Regional Floodplain Database:

Hydrologic and Hydraulic Modelling - Caboolture River (CAB)

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Regional Floodplain Database Hydrologic and Hydraulic Modelling

Caboolture (CAB) **June 2012**

Moreton Bay Regional Council

Emergency Management Queensland

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Regional Floodplain Database Hydrologic and Hydraulic Modelling Caboolture (CAB)

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Title :	Regional Floodplain Database, Hydrologic and Hydraulic Modelling: Caboolture (CAB)
Author :	Melissa Hovey \ Richard Sharpe
Synopsis :	Report outlining the study data, methodology and delivery of the detailed modelling of the Caboolture catchment, as part of Moreton Bay Regional Council's Regional Floodplain Database (Stage 2, Package 4) project.

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1 INTRODUCTION

Moreton Bay Regional Council (MBRC) is currently undertaking Stage 2 of developing the Regional Floodplain Database (RFD). The RFD includes the development of coupled hydrologic and hydraulic models for the entire local government area (LGA) that are capable of seamless interaction with a spatial database to deliver detailed information about flood behaviour across the region.

Stage 2 includes the detailed hydrologic and hydraulic modelling of 5 packages, which cover 11 catchments in the MBRC LGA. This report discusses the study data, methodology and results for Stage 2, Package 4 of the RFD (i.e the detailed hydrologic and hydraulic modelling) for the Caboolture catchment. Furthermore, this stage will form the basis of Stage 3 of the RFD, which aims to analyse the results of the detailed modelling for the purposes of understanding and managing flood risk in the MBRC LGA.

1.1 Scope

The detailed models of the Caboolture catchment will provide MBRC with an enhanced understanding of the flood behaviour in the catchment for a large range of flood events, from the 1 year Average Recurrence Interval (ARI) event to the Probable Maximum Flood (PMF). The detailed model was developed from a pre-existing broad scale model that was developed by MBRC as part of the RFD. The following primary alterations were made to convert the broad scale model to a detailed model:

- The model computational grid resolution was refined from 10m to 5m;
- The latest 2009 LiDAR (**L**ight **D**etection **A**nd **R**anging) topographic data was used, incorporating terrain modifiers to enhance the capture of road embankments and stream lines in the Digital Elevation Model (DEM);
- Additional hydraulic structures were included in the model; and
- Utilisation of detailed land use delineation (developed as part of Stage 1, but not included in broadscale models).

A broad range of design flood events were simulated, as well as a number of sensitivity analyses which investigated the influence of various parameters and conditions on model results. The model results provide detailed flood information such as levels, depths, velocities, hazard, flood extents and the time at which flooding occurs.

1.2 Objectives

Key objectives of this study are as follows:

- Utilise the existing broadscale model to develop a detailed and dynamically linked two-dimensional and one-dimensional (2D/1D) hydrodynamic model of the Caboolture Catchment using input data that were determined and provided by MBRC or other consultants; and
- Provision of all relevant flood information obtained from the modelling, which will form the base input data for Stage 3 of the RFD.

1.3 General Approach

The general approach for this study is summarised as follows:

- Review existing broad scale WBNM hydrologic model and results;
- Review existing broad scale TUFLOW modelling;
- Refine the TUFLOW modelling to include a refined grid size and any additional structure and topographical information;
- Investigate the feasibility of calibrating and/or verifying the combined WBNM and TUFLOW models using two historical events. There was sufficient historical information available for this task, therefore calibration was undertaken;
- Undertake a critical storm duration assessment for the 10 year ARI event, 100 year ARI event and the PMF;
- Simulate a large range of design flood events (1, 2, 5,10, 20, 50,100, 200, 500, 1000, 2000 year ARI events and PMF events) for up to three selected critical durations;
- Assess model sensitivity to future landuse patterns, Manning's 'n', structure blockage, climate change and downstream boundary conditions;
- Provide a concise report describing the adopted methodology, study data, model results and findings. The emphasis of the RFD project is on digital data management. Therefore only the 100 year ARI event was mapped in this report; and
- Compilation of models and model outputs for provision to MBRC.

1.4 Related Sub-Projects (RFD Stage 1 and Stage 2 Pilot)

The following RFD sub-projects provide input data and/or methodologies for the Caboolture Stage 2 models:

- **1D – Hydrologic and Hydraulic Modelling (Broadscale),** sub-project 1D defined model naming conventions and model protocols to be used in this sub-project (BMT WBM, 2010);
- **1E – Floodplain Topography (2009 LiDAR) including 1F, 2E, 2I,** sub-project 1E provided the topographic information, such as model Z points layer and digital elevation models (DEM). This was achieved using a bespoke DEM tool developed for the RFD (Worley Parsons, 2010a);
- **1G – Hydrography (MBRC),** sub-project 1G supplied the subcatchment delineation of the catchment including stream lines and junctions (used in the WBNM model);
- **1H – Floodplain Landuse,** sub-project 1H delivered the current percentage impervious cover (utilised in the hydrologic model) and the roughness Manning's 'n' values (utilised in the hydraulic model) (SKM, 2010);
- **1I – Rainfall and Stream Gauges Information Summary (MBRC),** sub-project 1I summarised available rainfall and stream gauge information for the study area;
- **2C – Floodplain Structures (Culverts),** sub-project 2C supplied the GIS layer of the culverts to be included in the model (Aurecon, 2010). A TUFLOW-specific MapInfo file was provided,

however appropriate model linkages between the culvert data and the 2D domain had to be established;

- **2D - Floodplain Structures (Bridges),** sub-project 2D provided a GIS layer of the major bridges and foot bridges (Aurecon, 2010). A TUFLOW-specific MapInfo file was provided;
- **2F – Floodplain Structures (Trunk Underground Drainage),** sub-project 2F provided trunk underground drainage information;
- **2G - Floodplain Structures (Basins),** sub-project 2G consolidated and surveyed the existing basin information in the study area (Aurecon, 2010);
- **2I - Floodplain Structures (Channels),** sub-project 2I identified channels within the catchment (Aurecon, 2010);
- **2J – Floodplain Landuse (Historic and Future),** sub-project 2J defined the historic and future percentage impervious cover (utilised in the hydrologic model) and the roughness (Manning's 'n') values representing landuse for historical events (utilised in the hydraulic model) (SKM, 2010);
- **2K – Flood Information Historic Flooding,** sub-project 2K collected and surveyed flood levels for the historic May 2009 and February 1999 flood event (GHD, 2010);
- **2L – Design Rainfall and Infiltration Loss,** sub-project 2L developed the hydrologic models for the catchment and provided the design rainfall hydrographs for the pilot study (Burpengary Creek catchment) TUFLOW models (Worley Parsons, 2010b). A similar methodology was adopted for the Caboolture catchment;
- **2M – Boundary Conditions, Joint Probability and Climate Risk Scenarios,** sub-project 2M defined the boundary conditions and provided recommendations in regards to joint probability (i.e. occurrence of storm surge in combination with river flooding events, or river flooding in combination with local tributary flooding). This project also recommended certain sea level rise and rainfall intensity values to assess Climate Risk Scenarios (SKM, 2012a); and
- **2N – Floodplain Parameterisation,** sub-project 2N provided recommendations of the floodplain parameters, such as a range of values for various impervious percentages for various landuse types (i.e. residential or rural landuse, dense vegetation), a range of values for various roughness types (i.e. long grass, dense vegetation) and structure losses (SKM, 2012b).

