Appendix C

Flood impact assessment report

Singleton Bypass Project

Singleton Bypass Detailed Design Flood Assessment

Transport for New South Wales

Reference: P525567

Revision: 3

2024-08-22

Bringing ideas to life

Document control record

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1 Introduction

1.1 Project Background

Singleton Council completed the Singleton Flood Study in 2003. The study, along with subsequent flood risk assessments, highlighted that the town of Singleton is susceptible to a relatively high level of flood risk. It was found that the existing levee system provides a limited level of flood immunity, and significant parts of the town are expected to experience flooding during major flood events, such as the 1% Annual Exceedance Probability (AEP) event. A notable historical flood event that serves as a point of reference for the potential impact of flooding at Singleton is the 1955 Hunter River flood. During this flood event extensive flooding occurred in Singleton.

Currently, Transport for New South Wales (Transport) is in the process of developing the detailed design for the Singleton bypass (the Project). A preferred option for the Project was announced in 2016 and involved building a new section of highway across the Hunter River and Doughboy Hollow floodplains, starting west of Singleton near Newington Lane, and rejoining the New England Highway north of McDougall's Hill at Rixs Creek Lane. A review of environmental factors (REF) was prepared for the Project in December 2019 (hereafter referred to as the project REF (December 2019)). The project REF (December 2019) was placed on public display between Monday 16 December 2019 and Sunday 1 March 2020 for community and stakeholder comment. A submissions report dated 7 August 2020 was prepared to respond to issues raised.

In addition, the following addendum REFs for the New England Highway bypass of Singleton have been prepared:

- An addendum REF, determined in May 2023, was prepared to adjust the proposal area following consultation and to facilitate general constructability.
- An addendum REF, determined in October 2023, was prepared to provide a full interchange at Putty Road for ease of access to Singleton's town centre from the bypass, extending the bridge over the Doughboy Hollow floodplain and reconfiguring the design at the southern connection. The design presented in the addendum REF (October 2023) will hereafter be referred to as the approved project.

Transport awarded a design and construction contract to ACCIONA Construction Australia Pty Ltd to deliver the Singleton Bypass. As a result of design progression, modifications to the approved project were required to further improve road safety, constructability and has resulted in revised interchange arrangements and property accesses. This report will support an addendum REF which captures these design changes, hereafter known as the proposed modification.

1.2 Study Area

The study area for the flood impact assessment encompasses the town of Singleton and the Hunter River and Doughboy Hollow floodplains, extending from Hambledon Hill in the west to Lower Belford and Glendon in the east. The Hunter River and Doughboy Hollow floodplains are bounded by steep terrain to the north and the Golden Highway to the south. A depiction of the study region created using a Digital Elevation Model (DEM) based on Shuttle Radar Topography Mission (SRTM) data, along with significant locations, can be seen in Figure 1. For the flood risk assessment of the proposed Singleton bypass, the specific study area and Project alignment is displayed in Figure 2.

In terms of land use, the urban centre of Singleton occupies a considerable portion of the study area and comprises residential, commercial, and some industrial developments. Surrounding Singleton, the predominant land use consists of agricultural land and pasture, predominantly located within the Hunter River and Doughboy Hollow floodplains. There are also numerous rural properties dispersed throughout the study area.

Noteworthy geographical features and structures within the study area include the New England Highway and the Main North Railway Line, both of which traverse the Hunter River and Doughboy Hollow floodplains from Whittingham to Singleton. The existing levee system on the north-western side of the Singleton township, which intersects with the embankment of the Main North Railway Line at Glenridding, also impacts flood dynamics in the vicinity. Additionally, Doughboy Hollow is an area of natural prominence that becomes active during floods of the 10% AEP event or greater. Several flow constrictions can be identified, including major bridge crossings provided along the Main North Railway Line, the New England Highway, Dunolly Road, and Queen Street. Numerous other drainage and flow control structures have been implemented beneath the Main North Railway Line and the New England Highway to facilitate the conveyance of flood flows across the Doughboy Hollow floodplain during significant flood events.

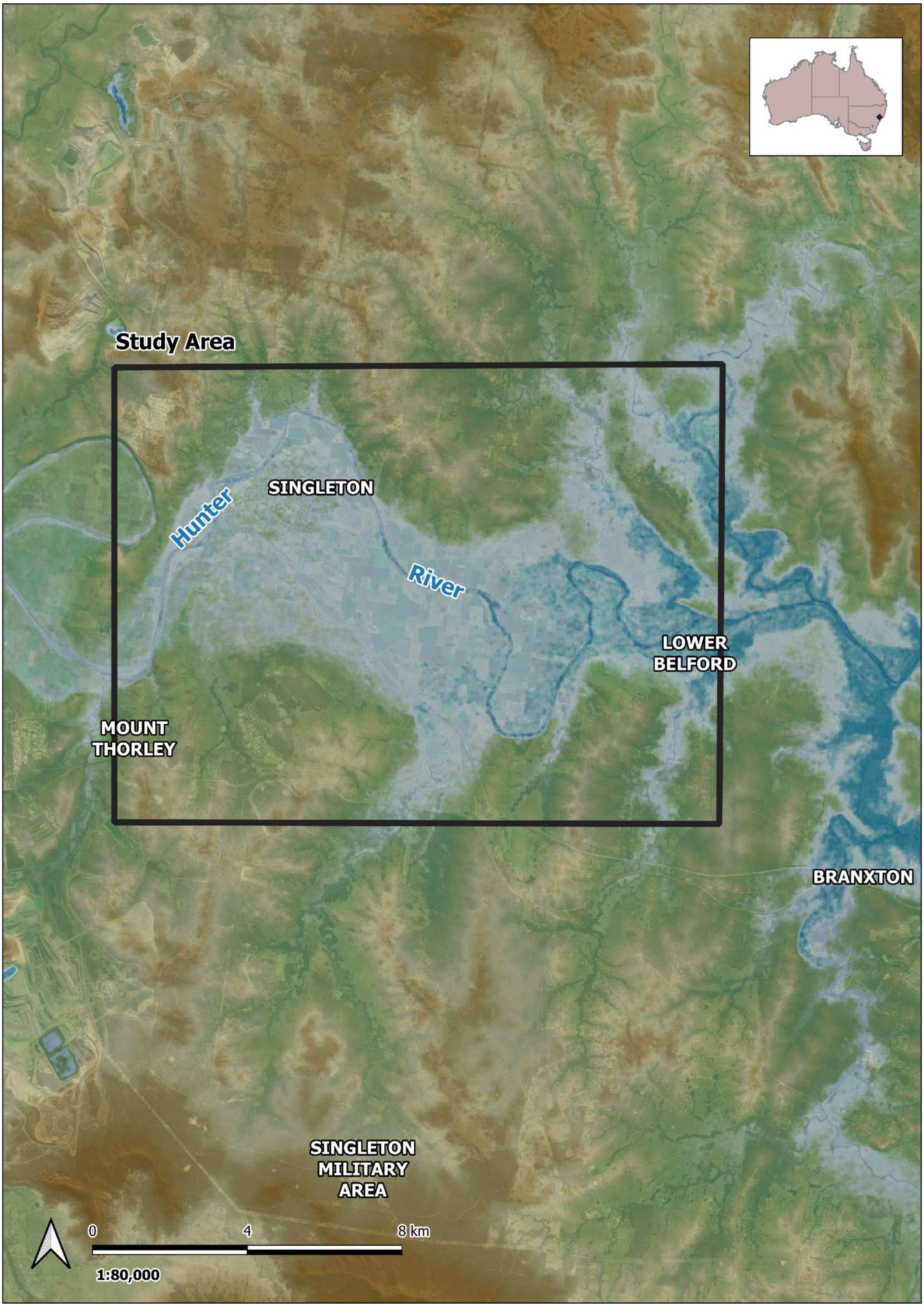
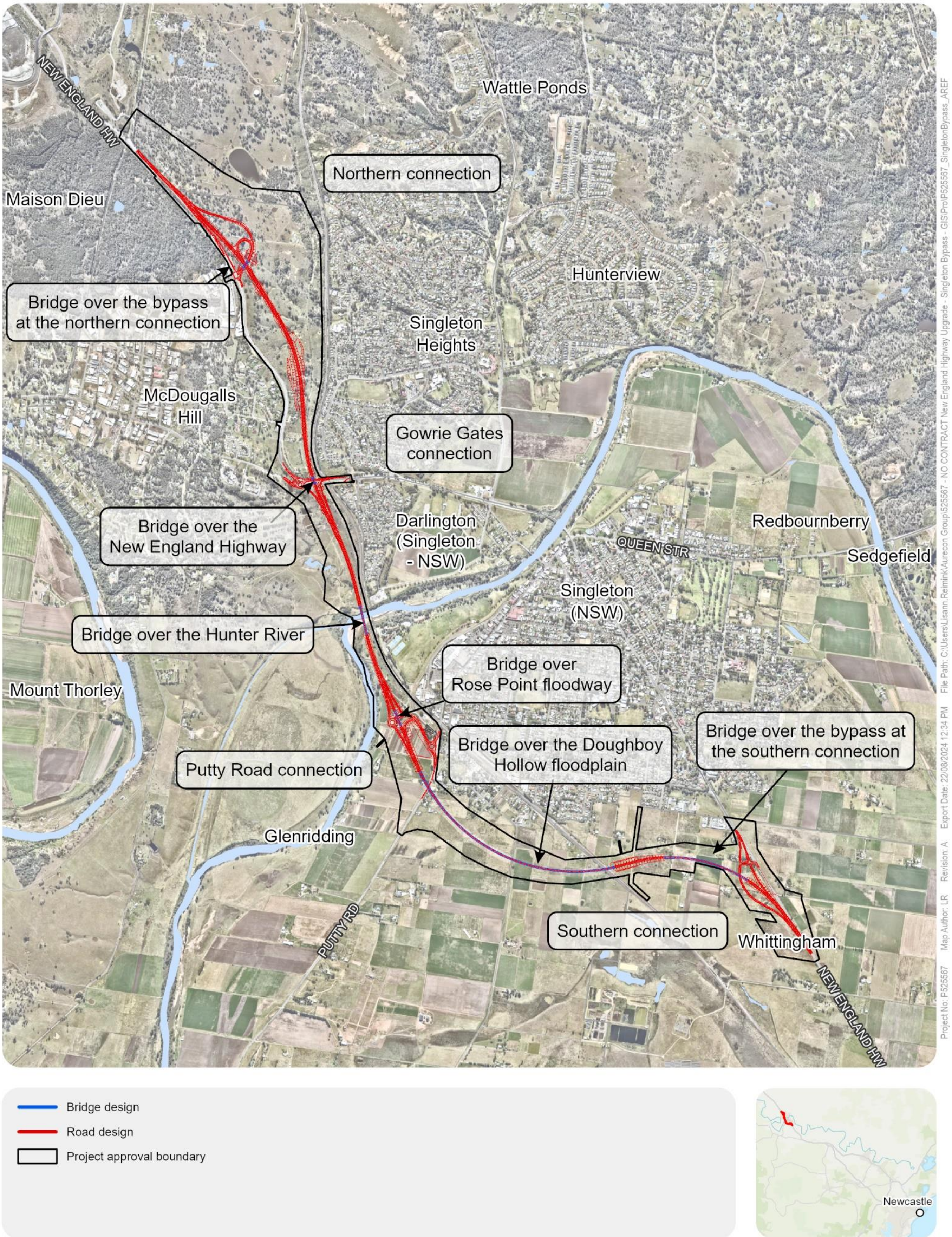


Figure 1 Study Locality



Sources: Aurecon, Spatial Services (DCS), Esri Basemap, Nearmap

1:35,000
0 460 920 m

Projection: GDA 1994 MGA Zone 56

Singleton Bypass **Addendum REF**

Figure 2: Singleton Bypass Project Alignment

1.3 Report Purpose

This report documents the flood impact assessment of the proposed modification for the Project. The assessment encompasses a comprehensive evaluation of the following aspects:

- Flood simulations for a range of flood event return periods
- Estimation of pre-Project (existing) flood conditions (to be used as the baseline comparison for an impact assessment)
- Estimation of post-Project (detailed design) flood conditions and the impacts of the Project design
- Assess the scour potential at bridge structures
- Consider potential flood mitigation and design modifications that may be required to minimise flood impacts.

1.4 Abbreviations / Definitions

The abbreviations and definitions adopted in this report are presented in Table 1 below.

Table 1 Abbreviations / Definitions

Term	Description
AEP	Annual Exceedance Probability - The probability of a flood event being equalled or exceeded in any year
AREF	Addendum Review of Environmental Factors
ARR	Australian Rainfall and Runoff
Council	Singleton Council
HEC-18	Hydraulic Engineering Circular No. 18
HEC-23	Hydraulic Engineering Circular No. 23
FRMSP	Singleton Floodplain Risk Management Study and Plan
Local Council(s)	Singleton Council
PMF	Probable Maximum Flood - The flood associated with the probable maximum precipitation. This is the statistically maximum flood that can be reasonably expected to occur.
PMP	Project Management Plan
Project REF	The REF that was prepared for the project in December 2019 and determined on 10 August 2020.
Proposed modification	The detailed design being assessed in this flood assessment.
REF	Review of Environmental Factors
SLS	Serviceability Limit State
SWTC	Scope of Works and Technical Criteria
The Project	The New England Highway bypass of Singleton project
Transport	Transport for NSW
TIN	Triangulated Irregular Network
ULS	Ultimate Limit State

2 Development of the Singleton Flood Model

2.1 Model Background

The TUFLOW flood model has undergone comprehensive calibration and development to date. The model was originally developed for the Singleton Flood Study in 2003. It was then updated as part of the project REF (December 2019) in 2018. The REF model updates included the use of improved LiDAR and additional calibration to the June 2007 flood event. Following this, the model was again updated for the Project design in December 2022. These updates incorporated more comprehensive calibration undertaken as part of the Singleton Floodplain Risk Management Study and Plan (FRMSP). The adopted Manning's roughness and Hunter River inflows were updated for consistency with the FRMSP to establish the baseline hydraulic model for assessing the existing flood conditions.

2.2 Design Flood Estimation

A design flood is a statistical estimate of a flood event with a magnitude which is based on a probability analysis of actual rainfall or recorded flow data. An AEP is attributed to the estimate. The AEP of design flood event is the probability of the event being equalled or exceeded within a year.

2.2.1 Flood Frequency Analysis

Following the updated model calibration undertaken for the FRMSP and as part of the Project design, a Flood Frequency Analysis (FFA) was derived based on historic peak flood levels recorded at the Dunolly Bridge gauge in Singleton.

Although the Dunolly Bridge gauging site has a number of limitations for estimating peak flood flows, it was chosen due to its extensive record spanning over 100 years, including the recording of the significant 1955 event. Annual maximum water level records were extracted from the gauge records, and three rating curves were developed to convert these records into the best estimate of peak flows. Two rating curves were constructed for historic conditions, one representing pre-levee construction (pre-1963) and another for post-levee construction (post-1963). The third rating curve was developed considering more recent conditions with extensive riparian vegetation and applied to events from 1998 onwards. The rating curves were based on the actual flood level ratings provided by Water NSW for levels below 41 m Australian Height Datum (AHD), transitioning to modelled rating curves for levels above 41 m AHD.

An annual maximum flow series comprising 106 records from 1913 to 2019 was analysed using the FLIKE FFA software. A Bayesian inference method was employed, utilizing a Log Pearson III probability model. Table 2 presents the ten largest recorded flood events in Singleton, along with their corresponding peak flow estimates. The resulting fitted distribution is displayed in Figure 3 alongside the plotting positions of the annual maxima, determined using the Cunnane formula.

2.2.2 Very Rare to Extreme Flood Events

To estimate very rare and extreme flood events, it is necessary to extrapolate beyond the typical range derived from an FFA. Peak design flows for the 0.05% AEP and Extreme events were determined based on the extrapolation presented in Figure 4.

Based on guidance provided in Australian Rainfall and Runoff (ARR) 2019, the expected AEP of the Probable Maximum Flood (PMF) event for the Hunter River catchment area at Singleton is approximately 0.0016% or a 1 in 62,500 year AEP. The FLIKE FFA analysis estimated a peak flow of around 32,000 m^3/s for an event of this rarity. It is essential to note that the estimation of the PMF event for large catchments carries a high level of uncertainty. A common practice for representing extreme event magnitudes in large river catchments is to adopt a peak flow of three times the 1% AEP event, which equates to around 25,200 m^3/s.

For the purpose of assessing the Singleton bypass approved project and proposed modification, an extreme flood event condition with a peak flow of 25,200 m^3/s has been adopted to represent the PMF. Additionally, a peak flow of 16,500 m^3/s has been adopted for the 0.05% AEP flood event.

Table 2 Ten Largest Flood Events Recorded at Singleton (WBM, 2022)

Flood Event	Flood Level (m AHD)
20% AEP	39.5
10% AEP	41.5
2007[1]	41.8
1913[1]	41.8
5% AEP	41.8
2% AEP	42.2
1955[1]	42.2
1% AEP	42.4
0.05% AEP	43.0
PMF	43.7

1 Recorded level associated with historic flood events through Singleton. Note that the Singleton levee scheme was constructed in 1963. Peak flood levels for events prior to 1963 would be lower than for a similar sized event occurring after the levee construction.

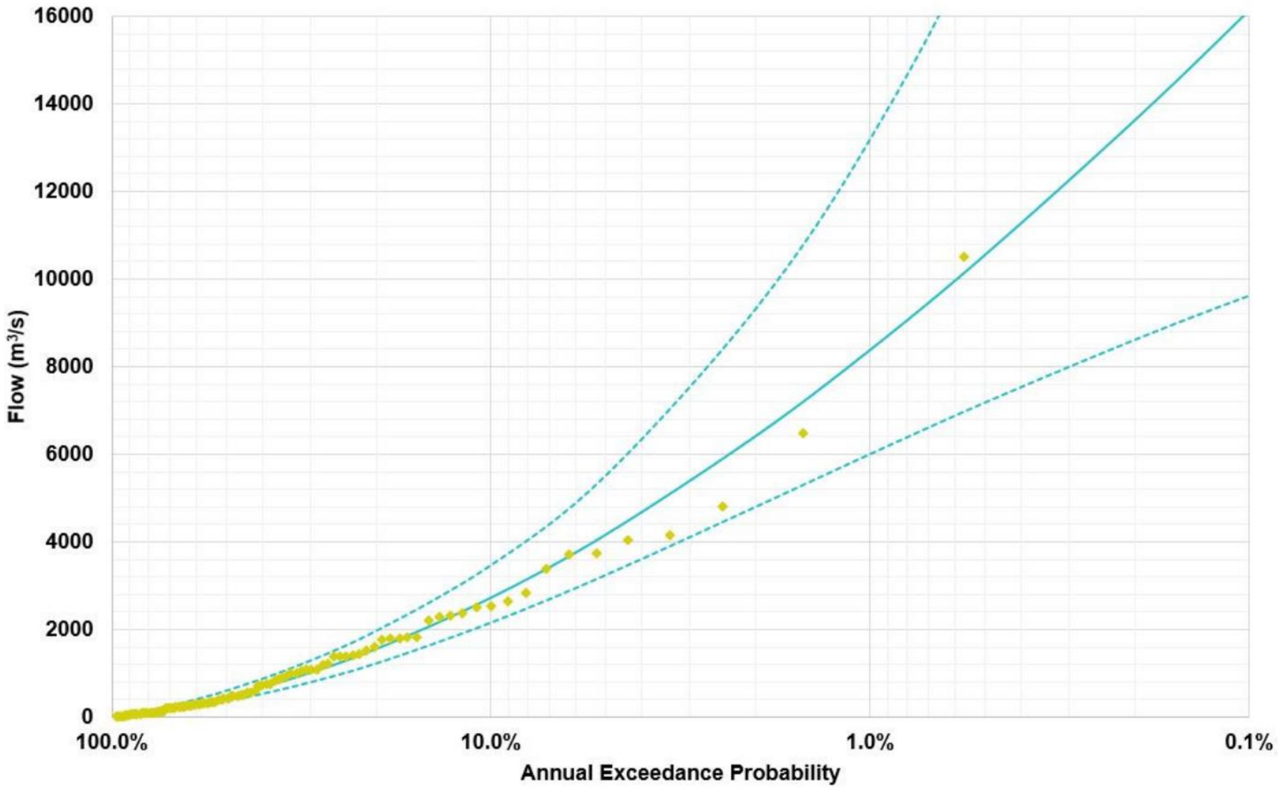


Figure 3 Singleton Flood Frequency Analysis (WBM, 2022)

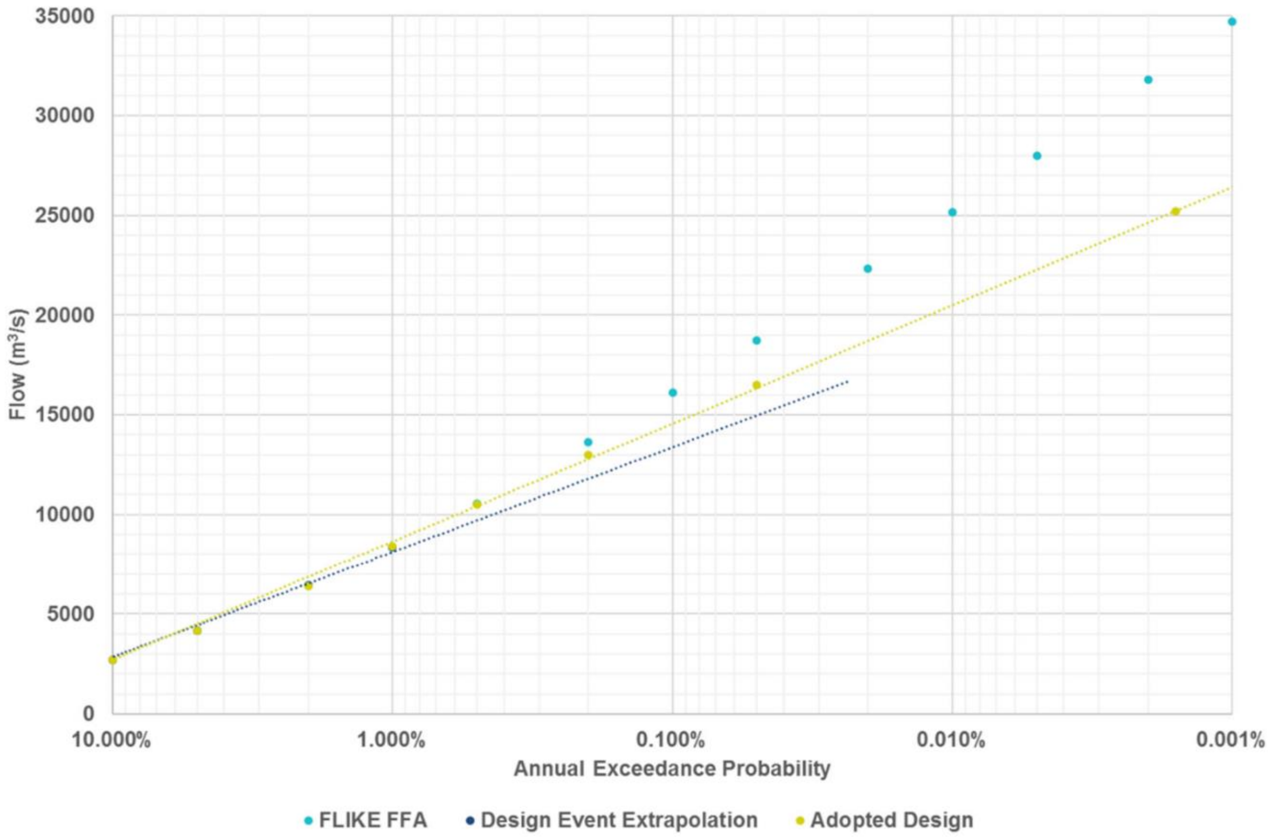


Figure 4 Estimation of Very Rare to Extreme Flood Events (WBM, 2022)

2.2.3 Existing Design Flood Conditions

The TUFLOW model was simulated, using the design flow estimates from the FFA, to derive existing design flood conditions for the study area. These relate to existing flood conditions associated with a return period. The model configuration adopted the recent riparian vegetation conditions, which were used for calibrating the June 2007 flood event.

