Maranoa Regional Council

Roma Flood Mitigation Study

Hydrology and Hydraulics for Stage 2 Western Levee & Eastern Diversion Drain

September 2016

Executive summary

In 2012, GHD was commissioned by Maranoa Regional Council (MRC) to investigate flood mitigation options to address regional flood risk in response to the flood event in 2012. The project is being undertaken in stages, i.e. Stage 1 (complete) and Stage 2 (Current) to align with government funding programmes and timeframes.

The 2012 flood event was the largest on record for Roma. Typically, a 100 year ARI design storm event is the recommended design event for flood planning (*Queensland State Planning Policy 1/03 Guideline*, June 2003). However, MRC have adopted the 2012 regional storm event, which was greater than a 100 ARI design storm event, as the Defined Flood Event (DFE) for the assessment and design of mitigation measures and planning. In addition to hydrological modelling of the 2012 DFE, a standard range of design flood events were modelled to assess the behaviour of the catchment during various storm events.

The design construction of the Stage 1 levee was completed mid-2014. The implementation of the Stage 1 levee results in a reduction of properties at risk of above floor flooding from approximately 580 (during 2012 flood) down to approximately 120, based on the information at the time of assessment. During the construction of the Stage 1 levee, GHD undertook further flood mitigation assessment and prepared concept designs for the subsequent Stage 2 to determine measures to further reduce the risk of above floor flooding from storms similar to the 2012 flood event.

The assessment of a suite of preferred mitigation measures for Stage 2 followed a series of design consultations between MRC, the community and GHD. The outcome of the comprehensive assessment and optioneering undertaken in Stage 2 of the study was the development of a 10-year flood mitigation strategy for Roma. The preferred combination of mitigation options (GHD, 2014) was recommended and MRC prepared business case funding applications for Stage 2 works. Given the available funding, Stage 2 was sub-divided into Stage 2A and 2B.

The selected infrastructure for the detail design of Stage 2A was based on the cost-benefit analysis with regard to the number of properties benefiting by reduced flood risk. The funded work includes the western levee and eastern diversion drain, which are the subject of this design report. The benefit of the implementation of the Stage 2A works are the further reduction of buildings at risk of above habitable floor flooding from the residual 120 estimated in Stage 1. Based on the modelling, survey and property database information, it is estimated that the Stage 2A works when in place offer reduction in risk of above floor flooding to an additional 31 properties. The proposed Stage 2B works will again aid in reducing flood depths from a similar 2012 DFE event, with approximately 20 properties at less risk of flooding.

It is acknowledged that during the course of the project that changes have occurred in the catchment, such as development, road works and agricultural activities. MRC have also implemented a new planning scheme which will alter the stormwater runoff characteristics within the catchment and more accurate ground survey has become available over time. The modelling has progressively been upgraded to reflect these changes, so that the ongoing assessment of flood risk and mitigation options analysis can be based on the best information at the time. Therefore, changes in predicted property numbers may also change with time as flood mitigation funding becomes available and the scheme progresses.

The objectives of the Stage 2A mitigation options assessment and detail design comprised:

- Modifying existing hydrological and hydraulic models that were developed for the Roma Flood Mitigation Project, by GHD and others. The modified models reflect updated land use and surface types assigned in the most recent MRC Planning instrument as well as the most recent topographic data compiled for Stage 2 (provided by Bennett and Bennett Surveyors);

- Using TUFLOW, HEC-RAS and URBS software to provide consistency between updated and previously reported outcomes for the regional flood investigation and to present results in effects of the mitigation options modelled for the 2012 DFE;
- Incorporation of local drainage with the proposed levee design, adopting the Queensland Urban Drainage Manual (QUDM) guidelines, MRC Engineering Design guidelines and the Department of Natural Resources and Mines Levee Guidelines for category 2 or 3 levees (DNRM 2014);
- Designing the local drainage to convey the 10% Annual Exceedance Probability (AEP) design event from the contributing upstream catchment during local rainfall events and considering the effects of combined backwater from Bungil Creek;
- Determining adequate measures to mitigate velocities at the entrance to, exit of and at the Ashburn Road causeway across the diversion drain;
- Development of regional flood depth and velocity maps for the 2012 DFE as well as the 10% AEP and 50% AEP minor design flood events.
- Identifying and recommending potential further options to reduce flood risk to the community in future stages of the Roma flood mitigation project.

Variations on the alignment of the diversion drain were trialled for the purposes of the Stage 2 options assessment. The selected configuration of the drain was the result of the options assessment, to provide the maximum benefit relative to cost to surrounding properties in the 2012 DFE. Hydraulic modelling undertaken in this detail design assessment has indicated that the capacity of the drain corresponds to approximately a 50% AEP Regional flood event.

The western levee cross drainage has been designed to convey the local 10 % AEP design flood. This is consistent with standards referenced in both the Capricornia Municipal Development Guidelines (2015) and the Queensland Urban Drainage Manual (2013 Provisional). For this stage of the project, local hydraulic modelling (Sections 6 and 8) was undertaken for the purposes of verifying cross drainage in the western levee. The resulting modelled water depths and velocities are not shown to affect the habitable buildings on the properties and show a ‘no-worsening’ in terms of above floor flooding to habitable buildings and flood extent when compared to the existing 2012 DFE conditions.

It is proposed that the extent of flooding and flood risk can be further alleviated through a range of local options on the dry side of the levee, which are currently being considered under Stage 2B of the Roma flood mitigation project. These options include local drainage improvement works within the long-drain system including Shady’s lagoon and the watercourses in the vicinity of the Bungil Street bridge, upgrade works in the vicinity of the Railway Dam and mitigation works east of Bungil Creek.

Council is progressively up-dating the flood emergency and evacuation plans as subsequent stages of the mitigation project come on line. The updated plans will be in place prior to construction of Stage 2A works commencing. Council’s emergency and evacuation planning includes the timely closure of penstocks fitted to culverts draining through the levees to arrest regional flood waters backing up through the levee drainage system. Council have also included in their planning for the implementation of emergency pumps to be deployed at key locations along the existing and proposed levees. The pumps will act to reduce to build up of local overland flow behind the levee during coincident regional and local storm events.

As part of the future Stage 2B assessment and design phase, the Council's flood model will continue to be updated to reflect changes in the catchment and the adoption of the future development scheme. This may also include areas in the vicinity of the Hay Roma Dam, eastern industrial precinct and areas north of town such as Bassett Park and the airport. The Council will consider the findings of the ultimate development and where possible seek opportunities to plan for and mitigate changes in flood characteristics across the floodplain. Acknowledging that any future mitigation work is totally dependent upon Council receiving funding from State of Federal government.

The results of the Stage 2A mitigation works, when combined with the existing Stage 1 levee, show further reductions in flood water levels, hence reducing risk of above floor flooding to more properties within the flood plain in line with MRC's project objective.

Abbreviations

Acronym	Definition
1D	One-dimensional
2D	Two-dimensional
AAD	Average annual damages
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff, 1987
BOM	Bureau of Meteorology
CBA	Cost Benefit Analysis
CRC-FORGE	A regional catchment-based rainfall data source
DEM	Digital Elevation Model
DFE	Defined Flood Event
DNRM	Department of Natural Resources and Mines
DTM	Digital Terrain Model
EMR/CLR	Environmental Management and Contaminated Land Registers
GHD	GHD Pty Ltd
HEC-RAS	Hydrologic Engineering Centre's River Analysis System software
IFD	Intensity Frequency Duration
km	Kilometre
km^2	Square kilometre
km^3	Cubic kilometre
LiDAR	Light detection and ranging data
m	Metre
m^2	Square metre
m^3	Cubic metre
Manning's n	Manning's n roughness coefficient
MCA	Multi Criteria Analysis
mm	Millimetre
MRC	Maranoa Regional Council
NCCOE	National Committee on Coastal and Ocean Engineering
PMF	Probable maximum flood

PMP	Probable maximum precipitation
QRA	Queensland Reconstruction Authority
QUDM	Queensland Urban Drainage Manual
RCBC	Reinforced concrete box culvert
TMR	Department of Transport and Main Roads
TUFLOW	Two-dimensional Unsteady Flow Software
URBS	Unified River Basin Simulator tool
WaterRIDE	Water Resources Integrated Development Environment Software
yr	Year

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1. Introduction

1.1 Background

The Roma township experienced flooding in 2010, 2011 and 2012. The 2012 event caused the most extreme impacts on record. The 2012 flood adversely affected local residents, businesses, agriculture and infrastructure. Extensive negative impacts were the result of a combination of both localised inland flooding from overland flow across the township and major regional flooding from the Bungil Creek and Mooga Mooga catchments. Approximately 580 buildings experienced above habitable floor flooding as a result of the 2012 event.

Stage 1

In 2012, GHD was commissioned by Maranoa Regional Council (MRC) to further develop the hydrology and hydraulic study and to investigate flood mitigation options to address regional flood risk in response to the flooding in Roma. MRC's objective for the Roma Flood Mitigation Project is to implement measures that will reduce the risk of above floor flooding from a similar 2012 flood event. Council adopted the 2012 flood event as the Defined Flood Event (DFE) for mitigation and planning purposes. The Roma Flood Mitigation Project is being undertaken in stages and the mitigation works are being taken forward upon the successful award of government funding mechanisms and in line with funding timeframes.

The first stage of the concept level flood study was of a regional-scale focus. This included to further development of the hydrology model and hydraulic modelling of the catchment and optioneering of mitigation measures. This multi-disciplined assessment work, including site investigations, community consultation and cost-benefit analysis led to the conceptual design of the Stage 1 levee. The analysis of the benefits of the constructed Stage 1 levee showed a significant reduction of the number of buildings at risk of above floor flooding from 580 to an estimated 120 properties.

Once the preferred Stage 1 levee option was adopted by MRC, GHD undertook the preparation of the reference design documentation for Design and Construction tender, which was awarded to Ostwald Bros. The detail design of the infrastructure was undertaken by SMEC Engineers. The development of the reference design included a number of public and individual stakeholder meetings, where feedback and comments were received from the public. Individual property owner liaison was also undertaken to optimise the alignment of the levee where it crossed their properties. The construction of the Stage 1 levee was completed in 2014. The Stage 1 levee is approximately 5.2 km long with an average 2.8 m and meanders from the north of the town near the airport to the south of East Miscamble Street.

Stage 2

During construction of the Stage 1 levee, GHD was engaged to undertake the concept design of the subsequent Stage 2 phase of the project with the purpose to determine measures to further reduce risks of above floor flooding in an event similar to the 2012 flood event across the floodplain in Roma. The Stage 2 assessment was comprehensive and included both regional and local flood risk and considered a number of mitigation options.

The comprehensive mitigation option assessment considered high flow diversion channels, localised levees, and retarding basins, as well as improvements to major and minor stormwater drainage in a number of areas across Roma. With reference to GHD's report, *Maranoa Regional Council Roma Flood Mitigation Study Hydrology and Hydraulics for Stage 2 Regional Mitigation Options (GHD, 2014),* the preferred suite of mitigation measures that were identified from the Stage 2 and included within the Mitigation Combination 6 and 7. These included:

Regional Mitigation Combination 6

- Eastern Levee (to the east of the Bungil Creek Bridge)
- Western Levee (continuation of Stage 1 Levee south to the junction of Bungil Creek
- and Shady's Lagoon)
- Extended Eastern Diversion
- Bungil Creek Widening at Bungil Street Bridge
- Levees around Properties within Floodplain
- Western Diversion Drain B

Regional Mitigation Combination 7

- – Eastern Levee
- – Western Levee
- – Extended Eastern Diversion
- – Bungil Creek Widening at Bungil Street Bridge
- – Levees around Properties within Floodplain

The scope of options was also informed by a series of design consultations between GHD, MRC, regulatory authorities, individual property owners and the broader community. The outcome of the Stage 2 assessment was a flood mitigation strategy including short term options and a longer term plan spanning a 10-year horizon for Roma, to be implemented once funding is secured, refer to Appendix H

Based on the findings of this stage, GHD worked with MRC's team to prepare a business case for funding of Stage 2 mitigation works. Using the results of the cost benefit analysis (number of properties with reduced risk of above floor flooding) and with limitations of available state and federal funding, Stage 2 was divided into two sub stages A and B. Of the preferred combination of measures identified in GHD report (2014), the elements of Stage 2 that showed the most benefit and which were affordable within the available funding were the western levee and the eastern diversion drain. The preliminary analysis of the number of properties with reduced risk of above floor flooding showed a decrease from the estimated residual number of properties in Stage 1 of 120 properties down to approximately 70 (Stage 2 A & B). The western levee and eastern diversion drain elements became the scope of work for Stage 2A, and the subject of this design report

In 2015, a subsequent business case funding application was prepared for the State government by MRC and comprised the elements of Stage 2B. Again, based on the preferred combination of mitigation options identified in the GHD report (2014), the proposed mitigation measures included works east of the township in the vicinity of Beaumont Drive and Clayton Road, the Railway Dam and in the Shady's lagoon / Bungil Street bridge area. MRC were successful in being granted funding for Stage 2B works. The further development of the scope of Stage 2B will be the subject of a subsequent assessment and design process currently being undertaken by GHD and the MRC project team.

It is understood the MRC will continue to roll out the long term flood mitigation strategy as and when funding becomes available. With each stage and implementation of mitigation measures, the risk of damage to properties and broader impacts on the community from flooding reduces.

History of Studies

An outline of studies and reports relating to the progression of this project since GHD's involvement in 2012 is presented in Table 1-1. It is important to note that information provided in these documents relates to the studies undertaken in the history of the project. Discussion and results presented within this report for Stage 2 reflect developments that have been made since these past studies were undertaken. Examples of such developments include but are not limited to; consultations with property owners resulting in changes to design concepts, environmental and socio-economic factors, the release of updated Council data and general progressive development within the catchment that has occurred over the course of the flood mitigation project.

Table 1-1 Timeline of Key Reporting Deliverables in the Roma Flood Mitigation Project

Month/Year	Activity Description	Document Reference
GHD, April 2013	GHD Stage 1 Regional Flood Mitigation Concept	*Maranoa Regional Council, Roma Flood Mitigation Project, Stage 1, Hydrology and Hydraulic Assessment Report (GHD, 2013a).*
December 2013	GHD Stage 2 Local Flood Options Assessment	*Maranoa Regional Council Roma Flood Mitigation Study Hydrology and Hydraulics for Stage 2 Local Mitigation Options (GHD,2013)*
January 2014	GHD Stage 2 Regional & Local Combination Options Assessment	*Maranoa Regional Council Roma Flood Mitigation Study Hydrology and Hydraulics for Stage 2 Regional Mitigation Options (GHD, 2014).*
August 2014	SMEC Detail Design Report for Stage 1	*Roma Flood Levee Project Final Design Report (SMEC, 19th August 2014 Revision F)*
May 2016	GHD Detail Design Report for Stage 2	*This report.*

1.1 Purpose and Scope of Stage 2A Report

In line with MRC's project objective, the aim of the Stage 2A mitigation works is to further reduce the risk of above habitable floor flooding to properties for flood events up to the 2012 Defined Flood Event (DFE). The impacts of property inundation were reviewed in the Stage 2 options assessment process. Mitigation options reducing the number of properties at risk were analysed to ascertain the most feasible outcomes during the multi-criteria analysis undertaken as part of the Stage 2 options study.

This report covers the analysis and assessment of hydrology and hydraulics undertaken to inform the detail design of the Stage 2A works comprising the western levee and eastern diversion drain. The tasks undertaken during the detail design phase included:

- Modification of existing hydrological and hydraulic models that were developed for the Roma Flood Mitigation Project, by GHD and others. The modified models reflect updated land use and surface types assigned in the most recent MRC Planning instrument as well as the most recent topographic data compiled for Stage 2 (provided by others);

- Use of TUFLOW, HEC-RAS and URBS software to provide consistency between updated and previously reported outcomes for the regional flood investigation and present results in an afflux map for the modelled 2012 DFE;
- Incorporation of local drainage to the proposed levee design to the Queensland Urban Drainage Manual (QUDM) standards referenced in the *Department of Natural Resources and Mines Levee Guidelines for category 2 or 3 levees (DNRM 2014)*;
- Design of the local drainage to convey the 10% Annual Exceedance Probability (AEP) design storm event flows;
- Consideration of the effects of combined local flooding and backwater from Bungil Creek;
- Determining adequate measures to mitigate velocities at the entrance to, exit of and at the Ashburn Road causeway across the diversion drain;
- Developing regional flood depth and velocity maps for the 2012 DFE as well as the 10% AEP and 50% AEP minor design flood events.
- Participation in community and stakeholder engagement and awareness sessions
- Updating emergency and evacuation mapping for MRC's disaster management plans
- Identifying and recommending options to further reduce flood risk to the community in future stages of the Roma Flood Mitigation project.

2. Methodology and Data Collection

2.1 Stage 2A Methodology

The following methodology was undertaken for this hydrologic and hydraulic study for the detail design:

- Conduct desktop assessment to review past reports and documentation for Stage 1 Levee and Stage 2 options assessment as well as legislative requirements and data from Council;
- Gather Stage 1 levee as-constructed data and topographical surveys for the area encompassing the western levee and eastern diversion drain;
- Adopt limitations and constraints from the geotechnical, ecological and geomorphological assessments into refinement of the western levee and eastern diversion drain alignments;
- Review past concept design of levee and drain to verify results with most current and updated data for project;
- Provided assistance to Council in consulting with affected property owners;
- Undertake detail design of levee and drain, including drainage structures and scour protection;
- Comment and present results on flood afflux i.e. changes in flood behaviour between previous results and updated results for the regional 2012 DFE following model updates;
- Compile Stage 2 flood results (flood depth and velocity) and present to Council for discussion.
- Update flood evacuation mapping prior to commencement of construction of Stage 2A works.

2.2 Historic Flooding and 2012 Defined Flood Event

The 2012 flood event was the largest on record for Roma. Typically, a 100 year ARI storm event is the recommended design event for flood planning (*Queensland State Planning Policy 1/03 Guideline*, June 2003), however MRC have adopted the slightly larger 2012 regional event as the Defined Flood Event (DFE) for the Roma Flood mitigation project.

In 2012, an unprecedented storm event occurred with the following consequences:

- One fatality resulted from the event
- Approximately 580 buildings experienced above floor flooding, with approximately 1,028 properties within the flood extent
- Significant damage costs resulting from the flood events
- The storm was greater than a 1% AEP flood event
- An estimated 2,200 m^3/s flow rate at the peak of the flood

Refer to the GHD Stage 1 report for details of the analysis of data from recent floods and hydraulic model calibration.

2.3 Design Flood Events

In addition to hydrological modelling of the 2012 DFE, a standard range of design flood events were modelled to assess the behaviour of the catchment resulting from different storm events. Modelled AEPs included the 50%, 10% and 1% AEPs.

Design floods are typically assigned a probability of occurrence that is specified as an Average Recurrence Interval (ARI) or as an Annual Exceedance Probability (AEP). Average Recurrence Interval events (ARI's) are expressed in years whilst Annual Exceedance Probability events are expressed as a percentage. A description of the storm events is outlined in Table 2-1,

Table 2-1 AEP and ARI Description

AEP	ARI	Description
0.2%	500 Year	The best estimate of a flood which has 1 chance in 500 of being equalled or exceeded at least once in any one year. This flood is likely to be equalled or exceeded on average once every 500 years.
0.5%	200 Year	The best estimate of a flood which has 1 chance in 200 of being equalled or exceeded at least once in any one year. This flood is likely to be equalled or exceeded on average once every 200 years.
1%	100 Year	The best estimate of a flood which has 1 chance in 100 of being equalled or exceeded at least once in any one year. This flood is likely to be equalled or exceeded on average once every 100 years.
2%	50 Year	The best estimate of a flood which has 1 chance in 50 of being equalled or exceeded at least once in any one year. This flood is likely to be equalled or exceeded on average once every 50 years.

2.4 Design Standards & Criteria

On a regional scale, the historic 2012 flood event sets the basis for the selection of design criteria of regional flood mitigation infrastructure within the Bungil Creek catchment. This is consistent with the overall project aim to reduce risk from an event similar to the 2012 flood event.

The Stage 1 Flood Mitigation detailed design and construction and the preliminary Stage 2 options assessment were occurred prior to the release of the Department of Natural Resources and Mines Levee Guidelines for category 2 or 3 levees (DNRM 2014). The Stage 2 Flood Mitigation Detailed Design has been undertaken in accordance with these guidelines.

Diversion Drain

Variations on the alignment of the diversion drain were trialled for the purposes of the Stage 2 options assessment. The preferred configuration of the drain was the result of the options assessment, to provide the maximum benefit relative to cost to surrounding properties in the 2012 DFE. The subsequent refinement of the alignment was subject to engineering constraints including the location of key infrastructure and services and those determined from the environmental and geomorphological (study of creek systems) investigations. Hydraulic modelling undertaken in this study has shown that the final drain design has capacity to convey the 50% AEP flows resulting from a DFE regional flood event.

Western Levee

The Stage 2 western levee has been designed in accordance with the Department of Natural Resources and Mines Levee Guidelines for category 2 or 3 levees (DNRM 2014). These guidelines state that the levee shall be designed to provide a minimum requirement of a crest level to be 300 mm higher than the DFE flood water level. In line with the adopted Stage 1 levee design criteria, the top of crest level has been based on the 2012 DFE flood water level plus 800mm freeboard.

The main purpose of the western levee differs from the Stage 1 Flood Levee, as it has been incorporated as a measure to mitigate the effects of flood waters back flowing from Bungil Creek and inundating properties. Stage 1 levee provides mitigation of the greater hydro-dynamic forces of the flood flows resulting from a 2012 DFE event.

The GHD Mitigation Study, Hydrology and Hydraulics for Stage 2 Regional Mitigation Options report (GHD, 2014), documents the assessment process undertaken during the mitigation options selection phase to develop the adopted levee alignment, freeboard and construction type. A summary of the assessment is outlined below:

- Assessment of flood risk across a range of design storm events post Stage 1 levee construction
- Multi Criteria Assessment
- Cost Benefit Analysis (based on reducing numbers of properties impacted by above habitable floor flooding)
- preliminary construction cost estimates developed for MRC's business case.

To inform the detailed design of the levee alignment and to provide a robust design solution that accounts for site constraints such as tight "back yard" alignments, sandy soil foundation conditions and the updated Council planning scheme, subsequent detailed site investigations and assessments were undertaken including:

- Topographic survey
- Geotechnical investigations
- Ecological assessments
- Geomorphological assessments
- Refinement of regional and local models, including the adoption of the revised MRC Planning Scheme

The comprehensive assessment and design process has resulted in a cost effective levee design that:

- Provides additional flood risk mitigation in terms of further reducing the number of properties at risk of damage from above habitable floor flooding arising from flood water backflow
- Enhances Council's disaster management plans and reduces risks to the community during a major flood event
- Minimises its impact upon the land owners in terms of land area required to accommodate the levee and associated infrastructure

- Minimises encroachment onto unfavourable foundation conditions present within the Bungil Creek low flow channel
- Complies with design requirements of the Levee Guidelines for category 2 or 3 levees (DNRM 2014)
- Provides a freeboard to levee crest greater than the minimum risk based 300 mm above the DFE flood water surface (DNRM, 2014). An 800 mm freeboard has been adopted along the alignment.
- Is shown not to overtop during the DFE event and provides additional level of immunity above the DFE flood event, similar to the Stage 1 levee
- Accounts for the additional surface water runoff modelled from the revised MRC Planning Scheme that reflects changes in the catchment due to potential future development over the time frame of the new planning scheme.

The Stage 1 levee cross drainage was sized to convey minor localised flows between approximately a 50% AEP and a 10% AEP design event (SMEC, 2014). The Stage 2 local drainage assessment includes the modelling of culvert performance for a series of local flooding scenarios (refer to Sections 6 and 8). A risk based approach has been adopted to simulate the function of the culverts in a regional flood where the culverts have been 'closed' in the regional flood model, to show the effect of penstock closure during a coincident local and regional storm event occurring. The western levee cross drainage has been designed to convey the local 10 % AEP design flood. This is consistent with standards referenced in the Capricornia Municipal Development Guidelines (2015) and the Queensland Urban Drainage Manual (2013 Provisional)

As part of the detail design process, additional local hydrology impacts for minor and major AEPs (i.e. the 50% and 10% AEP design floods and 2012 DFE) have been assessed for verification of the western levee design. The findings are discussed in Section 8.

2.5 Data Collection

2.5.1 Qualifications

The main qualifications made in the preparation of this report relate to the accuracy of the data provided by others. Data sources and relevant disclaimers on data provided to GHD by others for the display of results in figures and maps have been included in the maps attached in Appendix A and Appendix B.

Additionally, for the purpose of the Roma Flood Mitigation Project, a specific combination of events was chosen to simulate the extent and behaviour of the 2012 historical flood. That is, a 3 hour peak duration local flood and an 18 hour peak duration regional flood. While there exists a probability of these two events occurring concurrently, it is important to note that there are a series of other possible combinations of flooding that could occur to varying likelihoods.

2.5.2 Survey

It is assumed that the contours, spot levels, orthophoto imagery, topographic survey and digital cadastral database provided by Bennett and Bennett Surveyors within the extents of the proposed infrastructure for Stage 2 are consistent with the metadata limitations.

2.5.3 Stage 1 Levee

The hydraulic modelling process has incorporated the Stage 1 'as-constructed' surface levels and associated terrain modifications provided to GHD by MRC.

2.5.4 Drainage Structures

Local drainage structures across the Stage 1 levee and Stage 2 western levee have been assessed using a series of local-scale hydraulic models to determine their capacity and effectiveness in minor local flood events. While the effect of regional flooding on the operation of these structures have been noted and discussed in Section 5 of this report, the structures have not been included in the regional flood model. It is expected that the penstocks installed on the structures will be closed once the creek flood levels reach the downstream inverts of the structures. An explanation is provided in Section 5.

The local stormwater drainage pipe network layers for the Major Local hydraulic model were adopted directly from the study documented in the Roma Flood Mitigation Project, Flood Study and Report, Stage 1 (Engeny, May 2012).

With the exception of the levee cross drainage, only major hydraulic structures were included within the regional model, i.e. bridges and large diameter culverts and local drainage pipes greater than 450 mm in diameter.

2.5.5 Stage 1 Property Database

The Stage 1 property database has not been ground-truthed by GHD and utilises data provided by others as part of the Stage 1 assessment. Collated data includes property point location, lot and plan number, owner details, property address, ground level, floor level of buildings on the property and floor construction type. The database was built from the several sources, including:

- Bennett & Bennett survey (2012) provided to GHD on the 31st January, 2013;
- Engeny property database (.mif file and spreadsheet), based on 2002 survey, provided to GHD on the 5th February, 2013;
- Stakeholder engagement database developed by Engeny with EngagementPlus provided to GHD on the 7th February, 2013;
- QRA flood damage records for Roma as provided by MRC;
- Drive-by observations by MRC staff; and
- Cadastral data as provided by MRC.

This database was subsequently updated with further survey collected by Bennett & Bennett (2014). The updated database forms the basis for the assessment of property flooding impacts and residual flooding risk for the Stage 2 assessment. MRC officers have undertaken field investigations to confirm the construction type of buildings and properties during the development of the Stage 2 detailed design.

2.5.6 Regional Hydraulic Modelling

The results of a 10m grid regional TUFLOW model have been used to present flood results over the area which covers the properties in the property database within the entire township of Roma. This model is suitable for displaying simulated flooding characteristics on a regional scale. The limitations of this approach lies in the model’s potential inability to accurately capture the various topographical and land surface details (such as ridges and valleys) that fall within the 10m x 10m grid. To enhance the model results, two local-scale models (for the western levee and eastern diversion drain) were set up, with a refined 2m x 2m grid to verify the regional model results. Findings are outlined in Section 7.

