Townsville

TOWNSVILLE CITY COUNCIL

GORDON CREEK FLOOD STUDY
BASELINE FLOODING ASSESSMENT

Volume 1
APRIL 2014

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Executive Summary

The *Gordon Creek Flood Study – Baseline Flooding Assessment* has been undertaken as part of Townsville City Council's City Wide Flood Constraints Project. This study builds on previous hydrologic and hydraulic analysis projects completed for Townsville City Council and incorporates the latest Light Detection and Ranging (LiDAR) topographic data as well as recent hydrographic survey to form up-to-date hydraulic flood model for the Gordon Creek and its catchment.

The study has developed a MIKE FLOOD coupled two-dimensional / one-dimensional hydraulic model for quantifying the flood risk in the Gordon Creek catchment area. The model has been calibrated to two representative historical events (i.e. January 1998 and February 2002) and verified with the previous flood modelling studies completed in the Gordon Creek area. The model represents in fine-scale resolution the topography and the drainage systems of the Gordon Creek catchment area, including:

- a digital elevation model resolved to a 10m grid;
- the larger components of the underground drainage network (greater than 900 mm diameter equivalent diameter);
- open drains narrower that the 10m grid resolution using one-dimensional branches; and
- application of rainfall directly on the model grid.

The calibrated and verified flood model has been used to assess design storm flood events for the 2, 5, 10, 20, 50, 100, 200 and 500 Year Average Recurrence Intervals (ARI) as well as the Probable Maximum Precipitation flood event. The 100 Year and 50 Year design storm events have been run for a range of storm durations in order to assess the critical duration event for all points of the floodplain.

The flood model results for the design storm events have been used to:

- quantify the floodplain hydraulic response with hydraulic grade lines and flow distributions;
- evaluate the potential impact on residential properties;
- identify flood hazard zones on the floodplain;
- inform flood overlay development for the new City Plan; and
- identify emergency management considerations.

The base-line flood maps for all the design flood events have been developed focussing on the area of interest. **Table E-1** provides a summary of the flooding results for the study area. Within the **Table E-1** indicative rainfall for the design events have been provided so that real events can easily be evaluated against the results of this study.

The impact of Highest Astronomical Tide (i.e. 2.25 m AHD) on flood levels has been assessed for 50 Year and 100 Year ARI events. For both the ARIs, the model results show increases in flood levels up to 0.01 m in the Fairfield Waters Lake system, the open drains within the study area, the localized flooding area in Oonoonba and the flood plains of Stuart Creek.

The impact of climate change on flooding by the year 2100 has been assessed considering 0.8 m sea level rise and 15% increase in rainfall intensities. The model results show that the flood levels increase up to 100 mm in the Fairfield Waters lake system in 100 Year ARI flood event.

Table E-1 Summary of Gordon Creek Flooding Results

Event	Indicative Rainfall	Properties Inundated	Major Evacuation Route Closures	Emergency Management Issues	Flooding Description
2 Y	63 mm in 1.5 hours 168 mm in 18 hours 189 mm in 24 hours 277 mm in 72 hours	**35**	• Bruce Highway- at the intersection with Jurekey Street • Abbott Street- near the intersection with Bruce Highway	Access road to Wulguru Community Centre and Wulguru State Primary School inundated.	Flooding is mostly contained to roads, drainage reserves, playground, lakes and flow paths with some inundation of lots particularly in Oonoonba, Wulguru, Cluden and Stuart. Significant number of residential lots (24) is inundated in Oonoonba.
5 Y	83 mm in 1.5 hours 226 mm in 18 hours 256 mm in 24 hours 393 mm in 72 hours	**43**	• Bruce Highway- at the intersection with Jurekey Street • Abbott Street- near the intersection with Bruce Highway	Access road to Wulguru Community Centre and Wulguru State Primary School inundated.	Flooding is mostly contained to roads, drainage reserves, playground, lakes and flow paths with some inundation of lots particularly in Oonoonba, Wulguru, Cluden and Stuart. Significant number of residential lots (31) is inundated in Oonoonba.
10 Y	95 mm in 1.5 hours 261 mm in 18 hours 298 mm in 24 hours 467 mm in 72 hours	**56**	• Racecourse Road- in between Stuart Drive and Lakeside Drive • Bruce Highway- at the intersection with Jurekey Street • Abbott Street- near the intersection with Bruce Highway • Bruce Highway- near Stuart Creek Bride • Stuart Bypass connecting Stuart Drive and Bruce Highway	Access road to Wulguru Community Centre and Wulguru State Primary School inundated.	Flooding is mostly contained to roads, drainage reserves, playground, lakes and flow paths with some inundation of lots particularly in Oonoonba, Wulguru, Cluden and Stuart. Significant number of residential lots (36) is inundated in Oonoonba.
20 Y	111 mm in 1.5 hours 307 mm in 18 hours 351 mm in 24 hours 561 mm in 72 hours	**74**	• Racecourse Road- in between Stuart Drive and Lakeside Drive • Bruce Highway- at the intersection with Jurekey Street • Abbott Street- near the intersection with Bruce Highway • Bruce Highway- near Stuart Creek Bridge • Stuart Bypass- near the intersection with Burdell Street	Edison Street, an access road from Major Evacuation Route to Wulguru Community Centre and Wulguru State Primary School, remains closed.	Flooding is mostly contained to roads, drainage reserves, playground, lakes and flow paths with some inundation of lots particularly in Oonoonba, Wulguru, Cluden, Stuart and Annandale. Significant number of residential lots (48) is inundated in Oonoonba.

Table E-1 Summary of Gordon Creek Flooding Results (continued)

Event	Indicative Rainfall	Properties Inundated	Major Evacuation Route Closures	Emergency Management Issues	Flooding Description
50 Y	111mm in 1 hour 132mm in 1.5 hour 148mm in 2 hours 174mm in 3 hours 229mm in 6 hours 301mm in 12 hours 368mm in 18 hours 424mm in 24 hours 692mm in 72 hours	**114**	• Racecourse Road- in between Stuart Drive and Lakeside Drive • Bruce Highway- at the intersection with Jurekey Street • Abbott Street- near the intersection with Bruce Highway • Bruce Highway- near Stuart Creek Bride • Stuart Bypass- near Burdell Street intersection • Stuart Drive- in between Edison Street and Marconi Street • Stuart Drive- in between Racecourse Road and Gartrell Drive	Edison Street, an access road from Major Evacuation Route to Wulguru Community Centre and Wulguru State Primary School, remains closed.	Flooding is mostly contained to roads, drainage reserves, playground, lakes and flow paths with some inundation of lots particularly in Oonoonba, Wulguru, Cluden, Stuart and Annandale. Significant number of residential lots (57) is inundated in Oonoonba.
100 Y	125mm in 1 hour 148mm in 1.5 hour 166mm in 2 hours 195mm in 3 hours 257mm in 6 hours 338mm in 12 hours 416mm in 18 hours 481mm in 24 hours 796mm in 72 hours	**142**	• Racecourse Road- in between Stuart Drive and Lakeside Drive • Bruce Highway- at the intersection with Jurekey Street • Abbott Street- near the intersection with Bruce Highway • Bruce Highway- near Stuart Creek Bride • Stuart Bypass- near the intersection with Burdell Street • Stuart Drive- in between Edison Street and Marconi Street • Stuart Drive- in between Racecourse Road and Gartrell Drive • University Road- near the intersection with Stuart Drive	Edison Street, an access road from Major Evacuation Route to Wulguru Community Centre and Wulguru State Primary School, remains closed.	Flooding is mostly contained to roads, drainage reserves, playground, lakes and flow paths with some inundation of lots particularly in Oonoonba, Wulguru, Cluden, Stuart and Annandale. Significant number of residential lots (64) is inundated in Oonoonba.

Table E-1 Summary of Gordon Creek Flooding Results (continued)

Event	Indicative Rainfall	Properties Inundated	Major Evacuation Route Closures	Emergency Management Issues	Flooding Description
200 Y	165 mm in 1.5 hours 466 mm in 18 hours 540 mm in 24 hours 905 mm in 72 hours	**179**	• Racecourse Road- in between Stuart Drive and Lakeside Drive • Bruce Highway- at Jurekey Street Intersection and near Stuart Creek Bridge • Abbott Street- near the intersection with Bruce Highway • Stuart Bypass- near the intersection with Burdell Street • Stuart Drive- near Edison Street, Racecourse Road and Wulguru-Stuart drain culvert. • University Road- near the intersection with Stuart Drive	Edison Street, an access road from Major Evacuation Route to Wulguru Community Centre and Wulguru State Primary School, remains closed.	Flooding is mostly contained to roads, drainage reserves, playground, lakes and flow paths with some inundation of lots particularly in Oonoonba, Wulguru, Cluden, Stuart and Annandale. Significant number of residential lots (79) is inundated in Oonoonba.
500 Y	187 mm in 1.5 hours 534 mm in 18 hours 621 mm in 24 hours 1058 mm in 72 hours	**604**	• Racecourse Road- in between Stuart Drive and Lakeside Drive • Bruce Highway- at Jurekey Street Intersection and near Stuart Creek Bridge • Abbott Street- near the intersection with Bruce Highway • Stuart Bypass- near the intersection with Burdell Street • Stuart Drive- near Edison Street, Racecourse Road and Wulguru-Stuart drain culvert. • University Road- near the intersection with Stuart Drive	Edison Street, an access road from Major Evacuation Route to Wulguru Community Centre and Wulguru State Primary School, remains closed.	Flooding is mostly contained to roads, drainage reserves, playground, lakes and flow paths with some inundation of lots particularly in Oonoonba, Wulguru, Cluden, Stuart and Annandale. Significant number of residential lots (358) is inundated in Idalia.

Table E-1 Summary of Gordon Creek Flooding Results (continued)

Event	Indicative Rainfall	Properties Inundated	Major Evacuation Route Closures	Emergency Management Issues	Flooding Description
PMF	330 ~ 394 mm in 1.5 hours 1315 mm in 18 hours 1490 mm in 24 hours 2520 mm in 72 hours	**1759**	• Racecourse Road- in between Stuart Drive and Lakeside Drive • Bruce Highway- at the intersection with Jurekey Street • Bruce Highway- near Stuart Creek Bride • Abbott Street- near the intersection with Bruce Highway • Stuart Drive- in between Edison Street and Marconi Street • Stuart Drive- in between Racecourse Road and Gartrell Drive • Stuart Drive- at the culvert on Wulguru-Stuart Drain • University Road- near the intersection with Stuart Drive • Stuart Bypass- near the intersection with Burdell Street	• Edison Street, an access road from Major Evacuation Route to Wulguru Community Centre and Wulguru State Primary School, remains closed; and • Access road of Wulguru Community Centre from Edison Street remains closed.	Significant widespread flooding with most flows running towards the Gordon Creek. Few areas of Annandale, Murray and Wulguru remain flood free. Isolated flood islands in • Cluden; • Idalia; and • Oonoonba.

Glossary

1D	One-Dimensional
2D	Two-Dimensional
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
AR&R	Australian Rainfall and Runoff
AVM	Average Variability Method
BoM	Bureau of Meteorology
DEM	Digital Elevation Model
DERM	Department of Environment and Resource Management
DFE	Defined Flood Event
GTSMR	Generalised Tropical Storm Method Revised – Methodology for estimating the PMP
HAT	Highest Astronomical Tide – The highest level of water which can be predicted to occur under any combination of astronomical conditions.
Hydraulic model	A model used for assessing flood levels and velocities from inflows and topography
Hydrologic model	A model used for assessing catchment outflows from rainfall and catchment conditions
IFD	Intensity–Frequency-Duration
LiDAR	Light Detection and Ranging (Aerial Laser Survey)
LGAQ	Local Government Association of Queensland
MHWS	Mean High Water Springs – the average height of the high waters of spring tides
MIKE11	Fully dynamic 1D hydraulic model
MIKE21	Fully dynamic 2D hydraulic model
MIKE FLOOD	Coupled 2D/1D hydraulic model combining MIKE11 and MIKE21
Pluviometer	Automated sampling device for measuring rainfall variability in short

	time periods
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
QUDM	Queensland Urban Drainage Manual
TFHAS	Townsville Flood Hazard Assessment Study (Maunsell, 2005)
XP-RAFTS	An urban and rural runoff-routing hydrologic model

1.0 Introduction

1.1 Overview

The *Gordon Creek Flood Study – Baseline Flooding Assessment* has been undertaken as part of Townsville City Council's City Wide Flood Constraints Project. The project seeks to develop up to date flood models for the city of Townsville at scales suitable for:

- defining flood levels for most urban properties;
- identifying the flood hazard overlay for the planning scheme;
- evaluating future flood mitigation projects; and
- assisting the disaster management process.

This study builds on previous hydrologic and hydraulic analysis projects completed for Townsville City Council and incorporates the latest Light Detection and Ranging (LiDAR) topographic data as well as recent hydrographic survey to form up to date hydraulic flood model for Gordon Creek floodplain.

1.2 Study Area

Gordon Creek and its catchment are the study area. Gordon Creek, a tributary of the Ross River, is located at the south-east of Townsville and drains a catchment area of about 19 square km. Average width of the Gordon Creek towards the confluence with Ross River is about 25 m and length is about 4 km. The suburbs within the catchment of Gordon Creek are:

- Idalia;
- Wulguru;
- Oonoonba (part of);
- Cluden (part of);
- Murray (Eastern part);
- Annandale (Eastern part); and
- Stuart (part of).

All of the catchment is urbanised except parts of Stuart and Cluden. The study area showing important features is presented in **Figure 1-1**.

Fairfield Waters lake system in Idalia

The Fairfield Waters lake system in Idalia is one of the important features of the Gordon Creek and it consists of a series of three lakes designated as Lake 1, Lake 2 and Lake 3. The water of the lake system are sourced from the tidal reaches of the Ross River through a permanent pump station located on the banks of the Ross River, waters from the river are directed into Lake 1 from where a transfer pipeline and open drain conveys flows into Lake 2 and through to Lake 3 which is co-joined under

Lakeland Boulevard. The lake system is designed so that flows through the lake system will recirculate back to the tidal reaches of the Ross River system, via a pump station.

The catchment of the lakes system is approximately 950 ha and extends west to the suburb of Annandale and south to Mount Stuart. Runoff from the catchment is directed into the lake system which provides flood immunity for developed properties both within Fairfield Waters and externally to the larger region.

Rainfall

The Townsville area has a tropical climate but, due to its geographical location, rainfall is not as high as the wet tropics area. The average annual rainfall is 1,143 mm on an average 91 rain days, most of which falls in the six month "wet season" November to April.

On the night of 10 January 1998 Ex Tropical Cyclone Sid dumped 549 mm of rain, the highest 24 hour recording at Townsville Airport. Unofficial figures from some suburbs were over 700mm. The year 2000 was the wettest year on record, with 2400mm of rain. This was followed by second driest year in 2001 with 467mm of rain (driest year was 1969 - 464mm).

1.3 Scope of Works

The scope of works for this *Baseline Flooding Assessment* includes:

- review of previous engineering reports and data;
- compilation and analysis of relevant data including rainfall, stream gauging, construction drawings, topographic survey and hydrographic survey;
- identification of data gaps and collection of data through survey;
- identification of a suitable approach for hydrologic and hydraulic modelling;
- development and calibration of Gordon Creek hydraulic model; and
- review and detailing the base-line flooding determined for the study area.

GORDON CREEK FLOOD STUDY
Study Area

Figure 1-1

LEGEND

- Suburbs
- Waterway or Waterbody
- Model Domain

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350 175 0 350 700 1,050 Metres

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1.4 Study Approach

This study is mainly based on the existing data, the numerous past studies carried out under Townsville City Council (TCC) and a small scale survey data.

Several hydrologic models, developed under Ross Creek Flood Study, have been used to represent the flows from the catchments draining into the study area in combination with a "Rain on Grid" approach to represent a majority of the local rain within the bounds of the hydraulic model. Details of the development of XP-RAFTS model can be found in Ross Creek Flood Study (TCC 2013). The catchments that were represented through XP-RAFTS hydrological models for this study are:

- Douglas & Annandale;
- Gordon Creek; and
- Stuart Creek;

The Gordon Creek hydraulic model is a three-way coupled MIKE FLOOD model representing two-dimensional floodplain topography, one-dimensional flow paths and structures and trunk underground drainage.

Results of the model are intended to be used for floodplain planning and evaluation of flood mitigation works for future investigations.

The report has been prepared in two volumes:

- Volume 1 (this Volume) – provides the majority of the report including methodology and discussion of results; and
- Volume 2 – provides the flood map results from the study.

2.0 Available Data

2.1 Historical Rainfall and Water Level

All the historical rainfall records related to January 1998 and February 2002 hydrological events have been retrieved from the database of Townsville City Council (TCC) and applied for model calibration.

There are a range of gauges within and around the study area which includes daily rainfall gauges, meteorological pluviometers and flood alert pluviometers. **Figure 2-1** shows the map of rainfall and water level gauges. The nearby meteorological pluviometer is provided in **Table 2-1**.

Table 2-1 Rainfall data

Station Number	Location	Start of Record	End of Record
032040	Townsville Aero	3/03/1953	31/12/2009

This pluviometer has been used to generate rainfall data at Oonoonba, Mundingburra and Serene Valley gauge stations based on daily average rainfall data for January 1998 calibration. Rainfall and water level data retrieved from TARDIS (Torrent and Rainfall Distribution Imaging System) of TCC have been used for February 2002 calibration. The retrieved TARDIS data is presented in **Table 2-2**:

Table 2-2 TARDIS data

Station Number	Location	Data Type	Start of Record	End of Record
532029	Aplin Weir	Rainfall time series	13/2/2002	16/2/2002
532037	Mysterton	Rainfall time series	13/2/2002	16/2/2002
532035	Stuart Creek	Rainfall & Water Level time series	13/2/2002	16/2/2002
532036	Stuart	Rainfall time series	13/2/2002	16/2/2002

2.2 Topographic and Bathymetric Data

An accurate representation of topography and bathymetry is a key to any hydrologic/ hydraulic investigation. In this study, topographic and bathymetric data have been collected from different sources to ensure appropriate representation of topography and bathymetry of the study area. The main datasets and sources are:

Topographic data

- Townsville City Council LiDAR obtained from a joint government agency project, with capture around September/October 2009;
- Eastern Access Corridor – source: Department of Transport and Main Roads (DTMR);
- Highways, roads and streets- source: TCC database; and
- Bruce Highway, Racecourse Road and part of Stuart Drive and University Road– source: DTMR.

Bathymetric Data

- Ross River- obtained from Townsville Flood Hazard Assessment Study (Maunsell 2005);
- Gordon Creek and Stuart Creek cross-sections- obtained from MIKE 11 model setup of Townsville Flood Hazard Assessment Study;
- Upstream and downstream of the dual culverts (i.e. which are facilitating drainage flow between Fairfield Waters Lakes and Cluden area underneath Railway line and Abbott Street) at Fairfield Waters and Cluden - surveyed under present study;
- Fairfield Waters drain survey data (March 2011)- survey done for Fairfield Constructions Pty Ltd; and
- Fairfield lake system- data obtained from past study (Cardno 2012);

Figure 2-2 shows the extent of the topographic and bathymetric datasets.

2.3 Surveyed Historical Flood Levels

The largest flood event in recent history for the Gordon Creek catchment was the January 1998 flood event. The debris marks and peak flood levels of this event was surveyed by Townsville City Council. This is the only flood event with a significant surveyed dataset held by Council. These surveyed flood levels have been used to calibrate the hydraulic model for this study.

Figure 2-3 shows the surveyed flood levels from the January 1998 event.

GORDON CREEK FLOOD STUDY
Gauging Stations

Figure 2-1

LEGEND

- Rain Alerts
- Level Alerts
- ModelDomain
- Rain on Grid Extent

SCALE: 1:30,000 @A3

350 175 0 350 700 1,050 Metres

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GORDON CREEK FLOOD STUDY Data

Figure 2-2

LEGEND

Bruce Highway

Eastern Access Corridor

Streets

Survey Data

Existing Data

Ross River

LiDAR

N

SCALE: 1:30,000 @A3

350 175 0 350 700 1,050 Metres

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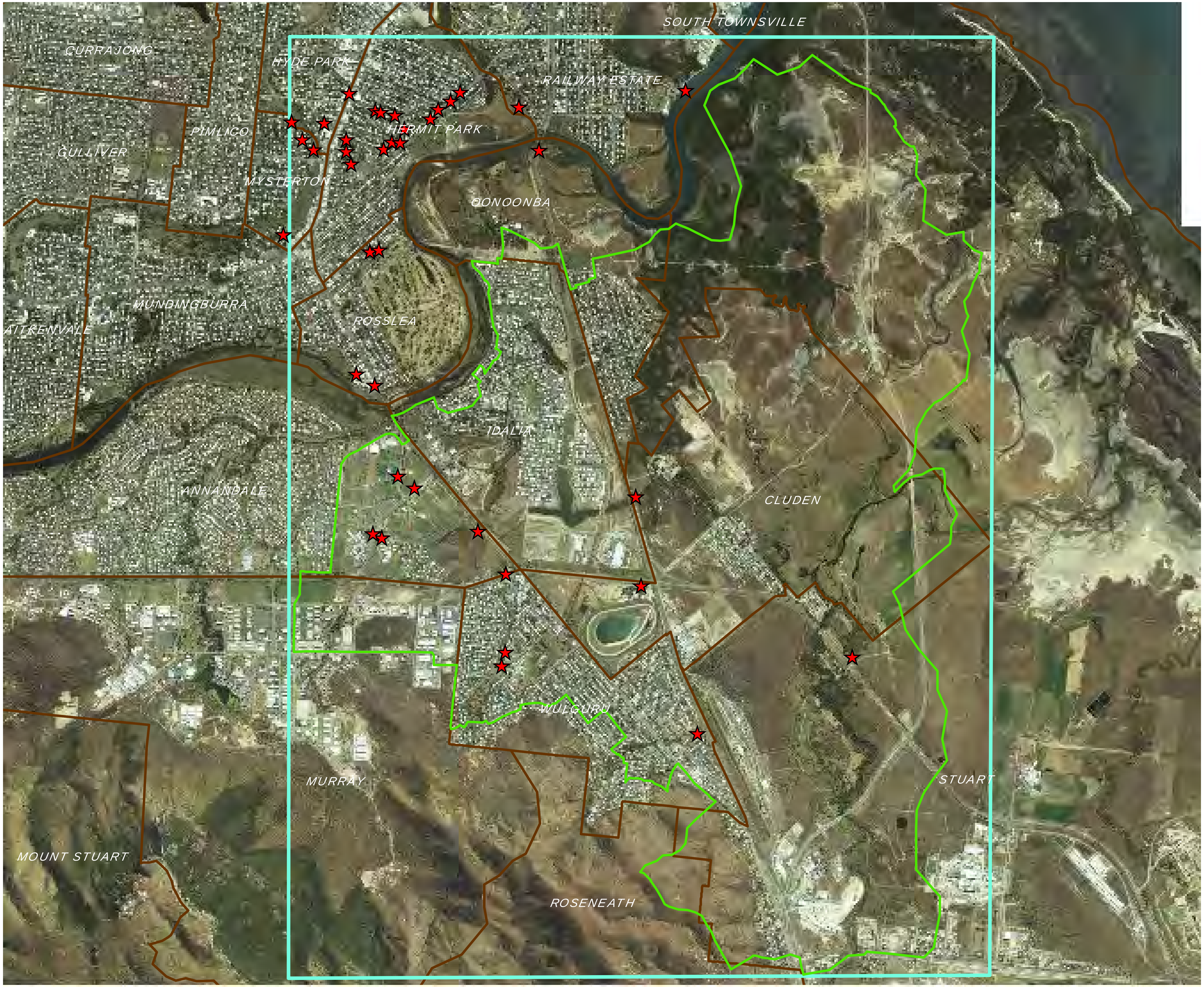
GORDON CREEK FLOOD STUDY
JAN 1998 SURVEY

Figure 2-3



LEGEND

- 1998 Flood Levels
- ModelDomain
- Rain on Grid Extent
- Suburbs

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City of Townsville

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2.4 Cadastral Data

Cadastral data from the study areas has been used for evaluating catchment and floodplain parameters as part of the hydrological and hydraulic modelling.

2.5 Structure Design Drawings

Drawings have been sourced for the bridge and culvert structures within the Study Area, to provide details for the hydraulic modelling. Where there was no design drawings, field survey was carried out to determine the geometrical parameters for the bridges and culverts.

2.6 Aerial Photography

Townsville City Council's aerial photography captured in 2011 has been used to assign the fraction impervious and the hydraulic roughness within model domain.

2.7 Previous Flooding Reports

Ross Creek Flood Study – Base Line Flooding Assessment (TCC, May 2013)
Ross Creek Flood Study– Base Line Flooding Assessment completed in 2013 as a component of TCC under City Wide Flood Constraints Project. That study developed a detailed flood model for quantifying the flood risk on portions of the Townsville Floodplain that drains to Ross Creek.

The study developed MIKE FLOOD coupled two-dimensional/one-dimensional hydraulic model in a 10 m grid resolution based on recent data.

As the Gordon Creek model overlaps the Ross Creek hydraulic model on the Ross River, the extracted flows and water levels from the Ross Creek model results have been used in present study.

Fairfield Estate- Racecourse Road Drainage (CARDNO, Sept 2010)

Cardno carried out a modelling investigation for the Fairfield Waters area in September 2010 for Fairfield Construction Pty Ltd based on existing two-dimensional hydraulic model developed by Maunsell AECOM. It has also reviewed the previous flood study done by Maunsell AECOM under Southern Access Corridor Planning Study, Stuart Creek and Gordon Creek (May 2009) for DTMR.

The investigation determined channel widths required to convey 50 Year ARI peak flow entering Fairfield Waters through Racecourse road.

Cardno updated the hydraulic model setup developed by Maunsell AECOM with additional survey data of the Fairfield Waters Estate and the lakes, a number of culverts along the Bruce Highway between Lakeside Drive and Stuart Creek and the

Lake 3 outlets and downstream channel which connected to the culverts underneath Abbotts street. The grid size resolution of updated model was reduced to 5 meter at Fairfield Waters area through nesting.

The Maunsell AECOM study indicates that a flow of 47m3/s crosses the Bruce Highway immediately to the west of the North Coast Railway and is conveyed through the south-eastern portion of the Fairfield Waters development for the 50 Year development. Cardno found that the flow assessed by Maunsell AECOM was high as it considered the filling of the Pony Club. According to Cardno, the maximum flow rate that is applicable to the design for a channel across the south-eastern corner of the site is 25m3/s.

After investigation, Cardon recommended a 10 meter wide concrete channel (with vertical sides) to convey 50 Year peak flow. In conjunction with the construction of channel, a levee was recommended between Racecourse Road and Fairfield Waters to allow flow in Gordon Creek to be directed to Lake 3.

Oonoonba Flood and Stormwater Management Study (AECOM, 2010)

AECOM carried out a flood study in connection with the development work in Oonoonba in 2010 for Urban Land Development Authority (ULDA).

The study used existing hydraulic model developed based on MIKE FLOOD under Townsville Flood Hazard Assessment Study (2005) for floodplain modelling. The hydraulic model was run for a range of ARI flood events with MHWS level as tail water condition. Sub-catchment inflow hydrographs were determined from the XP-RAFTS hydrologic modelling and applied as source points and boundary inflows in the hydraulic model.

The flood study determined preliminary baseline flood levels at and around the site, evaluated the impact of development work on flood levels for 100 Year ARI flood event and provided recommendations for flood mitigation works.

Southern Access Corridor Planning Study, Stuart Creek and Gordon Creek (Maunsell AECOM, May 2009)

Maunsell AECOM engaged by QDMR and TCC carried out a flooding assessment of Stuart Creek and Gordon Creek in conjunction with the Southern Access Corridor (SAC) Planning Study to determine the impacts of Stuart Creek crossing options and drainage along the SAC alignment.

An existing MIKE FLOOD hydraulic model developed and refined under past studies was applied for flood modelling. The sources of topographic data were photogrammetry, site examination and topographic description about the final design of Fairfield Waters development area. In topography all fill areas defined and set to 4 m AHD in the Fairfield Waters.

The study considered the hydraulic structures/culverts within Fairfield Waters and on highways but not within the other suburbs. In that study, only sub-catchments of Gordon Creek and Stuart Creek were considered for hydrologic modelling using XP-

RAFTS. The critical storm duration for Stuart Creek and Gordon Creek was found to be 3 hours and it was considered for design runs.

Study findings relevant to the present study are presented below:

- Stuart Creek Bridge, with the existing deck level at 6.9 m AHD has an estimated flood immunity of less than 20 Year ARI. The bridge is completely submerged in 100 Year ARI flood event;
- Bruce Highway section adjacent to Stuart Creek Bridge overtops in all flood events equal to or greater than 10 Year ARI; and
- Overflow from the Stuart Creek floodplain to Gordon Creek catchment occurs in the storms larger than 10 Year ARI.

The study proposed drainage works for the flow containment option, which will prevent Stuart Creek flows from surcharging into Gordon Creek through the Racecourse Road area.

Townsville Flood Hazard Assessment Study (2005)

Townsville City Council commissioned Maunsell to undertake the *Townsville Flood Hazard Assessment Study* as part of the Natural Disaster Risk Management Studies Program. The Study was completed in 2005 and involved 3 phases:

- Phase 1 – Data Acquisition;
- Phase 2 – Flood Hazard Assessment; and
- Phase 3 – Vulnerability Assessment and Risk Analysis.

The flood modelling was completed for Phase 2 of the report. The study covers the Gordon Creek and its catchment. The runoff/ routing model XP-RAFTS was used to simulate the hydrological response of the local catchments of Townsville.

The hydraulic assessment developed a MIKE11 model for flood events up to the 20 Year ARI, while a MIKE21 model was developed for the flood events greater than and including the 50 Year ARI. To simplify the computational requirements of the project, only the 2 hour and 6 hour storm durations were assessed.

In the present study, the Ross River bathymetry and the hydraulic structure data acquired for *Townsville Flood Hazard Assessment Study (2005)* have been used in the development of hydraulic model.

3.0 Hydrological Assessment

3.1 Catchment Overview

The north-eastern slopes of Mount Stuart drain the stormwater runoff to the Ross River through Gordon Creek. The catchment of the Gordon Creek includes following suburbs:

- Idalia;
- Wulguru;
- Oonoonba (part of);
- Cluden (part of);
- Murray (eastern part);
- Annandale (eastern part);
- Stuart (part of); and
- Roseneath (part of).

Most of the catchment is urbanised except parts of Stuart and Cluden as well as parts of Mount Stuart. The urbanised area includes residential areas, commercial areas and the Murray sporting complex. The total area of the Gordon Creek catchment is approximately 19 km^2.

3.2 Hydrological Modelling Software

XP-RAFTS

The hydrologic modelling software XP-RAFTS calculates catchment flows from rainfall based on Laurenson's non-linear routing method. The model is able to predict flows for catchments containing both urban and rural land uses accounting for surface roughness, catchment slope, soil infiltration and depression storage losses. It is well suited to the study area due to the need for detailed sub-catchment definition and representation of both rural and urban areas combined.

The study area is influenced by two other adjacent catchments: Annandale & Douglas and Stuart Creek. The XP-RAFTS models for the sub-catchments of Stuart Creek and Annandale & Douglas are described in their respective Base-line Flood Study Reports (*Ross River Flood Study 2013 & Ross Creek Flood Study 2013*).

Rain on Grid Approach

The rain on grid approach involves directly applying rainfall excess to the two-dimensional grid of the MIKE-FLOOD model. Rainfall excess is the rainfall less initial and continuing losses associated with surface depression storage and infiltration.

3.3 Catchment Delineation and Sub-Catchment Parameters

The Gordon Creek catchment was divided into 199 sub-catchments. The catchment delineation was done based on the 2009 LiDAR, the aerial photograph, the stormwater infrastructure GIS layers and the cadastral boundaries. **Figure 3-1** shows an overview of the sub-catchments delineation of Gordon Creek adopted for this study.

The sub-catchment parameters of the Gordon Creek hydrological model were determined from topographic data, aerial photography, cadastral and site information. The adopted sub-catchment parameters are given in **Table A1** in **Appendix A**.

3.4 Design Rainfall

Design rainfall for the Gordon Creek catchment was developed from the Intensity Frequency Duration (IFD) methods outlined in Australian Rainfall and Runoff (1998) using catchment specific IFD input parameters. The IFD input parameters adopted are provided in **Table 3-1**. The resulting IFD rainfall intensities for Gordon Creek are provided in **Table 3-2**.

Table 3-1 Gordon Creek IFD Input Data

Parameter	**Value**
Latitude	19.3171 Deg S
Longitude	146.8227 Deg E
2 Year, 1 Hour Intensity	53.82 mm/h
2 Year, 12 Hour Intensity	11.92 mm/h
2 Year, 72 Hour Intensity	3.87 mm/h
50 Year, 1 Hour Intensity	110.12 mm/h
50 Year, 12 Hour Intensity	24.8 mm/h
50 Year, 72 Hour Intensity	9.48 mm/h
Skewness (G)	0.05
Geographical Factor (F2)	3.93
Geographical Factor (F50)	17.08

Table 3-2 Gordon Creek IFD Rainfall Data

Storm Duration	**Rainfall Intensity (mm/h) for Given ARI**								
	1Y	**2Y**	**5Y**	**10Y**	**20Y**	**50Y**	**100Y**	**200Y**	**500Y**
5 min	115.47	149.70	195.51	222.87	258.76	306.49	343.23	381.04	432.56
6 min	109.14	141.51	184.87	210.78	244.75	289.94	324.73	360.53	409.33
10 min	91.54	118.73	155.26	177.10	205.74	243.84	273.19	303.40	344.58
15 min	78.22	101.49	132.83	151.59	176.16	208.87	234.08	260.03	295.42
20 min	69.33	89.98	117.84	134.53	156.38	185.48	207.91	231.00	262.51
30 min	57.81	75.05	98.39	112.38	130.69	155.09	173.90	193.28	219.72
45 min	47.64	61.87	81.19	92.79	107.96	128.18	143.78	159.85	181.79
1 hour	41.28	53.64	70.44	80.54	93.74	111.34	124.92	138.91	158.02
1.5 hour	32.48	42.21	55.50	63.49	73.93	87.85	98.61	109.69	124.83
2 hour	27.30	35.49	46.69	53.44	62.25	74.01	83.08	92.45	105.24
3 hour	21.31	27.71	36.51	41.80	48.72	57.95	65.09	72.45	82.51
4.5 hour	16.61	21.62	28.51	32.66	38.09	45.33	50.93	56.71	64.61
6 hour	13.93	18.13	23.92	27.42	31.99	38.09	42.80	47.67	54.33
9 hour	10.87	14.15	18.70	21.45	25.03	29.82	33.53	37.35	42.59
12 hour	9.12	11.88	15.71	18.03	21.04	25.08	28.20	31.43	35.85
18 hour	7.14	9.35	12.54	14.50	17.04	20.45	23.11	25.87	29.66
24 hour	5.99	7.87	10.67	12.41	14.64	17.66	20.03	22.49	25.88
30 hour	5.21	6.87	9.39	10.96	12.99	15.73	17.88	20.13	23.24

36 hour	4.64	6.14	8.44	9.89	11.75	14.28	16.27	18.36	21.24
48 hour	3.84	5.10	7.09	8.36	9.98	12.19	13.95	15.79	18.35
72 hour	2.89	3.85	5.45	6.48	7.80	9.61	11.05	12.57	14.70

Probable Maximum Precipitation
Estimates of the Probable Maximum Precipitation (PMP) have been made for a range of storm durations. The Generalised Short Duration Method (GSDM) has been used for storm events up to 6 hours, while the Generalised Tropical Storm Method - Revised (GTSMR) has been used for storm events longer than 24 hours.

3.5 Rainfall Loss Values

Rainfall loss values for the design events were assigned based on results of the calibration with the hydraulic model. A summary of the loss values determined from the calibration events for the Gordon Creek model is presented in **Table 3-3**.

Table 3-3 GordonCreek Calibration Event Rainfall Losses

Event	Surface Type	Initial Loss	Continuing Loss
January 1998	Pervious	25 mm	2.5 mm/h
	Impervious	1 mm	0 mm/h
February 2002	Pervious	60 mm	3 mm/h
	Impervious	1 mm	0 mm/h

The February 2002 rainfall event followed an extended period without rain, as noted within the Townsville Flood Hazard Assessment Study. The losses considered for February 2002 reflect the dry antecedent conditions of the catchment.

On the basis of these results the following rainfall losses were adopted for design events:

- Impervious – 1 mm IL and 0 mm CL;
- Pervious – 25 mm IL and 2.5 mm CL.

GORDON CREEK FLOOD STUDY
Catchment Overview

Figure 3-1

LEGEND

- Model Domain
- GordonCk
- Douglas
- StuartCk
- SandflyCk
- Rain on Grid Extent

City of Townsville

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350 175 0 350 700 1,050 Metres

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3.6 Hydrologic Results

Although the Gordon Creek catchment hydrology was represented through the Rain on Grid approach in MIKE FLOOD model, the local/ total sub-catchment flows near the Gordon Creek catchment boundaries were generated using XP-RAFTS model and incorporated in the MIKE FLOOD model as sources. The results of the hydrologic models at those sources are presented below:

Table 3-4 Gordon Creek XP-RAFTS Design Flood Flows

Location	Sub-catchment ID	Peak Flood Flows (m^3/s)								
		2Y	**5Y**	**10Y**	**20Y**	**50Y**	**100Y**	**200Y**	**500Y**	**PMF**
Annandale	A1-1.00	39.6	59.8	74.1	99.9	135.8	165.0	201.8	248.8	1067.7
Murray	GC-16.00	16.1	27.7	35.0	45.7	58.66	69.18	79.14	96.63	320.02
Murray	LB-1.12	2.6	4.4	5.9	7.7	9.4	11.2	12.8	15.2	46.5
Murray	LW2-1.51	2.1	3.6	4.6	6.2	7.5	8.9	10.2	12.0	35.2
Wulguru	RY-2.41.01	0.5	0.8	1.0	1.4	1.6	1.8	2.1	2.4	6.0
Wulguru	RY-2.51	0.7	1.3	1.7	2.2	2.5	2.9	3.3	3.8	10.9
Wulguru	RY-3.04	0.5	1.0	1.2	1.6	1.8	2.1	2.3	2.7	7.6
Wulguru	RY-3.04.01	0.8	1.3	1.5	1.8	2.1	2.4	2.7	3.1	7.1
Wulguru	RY-7.00	0.7	1.3	1.6	2.1	2.3	2.7	3.0	3.5	8.6
Wulguru	W1-3.05	0.7	1.3	1.7	2.2	2.5	2.8	3.2	3.9	10.9
Wulguru	W1-5.02	1.3	1.8	2.2	2.7	3.1	3.5	4.0	4.6	10.3
Wulguru	W1-7.00	0.8	1.2	1.4	1.7	2.0	2.3	2.5	2.9	6.6
Wulguru	W1-8.00	0.7	1.1	1.5	1.9	2.2	2.5	2.9	3.3	8.1
Wulguru	W2-2.03	0.4	0.8	0.9	1.2	1.4	1.7	1.9	2.3	5.9
Wulguru	W2-2.04	0.25	0.42	0.52	0.63	0.69	0.79	0.88	1.01	2.3
Wulguru	W2-5.00	1.7	2.6	3.3	4.0	4.6	5.3	5.9	6.8	16.0
Stuart	St-8.01	1.2	2.6	3.5	4.8	6.6	7.9	9.7	11.9	33.7
Stuart	St-9.00	203 (24h)	341 (24h)	441 (24h)	556 (24h)	643 (24h)	782 (24h)	900 (24h)	1063 (24h)	1545 (24h)

4.0 Hydraulic Assessment

4.1 Floodplain Overview

The Gordon Creek floodplain is predominately urbanized with some rural areas. The urbanized areas are mainly Oonoonba, Idalia, Wulguru, Murray and Annandale. Over the past few years development has taken place in Idalia especially in Fairfield Waters. This area has a lake system which includes three lakes and wetlands. The catchment of the lakes system is approximately 950 ha and extends west to the suburb of Annandale and south to Mount Stuart. Runoff from the catchment is directed into the lake system which provides flood immunity for developed properties both within Fairfield Waters and the surrounding areas.

The Gordon Creek floodplain is crossed by important highways: Abbott Street and Bruce Highway, Racecourse Road and Stuart Drive (Flinders Highway). These roads have influence on stormwater runoff in the floodplain. The major surface flow paths that are dedicated to stormwater conveyance are:

- Annandale Drains;
- Annandale Table Drains
- Murray Drains;
- Wulguru Drains;
- Fairfield Drains; and
- Gordon Creek.

4.2 MIKE FLOOD

MIKE FLOOD is a dynamically linked 3-way hydraulic modelling package, which couples the 1D river hydraulics model, MIKE11 and the 1D sub-surface drainage model, MIKE URBAN with the 2D surface water model, MIKE21. MIKE FLOOD can be used to simulate:

- coincident river and storm surge flooding in coastal areas;
- the detailed flooding patterns on floodplains in terms of flow velocities and water levels;
- water exchange between channels, canals, sub-surface drainage and adjacent floodplains, ponds, reservoirs, etc; and
- flood waves in channels and on flood plains associated with a dam failure.

The MIKE21 2D component of the MIKE FLOOD model has been used to adequately represent the complex two dimensional hydraulics of the Gordon Creek floodplain. The MIKE11 1D component of the MIKE FLOOD model was required to provide a more accurate representation of the hydraulics of structures (such as culverts and bridges) and narrow open channels. The MIKE URBAN 1D component of the MIKE FLOOD model was required to represent sub-surface drainage that has the potential to impact on flood levels. Sub-surface drainage generally larger than or equal to the equivalent waterway area of 900 mm diameter pipe were considered to have the potential to impact on flood levels.

4.3 Model Setup

Topographic Grid

The MIKE FLOOD model developed for the Gordon Creek is based on 10 m topographic grid covering an area of 48.44 km^2 (6.01 km X 8.06 km). The model set-up is shown in **Figure 4-1**. The topographic grid for the Gordon Creek flood plain is based on the LiDAR obtained in 2009 and it has been updated with the crest level of highways, roads and streets.

