
# AUCKLAND CREEK FLOOD STUDY

AUGUST 2019

PREPARED FOR

Gladstone Regional Council

| Project Details | |
|---|---|
| **Report Title** | Auckland Creek Flood Study |
| **Prepared for** | Gladstone Regional Council |
| **Document Name** | 10335-R01-AucklandCkFS-D.docx |

| Document Control | | | | | |
|---|---|---|---|---|---|
| **Revision** | **Author** | **Reviewer** | **Approved for Issue** | | |
| | | | **Name** | **Signature** | **Report Date** |
| A | MPB | EO | M. Balicki, RPEQ 18349 | | 08/04/2019 |
| B | MPB | EO | M. Balicki, RPEQ 18349 | | 12/04/2019 |
| C | DR | EO | M. Balicki, RPEQ 18349 | | 24/06/2019 |
| D | DR | EO | M. Balicki, RPEQ 18349 |  | 01/08/2019 |

| Revision Status | |
|---|---|
| **Revision** | **Description** |
| A | Draft Report - Hydrologic Modelling Summary |
| B | Draft Report - Hydrologic and Hydraulic Modelling |
| C | Draft Report - Updated following Stormwater Pit and Pipe Survey and Revised Modelling |
| D | Final Report |

## TABLE OF CONTENTS

## APPENDICES



## LIST OF TABLES



## LIST OF FIGURES

# 1 INTRODUCTION

## 1.1 BACKGROUND

Water Modelling Solutions Pty Ltd (WMS) has been engaged by Gladstone Regional Council to update the hydrological and hydraulic models for Auckland Creek in accordance with the new Australian Rainfall and Runoff (ARR) 2016 and provide an updated Flood Study report. The most recent Flood Study of Auckland Creek was undertaken in 2015 by Engeny which was based on an uncalibrated model. The aim of this study is to:

- Review existing data including supplied hydrologic and hydraulic models;
- Identify storm events for hydrologic and hydraulic modelling calibration;
- Update the hydrological model in accordance with ARR 2016 for a range of design storm events;
- Validate design flows against the Regional Flood Frequency Analysis (RFFE) and the Quantile Regression Technique (QRT) and compare the March 2017 flows to the validated design flows and provide an estimate of the approximate AEP of these events; and
- Update and calibrate the TUFLOW hydraulic model to produce updated design flood levels to inform future town planning and flood risk management with the Auckland Creek catchment.

This report summarises the details of the hydrologic model update and new data received to be used in the hydraulic model in order to proceed with the calibration of the hydraulic model and production of the design event runs.

## 1.2 SCOPE

The following scope of works has been completed as part of this report:

- Analysis of available data to identify the largest two flood events for which calibration data exists (March 23, 2017 and March 30, 2017);
- Derivation of flows in XP-RAFTS from the rainfall data for the two historical flood events;
- Updating of the XP-RAFTS design storm events in accordance with ARR 2016 guidelines;
- Updating and calibrating the TUFLOW hydraulic model; and
- Running the calibrated TUFLOW hydraulic model with ARR 2016 design event flows - to be continued.

## 1.3 STUDY AREA

The Auckland Creek catchment is located within the Gladstone Council Local Government Area (LGA), and covers the majority of the urban areas of Gladstone. It has a catchment area of 56 $km^2$ and drains in a predominantly northern direction through the catchment, discharging to Port Curtis. Due to the proximity to the Gladstone CBD, the catchment contains a significant area of urban development; however, there are some areas within the upper and middle catchment that are largely in an undeveloped state.

The major tributaries of the Auckland Creek Catchment include Police Creek, Carthurbie Creek, Briffney Creek, Tigalee Creek and Auckland Creek, see Figure 1-1. Auckland Creek rises at the confluence of Police and Briffany Creeks. Police Creek drains the majority of the northern area of the catchment with its tributaries of Toondon and Tigalee Creeks. Briffany Creek runs from upstream of Kirkwood Rd to the confluence with Police Creek near the Dawson Highway. The lower area of the catchment downstream of the Dawson Highway is drained by Auckland Creek.

The upper catchment area is largely undeveloped and characterised by steep hilly terrain and elevations vary from 30 mAHD to 220 mAHD. The middle part of the catchment is mostly urbanised with some undeveloped areas. Elevations in this section range from 5 mAHD to 100 mAHD and has moderate to flat grades. The lower half of the catchment is significantly urbanised with commercial, industrial and residential development. Elevations in the lower catchment vary from 0 mAHD to 40 mAHD with flat grades. Both Lake Callemondah and the Gladstone CBD are located in this part of the catchment. Auckland Creek is tidal from downstream of the Lake Callemondah weir to the outlet into Port Curtis.

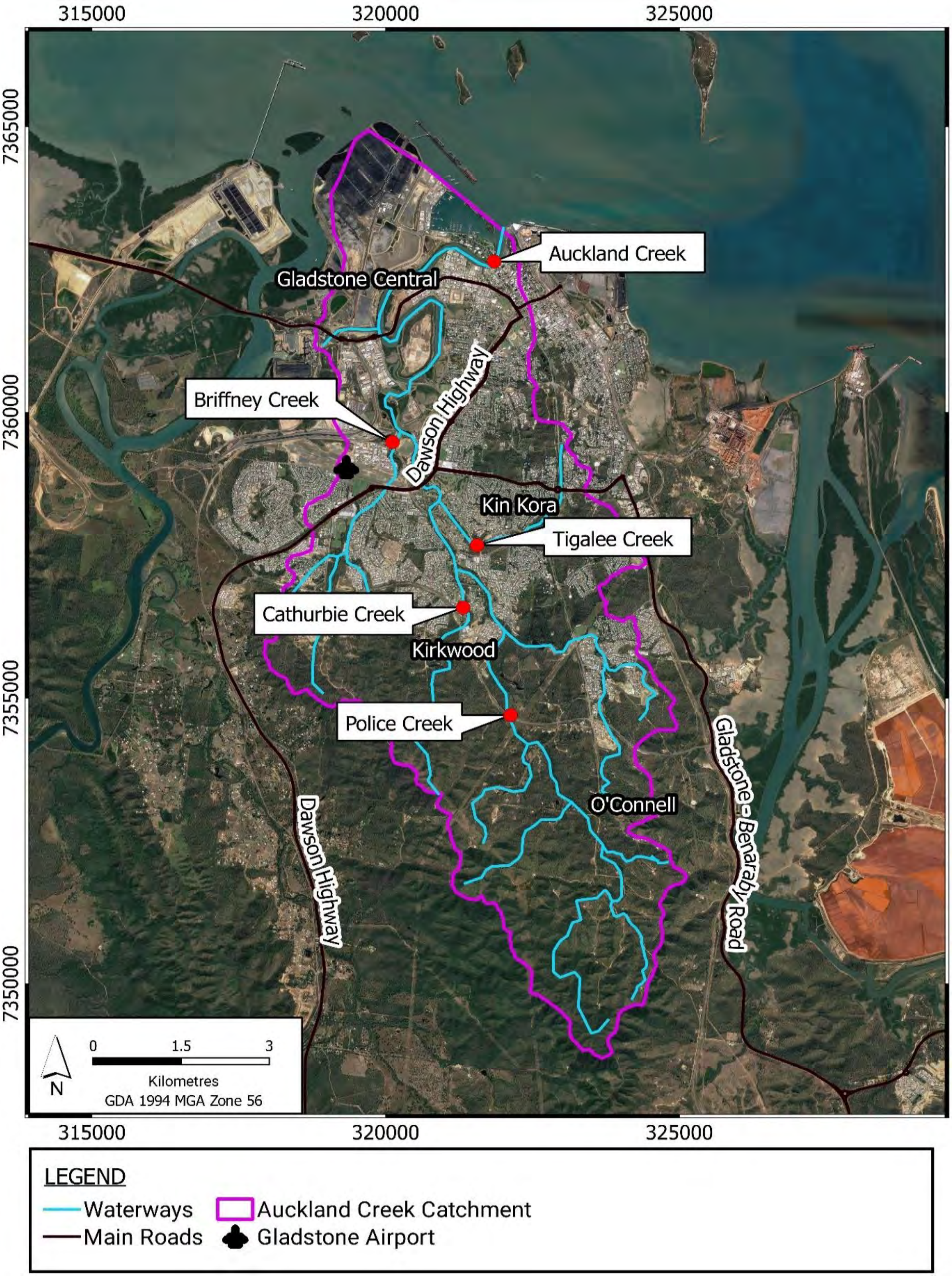


*Figure 1-1 Auckland Creek Study Area*

## 1.4 NEW AUSTRALIAN RAINFALL AND RUNOFF (ARR) PROBABILITY TERMINOLOGY

A change in the use of probability terminology has been adopted in the latest version of ARR 2016. In line with these changes, WMS has adopted the following changes in terminology:

- The terminology "Annual Exceedance Probability" (AEP) with results being presented as a percentage for all events of probability equal to or rarer than 39% AEP;
- For probabilities more frequent than the 39% AEP, results will be presented in terms of X Exceedances per Year (EY); and
- The terminology "Average Recurrence Interval" (ARI) will be phased out when it is no longer necessary to refer to it.

AEP is defined as the probability of an event occurring or being exceeded in any year. It is related to ARI by the following relationship:

$$\mathrm{AEP} = 1 - \exp\left(\frac{-1}{\mathrm{ARI}}\right)$$

Design rainfall intensities calculated in accordance with ARR 2016 are produced on AEP intervals and are a key input to the hydrological analysis in this study.

# 2 AVAILABLE DATA

The following available data was utilised to inform the flood model build, reporting, advice and recommendations.

## 2.1 DATA COLLECTION

A number of sources were utilised for data collection which included:

- Bureau of Meteorology (BOM) rainfall gauge records located in the Auckland Creek catchment;
- Peak water level records for the calibration events;
- Historical tidal levels at the Auckland Point tidal gauging station;
- Site inspection photos and sketches;
- Locations and details of culvert and bridge crossings along Auckland Creek;
- 2015 LiDAR survey data covering the area of the Auckland Creek catchment;
- 2014 LiDAR survey data covering approximately a fifth of the catchment in the most upstream area
- Gladstone aerial imagery from 2017;
- Updated bathymetric survey from the mouth of Auckland Creek to the Dawson Highway crossing; and
- XP-RAFTS and TUFLOW models from the previous study.

The primary topographic data used for this study was a 1 m DEM based on the 2015 LiDAR survey and the updated bathymetric survey of the Auckland Creek mouth and Lake Callemondah.

### 2.1.1 Relevant Previous Studies

Gladstone Regional Council provided the *Auckland Creek Flood Study - Volume 1: Final Report* (Engeny, November 2015) as well as hydrologic and hydraulic modelling files and results as part of the background to this study. The Engeny report was based on an update of the *Auckland Creek Flood Study* carried out by GHD in 2006. The GHD study was also provided but only the Engeny study has been reviewed and used as a basis for the present study. Commentary will be included in relation to the findings of the preliminary investigation and review of the Engeny study. The Engeny study was also used as a source of data for hydraulic structures, roughness and peak design flow comparisons.

The GHD report notes a number of earlier drainage studies that have been carried out of the various tributaries of Auckland Creek and an earlier hydraulic study of Auckland Creek by Pak-Poy & Kneebone Pty Ltd in 1986. These earlier reports are not available for the present study.

### 2.1.2 River Height Stations

Data from one river height station owned by Gladstone Regional Council and located immediately upstream of the Dawson Highway crossing on Police Creek was made available, see Table 2-1. The gauge was installed in 2016 as a recommendation of the Engeny flood study. The water level record at the gauging station can be used in aiding the calibration of the March 2017 storm events.

*Table 2-1 Water Level Gauge*

| Crossing | Gauge Name | Gauge Number | Latitude | Longitude |
|---|---|---|---|---|
| Dawson HWY | Police Ck at Dawson Highway | 539228 | 23°52'26" S | 151°14'19" E |

### 2.1.3 Aerial Imagery

WMS utilised the Queensland Globe Imagery from Geoscience Australia for 2017 aerial imagery of the Gladstone area.

### 2.1.4 Rainfall Data

Rainfall data was sourced from BOM for the stations listed in Table 2-2. The design rainfall data referred to in Section 4 was sourced from the BOM website.

*Table 2-2 Rainfall Gauge Information*

| Gauge Name | Gauge Number | Latitude | Longitude |
|---|---|---|---|
| Gladstone Radar | 039123 | 23°51'19" S | 151°15'47" E |
| Gladstone Airport | 039326 | 23°52'11" S | 151°13'18" E |

### 2.1.5 Calibration Data

GRC provided a set of locations of recorded flood heights for the two calibration events of March 23 and March 30, 2017. The data for the March 23 event was a series of observed levels without any timings and the data for the March 30 event consisted of a series of observed levels and the time at which the observation was made. It has been communicated to WMS by GRC that these observations are not necessarily observations of maximum flood levels.

### 2.1.6 Tide Gauge

Tide gauge levels from the Auckland Point tidal gauge were supplied from Maritime Safety Queensland (MSQ). Tide levels were offset by 2.268 m from mAHD and were adjusted. Tide levels during the March 2017 events were used to define the downstream boundary condition in the hydraulic model for these historical storm events.

### 2.1.7 Structure Survey

The hydraulic structures in the existing TUFLOW model were used as the basis for this study. Additional structures were identified for inclusion in the updated hydraulics model. WMS commissioned Capricorn Survey Group to provide the details of these missing structures. The identity and information of the structures have been incorporated into the updated hydraulics model are summarised in Table 2-3. Where the road level surface data varies, survey points were supplied in a dwg file.

In addition to identifying missing structures, Capricorn Survey Group also undertook survey of the stormwater pit and pipe network in the lower Auckland Creek catchment. The stormwater pipes structure information has been tabulated in Appendix A. Due to the number of stormwater pits surveyed, pit size details have not been listed. Surveyed stormwater network details in dwg format are however part of the electronic data handover for the project. Drawings of the surveyed stormwater pit and pipe network are also provided in Appendix A.

*Table 2-3 Data for Structures Added to Upgraded Model*

| Name | Number of and Dimensions (m) | US Invert (mAHD) | DS Invert (mAHD) | Soffit RL (mAHD) | Road Surface Level (mAHD) | Deck Thickness (m) |
|---|---|---|---|---|---|---|
| Little Creek Culvert | 3/0.7 RCP | 23.66 | 23.65 | NA | NA | NA |
| Allunga Dr Ped Crossing | 1/4.95 x 2.2 | NA | NA | 34.35 | 34.54 | 0.19 |
| Glen Lyon Rd Ped Bridge | 1/11.5x2.5 | NA | NA | 27.2 | 27.52 | 0.33 |
| Kirkwood Dr / Skyline Dr Arch | NA | NA | NA | | Varies | 1.42 |
| Powell Close Ped Crossing | 1/10.1x2.235 | | | 9.77 | 9.99 | 0.22 |
| Powell Close Rd Long Grated Pit | 1/79.35x1.80 | 8.7 | 8.17 | NA | NA | NA |
| Penda Ave Spillway Ped Crossing | 1/5.1x1.72 | NA | NA | 17.55 | 17.75 | 0.2 |
| Boardwalk through Callemondah Lake Mangrove Area | 1/0.8x0.25 | NA | NA | 3.45 | 3.7 | 0.25 |

| Name | Number of and Dimensions (m) | US Invert (mAHD) | DS Invert (mAHD) | Soffit RL (mAHD) | Road Surface Level (mAHD) | Deck Thickness (m) |
|---|---|---|---|---|---|---|
| Blain Dr Channel and Culvert Crossing adjacent Hungry Jacks | 2/1.6 RCP | 4.735 | 4.635 | NA | NA | NA |
| Breslin St Ped Crossing | 1/7.3x1.5 | NA | NA | 8.42 | 8.88 | 0.425 |
| O'Malley St Palm Dr Ped Crossing | 1/22.0x2.0 | NA | NA | Varies | Varies | Varies |
| Glenlyon St NCL Bridge | 1/36.45x7.7 | NA | NA | 7.75 | Varies | 0.64 |
| Bryan Jordan Dr Bridge | 1/142.7x10.8 | NA | NA | Varies | Varies | Varies |
| Glenyon Rd Short Railway Ped Crossing and Car Bridge | Varies | NA | NA | Varies | Varies | Varies |

#### 2.1.8 Topography

According to the Engeny report, the 1 m DEM is based on the most recent LiDAR survey captured in 2015 by AAM Group. The report notes the LiDAR does not come with any metadata but based on communication with Council personnel at the time the data accuracy was similar to previous LiDAR surveys which had a vertical accuracy of 0.15 m at a 67% confidence level. The DEM based on this LiDAR survey has been provided in Map Grid of Australia (MGA94) Zone 56 projection. The elevations are based on the Datum of Australia (1994) (mAHD).

The present study has also expanded the extent of the hydraulic model in the upstream area of the catchment so that the entire catchment area is included in the extent of the hydraulic model. The 2015 LiDAR did not extend to cover approximately one fifth of the catchment area in the most upstream portion of the catchment. The Engeny model applied a total area inflow from the hydrological model at most upstream location possible to represent the flow derived from the most upstream portion of the catchment. WMS has sourced 2014 LiDAR data from GeoScience Australia covering this area of the catchment that was not previously modelled explicitly in the hydraulic model.

As part of this study WMS has also undertaken a bathymetric survey of Auckland Ck which has been stamped onto the base DEM.

#### 2.1.9 XP-RAFTS

The XP-RAFTS model that was used in the Engeny study was supplied by GRC. The model was reviewed as part of this study. It was found that a sub-catchment that was further subdivided in the hydraulic model was not present in the hydrological model. This sub-catchment was added to the XP RAFTS model as the subdivision made good modelling sense given the catchment is traversed by a road and the new sub-catchment provides a flow source upstream of the road crossing.