2.5.7 Maranoa Regional Council Planning Documents

Council's most recent planning scheme document, i.e. the MRC Planning Scheme Zone Map 9 (attached in Appendix F) has been sourced to update the land uses and surface types for hydrologic and hydraulic model input for Stage 2. Under the DNRM guidelines for category 2 and 3 levees, flood mitigation projects are to consider the longer term impacts based on ultimate development within the contributing catchment. The impacts of the change to the runoff and flooding characteristics for the Roma project are outlined in section 4.

3. Catchment Overview

The Bungil Creek catchment is located upstream of Roma which covers an area of approximately 1400 km^2. The Bungil Creek catchment at Roma extends 65 km to the north and is typically between 20 and 35 km wide. The catchment is located on the southern foothills of the Carnarvon Range. Bungil Creek flows in a fairly constant southerly direction; approximately 70km further downstream from Roma, Bungil Creek joins with the Balonne River which is part of the greater Murray-Darling Basin System.

Flooding experienced in Roma could be caused by two different mechanisms:

- Local flood flow resulting from very localised rainfall within the Roma urban area and its immediate surroundings; or
- Bungil Creek flood flows resulting from the rainfall over the wider Bungil Creek catchment area.

Annual average rainfall throughout the Bungil Creek catchment is relatively constant. The mean annual rainfall is reported to be approximately 700 [mm].

There is a degree of variability in regard to monthly rainfall, and records show that the summer months dominate rainfall totals within the catchment. Generally, major flooding in the Bungil Creek is considered to be infrequent. However, under certain meteorological conditions such as tropical low pressure systems, heavy rainfalls can occur throughout the catchment which results in significant riverine flooding.

4. Hydrological Model Setup

4.1 Introduction

This section of the report provides a summary of the hydrologic model setup including a description of the software, catchment delineation, and key model parameters.

4.2 Software

Rainfall intensity data was generated for Roma using CRC-FORGE software. The URBS hydrology model developed as part of Stage 1 was adopted for this assessment. Updates made to the existing hydrology are further discussed in the following sections of the report.

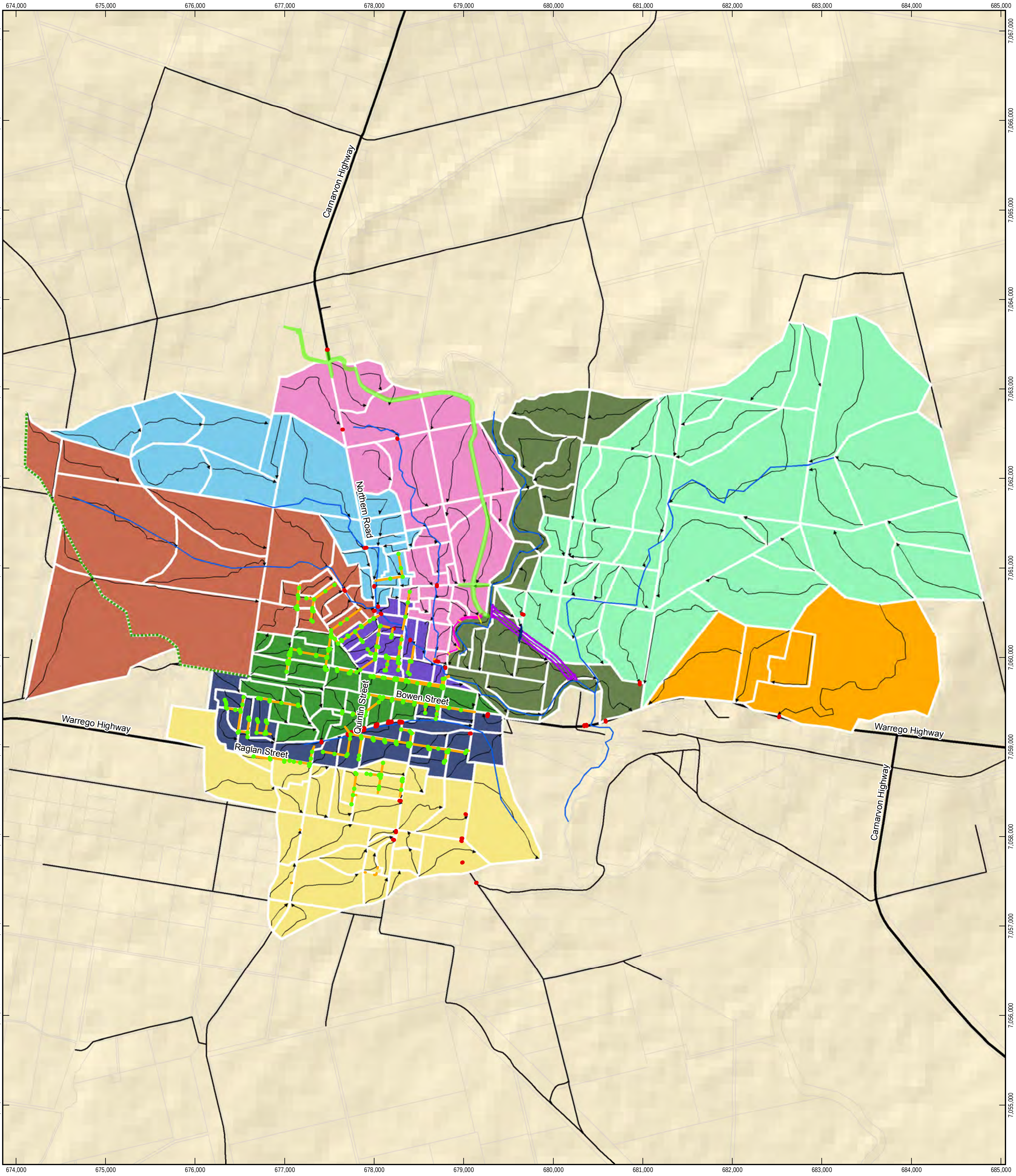
4.3 Adopted Base Case Hydrology

The regional URBS model output hydrographs were adopted from the Stage 1 levee design (refer to GHD Stage 1 report). This assessment has been based on the upstream catchment conditions being consistent with the calibrated hydrographs from Stage 1. Within the township however, modifications were applied to account for infrastructure alignments and future planning considerations. The following points present an overview of the applied modifications, which reflect the hydrological condition post Stage 2, for the local catchment:

- Surface roughness values used to represent the land use and surface types were updated to reflect the MRC Planning Scheme Zone Map 9, as shown in Appendix F. The updates are shown in Table 4-1;
- Minor refinements to sub-catchment boundaries were applied to specific areas of the township to account for the two levees (i.e. Stage 1 levee and western levee);
- To maintain consistency with previous design standards used in the concept studies, two development scenarios were modelled in URBS. As per the standards outlined in the Queensland Drainage Manual (QUDM 2013 - Provisional), hydrological models were developed for both existing land use and surface types (using aerial imagery which now also includes the Stage 1 levee) and an ultimate scenario as shown in the MRC Planning Zone Map.

4.3.1 Sub-catchment Delineation

To account for the changes in the contributing catchments as a result of the Stage 2 western levee, the sub-catchment delineation has been updated as shown in Figure 4-1. These changes have altered the catchment areas and the flow path lengths and direction.



LEGEND

- Stormwater Pit
- Highway
- Road
- Catchment Boundary for Possible Future Development Diversions
- Stormwater Pipe
- Major Flowpaths
- Approx Drainage Path
- Culvert
- Ashburn Road Causeway
- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee Culverts
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Cadastre

Subcatchments

- Bungil
- East
- FSOUTH
- LDRAI1
- LDRAI2
- LDRAI3
- LDRAIU
- NW
- RWAY
- South

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Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Maranoa Regional Council
Roma Flood Study

Job Number | 41-29431
Revision | 0
Date | 27 May 2016

Revised Local Subcatchment Delineation

Figure 4-1

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Level 9, 145 Ann Street Brisbane QLD 4000 Australia **T** 61 7 3316 3000 **F** 61 7 3316 3333 **E** bnemail@ghd.com **W** www.ghd.com

Data Source: ©Commonwealth of Australia (Geoscience Australia): Watercourses/2007; USGS - Relief/2009; DNRM: Locality, Roads/2010, Cadastre, River/2012; GHD: Catchments, Drainage & Flow Paths, Eastern Diversion Drain (2016); MRC: Stormwater drainage; Western Levee & drainage/2016, Causeway location (2016); SMEC: As Constructed Stage 1 Levee Alignment (2014) Created By: DSR

4.3.2 Losses

Initial and continuing losses have been adopted as per the original Stage 1 local hydrology model.

4.3.3 Roughness

The hydrological roughness has been defined for Stage 2 using a combination of Aerial Imagery, and the most up to date planning information made available, namely the MRC Planning Scheme Zone Map 9. This data was used to update the Stage 2 local URBS hydrological model catchment parameters, as shown in Table 4-1.

Table 4-1 Updated hydrological roughness

Catchment	Stage 1	Stage 2	
	Ultimate Land use	Existing Land use	Ultimate Land use
LDRAIU_15	UL	UR	UR
LDRAIU_14	UR	UR	UR
LDRAIU_16	UR	UR	UR
LDRAIU_11	UR	UR	UR
LDRAIU_13	UR	UR	UR
LDRAIU_12	UL	0.2UH;0.8UR	0.3UH;0.7UR
LDRAIU_10	UR	0.2UH;0.8UR	0.5UH;0.5UR
LDRAI3_1	UL	UR	UR
LDRAI3_2	UR	UR	UR
LDRAI3_3	UR	UL	UL
LDRAI3_7	UL	0.2UH;0.8UR	0.5UH;0.5UR
NW_S1	UM	UM	UH
BUNGIL_2_S1	UL	UR	UR
BUNGIL_2_S3	UL	UR	UR
EAST_S29	UL	UR	UR
SOUTH_S2	UR	UR	0.2UH;0.8UR
RWAY_S104	-	UH	UH
ROMA_1_West	-	UR	UH
ROMA_1_East	-	UR	UH

4.4 Updated Planning Scheme and Land Use

The updated hydrology model for Stage 2 of the Roma Flood Mitigation Project includes for the latest MRC planning scheme. The outcome of the proposed changes in land use across the development area of Roma is the potential that the stormwater runoff characteristics will change over time as the area is progressively developed.

The modelling incorporates the various land use types across the study area and designates a roughness factor to represent the scale and type of development that may occur in various areas, e.g. intensively developed industrial land has the potential to have a higher level of runoff compared to parklands which generally have grass and vegetation cover.

Therefore, the hydrology model adopted for Stage 2 and subsequent stages of the flood mitigation project has been adopted to show the ultimate development case. This approach is typical in floodplain management planning and also a requirement of the DNRM 2014 guidelines.

The difference (measured as afflux) between the hydrology model for MRC's previous scheme and the current planning scheme is shown in Figure B.3 in Appendix B.

4.5 Results

The hydrology results have been used as inflow points to both the regional and local hydraulic models that are discussed further in Section 5 and Section 6 respectively.

In addition to this, the hydrology results have been used to size the Stage 2 western levee cross drainage to convey the 10% AEP flows. The sizing of the cross drains has been based on free flowing outlet. The effect of a regional flood event that requires the penstocks to be closed is discussed in Section 5.

5. Regional Hydraulic Model Setup

5.1 Overview

The chapter provides an overview of the setup of the hydraulic model including the software, model domain, model topography & bathymetry, hydraulic roughness, hydraulic structures and boundary conditions is provided.

5.2 Software

TUFLOW Classic 1D and 2D grid based software has been utilised for this study.

5.3 Stage 2 Regional Model Setup

The regional hydraulic modelling undertaken for this study was based on an earlier version of the 10 m grid cell, 2D hydrodynamic Two-dimensional Unsteady Flow (TUFLOW) model of Roma and the surrounding Bungil Creek floodplain developed for Maranoa Regional Council as part of the Stage 2 optioneering assessment.

The following revisions were applied to set up the “Stage 2” hydraulic model.

- Source point inflow hydrograph outputs from the updated local hydrology;
- Refinements to the Manning’s n roughness map layer, particularly within the township area to better represent the varying surfaces and land uses within the local catchment (recent developments as well as ultimate conditions as per the Roma Planning Scheme); and
- Additional survey data at 1m resolution around the western levee and eastern diversion drain provided by Bennett & Bennett Surveyors. This was superimposed to the DEM at 1m resolution used in the previous studies.

The regional Stage 2 model setup is shown in Figure 5-1.

5.3.1 Critical Storm Duration

Modelled storms in the regional hydraulic model combines a calibrated regional hydrograph for Bungil Creek that is a critical duration of 18 hours and an un-calibrated local flood within the township that is of a critical duration of 3 hours. Considerations and assumptions made towards the selected combination of flooding behaviour is documented in the Stage 2 Regional Mitigation Options report.

5.3.2 Model Domain & Extent

The original model domain and extent were adopted from the modelling undertaken previously to inform Stage 1 of the project.

5.3.3 Hydraulic Roughness

Refinements were made to the land use and ground surface representation in the original hydraulic model through the adoption of the Roma Planning Scheme Zone Map 9 (refer to Appendix F). The map provides an indication of the ‘Ultimate’ catchment land use conditions, which will provide the basis for a more conservative set of outcomes for future planning considerations within the township. This approach is in line with the requirements of the DNRM

(2014) guideline. The hydraulic roughness values used in the TUFLOW model is shown in Table 5-1.

Table 5-1 Stage 2 Regional Hydraulic Model Roughness Values

Category	Manning's 'n' Value
Bungil Creek Watercourse	0.065
Open Water Bodies (Reservoirs, Dams)	0.0275
Bitumen (e.g. car park)	0.015
Road Reserve	0.025
Railway	0.03
Airport	0.03
Short Grass	0.03
Open Paddock, Open Space with Minimal Vegetation	0.035
Recreation, Open Space with Moderate Vegetation	0.045
Rural Residential	0.05
Residential and Schools	0.1
Cemetery	0.1
Commercial and Industrial	0.3
Services and Other Buildings	0.4

5.3.4 Hydraulic Structures

A culvert levels assessment was conducted to determine the height of water in Bungil Creek in a frequent flooding event (50% AEP design flood event) relative to the invert levels of the proposed cross-drainage culverts. During the minor, frequent flood events, the flood level in Bungil Creek is such that the local drainage flows freely into the creek. During a regional event, the culverts may be submerged in a regional storm event and stormwater flows generated from the local catchment may be impeded into the creek. Based on the results of the culvert assessment, levee cross drainage has been considered to be 'closed' during a regional flood event. Table 5-2 presents the results of the assessment.

Table 5-2 Culvert Levels Assessment for 50% & 10% AEP Regional Design Floods

Culvert I.D*	Pipe Number x Diameter (mm)	Downstream Pipe Invert Level (m AHD)	Bungil Creek Flood Level in 50% AEP Design Flood (m AHD)	Bungil Creek Flood Level in 10% AEP Design Flood (m AHD)
Northern	1 x 1200	296.25	296.77	298.42
Central	1 x 750	295	296.66	298.27
Southern 1	1 x 375	297.25	296.41	298.02
Southern 2	1 x 600	297.25	296.3	297.9

Refer to maps in Appendix C

5.3.5 Boundary Conditions

The upstream and downstream boundary conditions within Bungil Creek were adopted from the modelling undertaken previously.

Source point inflow hydrographs were applied to simulate the effect of rain falling on the catchment within the township and draining out to Bungil Creek through local stormwater infrastructure. The original inflows were updated in concurrence with the revision of the hydrological modelling for Stage 2.

5.3.6 Western Levee

The concept design of the western levee alignment was undertaken in the Stage 2 optioneering process. Levee design criteria from Stage 1 was adopted for the design of the western levee, with the final levee crest level set with a freeboard of 800mm above the modelled Stage 2, 2012 DFE flood level.

Community consultation and stakeholder engagement was undertaken as part of the development of Stage 2 options. This included face to face meetings with potentially affected land owners. Subsequent to the consultation and preliminary investigations and assessments the concept design was completed and adopted by Council.

The design surface for the levee was incorporated into the TUFLOW model as a terrain modification. Following a number of revisions to the alignment, the final design for the levee alignment, culverts and penstock locations was achieved after consultation with property owners. The alignment and construction types were also governed by the results of the ground investigations conducted by GHD. Design drawings for the western levee, including cross-drainage and penstock details are included in the main design report (GHD, 2016).

5.3.7 Eastern Diversion Drain

The concept design of the drain alignment was undertaken in the Stage 2 optioneering process. As part of a cost-benefit analysis during the optioneering process, the drain configuration that provided the most benefit in terms of reducing flood water level during a 2012 DFE was taken forward for refinement during the detail design process.

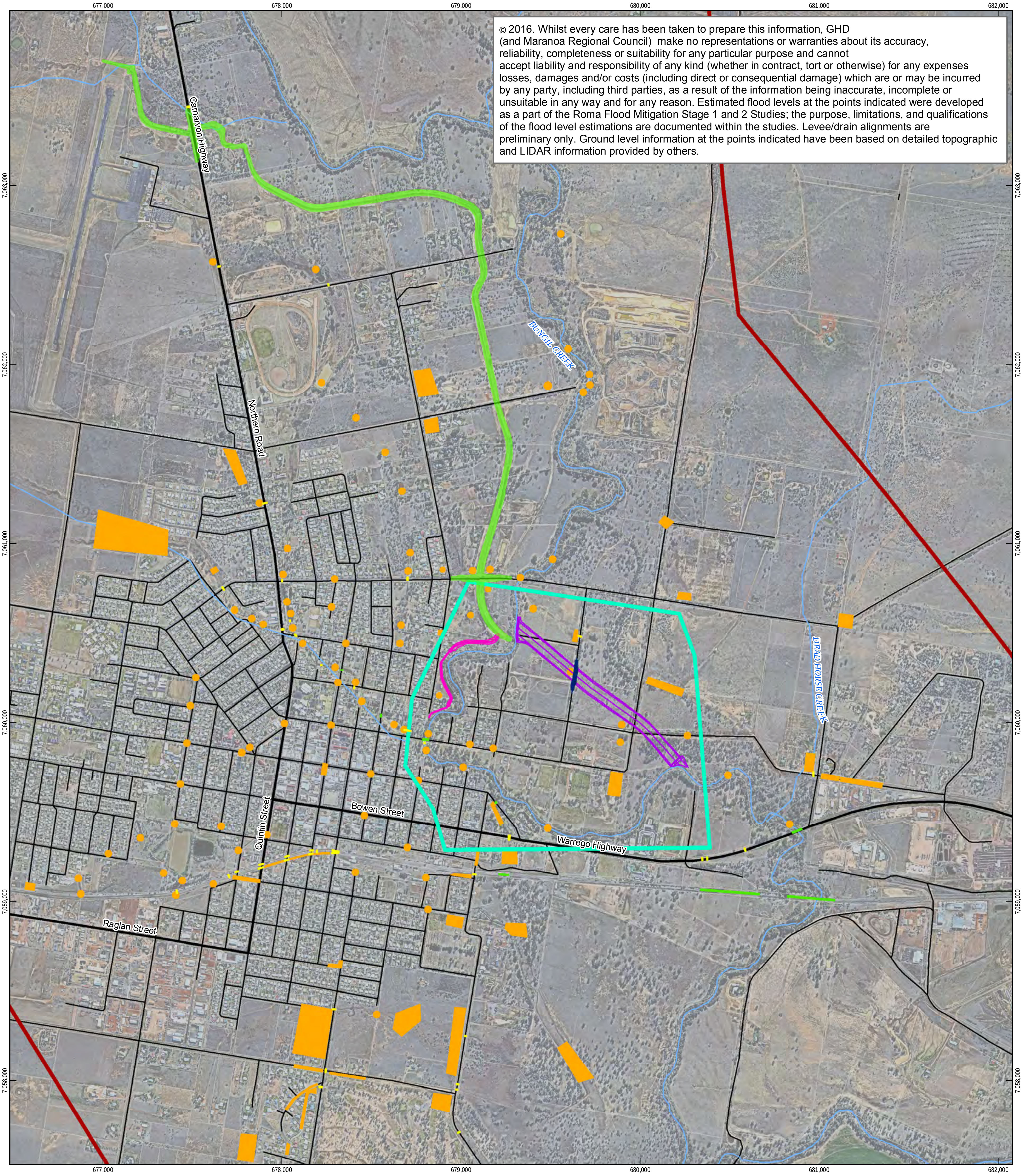
The hydraulic modelling indicates that the drain has the capacity to convey the 50% AEP design flow and is contained within the drain, while flow from the 20% AEP design event overtops the drain. A suite of profiles for the diversion drain were put through a process of refinement using HEC-RAS 1D hydraulically modelling software. Results of the 1D hydraulic assessment show benefits of a drain design with drop structures in reducing both velocities and potential erosion along the channel.

Results indicate that the behaviour of flow in the southern portion of the channel is dictated by the downstream tailwater conditions of Bungil Creek. For this reason, the number of drop structures along the drain was adjusted to determine a cost-effective and streamlined design. The final configuration of the channel incorporates a downstream drop structure upstream of a stilling basin and a causeway over the current Ashburn Road crossing. The downstream drop structure and stilling basin will function to reduce flow velocities before the channel merges with Bungil Creek.

Figure 5-2, Figure 5-3, Figure 5-4 and Figure 5-5 present the refinement process, based on an approximate flow in the drain in a 50% AEP regional design flood event in Bungil Creek. HEC-RAS results indicate that velocities in the channel are maintained at or below 1m/s in the 50% AEP. This behaviour was also confirmed in the regional TUFLOW model (refer to Appendix A). Velocity spikes over the causeway will be managed through the incorporation of rock scour protection within the channel. Rock protection also forms part of the channel inlet and outlet design. The design surface for the drain was incorporated into the TUFLOW model as a terrain modification. The final alignment of the drain as well as scour protection measures to be adopted in its operation are included in the main design report (GHD 216).

Refined Regional Flood Model

In addition to the regional 10m grid cell size model, an assessment using a refined 2m grid cell model with extents capturing the area surrounding the diversion drain was also undertaken using boundary conditions derived from the regional model as a verification process. Figure 5-1 presents the model extents of the refined grid regional model.



LEGEND

- Highway
- Road
- Watercourse
- Culvert
- Ashburn Rd Causeway
- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Tuflow Refined Model Hydraulic Boundary
- Bridge
- Tuflow Regional Hydraulic Model Boundary
- Cadastre
- Tuflow Local Source Point Inflows

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Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Maranoa Regional Council
Roma Flood Study

Job Number 41-29431
Revision 0
Date 29 Apr 2016

Stage 2 Regional & Local Hydraulic Model Setup

Figure 5-1

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Level 9, 145 Ann Street Brisbane QLD 4000 Australia T 61 7 3316 3000 F 61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: ©Commonwealth of Australia (Geoscience Australia): Watercourses/2007; DNRM: Locality, Roads/2010, Cadastre, River/2012; SMEC: As Constructed Levee Alignment; GHD: Stage 2 levee and drain alignments, TUFLOW model boundaries, point source inflows; NearMap:Imagery (Date extracted: 05/02/2016, Image date: 04/07/2015.

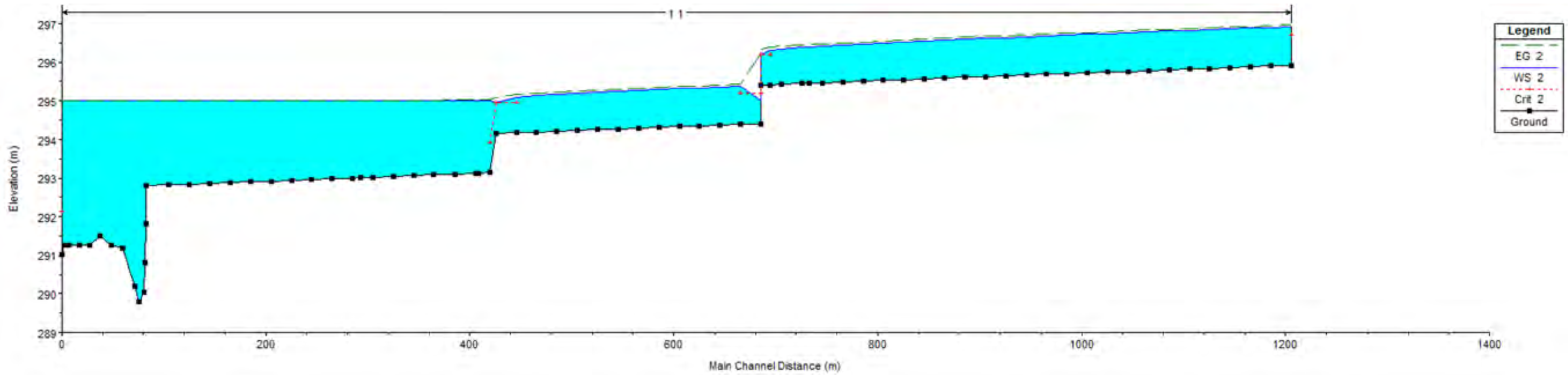


Figure 5-2 Water Surface Profile (3 Drop Structures, approx. 50% AEP flow)

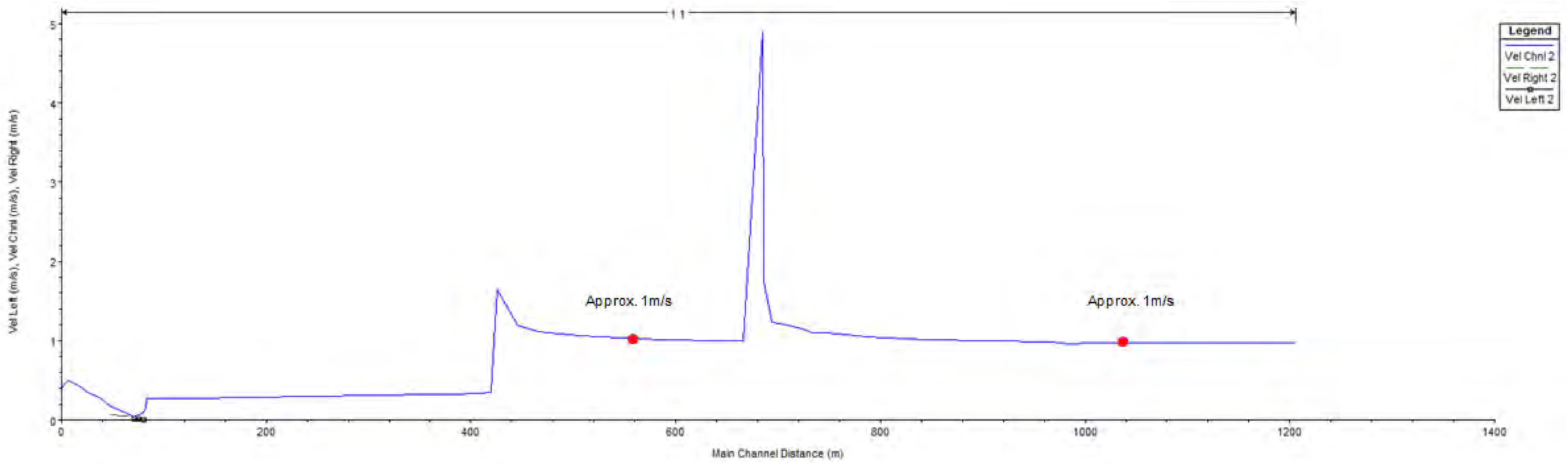


Figure 5-3 Velocity Profile (3 Drop Structures, approx. 50% AEP flow)