The bathymetry of the Ross River, Gordon Creek and Stuart Creek is based on underwater survey (i.e. bathymetric/ cross-section) data obtained as part of the *Townsville Flood Hazard Assessment Study*. The bathymetry of Fairfield Waters Lakes and drains updated based on past study report and existing data respectively. In this study a small scale bathymetric survey was carried out at Fairfield Waters and Cluden areas immediately upstream and downstream of the dual culverts, which are facilitating the drainage of Fairfield Waters to Cluden through Railway line and Abbott Street.

Boundary Conditions

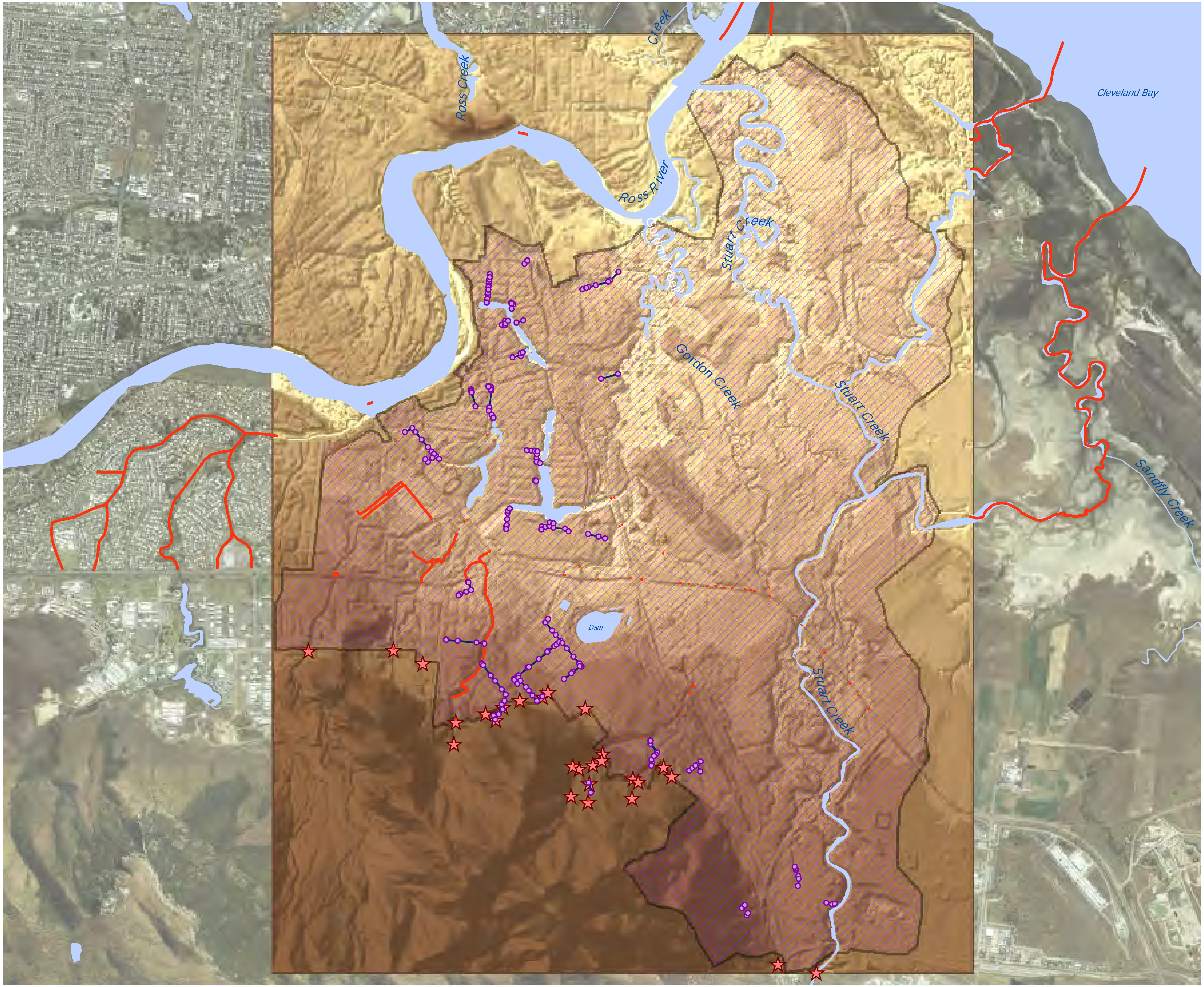
In this model two upstream boundaries have been assigned as inflows; one at the Ross River and another one at the Stuart Creek. The Ross River and the Stuart Creek boundaries for different ARIs have been obtained from the Ross Creek model and the hydrological model respectively.

The base-line flooding assessment of design flood events has used downstream water levels set to a fixed level of the Mean High Water Springs (MHWS) tide. A sensitivity assessment has also evaluated the impact of increase to Highest Astronomical Tide (HAT) as a tailwater condition as well as the potential impact of sea level rise. Within the calibration events, downstream water level boundaries were set to recorded water levels from the Townsville Harbour gauge, appropriate for the event.

The key boundaries for the model are:

- The Ross River Flows (inflow to the model just 1 km upstream of Bowen Bridge at Stuart Drive);
- Stuart Creek Flows (inflow to the model immediately upstream of Southwood Road Bridge);
- Downstream of the Ross River (water level to the MIKE 11 branch connecting Cleveland Bay)
- Downstream of Sandfly Creek (water level to the MIKE 11 branch connecting Cleveland Bay);
- Downstream of the Stuart Creek (water level to the 1D branch connecting the Cleveland Bay);

The locations of the model boundaries are shown in **Figure 4-1**.



GORDON CREEK FLOOD STUDY
Hydraulic Model Setup

Figure 4-1

LEGEND

- MIKE URBAN Nodes
- MIKE URBAN Links
- MIKE 11 Branches
- MIKE21 Source Points
- Rain on Grid Extent

Topography (m AHD)

- < 0
- 0 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- 3 - 5
- 5 - 7
- 7 - 10
- 10 - 20
- 20 - 30

N

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Rain on Grid

The application of rainfall excess directly to the MIKE FLOOD two-dimensional (2D) grid was limited to flat portions of the study area to ensure model stability. The extent of the “Rain on Grid” area is shown in **Figure 4-1**. The rainfall excess was applied in the MIKE FLOOD 2D grid with a spatial distribution representing the impervious areas within study area. The impervious areas have been identified from the detailed review of aerial photography and zoning information. The spatial distribution of impervious areas is shown in **Figure 4-2**.

Rainfall loss values have been determined from the review of rainfall losses determined from the model calibration (refer to **Section 4.4**). The loss values adopted for the design flood events are:

- initial loss - 25mm; and
- continuing loss 2.5 mm/h.

For the calibration events the spatial distribution of rainfall has been applied to the grid also accounted for the spatial rainfall distribution determined from the recorded rainfall records (refer to **Section 4.4**).

The derivation of the design rainfall applied using “Rain on Grid” is provided in **Section 3.4**.

Source Points

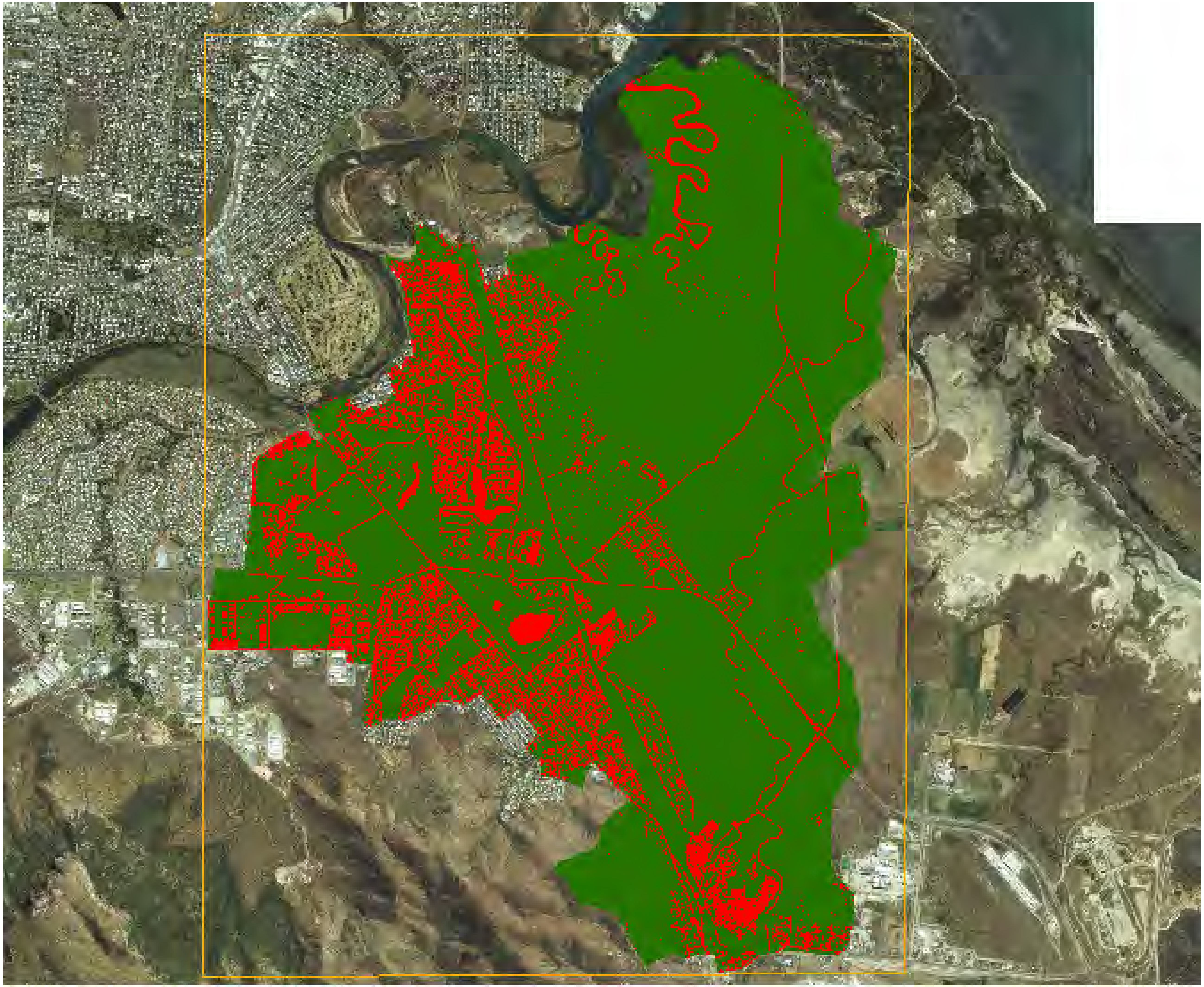
Inflows from surrounding catchments or sub-catchments outside of the “Rain on Grid” area are included in MIKE FLOOD model as sources (shown in **Figure 4-1**). Sub-catchments represented by these source-points include:

- Gordon Creek;
- Douglas/Annandale; and
- Stuart Creek.

In the source points, the flows for different ARI rainfalls have been determined through hydrological modelling with XP-RAFTS.

GORDON CREEK FLOOD STUDY
Fraction Impervious

Figure 4-2



LEGEND

Impervious Assignment

- Pervious
- Impervious
- Model Domain

N

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Hydraulic Structures

Major structures on Ross River have been represented as one-dimensional (1D) elements in the model by either:

- representing the structure as an implicit coupled structure;
- representing the structure as an explicit coupled structure (for branches longer than the cell width – 10m); or
- representing the structure within a 1D branch that was laterally coupled immediately upstream and downstream of the structure.

The major structures represented include:

- Abbott Street Bridges over Ross River (rail, pedestrian and road);
- Bowen Road Bridge over Ross River;
- Stuart Creek Bridge on Bruce Highway;
- 2 culverts on Stuart Drive facilitating cross-drainage between Annandale and Idalia;
- 3 culverts on University Road facilitating cross-drainage from Murray to Annandale;
- 2 culverts on University Road facilitating cross-drainage from Wulguru to Annandale;
- 3 culverts on Racecourse Road facilitating cross-drainage from Cluden to Idalia;
- 11 culverts on Bruce Highway facilitating cross-drainage within Cluden;
- 6 culverts on Bruce Highway facilitating cross-drainage from Stuart to Cluden;
- 1 culvert on Stuart Drive facilitating cross-drainage from Wulguru to Cluden;
- 1 culvert on Normanby Street facilitating cross-drainage from Wulguru to Stuart;
- Queensland Railway culverts in Stuart;
- 2 culverts on Abbott Street and 2 culverts under Railway line facilitating cross-drainage between Fairfield Waters and Cluden;
- 4 Culverts within Fairfield Waters;
- 6 culverts within Wulguru; and
- 6 culverts within Annandale.

Details of the culverts and bridges represented within the Gordon Creek model are provided in **Appendix B**.

Narrow Flow Paths

Surface flow paths that are too narrow to be represented with the MIKE21 topographic grid component of the MIKE FLOOD model have been represented using MIKE11 branches. Overflows from the MIKE11 branches have been transferred to the MIKE21 topographic grid of the broader floodplain via lateral couples.

In the Gordon Creek model, the narrow flow paths represented by MIKE11 branches are:

- Table drains beside Crossman Drive, Annandale;
- Annandale drain network conveying runoff from Annandale, Murray and Wulguru catchments; and
- Wulguru Drain.

Cross sections for the narrow flow path drains have been digitised from the LiDAR survey, which has elevation points identified at 1m centres. The locations of the narrow flow path branches represented within MIKE11 are shown in **Figure 4-1**.

Underground Drainage

Components of the underground drainage network that have potential to impact on surface flood levels have been represented using the MIKE URBAN component of the MIKE FLOOD model. Following an assessment of the conveyance within a typical street cross-section, with typical grades experienced in Townsville, it was identified that underground drainage with a cross-sectional area equal to a 900mm diameter pipe or greater was able to impact flood levels within the street cross-section by 10mm or greater. Generally only sections of the underground drainage, where the pipe cross-sectional area is greater than the equivalent of a 900mm pipe have been represented.

Figure 4-1 shows the general layout of the underground drainage network represented in the MIKE FLOOD model. Details of the underground drainage network represented in the MIKE FLOOD model are provided in **Appendix C** as small-scale layout plans and tabulated details of the network. Information to specify levels and dimensions of the network have been sourced from Council's corporate GIS database.

Lower Floodplain

Much of the overbank area of the southern side of Ross River is inundated in larger flood events. The lower floodplains at this area drain flood water through Gordon Creek, Sandfly Creek and the other downstream branches of Stuart Creek. These branches except Gordon Creek are represented in MIKE FLOOD model using MIKE 11 branches. The MIKE11 branches represented large areas that are major flow paths within the floodplain are:

- Downstream of the Ross River and its branch connecting lower floodplain at the southern side of the Ross River;
- Sandfly Creek; and
- Sandfly Creek – second outlet; and downstream braches of Stuart Creek.

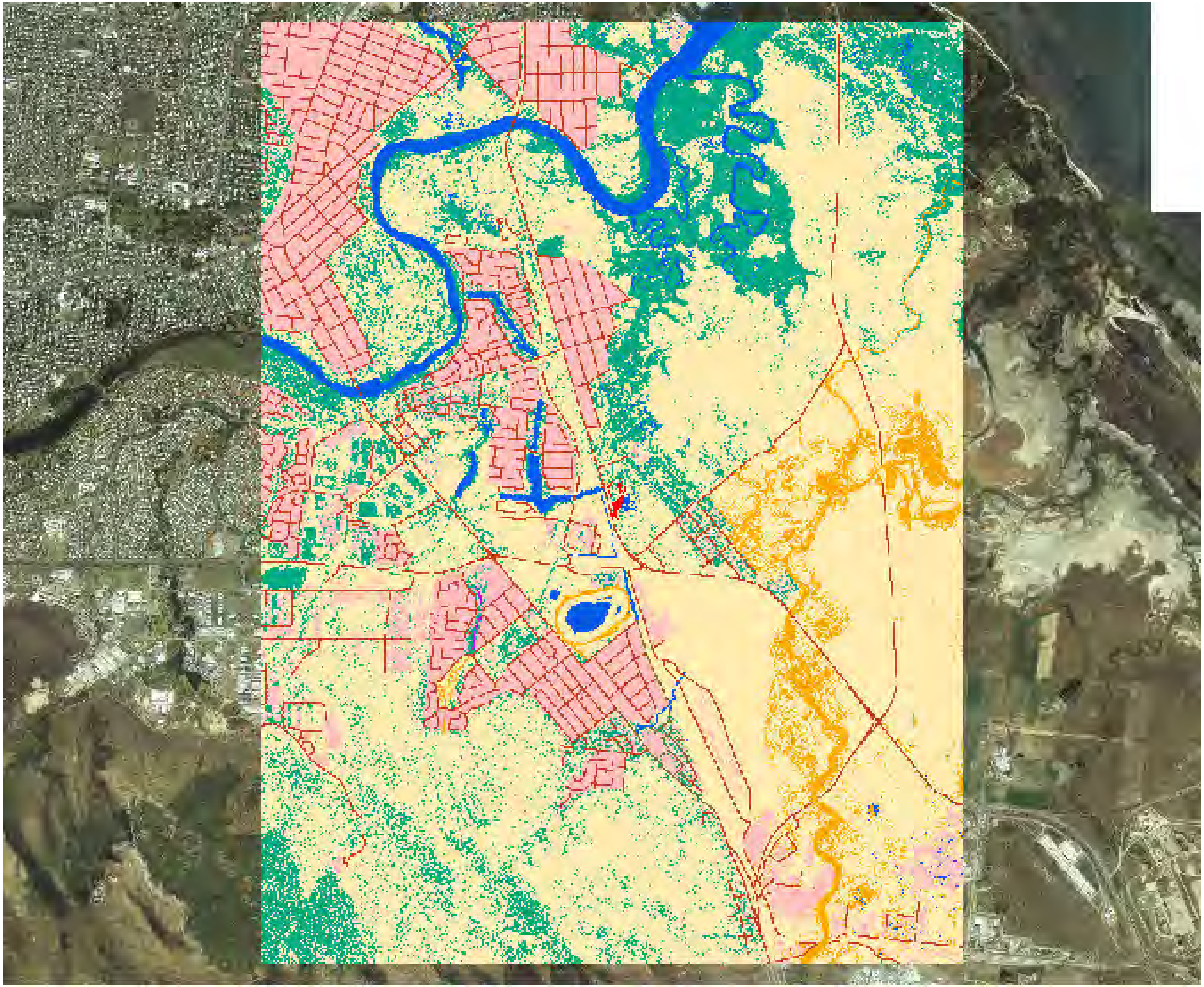
These branches are shown in **Figure 4-1**.

Hydraulic Roughness

Hydraulic roughness within the model is specified as Manning's n values and was determined from review of land-use data, aerial photography and site assessment. The joint calibration of the model to recorded water levels (refer to **Section 4.4**) has confirmed the selection of the Manning's n values.

The roughness values adopted within the MIKE21 component of the MIKE FLOOD model are shown in **Figure 4-3**. Details of the roughness values adopted in the underground drainage (MIKE URBAN) of the MIKE FLOOD model are provided in **Appendix C**. The open channels represented with the MIKE11 component of the MIKE FLOOD were generally represented with Manning's n values of 0.033; however the following drains had different values applied:

- Wulguru-Stuart Drain located at Normanby Street– 0.025;
- Stuart Drain connecting QR culverts; and
- Wulguru Drain – 0.067 (very weedy reaches and heavy underbrush).



GORDON CREEK FLOOD STUDY MIKE 21 Roughness

Figure 4-3

LEGEND

Manning's n

- 0.08
- 0.067
- 0.06
- 0.05
- 0.035
- 0.03
- 0.025
- 0.022
- 0.02
- 0.018

N

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Flow Couples

In MIKE FLOOD model, several types of coupling can be done to simultaneously represent 2D floodplain flows (based on MIKE 21 model) with, 1D channel flows (based on MIKE 11 model) and 1D pipe flows (based on MIKE URBAN model) and also for transferring flow between models. The following is a general description of the couple types adopted within the MIKE FLOOD model setup:

- *Standard Couple* – representing flow transfer between MIKE21 and MIKE11 where one or more MIKE21 cells are linked to the end of a MIKE11 branch (either upstream or downstream end). This type of couple is useful for connecting a detailed MIKE21 grid into a broader MIKE 11 network, or to connect an internal MIKE11 branch/structure (with an extent of more than a grid cell) inside the MIKE 21 grid.
- *Lateral Couple* – representing flow transfer between MIKE21 and MIKE11 where a string of MIKE21 cells are laterally linked to MIKE11 for either a section of a branch or an entire branch. This type of couple is useful for simulating overflow from a channel onto a flood plain.
- *Structure Couple* – representing flow transfer between MIKE21 and MIKE11 where a structure is represented in MIKE11. The structure couple takes the flow terms from a structure in MIKE11 and inserts them directly into the momentum equations of MIKE21.
- *Zero Flow Couple* – prevent flow through a series of MIKE21 cells. These zero flow couples have been used in conjunction with standard couples, when the standard couples are used for structure branches. These couples ensure all flow travels through the MIKE11 branch.
- *River / Urban Couple* – representing flow transfer between MIKE11 and MIKE URBAN where a chainage in MIKE11 and a Node in MIKE URBAN are linked. This kind of couple is used for representing outlets from the underground drainage network. Flow can travel both ways through this couple depending on the head difference in MIKE11 and MIKE URBAN.
- *Urban Outlet Couple* – representing flow transfer between MIKE21 and MIKE URBAN where a MIKE21 cell and a Node in MIKE URBAN are linked. This kind of couple is used for representing outlets from the underground drainage network. Flow can travel both ways through this couple depending on the head difference in MIKE21 and MIKE URBAN.
- *Urban Inlet Couple* – representing flow transfer between MIKE21 and MIKE URBAN where a MIKE21 cell and a Node in MIKE URBAN are linked. This kind of couple is used for representing inlets to the underground drainage network. Flow can travel both ways through this couple depending on the head difference in MIKE21 and MIKE URBAN.

The Gordon Creek MIKE FLOOD model has a total of 198 couples comprising:

- 115 standard couples;
- 13 lateral couples;
- 2 structure couples;
- 4 zero flow couples;
- 1 river/urban couples; and
- 62 urban inlet/outlet couples.

4.4 Model Calibration

The Gordon Creek MIKE FLOOD model, has been calibrated to two representative historical events on the following basis:

- **January 1998** – was a large flood event resulting from rainfall directly on the local catchment and a large peak water level data set was obtained; and
- **February 2002** – was a moderate flood event resulting from rainfall directly on the local catchment and had records at the Stuart Creek stream gauge;

Specific details of the calibration for each event are provided in the sections below.

January 1998

The January 1998 event was a large rainfall event that occurred between 5pm on the 10^{th} of January 1998 and 8am on the 11^{th} of January 1998. Approximately 510 mm of rain was recorded at the Townsville Airport Gauge during that period. The 1998 storm event was estimated as a 500 Year ARI storm event according to an Intensity-Frequency-Duration (IFD) analysis of rainfall at the Townsville Airport rainfall gauge as presented in the Townsville Flood Hazard Assessment Study (Maunsell 2005) report.

A spatial distribution of flood levels surveyed by Townsville City Council in the immediate aftermath of the event was used for calibration. During the event the only pluviometer close to the Gordon Creek catchment was the Townsville Airport Gauge. In this calibration daily rainfall gauges around Gordon creek area have been used.

Thiessens polygons based on the daily rainfall gauges is presented in **Figure 4-4.** Rainfall hyetographs for each polygon have been determined by scaling the Townsville Airport gauge records with the daily rainfall totals for the daily rainfall gauges within each polygon. Rainfall excess has been applied to the MIKE FLOOD model by applying rainfall losses to the rainfall hyetographs. Sensitivity analysis has been done for different rainfall losses. It has been observed that the influence of rainfall losses is less close to the local catchment boundary. Following rainfall losses have been adopted for this event:

Table 4-1 January 1998 Rainfall Losses

Loss Type	Pervious	Impervious
Initial	25 mm	1mm
Continuing	2.5 mm/h	0mm/h

In the calibration process, the model has been run for 15 hours during the peak period of the event and the model results have been compared with the surveyed data. **Figure 4-5** shows the difference between the simulated and the surveyed flood levels. Here, positive and negative values indicate higher and lower simulated flood levels with respect to the measured levels.

The comparison results show that the flood levels determined from the model are generally within ±0.3m of the surveyed flood levels, except at one location at Wulguru. The model results show very good agreement at the Stuart Creek bridge location, as less development took place in the Stuart Creek flood plain since 1998.

GORDON CREEK FLOOD STUDY JAN 1998 RAINFALL

Figure 4-4

LEGEND

- Rain on Grid Extent
- Rain Gauges
- Thiessen Polygon
- Model Domain

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GORDON CREEK FLOOD STUDY JAN 1998 CALIBRATION

Figure 4-5

LEGEND

Flood Level Difference
(Simulated - Measured data)
Rain on Grid Extent
Suburbs

N

City of Townsville

SCALE: 1:30,000 @A3

350 175 0 350 700 1,050 Metres

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February 2002

The February 2002 event was a moderate rainfall event that occurred during the period from 13 to 16 February. In that event, rainfall in the range between 300mm and 450mm fell at various rainfall alert stations throughout the Townsville area. The rainfall gauges relevant to the Gordon Creek catchment that recorded data during the event were Mysterton, Aplins Weir, Stuart Creek and Stuart. A comparison between the recorded rainfall at the above gauges and the IFD relationship for Gordon Creek is shown in **Figure 4-6**. It shows that the event was up to a 20 Year ARI rainfall event particularly for the 18 hour duration event.

Figure 4-6 IFD relationship for Gordon Creek

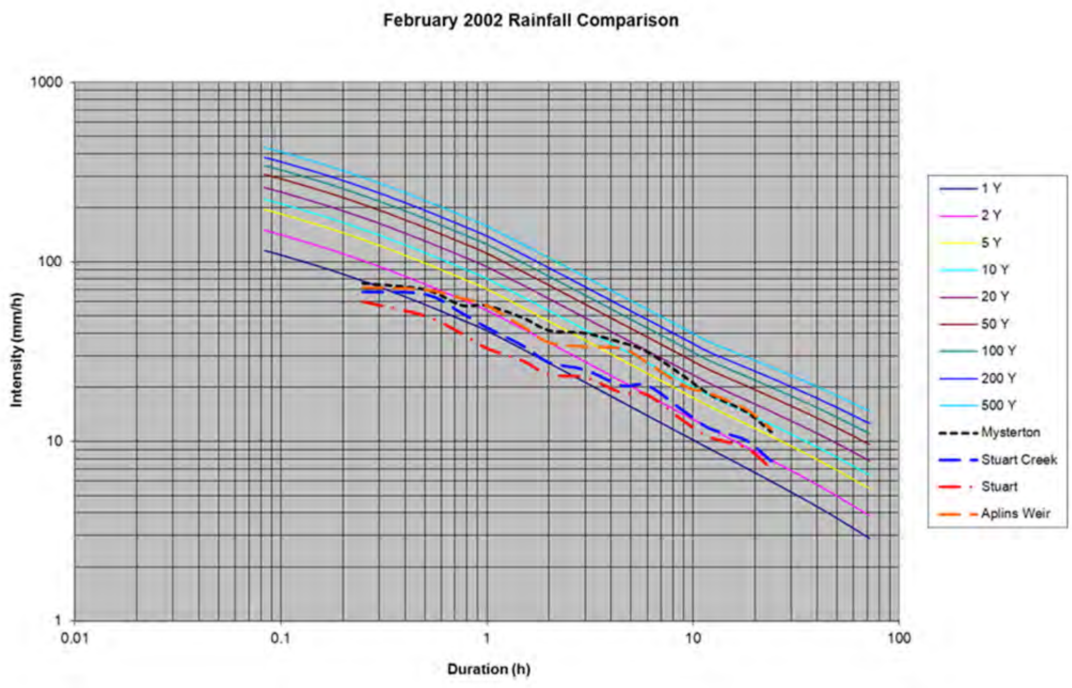


Figure 4-7 shows the Thiessens polygons used in assigning rainfall to the model.

The time series of rainfall intensity data for Mysterton, Aplins Weir, Stuart Creek and Stuart stations have been extracted from TARDIS (Torrent and Rainfall Distribution Imaging System maintained by Townsville City Council). Rainfall excess has been applied to the MIKE FLOOD model by incorporating rainfall losses to the rainfall hyetographs. The rainfall losses adopted for this event are shown in **Table 4-2**. In this event higher rainfall losses have been considered based on the previous studies (*Ross Creek Flood Study 2013 & Townsville Flood Hazard Assessment Study 2005*) and presented in **Table 4-2**.

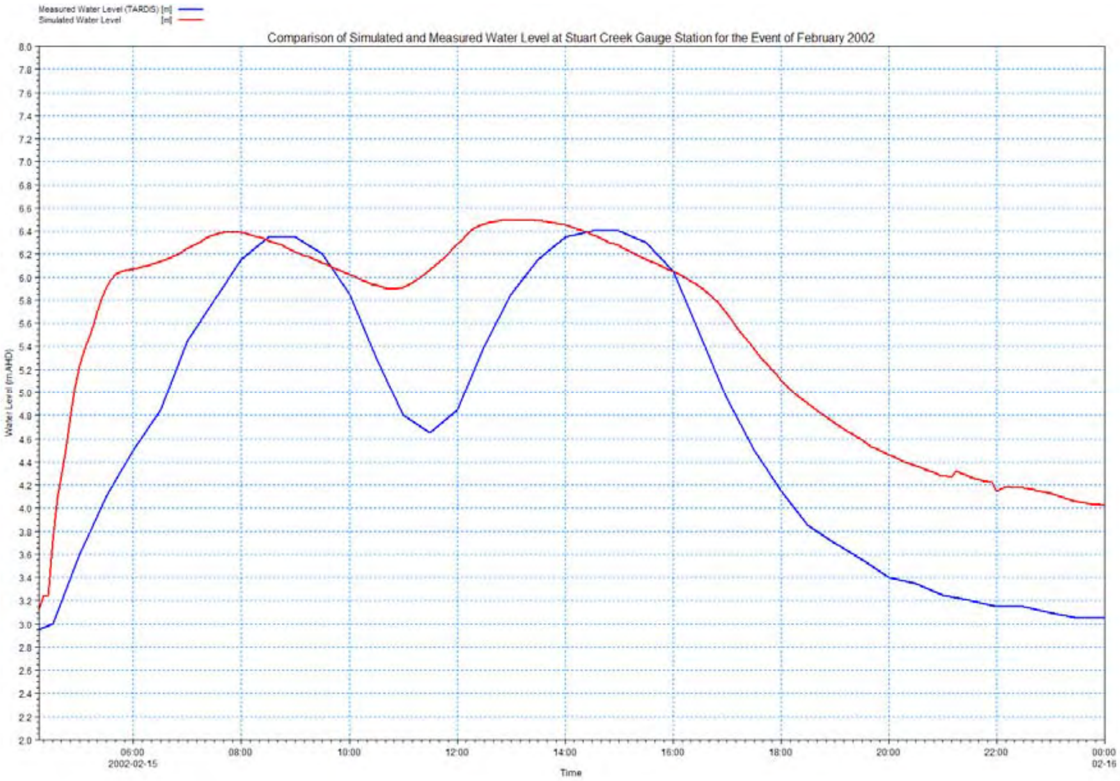
Table 4-2 February2002 Rainfall Losses

Loss Type	Pervious	Impervious
Initial	60mm	1mm
Continuing	3mm/h	0mm/h

The Stuart Creek stream gauge is the only water level gauge station available within the current study area. The water level time series data for the February 2002 event at the Stuart Creek gauge station has been obtained from TARDIS and used for model calibration.

The hydraulic model has been run from 15/2/2002 1:00:00 AM to 16/2/2002 1:00:00 AM to catch the peak discharge at the Stuart Creek stream gauge for the February 2002 event. **Figure 4-8** shows the comparison of simulated and recorded water levels at the Stuart Creek stream gauge. In the figure, the blue continuous line shows the recorded water level and the red continuous line shows that simulated water level. The comparison result shows good agreement in peak water levels, within the limitations of the available rainfall data.

Figure 4-8 February 2002 Comparison between simulated and recorded water levels



GORDON CREEK FLOOD STUDY FEB 2002 RAINFALL

Figure 4-7

LEGEND

- Rain on Grid Extent
- Rainfall Guages
- Thiessens Polygons

N

City of Townsville

SCALE: 1:40,000 @A3

400 200 0 400 800 1,200 Metres

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4.5 Model Verification

The Gordon Creek model results have been verified with the previous flood modelling studies completed in the Gordon Creek area. Comparisons have been made using tables and flood maps of the published reports.

Background of the Previous Work

In May 2009, Maunsell AECOM carried out a flooding assessment of Stuart Creek and Gordon Creek and associated floodplains for the Department of Main Roads and Townsville City Council under study titled "Southern Access Corridor Planning Study- Stuart Creek and Gordon Creek, Hydraulic Assessment". In that study, Maunsell AECOM developed two hydraulic models covering the Stuart and Gordon Creeks and their associated floodplains using MIKE FLOOD modelling tool. One of the hydraulic models is the Racecourse Road model which represents Gordon Creek area.

> The Maunsell AECOM study indicated that a flow of $47m^3/s$ overtops the Bruce Highway immediately west of the North Coast Rail for the base case 50 Year ARI flood event.

In September 2010, Cardno engaged by Fairfield Construction Pty Ltd carried out a modelling investigation for the Fairfield Waters area. In that study, Cardno also reviewed the work done by Maunsell AECOM under Southern Access Corridor Planning Study- Stuart Creek and Gordon Creek (May 2009). The objective of the investigation was to determine the channel widths required to convey 50 Year peak flow entering the Fairfield Waters site across Racecourse road.

Cardno used the same model setup (in TUFLOW format) of Maunsell AECOM and reduced the grid resolution to 5 m at Fairfield Waters through nesting. The nested model was updated with additional survey data of the Fairfield Waters Estate and the lakes, a number of culverts along the Bruce Highway between Lakeside Drive and Stuart Creek and the Lake 3 outlets and downstream channel which connected to the culverts underneath Abbotts street.

> Cardno found that the flow of $47m^3/s$ nominated in the Maunsell AECOM report is too high as it includes filling of the Pony Club. Removing this fill allows the flow to be conveyed through the site to be reduced to 30 m^3/s at most. Even then, the provision of works to direct flow in Gordon Creek to Lake 3 and prevent the current short-circuiting of flow to the east would allow a further reduction in flow rate. According to Cardno, the maximum flow rate that is applicable to the design for a channel across the south-eastern corner of the site is $25m^3/s$.
>
> After investigation, Cardon recommended a 10 metre wide concrete channel (with vertical sides) to convey 50 Year peak flow. In conjunction with the construction of channel, a levee was recommended between Racecourse Road and Fairfield Waters to allow flow in Gordon Creek to be directed to Lake 3.

In April 2013, GHD carried out a study titled "Bruce Highway Upgrade (Vantassel to Cluden)- Detailed Design, Hydraulic Assessment" for Department of Transport and Main Roads. The study assessed the hydraulic implications of the proposed upgrade of

Bruce Highway between Vantassel Street and Stuart Drive in Cluden (i.e. 7.5 km stretch), and built on the work conducted during the concept design and business case phase of this project. This stretch of Bruce Highway crosses through the Stuart Creek, Gordon Creek and Vantassel (or Sandfly) Creek catchments.

> The model for this study was setup using a combination of the data from a number of previous studies in the area and newly available information. No additional calibration of the hydraulic and hydrologic model was done in the study. The model results for various scenarios were presented based on the maximum envelope of a number of durations.

Model Verification Comparing Previous Works

The Gordon Creek model developed under the present study has been verified with the previous modelling results done by Maunsell AECOM, Cardno and GHD. In this verification process, the Gordon Creek model has been run for 50 Year ARI and 3 hour storm duration event using the rainfall losses determined by calibration with January 1998 event (see section 4.4).

Table 4-3 shows the comparison of model results for the base case 50 Year ARI and 3 hour storm duration flood event. **Figure 4-9,** taken from Cardno's report (September 2010), shows the locations of comparison points/ sections. In **Table 4-3**, the columns 1-3 describe the comparison locations and notations for cross-reference with **Figure 4-9**, the columns 4-5 include previous model results (as presented in the Cardno's report) and rest of the columns show the comparison with Gordon Creek model results.

The comparison results show that the peak water level difference between the present and the previous results remain within ± 300 mm except at upstream of Lakeside Drive Intersection, where 410 mm deviation is found with Cardno's model result. Discharge comparison in three sections shows good agreement with the Cardno's model results (i.e. ± 1 m3/s) but poor agreement with Maunsell AECOM's result.

Figure 4-9 Comparison Locations for Model Verification (source: Cardno Report, Sept. 2010)

The Gordon Creek model result has also been compared with the flood map produced by Cardno and presented in **Figure 4-10**. Although it is a qualitative comparison, the result shows a good agreement in Stuart Creek and its floodplains and around Fairfield area, but a significant difference at Wulguru and Stuart suburbs. In the figure, Cardon's model result shows no surface runoff in Wulguru and Stuart sub-catchments. This may be the reason for significant difference between two model results at Wulguru and Stuart suburbs.

Another comparison is made with the GHD model results based on flood extent for 50 Year ARI and 100 Year ARI events and shown in **Figure 4-11** and **Figure 4-12** respectively. Both the figures show good agreement in Stuart Creek and its floodplains, and Cluden, Stuart and Wulguru suburbs but dissimilarity in Fairfield area. Differences within the Fairfield area compared to the GHD model are a result of improved topographic data within the present model.

Table 4-4 Comparison with past study results

Location		Recording Point	Previous Model Results		**Gordon Creek Model Results**	Difference with	
			Maunsell AECOM Model	Cardno Model		Maunsell AECOM Model	Cardno Model
(1)	(2)	(3)	(4)	(5)	**(6)**	(6)-(4)	(6)-(5)
Peak Water Level (mAHD)							
Stuart Creek Bridge	Upstream	B1	7.1	7.0	**7.1**	0.0	0.1
	Downstream	B2	6.8	6.8	**6.9**	0.2	0.2
Bruce Highway	NW Bridge	B3	6.9	6.7	**7.0**	0.1	0.3
	SW Bridge	B4	7.2	7.0	**7.2**	0.0	0.2
Lakeside Drive Intersection	Upstream	B5	4.0	3.6	**4.0**	0.0	0.4
	Downstream	B6	3.9	3.5	**3.8**	-0.2	0.3
Abbott Street Intersection	Upstream	B7	4.1	3.6	**3.8**	-0.3	0.2
	Downstream	B8	3.7	3.5	**3.7**	0.1	0.3
Peak Flow Rate (m^3/s)							
Bruce Highway	West of the North Coast Rail	QB1	47.0	27.7	**26.7**	-20.3	-1.0
Bruce Highway	East of the North Coast Rail	QB2	38.0	29.0	**29.3**	-8.7	0.3
Bruce Highway	Between Dale Street and Stuart Creek Bridge	QB3	15.0	24.4	**23.4**	8.4	-1.0

Note: This table is taken from Cardno's Report (Sept 2010), only the last three columns have been added for comparison.

