GOONDIWINDI REGIONAL COUNCIL

Inglewood Flood Study

Report

June 2015

M7000_085

www.engeny.com.au

P: 07 3221 7174 | F: 07 3236 2399

Lvl 11, 344 Queen st Brisbane QLD 4000 | PO Box 10183 Brisbane QLD 4000

DISCLAIMER

This report has been prepared on behalf of and for the exclusive use of GOONDIWINDI REGIONAL COUNCIL and is subject to and issued in accordance with GOONDIWINDI REGIONAL COUNCIL instruction to Engeny Water Management (Engeny). The content of this report was based on previous information and studies supplied by GOONDIWINDI REGIONAL COUNCIL.

Engeny accepts no liability or responsibility whatsoever for it in respect of any use of or reliance upon this report by any third party. Copying this report without the permission of GOONDIWINDI REGIONAL COUNCIL or Engeny is not permitted.

M7000_085 INGLEWOOD FLOOD STUDY					
M:\Projects\M7000_Miscellaneous Clients\M7000_085 Inglewood FS\Documents\Revisions\Rev_0\Inglewood Flood Study_Rev0.docx					
REV	**DESCRIPTION**	**AUTHOR**	**REVIEWER**	**APPROVED BY**	**DATE**
Rev 0	Issued to Client	Britta Jensen / Kelsey Mundt	Mark Page	Adrian Howard	3 June 2015
Signatures					

EXECUTIVE SUMMARY

Engeny has been commissioned by Goondiwindi Regional Council (GRC) to undertake a flood study for the Inglewood Township. The **study objective** was to define the nature, extent and risks of flooding in Inglewood in order to inform disaster management planning and response, as well as control future development.

An **URBS** hydrologic model and calibrated **TUFLOW** (1D/2D) hydraulic model was developed as part of this study for assessment of the following:

- 1976 historical event for model validation.
- 1:10, 1:50, 1:100 and 1:500 AEP design events.
- Sensitivity analysis for Coolmunda Dam storage capacity.

A **flood frequency analysis** (FFA) was undertaken for the MacIntyre Brook at Inglewood gauge which had 61 years of data, however 45 years of data was adopted for the FFA which represented flood data post dam construction in order to maintain a consistent data set.

The FFA for the MacIntyre Brook at Inglewood gauge identified that the 1976 flood, which is the largest event in the adopted record, was between a 1:50 and 1:5 AEP event (i.e. average return period of between 50 and 20 years). The 1996 and 2011 events, which are the largest recent flood events at Inglewood, were of significantly smaller magnitude (i.e. approximately 1:10 AEP).

The largest flood event to have impacted Inglewood since the construction of Coolmunda Dam occurred in February 1976. The May 1996 and January 2011 floods are the largest recent events. Suitable pluviograph data was not available for the purpose of simulating either the 1996 or 2011 events for **model validation** purposes, however for the 1976 event, a nearby pluviograph station was identified at Yelarbon (41122). A comparison of the recorded and modelled 1976 hydrographs shows that the URBS model provided a good agreement to the recorded flood peak (within 4%).

Furthermore, the URBS model was also validated to the FFA for MacIntyre Brooke at Inglewood gauge. The URBS estimated peak flood provided an acceptable match with the FFA peak flow for the 1:50 and 1:100 AEP events and for the 1:10 AEP if the dam was at 25% capacity (i.e. 75% available storage) at the start of the event. There is little confidence in the FFA peak flow estimate for the 0.1:50 AEP event as the station has a maximum flood height gauge of 279.38 m AHD (i.e. less than 1:10 AEP) and extrapolated to account for large and extreme events.

Validation of the TUFLOW hydraulic model was also undertaken using anecdotal and gauged 1976 flood information. The modelled flood level was within 220 mm of the recorded 1976 flood height at the MacIntyre Brook at Inglewood Gauge. The majority of modelled flood levels in Inglewood were generally within 100 to 200 mm of the surveyed 1976 flood levels.

Given the sensitivity of the URBS model to the available capacity of Coolmunda Dam in smaller flood events (i.e. 1:10 AEP), a **sensitivity analysis** was undertaken using the URBS model for the larger 1956 flood under 'no dam', 'dam starting full' and 'dam starting half full' scenarios. It was determined that there was negligible difference in the peak discharge between the three scenarios for a flood of this magnitude; however, there is increasing delay in the rising limb and time to peak as a result of additional dam storage volume available. Thus, it is concluded that for rare events, the dam has minimal impact on reducing the peak flow at Inglewood.

The **hydraulic assessment** identified that for events greater than 1:10 AEP, the obstruction caused by the railway line is considered to cause flows in excess of bank full capacity to be diverted towards Brook Street in a westerly direction and then re-enter the MacIntyre Brook floodplain downstream of the Canning Creek confluence. Whilst the smaller events have not been analysed, it is considered that the MacIntyre Brook and Canning Creek main channels have a capacity of less than the 1:10 AEP flood.

The flood hazard assessment has identified that the flood hazard within the MacIntyre Brook and Canning Creek channel banks is classified as Extreme due to the high velocities and flood depths whilst the broader flood plain including the Inglewood Township is mostly classified as Significant with flood depths of up to 3.5 m in the 1:100 AEP event. Average 1:100 and 1:10 AEP flood depths within the Inglewood Township are approximately 1.5 m and 0.25 m respectively.

An assessment of **road closure and evacuation routes** was undertaken using hydraulic modelling results and road height information. During a flood event, the risk of Inglewood residents becoming isolated is considered to be high. The main evacuation route for Inglewood is via the Cunningham Highway Bridge in an easterly direction. The highway is predicted to become inundated after 12 hours and 8.5 hours in the 1:10 and 1:100 AEP events respectively. Closure of the highway bridge would occur for approximately 8.5 hours and 26 hours in the 1:10 and 1:100 AEP events respectively. The highway bridge is predicted to have a peak flood depth of approximately 0.4 m and 2 m in the 1:10 and 1:100 AEP events respectively.

Conclusions from the Inglewood Flood Study are summarised as follows:

- Whilst Coolmunda Dam does not serve as a flood mitigation measure for Inglewood, the availability of storage within Coolmunda Dam does have a significant influence on flood events up to the 1:100 AEP.

- For flood events greater than 1:10 AEP, the obstruction caused by the railway line causes flows in excess of bank full capacity to be diverted towards Brook Street in a westerly direction.

- The MacIntyre Brook and Canning Creek channel banks have a 1:20 to 1:10 AEP capacity
- The **flood hazard** within the MacIntyre Brook and Canning Creek channel banks is classified at Extreme whilst the broader flood plain including the Inglewood Township is mostly classified as Significant
- The ***Inglewood Hospital*** is estimated to have a flood immunity of approximately 1:500 AEP.
- The main ***evacuation route*** for Inglewood is via the Cunningham Highway Bridge in an easterly direction
- The Cunningham Highway Bridge is predicted to become ***flooded and closed*** after 12 hours and 8.5 hours in the 1:10 and 1:100 AEP events respectively
- The ***closure duration*** for the Cunningham Highway Bridge is approximately 8.5 hours and 26 hours in the 1:10 and 1:100 AEP events respectively

It is **recommended** that Goondiwindi Regional Council utilise the flood information provided in this study to assist with the management of ***flood risks*** and future ***development planning***.

CONTENTS

List of Tables

List of Figures

1. INTRODUCTION

Engeny Water Management (Engeny) has been commissioned by Goondiwindi Regional Council (GRC) to undertake a flood study for the Inglewood Township. The primary objective of this project was to define the nature, extent and risks of flooding to Inglewood from MacIntyre Brook and Canning Creek for design storm events. The locality plan is presented in **Figure 1.1**.

Details of the study background and objectives, scope and limitations, location and previous studies are outlined as follows.

1.1 Study Location

Inglewood is located at the junction of Canning Creek and MacIntyre Brook which are tributaries of the Dumaresq River. The catchment has an area of approximately 3,484 km^2 and is predominately rural land use. Situated 13 km east of Inglewood on the Cunningham Highway is Coolmunda Dam which is owned and operated by SunWater. The dam is an earth-fill embankment dam with a gated spillway across MacIntyre Brook. The dam holds 69,090 ML of water at 100% capacity at an average depth of 4.3 m and has a surface area of 1,740 ha.

Located to the west of the Toowoomba range, the upper reaches of the Inglewood catchment consist of moderate mountain ranges with well-defined flow paths that have sufficient capacity to convey the catchment runoff. At the junction of MacIntyre Brook and Canning Creek, the topography changes to a fairly flat gradient with a significant floodplain associated with MacIntyre Brook.

The locality plan is presented in **Figure 1.1**, whilst **Figure 1.2** presents the surface topography within the catchment.

1.2 Study Background and Objectives

Inglewood suffered major flooding in 1956 and 1976 and has since been threatened by floodwaters reaching the lower elevations of the town. The events in April 1988 and May 1996 were also considered to be major events. Historically, floods within Inglewood are understood to have behaved in different ways, and have had different effects on the Township. The MacIntyre Brook, Canning Creek and Pariagara Creek all influence flooding at Inglewood, although to varying degrees.

Coolmunda Dam was constructed in 1968. The dam’s construction has altered the flow characteristics of MacIntyre Brook and the behavior of flood flows.

As well as flood inundation to properties, the Township is also subject to isolation during a major flood and therefore GRC has identified the need to develop a better understanding of flood risks.

The key objectives of the study were to:

- Develop an understanding of flood behaviour for a range of flood events.
- Identify flood hazards to Inglewood and their impacts in terms of flood inundation and isolation caused by road closure.
- Develop flood mapping that can be used by GRC to assist with land use planning and assessing future development.
- Enable GRC to be better informed in the emergency planning, preparation and response to flood events.

1.3 Study Scope

The scope of the study included:

- Project inception meeting
- Site inspection
- Data compilation, review and gap analysis
- Hydrological modelling
- Sensitivity analysis of flood hydrology to Coolmunda Dam capacity
- Flood frequency analysis
- Hydraulic modelling
- Presentation of preliminary results to Council
- Flood Risk Assessment including hazard classification and evaluation of road closure times along potential evacuation routes
- Preparation of Flood Study Report

A number of key limitations were identified in the process of the study. These were:

- The supplied LiDAR coverage is limited to the Inglewood Township only and therefore does not represent the entire floodplain. As such, the following measures were adopted to undertake the study:
  - SRTM hydro-enforced DEM (1 second, 30 m resolution) was adopted for the hydrologic analysis.
  - Manipulation of topography to create an artificial boundary near Thornton Road on Pariagara Creek.

- Detailed plans or survey of key hydraulic structures (i.e. bridges) were not available. Structure details were based on information provided by GRC. The rail embankment was represented within the 2D domain of the hydraulic model. The rail bridge was omitted, however given the width of the flood plain it is not anticipated that the bridge itself would have a significant influence on flood levels for major events.

- A strong calibration of the hydrological modelling could not be achieved tdue to a lack of rainfall pluviograph and river level data for key historical events. For model validation purposes, the 1976 flood was simulated in the URBS and TUFLOW models using pluviograph rainfall data from the Yelarbon Station (41122) which is outside the catchment boundary but is the closest station with available data.

- Flood levels in Inglewood are likely to be heavily influenced by the timing of peak flows and interaction between the MacIntyre Brook and Canning Creek. Given the lack of suitable historical rainfall data available within the catchment, model calibration could not be achieved.

- The hydraulic model only included hydraulic structures used for flood conveyance (i.e. not included subsurface culverts associated with local stormwater conveyance).

1.4 Previous Studies

It is understood that there are no comprehensive flood studies that have been undertaken previously for Inglewood; however the following studies are known to have been undertaken within the catchment:

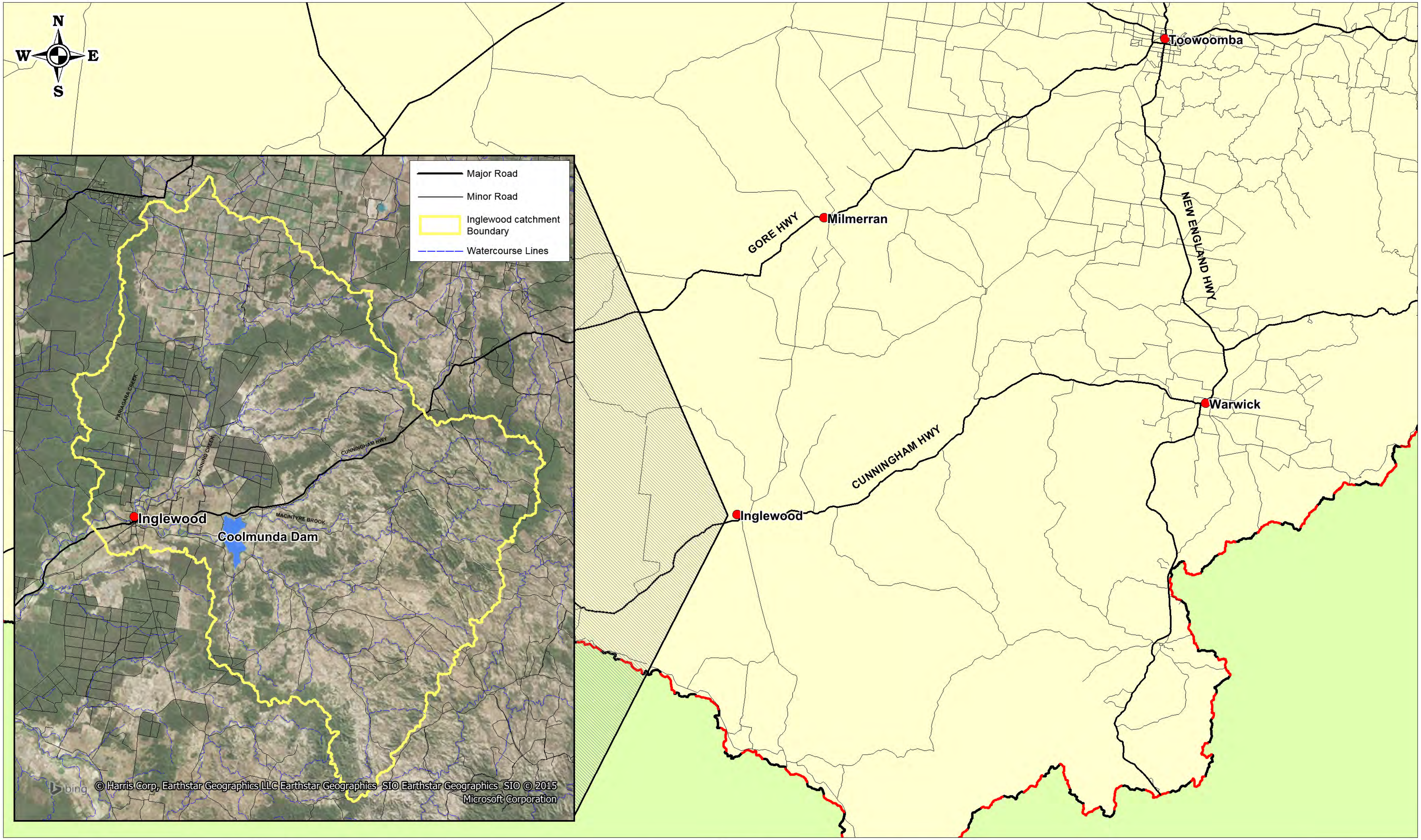
- Flood Hazard Mapping for Inglewood (Level 2) (SKM, 2013)

- Coolmunda Dam Break Analysis (SunWater, 2004)

- Flood Modelling Data – Inglewood (Goondiwindi Regional Council, 2012)

The high level flood hazard mapping for Inglewood was undertaken by the Queensland Reconstruction Authority (QRA) as part of Phase 2 of the Queensland Flood Mapping Program. This study was an analysis of the 1956 historical event as well as design flood events. Catchment runoff for design events were based upon flood frequency analyses and an artificial hydrograph derived from the 1956 event. Hydraulic model inflows were applied to Canning Creek and MacIntyre Brook at the same time and are therefore not representative of the actual differences in timing between the two waterway systems and the associated influence on flood behaviour downstream of the confluence. Given the high level nature of this previous study and the absence of a detailed hydrological analysis for the catchment, the study has not been considered in the Inglewood Flood Study.

A spillway rating curve was obtained from the Coolmunda Dam Break Analysis for use in the Inglewood Flood Study. The spillway rating curve was applied within the URBS model to represent outflows from the dam for all flood events analysed.