# 3 HISTORICAL HYDROLOGIC DATA ANALYSIS

An analysis of available water level records indicated the 2017 events were the highest on record (within the data provided).

## 3.1 WATER LEVEL DATA

The Auckland Creek's downstream boundary is tidal and historical tide level information from the Auckland Point gauge was provided for the period of the calibration events and is displayed in Figure 3-1. Historical water level data from the Police Creek gauge was received by BOM and checked for quality. The details of tshe gauges are summarised in Table 3-1.

*Table 3-1 Water Level Gauge Details*

| Gauge Number | Gauge Name | Latitude | Longitude | Gauge Zero | Recording Timeframe |
|---|---|---|---|---|---|
| 539228 | Police Creek | 23°52'26" S | 151°14'19" E | 0 mAHD | 1 January 2017 to present |
| 052027A | Auckland Point Tidal Gauge | 23°50'" S | 151°15" E | -2.268 mAHD | 1 January 1996 to present |

The Police Creek gauge is located immediately upstream side of Dawson Highway crossing. This is approximately 1100 m upstream of the confluence of Brittany and Police Creek which is the beginning of Auckland Creek and as such is highly relevant for this assessment. This gauge was installed in 2016 following a recommendation from the previous Engeny flood study. Unfortunately, the gauge does not have a rating curve to enable conversion from level to flow. The Police Creek water level gauge data supplied was between January 1, 2017 to present (see Figure 3-2).

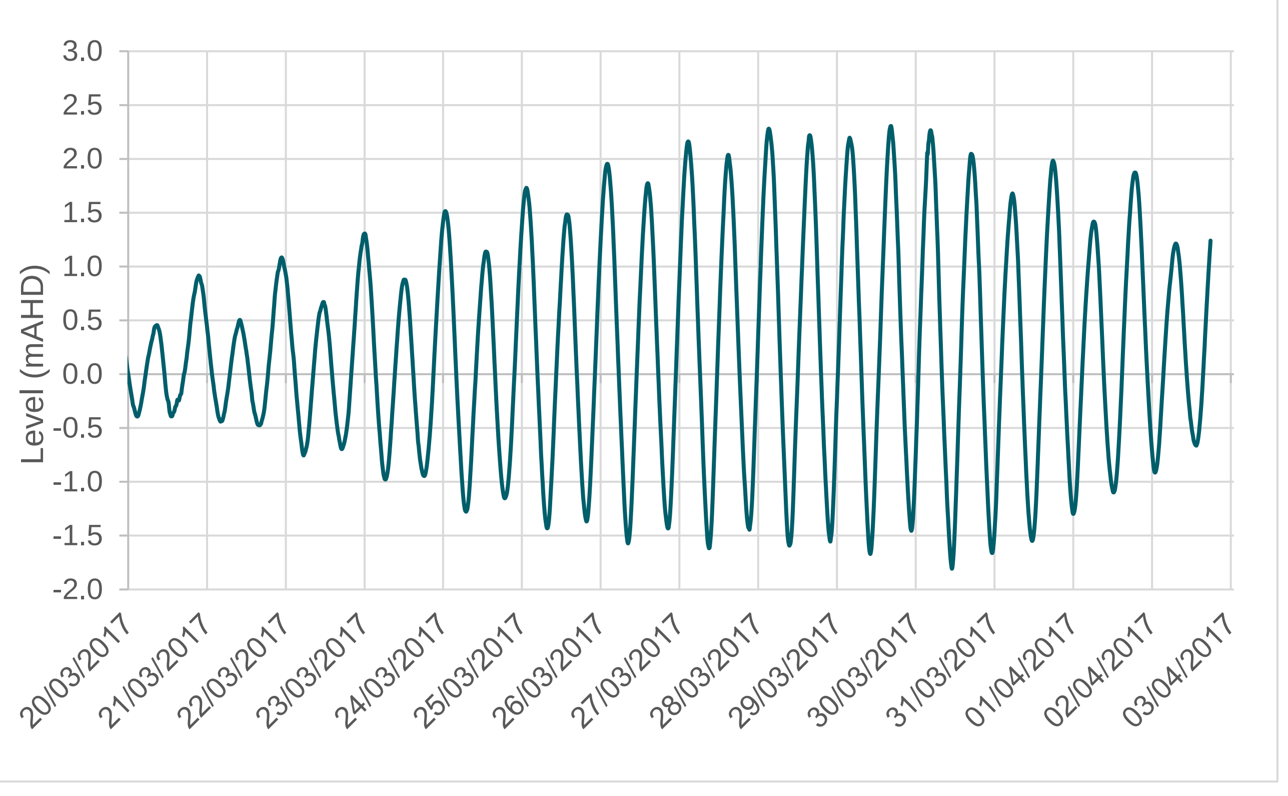


*Figure 3-1 Auckland Point Tide Gauge Recording for Period of Calibration Storms*

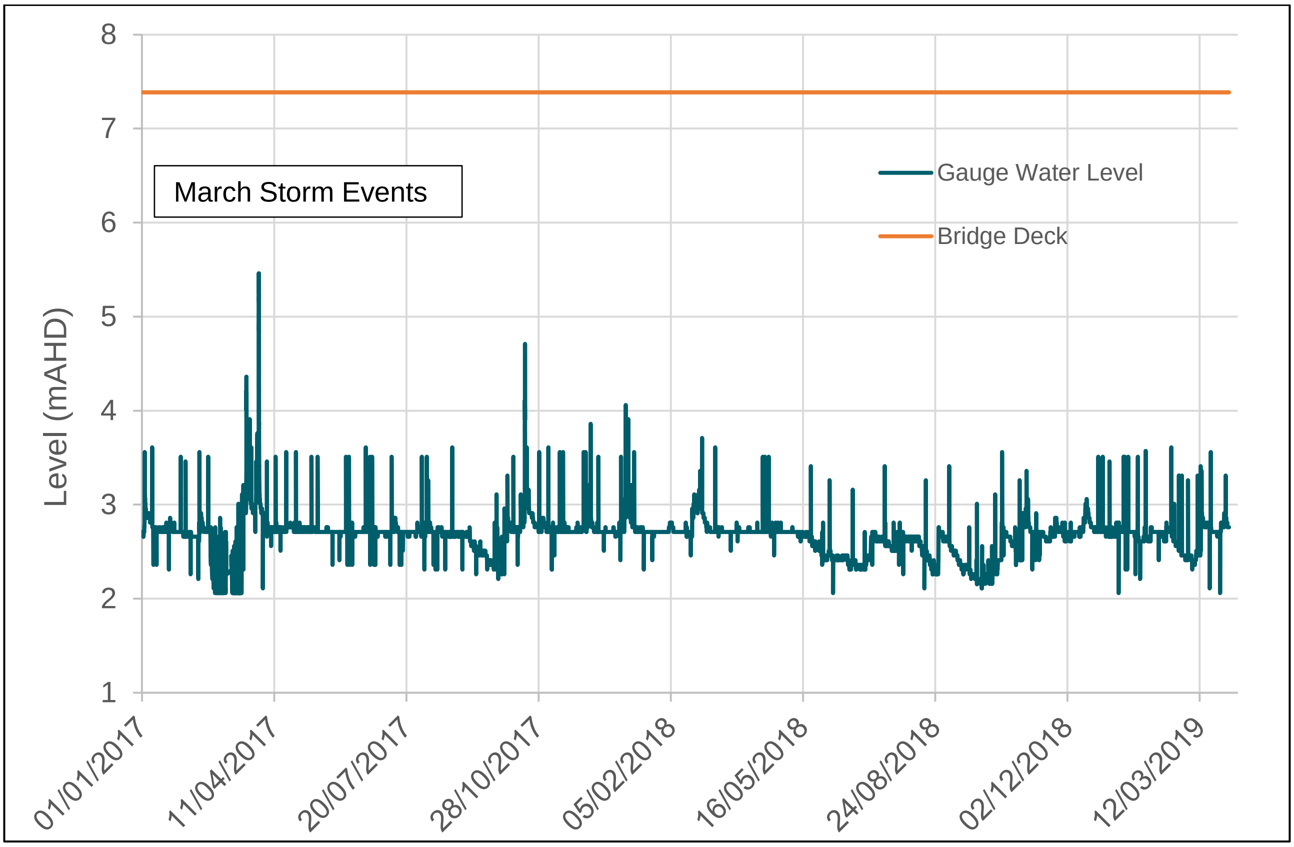


*Figure 3-2 Police Creek Gauge Recorded Water Level for the Entire Gauge Record*

The peak recorded gauge levels for the two calibration events in March 2017 are shown below in Table 3-2 with the recorded hydrographs for each of the events shown in Figure 3-3 and Figure 3-4 respectively.

For the March 23, 2017 flood event, a maximum gauge height of 3.91 mAHD was recorded and for the March 30, 2017 flood event a maximum gauge height of 5.46 mAHD was recorded. Both of these levels are below the bridge deck level of 7.386 mAHD of the Dawson Highway crossing. The March 30, 2017 peak recording of 5.46 mAHD is the highest recorded level at the gauge. There were two other recordings that exceeded the level of the March 23, 2017 water level. Two days prior on March 21, 2017 the gauge reached a level of 4.36 mAHD and on October 17, 2017 the gauge recorded 4.71 mAHD. However, given calibration data was only provided for the March 23 and March 30, 2017 flood events, these two events were chosen for further analysis.

*Table 3-2 Historical Flood Event Detail*

| Flood Event | Event Duration (hours) | Peak Flood Level (mAHD) |
|---|---|---|
| March 23, 2017 | 11 | 3.91 |
| March 30, 2017 | 13 | 5.46 |

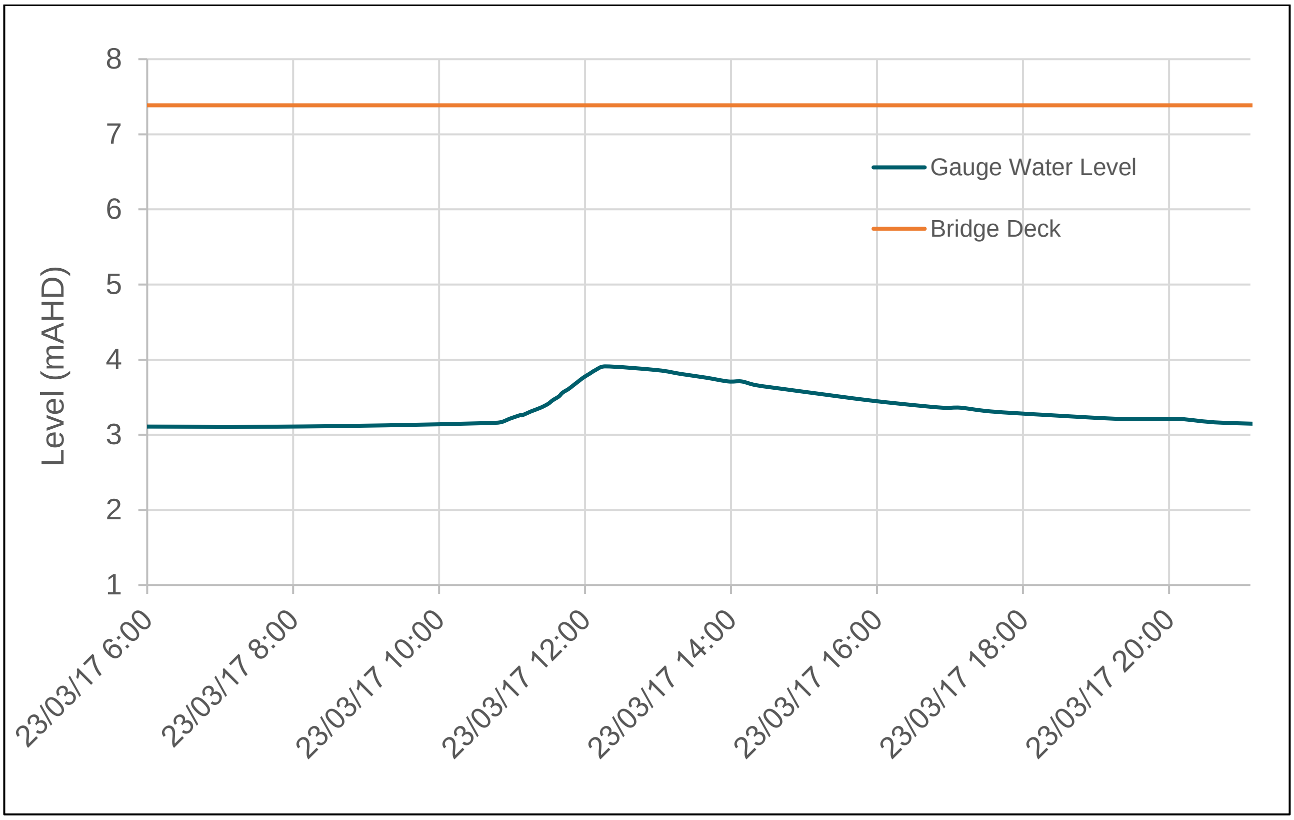


*Figure 3-3 Police Creek Gauge Recorded Water Level - March 23, 2017 Event*

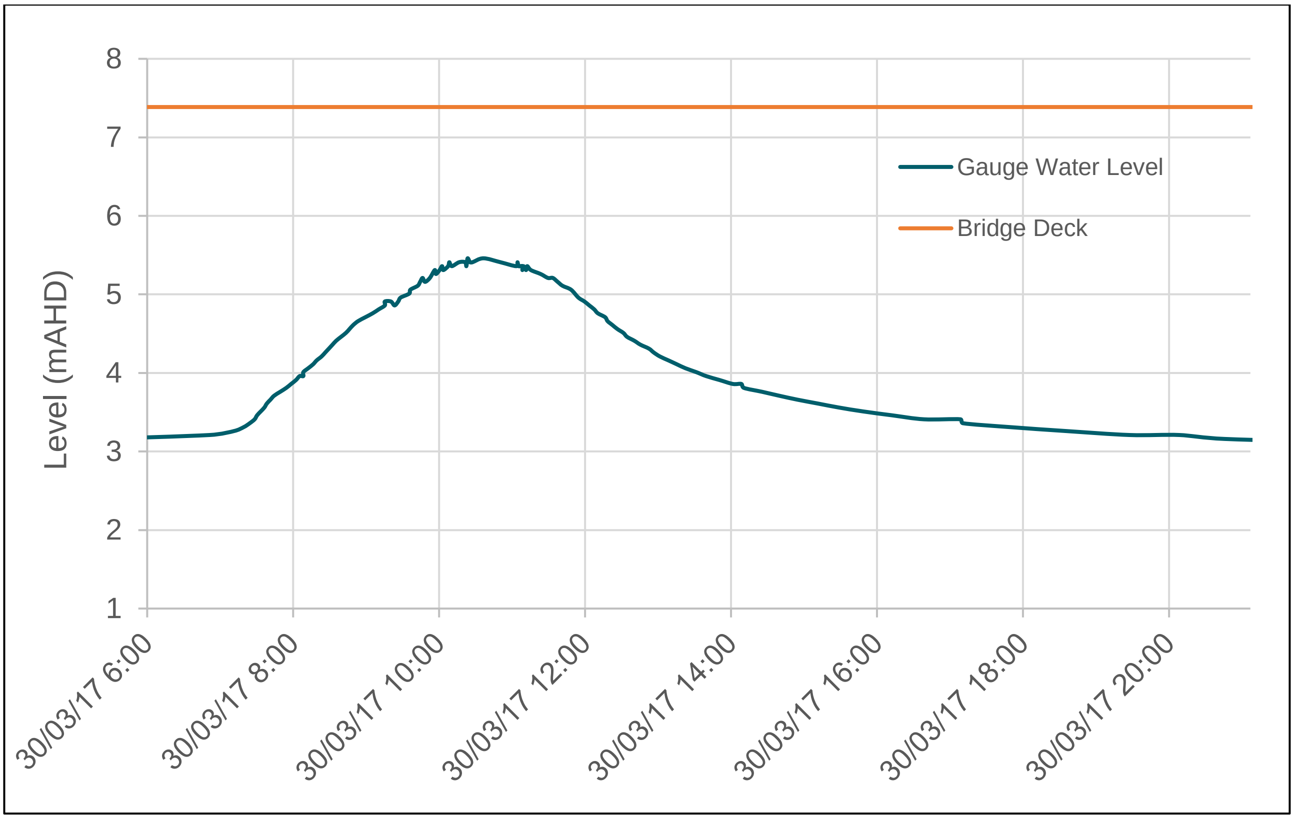


*Figure 3-4 Police Creek Gauge Recorded Water Level - March 30, 2017 Event*

### 3.1.1 Recorded Water Level Points

Council provided a number of observed water level elevation points for both the March 23 and March 30 event located throughout the middle and upstream areas of the catchment. The March 23 data consists of seven observations of water elevations but without any detail as to the time the observations were made. The March 20 data consists of thirteen observation points along with a time recording. There is some degree of uncertainty as to whether these observations record the highest level the water reached at these locations.

## 3.2 RAINFALL DATA

Historical rainfall data recorded at two gauges was received from BoM and checked for quality. The Gladstone Radar and Gladstone Airport were the only rainfall gauges near the catchment. The recording periods of the gauges that were received are detailed in Table 3-3. The rainfall recorded by these gauges includes the two storm events in March 2017.