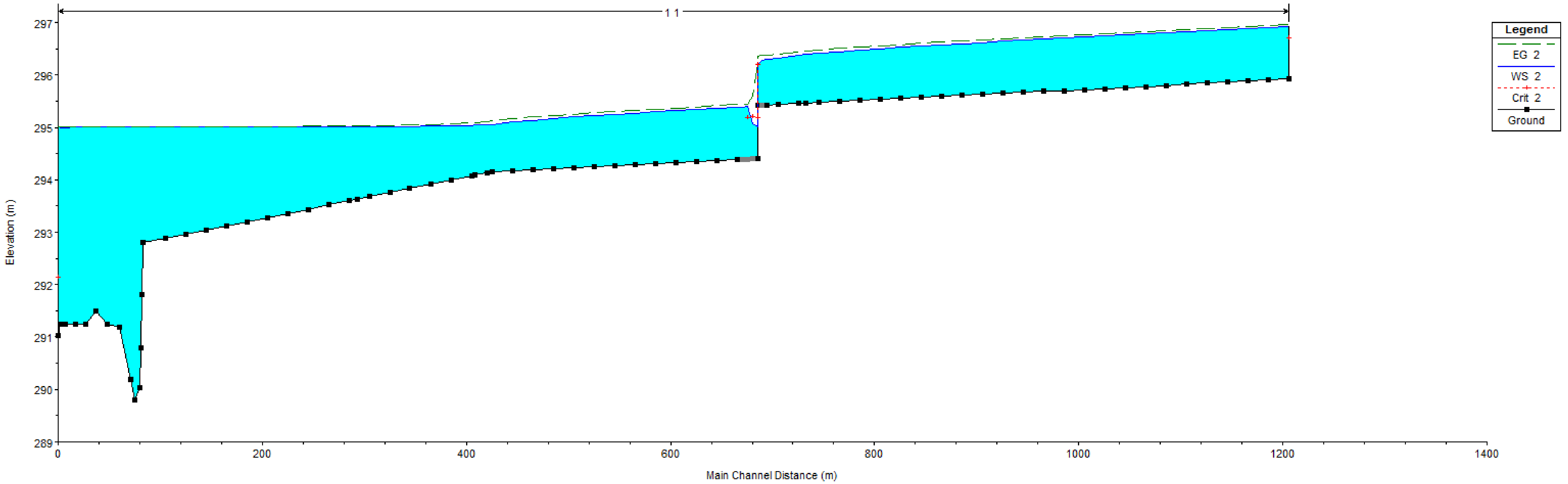


Figure 5-4 Water Surface Profile (2 Drop Structures, approx. 50% AEP flow)

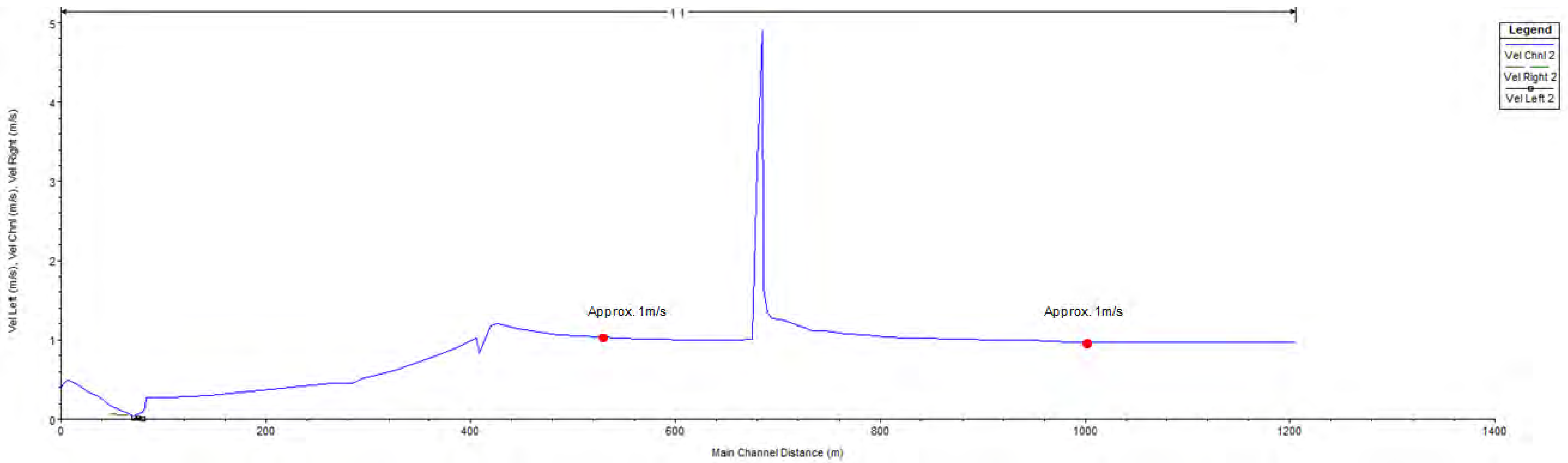


Figure 5-5 Velocity Profile (2 Drop Structures, approx. 50% AEP flow)

6. Local Hydraulic Model Setup

6.1 Overview

In this chapter, an overview of the setup of the local hydraulic model including the software, model domain, model topography & bathymetry, hydraulic roughness, hydraulic structures and boundary conditions is provided. The local hydraulic model has been used for the sizing of cross drainage through the levee and to assess changes in local drainage.

The local hydraulic model allows analysis of flood impacts at a finer resolution than the regional model. This is a result of a smaller grid cell size in the model domain, which has been used in conjunction with a rain on grid approach in the sub-catchments adjacent to the Stage 2 western levee. The rain on grid approach applies the design storm rainfall to each grid cell, and this water is routed through the hydraulic model. This approach has been used in conjunction with the more traditional method of applying hydrographs at defined locations in the model which have been determined from a separate hydrological model.

6.2 Software

TUFLOW Classic 1D and 2D grid based software has been utilised for this study.

6.3 Stage 2 Local Model Setup

The local hydraulic modelling undertaken for this study was based on an updated version of the 10 m grid cell, 2D hydrodynamic Two-dimensional Unsteady Flow (TUFLOW) model of Roma and the surrounding Bungil Creek floodplain developed for MRC as part of the Stage 2 optioneering assessment.

This model has been adapted to assess the local hydraulic issues associated with the Stage 2 western levee, in particular the functionality of the cross drainage. The main variation between the original model and the revised local model includes:

- Decreased model extents to focus on the western levee and its' upstream contributing catchments
- Downstream boundary condition has been moved to a location closer to the western levee
- Reduced grid cell size of 5m
- Additional survey data at 1m resolution around the western levee and eastern diversion drain provided by Bennett & Bennett Surveyors. This was superimposed to the DEM at 1m resolution used in the previous studies.
- Assessment of the critical 3 hour storm duration for the scenario where the Western Levee culverts are unblocked (penstocks up)
- Assessment of the 48 hour storm duration for the scenario where the Western Levee culverts are fully blocked (penstocks down)
- Rain on grid modelling of catchments directly upstream of Western Levee
- Updated inflow hydrographs from the updated URBS local hydrology model; and
- Refinements to the Manning's n roughness map layer, particularly within the township area to better represent details of the local catchment (recent developments as well as ultimate conditions as per the Roma Planning Scheme).

The scenarios run for the local hydraulic model include two main cases looking at:

- Western levee cross drains are flowing (penstocks open)
- Western levee cross drains are not flowing (penstocks closed)

The purpose of this assessment is to quantify the local impacts of the western levee for a minor (50% AEP) and major event (1% AEP), as well as the cross drainage design event (10% AEP).

6.3.1 Model Domain and Extent

The local hydraulic model domain and extent is shown in Figure 6-1. The inflow hydrograph locations and rain on grid extents are also shown in Figure 6-1.

6.3.2 Hydraulic Roughness

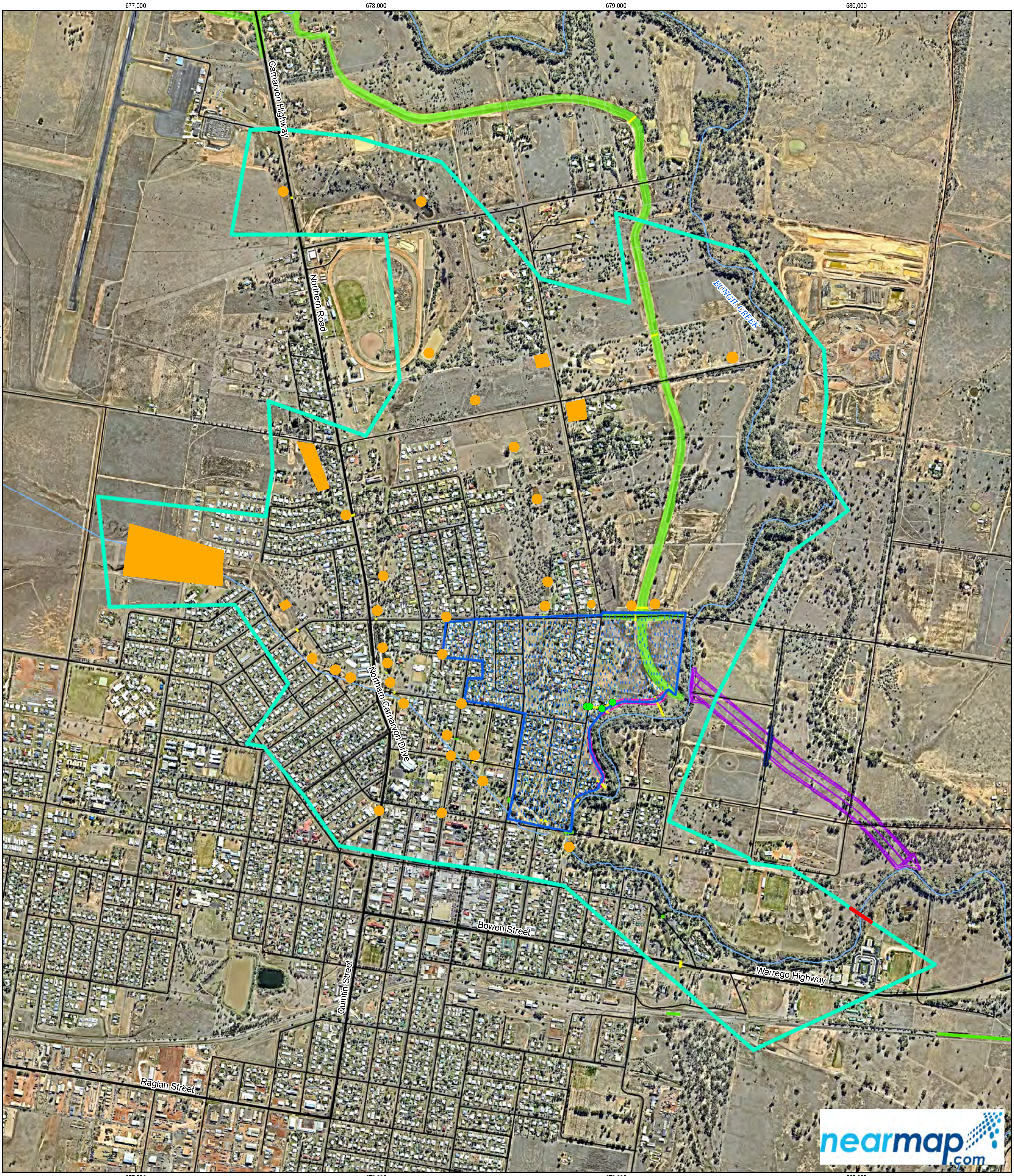
The hydraulic roughness adopted for the local model is as per that used in the updated regional model.

6.3.3 Hydraulic Structures

Hydraulic structures have been included in the model as per the Stage 1 regional hydraulic model with the addition of the cross drainage culverts. The only additional hydraulic structures included are the cross drains through the western levee.

6.3.4 Boundary Conditions

A downstream tailwater level of 294.5 mAHD has been adopted with an initial water level of 295 mAHD. The initial water level of 295 mAHD ensures that water is at a downstream invert of the long drain confluence with Bungil Creek, which is directly adjacent to Bungil Street.



LEGEND

- 1d Pit Locations
- Stage 1 As Constructed Levee Alignment
- Highway
- Road
- Watercourse
- Tuflow Tailwater Boundary
- Culverts
- Bridge
- Tuflow Local Source Point Inflows
- Rain On Grid Extent
- Tuflow Local Hydraulic Model Boundary
- Cadastre

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Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Maranoa Regional Council
Roma Flood Study

Stage 2 Local Hydraulic Model Setup

Job Number	41-24931
Revision	0
Date	26 May 2016

Figure 6-1

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Data Source: ©Commonwealth of Australia (Geoscience Australia): Watercourses/2007; DNRM: Locality, Roads/2010, Cadastre, River/2012; GHD: Diversion Drain (2016), Levee/2016; Rain on Grid Extent (2016), Source inflows (2016), Tailwater Bdy (2016), Tuflow Hydraulic bdy (2016), SMEC: As Constructed Stage 1 Levee (2014); NearMap Imagery (Date extracted: 05/02/2016, Image date: 04/07/2015. Created By: DSR

7. Regional Hydraulic Model Results

7.1 Regional Model Results

The results of the regional flood modelling are presented in two components that form the major flood mitigation infrastructure for Stage 2; the western levee and eastern diversion drain.

7.1.1 Western Levee

Figures A.1 to A.6 in Appendix A present regional model results for Stage 2A. The results of the Stage 2A mitigation works, when combined with the existing Stage 1 levee, show further reductions in flood water levels, hence reducing risk of above floor flooding to more properties within the flood plain in line with MRC's project objective. Figure 7-1-shows a longitudinal section along the entire Stage 1 levee and continuing along the Stage 2A western levee in a north-south direction. This figure illustrates the existing ground level adjoining the constructed levees; the 2012DFE flood water level (post-construction); and the levee crest level, which has been set as a minimum of 800mm above the DFE water level.

Results indicate that localised ground inundation is observed adjacent to the northern section of the western levee and at a low point towards the southern end of the levee, within the boundaries of the Defence Support Building and St Vincent De Paul Society QLD properties. This overland flow and localised ponding behaviour is observed in the existing, pre-western levee scenario during minor design flood events and the 2012 DFE. Prior to the Stage 1 levee being constructed, flood depths of approximately 2.0m were recorded in this vicinity. With the Stage 1 and 2A works in place, maximum depths of local flooding range from 0.1 m in the 10% AEP design event to 1.15m in the 2012 DFE in the area adjacent to the existing low ground levels near the dam located in the northern section of the levee. Velocities along the boundary of the levee within the township are maintained below 0.5m/s.

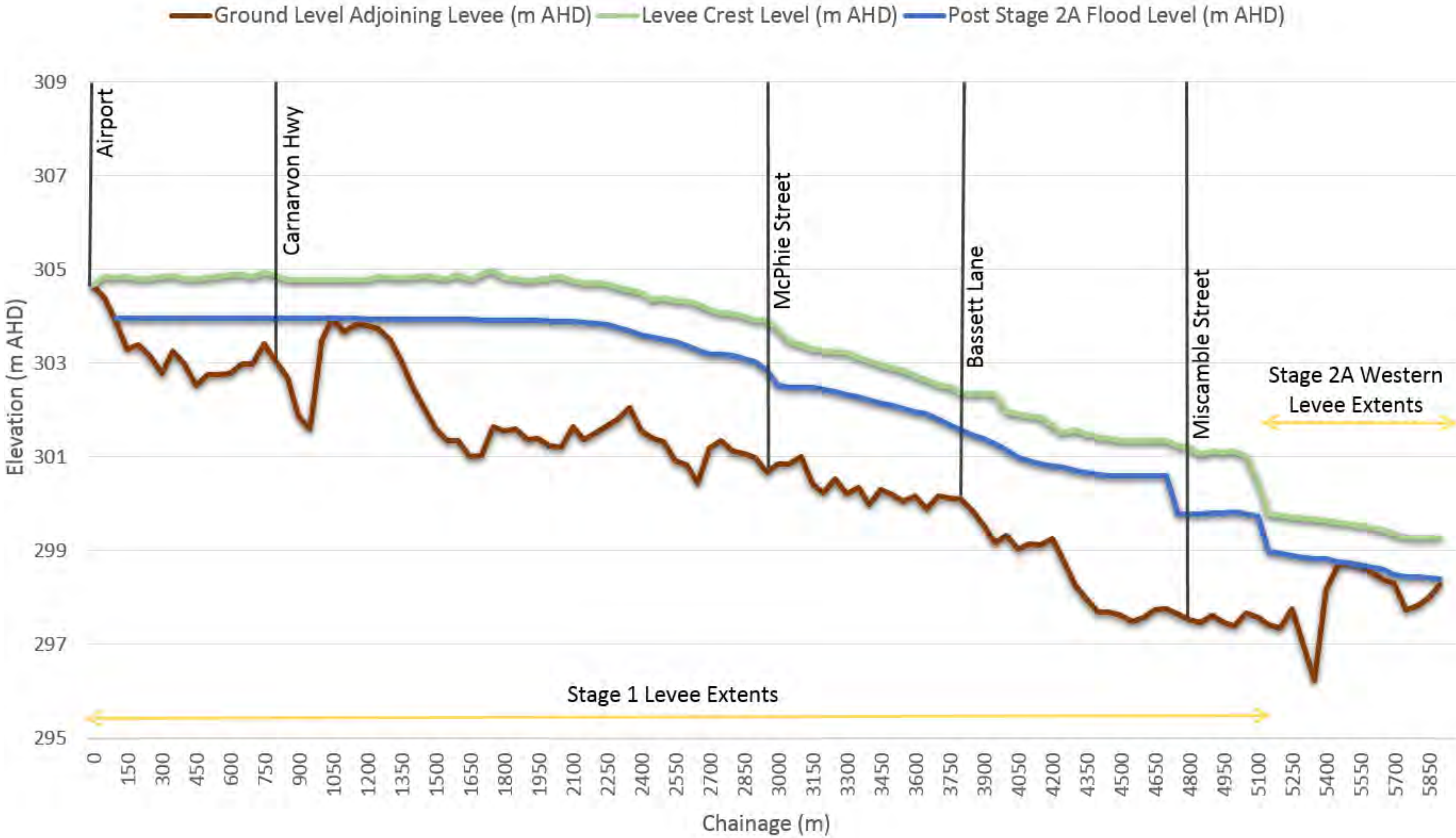
The modelled flood water depths and flow velocities are not shown to affect the buildings on the properties adjoining the western levee in terms of above habitable floor flooding and are contained in existing low lying areas adjacent to the levee. It is expected that levee cross-drainage will assist in mitigating these localised areas of ponding.

The local flooding and drainage model results indicate that although the cross-drainage culverts provide an outlet for localised areas of flooding, if local overland flow was to build up adjacent to the levee, it would ultimately flow along the inside face of the levee and discharge into the Edwardes Street road reserve and drainage system. To further alleviate impacts of local stormwater, additional drainage works are being considered in the next Stage of the mitigation project. In the vicinity of the western levee, it is proposed that a new road-side channel along Edwardes Street be provided which will increase the capacity and efficiency in diverting flows away from the properties in this area. Refer to Section 8 for further details.

7.1.2 Eastern Diversion Drain

Figures A.1 to A.6 in Appendix A indicate the behaviour of the diversion drain in the minor design flood events and the 2012 DFE. Flood depths along the drain range from approximately a maximum of 0.75 m in the 50% AEP design flood to approximately a maximum of 3.8 m in the 2012 DFE. Corresponding velocities range from 0.8 m/s to 2.2 m/s. Higher velocities of up to 4.5m/s in the 2012 DFE are observed over the proposed causeway along Ashburn Road. These velocities are maintained for storm durations ranging from 30mins to 1 hour of the modelled storm events. Rock protection has been designed to the 2012 DFE maximum velocities over the causeway. Construction drawings for the eastern diversion drain are attached in the main design report, (GHD 2016).

Figure 7-1 Longitudinal Section Along Stage 1 & Stage 2A Levees*



*Approximation only, not to scale.

8. Local Hydraulic Model Results

8.1 Cross drainage sizing

Levee cross drainage as listed in Table 5-2 have been sized using rational method hydrology calculations to determine peak design flow rates, in conjunction with Culvert Master software to determine the appropriate culvert size. These calculations have been included in Appendix E. Note that the culvert sizing calculations are not provided for ‘Southern 1’ culvert, which was sized to convey flows off a negligible local catchment for purposes of providing relief drainage to avoid potential ponding issues. Localised earthworks should be undertaken at the inlets of the culverts to ensure the catchments drain to these locations.

To confirm the culvert sizes calculated are adequate, these culverts were included in the local hydraulic model. This was to provide a flow path for overland flow from adjoining catchments. The model results indicate for the 10% AEP, 3 hour critical duration event, that the proposed drainage appropriately conveys the contributing flows as demonstrated by the results in Appendix C.

8.2 Local Model Results

The local hydraulic model results for depth, velocity and afflux for the scenarios with the penstocks open and closed are shown in Appendix C and Appendix D. As a rainfall on grid methodology has been used, the results have required filtering. If the results were not filtered the flood mapping would indicate water covering the entire area that has been modelled using the rain on grid approach. To better illustrate the extent of flooding only the major flow areas and regions of surface water ponding are shown and depths below 0.05 m or velocities less than 0.2 m/s have been filtered from the results.

The results from the local hydraulic model indicate the following:

- The culvert sizes are adequate to convey the 10% AEP critical duration event in a free flowing condition, i.e. no coincidental regional flood
- The culvert sizes are able to convey the major 1% AEP event with no increase in flooding above building habitable floor level to the properties adjacent to the western levee in a free flowing condition, i.e. no coincidental regional flood
- In the minor 50% AEP event, having the penstocks closed will result in a maximum depth less than 0.5 m adjacent to the western levee.
- In the 10% AEP design event, having the penstocks closed will result in a maximum depth of approximately 0.5 m adjacent to the western levee.
- In the major 1% AEP event, having the penstocks closed will result in a maximum depth of approximately 0.8 m adjacent to the western levee at the existing low-point in the ground level (existing farm dam).

These results reflect the existing flooding characteristics from localised flows and flooding that occur in the pre-levee condition. Based on the scenarios modelled, the flood levels are below the surveyed building habitable floor levels for buildings in the vicinity of the new levee, providing a no-worsening effect.

It is proposed that the extent of flooding and flood risk can be further alleviated through a range of local options on the dry side of the levee to be considered as part of the Stage 2B works. Some of these options, such as improvements to the existing stormwater trunk drainage, improved conveyance and capacity of the long-drain and Shady's lagoon system will aid in reducing the contributing flows to the subject areas.

Subsequent to the SMEC design and construction of Stage 1 levee, MRC have installed pumps to drain local areas behind the levee system as part of the updated emergency and evacuation planning. The pumps will function to discharge local stormwater flows once culvert penstocks are closed during flooding events in the Bungil Creek.

8.2.1 Coincident Flooding

During a regional flood exceeding the 50% AEP design event, there is the potential for surface water flows to build up behind the Stage 2 western levee. In such an event, i.e. where the Bungil Creek starts to break its banks at the same time that rainfall is occurring over the local Roma catchment, and when the culvert penstocks are closed, the local stormwater drainage model results show the potential for overland flow to build up and pond at low points in the land behind the levee. These results reflect a worst-case scenario for flood risk, as it involves coincident flood events in both the regional and local catchment.

The model results show that in the scenario of a coincident event, the local stormwater will build up and start to drain toward the Edwardes Street road reserve and existing drainage, which ultimately discharges to the long-drain and Bungil Creek. The depth of local flood water flows is not shown to exceed the height of habitable floor levels of the adjoining houses in this area.

Furthermore, as identified in Table 5-2, the regional flood will start to impact the Stage 2 western levee cross drains during a regional 50% AEP event. While no quantitative assessment has been carried out to assess the joint probability of the regional and local events occurring simultaneously, it is likely that a coincident flood event could take place. As such, it is recommended that measures to reduce surface water depths behind the levee be further examined in the Stage 2B works in consultation with MRC's engineering department and prior to construction of the western levee. An overview of the proposed Stage 2B flood mitigation and drainage works are included in section 9.

To aid in flood risk mitigation, the Council are progressively updating the flood emergency and evacuation plans as subsequent stages of the mitigation project come on line. The updated plans will be in place prior to construction of Stage 2A works commencing. Council's emergency and evacuation planning includes the timely closure of penstocks to arrest regional flood waters backing up through the levee drainage system. Council have also included in their planning for the implementation of emergency pumps located at key locations along the existing and proposed levees. The pumps will act to reduce to build up of flood waters behind the levee from local overland flow during coincident regional and local storm events.

9. Proposed Stage 2B Flood Mitigation Works

MRC have been successful in obtaining additional funding for mitigation works in Roma. The next stage of mitigation works aims to further reduce flood risk in terms of addressing buildings still at risk of above habitable floor flooding from a 2012 DFE flood event.

The key elements of Stage 2B of the Roma flood mitigation project include:

- Augmentation and drainage improvements at the Railway Dam
- Mitigation works east of the town centre, and
- Drainage improvement works in the long-drain system and Shady's lagoon area.

The location of the proposed Stage 2B works are shown on Sketch SK01 in Appendix G

The details of the proposed works are outlined in GHD report, 'Hydrology and Hydraulics for Stage 2 Local Mitigation Options (2013). A summary of the three elements is provided below.

9.1 Railway Dam

The works to the railway dam will aim to improve the flood storage capacity of the dam system during major storm events. The works will also reduce the peak stormwater flows that enter the dams and attenuate the flood waters. These works will reduce the risk of over topping, which has historically resulted in the flooding of local properties and increased stormwater flow entering the long-drain system.

The proposed works do not including expanding the existing two dams within the area or impacting on the existing paths and amenity. The scope of the work may include the provision of additional detention areas upstream and downstream of the existing dams to increase the storage capacity within the system and improved drainage to control discharges to the existing stormwater trunk drainage.

MRC will work with the community groups to optimise the design so that the stormwater function is improved and mitigation objectives are met whilst adverse impacts on the amenity are minimised.

9.2 Eastern Mitigation Area

The eastern study area includes land located between Beaumont Drive, Clayton Road and East Miscamble Street. The existing development in this area includes rural, rural residential and industrial land. During the 2012 (pre-mitigation) flood, a number of properties experienced flooding across the land and inundation of sheds and outbuildings. The flood water level was reported to almost reach the habitable floor of some buildings.

With the Stage 1 levee in place, the flood modelling results show that there is the potential for flood water levels to increase slightly in this area if a similar scale 2012 flood event was to occur. The modelled increases in flood water level do not show to be causing additional above habitable floor flooding, but the depth and extent of flood water across the land is potentially greater. The Stage 2A works do mitigate the increase in land flooding, but as part of the longer term flood mitigation strategy, Council is considering additional local mitigation works to further reduce the risk of above floor flooding, which may incorporate levees and improved drainage infrastructure within this area.

9.3 Long-drain and Shady's Lagoon

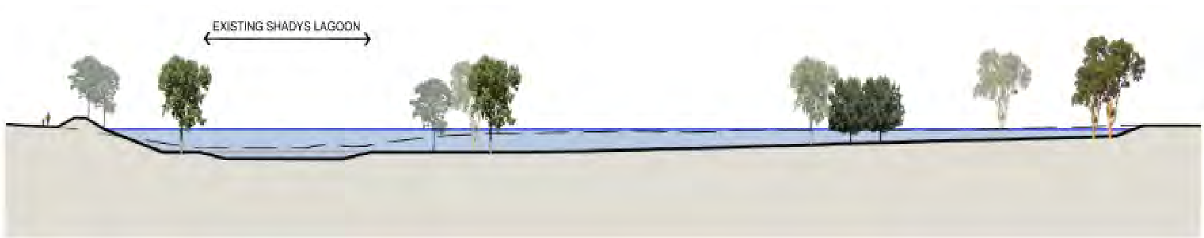
The Stage 2B works will also include drainage augmentation within the long-drain overland flow path system and the Shady's lagoon area. The intention of the proposed works is to improve the flow conveyance and capacity of the open channels, to allow local stormwater flows to discharge through the system more efficiently. The improvement of the flow characteristics will result in overland flow from local storm events to discharge quicker into Bungil Creek. In the event of a regional flood coinciding with a local storm, the improved flow conveyance will also provide additional storage capacity within the long-drain system for flood water that backflows from Bungil Creek. Ultimately these works will further reduce flood risk within the town area and improve local stormwater drainage performance.