Level 11, 344 Queen St, Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 07 3221 7174
F: 07 3236 2399
E: admin@engeny.com.au

ENGENY WATER MANAGEMENT

Goondiwindi REGIONAL COUNCIL

0 14 28
Scale in Kilometres (1:700,000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

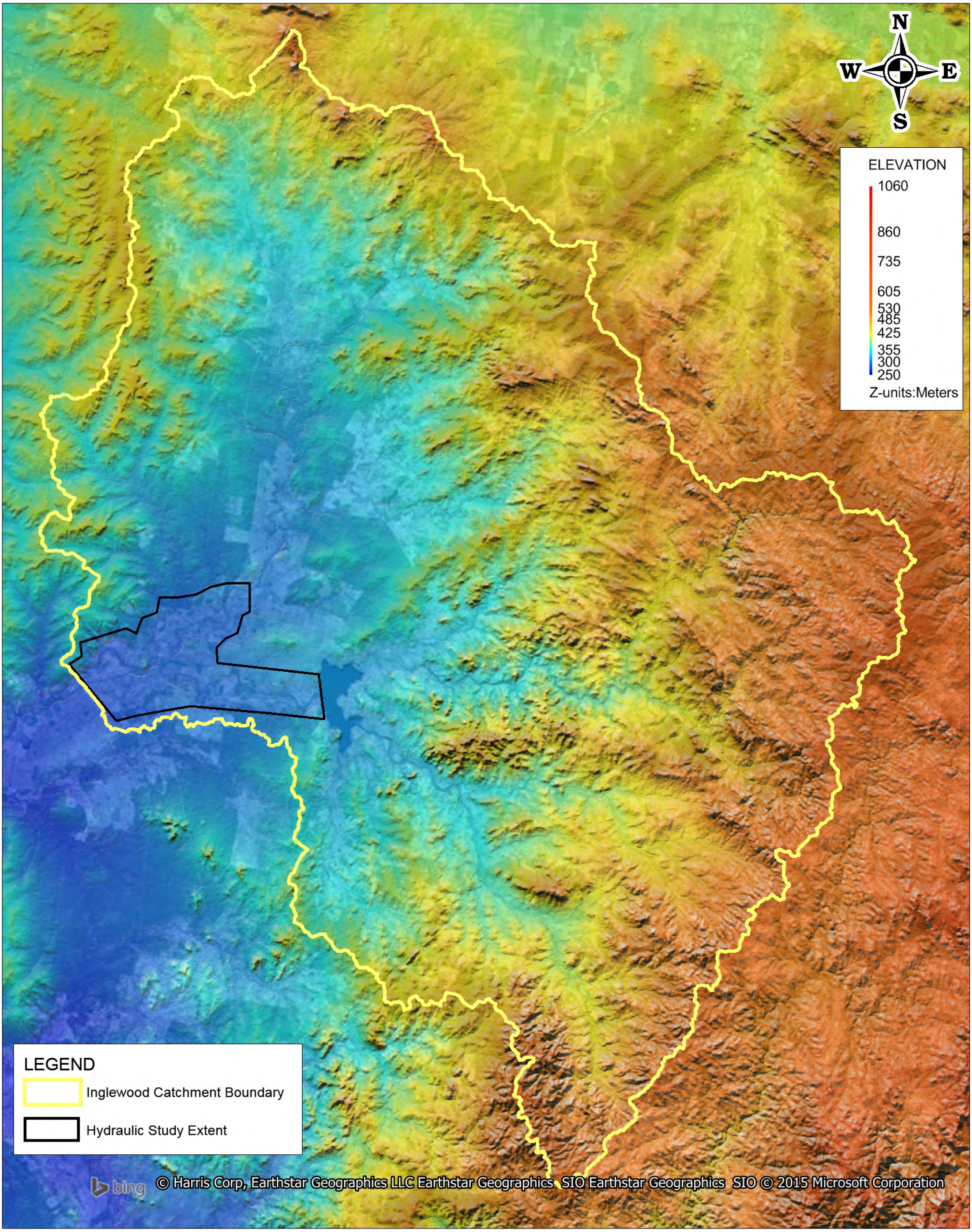
Inglewood Flood Study

Figure 1.1

Locality Plan

Job Number: M7000_085
Revision: 0
Drawn: KJM
Date: 05 MAR 2015

M:\Projects\M7000_Miscellaneous Clients\M7000_085 Inglewood FS\Design\MapInfo\Figures\



Level 11: 344 Queen St Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 07 3221 7174
F: 07 3236 2399
E: admin@engeny.com.au

0 8 16

Scale in Kilometres (1:400,000 @ A4)

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Inglewood Flood Study

Figure 1.2

Catchment Topography

Job Number: M7000_085
Revision: 0
Drawn: KJM
Date: 05 MAR 2015

2. PROJECT DATA

2.1 GIS Data

The following Geographic Information System (GIS) data was provided by GRC for use in the study:

- Digital Elevation Model (DEM) topographical data captured in 2011.
- Various MapInfo GIS layers including road alignment and road crossing locations.

2.2 Historical Rainfall Data

Historical rainfall data was provided by the Bureau of Meteorology (BoM) from daily rainfall and pluviometric stations located within and surrounding the catchments contributing to the flooding of Inglewood. **Table 2.1** presents the rainfall stations considered in the study. The locations of these stations are illustrated in **Figure 1.1**.

Table 2.1 Adopted Rainfall Stations

Station Name (ID Number)	Station Type	Operational for 1976 Event	Operational for 1999 Event	Operational for 2011 Event
Coolmunda Dam (41457)	Automatic rainfall (pluvio) and daily rainfall	No	Yes	Yes
Woodspring (41391)	Daily rainfall	Yes	No	No
Inglewood Forestry (41340)	Daily rainfall	Yes	Yes	No
Glenelg (41034)	Daily rainfall	No	Yes	Yes
Inglewood Post Office (41047)	Daily rainfall	No	Yes	Yes

Unfortunately there were no stations within the catchment that provided sub-daily rainfall records for the 1976 event, which was the event used as the validation event. As such, pluviograph rainfall records from the Yelarbon Station were used, which is located (30 km) beyond the catchment boundary. This is discussed further in **Section 4.3**.

2.3 Design Rainfall Data

Design rainfall estimates for the MacIntyre Brook (Inglewood) catchment were derived based upon the procedures outlined in Australian Rainfall and Runoff (AR&R) (IEAust, 1987) and sourced using the CRC-FORGE application. Storm durations ranging from 10 minutes to 24 hours for each ARI event were simulated in the hydrologic model to establish flow estimates for a complete range of design flood events in order to determine the critical storm duration.

An Area Reduction Factor (ARF) was calculated for the durations above the 24 hour event by CRC-FORGE. A summary of the ARFs are provided in **Table 2.2**.

Table 2.2 Area Reduction Factors

Duration	ARF
24 hour	0.8219
48 hour	0.8770
72 hour	0.9014
96 hour	0.9159
120 hour	0.9257

2.4 Streamflow Data

Historical stream flow data was sourced from the Department of Natural Resources and Mines (DNRM). Water monitoring data portal for the MacIntyre Brook at Inglewood (414602B/C) station and the Canning Creek at Woodspring (416407A) station to undertake a Flood Frequency Analysis (FFA) for validation of catchment flows. Further details on the FFA and stream flow hydrographs at the gauging station are discussed in **Section 3**.

2.5 Site Inspection

A site inspection was undertaken to gather an appreciation of the catchment in terms of catchment roughness (Manning's n), hydraulic controls (i.e. bridges, culverts, earth embankments, etc.) and to obtain measurements (where possible) of hydraulic structures. Some photos obtained during the site inspection are presented in the figures below.

Figure 2.1 Cunning Highway Bridge facing downstream

Figure 2.2 Elizabeth Street Bridge facing north

Figure 2.3 Potters Road Bridge facing downstream

3. FLOOD FREQUENCY ANALYSIS

A flood frequency analysis (FFA) of gauged stream flows within the Inglewood catchment was undertaken in order to verify the hydrologic model against other flood estimation methods. A review of the study area identified that the DNRM operates a streamflow gauging station on the MacIntyre Brook at Inglewood (416402B/C). This gauge is located in the Inglewood Township and was well suited to the purposes of this study.

The Inglewood gauge station has a full record of 61 years. However, due to the commissioning of Coolmunda Dam in 1968, the record was reduced to exclude the period prior to the dam in order to maintain a consistent data set. This resulted in an adopted record of 45 years.

Given the length of record for the MacIntyre Brook at Inglewood gauge station and its position within the area of interest of the study, it has been adopted for validation of the hydrologic model (refer **Section 4.4**).

Key details of the gauging station are listed in **Table 3.1.**

Table 3.1 DNRM Stream Flow Gauging Station Summary Details

Gauging Station	Years on Record	Maximum Gauged Level	Maximum Recorded Level	Maximum Recorded Discharge
MacIntyre Brook at Inglewood (416402B/C)	45 1	9.15 m (279.38 m AHD)	10.22 m (282.49 m AHD) 2 11/02/1976	2,550 m3/s 2 11/2/1976

Note 1: Full record is 61 years. Adopted 45 years after construction of Coolmunda Dam (1968)

Note 2: Peak recorded level/discharge post 1968

The FFA was undertaken in accordance with industry best practice (i.e. AR&R standards). The Log Pearson Type III (LP3) distribution was found to give the best fit to the recorded data. **Figure 3.1** shows the FFA distribution for the MacIntyre Brook at Inglewood gauge and **Table 3.2** summarises the peak flow estimates for various AEP events.

It is noted that the LP3 distribution gives a good fit to the recorded data for frequent and large events (i.e. up to 1 to 1:50 AEP); however, for rare flows (i.e. beyond the 1:100 AEP) the recorded annual flow series appears to flatten out more quickly than the LP3 distribution. Consequently, the FFA may over-estimate peak flows for rare and extreme events.

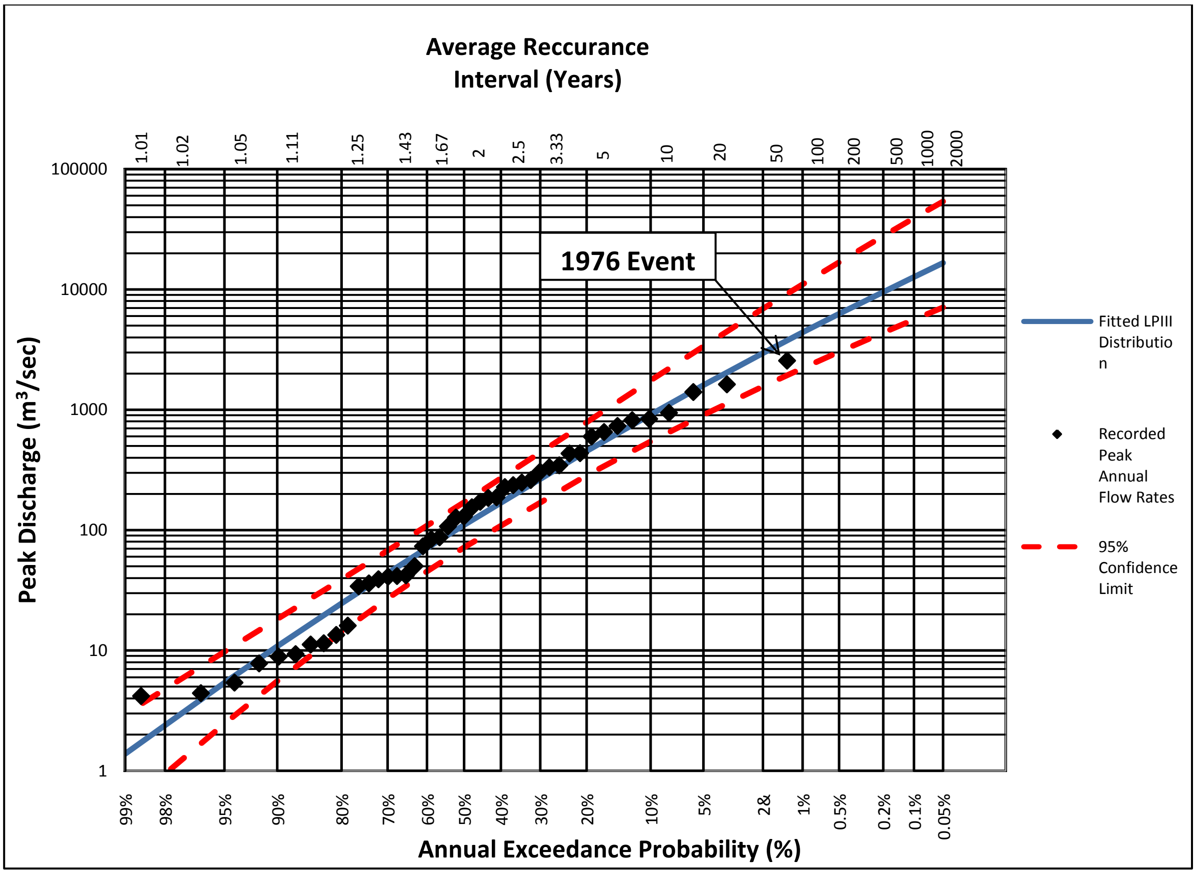


Figure 3.1 MacIntyre Brook at Inglewood (416402) Flood Frequency Analysis

Table 3.2 MacIntyre Brook at Inglewood (416402) Peak Flow Estimates (LP3)

AEP	FFA Peak Flow (m^3/s)
1:10	910
1:20	1,600
1:50	2,950
1:100	4,390
1:500	9,540

The FFA for the MacIntyre Brook at Inglewood gauge station identified that the 1976 flood, which is the largest event in the adopted record, was between a 1:50 and 1:100 AEP event (i.e. between a 50 and 100 year ARI). The 1996 and 2011 events, which are the largest recent flood events at Inglewood, were of significantly smaller magnitude (i.e. approximately 1:10 AEP).

4. HYDROLOGICAL ANALYSIS

4.1 Introduction

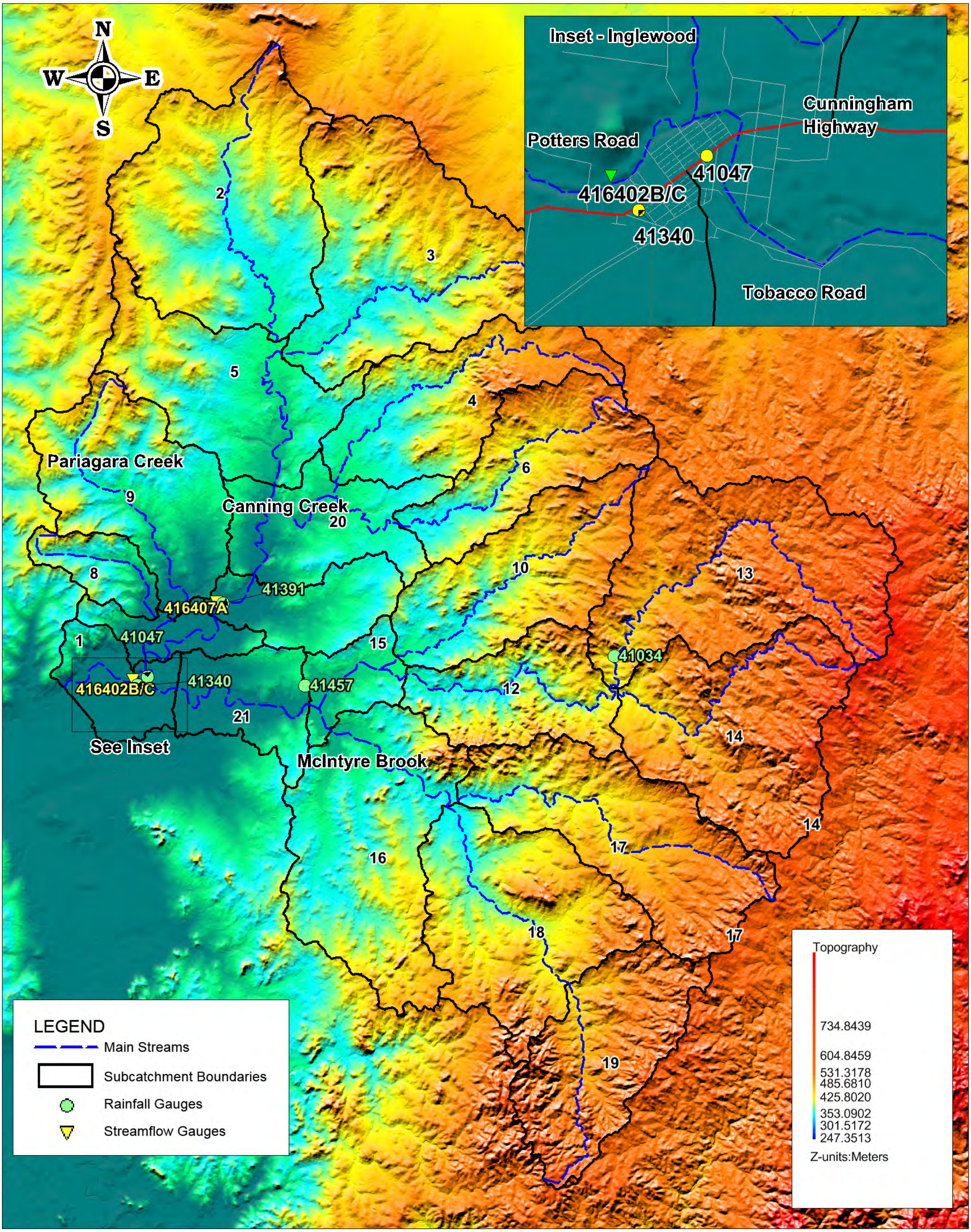
A hydrological analysis has been undertaken for the Inglewood catchment using the URBS modelling software. The URBS model was used to estimate design flood hydrographs for input to the TUFLOW hydraulic model for both historical and design flood events.

4.2 Model Description

The downstream extent of the detailed LiDAR available for hydraulic modelling has been adopted as the downstream boundary for the hydrologic model. This is on MacIntyre Brook approximately 7.5 km downstream of the DNRM stream flow gauge at Inglewood.

Catchment delineation was undertaken using the CatchmentSIM, software, which analyses terrain data for hydrologic analysis. The 30 m Shuttle Radar Topography Mission (SRTM) dataset has been adopted for the catchment delineation.

The total area of the resulting catchment is approximately 3,500 km^2, which was divided into 21 sub-catchments. The layout of the hydrology model is presented in **Figure 4.1**.