For the flood event simulations, the inflow hydrographs were based on the shape of the June 2007 flood hydrograph but scaled to match the peak flows derived from the FFA. Validating this approach, the recorded February 1955 event hydrograph resulted in an almost identical hydrograph shape to that of June 2007.

The peak flood levels modelled at Dunolly Bridge from these design simulations are presented in Table 3. These modelled flood levels are compared to the levels recorded for three significant historic flood events. It is important to note that the design event flood levels may appear inconsistent with those recorded for the 1913 and 1955 events. However, this difference is associated with the Singleton levee scheme, which was constructed following these flood events in 1963. As a result of the levee construction, the flood levels for a given flow at Dunolly Bridge have increased.

The existing flood conditions for the study area are presented in Appendix A or a range of design flood events. These form the baseline or existing flood conditions against which the proposed modification is assessed.

Table 3 Comparison of Design and Historic Flood Levels at Singleton (WBM, 2022)

Flood Event	Flood Level (m AHD)
20% AEP	39.5
10% AEP	41.5
2007[1]	41.8
1913[1]	41.8
5% AEP	41.8
2% AEP	42.2
1955[1]	42.2
1% AEP	42.4
0.05% AEP	43.0
PMF	43.7

1 Recorded level associated with historic flood events through Singleton. Note that the Singleton levee scheme was constructed in 1963. Peak flood levels for events prior to 1963 would be lower than for a similar sized event occurring after the levee construction.

3 Existing Conditions and Constraints

3.1 Existing Conditions

Establishing the existing design flood conditions allows for a comprehensive description of various aspects related to flood behaviour in the study area. This includes:

- General flood behaviour and flow patterns throughout the study area
- Existing flooding hydraulic properties such as water levels, velocities, hazard categories and duration of inundation, considered across a range of design flood events
- Constraints and limitations along potential routes with respect to flooding regimes.

Table 4 summarises the peak flood levels for various design flood events, including the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.05% AEP, and Extreme events. The reporting locations for these peak flood levels are noted on Figure 3-1. The peak flood levels and depths associated with these events are presented in the flood mapping included in Appendix A.

Peak flood depths in the Hunter River reach up to 15 metres in a 1% AEP flood event. Across the Doughboy Hollow floodplain 1% AEP flood depths are typically between 2 metres to 4 metres.

Peak flood velocities of between 2 metres per second (m/s) and 4 m/s are typical in the Hunter River. This reduces to between 0.5 m/s and 1.5 m/s across the Doughboy Hollow floodplain.

Table 4 Peak Design Flood Levels at Selections Locations within the Study Area (WBM, 2022)

Design Flood Event	Peak Flood Level (m AHD)			
	U/S Singleton Gauge	Dunolly Bridge	Redbourneberry Bridge	Newington Lane
20% AEP (1 in 5 year)	40.1	39.5	37.6	36.0
10% AEP (1 in 10 year)	42.1	41.5	39.2	37.6
5% AEP (1 in 20 year)	42.8	41.8	39.7	37.9
2% AEP (1 in 50 year)	43.3	42.2	40.0	38.2
1% AEP (1 in 100 year)	43.8	42.4	40.3	38.5
0.05% AEP (1 in 2,000 year)	45.0	43.0	41.5	39.8
PMF (1 in 62,500 year)	46.0	43.7	42.7	41.6

3.2 Flooding Constraints

The banks of the Hunter River channel, at Singleton, are elevated above the adjacent Doughboy Hollow floodplain. The natural flow path of major flood flows, which overtop the riverbanks, is away from the main Hunter River channel and across Glenridding and the Doughboy Hollow floodplain. The Main North railway line and New England Highway bisect this natural flow path. To protect against flooding, a flood levee was constructed along the riverbank in Singleton, initially in 1963, with subsequent extensions completed in 1982-1983 and again in 1987. The purpose of this levee is to withstand flood events similar to the historic 1955 event, and it effectively prevents overtopping by floods up to and including the 1% AEP event.

However, according to the findings from the REF flood modelling analysis, the Main North railway line is susceptible to overtopping during the 1% AEP flood event near John Street South and the railway station area. Furthermore, high tailwaters within the downstream reaches of the Hunter River, north of Singleton, back up into Singleton around Queen Street. The combined impact of these flood mechanisms results in extensive inundation of residential properties within Singleton.

The modelling results also indicate a considerable damming effect caused by the railway embankment and a small ridge next to the Wastewater Treatment Works, leading to deeper flooding within the Doughboy Hollow floodplain.

In terms of flood protection, the New England Highway currently provides a limited level of immunity against floods. This ranges somewhere between the 20% AEP and 10% AEP.

Figure 5 presents an overview of the existing flood behaviour, visually displaying the spatial distribution of flood flows. The figure delineates the two primary flow path alignments within the region:

- The Hunter River channel and adjacent Doughboy Hollow floodplain, which winds around the northern side of Singleton
- The Doughboy Hollow floodplain, which diverges from the Hunter River at Glenridding, flows along the southern side of Singleton, and eventually merges with the Hunter River floodplain near Whittingham.

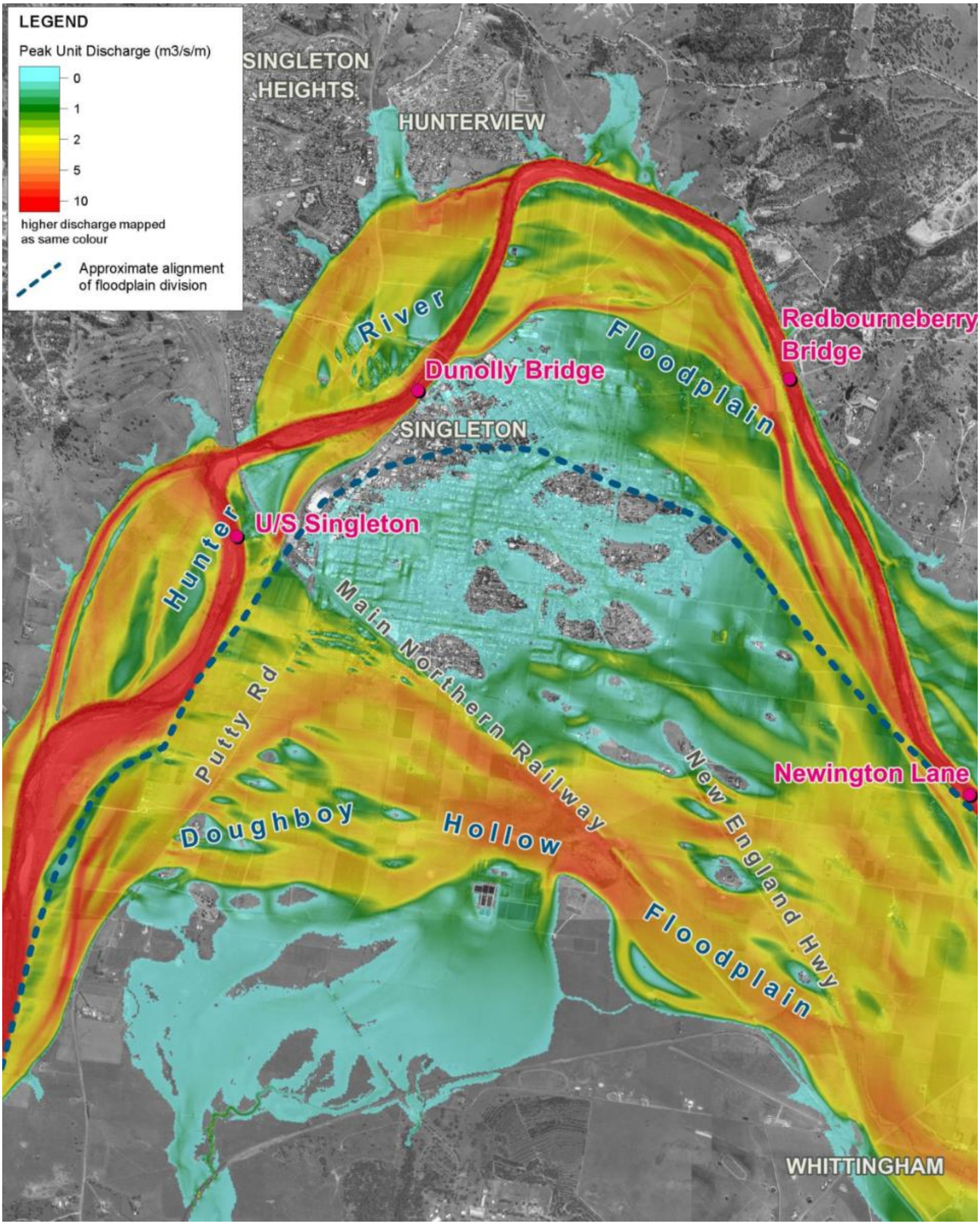


Figure 5 Singleton existing 1% AEP Flood Flow Distributions (WBM, 2022)

4 Assessment of the Proposed Modification

The building of a road embankment over a floodplain has the potential to raise flood levels, redistribute water flow, increase the time of inundation and increase velocities. It is crucial to minimise these effects, particularly in populated areas and areas of agricultural or environmental importance. Section 4.1 provides a summary of the flood mitigation measures and design adjustments that are necessary to meet the chosen design criteria. In Section 4.2, the flood impacts are presented, and the performance of potential alternative routes evaluated.

4.1 Flood Mitigation and Design Modification

The Project design has been assessed for flood impacts at various stages of design development from early concept design through to ongoing detailed design. Throughout this process the design development has considered minimising flooding impacts. Key design modifications, implemented to aid flood impact mitigation, include addition of a 1636 metre raised viaduct over the Doughboy Hollow floodplain and an additional 600 metre long viaduct near the southern connection of the Singleton bypass. These viaducts, along with other bridges associated with the Project, are designed to reduce any obstruction the Project might otherwise cause to the flows across the Hunter River and Doughboy Hollow floodplain. The final flood impact mitigation structures, adopted for the detailed design, are outlined below.

- 600 metre bridge (viaduct) over the bypass at the southern connection
- 1636 metre bridge (viaduct) over the Doughboy Hollow floodplain
- 98 metre bridge over the Rose Point floodway
- 190 metre bridge over the Hunter River.

4.2 Potential Impacts

4.2.1 Overview

The detailed design model was used to simulate floods ranging from the 20% AEP to the 1% AEP design event. The results of these simulations are provided in Appendix B, and compared with simulations of the existing conditions in Appendix C and Appendix D. This allows for a comparative evaluation of the potential impacts and performance of the Project design.

The modelling enables the quantification of several potential impacts, including:

- Changes in peak flood level within the study area
- Increases in velocity and scour potential
- Increase in flood hazard
- Identification of adjacent property that may be adversely impacted by changed flooding behaviour.

Additionally, the performance of the proposed modification can be assessed in terms of:

- Flood immunity level
- Relative timing of overtopping
- Duration of inundation.

4.2.2 Changes in Peak Flood Level

Appendix C provides flood impact mapping, specifically illustrating the changes in peak flood levels between the existing conditions and the modelled proposed modification. The mapping includes seven different design flood magnitudes, namely the 20% AEP, 10% AEP, 5% AEP, 2% AEP, and 1% AEP design events.

At the 20% AEP event, there are minimal notable impacts on the modelled peak flood levels due to the limited extent of out-of-bank flooding and the presence of existing bridges over the Hunter River. However, at the 10% AEP event, there are some increases in peak flood levels in lower-lying parts of Doughboy Hollow. These increases are primarily associated with the proposed Putty Road connection. The Putty Road connection is proposed as an essential emergency access and egress route for the town of Singleton. In the 10% AEP event, it provides the only flood free connection road to the south of Singleton. It also provides emergency access to the southbound lanes out of Singleton for rarer flood events up to and including the 1% AEP flood event. However, the Putty Road connection partially obstructs the Hunter River flows, leading to a slight redistribution of flood waters and impacting flood levels. The impacts occur in areas where flow is already active, with peak flood level increases typically ranging from 0.03 metres to 0.05 metres, although localised increases of up to 0.06 metres can be observed against the railway near Collett Street south of the bridge over the bypass at the southern connection. There are also localised differences in peak flood levels immediately upstream of the Putty Road connection, with some adjacent properties experiencing increases in peak flood levels of up to 0.09 metres.

At the 5% AEP event, there are increases in peak flood levels of approximately 0.04 metres upstream of the proposed Singleton bypass in the Hunter River. Within the Doughboy Hollow floodplain, there are increases of around 0.06 metres. Localised increases of up to 0.09 metres, can be observed immediately upstream of the Putty Road connection. Dwellings at this location experience above floor flooding of more than 1.5 metres for the 5% AEP existing flood conditions. Consequently, the relatively minor increases in flood levels do not increase the flood risk at these properties.

During the 2% AEP event, peak flood level increases in the Hunter River of approximately 0.06 metres are observed. Within the Doughboy Hollow floodplain, there are increases ranging from 0.02 metres to 0.05 metres. However, there is a decrease in peak flood levels to multiple properties south and southeast of the Putty Road connection, with decreases of up to -0.08 metres at residential properties in Glenridding. These decreases are a result of flow redistribution caused by the Putty Road connection and the northern abutment of the bridge over the Doughboy Hollow floodplain. The Doughboy Hollow floodplain near the southern connection becomes active, resulting in increases in peak flood levels of up to 0.1 metres. However, the impacts are localised and predominantly confined to rural properties. Impacts on existing dwellings at the southern connection do not result in new above floor flooding.

At the 1% AEP event, the flood impacts near the Putty Road connection and the southern connection generally increase in both extent and magnitude. Peak flood level increases in the Hunter River of approximately 0.08 metres are observed. Within the Doughboy Hollow floodplain and at the southern connection, there are increases ranging from 0.02 metres to 0.05 metres. At dwelling locations immediately upstream of Putty Road connection, the modelled peak flood levels show increases of up to 0.12 metres. However, existing flood levels at these properties are typically more than 2 metres above floor levels and the impacts do not contribute to the flood risk. Across the Doughboy Hollow floodplain, flooding impacts do not result in new over floor flooding. In contrast, large urban areas of Singleton experience reduced peak flood levels, with decreases of approximately -0.06 metres. Approximately 1,200 properties within the study area experience a decrease in flood level of at least -0.03 metres.

4.2.3 Changes in Peak Flood Velocity

Appendix D presents changes in peak flood velocity distribution associated with the proposed modification for various modelled design events. The mapping shows that changes in floodplain velocity distribution are primarily localised for all considered design events. These impacts are mainly linked to the local redistribution of flows around the southern abutment of the bridge over the Hunter River, Putty Road connection, the northern abutment of the bridge over Doughboy Hollow floodplain, and the southern connection.

At the 20% AEP event, there is no significant impact on the modelled peak flood velocities due to the limited extent of out-of-bank flooding and the presence of existing bridges over the Hunter River. Localised velocity increases of up to 0.7 m/s are observed at the southern abutment of the bridge over the Hunter River. At the 10% AEP event, minor impacts on the modelled peak flood velocities are again observed at the southern abutment of the bridge over the Hunter River as well as the proposed Putty Road connection. The impacts at Putty Road connection are generally reductions in velocity due to the presence of the bypass embankments.

However, peak velocities are locally increased by 0.7 m/s between the culverts at the Putty Road connection ramps.

During the 5% AEP event, localized velocity increases of up to 0.7 m/s are again observed at the southern abutment of the bridge over the Hunter River with minor increases of 0.2 m/s through the Hunter River main channel. The proposed Putty Road connection leads to generally reductions in velocity with minor local increases limited to locations where flows overtop the ramps. There are reductions in peak velocity through the floodway rail culverts ranging from -1.2 m/s to -1.6 m/s. Further south, there are localised increases of up to 0.3 m/s at the northern abutment of the bridge over the Doughboy Hollow floodplain.

During the 2% AEP event, the peak velocity impacts align with those observed for the 5% AEP event but with a larger magnitude of increases. Some localised peak velocity increases of up to 0.3 m/s can be observed adjacent to the southern abutment of the Hunter River railway bridge and increases of up to 0.7 m/s immediately downstream of this location. Through the bridge over the Rose Point floodway, peak velocity increases of between 0.8 m/s and 2.2 m/s are observed. The larger increases are isolated to flows overtopping the proposed connection ramps. There is a reduction in peak velocity in the floodway through the railway bridge from around -1.0 m/s to -1.6 m/s, extending for approximately 800 metres downstream of the Project. Peak flood velocities also increase by up to 0.8 m/s at the northern abutment of the bridge over the Doughboy Hollow floodplain where the Putty Road connection redistributes floodwater within the Doughboy Hollow floodplain. At the southern connection, impacts are generally localised within the Project approval boundary. There are localised increases of approximately 0.4 m/s outside the boundary associated with the redistribution of flows around the southern connection.

At the 1% AEP event, the peak velocity impacts are generally consistent with those for the 2% AEP event, but with a further increase in magnitude. Some localised peak velocity increases of up to 0.3 m/s can be observed adjacent to the southern abutment of the Hunter River railway bridge and increases of up to 0.7 m/s immediately downstream of this location. Additionally, there are reduced peak velocities in areas that become partially sheltered by the bypass embankment at this location. Through the bridge over the Rose Point floodway, upstream of the railway, peak velocity increases of between 1.4 m/s and 2.4 m/s are observed. There is a reduction in peak velocity in the floodway downstream of the railway from between -0.8 m/s and -1.6 m/s. Peak flood velocities also increase by up to 1.2 m/s at the northern abutment of the bridge over the Doughboy Hollow floodplain where the Putty Road connection redistributes floodwater within the Doughboy Hollow floodplain. At the southern connection, impacts are generally localised within the Project approval boundary. There are localised increases of approximately 0.2 m/s outside this boundary associated with the redistribution of flows around the southern connection.

At the 1% AEP event, the embankment between the bridge over the Doughboy Hollow floodplain and the bridge over the bypass at the southern connection, results in minor localised increases in peak flood velocity due to a slight concentration of flow as water passes alongside and around the embankment. The maximum increase observed is 0.6 m/s. There are also reduced peak velocities in areas that become partially sheltered by the bypass embankment.

4.2.4 Other Impacts

The flood impact assessment has taken into account the mainstream flooding of the Hunter River. In areas where the Project crosses creeks and gully lines, the local cross-drainage has been included as part of the development of the detailed design.

The duration of flooding currently varies between flood events. In Singleton, where the Hunter River has a significant contributing catchment, major flood events typically last for one to two days. Although the central business district (CBD) of Singleton may not be directly affected by flood waters, the CBD may need to be evacuated and closed for a few days during major flood events, until the peak floodwaters recede. At present, it is expected that current access routes would be closed for a few days during major flood events.

Whilst there may be minor impacts to local drainage patterns, when compared to existing conditions, the proposed modification does not have an impact on the overall duration of inundation. The Project would be advantageous to the community by providing a flood evacuation route and allowing for local accessibility during a flood event.

4.3 Hydraulic Assessment

This section provides an overview of the hydraulic assessment conducted on the bridge structures to aid in the design process. Peak flood levels and velocities are taken at the upstream face of each bridge structure.

Estimation of scour at bridge abutments and piers presents significant challenges and uncertainty. A scour assessment was undertaken using two independent methods for comparison, namely Hydraulic Engineering Circular No. 18 (*HEC-18)* and '*Scour Estimation for Roads and Maritime Services NSW*' *(Sheppard-Melville, 2022)*. Each method separates scour into the following elements:

- Abutment scour
- Pier scour
- Horizontal contraction scour
- Vertical contraction scour (if the bridge lower chord is submerged).

Different sections of bridges may experience some or all of the above forms of scour depending on site specific conditions. Inputs from the hydraulic modelling were used to inform the scour assessment. Using the above methods, scour depths were determined for the 1% AEP Serviceability Limit State (SLS) and 0.05% AEP Ultimate Limit State (ULS) flood events. Scour protection is provided at bridge abutments and designed for the 1% AEP SLS flood event. The design of the bridge abutment rock protection follows Hydraulic Engineering Circular No. 23 (HEC-23) guidelines. It is noted that all piling for the bridges and piers is socketed in medium to high strength rock which is resistant to scour.

4.3.1 Bridge over the Bypass at the Southern Connection

Flood flows begin to pass through the 600 metre long bridge at the southern connection from approximately the 2% AEP flood event. This occurs as a result of an existing flood flow path within the broader Doughboy Hollow floodplain being activated in these rare events. In more frequent flood events, flood waters are contained in the Doughboy Hollow floodplain and there is no flow through the bridge over the bypass at the southern connection. The modelled peak flow rates through the bridge structure are approximately 98 cubic metres per second (m^3/s) for the 1% AEP event and 692 m^3/s for the 0.05% AEP event.

Figure 6 summarises the modelled peak flood levels along the length of the bridge structure, while Figure 7 provides the peak velocities. It should be noted that the velocities represented are the peak depth-averaged velocities associated with the two-dimensional modelling approach.

The bridge consists of 17 piers across a wide floodplain. Each of these is a twin column pier. There is no contraction scour through this structure. The total scour is associated with the local pier and abutment scour. The results for the scour are summarised in Figure 8. For the 1% AEP event, typical scour depths at the pier locations along the bridge structure are 1.2 metres, increasing to 3.2 metres for the 0.05% AEP event.