In general, the scope of work comprises undertaking earthworks to widen existing open grassed channels. In the Shady's lagoon area there are existing weir structures that have been built upstream of the Charles Street bridge and downstream of the lagoon. Figure 9-1 and Figure 9-2 provide a concept layout and cross section of the proposed works. The Stage 2B study will assess the removal of the weir structures, so that the impoundment of water in the lagoon is removed. It is proposed that the reconfiguration of Shady's lagoon will increase the stormwater storage capacity within the system during flooding events.

There are also existing water quality issues within the lagoon, as it currently traps gross pollutants and putrescible material after storm events and does not function to improve water quality. The proposed works will also mitigate the stormwater quality and maintenance issues.

Figure 9-1 Shady's Lagoon Concept

Figure 9-2 Shady's Lagoon Concept – Typical Section (Not to Scale)



However, it is acknowledged that the Shady's Lagoon area provides a community amenity that is well used and offers a level of bio-diversity. Environmental assessments and community consultation will also be critical activities to be undertaken to inform the best solution for this area.

This proposed work will also include carrying out clearing and bulk earthworks in the vicinity of the Bungil Street bridge. These works will aim to re-shape the long-drain channel where it discharges into the creek, remove the build-up of sediment at the bridge and ultimately improve the conveyance of flows where the long-drain converges with Bungil Creek.

As part of the future Stage 2B assessment and design phase, the Council's flood model will continue to be updated to reflect changes in the catchment and the adoption of the future development scheme. This may also include areas in the vicinity of the Hay Roma Dam, eastern industrial precinct and areas north of town such as Bassett Park and the airport. The Council will consider the findings of the ultimate development and where possible seek opportunities to plan for and mitigate changes in flood characteristics across the floodplain. Acknowledging that any future mitigation work is totally dependent upon Council receiving funding from State of Federal government.

10. Conclusion and Recommendations

The primary objective of Stage 2A of the Roma flood mitigation project is to further reduce above habitable floor flooding to properties in the township. Results from the Stage 2A regional hydraulic modelling indicate that no properties west of the western levee experience above floor flooding in the 2012 DFE. The levee and drain do not cause any additional risk of above floor flooding to properties with the study area.

GHD makes the following points for Council to consider as part of design considerations for upcoming phases of the project:

- Potential to undertake additional measures to divert localised flood waters from properties in Stage 2B of the mitigation project;
- It is noted that additional improvements to trunk drainage and long-drain to be reviewed as part of Stage 2B could act to further improve flood risk adjacent to the Stage 2A western levee. These measures may involve a road-side channel along Edwardes Street to divert flow to Bungil Creek south of the western levee;
- In conjunction with any flood mitigation measures, it is recommended that MRC consider stipulating that any future developments that drain toward the long-drain system and Bungil Creek systems incorporate onsite detention of stormwater flows to achieve pre-development flow rates. This would assist in alleviating current pressures on the local drainage network during more frequent storm events
- Council’s emergency and evacuation plan be updated for Roma that incorporates Stage 1 and 2 flood mitigation options, prior to construction of the Stage 2A elements; and
- Council’s Property Database is continuously updated to include the changes resulting from the constructed mitigation infrastructure to assist in future planning considerations for the township.

It is acknowledged that during the course of the project that changes have occurred in the catchment, such as development, road works and agricultural activities. MRC have also implemented a new planning scheme which will alter the stormwater runoff characteristics within the catchment and more accurate ground survey has become available over time. The modelling has progressively been upgraded to reflect these changes, so that the ongoing assessment of flood risk and mitigation options analysis can be based on the best information at the time. Therefore, changes in predicted numbers of properties at risk of flooding may also change with time as the scheme progresses.

11. Scope and limitations

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The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

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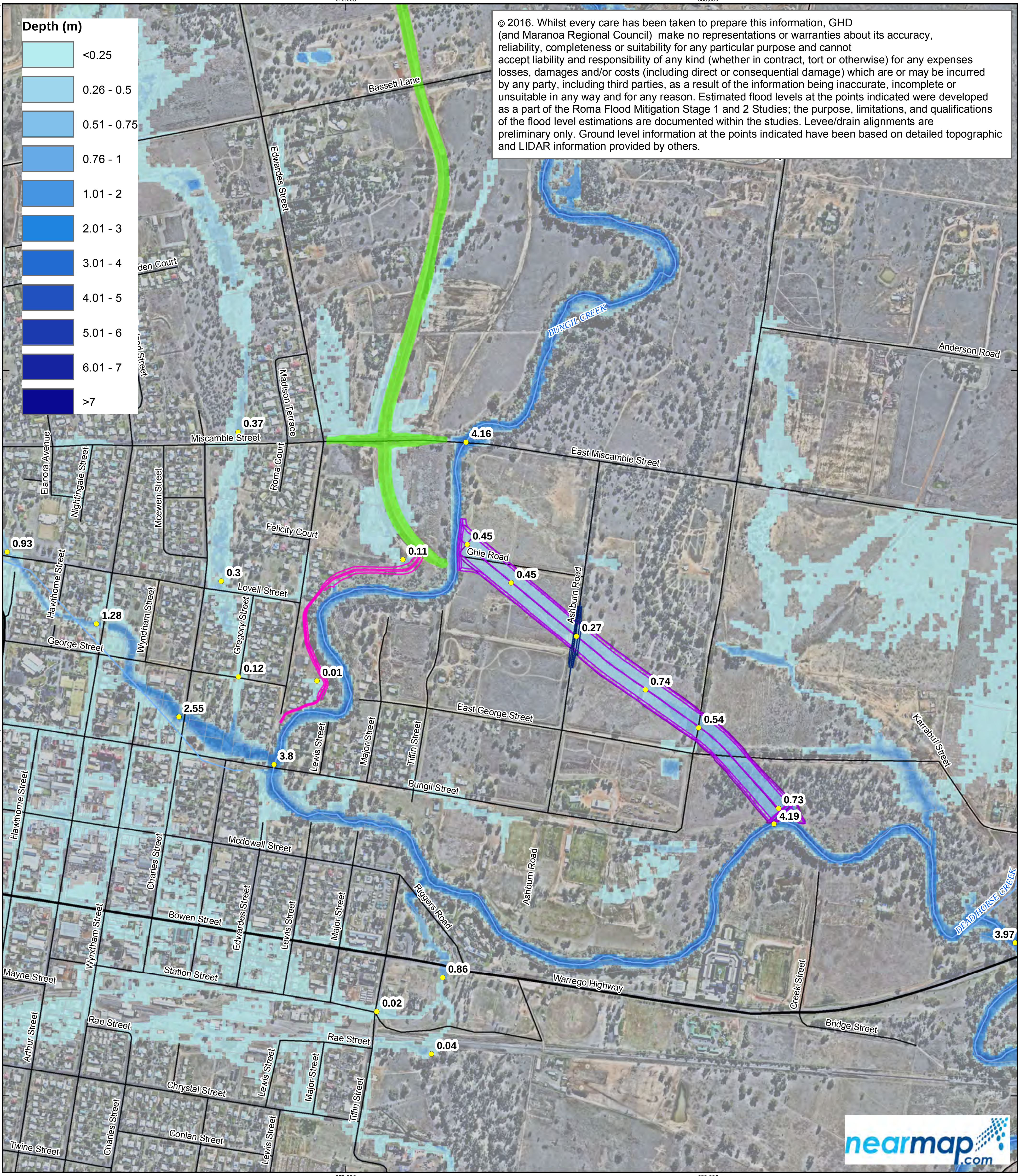
Appendices

Appendix A – Stage 2 Regional Flood Depth & Velocity Maps



Legend

- Sample Point
- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

Paper Size A3
0 200 400
Metres
Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Roma Flood Study

Roma Stage 2 Mitigation Options
50% AEP Flood Depth

Job Number	41-29431
Revision	0
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Figure A.1

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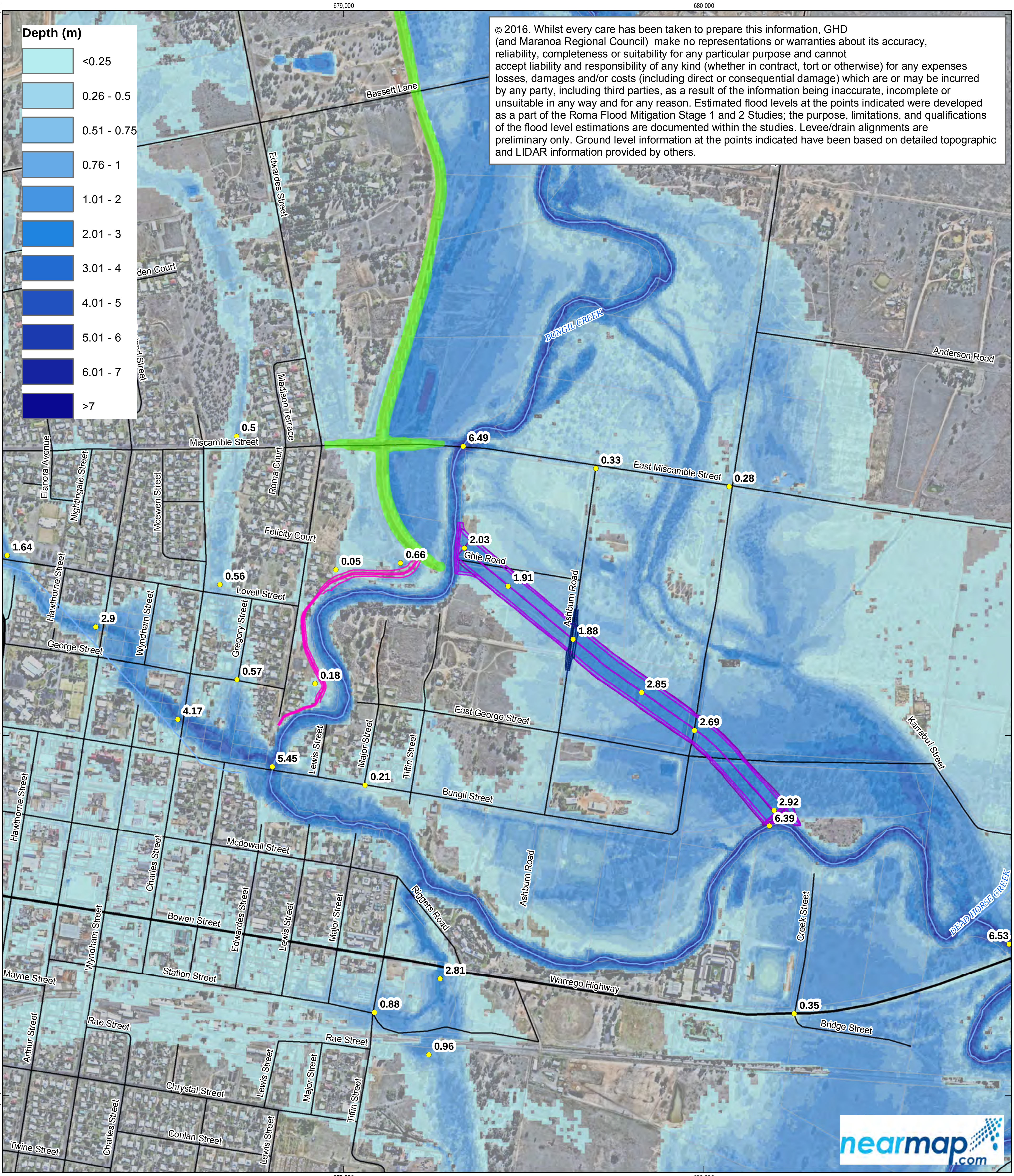

Legend

- Sample Point
- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

Paper Size A3
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Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Roma Stage 2 Mitigation Options
10% AEP Flood Depth

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Figure A.2

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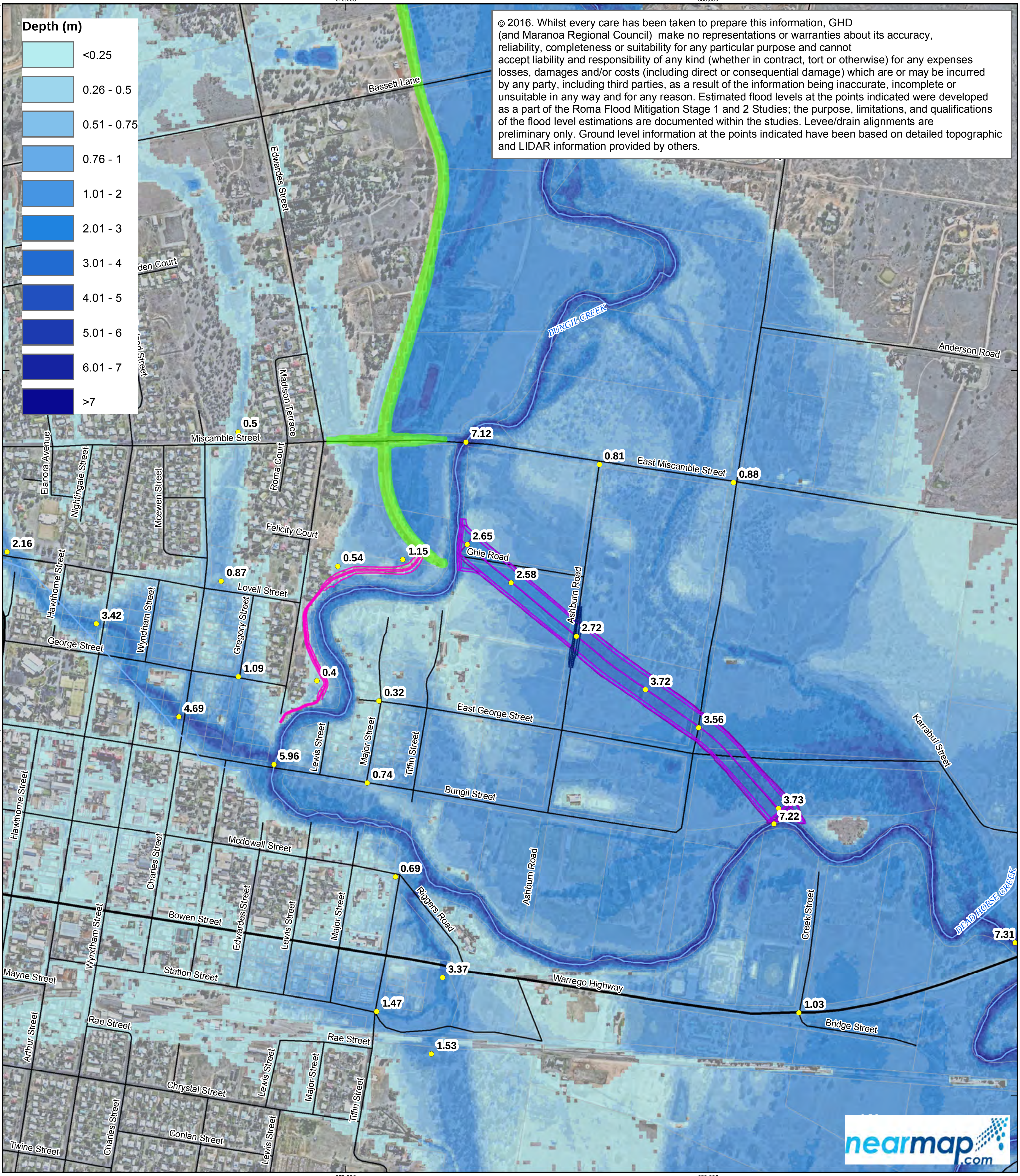

Legend

- Sample Point
- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

Paper Size A3
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Metres
Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Maranoa Regional Council
Roma Flood Study

Roma Stage 2 Mitigation Options
2012 DFE Flood Depth

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Revision	0
Date	27 May 2016

Figure A.3

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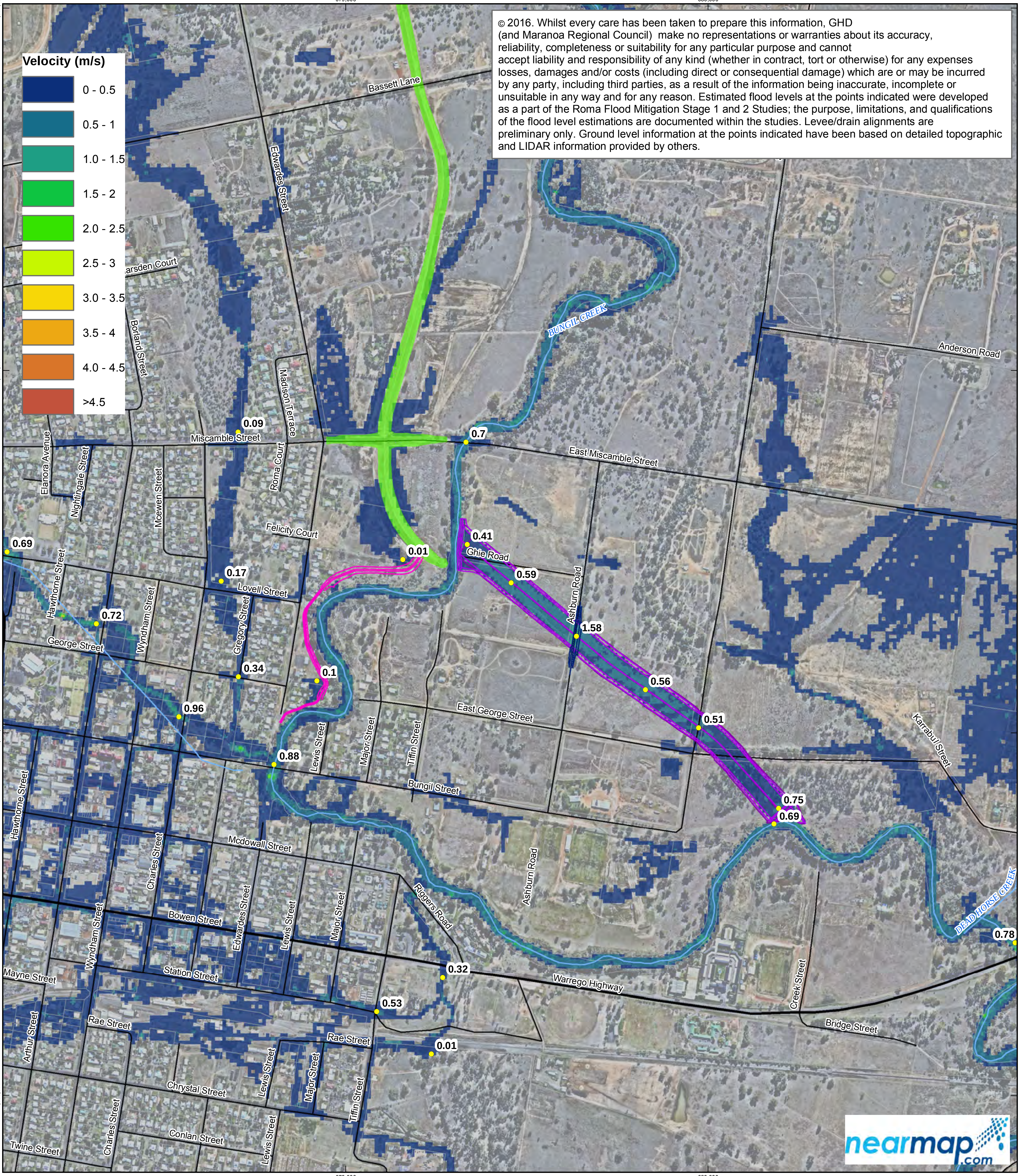

Legend

- Sample Point
- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

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Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Roma Stage 2 Mitigation Options
50% AEP Flood Velocity

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Figure A.4

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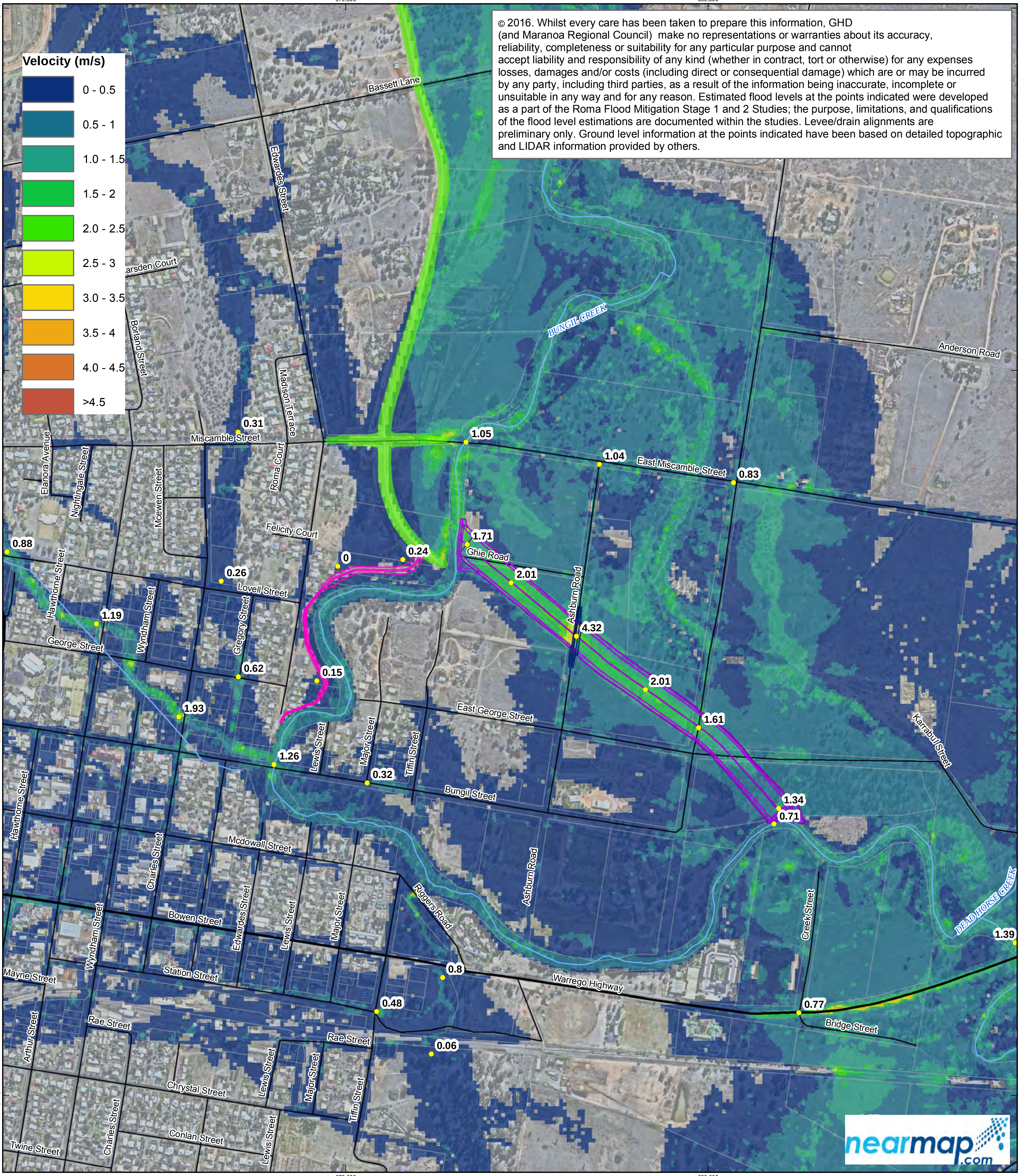

Legend

- Sample Point
- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

Paper Size A3
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Map Projection: Universal Transverse Mercator
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Grid: GDA 1994 MGA Zone 55

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Roma Flood Study

Roma Stage 2 Mitigation Options
10% AEP Flood Velocity

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Figure A.5

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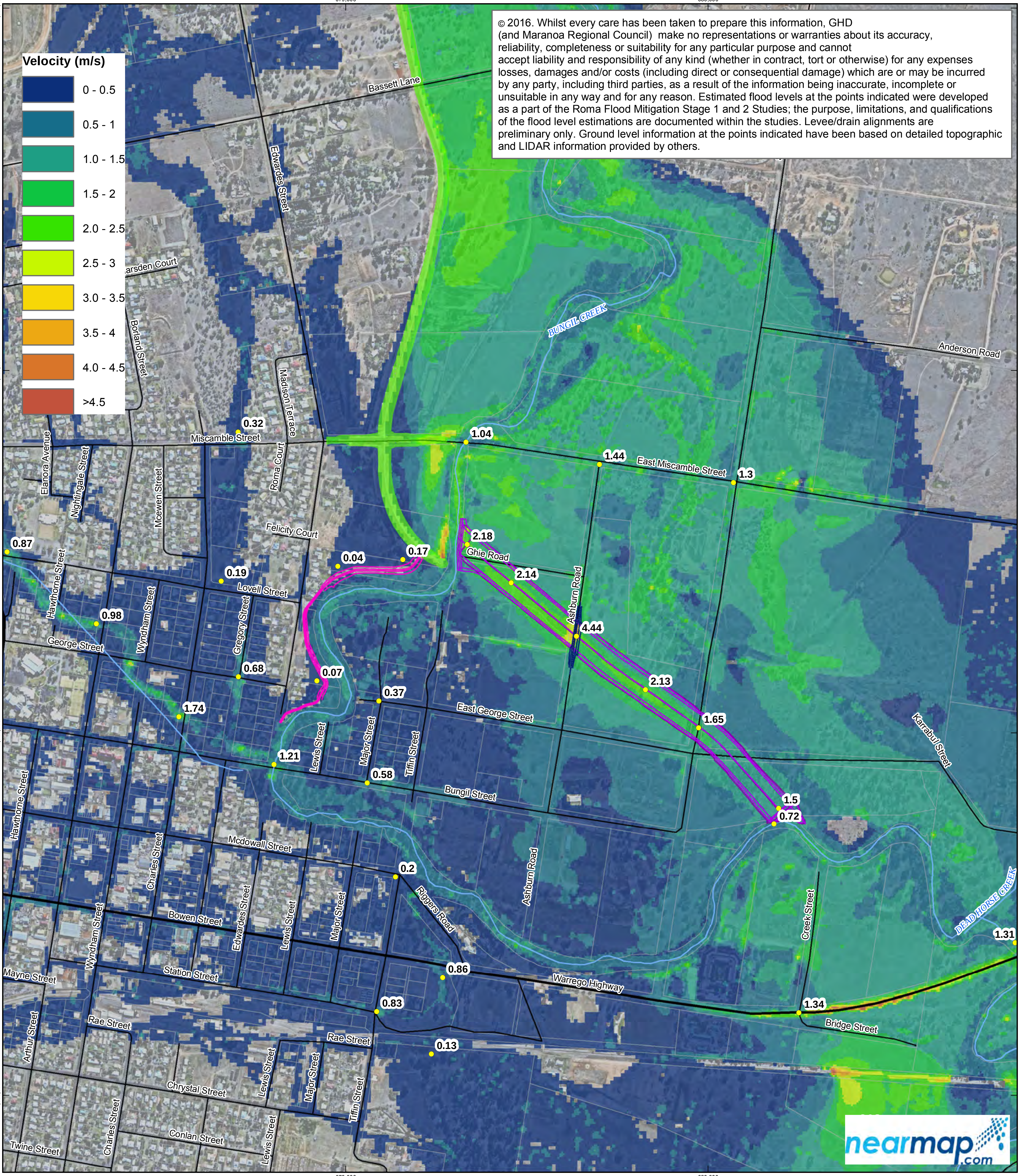