M:\Projects\M7000_Miscellaneous Clients\M7000_085 Inglewood FS\Design\MapInfo\Figures

Level 11: 344 Queen St Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 07 3221 7174
F: 07 3236 2399
E: admin@engeny.com.au

ENGENY WATER MANAGEMENT

Goondiwindi REGIONAL COUNCIL

0 8 16
Scale in Kilometres (1:400,000 @ A4)

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Inglewood Flood Study

Figure 4.1

Hydrology Model Layout

Job Number: M7000_085
Revision: 0
Drawn: KJM
Date: 05 MAR 2015

4.3 Model Data

4.3.1 Rainfall Data

Design Events

Design rainfall depths for the Inglewood catchment were derived based upon the procedures outlined in Australian Rainfall and Runoff (AR&R) (IEAust, 1987) and sourced from the Bureau of Meteorology (BOM) using the online IFD application (BOM, 2012). Storm durations ranging from 10 minutes to 24 hours for each AEP event were simulated in the hydrologic model to establish flow estimates for a complete range of design flood events.

A critical duration assessment has been undertaken in order to refine the number of storm durations required to be assessed within the TUFLOW model. A summary of the critical durations at the MacIntyre Brook and Canning Creek inflow boundaries and at the outlet of the model are summarised in **Table 4.1**.

Table 4.1 Critical Duration Summary

Location	1:10 AEP Critical Duration	1:50 AEP Critical Duration	1:100AEP Critical Duration	0.1:50 AEP Critical Duration
MacIntyre Brook Inflow Boundary	24 Hr	18 Hr	18 Hr	18 Hr
Canning Creek Inflow Boundary	24 Hr	18 Hr	18 Hr	18 Hr
Model Outlet	24 Hr	18 Hr	24 Hr	18 Hr

Historic Events

The largest flood event to have impacted Inglewood since the construction of Coolmunda Dam occurred in February 1976. The May 1996 and January 2011 floods are the largest recent events.

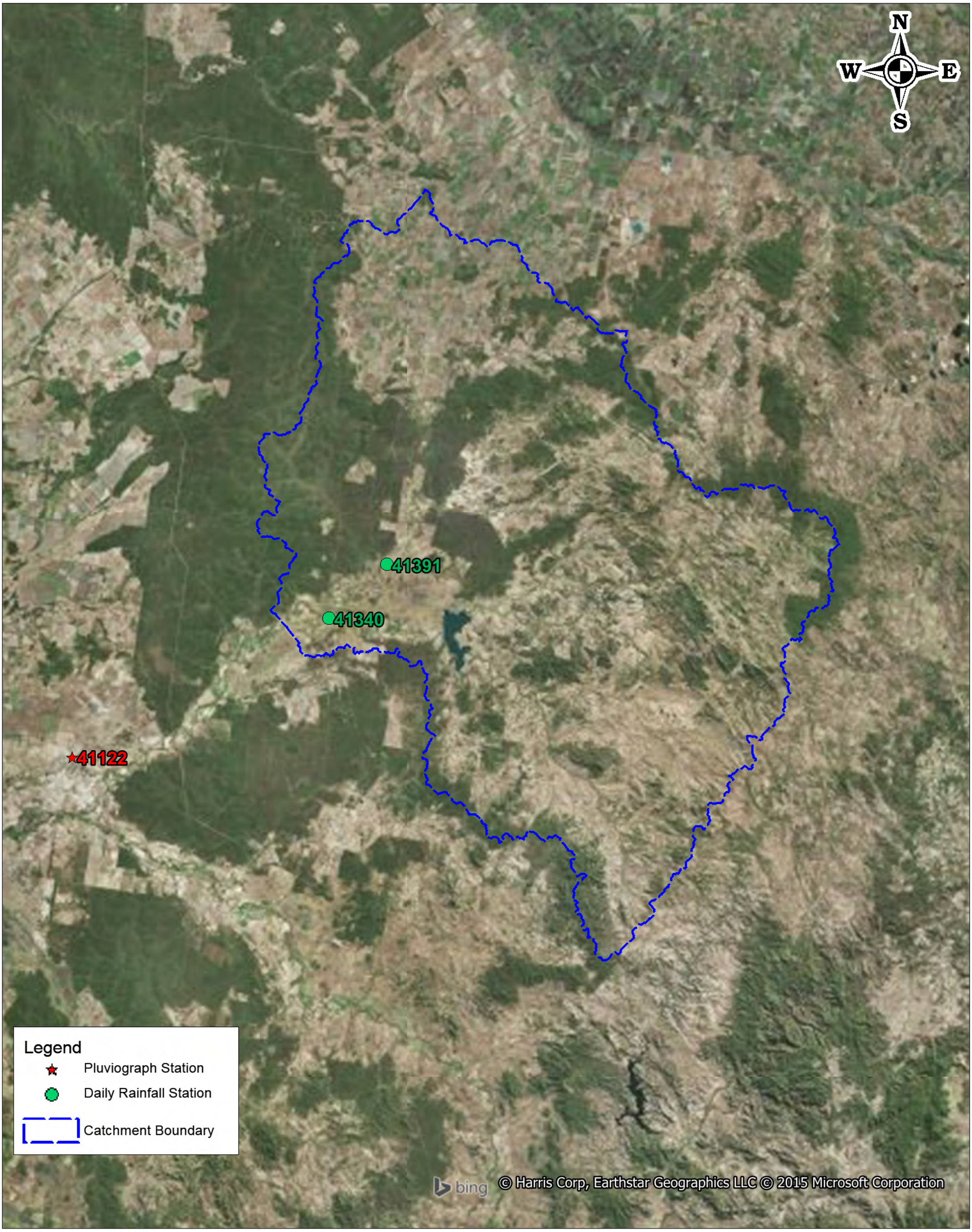
Suitable pluviograph data was not available for the purpose of simulating either the 1996 or 2011 events. Although no pluviograph stations were located within the catchment for the 1976 event, a nearby pluviograph station was identified at Yelarbon (41122).

The location of the pluviograph station is shown in **Figure 4.2**. In order to assess the suitability of the station for model simulation, a comparison was made between the total rainfall measured for the event at two daily rainfall gauges located within the catchment to the rainfall total measured at Yelarbon. A summary of these comparative totals for the period 10th to 11th February 1976 is presented in **Table 4.2** .

The high level of agreement (i.e. < 10% difference) between the recorded rainfall total at the external pluviograph station and the internal daily stations suggests that the pluviograph provides a reasonable estimate of the catchment rainfall during the February 1976 event; however, based on the limited coverage it was adopted for validation purposes only.

Table 4.2 10th to 11th February 1976 Historical Event Rainfall Totals

Rainfall Station	10th – 11th February 1976 Rainfall (mm)
Yelarbon (41122) –external pluviograph	192
Woodspring (41391) – internal daily	175
Inglewood Forestry (41340) – internal daily	182



M:\Projects\M7000_Miscellaneous Clients\M7000_085 Inglewood FS\Design\MapInfo\Figures

Level 11: 344 Queen St Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 07 3221 7174
F: 07 3236 2399
E: admin@engeny.com.au

ENGENY

Goondiwindi REGIONAL COUNCIL

0 8 16

Scale in Kilometres (1:600,000 @ A4)

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Inglewood Flood Study

Figure 4.2

1976 Historical Event Rainfall Stations

Job Number: M7000_085
Revision: 0
Drawn: KJM
Date: 11 MAY 2015

4.3.2 Temporal Patterns

Design rainfall events were simulated through the URBS hydrological model using the AR&R zone 2 temporal patterns.

The February 1976 historical event was simulated using 5 minute rainfall totals recorded at the Yelarbon pluviograph station.

4.3.3 Rainfall Losses

Catchment losses adopted for the design events are summarised in **Table 4.3** and are within the range of typical values for Queensland catchments.

Table 4.3 Adopted Rainfall Losses

Initial Loss (mm)	Continuing Loss (mm/hr)
15	1

4.3.4 Coolmunda Dam

The Coolmunda Dam is located on the MacIntyre Brook approximately 13 km upstream of Inglewood. Constructed in 1968, Coolmunda Dam is owned and operated by SunWater. The purpose of the dam is to supply irrigation water to the farming areas along the lower reach of MacIntyre Brook and Dumeresq River (SunWater, 2004).

The dam has been represented within the hydrological model using a discharge rating curve extracted from the *Coolmunda Dam: Dam-Break Analysis* undertaken by SunWater (2004). Key details of the dam are summarised in **Table 4.4**.

Table 4.4 Coolmunda Dam Summary Details (SunWater 2004)

Item	Description
Date of Construction	1968
Embankment Description	Zoned earthfill and homogeneous earthfill embankment
Embankment Details	1.9 km long 18.6 m max height 6.1 m crest width 1 V in 1.75 H slopes
Spillway Details	107 m long concrete ogee crest 7 x 12.8 m wide x 11.15 m high radial gates Gates operate automatically by a control system

Item	Description
	referencing reservoir levels
Fuse Plug Description	Homogeneous earthfill embankment built over 150m long concrete control wall
Outlet Works	1 x 915 mm steel pipe Capacity of 5.24 m^3/s at FSL
Full Supply Level (FSL)	314.07 m AHD 69,090 ML

4.4 Model Validation

Due to a lack of recorded rainfall data for large flood events, a calibration of the URBS model to historic events was not considered possible. However, as noted in **Section 4.3.1**, a pluviograph station at Yelarbon was considered suitable for the purpose of validating the URBS model to the February 1976 event. Further, the model has been validated to the FFA of MacIntyre Brooke at Inglewood stream flow gauge (refer **Section 3**).

The Basic Model option has been adopted within URBS, which assumes that the catchment and channel storage for each sub-catchment is lumped together and represented as a single non-linear reservoir. Standard model parameters have been adopted as summarised in **Table 4.5**. The storage lag parameter (α) has been verified to be a reasonable value against the fitting method presented in the URBS manual (Carroll D.G., 2009).

Table 4.5 Adopted URBS Model Parameters

Parameter	Adopted Value
Storage lag parameter (α)	1.7
Catchment non-linearity parameter (m)	0.8

4.4.1 February 1976 Event

The February 1976 historical event has been simulated in the URBS model and the resulting stream flow has been compared to the gauged flows at MacIntyre Brooke at Inglewood. The peak flows are summarised in **Table 4.6** and a graphical comparison of the modelled and gauged hydrographs is shown in **Figure 4.3**.

The model is shown to provide a good agreement to the recorded flood peak (i.e. within 4%). However, the timing of the modelled peak is approximately 4 hours too early.

Further, an initial loss value of 45 mm was needed to give a good fit to the timing of the rising limb of the hydrograph.

The discrepancies in timing of the modelled hydrograph are considered to be primarily due to the limited pluviograph data available (i.e. the timing of rainfall at Yelarbon may have been significantly different to rainfall over portions of the Inglewood catchment). Further model adjustments to improve the timing of the hydrographs were not considered to be warranted due to these constraints.

The model parameters adopted for design flood events were considered appropriate based on validation to the February 1976 event.

Table 4.6 Validation to February 1976 Flood Event – Peak Flows

URBS Peak Flow (m^3/s)	MacIntyre Brook at Inglewood Peak Flow (m^3/s)	Difference (%)
2,640	2,540	+4

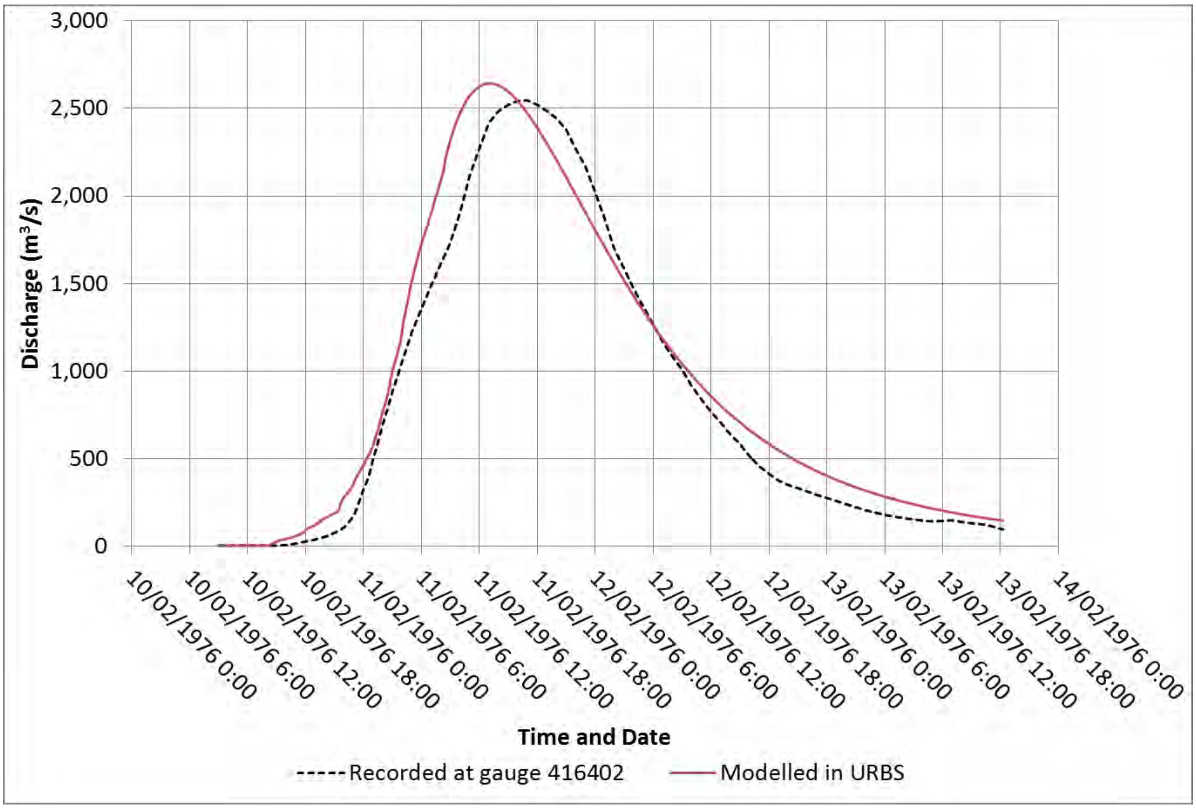


Figure 4.3 Validation to February 1976 Flood Event

4.4.2 MacIntyre Brook at Inglewood FFA

The hydrological model has been further validated by comparison to FFA results for the MacIntyre Brook at Inglewood stream flow gauging station (refer **Section 3**). **Table 4.7** presents a comparison of the peak flow estimates for a range of flood events.

Model results compare reasonably well for the 1:100 and 1:50 AEP events. The FFA results for the 1:500 AEP event are significantly larger than modelled; however, as noted in **Section 3**, there is insufficient data to forecast beyond 1:50 AEP.

The modelled peak flow for the 1:10 AEP event was found to be significantly larger than the FFA estimate. However, as indicated in Section 4.5.1, the peak flow at Inglewood was found to be sensitive to the initial volume in Coolmunda Dam for frequent flood events (i.e. in the order of 1:10 AEP). Results in **Table 4.7** indicate reasonable agreement to the FFA results for the 1:10 AEP when the dam is assumed to start at a reduced volume (i.e. 25% capacity).

Overall, the model was considered to validate well to the FFA results. As agreed with GRC, the assumption of the dam starting full for design event was maintained as a conservative and consistent approach across the range of flood events simulated.

Table 4.7 Validation to MacIntyre Brook at Inglewood (416402) FFA

AEP (%)	MacIntyre Brook at Inglewood FFA Peak Flow (m^3/s)	URBS Peak Flow (m^3/s)	Difference (%)
10	910	1,780 [1]	+94 [1]
		1060 [2]	+16 [2]
2	2,950	3,000	+2
1	4,390	3,610	-18
0.2	9,540	5,220	-46

Note 1: Coolmunda Dam starting full

Note 2: Coolmunda Dam starting 25% full

4.5 Sensitivity Analyses

4.5.1 Dam Capacity Sensitivity Analysis

It is expected that Coolmunda Dam, located upstream of the Inglewood Township on MacIntyre Brook, will provide flood mitigation effects if there is sufficient available capacity for storage in the dam. A sensitivity analysis was undertaken using the URBS model to quantify the effect of available storage in the dam upon the 1:100 and 1:10 AEP design events. Two scenarios were modelled in URBS, one with Coolmunda Dam being at full capacity (i.e. no available storage) and a second with the dam at half capacity (i.e. 35 GL of available storage) at the start of the flood events.

A summary of the resulting peak flow estimates at the MacIntyre Brook at Inglewood gauge location is provided in **Table 4.8** and the modelled hydrographs are shown in **Figure 4.4**.