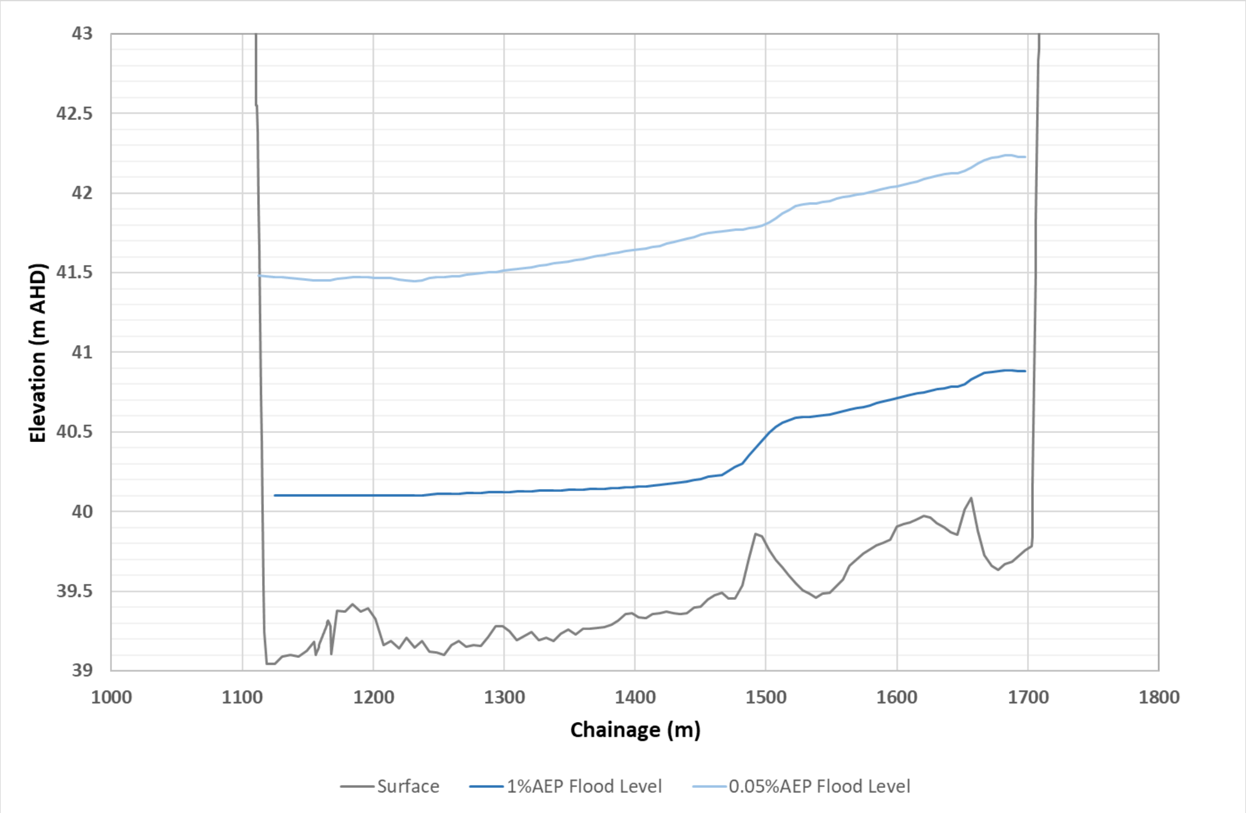


Figure 6 Modelled Peak Flood Levels at the Bridge over the Bypass at the Southern Connection

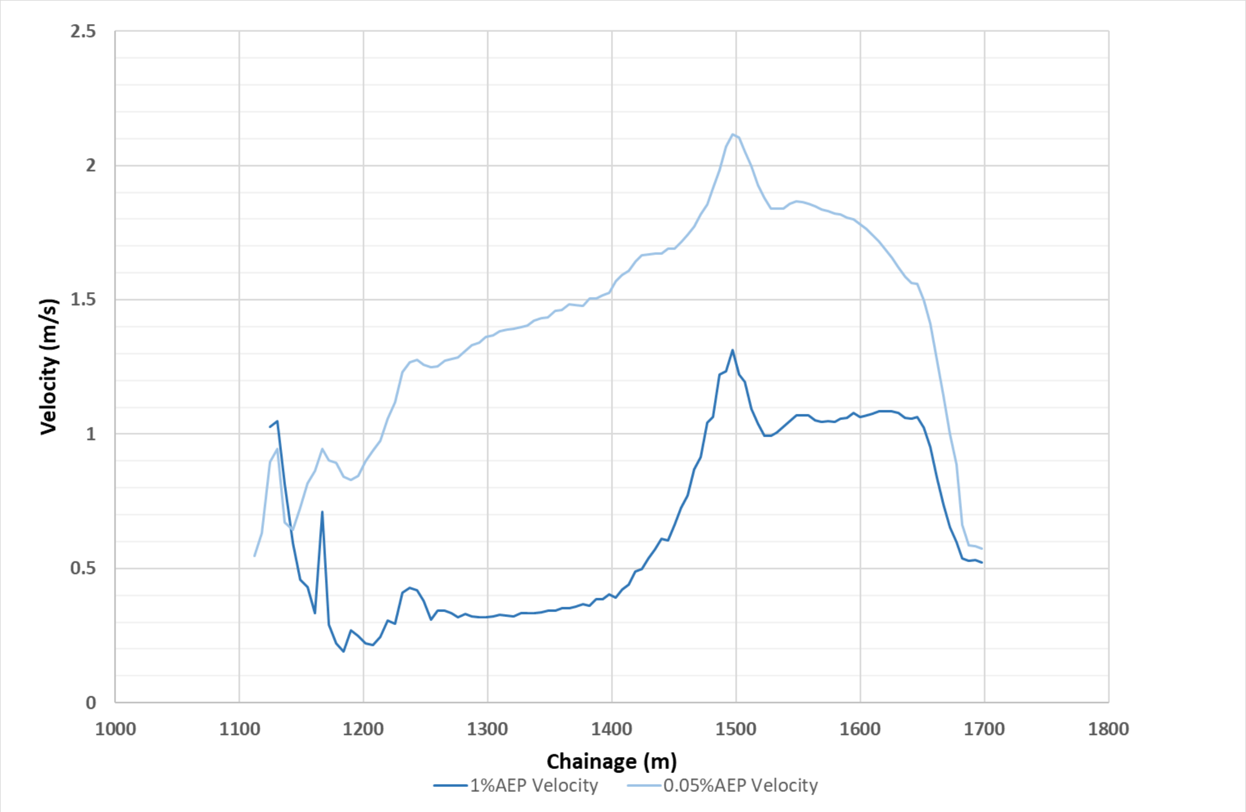


Figure 7 Modelled Peak Velocities at the Bridge over the Bypass at the Southern Connection

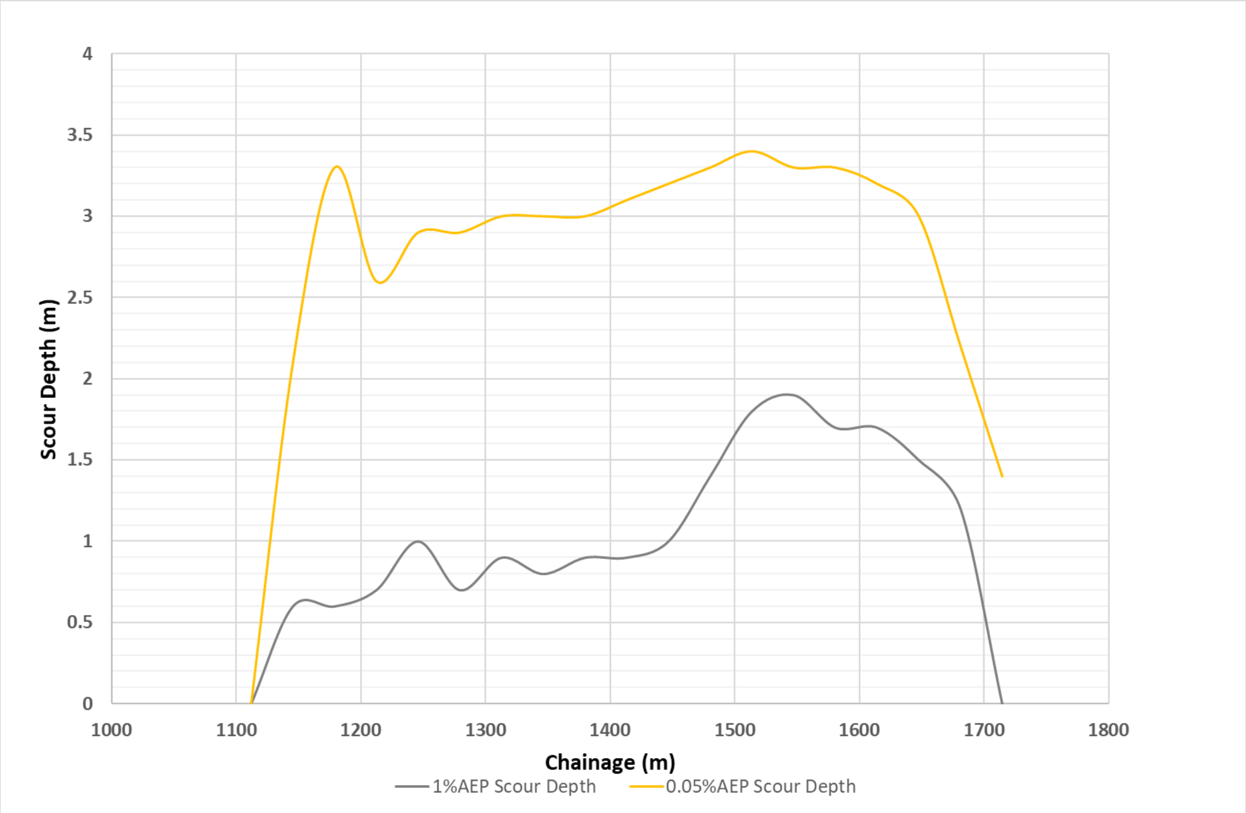


Figure 8 Estimated Scour Depth at the Bridge over the Bypass at the Southern Connection

4.3.2 Bridge over the Doughboy Hollow Floodplain

Flood flows begin to pass through the bridge over the Doughboy Hollow floodplain from approximately the 10% AEP flood event, coinciding with the activation of the Doughboy Hollow floodplain. The modelled peak flow rates through the bridge structure are estimated to be around 1,180 m^3/s for the 1% AEP event and 2,830 m^3/s for the 0.05% AEP event.

The bridge consists of 49 piers across a wide floodplain. Piers 1-2 are blade piers and Piers 22-23, 46-47 are twin column piers with tie beams. Figure 9 provides an overview of the modelled peak flood levels along the length of the bridge structure, while Figure 10 summarises the peak velocities. As with the bridge over the Rose Point floodway, there is no contraction scour through this structure. The total scour is associated with local pier and abutment scour. The scour results are presented in Figure 11. For the 1% AEP event, typical scour depths at the pier locations along the bridge structure are 2.8 metres, which increases to 3.9 metres for the 0.05% AEP event.

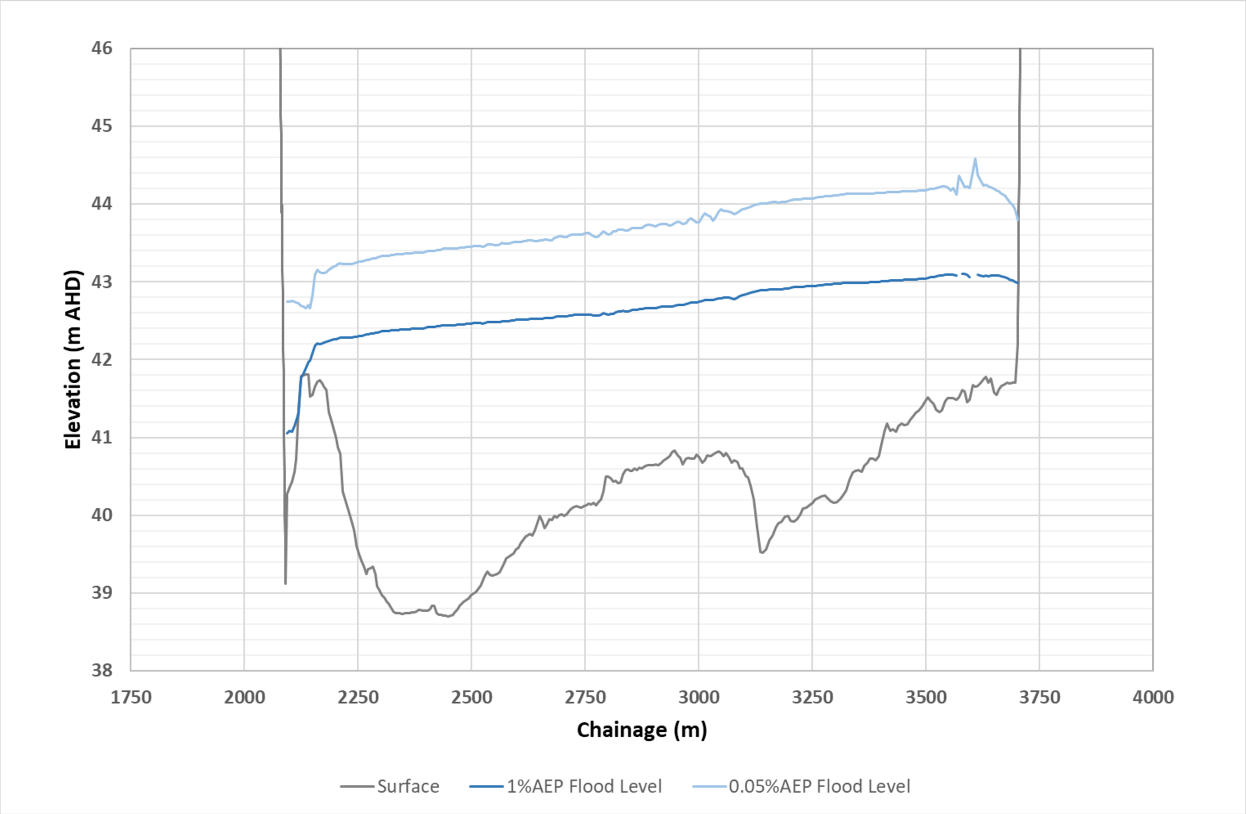


Figure 9 Modelled Peak Flood Levels at the Bridge over the Doughboy Hollow Floodplain

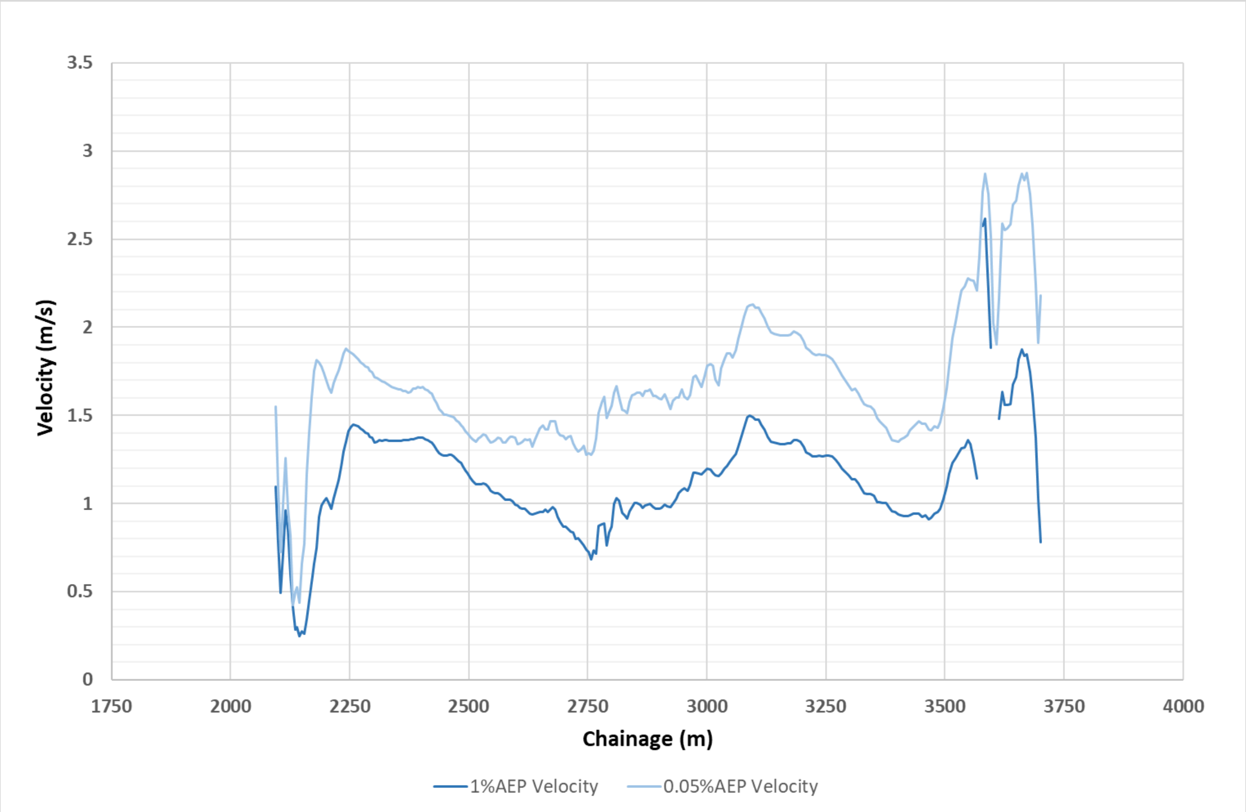


Figure 10 Modelled Peak Velocities at the Bridge over the Doughboy Hollow Floodplain

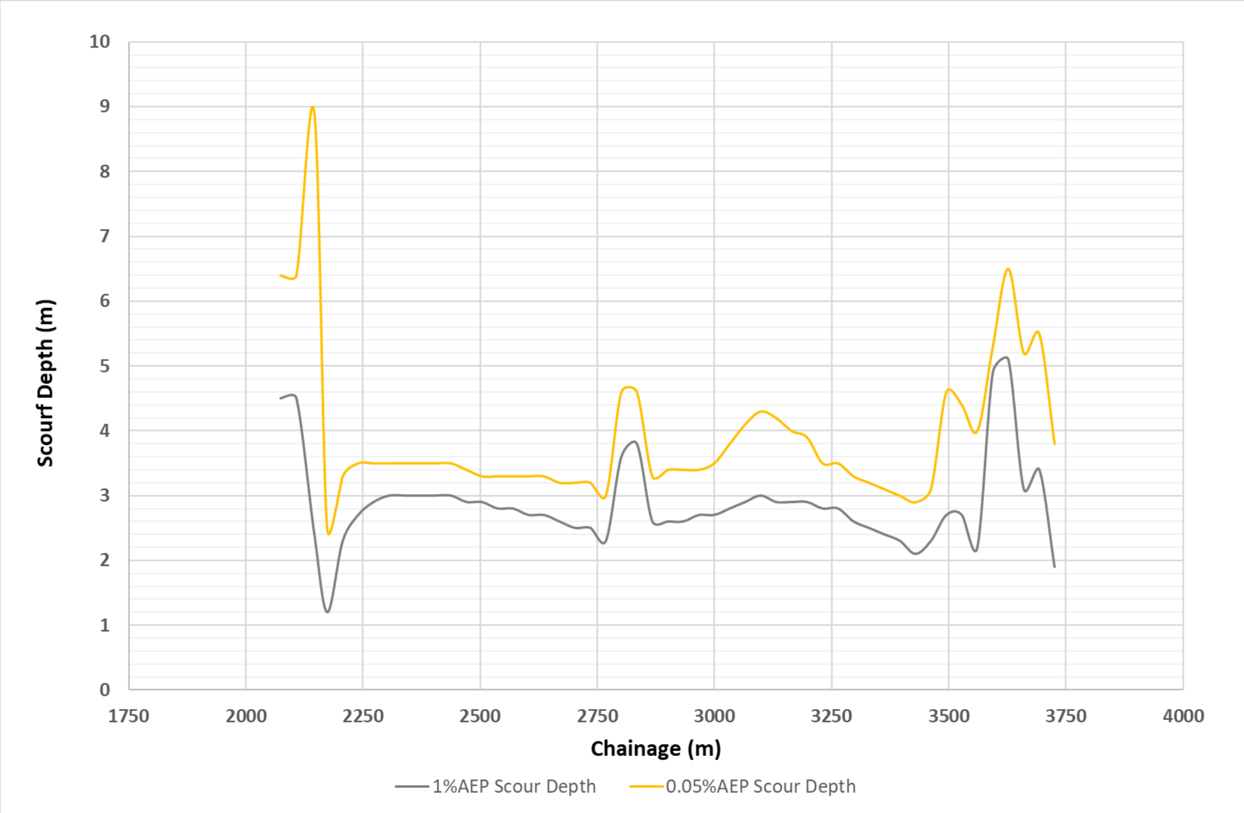


Figure 11 Estimated Scour Depth at the Bridge over the Doughboy Hollow Floodplain

4.3.3 Bridge over the Rose Point Floodway

The bridge over Rose Point floodway spans approximately 100 metres and comprises of two piers, each with two columns, situated across a wide floodplain. The pier columns in this bridge share a common cylindrical column and tie beam configuration at the base of each pier location. Flood flows start to occur from around the 10% AEP flood event, coinciding with the activation of the Doughboy Hollow floodplain. The modelled peak flow rates through the bridge structure are estimated to be around 204 m^3/s for the 1% AEP event and 644 m^3/s for the 0.05% AEP event.

Table 5 provides a summary of the modelled peak flood levels and velocities at the bridge structure.

For the 1% AEP event, typical scour depths at the pier and abutment locations along the bridge structure are 2.8 metres, which increases to 5.6 metres for the 0.05% AEP event. Figure 12 shows the estimated scour depth across the entire structure.