Legend

- Sample Point
- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

Paper Size A3

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Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Roma Flood Study

Roma Stage 2 Mitigation Options
2012 DFE Flood Velocity

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Figure A.6

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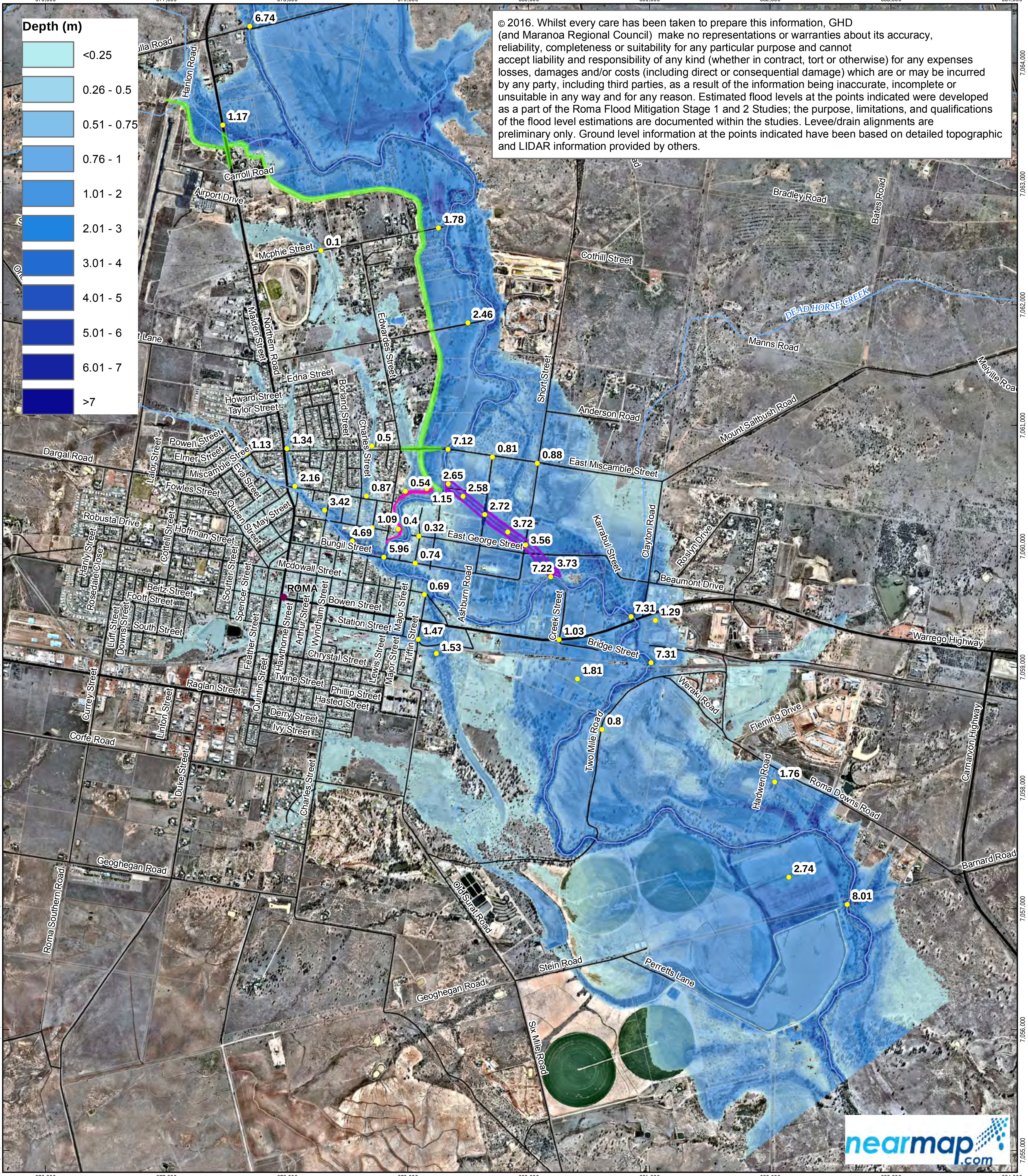

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Legend

- Sample Point
- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

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Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Maranoa Regional Council
Roma Flood Study

Job Number 41-29431
Revision 0
Date 15 Sep 2016

Roma Stage 2 Mitigation Options
2012 DFE Flood Depth - Full Extents

Figure A.7

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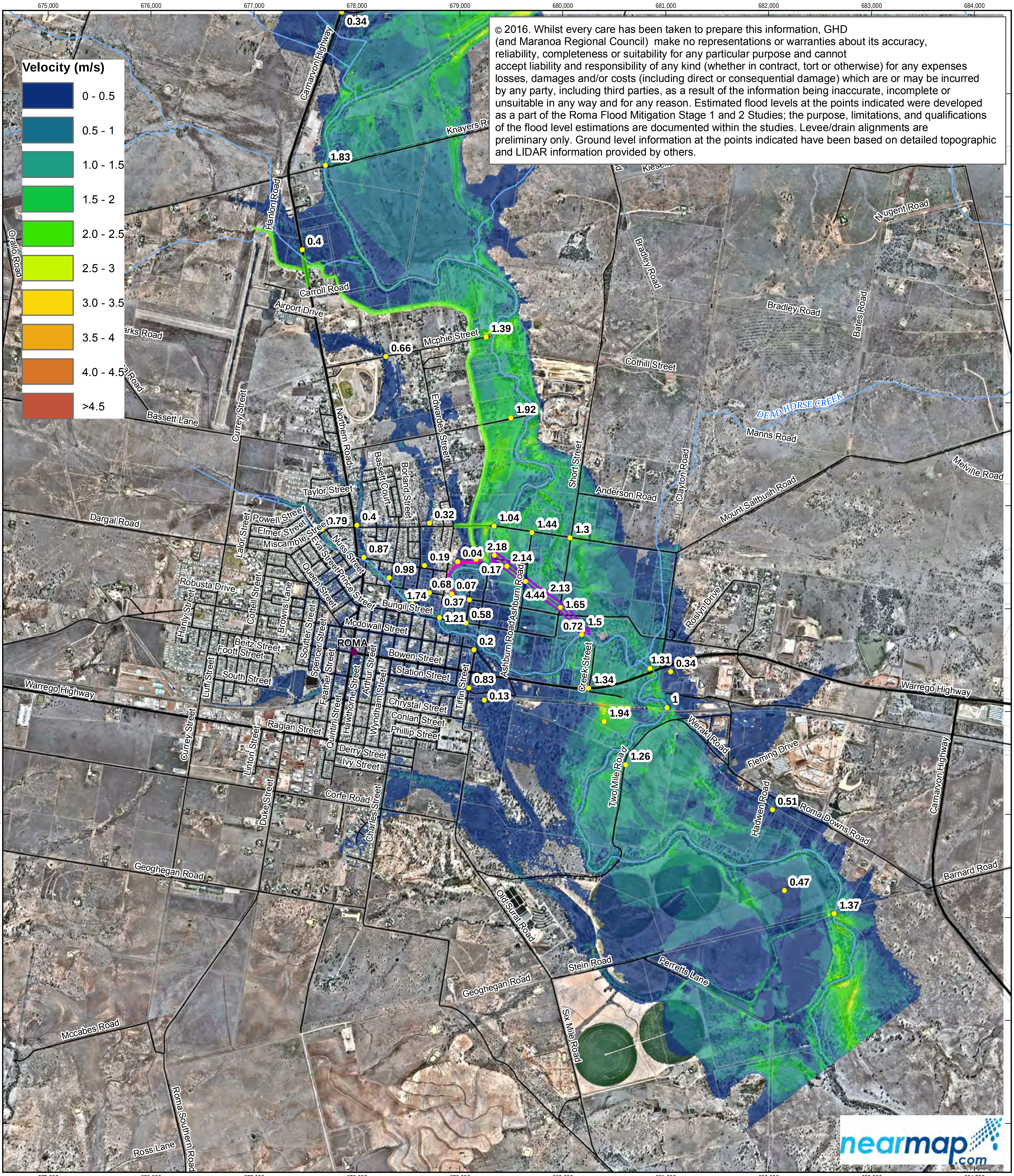

Legend

- Sample Point
- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

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Grid: GDA 1994 MGA Zone 55

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Roma Flood Study

Roma Stage 2 Mitigation Options
2012 DFE Flood Velocity - Full Extents

Job Number	41-29431
Revision	0
Date	15 Sep 2016

Figure A.8

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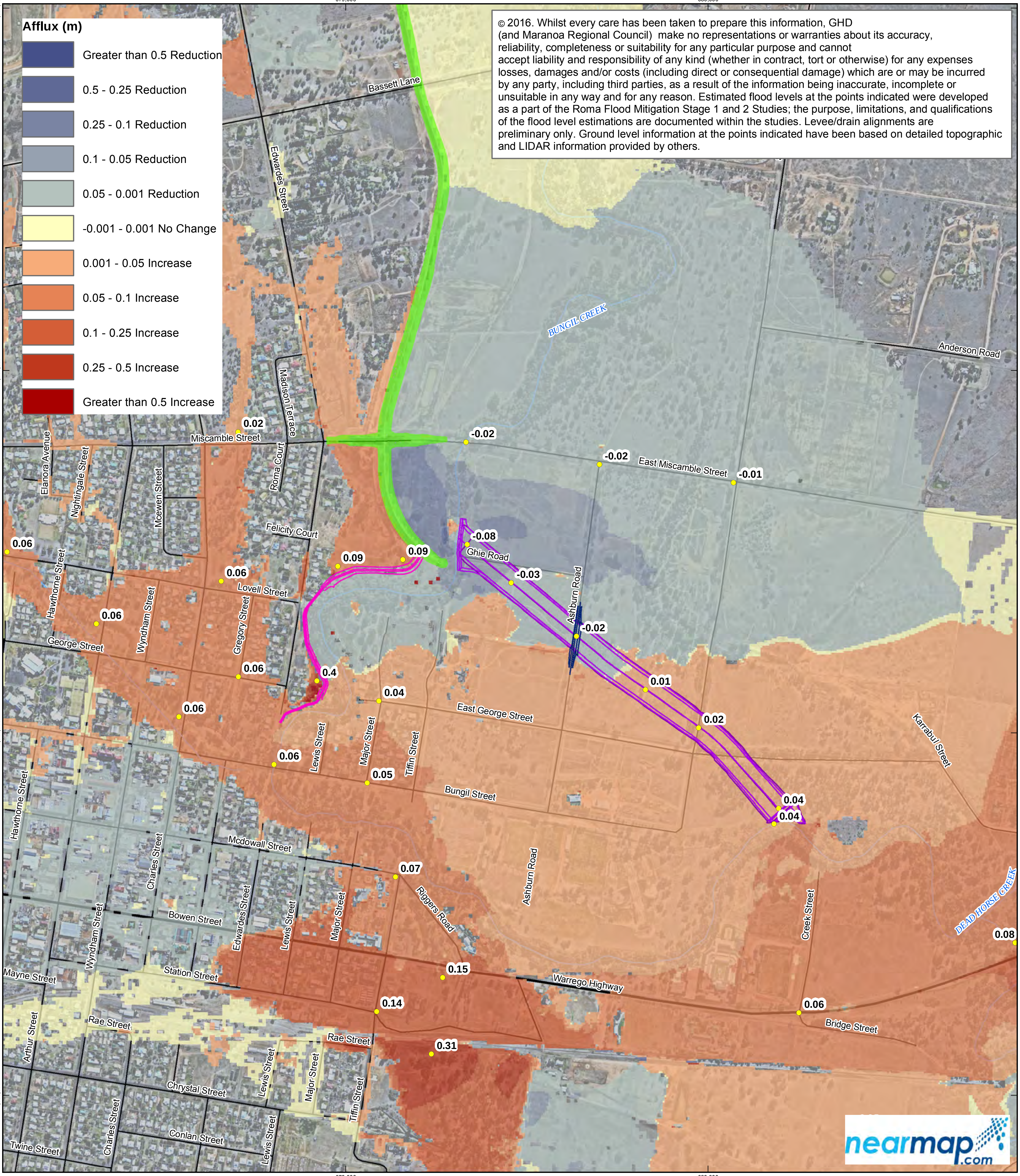
Appendix B – Stage 2 Regional Afflux Map



Legend

Sample Point	Stage 1 As Constructed Levee Alignment	Ashburn Rd Causeway	Highway
	Stage 2 Western Levee	Watercourse	Road
	Stage 2 Eastern Diversion Drain	Bungil Creek	Cadastre

Paper Size A3
0 200 400
Metres
Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Maranoa Regional Council
Roma Flood Study

Roma Stage 2 Mitigation Options
2012 DFE Flood Afflux (Old Vs New Hydrology)

Job Number 41-29431
Revision 0
Date 27 May 2016

Figure B.1

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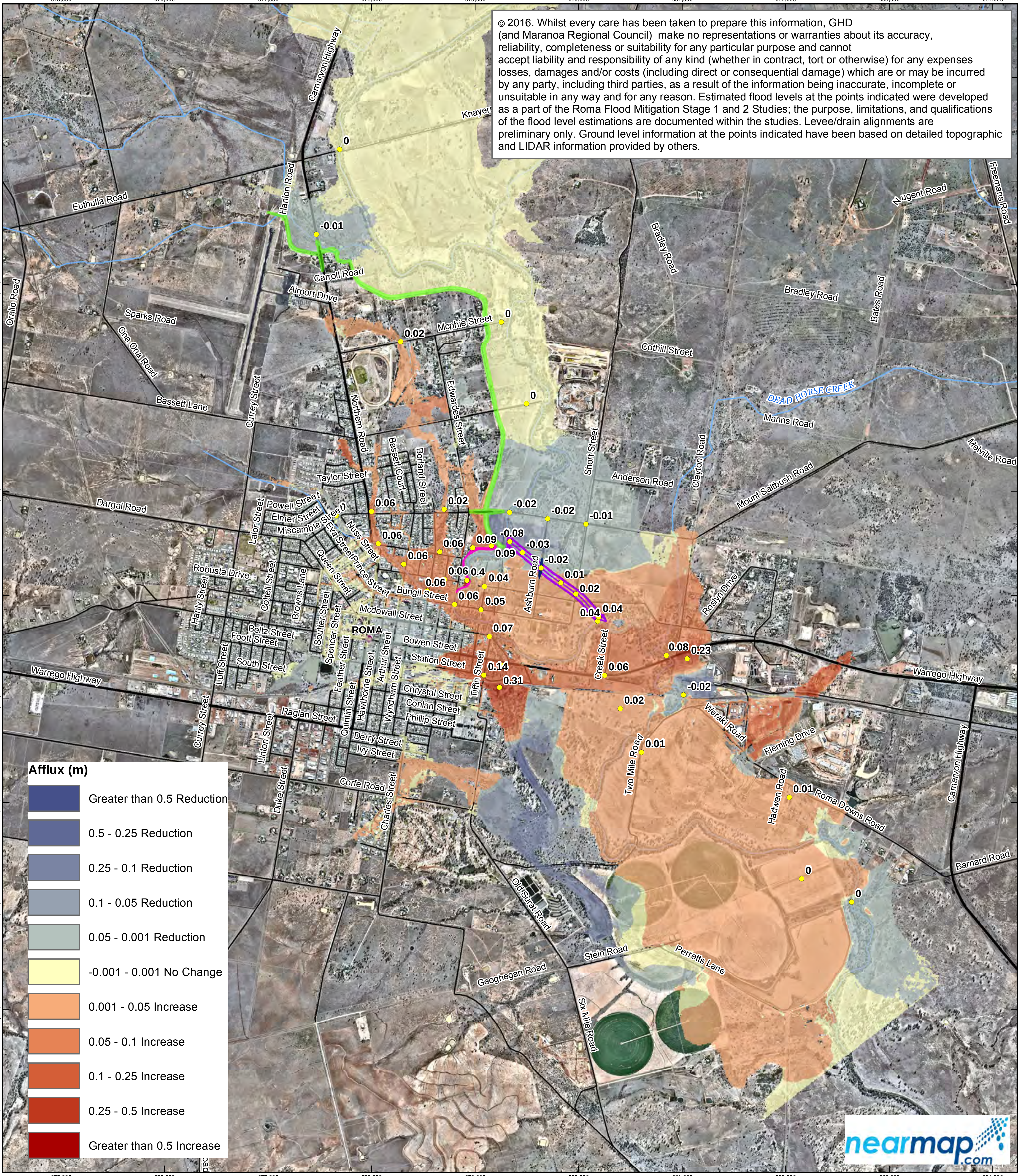

Legend

- Sample Point
- Ashburn Rd Causeway
- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

Paper Size A3

0 500 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Maranoa Regional Council
Roma Flood Study

Job Number 41-29431
Revision 0
Date 15 Sep 2016

Roma Stage 2 Mitigation Options
2012 DFE Flood Afflux (Old Vs New Hydrology) - Full Extents

Figure B.2

G:\41\29431\GIS\Maps\Deliverables\Stage 2 FINAL ISSUE Regional Maps\pdfv2\Fig_B.2_Regional_DFEyr_Afflux_Stage_2_Full_Model_.mxd

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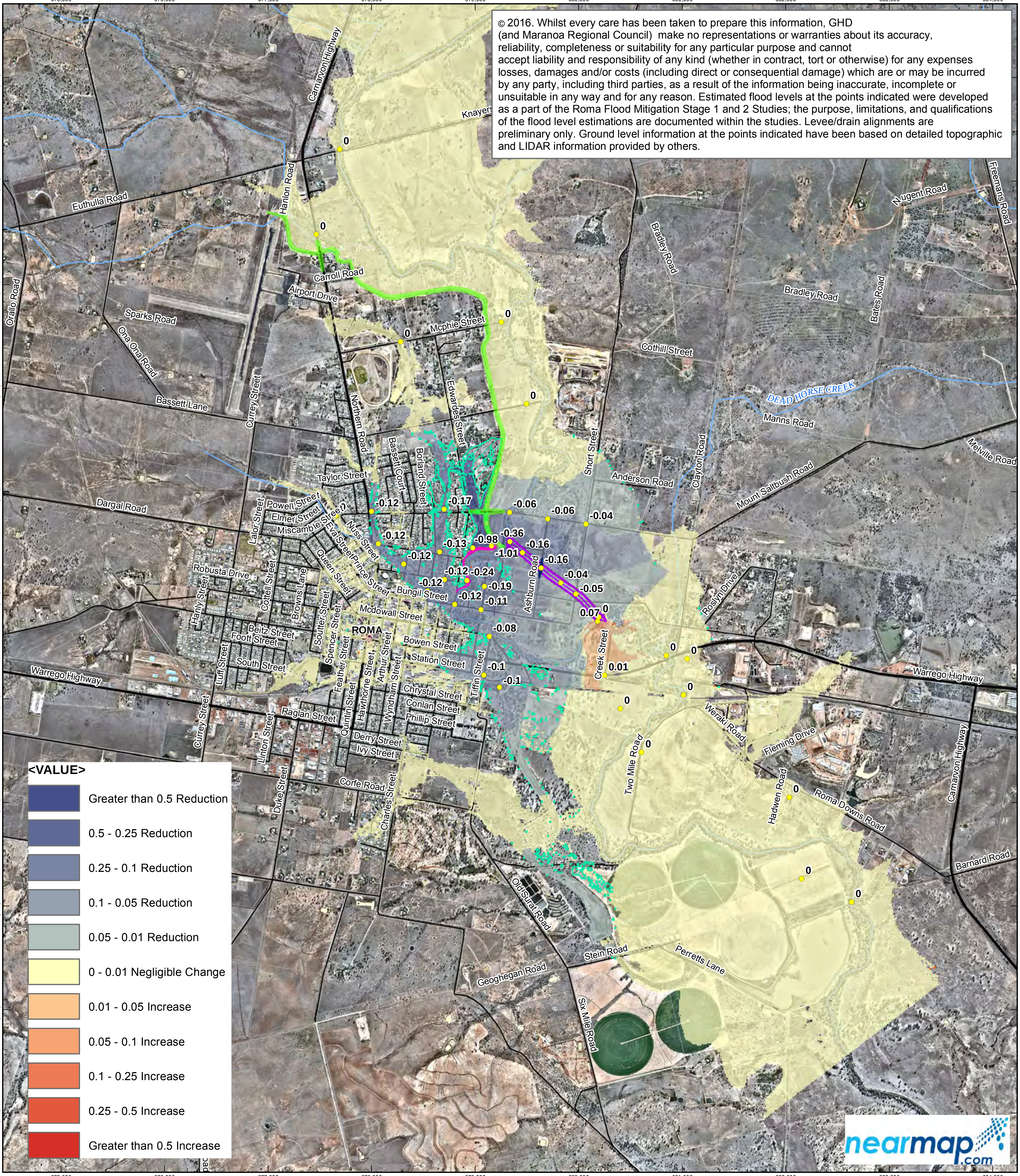
Data Source: ©Commonwealth of Australia (Geoscience Australia): Watercourses/2007; DNRM: Locality, Roads/2010, Cadastre, River/2012; SMEC: As Constructed Levee Alignment; GHD: Stage 2 levee and drain alignments, ashburn rd causeway; NearMap:Imagery (Date extracted: 01/08/2016, Image date: 04/07/2015;



Legend

- Sample Point
- Ashburn Rd Causeway
- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre
- Decrease in Flood Extents

Paper Size A3
0 500 1,000
Metres
Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Maranoa Regional Council
Roma Flood Study

Job Number	41-29431
Revision	0
Date	20 Sep 2016

Roma Stage 2 Mitigation Options - St1 Vs St2A
2012 DFE Flood Afflux (Updated Hydrology & Planning Scheme)

Figure B.3

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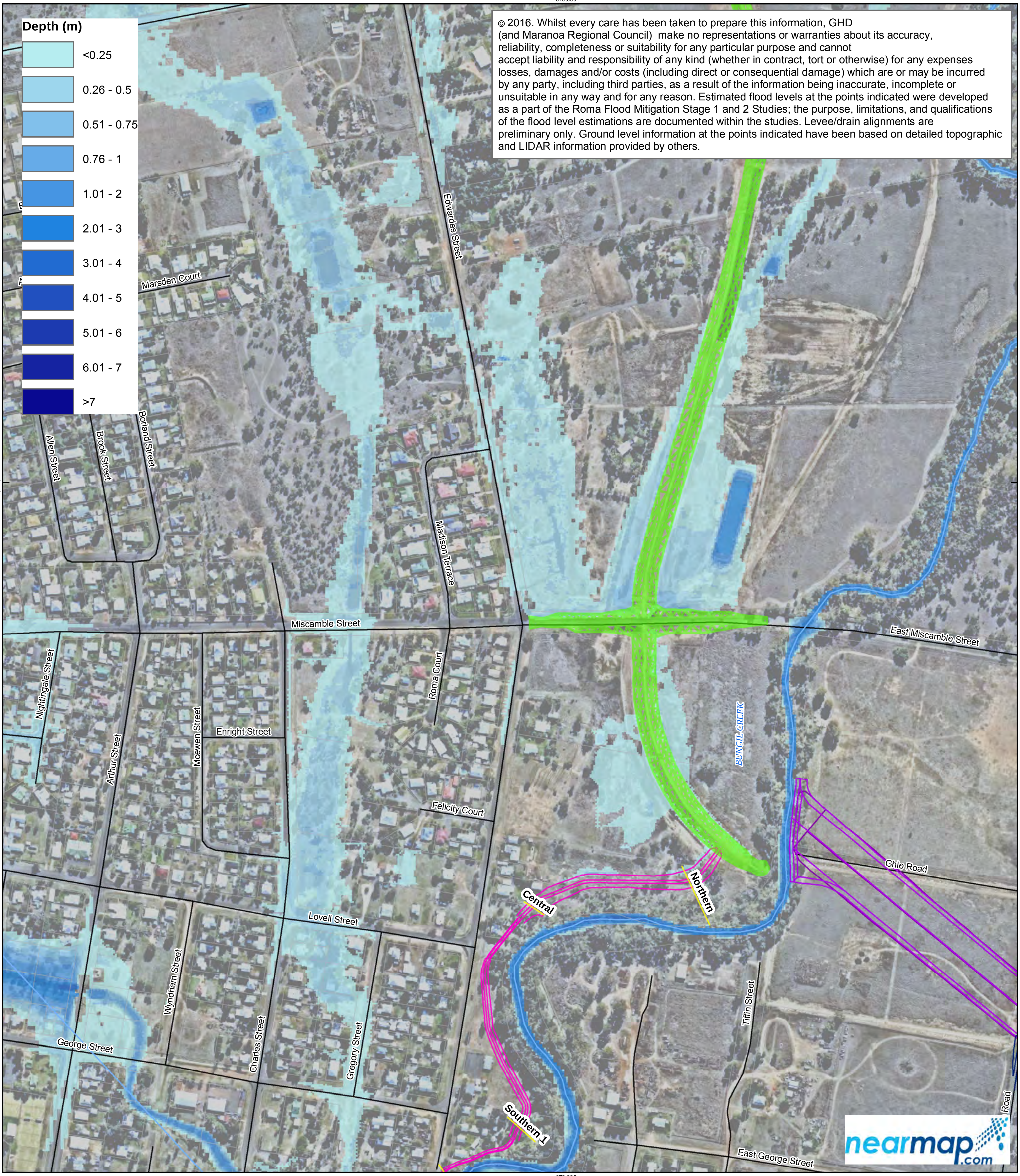
Appendix C – Stage 2 Local Flood Depth & Velocity Maps



Legend

- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Stage 2 Western Levee Culvert
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

Paper Size A3
0 100 200
Metres
Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Maranoa Regional Council
Roma Flood Study