*Table 3-3 Rain Gauge Records*

| Gauge Number | Gauge Name | Latitude | Longitude | Recording Timeframe |
|---|---|---|---|---|
| 039123 | Gladstone Radar | 23°51'19" S | 151°15'47" E | 17 December 2003 to 25 March 2019 |
| 039326 | Gladstone Airport | 23°52'11" S | 151°13'18" E | 17 December 2003 to 25 March 2019 |

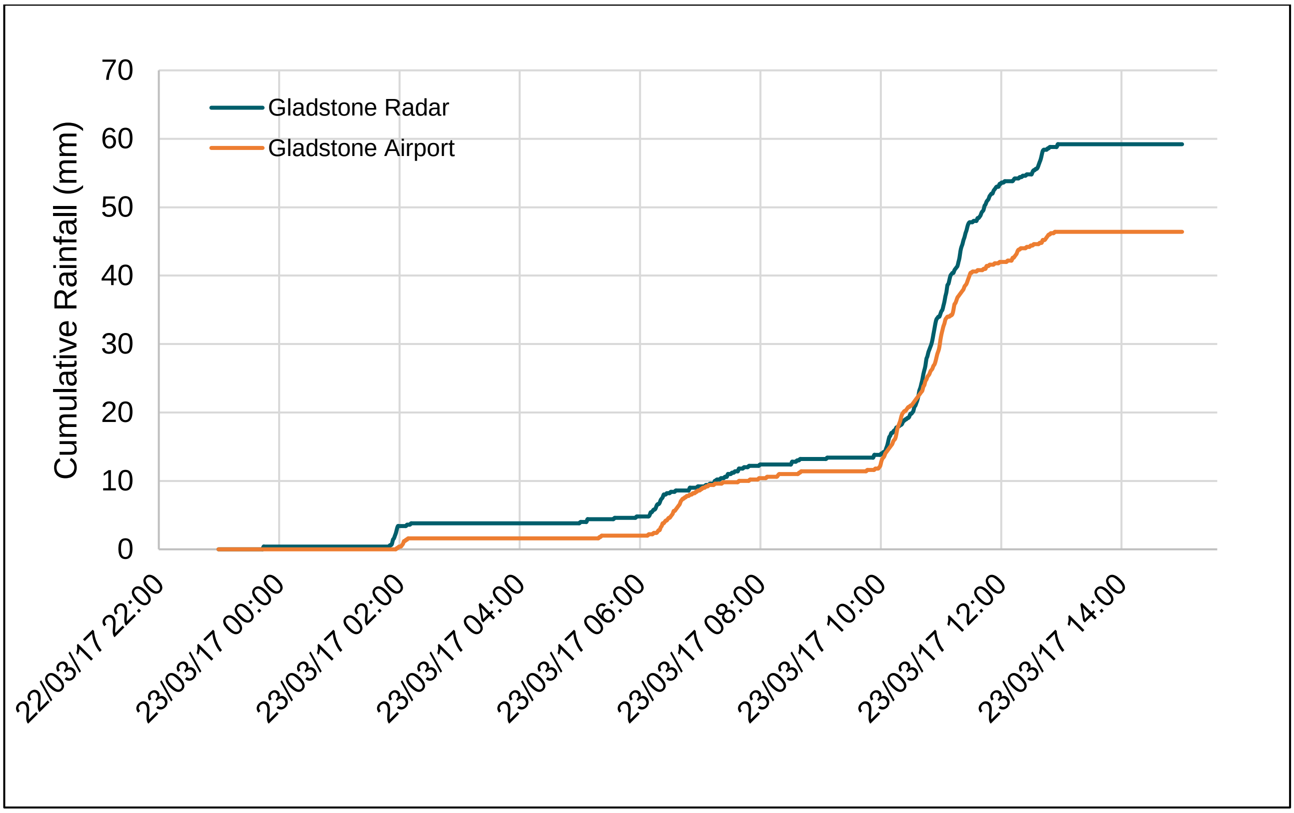


*Figure 3-5 Recorded Rainfall - March 23, 2017 Storm Event*

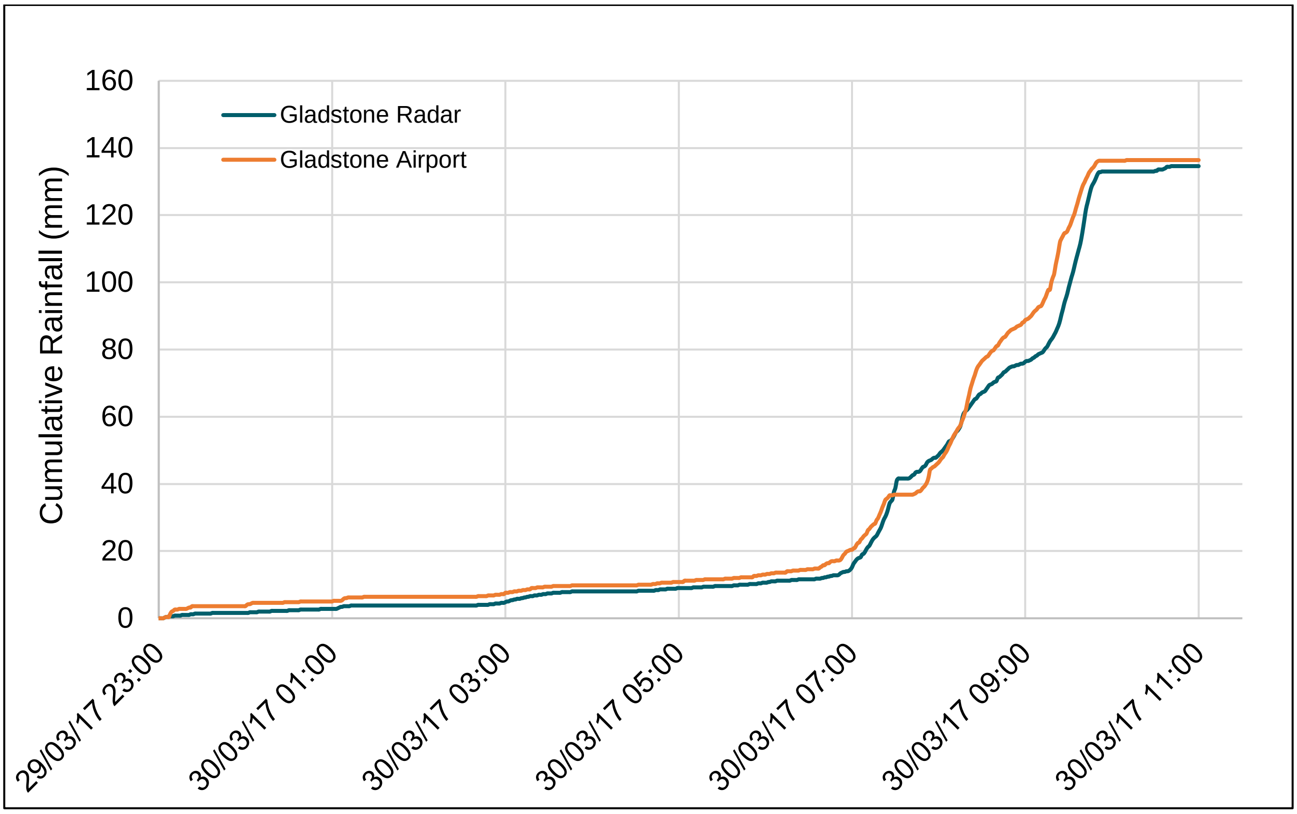


*Figure 3-6 Recorded Rainfall - March 30, 2017 Storm Event*

The gauge rainfall data was analysed to assess the approximate annual exceedance probability (AEP) of the historical March storm events. The process required summing the data points for selected durations (30 minute through to 72 hours (4320 minutes)) across both events. A comparison between the historic rainfall events and IFD curves for Gladstone Radar and Gladstone Airport for the two March 2017 events was undertaken to identify the magnitude of the historic rainfall event across a number of durations. The calculated rainfall AEPs for selected durations for each of the gauges and events are listed in Table 3-4. The range of durations for each event and gauge is shown in Figure 3-7 and Figure 3-9 for Gladstone Radar and Figure 3-8 and Figure 3-10 for Gladstone Airport.

For all durations the March 23, 2017 storm event was less than a 63.2% AEP. The AEP of the March 30, 2017 storm event ranged from 50% to 10% for durations of one hour or less to intensities ranging between 5% to 2% AEP for durations of approximately 3 hours.

*Table 3-4 Rainfall AEP Translation for Historical Events*

| Gauge | Event | < 30 min | 30 min | 1 hour | 3 hours | 6 hours | 12 hours |
|---|---|---|---|---|---|---|---|
| Gladstone Radar | March 23 2017 | Less than 63% AEP | Less than 63% AEP | Less than 63% AEP | Less than 63% AEP | Less than 63% AEP | Less than 63% AEP |
| | March 30 2017 | Between 20% and 50% AEP | Between 20% and 10% AEP | Between 20% and 10% AEP | Between 5% and 2% AEP | Between 20 and 5% AEP | Between 50% and 63% AEP |
| Gladstone Airport | March 23 2017 | Less than 63% AEP | Less than 63% AEP | Less than 63% AEP | Less than 63% AEP | Less than 63% AEP | Less than 63% AEP |
| | March 30 2017 | Between 20% and 50% AEP | Between 20% and 10% AEP | Between 20% and 10% AEP | Between 5% and 2% AEP | Between 20% and 5% AEP | Between 50% and 63% AEP |

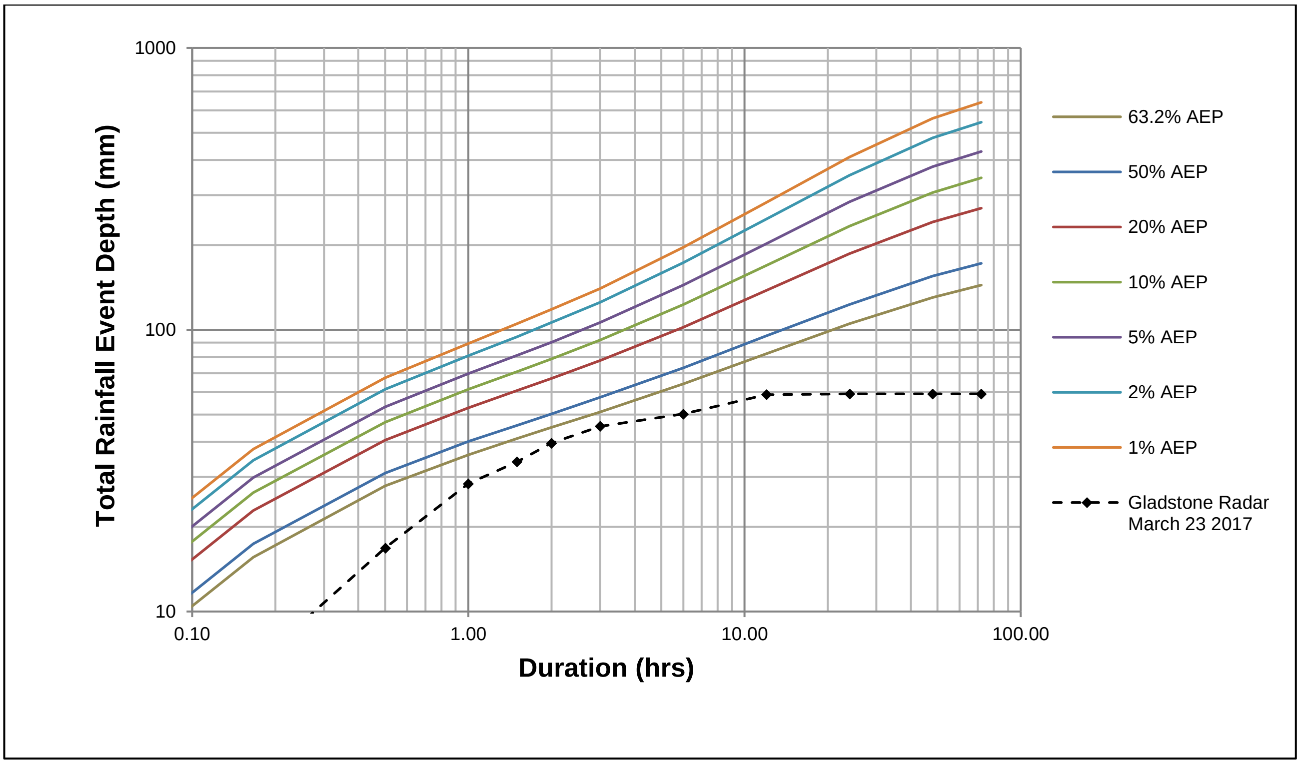


*Figure 3-7 Rainfall AEP Comparison for Gladstone Radar - March 23, 2017 Storm Event*

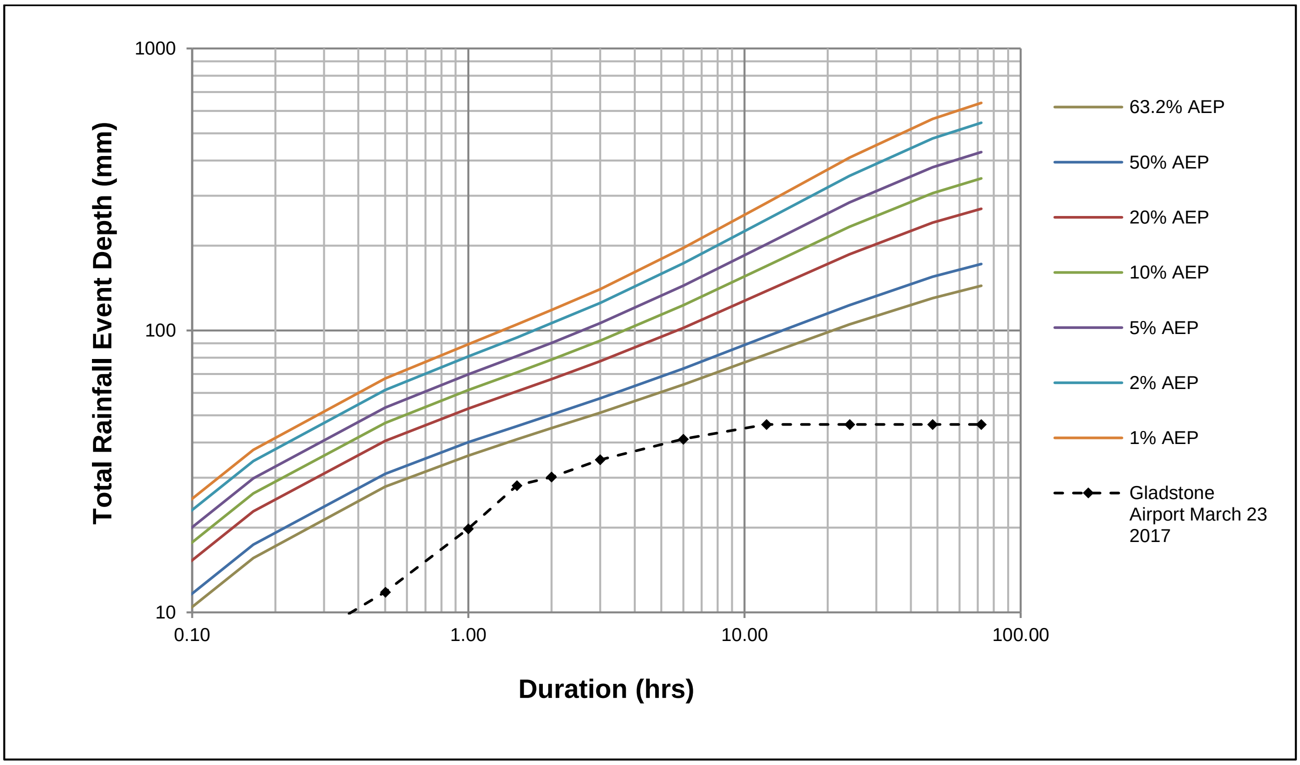


*Figure 3-8 Rainfall AEP Comparison for Gladstone Airport - March 23, 2017 Storm Event*

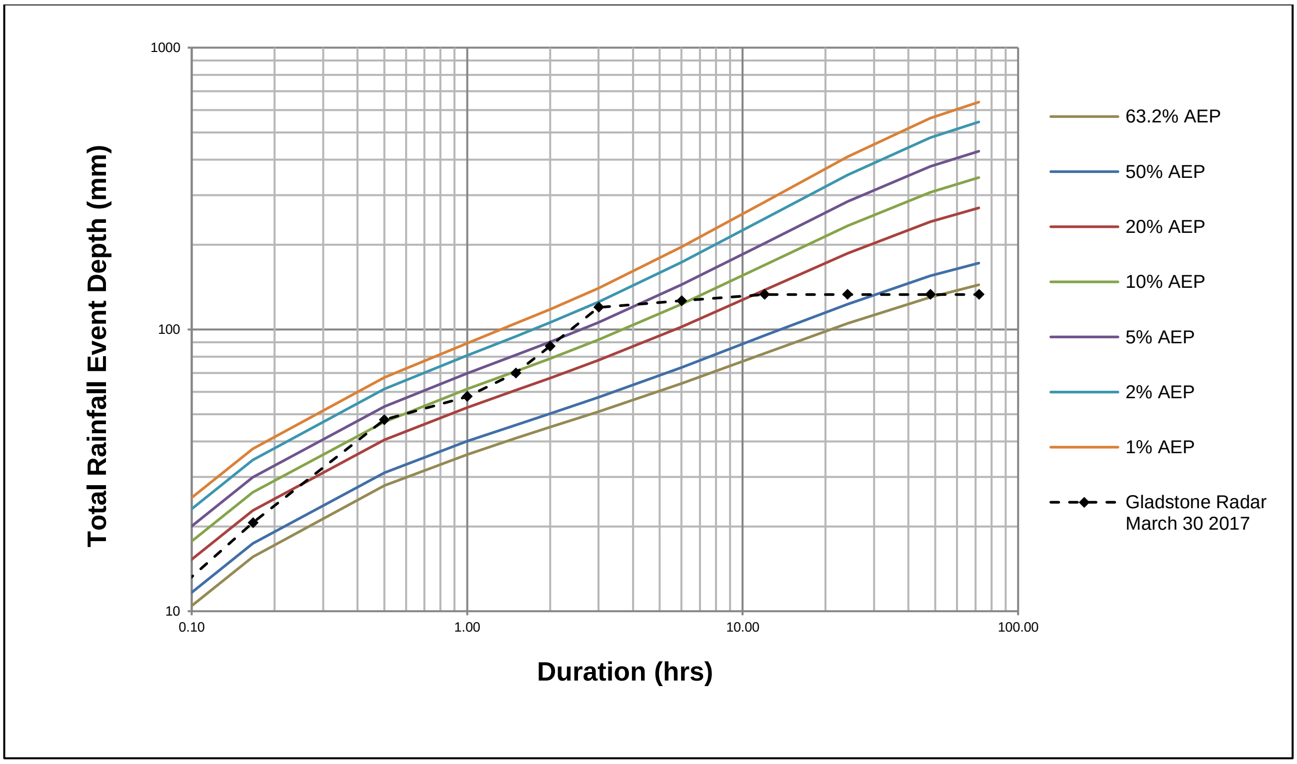


*Figure 3-9 Rainfall AEP Comparison for Gladstone Radar - March 30, 2017 Storm Event*