Figure 4-10 Comparison of the extent of flooding (50 Year ARI) between Gordon Creek model and Cardno model

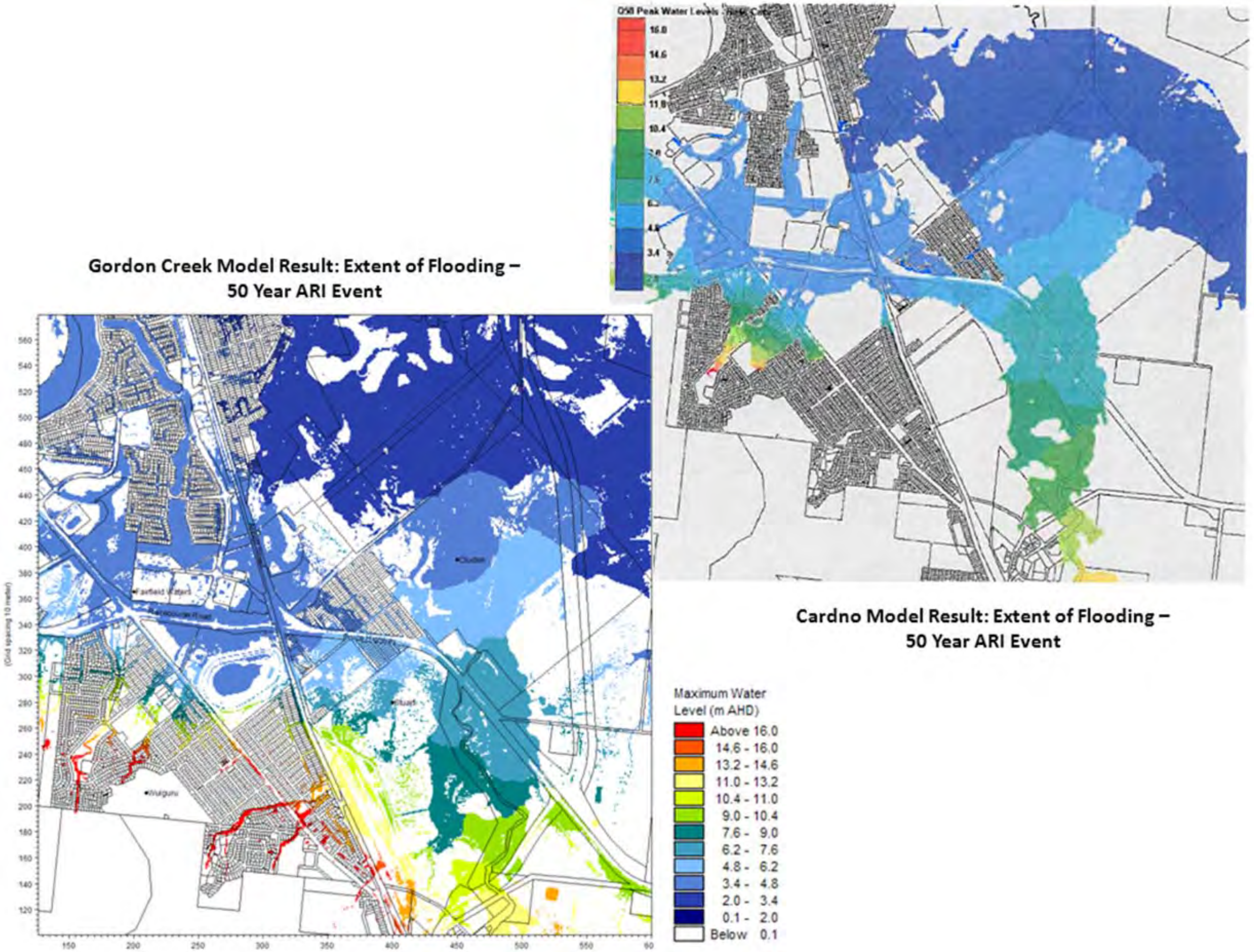


Figure 4-11 Comparison of the extent of flooding (50 Year ARI) between Gordon Creek model and GHD model

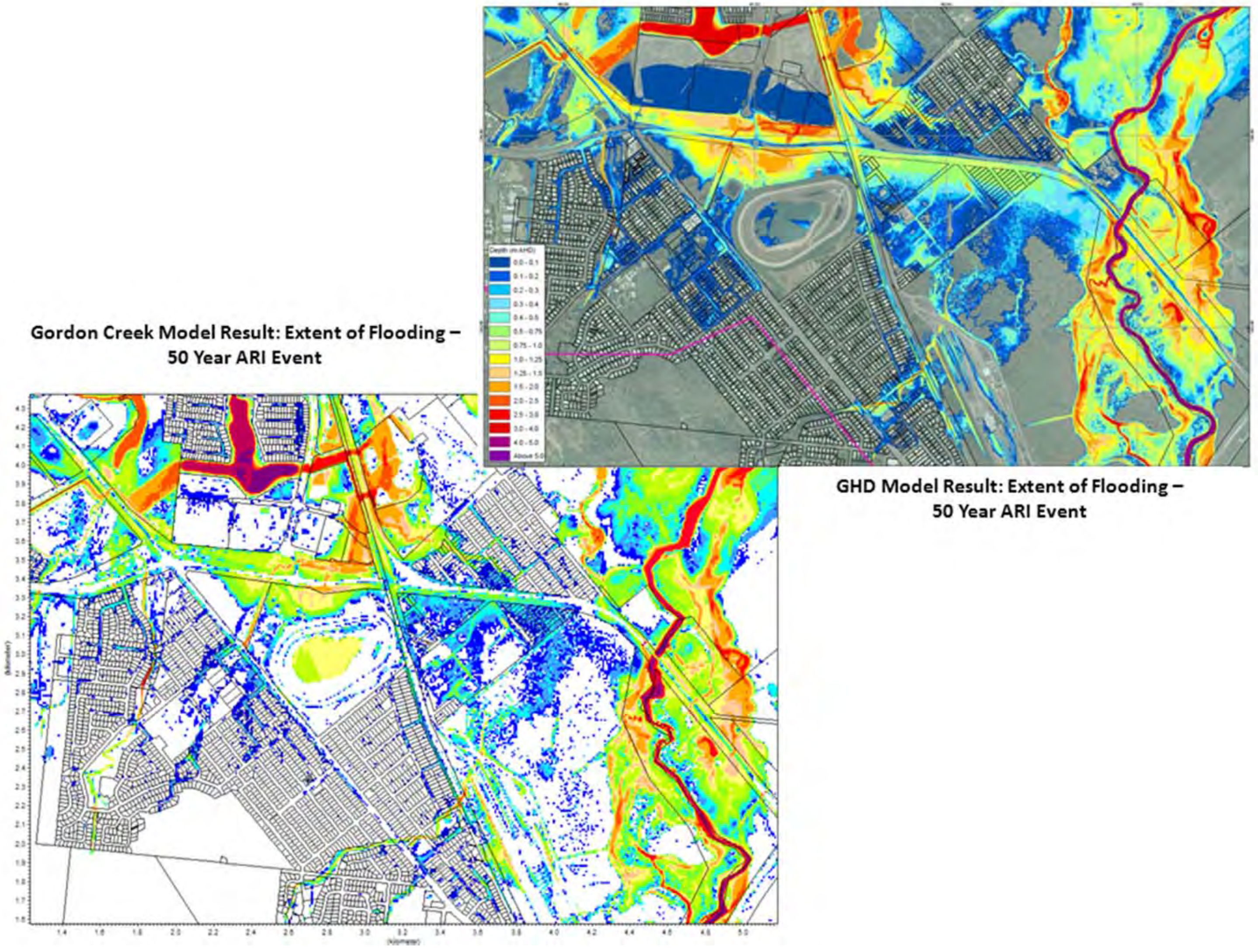
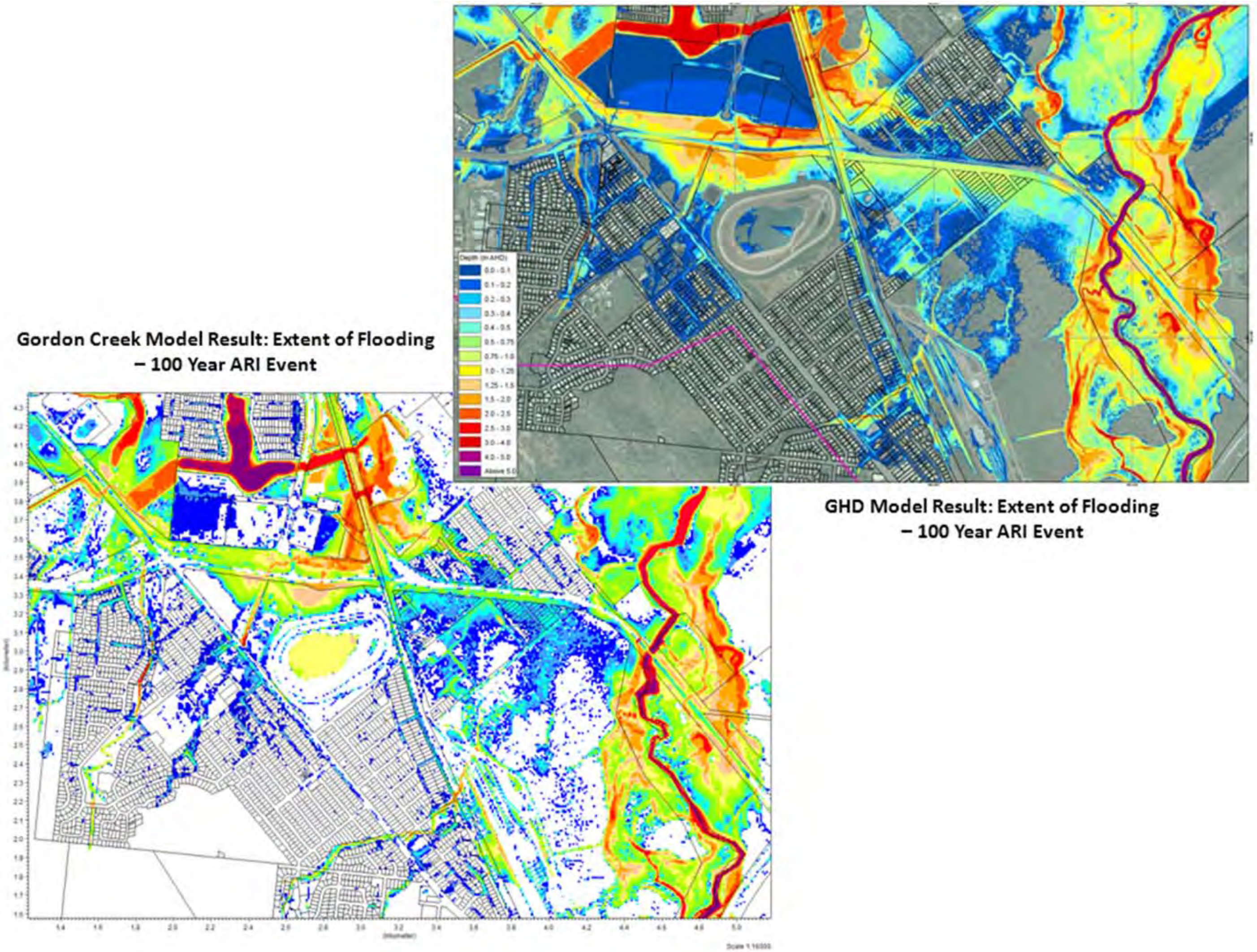


Figure 4-12 Comparison of the extent of flooding (100 Year ARI) between Gordon Creek model and GHD model



4.6 Design Flood Assessment

Following calibration of the hydraulic model, the model has been updated to represent design flood events, by ensuring the topography and underground network represent 2011 conditions. All the design runs have been carried out using the rainfall losses determined by calibration with January 1998 event (see **section 4.4**).

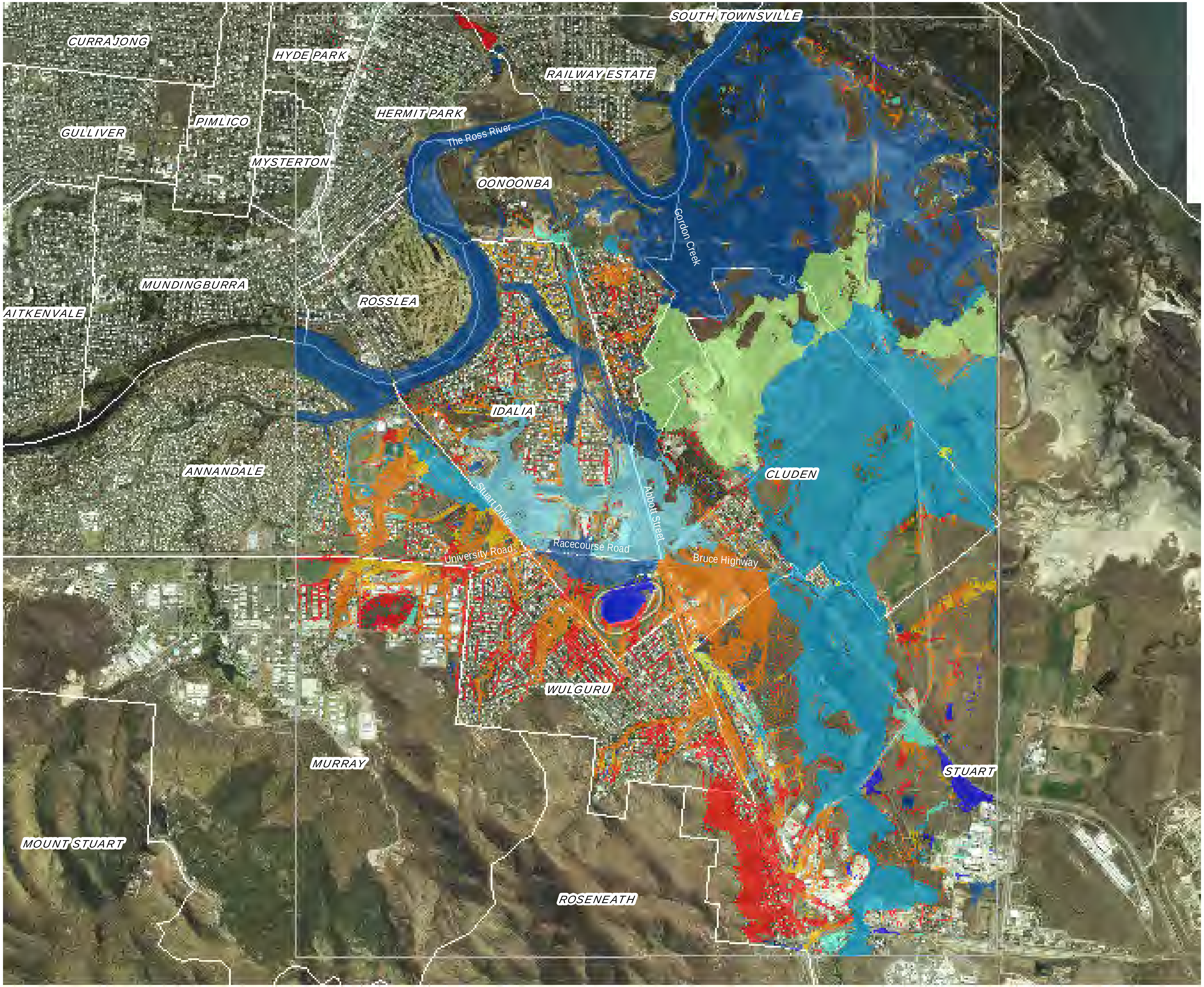
Initially the 50 Year ARI and 100 Year ARI have been run for a range of event durations to establish the critical durations across the floodplain. **Figures 4-13** and **4-14** show the critical flood durations for the 50 and 100 Year ARI events respectively. The results show that there is no definite critical storm duration across the floodplain of Gordon Creek, however 72-hour duration has been found critical in the Ross River, in the downstream of Gordon Creek and the northern lakes of Fairfield Waters (i.e. Lake 1, Wetlands, Freshwater Lake and Lake 2). In both the flood events, 24 hours duration has been found critical in Stuart Creek and 18 hours in the Fairfield Waters Lake 3 and its surrounding area. The critical storm duration varies from 1 hour to 2 hours in the residential area. Model results show that the flood levels of 1.5-hour storm event are very close to the flood levels of 1-hour and 2-hour storm events. For this reason, four storm durations (i.e. 1.5 hours, 18 hours, 24 hours and 72 hours) have been considered for rest of design runs including 200 Year ARI, 500 Y ARI and Probable Maximum Flood (PMF).

Flood map results are provided in **Appendix D**, for water depths, flood levels and flow velocities. For all storm frequencies the flood map results are based on the critical flood envelope from all storm durations. Given the “Rain on Grid” approach has all cells within the model wet areas with depths of less than 0.1 m have not been shown as inundated.

Detailed discussion of the flood model results are provided in subsequent chapters.

GORDON CREEK FLOOD STUDY
Critical Storm Duration

Figure 4-13



LEGEND

Critical Storm Duration (50 Y ARI)

- 1 h
- 1.5 h
- 2 h
- 3 h
- 6 h
- 12 h
- 18 h
- 24 h
- 48h
- 72h

N

City of Townsville

SCALE: 1:30,000 @A3

350 175 0 350 700 1,050 Metres

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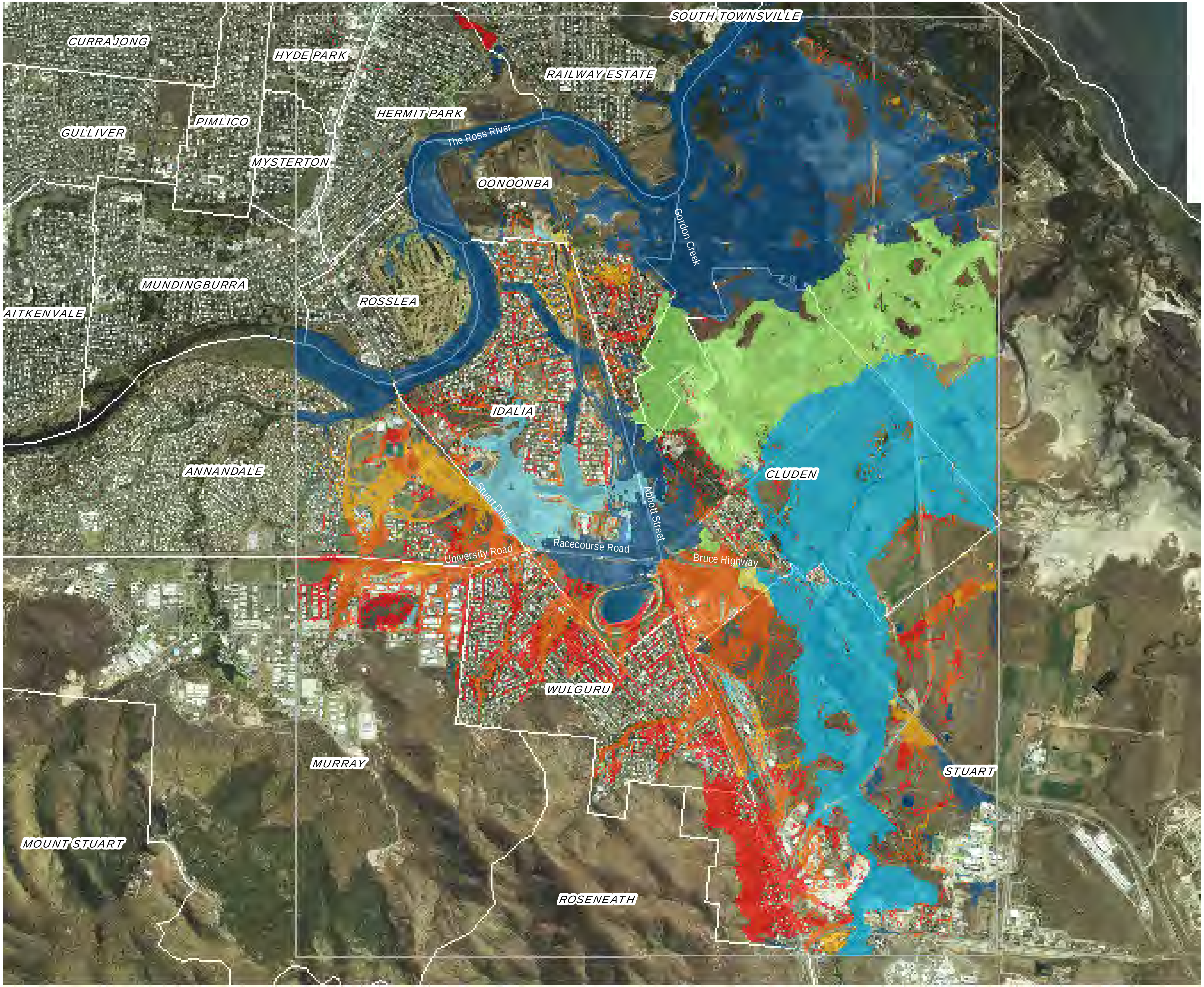
GORDON CREEK FLOOD STUDY
Critical Storm Duration

Figure 4-14



LEGEND

Critical Storm Duration (100 Y ARI)

- 1h
- 1.5h
- 2h
- 3h
- 6h
- 18h
- 24h
- 72h

N

City of Townsville

SCALE: 1:30,000 @A3

350 175 0 350 700 1,050 Metres

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5.0 Baseline Flooding Summary

5.1 Description of Flooding Results

Base-line flood maps for the design floods are provided in **Appendix D**. These maps are provided for water depths, flood levels and flow velocities of the:

- 2 Year ARI;
- 5 Year ARI;
- 10 Year ARI;
- 20 Year ARI;
- 50 Year ARI;
- 100 Year ARI;
- 200 Year ARI;
- 500 Year ARI; and
- Probable Maximum Flood.

Descriptions of the flooding for the various design events are provided in the following sections for discrete areas of the floodplain. Where numbers of inundated residential properties are provided, they are on the basis of 0.20 m water depth within the lot, which does not mean floor levels are exceeded (though in some cases they may be when floor levels are less 0.20 m above the ground). To undertake a comparison to floor levels would require survey of all floor levels within the study area.

Eastern Parts of Murray and Annandale

The eastern part of Annandale contains Murray Sporting Complex and two schools. This area drains stormwater runoff to Idalia through open drains. **Figure 5-1** outlines the key drainage features within the eastern parts of Annandale and Murray, which shows two major flow paths:

- One flow path that runs from eastern part of Annandale to Gartrell Drive before discharging into Fairfield Waters Lake in Idalia; and
- Another flow path that runs from Lavarack Barracks, under university drive and then adjacent to Gartrell Drive to Stuart drive before discharging into Fairfield Waters Lake in Idalia.

A summary of the Key flooding issues within the Murray area relative to the ARI of floods is provided in **Table 5-1** following inspection of the flood mapping as presented in **Appendix D**.

Table 5-1 Murray Area Flooding Issues

Event	Description
2 Year ARI	Generally the critical duration event is: • 1.5 hours within the residential area; • 24 hours for the Murray Drain system; and • 24 hours for the Murray Sporting Complex flow path. Flooding generally contained to the road reserves, however there are some sporting fields within the Murray sporting complex where flooding is more evident. Both lanes of Stuart Drive section between Gartrell Drive and University Road are inundated as a result of

Event	Description
	converging flow paths. Inundation of major roads includes: • 0.12 m of water over Gartrell Drive adjacent to Stuart Drive; • up to 0.55 m of water on Murray Lyons Crescent between the hockey and cricket fields; and • 0.1 m of water over the Stuart Drive section between Gartrell Drive and University Road. Flow velocities are generally under 0.5 m/s, however there is a higher velocity in William Angliss Drive (~ 0.66 m/s) and Stuart Drive north of the intersection with University Road (~ 0.8 m/s).
5 Year ARI	Generally the critical duration event is: • 1.5 hours within the residential area; • 24 hours in the Murray Drain system; and • 24 hours in the Murray Sporting Complex flow paths. Flooding is largely contained to the road reserves and areas of the sporting fields within the Murray Sporting Complex. Inundation within the William Ross State High School is increasing. The entrance to the school from the William Angliss Drive and Mervyn Crossman Drive roundabout is now inundated, along with the carparks to the south. Mervyn Crossman Drive is close to being impacted by inundation. Inundation of major roads includes: • 0.3 m of water over Gartrell Drive adjacent to Stuart Drive; • 0.15 m of water over William Angliss Drive at the intersection with Mervyn Crossman Drive; • up to 0.65 m of water over Murray Lyons Crescent adjacent to the hockey fields; and • 0.18 m of water over the Stuart Drive section between Gartrell Drive and University Road. Within the residential area and the Murray Sporting Complex velocities are generally below 0.5 m/s, however there are higher velocities in William Angliss Drive (~ 0.83 m/s), Gartrell Drive adjacent to Stuart Drive (~ 0.52 m/s), Downey Crescent (~ 0.59 m/s) and Stuart Drive section between Gartrell Drive and University Road (~ 1.0 m/s).
10 Year ARI	Generally the critical duration event is: • 1.5 hours in the residential area; • 24 hours in the Murray Drain; and • 24 hours in the Murray Sporting Complex flow paths. Flooding within the residential area is largely contained to the road reserves. Flooding is becoming more widespread. There is also significant ponding occurring along Murray Lyons Crescent between the Hockey and Cricket Fields. Inundation is continuing to increase within William Ross State High School. The entrance to the school from the William Angliss Drive and Mervyn Crossman Drive roundabout is now inundated and closed, along with the carparks to the south. Areas of the Southern Cross Catholic School grounds are at risk of inundation. Inundation of Major roads includes: • up to 0.4 m of water over both lanes of Gartrell Drive adjacent to Stuart Drive; • 0.2 m of water over both lanes of William Angliss Drive at the intersection with Mervyn Crossman Drive; • up to 0.15 m of water over Mervyn Crossman Drive before the intersection with Stuart Drive; • up to 0.15 m of water over Murray Lyons Crescent adjacent to the RSL Stadium;

Event	Description
	• up to 0.7 m of water over Murray Lyons Crescent before the intersection with Mervyn Crossman Drive; and • 0.21 m of water over the Stuart Drive section between Gartrell Drive and University Road. Flow velocities through residential areas and William Ross State High School are generally under 0.5 m/s. The Murray Sporting Complex Flow Path has flow velocities no more than 0.5 m/s, however there are higher velocities in William Angliss Drive (~ 0.99 m/s), Gartrell Drive adjacent to Stuart Drive (~ 0.59 m/s), Downey Crescent (~ 0.66 m/s) and Stuart Drive section between Gartrell Drive and University Road (~ 1.1 m/s).
20 Year ARI	Generally the critical duration event is: • 1.5 hours within the residential area. • 24 hours in the Murray Drain; and • 24 hours in the Murray Sporting Complex flow path. Flooding within the residential area is largely contained to the road reserves. Flooding is becoming more widespread through the Murray Sporting Complex. Most of the Hockey and Cricket fields are now inundated along with the Soccer fields adjacent to Stuart Drive. The clubhouses at both the Cricket and Soccer grounds are now inundated. Flooding is also beginning to affect the Netball courts adjacent to William Angliss Drive. Flooding within the William Ross School grounds is now affecting a number of buildings. The entrance to the school and the car park to the east of the grounds is now completely inundated and closed. There are areas of inundation within the Southern Cross Catholic school and ponding is occurring within the car park at the front of the school. Inundation of the major roads includes: • up to 0.5 m of water over both lanes of Gartrell Drive before the intersection with Stuart Drive; • Up to 0.25 m of water over both lanes of William Angliss Drive at the intersection with Mervyn Crossman Drive; • 0.15 m of water over Murray Lyons Crescent opposite the RSL Stadium; • up to 0.8 m of water over Murray Lyons Drive at the intersection with Mervyn Crossman Drive; • up to 0.2 m of water over Mervyn Crossman Drive before the intersection with Stuart Drive; and • 0.23 m of water over the Stuart Drive section between Gartrell Drive and University Road. Flow velocities within the residential area are generally under 0.5m/s, however there are higher velocities in Mervyn Crossman Drive near intersection with Stuart Drive (~ 0.52 m/s), William Angliss Drive (~ 1.12 m/s), Gartrell Drive adjacent to Stuart Drive (~ 0.7 m/s), Downey Crescent (~ 0.73 m/s) and Stuart Drive section between Gartrell Drive and University Road (~ 1.2 m/s).
50 Year ARI	Generally the critical duration event is: • 1 - 1.5 hours within the residential area; • 1.5 hours in the William Ross State High School; • 1.5 - 2 hours in the Murray Drain but 24 hours immediately adjacent to Stuart Drive where storage increases; • 1.5 hours at the intersection of Mervyn Crossman Drive and William Angliss Drive; • 24 hours in the Murray Sporting Complex flow path area adjacent to Stuart Drive; and • 1.5 - 3 hours in the vacant land adjacent to the intersection of University Drive and Stuart Drive. Flooding within the residential area is manly contained to the road reserves. Only 1 property in Annandale is inundated. Flooding is widespread through the Murray Sporting complex and adjacent to Stuart Drive. The section of Murray Lyons Crescent between the Hockey and Cricket fields is

<table>
<tr><th>Event</th><th>Description</th></tr>
<tr><td></td><td>completely inundated due to significant ponding prior to the intersection with Mervyn Crossman Drive. The car park at the soccer grounds is completely inundated and inaccessible.

William Ross State High School is now inaccessible with flooding surrounding the perimeter of the school. A number of buildings on the southern side of the school are now affected by inundation. Inundation in the Southern Cross Catholic School grounds is increasing and a number of buildings are at risk of inundation.

Inundation of major roads includes:
up to 0.45 m of water over both lanes of Gartrell Drive before the intersection with Stuart Drive;
up to 0.25 m of water over both lanes of William Angliss Drive at the intersection with Mervyn Crossman Drive;
up to 0.2 m of water over Murray Lyons Crescent adjacent to the Soccer fields;
up to 0.2 m of water over Murray Lyons Crescent adjacent to the RSL stadium;
up to 0.7 m of water over Murray Lyons Crescent before the intersection with Mervyn Crossman Drive;
0.2 m of water over both lanes of Mervyn Crossman Drive before the intersection with Stuart Drive; and
0.26 m of water over the Stuart Drive section between Gartrell Drive and University Road.
Flow velocities within the residential area are generally under 0.5 m/s, however there are higher velocities in Mervyn Crossman Drive near intersection with Stuart Drive (~ 0.54 m/s), William Angliss Drive (~ 1.2 m/s), Gartrell Drive adjacent to Stuart Drive (~ 0.76 m/s), Downey Crescent (~ 0.77 m/s) and Stuart Drive section between Gartrell Drive and University Road (~ 1.3 m/s).</td></tr>
<tr><td>100 Year ARI</td><td>Generally the critical duration event is:
1-2 hours for the residential area, the Murray Drain system; and the Murray Sporting Complex.
Flooding is generally contained to the road reserves.

There is widespread inundation within the Murray Sporting Complex. Much of the road of Murray Lyons Crescent is inundated. The section of Murray Lyons Crescent between the Hockey and Cricket fields is completely inundated due to significant ponding prior to the intersection with Mervyn Crossman Drive. The car park at the soccer grounds is completely inundated and inaccessible. A number of sporting clubhouses are affected by inundation.

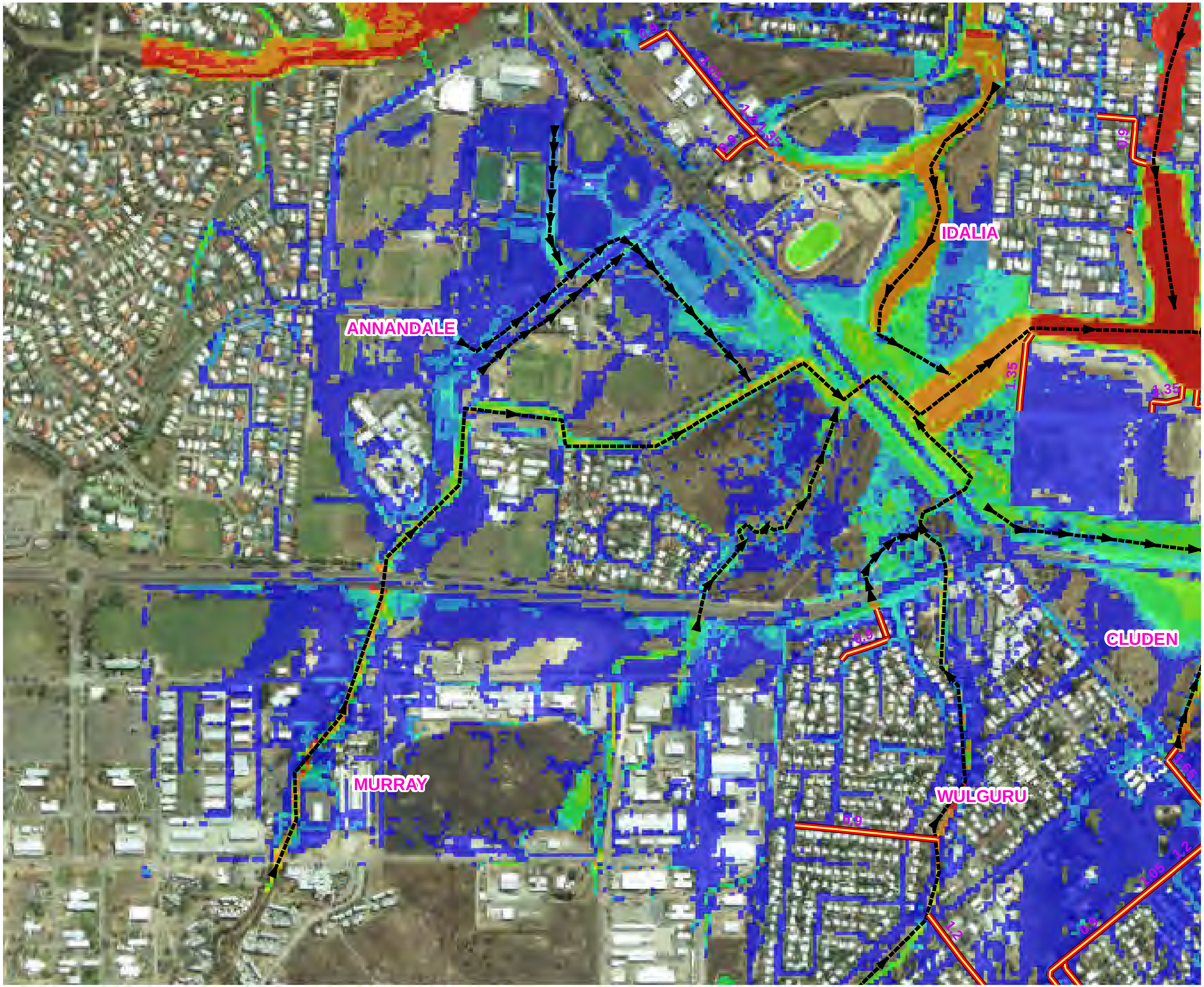
Inundation within the grounds of William Ross State High School is increasing. A number of buildings in the centre of the school are now affected by flooding. The intersection of Mervyn Crossman Drive and William Angliss Drive is almost completely inundated with water.

Inundation of Stuart Drive between Gartrell Drive and University Road is increasing.

Inundation of major roads includes:
0.53 m of water over Gartrell Drive before the intersection with Stuart Drive;
0.26 m of water over William Angliss Drive adjacent to the soccer field car parks;
0.75 m of water over Murray Lyons Crescent immediately north of the intersection with Mervyn Crossman Drive;
up to 0.2 m of water over Mervyn Crossman Drive before the intersection with Stuart Drive; and
0.3 m of water over the Stuart Drive section between Gartrell Drive and University Road.
Flow velocities within the residential area are generally under 0.5 m/s, however there are higher velocities in Mervyn Crossman Drive near intersection with Stuart Drive (~ 0.56 m/s), William Angliss Drive (~ 1.25 m/s), Gartrell Drive adjacent to Stuart Drive (~ 0.81 m/s) , Downey Crescent (~ 0.8 m/s) and Stuart Drive section between Gartrell Drive and University Road (~ 1.4 m/s).</td></tr>
</table>

<table>
<tr><th>Event</th><th>Description</th></tr>
<tr><td>200 Year ARI</td><td>Generally the critical duration event is:
1.5 hours for most of the residential area;
1.5 hours for the Murray Drain system and the William Ross State High School Grounds;
24 hours for the areas adjacent to Stuart Drive including Murray Sporting Complex; and
1.5 - 24 hours for much of Murray Lyons Crescent and 72 hours for northern section which has connections with the Ross River through natural drain.
Flooding for the most part is contained to the road reserves for this area.
There is widespread inundation within the Murray Sporting complex. Most of the road of Murray Lyons Crescent is now inundated and there is significant ponding prior to the intersection with Mervyn Crossman Drive.
William Ross State High School is inaccessible. Inundation within the school grounds is affecting a number of buildings. Southern Cross Catholic School is also experiencing some inundation.
Inundation of major roads includes: 0.56 m of water over Gartrell Drive at intersection with Stuart Drive;
up to 0.3m of water over intersection of Mervyn Crossman Drive and William Angliss Drive;
0.8m of water over Murray Lyons Crescent before the intersection with Mervyn Crossman Drive;
0.25m of water over Mervyn Crossman Drive between Stuart Drive and Murray Lyons Crescent; and
up to 0.39m of water over Stuart Drive between Gartrell Drive and University Drive.
Within the residential area flow velocities are generally below 0.5m/s, however there are higher velocities in Mervyn Crossman Drive near intersection with Stuart Drive (~ 0.58 m/s), William Angliss Drive (~ 1.29 m/s), Gartrell Drive adjacent to Stuart Drive (~ 0.88 m/s), Downey Crescent (~ 0.83 m/s) and Stuart Drive section between Gartrell Drive and University Road (~ 1.46 m/s). </td></tr>
<tr><td>500 Year ARI</td><td>Generally the critical duration event is:
1.5 hours within the residential areas;
1.5 hours within Murray Drain, however 24hrs downstream of Shanahan Drive;
1.5 hours within William Ross school grounds;
24 hours at the outfalls of Annandale and Murray drains near Stuart Drive;
72 hours for Murray Sporting Complex.
Within the residential area inundation is largely contained to roads with the exception of up to 2 houses being inundated.
Flooding is widespread in Murray Sporting complex, Murray Lyons Crescent, Mervyn Crossman Drive and William Angliss Drive. The RSL Stadium and adjacent Basketball courts are affected by inundation. The hockey and cricket fields are almost completely inundated.
Inundation within the grounds of William Ross State High School is affecting a number of the school buildings. Areas of inundation are occurring within the Southern Cross Catholic School grounds. Buildings towards the rear of the school are at risk of inundation.
Inundation of major roads includes: 0.6m of water over Gartrell Drive at the intersection with Stuart Drive;
Up to 0.3m of water over the intersection of Mervyn Crossman Drive with Willaim Angliss Drive;
Up to 1.2m of water over Murray Lyons Crescent adjacent to the basketball courts;
0.8m of water over Murray Lyons Crescent before the intersection with Mervyn</td></tr>
</table>

Event	Description
	Crossman Drive; • up to 0.5m of water over Mervyn Crossman Drive between Stuart Drive and Murray Lyons Crescent; and • up to 0.5m of water over Stuart Drive between Mervyn Crossman Drive and University Drive. Within the residential area flow velocities are generally below 0.5 m/s, however there are higher velocities in Mervyn Crossman Drive near intersection with Stuart Drive (~ 0.8 m/s), William Angliss Drive (~ 1.3 m/s), Gartrell Drive adjacent to Stuart Drive (~ 1.28 m/s), Downey Crescent (~ 0.85 m/s) and Stuart Drive section between Gartrell Drive and University Road (~ 1.57 m/s).
PMF	The critical duration event is 1.5 hours for all areas. There is significant flooding throughout the Murray Sporting Complex with depths up to 1.2m over the sporting fields. The grounds of William Ross State High School and Southern Cross Catholic School are both affected by significant inundation. Inundation of major roads includes: • 1.2m of water over Gartrell Drive at the intersection with Stuart Drive; • 0.45m of water over William Angliss Drive between Murray Lyons Crescent and Mervyn Crossman Drive; • up to 0.45m of water on Mervyn Crossman Drive between William Angliss Drive and Murray Lyons Crescent; • 1.2m of water over Murray Lyons Crescent, reaching up to 1.6m in some areas; • 1.0m of water over Mervyn Crossman Drive between Stuart Drive and Murray Lyons Crescent; and • up to 1.1m of water over Stuart Drive between University Drive and Mervyn Crossman Drive. Within the residential area flow velocities generally below 0.8m/s, however there are higher velocities in Mervyn Crossman Drive near intersection with Stuart Drive (~ 1.3 m/s), William Angliss Drive (~ 1.6 m/s), Gartrell Drive adjacent to Stuart Drive (~ 1.65 m/s), Downey Crescent (~ 1.1 m/s) and Stuart Drive section between Gartrell Drive and University Road (~ 2.0 m/s).



GORDON CREEK FLOOD STUDY
Major Flow Paths
Murray

FIGURE 5-1

LEGEND

Drainage Flow Direction

UnderGroundPipes

100 Y ARI Water Depth (m)

- 0.01 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- 3 - 25

N

City of Townsville

SCALE: 1:8,000 @A3

100 50 0 100 200 Metres

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Wulguru, Southern Part of Cluden and Western Part of Stuart

Figure 5-2 outlines the key drainage features within Wulguru. There are a number of open drains and surface flow paths for the area:

- The Wulguru north drain runs down a steep slope through parkland between Wright Street and Edison Street before passing under Edison Street and running adjacent to Newton Street out to University Drive and up to Stuart Drive and discharges stormwater runoff to Idalia;
- The Wulguru east drain flows down the hill from Bellevue Court, along Hynch Street, under Stuart drive and down to Normanby Street and discharges stormwater runoff to the Stuart Creek floodplain; and
- Stormwater runoff in between north and east drains accumulates at the race course area of Cluden through surface and sub-surface drains and discharges into Idalia drain through culverts underneath Racecourse Road.

The area south of Racecourse Road, directly adjacent to the Cluden Park Race Course is low lying and results in significant ponding.

Additionally for events 50 Year ARI or greater there are surface flows along Normanby Street towards Racecourse Road.

There are a number of underground pipe systems within the Wulguru area. These systems include:

- 1/900 RCP runs east down Rayleigh Street before it becomes 2/900 RCPs which run north and then converge into 1/1275 RCP at University Drive.
- 1/900 RCP runs east along Hargreaves Street and discharges into the ***Wulguru north drain***.
- 1/1050 RCP runs from behind residences at the top of Lexington Drive before running east towards Wright Street and becoming a 1/1200 RCP which then runs down Haldane Street and discharges into the ***Wulguru north drain*** at Edison Street.
- 1/1650 RCP discharges into the ***Wulguru northeast drain***. It connects to a 1/1650 RCP which runs south-east along Stuart Drive before downsizing to a 1/900 RCP after Marconi Street and runs to Wright Street. At Wright Street 2/900 RCP branch off of the Stuart Street Pipe and runs south-west before becoming a 1/900 RCP at Neelsen Street. 1/1200 RCP connects to the 1/1650 RCP on Stuart Drive at Marconi Street. The 1/1200 RCP becomes a 1/1050 at Burnett Crescent and which then becomes a 1/900 RCP at Jenner Street. The 1/900 RCP continues south-west along Marconi Street to the inlet behind residents on Faraday Street and Kelvin Street. At Faraday Street the 1/900 RCP connects with a 1/1050 RCP which runs to Wright Street and then north-east on Wright Street to Yaralla Street.
- 1/1200 RCP from Linden Crescent and discharges into the Wulguru East Drain.
- 1/1200 RCP at Diamantina Street near Stuart Drive becomes 2/1200 RCP which extends across and long Stuart Drive, then becomes 1/1350 RCP which discharges into the ***Wulguru east drain***.
- 1/900 RCP runs between Georgina Street and Gloucester Crescent. At Gloucester Crescent 1/900 RCP becomes a 1/1050 RCP to Normanby Street. 1/1050 RCP which runs south along Gloucester Crescent connects to the 1/1050 RCP which runs to Normanby Street.

A summary of the key flooding issues within the Wulguru area relative to the ARI of floods is provided in **Table 5-2** following inspection of the flood mapping as presented in **Appendix D**.

Table 5-2 Wulguru Area Flooding Issues

<table>
<tr><th>Event</th><th>Description</th></tr>
<tr><td>2 Year ARI</td><td>Generally the critical storm duration is:
1.5 hours in the residential area;
24 hours in the Wulguru North and East drains;
24 hours in the Stuart Creek and its floodplain; and
1.5 hours in the northeast drains and 72 hours at their outfalls prior Racecourse Road;
Flooding is generally contained to roads, drainage reserves, playground and flow paths.