Table 5 Hydraulic Properties at the Bridge over the Rose Point Floodway – Peak Flood Levels and Velocities

Description	1% AEP (SLS)		0.05% AEP (ULS)	
	Flood Level (m AHD)	Velocity (m/s)	Flood Level (m AHD)	Velocity (m/s)
Abutment A	43.59	1.6	44.71	2.5
Pier 1	43.60	1.0	44.76	2.1
Pier 2	43.60	1.7	44.84	2.9
Abutment B	43.50	1.8	44.65	3.3

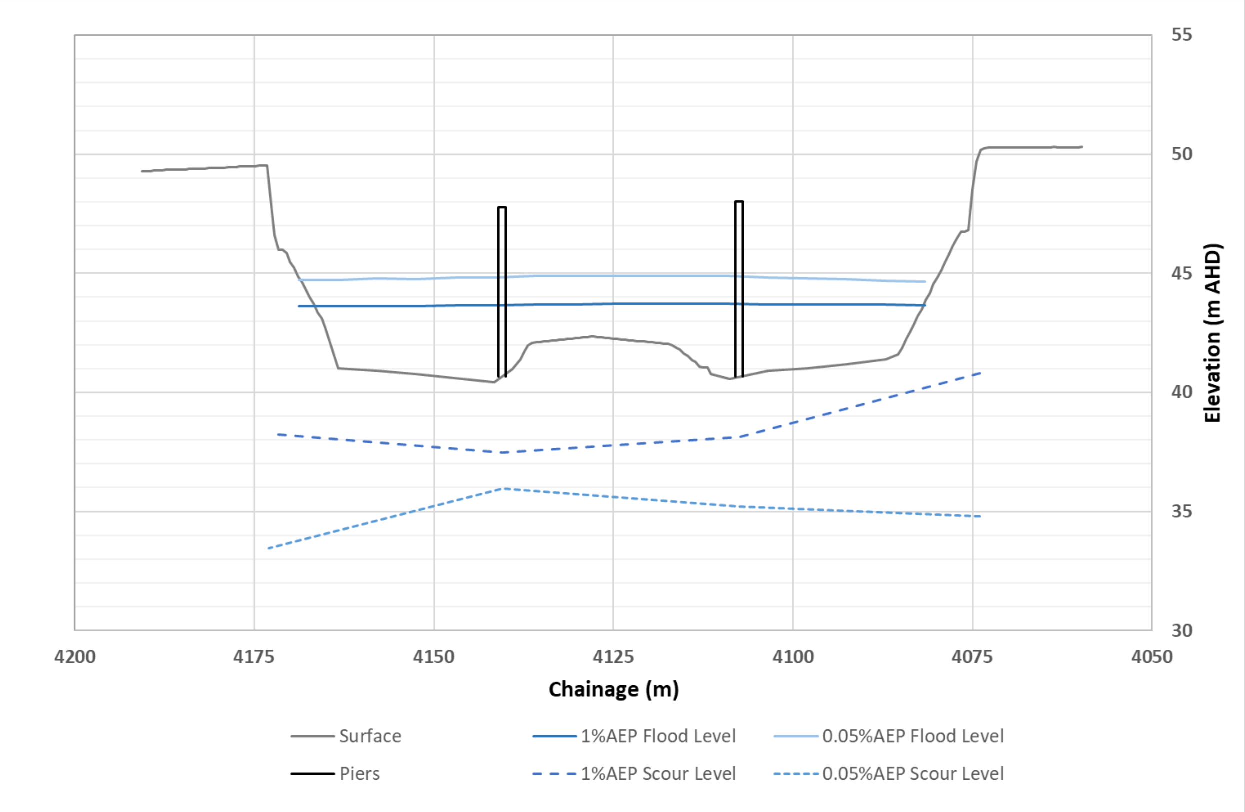


Figure 12 Modelled Peak Flood Levels and Scour Depths at the Bridge over the Rose Point Floodway

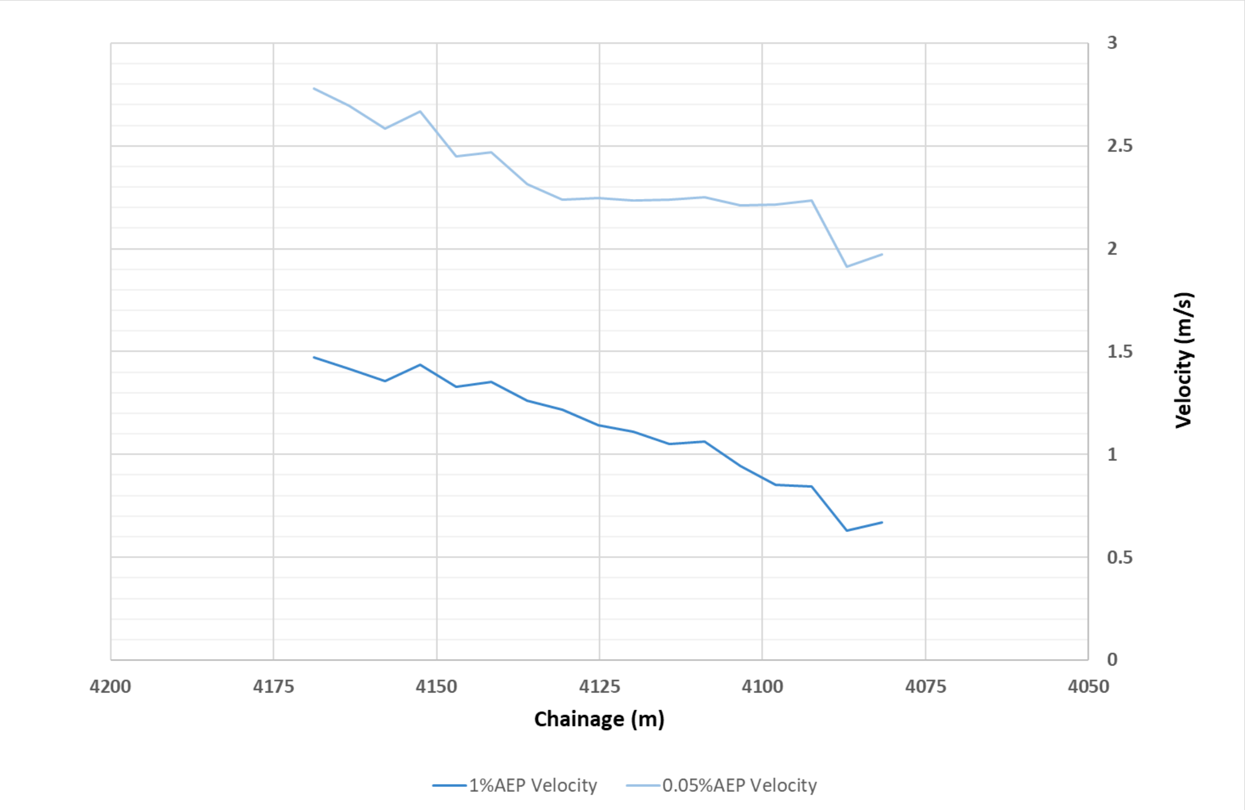


Figure 13 Modelled Peak Velocities at the Bridge over the Rose Point Floodway

4.3.4 Bridge over the Hunter River

The bridge over the Hunter River spans 190 metres and consists of four piers. Each pier is made up of a twin set of columns with a diameter of 1.3 metres. As the bridge crosses the mainstream channel, flood flows pass through the bridge for all modelled events. The modelled peak flow rates through the bridge structure are estimated to be around 4,375 m^3/s for the 1% AEP event and 6,000 m^3/s for the 0.05% AEP event.

Table 6 provides a summary of the modelled peak flood levels and velocities at the bridge structure. It should be noted that the significant head loss observed across the bridge is primarily attributed to the flow contraction through the existing railway bridge.

Furthermore, it is noteworthy that the velocities are highest on the inside of the bend rather than the outside. While at bank-full capacity, the highest velocities are concentrated on the outside of the bend, once out-of-bank flooding occurs, the overall velocity distribution changes and is influenced by the broader-scale Hunter River floodplain topography. This is mainly related to the contraction and expansion of the Hunter River floodplain flows along the existing rail embankment and through the rail bridge structure.

For the 1% AEP event, typical scour depths at the pier and abutment locations along the bridge structure are 5.8 metres, which increases to 7.8 metres for the 0.05% AEP event. The deepest scour depths are predicted at Pier 3, which has SLS and ULS scour depths of 9.3 metres and 10.5 metres respectively. However, this will be limited by the depth to medium-high strength rock which is inferred to be at approximately 4 metres below the bed level at Pier 3. This rock depth is based on geotechnical bore logs around the structure. Figure 14 shows the estimated scour depth across the entire structure.

Table 6 Hydraulic Properties at the Bridge over the Hunter River – Peak Flood Levels and Velocities

Description	1% AEP (SLS)		0.05% AEP (ULS)	
	Flood Level (m AHD)	Velocity (m/s)	Flood Level (m AHD)	Velocity (m/s)
Abutment A	43.28	2.9	44.48	3.6
Pier 1	43.20	2.9	44.39	3.6
Pier 2	43.30	3.1	44.47	3.8
Pier 3	43.35	2.9	44.56	3.6
Pier 4	43.47	2.7	44.69	3.3
Abutment B	43.50	2.2	44.74	2.8

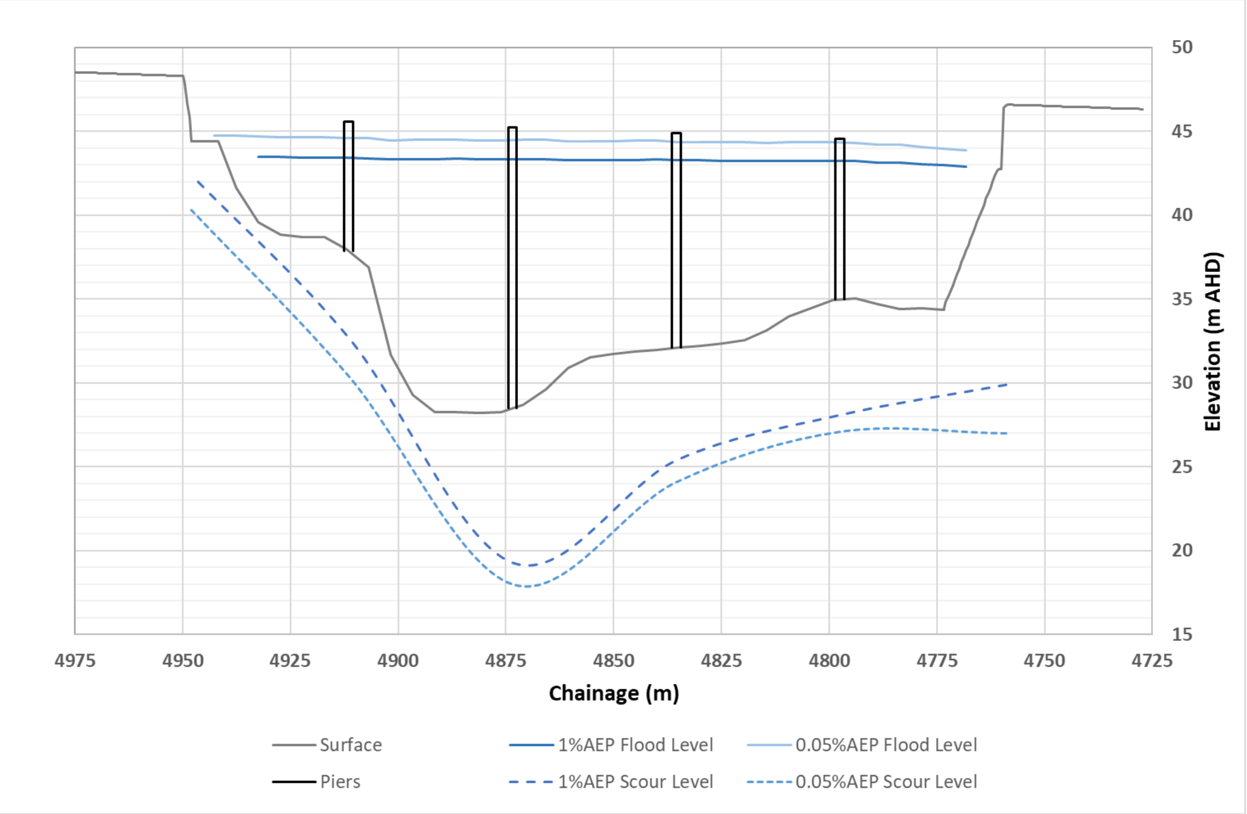


Figure 14 Modelled Peak Flood Levels and Scour Depths at the Bridge over the Hunter River

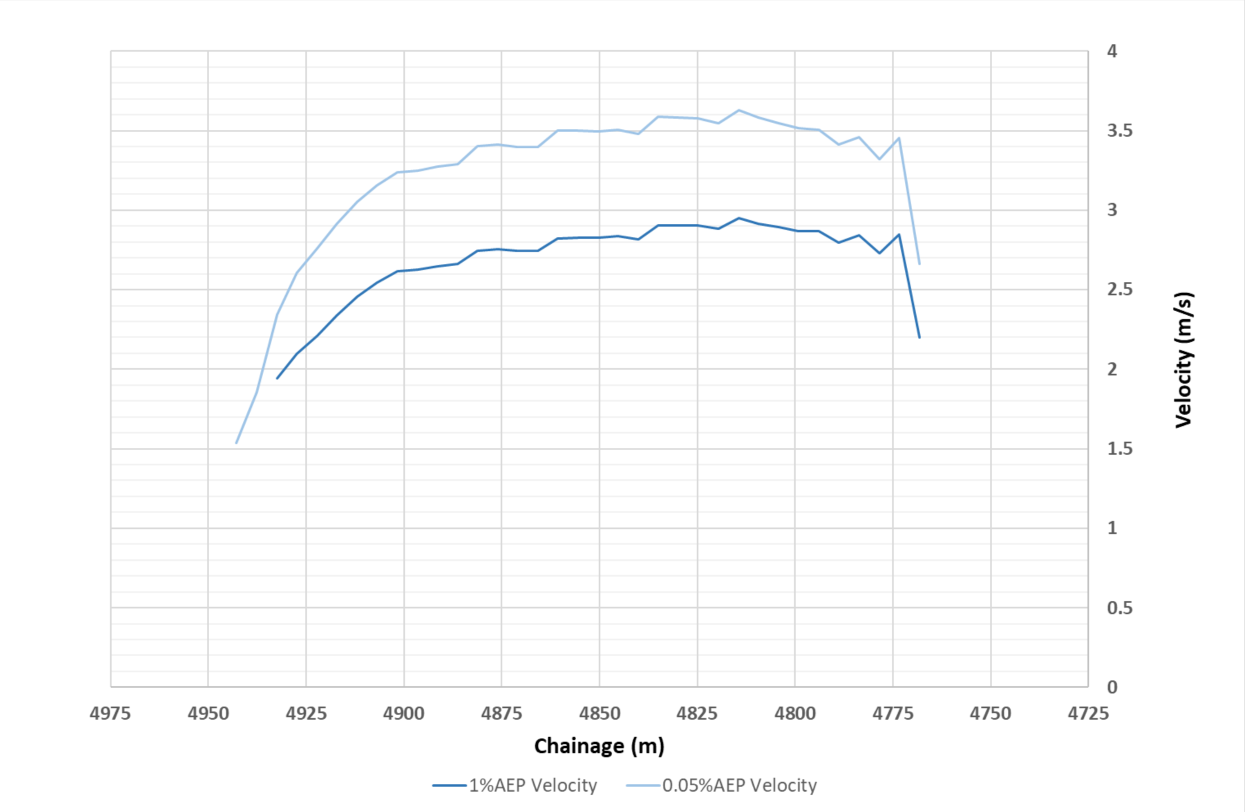


Figure 15 Modelled Peak Velocities at the Bridge over the Hunter River

4.3.5 Hydraulic Assessment Flood Level Summary

Table 7 provides a summary of the bridge levels in relation to the expected 1% AEP and 0.05% AEP flood levels. For all bridges, the deck is elevated above the 0.05% AEP (1 in 2,000 year) except at the southern abutment of the bridge over the Hunter River, where the underside of the deck is just at the 0.05% AEP level.

Table 7 Summary of Flood Levels at Bridges[1]

Description	Soffit Elevation (m AHD)	Deck Thickness (m)	Peak Flood Level (m AHD)	
			1%	0.05%
Bridge at southern connection	44.34	1.8	40.85	42.09
Bridge over Doughboy Hollow floodplain	46.73	1.8	43.18	44.56
Bridge over Rose Point floodway	47.61	1.8	43.60	44.84
Bridge over Hunter River	44.37	2.1	43.28	44.39

1 For reporting purposes, except for the bridge over the Hunter River, the maximum flood level and the minimum soffit along each bridge length is presented. These levels vary across the alignment. At the bridge over the Hunter River, the levels at the southern abutment are provided as the clearance to flood levels are lowest at this location.

4.4 Scour Protection Works

All bridge piers and abutments are designed considering the full depth of scour without any allowance for scour protection or remedial measures after a flood event. All piles are socketed in medium to high strength rock. Rock protection is provided at all bridge abutments and sized to withstand the SLS floods.

5 Conclusion

This report examines the current flooding conditions in the study area and the potential flood impacts of the Project. The assessment considers the effects of the Project on the existing flood conditions in the Hunter River, as well as the necessary bridge structures to minimize any adverse flood impact.

The Project design has been assessed for flood impacts at various stages of design development from early concept design through to ongoing detailed design. Throughout this process the design development has considered minimising flooding impacts. The proposed bridges are designed to reduce any obstruction the Project might otherwise cause to the flows across the Hunter River and Doughboy Hollow floodplains.

Even with the proposed bridges, there remains a residual increase in flood levels at rural properties within the Hunter River and Doughboy Hollow floodplains, upstream of Singleton. The increases in flood levels compared to existing conditions, for flood events from the 10% AEP up to the 1% AEP, range from 0.03 metres to 0.09 metres within the Hunter River, 0.04 metres to 0.06 metres across the Doughboy Hollow floodplain, and localised increases of up to 0.15 metres at properties immediately upstream of the Putty Road connection. At the same time, a reduction in flood levels of approximately -0.06 metres, compared to existing conditions, is achieved in the 1% AEP across large portions of the town of Singleton. The impacts to flood levels are presented in the flood mapping provided in Appendix C. The increases in flood levels are primarily associated with the proposed Putty Road connection. The Putty Road connection is proposed as an essential emergency access and egress route for the town of Singleton.

Across the Hunter River and Doughboy Hollow floodplain, flow velocities generally remain unchanged. However, there are localised increases in flow velocities associated with the Project. These are observed at the bridge over the Hunter River, through the bridge over the Rose Point Floodway, at the northern abutment of the bridge over Doughboy Hollow floodplain and at the southern connection. The magnitude of the velocity increases is greatest in the larger more rare flood events. In a 1% AEP flood, these localised velocity increases to the existing flood conditions typically range from 0.3 m/s to 1.2 m/s. Through the bridge over the Rose Point floodway, there are higher localised velocity increases of up to 2.4 m/s above existing conditions. These larger increases are isolated to flows overtopping the proposed connection ramps. The impacts to flood velocities compared against the existing flood conditions are presented in the flood mapping provided in Appendix D.

1% AEP flood velocities through the bridges are less than 2 m/s. Through the bridge over the Hunter River, velocities of up to 3 m/s are observed. An assessment of the bridge structures was undertaken to determine the expected depth of scour to inform bridge design. The presence of localised flow obstructions such as bridge piers and abutments, as well as flow contraction through bridge openings, create the potential for scour. Scour depths at each bridge were determined for the 1% AEP (SLS) and 0.05% AEP (ULS) flood events. Scour protection is provided at bridge abutments and designed for the 1% AEP (SLS) flood event. It is noted that all piling for the bridges and piers is socketed in medium to high strength rock which is resistant to scour.

Whilst there may be minor impacts to local drainage patterns, when compared to existing conditions, the proposed modification does not have an impact on the overall duration of inundation. The Project offers advantages to the community by providing a flood evacuation route and enabling local accessibility during flood events.

6 References

BMT, 2022. Singleton Bypass Concept Design Flood Assessment, October 2022.

BMT, 2022. Singleton Floodplain Risk Management Study and Plan, Draft, December 2022.

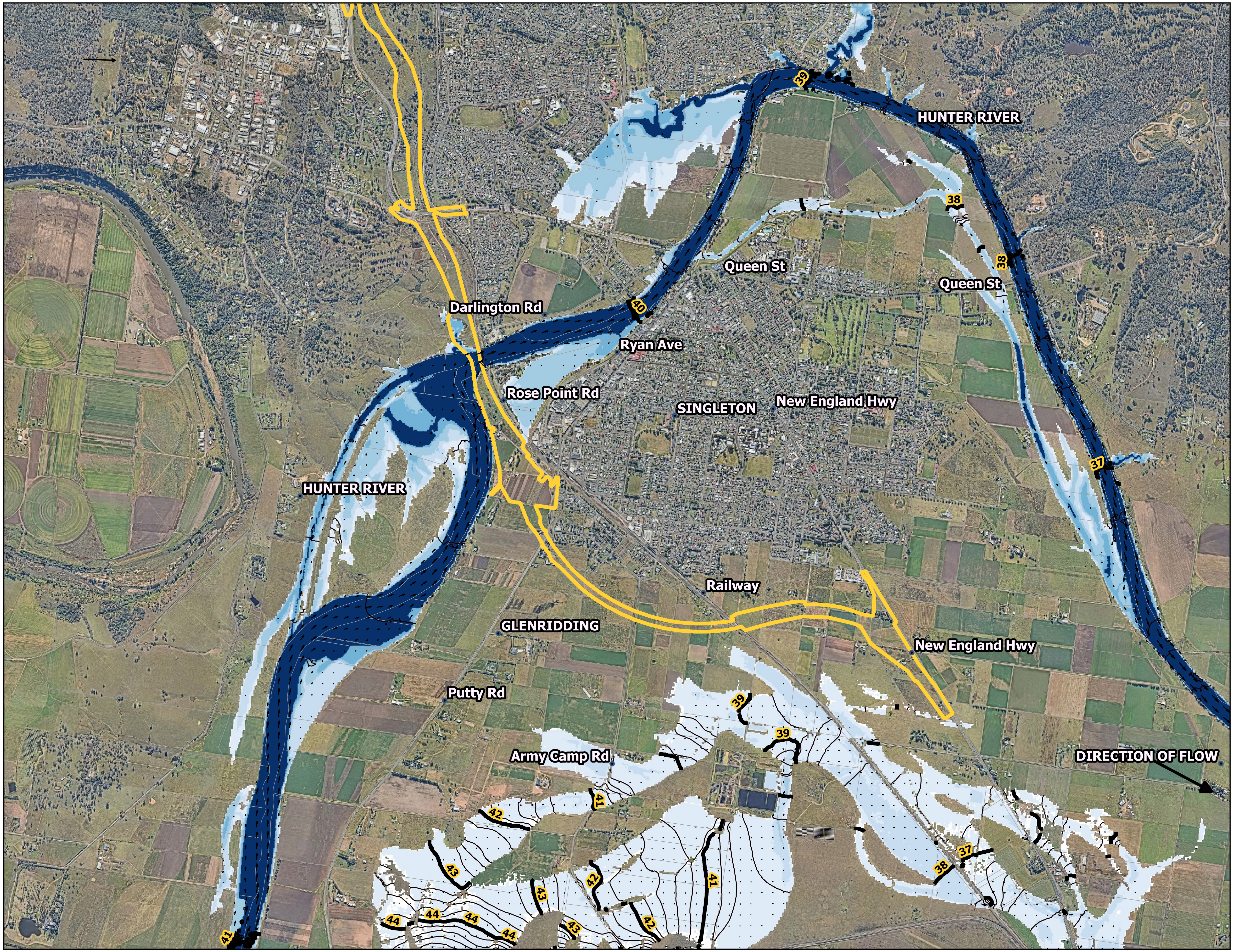
HEC-18. Evaluating Scour at Bridges, Fifth Edition, Hydraulic Engineering Circular No. 18, 2012.

HEC-23. Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance-Third Edition, Hydraulic Engineering Circular No. 23, 2009.

Sheppard-Melville, 2022. Scour Estimation for Roads and Maritime Services NSW, Final Report, Bruce Melville, D. Max Sheppard, Yifan Yang, 1 July 2022.

WBM, 2003. Singleton Flood Study, Final Draft Report prepared for Singleton Shire Council, May 2003.

