APPENDIX
M

Hydrology and Flooding Technical Report

HELIDON TO CALVERT ENVIRONMENTAL IMPACT STATEMENT

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.

Inland Rail: Phase 2 – Helidon to Calvert

Appendix M - Hydrology and Flooding Technical Report

Australian Rail Track Corporation

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Contents

Appendices

Figures

Tables

Glossary

The following terms and acronyms are used within this document:

Term or acronym	Description
AAToS	Annual Average Time of Submergence (hrs/yr)
	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
ARF	Areal Reduction Factors
ARR 2016	ARR 2016 Guidelines – 2016 edition
ARTC	Australian Rail Track Corporation
BCC	Brisbane City Council
BoM	Bureau of Meteorology
BRCFS	Brisbane River Catchment Flood Study
C2K	Calvert to Kagaru
CC	Climate change
Ch	Chainage
CL	Continuing loss rate (mm/hr)
DCDB	Digital Cadastral Data Base
DEA	Design Event Approach
DEM	Digital Elevation Model
Developed Case	Hydraulic modelling case with Project in place
Disturbance footprint	The Disturbance footprint is the footprint areas (both temporary and permanent) associated with the Project subject to direct disturbance
DRDMW	Department of Regional Development, Manufacturing, and Water
DNRME	Department of Natural Resources, Mines and Energy (Qld)
Existing Case	Hydraulic modelling case pre-Project
FFA	Flood Frequency Analysis
FFJV	Future Freight Joint Venture
G2H	Gowrie to Helidon
GIS	Geographic Information System
GSDM	Generalised Short Duration Method
GTSMR	Generalised Tropical Storm Method Revised
H2C	Helidon to Calvert
ICC	Ipswich City Council
IFD	Intensity-Frequency-Duration
IL	Initial loss (mm)
km	kilometres
LCC	Logan City Council
LGA	Local government area
LiDAR	Light Detection and Ranging
LVRC	Lockyer Valley Regional Council
MCS	Monte Carlo Simulation
m	metres

Term or acronym	Description
mm	millimetres
m AHD	metres above Australian Height Datum
PMF	Probable Maximum Flood
PMP	
QLD	Queensland
QR	Queensland Rail
RCBC	Reinforced concrete box culvert
RCP	Reinforced concrete pipe
RCP8.5	Representative Concentration Pathway 8.5 case (business as usual)
RFFE	Regional Flood Frequency Estimation
SRRC	Scenic Rim Regional Council
The Project	The Helidon to Calvert Project
TOF	Top of rail formation level
ToR	Terms of Reference
TOR	Top of rail
ToS	Time of Submergence (hrs)
WSL	Water Surface Level
WTTP	Wastewater treatment plant

Executive summary

The Inland Rail Helidon to Calvert (H2C) Project (the Project) provides a connection between the eastern end of the Calvert to Kagaru (C2K) Project, adjacent to the existing Queensland Rail (QR) West Moreton System rail corridor, and the ARTC Gowrie to Helidon (G2H) Line running west towards Toowoomba. The proposed alignment is approximately 47 kilometres (km) long, with approximately 24 km of the track is situated in existing rail corridor (adjacent to the QR West Moreton System) with the alignment passing through or close by several Lockyer Valley communities.

There are two major catchments that the Project alignment crosses, being Lockyer Creek, including its tributaries Sandy Creek (upstream of Grantham), Sandy Creek (adjacent to Forest Hill) and Laidley Creek, and Western Creek, a tributary of the Bremer River. Lockyer Creek and Western Creek form part of the larger Brisbane River system. Detailed hydrologic and hydraulic assessments have been undertaken due to the size of the catchments and associated watercourse floodplain flows.

The purpose of this investigation was to better understand and quantify the existing flooding characteristics of the each of the high-risk waterways in the vicinity of the Project alignment and to assess and mitigate any potential impacts on properties and infrastructure. The key objectives of the report are to provide information on the data investigation, development and calibration of the hydrology and hydraulic models, document impacts and mitigation measures and to provide comment on the performance on the Project design.

Available background information including existing hydrologic and hydraulic models, survey, streamflow data, available calibration information and anecdotal flood data was collected and reviewed. This data was sourced from a wide range of stakeholders and was used to develop calibrated hydrologic and hydraulic models for each waterway. These models were calibrated against multiple historical events including the most recent 2011 and 2013 events. Modelling results from these events was validated through stakeholder and community feedback.

Design flood estimation techniques in accordance with Australian Rainfall and Runoff 2016 (ARR 2016) were applied to the hydrologic and hydraulic models to determine Existing Case flood conditions on each of the floodplains. This modelling was undertaken for a range of design events from the 20% Annual Exceedance Probability (AEP) event up to the 1 in 10,000 AEP event and the Probable Maximum Flood (PMF).

A Developed Case was prepared using the Existing Case models and incorporated the Project design. The Developed Case models were run for the same range of design events with results compared to determine impacts on peak water levels, flows, flood flow distribution, velocities and duration of inundation on each floodplain and, in particular, upon identified flood sensitive receptors.

The refinement of the Project design was guided using hydraulic design criteria and flood impact objectives (refer Table 1) that were developed for the Project. The flood impact objectives were initially developed based on a review of objectives used for other large infrastructure projects in rural and urban areas as well as consideration of industry practice and use of engineering judgement.

Table 1 Flood impact objectives

Parameter	Objectives				
Change in peak water levels[1]	Existing habitable and/or commercial and industrial buildings/premises (e.g. dwellings, schools, hospitals, shops)	Residential or commercial/industrial properties/lots where flooding does not impact dwellings/ buildings (e.g. yards, gardens)	Existing non-habitable structures (e.g. agricultural sheds, pump-houses)	Roadways	Agricultural and grazing land/forest areas and other non-agricultural land
	≤ 10 mm	≤ 50 mm	≤ 100 mm	≤ 100 mm	≤ 200 mm with localised areas up to 400 mm

Parameter	Objectives
	Changes in peak water levels to be assessed against the above proposed limits. It is noted that changes in peak water levels can have varying impacts upon different infrastructure/land and flood impact objectives were developed to consider the flood sensitive receptors in the vicinity of the Project. It should be noted that in many locations the presence of existing buildings or infrastructure limits the change in peak water levels.
Change in duration of inundation[1]	Identify changes to time of inundation through determination of time of submergence (ToS). For roads, determine Annual Average Time of Submergence (AATOS) (if applicable) and consider impacts on accessibility during flood events. Justify acceptability of changes through assessment of risk with a focus on land-use and flood sensitive receptors.
Flood flow distribution[1]	Aim to minimise changes in natural flow patterns and minimise changes to flood flow distribution across floodplain areas. Identify any changes and justify acceptability of changes through assessment of risk with a focus on land-use and flood sensitive receptors.
Velocities[1]	Maintain existing velocities where practical. Identify changes to velocities and impacts on external properties. Determine appropriate scour mitigation measures taking into account existing soil conditions. Justify acceptability of changes through assessment of risk with a focus on land-use and flood sensitive receptors.
Extreme event risk management	Consider risks posed to neighbouring properties for events larger than the 1% AEP event to ensure no unexpected or unacceptable impacts.
Sensitivity testing	Consider risks posed by climate change and blockage in accordance with ARR 2016. Undertake assessment of impacts associated with Project alignment for both scenarios.

Table note:

1 These flood impact objectives apply for events up to and including the 1% AEP event

Detailed hydrologic and hydraulic modelling was undertaken to meet the hydraulic design criteria and flood impact objectives, with a series of iterations undertaken to incorporate design refinement and stakeholder and community feedback.

The hydrologic and flooding assessment undertaken has demonstrated that the Project is predicted to result in impacts on the existing flooding regime that generally comply the flood impact objectives and that the Project design meets the hydraulic design criteria.

A consultation exercise has been undertaken to provide the community with detailed information and certainty around the flood modelling and the Project design. The consultation with stakeholders, including landholders, was undertaken at key stages including validation of the performance of the modelling in replicating experienced historical flood events and presentation of the design outcomes and impacts on properties and infrastructure. In future stages, consultation and engagement will continue with:

- Landowners concerned with hydrology and flooding throughout the detailed design, construction and operational phases of the Project
- Directly impacted landowners affected by the alignment throughout the detailed design, construction and operational phases of the Project
- Local councils and State government departments throughout the detailed design, construction and operational phases of the Project.

1 Introduction

1.1 Inland Rail Program

Inland Rail is a once-in-a-generation program connecting regional Australia to domestic and international markets, transforming the way we move freight around the country. It will complete the 'spine' of the national freight network between Melbourne and Brisbane via regional Victoria, New South Wales (NSW) and Queensland (QLD).

This new 1,700 km line is the largest freight rail infrastructure project in Australia and is expected to commence operations in 2026.

1.2 Helidon to Calvert alignment

The Helidon to Calvert (H2C) section of Inland Rail (the 'Project') consists of a single 47 kilometre (km) long dual gauge track with four crossing loops to accommodate double stack freight trains up to 1,800 metres (m) in length. It will ultimately accommodate trains up to 3,600 metres (m) long, based on business needs, but will be initially constructed to accommodate 1,800 m long double-stack freight trains. Approximately 24 km of the track is situated adjacent to the Queensland Rail (QR) West Moreton System rail corridor with the alignment passing through or close by several Lockyer Valley communities. It also involves the construction of an approximately 850 m long tunnel through the Little Liverpool Range to facilitate the required Project design standards.

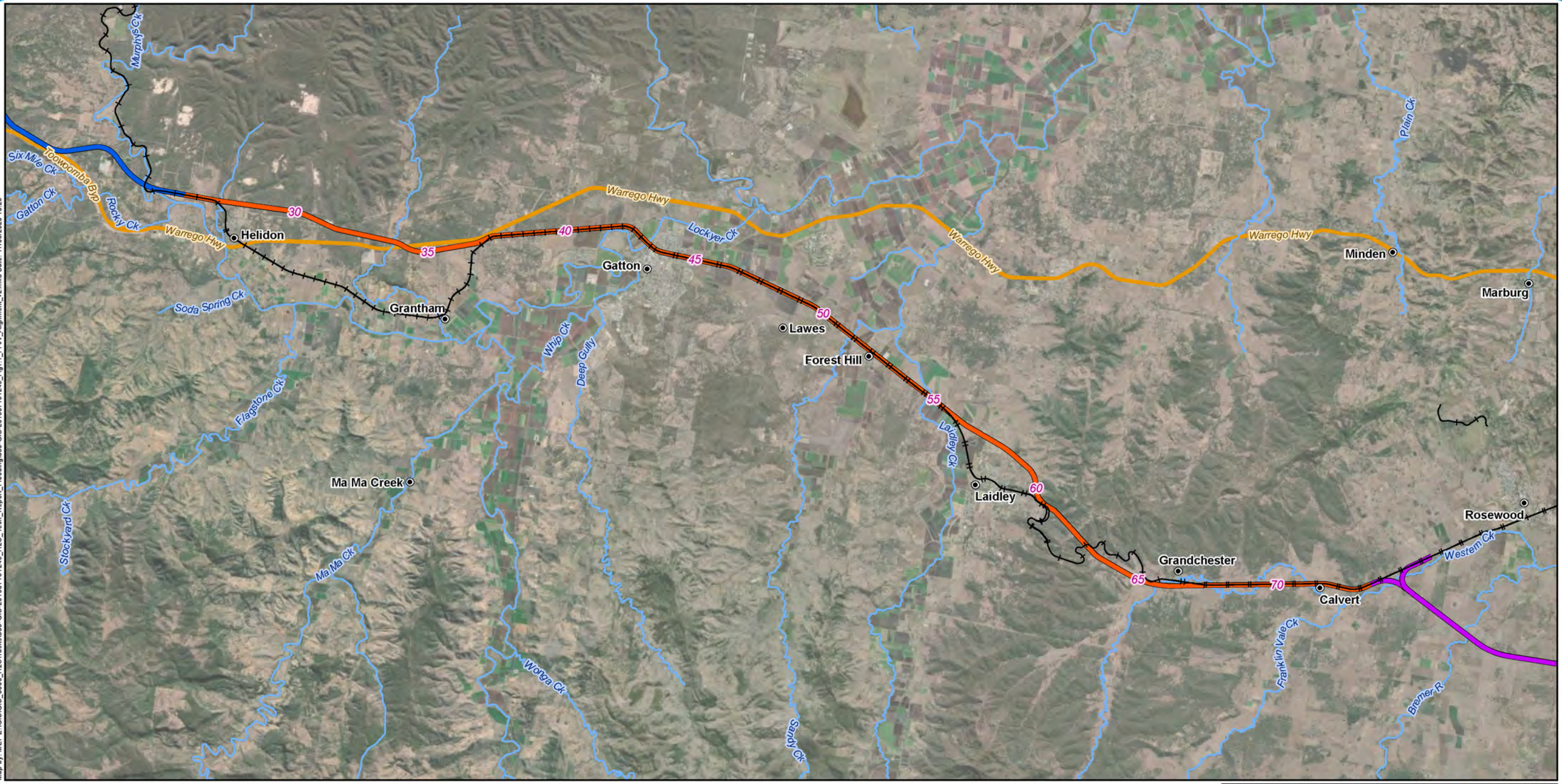
The Project provides a connection between the eastern end of the Calvert to Kagaru (C2K) Inland Rail Project, adjacent to the existing QR West Moreton System rail corridor, and the ARTC Gowrie to Helidon (G2H) Inland Rail Project running west towards Toowoomba (refer Figure 1.1).

1.3 Objectives of this report

This investigation has been undertaken to firstly identify high-risk watercourse crossings or floodplain locations that may be impacted by the Project alignment. Secondly a detailed quantitative assessment has been undertaken to better understand and quantify the existing flooding characteristics of each of the high-risk waterways in the vicinity of the Project alignment and to assess and mitigate any potential impacts associated with the Project alignment on the existing flooding regime of each waterway.

The key purpose of this report is to provide details of investigations undertaken including data collection and review, development and calibration of hydrology and hydraulic models, design event modelling, impact assessment of the Project alignment, development of mitigation measures and to provide comment on the performance of the Project design. Consultation with stakeholders and the community has been progressively undertaken with feedback used to inform the development and calibration of the models and to refine the Project design.

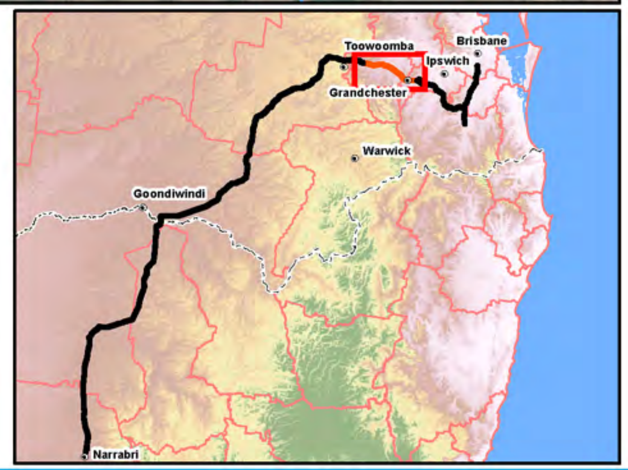
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: MEF Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_Fig1.1_FFJV_Alignment_v2.mxd Date: 17/06/2020 13:25

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- G2H project alignment
- H2C project alignment
- C2K project alignment
- Watercourses
- Major roads



A3 scale: 1:150,000

0 1 2 3 4 5km

Future Freight
Integrating Community, Environment and Engineering

Issue date: 10/02/2020 Version: 1
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert
Figure 1.1: Alignment

Key objectives of the hydrology and flooding investigation were to:

- Consult with local authorities regarding existing flood studies relevant to the design and consider these previous flood studies in the design
- Consult with landholders, stakeholders and government agencies to obtain flood data to assist in model development and calibration, and to discuss impacts associated with the Project
- Undertake detailed hydrologic and hydraulic modelling for each major catchment to establish the Base Case (or Existing Case) flood conditions for the range of floods up to 1% Annual Exceedance Probability (AEP) as well as the 1 in 2,000 AEP, 1 in 10,000 AEP and Probable Maximum Flood (PMF) events
- Determine existing flood conditions including flood levels, flows and velocities
- Analyse the Project design including the alignment design, drainage infrastructure and associated infrastructure works
- Assess the impacts of the Project design on neighbouring properties, infrastructure and the surrounding environment
- Identify and assess potential mitigation measures. The requirement for mitigation was based on the magnitude of impacts and how this aligned with the flood impact objectives.

2 Assessment methodology

The hydrology and flooding assessment involved the following activities:

- Collation and review of available background information including existing hydrologic and hydraulic models, survey, rainfall and streamflow data, calibration information and anecdotal flood related data. This review established which datasets were suitable to use for the Project design.
- Determination of critical flooding mechanisms for waterways and drainage paths in the study area, i.e. regional flooding versus local catchment flooding
- Determination of high-risk watercourses that the alignment crosses qualitatively considering:
  - The catchment size, resulting flood flows and velocities
  - The land use in the vicinity of the rail alignment
  - The extent and depth of flood inundation
  - The duration of flood events and catchment response time
  - The proximity to and nature of flood sensitive receptors (eg. houses, sheds, roads etc)
- Adoption of the Brisbane River Catchment Flood Study (BRCFS) hydrologic modelling for the Project
- Update of the existing Lockyer Valley Regional Council (LVRC) Lockyer Creek hydraulic model, and development of a localised hydraulic model for Western Creek, for use on the Project
- Validation of the hydrologic models and hydraulic models against available recorded data for five historical flood events
- Community and stakeholder engagement to validate model performance and gain acceptance of modelling and calibration outcomes. Anecdotal flood event information such as flood photography, recorded flood markers and personal observations from landholders were sourced to validate the calibration of the hydrologic and hydraulic models.
- Update of hydrologic models to include Australian Rainfall and Runoff 2016 (ARR 2016) design events. ARR 2016 was adopted for this Project as ARR 2019 was not released when this investigation commenced.
- Simulation of ARR 2016 design events for the Existing Case and comparison to previous studies to confirm drainage paths, waterways, and associated floodplain areas, and establish the existing flood regime in the vicinity of the Project
- Inclusion of Project alignment and drainage structures (Developed Case) in the hydraulic models and simulation of ARR 2016 design events including the 20%, 10%, 5%, 2%, 1%, 1 in 2,000, 1 in 10,000 AEP and PMF events
- Assessment of impacts of Project alignment using the suite of design flood events including consideration of change in flood levels, flow distributions, velocities and inundation periods
- Determination of appropriate mitigation measures to manage potential impacts including refinement of location and dimensions of drainage structures under the Project alignment. Iterations were undertaken in the hydraulic models to achieve a design that addresses the flood impact objectives.
- Sensitivity analysis on the design for factors including climate change and blockage risk.

The hydrology and hydraulic impact assessment provided key inputs to the Project design where the alignment is located within the modelled flood extents. Key dependencies for the Project design include:

- Modelling of the Existing Case 1% AEP event to ascertain existing conditions and inform the flood immunity for the Project alignment and to size drainage structures
- Modelling of 1 in 2,000 AEP event to provide inputs for bridge design and wider resilience assessment

- Modelling of rare flood events (1 in 10,000 AEP and PMF events) to assist in consideration of overtopping risk
- Modelling the full range of flood events to quantify potential impacts and inform mitigation measures
- Input to drainage design including scour protection design – water levels, flows and velocities from this assessment have been used to inform the design of scour protection
- Input to structure selection and design for culverts and bridges.

3 Existing environment

3.1 Waterways

The Project alignment crosses two major catchments being Lockyer Creek and Western Creek (a tributary of the Bremer River). Waterway crossings occur over both creeks as well as Sandy Creek (upstream of Grantham), Sandy Creek (adjacent to Forest Hill) and Laidley Creek, tributaries of Lockyer Creek.

Details on each of the catchments are outlined below.

3.1.1 Lockyer Creek

Lockyer Creek is a major tributary of the Brisbane River catchment, joining the Brisbane River approximately 3 km downstream of Wivenhoe Dam. The Lockyer Creek hydrologic model extends down to O'Reilly's Weir, with a total catchment area of 2,964 square kilometres (km^2). The catchment features numerous tributaries, including Fifteen Mile Creek, Murphys Creek and Alice Creek (upstream of Helidon), Flagstone Creek and Sandy Creek (upstream of Grantham), Ma Ma Creek and Tenthill Creek upstream of Gatton, and Sandy Creek (adjacent to Forest Hill) and Laidley Creek and Buaraba Creek between Gatton and the Brisbane River. The Lockyer Creek catchment varies significantly, with steep headwater areas and wide flat floodplain in the lower reaches.

A notable feature of Lockyer Creek is that the main channel is perched (i.e. the elevation of the creek banks is higher than the surrounding floodplain). This feature is particularly dominant in the lower catchment. Flows in excess of the channel capacity break out of the main creek channel around the confluence of Lockyer Creek and Laidley Creek at Glenore Grove. Overbank flows have limited opportunity to interact with the channel flows and exhibit a longer travel time between Glenore Grove and the confluence with the Brisbane River.

3.1.2 Western Creek (Bremer River)

Western Creek is a tributary of the Bremer River, a major tributary of the Brisbane River that joins the Brisbane River near the city of Ipswich approximately 80 km downstream of Wivenhoe Dam. The Bremer River hydraulic model extends to Walloon, approximately 8 km upstream of the Bremer River confluence with Warrill Creek and 36 km upstream of the Brisbane River. Approximately 20 km of Western Creek is included within the hydraulic model from the confluence with Bremer River to 2 km upstream of Grandchester.

3.2 Floodplain Infrastructure

Existing infrastructure on the floodplains that the Project alignment crosses includes:

- Burgess Road
- Smithfield Road
- Old College Road
- Dodt Road
- Hunt Street
- Old Laidley Forest Hill Road
- Laidley Plainland Road
- Grandchester Mount Mort Road
- QR West Moreton System rail corridor
- Levees and dams from farming practices.

Burgess Road, Smithfield Road and Old College Road are located near the existing Gatton QR West Moreton System rail corridor bridge. All of these roads are elevated compared to the surrounding floodplain areas and only start to be impacted by flooding under the larger flood events.

Dodt Road runs parallel to the QR West Moreton System rail corridor on its southern side and traverses a number of low-lying areas and is prone to overtopping under frequent flood events.

Hunt Street forms a level crossing with the QR West Moreton System rail corridor in Forest Hill. The QR West Moreton System rail corridor is overtopped under large flood events to the east of the level crossing.

Old Laidley Forest Hill Road is located in Laidley North and runs north-west from its intersection to Laidley Plainland Road. Old Laidley Forest Hill Road is inundated by frequent flood events while Laidley Plainland Road is only impacted by larger flood events.

Grandchester Mount Mort Road crosses Western Creek in Grandchester. To the south of Western Creek, the road is low-level and is inundated by overbank flow during frequent flood events.

Waters Road runs parallel to the QR West Moreton System rail corridor as it nears Calvert. This road is low-level and is inundated during frequent flood events.

The Project alignment connects into the QR West Moreton System rail corridor at Calvert. The QR West Moreton System rail corridor crosses Lockyer Creek, Sandy Creek (adjacent to Forest Hill), Laidley Creek and Western Creek. The QR West Moreton System rail corridor runs parallel to Western Creek and crosses Western Creek in multiple locations through existing cross drainage structures under the QR West Moreton System rail corridor. Historically the QR West Moreton System rail corridor has overtopped at several locations during flood events on both Western Creek and Lockyer Creek floodplain.

4 Design requirements, standards and guidelines

4.1 Hydraulic design criteria

Table 4.1 outlines the hydraulic design criteria that have guided the Project design. Detailed hydrologic and hydraulic modelling has been undertaken to meet these design criteria with a series of iterations undertaken to incorporate design refinement and stakeholder and community feedback. The resulting design outcomes relative to these design criteria are detailed in Section 9.

Table 4.1 Project hydraulic design criteria

Performance criteria	Requirement
Flood immunity	Rail line – 1% AEP flood immunity with 300 millimetre (mm) freeboard to formation level. Tunnel portals – 1 in 10,000 AEP event flood immunity.
Hydraulic analysis and design	Hydrologic and hydraulic analysis and design to be undertaken based on ARR 2016 and State/local government guidelines. ARR 2016 interim climate change guidelines are to be applied with an increase in rainfall intensity to be considered. No sea level change consideration required due to location outside tidal zone. ARR 2016 blockage assessment guidelines are to be applied.
Scour protection of structures	All bridges and culverts will be designed to reduce the risk of scour with events up to 1% AEP event considered. Mitigation to be achieved through providing appropriate scour protection or energy dissipation or by changing the drainage structure design.
Structural design	1 in 2,000 AEP event to be modelled for bridge design purposes.
Extreme events	Damage resulting from overtopping to be minimised.
Flood flow distribution	Locate structures to ensure efficient conveyance and spread of floodwaters.
Sensitivity testing	Consider climate change and blockage in accordance with ARR 2016. Understand risks posed and Project design sensitivity to climate change and blockage of structures.

4.2 Flood impact objectives

The potential impact of the Project on existing flood regime was quantified and compared against flood impact objectives as detailed in Table 4.2. These objectives address the requirements of the Terms of Reference (ToR) and have been used to guide the Project design. Acceptable impacts will ultimately be determined on a case by case basis with stakeholders/landholders interaction through the community engagement process using these objectives as guidance. The resulting design outcomes relative to these flood impact objectives are detailed in Section 9.

Table 4.2 Flood impact objectives

Parameter	Objectives				
Change in peak water levels[1]	Existing habitable and/or commercial and industrial buildings/premises (e.g. dwellings, schools, hospitals, shops)	Residential or commercial/industrial properties/lots where flooding does not impact dwellings/ buildings (e.g. yards, gardens)	Existing non-habitable structures (e.g. agricultural sheds, pump-houses)	Roadways	Agricultural and grazing land/forest areas and other non-agricultural land
	≤ 10 mm	≤ 50 mm	≤ 100 mm	≤ 100 mm	≤ 200 mm with localised areas up to 400 mm

Parameter	Objectives
	Changes in peak water levels are to be assessed against the above proposed limits. It is noted that changes in peak water levels can have varying impacts upon different infrastructure/land and flood impact objectives were developed to consider the flood sensitive receptors in the vicinity of the Project. It should be noted that in many locations the presence of existing buildings or infrastructure limits the change in peak water levels.
Change in duration of inundation[1]	Identify changes to time of inundation through determination of time of submergence (ToS). For roads, determine Annual Average Time of Submergence (AATOS) (if applicable) and consider impacts on accessibility during flood events. Justify acceptability of changes through assessment of risk with a focus on land-use and flood sensitive receptors.
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Velocities[1]	Maintain existing velocities where practical. Identify changes to velocities and impacts on external properties. Determine appropriate scour mitigation measures taking into account existing soil conditions. Justify acceptability of changes through assessment of risk with a focus on land-use and flood sensitive receptors.
Extreme event risk management	Consider risks posed to neighbouring properties for events larger than the 1% AEP event to ensure no unexpected or unacceptable impacts.
Sensitivity testing	Consider risks posed climate change and blockage in accordance with ARR 2016. Undertake assessment of impacts associated with Project alignment for both scenarios.

Table note:

1 These flood impact objectives apply for events up to and including the 1% AEP event

4.3 Project nomenclature for design events

The flood analysis adopts the latest approach to design flood terminology as detailed in ARR 2016.

Accordingly, all design events are quoted in terms of AEP using percentage probability. An extract of Figure 1.2.1 from Book 1 (shown in Table 4.3) details the relationship between Average Recurrence Interval (ARI) and AEP for a range of design events.

Table 4.3 Event nomenclature

Exceedances per year (EY)	AEP (%)	AEP (1 in x)	ARI
0.22	**20.00**	5	4.48
0.20	18.13	5.52	5.00
0.11	**10.00**	10	9.49
0.05	**5.00**	20	20
0.02	**2.00**	50	50
0.01	**1.00**	100	100
0.005	0.50	200	200
0.002	0.20	500	500
0.0005	0.05	**2,000**	2,000
0.0001	0.01	**10,000**	10,000

Source: ARR (2016)

Table note:

Values **bolded** adopted in simulation design events

In line with ARR 2016 recommendations, the following terminology has been adopted for the simulated design events:

- 20% AEP
- 10% AEP
- 5% AEP
- 2% AEP
- 1% AEP
- 1 in 2,000 AEP
- 1 in 10,000 AEP
- PMF.

4.4 Relevant standards and guidelines

The design standards applicable for the hydrologic and hydraulic analysis are listed below:

- AS7637:2014: Railway Infrastructure – Hydrology and Hydraulics
- Austroads (2013). Guide to Road Design Part 5: Drainage – General and Hydrology Considerations, Sydney
- Commonwealth of Australia. (2016). Australian Rainfall and Runoff: A Guide to Flood Estimation. Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors)
- Evaluating Scour at Bridges, Hydraulic Engineering Circular Number 18 (HEC-18), Fourth Edition, US Department of Transport – Federal Highway Administration, Virginia, USA, Richardson, EV and Davis, SR: 2001
- Hydraulic Design of Energy Dissipaters for Culverts and Channels, Hydraulic Engineering Circular Number 14 (HEC-14), Third Edition US Department of Transport – Federal Highway Administration, Virginia, USA, Thompson, PL & Kilgore, RT; 2006
- Department of Transport and Main Roads (2013) Bridge Scour Manual http://www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Bridge-scour-manual.

5 Data collection and review

Available background information including existing hydrologic and hydraulic models, survey, streamflow data, available calibration information and anecdotal flood data has been gathered. Data was sourced from a wide range of stakeholders including:

- Local government areas including LVRC and Ipswich City Council (ICC)
- The Bureau of Meteorology (BoM) – rainfall and stream gauging data
- Department of Regional Development, Manufacturing, and Water (DRDMW (formerly Department of Natural Resources, Manufacturing, and Energy (DNRME)) – stream gauging data
- QR – existing infrastructure details
- Queensland Reconstruction Authority – Brisbane River Catchment Flood Study (BRCFS).

The following sections detail the existing information sourced and reviewed for the hydrologic and hydraulic assessment.

5.1 Previous studies

A number of previous hydrology and hydraulic studies were sourced as part of this study. A review of each study was undertaken to determine suitability for use on the Project as documented in the following sections.

5.1.1 Lockyer catchment

5.1.1.1 Brisbane River Catchment Flood Study Hydrology Phase Final Report, Aurecon (2015)

This report covers a study area which covers the entire Brisbane River Catchment, more specifically, the modelling includes Lockyer Creek and the Bremer River and its Western Creek tributary catchments. Hydrologic models were developed and calibrated against a range of historical flood events and these models were used to determine design flood estimates. Key aspects of the hydrologic component of the study included:

- Review and update of stream gauge flow ratings
- Recalibration of the Brisbane River hydrologic models developed by Seqwater in 2013
- Estimate of stream flows and volumes using hydrologic/rainfall-based methods (Design Event approach in accordance with ARR (1987) and Monte-Carlo Simulation)
- Flood frequency analysis at key stream gauge locations throughout the catchment
- Reconciliation of flows predicted by the different methods to produce design flow estimates to be adopted for the Brisbane River catchment.

Key review findings were:

- The hydrologic model has been well calibrated against a range of recent flood events including the 1974, 1996, 1999, 2011 and 2013 flood events
- The hydrologic models needed to be modified to produce flow estimates at the location of the Project
- The resulting hydrologic models needed to be updated to be compliant with the hydraulic design requirements (refer Section 4.1).

5.1.1.2 Lockyer Valley Flood Model Update Stage 2, Jacobs (2016)

The Stage 2 Lockyer Valley Flood Model Study incorporated amendments to the original Lockyer Valley flood model which was originally developed for LVRC for the purposes of development control and assessment of flood mitigation options.

Key review findings were:

- The hydrologic model was well calibrated against a range of recent flood events and the hydraulic model was also been calibrated to the January 2011 and January 2013 flood events. It should be noted that this is not the BRCFS (Aurecon 2015) URBS Hydrology model.
- The resulting hydrologic model was considered to be non-compliant with the design requirements as it did not fully follow ARR 2016 guidelines. The key aspect of the application of the design flood hydrology in the Jacobs (2016) study that could be questioned is the use of temporal patterns derived from ARR 1987. Two additional events (20% and 5% AEP) would need to be simulated for this model to satisfy the hydraulic design requirements.

5.1.1.3 The Big Flood: Will It Happen Again, Final Report, The Big Flood Project team (2016)

The Big Flood study aimed to enhance historical flood records with non-stream gauge data sources (e.g. paleoflood data) while developing an understanding of channel and floodplain geomorphic flood risks throughout Lockyer Valley to better manage and predict future floods and associated impacts.

Key review findings were:

- Information on hydrologic models for Lockyer Creek or their calibration against recorded events including the recent 2011 and 2013 floods were not detailed
- Information on hydraulic models for Lockyer Creek or their calibration against recorded events including the recent 2011 and 2013 floods were not detailed.

5.1.2 Western Creek

5.1.2.1 Brisbane River Catchment Flood Study Hydrology Phase Final Report, Aurecon (2015)

This report covers a study area which includes the entire Brisbane River Catchment, more specifically, the model includes the Bremer River and its Western Creek tributary sub-catchments. Hydrologic models of each of these sub-catchments were developed and calibrated against a range of recent flood events and these models were used to determine design flood estimates. Key aspects of the hydrologic component of the study included:

- Review and update of stream gauge flow ratings
- Recalibration of the existing Brisbane River hydrologic models
- Estimate of stream flows and volumes using hydrologic/rainfall-based methods (Design Event approach in accordance with ARR (1987) and Monte-Carlo Simulation)
- Flood frequency analysis at key stream gauge locations throughout the catchment
- Reconciliation of flows predicted by the different methods to produce design flow estimates to be adopted for the Brisbane River catchment.

Key review findings were:

- The hydrologic model was well calibrated against a range of recent flood events including the 1974, 1996, 1999, 2011 and 2013 flood events

- The hydrologic models would need to be modified to produce estimates at the location of the Project
- The resulting hydrologic models would need to be updated to be compliant with the hydraulic design requirements (refer Section 4.1).

5.1.2.2 Bremer River Flood Study, BMT (draft provided in early 2020)

ICC commissioned BMT to undertake a joint hydrologic and hydraulic calibration of the entire Bremer River catchment. This modelling covers Western Creek, Bremer River, Warrill Creek and Purga Creek. The ICC study was in progress at the time of this current investigation with no reporting available until a draft report was issued in early 2020. This was after finalisation of the modelling for the Project alignment.

ICC advised that the hydrologic assessment for the study was undertaken using the BRCFS URBS hydrologic model with a TUFLOW hydraulic model developed for the hydraulic assessment. ICC provided the material files that were to be used in the TUFLOW hydraulic model for the ICC study.

As part of the Detailed Design stage, the hydrologic and hydraulic modelling for Western Creek, Bremer River, Warrill Creek and Purga Creek will be reviewed and updated to consider the current Ipswich City Council hydrologic and hydraulic modelling completed in early 2020.

5.1.2.3 Western Creek, Engeny (2014)

This report covers the Project alignment that runs parallel to Western Creek. From the summary report provided it is unclear what hydrologic and hydraulic software has been used. The hydraulic modelling appears to have been undertaken in a 2D modelling software. The model has been calibrated to the 2011 historical event, but the calibration methodology was not outlined in the report.

5.1.2.4 Ipswich Flood Studies, Phase 3 Final Report, Halliburton, KBR (2002)

This report covers the Bremer River, Western Creek, Franklyn Vale Creek and Purga Creek and involved both the development and calibration of hydrologic models and 1D hydraulic models of these catchments. The study is however based upon design flood hydrology inputs derived from ARR (1987) and so therefore the design flood estimates are not consistent with ARR 2016.

Key review findings were the:

- Hydrologic model was calibrated against a range of historical flood events
- Hydrologic models would need to be modified to produce estimates at the location of the proposed Project alignment
- Study would need to be updated to include an assessment of the 1 in 2,000 and 1 in 10,000 AEP events to satisfy the hydraulic design requirements (Section 4.1)
- Hydrologic models are considered to be non-compliant with the design requirements and as a consequence the design flood hydrology would need to be completely revised
- Hydraulic models are 1D and not appropriate for this assessment.

5.1.2.5 SFRC Study – Draft Impact Assessment Report – Technical Paper 4, Revision A Maunsell (2008)

This report covers the alignment of the proposed Southern Freight Rail Corridor and includes the Bremer River and Western Creek catchments. The study involved the development of both hydrologic and 1D hydraulic models which were calibrated to historical flood events, principally January 1974. The design flood hydrology was based upon ARR 1987 and so design flood estimates are not consistent with ARR 2016. Key review findings were the:

- Hydrologic and hydraulic models have been calibrated against a range of historic flood events, but would need to be updated to include the January 2011 and January 2013 flood events

- Hydrologic and hydraulic models would need to be modified to produce flow estimates at the location of the proposed Project alignment
- Study only investigated the 1% AEP event and would need to be revised to cover the full range of events specified in the Design requirements
- Resulting hydrologic models are considered to be non-compliant with the hydraulic design criteria and as a consequence the design flood hydrology would need to be completely revised.

Full details of the adopted hydrologic and hydraulic models and updates/refinements carried out are provided in Section 6.

5.2 Survey data

ARTC provided LiDAR data from 2015 as 1 m grid DEM tiles. Using GIS software, a Digital Elevation Model (DEM) was generated with a 1 m grid resolution for use in the Project based on the 2015 dataset. This was used for modelling within the disturbance footprint and up to the full extent of the 2015 LiDAR where relevant.

Additional LiDAR data was required to appropriately model downstream boundary conditions and facilitate calibration against stream flow gauges. In areas that were not covered by the LiDAR provided by ARTC, LiDAR tiles were sourced from Geoscience Australia. The DEM datasets utilised for modelling were based on surveys flown between 2009 and 2015, with preference given to the most recent data available.

Survey of general culvert arrangements along the QR West Moreton System rail corridor has been incorporated into the hydraulic model. It is proposed that in the next stage of design this information will be reviewed to ensure current existing catchment conditions are modelled.

5.3 Aerial imagery

Aerial imagery of the study area was provided by ARTC and was used to identify and confirm topographic and vegetative characteristics of the catchment areas. Aerial imagery captured in 2015 was provided. Additional imagery outside the study area was sourced from QGIS imagery in an open source format.

5.4 Existing drainage structure data

Drainage structure geometry information was obtained from the following sources:

- Previous studies
- Site inspection
- QR As-Constructed Drawings – sourced for culvert sizes along the existing QR West Moreton System rail corridor where no other information was available.

Details of existing drainage structures and sources are outlined in Section 6.

5.5 Stream gauges

Stream gauges are used to provide a record of observed stream levels. These were originally manually recorded staff levels (typically recorded on a daily basis with more frequent records during flood events) with modern gauges providing a continuous automated record.

Although levels may be adequate for flood warning services, hydrologic investigations are usually more interested in streamflow. A rating curve is required to convert recorded levels into an equivalent stream discharge. The most reliable source of data for deriving a rating curve are actual instream flow measurements taken during flood events. These are often difficult/dangerous to obtain during major flood events unless the gauge site is located near an appropriate structure spanning the waterway (e.g. a high-level bridge), and so are often only available for low to moderate flows. The rating must therefore be extrapolated to higher flows. This is often based on simple power-law best fit through the available data, however ideally the extrapolation is based on more reliable means, such as a hydraulic model calibrated to the reliable part of the rating curve.

Other factors can also influence the short- and long-term reliability of the rating curve. Changes to channel bed or roughness, either long-term or during a flood event, can change the hydraulic properties and hence the rating curve. Gauges are preferably located at a hydraulic control, either natural or artificial, (e.g. a weir), or where the bed material has low erodibility. The gauge location may also not produce a singular relationship between flow and level. This may occur in areas where there is significant floodplain storage, and hence the level is dependent on the duration and rate of change of the flow, or the gauge location may be affected by backwater from a downstream tributary.

During the BRCFS, a review and update of available gauge rating curves was undertaken throughout the Brisbane River catchment to identify reliable gauge sites and, where possible, improve the confidence in the gauge rating curve. This included independent hydraulic modelling at a number of key gauge locations. A summary of BRCFS reviewed stream gauge ratings assessed for the Project is provided in the following sections. The relevant stream gauge locations are presented in Appendix A Figure A-1B and Appendix B Figure B-1B respectively.

5.5.1 Lockyer Creek

Although there are several stream gauges located throughout the Lockyer Creek catchment, including long-term records at Gatton and Helidon, the majority of these sites are not considered to be particularly reliable. The primary gauge location used in the BRCFS was at Glenore Grove. This is not an ideal gauge site, being located near the confluence of Lockyer and Laidley Creeks, however it is the most downstream location where a relatively consistent relationship between water level and flow can be obtained. Downstream of Glenore Grove the perched banks of the Lockyer Creek main channel enable the channel and floodplain to have different and independent flood levels.

The Glenore Grove rating curve was derived during the BRCFS using a hydraulic model of the confluence area, calibrated against recorded levels and in-stream flow measurements recorded downstream at Lyons Bridge. Flow distribution issues affecting the gauge site are highlighted in Figure 5.1. Laidley Creek bifurcates at the confluence with Lockyer Creek, with flows able to combine both upstream and downstream of the Glenore Grove gauge site. Gauge levels however are dependent primarily on water levels generated by the combined flows in the channel downstream of the confluence, and sensitivity testing using different flow splits between Lockyer and Laidley Creeks confirmed that the gauge is relatively independent of the source of the flows. During larger events, flow breaks out of both Lockyer and Laidley Creeks, including areas upstream of the gauge site, and spills into the lower Lockyer floodplain. However, the breakout is a function of the capacity of the creek channel in the vicinity of the gauge. Thus, although only a proportion of the flow actually passes the gauge site, the gauge level still exhibits a response that can be related to the total creek flow. The rating curve is therefore considered to provide a reasonable estimate of the combined Lockyer and Laidley Creek flow, but it is very sensitive to changes in level at high flows; small changes (or errors) in water level potentially represent large changes in flow.

Figure 5.1 Flow patterns around the Glenore Grove gauge site for low and high flows

Three stream gauges are located downstream of Glenore Grove; at Lyons Bridge; Rifle Range Road; and O'Reilly's Weir. O'Reilly's Weir is near the confluence with the Brisbane River and is strongly influenced by backwater during Brisbane River floods. The BRCFS did not investigate this site in any detail, (since it was interested primarily in Brisbane River flood events). The other two gauges have reliable ratings based on numerous instream flow measurements, but due to the perched nature of the lower Lockyer Creek channel can only reliably record in-stream flows. Significant flows can bypass the gauge locations at Lyons Bridge and Rifle Range Road without being registered by the stream gauges.

The most reliable rating in the Lockyer Creek catchment in terms of flow measurement is located on Laidley Creek at the Warrego Highway. This site has stream flow measurements up to 985 cubic metres per second (m^3/s), which is over 70 per cent of the highest recorded flow (this is a very high ratio for most stream gauges). Unfortunately, Laidley Creek represents only 16 per cent of the overall Lockyer Creek catchment and the gauge site is potentially affected by backwater from Lockyer Creek.

Two stream gauges are located in relatively close proximity in the Gatton area. The flood warning gauge operated by the BoM at Gatton has isolated flood peak records dating as far back as 1893. Although it appears to be a reasonable location, with large flows well contained within the main channel, the site has no official rating and no at-site flow measurements. A rating for the gauge was derived from hydraulic modelling conducted by SKM in 2013 as part of the '*Lockyer Creek Flood Study*', however the flows used to calibrate this model (and hence derive the rating) are not necessarily consistent with the BRCFS. Since 2000, Seqwater has operated a gauge further upstream at Gatton Weir, although there is limited information available at this site due to the short period of operation.

DNRME has historically operated three separate stream gauges in the upper Lockyer Creek catchment at Helidon, located at different sites, but with some period of overlap. Although the combined records extend back to 1926, review of the data identified issues with the gauge data availability and consistency:

- Helidon No.1 (1926-1971) has only minor flow gauging and exhibits a number of minor drifts in datum
- Helidon No.2 has the highest flow gauging but both level record and flow measurements indicate that a significant datum shift occurred in 1976
- Helidon No.3 (1987-) has limited flow gauging (up to 3.4 m and 110 m^3/s).

The Helidon stream gauge is noteworthy for its record of the 2011 flood event. The gauge record identifies a peak level of 14 m gauge height, nearly double the highest level recorded in the previous 86 years of records. This corresponds to a flow of over 3,000 m^3/s based on extrapolation of the rating curve, 3.4 times larger than the next largest flood. Since the gauge failed during the 2011 flood with the last reliable level of ~11 m, and the projected peak water level is so far above the level to which the rating curve can be confidently be extrapolated from the flow measurement data, the exact magnitude and probability of the flood is subject to significant uncertainty.

5.5.2 Western Creek (Bremer River)

The primary stream gauge for calibration of the Bremer River sub-model is located at Walloon. The site has a long historical record and over 150 recorded flow measurements, although the majority are for low discharges. The maximum recorded gauging is 835 m^3/s. The rating was confirmed and extended during the BRCFS using a calibrated hydraulic model. The rating is derived for local Bremer River tributary flows. However, review of Brisbane River hydraulic flood modelling undertaken by Brisbane City Council identified that the gauge location is potentially affected by backwater during major Brisbane River flood events.

BoM flood warning gauges are located upstream of Walloon at Five Mile Bridge and Rosewood. The Rosewood gauge has a significantly longer flood record than Walloon, (dating back to 1922 as compared to 1962). These gauges have no rating curves or recorded flow data and therefore provide only level data, making them of limited use for hydrologic assessment. The gauge levels can be correlated to those at Walloon, and a rating curve was derived for the Rosewood gauge during the BRCFS but is considered to have a lower reliability than the Walloon gauge.

The DNRME gauge at Adams Bridge in the upper Bremer River catchment has a relatively reliable rating but captures only 20 per cent of the catchment.

A number of other gauges throughout the catchment also provided limited information. On Western Creek, BoM has flood warning gauges at Rosewood Wastewater Treatment Plant (WWTP) upstream of the confluence with Bremer River, and further upstream at Kuss Road (although this gauge failed to register the 2011 flood). DNRME also operates a stream gauge at Kuss Road, although it has only been operational since September 2011.

5.5.3 Gauge summary

A list of gauges used as part of this assessment, detailed in Section 6, is presented in Table 5.1.

Table 5.1 Stream gauges utilised for assessment

Gauge number	Gauge name	Gauge owner	Usage
143807	Lockyer Creek at Glenore Grove	BoM	Primary stream gauge for calibration
143904	Lockyer Creek at Gatton	BoM	Secondary stream gauge for calibration
143229a	Laidley Creek at Warrego Hwy	DNRME	Secondary stream gauge for calibration
143107a	Bremer River at Walloon	DNRME	Primary stream gauge for calibration
143909	Western Creek at Rosewood WWTP	BoM	Secondary stream gauge for calibration
143121A	Western Creek at Kuss Road	DNRME	Secondary stream gauge for calibration

5.6 Rainfall data

Rainfall data for all historical events modelled was embedded within the previous BRCFS and LVRC hydrologic models. The embedded historical rainfall data was adopted for this assessment.

Design rainfall data for the Existing Case and Developed Case modelling is outlined in Section 8.1.2.

5.7 Anecdotal flood data

Anecdotal flood data for the historical flood events has been collected from many sources including:

- Previous studies
- Local councils
- Landholders and stakeholders.

Anecdotal data includes information obtained from a wide range of sources and as such it is of varying levels of accuracy and reliability. The anecdotal data has been used to assess of the performance of the hydraulic model to replicate historical flood conditions.

5.8 Site inspection

A site inspection was undertaken during February 2018. During the site inspection, all proposed major waterway crossings were inspected with photographs taken and details recorded of the crossing, existing drainage structures and surrounding catchment and waterway environment. An assessment of the relative roughness and blockage potential was undertaken during the site inspection. The site visit confirmed that the catchment conditions were consistent with the LiDAR and aerial imagery provided.

5.9 Queensland Rail infrastructure

Existing QR West Moreton System rail corridor infrastructure between Helidon to Laidley is included in the Lockyer Creek hydraulic model and from Grandchester to Calvert in the Western Creek (Bremer River) hydraulic model.

Anecdotally, the QR West Moreton System rail corridor has overtopped at locations around Sandy Creek (adjacent to Forest Hill), Laidley Creek and Western Creek during historical flood events. Commentary around QR West Moreton System rail corridor overtopping under Existing Case design event modelling is presented in Section 8.2.4.

6 Development of models

6.1 Summary

A summary of the modelling approach for each catchment is listed Table 6.1. Validation with historical data was undertaken where available and sensitivity checks were undertaken to test assumptions. The development of these models is outlined in the sections below.

Table 6.1 Hydrologic and hydraulics modelling approach summary

Catchment	Hydrologic modelling approach	Hydraulic modelling approach
Lockyer Creek	Adopted the BRCFS URBS hydrology and updated to be ARR 2016 compliant.	Adopted LVRC TUFLOW model of Lockyer Creek (including Laidley Creek) and updated to run with TUFLOW's HPC solution scheme. Some structures along the existing QR West Moreton System rail corridor updated based on As-Built drawings.
Bremer River	Adopted the BRCFS URBS hydrology and updated to be ARR 2016 compliant.	Created a TUFLOW model of Western Creek (including Bremer River) using data from the Bremer River study (BMT, Current)

6.2 Hydrologic models

For the Lockyer Creek, and Western Creek, the hydrologic modelling from the BRCFS (Aurecon 2015) has been adopted. This modelling was considered to be the most robust and up-to-date and had been recently accepted by LVRC and ICC.

The BRCFS undertook a detailed hydrologic assessment of the Brisbane River catchment, followed by hydraulic modelling of the Brisbane River (downstream of Wivenhoe Dam) and lower tributaries. Hydrologic modelling for the BRCFS was undertaken using the URBS software package. The hydrologic models were originally developed by Seqwater but were reviewed and revised as part of the BRCFS in response to changes to the gauge ratings and (preliminary) hydraulic modelling of the lower Brisbane River undertaken by Brisbane City Council. Initial development of the models is reported in '*Brisbane River Flood Hydrology Models*' (Seqwater, December 2013).

The Brisbane River hydrologic model configuration separates the catchment into seven separate sub-models – the Upper Brisbane (upstream of Wivenhoe), its major tributary Stanley River (upstream of Somerset Dam), the Lower Brisbane, Lockyer Creek, the Bremer River and two of its tributaries, Warrill Creek and Purga Creek, which join upstream of Ipswich. Two of these hydrologic sub-models have been used for the current investigation. Minor modifications were made to the hydrologic models in order to produce flow estimates at locations of interest along the Project alignment.

6.3 Lockyer Creek hydraulic model

6.3.1 Model setup and resolution

The LVRC hydraulic model previously updated by Jacobs (2016) and provided to Aurecon was a TUFLOW nested-grid model. The nested grid model contained eight separate sub-model areas with varying degrees of terrain resolution; ranging from 40 m to 5 m. This model was converted into a single-area model and a comparison between the terrain resolutions is presented in Table 6.2.

It is noted that while this approach increases model resolution around the majority of the alignment and at the streamflow gauges utilised in this assessment, a slight reduction occurs around Forest Hill. However, although absolute model resolution for Forest Hill has been slightly reduced (e.g. modelling of small local-scale drains designed for local runoff may not be possible on grids >5 m), the adopted 10 m resolution is considered sufficient for a regional-scale flood model to represent key infrastructure crest levels (e.g. roads, the Project alignment, bridges) at locations where the Project alignment runs parallel to the existing QR West Moreton System rail corridor or local roads. Elements such as rail and road crest levels, floodplain storage lost due to the proposed Project alignment, and drains are all representable with a 10 m grid size and delivered acceptable model run times.

Table 6.2 Lockyer Creek hydraulic model areas and terrain resolutions

Previous model area	LVRC model resolution (m)	Adopted model resolution (m)
Upper Lockyer Creek: Withcott to Gatton	20	10
Upper Lockyer Creek: Gatton to Lake Clarendon	20	10
Laidley Creek and Sandy Creek surrounding Forest Hill	20	10
Laidley Creek North	10	10
Laidley Creek South	20	10
Lower Lockyer Creek	40	10
Forest Hill Township	5	10

Along with the consistent model resolution, the hydraulic model was changed to run with the TUFLOW HPC software. The hydraulic model has been reviewed for stability. The cumulative mass error is recorded as 0 per cent from the model log, indicating the model is not gaining or losing water through the simulation. The water levels and flows have been plotted for culverts (one dimensional structures) to check for any peak instabilities that may affect the results. The hydraulic mode was determined appropriate for use. The TUFLOW HPC model and the TUFLOW nested-grid model and were compared around the Project disturbance footprint and determined to be sufficiently consistent. The adopted hydraulic model layout is presented in Appendix A Figure A-1C.

6.3.2 Hydraulic structures

All hydraulic structures were maintained from the LVRC base model (Jacobs 2016) except for an Existing Case culvert around Ch 49.56 km. The QR As-Built drawings indicated this drainage structure is actually a bridge and this structure was changed accordingly. The existing structure sizes were confirmed using provided survey information. Hydraulic structures were modelled as outlined in Table 6.3.

Table 6.3 Model representation of hydraulic structures – Lockyer Creek

Hydraulic structure	Model representation
Culvert	1-Dimensional structure
Bridges	2-Dimensional layered flow constriction
Longitudinal drainage	2-Dimensional channels

6.3.3 Boundary conditions

The BRCFS URBS model outputs were applied as inflows into the TUFLOW model. Total inflows from catchments upstream of the hydraulic model extents were applied at the upstream model boundary and local inflows from areas within the TUFLOW model were applied throughout the model.

The TUFLOW hydraulic model covers a significant proportion of the middle of the Lockyer Creek catchment. It uses inflows taken from the URBS hydrologic model as both total channel flows at creek inflows at the hydraulic model boundary and local sub-catchment flows at points within the model boundary. Initial comparisons of the URBS hydrologic routing and TUFLOW hydraulic routing identified that the TUFLOW flows tended to lag the URBS flows. This trend was also identified in the Jacobs (2016) study. The sub-catchment hydrographs that are input into TUFLOW include attenuation and lag due to local catchment storage routing from URBS. Because a real catchment does not have a distinct interface between sub-catchment and main-stream routing, this carries the risk of double-counting storage in the lower sub-catchment tributaries. It was found that reducing the sub-catchment lag parameter, β, improved the match between the two models. Note that this modification is applied to the inflows within the TUFLOW model domain, not the calibrated URBS model. Table 6.4 shows the adopted lag parameters for hydraulic model inflows.

Table 6.4 Adopted catchment routing lag parameters for the Lockyer Creek hydraulic model

Hydraulic model inflow location	Adopted routing lag parameter (β)
Hydraulic model boundary	3.1
Sub-catchments within hydraulic model	1.5

A normal depth boundary condition was applied at the downstream boundary. It was confirmed the downstream boundary is sufficiently downstream as to not influence flow conditions at the Project alignment.

6.4 Western Creek hydraulic model

6.4.1 Model setup

Several hydraulic models of the BRCFS catchments have previously been developed as outlined in Section 5.1. These models generally either do not cover the area affected by the Project alignment or do not have sufficient detail in the required area along the Project alignment. Therefore, for the current investigation a new TUFLOW hydraulic model was developed based on topographic information provided by ARTC. The topography is represented in the hydraulic model using a 10 m grid size. Elements such as rail and road crest levels, floodplain storage lost due to the Project alignment, and drains are all representable with a 10 m grid size.

This grid size was also selected to allow sufficient detail for the channel and floodplain representation within the hydraulic model whilst maintaining reasonable model run times. The hydraulic model was extended to include the Bremer River to account for backflow. The hydraulic model has been reviewed for stability. The cumulative mass error is recorded as 0 per cent from the model log, indicating the model is not gaining or losing water through the simulation. The water levels and flows have been plotted for culverts (one dimensional structures) to check for any peak instabilities that may affect the results. The extent of the hydraulic model is presented in Appendix B Figure B-1C.

6.4.2 Hydraulic structures

Only limited information for existing bridges and cross drainage structures was available at the start of the Project. Along the QR West Moreton System rail corridor, As-Constructed drawings were used to provide culvert details. Additional structure data was also provided by ICC. The following simplified assumptions have been made regarding existing bridge structures:

- The bridge deck (i.e. Top of formation level – ToF) is assumed to have the same elevation as the adjacent rail level
- A flow constriction factor of 20 per cent has been assumed to allow for pier losses.

Upon receipt of field survey data, the details of existing culverts were incorporated into the hydraulic model.

6.4.3 Boundary conditions

The BRCFS URBS model outputs were applied as inflows into the TUFLOW model. Total inflows from catchments upstream of the hydraulic model extents were applied at the upstream model boundary and local inflows from areas within the TUFLOW model were applied throughout the model.

The TUFLOW hydraulic model covers a significant proportion of the Western Creek catchment; inclusive of Bremer River sections. It uses inflows taken from the URBS hydrologic model as both total channel flows at creek inflows at the hydraulic model boundary and local sub-catchment flows at points within the model boundary. As with the Lockyer model, initial comparisons of the URBS hydrologic routing and TUFLOW hydraulic routing identified that the TUFLOW flows tended to lag the URBS flows. The sub-catchment hydrographs that are input into TUFLOW include attenuation and lag due to local catchment storage routing from URBS. Because a real catchment does not have a distinct interface between sub-catchment and main-stream routing, this carries the risk of double-counting storage in the lower sub-catchment tributaries. It was found that reducing the sub-catchment lag parameter, β, improved the match between the two models. Note that this modification is applied to the inflows within the TUFLOW model domain, not the calibrated URBS model. Table 6.5 shows the adopted lag parameters for hydraulic model inflows.

Table 6.5 Adopted catchment routing lag parameters for the Western Creek/Bremer River hydraulic model

Hydraulic model inflow location	Adopted routing lag parameter (β)
Hydraulic model boundary	2.8
Sub-catchments within hydraulic model	1.5

A normal depth boundary condition was applied at the downstream boundary. It was confirmed the downstream boundary is sufficiently downstream as to not influence flow conditions at the Project alignment.

6.5 Implementation of baseflow

Baseflow in URBS is estimated using an empirical power-law equation. Baseflow parameters for each model were estimated as part of the hydrologic model calibration process. The baseflow is not routed through the hydrologic model, but rather is calculated at a specific location of interest and then added to the routed flow at that location. The assumed baseflow at a location is therefore not the sum of the baseflow from the upstream sub-catchments routed through the model. This makes it difficult to achieve exact equivalence of the hydrologic model (empirical baseflow at a point location) and hydraulic model (flow at a point is cumulative routing of upstream inflows).

For the historical calibration events, baseflow has been estimated using the URBS model at each of the major tributary inflows and included in the inflows. The baseflow from the boundary inflows is routed through the hydraulic model and may therefore affect slightly the attenuation of the combined flows. URBS does not calculate baseflow contribution from the local sub-catchments, these are therefore not included in the hydraulic model. Overall, baseflow represents a relatively small component of the peak flow (e.g. typically less than 2 per cent). Since the focus of the calibration is to confirm the hydraulic model routing and level-flow relationships rather than match an exact flow, these minor differences will have no impact on the outcome of the hydraulic model calibration.

6.6 Model review

The Lockyer Creek and Western Creek hydrologic and hydraulic models have been reviewed. The cumulative mass error is recorded as 0 per cent from the model log, indicating the model is not gaining or losing water through the simulation. Water levels and flows have been checked at culverts (one dimensional structures) to identify significant peak instabilities that may affect the results. No structures in the hydraulic models are demonstrating instabilities that may significantly impact peak water levels and flows were identified.

7 Joint calibration

7.1 Introduction

The hydraulic models developed generally cover the mid to lower portion of the hydrologic models. Routing and attenuation of the hydrologic model is therefore partially replicated within the hydraulic model. The hydraulic model inflows therefore consist of total reach flows where the hydraulic model boundary intersects any major tributary (more than one upstream catchment) and local sub-catchment flows where the catchment centroid lies inside the hydraulic model boundary.

Hydrologic models are based on simplistic empirical runoff routing equations using coefficients determined primarily by calibration to a specific point of interest. By contrast, hydraulic models are more physically based, providing a (relatively) realistic representation of the catchment geometry and solving equations of motion within the model domain. Some differences between the hydrologic and hydraulic routing must realistically be expected. Nevertheless, the hydraulic model should closely replicate the flow characteristics (attenuation, timing) that in the hydrologic model have been validated by calibration to historical flood events.

The hydraulic model must also produce flood levels consistent with the flows. This can be confirmed by comparison with flood levels recorded during historical flood events, although the reliability is dependent upon the accuracy of the modelled flows, which are in turn dependent on the accuracy of the recorded rainfall. Further validation across a wide range of flows can be achieved by comparison of the modelled level-flow relationships at the stream gauge sites with the gauge ratings, which allows the level-flow relationship to be confirmed without necessarily having to exactly match a specific flow.

7.2 Historical events

The TUFLOW hydraulic models have been validated using the five historical events used for calibration of the hydrologic and hydraulic models (1974, 1996, 1999, 2011 and 2013). The primary objectives of the assessment have been:

- To confirm model roughness factors required to match level-flow relationships at the stream gauges, particularly those where the ratings are well defined by in-stream flow measurements
- To confirm that the flood routing through the TUFLOW model reasonably matches the hydrologic model (TUFLOW physically represents storage and other catchment characteristics that are represented in URBS by empirical coefficients) and that the adopted roughness parameters do not adversely affect the timing or attenuation of the flood routing.

The historical events were selected for the range of magnitudes and duration. A brief summary of each event is outlined in the following sections.

7.2.1 January 1974

January 1974 was a major flood event that affected much of the Brisbane River, typified by a single flood peak of similar magnitude and duration to the major peak of the 2011 flood in much of the mid- and lower Lockyer catchment, but without the preceding flash floods in the upper catchment (see discussion below). The 1974 flood remains the largest recorded in the Bremer River catchment, including the largest historical Brisbane River floods of 1893. Key points to note are:

- The duration of peak inundation extent was approximately 8 to 15 hours around Laidley, Forest Hill, Gatton and Glenore Grove (defined here as: time from 80 per cent of peak water surface level (WSL) on the rising limb, up to peak WSL, through to 20 per cent recession of peak WSL on the falling limb). The duration of peak inundation extent through Western Creek was approximately 2 days.
- The duration of the entire 1974 event ranged from 3 to 7 days depending on location (duration of entire event defined here as: time between the rising limb being detected at the stream gauge through to a 90 per cent recession of peak WSL on the falling limb)

- Notable local landmarks that experienced encroaching flood waters included:
  - **Laidley**
    - Drayton Street, Pike Street, Patrick Street, Laidley Railway Bridge north of the station, Laidley-Plainland Road, William Street, Gatton-Laidley Road East, Blenheim Road, Malgowie Road and Old Malgowie Road
  - **Forest Hill**
    - Gatton-Laidley Road, and Harm Road around Sandy Creek at Forest Hill, Foresthill-Fernvale Road, Whiteway Road, Dodt Road, Gill Street, Railway Street and the railway bridge north of Forest Hill Station
  - **Gatton**
    - Gatton-Helidon Road, Robinson Road, Tenthill Creek Road, Gatton-Clifton Road, Wells Road, McLucas Road, Eastern Drive, Gatton-Laidley Road West, Gatton-Esk Road, the Warrego Highway, Lake Clarendon Way, Croftby Vale Road and the Gatton railway bridge
  - **Glenore Grove**
    - Forest Hill-Fernvale Road, Brightview Road, Lorikeet Road, Gehrke Road, Lake Clarendon Way, the Warrego Highway and Crowley Vale Road
  - **Western Creek**
    - Ipswich Street, Rosewood-Laidley Road, Grandchester Mount Mort Road, Grandchester Railway, School Road, Calvert Station Road, Hiddenvale Road, Gipps Street, Bourkes Road West, Rosewood Warrill View Road, Keanes Road and Ipswich-Rosewood Road.

7.2.2 May 1996

The May 1996 event had widespread but patchy rainfall across the Brisbane River catchment that resulted in moderate flooding in the Lockyer Creek and Bremer River catchments. Inconsistency between the rainfall record and observed runoff in the Lockyer Creek catchment made achieving a consistent catchment-wide calibration difficult, however the fluctuation of the hydrograph provided some benefit in validating the timing of the flow routing through the system.

7.2.3 February 1999

February 1999 was a relatively large flood concentrated over the upper Brisbane catchment but well contained by Wivenhoe and Somerset Dams. Rainfall over the downstream catchments, including Lockyer Creek and Bremer River, was relatively light resulting only minor flooding. This event was useful for confirmation of channel routing of low flows. Key points to note are:

- The duration of peak inundation extent was approximately 6 to 12 hours around Laidley, Forest Hill, Gatton and throughout Western creek. The duration of peak inundation through Glenore was approximately 16 hours.
- The duration of the entire 1999 event ranged from 1 to 6 days depending on location
- Notable local landmarks that experienced encroaching flood waters include:
  - **Laidley**
    - Drayton Street, Pike Street, Patrick Street and the Laidley Railway Bridge north of the station
  - **Forest Hill**
    - Gatton-Laidley Road and Harm Road around Sandy Creek at Forest Hill

- **Gatton**
  - Gatton-Helidon Road, Warrego Highway east of Gatton, the railway bridge north of Gatton Station and Adare Road
- **Glenore Grove**
  - Forest Hill-Fernvale Road and the Warrego highway around Glenore Grove
- **Western Creek**
  - Rosewood-Laidley Road, Ipswich-Rosewood Road, Grandchester Mount Mort Road, School Road and Calvert Station Road.

7.2.4 January 2011

January 2011 was a major flood event affecting the Brisbane River catchment and causing major damage within the Lockyer Creek, Bremer and Brisbane River catchments. The event was typified by a number of separate bursts of very heavy rainfall over several days resulting in a flow hydrograph in the downstream catchment with a series of sharp peaks. Initial rainfall bursts were concentrated over the upper Lockyer catchment causing extreme flash flooding in Helidon and Grantham, followed by more widespread flooding across the catchment that caused higher peaks at Gatton and in the southern Lockyer Creek catchment and Bremer River. Key points to note are:

- The duration of peak inundation extent was approximately 15 to 30 hours around Gatton and through Western Creek, and ranging from 2 to 3 days for Laidley, Forest Hill and Glenore Grove
- The duration of the entire 2011 event was consistently longer than 7 days for each location along the Project alignment
- Notable local streets and landmarks that experienced encroaching flood waters include:
  - **Laidley**
    - Drayton Street, Pike Street, Patrick Street, Laidley Railway Bridge north of the station, Laidley-Plainland Road, William Street, Laidley District State School, Gatton Laidley Road East, Whites Road, Lakes drive, Blenheim Road, Malgowie Road and Old Malgowie Road
  - **Forest Hill**
    - Gatton-Laidley Road, and Harm Road around Sandy Creek at Forest Hill, Foresthill-Fernvale Road, Whiteway Road, Dodt Road, Gill Street, Woodlands Road, Railway Street and the railway bridge north of Forest Hill Station
  - **Gatton**
    - Gatton-Helidon Road, Warrego Highway east of Gatton, the railway bridge north of Gatton Station, Adare Road, Cahill Park Sports Complex, Eastern Drive, Brooks Road, Tenthill Creek Road and Gatton Esk Road
  - **Glenore Grove**
    - Forest Hill-Fernvale Road, Warrego highway around Glenore Grove, Lake Clarendon Way, Brightview Road and Crowley Vale Road
  - **Western Creek**
    - Rosewood-Laidley Road, Ipswich-Rosewood Road, Grandchester Mount Mort Road, School Road and Calvert Station Road, Rosewood-Warrill View Road, Gipps Street, Hiddenvale Road, Bourke Road West and Ipswich Road.

7.2.5 January 2013

January 2013 was a moderate flood across much of the Brisbane River catchment (although mitigation by Wivenhoe minimised impacts in the lower Brisbane River). More spatially and temporally consistent rainfall produced a single broad flood peak. Key points to note are:

- The duration of peak inundation extent was approximately 1 day around Laidley, Forest Hill, Gatton and through Western Creek, with a peak inundation extent of approximately 2 days around Glenore Grove
- The duration of the entire 2013 event was approximately 5 days around Laidley, Forest Hill, Gatton and through Western Creek, with a duration of approximately 8 days around Glenore Grove
- Notable local streets and landmarks that experienced encroaching flood waters include:
  - **Laidley**
    - Drayton Street, Pike Street, railway bridge North of Laidley Station, Patrick Street, Whites Road, local IGA and pharmacy/doctor's clinics
  - **Forest Hill**
    - Forest Hill-Fernvale Road, Gatton-Laidley Rd West, Whiteway Road, Forest Hill-Bleinheim Road, Gatton-Laidley Road East, Gill Street, Dodt Street, Hall Road and Harm Road
  - **Gatton**
    - Gatton-Helidon Road, Robinson Road, Tenthill Creek Road, Warrego Highway, Gatton Railway bridge, Lake Clarendon Way and Gatton-Esk Road
  - **Glenore Grove**
    - Forest Hill-Fernvale Road, Brightview Road, Gehrke Road, Lorikeet Road, Lake Clarendon Way, Crowley Vale Road and the Warrego Highway
  - **Western Creek**
    - School Road, Grandchester Mount Mort Road, Rosewood-Laidley Road, Ipswich Street, Hiddenvale Road, Gipps Street, Waters Road, Bourkes Road West, Rosewood-Warrill View Road.

7.3 Review of BRCFS hydrologic investigation

The hydrologic models developed and calibrated by Seqwater were revised and recalibrated as part of the BRCFS. The recalibration process focussed initially on five flood events: January 1974, May 1996, February 1999, January 2011 and January 2013. These events were selected as they represent moderate to major floods and they also contain the best recent records in terms of spatial and temporal rainfall and stream flow information. The calibration parameters were then validated against a further 38 historical flood events, (28 events from between 1955 and 2013 and 10 older events dating back to 1887). Events prior to 1955 have limited pluivograph data and so the temporal representation of these events is generally less reliable.

Recommended parameters derived from the calibration/validation process are listed in Table 7.1. Model results using the recommended parameters were compared across the full range of verification events, generally showing a good correlation between calculated and rated peak flow rates and event volumes with no obvious flow rate related bias at all the examined flow gauges.

Table 7.1 Tributary sub-model adopted parameters

Sub-catchment	Alpha	Beta	m	n
Lockyer Creek	0.49	3.1	0.8	0.85
Bremer River	0.79	2.8	0.8	0.85
Warrill Creek	0.79	2.5	0.8	0.85
Purga Creek	0.93	3.8	0.8	0.85

For each of the tributary hydrologic sub-models, the calibration process focussed on achieving a good match of the flow hydrograph at the primary calibration gauge site (refer Section 5.5), typically at or near the downstream end of the catchment. The calibration parameters are therefore not necessarily optimised for individual tributaries or areas in the upper catchments.

For calibration events, losses can act to make up for inaccuracies in the rainfall data. The calibration rainfall data are recorded at isolated gauge sites and then interpolated across the catchment. If the rainfall was concentrated around the gauge site, therefore leading to an overestimate of the actual rainfall across the catchment, this can be compensated for by increasing losses, and vice versa. Forty-eight historical rainfall/flood events were simulated during the BRCFS to calibrate/validate the hydrologic models. The median initial and continuing losses are shown in Figure 7.1 and Figure 7.2 respectively. The 25th and 75th percentile losses are shown to give an indication of variability.

Figure 7.1 BRCFS calibration events median initial losses

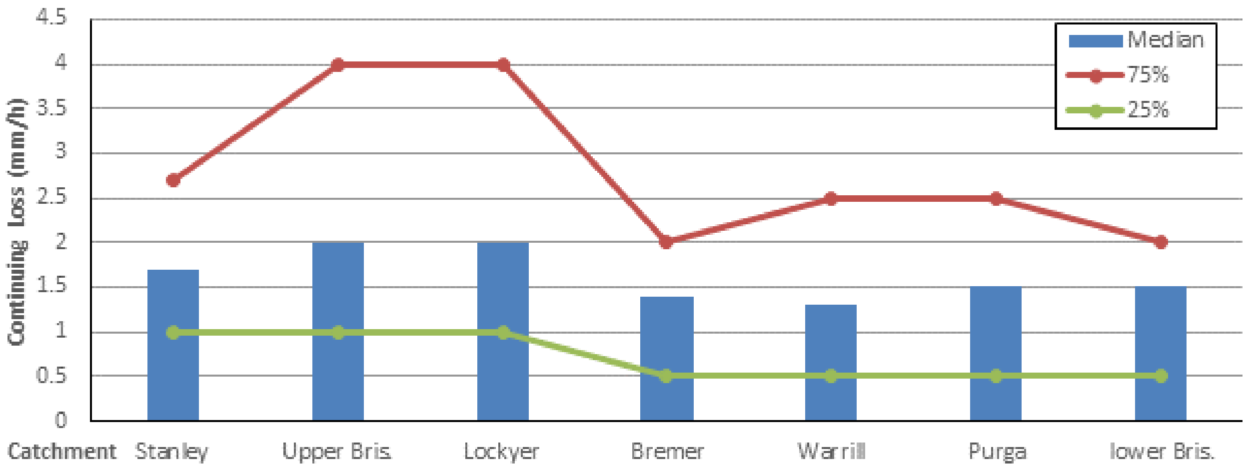


Figure 7.2 BRCFS calibration events median continuing losses

7.4 Hydrologic model calibration

Detailed calibration of the URBS hydrologic models was undertaken for the BRCFS. These hydrologic models have been adopted for the current investigation with minimal changes. No additional calibration of the hydrologic models has been undertaken.

7.5 Hydraulic model calibration process

The primary calibration parameter for the hydraulic models is the hydraulic roughness, represented in TUFLOW hydraulic model as a Manning's roughness coefficient, *n*. Calibration of the hydraulic models has involved:

- Comparison of the TUFLOW hydraulic model prediction of the relationship between level and flow with gauge ratings. As discussed in Section 5.5, detailed review of the stream gauge ratings was undertaken for a number of key gauges in the Lockyer Creek and Bremer River catchments, which provided a relationship between observed flows and levels that were consistent.
- Comparison of TUFLOW hydraulic model level and flow hydrographs for the calibration events to confirm that they match both the shape and timing of observed flow
- Comparison of TUFLOW hydraulic model levels with anecdotal flood level data from local councils and the stakeholders.

7.6 Lockyer Creek joint calibration results

Initial estimates for roughness were based on the previous nested LVRC TUFLOW hydraulic model (Jacobs, 2016). These values were then refined within the hydraulic model to achieve the desired relationship between flow and level through the model calibration process. Refined roughness values fall within the ranges outlined in Table 7.2 and are indicative of the conditions present in each waterway. It should be noted that, as with the ratings, these values are understood to be indicative of typical creek/catchment conditions and may be different during any individual flood event.

Table 7.2 Lockyer Creek Manning's Roughness coefficients adopted for the TUFLOW models

Land use	Manning's n
Roads and paved areas	0.025 to 0.030
Water bodies/farm dams	0.025 to 0.045
Channels and low vegetated creeks	0.045 to 0.060
Low-medium vegetation	0.045 to 0.070
Medium vegetated creeks	0.060 to 0.080
Riparian and dense vegetation	0.080 to 0.110
Demolished buildings	0.030 to 1.000
Farmland, pasture and crops	0.050 to 1.000
Urbanised areas	0.090 to 0.500
Fences	1.200
Buildings	4.000

It is difficult to define a specific hydraulic roughness for Lockyer Creek with certainty. The creek has a large main channel, varying in depth from approximately 14 m at Glenore Grove to over 18 m at Gatton. Due to the intermittent nature of flows and floods in the creek, the channel appears to have a relatively rough invert in terms of both elevation and vegetation. Aerial and local photography shows areas with ponding and clear of vegetation, while other areas are covered in trees and bushes. Similarly, the channel banks vary between grassed and heavy vegetation, often within a short distance. These areas are to some degree influenced by a series of low-level recharge weirs along the creek. Catchment conditions change with time this may influence flood behaviour. For the purpose of consistency, the same Manning's Roughness has been used for design and historical event modelling.

The roughness and stream conditions are also likely to vary historically. The area around Gatton where in particular, very high flows are fully contained within the creek channel, was subject to significant vegetation loss and scour during the major floods in 2011 and 2013, as shown in Figure 7.3. It should be noted that, even without the vegetation, the channel is not hydraulically ‘smooth’, as small to mid-scale irregularities in the channel section and the significant large-scale meandering of the channel are accounted for in the Manning’s roughness parameters.

Figure 7.3 Lockyer Creek channel condition at Gatton (a) 2009 and (b) 2014 (Google StreetView)

Roughness parameters for the Lockyer Creek hydraulic model were determined by comparing the model level-depth relationships with the ratings at the gauge sites within the model limits, while also ensuring that flow velocities are reflective of travel speed through the catchment, as demonstrated by validation to historical floods.

Figure 7.4 shows the relationship between level and flow at Glenore Grove for the 2011 flood event. As discussed in Section 5.5.1, Glenore Grove was the primary gauge site used to calibrate the URBS hydrologic model. The rating curve is generally considered to be reliable up to bank-full flow, which is approximately 1000 m³/s. Larger flows overflow away from the channel, resulting in a very flat rating curve sensitive to changes in water level. Despite being located at a complex junction of Lockyer and Laidley Creeks, the hydraulic model shows good agreement with the BRCFS rating relationship.

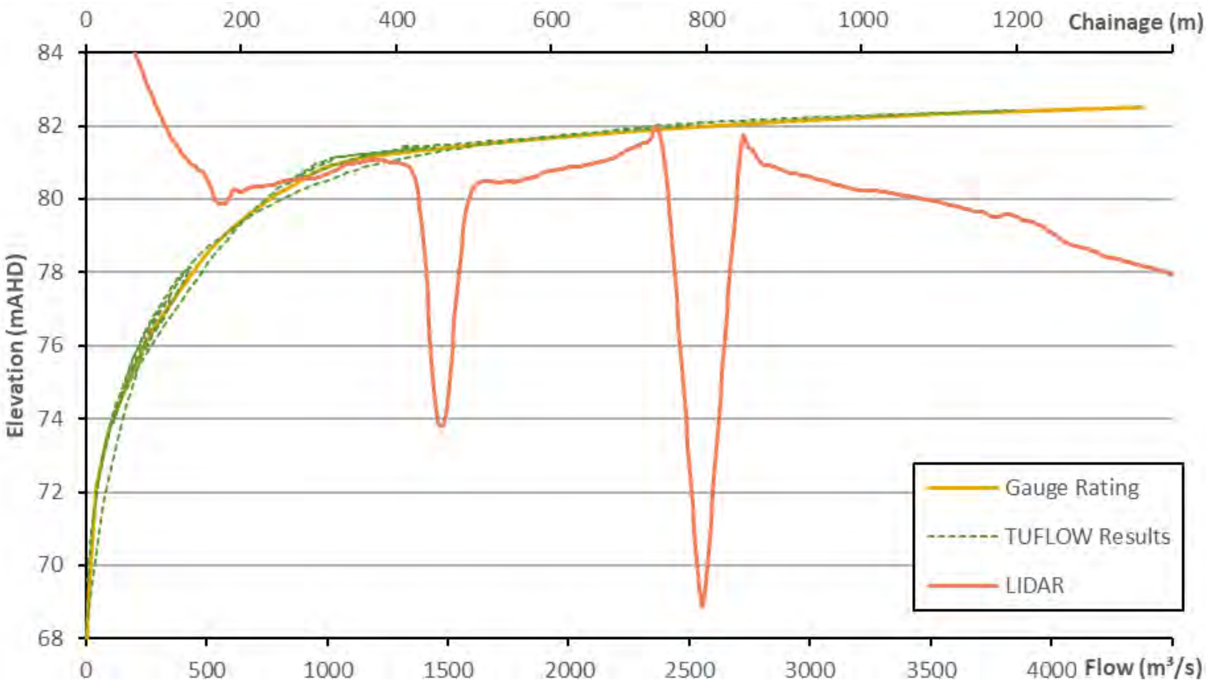


Figure 7.4 Comparison of hydraulic model level-depth relationship with Glenore Grove gauge rating

Similar figures for Gatton and Gatton Weir are provided in Figure 7.5. Both rating curves are based primarily on a best-fit of observed peak level and hydrologic model estimates of the peak flow for several historical flood events. Neither rating curve is considered to be particularly reliable, but nevertheless should give an indication of the expected flood levels corresponding to a modelled flow. The hydraulic model appears to underestimate low level floods (in the range of 90 to 95 m AHD) at the Gatton gauge. It has been identified that the current hydraulic model does not include the low-level Smithfield Road crossing, located approximately 400 m downstream of the Gatton gauge location, which may contribute to this discrepancy. Otherwise, the match is considered to be reasonable given the uncertainty in the gauge ratings.

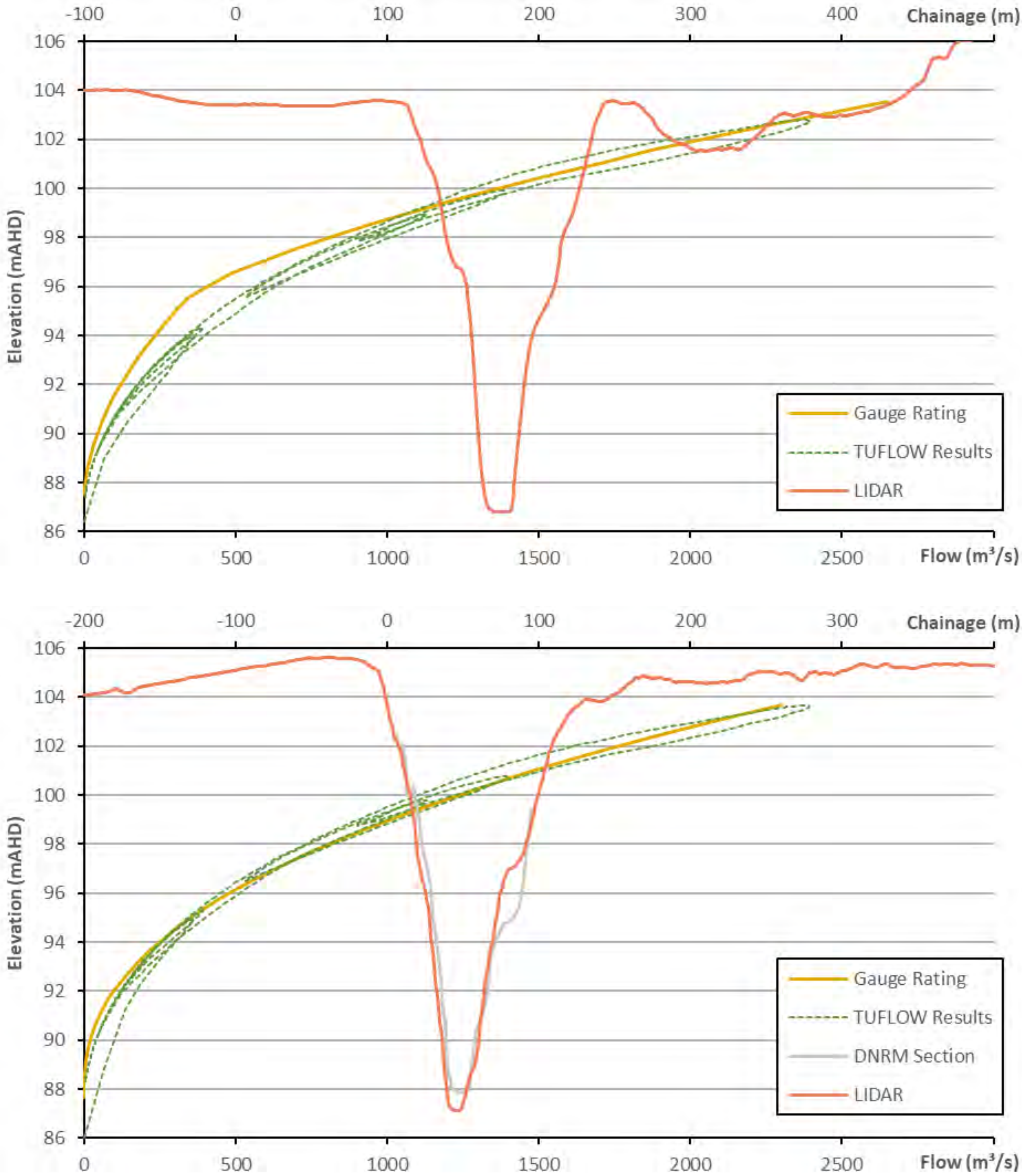


Figure 7.5 Comparison of hydraulic model with Gatton (top) and Gatton Weir (bottom) gauge ratings

The Warrego Highway stream gauge provides information on flows in Laidley Creek, the major tributary that joins Lockyer Creek at Glenore Grove. The gauge rating is theoretically reliable, being based on measured flow data up to nearly 1,000 m³/s, however no additional review/improvement was undertaken during the BRCFS. The relationship between level and flow at Warrego Highway for the 2011 flood hydrograph, shown in Figure 7.6, identifies significant hysteresis (floodplain storage effects that result in the level and flow having different relationships on the rising and falling limbs of the flood) for higher flows. While there is potentially some backwater effect from Lockyer Creek, which is less than 5 km downstream, these effects are also likely the product of a wide floodplain constrained by the Warrego Highway. Therefore, although the hydraulic model generally shows good agreement with the stream flow measurements, it suggests that there may be some uncertainty in the gauged flows. Notably, the hydraulic model rating curve deviates from the gauge rating curve above ~1,000 m³/s. This issue is discussed further in Section 7.6.4.

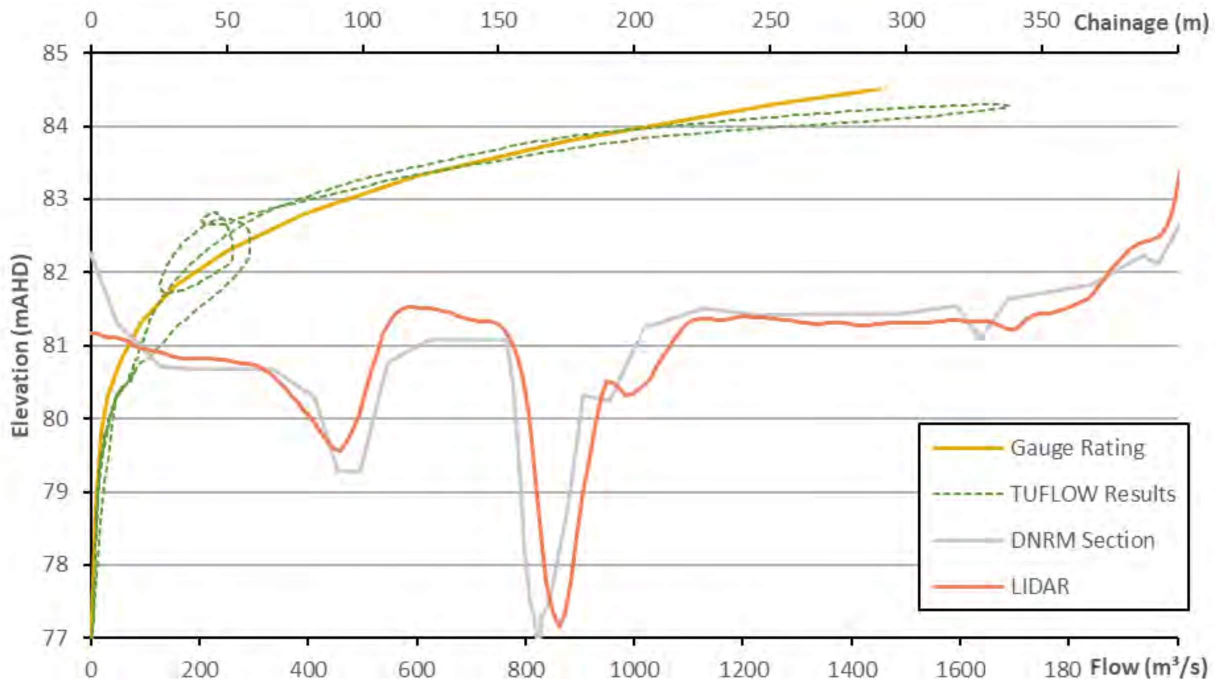


Figure 7.6 **Comparison of hydraulic model level-depth relationship with Warrego Highway gauge rating**

The Helidon stream gauge is located near the upstream boundary of the hydraulic model and is well removed from the primary area of interest for the study. The hydraulic model results, shown in Figure 7.7, match very closely the BRCFS rating. Several other stream gauges are located in the catchment but are located on minor streams or have limited or unreliable calibration data and have not been subjected to detailed assessment.

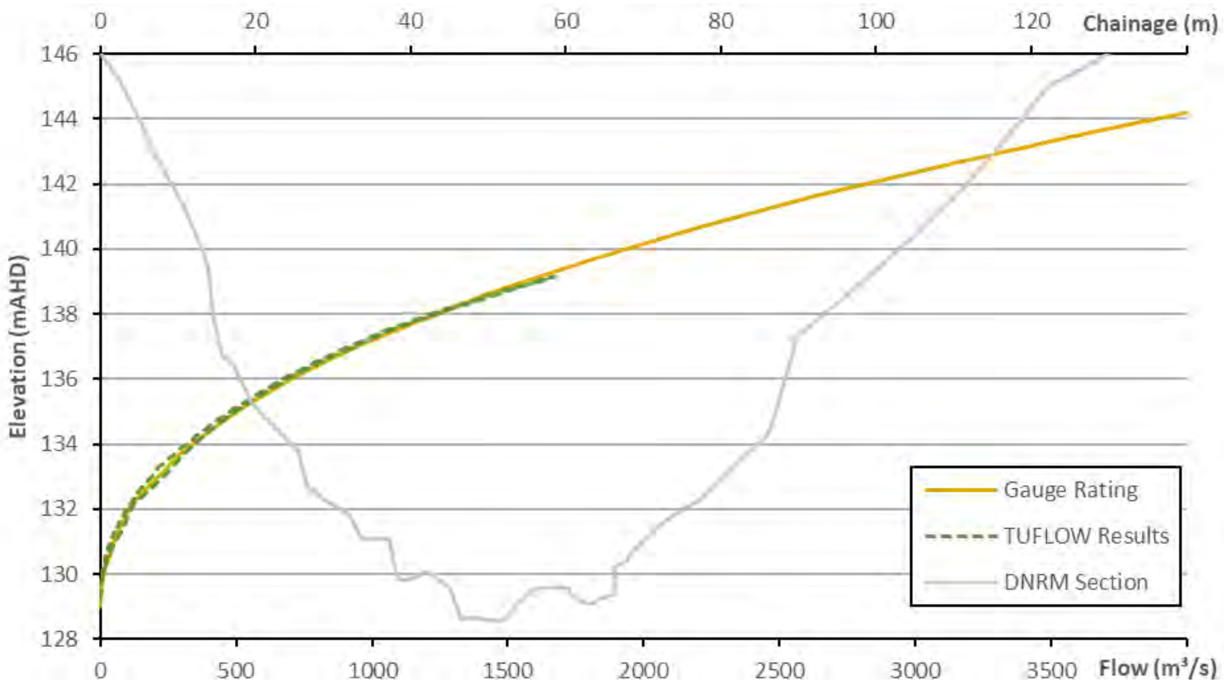


Figure 7.7 Comparison of hydraulic model level-depth relationship with the Helidon gauge rating

7.6.1 January 1974

The 1974 flood was a major flood event affecting much of the Brisbane River catchment. It was (and for much of the catchment still is) the largest flood since 1893. Unfortunately, limited historical information is available for the Lockyer Creek catchment for both stream gauge and rainfall data. Significant variation in rainfall depth was recorded across the catchment with depths in excess of 600 mm recorded in the Laidley Creek catchment upstream of Mulgowie but less than 250 mm registered across much of the central catchment around Tenhill. Only 24-hour rainfall totals are available across most of the catchment.

Comparisons of the flow hydrographs for the 1974 flood event produced by the URBS hydrologic model and TUFLOW hydraulic model at Gatton and Glenore Grove are provided in Figure 7.8 and Figure 7.9 respectively. A good match of the hydrograph shape and timing is achieved at Gatton, however, the match at Glenore Grove was predominantly focused on the rising limb as the gauge failed on 27 January 1974.

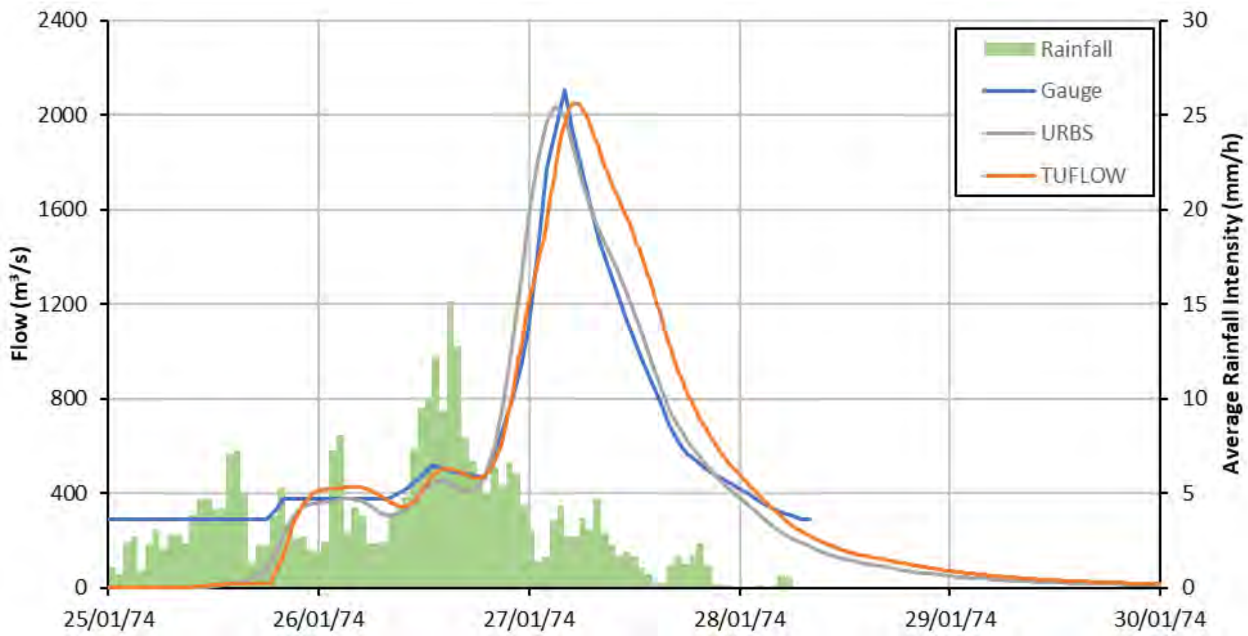


Figure 7.8 Modelled and rated flow hydrographs at Gatton for the January 1974 flood

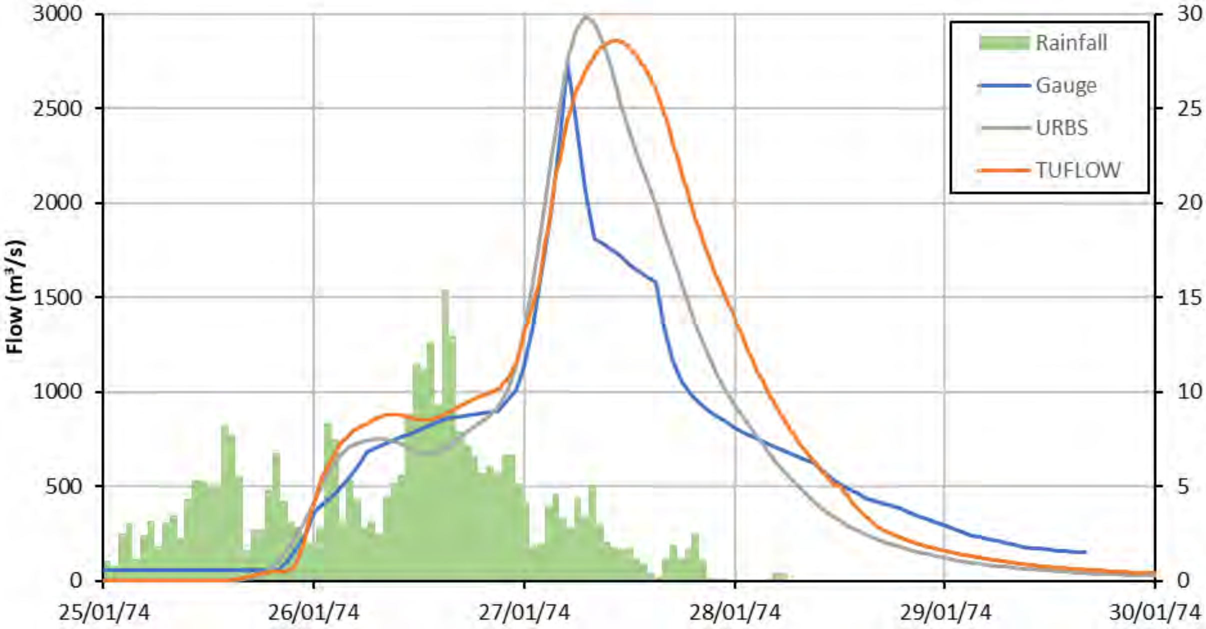


Figure 7.9 **Modelled and rated flow hydrographs at Glenore Grove for the January 1974 flood**

The modelled hydrographs at Helidon, shown in Figure 7.10, tend to underestimate the peak flow (this could potentially be improved by modifying the rainfall losses, which were selected based on the major gauges downstream), but the overall shape of the hydrograph is relatively well matched considering the lack of detail in the rainfall data.

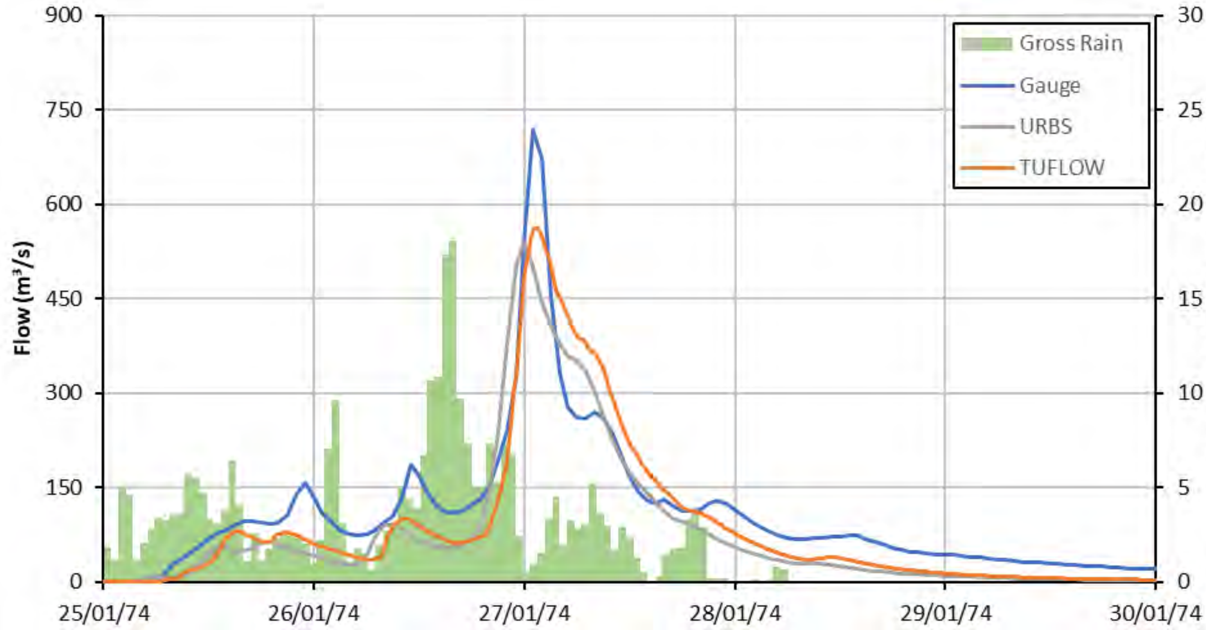


Figure 7.10 **Modelled and rated flow hydrographs at Helidon for the January 1974 flood**

There is little useful historical information to confirm calibration of Laidley Creek for the 1974 flood as the Warrego Highway gauge on Laidley Creek was not open. The gauge in the upper Laidley Creek catchment at Mulgowie matches the rising limb very well up to ~280 m³/s but then appears to have failed. Comparing the hydraulically routed flows from the hydraulic model with the hydrologically routed flows at the Warrego Highway, shown in Figure 7.11 identifies two issues:

- Although the overall shape of the hydrograph appears similar, the hydraulic model flows lag the hydrologic model flows

- During large events, flows break out of Lockyer Creek and flow southward into Laidley Creek upstream of the Warrego Highway. The flows extracted from the hydraulic model include this additional flow, whereas the hydrologic model does not currently include this bypass flow and reports only the flows arriving from the Laidley Creek catchment.

These issues are discussed further in Sections 7.6.2 and 7.6.4 respectively. Effects of this additional overflow and delay downstream at Glenore Grove appear to be minimal and the hydrographs match relatively well. It should be noted that due to the complex flow patterns around Glenore Grove, which include breakouts from Lockyer Creek to the north and eastwards from Laidley Creek during high flows, it is difficult to ensure an exactly consistent comparison between the extracted hydraulic model flows and the hydrologic model flows (which for more practical purposes should be considered as 'flows arriving within the Glenore Grove region').

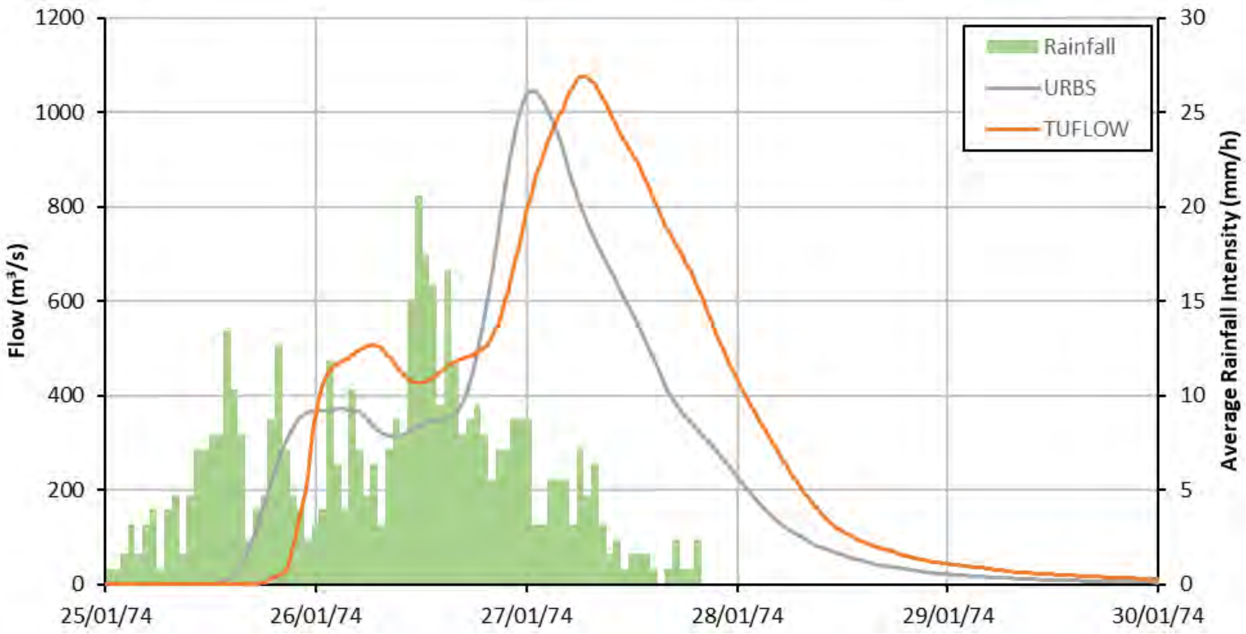


Figure 7.11 Modelled and rated flow hydrographs at Warrego Highway for the January 1974 flood

7.6.2 May 1996

Similar to other events affecting Lockyer Creek (e.g. 2011), the 1996 flood appears to be the combination of several different rainfall storm cells affecting different tributaries and resulting in a number of distinct peaks over several days. Total rainfall depths across the catchment were typically of the order of 300mm to 400mm, however isolated gauges recorded depths in excess of 550mm to 600mm. This rainfall distribution makes it difficult to select rainfall losses or other model parameters that can calibrate the model across multiple gauges, or even for different flood peaks at the same gauge. Some of these issues are illustrated in flow hydrographs at Helidon shown in Figure 7.12, where the models achieve a reasonable match of the shape of the largest peak on 3 May (which could be improved by slightly increasing the losses), but the gauge records a second peak not reflected in the rainfall record. This has flow-on effects throughout the system, as the 'missing' peak would help fill in the distinct trough in the modelled flow hydrographs at Gatton and Glenore Grove. Overall, a reasonable match can be achieved at most of the smaller gauges, including the Warrego Highway, Mulgowie (refer Figure 7.15) albeit using different losses at each location, however the way the flows combine at Glenore grove is not particularly well matched. This may be attributed to the limited number of continuous rainfall records (and hence temporal patterns) available in the catchment, which will tend to reinforce each recorded burst when interpolated across a wider area.

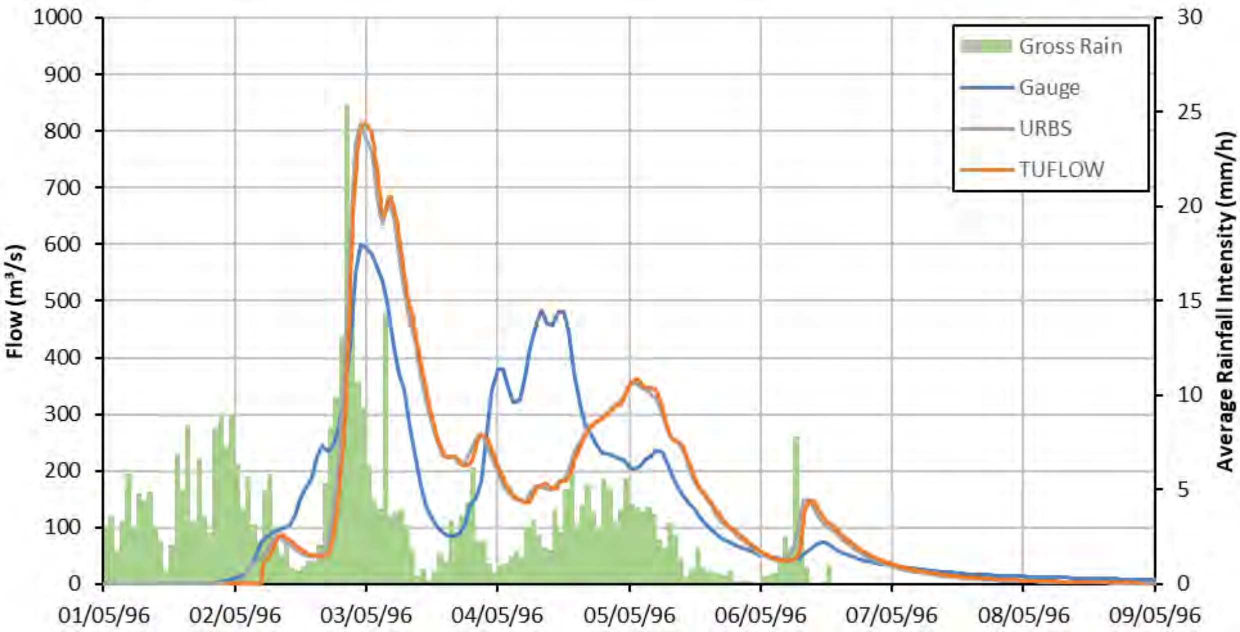


Figure 7.12 **Modelled and rated flow hydrographs at Helidon for the May 1996 flood**

Although 1996 is not an ideal historical event for calibration of the Lockyer Creek model, it does provide an example of a mid-size multi-peak flood event to compare the hydrologic and hydraulic routing. Comparisons of the flow hydrographs for the 1996 flood event produced by the hydrologic model and hydraulic model at Gatton Weir, Glenore Grove and Warrego Highway are provided in Figure 7.13, Figure 7.14 and Figure 7.15 respectively. These show very good agreement between the routed flows at Gatton. For Laidley Creek at the Warrego Highway, the shape of the hydrographs is similar, however the hydraulic model flows tend to lag the hydrologic flows. Notably, the timing of the hydraulic model appears to provide a better match to the recorded historical flows/levels. Although this may suggest that it may better represent the hydraulic hydrograph travel speeds in Laidley Creek over the hydrologic model, this does not seem to produce consistency as in the 2011 flood the hydrologic model shows good agreement with the recorded timing while the hydraulic model lags behind.

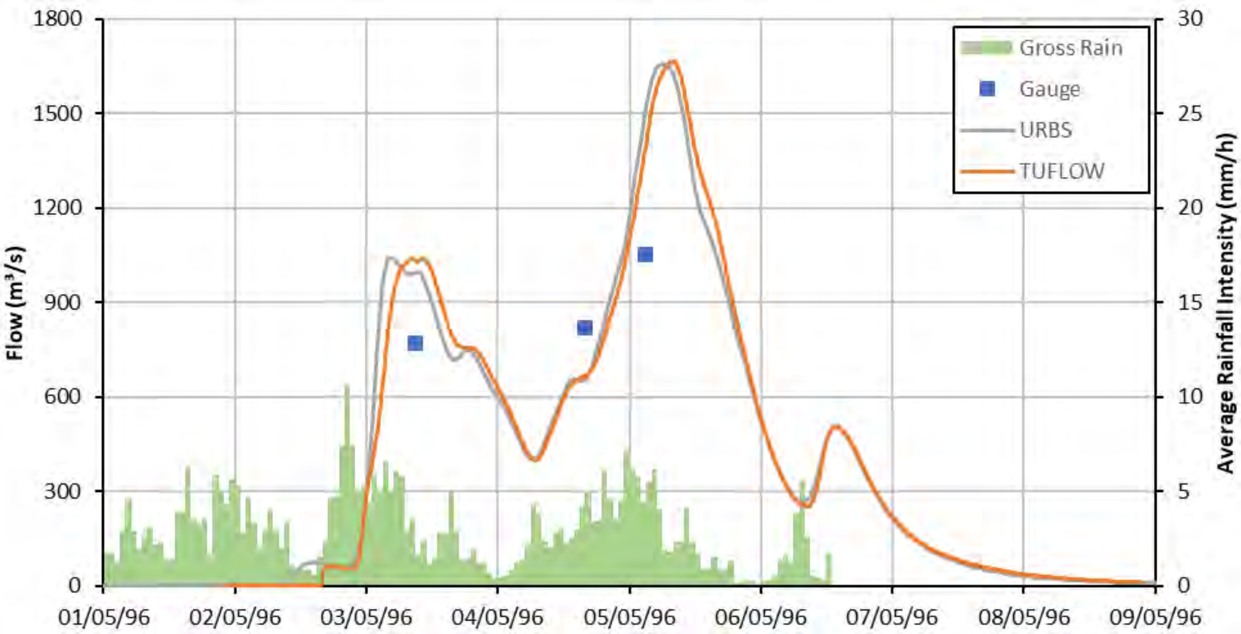


Figure 7.13 **Modelled and rated flow hydrographs at Gatton for the May 1996 flood**

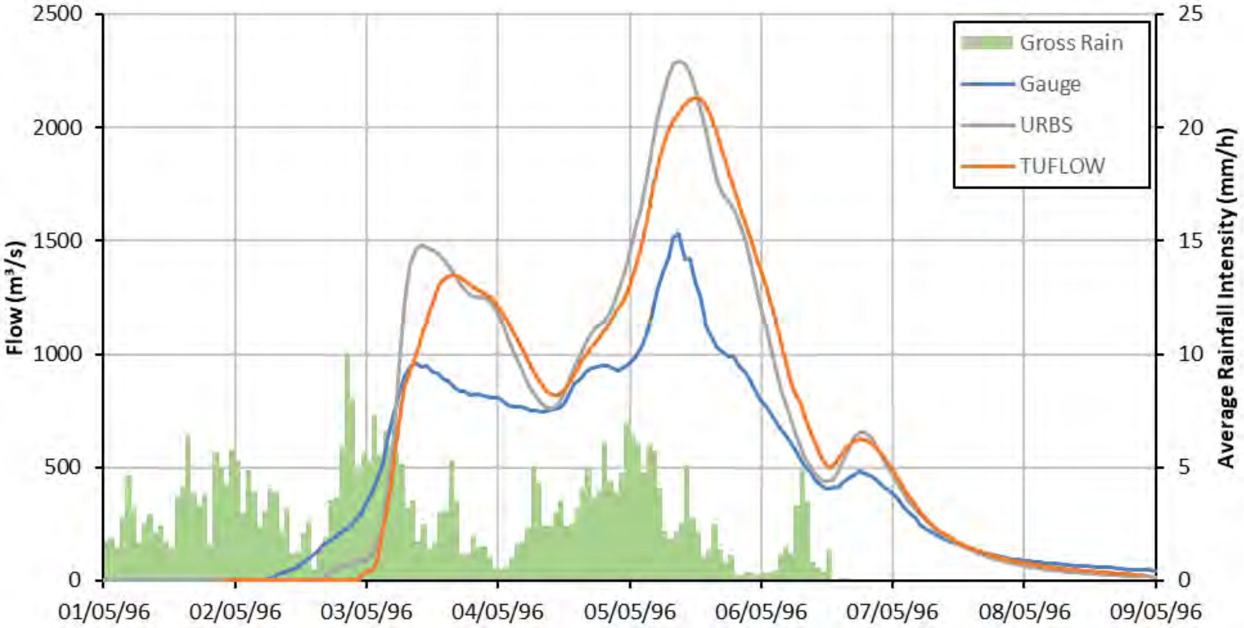


Figure 7.14 **Modelled and rated flow hydrographs at Glenore Grove for the May 1996 flood**

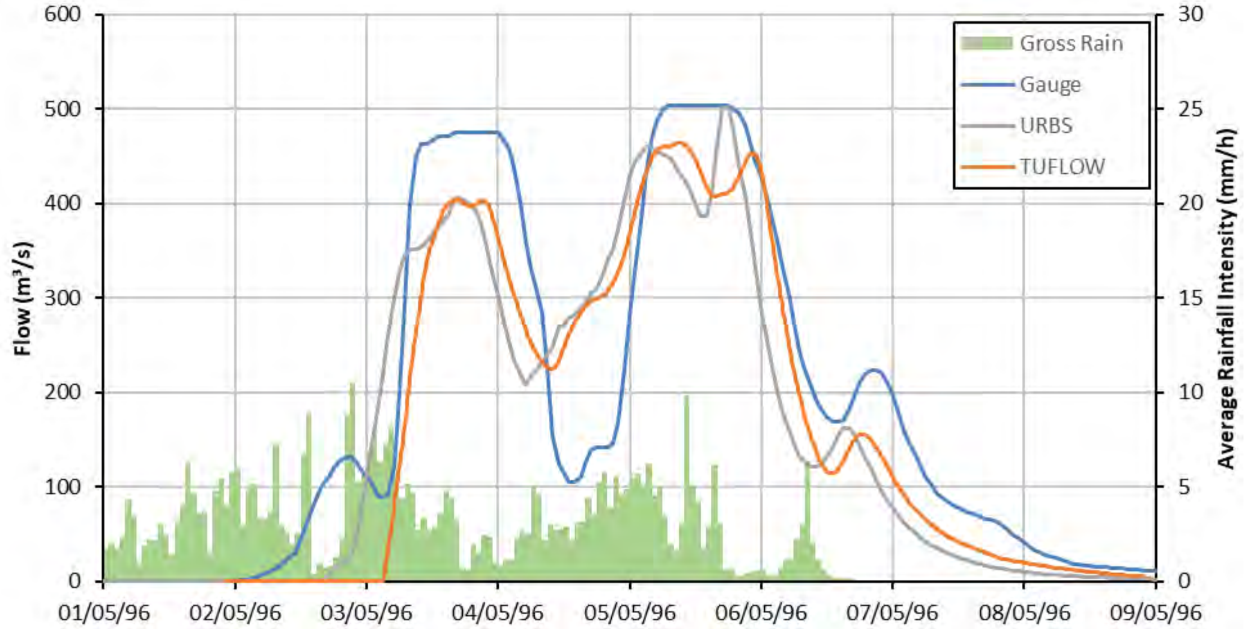


Figure 7.15 **Modelled and rated flow hydrographs at Warrego Highway for the May 1996 flood**

7.6.3 February 1999

Despite being a relatively large flood in the upper Brisbane River upstream of Wivenhoe, the 1999 flood event was only a minor flood in the Lockyer Creek catchment, with rainfall more heavily concentrated over the upper Lockyer catchment (note the disparity in rainfall depths between Warrego Highway and Helidon shown in Figure 7.18 and Figure 7.19). The catchment was relatively dry at the commencement of the 1999 event, evidenced by nearly two days of rain before any significant flow is recorded at any of the stream gauges, and large initial losses are required to match the observed runoff volumes. A good match of the recorded flows was achieved at the major stream gauges at Gatton and Glenore Grove in Figure 7.16 and Figure 7.17 respectively. Due to the relatively minor rainfall volumes over the Lockyer catchment, adopted rainfall losses have a significant influence on the resulting flow hydrographs. Similarly, the 'missing' first peak in the hydrograph at Helidon in Figure 7.19 is highly dependent on the adopted initial loss, and more notably the loss used to calibrate to Glenore Grove almost completely removes the Laidley Creek rainfall and flows from the hydrologic model (and consequently in the hydraulic model), as shown in Figure 7.18. A greatly improved match of the Laidley Creek records at Mulgowie and Warrego Highway can be achieved by adopting lower rainfall losses in the hydrologic model, however this results in too much flow in Lockyer Creek.