There is some inundation of major roads including:
up to 0.1 m of water over the Stuart Drive section in between Edition Street and Marconi Street;
up to 0.3 m of water over Edison Street adjacent to Stuart Drive; and
up to 0.3 m of water over Newton Street near the intersection with University Road.
Flow velocities within the residential area are generally under 0.5 m/s, however there are higher velocities in Stuart Drive section in between Edition Street and Marconi Street (~ 0.93 m/s), Edison Street near the intersection with Stuart Drive (~ 0.8 m/s), Marconi Street near the intersection with Stuart Drive (~ 1.0 m/s), Newton Street near the intersection with University Road (~ 0.7 m/s) and Rayleigh Street (~ 1.3 m/s).

Stormwater runoff over Lexington Drive and Haldane Street reaches its maximum velocity up to 1.3 m/s near the intersection with Wright Street.</td></tr>
<tr><td>5 Year ARI</td><td>Generally the critical storm duration is:
1.5 hours in the residential area;
24 hours in the Wulguru North Drain;
24 hours in the upstream section of the Wulguru East Drain and 1.5hrs for the downstream areas of the drain;
24 hours in the Stuart Creek and its floodplain; and
1.5 hours in the northeast drains and 72 hours at their outfalls prior Racecourse Road.
Flooding is generally contained to roads and drainage reserves, playground and flow paths. The Kindergarten on the corner of Stuart Drive and Marconi Street is experiencing inundation.

Inundation of major roads includes:
up to 0.16 m of water over the Stuart Drive section in between Edition Street and Marconi Street;
up to 0.39 m of water over Edison Street adjacent to Stuart Drive; and
up to 0.34 m of water over Newton Street near the intersection with University Road; and
Up to 0.3 m of water over Marconi Street near the Kindergarten.
Flow velocities within the residential area are generally under 0.8 m/s, however there are higher velocities in Stuart Drive section in between Edition Street and Marconi Street (~ 1.08 m/s), Edison Street near the intersection with Stuart Drive (~ 1.03 m/s), Marconi Street near the intersection with Stuart Drive (~ 1.13 m/s), Newton Street near the intersection with University Road (~ 0.8 m/s) and Rayleigh Street (~ 1.5 m/s).</td></tr>
</table>

Event	Description
	Stormwater runoff over Lexington Drive and Haldane Street reaches its maximum velocity up to 1.6 m/s near the intersection with Wright Street.
10 Year ARI	Generally the critical storm duration is: • 1.5 hours in the residential area; • 24 hours in the upper area of Wulguru North Drain and 1.5 hours in the downstream section of the drain; • 1.5 hours in the Wulguru East Drain; • 24 hours in the Stuart Creek and its floodplain; and • 1.5 hours in the northeast drains and 72 hours at their outfalls prior Racecourse Road. Flooding is generally contained to roads and drainage reserves, playground and flow paths with the exception of few residential lots inundated. The Kindergarten on the corner of Stuart Drive and Marconi Street is now completely inundated. Wulguru Community Centre is inundated partially. Inundation of major roads includes: • up to 0.18 m of water over the Stuart Drive section in between Edition Street and Marconi Street; • 0.38 m of water over Newton Street at the intersection with University Drive; • up to 0.4 m of water over the entrance of Edison Street at Stuart Drive; and • up to 0.4 m of water over Marconi Street near the Kindergarten. Flow velocities within the residential area are generally under 0.8 m/s, however there are higher velocities in Stuart Drive section in between Edition Street and Marconi Street (~ 1.2 m/s), Edison Street near the intersection with Stuart Drive (~ 1.1 m/s), Marconi Street near the intersection with Stuart Drive (~ 1.2 m/s), Newton Street near the intersection with University Road (~ 0.87 m/s) and Rayleigh Street (~ 1.6 m/s). Stormwater runoff over Lexington Drive and Haldane Street reaches its maximum velocity up to 1.8 m/s near the intersection with Wright Street.
20 Year ARI	Generally the critical storm duration is: • 1.5 hours in the residential area; • 1.5 hours in the Wulguru North, Northeast and East drains; • 72 hours at the low-lying area in between Cluden Racecourse and Racecourse Road.; and • 24 hours in the Stuart Creek and its floodplain. Flooding is generally contained to roads and drainage reserves, playground and flow paths however there is increasing inundation in the area between Marconi Street and Edison Street and their intersections with Stuart Drive. The inundation is increasing over the sporting fields located behind Wulguru State School. The Kindergarten on the corner of Stuart Drive and Marconi Street is completely inundated. Inundation of major roads includes: • up to 0.12 m of water over all lanes of University Road adjacent to the Caravan Park; • up to 0.45 m of water over Newton Street at the intersection with University Road; • 0.4 m of water over Edison Street at the intersection with Stuart Drive, further down the street is 0.2 m of water overtopping the street; • 0.15 m of water over Stuart Drive south of the roundabout with Edison Street; and • 0.4 m of water over Marconi Street at the intersection with Stuart Drive. Flow velocities within the residential area are generally under 0.8 m/s, however there are higher velocities in Stuart Drive section in between Edition Street and Marconi Street (~ 1.3 m/s), Edison Street (~ 1.3 m/s), Marconi Street near the intersection with Stuart Drive (~ 1.5 m/s), Newton Street near the intersection with University Road (~ 0.9 m/s) and

Event	Description
	Rayleigh Street (~ 1.7 m/s). Stormwater runoff over Lexington Drive and Haldane Street reaches its maximum velocity up to 1.9 m/s near the intersection with Wright Street.
50 Year ARI	Generally the critical storm duration is: • 1 – 1.5 hours in the residential area; • 1.5 hours in the Wulguru North drain, with the exception of the middle of the drain at 1 hour; • 1.5 hours in the Wulguru Northeast drains and 72 hours at their outfalls prior Racecourse Road; • 1.5 hours in the Wulguru East drain; and • 24 hours in the Stuart Creek and 1.5 hours in its floodplain. Flooding is generally contained to roads and drainage reserves, playground and flow paths but is spreading in few residential areas beside Wulguru drains. There is also a wide spread inundation on the playground of Wulguru Sate School and Community Centre. The inundation is increasing over the sporting fields located behind Wulguru State School. The Kindergarten on the corner of Stuart Drive and Marconi Street is completely inundated. Inundation of major roads includes: • up to 0.2 m of water over all four lanes of University Road adjacent to the Caravan Park; • up to 0.5 m of water over Edison Street prior to the intersection with Stuart Drive; • 0.3 m of water over Marconi Street prior to the intersection with Stuart Drive; and • up to 0.2 m of water over Stuart Drive both north and south of the Edison Street roundabout. Flow velocities within the residential area are generally under 0.8 m/s, however there are higher velocities in Stuart Drive section in between Edition Street and Marconi Street (~ 1.39 m/s), Edison Street (~ 1.34 m/s), Marconi Street near the intersection with Stuart Drive (~ 1.6 m/s), Newton Street near the intersection with University Road (~ 1.08 m/s) and Rayleigh Street (~ 1.8 m/s). Stormwater runoff over Lexington Drive and Haldane Street reaches its maximum velocity up to 2.0 m/s near the intersection with Wright Street.
100 Year ARI	Generally the critical storm duration is: • 1.5 hours for the residential area and the Wulguru drains; • 24 hours for the Stuart Creek and its flood plain; and • 72 hours for the low-lying area in between Racecourse Road and Cluden Racecourse and the Cluden Racecourse pond. Flooding is generally contained to roads and drainage reserves, playground and flow paths but is spreading in few residential areas beside Wulguru drains. There is also a wide spread inundation on the playground of Wulguru Sate School and Community Centre. Inundation of major roads includes: • up to 0.22 m of water over all four lanes of University Road adjacent to the Caravan Park; • up to 0.52 m of water over Edison Street prior to the intersection with Stuart Drive; • 0.4 m of water over Marconi Street prior to the intersection with Stuart Drive;

<table>
<tr><th>Event</th><th>Description</th></tr>
<tr><td></td><td>and
• up to 0.24 m of water over Stuart Drive in between Edison Street and Marconi Street.

Flow velocities within the residential area are generally under 0.8 m/s, however there are higher velocities in Stuart Drive section in between Edition Street and Marconi Street (~ 1.52 m/s), Edison Street (~ 1.4 m/s), Marconi Street near the intersection with Stuart Drive (~ 1.7 m/s), Newton Street near the intersection with University Road (~ 1.1 m/s) and Rayleigh Street (~ 1.89 m/s).

Stormwater runoff over Lexington Drive and Haldane Street reaches its maximum velocity up to 2.1 m/s near the intersection with Wright Street.</td></tr>
<tr><td>200 Year ARI</td><td>Generally the critical storm duration is:

• 1.5 hours for the residential area and the Wulguru drains;
• 24 hours for the Stuart Creek and its flood plain and the low-lying area in between Racecourse Road and Cluden Racecourse; and
• 72 hours for the Cluden Racecourse pond.

Flooding is generally contained to roads and drainage reserves, playground and flow paths but is spreading in few residential areas beside Wulguru drains. There is also a wide spread inundation on the playground of Wulguru Sate School and Community Centre.

Inundation of major roads includes:
• up to 0.25 m of water over all four lanes of University Road adjacent to the Caravan Park;
• up to 0.54 m of water over Edison Street prior to the intersection with Stuart Drive;
• 0.49 m of water over Marconi Street prior to the intersection with Stuart Drive; and
• up to 0.25 m of water over Stuart Drive in between Edison Street and Marconi Street.

Flow velocities within the residential area are generally under 0.8 m/s, however there are higher velocities in Stuart Drive section in between Edition Street and Marconi Street (~ 1.6 m/s), Edison Street (~ 1.5 m/s), Marconi Street near the intersection with Stuart Drive (~ 1.75 m/s), Newton Street near the intersection with University Road (~ 1.2 m/s) and Rayleigh Street (~ 1.95 m/s).

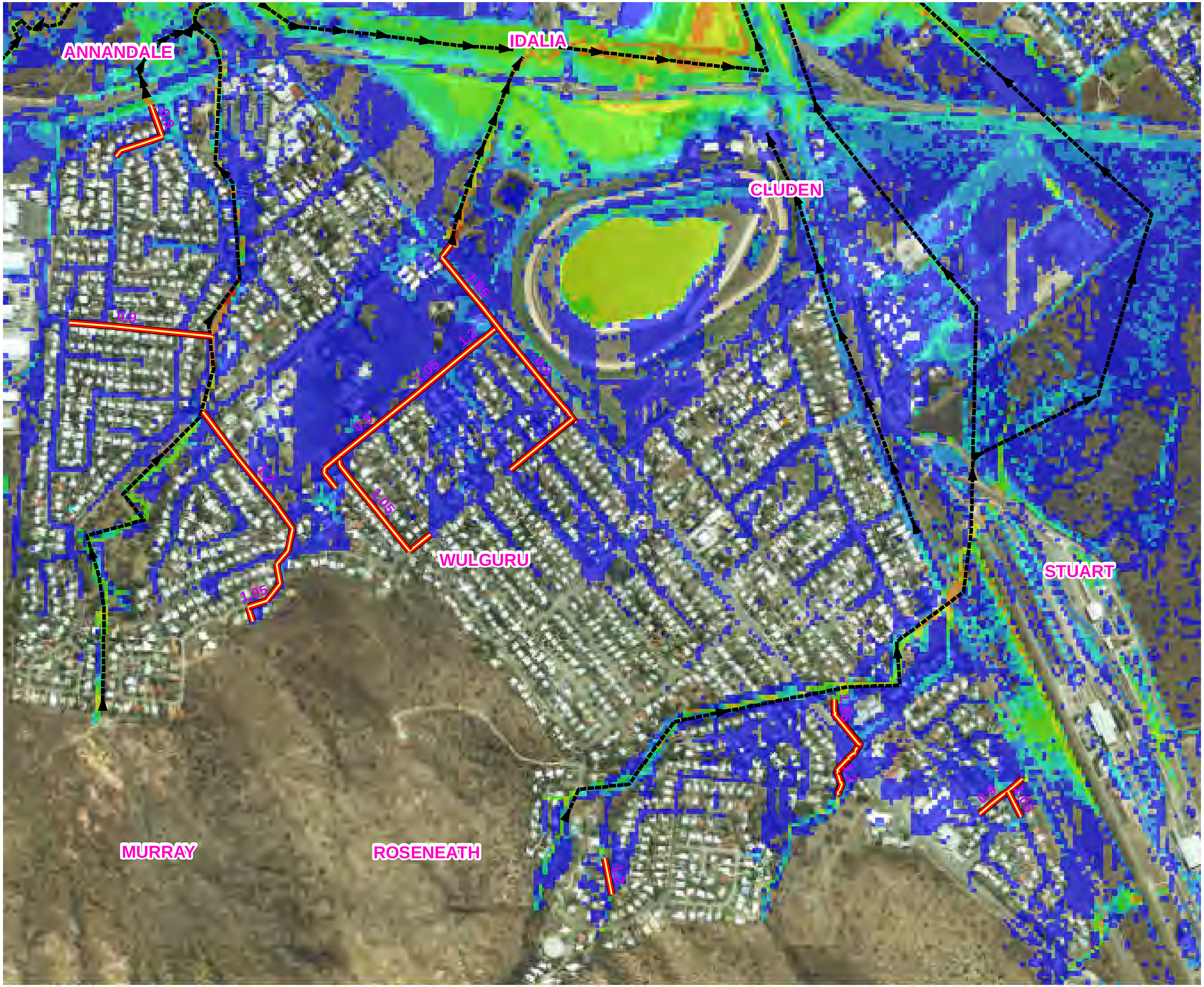
Stormwater runoff over Lexington Drive and Haldane Street reaches its maximum velocity up to 2.3 m/s near the intersection with Wright Street.</td></tr>
<tr><td>500 Year ARI</td><td>Generally the critical storm duration is:

• 1.5 hours for the residential area and the Wulguru drains;
• 24 hours for the Stuart Creek and its flood plain and the low-lying area in between Racecourse Road and Cluden Racecourse; and
• 18 hours for the Cluden Racecourse pond.

Flooding is generally contained to roads and drainage reserves, playground and flow paths but is spreading in few residential areas beside Wulguru drains. There is also a wide spread inundation on the playground of Wulguru Sate School and Community Centre.

Inundation of major roads includes:
• up to 0.27 m of water over all four lanes of University Road adjacent to the Caravan Park;
• up to 0.58 m of water over Edison Street prior to the intersection with Stuart Drive;
• 0.52 m of water over Marconi Street prior to the intersection with Stuart Drive; and</td></tr>
</table>

Event	Description
	• up to 0.26 m of water over Stuart Drive in between Edison Street and Marconi Street. Flow velocities within the residential area are generally under 0.8 m/s, however there are higher velocities in Stuart Drive section in between Edition Street and Marconi Street (~ 1.9 m/s), Edison Street (~ 1.53 m/s), Marconi Street near the intersection with Stuart Drive (~ 1.77 m/s), Newton Street near the intersection with University Road (~ 1.26 m/s) and Rayleigh Street (~ 1.96 m/s). Stormwater runoff over Lexington Drive and Haldane Street reaches its maximum velocity up to 2.46 m/s near the intersection with Wright Street.
PMF	Generally the critical storm duration is: • 1.5 hours in the residential area, the Wulguru drains, the Stuart Creek and its flood plain and the low-lying area in between Racecourse Road and Cluden Racecourse; and • 18 hours in the Cluden Racecourse pond and the residential area beside Stuart Drive in Stuart suburb. Flooding is generally contained to roads and drainage reserves, playground and flow paths but is spreading further in few residential areas beside Wulguru drains. There is also a wide spread inundation on the playground of Wulguru Sate School and Community Centre. Inundation of major roads includes: • up to 0.52 m of water over all four lanes of University Road adjacent to the Caravan Park; • up to 0.73 m of water over Edison Street prior to the intersection with Stuart Drive; • 0.54 m of water over Marconi Street prior to the intersection with Stuart Drive; and • up to 0.35 m of water over Stuart Drive in between Edison Street and Marconi Street. Flow velocities within the residential area are generally under 0.8 m/s, however there are higher velocities in Stuart Drive section in between Edition Street and Marconi Street (~ 2.0 m/s), Edison Street (~ 1.63 m/s), Marconi Street near the intersection with Stuart Drive (~ 1.88 m/s) and Newton Street near the intersection with University Road (~ 1.33 m/s). Stormwater runoff over Lexington Drive and Haldane Street reaches its maximum velocity up to 3.07 m/s near the intersection with Wright Street.



GORDON CREEK FLOOD STUDY
Major Flow Paths

Wulguru

FIGURE 5-2

LEGEND

Drainage Flow Direction

UnderGroundPipes

100 Y ARI Water Depth (m)

- 0.01 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- 3 - 25

N

City of Townsville

SCALE: 1:8,000 @A3

100 50 0 100 200 Metres

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Idalia

Figure 5-3 outlines the key drainage features within Idalia. This area receives stormwater runoff from the eastern part of Annandale and Murray, the northern part of Wulguru and the racecourse area of Cluden. In Idalia, Fairfield Waters Lake system and a number of surface and sub-surface drains carry stormwater runoff and discharge to Gordon Creek via culverts underneath Abbott Street. Underground drainage details are provided in **Appendix-C**.

A summary of the key flooding issues within the Idalia area relative to the ARI of floods is provided in **Table 5-3** following inspection of the flood mapping as presented in **Appendix D**

Table 5-3 Flooding Issues in Idalia

Event	Description
2 Year ARI	Generally the critical storm duration is: • 1.5 hours in the residential area; and • 72 hours in the Fairfield Waters Lakes and drains; Flooding is mostly contained to roads, drainage reserves and lakes. There is some inundation of major roads including: • up to 0.6 m of water over Abbott Street in between two railway culverts; • up to 0.22 m of water over Bruce Highway near the intersection with Jurekey Street; • up to 0.125 m of water over Oonoonba Road near Oonoonba State School; • up to 0.21 m of water over Lakeside Drive near the intersection with Oonoonba Road; • up to 0.48 m of water over Fairfield Waters Drive near the intersection with Village Drive; and • up to 0.35 m of water over Kokoda Street. Flow velocities within the residential area are generally under 0.5 m/s, however there are higher velocities in Bruce Highway near the intersection with Jurekey Street (~ 1.0 m/s) and in Abbott Street near the intersection with Bruce Highway (~ 0.6 m/s).
5 Year ARI	Generally the critical storm duration is: • 1.5 hours in the residential area; and • 72 hours in the Fairfield Waters Lakes and drains; Flooding is mostly contained to roads, drainage reserves and lakes. There is some inundation of major roads including: • up to 0.7 m of water over Abbott Street in between two railway bridges; • up to 0.16 m of water over Racecourse Road near the intersection with Stuart Drive; • up to 0.24 m of water over Bruce Highway near the intersection with Jurekey Street; • up to 0.15 m of water over Oonoonba Road near Oonoonba State School; • up to 0.24 m and 0.18 m of water over Lakeside Drive near the intersection with Oonoonba Road and Racecourse Road respectively; • up to 0.51 m of water over Fairfield Waters Drive near the intersection with Village Drive; and • up to 0.38 m of water over Kokoda Street. Flow velocities within the residential area are generally under 0.5 m/s, however there are higher velocities in Bruce Highway near the intersection with Jurekey Street (~ 1.2 m/s)

Event	Description
	and in Abbott Street near the intersection with Bruce Highway (~ 0.63 m/s).
10 Year ARI	Generally the critical storm duration is: • 1.5 hours in the residential area; and • 72 hours in the Fairfield Waters Lakes and drains; Flooding is mostly contained to roads, drainage reserves and lakes. There is some inundation of major roads including: • up to 0.8 m of water over Abbott Street in between two railway bridges; • up to 0.2 m of water over Racecourse Road near the intersection with Stuart Drive; • up to 0.27 m of water over Bruce Highway near the intersection with Jurekey Street; • up to 0.2 m of water over Oonoonba Road near Oonoonba State School; • up to 0.3 m and 0.24 m of water over Lakeside Drive near the intersection with Oonoonba Road and Racecourse Road respectively; • up to 0.53 m of water over Fairfield Waters Drive near the intersection with Village Drive; and • up to 0.4 m of water over Kokoda Street. Flow velocities within the residential area are generally under 0.5 m/s, however there are higher velocities in Bruce Highway near the intersection with Jurekey Street (~ 1.29 m/s) and in Abbott Street near the intersection with Bruce Highway (~ 0.69 m/s).
20 Year ARI	Generally the critical storm duration is: • 1.5 hours in the residential area; and • 72 hours in the Fairfield Waters Lakes and drains; Flooding is mostly contained to roads, drainage reserves and lakes, but is spreading beside Kokoda Street. There is some inundation of major roads including: • up to 0.88 m of water over Abbott Street in between two railway bridges; • up to 0.3 m of water over Racecourse Road near the intersection with Stuart Drive; • up to 0.3 m of water over Bruce Highway near the intersection with Jurekey Street; • up to 0.31 m of water over Oonoonba Road near Oonoonba State School; • up to 0.31 m and 0.26 m of water over Lakeside Drive near the intersection with Oonoonba Road and Racecourse Road respectively; • up to 0.55 m of water over Fairfield Waters Drive near the intersection with Village Drive; and • up to 0.43 m of water over Kokoda Street. Flow velocities within the residential area are generally under 0.5 m/s, however there are higher velocities in Bruce Highway near the intersection with Jurekey Street (~ 1.34 m/s) and in Abbott Street near the intersection with Bruce Highway (~ 0.76 m/s).
50 Year ARI	Generally the critical storm duration is: • 1 to 2 hours in the residential area; • 18 hours in the Idalia drains and the southern part of Fairfiled Waters lake system; and • 72 hours in the northern parts of Fairfield Waters lake system. Flooding is mostly contained to roads, drainage reserves and lakes, but is spreading beside Kokoda Street. There is some inundation of major roads including: • up to 0.9 m of water over Abbott Street in between two railway bridges; • up to 0.36 m of water over Racecourse Road near the intersection with Stuart Drive;

Event	Description
	• up to 0.35 m of water over Bruce Highway near the intersection with Jurekey Street; • up to 0.34 m of water over Oonoonba Road near Oonoonba State School; • up to 0.36 m and 0.32 m of water over Lakeside Drive near the intersection with Oonoonba Road and Racecourse Road respectively; • up to 0.57 m of water over Fairfield Waters Drive near the intersection with Village Drive; and • up to 0.43 m of water over Kokoda Street. Flow velocities within the residential area are generally under 0.5 m/s, however there are higher velocities in Bruce Highway near the intersection with Jurekey Street (~ 1.51 m/s) and in Abbott Street near the intersection with Bruce Highway (~ 0.97 m/s).
100 Year ARI	Generally the critical storm duration is: • 1.5 hours in the residential area; • 18 hours in the southern part of Fairfiled Waters lake system; and • 72 hours in the northern parts of Fairfield Waters lake system and Idalia drains. Flooding is mostly contained to roads, drainage reserves and lakes, but is spreading beside Kokoda Street. There is some inundation of major roads including: • up to 0.99 m of water over Abbott Street in between two railway bridges; • up to 0.41 m of water over Racecourse Road near the intersection with Stuart Drive; • up to 0.37 m of water over Bruce Highway near the intersection with Jurekey Street; • up to 0.35 m of water over Oonoonba Road near Oonoonba State School; • up to 0.37 m and 0.38 m of water over Lakeside Drive near the intersection with Oonoonba Road and Racecourse Road respectively; • up to 0.59 m of water over Fairfield Waters Drive near the intersection with Village Drive; and • up to 0.44 m of water over Kokoda Street. Flow velocities within the residential area are generally under 0.5 m/s, however there are higher velocities in Bruce Highway near the intersection with Jurekey Street (~ 1.54 m/s) and in Abbott Street near the intersection with Bruce Highway (~ 1.01 m/s).
200 Year ARI	Generally the critical storm duration is: • 1.5 hours in the residential area; • 18 hours in the southern part of Fairfield Waters lake system and Idalia drains; and 72 hours in the northern parts of Fairfield Waters lake system. Flooding is mostly contained to roads, drainage reserves and lakes, but is spreading further beside Kokoda Street. There is some inundation of major roads including: • up to 1.1 m of water over Abbott Street in between two railway bridges; • up to 0.5 m of water over Racecourse Road near the intersection with Stuart Drive; • up to 0.39 m of water over Bruce Highway near the intersection with Jurekey Street; • up to 0.40 m of water over Oonoonba Road near Oonoonba State School; • up to 0.39 m and 0.46 m of water over Lakeside Drive near the intersection with Oonoonba Road and Racecourse Road respectively; • up to 0.62 m of water over Fairfield Waters Drive near the intersection with Village Drive; and • up to 0.45 m of water over Kokoda Street. Flow velocities within the residential area are generally under 0.5 m/s, however there are higher velocities in Bruce Highway near the intersection with Jurekey Street (~ 1.6 m/s)

Event	Description
	and in Abbott Street near the intersection with Bruce Highway (~ 1.08 m/s).
500 Year ARI	Generally the critical storm duration is: • 1.5 hours and 72 hours in the residential area; • 18 hours in the southern part of Fairfield Waters lake system and Idalia drains; and 72 hours in the northern parts of Fairfield Waters lake system and the Pony Club racecourse. Flooding is mostly contained to roads, drainage reserves and lakes, but is spreading further beside Kokoda Street. There is some inundation of major roads including: • up to 1.2 m of water over Abbott Street in between two railway bridges; • up to 0.6 m of water over Racecourse Road near the intersection with Stuart Drive; • up to 0.49 m of water over Bruce Highway near the intersection with Jurekey Street; • up to 0.70 m of water over Oonoonba Road near Oonoonba State School; • up to 0.4 m and 0.6 m of water over Lakeside Drive near the intersection with Oonoonba Road and Racecourse Road respectively; • up to 0.71 m of water over Fairfield Waters Drive near the intersection with Village Drive; and • up to 0.48 m of water over Kokoda Street. Flow velocities within the residential area are generally under 0.5 m/s, however there are higher velocities in Bruce Highway near the intersection with Jurekey Street (~ 1.64 m/s) and in Abbott Street near the intersection with Bruce Highway (~ 1.1 m/s).
PMF	Generally the critical storm duration is 1.5 hours in all over Idalia except the Pony Club racecourse, which is 24 hours. There is a significant widespread flooding in all over Idalia. There is some inundation of major roads including: • up to 1.8 m of water over Abbott Street in between two railway bridges; • up to 1.2 m of water over Racecourse Road near the intersection with Stuart Drive; • up to 1.1 m of water over Bruce Highway near the intersection with Jurekey Street; • up to 1.2 m of water over Oonoonba Road near Oonoonba State School; • up to 0.8 m and 1.2 m of water over Lakeside Drive near the intersection with Oonoonba Road and Racecourse Road respectively; • up to 1.5 m of water over Fairfield Waters Drive near the intersection with Village Drive; and • up to 1.03 m of water over Kokoda Street. Flow velocities within the residential area are generally under 0.5 m/s, however there are higher velocities in Bruce Highway near the intersection with Jurekey Street (~ 1.8 m/s) and in Abbott Street near the intersection with Bruce Highway (~ 1.2 m/s).

GORDON CREEK FLOOD STUDY
Major Flow Paths
Idalia

FIGURE 5-3

LEGEND

Drainage Flow Direction

UnderGroundPipes

100 Y ARI Water Depth (m)

- 0.01 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- 3 - 25

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100 50 0 100 200 Metres

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Oonoonba

There is no defined open drain in Oonoonba except few sub-surface drains. Stormwater runs off roads, streets and properties and flows to Gordon Creek either by gravity or sub-surface drains. The Gordon Creek discharges all the stormwater runoff coming from Annandale, Murray, Wulguru, Idalia and part of Stuart Creek floodplain to the Ross River. **Figure 5-4** outlines the key drainage features of the Oonoonba area.

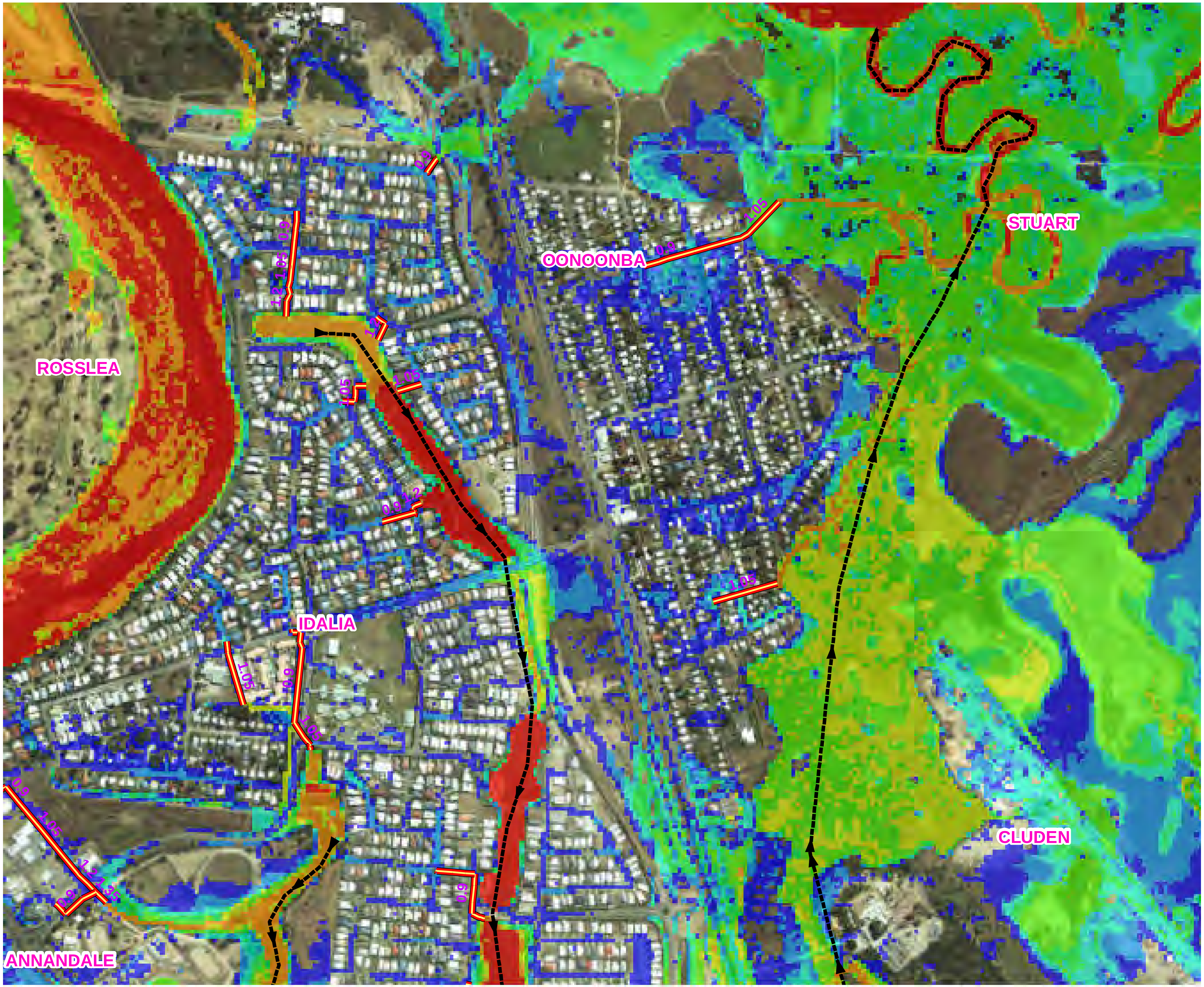
A summary of the key flooding issues within the Oonoonba area relative to the ARI of floods is provided in **Table 5-4** following inspection of the flood mapping as presented in **Appendix D**.

Table 5-4 Flooding Issues in Oonoonba

Event	Description
2 Year ARI	Generally the critical storm duration is: • 24 hours in the residential area; and • 72 hours in the Gordon Creek and its floodplain; Flooding is mostly contained to roads except some localized flooding. The localized flooding occurs around the intersection of Frederick Street and Findlater Street and the intersection of Keenan Street and Mcalister Street. There is some inundation of major roads including: • up to 0.37 m of water over the intersection of Frederick Street and Findlater Street; and • up to 0.35 m of water over Mcalister Street near the intersection with Keenan Street; Flow velocities within the residential area are generally under 0.5 m/s.
5 Year ARI	Generally the critical storm duration is: • 1.5 hour and 24 hours in the residential areas; and • 72 hours in the Gordon Creek and its floodplain; Flooding is mostly contained to roads except some localized flooding. The localized flooding occurs around the Frederick Street, the Mcalister Street and the Mcpherson Street. There is some inundation of major roads including: • up to 0.4 m of water over the intersection of Frederick Street and Findlater Street; and up to 0.38 m and 0.53 m of water over Mcalister Street near the intersection with Keenan Street and Mcpherson Street respectively. Flow velocities within the residential area are generally under 0.5 m/s.
10 Year ARI	Generally the critical storm duration is: • 1.5 hour and 24 hours in the residential areas; and • 72 hours in the Gordon Creek and its floodplain; Flooding is mostly contained to roads except some localized flooding. The localized flooding occurs around the Frederick Street, the Mcalister Street and the Mcpherson Street. The flooding extent spreads further in this ARI. There is some inundation of major roads including: • up to 0.44 m of water over the intersection of Frederick Street and Findlater Street; and • up to 0.4 m and 0.53 m of water over Mcalister Street near the intersection with Keenan Street and Mcpherson Street respectively. Flow velocities within the residential area are generally under 0.5 m/s.

Event	Description
20 Year ARI	Generally the critical storm duration is: • 1.5 hour and 24 hours in the residential areas; and • 72 hours in the Gordon Creek and its floodplain; Flooding is mostly contained to roads except some localized flooding. The localized flooding occurs around the Frederick Street, the Mcalister Street and the Mcpherson Street. The flooding extent spreads further in this ARI. There is some inundation of major roads including: • up to 0.5 m of water over the intersection of Frederick Street and Findlater Street; and • up to 0.44 m and 0.53 m of water over Mcalister Street near the intersection with Keenan Street and Mcpherson Street respectively. Flow velocities within the residential area are generally under 0.5 m/s.
50 Year ARI	Generally the critical storm duration is: • 1.0 hour to 2 hours in the residential areas; • 6 hours in the upstream of the Gordon Creek and its floodplain; and • 72 hours in the downstream of Gordon Creek up to the Ross River and its floodplain; Flooding is mostly contained to roads except some localized flooding. The localized flooding occurs around the Frederick Street, the Mcalister Street and the Mcpherson Street. The flooding extent spreads further in this ARI. There is some inundation of major roads including: • up to 0.53 m of water over the intersection of Frederick Street and Findlater Street; and • up to 0.44 m and 0.57 m of water over Mcalister Street near the intersection with Keenan Street and Mcpherson Street respectively. Flow velocities within the residential area are generally under 0.5 m/s.
100 Year ARI	Generally the critical storm duration is: • 1.5 hours in the residential area; and • 72 hours in the Gordon Creek and its floodplain; Flooding is mostly contained to roads except some localized flooding. The localized flooding occurs around the Frederick Street, the Mcalister Street and the Mcpherson Street. The flooding extent spreads further in this ARI. There is some inundation of major roads including: • up to 0.55 m of water over the intersection of Frederick Street and Findlater Street; and • up to 0.45 m and 0.66 m of water over Mcalister Street near the intersection with Keenan Street and Mcpherson Street respectively. Flow velocities within the residential area are generally under 0.5 m/s.
200 Year ARI	Generally the critical storm duration is: • 1.5 hours in the residential area; • 24 hours in the upstream of Gordon Creek and its floodplain; and • 72 hours in the downstream of Gordon Creek up to the Ross River and its floodplain; Flooding is mostly contained to roads except some localized flooding. The localized flooding occurs around the Frederick Street, the Mcalister Street and the Mcpherson Street. The flooding extent spreads further in this ARI. There is some inundation of major roads including: • up to 0.57 m of water over the intersection of Frederick Street and Findlater Street; and

Event	Description
	• up to 0.46 m and 0.78 m of water over Mcalister Street near the intersection with Keenan Street and Mcpherson Street respectively. Flow velocities within the residential area are generally under 0.5 m/s.
500 Year ARI	Generally the critical storm duration is: • 1.5 hours and 72 hours in the residential areas; • 24 hours in the upstream of Gordon Creek and its floodplain; and • 72 hours in the downstream of Gordon Creek up to the Ross River and its floodplain. Flooding in the residential area is significant. The localized flooding depth and extent increases further around the Frederick Street, the Mcalister Street and the Mcpherson Street. The flooding extent spreads further in this ARI. There is some inundation of major roads including: • up to 0.6 m of water over the intersection of Frederick Street and Findlater Street; and • up to 0.47 m and 1.1 m of water over Mcalister Street near the intersection with Keenan Street and Mcpherson Street respectively; Flow velocities within the residential area are generally under 0.5 m/s, however there is higher velocity in Mcpherson Street (~ 0.9 m/s).
PMF	Generally the critical storm duration is: • 1.5 hours and 18 hours in the residential areas; and • 18 hours in the Gordon Creek and its floodplain; There is significant widespread flooding in most of the residential area. There is some inundation of major roads including: • up to 1.3 m of water over the intersection of Frederick Street and Findlater Street; and • up to 1.02 m and 1.5 m of water over Mcalister Street near the intersection with Keenan Street and Mcpherson Street respectively; Flow velocities within the residential area are generally under 0.75 m/s, however there is higher velocity in Mcpherson Street (~ 1.01 m/s).



GORDON CREEK FLOOD STUDY
Major Flow Paths

Oonoonba

FIGURE 5-4

LEGEND

Drainage Flow Direction

UnderGroundPipes

100 Y ARI Water Depth (m)

- 0.01 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- 3 - 25

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100 50 0 100 200 Metres

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5.2 Hydraulic Grade Line

There are four major flow paths/ open drains in the Gordon Creek catchment, which are contributing major portions of the flow in Gordon Creek. There is also flow in Gordon Creek from the Stuart Creek overflows. These four major flow paths, shown in **Figure 5-5**, have been considered for hydraulic grade line analysis. The major flow paths are:

- Wulguru-Idalia Drain;
- Murray-Annandale Drain;
- Annandale-Idalia-Gordon Creek Drain; and
- Wulguru-Stuart Drain.

In these flow paths, hydraulic grade lines for different ARIs have been extracted from the flood model results. Long-sections showing these hydraulic grade lines are provided in **Appendix E**. Note that the chainages for all flow paths start at the upstream end of the branches shown in **Figure 5-5**.

Review of the hydraulic grade-line results identifies the following issues:

Wulguru-Idalia Drain

This drain runs from north of Wulguru to Idalia and carries the stormwater runoff from the north of Wulguru, the racecourse area of Cluden and the part of Idalia before it discharges to Fairfield Waters Lake system. On its way it passes through the culverts under Edison Street, one internal street near Newton Street, University Road and Stuart Drive. Hydraulic grade line analysis shows that:

- *Edison Street Culvert*- model result shows overtopping in all ARIs but flood depth exceeds 0.2 m in more than 20 Year ARI;
- *Culvert near Newton Street*- overtops in all ARIs with flood depth greater than 0.2 m;
- *University Road Culvert*- has a flood immunity of 500 Year ARI; and
- Stuart Drive Culvert- overtops in more than 2 Year ARI and flood depth greater than 0.2 m exceeds in 50 Year ARI.

The greatest head-losses have been found in the Edision Street culvert and the University Road culvert.

Murray-Annandale Drain

The Murray-Annandale drain carries stormwater runoff from north-eastern part of Murray, Murray sport complex of Annandale and its surrounding area. This drain passes through the culverts under Robert Towns Boulevard, University Road, Gartrell Drive and Shahahan Drive. Hydraulic grade line analysis shows that:

- Culvert at Robert Towns Boulevard- has only 2 Year ARI flood immunity;
- University Road Culvert- has a flood immunity up to 500 Year ARI;

- Gartrell Drive Culvert- has a flood immunity of 50 Year ARI but flood depth over it exceeds 0.2 m beyond 200 Year ARI; and
- Shahahan Drive Culvert- overtops in 10 Year ARI but flood depth remains less than 0.2 m all rest of the ARIs including PMP.

Annandale-Idalia-Gordon Creek Drain

The Annandale-Idalia-Gordon Creek drain carries stormwater runoff from the north-eastern part of Murray, Murray sport complex of Annandale, Fairfield Waters lake system, Oonoonba and Cluden before discharging into the Ross River. This drain passes through the culverts under University Road, Sturt Drive, Lakeside Drive, Railway line and Abbott Street. Hydraulic grade line analysis shows that:

- University Road Culvert- has a flood immunity of 500 Year ARI and only overtops in PMF;
- Stuart Drive Culvert - overtops in 5 Year ARI but flood depth over it exceeds 0.2 m in 200 Year ARI;
- Lakeside Drive Culvert- has a flood immunity of 2 Year ARI;
- Railway line Culvert- has less than 2 Year ARI flood immunity; and
- Abbott Street Culvert –has less than 2 Year ARI flood immunity.