Appendix A Existing Conditions Flood Mapping



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Legend

- Project Approval Boundary
- Property Boundary
- Major WSL Contours in m AHD (1m)
- Minor WSL Contours in m AHD (0.2m)

Existing 20%AEP Depth Grid (m)

- 0.05 - 0.10
- 0.10 -0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- \> 3

Peak Velocity (m/s)

- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Existing Run 122 EXG,
Design Run 134a DES

Map by: CK

0 1,000 2,000 m

A3 Scale: 1:25,000

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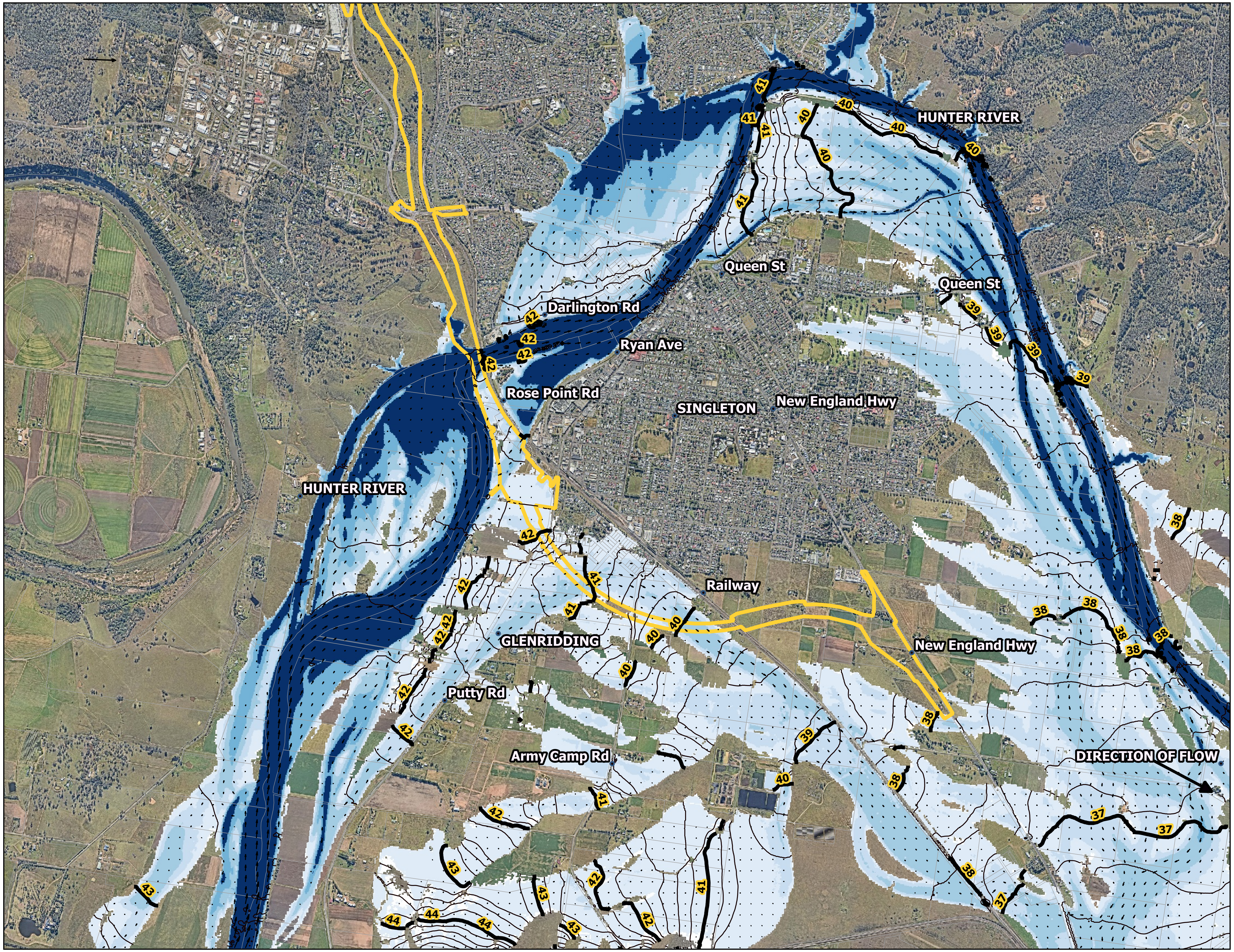
Singleton Bypass Addendum REF

Figure A1-1 / Water Surface Levels and Flood Depths - Existing 20%AEP



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Legend

- Project Approval Boundary
- Property Boundary
- Major WSL Contours in m AHD (1m)
- Minor WSL Contours in m AHD (0.2m)

Existing 10%AEP Depth Grid (m)

- 0.05 - 0.10
- 0.10 -0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- > 3

Peak Velocity (m/s)

- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Existing Run 122 EXG,
Design Run 134a DES

Map by: CK

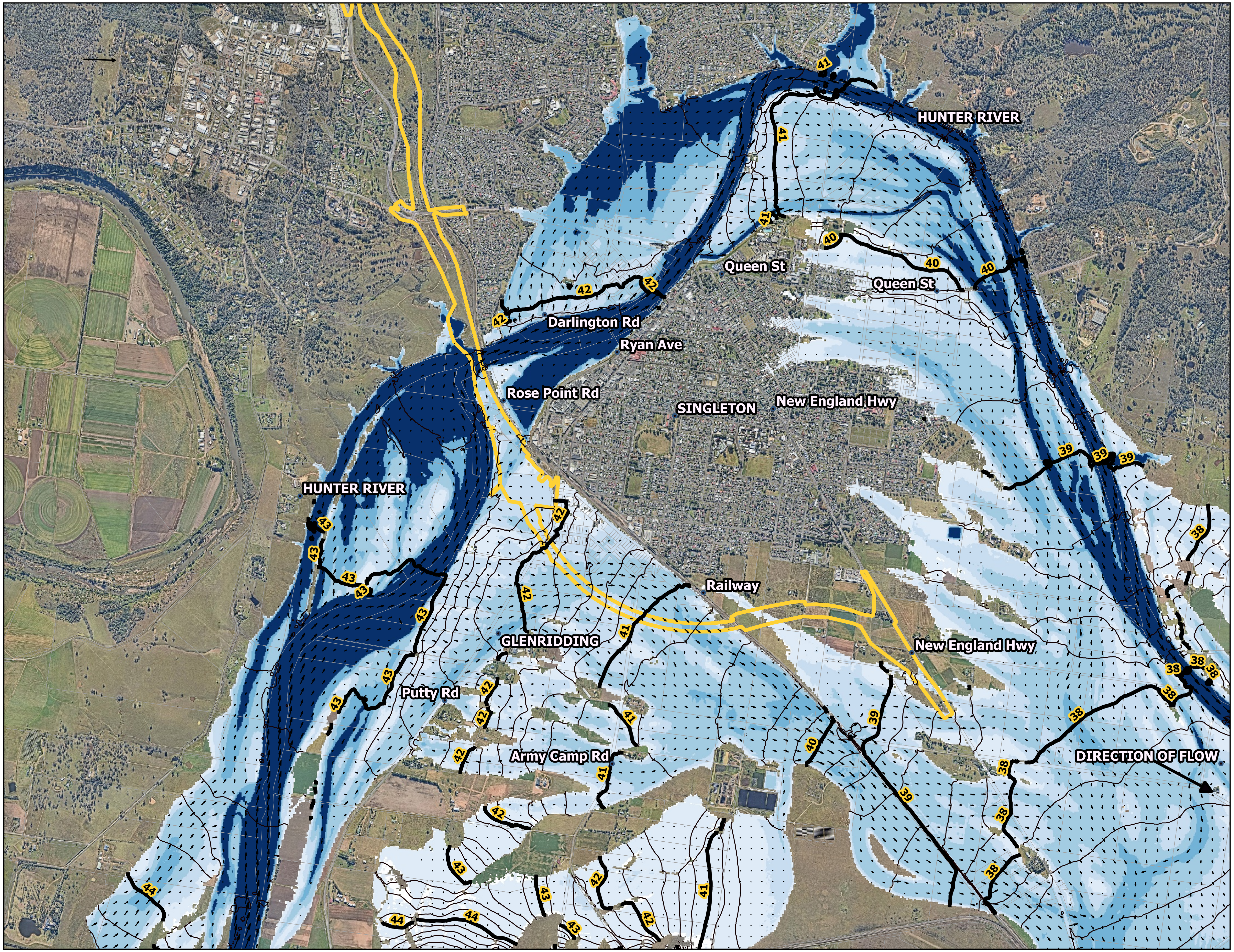
0 1,000 2,000 m

A3 Scale: 1:25,000

6/6/2024 GDA 94 MGA 56

Singleton Bypass Addendum REF

Figure A1-2 / Water Surface Levels and Flood Depths - Existing 10%AEP



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Legend

- Project Approval Boundary
- Property Boundary
- Major WSL Contours in m AHD (1m)
- Minor WSL Contours in m AHD (0.2m)

Existing 5%AEP Depth Grid (m)

- 0.05 - 0.10
- 0.10 -0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- > 3

Peak Velocity (m/s)

- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Existing Run 122 EXG,
Design Run 134a DES

Map by: CK

0 1,000 2,000 m

A3 Scale: 1:25,000

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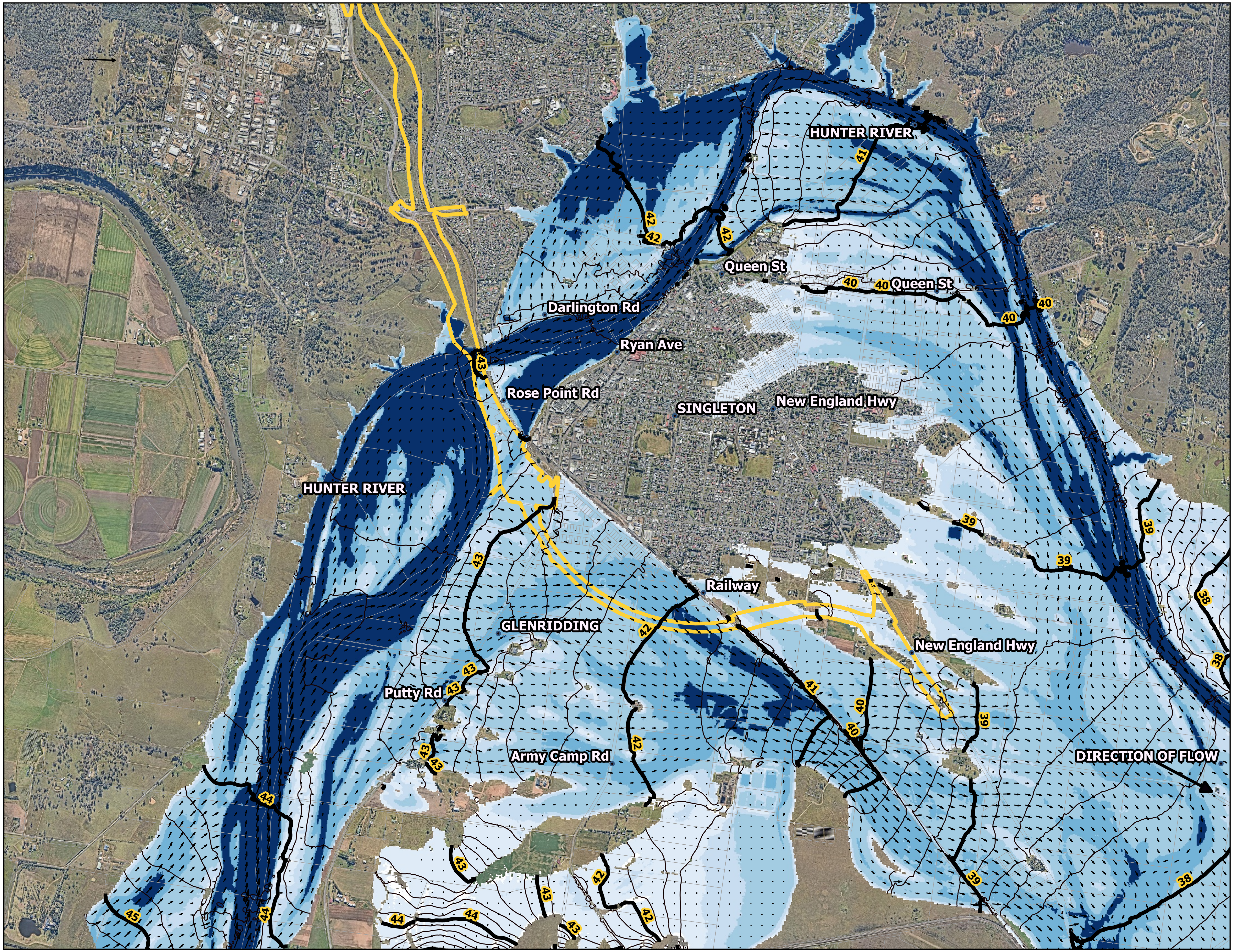
Singleton Bypass Addendum REF

Figure A1-3 / Water Surface Levels and Flood Depths - Existing 5%AEP



Legend

- Project Approval Boundary
- Property Boundary
- Major WSL Contours in m AHD (1m)
- Minor WSL Contours in m AHD (0.2m)

Existing 2%AEP Depth Grid (m)

- 0.05 - 0.10
- 0.10 -0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- > 3

Peak Velocity (m/s)

- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Existing Run 122 EXG,
Design Run 134a DES

0 | 1,000 | 2,000 m

A3 Scale: 1:25,000

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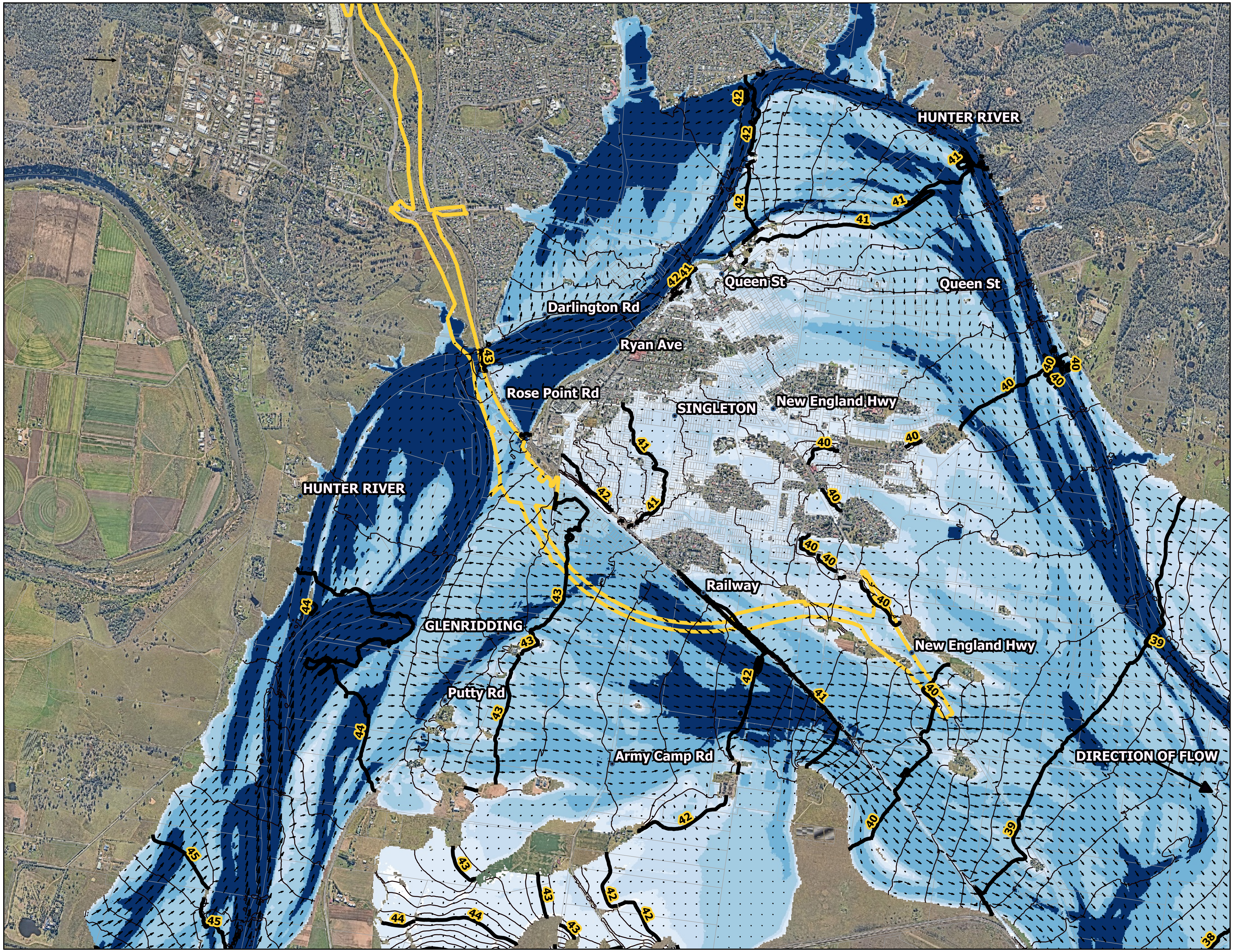
Singleton Bypass Addendum REF

Figure A1-4 / Water Surface Levels and Flood Depths - Existing 2%AEP



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Legend

- Project Approval Boundary
- Property Boundary
- Major WSL Contours in m AHD (1m)
- Minor WSL Contours in m AHD (0.2m)

Existing 1%AEP Depth Grid (m)

- 0.05 - 0.10
- 0.10 -0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- > 3

Peak Velocity (m/s)

- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Existing Run 122 EXG,
Design Run 134a DES

Map by: CK

0 1,000 2,000 m

A3 Scale: 1:25,000

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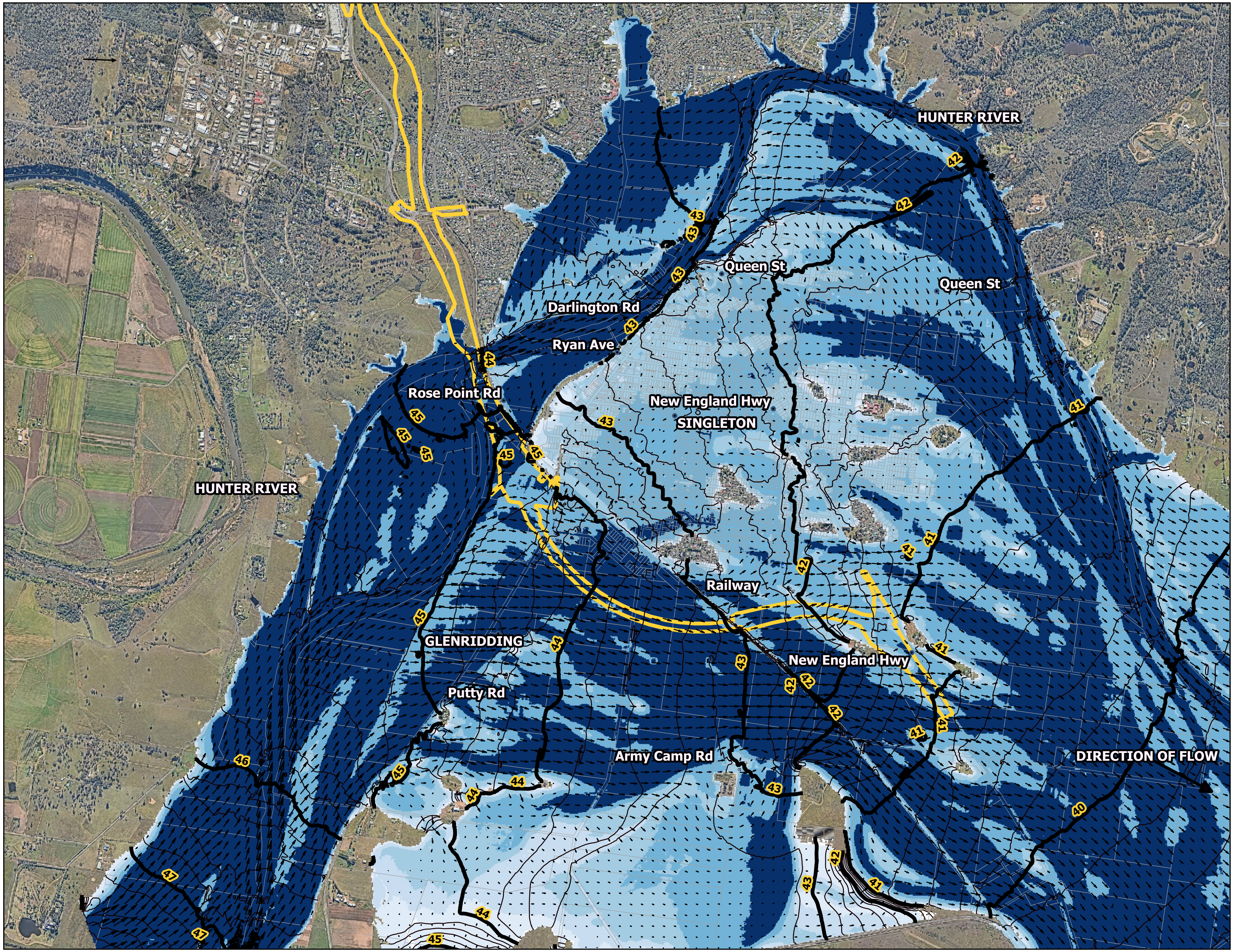
Figure A1-5 / Water Surface Levels and Flood Depths - Existing 1%AEP



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Legend

- Project Approval Boundary
- Property Boundary
- Major WSL Contours in m AHD (1m)
- Minor WSL Contours in m AHD (0.2m)

Existing 0.05%AEP Depth Grid (m)

- 0.05 - 0.10
- 0.10 -0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- > 3

Peak Velocity (m/s)

- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Existing Run 122 EXG, Design Run 134a DES

Map by: CK

0 1,000 2,000 m

A3 Scale: 1:25,000

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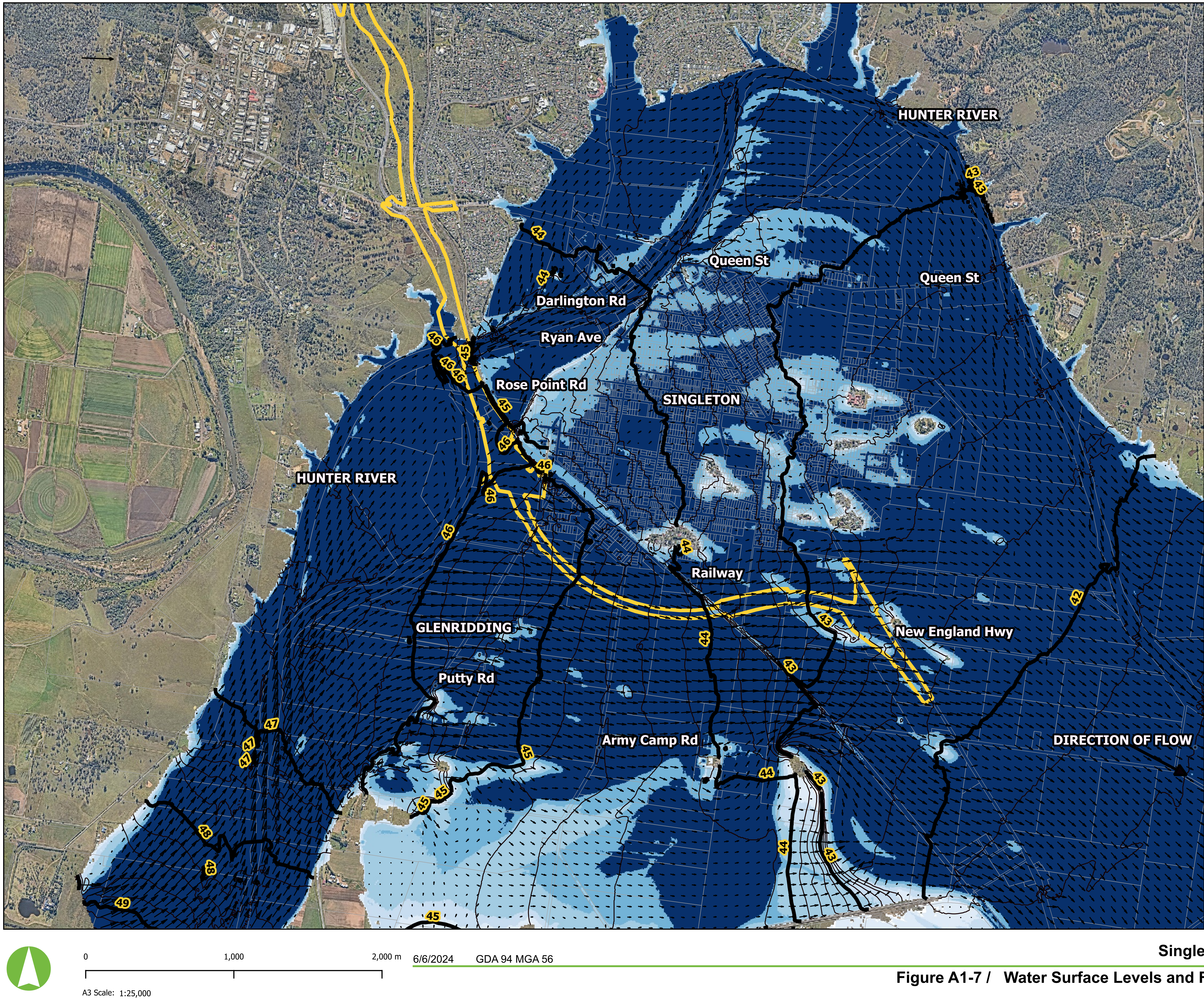
Figure A1-6 / Water Surface Levels and Flood Depths - Existing 0.05%AEP



