the project are unlikely to result in long term impacts to aquatic biodiversity and impacts to aquatic habitat within waterways would be highly localised and temporary. Importantly, construction activities are not expected to significantly alter flow in the Hunter River therefore long term impacts to aquatic species and aquatic habitat within the waterway are not anticipated. Despite the low likelihood of impacts, the project proposes to employ environmental management measures that aim to protect the existing aquatic values of all waterways within the construction footprint by minimising or avoiding hydrological changes. This would be achieved by implementing appropriate erosion and sediment controls, site-specific drainage design for the construction footprint, as well as temporary erosion and scour protection and flow dissipation where required.

With respect to the creek adjustments of Purgatory Creek and the tributary of Viney Creek, temporary damming and bypassing of the existing drainage channels may be required during construction if water is present, however temporary erosion and scour protection, as well as flow dissipation will be implemented where required.

In addition, temporary waterway crossings have been designed to be in accordance with the NSW Fisheries guidelines ‘Why do fish need to cross the road? Fish passage requirements for waterway crossings’ (Fairfull & Witheridge 2003) in order to ensure conditions for fish passage are maintained where required (described in **Table 9-16**).

Regular monitoring of key waterways for evidence of initiation of erosion and scour would be conducted for the duration of construction and, if required, appropriate remediation measures would be carried out.

With the implementation of measures, it is expected that impacts to aquatic ecosystems from hydrological changes during construction would be minimal and temporary, and long-term impacts are not anticipated. The potential changes to hydrology during construction of the project are discussed further in **Chapter 10** (hydrology and flooding).

Impacts to groundwater dependent ecosystems

Potential impacts to GDEs would be predominately associated with the following activities:

- Direct clearing of GDE vegetation (refer to **Table 9-7**)
- Localised ground-water drawdown during construction.

It should be noted that potential contamination of groundwater during construction and operation of the project would be minimised and managed via the environmental management measures outlined in the **Chapter 11** (surface water and groundwater quality) and **Chapter 16** (soils and contamination).

GDE vegetation clearing

As described in **Section 9.3.4**, based on the PCTs identified in the construction footprint during field surveys and a review of Bell and Driscoll (2006), Kuginis et al. (2012) and the GDE Atlas, it is likely that some of the PCTs present in the construction footprint would have a degree of groundwater dependence (refer to **Table 9-7**). Impacts associated with vegetation clearance is described in above.

Impacts to GDEs associated with temporary groundwater drawdown are discussed in the sections below.

Localised groundwater drawdown during construction

Chapter 11 (surface water and groundwater quality) identifies that the drawdown effect on groundwater would be short-term and localised. For example, temporary construction dewatering of excavations may be required where excavations are required below the water table. These would typically be of short duration, however, may still result in localised, short term, changes to the water table during some construction activities.

One Coastal Management SEPP coastal wetland located south of the Tarro interchange on the New England Highway has a predicted decrease in water level between 0.75 and 2.0 metres during some construction activities. However, this level of impact is a conservative modelled maximum predicted drawdown and the actual drawdown would likely be less and occur over a short duration (less than 10 days). These short term construction impacts are consistent with fluctuating groundwater levels typically experienced by these floodplain wetlands. As such, these short term changes are not expected to significantly impact on the extent or condition of any of the potential GDEs in or adjacent to the construction footprint, particularly as the GDEs identified are not obligate GDEs, and therefore predominantly rely on surface water.

Fragmentation of identified biodiversity links and habitat corridors

The project would not result in excessive landscape scale habitat fragmentation, due to its location, as there is already a high degree of fragmentation in the landscape associated with a long history of clearing floodplain forests and extensive road, rail and power networks in the area. The project has also been designed to minimise fragmentation by aligning closely to existing infrastructure and land uses.

In general, the project corridor has been well positioned to minimise further fragmentation of habitat and disruption of connectivity for fauna however, construction of the project would result in small-scale localised fragmentation of small patches of habitat (five to 20 hectares) including habitat used by threatened flora and fauna. Although the project has minimal impact on habitat connectivity at a landscape scale, it would result in minor small-scale localised fragmentation of habitat and barriers to fauna movement as described in **Table 9-17**.

These small-scale fragmentation impacts would be addressed by habitat connectivity measures as described in **Section 9.5.1**.

Table 9-17 Habitat fragmentation impacts

Fragmentation	Location
Black Hill About 26 hectares of dry sclerophyll forest with a grassy / shrubby understorey would be fragmented at Black Hill with the habitat surrounded by roads (shown in red hatching). This habitat is part of a larger area of vegetation about 130 hectares that would be divided in two. A small patch (four hectares) would also be temporarily isolated by construction access and an ancillary facility (AS2), however this patch is already somewhat disconnected by the clearing due to the Hunter Water Corporation Trunk Main and overhead electrical corridors to the south. Glider crossing structures, bridge underpass and fencing have been added to the design at this location to reconnect this area for arboreal fauna during operation.	
Tomago Habitat in the area of the Old Punt Road at Tomago is already fragmented by exiting roads and cleared power easements. Further development of the road network in this location would contribute to the cumulative fragmentation of smaller patches of isolated vegetation (around 9.5 hectares) due to widening of the existing Old Punt Road corridor. Sugar Gliders were confirmed in this location from the trapping surveys and the Squirrel Glider has been recorded one kilometre east of this patch (Kleinfelder 2019). Glider crossing structures have been added to the design at this location to reconnect this area for arboreal fauna during operation This fragmented vegetation would remain in the context of development of the approved AGL Newcastle Power Station in this location.	
Heatherbrae The project would result in the fragmentation of blackbutt open forest (around 5.3 hectares) providing potential habitat for the Squirrel Glider, New Holland Mouse and koala near Heatherbrae. This small area of habitat is already bound by industrial land to the north and west and therefore movements for fauna to the north are already limited. Given the small size of the area, and surrounding development, a crossing at this location may draw fauna into a sub-optimal patch and is not warranted, particularly given the extent of habitat to the south. Fauna fencing would be used at this location.	

Edge effects on adjacent native vegetation and habitat

Edge effects may be difficult to identify in the expansive areas of floodplain freshwater wetlands which have been extensively cleared, drained and grazed. Similarly, some forested areas next to the M1 Pacific Motorway and at the far northern end of the construction footprint are already edge affected.

The project has the potential to create edge effects within the newly created edges traversing the dry sclerophyll forests and forested wetland habitats, in particular at Black Hill and Heatherbrae as follows:

- **Black Hill:** where the project deviates from the M1 Pacific Motorway across to the bridge crossing of the Glenrowan Creek. All habitat in this location has already been degraded over time by track development, extensive rubbish dumping, selective clearing, grazing and construction of water pipeline infrastructure. Edge effects from the new road would contribute to this general degradation and could include up to 140 hectares of PCT1593 and PCT1588. This area is calculated based on a 50-metre edge effect from the construction footprint and has been calculated for the southern edge only as the northern edge would largely adjoin the existing cleared Hunter Water Corporation easement
- **Heatherbrae:** from the entrance to the Hunter Region Botanic Gardens north to Masonite Road a potential edge effect of up to 180 hectares of PCT1646 has been calculated. This is based on a 50 metre buffer on the construction footprint mostly on the southern and eastern boundary which would be a newly-created edge.

Degradation of the forest edges would be long-term but impacts would be localised and would not constitute or exacerbate any KTP as defined by the TSC Act or EPBC Act. The potential indirect impacts from edge effects were included in the overall calculation of impacts and offsets for this project, as the broader construction footprint includes a buffer around the design to allow for all potential construction activity.

Fauna injury and mortality

The construction of the project has the potential to result in injury and mortality of fauna. This has the greatest potential to occur from vegetation clearing and the extent of this impact would be proportionate to the extent of vegetation that is cleared. Some mobile species, such as birds, may be able to move away from the path of vegetation clearing and may not be greatly affected unless they are nesting. However, other species that are less mobile (for example, ground dwelling reptiles), or those that are nocturnal and nest or roost in trees during the day (for example arboreal mammals and microchiropteran bat species), may find it difficult to move rapidly when disturbed.

During construction, entrapment of wildlife in any trenches that are dug is a possibility if the trenches are deep and steep sided. Wildlife may also become trapped in machinery that is stored in the construction footprint overnight that may result in injury or death.

Injury and mortality of fauna would be minimised through the implementation of management and mitigation measures, such as pre-clearing surveys and fauna handling procedures, as outlined in **Section 9.5**.

Invasion and spread of weeds, pests, pathogens and disease

Project activities have the potential to disperse and import new weed species into the construction footprint, particularly through earthwork, movement of soil, and attachment of seed (and other propagules) to vehicles and machinery. Without appropriate management strategies, this has potential to compromise the quality and integrity of receptors in areas adjacent to those being cleared, including TECs, remnant vegetation, habitat for threatened species, wetlands and waterways.

The legal requirements associated with weed species identified in the construction footprint is provided in **Table 9-18**.

Table 9-18 Biosecurity duty associated with weeds in the construction footprint

High threat exotic species (BAM)	Priority weed duties (Hunter region)	Weed of National Significance?
Ageratina adenophora	Not a priority weed	No
Alternanthera philoxeroides	Prohibition on dealings Must not be imported into the State or sold Biosecurity Zone The Alligator Weed Biosecurity Zone is established for all land within the state except land in the following regions: Greater Sydney; Hunter (but only in the local government areas of City of Lake Macquarie, City of Maitland, City of Newcastle or Port Stephens). This project is not in the Alligator weed biosecurity zone.	Yes
Andropogon virginicus	Not a priority weed	No
Araujia sericifera	Not a priority weed	No
Asparagus aethiopicus	Must not be imported into the State or sold	Yes
Axonopus fissifolius	Not a priority weed	No
Baccharis halimifolia	Regional Recommended Measure Land Area 1: core infestation within Newcastle, Greater Taree and Lake Macquarie. Land Area 2: rest of region Land Area 1: Land managers should mitigate the risk of new weeds being introduced to their land. Land Area 2: The plant should be eradicated from the land and the land kept free of the plant. Notify the Local Control Authority if found. The plant should not be bought, sold, grown, carried or released into the environment.	No
Chloris gayana	Not a priority weed	No
Cinnamomum camphora	Not a priority weed	No
Cortaderia selloana	Not a priority weed	No
Ehrharta erecta	Not a priority weed	No
Eragrostis curvula	Not a priority weed	No
Hyparrhenia hirta	Regional Recommended Measure The plant should not be bought, sold, grown, carried or released into the environment. Land managers should mitigate the risk of the plant being introduced to their land. Land managers should mitigate spread from their land. Land managers to reduce impacts from the plant on priority assets.	No
Ipomoea cairica	Not a priority weed	No
Juncus acutus	Not a priority weed	No
Lantana camara	Prohibition on dealings Must not be imported into the State or sold	Yes
Ligustrum sinense	Not a priority weed	No

High threat exotic species (BAM)	Priority weed duties (Hunter region)	Weed of National Significance?
Megathyrus maximus	Not a priority weed	No
Ochna serrulata	Not a priority weed	No
Olea europaea subsp. *cuspidata*	Regional Recommended Measure Land managers mitigate the risk of the plant being introduced to their land. Land managers reduce impacts from the plant on priority assets. Land managers prevent spread from their land where feasible. The plant or parts of the plant are not traded, carried, grown or released into the environment	No
Paspalum dilatatum	Not a priority weed	No
Paspalum quadrifarium	Not a priority weed	No
Pennisetum clandestinum	Not a priority weed	No
Phyla nodiflora	Not a priority weed	No
Pinus radiata	Not a priority weed	No
Ricinus communis	Not a priority weed	No
Rosa rubiginosa	Not a priority weed	No
Rubus fruticosus agg.	Prohibition on dealings Must not be imported into the State or sold All species in the *Rubus fruiticosus* species aggregate have this requirement, except for the varietals Black Satin, Chehalem, Chester Thornless, Dirksen Thornless, Loch Ness, Murrindindi, Silvan, Smooth Stem, and Thornfree Regional Recommended Measure The plant should not be bought, sold, grown, carried or released into the environment. Land managers should mitigate the risk of the plant being introduced to their land. Land managers should mitigate spread from their land. Land managers to reduce impacts from the plant on priority assets.	Yes
Senecio madagascariensis	Prohibition on dealings Must not be imported into the State or sold	Yes
Senna pendula	Not a priority weed	No
Stenotaphrum secundatum	Not a priority weed	No
Tradescantia fluminensis	Not a priority weed	No

Construction of linear infrastructure, such as the project, through large patches of intact vegetation can result in the establishment of pest species (particularly predators such as foxes and cats) into areas where they are currently absent or in low numbers due to habitat removal, noise and human presence. However, in the context of the project this impact is predicted to be minimal as all vegetation in the construction footprint is likely to already be impacted by foxes and cats. The magnitude of this impact would be low.

Construction of the project has the potential to introduce pathogens and disease, such as Phytophthora, amphibian chytrid fungus and exotic Rust Fungi, into the construction footprint and adjacent areas. Pathogens were not observed in the construction footprint, however, the potential for pathogens to occur should be treated as a risk during construction as pathogens can be transported by machinery or vehicles. While forested areas are likely at greater risk from plant disease than the freshwater wetland areas of the construction footprint, all areas should be treated equally in terms of the potential risk and managing the spread of pathogens and disease.

Strict hygiene measures will be implemented during construction that would assist in preventing the spread of weeds, pests, pathogens and disease and any potential impacts on native vegetation, threatened species habitat and threatened fauna. These measures are detailed in **Section 9.5** and address the general biosecurity duty, as defined by Part 3 of the *Biosecurity Act 2015*.

Noise, dust, light and contaminants

Construction of the project has the potential to disturb habitats as a result of increased noise and vibration, dust, light and accidental release of contaminants. These impacts are likely to have cumulative effects particularly during a lengthy construction period and in areas where construction activities are adjacent to vegetated areas. These impacts are discussed further in **Table 9-19**.

Table 9-19 Impacts from construction noise, dust, light and contaminants on biodiversity

Potential impact	Description
Noise and vibration	There would be increased noise and vibration levels in the construction footprint and immediate surrounds due to vegetation clearing, ground disturbance, machinery and vehicle movements, and general human presence. The noise and vibration from activities associated with the project would potentially disturb fauna and may disrupt foraging, reproductive (calling behaviour), or movement behaviours. The impacts from noise and vibration emissions on resident fauna would likely be localised to the construction footprint and adjacent areas. However, considering most of the construction would be located along existing road infrastructure, the impacts of noise pollution on wildlife populations would likely be low.
Dust	Dust pollution would be greatest during construction due to earthwork, vegetation clearing, vehicle movements for construction and decommissioning activities and during adverse weather conditions. Areas at greatest risk would be Black Hill and Heatherbrae, where remnant vegetation is to be retained next to the construction footprint. Dust impacts may also occur at the bridge crossing of Hunter River, where adjacent saltmarsh and mangrove forest would remain. The deposition of dust on foliage would likely be highly localised, intermittent, and temporary (can be removed by rain) and is therefore not considered likely to be a major impact of the project. Most of the construction would be carried out along existing road infrastructure so the impact of dust pollution in these areas would likely be low. Further information on air quality impacts on ecological receivers are provided in **Chapter 18** (air quality).
Temporary lighting	The construction footprint would be subject to artificial lighting, essentially creating ‘daylight’ conditions during the night construction works. Ecological light pollution may potentially affect nocturnal fauna by interrupting their life cycle. Some species (i.e. light tolerant microchiropteran bats) may benefit from the lighting due to increased food availability (insects attracted to lights) around these areas. Most construction activities would take place over a relatively short period of time. The need for artificial lighting during construction will be minimised where feasible, including directing lighting away from vegetated areas where practicable (refer to **Section 9.5**). As a result, the impacts of light pollution on fauna activity and movements would likely be low and short-term in nature.

Potential impact	Description
Contaminants (i.e. hydraulic fluids, oils, drilling fluids, etc.)	Localised release of contaminants into the surrounding environment (including drainage lines and freshwater wetlands) may accidentally occur. The most likely result of contaminant discharge would be the localised contamination of soil and potential direct physical trauma and or death to flora and fauna that come into contact with contaminants. Accidental spills would be managed during construction in accordance with the CSWMP prepared for the project (refer to **Chapter 11** (surface water and groundwater quality)).

9.4.3 Assessment of potential operational impacts

Removal of native vegetation, flora and fauna habitat

Removal of native vegetation, threatened flora and fauna habitat (including habitat for migratory species) would occur during construction of the project. Operation of the project would not require additional clearing.

Landscape features and values

Impacts on riparian buffer of important rivers, streams and estuaries

All impacts on riparian buffers are discussed in **Section 9.4.2** and would occur during construction of the project. Operation of the project would not impact further on riparian buffers.

Impacts on important wetlands

All impacts on important wetlands would occur during construction of the project, as discussed in **Section 9.4.2**. As described previously, mapped important wetlands associated with the Hunter River floodplain in this location have a long history of impacts. These impacts are associated with clearing and modification for past agricultural land use.

Long-term downstream impacts are expected to be minor as the viaduct (B05) completely spans the Hunter River and existing bridge structures already occur downstream of the construction footprint. Impacts to aquatic habitats during operation of the project are discussed below.

Impacts on Matters of National Environmental Significance

All impacts on MNES would occur during construction of the project, as discussed in **Section 9.4.2**.

As described in **Chapter 11** (surface water and groundwater quality), operation of the project is not expected to result in any significant impacts to water quality at the Hunter Estuary Wetland Ramsar site at Kooragang Nature Reserve. A dilution assessment demonstrated that the minor contribution of basin discharge to the Hunter River would be adequately diluted such that the basin discharges would not contribute to higher turbidity, total nitrogen or total phosphorus at the Hunter Estuary Wetland Ramsar site at Kooragang Nature Reserve.

Operation of the project would not impact further on MNES.

Aquatic impacts and changes to hydrology

Operation of the project has the potential to impact aquatic ecosystems and result in changes to existing hydrology. Aquatic impacts could occur due to changes in water quality, habitat loss, permanent instream barriers and potential impacts to KFH.

The operation of the project would not have significant direct impact on aquatic biodiversity. Following the completion of construction, all temporary instream structures would be removed, riparian and aquatic habitat within disturbed waterways (i.e. in Glenrowan Creek, Coastal wetland (east of the Hunter River) and Windeyers Creek) would be rehabilitated where possible, and disturbed soils in construction areas would be stabilised. Potential impacts as a result of operation of the project are discussed in the sections that follow.

Bridge crossings over waterways and wetlands

As described in **Section 9.4.2**, the project includes three bridge crossings (B05, B11 and B02) over waterways or wetlands.

Shading from bridge or viaduct structures over waterways or wetlands can impact on water quality by influencing temperature and biomass growth. This impact would be unlikely to occur in the Hunter River due to the height of the viaduct and the large and dynamic nature of the waterway. These impacts would be more likely to occur in slow moving aquatic environments, such as Windeyers Creek. However, the area of shading is only a small proportion of the relatively large wetland system, which is already subject to shading from surrounding woodland and pine vegetation. The impacts associated with shading on aquatic environments would be likely to be minor.

Based on the bridge design, scour protection and drainage infrastructure of the viaduct and bridge crossings as well as the implementation of management measures outlined in **Section 9.5**, downstream water quality impacts are considered to be low and any residual impacts (such as minor increases in turbidity and sediment deposition) that are expected would be localised and minor. In addition, the project would implement management measures to mitigate impacts to water quality as described in **Chapter 11** (surface water and groundwater quality).

Potential impacts to aquatic ecosystems

Operation of the project generally has limited potential to impact aquatic ecosystems. The potential impacts to waterways during operation of the project are described in **Table 9-20**.

Potential impacts to fish habitat

As described in **Section 9.3.6**, the project crosses mapped KFH (as identified by DPI and based on field observations) (refer to **Figure 9-8**). The potential impacts to KFH during operation of the project are generally the same as those identified for aquatic ecosystems and are described in **Table 9-20**.

Table 9-20 Potential impacts to aquatic ecosystems during operation of the project

Type of impact	Associated operational activity	Potential impact
Impacts to fish passage	Bridge/culvert design	The design of the bridges and culverts over waterways has complied with DPI Fisheries design guidelines reported in Fairfull & Witheridge (2003) to ensure that barriers to fish passage are not created in the long-term. Based on the assessment of waterway 'class' (Fairfull & Witheridge 2003), fish-friendly bridge crossings are only required over the Hunter River. This waterway was classified as Class 1 – Major fish habitat and therefore require a minimum crossing type of a bridge, arch structure or tunnel (Fairfull & Witheridge 2003). All other waterways where there would be permanent crossings were classified as either 'Class 4 – Unlikely fish habitat' or 'Class 3 – Minimal fish habitat' which only require a minimum crossing type of a culvert or ford (Fairfull & Witheridge 2003). Despite this, bridge structures have been designed at all of these waterway crossing locations, with the exception of Purgatory Creek and a tributary of Viney Creek where culverts have been proposed (discussed below).

Type of impact	Associated operational activity	Potential impact
Changes to water quality	Discharge from permanent water quality basins	While permanent water quality basins are not subject to a dewatering regime during operation, surface water runoff during and following rainfall may result in permanent water quality basins occasionally discharging to downstream receiving environments during large rainfall events that exceed the detention capacity of the basin. Operational discharges may potentially contain contaminants associated with surface water from new impervious surfaces and the operation of a new motorway including sediment and other contaminants (hydrocarbons etc). Operational discharges would be limited to periods of higher rainfall (a rainfall event of 38.9mm or greater), when the wider catchment is also at peak surface water flows (which is when water typically has higher volumes of contaminants). As per the project design, the operational surface water capture and treatment system shall predominately direct basin discharge into the local minor waterways which are not KFH. Ten of the permanent water quality basins that have been proposed would interact with the groundwater table where groundwater quality is saline. For these basins with saline groundwater inflows, the discharge may be more saline than the receiving environment. This risk is most likely at the three basins (PB05, PB06 and PB07) which would discharge into Glenrowan Creek and the tributary of Viney Creek as these waterways are freshwater and typically have lower salinity levels than groundwater. Since both of the waterways are not KFH and do not present significant aquatic habitat features, risks to aquatic biodiversity from saline discharge is considered low. Further, any overflow of the structures would occur during a period of peak charge (during a rainfall event of 38.9mm or greater) in the system, suggesting that the influence of saline water would be minimal. As discussed in **Chapter 11** (surface water and groundwater quality), the quality of the operational discharges would be generally consistent with the range of existing surface water quality and hence is unlikely to have a significant impact of aquatic biodiversity within the waterway.
Changes to water quality	Project operation	The project has been designed to include permanent water quality controls in order to mitigate long-term water quality impacts to downstream waterways including KFH. These controls include permanent water quality basins and vegetated swales. Water quality basins have been designed to contain a 20,000L spill (with the exception of the Tomago Sandbeds Catchment Area where the minimum containment volume is 30,000L) and would promote settlement of sediments by slowing down and temporarily detaining flows. Due to the implementation of these controls during operation, risk of potential changes to water quality within waterways and KFH would be minimised therefore aquatic flora and fauna are is also not expected to be significantly impacted. This is discussed further in the **Chapter 11** (surface water and groundwater quality).

Changes to hydrology

As described in **Chapter 10** (hydrology and flooding), operation of the project has the potential to change surface water hydrology as a result of road paving and soil compaction, changes to drainage paths and catchments, additional stormwater runoff and stormwater discharge from permanent water quality basins.

Similar to the construction phase, potential changes to hydrology include moderate increases to the rate, volume and velocity of stormwater discharged, changes to the existing flow regime at or immediately downstream of stormwater discharge locations during operation, as well as changes on existing drainage. These changes have potential to impact on the aquatic ecosystems of the downstream receiving environment from potential increased erosion and sedimentation, impacts on aquatic organisms such as clogging fish gills or smothering aquatic vegetation, or may result in physical or behavioural barriers to fish passage due to increased velocities, reduced water levels or physical obstructions.

During operation, environmental management measures have been proposed which aim to minimise or avoid hydrology impacts to downstream waterways, including appropriate erosion and sediment controls, site-specific drainage design, scour protection and flow dissipation where required. Further, the adjusted Purgatory Creek and tributary of Viney Creek have been designed with controls to minimise potential areas of erosion and scour and any subsequent downstream impacts.

Permanent waterway crossings have been designed in accordance with NSW Fisheries guidelines 'Why do fish need to cross the road? Fish passage requirements for waterway crossings' (Fairfull & Witheridge 2003) in order to ensure conditions for fish passage are maintained where required.

Regular monitoring of key waterways downstream of the project discharge locations for evidence of initiation of erosion and scour would be conducted for a minimum of twelve months after construction and, if required, appropriate remediation measures would be carried out.

With the implementation of these measures, changes to hydrology within downstream waterways is anticipated to be minor and would not result in a long-term impact to downstream aquatic ecosystems. The potential changes to hydrology during construction of the project are discussed further in **Chapter 10** (hydrology and flooding).

Impacts on groundwater dependent ecosystems

As described in **Chapter 10** (hydrology and flooding) and **Chapter 11** (surface water and groundwater quality), the project would not result in ongoing lowering of the water table during operation of the project suggesting no long-term, permanent impacts on GDEs.

Chapter 10 (hydrology and flooding) provides an assessment of the potential short term increases in flooding heights on the floodplain where PCT1736 (Water Couch – Tall Spike Rush freshwater wetland of the Central Coast and lower Hunter) has been mapped. The assessment discusses minor increases to the duration and depth of inundation for overbank events adjacent to the Hunter River as a result of finished road levels (i.e. the embankment/fill). These localised changes would likely have a negligible impact to the wetland vegetation which is already subject to periodic inundation of different levels and duration. This is further supported by the high groundwater levels in the floodplain surrounding the Hunter River, and the fact that there is no anticipated drawdown

Minor changes to operational drainage structures that service the wetland south of the Hunter Region Botanic Gardens may result in changes of water levels upstream of the existing Pacific Highway of up to 0.2 metres. The area potentially impacted by this change in design is currently a wetland community (sedge spp, typha spp, paperbark spp) that is subject to rainfall dependent changes in surface water levels, and possibly changes in groundwater levels (although not an obligate GDE). The potential changes to water levels due to operational drainage upgrades would generally reflect the existing variations in the hydrological regime and is unlikely to significantly impact on this aquatic environment.

Fauna injury and mortality

It is anticipated that the primary cause of fauna injury and mortality during the operation of the project would be vehicle collisions. This direct impact could reduce local population numbers and is a common occurrence in Australia (Coffin 2007; Rowden et al. 2008). Mammals, reptiles, amphibians and birds are all at risk of vehicle strike, particularly those common species (such as Kangaroos) that are tolerant of disturbance and/or those species that can use roadways for movement pathways or roadside vegetation as foraging habitat.

A population of Eastern Grey Kangaroo (*Macropus giganteus*) was noted in the Black Hill area during the survey which may be at an increased risk over the medium to long term of vehicle strike during the operation of the new motorway at the Black Hill and Beresfield area.

Opportunities to provide crossings for fauna have been considered as part of the habitat connectivity for the project, as described in **Section 9.5.1**.

Koala

The potential for the project to impact koala during operation is generally restricted to injury or mortality from vehicle strike. As the project is located adjacent to existing roads and industrial areas impacts on the movements of koalas, notably the known Port Stephens koala population, would be minimal. With the exception of a small area of potential habitat just south of Heatherbrae (noted in **Table 9-17** above) there are no known areas of koala habitat to the west of the project. As such, it is considered unlikely that koalas would cross from the large extent of habitat east of the project to the highly developed land located to the west of the project. Furthermore, the project includes fauna exclusion fencing at strategic locations to prevent fauna, such as koalas, from entering the road corridor. Operational impacts on the koala are therefore considered to be minimal.

Invasion and spread of weeds, pests, pathogen and disease

Minimal native vegetation, threatened species and agricultural land would be disturbed during operation of the project as described in **Chapter 14** (land use and property) and **Chapter 22** (safety and risk). During operation, the risk of weed dispersal into adjoining bushland is low due to landscaping of bare ground adjacent to the road. However, the road verge environment may create a modified landscape where weeds become established.

The operation of the project has the potential to disperse pest species (such as foxes and cats) across the surrounding landscape due to noise and human presence. However, in the context of the project, this impact is predicted to be minimal as areas within the operational footprint are likely to already be impacted by foxes and cats.

Operation of the project has the potential to introduce pathogens and disease, such as *Phytophthora cinnamomi* (Root Rot Fungus), amphibian chytrid fungus and exotic Rust Fungi, into the construction footprint and adjacent areas by machinery or vehicles. While forested areas are likely at greater risk from plant disease than the freshwater wetland areas of the construction footprint, all areas should be treated equally in terms of the potential risk and managing the spread of pathogens and disease.

Strict hygiene measures will be implemented during operation that would assist in preventing the spread of weeds, pests, pathogens and disease and any potential impacts on native vegetation, threatened species habitat and threatened fauna. These measures are detailed in **Section 9.5** and address the general biosecurity duty, as defined by Part 3 of the *Biosecurity Act 2015*.

Noise, dust, light and contaminants

Operation of the project has the potential to impact fauna and habitats as a result of increased noise, dust and light. These impacts are not considered to be significant.

Table 9-21 Impacts from noise, dust, light and contaminants on biodiversity during operation of the project

Potential impact	Description
Noise and vibration	Potential impacts from noise emissions would be localised to the areas immediately adjacent to the project. Some sensitive species (e.g. woodland birds) may avoid the noise, while some more tolerant species (e.g. small mammals) would habituate over the longer term. All areas of the project are subject to noise impacts on resident fauna, including common and threatened species. Considering most of the construction would be located along existing road infrastructure, the impacts of noise pollution on wildlife populations would likely be low.
Dust	As described in **Chapter 11** (surface water and groundwater quality), project operation would generate litter and transport dust as part of road use by vehicles. Gross pollutants may result in increased levels of nutrients and toxicants which may be harmful to aquatic life and reduce visual amenity in receiving waterways and wetlands. With the implementation of the environmental management measures described in **Section 11.5**, dust and litter, if managed correctly, are not likely to result in a significant impact to water quality.
Lighting	The project would include artificial lighting at interchanges, associated ramps, and roads in the vicinity of interchanges, essentially creating permanent 'daylight' conditions. Ecological light pollution may potentially affect nocturnal fauna by interrupting their life cycle. Some species (i.e. light tolerant microchiropteran bats) may benefit from the lighting due to increased food availability (insects attracted to lights) around these areas. Due to the frequency and sustained nature of the lighting, it is unlikely that animals would habituate to the light disturbance and a long-term impact in the area of lighting is likely.
Contaminants (i.e. hydraulic fluids, oils, drilling fluids, etc.)	Stormwater quality management for road runoff includes managing the export of suspended solids and associated contaminants, namely heavy metals, nutrients, and organic compounds (refer to **Chapter 11** (surface water and groundwater quality)). Pollutants such as nutrients, heavy metals and hydrocarbons are usually attached to fine sediments. To minimise water quality impacts from additional stormwater runoff and spills, the project has been designed to include permanent water quality controls, including permanent water quality basins and vegetated swales as detailed in **Section 11.4.3**. Due to these controls, risk of potential changes to water quality within downstream waterways and wetlands would be minimised. Stormwater runoff from the project would not be expected to have a significant impact on water quality during operation. There would be sufficient opportunity for any spill event to be contained near the project within the permanent water quality basins which include spill containment across the project. The risk associated with accidental spills within the project are considered comparable to those of similar roads. As such, potential risk of poor water quality mobilising to downstream waterways from spills would be negligible and would be sufficiently managed through proposed design and management measures (refer to **Chapter 11** (surface water and groundwater quality).

9.5 Environmental management measures

The management measures that will be implemented to minimise the biodiversity impacts of the project, along with the responsibility and timing for those measures, are presented in **Table 9-22**.

Table 9-22 Environmental management measures (biodiversity)

Impacts	Reference	Management measures	Responsibility	Timing
Loss of vegetation and habitat for flora and fauna including threatened species	B01	A Flora and Fauna Management Plan (FFMP) will be prepared in accordance with the 'Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects' (RTA 2011). It will address terrestrial and aquatic matters and include, but not necessarily be limited to: • Plans for the construction footprint and adjoining areas showing native vegetation, flora and fauna habitat, threatened species and endangered ecological communities • Procedures addressing relevant matters specified in the 'Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects' (RTA 2011) • Procedures for the protection of aquatic fauna associated with instream works. All personnel working on site will receive training to ensure awareness of requirements of the FFMP and relevant statutory responsibilities.	Contractor	Detailed design/ prior to construction
	B02	Pre-clearing surveys will be carried out in accordance with 'Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects' (Guide 1: Pre-clearing process) (RTA 2011).	Contractor	Prior to construction
	B03	If any threatened species, not assessed in the biodiversity assessment, are identified in the construction footprint, the unexpected species find procedure is to be followed under 'Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects' (RTA 2011).	Contractor	Construction
	B04	Vegetation and habitat removal will be carried out in accordance with 'Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects' (Guide 4: Clearing of vegetation and removal of bushrock) (RTA 2011).	Contractor	Construction
	B05	Revegetation will be carried out in accordance with 'Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects' (RTA 2011) (Guide 3: Re-establishment of native vegetation) and the Landscape Plan prepared for the project.	Contractor	Construction
	B06	Re-use of woody debris and bushrock and installation of nest boxes would be carried out in accordance with the 'Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects' (RTA 2011), Guide 5 & Guide 8.	Contractor	Construction

Impacts	Reference	Management measures	Responsibility	Timing
Potential impacts to aquatic habitat	B07	Aquatic habitat will be protected in accordance with Guide 10: Aquatic habitats and riparian zones of the 'Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects' (RTA 2011) and where practicable, Section 3.3.2 Standard precautions and mitigation measures of the 'Policy and guidelines for fish habitat conservation and management Update 2013' (DPI 2013a)	Contractor	Construction
Fragmentation of habitat and barrier effects and fauna mortality during operation	B08	Fauna crossing and exclusion fencing structures would be designed and constructed to facilitate fauna connectivity and exclusion across the project in accordance with the Biodiversity Assessment Report.	Transport/Contractor	Detailed design/ construction
Edge effects on adjacent native vegetation and habitat	B09	Exclusion zones will be set up at the limit of clearing in accordance with 'Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects' (RTA 2011) (Guide 2: Exclusion zones).	Contractor	Construction
Injury and mortality of fauna during clearing and construction	B10	Fauna will be managed in accordance with 'Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects' (RTA 2011) (Guide 9: Fauna handling).	Contractor	Construction
Invasion and spread of weeds	B11	Weed species will be managed in accordance with 'Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects' (RTA 2011) (Guide 6: Weed management).	Contractor	Construction
Invasion and spread of pest animal, pathogens and disease	B12	Pest species and pathogens will be managed in accordance Guide 2: Exclusion zones of the 'Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects' (RTA 2011), the Commonwealth *Biosecurity Act 2015,* NSW *Biosecurity Act 2015* and where relevant, the Australian Ballast Water Management Requirements.	Contractor	Construction
Noise, light and vibration	B13	The need for artificial lighting during construction and operation will be minimised where feasible, including directing lighting away from vegetated areas where practicable.	Contractor	Detailed design/ construction

Impacts	Reference	Management measures	Responsibility	Timing
Other relevant management measures				
Landscape character and visual impacts including during construction	UD02	Disturbed areas outside the operational footprint and within the construction footprint will be revegetated following completion of construction activities.	Contractor	Construction
	UD03	Cut batters and fill embankments for the project will be designed to allow revegetation to assist with the integration of the project into the surrounding landscape where possible depending on site conditions.	Contractor	Construction

9.5.1 Habitat connectivity measures

Fauna connectivity structures proposed for the project include glider poles and rope crossings to link areas of vegetation and provide connections for tree-dwelling mammals. As the project has been identified as having minimal impact on landscape connectivity for ground-dwelling fauna, dedicated underpass crossing structures are not proposed. The viaduct across the Hunter River and adjacent floodplain will allow the movement of fauna either side of the corridor and retains habitat connectivity of a large scale. Bridges at Black Hill and Windeyers Creek will also provide for incidental movements by fauna across the construction footprint and will be combined with fauna exclusion fencing to aid fauna movements and minimise vehicle strike.

Proposed crossing structures and associated fencing for the project is detailed in **Table 5-8** and shown in **Figure 5-1**.

9.6 Offsetting requirements

9.6.1 Biodiversity offsets

Under the FBA, any residual impacts that cannot be avoided, minimised or mitigated, must be offset, with the offset requirements quantified as biodiversity credits. The BOS provides greater detail regarding the potential mechanisms for meeting this offset obligation, including an assessment of Transport properties adjacent to the construction footprint. The BOS is provided as Appendix I of the BAR (**Appendix I**).

A total of 8,076 ecosystem credits were identified as being required, as summarised in **Table 9-23**.

Table 9-23 Ecosystem credit requirements

Vegetation zone	Plant community type (BVT)	Threatened species with highest credit requirement	Loss in site value score	Project impact within construction footprint (ha)	Ecosystem credits required
1. 1590 – Good	Spotted Gum – Broad-leaved Mahogany – Red Ironbark shrubby open forest (1590) (HU804)	Powerful Owl	77.08	25.16	1626
2. 1590 – Moderate			64.58	8.35	461
3.1590 – Regenerating			29.17	8.37	240
4.1588 – Moderate	Grey Ironbark – Broad-leaved Mahogany – Forest Red Gum shrubby open forest on Coastal Lowlands of the Central Coast (1588) (HU802)	Spotted-tailed Quoll	79.69	6.78	397
5.1588 – Regenerating			49.48	0.82	32
6. 1646 – Good	Smooth-barked Apple – Blackbutt – Old Man Banksia woodland on coastal sands of the Central and Lower North Coast (1646) (HU860)	Powerful Owl	59.90	20.76	1074
7.1646 – Poor			50.00	7.83	347

Vegetation zone	Plant community type (BVT)	Threatened species with highest credit requirement	Loss in site value score	Project impact within construction footprint (ha)	Ecosystem credits required
8.1649 – Good	Smooth-barked Apple – Red Mahogany – Swamp Mahogany – *Melaleuca sieberi* heathy swamp woodland of coastal lowlands (1649) (HU863)	Spotted-tailed Quoll	61.33	1.36	72
9.1598 – Poor	Forest Red Gum grassy open forest on floodplains of the lower Hunter (1598) (HU812)	Spotted-tailed Quoll	71.33	0.45	27
10.1716 – Good	Prickly-leaved Paperbark forest on coastal lowlands of the Central Coast and Lower North Coast (1716) (HU930)	Spotted-tailed Quoll	66.67	1.82	103
11.1717 – Good	Broad-leaved Paperbark – Swamp Mahogany – Swamp Oak – Saw Sedge swamp forest of the Central Coast and Lower North Coast (1717) (HU931)	Spotted-tailed Quoll	62.00	3.85	205
12.1717 – Poor			44.00	6.64	264
13.1724 – Good	Broad-leaved Paperbark – Swamp Oak – Saw Sedge swamp forest on coastal lowlands of the Central Coast and Lower North Coast (1724) (HU938)	Spotted-tailed Quoll	53.33	1.61	75
14.1727 – Moderate	Swamp Oak – Sea Rush – *Baumea juncea* swamp forest on coastal lowlands of the Central Coast and Lower North Coast (1727) (HU941)	Spotted-tailed Quoll	55.33	8.76	423
15.1736 – Good	Water Couch – Tall Spike Rush freshwater wetland of the Central Coast and lower Hunter (1736) (HU950)	Little Eagle	48.06	33.23	1424
16.1736 – Moderate			36.43	25.81	881
17.1742 – Good	Jointed Twig-rush sedgeland (1742) (HU956)	Little Eagle	82.17	1.45	99
18.1071 – Good	*Phragmites australis* and *Typha orientalis* coastal freshwater wetlands of the Sydney Basin Bioregion (1071) (HU673)	Little Eagle	47.29	7.71	326
Total				**170.76***	**8,076**

*This total is different to what is listed in **Table 9-12** as it does not include the saline communities Grey Mangrove Low Closed Forest (HU961) or Saltmarsh Estuarine Complex (HU960). These are discussed in **Section 9.6.2**.

Species credits were calculated for four threatened flora species and five threatened fauna species listed under the TSC Act and/or EPBC Act. A total of 17,895 species credits were identified as being required, as summarised in **Table 9-24**.

Table 9-24 Species credit requirements

Species	Extent of impact (ha) or individuals	Species credits required
Eucalyptus parramattensis subsp. *decadens*	34 plants	476
Diuris arenaria	161 plants	12,397
Callistemon linearifolius	157 plants	2,198
Persicaria elatior	3 plants	39
Australian Bittern	43.64ha	567
Black Bittern	61.95ha	805
Koala	51.12ha	1,329
Wallum Froglet	3.21ha	42
Mahony's Toadlet	3.21ha	42
Total		**17,895**

9.6.2 Offsets for impacts to aquatic habitats

According to the FBA, PCTs that are classified under the VIS classification database as being in the saline wetlands vegetation formation must be assessed according to the Fisheries NSW policy and guidelines. Two of the PCTs that would be impacted by the project are saline wetland formations, and monetary offset requirements have been calculated in accordance with policy and guidelines for fish habitat conservation and management (DPI 2013a). These guidelines identify habitat compensation on a minimum 2:1 basis for all KFH (TYPE1-3), which includes 1.26 hectares of Saltmarsh Estuarine Complex (PCT 1746) and 2.27 hectares of Grey Mangrove Low Closed Forest (PCT 1747).

It is recognised that there may also be alternatives to a monetary compensation to provide an adequate offset or compensation (e.g. remediation work) for impacts to saline vegetation types. Consultation with NSW DPI will be carried out to discuss other potential alternative options for compensation that are consistent with meeting the 2:1 offset ratio applied.

The project would also impact around 16.4 hectares of mapped Coastal Management SEPP coastal wetlands, which includes about 3.53 hectares of the saltmarsh and mangrove communities. The remaining areas of the Coastal Management SEPP coastal wetland impacted by the project are covered by the PCTs 1736 and 1071 and will be offset as per the ecosystem credit calculations for these respective PCTs shown in **Table 9-23**.

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Environmental impact statement – Chapter 10: Hydrology and flooding

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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**).