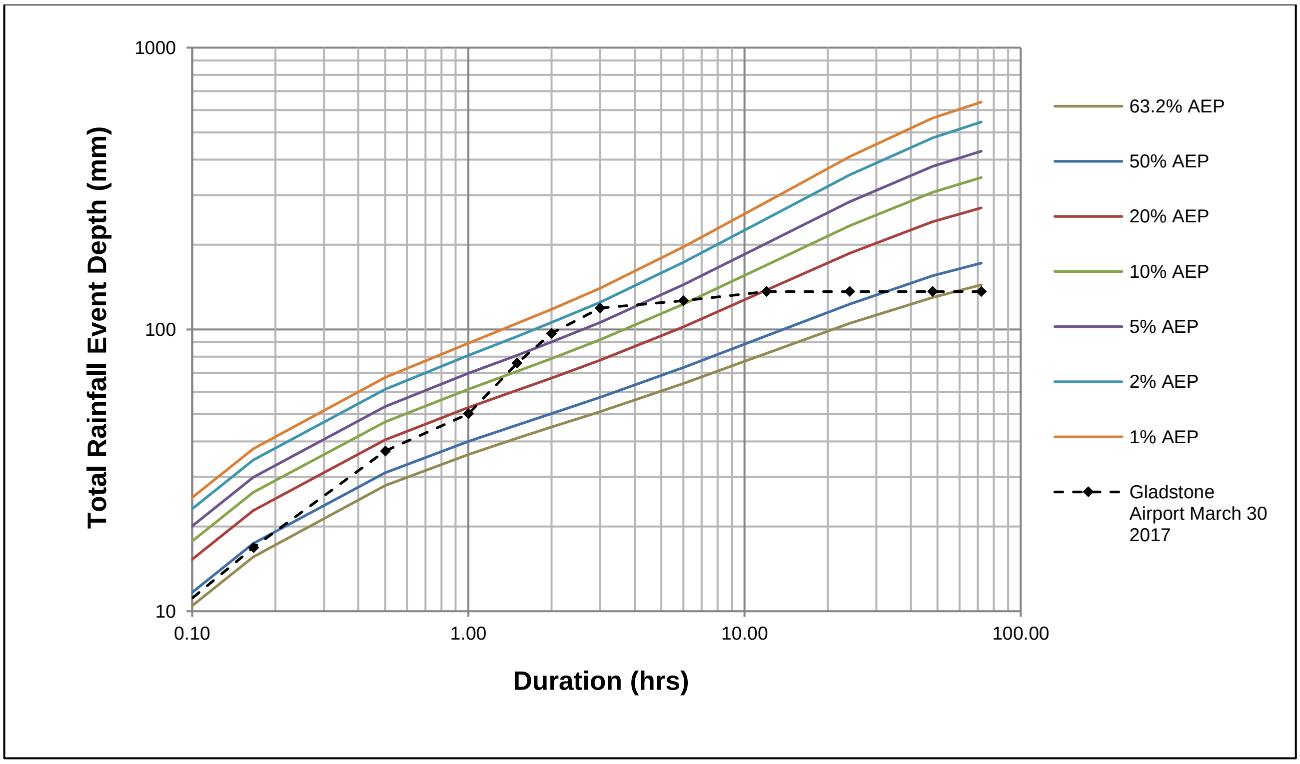


*Figure 3-10 Rainfall AEP Comparison for Gladstone Airport - March 30, 2017 Storm Event*

# 4 HYDROLOGICAL MODELING

The hydrological model was based upon the XP-RAFTS model from the Engeny study. The hydrological model was updated to ARR 2016 for all design events. The model was the basis for determining the flows for the two March 2017 calibration events. The following sections detail the hydrologic modelling undertaken and discusses the results.

## 4.1 CATCHMENT DELINEATION

According to the Engeny report, catchment delineation was undertaken using CatchmentSIM. The DEM used for the delineation was based on a 1 m resolution Digital Elevation Model (DEM) from the 2009/2010 LiDAR survey resampled to a 5 m grid size. The size of the Auckland Creek catchment based on this analysis was found to be 56 $km^2$. The original CatchmentSIM model was not provided as part of this study.

The delineated catchment was exported into XP-RAFTS provided as the basis for this study. The modelling parameters determined in the Engeny CatchmentSIM model such as lag times and percentage impervious areas in each sub-catchment have been preserved.

The only change to the provided XP-RAFTS model is the addition of sub-catchment AC76, which was present in the Engeny TUFLOW model, but not in the XP-RAFTS hydrological model. The AC76 sub-catchment is a portion of the AC65 sub-catchment located upstream of Kirkwood Rd. Kirkwood Rd has a couple of culverts at this point and therefore it is appropriate to have an inflow point upstream of the road crossing at this location. XP-RAFTS sub-catchment details are listed in Table 4-1.

*Table 4-1 XP-RAFTS Sub-catchment Details*

| Sub-catchment ID | Pervious Area (ha) | Impervious Area (ha) | Slope (%) | Lag Time (mins) |
|---|---|---|---|---|
| AC1 | 16.67 | 133.82 | 0.24 | NA |
| AC2 | 25.98 | 36.00 | 0.88 | 28 |
| AC3 | 34.60 | 38.2 | 0.52 | 22 |
| AC4 | 25.95 | 81.3 | 0.47 | 48 |
| AC5 | 122.12 | 80.47 | 0.10 | 46 |
| AC6 | 16.56 | 14.98 | 0.60 | 47 |
| AC7 | 63.83 | 22.30 | 0.33 | 52 |
| AC8 | 54.21 | 62.53 | 1.50 | 13 |
| AC9 | 21.84 | 32.00 | 0.50 | 16 |
| AC10 | 15.91 | 38.51 | 1.71 | 15 |
| AC11 | 20.03 | 11.11 | 0.10 | 14 |
| AC12 | 15.27 | 16.53 | 0.57 | 22 |
| AC13 | 38.70 | 44.56 | 0.31 | 6 |
| AC14 | 16.53 | 65.27 | 0.51 | 7 |
| AC15 | 10.03 | 21.80 | 2.28 | 21 |
| AC16 | 30.46 | 17.72 | 0.41 | 15 |
| AC17 | 11.18 | 19.99 | 0.63 | 17 |
| AC18 | 5.43 | 12.45 | 1.63 | 14 |
| AC19 | 18.91 | 28.91 | 2.00 | 5 |
| AC20 | 23.56 | 29.66 | 1.38 | 12 |

| Sub-catchment ID | Pervious Area (ha) | Impervious Area (ha) | Slope (%) | Lag Time (mins) |
|---|---|---|---|---|
| AC21 | 8.76 | 11.63 | 1.93 | 12 |
| AC22 | 4.01 | 12.94 | 2.48 | 11 |
| AC23 | 21.33 | 34.13 | 1.61 | 14 |
| AC24 | 16.16 | 20.21 | 1.39 | 16 |
| AC25 | 6.02 | 48.98 | 0.28 | 10 |
| AC26 | 29.95 | 38.71 | 1.73 | 14 |
| AC27 | 21.52 | 30.92 | 1.52 | 5 |
| AC28 | 25.58 | 32.62 | 0.79 | 19 |
| AC29 | 21.99 | 29.92 | 1.42 | 17 |
| AC30 | 24.03 | 33.78 | 1.86 | 2 |
| AC31 | 11.38 | 19.05 | 2.53 | 6 |
| AC32 | 11.74 | 23.56 | 1.87 | 4 |
| AC33 | 12.68 | 12.66 | 1.00 | 8 |
| AC34 | 26.94 | 16.40 | 0.82 | 8 |
| AC35 | 22.59 | 10.17 | 2.84 | 17 |
| AC36 | 44.44 | 5.26 | 0.6 | 16 |
| AC37 | 15.05 | 25.69 | 1.45 | 15 |
| AC38 | 18.40 | 25.33 | 1.47 | 17 |
| AC39 | 111.37 | 27.02 | 1.48 | 9 |
| AC40 | 62.27 | 15.36 | 1.41 | 10 |
| AC41 | 32.72 | 13.00 | 1.84 | 10 |
| AC42 | 28.77 | 8.96 | 2.00 | 23 |
| AC43 | 47.23 | 60.71 | 1.16 | 16 |
| AC44 | 61.76 | 12.61 | 1.14 | 10 |
| AC45 | 37.44 | 2.93 | 3.00 | 12 |
| AC46 | 29.98 | 2.09 | 0.90 | 11 |
| AC46 | 48.54 | 23.51 | 1.70 | 12 |
| AC47 | 61.81 | 16.32 | 0.96 | 24 |
| AC48 | 47.69 | 33.74 | 1.21 | 23 |
| AC49 | 112.9 | 13.68 | 1.52 | 24 |
| AC50 | 105.99 | 10.29 | 1.06 | 16 |
| AC51 | 162.66 | 21.27 | 1.65 | 20 |
| AC52 | 21.33 | 43.05 | 0.57 | 18 |
| AC53 | 17.94 | 124.77 | 0.12 | 18 |
| AC54 | 103.13 | 6.29 | 2.66 | 11 |
| AC55 | 93.97 | 10.22 | 2.22 | 19 |

| Sub-catchment ID | Pervious Area (ha) | Impervious Area (ha) | Slope (%) | Lag Time (mins) |
|---|---|---|---|---|
| AC56 | 45.75 | 16.69 | 1.88 | 19 |
| AC57 | 154.15 | 8.12 | 2.49 | 21 |
| AC58 | 151.64 | 8.38 | 2.48 | 17 |
| AC59 | 176.67 | 30.16 | 2.58 | 25 |
| AC60 | 141.10 | 23.53 | 2.01 | 18 |
| AC61 | 193.35 | 10.49 | 2.41 | 26 |
| AC62 | 41.56 | 17.07 | 0.79 | 7 |
| AC63 | 86.45 | 19.22 | 1.27 | 11 |
| AC64 | 22.00 | 48.17 | 1.31 | 7 |
| AC65 | 29.41 | 7.07 | 5.15 | 12 |
| AC66 | 1.29 | 3.03 | 0.27 | 13 |
| AC67 | 18.18 | 8.23 | 3.08 | 11 |
| AC68 | 23.03 | 25.00 | 2.40 | 8 |
| AC69 | 9.50 | 16.3 | 2.82 | 14 |
| AC70 | 21.72 | 70.07 | 0.88 | 10 |
| AC71 | 104.23 | 32.31 | 1.55 | 22 |
| AC72 | 23.53 | 34.41 | 1.19 | 9 |
| AC73 | 13.97 | 17.20 | 0.22 | 5 |
| AC74 | 17.09 | 20.45 | 1.47 | 11 |
| AC75 | 28.50 | 1.50 | 1.31 | 6 |
| AC76 | 16.67 | 133.82 | 0.52 | 28 |

## 4.2 MODEL PARAMETERS

### 4.2.1 Roughness

Roughness values of 0.04 and 0.025 were adopted for pervious and impervious areas respectively and have remained unchanged from the Engeny XP-RAFTS model.

### 4.2.2 Ground Coverage

According to the Engeny report, the catchment areas were divided into pervious and impervious based on information of land use types inferred from cadastral data and aerial images. This data has not been changed in the XP-RAFTS model. The pervious and impervious areas for each sub-catchment are summarised in Table 4-1.

### 4.2.3 Channel Routing

The Engeny CatchmentSIM model used the average velocity method to estimate the stream lag between the sub-catchments. This estimation was based on an average velocity of 0.9 m/s. The lag times for each sub-catchment are summarised in Table 4-1.

### 4.2.4 Rainfall

To simulate the historic events the recorded rainfall data at the Gladstone Airport and Gladstone Radar gauges was applied to the sub-catchments as local XP-RAFTS storms. The distribution of the gauge data to the sub-catchment was based on the proximity of the sub-catchment to the rainfall gauge, see Figure 4-1. No factorisation of rainfall was applied.

The March 23, 2017 event was modelled from the 23rd March, 2017 at 00:00 through to 23rd March, 2017 at 13:00.

The March 30, 2017 event was modelled from the 30th March 2017 at 00:00 through to 30th March, 2017 at 11:00.

### 4.2.5 Historical Storm Event Losses

Initial and continuing losses in the hydrological model were adjusted as part of the calibration process for the two March 2017 storm events in order to achieve a good match in the water level at the Police Creek gauge. The initial and continuing losses for pervious and impervious areas for the two storm events are summarised in Table 4-2. A higher initial loss for the March 30 2017 event conforms well with the historical rainfall record. The March 23, 2017 event was preceded by a storm event two days earlier on March 21, 2017 which would contribute to wetter catchment conditions. There was no storm event between the March 23, 2017 and March 30, 2017 events providing the catchment with more time to dry out from the preceding storm event. Drier conditions at the beginning of the storm would contribute to a higher initial loss of rainfall.

*Table 4-2 Loss Values for Calibration Events*

| Storm Event | Pervious Areas | | Impervious Areas | |
|---|---|---|---|---|
| | Initial Loss (mm) | Continuing Loss (mm/h) | Initial Loss (mm) | Continuing Loss (mm/h) |
| March 23, 2017 | 30 | 3.5 | 1 | 0 |
| March 30, 2017 | 50 | 3.5 | 1 | 0 |

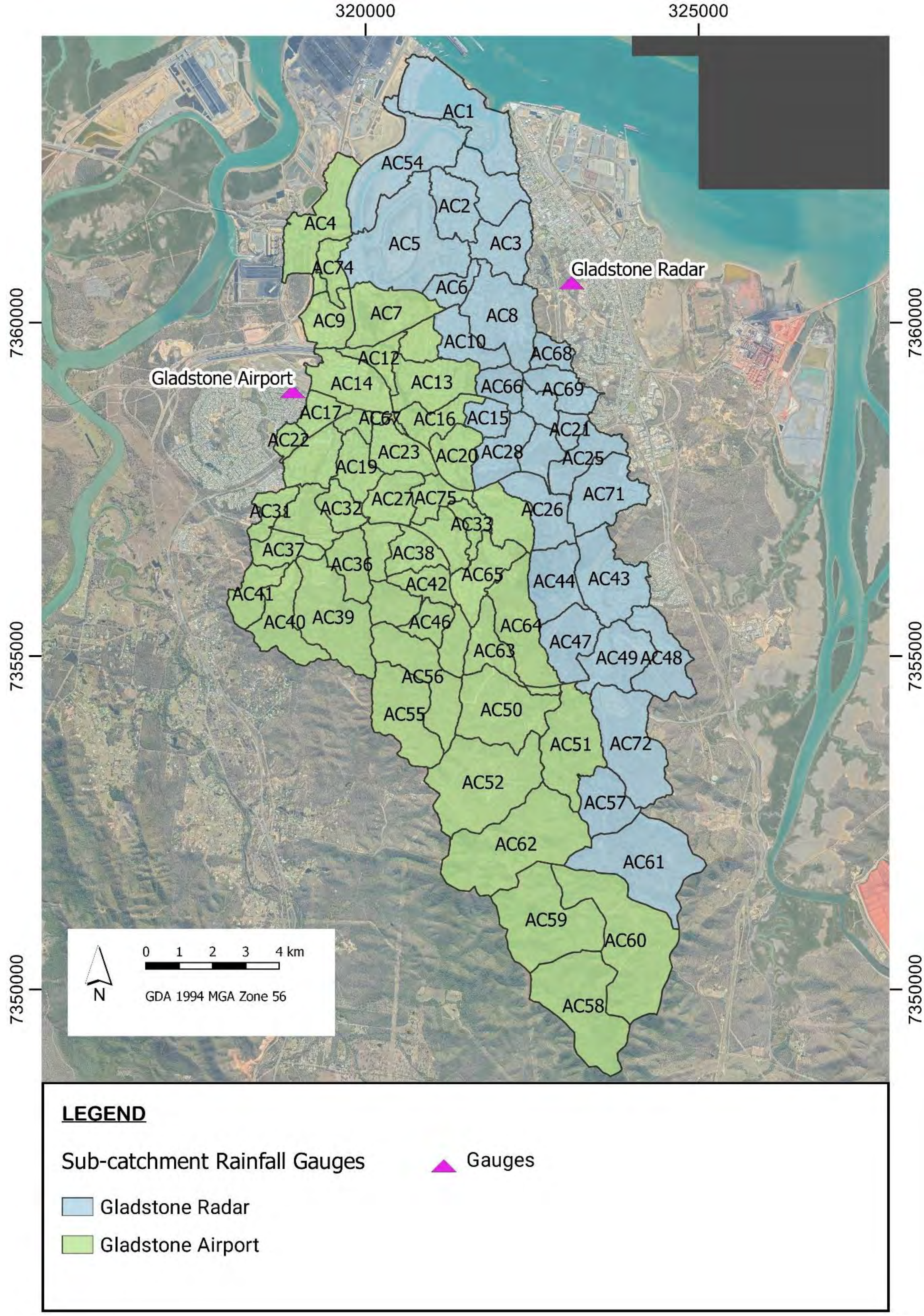


*Figure 4-1 Catchment Rainfall Distribution*

The derived peak flows from the XP-RAFTS model for both historical events are summarised in Table 4-3, with Figure 4-2 and Figure 4-3 providing a comparison of the hydrograph shapes and timing vs the water level at the Police Creek gauge for the 23rd of March and 30th of March events respectively. These plots are only to be used for comparisons as the Police Creek gauge does not have a discharge rating curve. Both XP-RAFTS hydrographs generally show a very similar shape to that of the record gauge water levels.