The minor inflows from Laidley Creek during the 1999 flood demonstrate that the timing and routing of low flows in Lockyer Creek through to Glenore Grove are well represented in both the hydrologic and hydraulic models.

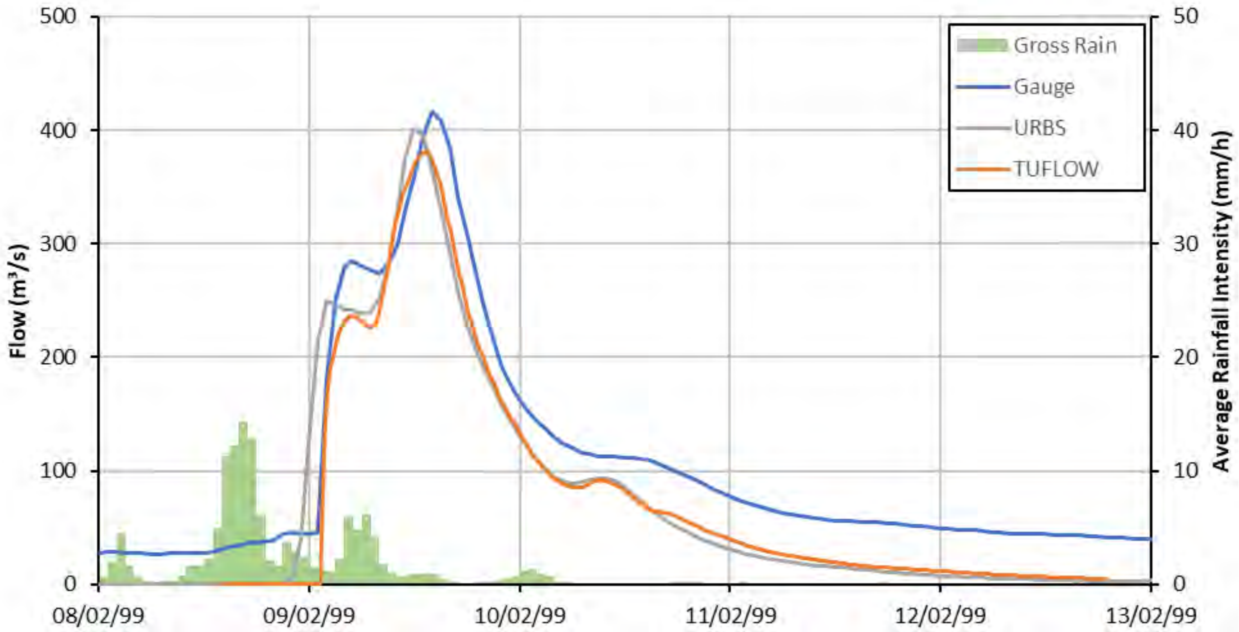


Figure 7.16 Modelled and rated flow hydrographs at Gatton for the February 1999 flood

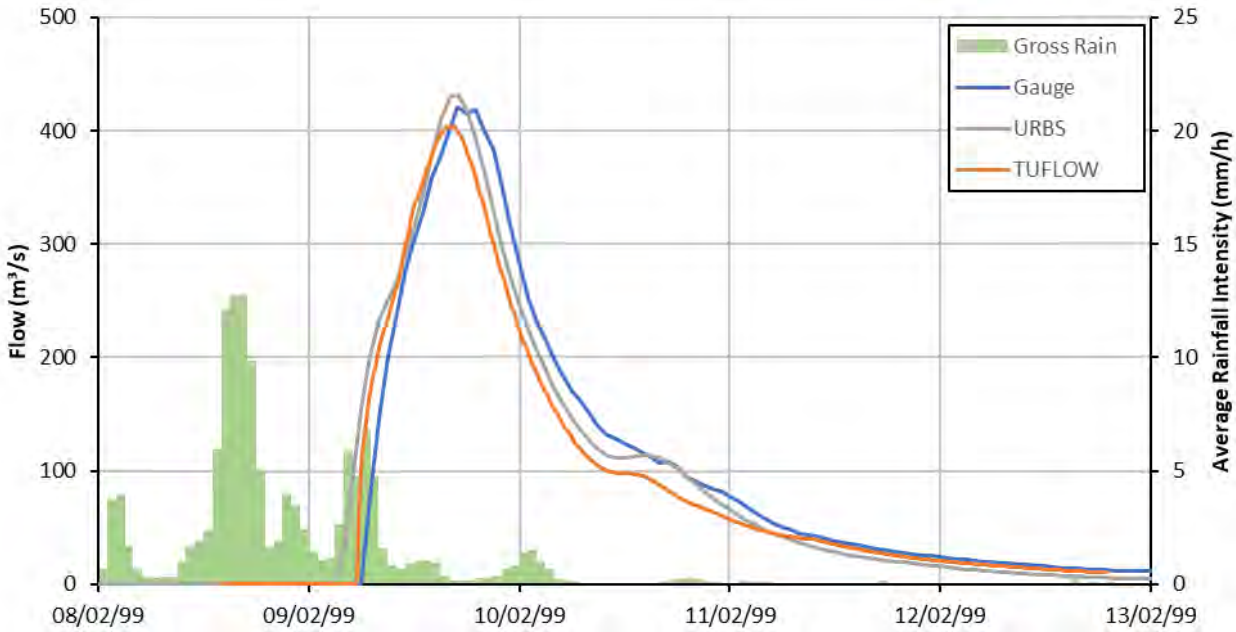


Figure 7.17 **Modelled and rated flow hydrographs at Glenore Grove for the February 1999 flood**

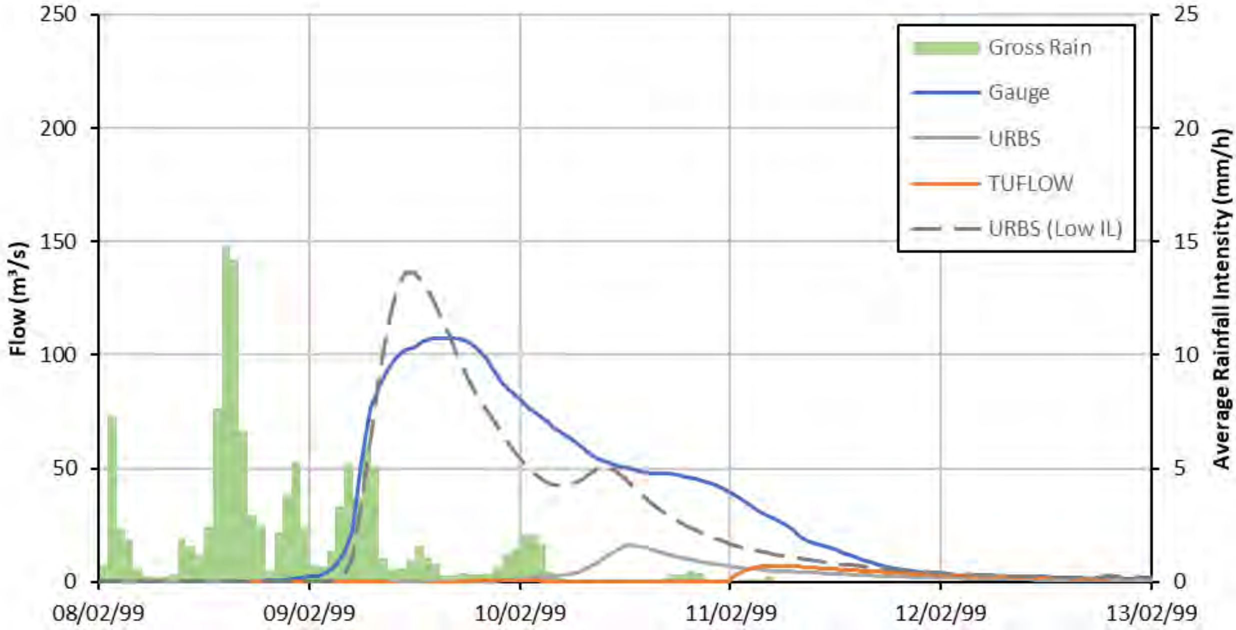


Figure 7.18 **Modelled and rated flow hydrographs at Warrego Highway for the February 1999 flood**

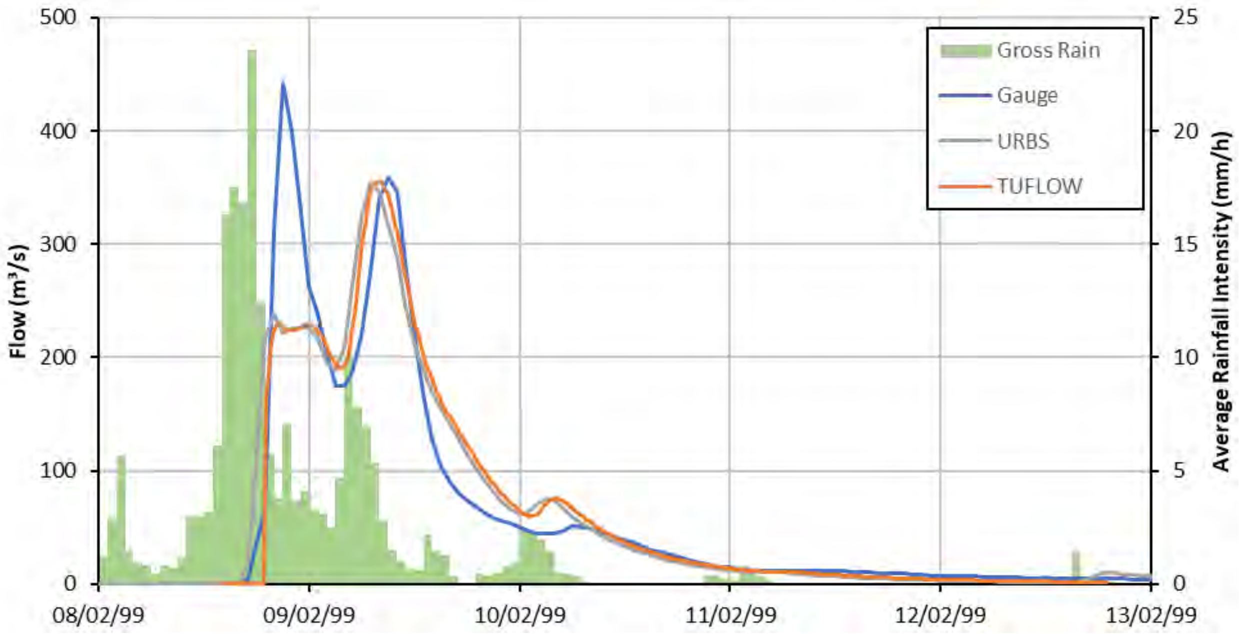


Figure 7.19 **Modelled and rated flow hydrographs at Helidon for the February 1999 flood**

7.6.4 January 2011

The 2011 flood is the largest recorded flood in much of the Lockyer Creek catchment. The overall event is actually the combination of several distinct rainfall bursts originating at different times in different parts of the catchment. Flash flooding in the upper Lockyer Creek catchment on 10 January 2011 caused significant loss of life and property damage at Murphys Creek and Grantham and was followed by more widespread flooding on 11 January 2011 that resulted in larger flows at Gatton and across the southern catchment. These are respectively the second last and last of five distinct peaks observed at Gatton shown in Figure 7.21.

Significant attention has been given to examining the flash flood that struck Grantham. Unfortunately, relatively little data is available for reliably estimating the peak flow. As discussed in Section 5.5.1, the Helidon stream gauge failed prior to the peak. A peak level of just under 14 m has been estimated, corresponding to a flow of around 3,000 m³/s using the BRCFS derived rating curve. Other attempts to generate the flow hydrograph (e.g. Water Solutions and WRM water) have estimated a peak flow as high as 4,600 m³/s. These estimates do not appear to have been reconciled with the expected flood recurrence, and when compared to both flood frequency analysis (FFA) and rainfall-based methods (Monte-Carlo simulation and Design Event modelling), would appear to correspond to events within excess of a 1 in 100,000 AEP event. They also do not address the fact that flows of this magnitude at Helidon would cause the second-last flood peak to exceed the following larger peak observed at Gatton. Another complicating issue for a flow of this magnitude is that it would necessitate significant attenuation of the flood peak to have occurred between Helidon and Gatton, where the 10 January flood peaked over 1.2 m lower than the peak on the following day (estimated at around 1,800 m³/s and 2,200 m³/s respectively). This would only be possible for a very sharp flood peak. There is no reliable data in this regard due to the failure of the gauge.

Some reports (e.g. Gearing 2015) suggest that the 2011 flood resulted in flood levels at Grantham similar to those caused by the 1974 flood, with the significant difference between the two events being the rate of rise and lack of warning in the 2011 flood. The 1974 flood produced a rated flow of 840 m³/s at Helidon, with other tributary flows bringing the estimated peak at Grantham to around 2,000 m³/s. Assuming that the 10 January 2011 flow was of similar magnitude, mostly originating from the upper Lockyer Creek, this would correspond to a peak of around 1 in 2,000 AEP at Helidon. Although this appears to be a more statistically probable estimate of the magnitude of the event, it is far from conclusive evidence, noting that other reports suggest that 2011 was larger than 1974 at Grantham and large changes in flow may not correspond to large differences in water level once flow breaks out onto the floodplain around Grantham.

Review of radar data conducted by the BoM (Report to QLD Floods Commission of Inquiry, March 2011), identified that the limited rainfall gauges in the upper Lockyer catchment did not capture the highest rainfall bursts that occurred. Conversely, ground truthing of the radar data (comparison with recorded rainfall) indicated that the storm complex had relatively low radar intensity returns for a storm in South East QLD with such high rainfall amounts. This appears to be consistent with the Jacobs assessment (Jacobs 2016), which noted that runoff from rainfall patterns developed from radar data produced too much total flow volume. This demonstrates that there is a high degree of uncertainty regarding the rainfall that occurred during the 2011 flood.

A key characteristic of the 10 January 2011 flash flood was its extreme rate of rise. It is described by witnesses as a flood wave more reminiscent of a dam break, spawning the colloquial description as an 'inland tsunami', carrying a significant debris load. The stream channel of Lockyer Creek was heavily vegetated prior to the flood and experienced significant scour and removal of vegetation throughout the flood event as shown in Figure 7.3. This could potentially have had significant influence on the shape and magnitude of the flood wave. The forefront of the flood would have to push through heavy vegetation while the tail of the flood travelled faster through cleared channel, causing concentration of the flow peak. (Note that this would also produce higher flood levels than would be estimated using a smoother post-flood channel roughness). The debris picked up and carried by the flow could also act to retard the front of the flood-wave. High debris flows in steep channels are often characterised by a very steep front as flow builds up behind a 'moving dam' of debris. Both phenomena would contribute to a concentrated peak flow well in excess of a rainfall-generated flood. The simplified routing parameters of a standard hydrologic model would struggle to represent these complex phenomena, and indeed they are difficult to represent even in a 2D hydraulic model. A time or depth-dependent roughness could be used to represent the higher roughness experienced by the front of the flood wave, but still may not truly represent changes to the fluid properties caused by high-debris concentration.

The above discussion is provided to highlight the significant uncertainties regarding the calibration of the models to the 10 January flash flood encompassing all calibration process (unreliable input rainfall data, unreliable peak and unknown duration of the target hydrograph, uncertain and variable condition of the stream during the event). The BRCFS URBS model results, shown in Figure 7.20, shows a reasonable match of a number of the minor flood peaks, particularly the longer duration burst commencing 9 January, but significantly underestimates the magnitude of the 10 January 2011 flood peak. This was not considered a serious issue for the BRCFS, which was focussed on the lower Lockyer and Brisbane River catchments for which the subsequent peak was more important. Similarly, the current investigation is focussed more on the mid Lockyer reaches around and downstream of Gatton. Although the 10 January flood is recognised as being a very significant event in the upper Locker catchment, both in terms of its magnitude and consequence, placing undue weight on attempting to replicate the characteristics of a flash flood may be to the detriment of the overall model calibration, given the significant uncertainties regarding the event. The study has therefore not attempted to replicate the characteristics of the 10 January flood It is nevertheless noted that:

- Modelled flood levels in areas upstream of Gatton where the 10 January flash flood peaked higher than the 11 January peak will not be represented correctly
- Design event modelling (particularly the hydrologic assessment) may not correctly assess the severity of flash floods that could potentially occur in the upper catchment. Flood frequency analysis suggests that significant events are rare (> 1 in 100 AEP), but they may occur more frequently than estimated by standard analysis techniques. Assessment of such events will not impact on the Project design and assessment is outside the scope of the current investigation.

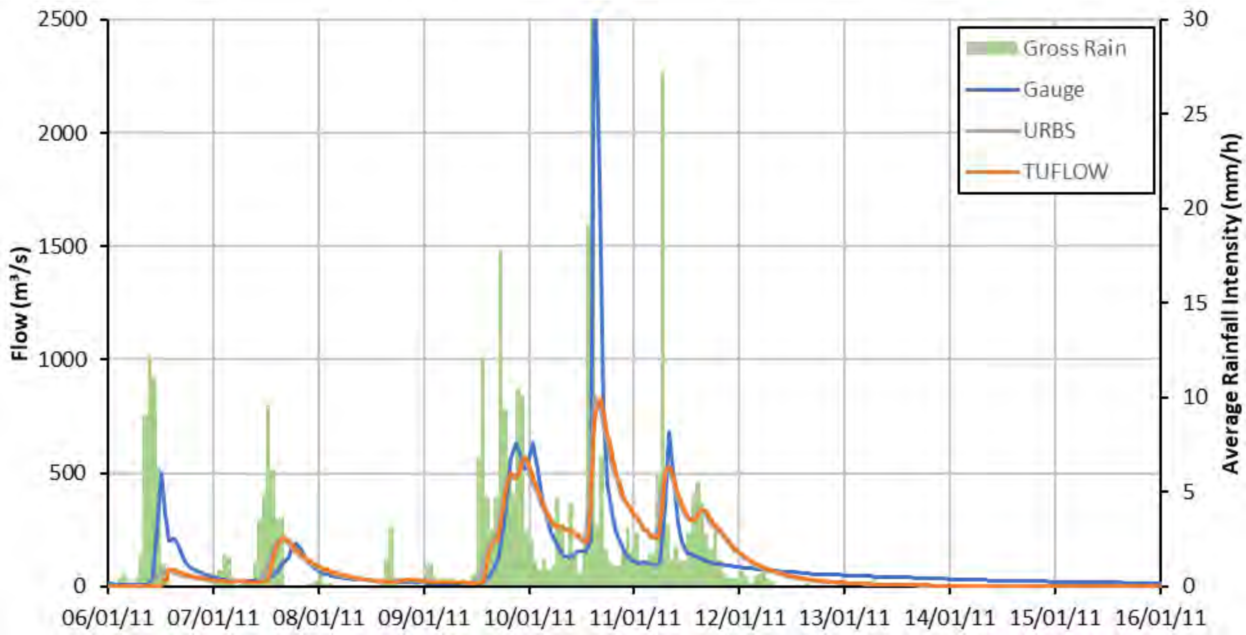


Figure 7.20 Modelled and rated flow hydrographs at Helidon for the January 2011 flood

Comparisons of the flow hydrographs for the 2011 flood event produced by the hydrologic model and hydraulic model at Gatton Weir, Glenore Grove and Warrego Highway are provided in Figure 7.21, Figure 7.22 and Figure 7.23 respectively. These show that both the hydrologic and hydraulic models achieve a good match of the hydrograph shape and timing at Gatton (note that the rating is not particularly reliable at high flows).

In Laidley Creek at the Warrego Highway, the hydraulic hydrograph again lags behind the hydrologic hydrograph by approximately 2 hours. Unlike the 1996 and 2013 events, for the 2011 flood the hydrologic hydrograph appears to better match the timing of the observed flood. As with the 1974 flood, flows from Lockyer Creek overflow southward into Laidley Creek upstream of the Warrego Highway gauge. At the flood peak, the combined flows at the gauge are therefore higher than are predicted by the hydrologic model. This suggests the good match between the hydrologic and historical peaks is somewhat of a coincidence. As shown in Figure 7.6, the current DNRME rating and the hydraulic level-depth relationship begin to deviate above 84 m AHD (~1,000 m^3/s), which is coincidentally also the level to which flow measurements provide good confidence in the rating curve. The DNRME rating curve was reviewed during the BRCFS and was adopted without change due to the (apparent) good match between the hydrologic peak and the rated flow. The TUFLOW relationship would suggest that the observed levels should correspond to higher flows than are predicted, which is consistent with the inclusion of additional overflow from Lockyer Creek.

At Glenore Grove, the hydraulic and hydrologic hydrographs show good agreement early in the event when flows are primarily contained within the main Lockyer Creek channel, (where the major floods are coming from the upper Lockyer region). Later in the event, when Laidley Creek provides a more significant contribution, the hydraulic hydrograph tends to lag behind the hydrologic during the flood peak. The mismatch in timing between the Lockyer and Laidley Creek flows appears to be the greatest contributor to the difference in the hydrograph at Glenore Grove. Adopting a lower β value in the for the entire hydrologic model, (for other events β was only modified for the sub-catchments inflows within the hydraulic model boundary), was found to slightly improve the timing issue.

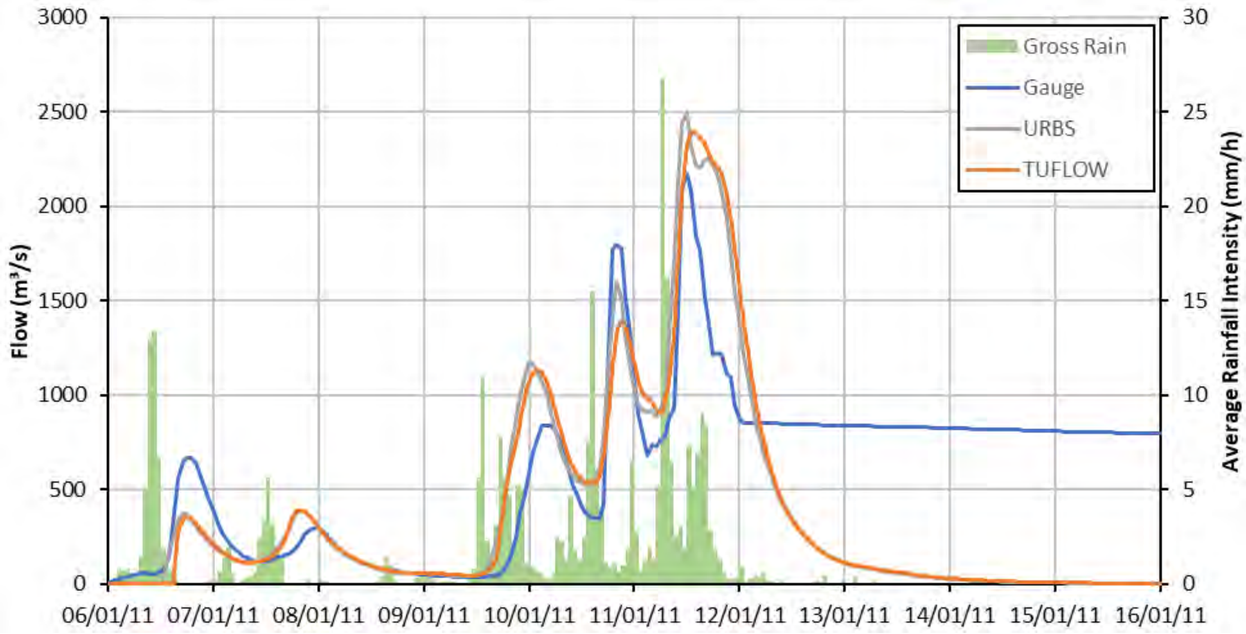


Figure 7.21 Modelled and rated flow hydrographs at Gatton Weir for the January 2011 flood

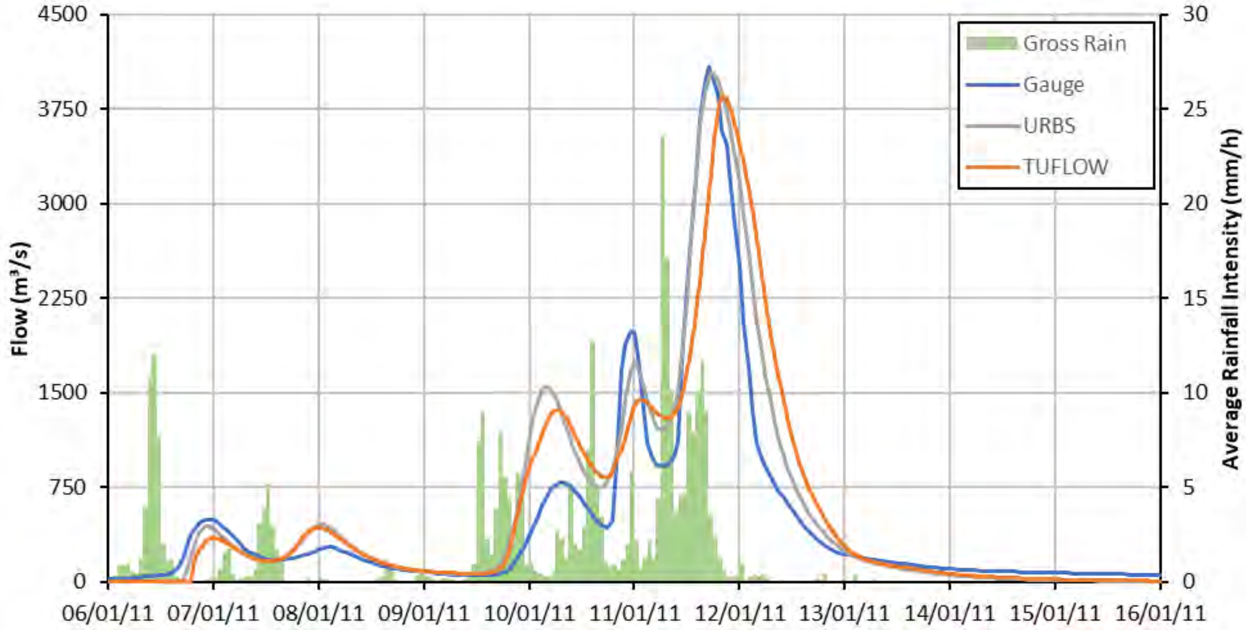


Figure 7.22 Modelled and rated flow hydrographs at Glenore Grove for the January 2011 flood

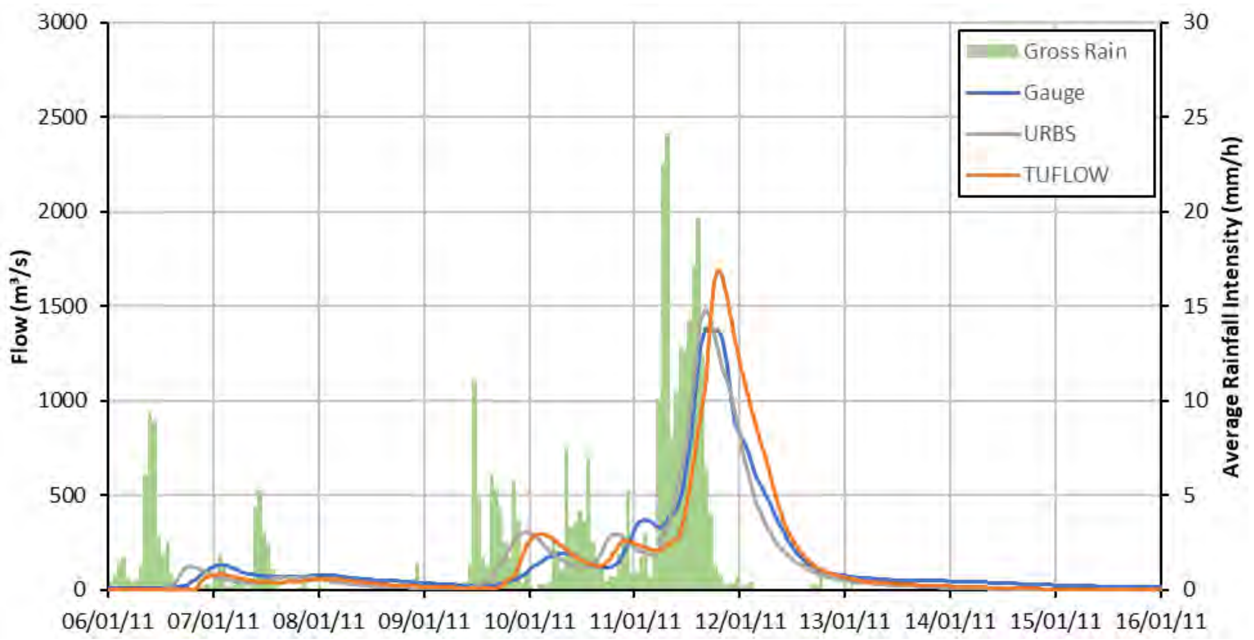


Figure 7.23 **Modelled and rated flow hydrographs at Warrego Highway for the January 2011 flood**

LVRC provided a number of flood markers in the Lockyer Catchment for the 2011 event. These recorded levels have a range of accuracies based on their source. Of these markers 162 were relevant for the area of interest upstream and downstream of the alignment. The flood markers analysed are presented in Appendix A Figure A-2D.

As outlined above the hydrologic model does not replicate the magnitude of the 10 January 2011 flash flood, and consequently flood levels in the area between Helidon and Grantham are consistently underestimated. Excluding this region, 75 per cent of the flood marker points are within 300 mm of the hydraulic model results and 92 per cent of the flood markers are within 500mm of the hydraulic model results. Importantly, the hydraulic model does not consistently under- or over-estimate the flood levels. The distribution of these calibration points is outlined in Figure 7.24. The model calibration performance is similar to the previous calibration undertaken in the SKM “Lockyer Creek Flood Study”.

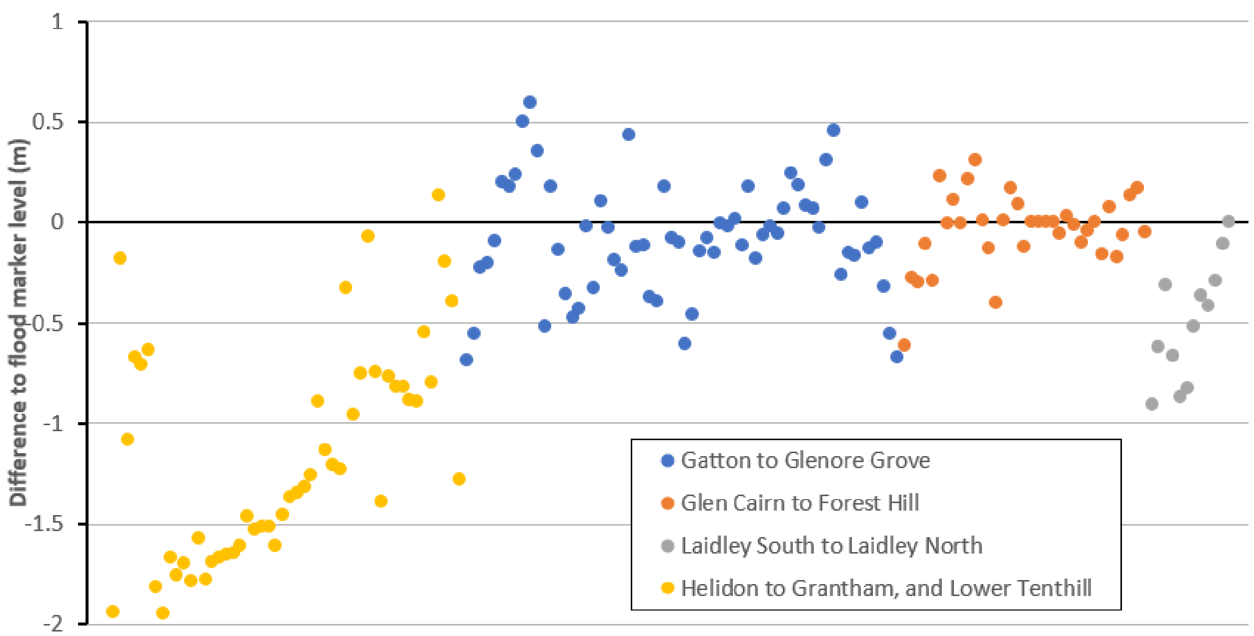


Figure 7.24 **Lockyer Creek 2011 – Flood marker difference**

7.6.5 January 2013

Unlike the short bursts of the 2011 flood, the 2013 flood was caused by prolonged, wide-spread rainfall producing a single flood peak. Comparisons of the flow hydrographs for the 2013 flood event produced by the hydrologic model and hydraulic model at Gatton Weir, Glenore Grove and Warrego Highway are provided in Figure 7.25, Figure 7.26 and Figure 7.27 respectively.

A good match of the hydrograph shape and timing is achieved at Gatton Weir (note that the rating is not particularly reliable at high flows). The hydrograph shape is also reasonable at Warrego Highway (note that the gauge did not capture the flood peak). As with the other calibration events, the timing of the hydraulic hydrograph lags behind the hydrologic hydrograph by a few hours. In this case the hydraulic model appears to better match the rising limb of the recorded flood, but the receding limb is closer to the hydrologic model (as are flows at Glenore Grove). The effect of this delay carries downstream to Glenore Grove where there is some lag of and minor attenuation of the hydrograph but otherwise a reasonable match of the general shape.

Notably, due to the more consistent rainfall (and potentially aided by the installation of more rainfall gauges within the catchment), the hydrologic calibration could also achieve a good match of the recorded flood hydrographs at most of the minor stream gauges throughout the catchment, including Helidon, Tenthill, Sandy Creek, Mulgowie, Showground and Forest Hill (noting that the reliability of some of these gauge ratings has not been confirmed and some gauges are located at sites where the channel is perched and can only record flows up to bank full) using consistent rainfall losses across the entire catchment (e.g. the Helidon record shown in Figure 7.28 requires only a 5per cent increase in initial loss to match the recorded peak).

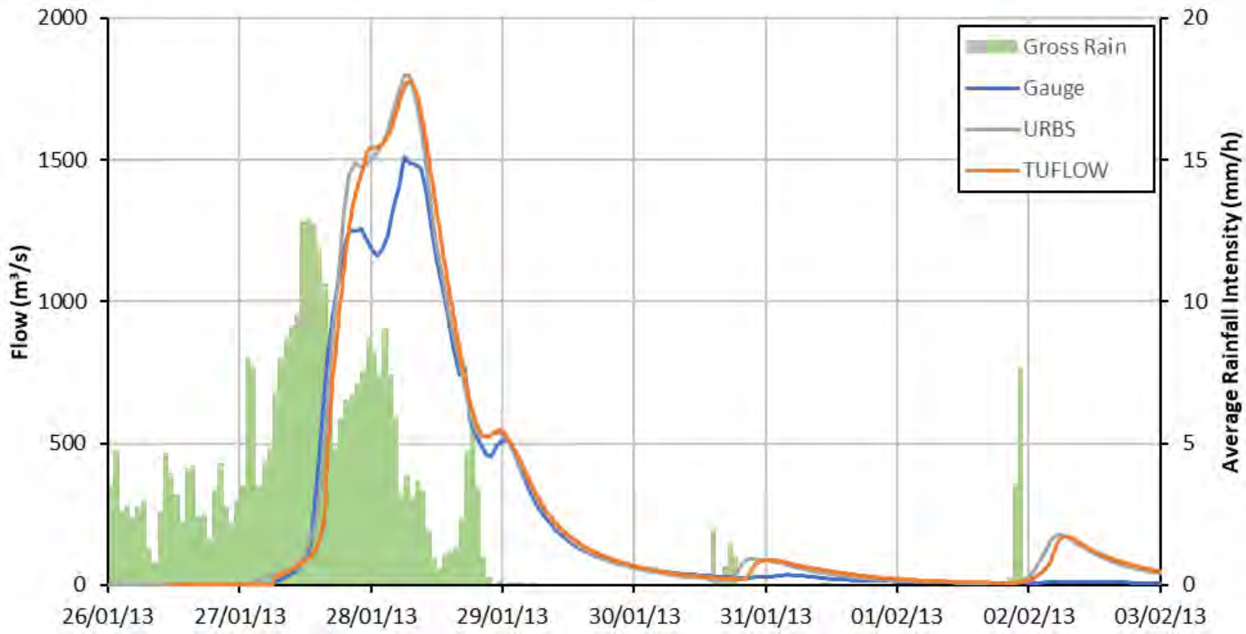


Figure 7.25 Modelled and rated flow hydrographs at Gatton Weir for the January 2013 flood

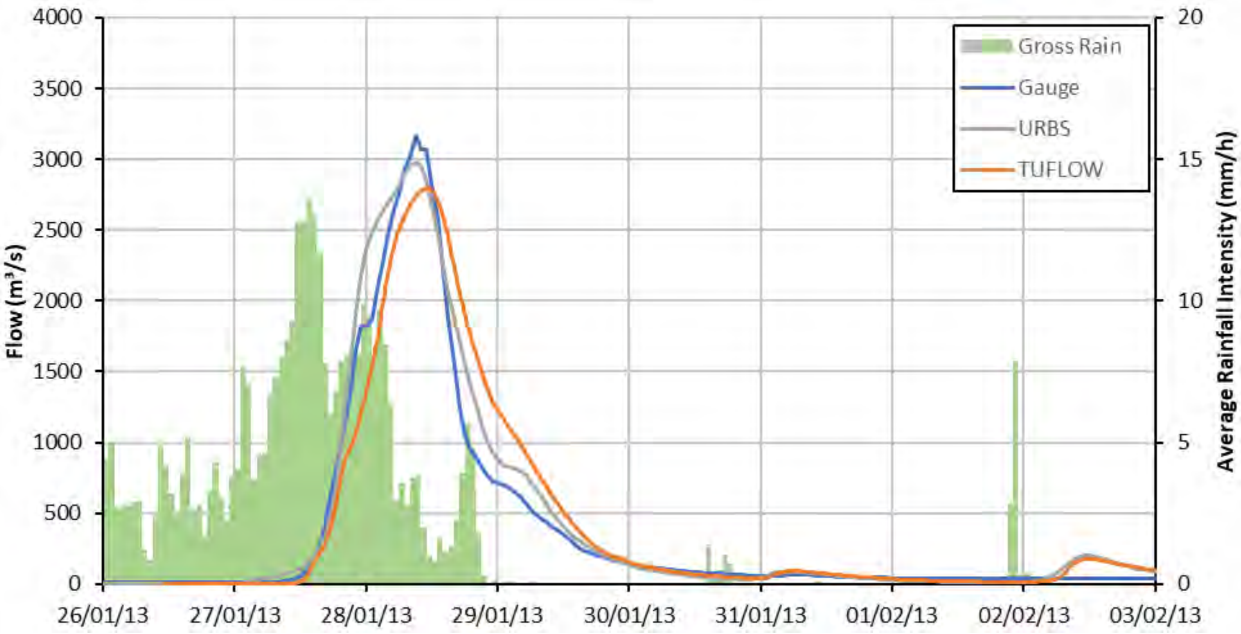


Figure 7.26 **Modelled and rated flow hydrographs at Glenore Grove for the January 2013 flood**

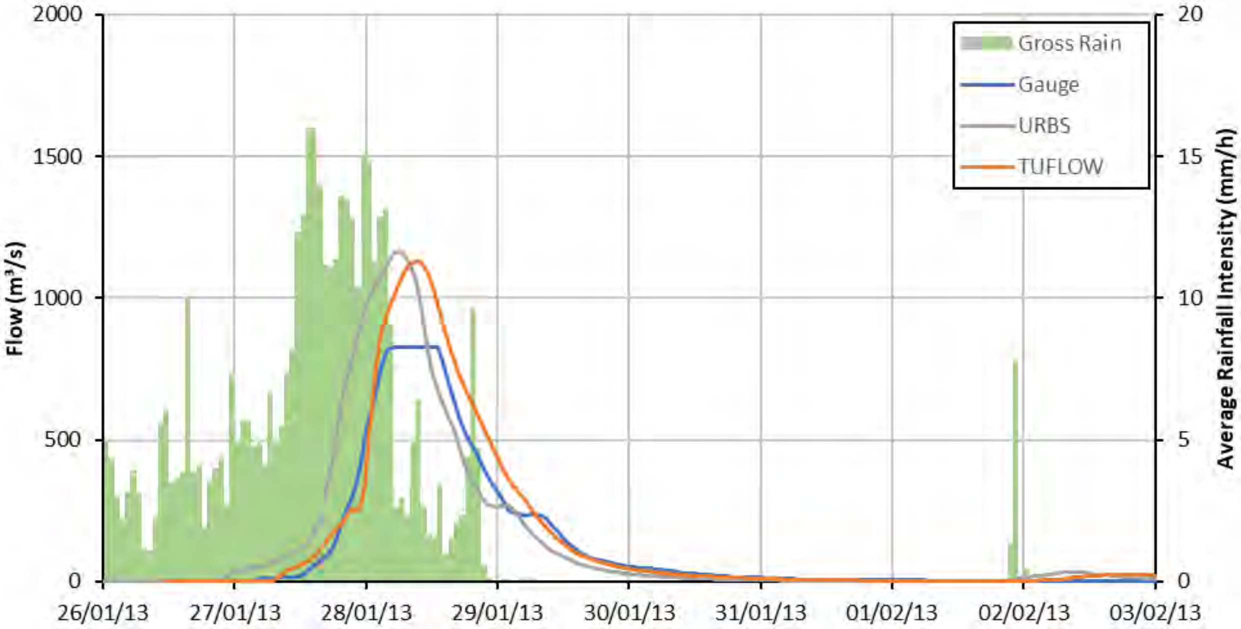


Figure 7.27 **Modelled and rated flow hydrographs at Warrego Highway for the January 2013 flood**

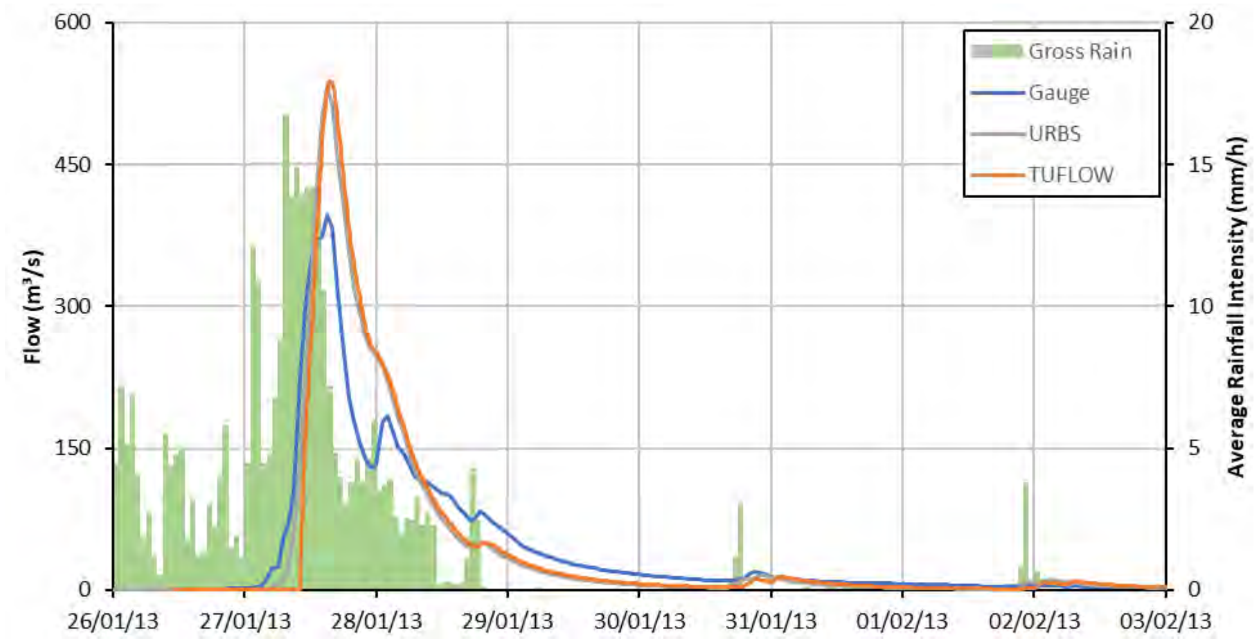


Figure 7.28 **Modelled and rated flow hydrographs at Helidon for the January 2013 flood**

LVRC provided a number of flood markers in the Lockyer Catchment for the 2013 event. These recorded levels have a range of accuracies based on their source. Of these markers 168 were relevant for the area of interest upstream and downstream of the alignment. The flood markers analysed are presented in Appendix A Figure A-2G.

In general, 71 per cent of the flood marker points are within 300 mm of the hydraulic results. Further to this 86 per cent of the flood markers are within 500 mm of the hydraulic results. The hydraulic model does not consistently under- or over-estimate the flood levels. The distribution of these calibration points is outlined in Figure 7.29.

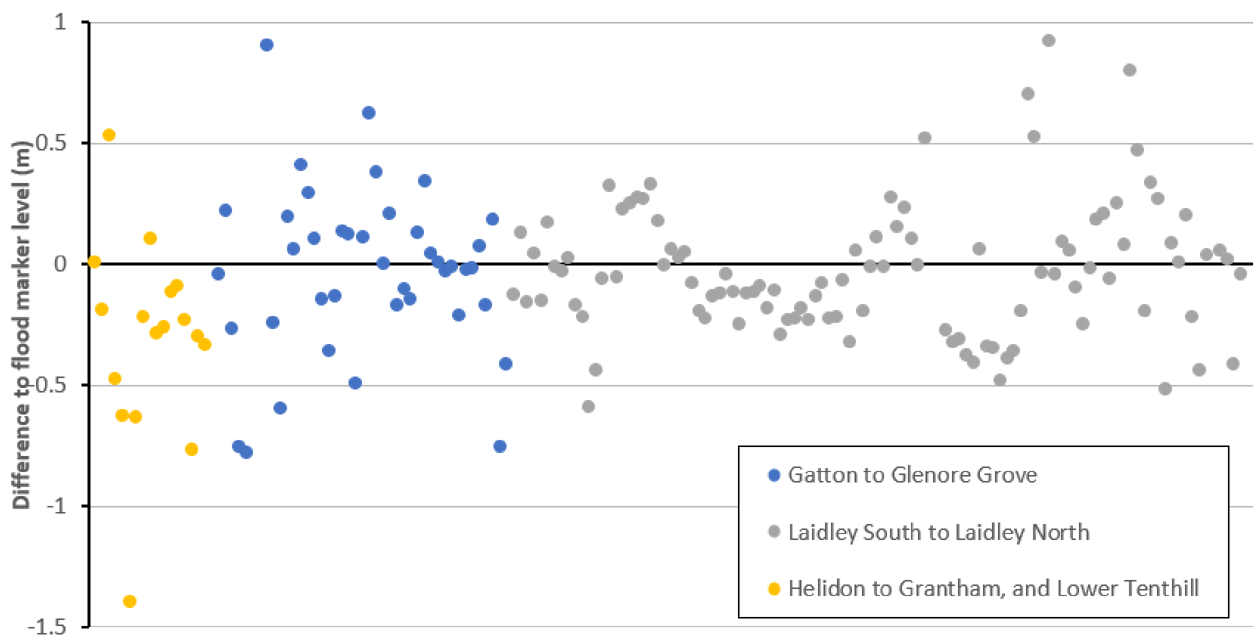


Figure 7.29 **Lockyer Creek 2013 – Flood marker difference**

7.7 Western Creek joint calibration results

Initial estimates for roughness were based on the BMT (current) Bremer River Flood Study for ICC and confirmed using aerial imagery. The TUFLOW model set up is presented Appendix B Figure B-1C. These values were then refined to achieve the desired relationship between flow and level at the stream gauges. Typical roughness parameters adopted for the hydraulic model are summarised in Table 7.3, and are indicative of the conditions present. It should be noted that, as with the ratings, these values are understood to be indicative of typical creek/catchment conditions and may be different during any individual flood event.

Table 7.3 Western Creek Manning's Roughness parameters adopted for the hydraulic model

Land use	Manning's roughness coefficient n
Non-tidal waterway	0.030
Grassland (Long)	0.040
Light vegetation	0.040
Agriculture/fields/parks	0.035
Dense vegetation	0.080
Very dense vegetation	0.120
Rough pasture/Light brush	0.060
Roads/carparks	0.025
Medium density urban block	0.100
Mining	0.070

Appropriate roughness parameters for the Bremer River/Western Creek TUFLOW model were determined by comparing the model level-depth relationship with the rating at the Walloon gauge. Figure 7.30 shows the relationship between level and flow for the 1974 flood hydrograph. Walloon has a reliable rating curve that is based on flow measurements up to ~900 m³/s and extended using a MIKE 21 model for the BRCFS. The TUFLOW model identifies minor hysteresis effects above ~500 m³/s, however in general shows excellent agreement with the BRCFS rating curve.

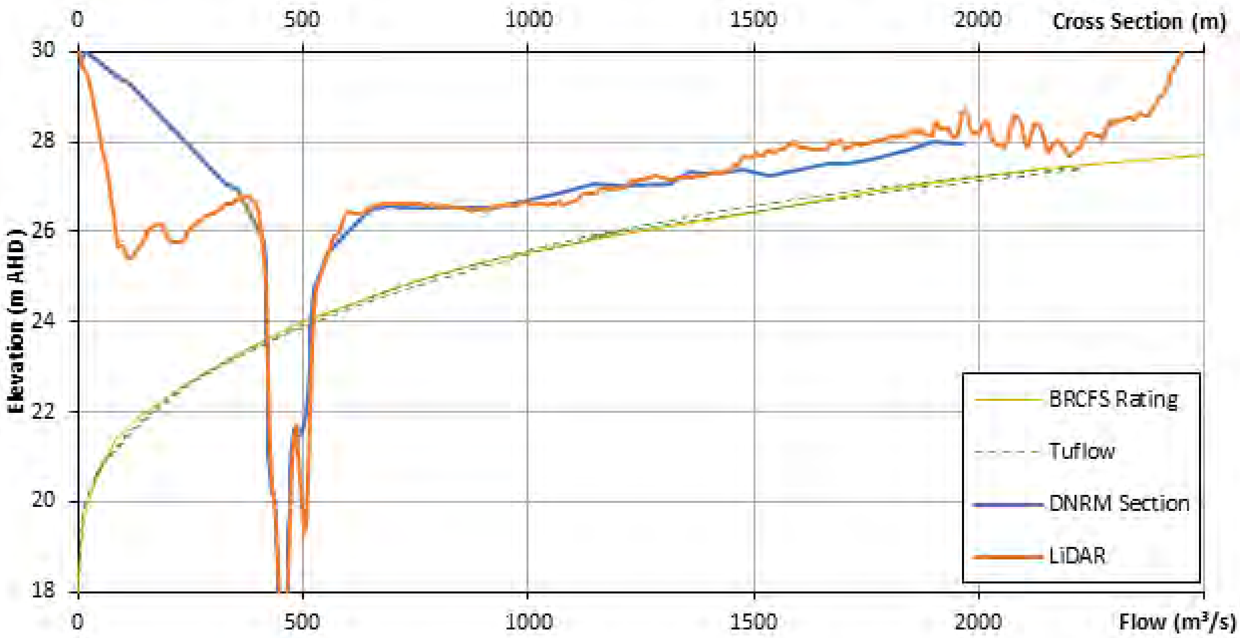


Figure 7.30 Comparison of TUFLOW flow-depth relationship with the Walloon rating

The BOM Alert gauge at Rosewood does not have any stream flow measurements or an official flow rating curve. A validation rating curve was developed for the BRCFS by fitting a power-law relationship through estimated event peak flows in the Bremer River at Rosewood (from the URBS model calibrated to Walloon) with corresponding peak levels observed at the Walloon gauge. The rating was developed using data from 17 historical events, typically between 100 m³/s and 1,200 m³/s, noting that the rating reliability decreases away from this range. Comparison between the derived rating and the TUFLOW level-flow relationship is shown in Figure 7.31. Although this does not provide independent confirmation of the modelled flows, it does identify a good consistency between the modelled flows and the observed flood levels.

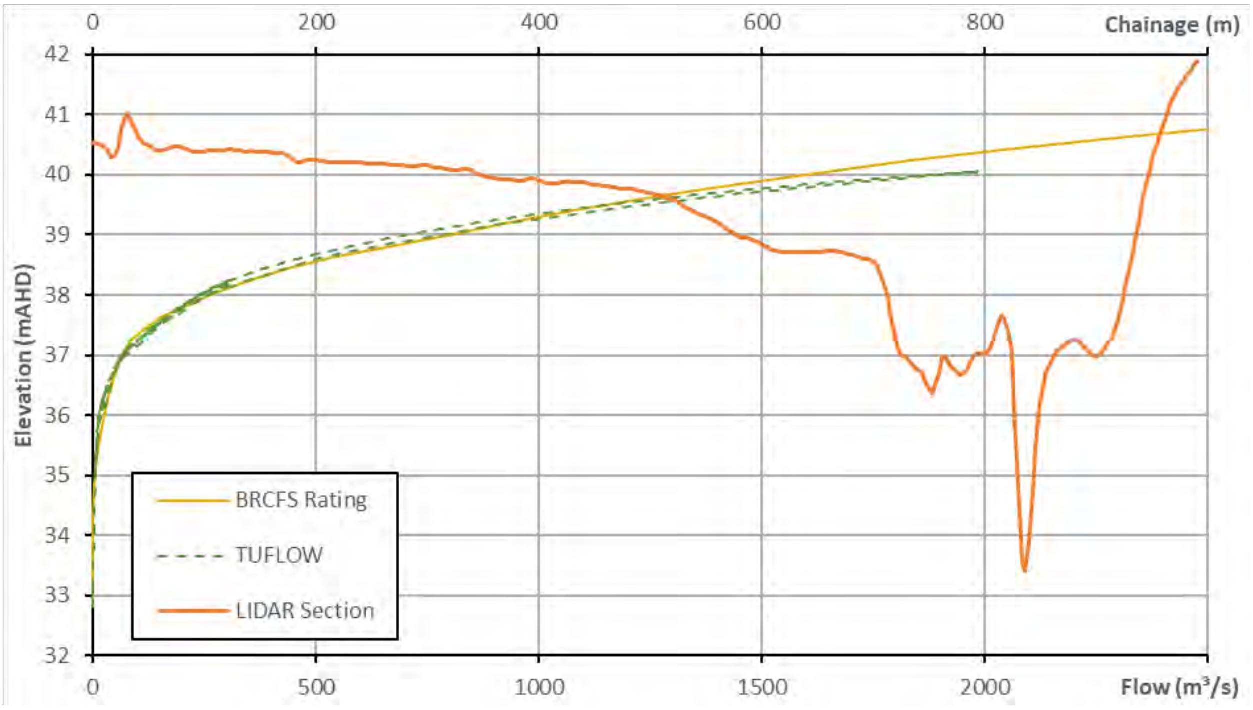


Figure 7.31 Comparison of TUFLOW level-depth relationship with the Rosewood rating

The DNRME Kuss Road stream gauge in the upper Western Creek catchment has only been operational since September 2011. A BoM gauge site was located on the site prior to this, but only limited peak water level records are available and the gauge was rated. The DNRME gauge rating curve is based on a maximum measured flow at site of 120 m³/s at 52.5 m AHD, recorded during the 2013 flood. Review of the cross-section suggests that flows capacity would increase significantly above this level, so extrapolation beyond this level is highly uncertain. The DNRME rating and the TUFLOW level-flow relationship are shown in Figure 7.32. Also shown in the figure are the flood levels recorded at the DNRME gauge for the 2013 flood plotted against flow modelled in URBS and older historical flood peaks recorded at the BOM gauge against the peak flow predicted by the URBS model.

The TUFLOW level-flow relationship shows very good agreement with the DNRME rating up to 50.5 m AHD. Above this level it appears to show good consistency with the BoM historic flood peaks but not the DNRME gauge levels. Review of historical aerial photographs identified that the bridge and approach road underwent a significant upgrade at some time between 1997 and 2002. The current bridge level is 53m AHD, and interference of the bridge deck is a likely cause for the discrepancy between the BoM gauge record (1974 and 1996) and the current DNRME gauge records (2013). This bridge is not included in the TUFLOW model. The TUFLOW model parameters are considered to give a good representation of the channel characteristics excluding impacts of the bridge. Considering the hydraulic grade during flood events, these are expected to be localised to several hundred metres upstream of the bridge and should decrease during major flood events when large flows are conveyed outside the channel.

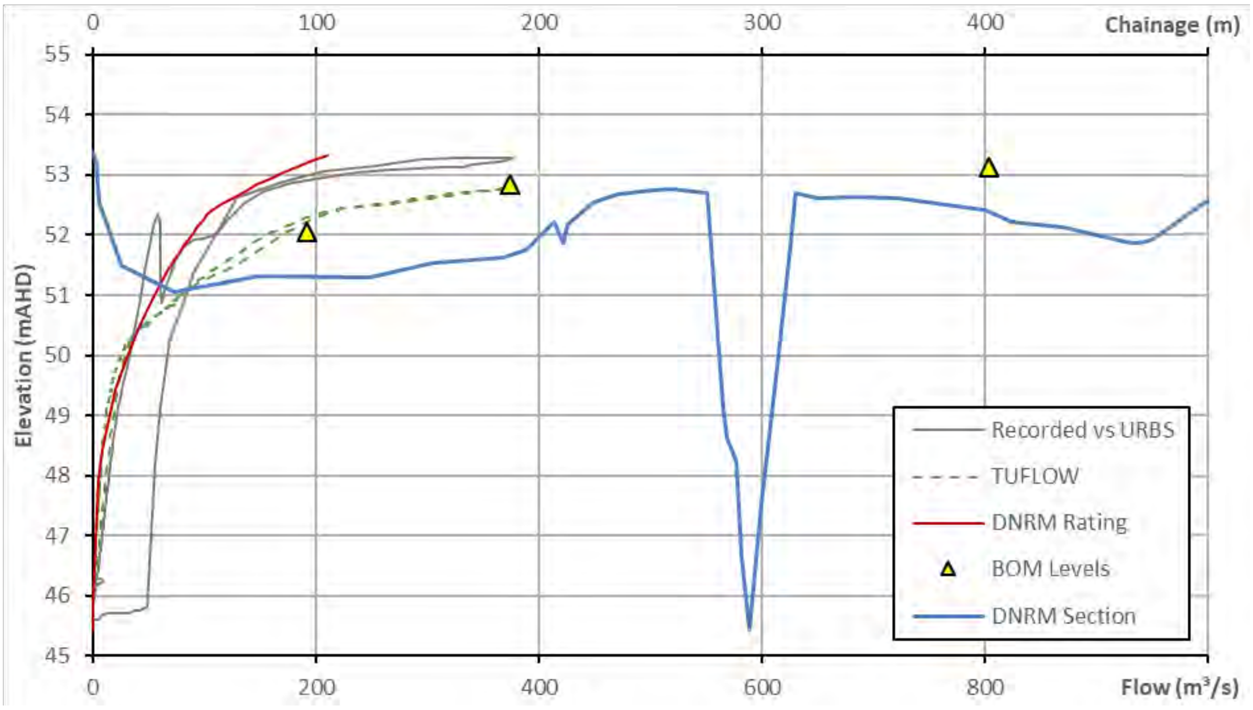


Figure 7.32 Comparison of TUFLOW flow-depth relationship with the Kuss Road rating

7.7.1 January 1974

The 1974 flood is the largest flood known to have occurred in the Bremer River catchment, exceeding even the 1893 floods (the largest recorded Brisbane River floods) which were caused by heavy rainfall in the Upper Brisbane and Stanley River catchments. Unfortunately, the continuous stream gauge at Walloon was not operational during the 1974 flood and only a flood peak flood level is available, reducing the usefulness of the event for calibration purposes. Rainfall losses for the event were estimated based on adjacent catchments. The only site at which continuous stream gauge data is available is at Adams Bridge in the upper Bremer River. Comparison between the URBS hydrologic model and rated stream gauge flows is shown in Figure 7.33. Although the model overestimates the flow at the start and end of the event, the timing, shape and magnitude of the main peak are considered a reasonable match given the small size of the catchment and limited rainfall data.

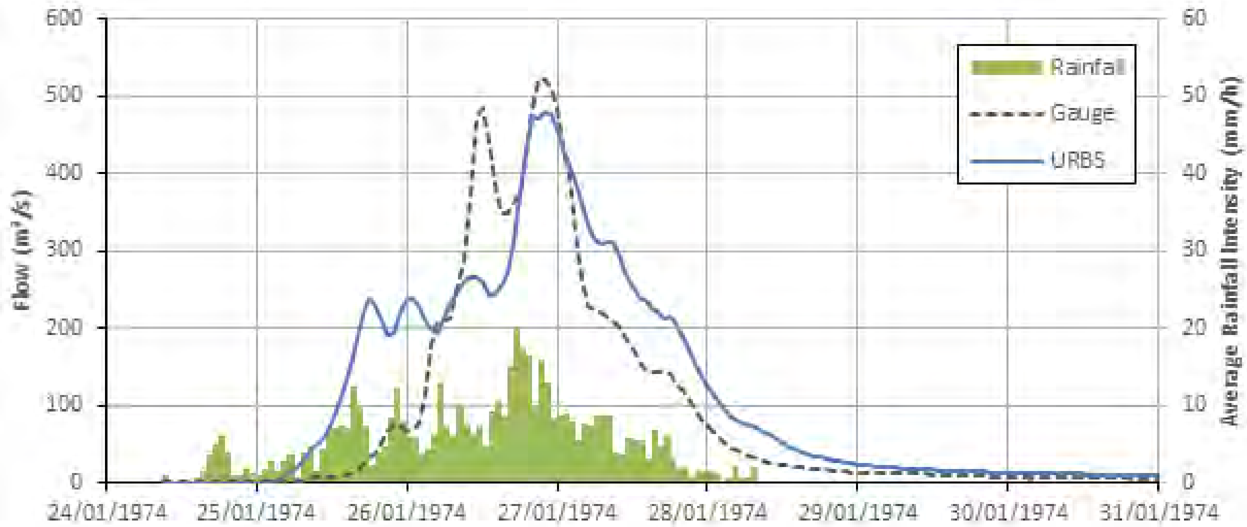


Figure 7.33 Comparison of URBS and stream gauge hydrographs at Adam's Bridge for the 1974 event

The flow hydrographs for the 1974 flood event produced by the hydrologic model and hydraulic model at Kuss Road and Walloon are compared in Figure 7.34 and Figure 7.35 respectively. These demonstrate that although there are a few minor differences in timing, the overall shape and peak of the hydrograph are very similar at both locations. At Kuss Road the timing differences are negligible, while at Walloon the mid-range (between 300 m³/s and 1,200 m³/s) TUFLOW flows tend to lag behind URBS by around 2 hours, particularly on the rising limb, but agree relatively well for lower and higher flows including the peak.

The hydrologic model flows (and consequently the hydraulic model) underestimate the rated peak flow at Walloon by approximately 500 m³/s (note that this corresponds to only 0.44 m difference in gauge height). There are several potential causes for this, including rating error and sensitivity, variability of floodplain vegetation. or simply a shortfall in the recorded rainfall. Alternatively, the gauge site is also suspected to have some minor backwater influence from the downstream confluence with Warrill and Purga Creeks during major events, which would cause the flood level (and corresponding rated flow) to be increase.

A peak level of 53.12 m AHD was recorded at the BoM alert gauge at Kuss Road. The hydraulic model reaches a peak of 53.17 m AHD, only 50 mm higher (refer Figure 7.32).

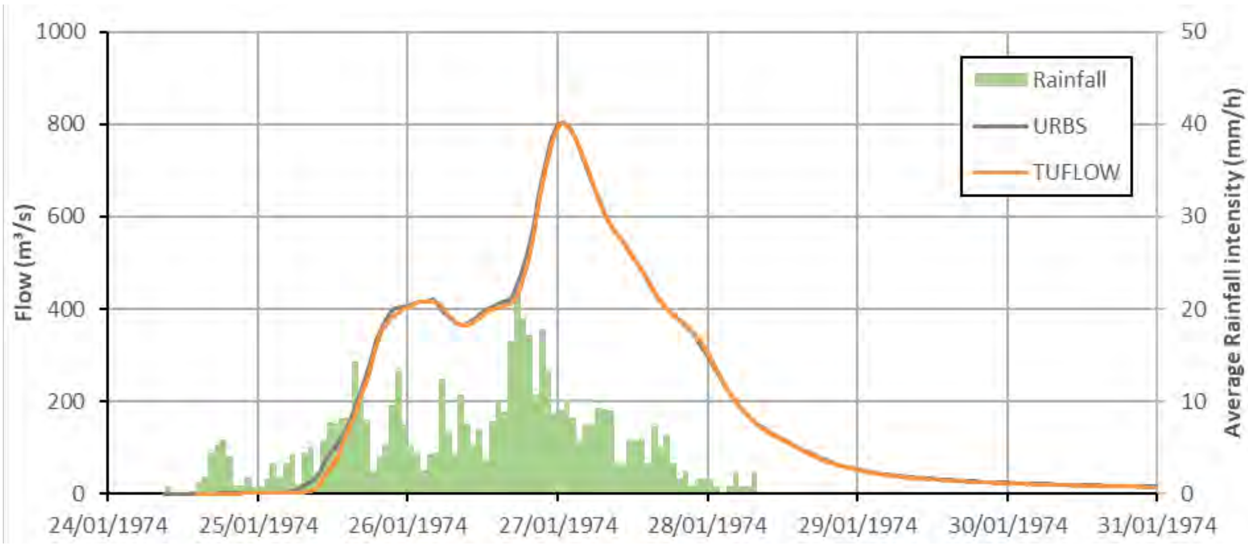


Figure 7.34 Comparison of URBS and TUFLOW hydrographs at Kuss Road for the 1974 event

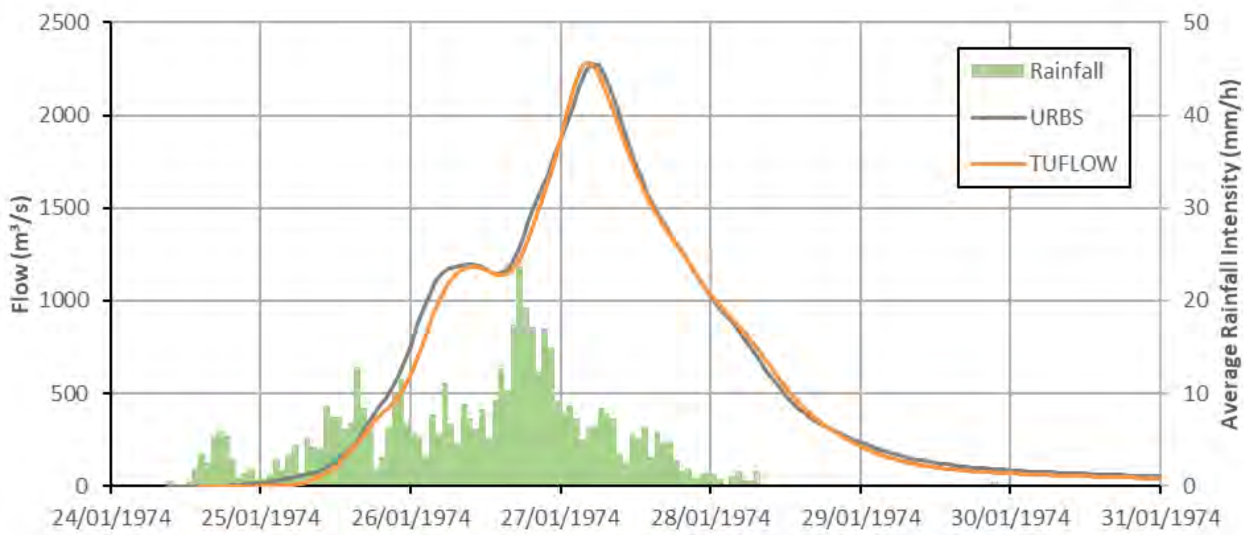


Figure 7.35 Comparison of URBS and TUFLOW hydrographs at Walloon for the 1974 event

7.7.2 May 1996

As discussed in Section 7.6.2, the 1996 flood is the combination of several different rainfall storm cells resulting in a number of distinct peaks over several days. The largest of these peaks was approximately half the size of the 1974 flood. Comparisons of the flow hydrographs for the 1996 flood event produced by the URBS hydrologic model and TUFLOW hydraulic model (where available) at Adams Bridge in the upper Bremer River, Kuss Road in upper Western Creek and Walloon in the lower Bremer are provided in Figure 7.36, Figure 7.37, and Figure 7.37 respectively.

Despite using parameters focussed on calibrating flows at Walloon, a reasonable match of the hydrograph shape and timing is achieved at Adams Bridge in the upper catchment. Flood peaks of 52.05 m AHD and 52.85 m AHD were recorded at the BoM gauge at Kuss Road on the 2^{nd} and 3^{rd} of May respectively. The TUFLOW model replicates these levels to within ±150 mm (refer Figure 7.32). The rising limb of the TUFLOW hydrograph at Kuss Road initially lags behind the URBS hydrograph. This is likely to be related to an initial wetting of the channel, which has a relatively course definition in the 10 m grid, as the receding limb matches almost exactly.

The TUFLOW hydrograph shape at Walloon tends to lag slightly behind the URBS hydrograph and the sharp peak is slightly more attenuated. This appears to align the TUFLOW hydrograph peak closer to the rated hydrograph. Although this may be coincidence considering other parts of the hydrograph and other events, it is likely to be related to initial flooding of the floodplain around the confluence of the Bremer River and Western Creek and between Rosewood and Walloon that is constrained by high ground around the Walloon gauge site (refer Figure 7.30). Ponding caused by this restriction would not be specifically modelled by the basic URBS routing. Overall, this is considered a good match considering the variability/uncertainty of the rainfall data involved in this event.

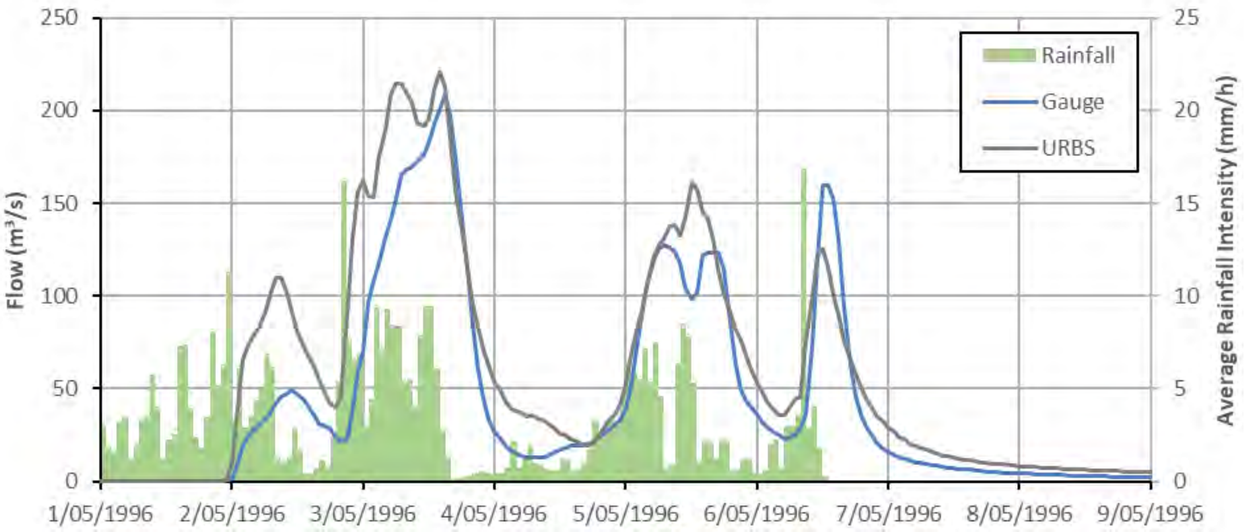


Figure 7.36 Comparison of URBS and stream gauge hydrographs at Adam's Bridge for the May 1996 flood

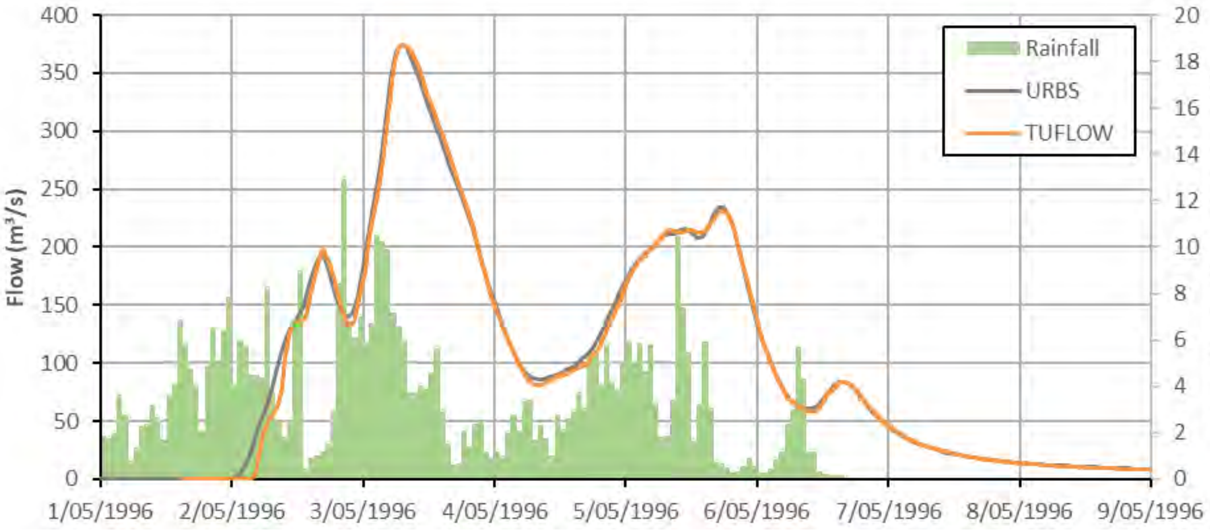


Figure 7.37 **Comparison of TUFLOW and URBS hydrographs at Kuss Road for the May 1996 flood**

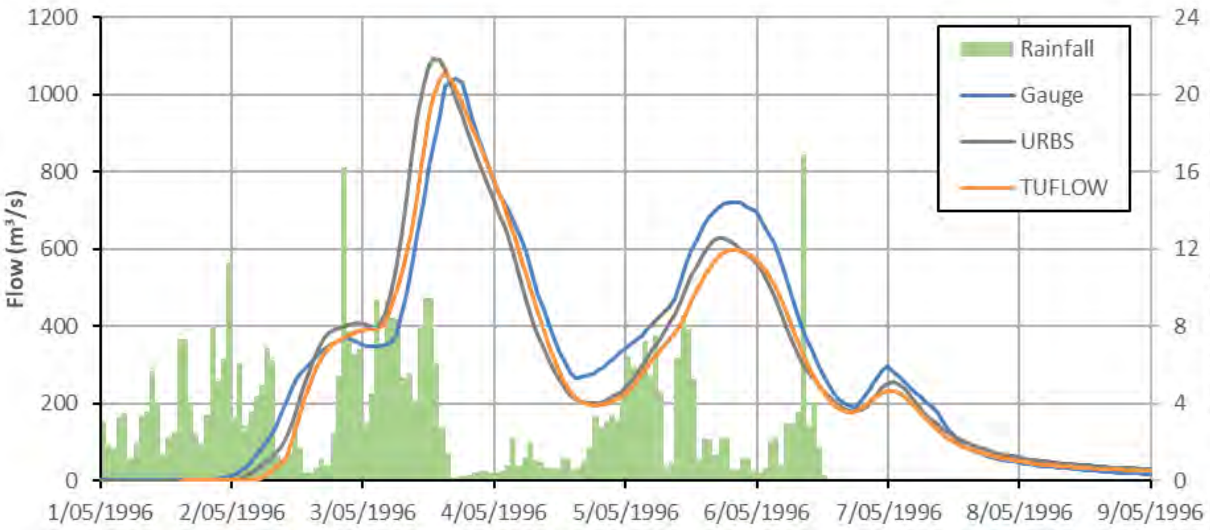


Figure 7.38 **Comparison of URBS, TUFLOW and stream gauge hydrographs at Walloon for the May 1996 flood**

7.7.3 February 1999

The 1999 flood event was only a minor flood in the Bremer River catchment despite being a relatively large flood in the upper Brisbane River upstream of Wivenhoe, being roughly a fifth of the size of the 1974 and 2011 floods. Rainfall occurred over the catchment for around 2.5 days, containing numerous bursts. Comparison of the URBS flows with the rated gauge flows at Adams Bridge in the upper Bremer River, shown in Figure 7.39, indicate that although the model replicates the general timing of the bursts and shape of the hydrograph, the rainfall losses selected for calibration of the model at Walloon do not replicate the magnitude of the peaks in the upper catchment.

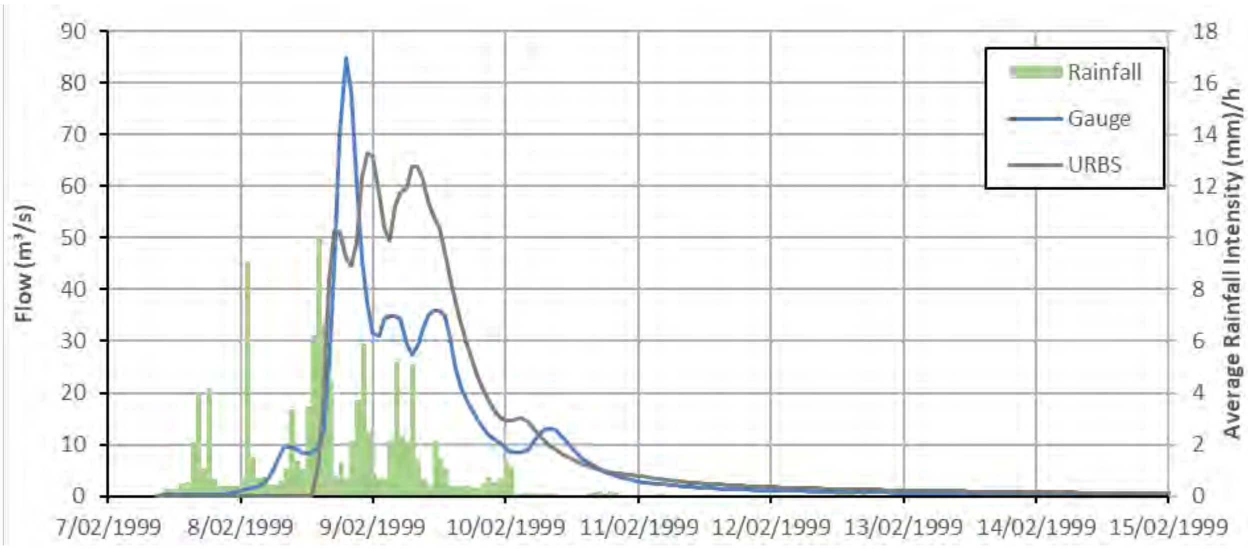


Figure 7.39 **Comparison of the URBS and stream gauge hydrographs at Adam's Bridge for the February 1999 flood**

The Kuss Road gauge record does not include a peak for the 1999 flood. The TUFLOW hydrograph shows the same initial lag on the rising limb of the hydrograph as is observed for other events, but otherwise matches the URBS model hydrograph.

Flow hydrographs for the 1999 flood event produced by the URBS hydrologic model and TUFLOW hydraulic model at Walloon, shown in Figure 7.41, display some minor timing differences and a slight attenuation of the peak. Considering the burst-like rainfall distribution across the catchment, a relatively good agreement of the recorded hydrograph shape and timing is achieved.

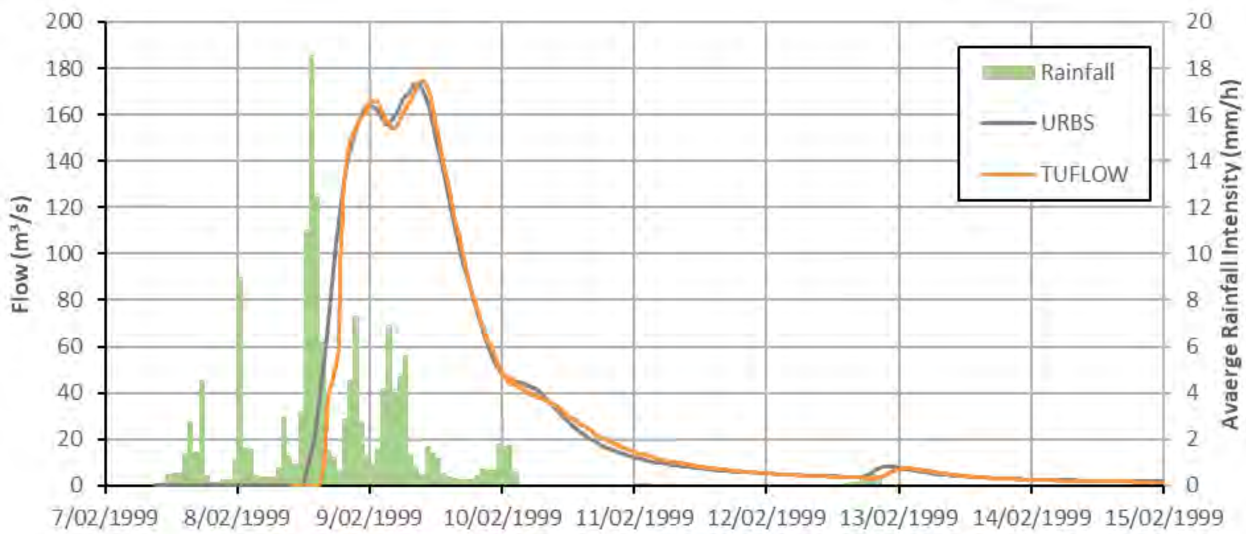


Figure 7.40 **Comparison of the URBS and TUFLOW hydrographs at Kuss Road for the February 1999 flood**

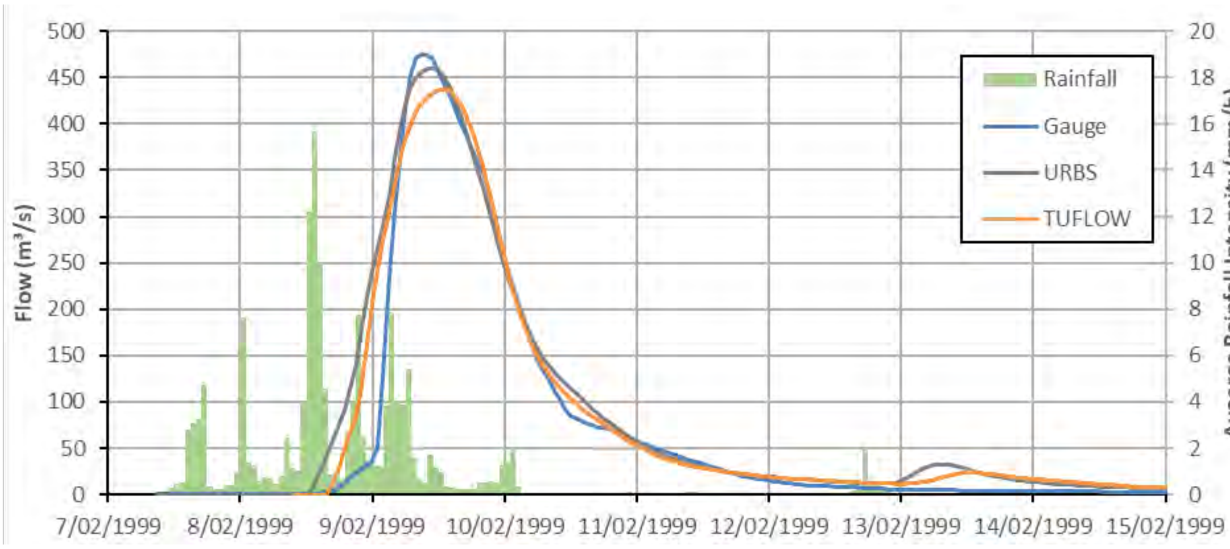


Figure 7.41 **Comparison of URBS, TUFLOW and stream gauge hydrographs at Walloon for the February 1999 flood**

7.7.4 January 2011

The 2011 flood is the largest recorded flood in the upper Bremer River at Adams Bridge, but peaked slightly lower than 1974 in the lower Bremer River. As with the Lockyer Creek catchment, the overall event was the combination of several distinct rainfall bursts across 10 and 11 January 2011. Comparison of URBS model and rated flows at Adams Bridge in Figure 7.42 demonstrates that the URBS model replicates the timing, shape and approximate magnitude of the hydrographs in the upper catchment, noting that the model calibration considered the wider Bremer and Brisbane River model calibration, hence the overall shape and volume of the hydrograph was as or more important than the absolute peak at this location.

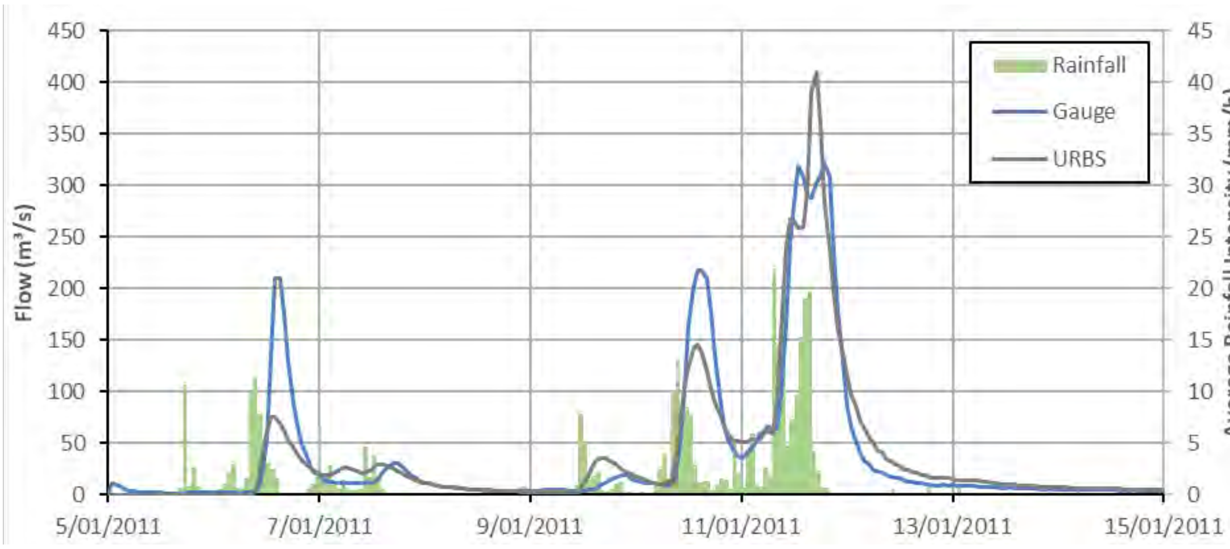


Figure 7.42 **Comparison of URBS and stream gauge hydrographs at Adam's Bridge for the 2011 flood**

The BoM gauge at Kuss Road on Western Creek failed during the 2011 event and did not capture the flood event, however flood levels for the 2011 event were recorded by the BoM ALERT gauge on Western Creek at the Rosewood WWTP, just upstream of the confluence with the Bremer River. There is no official gauge rating for the BoM gauge, and although Seqwater has estimated a rating based on comparison of URBS flows and recorded levels, the gauge has only been operational since 2001 and there are therefore few historical events and the rating has very low reliability. Widespread flooding also occurs around the confluence during large events and flow transfers between Western Creek and the Bremer River, making it difficult to define a specific 'Western Creek flow' for comparison. Water levels from the TUFLOW model are compared with gauge levels in Figure 7.43. The model nevertheless appears to replicate very well both the levels and timing of the recorded flood.

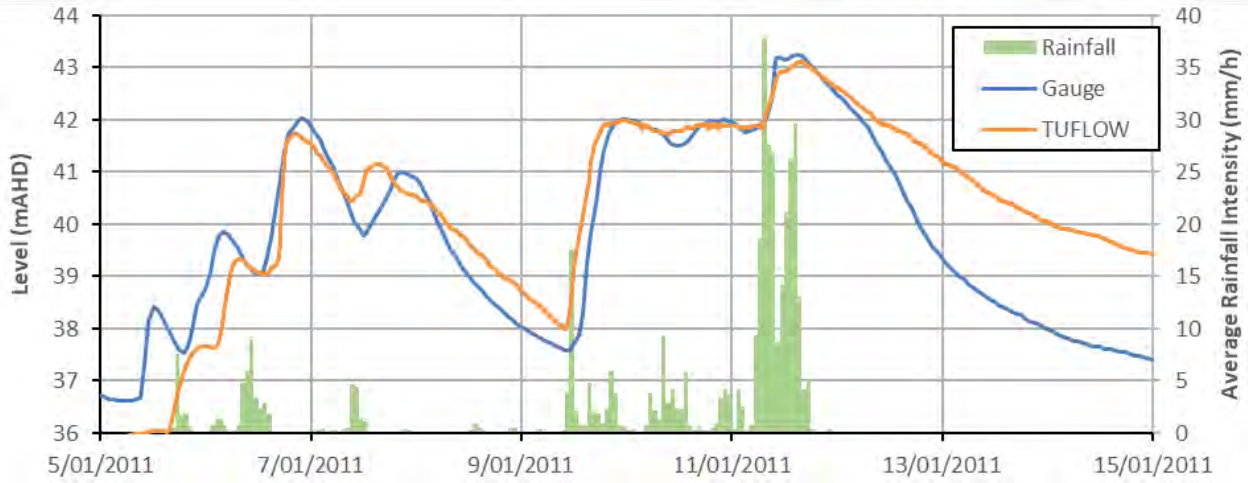


Figure 7.43 **Comparison of TUFLOW and recorded water levels at Rosewood Wastewater Treatment Plant for the 2011 flood**

The hydrologic and hydraulic model hydrographs for the 2011 flood at Walloon are compared in Figure 7.45. As with the other flood events, the TUFLOW hydrograph tends to lag behind the URBS hydrograph for flows between 300 m³/s and 1500 m³/s but matches the peak. The hydrographs generally match the shape of the observed hydrograph. The difference in timing between the recorded peak and modelled peaks is only 1 hour. The URBS flows, calibrated with consideration to gauges further upstream (Adams Bridge) and downstream (Moggill, Centenary Bridge and Brisbane) does not match the exact peak of the event due to concerns the Walloon gauge level near the flood peak may have been influenced by backwater and hence overestimated the rated flow.

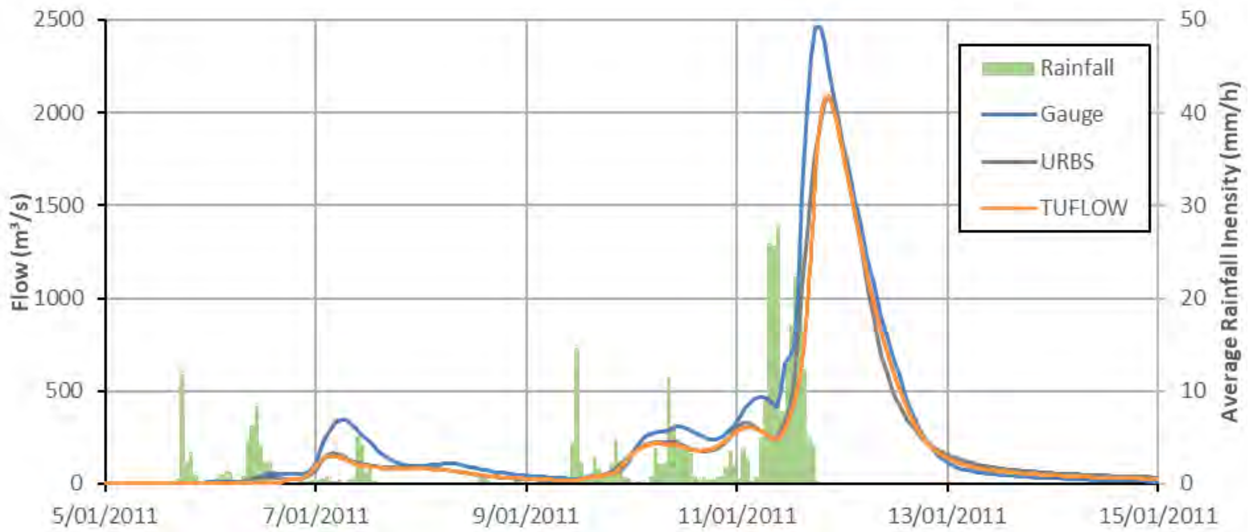


Figure 7.44 **Comparison of URBS, TUFLOW and stream gauge hydrographs at Walloon for the 2011 flood**

ICC provided a number of flood markers in the Bremer Catchment for the 2011 event. These recorded levels have a range of accuracies based on their source. Of these markers 47 were relevant for the Western Creek Catchment. The flood markers are presented in Appendix B Figure B-2F.

In general, 74 per cent of the flood marker points are within 300 mm of the hydraulic results. Further to this 93 per cent of the flood markers are within 500 mm of the hydraulic results. The remaining three flood markers appear to be outliers. The distribution of these calibration points is outlined in Figure 7.45.

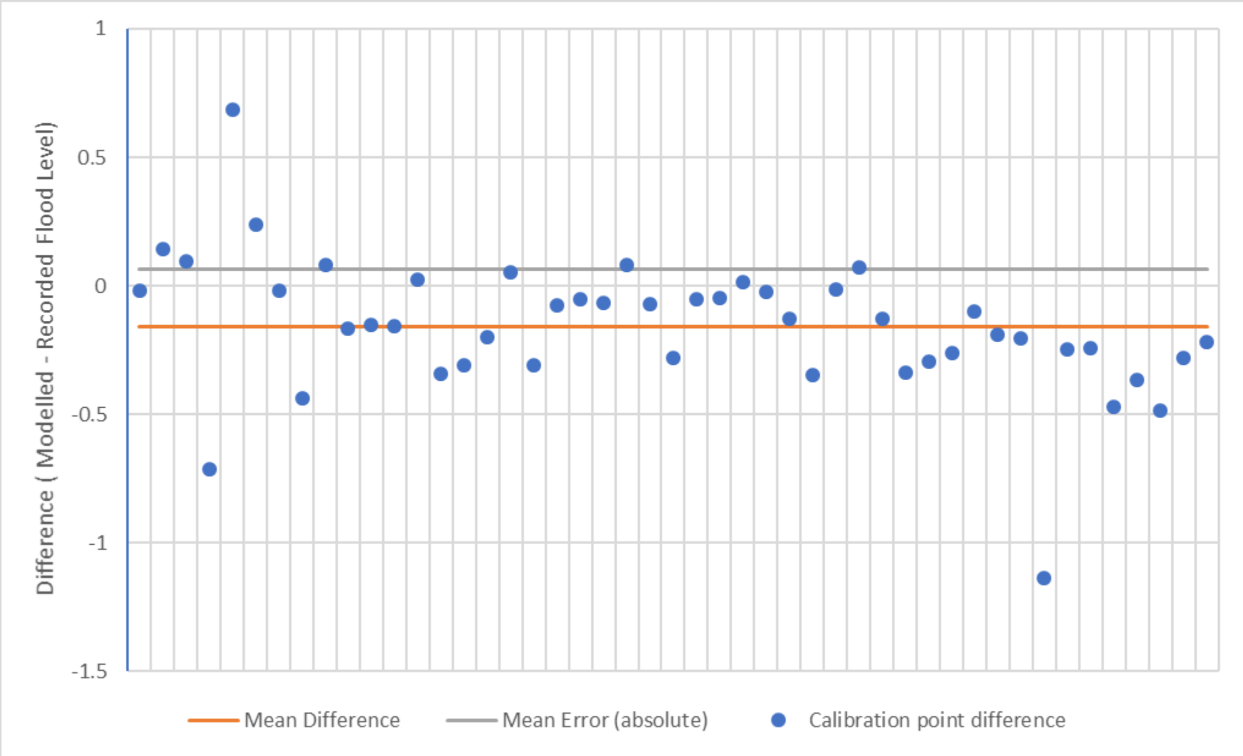


Figure 7.45 Western Creek 2011 – Flood Marker Difference

7.7.5 January 2013

The 2013 flood was caused by prolonged, wide-spread rainfall producing a single flood peak in the lower catchment. The rainfall event consisted of several days of light rainfall followed by nearly a day of relatively consistent rainfall. While moderate rainfall occurred several days prior to the 2011 flood, the 2013 flood occurred on a very dry catchment. Significant rainfall (>150 mm) occurred before any runoff was observed. The URBS and recorded hydrograph at the Adams Bridge gauge in Figure 7.46 show good match of the hydrograph shape, noting that the loss parameters are not specifically selected for this site.

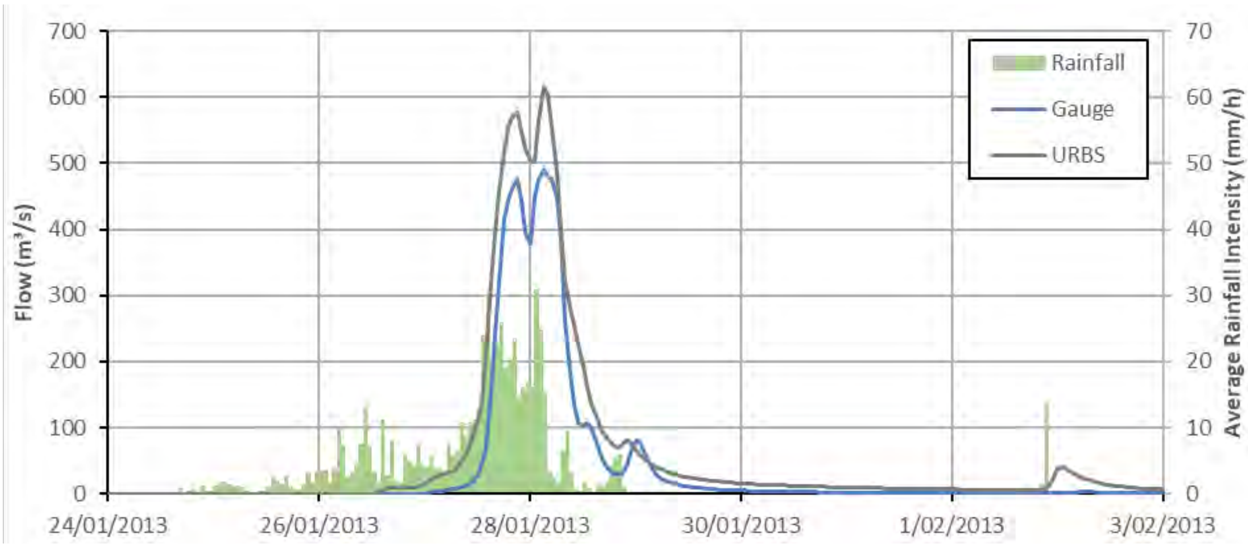


Figure 7.46 Comparison of URBS and stream gauge hydrographs at Adam's Bridge for the 2013 flood

Flood levels at Kuss Road on Western Creek were recorded by the new DNRME gauge. Rated flows using the current DNRME rating are compared with the Hydrologic and hydraulic model hydrographs in Figure 7.47. The rated hydrograph shows a good match of the timing but predicts significantly lower flows for the flood peak. The TUFLOW model does not include the Kuss Road bridge, hence the model underestimates peak levels by approximately 0.5 m (refer Figure 7.32).

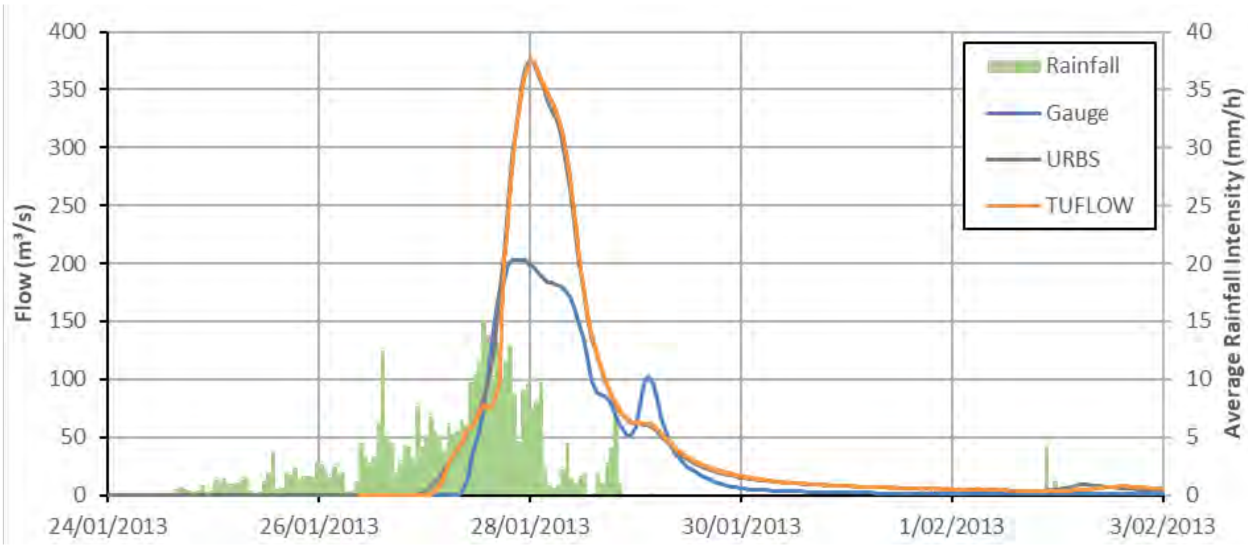


Figure 7.47 Comparison of URBS and TUFLOW hydrographs at Kuss Road for the 2013 flood

Hydrologic and hydraulic model hydrographs for the 2013 event at Walloon are compared in Figure 7.48. As with other mid-sized floods (<1400 m³/s) there is a slight offset between the modelled hydrographs. Although the models do not exactly match the recorded 'spike' at the peak of the flood, the overall shape of the hydrograph is well represented.

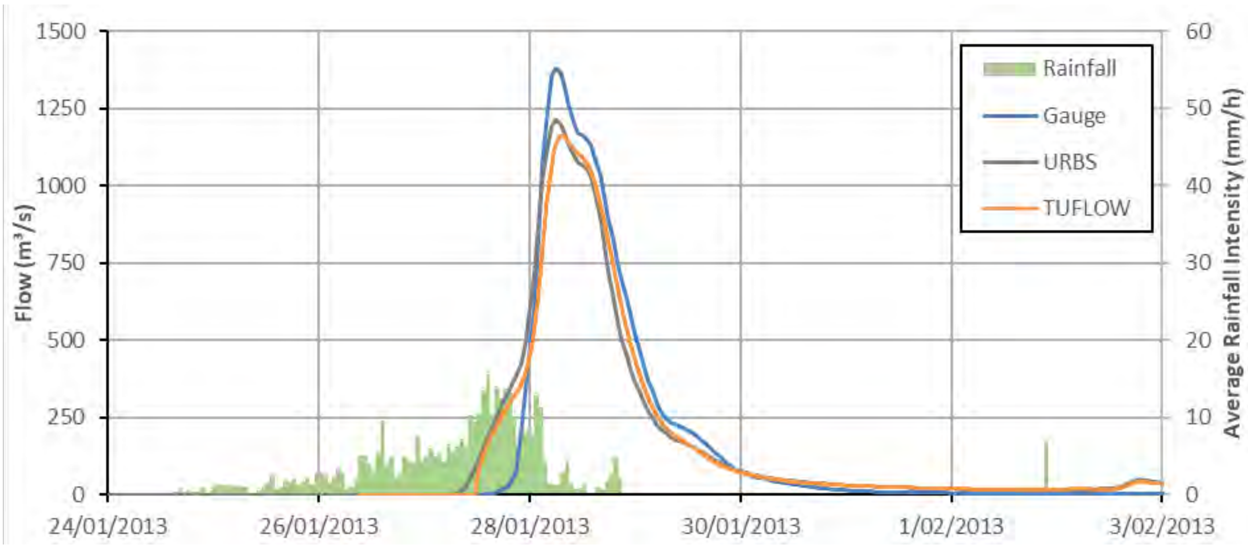


Figure 7.48 Comparison of URBS, TUFLOW and stream gauge hydrographs at Walloon for the 2013 flood

7.8 Estimation of Annual Exceedance Probability

For each of the major stream gauges the AEP of each historical event has been estimated and is outlined in Table 7.4.

Table 7.4 AEP of historical events

Stream gauge	Historical event AEP (Peak discharge (m³/s))				
	1974	1996	1999	2011	2013
Gatton Weir	~2.4% (2054)	~3.2% (1666)	~21% (381)	~1.8% (2394)	~29% (1777)
Gatton	~2.4% (2050)	~3.2% (1667)	~21% (380)	~1.8% (2395)	~29% (1776)
Glenore Grove	~2.5% (2859)	~4% (2131)	~25% (405)	~1.1% (3854)	~2.5% (2794)
Walloon	~0.5% (2282)	~10% (1050)	~30% (437)	~0.6% (2084)	~8% (1163)

7.9 Calibration model comparison

A summary of available peak recorded gauge levels for each of the primary gauges is presented in Table 7.5 below. Modelled levels for the URBS and TUFLOW models are also included in the table for reference.

Table 7.5 Historical level comparison

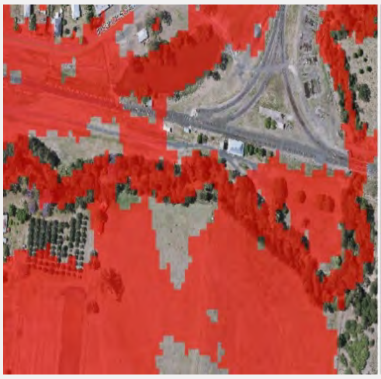
Year	Stream gauge	Recorded gauge level (m AHD)	Modelled URBS gauge level (m AHD)	Modelled TUFLOW level (m AHD)
1974	Helidon	136.08	136.12	135.44
1974	Gatton	102.17	104.07	102.09
1974	Glenore Grove	82.06	82.47	82.23
1996	Helidon	135.49	136.47	136.56
1996	Warrego Hwy	83.08	83.08	83.47
1996	Glenore Grove	81.42	81.86	81.78
1999	Helidon	134.66	134.09	134.27
1999	Gatton	96.04	95.94	94.36
1999	Warrego Hwy	81.43	79.58	78.99
1999	Glenore Grove	77.79	77.90	78.00
2011	Helidon	141.99	136.56	136.60
2011	Gatton Weir	103.31	104.22	103.81
2011	Forest Hill	93.82	94.58	93.82
2011	Warrego Hwy	84.44	84.54	84.29
2011	Glenore Grove	82.45	82.44	82.41
2011	Walloon	27.68	27.34	27.20
2013	Helidon	134.37	135.15	135.32
2013	Gatton Weir	101.10	102.11	102.27
2013	Forest Hill	93.79	94.11	93.77
2013	Warrego Hwy	83.72	84.19	83.98
2013	Glenore Grove	82.21	82.15	82.23
2013	Walloon	26.25	25.97	25.87

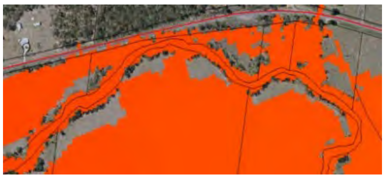
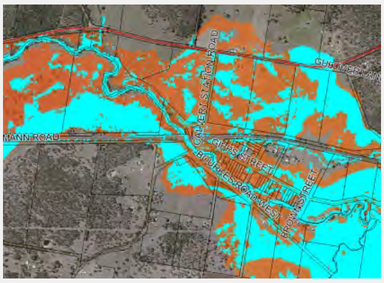
To gain an understanding of the potential Project impacts relative to these historical events, the estimated AEP for each historical event can be compared to the results for the design events (e.g. 1% AEP) documented in Section 9.

7.10 Community consultation feedback

Community consultations sessions were undertaken to gather historical hydraulic validation information. Table 7.6 outlines several photographs and statement received from the community which have been used to validate calibration of the hydraulic models. More details regarding the Community Consultation sessions are included in EIS Appendix D: Consultation report.

Table 7.6 Community feedback information

Description	Photo or community feedback	Model results	Modelling results
Forest Hill Comment from community consultation session referring to sporting fields in Forest Hill	*"Flooding came to the batting square. Town is totally isolated in times of flooding."*		Flood waters reach the outskirts of the sporting complex in both 2011 and 2013 historical calibration results.
Laidley Comment from community consultation session referring to the QR rail/road crossing in Laidley.	*"Could stand on level crossing in Laidley and one side was dry while other side water lapping rail lines."*		The 2013 calibration model results show the northern side of the level crossing is dry whilst the southern side is inundated.
Grandchester Comment from community consultation session referring to Grandchester Hotel.	*"Big floods – level was about two steps up to the pub"*		In the 2011 and 2013 historical calibration model results show flood waters reach the Grandchester Hotel.
Grandchester Comment from community consultation session referring to the QR Rail in Grandchester.	*"Existing alignment prone to flooding."*		Historical calibration event results show overtopping of existing QR West Moreton System rail corridor.
Grandchester Comment from community consultation session referring to 10 School Road, Grandchester.	*"Flood levels came into inside the house. The house was elevated but it still flooded internally."*		2011 historical calibration results show levels of 250 mm to 1.4 m on the property. The house on the property shown to be within the flood extent.

Description	Photo or community feedback	Model results	Modelling results
Grandchester Comment from community consultation session referring to 40 School Road, Grandchester.	*"In 2011 event, water came up to feed shed in paddock. Water hangs there for 3-4 days. Water was very fast flowing - like rapids. Water came up fast. 2013 event wasn't as bad - just got to pig sty."*	 	Blue = 2013 and Red = 2011 events. The historical calibration results show that the 2011 flood extent reaches up to the feeding shed as described. Whereas the 2013 event shows flood waters reaching the pig sty.
Calvert Comment from community consultation session referring to Rosewood-Laidley Road.	*Stakeholder walked to two properties (toward Rosewood) and water was lapping at Rosewood-Laidley Road.*		The 2011 historical calibration results show the water reaching the road approximately two properties over as described.
Calvert Comment from community consultation session referring to Calvert.	*"This area floods up until you get to the high country around Calvert."*		2011 (blue) calibration results and 2013 (orange) calibration event results at Calvert showing higher country is dry.

7.11 Calibration summary

Available calibration data and previous hydrologic and hydraulic models have been collected and reviewed to support the development and calibration of the hydrologic and hydraulic models. The hydrologic models that have been adopted for this assessment are BRFCS URBS models for the Brisbane River catchments. The LVRC hydraulic model was adopted for major waterways crossing the Project alignment from Helidon to Laidley. A TUFLOW hydraulic model was developed for Western Creek between Grandchester and the C2K Project tie-in. Each hydraulic model was calibrated against five historical events with results matched to recorded data from several stream gauges. A summary of the calibration information is outlined in Table 7.7.

Table 7.7 Calibration summary

Catchment	Hydrologic modelling approach	Hydraulic modelling approach	Calibration events	Stream gauge data used
Lockyer Creek	URBS (BRCFS)	TUFLOW	1974, 1996, 1999, 2011, and 2013	Helidon, Gatton Weir, Gatton, Warrego Highway, and Glenore Grove
Western Creek (Bremer River)	URBS (BRCFS)	TUFLOW	1974, 1996, 1999, 2011, and 2013	Walloon, Rosewood, Kuss Road, Adam's Bridge, and Rosewood WWTP

Available background information was identified and collected including existing hydrologic and hydraulic models, survey, streamflow data, available calibration information and anecdotal flood data. This data was sourced from a wide range of stakeholders and is summarised throughout Section 5 and Section 6 of the report. This information was used to develop calibrated hydrologic and hydraulic models for each waterway. A good calibration was achieved for all catchments. Based on this performance, the hydrologic and hydraulic models were considered suitably calibrated to use to assess the potential impacts associated with the Project alignment.

7.12 Limitations of the calibration of historical events

In an URBS hydrologic model, the runoff characteristics of the catchment are represented by physically measured properties (area, stream length) and hydrologic storage routing governed by empirical coefficients for sub-catchment routing (lag parameter β and non-linearity exponent m) and channel storage routing (lag parameter α, non-linearity exponent n, and Muskingum translation parameter x). Although it is possible to modify these parameters to reflect localised characteristics, with the easiest method being factoring of the storage lengths, generally the coefficients are selected to be reflective of catchment characteristics at a downstream location.

Hydrologic model calibration using an historical event converts recorded rainfall, traditionally based on rainfall gauge data interpolated across the catchment, into a runoff via an assumed loss-model (typically an initial loss at the start of the rainfall and an ongoing continuing loss rate), which is then hydrologically routed to produce a flow hydrograph for comparison with flows estimated at an appropriate stream gauge. Discrepancies in the rainfall volume can to some extent be accounted for using the rainfall losses. Losses are typically assumed to be constant across the catchment, whereas rainfall discrepancies are unlikely to be so consistent. The ability to calibrate at multiple points across the catchment using the same losses is therefore contingent on both the reliability and uniformity of the rainfall data, which for a complex system such as the Lockyer catchment, with Lockyer Creek flowing from the north merging with Laidley Creek from the south at Glenore Grove, may be the exception rather than the norm. These issues are typified in the 1999 and 2011 historical events and discussed in greater detail in the sections below. Model calibration is therefore ideally based on multiple events and focusses on representing the overall catchment characteristics such as timing and shape of hydrograph, rather than just matching flow peaks.

8 Existing Case modelling

8.1 Hydrology

8.1.1 Approach

Hydrologic modelling has been undertaken using the ARR 2016 methodology. This methodology adopts a design event type approach (DEA), whereby a spatially uniform temporal pattern is applied across the whole catchment. The major difference from the previous ARR 1987 Design Event approach is that an ensemble of ten different temporal patterns are simulated for each duration and frequency rather than a single pattern. The general procedure for conducting the design event assessment was:

- Obtaining rainfall Intensity-Frequency-Duration (IFD) relationships, temporal patterns, losses and other parameters pertinent to each catchment
- Simulation of the ensemble of design events for a range of durations for each AEP using the hydraulic models developed for the BRCFS
- Application of Areal Reduction Factors (ARF) to account for catchment size (rainfall IFD is based on point intensities; ARF modifies this to provide areal average values). In each catchment, key stream gauges closest to the alignment were taken as the focal point where ARF were applied. The selection of location for the ARF (i.e. stream gauge location versus alignment location) has minimal impact on the estimated peak discharges. Therefore, the stream gauge locations were used for consistency with the FFA comparison.
- Determination of design flows for each AEP. The median peak flow of the critical storm duration (the duration that causes the highest median peak flow) was adopted. Since an ensemble of ten patterns was tested, the median value technically lies between the fifth and sixth ranked values, so current practice is to conservatively take the sixth.
- Comparison of the resulting 2016 design event flow estimates with a FFA, and, where applicable, the results of the BRCFS. Modification of the design parameters where necessary to achieve consistency (see discussion for each catchment in Section 8.1.6)
- Extraction of design hydrograph(s) for use in the hydraulic models for each catchment.

8.1.2 Rainfall data

Rainfall IFD relationships for each sub-catchment within each hydrologic model were obtained from the BoM online Data Hub. Comparison with the IFD data used for the BRCFS, based on the 2013 IFD data release, indicates that there is typically a slight increase in rainfall intensity across the Lockyer Creek and Bremer River catchments with the 2016 IFD. Table 8.1 shows the change in catchment average 24-hour rainfall depth between the 2013 IFD and 2016 IFD tables (note that these trends are not necessarily consistent for different durations or across the entire catchment). Due to the size of the catchments, IFDs were extracted at multiple locations.

Table 8.1 Change in 24-hour rainfall depth from 2013 to 2016 Intensity-Frequency-Duration tables

Catchment	50% AEP	10% AEP	1% AEP
Lockyer Creek to Glenore Grove	69.9 → 79.4 (14%)	112.9 → 119.0 (5%)	173.7 → 183.2 (5%)
Bremer River to Walloon	77.5 → 80.2 (3%)	129.8 → 134.0 (3%)	210.2 → 217.2 (3%)

8.1.3 Extreme rainfall data

Extreme rainfall events have been assessed. For extreme rainfall estimates (Probable Maximum Precipitation (PMP)), the generalised techniques described by the Generalised Short Duration Method (GSDM) and Generalised Tropical Storm Method Revised (GTSMR, BoM 2003) were adopted. The techniques specified in Book VIII of ARR 2016 have been used to interpolate design rainfall estimates between 1 in 2,000 AEP (i.e. credible limit of extrapolation) and the PMP.

Ten temporal patterns were adopted for 15 durations from 1 to 120 hours for 1 in 10,000 AEP, 1 in 100,000 AEP and the PMP.

8.1.4 Design rainfall losses

Rainfall losses are applied to a hydrologic model to represent rainfall that does not contribute to overland flow (i.e. infiltrates the ground or is lost to evaporation). The loss method adopted was the initial/continuing loss model, where the initial loss (in mm) represents initial catchment wetting where no runoff is produced, followed by a constant continuing loss rate (in millimetres per hour (mm/h)) to account for infiltration/evaporation during the rainfall runoff process.

Design event IFD data and temporal patterns are based on 'bursts' rather than complete storms; that is, they represent the worst part of a rainfall event that may (or may not) be preceded or followed by additional rainfall. The initial losses applied to a design event may therefore be different from those applied to a full storm (e.g. a calibration event). The ARR (2016) design event methodology tries to address this issue by combining a constant Initial Loss depth with a variable pre-burst depth, a depth of rainfall assumed to occur sometime before the design burst[1]. The pre-burst depth is a function of event duration and frequency. Recommended loss and pre-burst depths are accessed from the online ARR Data Hub. ARR losses for each sub-model are listed in Table 8.2.