Table 4.8 Dam Capacity Sensitivity Analysis

AEP (%)	Dam Full (m3/s)	Dam Half-Full (m3/s)	Difference (%)
1	3,610	3,310	-8
10	1,780	1,390	-21

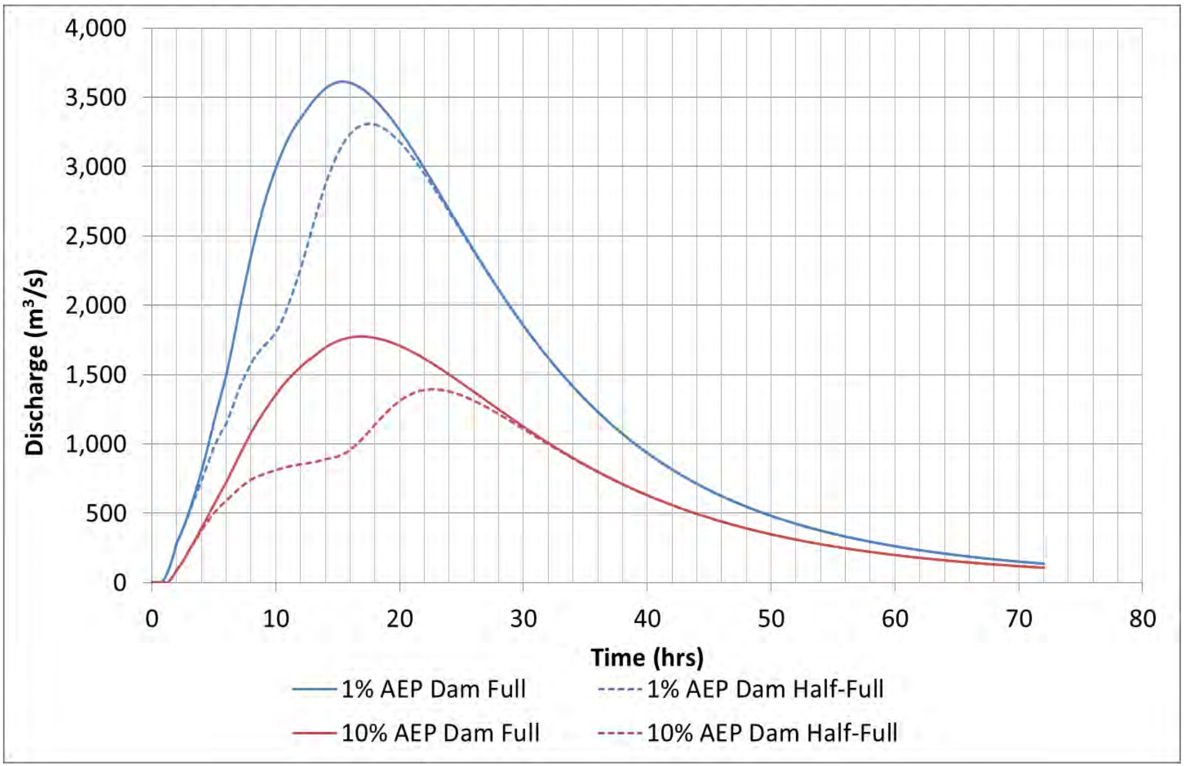


Figure 4.4 Dam Capacity Sensitivity Analysis

As expected, there is a reduction in estimated peak flow and volume at Inglewood when the available storage volume in Coolmunda Dam is increased. This impact is more pronounced for smaller, more frequent events. For analysis of design events, the conservative assumption of the dam being at full capacity at the start of the flood event is considered appropriate.

4.5.2 Coolmunda Dam Sensitivity Analysis

The January 1956 event is the largest event recorded at the MacIntyre Brook at Inglewood stream flow gauge. This event occurred prior to the construction of the Coolmunda Dam and was therefore excluded from the FFA presented in **Section 3.**

No pluviograph rainfall data was available for this event to allow a direct simulation in the hydrological model. In order to assess the impact of the dam on stream flows at Inglewood for the rare flood events, a sensitivity analysis has been undertaken using the January 1956 gauged stream flows.

The gauged flow has been applied to the model upstream of Coolmunda Dam. This is a simplistic approach that neglects the flow split between MacIntyre Brook and Canning Creek and is for the purpose of sensitivity testing only.

The model has been simulated for three scenarios: 'no dam', 'dam starting full' and 'dam starting half full'. The resulting modelled discharge at Inglewood is shown in **Figure 4.5**. There is negligible difference in the peak discharge between the three scenarios for a flood of this magnitude; however, there is increasing delay in the rising limb and time to peak as a result of additional dam storage volume available.

Thus, it is concluded that for rare events, the dam has minimal impact on reducing the peak flow at Inglewood. However, the delay in the flow would provide some benefit in terms of flood warning times.

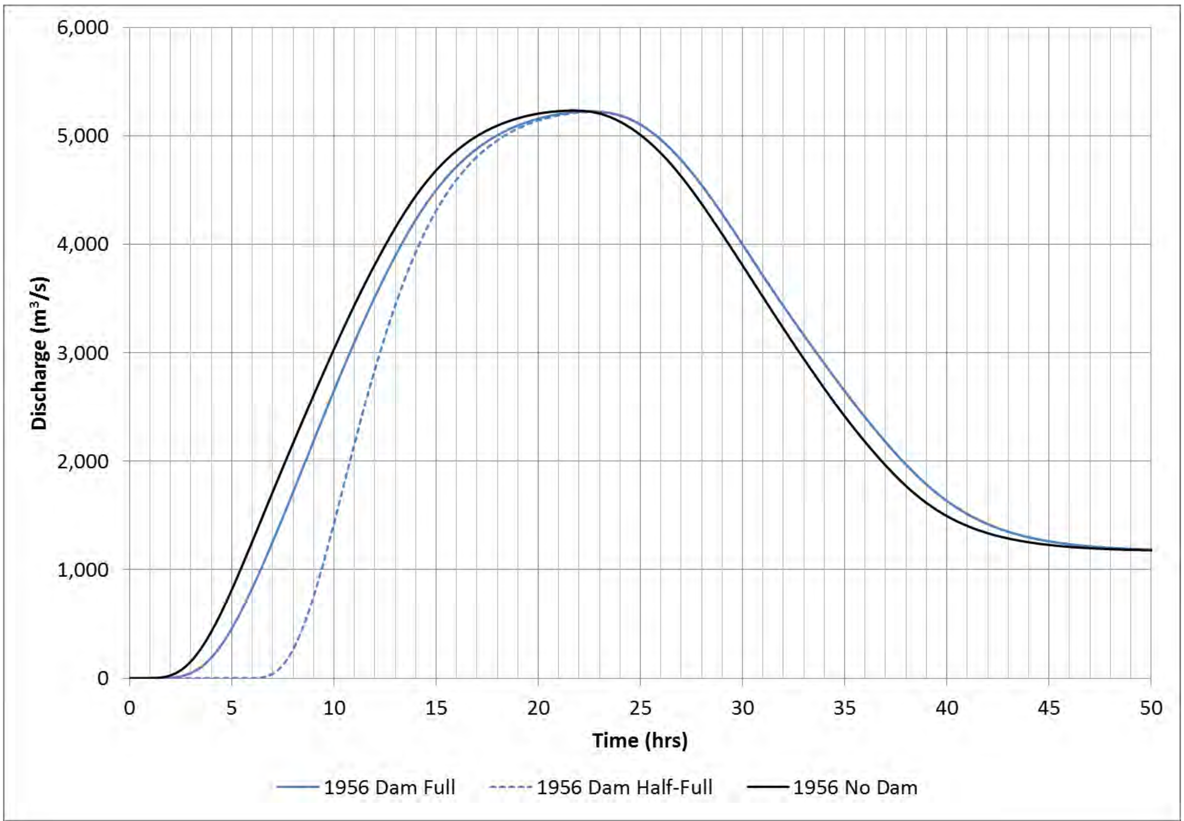


Figure 4.5 Sensitivity Analysis of Coolmunda Dam Impact on Inglewood Flows

5. HYDRAULIC ASSESSMENT

The hydraulic modelling package chosen for use in this study was the TUFLOW finite difference hydrodynamic flood simulation software. TUFLOW simulates depth-averaged, two and one-dimensional free-surface flows and uses a combination of 2D and 1D modelling schemes to model complex flooding behaviour.

The model development details, historical flood analysis and hydraulic model results are presented in the following sections.

5.1 Hydraulic Model Development

5.1.1 Model Extent and Grid Cell Size

The hydraulic model extent is illustrated in **Figure 5.1**. The model topography was represented in the 2D domain using a grid cell size of 10 m. It was considered that the 10 m grid resolution provided adequately definition of the main channel and road/rail embankments whilst maintaining reasonable model simulation times. The 2D domain utilised the 1 m DEM provided by GRC.

The MacIntyre Brook floodplain extends beyond the limits of the topographical survey (DEM) coverage provided by GRC. At the locations where topographic data was missing, a z shape polygon was used to interpolate terrain levels to fill in gaps. In some areas where interpolation of the terrain was unable to be undertaken, a glass wall approach was adopted as a conservative approach. As such, it is advised that the hydraulic model be extended when a greater coverage of topographic data becomes available.

5.1.2 Boundary Conditions

Boundary conditions within the model consisted of:

- Total catchment inflow boundaries at Canning Creek, MacIntyre Brook and Pariagara Creek.
- Local catchment inflow boundaries (source area inflows within the 2D domain).
- Model outflow boundary (represented as normal depth condition).

Catchment inflows were obtained from the URBS model as discussed in **Section 4**.

5.1.3 Hydraulic Roughness

The hydraulic roughness of ground surfaces within the model is specified as Manning's 'n' roughness values. Roughness values were determined from a review of aerial photography and observations undertaken during site inspections. The Manning's roughness values for the different land uses applied within the hydraulic model are listed in **Table 5.1**.

Table 5.1 Mannings's 'n' Roughness Values

Material Classification	Manning's 'n' Roughness Coefficient
Pasture / Open Grassland	0.06
Open Water	0.02
Dense Vegetation	0.08
Township/Buildings	0.40

The suitability of the adopted hydraulic roughness parameters was verified by the relatively good correlation between modelled and recorded flood levels for the 1976 historical flood event as discussed in **Section 5.3**.

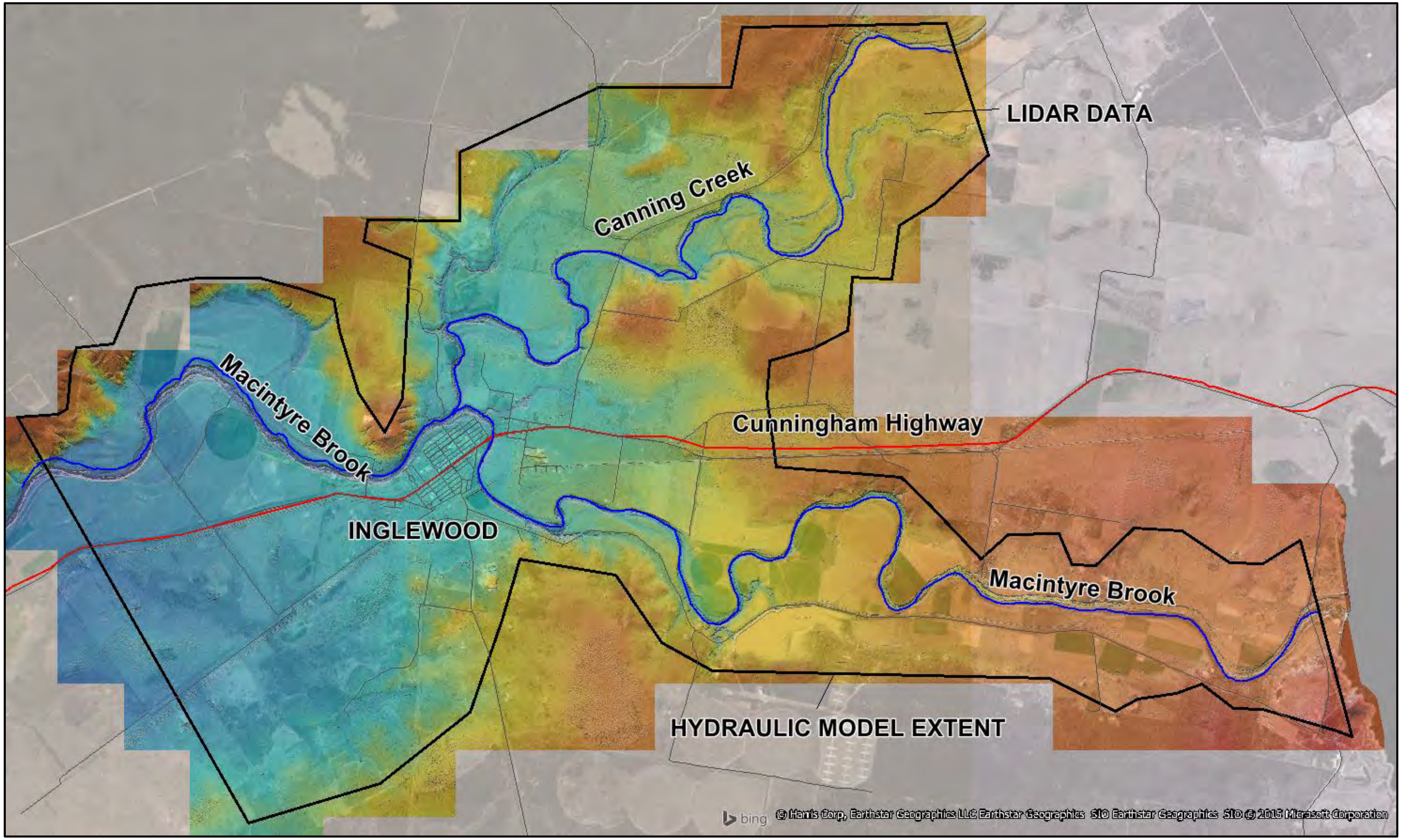


Figure 5.1 Hydraulic Model Extent

5.1.4 Hydraulic Structures

Bridge structures located within the 2D domain have been represented in the TUFLOW model as 2D layered flow constrictions. Causeway and cross drainage structures (1D element) were also included within the TUFLOW model.

The bridge and causeway structures modelled in the TUFLOW model and their adopted deck heights are provided in **Table 5.2**. The location of these structures are illustrated in **Figure 5.1**.

Table 5.2 Bridge Structures Modelled in TUFLOW

Road/Bridge Name	Structure Type	Road Deck Height (m AHD)	Representation in TUFLOW
Bybera Rd	Bridge	270.5	Layered Flow Constriction (lfcsh)
Cunningham Highway (Inglewood)	Bridge	282.7	Layered Flow Constriction (lfcsh)
Millmerran - Inglewood Road	Bridge	285	Layered Flow Constriction (lfcsh)
Potters Road	Culvert: 1 No. 1.5 (h) x 1.8 (w) RCBC; Causeway	272.2	1D Network
Lovells Crossing Road	Causeway	273.3	Layered Flow Constriction (lfcsh)

Structure details used for modelling were estimated using information provided by GRC including the DEM, design drawings, field hand measurements, and aerial photography as well as first hand site observations. It is noted that stormwater drainage infrastructure (pits and pipes) have not been modelled as part of the study.

Form loss coefficients and other parameters for all bridges were estimated using recommendations outlined in the Hydraulics of Bridge Waterways (FHWA, 1965).

5.2 1976 Historical Flood Analysis and Hydraulic Model Validation

The 1956 flood has the highest stream flow data recorded at the MacIntyre Brook Gauge at Inglewood, however due to the construction of Coolmunda Dam in 1968, it was considered that the 1976 event would be more appropriate to adopt for model validation purposes. The February 1976 flood event is considered to be the most significant event to impact Inglewood subsequent to the construction of dam and therefore has been used for validation of the TUFLOW hydraulic model. Validation of the hydraulic model to the 1976 flood has been undertaken using the following methods:

- Comparison of modelled flood levels to survey levels within Inglewood based upon anecdotal 1976 flood evidence
- Comparison of modelled design event flood levels against recorded flood levels of similar magnitude using the rating curve at the MacIntyre Brook Gauge at Inglewood.

5.2.1 Anecdotal 1976 Flood Evidence

Fifty-three (53) flood level observations of the 1976 event were recorded in 2012 as part of the 1976 flood event water depth mapping exercise undertaken by GRC in 2012. The work is outlined the GRC's report titled: *Flood Data Modelling – Inglewood* (refer to **Appendix B**). The surveyed levels were developed into a flood level map over the township. Due to the period of time between data collection and the 1976 historical event, there are likely to be some inaccuracies in the anecdotal evidence provided by the community.

5.2.2 MacIntyre Brook at Inglewood (416402B) Gauge

The 1976 flood discharge was recorded by the MacIntyre Brook (416402B) at Inglewood Gauge. This gauge was weir controlled and has subsequently been replaced by a new gauge (416402C) downstream in 1981.

A peak flood level for the 1976 flood of 282.27 m AHD was recorded at 4:38 pm on the 11th of February. The maximum recorded water level height was 10.22 m above gauge zero which is 272.046 m AHD.

5.2.3 Validation Results

Flood mapping of the anecdotal 1976 flood event is provided in **Appendix B**.

Figure 5.2 indicates there is a good correlation between the modelled results and the recorded river levels and timing of peak levels for the February 1976 flood at the MacIntyre Book Gauge at Inglewood. **Figure 5.3** shows the modelled hydrograph at Inglewood for the 1976 flood compared to the recorded hydrograph at the streamflow gauge. **Table 5.3** presents the comparison between recorded and modelled peak flood levels and timing at the Inglewood Gauge. Modelled flood levels are within 100 mm of the recorded peak flood levels and timing of the modelled peak flood level is shown to be within 2 hours of the recorded flood level.