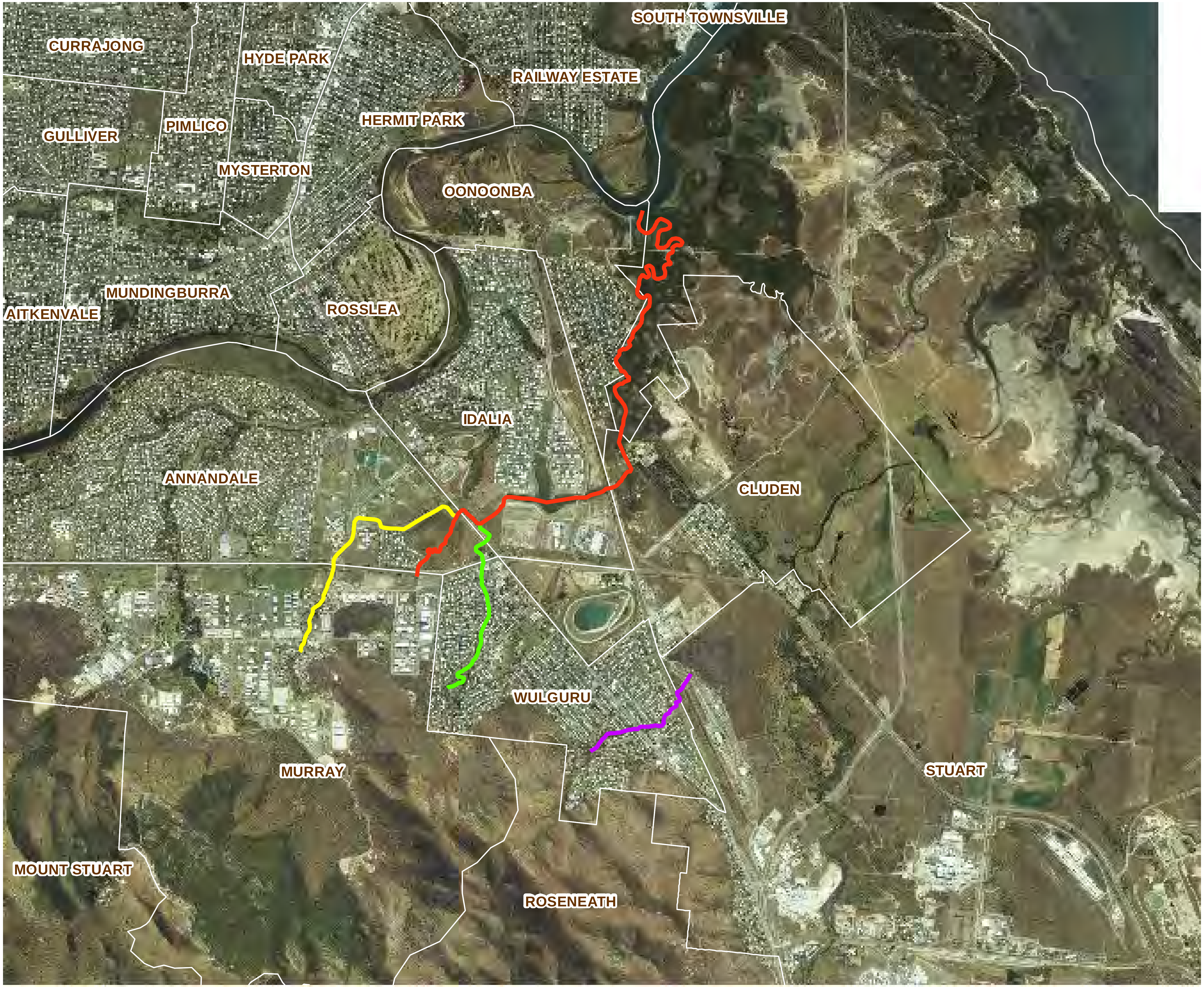
Wulguru-Stuart Drain

The Wulguru-Stuart Drain carries stormwater runoff from the south-eastern part of Wulguru and discharges to the floodplain of Stuart Creek. The drain has a steep slope of approximately 0.0167 (i.e. or 1.67% or 16 m/km) and it passes through the culverts under Stuart Drive and Normanby Street. Hydraulic grade line analysis shows that:

- Stuart Drive Culvert (at southern Wulguru)- has a flood immunity of 5 Year ARI.
- Normanby Street Culvert –has a flood immunity of 500 Year ARI; and
- Queensland Railway Culverts- both have flood 500 Year flood immunity.

GORDON CREEK FLOOD STUDY HGL Locations

Figure 5-5



LEGEND

- Wulguru-Idalia Drain
- Murray-AnnandaleDrain
- Annan-Idalia-GordonCk
- Wulguru-Stuart Drain

N

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SCALE: 1:30,000 @A3

350 175 0 350 700 1,050 Metres

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5.3 Flow Distributions

Flows at different locations of the Gordon Creek catchment have been calculated from the Gordon Creek model results. The locations have been selected based on the flood maps and the stormwater drainage paths. Maximum flows for the design flood events have been provided in **Table 5-5** at the locations shown in **Figure 5-6**. Note that the maximum flow is the maximum peak flow attained in one of the storm durations of a given ARI flood event. The peak flows in all storm durations for all ARIs have been presented in **Appendix-F**.

Table 5-5 Peak Flow Distribution Results

Locations	Peak Flow (m^3/s)								
	2 Y ARI	5 Y ARI	10 Y ARI	20 Y ARI	50 Y ARI	100 Y ARI	200 Y ARI	500 Y ARI	PMF
1	0.5	2.0	2.9	4.4	6.2	8.0	10.2	18.6	60.4
2	7.1	14.2	19.8	28.8	38.1	49.0	62.3	75.2	209.6
3	23.2	38.8	48.0	58.6	62.7	66.8	70.8	74.4	140.7
4	21.1	33.8	42.3	51.1	58.5	66.3	71.9	78.8	156.2
5	3.0	4.0	4.7	6.0	7.6	8.6	9.1	9.4	8.3
6	26.5	32.5	35.1	39.5	55.6	60.5	66.1	71.7	153.9
7	12.0	18.7	22.5	27.4	36.9	43.5	50.7	54.3	107.1
8	17.3	22.8	25.9	29.4	34.0	36.0	45.8	59.7	176.2
9	61.9	83.1	95.7	113.6	129.1	147.8	180.5	229.5	625.5
10	32.2	41.3	46.8	53.5	60.2	67.6	73.1	116.7	201.4
11	7.5	7.7	8.6	10.0	13.0	14.9	28.4	42.2	118.3
12	10.4	15.7	18.8	22.9	27.4	31.9	37.3	42.3	81.2

GORDON CREEK FLOOD STUDY
Peak Flow Distribution

Figure 5-6

LEGEND

- Flow Locations
- MIKE 11 Branches
- MIKE URBAN Links

N

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150 75 0 150 300 450 Metres

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DIGITAL FILE: Figure 5-6_FlowDistribution.mxd

5.4 Impact on Residential Properties

A summary of the number of residential properties impacted by flooding within the suburbs of the Study Area is provided in **Table 5-6**. The numbers of inundated residential properties are on the basis of 0.20 m water depth within the lot, which does not mean floor levels are exceeded (though in some cases they may be when floor levels are less 0.20 m above the ground). To undertake a comparison to floor levels would require survey of all floor levels within the study area.

Table 5-6 Summary of Inundated Residential Properties

Suburb	Number of Impacted Properties								
	2 Y	5 Y	10 Y	20 Y	50 Y	100 Y	200 Y	500 Y	PMF
Idalia	-	-	5	5	23	32	46	358	1075
Oonoonba	24	31	36	48	57	64	79	168	327
Wulguru	5	6	9	13	26	37	45	61	225
Cluden	2	2	2	3	3	3	3	11	78
Stuart	4	4	4	4	4	4	4	4	46
Annandale	-	-	-	1	1	2	2	2	8
Total	35	43	56	74	114	142	179	604	1759

5.5 Floodplain Hazard

The safety of people and potential for damage to property is dependent on both the depth of inundation and the velocity of the flood waters. Floodwaters that flow deep and swift are obviously more hazardous than those areas where flows are shallow and slow.

The degree of hazard varies across the floodplain in response to:

- flood severity;
- floodwater depth and velocity;
- rate of rise of floodwater;
- duration of flooding;
- evacuation capacity;
- population at risk;
- land-use;
- flood awareness; and
- warning time.

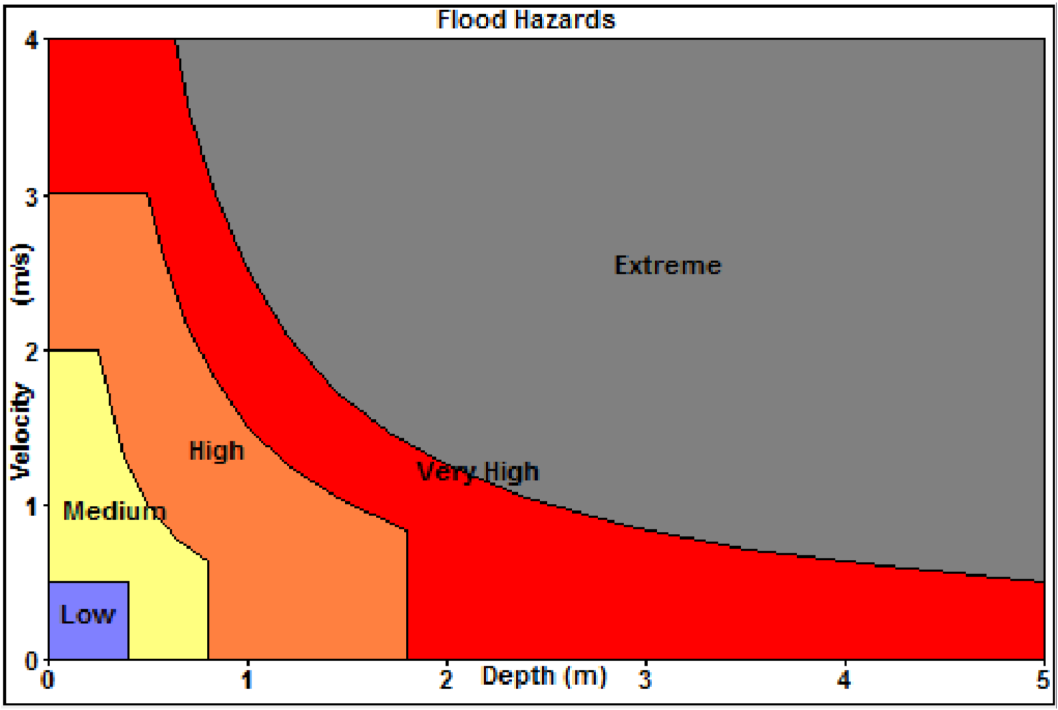
To assist with floodplain management it is necessary to determine the hazard and ensure land uses are suitably aligned. Five degrees of hazard have been adopted according to McConnell and Low (2000):

- **Low Hazard** – depth <0.4m and velocity <0.5m/s, suitable for cars;
- **Medium Hazard** – depth <0.8m, velocity <2m/s and velocity times depth <0.5, suitable for heavy vehicles and wading by able bodied adults;
- **High Hazard** – depth <1.8m, velocity <3m/s and velocity times depth <1.5, suitable for light construction (timber frame, brick veneer, etc.);

- **Very High Hazard** – velocity >0.5m/s and <4m/s with velocity times depth <2.5, suitable for heavy construction (steel frame, concrete, etc.); and
- **Extreme Hazard** – greater than very high, significant flow path development considered unsuitable and likely to significantly impact flood levels.

Prior to detailed assessment of floodplain hazard based on all the factors influencing hazard, preliminary assessment is often undertaken based on flood depth and velocity. **Figure 5-7** provides the basis for defining hazard as a function of depth and velocity as provided in McConnell and Low (2000).

Figure 5-7 Estimation of Flood Hazard



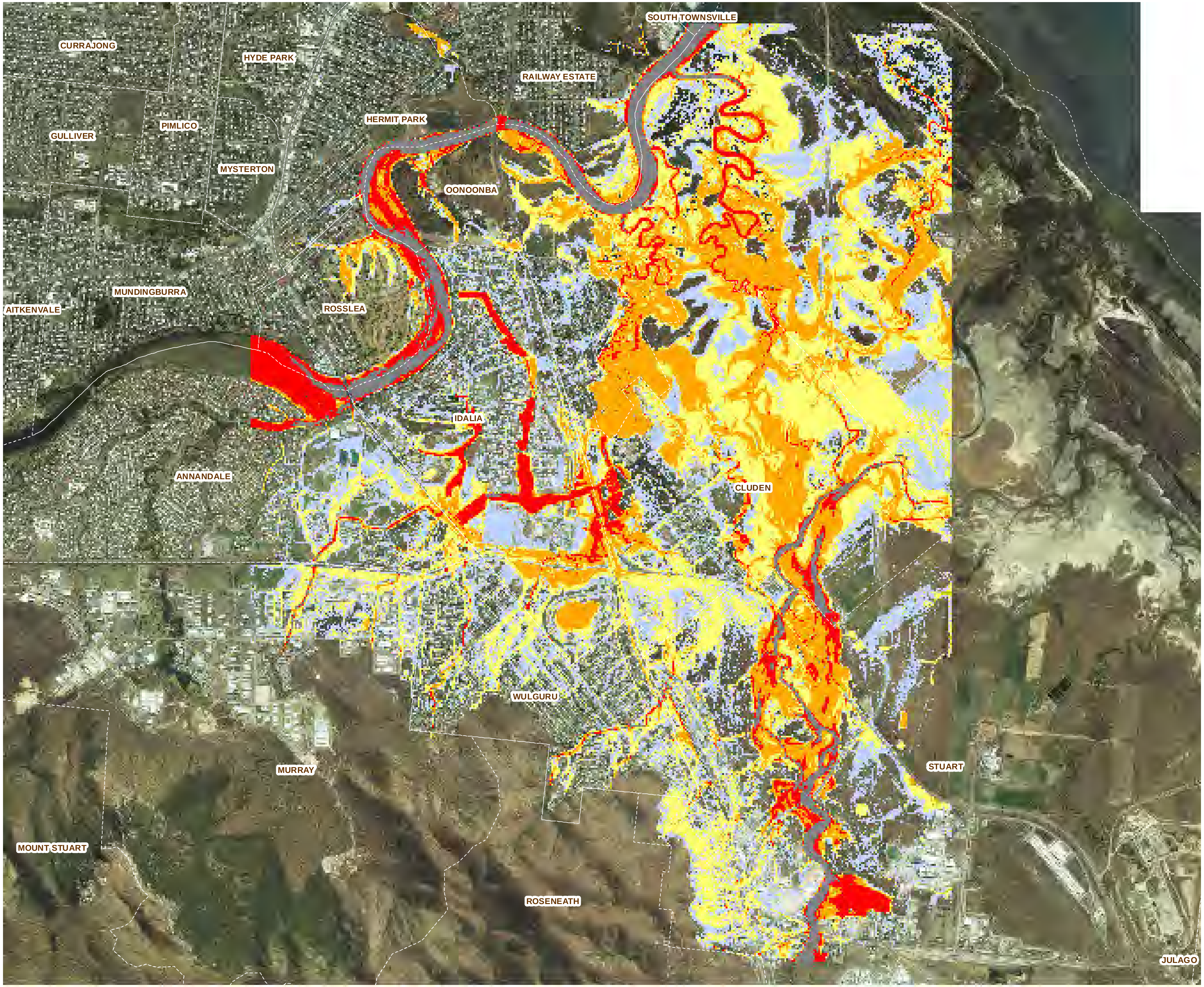
On the basis of the flood model results floodplain hazard has been mapped for the following events:

- **100 Year ARI** – representing the level of risk the *State Planning Policy* recommends for the Defined Flood Event*;*
- **500 Year ARI** – representing a rare event that is often used for design for critical infrastructure.
- **Probable Maximum Flood** – representing the extreme upper limit of flood hazard within the Douglas-Annandale floodplain.

Figures 5-8, **5-9** and **5-10** show the resulting floodplain hazard maps for the 100 Year ARI, 500 Year ARI and Probable Maximum Floods respectively. A summary of the number of residential properties within given hazard areas of the floodplain is provided in **Table 5-7**. The hazard category of a residential property has been determined based on the median cell value of that property.

Table 5-7 Floodplain Hazard Summary

Event	Number of Residential Properties				
	Low Hazard	Medium Hazard	High Hazard	Very High Hazard	Extreme Hazard
100 Year ARI	652	133	3	-	-
500 Year ARI	701	203	9	-	-
PMF	1142	1512	288	2	2



GORDON CREEK FLOOD STUDY 100 Year ARI HAZARD

Figure 5-8

LEGEND

- Low Hazard
- Medium Hazard
- High Hazard
- Very High Hazard
- Extreme Hazard

N

City of Townsville

SCALE: 1:30,000 @A3

200 100 0 200 400 600 800 1,000 Metres

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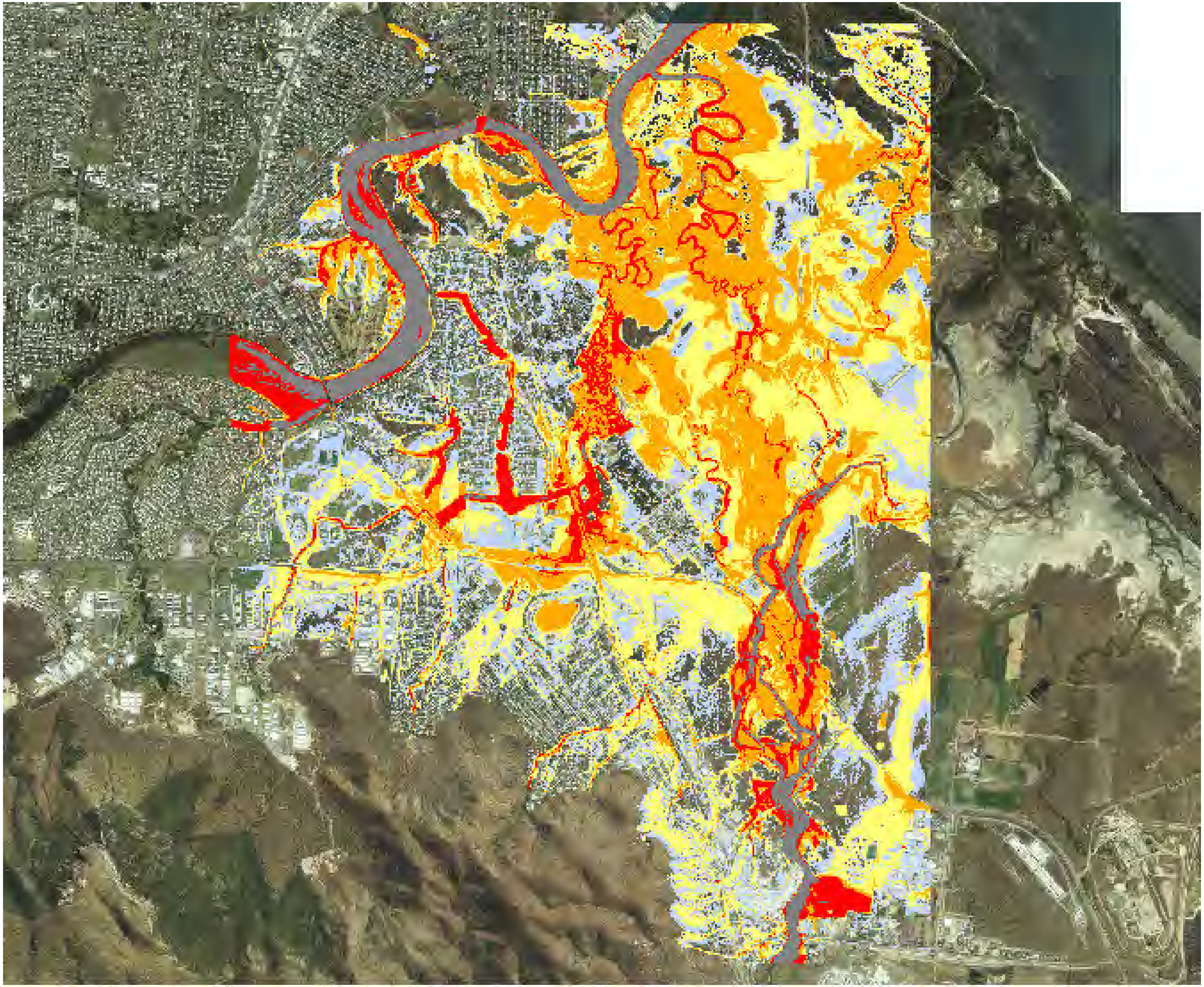

GORDON CREEK FLOOD STUDY 500 Year ARI HAZARD

Figure 5-9

LEGEND

- Low Hazard
- Medium Hazard
- High Hazard
- Very High Hazard
- Extreme Hazard

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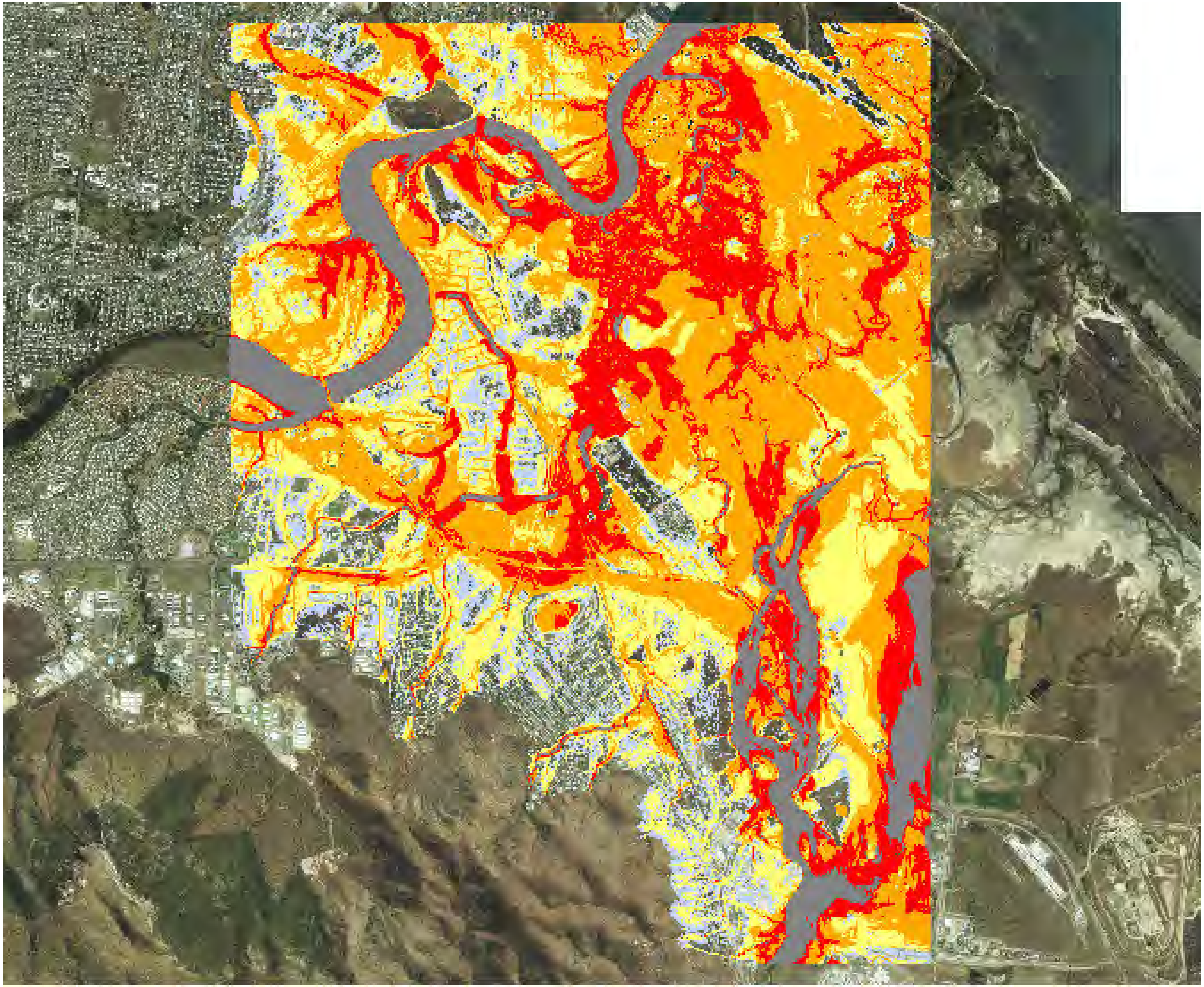

GORDON CREEK FLOOD STUDY PMP HAZARD

Figure 5-10

LEGEND

- Low Hazard
- Medium Hazard
- High Hazard
- Very High Hazard
- Extreme Hazard

N

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SCALE: 1:30,000 @A3

200 100 0 200 400 600 800 1,000 Metres

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5.6 Floodplain Planning Considerations

Flood Hazard Overlay Mapping

The draft City Plan for Townsville City Council considers the 100 Year ARI (1% AEP) flood as the Defined Flood Event (DFE) for establishing floor levels and providing planning controls for development. Flood Hazard Overlay maps have been prepared based on the following flood hazard criteria:

- Low Flood Hazard – areas of residual flood risk beyond the 100 Year ARI;
- Medium Flood Hazard – areas of shallower and slower moving flood waters in the 100 Year ARI as per the criteria in **Figure 5-11**;
- High Flood Hazard – areas of deeper and faster moving flood waters in the 100 Year ARI as per criteria in **Figure 5-11**.

These hazard maps differ from the previous hazard maps provided in Section 5-5 due to the different hazard criteria and flood probability.

Figure 5-11 Flood Hazard Overlay Definitions (Medium and High Hazard)

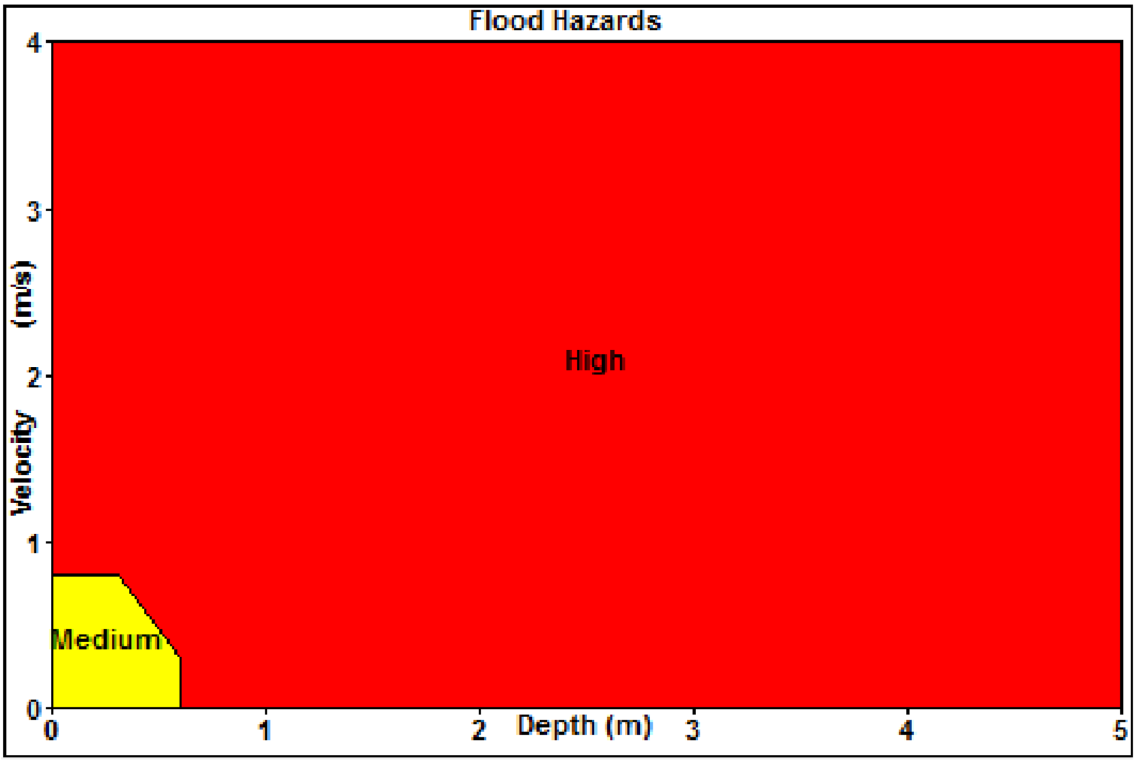
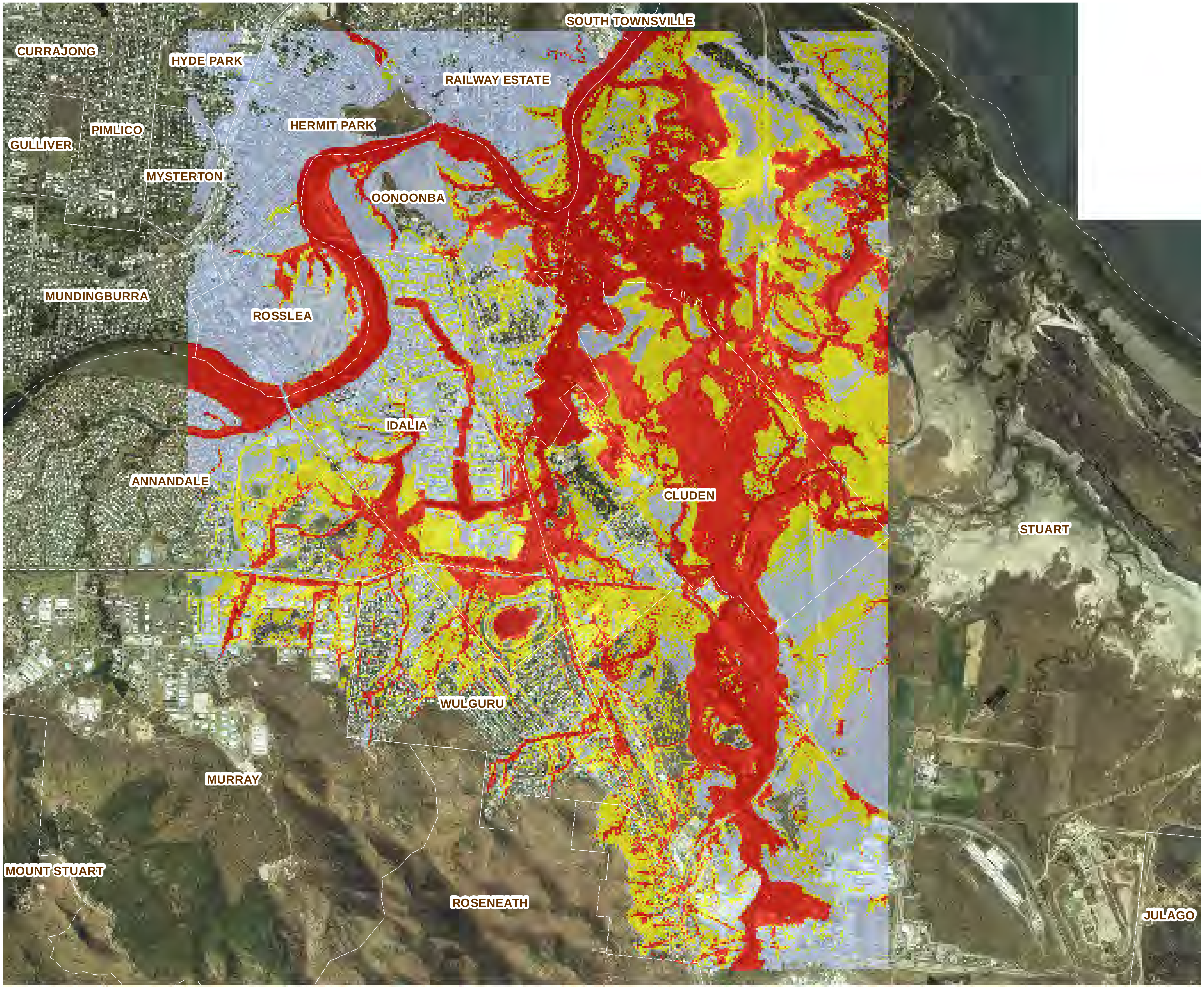


Figure 5-12 shows the flood hazard overlay map for the Gordon Creek area based on the above criteria.

GORDON CREEK FLOOD STUDY
Flood Hazard Overlay

Figure 5-12



LEGEND

Hazard Overlay

- Low
- Medium
- High

SCALE: 1:30,000 @A3

200 100 0 200 400 600 800 1,000 Metres

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DIGITAL FILE: Figure 5-12_FloodHz_Overlay.mxd

The new City Plan for Townsville proposes to adopt the 100 Year ARI flood as the Defined Event and will adopt a Flood Overlay map comprising three hazard categories for flooding:

- Low flood hazard- areas of residential flood risk beyond the 100 Year ARI;
- Medium flood hazard- areas of shallower and slower moving flood waters in the 100 Year ARI; and
- High flood hazard- areas of deeper and faster moving flood waters in the 100 Year ARI.

The number of properties falls under different hazard categories in Gordon Creek area is provided in Table 5-8.

Table 5-8 Number of properties under different hazard categories

Suburb	Low Flood Hazard Rating	Medium Flood Hazard Rating	High Flood Hazard Rating
Idalia	1136	62	-
Oonoonba	261	95	-
Wulguru	325	306	12
Cluden	94	69	-
Stuart	77	21	7
Annandale*	13	9	-

* *in this study only Murray Sporting complex and its surrounding area within Annandale have been considered.*

5.7 Emergency Management Considerations

Evacuation Route Closures

Bruce Highway, Stuart Drive, Abbott Street, University Road, Racecourse Road and Stuart Bypass are the major evacuation routes of Wulguru, Idalia, Cluden, Oonoonba, Murray, eastern part of Annandale and north-western part of Stuart. **Figure 5-13** shows the locations where the major evacuation routes are closed under different flood events.

Gartrell Drive, the only evacuation route of a local community in Annandale, remains cut-off in 5 Year ARI flood event. The cut-off location is shown in **Figure 5-13**.

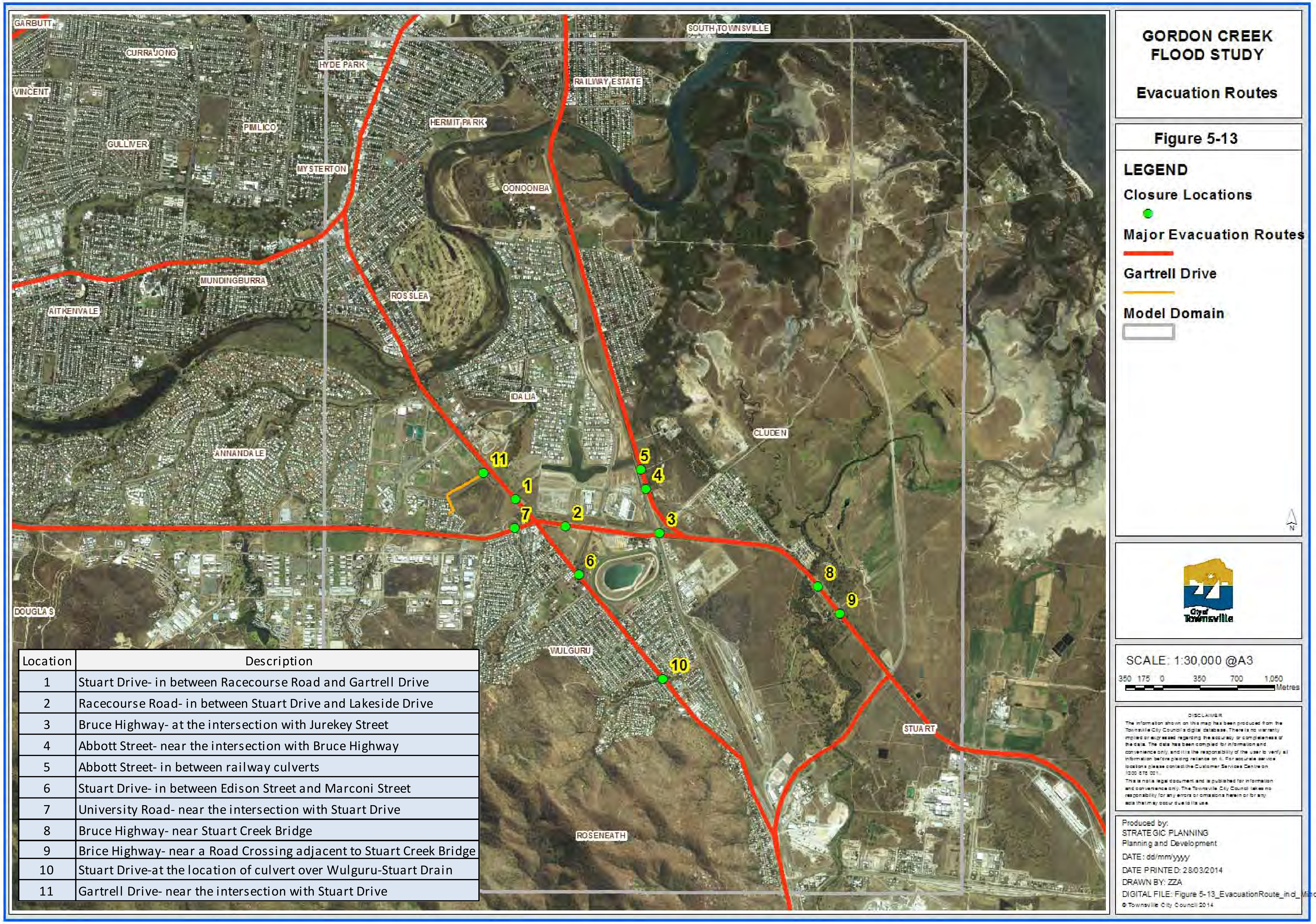
Based on the flood study results the flood immunity of the evacuation routes is provided in **Table 5-9**. The evacuation routes have been assumed to be closed with flood depths greater than 200 mm. The following table shows that:

- Stuart Drive (in between Bowen Road Bridge and Racecourse Road intersection)- remains closed in greater than 20 Year ARI flood event;
- Stuart Drive (in between the intersections with Racecourse Road and Stuart Bypass)- remains closed in greater than 10 Year ARI flood event;
- Stuart Drive (at the location of culvert in Wulguru-Stuart Drain)- remains closed in greater than 50 Year flood event;
- Racecourse Road (in between the intersections with Stuart Drive and Lakeside Drive)- remains closed in greater than 5 Year ARI flood event;
- Abbott Street near the intersection with Bruce Highway remains closed in all ARI flood events;

- Bruce Highway near the intersection with Jurekey Street remains closed in all ARIs;
- Bruce Highway near Stuart Creek Bridge remains closed in 10 Year and above ARI flood event;
- University Road near the intersection with Stuart Drive remains closed in greater than 50 Year ARI flood event; and
- Gartrell Drive near the intersection with Stuart Drive remains closed in 5 Year and above ARI flood event.

Table 5-9 Major Evacuation Route Flood Immunity

Location	Description	Depth over Road (m)								
		2 Year ARI	5 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI	200 Year ARI	500 Year ARI	PMP
1	Stuart Drive- in between intersections with Racecourse Road and Gartrell Drive	0.06	0.11	0.13	0.17	0.24	0.30	0.38	0.50	1.17
2	Racecourse Road- in between intersections with Stuart Drive and Lakeside Drive	-	0.15	0.22	0.30	0.36	0.42	0.51	0.62	1.27
3	Bruce Highway- at the intersection with Jurekey Street	0.23	0.25	0.29	0.32	0.38	0.39	0.46	0.57	1.28
4	Abbott Street- near the intersection with Bruce Highway	0.76	0.89	0.95	1.03	1.09	1.16	1.25	1.38	2.02
5	Abbott Street- in between railway culverts near the intersection with Bruce Highway	0.61	0.74	0.80	0.87	0.93	0.99	1.10	1.22	1.85
6	Stuart Drive- in between the intersections with Edison Street and Marconi Street	0.12	0.15	0.18	0.20	0.22	0.24	0.26	0.27	0.35
7	University Road- near the intersection with Stuart Drive	-	-	0.07	0.12	0.18	0.23	0.29	0.36	0.51
8	Bruce Highway- near Stuart Creek Bridge	-	-	0.04	0.11	0.18	0.25	0.35	0.43	0.90
9	Bruce Highway- near a Road Crossing adjacent to Stuart Creek Bridge	-	0.12	0.20	0.28	0.34	0.41	0.51	0.60	1.09
10	Stuart Drive- at the location of culvert in Wulguru-Stuart Drain	-	0.02	0.06	0.1	0.18	0.24	0.28	0.32	0.78
11	Gartrell Drive- near the intersection with Stuart Drive	0.12	0.3	0.4	0.45	0.5	0.53	0.56	0.6	1.20



Location	Description
1	Stuart Drive- in between Racecourse Road and Gartrell Drive
2	Racecourse Road- in between Stuart Drive and Lakeside Drive
3	Bruce Highway- at the intersection with Jurekey Street
4	Abbott Street- near the intersection with Bruce Highway
5	Abbott Street- in between railway culverts
6	Stuart Drive- in between Edison Street and Marconi Street
7	University Road- near the intersection with Stuart Drive
8	Bruce Highway- near Stuart Creek Bridge
9	Brice Highway- near a Road Crossing adjacent to Stuart Creek Bridge
10	Stuart Drive-at the location of culvert over Wulguru-Stuart Drain
11	Gartrell Drive- near the intersection with Stuart Drive

Emergency Management Facilities

Emergency Management Facilities within study area include only three Pre- and Post-impact Evacuation Centres: Wulguru Community Centre (pre-impact type), Wulguru State Primary School (post-impact type) and Oonoonba Community Centre (pre-impact type). The Wulguru Community Centre and the Wulguru State Primary School are located side by side on the Edison Street. **Figure 5-14** shows the potential emergency management facilities within the study area.

Flood depths at all the emergency management facilities has been derived from model results and presented in **Table 5-10**. Given the flood depths indicated are only depths relative to lot levels, they may not necessarily indicate whether the facilities themselves are inoperable as a result of flooding.