Table 8.2 ARR 2016 catchment losses

Catchment	ARR Data Hub		Adopted	
	Initial loss (mm)	Continuing loss (mm/h)	Initial loss (mm)	Continuing loss (mm/h)
Lockyer Creek	31	1.3	31 (>=1% AEP) 56 (2% AEP) 110 (<2% AEP)	2.0
Bremer River	23	1.5	23 (>=20% AEP) 46 (<20% AEP)	1.5

It is noted that ARR Data Hub values (in particular losses) are based on generalised regression of catchment characteristic and are intended to provide typical values for use where local catchment specific data is unavailable. Forty-eight historical rainfall/flood events were simulated during the BRCFS to calibrate/validate the hydrologic models. Median initial and continuing losses and confidence limits for the Brisbane River catchments are presented in Figure 7.1 and Figure 7.2.

Although significant variability of the losses is observed, at least partially due to discrepancies in the recorded rainfall distribution, the median losses should give a reasonable indication of the typical catchment characteristics assuming equal probability that the rainfall is over- or under-estimated.

[1] Note that ARR 2016 advises that there is currently little research into the temporal pattern of pre-burst rainfall. The appropriate methodology for applying pre-burst rainfall is open to interpretation. If the pre-burst depth is less than the initial loss, it can be simply considered to reduce the initial loss by that amount. However, if the pre-burst depth exceeds the initial loss then different software packages treat the excess pre-burst rainfall in different ways.

Although the initial and continuing losses can be attributed to physical properties of the catchment (respectively unfilled storages and infiltration for example), losses can serve other less physically based purposes in both calibration and design event modelling. Design event methodology assumes that the process for transforming design rainfall to design flood estimates is AEP neutral; that is, rainfall AEP can be directly correlated to flow AEP and there is no introduced bias that would result in the design flood estimates having a different frequency to that of the original design rainfall. Although there is almost certainly some correlation, other factors such as losses and temporal patterns can influence the relationship. It is therefore implicit in the assumption that the adopted losses are 'AEP neutral'. Modification of the losses provides a mechanism for reconciling the flow produced by rainfall-based design event methods with that determined by alternative independent methods as discussed in Section 8.1.6.

8.1.5 Areal Reduction Factor

ARF are applied to a hydrologic model to represent the statistical improbability of point design rainfall intensities affecting the whole catchment area simultaneously. As catchment size increases, the chance that the whole catchment experiences the full point design rainfall intensity decreases. It is worth noting that ARFs do not include adjustments for spatial/temporal patterns and are primarily focused on representing rainfall's average depth over a given catchment.

The ARFs applied to the Lockyer Creek and Western Creek models were based on the catchment areas upstream of the primary calibration gauges, being Glenore Grove and Walloon respectively.

8.1.6 Comparison of ARR 2016 DEA and BRCFS hydrologic outcomes

For the Project design event, flows have been estimated using the ARR 2016 design event approach (DEA) validated against flood frequency analyses at key stream gauges.

The BRCFS used two separate methods for estimating design discharges, being:

- Flood frequency analysis of stream gauge peaks
- Monte Carlo Simulation (MCS) involving stochastic assessment of randomly selected model parameters including rainfall patterns, losses and reservoir levels. Unique to the BRCFS, space-time rainfall patterns for the Brisbane River catchment were produced using a world-leading technique for generating space-time rainfall fields based on stochastic manipulation of radar data obtained from historic rainfall events to represent the complex variability of rainfall both spatially and temporally across the catchment. The MCS flows were adopted for the hydraulic component of the BRCFS.

Flow estimates from the different approaches were reconciled to produce a consistent set of recommended design flows at each location of interest within the catchment.

The first step in this process was to review and select initial and continuing loss parameters in the DEA and MCS models such that DEA and MCS results were as much as possible in accordance with FFA results for frequent events, recognising that loss values need to be consistent with those generally adopted in practice and relatively consistent (within rational explanation) across sub-catchments. Where values could not be reconciled in this manner, reconciliation required use of engineering judgement to determine which method was likely to carry the greatest confidence. In general, this meant:

- At locations where, reliable gauge records (in terms of both rating and record length) were available, FFA results were generally given greater weight
- For rare events where extrapolation of FFA curves have high uncertainty, greater reliance was placed in rainfall-based methods.

8.1.6.1 Lockyer Creek

Flow estimates for Lockyer Creek at Glenore Grove determined using the ARR 2016 design event methodology were compared with the results of the BRCFS MCS and flood frequency analyses as presented in Figure 8.1. An initial assessment was undertaken using the recommended ARR loss parameters (IL=31 mm, CL=1.3 mm/h). These showed a good agreement with the BRCFS assessment for rare events (≥ 1% AEP), however significantly overestimated the flows for frequent events. This phenomenon was also observed during the BRCFS when using constant losses, and significantly higher losses were applied to the frequent events to reconcile the MCS and ARR 1987 design event flows with the observed flood record.

Examination of the Lockyer Creek catchment identifies several reservoirs (Atkinson, Clarendon and Dyer) that are not explicitly represented in the hydrologic model, as well as a large number of farm dams and minor-stream storages, as typified in Figure 8.2. These are likely to significantly increase the amount of water storage available within the catchment, particularly during drier seasons when water levels are low. Local farmers are also known to pump directly from Lockyer Creek alluvium when the creek it is flowing. A significant proportion of the catchment is also cultivated for agriculture, which potentially leads to higher infiltration rates as compared to untilled natural catchment areas. These characteristics are consistent with Initial and Continuing Loss trends observed in the calibration events, where losses in the Lockyer Creek catchment are higher than in the other Brisbane River sub-catchments as discussed in Section 8.1.3. They have also been confirmed through discussions with LVRC and Seqwater, who have observed that flows from Lockyer Creek can often be significantly lower than would have been expected from the amount of rainfall that fell on the catchment.

To reconcile the 2016 design event peak flows with observed flood frequency records, the design event modelling was revised to adopt a continuing loss of 2 mm/h based on the model calibration losses, consistent across all AEP, while initial losses were increased for the frequent events (refer Table 8.2 for the adopted AEP varying initial losses). The reconciled values are shown in Table 8.3 and Figure 8.1.

Table 8.3 Comparison of 2016 FFJV DEA with BRCFS results at Glenore Grove

AEP (%)	BRCFS Lower 90% Confidence Interval (m^3/s)	BRCFS FFA (m^3/s)	BRCFS Upper 90% Confidence Interval (m^3/s)	BRCFS MCS (m^3/s)	FFJV DEA (m^3/s)
50	80	120	200	160	140
20	420	620	940	750	630
10	840	1,240	1,900	1,400	1,300
5	1,380	2,050	3,200	2,000	2,170
2	2,200	3,340	5,460	3,200	3,280
1	2,870	4,450	7,560	4,000	4,250

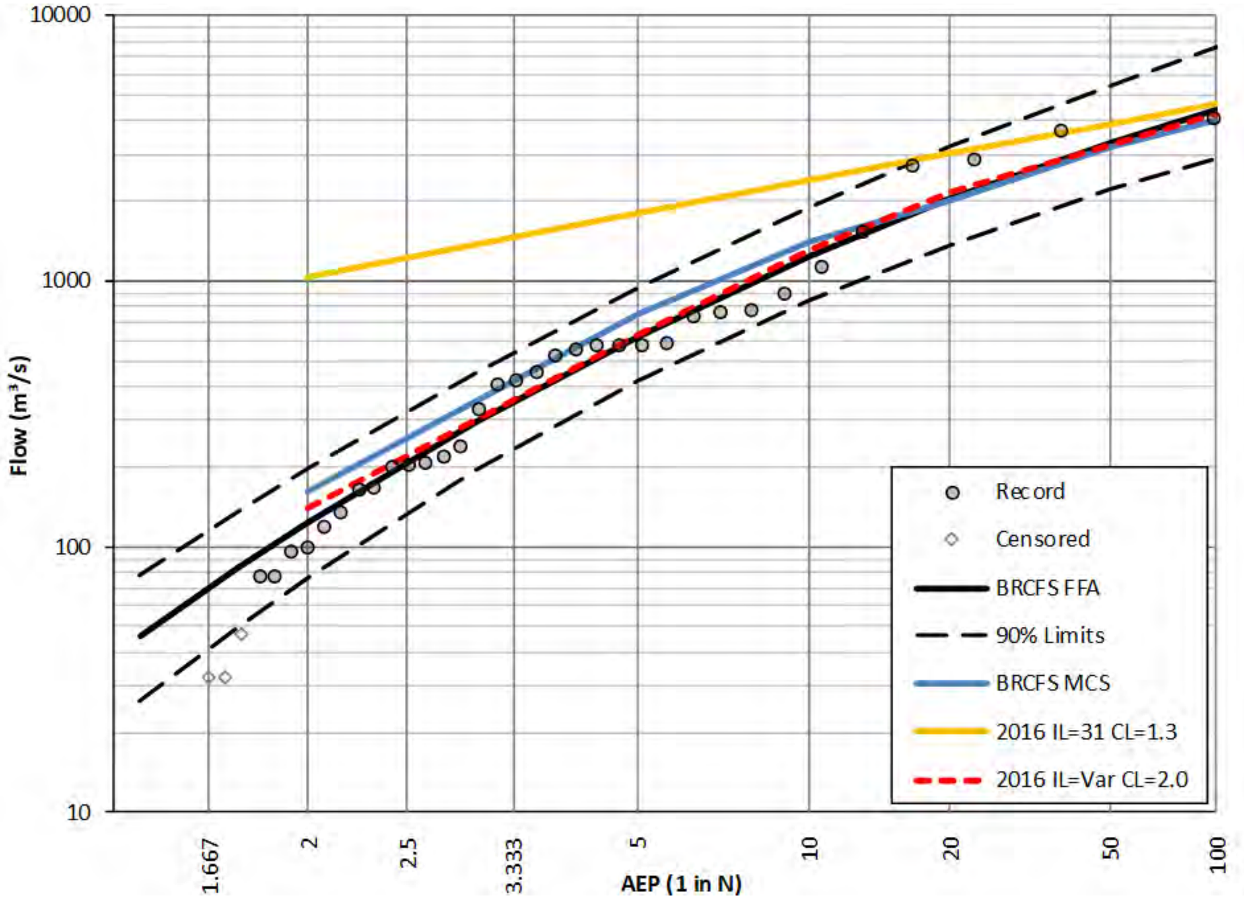


Figure 8.1 **Comparison of 2016 FFJV DEA with BRCFS results at Glenore Grove**

Figure 8.2 **Example of water storages scattered throughout the Lockyer Creek catchment**

8.1.6.2 Bremer River/Western Creek

Design flow estimates for the Bremer River at Walloon are compared with the FFA and MCS results in Table 8.4 and Figure 8.3. The ARR 2016 flows are typically higher than the MCS results, particularly for frequent events, but generally show good agreement with FFA predictions in this range. The trend for the rainfall-based flows to underestimate the FFA results for large events was investigated in detail in the BRCFS. The peak flows and discharge ratings used in the FFA were confirmed using the same URBS model used to produce the design event and Monte Carlo flows. A discrepancy between the BoM IFD tables and the historical rainfall depths would explain the observed discrepancy between rainfall IFD based methods and the historical flood event based FFA. Possible explanations are that:

- The historical rainfall and flood record are skewed by the occurrence of a number of major flood events in the catchment (statistically unlikely, but nevertheless possible)
- The BoM IFD tables underestimate rainfall depths for the catchment.

Reality most probably lies somewhere between the two options. Overall, the results are consistent with the reconciled values adopted for the BRCFS (allowing for a slight increase in design rainfall intensity; refer Table 8.1). Initial losses for the 50% AEP event were increased to reconcile flows with the FFA, however no other changes were required.

Table 8.4 Comparison of 2016 FFJV DEA with BRCFS results at Walloon

AEP (%)	BRCFS Lower 90% Confidence Interval (m³/s)	BRCFS FFA (m³/s)	BRCFS Upper 90% Confidence Interval (m³/s)	BRCFS MCS (m³/s)	FFJV DEA (m³/s)
50	170	230	320	170	260
20	510	680	920	420	640
10	800	1,080	1,500	670	870
5	1,100	1,500	2,150	890	1,110
2	1,470	2,070	3,080	1,300	1,440
1	1,730	2,490	3,830	1,600	1,700

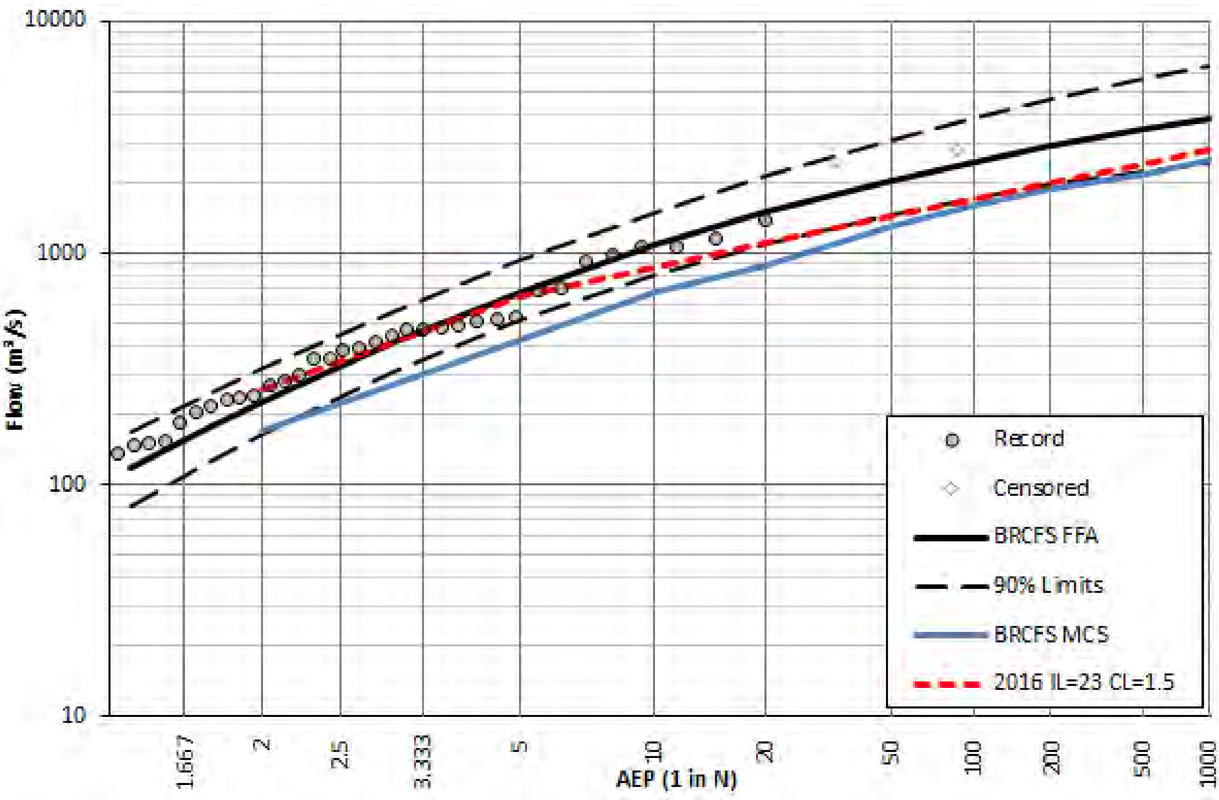


Figure 8.3 Comparison of 2016 FFJV DEA with BRCFS results at Walloon

8.1.7 Climate change

The impacts of climate change were assessed for the 1% AEP design event to determine the sensitivity of the Project alignment design to the potential increase in rainfall intensity. The assessment was undertaken in accordance with ARR 2016 guidelines.

The selected representative concentration pathway for the climate change analysis was 8.5 for a 2090 design horizon. The climate change analysis was undertaken by increasing rainfall intensities in the IFDs for the contributing catchments

8.2 Existing Case results

8.2.1 Hydrologic model peak flow assessment

A critical duration assessment was undertaken to determine which storm duration(s) produced peak flood flows at the following locations: the stream flow gauges at Gatton, Glenore Grove and Warrego Highway, and at major waterways that are intersected by the Project alignment. To assess the critical storm duration the following methodology was adopted:

- The models were simulated for a range of AEP events: 20%, 10%, 5%, 2%, 1%, 1 in 2,000, 1 in 10,000 AEP and PMF events
  - Each AEP was simulated for a range of durations from 30 minutes to 168 hours, and
  - Each duration was simulated for each of the ten associated temporal patterns
- Peak flood levels were mapped for each storm duration
- A critical duration assessment was undertaken at the locations mentioned above to determine which duration produced the highest median flow of the ten temporal patterns for each event.

The critical durations and median temporal patterns selected for this study are outlined in Table 8.5 and Table 8.6. It is noted there is significant difference in critical duration between frequent and rare AEP events. This is caused by a combination of elements including: the magnitude of the losses, how long the continuing loss is applied for during the length of the storm, and whether the pattern distribution is uniform or peaky. The chainages for each of the catchments in Table 8.5 and Table 8.6 represent the locations of the proposed bridge crossings.

Table 8.5 Critical duration assessment for Lockyer hydrologic model

Location (Ch = chainage)	Event	Duration (hours)	URBS temporal pattern	Peak flow (m^3/s)
Gatton	20% AEP	120h	E4	425
Ch 55.77 km – Ch 57.32 km[1]		120h	E4	18
Ch 50.28 km – Ch 53.97 km[2]		120h	E4	39
Warrego Hwy		168h	E4	205
Glenore Grove		120h	E4	627
Gatton	10% AEP	168h	E4	878
Ch 55.77 km – Ch 57.32 km[1]		120h	E5	37
Ch 50.28 km – Ch 53.97 km[2]		168h	E4	78
Warrego Hwy		168h	E4	406
Glenore Grove		168h	E4	1295

Location (Ch = chainage)	Event	Duration (hours)	URBS temporal pattern	Peak flow (m^3/s)
Gatton	5% AEP	168h	E4	1500
Ch 55.77 km – Ch 57.32 km[1]		168h	E6	56
Ch 50.28 km – Ch 53.97 km[2]		168h	E6	117
Warrego Hwy		168h	E6	581
Glenore Grove		168h	E4	2170
Gatton	2% AEP	48h	E0	2338
Ch 55.77 km – Ch 57.32 km[1]		48h	E8	93
Ch 50.28 km – Ch 53.97 km[2]		48h	E0	174
Warrego Hwy		48h	E8	888
Glenore Grove		48h	E0	3277
Gatton	1% AEP	12h	E7	3131
Ch 55.77 km – Ch 57.32 km[1]		12h	E7	118
Ch 50.28 km – Ch 53.97 km[2]		12h	E7	219
Warrego Hwy		48h	E8	1077
Glenore Grove		12h	E7	4245
Gatton	1 in 2,000 AEP	12h	E7	5657
Ch 55.77 km – Ch 57.32 km[1]		12h	E7	217
Ch 50.28 km – Ch 53.97 km[2]		48h	E8	410
Warrego Hwy		48h	E8	2044
Glenore Grove		48h	E8	7900
Gatton	1 in 10,000 AEP	9h	E3	6553
Ch 55.77 km – Ch 57.32 km[1]		9h	E3	254
Ch 50.28 km – Ch 53.97 km[2]		36h	E1	475
Warrego Hwy		36h	E1	2421
Glenore Grove		36h	E6	9509
Gatton	PMF	18h	E4	20522
Ch 55.77 km – Ch 57.32 km[1]		9h	E3	606
Ch 50.28 km – Ch 53.97 km[2]		12h	E7	1233
Warrego Hwy		12h	E7	5960
Glenore Grove		12h	E7	27242

Table notes:

1 Laidley Creek and associated floodplain breakout and tributaries around Laidley
2 Sandy Creek and associated floodplain breakout and tributaries around Forest Hill

Table 8.6 Critical duration assessment for Western Creek hydrologic model

Location	Event	Duration (hours)	URBS temporal pattern	Peak flow (m^3/s)
Walloon	20% AEP	18h	_E6	644
Ch 65.69 km[1]		18h	_E8	68
Ch 73.21 km[2]		18h	_E3	256
Walloon	10% AEP	18h	_E2	869
Ch 65.69 km[1]		24h	_E5	90
Ch 73.21 km[2]		18h	_E2	342

Location	Event	Duration (hours)	URBS temporal pattern	Peak flow (m^3/s)
Walloon	5% AEP	18h	_E5	1,107
Ch 65.69 km[1]		24h	_E5	113
Ch 73.21 km[2]		18h	_E2	433
Walloon	2% AEP	18h	_E2	1,438
Ch 65.69 km[1]		24h	_E4	145
Ch 73.21 km[2]		18h	_E2	558
Walloon	1% AEP	24h	_E0	1,702
Ch 65.69 km[1]		24h	_E4	171
Ch 73.21 km[2]		24h	_E4	820
Walloon	1 in 2,000 AEP	24h	_E5	3,156
Ch 65.69 km[1]		24h	_E4	311
Ch 73.21 km[2]		24h	_E4	1,217
Walloon	1 in 10,000 AEP	12h	_E5	3,764
Ch 65.69 km[1]		9h	_E3	383
Ch 73.21 km[2]		9h	_E3	1,453
Walloon	PMF	12h	_E8	9,095
Ch 65.69 km[1]		6h	_E3	975
Ch 73.21 km[2]		9h	_E3	3,504

Table notes:

1 Western Creek and associated floodplain breakout and tributaries at Grandchester
2 Western Creek and associated floodplain breakout and tributaries at Calvert/connection to C2K Project

8.2.2 Lockyer Creek design events

Inflow hydrographs for the critical durations and associated temporal patterns as outlined in Table 8.5 (refer Section 8.2.1) were used as a starting point for the hydraulic modelling. Rank 5, Rank 6 and Rank 7 temporal patterns for were run in order to help determine the reliability of this selection methodology.

In addition to the critical durations, a check of the Rank 5, Rank 6 and Rank 7 temporal patterns for some durations either side of the identified critical duration were also modelled in case the 2D domain affected peak timings by way of attenuation.

The hydraulic modelling results for critical durations and temporal patterns at the gauge sites were identical to the hydrologic model estimations from Table 8.5; with the gauge at Glenore Grove being the notable exception. The hydrologic model Rank 6 peak estimates at Glenore Grove for the 12 hour and 48 hour durations were 4,244 m^3/s and 4,175 m^3/s respectively; representing less than 2 per cent difference. While the 12 hour duration has the higher peak, the large floodplain storage area around Glenore Grove and the known complex floodplain interactions of this location meant the critical duration was actually the 48 hour storm. The Rank 6 temporal pattern for the 48 hour storm at Glenore Grove did not change.

Peak water level and velocity figures are presented in Appendix A.

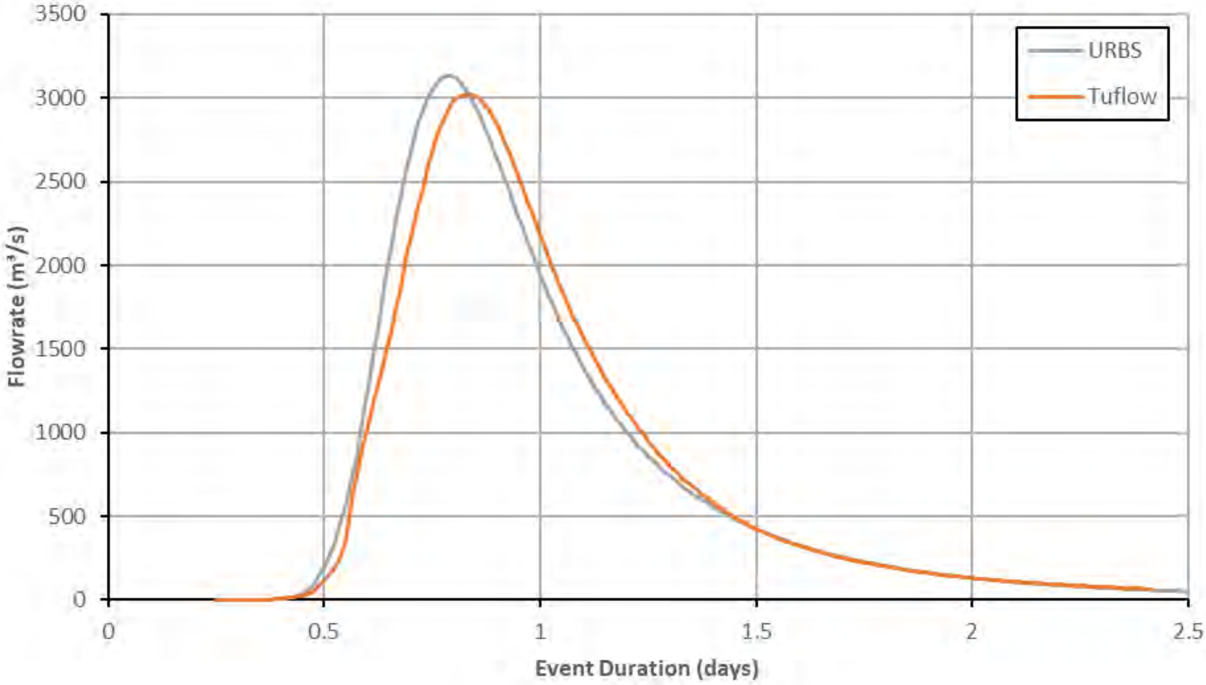


Figure 8.4 Comparison of URBS and TUFLOW hydrographs at Gatton Weir for 1% AEP design event

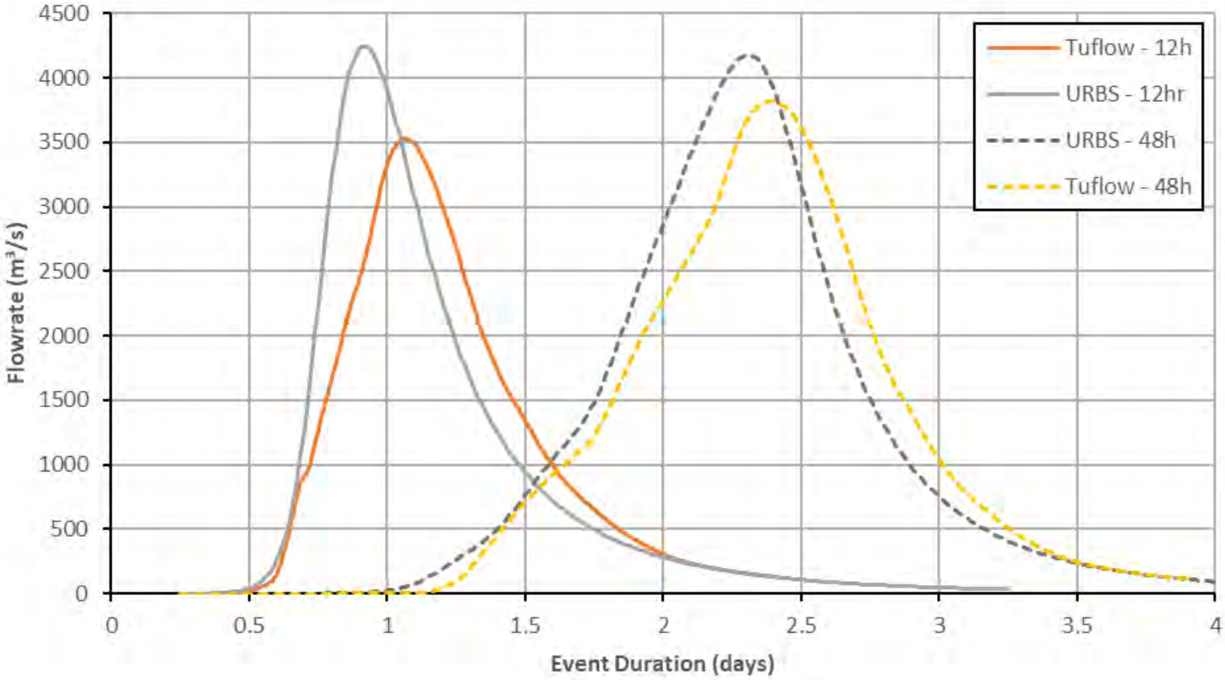


Figure 8.5 Comparison of URBS and TUFLOW hydrographs at Glenore Grove for 1% AEP design events

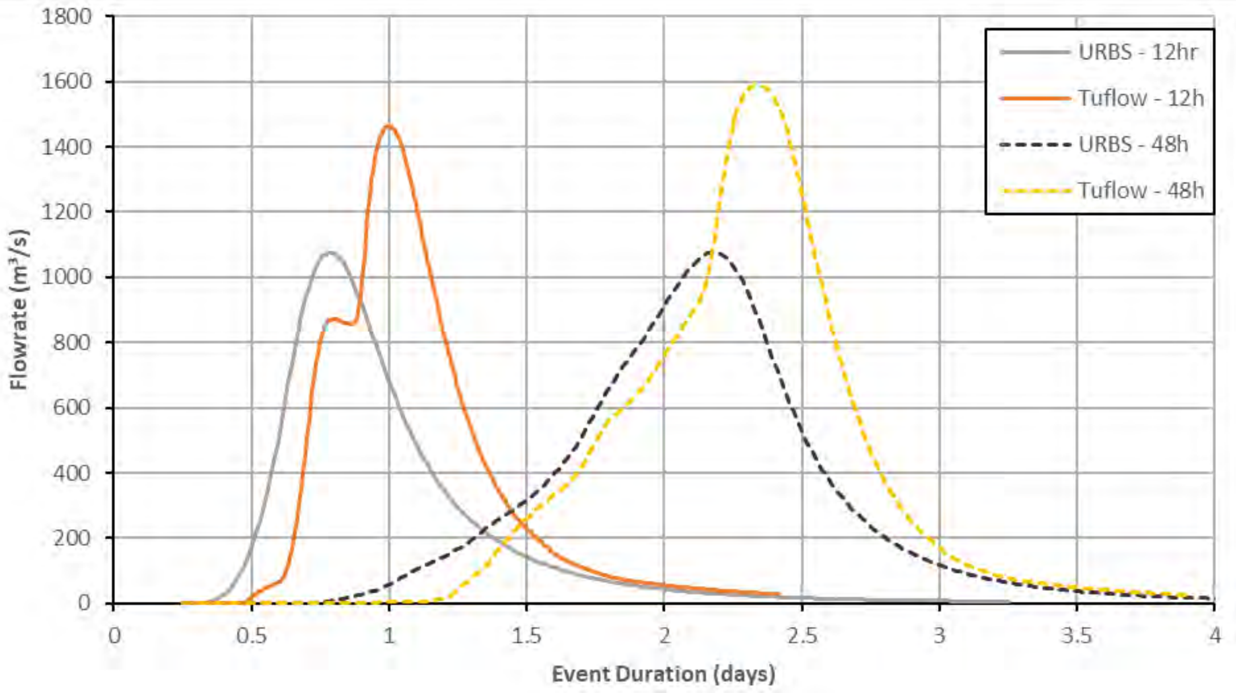


Figure 8.6 **Comparison of URBS and TUFLOW hydrographs at Warrego Highway for 1% AEP design events**

Lockyer Creek is a very complicated catchment in terms of both hydrologic and hydraulic modelling. Lockyer Creek, a roundish catchment with multiple contributing tributaries, and Laidley Creek, an elongated catchment of similar length but much smaller area, come together at Glenore Grove, where perched channels and overflows complicate flow patterns. This variability may be due to the vegetation (both channel and floodplain) present at the time of each flood event.

Despite these issues, the hydrologic model appears to give a good representation of the catchment runoff characteristics and the selected model parameters give a good representation of typical flow conditions. The hydraulic model appears to validate the flow routing behaviour predicted by the hydrologic model, displaying a good match of routing in Lockyer Creek down to Glenore Grove. In Laidley Creek, the hydraulic model generates similar hydrograph shape and peaks but arriving at Warrego Highway approximately 2 to 3 hours after the hydrologic model. Comparison with the recorded flood levels suggests that the hydrologic model gives a better representation of the timing for the 2011 flood, while the hydraulic model better represents the 1996 event, with the 2013 event somewhere in between.

Although the variability appears to be only of the order of 2 to 3 hours, the timing of the Lockyer Creek and Laidley Creek flows potentially impact the cumulative peak at Glenore Grove. As shown in Figure 8.5, delay to the Laidley Creek flow tends to produce a lower peak discharge, having more pronounced affect shorter duration events. Although this means that the hydraulic model may not be conservative in terms of peak flow at Glenore Grove, the results are considered appropriate for assessment of the Project alignment since:

- Individual flow hydrographs of the Lockyer Creek and Laidley Creek tributaries are relatively consistent and total flow volumes are not affected
- The impact on peak water levels at Glenore Grove is relatively minor, as shown in Figure 8.7
- If anything, a later peak in Laidley Creek produces a higher (conservative) peak flow in Laidley Creek upstream of the Warrego Highway as the peak creek flow more closely corresponds to the overflow coming from Lockyer Creek, as shown in Figure 8.6.

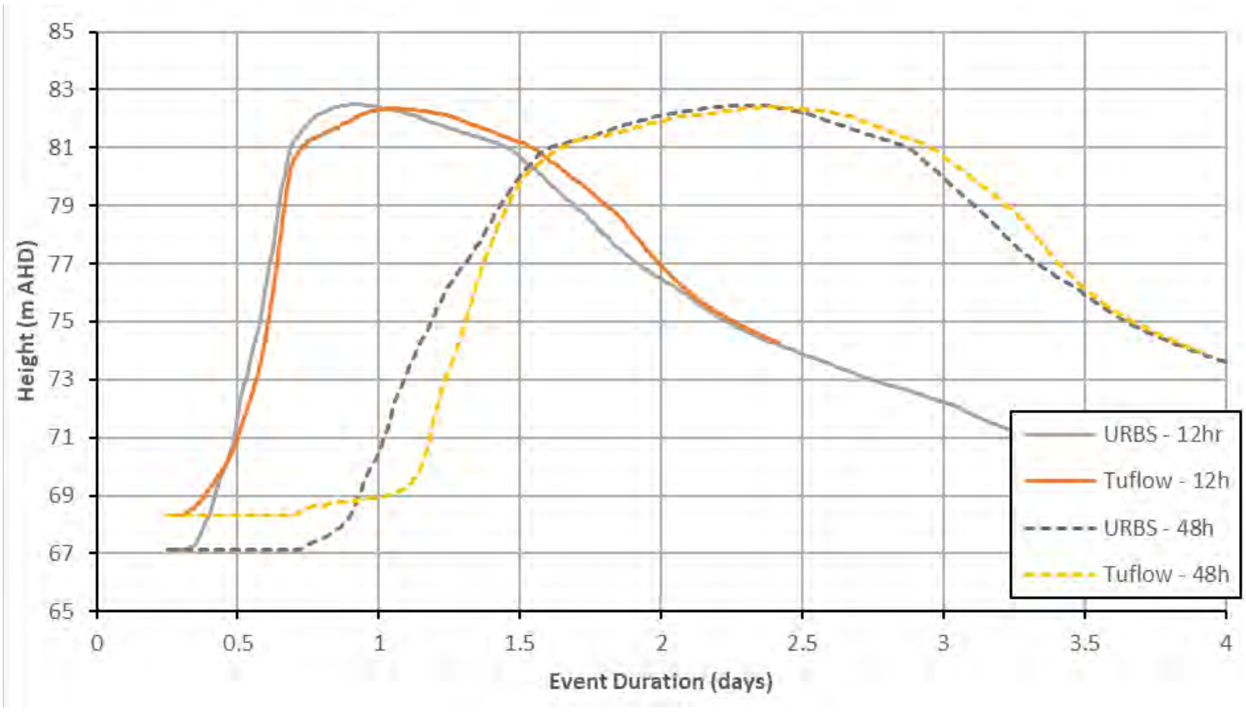


Figure 8.7 **URBS rated level and TUFLOW water levels at Glenore Grove for 1% AEP design events**

8.2.3 Western Creek design events

Inflow hydrographs for the critical durations and associated temporal patterns as outlined in Table 8.6 (refer Section 8.2.1). The hydraulic model results for critical durations and temporal patterns at the Walloon Gauge are presented in Figure 8.8. Peak water levels and velocity results are presented in Appendix B, Figures B-3A and B-4A respectively.

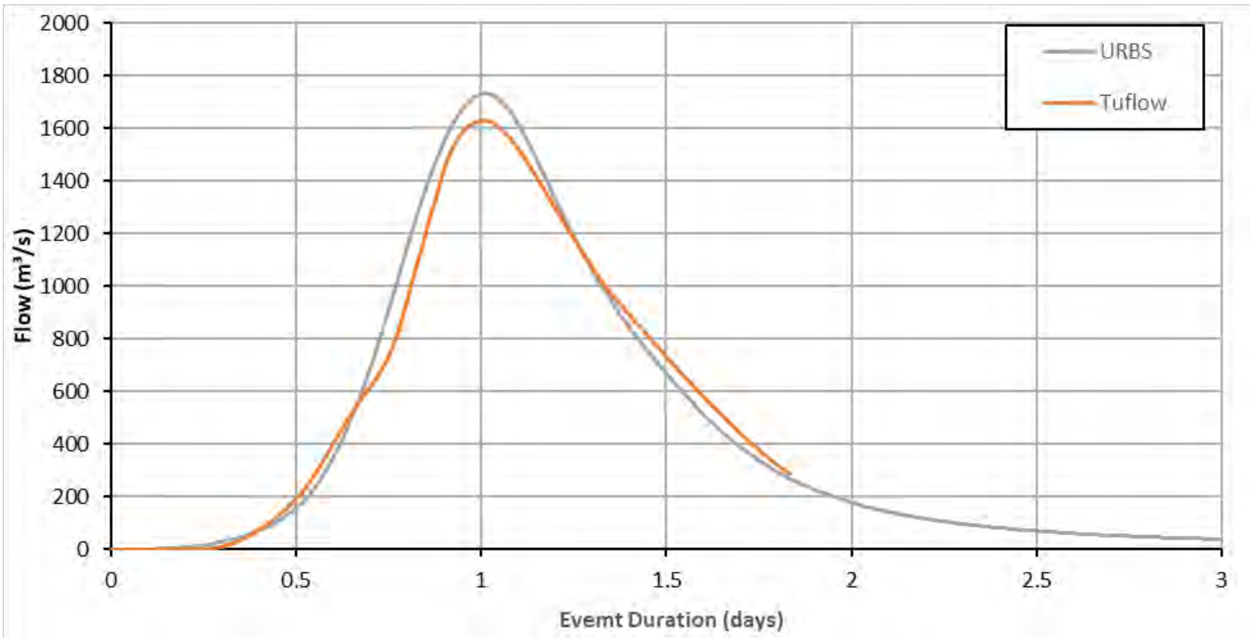


Figure 8.8 **Comparison of URBS and TUFLOW hydrographs at Walloon for the 1% AEP design event**

8.2.4 Queensland Rail Line

Existing Case hydraulic modelling indicates that the existing QR West Moreton System rail corridor overtops during a 1% AEP event with flood levels above Top of Rail (TOR). This means that the QR West Moreton System rail corridor has less than a 1% AEP flood immunity in a number of areas including:

- Between Gatton and Forest Hill
- At Forest Hill
- Between Forest Hill and Laidley Creek
- At Calvert near Lanefield.

Flood maps illustrating Existing Case results are included in Appendix A and Appendix B.

A comparison of QR West Moreton System rail corridor with the Project alignment where they run parallel to each other is discussed in more detail in the relevant subsections of Section 9.

9 Developed case modelling

The Developed Case incorporates the Project design into the Existing Case hydraulic models. The Developed Case models have been run for the nominated design events and assessed against the hydraulic design criteria and flood impact objectives. Mitigation measures that have been incorporated into the Project design include:

- The Project has been designed to achieve the hydraulic design criteria (refer Section 4.1), and key design criteria including:
  - 50-year design life for formation and embankment performance
  - Track drainage ensures that the performance of the formation and track is not affected by water
  - Earthworks designed to ensure that the rail formation is not overtopped during a 1% AEP flood event
  - Embankment cross section can sustain flood levels up to the 1% AEP
- Bridges are designed to withstand flood events up to and including the 1 in 2,000 AEP event
- Where possible, the Project utilises the existing QR West Moreton System rail corridor as much as possible to avoid introducing a new linear infrastructure corridor across floodplains
- The Project incorporates bridge and culvert structures to maintain existing flow paths and flood flow distributions
- Bridge and culvert structures have been located and sized to avoid increases in peak water levels, velocities and/or duration of inundation, and changes flow distribution in accordance with the flood impact objectives
- Progressive refinement of bridge extents and culvert banks (number of barrels and dimensions) has been undertaken as the Project design has evolved. This refinement process has considered engineering requirements as well as progressive feedback from stakeholders to achieve acceptable outcomes that address the flood impact objectives.
- Scour and erosion protection measures have been incorporated into the design in areas determined to be at risk, such as around culvert headwalls, drainage discharge pathways and bridge abutments
- A climate change assessment has been incorporated into the design of cross drainage structures for the Project in accordance with the Australian Rainfall and Runoff Guidelines (2016) for the 1% AEP design event to determine the sensitivity of the design, and associated impacts, to the potential increase in rainfall intensity
- Identification of flood sensitive receptors and engagement with stakeholders to determine acceptable design outcomes.

The following sections outline how the Project design addresses the hydraulic design criteria and flood impact objectives on each floodplain. It is noted that the Project tunnel portals are not located within the Lockyer Creek or Bremer River floodplains. For the hydraulic modelling the adjacent C2K and G2H Project alignments have been included in the Developed Case to quantify cumulative impacts.

Details of drainage structures for local drainage catchments that cross the alignment are provided in Section 9.4.

9.1 Lockyer Creek

Lockyer Creek crosses the Project alignment at approximately Ch 43.20 km which is in north-west Gatton. Under a 1% AEP event approximately 3,040 m³/s of flow passes through this crossing. The creek continues to the east of the Project alignment towards Glenore Grove, however, some high flow from Lockyer Creek breaks out to the south and flows parallel to the existing QR West Moreton System rail corridor and the Project alignment.

Modelling shows that numerous properties, roads and the existing QR West Moreton System rail corridor are inundated under the 1% AEP event in existing conditions. The Project alignment runs through a significant portion of the breakout flow and major drainage structures are needed to maintain existing flow behaviour.

The QR West Moreton System rail corridor directly to the east of Gatton has less than a 1% AEP immunity for a 350 m section around Ch 45.68 km. At this location there are no existing cross drainage structures under the QR West Moreton System rail corridor. As such, flow from Lockyer Creek only inundates the area south of the QR West Moreton System rail corridor under events when the QR West Moreton System rail corridor is overtopped. This flow over the QR West Moreton System rail corridor introduces a significant level of flow complexity, not just at this location but also further downstream. The area immediately downstream of this overflow appears to be a mixture of cropping land and rural or grazing land.

In order to achieve a workable design solution, significant numbers of additional drainage structures were required to be added under the existing QR West Moreton System rail corridor as detailed in Section 9.1.1. A number of sizeable lined channels were also included to address impacts on flood sensitive receptors.

9.1.1 Drainage structures

The proposed local drainage structures along the Project alignment from Ch 26.00 km to Ch 39.50 km are not within the Lockyer Creek floodplain and therefore not within the hydraulic model. As a result, the local drainage structures in this area are not documented in this technical report.

The hydraulic design of the major drainage structures was undertaken using the hydraulic model (1d and 2d approach). Within the Lockyer Creek section of the Lockyer Creek hydraulic model the Project design includes:

- Two (2) rail bridges
- Two (2) road bridges
- Eight (8) rail reinforced concrete box culverts (RCBC) locations (multiple cells in places)
- Nine (9) rail reinforced concrete pipe culvert (RCP) locations (multiple cells in places).

Details of these structures are listed in Table 9.1 and Table 9.2. The G2H Project alignment has been included in the Developed Case hydraulic modelling as well to quantify accumulative impacts from the Inland Rail works. There are no proposed stream diversions within the Lockyer Creek Floodplain. Sandy Creek (upstream of Grantham) is not impacted by the Project as it is on a viaduct in this area.

Table 9.1 Lockyer Creek – Flood rail structure locations and details

Chainage (km)	Structure name	Structure type	No of cells	Diameter or width (m)	Height (m) or Soffit level (m AHD)	Bridge length (m)
40.05	C40.05	RCP[2]	2	1.50	-	-
40.33	C40.33	RCBC[1]	4	2.082	1.98	-
41.07	C41.07	RCP[1]	2	0.425	-	-
41.99	C41.99	RCP[1]	2	0.75	-	-
42.60	C42.60	RCP[1]	2	1.00	-	-
43.15	330-BR06	Bridge	-	-	104.41	122.0
43.58	C43.58	RCBC[1]	1	0.60	0.375	-
43.94	C43.94	RCP[1]	3	0.45	-	-
44.45	C44.45	RCBC[2]	8	2.40	0.90	-
46.49	C46.49	RCBC[1]	1	0.75	0.90	-
47.22	C47.22	RCBC[1]	1	2.9	1.94	-
47.24	C47.24	RCP[2]	10	1.20	-	-
47.57	C47.57	RCP[2]	2	1.20	-	-

Chainage (km)	Structure name	Structure type	No of cells	Diameter or width (m)	Height (m) or Soffit level (m AHD)	Bridge length (m)
47.81	C47.81	RCBC[1]	1	2.40	1.80	-
48.46	C48.46	RCBC[1]	1	1.60	1.40	-
49.52	330-BR10	Bridge	-	-	90.22	28.0
49.57	C49.57	RCBC[2]	6	2.40	1.20	-

Table notes:

1 The Developed Case alignment runs parallel to the QR West Moreton System rail corridor at this location. The existing culvert is proposed to be extended and matched through the Project alignment.

2 The Developed Case alignment runs parallel to the QR West Moreton System rail corridor at this location. A new culvert(s) is proposed to be inserted through the QR West Moreton System rail corridor and the proposed Project alignment.

Table 9.2 Lockyer Creek – Road structure locations and details

Road Name	Structure name	Structure type	Soffit level (m AHD)	Bridge Length (m)
Eastern Drive – northbound	330-BR09N	Bridge	106.97	103.0
Eastern Drive – southbound	330-BR09S	Bridge	107.81	103.0

9.1.2 Hydraulic design criteria outcomes

The hydraulic model was run for the Developed Case with the drainage structures and embankment areas included. Modelling of a range of events was undertaken (20%, 10%, 5%, 2%, 1% AEP events and 1 in 2,000 AEP, 1 in 10,000 AEP and PMF events). The Project design outcomes relative to the hydraulic design criteria (refer Table 4.1) are presented in the following sections.

9.1.2.1 Flood immunity and overtopping risk

A 350 m length of the existing QR West Moreton System rail corridor around Chadwick Road, between Gatton and Lawes, overtops under the 1% AEP event (water levels above TOR level). This is the only location between Gatton and Forest Hill where the existing QR West Moreton System rail corridor overtops. The overtopping flood waters run parallel to the existing rail line as shown in Appendix A, Figure A-7A-1. The Project alignment is raised above the existing QR West Moreton System rail corridor at this location to meet the Project design requirements of 1% AEP flood immunity plus 300 mm freeboard to formation level.

A summary of how the TOR levels for the proposed Project alignment compares with the QR West Moreton System rail corridor is presented in Table 9.3.

Table 9.3 Lockyer Creek – Comparison of Project alignment and Queensland Rail Top of Rail levels

Location	Comparison of TOR levels
West of Gatton	Project alignment varies between 0.2 m and 2.0 m higher than QR West Moreton System rail corridor
Through Gatton	Project alignment varies between 0.2 m and 1.0 m higher than QR West Moreton System rail corridor
Eastern Drive	Project alignment varies between 0.7 m lower and 0.7 m higher than QR West Moreton System rail corridor
East of Gatton to Lawes	Project alignment varies between 0.2 m and 1.0 m higher than QR West Moreton System rail corridor

The depth of overtopping of the Project alignment has been assessed for a range of extreme events (1 in 2,000 AEP, 1 in 10,000 AEP and PMF events). During these extreme events the Project alignment (TOR) overtops at a number of locations as shown in Table 9.4.

Table 9.4 Lockyer Creek – Rail overtopping details during extreme events

Approximate chainages (km)	1 in 2,000 AEP event overtopping depth (m)[1]	1 in 10,000 AEP event overtopping depth (m)[1]	PMF event overtopping depth (m)[1]
Ch 38.48 to Ch 41.79	0.30	0.50	4.30
Ch 44.05 to Ch 44.26	0.60	1.00	4.20
Ch 44.47 to Ch 46.24	0.50	0.65	1.65
Ch 48.09 to Ch 49.90	0.25	0.45	2.20

Table note:

1 Depths vary over the length of the rail that overtops. The length of rail that overtops increases with event rarity.

9.1.2.2 Structure results

Table 9.5 and Table 9.6 present hydraulic model results at each structure for the 1% AEP event. The hydraulic results at structures for flows, velocities and water surface levels for all events are presented in Appendix C.

Table 9.5 Lockyer Creek – 1% AEP event rail structure results

Chainage (km)	Structure name	Structure type	Upstream peak water level (m AHD)	Freeboard to top of formation level (m)	Outlet velocity (m/s)	Peak discharge (m^3/s)
40.05	C40.05	RCP[2]	102.18	2.96	0.8	0.4
40.33	C40.33	RCBC[1]	Dry[3]	-	-	-
41.07	C41.07	RCP[1]	Dry[3]	-	-	-
41.99	C41.99	RCP[1]	Dry[3]	-	-	-
42.60	C42.60	RCP[1]	Dry[3]	-	-	-
43.15	330-BR06	Bridge	103.54	2.87	2.9	3035.1
43.58	C43.58	RCBC[1]	Dry[3]	-	-	-
43.94	C43.94	RCP[1]	Dry[3]	-	-	-
44.45	C44.45	RCBC[2]	Dry[3]	-	-	-
44.90	C44.90	RCP[1]	97.64	0.59	1.5	1.8
45.76	C45.76	RCP[1]	97.09	0.30	3.5	2.2
46.49	C46.49	RCBC[1]	95.11	0.30	2.8	1.9
47.22	C47.22	RCBC[1]	93.22	0.76	3.3	14.3
47.24	C47.24	RCP[2]	93.12	0.81	2.2	16.9
47.57	C47.57	RCP[2]	92.20	1.06	1.8	2.5
47.81	C47.81	RCBC[1]	91.95	0.77	2.8	8.1
48.46	C48.46	RCBC[1]	90.83	0.54	1.6	2.4
49.52	330-BR10	Bridge	90.03	1.19	2.9	55.0
49.57	C49.57	RCBC[2]	90.01	1.09	2.4	25.1

Table notes:

1 The Developed Case alignment runs parallel to the QR West Moreton System rail corridor at this location. The existing culvert is proposed to be extended and matched through the Project alignment.

2 The Developed Case alignment runs parallel to the QR West Moreton System rail corridor at this location. A new culvert(s) is proposed to be inserted through the QR West Moreton System rail corridor and the Project alignment.

3 This Developed Case structure is outside the 1% AEP event extents. This structure was included in the Developed Case as it conveys flow during extreme events.

Table 9.6 Lockyer Creek – 1% AEP event road structure results

Structure name	Structure type	Upstream peak water level (m AHD)	Outlet velocity (m/s)	Peak discharge (m^3/s)
330-BR09N	Bridge	Dry[1]	-	-
330-BR09S	Bridge	Dry[1]	-	-

Table note:

This Developed Case structure is outside the 1% AEP event extents. This structure was included in the Developed Case as it conveys flow during the 1 in 2,000 AEP event.

Scour protection requirements for culverts have been calculated based on the velocities predicted from the hydraulic modelling. The scour protection has been designed in accordance with Austroads Guide to Road Design Part 5B: Drainage (AGRD). Scour protection was specified where the culvert outlet velocities for the 1% AEP event exceeded the allowable soil velocities shown in Table 3.1 of AGRD as follows:

- Stable rock – 4.5 m/s
- Stones 150 mm diameter or larger – 3.5 m/s
- Gravel 100 mm or grass cover – 2.5 m/s
- Firm loam or stiff clay – 1.2 to 2 m/s
- Sandy or silty clay – 1.0 to 1.5 m/s.

The particular soil type for each location was identified from published soil mapping. The scour protection length and minimum rock size (d50) were determined from Figure 3.15 and Figure 3.17 in AGRD. The resulting lengths of scour protection required were determined through the drainage assessment. All required scour lengths were predicted to fit within the disturbance footprint.

A conservative scour estimation has been undertaken at each bridge site based on available information and will be refined during detailed design.

9.1.3 Flood impact objective outcomes

The Project design outcomes relative to the flood impact objectives (refer Table 4.2) are presented in the following sections.

9.1.3.1 Change in peak water levels

The impact of the Developed Case has been assessed through inclusion of the Project design drainage structures and comparison of model results against the Existing Case results. Resulting changes in peak water levels have been mapped (refer Appendix A).

Under the 1% AEP event there are no predicted increases in peak water levels of greater than 200 mm. However, there are a few occurrences of changes in peak water levels predicted to be between 100 mm and 200 mm. These are:

- On the southern side of the Project alignment between Ch 47.08 km and Ch 47.81 km an increase of 195 mm is expected. This is a direct result of balancing the loss of flood storage from the existing QR West Moreton System rail corridor overtopping under the 1% AEP event. Based on the aerial imagery, the increase occurs on what appears to be rural land or lower-yield farm land as compared to the northern side of the Project alignment. An unsealed road (Dodt Road) is also affected by this increase in peak water levels. Existing Case flood depths under the 1% AEP event along Dodt Road range from 0.25 m to 0.9 m. Changes to trafficability as a result of this additional flood depth are minimal.

As seen in Appendix A Figure A-7E, there are a number of flood sensitive receptors in the Lockyer Creek catchment. Details of where afflux is greater than 10 mm, under the 1% AEP event, at a flood sensitive receptor are outlined in Table 9.7. Where afflux is 10 mm or greater at a flood sensitive receptor under the 1% AEP event a summary of afflux for all modelled events up to the 1% AEP event is presented in Appendix D. These impacts for the minor events satisfy the flood impact objectives.

Table 9.7 Lockyer Creek – Afflux at flood sensitive receptors

Location	Change in peak water levels (mm)	Comment
Burgess Road and agricultural land (Ch 42.70 km to Ch 43.31 km)	+14	Caused by additional flow constrictions added to the Existing Case structures. This increase in peak water levels of between 14 mm and 11 mm appears to be constrained to agricultural land, easements and local roads. Permanent dwelling footprints are within the ±10 mm afflux criteria.
Agricultural land (near Ch 45.20 km)	+16	Increase resulting from addressing the loss of 350 m flow over existing QR West Moreton System rail corridor. A lined channel to help balance this QR West Moreton System rail corridor overflow was included at this location. A shared path connecting University of Queensland (UQ) Gatton campus is included at this location.
Agricultural land (Ch 46.31 km to Ch 47.44 km)	+100	Increase resulting from addressing the loss of 350 m flow over existing QR West Moreton System rail corridor. Afflux generally ranges between 60 mm and 10 mm over this agricultural land. Existing Case flood depths are greater than 1.3 m in locations. A lined channel to help balance this QR West Moreton System rail corridor overflow is included at this location. A shared path connecting UQ Gatton campus is included at this location
Dodt Road and rural land (between Ch 47.08 km and Ch 47.81 km)	+200	Increase resulting from addressing the loss of 350 m weir flow over existing QR West Moreton System rail corridor. Existing Case flood depths along Dodt Road range from 0.25 m to 0.75 m. Trafficability as a result of the Project alignment is largely unchanged.
Rural land (around Ch 48.66 km)	+40	Afflux behind the shared path leading to UQ Gatton Campus is between 10 mm and 20 mm. Afflux from longitudinal drain dissipates to 10 mm within 100 m of the Project alignment. A lined channel to help balance this QR West Moreton System rail corridor overflow is included at this location. A shared path connecting UQ Gatton campus is included at this location
Rural land (around Ch 49.57 km)	+60	Afflux from culverts dissipates to 10 mm within 70 m of the Project alignment.

9.1.3.2 Average annual time of submergence and time of submergence

Assessment of the change in the Time of Submergence (ToS) is presented in Appendix A Figure A-7D.

Under the 1% AEP event where the increase in peak water levels was predicted to be between 100 mm and 200 mm, the ToS is as follows:

- On the southern side of the existing QR West Moreton System rail corridor between Ch 47.08 km and Ch 47.81 km (Dodt Road and adjacent rural land) the ToS is 39 hours for the Existing Case and this increases by an hour in the Developed Case. The Average Annual Time of Submergence (AAToS) does not change as a result of the proposed works. It is worth noting that while afflux under the Developed Case has limited effect on AAToS in this area, the proposed Developed Case provides significant reductions in AAToS between Ch 45.70 km and Ch 47.08 km as the agricultural and rural land was previously affected by the QR West Moreton System rail corridor overtopping.

9.1.3.3 Change in velocities

Appendix A Figure A-7D presents the changes in peak velocities under the 1% AEP event associated with the Project alignment. In general, the changes are minor, with most changes in velocities experienced between approximately Ch 46.0 km and Ch 49.5 km. This is where new and extended culvert structures are introduced to address flow complexity where the existing QR West Moreton System rail corridor is overtopped.

9.1.3.4 Flood flow distribution

Overall, the Project has minimal impacts on flood flows and floodplain conveyance/storage with significant floodplain structures included to maintain the existing flood regime.

9.1.3.5 Extreme event risk management

During extreme events there is widespread floodplain inundation with high flood depths as shown in Appendix A Figures A-8 to A-10. These impacts have been considered in relation to the Existing Case flood depths at flood sensitive receptors. Under these rare events, the bridge structures and culverts allow adequate passage of flow during the flood events and “damming” effects are therefore not expected to occur.

As can be seen the flood inundation extent and peak water levels increase across the floodplain between Helidon and Lawes as the severity of the flood event increases. Review of changes in peak water levels at flood sensitive receptors indicates that the increases associated with the Project alignment are a small percentage change as compared to the flood depth (<10 per cent for most locations). Larger impacts occur under the PMF event where there are already high flood depths as would be expected under such a rare event. The depth of inundation for each of the extreme events are presented in Figures A-8A, A-9A and A-10A. No new flow paths or significant additional areas of inundation are created due to the Project alignment under these extreme events.

The Project alignment runs parallel to the existing QR West Moreton System rail corridor which governs the existing flood conditions. With the Project alignment in place, there are no significant changes in flood inundation extents or velocities, and flow behaviour is consistent with the existing conditions. There are changes in peak water levels which are attributed to the height of the proposed Project alignment required to achieve the desired flood immunity standard. Mitigation of impacts has been carried out through the extension of QR culverts under the Project alignment and inclusion of new culverts under both the Project and QR alignments.

9.1.4 Sensitivity analysis

9.1.4.1 Blockage

The hydraulic design has included an assessment regarding the blockage of culverts. Blockage potential has been assessed in accordance with the guidelines in ARR 2016. The blockage assessment resulted in no blockage factor being applied to bridges and a blockage factor of 25 per cent being applied to culverts.

A minimum culvert size of 900 mm diameter was adopted to reduce the potential for blockage and for ease of maintenance. It is noted that some existing QR West Moreton System rail corridor culverts marked for extension through the Project alignment have diameters smaller than 900mm. In these instances, proposed Project alignment culvert diameters match existing QR West Moreton System rail corridor culverts (i.e. remain unchanged).

Two culvert blockage sensitivity scenarios were tested; 0 per cent and 50 per cent blockage. The results are presented in Appendix A Figures A-7H and A-7I for the 0 per cent and 50 per cent blockage respectively.

ARR 2016 guidelines are focused on blockage of small bridges and culverts. The floodplain bridges proposed for the Project alignment are all multi-span large bridges and ARR 2016 notes that there are limited instances of multiple span bridges being observed with blockages similar to those seen at single span bridges or culverts.

A bridge blockage sensitivity scenario was also modelled. For bridges represented in 1D channels this was determined by doubling bridge obstruction (e.g. caused by piers) and determining the associated form loss/bend loss. For bridges represented in the 2D domain a 20 per cent blockage factor was adopted. The results are presented in Appendix A Figure A-7J.

The following changes to flood sensitive receptors under culvert blockage scenarios were identified:

- The afflux level on Dodt Road between Ch 47.08 km and Ch 47.81 km is predicted to vary between 220 mm (0 per cent blockage) and 14 mm (50 per cent blockage).

The outcomes of culvert blockage sensitivity scenarios indicate that peak water levels only change by small amounts with varying the culvert blockage levels and that the resulting impacts are similar.

The following changes to flood sensitive receptors under the bridge blockage scenario were identified:

- At approximately Ch 43.31 km afflux has increased by up to 30 mm in the bridge blockage scenario. The afflux extent has been extended to around permanent dwelling footprints.

The outcomes of the bridge blockage sensitivity scenario indicate that peak water levels only change by a small amount and that the resulting impacts are similar.

During detailed design the blockage factors will be reviewed in line with the final design and local catchment conditions. This may result in varied and/or lower blockage factors being applied along the project alignment. It may also take into account risk assessments associated with blockage, and/or risk mitigation where required.

9.1.4.2 Climate change assessment

The impacts of climate change were assessed for the 1% AEP event to determine the sensitivity of the Project design to the potential increase in rainfall intensity. The assessment was undertaken in accordance with ARR 2016 guidelines.

The selected representative concentration pathway for the climate change analysis was 8.5 (RCP8.5). The climate change analysis was undertaken by increasing rainfall intensities in the IFDs for the contributing catchments. For the Project, RCP8.5 corresponds to an increase in temperature of 3.7 Degrees Celsius in 2090 and an increase in rainfall intensity of 18.7 per cent which was obtained from the ARR 2016 Data Hub.

The resulting peak water levels are presented in Table 9.8 and Table 9.9. Climate change results increases in water levels between 0.4 m and 1 m at most structure locations under the 1% AEP event, with two structures appearing to experience an increase of 2.7 m to peak water levels.

The 2.7 m difference between these peak water levels is somewhat deceptive. Significant increases in peak water levels at these locations are as a result of varying floodplain and tailwater interactions. Under the 1% AEP event, flow through these culverts is limited to backflow from the northern side of the existing QR West Moreton System rail corridor. However, during the 1% AEP CC event, Lockyer Creek overbank flow reaches the upstream side of these culverts and has a significantly higher peak water surface level. The difference between peak water surface levels at the upstream and downstream side of these culverts during the 1% AEP event with climate change is approximately 2.2 m.

The formation level is significantly higher than the 1% AEP climate change peak water levels at these locations.

Table 9.8 Lockyer Creek – 1% AEP event rail drainage – Climate change assessment

Chainage (km)	Structure name	Structure type	1% AEP peak water levels (m AHD)	1% AEP + CC peak water levels (m AHD)	Difference in peak water levels (m)	Freeboard to rail formation[2] with CC (m)
40.05	C40.05	RCP	102.18	104.89	+2.71	0.25
40.33	C40.33	RCBC	Dry[1]	Dry[1]	-	-
41.07	C41.07	RCP	Dry[1]	Dry[1]	-	-
41.99	C41.99	RCP	Dry[1]	Dry[1]	-	-
42.60	C42.60	RCP	Dry[1]	Dry[1]	-	-
43.15	330-BR06	Bridge	103.54	104.53	+0.98	1.88
43.58	C43.58	RCBC	Dry[1]	Dry[1]	-	-
43.94	C43.94	RCP	Dry[1]	Dry[1]	-	-
44.45	C44.45	RCBC	Dry[1]	Dry[1]	-	-
44.90	C44.90	RCP	97.64	98.53	+0.89	-0.30
45.76	C45.76	RCP	97.09	97.83	+0.73	-0.43
46.49	C46.49	RCBC	95.11	95.67	+0.55	-0.25
47.22	C47.22	RCBC	93.22	93.68	+0.46	0.30
47.24	C47.24	RCP	93.12	93.57	+0.46	0.35
47.57	C47.57	RCP	92.20	92.27	+0.07	0.99
47.81	C47.81	RCBC	91.95	92.53	+0.57	0.19
48.46	C48.46	RCBC	90.83	91.17	+0.33	0.20
49.52	330-BR10	Bridge	90.03	90.52	+0.49	0.70
49.57	C49.57	RCBC	90.01	90.48	+0.47	0.62

Table notes:

1 This Developed Case structure is outside the 1% AEP event extents. This structure was included in the Developed Case as it conveys flow during the extreme events

2 Rail formation is taken to be the top or finished level of the Project alignment and includes the capping layer. Ballast (e.g. rocks), rail sleepers and rail heads are built on top of the formation and create the TOR. Nominal height from rail formation to TOR is 0.701 m

Table 9.9 Lockyer Creek – 1% AEP event road drainage – Climate change assessment

Structure name	Structure type	1% AEP peak water levels (m AHD)	1% AEP + CC peak water levels (m AHD)	Difference in peak water level (m)
330-BR09N	Bridge	Dry	Dry	-
330-BR09S	Bridge	Dry	Dry	-

Table note:

1 This Developed Case structure is outside the 1% AEP event extents. This structure was included in the Developed Case as it conveys flow during the 1 in 2000 AEP event.

As a point of comparison, although changes throughout the model are not uniform and vary between locations, the increase in rainfall intensity of 18.7 per cent generated a 24.3 per cent increase in peak flow at the QR rail bridge over Lockyer Creek at Gatton.

9.2 Forest Hill and Laidley

Sandy Creek and Laidley Creek, as well as breakouts from both creek systems, cross the Project alignment between Ch 50.28 km and Ch 56.83 km. The Project alignment runs parallel to the existing QR West Moreton System rail corridor. In the Existing Case, under the 1% AEP event, the existing QR West Moreton System rail corridor overtops to the south-east of Forest Hill for approximately a kilometre starting around Ch 53.20 km. Modelling shows that numerous properties, roads and the existing QR West Moreton System rail corridor are inundated during this event.

The QR West Moreton System rail corridor around Gordon Street in Forest Hill (Ch 52.33 km) and east of Forest Hill between Ch 53.22 km and Ch 54.19 km, has less than 1% AEP event flood immunity and experiences overtopping for 100m (refer Appendix A Figure A-7A-2). The area around Hunt Street is residential with significant numbers of dwellings and commercial buildings. Constructing the Project alignment to achieve the required flood immunity prevents the overtopping of the QR West Moreton System rail corridor with additional culverts required under the QR West Moreton System rail corridor to compensate for elimination of the overtopping flows. These additional culverts under both the QR West Moreton System rail corridor and the Project increases the available culvert flow area. As outlined in Section 9.2.3 this reduces the impacts in several areas in Forrest Hill and the surrounding area.

The area east of Forest Hill experiences extensive overtopping starting under the 2% AEP event, with overtopping extending to approximately 970 m under the 1% AEP event. Constructing the Project alignment to achieve the required flood immunity prevents the flow over the QR West Moreton System rail corridor with additional culverts under the QR West Moreton System rail corridor required to compensate elimination of the overtopping flows.

9.2.1 Drainage structures

The hydraulic design of the major drainage structures was undertaken using the TUFLOW model (1d and 2d approach). Within the Forest Hill and Laidley section of the Lockyer Creek hydraulic model the design includes:

- Nine rail bridges
- Eleven rail RCBC locations (multiple cells in places)
- Five road RCBC locations (multiple cells in places)
- Three rail RCP locations (multiple cells in places).

Details of these structures are Table 9.10 and Table 9.11. At Forrest Hill this is a significant increase in the number of structures under the QR and ARTC lines. This increased conveyance area reduces flood levels throughout the town area for events up to the 1% AEP. There are no proposed stream diversions within the Western Creek floodplain. Bridges have been represented within the TUFLOW model through use of layered flow constrictions. Each bridge within the model has had a flow constriction coefficient applied to represent obstruction of waterway area due to the piers.

Table 9.10 Forest Hill and Laidley – Flood rail structure locations and details

Chainage (km)	Structure name	Structure type	No of cells	Diameter or width (m)	Height (m) or Soffit level (m AHD)	Bridge length (m)
50.27	330-BR11	Bridge	-	-	90.24	28.0
51.37	330-BR12	Bridge	-	-	94.04	29.0
51.57	C51.57	RCBC[2 4]	15	2.40	1.20	-
51.60	330-BR13	Bridge	-	-	92.97	44.0
52.55	C52.55	RCBC[1]	1	1.15	1.20	-
52.67	C52.67	RCBC[2 4]	15	2.40	1.20	-
52.68	C52.68	RCP[1]	1	0.90	-	-
53.39	C53.39	RCBC[2 4]	15	2.40	1.20	-
53.48	C53.48	RCBC[2]	6	2.40	1.20	-
53.50	C53.50	RCBC[1]	2	2.215	2.01	-
53.97	C53.97	RCBC[2]	8	2.40	1.20	-
53.99	C53.99	RCBC[1]	2	2.05	1.99	-
54.74	330-BR14	Bridge	-	-	95.95	128.0
54.81	C54.81	RCBC[1]	8	2.10	2.10	-

Chainage (km)	Structure name	Structure type	No of cells	Diameter or width (m)	Height (m) or Soffit level (m AHD)	Bridge length (m)
54.83	C54.83	RCBC[1]	8	2.10	2.10	-
54.84	C54.84	RCBC[1]	9	2.10	2.10	-
55.45	C55.45	RCP[1]	1	0.90	-	-
55.83	330-BR26	Bridge	-	-	99.65	760.0
0.72[3]	330-BR27	Bridge	-	-	99.65	760
55.85	C55.85	RCP	15	1.20	-	-
56.72	330-BR28	Bridge	-	-	103.00	437
1.62[3]	330-BR29	Bridge	-	-	103.00	437
57.30	330-BR16	Bridge	-	-	103.96	75

Table notes:

1 The Developed Case alignment runs parallel to the QR West Moreton System rail corridor at this location. The existing culvert is proposed to be extended and matched through the Project alignment.

2 The Developed Case alignment runs parallel to the QR West Moreton System rail corridor at this location. A new culvert (s) is proposed to be inserted through the QR West Moreton System rail corridor and the Project alignment.

3 The Developed Case alignment introduces a passing point near this location. Chainage referenced is for the deviation that runs parallel to the main Project alignment

4 A bank of 15/2.4 m x 1.2 m RCBCs are included at this location to minimise impacts upstream of the QR West Moreton System rail corridor during some extreme events.

Table 9.11 Forest Hill and Laidley – Road structure locations and details

Road Name	Structure name	Structure type	No of cells	Width x height (m)
Gordon Street – at level crossing	GordonStreet1	RCBC	2	1.80 x 0.90
Gordon Street – 1	GordonStreet2	RCBC	2	1.80 x 0.90
Gordon Street – 2	GordonStreet3	RCBC	3	1.20 x 0.45
Gordon Street – 3	GordonStreet4	RCBC	1	1.50 x 0.60
Old Laidley Forest Hill Road	LaidlyRdMove	RCBC	3	1.80 x 0.90

9.2.2 Hydraulic design criteria outcomes

The hydraulic model was run for the Developed Case with the drainage structures and embankment areas included. Modelling of a range of events was undertaken (20%, 10%, 5%, 2%, 1% AEP events and 1 in 2,000 AEP, 1 in 10,000 AEP and PMF events). The Project design outcomes relative to the hydraulic design criteria (refer Table 4.1) are presented in the following sections.

9.2.2.1 Flood immunity and overtopping risk

In the Existing Case, under the 1% AEP event, a 900 m length of the QR West Moreton System rail corridor overtops (over the TOR level) around Hall Road from Forest Hill eastwards towards Laidley. This is the only location between Forest Hill and Laidley where the existing QR West Moreton System rail corridor overtops. In the Developed Case, the Project alignment (TOR) is raised above the existing QR West Moreton System rail corridor to meet freeboard requirements and achieve flood immunity for the 1% AEP event.

A summary of how the TOR levels of for the Project alignment compares with the QR West Moreton System rail corridor is presented in Table 9.12.

Table 9.12 Forest Hill to Laidley – Comparison of Project alignment and QR Top of Rail levels

Location	Comparison of TOR levels
West of Forest Hill	Project alignment varies between 0.2 m and 1.2 m higher than QR West Moreton System rail corridor
Forest Hill	Project alignment varies between 0.2 m and 1.5 m higher than QR West Moreton System rail corridor
East of Forest Hill	Project alignment varies between 0.2 m and 1.5 m higher than QR West Moreton System rail corridor
West of Laidley	Project alignment varies between 2.0 m and 3.0 m higher than QR West Moreton System rail corridor

The risk of overtopping of the Project alignment has been assessed for a range of extreme events (1 in 2,000, 1 in 10,000 AEP and PMF events). During these extreme events the rail overtops at the following locations outlined in Table 9.13.

Table 9.13 Forest Hill and Laidley – Rail overtopping details during extreme events

Approximate Chainages (km)	1 in 2,000 AEP event overtopping depth (m)[1]	1 in 10,000 AEP event overtopping depth (m)[1]	PMF event overtopping depth (m)[1]
Ch 51.95 to Ch 52.16	-	-	0.30
Ch 53.29 to Ch 54.19	-	-	0.50

Table note:

1 Depths vary over the length of the rail that overtops. The length of rail that overtops increases with event rarity.

9.2.2.2 Structure results

Table 9.14 and Table 9.15 present hydraulic model results at each structure for the 1% AEP event. Impacts that do not meet the guiding design criteria are discussed in the following sub-sections. Refer to Appendix A for details of structure locations and associated impact mapping.

Impacts on flood sensitive receptors identified for a range of AEPs including extreme events can be found in Appendix C.

Table 9.14 Forest Hill and Laidley – 1% AEP event rail drainage structure results

Chainage (km)	Structure name	Structure type	Upstream peak water levels (m AHD)	Freeboard to top of formation level (m)	Outlet velocity (m/s)	Peak discharge (m^3/s)
50.27	330-BR11	Bridge	89.56	1.68	1.6	29.9
51.37	330-BR12	Bridge	93.91	1.13	2.2	34.7
51.57	C51.57	RCBC[2 3]	91.67	2.54	1.6	44.2
51.60	330-BR13	Bridge	91.75	2.22	2.5	58.8
52.55	C52.55	RCBC[1]	91.54	1.21	1.1	1.4
52.67	C52.67	RCBC[2 3]	91.57	1.21	0.9	20.4
52.68	C52.68	RCP[1]	91.56	1.22	1.1	0.4
53.39	C53.39	RCBC[2 3]	92.00	1.02	2.8	63.9
53.48	C53.48	RCBC[2]	91.56	1.50	2.4	26.3
53.50	C53.50	RCBC[1]	91.40	1.67	2.4	19.5
53.97	C53.97	RCBC[2]	91.10	0.61	2.0	11.9
53.99	C53.99	RCBC[1]	91.10	2.13	0.8	5.9
54.74	330-BR14	Bridge	94.78	2.17	2.3	148.3
54.81	C54.81	RCBC[1]	94.78	2.69	1.5	54.2

Chainage (km)	Structure name	Structure type	Upstream peak water levels (m AHD)	Freeboard to top of formation level (m)	Outlet velocity (m/s)	Peak discharge (m^3/s)
54.83	C54.83	RCBC[1]	94.78	2.75	1.5	54.2
54.84	C54.84	RCBC[1]	94.78	2.78	1.5	61.0
55.45	C55.45	RCP[1]	Dry	5.31	-	-
55.83	330-BR26	Bridge	97.13	5.24	0.9	87.2
0.72[3]	330-BR27	Bridge	97.13	4.79	0.9	87.2
55.85	C55.85	RCP	96.43	4.29	1.3	6.7
56.72	330-BR28	Bridge	97.71	7.29	1.4	203.9
1.62[3]	330-BR29	Bridge	97.71	6.86	1.4	203.9
57.30	330-BR16	Bridge	98.18	7.78	0.5	7.5

Table notes:

1 The Developed Case alignment runs parallel to the QR West Moreton System rail corridor at this location. The existing culvert is proposed to be extended and matched through the Project alignment.

2 The Developed Case alignment runs parallel to the QR West Moreton System rail corridor at this location. A new culvert(s) is proposed to be inserted through the QR West Moreton System rail corridor and the Project alignment

3 A bank of 15/ 2.4 m x 1.2 m RCBCs included at this location to minimise impacts upstream of the QR West Moreton System rail corridor during some extreme events.

Table 9.15 Forest Hill and Laidley – 1% AEP event road drainage structure results

Structure name	Structure type	Upstream peak water level (m AHD)	Outlet velocity (m/s)	Peak discharge (m^3/s)
GordonStreet1	RCBC	91.90	2.0	3.7
GordonStreet2	RCBC	91.91	0.5	0.2
GordonStreet3	RCBC	92.00	1.4	0.7
GordonStreet4	RCBC	91.55	0.5	0.4
LaidlyRdMove	RCBC	98.11	2.3	4.5

9.2.3 Flood impact objective outcomes

The Project design outcomes relative to the flood impact objectives (refer Table 4.2) are presented in the following sections.

9.2.3.1 Change in peak water levels

The impact of the Developed Case has been assessed through inclusion of the drainage structures and comparison of model results against the Existing Case results. Resulting changes in peak have been mapped (refer Appendix A).

Under the 1% AEP event there is an isolated occurrence of afflux predicted to be greater than 200 mm, being:

- On the northern side of the Project alignment to the west of the Forest Hill bridge (around Ch 51.57 km) there is up to 400 mm afflux. This increase is concentrated against the Project alignment and dissipates to less than 100 mm immediately downstream. Afflux at this location is caused by the introduction of 15/2.4 m x 1.2 m RCBCs to help reduce impacts to upstream suburban areas of Forest Hill.
- Downstream of the existing QR West Moreton System rail corridor, within the Forest Hill township (Ch 53.40 km), approximately 200 mm of afflux is predicted on Hall Road (unsealed) at the culvert outlets which immediately reduces to less than 100 mm on the adjacent agricultural land. Afflux at this location is caused by the introduction of culverts to both remove the overtopping of the QR West Moreton System rail corridor and to help reduce impacts to upstream suburban areas of Forest Hill during extreme events.

- On the southern side of the Project alignment to the west of Laidley-Plainlands Road (Ch 57.25 km) there is up to 360 mm afflux. This increase is concentrated against the Project alignment and dissipates to less than 100 mm immediately west of the partial Old Laidley-Forest Hill Road diversion. The placement of the Project alignment provides a reduction in peak water levels of up to 125 mm to the community facilities (cricket pitch and associated grounds) and the local access road immediately to the north.

Under the 1% AEP event there are several occurrences of afflux predicted to be between 100 mm and 200 mm. These are:

- Downstream of the existing QR West Moreton System rail corridor, within the Forest Hill township (Ch 52.68 km), approximately 175 mm of afflux is predicted on Hall Road (unsealed) and up to 100 mm afflux on agricultural land. The agricultural land appears to be a mix of open cropping land and raised outdoor hydroponics under scaffold-shade coverings which runs alongside an existing flood drain. Afflux at this location is caused by the introduction of culverts to both: remove the overtopping of the QR West Moreton System rail corridor and to help reduce impacts to upstream suburban areas of Forest Hill during extreme events.
- On the southern side of the Project alignment tie-in to the existing QR West Moreton System rail corridor (Ch 55.85 km) approximately 160 mm of afflux is predicted on rural land.
- Between the Project alignment and Old Laidley-Forest Hill Road, south-east of the 330-BR26 bridge abutment (Calvert end), approximately 135 mm of afflux is predicted; dissipating to 100 mm immediately downstream of the bridge abutment on rural land. Areas with afflux greater than 100 mm are located on high-value agricultural land, however, this land is within the Project boundary (i.e. nominally 30 m from the top of Project alignment; within the rail corridor but not part of the permanent infrastructure).
- Realignment works on the eastern end of Old Laidley-Forest Hill Road (Ch 57.15 km) lead to an afflux of 180 mm. This is 80 mm in exceedance of the 100 mm guiding criteria. However, the ground level of the road diversion has increased by approximately 100 mm as compared to the existing road levels. This results in a reduction in the time of inundation whilst maintaining previous immunity levels for frequent events.

As seen in Appendix A Figure A-7E-2 there are a number of flood sensitive receptors in the Forest Hill and Laidley areas that were identified. Where afflux is 10 mm or greater at a flood sensitive receptor under the 1% AEP event a summary of afflux for all modelled events up to the 1% AEP event is presented in Appendix D. These impacts for the minor events satisfy the flood impact objectives.

Details of where afflux is greater than 10 mm at areas adjacent to the Project alignment is outlined in Table 9.16.

Table 9.16 Afflux at flood sensitive receptors during the 1% AEP event

Location	Afflux (mm)	Comment
Dodt Road (330-BR11, Ch 50.30 km. West of Greyfriars Road)	45	Afflux at this location impacts on Dodt Road and adjacent rural land.
Agricultural land (Ch 51.57 km)	400	Agricultural land appears to be open cropping land. Afflux caused by introduction of culverts to minimise impacts to Forest Hill township during extreme events. Dissipates to less than 100 mm within 100 m downstream of the Project alignment.
Hall Road (Ch 52.68 km)	175	Afflux caused by introduction of culverts to minimise impacts to Forest Hill township during extreme events and prevent QR West Moreton System rail corridor overtopping present in the existing case. Dissipates to less than 100 mm within 30 m downstream of the Project alignment.

Location	Afflux (mm)	Comment
Agricultural land (Ch 52.68 km)	100	Agricultural land appears to be a mix of open cropping land and raised outdoor hydroponics under scaffold-shade coverings. Afflux caused by introduction of culverts to minimise impacts to Forest Hill township during extreme events and prevent QR West Moreton System rail corridor overtopping present in the existing case. Area around dwelling in the western corner of the block appears to experience shallow (<45 mm) sheet flow. Ground survey of this dwelling will be sought in detailed design.
Hall Road (Ch 53.40 km)	200	Afflux caused by introduction of culverts to minimise impacts to Forest Hill township during extreme events and prevent QR West Moreton System rail corridor overtopping present in the existing case. Immediately dissipates to less than 100 mm on the adjacent agricultural land.
Agricultural land (Ch 54.40 km)	90	Agricultural land appears to be open cropping land. Afflux resulting from the Project alignment filling floodplain area. Dissipates to 35 mm within 30 m of the Project alignment.
Rural Land (Ch 54.87 km)	260	Resulting from the Project alignment filling floodplain area. Dissipates to 50 m within 110 m of the Project alignment.
Agricultural land (Ch 55.00 km)	80	Agricultural land appears to be open cropping land. Afflux caused by bridge arrangement and western end of Project alignment (embankment) filling a low area in LiDAR survey.
QR West Moreton System rail corridor (Ch 55.85 km)	160	Caused by shallow sheetflow being trapped behind the Project alignment. Localised impacts.
Project alignment/ agricultural land (Ch 56.70 km)	135	Agricultural land affected by +100 mm afflux at this location is within the Project boundary (i.e. nominally 30 m from the toe of Project alignment, varying in locations; within the rail corridor but not part of the permanent infrastructure). Afflux dissipates to below 30 mm around the downstream end (west) of bridge 330-BR26.
Old Laidley-Forest Hill Road diversion (Ch 57.15 km)	180	Afflux is 80 mm in exceedance of the 100 mm criteria for roads. However, the ground level of the road diversion has increased by approximately 100 mm as compared to the previous road level. This results in a reduction of time of inundation whilst maintaining previous immunity levels for frequent events.
Between Old Laidley-Forest Hill Road and Project alignment (Ch 57.25 km)	360	The afflux is concentrated against the Project alignment and dissipates to less than 100 mm afflux immediately west of the partial Old Laidley-Forest Hill Road diversion. The Project alignment provides a reduction in peak water levels of 125 mm to community facilities (cricket pitch and associated grounds) and local access.
Residential lot – 2RP25655 (approximately Ch 57.45 km)	-	The residential structure is located 30 m from the toe of the Project alignment. This property is included as part of the Project boundary.

9.2.3.2 Average annual time of submergence and time of submergence

Assessment of the change in the Time of Submergence (ToS) is presented in Appendix A Figure A-7D.

In the 1% AEP event where afflux was predicted to be greater than 200 mm the behaviour of ToS is as follows:

- Northern side (downstream) of the Project alignment, east of the bridge at Forest Hill (Ch 51.57 km), the predicted ToS is 50.8 hours for the Existing Case and 51.7 hours for the Developed Case during a 1% AEP event. AAToS is expected to increase by 0.5 hours as a result of the Project alignment.
- Northern side of the Project alignment just east of Laidley Creek (Ch 54.87 km) the predicted ToS is 53 hours for the Existing Case and 57.5 hours for the Developed Case during a 1% AEP event. AAToS is expected to increase by 2 hours as a result of the Project alignment.

- Southern side of the Project alignment to the west of Laidley-Plainlands Road (Ch 57.25 km) the predicted ToS is 37.8 hours for the Existing Case and 32.3 hours for the Developed Case during a 1% AEP event. AAToS is expected to increase by 0.5 hours as a result of the Project alignment.

Under the 1% AEP event where afflux was predicted to be between 100 mm and 200 mm the impact on ToS is as follows:

- Southern side (downstream) of the Project alignment at Forest Hill (Ch 52.68 km) the predicted ToS is 42.6 hours for the Existing Case and 44.4 hours for the Developed Case during a 1% AEP event. AAToS is not expected to increase as a result of the Project alignment.
- Southern side (downstream) of the Project alignment, east of Forest Hill (Ch 53.40 km), the predicted ToS is 48.3 hours for the Existing Case and 57.4 hours for the Developed Case during a 1% AEP event. AAToS is expected to increase by 2.6 hours as a result of the Project alignment. This is a localised increase in ToS and is due to the overtopping of the existing QR West Moreton System rail corridor being eliminated through the inclusion of additional culverts and extension of existing culverts to pass under the Project alignment. These culverts also mitigate impacts on habitable dwellings under extreme flood events. The overall trafficability of Hall Road is controlled by a low point near Ch 53.99 km which does not experience any change in ToS.
- On the southern side of the Project alignment tie-in to the existing QR West Moreton System rail corridor (Ch 55.85 km) the predicted ToS is 23.7 hours for the Existing Case and 45.4 hours for the Developed Case. AAToS is expected to increase by less than 2 hours as a result of the Project alignment.
- Between the Project alignment and Old Laidley Forest Hill Road, south-east of the 330-BR26 bridge abutment (Calvert end – Ch 56.70 km), the predicted ToS is 19.7 hours for the Existing Case and 41.8 hours for the Developed Case. Less than an hour increase in AAToS is expected as a result of the Project alignment.
- At the realignment works on the eastern end of Old Laidley-Forest Hill Road (Ch 57.15 km) the predicted ToS over the road is 42.7 hours for the Existing Case and 32.4 hours for the Developed Case. AAToS is expected to decrease by 1.8 hours as a result of the Project alignment. It is worth noting that the significant reduction in AAToS is restricted to the roadway (due to the elevated proposed road levels). The creek area immediately upstream (south) of this realignment work is only expected to experience minor AAToS decreases of less than 30 minutes.

9.2.3.3 Change in velocities

Appendix A Figure A-7D present the change in peak velocities under the 1% AEP event associated with the Project alignment. In general, the changes are minor and located close to the Project alignment. The area with the most changes in peak velocities is between approximately Ch 53.00 km and 54.00 km where new and extended culvert structures are required to address flow complexity where the existing QR West Moreton System rail corridor is overtopped.

9.2.3.4 Flood flow distribution

Overall, the Project has minimal impacts on flood flows and floodplain conveyance/storage with significant floodplain structures included to maintain the existing flood regime.

9.2.3.5 Extreme event risk management

During extreme events there is widespread floodplain inundation with high flood depths as shown in Figures A-8A, A-9A and A-10A. These impacts have been considered in relation to the Existing Case flood depths at flood sensitive receptors. Under these rare events, the bridge structures and culverts allow adequate passage of flow during the flood events and “damming” effects are therefore not expected to occur.

Several design events larger than the 1% AEP event, including the 1 in 2,000 AEP, 1 in 10,000 AEP and PMF, have been modelled to assess the performance of the Project and to review impacts on the flooding regime. Appendix A Figures A-8B, A-9B and A-10B present the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events respectively. As can be seen the flood inundation extent and peak water levels increase across the floodplain between Lawes and Laidley as the severity of the flood event increases.

The Project alignment runs parallel to the existing QR West Moreton System rail corridor which governs the existing flood conditions. Under the extreme events, with the Project alignment in place, there are no significant changes in flood inundation or velocities, and flow behaviour is consistent with the existing conditions. There are changes in peak water levels which are attributed to the height of the proposed Project alignment required to achieve the desired flood immunity standard. Mitigation of impacts has been carried out through the extension of QR culverts under the Project alignment and inclusion of a significant number of new culvert banks under both the Project alignment and the QR West Moreton System rail corridor. A number of these culvert banks have been included to specifically mitigate impacts under the extreme events. This has resulted in slight decreases in peak water levels in Forest Hill under the 1 in 2,000 AEP and 1 in 10,000 AEP events.

9.2.4 Sensitivity analysis

9.2.4.1 Blockage

The hydraulic design has included an assessment regarding the blockage of culverts. Blockage potential has been assessed in accordance with the guidelines in ARR 2016. The blockage assessment resulted in no blockage factor being applied to bridges and a blockage factor of 25 per cent being applied to culverts.

A minimum culvert size of 900 mm diameter was adopted to reduce the potential for blockage and for ease of maintenance. It is noted that some existing QR West Moreton System rail corridor culverts marked for extension through the Project alignment have diameters smaller than 900 mm. In these instances, Project culvert diameters match existing QR West Moreton System rail corridor culverts (i.e. remain unchanged).

Two culvert blockage sensitivity scenarios were tested; 0 per cent and 50 per cent blockage. The results are presented in Appendix A Figures A-7G and A-7H for the 0 per cent and 50 per cent blockage respectively.

ARR 2016 guidelines are focused on blockage of small bridges and culverts. The floodplain bridges proposed for the Project alignment are all multi-span large bridges and ARR 2016 notes that there are limited instances of multiple span bridges being observed with blockages similar to those seen at single span bridges or culverts.

A bridge blockage sensitivity scenario was also modelled. For bridges represented in 1D channels this was determined by doubling bridge obstruction (e.g. caused by piers) and determining the associated form loss/bend loss. For bridges represented in the 2D domain a 20 per cent blockage factor was adopted. The results are presented in Appendix A Figure A-7I.

The following changes to flood sensitive receptors under culvert blockage scenarios were identified:

- The change in peak water levels on the agricultural land around Ch 51.57 km increases from 400 mm to 410 mm in the 0 per cent blockage scenario and reduces to 350 mm in the 50 per cent blockage scenario
- The change in peak water levels on the western corner of the property at Ch 52. 55 km reduces from 40 mm to 31 mm in the 0 per cent blockage scenario and increases to 53 mm in the 50 per cent blockage scenario
- The change in peak water levels on the agricultural land around Ch 52.68 km decreases from 100 mm to 80 mm in the 0 per cent blockage scenario and increases to 125 mm in the 50 per cent blockage scenario
- The change in peak water levels on Hall Road at Ch 53.40 km increases from 200 mm to 260 mm in the 0 per cent blockage scenario and reduces to 120 mm in the 50 per cent blockage scenario

- The change in peak water levels on the QR West Moreton System rail corridor at Ch 55.85 km reduces from 160 mm to 145 mm in the 0 per cent blockage scenario and increases to 175 mm in the 50 per cent blockage scenario
- The rural area upstream (north) of the Project alignment around Ch 53.99 km, and associated farm dams, are predicted to experience up to 95 mm afflux in the 50 per cent blockage scenario
- Afflux is predicted to vary by 10 mm between the 0 per cent Blockage and 50 per cent blockage scenarios around the Project alignment at Ch 56.72 km and Old Laidley-Forest Hill Road diversion (Ch 57.15 km).

The outcomes of culvert blockage sensitivity scenarios indicate that peak water levels only change by small amounts with varying the culvert blockage levels and that the resulting impacts are similar.

The following changes to flood sensitive receptors under the bridge blockage scenario were identified:

- The change in peak water levels on Dodt Road around Ch 50.30 km (330-BR11) increases from 45 mm to 140 mm in the bridge blockage scenario
- The change in peak water levels on the agricultural land around Ch 51.57 km (330-BR12) increases from 45 mm to 410 mm in the bridge blockage scenario
- The change in peak water levels on the agricultural land around Ch 56.70 km (330-BR26) increases by less than 10 mm to a maximum of 145 mm in the bridge blockage scenario
- The change in peak water levels between Old Laidley-Forest Hill Road and the Project alignment (around Ch 57.25 km, east of 330-BR26) increases by less than 10 mm to a maximum of 370 mm in the bridge blockage scenario.

The outcomes of the bridge blockage sensitivity scenario indicate that peak water levels only change by small amounts and that the resulting impacts are similar.

During detailed design the blockage factors will be reviewed in line with the final design and local catchment conditions. This may result in varied and/or lower blockage factors being applied along the project alignment. It may also take into account risk assessments associated with blockage, and/or risk mitigation where required.

9.2.4.2 Climate change assessment

The impacts of CC were assessed for the 1% AEP event to determine the sensitivity of the Project design to the potential increase in rainfall intensity. The assessment was undertaken in accordance with ARR 2016 guidelines.

The selected representative concentration pathway for the climate change analysis was 8.5. The climate change analysis was undertaken by increasing rainfall intensities in the IFDs for the contributing catchments. For the Project, RCP8.5 corresponds to an increase in temperature of 3.7 degrees Celsius in 2090 and an increase in rainfall intensity of 18.7 per cent which was obtained from the ARR 2016 Data Hub.

The climate change analysis was undertaken by increasing rainfall intensities within the IFDs for the local catchments and the resulting peak water levels are presented in Table 9.17 and Table 9.18. Climate change results increase peak water levels by up to 460 mm at structure locations for the 1% AEP. The formation level is significantly higher than the 1% AEP climate change peak water levels at these locations.

Table 9.17 Forest Hill and Laidley – 1% AEP event rail drainage – Climate change assessment

Chainage (km)	Structure name	Structure type	1% AEP peak water level (m AHD)	1% AEP + CC peak water level (m AHD)	Difference (m)	Freeboard to rail formation[2] with CC (m)
50.27	330-BR11	Bridge	89.56	89.81	0.25	1.43
51.37	330-BR12	Bridge	93.91	93.91	0.01	1.13
51.57	C51.57	RCBC	91.67	91.79	0.12	2.42
51.60	330-BR13	Bridge	91.75	91.89	0.13	2.08

Chainage (km)	Structure name	Structure type	1% AEP peak water level (m AHD)	1% AEP + CC peak water level (m AHD)	Difference (m)	Freeboard to rail formation[2] with CC (m)
52.55	C52.55	RCBC	91.54	91.67	0.13	1.08
52.67	C52.67	RCBC	91.57	91.66	0.10	1.12
52.68	C52.68	RCP	91.56	91.67	0.11	1.11
53.39	C53.39	RCBC	92.00	92.17	0.17	0.84
53.48	C53.48	RCBC	91.56	91.76	0.20	1.30
53.50	C53.5	RCBC	91.40	91.68	0.28	1.39
53.97	C53.97	RCBC	91.10	91.54	0.44	0.17
53.99	C53.99	RCBC	91.10	91.54	0.43	1.69
54.74	330-BR14	Bridge	94.78	94.91	0.13	2.04
54.81	C54.81	RCBC	94.78	94.83	0.04	2.64
54.83	C54.83	RCBC	94.78	94.83	0.04	2.71
54.84	C54.84	RCBC	94.78	94.83	0.04	2.73
55.45	C55.45	RCP	Dry[1]	Dry[1]	-	-
55.83	330-BR26	Bridge	97.13	97.59	0.46	4.78
0.72[3]	330-BR27	Bridge	97.13	97.59	0.46	4.78
55.85	C55.85	RCP	96.43	96.74	0.31	3.99
56.72	330-BR28	Bridge	97.71	98.00	0.29	7.00
1.62[3]	330-BR29	Bridge	97.71	98.00	0.29	7.00
57.30	330-BR16	Bridge	98.18	98.37	0.20	7.59

Table notes:

1 This Developed Case structure is outside the 1% AEP event extents. This structure was included in the Developed Case as it conveys flow during the extreme events

2 Rail formation is taken to be the top or finished level of the Project alignment and includes the capping layer. Ballast (e.g. rocks), rail sleepers and rail heads are built on top of the formation and create the TOR. Nominal height from rail formation to TOR is 0.701 m

Table 9.18 Forest Hill and Laidley – 1% AEP event road drainage – Climate change assessment

Structure name	Structure type	1% AEP peak water levels (m AHD)	1% AEP + CC peak water levels (m AHD)	Difference in peak water levels (m)
GordonStreet1	RCBC	91.90	92.17	0.27
GordonStreet2	RCBC	91.91	92.17	0.26
GordonStreet3	RCBC	92.00	92.18	0.17
GordonStreet4	RCBC	91.55	91.68	0.13
LaidlyRdMove	RCBC	98.11	98.20	0.08

The flow complexities and varying timings in this area make it difficult to reliably identify a precise comparison between the increase in rainfall intensity of 18.7 per cent for climate futures and a resulting percentage increase of peak flow passed both the QR West Moreton System rail corridor and the Project alignment. However, it is estimated that the increase in peak flows could be between 10 per cent and 25 per cent.

The justification for this variation in percentage peak flow increase relates to the flood attenuation provided by the QR West Moreton System rail corridor, the impact of the QR West Moreton System rail corridor on flows in the Existing Case and the removal of overtopping of the QR West Moreton System rail corridor in the Developed Case with the introduction of additional culverts.

9.3 Western Creek

Western Creek initially crosses the proposed Project alignment at approximately Ch 65.69 km to the west of Grandchester. Under a 1% AEP event approximately 120 m^3/s of flow passes through this crossing. Western Creek and the Project alignment continue westwards, with the Project alignment crossing Western Creek at a number of locations before connecting up to the C2K Project at Calvert.

Under the 1% AEP event the floodplain inundation is wide and in places relatively shallow (less than 1 m). Modelling shows that numerous properties, roads and the existing QR West Moreton System rail corridor are inundated in the Existing Case. The Project alignment crosses through a significant portion of the creek floodplain and hydraulic structures are needed to maintain existing flow behaviour.

From Ch 67.65 km to the end of the Project the Project alignment runs parallel to the existing QR West Moreton System rail corridor. There are localised areas of the QR West Moreton System rail corridor that is overtopped under the 2% AEP and 1% AEP events. The primary overtopping location is at approximately Ch 70.00 km.

The area immediately downstream of this overflow location is rural or grazing land based on the aerial imagery provided. However, the flow passing this location appears to have limited interaction with the Western Creek channel. The Project alignment is higher than the QR West Moreton System rail corridor in order to achieve the Design requirements and additional culverts are required under the QR West Moreton System rail corridor to convey the flow that was overtopping the QR West Moreton System rail corridor. These culverts have been sized to minimise impacts on flood sensitive receptors and are detailed in Section 9.3.1.

9.3.1 Drainage structures

The hydraulic design of the major drainage structures was undertaken using the TUFLOW hydraulic model (1d and 2d approach). Within the Project hydraulic model, the design includes:

- Five rail bridges
- Ten rail RCBC locations (multiple cells in places)
- Four road RCBC locations (multiple cells in places
- Twenty rail RCP locations (multiple cells in places).

Details of these structures are listed Table 9.19 and Table 9.20. The C2K alignment has been included in the design case hydraulic modelling as well to quantify accumulative impacts on the Project structures in Table 9.23 and Table 9.24.

Table 9.19 Western Creek – Flood rail structure locations and details

Chainage (km)	Structure name	Structure type	No of cells	Diameter or width (m)	Height (m) or Soffit level (m AHD)	Bridge length (m)
65.29	330-BR20	Bridge	-	-	88.24	516.0
65.90	C65.90	RCP	7	1.20	-	-
66.00	C66.00	RCP	15	1.20	-	-
66.04	C66.04	RCP	15	1.20	-	-
66.25	C66.25	RCP	30	1.20	-	-
66.43	C66.43	RCP	20	1.20	-	-
66.48	C66.48	RCP	10	1.20	-	-
66.52	C66.52	RCP	10	1.20	-	-
66.55	C66.55	RCP	10	1.20	-	-
66.58	C66.58	RCP	10	1.20	-	-
66.61	C66.61	RCP	10	1.20	-	-

Chainage (km)	Structure name	Structure type	No of cells	Diameter or width (m)	Height (m) or Soffit level (m AHD)	Bridge length (m)
66.76	C66.76	RCP	10	1.20	-	-
66.82	C66.82	RCP	10	1.20	-	-
66.93	C66.93	RCP	30	1.20	-	-
67.04	C67.04	RCP	10	1.20	-	-
67.25	C67.25	RCP	5	1.20	-	-
67.31	C67.31	RCP	25	1.20	-	-
67.36	C67.36	RCP	5	1.20	-	-
67.41	C67.41	RCP	5	1.20	-	-
67.63	330-BR21	Bridge	-	-	78.68	32.0
68.69	C68.69	RCBC[1]	2	1.20	1.20	-
69.10	330-BR25	Bridge	-	-	70.60	56.0
69.29	330-BR22	Bridge	-	-	69.93	84.0
69.90	C69.90	RCBC[2]	3	1.20	0.90	-
69.91	C69.91	RCBC[1]	2	1.20	0.90	-
69.98	C69.98	RCP[2]	15	0.90	-	-
70.02	C70.02	RCP[2]	5	0.90	-	-
70.05	C70.05	RCBC[1]	1	1.40	1.00	-
70.98	C70.98	RCBC[1]	4	1.50	1.50	-
71.12	330-BR23	Bridge	-	-	60.00	47.0
71.54	C71.53	RCBC[2]	1	1.50	1.20	-
71.54	C71.54	RCBC[1]	1	1.50	1.20	-
71.90	C71.90	RCBC[1]	1	1.20	1.20	-
72.43	C72.43	RCBC[1]	1	1.80	0.90	-
73.21	C73.21	RCBC[1]	2	1.20	1.20	-

Table notes:

1 The Developed Case alignment runs parallel to the QR West Moreton System rail corridor at this location. The existing culvert is proposed to be extended and matched through the Project alignment.

2 The Developed Case alignment runs parallel to the QR West Moreton System rail corridor at this location. A new culvert(s) is proposed to be inserted through the QR West Moreton System rail corridor and the Project alignment.

Table 9.20 Western Creek – Road structure locations and details

Road Name	Structure name	Structure type	No of cells	Width x height (m)
Grandchester Mount Mort Road – Access Road	GrandchesterMtMortAccessRoad	RCBC	10	2.40 x 0.90
Grandchester Mount Mort Road – North	GrandchesterMtMortRoadNorth	RCBC	6	2.40 x 1.20
Grandchester Mount Mort Road – South	GrandchesterMtMortRoadSouth	RCBC	13	2.40 x 1.20
Newmann Road – East	NewmannRoadEast	RCBC	7	2.40 x 1.20

9.3.2 Hydraulic design criteria outcomes

The hydraulic model was run for the Developed Case with the drainage structures and embankment areas included. Modelling of a range of events was undertaken (20%, 10%, 5%, 2%, 1% AEP events and 1 in 2,000 AEP, 1 in 10,000 AEP and PMF events). The Project design outcomes relative to the hydraulic design criteria (refer Table 4.1) are presented in the following sections.

9.3.2.1 Flood immunity and overtopping risk

A 330 m length of the existing QR West Moreton System rail corridor around Ch 70.00 km, near Neuman Road at Calvert between meanders of Western Creek, overtops under the 2% AEP event (above TOR level). This is the only location between Grandchester and Calvert where the existing QR West Moreton System rail corridor overtops. The Project alignment is raised slightly above the existing QR West Moreton System rail corridor at this location to meet the Project design requirements and achieve the required flood immunity.

A summary of how the TOR levels of for the Project alignment compares with the QR West Moreton System rail corridor is presented in Table 9.23.

Table 9.21 Grandchester to Calvert – Comparison of Project alignment and QR Top of Rail levels

Approximate chainage (km)	Comparison of TOR levels
East of Grandchester	Project alignment varies between 0.7 m and 2.0 m higher than QR West Moreton System rail corridor
West of Calvert	Project alignment varies between 0.2 m and 1.0 m higher than QR West Moreton System rail corridor
Calvert (Tie-in to C2K Project)	Project alignment varies between 1.0 m and 3.0 m higher than QR West Moreton System rail corridor

The risk of overtopping of the Project alignment has been assessed for a range of extreme events (1 in 2,000 AEP, 1 in 10,000 AEP and PMF events). During these extreme events the Project alignment overtops in a number of locations as shown in Table 9.22.

Table 9.22 Western Creek – Rail overtopping details during extreme events

Approximate chainages (km)	1 in 2,000 AEP event overtopping depth (m)[1]	1 in 10,000 AEP event overtopping depth (m)[1]	PMF event overtopping depth (m)[1]
65.90 to 66.00	-	-	0.15
67.35 to 67.60	-	-	0.10
Area around Ch 70.00[2]	-	-	0.37

Table notes:

1 Depths vary over the length of the Project alignment that overtops. The length of rail that overtops increases with event rarity.
2 At this location the QR West Moreton System rail corridor TOR has less than 1% AEP immunity and overtops in the Existing Case.

9.3.2.2 Structure results

Table 9.23 and Table 9.24 presents hydraulic model results at each structure for the 1% AEP event. Consultation has been undertaken with landowners and other stakeholders on the initial flood modelling results (refer to the EIS Chapter 5: Stakeholder engagement and Appendix D: Consultation report). Additional consultation on any impacts resulting from the Project alignment will be addressed through further consultation with the relevant stakeholders during the detailed design phase of this Project. Impacts are discussed in the following sub-sections. Refer to Appendix B for the supporting mapping.

Impacts on flood sensitive receptors identified for a range of AEPs including extreme events can be found in Appendix C.

Table 9.23 Western Creek – 1% AEP event rail drainage structure results

Chainage (km)	Structure name	Structure type	Upstream peak water level (m AHD)	Freeboard to top of formation level (m)	Outlet velocity (m/s)	Peak discharge (m^3/s)
65.29	330-BR20	Bridge	88.98	1.26	2.4	141.9
65.90	C65.90	RCP	86.81	2.02	1.1	3.3
66.00	C66.00	RCP	85.91	1.68	1.7	14.8
66.04	C66.04	RCP	85.68	1.74	1.4	8.0

Chainage (km)	Structure name	Structure type	Upstream peak water level (m AHD)	Freeboard to top of formation level (m)	Outlet velocity (m/s)	Peak discharge (m^3/s)
66.25	C66.25	RCP	84.50	2.05	1.1	27.2
66.43	C66.43	RCP	84.32	1.54	1.4	15.0
66.48	C66.48	RCP	84.20	1.49	1.0	8.2
66.52	C66.52	RCP	83.85	1.70	1.0	2.0
66.55	C66.55	RCP	83.65	1.72	0.9	1.1
66.58	C66.58	RCP	83.16	1.99	0.9	1.2
66.61	C66.61	RCP	82.77	2.21	0.7	0.5
66.76	C66.76	RCP	81.47	2.64	1.0	1.7
66.82	C66.82	RCP	81.32	2.48	1.1	3.4
66.93	C66.93	RCP	81.08	2.03	1.3	13.5
67.04	C67.04	RCP	80.73	1.79	1.1	3.2
67.25	C67.25	RCP	79.78	1.55	1.7	4.6
67.31	C67.31	RCP	79.18	1.68	1.1	13.8
67.36	C67.36	RCP	78.96	1.76	1.4	2.9
67.41	C67.41	RCP	78.66	1.80	1.2	1.7
67.63	330-BR21	Bridge	78.30	1.38	2.0	170.8
68.69	C68.69	RCBC[1]	Dry	1.22	-	-
69.10	330-BR25	Bridge	70.36	1.24	1.8	65.1
69.29	330-BR22	Bridge	70.20	0.73	2.4	139.4
69.90	C69.90	RCBC[2]	69.15	0.66	5.3	7.7
69.91	C69.91	RCBC[1]	69.16	0.72	5.3	6.8
69.98	C69.98	RCP[2]	67.39	2.52	1.1	3.2
70.02	C70.02	RCP[2]	67.38	2.48	1.1	1.0
70.05	C70.05	RCBC[1]	67.38	2.42	0.9	0.1
70.98	C70.98	RCBC[1]	61.83	1.71	3.1	16.5
71.12	330-BR23	Bridge	61.26	0.74	1.9	194.5
71.54	C71.53	RCBC[2]	58.90	1.10	1.0	0.3
71.54	C71.54	RCBC[1]	58.90	1.20	1.0	0.4
71.90	C71.90	RCBC	Dry	2.44	-	-
72.43	C72.43	RCBC[1]	Dry	1.58	-	-
73.21	C73.21	RCBC[1]	54.46	3.12	2.7	4.2

Table notes:

1 The Developed Case alignment runs parallel to the QR West Moreton System rail corridor at this location. The existing culvert is proposed to be extended and matched through the Project alignment.

2 The Developed Case alignment runs parallel to the QR West Moreton System rail corridor at this location. A new culvert(s) is proposed to be inserted through the QR West Moreton System rail corridor and the Project alignment.

Table 9.24 Western Creek – 1% AEP event road drainage structure results

Road Name	Structure name	Structure type	Upstream peak water level (m AHD)	Outlet velocity (m/s)	Peak discharge (m^3/s)
Grandchester Mount Mort Road – Access Road	GrandchesterMtMortAccessRoad	RCBC	85.45	1.0	13.4
Grandchester Mount Mort Road – North	GrandchesterMtMortRoadNorth	RCBC	86.23	1.9	6.4
Grandchester Mount Mort Road – South	GrandchesterMtMortRoadSouth	RCBC	86.73	2.3	27.1
Newmann Road – East	NewmannRoadEast	RCBC	61.65	1.7	18.4

9.3.3 Flood impact objective outcomes

The Project design outcomes relative to the flood impact objectives (refer Table 4.2) are presented in the following sections.

9.3.3.1 Change in peak water levels

The impact of the Developed Case has been assessed through inclusion of the drainage structures and comparison of model results against the Existing Case results. Resulting changes in peak water levels have been mapped (refer Appendix B).

In the 1% AEP event there are a few isolated occurrences of afflux predicted to be greater than 200 mm. These are:

- On the east abutment of the Western Creek Bridge (Ch 65.88 km) where there is up to 370 mm afflux. This afflux is localised and on rural land with no flood sensitive receptors directly impacted. Placement of the Project alignment and elevated road levels of Grandchester Mount Mort Road associated with the proposed level crossing provides a reduction in peak water levels to most permanent dwellings within 150 m of the level crossing. The remaining dwellings within 150 m of the level crossing comply with the guiding design criteria or are dry.
- Between Ch 66.12 km and 66.50 km there is up to 285 mm afflux contained within rural allotments. As seen in Appendix B Figure B-7A during the 1% AEP event the flow is shallow (between 0.2 m and 0.6 m deep) with an overland flow path of around 150 m wide. No permanent dwellings are affected based on the aerial imagery provided.
- Between the existing QR West Moreton System rail corridor and the Project alignment (around Ch 67.30 km) there is up to 330 mm afflux. This afflux is located within the Project boundary (i.e. nominally 30 m from the toe of Project alignment (embankment), varying in locations; within the rail corridor but not part of the permanent infrastructure) and is due to sheetflow ponding at the Project alignment junction. This afflux does not affect any flood sensitive receptors.
- The area east of bridge 330-BR22 (between Ch 69.25 km and Ch 69.92 km) is predicted to experience 390 mm afflux on the rural land abutting the Project alignment. As the existing QR West Moreton System rail corridor overtops at this location, the drainage solution proposed balances releasing additional flows in more frequent flood events with storage of the Existing Case overtopping flows across the QR West Moreton System rail corridor.

Under the 1% AEP event there are also occurrences of afflux predicted to be between 100 mm and 200 mm. These are:

- Between Ch 66.50 km and Ch 66.80 km there is up to 150 mm afflux contained within rural allotments. Afflux dissipates to under 60 mm outside of the Project boundary
- Between Ch 66.80 km and Ch 67.25 km there is up to 175 mm afflux contained within rural allotments. Afflux outside the Project boundary is below 100 mm

- Between Ch 67.70 km and Ch 68.30 km there is up to 150 mm afflux contained within rural allotments. Afflux outside the Project boundary is below 100 mm
- Between Ch 68.45 km and Ch 68.70 km there is up to 140 mm afflux contained within rural allotments. Afflux outside the Project boundary is below 100 mm within 40 m of the toe of the Project alignment
- Approximately 175 mm afflux is predicted between Ch 68.94 km and Ch 69.29 km. The afflux is caused by a combination of loss of low flow area due to Project alignment placement and the flow constriction imposed at bridge 330-BR25. The permanent residential dwellings immediately west of this location are not directly impacted by the predicted increase in peak water levels.
- 175 mm afflux is predicted around Ch 70.00 km within the Project boundary, at the downstream side of the Existing Case overtopping flow over the QR West Moreton System rail corridor. Afflux on this rural property dissipates to less than 100 mm within 40 m downstream of the Project alignment and is within ±10 mm afflux approximately 300 m on the same rural property.
- 155 mm afflux is predicted around Ch 71.00 km around the Newmann Road realignment for the level crossing, on the downstream side of the Project alignment. Afflux on adjacent downstream rural property immediately dissipates to within ±10 mm afflux or less.

Details of where afflux is greater than 10 mm in areas adjacent the Project alignment are outlined in Table 9.25.

As seen in Appendix B Figure B-7E there are a number of flood sensitive receptors in the Western Creek catchment. Where afflux is 10 mm or greater at a flood sensitive receptor under the 1% AEP event a summary of afflux for all modelled events up to the 1% AEP event is presented in Appendix D. These impacts for the minor events satisfy the flood impact objectives.

Table 9.25 Afflux at flood sensitive receptors during the 1% AEP event

Location	Afflux (mm)	Comment
Rural land (Ch 65.88 km)	370	Rural land experiences up to 400 mm afflux; constrained by the raised level crossing. Afflux of up to 370 mm was only predicted at the toe of the Project alignment, then reduces to less than 200 mm within 30 m of the toe of the Project alignment. Permanent dwellings close to the crossing experience a range of impacts from between a 55 mm reduction of peak water levels or are within the ±10 mm afflux zone.
Rural land (Ch 66.12 km to Ch 66.50 km)	285	Land appears to be rural and not used for high-value agricultural farming based on provided aerial imagery. Afflux caused in part by Project alignment passing through an area of shallow flow and changing the localised flow characteristics. Project alignment provides a reduction in afflux to structures around the farm dam located around Ch 66.37 km.
Rural land (Ch 66.50 km to Ch 66.80 km)	150	Land appears to be rural and not used for high-value agricultural farming based on provided aerial imagery. Within 30 m of the toe of the Project alignment afflux dissipates from 150 mm to less than 50 mm.
Ch 66.80 km to Ch 67250 km	175	Land appears to be rural and not used for high-value agricultural farming based on provided aerial imagery. Within 30 m of the toe of the Project alignment afflux dissipates from 175 mm to less than 100 mm.
QR West Moreton System rail corridor (Ch 67.30 km)	330	Land appears to be rural based on provided aerial imagery. Afflux above 100 mm at this location is within the Project boundary (i.e. nominally 30 m from the toe of Project alignment, varying in locations; within the rail corridor but not part of the permanent infrastructure). Caused by shallow sheet flow being trapped behind the Project alignment. Localised impacts.

Location	Afflux (mm)	Comment
Rural land (Ch 67.70 km to Ch 68.30 km)	150	Land appears to be rural and not used for high-value agricultural farming based on provided aerial imagery. Afflux appears to dissipate to less than 100 mm within the Project boundary (i.e. nominally 30 m from the toe of Project alignment, varying in locations; within the rail corridor but not part of the permanent infrastructure).
Rural land (Ch 68.45 km to Ch 68.70 km)	150	Land appears to be rural and not used for high-value agricultural farming based on provided aerial imagery. Afflux appears to dissipate to less than 100 mm within 50 m of the Project alignment.
Agricultural land (around Ch 69.10 km)	55	Land appears to be used for agricultural farming based on provided aerial imagery. As the areas upstream of this location (northern side of the alignment) appear to experience a reduction in afflux, the cause of this 20 mm afflux appears to be the change in peak flow timing caused by Project alignment on the upstream side of the existing QR West Moreton System rail corridor. Afflux appears to dissipate to within the ±10 mm guiding design criteria east of bridge 330-BR25.
Rural area (Ch 68.94 km to Ch 69.29 km)	175	Land appears to be rural and not used for high-value agricultural farming based on provided aerial imagery. Afflux greater than 50 mm extends up to 50 m from the toe of the Project alignment in some locations. Flood sensitive receptors to the west of this location are unaffected. Afflux appears to be primarily caused by the loss of significant low-flow channel on the southern side of the existing QR West Moreton System rail corridor. Assumed flowable area for this bridge was lower (i.e. higher flow constriction adopted) than some other bridges in Western Creek model due to bridge arrangement.
Rural area (Ch 69.25 km to Ch 69.92 km)	390	Land appears to be rural and not used for high-value agricultural farming based on provided aerial imagery. Afflux around 390 mm extends up to 480 m from the Existing Case culvert under the QR West Moreton System rail corridor upstream towards bridge 330-BR22. Principal cause of high afflux at this location is that the existing QR West Moreton System rail corridor overtops in events larger than 5% AEP (i.e. 2% AEP, 1% AEP, 1 in 2,000). The Project alignment and associated drainage structures were selected to balance peak flow during frequent events and additional storage requirements for the 1% AEP event.
Rural area (Ch 70.00 km)	175	Land appears to be rural and not used for high-value agricultural farming based on provided aerial imagery. Afflux dissipates to less than 50 mm within 100 m of the toe of QR's West Moreton System rail corridor and to ±10 mm up to 250 m further downstream. Principal cause of high afflux at this location is that the existing QR West Moreton System rail corridor overtops in events larger than 5% AEP (i.e. 2% AEP, 1% AEP, 1 in 2,000). The Project alignment and associated drainage structures were selected to balance peak flow during frequent events and additional storage requirements for the 1% AEP event.
Road and rural area (Ch 71.00 km)	160	Land appears to be rural and not used for high-value agricultural farming based on provided aerial imagery. Afflux on Newmann Road north of the Project alignment is 51 mm (i.e. within the 100 mm guiding design criteria for roads). The ground level of the road diversion has also increased by approximately 500 mm as compared to the previous road levels. This results in a reduction of time of inundation whilst maintaining previous immunity levels for frequent events.