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Legend

- Project Approval Boundary
- Property Boundary
- Major WSL Contours in m AHD (1m)
- Minor WSL Contours in m AHD (0.2m)

Existing PMF Depth Grid (m)

- 0.05 - 0.10
- 0.10 -0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- > 3

Peak Velocity (m/s)

- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Existing Run 122 EXG,
Design Run 134a DES

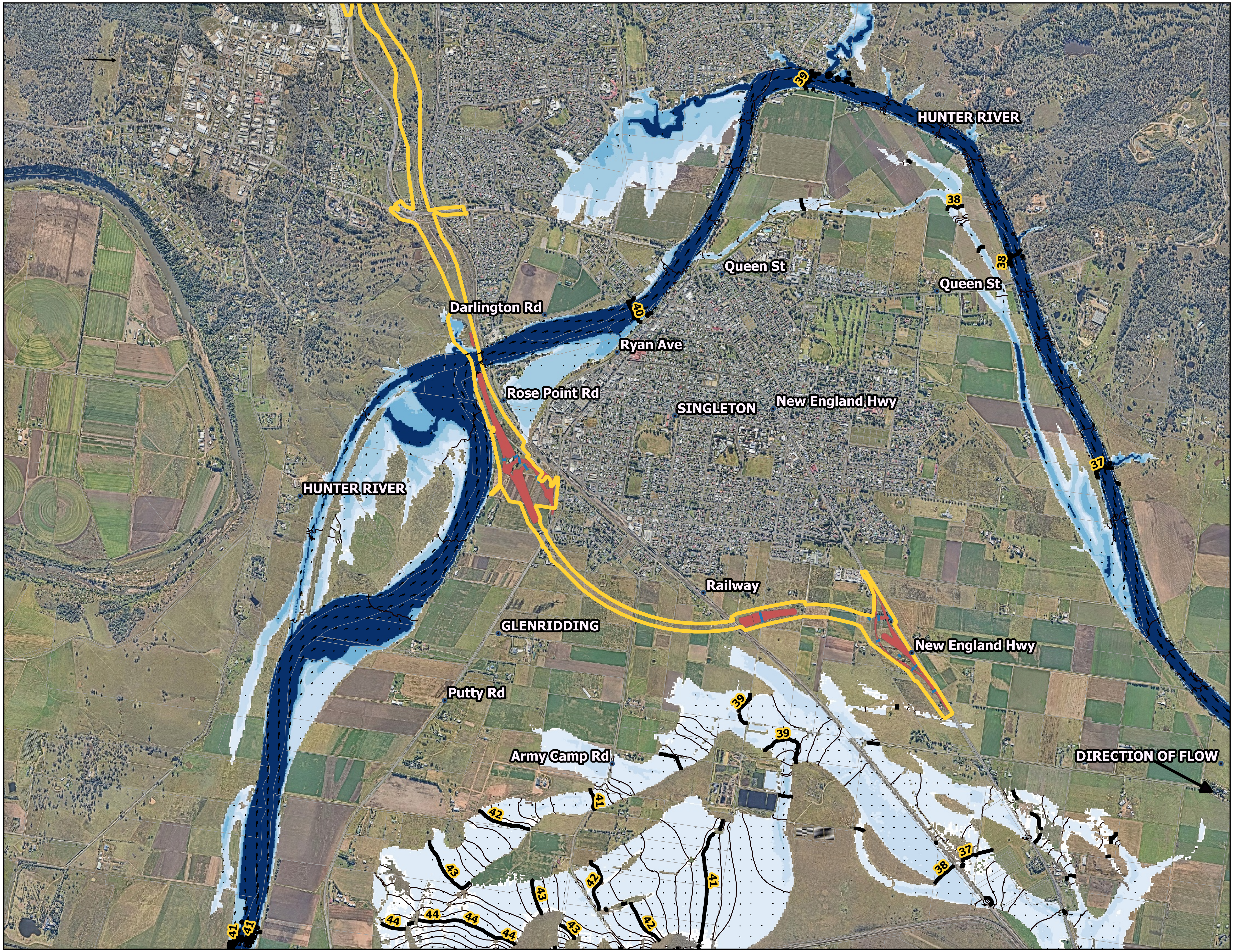
Map by: CK

6/6/2024 GDA 94 MGA 56

Singleton Bypass Addendum REF

Figure A1-7 / Water Surface Levels and Flood Depths - Existing PMF

Appendix B Detailed Design Flood Mapping



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Legend

- Project Approval Boundary
- Culverts
- Property Boundary

Design Road Embankment

- Major WSL Contours in m AHD (1m)
- Minor WSL Contours in m AHD (0.2m)

Design 20%AEP Depth Grid (m)

- 0.05 - 0.10
- 0.10 -0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- > 3

Peak Velocity (m/s)

- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Existing Run 122 EXG,
Design Run 134a DES

Map by: CK

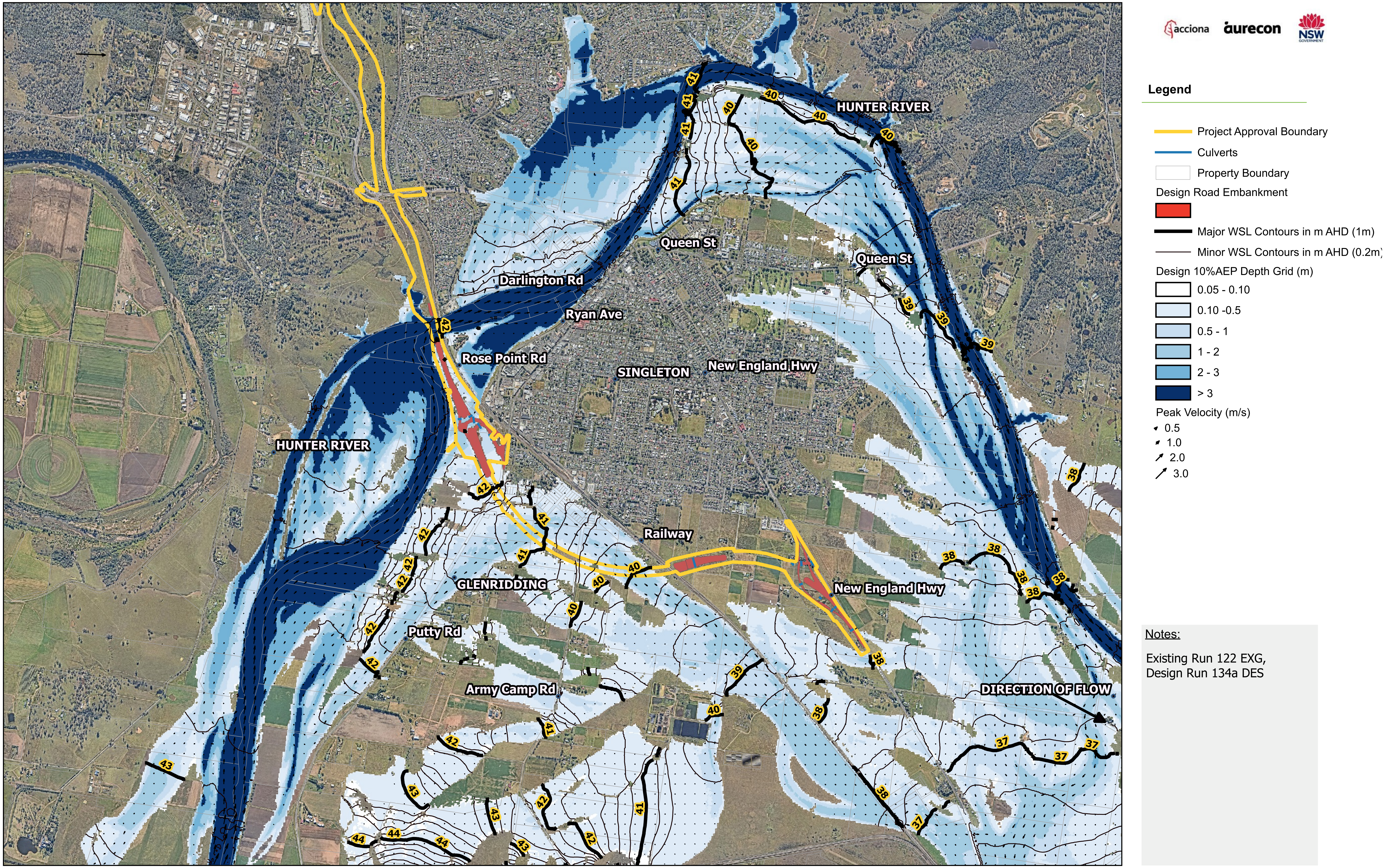
0 1,000 2,000 m

A3 Scale: 1:25,000

6/6/2024 GDA 94 MGA 56

Singleton Bypass Addendum REF

Figure A2-1 / Water Surface Levels and Flood Depths - Proposed Modification Design 20%AEP



Notes:

Existing Run 122 EXG,
Design Run 134a DES

Map by: CK

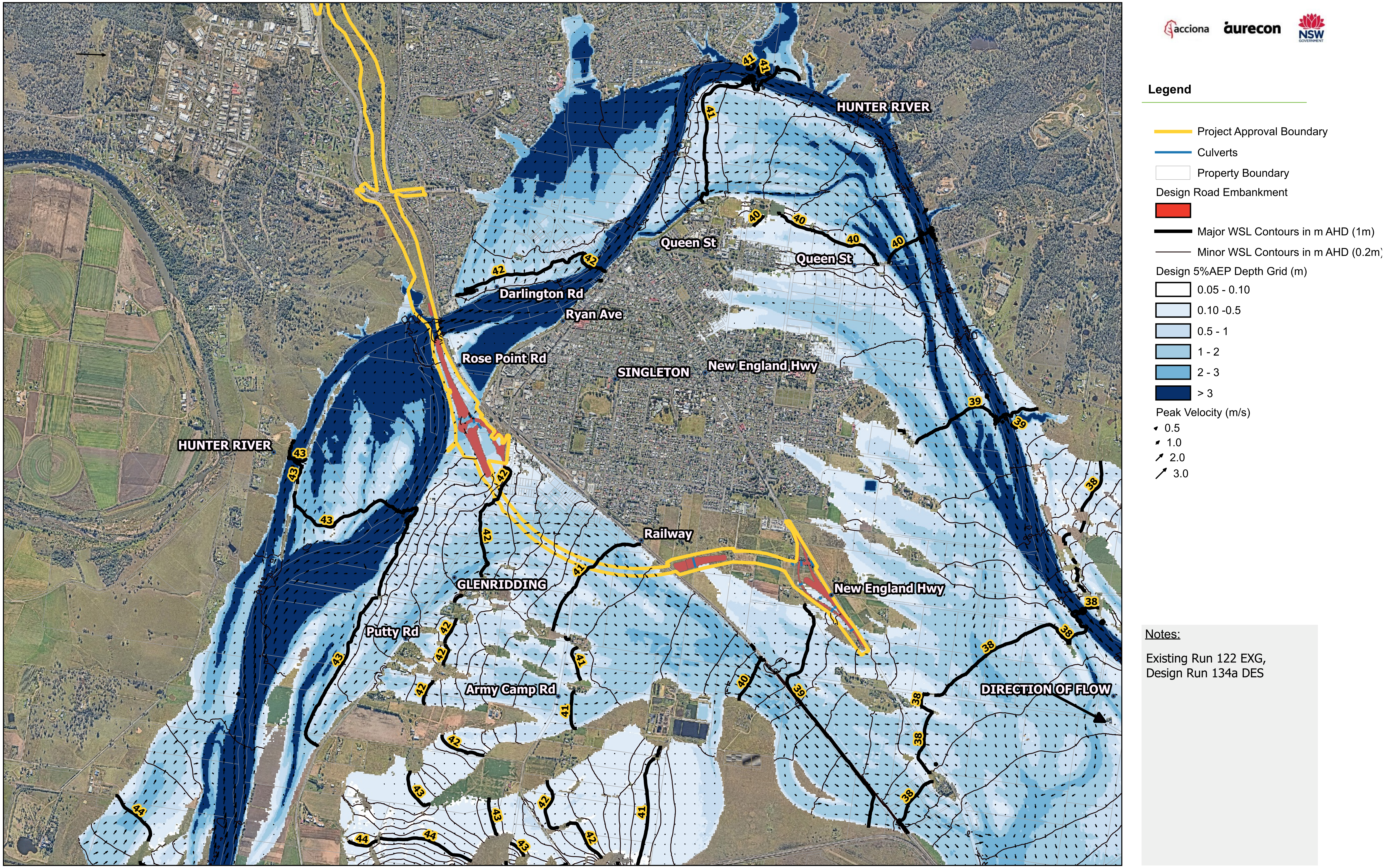
0 1,000 2,000 m

A3 Scale: 1:25,000

6/6/2024 GDA 94 MGA 56

Singleton Bypass Addendum REF

Figure A2-2 / Water Surface Levels and Flood Depths - Proposed Modification Design 10%AEP



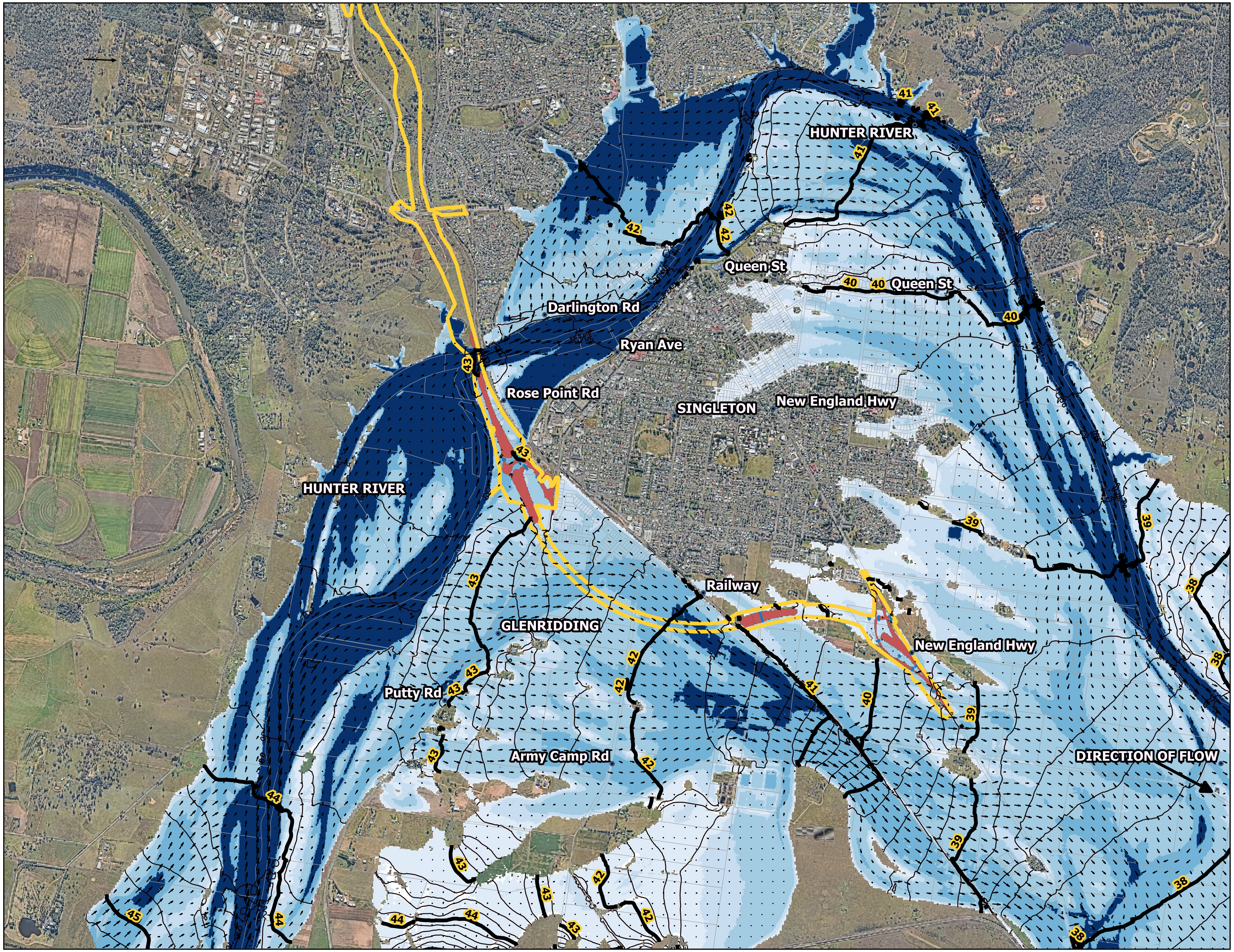
0 1,000 2,000 m

A3 Scale: 1:25,000

6/6/2024 GDA 94 MGA 56

Singleton Bypass Addendum REF

Figure A2-3 / Water Surface Levels and Flood Depths - Proposed Modification Design 5%AEP



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Legend

- Project Approval Boundary
- Culverts
- Property Boundary
- Design Road Embankment
- Major WSL Contours in m AHD (1m)
- Minor WSL Contours in m AHD (0.2m)

Design 2%AEP Depth Grid (m)

- 0.05 - 0.10
- 0.10 -0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- > 3

Peak Velocity (m/s)

- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Existing Run 122 EXG,
Design Run 134a DES

Map by: CK

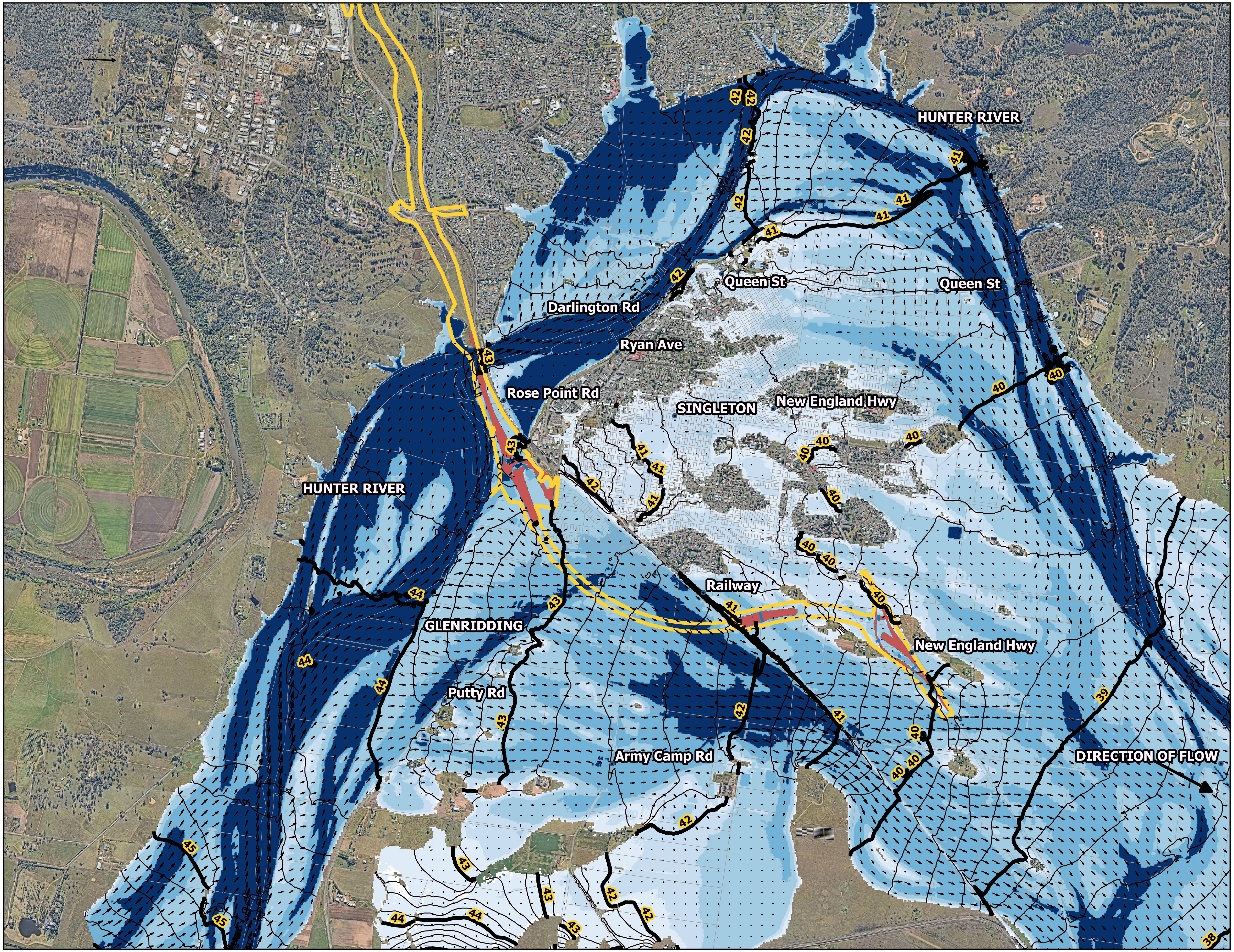
0 1,000 2,000 m

A3 Scale: 1:25,000

6/6/2024 GDA 94 MGA 56

Singleton Bypass Addendum REF

Figure A2-4 / Water Surface Levels and Flood Depths - Proposed Modification Design 2%AEP



acciona aurecon NSW GOVERNMENT

Legend

- Project Approval Boundary
- Culverts
- Property Boundary
- Design Road Embankment
- Major WSL Contours in m AHD (1m)
- Minor WSL Contours in m AHD (0.2m)

Design 1%AEP Depth Grid (m)

- 0.05 - 0.10
- 0.10 -0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- > 3

Peak Velocity (m/s)

- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Existing Run 122 EXG,
Design Run 134a DES