Table 5-10 Emergency Management Facility Flooding

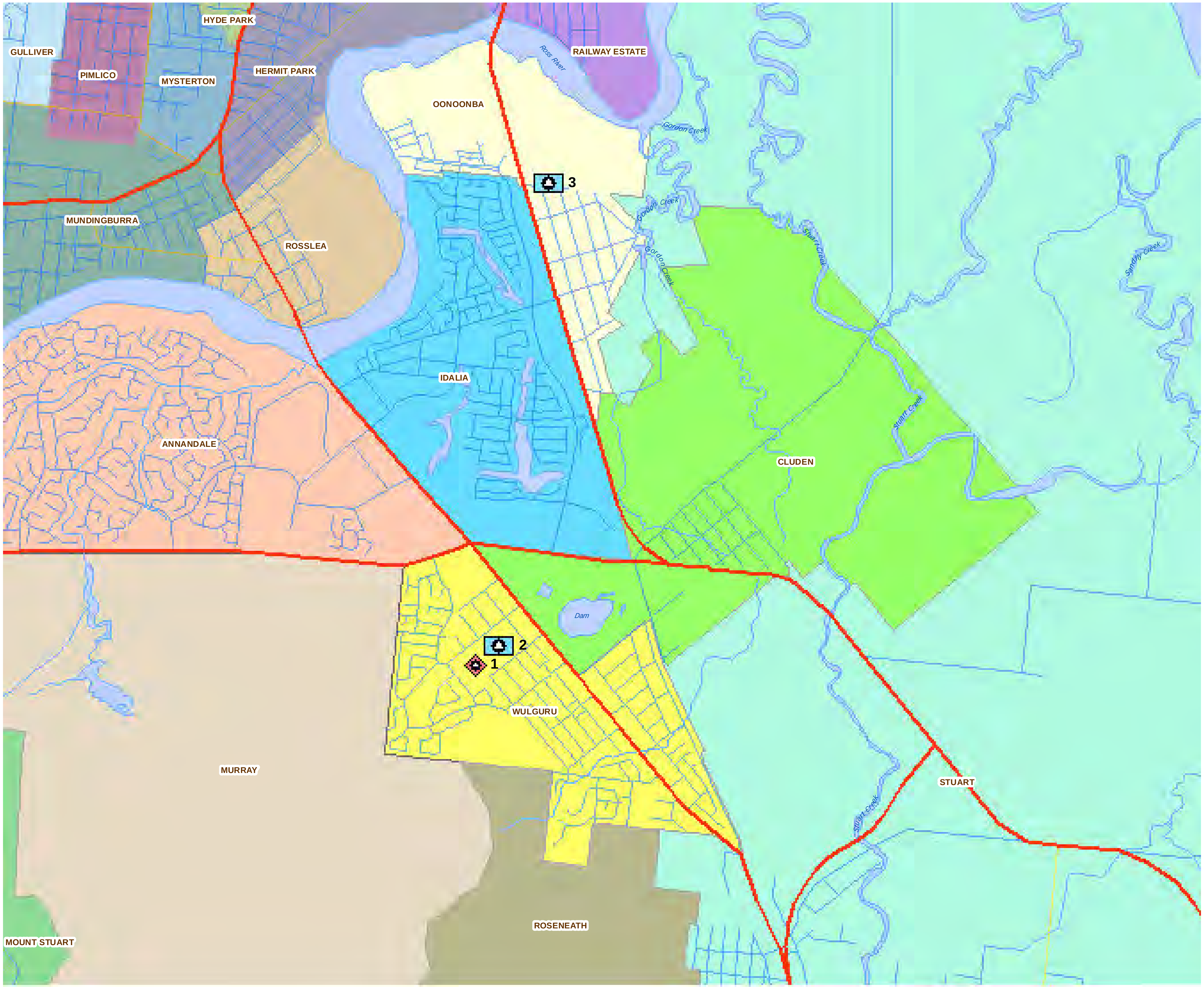
Location	Description	Facility Type	Depth over Road (m)								
			2 Year ARI	5 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI	200 Year ARI	500 Year ARI	PMP
1	Wulguru State Primary School	POST - IMPACT	-	-	-	-	0.07	0.08	0.09	0.10	0.16
2	Wulguru Community Centre	PRE-IMPACT	0.01	0.02	0.02	0.03	0.03	0.05	0.06	0.07	0.35
3	Oonoonba Community Centre	PRE-IMPACT	-	-	-	-	-	-	-	-	-

Model results show that:

- Edison Street, an access road from Major Evacuation Route to Wulguru Community Centre and Wulguru State Primary School, remains closed in all ARI flood events;
- the access road of Wulguru State Primary School from Edison Street gets inundated in more than 20 year ARI flood event. The maximum inundation remains less than 0.2 m in PMP;
- the access road of Wulguru Community Centre from Edison Street remains inundated in all ARI flood events, but the inundation depth exceeds 0.2 m only in PMP; and
- Shannon Street, an access road of Oonoonba Community Centre, remains flood free in all ARI flood events.

GORDON CREEK FLOOD STUDY
Disaster Management

Figure 5-14



LEGEND

Evacuation Facilities

Post-Impact

Pre-Impact

Major Evacuation Routes

Waterway or Waterbody

N

SCALE: 1:25,000 @A3

250 125 0 250 500 750 Metres

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5.8 Tailwater Conditions

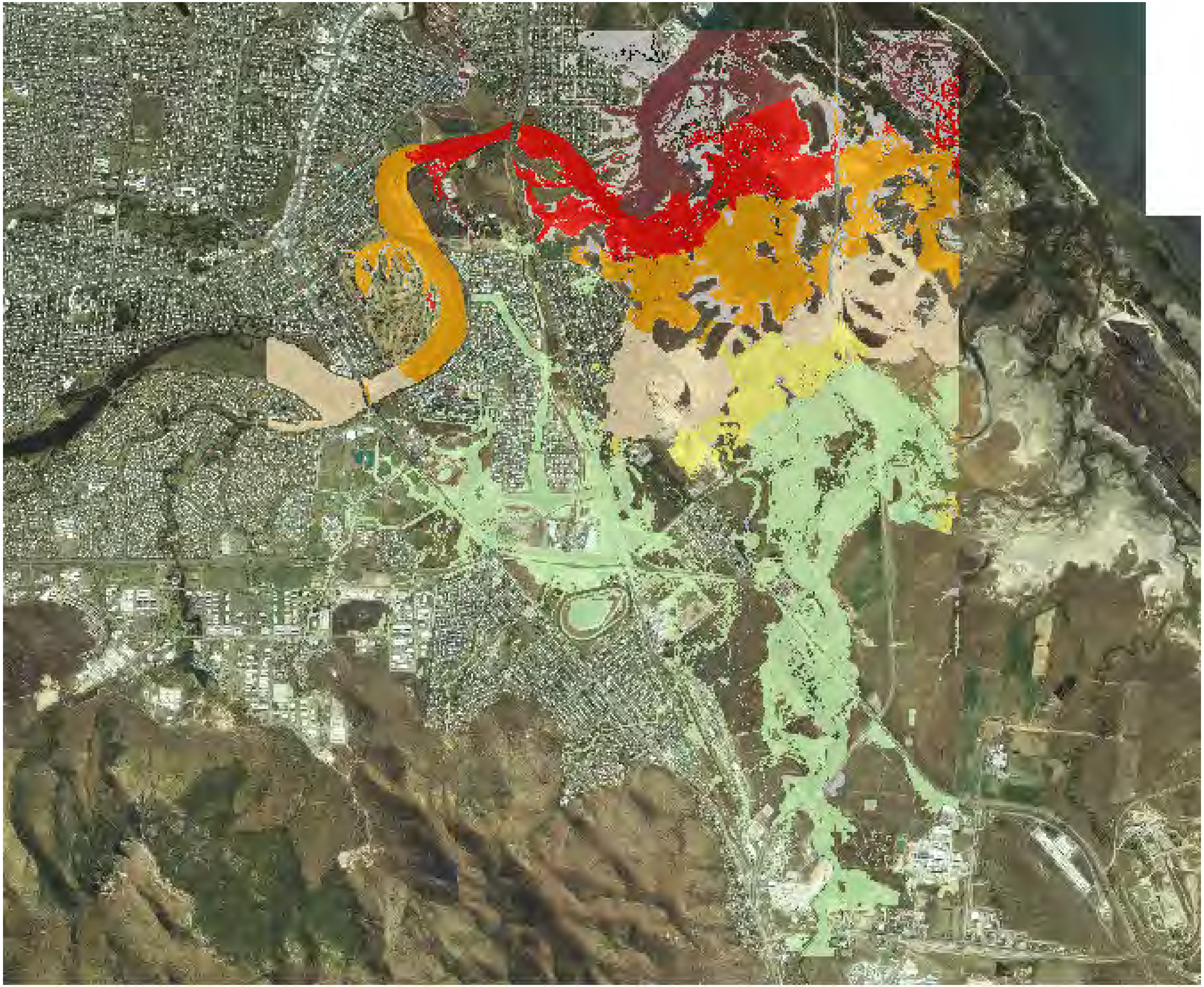
For all the design storm events the MIKE FLOOD hydraulic model has adopted a fixed tailwater condition at the MHWS tidal level (1.254 m AHD). This is considered somewhat conservative as in reality a flood is likely to coincide with a combination of low and high tides across a tidal cycle.

There has also been an evaluation of adopting the Highest Astronomical Tide (HAT) level (2.25 m AHD) as the tailwater condition for the model. The 50 Year ARI and 100 Year ARI, 18 hour floods were both run with a tailwater condition equal to HAT.

Figure 5-15 and **5-16** show changes in flood levels for the 50 and 100 Year ARI floods as a result of the HAT tailwater condition.

For both the ARIs, HAT level is 1.00 m higher than the flood level at the Ross River estuary and the flood level difference decreases gradually towards upstream.

For both the ARIs, the model results show increases in flood levels up to 0.01 m in Wulguru drains, open drains in Murray and Annandale, Fairfield Waters Lake system, Racecourse area in Cluden, open drains in Idalia, few properties at the intersection of Frederick Street and Findlater Street in Oonoonba and the flood plain of Stuart Creek. In the Gordon Creek flood plain, the flood level difference increases gradually from 0.01 m to 1.0 m towards the Ross River.



GORDON CREEK FLOOD STUDY 50 Y ARI & HAT

Figure 5-15

LEGEND

Water Level Differecen (m)

- Previously Inundated
- < -1
- -1 - -0.5
- -0.5 - -0.3
- -0.3 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- > 1
- Now Inundated

N

City of Townsville

SCALE: 1:30,000 @A3

200 100 0 200 400 600 800 1,000 Metres

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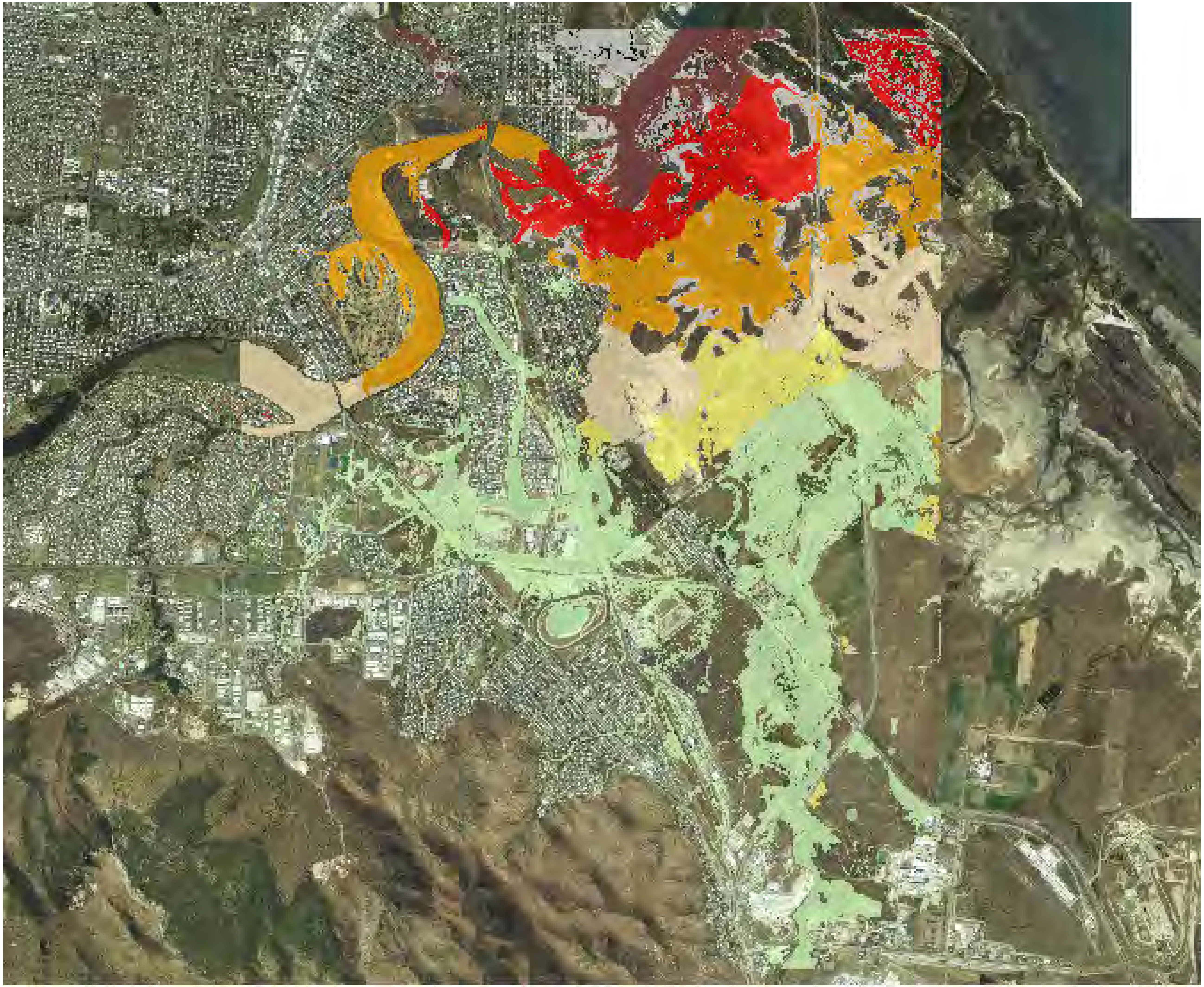

GORDON CREEK FLOOD STUDY 100 Y ARI & HAT

Figure 5-16

LEGEND

Water Level Differecen (m)

- Previously Inundated
- < -1
- -1 - -0.5
- -0.5 - -0.3
- -0.3 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- > 1
- Now Inundated

N

City of Townsville

SCALE: 1:30,000 @A3

200 100 0 200 400 600 800 1,000 Metres

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DIGITAL FILE: Figure 5-16_HAT_100y.mxd

6.0 Impact of Climate Change on Flooding

In this study, the impact of climate change on 100 year ARI flood event has been assessed based on model results. The model runs for 18 hour storm duration considering the sea level rise and the increased intensity of extreme rainfall under climate change scenario.

The sea-level rise specified within the *Queensland Coastal Plan* of 0.8 m to allow for conditions in 2100 has been adopted. This value is consistent with advice from *the IPCC Fifth Assessment Report: Climate Change (2013)* and within the range of projections within *Climate Change Projections for the Townsville Region* (Hennessy et al, 2008).

In a joint project between, Department of Environment and Resource Management (DERM), the Department of Infrastructure and Planning (DoIP) and the Local Government Association of Queensland (LGAQ), a review of the potential for climate change to alter extreme rainfall intensities has been completed. *Increasing Queensland's resilience to inland flooding in a changing climate* (DERM, 2010) provides recommendation for extreme rainfall intensities in the interim until a new revision of *Australian Rainfall and Runoff* addresses the issue. The Scientific Advisory Group (SAG) agreed that:

- an increase in rainfall intensity is likely;
- the available scientific literature indicates this increased rainfall intensity to be in the range of 3–10% per degree of global warming; and
- in the interim the SAG would consider a figure of a 5% increase in rainfall intensity per degree of global warming reasonable for informing policy development in the interim.

To evaluate the impact of sea-level rise and changes in extreme rainfall intensities on the flooding of Gordon Creek catchment area, the climate change simulations have been carried out by:

- increasing rainfall intensities by 15% allowing for a 3ºC rise in temperature to 2100;
- re-calculating catchment runoff based on the new rainfall intensities;
- updating the rain on grid data based on the new rainfall intensities;
- applying the revised flows as boundary conditions and source points to the MIKE FLOOD model; and
- updating the tail water level to account for a 0.8 m rise in sea level to 2100.

Assessing the change in rainfall intensities relative to existing IFD data presented in **Table 3-3** suggest that:

- the climate change 100 Year ARI, 18 hour intensity of 26.33 mm/h is between the existing 200 and 500 Year ARI, 18 hour intensities.

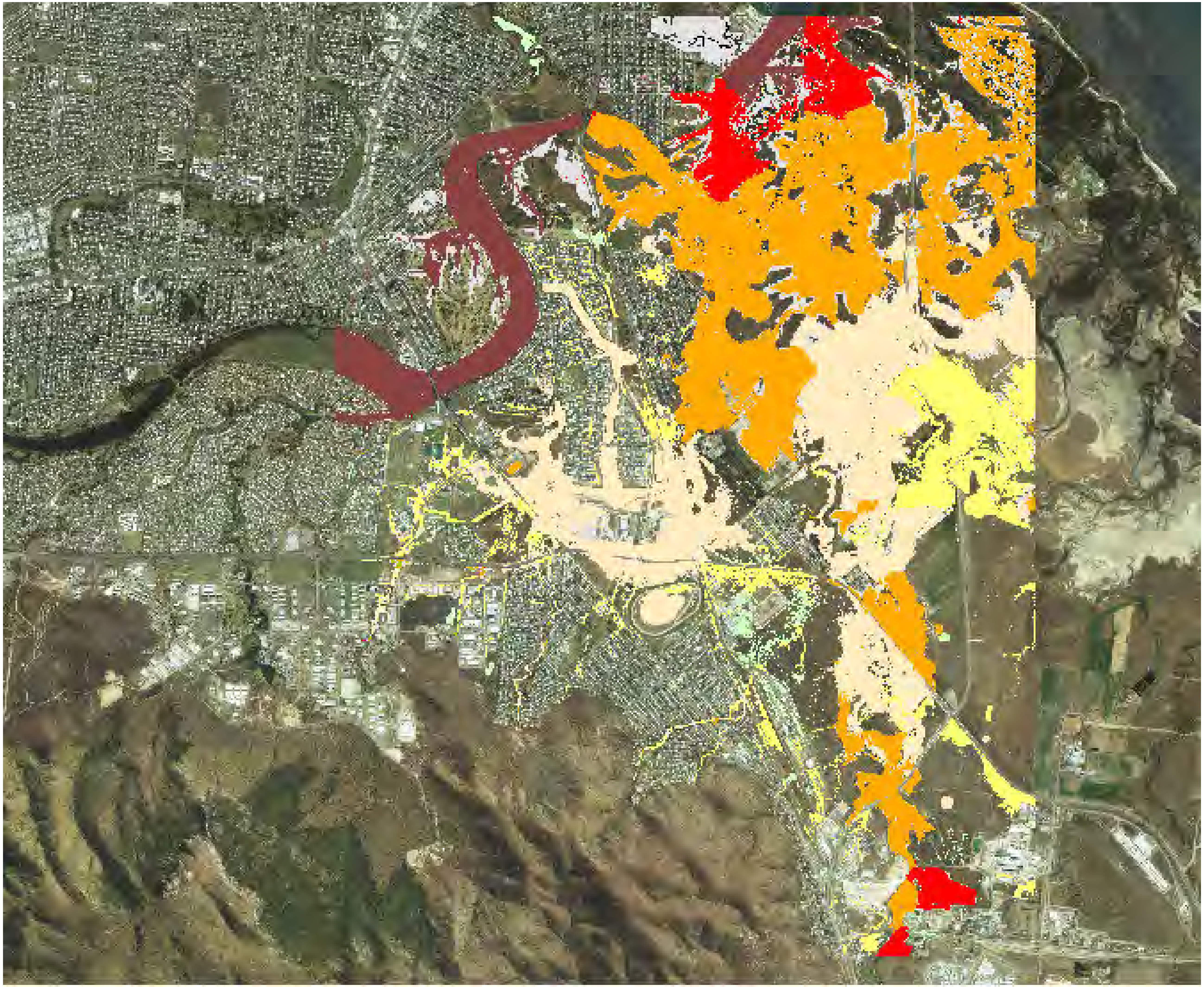
It should be noted that the following assumptions are implied in this methodology:

- initial and continuing rainfall losses remain unchanged from present conditions;
- rainfall temporal patterns remain unchanged from present conditions;
- catchment surface retardances remain unchanged from present conditions;
- channel and floodplain hydraulic roughness remains unchanged from present conditions; and
- fraction impervious remains unchanged from present conditions.

Figures 6-1 shows the changes in flood levels of 100 Year ARI flood event respectively due to climate change.

Impact of climate change on 100 Year ARI flood levels:

- Fairfield Waters lake system, Open drains in Idalia and Racecourse area in Cluden – flood level increases up to 100 mm;
- Open drains in Wulguru, Murray and Annandale-flood levels increase up to 300 mm;
- Oonoonba- localized flooding depth at the intersection of Frederick Street and Findlater Street and at the Mcalister Street increases up to 50 mm and 150 mm respectively; and
- Gordon Creek and Stuart Creek- flood levels increase up to 300 mm and 500 mm respectively.



GORDON CREEK FLOOD STUDY
100 Year ARI Climate Change
Figure 6-1

LEGEND

Water Level Difference (m)

- Previously Inundated
- < -1
- -1 - -0.5
- -0.5 - -0.3
- -0.3 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- > 1
- Now Inundated

N

City of Townsville

SCALE: 1:30,000 @A3

200 100 0 200 400 600 800 1,000 Metres

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7.0 Summary and Conclusions

The *Gordon Creek Flood Study – Baseline Flooding Assessment* has been undertaken as part of Townsville City Council's City Wide Flood Constraints Project. This study builds on previous hydrologic and hydraulic analysis projects completed for Townsville City Council and incorporates the latest Light Detection and Ranging (LiDAR) topographic data as well as recent hydrographic survey to form up-to-date hydraulic flood model for the Gordon Creek and its catchment.

The study has developed a MIKE FLOOD coupled two-dimensional / one-dimensional hydraulic model for quantifying the flood risk in the Gordon Creek catchment area. The model has been calibrated to two representative historical events (i.e. January 1998 and February 2002) and verified with the previous flood modelling studies completed in the Gordon Creek area. The model represents in fine-scale resolution the topography and the drainage systems of the Gordon Creek catchment area, including:

- a digital elevation model resolved to a 10m grid;
- the larger components of the underground drainage network (greater than 900 mm diameter equivalent diameter);
- open drains narrower that the 10m grid resolution using one-dimensional branches; and
- application of rainfall directly on the model grid.

The calibrated and verified flood model has been used to assess design storm flood events for the 2, 5, 10, 20, 50, 100, 200 and 500 Year Average Recurrence Intervals (ARI) as well as the Probable Maximum Precipitation flood event. The 100 Year and 50 Year design storm events have been run for a range of storm durations in order to assess the critical duration event for all points of the floodplain.

The flood model results for the design storm events have been used to:

- quantify the floodplain hydraulic response with hydraulic grade lines and flow distributions;
- evaluate the potential impact on residential properties;
- identify flood hazard zones on the floodplain;
- inform flood overlay development for the new City Plan; and
- identify emergency management considerations.

7.1 Floodplain Hydraulic Mechanisms

Floodplain hydraulic mechanisms in the Gordon Creek catchment area have been examined in detailed in **Section 5.1**.

There are four major flow paths in the Gordon Catchment, which are contributing major portion of the flow /discharge in Gordon Creek. Rest of the flow in the Gordon Creek is coming from Stuart Creek overflows.

7.2 Inundation of Residential Properties

The residential properties potentially inundated by flooding within the suburbs of the study area have been assessed for all the design flood events. The number of residential properties inundated by depths of greater than 0.2 m above ground level is provided in **Table 6-1**.

Table 6-1 Summary of Inundated Residential Properties

Suburb	Number of Impacted Properties								
	2 Y	5 Y	10 Y	20 Y	50 Y	100 Y	200 Y	500 Y	PMF
Idalia	-	-	5	5	23	32	46	358	1075
Oonoonba	24	31	36	48	57	64	79	168	327
Wulguru	5	6	9	13	26	37	45	61	225
Cluden	2	2	2	3	3	3	3	11	78
Stuart	4	4	4	4	4	4	4	4	46
Annandale	-	-	-	1	1	2	2	2	8
Total	35	43	56	74	114	142	179	604	1759

7.3 Floodplain Hazard

Flood plain hazard has been characterised based on the function of flood depth and velocity. Five degrees of hazard have been adopted according to McConnell and Low (2000):

- **Low Hazard** – depth <0.4m and velocity <0.5m/s, suitable for cars;
- **Medium Hazard** – depth <0.8m, velocity <2m/s and velocity times depth <0.5, suitable for heavy vehicles and wading by able bodied adults;
- **High Hazard** – depth <1.8m, velocity <3m/s and velocity times depth <1.5, suitable for light construction (timber frame, brick veneer, etc.);
- **Very High Hazard** – velocity >0.5m/s and <4m/s with velocity times depth <2.5, suitable for heavy construction (steel frame, concrete, etc.); and
- **Extreme Hazard** – greater than very high, significant flow path development considered unsuitable and likely to significantly impact flood levels.

The floodplain hazard has been evaluated for the 100 Year ARI, 500 Year ARI and PMF events. The hazard mapping indicates that:

- Majority of the residential properties inundated in the 100 Year ARI are characterised by Low, Medium and High Hazards in the study area (82.8%, 16.8% and 0.4% respectively);

- Majority of the residential properties inundated in the 500 Year ARI are characterised by Low, Medium and High Hazards in the study area (77%, 22% and 1% respectively); and
- Majority of the residential properties inundated in the PMF are characterised by Low, Medium and High Hazards in the study area (39%, 51% and 9.8% respectively) with remaining 0.2% properties in Very High and Extreme.

7.4 Floodplain Planning

The new City Plan for Townsville proposes to adopt the 100 Year ARI flood as the Defined Event and will adopt a Flood Overlay map comprising three hazard categories for flooding:

- Low flood hazard- areas of residential flood risk beyond the 100 Year ARI;
- Medium flood hazard- areas of shallower and slower moving flood waters in the 100 Year ARI; and
- High flood hazard- areas of deeper and faster moving flood waters in the 100 Year ARI.

The number of properties falls under different hazard categories in the suburbs of the study area are provided in **Table 6-2**.

Table 6-2 Number of properties under different hazard categories

Suburb	Low Flood Hazard Rating	Medium Flood Hazard Rating	High Flood Hazard Rating
Idalia	1136	62	-
Oonoonba	261	95	-
Wulguru	325	306	12
Cluden	94	69	-
Stuart	77	21	7
Annandale*	13	9	-

* in this study only Murray Sporting complex and its surrounding area within Annandale have been considered.

7.5 Emergency Management

The major evacuation routes within the study area are Bruce Highway, Stuart Drive, Abbott Street, University Road, Racecourse Road and Stuart Bypass. There are eleven (11) vulnerable locations in the evacuation routes, which remains closed (due to the flood depth greater than 200 mm) under different ARI flood events. The vulnerable locations are:

- Stuart Drive (in between Bowen Road Bridge and Racecourse Road intersection)- remains closed in greater than 20 Year ARI flood event;
- Stuart Drive (in between the intersections with Racecourse Road and Stuart Bypass)- remains closed in greater than 10 Year ARI flood event;
- Stuart Drive (at the location of culvert over Wulguru-Stuart Drain)- remains closed in greater than 50 Year flood event;

- Racecourse Road (in between the intersections with Stuart Drive and Lakeside Drive)- remains closed in greater than 5 Year ARI flood event;
- Abbott Street near the intersection with Bruce Highway remains closed in all ARI flood events;
- Bruce Highway near the intersection with Jurekey Street remains closed in all ARIs;
- Bruce Highway near Stuart Creek Bridge remains closed in 10 Year ARI flood event and above;
- University Road near the intersection with Stuart Drive remains closed in greater than 50 Years ARI flood event; and
- Gartrell Drive near the intersection with Stuart Drive remains closed in 5 Year and above ARI flood event.

Emergency Management Facilities of the study area include only Pre- and Post-impact Evacuation Centres. The model results show that all the Pre- and Post-impact Evacuation Centres remain unaffected up to the large flood event (i.e. 500 Year ARI).

7.6 Impact of Higher Tides

The impact of Highest Astronomical Tide (i.e. 2.25 m AHD) on flood levels has been assessed for 50 Year and 100 Year ARI events using the Gordon Creek flood model. For both the ARIs, the model results show increases in flood levels up to 0.01 m in the Fairfield Waters lakes, the open drains within the study area, the localized flooding area in Oonoonba and the flood plains of Stuart Creek.

7.7 Impact of Climate Change

The impact of climate change on 100 year ARI flood event has been assessed based on the model results. To account for climate change conditions in 2100, the modelling has been updated to:

- Include the sea level rise of 0.8 m on the Mean High Water Springs level to give a resulting sea level of 2.054 m AHD; and
- Increase rainfall intensities by 15% in accordance with Increasing Queensland resilience to inland flooding in a changing climate (DERM, 2010).

The model results show that the flood levels increase up to 100 mm in the Fairfield Waters lakes in 100 Year ARI.

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Appendix A – Gordon Creek Sub-Catchments

GORDON CREEK FLOOD STUDY Sub-Catchments

Upper Study Area

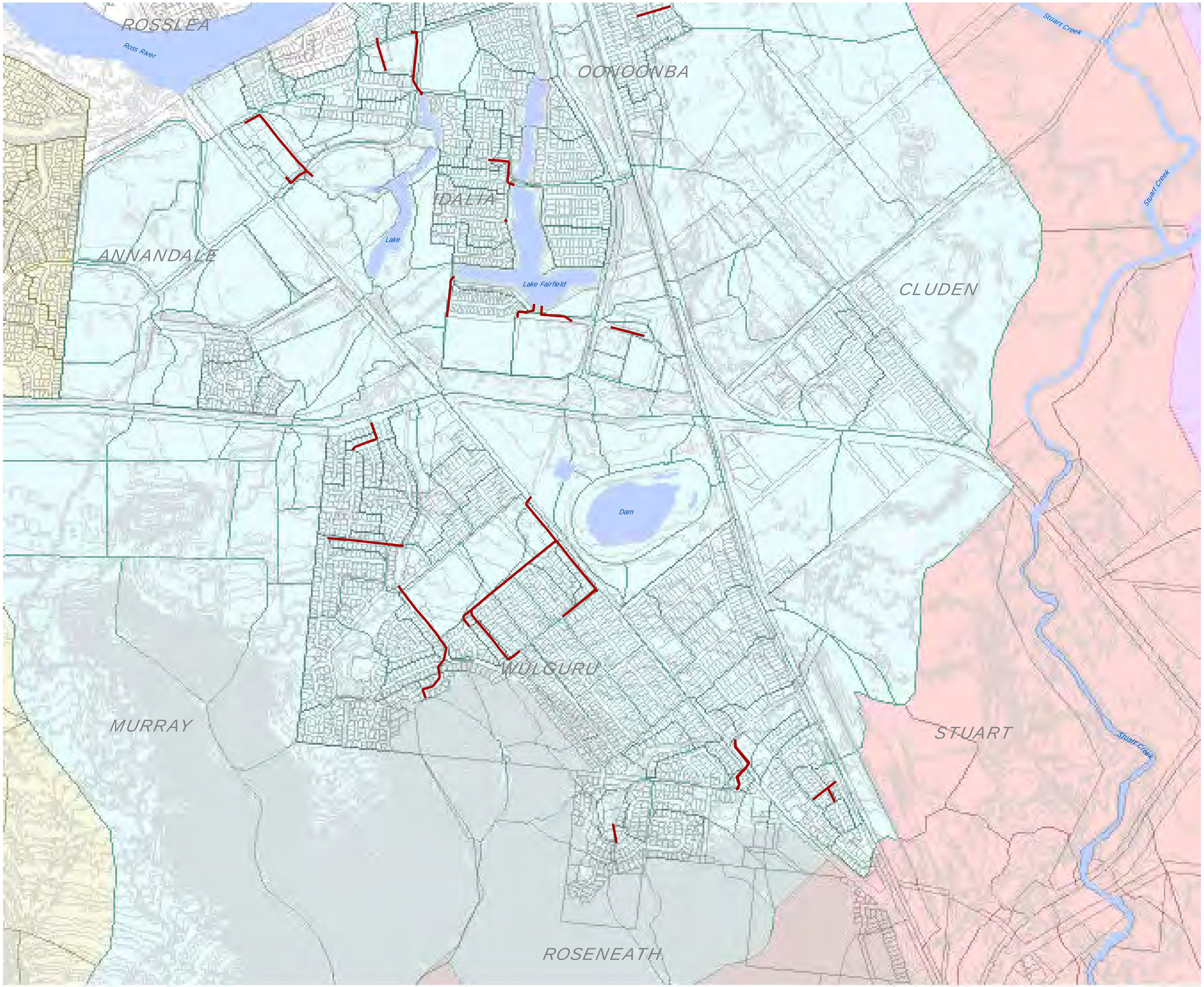

Figure A-1

LEGEND
Sub-Catchments

- GordonCk
- Douglas
- SandflyCk
- StuartCk
- Underground Drainage

N

City of Townsville

SCALE: 1:15,000 @A3

150 75 0 150 300 450 Metres

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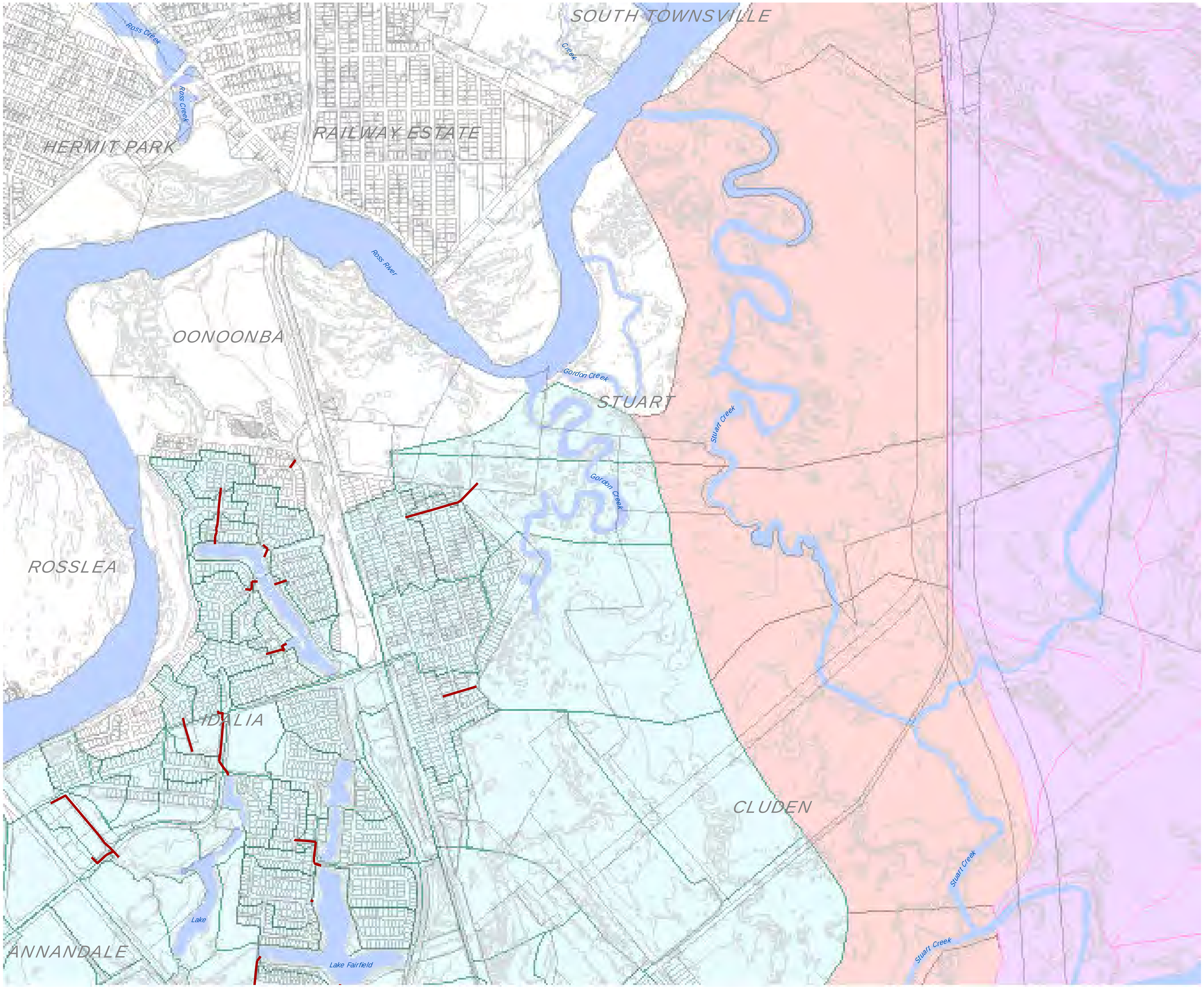
GORDON CREEK FLOOD STUDY Sub-Catchments

Lower Study Area

Figure A-2



LEGEND
Sub-Catchments

- GordonCk
- Douglas
- SandflyCk
- StuartCk
- Underground Drainage

N

City of Townsville

SCALE: 1:15,000 @A3

150 75 0 150 300 450 Metres

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Planning and Development
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Sub-catchment Parameters

Sub-Catchment ID	Area (ha)	Slope (%)	Fraction Impervious	Pern (n*) Pervious	Pern (n*) Impervious	Reach Slope (m/m)	Area Pervious (ha)	Area Impervious (ha)	Reach Width (m)	Reach Manning's n
GC-9.02	6.62	2.73	0.41	0.07	0.02	0.00	3.88	2.75	15.00	0.06
FW-6.00	7.34	3.93	0.18	0.06	0.02	0.00	6.05	1.29	0.00	0.00
W1-1.00	6.71	1.63	0.13	0.06	0.02	0.01	5.84	0.87	3.50	0.03
GC-5.11	12.30	1.58	0.37	0.06	0.02	0.00	7.73	4.58	20.00	0.06
GC-3.02	13.42	1.48	0.70	0.06	0.02	0.00	3.96	9.46	5.00	0.06
GC-2.00	34.95	2.45	0.06	0.08	0.02	0.00	32.96	1.99	25.00	0.04
GC-5.01.01	4.69	2.45	0.23	0.06	0.02	0.00	3.61	1.08	20.00	0.06
GC-5.01	14.11	3.08	0.11	0.08	0.02	0.00	12.58	1.53	20.00	0.06
RY-1.00	57.49	1.33	0.06	0.07	0.02	0.00	53.99	3.50	10.00	0.05
RY-2.01	4.97	2.58	0.78	0.07	0.02	0.00	1.12	3.85	0.00	0.00
GC-11.43	13.41	1.30	0.30	0.06	0.02	0.01	9.35	4.06	5.00	0.04
RC-1.00	4.12	2.91	0.81	0.05	0.01	0.00	0.78	3.35	0.00	0.00
GC-7.02	10.35	0.71	0.80	0.05	0.01	0.01	2.11	8.24	30.00	0.03
GC-11.42	19.74	0.99	0.16	0.07	0.02	0.00	16.52	3.22	5.00	0.04
GC-11.31	8.94	1.25	0.13	0.07	0.02	0.00	7.74	1.21	10.00	0.05
GC-11.20	12.44	1.27	0.11	0.07	0.02	0.01	11.08	1.35	10.00	0.05
GC-13.00	11.45	2.77	0.17	0.06	0.02	0.01	9.49	1.96	15.00	0.05
W2-1.21	2.86	2.07	0.62	0.06	0.02	0.00	1.10	1.77	0.00	0.00
RC-4.02	5.61	1.42	0.74	0.06	0.02	0.00	1.47	4.14	10.00	0.06
W2-1.00	6.79	2.97	0.67	0.06	0.02	0.00	2.22	4.57	5.00	0.05
W2-2.00.02	6.05	2.09	0.64	0.06	0.02	0.00	2.19	3.86	3.50	0.03
W2-4.00	10.84	4.19	0.39	0.06	0.02	0.01	6.57	4.27	10.00	0.04
W1-5.00	6.26	1.85	0.64	0.06	0.02	0.01	2.28	3.98	3.50	0.03
RY-6.00	3.23	4.16	0.48	0.06	0.02	0.01	1.67	1.56	10.00	0.05
RC-2.03	11.34	1.85	0.61	0.06	0.02	0.01	4.45	6.90	5.00	0.04
RY-2.51	6.59	15.00	0.07	0.08	0.02	0.02	6.14	0.45	3.50	0.03
RY-3.00	4.81	2.57	0.37	0.06	0.02	0.01	3.01	1.80	15.00	0.05
RC-5.00	16.76	1.97	0.13	0.07	0.02	0.00	14.56	2.20	5.00	0.06
RC-2.02	6.45	1.69	0.03	0.07	0.02	0.00	6.26	0.20	5.00	0.04
RC-6.01	18.55	2.55	0.00	0.07	0.02	0.00	18.55	0.00	5.00	0.06
GC-11.00	6.51	4.06	0.15	0.07	0.02	0.00	5.54	0.97	0.00	0.00
RY-2.12	3.08	2.31	0.51	0.06	0.02	0.00	1.50	1.58	5.00	0.05
GC-15.00	21.07	2.30	0.50	0.06	0.02	0.01	10.54	10.54	10.00	0.04
W2-1.31	4.39	1.81	0.33	0.06	0.02	0.01	2.92	1.47	10.00	0.05
W2-6.00	80.07	15.00	0.00	0.08	0.02	0.01	80.07	0.00	20.00	0.04
RY-3.05	21.63	15.00	0.01	0.08	0.02	0.04	21.52	0.11	10.00	0.04
W1-3.00	2.08	1.92	0.62	0.06	0.02	0.01	0.78	1.29	3.50	0.03
RY-9.00	56.38	15.00	0.02	0.08	0.02	0.03	55.23	1.14	10.00	0.04
W2-2.05	15.29	15.00	0.00	0.08	0.02	0.03	15.28	0.02	3.50	0.03
RY-7.03	8.33	15.00	0.02	0.08	0.02	0.02	8.19	0.14	10.00	0.05
W1-8.00	4.78	15.00	0.30	0.06	0.02	0.03	3.33	1.45	3.50	0.03
GC-16.00	257.74	15.00	0.03	0.08	0.02	0.01	251.05	6.69	10.00	0.04
GC-4.00	61.41	1.98	0.01	0.08	0.02	0.00	60.53	0.88	10.00	0.06
GC-3.13	52.40	1.90	0.09	0.08	0.02	0.00	47.73	4.67	20.00	0.06
GC-3.00	66.61	1.61	0.06	0.08	0.02	0.00	62.84	3.78	15.00	0.06
LB-1.12	29.40	15.00	0.17	0.08	0.02	0.01	24.27	5.13	10.00	0.04
FW-7.00	3.05	4.28	0.13	0.06	0.02	0.00	2.66	0.39	50.00	0.04
GC-2.11	12.60	1.09	0.71	0.06	0.02	0.00	3.65	8.95	3.50	0.03
RY-2.11	4.19	3.73	0.10	0.07	0.02	0.00	3.78	0.42	5.00	0.05
LB-1.00.01	9.16	1.49	0.20	0.06	0.02	0.02	7.31	1.85	10.00	0.04
GC-14.00	12.17	2.00	0.11	0.06	0.02	0.00	10.85	1.32	15.00	0.04
LB-1.02	22.41	7.38	0.21	0.06	0.02	0.01	17.71	4.70	10.00	0.04
W2-1.51	22.01	15.00	0.06	0.08	0.02	0.01	20.78	1.23	10.00	0.04
LB-1.01	8.56	2.18	0.50	0.06	0.02	0.01	4.28	4.28	10.00	0.04
LB-1.00	3.72	3.00	0.13	0.06	0.02	0.00	3.23	0.49	10.00	0.04
W2-1.41	5.23	2.34	0.50	0.06	0.02	0.01	2.62	2.62	10.00	0.04
W2-5.00	9.68	13.43	0.52	0.06	0.02	0.01	4.65	5.02	10.00	0.04
W2-3.00	8.86	3.04	0.49	0.06	0.02	0.01	4.52	4.35	10.00	0.04
W2-1.23	2.72	2.28	0.64	0.06	0.02	0.01	0.97	1.75	3.50	0.03
W2-1.33	3.80	2.62	0.65	0.06	0.02	0.01	1.35	2.45	3.50	0.03
W2-1.32	5.70	2.45	0.64	0.06	0.02	0.00	2.04	3.66	3.50	0.03
W2-1.22	2.08	1.84	0.66	0.06	0.02	0.00	0.72	1.36	3.50	0.03