Location	Afflux (mm)	Comment
Road and rural area (Ch 71.00 km)	440	Land appears to be rural and not used for high-value agricultural farming based on provided aerial imagery. Afflux on Newmann Road south of the Project alignment is caused by Western Creek breakout flow ponding against the road embankment. Afflux is 340 mm in exceedance of the 100 mm guiding design criteria for roads. However, the ground level of the road diversion has increased by approximately 500 mm as compared to the previous road levels (range: 250 mm to 1,200 mm). This results in a reduction of time of inundation whilst maintaining previous immunity levels for frequent events. Afflux on rural land between Western Creek and this location is highly localised (within 10 m of the road embankment – in the Right of Way of the road). Impacts at this location could be reduced with local road culverts during detailed design.
Rural area (around Ch 73.20 km)	70	Near junction with C2K Project alignment. Land appears to be rural and not used for high-value agricultural farming based on provided aerial imagery. Afflux south of the Project alignment appears to be a result of loss of channelised flow along the existing QR West Moreton System rail corridor and reduced culvert performance. Afflux north of the Project alignment appears to be a result of flow constrictions amplifying minor changes (≤5 mm) in upstream peak water levels.

9.3.3.2 Average annual time of submergence and time of submergence

Assessment of the change in the Time of Submergence (ToS) is presented in Appendix B Figure B-7D.

Under the 1% AEP event where afflux was predicted to be greater than 200 mm the behaviour of ToS is as follows:

- On the east abutment of the Western Creek Bridge (Ch 65.88 km) the predicted ToS is 25.5 hours for the Existing Case and 19.5 hours for the Developed Case. This reduction in ToS is due to the upgrade of the culverts under Grandchester Mount Mort Road which increases low flow drainage capacity and prevents ponding. AAToS is expected to decrease by approximately 1 hour as a result of the proposed Project alignment.
- Between Ch 66.12 km to Ch 66.50 km the predicted ToS is 51.6 hours for the Existing Case and 69 hours for the Developed Case. This low-lying road currently has limited drainage and this leads to localised increases in ToS of up to 17.5 hours. Increases to AAToS of around 15 hours is expected as a result of the Project alignment. It is expected this ponding location will be resolved at a local catchment scale with road drainage.
- Between the existing QR West Moreton System rail corridor and the Project alignment (around Ch 67.30 km) the predicted ToS is 32.0 hours for the Existing Case and 46.0 hours for the Developed Case. This increase in ToS is within the Project disturbance footprint and caused by shallow sheet flow being trapped behind the Project alignment. AAToS is expected to increase by approximately 7.5 hours as a result of the Project alignment.
- East of bridge 330-BR22 (between Ch 69.25 km to Ch 69.92 km) the predicted ToS is 20.9 hours for the Existing Case and 16.5 hours for the Developed Case. Decrease in AAToS of around 0.3 hours is expected as a result of the Project alignment.
- On the Newmann Road works south of the Project alignment (Ch 71.00 km) the predicted ToS is 5.5 hours for the Existing Case and 6.9 hours for the Developed Case. Though ToS at the toe of the road embankment is shown as 43.5 hours this is a function of water ponding as culverts were not modelled in this location. Limited reduction in AAToS is expected as a result of the proposed road and rail embankment/alignment (average variance of less than 5 minutes over the area).

Under the 1% AEP event where afflux was predicted to be between 100 mm and 200 mm behaviour of ToS was as follows:

- Between Ch 66.50 km to Ch 66.80 km the predicted ToS is 6.7 hours for the Existing Case and 16.8 hours for the Developed Case. Only a 1 hour increase in AAToS is expected as a result of the Project alignment.
- Between Ch 66.80 km to Ch 67.25 km the predicted ToS is 62 hours for the Existing Case and 62 hours for the Developed Case. AAToS is not expected to significantly change as a result of the proposed drainage structures. It is worth noting that long submergence times (and afflux changes in this area) are a combination of changing low flow and sheet flow paths in the Existing Case to more concentrated culvert flow in the Developed Case, with ponding occurring at the toe of the QR West Moreton System rail corridor and Project alignment due to existing topography conditions. It is expected these effects could be reduced by including longitudinal drains at the upstream toe of the Project alignment and changing the spacing between culverts.
- Between Ch 67.70 km to Ch 68.30 km the predicted ToS is 40.2 hours for the Existing Case and 43.7 hours for the Developed Case. AAToS is expected to increase by less than 0.5 hours as a result of the Project alignment. It is worth noting that these large ToS values are a result of ponding occurring at the toe of the QR West Moreton System rail corridor and the Project alignment due to existing topography conditions. It is expected this effect could be significantly reduced by including longitudinal drains along the toe of the Project alignment.
- Between Ch 68.45 km to Ch 68.70 km the predicted ToS is 59.1 hours for the Existing Case and 59.0 hours for the Developed Case. AAToS is expected to increase by less than 0.5 hours as a result of the Project alignment. It is worth noting that these large ToS values are a result of ponding occurring at the toe of the QR West Moreton System rail corridor and the Project alignment due to existing topography conditions. It is expected these effects could be significantly reduced by including longitudinal drains along the toe of the Project alignment.
- Between Ch 68.94 km to Ch 69.29 km, the predicted ToS is 4.3 hours for the Existing Case and 4.4 hours for the Developed Case. Change in AAToS as a result of the Project alignment is expected to be minor.
- Around Ch 70.00 km within the Project boundary, the predicted ToS is 51.6 hours for the Existing Case and 51.7 hours for the Developed Case. Limited change in AAToS is expected as a result of the Project alignment.
- On Newmann Road, south of the Project alignment (Ch 71.00 km), the predicted ToS is 17.0 hours for the Existing Case and 16.0 hours for the Developed Case. Limited change in AAToS is expected as a result of the proposed road and Project alignment (average variance of less than 10 minutes).

9.3.3.3 Change in velocities

Appendix B Figure B-7D present the changes in peak velocities under the 1% AEP event associated with the Project alignment. In general, the changes are minor and located close to the Project alignment.

9.3.3.4 Flood flow distribution

Overall, the Project has minimal impacts on flood flows and floodplain conveyance/storage with significant floodplain structures included to maintain the existing flood regime.

9.3.3.5 Extreme event risk management

During extreme events there is widespread floodplain inundation with high flood depths as shown in Appendix B Figures B-8A, B-9A and B-10A. These impacts have been considered in relation to the Existing Case flood depths at flood sensitive receptors. Under these rare events, the bridge structures and culverts allow adequate passage of flow during the flood events and “damming” effects are therefore not expected to occur.

Several design events larger than the 1% AEP event, including the 1 in 2,000 AEP, 1 in 10,000 AEP and PMF, have been modelled to assess the performance of the Project and to review impacts on the flooding regime. Appendix B Figures B-8B, B-9B and B-10B present the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events respectively. As can be seen the flood inundation extent and peak water levels increase across the floodplain between Grandchester and Calvert as the severity of the flood event increases.

From the outskirts of Grandchester, the Project alignment runs parallel to the existing QR West Moreton System rail corridor with the QR West Moreton System rail corridor influencing the existing flood conditions. Under the extreme events, with the Project alignment in place, there are no significant changes in flood inundation or velocities, and flow behaviour is consistent with the existing conditions. There are changes in peak water levels which are attributed to the height of the proposed Project alignment required to achieve the desired flood immunity standard. Mitigation of impacts has been carried out through the extension of QR culverts under the Project alignment and inclusion of new culvert banks under both the Project alignment and the QR West Moreton System rail corridor.

9.3.4 Sensitivity analysis

9.3.4.1 Blockage

The hydraulic design has included an assessment regarding the blockage of culverts. Blockage potential has been assessed in accordance with the guidelines in ARR 2016. The blockage assessment resulted in no blockage factor being applied to bridges and a blockage factor of 25 per cent being applied to culverts.

A minimum culvert size of 900 mm diameter was adopted to reduce the potential for blockage and for ease of maintenance. It is noted that some existing QR West Moreton System rail corridor culverts marked for extension through the Project alignment have diameters smaller than 900 mm. In these instances, proposed Project alignment culvert diameters match existing QR West Moreton System rail corridor culverts (i.e. remain unchanged).

Two culvert blockage sensitivity scenarios were tested; 0 per cent and 50 per cent blockage. The results are presented in Appendix B Figures B-7G and B-7H for the 0 per cent and 50 per cent blockage respectively.

ARR 2016 guidelines are focused on blockage of small bridges and culverts. The floodplain bridges proposed for the Project alignment are all multi-span large bridges and ARR 2016 notes that there are limited instances of multiple span bridges being observed with blockages similar to those seen at single span bridges or culverts.

A bridge blockage sensitivity scenario was also modelled. For bridges represented in 1D channels this was determined by doubling bridge obstruction (e.g. caused by piers) and determining the associated form loss/bend loss. For bridges represented in the 2D domain a 20 per cent blockage factor was adopted. The results are presented in Appendix B Figure B-7I.

The following changes to flood sensitive receptors under culvert blockage scenarios were identified:

- On the eastern abutment toe of the Western Creek level crossing (Ch 65.88 km) the change in peak water levels increases from 370 mm to 560 mm in the 50 per cent blockage scenario and reduces to 265 mm in the 0 per cent blockage scenario
- North of Ch 65.89 km there is a residential dwelling which has up to a 15 mm reduction in peak water levels in the Developed Case (25 per cent blockage). In the 50 per cent blockage scenario this property has an increase in peak water levels of 45 mm and in the 0 per cent blockage scenario it has a reduction of up to 40 mm
- The change in peak water levels on the agricultural land around Ch 66.12 km to Ch 66.50 km increases from 285 mm to 290 mm in the 0 per cent blockage scenario and reduces to 275 mm in the 50 per cent blockage scenario

- Between existing QR West Moreton System rail corridor and the Project alignment (around Ch 67.30 km) the change in peak water levels increases from 330 mm to 345 mm in the 50 per cent blockage scenario and reduces to 305 mm in the 0 per cent blockage scenario
- East of bridge 330-BR22 (between Ch 69.25 km and Ch 69.92 km) the change in peak water levels increases from 390 mm to 510 mm in the 50 per cent blockage scenario and reduces to 265 mm in the 0 per cent blockage scenario.

The outcomes of culvert blockage sensitivity scenarios indicate that peak water levels only change by small amounts with varying the culvert blockage levels and that the resulting impacts are similar.

The following changes to flood sensitive receptors under the bridge blockage scenario were identified:

- The change in peak water levels on rural land around Ch 65.88 km (330-BR20) increases from 370 mm to 556 mm in the bridge blockage scenario
- The change in peak water levels on rural land between Ch 69.25 km and Ch 69.92 km (east of bridge 330-BR22) increases from 390 mm to 510 mm in the bridge blockage scenario
- The change in peak water levels on rural land between Ch 69.25 km and Ch 69.92 km (east of bridge 330-BR22) increases from 390 mm to 510 mm in the bridge blockage scenario
- The change in peak water levels on rural land around Ch 71.00 km (east of bridge 330-BR23) increases from 390 mm to 510 mm in the bridge blockage scenario. Two residential dwellings experience increases of at least 30 mm as compared to the Design Case. Afflux to the east of these properties generally ranges between 20 mm and 30 mm, increasing up to 255mm afflux as overland flow becomes more channelised.

The outcomes of the bridge blockage sensitivity scenario indicate that peak water levels generally change by small amounts with similar resulting impacts. Locations affected by larger affluxes are located at areas with significant ponding potential or at floodplain to channel flow transition zones.

During detailed design the blockage factors will be reviewed in line with the final design and local catchment conditions. This may result in varied and/or lower blockage factors being applied along the project alignment. It may also take into account risk assessments associated with blockage, and/or risk mitigation where required.

9.3.4.2 Climate change assessment

The impacts of CC were assessed for the 1% AEP event to determine the sensitivity of the Project design to the potential increase in rainfall intensity. The assessment was undertaken in accordance with ARR 2016 guidelines.

The selected representative concentration pathway for the climate change analysis was 8.5. The climate change analysis was undertaken by increasing rainfall intensities in the IFDs for the contributing catchments. For the Project, RCP8.5 corresponds to an increase in temperature of 3.7 degrees Celsius in 2090 and an increase in rainfall intensity of 18.7 per cent which was obtained from the ARR 2016 Data Hub.

The resulting peak water levels are presented in Table 9.26 and Table 9.27. Climate change results increase water levels up to 380 mm at some structure locations for the 1% AEP. The formation level is significantly higher than the 1% AEP climate change water levels at these locations.

Table 9.26 Western Creek – 1% AEP event rail drainage – Climate change assessment

Chainage (km)	Structure name	Structure type	1% AEP peak water level (m AHD)	1% AEP + CC peak water level (m AHD)	Difference in peak water level (m)	Freeboard to rail formation with CC (m)
65.29	330-BR20	Bridge	88.98	89.07	0.10	1.17
65.90	C65.90	RCP	86.81	86.94	0.13	1.89
66.00	C66.00	RCP	85.91	85.97	0.06	1.61
66.04	C66.04	RCP	85.68	85.75	0.07	1.68
66.25	C66.25	RCP	84.50	84.67	0.17	1.88

Chainage (km)	Structure name	Structure type	1% AEP peak water level (m AHD)	1% AEP + CC peak water level (m AHD)	Difference in peak water level (m)	Freeboard to rail formation with CC (m)
66.43	C66.43	RCP	84.32	84.43	0.11	1.43
66.48	C66.48	RCP	84.20	84.33	0.13	1.36
66.52	C66.52	RCP	83.85	83.94	0.10	1.61
66.55	C66.55	RCP	83.65	83.70	0.05	1.66
66.58	C66.58	RCP	83.16	83.22	0.06	1.94
66.61	C66.61	RCP	82.77	82.81	0.04	2.17
66.76	C66.76	RCP	81.47	81.55	0.07	2.57
66.82	C66.82	RCP	81.32	81.40	0.08	2.40
66.93	C66.93	RCP	81.08	81.16	0.08	1.95
67.04	C67.04	RCP	80.73	80.79	0.06	1.73
67.25	C67.25	RCP	79.78	79.91	0.13	1.42
67.31	C67.31	RCP	79.18	79.28	0.10	1.58
67.36	C67.36	RCP	78.96	79.03	0.07	1.69
67.41	C67.41	RCP	78.66	78.71	0.05	1.75
67.63	330-BR21	Bridge	78.30	78.31	0.01	1.37
68.69	C68.69	RCBC[1]	Dry	Dry	-	-
69.10	330-BR25	Bridge	70.36	70.71	0.35	0.89
69.29	330-BR22	Bridge	70.20	70.25	0.05	0.68
69.90	C69.90	RCBC[2]	69.15	69.53	0.38	0.28
69.91	C69.91	RCBC[1]	69.16	69.54	0.38	0.34
69.98	C69.98	RCP[2]	67.39	67.62	0.23	2.29
70.02	C70.02	RCP[2]	67.38	67.60	0.22	2.26
70.05	C70.05	RCBC[1]	67.38	67.60	0.21	2.20
70.98	C70.98	RCBC[1]	61.83	61.97	0.15	1.57
71.12	330-BR23	Bridge	61.26	61.37	0.11	0.63
71.54	C71.53	RCBC[2]	58.90	59.15	0.26	0.84
71.54	C71.54	RCBC[1]	58.90	59.15	0.26	0.94
71.90	C71.90	RCBC	Dry	Dry	-	-
72.43	C72.43	RCBC[1]	Dry	Dry	-	-
73.21	C73.21	RCBC[1]	54.46	54.57	0.10	3.01

Table notes:

1 The Developed Case alignment runs parallel to the QR West Moreton System rail corridor at this location. The existing culvert is proposed to be extended and matched through the Project alignment.

2 The Developed Case alignment runs parallel to the QR West Moreton System rail corridor at this location. A new culvert(s) is proposed to be inserted through the QR West Moreton System rail corridor and the Project alignment.

Table 9.27 Western Creek – 1% AEP event road drainage – Climate change assessment

Road Name	Structure name	Structure type	1% AEP Peak water levels (m AHD)	1% AEP + CC Peak water levels (m AHD)	Difference in peak water level (m)
Grandchester Mount Mort Road – Access Road	GrandchesterMtMortAccessRoad	RCBC	85.45	85.58	0.13
Grandchester Mount Mort Road – North	GrandchesterMtMortRoadNorth	RCBC	86.23	86.53	0.30
Grandchester Mount Mort Road – South	GrandchesterMtMortRoadSouth	RCBC	86.73	86.85	0.13
Newmann Road – East	NewmannRoadEast	RCBC	61.65	61.91	0.27

As a point of comparison, although changes throughout the model are not uniform and vary between locations, the increase in rainfall intensity of 18.7 per cent generates approximately a 25 per cent increase in peak flows at the Walloon stream gauge.

9.4 Local catchment drainage

The following section details the hydraulic assessment that has been undertaken for cross drainage for the local catchments along the rail alignment which are outside the regional floodplain extents.

9.4.1 Hydrology

The proposed rail alignment crosses a number of existing flow paths of varying contributing catchment areas that contribute flows to the cross drainage structures. To determine the appropriate hydrologic methods for the local drainage design, the existing catchments were categorised based on the contributing catchment areas.

Table 9.28 shows the drainage catchment classification criteria and number of catchments relating to each classification.

Table 9.28 Drainage catchment classification

Catchment size	Drainage catchment classification	Number of catchments
Less than or equal to 10 km^2	Minor	41
Greater than 10 km^2 and less than or equal to 100 km^2	Moderate	2
Greater than 100 km^2	Major	2

The major floodplains are addressed in Sections 9.1 to 9.3.

9.4.2 Minor catchments

The 1% AEP and 1 in 2,000 AEP catchment flows for the minor catchments were generated in accordance with ARR2016 using ILSAX within the 12D Drainage Network Editor.

The design IFDs, temporal patterns and aerial reduction factors were extracted from the ARR 2016 datahub at two locations along the alignment to account for any changes in rainfall parameters along the alignment. As the proposed alignment is less than 50 km long, the rainfall parameters do not vary substantially at these locations.

Ten temporal patterns were run for each storm duration and the median temporal patterns from each duration were compared to determine the peak runoff for each catchment.

The losses adopted within ILSAX were taken from the calibrated hydrologic models for the Lockyer Creek and Western Creek catchments. The 12D Drainage Network Editor applied the initial loss at the first time step and the final loss proportionately at each following time step which was at one minute increments.

As no calibration data was available to compare against the local catchment flows, the 1% AEP flows generated from ILSAX were compared against the traditional Rational Method. The flows generated using ILSAX compare closely to the flows generated from the traditional Rational Method and are within a tolerance of -6 to 7%.

Rational Method is no longer compliant with ARR 2016; however, it is still considered to give a reasonable approximation of local catchment flows and therefore the parameters and resultant ILSAX flows were adopted for the design.

9.4.3 Moderate catchments

Catchments at Ch 27.40 km and Ch 33.50 km are categorised as moderate catchments due to their size and therefore flow calculated from a single catchment delineation was not considered appropriate. Two URBS hydrologic models were created to generate flows for these catchments. One URBS model included the catchments at Ch 27.40 km and Ch 28.00 km and another model included the catchments at Ch 32.50 km and Ch 33.60 km. The URBS hydrologic models used the same parameters as the Lockyer Creek calibrated hydrologic model.

The models were run for ten temporal patterns for all durations from 10 minutes to 168 hours and the median temporal patterns from each duration were compared to determine the critical design storm for each catchment.

9.4.4 Hydraulic design

Cross drainage structures are provided where the rail intercepts existing flow paths. The type of structures adopted in the design depends on various factors such as the natural topography, rail formation levels, design flow and soil type.

The cross drainage design was undertaken in accordance with the Project hydraulic design criteria set out in Table 4.1. Cross drainage structures outside the regional floodplains were sized based on the flows generated from the local drainage catchments. Cross drainage structures that have a well-defined local catchment boundary and are located within or near the regional floodplains were assessed for both the local catchment flows and regional floodplain conditions to determine the governing design conditions.

9.4.4.1 Minor catchments

Cross drainage structures located within minor catchments where the upstream flow path is primarily 1-Dimensional (1D) were assessed as per the following methodology:

- Culverts were initially sized and optimised using 12D Dynamic Culvert
- The resultant afflux was assessed in TUFLOW and the culvert designs were adjusted as required to meet the afflux criteria. Further details of the impact assessment are detailed in Section 9.4.4.3
- Final culvert designs were analysed back in 12D Dynamic Culvert to determine final design water levels and velocities at the culverts which are detailed in Appendix E.

9.4.4.2 Moderate catchments

A 2-Dimensional (2D) hydraulic analysis was undertaken in TUFLOW for the Sandy Creek and Sheep Station Creek catchments to size the cross drainage culverts and bridge structures at these locations.

The model attributes were adopted from the calibrated Lockyer regional TUFLOW model. The extent and details of the TUFLOW model are presented in Figure 9.1.

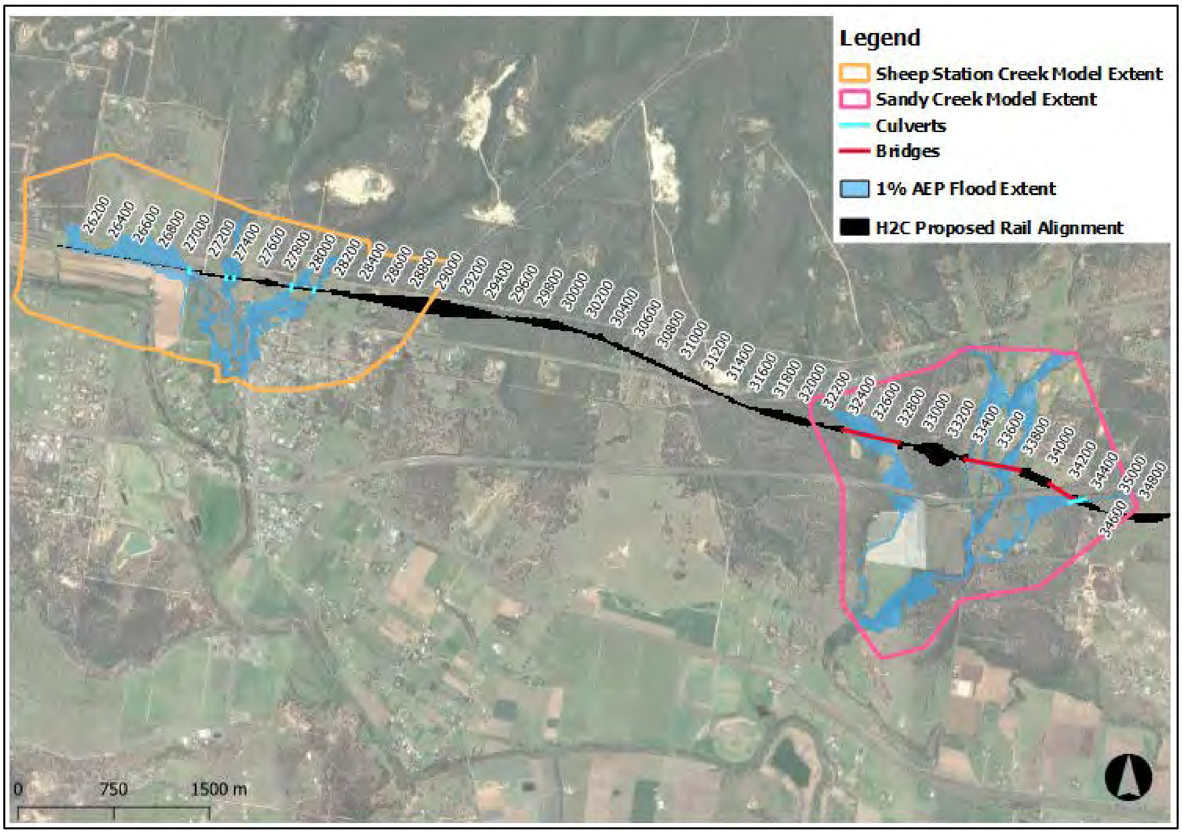


Figure 9.1 **Location of Sandy Creek and Sheep Station Creek TUFLOW models**

The resultant flows through the structures, upstream water levels and downstream velocities were extracted from the TUFLOW model for the cross drainage structures in the Sandy Creek and Sheep Station Creek catchments and are documented in Appendix E.

9.4.4.3 Impact assessment

For each of the local catchment crossings the impact of the Project upon the existing flood regime was quantified and compared against flood impact objectives as detailed in Table 4.2. These objectives have been used to guide the Project design. Acceptable impacts will ultimately be determined on a case by case basis with interaction with stakeholders/landholders through the community engagement process using these objectives as guidance. This takes into account flood sensitive receptors and land use.

Dams located within the local drainage flood extents upstream and downstream of the alignment had the downstream dam wall taken out in the existing and proposed scenarios to increase the flood extents and potential impacts. This was considered a conservative approach for the impact assessment.

The land use across the Project area has been classified as agricultural grazing/pasture land or forest areas based on aerial imagery. Sensitive agricultural land may be identified during further consultation with landowners which will need to be considered in Detailed Design. The hydraulic impacts in the local catchments are considered ‘localised’ in comparison to regional flood impacts due to the shorter time of flood inundation and smaller flood extents. Therefore, afflux up to 400 mm was considered acceptable at the rail corridor in the local drainage catchments.

Sensitive receptors which included houses, sheds, dams and existing rail and road infrastructure have been identified from aerial imagery for the purposes of the hydraulic impact assessment. A maximum afflux of 400 mm has been achieved at the rail corridor in the local drainage catchments which meets the adopted criteria. For dams the design intent was to maintain existing flow paths as much as possible thus continuing local runoff to dams. During detailed design this will be reviewed with landholders to determine if any refinement of the location of local drainage culverts is required.

The afflux and change in time of inundation at each structure is tabulated in Appendix E.

9.4.5 Sensitivity analysis

9.4.5.1 Blockage

A blockage assessment for the 1% AEP event was undertaken in accordance with ARR 2016 Book 6 Chapter 6 Blockage of Hydraulic Structures.

The H2C Project contains some steep catchments with dense vegetation near the alignment. These catchments are located near Helidon between Ch 29.00 km and Ch 30.70 km and near the tunnel between Ch 60.70 km and Ch 63.00 km. At these locations, the blockage factor was calculated to be between 50 and 100% for the 1% AEP as per ARR 2016 which results in a high number of culverts to achieve the required change in peak water level criteria and design flood immunity. To mitigate the blockage potential at these culverts, debris deflector walls have been specified at the inlets of the culverts which decreases the blockage factor to 25% to account for sediment blockage.

A 25% blockage was adopted for all culvert structures along the alignment. The blockage factor was applied by reducing the culvert opening by 25% within the 12D Dynamic Culvert Editor and was applied in TUFLOW within the culvert network layer.

A minimum diameter or height of 900 mm was applied where possible for proposed culverts along the alignment to reduce the risk of blockage and maintenance requirements.

9.4.5.2 Climate change assessment

The impacts of climate change were assessed in accordance with ARR 2016 Book 1 Chapter 6 for the local drainage catchments for the 1% AEP design event to determine the sensitivity of the design to the potential increase in rainfall intensity. The selected representative concentration pathway for the climate change analysis was 8.5 which represents a high emissions scenario. For the Project, a representative concentration pathway of 8.5 corresponds to an increase in temperature of 3.7°C in 2090 and an increase in rainfall intensity of 18.7% which was obtained from the ARR 2016 Datahub.

The climate change analysis was undertaken by increasing rainfall intensities within the IFDs for the local catchments. The climate change factor increases the 1% AEP local drainage water levels by a maximum of 1.7 m along the alignment. However, the flood immunity of the rail formation is not adversely affected by climate change within the local catchments with the minimum freeboard along the alignment being 0.23 m to rail formation.

10 Limitations

FFJV has prepared this report in accordance with the usual diligence and thoroughness of the consulting profession with reference to current standards, procedures and practices.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by FFJV for use of any part of this report in any other context.

This report was prepared for the exclusive use of the Project. FFJV accepts no liability or responsibility whatsoever for, any use of, or reliance upon, this report by any third party.

This report was prepared based on information available at the time of writing. The models detailed in this report are based on LiDAR survey taken generally in 2015 (or as detailed in each catchment section). Therefore, any development or topographical change occurring within the catchment after the surveys taken is not included in this investigation, unless directly specified.

There are a number of limitations that apply to the modelling, some of which include:

- No field survey of the QR West Moreton System rail corridor bridge structures or associated ground survey levels was included in this assessment as a result of the delay in acquiring this data
- Stakeholder engagement will continue during detailed design, construction and operation. As such proposed impacts and structural solutions still need to be confirmed with relevant stakeholders. Modelling may need to be updated as a result of any ongoing stakeholder engagement.
- Future proofing for future 3,600 m train lengths has not been included in the flood modelling.

ARR 2016 outlines several fundamental themes which are also particularly relevant to this investigation:

- All models are coarse simplifications of very complex processes. No model can therefore be perfect, and no model can represent all of the important processes accurately.
- Model accuracy and reliability will always be limited by the accuracy of the terrain and other input data
- Model accuracy and reliability will always be limited by the reliability/uncertainty of the inflow data
- No model is ‘correct’ therefore the results require interpretation
- A model developed for a specific purpose is probably unsuitable for another purpose without modification, adjustment, and recalibration. The responsibility must always remain with the modeller to determine whether the model is suitable for a given problem.
- Recognition that no two flood events behave in exactly the same manner
- Design floods are a best estimate of an “average” flood for their probability of occurrence.

It is noted that ARR 2019 has recently been released as an update to the ARR 2016 guidelines. Although there is limited difference in methodology between these versions it is proposed that in the next phase ARR 2019 guidelines are adopted.

The interpretation of results and other presentations in this report should be done with an appreciation of any limitations in their accuracy, as noted above.

Unless otherwise stated, presentations in this report are based on peak values of water surface level, flow, depth and velocity. Therefore, using water levels as an example, the peak level does not occur everywhere at the same time and, therefore, the values presented are based on taking the maximum value which occurred at each computational point in the model during the entire flood event. Hence, a presentation of peak water levels does not represent an instantaneous point in time, but rather an envelope of the maximum values that occurred at each computational point over the duration of the flood event.

11 Conclusions

The key objectives of this report are to provide information on the data investigation, hydrology and hydraulic calibration, impact assessment and mitigation and to provide comment on the performance on the Project design. This report outlines the methodology followed, the outcomes of this investigation and the assessment of the Project design.

There are two major catchments that the Project alignment crosses being Lockyer Creek and Western Creek (which is a tributary of the Bremer River). Sandy Creek (upstream of Grantham), Sandy Creek (adjacent to Forest Hill) and Laidley Creek are tributaries of Lockyer Creek. Detailed hydrologic and hydraulic assessments have been undertaken due to the catchment size and substantial floodplain flows associated with each of these watercourses. Lockyer Creek and Western Creek form part of the larger Brisbane River system.

Hydrologic and hydraulic modelling was undertaken for each of these catchments with the models calibrated to multiple historical events (1974, 1996, 1999, 2011 and 2013) using stream gauges records and anecdotal data where available. Based on this performance, the hydrologic and hydraulic models were considered validated and appropriate to use to assess the potential impacts associated with the Project.

Design event hydrology was developed using the calibrated (and validated) hydrologic models using ARR 2016 flood flow estimation techniques. The hydraulic models were run for a suite of design events from the 20% AEP event to the 1 in 10,000 AEP and PMF events. The flows and levels predicted by the hydrologic and hydraulic models were compared to the results of a Flood Frequency Analysis (FFA) at stream gauges within each catchment as well as results from previous flood studies.

Modelling of the current state of development (Existing Case) was undertaken and details of the existing flood regime were determined for the modelled design events. The proposed works associated with the Project were incorporated into the hydraulic models to form the Developed Case. Assessment of the potential impacts upon the existing flood regime was undertaken and refinement of the Project design was undertaken to mitigate impacts.

Consultation with stakeholders, including landholders, was undertaken at key stages including validation of the performance of the modelling in replicating experienced historical flood events and presentation of the design outcomes and impacts on properties and infrastructure.

The Project design has been guided and refined using hydraulic design criteria (refer Table 4.1) and flood impact objectives (refer Table 4.2). The resulting design outcomes relative to the hydraulic design criteria are detailed in Table 11.1.

Table 11.1 Project hydraulic design criteria outcomes

Performance criteria	Design outcomes
Flood immunity	Rail line – 1% AEP flood immunity with minimum of 300 mm freeboard to formation level has been achieved. Tunnel portals – 1 in 10,000 AEP event flood immunity has been achieved.
Hydraulic analysis and design	Hydrologic and hydraulic analysis and design has been undertaken using ARR 2016 (ARR 2016) and State/local government guidelines. The Project design includes significant rail drainage structures under the Project alignment to convey flood flows on floodplains and minimise impacts under the full range of design events, being: ▪ Sixteen rail bridges over floodplain waterways ▪ Two road bridges ▪ Twenty-nine rail RCBC banks ▪ Thirty-two rail RCP banks ▪ Inclusion of road drainage structures under local roads adjacent to the Project alignment, being: – Nine road RCBC banks

Performance criteria	Design outcomes
Scour protection of structures	Culvert scour protection has been designed in accordance with Austroads Guide to Road Design Part 5B: Drainage (AGRD). Scour protection was specified where the culvert outlet velocities for the 1% AEP event exceeded the allowable soil velocities shown in Table 3.1 of AGRD. Required lengths of scour protection have been determined and are predicted to fit within the disturbance footprint. A conservative scour estimation has been undertaken at each bridge site based on available information and will be refined during detailed design.
Structural design	1 in 2,000 AEP event has been modelled with details used for bridge design purposes.
Extreme events	Overtopping of the Project alignment under extreme events occurs at limited locations being: ▪ Lockyer Creek – Above formation level and top of rail (TOR) level at Ch 38.48 km, Ch 44.05 km, Ch 44.47 km and Ch 48.09 km for 1 in 2,000, 1 in 10,000 AEP and PMF events ▪ Forest Hill and Laidley – Above formation level and TOR level at Ch 51.95 km and Ch 53.29 km for PMF event ▪ Western Creek – Above formation level and TOR level at Ch 65.9 km, Ch 67.35 km and Ch 70.00 km for PMF event
Flood flow distribution	Structures have been located along the Project alignment to maintain existing flood conveyance and spread of floodwaters.
Sensitivity testing	The risk to the Project design from climate change and blockage has been assessed in accordance with ARR 2016 2016. Key outcomes are: ▪ The Project design maintains 1% AEP flood immunity under 2090 climate change conditions ▪ Based on ARR 2016, a blockage factor of 25 per cent has been applied to culverts and no blockage factor has been applied to bridges ▪ Varying the level of blockage to culverts between 0 per cent and 50 percent does not impact upon the Project design.

Flood impact objectives, as presented in Table 4.2 , have been established and used to guide the Project design including mitigation of impacts through refinement of the hydraulic design, including adjustment of the numbers, dimensions and location of major drainage structures. Table 11.2 summarises how the Project design performs against each of the established flood impact objectives.

Table 11.2 Flood impact objectives and outcomes

Parameter	Objectives and Outcomes				
Change in peak water levels	Existing habitable and/or commercial and industrial buildings/premises (e.g. dwellings, schools, hospitals, shops)	Residential or commercial/industrial properties/lots where flooding does not impact dwellings/ buildings (e.g. yards, gardens)	Existing non-habitable structures (e.g. agricultural sheds, pump-houses)	Roadways	Agricultural and grazing land/forest areas and other non-agricultural land
	≤ 10 mm	≤ 50 mm	≤ 100 mm	≤ 100 mm	≤ 200 mm with localised areas up to 400 mm
	Objective: Changes in peak water levels are to be assessed against the above proposed limits. **Outcome:** Generally, the Project design meets the above limits with number of localised areas along the Project alignment where these limits are slightly exceeded. These areas are generally agricultural land or local roadways. No existing flood sensitive receptors are impacted by the changes in peak water levels under the 1% AEP event.				
Change in duration of inundation	**Objective:** Identify changes to time of inundation through determination of time of submergence (ToS). For roads, determine AATOS (if applicable) and consider impacts on accessibility during flood events. **Outcome:** There are localised increases in duration of inundation (ToS) at the same locations where peak water levels are increased. These changes in inundation duration do not affect flood sensitive receptors except for two local roads being Dodt Road and Hall Road. Dodt Road has a very minor increase in ToS and hence no increase in AAToS. Hall Road experiences an increase in AAToS (+2.7 hrs/yr) which is considered a negligible impact on the amenity of the roadway.				

Parameter	Objectives and Outcomes
Flood flow distribution	**Objective:** Aim to minimise changes in natural flow patterns and minimise changes to flood flow distribution across floodplain areas. Identify any changes and justify acceptability of changes through assessment of risk with a focus on land-use and flood sensitive receptors. **Outcome:** The Project has minimal impacts on flood flows and floodplain conveyance/storage with significant floodplain structures included to maintain the existing flood regime.
Velocities	**Objective:** Maintain existing velocities where practical. Identify changes to velocities and impacts on external properties. Determine appropriate scour mitigation measures taking into account existing soil conditions. **Outcome:** In general, changes in velocities are minor, with most changes in velocities experienced immediately adjacent to the Project alignment and no existing flood sensitive receptors impacted. Scour protection has been specified where the outlet velocities for the 1% AEP event exceed the allowable soil velocities for the particular soil type for each location, which was identified from published soil mapping.
Extreme event risk management	**Objective:** Consider the risks posed to neighbouring properties for events larger than the 1% AEP event to ensure no unexpected or unacceptable impacts. **Outcome:** A review of impacts under the 1 in 2,000 AEP, 1 in 10,000 AEP and PMF events has been undertaken. Between Helidon and Lawes, the changes in peak water levels at flood sensitive receptors are a small percentage change as compared to the existing flood depth (<10 per cent for most locations). Larger impacts occur under the PMF event where the Existing Case modelling demonstrated there are already high flood depths. In the vicinity of Forest Hill there are slight decreases in peak water levels under the 1 in 2,000 AEP and 1 in 10,000 AEP events due to the mitigation culvert banks included under the Project alignment and QR West Moreton System rail corridor. Under the PMF event there is a small percentage increase in overall depth due to the Project alignment with high flood depths occurring as would be expected under such a rare event. At flood sensitive receptors between Grandchester and Calvert, increases associated with the Project alignment are generally small (<50 mm) under the 1 in 2,000 AEP and 1 in 10,000 AEP events. Larger impacts occur under the PMF event where there are already high flood depths as would be expected under such a rare event. No new flow paths or significant additional areas of inundation are created due to the Project alignment under these extreme events.
Sensitivity testing	**Objective:** Consider risks posed by climate change and blockage in accordance with ARR 2016 2016. Undertake assessment of impacts associated with Project alignment for both scenarios. **Outcomes:** Climate change – climate change has been assessed in accordance with ARR 2016 requirements with the RCP8.5 (2090 horizon) scenario adopted giving an increase in rainfall intensity of 18.7 per cent across the catchment areas. Potential impacts resulting from changes in peak water levels under the 1% AEP event with climate change are generally similar to those seen under the 1% AEP event. There is one exception to this between Gatton and Lawes where there are two properties (houses and sheds) experience increases under the climate change scenario which will be looked at further in detailed design. The flood depth at both locations is approximately 1 m under the 1% AEP event with climate change and further information regarding the existing infrastructure is required to refine the outcomes. Blockage – Blockage of drainage structures has been assessed in accordance with ARR 2016 requirements. The blockage assessment resulted in no blockage factor being applied to bridges and a blockage factor of 25 per cent being applied to culverts. Two blockage sensitivity scenarios were tested with both 0 per cent and 50 per cent blockage of all culverts assessed. The resulting changes in peak water levels associated with the Project alignment remain localised and do not impact on any flood sensitive receptors.

The hydrologic and flooding assessment demonstrates that the potential Project impacts will generally comply with the flood impact objectives. Calibrated and validated model predictions indicate that no adverse impacts to existing flood regimes are expected.
A consultation exercise has been undertaken to provide the community with detailed information and certainty around the flood modelling and the Project design.

Throughout the detailed design, construction and operational phases of the Project, ARTC will continue to work with:

- Landowners concerned with hydrology and flooding
- Directly impacted landowners affected by the alignment
- Local councils and State government and local specialists.

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APPENDIX M

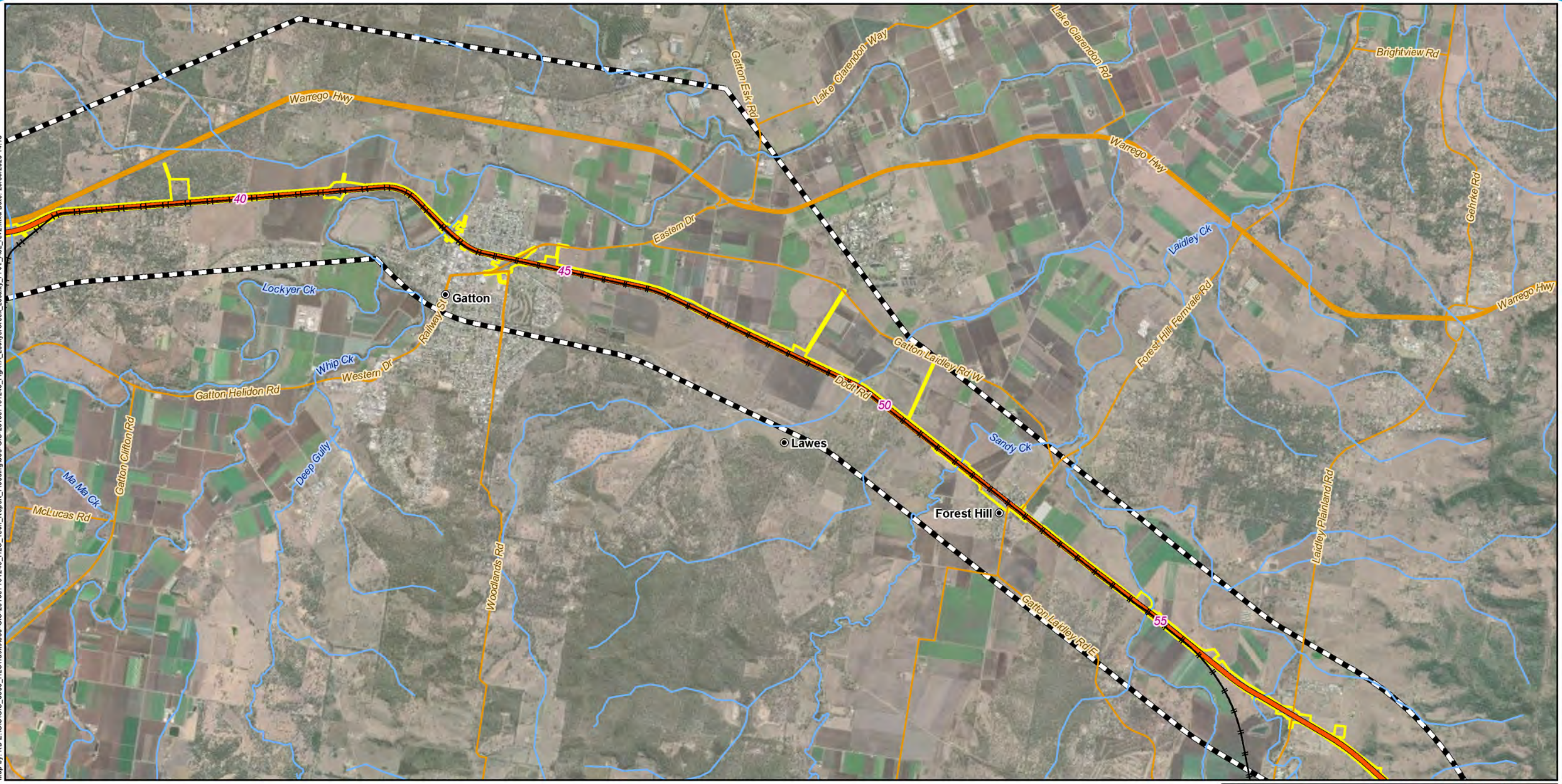
Hydrology and Flooding Technical Report

Appendix A Lockyer Creek Figures

HELIDON TO CALVERT ENVIRONMENTAL IMPACT STATEMENT

IR_1381

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Watercourses
- Major roads
- Minor roads
- EIS disturbance footprint
- EIS investigation corridor

A3 scale: 1:60,000

0 0.45 0.9 1.35 1.8 2.25 km

Future Freight
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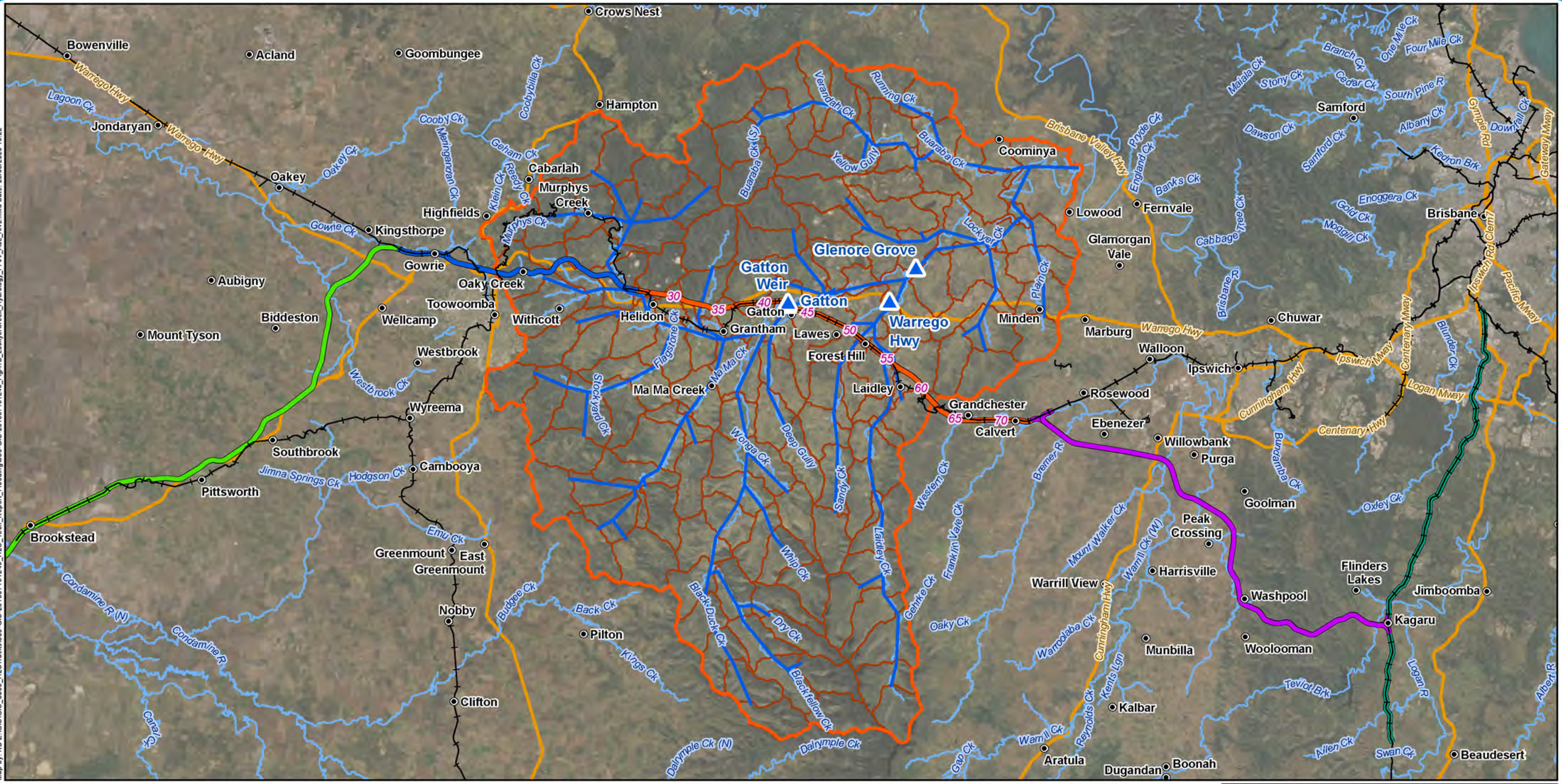
Issue date: 29/05/2020 Version: 2

Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-1A: Locality: Lockyer Creek

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- 5 Chainage (km)
- Localities
- Existing rail
- B2G project alignment
- G2H project alignment
- H2C project alignment
- C2K project alignment
- K2ARB project alignment
- Watercourses
- Major roads
- Stream gauge
- Hydrologic model links
- Lockyer Creek catchment boundary
- Model subcatchments

A3 scale: 1:450,000

0 3 6 9 12 15km

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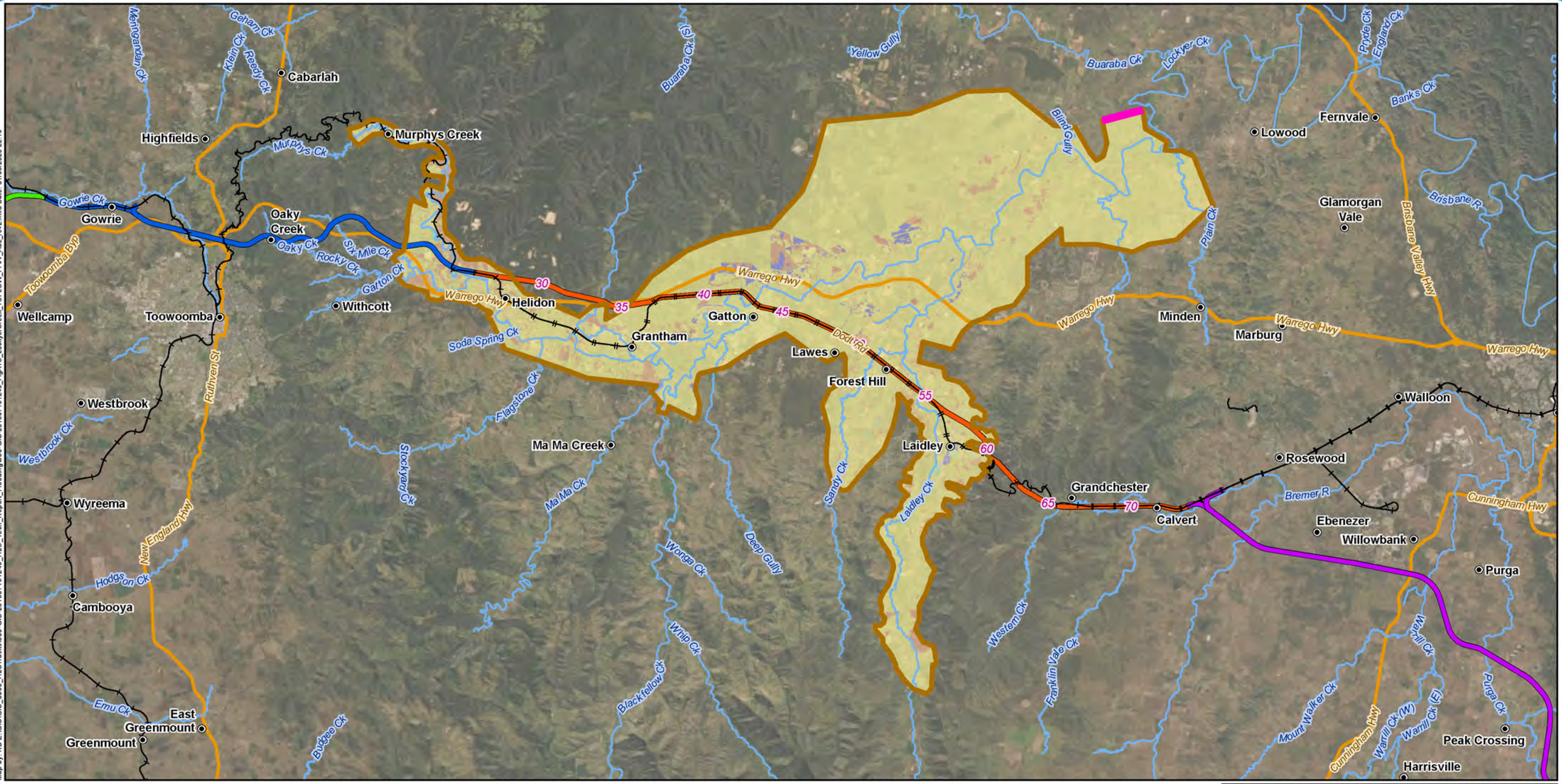
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-1B: Hydrology setup: Lockyer Creek

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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Legend

- 5 Chainage (km)
- Localities
- Existing rail
- B2G project alignment
- G2H project alignment
- H2C project alignment
- C2K project alignment
- Watercourses
- Major roads
- Downstream Boundary
- Code Boundary

Materials

- Demolished Building
- Farmdam Open Water
- Dense Vegetation
- Low-Medium Vegetation
- Building
- Road
- Clear Paved Area
- Riparian Vegetation
- Farmland/ General Area
- Urban
- Waterbodies
- Fallow
- Houses
- Creek Banks
- Non Tidal Waterway
- Urban General Yards
- Low-Medium Vegetation

A3 scale: 1:250,000

0 1.5 3 4.5 6 7.5km

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Issue date: 31/05/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-1C: TUFLOW model setup: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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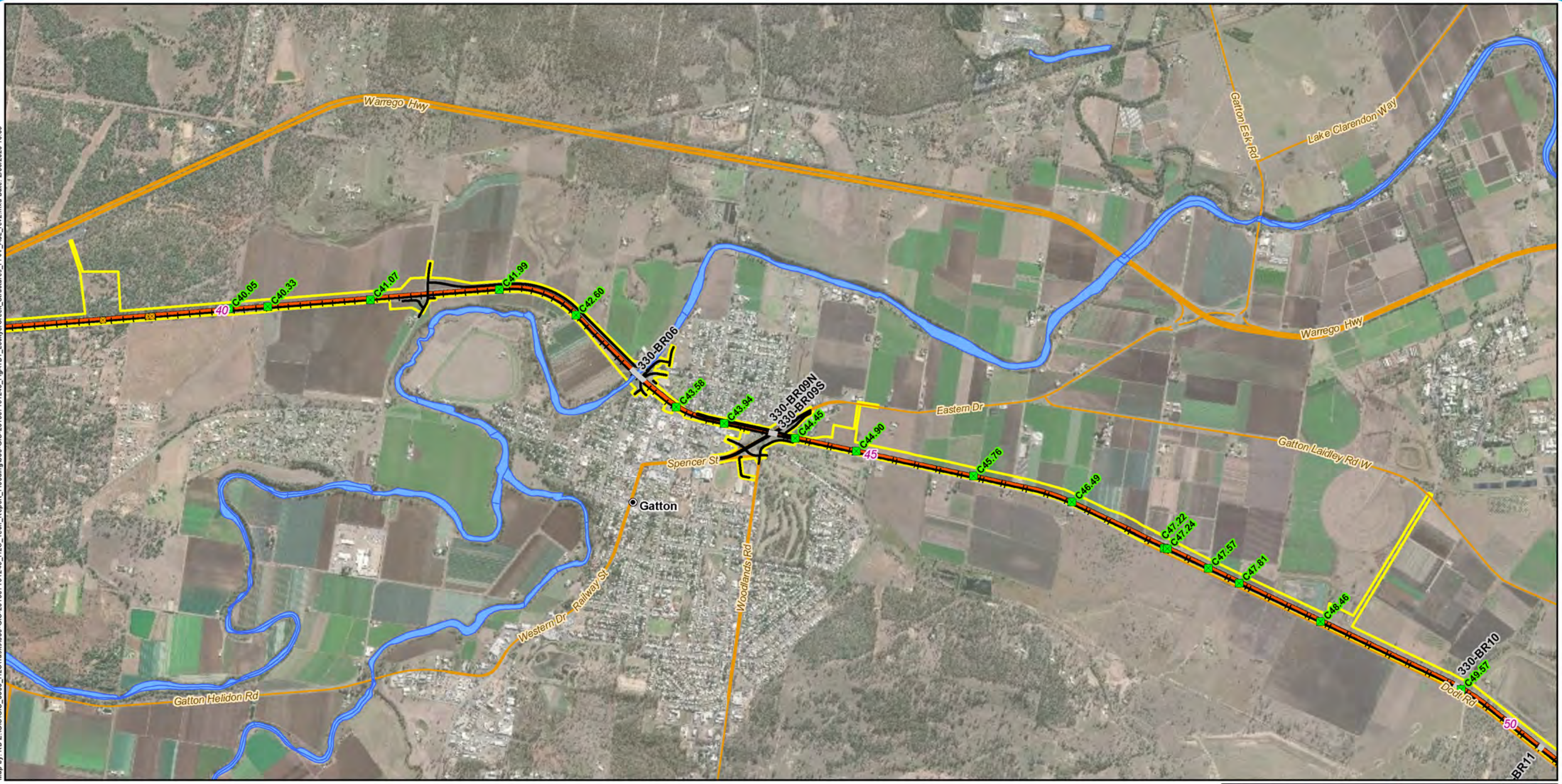

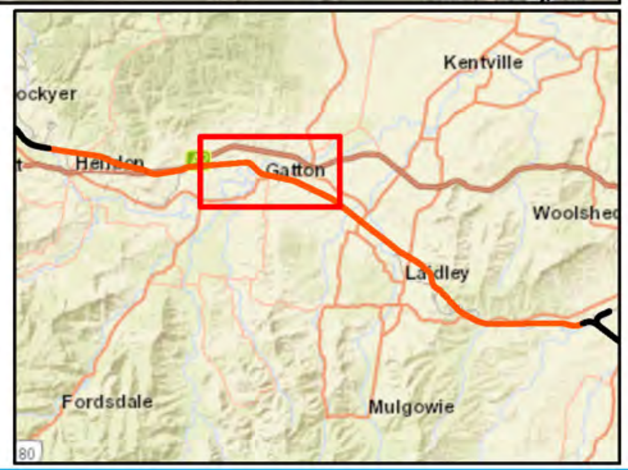

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- Watercourses
- EIS disturbance footprint

Drainage Structures

- Floodplain culvert
- Local drainage culvert
- Bridges

A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1 km

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Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-1D-1: 100% Design Structures: Lockyer Creek

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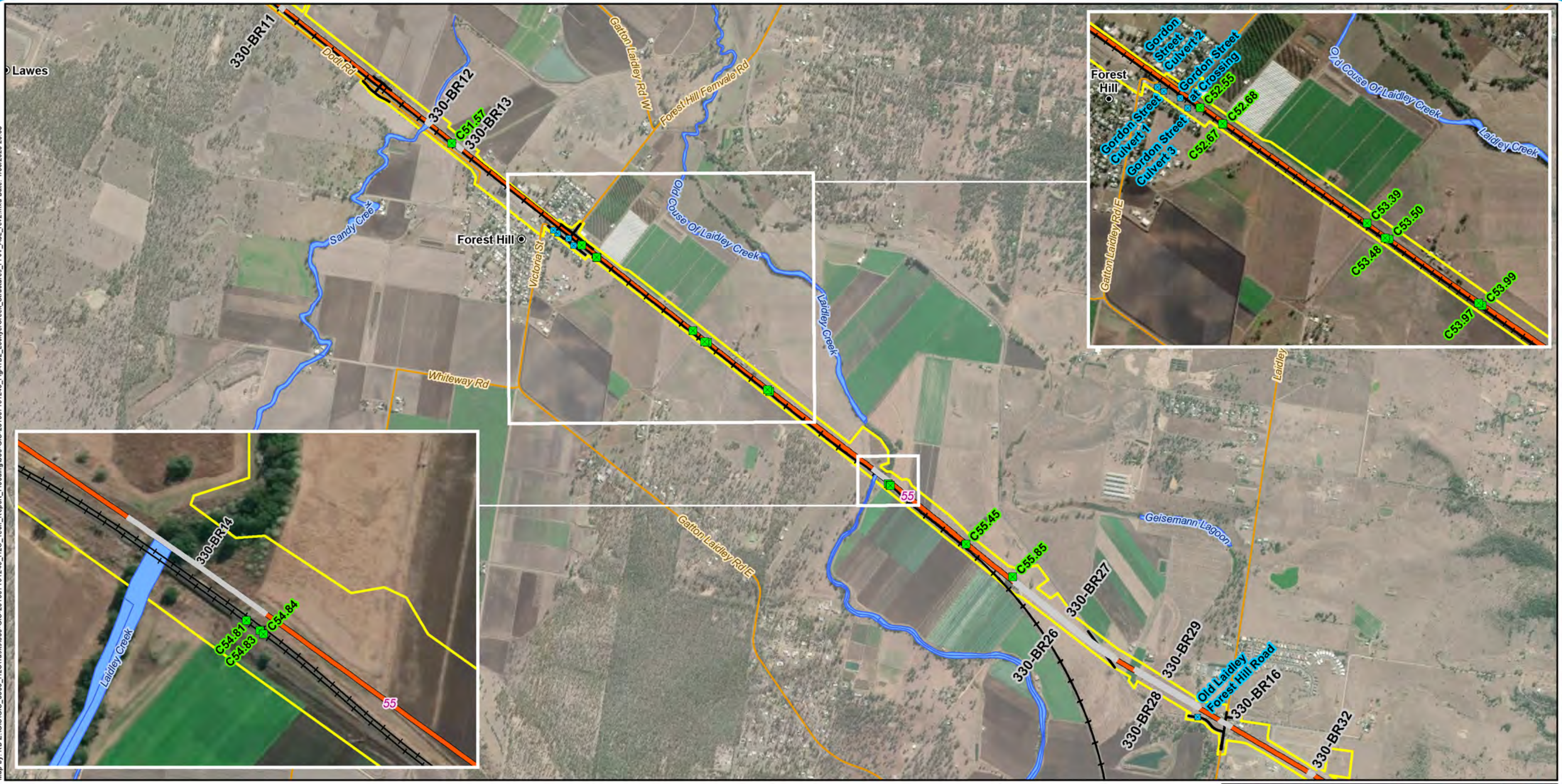
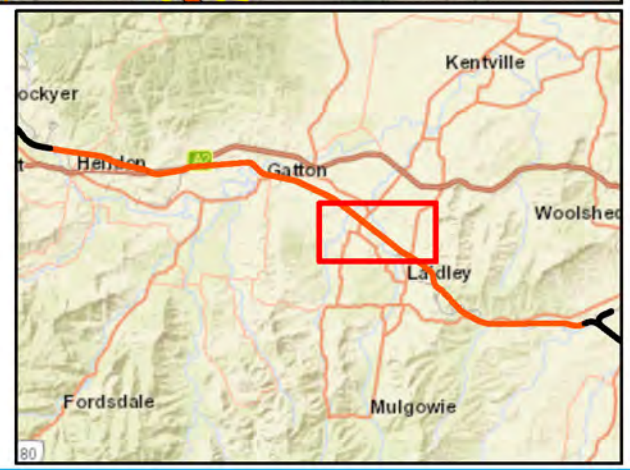
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

Future Freight
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Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-1D-2: 100% Design Structures: Lockyer Creek

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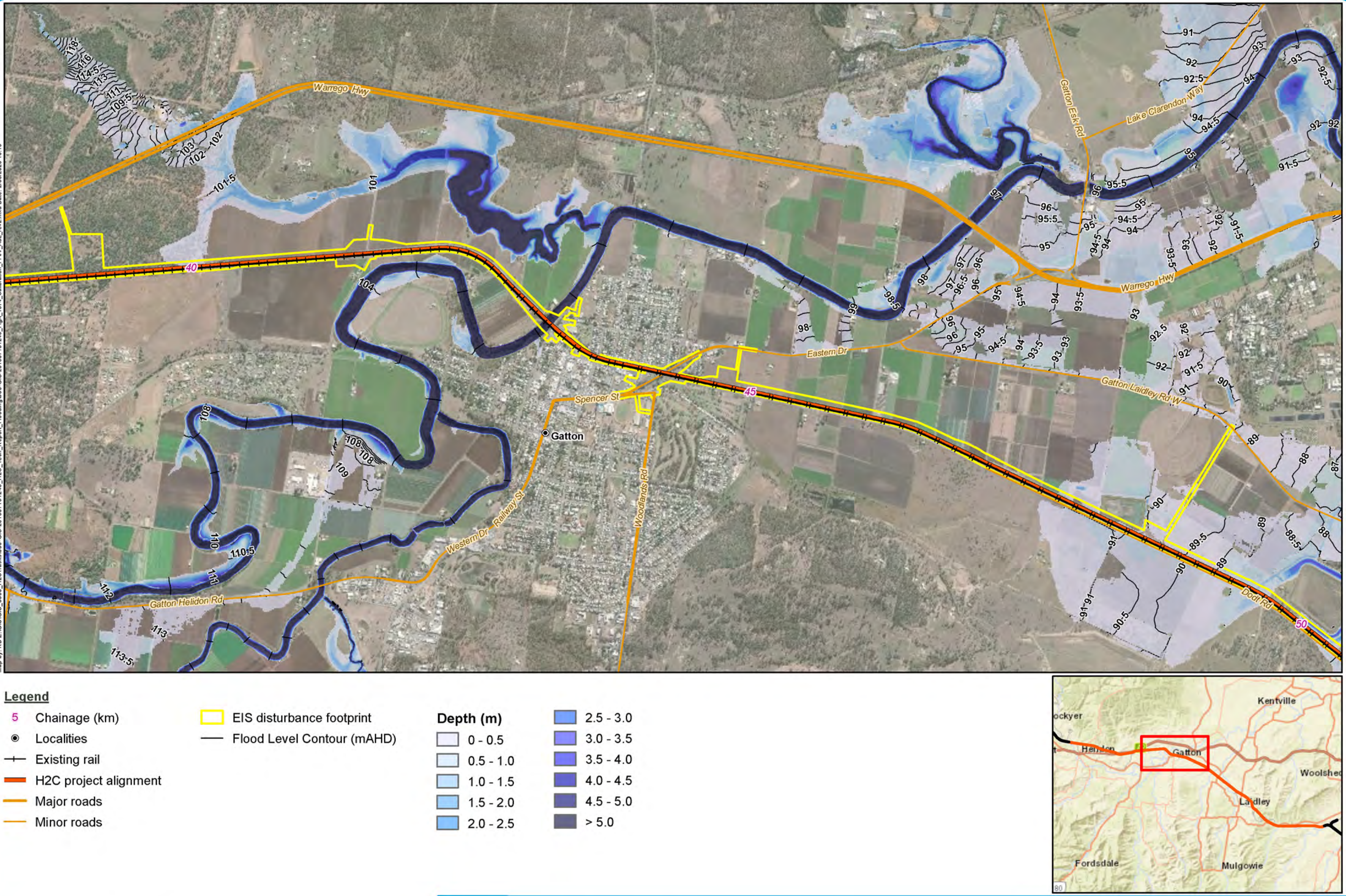

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Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Major roads
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

Future Freight
Integrating Community, Environment and Engineering

Issue date: 02/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-2A-1: 1974 Calibration Event: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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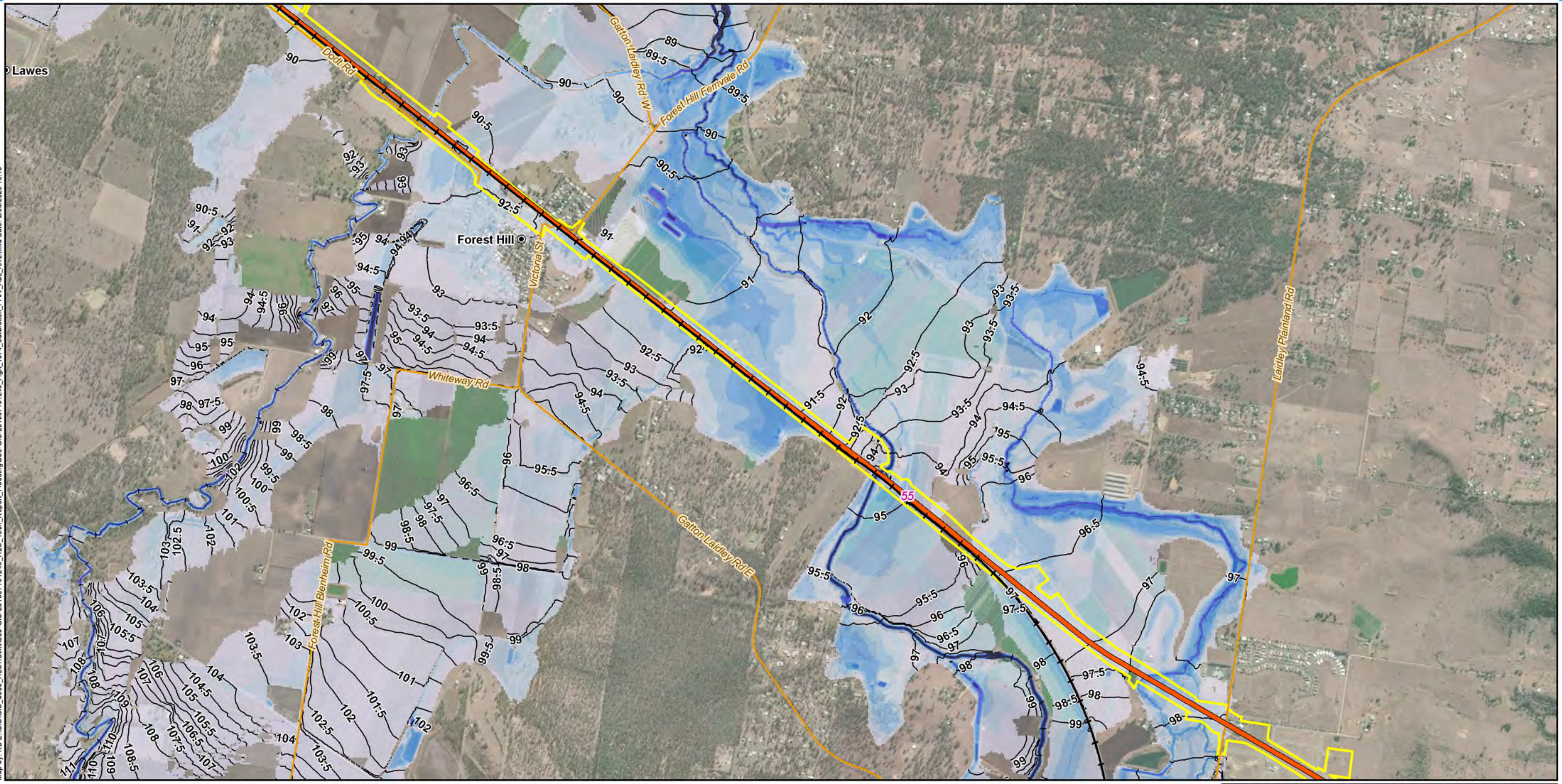
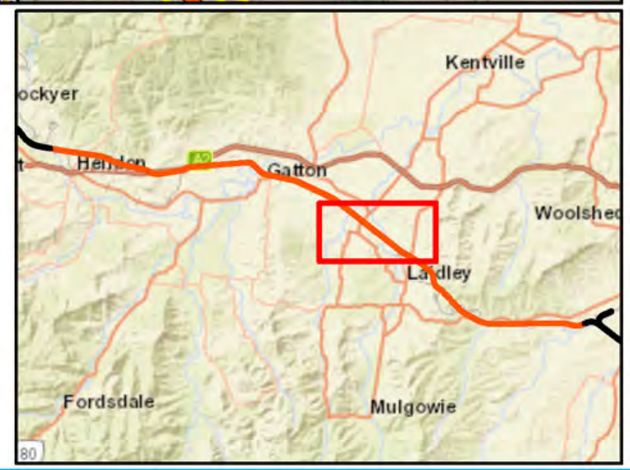


Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0



A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

Future Freight
Integrating Community, Environment and Engineering

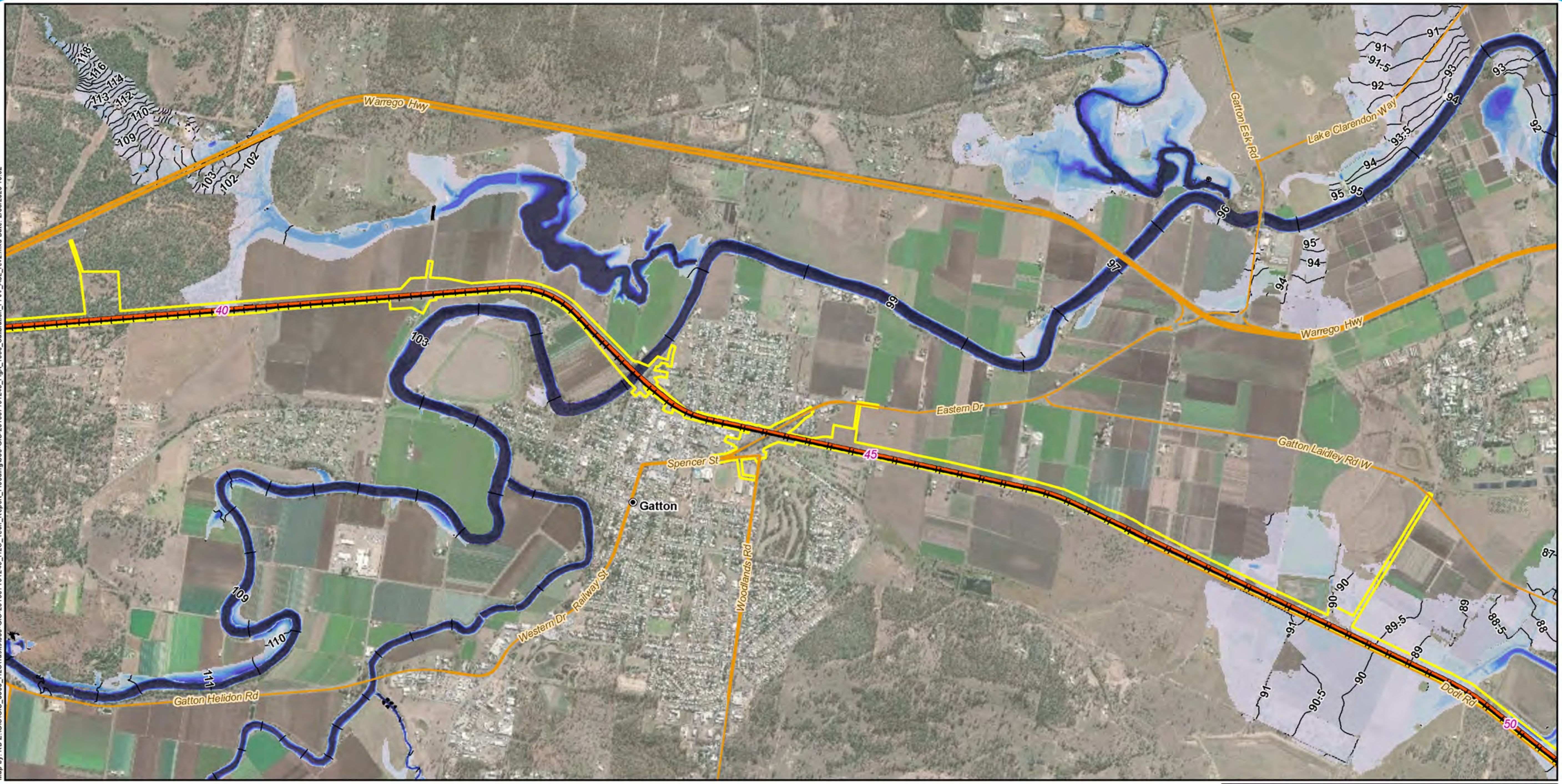
Issue date: 02/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

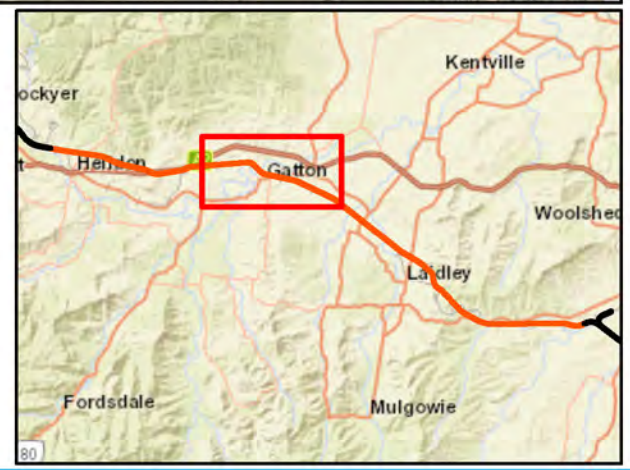
Helidon to Calvert

Figure A-2A-2: 1974 Calibration Event: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715\1245_H2C_Tech_Report_Flooding\330-GIS-20190715\1245_FigX_1996_Calibration_FFJV_A3L_rev2.mxd Date: 2/06/2020 10:02





Legend

5	Chainage (km)
◉	Localities
	Existing rail
	H2C project alignment
	Major roads
	Minor roads
	EIS disturbance footprint
	Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

Future Freight
Integrating Community, Environment and Engineering

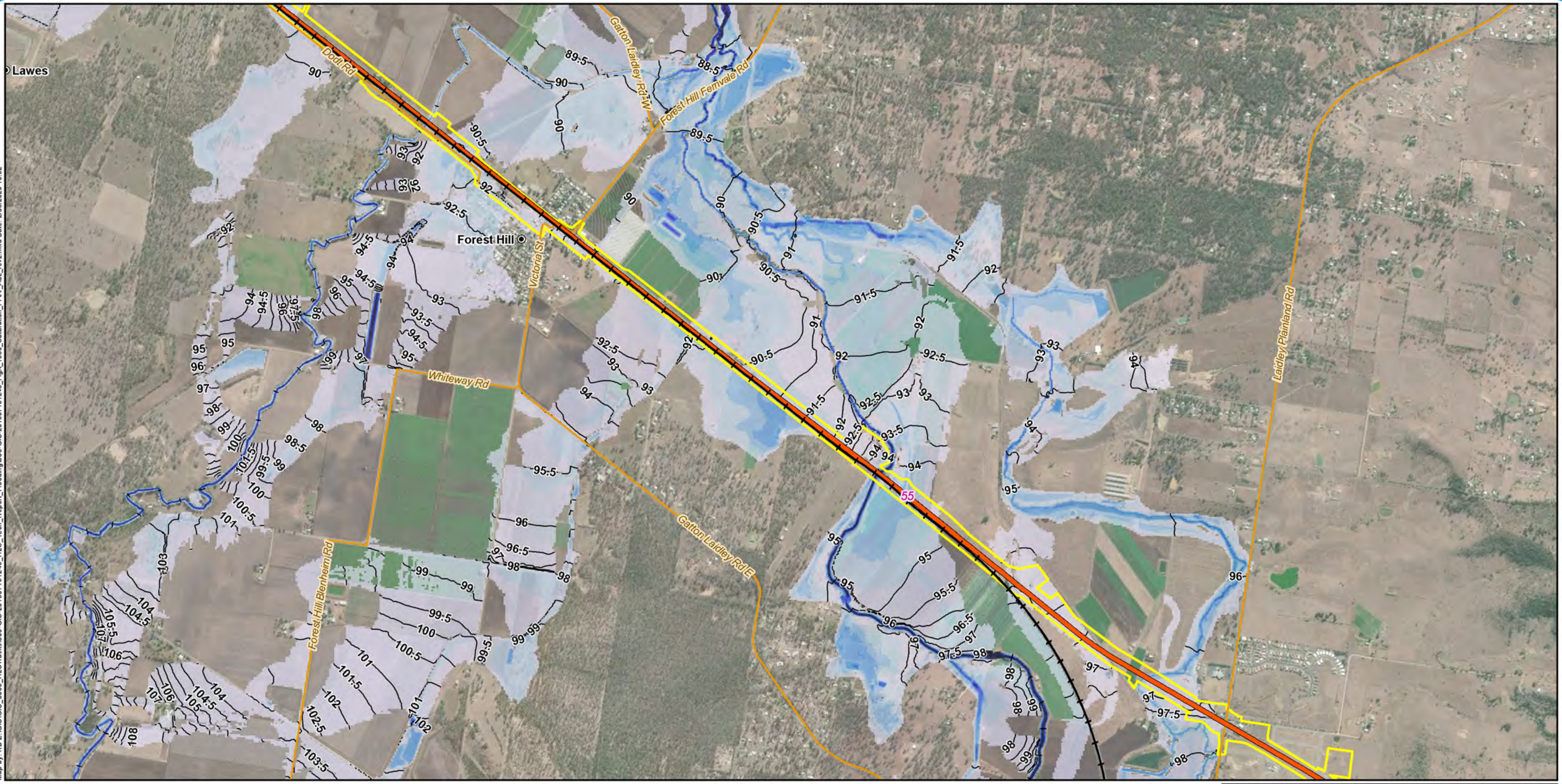
Issue date: 09/09/2019 Version: 1
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-2B-1: 1996 Calibration Event: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715124_H2C_Tech_Report_Flooding\330-GIS-20190715124_FigX_1996_Calibration_FFJV_A3L_rev2.mxd Date: 2/06/2020 10:02

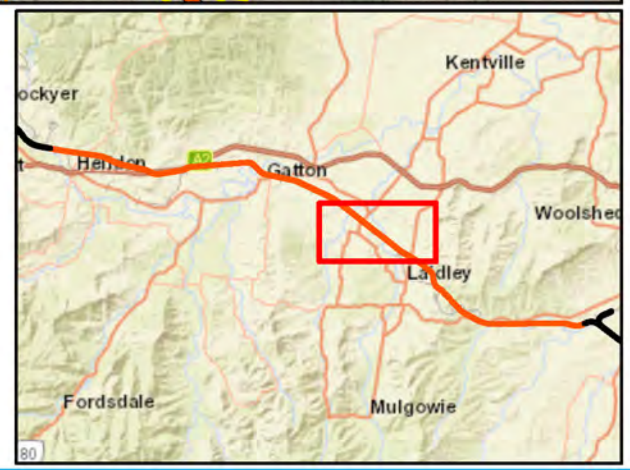


Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0



A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

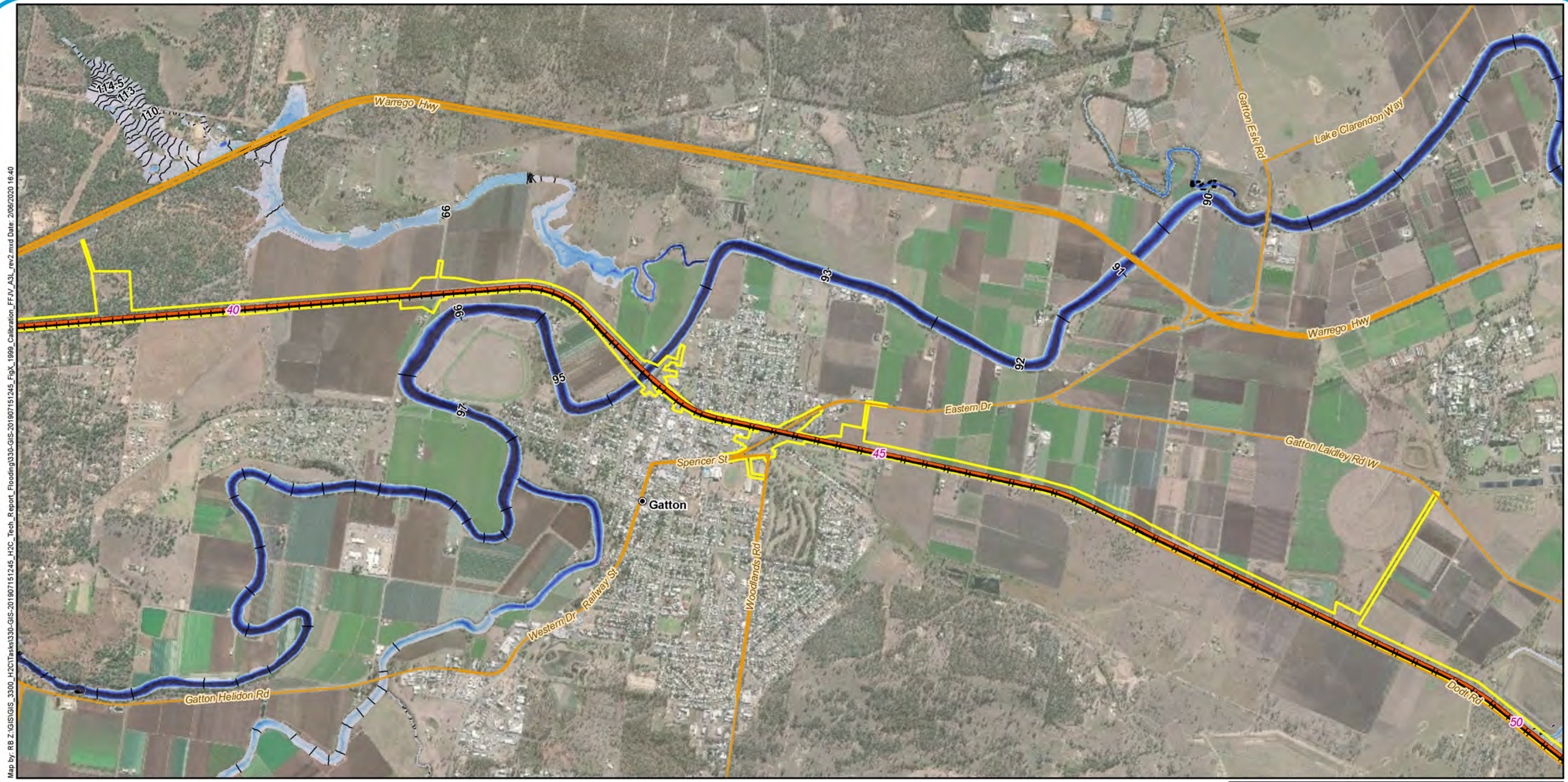
Future Freight
Integrating Community, Environment and Engineering

Issue date: 09/09/2019 Version: 1
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-2B-2: 1996 Calibration Event: Lockyer Creek

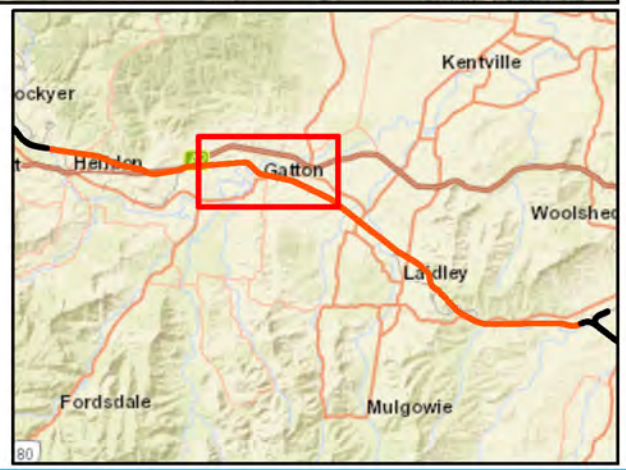
Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

5 Chainage (km)
Localities
Existing rail
H2C project alignment
Major roads
Minor roads
EIS disturbance footprint
Flood Level Contour (mAHD)

Depth (m)
0 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 2.5
2.5 - 3.0
3.0 - 3.5
3.5 - 4.0
4.0 - 4.5
4.5 - 5.0
> 5.0



A3 scale: 1:30,000
0 0.2 0.4 0.6 0.8 1km

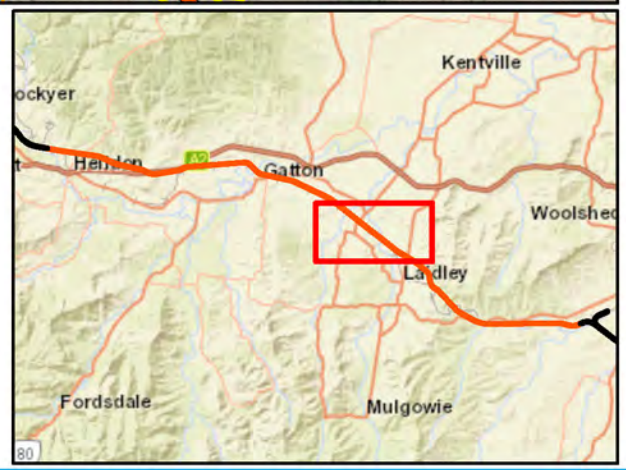
Future Freight
Integrating Community, Environment and Engineering

Issue date: 02/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert
Figure A-2C-1: 1999 Calibration Event: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_1999_Calibration_FFJV_A3L_rev2.mxd Date: 2/06/2020 16:40



Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

A3 scale: 1:25,000

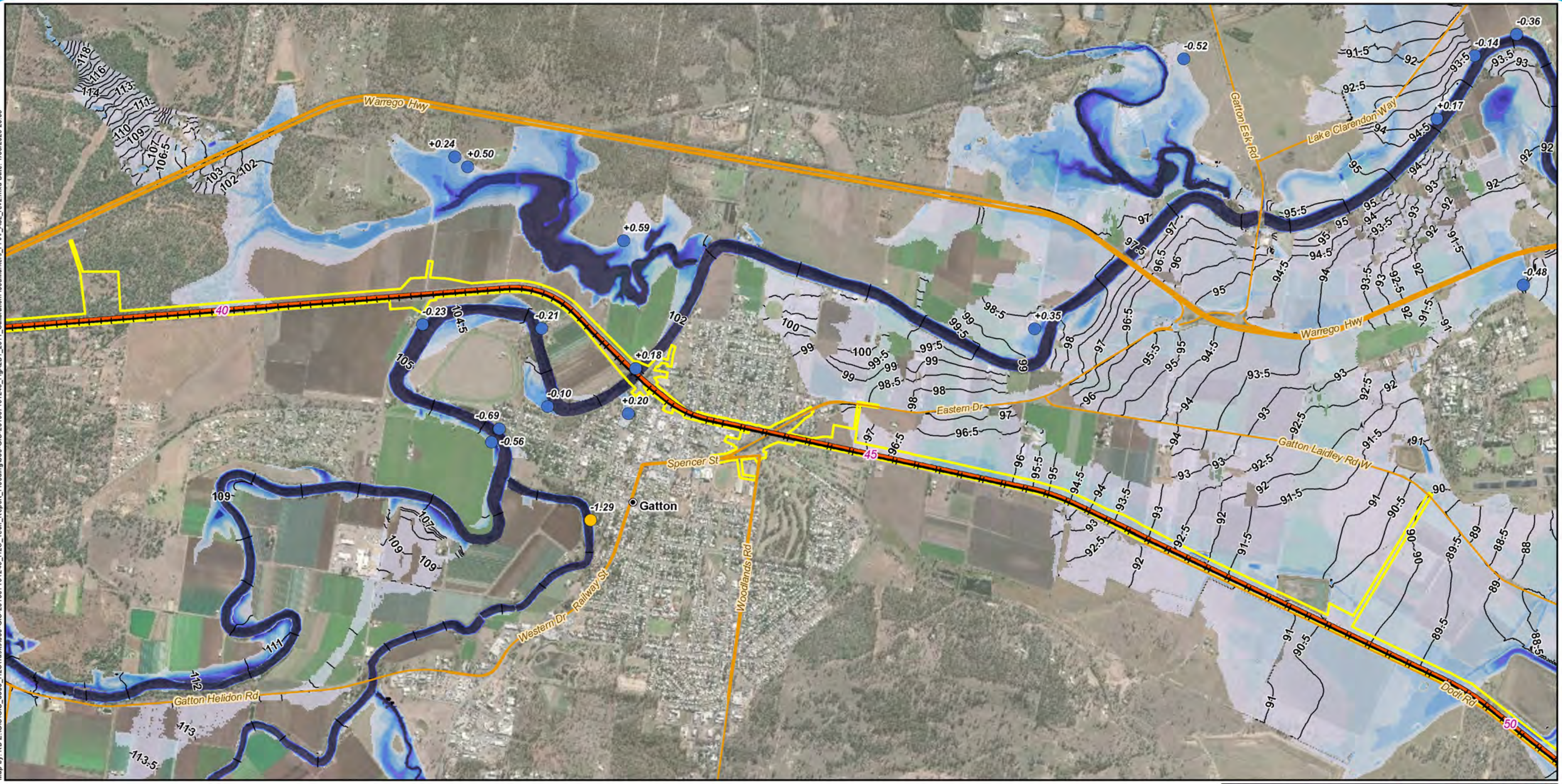
0 0.15 0.3 0.45 0.6 0.75km

Future Freight
Integrating Community, Environment and Engineering

Issue date: 02/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert
Figure A-2C-2: 1999 Calibration Event: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715145_H2C_Tech_Report_Flooding\330-GIS-20190715145_FigA2D1_2011_CalibrationFloodMarkers_FFJV_A3L_rev2.mxd Date: 1/06/2020 20:09

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Major roads
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

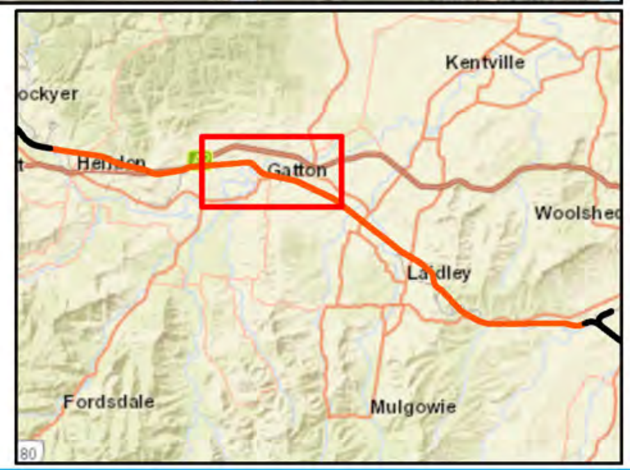
2011 flood marker comparison (m)

- Gatton to Glenore Grove
- Helidon to Grantham, and Lower Tenthill

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

Note:
Information presented is from a regional Lockyer Creek flood model. Local catchment surface flows are not presented.



A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

Future Freight
Integrating Community, Environment and Engineering

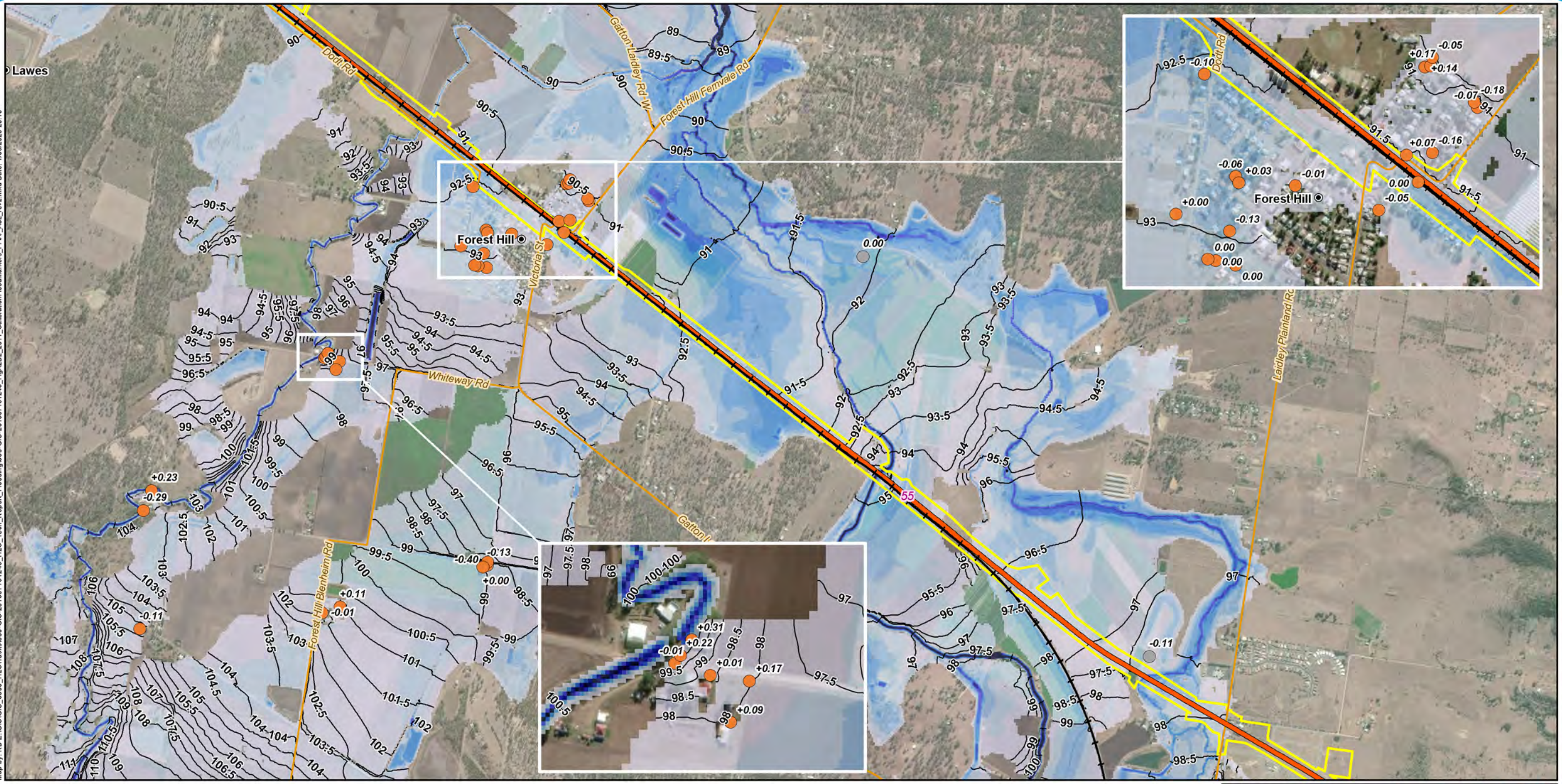
Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A2-D-1: 2011 Calibration Event with Flood markers: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigA2D2_2011_CalibrationFloodMarkers_FFJV_A3L_rev2.mxd Date: 1/06/2020 20:10



Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

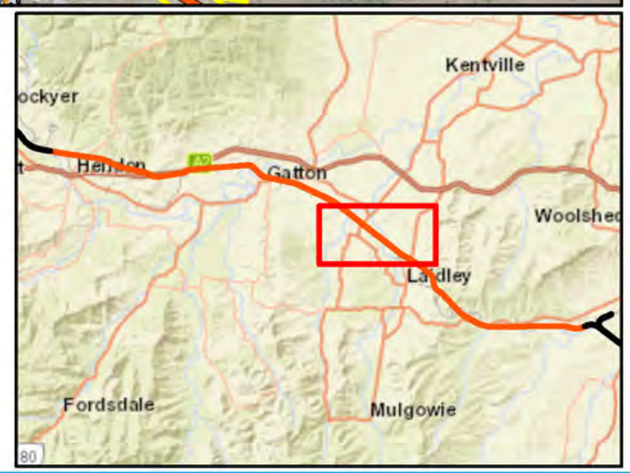
2011 flood marker comparison (m)

- Glen Cairn to Forest Hill
- Laidley South to Laidley North

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

Note:
Information presented is from a regional Lockyer Creek flood model. Local catchment surface flows are not presented.



A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75 km

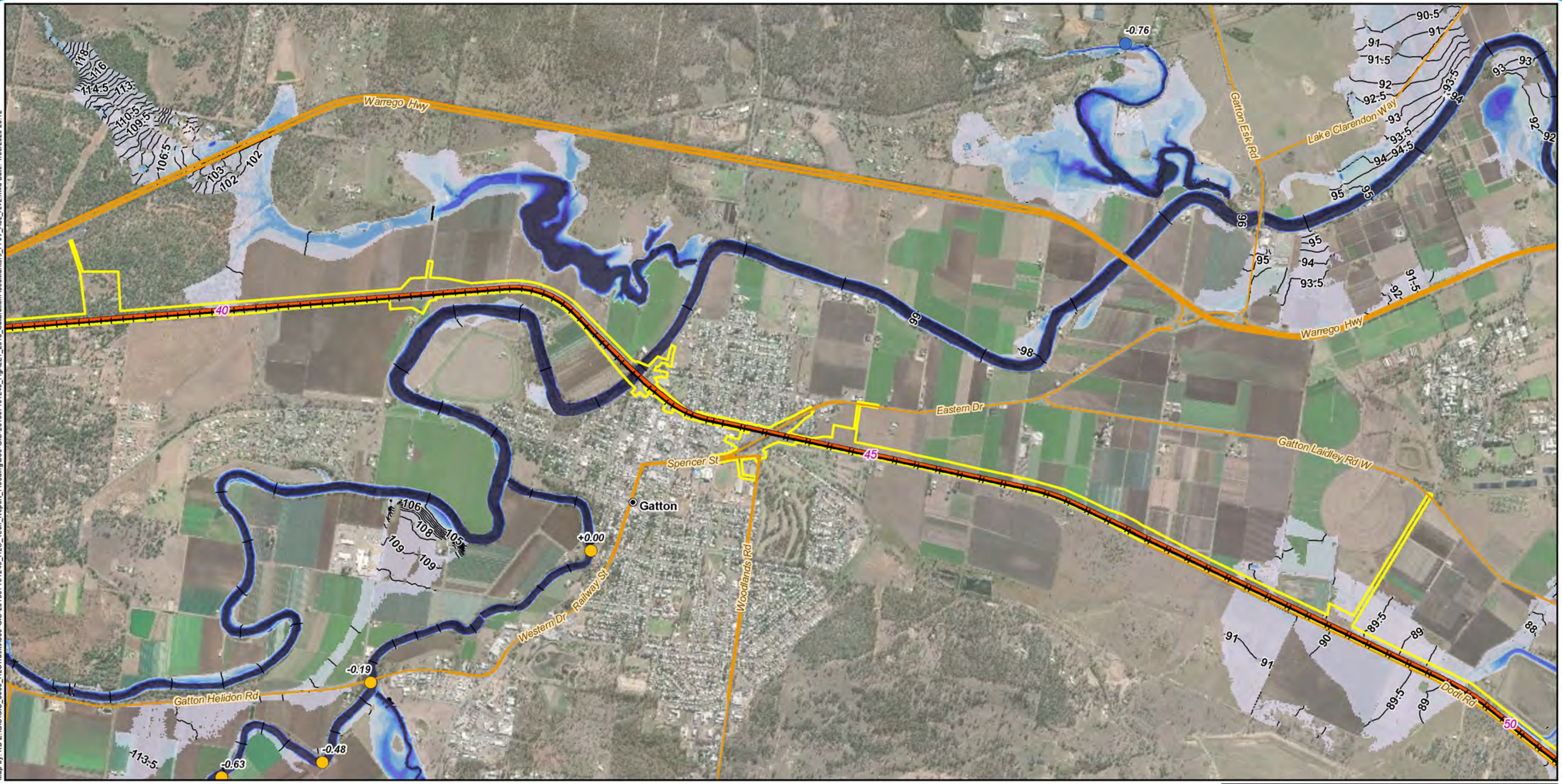
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A2-D-2: 2011 Calibration Event with Flood markers: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715124S_H2C_Tech_Report_Flooding\330-GIS-20190715124S_FigA2E1_2013_CalibrationFloodMarkers_FFJV_A3L_rev2.mxd Date: 1/06/2020 20:12

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Major roads
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

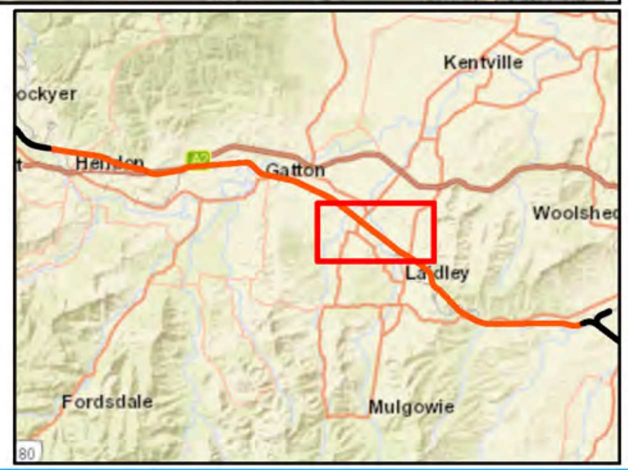
2013 flood marker comparison (m)

- Gatton to Glenore Grove
- Helidon to Grantham, and Lower Tenthill

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

Note:
Information presented is from a regional Lockyer Creek flood model. Local catchment surface flows are not presented.



A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

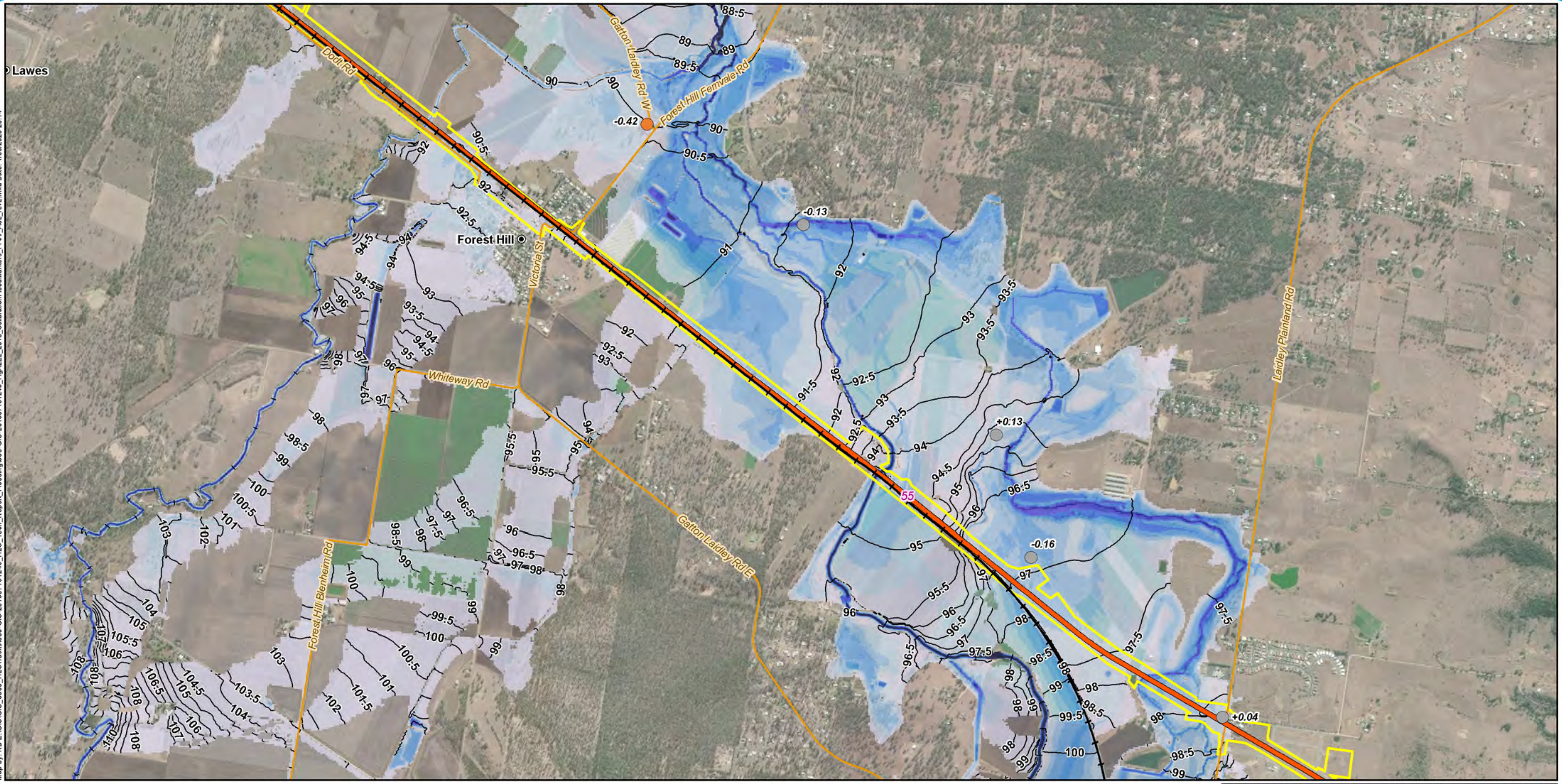
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A2-E-1: 2013 Calibration Event with Flood markers: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

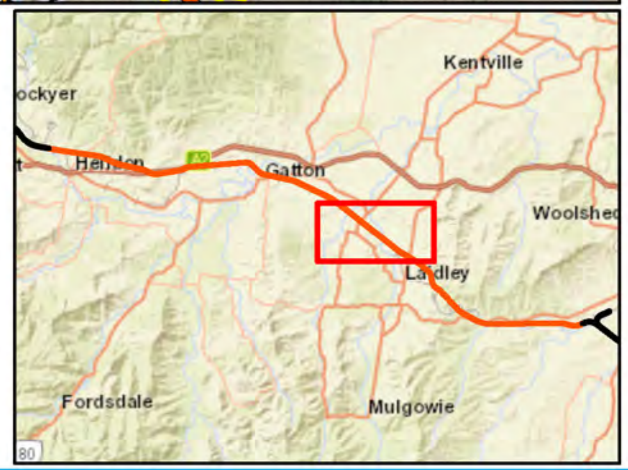
2013 flood marker comparison (m)

- Glen Cairn to Forest Hill
- Laidley South to Laidley North

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

Note:
Information presented is from a regional Lockyer Creek flood model. Local catchment surface flows are not presented.