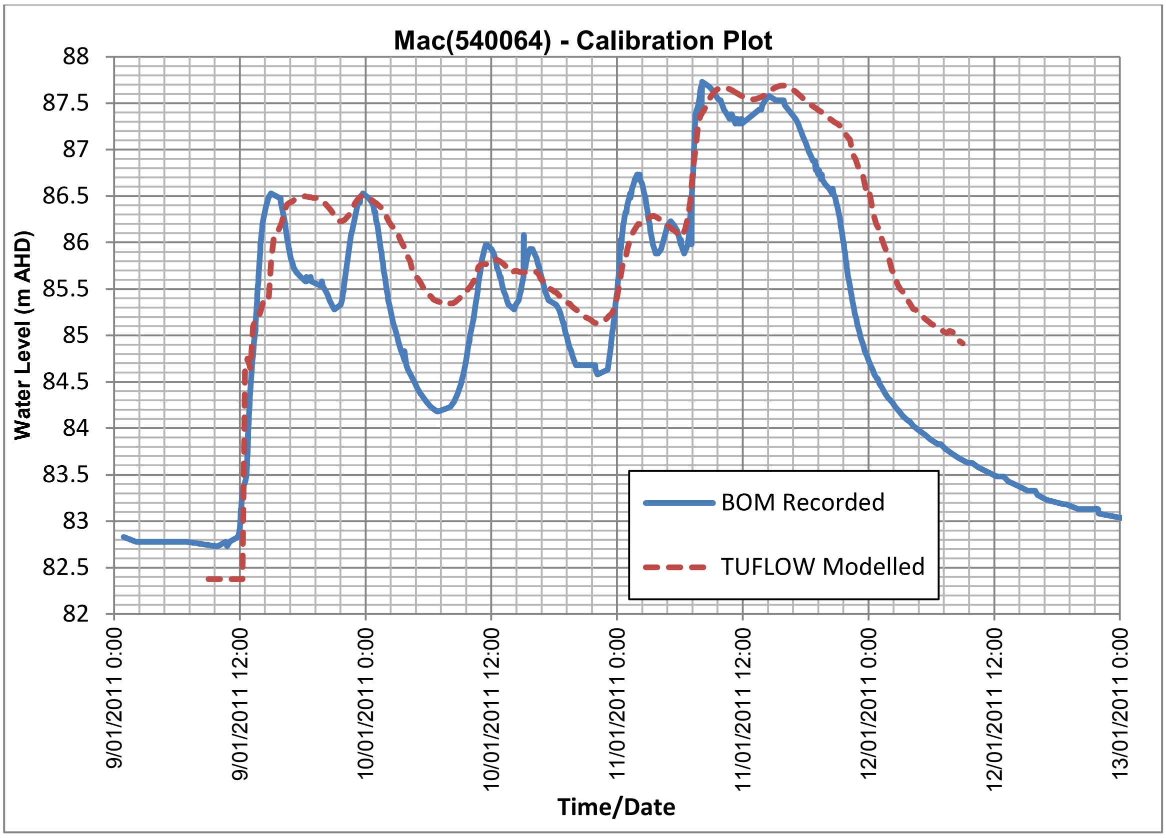


Figure 5.2 February 1976 Validation Event Flood Level Comparison (Modelled vs Recorded) at Inglewood

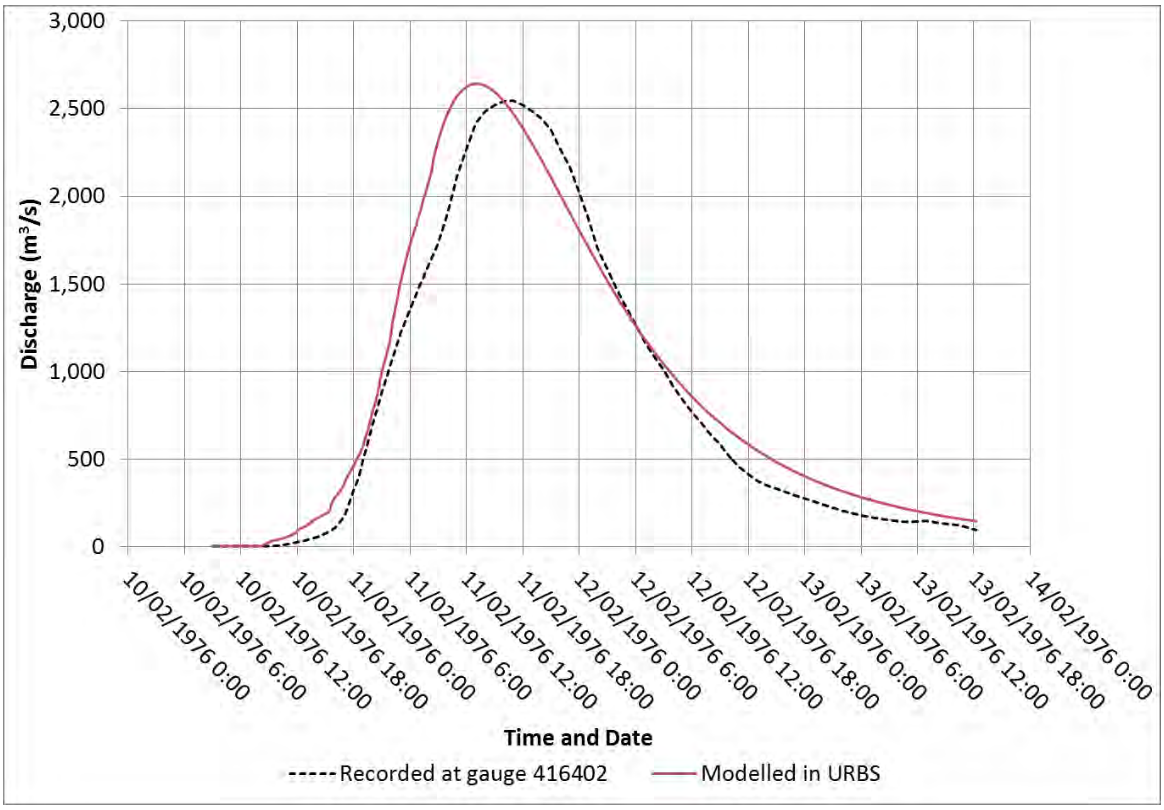


Figure 5.3 February 1976 Validation Event Flood Peak Comparison

Table 5.3 TUFLOW 1976 Validation Results

Calibration Parameter	Recorded Peak Flood Level at MacIntyre Gauge at Inglewood (OLD GAUGE) (m AHD)	TUFLOW Modelled Peak Flood Level (m AHD)
Stream Height (m AHD)	282.27	282.49

The modelled flood level is within 220 mm of the recorded 1976 flood height at the MacIntyre Brook at Inglewood Gauge. Comparison of the modelled 1976 event flood level results against surveyed flood debris and anecdotal flood levels at various reporting locations was also undertaken for model validation purposes. **Table 5.4** presents the comparison of surveyed anecdotal flood levels and modelled flood levels as presented in the Flood Modelling Data – Inglewood report (GRC, 2012). Reporting locations are illustrated in **Figure 5.4**.

Table 5.4 TUFLOW 1976 Validation Results in Inglewood

Reporting ID	Surveyed Flood Level from 1976 Anecdotal Evidence (m AHD)	1976 Modelled Flood Level (m AHD)	Difference (m)
1	283.67	283.65	0.02
2	283.60	283.80	-0.20
3	283.72	283.88	-0.16
4	283.61	283.67	-0.06
5	284.04	284.10	-0.06
6	284.15	284.09	0.06
7	283.87	283.75	0.13
8	283.69	283.46	0.23
9	283.72	283.63	0.09
10	283.94	283.87	0.07
11	248.45	284.21	0.24
12	284.13	283.42	0.71
13	284.83	284.17	0.66

Reporting ID	Surveyed Flood Level from 1976 Anecdotal Evidence (m AHD)	1976 Modelled Flood Level (m AHD)	Difference (m)
14	283.87	283.65	0.22
15	283.18	282.92	0.26
16	285.14	284.42	0.72
17	285.02	283.71	1.31
18	282.98	282.67	0.31
19	284.17	283.98	0.19

The majority of modelled flood levels north of the Cunningham Highway in Inglewood are within 100 mm to 200 mm of the surveyed flood levels, however there is a discrepancy between the modelled and anecdotal flood levels south of the highway. This was discussed with GRC to determine whether there were any significant infrastructure developments or land use changes since the 1976 event, and although changes were noted, there was no definitive conclusion. It is noted that there is a discrepancy between the anecdotal levels within the same immediate area and therefore the accuracy of the anecdotal evidence is questionable in areas. The validation results have been discussed with GRC and it was decided to accept the modelled results for this study.

It is considered that the modelled February 1976 flood event as simulated in TUFLOW has generally provided an acceptable match to observed flood levels at the gauging station and the majority of the surveyed anecdotal flood levels. Therefore the parameters adopted within the TUFLOW model are considered acceptable for use in the design event analysis.

However, it is recommended that comprehensive model calibration be undertaken once appropriate rainfall and river height data for the catchment and additional LiDAR data becomes available.

Level 11, 344 Queen St, Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 07 3221 7174
F: 07 3236 2399
E: admin@engeny.com.au

ENGENY WATER MANAGEMENT

Goondiwindi REGIONAL COUNCIL

meters
0 100 200
Scale in Metres (1:50,000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

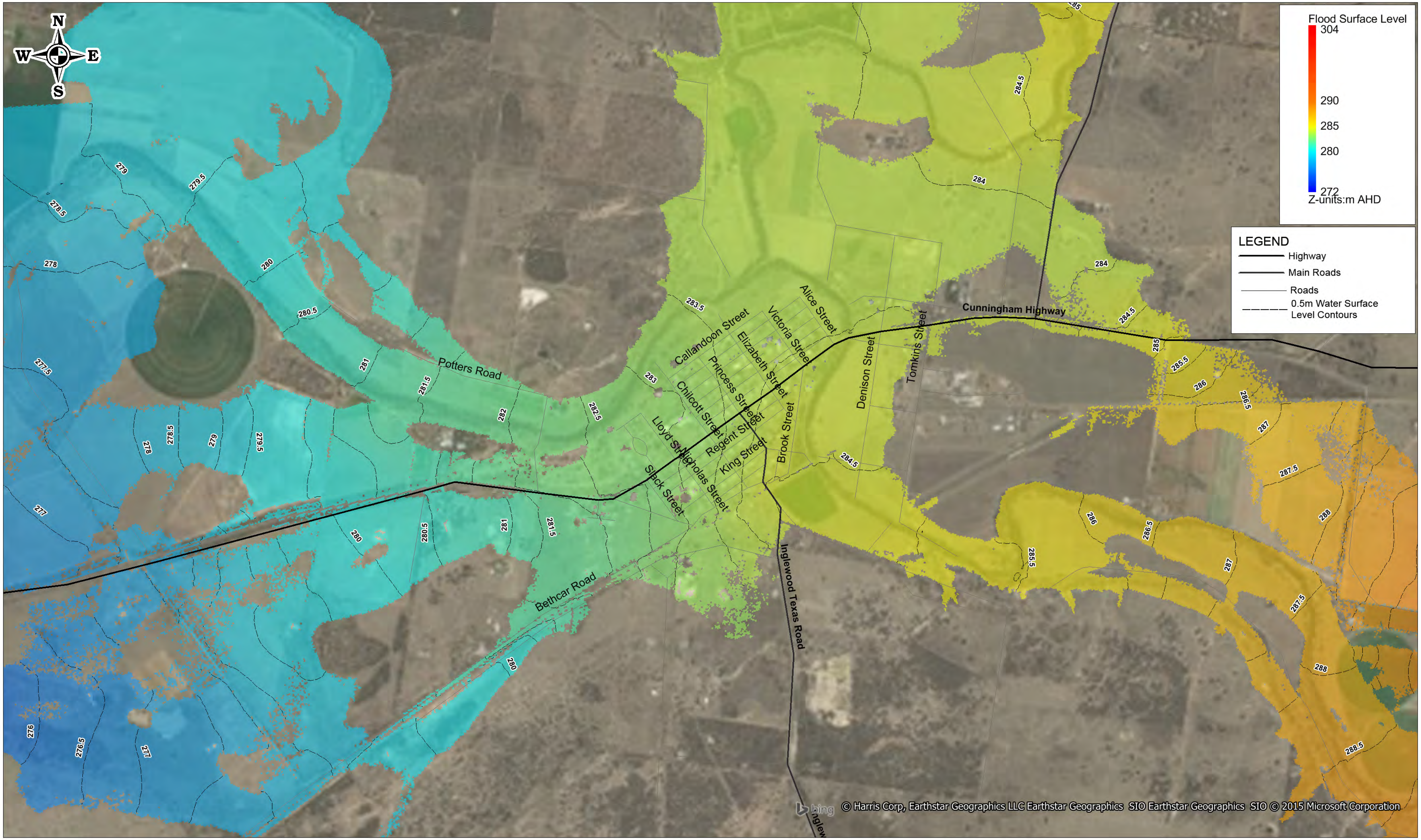
Inglewood Flood Study

Figure 5.4

1976 Historical Event Validation Locations

Job Number: M7000_085
Revision: 0
Drawn: KJM
Date: 26 MAY 2015

M:\Projects\M7000_Miscellaneous Clients\M7000_085 Inglewood FS\Design\MapInfo\Figures



Level 11, 344 Queen St, Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 07 3221 7174
F: 07 3236 2399
E: admin@engeny.com.au
ENGENY WATER MANAGEMENT

Goondiwindi REGIONAL COUNCIL

meters
0 100 200
Scale in Metres (1:50,000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Inglewood Flood Study

Figure 5.5

1976 Flood Surface Level for Inglewood

Job Number: M7000_085
Revision: 0
Drawn: KJM
Date:26 MAY 2015

M:\Projects\M7000_Miscellaneous Clients\M7000_085 Inglewood FS\Design\MapInfo\Figures

5.3 Hydraulic Modelling Results - Design Events

The TUFLOW hydraulic model was used to simulate the 1:10, 1:50, 1:100 and 0.1:50 AEP flood events. The 1:10 AEP was simulated for the critical durations which was the 24 hour storm however all other design events were simulated for the 18 hour duration which was found to produce the maximum peak flows at the Canning Creek and MacIntyre Brook hydraulic model inflow locations. The 1:100 AEP flood level, depth and hazard maps are presented in **Figure 5.7** to **Figure 5.10**. Flood level maps for all events analysed are provided in **Appendix A**.

A summary of the modelled flood levels at the Cunningham Highway Bridge and the MacIntyre Brook at Inglewood gauge are presented in **Table 5.5**. Analysis of the model results indicated that the return period for the February 1976 event was predicted to be between the 1:10 AEP and 1:50 AEP events.

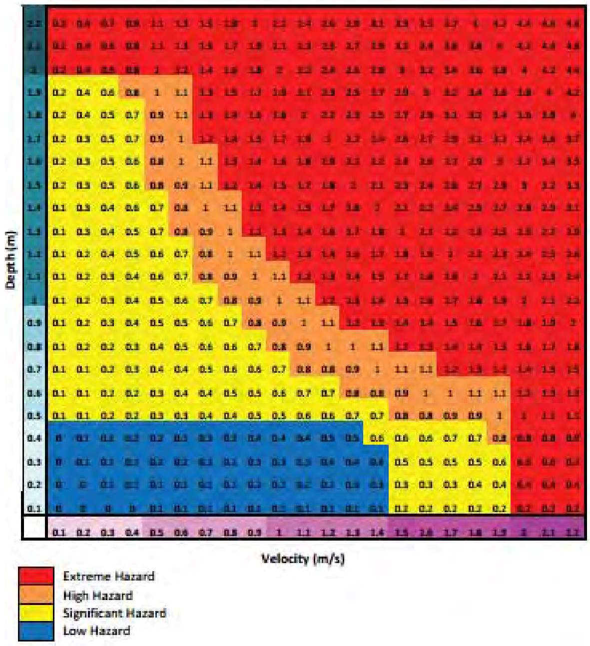
Table 5.5 Flood Level Results at Inglewood Bridge and MacIntyre Brook at Inglewood Gauging Stations

Event	MacIntyre Brook at Inglewood Gauge	
	Peak Flood Level (m AHD)	Peak Flood Level (m AHD)
1976 Flood (TUFLOW)	284.15	282.49
1:10 Year AEP (TUFLOW)	283.29	281.59
1:50 Year AEP (TUFLOW)	284.50	282.78
1:100 Year AEP (TUFLOW)	284.89	283.08
1:500 Year AEP (TUFLOW)	285.38	283.39

[1] *Bridge deck level is approximately 282.7 m AHD*

The hydraulic modelling found that,in events greater than 1:10 AEP, the obstruction caused by the railway line is considered to cause flows in excess of bank full capacity to be diverted towards Brook Street in a westerly direction and then re-enter the MacIntyre Brook flood plain downstream of the Canning Creek confluence. Whilst the smaller events have not been analysed, it is considered that the MacIntyre Brook and Canning Creek channel banks have a capacity less than the 1:10 AEP flood. As such, the flood plain is engaged in events greater than a 1:10 AEP flood.

A flood hazard assessment has been undertaken for the 1:100 AEP event based on the Queensland Reconstruction Authority (QRA) flood hazard criteria as outlined in the QRA's Building for Stronger, More Resilient Floodplains report (QRA, 2012). The criteria is presented as follows.