2 AVAILABLE DATA

The following provides a list of the data available for this study:

- **Floodplain Topography** – MBRC provided a DEM and Z points that were generated using a tool that was developed and run by Worley Parsons. The DEM resolution was 2.5m (half the 2D computational grid resolution). The topography is based on LiDAR data collected in 2009 and provided by the Department of Environment and Resource Management (DERM);
- **Hydrography (MBCR)** – Catchment delineation and hydrology model dataset provided by MBRC;
- **Floodplain Landuse** (Current and Future) – Polygon data for 9 different landuse categories established as part of Stage 1;
- **Floodplain Structures (Culverts and Bridges)** – As-constructed bridge plans for selected minor roads in MBRC LGA (provided by MBRC where available). Additional structure survey data, as undertaken by MBRC when no structure data was available. State controlled roads and minor road GIS layers provided by MBRC;
- **Design Rainfall** – Amendment of WBNM models, development of design simulations and provision of design rainfall hydrographs (from the 1 year ARI to the PMF);
- **Boundary Conditions, Joint Probability and Climate Risk Scenarios** – Report with recommendations for boundary conditions, joint probability and climate change scenarios; and
- **Floodplain Parameterisation** information, specifically about impervious percentages for various landuse types, roughness types and structure losses.

3 METHODOLOGY

3.1 Data Review

A number of data reviews were undertaken by BMT WBM. These reviews concern:

- The infrastructure data within the catchments;
- The historical flooding information of the catchments; and
- The broadscale subcatchment delineations.

The review and analysis of these data was compiled into three reports and issued to MRBC prior to completion of a draft detailed model. A summary of the data review reports is described below.

3.1.1 Infrastructure Data Assessment

This report reviewed the available infrastructure data provided by MBRC and the Department of Transport and Main Roads (DTMR) and identified any infrastructure data that needed to be collected for the detailed modelling of the Caboolture Catchment. Furthermore, this required data was prioritised into two categories: Priority A data (data which is critical for a high quality model) and Priority B data (all other data for which assumptions can be used and still achieve a relatively high quality model).

The key findings from this report include:

- 9 DTMR bridge and culvert structures were prioritised as category A, along with 14 additional crossings;
- 3 DTMR bridge and culvert structures were prioritised as category B, along with 41 additional crossings; and
- The details for the Caboolture River weir were required.

A full copy of this report is provided in Appendix A.

3.1.2 Calibration and Validation

The available information on historical flooding was provided by MBRC and reviewed as part of this report, along with the collection of gauge data from the Bureau of Meteorology (BoM). The feasibility of using historic flood events for calibrating the Caboolture model was assessed. The assessment concluded that there is sufficient data available in the catchment to perform calibration and validation to historical flood events, which was as follows:

- The January 2011 flood event was used for the model calibration; and
- The May 2009 flood event was used for the model verification.

A full copy of this report is provided in Appendix C.

3.1.3 Hydrography Review

The subcatchment delineation completed as part of Stage 1 was reviewed; a copy of the report letter is provided in Appendix B. The review recommended refinement of the subcatchment delineation in some locations (in the upper reaches of the catchment). MBRC adopted most of these recommendations, and re-issued the subcatchment delineation.

3.2 Hydrologic Model

The existing hydrological WBNM model for the Caboolture catchment was reviewed and updated using relevant data, utilising the WBNM 2010 beta version. The WBNM software was nominated by MBRC as the hydrologic software package for the RDF, and was used to model the design events (utilising existing landuse) and a future landuse scenario.

The subcatchment delineation and hydrology model were supplied by MBRC. Detailed hydrologic model parameters, such as adopted losses, design gauge locations and Intensity Frequency Duration (IFD) data, was based on methods adopted for the Burpengary Stage 2 Pilot Study and SKM (2010). The following methods were used for definition of design storms:

- 1 year ARI to 100 year ARI – AR&R (The Institution of Engineers Australia, 2001) was used to define rainfall depths and rainfall temporal patterns for storm events from 1 year ARI to 100 year ARI;
- 200 year ARI to 2000 year ARI – CRC Forge was used to define rainfall depths and temporal patterns were based on the temporal patterns adopted for the PMF events; and
- PMF – The Generalised Short Duration Method (GSDM) and the Revised Generalised Tropical Storm Method (GTSMR) were used, depending on the storm duration, to determine the Probable Maximum Precipitation and rainfall temporal patterns.

The flows derived from the hydrologic model were used as inflow to the hydraulic model.

3.3 Hydraulic Model

3.3.1 Model Software

Because of the complex nature of floodplain flow patterns in urban and rural catchments, MBRC has adopted TUFLOW, a dynamically-linked 2D/1D hydrodynamic numerical model, to predict the flood behaviour of the catchments in their LGA. TUFLOW has the ability to:

- Accurately represent overland flow paths, including flow diversion and breakouts (2D modelling);
- Model the waterway structures of the entire catchment with a relatively high level of accuracy (1D or 2D modelling);
- Dynamically link components of the 1D models (i.e. culverts) to any point in the 2D model area; and
- Produce high quality flood map output (i.e. flood extent, flood levels, depths, velocities, hazard and stream power), which are fully compatible with Geographic Information Systems (GIS).

3.3.2 Model Geometry

The TUFLOW model was based on two sets of Z points provided by MBRC for two computational grid resolutions: 5m and 10m. These Z point layers were used to develop a 5m grid model and a 10m grid model. The 5m grid resolution model was used for events up to and including the 100 year ARI Event. The 10m model was used for events larger than the 100 year ARI event, and also included the sensitivity runs. The two grid resolutions were adopted due to the catchment size and the model run times; i.e. the 10 grid resolution model was used to expedite the model run times. The origin of the Z points was used to set the origin of the 2D domain, and 2D domain orientation was set to zero (or horizontal; i.e. no rotation).

The elevation information was based on 2009 ALS data that was processed using a bespoke tool (processed by Worley Parsons). Stream and road modifiers were developed and supplied to MBRC to be incorporated in the DEM tool. These terrain modifiers generate break lines to capture streams gullies and road embankments in the Z points layer and DEM.

Figure 3-1 illustrates the Caboolture model layout.

3.3.3 Model Structures

The Caboolture catchment is moderately urbanised with large vegetated areas, particularly in the upper catchment. The waterways within the catchment were represented in the 2D domain using break line terrain modifiers, with invert levels inspected from a combination of the supplied DEM. Culvert crossings were typically represented in the model as 1D structures, with flow over these structures modelled within the 2D domain. Bridges and footbridges were represented in the 2D domain (using TUFLOW layered flow constriction features). The hydraulic structure details were provided by MBRC in the form of engineering drawings or digital data derived from a survey.

The adopted exit and entry loss coefficients applied to the hydraulic structures were based on values reported in SKM (2012b). Structure locations are shown on Figure 3-1.

3.3.4 Landuse Mapping

Landuse mapping was used to define the spatially varying hydraulic roughness within the hydraulic model. In total, ten different types of landuse were mapped and provided by MRBC, together with associated Manning's 'n' values as presented in Table 3-1 and Figure 3-2.