*Table 4-3 XP-RAFTS Peak Flows for Historical Events*

| Event | Auckland Creek Outlet ($m^3/s$) | Police Creek Gauging Station ($m^3/s$) |
|---|---|---|
| March 23, 2017 | 122 | 90 |
| March 30, 2017 | 310 | 253 |

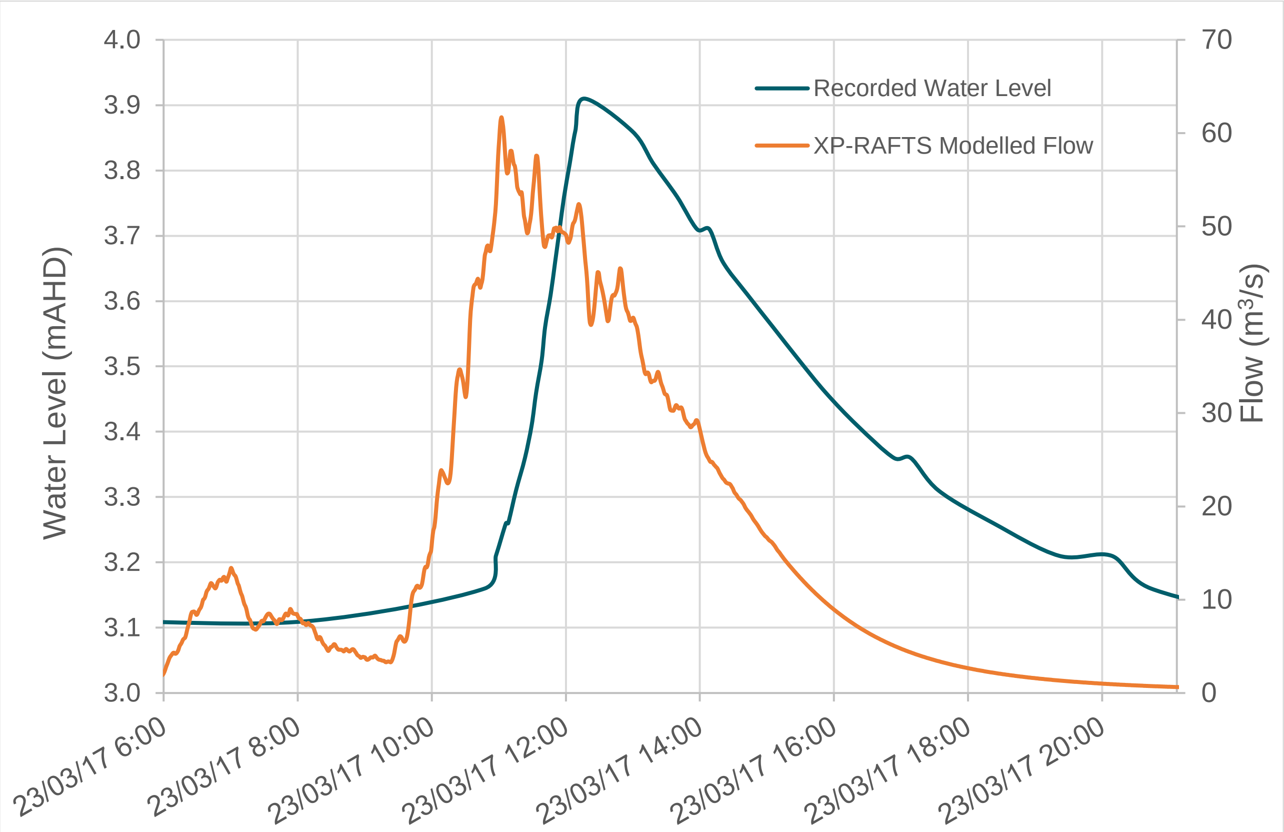


*Figure 4-2 XP-RAFTS Flow Hydrograph and Recorded Water Levels at Police Creek Gauge - March 23, 2017 Event*

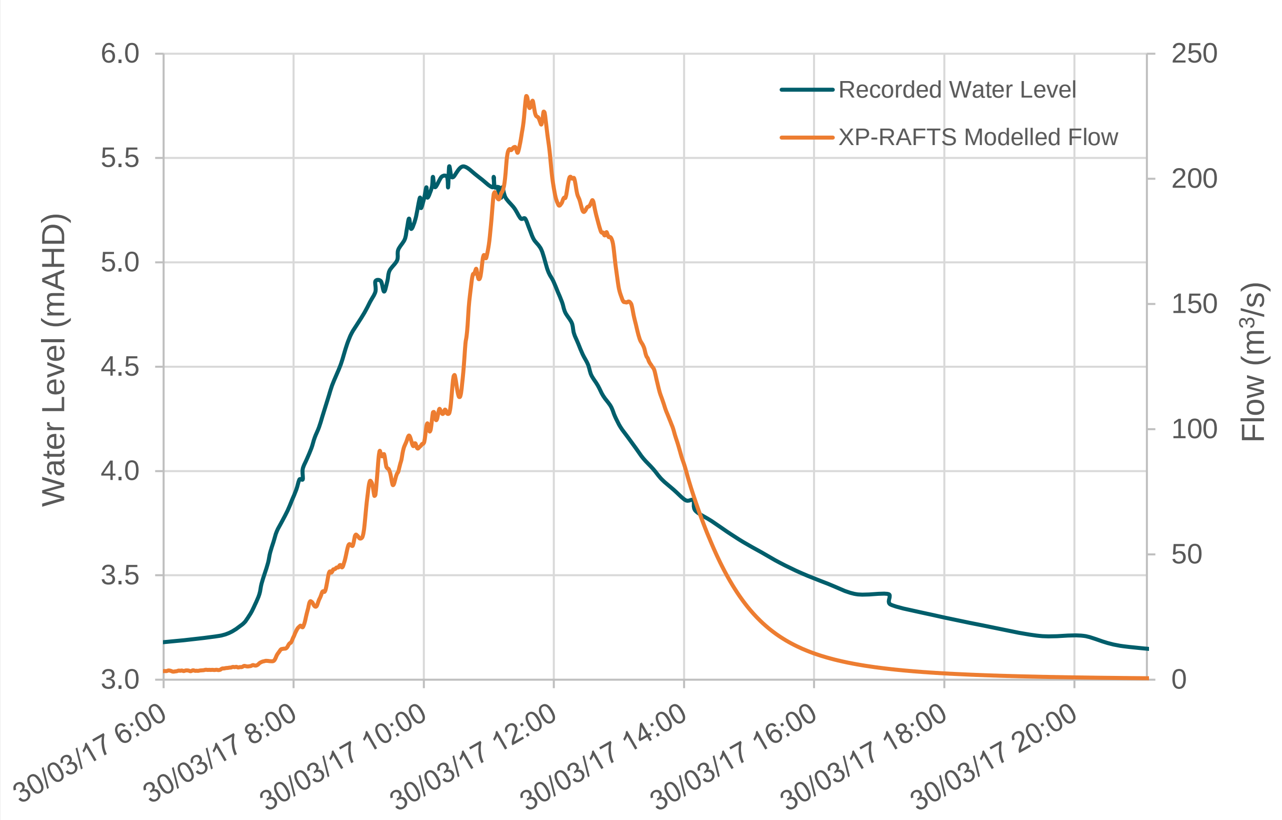


*Figure 4-3 XP-RAFTS Flow Hydrograph and Recorded Water Levels at Police Creek Gauge - March 30, 2017 Event*

## 4.3 DESIGN RAINFALL

Design rainfall for the Auckland Creek catchment was sourced from the Bureau of Meteorology's 2016 Intensity Frequency Duration (IFD) website for coordinate (-23.9 Lat; 151.25 Long). The rainfall depths are listed in Table 4-4.

*Table 4-4 IFD Design Rainfall Depth (mm) For Auckland Creek*

| Duration | Duration (min) | Annual Exceedance Probability (AEP) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 63% AEP | 50% AEP | 20% AEP | 10% AEP | 5% AEP | 2% AEP | 1% AEP | 1 in 200 AEP | 1 in 500 AEP |
| 1 min | 1 | 2.57 | 2.86 | 3.76 | 4.35 | 4.93 | 5.67 | 6.23 | 7.08 | 8.35 |
| 2 min | 2 | 4.25 | 4.71 | 6.16 | 7.14 | 8.1 | 9.33 | 10.3 | 11.8 | 14.0 |
| 3 min | 3 | 6.04 | 6.71 | 8.79 | 10.2 | 11.6 | 13.3 | 14.7 | 16.7 | 19.8 |
| 4 min | 4 | 7.75 | 8.62 | 11.3 | 13.1 | 14.8 | 17.1 | 18.8 | 21.5 | 25.4 |
| 5 min | 5 | 9.34 | 10.4 | 13.6 | 15.8 | 17.9 | 20.6 | 22.7 | 25.8 | 30.5 |
| 10 min | 10 | 15.6 | 17.4 | 22.8 | 26.4 | 29.9 | 34.4 | 37.7 | 42.8 | 50.4 |
| 15 min | 15 | 19.9 | 22.2 | 29.1 | 33.7 | 38.1 | 43.8 | 48.1 | 54.6 | 64.3 |
| 20 min | 20 | 23.2 | 25.8 | 33.8 | 39.2 | 44.3 | 51.0 | 56.0 | 63.5 | 74.9 |
| 25 min | 25 | 25.8 | 28.6 | 37.5 | 43.5 | 49.2 | 56.6 | 62.2 | 70.7 | 83.3 |
| 30 min | 30 | 27.9 | 31.0 | 40.6 | 47 | 53.3 | 61.4 | 67.5 | 76.7 | 90.5 |
| 45 min | 45 | 32.6 | 36.3 | 47.6 | 55.2 | 62.7 | 72.4 | 79.8 | 90.8 | 107 |

| Duration | Duration (min) | Annual Exceedance Probability (AEP) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 63% AEP | 50% AEP | 20% AEP | 10% AEP | 5% AEP | 2% AEP | 1% AEP | 1 in 200 AEP | 1 in 500 AEP |
| 1 hour | 60 | 36.0 | 40.1 | 52.8 | 61.4 | 69.8 | 80.9 | 89.4 | 102 | 120 |
| 1.5 hour | 90 | 41.1 | 45.8 | 60.8 | 71.0 | 81.0 | 94.4 | 105 | 119 | 141 |
| 2 hour | 120 | 45.0 | 50.3 | 67.2 | 78.8 | 90.3 | 106 | 118 | 134 | 158 |
| 3 hour | 180 | 51.1 | 57.5 | 77.8 | 91.9 | 106 | 125 | 140 | 159 | 188 |
| 4.5 hour | 270 | 58.4 | 66.1 | 91.0 | 108 | 126 | 150 | 169 | 192 | 226 |
| 6 hour | 360 | 64.3 | 73.3 | 102 | 123 | 144 | 173 | 196 | 222 | 261 |
| 9 hour | 540 | 74.1 | 85.2 | 122 | 148 | 175 | 212 | 242 | 274 | 322 |
| 12 hour | 720 | 82.1 | 95.0 | 138 | 169 | 202 | 247 | 283 | 321 | 377 |
| 18 hour | 1080 | 94.8 | 111 | 165 | 205 | 247 | 305 | 353 | 400 | 471 |
| 24 hour | 1440 | 105 | 123 | 186 | 233 | 284 | 353 | 410 | 466 | 549 |
| 30 hour | 1800 | 113 | 133 | 204 | 257 | 314 | 393 | 458 | 520 | 615 |
| 36 hour | 2160 | 119 | 142 | 218 | 277 | 339 | 426 | 498 | 567 | 672 |
| 48 hour | 2880 | 130 | 155 | 241 | 307 | 379 | 479 | 562 | 643 | 767 |
| 72 hour | 4320 | 144 | 172 | 270 | 346 | 429 | 545 | 641 | 745 | 896 |
| 96 hour | 5760 | 153 | 183 | 287 | 368 | 456 | 580 | 684 | 802 | 972 |
| 120 hour | 7200 | 159 | 190 | 298 | 380 | 470 | 598 | 705 | 833 | 1010 |
| 144 hour | 8640 | 164 | 196 | 304 | 387 | 476 | 606 | 714 | 846 | 1030 |
| 168 hour | 10080 | 168 | 200 | 309 | 390 | 477 | 608 | 714 | 847 | 1040 |

### 4.3.1 Areal Reduction Factors (ARF)

As the Auckland Creek is in East Coast North region, Areal Reduction Factors (ARF) have been applied to design rainfall based on the recommended coefficients.

### 4.3.2 Design Losses

Losses have been applied in the hydrologic model based on the AR&R Data Hub (2016) recommended initial and continuing losses and are presented in Table 4-5. Median pre-burst depths for each storm event were subtracted from these values in accordance with ARR 2016.

*Table 4-5 Initial and Continuing Losses for Auckland Creek Catchment*

| Initial Loss (mm) | Continuing Loss (mm/Hour) |
|---|---|
| 22 | 2 |

### 4.3.3 Temporal Patterns

A range of design storms have been modelled for durations ranging from 30 minutes to 24 hours. The model was run for the 63.2%, 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP events as well as a 20% increase in rainfall intensity for the 1%, 0.5% and 0.2% AEP events to reflect climate change impacts. In line with ARR 2016, an ensemble of ten temporal patterns for the East Coast North region was assessed for each storm duration to identify the median temporal pattern.

#### 4.3.3.1 Analysis of Rainfall in East Coast North Region

Preliminary hydraulic modelling indicated that storm durations significantly longer than those previously adopted in the Auckland Creek Flood Study were critical in the catchment. Furthermore, these longer durations were critical throughout the vast extent of the catchment including locations in the far upstream sections where much shorter durations would be expected to be critical.

An analysis of the temporal patterns for storm durations ranging from 6 hours to 24 hours for the 1% AEP for the East Coast North region revealed that some of the temporal patterns had embedded bursts within them that had a higher intensity of rainfall than shorter duration events of the same AEP. This was found to in some occasions affect the median temporal pattern for a particular storm duration. Additionally, the impact of areal reduction factors, which are greater for shorter events, was observed to further exacerbate the issue.

Further analysis of temporal patterns was undertaken for storm durations ranging from 3 hours to 18 hours for the 63.2% to 1% AEP events. Temporal patterns which displayed issues with embedded bursts were excluded from the analysis. Engineering judgement was used to identify the new median storm temporal pattern from those that remained for each duration and AEP event modelled. This involved excluding the problematic temporal patterns and recalculating the median temporal pattern. Where there were an odd number of temporal patterns left after the analysis the temporal pattern produced the median peak flow was chosen. Where there were an even number of temporal patterns left after the analysis, the temporal pattern that produced the flow that was the first exceeding the median peak flow was chosen.

A full analysis of the temporal patterns and the adopted methodology for their selection is provided in Appendix B for the 1% AEP event and 9-hour storm duration. The selection of temporal patterns for the remaining design events and storm durations is summarised in spreadsheets which are part of the electronic data handover for the project.

## 4.4 DESIGN EVENT MODEL RESULTS

The results of the hydrological model are presented in Table 4-6 and Table 4-7. Table 4-6 shows the critical duration for Auckland Creek catchment. Table 4-7 presents the peak discharges for modelled design events in the Auckland Creek catchment.

***Table 4-6 Critical Duration (mins) in Auckland Creek Catchment***

| Location | Duration (hrs) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 63.2% AEP | 50% AEP | 20% AEP | 10% AEP | 5% AEP | 2% AEP | 1% AEP | 0.5% AEP | 0.2% AEP |
| Outlet | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |

***Table 4-7 Design Discharge in Auckland Creek Catchment***

| Location | Flow ($m^3/s$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 63.2% AEP | 50% AEP | 20% AEP | 10% AEP | 5% AEP | 2% AEP | 1% AEP | 0.5% AEP | 0.2% AEP |
| Outlet | 108 | 129 | 197 | 267 | 319 | 353 | 404 | 460 | 545 |

## 4.5 VALIDATION

To aid in the validation of the design discharges estimated using XP-RAFTS, the Quantile Regression Technique (QRT) (Palmen, L.B. and Weeks, W.D. (2009)) and the Regional Flood Frequency Estimation (RFFE) were utilised to estimate the catchments peak design flows.

The RFFE transfers flood frequency characteristics from a group of gauged catchments to the location of interest. Even in cases where there is recorded streamflow data it is beneficial to pool the information in the gauged record with the RFFE information. The RFFE was undertaken utilising the ARR online Regional Flood Frequency Estimation Model. It requires that the location of the catchment outlet and centroid along with the catchment area in square kilometres ($km^2$). This estimate provides an expected peak flow based on catchments of similar size and based on the gauged flows from nearby catchments, along with upper and lower confidence bounds (see Table 4-8 and Table 4-9).