Rules

	Low	Significant	High	Extreme
Depth	<0.5	<2	<2	2+
Velocity	<1.5	<2	<2	2+
DxV Ratio	<0.6	0.6 to <0.8	0.8 to <1.2	1.2 +

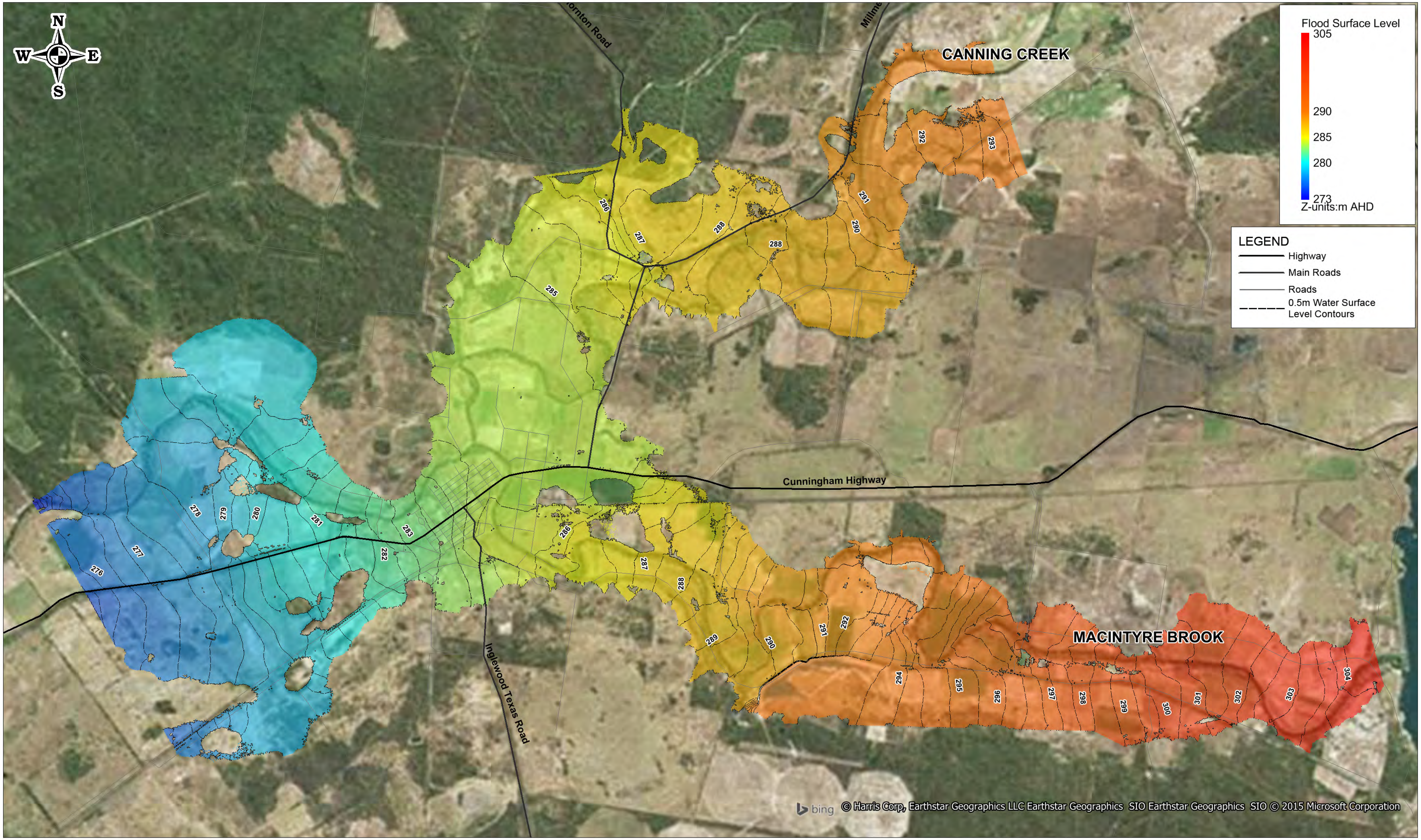
Rationale

1. **Low** – self evacuation possible for adults and children, vehicle stability within tolerance for large 4WD
2. **Significant** – working limit for trained safety workers, Vehicle evac unsuitable, Building Code limitation
3. **High** – limit of uncompromised stability for adults (dangerous to most)
4. **Extreme** – in excess of known stability limits

Figure 5.6 Flood Hazard Criteria

The hazard assessment has identified that the flood hazard within the main MacIntyre Brook and Canning Creek channels is classified at Extreme due to the combination of high velocities and flood depths whilst the broader flood plain including the Inglewood Township is generally classified as Significant with flood depths of up to 3.5 m in the 1:100 AEP event. Average 1:100 and 1:10 AEP flood depths within the Inglewood Township are approximately 1.5 m and 0.25 m respectively.

There was no critical infrastructure identified as being impacted by major flooding. The Inglewood Hospital was reported to be at elevations higher than 282.28 m AHD, whilst the 1:100 and 1:500 AEP flood levels surrounding the hospital are approximately 281.94 m AHD and 282.31 m AHD respectively. As such, the hospital may have a flood immunity of approximately 1:500 AEP.



Level 11, 344 Queen St, Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 07 3221 7174
F: 07 3236 2399
E: admin@engeny.com.au

ENGENY WATER MANAGEMENT

Goondiwindi REGIONAL COUNCIL

0 100 200 meters
Scale in Metres (1:50,000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Inglewood Flood Study

Figure 5.7

1% AEP Flood Surface Level for Study Area

Job Number: M7000_085
Revision: 0
Drawn: KJM
Date:26 MAY 2015

Level 11, 344 Queen St, Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 07 3221 7174
F: 07 3236 2399
E: admin@engeny.com.au

ENGENY WATER MANAGEMENT

Goondiwindi REGIONAL COUNCIL

meters
0 100 200
Scale in Metres (1:50,000 @ A3)

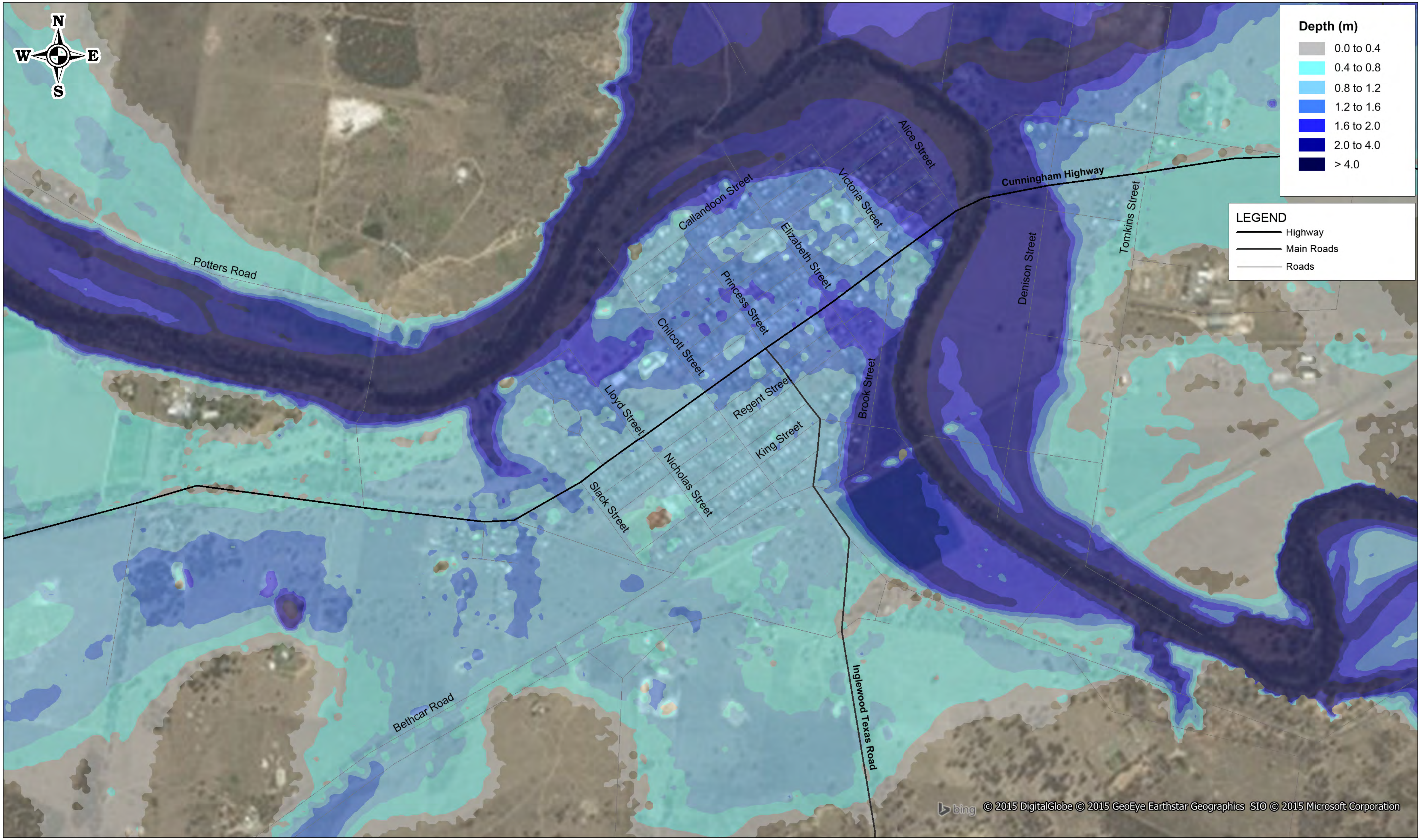
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Inglewood Flood Study

Figure 5.8

1% AEP Flood Surface Level for Inglewood

Job Number: M7000_085
Revision: 0
Drawn: KJM
Date: 26 MAY 2015



Level 11, 344 Queen St, Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 07 3221 7174
F: 07 3236 2399
E: admin@engeny.com.au

ENGENY WATER MANAGEMENT

Goondiwindi REGIONAL COUNCIL

meters
0 100 200
Scale in Metres (1:50,000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

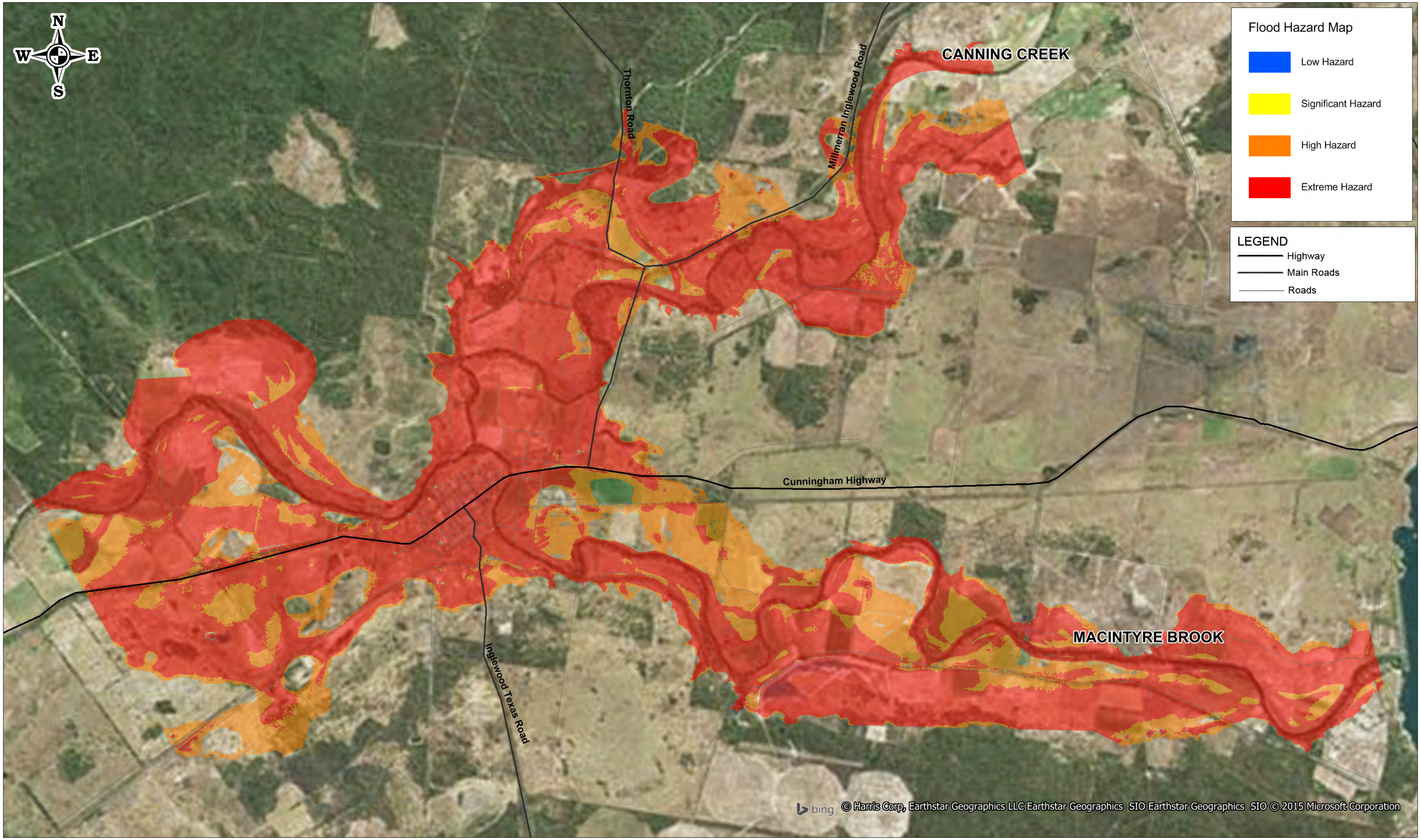
Inglewood Flood Study

Figure 5.9

1% AEP Flood Depth for Inglewood

Job Number: M7000_085
Revision: 0
Drawn: KJM
Date:26 MAY 2015

M:\Projects\M7000_Miscellaneous Clients\M7000_085 Inglewood FS\Design\MapInfo\Figures



Level 11, 344 Queen St, Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 07 3221 7174
F: 07 3236 2399
E: admin@engeny.com.au

ENGENY WATER MANAGEMENT

Goondiwindi REGIONAL COUNCIL

meters
0 100 200
Scale in Metres (1:50,000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Inglewood Flood Study

Figure 5.10

1% AEP Flood Hazard for Study Area

Job Number: M7000_085
Revision: 0
Drawn: KJM
Date:26 MAY 2015

M:\Projects\M7000_Miscellaneous Clients\M7000_085 Inglewood FS\Design\MapInfo\Figures

5.3.1 Road Closure and Evacuation Routes

Time of submergence, time of closure and road closure periods (duration) have been estimated for a number of roads within the study area. These road inundation and closure estimates are provided in **Table 5.6** for the 1:10 and 1:100 AEP events and the road locations are illustrated in **Figure 5.11**. The main evacuation route for Inglewood is via the Cunningham Highway Bridge in an easterly direction. The highway is predicted to become inundated after 12 hours and 8.5 hours in the 1:10 and 1:100 AEP events respectively. Closure of the highway bridge would occur for approximately 8.5 hours and 26 hours in the 1:10 and 1:100 AEP events respectively. The highway bridge is predicted to have a peak flood depth of approximately 0.4 m and 2 m in the 1:10 and 1:100 AEP events respectively.

Table 5.6 Road Closure Summary

Reporting Location	Location ID	Road Level/Bridge Deck Level (m AHD)	1:10 AEP Flood Event			1:100 AEP Flood Event		
			Peak Water Depth Over Road (m)	Time of First Submergence (hours)	Period of Closure (hours)	Peak Water Depth Over Road (m)	Time of First Submergence (hours)	Period of Closure (hours)
MILLMERRAN - INGLEWOOD RD (SAG IN ROAD)	LOC 1	291.0	- (may occur in localised events only)	0	0	0.03	13.1	0
MILLMERRAN - INGLEWOOD RD (SAG IN ROAD)	LOC 2	288.7	- (may occur in localised events only)	0	0	0.06	13	0
MILLMERRAN - INGLEWOOD BRIDGE	LOC 3	285.92	0.88	6.5	7.3	0.9	6.5	24.6
MILLMERRAN - INGLEWOOD FLOODWAY	LOC 4	283.1	- (may occur in localised events only)	0	0	1.8	9	23
TOBACCO RD TRIBUTARY CROSSING 1	LOC 5	284.45	0.6	9	14.7	1.9	6.7	27.3
TOBACCO RD TRIBUTARY	LOC 6	286.7	1.3	7.5	21.8	2.6	5.8	31.6

Reporting Location	Location ID	Road Level/Bridge Deck Level (m AHD)	1:10 AEP Flood Event			1:100 AEP Flood Event		
			Peak Water Depth Over Road (m)	Time of First Submergence (hours)	Period of Closure (hours)	Peak Water Depth Over Road (m)	Time of First Submergence (hours)	Period of Closure (hours)
CROSSING 2								
TOBACCO RD TRIBUTARY CROSSING 3	LOC 7	287.7	0.2	12.2	0	1.9	8	24.2
CUNNINGHAM HWY BRIDGE AT INGLEWOOD	LOC 8	282.7	0.4	12.5	8.5	2	8	26.3
LOVELS CROSSING ROAD FLOODWAY	LOC 9	273.3	9.3	2	>72	11.2	1.5	>72
POTTERS ROAD CROSSING	LOC 10	272.5	8.9	3	>72	10.3	2.3	>72
BYPERA ROAD CROSSING	LOC 11	270.5	6.9	5	>72	8	3.8	>72