A3 scale: 1:25,000
0 0.15 0.3 0.45 0.6 0.75km

Future Freight
Integrating Community, Environment and Engineering

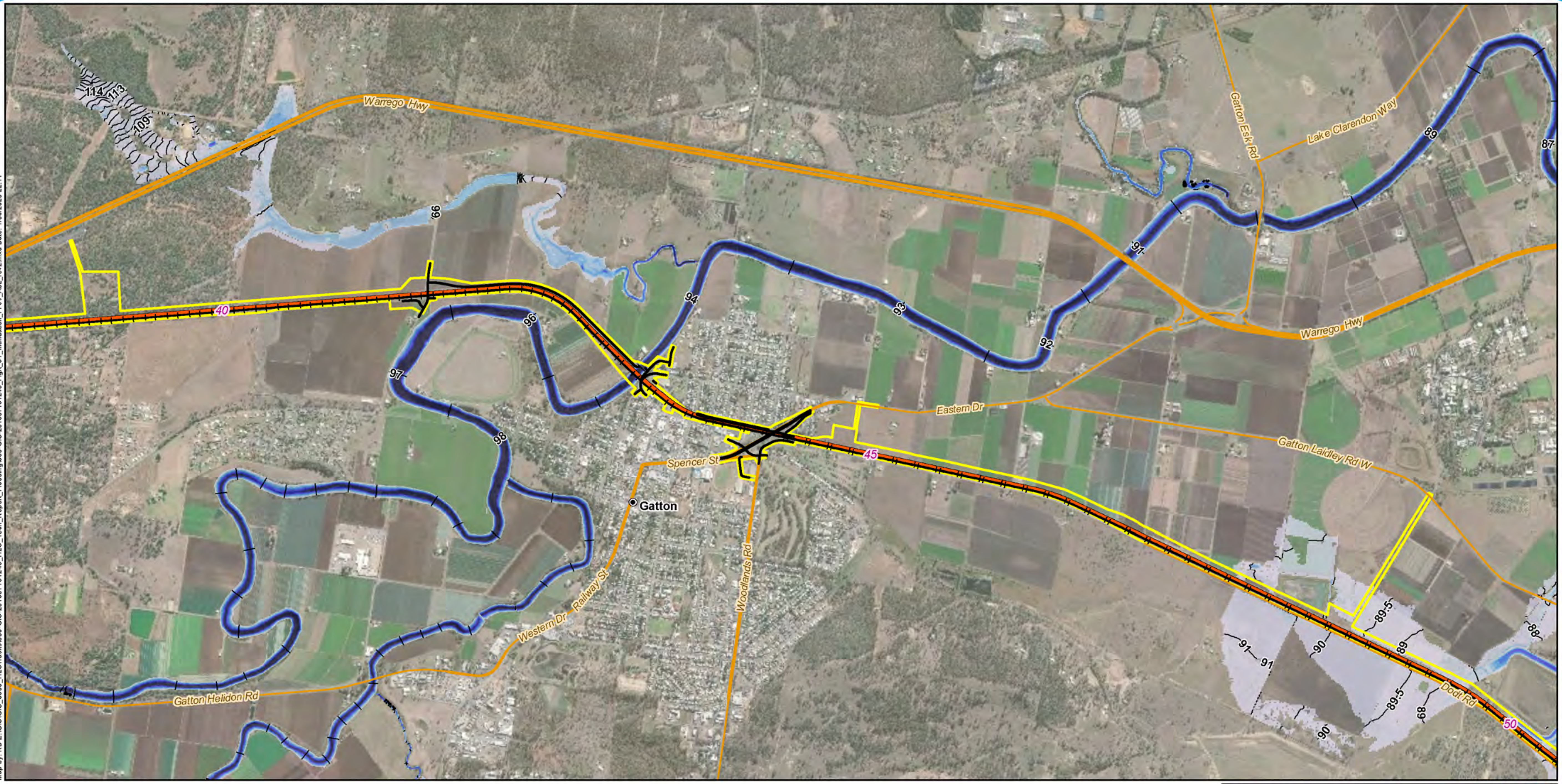
Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A2-E-2: 2013 Calibration Event with Flood markers: Lockyer Creek

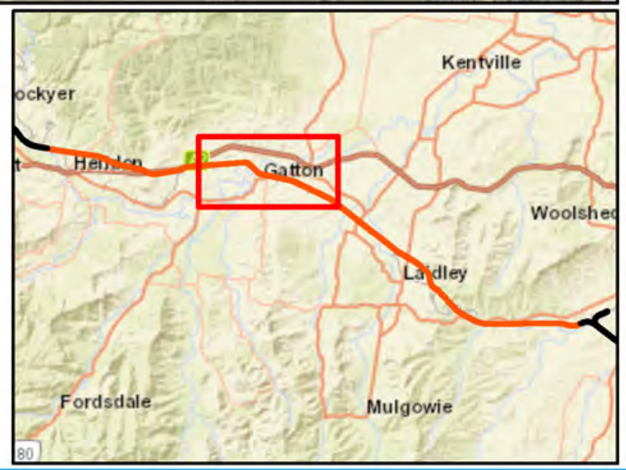
Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715245_H2C_Tech_Report_Flooding\330-GIS-20190715245_FigA2E2_2013_CalibrationFloodMarkers_FFJV_A3L_rev2.mxd Date: 1/06/2020 20:14

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

5 Chainage (km)	EIS disturbance footprint	**Depth (m)**
Localities	Flood Level Contour (mAHD)	0 - 0.5
Existing rail		0.5 - 1.0
H2C project alignment		1.0 - 1.5
Road design		1.5 - 2.0
Major roads		2.0 - 2.5
Minor roads		2.5 - 3.0
		3.0 - 3.5
		3.5 - 4.0
		4.0 - 4.5
		4.5 - 5.0
		> 5.0



A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

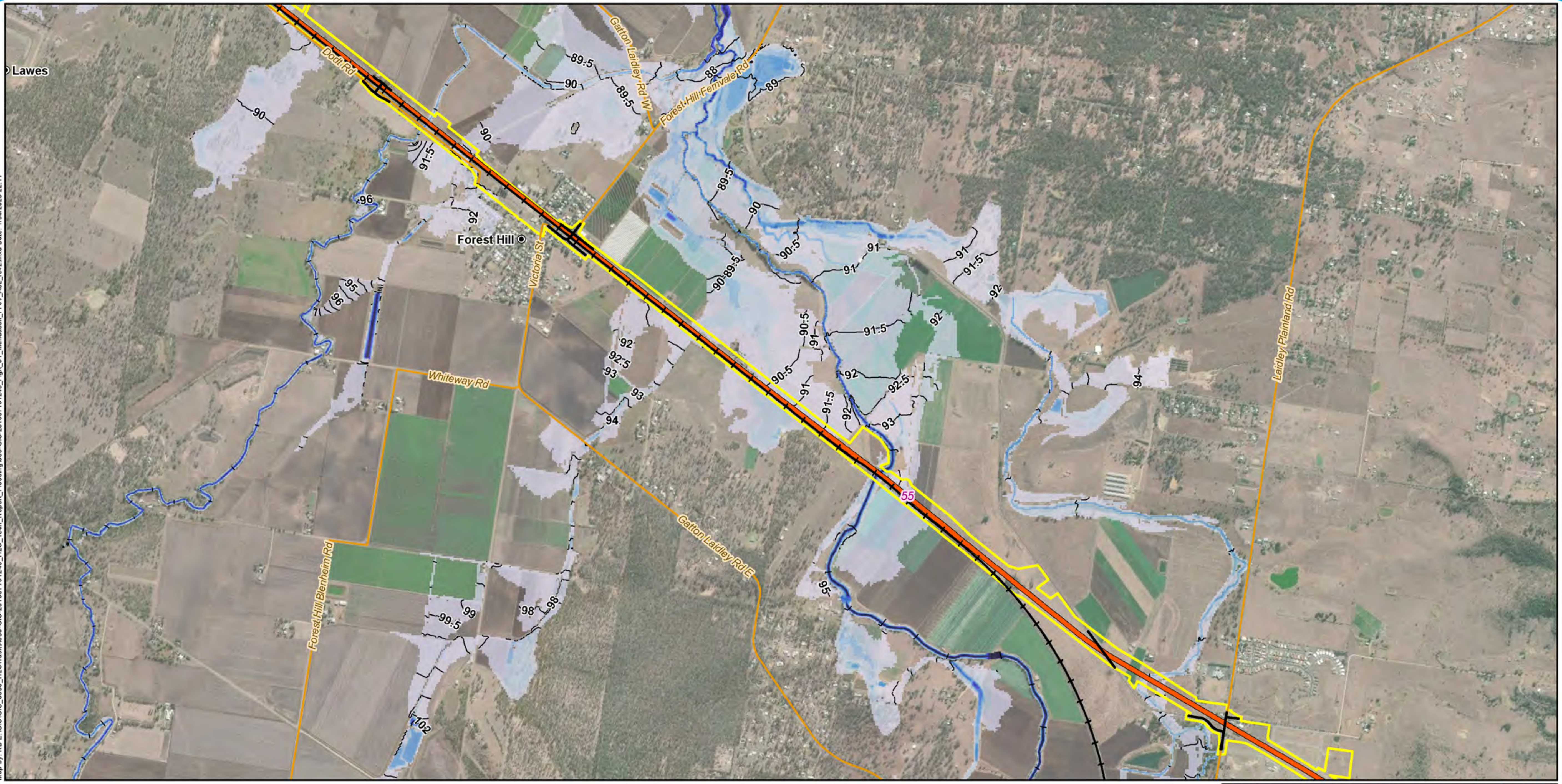
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-3A-1: 20% AEP Event - Existing Case - Inundation Extent: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_5Y_Inundation_FFJV_A3L_rev2.mxd Date: 1/06/2020 22:11

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

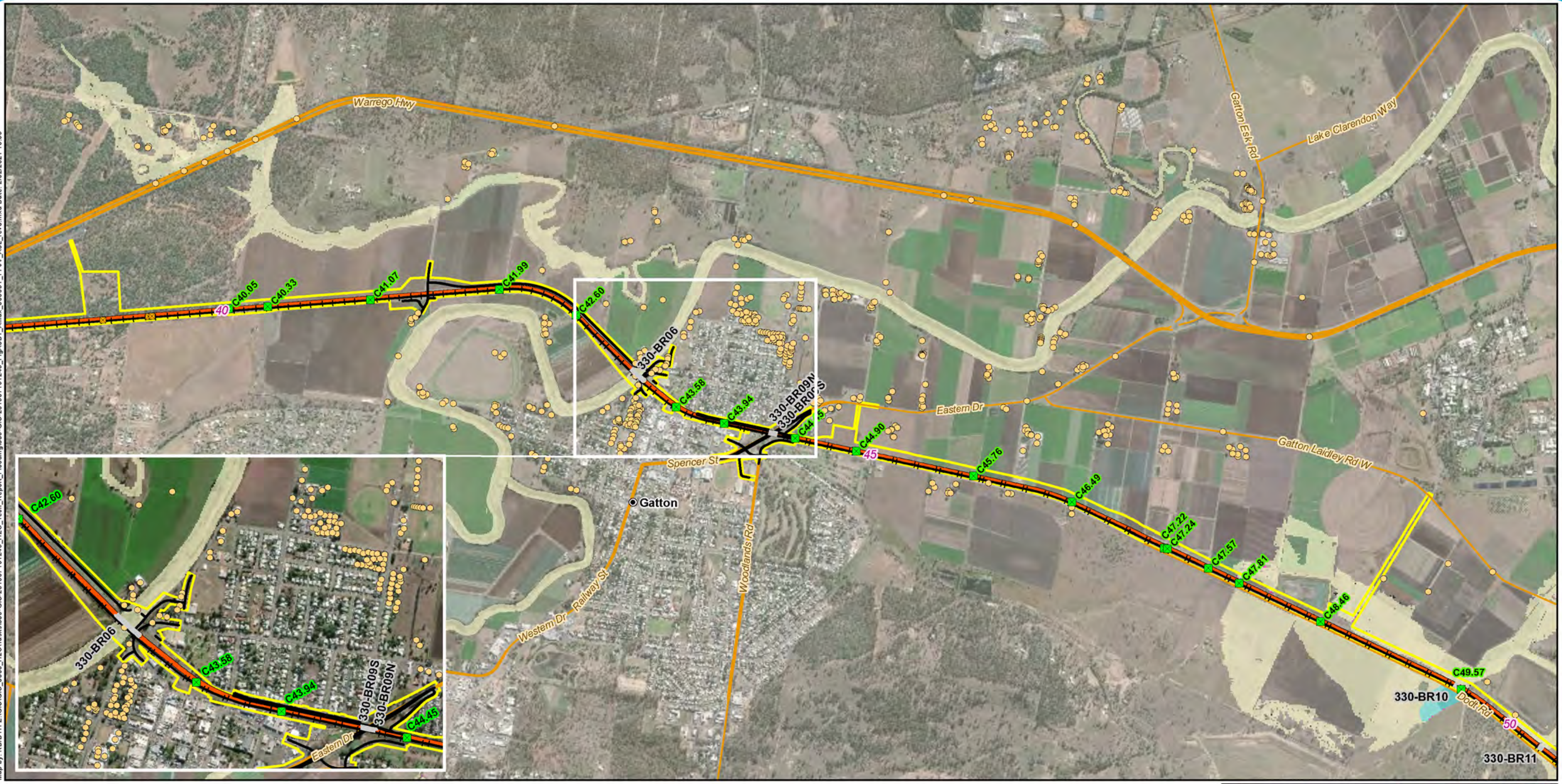
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

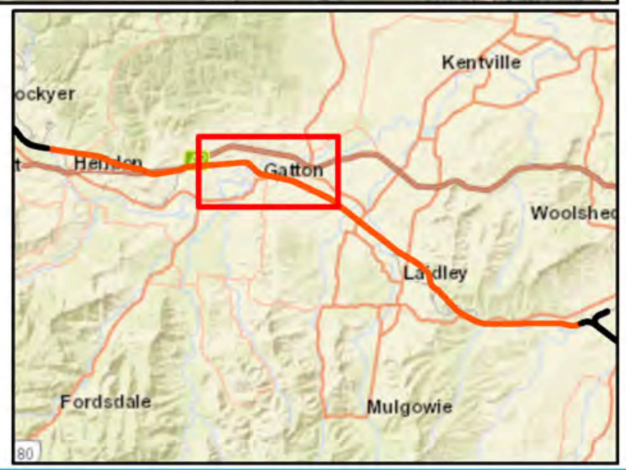
Helidon to Calvert

Figure A-3A-2: 20% AEP Event - Existing Case - Inundation Extent: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigA3B1_Afflux_00005Y_FFJV_A3L_rev3.mxd Date: 2/02/2021 19:55



Legend

- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Local drainage culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

A3 scale: 1:30,000
0 0.2 0.4 0.6 0.8 1km

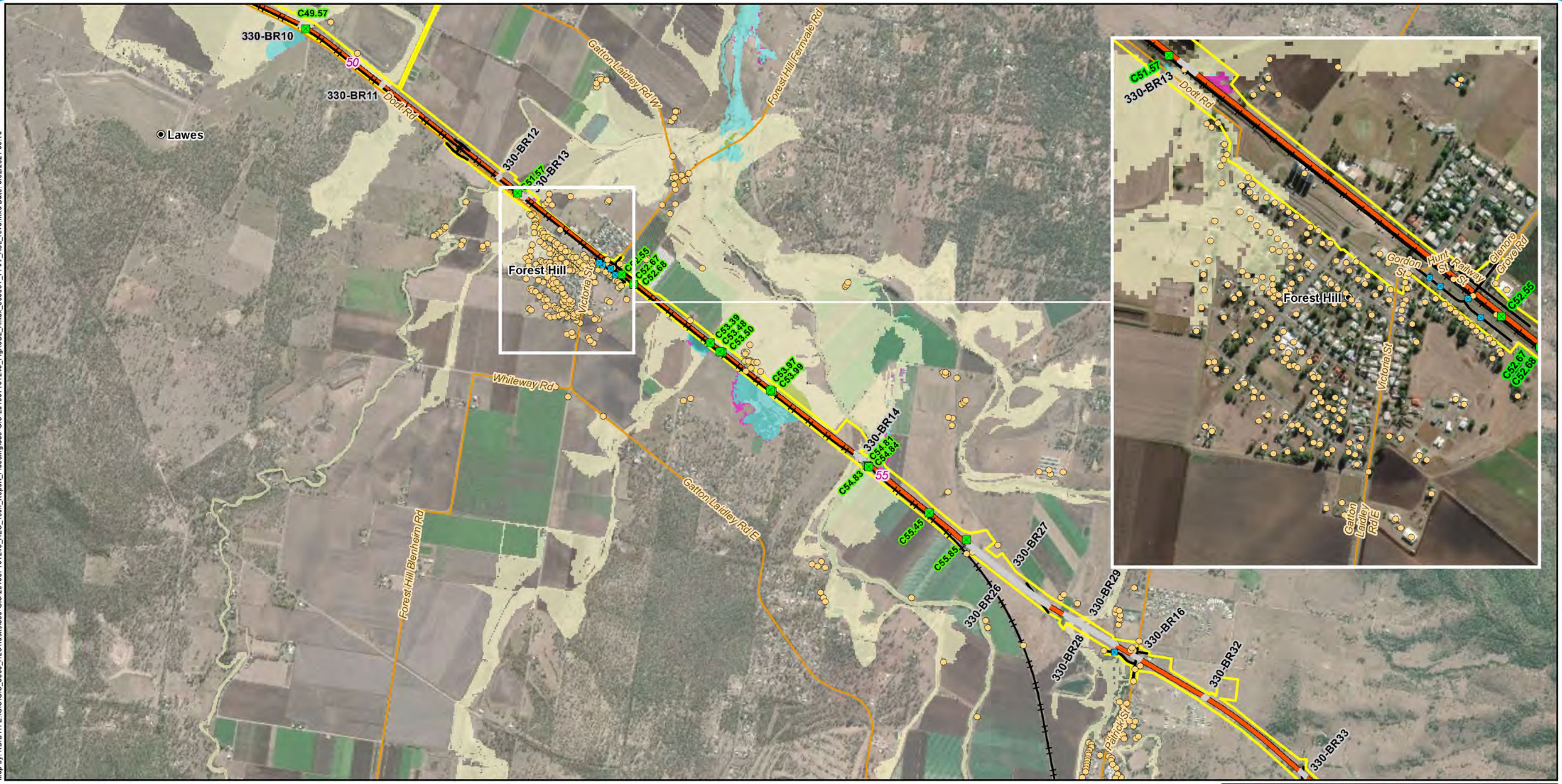
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-3B-1: 20% AEP Event - Developed Case - Afflux: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigA3B2_Afflux_00005Y_FFJV_A3L_rev3.mxd Date: 3/02/2021 09:16

Legend

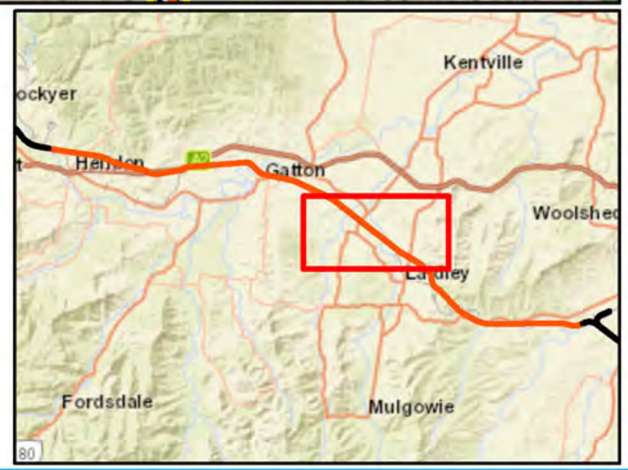
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:31,250
0 0.2 0.4 0.6 0.8 1 km

Future Freight
Integrating Community, Environment and Engineering

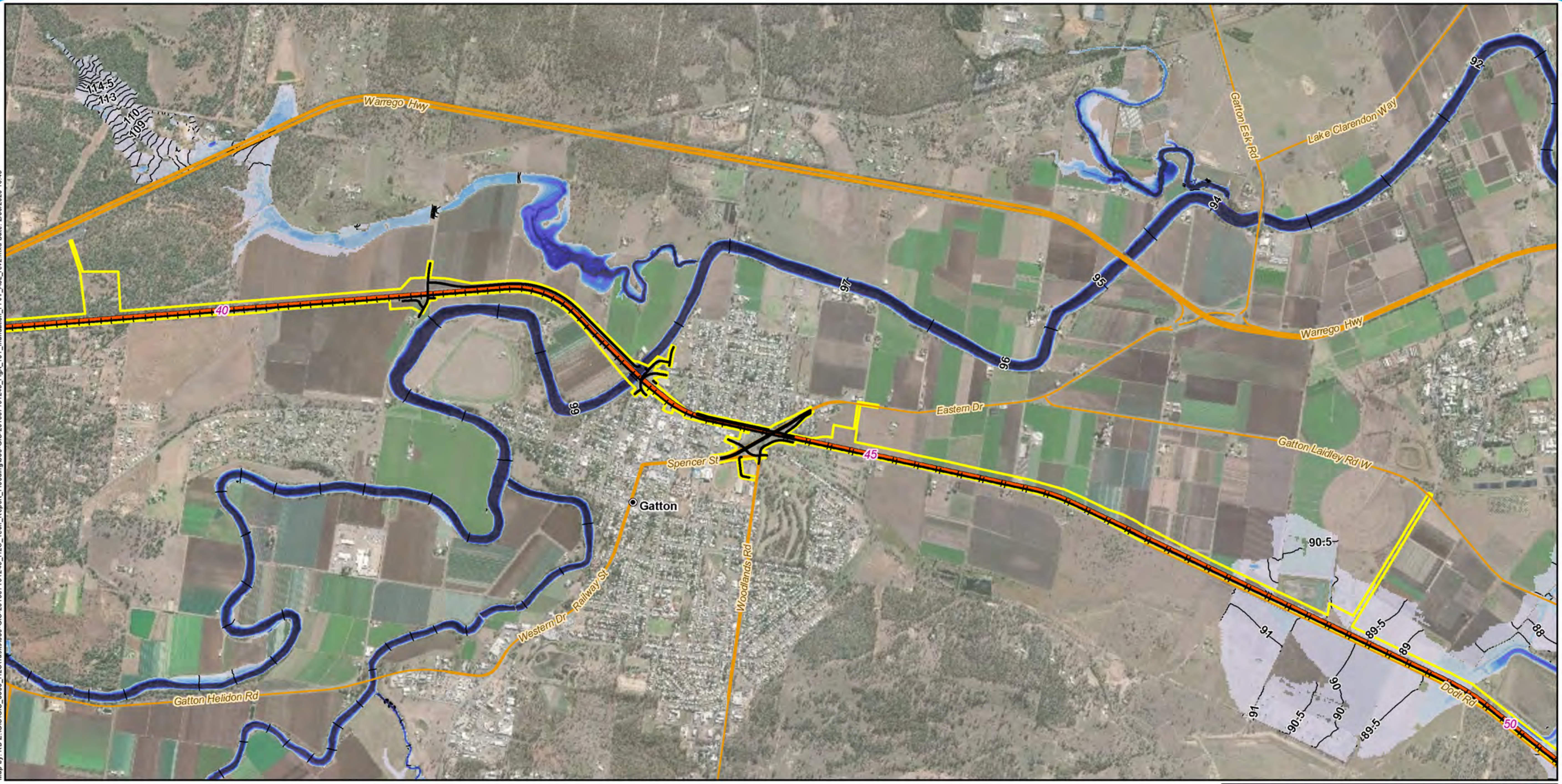
Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

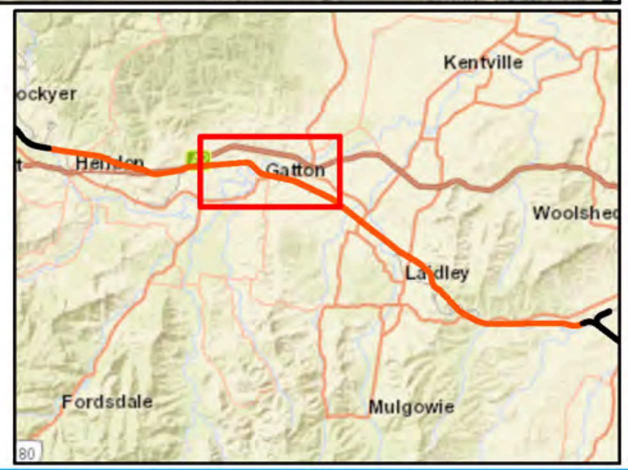
Helidon to Calvert

Figure A-3B-2: 20% AEP Event - Developed Case - Afflux: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_10Y_Inundation_FFJV_A3L_rev2.mxd Date: 2/06/2020 16:45





Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

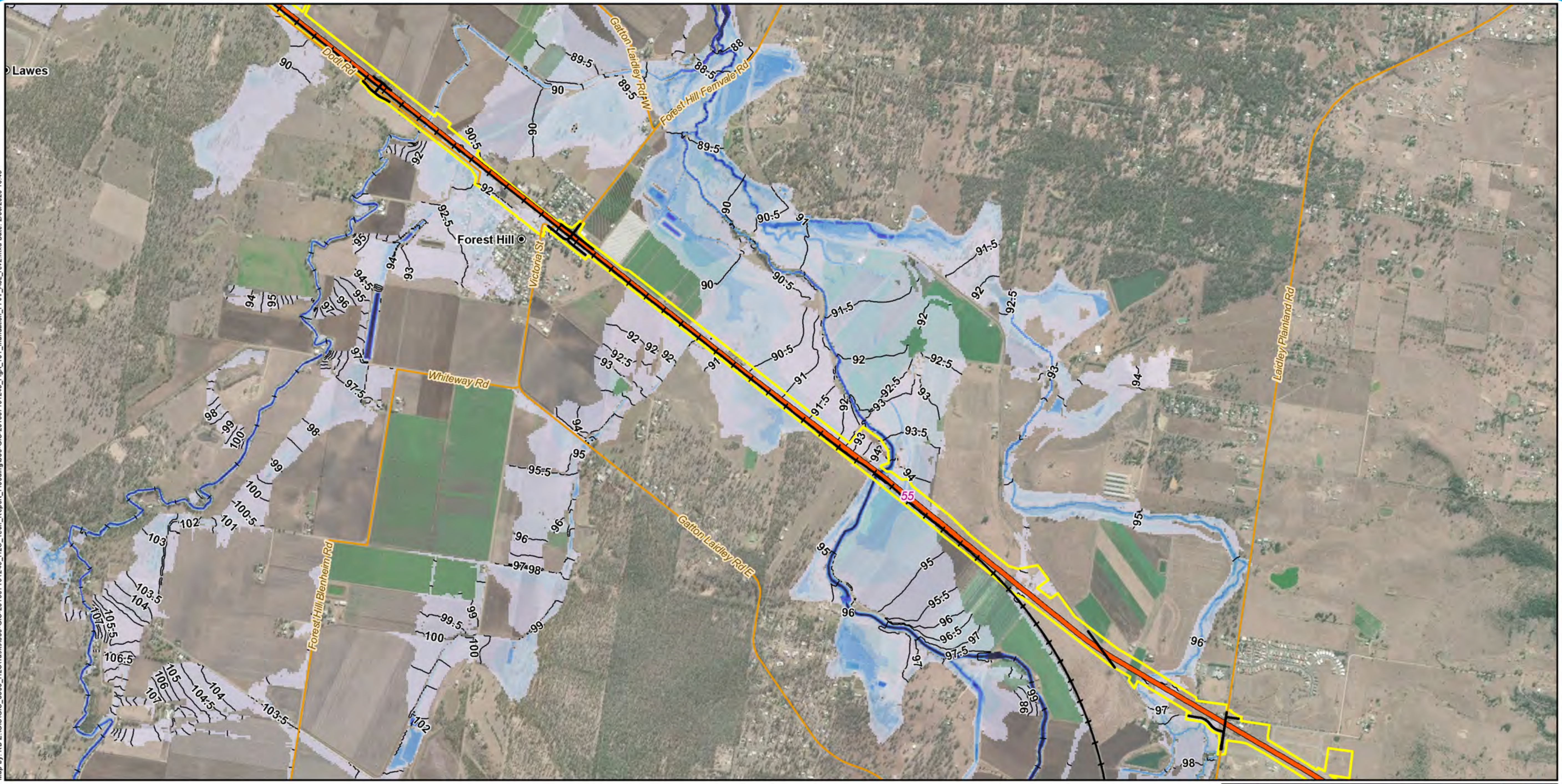
Future Freight
Integrating Community, Environment and Engineering

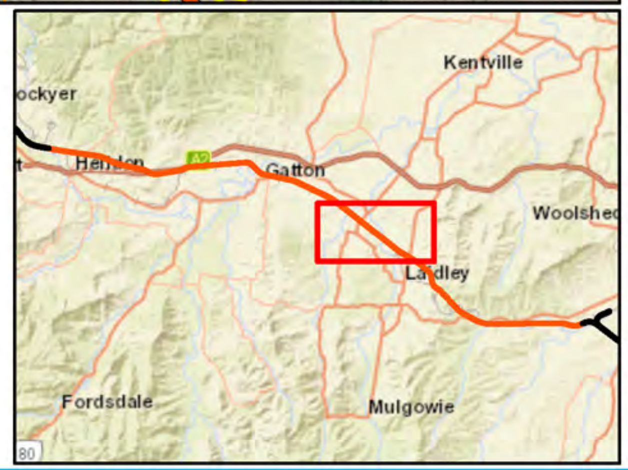
Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-4A-1: 10% AEP Event - Existing Case - Inundation Extent: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

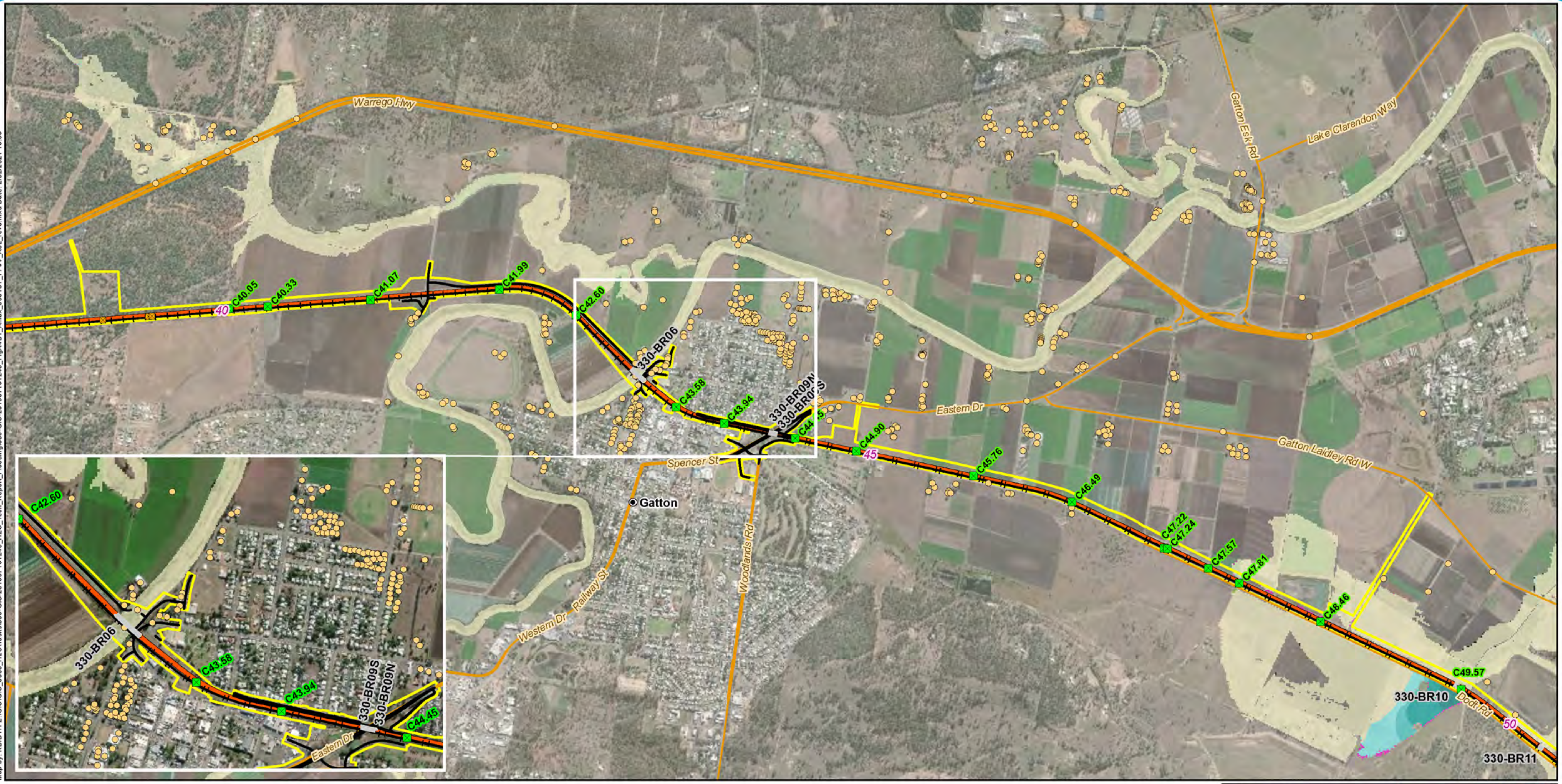
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-4A-2: 10% AEP Event - Existing Case - Inundation Extent: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigA4B1_Afflux_00010Y_FFJV_A3L_rev3.mxd Date: 2/02/2021 19:55

Legend

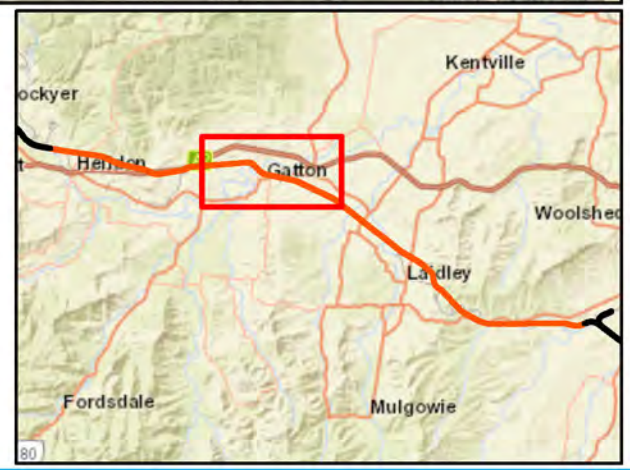
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Local drainage culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:30,000
0 0.2 0.4 0.6 0.8 1km

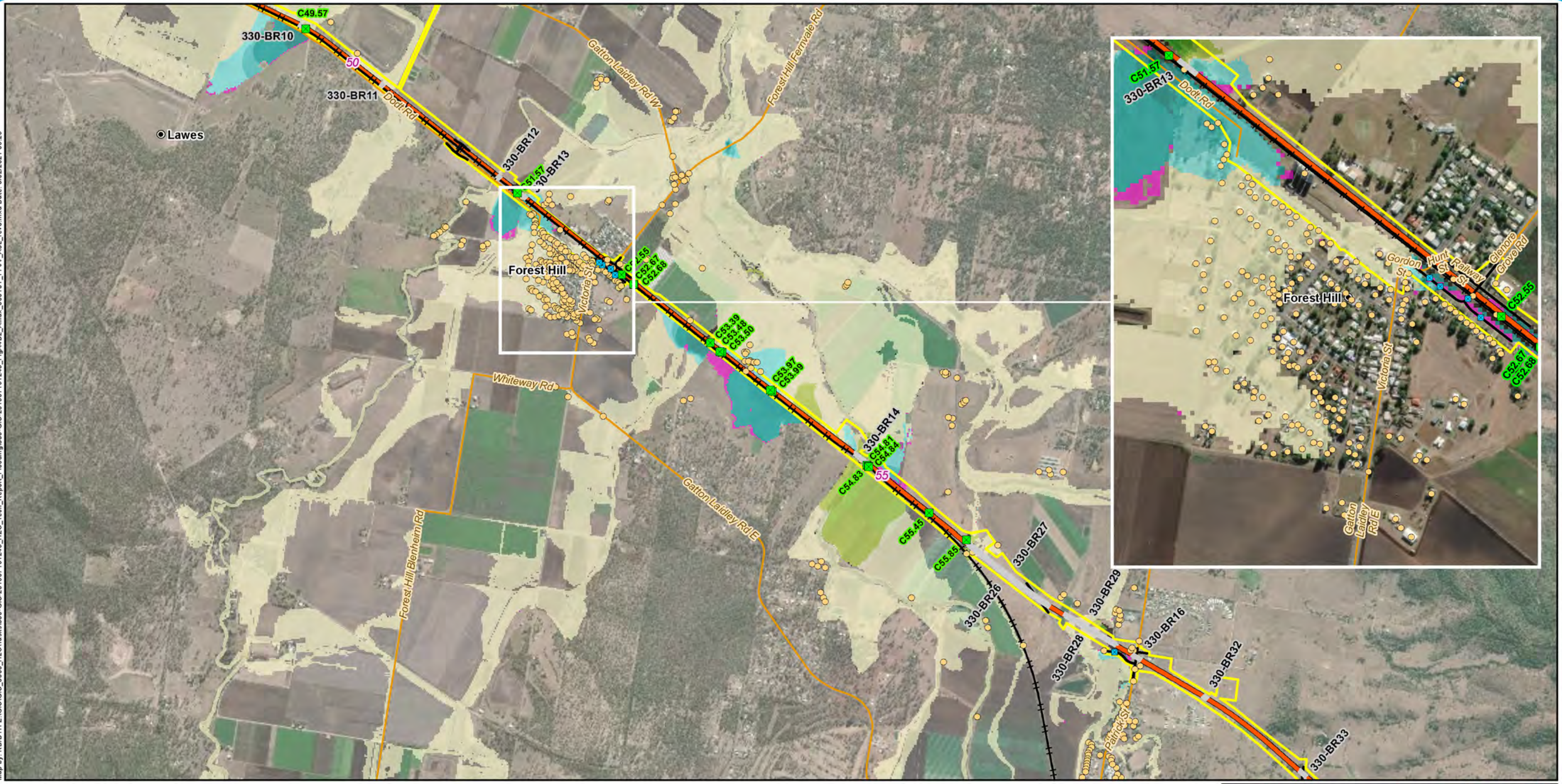
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-4B-1: 10% AEP Event - Developed Case - Afflux: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigA4B2_Afflux_00010Y_FFJV_A3L_rev3.mxd Date: 3/02/2021 09:29

Legend

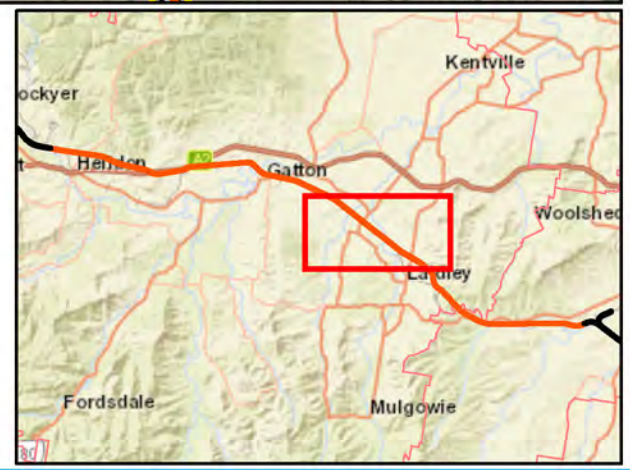
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

Future Freight
Integrating Community, Environment and Engineering

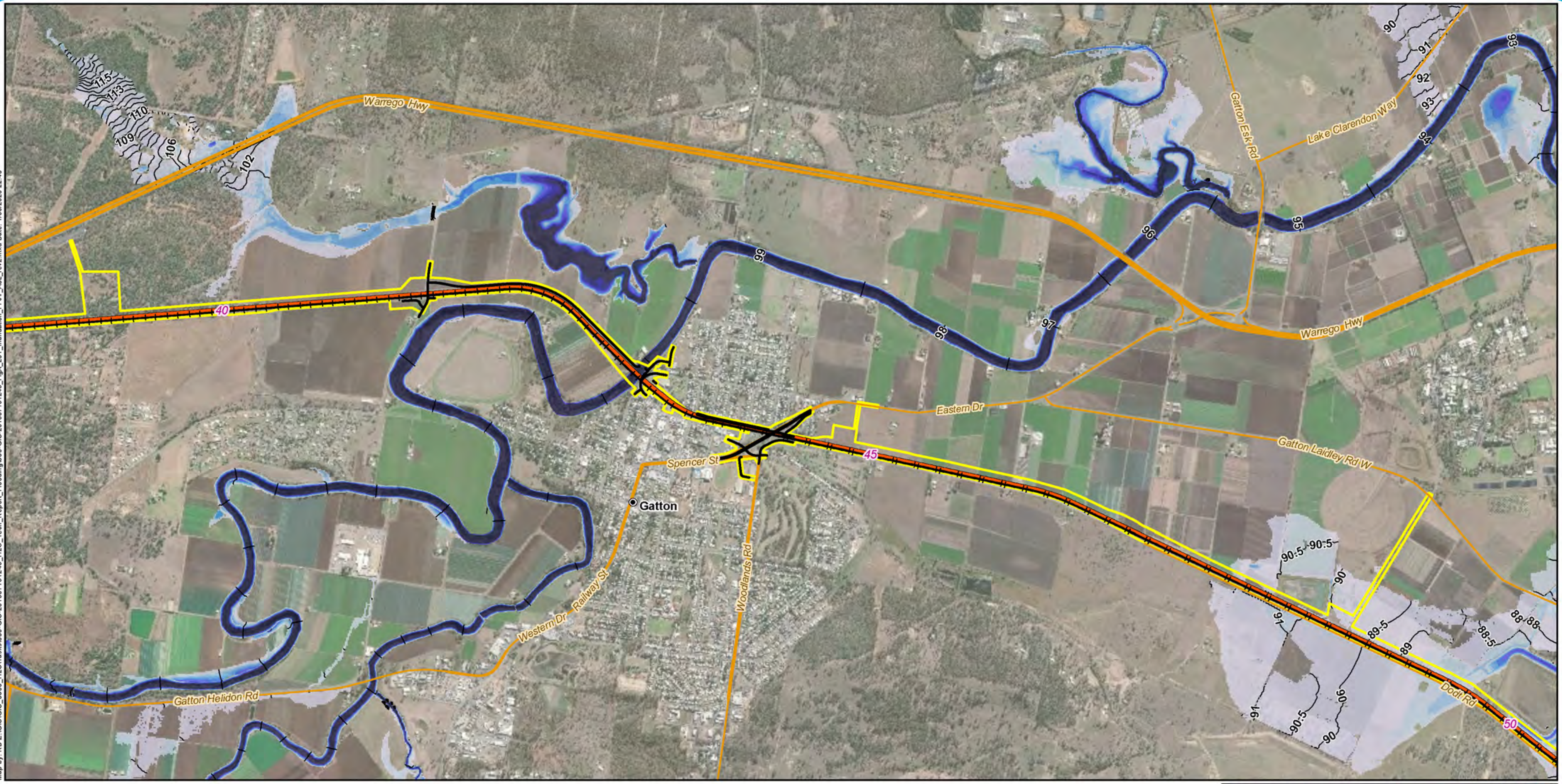
Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

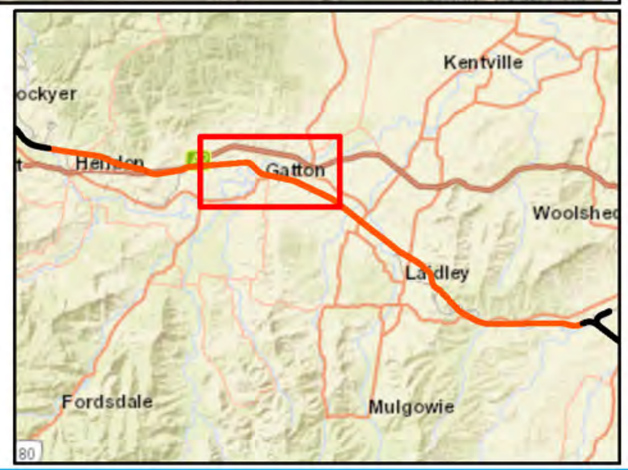
Helidon to Calvert

Figure A-4B-2: 10% AEP Event - Developed Case - Afflux: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715\245_H2C_Tech_Report_Flooding\330-GIS-20190715\245_FigX_20Y_Inundation_FFJV_A3L_rev2.mxd Date: 1/06/2020 22:40





Legend

5	Chainage (km)
◉	Localities
	Existing rail
	H2C project alignment
	Road design
	Major roads
	Minor roads
	EIS disturbance footprint
	Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1 km

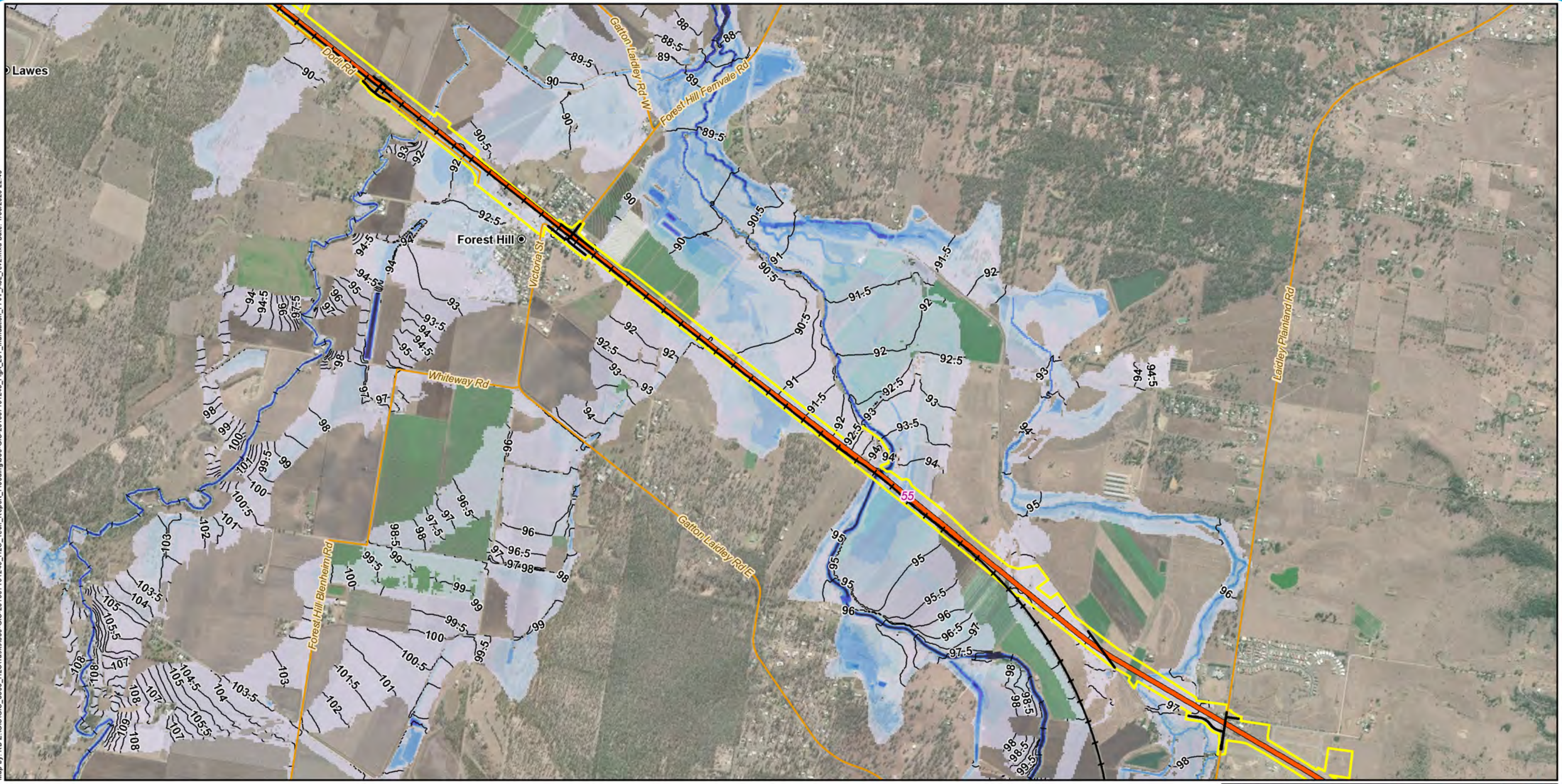
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-5A-1: 5% AEP Event - Existing Case - Inundation Extent: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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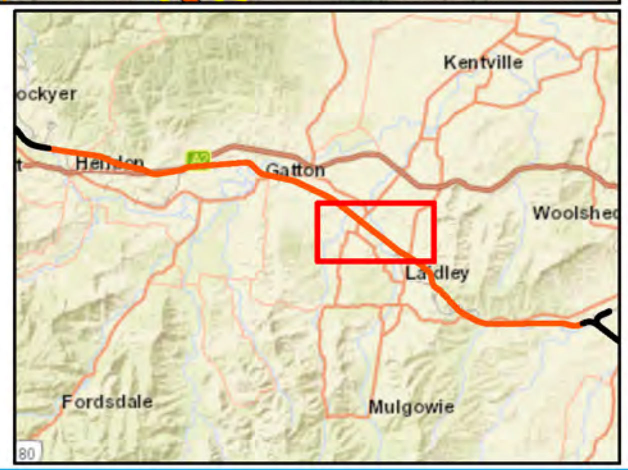
Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0



A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

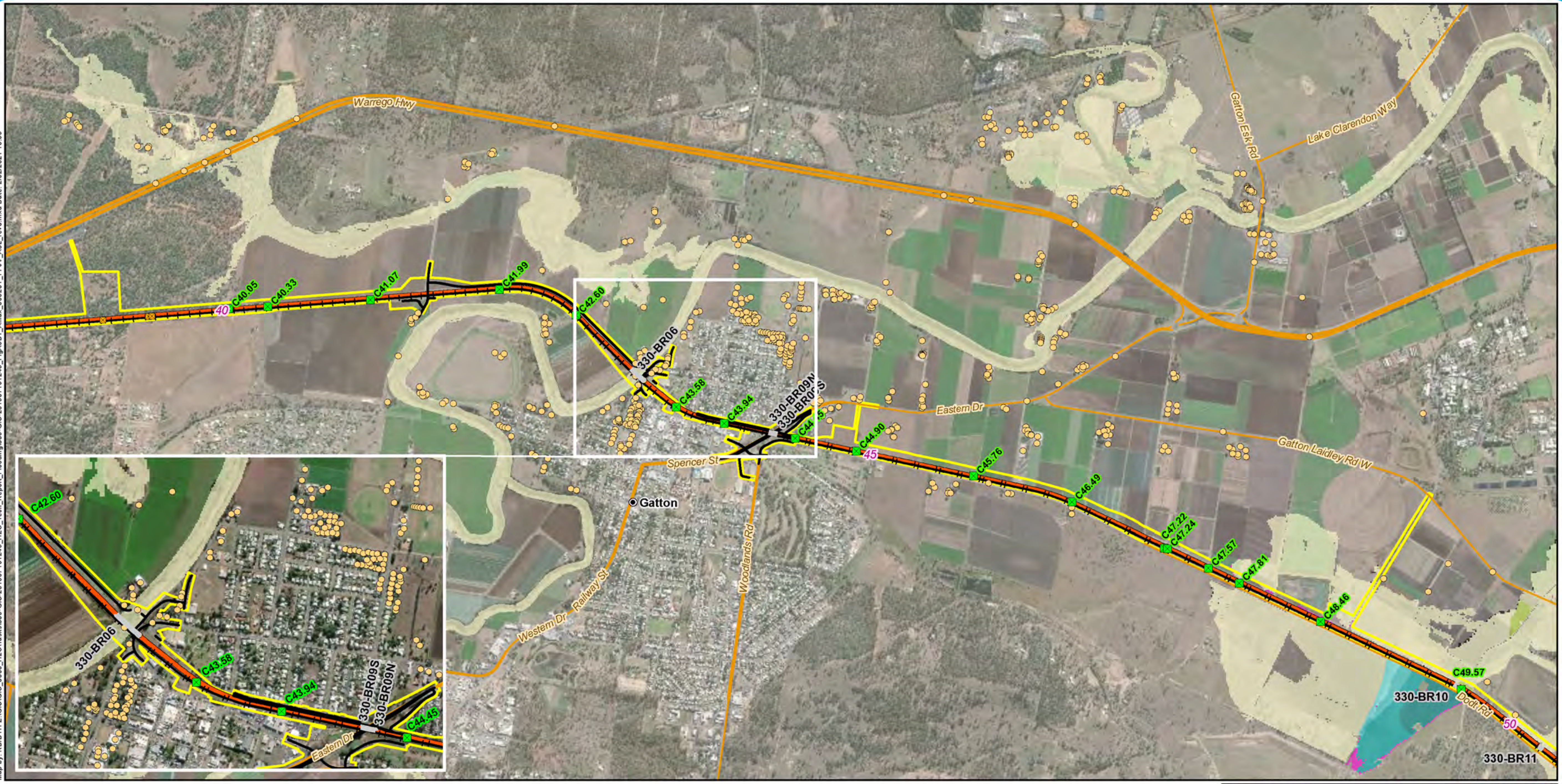
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-5A-2: 5% AEP Event - Existing Case - Inundation Extent: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigA5B1_Afflux_00020Y_FFJV_A3L_rev3.mxd Date: 2/02/2021 19:55

Legend

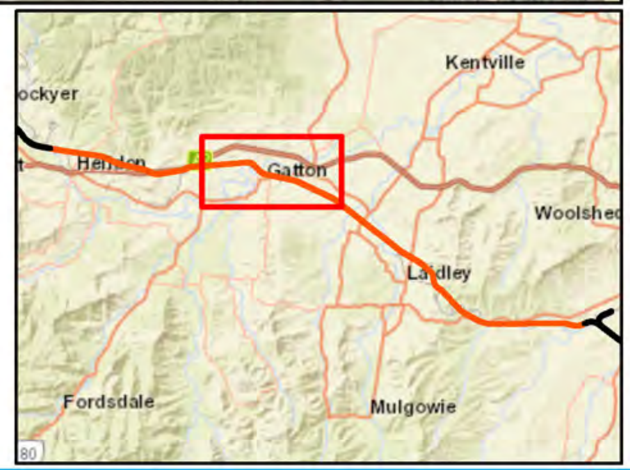
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Local drainage culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

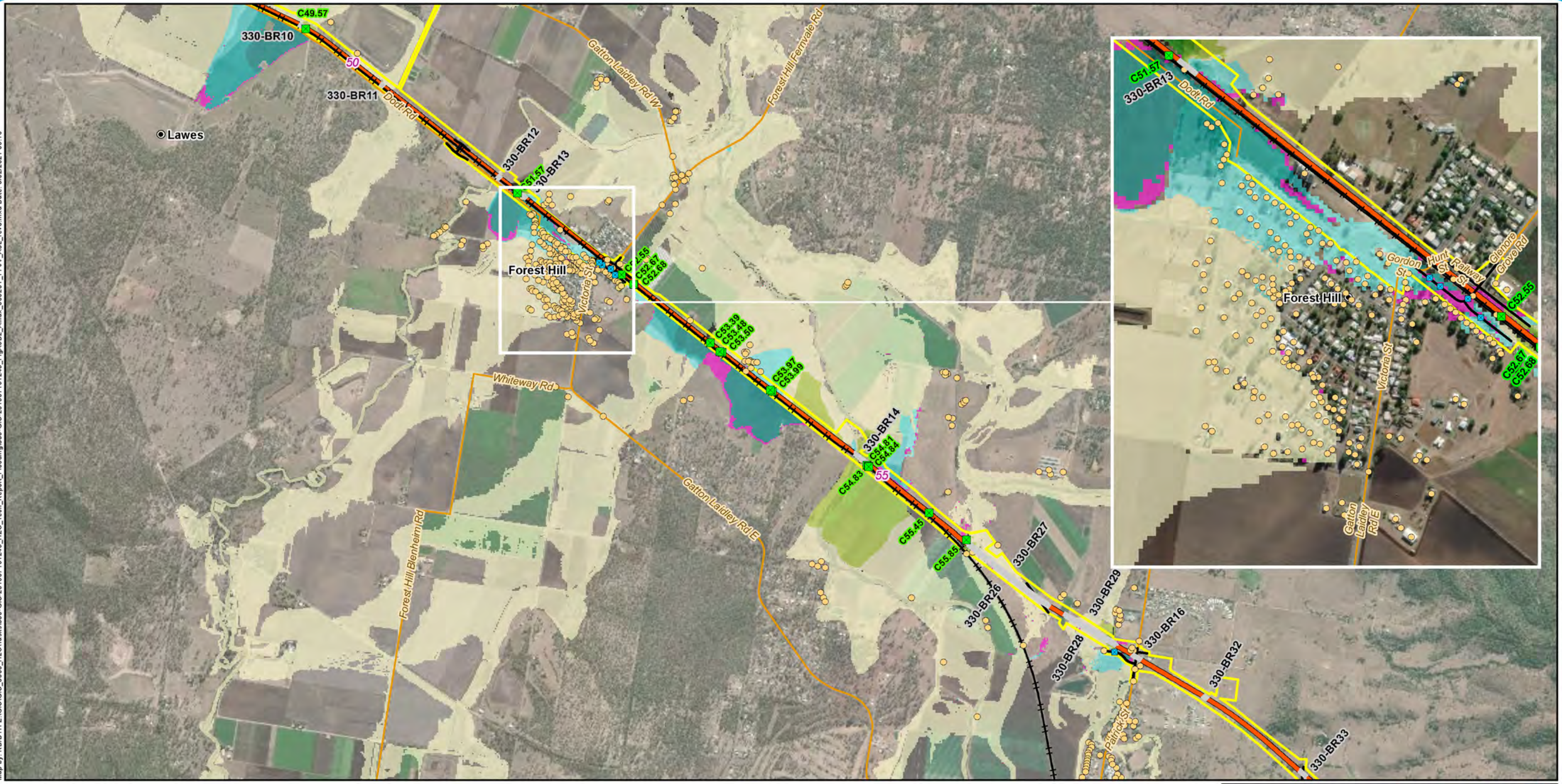
Future Freight
Integrating Community, Environment and Engineering

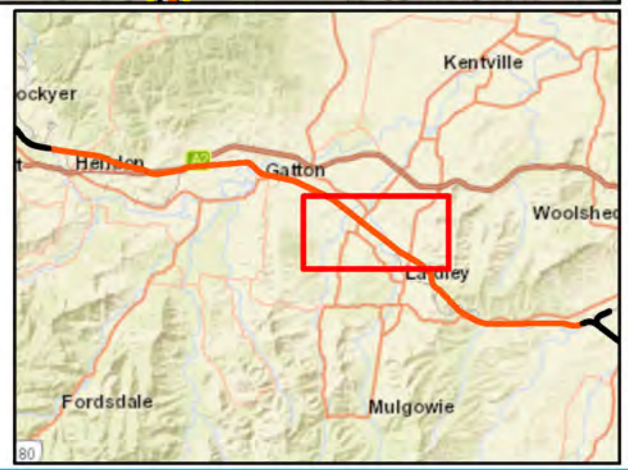
Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-5B-1: 5% AEP Event - Developed Case - Afflux: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community





Legend

- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

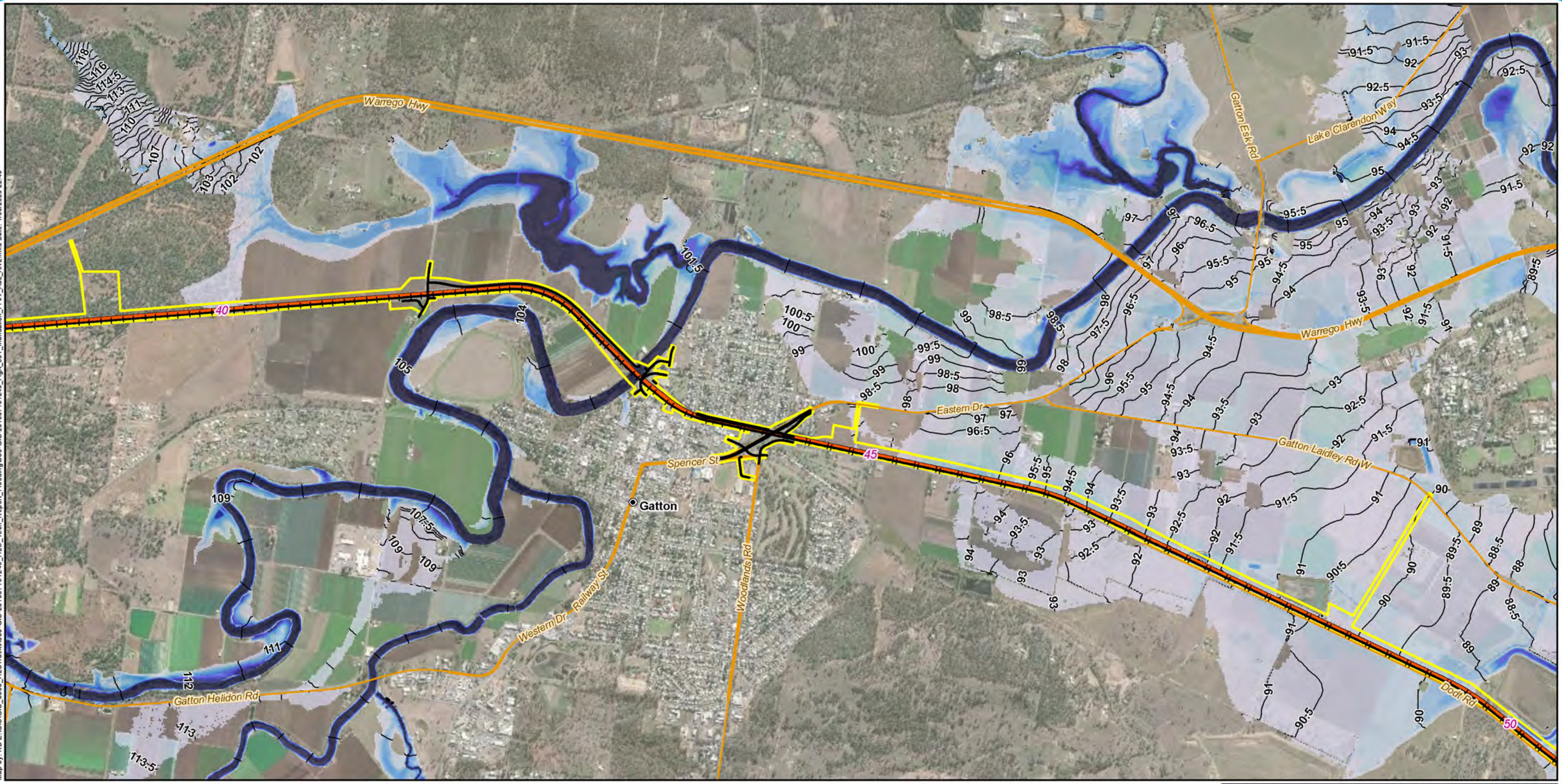
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-5B-2: 5% AEP Event - Developed Case - Afflux: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



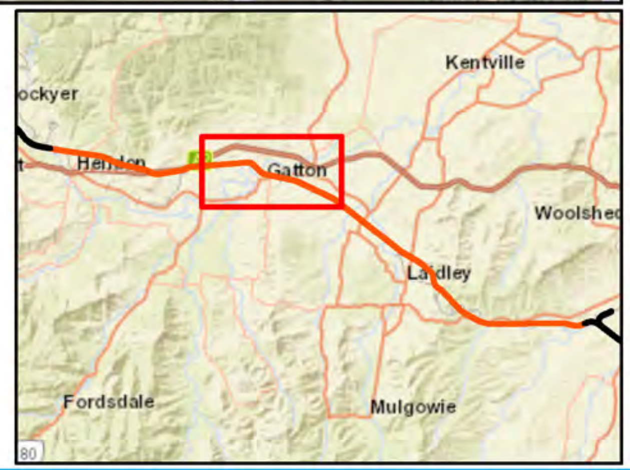
Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715245_H2C_Tech_Report_Flooding\330-GIS-20190715245_FigX_50Y_Inundation_FFJV_A3L_rev2.mxd Date: 1/06/2020 22:49

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0



A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

Future Freight
Integrating Community, Environment and Engineering

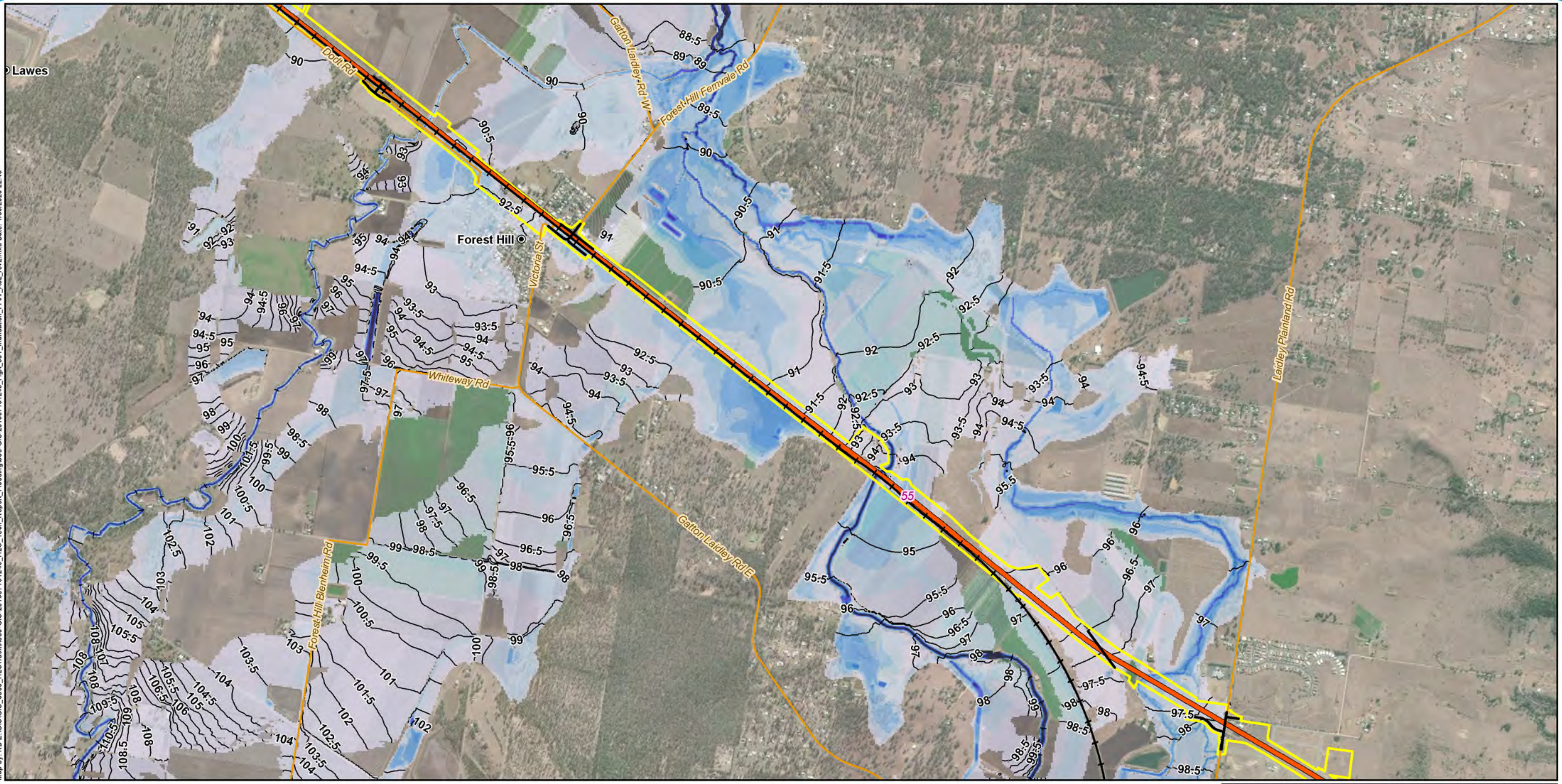
Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-6A-1: 2% AEP Event - Existing Case - Inundation Extent: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715\1245_H2C_Tech_Report_Flooding\330-GIS-20190715\1245_FigX_50Y_Inundation_FFJV_A3L_rev2.mxd Date: 1/06/2020 22:49

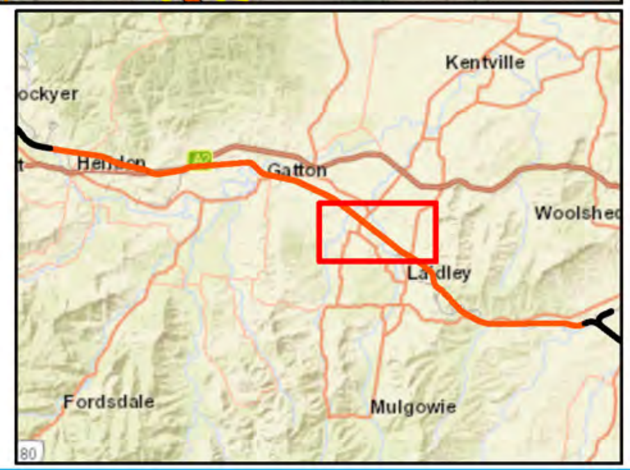


Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0



A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

Future Freight
Integrating Community, Environment and Engineering

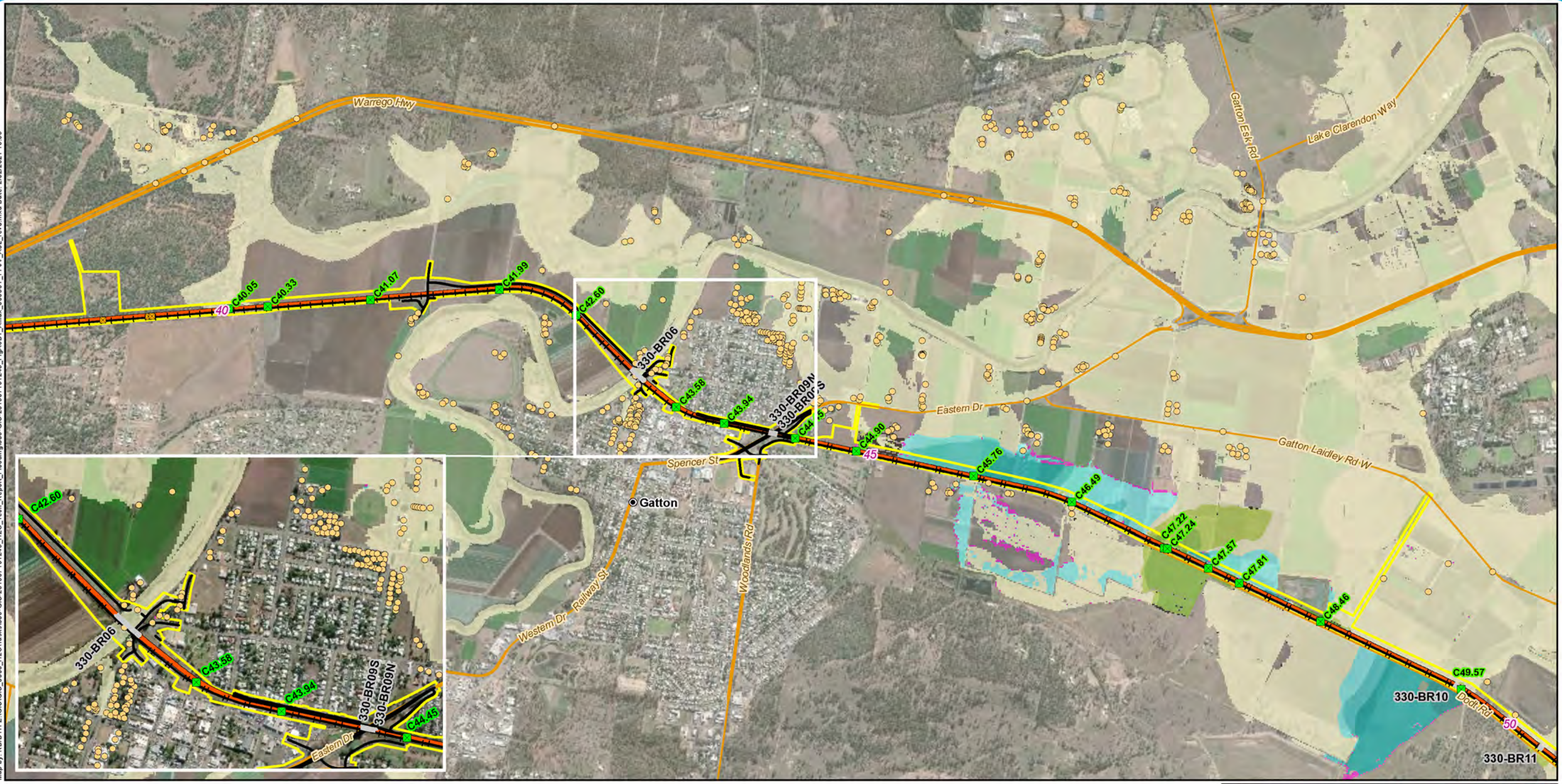
Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-6A-2: 2% AEP Event - Existing Case - Inundation Extent: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigA6B1_Afflux_00050Y_FFJV_A3L_rev3.mxd Date: 2/02/2021 19:59



Legend

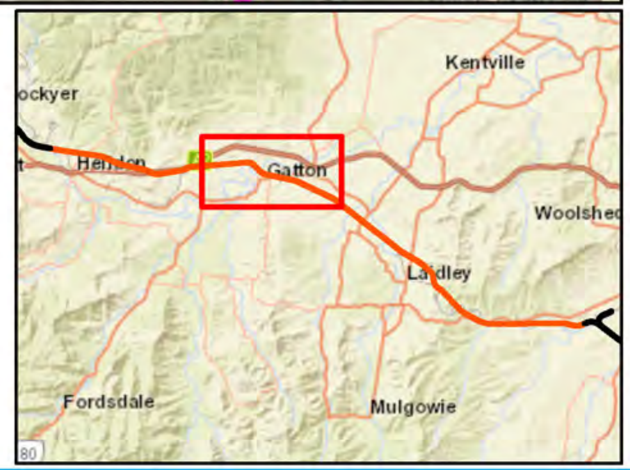
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Local drainage culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

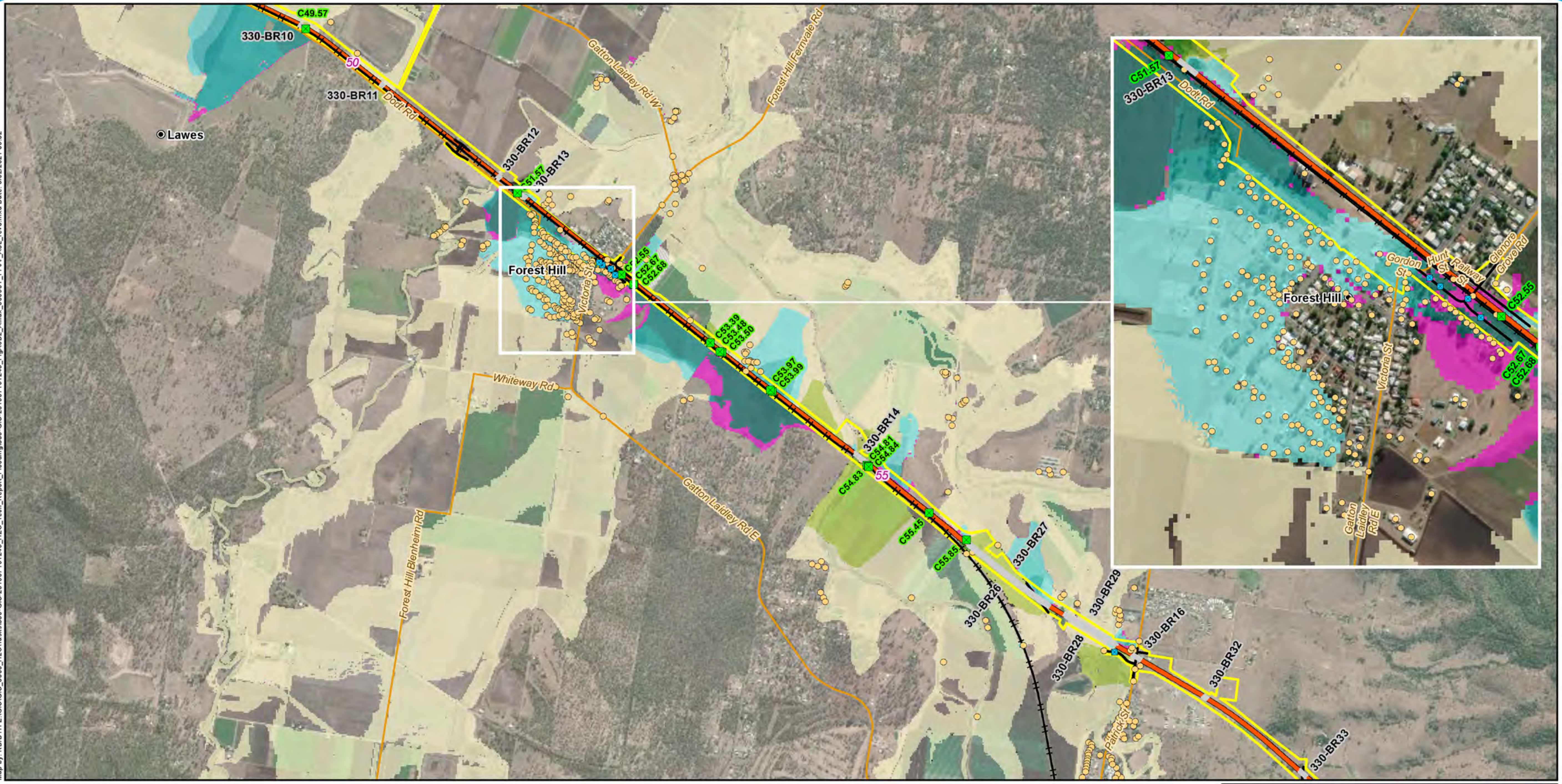
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-6B-1: 2% AEP Event - Developed Case - Afflux: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigA6B2_Afflux_00050Y_FFJV_A3L_rev3.mxd Date: 3/02/2021 09:32

Legend

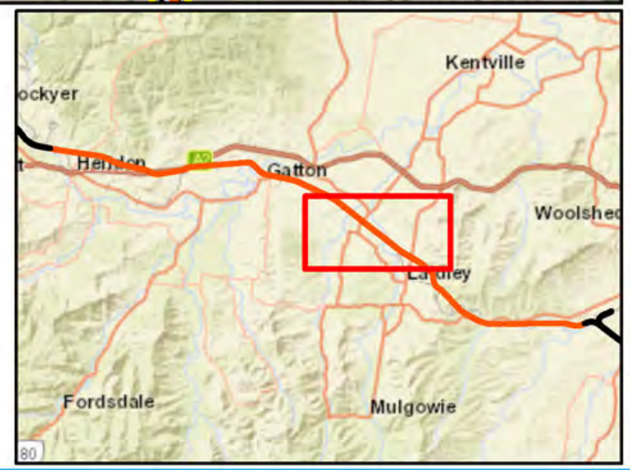
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

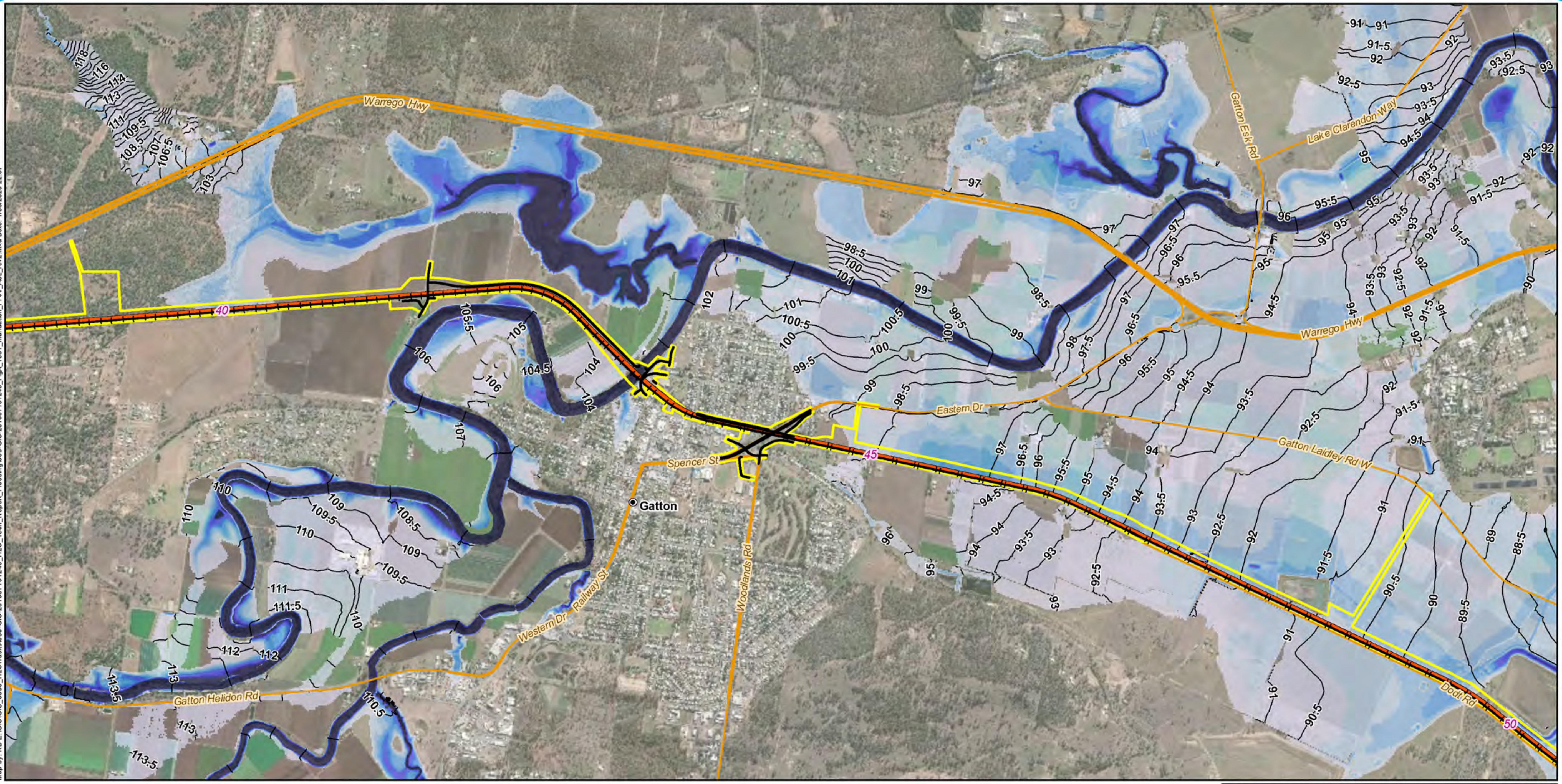
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-6B-2: 2% AEP Event - Developed Case - Afflux: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



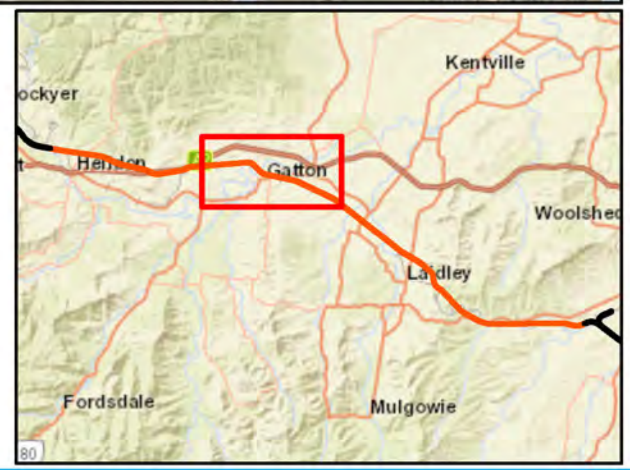
Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_100Y_Inundation_FFJV_A3L_rev2.mxd Date: 1/06/2020 22:57

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0



A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

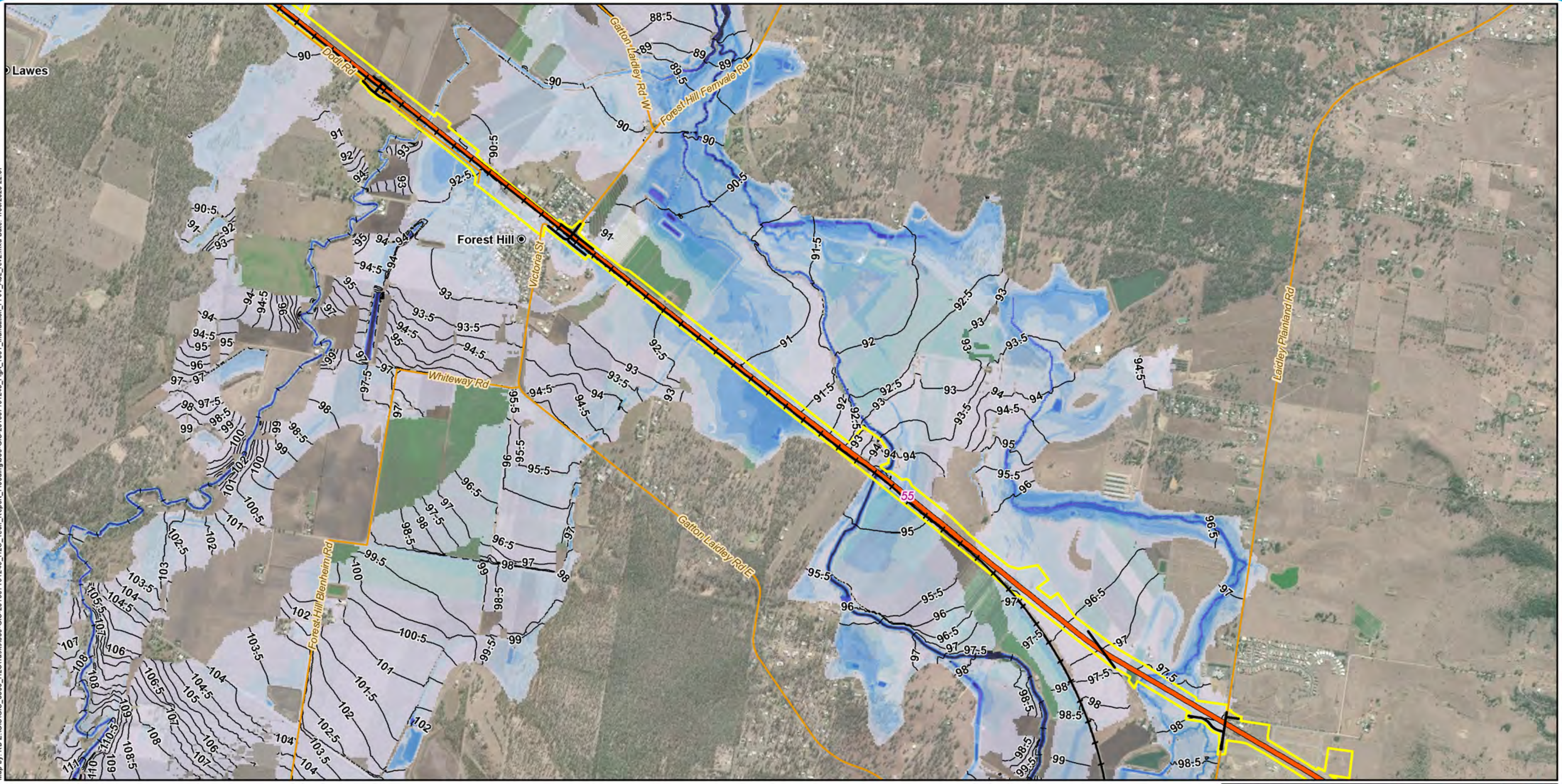
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

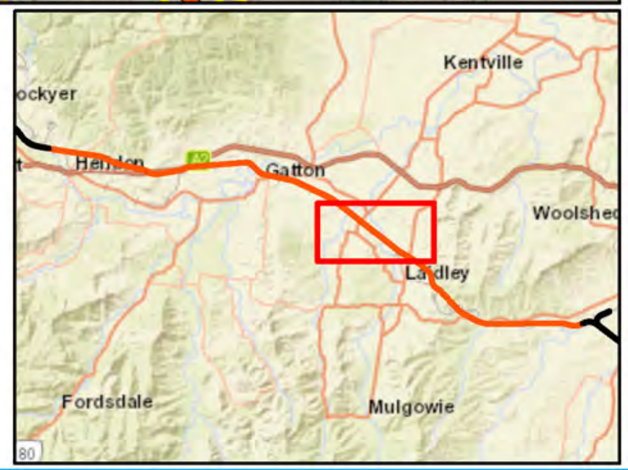
Helidon to Calvert

Figure A-7A-1: 1% AEP Event - Existing Case - Inundation Extent: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715\1245_H2C_Tech_Report_Flooding\330-GIS-20190715\1245_FigX_100Y_Inundation_FFJV_A3L_rev2.mxd Date: 1/06/2020 22:57



Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

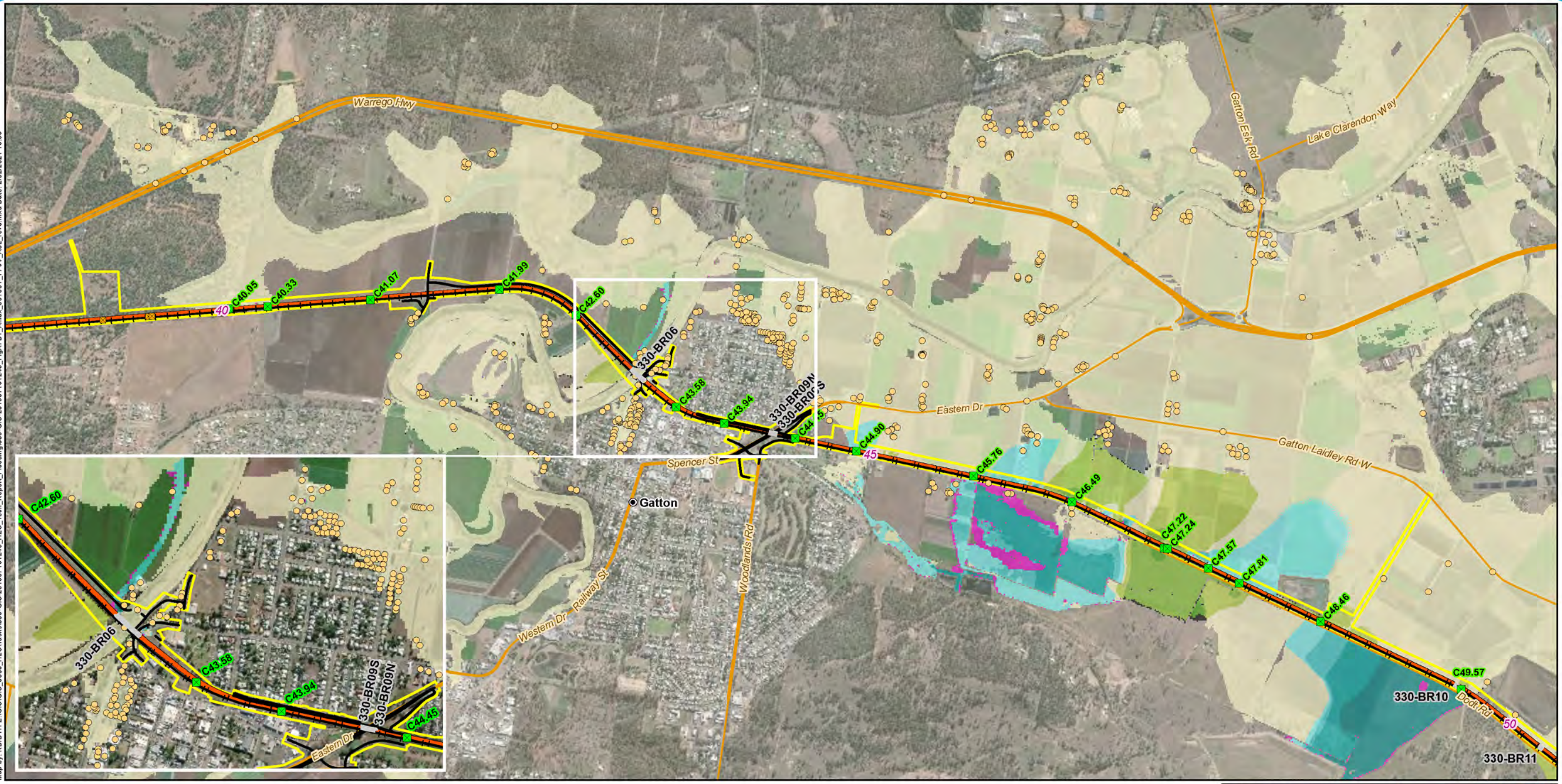
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-7A-2: 1% AEP Event - Existing Case - Inundation Extent: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigA7B1_Afflux_00100Y_FFJV_A3L_rev3.mxd Date: 2/02/2021 19:55

Legend

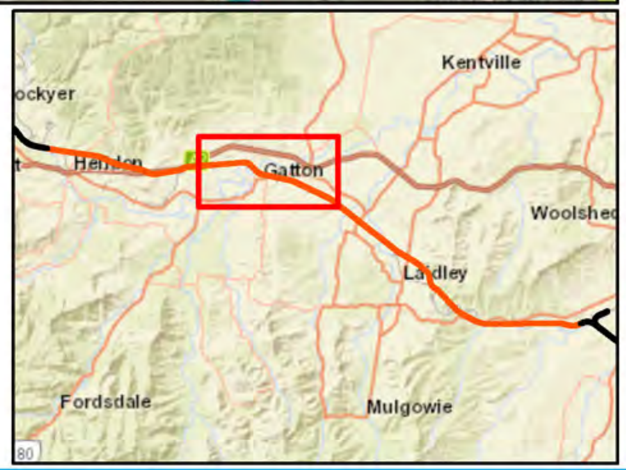
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Local drainage culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:30,000
0 0.2 0.4 0.6 0.8 1km

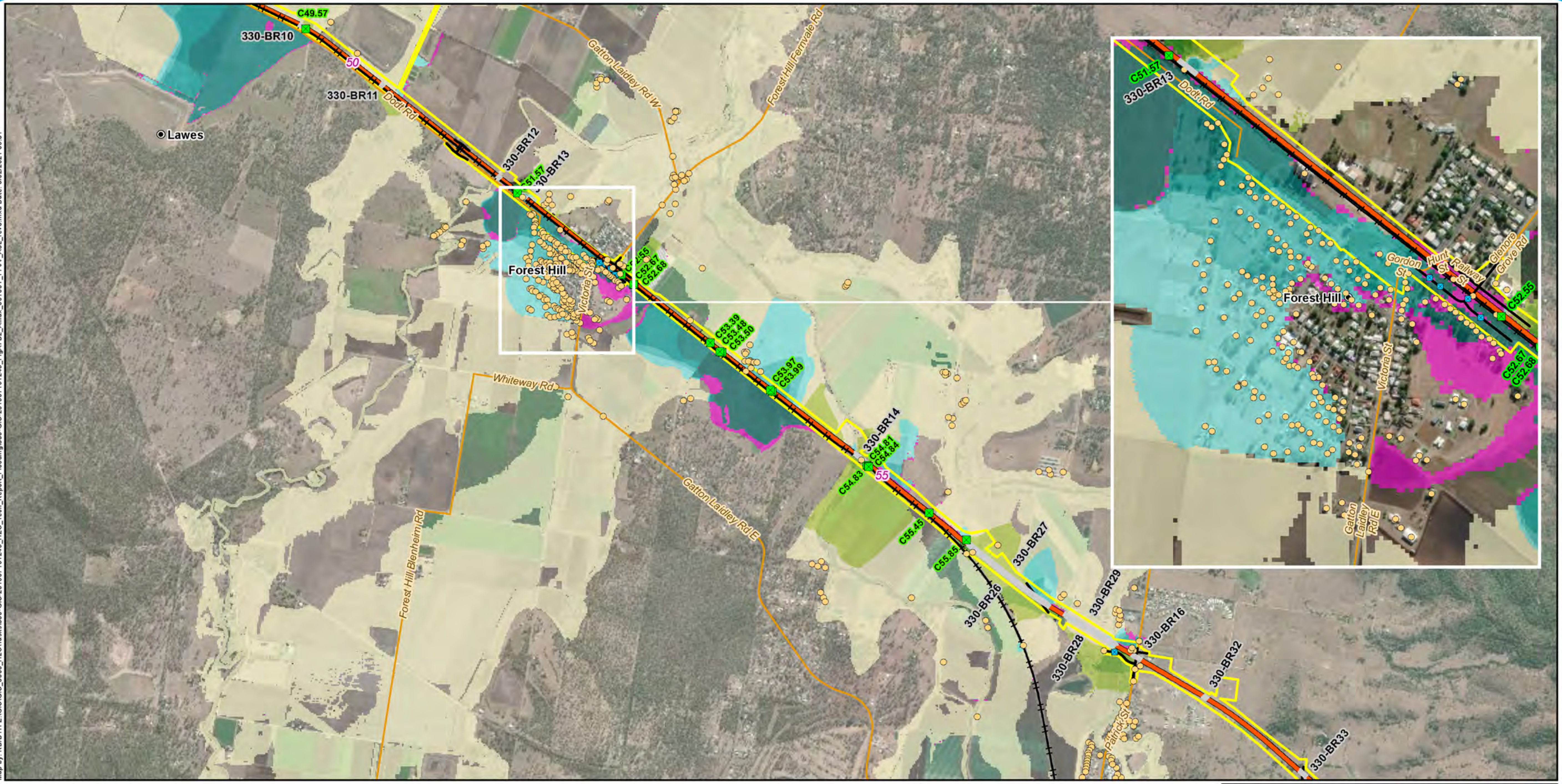
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-7B-1: 1% AEP Event - Developed Case - Afflux: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715 1245_H2C_Tech_Report_Flooding\330-GIS-20190715 1245_FigA7B2_Afflux_00100Y_FFJV_A3L_rev3.mxd Date: 3/02/2021 09:31

Legend

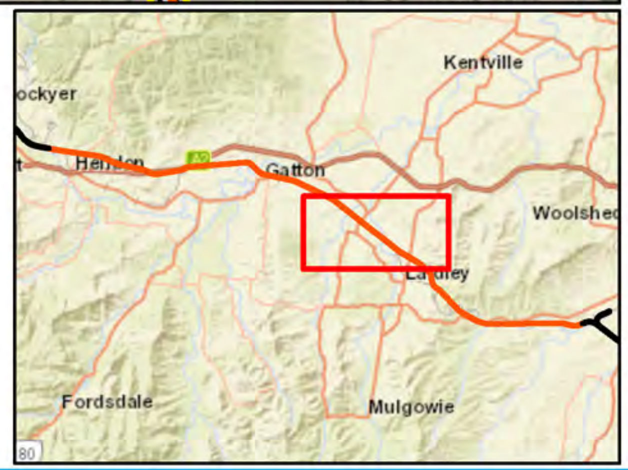
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

Future Freight
Integrating Community, Environment and Engineering

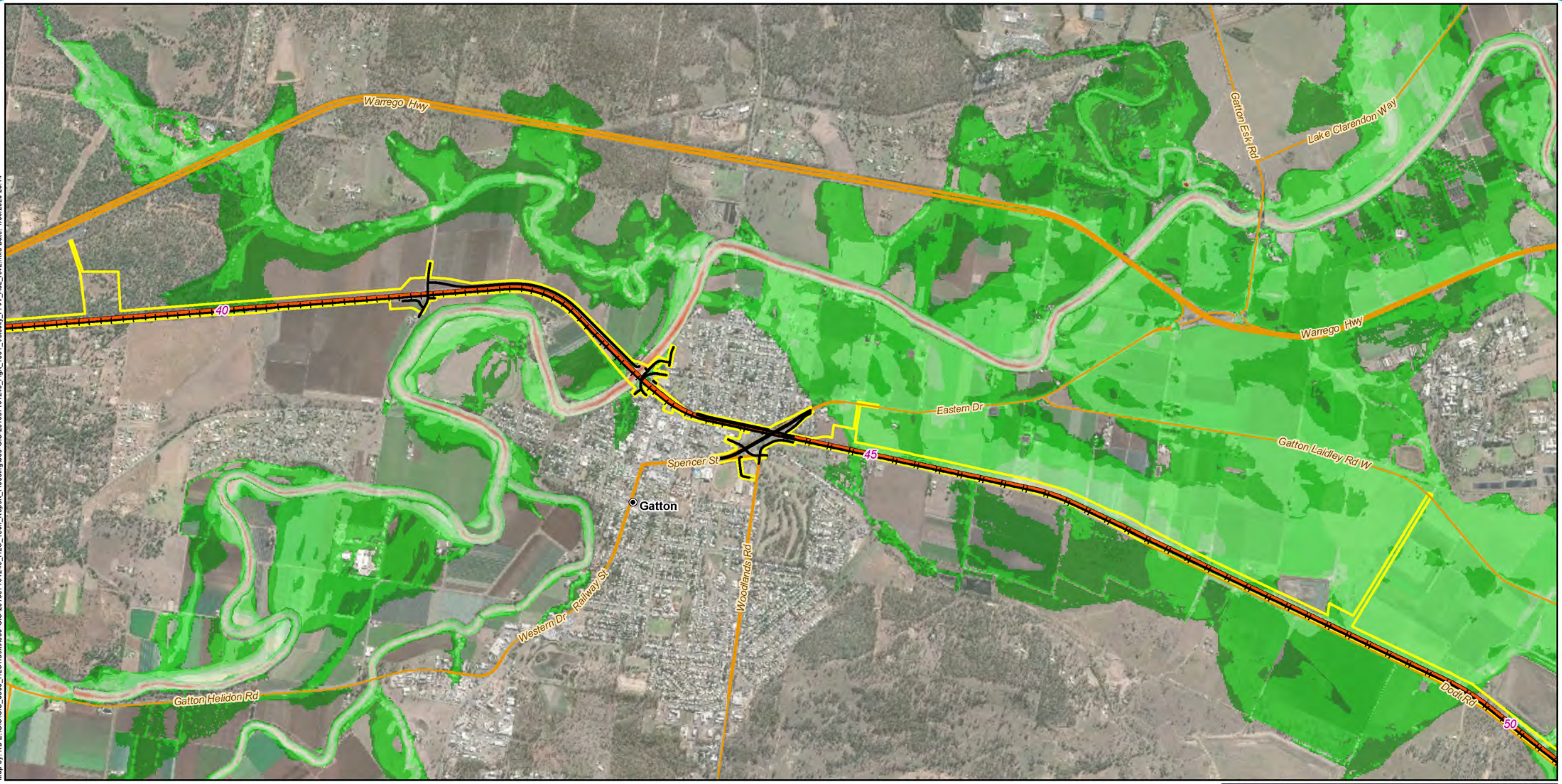
Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

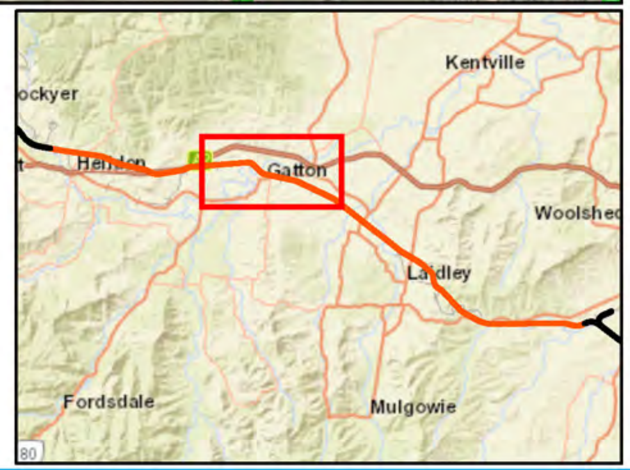
Helidon to Calvert

Figure A-7B-2: 1% AEP Event - Developed Case - Afflux: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_100Y_Velocity_FFJV_A3L_rev2.mxd Date: 1/06/2020 23:14





Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- EIS disturbance footprint

Peak velocity (m/s)

- 0.0
- 0.5
- 1.0
- 1.5
- 2.0
- 2.5
- 3.0
- 3.5
- 4.0
- 4.5
- 5.0

A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

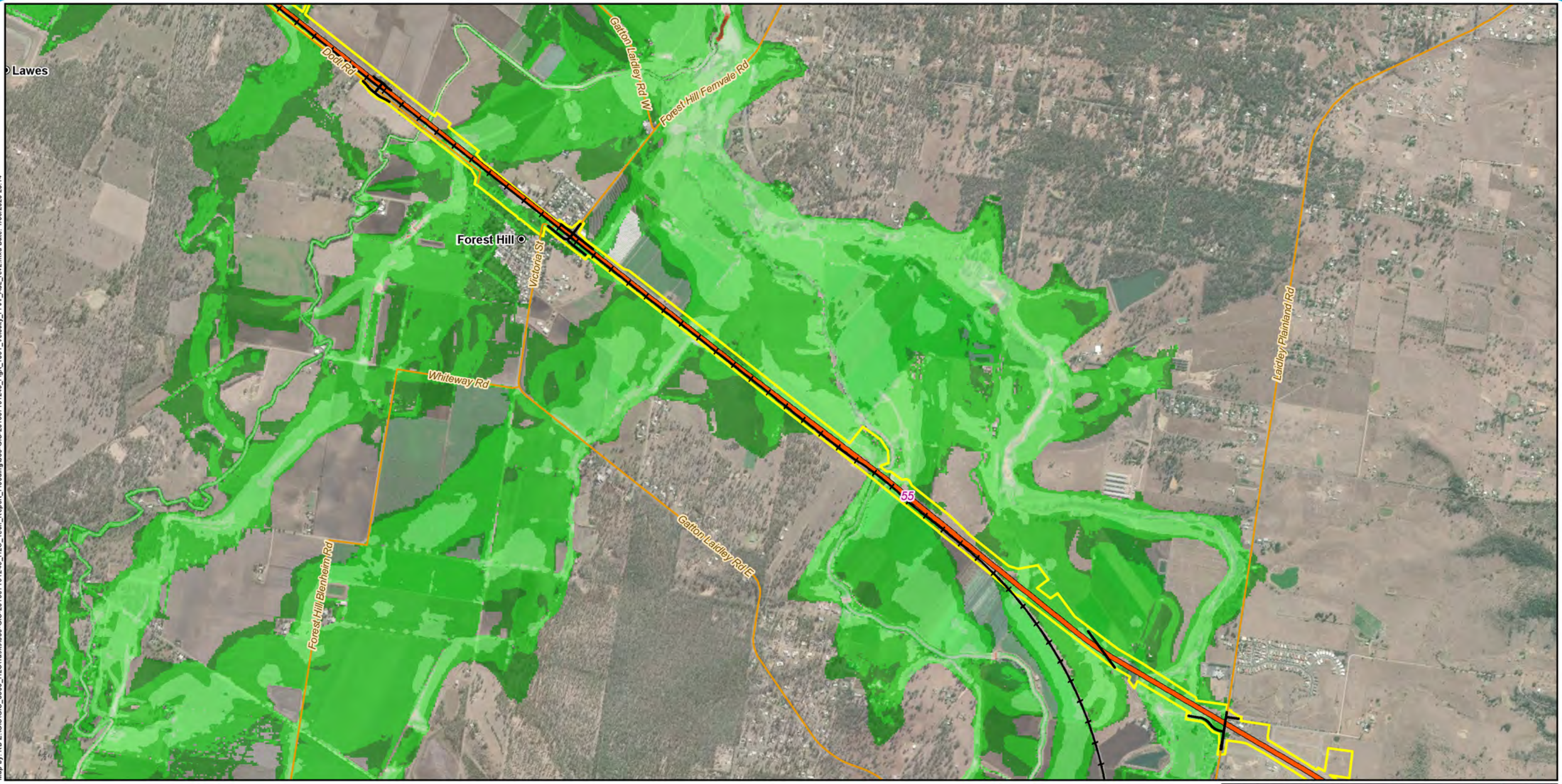
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

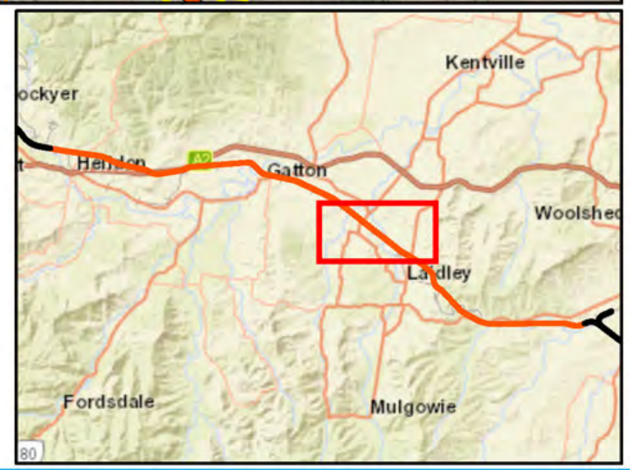
Helidon to Calvert

Figure A-7C-1: 1% AEP Event - Developed Case - Velocity: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_100Y_Velocity_FFJV_A3L_rev2.mxd Date: 1/06/2020 23:14



Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint

Peak velocity (m/s)

- 0.0
- 0.5
- 1.0
- 1.5
- 2.0
- 2.5
- 3.0
- 3.5
- 4.0
- 4.5
- 5.0

A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

Future Freight
Integrating Community, Environment and Engineering

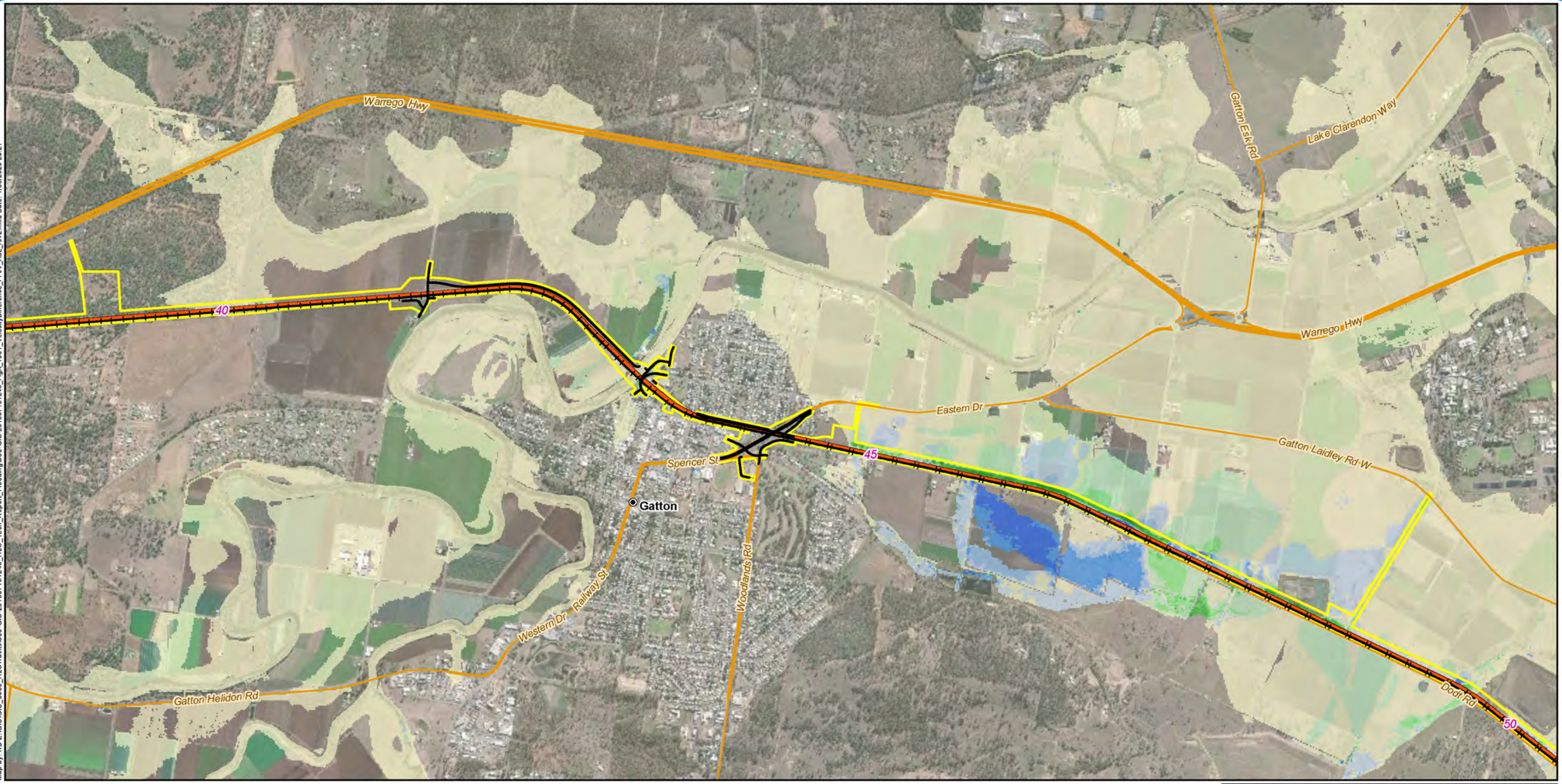
Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

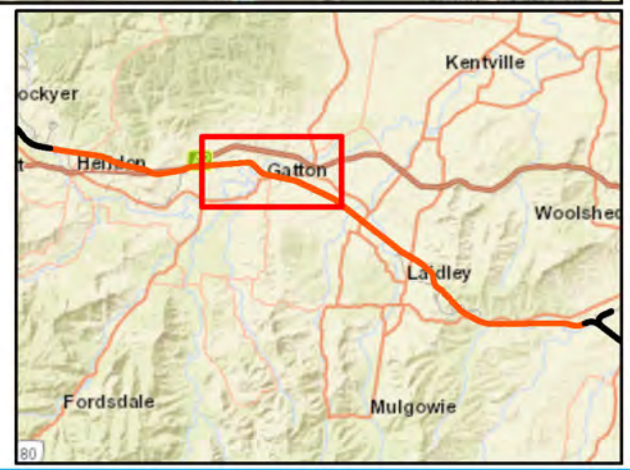
Helidon to Calvert

Figure A-7C-2: 1% AEP Event - Developed Case - Velocity: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_100Y_VelocityDifference_FFJV_A3L_rev2.mxd Date: 1/06/2020 23:21





Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- EIS disturbance footprint

Change in peak velocity (m/s)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

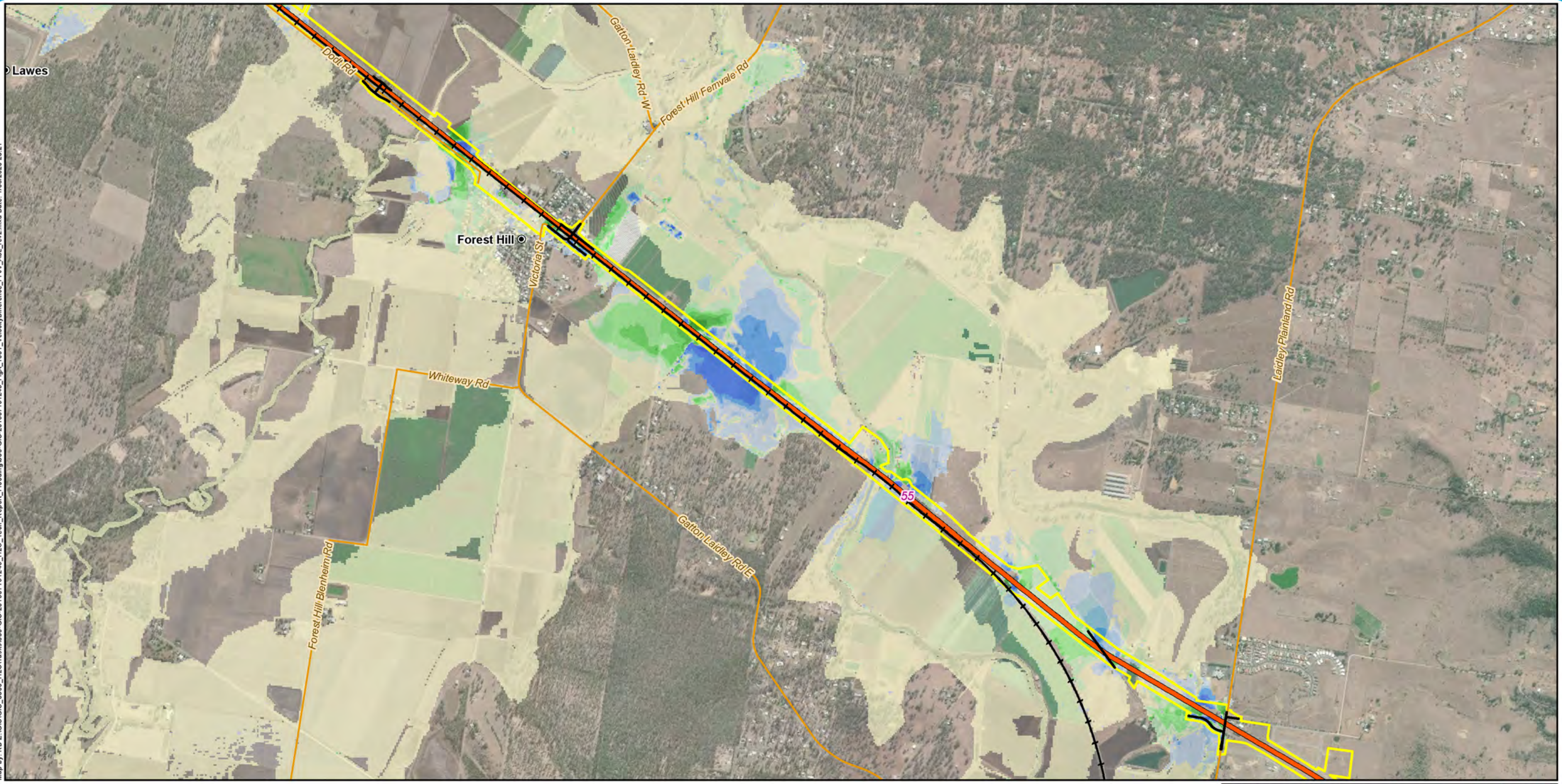
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

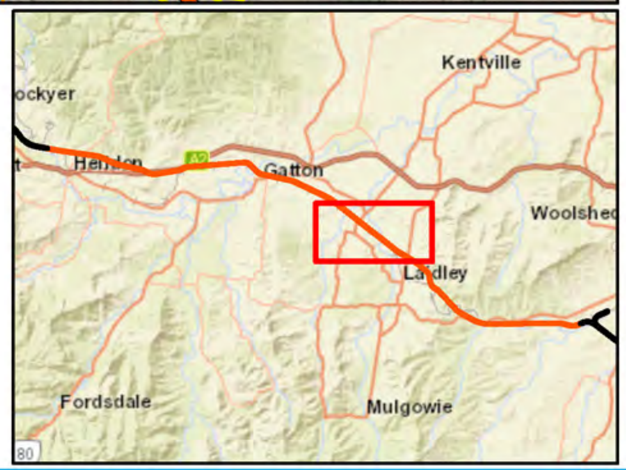
Helidon to Calvert

Figure A-7D-1: 1% AEP Event - Developed Case - Change in peak velocities: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_100Y_VelocityDifference_FFJV_A3L_rev2.mxd Date: 1/06/2020 23:21



Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint

Change in peak velocity (m/s)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

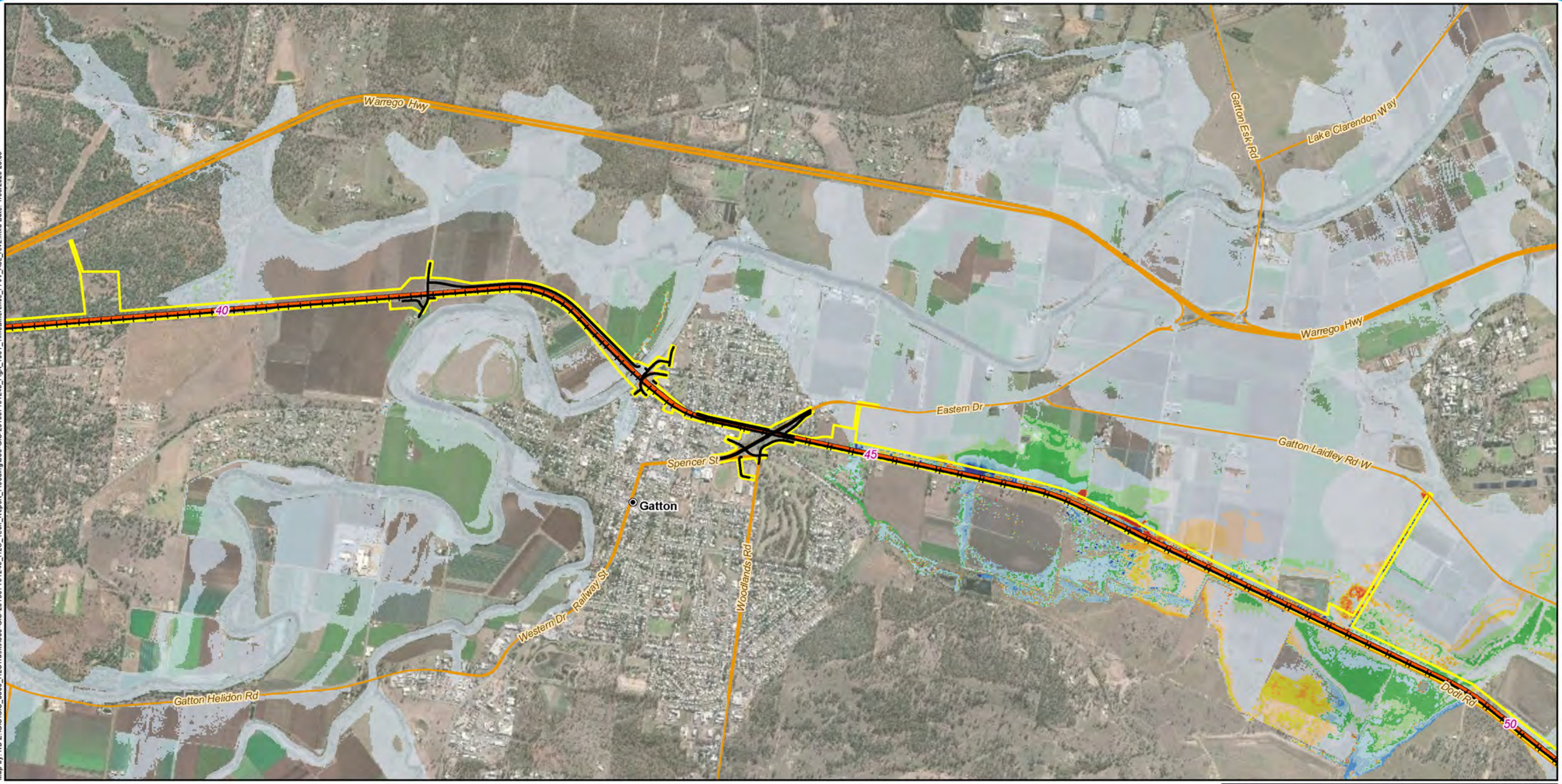
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-7D-2: 1% AEP Event - Developed Case - Change in peak velocities: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



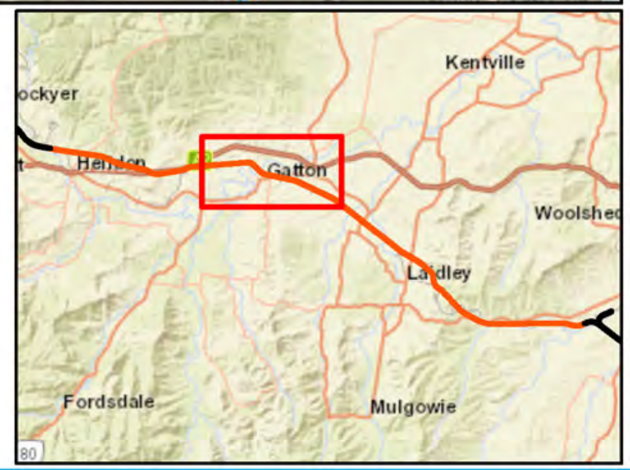
Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_100Y_TimeDifference_FFJV_A3L_rev2.mxd Date: 1/06/2020 23:05

Legend

5 Chainage (km)
Localities
Existing rail
H2C project alignment
Road design
Major roads
Minor roads
EIS disturbance footprint

Difference in Time of Submergence

Over 10 hour decrease
Up to 10 hour decrease
Up to 5 hour decrease
Up to 2 hour decrease
Up to 1 hour decrease
Up to 0.5 hour decrease
Within 15 minutes
Up to 0.5 hour increase
Up to 1 hour increase
Up to 2 hour increase
Up to 5 hour increase
Up to 10 hour increase
Over 10 hour increase



A3 scale: 1:30,000
0 0.2 0.4 0.6 0.8 1km

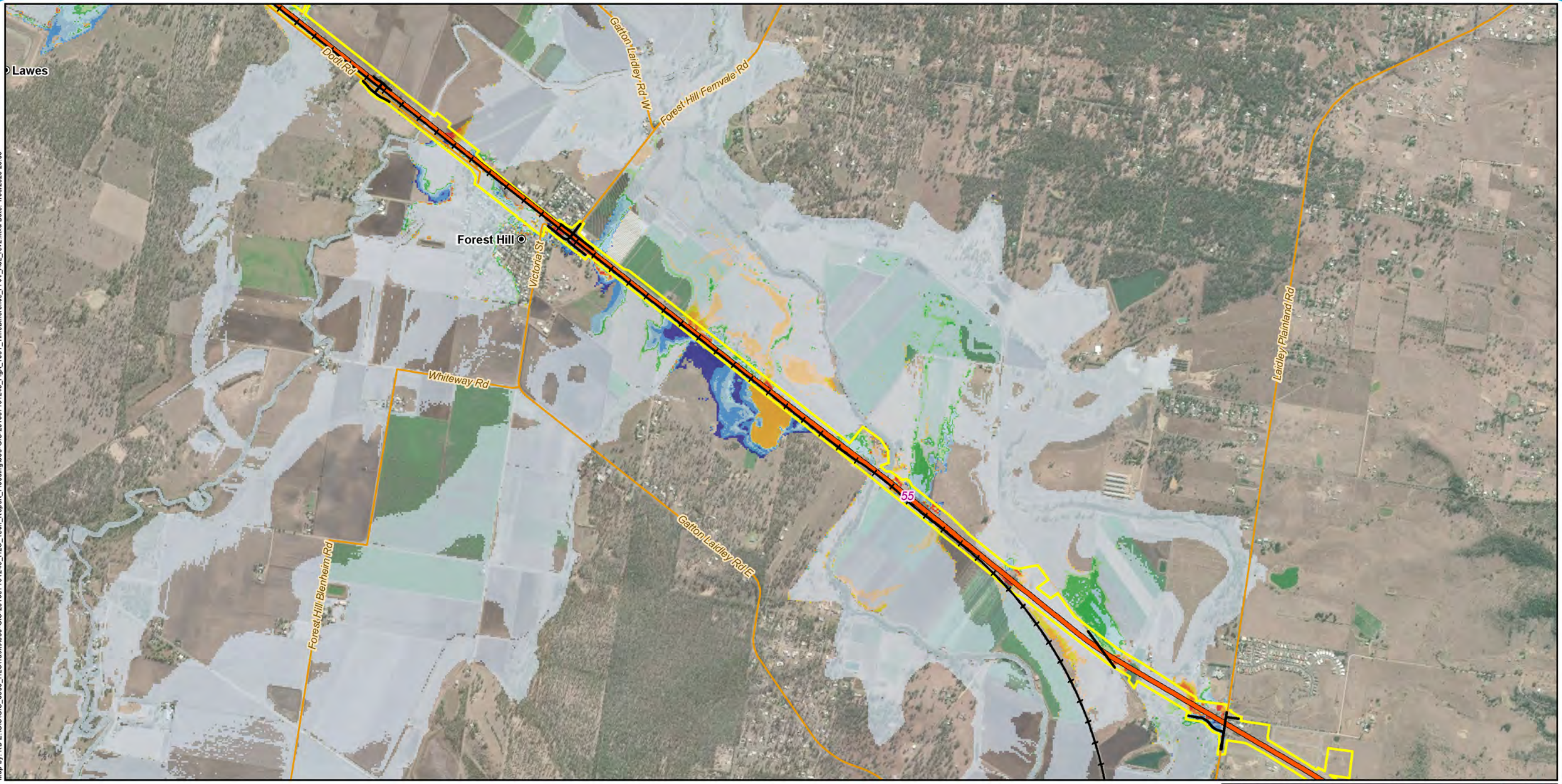
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-7E-1: 1% AEP Event - Developed Case - Difference in Time of Submergence: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



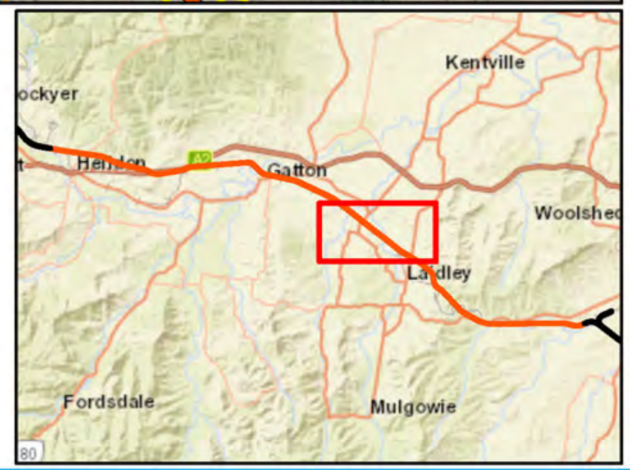
Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_100Y_TimeDifference_FFJV_A3L_rev2.mxd Date: 1/06/2020 23:05

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint

Difference in Time of Submergence

- Over 10 hour decrease
- Up to 10 hour decrease
- Up to 5 hour decrease
- Up to 2 hour decrease
- Up to 1 hour decrease
- Up to 0.5 hour decrease
- Within 15 minutes
- Up to 0.5 hour increase
- Up to 1 hour increase
- Up to 2 hour increase
- Up to 5 hour increase
- Up to 10 hour increase
- Over 10 hour increase



A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

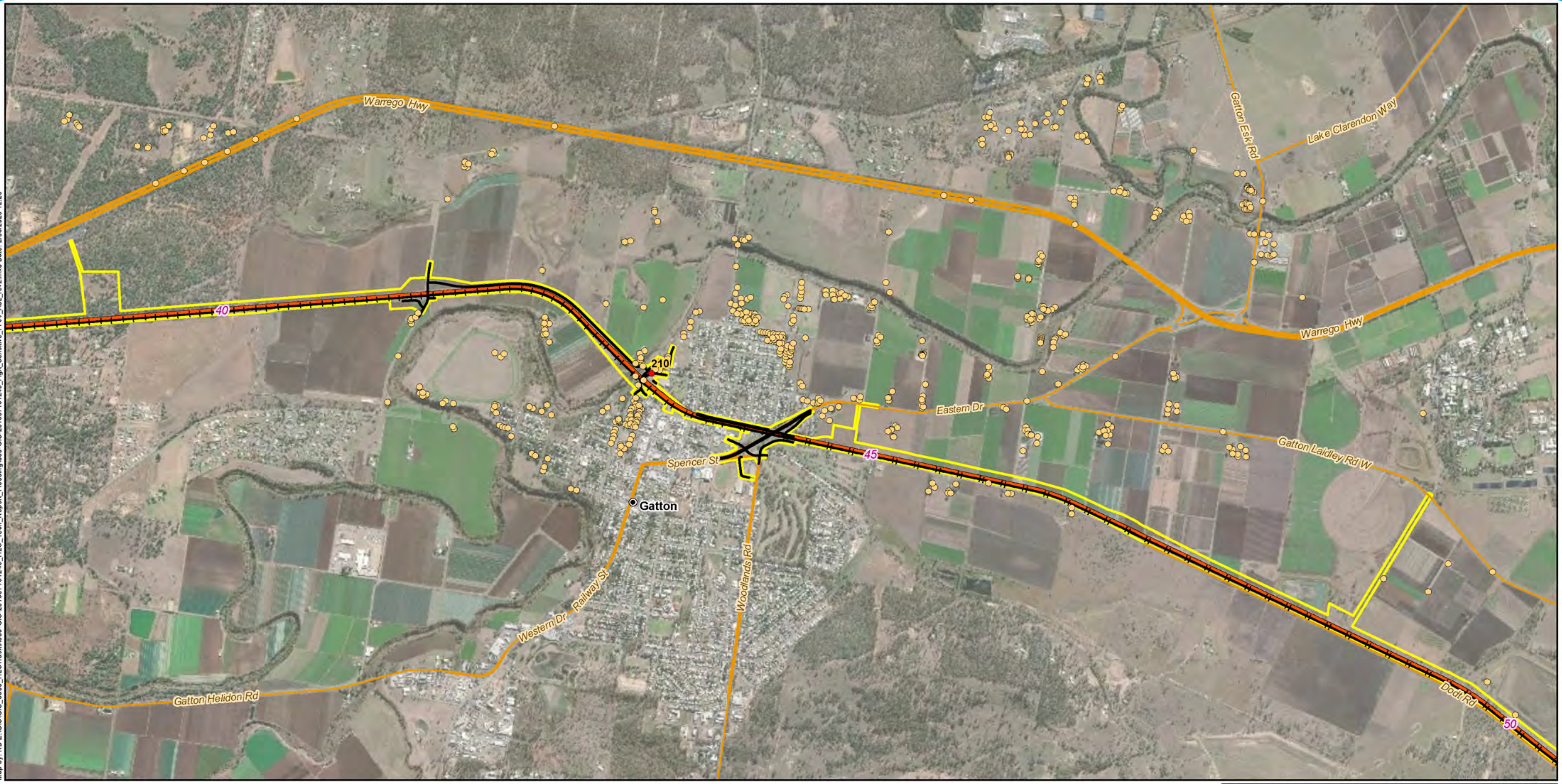
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

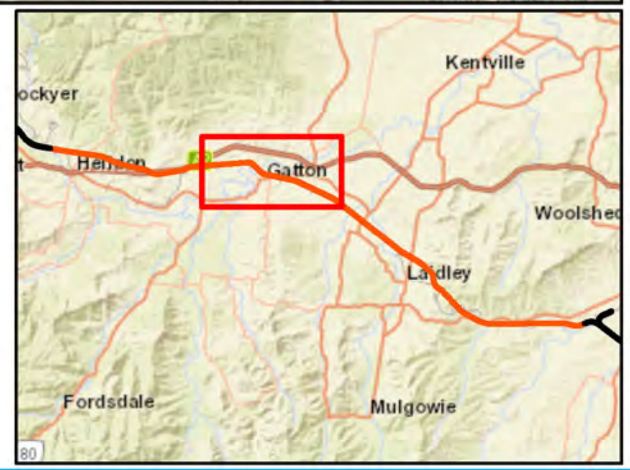
Helidon to Calvert

Figure A-7E-2: 1% AEP Event - Developed Case - Difference in Time of Submergence: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_Sensitive_FFJV_A3L_rev2.mxd Date: 2/06/2020 12:26



Legend

Flood sensitive receptors

- 100 Labelled (see note)
- Unlabelled (see note)
- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- EIS disturbance footprint

Note:
Due to the large number of flood sensitive receptors, only those which experience a change in peak water level of greater than 10mm under the 1% AEP event are labelled.