*Table 4-8 RFFE Peak Flows for the Auckland Creek Catchment Outlet*

| AEP | Expected ($m^3/s$) | Lower 5% ($m^3/s$) | Upper 95% ($m^3/s$) |
|---|---|---|---|
| 1% | 1100 | 268 | 4480 |
| 2% | 790 | 218 | 2840 |
| 5% | 481 | 157 | 1470 |
| 10% | 311 | 114 | 845 |
| 20% | 185 | 74 | 468 |
| 50% | 70 | 27 | 181 |

*Table 4-9 RFFE Peak Flows at Police Gauge Station*

| AEP | Expected ($m^3/s$) | Lower 5% ($m^3/s$) | Upper 95% ($m^3/s$) |
|---|---|---|---|
| 1% | 760 | 182 | 3130 |
| 2% | 547 | 149 | 2000 |
| 5% | 335 | 108 | 1040 |
| 10% | 219 | 79 | 601 |
| 20% | 131 | 52 | 338 |
| 50% | 51 | 19 | 133 |

The Quantile Regression Technique (QRT) developed by Palmen, L.B. and Weeks, W.D. (2009) for Queensland is based on the 2% AEP 72-hour rainfall intensity and the catchment size. The QRT was used to calculate flows for the entire catchment as well as at the location of the Police Creek gauging station. The QRT results are summarised in Table 4-10.

*Table 4-10 QRT Peak Flows for the Auckland Creek Catchment Outlet and Police Creek Gauge*

| AEP | Auckland Creek Outlet ($m^3/s$) | Police Creek Gauge ($m^3/s$) |
|---|---|---|
| 1% | 580 | 436 |
| 2% | 471 | 352 |
| 5% | 336 | 250 |
| 10% | 238 | 176 |
| 20% | 160 | 117 |
| 50% | 64 | 46 |

A comparison of the design event peak flows derived from the XP-RAFTS model and the RFFE for both the catchment outlet and the Police Creek gauge, shows that all design events are within the 5% and 95% confidence levels. The QRT and XP-RAFTS model show a good match especially for the 20% to 5% AEP events.

A comparison of the flows derived in XP-RAFTS for the historic events and the design events shows, that the March 23, 2017 event was approximately a 50% AEP event. When assessing the March 23, 2017 event against the QRT and RFFE flows, it was approximated to between a 50% AEP and 20% AEP flow event.

The March 30, 2017 event was between a 2% and 1% AEP in comparison with the XP-RAFTS design events, but between a 5% AEP and 2% AEP compared to the QRT method and between a 10% AEP and 5% AEP for the RFFE.

# 5 HYDRAULIC MODELLING

It should be noted that both calibration and design events were modelled utilising local hydrograph source area inflows, with the flows derived from the XP-RAFTS sub-catchments. The flows from the XP-RAFTS models for the calibration storm events were derived from historical rainfall data. The information and data that was utilised to build and calibrate the hydraulic model is provided in the following section.

## 5.1 MODEL BUILD

### 5.1.1 Model Topography

The model topography was based on the 1 m DEM derived from the 2015 LiDAR survey by AAM and provided to WMS by GRC. The upstream area of the catchment that was not covered by the 2015 LiDAR was based upon a 1m DEM derived from a 2014 LiDAR survey and provided by GeoScience Australia.

A 5 m grid size was adopted for the hydraulic model, as this provides sufficient resolution to accurately define the terrain features whilst keeping reasonable simulation times. This allows for detailed representation of overland and road flow paths. The current TUFLOW model build allows for relatively simple switches between grid sizes, although a general rule of thumb is that if you half the grid size the model run time is approximately eight times as long.

### 5.1.2 DEM Development

In addition to the LiDAR data that was utilised, a number of additional modifications and additions were made to the DEM which included:

- TUFLOW terrain modifiers (z shapes) were added to re-instate road and rail embankments on creek crossings missing in the model.
- The data from the bathymetric survey undertaken by WMS in March 2019, which includes the Marina, Auckland Creek and Lake Callemondah was used to represent the waterway bathymetry in these areas.

As the chosen historical storm events were fairly recent (<3 years ago), the terrain required no modification for historical reference.

### 5.1.3 Hydraulic Roughness

The hydraulic roughness applied in the TUFLOW model was based on the layer used in the Engeny study (Engeny, 2015). This layer has been updated to include a better representation of the hydraulic roughness along the creek and tributary flow paths.

The Manning's 'n' hydraulic roughness values for different land use types are listed in Table 5-1, these differ from the Engeny 2015 models Mannings' 'n' values as these have assigned through the calibration process. The spatial hydraulic roughness distribution is shown in Figure 5-1. The base Manning's layer applied in the first instance was the "Bush and Trees" with all others layered on top of this in the appropriate order. The Manning's value for "Bush and Trees" was adjusted from a value of 0.10 in the Engeny study to 0.70 as an outcome of the hydraulic calibration of the model.

A roughness value of 0.5 was applied to represent the presence of buildings including large industrial and commercial complexes and houses. A sensitivity scenario was run for the 1% AEP which removed the buildings areas from the active domain of the model in accordance with the recommendation of ARR 2016.

As no significant development has occurred in the area within the short timeframe for the historical storms, Manning's roughness values and areas have been applied as the same for both calibration and existing scenario design simulations.

*Table 5-1 Adopted Hydraulic Roughness*

| Land Use Type | Manning's Roughness |
|---|---|
| Water – Creeks and Dams | 0.02 |
| Roads and Railway | 0.02 |
| Mangroves/Swamp/Dense Vegetation | 0.10 |
| Grass | 0.05 |
| Bush and Trees | 0.06 |
| Rural Residential | 0.20 |
| Bare Soil | 0.03 |
| Buildings | 0.50 |

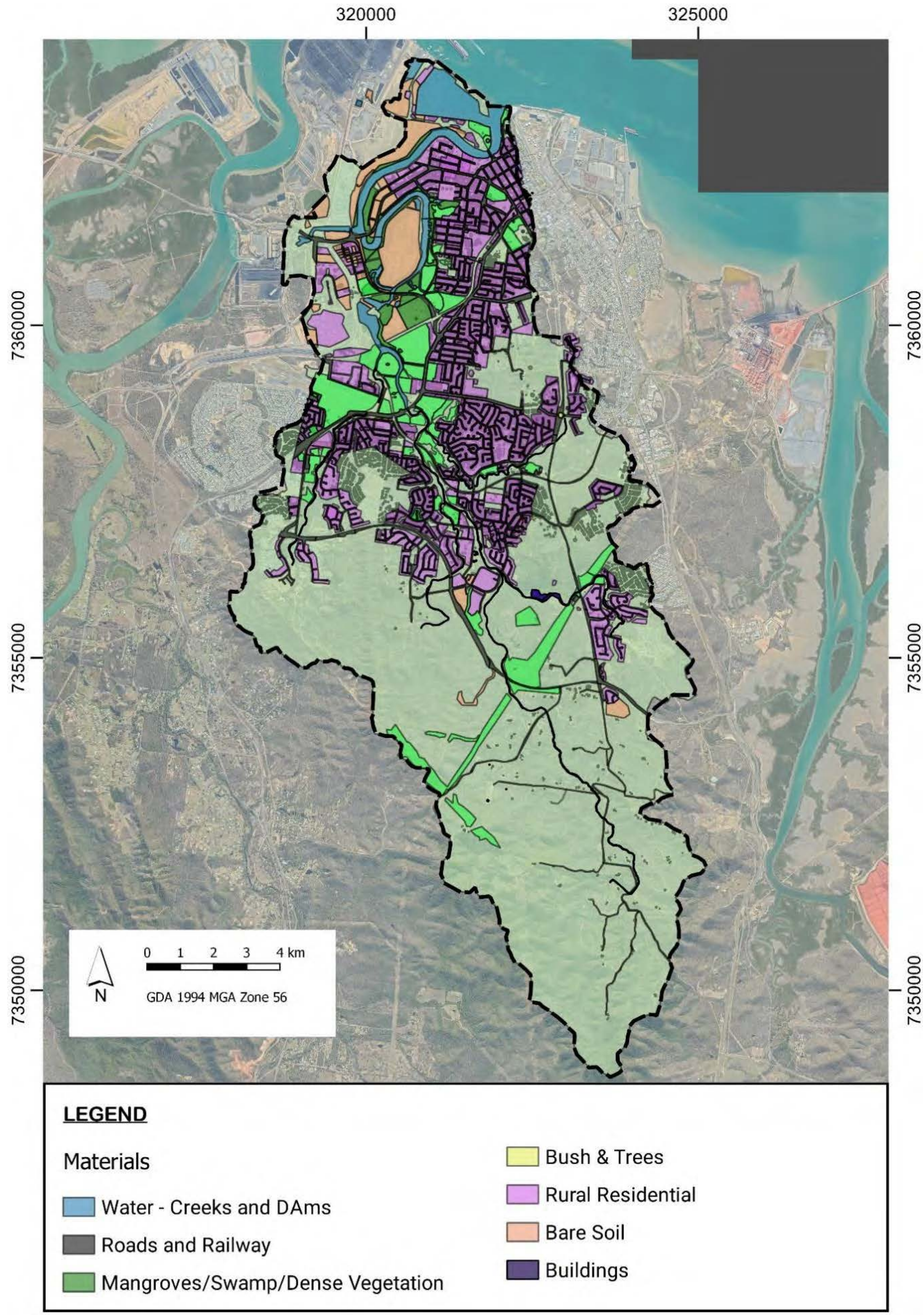


*Figure 5-1 Hydraulic Roughness Map*

### 5.1.4 Downstream Boundary Condition

The downstream boundary of the TUFLOW model is located at the outlet of Auckland Creek into Port Curtis. For the calibration storm events the downstream boundary condition was based historical tidal heights over the period of each of the storm events from the Auckland Point tidal gauge data provided by Maritime Safety Queensland.

The boundary conditions for the design events were based on a variety of static tidal levels. These levels include:

- Mean High Water Springs (MHWS), 1.692 mAHD
- Highest Astronomical Tide (HAT), 2.562 mAHD
- 1% AEP storm surge, 3.2 mAHD
- 2100 climate change, 2.492 mAHD (MHWS + 0.8 m)

With the exception of the 2100 climate change tide level, the standard tide levels are the same as those adopted in the Engeny report which were sourced from the 2014 Tide Tables published by Maritime Safety Queensland (MSQ, 2014). These levels were checked against the latest Tide Tables (MSQ, 2019) and no changes were noted. The 1% AEP storm surge level according to the Engeny report was derived from *Storm Tide Threat in Queensland: History, Prediction and Relative Risks* (Harper, 1998) and was adopted for this study. The MHWS tidal level was used for all standard design events except the PMF which used the HAT.

The 2100 climate change level was reported and modelled as 2.192 m (MHWS + 0.5 m) in the Engeny report. This level has been increased to 2.492 m (MHWS + 0.8 m) based on the adopted Queensland Government projected sea-level rise which was based on climate modelling for probable scenarios of world development presented in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report released in 2014 (AR5).

### 5.1.5 Hydraulic Structures

TUFLOW has the ability to model hydraulic structures in 1d and 2d depending on the size or method employed to model the structure. For structures that are relatively small they have been modelled as 1 d structures, these include all box culverts and pipes. A 20% blockage factor was applied to culverts in accordance with general practice. The bridges have been applied as 2d layered flow constriction shapes.

The details of the hydraulic structures within the model initially came from the model files in the Engeny TUFLOW model. These were updated based on the data review and the new data supplied by the Capricorn Survey Group that was summarised in Table 2-3.

The lower catchment stormwater pit and pipe network was also included in the updated hydraulic model. This network included the trunk drainage that the Engeny study identified as critical to modelling the flood behaviour. To provide a more realistic assessment of flood behaviour in the lower catchment, an additional pit and pipe network was included.

Features such as pipe type, length and IL were based on the outcome of the field survey conducted. Where information was not available due to inaccessible pits and pipes, assumptions were made by using engineering judgement and slope calculations.

Figure 5-2 displays the TUFLOW model setup.

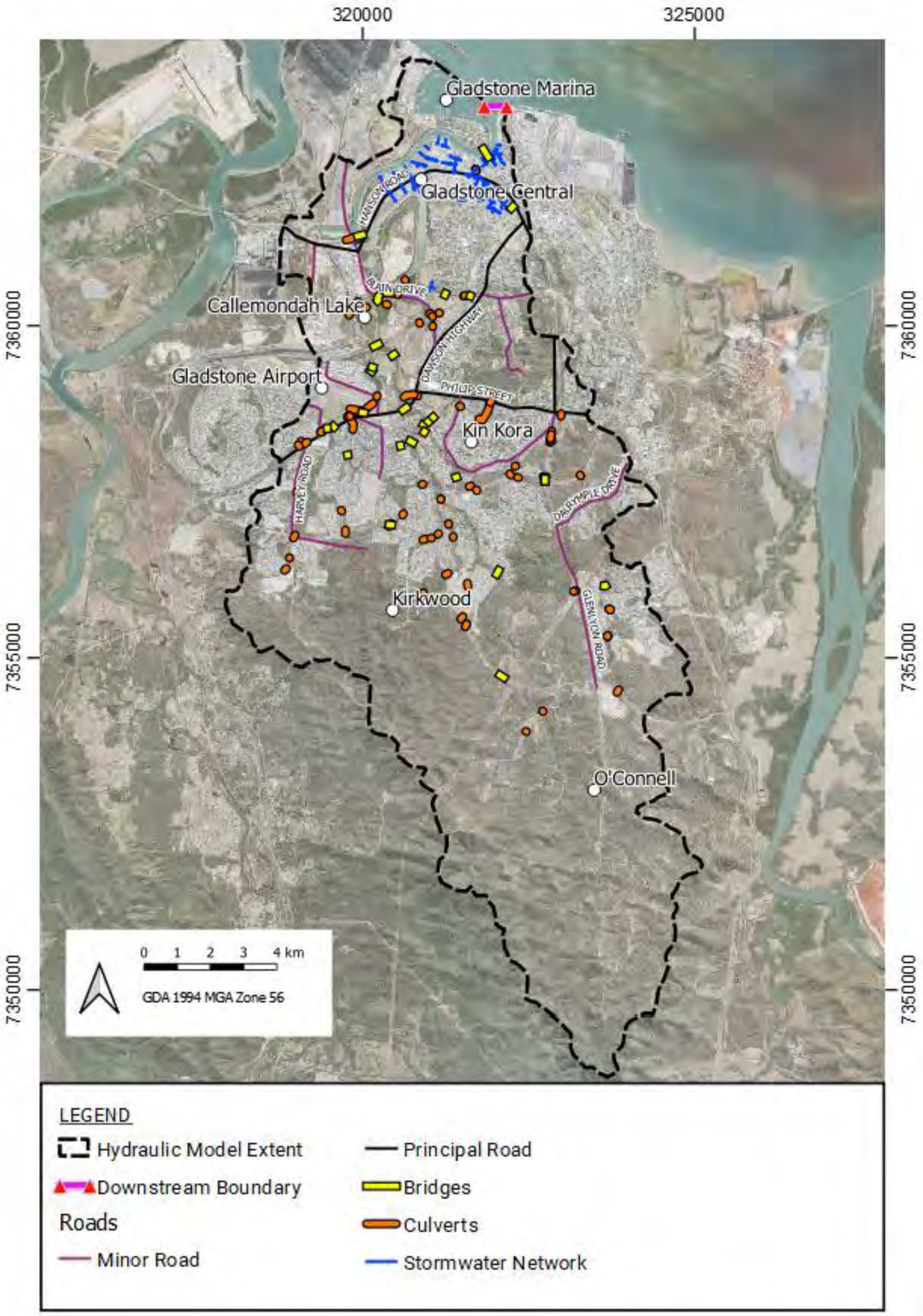


*Figure 5-2 TUFLOW Model Setup*

# 6 MODELLING RESULTS

## 6.1 CALIBRATION RESULTS

The calibration data and evidence supplied was sufficient to perform a reliable calibration. Initial calibration efforts concentrated on using only the Gladstone Airport and Gladstone Radar rainfall gauges. As identified in Section 3, two events were chosen for calibration (March 23, 2017 and March 30, 2017). Calibration mapping for both events is supplied in Appendix C.

Hydrographs depicting the water level at the Police Creek gauge are shown in Figure 6-1 and Figure 6-2 for the March 23 and March 30 events respectively. Table 6-1 provides a comparison of the recorded and modelled peaks for each of the calibration events at the Police Creek gauging station. It shows that the model was able to very closely represent the recorded events particularly the peak levels. The peak levels were within 0.09 m and for the largest event of March 30, 2017 the peak was matched within 0.01 m. The timing for both peaks was late with a one-hour difference for the March 30 event and approximately half an hour for March 23. The results show that the calibrated model is able to represent peak water levels with a great degree of accuracy and peak timing within an acceptable margin.

*Table 6-1 Comparison of Recorded Peaks and the Modelled Peaks at the Police Creek Gauge*

| Event | Recorded Level (mAHD) | Recorded Time | Model level (mAHD) | Modelled Time | Level Diff (M-R) (m) | Time Diff (M-R) (hours) |
|---|---|---|---|---|---|---|
| March 23, 2017 | 3.91 | 23/03/2017 12:17 | 3.97 | 23/03/2017 12:15 | 0.06 | - 0:02 |
| March 30, 2017 | 5.46 | 30/03/2017 10:24 | 5.51 | 30/03/2017 11:40 | 0.05 | 1:16 |

Figure 6-1 shows that the model represents the recorded March 23 event well for peak level and timing. The records at the gauge showed that water levels began to rise rapidly from approximately 3.1 mAHD at approximately 10:45 am on March 23 and reached the peak level of 3.91 mAHD at approximately 12:15 pm, approximately 2.5 hours later. The water levels then subsided slowly to approximately 3.2 mAHD at approximately 7:00 pm on March 23. The model showed an initial rapid rise from its starting level of 2.2 mAHD to 3.2 mAHD, similar to the gauge water level. The modelled water level then showed a rapid rise from approximately 10:00 am to 11:00 am where the rate of rise slowed. The model then peaked at 3.97 mAHD at approximately 12:15 pm. From then it slowly decreased to approximately 3.2 mAHD at approximately 7:00 pm on March 23. These results show that the modelled event produced similar results to that of the recorded event at the Police Creek gauge.