Roma Stage 2 Mitigation Options
50% AEP Flood Depth - Penstocks Closed

Job Number	41-29431
Revision	0
Date	27 May 2016

Figure C.1

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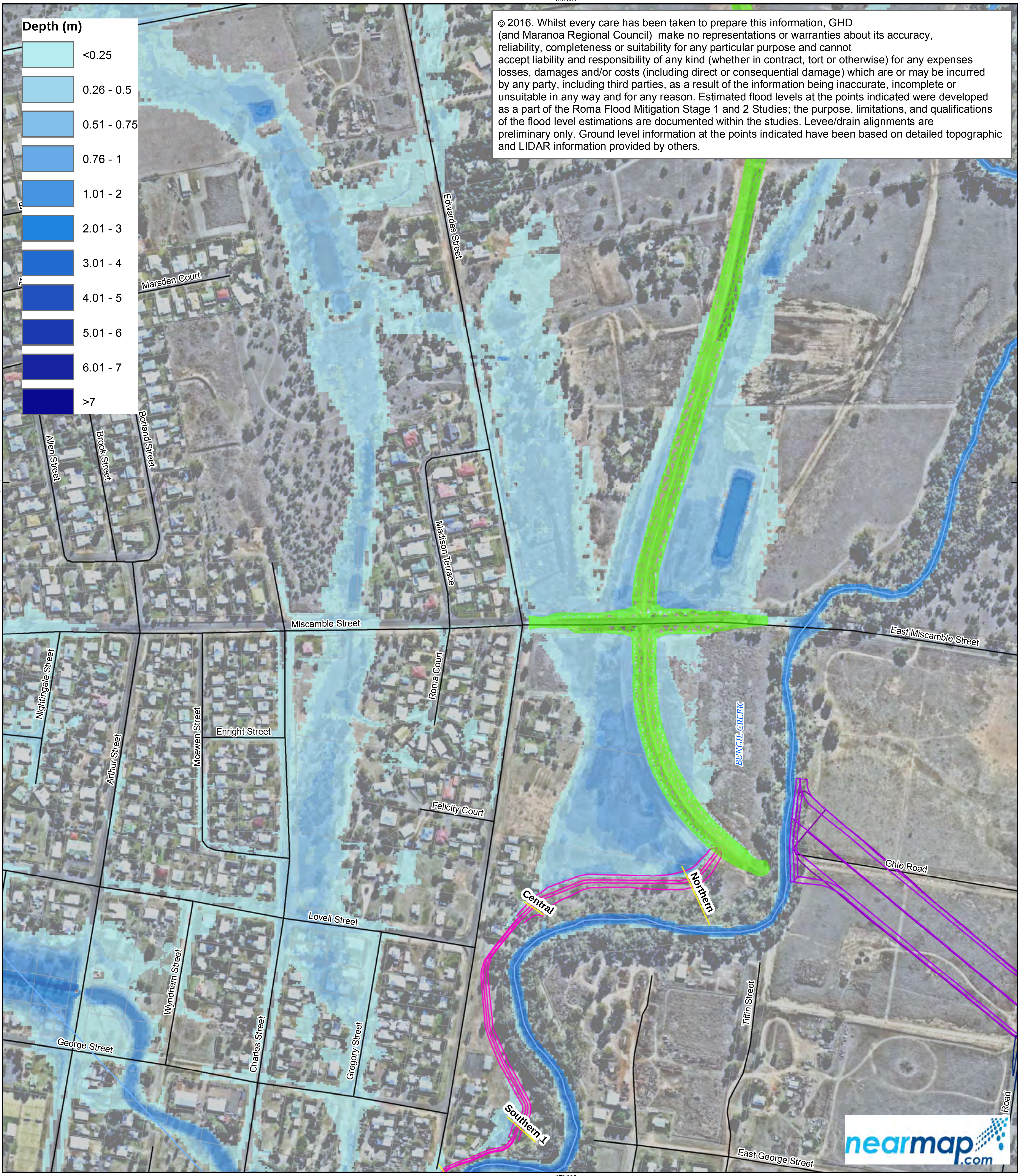

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Legend

- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Stage 2 Western Levee Culvert
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

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Paper Size A3
0 100 200
Metres
Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Maranoa Regional Council
Roma Flood Study

Roma Stage 2 Mitigation Options
10% AEP Flood Depth - Penstocks Closed

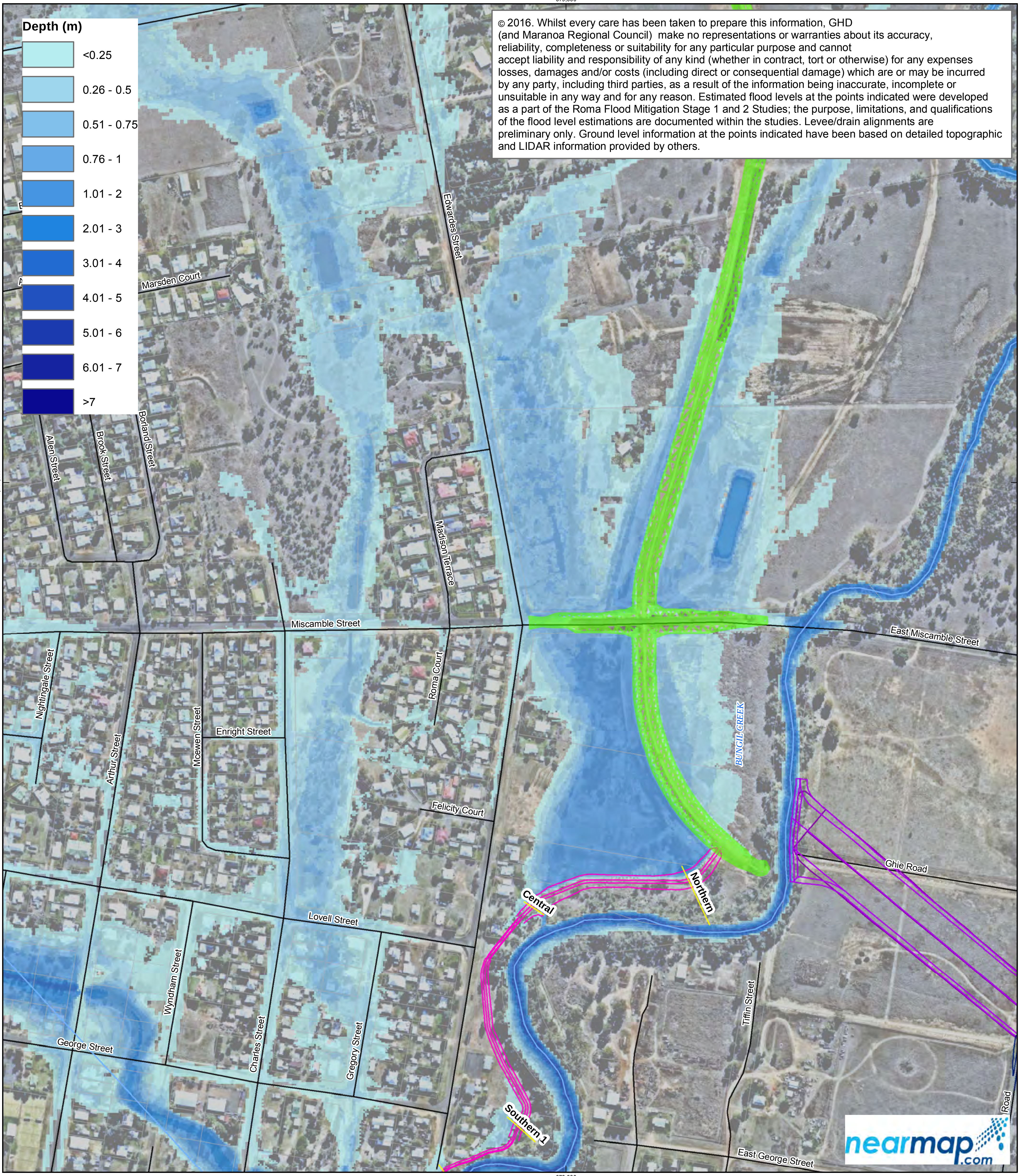
Job Number	41-29431
Revision	0
Date	27 May 2016

Figure C.2

G:\41\29431\GIS\Maps\Deliverables\Stage 2 FINAL ISSUE Local Maps\pdfv2\Fig_C.2_Local_10yr_Depth_Stage_2.mxd

145 Ann Street Brisbane QLD 4000 Australia T 61 7 3316 3000 F 61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: ©Commonwealth of Australia (Geoscience Australia): Watercourses/2007; DNRM: Locality, Roads/2010, Cadastre, River/2012; SMEC: As Constructed Levee Alignment; GHD: Stage 2 levee and drain alignments, Ashburn Rd causeway, culvert locations/2016; NearMap:Imagery (Date extracted: 05/02/2016, Image date: 04/07/2015.



Legend

- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Stage 2 Western Levee Culvert
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

Paper Size A3
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Metres
Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Maranoa Regional Council
Roma Flood Study

Roma Stage 2 Mitigation Options
1% AEP Flood Depth - Penstocks Closed

Job Number	41-29431
Revision	0
Date	27 May 2016

Figure C.3

G:\41\29431\GIS\Maps\Deliverables\Stage 2 FINAL ISSUE Local Maps\pdfv2\Fig_C.3_Local_100yr_Depth_Stage_2.mxd

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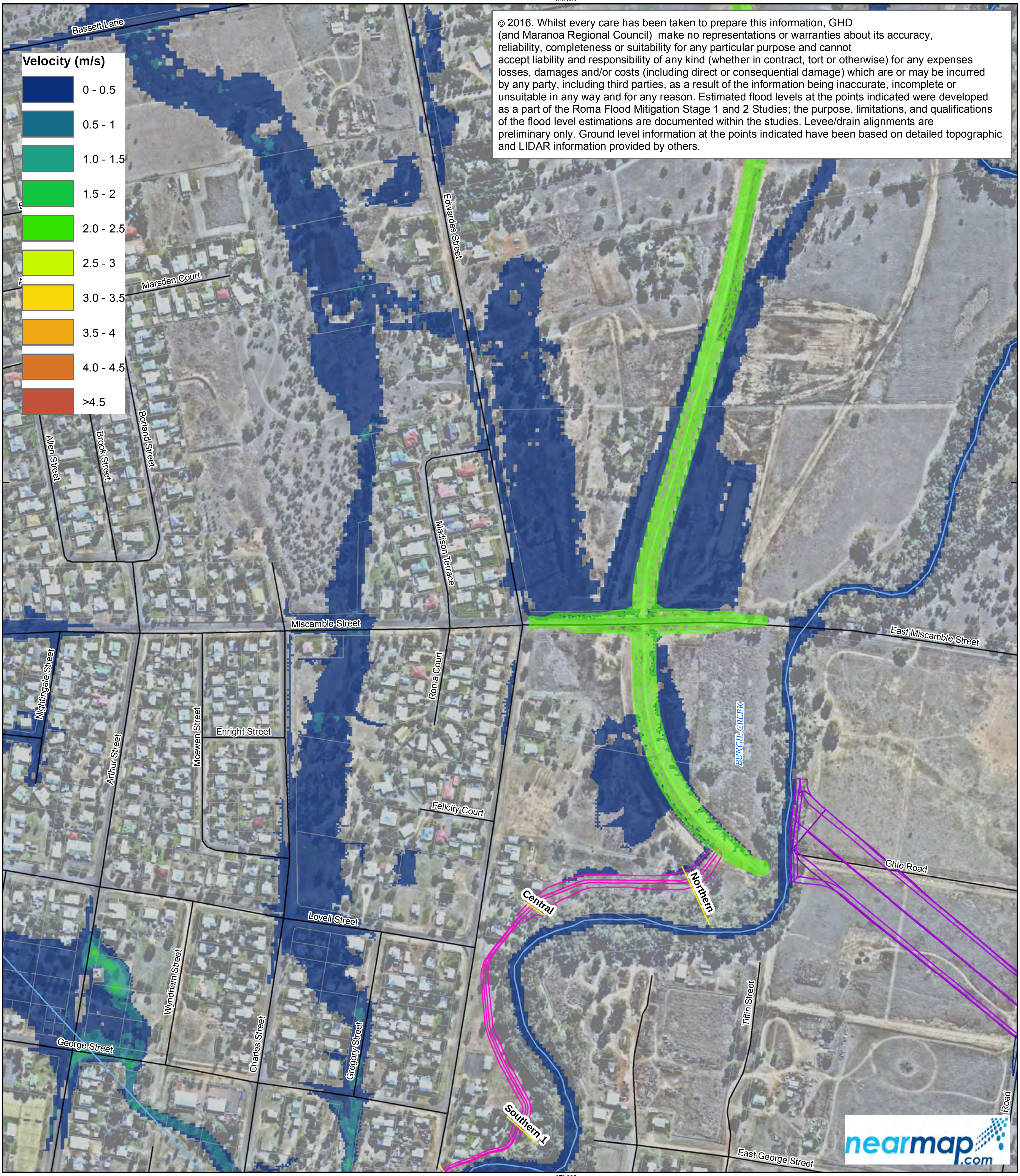

Legend

- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Stage 2 Western Levee Culvert
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

Paper Size A3
0 100 200
Metres
Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

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Roma Flood Study

Roma Stage 2 Mitigation Options
50% AEP Flood Depth - Penstocks Closed

Job Number	41-29431
Revision	0
Date	27 May 2016

Figure C.4

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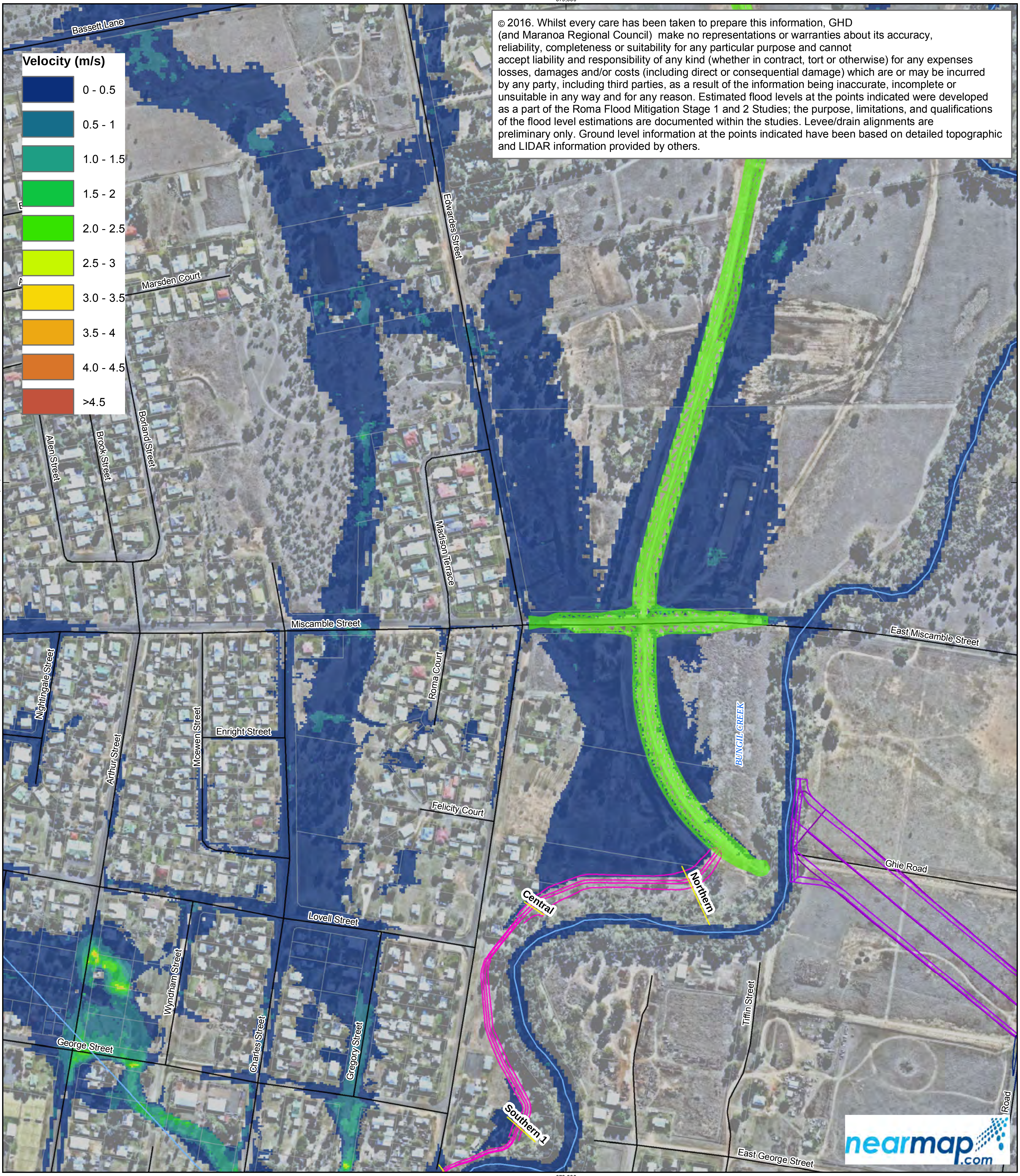

Legend

- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Stage 2 Western Levee Culvert
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

Paper Size A3

0 100 200

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Roma Flood Study

Roma Stage 2 Mitigation Options
10% AEP Flood Depth - Penstocks Closed

Job Number	41-29431
Revision	0
Date	27 May 2016

Figure C.5

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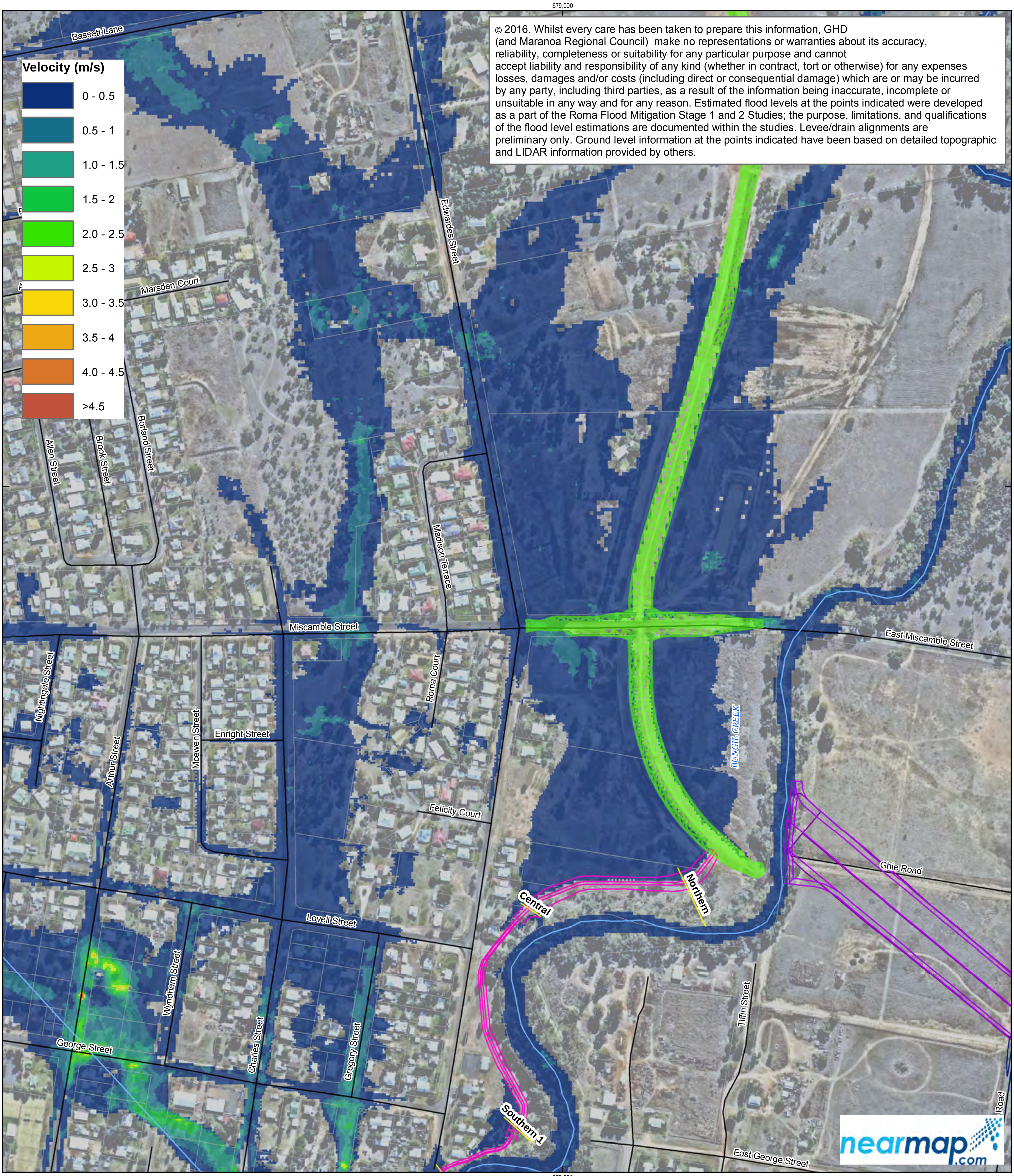
Data Source: ©Commonwealth of Australia (Geoscience Australia): Watercourses/2007; DNRM: Locality, Roads/2010, Cadastre, River/2012; SMEC: As Constructed Levee Alignment; GHD: Stage 2 levee and drain alignments, Ashburn Rd causeway, culvert locations/2016; NearMap:Imagery (Date extracted: 05/02/2016, Image date: 04/07/2015.



Legend

Stage 1 As Constructed Levee Alignment	Ashburn Rd Causeway	Cadastre
Stage 2 Western Levee	Watercourse	
Stage 2 Eastern Diversion Drain	Bungil Creek	
Stage 2 Western Levee Culvert	Highway	
	Road	

Paper Size A3

0 100 200

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Maranoa Regional Council
Roma Flood Study

Roma Stage 2 Mitigation Options
1% AEP Flood Depth - Penstocks Closed

Job Number	41-29431
Revision	0
Date	27 May 2016

Figure C.6

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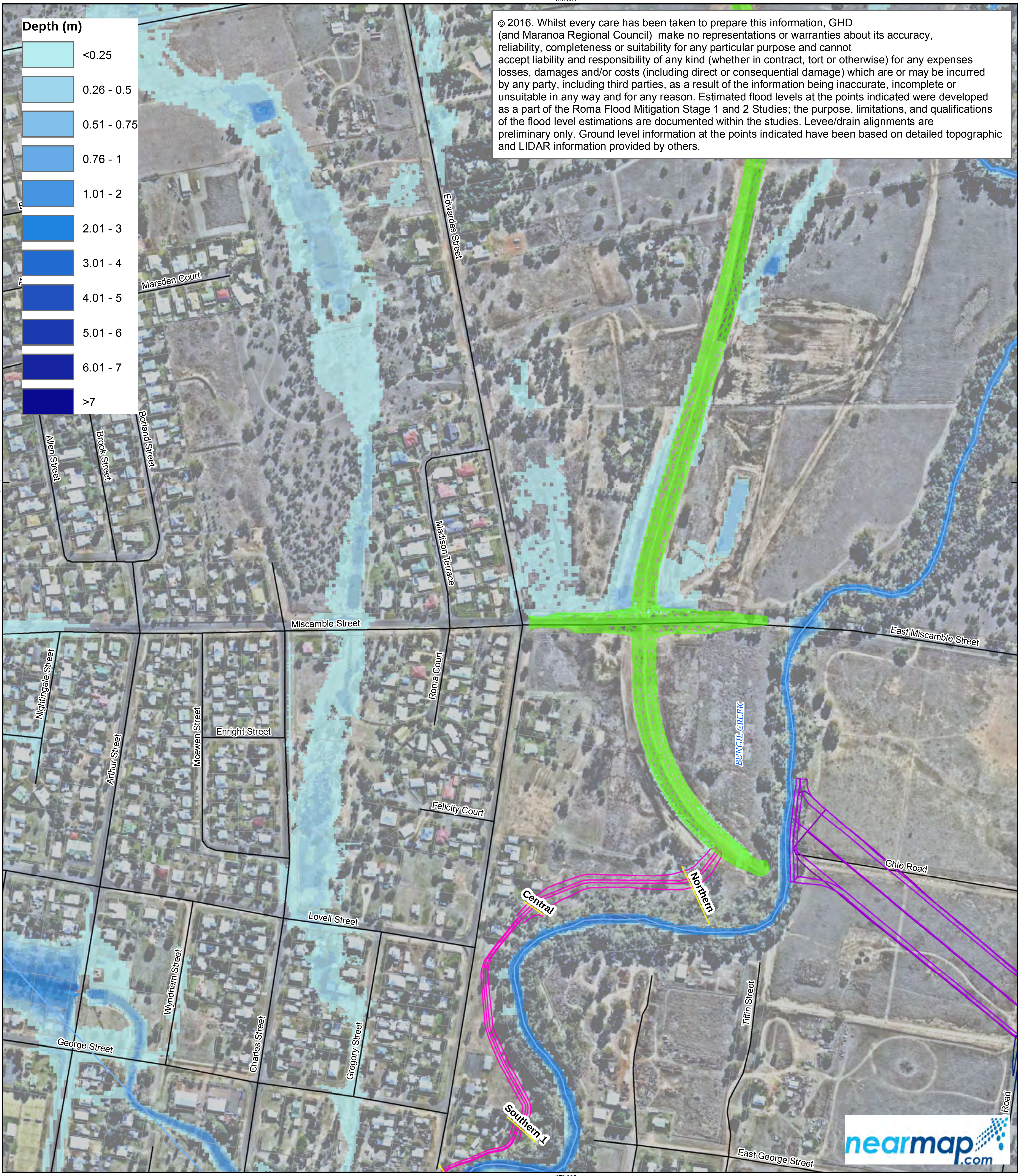

Legend

- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Stage 2 Western Levee Culvert
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

Paper Size A3
0 100 200
Metres
Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Maranoa Regional Council
Roma Flood Study

Job Number	41-29431
Revision	0
Date	27 May 2016

Roma Stage 2 Mitigation Options
50% AEP Flood Depth - Penstocks Open

Figure C.7

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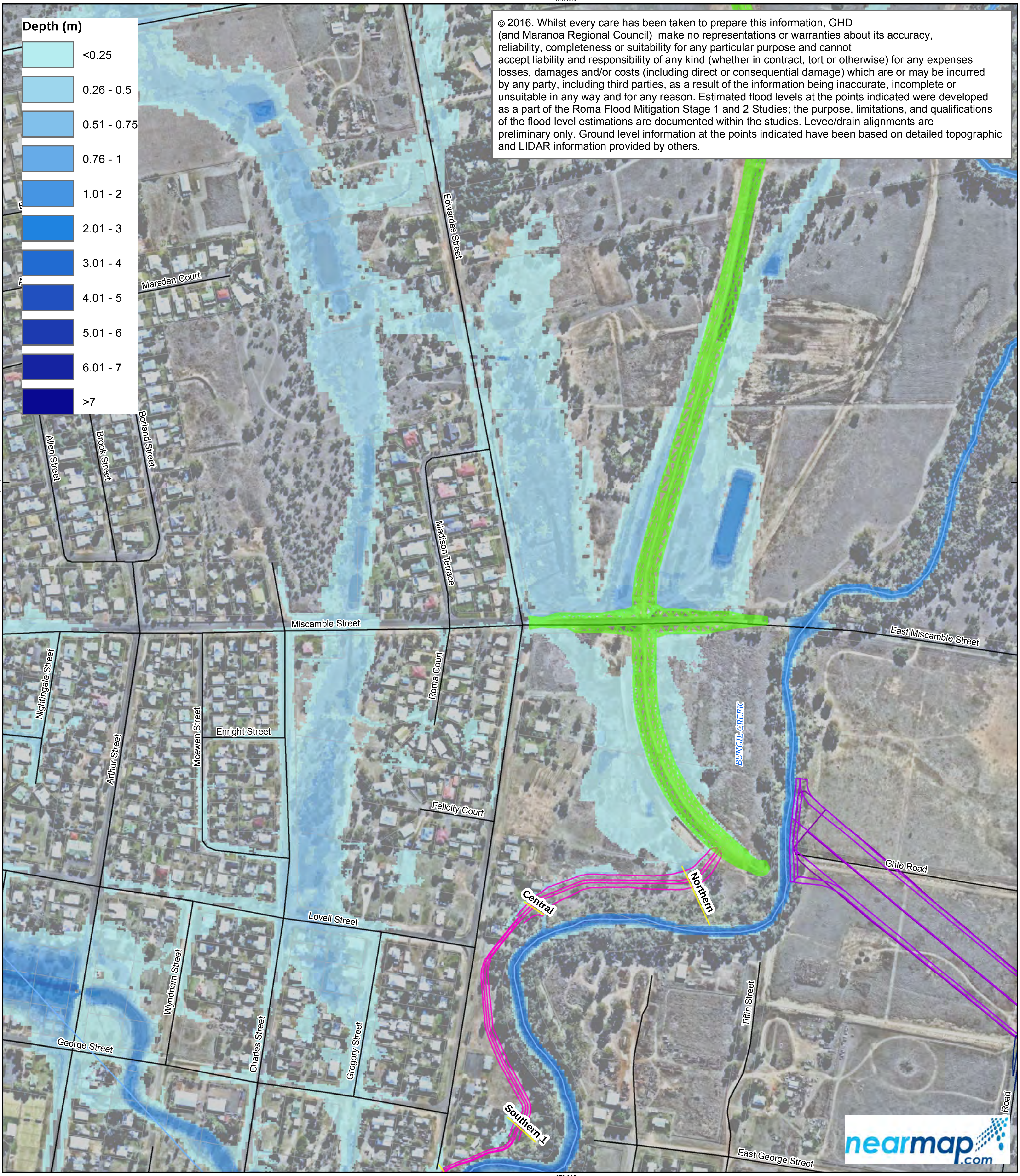
Data Source: ©Commonwealth of Australia (Geoscience Australia): Watercourses/2007; DNRM: Locality, Roads/2010, Cadastre, River/2012; SMEC: As Constructed Levee Alignment; GHD: Stage 2 levee and drain alignments, Ashburn Rd causeway, culvert locations/2016; NearMap:Imagery (Date extracted: 05/02/2016, Image date: 04/07/2015.