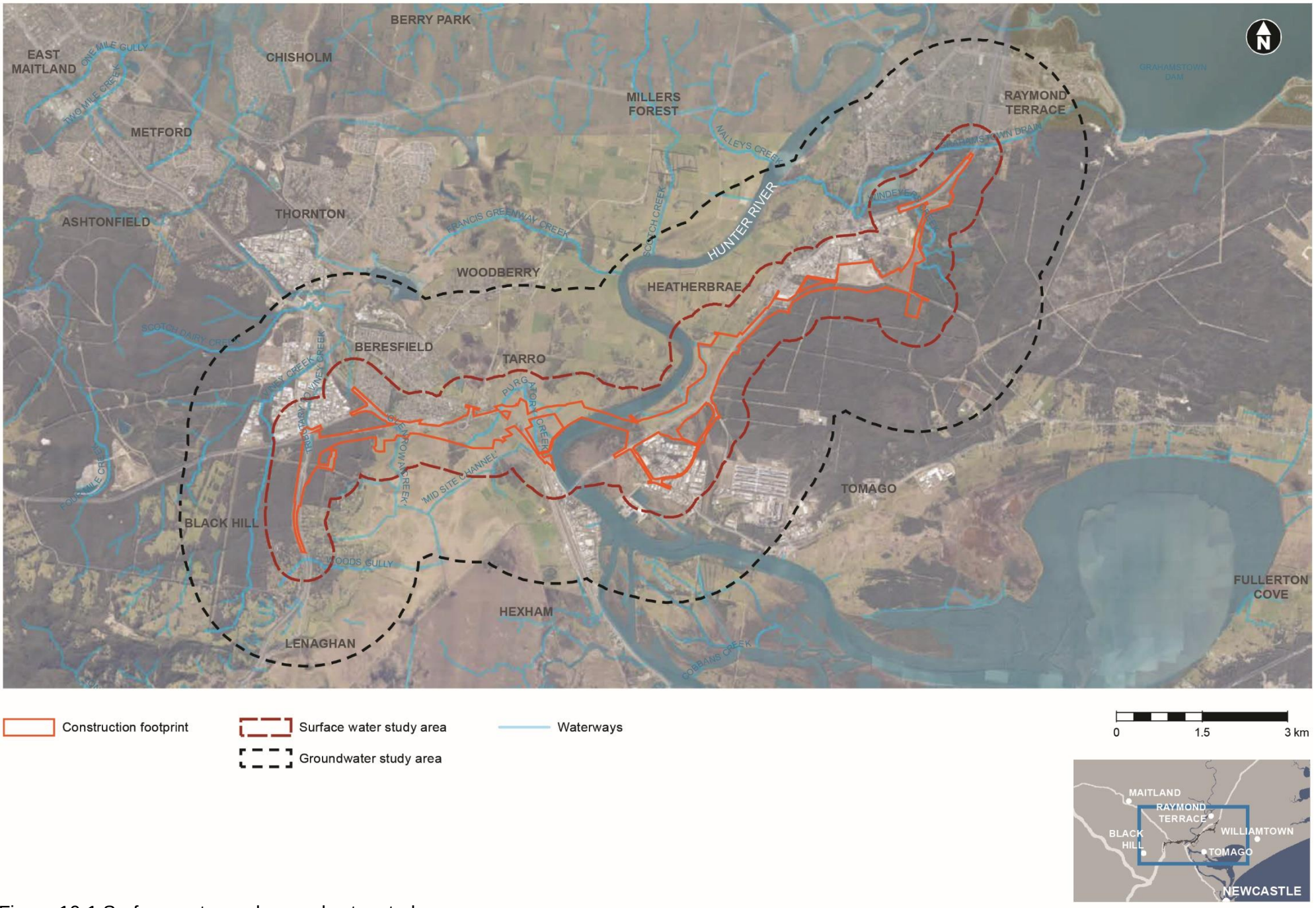


Figure 10-1 Surface water and groundwater study areas

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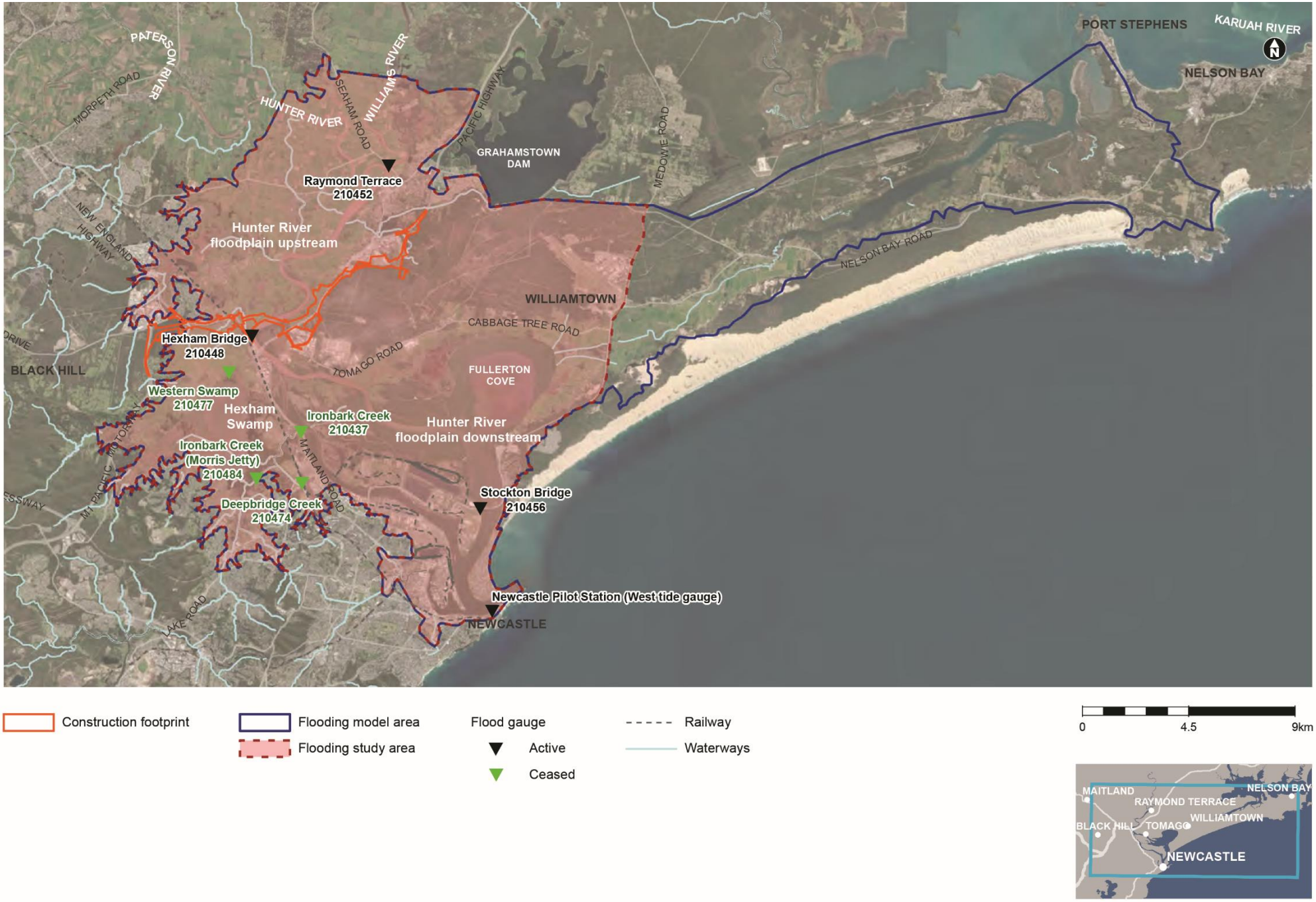


Figure 10-2 Flooding study area

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.

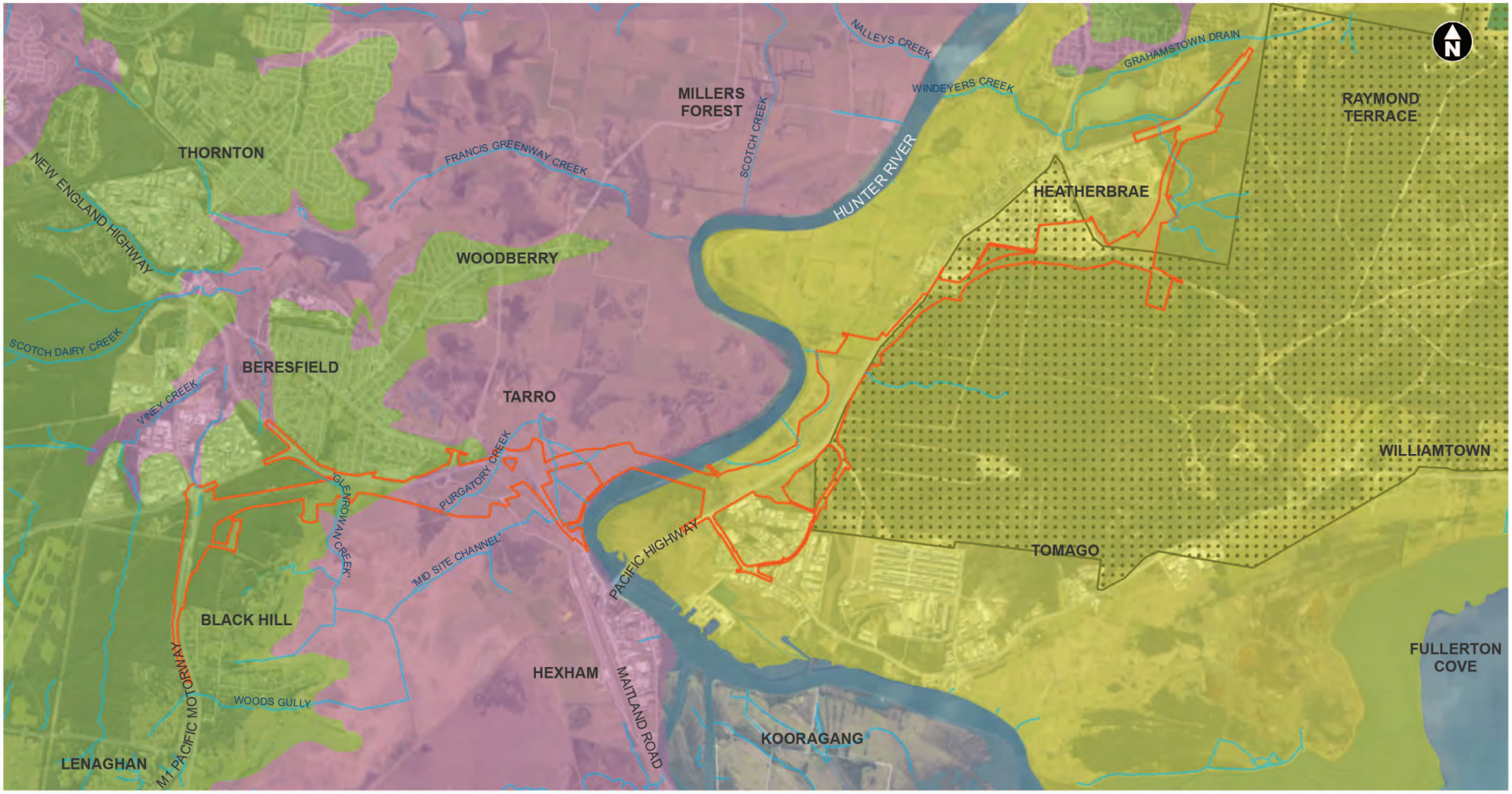


Figure 10-3 Water sharing plans



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.

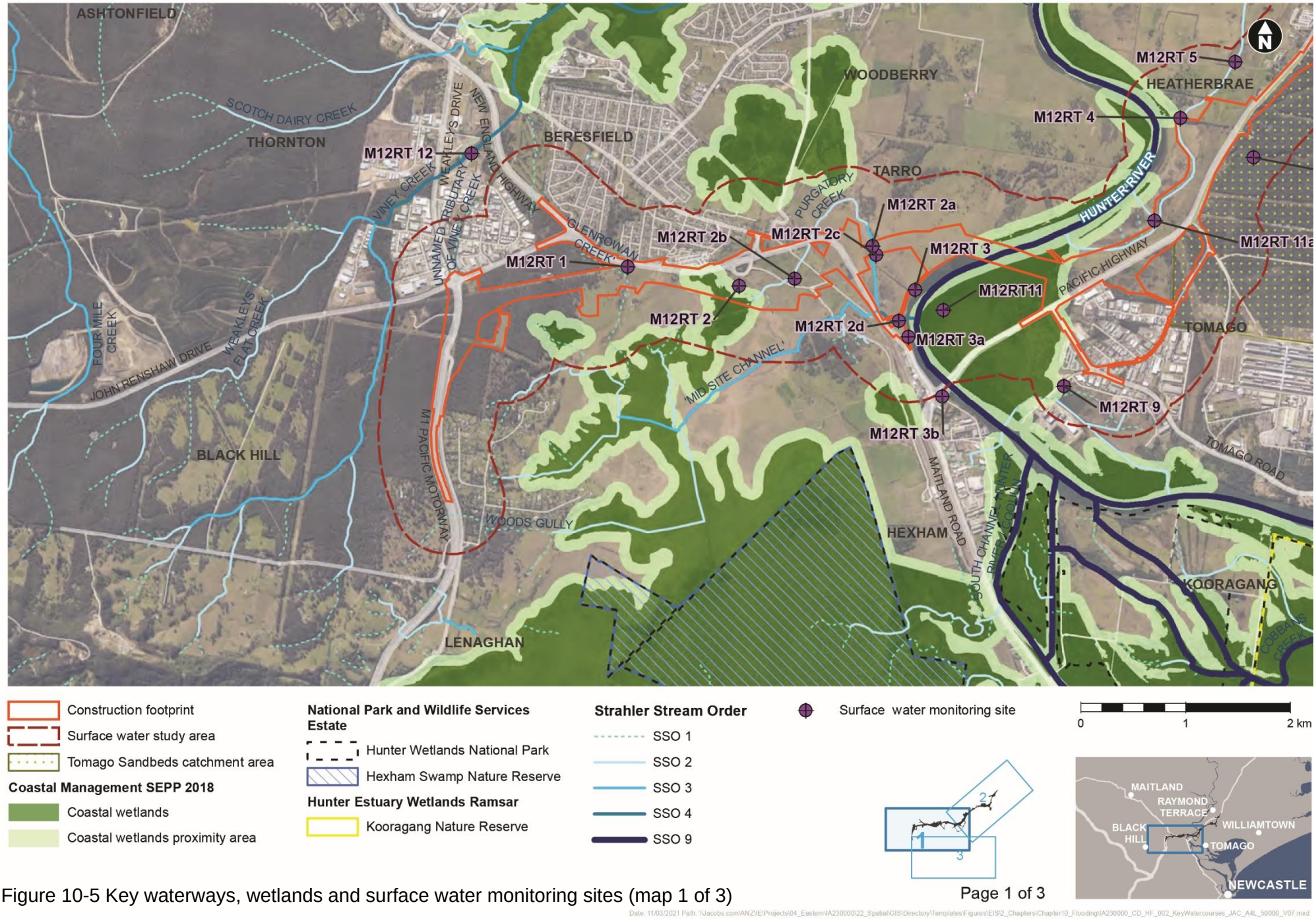


Figure 10-5 Key waterways, wetlands and surface water monitoring sites (map 1 of 3)

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

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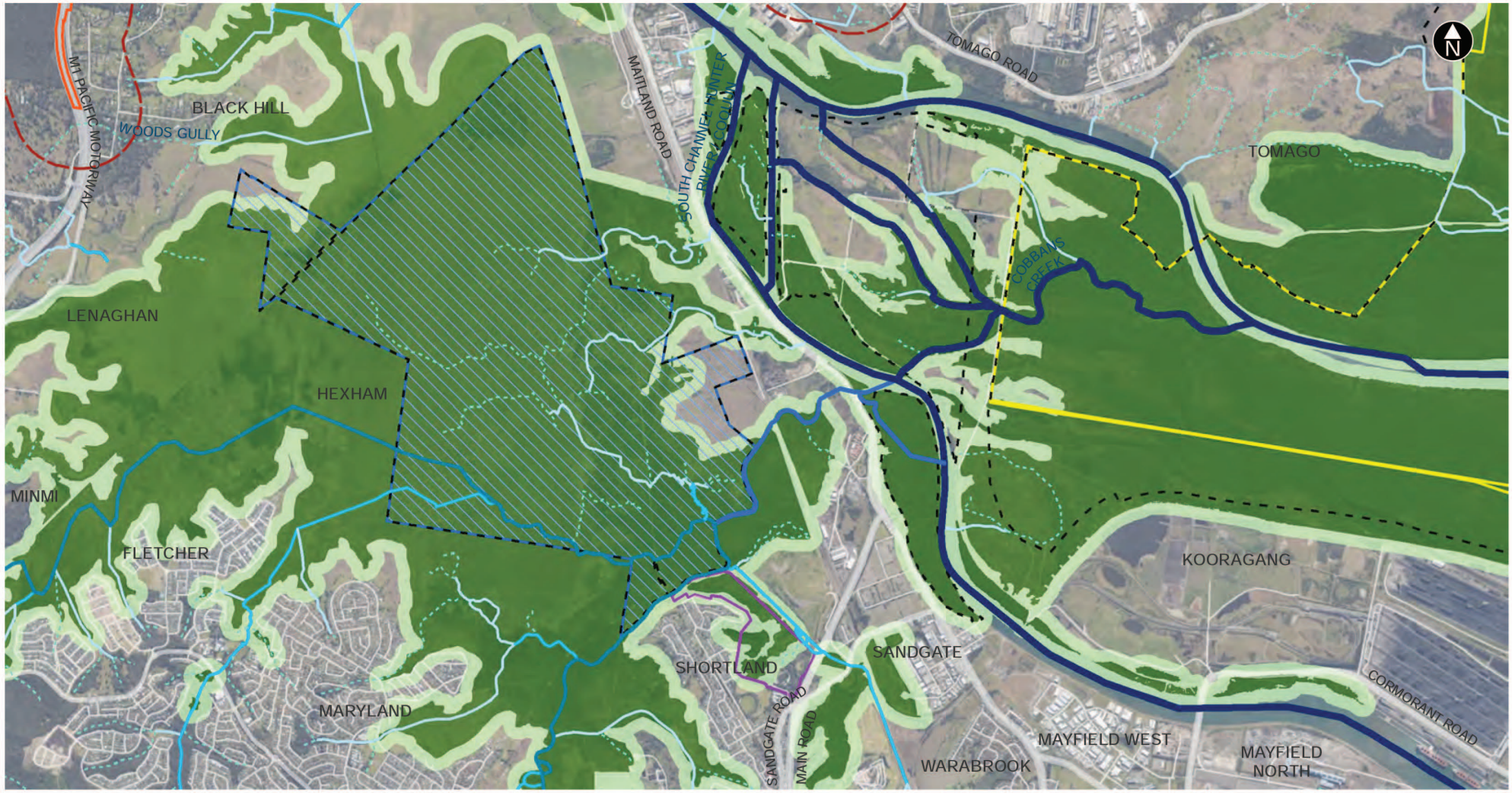


Figure 10-5 Key waterways, wetlands and surface water monitoring sites (map 3 of 3)

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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.

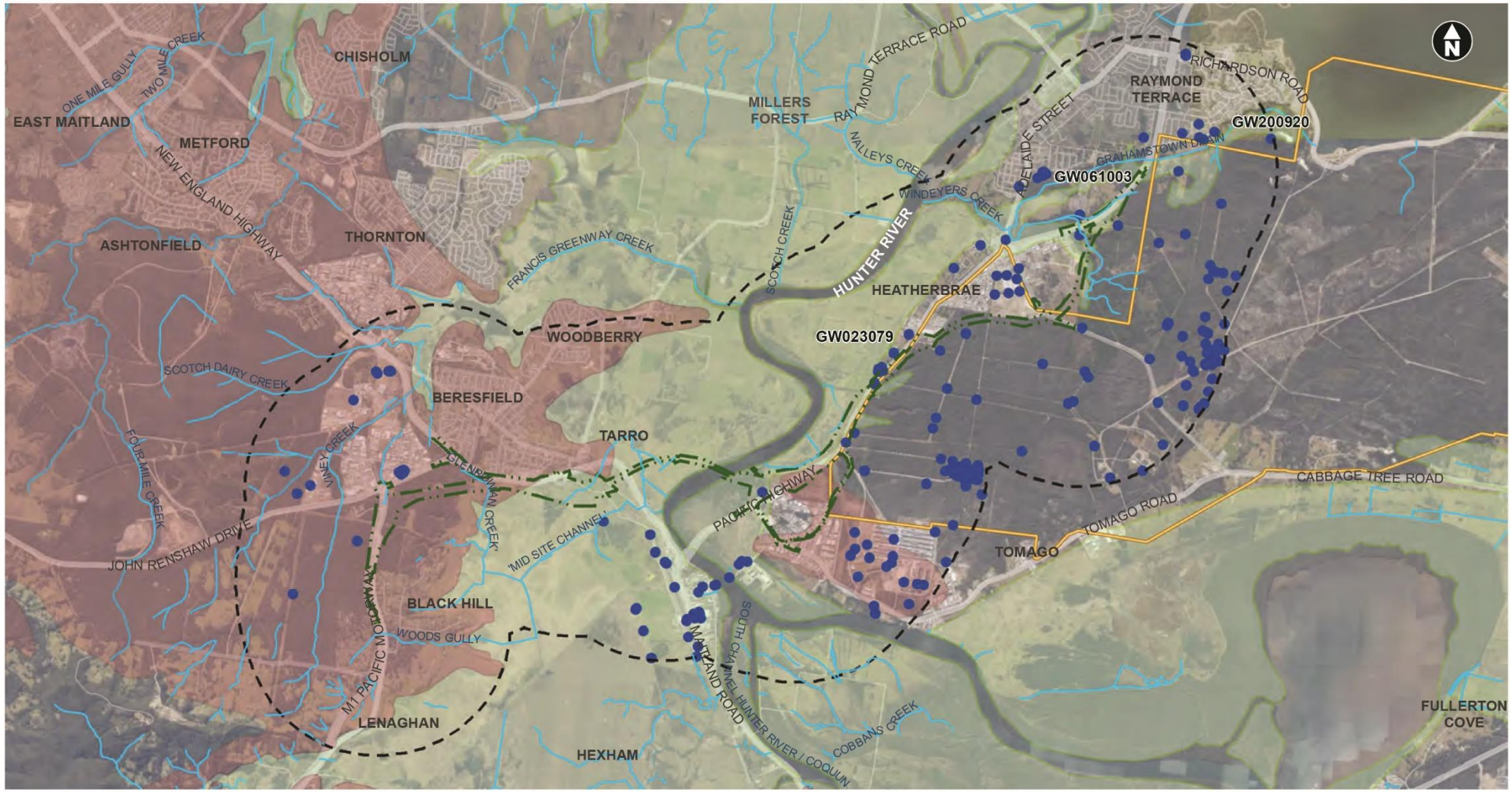


Figure 10-6 Groundwater systems in the vicinity of the project

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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

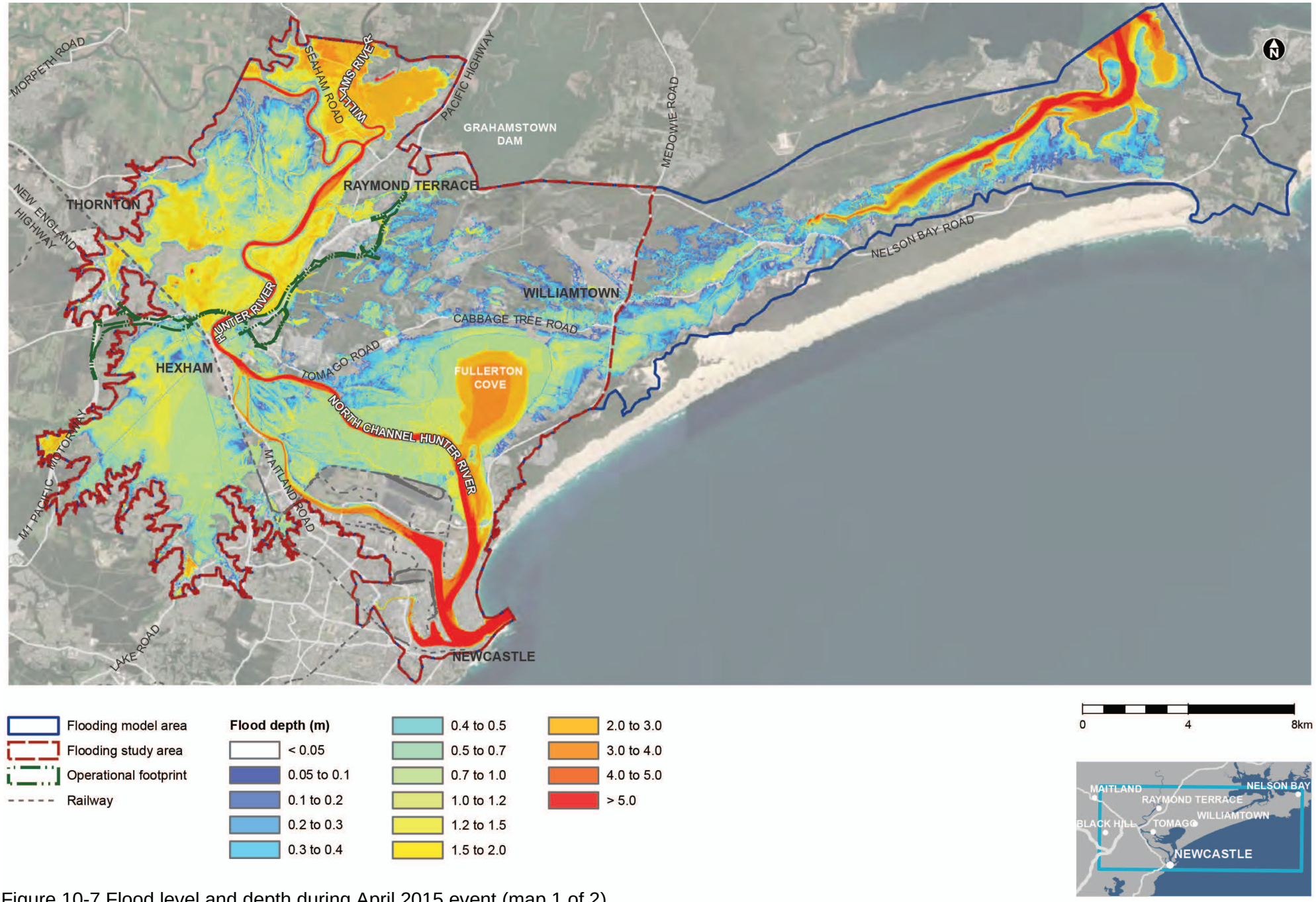


Figure 10-7 Flood level and depth during April 2015 event (map 1 of 2)

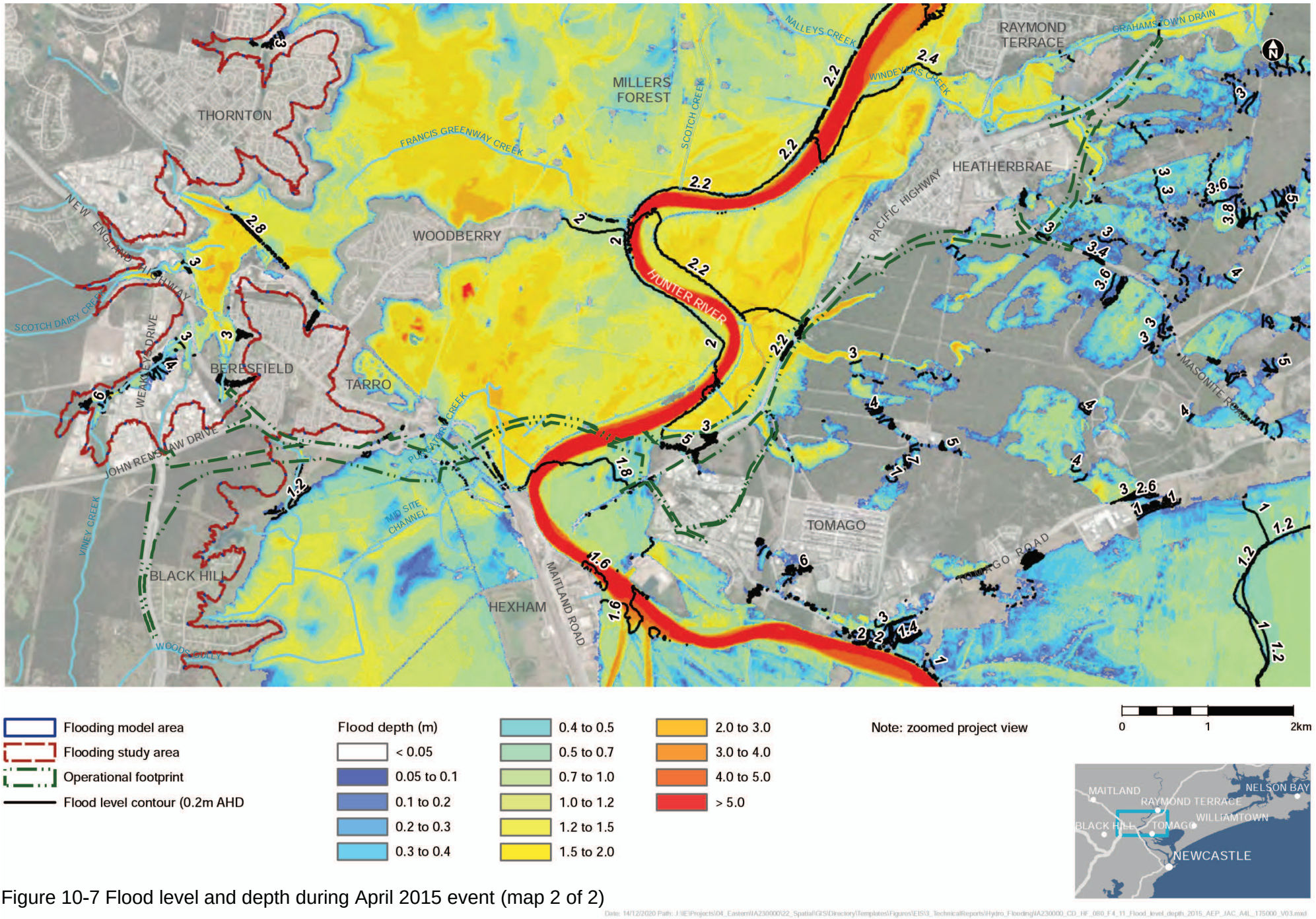


Figure 10-7 Flood level and depth during April 2015 event (map 2 of 2)



Figure 10-8 Hunter Valley Flood Mitigation Scheme

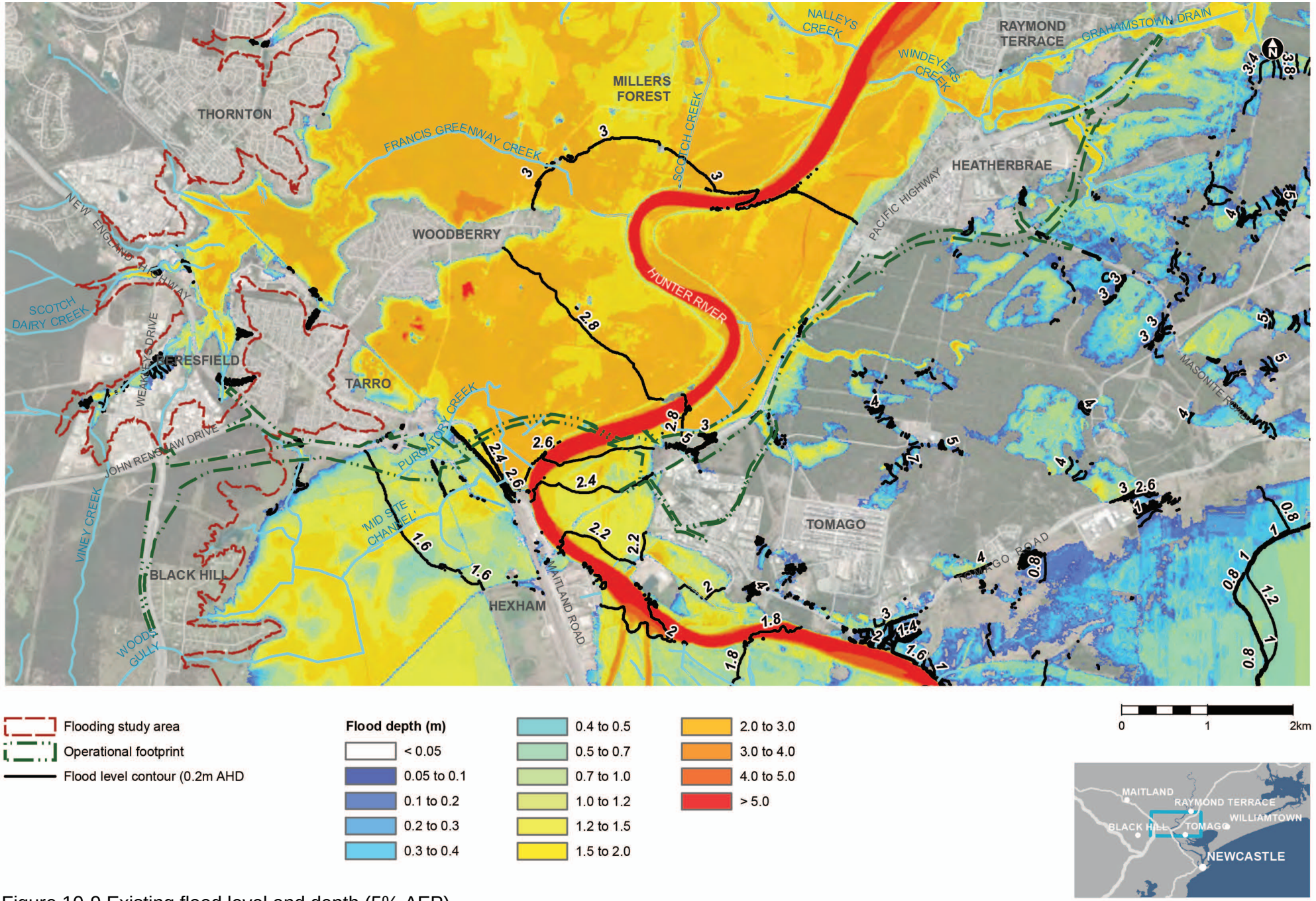


Figure 10-9 Existing flood level and depth (5% AEP)

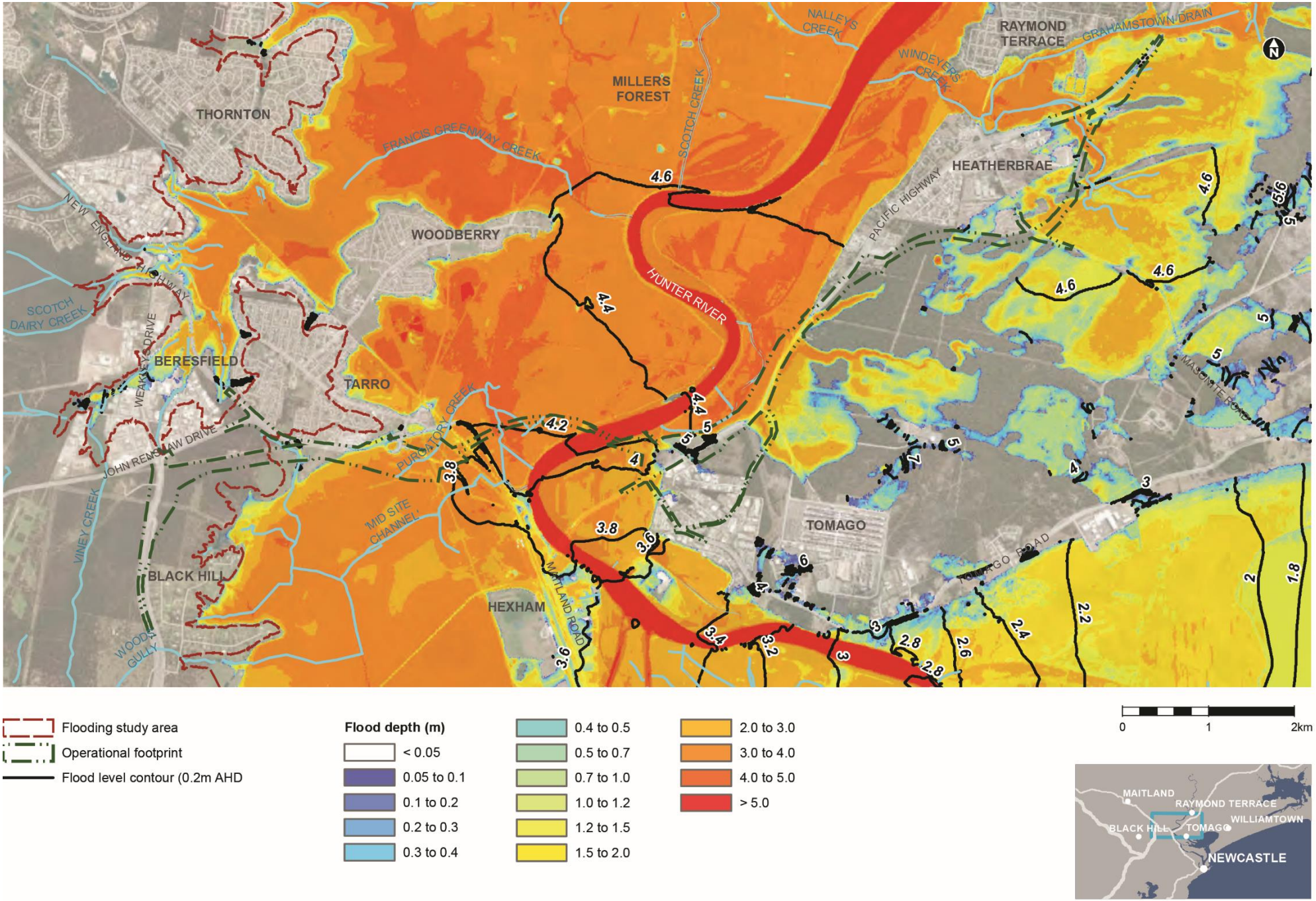


Figure 10-10 Existing flood level and depth (1% AEP)

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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

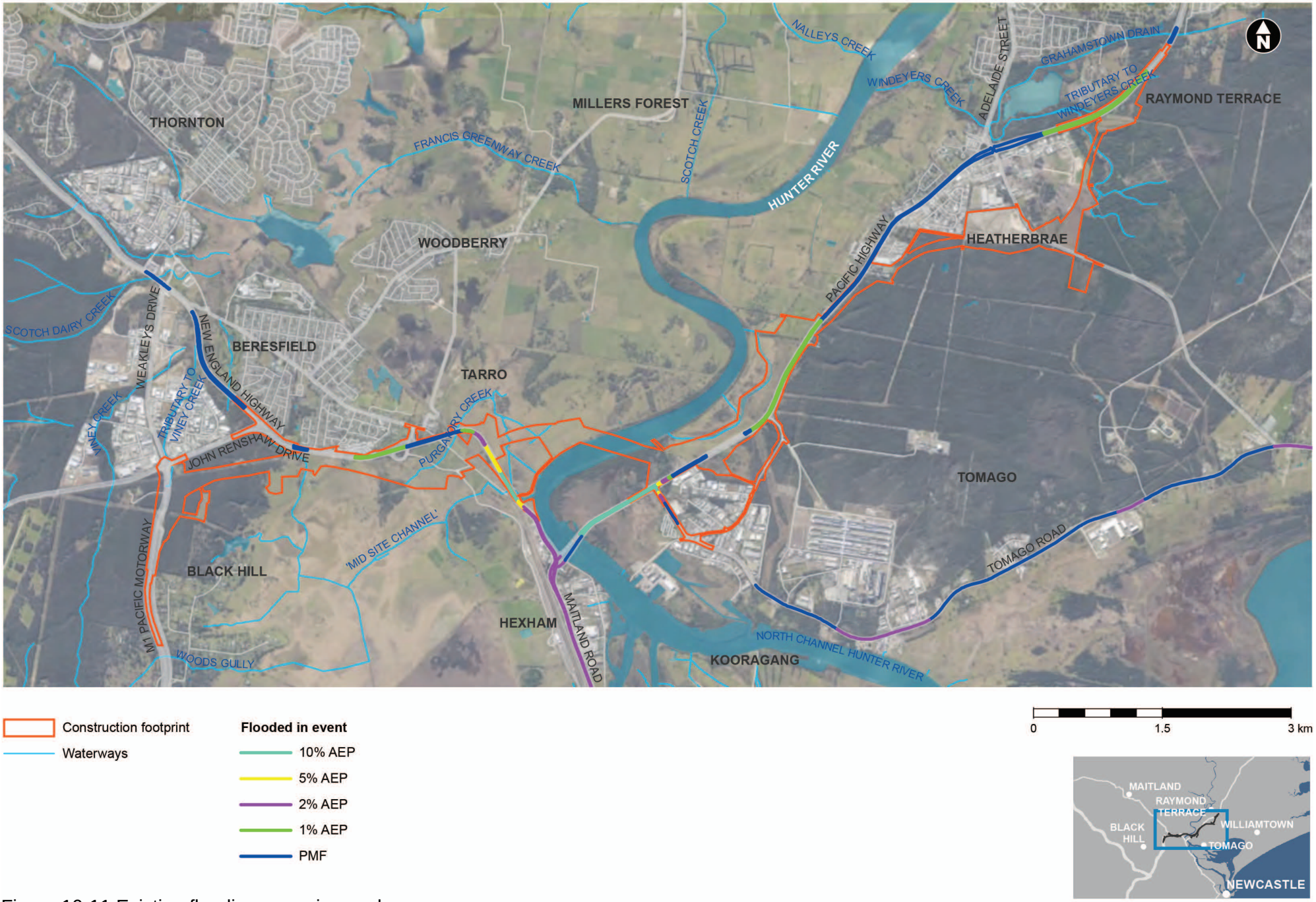


Figure 10-11 Existing flooding on major roads



Figure 10-12 Existing flooding at railways

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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**.

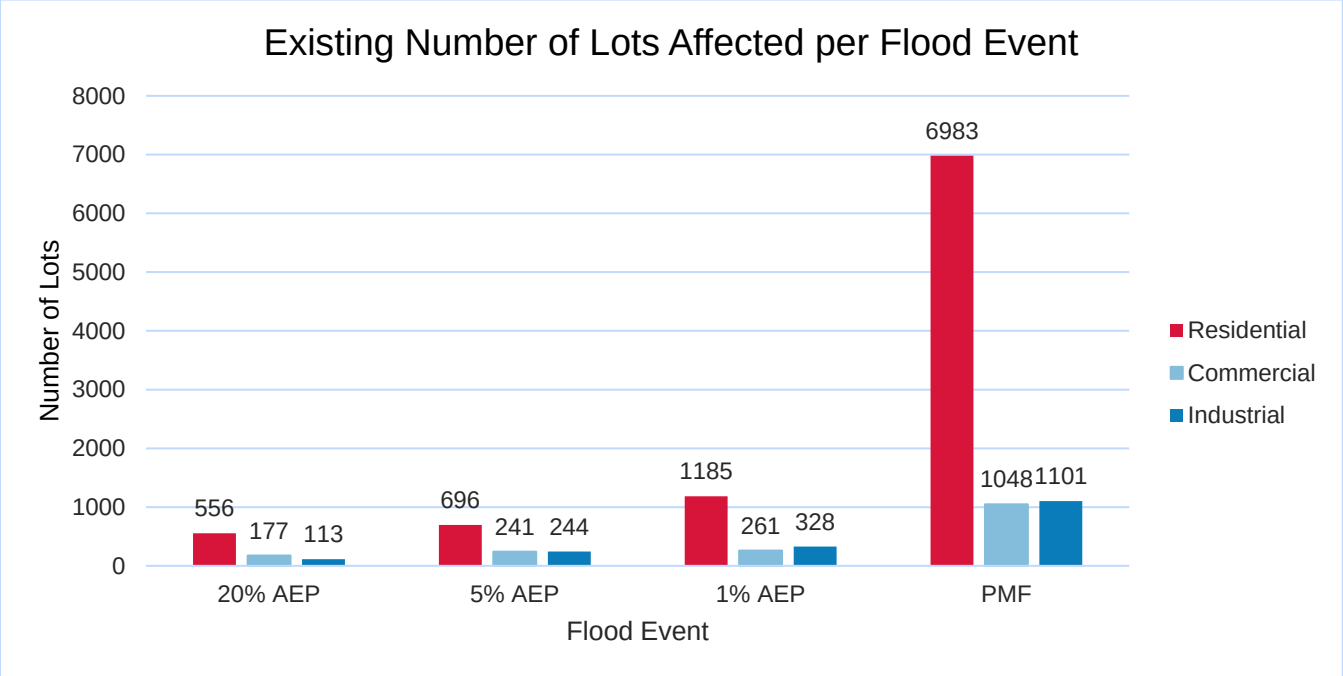


Figure 10-13 Number of existing lots affected

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.