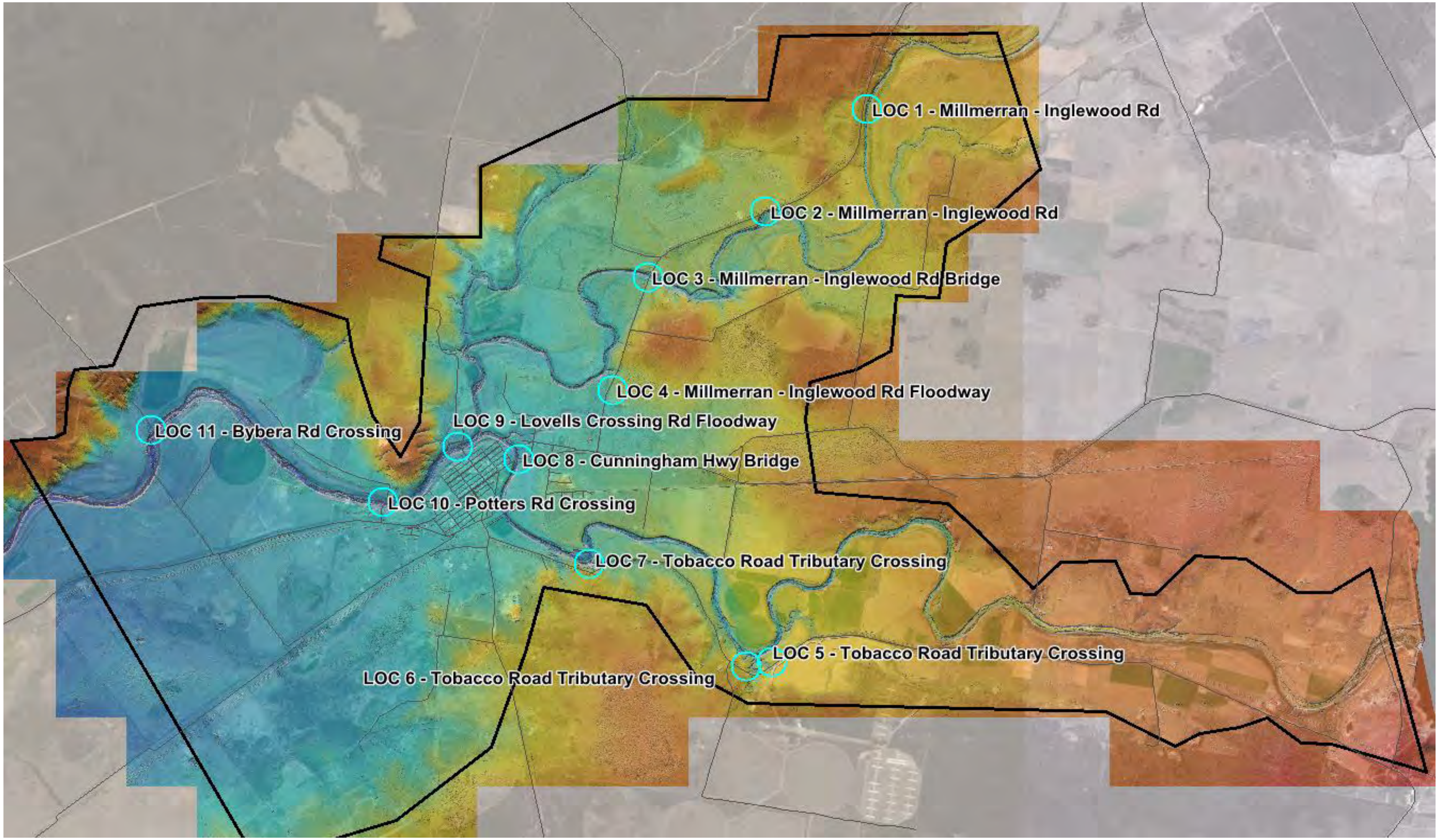


Figure 5.11 Time of Submergence/Closure Estimate Locations

6. STUDY LIMITATIONS

There are a number of key limitations to the study that were identified. These were:

- The supplied LiDAR coverage is limited to the Inglewood Township only and therefore does not represent the entire floodplain. As such, the following measures were adopted to undertake the study:
  - SRTM hydro-enforced DEM (1 second, 30 m resolution) was adopted for the hydrologic analysis.
  - Manipulation of topography to create an artificial boundary near Thornton Road on Pariagara Creek.
- Detailed plans or survey of key hydraulic structures (i.e. bridges) were not available. Structure details were based on information provided by GRC. The rail embankment was represented within the 2D domain of the hydraulic model. The rail bridge was omitted, however given the width of the flood plain it is not anticipated that the bridge itself would have a significant influence on flood levels for major events.
- A strong calibration of the hydrological modelling could not be achieved tdue to a lack of rainfall pluviograph and river level data for key historical events. For model validation purposes, the 1976 flood was simulated in the URBS and TUFLOW models using pluviograph rainfall data from the Yelarbon Station (41122) which is outside the catchment boundary but is the closest station with available data.
- Flood levels in Inglewood are likely to be heavily influenced by the timing of peak flows and interaction between the MacIntyre Brook and Canning Creek. Given the lack of suitable historical rainfall data available within the catchment, model calibration could not be achieved.
- The hydraulic model only included hydraulic structures used for flood conveyance (i.e. not included subsurface culverts associated with local stormwater conveyance).

These limitations need to be considered in the use of the study outputs, however it is believed that the study represents the most detailed analysis of flood behaviour and associated risks for Inglewood.

7. CONCLUSIONS & RECOMMENDATIONS

In large events (i.e. greater than 1:10 AEP), the obstructions caused by the railway line is considered to cause flows in excess of bank full capacity to be diverted towards Brook Street in a westerly direction and then re-enter the MacIntyre Brook floodplain downstream of the Canning Creek confluence.

The hydrological model estimated peak floods with an acceptable match with the FFA peak flow for the 1:50 and 1:100 AEP events and for the 1:10 AEP if the dam was at 25% capacity (i.e. 75% available storage) at the start of the event. There is little confidence in the FFA peak flow estimate for the 1:500 AEP event as the station has a maximum flood height gauge of 279.38 m AHD (i.e. less than 1:10 AEP) and extrapolated to account for large and extreme events.

There are no critical infrastructure that are considered to be impacted by major flooding. The Inglewood Hospital is reported to be at elevations higher that 282.28 m AHD, whilst the 1:100 and 0.1:50 AEP flood levels surrounding the hospital are approximately 281.94 m AHD and 282.31 m AHD respectively.

During a flood event, the risk of Inglewood residents becoming isolated is considered high. The main evacuation route for Inglewood is via the Cunningham Highway Bridge in an easterly direction. The bridge is predicted to become inundated after 12 hours and 8.5 hours in the 1:10 and 1:100 AEP events respectively. Closure of the highway bridge would occur for approximately 8.5 hours and 26 hours in the 1:10 and 1:100 AEP events respectively. The highway bridge is predicted to have a peak flood depth of approximately 0.4 m and 2 m in the 1:10 and 1:100 AEP events respectively.

Conclusions from the Inglewood Flood Study are summarised as follows:

- Whilst Coolmunda Dam does not serve as a flood mitigation measure for Inglewood, the availability of storage within Coolmunda Dam could have a significant influence on flood events up to the 1:100 AEP.
- For flood events greater than 1:10 AEP, the obstruction caused by the railway line is considered to cause flows in excess of bank full capacity to be diverted towards Brook Street in a westerly direction.
- The MacIntyre Brook and Canning Creek channel banks have a 5% to 1:10 AEP capacity
- The **flood hazard** within the MacIntyre Brook and Canning Creek channel banks is classified at Extreme whilst the broader flood plain including the Inglewood Township is mostly classified as Significant
- The ***Inglewood Hospital*** is estimated to have a flood immunity of approximately 1:500 AEP.

- The main ***evacuation route*** for Inglewood is via the Cunningham Highway Bridge in an easterly direction

- The Bridge is predicted to become ***flooded and closed*** after 12 hours and 8.5 hours in the 1:10 and 1:100 AEP events respectively

- The ***closure duration*** for the Bridge is approximately 8.5 hours and 26 hours in the 1:10 and 1:100 AEP events respectively

It is **recommended** that Goondiwindi Regional Council utilise the flood information provided in this study to assist with the management of ***flood risks*** and future ***development planning***.

8. QUALIFICATIONS

a. In preparing this document, including all relevant calculation and modelling, Engeny Management Pty Ltd (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b. Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

c. Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

   (i) Additional sources of information not presently available (for whatever reason) are provided or become known to Engeny; or

   (ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

d. Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the works, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works. All limitations of liability shall apply for the benefit of the employees, agents and representatives of Engeny to the same extent that they apply for the benefit of Engeny.

e. This document is for the use of the party to whom it is addressed and for no other persons. No responsibility is accepted to any third party for the whole or part of the contents of this report.

f. If any claim or demand is made by any person against Engeny on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the report or information therein, Engeny will rely upon this provision as a defence to any such claim or demand.

9. REFERENCES

BMT WBM (2010) TUFLOW User Manual.

Engineers Australian (1998), Australian Rainfall and Runoff – Volume 1.

Engineers Australian (1987), Australian Rainfall and Runoff – Volume 2.

Goondiwindi Regional Council (2012), Flood Modelling Data – Inglewood.

IEAUST (1999), Australian Rainfall and Runoff – Volume 1: A Guide to Flood Estimation The Institution of Engineers, Australia, Barton, ACT.

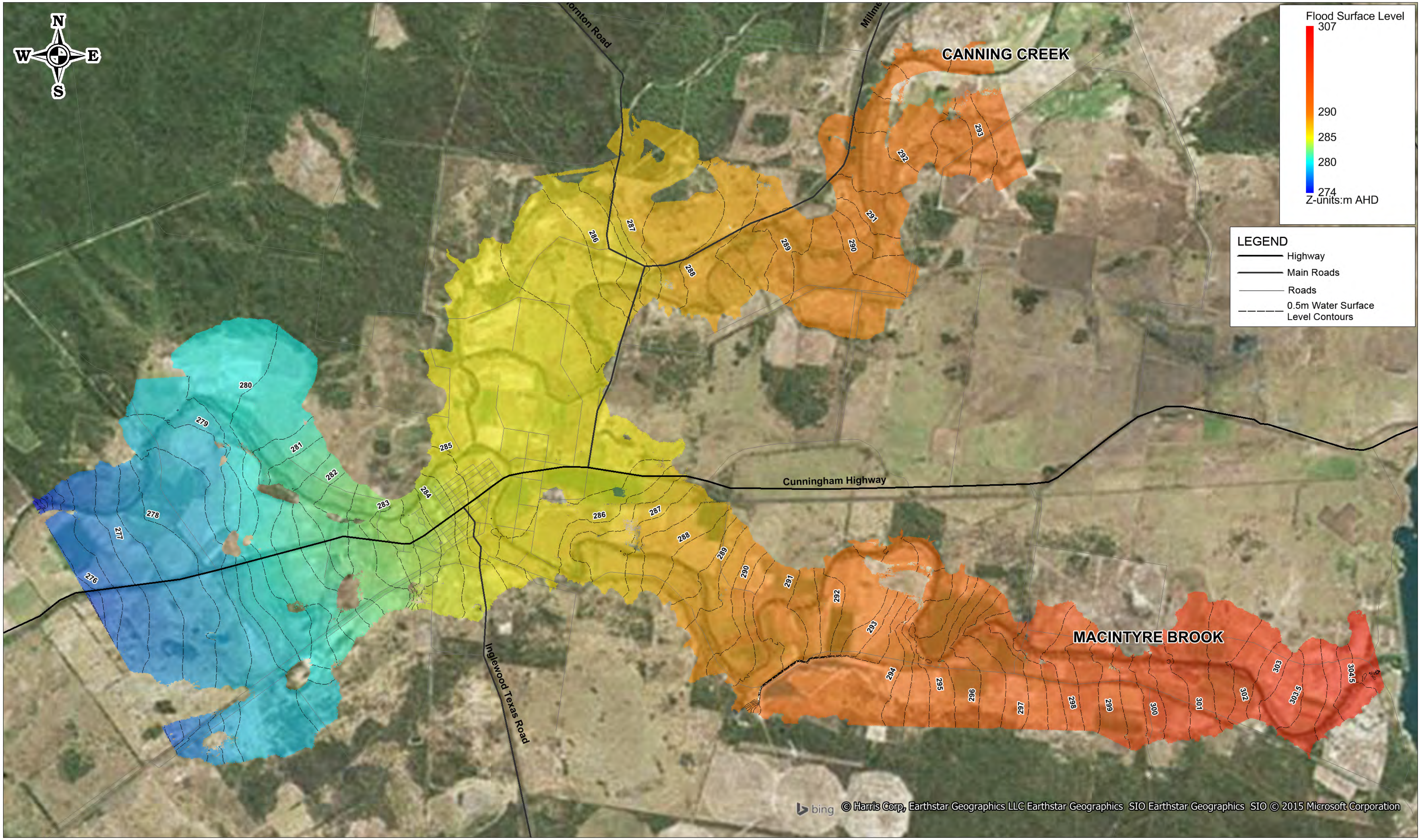
Queensland Reconstruction Authority (2012), Planning for stronger, more resilient floodplains (Part 2).

SKM (2013), Flood Hazard Mapping for Inglewood (Level 2).

SunWater (2004), Coolmunda Dam Break Analysis

APPENDIX A

Flood Maps



Level 11, 344 Queen St, Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 07 3221 7174
F: 07 3236 2399
E: admin@engeny.com.au

ENGENY WATER MANAGEMENT

Goondiwindi REGIONAL COUNCIL

meters
0 100 200
Scale in Metres (1:50,000 @ A3)

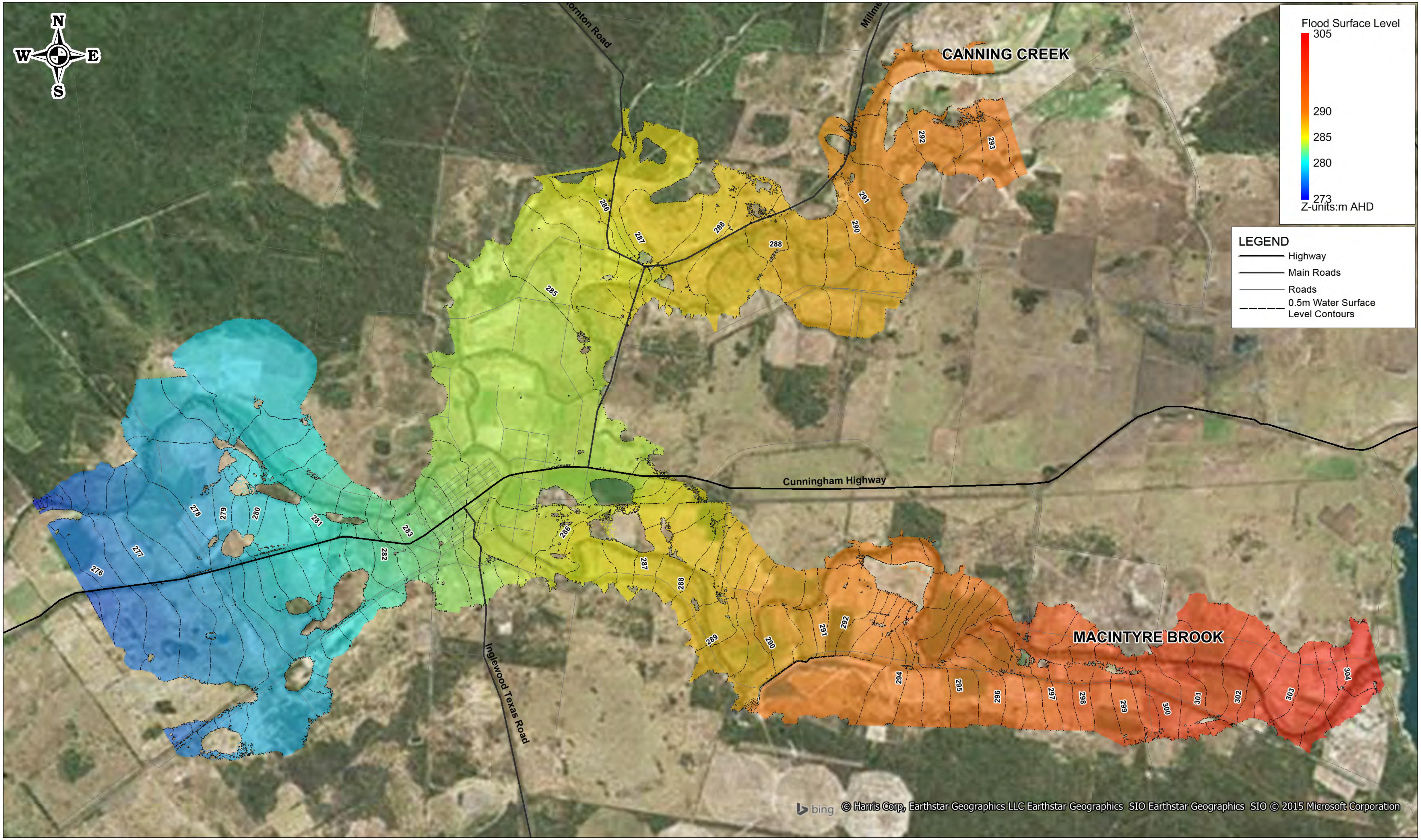
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Inglewood Flood Study

Appendix A1

0.2% AEP Flood Surface Level for Study Area

Job Number: M7000_085
Revision: 0
Drawn: KJM
Date:26 MAY 2015



Level 11, 344 Queen St, Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 07 3221 7174
F: 07 3236 2399
E: admin@engeny.com.au
ENGENY WATER MANAGEMENT

Goondiwindi REGIONAL COUNCIL

meters
0 100 200
Scale in Metres (1:50,000 @ A3)