Map by: CK

0 1,000 2,000 m

A3 Scale: 1:25,000

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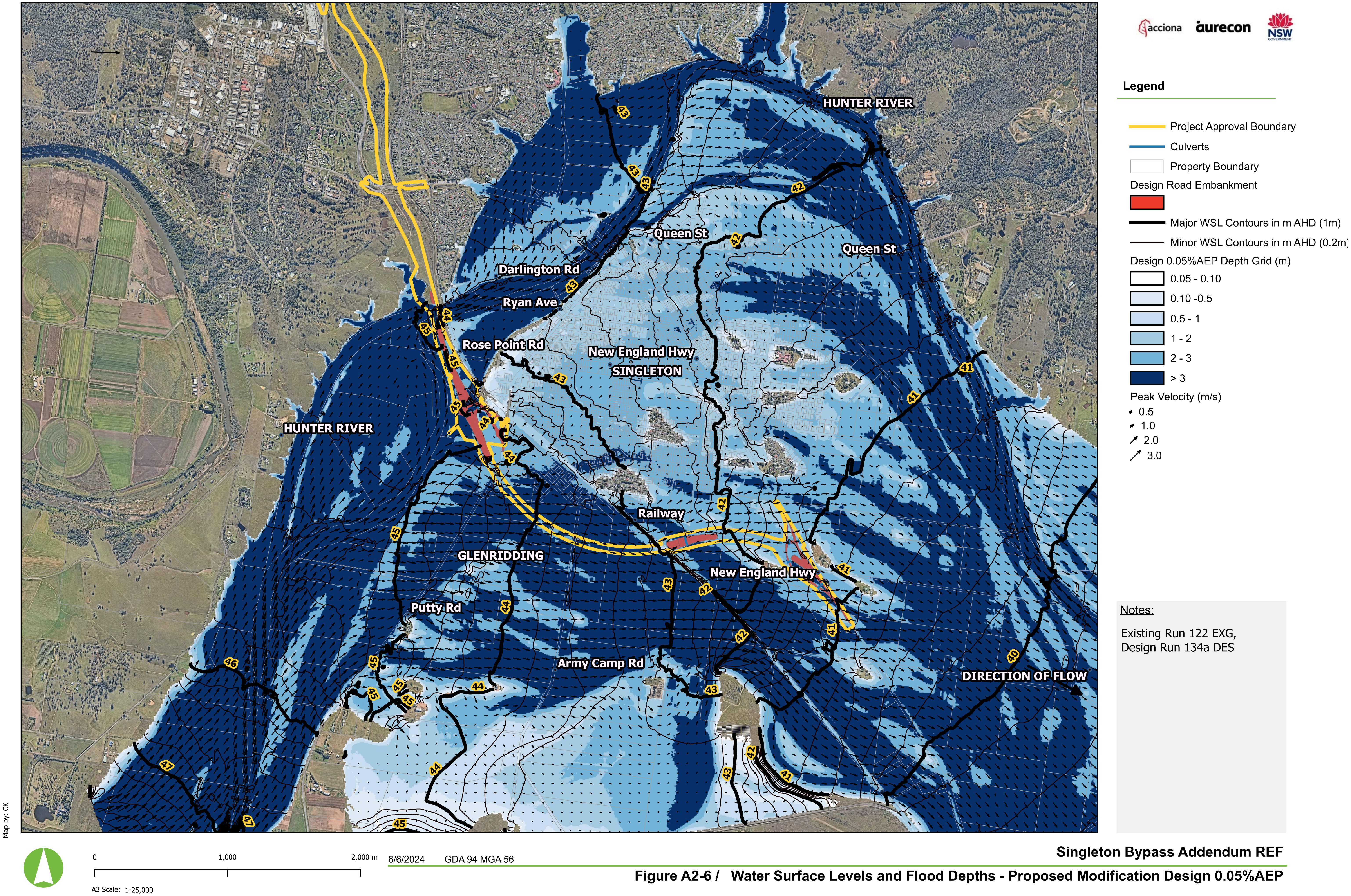
Figure A2-5 / Water Surface Levels and Flood Depths - Proposed Modification Design 1%AEP



Notes:

Existing Run 122 EXG,
Design Run 134a DES

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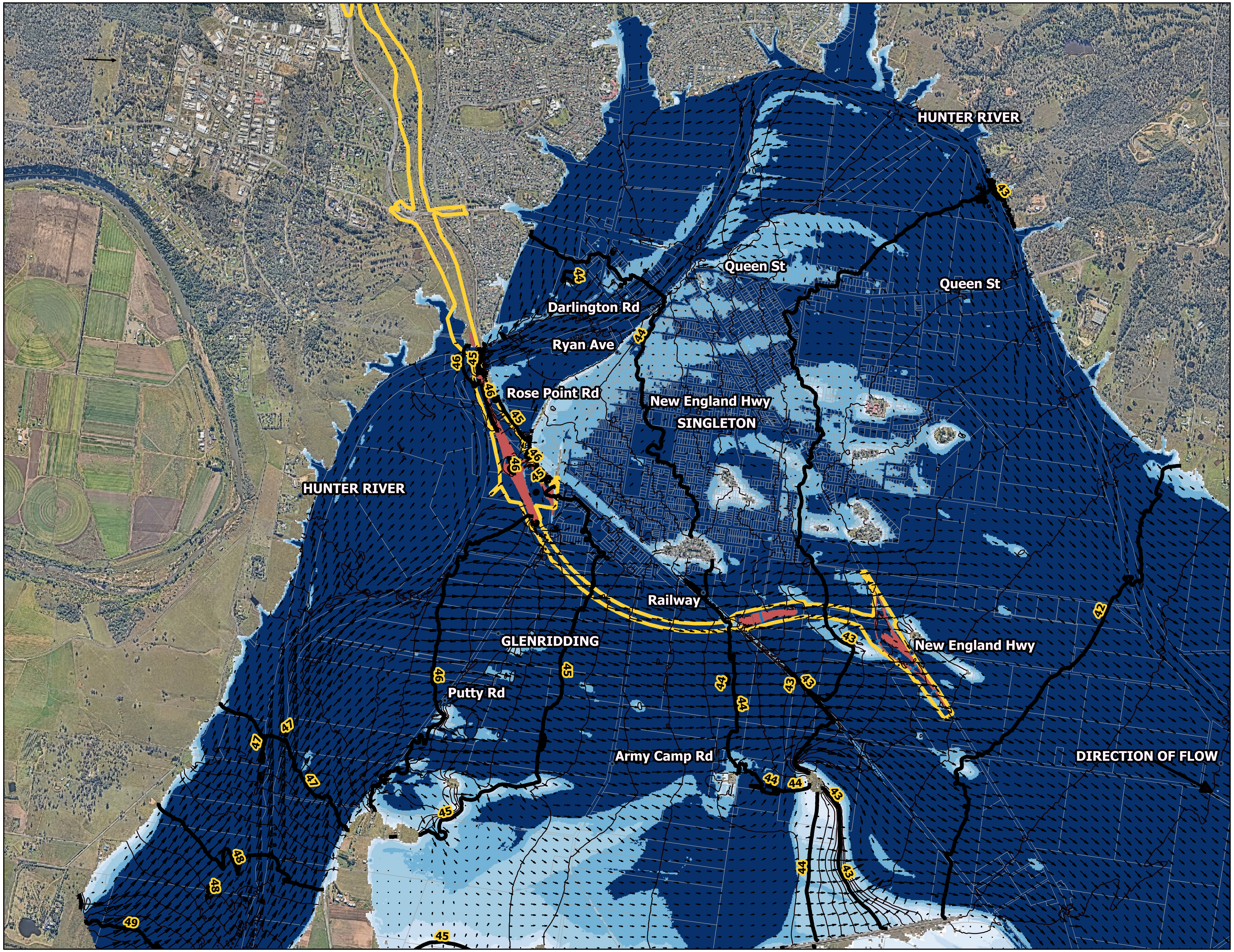
Figure A2-6 / Water Surface Levels and Flood Depths - Proposed Modification Design 0.05%AEP



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Legend

- Project Approval Boundary
- Culverts
- Property Boundary

Design Road Embankment

- Major WSL Contours in m AHD (1m)
- Minor WSL Contours in m AHD (0.2m)

Design PMF Depth Grid (m)

- 0.05 - 0.10
- 0.10 -0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- > 3

Peak Velocity (m/s)

- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Existing Run 122 EXG,
Design Run 134a DES

Map by: CK

0 1,000 2,000 m

A3 Scale: 1:25,000

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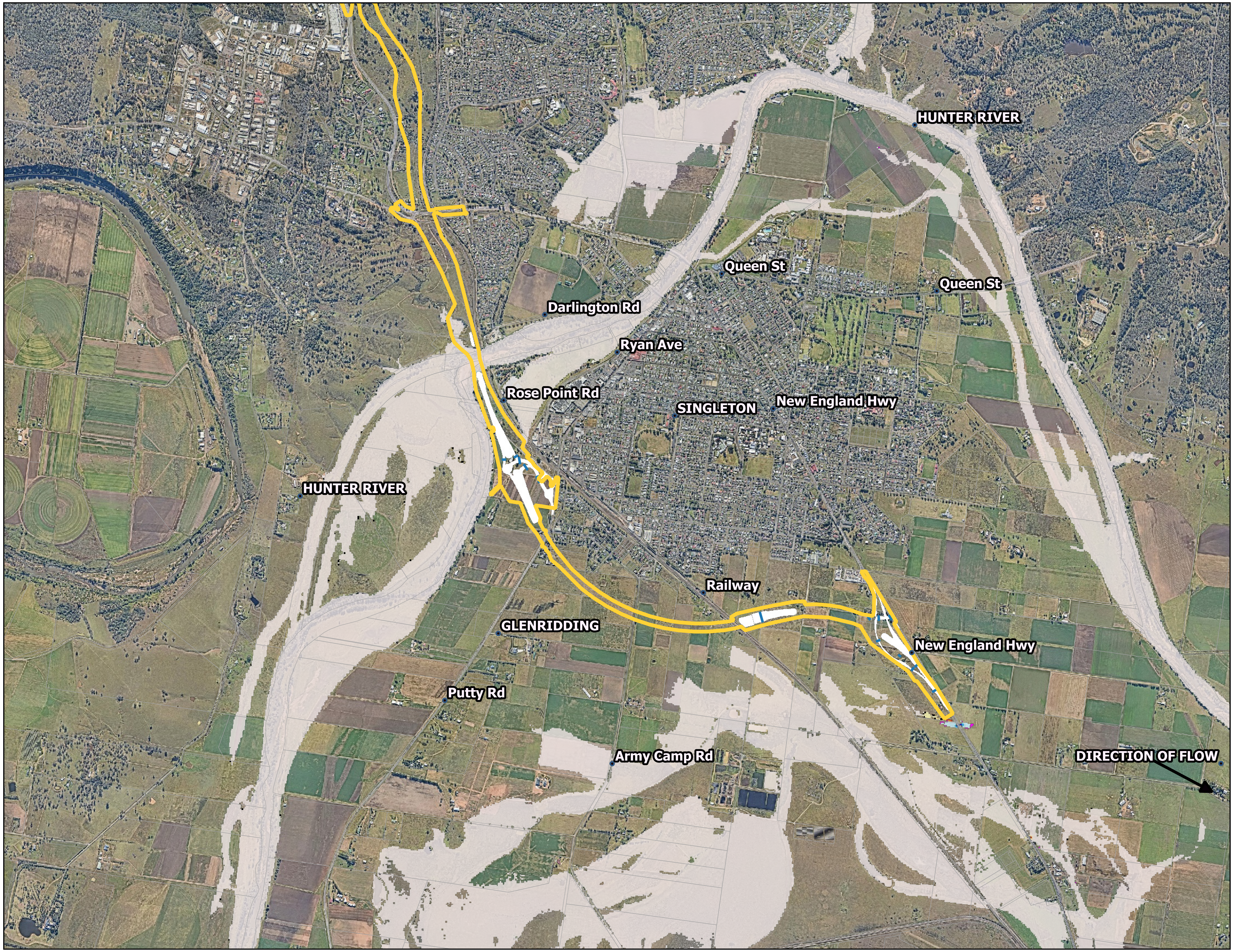
Figure A2-7 / Water Surface Levels and Flood Depths - Proposed Modification Design PMF

Appendix C Flood Level Impact Mapping



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Legend

- Project Approval Boundary
- Culverts
- Property Boundary
- Design Road Embankment

Impacts

Wet/ Dry

- Was Wet Now Dry
- Was Dry Now Wet

20%AEP Afflux (m)

- <= -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.02
- -0.02 to +0.02
- +0.02 to +0.05
- +0.05 to +0.10
- +0.10 to +0.20
- >+0.20

Notes:

Existing Run 122 EXG,
Design Run 153 DES

Map by: CK

0 1,000 2,000 m

A3 Scale: 1:25,000

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Figure E1 /Flood Impacts - Change in Water Surface Levels 20%AEP

Legend

- Project Approval Boundary
- Culverts
- Property Boundary

Design Road Embankment

Impacts

Wet/ Dry

- Was Wet Now Dry
- Was Dry Now Wet

10%AEP Afflux (m)

- <= -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.02
- -0.02 to +0.02
- +0.02 to +0.05
- +0.05 to +0.10
- +0.10 to +0.20
- >+0.20

Notes:

Existing Run 122 EXG,
Design Run 153 DES

Map by: CK

0 1,000 2,000 m

A3 Scale: 1:25,000

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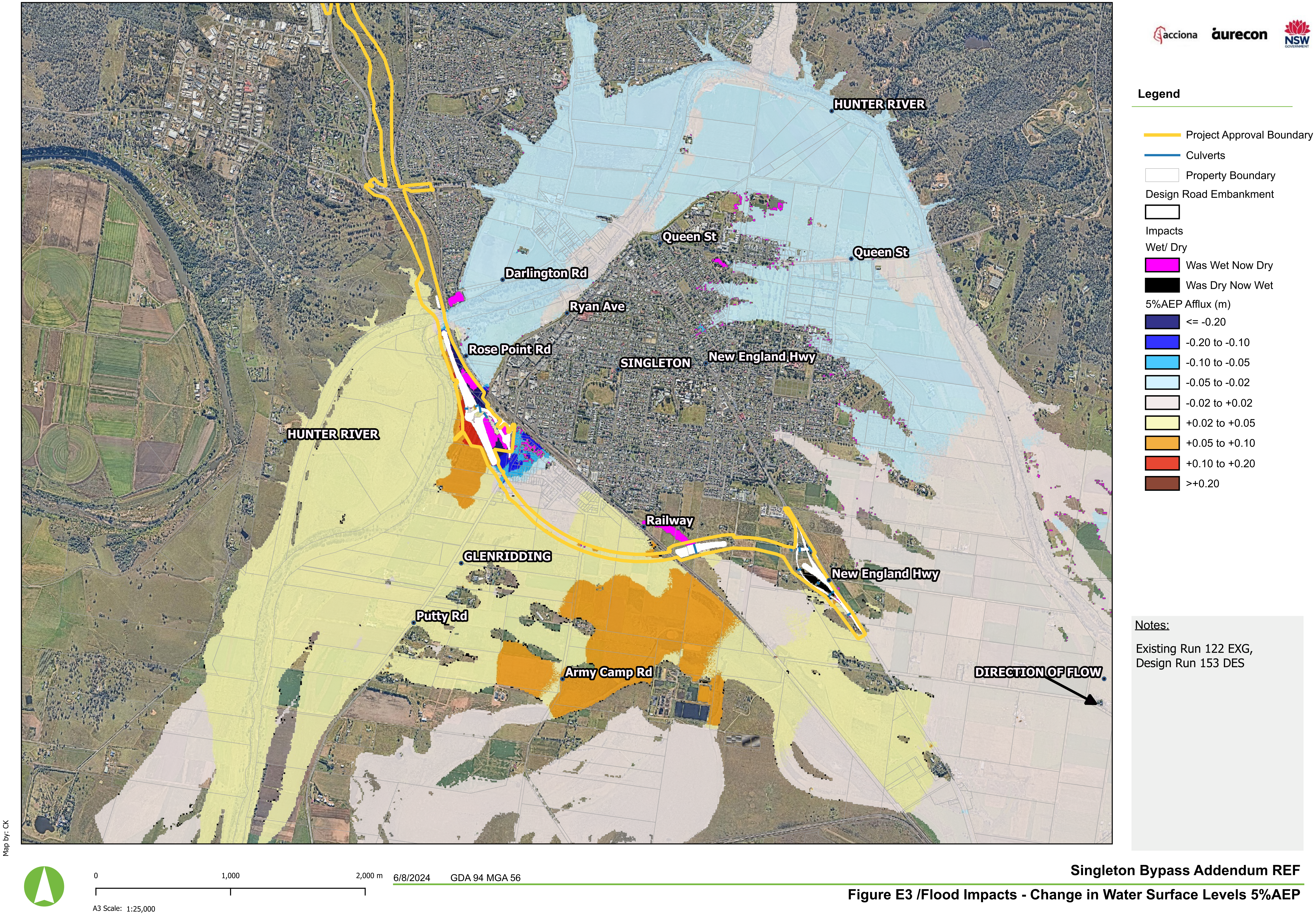
Figure E2 /Flood Impacts - Change in Water Surface Levels 10%AEP



Notes:

Existing Run 122 EXG,
Design Run 153 DES

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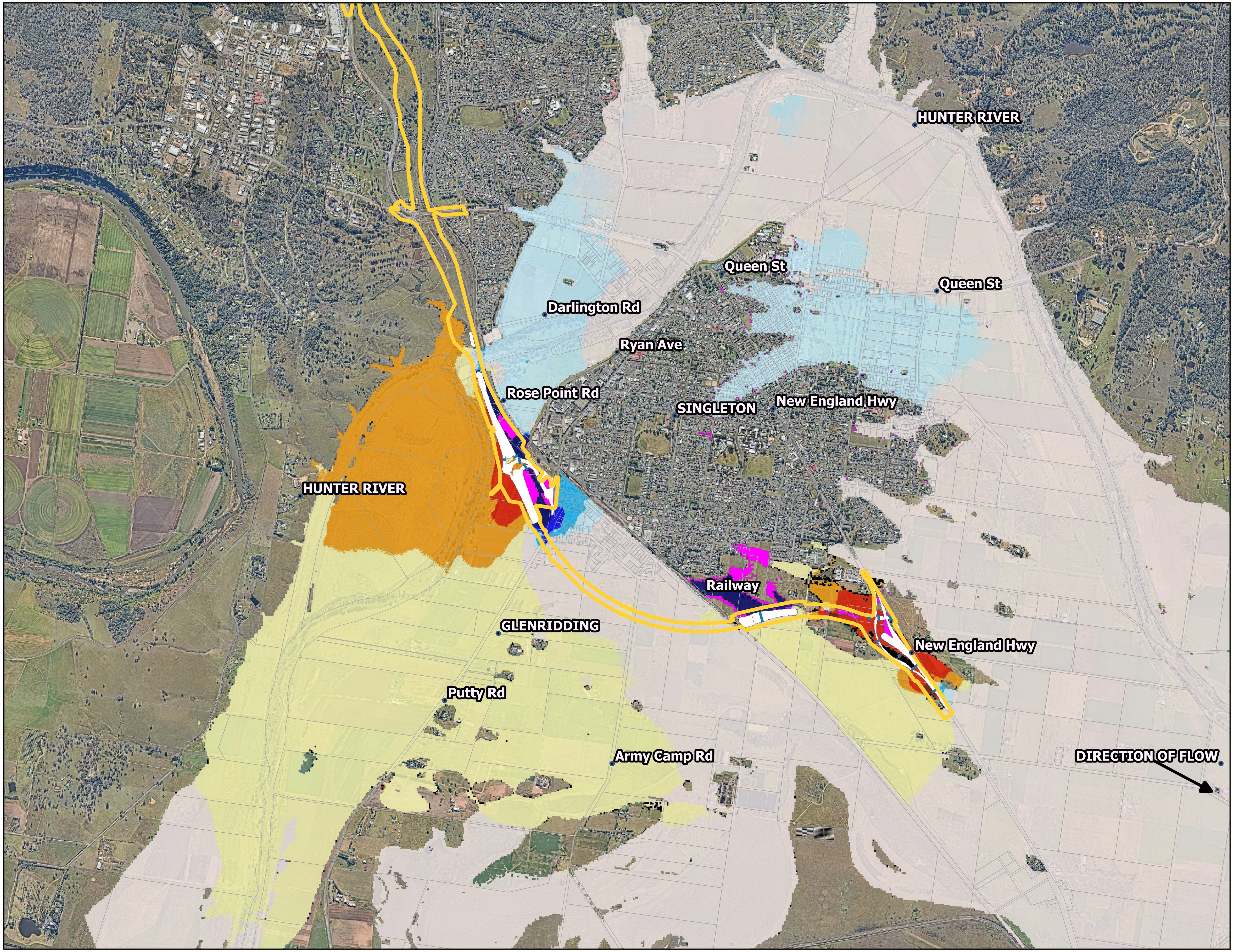
Figure E3 /Flood Impacts - Change in Water Surface Levels 5%AEP



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Legend

- Project Approval Boundary
- Culverts
- Property Boundary
- Design Road Embankment

Impacts

Wet/ Dry

- Was Wet Now Dry
- Was Dry Now Wet

2%AEP Afflux (m)

- <= -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.02
- -0.02 to +0.02
- +0.02 to +0.05
- +0.05 to +0.10
- +0.10 to +0.20
- >+0.20

Notes:

Existing Run 122 EXG,
Design Run 153 DES

Map by: CK

0 1,000 2,000 m

A3 Scale: 1:25,000

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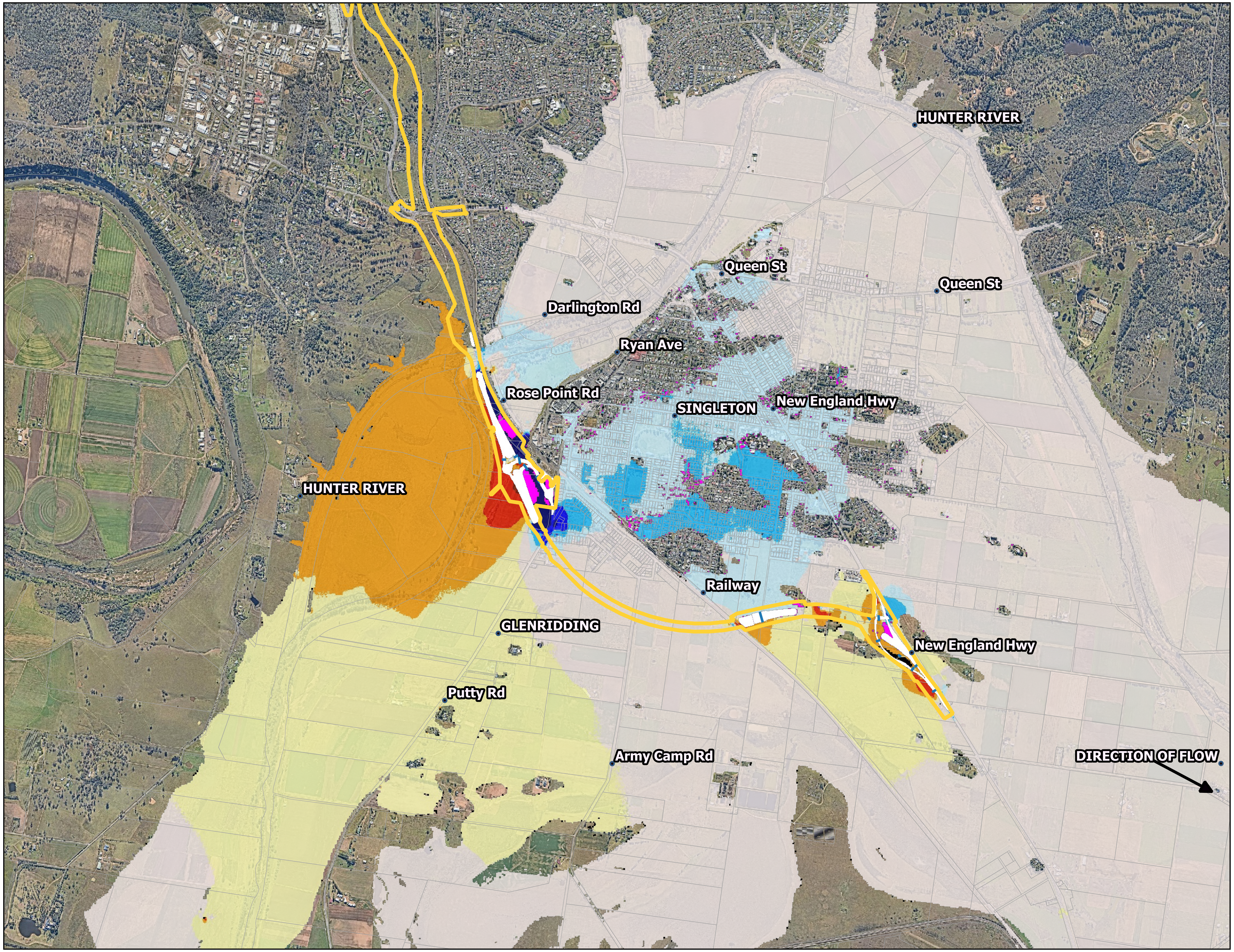
Figure E4 /Flood Impacts - Change in Water Surface Levels 2%AEP