Sub-catchment Parameters

Sub-Catchment ID	Area (ha)	Slope (%)	Fraction Impervious	Pern (n*) Pervious	Pern (n*) Impervious	Reach Slope (m/m)	Area Pervious (ha)	Area Impervious (ha)	Reach Width (m)	Reach Manning's n
W2-1.10	1.12	1.65	0.58	0.06	0.02	0.00	0.47	0.65	10.00	0.06
W2-2.00	2.97	2.35	0.46	0.06	0.02	0.01	1.60	1.37	15.00	0.04
W2-2.00.01	1.71	1.81	0.64	0.06	0.02	0.01	0.62	1.09	3.50	0.03
W2-2.04	1.38	12.17	0.49	0.06	0.02	0.03	0.70	0.67	3.50	0.03
W2-2.03	3.62	15.00	0.18	0.08	0.02	0.01	2.96	0.67	3.50	0.03
W2-2.01	1.87	3.32	0.60	0.06	0.02	0.00	0.74	1.13	0.00	0.00
W1-3.05	6.65	15.00	0.15	0.08	0.02	0.01	5.65	1.00	3.50	0.03
W2-2.02	2.23	3.59	0.64	0.06	0.02	0.02	0.80	1.44	3.50	0.03
W1-3.03.01	2.35	3.32	0.65	0.06	0.02	0.02	0.82	1.53	3.50	0.03
W1-3.04	1.08	2.83	0.63	0.06	0.02	0.02	0.40	0.67	3.50	0.03
W1-3.03	3.21	2.41	0.66	0.06	0.02	0.02	1.10	2.11	3.50	0.03
W1-7.00	4.01	9.87	0.63	0.06	0.02	0.01	1.50	2.51	3.50	0.03
W1-3.02	3.28	1.93	0.65	0.06	0.02	0.01	1.16	2.12	3.50	0.03
W1-3.01	3.17	1.73	0.63	0.06	0.02	0.01	1.17	2.00	3.50	0.03
W1-4.00	1.53	1.76	0.63	0.06	0.02	0.00	0.57	0.96	0.00	0.00
W1-5.02	6.47	6.78	0.64	0.06	0.02	0.01	2.31	4.16	3.50	0.03
W1-5.01	5.99	1.79	0.61	0.06	0.02	0.01	2.31	3.68	3.50	0.03
W1-6.00	5.38	3.27	0.65	0.06	0.02	0.00	1.88	3.50	3.50	0.03
RY-8.00	5.12	15.00	0.30	0.06	0.02	0.02	3.57	1.54	10.00	0.04
RY-7.22	6.28	15.00	0.02	0.08	0.02	0.04	6.13	0.15	5.00	0.04
RY-7.12	2.40	15.00	0.58	0.06	0.02	0.04	1.00	1.40	5.00	0.04
RY-7.02	2.08	7.13	0.65	0.06	0.02	0.02	0.72	1.35	5.00	0.04
RY-7.01	2.57	6.05	0.64	0.06	0.02	0.00	0.92	1.65	0.00	0.00
RY-7.00	5.06	14.72	0.35	0.06	0.02	0.01	3.28	1.78	10.00	0.04
RY-5.02	3.85	2.83	0.63	0.06	0.02	0.03	1.43	2.42	5.00	0.04
RY-5.01	1.18	3.38	0.66	0.06	0.02	0.00	0.40	0.77	0.00	0.00
RY-5.00	2.99	2.36	0.53	0.06	0.02	0.02	1.39	1.60	10.00	0.05
RY-3.04.01	4.37	7.04	0.64	0.06	0.02	0.02	1.57	2.80	5.00	0.04
RY-3.04	4.59	15.00	0.07	0.08	0.02	0.02	4.27	0.32	10.00	0.04
RY-2.41.01	3.52	15.00	0.21	0.06	0.02	0.01	2.79	0.72	3.50	0.03
RY-3.02	0.80	3.13	0.62	0.06	0.02	0.02	0.31	0.49	3.50	0.03
RY-3.03	5.35	4.27	0.41	0.06	0.02	0.00	3.17	2.17	3.50	0.03
RY-2.31.02	2.75	3.21	0.49	0.06	0.02	0.01	1.40	1.34	3.50	0.03
W1-1.01	7.42	2.08	0.20	0.06	0.02	0.01	5.95	1.47	3.50	0.03
W1-2.00	2.70	1.35	0.55	0.06	0.02	0.01	1.22	1.47	3.50	0.03
W1-1.00.02	2.07	1.84	0.65	0.06	0.02	0.01	0.72	1.35	3.50	0.03
W1-1.00.01	3.52	1.36	0.65	0.06	0.02	0.01	1.24	2.29	3.50	0.03
RC-4.03	3.98	1.26	0.66	0.06	0.02	0.00	1.35	2.63	3.50	0.03
RY-2.41	5.24	3.37	0.70	0.06	0.02	0.01	1.60	3.64	3.50	0.03
RY-2.31	1.79	2.08	0.63	0.06	0.02	0.02	0.66	1.14	3.50	0.03
RY-2.31.01	1.24	3.12	0.64	0.06	0.02	0.00	0.45	0.80	3.50	0.03
RY-2.21	1.78	2.57	0.27	0.06	0.02	0.01	1.30	0.48	5.00	0.05
RY-2.02	4.08	3.78	0.10	0.07	0.02	0.01	3.69	0.39	5.00	0.05
RY-3.01	1.26	2.89	0.68	0.06	0.02	0.00	0.41	0.85	0.00	0.00
RY-4.00	1.43	2.43	0.60	0.06	0.02	0.01	0.57	0.86	10.00	0.05
RY-3.00.01	2.63	2.21	0.69	0.06	0.02	0.00	0.82	1.82	10.00	0.05
RY-2.00	1.09	4.02	0.39	0.07	0.02	0.00	0.66	0.42	10.00	0.05
GC-5.01.03	3.08	2.15	0.30	0.07	0.02	0.01	2.17	0.91	5.00	0.04
RC-2.05	7.17	1.64	0.63	0.06	0.02	0.01	2.65	4.52	5.00	0.04
RC-2.04	10.47	1.96	0.58	0.06	0.02	0.01	4.42	6.05	5.00	0.04
RC-2.03.01	5.12	2.04	0.59	0.06	0.02	0.01	2.10	3.02	3.50	0.03
RC-7.00	4.23	2.57	0.00	0.07	0.02	0.00	4.22	0.01	5.00	0.06
RC-6.00	3.70	2.39	0.05	0.07	0.02	0.00	3.51	0.19	0.00	0.00
RC-3.01	7.83	2.18	0.24	0.07	0.02	0.00	5.94	1.89	5.00	0.06
RC-2.01	2.99	1.73	0.21	0.07	0.02	0.01	2.35	0.64	5.00	0.05
RY-1.01	2.08	2.66	0.80	0.07	0.02	0.00	0.42	1.66	5.00	0.05
GC-5.01.02	29.20	1.31	0.26	0.07	0.02	0.00	21.56	7.64	5.00	0.04
GC-10.01	6.62	1.59	0.12	0.07	0.02	0.01	5.84	0.79	10.00	0.05
GC-11.33	2.96	1.39	0.22	0.07	0.02	0.00	2.31	0.65	0.00	0.00
GC-11.10	0.41	2.14	0.36	0.07	0.02	0.00	0.26	0.15	10.00	0.06
GC-11.01	7.11	1.27	0.11	0.07	0.02	0.01	6.34	0.77	10.00	0.06
GC-11.32	9.33	1.27	0.27	0.07	0.02	0.00	6.82	2.51	0.00	0.00

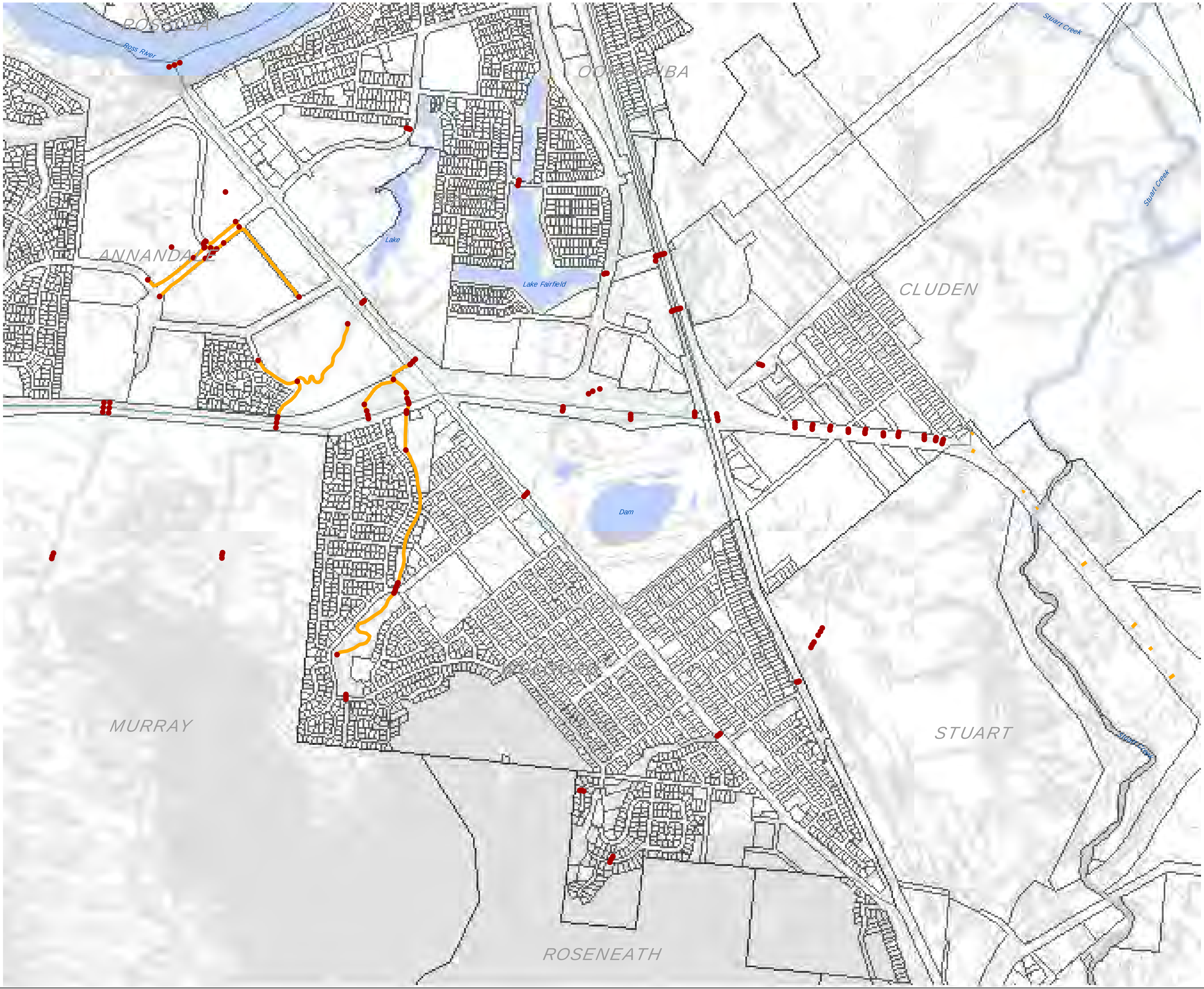
Sub-catchment Parameters

Sub-Catchment ID	Area (ha)	Slope (%)	Fraction Impervious	Pern (n*) Pervious	Pern (n*) Impervious	Reach Slope (m/m)	Area Pervious (ha)	Area Impervious (ha)	Reach Width (m)	Reach Manning's n
GC-10.22	5.45	1.91	0.60	0.06	0.02	0.01	2.15	3.29	10.00	0.05
GC-10.12	2.13	2.12	0.55	0.06	0.02	0.00	0.96	1.17	0.00	0.00
GC-10.02	3.41	2.76	0.35	0.07	0.02	0.00	2.22	1.19	10.00	0.06
GC-10.00	8.80	2.06	0.01	0.07	0.02	0.00	8.69	0.11	15.00	0.05
GC-6.00	9.73	4.38	0.49	0.05	0.01	0.00	4.93	4.79	45.00	0.06
GC-6.01	9.93	2.67	0.13	0.05	0.01	0.00	8.65	1.28	10.00	0.05
ID-8.02	2.89	1.76	0.64	0.06	0.02	0.00	1.05	1.84	3.50	0.03
ID-3.02	6.20	1.24	0.53	0.06	0.02	0.00	2.91	3.29	10.00	0.05
ID-2.30	5.07	2.74	0.13	0.07	0.02	0.00	4.38	0.68	3.50	0.03
FW-10.00	4.26	1.14	0.64	0.06	0.02	0.00	1.52	2.73	3.50	0.03
FW-9.00	5.46	1.68	0.62	0.06	0.02	0.00	2.09	3.37	3.50	0.03
FW-7.01	5.66	1.42	0.69	0.06	0.02	0.00	1.75	3.91	3.50	0.03
FW-8.00	2.38	1.69	0.65	0.06	0.02	0.00	0.85	1.54	40.00	0.04
FW-6.13	2.06	1.56	0.65	0.06	0.02	0.00	0.73	1.33	3.50	0.03
FW-6.23	4.82	1.45	0.64	0.06	0.02	0.00	1.72	3.10	3.50	0.03
FW-6.03	2.04	2.04	0.59	0.06	0.02	0.00	0.85	1.20	5.00	0.03
ID-8.00	3.04	1.15	0.64	0.06	0.02	0.00	1.09	1.95	3.50	0.03
ID-8.01	0.73	1.74	0.59	0.06	0.02	0.00	0.30	0.43	0.00	0.00
FW-6.21	3.44	1.36	0.60	0.06	0.02	0.00	1.37	2.07	3.50	0.03
FW-6.11	5.00	1.56	0.65	0.06	0.02	0.00	1.75	3.25	3.50	0.03
FW-6.02	6.76	1.61	0.69	0.06	0.02	0.00	2.08	4.68	5.00	0.03
FW-6.01	2.02	2.23	0.63	0.06	0.02	0.00	0.75	1.27	5.00	0.03
FW-5.00	0.81	2.66	0.50	0.06	0.02	0.00	0.40	0.40	15.00	0.05
ID-6.00	3.08	1.67	0.66	0.06	0.02	0.01	1.04	2.04	3.50	0.03
ID-7.00	3.43	1.78	0.78	0.05	0.01	0.01	0.76	2.67	3.50	0.03
ID-3.04	3.84	2.73	0.57	0.06	0.02	0.00	1.64	2.20	10.00	0.05
ID-3.03	3.12	1.30	0.31	0.06	0.02	0.00	2.17	0.96	10.00	0.05
ID-3.01	4.87	2.26	0.35	0.06	0.02	0.00	3.16	1.71	15.00	0.06
ID-2.31	3.15	1.62	0.54	0.07	0.02	0.00	1.44	1.71	3.50	0.03
ID-2.20	5.40	1.86	0.43	0.07	0.02	0.00	3.10	2.31	20.00	0.06
FW-4.00	11.90	2.33	0.46	0.06	0.02	0.00	6.47	5.43	40.00	0.03
ID-5.00	6.53	0.69	0.28	0.06	0.02	0.00	4.69	1.84	15.00	0.06
GC-7.00.03	0.72	3.10	0.51	0.05	0.01	0.00	0.35	0.37	5.00	0.04
FW-3.00	10.54	2.29	0.51	0.06	0.02	0.00	5.21	5.32	40.00	0.03
GC-7.00.02	0.58	4.18	0.51	0.05	0.01	0.00	0.29	0.30	10.00	0.05
FW-2.00	7.95	2.91	0.49	0.06	0.02	0.00	4.08	3.87	100.00	0.03
FW-1.24	3.91	1.22	0.72	0.06	0.02	0.00	1.09	2.82	3.50	0.03
FW-1.14	0.72	1.46	0.70	0.06	0.02	0.00	0.22	0.50	3.50	0.03
FW-1.04	2.54	1.34	0.64	0.06	0.02	0.00	0.91	1.63	5.00	0.03
FW-1.02	6.72	1.31	0.55	0.06	0.02	0.00	3.05	3.67	5.00	0.03
GC-7.03	3.65	1.36	0.50	0.06	0.02	0.00	1.81	1.83	0.00	0.00
GC-7.00.01	0.95	5.66	0.51	0.05	0.01	0.03	0.47	0.49	10.00	0.05
FW-1.03	5.35	1.49	0.55	0.06	0.02	0.00	2.43	2.92	5.00	0.03
FW-1.01	4.15	1.52	0.60	0.06	0.02	0.00	1.68	2.48	5.00	0.03
ID-4.00	5.37	2.95	0.50	0.06	0.02	0.00	2.67	2.69	30.00	0.06
ID-2.21	0.38	2.50	0.39	0.07	0.02	0.00	0.23	0.15	0.00	0.00
ID-2.10	7.40	2.49	0.06	0.07	0.02	0.00	6.96	0.44	0.00	0.00
ID-3.00	4.03	3.01	0.04	0.07	0.02	0.00	3.86	0.17	40.00	0.03
ID-2.00	9.30	2.46	0.02	0.07	0.02	0.00	9.16	0.14	5.00	0.05
ID-1.00	9.37	2.86	0.19	0.07	0.02	0.00	7.56	1.81	10.00	0.05
GC-8.01	4.20	1.03	0.00	0.07	0.02	0.02	4.20	0.01	5.00	0.06
GC-7.00	9.96	4.47	0.23	0.05	0.01	0.00	7.62	2.34	30.00	0.03
GC-9.01	3.48	2.27	0.24	0.07	0.02	0.00	2.64	0.84	0.00	0.00
GC-9.00	1.66	2.89	0.22	0.07	0.02	0.00	1.29	0.37	50.00	0.05
GC-8.00	6.44	2.21	0.01	0.07	0.02	0.00	6.37	0.06	45.00	0.02
RC-4.00	1.75	2.50	0.50	0.05	0.01	0.00	0.87	0.88	10.00	0.06
RC-4.01	6.21	1.87	0.50	0.05	0.01	0.00	3.09	3.11	5.00	0.06
GC-7.01	8.54	0.76	0.75	0.05	0.01	0.01	2.11	6.43	30.00	0.03
RC-1.01	2.79	1.13	0.74	0.05	0.01	0.00	0.73	2.06	5.00	0.06
RC-3.02	1.66	0.98	0.77	0.05	0.01	0.00	0.38	1.28	5.00	0.06
RC-2.00.01	3.31	1.39	0.84	0.05	0.01	0.00	0.54	2.77	5.00	0.06
RC-3.00	3.80	2.85	0.51	0.05	0.01	0.00	1.85	1.95	10.00	0.06

Sub-catchment Parameters

Sub-Catchment ID	Area (ha)	Slope (%)	Fraction Impervious	Pern (n*) Pervious	Pern (n*) Impervious	Reach Slope (m/m)	Area Pervious (ha)	Area Impervious (ha)	Reach Width (m)	Reach Manning's n
RC-2.00	3.89	2.45	0.55	0.05	0.01	0.00	1.74	2.15	10.00	0.06
GC-5.31	12.47	1.47	0.61	0.06	0.02	0.00	4.84	7.62	10.00	0.05
GC-5.21	9.80	1.76	0.46	0.06	0.02	0.00	5.24	4.56	10.00	0.06
GC-5.00	18.70	3.08	0.05	0.08	0.02	0.00	17.68	1.03	50.00	0.06
GC-5.02	12.36	2.16	0.00	0.08	0.02	0.00	12.36	0.00	20.00	0.06
GC-3.03	43.49	1.44	0.00	0.08	0.02	0.00	43.49	0.00	15.00	0.06
GC-4.01	5.62	2.20	0.30	0.06	0.02	0.00	3.94	1.68	5.00	0.06
GC-3.01	16.13	1.18	0.72	0.06	0.02	0.00	4.55	11.58	5.00	0.06
GC-2.01	7.86	1.12	0.73	0.06	0.02	0.00	2.13	5.73	5.00	0.06
GC-1.00	19.14	3.71	0.00	0.08	0.02	0.00	19.14	0.00	0.00	0.00
GC-12.00	9.75	3.27	0.31	0.06	0.02	0.00	6.70	3.05	15.00	0.05
LB-1.00.02	2.47	1.34	0.37	0.06	0.02	0.03	1.55	0.92	5.00	0.04
FW-1.00	5.91	4.36	0.01	0.06	0.02	0.00	5.85	0.07	20.00	0.03

Appendix B – Culvert and Bridge Details



GORDON CREEK FLOOD STUDY MIKE 11 Model

Upper Study Area

Figure B-1

LEGEND

- MIKE 11 Nodes
- MIKE 11 Branches
- Suburbs

SCALE: 1:15,000 @A3

150 75 0 150 300 450 Metres

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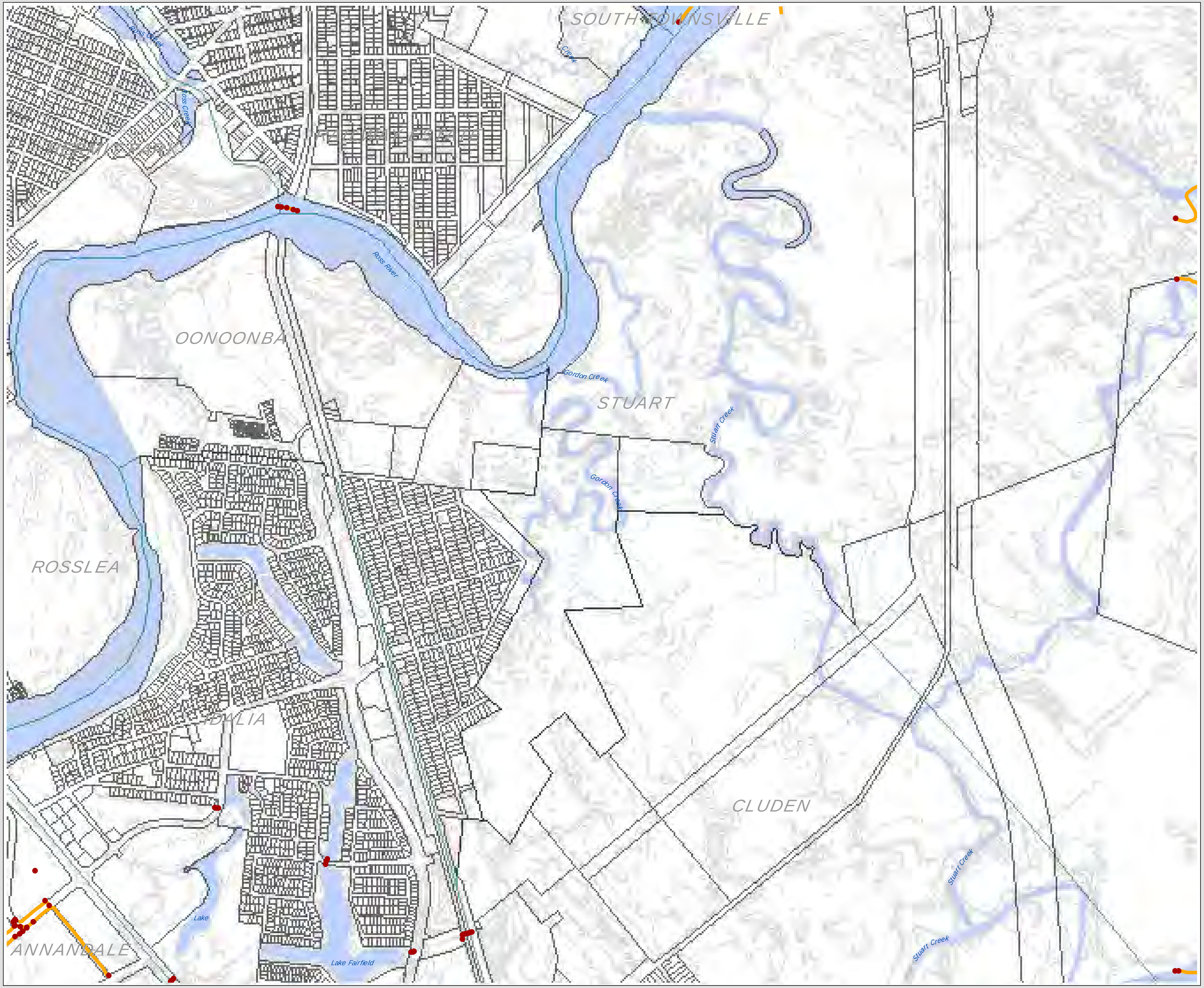
DIGITAL FILE: Appendix-B_MIKE11_Setup.mxd



GORDON CREEK FLOOD STUDY MIKE 11 Model

Lower Study Area

Figure B-2

LEGEND

- MIKE 11 Nodes
- MIKE 11 Branches
- Suburbs

City of Townsville

SCALE: 1:15,000 @A3

150 75 0 150 300 450 Metres

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DIGITAL FILE: Appendix-B_MIKE11_Setup.mxd

Bridge Details

Branch	Chainage (m)	ID	Soffit (m AHD)	Deck (m AHD)	Width (m)
Abbott Street	71.5	Existing Road Abbot	3	4	11
Abbott Street	41	Pedestrian Bridge Abbot	2.5	3.2	6.7
Abbott Street	15.5	Rail Bridge Abbot	2.94	3.235	4
Bowen Road	25	Bowen Road	5.5	6.4	10.4
Stuart Creek	15	Bruce Highway, St Ck	6.5	7.3	8.53

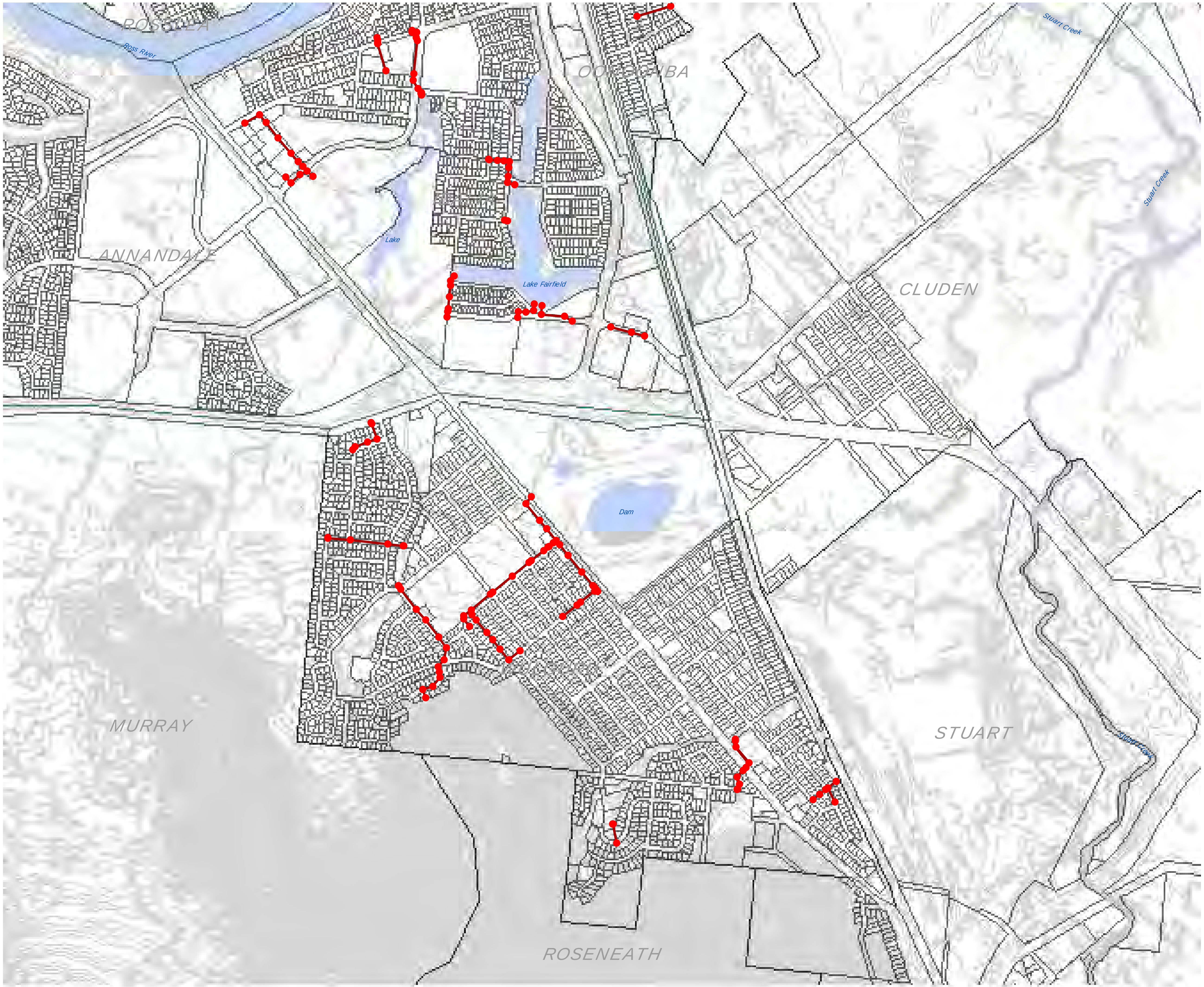
Culvert Details

Sl. No.	Branch	Chainage	ID	Geometry	No. of Culverts	Diameter (m)	Width (m)	Height (m)	Length (m)	Upstream Invert (m AHD)	Downstream Invert (m AHD)	Mannings 'n'
1	Murray Drain 1	20	University Road	Rectangular	1		2.4	2.4	40	8.52	7.95	0.013
2	Cluden Drain 5	10	Bruce Highway	Rectangular	1		1.2	0.375	19.43	4.25	4.15	0.013
3	Cluden Drain 6	10	Bruce Highway	Rectangular	1		1.2	0.3	19.52	4.25	4.15	0.013
4	Cluden Drain 7	7	Bruce Highway	Rectangular	1		1.2	0.3	10.98	4.38	4.32	0.015
5	Cluden Drain 9	7.5	Bruce Highway	Rectangular	1		1.2	0.375	15.01	4.85	4.75	0.013
6	Cluden Drain 11	8.5	Bruce Highway	Rectangular	1		1.2	0.375	17.13	5.2	5.1	0.013
7	Cluden Drain 12	9	Bruce Highway	Rectangular	1		1.2	0.375	17.5	5.8	5.7	0.013
8	Cluden Drain 13	7	Bruce Highway	Rectangular	1		1.2	0.375	13.52	5.7	5.6	0.013
9	Cluden Drain 14	8	Bruce Highway	Rectangular	1		1.2	0.375	16.75	5.9	5.8	0.013
10	Fairfield Lake Culvert-2	11.5	Lakeland Boulevard	Rectangular	3		2.4	1.2	23	1.958	1.85	0.013
11	Stuart Drain-1	12.5	QR	Rectangular	6		3	1.2	24.5	9.326	9.203	0.015
12	Stuart Drain-2	18	QR,	Rectangular	6		3	1.2	35.7	8.823	8.718	0.013
13	Cluden Drain-1	10	Racecourse Road	Rectangular	2		1.2	0.3	19.3	1.516	1.717	0.013
14	Cluden Drain-2	10	Racecourse Road	Circular	1	0.9			17.21	2.765	2.647	0.013
15	Wulguru Drain 1	485	Edison Street	Rectangular	2		2.16	1.22	21.513	10.264	10.079	0.015
16	Murray Drain 3	20	University Road	Rectangular	8		1.2	0.9	39.89	4.73	4.58	0.013
17	Wulguru Drain 2	16	University Road	Rectangular	5		1.2	0.6	33.3	2.884	2.64	0.013
18	Wulguru Drain 3	11	University Road	Rectangular	15		1.2	0.6	24.98	2.94	2.85	0.013
19	Annandale-Idalia Drain-1	14	Stuart Drive	Rectangular	4		2.15	1.52	25.711	1.478	1.452	0.015
20	Annandale Drain 5	6	Murray Lyons Crescent	Rectangular	1		1.2	0.3	12	4.2	4.17	0.013
21	Annandale Drain 6	25	MarvynCrossmanDrive	Rectangular	3		1.2	0.6	50	4.12	3.88	0.013
22	Annandale Table Drain 2	297	Mervyn Crossman Drive	Rectangular	2		1.2	0.9	18	4.31	4.29	0.013
23	Wulguru-Cluden Drain	11	Stuart Drive	Rectangular	11		1.2	0.6	22	4.27	4.18	0.013
24	Cluden Drain-4	14	Bruce Highway	Rectangular	6		1.2	0.3	26.84	2.9	2.7	0.015
25	Idalia-Cluden Drain-1	8	Abott Street South	Rectangular	11		2.1	0.9	10.338	1.291	1.233	0.013
26	Idalia-Cluden Drain-2	8	Abott Street North	Rectangular	4		2.1	0.9	15.86	1.388	1.357	0.015
27	Cluden Drain 8	7	Bruce Highway	Rectangular	1		1.2	0.3	10.98	4.7	4.43	0.013
28	Cluden Drain 10	7	Bruce Highway	Rectangular	1		1.2	0.375	14.5	4.95	4.86	0.013
29	Fairfield Lake Culvert-1	6	Lakeside Drive	Rectangular	15		2.5	2.75	12.2	0.89	0.83	0.013
30	Murray Drain 2	22	University Road	Rectangular	3		2.1	2.1	43.851	8.497	7.972	0.015
31	Wulguru Drain 4	8	Stuart Drive	Rectangular	3		1.8	1.05	16.4	14.757	14.725	0.015
32	Idalia Drain 2	8	Fairfield Water Drive	Rectangular	3		1.5	1.5	15.93	2.7	2.5	0.013
33	Wulguru Drain 5	11	Wright Street	Circular	3	1.5			20.265	18.427	18.297	0.015
34	Wulguru Drain 6	5	Parallel Newton Street	Rectangular	1		12.1	1.33	10	2.81	2.81	0.015
35	Idalia-Cluden Drain 2a	5	QR FA001_06	Rectangular	3		2.4	1.2	10.14	0.762	0.689	0.015
36	Idalia-Cluden Drain 1a	5	QR FA003_07	Rectangular	9		2.4	1.2	10.17	0.857	0.783	0.015

Culvert Details

Sl. No.	Branch	Chainage	ID	Geometry	No. of Culverts	Diameter (m)	Width (m)	Height (m)	Length (m)	Upstream Invert (m AHD)	Downstream Invert (m AHD)	Mannings 'n'
37	Wulguru-Stuart Drain	5	QR FA004_04	Rectangular	6		1.5	1.5	10.134	10.668	10.628	0.015
38	Cluden Drain-3	8	Racecourse Road	Circular	2	1.2			16.7	1.629	1.571	0.013
39	Annandale-Idalia Drain-2	8	Stuart Drive	Rectangular	6		2.1	1.5	15.897	1.616	1.605	0.015
40	Murray Drain 4	6	Robert Towns Blvd LA 009_	Rectangular	7		2.35	1.2	11.257	15.745	15.741	0.015
41	Murray Drain 5	6	Robert Towns Blvd LA 011_	Circular	2	1.375			12.243	8.925	8.807	0.015
42	Wulguru RCP	14	Dahl Crescent	Circular	1	1.2			28.77	46.66	44.15	0.015
43	Wulguru RCBC	9	Bellevue Court	Rectangular	1		1.8	0.9	17.6	27.29	26.83	0.015
44	Stuart Drain-4	6	Bruce Highway	Circular	2	1.5			11.8	0.791	0.725	0.015
45	Stuart Drain-3	9	Bruce Highway	Circular	2	0.92			18	4.75	4.63	0.015
46	Stuart Drain-5	6	Minehane Street	Circular	2	0.75			11	4.04	3.89	0.015
47	Cluden-Idalia Drain 2	6	BP access FA003_06	Circular	4	1.2			11.048	1.634	1.561	0.015
48	Cluden-Idalia Drain 1	9	Racecourse Road	Rectangular	4		2.1	1.2	11.314	1.427	1.422	0.015
49	Stuart Drain 6	12.5	Highway-Ch78894	Circular	2	0.9			25	5.32	5.32	0.013
50	Stuart Drain 7	12.5	Highway-Ch78553	Circular	3	1.05			25	5.13	5.04	0.013
51	Stuart Drain 8	8.5	Culvert4A	Rectangular	1		0.6	0.45	17	6.072	6.008	0.013
52	Stuart Drain 9	12.5	Highway-Ch78283	Circular	3	1.2			25	5.25	5.2	0.013
53	Oonoonba RCP	6.3	Abbott Street	Circular	3	0.9			12.6	1.651	1.655	0.013
54	Wulguru RCP2	6	Stuart Drive	Circular	2	1.2			12.3	19.098	18.882	0.013
55	Annandale RCP2	10	Shanahan Drive	Circular	5	1.8			20.2	3.289	3.21	0.013
56	Annandale RCP1	10	Marvyn Crossman Drive	Circular	5	1.8			20	5.73	5.67	0.013
57	Annandale RCP3	13.5	Gartrell Drive	Circular	2	1.2			26.8	2.73	2.46	0.013
58	FairfieldWaters RCP	12.5	Lakeside Drive	Circular	1	0.9			25	1.66	1.54	0.013
59	Cluden RCBC1	1.8	Abbott St	Rectangular	9		1.8	0.9	3.6	1.121	1.111	0.013
60	Cluden RCBC2	2.3	Abbott St	Rectangular	3		4.13	1.5	4.6	1.771	1.707	0.013

Appendix C – Underground Drainage Details



GORDON CREEK FLOOD STUDY MIKE URBAN MODEL

Upper Study Area

Figure C-1

LEGEND

- MIKE URBAN Nodes
- MIKE URBAN Links
- Suburbs

City of Townsville

SCALE: 1:15,000 @A3

150 75 0 150 300 450 Metres

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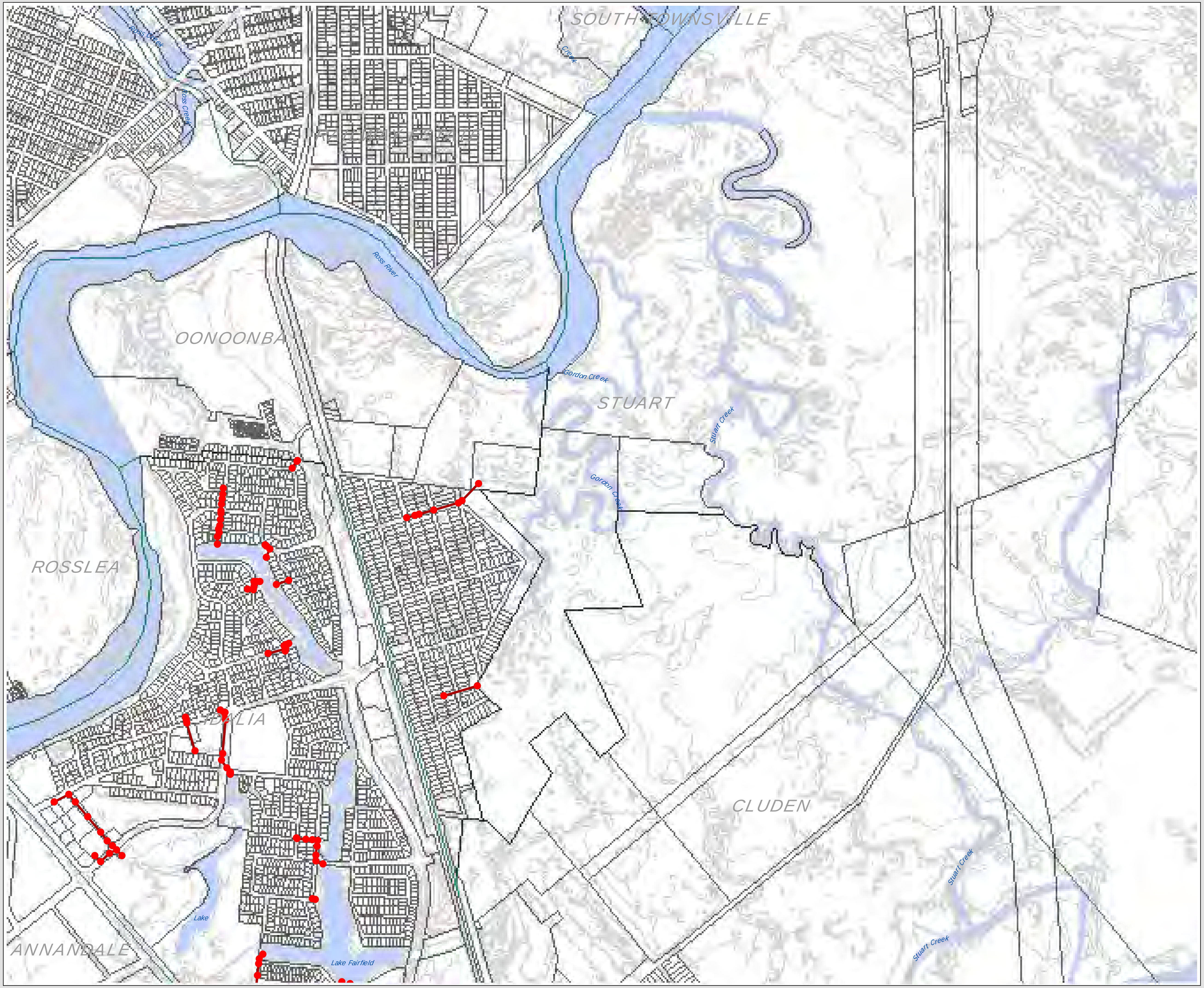