Table 3-1 Hydraulic Model Landuse Categorisation

Landuse Type	Manning's 'n' Roughness Coefficient
Roads/Footpaths	0.015
Waterbodies	0.030
Low Grass/Grazing*	Ranging from 0.025 at 2 m depth to 0.25 a 0m depth
Crops	0.040
Medium Dense Vegetation*	Ranging from 0.075 up to a depth of 1.5m and 0.15 above 1.5m
Reeds	0.08
Dense Vegetation*	Ranging from 0.09 up to a depth of 1.5m to 0.18 above 1.5m
Urban Block (> 2000m^2)	0.300
Buildings	1.000
*Depth varying (linear) Manning's 'n' roughness was applied.	

Three of the landuse categories used a depth varying Manning's roughness. This allows the Manning's roughness to be adjusted depending on the depth of water flowing over a surface. For example, when there is a small depth of water over grass, the resistance is high, and thus the Manning's roughness should be high. However, as the water gets deeper, the resistance of the grass is less, thus the Manning's roughness should be low. The depth varying Manning's roughness allows this to be represented.

In highly developed blocks, larger than 2000m^2, the urban block category was used (Manning's 'n' of 0.3). For areas outside the high density residential development, an individual building layer, showing the footprint of the building was used (Manning's 'n' of 1.0).

3.3.5 Model Boundaries

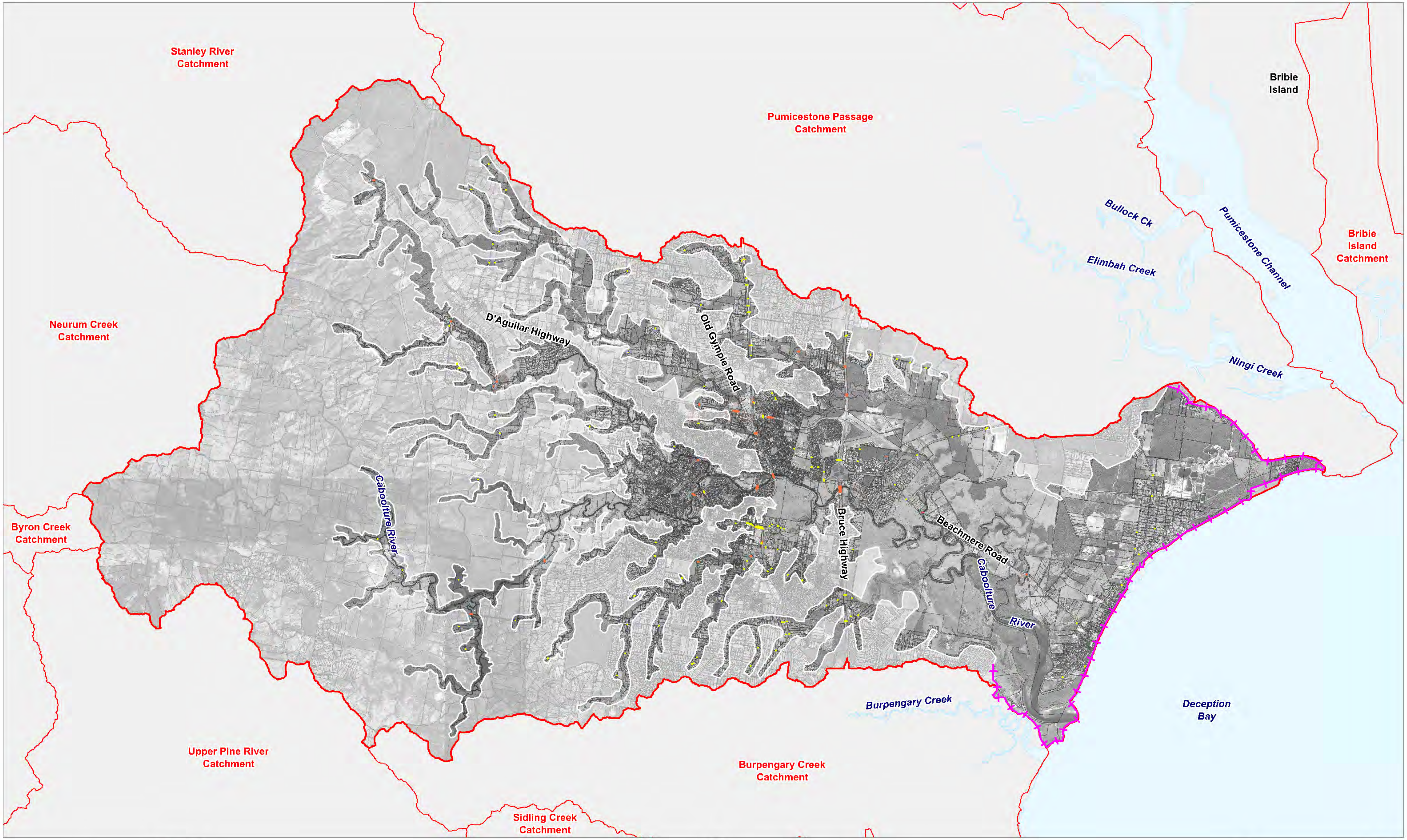
The results of the WBNM hydrologic model were used to generate rainfall inflows for the hydraulic model for all design events, as discussed in Section 0. The inflows were applied to the 2D domain using a flow-time source boundary spread over each subcatchment. This technique applies the inflow at the lowest grid cell in a subcatchment initially and then subsequently to all wet cells in that subcatchment.

The downstream boundary conditions, joint probability and climate change scenarios were based on recommendations in SKM (2012a). A static flood level was applied at the downstream boundary utilising the mean high water spring (MHWS) for all design events (see Table 3-2).

Sensitivity tests were undertaken for the downstream boundary (refer to Section 3.6).

Table 3-2 Downstream Boundary Water Level

Description	Level (mAHD)
Mean High Water Spring Tide (MHWS)	0.82



LEGEND

- Caboolture Catchment Boundary
- Hydraulic Model Boundary
- Cadastral Boundaries
- Downstream Boundary
- Culvert
- Bridge