Legend

- Project Approval Boundary
- Culverts
- Property Boundary
- Design Road Embankment

Impacts

Wet/ Dry

- Was Wet Now Dry
- Was Dry Now Wet

1%AEP Afflux (m)

- <= -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.02
- -0.02 to +0.02
- +0.02 to +0.05
- +0.05 to +0.10
- +0.10 to +0.20
- >+0.20

Notes:

Existing Run 122 EXG, Design Run 153 DES

Map by: CK

0 1,000 2,000 m

A3 Scale: 1:25,000

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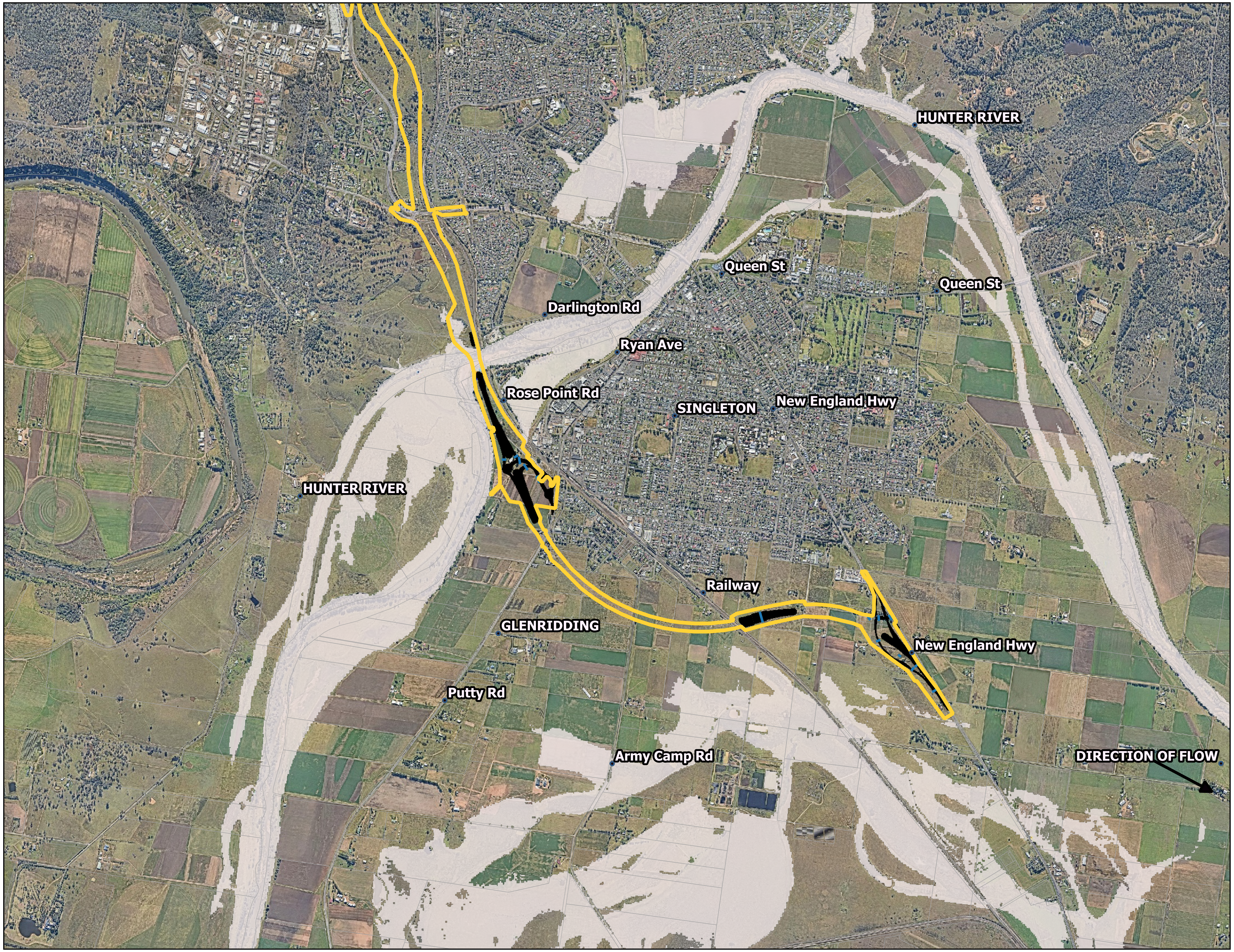
Figure E5 /Flood Impacts - Change in Water Surface Levels 1%AEP

Appendix D Velocity Impact Mapping



Legend

- Project Approval Boundary
- Culverts
- Property Boundary
- Design Road Embankment

Peak Flood Velocity Impact (m/s) - 20%AEP

- <= -0.4
- -0.4 to -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to +0.1
- +0.1 to +0.2
- +0.2 to +0.3
- +0.3 to +0.4
- >0.4

Notes:

Existing Run 122 EXG,
Design Run 153 DES

Map by: CK

0 1,000 2,000 m

A3 Scale: 1:25,000

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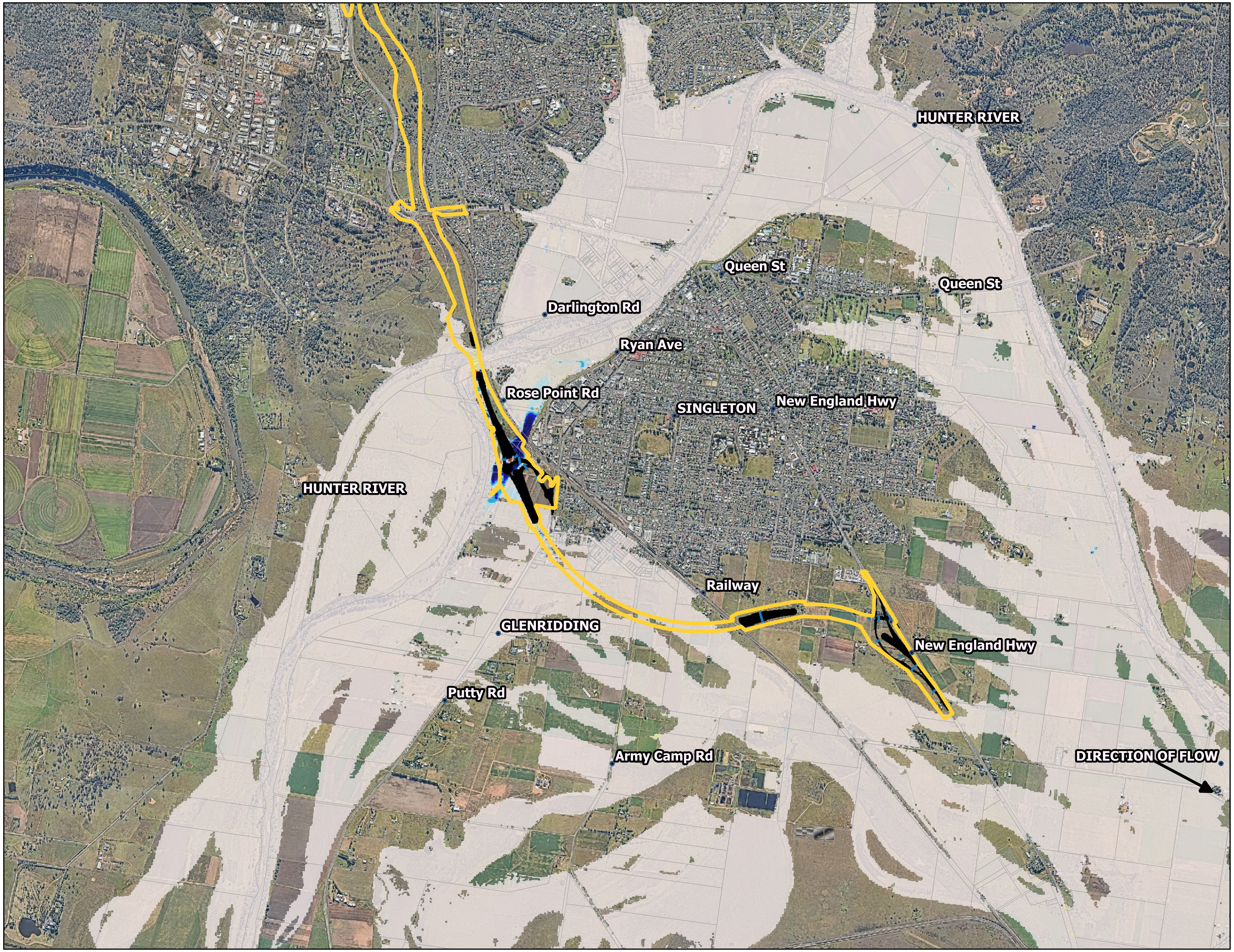
Figure I1 /Flood Impacts - Change in Flow Velocities 20%AEP



Legend

- Project Approval Boundary
- Culverts
- Property Boundary

Design Road Embankment

Peak Flood Velocity Impact (m/s) - 10%AEP

- <= -0.4
- -0.4 to -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to +0.1
- +0.1 to +0.2
- +0.2 to +0.3
- +0.3 to +0.4
- >0.4

Notes:

Existing Run 122 EXG,
Design Run 153 DES

Map by: CK

0 1,000 2,000 m

A3 Scale: 1:25,000

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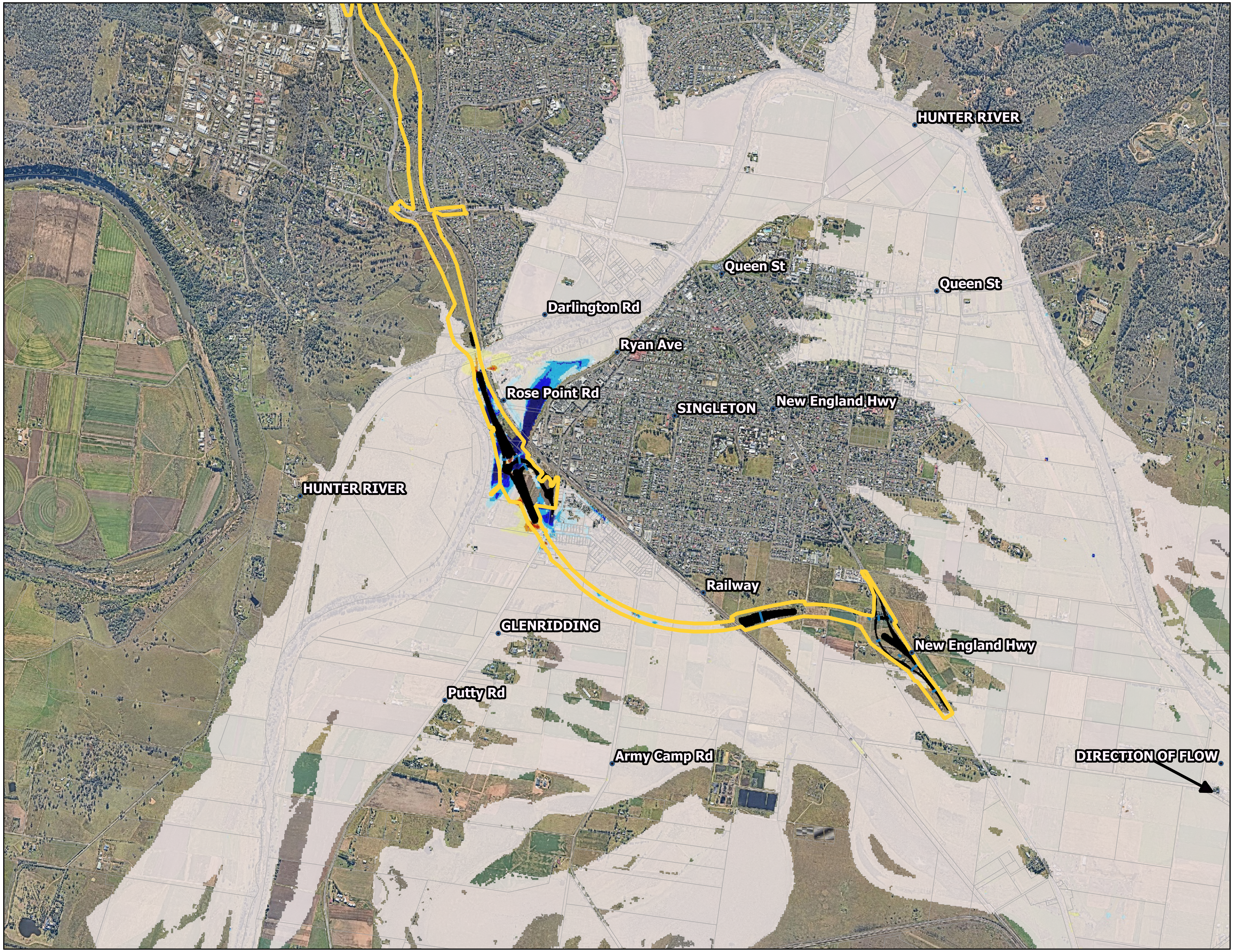
Figure I2 /Flood Impacts - Change in Flow Velocities 10%AEP



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Legend

- Project Approval Boundary
- Culverts
- Property Boundary
- Design Road Embankment

Peak Flood Velocity Impact (m/s) - 5%AEP

- <= -0.4
- -0.4 to -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to +0.1
- +0.1 to +0.2
- +0.2 to +0.3
- +0.3 to +0.4
- >0.4

Notes:

Existing Run 122 EXG,
Design Run 153 DES

Map by: CK

0 1,000 2,000 m

A3 Scale: 1:25,000

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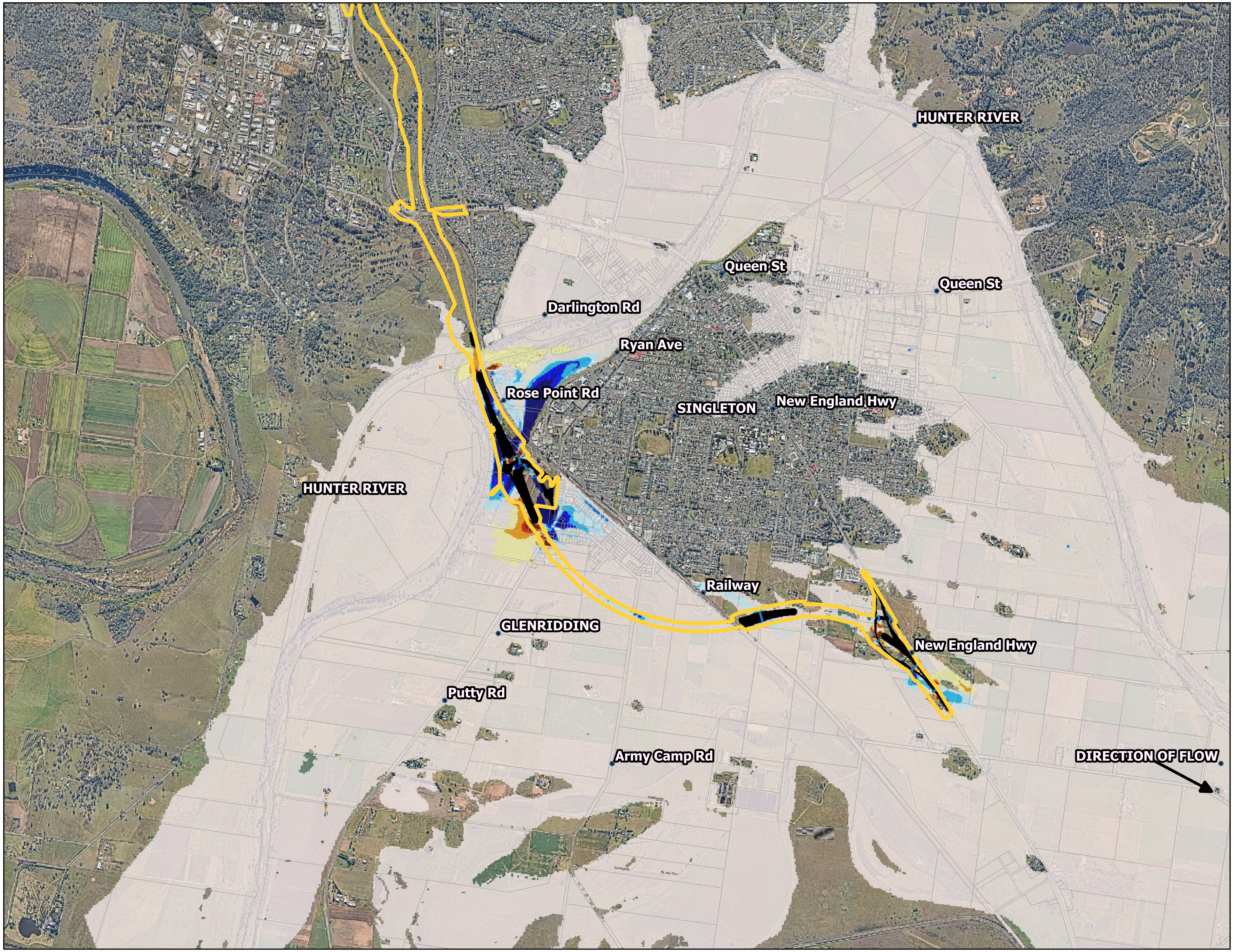
Figure I3 /Flood Impacts - Change in Flow Velocities 5%AEP



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Legend

- Project Approval Boundary
- Culverts
- Property Boundary
- Design Road Embankment

Peak Flood Velocity Impact (m/s) - 2%AEP

- <= -0.4
- -0.4 to -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to +0.1
- +0.1 to +0.2
- +0.2 to +0.3
- +0.3 to +0.4
- >0.4

Notes:

Existing Run 122 EXG,
Design Run 153 DES

Map by: CK

0 1,000 2,000 m

A3 Scale: 1:25,000

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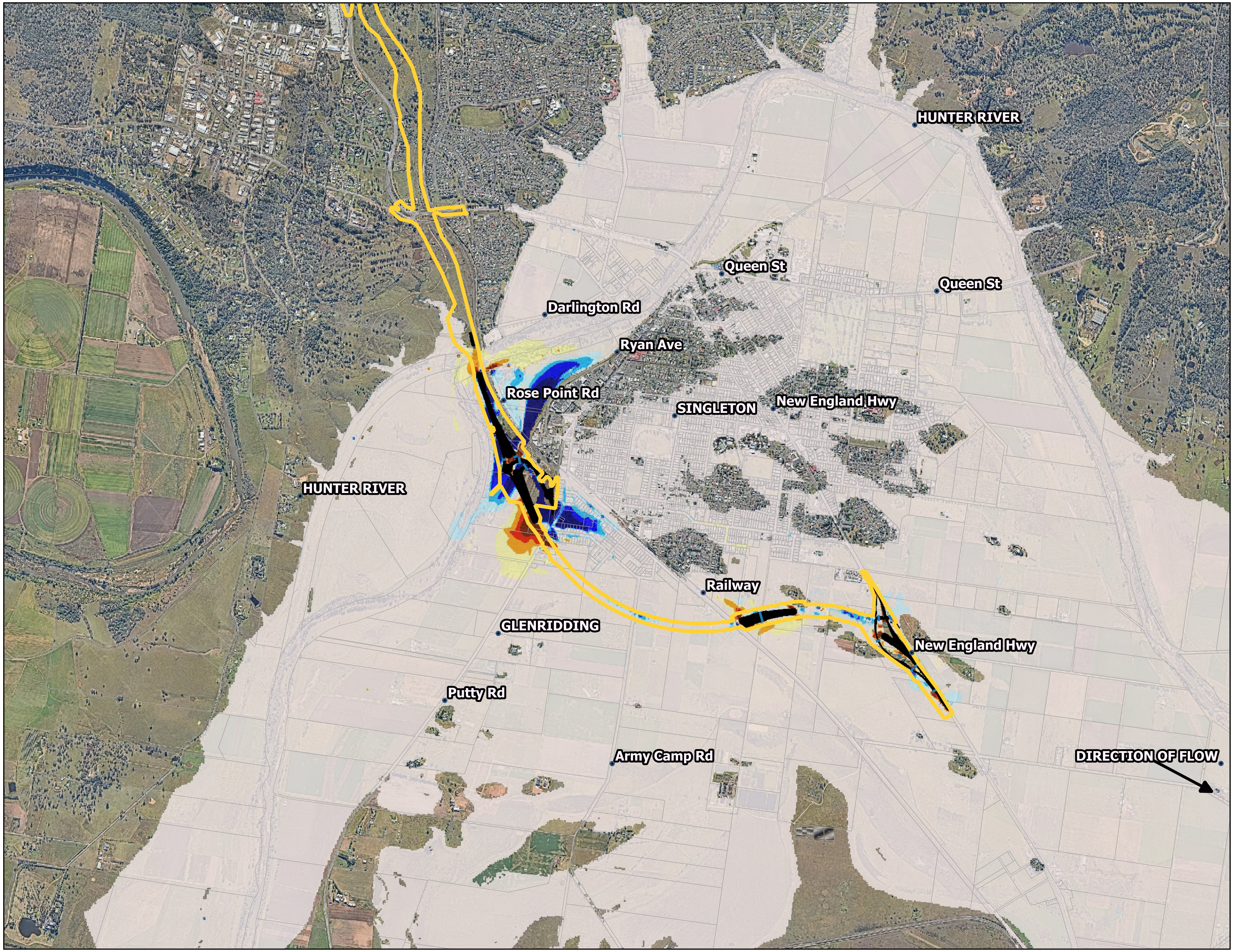
Figure I4 /Flood Impacts - Change in Flow Velocities 2%AEP



Legend

- Project Approval Boundary
- Culverts
- Property Boundary
- Design Road Embankment

Peak Flood Velocity Impact (m/s) - 1%AEP

- <= -0.4
- -0.4 to -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to +0.1
- +0.1 to +0.2
- +0.2 to +0.3
- +0.3 to +0.4
- >0.4

Notes:

Existing Run 122 EXG,
Design Run 153 DES

Map by: CK

0 1,000 2,000 m

A3 Scale: 1:25,000

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Figure I5 /Flood Impacts - Change in Flow Velocities 1%AEP

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