GORDON CREEK FLOOD STUDY MIKE URBAN MODEL

Lower Study Area

Figure C-2

LEGEND

- MIKE URBAN Nodes
- MIKE URBAN Links
- Suburbs

N

City of Townsville

SCALE: 1:15,000 @A3

150 75 0 150 300 450 Metres

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Link Details

Link ID	TypeNo	Conduit Type	Upstream Level (m AHD)	Downstream Level (m AHD)	Length (m)	Slope (m)	Diameter (m)	Width (m)	Height (m)	Manning's n	From Node	To Node
FFL1	1.00	RCP	1.82	1.33	23.25	2.09	1.35			0.025	0641GH1U	0641G6U
FFL2	1.00	RCP	1.20	1.15	24.67	0.20	1.35			0.025	0641EB1U	0641E4U
105328	1.00	RCP	16.16	15.90	25.25	1.03	1.20			0.025	0087A4U	0087A3U
105329	1.00	RCP	16.16	15.90	25.25	1.03	1.20			0.025	0087A4U	0087A3U
39316	1.00	RCP	17.52	17.24	30.29	0.92	1.20			0.025	0083A4U	0083A3U
39318	1.00	RCP	17.52	17.24	30.29	0.92	1.20			0.025	0083A4U	0083A3U
Link_6	1.00	RCP	17.24	16.89	38.85	0.90	1.20			0.025	0083A3U	0083B2U
Link_7	1.00	RCP	17.24	16.89	38.85	0.90	1.20			0.025	0083A3U	0083B2U
Link_8	1.00	RCP	16.89	16.60	17.83	1.63	1.20			0.025	0083B2U	0087A4U
Link_9	1.00	RCP	16.89	16.60	17.83	1.63	1.20			0.025	0083B2U	0087A4U
3378	1.00	RCP	15.13	14.82	90.81	0.34	1.20			0.025	0087A3U	0087A2U
41859	1.00	RCP	21.10	20.70	35.55	1.13	1.05			0.025	0129AA7U	0129AA6U
Link_12	1.00	RCP	15.38	14.93	52.17	0.86	1.20			0.025	0129AA1U	0129A8U
40778	1.00	RCP	14.93	14.62	57.43	0.54	1.20			0.025	0129A8U	0129A7U
53022	1.00	RCP	12.12	11.52	46.27	1.30	0.90			0.025	0309AH3U	0309AH2U
333474	1.00	RCP	3.12	2.96	69.40	0.23	0.90			0.025	0421A7U	0421A6U
76306	1.00	RCP	1.94	1.86	27.73	0.29	1.05			0.025	0503A4U	0503A3U
133123	1.00	RCP	2.27	2.04	123.62	0.19	1.05			0.025	0244B3U	0244B2U
Link_26	1.00	RCP	12.65	12.30	12.21	2.87	0.90			0.025	0087F3U	0087F2U
Link_27	1.00	RCP	12.71	12.68	34.51	0.09	0.90			0.025	0087F5U	0087F4U
39749	1.00	RCP	12.68	12.65	34.21	0.09	0.90			0.025	0087F4U	0087F3U
Link_29	1.00	RCP	4.53	4.49	5.00	0.80	1.20			0.025	SS416	0309A6U
87385	1.00	RCP	4.27	4.10	15.62	1.09	1.20			0.025	0309A5U	0309A4U
Link_31	1.00	RCP	3.69	3.34	65.44	0.53	1.65			0.025	0309A4U	0309A04U
Link_44	1.00	RCP	2.38	2.31	11.05	0.63	1.05			0.025	0244B4U	244002
133081	1.00	RCP	2.31	2.27	4.00	1.00	1.05			0.025	244002	0244B3U
Link_45	1.00	RCP	1.98	1.90	2.83	2.86	0.90			0.025	SS1167	0530A8U
99180	1.00	RCP	1.90	1.85	37.12	0.13	0.90			0.025	0530A8U	SS1264
Link_84	1.00	RCP	1.78	1.77	3.59	0.28	1.70			0.025	0503A1D	Node_50
133870	1.00	RCP	2.41	2.35	8.25	0.73	0.90			0.025	0503A9U	0503A8U
133900	1.00	RCP	2.35	2.28	19.00	0.36	0.90			0.025	0503A8U	0503A7U
135414	1.00	RCP	2.28	2.21	23.20	0.31	0.90			0.025	0503A7U	0503A6U
185163	1.00	RCP	1.24	1.20	12.86	0.31	0.90			0.025	0539A3U	0539A1D
197030	1.00	RCP	2.51	2.41	36.96	0.27	1.65			0.025	0309A2U	0309A1D
197062	1.00	RCP	3.11	2.51	91.44	0.66	1.65			0.025	0309A3U	0309A2U
197182	1.00	RCP	7.03	5.94	91.44	1.19	0.90			0.025	0309AA3U	0309AA2U
197230	1.00	RCP	7.84	7.03	74.39	1.09	0.90			0.025	0309AA4U	0309AA3U
199058	1.00	RCP	9.18	9.05	12.30	1.06	0.90			0.025	0309AAE1U	0309AA6U
253305	1.00	RCP	1.42	1.36	38.59	0.16	1.05			0.025	SS2025	0641AB1U
253307	1.00	RCP	1.36	1.22	100.79	0.14	1.20			0.025	0641AB1U	0641A3U
253318	1.00	RCP	1.22	1.15	37.97	0.18	1.20			0.025	0641A3U	0641A1D
197117	1.00	RCP	3.34	3.11	46.86	0.49	1.65			0.025	0309A04U	0309A3U
Link_32	1.00	RCP	9.59	9.50	11.40	0.79	0.90			0.025	0309A12U	0309A11U
357905	1.00	RCP	24.16	23.96	23.00	0.87	0.90			0.025	0280D1U	0280D1D
39210	1.00	RCP	0.61	0.54	111.30	0.06	1.05			0.025	0118A5U	0118A3U
53010	1.00	RCP	7.81	6.80	108.08	0.93	0.90			0.025	0309A11U	0309A10U
52021	1.00	RCP	8.41	8.37	78.25	0.05	0.90			0.025	0309AA9U	0309AA09U
Link_34	1.00	RCP	8.37	8.36	96.53	0.01	0.90			0.025	0309AA09U	0309AA8U
Link_38	1.00	RCP	9.60	9.59	1.00	1.00	0.90			0.025	0133A5U	0133AD1U
92250	1.00	RCP	1.89	1.63	29.00	0.90	1.20			0.025	0389B3U	SS1041
Link_40	1.00	RCP	1.63	1.58	26.91	0.19	1.20			0.025	SS1041	0389B2U
Link_25	1.00	RCP	1.86	1.83	39.96	0.08	1.05			0.025	0503A3U	SS1584
Link_23	1.00	RCP	1.86	1.83	39.96	0.08	1.05			0.025	0503A3U	SS1584
Link_42	1.00	RCP	1.83	1.82	23.38	0.03	1.05			0.025	SS1584	0503A2U
39344	1.00	RCP	17.98	17.75	22.44	1.03	1.20			0.025	0083A5U	0083A4U
39346	1.00	RCP	17.98	17.75	22.44	1.03	1.20			0.025	0083A5U	0083A4U
39347	1.00	RCP	17.98	17.98	3.83	0.03	1.20			0.025	0083AC1U	0083A5U
39350	1.00	RCP	17.98	17.98	3.83	0.03	1.20			0.025	0083AC1U	0083A5U
39373	1.00	RCP	14.82	14.73	26.90	0.33	1.35			0.025	0087A2U	0087A1D
39375	1.00	RCP	14.82	14.73	26.90	0.33	1.35			0.025	0087A2U	0087A1D
39376	1.00	RCP	15.13	14.82	90.81	0.34	1.20			0.025	0087A3U	0087A2U
39409	1.00	RCP	12.30	11.49	43.80	1.85	1.05			0.025	0087F2U	0087F1D
39825	1.00	RCP	0.53	0.29	101.80	0.24	1.05			0.025	0118A2U	0118A1D

Link Details

Link ID	TypeNo	Conduit Type	Upstream Level (m AHD)	Downstream Level (m AHD)	Length (m)	Slope (m)	Diameter (m)	Width (m)	Height (m)	Manning's n	From Node	To Node
40486	1.00	RCP	12.56	12.30	66.62	0.39	1.05			0.025	0087FA1U	0087F2U
40554	1.00	RCP	0.69	0.66	19.71	0.15	0.90			0.025	0118A006U	0118A06U
40572	1.00	RCP	1.14	0.69	35.81	1.26	0.90			0.025	0118A6U	0118A006U
40642	1.00	RCP	0.66	0.61	64.43	0.08	0.90			0.025	0118A06U	0118A5U
40776	1.00	RCP	14.62	13.03	94.50	1.68	1.20			0.025	0129A7U	0129A6U
40784	1.00	RCP	15.86	15.38	39.70	1.21	1.20			0.025	0129AA2U	0129AA1U
98981	1.00	RCP	1.65	1.58	26.08	0.27	0.90			0.025	0530A6U	SS1253
40821	1.00	RCP	9.45	9.22	159.80	0.14	0.90			0.025	0133A4U	0133A3U
40825	1.00	RCP	9.59	9.45	98.40	0.14	0.90			0.025	0133AD1U	0133A4U
41849	1.00	RCP	16.24	16.00	23.10	1.04	1.20			0.025	0129AA3U	0129AA2U
41851	1.00	RCP	17.99	17.50	50.10	0.98	1.05			0.025	0129AA5U	0129AA4U
41853	1.00	RCP	19.79	19.40	43.30	0.90	1.05			0.025	0129AA6U	0129AA5U
41863	1.00	RCP	16.64	16.40	22.10	1.09	1.20			0.025	0129AA4U	0129AA3U
Link_43	1.00	RCP	1.83	1.82	23.38	0.03	1.05			0.025	SS1584	0503A2U
Link_46	1.00	RCP	1.58	1.53	1.00	5.00	0.90			0.025	SS1253	SS1254
Link_47	1.00	RCP	1.53	1.52	37.22	0.02	0.90			0.025	SS1254	SS1261
Link_48	1.00	RCP	2.04	1.98	14.14	0.42	1.05			0.025	0516A4U	SS198
78118	1.00	RCP	1.98	1.89	23.02	0.39	1.05			0.025	SS198	0516A3U
88554	1.00	RCP	1.61	1.60	23.20	0.04	1.05			0.025	0522A7U	SS568
Link_49	1.00	RCP	1.60	1.59	1.00	1.00	1.05			0.025	SS568	SS569
Link_50	1.00	RCP	1.58	1.56	26.08	0.08	1.05			0.025	SS569	0522A6U
88807	1.00	RCP	1.93	1.92	22.23	0.02	0.90			0.025	0522A9U	SS613
Link_54	1.00	RCP	1.97	1.93	8.49	0.47	1.20			0.025	0522B6U	SS609
44288	1.00	RCP	0.54	0.53	18.80	0.05	1.05			0.025	0118A3U	0118A2U
Link_51	1.00	RCP	1.92	1.80	23.04	0.52	0.90			0.025	SS613	SS560
Link_52	1.00	RCP	1.80	1.66	28.21	0.50	0.90			0.025	SS560	0522A8U
88597	1.00	RCP	1.93	1.84	18.60	0.48	1.20			0.025	SS609	0522B5U
197140	1.00	RCP	4.67	4.40	24.21	1.12	0.90			0.025	0309AA1U	0309A4U
Link_58	1.00	RCP	5.28	5.18	12.04	0.83	1.05			0.025	0309A9U	0309A8U
53002	1.00	RCP	6.80	6.00	93.09	0.86	1.05			0.025	0309A10U	0309A9U
45853	3.00	RCBC	11.38	10.03	15.28	8.83	1.20	2.10	1.20	0.025	0129A4U	0129A3U
Link_55	1.00	RCP	5.94	4.67	58.26	2.18	0.90			0.025	0309AA2U	0309AA1U
Link_60	1.00	RCP	11.11	11.09	57.28	0.03	1.05			0.025	0279F4U	0279FA2U
Link_62	1.00	RCP	11.09	10.58	10.44	4.87	1.05			0.025	0279FA2U	0279F2U
Link_63	1.00	RCP	30.17	30.12	3.04	1.65	0.90			0.025	0359A2U	0359A1D
Link_66	1.00	RCP	13.03	12.64	61.07	0.64	1.20			0.025	0129A6U	0129A5U
Link_68	1.00	RCP	8.38	8.25	78.41	0.17	0.90			0.025	0309AA8U	0309AA7U
52018	1.00	RCP	8.25	8.20	8.94	0.56	0.90			0.025	0309AA7U	0309AA6U
50578	1.00	RCP	23.72	23.45	11.30	2.39	1.20			0.025	0280B2U	0280B1D
50580	1.00	RCP	24.60	23.72	12.00	7.33	0.90			0.025	0280B3U	0280B2U
50584	1.00	RCP	25.33	24.60	16.20	4.51	0.90			0.025	0280B4U	0280B3U
51371	1.00	RCP	35.32	30.17	84.80	6.07	1.20			0.025	0359AA1U	0359A2U
52004	1.00	RCP	8.17	8.09	8.00	1.00	0.90			0.025	0309AA5U	0309AA4U
52007	1.00	RCP	8.20	8.17	13.20	0.23	0.90			0.025	0309AA6U	0309AA5U
52020	1.00	RCP	8.38	8.25	87.70	0.15	0.90			0.025	0309AA8U	0309AA6U
52285	1.00	RCP	8.87	8.44	2.90	14.62	0.90			0.025	0133A2U	0133A1D
52287	1.00	RCP	9.22	8.87	67.30	0.52	0.90			0.025	0133A3U	0133A2U
52986	1.00	RCP	4.49	4.27	24.84	0.89	1.20			0.025	0309A6U	0309A5U
Link_67	1.00	RCP	12.64	11.38	109.38	1.15	1.20			0.025	0129A5U	0129A4U
Link_69	1.00	RCP	1.85	1.76	28.07	0.32	0.90			0.025	SS1264	0530A7U
Link_72	1.00	RCP	11.50	11.09	69.66	0.59	1.05			0.025	0309A16U	0309A15U
Link_80	3.00	RCBC	11.38	11.20	18.79	0.95	1.65	2.10	1.20	0.025	0129A4U	0129A3U
53014	1.00	RCP	10.91	9.59	107.30	1.23	0.90			0.025	0309A13U	0309A12U
53016	1.00	RCP	10.95	10.91	20.20	0.20	1.05			0.025	0309A14U	0309A13U
53018	1.00	RCP	11.09	10.91	41.20	0.44	0.90			0.025	0309AH1U	0309A13U
53020	1.00	RCP	11.52	11.40	13.71	0.88	0.90			0.025	0309AH2U	0309AH1U
53028	1.00	RCP	11.09	10.95	30.60	0.46	1.05			0.025	0309A15U	0309A14U
53048	1.00	RCP	12.45	12.22	60.30	0.38	1.05			0.025	0309A20U	0309A19U
53139	1.00	RCP	3.12	2.96	69.40	0.23	0.90			0.025	0421A7U	0421A6U
53164	1.00	RCP	3.46	3.12	43.00	0.79	0.90			0.025	0421A8U	0421A7U
53172	1.00	RCP	3.69	3.46	57.00	0.40	0.90			0.025	0421A9U	0421A8U
53174	1.00	RCP	3.78	3.69	16.20	0.56	0.90			0.025	0421A10U	0421A9U
563966	1.00	RCP	1.03	1.02	27.00	0.05	1.35			0.025	0641G2U	0641G1D

Link Details

Link ID	TypeNo	Conduit Type	Upstream Level (m AHD)	Downstream Level (m AHD)	Length (m)	Slope (m)	Diameter (m)	Width (m)	Height (m)	Manning's n	From Node	To Node
563968	1.00	RCP	1.04	1.03	19.00	0.01	1.35			0.025	0641G3U	0641G2U
563970	1.00	RCP	1.20	1.04	50.25	0.33	1.35			0.025	0641G4U	0641G3U
563972	1.00	RCP	1.29	1.20	50.40	0.17	1.35			0.025	0641G5U	0641G4U
563974	1.00	RCP	1.33	1.29	11.90	0.38	1.35			0.025	0641G6U	0641G5U
564083	1.00	RCP	1.15	1.08	31.60	0.22	1.35			0.025	0641E4U	0641E3U
564086	1.00	RCP	1.08	1.02	35.60	0.19	1.35			0.025	0641E3U	0641E2U
564088	1.00	RCP	1.02	0.98	28.60	0.13	1.35			0.025	0641E2U	0641E1D
58369	1.00	RCP	1.13	0.82	151.90	0.20	1.05			0.025	0180B2U	0180B1D
62720	1.00	RCP	2.04	1.84	90.00	0.22	0.90			0.025	0388D2U	0388D02U
63553	1.00	RCP	2.45	2.38	11.20	0.60	0.90			0.025	0244B5U	0244B4U
68229	1.00	RCP	3.10	2.87	71.32	0.32	0.90			0.025	0389B8U	0389B7U
68236	1.00	RCP	2.87	2.71	42.77	0.38	0.90			0.025	0389B7U	0389B6U
68237	1.00	RCP	2.71	2.44	83.60	0.32	1.05			0.025	0389B6U	0389B5U
68248	1.00	RCP	2.44	2.16	86.80	0.32	1.05			0.025	0389B5U	0389B4U
68260	1.00	RCP	2.16	1.89	46.90	0.58	1.20			0.025	0389B4U	0389B3U
Link_74	1.00	RCP	11.67	11.50	40.46	0.42	1.05			0.025	0309A17U	0309A16U
Link_76	1.00	RCP	12.22	12.03	59.66	0.32	1.05			0.025	0309A19U	0309A18U
Link_77	1.00	RCP	12.03	11.67	51.23	0.70	1.05			0.025	0309A18U	0309A17U
73380	1.00	RCP	1.91	1.80	10.40	1.06	0.90			0.025	0504A5U	0504A4U
73404	1.00	RCP	1.76	1.65	13.20	0.83	1.20			0.025	0504A4U	0504A3U
73416	1.00	RCP	1.35	1.34	7.30	0.14	1.20			0.025	0504A3U	0504A2U
73417	1.00	RCP	1.34	1.32	14.90	0.13	1.20			0.025	0504A2U	0504A1D
73419	1.00	RCP	1.95	1.76	76.90	0.25	0.90			0.025	0504AD1U	0504A4U
76301	1.00	RCP	2.21	2.20	13.00	0.08	0.90			0.025	0503A6U	0503A5U
76303	1.00	RCP	2.20	1.94	144.00	0.18	0.90			0.025	0503A5U	0503A4U
76305	1.00	RCP	1.94	1.86	27.80	0.29	1.05			0.025	0503A4U	0503A3U
76332	1.00	RCP	1.82	1.79	5.00	0.60	1.20			0.025	0503A2U	0503A02U2
76333	1.00	RCP	1.82	1.79	5.00	0.60	1.20			0.025	0503A2U	0503A02U
52994	1.00	RCP	4.70	4.53	24.21	0.70	1.20			0.025	0309A7U	SS416
Link_82	1.00	RCP	5.18	4.70	68.25	0.70	1.20			0.025	0309A8U	0309A7U
Link_85	1.00	RCP	2.17	2.16	2.92	0.34	1.28			0.025	0523A1D	Node_51
76334	1.00	RCP	1.79	1.78	3.93	0.25	1.20			0.025	0503A02U2	0503A1D
76335	1.00	RCP	1.79	1.78	2.10	0.48	1.20			0.025	0503A02U	0503A1D
78109	1.00	RCP	2.21	2.04	27.00	0.63	0.90			0.025	0516AB1U	0516A4U
78122	1.00	RCP	1.89	1.84	12.10	0.41	1.05			0.025	0516A3U	0516A2U
78125	1.00	RCP	1.84	1.80	11.90	0.34	1.05			0.025	0516A2U	0516A1D
79183	1.00	RCP	10.58	10.40	18.70	0.97	0.90			0.025	0279F2U	0279F1D
85620	1.00	RCP	1.84	1.73	59.40	0.19	0.90			0.025	0388D02U	0388D1D
86055	1.00	RCP	11.31	11.11	24.00	0.83	0.90			0.025	0279F5U	0279F4U
86057	1.00	RCP	11.55	11.31	61.00	0.39	0.90			0.025	0279F6U	0279F5U
86067	1.00	RCP	13.35	13.20	23.00	0.65	0.90			0.025	0279H2U	0279H1D
86071	1.00	RCP	13.53	13.35	54.90	0.33	0.90			0.025	0279H3U	0279H2U
88545	1.00	RCP	1.42	1.40	34.70	0.06	1.20			0.025	0522A2U	0522A1D
Link_86	1.00	RCP	2.96	2.95	5.71	0.18	1.28			0.025	0421A6U	Node_52
Link_87	1.00	RCP	14.73	14.71	7.01	0.36	1.91			0.025	0087A1D	Node_53
Link_88	3.00	RCBC	10.03	9.99	2.20	1.82	2.55	4.20	1.20	0.025	0129A3U	Node_54
88547	1.00	RCP	1.49	1.42	18.70	0.37	1.20			0.025	0522A3U	0522A2U
88550	1.00	RCP	1.53	1.49	14.32	0.28	1.20			0.025	0522A5U	0522A3U
88552	1.00	RCP	1.56	1.53	16.40	0.18	1.20			0.025	0522A6U	0522A5U
88556	1.00	RCP	1.66	1.61	13.00	0.38	1.05			0.025	0522A8U	0522A7U
88592	1.00	RCP	1.84	1.75	39.80	0.23	1.20			0.025	0522B5U	0522B3U
88811	1.00	RCP	1.93	1.93	23.90	0.02	0.90			0.025	0522A10U	0522A9U
90132	1.00	RCP	2.20	2.17	36.00	0.08	0.90			0.025	0523A2U	0523A1D
90133	1.00	RCP	2.20	2.17	35.99	0.08	0.90			0.025	0523A2U	0523A1D
90997	1.00	RCP	1.56	1.37	57.49	0.33	1.05			0.025	0525A3U	0525A1D
92216	1.00	RCP	2.18	2.05	34.12	0.37	0.90			0.025	0389BH3U	0389BH2U
92218	1.00	RCP	2.05	1.85	52.17	0.38	0.90			0.025	0389BH2U	0389BH1U
92253	1.00	RCP	1.58	1.53	33.36	0.15	1.35			0.025	0389B2U	0389B1D
92257	1.00	RCP	1.85	1.58	33.69	0.80	1.05			0.025	0389BH1U	0389B2U
98978	1.00	RCP	1.39	1.19	32.77	0.61	0.90			0.025	0530A4U	0530A2U
98980	1.00	RCP	1.52	1.39	26.76	0.50	0.90			0.025	SS1261	0530A4U
99181	1.00	RCP	1.76	1.65	22.12	0.50	0.90			0.025	0530A7U	0530A6U

Node Details

Node ID	Node Type	Invert Level (m AHD)	Ground Level (m AHD)	Equivalent Diameter (m)
0503A2U	Manhole/Inlet	1.82	4.00	1.20
0309AA3U	Manhole/Inlet	7.03	8.60	0.90
0309AH1U	Manhole/Inlet	11.09	13.40	0.90
0309A12U	Manhole/Inlet	9.59	10.83	0.90
0309A13U	Manhole/Inlet	10.91	12.40	1.05
0309A14U	Manhole/Inlet	10.95	12.90	1.05
0118A6U	Manhole/Inlet	1.14	2.68	0.90
0309A15U	Manhole/Inlet	11.09	13.33	1.05
0309A10U	Manhole/Inlet	6.80	8.66	1.05
0309AAE1U	Manhole/Inlet	9.18	10.40	0.90
0309AA9U	Manhole/Inlet	8.41	11.16	0.90
0309A19U	Manhole/Inlet	12.22	16.29	1.05
0309A20U	Manhole/Inlet	12.45	14.17	1.05
0133A2U	Manhole/Inlet	8.87	10.75	0.90
0388D2U	Manhole/Inlet	2.04	3.72	0.90
SS560	Manhole/Inlet	1.80	4.05	0.90
0389B6U	Manhole/Inlet	2.71	4.72	1.05
0389B5U	Manhole/Inlet	2.44	4.38	1.05
0389B4U	Manhole/Inlet	2.16	4.05	1.20
0359A2U	Manhole/Inlet	30.17	34.30	1.20
0504A4U	Manhole/Inlet	1.76	3.80	1.20
0504A2U	Manhole/Inlet	1.34	3.71	1.20
0503A7U	Manhole/Inlet	2.28	3.70	0.90
0503A4U	Manhole/Inlet	1.94	3.67	1.05
0503A3U	Manhole/Inlet	1.86	3.75	1.05
0503A02U	Manhole/Inlet	1.79	4.00	1.20
0503A5U	Manhole/Inlet	2.20	3.95	0.90
0389B7U	Manhole/Inlet	2.87	4.91	0.90
0516A2U	Manhole/Inlet	1.84	4.00	1.05
0421A8U	Manhole/Inlet	3.46	4.96	0.90
0421A9U	Manhole/Inlet	3.69	5.23	0.90
0133A4U	Manhole/Inlet	9.45	11.10	0.90
0309A3U	Manhole/Inlet	3.11	5.69	1.65
0309A2U	Manhole/Inlet	2.51	4.95	1.65
0309A8U	Manhole/Inlet	5.18	7.40	1.20
0309A6U	Manhole/Inlet	4.49	6.40	1.20
0087F5U	Manhole/Inlet	12.71	15.03	0.90
0087F2U	Manhole/Inlet	12.30	13.61	1.05
0087FA1U	Manhole/Inlet	12.56	14.26	1.05
0503A02U2	Manhole/Inlet	1.79	4.00	1.20
0309AH3U	Manhole/Inlet	12.12	14.12	0.90
0309AH2U	Manhole/Inlet	11.52	13.75	0.90
0389B2U	Manhole/Inlet	1.58	4.06	1.35
0389B3U	Manhole/Inlet	1.89	3.87	1.20
0389BH2U	Manhole/Inlet	2.05	4.32	0.90

Node Details

Node ID	Node Type	Invert Level (m AHD)	Ground Level (m AHD)	Equivalent Diameter (m)
0523A2U	Manhole/Inlet	2.20	3.94	0.90
0129AA3U	Manhole/Inlet	16.24	18.96	1.20
0530A8U	Manhole/Inlet	1.90	4.16	0.90
0129AA4U	Manhole/Inlet	16.64	19.21	1.20
0129AA2U	Manhole/Inlet	15.86	18.75	1.20
0129AA5U	Manhole/Inlet	17.99	20.85	1.05
0129AA6U	Manhole/Inlet	19.79	22.27	1.05
0388D02U	Manhole/Inlet	1.84	3.65	0.90
0133A5U	Manhole/Inlet	9.60	10.93	0.90
0083A4U	Manhole/Inlet	17.51	20.26	1.20
0083A3U	Manhole/Inlet	17.24	19.55	1.20
0083A5U	Manhole/Inlet	17.98	19.92	1.20
0087A2U	Manhole/Inlet	14.82	16.62	1.35
0087A3U	Manhole/Inlet	15.13	17.42	1.20
0087A4U	Manhole/Inlet	16.16	18.11	1.20
0539A3U	Manhole/Inlet	1.24	3.92	0.90
0279F4U	Manhole/Inlet	11.11	12.49	1.05
0503A6U	Manhole/Inlet	2.21	3.78	0.90
0641A3U	Manhole/Inlet	1.22	3.80	1.20
0280B2U	Manhole/Inlet	23.72	25.36	1.20
0280B3U	Manhole/Inlet	24.60	26.32	0.90
0279F5U	Manhole/Inlet	11.31	12.59	0.90
0279FA2U	Manhole/Inlet	11.09	12.31	1.05
0522A5U	Manhole/Inlet	1.53	3.99	1.20
0522A3U	Manhole/Inlet	1.49	4.10	1.20
0522A2U	Manhole/Inlet	1.42	4.05	1.20
0522B5U	Manhole/Inlet	1.84	4.05	1.20
0522A8U	Manhole/Inlet	1.66	4.22	1.05
0522A10U	Manhole/Inlet	1.93	4.08	0.90
0421A7U	Manhole/Inlet	3.12	4.79	0.90
0421A6U	Manhole/Inlet	2.96	4.35	1.28
0129A8U	Manhole/Inlet	14.93	16.99	1.20
0129A6U	Manhole/Inlet	13.03	14.52	1.20
0389B8U	Manhole/Inlet	3.10	4.78	0.90
0118A5U	Manhole/Inlet	0.61	2.18	1.05
0118A2U	Manhole/Inlet	0.53	2.33	1.05
0118A3U	Manhole/Inlet	0.54	2.33	1.05
0641G6U	Manhole/Inlet	1.33	3.90	1.35
0641G5U	Manhole/Inlet	1.29	3.79	1.35
0641G4U	Manhole/Inlet	1.20	3.85	1.35
0641G3U	Manhole/Inlet	1.04	3.90	1.35
0641G2U	Manhole/Inlet	1.03	3.13	1.35
0641E4U	Manhole/Inlet	1.15	4.07	1.35
0641E3U	Manhole/Inlet	1.08	4.05	1.35
0641E2U	Manhole/Inlet	1.02	3.89	1.35

Node Details

Node ID	Node Type	Invert Level (m AHD)	Ground Level (m AHD)	Equivalent Diameter (m)
0421A10U	Manhole/Inlet	3.78	5.43	0.90
0309AA6U	Manhole/Inlet	8.20	10.07	0.90
0309AA8U	Manhole/Inlet	8.36	11.00	0.90
0309A4U	Manhole/Inlet	3.69	6.17	1.65
0309AA2U	Manhole/Inlet	5.94	7.30	0.90
0641AB1U	Manhole/Inlet	1.36	3.86	1.20
0309AA5U	Manhole/Inlet	8.17	10.02	0.90
0309AA4U	Manhole/Inlet	7.84	9.90	0.90
0118A06U	Manhole/Inlet	0.66	2.09	0.90
0133AD1U	Manhole/Inlet	9.59	10.85	0.90
0309A11U	Manhole/Inlet	7.81	10.60	0.90
0309AA09U	Manhole/Inlet	8.37	11.00	0.90
0309A16U	Manhole/Inlet	11.50	14.20	1.05
0309A17U	Manhole/Inlet	11.67	14.12	1.05
0309A18U	Manhole/Inlet	12.03	14.60	1.05
0133A3U	Manhole/Inlet	9.22	11.56	0.90
0279H3U	Manhole/Inlet	13.53	14.96	0.90
0279H2U	Manhole/Inlet	13.35	14.93	0.90
0516AB1U	Manhole/Inlet	2.21	3.82	0.90
0516A4U	Manhole/Inlet	2.04	4.08	1.05
0516A3U	Manhole/Inlet	1.89	4.05	1.05
SS198	Manhole/Inlet	1.98	4.13	1.05
244002	Manhole/Inlet	2.31	4.05	1.05
0504A5U	Manhole/Inlet	1.91	3.73	0.90
0504AD1U	Manhole/Inlet	1.95	4.07	0.90
0244B5U	Manhole/Inlet	2.45	4.13	0.90
0244B4U	Manhole/Inlet	2.38	3.76	1.05
0244B3U	Manhole/Inlet	2.22	3.73	1.05
0504A3U	Manhole/Inlet	1.35	3.81	1.20
0279F6U	Manhole/Inlet	11.55	13.42	0.90
0309A7U	Manhole/Inlet	4.70	7.50	1.20
0309A9U	Manhole/Inlet	5.28	7.60	1.05
0309A04U	Manhole/Inlet	3.34	5.80	1.65
SS416	Manhole/Inlet	4.53	6.59	1.20
0389BH3U	Manhole/Inlet	2.18	4.36	0.90
0503A9U	Manhole/Inlet	2.41	4.14	0.90
0503A8U	Manhole/Inlet	2.35	3.70	0.90
SS1584	Manhole/Inlet	1.83	4.18	1.05
SS1041	Manhole/Inlet	1.63	4.34	1.20
0522A7U	Manhole/Inlet	1.61	3.97	1.05
0522A6U	Manhole/Inlet	1.56	4.11	1.20
SS569	Manhole/Inlet	1.58	4.06	1.05
SS568	Manhole/Inlet	1.59	4.07	1.05
SS613	Manhole/Inlet	1.92	4.06	0.90
SS1261	Manhole/Inlet	1.52	3.85	0.90

Node Details

Node ID	Node Type	Invert Level (m AHD)	Ground Level (m AHD)	Equivalent Diameter (m)
SS1254	Manhole/Inlet	1.53	4.06	0.90
SS1253	Manhole/Inlet	1.58	4.06	0.90
SS1264	Manhole/Inlet	1.85	3.92	0.90
0525A3U	Manhole/Inlet	1.56	3.80	1.05
0522A9U	Manhole/Inlet	1.92	4.14	0.90
0522B6U	Manhole/Inlet	1.97	3.86	1.20
SS609	Manhole/Inlet	1.93	3.92	1.20
0530A4U	Manhole/Inlet	1.39	3.65	0.90
SS1167	Manhole/Inlet	1.98	4.09	0.90
0530A7U	Manhole/Inlet	1.76	3.70	0.90
0530A6U	Manhole/Inlet	1.65	3.81	0.90
0118A006U	Manhole/Inlet	0.69	2.40	0.90
0180B2U	Manhole/Inlet	1.12	2.35	1.05
0389BH1U	Manhole/Inlet	1.85	3.82	1.05
SS2025	Manhole/Inlet	1.42	3.90	1.05
0129A3U	Manhole/Inlet	10.03	12.59	4.20
0129AA1U	Manhole/Inlet	15.38	18.11	1.20
0087F4U	Manhole/Inlet	12.68	14.45	0.90
0087F3U	Manhole/Inlet	12.65	13.73	0.90
0083B2U	Manhole/Inlet	16.89	18.40	1.20
0129A7U	Manhole/Inlet	14.62	16.01	1.20
0129A4U	Manhole/Inlet	11.38	12.71	2.10
0129A5U	Manhole/Inlet	12.64	14.25	1.20
0309AA7U	Manhole/Inlet	8.25	10.80	0.90
0309A5U	Manhole/Inlet	4.27	6.20	1.20
0309AA1U	Manhole/Inlet	4.67	6.60	0.90
0641GH1U	Manhole/Inlet	1.82	3.76	1.35
0641EB1U	Manhole/Inlet	1.20	3.77	1.35
0523A1D	Manhole/Inlet	2.17	3.53	1.28
0503A1D	Manhole/Inlet	1.78	3.90	1.70
0359AA1U	Manhole/Inlet	35.32	37.92	1.20
0280D1U	Manhole/Inlet	24.16	25.95	0.90
0280B4U	Manhole/Inlet	25.33	27.09	0.90
0279F2U	Manhole/Inlet	10.58	12.20	1.05
0129AA7U	Manhole/Inlet	21.10	23.77	1.05
0087A1D	Manhole/Inlet	14.73	16.26	1.91
0083AC1U	Manhole/Inlet	17.98	20.43	1.20
Node_50	Outlet	1.77	3.60	1.70
Node_51	Outlet	2.16	3.50	1.28
Node_52	Outlet	2.95	4.34	1.28
Node_53	Outlet	14.71	16.62	1.91
Node_54	Outlet	9.99	12.58	4.20
0522B3U	Outlet	1.75	3.65	1.20
0244B2U	Outlet	2.04	3.40	1.05
0641G1D	Outlet	1.02	2.52	1.35

Node Details

Node ID	Node Type	Invert Level (m AHD)	Ground Level (m AHD)	Equivalent Diameter (m)
0641E1D	Outlet	0.98	2.63	1.35
0641A1D	Outlet	1.15	2.58	1.20
0539A1D	Outlet	1.20	2.20	0.90
0530A2U	Outlet	1.19	2.41	0.90
0525A1D	Outlet	1.37	2.72	1.05
0522A1D	Outlet	1.40	3.28	1.20
0516A1D	Outlet	1.80	4.00	1.05
0504A1D	Outlet	1.32	2.90	1.20
0389B1D	Outlet	1.53	3.23	1.35
0388D1D	Outlet	1.73	3.43	0.90
0359A1D	Outlet	30.12	31.00	0.90
0309A1D	Outlet	2.41	5.00	1.65
0280D1D	Outlet	23.96	25.76	0.90
0280B1D	Outlet	23.45	24.72	1.20
0279H1D	Outlet	13.20	14.43	0.90
0279F1D	Outlet	10.40	11.78	0.90
0180B1D	Outlet	0.82	2.22	1.05
0133A1D	Outlet	8.44	9.80	0.90
0118A1D	Outlet	0.29	1.60	1.05
0087F1D	Outlet	11.49	12.96	1.05

Appendix D – Flood Maps

(Refer to Volume 2)

Appendix E – Long Sections

Appendix F – Peak Surface Flow Results

Locations	Storm Duration (h)	Peak Flow (m^3/s)								
		2 Y ARI	5 Y ARI	10 Y ARI	20 Y ARI	50 Y ARI	100 Y ARI	200 Y ARI	500 Y ARI	PMF
1	1.5	0.0	0.5	1.0	2.3	4.3	6.3	8.2	10.1	60.4
	18	0.5	2.0	2.9	4.4	6.2	8.0	9.7	12.4	49.4
	24	0.2	0.6	1.3	2.7	3.5	4.3	10.2	14.9	25.1
	72	0.5	1.8	2.7	3.8	4.8	6.2	7.9	18.6	23.1
2	1.5	6.0	12.9	19.6	28.8	37.7	49.0	62.3	75.2	209.6
	18	7.1	9.4	11.8	14.9	18.5	25.2	31.0	42.2	74.3
	24	6.8	14.2	19.8	27.1	30.5	32.1	50.6	65.5	64.0
	72	5.4	6.7	8.2	10.9	13.2	16.1	19.5	25.6	57.7
3	1.5	20.3	33.9	42.2	52.9	62.0	66.0	68.8	70.6	140.7
	18	19.2	26.8	30.9	36.3	43.5	53.0	60.1	66.2	91.7
	24	23.2	38.8	48.0	58.6	62.7	63.0	70.8	74.4	59.5
	72	15.7	24.2	30.4	37.5	41.3	47.5	54.1	67.0	59.4
4	1.5	17.6	29.8	37.3	48.1	58.5	66.3	71.9	78.8	156.2
	18	14.0	20.9	25.6	33.4	38.9	47.6	55.4	65.3	77.1
	24	21.1	33.8	42.3	51.1	54.5	60.2	67.3	73.2	71.6
	72	13.2	20.4	24.4	29.5	32.6	37.6	43.3	50.4	69.5
5	1.5	3.0	4.0	4.7	6.0	7.6	8.1	9.1	9.4	8.0
	18	1.7	2.4	2.8	3.4	4.0	5.0	5.8	6.7	8.3
	24	2.4	3.2	3.7	4.7	5.1	5.2	6.8	7.8	7.4
	72	1.2	1.7	2.0	2.5	2.7	3.1	3.5	4.2	7.1
6	1.5	24.9	32.5	35.1	39.5	55.6	60.5	66.1	71.7	153.9
	18	22.9	28.0	30.2	33.4	35.9	38.0	39.8	45.2	71.0
	24	26.5	32.0	34.8	38.3	40.6	39.8	49.5	56.2	58.6
	72	18.2	24.2	27.7	31.4	33.1	35.8	38.7	40.9	56.5
7	1.5	12.0	18.7	22.5	27.4	35.0	43.5	50.7	54.3	107.1
	18	6.9	10.5	13.0	17.5	18.2	22.9	24.1	27.8	33.8
	24	10.0	14.6	17.0	20.1	21.5	22.2	28.0	32.4	31.2
	72	4.6	6.9	8.4	10.2	11.5	13.2	15.3	18.0	29.3
8	1.5	13.8	19.3	21.8	25.7	34.0	36.0	40.5	42.6	176.2
	18	16.1	19.5	21.3	23.4	25.2	27.1	30.4	35.1	130.0
	24	17.3	22.8	25.9	29.4	31.3	29.8	45.8	59.7	114.0
	72	12.2	16.4	19.0	21.4	22.8	28.4	37.0	50.1	104.4

Locations	Storm Duration (h)	Peak Flow (m^3/s)								
		2 Y ARI	5 Y ARI	10 Y ARI	20 Y ARI	50 Y ARI	100 Y ARI	200 Y ARI	500 Y ARI	PMF
9	1.5	8.7	17.6	25.5	38.3	62.4	87.3	108.8	120.2	625.5
	18	57.8	77.6	90.1	108.0	128.5	146.4	166.6	194.9	558.7
	24	46.9	59.1	68.6	90.7	110.1	119.0	180.5	229.5	515.7
	72	61.9	83.1	95.7	113.6	129.1	147.8	169.3	202.0	474.4
10	1.5	4.5	8.5	13.0	20.5	27.8	46.6	57.4	65.0	201.4
	18	29.9	37.4	42.4	52.0	60.2	67.6	73.1	81.8	191.0
	24	25.7	31.1	34.6	43.1	46.0	54.1	70.6	81.8	144.0
	72	32.2	41.3	46.8	53.5	58.4	63.8	70.1	116.7	133.8
11	1.5	7.0	7.5	8.6	7.0	13.0	6.4	9.3	14.7	109.3
	18	5.7	7.5	8.5	9.3	7.6	10.9	15.5	23.6	118.3
	24	7.5	7.7	5.8	10.0	11.0	8.5	28.4	42.2	108.5
	72	5.6	5.7	5.8	5.1	8.6	11.8	20.2	34.5	99.3
12	1.5	8.8	14.9	18.1	22.9	27.3	31.9	37.3	42.3	81.2
	18	8.6	12.4	13.8	15.6	17.9	21.3	24.0	29.2	27.4
	24	10.4	15.7	18.8	22.5	24.3	24.8	32.7	37.6	24.3
	72	5.9	10.1	12.2	14.3	15.8	17.6	19.2	21.0	24.8