Title: **Hydraulic Model Layout**

Figure: 3-1

Rev: A

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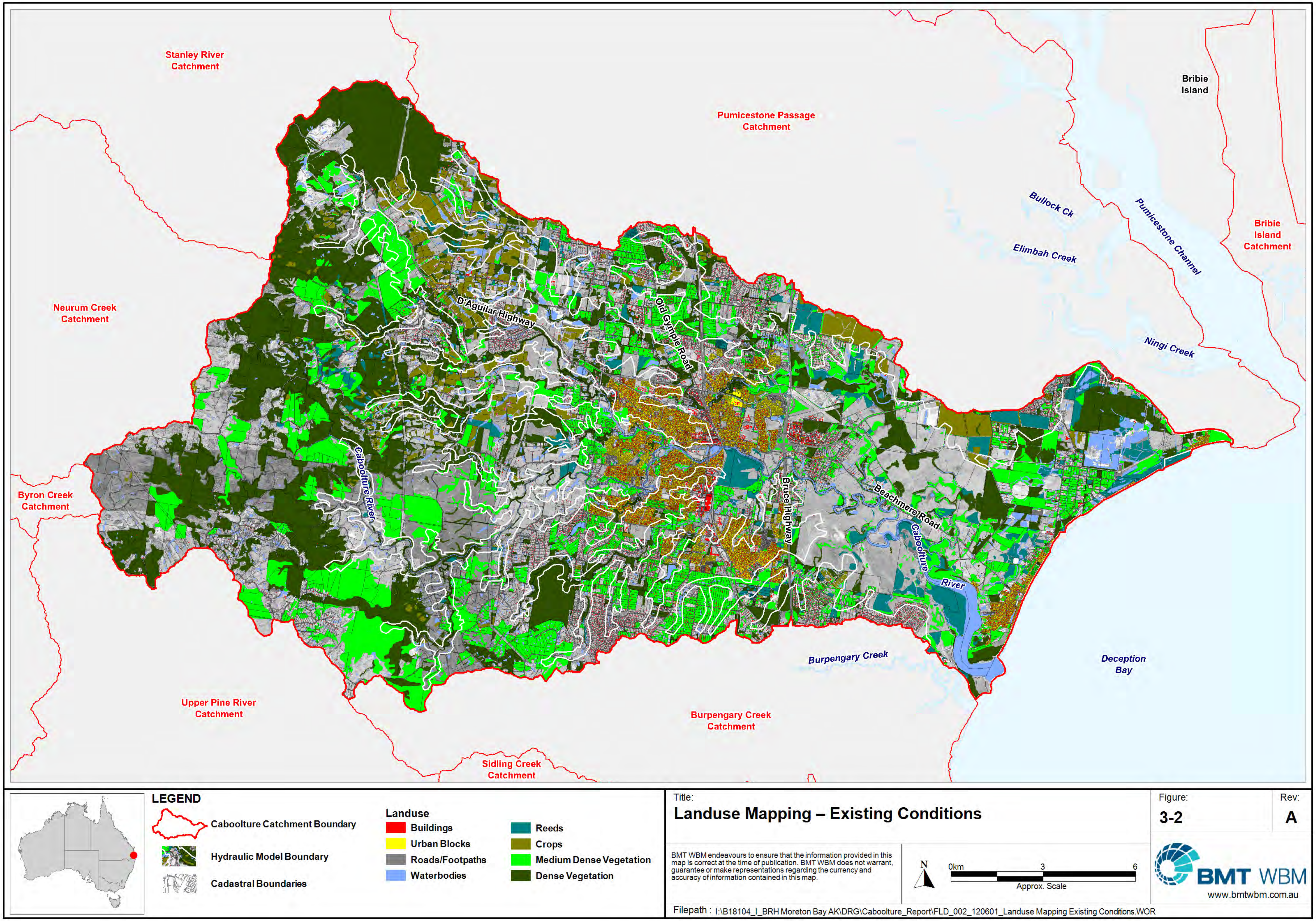

Title:

Landuse Mapping – Existing Conditions

Figure: 3-2

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3.4 Model Calibration and Verification

Where possible, MBRC have sought to calibrate and verify the models in their LGA to historical flood events. The Caboolture catchment hydraulic model was calibrated and verified against the following two historical events:

- January 2011 (Calibration event); and
- May 2009 (Verification event).

These events were chosen due to the availability of rainfall and river stream gauge data and the availability of flood marks. A detailed flood survey was undertaken, and the flood marks collected by MBRC were provided for comparison with the modelled results. Details of the calibration feasibility assessment are documented in Appendix C.

3.5 Design Flood Events

This section describes the design storm conditions that were used in the hydrodynamic modelling. Design storm events are hypothetical events that are used to estimate design flood conditions. They are based on probability of occurrence, usually specified as an Average Recurrence Interval (ARI).

3.5.1 Critical Storm Duration Assessment

An assessment of critical storm durations (storm duration/s that results in the highest peak flood level) was undertaken. The critical durations were selected based on the hydraulic model results, rather than the hydrological model results. This means that the selected critical durations were selected based upon the maximum flood levels rather than flows. Separate assessments were undertaken for three representative flood events;

- 10 year ARI event, to represent smaller events (1, 2, 5 and 10 year ARI events);
- 100 year ARI event, to represent larger events (20, 50 and 100 year ARI events); and
- Probable maximum flood (PMF), to represent extreme events (200, 500, 1000 and 2000 year ARI events and the PMF).

To determine the critical storm durations for the Caboolture model, the following methodology was adopted:

1. Hydrologic and hydraulic modelling of a range of storm durations (1hr, 3hr, 6hr, 12hr, 24hr and 48hr) for the 10 year, 100 year and PMF events; 5 hour storm duration was also tested for the PMF event.
2. Mapping of the peak flood level results for the ‘maximum envelope’ of all the storm durations for the three representative events.
3. Mapping of the peak flood level results for the ‘maximum envelope’ of selected storm durations for the three representative events.
4. Difference comparison between the mapped peak flood levels for selected critical durations and the results accounting for *all* storm durations.

5. The critical duration combination resulting in the lead difference compared with the mapping of the full envelope of durations was adopted. Selection of the critical durations was based on the storm durations generating the highest flood levels across the most widespread and developed areas.

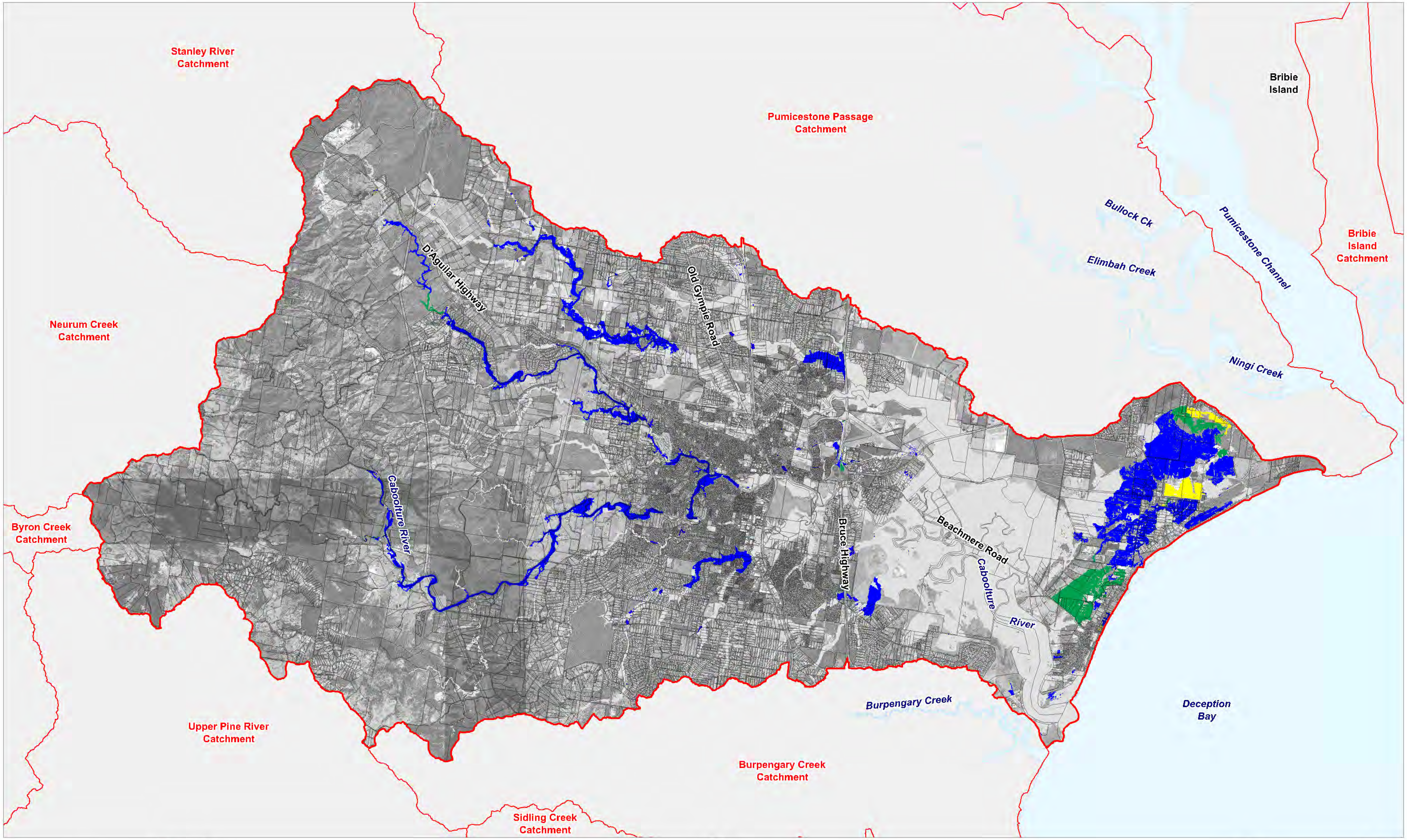
A summary of the selected critical storm durations for all events assessed is outlined in Table 3-3.