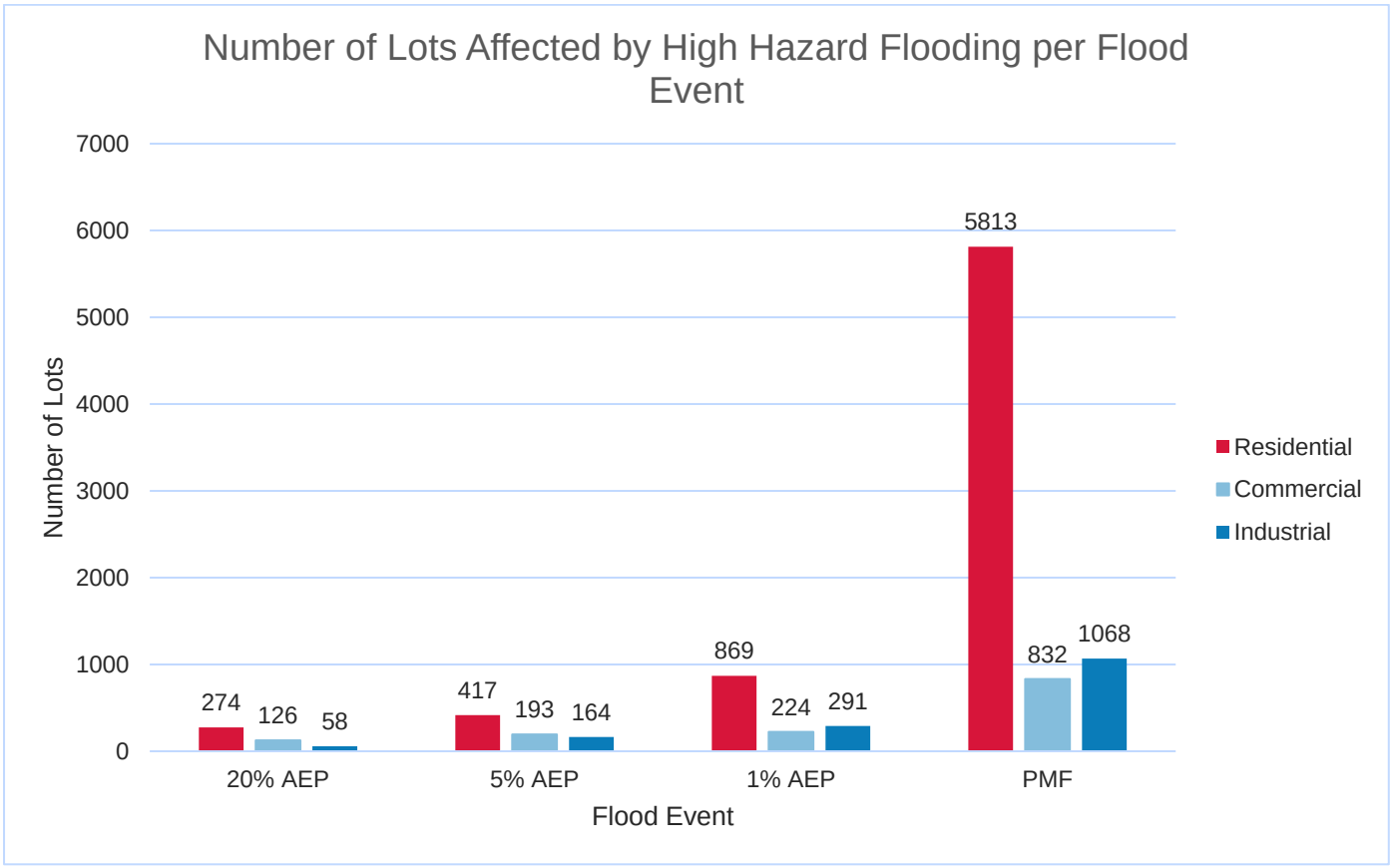


Figure 10-14 Number of lots affected by high hazard flooding

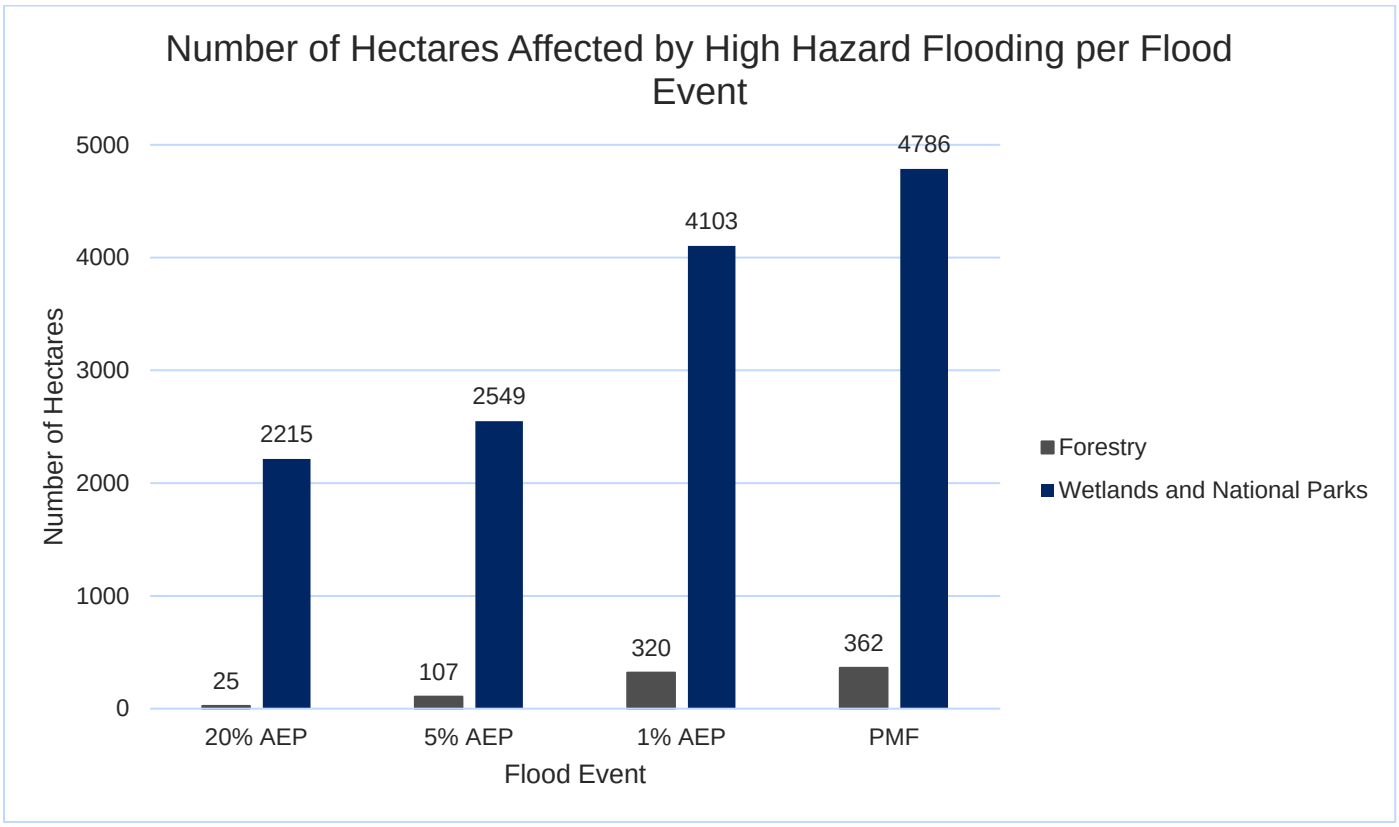


Figure 10-15 Hectares affected by high hazard flooding

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:

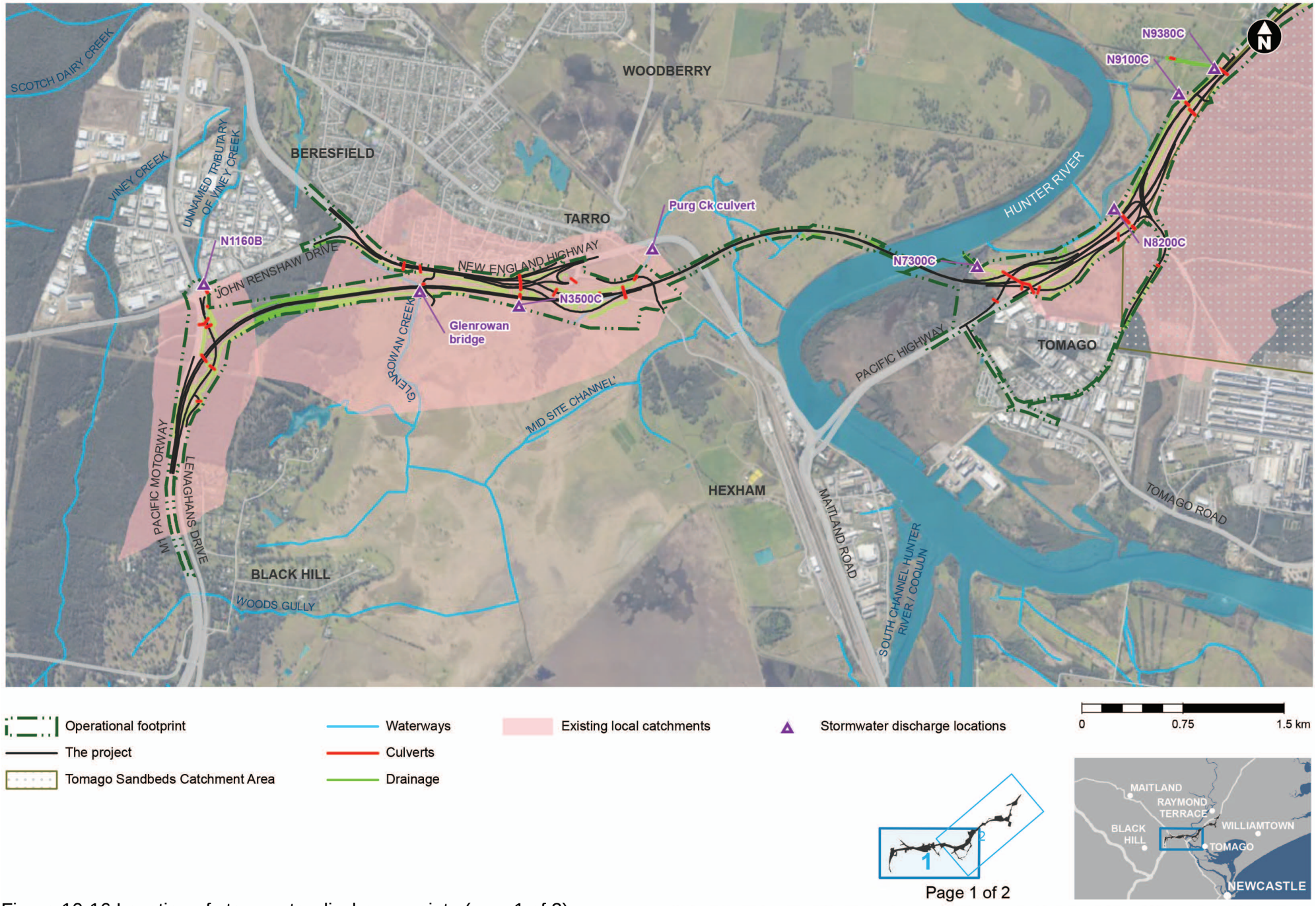
- Minor reductions in baseflow and moderate increases to quickflow[1] contributions to total streamflow as a result of lowered rates of rainfall infiltration, increase in effective rainfall depth and installation of drains
- Minor to moderate increases to the rate of stormwater discharged from the project 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.

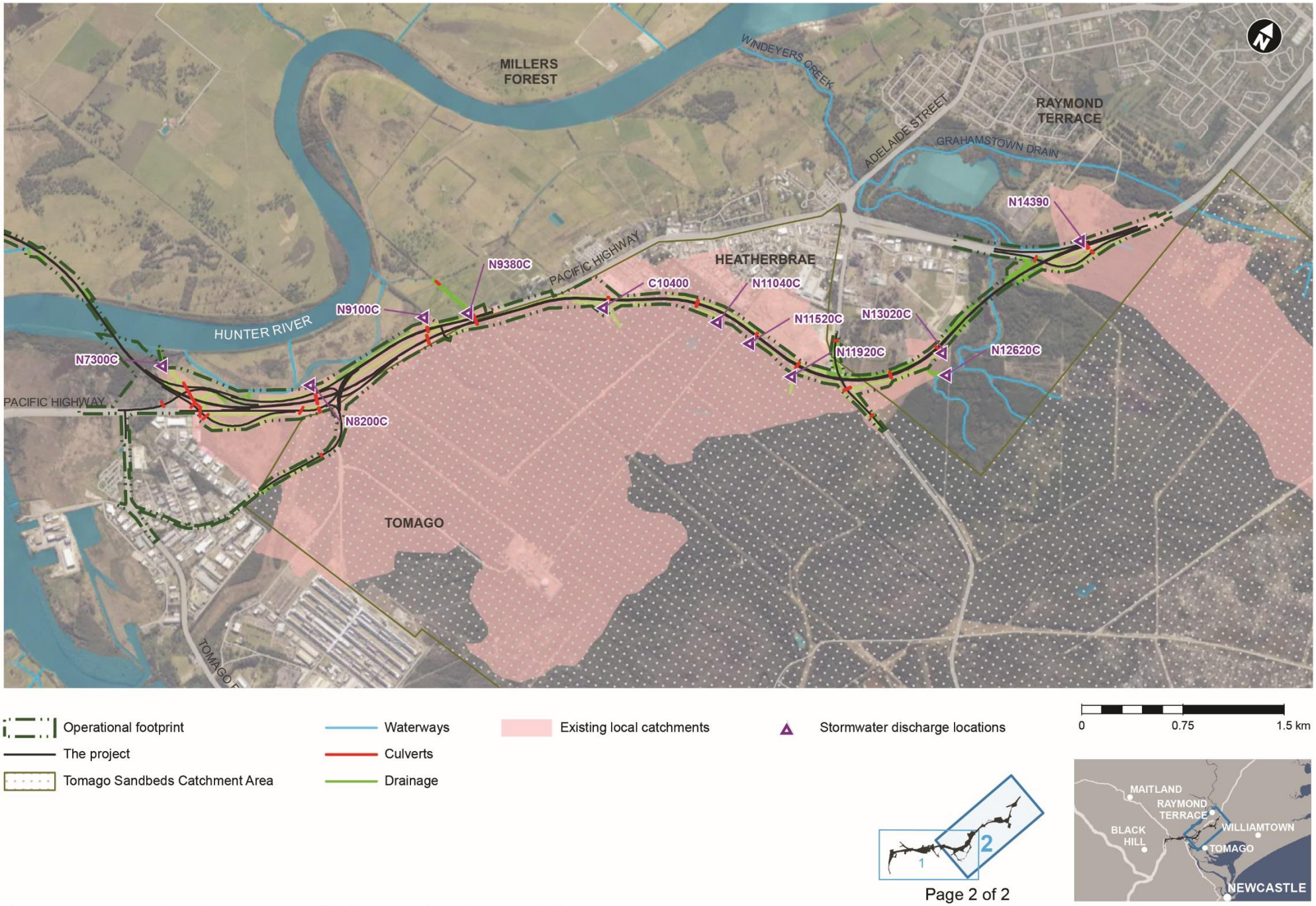
Changes in stormwater discharge, volume and velocity during construction are not expected to result in a material impact to the receiving environment as:

- 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.



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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)

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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.

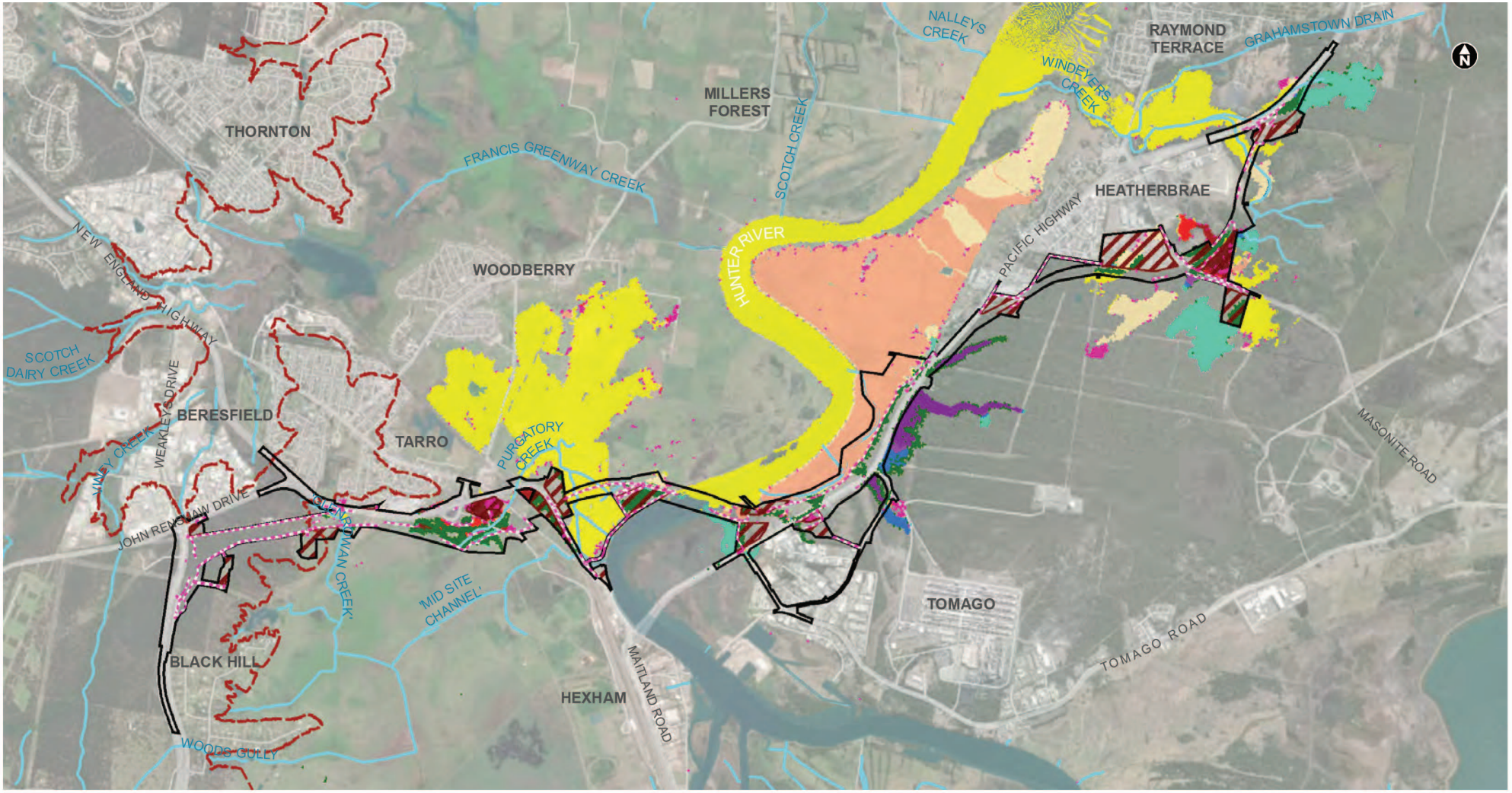


Figure 10-17 Change in flood level during construction (20% AEP)

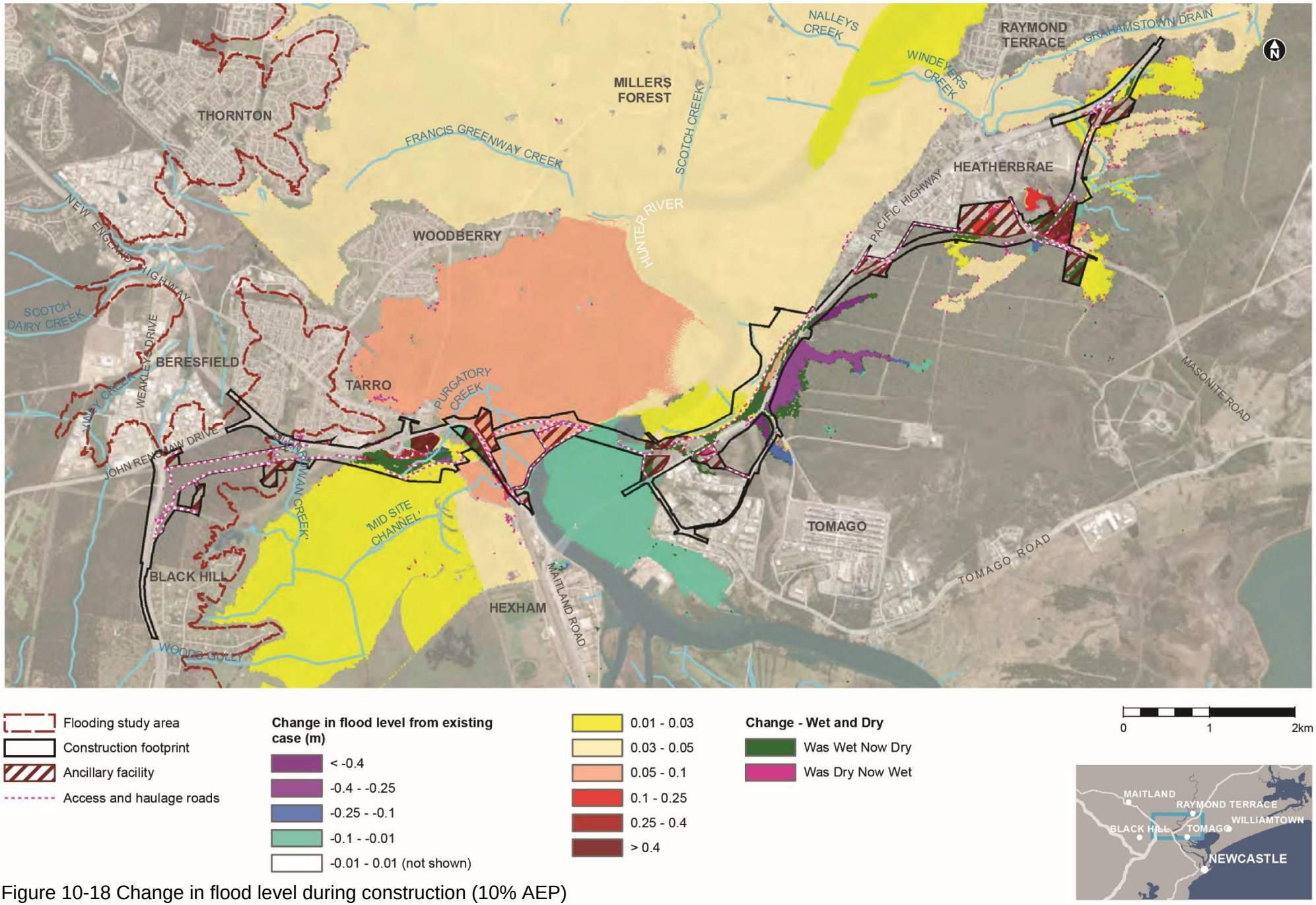


Figure 10-18 Change in flood level during construction (10% AEP)

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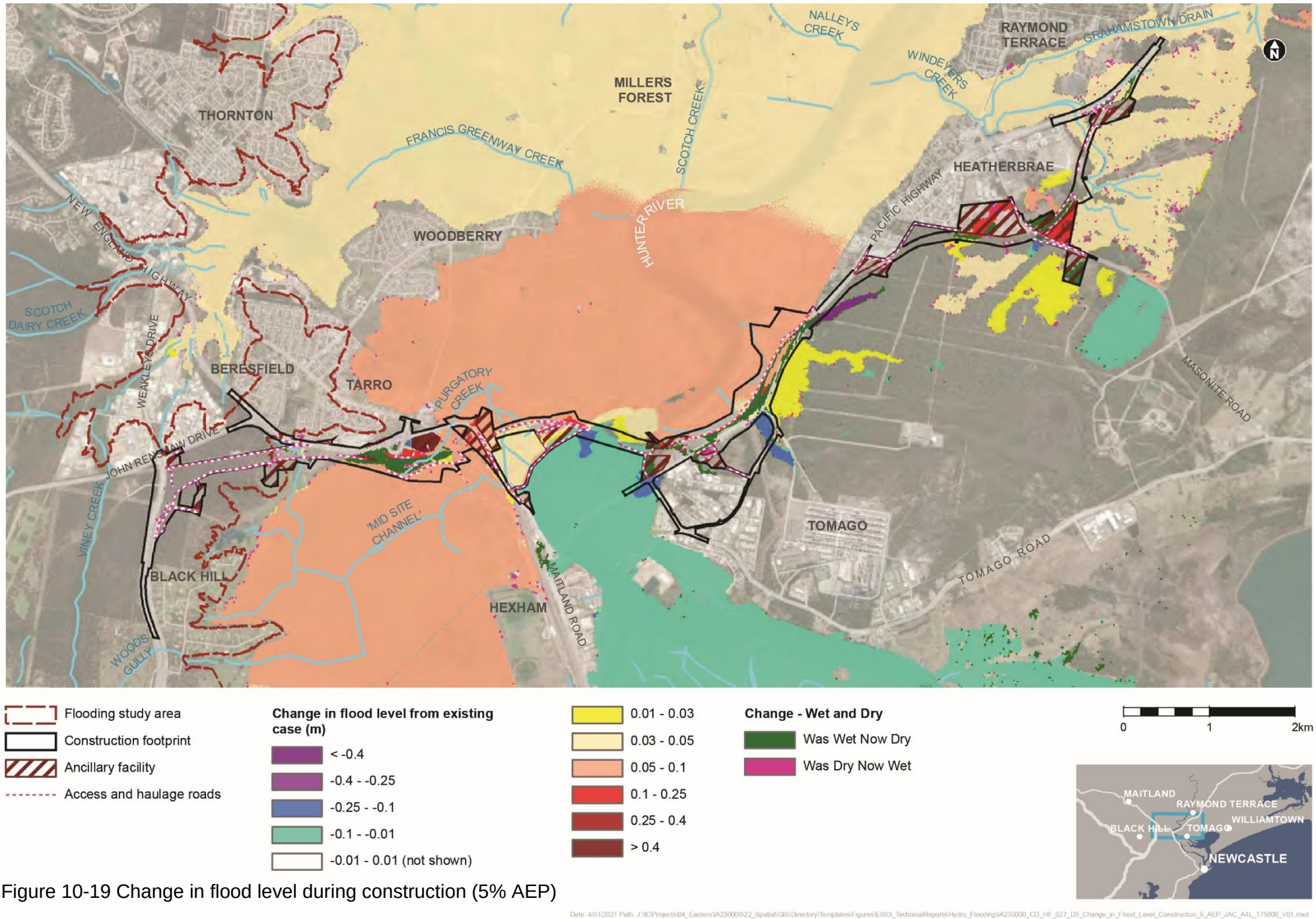


Figure 10-19 Change in flood level during construction (5% AEP)

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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.

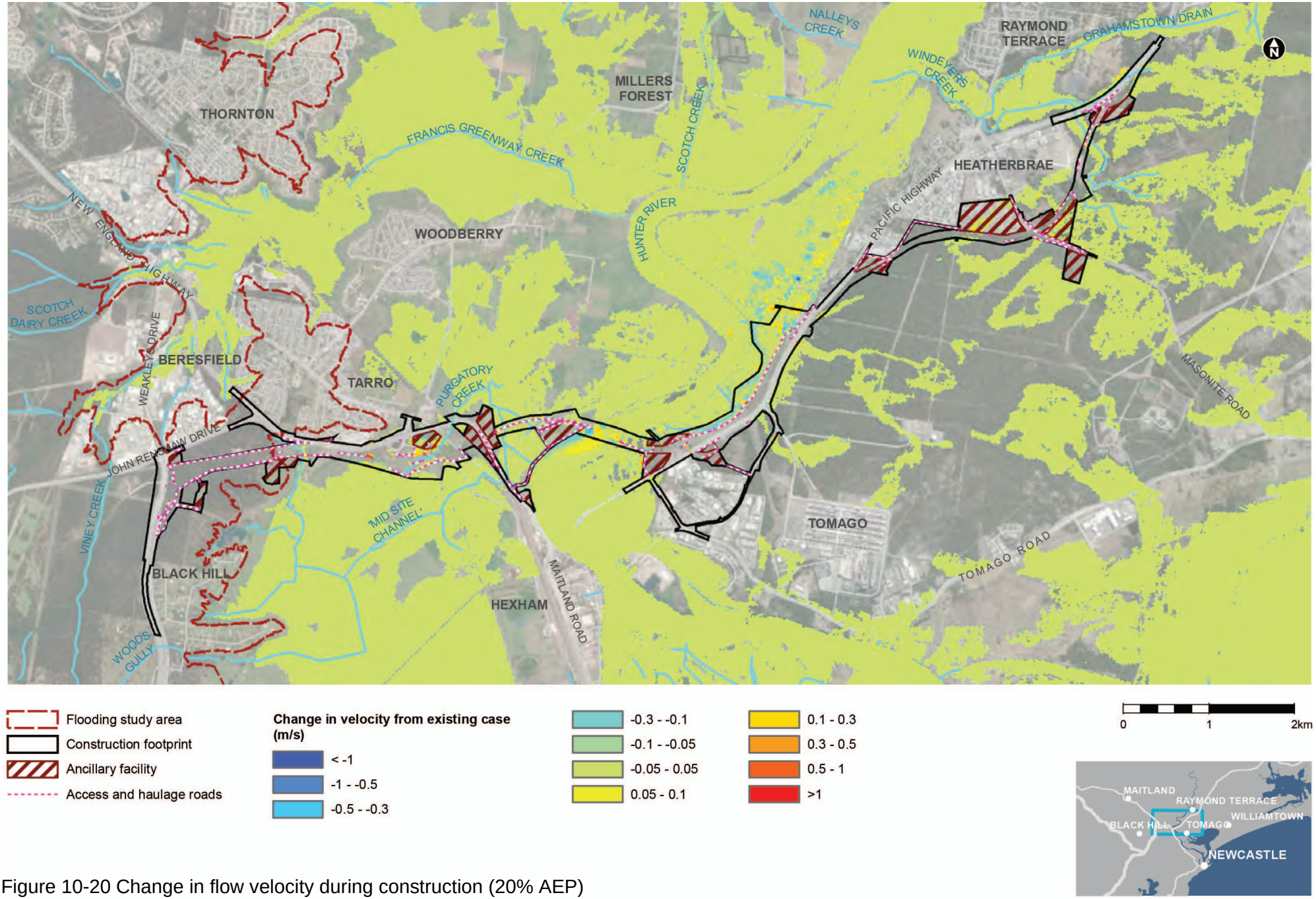


Figure 10-20 Change in flow velocity during construction (20% AEP)

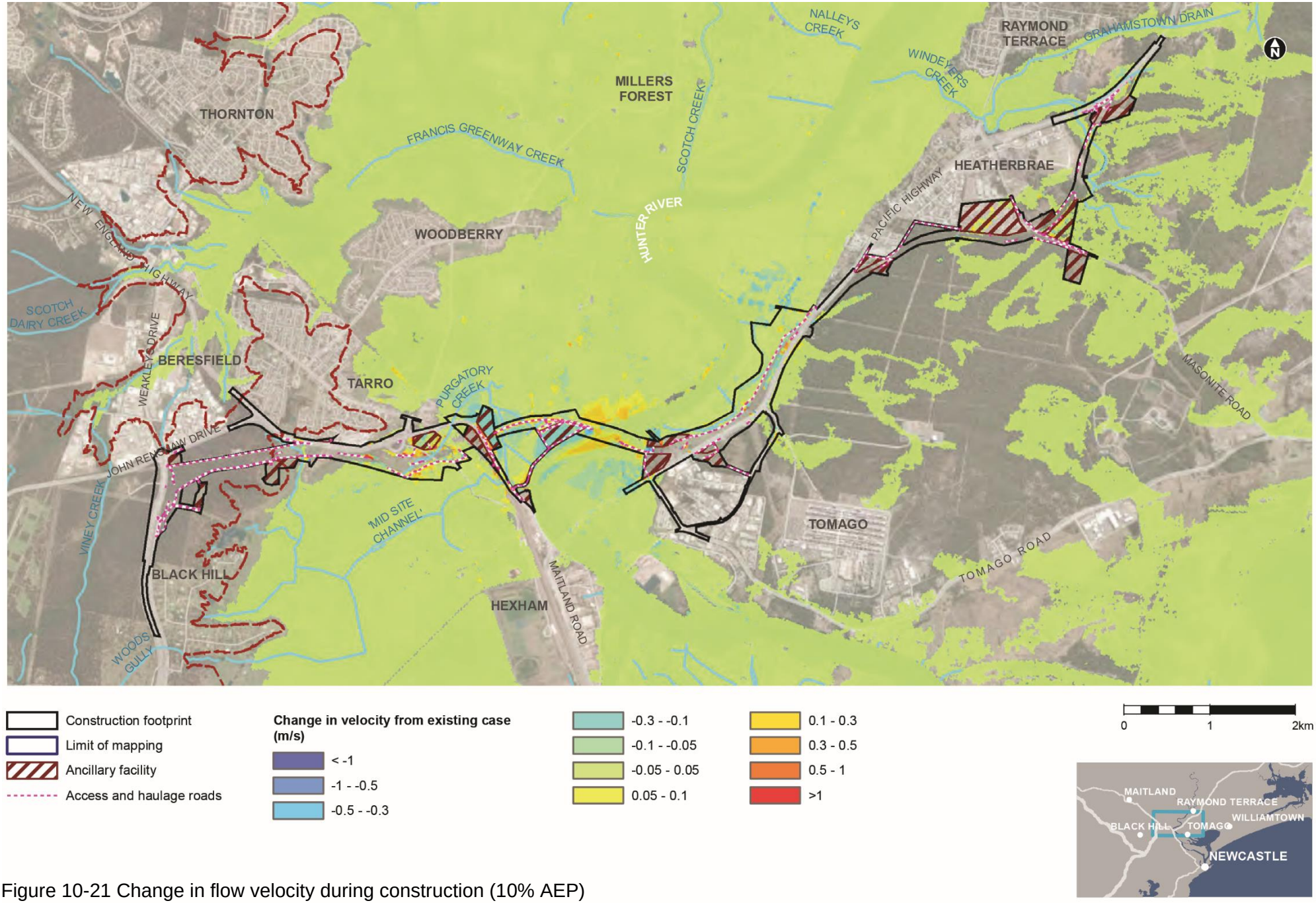


Figure 10-21 Change in flow velocity during construction (10% AEP)

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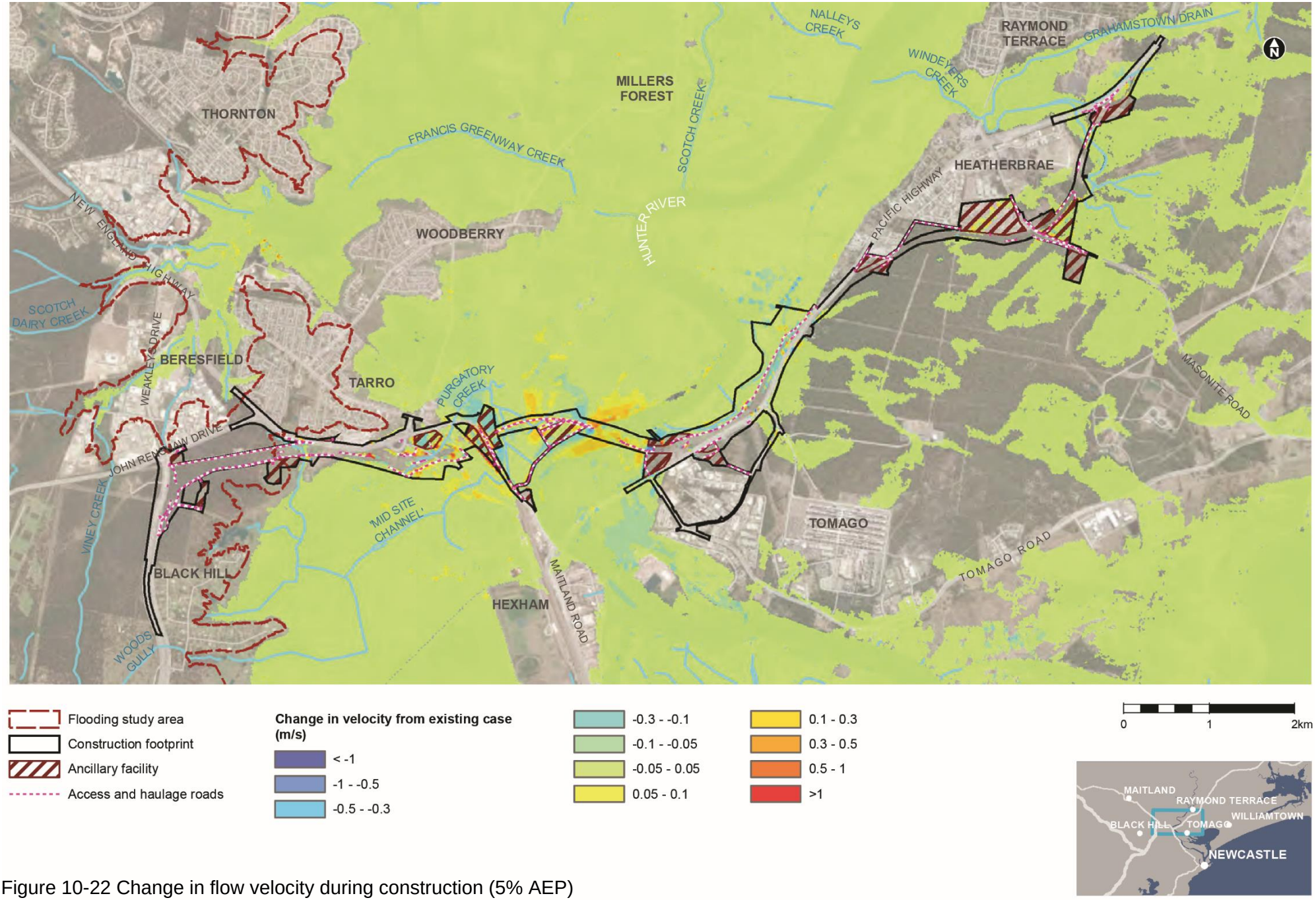


Figure 10-22 Change in flow velocity during construction (5% AEP)

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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.