A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

Future Freight
Integrating Community, Environment and Engineering

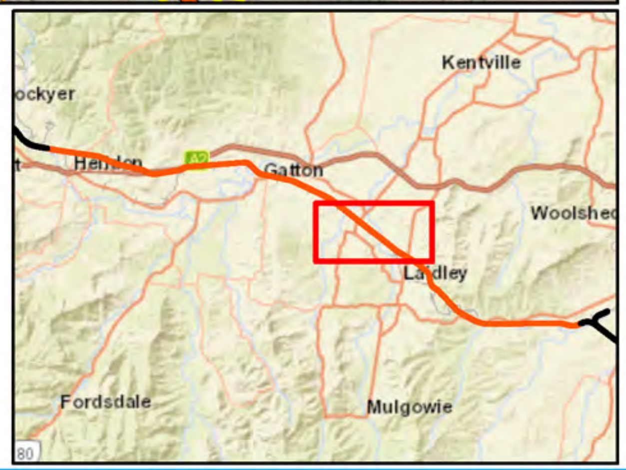
Issue date: 02/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-7F-1: Location of flood sensitive receptors: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715\1245_H2C_Tech_Report_Flooding\330-GIS-20190715\1245_FigX_Sensitive_FFJV_A3L_rev2.mxd Date: 2/06/2020 12:26



Legend

Flood sensitive receptors

- 100 Labelled (see note)
- Unlabelled (see note)
- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint

Note:
Due to the large number of flood sensitive receptors, only those which experience a change in peak water level of greater than 10mm under the 1% AEP event are labelled.

A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

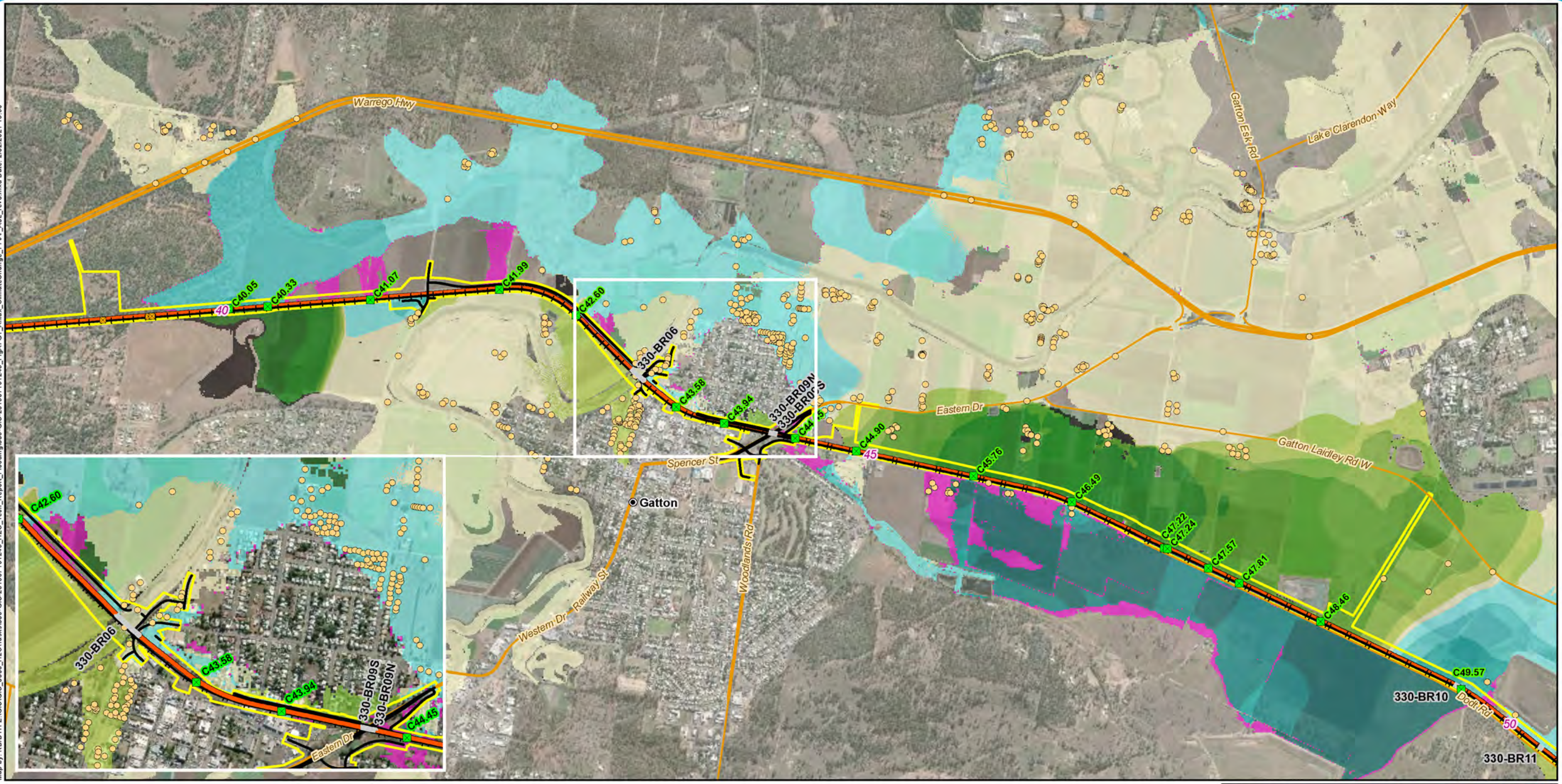
Future Freight
Integrating Community, Environment and Engineering

Issue date: 02/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

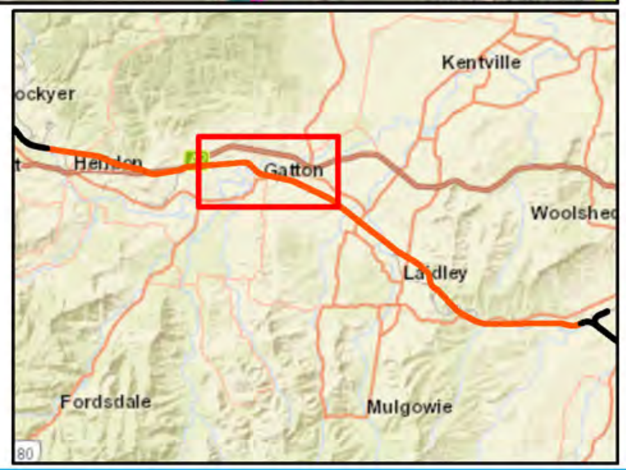
Helidon to Calvert

Figure A-7F-2: Location of flood sensitive receptors: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigA7G1_Afflux_ClimateChange_FFJV_A3L_rev3.mxd Date: 2/02/2021 19:56



Legend

- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Local drainage culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

A3 scale: 1:30,000
0 0.2 0.4 0.6 0.8 1km

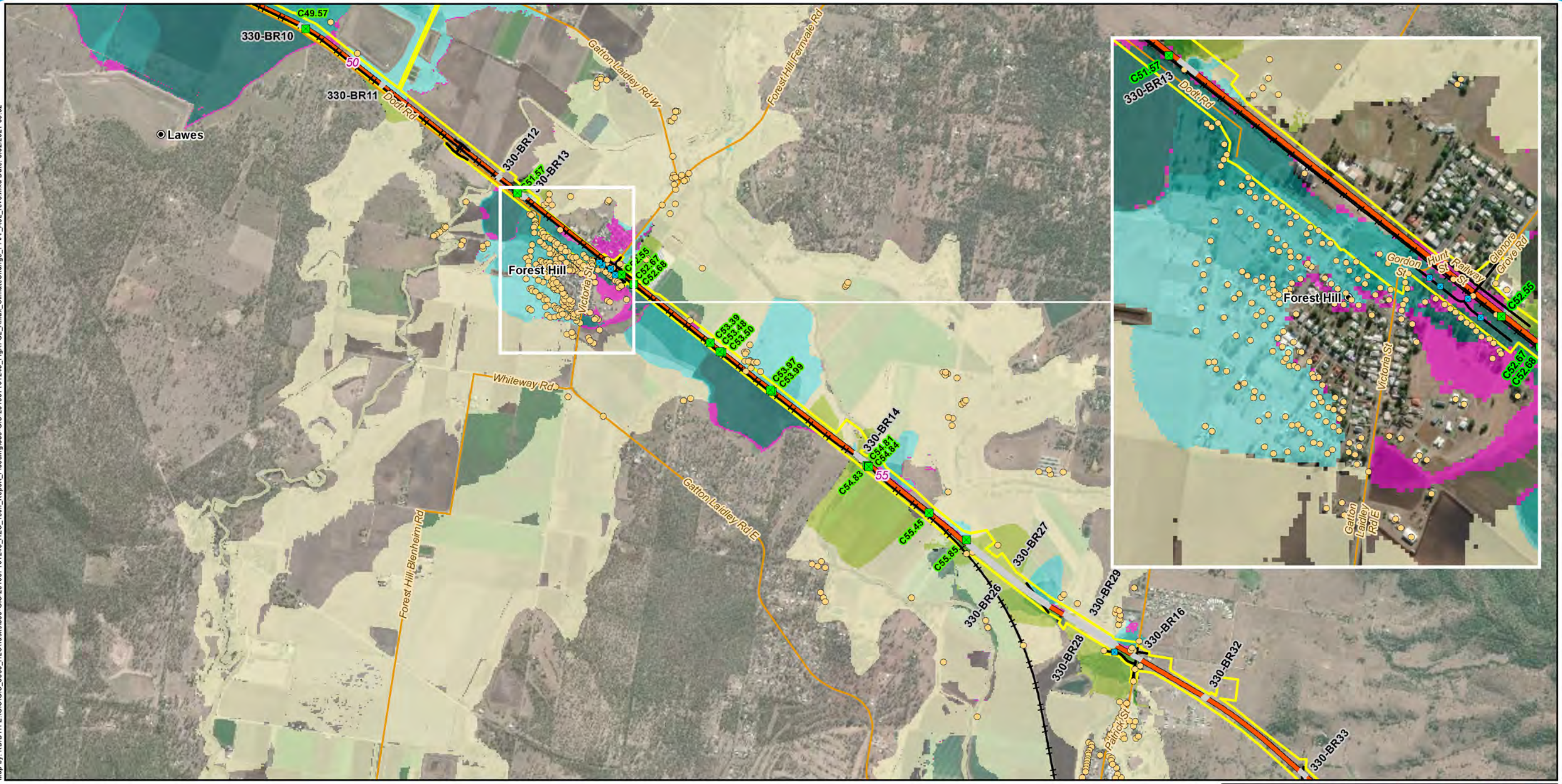
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-7G-1: 1% AEP Event with Climate Change: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigA7G2_Afflux_ClimateChange_FFJV_A3L_rev3.mxd Date: 3/02/2021 09:32

Legend

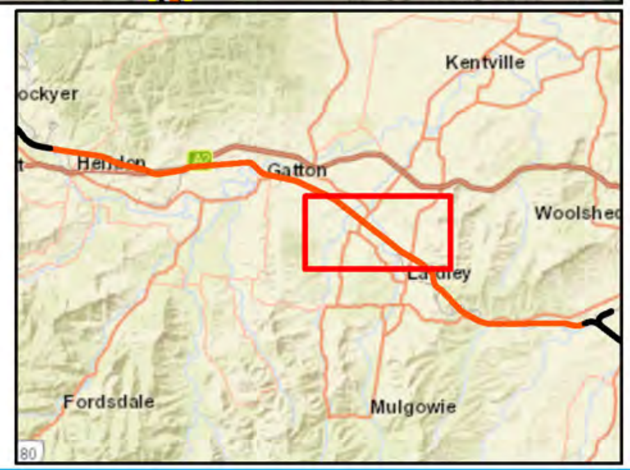
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

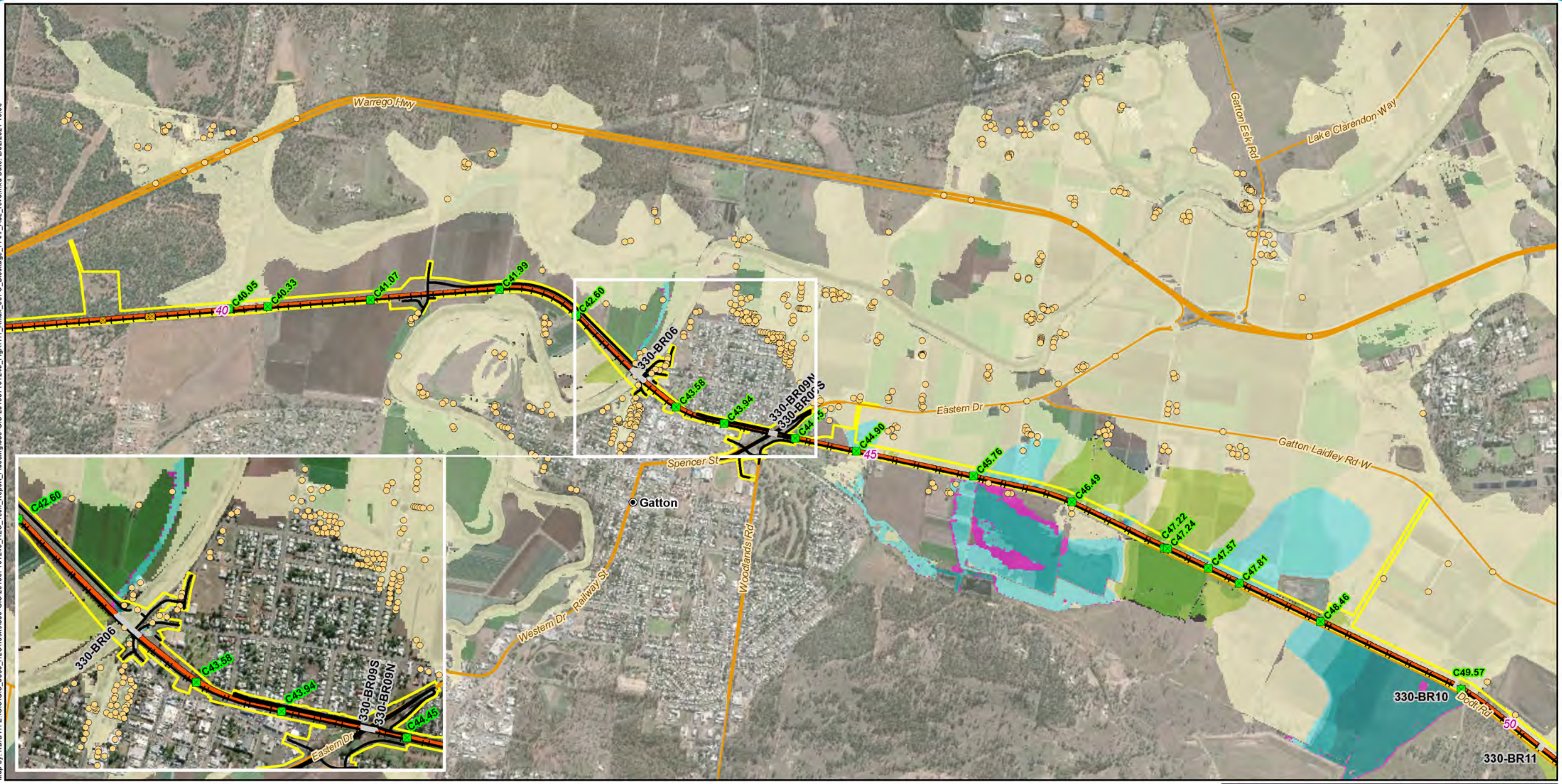
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

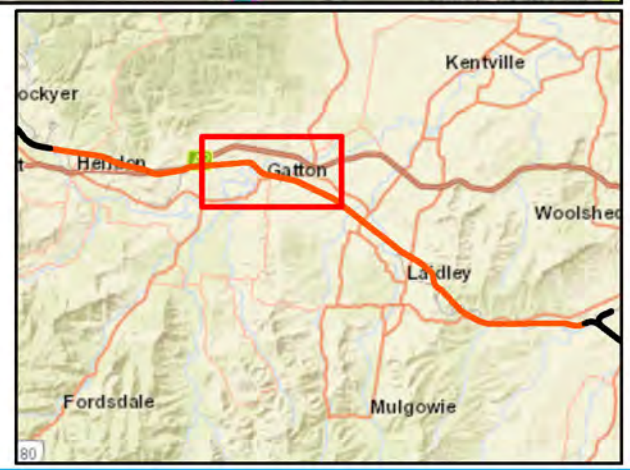
Figure A-7G-2: 1% AEP Event with Climate Change: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Legend

5 Chainage (km)	EIS disturbance footprint	**Change in peak water levels (m)**	-0.01 to 0.01
Flood sensitive receptors	Was Wet Now Dry	< -0.50	0.01 to 0.05
Localities	Was Dry Now Wet	-0.50 to -0.20	0.05 to 0.10
Existing rail	**Drainage Structures**	-0.20 to -0.10	0.10 to 0.20
H2C project alignment	Floodplain culvert	-0.10 to -0.05	0.20 to 0.50
Road design	Local drainage culvert	-0.05 to -0.01	> 0.50
Major roads	Bridges		
Minor roads			



A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

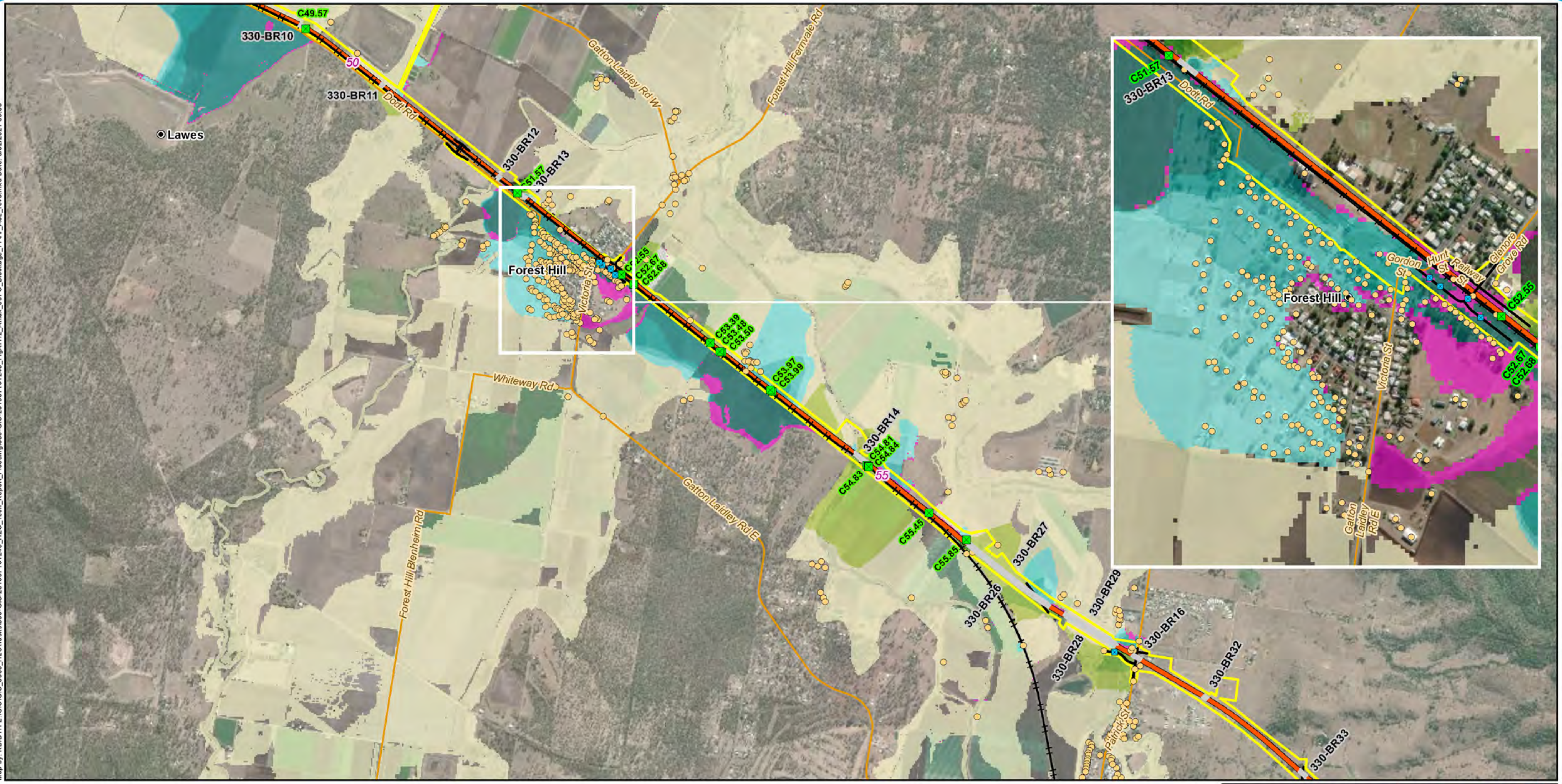
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-7H-1: 1% AEP Event with 0% Blockage on Culverts: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigA7H2_Afflux_00PC_Blockage_FFJV_A3L_rev3.mxd Date: 3/02/2021 09:30

Legend

- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

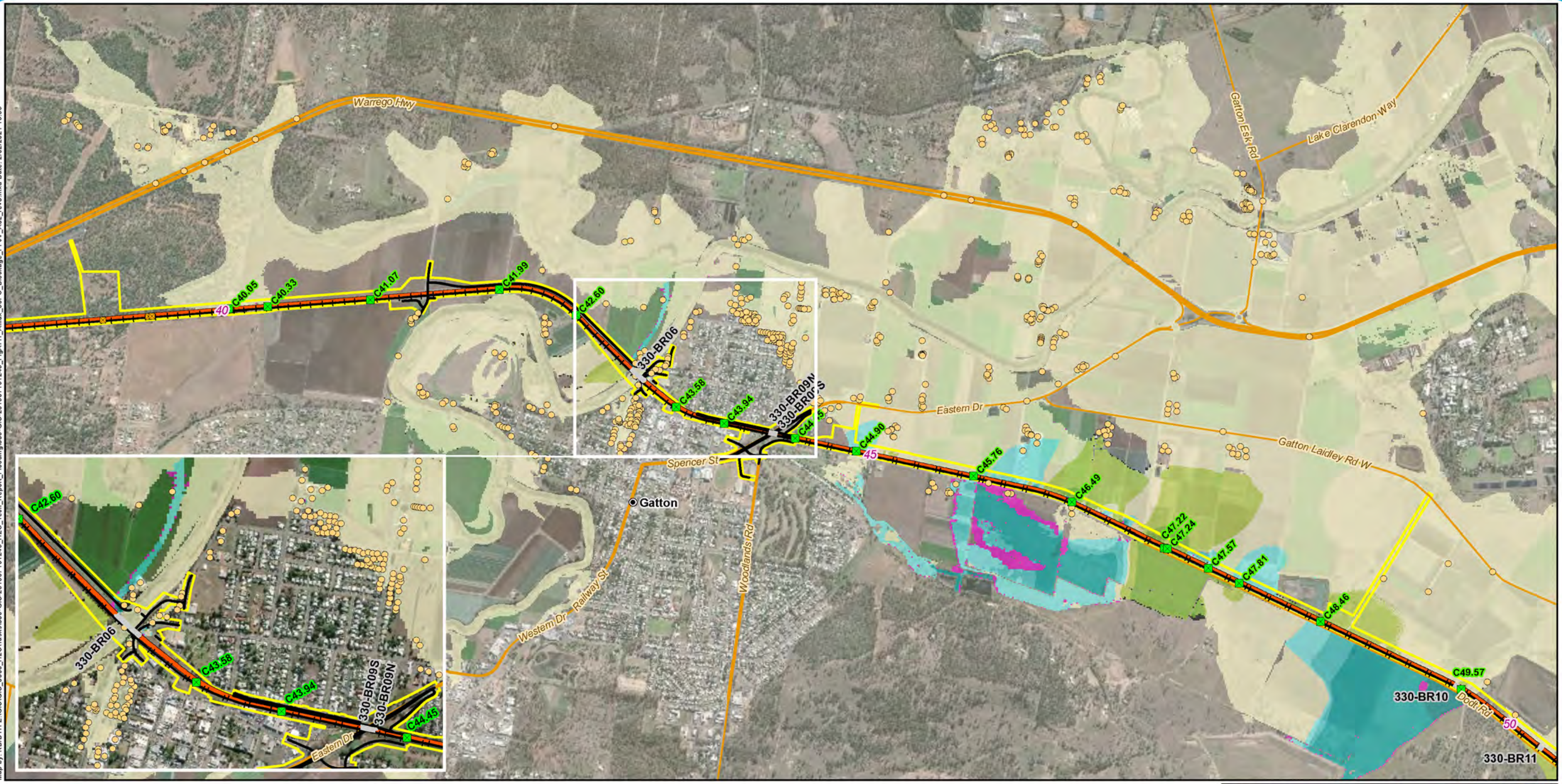
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-7H-2: 1% AEP Event with 0% Blockage on Culverts: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Legend

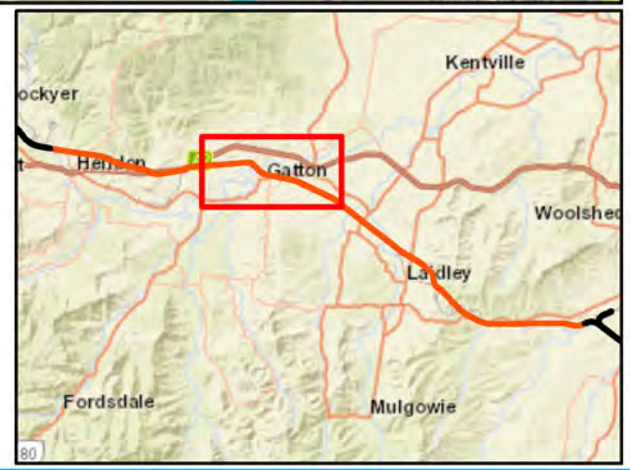
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Local drainage culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

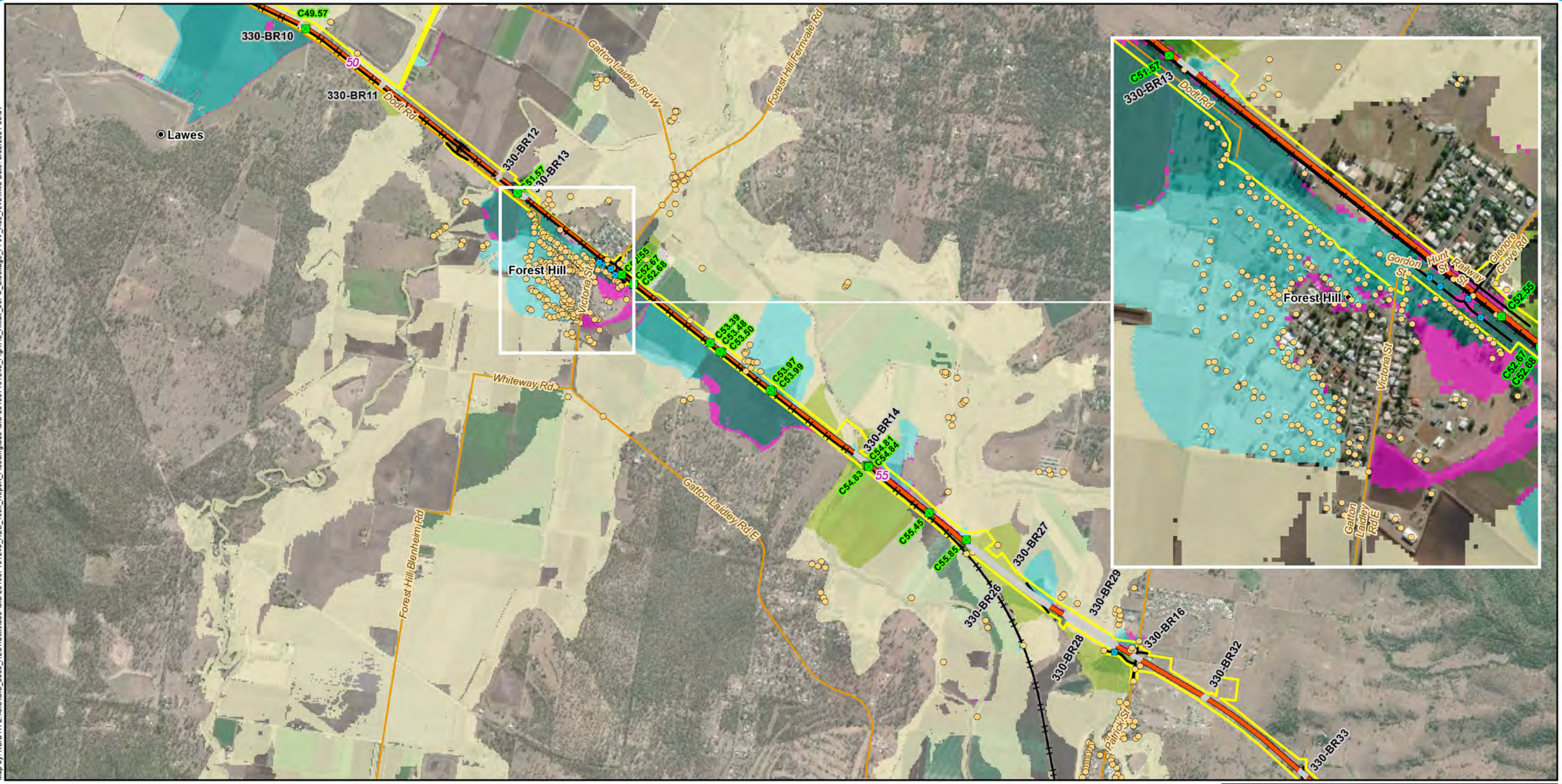
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

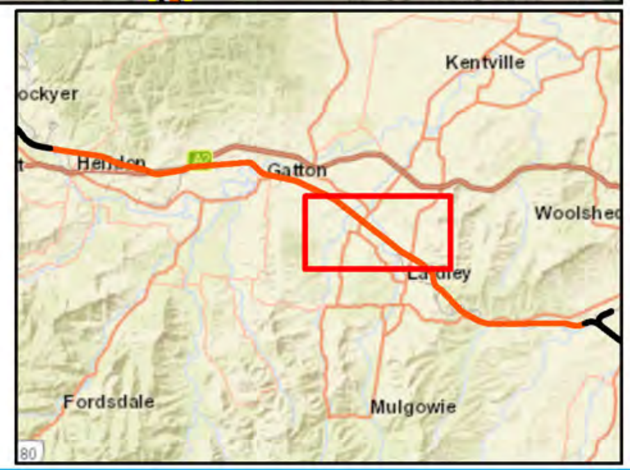
Helidon to Calvert

Figure A-7I-1: 1% AEP Event with 50% Blockage on Culverts: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigA7I2_Afflux_50PC_Blockage_FFJV_A3L_rev3.mxd Date: 3/02/2021 09:31



Legend

- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

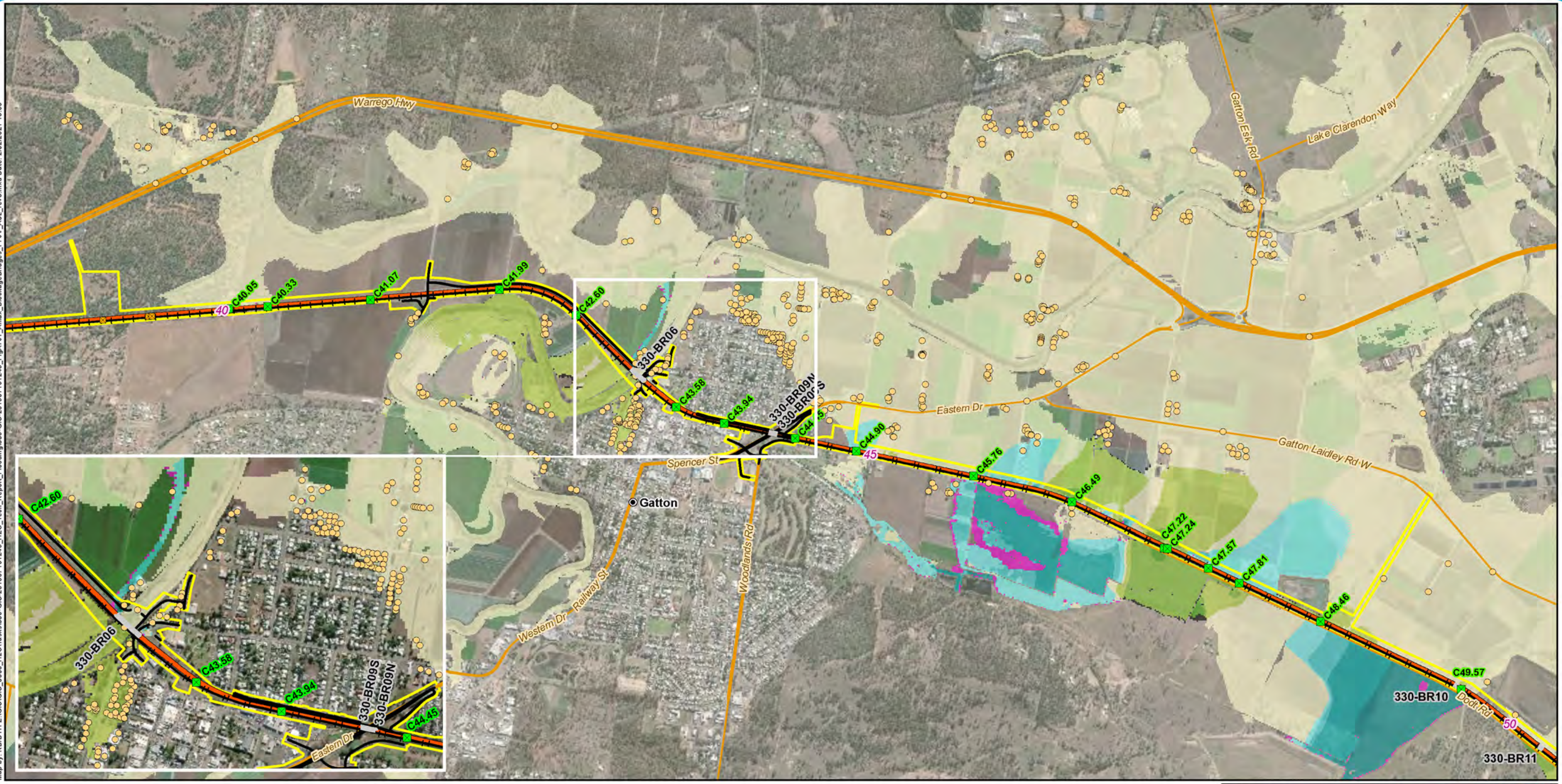
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-7I-2: 1% AEP Event with 50% Blockage on Culverts: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigA7J1_Afflux_BlockageBridges_FFJV_A3L_rev3.mxd Date: 2/02/2021 19:59

Legend

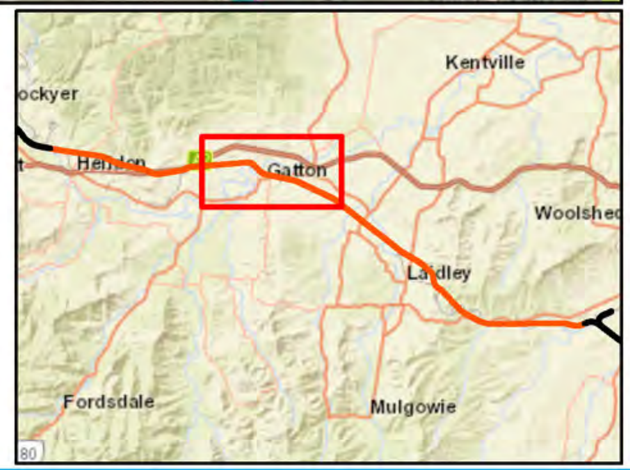
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Local drainage culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

Future Freight
Integrating Community, Environment and Engineering

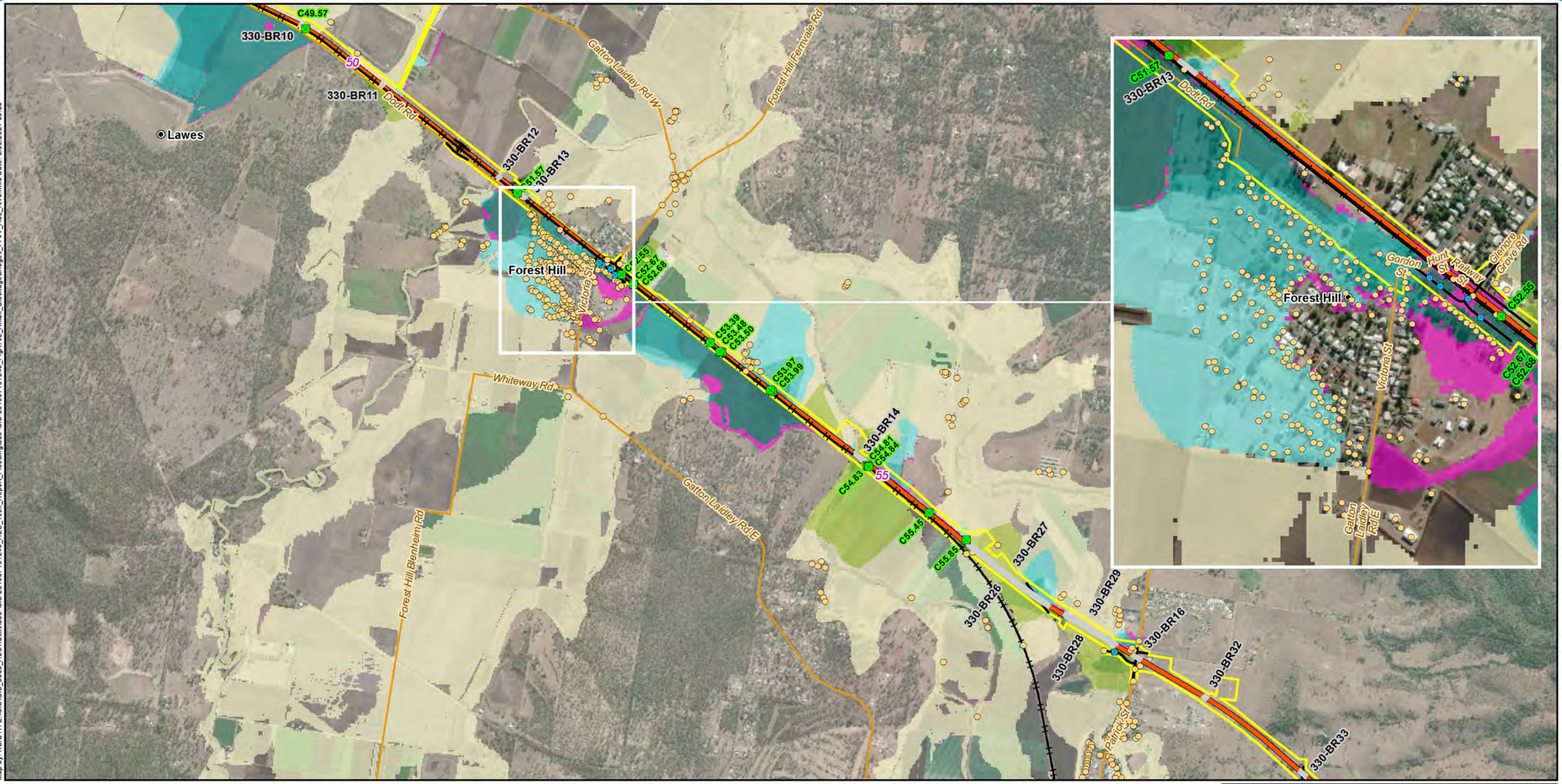
Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-7J-1: 1% AEP Event with Blockage on Bridges: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigA7J2_Afflux_BlockageBridges_FFJV_A3L_rev3.mxd Date: 3/02/2021 09:33



Legend

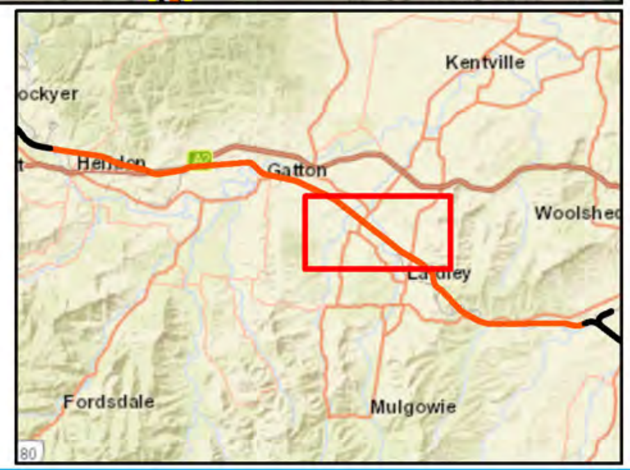
5	Chainage (km)
●	Flood sensitive receptors
◉	Localities
	Existing rail
	H2C project alignment
	Road design
	Minor roads
	EIS disturbance footprint
	Was Wet Now Dry
	Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

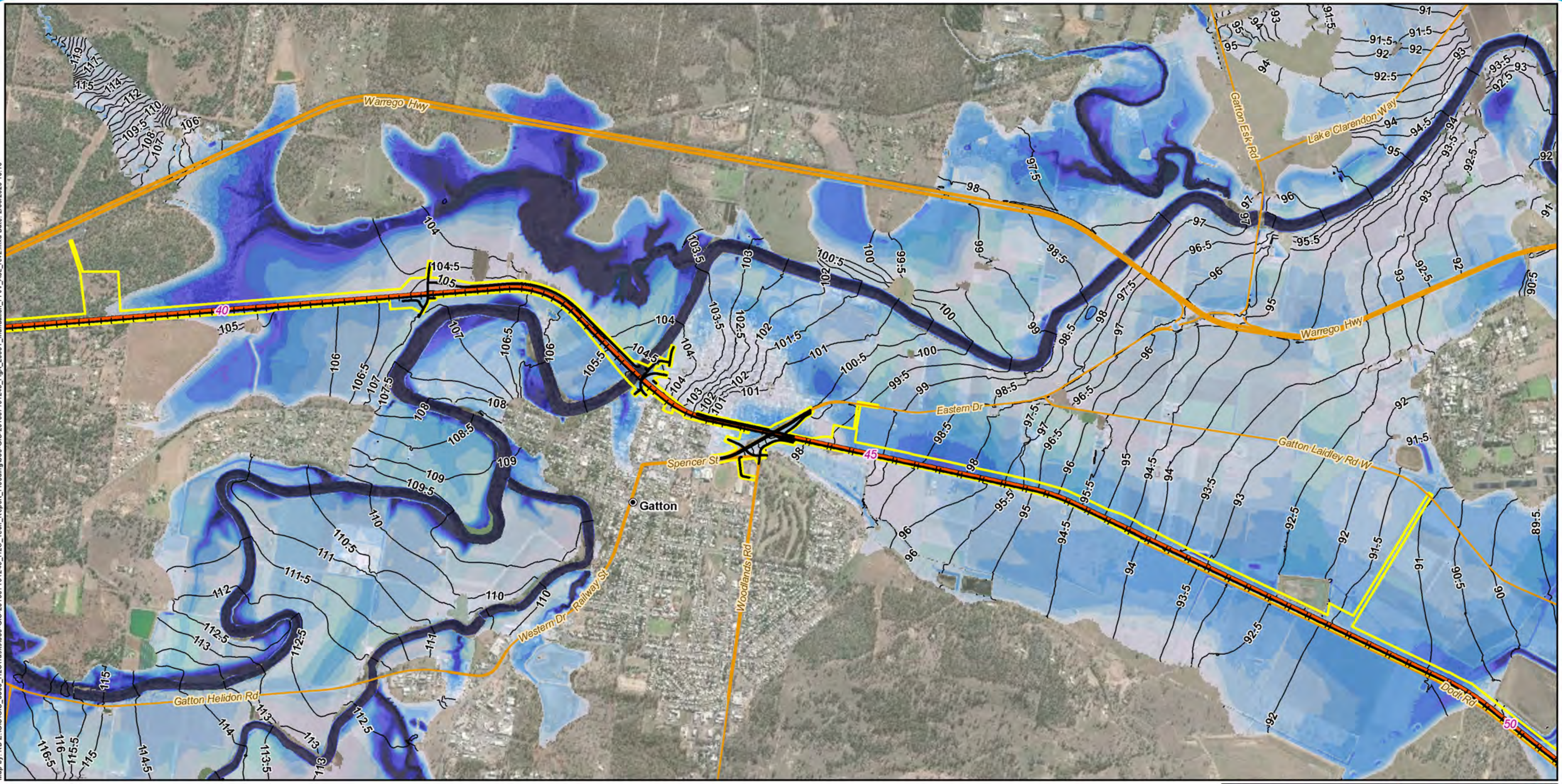
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-7J-2: 1% AEP Event with Blockage on Bridges: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



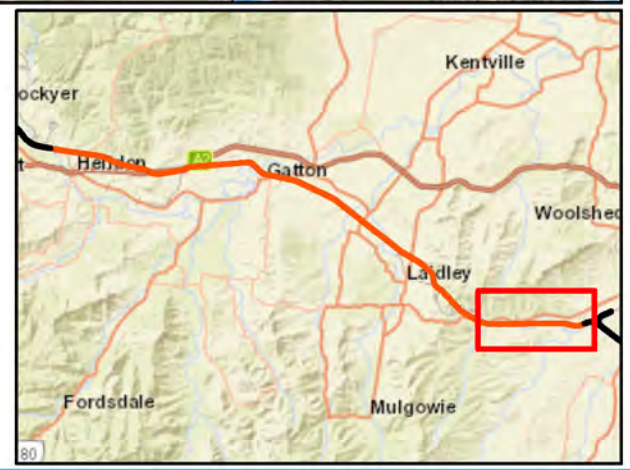
Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_2000Y_Inundation_FFJV_A3L_rev2.mxd Date: 2/06/2020 10:16

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0



A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

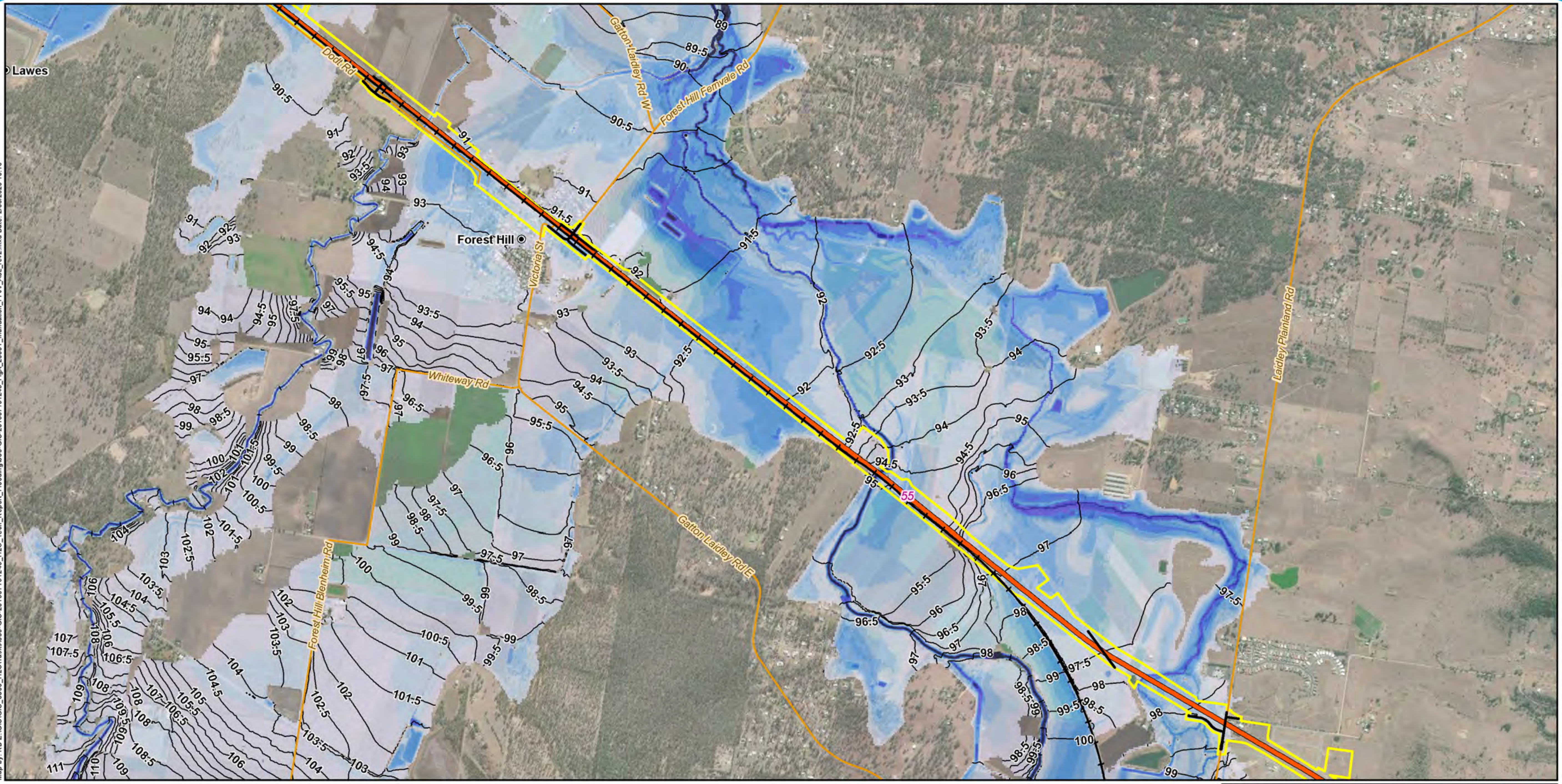
Future Freight
Integrating Community, Environment and Engineering

Issue date: 02/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

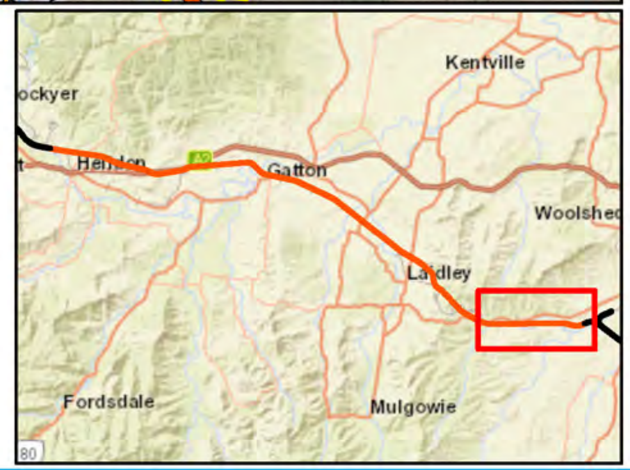
Helidon to Calvert

Figure A-8A-1: 1 in 2,000 AEP Event - Existing Case - Inundation Extent: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715\1245_H2C_Tech_Report_Flooding\330-GIS-20190715\1245_FigX_2000Y_Inundation_FFJV_A3L_rev2.mxd Date: 2/06/2020 10:16



Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

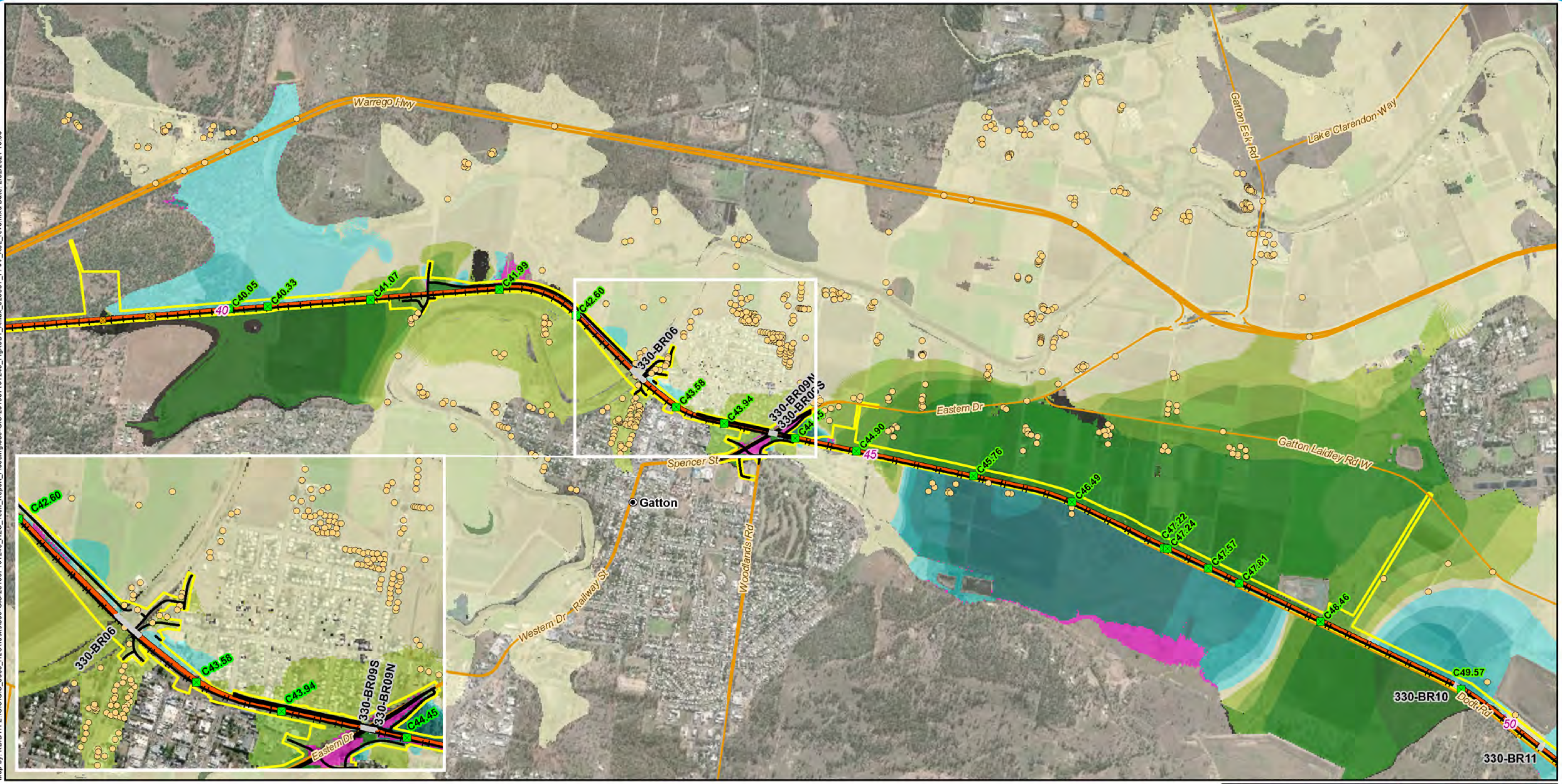
Future Freight
Integrating Community, Environment and Engineering

Issue date: 02/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

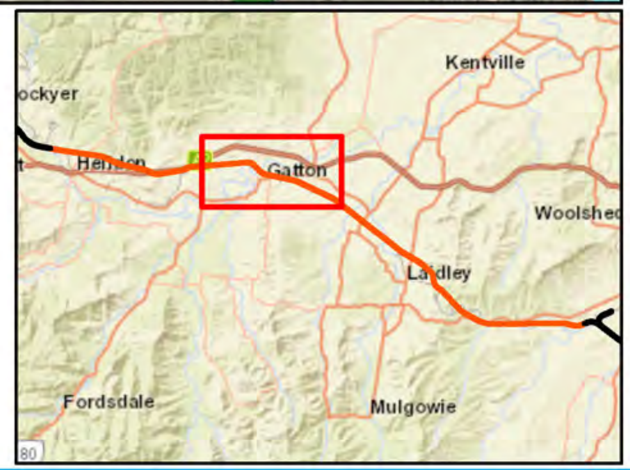
Helidon to Calvert

Figure A-8A-2: 1 in 2,000 AEP Event - Existing Case - Inundation Extent: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigA8B1_Afflux_02000Y_FFJV_A3L_rev3.mxd Date: 2/02/2021 19:56



Legend

- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Local drainage culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

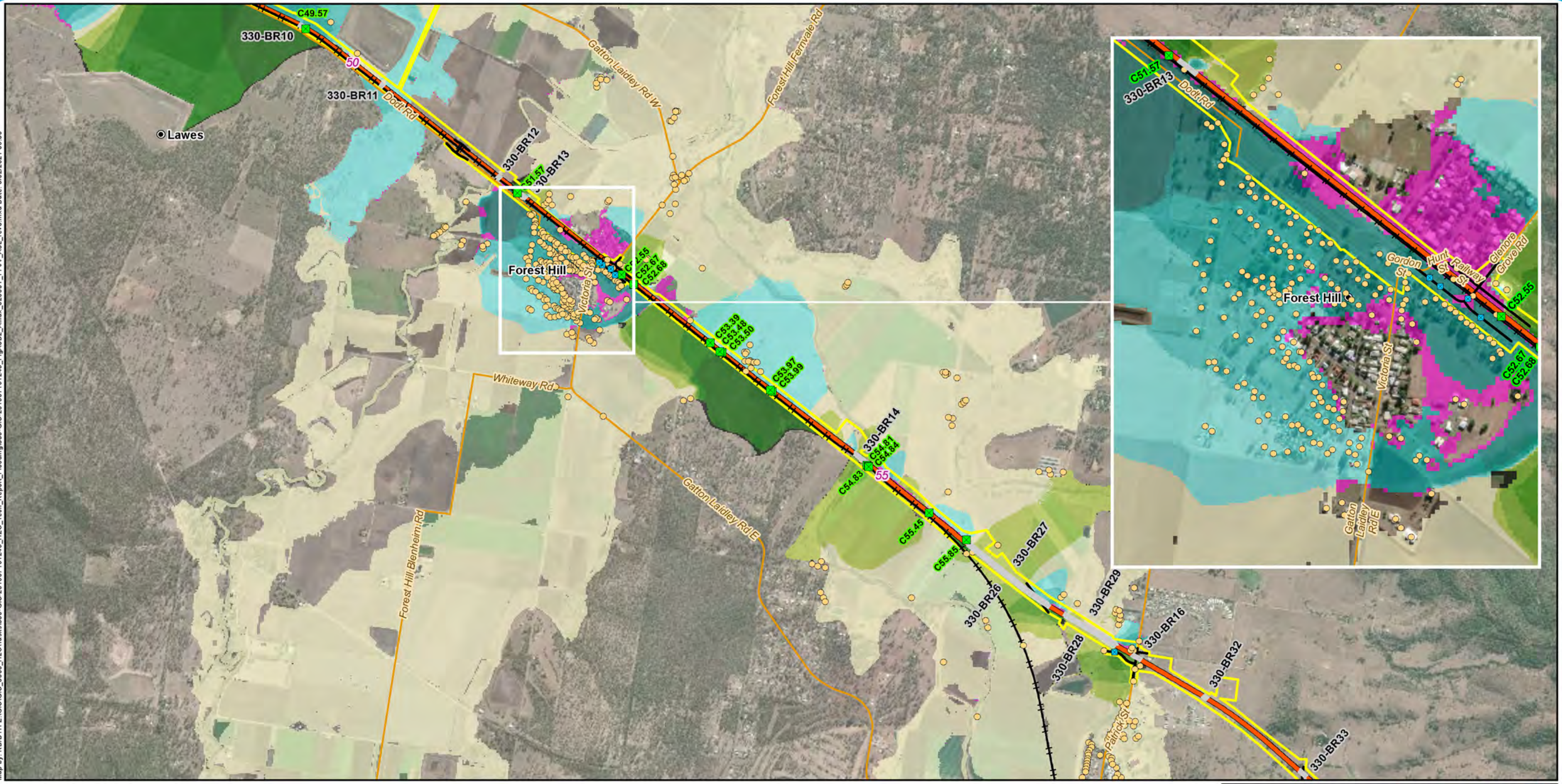
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-8B-1: 1 in 2,000 AEP Event - Developed Case - Afflux: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigA8B2_Afflux_02000Y_FFJV_A3L_rev3.mxd Date: 3/02/2021 09:30

Legend

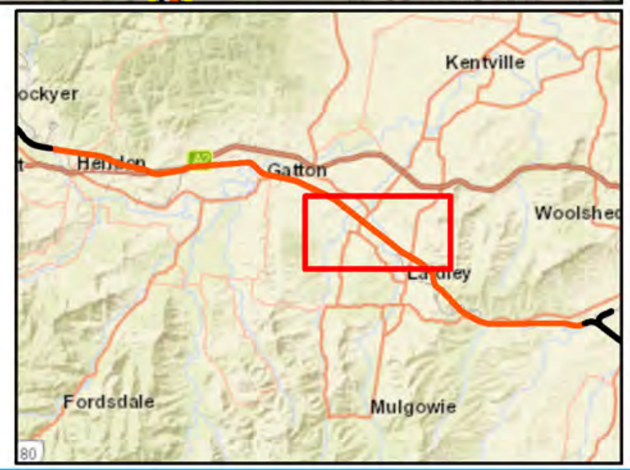
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:31,250
0 0.2 0.4 0.6 0.8 1 km

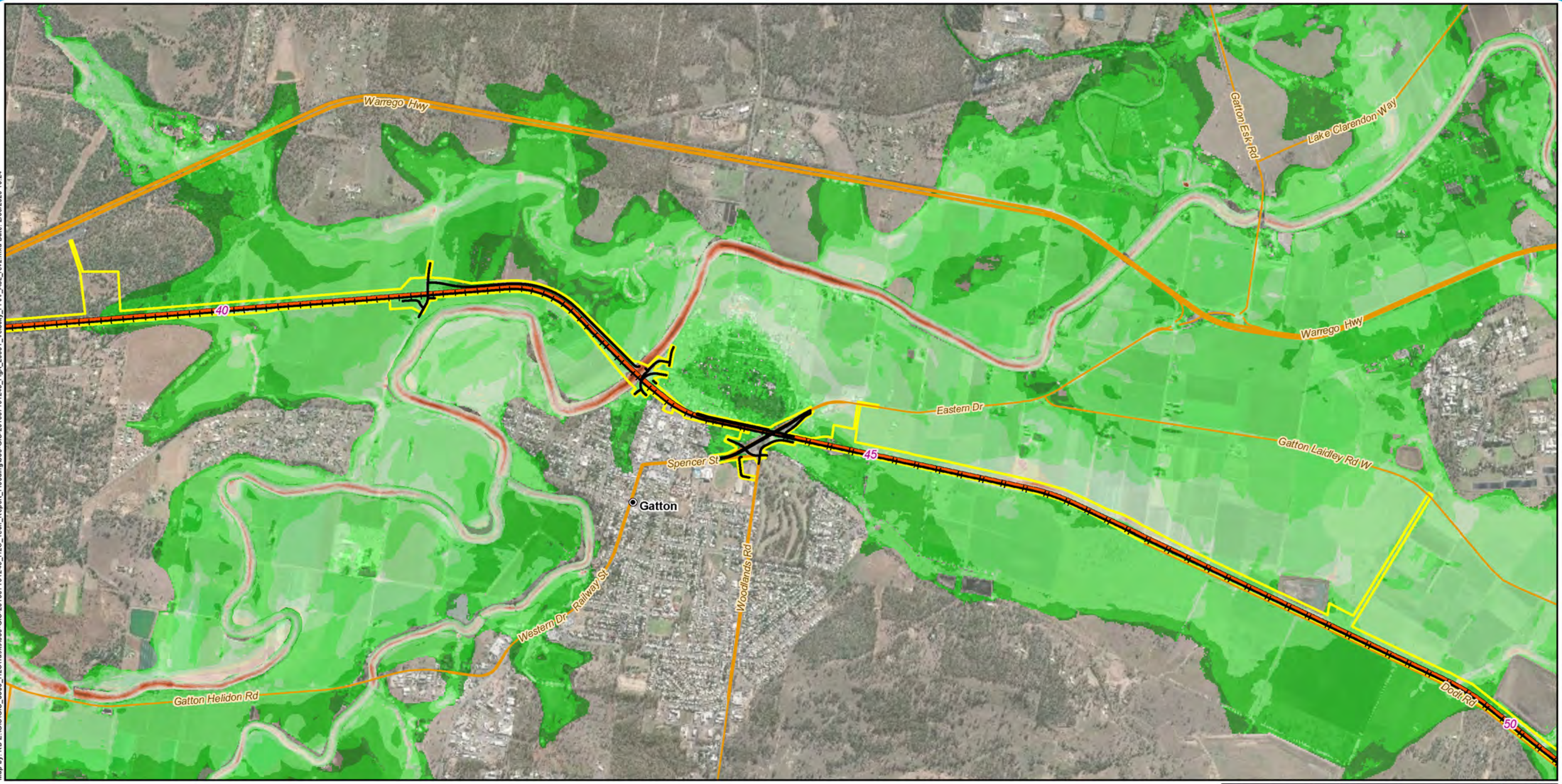
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-8B-2: 1 in 2,000 AEP Event - Developed Case - Afflux: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

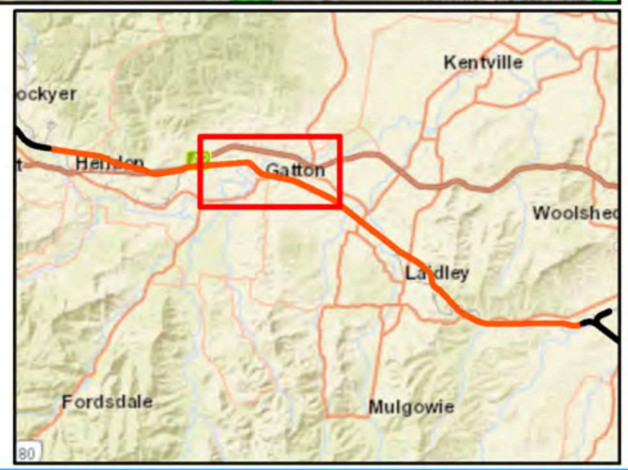


Legend

5	Chainage (km)
	Localities
	Existing rail
	H2C project alignment
	Road design
	Major roads
	Minor roads
	EIS disturbance footprint

Peak velocity (m/s)

0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0



A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

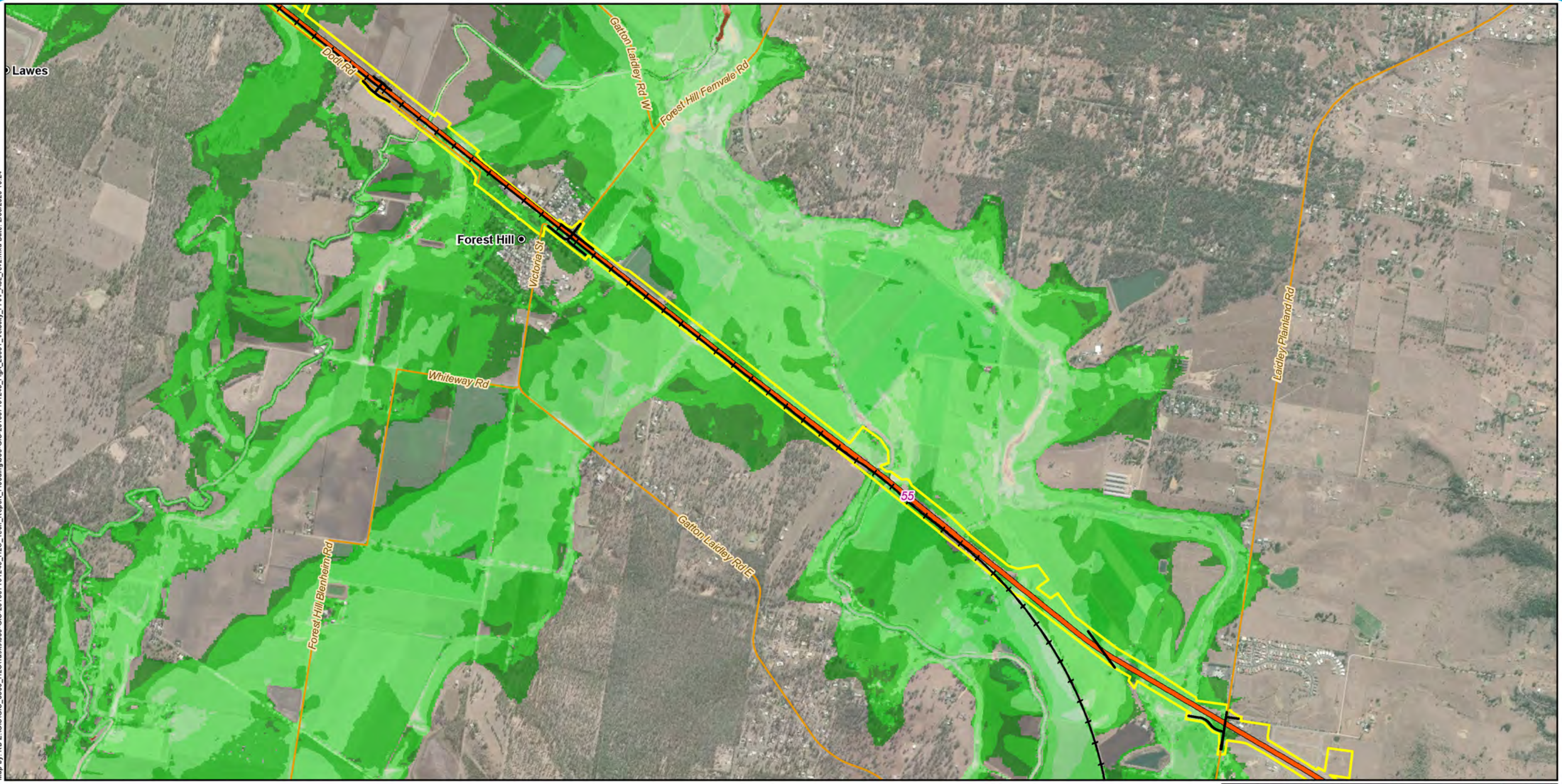
Future Freight
Integrating Community, Environment and Engineering

Issue date: 02/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-8C-1: 1 in 2,000 AEP Event - Developed Case - Velocity: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



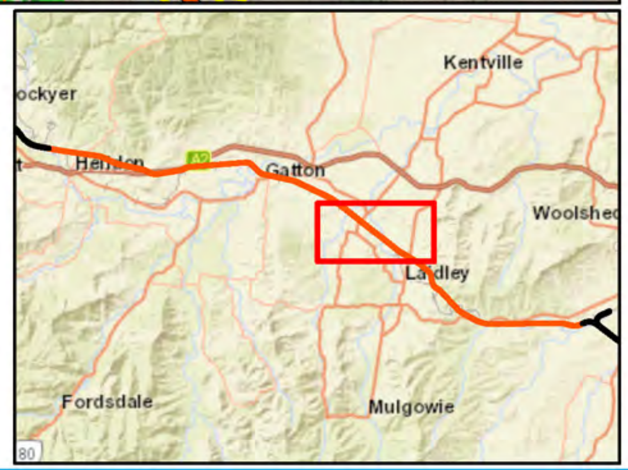
Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_2000Y_Velocity_FFJV_A3L_rev2.mxd Date: 2/06/2020 10:24

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint

Peak velocity (m/s)

0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0



A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

Future Freight
Integrating Community, Environment and Engineering

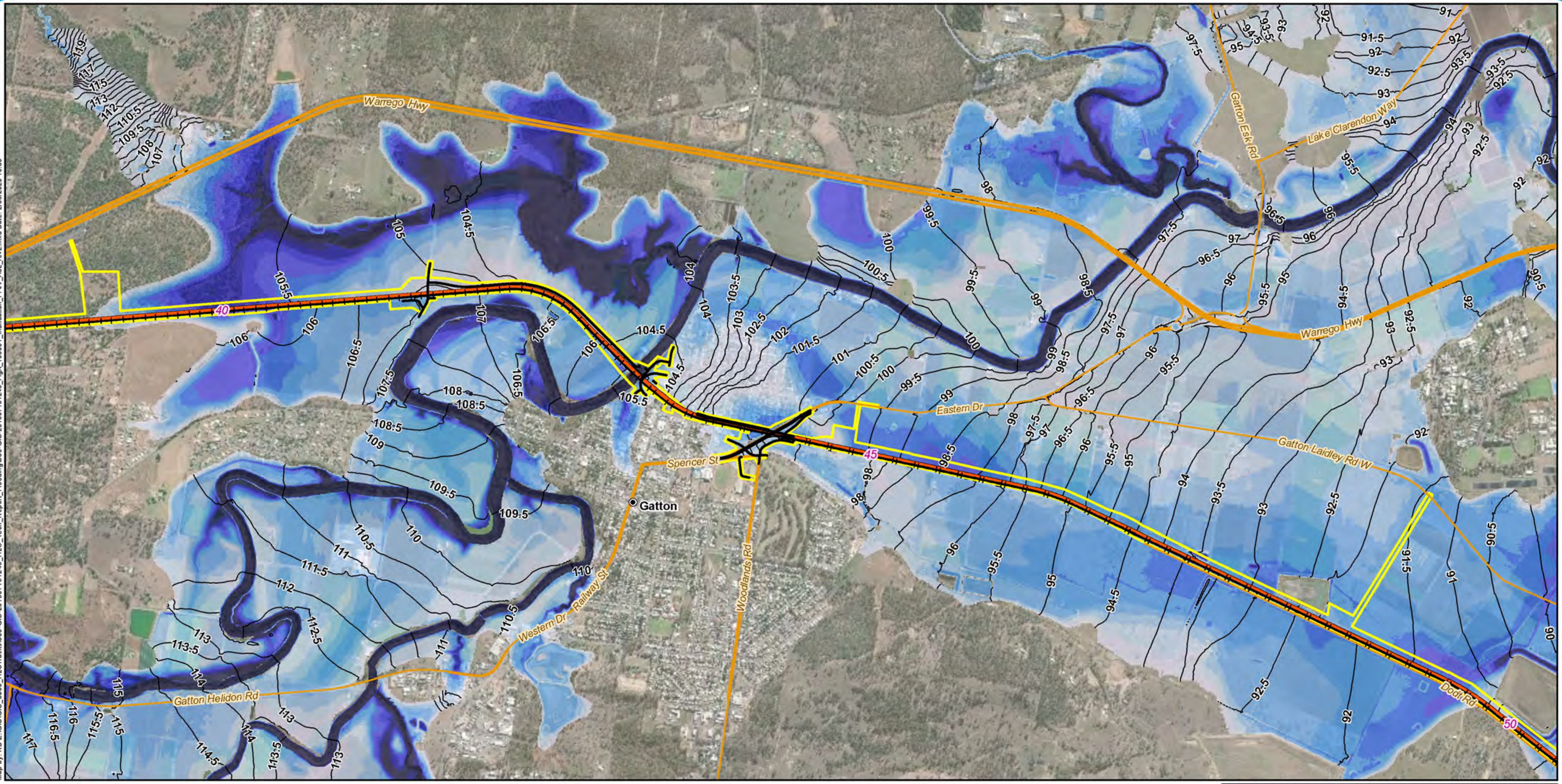
Issue date: 02/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

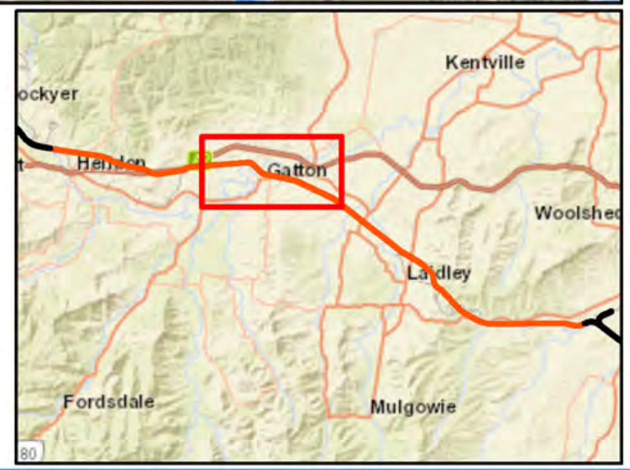
Helidon to Calvert

Figure A-8C-2: 1 in 2,000 AEP Event - Developed Case - Velocity: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_10000Y_Inundation_FFJV_A3L_rev2.mxd Date: 2/06/2020 10:35





Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

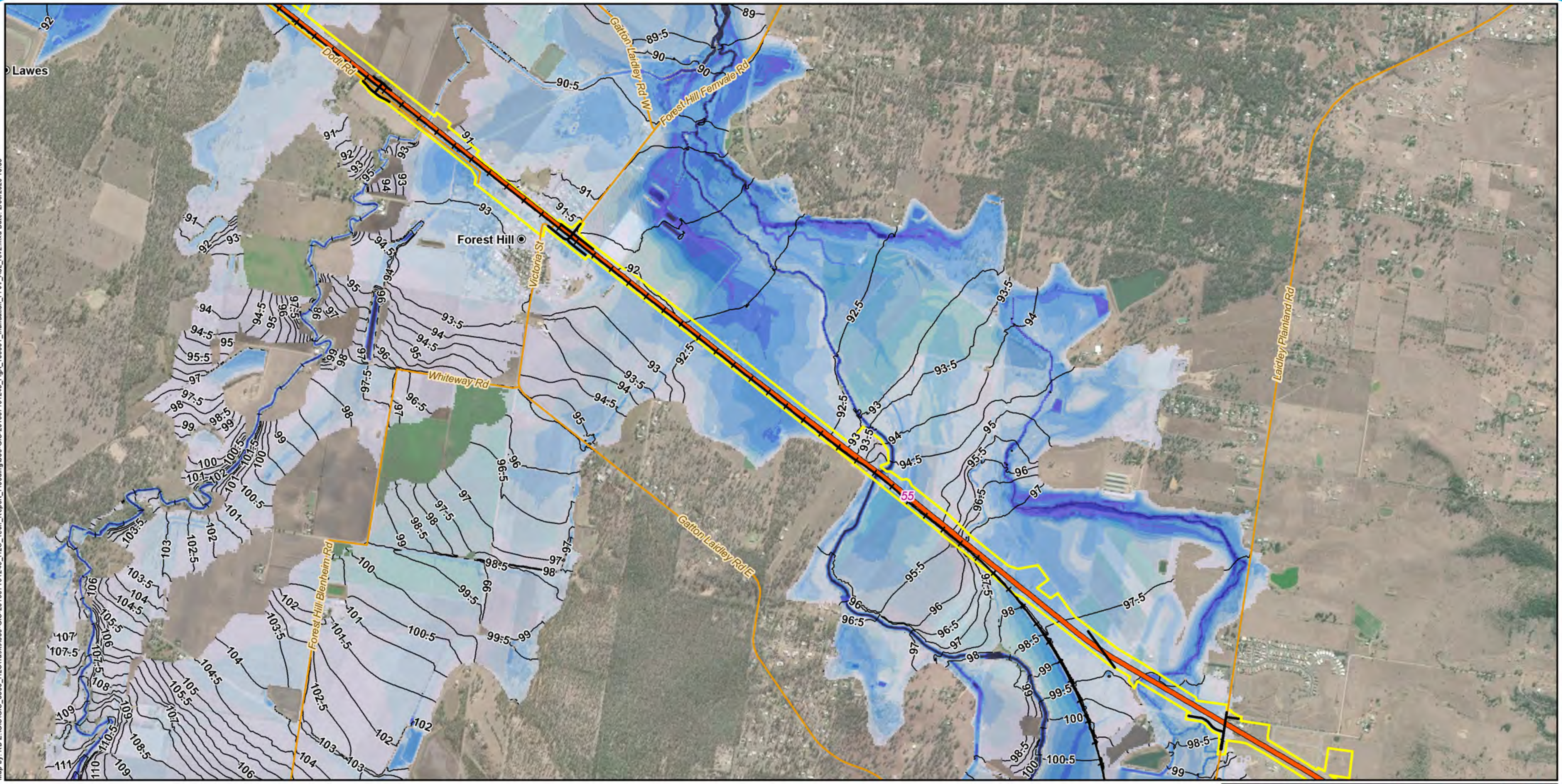
Future Freight
Integrating Community, Environment and Engineering

Issue date: 02/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

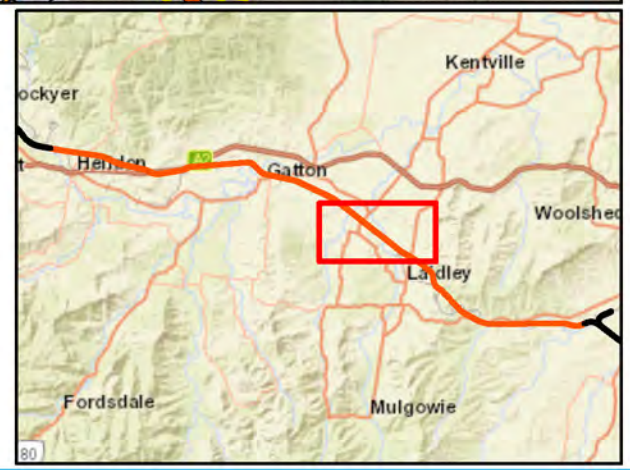
Helidon to Calvert

Figure A-9A-1: 1 in 10,000 AEP Event - Existing Case - Inundation Extent: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_10000Y_Inundation_FFJV_A3L_rev2.mxd Date: 2/06/2020 10:35



Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

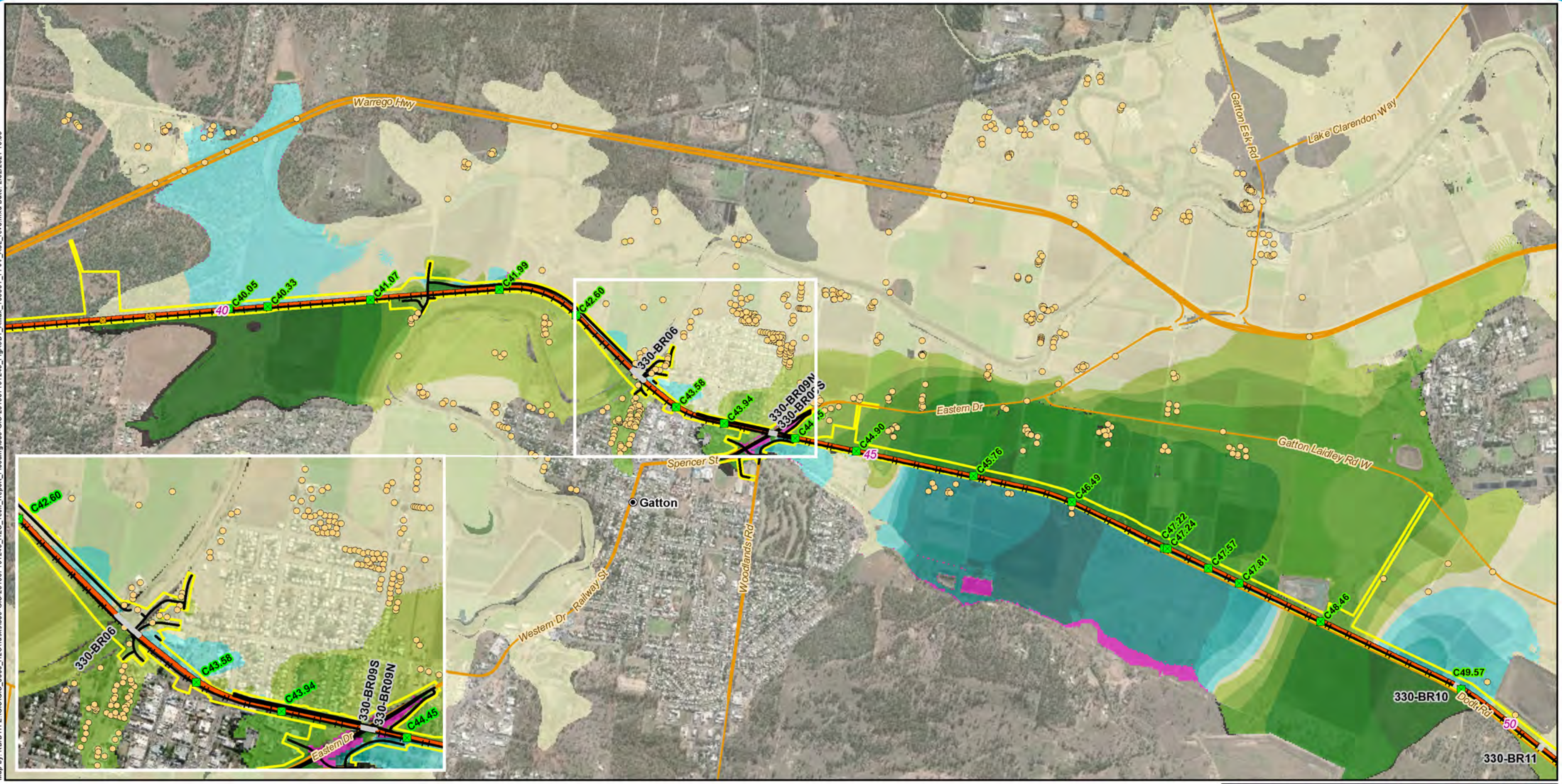
Future Freight
Integrating Community, Environment and Engineering

Issue date: 02/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-9A-2: 1 in 10,000 AEP Event - Existing Case - Inundation Extent: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigA9B1_Afflux_10000Y_FFJV_A3L_rev3.mxd Date: 2/02/2021 19:55

Legend

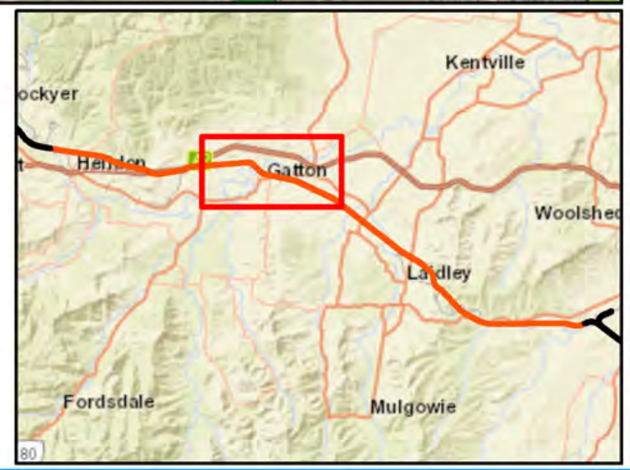
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Local drainage culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

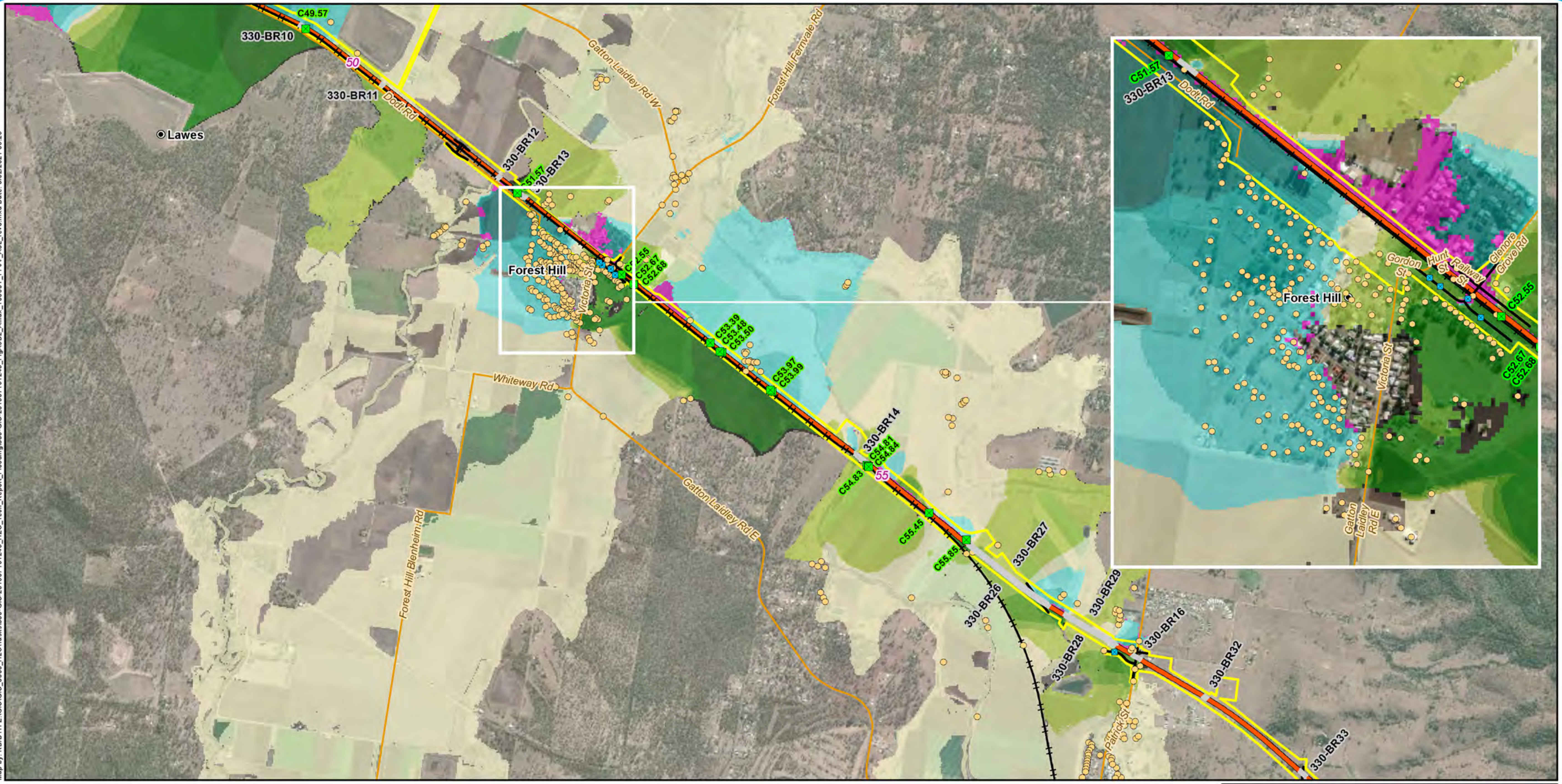
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-9B-1: 1 in 10,000 AEP Event - Developed Case - Afflux: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Legend

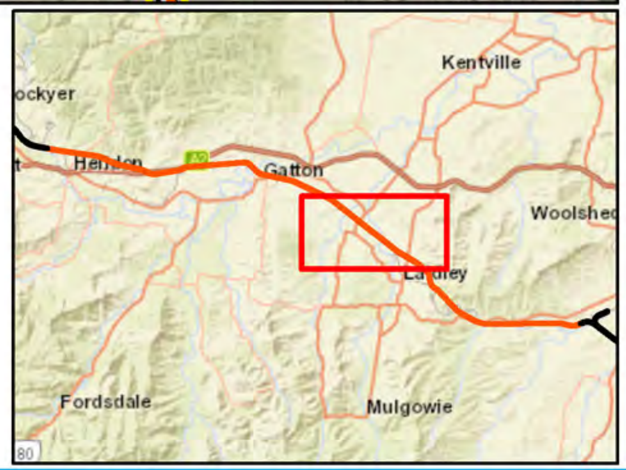
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

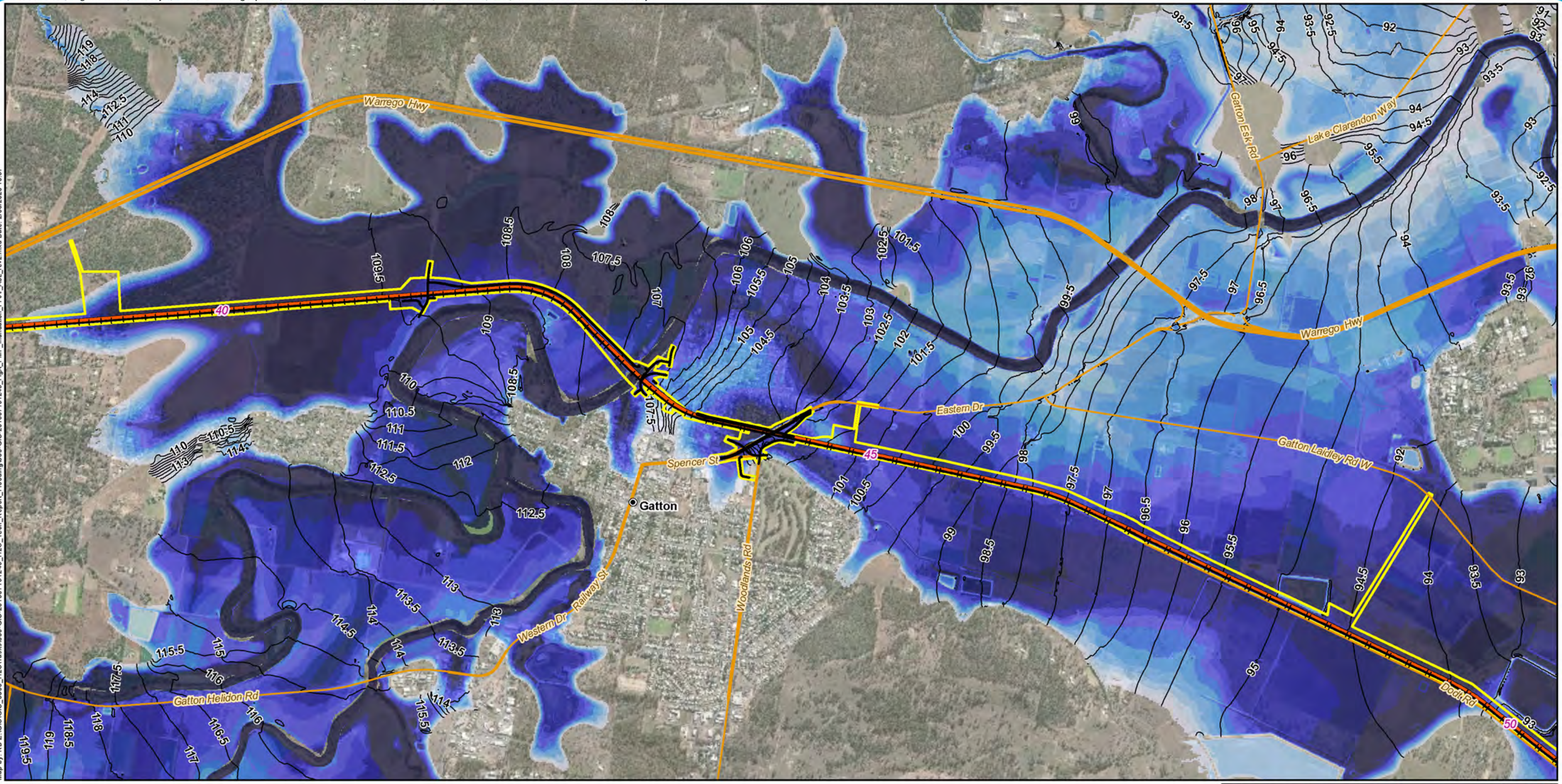
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-9B-2: 1 in 10,000 AEP Event - Developed Case - Afflux: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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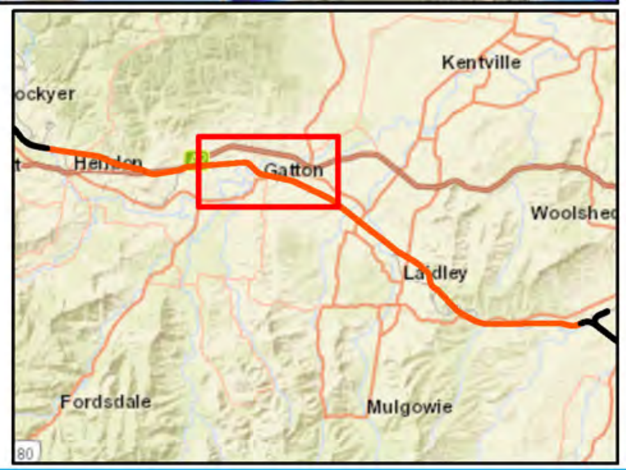
Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0



A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1 km

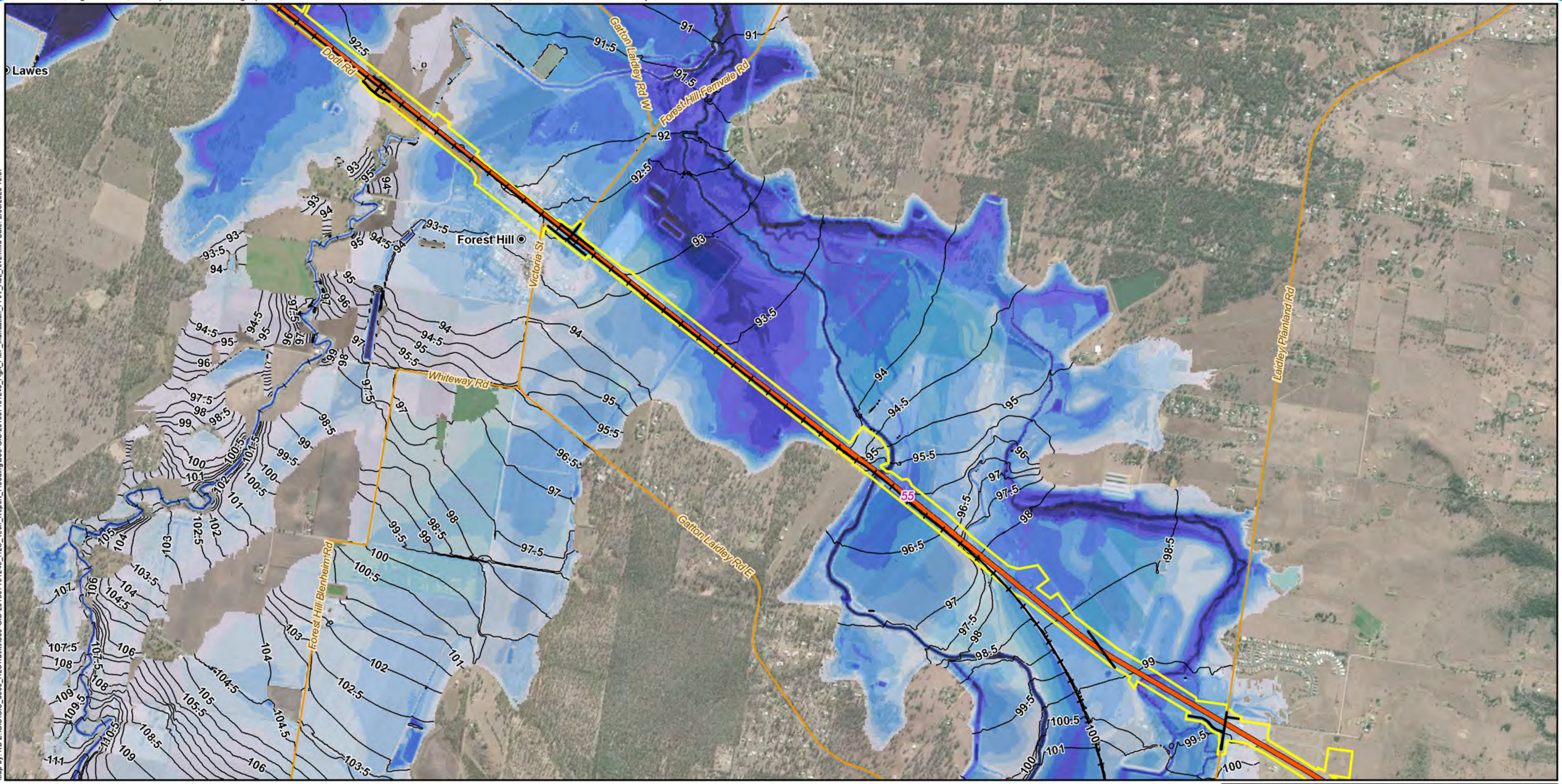
Future Freight
Integrating Community, Environment and Engineering

Issue date: 02/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-10A-1: PMF Event - Existing Case - Inundation Extent: Lockyer Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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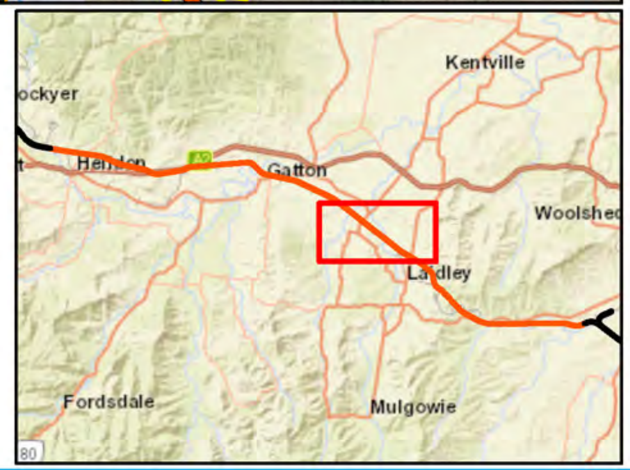


Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

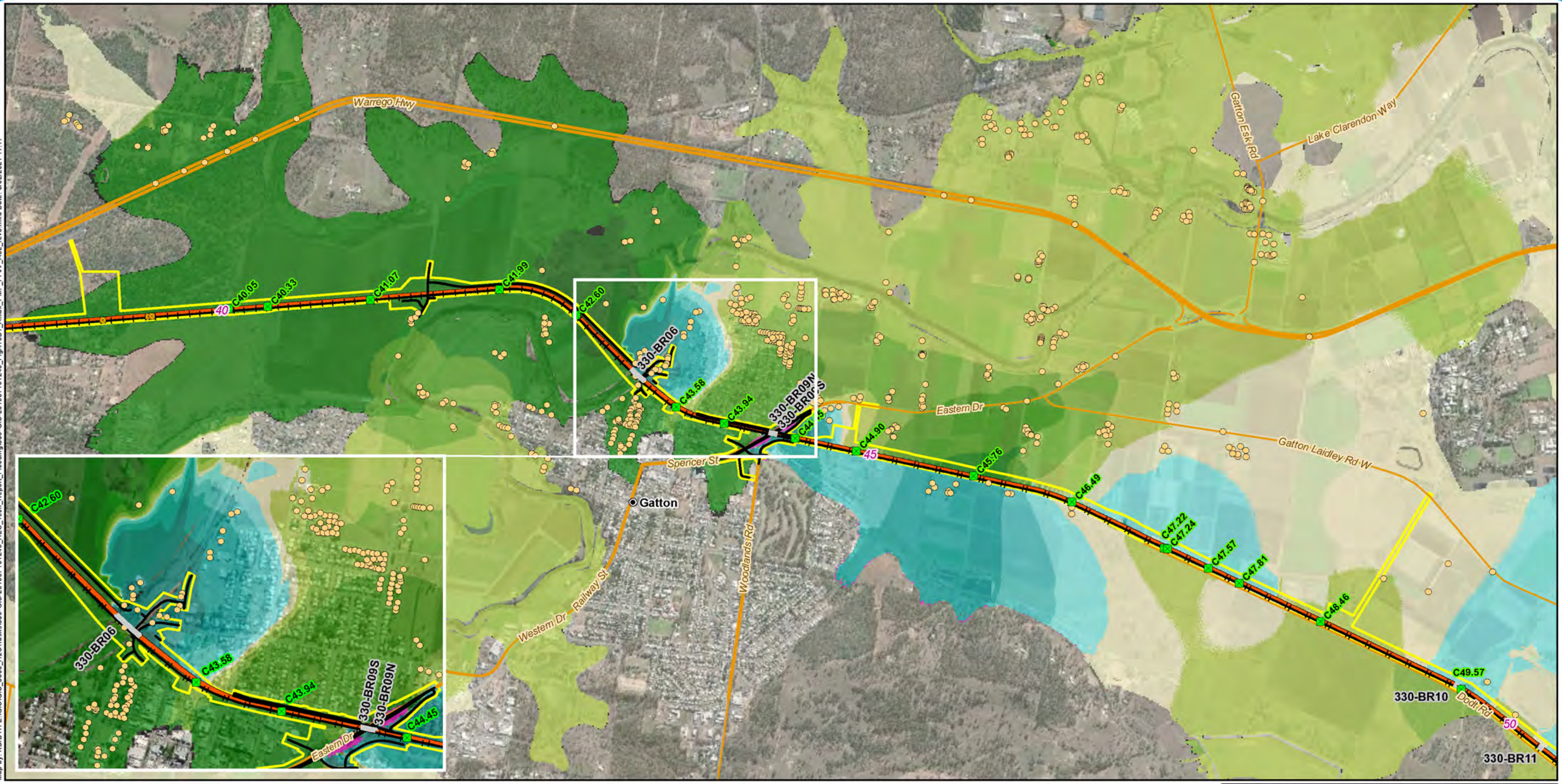
Future Freight
Integrating Community, Environment and Engineering

Issue date: 02/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-10A-2: PMF Event - Existing Case - Inundation Extent: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Legend

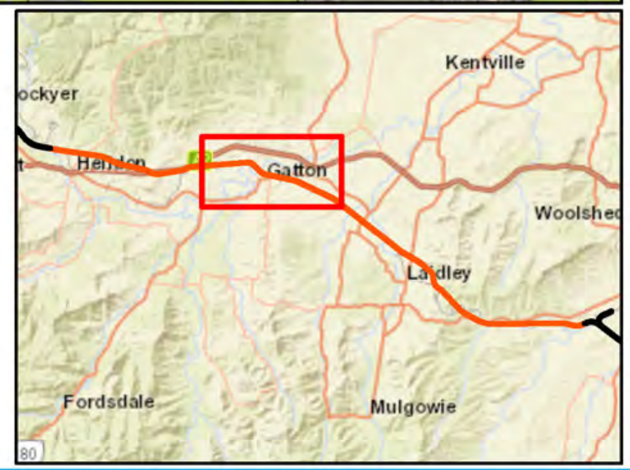
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Major roads
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Local drainage culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

Future Freight
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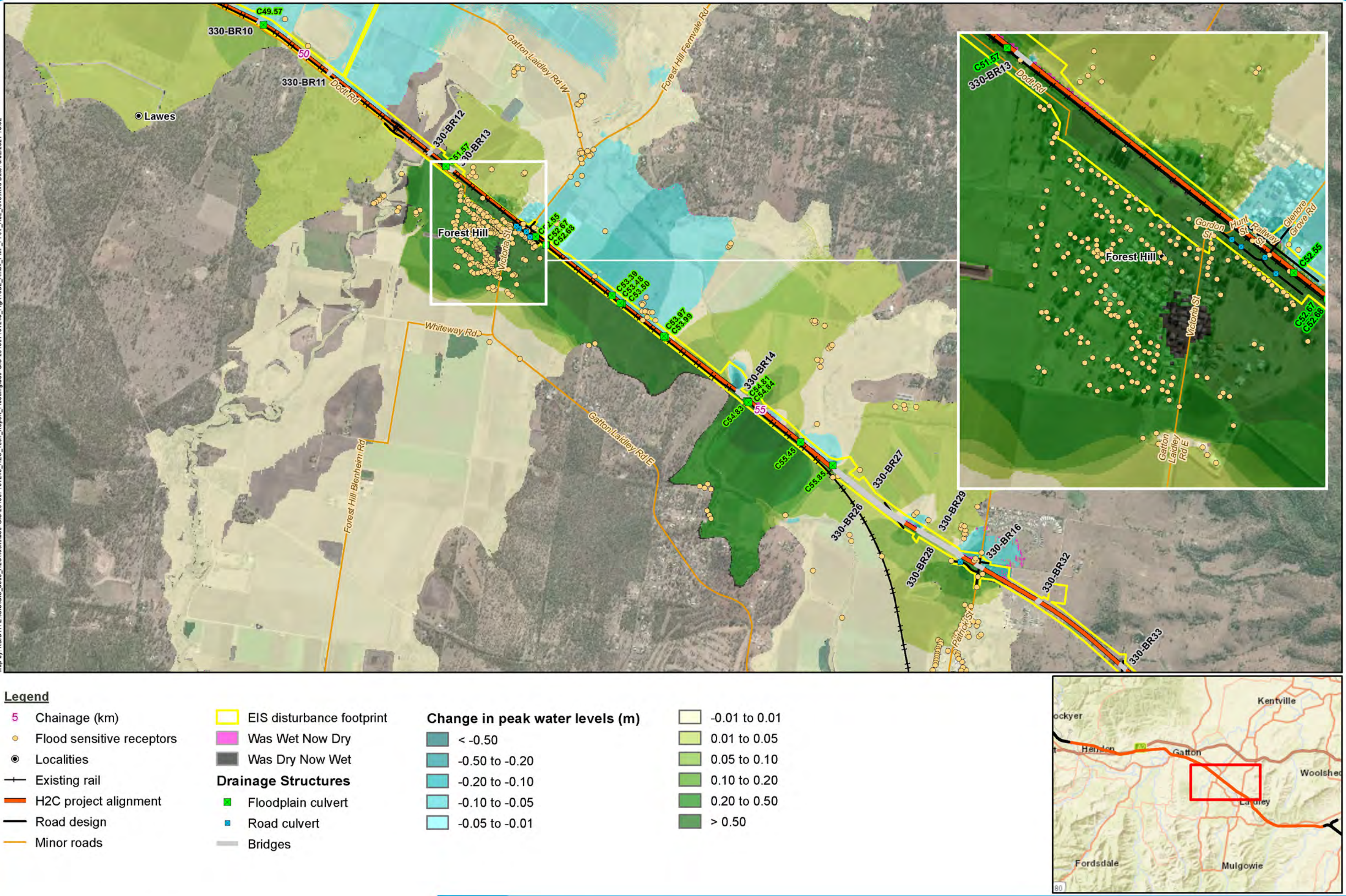
Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-10B-1: PMF Event - Developed Case - Afflux: Lockyer Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigA1082_Afflux_PMF_FFJV_A3L_rev3.mxd Date: 3/02/2021 10:52