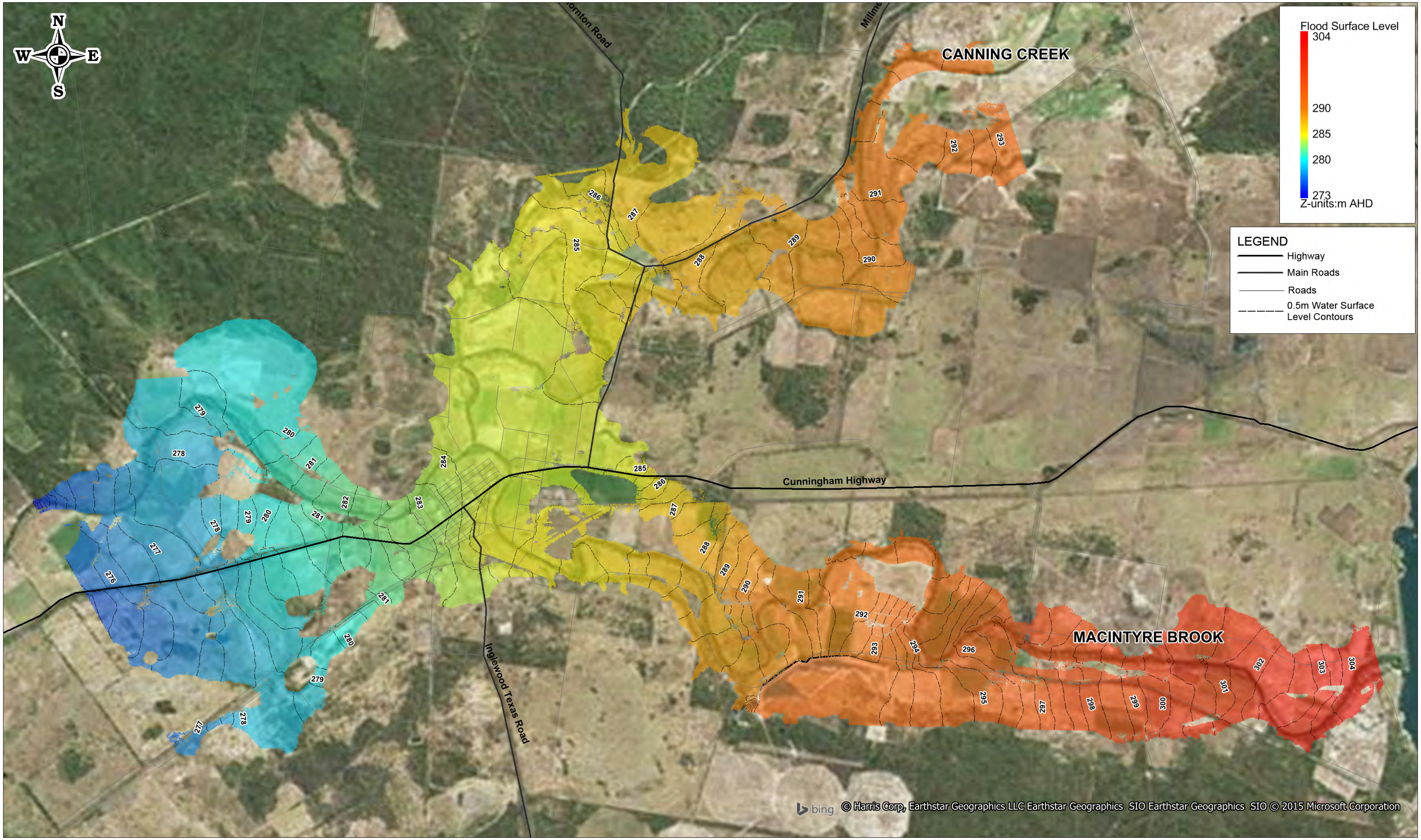
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Inglewood Flood Study

Appendix A2

1% AEP Flood Surface Level for Study Area

Job Number: M7000_085
Revision: 0
Drawn: KJM
Date:26 MAY 2015



Level 11, 344 Queen St, Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 07 3221 7174
F: 07 3236 2399
E: admin@engeny.com.au
ENGENY WATER MANAGEMENT

Goondiwindi REGIONAL COUNCIL

meters
0 100 200
Scale in Metres (1:50,000 @ A3)

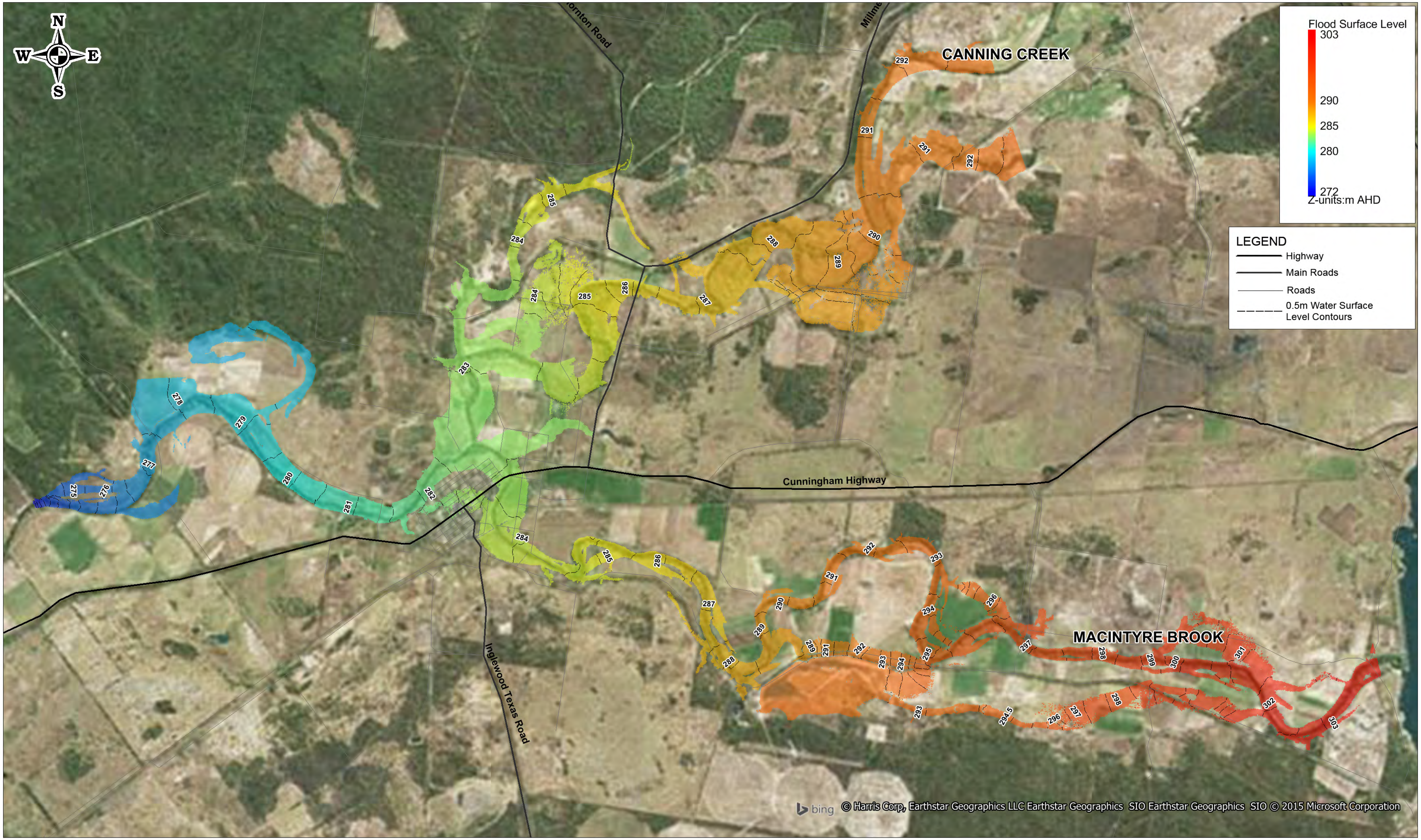
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Inglewood Flood Study

Appendix A3

2% AEP Flood Surface Level for Study Area

Job Number: M7000_085
Revision: 0
Drawn: KJM
Date:26 MAY 2015



Level 11, 344 Queen St, Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 07 3221 7174
F: 07 3236 2399
E: admin@engeny.com.au
ENGENY WATER MANAGEMENT

Goondiwindi REGIONAL COUNCIL

meters
0 100 200
Scale in Metres (1:50,000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

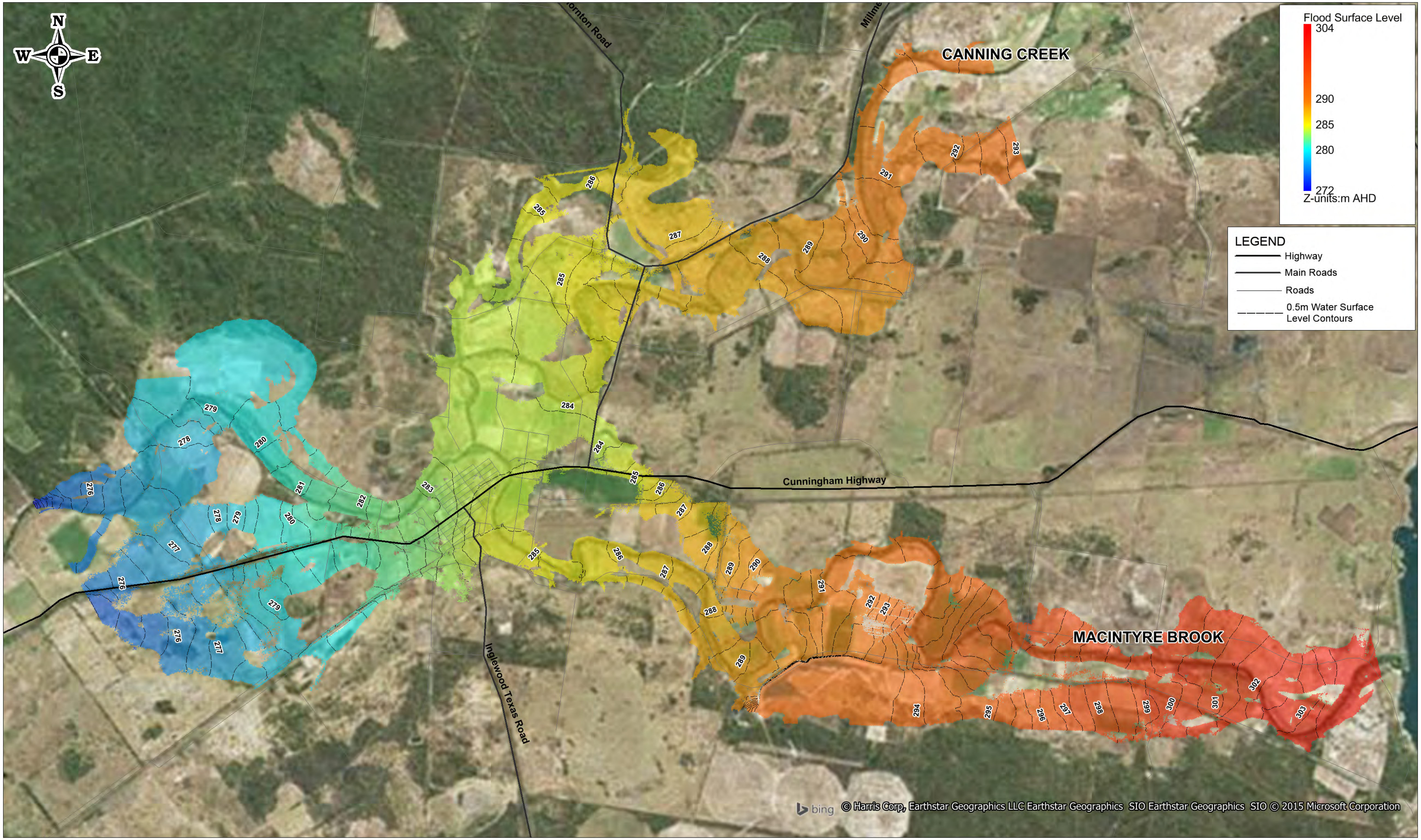
Inglewood Flood Study

Appendix A4

10% AEP Flood Surface Level for Study Area

Job Number: M7000_085
Revision: 0
Drawn: KJM
Date:26 MAY 2015

M:\Projects\M7000_Miscellaneous Clients\M7000_085 Inglewood FS\Design\MapInfo\Figures



Level 11, 344 Queen St, Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 07 3221 7174
F: 07 3236 2399
E: admin@engeny.com.au

ENGENY WATER MANAGEMENT

Goondiwindi REGIONAL COUNCIL

meters
0 100 200
Scale in Metres (1:50,000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Inglewood Flood Study

Appendix A5

1976 Flood Surface Level for Study Area

Job Number: M7000_085
Revision: 0
Drawn: KJM
Date:26 MAY 2015

M:\Projects\M7000_Miscellaneous Clients\M7000_085 Inglewood FS\Design\MapInfo\Figures

APPENDIX B

Flood Data Modelling – Inglewood (GRC, 2012)

FACT SHEET

FLOOD RESPONSE – INGLEWOOD AREA

(For internal use only)

1. Purpose

The purpose of this fact sheet is to provide information for a flooding event within the Inglewood area of Goondiwindi Regional Council.

2. Scope

This information applies to the Inglewood area of Goondiwindi Regional Council.

3. Flood Event Category – Inglewood Bridge

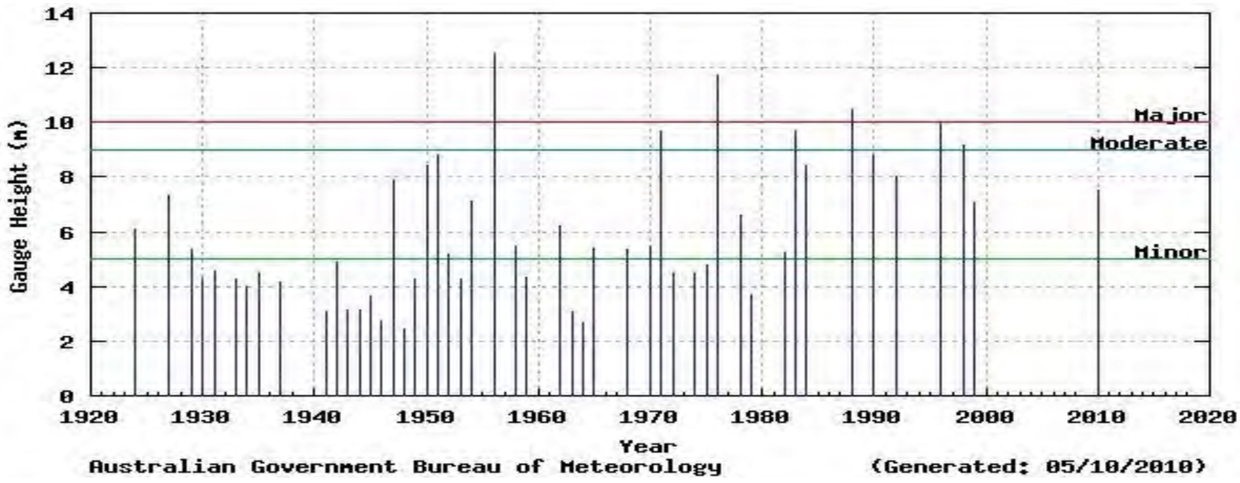
In general terms, a minor flood is designated as 5.0m to 9.0m, a moderate flood as 9.0m to 10.0m and a major flood as greater than 10.0m.

Category	Flood Height	
Minor	5.0m	9.0m
Moderate	9.0m	10.0m
Major	10.0m	Greater

4. Historical Flood Information

(i) Macintyre Brook at Inglewood Bridge Highest Annual Flood Peaks

Date	Gauge Ht (M)
28 January 1927	7.32m
22 January 1956	12.50m
11 February 1976	11.73m
12 April 1988	10.45m
3 May 1996	9.95m
26 September 2010	7.5m
6 January 2011	8.67m
10 January 2011	9.2m



(ii) **Inglewood Flood Effects (Station: COOLMUNDA DAM)**

Coolmunda Gauge	
Gauge Ht (M)	**Probable Flood Effect**
0.50m	McIntyre Brook Causeway
0.50m	Cement crossing below dam wall will be closed to normal vehicular traffic.
1.00m	First report
1.50m	Minor Flood Level
4.50m	Moderate Flood Level
4.60m	Tobacco Road between Coolmunda Dam and Inglewood is cut to all traffic
5.00m	Major Flood Level
5.00m	Approximately height of the primary banks at the gauge
5.45m	Water will enter some of the lower-lying houses in Inglewood
5.50m	Town/Houses

(iii) **Inglewood Flood Effects (Station: INGLEWOOD BRIDGE)**

Inglewood Gauge	
Gauge Ht (M)	**Probable Flood Effect**
3.00m	First Report
5.00m	Minor Flood Level
8.53m	Flooding of crops in downstream areas
9.00m	Moderate Flood Level

Inglewood Gauge	
Gauge Ht (M)	**Probable Flood Effect**
9.00m	Crops/Grazing
10.00m	Major Flood Level
10.00m	Primary banks full at the gauge
10.10m	Town/House
10.16m	Flooding in town area with large areas of crops and grazing land inundated
10.40m	Inglewood Bridge (Cunningham Highway)

5. Creeks & Rivers Contributing to Flooding

⇒ Bracker Creek
⇒ Chain of Ponds
⇒ Canning Creek
⇒ Mosquito Creek
⇒ MacIntyre Brook
⇒ Nanny's Creek

6. Flood Information Services

⇒ Main flood warning, rainfall & water level information website is at http://www.bom.gov.au/qld/flood/

⇒ A description of the flood warning system for the Macintyre/Weir system is available via: http://www.bom.gov.au/hydro/flood/qld/brochures/index.shtml

⇒ A flood monitoring network map is available via: http://www.bom.gov.au/hydro/flood/qld/brochures/river_maps.shtml

⇒ During floods, you can contact the Flood Warning Centre on 07 3239 8778.