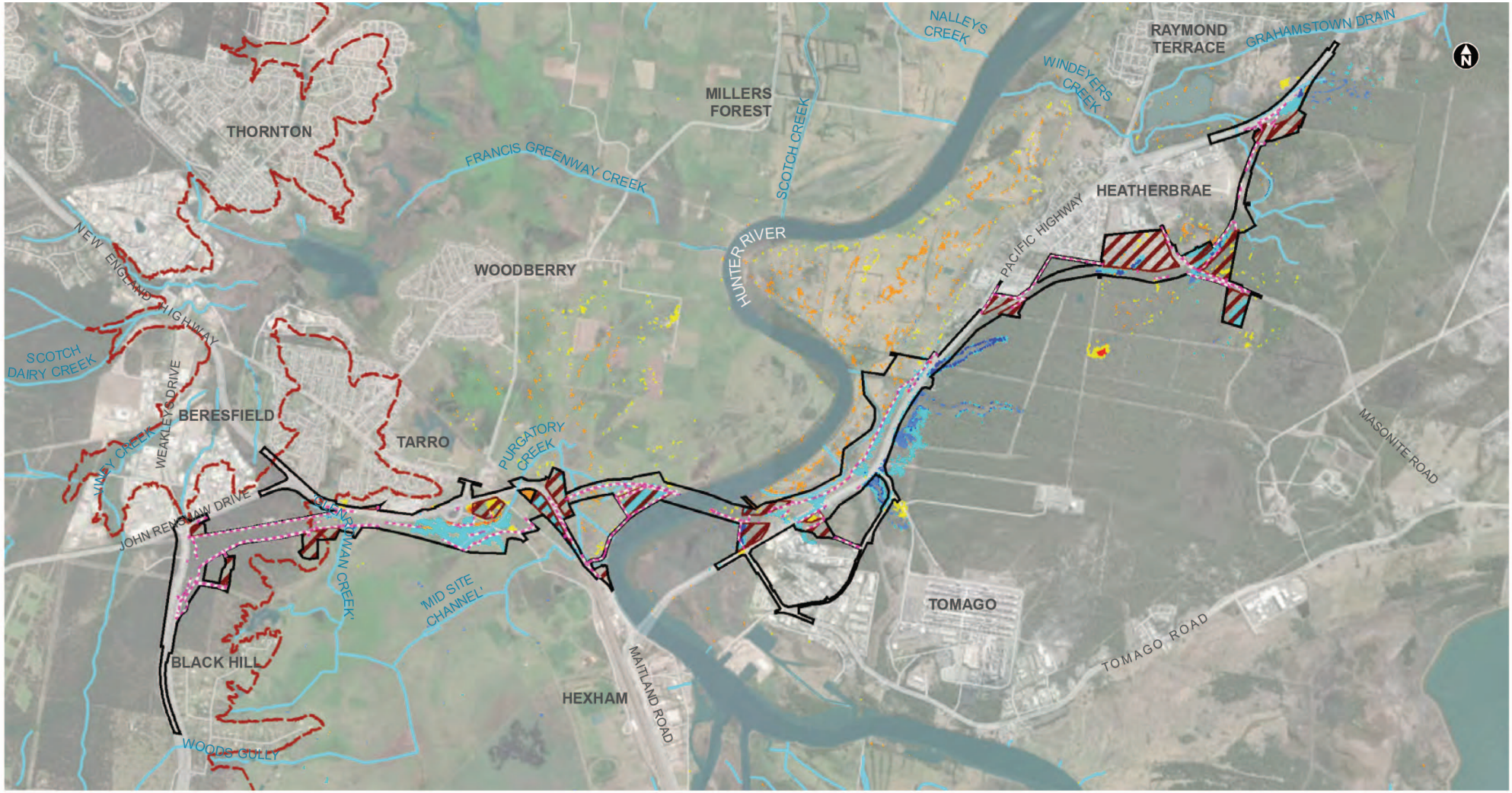


Figure 10-23 Change in flood hazard during construction (20% AEP)

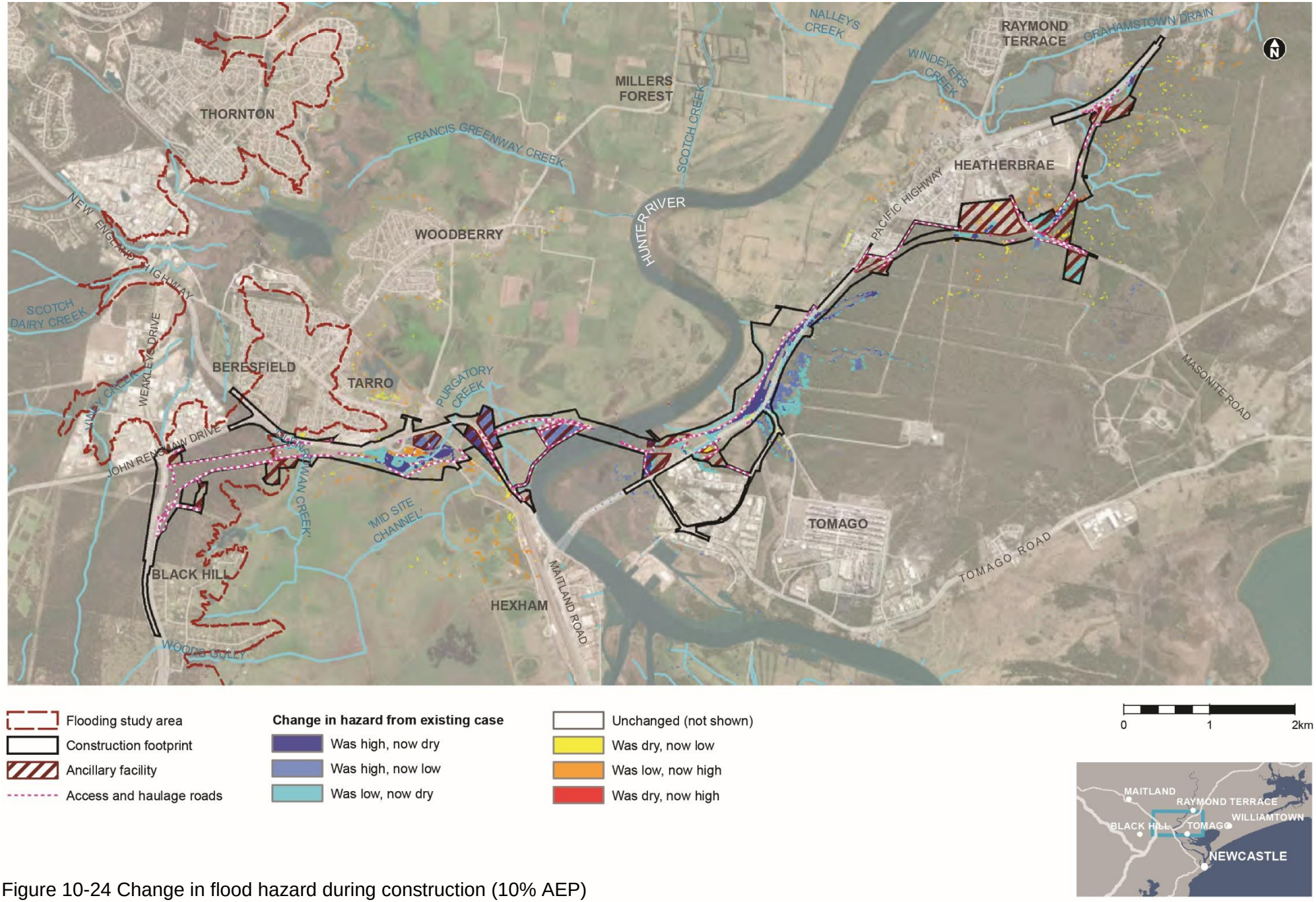


Figure 10-24 Change in flood hazard during construction (10% AEP)

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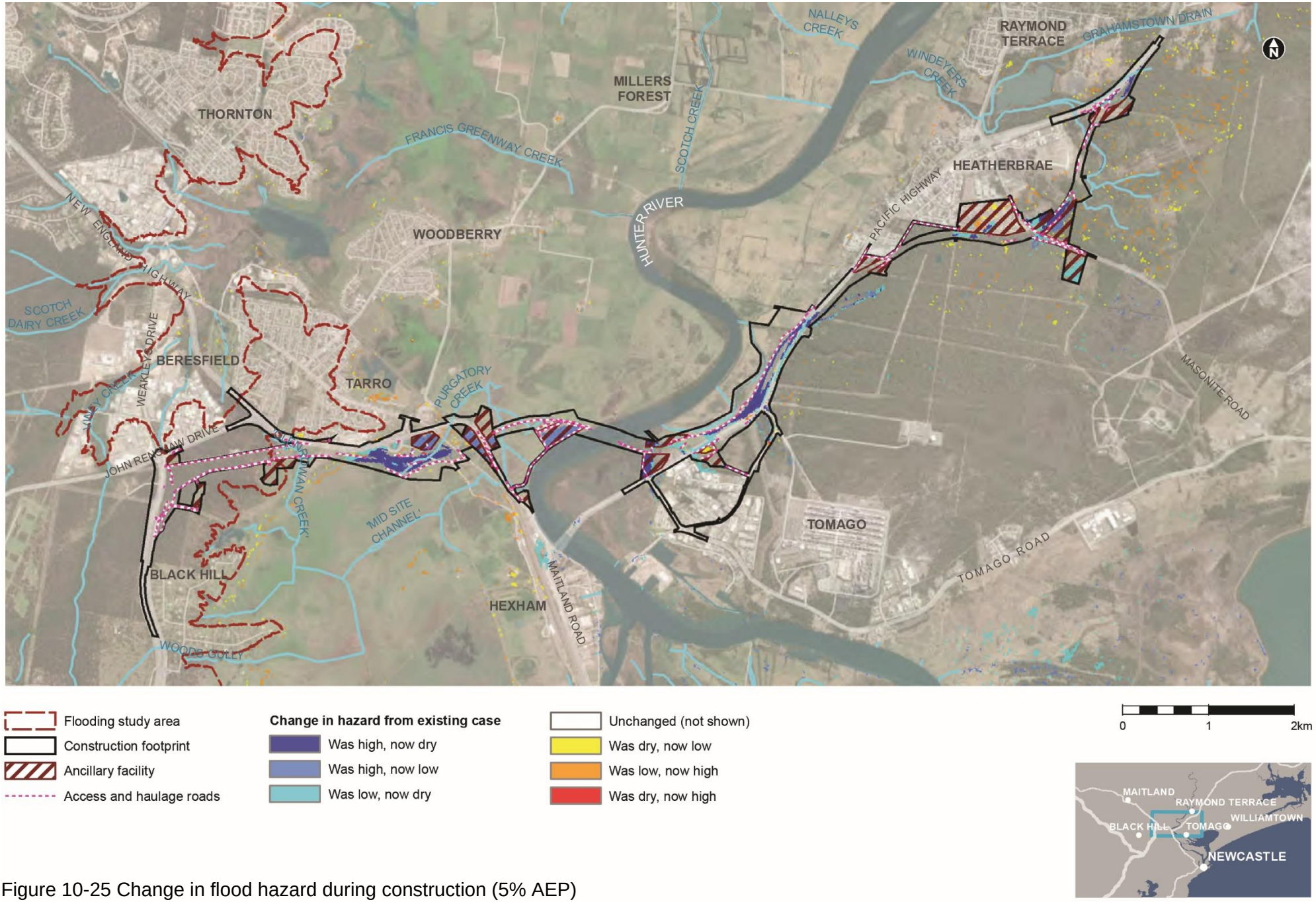


Figure 10-25 Change in flood hazard during construction (5% AEP)

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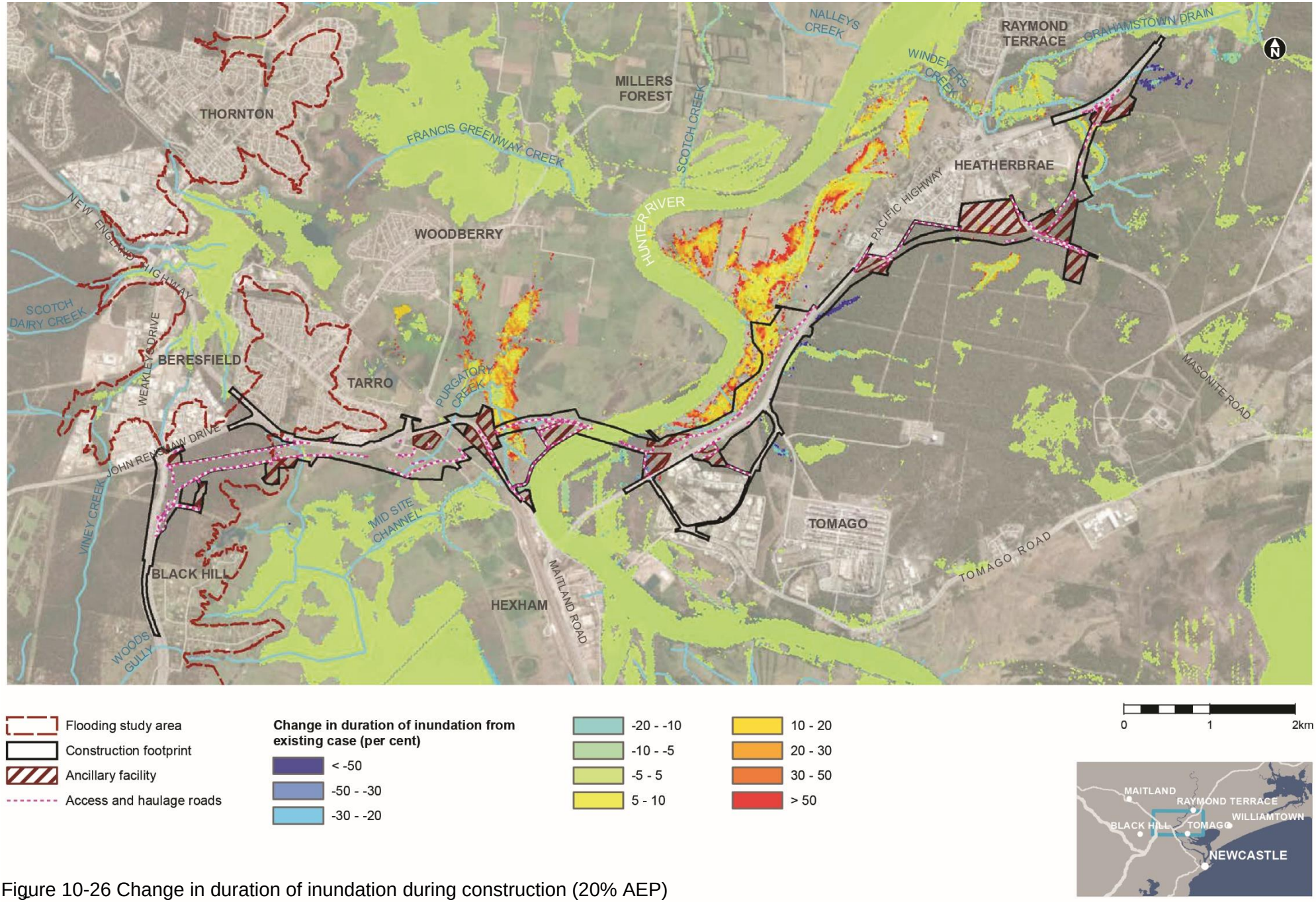


Figure 10-26 Change in duration of inundation during construction (20% AEP)

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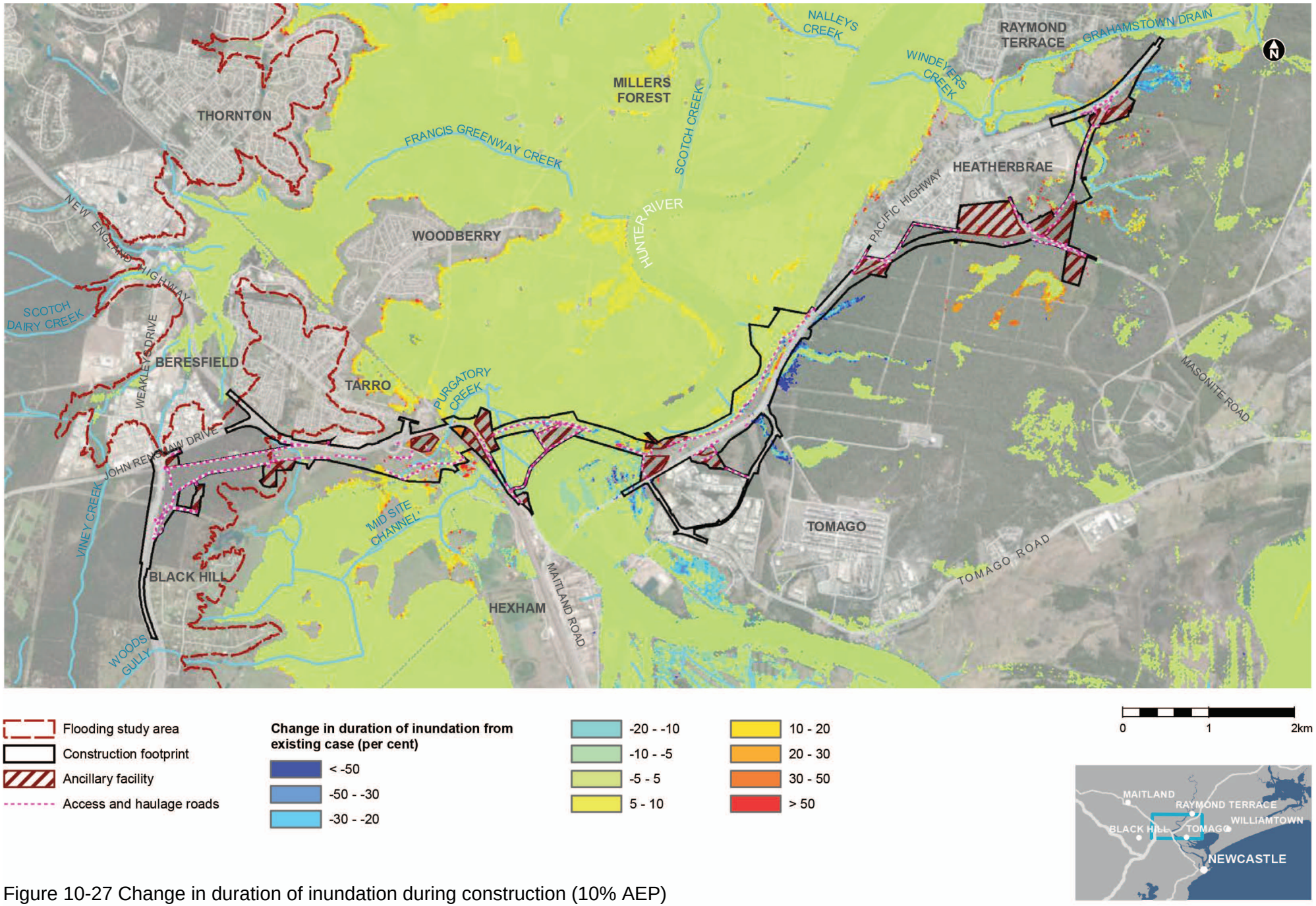


Figure 10-27 Change in duration of inundation during construction (10% AEP)

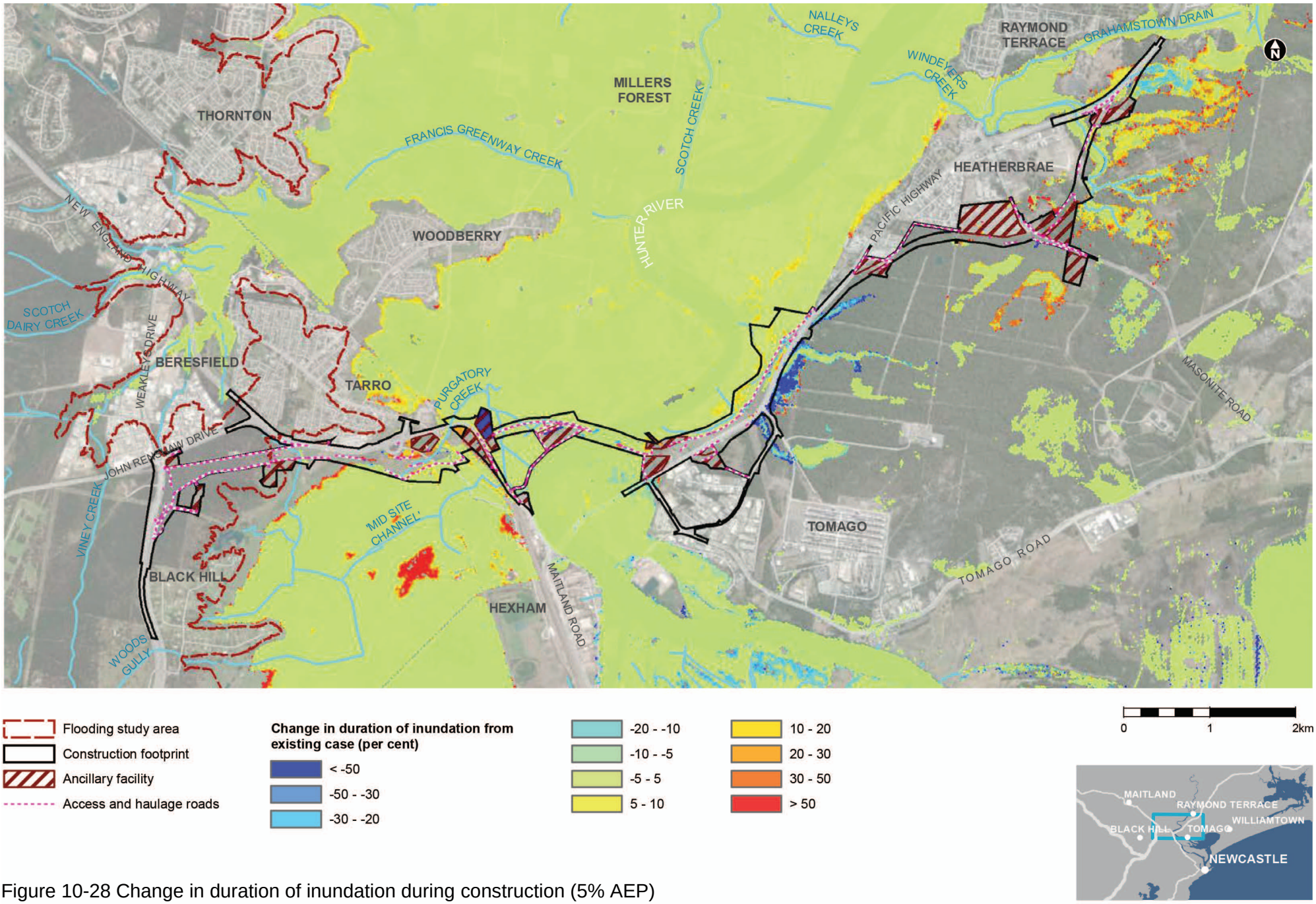


Figure 10-28 Change in duration of inundation during construction (5% AEP)

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.

[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.

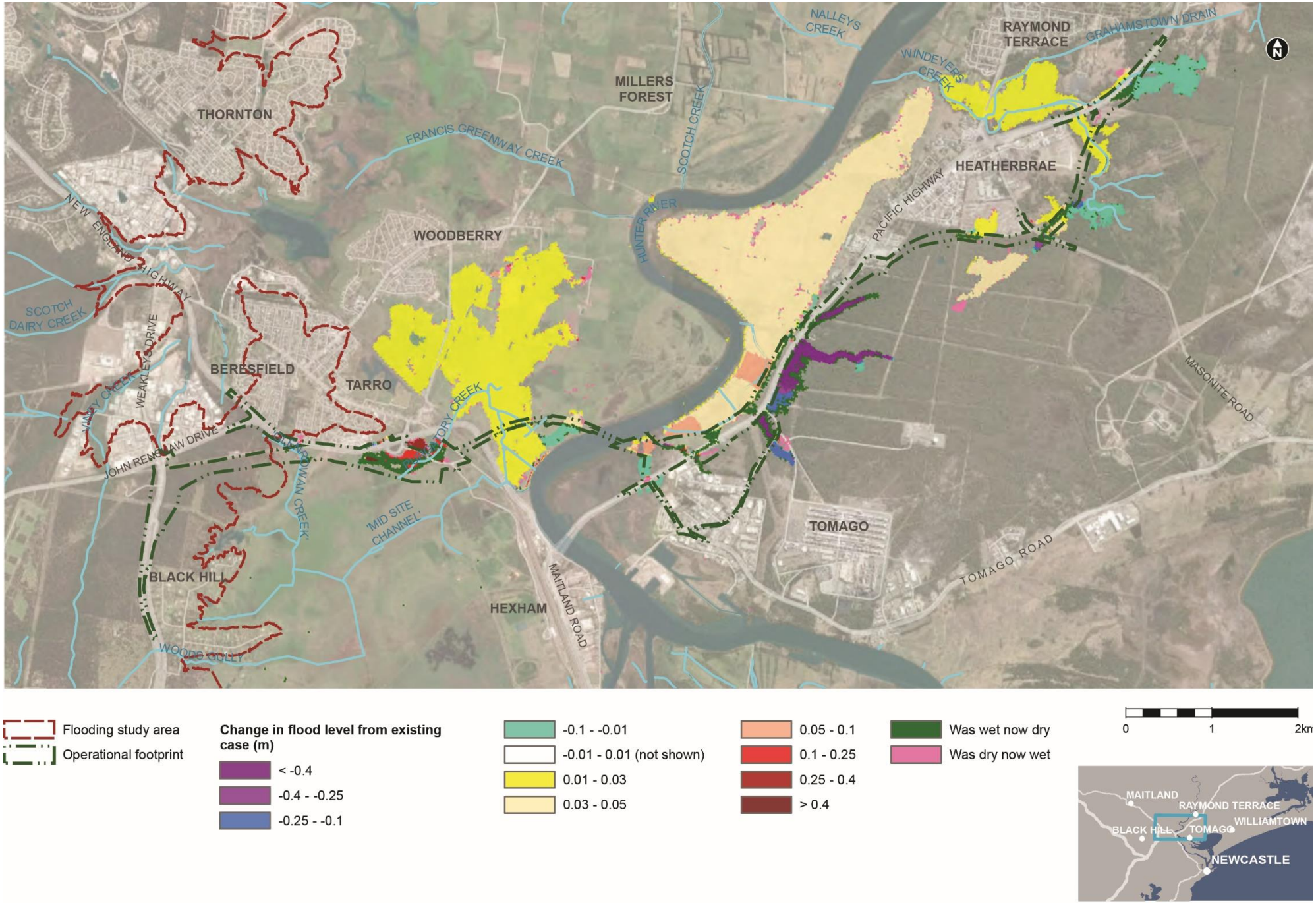


Figure 10-29 Change in flood level during operation (20% AEP)

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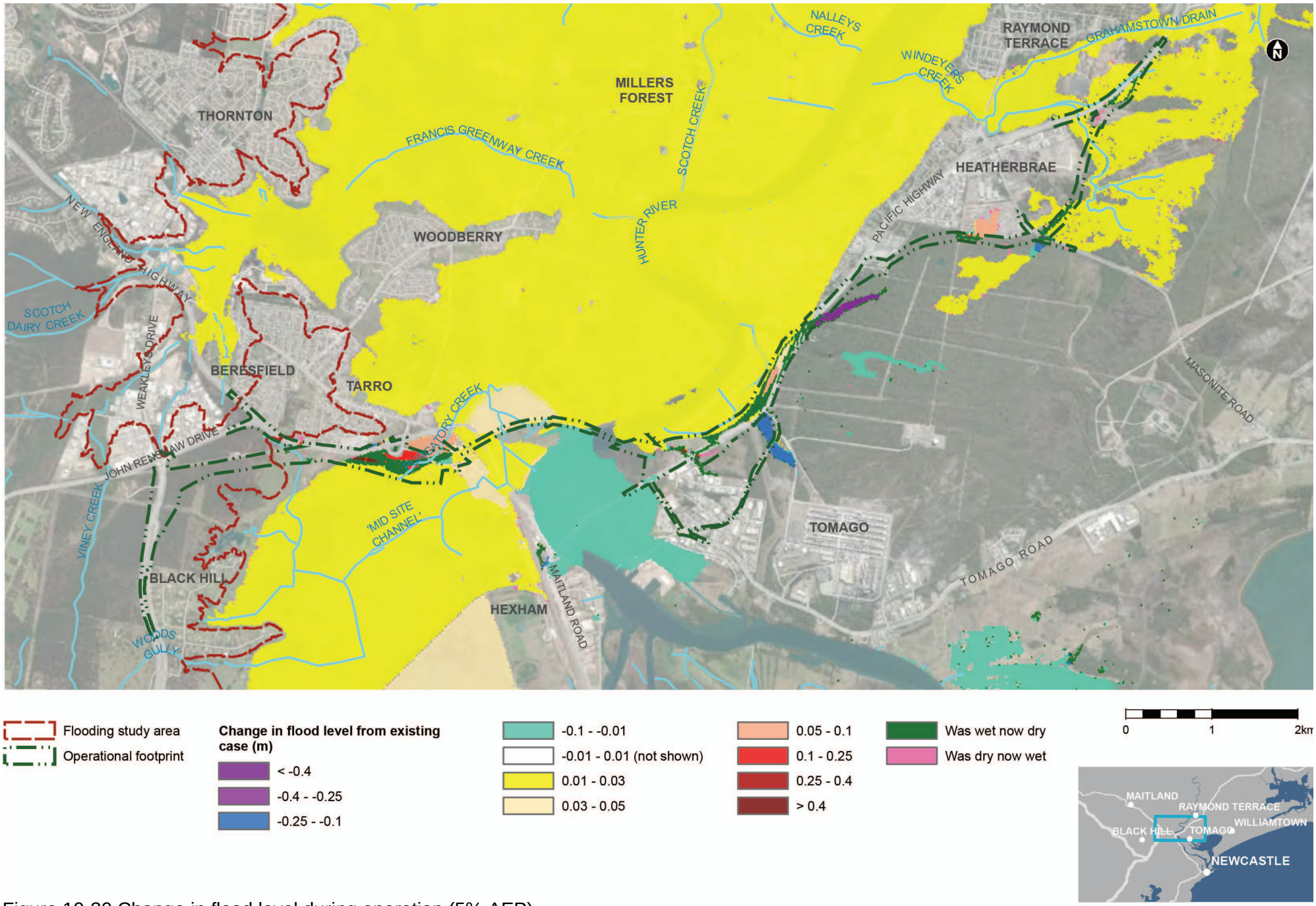


Figure 10-30 Change in flood level during operation (5% AEP)

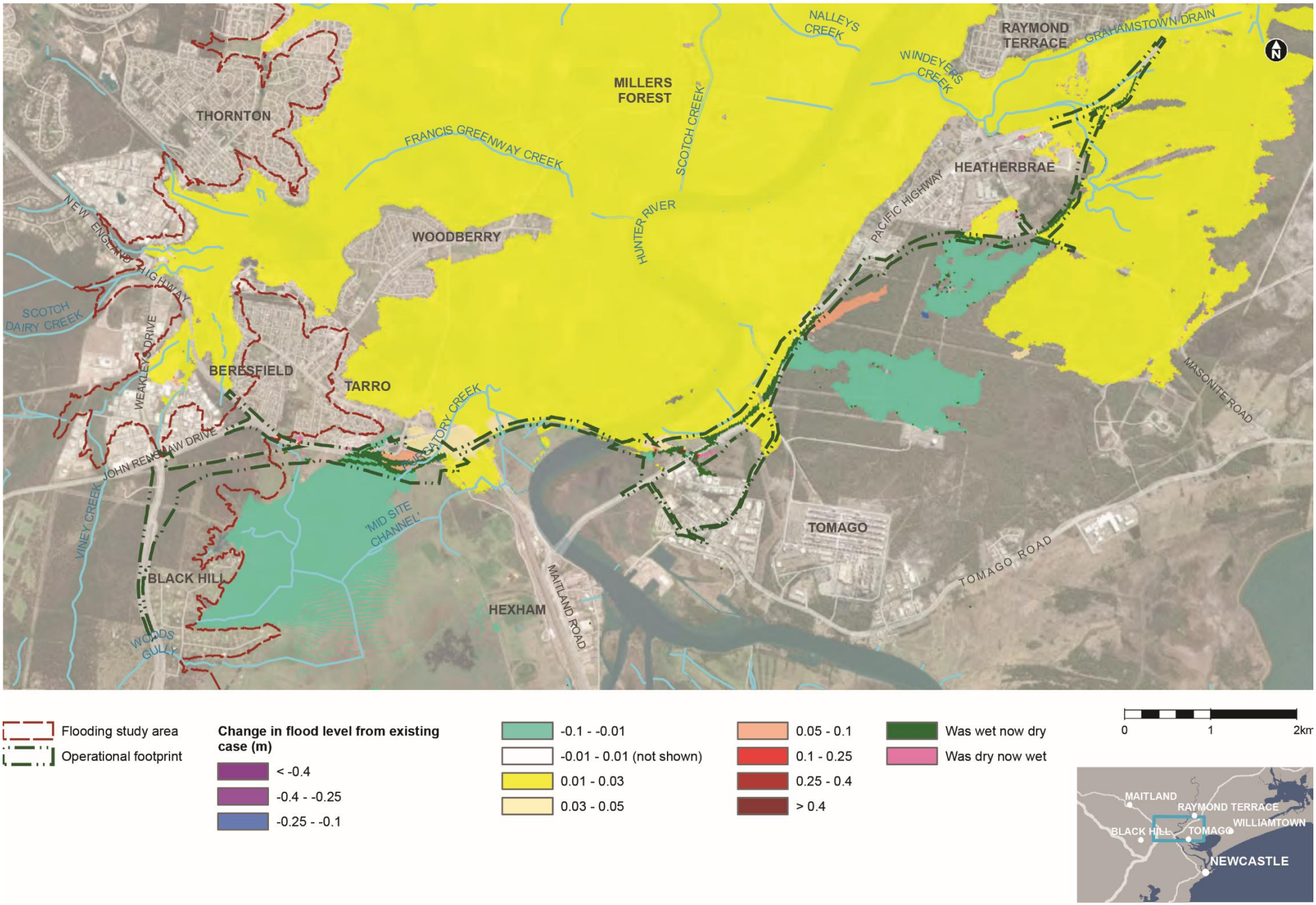


Figure 10-31 Change in flood level during operation (1% AEP)

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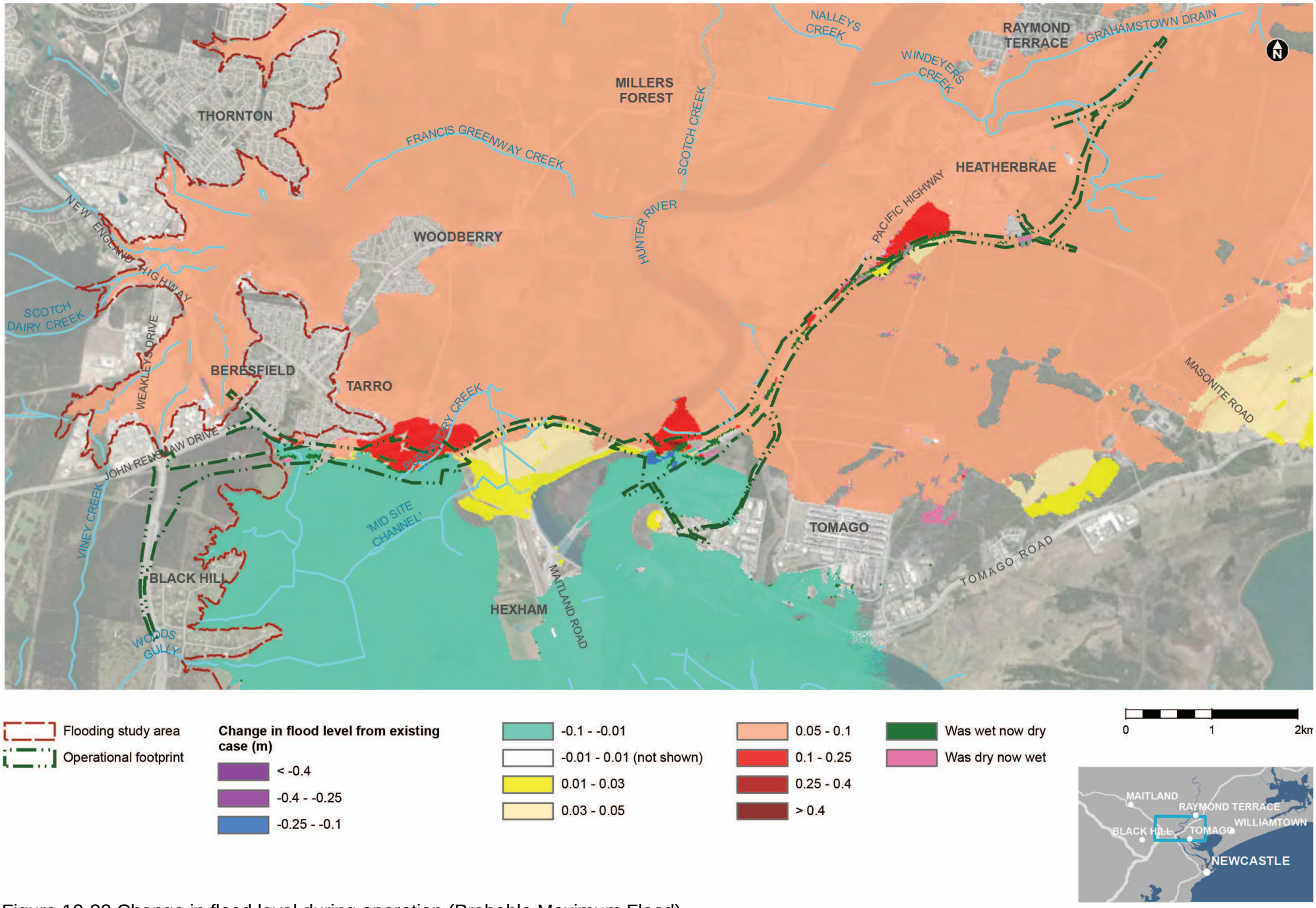


Figure 10-32 Change in flood level during operation (Probable Maximum Flood)

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.

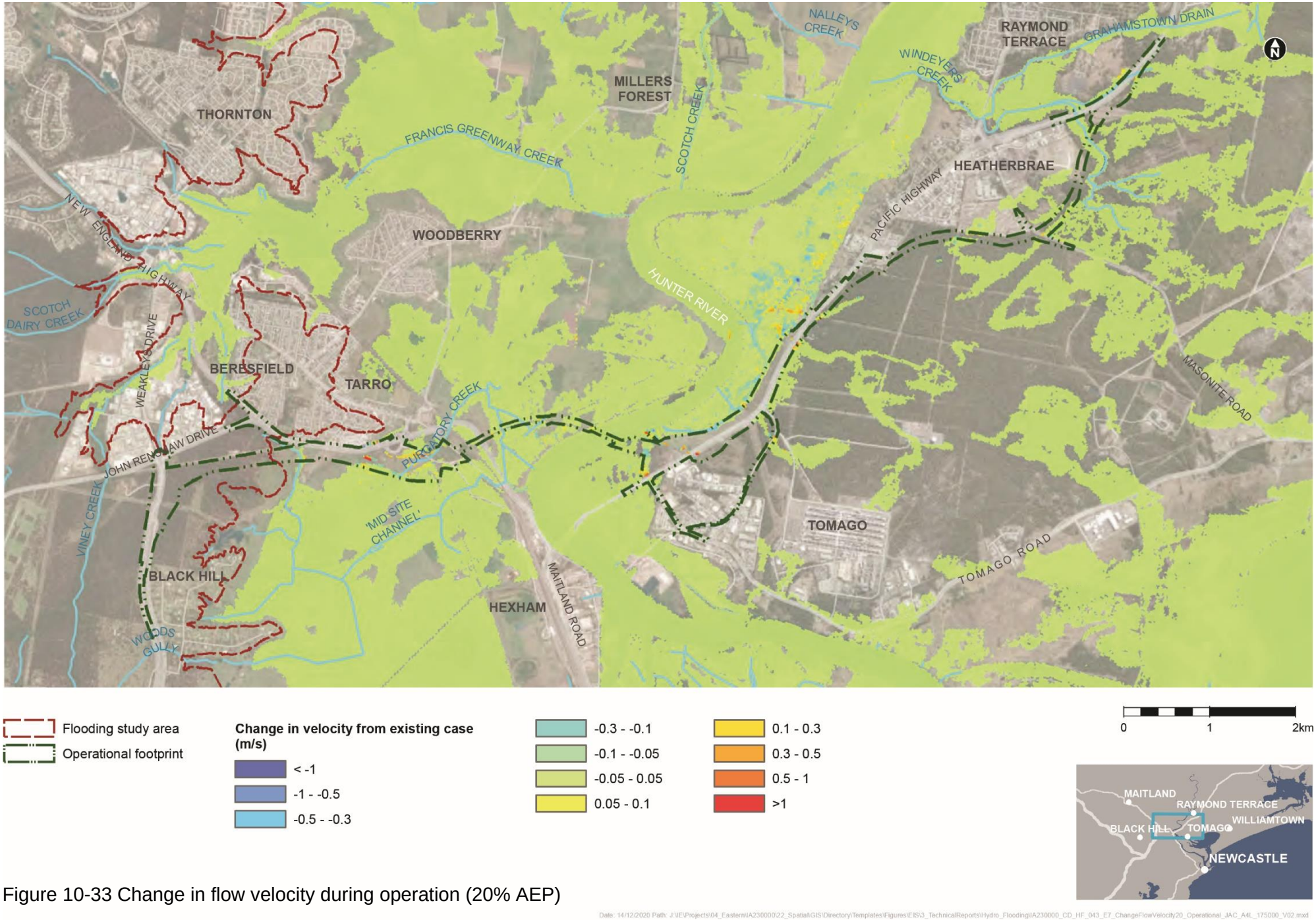


Figure 10-33 Change in flow velocity during operation (20% AEP)

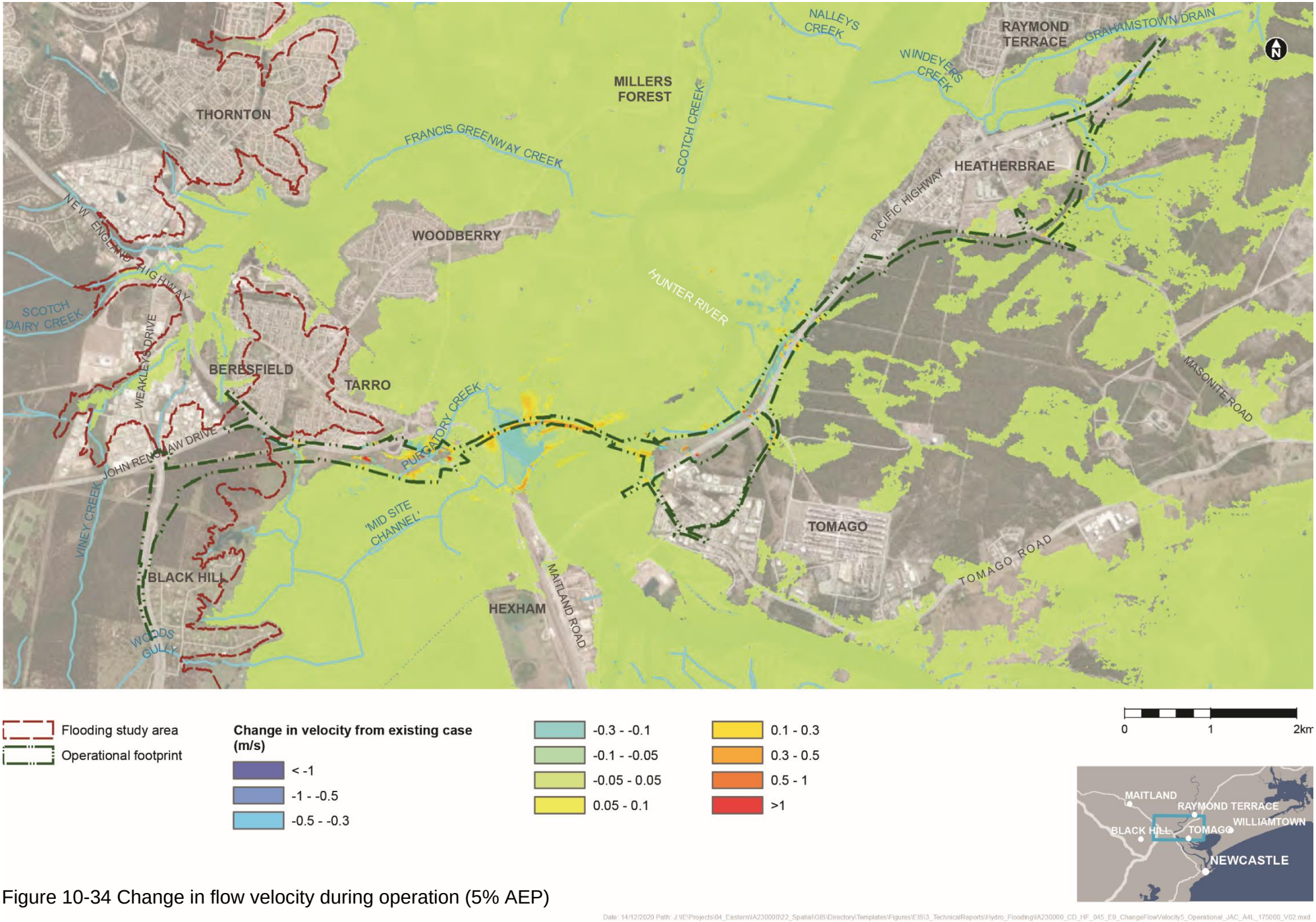


Figure 10-34 Change in flow velocity during operation (5% AEP)

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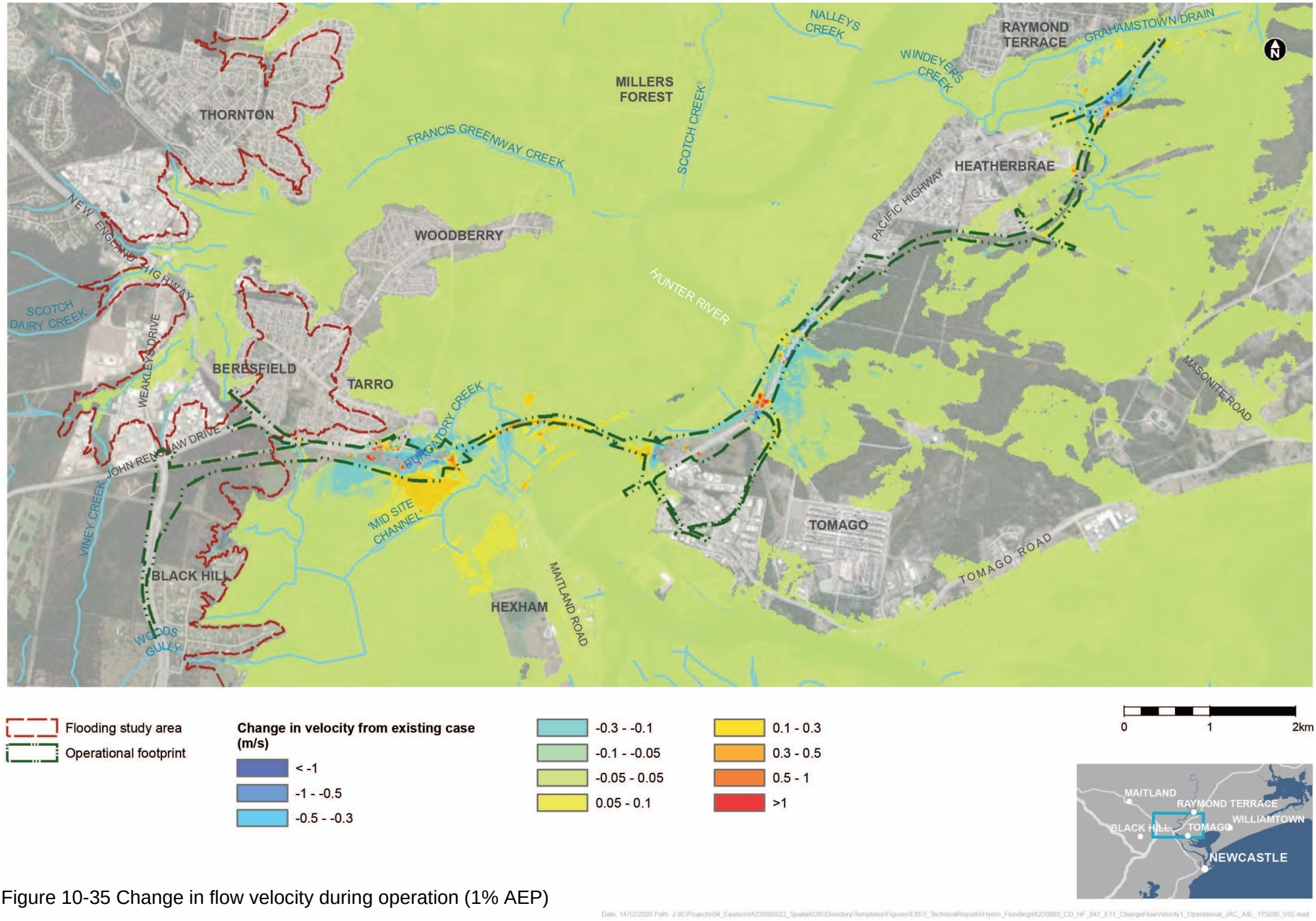


Figure 10-35 Change in flow velocity during operation (1% AEP)

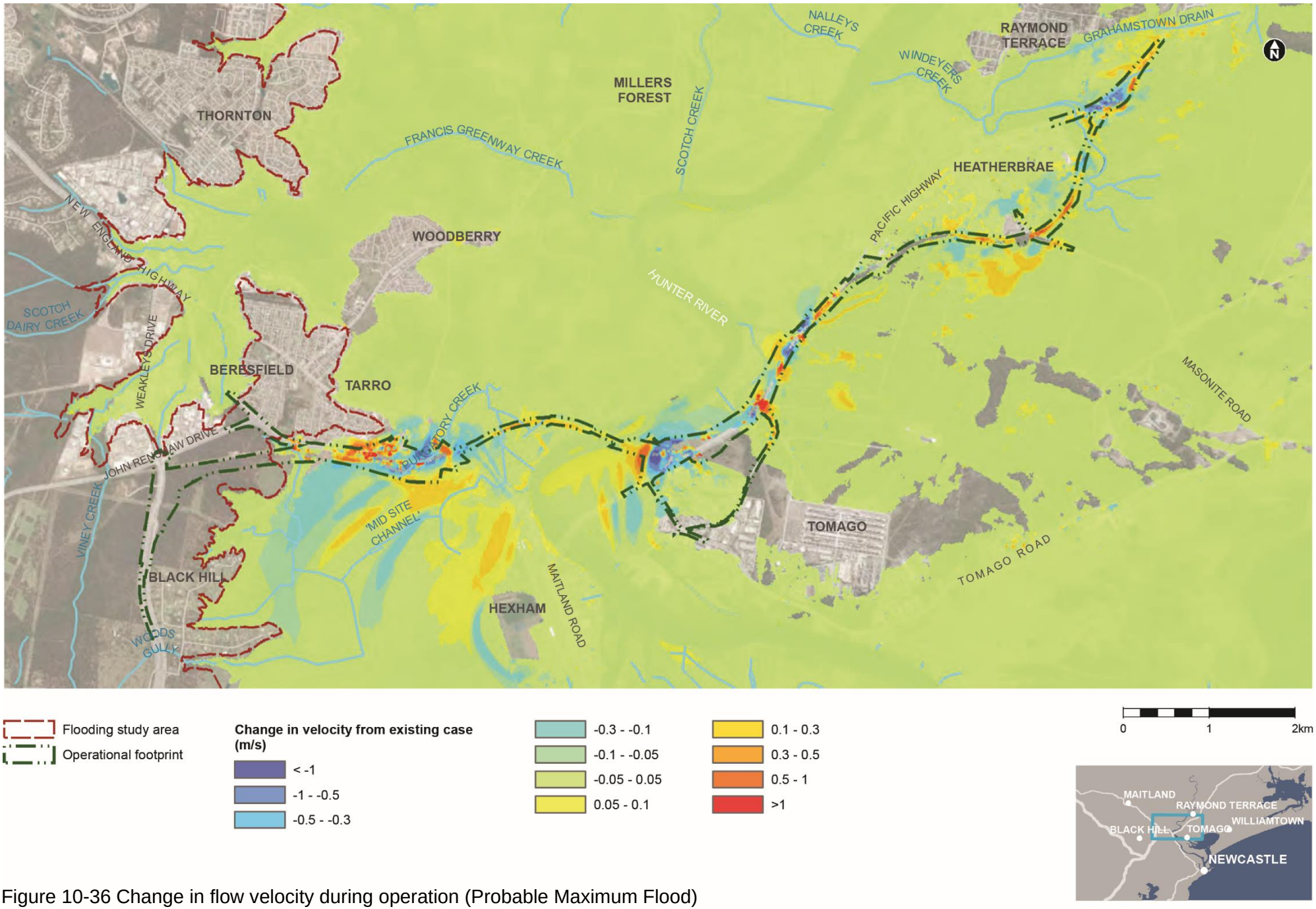


Figure 10-36 Change in flow velocity during operation (Probable Maximum Flood)

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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.