Legend

- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

Future Freight
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Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure A-10B-2: PMF Event - Developed Case - Afflux: Lockyer Creek

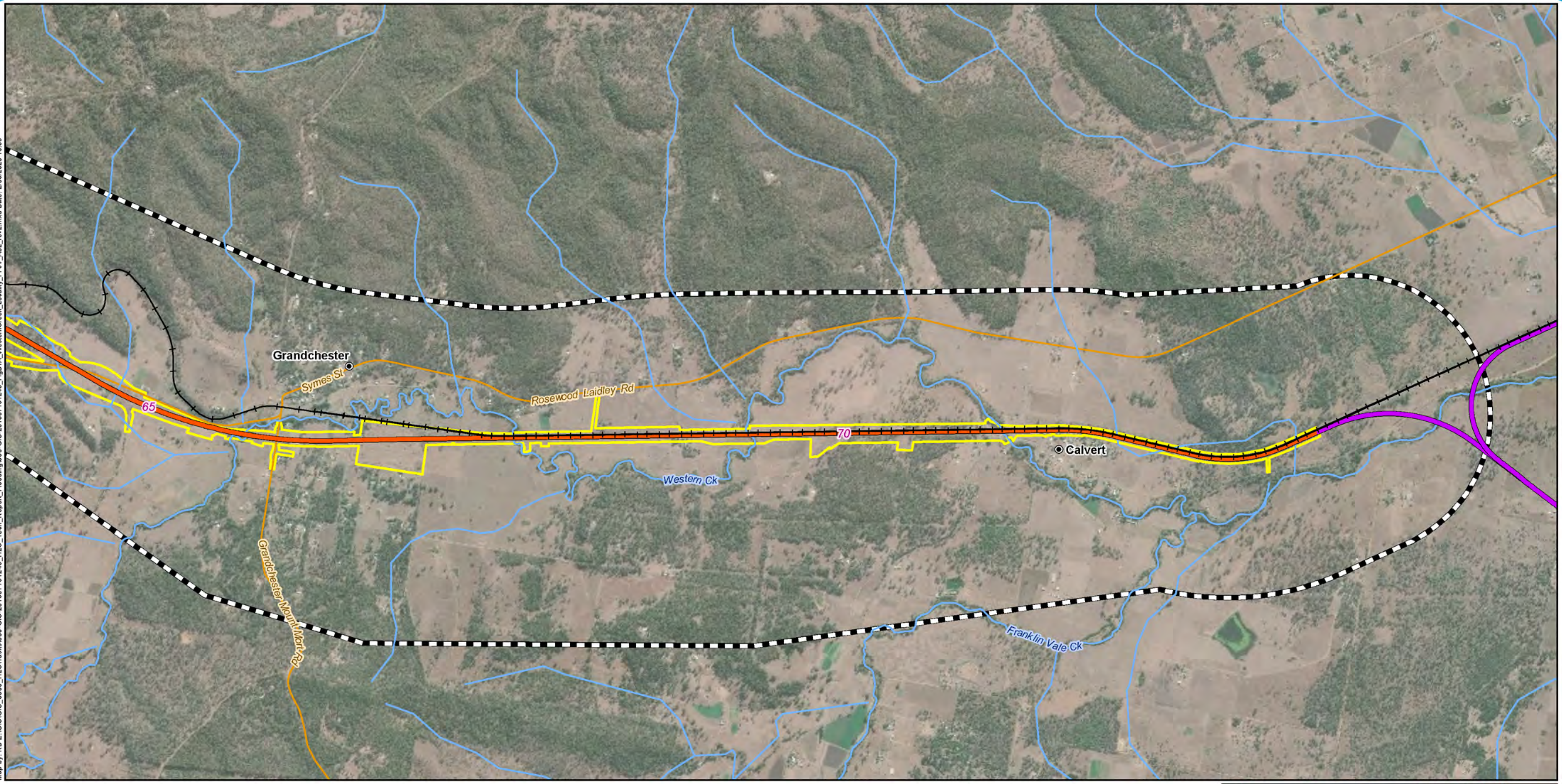
APPENDIX

M

Hydrology and Flooding Technical Report

Appendix B Western Creek Figures

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715124S_H2C_Tech_Report_Flooding\330-GIS-20190715124S_FigB1A_WesternCreek_Locality_FFJV_A3L_rev2.mxd Date: 2/06/2020 16:55

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Watercourses
- Minor roads
- EIS disturbance footprint
- EIS investigation corridor

A3 scale: 1:30,000

0 0.2 0.4 0.6 0.8 1km

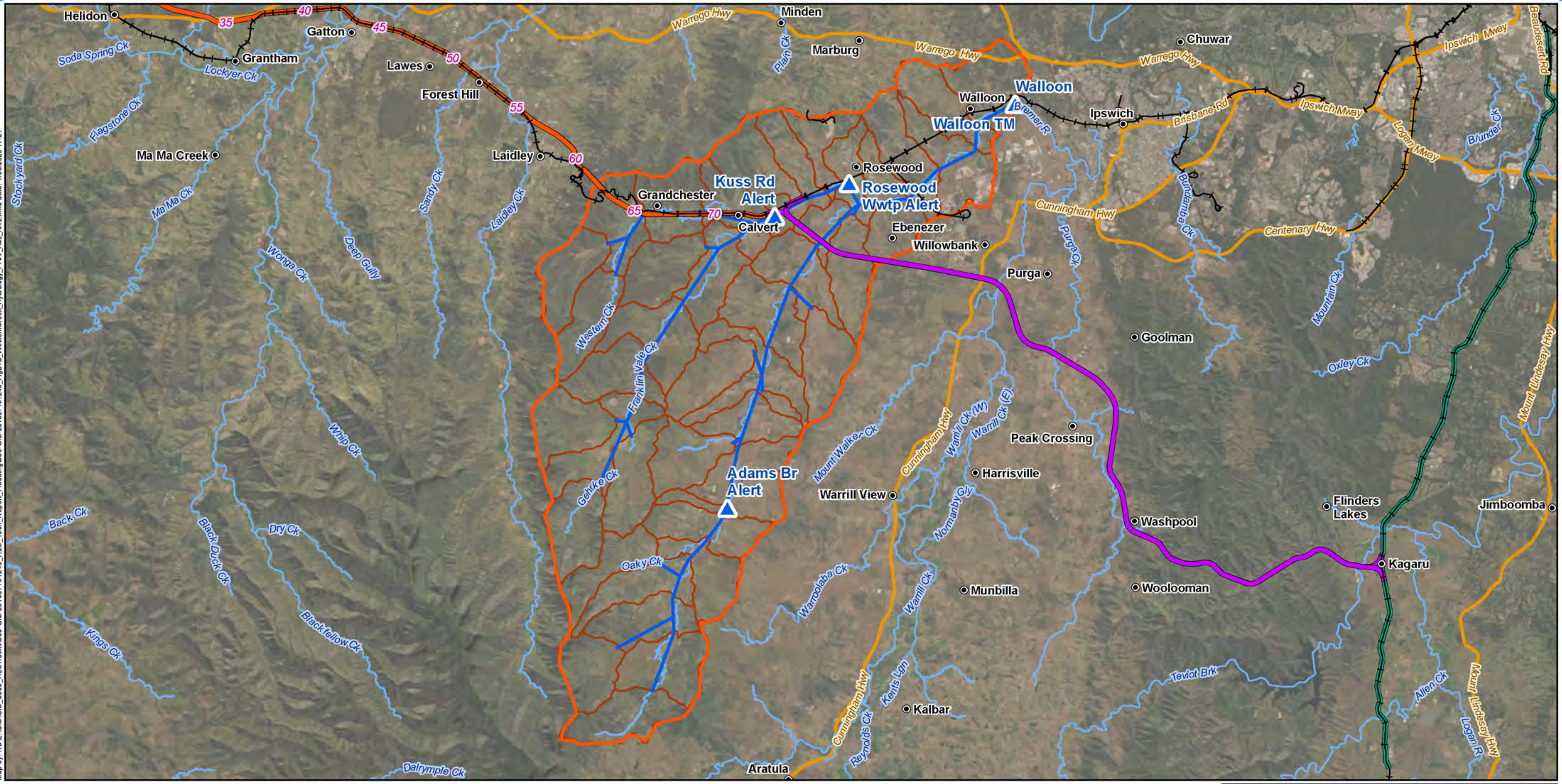
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure B-1A: Locality: Western Creek

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Chainage label points
- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- K2ARB project alignment
- Watercourses
- Major roads
- Stream Gauge
- Hydrologic model links
- Bremer Creek catchment boundary
- Model subcatchments

A3 scale: 1:260,769

0 2 4 6 8 10km

Future Freight
Integrating Community, Environment and Engineering

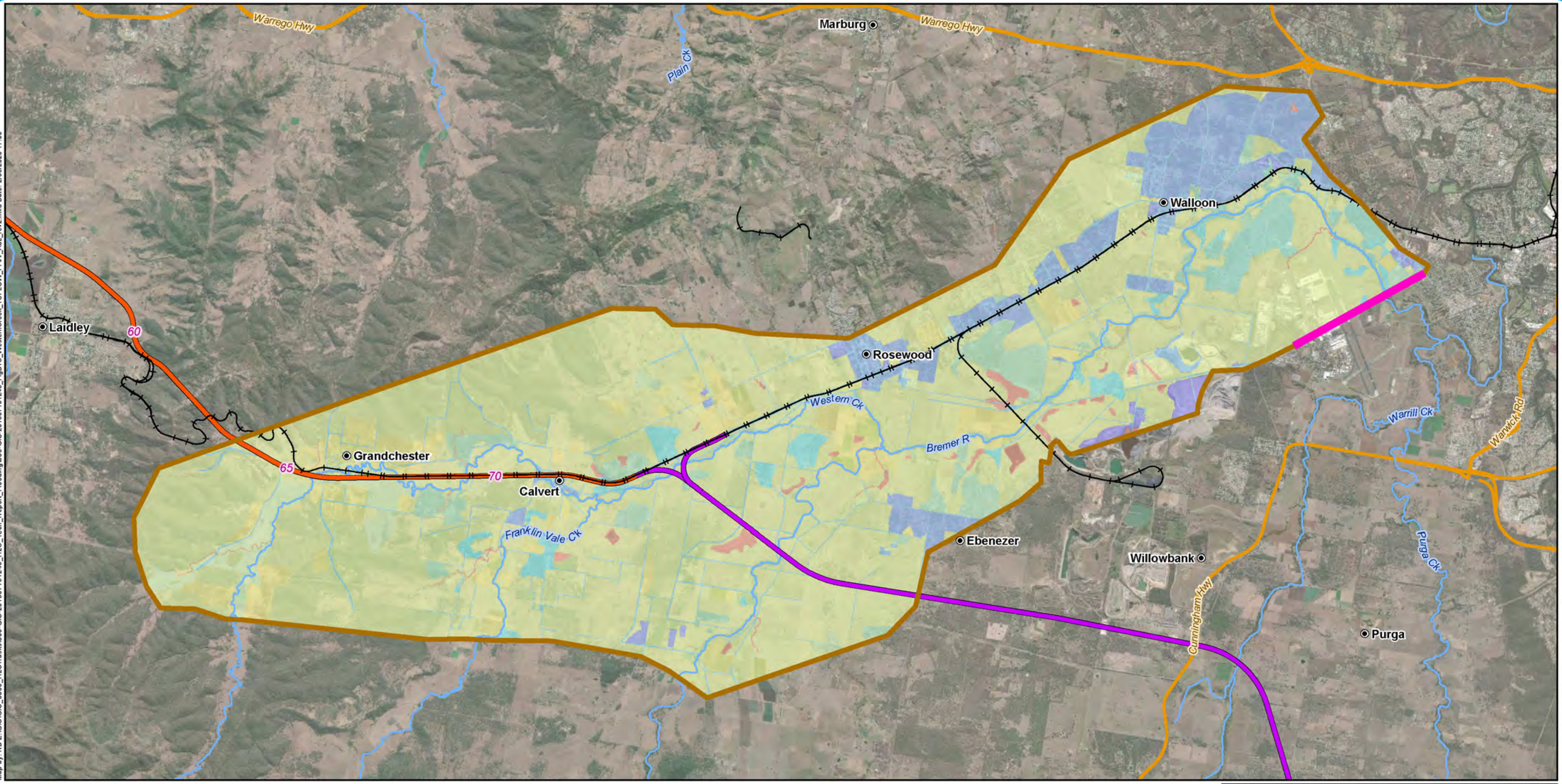
Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

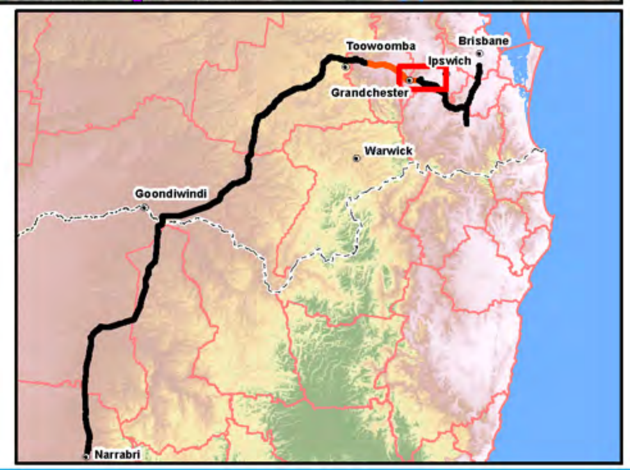
Helidon to Calvert

Figure B-1B: Hydrology setup: Western Creek

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigB1C_WesternCreek_TUFLOW_FFJV_A3L_rev2.mxd Date: 2/06/2020 17:00





Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Watercourses
- Major roads
- Downstream Boundary
- Code Boundary

Materials

- Non Tidal Waterway
- Waterbodies
- Low Density River Bank Vegetation
- Medium Denisty River Bank Vegetation
- High Density River Bank Vegetation
- Grassland
- Light Vegetation
- Fields/ Parks
- Dense Vegetation
- Very Dense Vegetation
- Rough Pasture/ Light Brush
- Roads
- Low Density Urban Block
- Medium Density Urban Block
- Commercial/ Industrial
- Mining

A3 scale: 1:100,000

0 0.75 1.5 2.25 3 3.75km

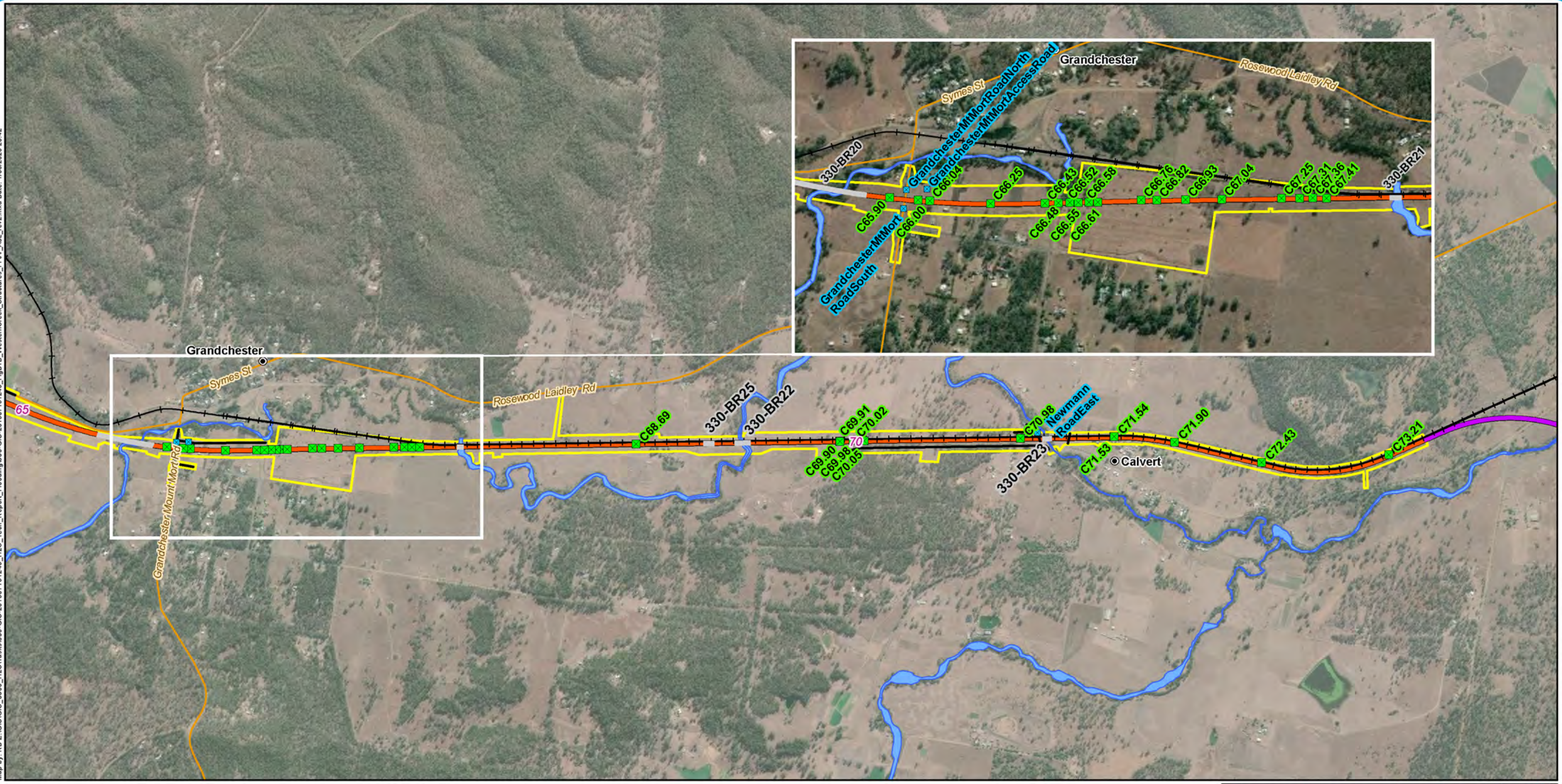
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure B-1C: TUFLOW model setup: Western Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



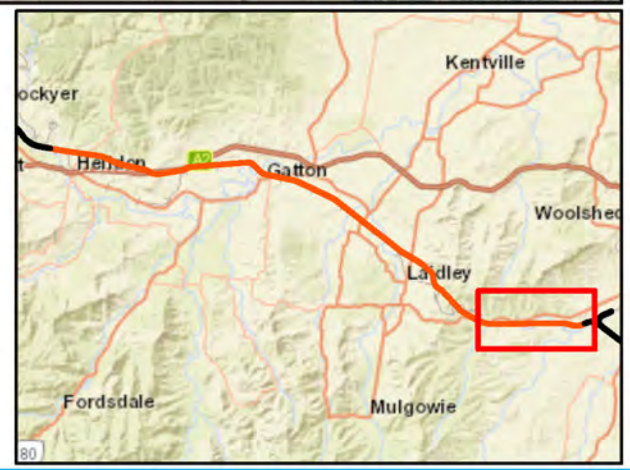
Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigB1D_WesternCreek_Structures_FFJV_A3L_rev2.mxd Date: 1/06/2020 20:42

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- Watercourses
- EIS disturbance footprint

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges



A3 scale: 1:25,000

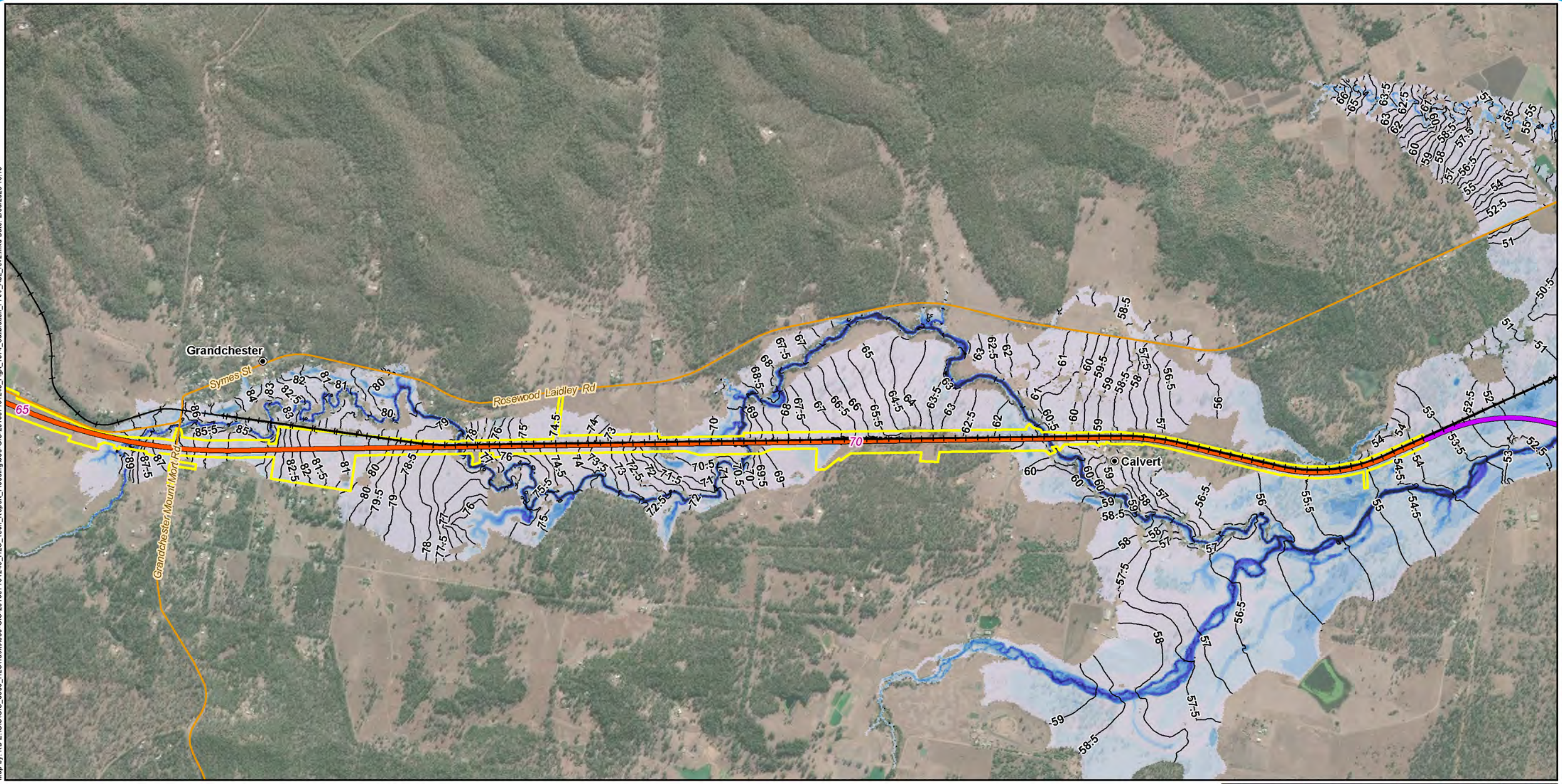
0 0.15 0.3 0.45 0.6 0.75km

Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert
Figure B-1D: 100% Design Structures: Western Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



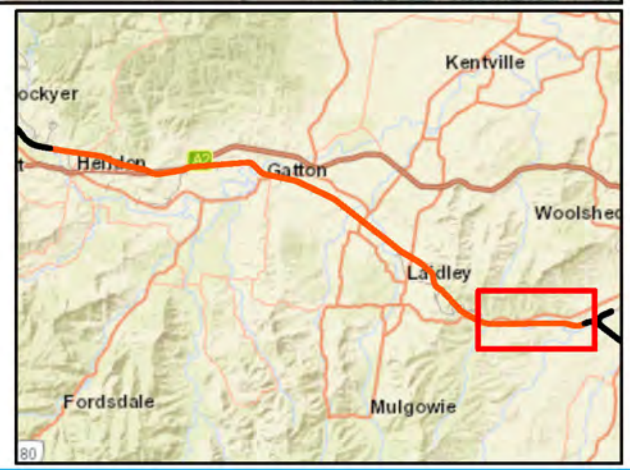
Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_1974_Calibration_FFJV_A3L_rev2.mxd Date: 2/06/2020 16:15

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0



A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

Future Freight
Integrating Community, Environment and Engineering

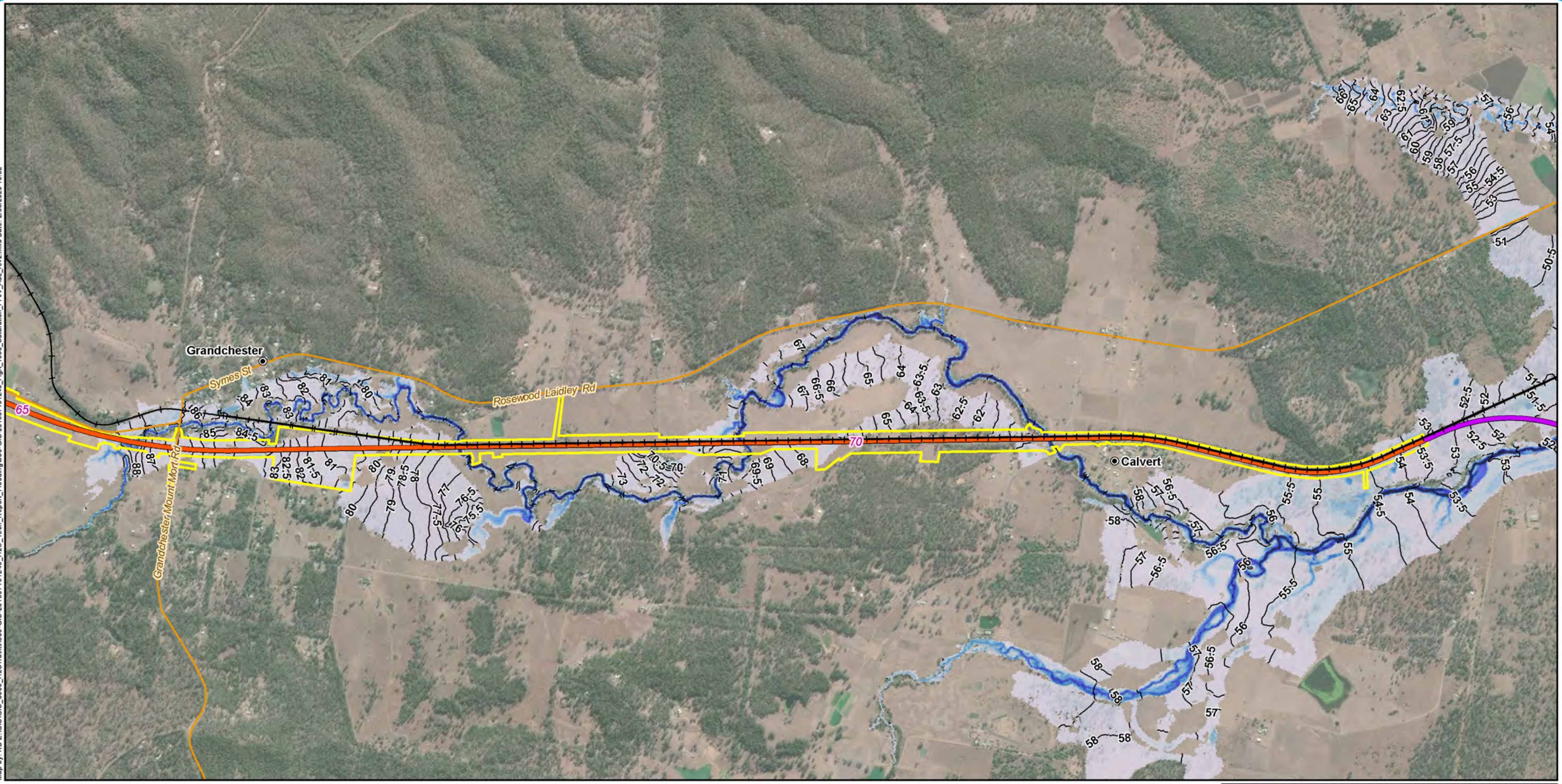
Issue date: 02/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

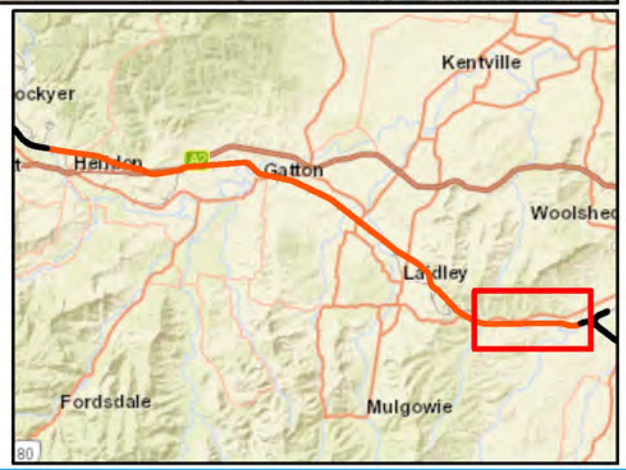
Helidon to Calvert

Figure B-2A: 1974 Calibration Event: Western Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_1996_Calibration_FFJV_A3L_rev2.mxd Date: 2/06/2020 10:02





Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

A3 scale: 1:25,000

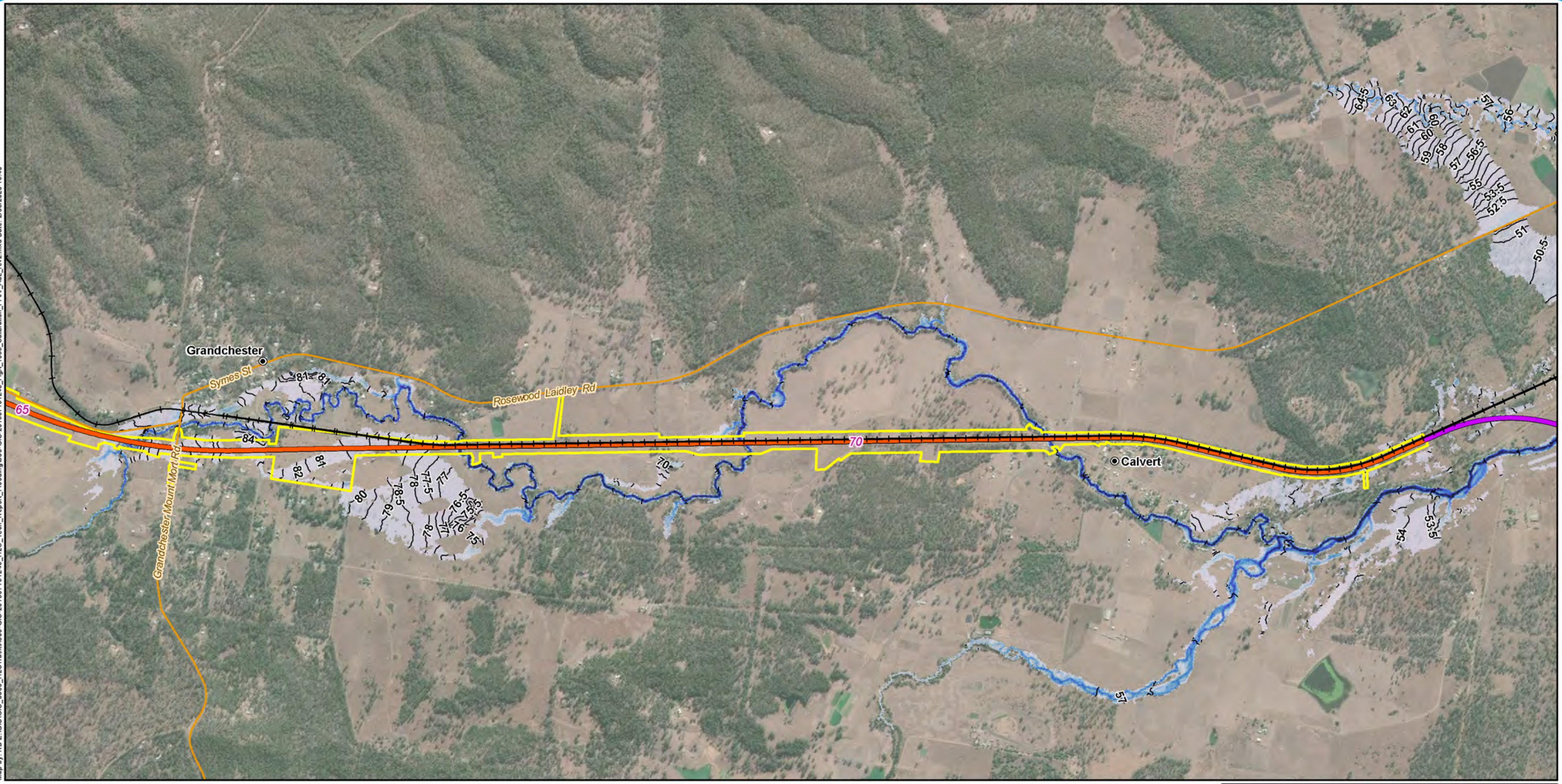
0 0.15 0.3 0.45 0.6 0.75km

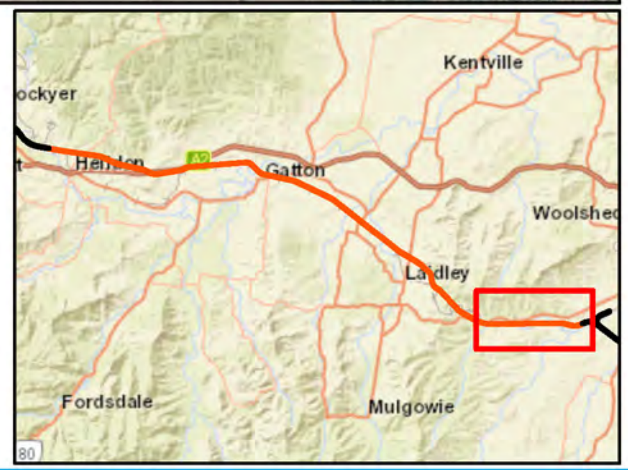
Future Freight
Integrating Community, Environment and Engineering

Issue date: 09/09/2019 Version: 1
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert
Figure B-2B: 1996 Calibration Event: Western Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

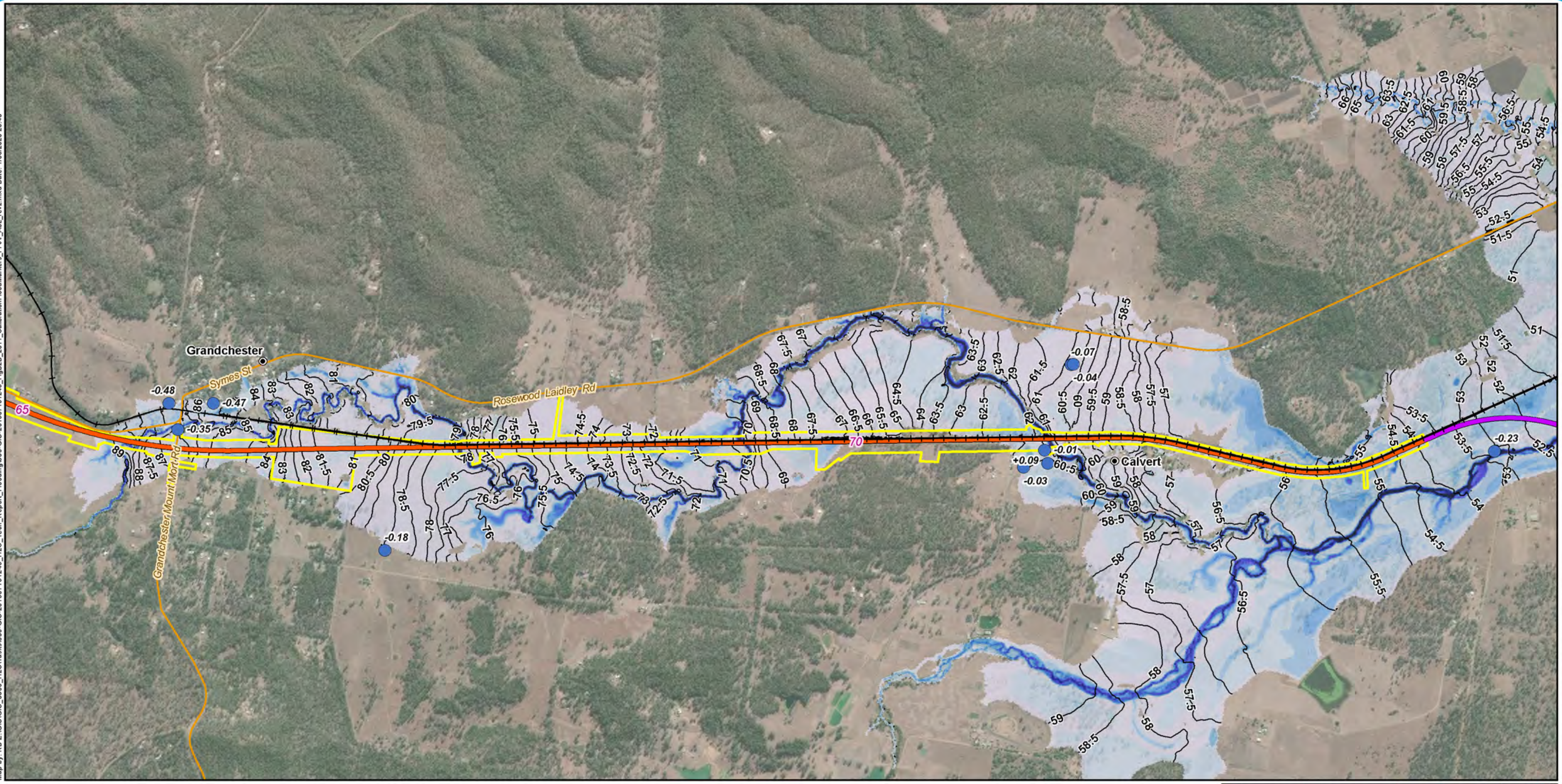
Future Freight
Integrating Community, Environment and Engineering

Issue date: 02/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert
Figure B-2C: 1999 Calibration Event: Western Creek

Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_1999_Calibration_FFJV_A3L_rev2.mxd Date: 2/06/2020 16:40

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715\245_H2C_Tech_Report_Flooding\330-GIS-20190715\245_FigB2D_2011_CalibrationFloodMarkers_FFJV_A3L_rev2.mxd Date: 1/06/2020 20:43

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

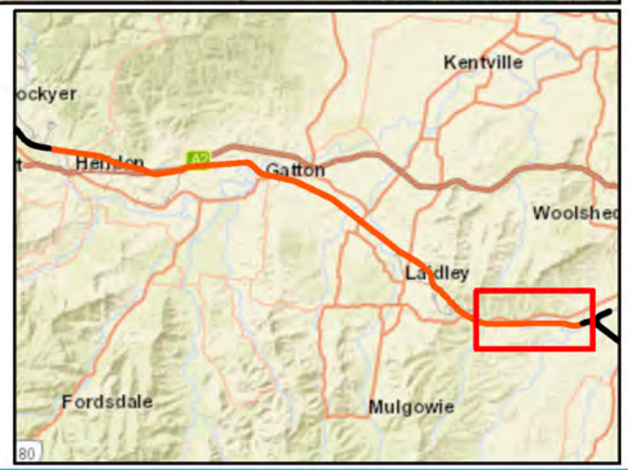
2011 flood marker comparison (m)

- Grandchester to Calvert

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

Note:
Information presented is from a regional Western Creek flood model. Local catchment surface flows are not presented.



A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

Future Freight
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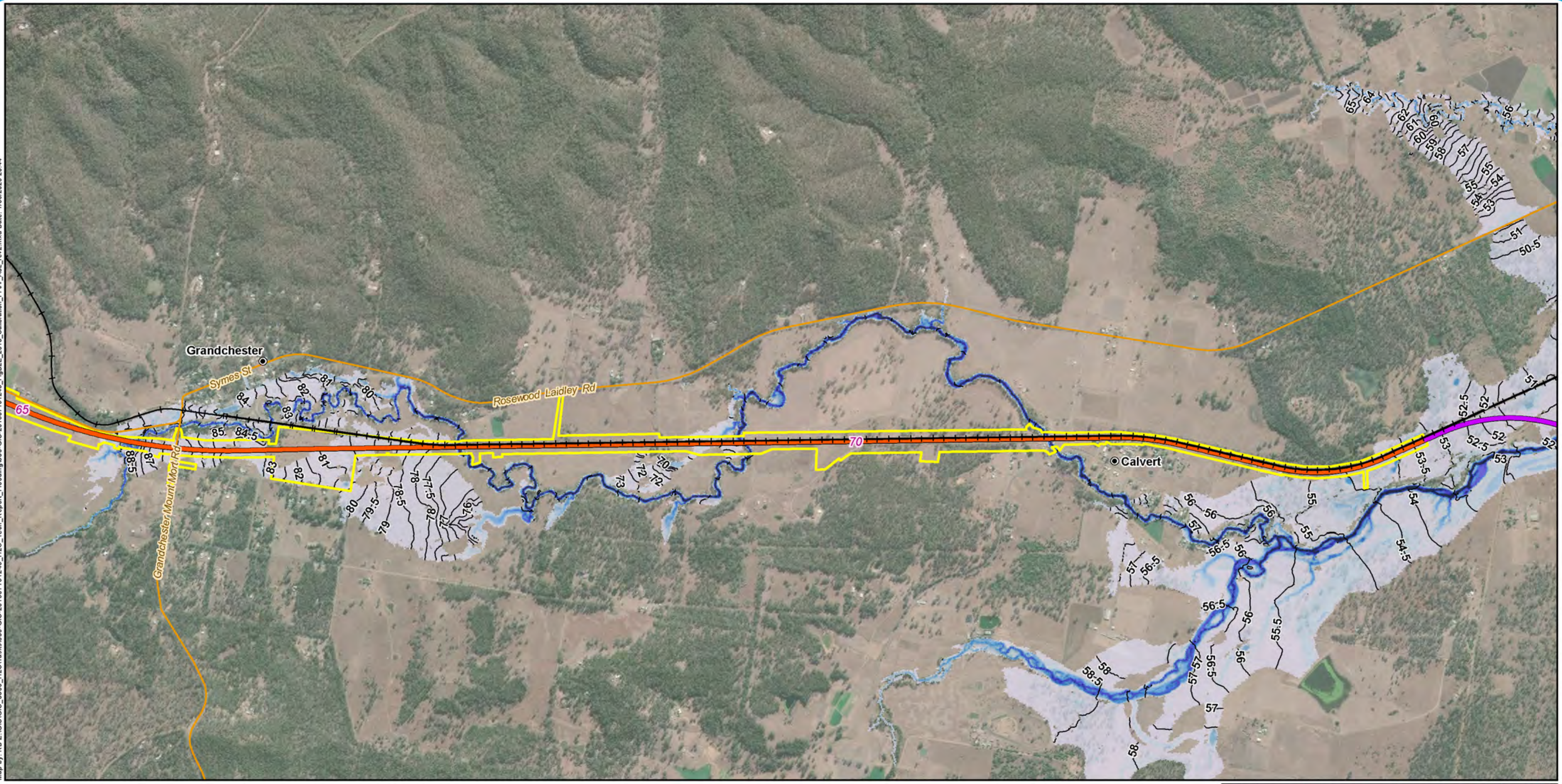
Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

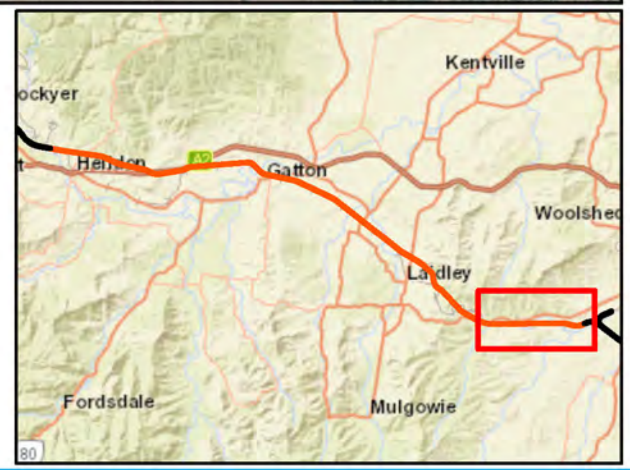
Helidon to Calvert

Figure B2-D: 2011 Calibration Event with Flood markers: Western Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigB2E_2013_Calibration_FFJV_A3L_rev2.mxd Date: 1/06/2020 20:44





Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

Note:
Information presented is from a regional Western Creek flood model. Local catchment surface flows are not presented.

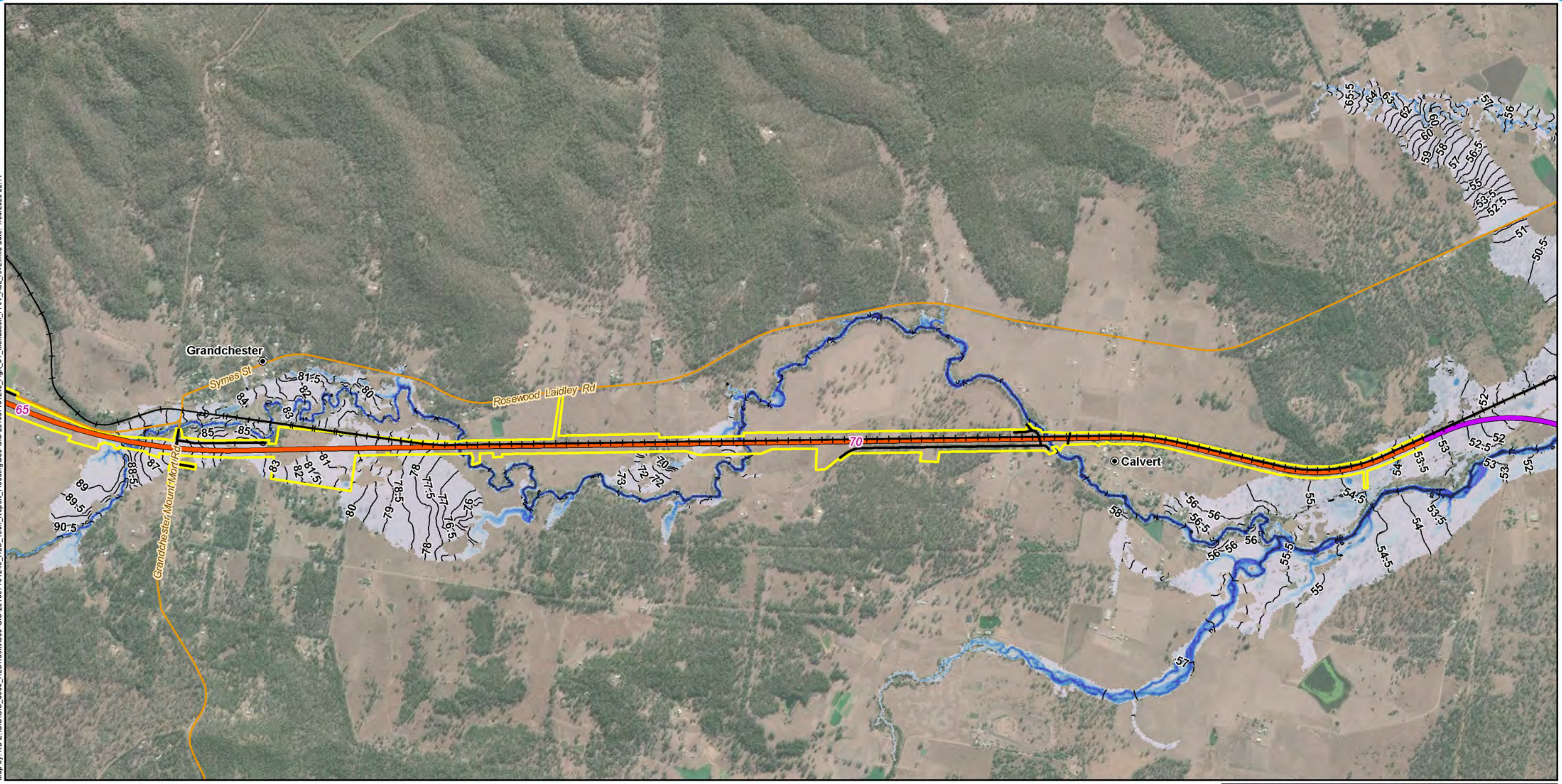
A3 scale: 1:25,000
0 0.15 0.3 0.45 0.6 0.75km

Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert
Figure B2-E: 2013 Calibration Event: Western Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



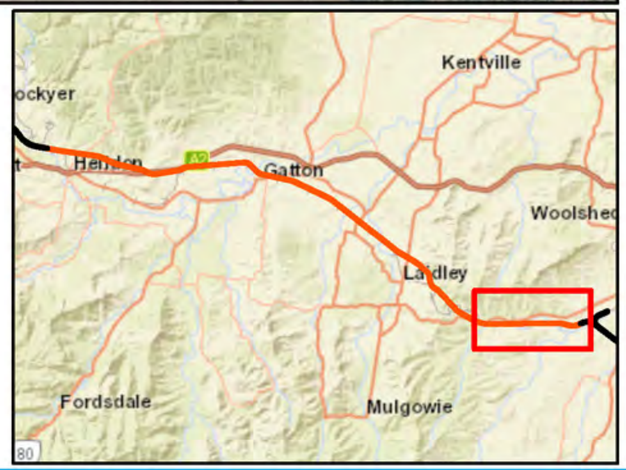
Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_5Y_Inundation_FFJV_A3L_rev2.mxd Date: 1/06/2020 22:11

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0



A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

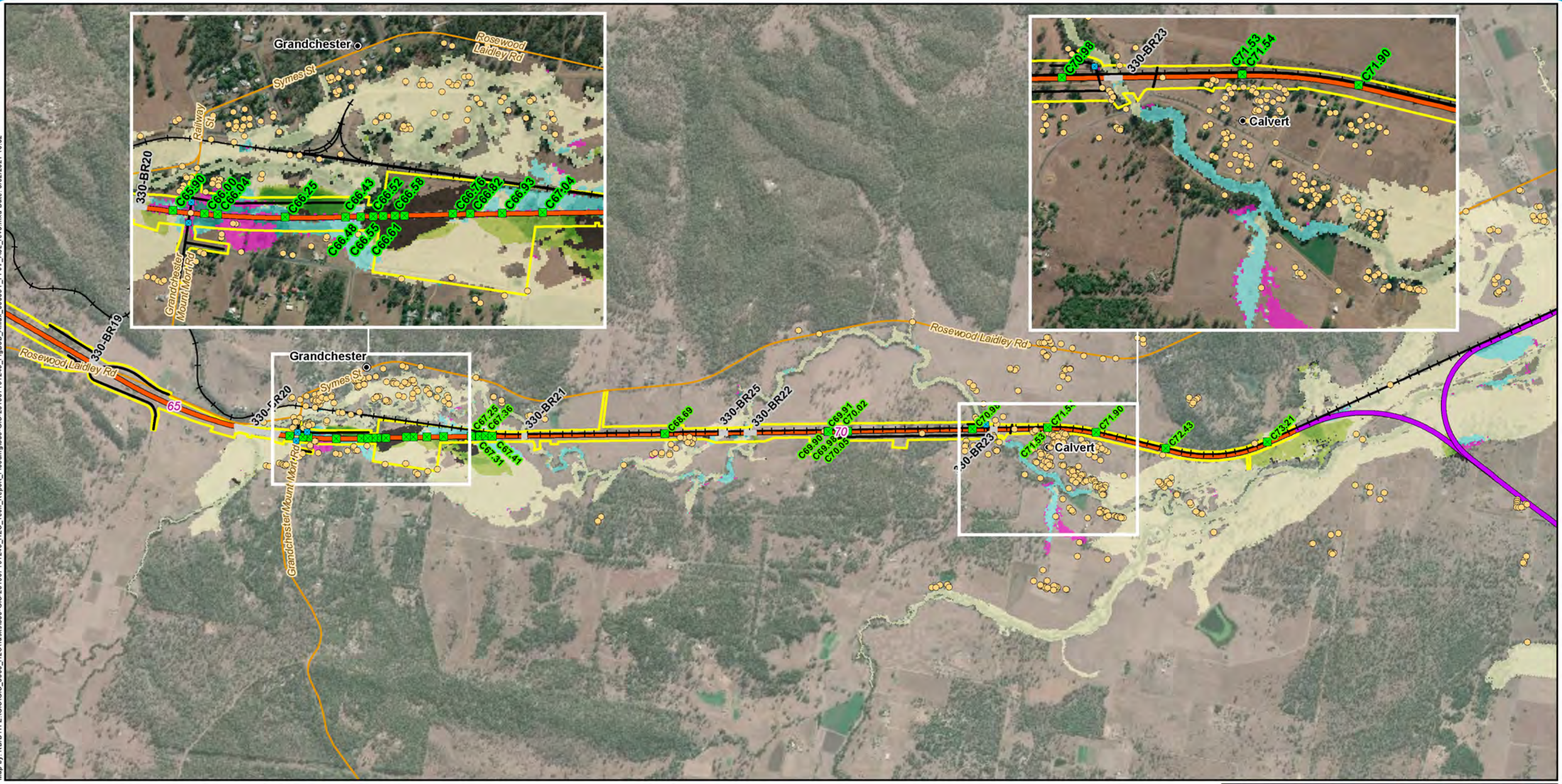
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure B-3A: 20% AEP Event Existing Case - Inundation Extent: Western Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigB3B_Afflux_00005Y_FFJV_A3L_rev3.mxd Date: 3/02/2021 16:32

Legend

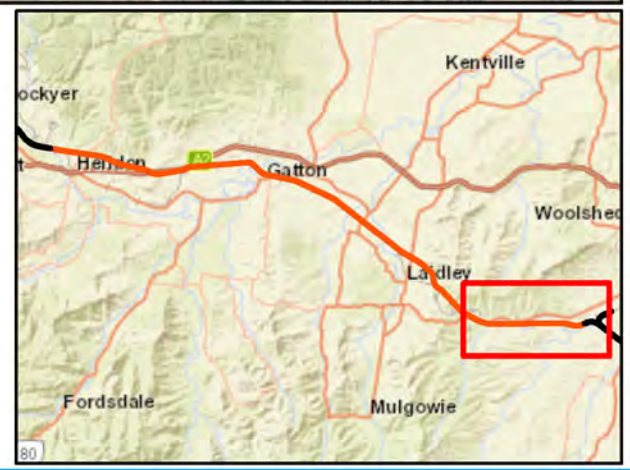
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

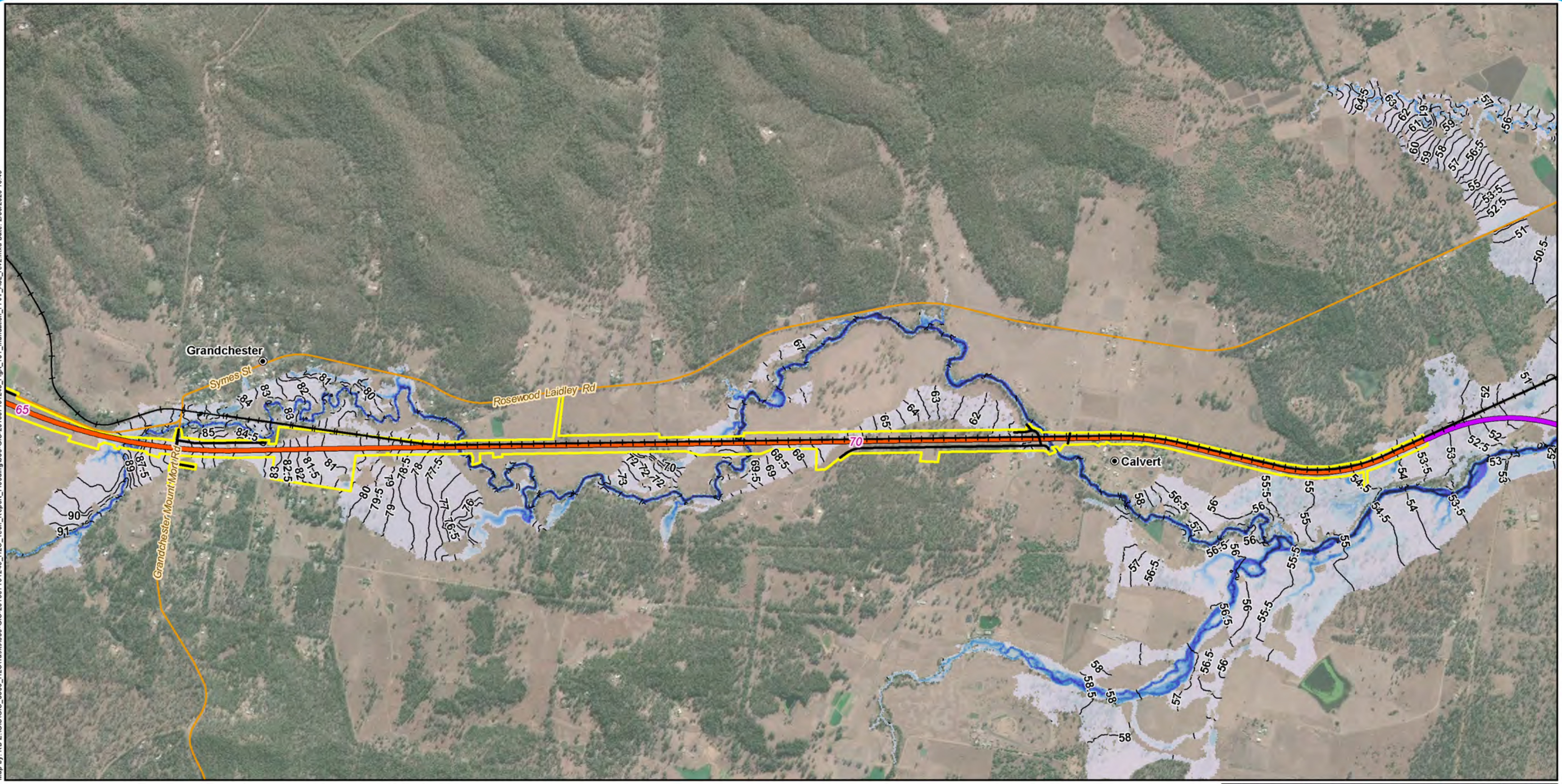
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure B-3B: 20% AEP Event - Developed Case - Afflux: Western Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



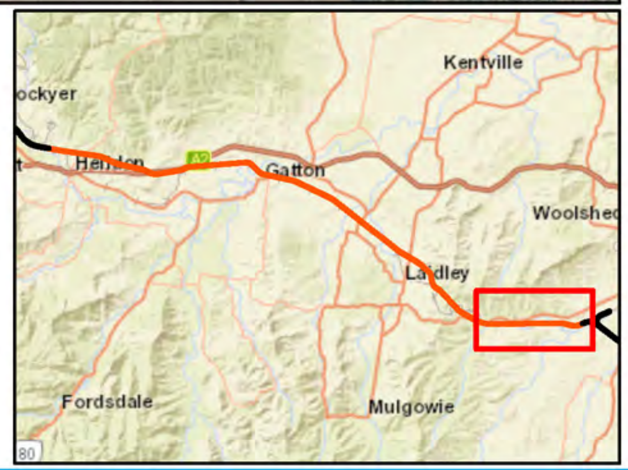
Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715124_H2C_Tech_Report_Flooding\330-GIS-20190715124_FigX_10Y_Inundation_FFJV_A3L_rev2.mxd Date: 2/06/2020 16:45

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0



A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

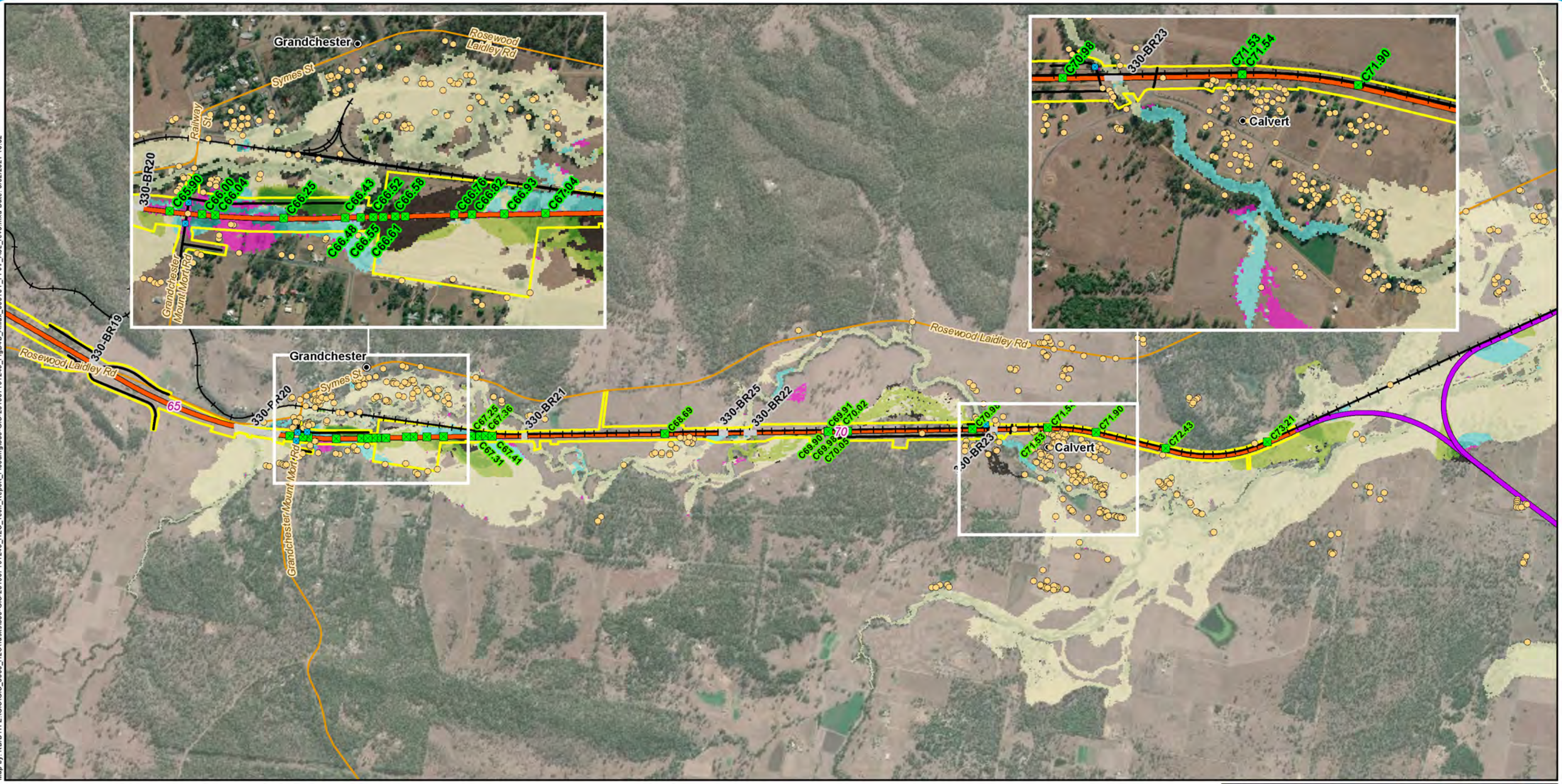
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

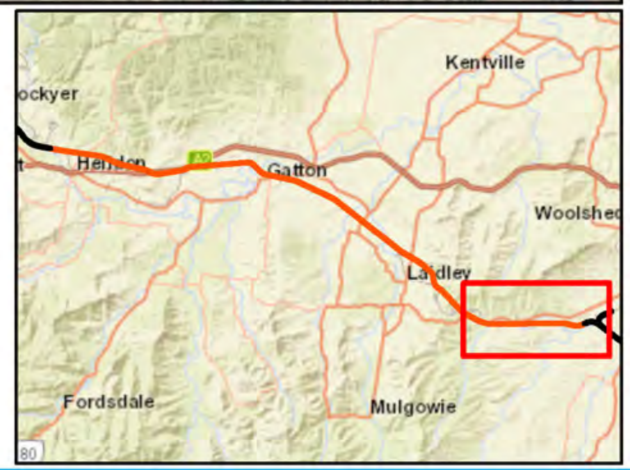
Helidon to Calvert

Figure B-4A: 10% AEP Event - Existing Case - Inundation Extent: Western Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715245_H2C_Tech_Report_Flooding\330-GIS-20190715245_FigB4B_Afflux_00010Y_FFJV_A3L_rev3.mxd Date: 3/02/2021 16:32



Legend

- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

Future Freight
Integrating Community, Environment and Engineering

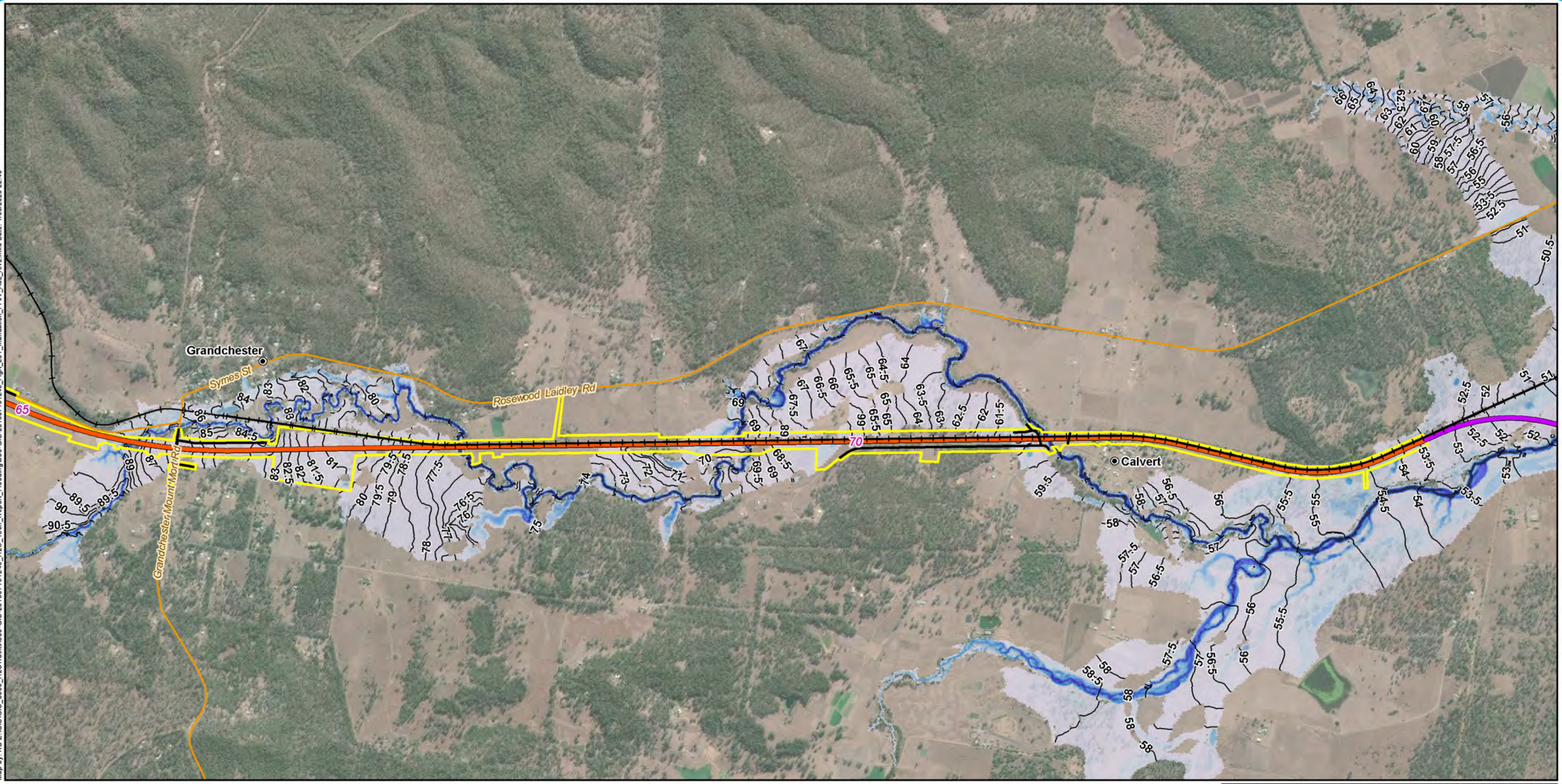
Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

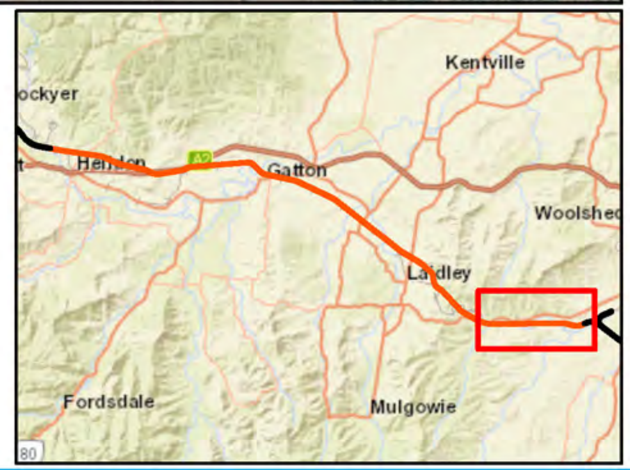
Helidon to Calvert

Figure B-4B: 10% AEP Event - Developed Case - Afflux: Western Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715 1245_H2C_Tech_Report_Flooding\330-GIS-20190715 1245_FigX_20Y_Inundation_FFJV_A3L_rev2.mxd Date: 1/06/2020 22:40





Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

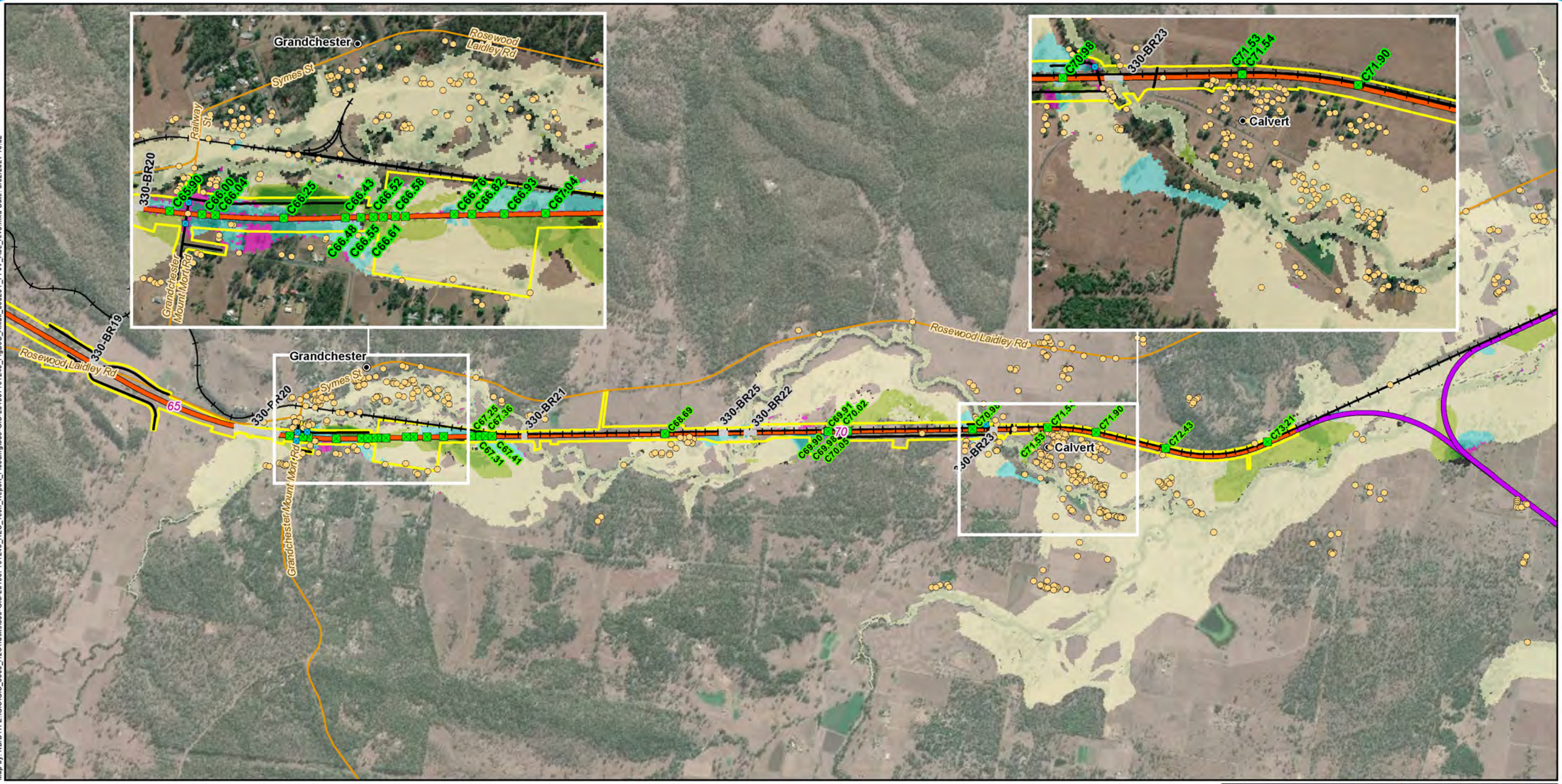
Future Freight
Integrating Community, Environment and Engineering

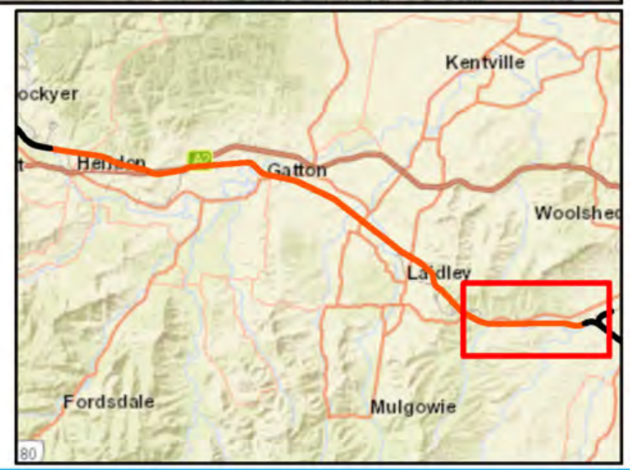
Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure B-5A: 5% AEP Event - Existing Case - Inundation Extent: Western Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community





Legend

- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

Future Freight
Integrating Community, Environment and Engineering

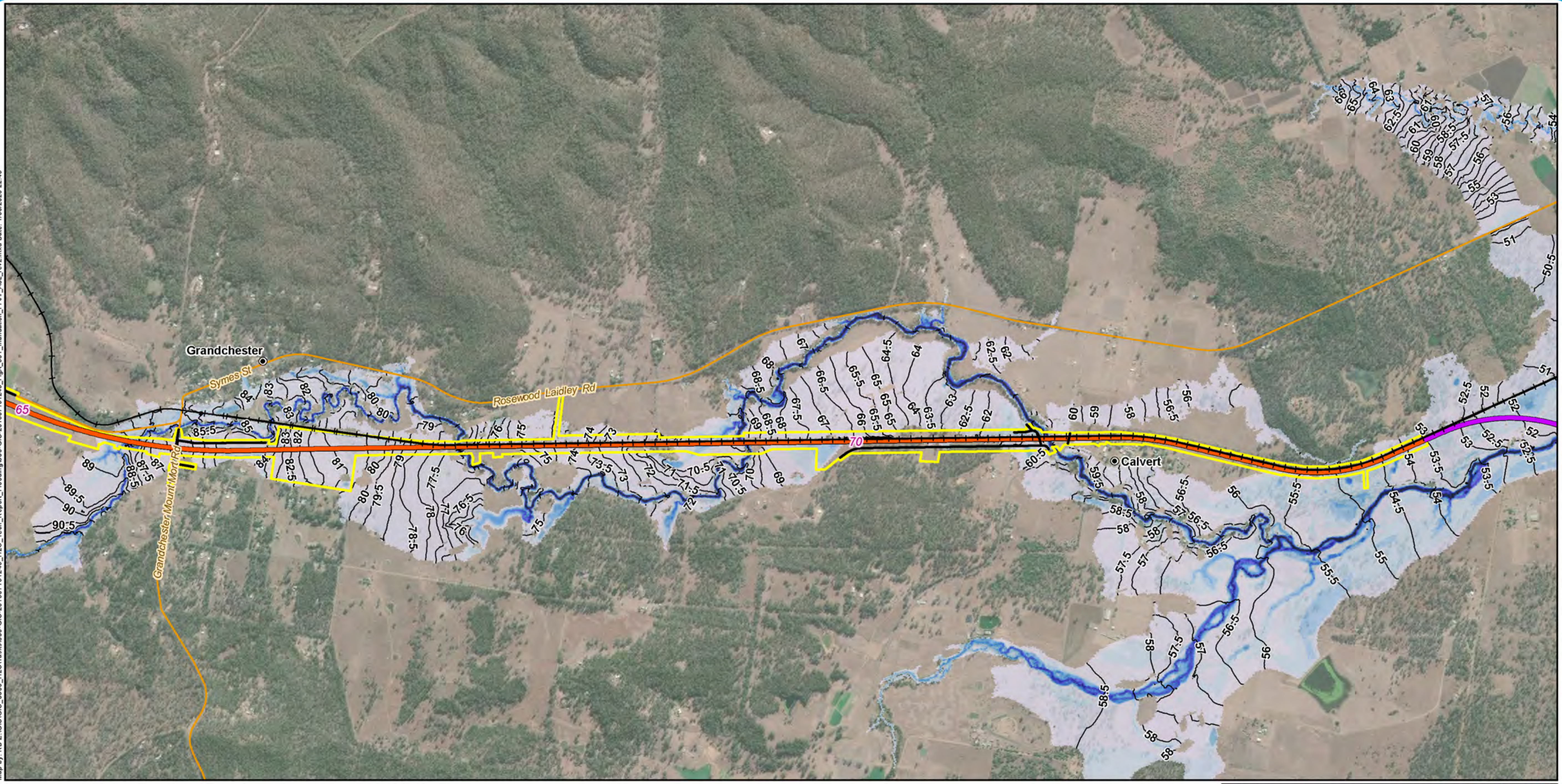
Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure B-5B: 5% AEP Event - Developed Case - Afflux: Western Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715124_H2C_Tech_Report_Flooding\330-GIS-20190715124_FigX_50Y_Inundation_FFJV_A3L_rev2.mxd Date: 1/06/2020 22:49

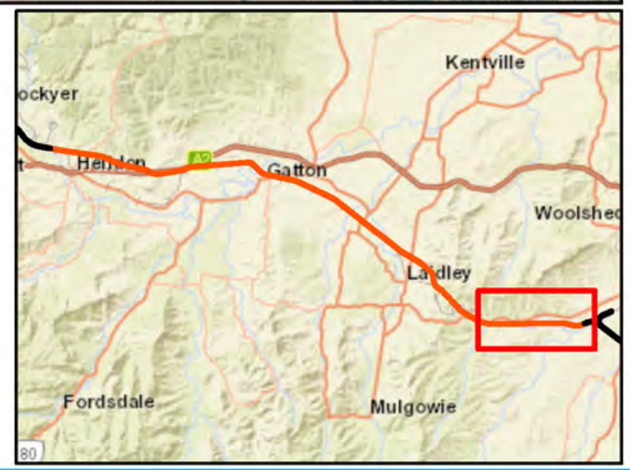


Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0



A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

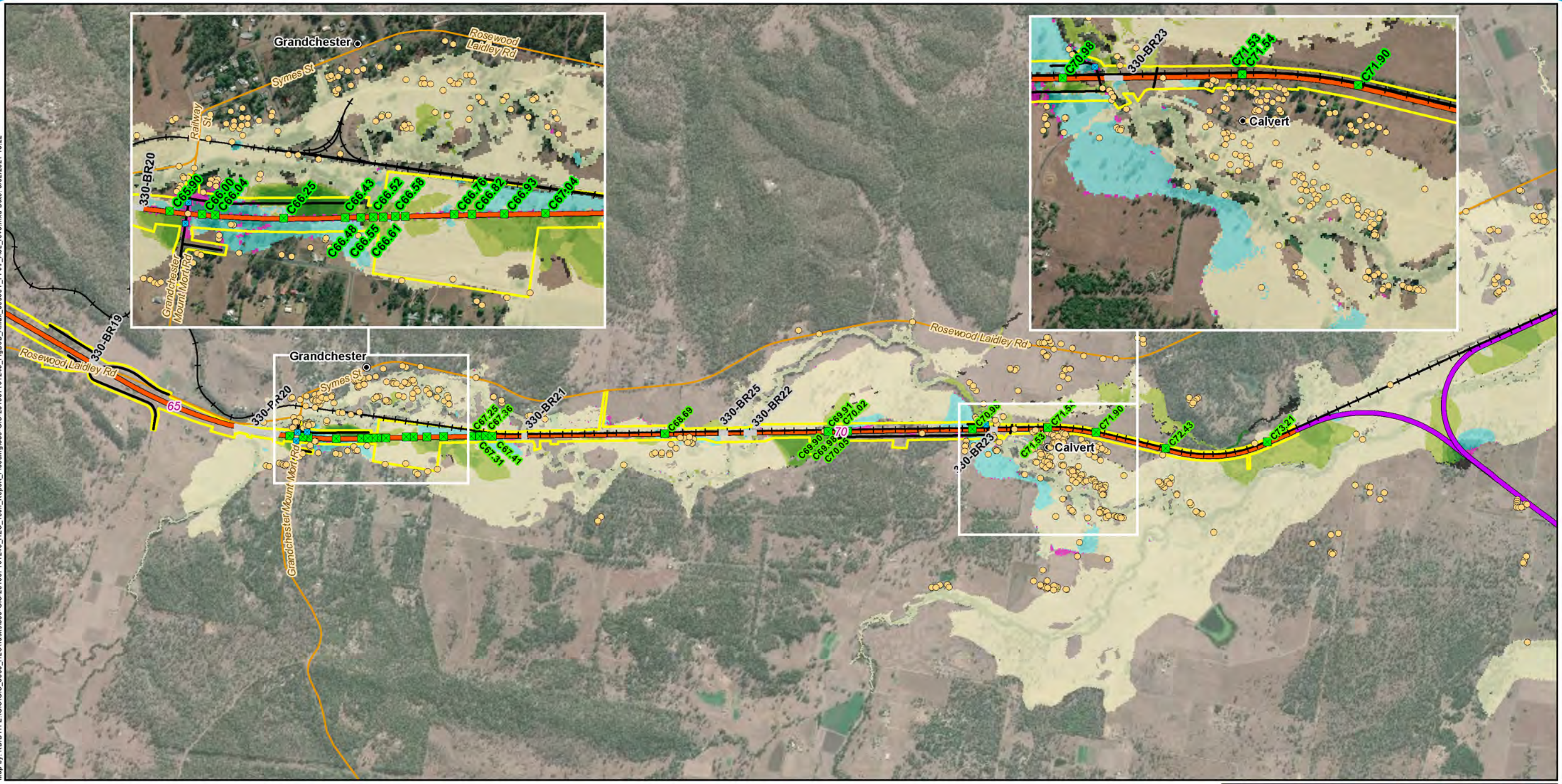
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure B-6A: 2% AEP Event - Existing Case - Inundation Extent: Western Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Legend

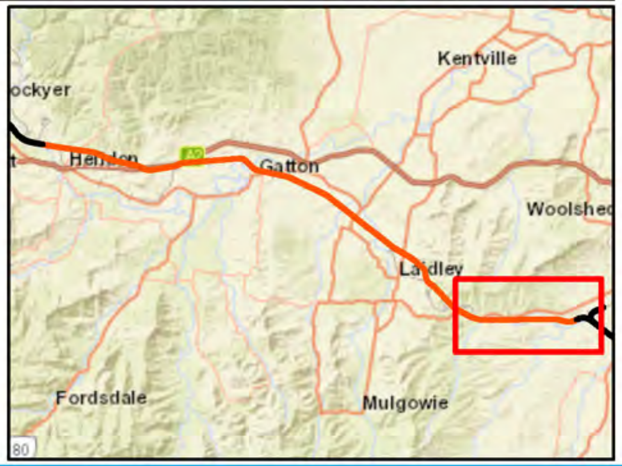
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

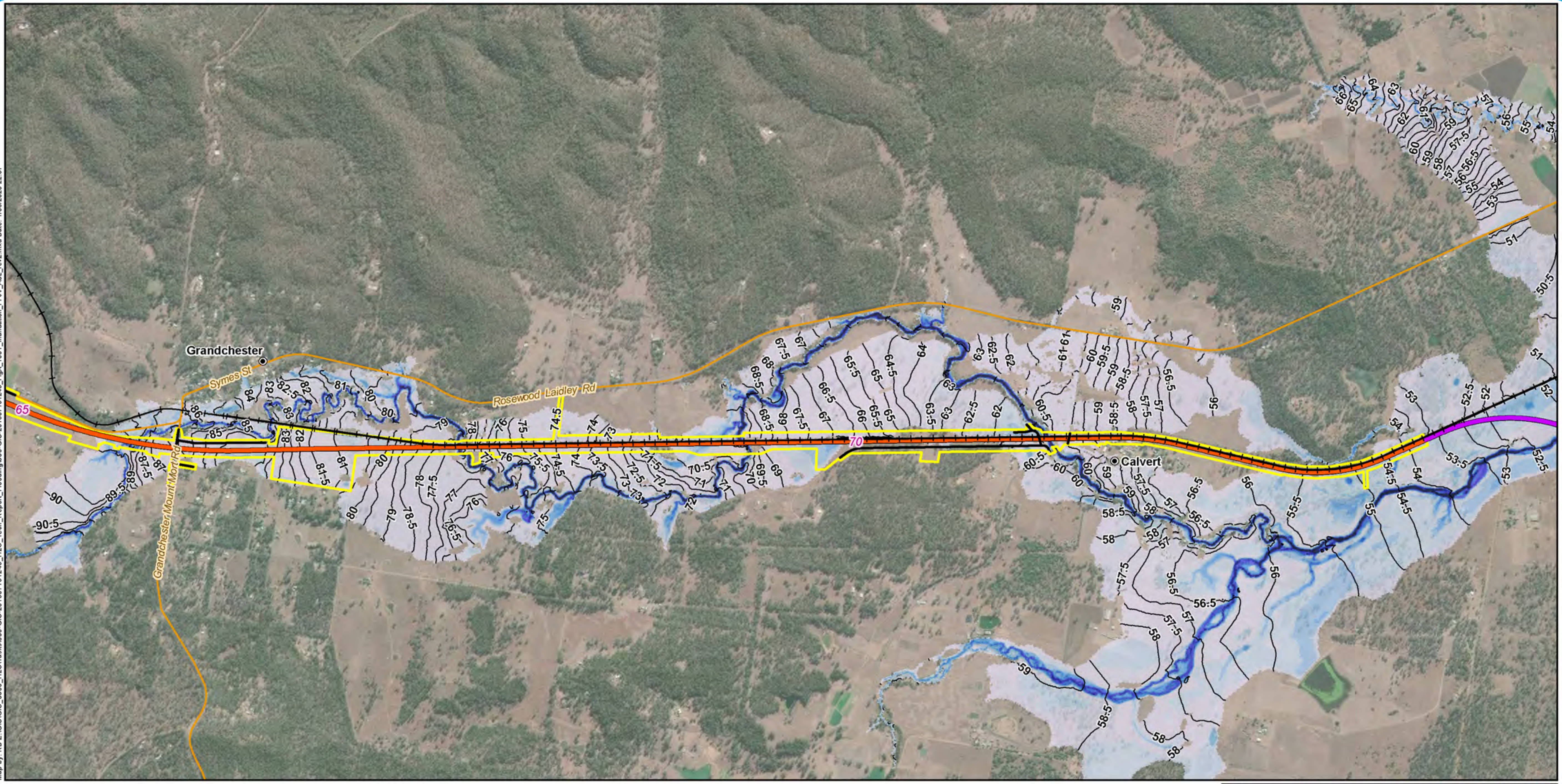
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure B-6B: 2% AEP Event - Developed Case - Afflux: Western Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

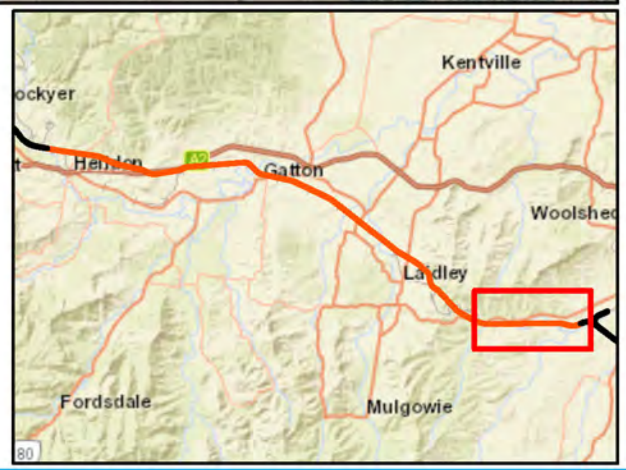


Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0



A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

Future Freight
Integrating Community, Environment and Engineering

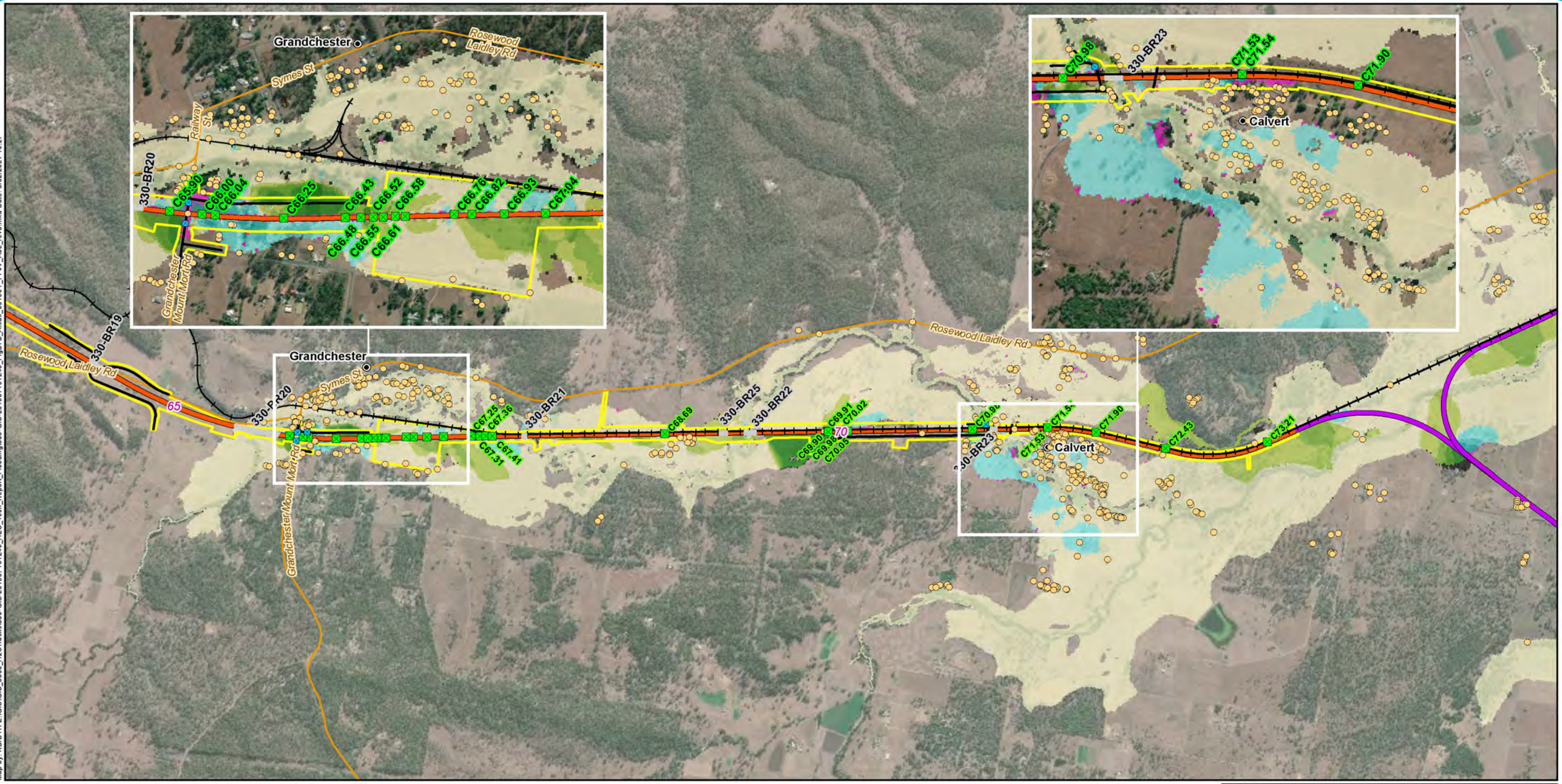
Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure B-7A: 1% AEP Event - Existing Case - Inundation Extent: Western Creek

Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_100Y_Inundation_FFJV_A3L_rev2.mxd Date: 1/06/2020 22:57

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigB7B_Afflux_00100Y_FFJV_A3L_rev3.mxd Date: 3/02/2021 16:27

Legend

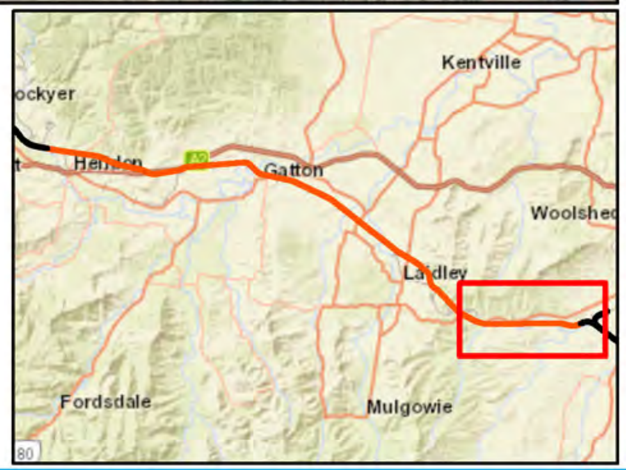
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

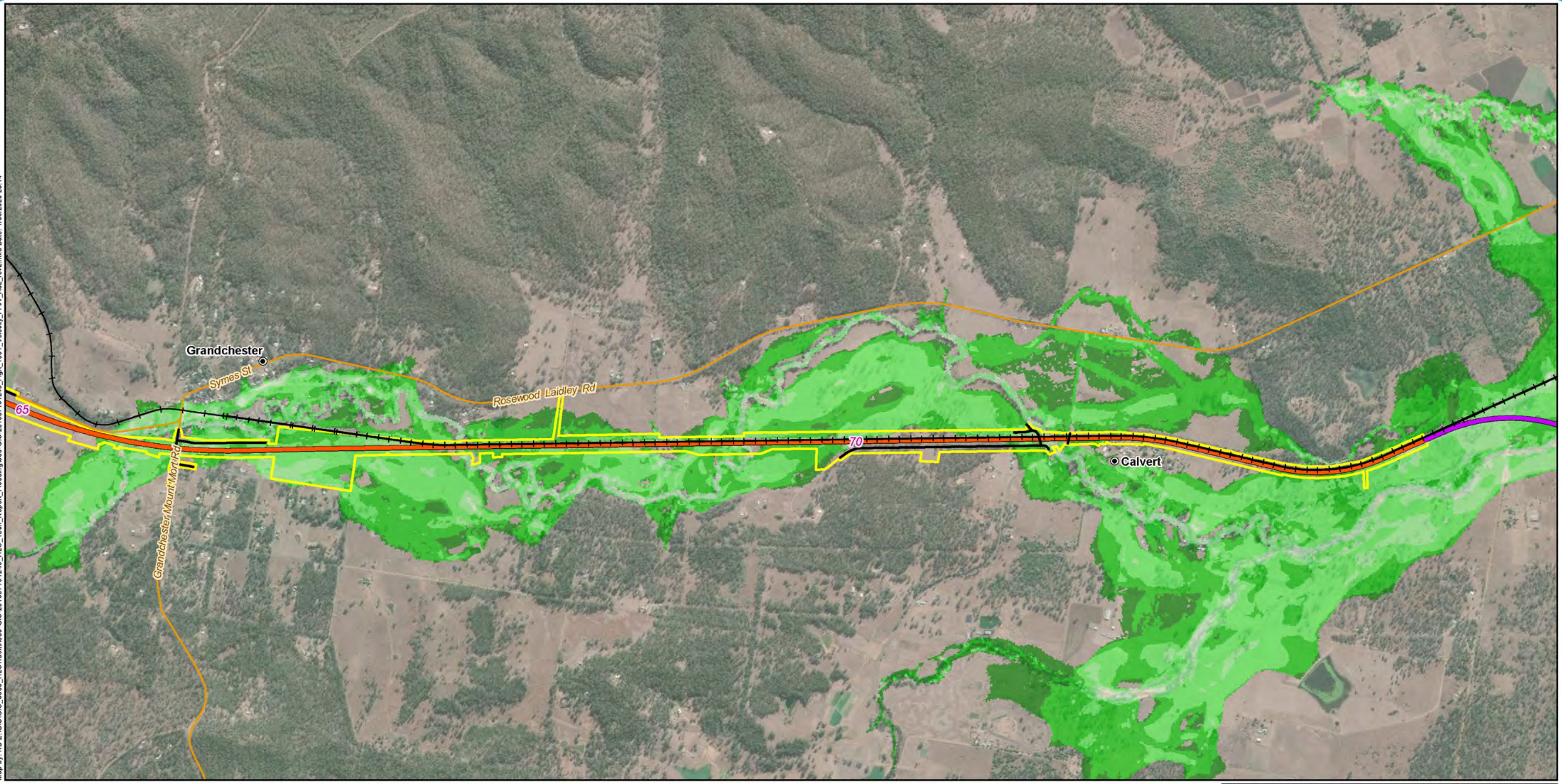
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

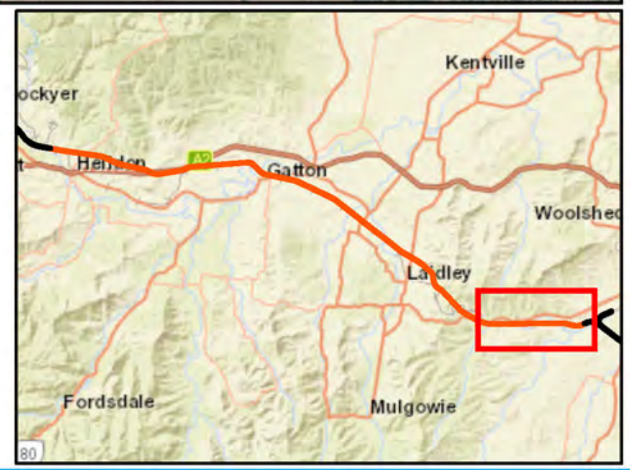
Helidon to Calvert

Figure B-7B: 1% AEP Event - Developed Case - Afflux: Western Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_100Y_Velocity_FFJV_A3L_rev2.mxd Date: 1/06/2020 23:14



Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint

Peak velocity (m/s)

0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0

A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

Future Freight
Integrating Community, Environment and Engineering

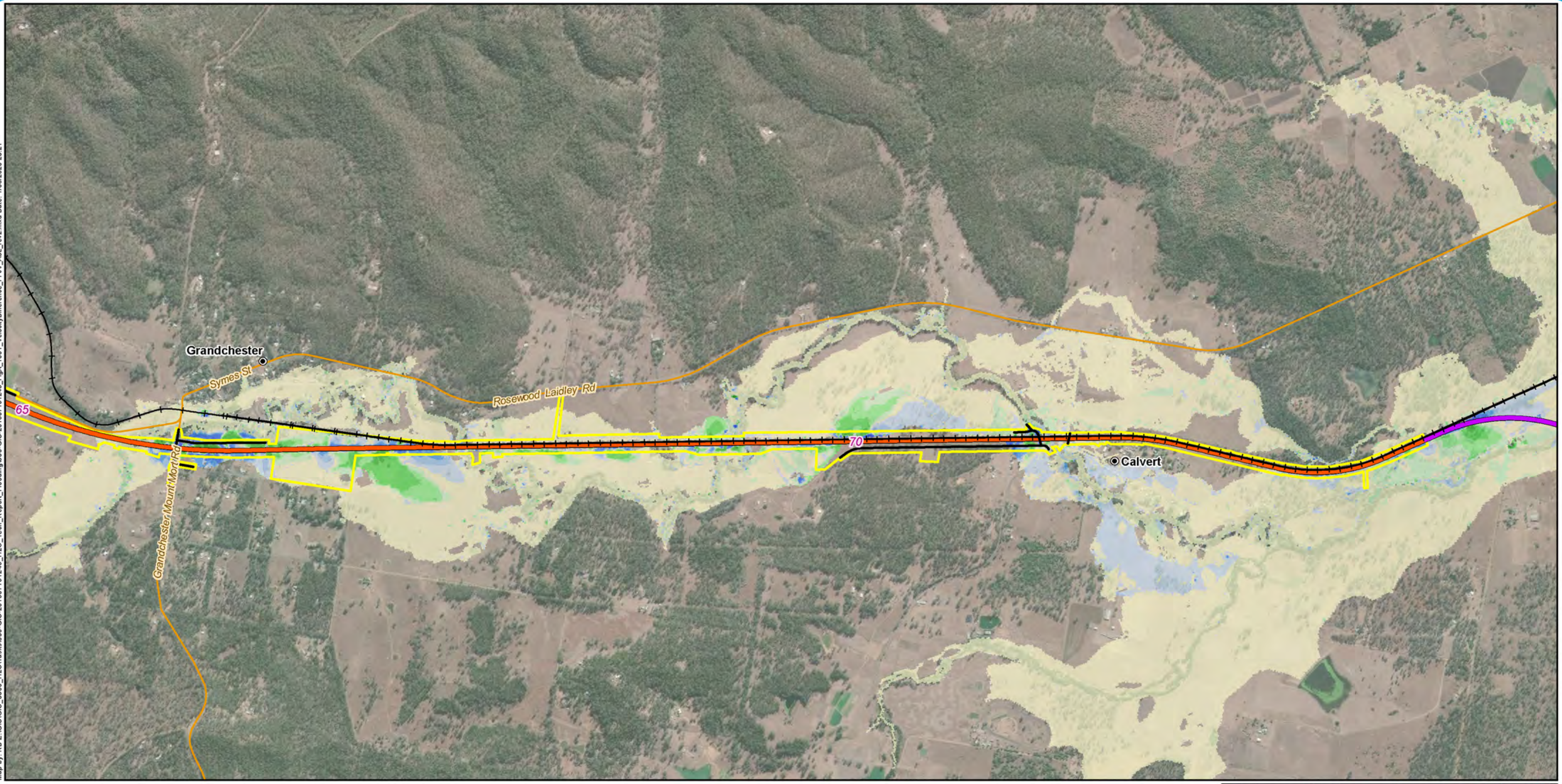
Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

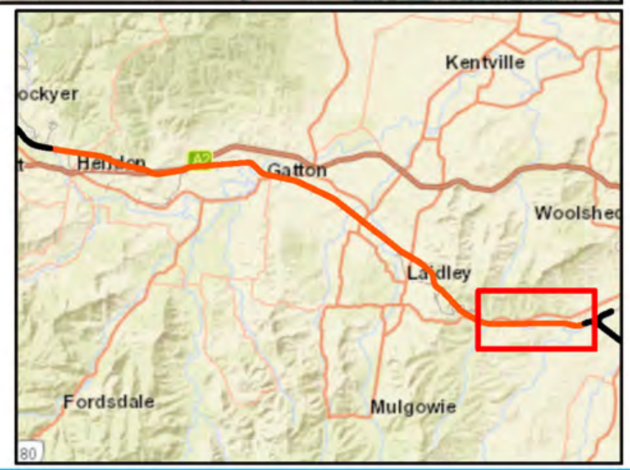
Helidon to Calvert

Figure B-7C: 1% AEP Event - Developed Case - Velocity: Western Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_100Y_VelocityDifference_FFJV_A3L_rev2.mxd Date: 1/06/2020 23:21





Legend

5	Chainage (km)
⊙	Localities
	Existing rail
	H2C project alignment
	C2K project alignment
	Road design
	Minor roads
	EIS disturbance footprint

Change in peak velocity (m/s)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

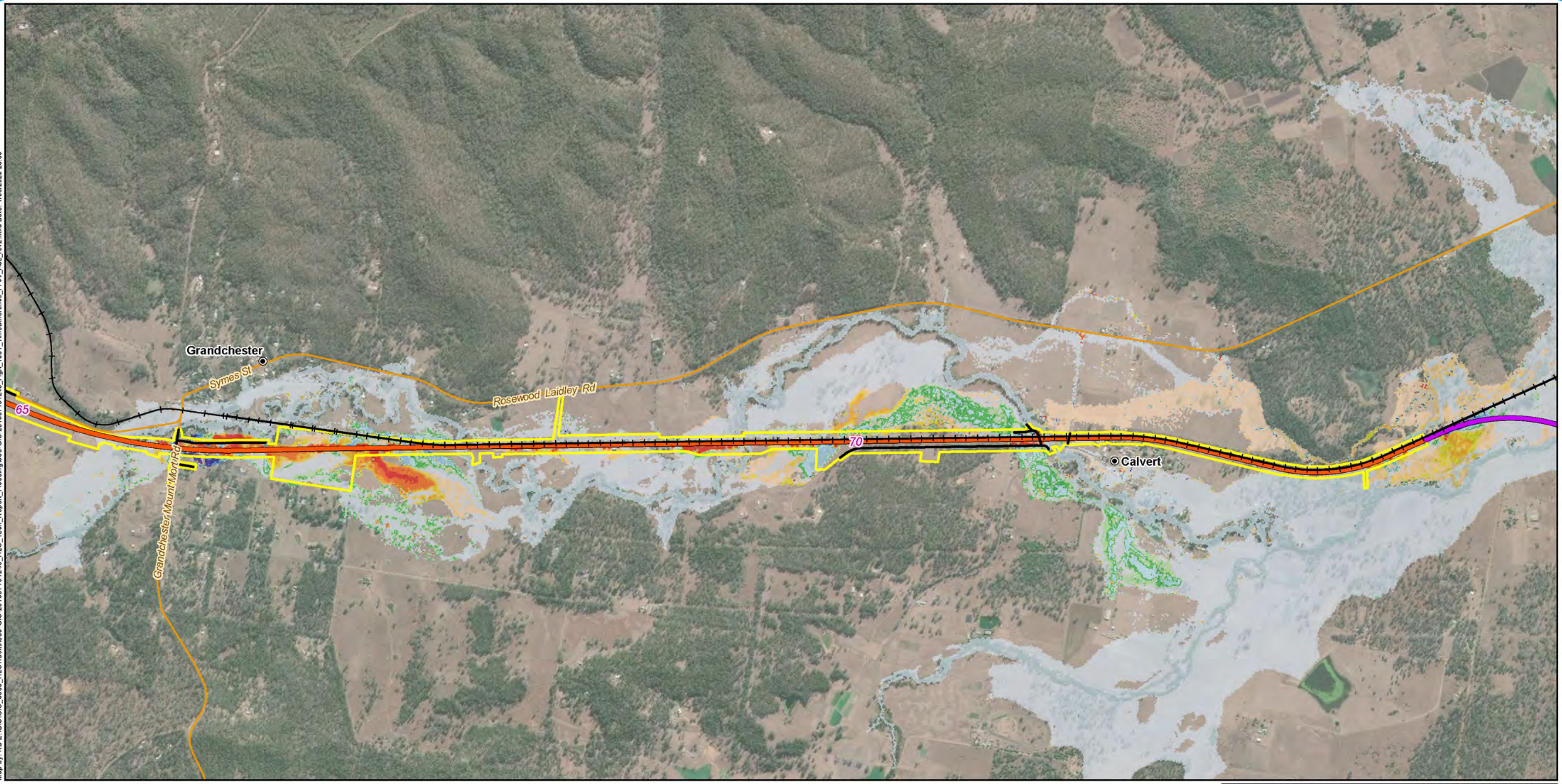
Future Freight
Integrating Community, Environment and Engineering

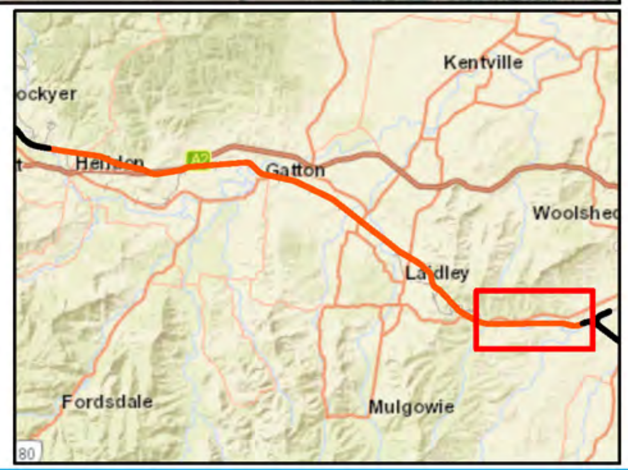
Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure B-7D: 1% AEP Event - Developed Case - Change in peak velocities: Western Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_100Y_TimeDifference_FFJV_A3L_rev2.mxd Date: 1/06/2020 23:05

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint

Difference in Time of Submergence

- Over 10 hour decrease
- Up to 10 hour decrease
- Up to 5 hour decrease
- Up to 2 hour decrease
- Up to 1 hour decrease
- Up to 0.5 hour decrease
- Within 15 minutes
- Up to 0.5 hour increase
- Up to 1 hour increase
- Up to 2 hour increase
- Up to 5 hour increase
- Up to 10 hour increase
- Over 10 hour increase

A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

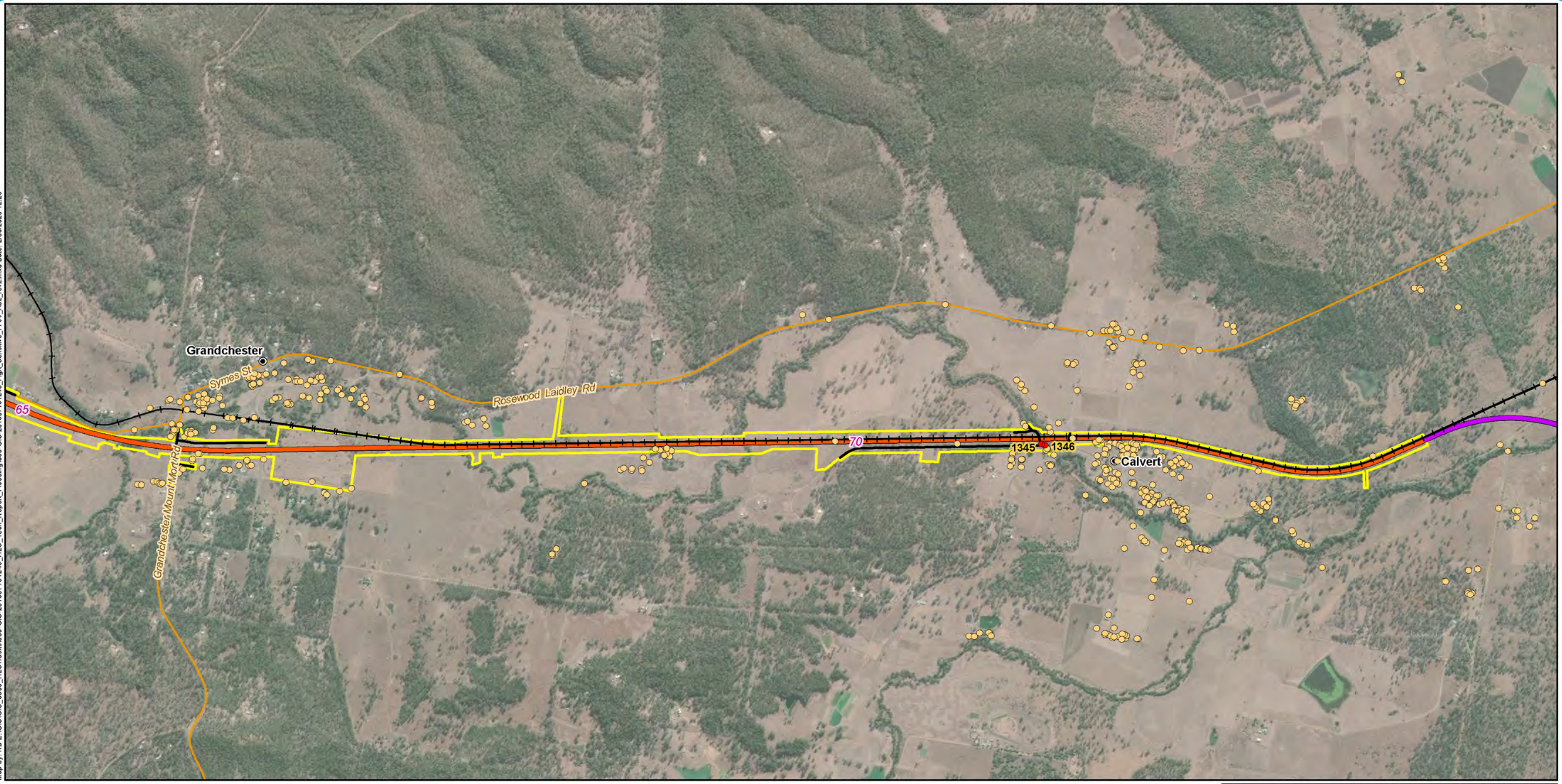
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

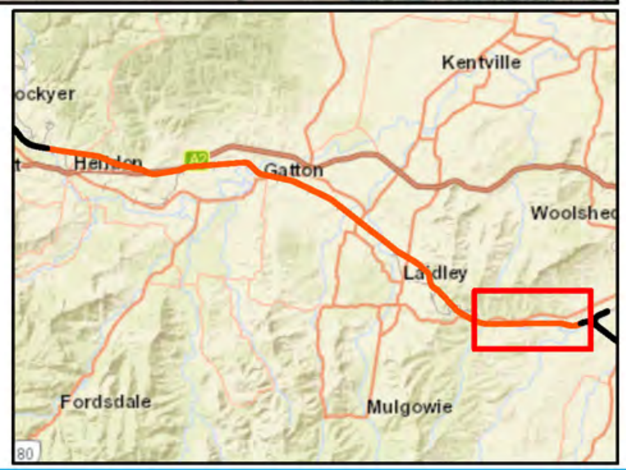
Helidon to Calvert

Figure B-7E: 1% AEP Event - Developed Case - Difference in Time of Submergence: Western Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_Sensitive_FFJV_A3L_rev2.mxd Date: 2/06/2020 12:26



Legend

Flood sensitive receptors
- 100 Labelled (see note)
- Unlabelled (see note)
- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint

Note:
Due to the large number of flood sensitive receptors, only those which experience a change in peak water level of greater than 10mm under the 1% AEP event are labelled.