The difference comparison for the 10 and 100 year ARI and the PMF peak flood levels (as described in step 4 above) is shown in Figure 3-3 to Figure 3-5. The figures illustrate that the selected critical durations generally capture the peak flood levels across the site in developed areas. There are some localised areas where flood levels are under predicted.

Table 3-3 Critical Storm Duration Selection

Assessment Event	Selected Critical Durations	Adopted Event
10 year ARI	3, 6 and 12 hour storm	1, 2, 5 and 10 year ARI
100 year ARI	3, 6 and 12 hour storm	20, 50 and 100 year ARI
Probable Maximum Flood	3, 5 and 24 hour storm	200, 500, 1000, 2000 year ARI and PMF

This process was undertaken in consultation with MBRC, as their knowledge on local catchment and development issues was a factor in the decision-making and selection of the critical durations.



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Caboolture Catchment Boundary

Cadastral Boundaries

Peak Flood Level Difference (m)

- < -1.00
- -1.00 to -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.01
- No Change

Title:

Critical Duration Assessment
Peak Flood Level Difference – 10 Year ARI

Figure: 3-3

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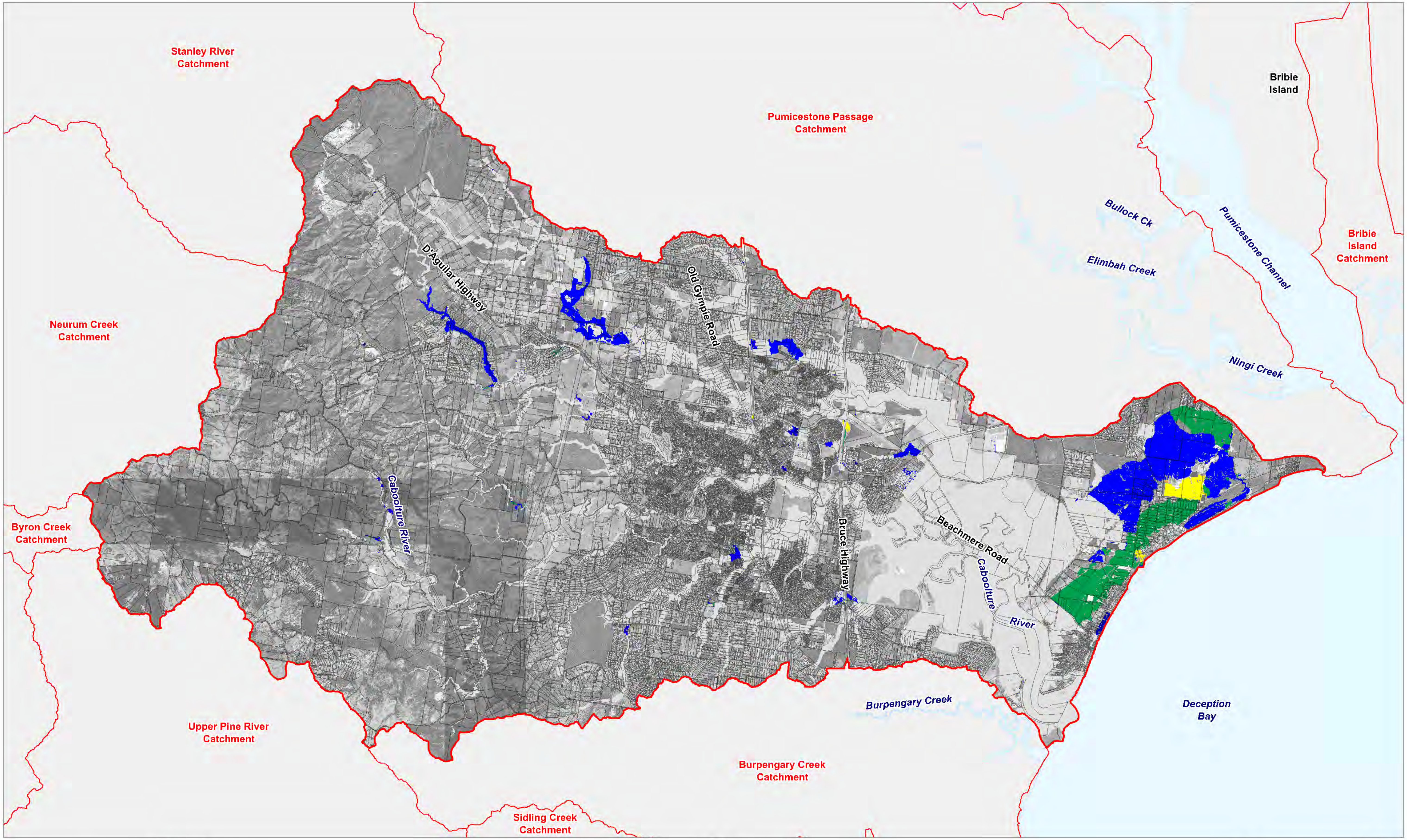

LEGEND

Caboolture Catchment Boundary

Cadastral Boundaries

Peak Flood Level Difference (m)

- < -1.00
- -1.00 to -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.01
- No Change

Title:

Critical Duration Assessment
Peak Flood Level Difference – 100 Year ARI

Figure: **3-4**

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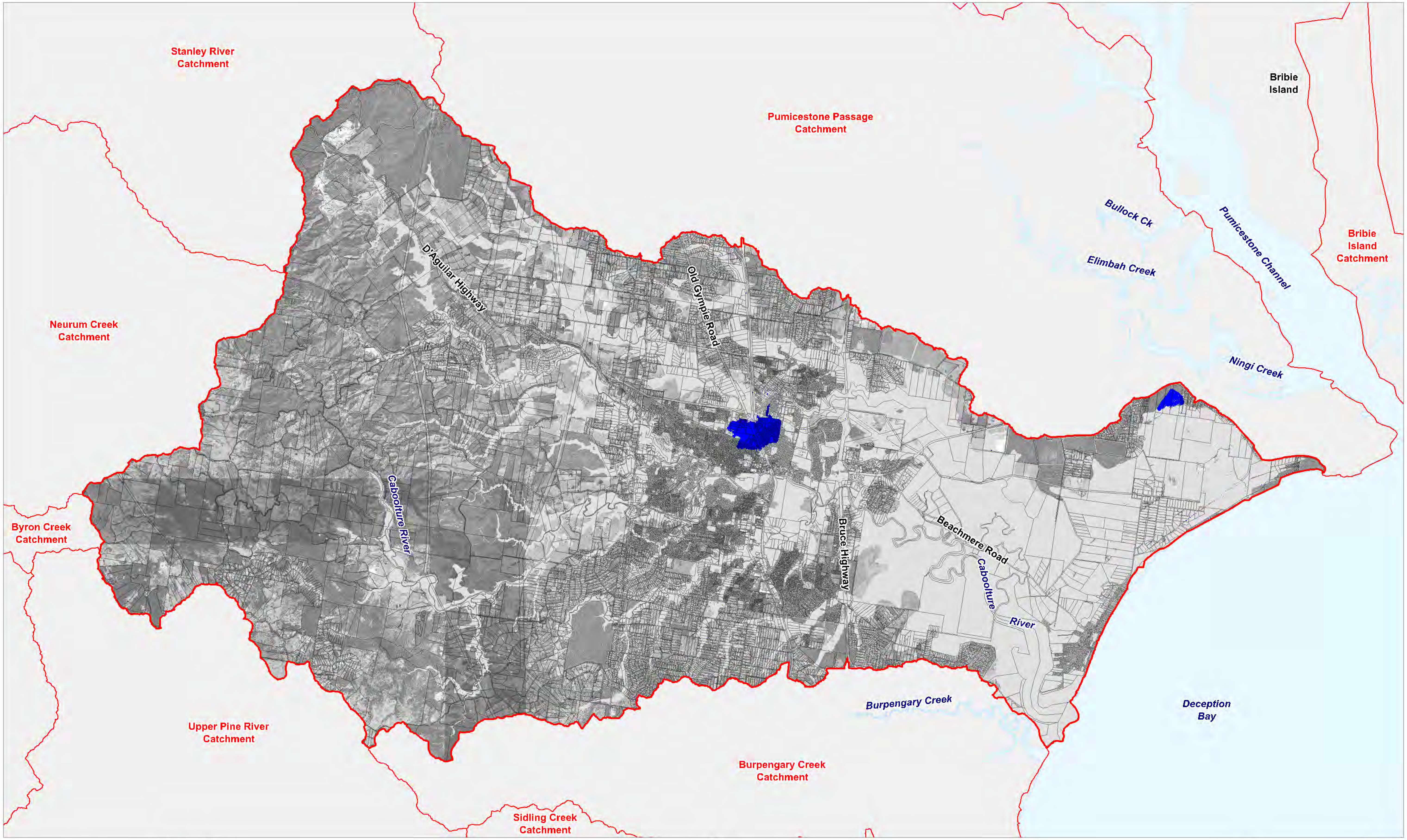

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Caboolture Catchment Boundary

Cadastral Boundaries

Peak Flood Level Difference (m)

- < -1.00
- -1.00 to -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.01
- No Change

Title:

Critical Duration Assessment
Peak Flood Level Difference – PMF

Figure: **3-5**

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3.5.2 Design Event Simulations

The Caboolture model was simulated for a range of ARI and storm durations and a 100 Year Embedded Design Storm (EDS). MBRC requested the use of a single EDS which synthesises a range of storm duration hyetographs into one representative design hyetograph. The EDS is useful for general investigations into changes in model parameters and catchment characteristics, as it reduces the number of model runs required (no need to run multiple storm durations).

MBRC advised that the100 year ARI 15 minute in 270 minute Embedded Design Storm was to be adopted. The adopted EDS storm was used as the base design storm for the sensitivity analyses.

In summary, the Caboolture model was simulated for the following design events:

- The 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000 year ARI events and the PMF events for the selected critical storm durations; and
- The 100 year Embedded Design Storm (EDS) for a 15 minute in 270 minute envelope storm.

3.6 Sensitivity Analysis

3.6.1 Future Landuse Analysis

Three future landuse scenarios were assessed using future landuse data provided by MBRC. The future scenarios did not include a change in rainfall intensities or sea level rise due to climate change. The 100 year EDS flood event was used.

The hydrologic model utilises a ‘fraction impervious’ parameter which described the proportion of each subcatchment where water is not able to infiltrate, i.e. there are no rainfall losses on paved surfaces. If the fraction impervious increases, there will be more rainfall runoff and quicker concentration of flows. The fraction impervious in each subcatchment of the WBNM model was updated to reflect the future landuse scenario provided by MBRC.

Landuse is defined in the hydraulic model through the materials layer. This information covers the entire hydraulic model extent and describes landuse and the Manning’s ‘n’ roughness values associated with each type of landuse. The materials layer was updated to reflect the future landuse scenario (change in vegetation density).

The landuse scenarios simulated included:

- **Future Landuse Scenario 1:** Investigated the impact of increased vegetation in the floodplains. This involved changing the ‘medium dense vegetation’ material class to a ‘high dense vegetation’ class and changing the ‘low grass/grazing’ material class to a ‘medium dense vegetation’ class.
- **Future Landuse Scenario 2:** Investigated the impact of an increase in residential development. The hydrology model was updated with forecast future development (provided by MBRC) to estimate future inflows for the TUFLOW model.
- **Future Landuse Scenario 3:** Investigated the impact of an increase in residential area and increased vegetation in floodplains. This scenario combines future landuse scenarios 1 and 2.

3.6.2 Hydraulic Roughness Analysis

The sensitivity of the model to landuse roughness (Manning's 'n') parameters was undertaken with the 100 year EDS design event. All Manning's 'n' values in the 2D domain were increased by 20%.

3.6.3 Structure Blockage Analysis

A blockage scenario was run to simulate the effects of waterway crossing (culverts) becoming blocked during a flood event. This is a reasonably common occurrence and is the result of debris being washed into the waterways during a flood. Recent storm event showed that blockages are generally caused by debris, or larger items, such as tree stems, wood planks, shopping trolleys or even cars. Blockages reduce the capacity for water to flow through stormwater infrastructure and force water out of the channel, often increasing overland flooding.

A moderate blockage scenario was adopted from the SKM *Floodplain Parameterisation* report (2012b), and includes:

- A full blockage is applied if the culvert diagonal is less than 2.4m; and
- A 15% blockage is applied if the culvert diagonal is greater than 2.4m.

3.6.4 Climate Change and Downstream Boundary Condition Analysis

A climate change and storm tide assessment investigated the possible impact of a storm tide and projected increases in sea level rise and rainfall intensity on flooding in the catchment. In total 6 scenarios were assessed:

- **Climate Change Scenario 1:** Investigated the impact of an increase in rainfall intensity of 20% (as per SKM (2012a) *Boundary Conditions, Joint Probability and Climate Change* Report);
- **Climate Change Scenario 2:** Investigated the impact of an increased downstream boundary of 0.8m due to predicted sea level rise;
- **Climate Change Scenario 3:** Investigated the impact of an increase in rainfall intensity and an increased downstream boundary. This scenario combines climate change scenarios 1 and 2;
- **Storm Tide Scenario 1:** Modelled a dynamic storm tide. No rainfall is applied and a dynamic storm tide (100 year current) boundary was applied (from the *Storm Tide Hydrograph Calculator* spreadsheet, developed by Cardno Lawson Treloar (2010). The MBC-016 reference point was used);
- **Storm Tide Scenario 2:** Investigated the impact of a 100 year static storm tide level (2.5mAHD) with concurrent 100 year EDS rainfall event; and
- S**torm Tide Scenario 3:** Investigated the impact of an increase in rainfall and an increase in sea level rise. An increase in rainfall of 20% was applied combined with a static storm tide level (100 year GHG) + 0.8m, resulting in a final static storm tide level of 3.6mAHD.