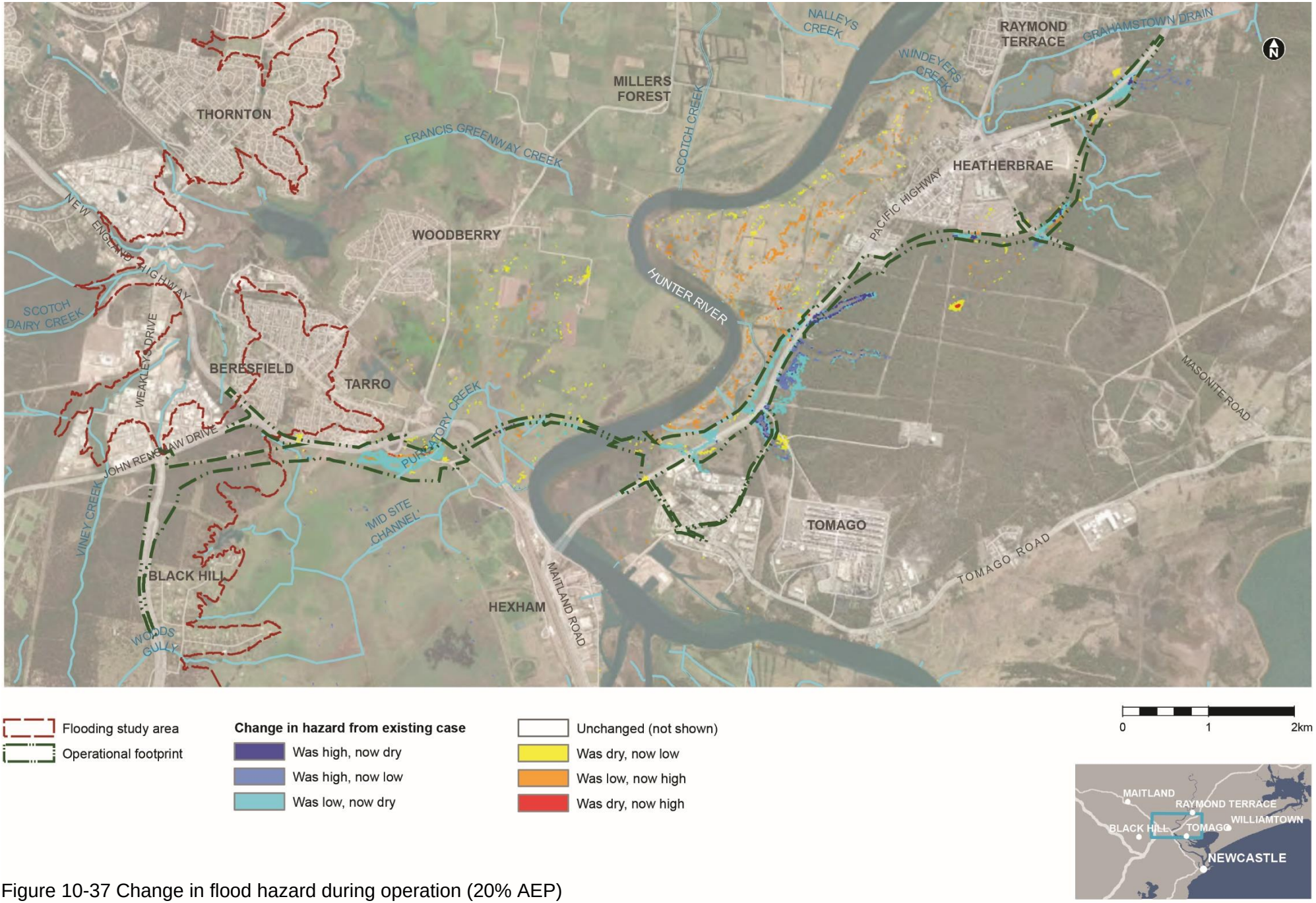


Figure 10-37 Change in flood hazard during operation (20% AEP)

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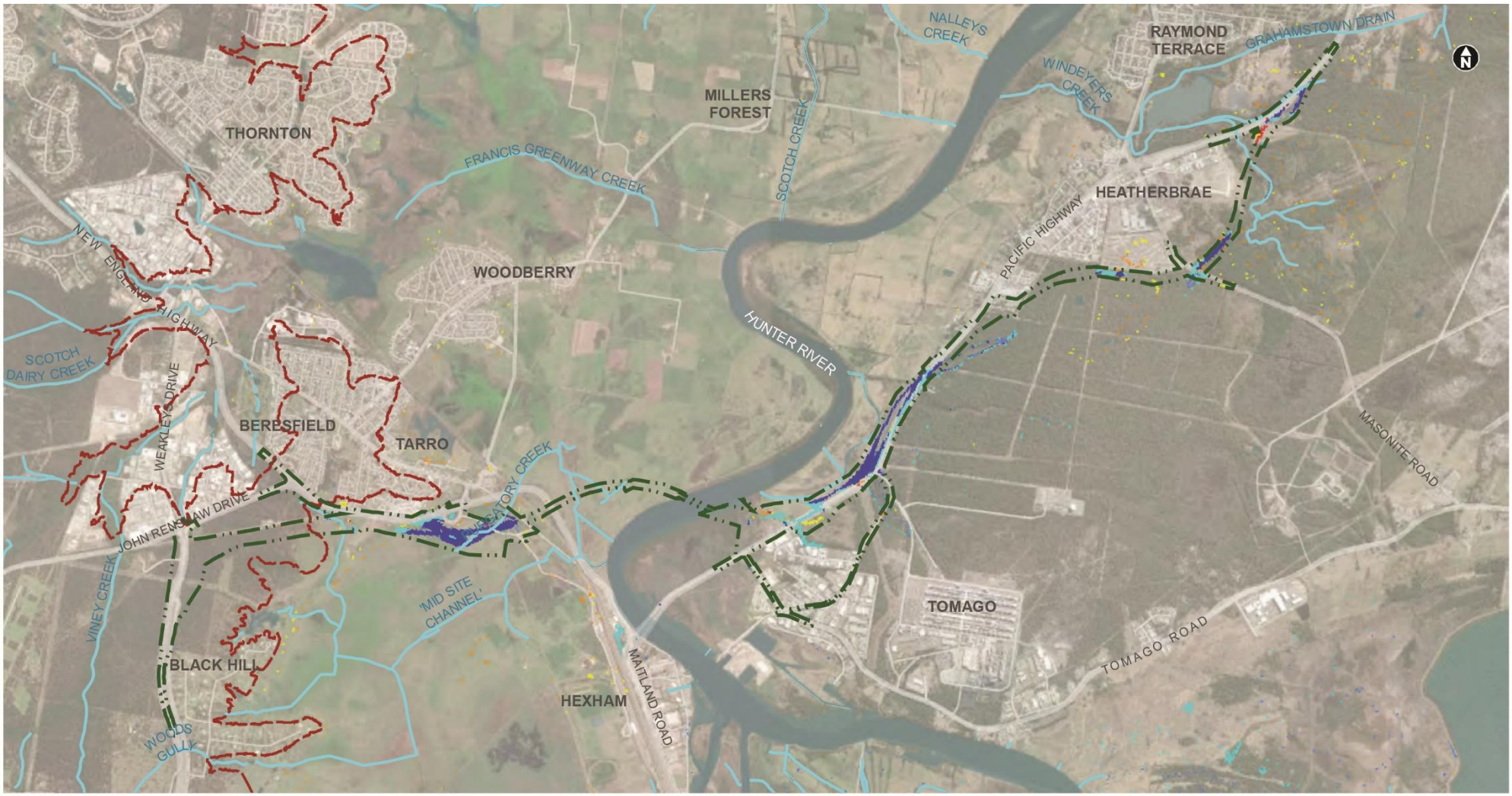


Figure 10-38 Change in flood hazard during operation (5% AEP)

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_051_E15_ChangeFloodHazard_5_Operational_JAC_A4L_175000_V02.mxd

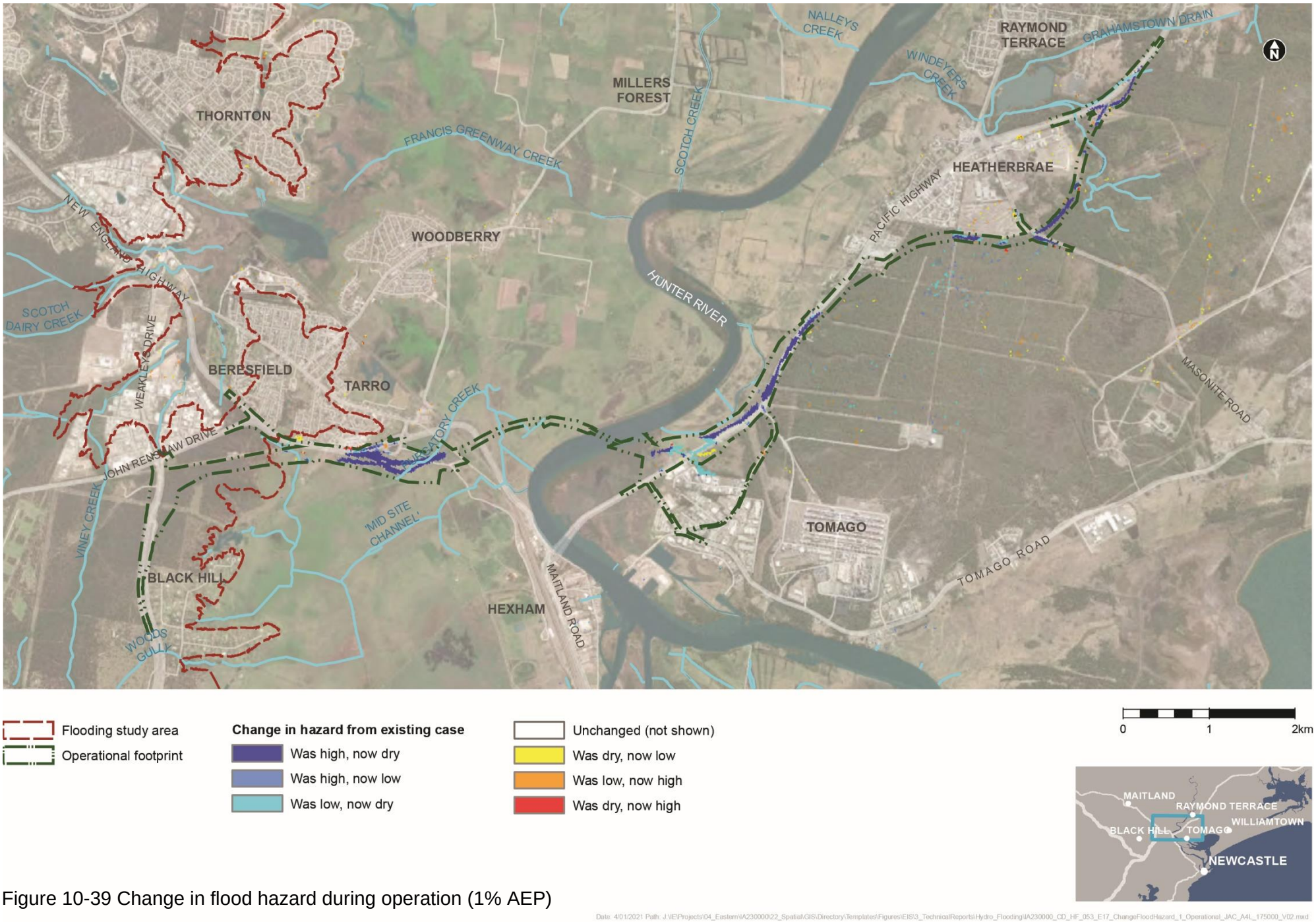


Figure 10-39 Change in flood hazard during operation (1% AEP)

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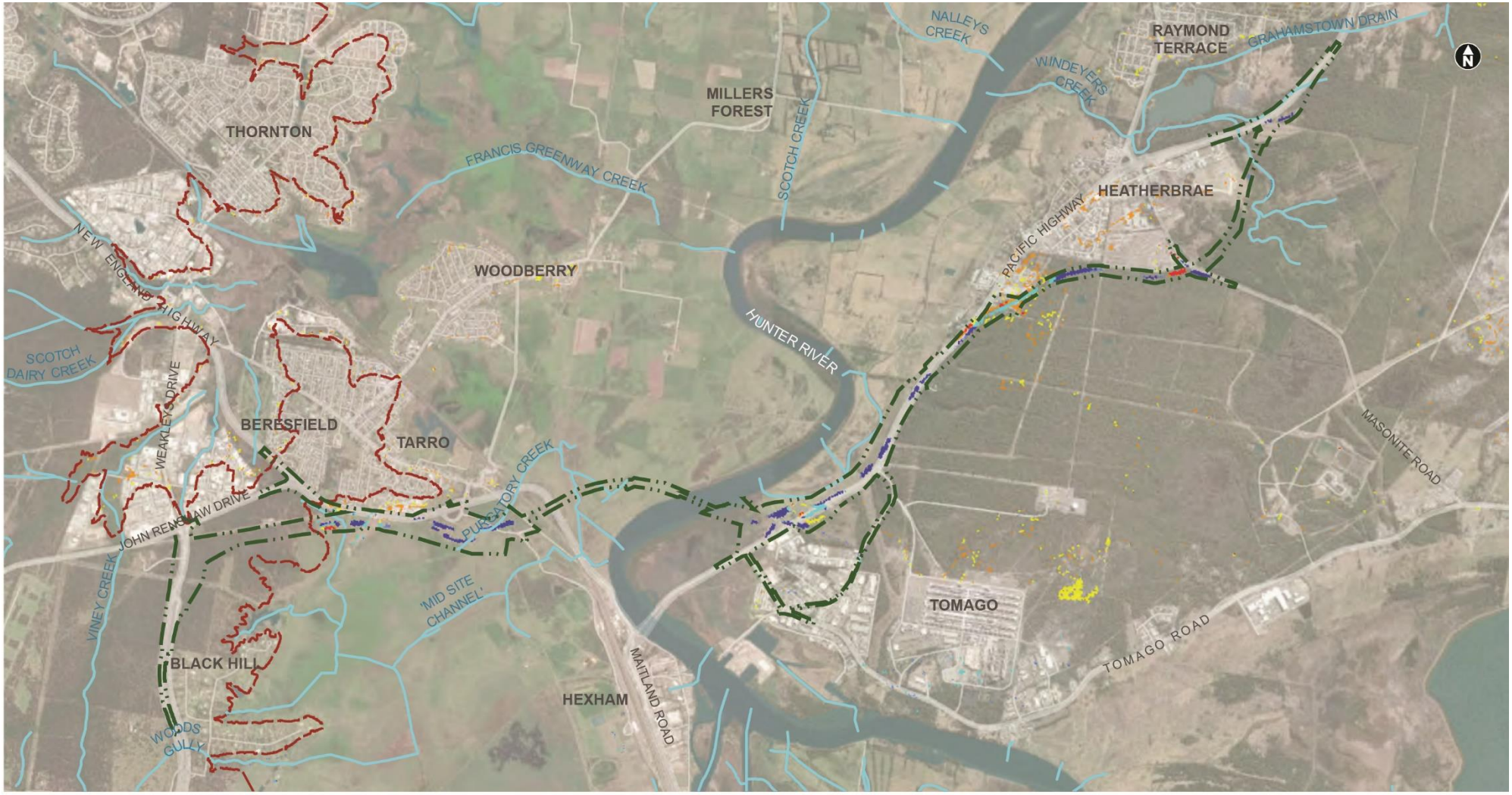


Figure 10-40 Change in flood hazard during operation (Probable Maximum Flood)

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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.

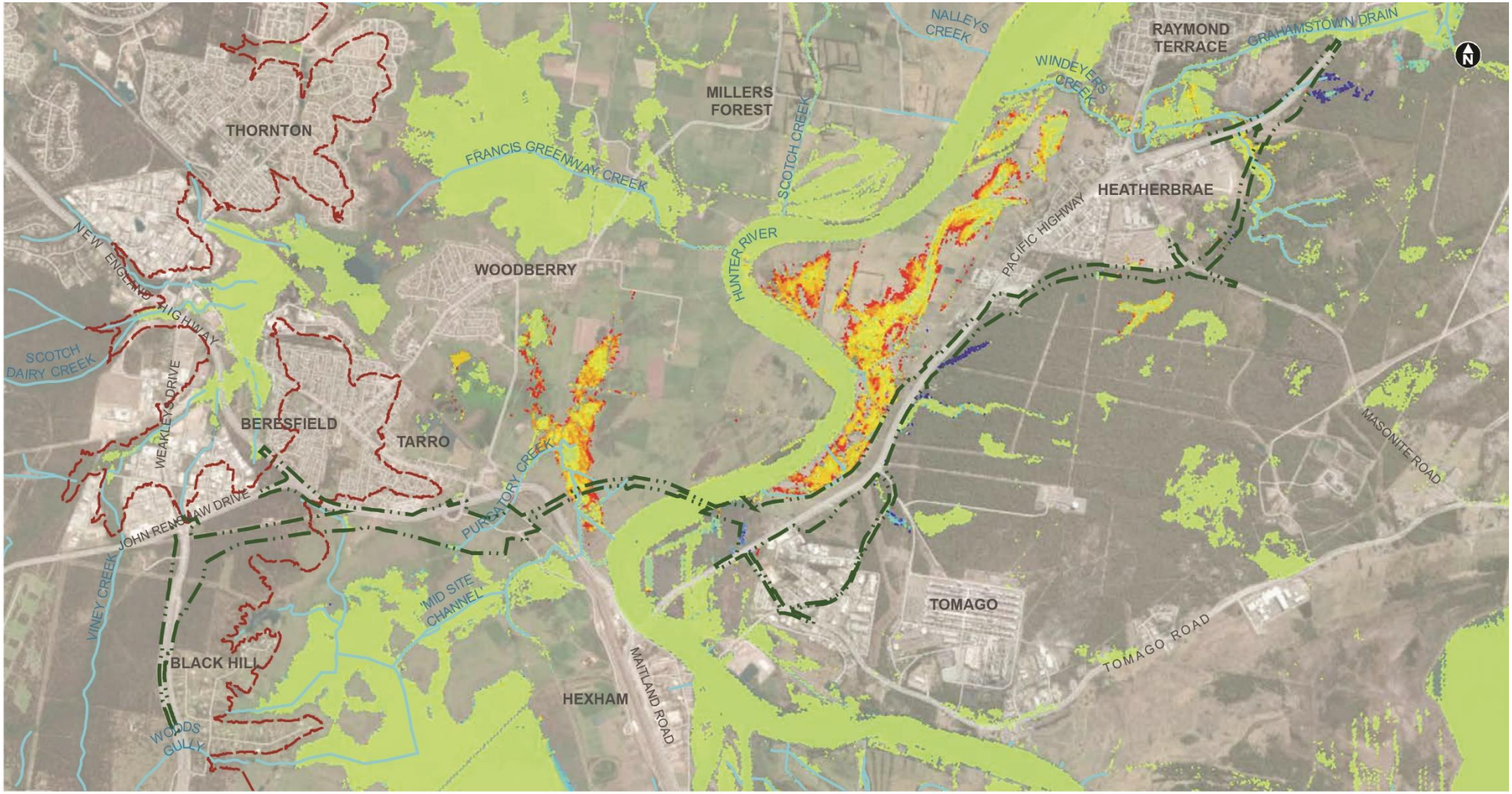


Figure 10-41 Change in duration of inundation during operation (20% AEP)

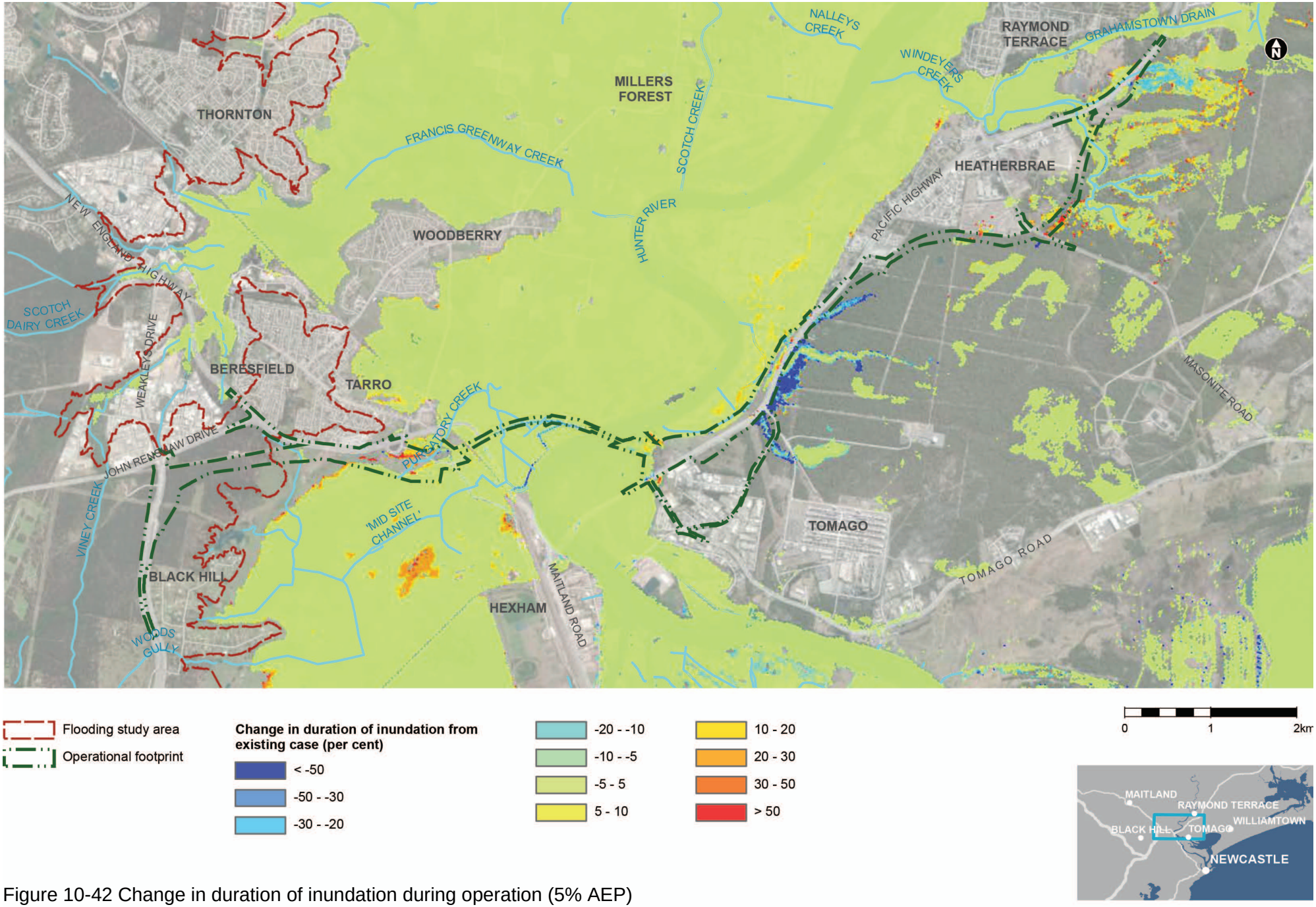


Figure 10-42 Change in duration of inundation during operation (5% AEP)

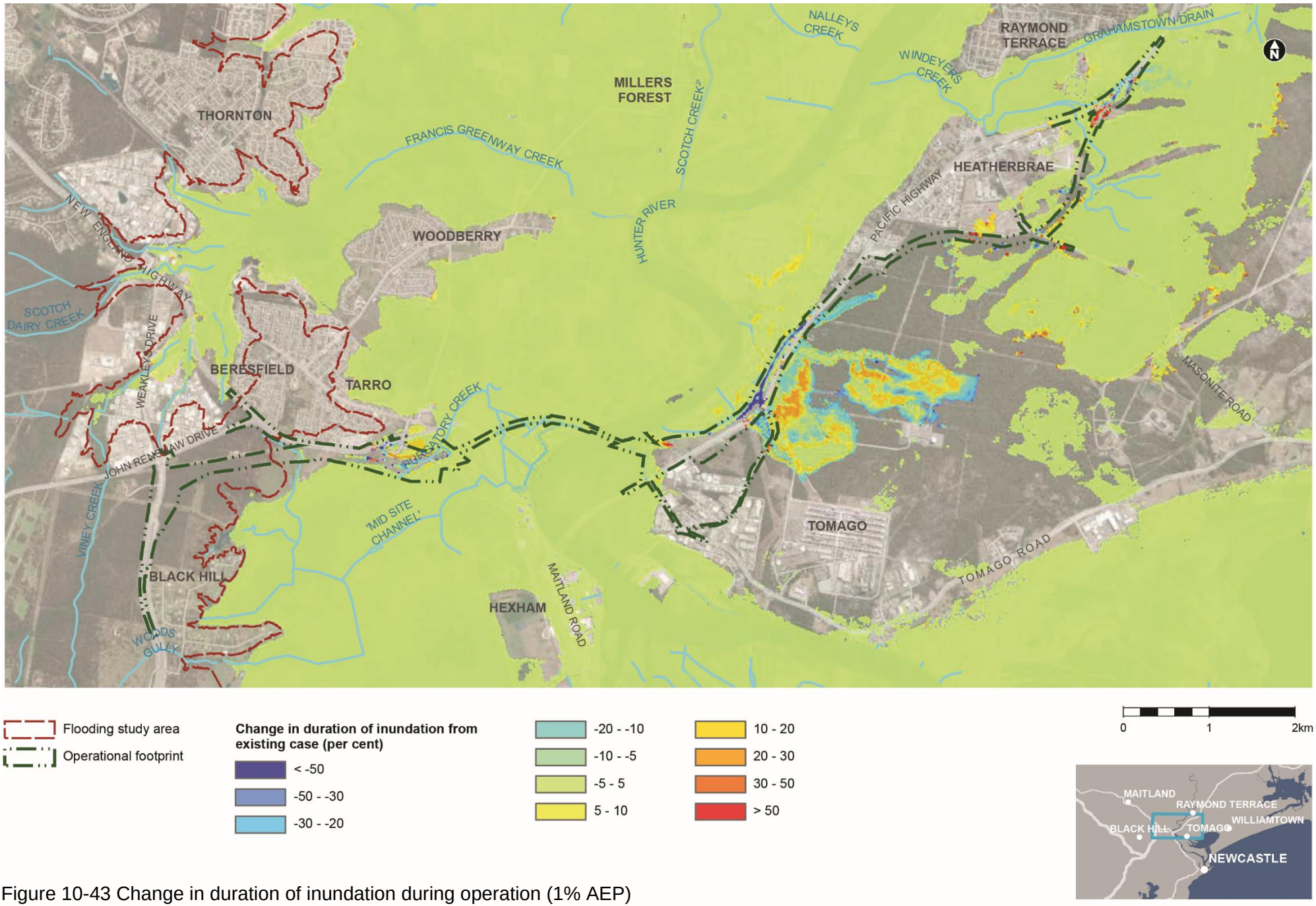


Figure 10-43 Change in duration of inundation during operation (1% AEP)

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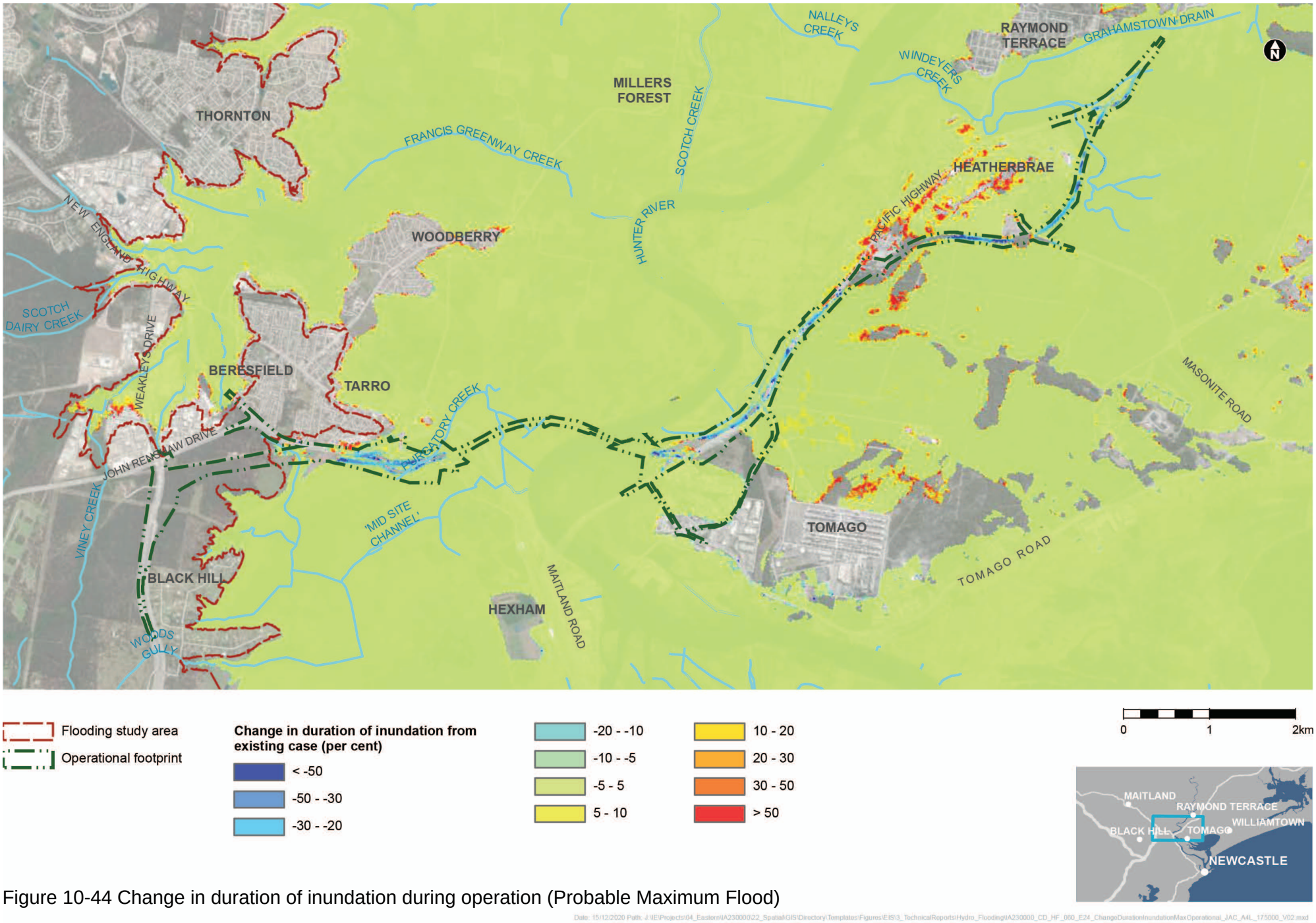


Figure 10-44 Change in duration of inundation during operation (Probable Maximum Flood)

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.

[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

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Environmental impact statement – Chapter 11: Surface water and groundwater quality

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11. Surface water and groundwater quality

This chapter describes the potential surface water and groundwater quality 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 surface water and groundwater quality, as outlined in the SEARs, are to:

- Ensure the project is designed, constructed and operated to protect the NSW Water Quality Objectives where they are currently being achieved, and contribute towards achievement of the Water Quality Objectives over time where they are currently not being achieved, including downstream of the project to the extent of the project impact including estuarine and marine waters
- Ensure that the environmental values of nearby, connected and affected water sources, groundwater and dependent ecological systems including estuarine and marine water (if applicable) are maintained (where values are achieved) or improved and maintained (where values are not achieved).

Table 11-1 outlines the SEARs that relate to surface water and groundwater quality and identifies where they are addressed in this EIS. The full assessment of surface water and groundwater quality impacts is provided in the Surface Water and Groundwater Quality Working Paper (**Appendix K**).

Table 11-1 SEARs (surface water and groundwater quality)

Secretary's requirement	Where addressed
8. Water – Quality	
1. The proponent must:	
(a) state the ambient NSW Water Quality Objectives (NSW WQO) and environmental values for the receiving waters relevant to the project, including the indicators and associated trigger values or criteria for the identified environmental values;	NSW Water Quality Objectives (NSW WQOs), associated trigger values and nominated environmental values for receiving waterways and wetlands relevant to the project are presented in **Section 11.2.4**.
(b) identify and estimate the quality and quantity of all pollutants that may be introduced into the water cycle by source and discharge point and describe the nature and degree of impact that any discharge(s) may have on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm to human health and the environment;	Pollutants that may be introduced into the water cycle by source and discharge point during construction, and their impacts to human health and the environment are discussed in **Section 11.4.2**. Estimated loads during operation and how they relate to WQOs are discussed in **Section 11.4.3**. Pollutants that may pose a risk to human health or the environment that may be introduced into the water cycle by source and discharge point during operation are discussed in **Section 11.4.3**.
(c) identify the rainfall event that the water quality protection measures will be designed to cope with;	**Section 11.4.2** identifies the rainfall event for which the water quality protection measures have been designed. Temporary sediment basin and permanent water quality basin sizing is provided in the Surface Water and Groundwater Quality Working Paper (**Appendix K**).

Secretary's requirement	Where addressed
(d) assess the significance of any identified impacts including consideration of the relevant ambient water quality outcomes;	Existing surface water quality of receiving waterways is described in **Section 11.3.1**. Identified impacts to surface water quality from construction, including impacts to water quality outcomes, are discussed in **Section 11.4.2**. Identified impacts to surface water quality from operation, including impacts to water quality outcomes, are discussed in **Section 11.4.3**.
(e) demonstrate how construction and operation of the project will, to the extent that the project can influence, ensure that: − where the NSW WQOs for receiving waters are currently being met they will continue to be protected; and − where the NSW WQOs are not currently being met, activities will work toward their achievement over time;	The NSW WQOs refer to the ANZG (2018) and other guidelines to assess compliance as further detailed in **Section 11.2**. Existing surface water quality and compliance with ANZG (2018) Water Quality Guideline values are discussed in **Section 11.3.1**. Water quality controls and management measures to protect water quality objectives are described in **Section 11.4.2**, **Section 11.4.3** and **Section 11.5**. The project's influence on meeting objectives during construction and operation is discussed in **Section 11.4.2** and **Section 11.4.3**.
(f) justify, if required, why the WQOs cannot be maintained or achieved over time;	Discussion about maintaining or achieving WQOs over time is provided in **Section 11.4.2** and **Section 11.4.3**.
(g) demonstrate that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented;	Construction and operational impacts on surface water and groundwater quality are discussed in **Section 11.4.2** and **Section 11.4.3** respectively. Avoidance of impacts to surface water and groundwater quality is discussed in **Section 11.4.1**. Water quality controls and management measures to protect human health and the environment are described in **Section 11.4.2**, **Section 11.4.3** and **Section 11.5**.
(h) identify sensitive receiving environments (including estuarine and marine waters downstream and the Tomago Sandbeds Catchment Area) and develop a strategy to avoid or minimise impacts on these environments; and	The method for identifying sensitive receiving environments (SREs) is provided in **Section 11.2.2.** SREs (including the Tomago Sandbeds Catchment Area) are discussed in **Section 11.3.3**. Water quality controls and management measures for protecting SREs are discussed in **Section 11.4.2**, **Section 11.4.3** and **Section 11.5**.
(i) identify proposed monitoring locations, monitoring frequency and indicators of surface and groundwater quality.	Proposed water monitoring locations are shown in **Figure 11-1** and discussed in **Section 11.5.1**. Water quality monitoring frequency and indicators details are provided in **Section 11.5.1**.
2. The assessment should consider the results of any current water quality studies, as available, in the project catchment.	Existing surface water quality in the surface water and groundwater study area is discussed in **Section 11.3.1** and **Section 11.3.2** respectively. Further discussion of the existing surface water and groundwater quality, including the literature sources reviewed and existing surface water quality data, is provided in the Surface Water and Groundwater Quality Working Paper (**Appendix K**).

Secretary's requirement	Where addressed
6. Soils	
5. The Proponent must assess the impacts of the project on soil salinity and how it may affect groundwater resources and hydrology.	Soil salinity impacts to surface water and groundwater quality during construction and operation are discussed in **Section 11.4.2** and **Section 11.4.3**. **Chapter 16** (soils and contamination) assesses the impacts of the project on soil salinity. Soil salinity risks in the vicinity of the project are discussed in **Section 16.3.4**.

11.1 Policy and planning setting

The surface water and groundwater quality assessment was prepared to assess the potential impacts of the project in accordance with the following relevant legislation and guidelines:

- Legislation:
  - *Environment Protection and Biodiversity Conservation Act 1999*
  - *Environmental Planning and Assessment Act 1979*
  - *Protection of the Environment Operations Act 1997*
  - *Water Management Act 2000* and *Water Act 1912*
  - *Fisheries Management Act 1994*
  - *Hunter Water Act 1991.*
- Plans and policies:
  - State Environmental Planning Policy (Coastal Management) 2018
  - NSW Aquifer Interference Policy (DPI 2012)
  - NSW Wetlands Policy
  - NSW State Rivers and Estuaries Policy.
- Guidelines:
  - Approved Methods for Sampling and Analysis of Water Pollutants in NSW (DECC 2008)
  - National Water Quality Management Strategy (Australian Government 2018)
  - NSW Water Quality and River Flow Objectives (DECCW 2006)
  - Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018)
  - Australian Drinking Water Guidelines (NHMRC 2011)
  - Managing Urban Stormwater (Volume 1 and 2) (Landcom 2004) (DECC 2008)
  - Guidelines for Controlled Activities on Waterfront Land.

Further detail on the above legislation, policies, and guidelines, and how they apply to the project, is provided in the Surface Water and Groundwater Quality Working Paper (**Appendix K**).

11.2 Assessment methodology

The assessment of surface water and groundwater quality involved:

- Carrying out a desktop review and analysis to characterise the existing environment and identify waterway and aquifer-specific risks
- Site visits and water quality monitoring to support and enhance the findings of the desktop analysis and refine the understanding of impacts (refer to **Section 11.2.3**)
- Identification and mapping of SREs (such as wetlands, marine parks and groundwater dependent ecosystems)

- Developing a numerical groundwater model to assess groundwater interaction during construction and operation of the project
- Analysis of existing water quality data from a variety of stakeholders, including Hunter Water Corporation, the former Office of Environment and Heritage (OEH, now EES Group), Australian Rail Track Corporation (ARTC), the Australian Bureau of Meteorology (BoM) and Transport (refer to **Section 11.2.5**)
- Assessing impacts from construction and operation of the project on water quality with reference to the ANZG (2018) Water Quality Guidelines, with regard to the relevant water quality objectives and environmental values as identified in the DECCW (2006) NSW Water Quality and River Flow Objectives and with reference to the minimal impact considerations of the NSW AIP (refer to **Section 11.2.6**)
- Qualitatively assessing cumulative water quality impacts by identifying major project(s) with a construction program that is likely to overlap with the project construction and/or is within the same catchment
- Identifying appropriate treatment measures to mitigate the impacts to surface water and groundwater quality resulting from project construction and operation.