Legend

- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Stage 2 Western Levee Culvert
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

Paper Size A3

0 100 200

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Roma Flood Study

Roma Stage 2 Mitigation Options
10% AEP Flood Depth - Penstocks Open

Job Number	41-29431
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Date	27 May 2016

Figure C.8

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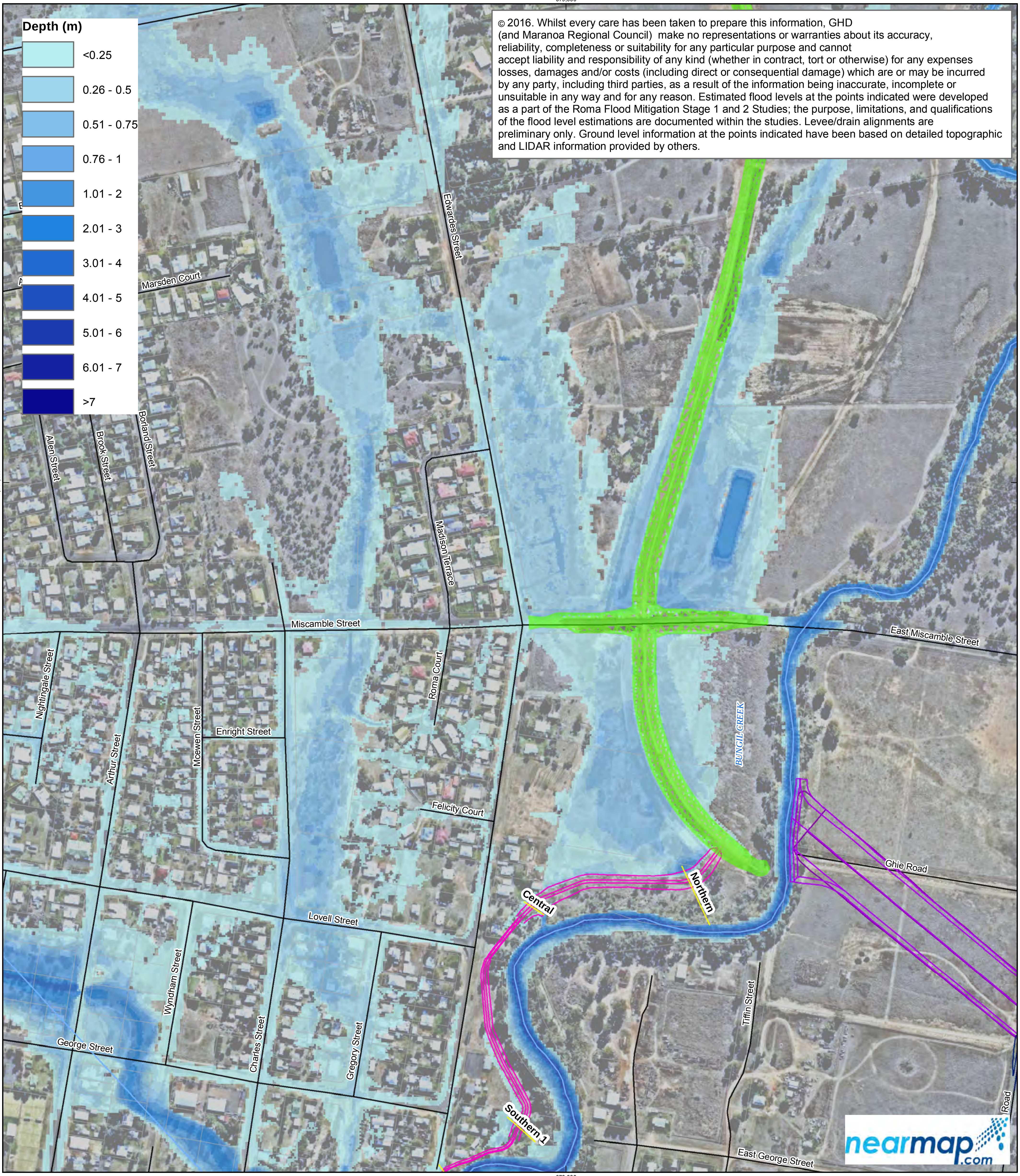

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Legend

- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Stage 2 Western Levee Culvert
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

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Metres
Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Roma Flood Study

Roma Stage 2 Mitigation Options
1% AEP Flood Depth - Penstocks Open

Job Number	41-29431
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Figure C.9

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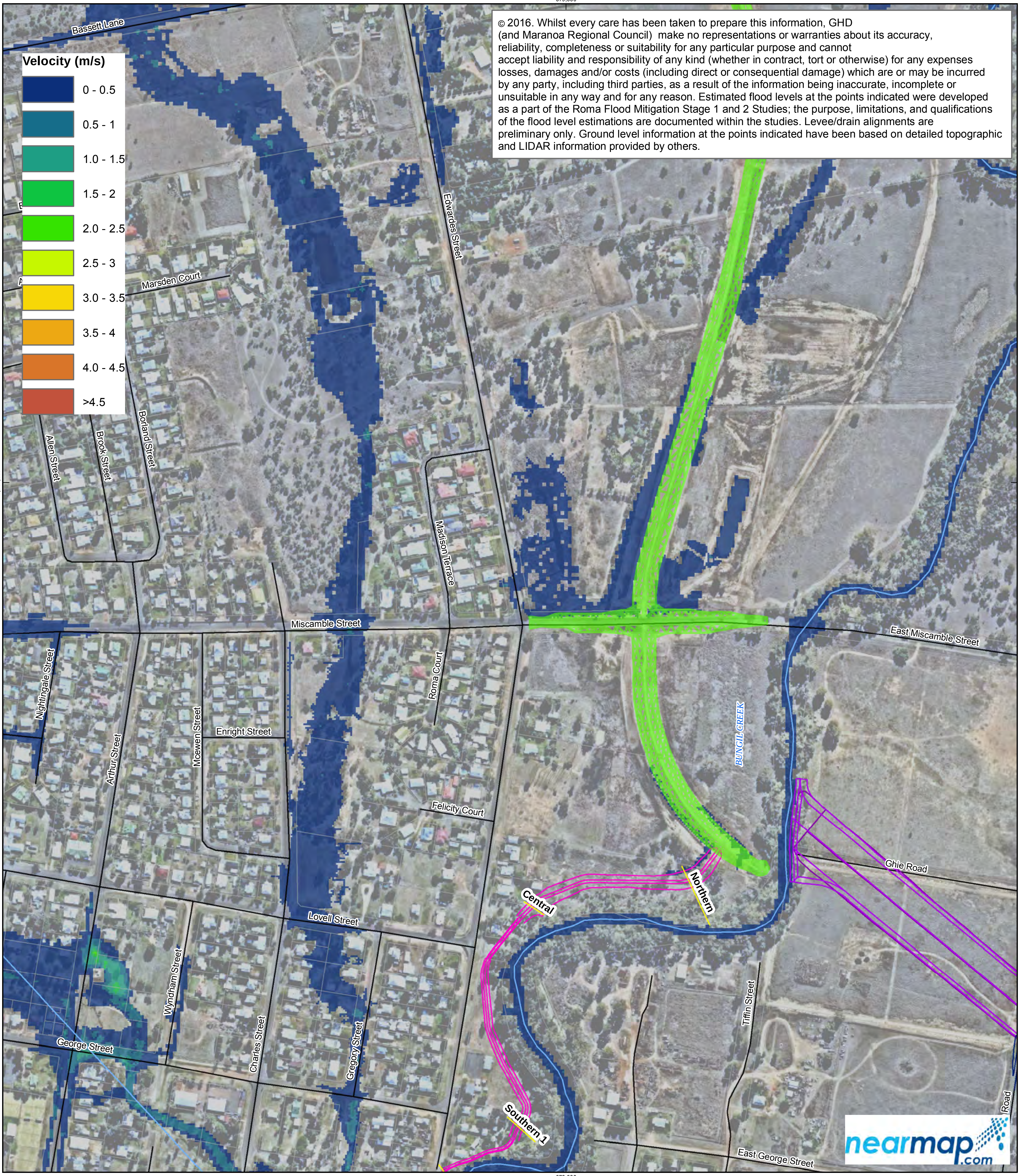

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Legend

- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Stage 2 Western Levee Culvert
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

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Paper Size A3

0 100 200

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Maranoa Regional Council
Roma Flood Study

Roma Stage 2 Mitigation Options
50% AEP Flood Depth - Penstocks Open

Job Number	41-29431
Revision	0
Date	27 May 2016

Figure C.10

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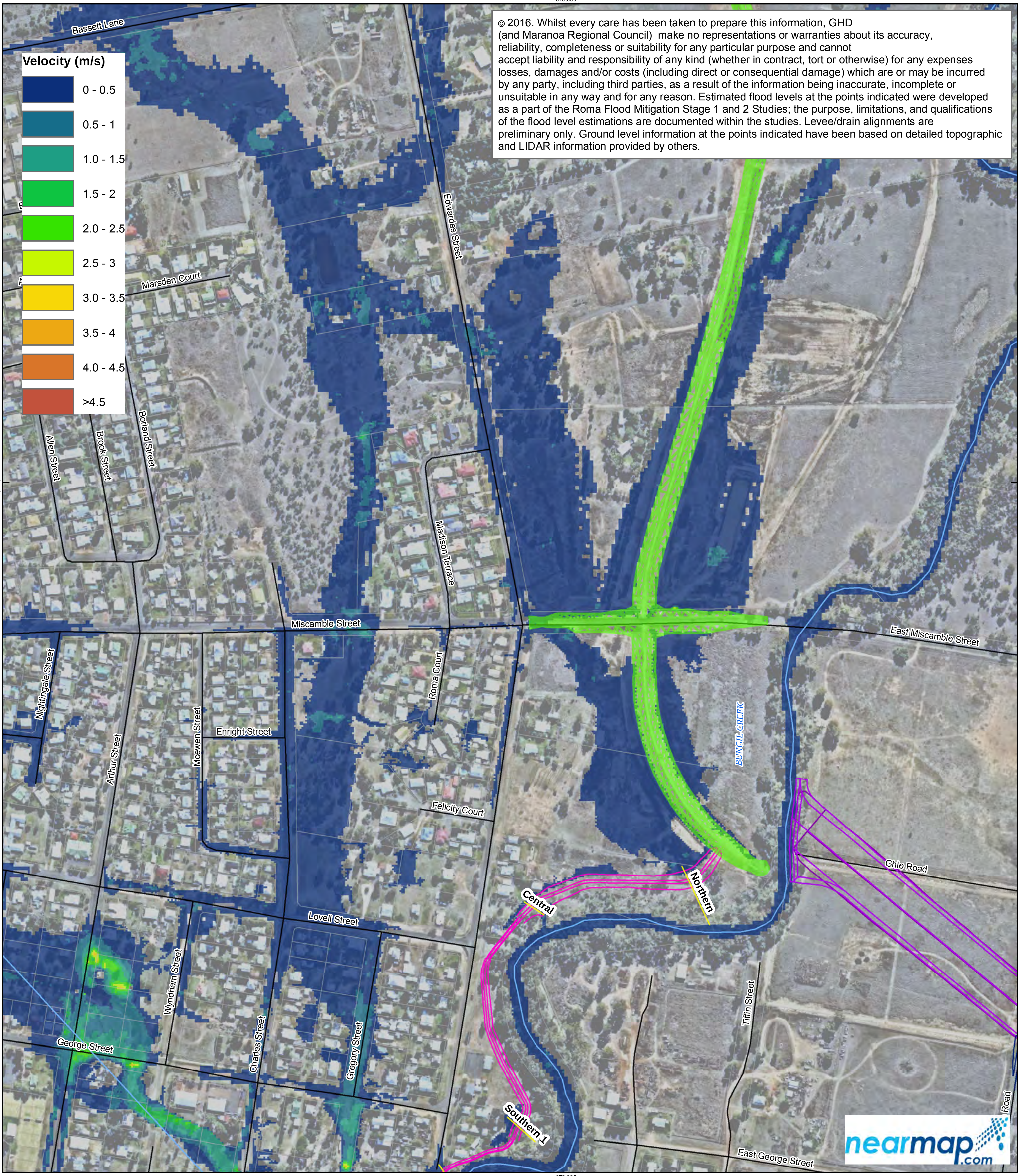

Legend

- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Stage 2 Western Levee Culvert
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

Paper Size A3
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Metres
Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Maranoa Regional Council
Roma Flood Study

Roma Stage 2 Mitigation Options
10% AEP Flood Depth - Penstocks Open

Job Number	41-29431
Revision	0
Date	27 May 2016

Figure C.11

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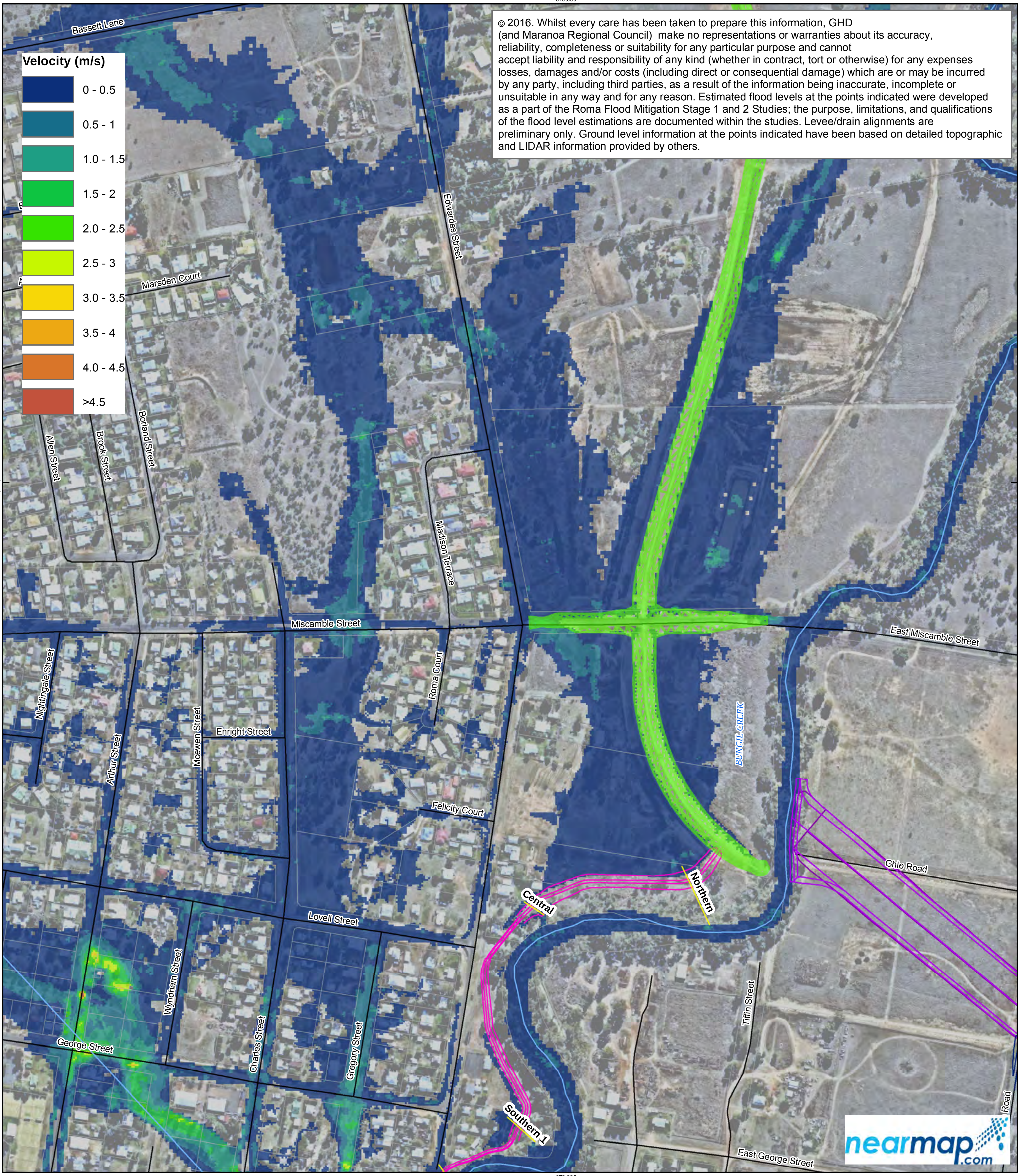

Legend

- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Stage 2 Western Levee Culvert
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

Paper Size A3
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Metres
Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Roma Flood Study

Roma Stage 2 Mitigation Options
1% AEP Flood Depth - Penstocks Open

Job Number	41-29431
Revision	0
Date	27 May 2016

Figure C.12

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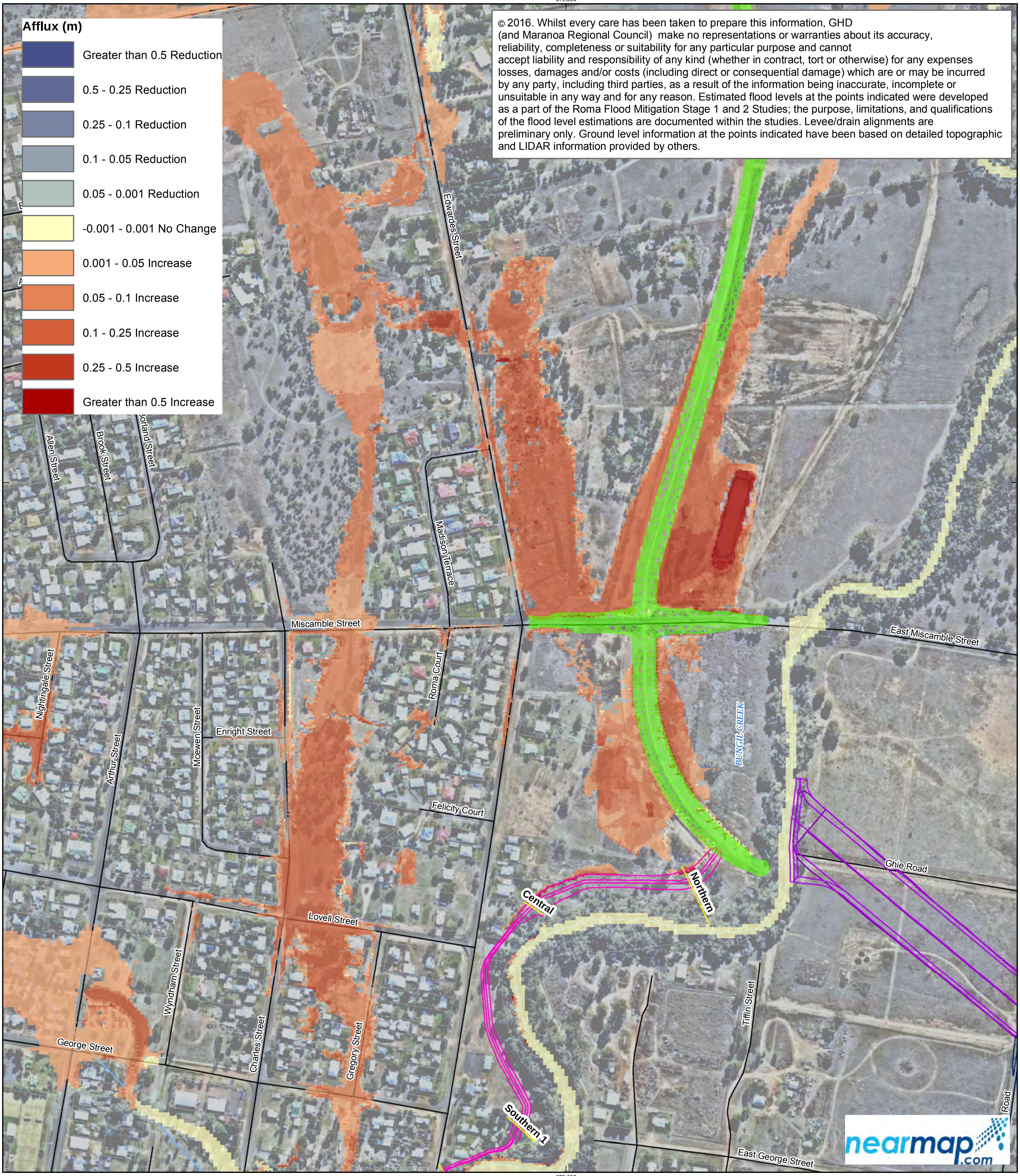
Appendix D – Stage 2 Local Flood Afflux Maps



Legend

- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Stage 2 Western Levee Culvert
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

Paper Size A3
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Metres
Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Roma Flood Study

Roma Stage 2 Mitigation Options
2 year ARI (Penstocks Closed vs Open)

Job Number	41-29431
Revision	0
Date	27 May 2016

Figure D.1

G:\41\29431\GIS\Maps\Deliverables\Stage 2 FINAL ISSUE Local Maps\pdfv3\Fig_D.1_Local_2yr_Afflux_Stage_2.mxd

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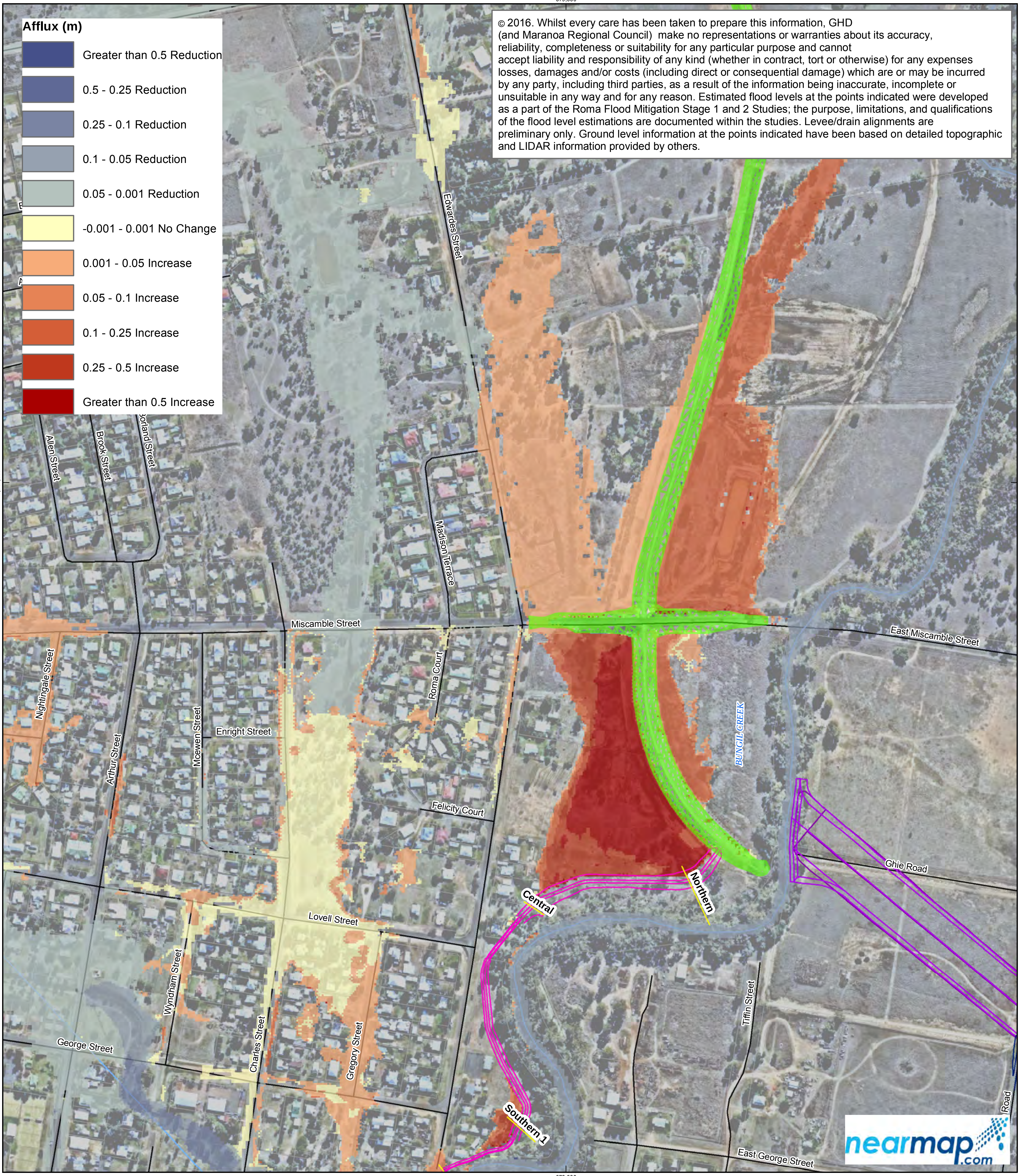
Data Source: ©Commonwealth of Australia (Geoscience Australia): Watercourses/2007; DNRM: Locality, Roads/2010, Cadastre, River/2012; SMEC: As Constructed Levee Alignment; GHD: Stage 2 levee and drain alignments, Ashburn Rd causeway, culvert locations/2016; NearMap:Imagery (Date extracted: 05/02/2016, Image date: 04/07/2015.