A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

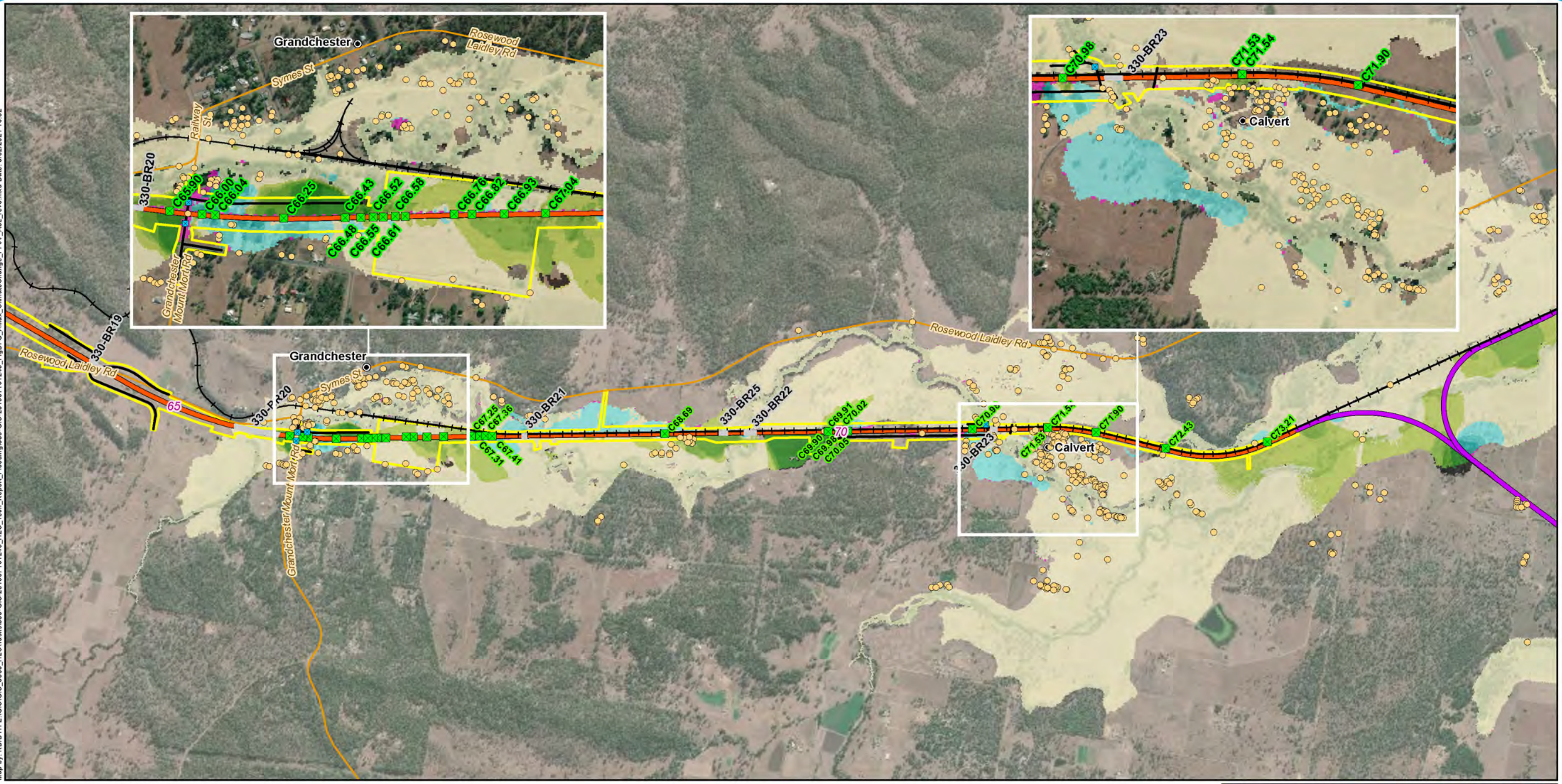
Future Freight
Integrating Community, Environment and Engineering

Issue date: 02/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure B-7F: Location of flood sensitive receptors: Western Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigB7G_Afflux_ClimateChange_FFJV_A3L_rev3.mxd Date: 3/02/2021 16:32

Legend

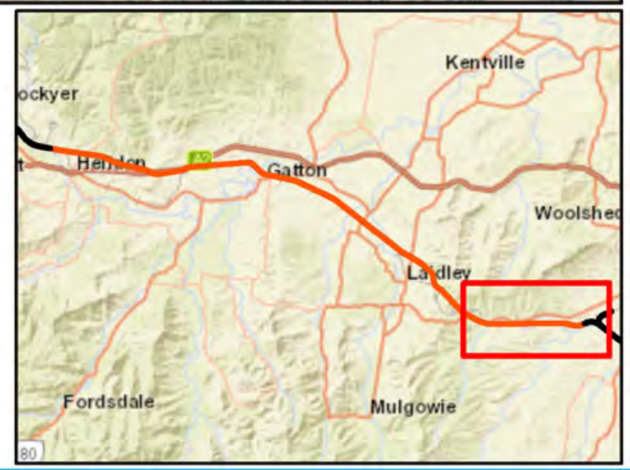
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

Future Freight
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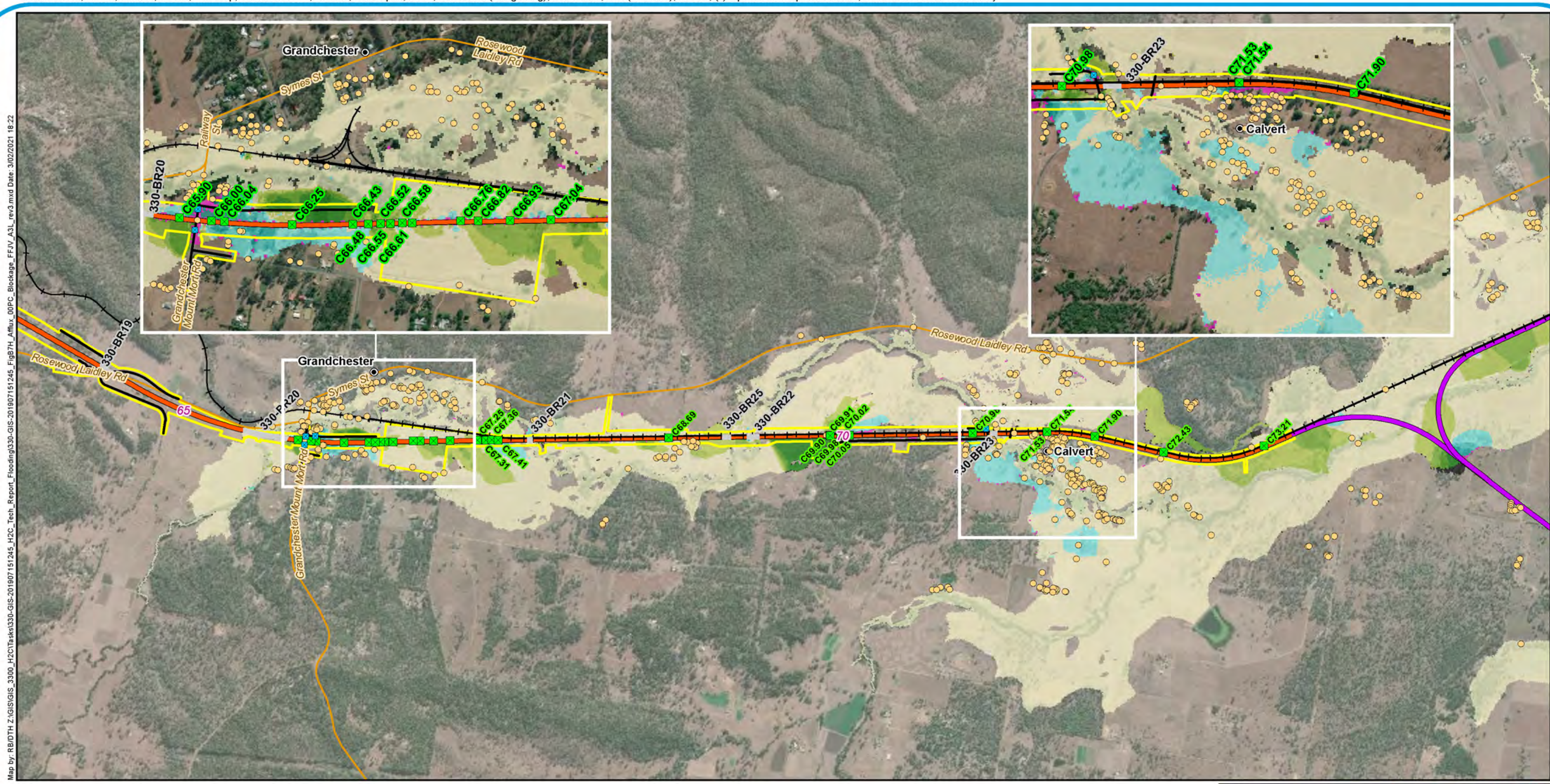
Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure B-7G: 1% AEP Event with Climate Change: Western Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Legend

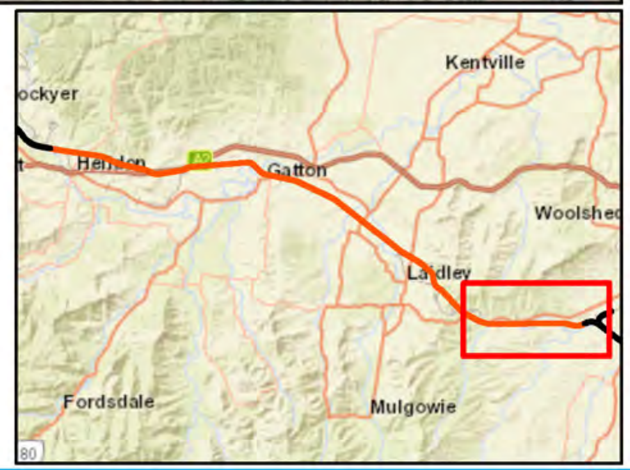
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- Road design
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

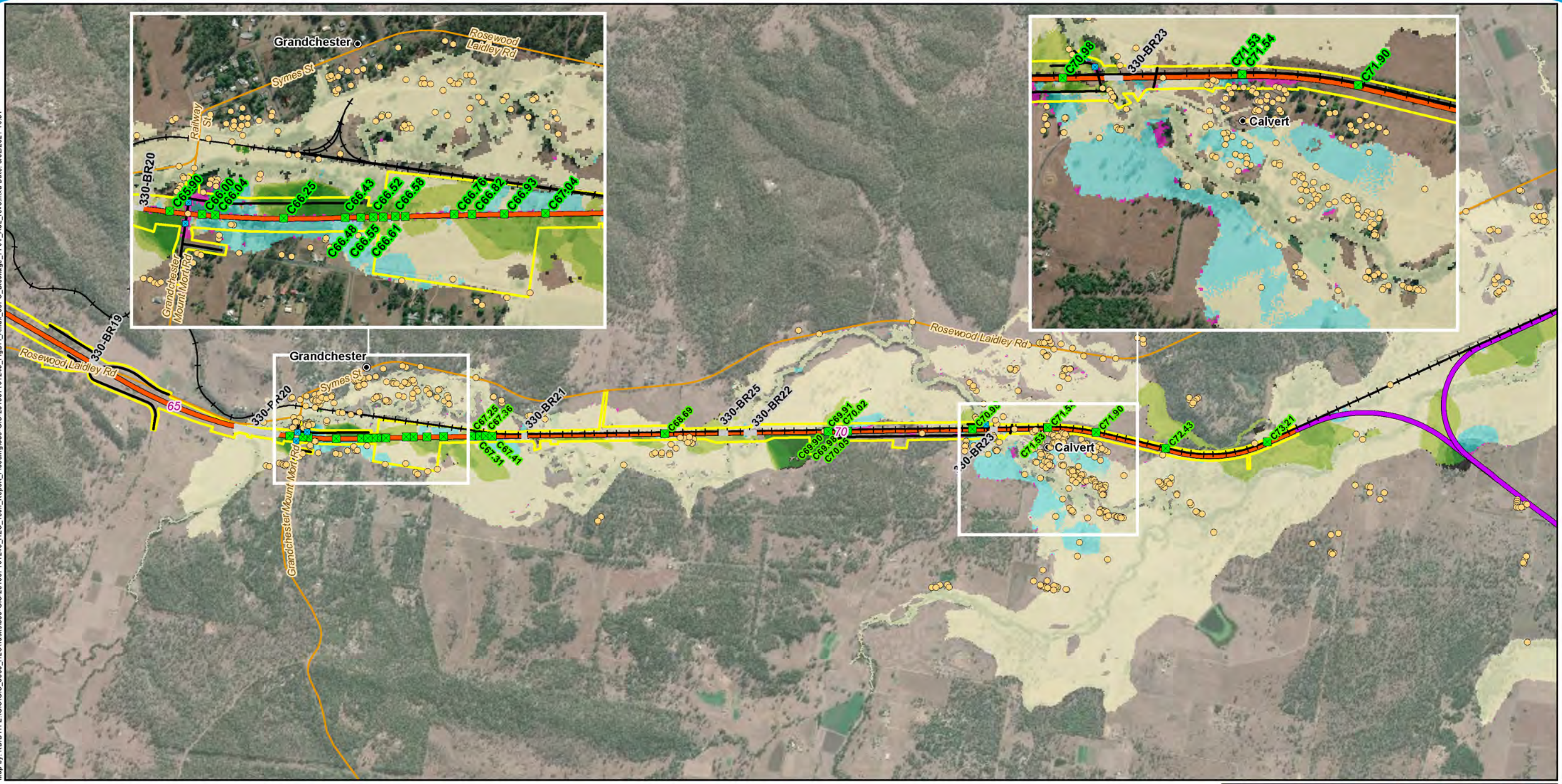
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

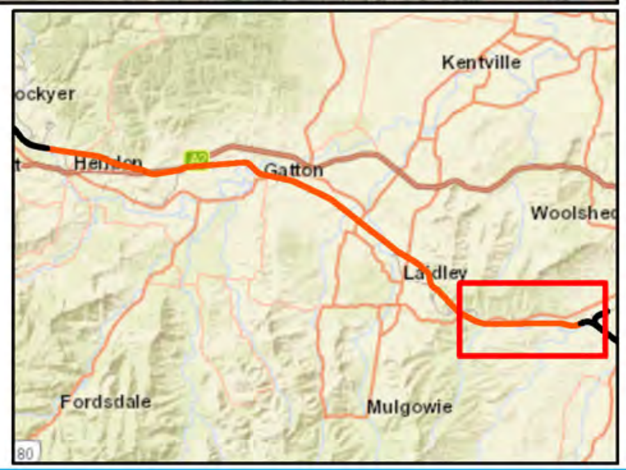
Helidon to Calvert

Figure B-7H: 1% AEP Event with 0% Blockage on Culverts: Western Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigB7I_Afflux_50PC_Blockage_FFJV_A3L_rev3.mxd Date: 3/02/2021 16:31



Legend

- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

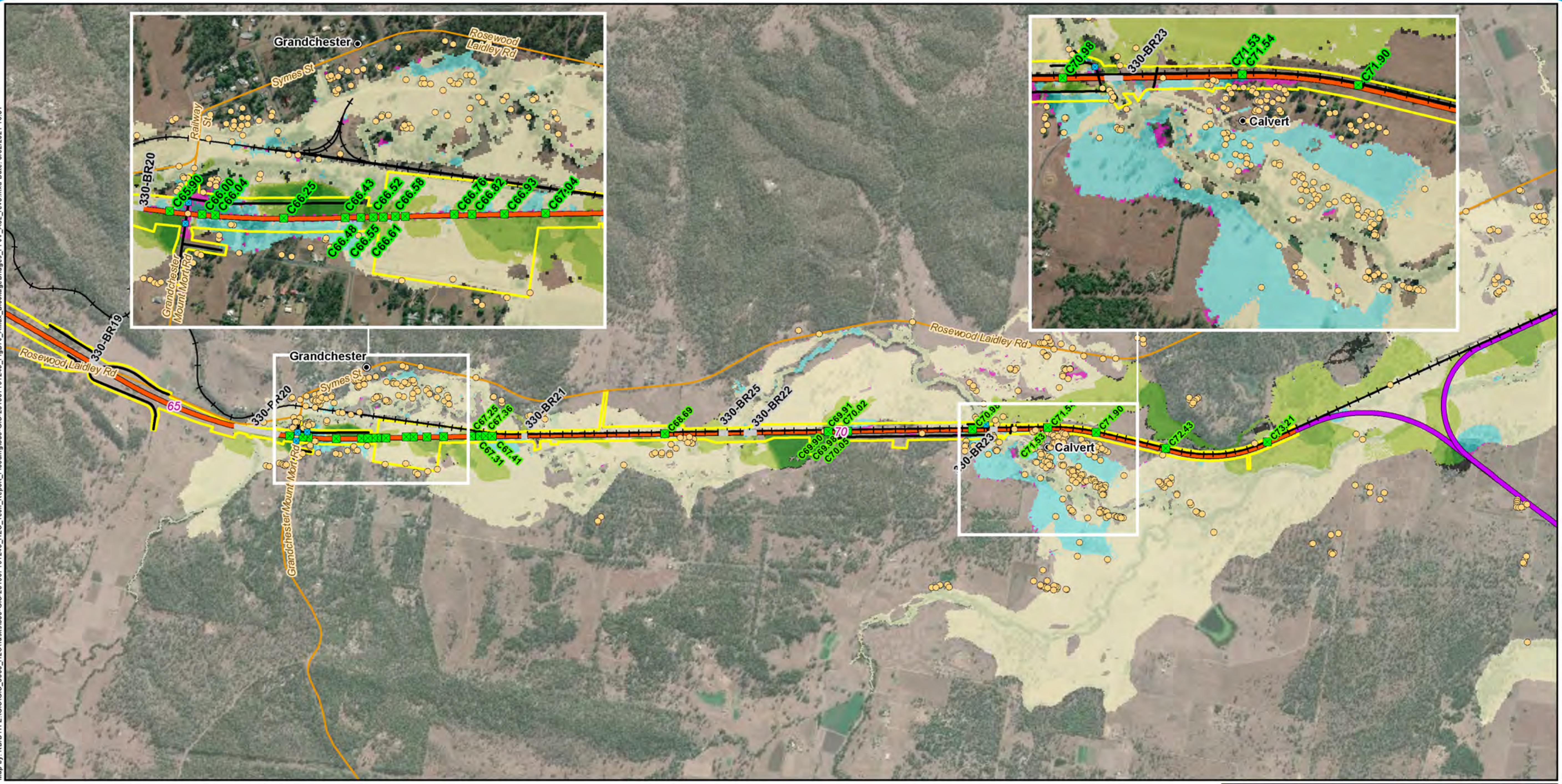
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure B-7l: 1% AEP Event with 50% Blockage on Culverts: Western Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715\1245_H2C_Tech_Report_Flooding\330-GIS-20190715\1245_FigB7J_Afflux_BlockageBridges_FFJV_A3L_rev3.mxd Date: 3/02/2021 16:31

Legend

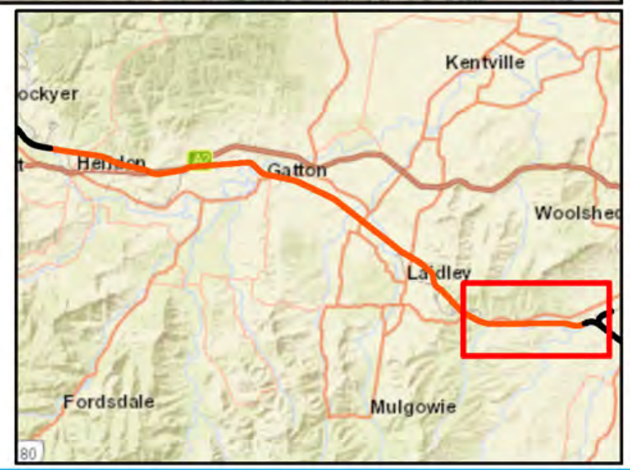
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

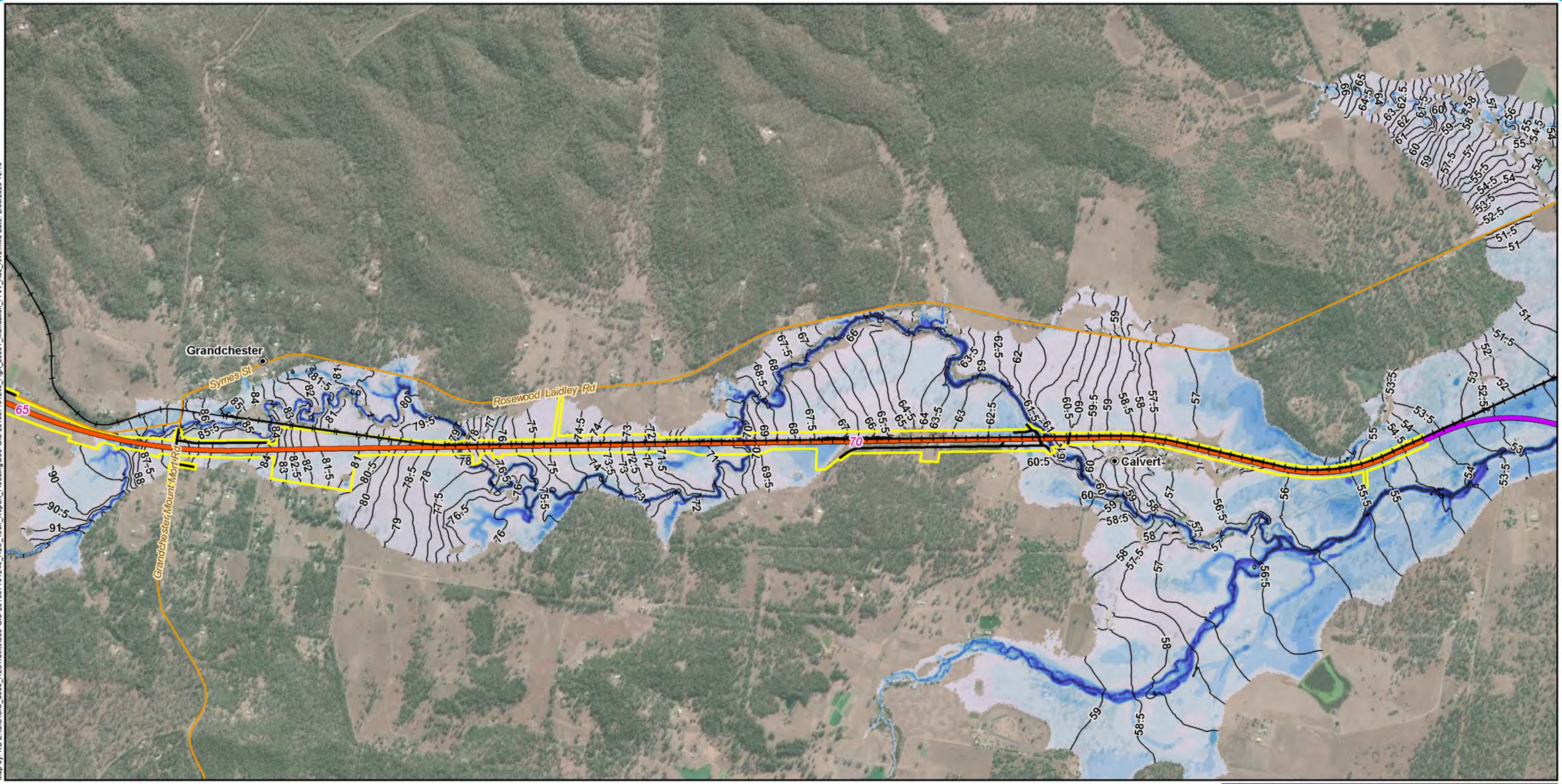
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure B-7J: 1% AEP Event with Blockage on Bridges: Western Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



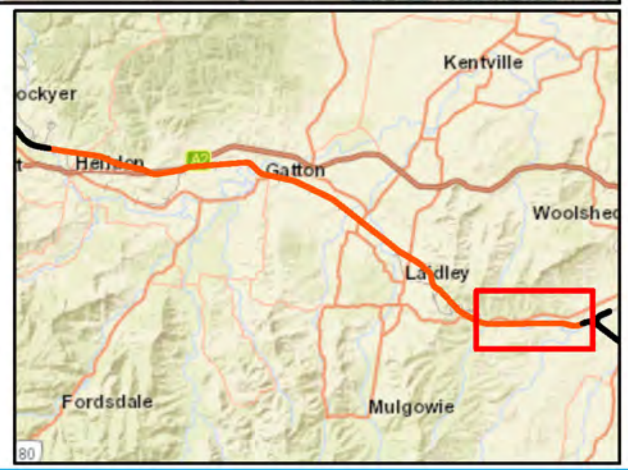
Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_2000Y_Inundation_FFJV_A3L_rev2.mxd Date: 2/06/2020 10:16

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0



A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

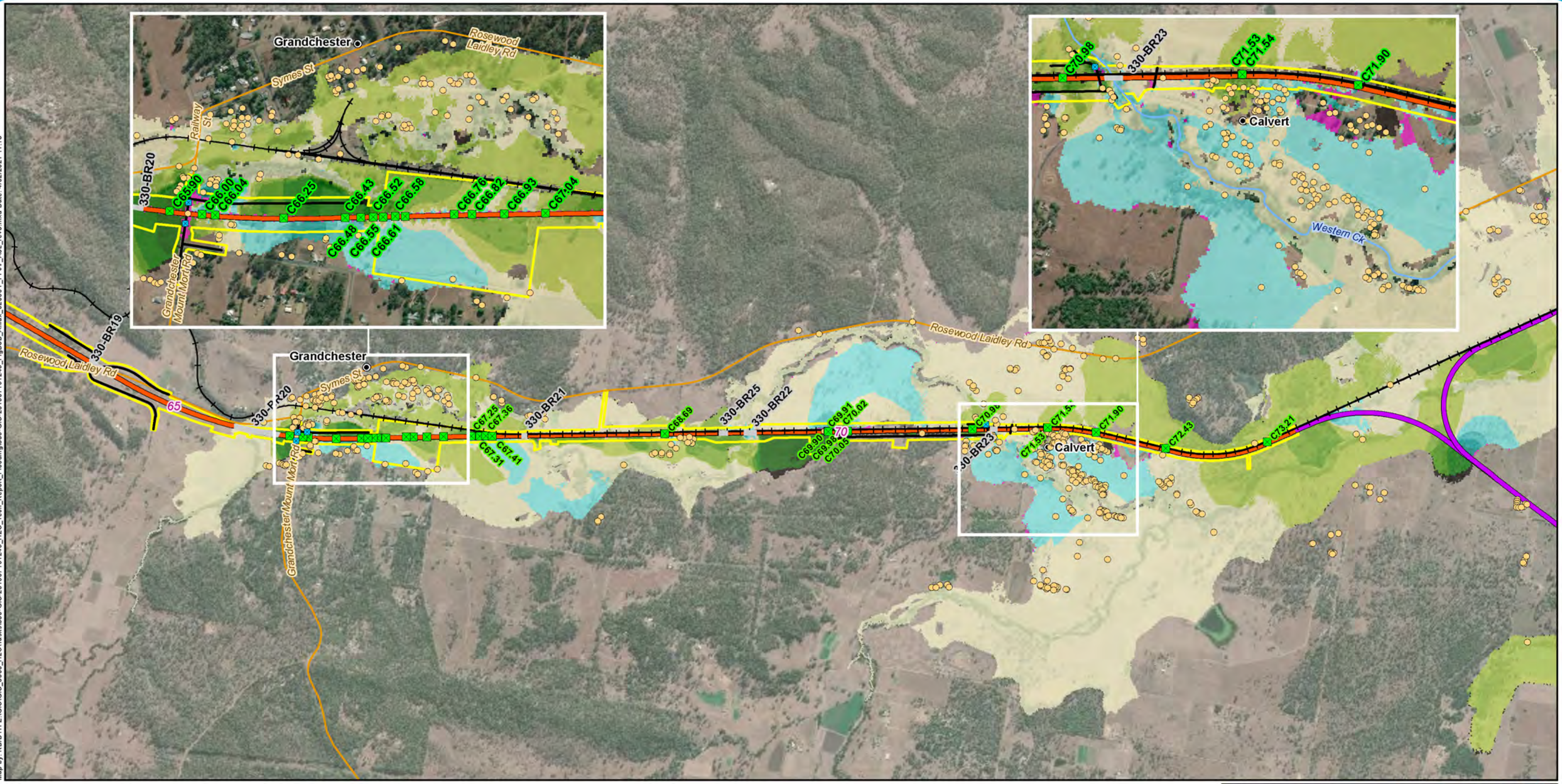
Future Freight
Integrating Community, Environment and Engineering

Issue date: 02/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure B-8A: 1 in 2,000 AEP Event - Existing Case - Inundation Extent: Western Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigB8B_Afflux_02000Y_FFJV_A3L_rev3.mxd Date: 4/02/2021 11:18

Legend

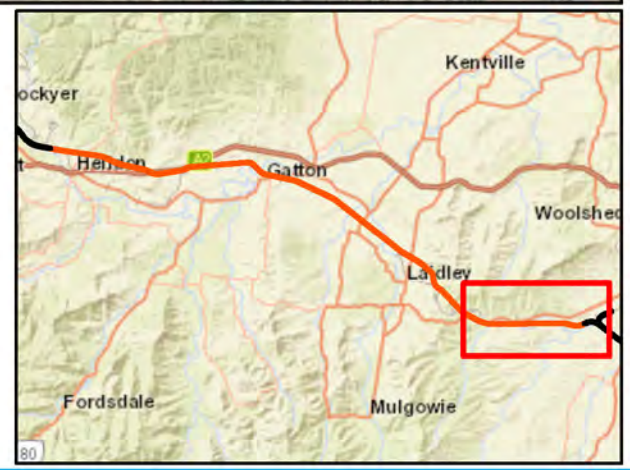
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:31,250
0 0.2 0.4 0.6 0.8 1 km

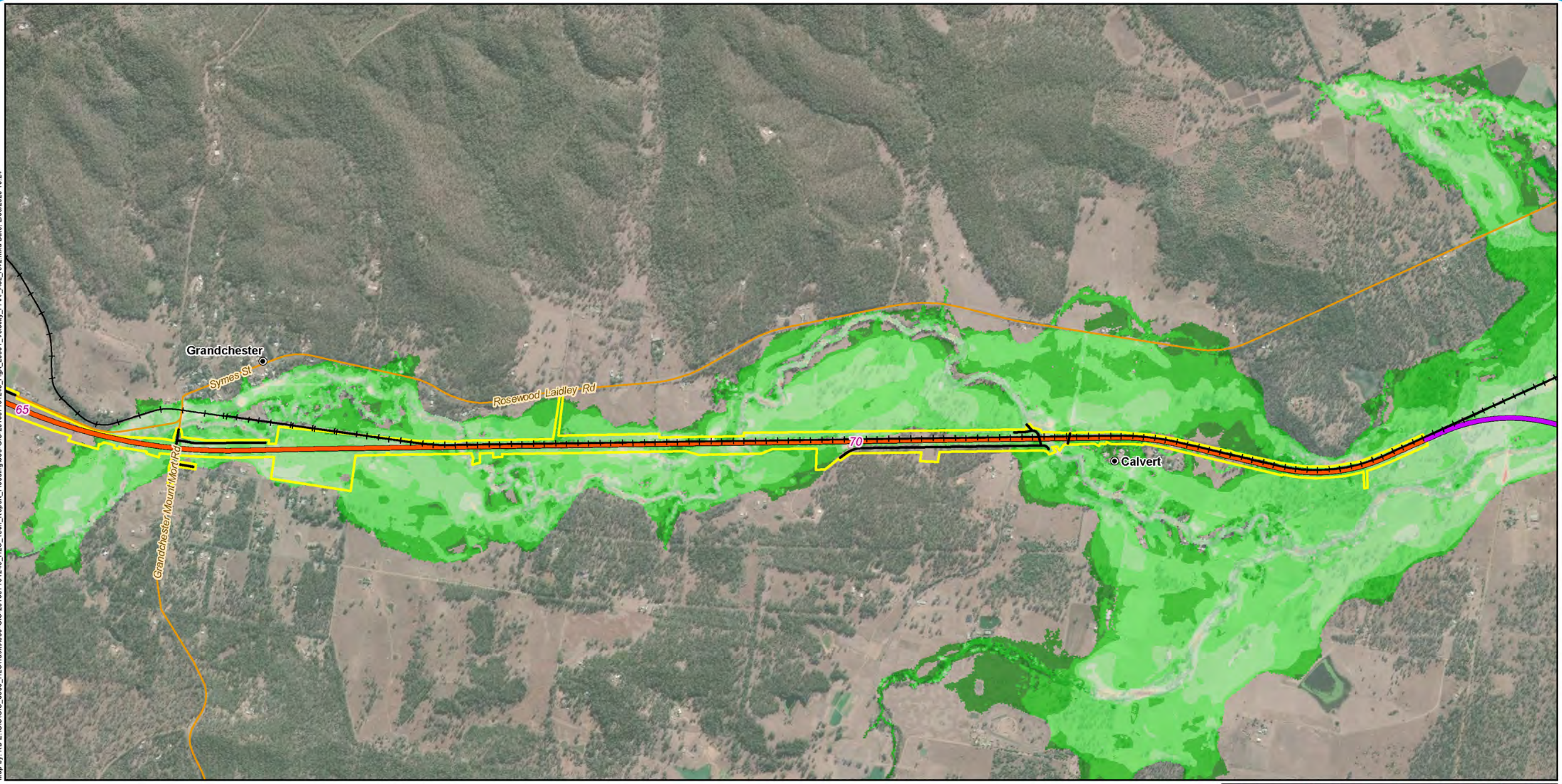
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure B-8B: 1 in 2,000 AEP Event - Developed Case - Afflux: Western Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



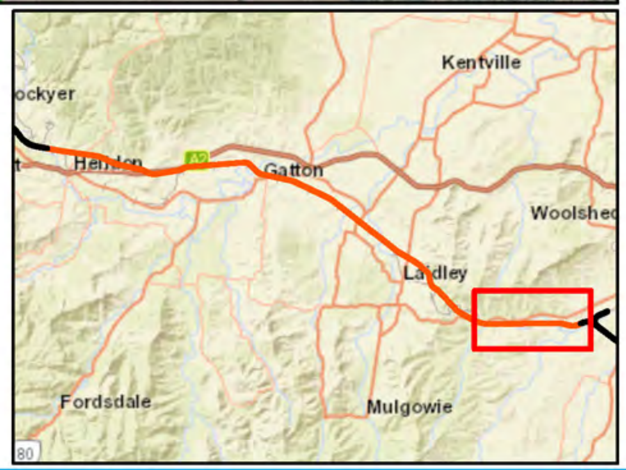
Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715124S_H2C_Tech_Report_Flooding\330-GIS-20190715124S_FigX_2000Y_Velocity_FFJV_A3L_rev2.mxd Date: 2/06/2020 10:24

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint

Peak velocity (m/s)

- 0.0
- 0.5
- 1.0
- 1.5
- 2.0
- 2.5
- 3.0
- 3.5
- 4.0
- 4.5
- 5.0



A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

Future Freight
Integrating Community, Environment and Engineering

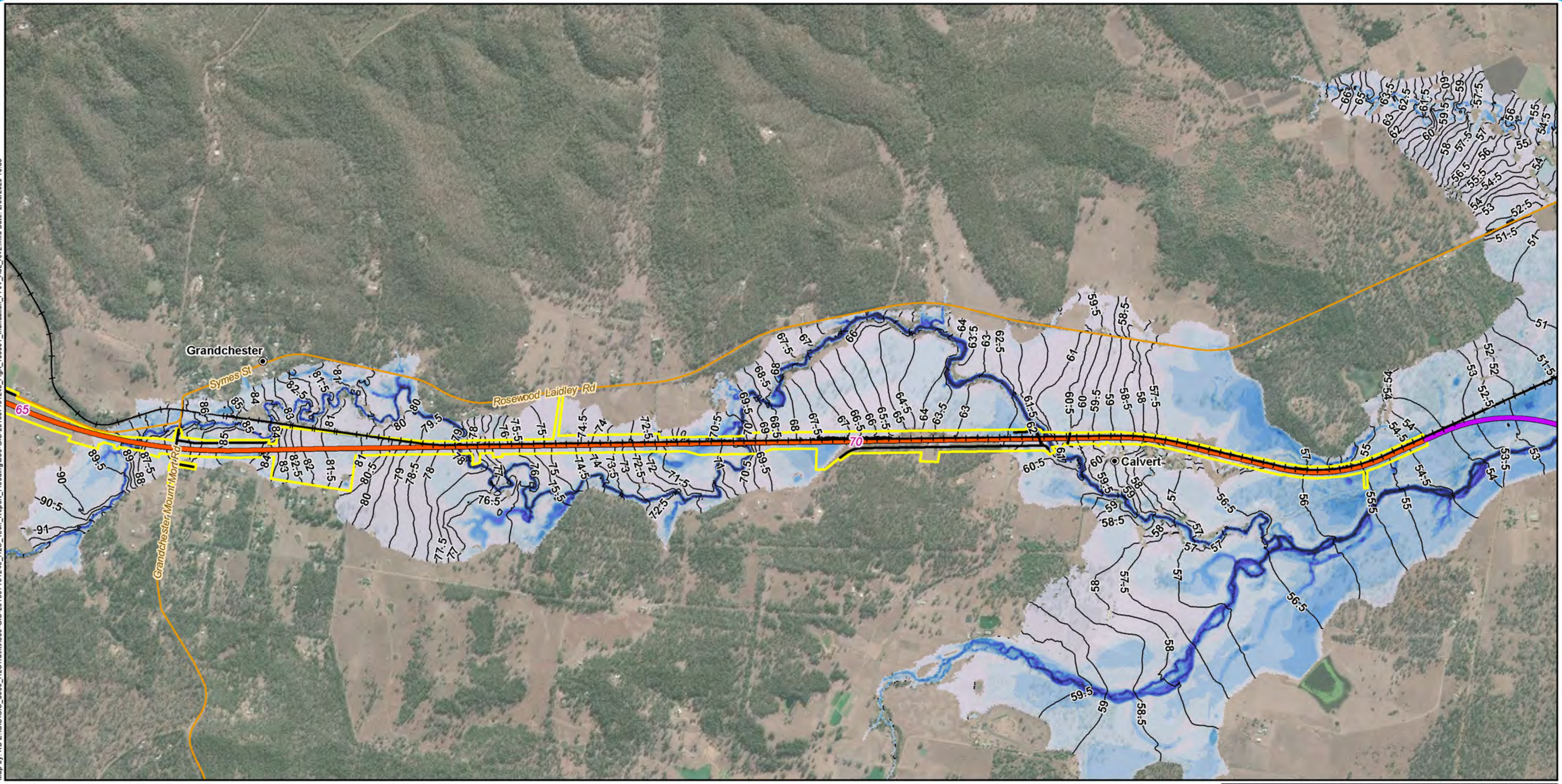
Issue date: 02/06/2020 Version: 2

Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure B-8C: 1 in 2,000 AEP Event - Developed Case - Velocity: Western Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



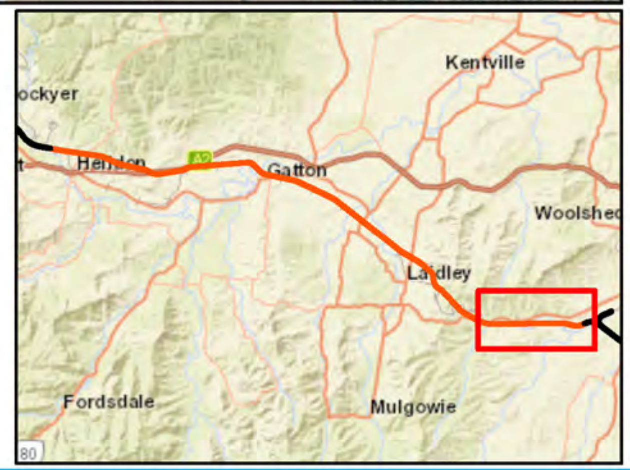
Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_10000Y_Inundation_FFJV_A3L_rev2.mxd Date: 2/06/2020 10:35

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0



A3 scale: 1:25,000
0 0.15 0.3 0.45 0.6 0.75km

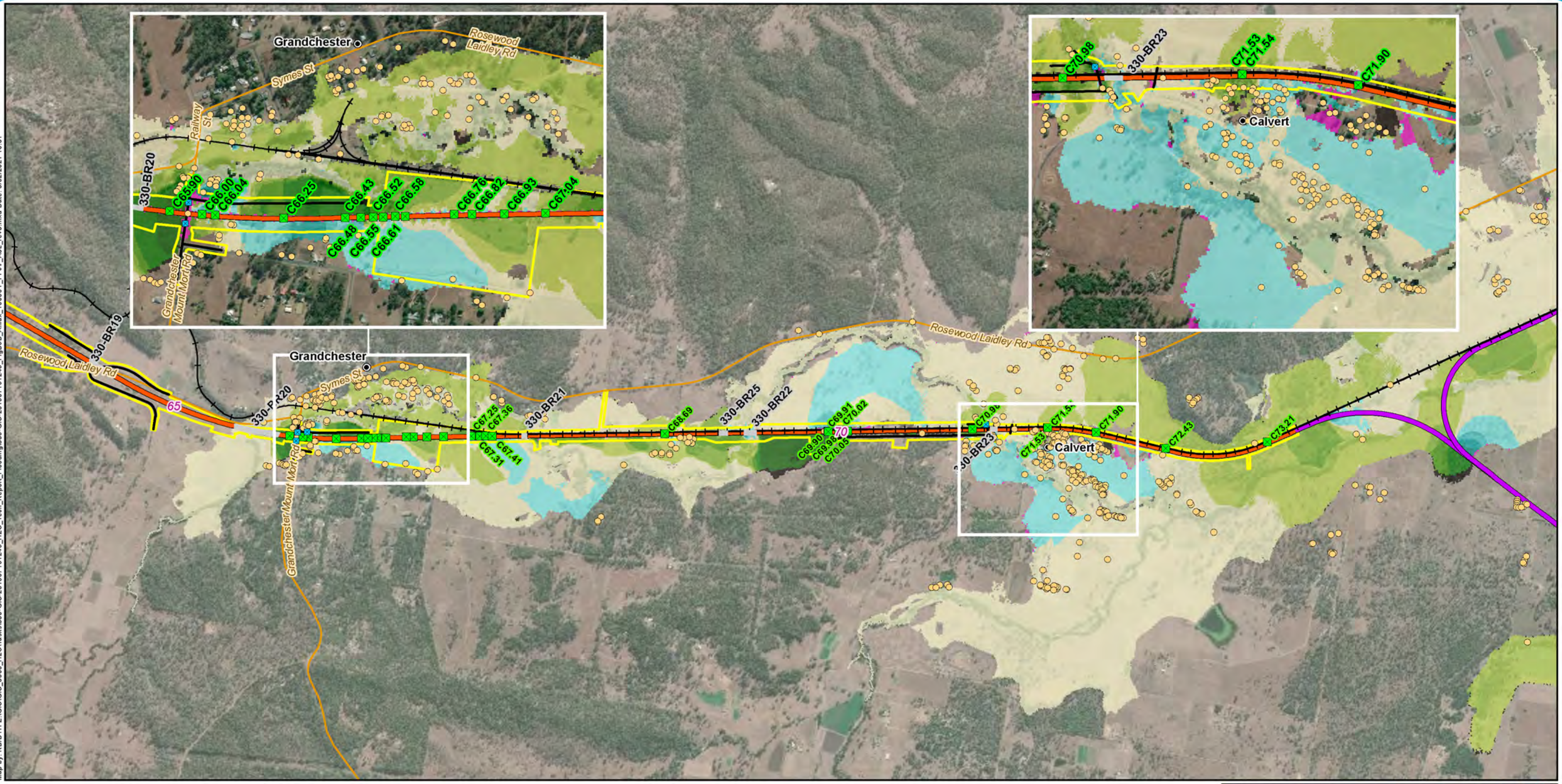
Future Freight
Integrating Community, Environment and Engineering

Issue date: 02/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure B-9A: 1 in 10,000 AEP Event - Existing Case - Inundation Extent: Western Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Map by: RB/DTH Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-20190715 1245_H2C_Tech_Report_Flooding\330-GIS-20190715 1245_FigB9B_Afflux_10000Y_FFJV_A3L_rev3.mxd Date: 3/02/2021 16:31

Legend

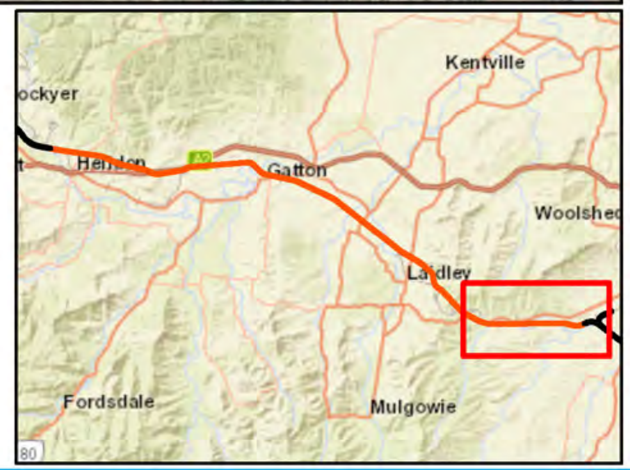
- 5 Chainage (km)
- Flood sensitive receptors
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Was Wet Now Dry
- Was Dry Now Wet

Drainage Structures

- Floodplain culvert
- Road culvert
- Bridges

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50



A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

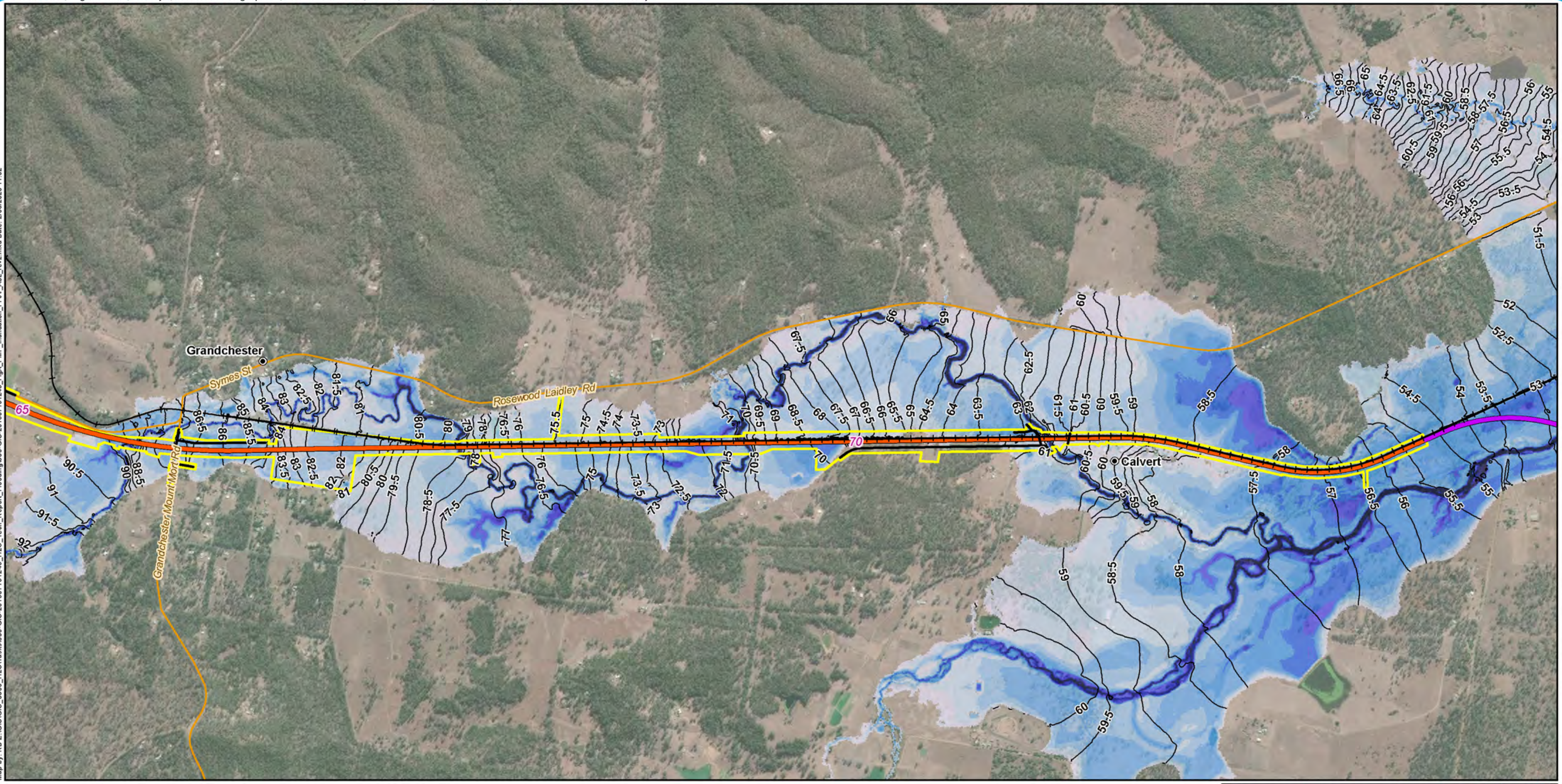
Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

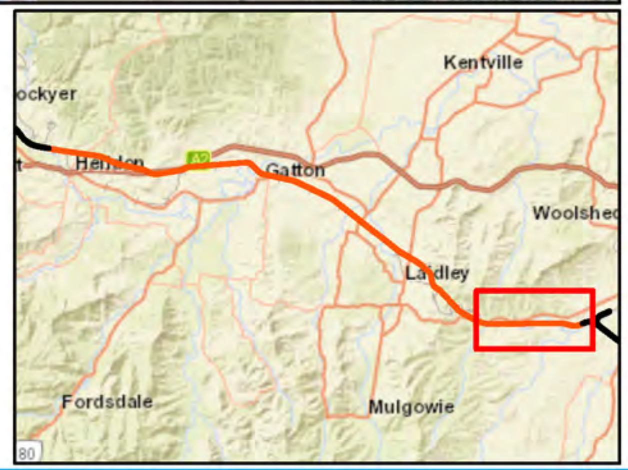
Helidon to Calvert

Figure B-9B: 1 in 10,000 AEP Event - Developed Case - Afflux: Western Creek

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: RB Z:\GIS\GIS_3300_H2C\Tasks\330-GIS-201907151245_H2C_Tech_Report_Flooding\330-GIS-201907151245_FigX_PMF_Inundation_FFJV_A3L_rev2.mxd Date: 2/06/2020 11:02



Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Road design
- Minor roads
- EIS disturbance footprint
- Flood Level Contour (mAHD)

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

A3 scale: 1:25,000

0 0.15 0.3 0.45 0.6 0.75km

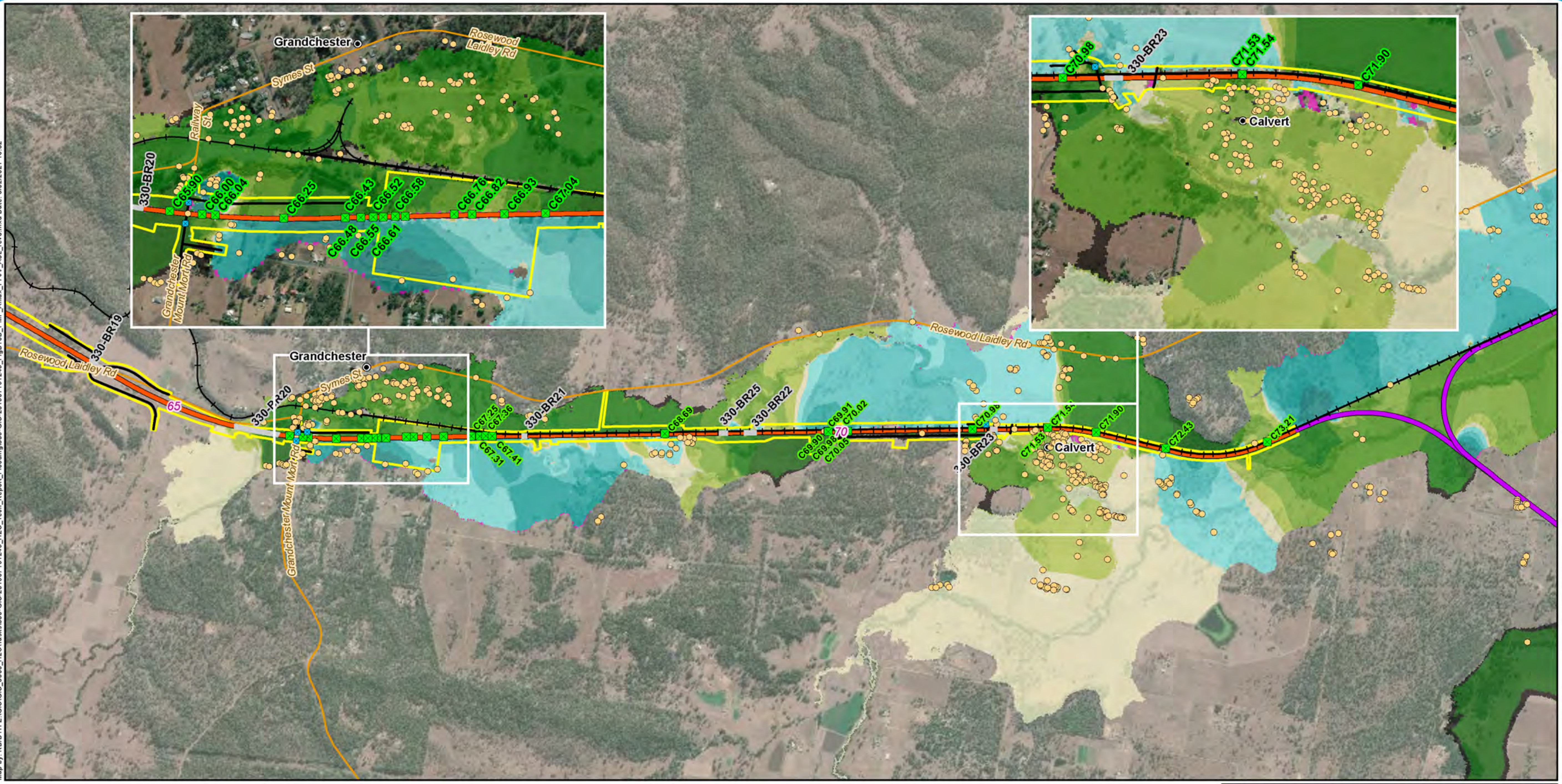
Future Freight
Integrating Community, Environment and Engineering

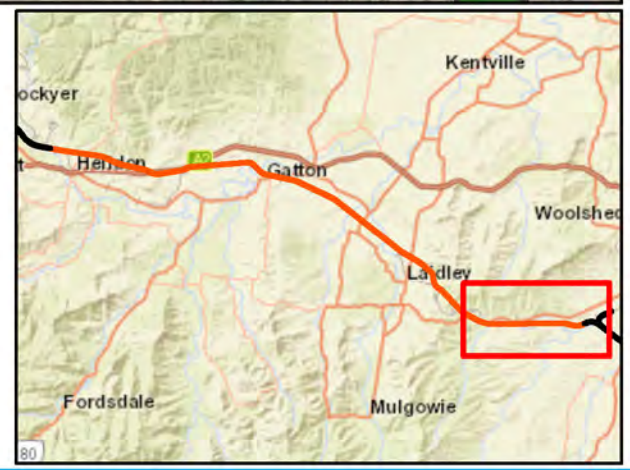
Issue date: 02/06/2020 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure B-10A: PMF Event - Existing Case - Inundation Extent: Western Creek

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community





Legend

5 Chainage (km)	EIS disturbance footprint	**Change in peak water levels (m)**	-0.01 to 0.01
Flood sensitive receptors	Was Wet Now Dry	< -0.50	0.01 to 0.05
Localities	Was Dry Now Wet	-0.50 to -0.20	0.05 to 0.10
Existing rail	**Drainage Structures**	-0.20 to -0.10	0.10 to 0.20
H2C project alignment	Floodplain culvert	-0.10 to -0.05	0.20 to 0.50
C2K project alignment	Road culvert	-0.05 to -0.01	> 0.50
Road design	Bridges		
Minor roads			

A3 scale: 1:31,250

0 0.2 0.4 0.6 0.8 1 km

Future Freight
Integrating Community, Environment and Engineering

Issue date: 01/02/2021 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Helidon to Calvert

Figure B-10B: PMF Event - Developed Case - Afflux: Western Creek

APPENDIX M

Hydrology and Flooding Technical Report

Appendix C Hydraulic Results at Structures

Appendix C
Hydraulic results at structures

20% AEP Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
40.05	Lockyer Creek	RCP[2]	Dry[3]	-	-	-
40.33		RCBC[1]	Dry[3]	-	-	-
41.07		RCP[1]	Dry[3]	-	-	-
41.99		RCP[1]	Dry[3]	-	-	-
42.60		RCP[1]	Dry[3]	-	-	-
43.15		Bridge	94.64	11.77	1.7	440
43.58		RCBC[1]	Dry[3]	-	-	-
43.94		RCP[1]	Dry[3]	-	-	-
44.45		RCBC[2]	Dry[3]	-	-	-
44.90		RCP[1]	Dry[3]	-	-	-
45.76		RCP[1]	Dry[3]	-	-	-
46.49		RCBC[1]	Dry[3]	-	-	-
47.22		RCBC[1]	Dry[3]	-	-	-
47.24		RCP[2]	Dry[3]	-	-	-
47.57		RCP[2]	Dry[3]	-	-	-
47.81		RCBC[1]	90.78	1.94	0.4	< 1
48.46		RCBC[1]	90.06	1.31	0.5	< 1
49.52		Bridge	88.89	2.33	1.1	8
49.57		RCBC[2]	88.80	2.30	0.9	2
50.27	Laidley Creek/ Sandy Creek	Bridge	88.61	2.63	1.1	3
51.37		Bridge	93.83	1.21	0.8	32
51.57		RCBC[2] [3]	90.61	3.60	< 0.1	< 1
51.60		Bridge	90.73	3.24	1.0	7
52.55		RCBC[1]	Dry[3]	-	-	-
52.67		RCBC[2] [3]	Dry[3]	-	-	-
52.68		RCP[1]	Dry[3]	-	-	-
53.39		RCBC[2] [3]	90.88	2.14	1.3	5
53.48		RCBC[2]	90.48	2.58	1.0	3
53.50		RCBC[1]	90.19	2.88	0.5	2
53.97		RCBC[2]	90.55	1.16	1.4	4
53.99		RCBC[1]	90.54	2.69	0.6	3
54.74		Bridge	94.03	2.92	1.5	36
54.81		RCBC[1]	94.03	3.44	1.0	30
54.83		RCBC[1]	94.03	3.50	1.0	30
54.84		RCBC[1]	94.03	3.53	1.0	34
55.45		RCP[1]	Dry[3]	-	-	-
55.83		Bridge	Dry[3]	-	-	-

20% AEP Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
0.72[3]		Bridge	Dry[3]	-	-	-
55.85		RCP	Dry[3]	-	-	-
56.72		Bridge	96.44	8.56	1.1	20
1.62[3]		Bridge	96.26	8.31	1.0	20
57.30		Bridge	Dry[3]	-	-	-
65.29	Western Creek	Bridge	88.67	1.57	1.6	74
65.90		RCP	86.40	2.43	0.6	< 1
66.00		RCP	85.61	1.97	1.3	6
66.04		RCP	85.38	2.05	0.9	2
66.25		RCP	83.88	2.67	1.0	6
66.43		RCP	83.99	1.87	1.1	5
66.48		RCP	83.82	1.88	0.4	3
66.52		RCP	83.63	1.92	0.7	< 1
66.55		RCP	83.48	1.88	0.5	< 1
66.58		RCP	82.96	2.20	0.5	< 1
66.61		RCP	82.64	2.34	0.4	< 1
66.76		RCP	81.23	2.89	0.5	< 1
66.82		RCP	80.98	2.82	0.3	< 1
66.93		RCP	80.79	2.32	0.9	3
67.04		RCP	80.50	2.02	1.0	1
67.25		RCP	79.38	1.95	1.0	< 1
67.31		RCP	78.84	2.02	0.7	4
67.36		RCP	78.72	2.00	1.1	1
67.41		RCP	Dry[3]	-	0.1	-
67.63		Bridge	77.59	2.09	1.4	100
68.69		RCBC[1]	Dry[3]	-	-	-
69.10		Bridge	69.33	2.27	0.7	5
69.29		Bridge	69.81	1.12	1.9	100
69.90		RCBC[2]	Dry[3]	-	-	-
69.91		RCBC[1]	Dry[3]	-	-	-
69.98		RCP[2]	Dry[3]	-	-	-
70.02		RCP[2]	Dry[3]	-	-	-
70.05		RCBC[1]	Dry[3]	-	-	-
70.98		RCBC[1]	Dry[3]	-	-	-
71.12		Bridge	60.24	1.76	1.3	102
71.54		RCBC[2]	Dry[3]	-	-	-
71.54		RCBC[1]	Dry[3]	-	-	-
71.90		RCBC	Dry[3]	-	-	-

20% AEP Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
72.43		RCBC[1]	Dry[3]	-	-	-
73.21		RCBC[1]	54.02	3.56	2.1	2

Table notes:

1 The Developed Case alignment runs parallel to the QR West Moreton System rail corridor at this location. The existing culvert is proposed to be extended and matched through the Project alignment.
2 The Developed Case alignment runs parallel to the QR West Moreton System rail corridor at this location. A new culvert(s) is proposed to be inserted through the QR West Moreton System rail corridor and the Project alignment.
3 This Developed Case structure is outside the 1% AEP event extents. This structure was included in the Developed Case as it conveys flow during extreme events.

10% AEP Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
40.05	Lockyer Creek	RCP[2]	Dry[3]	-	-	-
40.33		RCBC[1]	Dry[3]	-	-	-
41.07		RCP[1]	Dry[3]	-	-	-
41.99		RCP[1]	Dry[3]	-	-	-
42.60		RCP[1]	Dry[3]	-	-	-
43.15		Bridge	98.51	7.90	2.0	1068
43.58		RCBC[1]	Dry[3]	-	-	-
43.94		RCP[1]	Dry[3]	-	-	-
44.45		RCBC[2]	Dry[3]	-	-	-
44.90		RCP[1]	Dry[3]	-	-	-
45.76		RCP[1]	Dry[3]	-	-	-
46.49		RCBC[1]	Dry[3]	-	-	-
47.22		RCBC[1]	Dry[3]	-	-	-
47.24		RCP[2]	Dry[3]	-	-	-
47.57		RCP[2]	Dry[3]	-	-	-
47.81		RCBC[1]	90.83	1.89	1.2	2
48.46		RCBC[1]	90.16	1.21	0.6	< 1
49.52		Bridge	89.38	1.84	1.6	16
49.57		RCBC[2]	89.15	1.95	1.6	7
50.27	Laidley Creek/ Sandy Creek	Bridge	88.88	2.36	1.2	8
51.37		Bridge	93.88	1.16	1.9	34
51.57		RCBC[2,3]	91.11	3.10	0.7	13
51.60		Bridge	91.58	2.39	2.6	36
52.55		RCBC[1]	90.67	2.08	0.4	< 1
52.67		RCBC[2,3]	Dry[3]	-	-	-
52.68		RCP[1]	90.67	2.11	0.7	< 1
53.39		RCBC[2,3]	91.13	1.89	1.8	15
53.48		RCBC[2]	90.61	2.45	1.3	5
53.50		RCBC[1]	90.35	2.72	0.6	3
53.97		RCBC[2]	90.76	0.95	1.3	7

10% AEP Event						
Chainage (km)	Waterway	Structure type	Upstream peak water level (m AHD)	Freeboard to rail formation level (m)	Outlet velocity (m/s)	Peak discharge (m^3/s)
53.99		RCBC[1]	90.74	2.49	0.8	5
54.74		Bridge	94.54	2.41	1.0	86
54.81		RCBC[1]	94.54	2.93	1.3	46
54.83		RCBC[1]	94.54	2.99	1.3	46
54.84		RCBC[1]	94.54	3.02	1.3	52
55.45		RCP[1]	Dry[3]	-	-	-
55.83		Bridge	95.97	6.40	0.2	< 1
0.72[3]		Bridge	95.84	6.07	0.2	< 1
55.85		RCP	Dry[3]	-	-	-
56.72		Bridge	96.75	8.25	1.2	44
1.62[3]		Bridge	96.70	7.87	1.0	44
57.30		Bridge	97.66	8.30	0.2	< 1
65.29	Western Creek	Bridge	88.72	1.52	2.2	81
65.90		RCP	86.46	2.37	0.7	< 1
66.00		RCP	85.69	1.89	1.4	8
66.04		RCP	85.44	1.99	1.0	3
66.25		RCP	83.97	2.58	0.9	8
66.43		RCP	84.05	1.81	1.2	6
66.48		RCP	83.89	1.81	0.4	3
66.52		RCP	83.68	1.87	0.8	< 1
66.55		RCP	83.51	1.85	0.6	< 1
66.58		RCP	83.00	2.16	0.6	< 1
66.61		RCP	82.66	2.32	0.5	< 1
66.76		RCP	81.26	2.86	0.6	< 1
66.82		RCP	81.05	2.75	0.5	< 1
66.93		RCP	80.85	2.26	1.0	5
67.04		RCP	80.55	1.97	1.0	2
67.25		RCP	79.41	1.92	1.2	< 1
67.31		RCP	78.88	1.98	0.7	4
67.36		RCP	78.78	1.94	1.2	2
67.41		RCP	78.23	2.23	0.2	< 1
67.63		Bridge	77.70	1.98	1.4	107
68.69		RCBC[1]	Dry[3]	-	-	-
69.10		Bridge	69.56	2.04	0.8	9
69.29		Bridge	69.91	1.02	1.9	109
69.90		RCBC[2]	67.41	2.40	1.2	< 1
69.91		RCBC[1]	67.41	2.47	1.2	< 1
69.98		RCP[2]	Dry[3]	-	-	-
70.02		RCP[2]	Dry[3]	-	-	-
70.05		RCBC[1]	Dry[3]	-	-	-

10% AEP Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
70.98		RCBC[1]	60.74	2.80	0.7	< 1
71.12		Bridge	60.56	1.44	1.4	118
71.54		RCBC[2]	Dry[3]	-	-	-
71.54		RCBC[1]	Dry[3]	-	-	-
71.90		RCBC	Dry[3]	-	-	-
72.43		RCBC[1]	Dry[3]	-	-	-
73.21		RCBC[1]	54.12	3.46	2.2	2

Table notes:

1 The Developed Case alignment runs parallel to the QR West Moreton System rail corridor at this location. The existing culvert is proposed to be extended and matched through the Project alignment.

2 The Developed Case alignment runs parallel to the QR West Moreton System rail corridor at this location. A new culvert(s) is proposed to be inserted through the QR West Moreton System rail corridor and the Project alignment.

3 This Developed Case structure is outside the 1% AEP event extents. This structure was included in the Developed Case as it conveys flow during extreme events.

5% AEP Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
40.05	Lockyer Creek	RCP[2]	Dry[3]	-	-	-
40.33		RCBC[1]	Dry[3]	-	-	-
41.07		RCP[1]	Dry[3]	-	-	-
41.99		RCP[1]	Dry[3]	-	-	-
42.60		RCP[1]	Dry[3]	-	-	-
43.15		Bridge	100.23	6.18	2.2	1507
43.58		RCBC[1]	Dry[3]	-	-	-
43.94		RCP[1]	Dry[3]	-	-	-
44.45		RCBC[2]	Dry[3]	-	-	-
44.90		RCP[1]	Dry[3]	-	-	-
45.76		RCP[1]	Dry[3]	-	-	-
46.49		RCBC[1]	Dry[3]	-	-	-
47.22		RCBC[1]	Dry[3]	-	-	-
47.24		RCP[2]	Dry[3]	-	-	-
47.57		RCP[2]	Dry[3]	-	-	-
47.81		RCBC[1]	90.84	1.88	1.4	2
48.46		RCBC[1]	90.18	1.19	0.6	< 1
49.52		Bridge	89.65	1.57	1.8	20
49.57		RCBC[2]	89.33	1.77	1.9	10
50.27	Laidley Creek/ Sandy Creek	Bridge	88.94	2.30	1.2	11
51.37		Bridge	93.88	1.16	1.8	34
51.57		RCBC[2] [3]	91.35	2.86	1.1	25
51.60		Bridge	91.90	2.07	3.3	45
52.55		RCBC[1]	91.32	1.43	0.6	< 1
52.67		RCBC[2] [3]	91.34	1.44	0.7	11

5% AEP Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
52.68		RCP[1]	91.33	1.45	0.9	< 1
53.39		RCBC[2,3]	91.31	1.71	2.0	23
53.48		RCBC[2]	90.77	2.29	1.4	7
53.50		RCBC[1]	90.49	2.58	0.7	4
53.97		RCBC[2]	90.83	0.88	1.4	8
53.99		RCBC[1]	90.81	2.42	0.6	4
54.74		Bridge	94.68	2.27	1.5	120
54.81		RCBC[1]	94.68	2.79	1.4	50
54.83		RCBC[1]	94.68	2.85	1.4	50
54.84		RCBC[1]	94.68	2.88	1.4	57
55.45		RCP[1]	Dry[3]	-	-	-
55.83		Bridge	96.83	5.54	0.6	5
0.72[3]		Bridge	96.58	5.33	0.4	5
55.85		RCP	96.01	4.71	0.6	< 1
56.72		Bridge	97.13	7.87	1.2	62
1.62[3]		Bridge	97.09	7.48	1.0	62
57.30		Bridge	97.79	8.17	0.2	< 1
65.29	Western Creek	Bridge	88.82	1.42	2.3	102
65.90		RCP	86.51	2.32	0.7	< 1
66.00		RCP	85.73	1.85	1.4	9
66.04		RCP	85.48	1.95	1.1	4
66.25		RCP	84.06	2.49	0.9	11
66.43		RCP	84.12	1.74	1.3	8
66.48		RCP	83.96	1.74	0.6	5
66.52		RCP	83.73	1.82	0.8	< 1
66.55		RCP	83.54	1.82	0.7	< 1
66.58		RCP	83.03	2.13	0.7	< 1
66.61		RCP	82.69	2.29	0.6	< 1
66.76		RCP	81.30	2.82	0.7	< 1
66.82		RCP	81.11	2.69	0.6	1
66.93		RCP	80.90	2.21	1.0	6
67.04		RCP	80.59	1.93	1.0	2
67.25		RCP	79.48	1.85	1.2	1
67.31		RCP	78.95	1.91	0.7	6
67.36		RCP	78.82	1.90	1.2	2
67.41		RCP	78.37	2.09	0.7	< 1
67.63		Bridge	77.83	1.85	1.7	130
68.69		RCBC[1]	Dry[3]	-	-	-
69.10		Bridge	69.78	1.82	0.9	23
69.29		Bridge	70.03	0.90	2.3	125

5% AEP Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
69.90		RCBC[2]	67.91	1.90	2.2	2
69.91		RCBC[1]	67.91	1.97	2.2	2
69.98		RCP[2]	Dry[3]	-	-	-
70.02		RCP[2]	Dry[3]	-	-	-
70.05		RCBC[1]	Dry[3]	-	-	-
70.98		RCBC[1]	61.22	2.32	2.4	8
71.12		Bridge	60.81	1.19	1.6	143
71.54		RCBC[2]	Dry[3]	-	-	-
71.54		RCBC[1]	Dry[3]	-	-	-
71.90		RCBC	Dry[3]	-	-	-
72.43		RCBC[1]	Dry[3]	-	-	-
73.21		RCBC[1]	54.24	3.34	2.4	3

Table notes:

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3 This Developed Case structure is outside the 1% AEP event extents. This structure was included in the Developed Case as it conveys flow during extreme events.

2% AEP Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
40.05	Lockyer Creek	RCP[2]	Dry[3]	-	-	-
40.33		RCBC[1]	Dry[3]	-	-	-
41.07		RCP[1]	Dry[3]	-	-	-
41.99		RCP[1]	Dry[3]	-	-	-
42.60		RCP[1]	Dry[3]	-	-	-
43.15		Bridge	102.62	3.79	2.5	2372
43.58		RCBC[1]	Dry[3]	-	-	-
43.94		RCP[1]	Dry[3]	-	-	-
44.45		RCBC[2]	Dry[3]	-	-	-
44.90		RCP[1]	Dry[3]	-	-	-
45.76		RCP[1]	96.02	1.37	2.1	1
46.49		RCBC[1]	94.37	1.05	2.7	1
47.22		RCBC[1]	92.54	1.44	2.4	9
47.24		RCP[2]	92.38	1.54	0.8	5
47.57		RCP[2]	91.84	1.42	1.5	1
47.81		RCBC[1]	91.20	1.52	1.7	3
48.46		RCBC[1]	90.44	0.93	1.1	1
49.52		Bridge	89.97	1.25	2.6	36
49.57		RCBC[2]	89.74	1.36	2.3	20

2% AEP Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
50.27	Laidley Creek/ Sandy Creek	Bridge	89.27	1.97	1.5	21
51.37		Bridge	93.90	1.14	0.8	34
51.57		RCBC[2,3]	91.58	2.63	1.4	38
51.60		Bridge	92.22	1.75	4.2	54
52.55		RCBC[1]	91.42	1.33	0.8	1
52.67		RCBC[2,3]	91.43	1.35	0.7	14
52.68		RCP[1]	91.42	1.36	1.0	< 1
53.39		RCBC[2,3]	91.78	1.24	2.6	50
53.48		RCBC[2]	91.27	1.79	2.1	18
53.50		RCBC[1]	91.12	1.95	2.0	15
53.97		RCBC[2]	90.95	0.76	1.9	10
53.99		RCBC[1]	90.94	2.29	0.8	5
54.74		Bridge	94.74	2.21	1.4	135
54.81		RCBC[1]	94.74	2.73	1.5	53
54.83		RCBC[1]	94.74	2.79	1.5	53
54.84		RCBC[1]	94.74	2.82	1.5	59
55.45		RCP[1]	Dry[3]	-	-	-
55.83		Bridge	97.11	5.26	0.8	43
0.72[3]		Bridge	97.07	4.84	0.6	43
55.85		RCP	96.20	4.52	1.0	2
56.72		Bridge	97.50	7.50	1.4	154
1.62[3]		Bridge	97.50	7.07	1.5	154
57.30		Bridge	98.05	7.91	0.8	5
65.29	Western Creek	Bridge	88.90	1.34	2.4	125
65.90		RCP	86.67	2.16	1.0	2
66.00		RCP	85.84	1.74	1.6	12
66.04		RCP	85.60	1.83	1.3	6
66.25		RCP	84.33	2.22	0.9	21
66.43		RCP	84.24	1.62	1.4	13
66.48		RCP	84.11	1.59	0.8	7
66.52		RCP	83.81	1.74	1.0	2
66.55		RCP	83.62	1.74	0.8	< 1
66.58		RCP	83.11	2.05	0.8	< 1
66.61		RCP	82.75	2.23	0.7	< 1
66.76		RCP	81.41	2.71	0.9	1
66.82		RCP	81.25	2.55	0.9	2
66.93		RCP	81.02	2.09	1.2	11
67.04		RCP	80.68	1.84	1.0	3
67.25		RCP	79.66	1.67	1.5	3
67.31		RCP	79.09	1.77	1.0	10

2% AEP Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
67.36		RCP	78.92	1.80	1.4	3
67.41		RCP	78.53	1.93	1.0	< 1
67.63		Bridge	78.05	1.63	1.9	156
68.69		RCBC[1]	Dry[3]	-	-	-
69.10		Bridge	70.14	1.46	1.5	48
69.29		Bridge	70.11	0.82	2.3	131
69.90		RCBC[2]	68.75	1.06	4.4	6
69.91		RCBC[1]	68.76	1.12	4.5	6
69.98		RCP[2]	67.12	2.80	0.6	< 1
70.02		RCP[2]	67.11	2.75	0.6	< 1
70.05		RCBC[1]	Dry[3]	-	-	-
70.98		RCBC[1]	61.64	1.90	2.9	13
71.12		Bridge	61.16	0.84	1.8	175
71.54		RCBC[2]	Dry[3]	-	-	-
71.54		RCBC[1]	Dry[3]	-	-	-
71.90		RCBC	Dry[3]	-	-	-
72.43		RCBC[1]	Dry[3]	-	-	-
73.21		RCBC[1]	54.38	3.20	2.6	4

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1% AEP Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
40.05	Lockyer Creek	RCP[2]	102.18	2.96	0.8	< 1
40.33		RCBC[1]	Dry[3]	-	-	-
41.07		RCP[1]	Dry[3]	-	-	-
41.99		RCP[1]	Dry[3]	-	-	-
42.60		RCP[1]	Dry[3]	-	-	-
43.15		Bridge	103.54	2.87	2.9	3035
43.58		RCBC[1]	Dry[3]	-	-	-
43.94		RCP[1]	Dry[3]	-	-	-
44.45		RCBC[2]	Dry[3]	-	-	-
44.90		RCP[1]	97.64	0.59	1.5	2
45.76		RCP[1]	97.09	0.30	3.5	2
46.49		RCBC[1]	95.11	0.31	2.8	2
47.22		RCBC[1]	93.22	0.76	3.3	14

1% AEP Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
47.24		RCP[2]	93.12	0.80	2.2	17
47.57		RCP[2]	92.20	1.06	1.8	2
47.81		RCBC[1]	91.95	0.77	2.8	8
48.46		RCBC[1]	90.83	0.54	1.6	2
49.52		Bridge	90.32	0.90	3.4	55
49.57		RCBC[2]	90.01	1.09	2.4	25
50.27	Laidley Creek/ Sandy Creek	Bridge	89.52	1.72	1.7	30
51.37		Bridge	93.91	1.13	0.8	35
51.57		RCBC[2,3]	91.67	2.54	1.6	44
51.60		Bridge	92.42	1.55	4.2	59
52.55		RCBC[1]	91.54	1.21	1.1	1
52.67		RCBC[2,3]	91.57	1.21	0.9	20
52.68		RCP[1]	91.56	1.22	1.1	< 1
53.39		RCBC[2,3]	92.00	1.02	2.8	64
53.48		RCBC[2]	91.56	1.50	2.4	26
53.50		RCBC[1]	91.40	1.67	2.4	20
53.97		RCBC[2]	91.10	0.61	2.0	12
53.99		RCBC[1]	91.10	2.13	0.8	6
54.74		Bridge	94.78	2.17	2.2	148
54.81		RCBC[1]	94.78	2.69	1.5	54
54.83		RCBC[1]	94.78	2.75	1.5	54
54.84		RCBC[1]	94.78	2.78	1.5	61
55.45		RCP[1]	Dry[3]	-	-	-
55.83		Bridge	97.25	5.12	1.0	87
0.72[3]		Bridge	97.22	4.69	0.7	87
55.85		RCP	96.43	4.29	1.3	7
56.72		Bridge	97.69	7.31	1.4	204
1.62[3]		Bridge	97.69	6.88	1.4	204
57.30		Bridge	98.13	7.83	1.0	7
65.29	Western Creek	Bridge	88.98	1.26	2.4	142
65.90		RCP	86.81	2.02	1.1	3
66.00		RCP	85.91	1.67	1.7	15
66.04		RCP	85.68	1.75	1.4	8
66.25		RCP	84.50	2.05	1.1	27
66.43		RCP	84.32	1.54	1.4	15
66.48		RCP	84.20	1.50	1.0	8
66.52		RCP	83.85	1.70	1.0	2
66.55		RCP	83.65	1.71	0.9	1
66.58		RCP	83.16	2.00	0.9	1
66.61		RCP	82.77	2.21	0.7	< 1

1% AEP Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
66.76		RCP	81.47	2.65	1.0	2
66.82		RCP	81.32	2.48	1.1	3
66.93		RCP	81.08	2.03	1.3	13
67.04		RCP	80.73	1.79	1.1	3
67.25		RCP	79.78	1.55	1.7	5
67.31		RCP	79.18	1.68	1.1	14
67.36		RCP	78.96	1.76	1.4	3
67.41		RCP	78.66	1.80	1.2	2
67.63		Bridge	78.32	1.36	2.1	171
68.69		RCBC[1]	Dry[3]	-	-	-
69.10		Bridge	70.37	1.23	1.9	65
69.29		Bridge	70.18	0.75	2.5	139
69.90		RCBC[2]	69.15	0.66	5.3	8
69.91		RCBC[1]	69.16	0.72	5.3	7
69.98		RCP[2]	67.39	2.53	1.1	3
70.02		RCP[2]	67.38	2.48	1.1	1
70.05		RCBC[1]	67.38	2.42	0.9	< 1
70.98		RCBC[1]	61.83	1.71	3.1	17
71.12		Bridge	61.23	0.77	2.0	195
71.54		RCBC[2]	58.90	1.10	1.0	< 1
71.54		RCBC[1]	58.90	1.10	1.0	< 1
71.90		RCBC	Dry[3]	-	-	-
72.43		RCBC[1]	Dry[3]	-	-	-
73.21		RCBC[1]	54.46	3.12	2.7	4

Table notes:

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1 in 2,000 AEP Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
40.05	Lockyer Creek	RCP[2]	106.42	-1.28	5.6	15
40.33		RCBC[1]	106.51	-1.24	6.7	67
41.07		RCP[1]	106.71	-1.20	1.9	< 1
41.99		RCP[1]	106.66	-0.43	0.5	< 1
42.60		RCP[1]	105.92	-0.52	2.4	4
43.15		Bridge	104.97	1.44	3.9	4551
43.58		RCBC[1]	Dry[3]	-	-	-
43.94		RCP[1]	100.69	-0.76	1.4	< 1

1 in 2,000 AEP Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
44.45		RCBC[2]	99.04	-0.06	4.2	44
44.90		RCP[1]	99.47	-1.24	4.0	5
45.76		RCP[1]	98.47	-1.08	4.9	3
46.49		RCBC[1]	96.14	-0.72	4.0	3
47.22		RCBC[1]	94.12	-0.14	6.3	21
47.24		RCP[2]	93.99	-0.07	3.2	27
47.57		RCP[2]	92.97	0.29	2.8	5
47.81		RCBC[1]	93.05	-0.33	3.5	15
48.46		RCBC[1]	91.65	-0.28	1.9	4
49.52		Bridge	91.42	-0.20	4.1	232
49.57		RCBC[2]	92.10	-1.00	4.2	54
50.27	Laidley Creek/ Sandy Creek	Bridge	90.29	0.95	2.7	53
51.37		Bridge	93.92	1.12	1.0	35
51.57		RCBC[2 3]	92.02	2.19	2.1	66
51.60		Bridge	92.83	1.14	5.3	78
52.55		RCBC[1]	92.32	0.43	2.5	4
52.67		RCBC[2 3]	92.28	0.50	1.8	58
52.68		RCP[1]	92.27	0.51	1.5	< 1
53.39		RCBC[2 3]	92.82	0.20	5.4	105
53.48		RCBC[2]	92.87	0.19	3.6	46
53.50		RCBC[1]	92.81	0.26	3.7	33
53.97		RCBC[2]	92.86	-1.15	3.2	56
53.99		RCBC[1]	92.85	0.38	3.2	26
54.74		Bridge	95.02	1.93	2.0	213
54.81		RCBC[1]	95.02	2.45	1.8	65
54.83		RCBC[1]	95.02	2.51	1.8	65
54.84		RCBC[1]	95.02	2.54	1.8	73
55.45		RCP[1]	96.83	3.33	1.0	< 1
55.83		Bridge	97.66	4.71	1.4	431
0.72[3]		Bridge	97.64	4.27	1.1	431
55.85		RCP	97.33	3.39	1.6	19
56.72		Bridge	98.05	6.95	1.5	325
1.62[3]		Bridge	98.04	6.53	1.5	325
57.30		Bridge	98.35	7.61	1.2	13
65.29	Western Creek	Bridge	89.28	0.96	2.8	237
65.90		RCP	87.48	1.35	1.5	7
66.00		RCP	86.29	1.29	1.8	18
66.04		RCP	86.04	1.39	1.8	18
66.25		RCP	85.02	1.53	1.5	39
66.43		RCP	84.74	1.12	1.8	29

1 in 2,000 AEP Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
66.48		RCP	84.66	1.04	1.8	16
66.52		RCP	84.15	1.40	1.5	7
66.55		RCP	83.83	1.53	1.1	3
66.58		RCP	83.34	1.82	1.2	3
66.61		RCP	82.93	2.05	0.9	2
66.76		RCP	81.72	2.40	1.1	4
66.82		RCP	81.59	2.21	1.3	7
66.93		RCP	81.34	1.77	1.3	18
67.04		RCP	80.95	1.57	1.2	3
67.25		RCP	80.19	1.14	2.3	9
67.31		RCP	79.50	1.36	1.6	28
67.36		RCP	79.20	1.52	1.8	5
67.41		RCP	78.82	1.64	1.4	3
67.63		Bridge	78.56	1.12	2.8	246
68.69		RCBC[1]	72.79	0.93	1.4	< 1
69.10		Bridge	71.09	0.51	2.7	125
69.29		Bridge	70.68	0.25	2.9	184
69.90		RCBC[2]	70.35	-0.54	7.2	10
69.91		RCBC[1]	70.38	-0.50	7.2	9
69.98		RCP[2]	69.31	0.61	4.1	29
70.02		RCP[2]	69.34	0.52	4.1	10
70.05		RCBC[1]	69.34	0.46	5.4	5
70.98		RCBC[1]	62.21	1.33	3.3	22
71.12		Bridge	61.56	0.44	2.7	262
71.54		RCBC[2]	59.61	0.39	2.0	2
71.54		RCBC[1]	59.61	0.39	2.0	2
71.90		RCBC	57.26	1.68	0.5	< 1
72.43		RCBC[1]	57.03	0.55	1.6	< 1
73.21		RCBC[1]	54.85	2.73	3.0	6

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1 in 10,000 AEP Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
40.05	Lockyer Creek	RCP[2]	106.52	-1.38	5.7	15
40.33		RCBC[1]	106.64	-1.37	6.9	68
41.07		RCP[1]	106.88	-1.37	2.3	< 1

1 in 10,000 AEP Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
41.99		RCP[1]	106.92	-0.69	1.0	< 1
42.60		RCP[1]	106.24	-0.84	3.1	5
43.15		Bridge	105.32	1.09	4.1	4856
43.58		RCBC[1]	103.35	-0.01	0.4	< 1
43.94		RCP[1]	101.10	-1.17	1.4	< 1
44.45		RCBC[2]	99.85	-0.87	5.8	60
44.90		RCP[1]	99.75	-1.52	4.1	5
45.76		RCP[1]	98.63	-1.24	4.9	3
46.49		RCBC[1]	96.26	-0.84	4.1	3
47.22		RCBC[1]	94.26	-0.28	6.4	21
47.24		RCP[2]	94.14	-0.22	3.2	27
47.57		RCP[2]	93.47	-0.21	2.9	5
47.81		RCBC[1]	93.24	-0.52	3.5	15
48.46		RCBC[1]	92.02	-0.65	1.9	4
49.52		Bridge	91.61	-0.39	4.1	269
49.57		RCBC[2]	92.34	-1.24	4.2	54
50.27	Laidley Creek/ Sandy Creek	Bridge	90.49	0.75	3.3	69
51.37		Bridge	93.93	1.11	0.8	35
51.57		RCBC[2,3]	92.18	2.03	2.3	75
51.60		Bridge	92.92	1.05	5.3	94
52.55		RCBC[1]	92.96	-0.21	3.5	5
52.67		RCBC[2,3]	92.92	-0.14	2.8	89
52.68		RCP[1]	92.91	-0.13	2.6	2
53.39		RCBC[2,3]	93.16	-0.14	5.8	113
53.48		RCBC[2]	93.21	-0.15	3.9	51
53.50		RCBC[1]	93.16	-0.09	4.0	36
53.97		RCBC[2]	93.21	-1.50	3.5	61
53.99		RCBC[1]	93.20	0.03	3.5	29
54.74		Bridge	95.14	1.81	1.9	232
54.81		RCBC[1]	95.14	2.33	2.0	70
54.83		RCBC[1]	95.14	2.39	2.0	70
54.84		RCBC[1]	95.14	2.42	2.0	79
55.45		RCP[1]	96.95	3.21	1.3	< 1
55.83		Bridge	97.83	4.54	1.4	592
0.72[3]		Bridge	97.81	4.10	1.1	592
55.85		RCP	97.59	3.13	1.6	20
56.72		Bridge	98.15	6.85	1.5	364
1.62[3]		Bridge	98.15	6.42	1.5	364
57.30		Bridge	98.40	7.56	1.2	16

1 in 10,000 AEP Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
65.29	Western Creek	Bridge	89.34	0.90	2.8	264
65.90		RCP	87.67	1.16	1.6	7
66.00		RCP	86.36	1.22	1.8	18
66.04		RCP	86.12	1.31	1.8	18
66.25		RCP	85.12	1.43	1.6	40
66.43		RCP	84.82	1.04	1.9	31
66.48		RCP	84.73	0.97	1.9	16
66.52		RCP	84.22	1.33	1.8	8
66.55		RCP	83.88	1.48	1.2	4
66.58		RCP	83.39	1.77	1.2	4
66.61		RCP	82.97	2.01	0.9	2
66.76		RCP	81.78	2.34	1.1	4
66.82		RCP	81.64	2.16	1.3	7
66.93		RCP	81.40	1.71	1.3	18
67.04		RCP	81.00	1.52	1.2	3
67.25		RCP	80.28	1.05	2.4	9
67.31		RCP	79.59	1.27	1.7	32
67.36		RCP	79.25	1.47	1.8	6
67.41		RCP	78.89	1.57	1.5	4
67.63		Bridge	78.58	1.10	2.9	264
68.69		RCBC[1]	72.90	0.82	1.6	< 1
69.10		Bridge	71.21	0.39	2.7	136
69.29		Bridge	70.75	0.18	3.1	197
69.90		RCBC[2]	70.51	-0.70	7.4	11
69.91		RCBC[1]	70.54	-0.66	7.4	10
69.98		RCP[2]	69.76	0.16	4.5	32
70.02		RCP[2]	69.79	0.07	4.5	11
70.05		RCBC[1]	69.79	0.01	6.2	5
70.98		RCBC[1]	62.22	1.32	3.3	22
71.12		Bridge	61.59	0.41	2.8	270
71.54		RCBC[2]	59.65	0.35	2.0	2
71.54		RCBC[1]	59.65	0.35	2.0	2
71.90		RCBC	57.31	1.63	0.8	< 1
72.43		RCBC[1]	57.07	0.51	1.6	1
73.21		RCBC[1]	55.00	2.58	3.0	6

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PMF Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
40.05	Lockyer Creek	RCP²	109.98	-4.84	5.7	15
40.33		RCBC¹	109.98	-4.71	7.2	71
41.07		RCP¹	109.87	-4.36	3.3	< 1
41.99		RCP¹	109.19	-2.96	2.2	2
42.60		RCP¹	108.56	-3.16	4.3	7
43.15		Bridge	107.86	-1.45	5.1	6013
43.58		RCBC¹	105.30	-1.96	1.9	< 1
43.94		RCP¹	104.43	-4.50	1.6	< 1
44.45		RCBC²	101.50	-2.52	5.8	61
44.90		RCP¹	101.44	-3.21	4.4	6
45.76		RCP¹	99.68	-2.29	5.0	3
46.49		RCBC¹	97.42	-2.00	4.1	3
47.22		RCBC¹	96.14	-2.16	6.7	23
47.24		RCP²	96.09	-2.17	3.4	29
47.57		RCP²	95.76	-2.50	3.1	5
47.81		RCBC¹	95.33	-2.61	6.0	15
48.46		RCBC¹	94.59	-3.22	2.9	6
49.52		Bridge	94.04	-2.82	4.2	566
49.57		RCBC²	94.12	-3.02	4.8	62
50.27	Laidley Creek/ Sandy Creek	Bridge	92.58	-1.34	4.1	161
51.37		Bridge	93.95	1.09	2.5	36
51.57		RCBC² ³	93.52	0.69	3.7	119
51.60		Bridge	93.31	0.66	5.6	228
52.55		RCBC¹	93.95	-1.20	4.4	6
52.67		RCBC² ³	93.95	-1.17	3.8	123
52.68		RCP¹	93.93	-1.15	3.7	2
53.39		RCBC² ³	94.16	-1.14	7.2	140
53.48		RCBC²	94.18	-1.12	4.7	61
53.50		RCBC¹	94.16	-1.09	4.9	43
53.97		RCBC²	94.18	-2.47	4.3	74
53.99		RCBC¹	94.18	-0.95	4.3	35
54.74		Bridge	96.70	0.25	3.9	472
54.81		RCBC¹	96.70	0.77	3.9	139
54.83		RCBC¹	96.70	0.83	3.9	139
54.84		RCBC¹	96.70	0.86	3.9	156
55.45		RCP¹	97.18	2.98	2.6	2
55.83		Bridge	98.89	3.48	1.5	1051
0.72³		Bridge	98.87	3.04	1.2	1051
55.85		RCP	98.31	2.41	1.7	21
56.72		Bridge	99.30	5.70	1.6	1118

PMF Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
1.62[3]		Bridge	99.30	5.27	1.6	1118
57.30		Bridge	99.48	6.48	1.2	97
65.29	Western Creek	Bridge	90.05	0.19	2.9	662
65.90		RCP	89.19	-0.36	2.8	17
66.00		RCP	87.27	0.31	2.3	29
66.04		RCP	86.93	0.50	1.9	24
66.25		RCP	86.07	0.48	2.0	51
66.43		RCP	85.55	0.31	2.6	43
66.48		RCP	85.38	0.32	2.5	21
66.52		RCP	84.83	0.72	2.3	18
66.55		RCP	84.50	0.86	2.3	15
66.58		RCP	83.97	1.19	1.9	14
66.61		RCP	83.47	1.51	1.4	10
66.76		RCP	82.40	1.72	1.3	11
66.82		RCP	82.27	1.53	1.3	10
66.93		RCP	82.02	1.09	1.4	29
67.04		RCP	81.46	1.06	1.9	16
67.25		RCP	81.23	0.10	3.7	16
67.31		RCP	80.81	0.05	3.4	73
67.36		RCP	80.70	0.02	3.9	16
67.41		RCP	80.68	-0.22	4.1	17
67.63		Bridge	79.17	0.51	3.9	439
68.69		RCBC[1]	73.85	-0.13	3.0	6
69.10		Bridge	72.01	-0.41	3.0	240
69.29		Bridge	71.32	-0.39	3.5	309
69.90		RCBC[2]	71.41	-1.60	8.5	12
69.91		RCBC[1]	71.47	-1.59	8.6	11
69.98		RCP[2]	71.00	-1.08	5.4	38
70.02		RCP[2]	71.03	-1.17	5.4	13
70.05		RCBC[1]	71.02	-1.22	7.9	7
70.98		RCBC[1]	62.92	0.62	4.9	29
71.12		Bridge	61.87	0.13	3.6	352
71.54		RCBC[2]	60.01	-0.01	2.2	3
71.54		RCBC[1]	60.01	-0.01	2.2	3
71.90		RCBC	58.58	0.36	1.7	3

PMF Event						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
72.43		RCBC¹	57.47	0.11	3.6	6
73.21		RCBC¹	56.00	1.58	3.1	7

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1% AEP Event with climate change						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
40.05	Lockyer Creek	RCP²	104.89	0.25	4.7	12
40.33		RCBC¹	104.89	0.38	3.5	33
41.07		RCP¹	105.19	0.32	1.7	< 1
41.99		RCP¹	106.03	0.20	0.6	< 1
42.60		RCP¹	105.04	0.36	2.1	3
43.15		Bridge	104.26	2.15	3.4	3772
43.58		RCBC¹	Dry³	-	-	-
43.94		RCP¹	Dry³	-	< 0.1	< 1
44.45		RCBC²	Dry³	-	-	-
44.90		RCP¹	98.53	-0.30	3.0	4
45.76		RCP¹	97.83	-0.44	4.3	3
46.49		RCBC¹	95.67	-0.25	3.5	2
47.22		RCBC¹	93.68	0.30	3.2	18
47.24		RCP²	93.57	0.35	2.6	22
47.57		RCP²	92.27	0.99	2.3	4
47.81		RCBC¹	92.53	0.19	3.7	12
48.46		RCBC¹	91.17	0.20	2.0	4
49.52		Bridge	91.02	0.20	3.7	80
49.57		RCBC²	90.48	0.62	2.6	34
50.27	Laidley Creek/ Sandy Creek	Bridge	89.70	1.54	2.0	37
51.37		Bridge	93.91	1.13	2.0	35
51.57		RCBC² ³	91.79	2.42	1.8	52
51.60		Bridge	92.57	1.40	4.9	65
52.55		RCBC¹	91.67	1.08	1.4	2
52.67		RCBC² ³	91.66	1.12	0.9	22
52.68		RCP¹	91.67	1.11	1.1	< 1
53.39		RCBC² ³	92.17	0.85	3.0	74
53.48		RCBC²	91.76	1.30	2.7	31
53.50		RCBC¹	91.68	1.39	2.6	23
53.97		RCBC²	91.54	0.17	1.9	29

1% AEP Event with climate change						
Chainage (km)	Waterway	Structure type	Upstream peak water level (m AHD)	Freeboard to rail formation level (m)	Outlet velocity (m/s)	Peak discharge (m^3/s)
53.99		RCBC[1]	91.54	1.69	1.4	11
54.74		Bridge	94.83	2.12	1.3	161
54.81		RCBC[1]	94.83	2.64	1.6	56
54.83		RCBC[1]	94.83	2.70	1.6	56
54.84		RCBC[1]	94.83	2.73	1.6	63
55.45		RCP[1]	Dry[3]	-	-	-
55.83		Bridge	97.43	4.94	1.4	182
0.72[3]		Bridge	97.40	4.51	0.9	182
55.85		RCP	96.74	3.98	1.6	13
56.72		Bridge	97.84	7.16	1.5	251
1.62[3]		Bridge	97.84	6.73	1.4	251
57.30		Bridge	98.20	7.76	1.2	10
65.29	Western Creek	Bridge	89.07	1.17	2.7	172
65.90		RCP	86.94	1.89	1.5	5
66.00		RCP	85.97	1.61	1.8	17
66.04		RCP	85.75	1.68	1.5	10
66.25		RCP	84.67	1.88	1.3	33
66.43		RCP	84.43	1.43	1.4	19
66.48		RCP	84.33	1.37	1.3	11
66.52		RCP	83.94	1.61	1.2	3
66.55		RCP	83.70	1.66	1.0	2
66.58		RCP	83.22	1.94	1.0	2
66.61		RCP	82.81	2.17	0.8	< 1
66.76		RCP	81.55	2.57	1.1	2
66.82		RCP	81.40	2.40	1.1	4
66.93		RCP	81.16	1.95	1.3	15
67.04		RCP	80.79	1.73	1.1	3
67.25		RCP	79.91	1.42	1.8	6
67.31		RCP	79.28	1.58	1.3	18
67.36		RCP	79.03	1.69	1.5	4
67.41		RCP	78.71	1.75	1.3	2
67.63		Bridge	78.48	1.20	2.4	198
68.69		RCBC[1]	72.52	1.20	0.4	< 1
69.10		Bridge	70.66	0.94	2.4	88
69.29		Bridge	70.37	0.56	2.6	157
69.90		RCBC[2]	69.53	0.28	5.9	9
69.91		RCBC[1]	69.54	0.34	5.9	8
69.98		RCP[2]	67.62	2.30	1.5	8
70.02		RCP[2]	67.60	2.26	1.5	2
70.05		RCBC[1]	67.60	2.20	1.5	< 1

1% AEP Event with climate change						
Chainage (km)	**Waterway**	**Structure type**	**Upstream peak water level (m AHD)**	**Freeboard to rail formation level (m)**	**Outlet velocity (m/s)**	**Peak discharge (m^3/s)**
70.98		RCBC[1]	61.97	1.57	3.3	19
71.12		Bridge	61.43	0.57	2.3	221
71.54		RCBC[2]	59.15	0.85	1.4	< 1
71.54		RCBC[1]	59.15	0.85	1.4	< 1
71.90		RCBC	Dry[3]	-	-	-
72.43		RCBC[1]	Dry[3]	-	-	-
73.21		RCBC[1]	54.57	3.01	2.8	5

Table notes:

1 The Developed Case alignment runs parallel to the QR West Moreton System rail corridor at this location. The existing culvert is proposed to be extended and matched through the Project alignment.

2 The Developed Case alignment runs parallel to the QR West Moreton System rail corridor at this location. A new culvert(s) is proposed to be inserted through the QR West Moreton System rail corridor and the Project alignment.

3 This Developed Case structure is outside the 1% AEP event extents. This structure was included in the Developed Case as it conveys flow during extreme events.

APPENDIX

M

Hydrology and Flooding Technical Report

Appendix D Flood-Sensitive Receptors

Appendix D

Flood sensitive receptors

Identified flood sensitive receptor No	Identified flood sensitive receptor type	Catchment	20% AEP (mm)	10% AEP (mm)	5% AEP (mm)	2% AEP (mm)	1% AEP (mm)	1% AEP with Climate Change (mm)	1% AEP with 0% Culvert Blockage (mm)	1% AEP with 50% Culvert Blockage (mm)	1% AEP with 20% Bridge Blockage (mm)
85	Sheds and rural free	Lockyer	-	-	-	-	-	16	-	-	-
86	Residential dwelling	Lockyer	-	-	-	-	-	18	-	-	-
88	Sheds and rural free	Lockyer	-	-	-	-	-	37	-	-	-
89	Sheds and rural free	Lockyer	-	-	-	-	-	59	-	-	-
136	Industrial building	Lockyer	-	-	-	-	-	10	-	-	-
139	Residential dwelling	Lockyer	-	-	-	8	7	11	7	7	21
141	Residential dwelling	Lockyer	-	-	-	-	-	26	-	-	-
143	Sheds and rural free	Lockyer	-	-	-	-	-	10	-	-	-
151	Residential dwelling	Lockyer	-	-	-	-	6	12	6	6	25
152	Residential dwelling	Lockyer	-	-	-	-	6	12	6	6	24
153	Residential dwelling	Lockyer	-	-	-	-	6	12	6	6	24
154	Residential dwelling	Lockyer	-	-	-	-	6	12	6	7	25
155	Community infrastructure	Lockyer	-	-	-	8	7	12	7	7	26
156	Community infrastructure	Lockyer	-	-	-	-	7	12	7	7	26
157	Community infrastructure	Lockyer	-	-	-	8	7	12	7	7	26
158	Community infrastructure	Lockyer	-	-	-	-	7	12	7	7	26
159	Community infrastructure	Lockyer	-	-	-	8	6	12	6	6	25
160	Community infrastructure	Lockyer	-	-	-	8	7	12	7	7	26
161	Community infrastructure	Lockyer	-	-	-	-	-	12	-	-	-
162	Community infrastructure	Lockyer	-	-	-	-	5	12	5	6	24
163	Community infrastructure	Lockyer	-	-	-	-	-	12	-	-	-
164	Community infrastructure	Lockyer	-	-	-	-	5	12	5	6	24
165	Residential dwelling	Lockyer	-	-	-	9	10	12	10	10	27
166	Community infrastructure	Lockyer	-	-	-	-	-	12	-	-	-
168	Residential dwelling	Lockyer	-	-	-	9	6	12	6	6	25
169	Residential dwelling	Lockyer	-	-	-	9	7	12	7	7	26
170	Residential dwelling	Lockyer	-	-	-	-	6	12	6	6	25
171	Residential dwelling	Lockyer	-	-	-	-	7	12	7	7	25
172	Community infrastructure	Lockyer	-	-	-	-	-	12	-	-	-
173	Sheds and rural free	Lockyer	-	-	-	-	7	12	7	7	25
174	Residential dwelling	Lockyer	-	-	-	9	8	12	8	8	26
176	Community infrastructure	Lockyer	-	-	-	-	6	12	6	6	24
177	Sheds and rural free	Lockyer	-	-	-	-	6	12	6	6	25

Identified flood sensitive receptor No	Identified flood sensitive receptor type	Catchment	20% AEP (mm)	10% AEP (mm)	5% AEP (mm)	2% AEP (mm)	1% AEP (mm)	1% AEP with Climate Change (mm)	1% AEP with 0% Culvert Blockage (mm)	1% AEP with 50% Culvert Blockage (mm)	1% AEP with 20% Bridge Blockage (mm)
178	Residential dwelling	Lockyer	-	-	-	-	7	12	7	7	25
179	Residential dwelling	Lockyer	-	-	-	-	6	12	6	6	25
180	Sheds and rural free	Lockyer	-	-	-	-	7	12	7	7	26
181	Residential dwelling	Lockyer	-	-	-	-	8	12	8	8	26
182	Community infrastructure	Lockyer	-	-	-	-	-	12	-	-	-
183	Residential dwelling	Lockyer	-	-	-	-	6	12	6	6	25
184	Residential dwelling	Lockyer	-	-	-	-	9	11	9	9	26
186	Residential dwelling	Lockyer	-	-	-	-	6	12	6	6	25
187	Residential dwelling	Lockyer	-	-	-	-	8	12	8	8	26
188	Commercial building	Lockyer	-	-	-	-	8	12	8	8	26
191	Residential dwelling	Lockyer	-	-	-	-	-	12	-	-	-
192	Sheds and rural free	Lockyer	-	-	-	-	7	12	7	7	26
193	Residential dwelling	Lockyer	-	-	-	-	7	12	7	7	26
194	Residential dwelling	Lockyer	-	-	-	-	7	12	7	7	26
195	Sheds and rural free	Lockyer	-	-	-	-	7	12	7	7	25
197	Residential dwelling	Lockyer	-	-	-	-	7	12	7	7	25
198	Residential dwelling	Lockyer	-	-	-	-	7	11	7	7	25
199	Residential dwelling	Lockyer	-	-	-	-	-	12	-	-	-
200	Residential dwelling	Lockyer	-	-	-	-	7	12	7	7	25
201	Sheds and rural free	Lockyer	-	-	-	-	7	12	7	7	25
205	Residential dwelling	Lockyer	-	-	-	-	-	12	-	-	-
210	Sheds and rural free	Lockyer	-	-	-	-	42	66	42	42	42
219	Residential dwelling	Lockyer	-	-	-	-	-2	10	-2	-2	-2
369	Sheds and rural free	Lockyer	-	-	-	-	-3	105	-3	-3	-3
375	Water tank	Lockyer	-	-	-	-	3	122	3	3	3
376	Sheds and rural free	Lockyer	-	-	-	-	4	122	4	4	4
378	Sheds and rural free	Lockyer	-	-	-	-	5	126	5	5	5
379	Water tank	Lockyer	-	-	-	-	5	126	5	5	5
380	Residential dwelling	Lockyer	-	-	-	-	6	135	6	6	6
381	Water tank	Lockyer	-	-	-	-	5	135	5	5	5
383	Sheds and rural free	Lockyer	-	-	-	0	0	17	0	0	0
384	Water tank	Lockyer	-	-	-	0	0	12	0	0	0
388	Residential dwelling	Lockyer	-	-	-	0	0	18	0	0	0
389	Sheds and rural free	Lockyer	-	-	-	0	0	15	0	0	0
391	Sheds and rural free	Lockyer	-	-	-	0	0	12	0	0	0
392	Water tank	Lockyer	-	-	-	0	0	18	0	0	0
398	Roads	Lockyer	-	-	-	0	0	65	0	0	0

Identified flood sensitive receptor No	Identified flood sensitive receptor type	Catchment	20% AEP (mm)	10% AEP (mm)	5% AEP (mm)	2% AEP (mm)	1% AEP (mm)	1% AEP with Climate Change (mm)	1% AEP with 0% Culvert Blockage (mm)	1% AEP with 50% Culvert Blockage (mm)	1% AEP with 20% Bridge Blockage (mm)
421	Commercial building	Lockyer	-	-	-	0	0	219	0	0	0
422	Water tank	Lockyer	-	-	-	0	0	216	0	0	0
436	Sheds and rural free	Lockyer	-	-	-	-4	-10	291	-10	-10	-10
439	Sheds and rural free	Lockyer	-	-	-	-	-6	245	-6	-6	-6
440	Residential dwelling	Lockyer	-	-	-	-	-6	258	-6	-6	-6
444	Sheds and rural free	Lockyer	-	-	-	-	-2	358	-2	-2	-2
445	Sheds and rural free	Lockyer	-	-	-	-	-5	220	-5	-5	-5
452	Water tank	Lockyer	-	-	-	-	-4	344	-4	-4	-4
453	Water tank	Lockyer	-	-	-	-	-4	295	-4	-4	-4
459	Sheds and rural free	Lockyer	-	-	-	-	-15	243	-15	-15	-15
460	Sheds and rural free	Lockyer	-	-	-	-	-4	471	-4	-4	-4
521	Sheds and rural free	Lockyer	-	-	-	-	-	252	-	-	-
526	Sheds and rural free	Lockyer	-	-	-	-	-	193	-	-	-
529	Sheds and rural free	Lockyer	-	-	-	-	-	225	-	-	-
545	Sheds and rural free	Lockyer	-	-	-	-	-	292	-	-	-
566	Sheds and rural free	Lockyer	-	-	-	0	0	14	0	0	0
567	Sheds and rural free	Lockyer	-	-	-	0	0	38	0	0	0
568	Residential dwelling	Lockyer	-	-	-	0	0	16	0	0	0
570	Sheds and rural free	Lockyer	-	-	-	0	0	57	0	0	0
571	Sheds and rural free	Lockyer	-	-	-	0	0	27	0	0	0
572	Sheds and rural free	Lockyer	-	-	-	0	0	14	0	0	0
576	Sheds and rural free	Lockyer	-	-	-	0	0	21	0	0	0
577	Sheds and rural free	Lockyer	-	-	-	0	0	44	0	1	0
612	Roads	Lockyer	-	-	-	0	-2	79	-3	-1	-2
613	Sheds and rural free	Lockyer	-	-	-	-2	3	114	0	7	3
614	Sheds and rural free	Lockyer	-	-	-	0	0	22	0	0	0
615	Sheds and rural free	Lockyer	-	-	-	-3	3	52	1	7	3
616	Sheds and rural free	Lockyer	-	-	-	0	0	84	-1	4	0
618	Roads	Lockyer	-	-	-	0	0	18	-1	1	0
693	Sheds and rural free	Lockyer	-	-	-1	1	4	10	4	4	5
698	Sheds and rural free	Lockyer	-	-1	-1	3	8	12	8	7	8
700	Sheds and rural free	Lockyer	-	0	1	4	10	12	10	9	10
876	Water tank	Lockyer	-	-	-5	-33	71	80	54	96	70
877	Sheds and rural free	Lockyer	-	-	-5	-34	75	84	57	101	74
925	Rail infrastructure	Lockyer	2	33	48	51	53	56	53	53	54
942	Rail infrastructure	Lockyer	-	-	-	-	-	17	-	-	-
943	Sheds and rural free	Lockyer	-	7	28	64	68	90	66	69	91

Identified flood sensitive receptor No	Identified flood sensitive receptor type	Catchment	20% AEP (mm)	10% AEP (mm)	5% AEP (mm)	2% AEP (mm)	1% AEP (mm)	1% AEP with Climate Change (mm)	1% AEP with 0% Culvert Blockage (mm)	1% AEP with 50% Culvert Blockage (mm)	1% AEP with 20% Bridge Blockage (mm)
947	Roads	Lockyer	-	-1	1	26	22	23	21	22	22
973	Roads	Lockyer	-	-	-	20	31	40	30	32	33
1031	Roads	Lockyer	-	-	-	15	27	32	26	28	27
1032	Residential dwelling	Lockyer	-	-	-	228	230	227	227	232	225
1051	Residential dwelling	Lockyer	-	-	-	-	-	82	-	-	-
1169	Residential dwelling	Bremer	-	-	-	0	2	74	2	47	-4
1171	Sheds and rural free	Bremer	-	-	-	0	1	75	2	53	-23
1304	Sheds and rural free	Bremer	-	0	2	0	0	10	0	0	0
1313	Sheds and rural free	Bremer	-	-	-	-	-	21	-	-	-
1317	Sheds and rural free	Bremer	-	-	-	-	-	78	-	-	-
1340	Residential dwelling	Bremer	-	-	-26	-32	3	20	-1	15	9
1341	Residential dwelling	Bremer	-	-	-	-	0	20	0	1	2
1342	Sheds and rural free	Bremer	-	-	-38	-39	3	19	-2	15	9
1345	Sheds and rural free	Bremer	-	-	-	422	441	434	441	440	421
1346	Residential dwelling	Bremer	-	-	-	-	315	325	316	314	292
1347	Water tank	Bremer	-	-	-	-	-	195	-	-	-
1548	Paved road	Bremer	-	-	-	-	-	26	-	-	-
1588	Unpaved road	Bremer	-	-	4	1	0	27	0	-1	13
1610	Paved road	Bremer	0	0	1	4	7	14	8	8	7
1611	Bridge	Bremer	3	0	1	4	7	14	7	7	7
1786	Unpaved road	Bremer	3	4	3	5	8	14	5	27	8

APPENDIX

M

Hydrology and Flooding Technical Report

Appendix E Local Drainage Structures and Impact Outcomes

Appendix E
Local drainage structures and impact outcomes

Culvert ID	Chainage (km)	Type	Number	Diameter/ Span/ Width (m)	Height (m)/ Soffit Level (m AHD)	1% AEP Flow through Structure (m^3/s)	1% AEP Upstream Water Level - Design (m AHD)	1% AEP Upstream Headwater Depth - Design (m)	1% AEP Freeboard to Formation (m)	Impacts at Rail Corridor		
										1% AEP Afflux (mm)	Existing Time of Inundation (hrs)	Change in Time of Inundation (hrs)
C27.05	27.05	RCBC	4	3	1.8	16.4	146.10	1.73	1.16	+120	9.25	1.46
C27.35	27.35	RCBC	8	3	2.7	74.0	146.83	5.44	2.87	0	9.08	0.00
C27.40	27.40	RCP	10	2.4	-	59.0	146.87	3.01	3.31	+270	9.08	0.02
C27.86	27.86	RCP	2	1.2	-	1.4	151.22	0.72	2.86	+100	0.51	0.00
C28.05	28.05	RCBC	5	3	2.1	36.6	152.79	1.99	2.93	+60	8.96	0.42
C29.54	29.54	RCBC	4	2.1	1.8	22.4	165.52	1.87	0.53	+280	5.48	0.04
C30.18	30.18	RCBC	4	1.5	1.5	11.9	167.96	1.58	1.25	0	6.74	0.00
C30.47	30.47	RCBC	4	1.5	1.5	11.0	164.21	1.47	6.46	+110	0.92	0.00
C30.70	30.70	RCP	2	1.2	-	2.7	170.59	1.02	1.08	+40	0.89	0.51
330-BR02	32.58	BRIDGE		445	151.5	11.5	143.50	N/A	9.37	0	18.59	0.02
330-BR03	33.57	BRIDGE		427	147.6	135.0	134.90	N/A	15.17	+80	18.09	0.01
C34.32	34.32	RCP	8	1.2	-	10.5	140.18	0.98	11.44	+170	15.36	0.22
C35.09	35.09	RCBC	2	1.2	1.2	3.6	145.26	1.39	1.00	0	0.29	0.00
C35.49	35.49	RCP	3	1.2	-	4.1	142.01	1.05	1.29	+90	6.09	0.03
C35.88	35.88	RCP	2	1.5	-	6.8	129.62	1.74	9.88	0	6.18	0.00
C36.37	36.37	RCP	10	1.2	-	14.4	127.55	1.15	6.86	+90	5.08	0.52
C36.42	36.42	RCP	5	1.2	-	7.3	127.68	0.53	6.29	+70	6.39	0.36
C36.70	36.70	RCP	13	1.5	-	12.5	122.37	0.73	8.76	+300	4.89	3.40
C39.15	39.15	RCBC	4	2.4	0.9	13.5	105.51	1.06	0.87	+50	7.26	0.74
C39.48	39.48	RCBC	3	0.9	0.9	4.2	104.59	1.13	0.96	+30	8.80	0.71
C39.50	39.50	RCBC	1	1.2	0.9	1.6	104.58	0.97	0.92	+30	8.43	0.71
C58.80	58.80	RCP	2	1.5	-	7.3	112.57	1.86	8.71	+20	7.94	0.24
330-BR32	58.85	BRIDGE		78	121.0	11.7	114.10	N/A	14.70	+340	1.87	0.83
330-BR17	59.38	BRIDGE		102	126.7	42.8	122.88	N/A	5.92	+340	8.30	0.83
C59.61	59.61	RCP	3	1.2	-	2.7	124.34	0.78	8.15	0	1.33	0.00
C59.66	59.66	RCP	4	1.2	-	9.6	126.69	1.72	6.50	0	3.58	0.00
C60.28	60.28	RCP	2	1.2	-	4.2	140.29	1.49	1.35	0	8.82	0.00
C60.69	60.69	RCP	1	1.2	-	2.1	143.22	1.52	4.06	0	8.88	0.00
C60.88	60.88	RCP	2	1.8	-	5.7	140.27	1.28	9.69	0	0.90	0.00
C61.09	61.09	RCP	6	1.2	-	14.2	144.79	1.74	8.12	+390	6.13	0.23
C61.55	61.55	RCBC	5	2.4	1.2	13.1	155.47	1.16	3.45	+400	7.60	0.70
C61.62	61.62	RCP	3	1.2	-	5.8	155.87	1.38	3.10	+100	7.60	0.04
C62.87	62.87	RCBC	9	1.8	1.8	13.1	135.72	0.93	2.91	0	0.76	0.00
C63.08	63.08	RCP	8	1.8	-	31.5	128.16	2.29	7.26	+60	4.78	0.32
C63.20	63.20	RCP	10	1.2	-	2.0	122.87	0.62	10.47	+50	1.85	0.86
C63.59	63.59	RCP	6	1.5	-	12.7	116.24	1.86	10.64	0	5.84	0.00
330-BR19	64.39	BRIDGE		159	110.3	50.8	104.68	N/A	8.15	+250	5.76	0.00
C64.78	64.78	RCP	15	1.2	-	7.3	98.51	0.54	8.62	+120	6.46	0.32
C70.53	70.53	RCP	6	1.05	-	6.8	64.39	1.01	4.11	+190	7.96	0.04
C72.24	72.24	RCBC	1	1.2	0.9	0.7	56.83	0.58	1.03	0	0.42	0.00