4 RESULTS AND OUTCOMES

4.1 Calibration and Verification

4.1.1 Overview

Calibration and verification of the modeling was undertaken for the following two events:

1. The January 2011 flood event was used as a calibration event; and
2. The May 2009 flood event was used as a verification event.

Measured rainfall data was used in the hydrology model to estimate runoff flows through the catchment. These flows were then routed through the TUFLOW model, with the downstream boundary adjusted to represent the expected tidal conditions during the historical events.

MBRC provided a number of surveyed peak flood marks in the catchment for the two historical events. Measured water levels at three stream gauges were also provided for the analysis: Wamuran, Upper Caboolture and Caboolture Water Treatment Plant (WTP) gauges. These measured water levels were compared to the modelled water levels, and the model parameters were adjusted a number of times to improve the correlation between measured and modelled flood levels. Full details of the calibration/verification can be found in the model calibration report in Appendix C.

Following the calibration and verification exercise (and subsequent to the model calibration report in Appendix C), MBRC selected the final hydraulic roughness parameters in light of the calibration results across the whole region. These hydraulic roughness values are listed in Table 3-1. The results using the final adopted parameters are discussed below.

4.1.2 January 2011 Results

Comparisons of the measured and modelled water levels for the January 2011 flood are shown in Figure 4-1 to Figure 4-4.