Further detail on the methodology is provided in the following sections and in the Surface Water and Groundwater Quality Working Paper (**Appendix K**).

11.2.1 Study areas

The surface water study area is the area up to 500 metres from the construction and operation footprints. In addition, the Hunter Wetlands Ramsar site at Kooragang Nature Reserve has been included in the assessment despite its location outside of the nominated study area as it is a sensitive and nationally important wetland located downstream of the project on the Hunter River (about 5.1 kilometres downstream of the construction footprint).

The groundwater study area is defined as being two kilometres from the construction footprint. This area was adopted to include surrounding registered groundwater users, including the Tomago Sandbeds borefield.

The same study areas for this assessment were used in the hydrology and flooding assessment, and are shown on **Figure 10-1**.

11.2.2 Identification of sensitive receiving environments

SREs are environments that have a high conservation or community value or support ecosystems/human uses of water that are particularly sensitive to pollution or degradation of water quality. SREs relevant to the water quality assessment were identified based on the following considerations:

- Presence of Key Fish Habitat (KFH) based on NSW Fisheries KFH maps (DPI 2007)
- Presence of threatened aquatic species listed under the *Fisheries Management Act 1994* (FM Act) and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Likelihood of presence is based on threatened species distribution mapping (DPI 2016) and database searches including the Protected Matters Search Tool (DAWE, 2020), BioNet Atlas records (DPIE 2020) and Atlas of Living Australia (ALA) records (ALA 2020)
- Aquatic habitat field assessment (in accordance with the requirements of DPI (2013))
- Waterway classification (Fairfull and Witheridge 2003)
- Groundwater and surface water dependent vegetation and fauna communities listed under the BC Act and EPBC Act
- Proximity to a drinking water catchment
- Proximity to protected areas including Ramsar listed wetlands and National Parks
- Proximity to recreational swimming areas.

Areas mapped as ‘Coastal Wetlands’ under the Coastal Management SEPP that are within the construction footprint and immediately adjacent have been considered within this assessment to be SREs due to their environmental sensitivity.

SREs are described in **Section 11.3.3**.

11.2.3 Site investigations and monitoring

Project specific water quality monitoring was conducted as part of the surface water and groundwater quality impact assessment to supplement water quality data provided by external stakeholders.

Surface water quality monitoring

Surface water quality monitoring for the project was carried out in accordance with the Approved Methods for Sampling and Analysis of Water Pollutants in NSW (DEC 2008). Site visits were carried out to monitor surface water quality at representative sites and to visually assess the conditions of the waterways traversed by or in close proximity to the project.

Twenty-one monitoring locations were selected with monitoring generally carried out at the project crossing or downstream of discharge locations (as shown in **Figure 11-1**). Sampling was carried out between 2018 and 2020, with further water quality monitoring currently ongoing. The results of ongoing monitoring would be considered during the detailed design stage of the project. Monitoring dates and data are presented in the Surface Water and Groundwater Quality Working Paper (**Appendix K**).

Water quality sampling was carried out where sufficient water was present. In situ measurements were collected for temperature, electrical conductivity, salinity, oxygen reduction potential (ORP), pH, turbidity, and dissolved oxygen. For each parameter measured in situ, three replicate measurements were recorded and the average (arithmetic mean) of the measures reported. The following grab samples were collected at each site and sent to the laboratory for analysis:

- Total suspended solids (TSS)
- Turbidity
- Dissolved metals (arsenic, cadmium, chromium, copper, nickel, lead, zinc, and mercury)
- Oxidised nitrogen (NO_x)
- Total Kjeldahl Nitrogen (TKN)
- Total nitrogen (TN)
- Total phosphorus (TP)
- Enterococci.

Groundwater quality monitoring

Groundwater quality monitoring for the project was carried out in accordance with DEC (2008), the Guideline for Construction Water Quality Monitoring (RTA 2003) and the National Water Quality Management Strategy – Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC 2000).

The project has a groundwater monitoring bore network consisting of a total of 20 monitoring bores at 13 locations, comprising six single and seven paired (one deep and one shallow) installations (as shown in **Figure 11-1**). In general, three groundwater quality monitoring rounds were completed at each piezometer between September 2016 and 2017. Monitoring dates and data are presented in the Surface Water and Groundwater Quality Working Paper (**Appendix K**).

Parameters measured in situ included electrical conductivity (EC), pH, temperature, ORP and dissolved oxygen. Parameters measured through laboratory analysis included:

- Major ions and cations
- Dissolved heavy metals
- Total dissolved solids
- Nutrients
- Fluoride
- Faecal coliforms.

11.2.4 Identification of water quality criteria

Surface water criteria

Water quality objectives (WQOs) were identified for waterways within the surface water study area using NSW water quality objectives (DECCW 2006). The relevant water quality objectives endorsed within the surface water study area are provided in **Table 11-2**. The waterways within the surface water study area and their allocated category are described in **Table 11-3**, with WQOs that apply to waterway categories provided in **Figure 11-1**.

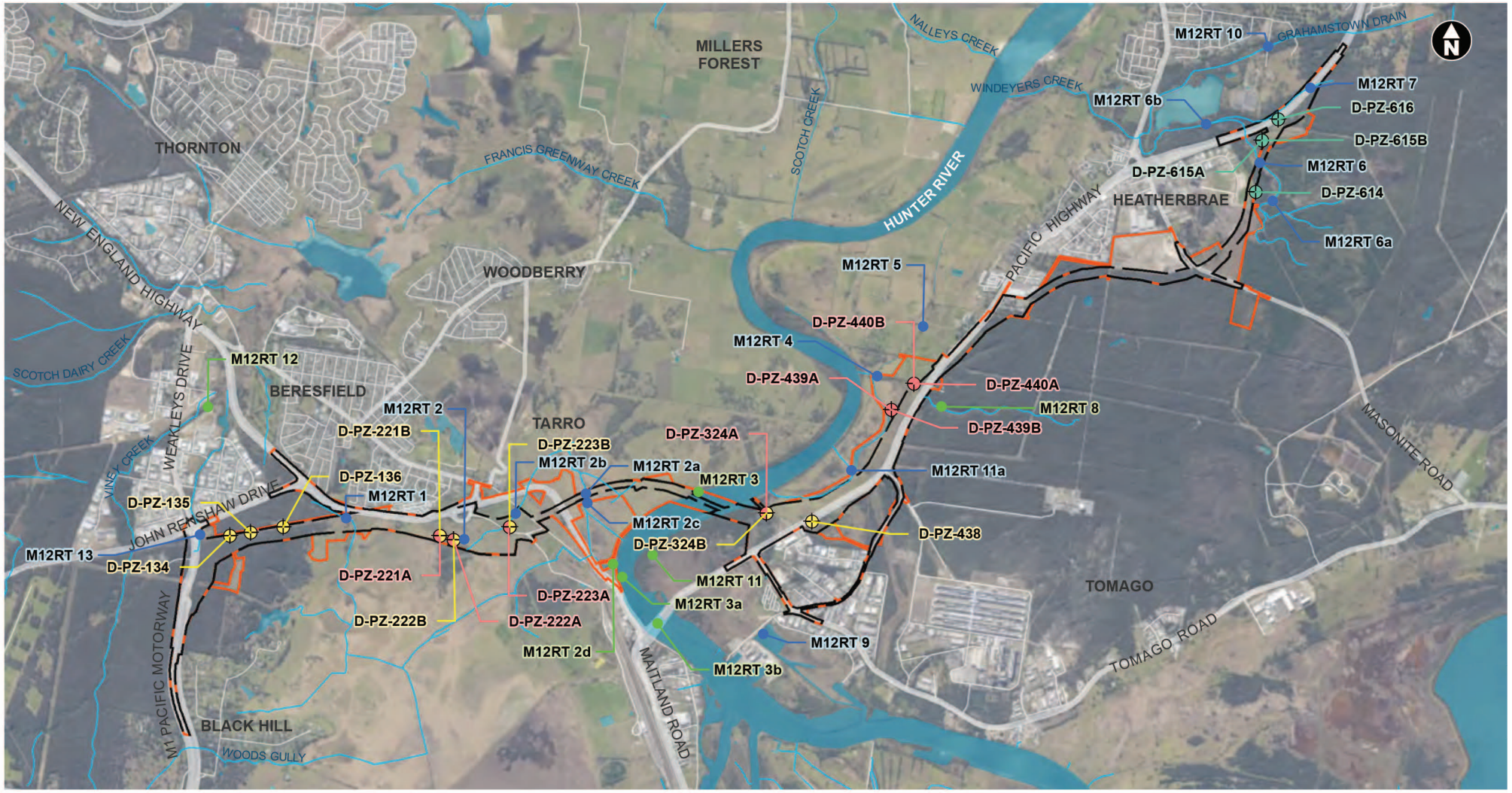
Table 11-2 NSW Water quality objectives (DGV's) for waterway categories

Category	Environmental value										
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Livestock water supply	Irrigation water supply	Homestead water supply	Drinking water at point of supply- disinfection only	Drinking water at point of supply – clarification and disinfection	Drinking water at point of supply – groundwater	Aquatic foods (cooked)
Estuaries: being dominated by saline conditions, estuary has hydraulic and water quality characteristic, and potential problems, that are often very different from those of freshwater systems	X	X	X	X							X
Town water supply sub catchments: streams or groundwater aquifers typically feed into a town's water supply	X	X								X	
Waterways affected by urban development: waterways within urban areas that are often substantially modified and generally carry poor quality stormwater	X	X	X	X							
National Parks, Nature Reserves and State Forests: streams mainly in forested areas including national parks or state forests	X	X	X	X							

Table 11-3 Assigned categories for waterways in the study area from DECCW mapping

Waterway	Category
Purgatory Creek	Estuaries
Hunter River	Estuaries
Windeyers Creek	Estuaries^
Hexham Swamp	National Parks, Nature Reserves and State Forest
Hunter River (at Raymond Terrace)	Waterways affected by urban development
Grahamstown Drain	Waterways affected by urban development
Tomago Sandbeds	Town water supply sub catchment / aquifers

^ whilst DECCW classify Windeyers Creek as estuarine, for the purposes of this assessment it has been considered as a 'lowland river' based on the absence of tidal influences in the upper reaches due to the presence of artificial barriers. As such, relevant WQO and Default Guideline Values (DGVs) applicable to this 'lowland river' have been applied for Windeyers Creek.



Construction footprint

Operational footprint

Groundwater monitoring locations

- Hunter Alluvium and Tomago Coal Measures paired bore location
- Hunter Alluvium
- Tomago Coal Measures
- Tomago Sandbeds

Surface water monitoring locations

- Monitoring site - Sensitive Receiving Environment
- Monitoring site - Non Sensitive Receiving Environment

Waterways

0 1 2 km



Figure 11-1 Water quality monitoring locations

Default guideline values (DGVs), which are nominated for water quality indicators that are associated with the WQOs, have been identified from relevant guidelines (ANZG 2018; NHMRC 2008; DECCW 2006). These DGVs are the recommended values for protecting the WQOs irrespective of existing water quality and river flow conditions in the study area. Key water quality indicators and related DGV have been nominated for each WQO and are presented in **Table 11-4**. The project's surface water quality performance has been assessed against these DGVs.

Table 11-4 Water quality indicators and associated default guideline values for water quality objectives nominated to waterways within the surface water study area

Water quality objective	Indicator	Default guideline value	
		Lowland rivers	Estuaries and marine
Aquatic ecosystems: maintaining or improving the ecological condition of waterbodies and their riparian zones over the long term	Total phosphorus	0.025mg/L	0.030mg/L
	Filterable reactive phosphorus	0.02mg/L	0.005mg/L
	Total nitrogen	0.35mg/L	0.3mg/L
	Ammonium	0.02mg/L	0.015mg/L
	Oxidised nitrogen	0.04mg/L	0.015mg/L
	Chlorophyll-a	0.003mg/L	0.004mg/L
	pH	6.5 – 8.5	7 – 8.5
	Turbidity	6 – 50 Nephelometric Turbidity Units (NTU)	0.5 – 10 NTU
	Dissolved oxygen	85 – 110%	80 – 110%
	Electrical conductivity	200 – 300 micro Siemens per centimetre (µS/cm)	N/A
	Chemical contaminants or toxicants	As per ANZG (2018)	As per ANZG (2018)
Visual amenity – aesthetic qualities of waters	Visual clarity and colour	Natural visual clarity should not be reduced by more than 20%. Natural hue of water should not be changed by more than 10 points on the Munsell Scale. The natural reflectance of the water should not be changed by more than 50%.	
	Surface films and debris	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour. Waters should be free from floating debris and matter.	
	Nuisance organisms	Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae, sewage fungus and leeches should not be present in unsightly amounts.	
Secondary contact recreation – maintaining or improving water quality for activities such as boating and wading, where there is a low probability of	Faecal coliforms, enterococci, algae, and blue-green algae	Median over bathing season of <230 enterococci per 100mL (maximum number in any one sample: 450-700 organisms/100mL) Median over bathing season of <1000 faecal coliforms per 100mL, with 4 out of 5 samples <4000/100mL Algae: <15000 cells/mL.	
	Nuisance organisms	As per the visual amenity guidelines Large numbers of midges and aquatic worms are undesirable.	

Water quality objective	Indicator	Default guideline value	
		Lowland rivers	Estuaries and marine
water being swallowed	Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucous membranes are unsuitable for recreation. Toxic substances should not exceed values in Table 9.3 of NHMRC (2008) Guidelines.	
	Visual clarity and colour	As per the visual amenity guidelines.	
	Surface films	As per the visual amenity guidelines.	
Primary contact recreation – maintaining or improving water quality for activities such as swimming where there is a high probability of water being swallowed	Faecal coliforms, enterococci, algae, and blue-green algae	Median over bathing season of <35 enterococci per 100mL (maximum number in any one sample: 60 – 100 organisms/100mL) Median over bathing season of <150 faecal coliforms per 100mL, with 4 out of 5 samples <600/100mL Algae: <15000 cells/mL.	
	Protozoans	Pathogenic free-living protozoans should be absent from bodies of fresh water.	
	Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucus membranes are unsuitable for recreation. Toxic substances should not exceed values in Table 9.2 of NHMRC (2008) guidelines.	
	Visual clarity and colour	As per the visual amenity guidelines.	
	Temperature	15°– 35°C for prolonged exposure	
Aquatic foods (cooked) – refers to protecting water quality so that it is suitable for production of aquatic foods for human consumption and aquaculture activities	Algae and blue-green algae	No guidelines are directly applicable, but toxins present in blue-green algae may accumulated in other aquatic organisms.	
	Faecal coliforms	Guideline in water for shellfish: The median faecal coliform concentration should not exceed 14 Most Probable Number (MPN)/100mL; with no more than 10 per cent of the samples exceeding 43 MPN/100mL. Standard in edible tissue: Fish destined for human consumption should not exceed a limit of 2.3 MPN E Coli/g of flesh with a standard plate count of 100,000 organisms/g.	
	Toxicants (as applied to aquaculture activities)	Metals: Copper: less than 0.005mg/L Mercury: less than 0.001mg/L Zinc: less than 0.005mg/L. Organochlorines: Chlordane: less than 0.004mg/L (saltwater production) PCBs: less than 0.002mg/L.	
	Physico-chemical indicators (as applied to aquaculture activities)	Suspended solids: less than 40mg/L (freshwater), 10mg/L (marine) Temperature: less than 2°C change over one hour.	

Groundwater

Groundwater quality criteria adopted for the project include:

- The NSW AIP (2012) beneficial use categories for in situ groundwater
- The Australian Drinking Water Guidelines (ADWG) for groundwater specifically within the Tomago Sandbeds Catchment Area
- Corresponding surface water quality criteria where groundwater would be extracted and discharged.

These criteria have been adopted for each groundwater source as described in **Table 11-5**. The water quality indicators and DGVs for groundwater sources are provided in **Table 11-4**.

Table 11-5 Groundwater sources in groundwater study area and adopted categories

Groundwater source	In situ category	Discharge category^
Hunter Alluvium (Hunter floodplain)	Beneficial use criteria – industrial water	Estuarine
Tomago Coal Measures	Beneficial use criteria – industrial water	Lowland River
Tomago Sandbeds	Beneficial use criteria – aquatic ecosystems / drinking water	Lowland River

^ for discharge categories classified as estuarine, the DGVs for toxicants in marine water apply. For discharge categories classified as lowland river, the DGVs for toxicants in freshwater apply

11.2.5 Data analysis

Water quality data used in this report is sourced from a variety of stakeholders including Hunter Water Corporation, Environment, Energy and Science (EES) Group (formerly OEH), ARTC, Bureau of Meteorology (BoM) and Transport. Each organisation has its own monitoring objectives for their monitoring and as such, data is variable throughout the catchment, spatially and temporarily and also vary in the types of indicators that are monitored. Some organisations have routine monitoring programs, while others only monitor water quality for specific projects. Further detail on the data used for the surface water and groundwater quality assessment is provided in the Surface Water and Groundwater Quality Working Paper (**Appendix K**).

Surface water

The data used to inform the surface water quality assessment is generally from 2011 onwards and is considered most representative of contemporary water quality. No minimum number of results was applied to the dataset due to a shortage in data. The location of monitoring sites is shown on **Figure 11-1**.

Data was analysed to determine water quality criteria exceedances for each site, and involved:

- Collating water quality data into a spreadsheet
- Calculating summary statistics for each site including number of samples, mean, median, maximum, and minimum value and the number and percentage of samples outside the guideline range
- Reporting compliance of the data using colour coded symbols for each of the different nominated WQOs, with respect to the percentage of samples that achieved WQOs. Colours and rating for compliance are outlined in **Table 11-6**.

Table 11-6 Compliance against water quality objectives

Per cent compliance	Colour and rating
75.1% – 100%	Good
50.1% – 75%	Fair
25.1% – 50%	Poor
0 – 25%	Very poor
Insufficient data	N/A

Non-compliance was determined when any single WQO indicator failed to meet the relevant guideline value.

Groundwater

For groundwater, five Hunter Water Corporation bores installed within the Tomago Sandbeds Catchment Area were used to inform the groundwater assessment. While not specifically located within the groundwater study area, the data are considered representative of the Tomago Sandbeds aquifer and drinking water resource within the study area.

Three rounds of groundwater quality sampling results from between August and September 2013 were available for each bore. In addition, available groundwater salinity data from the BOM's (2020) Australian Groundwater Explorer was reviewed to assess existing bore water salinity.

11.2.6 Impact assessment methodology

The assessment methodology for potential construction and operational impacts relating to surface water and groundwater quality are detailed in the sections below. Flows from Hunter River tributaries within the study area are controlled by floodgates, and therefore sediment and associated contaminants would likely be deposited in the disturbed waterways upstream of the floodgates and not reach the Hunter River.

Construction impacts

The assessment of potential impacts to surface water quality during construction involved:

- Identification of unmitigated risks to surface water quality from the construction activities (as described in **Section 5.4**)
- Identification of impacts to downstream waterways and SREs
- Assessment of impacts to the nominated WQOs of aquatic ecosystems, visual amenity, primary and secondary contact recreation and aquatic foods (cooked) with consideration to the criteria described in **Section 11.2.4**
- Assessment of construction related impacts and changes in water quality to the receiving environment
- A dilution assessment to estimate the reduction in TSS concentrations from temporary sediment basin discharges into the Hunter River at the Hunter Estuary Wetlands Ramsar site downstream of the project. Flow from all other waterways within the study area are controlled by floodgates and therefore it is unlikely that any construction discharges to these waterways would reach the Hunter River
- Calculation of TSS annual average loads and maximum TSS discharges from temporary sediment basins during controlled and overflow conditions and assessment against WQOs for turbidity
- Identification of water quality treatment measures to mitigate the impacts of construction in accordance with ANZG (2018).

Assessment of impacts to groundwater quality during construction involved:

- Identification of unmitigated risks to groundwater quality from the construction activities (as described in **Section 5.4**)
- Identification of impacts to downstream users and SREs
- Assessment of impacts to groundwater quality within the Tomago Sandbeds Catchment Area
- Assessment of impacts to the relevant beneficial use of groundwater with consideration of the NSW AIP minimal impact considerations
- Identification of water quality treatment measures and other environmental management measures to mitigate the impacts.

Operational impacts

Assessment of potential impacts to surface water quality during operation involved:

- Assessment of operation impacts to water quality to receiving environments
- Identification of unmitigated risks to surface water quality from project operation
- Identification of impacts to downstream waterways and SREs
- Assessment of increased pollutant loading at each of the SREs or downstream waterways by considering the increase in impervious surfaces within each of their catchments
- Modelling of surface water pollutant loads and stormwater runoff discharges from the operational project
- Comparison of modelled pollutant loading and mean concentrations to existing water quality and the criteria described in **Section 11.2.4**
- Estimation of permanent water quality basin discharge concentrations of TSS, TN and TP at the Hunter Estuary Wetlands Ramsar site downstream of the Hunter River
- Identification of water quality controls to treat project runoff
- Identification of appropriate treatment measures to mitigate the residual impact of project operation.

Assessment of impacts to groundwater quality during operation involved:

- Identification of unmitigated risks to groundwater quality from project operation
- Identification of impacts to downstream users and SREs
- Assessment of impacts to groundwater quality within the Tomago Sandbeds Catchment Area
- Assessment of impacts to the relevant beneficial use of groundwater with consideration to the NSW AIP
- Identification of water quality treatment measures and other environmental management measures to mitigate impacts.

11.3 Existing environment

An overview of the catchment, topography and climate of the surface water and groundwater study areas is described in **Section 10.3**.

11.3.1 Existing surface water quality

Waterways and wetlands within the surface water study area are shown in **Figure 10-4**.

Table 11-7 summarises the existing water quality compliance with the ANZG (2018) Water Quality Guidelines default guideline values for the protection of aquatic ecosystems for slightly to moderately disturbed ecosystems (95 per cent level of species protection). These values are recommended thresholds. If an indicator or indicators fall outside of the threshold(s), it assumes that the environmental value is not being protected or requires further assessment.

The protection of the aquatic ecosystems WQO provides the most conservative water quality criteria of all nominated WQOs (for indicators relevant to the proposed work). Therefore, by meeting the protection of aquatic ecosystems, all other relevant values will be protected. Further detail of existing surface water quality is provided in **Table 11-8**.

Table 11-7 Summary of existing water quality compliance with recommended ANZG (2018) thresholds for aquatic ecosystems

Waterway/wetland	**Description of existing water quality (with reference to aquatic ecosystem values)**	
	Wet	**Dry**
Viney Creek	Very poor	Very poor
Glenrowan Creek	Very poor	Very poor
Purgatory Creek	Very poor	Very poor
Hexham Swamp Nature Reserve	Poor	Poor
Mid Site Channel	N/A – no wet weather samples	Very poor
Hunter River main stream	Poor	Very poor
Hunter River Drain	Very poor	Very poor
Hunter River wetland	Very poor	Very poor
Drainage canal, Old Punt Road	Very poor	Very poor
Unnamed Coastal Wetland	N/A – no wet weather samples	Very poor
Windeyers Creek	Very poor	Very poor
Grahamstown Drain	Very poor	Very poor

Table 11-8 Summary of existing water quality compliance with recommended ANZG (2018) thresholds for other relevant values

Waterway / wetland	Compliance with ANZG (2018) guideline values				
	Aquatic ecosystems	**Visual amenity**	**Primary contact recreation**	**Secondary contact recreation**	**Aquatic foods (cooked)**
Viney Creek	Currently not being protected (very poor during both dry and wet weather) due to: • Nutrient concentrations, electrical conductivity and turbidity were higher than the DGVs • Dissolved oxygen levels were lower than the DGV range • Apart from zinc, all other metals were below DGVs	Currently not being protected due to: • Murky, stagnant, odorous water with limited transparency during dry weather • Turbid with oily sheens during dry weather	Currently not being protected due to: • Median enterococci exceed the recommended threshold	Currently not being protected due to: • Median enterococci exceed the recommended threshold	-
Glenrowan Creek	Currently not being protected (very poor during both dry and wet weather) due to: • pH, turbidity, and electrical conductivity met the DGV • Metal concentrations were low and compliant with DGVs, with the exception of copper and zinc, which exceeded DGVs • Total nitrogen concentrations and total phosphorus concentrations were higher than DGVs • Dissolved oxygen levels were lower than the DGV range	Currently not being protected due to: • Presence of floating debris and nuisance organisms such as algae and aquatic weeds • Translucent brown water during dry conditions • Murky, cloudy water following rainfall	Currently not being protected due to: • Median enterococci exceed the recommended threshold.	Currently being protected	-

Waterway / wetland	Compliance with ANZG (2018) guideline values				
	Aquatic ecosystems	**Visual amenity**	**Primary contact recreation**	**Secondary contact recreation**	**Aquatic foods (cooked)**
Purgatory Creek	Currently not being protected (very poor during both wet and dry weather) due to: • Median nutrients and turbidity exceed DGVs • Total nitrogen and turbidity during dry weather considerably higher than the DGV • Both pH and dissolved oxygen levels, were very poor at the most upstream site but improved at the downstream site • Mercury, lead, and cadmium were the only metals to remain below the DGVs during dry weather • Median zinc, copper and nickel concentrations exceeded DGVs.	Currently not being protected due to: • Thick, turbid, brown stagnant water, often covered in aquatic weeds and algae, at the most upstream sites • Brown, slightly turbid and algae affected water with some transparency at other sites downstream	Currently not being protected due to: • Median enterococci exceed the recommended threshold	Currently not being protected	Currently not being protected due to: • Elevated zinc levels • TSS and dissolved oxygen did not meet DGVs.
Hexham Swamp Nature Reserve	There has been no current monitoring of Hexham Swamp Nature Reserve, with the only data available from August and September 2011 (Parsons Brinkerhoff 2012). Currently not being protected (poor during both dry and wet weather) due to: • pH and dissolved oxygen outside acceptable limits and elevated nutrients • At the time of sampling, the swamp was mildly acidic and dissolved oxygen levels were variable with both anoxic and supersaturated levels recorded • Ammonia, total nitrogen, total phosphorus, and filterable reactive phosphorus exceeded the guideline limit.	-	-	-	-

Waterway / wetland	Compliance with ANZG (2018) guideline values				
	Aquatic ecosystems	**Visual amenity**	**Primary contact recreation**	**Secondary contact recreation**	**Aquatic foods (cooked)**
Mid Site Channel	Currently not being protected (very poor during dry weather) due to: • Elevated nutrients and turbidity • Exceeds TP and TN concentrations • Metal concentrations were generally low with the exception of zinc, nickel and copper, which were recorded in elevated concentrations on occasion.	-	-	-	Currently not being protected due to: • Elevated TSS and zinc concentrations.
Hunter River main stream	Currently not being protected (poor or very poor at all sites except Newcastle Harbour where the water quality is improved by tidal flushing) due to: • Elevated TN, TP, turbidity, and chlorophyll-a • Metal concentrations were recorded as generally low, with the exception of copper and zinc which exceeded DGVs • Dissolved oxygen levels did not meet DGV • pH levels were within acceptable ranges.	Currently not being protected due to: • Brown and turbid water with an oily sheen • Surface water frothing during wet weather	Currently not being protected	Currently being protected	Currently not being protected due to: • Elevated TSS and zinc concentrations.
Hunter River Drain	Currently not being protected (very poor during both dry and wet weather) due to: • Turbidity and dissolved oxygen concentrations were outside DGVs • Total nitrogen and total phosphorus exceed DGVs • pH, cadmium, chromium, lead, and mercury levels met DGVs.	Currently not being protected due to: • Brown muddy turbid water and oily sheens	-	-	-
Hunter River wetland	Currently not being protected (very poor during both dry and wet weather) due to: • TN, TP, pH, dissolved oxygen, and median were outside DGVs • Metal concentrations were low at the time of sampling, all meeting the relevant species protection limit DGVs with the exception of zinc.	-	-	-	-

Waterway / wetland	Compliance with ANZG (2018) guideline values				
	Aquatic ecosystems	**Visual amenity**	**Primary contact recreation**	**Secondary contact recreation**	**Aquatic foods (cooked)**
Drainage canal, Old Punt Road	Currently not being protected (very poor during both dry and wet weather) due to: • pH, dissolved oxygen, turbidity, nutrient levels were outside DGVs • Concentrations of all metals except copper were outside DGVs.	Currently not being protected due to: • Turbid brown water • Water more turbid and oily following rainfall	Currently not being protected	Currently being protected	Currently not being protected due to: • Elevated TSS and zinc concentrations • Dissolved oxygen outside DGV.
Unnamed Coastal Wetland	Currently not being protected (very poor during wet weather) due to: • Dissolved oxygen, turbidity, TP, and TN were outside DGVs • Zinc and copper concentrations were outside DGVs.	Currently partially protected: • Brown, transparent water • Oily surface containing nuisance scums	-	-	-
Windeyers Creek	Currently not being protected (very poor during both dry and wet weather) due to: • TP, total and oxidised nitrogen, pH, and dissolved oxygen were outside DGVs • Zinc concentrations were outside DGV • Concentrations of arsenic, cadmium, nickel, and mercury were within DGVs • Turbidity and electrical conductivity generally met their respective DGVs.	Currently not being protected due to: • Oily films on surface • Surface covering of duckweed • Odour present	Currently not being protected due to: • Median enterococci exceed the recommended threshold.	Currently not being protected due to: • Median enterococci exceed the recommended threshold.	Currently not being protected due to: • Elevated TSS and zinc concentrations • Dissolved oxygen outside DGV.
Grahamstown Drain	Currently not being protected (very poor during both dry and wet weather) due to: • Elevated concentrations of TP and TN • Dissolved oxygen, pH, concentrations were outside DGVs • Concentrations of chromium and zinc were outside the DGVs.	Currently not being protected due to: • Milky white surface water • Containing iron bacteria	Currently not being protected due to: • Median enterococci exceed the recommended threshold.	Currently not being protected due to: • Median enterococci exceed the recommended threshold.	-

11.3.2 Existing groundwater quality

The groundwater systems within the ground water study area are shown on **Figure 10-6**.

Details of groundwater monitoring bores installed for the project and further results from those monitoring bores are described in the Surface Water and Groundwater Quality Working Paper (**Appendix K**).

Table 11-9 summarises the existing water quality compliance with the ANZG (2018) Water Quality Guidelines default guideline values for the protection of aquatic ecosystems for slightly to moderately disturbed ecosystems (95 per cent level of species protection), as outlined in **Table 11-5**. These values are recommended thresholds. If an indicator or indicators fall outside of the threshold(s), it assumes that the environmental value is not being protected.

Table 11-9 Summary of existing water quality comparison against ANZG (2018) DGVs for aquatic ecosystems

Groundwater System	Description of water quality (with reference to aquatic ecosystem values)
Hunter Alluvium	Poor (Estuarine)
Tomago Sandbeds	Very poor (Lowland river)
Tomago Coal Measures	Very poor (Lowland river)

Groundwater systems and existing groundwater quality within the groundwater study area are described in **Table 11-10**.

Table 11-10 Groundwater systems and existing groundwater quality

Groundwater system	Description	Existing groundwater quality
Hunter Alluvium	• The Hunter River floodplain and its associated alluvial groundwater systems form a regional groundwater sink for the Hunter Valley. • Groundwater levels are typically very shallow (0.2 to 2.4m below ground level) and often discharge to surface water. Wetlands and associated waterways on the floodplain are also expected to receive groundwater contribution.	• Existing groundwater quality is typically brackish to saline. pH values are typically mildly acidic. • Existing water quality samples are not compliant with relevant WQOs as they exceed estuarine/marine DGVs and estuarine physical and chemical stressors.
Tomago Sandbeds	• The Tomago Sandbeds are used for public drinking water supply by Hunter Water Corporation. • Groundwater levels are typically 1.6 to 2.7m below ground level. Some recharge to groundwater is likely during periods of elevated rainfall and runoff.	• Existing groundwater quality is typically fresh. pH values are typically mildly to moderately acidic. • Existing water quality samples are not compliant with WQO as they exceed freshwater DGVs and lowland river physical and chemical stressors. • Existing water quality samples comply with WQOs for drinking water guidelines.

Groundwater system	Description	Existing groundwater quality
Tomago Coal Measures	• Hardrock groundwater systems within the groundwater study area occur within the Permian Tomago Coal Measures. • Groundwater levels are typically 6.3 to 16.8m below ground level at Black Hill, with a potentiometric level of 0.3m above ground level at Tarro. • When flowing, waterways and surface drainages are typically sources of groundwater recharge. Wetlands, including the Hunter River wetland, are maintained by drainage from the aquifers or are windows to the water table where the water table is locally at a higher elevation than ground level.	• Existing groundwater quality is typically mildly brackish to saline. pH values are typically mildly to moderately acidic. • Existing water quality samples are not compliant with relevant WQOs as they exceed for freshwater DGVs and lowland river physical and chemical stressors.

Groundwater contamination from acid sulphate soils (ASS), acid rock and salinity is further discussed in **Chapter 16** (soils and contamination). In addition to potential for acid sulfate soils and soil salinity risk areas, key areas of potential contamination are noted in the following sections.

Former mineral sands processing facility

A former mineral sands processing facility is located within the construction footprint in Tomago. The facility is decommissioned, however the site retains pre-existing contamination in soil and groundwater. Investigations have found localised distribution of naturally occurring radioactive materials (NORM) with areas of elevated dose rates relative to surrounds identified on the site surface and at depth. However, concentrations of NORM in both surface water and groundwater were found to comply with all relevant guidelines for drinking water or guidelines for use of the water for livestock or irrigation. Concentrations of metals (cadmium, dissolved copper, dissolved nickel, and dissolved zinc) were also detected in surface water and groundwater that exceeded investigation levels (ANZG (2018) fresh water guidelines for 95 per cent ecosystem protection).

To ensure that the contaminants identified at the site are controlled to an acceptable level that limits harm to human health and the environment and to facilitate the overlying motorway project, Transport will remediate the former mineral sands processing facility site during construction of the project.

Transport will remediate the site in accordance with the Remediation Action Plan described in **Chapter 16** (soils and contamination). The Remediation Action Plan will address contamination risks and issues associated with NORM, metals and minor hydrocarbon contamination at the site, including areas where metals impacted soils may be interacting with surface water and approved by a NSW EPA accredited site auditor

Further information of potential contamination is provided in **Chapter 16** (soils and contamination).

Per- and poly-fluoroalkyl substances (PFAS)

The EPA is currently investigating potential PFAS contamination at two sites; Heatherbrae Total Fire Solutions and Our Lady of Lourdes Primary School, Tarro. Groundwater modelling for the project shows groundwater flows away from the project that decreases the potential for PFAS occurrence at project.

Predicted groundwater drawdown from temporary construction dewatering for the project (refer to **Chapter 10** (hydrology and flooding) is not predicted to interact with the areas of known or potential PFAS contamination. Contaminated groundwater from these sites is therefore considered unlikely to reach the project, and the project activities are not anticipated to influence or capture potential contaminant migration.

11.3.3 Sensitive receiving environments

A SRE is defined as one that has a high conservation or community value or supports ecosystems or water for human use and is particularly sensitive to pollution and/or degradation of water quality.

SREs identified in the surface water and groundwater quality assessment are summarised in **Table 11-11**.

Table 11-11 Description of SREs and reasons for determination

SRE	Description	Reason for determination
Tomago Sandbeds Catchment Area	• The Tomago Sandbeds Catchment Area is a designated 'Special Area' in the *Hunter Water Act 1991* and is protected as a public drinking water supply by the Hunter Water Corporation. The Tomago Sandbeds are operated as a backup to Grahamstown Dam, and can provide up to 20 per cent of the Lower Hunter's drinking water • The aquifer is predominantly comprised of fine sand, typically around 20m deep and receives direct recharge from rainfall. Water levels are generally relatively shallow.	• Due to the highly permeable nature of the Tomago Sandbeds and shallow depth to water, the aquifer is vulnerable to contamination and therefore is considered an SRE.
Groundwater users	• 303 existing registered bores are within the groundwater study area, with five located within the construction footprint itself.	• Due to distance from the project and potential risk of groundwater contamination, groundwater users are considered SREs.
Hunter River	• The Hunter River is a ninth order major river and an open, wave dominated barrier estuary in its lower reaches (where the project is located). • Despite the physical condition and water quality of the Hunter River within the surface water study area being generally poor and reflective of the urban, agricultural and industrial land uses within the catchment, the waterway is classified as "Type 1 – Major KFH'. • Hunter River is additionally accessed as fish grounds for the Estuary Prawn Trawl Fishery and there are oyster leases downstream near Stockton Bridge. • Hunter River is utilised for secondary contact recreation, for activities such as waterskiing, fishing and boating.	• Due to the environmental and human uses of the waterway, the Hunter River is considered an SRE.
Hunter Estuary Wetland Ramsar site	• Kooragang Nature Reserve, which is located 5.1km directly downstream from the project where the new viaduct crosses the Hunter River, forms part of the nationally important wetland the Hunter Estuary Wetlands Ramsar site. • The Hunter Wetlands Centre Australia in Shortland is located a minimum distance of about 3.8km south of the construction footprint. However due to the substantial distance from the project and several hydrological barriers which obstruct project discharges from reaching the Ramsar site area (rail embankment at the northern boundary of Hexham Swamp Nature Reserve and floodgates on Ironbark Creek), the	• Despite being a significant distance downstream, there is a potential direct flow path from the project to Kooragang Nature Reserve therefore it is considered an SRE.

SRE	Description	Reason for determination
	Hunter Wetland Centre in Shortland is not expected to be directly or indirectly impacted by the project.	
Important wetlands	• Six areas identified as Coastal wetlands under the Coastal Management SEPP are located within the surface water study area • Three are located within the construction footprint, these include: – South of the existing New England Highway – On the western banks of the Hunter River – On the eastern bank of the Hunter River. • Three are located outside of the construction footprint but within the study area, these include: – North of the project in Tarro, this wetland is commonly referred to as "Woodberry Swamp" – In Tomago, on the southern side of Masonite Road on the northern floodplain of the Hunter – In Tomago, located south east on the northern floodplain of the North Channel Hunter River. • Although not classified under the Coastal Management SEPP, the Hunter River wetland is located within the Tomago Sandbeds Catchment Area and has significant wetland habitat features • All above mentioned wetlands are likely to be supported by groundwater discharge therefore are considered to be GDEs.	• Due to these areas being either state-listed, protected wetlands or located on the Tomago Sandbeds Catchment Area, they are considered important wetlands and therefore are considered to be SREs.
GDEs	• A number of known and potential GDEs were identified in the study area, these include: – Aquatic GDEs: Floodplain wetlands (including Hexham Swamp Nature Reserve and surrounding wetlands, Hunter Wetlands National Park) – High Potential Terrestrial GDEs: Coastal Floodplain Wetlands on the floodplain of Hunter River, Mangrove Swamps on the margins on the Hunter River and Coastal Dune Dry Sclerophyll Forests on the Tomago Sandbeds – Moderate potential GDEs: Coastal Dune Dry Sclerophyll Forests on the Tomago Sandbeds. • It is noted that these potential and known GDEs coincide with the important wetlands outlined above.	• These aquatic and terrestrial GDEs are sensitive to groundwater changes and are therefore considered SREs.
Key Fish Habitat	• Based on aquatic habitat assessment, the following waterways and wetlands have been classified as Key Fish Habitat: – Viney Creek: Type 2, Moderately sensitive KFH – Purgatory Creek (downstream of the floodgates): Type 1, Highly sensitive KFH – Hunter River: Type 1, Highly sensitive KFH – Coastal Wetland (east of Hunter River): Type 1, Highly sensitive KFH.	• Waterways that were deemed KFH are considered to have high conservation value therefore have been considered SREs.

11.4 Impact assessment

11.4.1 Impacts avoided and minimised

As described in **Chapter 4**, various alternatives to the project were considered as part of the project development process. This included the relocation of the Hunter River viaduct crossing (described in **Section 5.3.5**) to about 1.4 kilometres north of the original location and thereby minimising the overlap with the Hunter River floodplain. As a result of this change and other design developments, the project design would:

- Minimise the extent of the project located within the flood plain and its soft soils to limit ongoing complex surface water and groundwater interactions
- Avoid substantial water quality impacts arising from substantial increases in flooding behaviour, flows and afflux associated with a large embankment across the Hunter River floodplain
- Avoid permanent drawdown of the various groundwater resources during operation as a result of design interface lowering the groundwater.

Design of the project has further minimised surface water and groundwater quality impacts through:

- Applying a strategy to minimise impacts to the Tomago Sandbeds Catchment Area, including lining water quality controls in the Catchment Area during construction and operation to avoid infiltration of untreated water and ensure runoff is treated prior to discharge
- Minimising vegetation clearance and disturbance of previously undisturbed areas by placing the project within or adjacent to existing development corridors
- Minimising disturbance of sediments on the Hunter River floodplain by crossing the floodplain with a 2.6 kilometre viaduct instead of an embankment
- Construction water quality controls to reduce water quality impacts during construction, including impacts on SREs and downstream estuarine and marine waters
- Operational water quality controls (including permanent water quality basins and grassed swales) to reduce water quality impacts during operation, including impacts on SREs and downstream estuarine and marine waters
- Lining selected temporary sediment, permanent water quality basins and grassed swales with the potential to discharge water with elevated salinity into receiving environments.

11.4.2 Construction impacts

Construction of the project presents a risk of degradation of downstream surface water and groundwater quality if management measures are not implemented, monitored and maintained throughout the construction phase.

A strategy to minimise impacts to water quality during construction, and in particular to SREs, is to provide a combination of water quality treatment measures typically consisting of erosion control, sediment control, sediment capture and treatment. This strategy is supported by management measures to be implemented during construction as detailed in **Section 11.5**.

Construction phase impacts to surface water and groundwater are discussed in the sections below.

Surface water quality

Construction activities which are considered to be the highest risk to water quality are:

- Bridge work: Involving instream work, including dredging, piling, as well as construction and use of temporary instream work platforms, bridges and wharfs, vegetation clearing in creek riparian zones, concrete work, steel work and dewatering. Bridges which are proposed to be constructed over or within proximity of waterway and wetlands include:
  - A 2.6 kilometre viaduct over Hunter River and areas classified as Coastal Wetlands (Coastal Management SEPP)
  - Bridge across minor waterways including Glenrowan Creek (B02) and Windeyers Creek (B11)
  - A bridge within proximity of the Hunter River wetland (B09).
- Drainage work: Including excavation and soft soil compaction, vegetation clearing on the streambed and banks, instream work, including streambed levelling for installation of culverts and temporary creek diversions, installation of drainage pipes and pits, construction of table drains and swales, and dewatering.