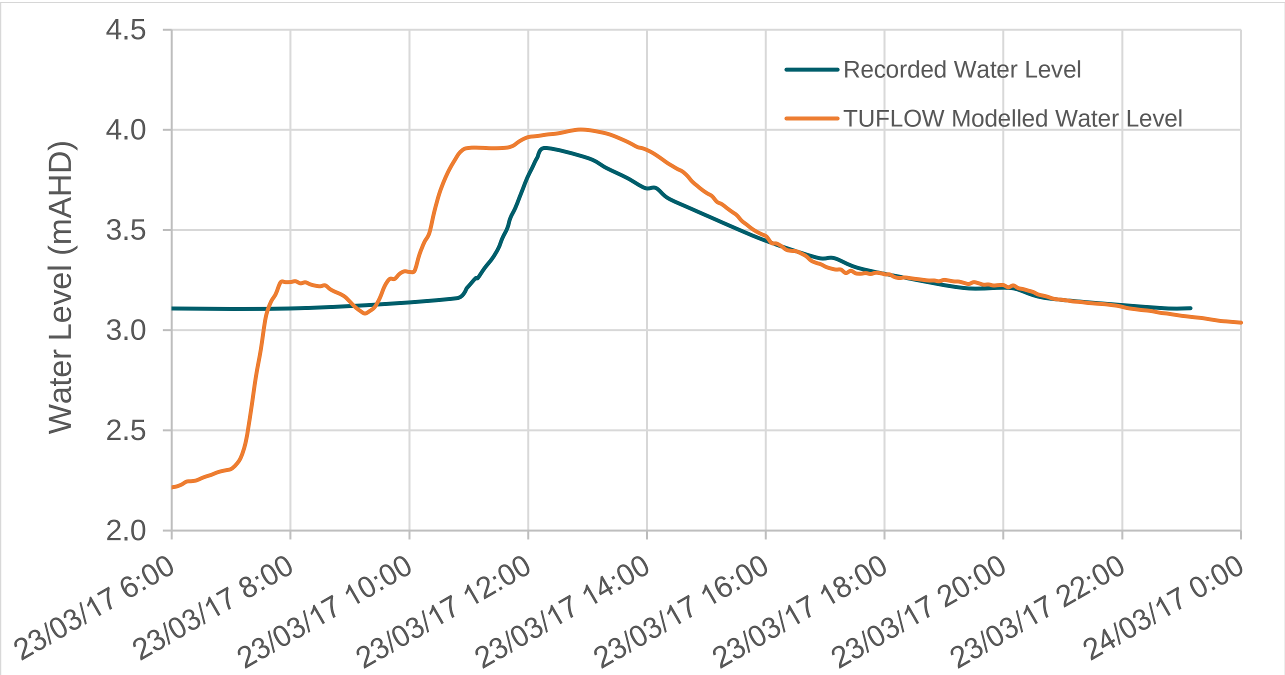


*Figure 6-1 Comparison of Recorded and Modelled Water Levels at Police Creek Gauge - March 23, 2017 Event*

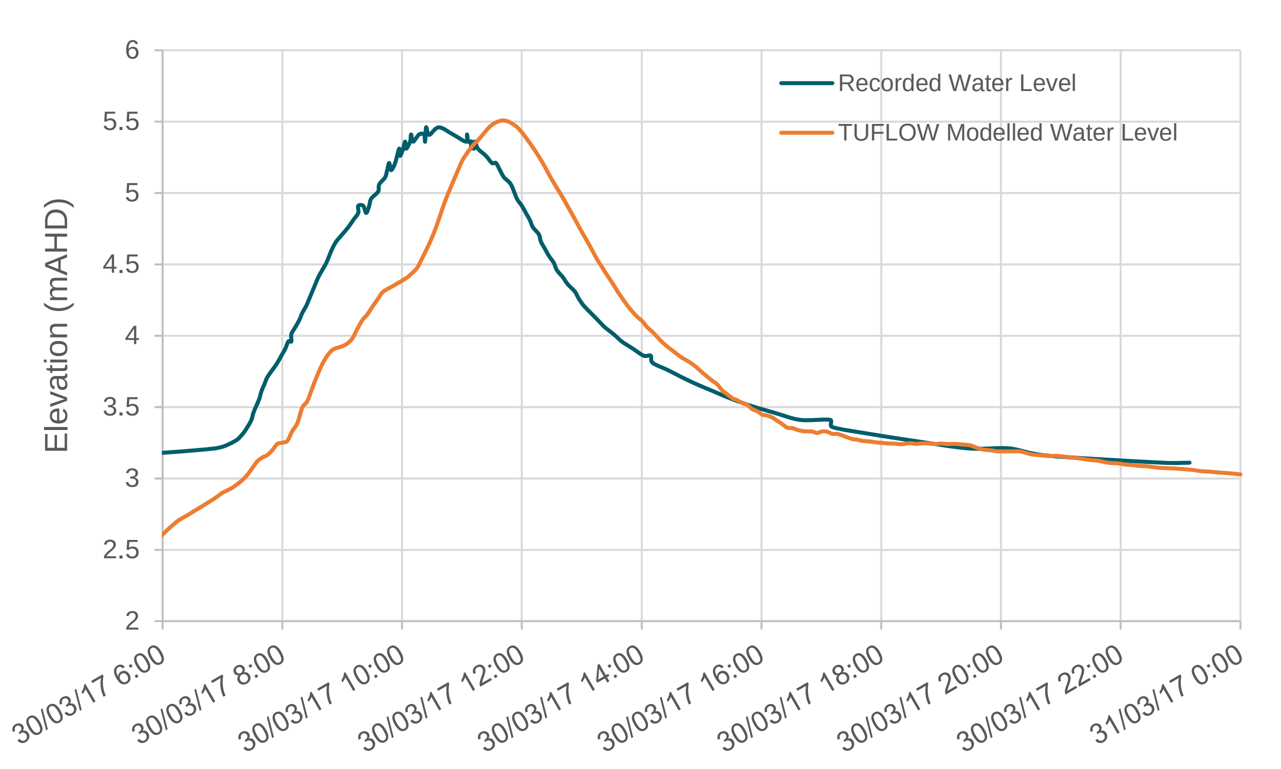


*Figure 6-2 Comparison of Recorded and Modelled Water Levels at Police Creek Gauge - March 30, 2017 Event*

Figure 6-2 shows that the model represents the recorded water levels during the 30th of March 2017 event well, especially the peak water level. Both the recorded and the modelled water levels showed a rapid rise at approximately 7:00 am on the 30th of March. The recoded water level then reached its peak water level of 5.46 mAHD at approximately 10:30 am on the 30th of March, while the modelled water level reached its peak water level of 5.51 mAHD at approximately 11:40 am on the 30th of March. The peak levels are extremely similar although the timing is approximately one and a quarter hours later for the modelled peak. Both the recorded and modelled water levels slowly decreased until approximately 5:30pm on the 30th of March to a level of approximately 3.3 mAHD.

There is a difference in the initial standing water level between the recorded and modelled events. This difference is due to the initial water level set downstream for Lake Callemondah which was determined on the basis of the height of the weir in order to provide model stability. This difference in initial height in the creek is not expected to make a significant difference to peak water levels as the additional flow capacity at the base level of the creek is small compared to the flow area at higher levels as the creek cross section broadens.

GRC also provided a series of points recording maximum observed flood heights for both the March 23 and March 30 2017 storm events. The data for the March 23 event consisted of levels only without times and the data for the March 30 event included both levels and time recordings. The data collected for these events and the modelling results obtained for these same locations are summarised in Table 6-2 and Table 6-3. The locations of the calibration points for both events are shown in the figures in Appendix C.

*Table 6-2 Comparison of Model Results and Observed Flood Levels for March 23, 2017 Storm Event*

| ID | Easting MGA94 Zone 56 | Northing MGA94 Zone 56 | Recorded Level (mAHD) | Recorded Time | Modelled Level | Modelled Time | Diff Level (M-R) (m) | Diff Time (M-R) (hours) |
|---|---|---|---|---|---|---|---|---|
| 1 | 322703 | 7354185 | 26.66 | Not provided | 27.63 | 23/03/2017 12:15 | 0.97 | NA |
| 2 | 323189 | 7355979 | 22.95 | Not provided | 23.35 | 23/03/2017 10:45 | 0.40 | NA |
| 3 | 322883 | 7358298 | 22.65 | Not provided | 23.12 | 23/03/2017 10:45 | 0.46 | NA |
| 4 | 322316 | 7357870 | 14.98 | Not provided | 15.85 | 23/03/2017 10:40 | 0.87 | NA |
| 5 | 321372 | 7356798 | 13.36 | Not provided | 13.79 | 23/03/2017 12:15 | 0.42 | NA |
| 6 | 320838 | 7357978 | 6.14 | Not provided | 6.77 | 23/03/2017 12:30 | 0.62 | NA |
| 7 | 318954 | 7356784 | 20.56 | Not provided | 20.81 | 23/03/2017 10:20 | 0.25 | NA |

The data provided for the March 23 event shows an uneven correlation between the modelling results and observed heights in contrast with the good comparison found at the Police Creek gauge. However, it has been made known to WMS by GRC that these are not necessarily maximum flood level observations. The good match between the modelled and recorded maximum level at the Police Creek gauge gives some degree of confidence that the model is able to adequately represent flooding levels within the catchment. Without any time data associated with the water level observations it is not possible to use these observations to assess how well the model represents catchment response time. However, the excellent match in peak level timings at the Police Creek gauge provides some degree of confidence that the model adequately represents catchment response.

*Table 6-3 Comparison of Model Results and Observed Maximum Flood Levels for March 30, 2017 Storm Event*

| ID | Easting MGA94 Zone 56 | Northing MGA94 Zone 56 | Recorded Level (mAHD) | Recorded Time | Modelled Level | Modelled Time | Diff Level (M-R) (m) | Diff Time (M-R) (hours) |
|---|---|---|---|---|---|---|---|---|
| 1 | 322748 | 7354215 | 29.58 | 30/03/2017 9:40 | 29.59 | 30/03/2017 11:05 | 0.01 | 1:25 |
| 2 | 323181 | 7355971 | 24.19 | 30/03/2017 9:50 | 24.06 | 30/03/2017 11:05 | -0.14 | 1:15 |
| 3 | 322880 | 7358323 | 22.99 | 30/03/2017 8:45 | 23.94 | 30/03/2017 10:50 | 0.94 | 2:05 |
| 4 | 322335 | 7357909 | 17.10 | 30/03/2017 8:50 | 17.09 | 30/03/2017 10:45 | -0.01 | 1:55 |
| 5 | 321397 | 7357688 | 11.11 | 30/03/2017 8:55 | 11.79 | 30/03/2017 11:05 | 0.68 | 2:10 |
| 6 | 321688 | 7356942 | 13.56 | 30/03/2017 9:00 | 13.35 | 30/03/2017 11:40 | -0.21 | 2:40 |
| 7 | 322026 | 7356224 | 17.05 | 30/03/2017 9:05 | 16.64 | 30/03/2017 11:25 | -0.41 | 2:20 |
| 8 | 321352 | 7356800 | 14.55 | Not provided | 14.66 | 30/03/2017 11:10 | 0.11 | NA |
| 9 | 320785 | 735798 | 8.41 | 30/03/2017 9:10 | 8.50 | 30/03/2017 11:40 | 0.09 | 2:30 |
| 10 | 319527 | 7358136 | 12.60 | 30/03/2017 9:20 | 12.60 | 30/03/2017 10:40 | 0.00 | 2:20 |
| 11 | 319953 | 7358650 | 8.36 | 30/03/2017 9:15 | 8.88 | 30/03/2017 10:50 | 0.51 | 1:35 |
| 12 | 318912 | 7356761 | 21.67 | 30/03/2017 9:21 | 22.19 | 30/03/2017 10:40 | 0.51 | 1:19 |
| 13 | 322128 | 7354713 | 24.25 | 30/03/2017 9:35 | 24.85 | 30/03/2017 11:25 | 0.60 | 1:50 |

Since the observed levels at the thirteen observation points do not necessarily record maximum water levels the results of the model have been analysed to see at what time the model most closely approximated the levels recorded in these locations and to compare the modelling times with the recorded times.

The modelled calibration water levels for the March 30, 2017 storm event shows that in comparison with the recorded peak water level points there was a mixture of small and large differences. Seven of the thirteen recorded water level points showed that there was only a difference of less than 0.2 m of the recorded maximum with four of these within 0.1 m. Five locations showed a poorer match with a difference in water level greater than 0.5 m.

Model timing generally lagged behind the recorded times by one and a half to two and half hours. This time difference could also be due to storage issues. It should be noted the time difference at these observation points was greater in all cases than the difference observed at the Police Creek gauge which was one and a quarter hour. A greater degree of confidence can be placed in the Police Creek timing compared to the water level points. A potential source of the timing error could be due to the direction of the storm events. As can be seen in Figure 4-1 the rainfall gauges are located adjacent to either side of the catchment in the downstream third of the catchment area. If the storm events travelled in the direction of upstream to downstream then the rainfall in the upstream areas of the catchment would have fallen earlier in time than is represented in the modelling of these storm events. In order to obtain a better calibration, it would be beneficial to have another rainfall gauge in the upstream area of the catchment to help better spatially distribute the rainfall from storm events without an over reliance on recordings made in the downstream area.

## 6.2 DESIGN EVENT RESULTS

Design events from the 63.2% AEP to the 0.2% AEP event were modelled for the durations ranging from 45 minutes to 18 hours. Peak of peak mapping of the storm durations for depth, velocity, water surface level and ZQRA hazard categories has been provided for the following scenarios in the listed appendices:

- Appendix D: Design storms (2% AEP to 0.2% AEP events);
- Appendix E: 2100 climate change events (1% AEP to 0.2% AEP events);
- Appendix F: 1% AEP HAT, 1% AEP Storm Surge and HAT (no rainfall); and
- Appendix G: PMP event mapping.

### 6.2.1 Design Storm Flood Behaviour

From the flood modelling undertaken, the following observations were made:

- The Auckland Creek catchment is not affected by widespread flood impacts in design storm events ranging from 2% AEP to 0.2% AEP. However, there are some isolated areas and proprieties within the catchment that experience inundation due to breakthrough flooding and undersized stormwater infrastructure;
- Road overtopping of the roundabout located at Dawson highway and Harvey Road and flood inundation of the Bunnings Warehouse and carpark occur in a 0.5% AEP flood event;
- Aerodrome Road and the BP service Station on Dawson Highway experience inundation in a 0.2% AEP event;
- Neil Street and Callemondah Drive becomes inundated in a 1% AEP event;
- Inundation of Wenitong Street occurs in a 2% AEP event;
- Flooding occurs in the vicinity of the Dawson Highway and Penda Avenue roundabout. In this area, Shaw Street, Willow Street and Willson Street experience inundation in a 2% AEP event as do a number of properties located between these streets. This inundation is likely caused by an overland flow path running from the Kaleentha Park, through to an RCP structure before discharging into Briffney Creek;
- Sun Valley Road experiences inundation from an open channel in between Kin Kora drive and Acacia Court in a 2% AEP event. Backyards and some properties along the western side of this open channel become inundated in a 2% AEP event. In a 0.2% AEP event, properties and a portion of Kin Kora Drive become inundated;
- Properties adjacent to Tigalee Creek and the Sun Valley Road shopping centre experience inundation in a 2% AEP event;
- A number of properties on Bradford Road, also in the vicinity of Tigalee Creek experience flooding in a 0.2% AEP event;
- Inundation of Dawson highway, in the vicinity of Breslin Street occurs in a 2% AEP event;
- Inundation occurs at a low point of Glenlyon Road in the vicinity of Railway Street and the Port Access Road in a 2% AEP event;
- Inundation occurs on the Dawson highway in between the Gladstone Hockey Association Fields and the Puma service station;
- Alf O'Rourke Drive experiences inundation in a 0.2% AEP event in the vicinity of the Hanson Road roundabout; and
- Haddock Drive experiences inundation at two culvert crossing locations in a 2% AEP event.

### 6.2.2 Storm Surge Flood Behaviour

In addition to the design storm flood behaviour listed above, the storm surge scenario resulted in widespread inundation of streets and properties in the lower region of the Auckland Creek catchment, on both sides of Hanson Road adjacent to Auckland Creek. This is due to an increased downstream boundary to replicate storm surge level of 3.2 mAHD from the MHWS downstream boundary of 1.692 mAHD. Figure 6-3 and Figure 6-4 show a comparison between the 1% AEP design storm event with a MHWS downstream boundary and the 1% AEP storm surge scenario with a downstream boundary of 3.2 mAHD.


*Figure 6-3 1% AEP Peak Depth in Lower Region of Auckland Creek*


*Figure 6-4 1% AEP Peak Storm Surge Depth in Lower Region of Auckland Creek*

The critical duration mapping for the 1% AEP event is shown in Figure 6-5.