Legend

- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Stage 2 Western Levee Culvert
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

Paper Size A3
0 100 200
Metres
Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Maranoa Regional Council
Roma Flood Study

Roma Stage 2 Mitigation Options
10 year ARI (Penstocks Closed vs Open)

Job Number	41-29431
Revision	0
Date	27 May 2016

Figure D.2

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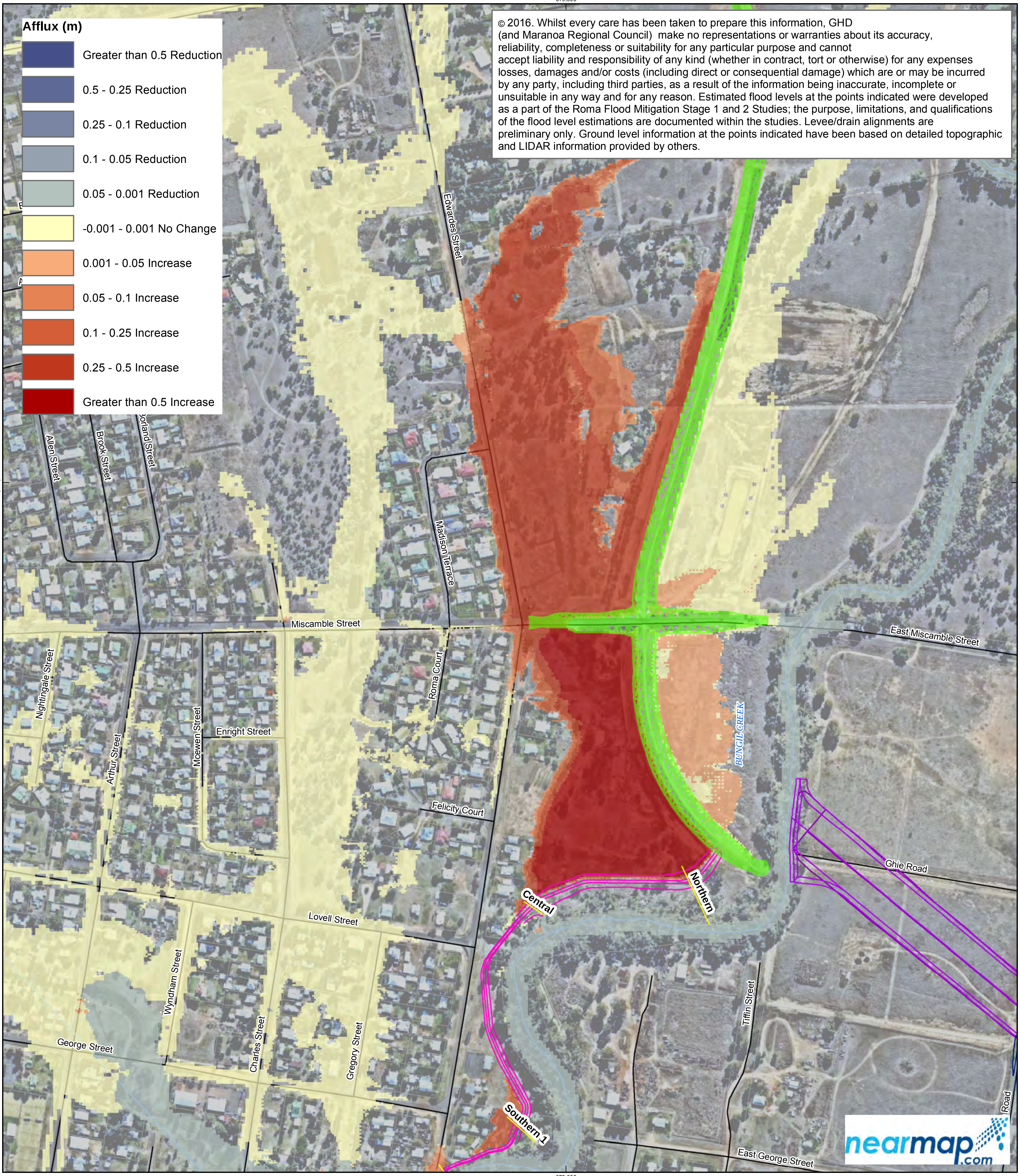

Legend

- Stage 1 As Constructed Levee Alignment
- Stage 2 Western Levee
- Stage 2 Eastern Diversion Drain
- Stage 2 Western Levee Culvert
- Ashburn Rd Causeway
- Watercourse
- Bungil Creek
- Highway
- Road
- Cadastre

Paper Size A3

0 100 200

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Maranoa Regional Council
Roma Flood Study

Roma Stage 2 Mitigation Options
100 year ARI (Penstocks Closed vs Open)

Job Number	41-29431
Revision	0
Date	27 May 2016

Figure D.3

Data Source: ©Commonwealth of Australia (Geoscience Australia): Watercourses/2007; DNRM: Locality, Roads/2010, Cadastre, River/2012; SMEC: As Constructed Levee Alignment; GHD: Stage 2 levee and drain alignments, Ashburn Rd causeway, culvert locations/2016; NearMap:Imagery (Date extracted: 05/02/2016, Image date: 04/07/2015.

Appendix E – Western Levee Culvert Sizing Calculations

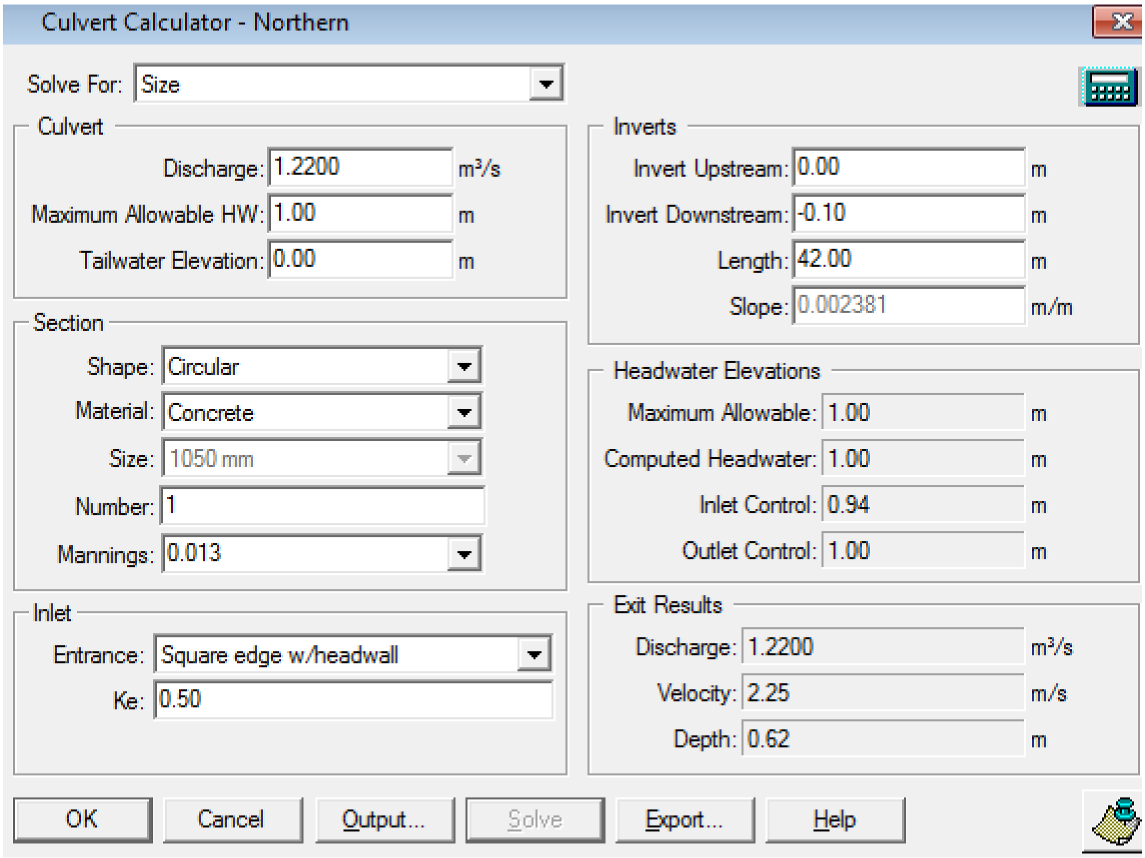
Rational Method Calculations for Western Levee Cross Drainage

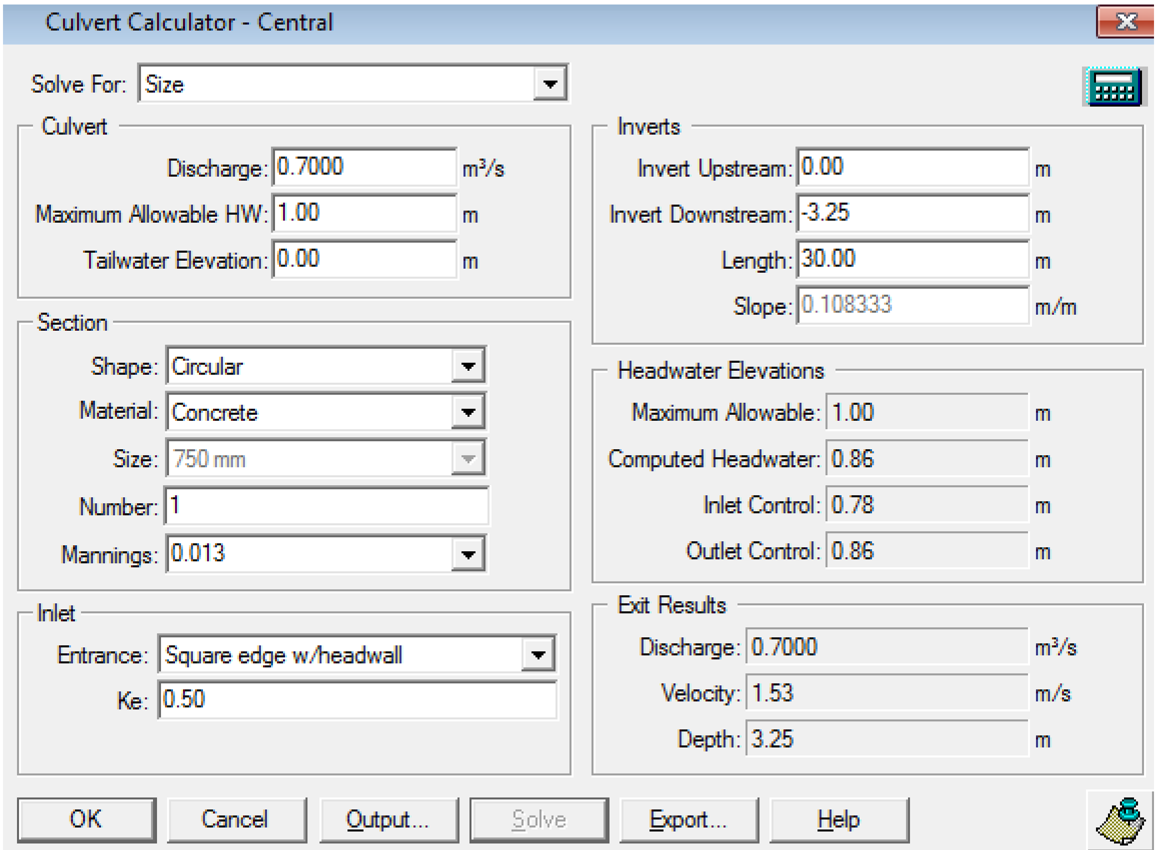
Roma Stage 2 Western Levee Drainage				
Culverts	Northern	Central	Southern 2	
Local Sub-Catchment	NW_S20	NW_S20b	NW_S20c	
Density	Urban Res	Urban Res	Urban Res	
Area (ha)	7	4	2	
QUDM fi	0.65	0.65	0.65	mid range urban res low density including roads QUDM Table 4.5.1
QUDM C10	0.745	0.745	0.745	QUDM Table 4.5.3
Frequency Factor 2 Year	*0.85*	*0.85*	*0.85*	Frequency Factors QUDM Table 4.5.2
Frequency Factor 5 Year	*0.95*	*0.95*	*0.95*	
Frequency Factor 10 Year	*1*	*1*	*1*	
Frequency Factor 50 Year	*1.15*	*1.15*	*1.15*	
Frequency Factor 100 Year	*1.2*	*1.2*	*1.2*	
Flow Length	562	395	302	
Sheet Flow (Max Allowable Length)	200	200	200	QUDM 4.6.4 Rural res/low urban res
Sheet Flow Slope	1	1	0.5	
Sheet Flow Time	22	22	25	Friends Eqtn 4.5, n = 0.045 medium grass cover
Channel flow (m)	362	195	102	
Channel Flow Time in mins at 1.5m/s	4	2	1	
Time of Concentration (approx) from QUDM	26	24	26	
Adopted Tc	**25**	**25**	**25**	
I2	57.8	57.8	57.8	BOM IFD
I5	74.25	74.25	74.25	
I10	84.5	84.5	84.5	
I50	117	117	117	
I100	131.5	131.5	131.5	
Q2	0.71	0.41	0.20	
Q5	1.02	0.58	0.29	
Q10	1.22	0.70	0.35	
Q50	1.95	1.11	0.56	
Q100	2.29	1.31	0.65	
Adopted Q100 Flow	**2.5**	**1.5**	**1**	

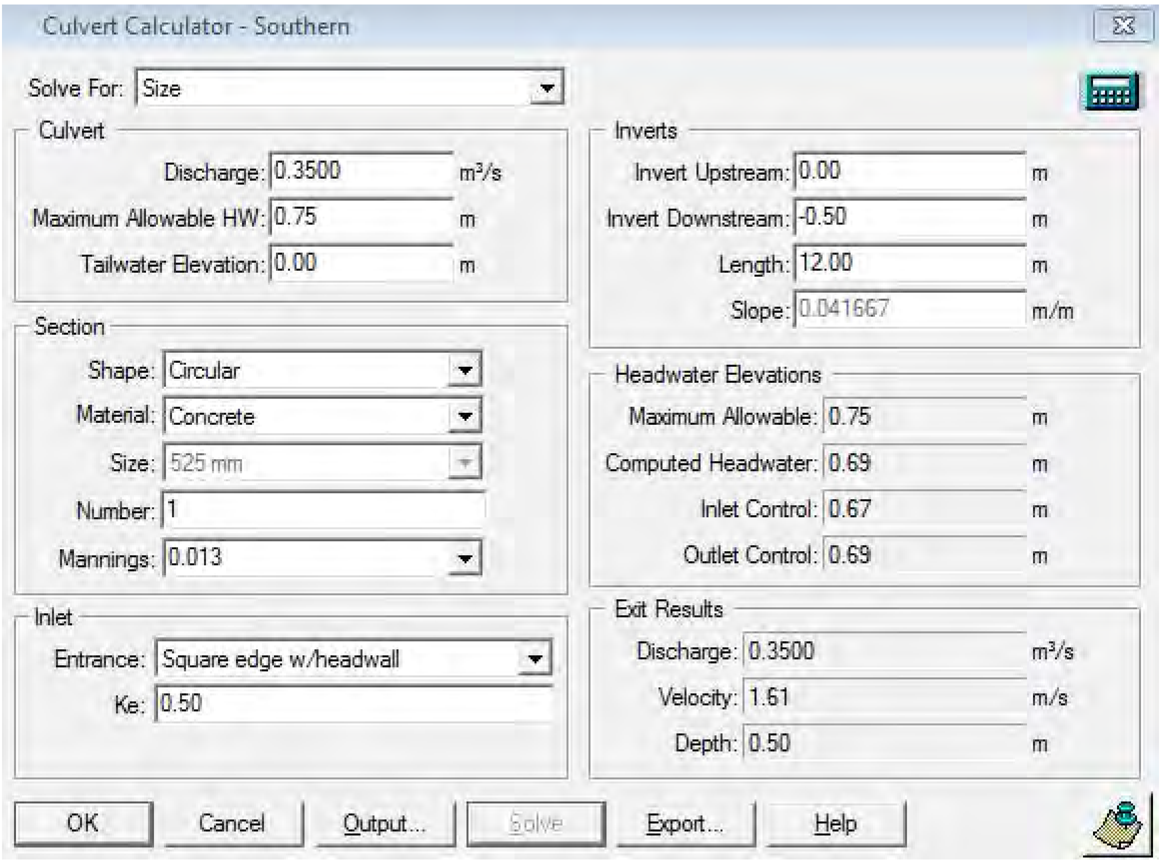
Rational method is above QRT low threshold so use Rational Method Flows

QRT Method Comparison		
NW_S20	NW_S20b	NW_S20c
0.08	0.05	0.03
0.36	0.24	0.15
0.73	0.50	0.31
2.14	1.48	0.94
3.07	2.14	1.37

Pipe sizing calculations (Culvert Master) ***Note: Subject to space limitaitons, pipe sizes have been upgraded as a conservative approach***.

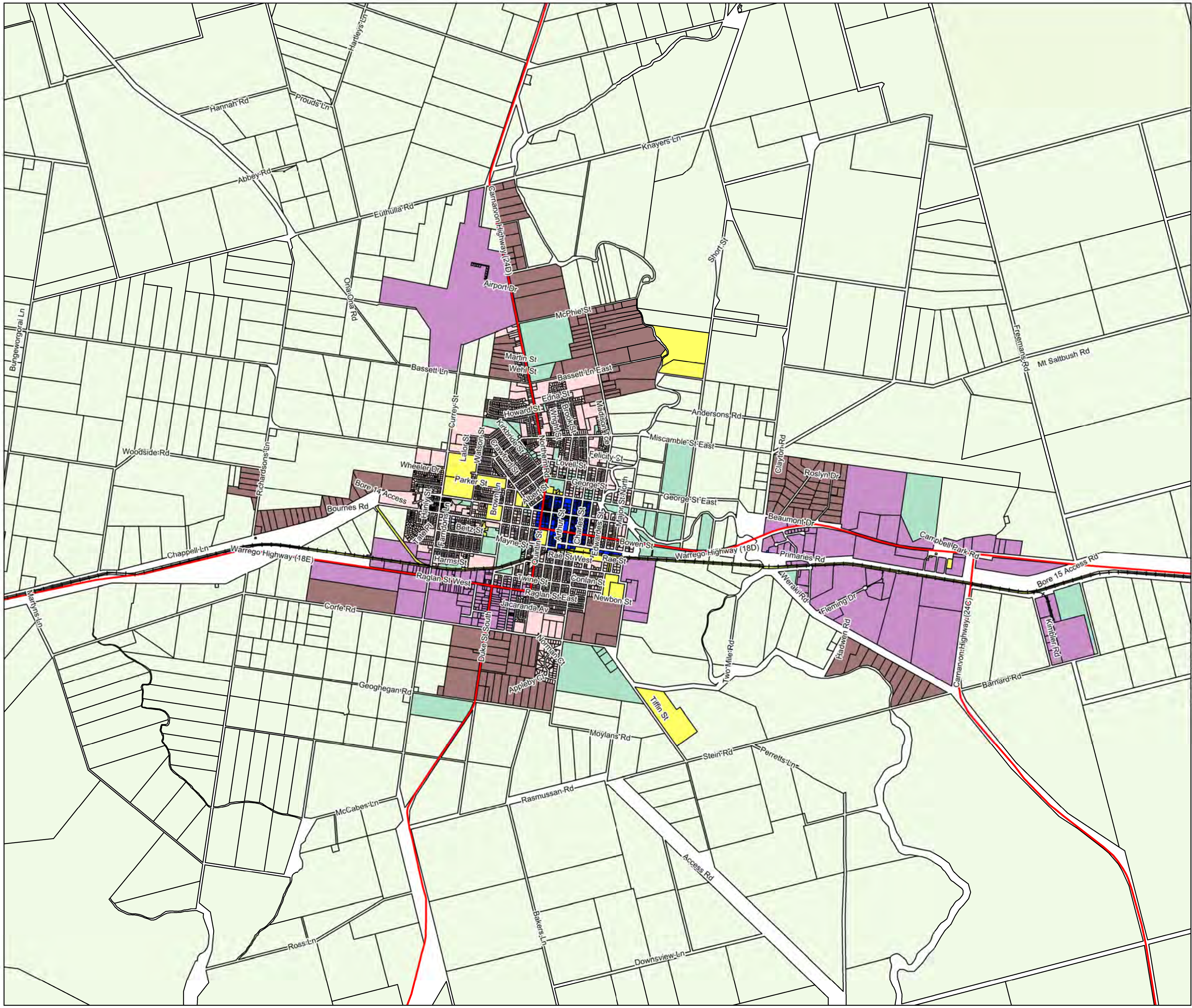





Culvert Calculator - Southern
Solve For: Size
Culvert
Discharge: 0.3500 m³/s
Maximum Allowable HW: 0.75 m
Tailwater Elevation: 0.00 m
Inverts
Invert Upstream: 0.00 m
Invert Downstream: -0.50 m
Length: 12.00 m
Slope: 0.041667 m/m
Section
Shape: Circular
Material: Concrete
Size: 525 mm
Number: 1
Mannings: 0.013
Headwater Elevations
Maximum Allowable: 0.75 m
Computed Headwater: 0.69 m
Inlet Control: 0.67 m
Outlet Control: 0.69 m
Inlet
Entrance: Square edge w/headwall
Ke: 0.50
Exit Results
Discharge: 0.3500 m³/s
Velocity: 1.61 m/s
Depth: 0.50 m
OK
Cancel
Output...
Solve
Export...
Help

Appendix F – MRC Zone Map 9

Maranoa Regional Council Planning Scheme Zone Map 9 - Roma



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Railway Network

State Controlled Road

Zone

- Community Purpose
- Industry
- Principal Centre
- Recreation and Open Space
- Residential Living
- Rural
- Rural Residential

N
W E
S

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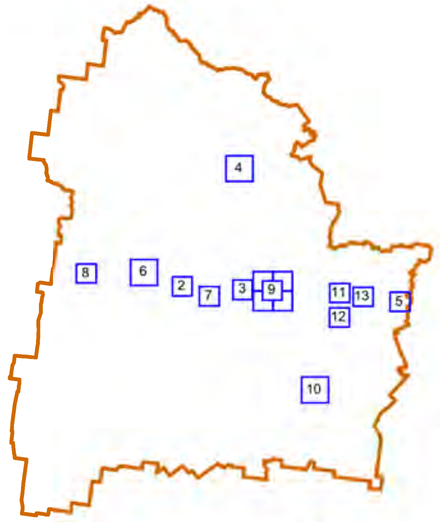
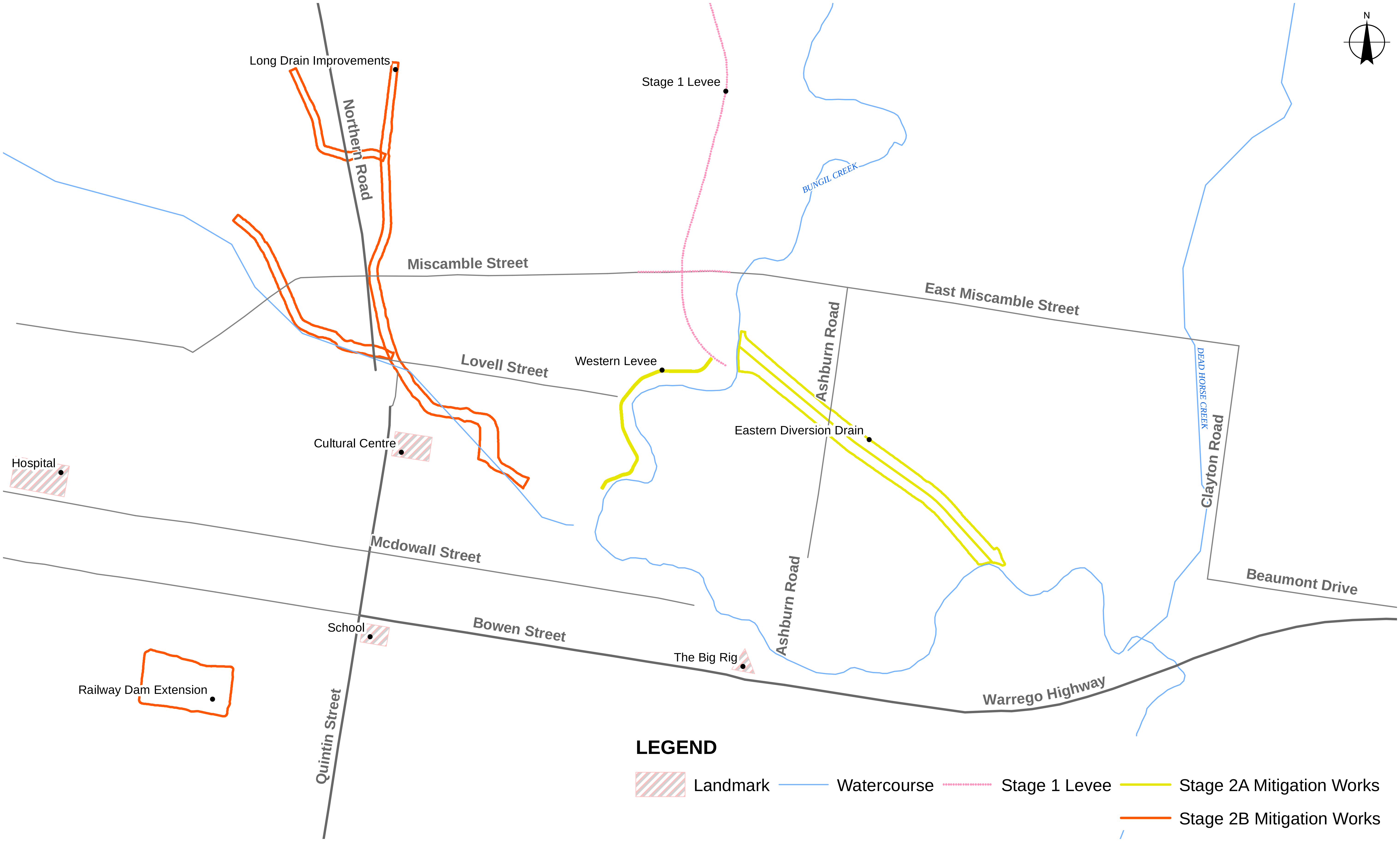
Projection: MGA94 Zone 55



Roma zone map 2.3.9.1

Appendix G – Stage 2B Sketch

Roma Flood Mitigation Project - Stage 2 CONCEPT



Date created: 21.06.2016. Refer to separate document for data disclaimers.

This disclaimer is to accompany the Stage 2 CONCEPT Plan [dated 21.06.16].

Data Source: ©Commonwealth of Australia (Geoscience Australia): Watercourses/2007; DNRM:, Roads/2010, Cadastre, River/2012; SMEC: As Constructed Levee Alignment; GHD: Concept Stage 2A & 2b levee and drain alignments, railway dam extension.

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Appendix H – Flood Mitigation Strategy

			2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	
REGIONAL													**SUM**
Description	**Amount**	**Incl. Misc + Contingency + Prelims**											
Levees													
SUBTOTAL			$ 1,466,414	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,466,414
Eastern Diversion Channel	1,554,786	2,281,709	$ 2,281,709										$ 2,281,709
Extended Eastern Diversion Channel	4,325,176	6,347,362.04	$ 380,842	$ 2,983,260	$ 2,983,260								$ 6,347,362
Western Diversion Drain	2,866,162	4,206,203							$ 1,402,068	$ 1,402,068	$ 1,402,068		$ 4,206,203
SUBTOTAL	9,745,359	14,301,688	$ 4,128,965	$ 2,983,260	$ 2,983,260	$ -	$ -	$ -	$ 1,402,068	$ 1,402,068	$ 1,402,068	$ -	$ 14,301,688
MAJOR LOCAL													
Long Drain Works						$ 3,020,319	$ 3,020,319	$ 3,020,319	$ 3,020,319				
Railway Dam widening	445,095	648,601								$ 648,601			$ 648,601
Mayne St / Station St drainage	5,706,000	8,314,887									$ 4,157,444	$ 4,157,444	$ 8,314,887
SUBTOTAL	14,441,737	21,044,762	$ -	$ -	$ -	$ 3,020,319	$ 3,020,319	$ 3,020,319	$ 3,020,319	$ 648,601	$ 4,157,444	$ 4,157,444	$ 21,044,762
MINOR LOCAL DRAINAGE													
Case 1		55,000		$ 55,000									$ 55,000
Case 3		330,000				$ 330,000							$ 330,000
Case 4		445,000					$ 445,000						$ 445,000
Case 5		2,480,000								$ 1,240,000	$ 1,240,000		$ 2,480,000
Case 7		1,490,000								$ 1,490,000			$ 1,490,000
Case 9		620,000						$ 620,000					$ 620,000
Case 10		28,000			$ 28,000								$ 28,000
Case 11		125,000									$ 125,000		$ 125,000
Case 12		3,520,000								$ 1,173,333	$ 1,173,333	$ 1,173,333	$ 3,520,000
Case 18		-											$ -
SUBTOTAL		9,093,000	$ -	$ 55,000	$ 28,000	$ 330,000	$ 445,000	$ 620,000	$ -	$ 3,903,333	$ 2,538,333	$ 1,173,333	$ 9,093,000
TOTAL			**$ 4,128,965**	**$ 3,038,260**	**$ 3,011,260**	**$ 3,350,319**	**$ 3,465,319**	**$ 3,640,319**	**$ 4,422,386**	**$ 5,954,001**	**$ 8,097,844**	**$ 5,330,777**	**$ 44,439,450**

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Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
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Rev 1	JP, AB	John Postlethwaite	[signature]	John Postlethwaite	[signature]	30/08/2016
Rev 2	JP, AB	John Postlethwaite		John Postlethwaite	[signature]	20/09/2016

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