Other construction activities with the potential to impact specific waterways include but are not limited to:

- Site establishment and access tracks: Involving movement and use of vehicles across exposed earth, excavation, vegetation clearing and mulching, and transport of materials to and from site
- Ancillary facilities: Activities occurring at ancillary facilities include movement and use of vehicles across exposed earth, stockpiling, vegetation clearing and mulching, batching plants, crushing plants, precast facilities, transport of materials to and from site and establishment of water quality controls (temporary sediment basins and permanent water quality basins)
- Earthworks: Activities including cut and fill of existing soils importing materials to work area, and stockpiling soils and treatment of soils
- Excavation and relocation of utilities: Utilities would need to be relocated, adjusted, or protected where they may be affected by project construction, particularly in areas where ground disturbance is required
- Waterway adjustments: Involving excavation, vegetation clearing in creek riparian zones, and instream work, including streambed levelling for installation of culverts and new channel alignments
- Construction discharges and dewatering: Involving dewatering of excavations and as a result of soil consolidation activities
- Site restoration: Restoration and landscaping of disturbed areas (including ancillary facilities and construction access roads) where required.

Waterways and wetlands with the potential to be impacted by these construction activities are described in **Table 11-12**.

Table 11-12 Waterways and wetlands with the potential to be impacted by construction activities

Waterway or wetland	Construction activities								
	Bridge work	Drainage work	Site establishment and access tracks	Ancillary facilities	Earthworks	Excavation and relocation of utilities	Waterway adjustment	Construction discharges and dewatering	Site restoration
Tributary of Viney Creek			✓	✓	✓	✓	✓	✓	✓
Glenrowan Creek and wetland near the twin bridge (B02) between Black Hill and Tarro	✓		✓	✓	✓	✓		✓	✓
Unnamed Coastal Wetland (Coastal Management SEPP) south of New England Highway		✓	✓	✓	✓	✓		✓	✓
Purgatory Creek	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hunter River	✓	✓	✓	✓				✓	✓
Unnamed Coastal Wetland (Coastal Management SEPP) east of Hunter River	✓	✓	✓	✓	✓			✓	✓
Hunter River wetland	✓	✓	✓	✓	✓		✓	✓	
Tomago Sandbeds (near Masonite Road)		✓	✓	✓	✓	✓	✓		✓
Windeyers Creek	✓	✓	✓	✓	✓			✓	✓
Tributary of Windeyers Creek		✓	✓	✓	✓	✓		✓	✓

The construction activities described above may result in release of pollutants described in **Table 11-13**. Work within waterways (comprising bridge work, drainage work and waterway adjustments) is considered to be the construction activity with the highest risk, as it would be carried out in a dynamic and fluid setting with minimal buffer area for control.

Pollutant-specific impacts are described in the sections that follow.

Table 11-13 Pollutants relating to construction activities and general impacts on surface water quality

Pollutant	Potential source of pollutant from construction activities
Sediment	• Instream work, including dredging and piling, streambed levelling for installation of culverts and temporary creek diversions • Vegetation clearing in waterways and riparian zones • Movement and use of vehicles across exposed earth • Cut and fill earthworks • Excavation • Transport of materials to and from site • Relocation of utilities, including under boring and trenching • Stockpiling • Waterway adjustments • Dewatering temporary sediment basins • Site restoration including landscaping.
Sulfuric acid	Disturbance of ASS from: • Excavation • Dredging • ASS treatment.
Salt	Disturbance of saline soils from: • Excavation • Cut and fill earthworks • Dewatering.
Concrete waste	• Release of concrete liquid by-products with high pH from concrete installation or batching plants/precast facilities.
Oils and fuels	Release of oils and fuels from: • Vehicle movements • Spills and leaks from construction plant and equipment • Dewatering temporary sediment basins.
Heavy metals, polyaromatic hydrocarbons (PAHs) and other hydrocarbons	Release or exposure of heavy metals and PAHs from: • Asphalt works (batching, transport, laying, milling) • Contaminated site remediation • Concrete works • Vegetation clearing and mulching • Spills.
Tannin leachate	Release of tannin leachate from: • Mulching and stockpiling of cleared vegetation.
Dust and litter	Release of dust and litter during: • Earthworks • Material transport • Stockpiling • Concrete work • Rock crushing and blasting • Demolition • Use of construction sites by construction workers.

Erosion and sedimentation

Erosion and sedimentation can result in increased turbidity and poor water clarity. This can impact visual amenity and could potentially leading smothering of aquatic ecosystems due to clogging fish gills or decrease trophic interactions due to reduced visibility. Mobilised sediments may contain elevated concentrations of metals and other contaminants, which can negatively impact aquatic life.

Sediments may also contain high concentrations of nutrients which can lead to algal blooms and result in reduced light penetration that limits the growth of aquatic and estuarine vegetation. Algal blooms may also result in a reduction of dissolved oxygen content of the water which can lead to the creation of 'dead zones' where aquatic life cannot survive.

While highly erodible soils are generally not located within the construction footprint, there would still be a risk of erosion and sedimentation from the activities presented in **Table 11-14**.

Table 11-14 Construction impacts on erosion and sedimentation

Activity	Erosion / sedimentation risk
Instream work, including dredging and piling, streambed levelling and alteration of banks for installation of culverts and temporary creek diversions	Carrying out instream works would result in disturbance of sediment during piling or dredging activities, or may destabilise the streambed and river banks when altering channel structure. This may result in potential sedimentation of downstream environment which can cause increased turbidity that can be detrimental to aquatic life, result in algal blooms and can reduce visual amenity.
Vegetation clearing in waterways and the riparian zone (comprising bridge work, drainage work and waterway adjustments)	Vegetation clearing within and near waterways may result in mobilisation of instream sediments, destabilisation of riverbanks and potential bank collapse, and/or erosion of exposed top soils via wind or runoff. Mobilised soils or sediments may result in increased turbidity within waterways which can be detrimental to aquatic life, result in algal blooms and can reduce visual amenity.
Cut and fill earthworks	Cut and fill earthworks are required along the main alignment due to the undulating topography. In areas of cut, there would be a risk of erosion and sedimentation from destabilisation of the landform. In areas of fill, soils and landform could become eroded during rainfall events, resulting in sedimentation of downstream waterways through mass movement of soils. There would be a risk of erosion and sedimentation from destabilisation at the large cut proposed at Black Hill and from smaller cuts at the Tomago interchange. Areas of fill around Purgatory Creek, Hunter River Drain and tributary to the Hunter River Drain also pose a risk to downstream water quality during rainfall events.
Excavation	Excavation could transport loose sediment to downstream waterways if able to mobilise via wind and runoff. Excavation would be required for establishing access tracks, road construction activities, piling activities, building bridge abutments, constructing drainage infrastructure, and adjusting waterway channel alignments along the entirety of the project.
Movement and use of heavy vehicles across exposed earth	Operation of heavy machinery can disturb soils, particularly in areas where vegetation has been removed or topsoil has been stripped. This increases the potential for erosion and sedimentation in downstream receiving environments, particularly those near access tracks, ancillary facilities, and construction areas where vehicles, plant and equipment would be used.
Transport of materials to and from site	Excavated material, as well as material brought to site to be used in construction, would need to be transported to and from site via access tracks which has the potential to be lost from the vehicle if not appropriately secured. This could result in sedimentation to downstream waterways if able to mobilise via wind or runoff. Material transport poses the highest risk to waterways that are near or crossed by access tracks and waterways in proximity to ancillary facilities or construction sites.

Activity	Erosion / sedimentation risk
Stockpiling	Excavated material would require stockpiling before being crushed and reused or transported off site. High rainfall events and high winds during construction can erode stockpiled areas and disturbed areas with exposed soils. This can result in increased turbidity, lower dissolved oxygen and increased nutrients which may exacerbate algal blooms and aquatic weed growth. Stockpiles are proposed at all ancillary facilities within the project construction footprint.
Relocation of utilities	A number of utilities are located within the construction footprint and may need to be relocated, adjusted, or protected where they may be impacted by project construction, particularly where excavation would be required. Relocation would involve soil disturbance from trenching and underboring, and disturbance of soil by machinery could increase the potential for soil erosion.
Construction dewatering and discharges	Dewatering discharge from construction (either from excavations or wick drains) can result in water that may be turbid. This water would be directed into temporary construction treatment controls to minimise impacts.
Site restoration	Minor earthworks are required during landscaping and site restoration activities that could result in the erosion of disturbed soils that have not yet stabilised, with potential for sediment to be transported downstream by wind or runoff. Impacts associated with landscaping and site restoration would be temporary as stabilisation and revegetation would act to prevent future soil erosion.

While sediment-laden runoff and pollutants from erosion and sedimentation may temporarily reduce downstream water quality, they would be unlikely to cause major or long term impacts to the overall condition of the surrounding waterway, as erosion and sedimentation would be managed with the implementation of erosion and sediment controls described in **Section 11.5** and **Chapter 5**).

Sulfuric acid

Sulfuric acid can be generated from the exposure of ASS to air and may mobilise to waterways and cause a decrease in pH which can be harmful to aquatic life. Vegetation clearing, excavation, dredging, piling, general ground disturbance and streambed levelling can result in moderate water quality impacts due to the potential to disturb ASS and mobilise poor water quality to downstream waterways. ASS is further discussed in **Chapter 16** (soils and contamination). The waterways at risk of being impacted by disturbance of ASS are the Hunter River and Windeyers Creek due to the excavation required for bridge construction, and Purgatory Creek due to disturbance for creek adjustment. Of lower risk are the Viney Creek tributary, unnamed tributaries, and drainage canals.

Inappropriate management of ASS could result in sulphuric acid and heavy metals being transferred to downstream waterways following rainfall, directly impacting aquatic life and water supply quality. With the implementation of the environmental management measures described in **Section 11.5** and **Section 16.5**, acid sulfate soil disturbance would not be likely to result in a significant impact to water quality.

Salts

Saline soils present a risk to downstream waterways if they are exposed and leach high concentrations of salt into runoff. Saline soils can alter the salinity of waterways which can alter instream biodiversity and ecosystem function. However, the risk of this occurring as a result of construction of the project is considered low as the receiving environment has habituated to catchment geology and salt impacted surface water flows. Surface water quality controls and management measures would be implemented to minimise the development of excessive saline water flows. Saline soils are further discussed in **Chapter 16** (soils and contamination).

Concrete waste

Concrete work, including batching, pre-casting and in situ pouring, can result in concrete dust, concrete slurries or washout water entering downstream waters. Concrete by-products are alkaline and therefore could alter the pH of downstream watercourses and be harmful to aquatic life that is sensitive to changes in water quality.

The main areas at risk from mobilisation of concrete waste are waterways which are in proximity to ancillary facilities where concrete batch plants and precast facilities would be located. However, the risk of transportation of concrete waste to waterways is considered low as water quality controls and management measures would be implemented to ensure no runoff is mobilised downstream prior to being captured and treated in temporary sediment basins.

Oils, fuels, and polycyclic aromatic hydrocarbons

Mobilisation of oils and/or fuels from leaks and spills or from temporary sediment basin discharges may lead to the introduction of hydrocarbons and heavy metals into the waterways. This may be harmful to aquatic life and could reduce visual amenity.

Release or exposure of polycyclic aromatic hydrocarbons (PAH) from asphalt can be toxic to aquatic life. Dewatering of surface water features for the establishment of construction areas and access tracks may mobilise poor quality water with high toxicant concentrations, including PAH to downstream receiving environments.

Heavy metals have the potential to be introduced into waterways from construction activities if mobilised by wind or stormwater runoff. Potential sources include:

- Steel cuttings from steel works required for road and bridge construction
- Changes in physico-chemical conditions may trigger release of accumulated trace metals from mangroves
- Concrete waste may contain elevated concentrations of chromium
- Other heavy metals associated with waste materials from contaminated site remediation.

With the implementation of the environmental management measures described in **Section 11.5** and **Section 16.5**, the release or exposure of oils, fuels, and PAH, if managed correctly, would not be likely to result in a significant impact to water quality.

Tannin leachate

Tannins from mulching and stockpiling of cleared vegetation can cause dark coloured water to be discharged into downstream waterways. This could alter the instream pH and reduce visibility and light penetration in the water column. Tannins could also increase biochemical oxygen demand, which could decrease instream dissolved oxygen concentrations. This can impact on aquatic ecosystems and lead to fish kills.

The implementation of the environmental management measures described in **Section 11.5,** tannin leachate, if managed correctly, would not be likely to result in a significant impact to water quality.

Dust and litter

Dust generated from concrete work, rock crushing and blasting may contain heavy metals which could be harmful to aquatic life. Dust associated with demolition of buildings and infrastructure may contain contaminants such as concrete, asbestos, or other pollutants. These may be harmful to aquatic ecosystems if mobilised to downstream environments.

Mobilisation of litter to waterways may lead to the introduction of gross pollutants, hydrocarbons and heavy metals into the waterways which may be harmful to aquatic life and reduce visual amenity.

With the implementation of the environmental management measures described in **Section 11.5** and **Section 16.5**, the dust and litter, if managed correctly, are not likely to result in a significant impact to water quality.

Water quality impacts from temporary sediment basin discharge

Pollutants

Project construction would result in discharge of temporary sediment basins. Pollutants of most concern during construction are total suspended solids, oil, and grease.

The primary aim of the temporary sediment basins is to capture sediment as nutrients and metals are typically bound to sediments in a dissolved (and often harmful) state. By capturing sediments (and subsequently nutrients and toxicants) via the grassed swales and temporary sediment basins, the risk to downstream water quality would be reduced. Environmental impact of discharge from basins is of greatest concern where they discharge directly to the SREs of the Hunter River and the downstream Ramsar wetlands.

Treatment of these pollutants would be in accordance with typical pollution controls for road projects. As the primary aim of the temporary sediment basins would be to capture sediment, the basins would also capture nutrients and metals that are bound to sediments. By capturing sediments the risk to downstream water quality would be reduced. As described in **Section 5.4.11**, a total of 47 temporary sediment basins are proposed (shown in **Figure 5-25**). Temporary sediment basins would be sized in accordance with the requirements of Landcom (2004) and DECC (2008) to provide sufficient volume for settling and storage of sediments. Further information on the location and design of temporary sediment basins are provided in Surface Water and Groundwater Quality Working Paper (**Appendix K**).

As per 85th percentile Blue Book requirements for the area, the rainfall event criteria is 38.9 millimetres.

Total annual average TSS loads discharged from temporary sediment basins under controlled conditions is shown in **Table 11-15**. It is noted that the Hunter River would receive lower direct discharge loads than smaller waterways, such as Viney Creek, as these smaller waterways would have a greater number of basins discharging into them.

Table 11-15 Annual average TSS loads (kg/yr) discharged from sediment basins under controlled conditions

Locations	Controlled discharge from sediment basins
R1-Glenrowan Creek	584
R2-Purgatory Creek	209
R3-Hunter River drain	2734
R4-Windeyers Creek	2066
R5-Viney Creek	2974
R6-Hunter River	104
R7-Unnamed coastal wetland	209

Salinity

Thirty temporary sediment basins would interact with groundwater. For the majority of the basins, modelled electrical conductivity of discharge is similar to the receiving environment. However, there are a number of basins where modelled conductivity would exceed background concentrations and the ANZG (2018) guidelines.

Dewatering discharge from these basins would be into Glenrowan Creek and the tributary of Viney Creek and may impact on biota that cannot tolerate higher salinity. Four temporary sediment basins are recommended to be lined to avoid discharge of highly saline water (greater than 7500µS/cm). There is potential for slightly more saline water to be released into some waterways classified as lowland river, which may temporarily increase waterway salinity, however given the temporary nature of construction, this is not expected to impact on achieving the WQOs. Given this, the project is unlikely to have long term impacts on the salinity of the affected waterways and is not expected to have a significant impact on water quality during construction.

pH

ANZG (2018) Water Quality Guidelines recommended water quality discharges have a pH between 6.5 and 8.5 to ensure protection of lowland river aquatic ecosystems or between pH 7 and 8.5 for protection of estuarine aquatic ecosystems. The pH of water will be tested prior to discharge to confirm it falls within these limits so that there is no impact to the pH of downstream waterways.

Groundwater quality impacts

Construction activities that may cause groundwater quality impacts include:

- Temporary construction dewatering, which may result in dewatered discharge of unknown quality to be managed and also resulting in localised lowering of the water table with potential to oxidise acid sulphate soils or impact GDEs
- Mounding of water table associated with soft soil consolidation, resulting in potential for mobilisation of salts within soil profile
- Operation of unlined temporary sediment basins and potential to introduce contaminants into groundwater via a new migration pathway
- Mobilisation of areas of existing or potential groundwater contamination due to construction activities (refer to **Chapter 16** (soils and contamination)).

These impacts, as well as water quality impacts to the public drinking supply of the Tomago Sandbeds Catchment Area, are discussed in the following subsections.

Acid sulphate soil risk associated with construction dewatering

Temporary construction dewatering would be required where excavations occur below the water table. As described in **Chapter 10** (hydrology and flooding), shallow excavations (such as for culverts and minor utilities) are not anticipated to require substantial dewatering. Key activities that have been assessed as requiring more substantial dewatering include, but are not limited to, the following:

- Excavations for large utility work
- Excavation of temporary and permanent basins, including 36 proposed temporary sediment basins that require excavation below the water table
- Excavations for bridge and viaduct piers at four sites (including a tributary to Mid Site Channel in Tarro, the Hunter River viaduct, an overbridge at Tomago interchange and Windeyers Creek)
- Excavations for the Purgatory Creek adjustment.

Temporary construction dewatering could lower groundwater levels in areas of high ASS risk, exposing sulphide minerals in soil to oxygen, creating acidic conditions. This is especially relevant in the low lying floodplain areas next to the Hunter River in Tarro and Tomago and Windeyers Creek (refer to **Chapter 16** (soils and contamination)).

Predicted groundwater drawdown due to temporary construction dewatering are typically of limited extent and short duration. The rate of oxidation of sulphide minerals in soil is primarily controlled by rate of oxygen diffusion through the soil and the initial soil pH. Given the relatively short durations of dewatering, the typically low permeability of the high risk ASS materials and the elevated initial pH conditions, acid generation resulting from short term dewatering is expected to be minor. Any potential for oxidation is likely

to be limited to oxidation within the exposed faces in the excavation, and the volume of acid generated is not expected to be significant. Acid sulphate soils are further discussed in **Chapter 16** (soils and contamination).

Soil salinity and acid sulphate soil risk from soft soil consolidation

Soft soil consolidation activities can change groundwater levels. Raised groundwater levels can increase soil salinity risk by mobilising salts accumulated in unsaturated soils, resulting in elevated shallow groundwater salinity. Lowered groundwater levels have potential to result in generation of ASS.

As discussed in **Section 10.5.2**, the use of surcharge embankments to facilitate soft soil consolidation for the project. Areas of groundwater level change across the groundwater study area include:

- Mounding (elevated groundwater levels up gradient of the surcharge embankment)
  - Tarro: Mounding would be minor in this area (0.2 metres). The degree of mounding is within seasonal fluctuations and is located in an area where there is frequent existing surface expression of groundwater. As such, the unsaturated zone would not be subject to salt accumulation and the rise in water level would have little effect from a salinity risk perspective
  - Tomago and Tomago Sandbeds: Mounding of up to 0.2 metres is predicted over most of the upstream area of consolidation, while the greatest magnitude of predicted mounding (up to 0.8 metres) is predicted within the highly permeable Tomago Sandbeds that are subject to frequent flushing by infiltrating rainfall. As such, the unsaturated zone is not subject to substantial salt accumulation and the rise in water level would have little effect from a salinity risk perspective. It is also noted that the level of mounding, at its highest point, would be about two metres below ground surface and as such is not expected to result in noticeable surface effects or impacts to other groundwater users.
- Shadowing (reduced groundwater levels down gradient of the surcharge embankment)
  - Tarro: Shadowing would be localised and negligible (less than 0.05 metres)
  - Tomago: Shadowing effects at the Tomago soft soil consolidation would be very localised and minor (less than 0.1 metre).
- Lowered groundwater water levels as a result of soft soil consolidation are predicted to be negligible and well within the range of seasonal groundwater fluctuation. Accordingly, there would be no significant risk of acid generation as a result of oxidation of PASS from groundwater shadowing.

Chapter 10 (hydrology and flooding) further discusses water levels and associated groundwater impacts associated with soft soil consolidation in this area.

Groundwater contamination risk from operation of unlined temporary sediment basins

Unlined temporary sediment basins that are excavated below the water table may potentially expose local groundwater to contaminants in the basin water. When full or partially full, water levels in the basins would be above that of the surrounding water table and the basins could act as temporary groundwater recharge points, dependant on local soil conditions. With runoff from the construction footprint entering the basins there would be potential for spills or contaminants to also enter the basin with subsequent migration to groundwater impacting on groundwater quality.

During construction, key risks from contaminants relate to hydrocarbon storage and the operation of mobile plant (leaks and spills). Hydrocarbon spills would be managed by site protocols and any spills would be cleaned up in the short term. In the event of any hydrocarbon spills substantial enough to impact a sediment basin, the spills would be obvious on the surface of the basins and rapid clean up based on site management protocols would be implemented to minimise the potential for groundwater contamination.

Non-spill related contaminants likely to enter the basin would be associated with suspended sediment. As sediment would settle out in the basin, the impact on groundwater is expected to be negligible.

Mobilisation of areas of existing or potential groundwater contamination

Construction dewatering and associated drawdown is not anticipated to interact with any of the areas of existing known contamination described in **Chapter 16** (soils and contamination). Drawdown is not predicted in areas of known contamination and is not predicted to encroach on areas of known contamination.

Impacts to Tomago Sandbeds Catchment Area

Eleven temporary sediment basins within the Tomago Sandbeds Catchment Area would be lined to avoid potential for any contamination to occur. As a result, no construction impacts to groundwater quality are anticipated within the Tomago Sandbeds Catchment Area.

Surface water reuse

Non-potable water would be required for a number of construction activities such as dust suppression and earthworks compaction. While water sources would be confirmed during detailed design, there is the potential to source this water from temporary sediment basins, which may comprise of surface runoff as well as groundwater. Water in temporary sediment basins may be acidic, saline, or turbid depending on its source. Where practicable, acidic water would be treated to reduce acidity, while turbid water would be treated through normal operation of the temporary sediment basins. However, highly saline water (greater than 7500µS/cm) 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.

With the appropriate sizing of the temporary sediment basins to allow for treatment of runoff and implementation of other management measures (including sediment basin water quality checks prior to reuse), reuse of this water for construction activities would not pose a risk to downstream surface water and groundwater quality including any risks to ecosystem and human health.

Coastal Management Areas

The construction footprint is located within or near Coastal Management Areas as defined in the Coastal Management SEPP. These include areas classified as Coastal Wetland, Coastal Wetlands Proximity Area, Coastal Environment Area or Coastal Use Area. In accordance with the Coastal Management SEPP, work carried out within these areas should be designed to avoid, minimise, or mitigate any adverse impacts on the integrity and reliance of the biophysical, hydrological, or ecological environment of the wetland, adjacent wetland, coastal environment area or coastal use area.

The Coastal Management Areas that would be cleared for use during construction are presented in **Table 11-16**. The majority of the mapped ‘Coastal Management Areas’ which fall within the construction footprint have already been cleared for agricultural purposes, and any remnant wetland vegetation within the mapped areas is in poor condition (refer to **Chapter 9** (biodiversity)). The mapped areas are therefore not expected to function as important wetland environments and clearing of vegetation from these areas would not result in a significant impact to their ecological function, with the exception of the Unnamed Coastal Wetland which is located on the eastern bank of the Hunter River.

The unnamed Coastal Wetland is known to include a number of threatened ecological communities (TECs) and functions as an estuarine habitat. While clearing in this section is unlikely to significantly disrupt the ecological processes of the wetland, there is potential for changes to the local biophysical and hydrological conditions during construction due to increased risk of erosion of disturbed soils and potential for overland flow. The risk of these impacts is considered unlikely due to establishment of erosion and sediment controls prior to any clearing being carried out within the construction areas. Therefore, all potential sediment-laden runoff would be directed to temporary sediment basins prior to reaching any undisturbed sections of the wetland.

Overall, water quality impacts from construction activities on Coastal Management Areas would be unlikely following the implementation of management measures and controls detailed in **Section 11.5**. Further, ancillary facilities, instream work platforms and wharves would be rehabilitated as far as practicable prior to demobilisation.

Table 11-16 Coastal Management Areas (Coastal Management SEPP) that would be cleared or occupied for use during construction

Coastal Management Area category	Area to be cleared for use	Project features that would occupy the area
Coastal Wetlands	16.5ha	• Main alignment (western side of Hunter River) • Hunter River crossing (the viaduct) • Main alignment (eastern side of Hunter River) • Ancillary facility 10 (AS10) • Ancillary facility 11 (AS11)
Coastal Wetlands Proximity Area	28.3ha	• Main alignment (western side of Hunter River) • Ancillary facility 9 (AS9) • Hunter River crossing (the viaduct) • Main alignment (eastern side of Hunter River) • Ancillary facility 10 (AS10) • Ancillary facility 11 (AS11)
Coastal Use Area	46.8ha	• Ancillary facility 6 (AS6) • Ancillary facility 7 (AS7) • Ancillary facility 8 (AS8) • Ancillary facility 9 (AS9) • Hunter River crossing (the viaduct) • Ancillary facility 10 (AS10) • Ancillary facility 11 (AS11)
Coastal Environment Area	140ha	• Ancillary facility 6 (AS6) • Ancillary facility 7 (AS7) • Ancillary facility 8 (AS8) • Ancillary facility 9 (AS9) • Hunter River crossing (the viaduct) • Ancillary facility 10 (AS10) • Ancillary facility 11 (AS11) • Ancillary facility 13 (AS13)

Assessment of project construction discharges against WQOs

As discussed in **Table 11-13**, a number of pollutants associated with construction of the project have potential to impact on nominated WQOs for waterways within the surface water study area. The proposed management measures including erosion and sediment controls have been designed to primarily prevent or reduce erosion and sediment impacts during construction. Where erosion does occur, the secondary aim of the temporary sediment basins is to capture runoff as close to the source as practicable to minimise pollutants entering downstream waterways.

As discussed in **Section 11.3.1**, the current water quality of waterways in the study area is considered poor due to elevated turbidity, nutrients, low dissolved oxygen and often high levels of zinc and copper. The WQO for protection of aquatic ecosystems is currently not being achieved at any site, nor is the objective for aquatic foods (cooked) where applicable. The WQOs of visual amenity, primary contact recreation and secondary contact recreation were also not met for any of the waterways.

Pollutant loading into waterways from temporary sediment basin discharges has been calculated for turbidity and compared against the DGV for protection of aquatic ecosystems (refer to **Table 11-17**). Representative waterways have been assessed to verify if they comply with the relevant WQO DGV or, to determine if the outcomes of the project construction activities work towards their achievement over time. Proposed calculated turbidity that is lower than the ambient DGV is shaded dark green to highlight that the WQO of the receiving waterway is met and protected, and that discharge is not considered cause significant harm to the waterway. Proposed calculated turbidity that does not meet the DGV but is generally lower than the existing ambient median values (determined by onsite monitoring) is shaded light green as it is contributing to achievement of the WQO DGV of the receiving waterway over time, is generally an improvement on the existing ambient water quality and is unlikely to cause significant harm to the waterway. Proposed calculated turbidity that exceeds the WQO DGV and existing ambient water quality is shaded red and are discussed in **Table 11-8**.

A detailed summary of the project's impact on water quality objectives during construction is presented in **Table 11-18**. When the calculated project pollutant point loading from basin discharges is considered against the WQO DGV and/or compared with pollutant loading from the wider catchments, impacts to ambient water quality due to the project are unlikely to be significant.

Table 11-17 Comparisons of calculated turbidity discharged from sediment basins during construction against existing conditions and guideline values

Waterway	Ecosystem turbidity guideline values (NTU)	Existing median turbidity values (NTU) (Dry)	Existing range of turbidity values (NTU) (Dry)	Proposed calculated turbidity (NTU)	Further discussion required (refer to Table 11-8)
R1-Glenrowan Creek	6-50	17.2	5.8-57.7	33 Achieves WQO DGV	No
R2-Purgatory Creek	0.5-10	14.1 – 41.65	4-115	92	Yes
R3-Hunter River drain	0.5-10	20.82 – 55.63	6-551	82	Yes
R4-Windeyers Creek	6-50	6.57 – 39.53	5.01-71.2	12 Achieves WQO DGV	No
R5-Viney Creek	6-50	31.58	20-58	67	Yes
R6-Hunter River	0.5-10	37.3 – 66.03	18-776	48 Contributes towards achieving WQO over time	No
R7- Unnamed coastal wetland	0.5-10	25.75	9-33	48	Yes

Table 11-18 Project impact on water quality objectives during construction

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during construction
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
R1 – Glenrowan Creek (Lowland river)	✓	✓	✓	✓	N/A	The proposed quality of the construction water discharge from basins at this waterway complies with the turbidity DGV and continues to protect aquatic ecosystems WQO. Construction basin discharges are unlikely to have a significant impact on water quality. A brief discussion on the WQO is provided below. Aquatic ecosystems: Turbidity of discharges from temporary sediment basins to Glenrowan Creek will comply with the DGV for the protection of aquatic ecosystems (lowland river) WQO. Electrical conductivity (EC), however, is expected to be slightly elevated above the DGV for protection of lowland river aquatic ecosystems as the sediment basin may interact with the saline groundwater table in this location, causing discharges to not meet the WQO. The impact of the potentially slightly elevated EC is considered to be negligible as the existing receiving environment is disturbed (refer to **Table 11-8**) and is anticipated to be habituated to the existing inputs. Despite the discharges from the temporary sediment basins not meeting the DGV for EC, the temporary nature of the discharge is unlikely to reduce existing water quality or impact aquatic ecosystems over time. Visual amenity: Turbidity of discharges will comply with the DGV and hence protect visual amenity. Construction discharges are expected to meet the WQO for visual amenity as turbidity levels are expected to be below the DGV and therefore visual clarity is not expected to be reduced. Primary and secondary contact: Secondary contact is possible due to landowner access and ongoing asset maintenance, however primary contact is considered highly unlikely due to the nature of the waterway as a shallow drainage channel within grazing land. Construction discharges are not anticipated to generate or consolidate enterococci. Additionally, since the turbidity of the discharges will be low, algal blooms are not anticipated. Concentrations of metals and toxicants that are hazardous to human health are not expected as they would be bound to sediment captured within the sediment basin. As the project would not generate any additional enterococci and is not expected to produce excessive sediment, the project is not anticipated to impact on the achievement of the relevant WQO DGV.

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during construction
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
R2 – Purgatory Creek (Estuarine)	✓	✓	✓	✓	N/A	The proposed turbidity of the construction water discharge from basins at this waterway does not comply with the DGV or the median turbidity in the existing environment. Further assessment is provided below. The existing water quality and receiving environment at Purgatory Creek is presented in **Table 11-8** where it is shown to be highly disturbed. Ongoing maintenance (flood conveyance) and surrounding livestock grazing land uses are anticipated to result in ongoing impacts to water quality and the aquatic environment. The range of values identified during site monitoring (<115 NTU) display the disturbed and variable condition of the waterway. The impacts of the surrounding land use on water quality in Purgatory Creek are evident in the water quality measured to date (**Table 11-8**). Without changes in surrounding land use it is unlikely that Purgatory Creek will meet WQO's over time. Flood gates at the downstream end of the creek alter surface flows by containing flows within the creek channel and hence increase residence time to aid sediment settlement within the confines of the disturbed environment. The proposed turbidity is calculated to require a dilution of 2.2 to meet the existing median ambient water quality and it is assumed that discharge inputs would generally occur during/after rainfall events where catchment surface water would be adequate to provide sufficient dilution. It is noted that the proposed calculated turbidity is lower that the upper limit of the existing environment and following dilution, the short term construction discharge is anticipated to be generally in accordance with the existing surface water and is unlikely to significantly impact on the receiving disturbed environment. A brief discussion on the WQO is provided below. Aquatic ecosystems: Turbidity in Purgatory Creek will not meet the DGV for protection of aquatic ecosystems (estuarine), however existing conditions do not comply with the DGV for turbidity. Due to surrounding land use, Purgatory Creek is not likely to meet the WQO over time and the proposed discharges (temporary for construction discharges) are unlikely to have a significant impact to existing water quality or aquatic ecosystems over time. Visual amenity: Existing water quality in Purgatory Creek does not meet the WQO for visual amenity due to high turbidity that reduces visual clarity. As stated above, turbidity of discharges to Purgatory Creek from the temporary sediment basins are within the range of existing turbidity experienced within Purgatory Creek and all discharges

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during construction
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						would be temporary in nature. Discharges are therefore not expected to result in further degradation of visual amenity. Primary and secondary contact: Secondary contact is possible due to landowner access and ongoing asset maintenance, however primary contact recreation is considered highly unlikely as it is a shallow modified drainage channel that is situated within private farmland. Construction discharges is not anticipated to generate or consolidate enterococci. Additionally, since the turbidity of the discharges will be low, algal blooms are not anticipated. Concentrations of metals and toxicants that are hazardous to human health are not expected as they would be bound to sediment captured within the sediment basin. As the project would not generate any additional enterococci and would not produce excessive sediment, the project is considered unlikely to have a significant impact to secondary contact values.
R3 – Hunter River Drain (Estuarine)	✓	✓	✓	✓	N/A	The existing water quality and receiving environment at Hunter River Drain (not a natural waterway) is presented in **Table 11-8** where it is shown to be highly disturbed (as per WQO supporting information). Ongoing maintenance (flood conveyance) and surrounding agricultural land uses are anticipated to result in ongoing impacts to water quality and aquatic environment impacts. The range of values identified during site monitoring (<551 NTU) display the disturbed and variable condition of the drain. Flood gates at the downstream end of the creek alter surface flows by containing low and medium flows within the creek channel and therefore increase residence time to aid sediment settlement within the confines of the disturbed environment. The proposed quality of the construction water discharge from basins at this waterway does not comply with the DGV or the median turbidity of the existing environment. The impacts of the surrounding land use on water quality in the Hunter River Drain are evident in the water quality measured to date (**Table 11-8**). Without changes in surrounding land use it is unlikely the Hunter River Drain will meet WQO's over time. The proposed turbidity is calculated to require a dilution of 1.5 to meet the existing median ambient water quality and it is assumed that discharges would generally occur during/after rainfall events where catchment surface water would be adequate to provide sufficient dilution.

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during construction
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						It is noted that the proposed calculated turbidity is lower that the upper limit of the existing environment and following dilution, the short term construction discharge is anticipated to be generally in accordance with the existing surface water and is unlikely to significantly impact on the receiving disturbed environment. A discussion on the WQO is provided below. Aquatic ecosystems: Discharges from temporary sediment basins to Hunter River Drain will not meet the turbidity DGVs for protection of aquatic ecosystems (estuarine), however existing conditions within the waterway are often found to be highly turbid. Despite the sediment basin discharges not meeting DGVs, the temporary nature of the discharge is unlikely to reduce existing water quality or impact aquatic ecosystems over time. Visual amenity: Existing water quality in Hunter River Drain does not meet the WQO for visual amenity due to high turbidity levels that reduce visual clarity. Turbidity of discharges to Hunter River Drain from the temporary sediment basins are within the range of existing turbidity experienced within Hunter River Drain and discharges would be temporary in nature, therefore it is not expected to significantly impact visual amenity. Primary and secondary contact: Secondary contact is possible due to private land owner access and ongoing asset maintenance, however, primary contact is considered highly unlikely as it is a drainage channel that receives degraded runoff from a stud farm. Discharges from the temporary sediment basin would not contribute any bacterial constituents, however elevated turbidity would mean that the discharges could contain contaminants that could be hazardous to human health and therefore would continue to not meet these.
R4 – Windeyers Creek (Lowland river)	✓	✓	✓	✓	N/A	The proposed turbidity of the construction water discharge from basins at this waterway complies with the DGV and continues to protect WQOs. A brief discussion on the WQO is provided below. Aquatic ecosystems: Turbidity associated with discharge from temporary sediment basins to Windeyers Creek will comply with the DGV for the protection of aquatic ecosystems (lowland river) WQO. Contaminants such as heavy metals or toxicants which are bound to sediments are unlikely to be elevated in basin discharge due to deposition of sediments prior to discharge. The discharge into the aquatic environment is unlikely to have significant impact to the aquatic ecosystem.

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during construction
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						Visual amenity: Proposed turbidity would meet the WQO for visual amenity as turbidity levels are expected to be below the DGV and therefore visual clarity is not expected to be reduced. Primary and secondary contact: Secondary contact is possible due to public access, although primary contact recreation is considered highly unlikely. WQO for primary and secondary contact would be met for recreation, as sediment basin discharges are not expected to generate bacteria (i.e. enterococci) that would result in the deterioration of recreational water quality. Additionally, since the turbidity of the waterway will be low, additional algal blooms are not anticipated.
R5 – Viney Creek (Lowland river)	✓	✓	✓	✓	N/A	The proposed turbidity at this waterway does not comply with the DGV or the median turbidity of the existing environment. Further assessment is provided below. The existing water quality and receiving environment at Viney Creek is presented in **Table 11-8** where it is shown to be disturbed and modified due to complete alteration for its passage through a light industrial precinct. Ongoing maintenance (flood conveyance) and surrounding light industrial land uses are anticipated to result in ongoing impacts to water quality and aquatic environment impacts. A dam constructed within the channel of the creek alter surface flows by containing low and medium flows within the dam, however the dam increases residence time to aid sediment settlement within the confines of the disturbed environment. The proposed turbidity is calculated to require a dilution of 1.3 to meet the existing median ambient water quality and it is assumed that discharges would generally occur during/after rainfall events where catchment surface water would be adequate to provide sufficient dilution. It is noted that the proposed turbidity is slightly higher that the upper limit of the existing environment however following dilution, the short term construction impact is anticipated to be generally in accordance with the existing surface water and is unlikely to significantly impact on the receiving disturbed environment. With the proposed attenuation, construction discharges would work towards achievement of the WQO DGV over time and are unlikely to have a significant impact on water quality.

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during construction
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						Aquatic ecosystems: Proposed turbidity in Viney Creek is marginally higher that the ambient DGV, however the diluted turbidity would generally correspond with the existing water quality. The existing aquatic ecosystems are habituated to existing water quality and therefore the diluted discharges are unlikely to have significant impact to the aquatic ecosystem and would not hinder the long-term achievement of this WQO. Visual amenity: Turbidity would not meet the WQO, however the proposed turbidity is only slightly above the DGV and existing turbidity levels and therefore significant changes to the clarity of the waterway are not expected. Discharges are therefore not expected to hinder the long term achievement of the WQO. Primary and secondary contact: Secondary contact with the water is possible due to its accessibility by the public and its ongoing of maintenance for flood conveyance through the industrial area, however primary contact is unlikely due to shallow water and access limitation due to dense reed growth. Construction discharges are not anticipated to generate or consolidate enterococci, and as the modelled turbidity output is lower than the existing range, the project is unlikely to have a significant impact to secondary contact values.
R6 – Hunter River (Estuarine)	✓	✓	✓	✓	✓	The proposed turbidity at this waterway does not comply with the DGV, however calculated turbidity levels are generally lower than existing ambient turbidity levels. Hence the temporary sediment basin discharges are unlikely to have a significant impact on water quality and are working towards achieving the WQO over time. A discussion on the WQO is provided below. Aquatic ecosystems: The proposed turbidity is generally consistent with the existing background levels and with the high levels of dilution available in the tidal Hunter River, the minor volumes of temporary sediment basins discharges are unlikely to impact water quality in the Hunter River. As the aquatic ecosystems present within the river are habituated to the proposed discharge levels and are well under the existing range in the river (<776 NTU), the proposed discharges are unlikely to have a significant impact on the aquatic ecosystems of the Hunter River Visual amenity: The proposed turbidity of discharges to Hunter River are below the median value of turbidity experienced within the waterway and all discharges would be temporary in nature. Discharges are therefore expected to be working towards improving visual amenity.

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during construction
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						Primary and secondary contact: The most probable primary recreational contact with water across the project will be in the Hunter River as it is infrequently used for water sports (skiing, paddling etc) Secondary contact is highly probable due to activities such as shore and boat fishing. The WQOs of primary and secondary contact recreation are currently not being met due to high turbidity and nutrient levels and suspended sediments may contain elevated concentrations of metals and toxicants that are hazardous to human health. Construction discharges would not contribute to conditions favouring the growth of or introducing bacteria (i.e. enterococci) to the waterway. Discharges therefore would work toward meeting these WQOs and improving existing conditions. Aquatic foods (cooked): The WQO of aquatic foods (cooked) is currently not being met due to elevated NTU and other contaminant levels above the DGV. The discharges from the temporary sediment basins would comply with the lowland river DGV. Additionally, due to the temporary nature of construction, the basin discharges are unlikely to hinder the long-term achievement of this WQO.
R7 – Unnamed coastal wetland (Estuarine)	✓	✓	✓	✓	N/A	The proposed turbidity at this waterway does not comply with the DGV and exceeds the existing median background levels. Further assessment is provided below. The existing water quality and receiving environment is presented in **Table 11-8**. Surrounding livestock grazing land uses are anticipated to result in ongoing impacts to water quality and the aquatic environment. The proposed turbidity calculated to require a dilution of 1.8 to meet the existing ambient water quality and it is assumed that discharges would generally occur during/after rainfall events where catchment surface water would be adequate to provide sufficient dilution. Additionally, the wetland is expected to receive ongoing groundwater inputs from the adjacent Hunter River and upgradient Tomago Sands aquifer and these inputs can also be expected to express as surface water in the channel resulting in further dilution. When the dilution factor is applied to the, the short duration discharges are unlikely to have a significant impact on the receiving aquatic ecosystem. A brief discussion on the WQO is provided below. Aquatic ecosystems: The wetland and channelised watercourse at the site reflects a wetland of low to moderate condition that is affected by livestock grazing, various underground and overhead utility installations and the flood

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during construction
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						levee bank that separates the wetland form the adjacent Hunter River. The aquatic ecosystems at the site have become habituated to the modified conditions and are anticipated to be resilient to further modified inputs over the construction period. The site is expected to receive ongoing groundwater inputs from the adjacent Hunter River and upgradient Tomago Sands aquifer and these inputs can be expected to consistently resupply the channel with water for dilution. When the dilution factor is applied to the waterway inputs from temporary sediment basins are unlikely to have a significant impact on the receiving aquatic ecosystem and work towards meeting the water quality objectives over time. Visual amenity: Existing water quality of the unnamed tributary does not meet the estuarine WQO for visual amenity due to elevated turbidity that reduces visual clarity, Diluted turbidity is anticipated to be generally consistent with the range of turbidity experienced within the waterway and temporary in nature. Discharges are therefore not expected to degrade the waterway further than existing conditions and are expected to work towards meeting the lowland river WQO over time. Primary and secondary contact: Secondary contact with surface water is possible due to access to the site for asset maintenance. Primary contact is highly unlikely due to shallow water at the site Whilst construction discharges would not contribute to conditions conducive to the growth of bacteria (i.e. enterococci) in the waterway, discharges could contribute sediment and therefore toxicants that may result in WQO not being met.

Hunter Estuary Wetlands Ramsar site

Due to substantial distance from the project, it is expected that there would be no direct impacts to the Hunter Estuary Wetlands Ramsar site, comprising the Hunter Wetlands National Park at Kooragang Nature Reserve and the Hunter Wetland Centre at Shortland. However, there is potential for indirect impacts to the Kooragang Nature Reserve, located about 5.1 kilometres from the construction footprint, from construction discharges to the Hunter River. No pollution pathway is expected for the Hunter Wetland Centre at Shortland, therefore the following assessment only relates to the Hunter Estuary Ramsar Wetland at Kooragang Nature Reserve.