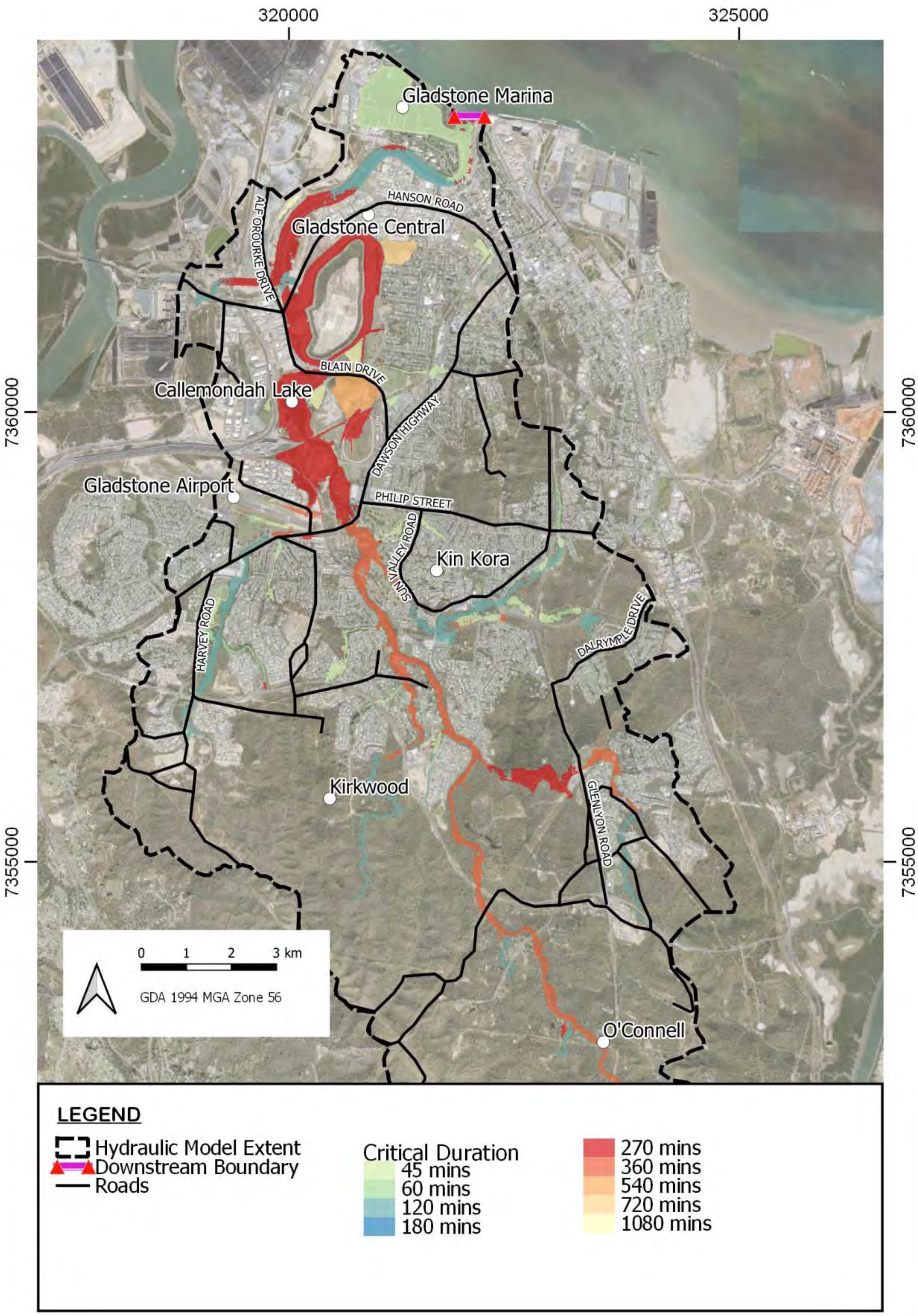


*Figure 6-5 1% AEP Critical Duration*

Table 6-4 lists peak water levels at several locations in the Auckland Creek catchment for all mapped design storm events. Figure 6-6 shows the locations of the plot output points.

A comparison of the design event peak water levels and the calibration event peak water levels can allow an inference of the approximate AEP of the calibration events. Based on the design event peak water levels the March 23, 2017 event (3.91 m) was less than a 2% AEP event and the March 30, 2017 event (5.46 m) was approximately between a 2% AEP event and a 1% AEP event.

**Table 6-4 Design Storm Events Water Surface Level (mAHD) at Plot Output Point Locations**

| Location | Water Surface Level (mAHD) | | | |
|---|---|---|---|---|
| | 2% AEP | 1% AEP | 0.5% AEP | 0.2% AEP |
| A | 39.70 | 39.78 | 39.87 | 39.94 |
| B | 31.66 | 31.71 | 31.80 | 31.89 |
| C | 29.78 | 29.98 | 30.14 | 30.37 |
| D | 41.34 | 41.41 | 41.50 | 41.63 |
| E | 24.23 | 24.30 | 24.53 | 24.70 |
| F | 28.10 | 28.20 | 28.35 | 28.49 |
| G | 25.22 | 25.27 | 25.51 | 25.81 |
| H | 16.35 | 16.54 | 16.75 | 17.02 |
| I | 16.47 | 16.65 | 16.87 | 17.13 |
| J | 20.45 | 20.88 | 21.38 | 22.06 |
| K | 25.50 | 25.79 | 25.81 | 25.84 |
| L | 22.14 | 22.39 | 22.61 | 22.92 |
| M | 11.35 | 11.39 | 11.55 | 11.81 |
| N | 11.26 | 11.44 | 11.65 | 11.93 |
| O | 21.53 | 21.73 | 21.88 | 22.08 |
| P | 27.23 | 27.47 | 27.95 | 28.21 |
| Q | 9.15 | 9.39 | 9.66 | 10.00 |
| R | 9.32 | 9.37 | 9.52 | 9.66 |
| S | 7.03 | 7.18 | 7.35 | 7.57 |
| T | 11.20 | 11.36 | 11.54 | 11.80 |
| U | 8.57 | 8.66 | 8.73 | 8.91 |
| V (Police Ck Gauge) | 5.37 | 5.57 | 5.73 | 5.99 |
| W | 5.10 | 5.21 | 5.41 | 5.59 |
| X | 3.91 | 3.93 | 4.04 | 4.14 |
| Y | 3.19 | 3.38 | 3.49 | 3.65 |
| Z | 9.12 | 9.29 | 9.48 | 9.67 |
| AA | 1.82 | 1.85 | 1.88 | 1.95 |
| AB | 4.09 | 4.30 | 4.46 | 4.58 |

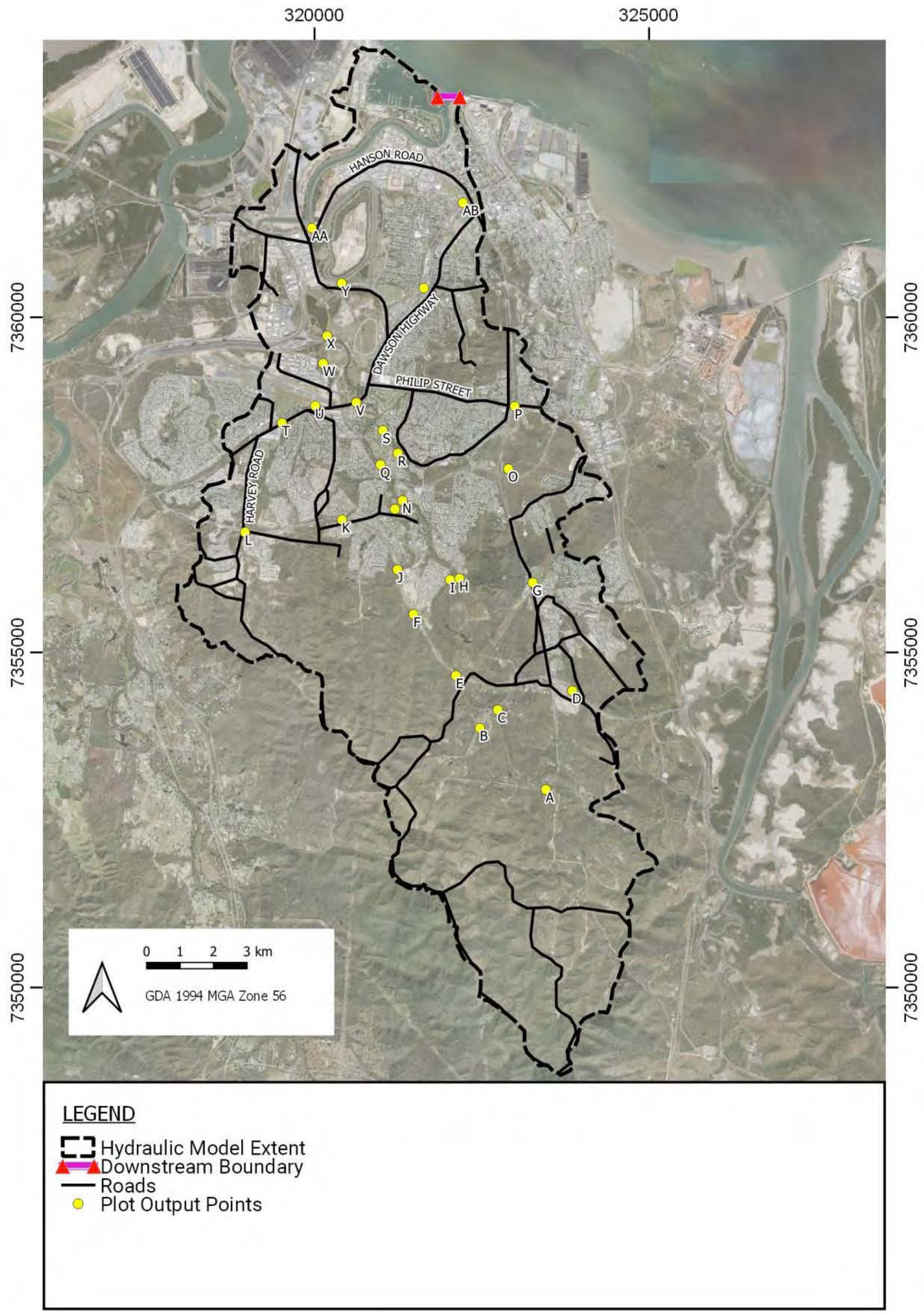


*Figure 6-6 Plot Output Point Locations*

### 6.2.3 Sensitivity Analysis

Further analysis was undertaken to assess the model's sensitivity to an increase in hydraulic structure blockages to assist in understanding the relative impacts of this particular parameter on model results.

The sensitivity analysis was undertaken on the 1% AEP 2100 climate change scenario to QUDM guidelines (2017). The sensitivity analysis parameters are provided in Table 6-5 and are based on values for severe storm scenarios (1% AEP storms and rarer).

*Table 6-5 Sensitivity Analysis Structure Blockage Parameters*

| Culvert/Bridge Conditions | Percentage Blocked |
|---|---|
| Inlet Height < 3 m, or Width < 5 m | 100% |
| Inlet Height > 3 m, or Width > 5 m | 25% |
| Clear Opening Height < 3 m | 100% |
| Clear Opening Height > 3 m | 25% |

Results indicate that the model is sensitive to a combination of the above blockages with notable increases in flood extent and depth in a number of areas throughout the catchment.

Figure 6-7 shows the afflux between the 1% AEP 2100 climate change scenarios (with structure blockage less no structure blockage). Blue highlights areas that were previously dry and are now wet and purple highlights areas that were previously wet and are now dry.

Overall there was a reduction in water levels within Auckland Creek which correlates with conveyance issues due to structural blockages and was dry/now wet areas throughout the catchment.

Sensitivity analysis mapping is provided in Appendix H.

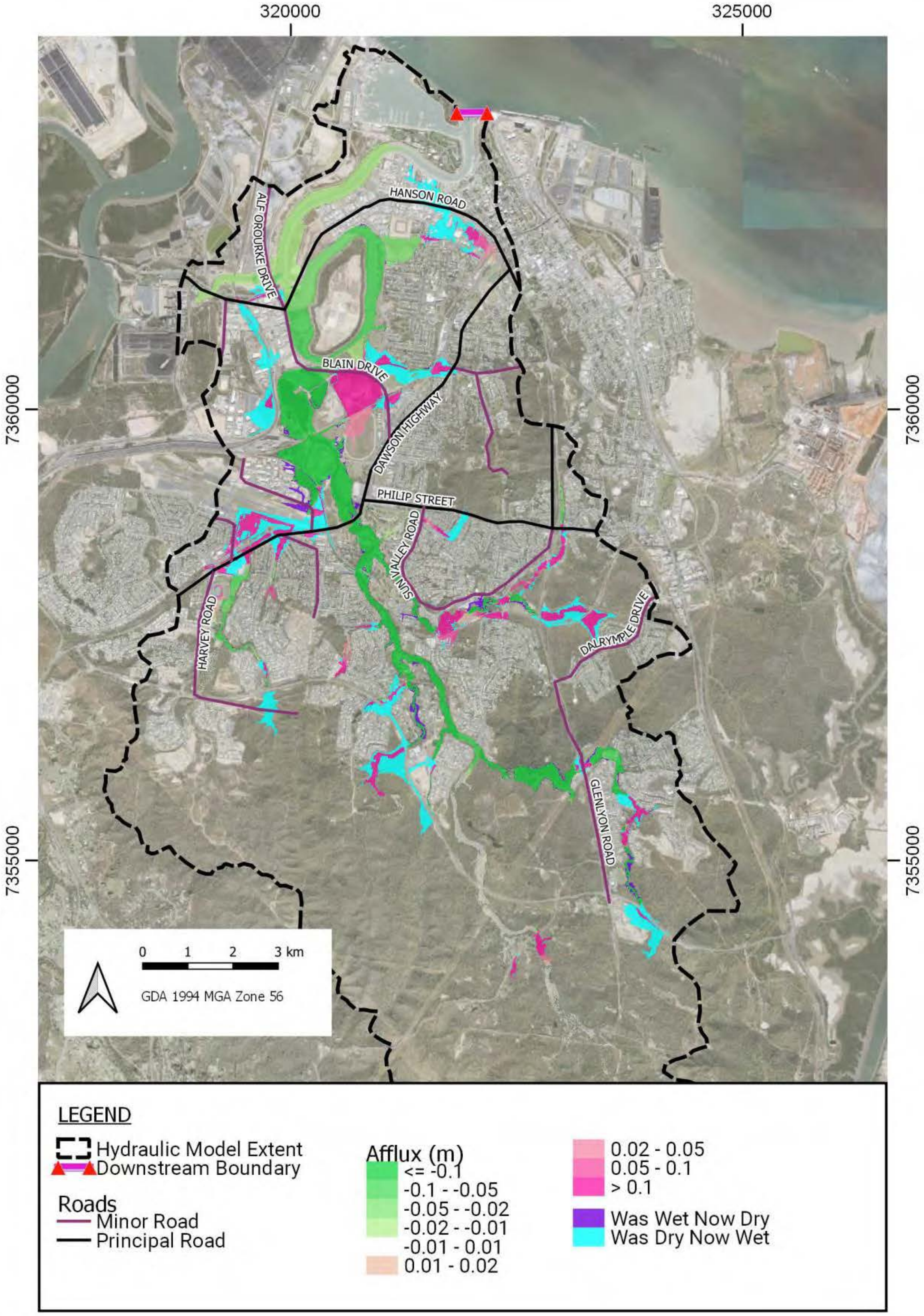


*Figure 6-7 1% AEP 2100 Climate Change Scenario Sensitivity Analysis Afflux Map*

# 7 SUMMARY

The Auckland Creek hydrologic and hydraulic models have been updated with the latest available data for the catchment. The hydrologic model has been calibrated to two recent historical rainfall events (March 23, 2017 and March 30, 2017) using rainfall data from the Gladstone Airport and Gladstone Radar rainfall gauges.

An estimate of the AEPs of the recorded rainfall during the two calibration events has indicated that the March 23, 2017 event was less than a 63% AEP event for both the Gladstone Airport and Gladstone Radar gauges for all storm durations. The March 30, 2017 event was between a 10% AEP and a 2% AEP event for storm durations of between 90 minutes and 6 hours.

Due to the short gauge record, an estimation of the AEP of the flow/water level at the Police Creek gauge could not be made at this time. Future studies may be able to estimate the AEPs once a longer record is available.

A bathymetric survey has been undertaken to provide the hydraulic model with the latest and most detailed bathymetry for Auckland Creek. In addition, several hydraulic structures that were found to either be missing or had parameters incorrectly assigned in the original hydraulic model were surveyed. This model has also had the roughness layer refined to better represent the existing conditions and improve model calibration.

The Auckland Creek flood model has been successfully calibrated to the March 23, 2017 and March 30, 2017 flood events using the best data available. Calibration to both events showed that the modelled and recorded water levels and timing of peaks were reasonably close. The difference between modelled and recorded peak levels during the March 30, 2017 event was minimal (0.05 m). The hydrograph shape was very similar for both the modelled and recorded levels at the Police Creek gauge. Calibration to the recorded water level points achieved mixed results, with the model results at more than half of the locations being within 0.2 m during the March 30, 2017 event.

The difference between recorded and modelled peak water levels during the March 23, 2017 event was 0.06 m and the timing was within approximately 5 minutes at the Police Creek gauge. However, the modelled peak water levels did not match the recorded water level points well with only one of the seven locations being within 0.3 m of the recorded levels and with two locations showing a difference in excess of 0.8 m. The model overestimated the water levels at all locations during the March 23, 2017 event. It should be noted however that it is unknown if the recorded water levels represent the flood peak. If the recorded levels do not represent the peak of the flood, the model is not overestimating the levels as significantly as the results would indicate.

Following hydraulic model calibration, several design event scenarios were run with mapping provided as listed below:

- Appendix D: Design storms (2% AEP to 0.2% AEP events);
- Appendix E: 2100 climate change events (1% AEP to 0.2% AEP events);
- Appendix F: 1% AEP HAT, 1% AEP Storm Surge and HAT (no rainfall); and
- Appendix G: PMP event mapping.

Based on the design event peak water levels the March 23, 2017 event was less than a 2% AEP event and the March 30, 2017 event was between a 2% AEP event and a 1% AEP event.

Hydraulic model results highlighted a number of areas and properties in the Auckland Creek catchment that experience inundation in a 2% AEP design storm event.

Coastal flooding hazards were considered and model results indicate that a significant area north of Hanson Road and along Lord Street, south of Auckland creek are affected by storm surge coupled with a 1% AEP rainfall event.

As per Gladstone Regional Council's planning policy, the Defined Flood Event (DFE) for the Auckland Creek Catchment will be based on the 1% AEP 2100 climate change scenario.

# 8 REFERENCES

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**IPCC (2014).** Pachauri R.K., Meyer L.A (editors). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Geneva, Switzerland, 2014

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