Potential indirect impacts to the Hunter Estuary Wetlands Ramsar site were considered in an assessment of significance required under the EPBC Act referral prepared for the project and described in the Biodiversity Assessment Report (**Appendix I**). Impacts to the Hunter Estuary Wetlands Ramsar site were not declared as part of the controlled action status identified for the project by the delegate for the Australian Minister for the Environment.

During construction of the project, three temporary sediment basins on the Hunter River could discharge directly into the river, travelling downstream to the Hunter Estuary Wetlands Ramsar site at Kooragang Nature Reserve. These basins have a direct flow path to the Hunter River (without obstruction by floodgates).

Dilution was modelled to estimate the concentrations of TSS that could be discharged from the three temporary sediment basins and transported downstream to the Hunter Estuary Wetlands Ramsar site at Kooragang Nature Reserve (refer to the Surface Water and Groundwater Quality Working Paper (**Appendix K**)). It is assumed that discharges from all other temporary sediment basins would not reach the Hunter River without dilution and treatment due to retention behind floodgates and therefore are not included in this assessment.

Dilution modelling found that the Hunter River generally provides sufficient dilution of the basin discharges into the Hunter River so that water flowing to the Hunter Estuary Wetlands Ramsar site at Kooragang Island meets the DGV for turbidity. As controlled discharges from temporary sediment basins would not contribute additional sediment to the wetland, it is expected that nutrient and toxicant concentrations would not materially increase as a result of discharges as these are typically bound to sediment. The WQO is met with the assistance of the dilution of the Hunter River and it is unlikely that the project will have a significant impact to the downstream Ramsar wetlands.

11.4.3 Operational impacts

Prior to the end of construction, disturbed areas would be stabilised with sealed operational surfaces, landscaping and in channel scour protection. Potential water quality impacts to waterways would therefore be limited to the accidental spills associated with vehicle accidents and road use, and stormwater runoff from new impervious surfaces.

The main strategy to minimise impacts to water quality during operation, in particular to SREs, is the provision of a water quality treatment sequence consisting of permanent water quality basins, and grassed swales (the controls are discussed further below). Rainfall runoff and accidental spills (such as petroleum hydrocarbons) within the footprint of the road would be treated and contained through these swales and water quality basins.

Operational surface water and groundwater quality impacts are discussed in the sections below.

Surface water quality from project operation

After construction, all temporary instream structures would be removed, scour protection and drainage would be installed where required, ancillary facilities would be rehabilitated, and disturbed soils would be stabilised. The main operation risks that could cause surface water quality impacts include:

- Accidental spills: Discharge of spills directly into waterways (should spill event happen on a bridge) or via runoff into the drainage system. Spills may include heavy metals, oils and/or fuels. This may result in transportation of dust, litter, or poor-quality runoff to downstream receiving environments from road use by vehicles or from car accidents
- Stormwater runoff: Untreated stormwater from impervious surfaces which are not conveyed to treatment systems. This may result in surface runoff that may cause erosion and sedimentation of downstream receiving environments, or may contain elevated levels of pollutants from new impervious surfaces which are not conveyed to treatment system
- Permanent water quality basin discharges: Discharges from permanent water quality basins following a rainfall event and dewatering of unlined basins with groundwater interaction which could result in elevated saline water being discharged to lowland river environments.

Waterways and wetlands that may be impacted by these operational risks are presented in **Table 11-19**. Further pollutant specific discussion is provided in the following sections.

Table 11-19 Operational water quality risks and waterways that may be impacted

Waterway or wetland	Operational risks		
	Accidental spill	Stormwater runoff	Permanent basin discharge of highly saline water
Tributary of Viney Creek	✓	✓	✓*
Glenrowan Creek and wetland near the twin bridge (B02) between Black Hill and Tarro	✓	✓	✓*
Unnamed Coastal Wetland (Coastal Management SEPP) south of New England Highway	✓	✓	
Purgatory Creek	✓	✓	
Hunter River	✓	✓	
Unnamed Coastal Wetland (Coastal Management SEPP) east of Hunter River	✓	✓	
Hunter River wetland	✓	✓	
Tomago Sandbeds (near Masonite Road)	✓^	✓	
Windeyers Creek	✓	✓	
Tributary of Windeyers Creek	✓	✓	

* These waterways/wetlands are considered lowland river environments that will receive saline discharge (<7500µS/cm). Windeyers Creek and Tributary of Windeyers Creek are not ticked for intrusion of elevated saline water, as indicative blends of water quality from basins are not saline.
^ The event of an accidental spill in this area is considered highly unlikely as all road pavements in the drinking water catchment areas drain to water quality basins which have spill containment of 30,000 litres and are lined.

Sediment

Sediment is most likely to be generated by the project during operation when surface runoff enters downstream receiving environments, causing erosion and sedimentation impacts. Sediment-laden runoff has the potential to temporarily reduce downstream water quality, particularly directly after a rainfall event. This would be unlikely to cause major or long term impacts to the overall condition of the surrounding waterways, as erosion and sedimentation would be managed with the implementation of erosion and sediment controls as detailed in **Section 11.4.2**.

Saline groundwater

During operation, 25 permanent water quality basins would interact with groundwater. Discharge from these basins following rainfall may result in the release of water that is more saline than the receiving environment during rainfall events. While permanent water quality basins are not subject to a dewatering regime, surface water runoff during and following rainfall may result in permanent water quality basins overtopping and discharging into receiving environments.

Risk of overflows that are more saline than the receiving environment would be most likely at basins which would discharge into Glenrowan Creek and the tributary of Viney Creek. These waterways are categorised as lowland river, and typically have lower salinity concentrations than groundwater. This discharge, if prolonged and regular, presents a risk to the long term health of these waterways. These, over time, may become more saline, and impact biota that are unable to tolerate higher salinities. However, discharge is expected to be limited to occasional rainfall events where basin capacity is exceeded. This is due to the design of the basin and gradually increasing impermeability of the basins caused by the settlement of fine particles sealing the basin and reducing the interaction between groundwater and surface water.

Potential impacts to surface water quality would be reduced through adequate project design and the implementation of management measures as discussed above and as detailed in **Section 11.4.2** and **Section 11.5**. Four basins that are considered the most likely to result in elevated saline water discharges (greater than 7,500µS/cm) have been recommended for lining to avoid groundwater ingress to the basins, reducing the potential for the release of highly saline water. As such, the risk of water quality impacts during operation would be low and would be manageable through proposed measures.

Heavy metals, oils, and fuels

During rainfall events, increased concentrations of heavy metals and hydrocarbons can be mobilised in runoff. Oils and fuels can also be mobilised from spill events or leaks. While mobilisation would be most likely during rainfall events, spills following vehicle accidents can still result in transportation of pollutants to downstream environments in dry weather. These pollutants (either directly transported to a waterway or attached to sediments) can damage the ecology of waterways and terrestrial ecosystems, they can be toxic to aquatic biota, result in fish kills and reduce visual amenity.

Stormwater quality management for road runoff includes managing the export of suspended solids and associated contaminants – namely heavy metals, nutrients, and organic compounds. Pollutants such as nutrients, heavy metals and hydrocarbons are usually attached to fine sediments. To minimise water quality impacts from additional stormwater runoff and spills, the project has been designed to include permanent water quality controls, including permanent water quality basins and vegetated swales as detailed in **Section 11.4.2**. Due to these controls, risk of potential changes to water quality within downstream waterways and wetlands would be minimised. Stormwater runoff from the project would not be expected to have a significant impact on water quality during operation.

There would be sufficient opportunity for any spill event to be contained near the project within the permanent water quality basins which include spill containment across the project. As such, potential risk of poor water quality mobilising to downstream waterways from spills would be negligible and would be sufficiently managed through proposed design and management measures.

Dust and litter

Project operation would generate litter and transport dust as part of road use by vehicles. Pollutants may result in increased levels of nutrients and toxicants which may be harmful to aquatic life and reduce visual amenity in receiving waterways and wetlands. With the implementation of the environmental management measures described in **Section 11.5**, dust and litter are not likely to result in a significant impact to water quality.

Water quality impacts from permanent water quality basins

Permanent water quality basins and grassed swales have been designed to minimise physical-chemical and toxicant levels from stormwater runoff from roads during operation. As described in **Section 5.3.9**, a total of 39 permanent water quality basins are proposed as shown in **Figure 5-1**. The volume and type of permanent water quality control basins are described in the Surface Water and Groundwater Quality Working Paper (**Appendix K**).

As with the temporary sediment basins, the permanent water quality basins would not be able to fully contain rainfall runoff from rainfall exceeding 38.9 millimetres, which is anticipated to happen about seven times per year for most basins except those which can only be partially emptied due to high groundwater levels. 25 of the permanent water quality basins proposed have the capacity to partially fill with groundwater. As the groundwater level would not be above the discharge water level of the basins, continuous drawdown and impact on the groundwater is not anticipated to occur. Four permanent water quality basins located within the Tomago Sandbeds Catchment Area are recommended to be lined, as well as four basins where elevated salinity discharge (i.e. more than 7500µS/cm) is expected to avoid contamination into the groundwater.

Grassed swales would also be implemented as described in **Section 5.3.9** to support the function of the permanent water quality basins. While swales alone may not achieve all of the water quality criteria for the project, the swales have allowed basin sizes to be reduced, therefore reducing the operational footprint. Grassed swales within the Tomago Sandbeds Catchment Area would be lined to avoid potential groundwater contamination.

As described in **Section 11.2.6**, TSS, TN and TP loads were derived at seven locations representative of receiving waterways and compared to the water quality indicators and associated DGVs shown in **Table 11-4**. Modelled residual annual pollutant loads for each receiving waterway are identified in **Table 11-20**. Lower loads discharged to the Hunter River are due to the smaller number of basins that have a direct connection to the Hunter River, where as smaller waterways such as Viney Creek receive a greater number of basin discharges.

Road pavement surface runoff is typically collected in the water quality basins and retained up until the next rainfall event when volume displacement occurs and the treated water leaves the basin. This process which is repeated provides hydraulic residence time for the collected runoff to start the treatment process of reducing concentrations and loads. TSS and particulate bound pollutants such as TP and heavy metals settle at the base of the basin and additional chemical and biological processes occur in the basin to reduce other pollutants such as TN.

Table 11-20 Average annual pollutant loads (kg/yr) discharged from water quality basins during operation under controlled conditions

Location	TSS	TN	TP
R1 – Glenrowan Creek	231	0.48	3.1
R2 – Purgatory Creek	2,200	4.47	28.4
R3 – Hunter River drain	2,260	4.11	22.7

Location	TSS	TN	TP
R4 – Purgatory Creek	2,270	5.39	39.2
R5 – Viney Creek	1,950	4.38	39.7
R6 – Hunter River	128	0.36	3.9
R7 – Unnamed coastal wetland	606	2.09	14.3

Operational groundwater quality impacts

Potential groundwater quality impacts during operation include:

- Permanent lowering of the water table and oxidation of PASS material
- Mounding of water table associated with soft soil consolidation, resulting in mobilisation of salts from the soil profile
- Operation of unlined permanent water quality basins and introduction of contaminants into groundwater via a new migration pathway.

These impacts, as well as water quality impacts to the public drinking supply of the Tomago Sandbeds Catchment Area, are discussed in the following subsections.

Acid sulphate soil risk associated with permanent lowering of the water table

No long term lowering of the water table is anticipated in association with operation of the project. Once temporary dewatering activities are completed, 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). In the vicinity of the Purgatory Creek adjustment, no long term reduction in water levels in the vicinity of the adjusted channel is anticipated. Accordingly, project operation is not expected to result in the oxidation of PASS material.

Soil salinity risk from soft soil consolidation

The long term mounding of the water table due to the consolidation of soft soil during operation is commensurate with that predicted during construction, with minor mounding predicted at Tarro and more substantial mounding predicted at Tomago. As such, and similar to construction, no significant impacts with respect to groundwater quality or soil salinity risk are anticipated.

Groundwater contamination risk from operation of unlined water quality basins

Unlined permanent water quality basins that have been excavated below the water table could expose local groundwater to any contaminants in the basin water. When full or partially full, water levels in the basins would be above that of the surrounding water table and the basins would act as temporary groundwater recharge basins. With runoff from the operational footprint entering the basins there is a risk that spills or contaminants could also enter the basin with subsequent migration to groundwater that may impact on groundwater quality.

The design of the permanent water quality basins incorporates spill containment measures to account for potential spills and the prevention of accidental discharge or migration to groundwater. Hydrocarbon spills would separate to the surface of the basins, be released to the atmosphere through volatilisation, therefore minimising the potential for migration to groundwater. Most non-spill related contaminants likely to enter the basin would be associated with suspended sediment or road particulate in runoff water. These particulates would settle out in the water quality basin and impacts of these contaminants on groundwater is expected to be negligible. Given that unlined water quality basins would be generally located in areas of relatively low permeability soils, the potential for contaminant migration, and water quality impacts would be substantially reduced.

Impacts to Tomago Sandbeds Catchment Area

No impacts to water quality within the Tomago Sandbeds Catchment Area are anticipated as a result of project operation. As the project has been designed to minimise and avoid impacts to the Tomago Sandbeds Catchment Area through the capture and conveyance of runoff leading to lined water quality basins, the risk impact to groundwater contamination at the Tomago Sandbeds Catchment Area from the project is considered to be minimal.

Coastal Management Areas

The operational footprint would be smaller than the construction footprint, providing opportunities for revegetation in Coastal Management Areas in accordance with the project urban design and landscape strategy (refer to **Section 15.3**).

Table 11-21 Coastal Management Areas (Coastal Management SEPP) that would be cleared or occupied for use during operation

Coastal Management Area category	Area to be permanently occupied by operational footprint
Coastal Wetlands	16.2ha
Coastal Wetlands Proximity Area	22.6ha
Coastal Use Area	15.3ha
Coastal Environment Area	78.2ha

Considering the existing roads (New England Highway and Pacific Highway) which traverse the Coastal Management Areas (and which the main alignment generally follows) the permanent clearance of these areas for the project is not expected to substantially impact on the functionality or visual amenity of the wetlands more than is already occurring.

Only two areas of wetland and floodplain vegetation are required to be permanently cleared and occupied from areas classified as 'Coastal Wetland' in the operational footprint, including wetland vegetation within the unnamed Coastal Wetland (south of the existing New England Highway) and Freshwater wetland and floodplain vegetation within the unnamed Coastal Wetland (east of the Hunter River). This vegetation is in poor to moderate condition with most areas showing signs of previous disturbance (i.e. regrowth following clearing and grazing). Further information is presented in **Chapter 9** (biodiversity).

Project operation has the potential to directly and indirectly impact the water quality of Coastal Management Areas that are within the surface water study area. These impacts would be related to:

- Changes to local hydrology at Purgatory Creek: The headwaters of Purgatory Creek are situated in the Coastal Wetland south of New England Highway near Tarro. The permanent adjustment of Purgatory Creek has the potential to result in a change in local hydrology for the area which may lead to changes in water quality such as build-up of contaminants in the wetland environment due to reduced flow or barriers to flow and therefore less flushing. The risk of this impact is considered low, and not significant, however, as the project design has ensured the revised operational drainage from the wetland to Purgatory Creek is generally maintained
- Road runoff: Road runoff to permanent water quality basins and subsequent discharge to downstream environments has the potential to result in deposition of sediment in wetlands or may introduce elevated levels of hydrocarbons, metals, or other contaminants such as litter to the wetland environment. As the environment surrounding already experiences runoff from existing roads, the operation of the project is not expected to result in a substantial increase in volume of runoff flowing to the downstream environment. As such, road runoff from the project is not expected to have a significant impact on Coastal Management Areas during operation.

To further minimise impacts to wetlands, the project design has ensured wetland fragmentation is minimised as much as practicable, with the main alignment only permanently occupying fringe areas of the wetlands and only requiring clearance and occupation of a small amount of the wetland relative to its size. As such, the permanent occupation of the main alignment is not expected to result in any significant impacts to Coastal Wetland areas listed under the Coastal Management SEPP.

Potential impacts to the Coastal Management Areas during operation of the project would therefore be limited to indirect impacts which would be related to changes to local hydrology at Purgatory Creek and road runoff during project operation.

Assessment of project operational discharges against WQOs

As discussed in **Table 11-19**, a number of pollutants associated with operation of the project may affect performance against the WQOs of the project described in **Section 11.2.4**. As described in **Section 11.3**, the WQOs are not currently being met.

While an improvement to existing water quality is anticipated for some indicators at modelled locations, water quality remains unlikely to meet the ANZG (2018) Water Quality Guidelines and nominated objectives in the short term. **Table 11-22** provides the expected concentrations of key pollutants from permanent water quality basin discharges against the DGVs for protection of aquatic ecosystems and existing water quality. The modelled median concentrations proposed in the discharge were compared against the WQOs DGV and against the existing background median values.

Representative waterways have been assessed to verify if they comply with the relevant WQO DGV or, to determine if the outcomes of the project construction activities work towards their achievement over time.

Proposed modelled water quality that is lower than the ambient DGV is shaded dark green to highlight that the WQO is protected. The compliant water quality is considered unlikely to cause significant harm to the waterway and a brief discussion on the relevant default WQO(s) is provided below in **Table 11-23**.

Proposed modelled water quality that does not meet the DGV but is generally lower than the existing ambient median values (determined by onsite monitoring) is shaded light green as it would contribute to achievement of the WQO DGV over time. The water quality is generally an improvement on the existing ambient water quality and is unlikely to cause significant harm to the waterway and a brief discussion on the relevant default WQO(s) is provided below in **Table 11-23**.

Proposed modelled water quality that exceeds the WQO DGV and existing ambient water quality is shaded red in **Table 11-22**. These representative locations are assessed in further detail in **Table 11-23.**

A detailed summary of the project's impact on water quality objectives during operation is presented in **Table 11-23**. The operation of the project is not expected to impact on achieving the WQOs of primary and secondary contact recreation with the key indicators of concern relevant to these objectives being pathogens, algae and toxicants. This is because the operation of the project would not result in an increase in bacteriological indicators. Additionally, increased algal numbers are not anticipated as there would be a reduction in nutrients entering the water via project runoff. It would be expected that a corresponding decrease in toxicants would also be observed into downstream waterway which could have posed a risk to human health. Therefore, operation of the project does not pose a significant risk to human health and the environment (refer to the Surface Water and Groundwater Quality Working Paper (**Appendix K**) for further details).

Table 11-22 Comparison of modelling water quality during operation with existing water quality and project water quality objectives

Waterway classification	Indicator	DGV aquatic ecosystem	Existing median concentrations when dry	Existing range concentrations when dry	Modelled median value and comparison against aquatic ecosystems WQO	Further discussion required (refer to Table 11-23)
R1 – Glenrowan Creek (Lowland river)	Turbidity	6-50 NTU	17.2	5.84 – 57.7	26.8 Complies with WQO DGV	No
	TN	0.35mg/L	1.6	0.5 – 1.6	0.69 Contributes towards achieving WQO over time	No
	TP	0.025mg/L	0.13	0.03 – 0.29	0.105 Contributes towards achieving WQO over time	No
R2 – Purgatory Creek (Estuarine)	Turbidity	0.5-10 NTU	14.1 – 41.65	2.26 – 115	62.67	Yes
	TN	0.3mg/L	0.5 – 5.1	0.5 –6.5	0.47 Contributes towards achieving WQO over time	No
	TP	0.03mg/L	0.27 – 0.58	0.02 – 0.81	0.07 Contributes towards achieving WQO over time	No
R3 – Hunter River Drain (Estuarine)	Turbidity	0.5-10 NTU	20.82 – 55.63	5.95 – 551	38.13 Contributes towards achieving WQO over time	No
	TN	0.3mg/L	1.15 – 3	0.6 – 5.1	0.28 Complies with WQO DGV	No
	TP	0.03mg/L	0.43 – 1.04	0.16 – 1.36	0.05 Contributes towards achieving WQO over time	No
R4 – Windeyers Creek (Lowland river)	Turbidity	6-50 NTU	6.57 – 39.53	5.01 – 71.2	9.32 Complies with WQO DGV	No
	TN	0.35mg/L	0.9 – 2.7	0.6 – 3.8	0.51 Contributes towards achieving WQO over time	No
	TP	0.025mg/L	0.08 – 0.2	0.03 – 0.32	0.068 Contributes towards achieving WQO over time	No

Waterway classification	Indicator	DGV aquatic ecosystem	Existing median concentrations when dry	Existing range concentrations when dry	Modelled median value and comparison against aquatic ecosystems WQO	Further discussion required (refer to Table 11-23)
R5 – Viney Creek (Lowland river)	Turbidity	6-50 NTU	31.58	19.7 – 57.7	55.25	Yes
	TN	0.35mg/L	0.9	0.5 – 0.9	0.59 Contributes towards achieving WQO over time	No
	TP	0.025mg/L	0.1	0.07 – 0.11	0.083 Contributes towards achieving WQO over time	No
R6 – Hunter River (Estuarine)	Turbidity	0.5-10 NTU	37.3 – 66.03	14.8 – 776	22.96 Contributes towards achieving WQO over time	No
	TN	0.3mg/L	1 – 1.6	0.3 – 3.1	1.34 Contributes towards achieving WQO over time	No
	TP	0.03mg/L	0.16 – 0.21	0.06 – 0.68	0.121 Contributes towards achieving WQO over time	No
R7 – Unnamed Coastal Wetland (Estuarine)	Turbidity	0.5-10 NTU	25.75	12.1 – 32.7	29.34	Yes
	TN	0.3mg/L	1.2	0.5 – 1.8	0.67 Contributes towards achieving WQO over time	No
	TP	0.03mg/L	0.07	0.07 – 0.09	0.093	Yes

Where a range is presented for the monitoring results it shows the range of the monitoring points on that stream, some streams only have one monitoring point and therefore have a single data point not a range.

Table 11-23 Project impact on water quality objectives during operation

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during operation
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
R1 – Glenrowan Creek (Lowland river)	✓	✓	✓	✓	N/A	The proposed water quality at this waterway complies with the DGV for turbidity and contributes toward the achieving the WQO over time for TN and TP. Therefore, discharges during operation of the project are unlikely to have a significant impact on water quality. A brief discussion on the WQO is provided below. Aquatic ecosystems: Proposed water quality has lower levels of contaminates then either the WQO or the existing environment and are unlikely to have a significant impact on the receiving aquatic ecosystem. Visual amenity: The project would meet the WQO for visual amenity with turbidity levels expected to be below the DGV. Visual clarity is therefore not expected to be reduced. Primary and secondary contact: Secondary contact may be possible for public access and maintenance of assets however primary contact is unlikely due to shallow water and degraded water quality. The project would meet the WQO secondary recreation as operation of the project is not expected to increase bacterial counts that would result in the deterioration of recreational water quality. Additionally, metal and toxicant concentrations are expected to be captured with sediment and therefore are unlikely to be in concentrations that are hazardous to human health.
R2 – Purgatory Creek (Estuarine)	✓	✓	✓	✓	N/A	The proposed water quality at this waterway does not comply with the DGVs for turbidity, however TN and TP however are modelled to be less than existing background and hence contribute to achieving the WQO over time. Further assessment is provided below. The existing water quality and receiving environment at Purgatory Creek is presented in **Table 11-8** where it is shown to be highly disturbed. Ongoing maintenance (flood conveyance) and surrounding livestock grazing land uses are anticipated to result in ongoing impacts to water quality and the aquatic environment. The range of values identified during site monitoring (<115 NTU) display the disturbed and variable condition of the waterway. Flood gates at the downstream end of the creek alter surface flows by containing low and medium flows within the creek channel and hence increase residence time to aid sediment settlement within the confines of the disturbed environment. The proposed turbidity is calculated to require a dilution of 6.2 to meet the existing median ambient

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during operation
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						water quality and as the permanent water quality basins passively discharge only during rainfall events that overtop the designed capacity, it is assumed that there would be adequate water within the catchment to provide sufficient dilution. It is noted that the proposed modelled water quality indicators are lower that the upper value of the existing ambient quality and following dilution, infrequent operational discharge is anticipated to be generally in accordance with the existing surface water and is unlikely to significantly impact on the receiving disturbed environment. Aquatic ecosystems: Turbidity in at Purgatory Creek will not meet the turbidity DGV for protection of aquatic ecosystems, however existing conditions do not comply. Proposed TN and TP levels are less that existing background. Due to the existing water quality, the receiving aquatic ecosystem is habituated to degraded conditions. As the permanent water quality basins passively discharge during rainfall (only) the discharge into the diluted creek is anticipated to reflect the existing variable water quality habitat and is unlikely to have significant impact to the aquatic ecosystem. Visual amenity: Existing turbidity levels do not meet the WQO. The sporadic addition of discharge water during rainfall events that generally complies with the existing turbidity range during rain fall events is unlikely to significantly impact on the visual amenity of the water. Primary and secondary contact: Secondary contact is possible due to landowner access and ongoing asset maintenance, however primary contact recreation is considered highly unlikely as it is a shallow modified drainage channel that is situated within private farmland. Construction discharges shall not generate or consolidate enterococci and as the turbidity of the discharges will be consistent with existing conditions, increased algal blooms are not anticipated. The project is unlikely to significantly impact on secondary contact values.
R3 – Hunter River Drain (Estuarine)	✓	✓	✓	✓	N/A	The proposed water quality at this drain complies with the WQO DGV for TN. Turbidity and TP do not meet the WQO DGV however are lower than the existing environment and hence contribute toward achieving the WQO over time. Therefore, discharges during operation of the project are unlikely to have a significant impact on water quality. A brief discussion on the WQO is provided below.

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during operation
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						Aquatic ecosystems: Discharges to the Hunter River Drain from the operation of the project would not meet the WQO for aquatic ecosystems (estuarine) due to elevated turbidity and TP concentrations. Noting that the drain is not a natural waterway, significant impacts to aquatic ecosystems are unlikely. Visual amenity: The proposed water quality generally consistent with the existing ambient condition and is unlikely to significantly impact on visual amenity. Primary and secondary contact: Secondary contact is possible due to landowner access for flood conveyance management and ongoing asset maintenance, however primary contact recreation is considered highly unlikely as it is a shallow modified drainage channel that is situated within private farmland. Construction discharges shall not generate or consolidate enterococci and as the turbidity of the discharges will be consistent with existing conditions, increased algal blooms are not anticipated. The project is unlikely to significantly impact on secondary contact values.
R4 – Windeyers Creek (Lowland river)	✓	✓	✓	✓	N/A	The proposed water quality at this waterway complies with the DGV for turbidity and contributes toward achieving the DGV over time for nutrients. Discharges from permanent basins are unlikely to have a significant impact on water quality. A brief discussion on the WQO is provided below. Aquatic ecosystems: As the proposed water quality meet the WQO or are better than the existing background levels, the operation of the project is unlikely to significantly impact on the receiving aquatic ecosystems. Visual amenity: The proposed water quality is generally consistent with the existing ambient turbidity and are unlikely to significantly impact on visual amenity Primary and secondary contact: Secondary contact is possible due to open public access to surrounding open spaces and access for maintenance for drainage from the Raymond Terrace Wastewater Treatment Works, however primary contact recreation is considered highly unlikely due to shallow water and poor water quality. Operational discharges shall not generate or consolidate enterococci and as the turbidity of the discharges will be consistent with existing conditions, increased algal blooms are not anticipated. The project is unlikely to significantly impact on secondary contact values.

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during operation
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
R5 – Viney Creek (Lowland river)	✓	✓	✓	✓	✓	The proposed water quality at this waterway does not meet the WQO or existing background levels for turbidity. TN and TP are lower than ambient conditions and therefore work towards improving water quality and meeting the WQO over time. Further detailed assessment is provided below. The existing water quality and receiving environment at Viney Creek is presented in **Table 11-8** where it is shown to be disturbed and modified due to complete alteration for its passage through a light industrial precinct. Ongoing maintenance (flood conveyance) and surrounding light industrial land uses are anticipated to result in ongoing impacts to water quality and aquatic environment impacts. A dam constructed within the channel of the creek alters surface flows by containing low and medium flows within the dam, however the dam increases residence time to aid sediment settlement within the confines of the disturbed environment. The proposed turbidity discharged from basins is calculated to require a dilution of 1.1 to meet the existing median ambient water quality and as the permanent water quality basins passively discharge only during rainfall events that overtop the designed capacity, it is assumed that there would be adequate water within the catchment to provide sufficient dilution. It is noted that the proposed modelled discharge is slightly higher in turbidity that the upper limit of the existing environment and following dilution, infrequent operational discharge is anticipated to be generally in accordance with the existing surface water and is unlikely to significantly impact on the receiving disturbed environment. The Aquatic foods (cooked) WQO would not apply to this waterway as there is no commercial fishery and no recreational fishing was identified during project consultation nor in background information reviewed for the EIS. Aquatic ecosystems: Proposed turbidity in Viney Creek is marginally higher that the ambient DGV and TN and TP are lower existing conditions, however the diluted turbidity corresponds with the existing water quality. The existing aquatic ecosystems is habituated to existing water quality and therefore the proposed impacts to water quality are considered unlikely to have significant impact to the aquatic ecosystem Visual amenity: The proposed water quality is generally consistent with the existing ambient water quality and is unlikely to significantly impact on visual amenity

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during operation
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						Primary and secondary contact: Secondary contact with the water is possible due to its accessibility by the public and its ongoing of maintenance for flood conveyance through the industrial area, however primary contact is unlikely due to shallow water and access limitation due to dense reed growth. Operational discharges shall not generate or consolidate enterococci, and as the modelled turbidity output is lower than the existing range, the project is unlikely to have a significant impact to secondary contact values.
R6 – Hunter River (Estuarine)	✓	✓	✓	✓	✓	The proposed water quality at this waterway would not meet the WQO however as it is lower that both the existing median and range values, the proposed discharges contributes toward the achieving the DGV over time. Discharges from permanent basins are unlikely to have a significant impact on water quality. In the Hunter River, dilution modelling was carried out which indicated that there is sufficient dilution provided by river flows so that basin discharges would not result in any long term changes in water quality. A brief discussion on the WQOs is provided below. Aquatic ecosystems: The existing water quality of the Hunter River does not meet the WQO DGV and is highly variable due to land uses in the catchment and the tidal influence, however the significant water volumes in the river and associated dilution from upstream and downstream sources support the existing aquatic ecosystems described in **Table 11-8**. The existing aquatic ecosystems (such as a lack of seagrass, but broad areas of mangrove forest) reflect the variable turbidity in the surface water quality and the aquatic ecosystems are habituated to the existing conditions. The infrequent operational discharges (point load) from the project are lower than the existing turbidity range and far lower than the existing upper limit observed onsite and are unlikely to have a significant impact on the SRE aquatic ecosystem. Proposed operational nutrient discharge is also well under the existing median and range and is unlikely to significantly impact the aquatic ecosystems Visual amenity: The proposed ambient water quality are generally better than the existing ambient quality and is unlikely to significantly impact on visual amenity Primary and secondary contact: The most probable primary recreational contact with water across the project will be in the Hunter River as it is infrequently used for water sports (skiing, paddling etc) Secondary contact is highly probable due to activities such as shore and boat fishing. The WQOs of primary and secondary contact recreation

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during operation
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						are currently not being met due to high turbidity and nutrient levels and suspended sediments may contain elevated concentrations of metals and toxicants that are hazardous to human health. Permanent operational discharges would not contribute to conditions favouring the growth of or introducing bacteria (i.e. enterococci) to the waterway. Discharges therefore would work toward meeting these WQOs and are unlikely to have a significant impact to primary and secondary contact values. Aquatic foods (cooked): The WQO of aquatic foods (cooked) is currently not being met due to elevated NTU and other contaminates levels above the DGV. The discharges from the permanent water quality basins would improve the background water quality. Additionally, with the large volume of dilution available, the basin discharges are unlikely to hinder the long-term achievement of this WQO and are unlikely to have a significant impact on aquatic food values.
R7 – Unnamed coastal wetland (Estuarine)	✓	✓	✓	✓	✓	The proposed turbidity of the water quality at this waterway does not comply with the DGV and exceeds the existing median background levels for both turbidity and TP. TN is below the existing environment is unlikely to have a significant impact on water quality. The Aquatic foods (cooked) WQO would not apply to this waterway as there is no commercial fishery and no recreational fishing was identified during project consultation nor in background information reviewed for the EIS. Further assessment on turbidity and TP is provided below. The existing water quality and receiving environment is presented in **Table 11-8**. Surrounding livestock grazing land uses are anticipated to result in ongoing impacts to water quality and the aquatic environment. The proposed turbidity is modelled to require a dilution of 1.1 for turbidity and 1.3 for TN to meet ambient median background water quality. As the permanent water quality basins passively discharge only during rainfall events that overtop the designed capacity, it is assumed that there would be adequate surface water within the catchment to provide sufficient dilution. Additionally, the wetland is expected to receive ongoing groundwater inputs from the adjacent Hunter River and upgradient Tomago Sands aquifer and these inputs can also be expected to express as surface water in the channel that may provide further dilution. The infrequent diluted permanent operational

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during operation
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						discharge is anticipated to be generally in accordance with the existing surface water and is unlikely to significantly impact on the receiving water quality. A brief discussion on the WQOs is provided below. Aquatic ecosystems: The wetland and channelized watercourse at the site presents as a wetland of low to moderate condition that is affected by livestock grazing, various underground and overhead utility installations and the flood levee bank that separates the wetland form the adjacent Hunter River. The disturbed aquatic ecosystems at the site have become habituated to the modified water quality and flow conditions. The proposed water quality is within the range(s) identified during site monitoring and the diluted discharges are unlikely to have a significant impact on the receiving aquatic ecosystem. Visual amenity: Existing water quality of the unnamed tributary does not meet the estuarine WQO for visual amenity due to elevated turbidity that reduces visual clarity, Diluted turbidity is anticipated to be generally consistent with the range of turbidity experienced within the waterway and are unlikely to have a significant impact on visual amenity. Primary and secondary contact: Secondary contact with surface water is possible due to access of the site for asset maintenance. Primary contact is unlikely due to shallow water at the site. Permanent operational discharges would not contribute to conditions favouring the growth of or introducing bacteria (i.e. enterococci) to the waterway. Discharges therefore would work toward meeting these WQOs and are unlikely to have a significant impact to secondary contact values.

Hunter Estuary Wetlands Ramsar site

The operation of the project has the potential to impact on the Hunter Estuary Wetlands Ramsar site at Kooragang Nature Reserve as a result of discharges from water quality basins to the Hunter River which have the potential to increase the TSS, TN and TP concentrations entering the wetland. Potential indirect impacts to the Hunter Estuary Wetlands Ramsar site were considered and highlighted in an assessment of significance required under the EPBC Act referral prepared for the project and described in the Biodiversity Assessment Report (**Appendix I**). Impacts to the Hunter Estuary Wetlands Ramsar site were not declared as part of the controlled action status identified for the project by the delegate for the Australian Minister for the Environment.

To gain an understanding of the impact operation of the project could have on the Hunter Estuary Wetlands Ramsar site, a dilution model was simulated to estimate TSS/turbidity, TN and TP concentrations discharged directly into the Hunter River. There are five water permanent water quality basins that discharge directly to the Hunter River, two on the western side and three on the eastern side of the river. It is assumed that discharges from all other permanent water quality basins would not reach the Hunter River and therefore not included in this assessment.

Estimated concentrations and volumes from each of the five water quality basins, together with existing streamflow and median dry weather concentrations in the Hunter River were used to model the concentrations at the discharge and at the downstream Hunter Estuary Wetlands Ramsar site at Kooragang Nature Reserve. Results for TSS were converted to turbidity using the results of the linear regression (refer to Appendix C of the Surface Water and Groundwater Quality Working Paper (**Appendix K**)).

The Hunter River would provide sufficient dilution of the basin discharges so that the basin discharges meet the WQO and do not contribute to higher turbidity, TN or TP at the Hunter Estuary Wetland Ramsar site at Kooragang Nature Reserve. The project is not expected to result in any significant impacts to water quality at the Hunter Estuary Wetland Ramsar site.

11.5 Environmental management measures

The environmental management measures that will be implemented to minimise the surface water and groundwater quality impacts of the project, along with the responsibility and timing for those measures, are presented in **Table 11-24**.

Table 11-24 Environmental management measures (surface water and groundwater quality)

Impact	Reference	Management measure	Responsibility	Timing
General	WQ01	A Construction Soils and Water Management Plan (CSWMP) would be developed as a sub plan of the CEMP and will outline measures to manage soil and water quality impacts associated with the construction work, including contaminated land. The CSWMP would include but not be limited to: • Measures to minimise/manage erosion and sediment transport both within the construction footprint and offsite including requirements for the preparation of erosion and sediment control plans (ESCP) for all progressive stages of construction and the implementation of erosion and sediment control measures • Erosion and sediment control measures, which will be implemented and maintained in accordance with Managing Urban Stormwater – Soils and Construction, Volume 1 (Landcom 2004) and Volume 2D (DECC 2008) • Measures to manage stockpiles including locations, separation of waste types, sediment controls and stabilisation in accordance with the Stockpile Site Management Guideline (Roads and Maritime Services 2015e). • Procedures for dewatering (including waterways, wetlands and excavations and temporary sediment basins) including relevant discharge criteria. • Concrete waste management procedures • Measures to manage accidental spills including the requirement to maintain materials such as spill kits, an emergency spill response procedure and regular visual water quality checks when working near waterways • Measures to manage tannin leachate and potential saline soils • Controls for sensitive receiving environments which may include but not be limited to identification of 'no go' zones for construction plant and equipment (where applicable).	Contractor	Prior to construction/ construction/ operation
	WQ02	A soil conservation specialist will be engaged for the duration of construction of the project to provide advice on the planning and implementation of erosion and sediment control including review of the CSWMP and ESCP.	Transport / Contractor	Prior to construction/ construction/ operation

Impact	Reference	Management measure	Responsibility	Timing
Water reuse	WQ03	A water reuse strategy will be developed as part of the CEMP for both construction and operational phases of the project to reduce reliance on potable water. Any water from sediment basins will be checked to ensure compliance with ANZG (2018) Water Quality Guidelines prior to reuse.	Contractor	Detailed design/ prior to construction/ construction
Discharge of saline groundwater to drinking catchment	WQ04	Basins and swales within the Tomago Sandbeds drawdown area will be lined during construction and operation.	Contractor	Detailed design
Discharge of saline groundwater to surface waterways	WQ05	Basins TB04, TB06, TPB10 (PB12), TPB18 (PB24), PB14 and PB15 shall be further investigated to confirm requirement for lining to avoid discharge of saline groundwater to surface waterways during construction and operation.	Transport	Detailed design
Surface water quality and groundwater quality impacts	WQ06	A water quality monitoring program will be developed in accordance with the Guidelines for Construction Water Quality Monitoring (RTA 2003b). The program will monitor surface water quality and groundwater quality during construction and during operation.	Transport / Contractor	Prior to construction/ construction/ operation
Other relevant management measures				
Salinity	SC02	A Salinity Management Plan will be prepared and implemented as part of the CSWMP and in accordance with the NSW Department of Primary Industries (2014) Salinity Training Handbook. The plan will include (but not be limited to): • Identification and management of saline groundwater discharge sites • Identification of areas sensitive to salinity and subject to saline soil import limitations (such as the Tomago Sandbeds Catchment Area) • Testing and reuse conditions of saline soils • Requirements for reuse of saline water.	Contractor	Prior to construction/ construction
Acid sulfate soils	SC03	An Acid Sulfate Soils Management Plan (ASSMP) will be prepared and implemented as part of the CSWMP and in accordance with TfNSW's Guidelines for the Management of Acid Sulfate Materials (RTA 2005c) and the Acid Sulfate Soil Manual (ASSMAC 1998). The ASSMP will outline how potential ASS within sediments of the waterways and soils that will be disturbed within the construction footprint will be handled, tested, treated and reused during construction.	Contractor	Prior to construction/ construction

11.5.1 Water quality monitoring program

A surface water and ground water monitoring program will be implemented as an environmental management measure to observe any changes in surface water and groundwater quality that may be attributable to the project and inform appropriate management responses. Monitoring locations for surface water and groundwater quality during pre-construction, construction and operation are shown in **Figure 11-1**.

Surface water quality monitoring program

The proposed surface water quality monitoring program will aim to continue monitoring the sites shown on **Figure 11-1**, however, the location of monitoring sites may be refined during detailed design based on site design and location of proposed water quality controls. Monitoring site locations which are expected to become unavailable after construction due to creek adjustment work will be reconsidered and relocated downstream. Additional sites, reference and control sites (i.e. up and downstream of the project) will be identified before construction.

The location, frequency and indicators of the surface water quality monitoring program are presented in **Table 11-25**.

Table 11-25 Location, frequency and indicators for surface water quality monitoring

	Additional baseline data[1]	**Construction phase**	**Operational phase**
Location	As per **Figure 11-1**[2]		
Frequency	Quarterly (wet and dry[3]) for a minimum of six months prior to construction	Quarterly (wet and dry[†]) for the duration of construction	Quarterly (wet and dry) for a period of 12 months during operation of the project (i.e. 12 months post construction)
Indicators	• Field parameters (electrical conductivity, pH, turbidity, dissolved oxygen and temperature) • Visible oil and grease[4] • Total dissolved solids and TSS • Total nitrogen • Total phosphorus • Dissolved metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc, iron and manganese)		

1. In addition to the existing baseline data described in the Surface Water and Groundwater Quality Working Paper (**Appendix K**)
2. As described above, the necessity for some of the monitoring sites may be rationalised during detailed design. As a result, the locations shown in **Figure 11-1** are indicative only and are subject to change
3. A wet weather event is classified as 20mm or more of rain within 24 hours, as recorded at the Newcastle University BOM rainfall gauge (#061390). Sampling would occur within 24 hours of the rain event. If rainfall events are regularly less than 20mm, opportunistic wet weather monitoring would be carried out to ensure that some wet weather data is collected
4. If oil and grease visible, sample to be assessed for total petroleum hydrocarbons

Groundwater quality monitoring program

The proposed groundwater quality monitoring program will continue monitoring the existing monitoring network (as shown in **Figure 11-1**). However, the necessity for some of the monitoring sites may be rationalised or adjusted during detailed design based on site design and anticipated impacts. It is also likely during detailed design that additional groundwater investigations will be required that will likely result in further monitoring bores being installed to target specific elements or areas of risk during construction, such as confirming groundwater level and quality at water quality basin locations. Before construction all available groundwater monitoring locations will be reviewed and rationalised as required. Additional sites may be identified before construction as an outcome of detailed site investigation. Sentinel monitoring

locations, situated between high risk activities and sensitive receptors, may also considered where applicable.

The location, frequency and indicators of the groundwater quality monitoring program are presented in **Table 11-26**.

Table 11-26 Location, frequency and indicators for groundwater quality monitoring

	Additional baseline data[1]	**Construction phase**	**Operational phase**
Location	As per **Figure 11-1**[2]		
Frequency	Two monthly for 12 months prior to construction	Quarterly for the duration of construction	Quarterly for a period of 12 months during operation of the project (i.e. 12 months post construction)
Indicators	• Field parameters (electrical conductivity, pH, turbidity, dissolved oxygen and temperature) • Total dissolved solids • Major ions (sodium, magnesium, calcium, chloride, bicarbonate/carbonate and sulfate)[3] • Nutrients (ammonia, nitrate, TN, TP)[3] • Dissolved metals (aluminium, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel and zinc)[3]		

1. In addition to the existing baseline data described in the Surface Water and Groundwater Quality Working Paper (**Appendix K**)
2. As described above, the necessity for some of the monitoring sites may be rationalised during detailed design. As a result, the locations shown in **Figure 11-1** are indicative only and are subject to change