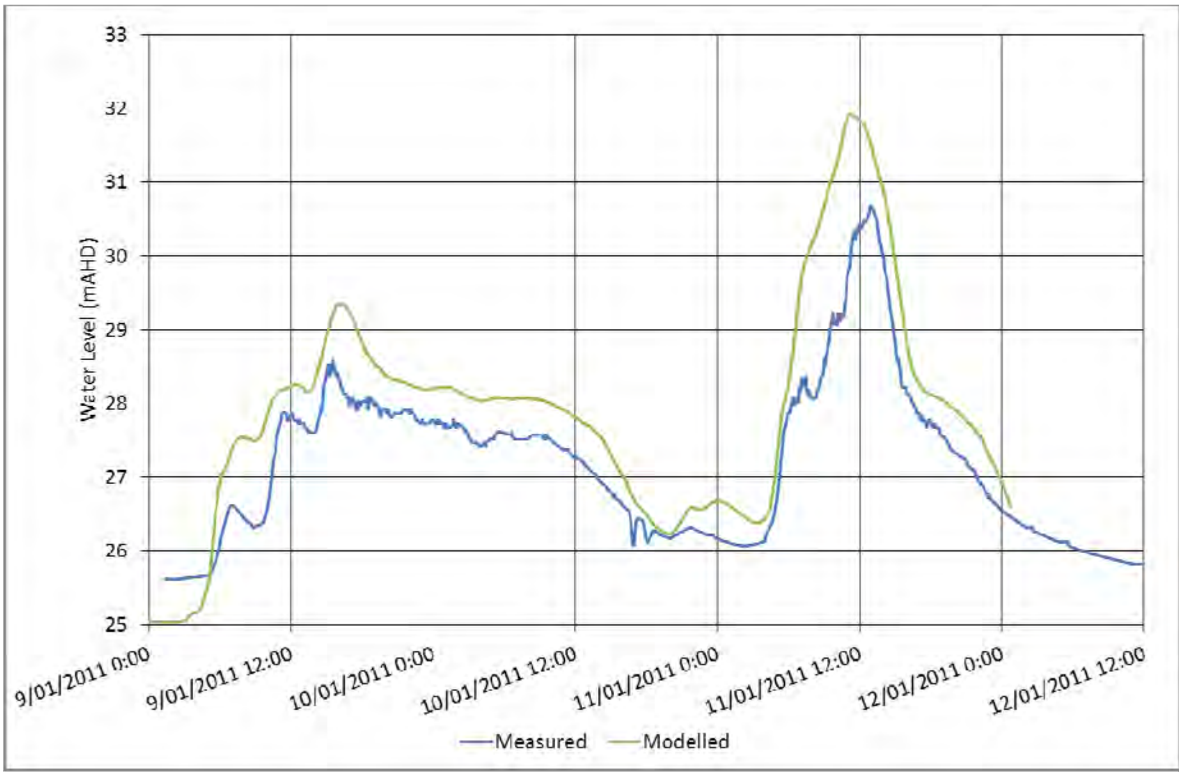

Figure 4-1 Flood Level Comparison at Wamuran Gauge for January 2011

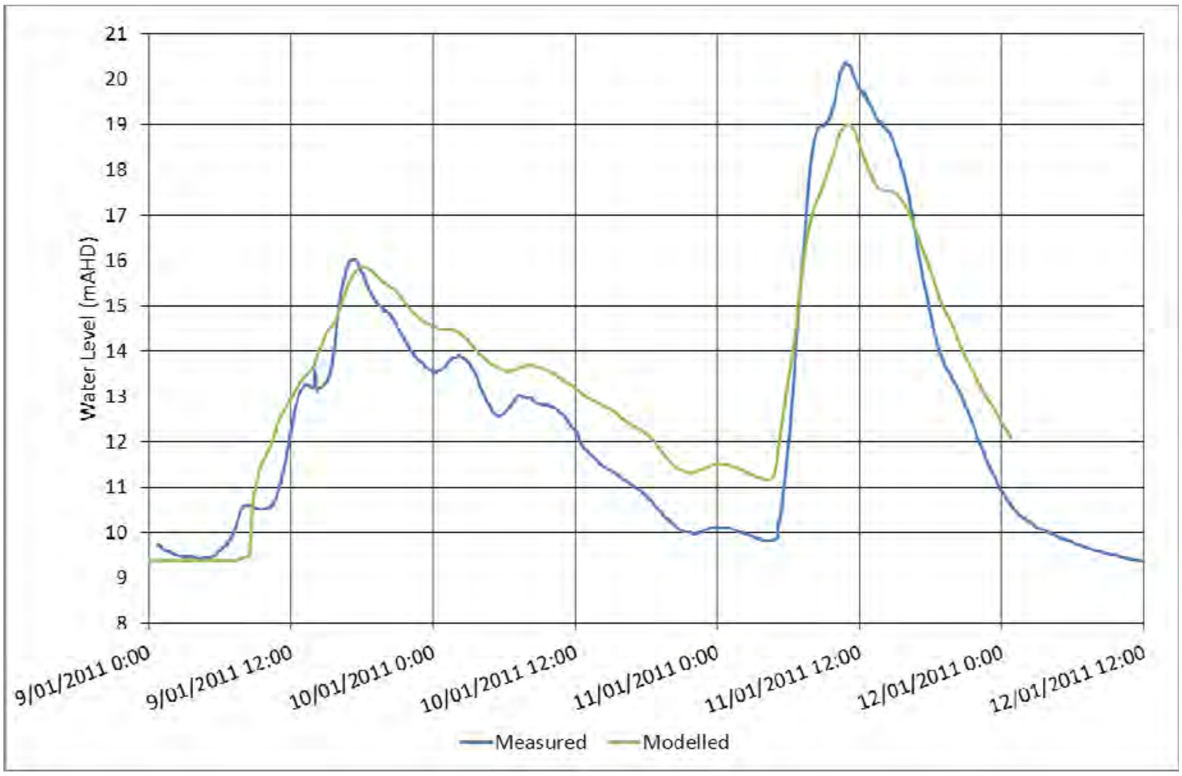

Figure 4-2 Flood Level Comparison at Upper Caboolture Gauge for January 2011

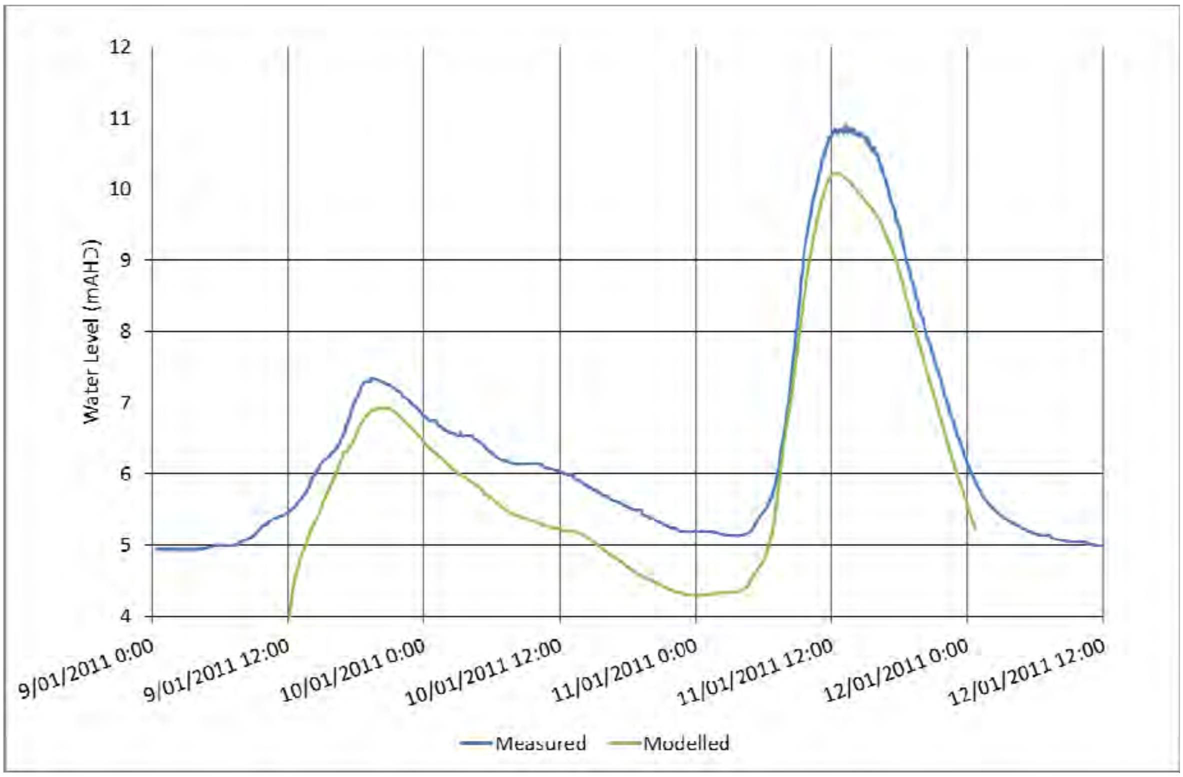

Figure 4-3 Flood Level Comparison at Caboolture WTP Gauge for January 2011

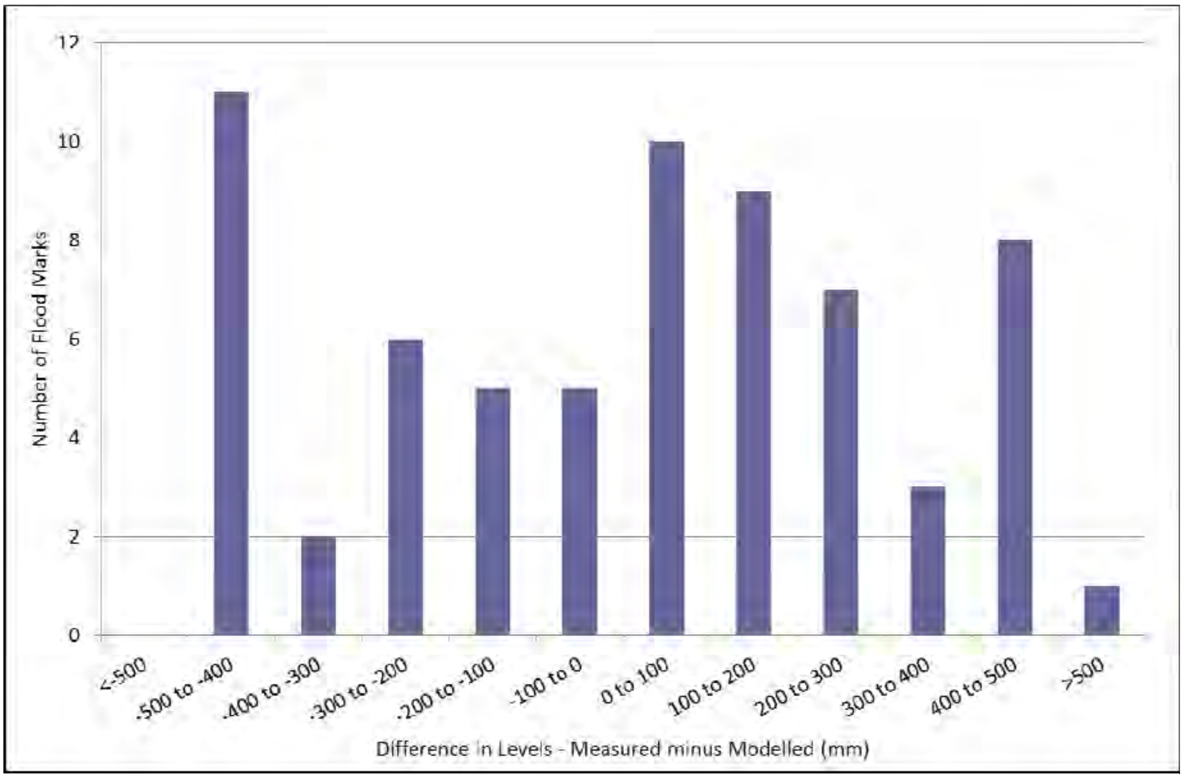

Figure 4-4 Flood Mark Histogram for January 2011 Flood

Comparison of the modelled and measured levels at the three gauges indicates that:

- The model over predicted the peak flood level at the Wamuran gauge by 1.26m;
- The model under predicted the peak flood level at the Upper Caboolture gauge by 1.37m;
- The model under predicted the peak flood level at the Caboolture WTP gauge by 0.66m; and
- The general profiles of the modelled and measured hydrographs match relatively well.

Comparison of the surveyed flood marks with modelled peak flood levels indicates that:

- 41% of the surveyed flood marks were within 0.3m of the modelled peak flood level;
- 37% of the surveyed flood marks were more than 0.3m higher than the modelled peak flood level; and
- 22% of the surveyed flood marks were more than 0.3m lower than the modelled peak flood levels.

4.1.3 May 2009 Results

Comparisons of the measured and modelled water levels for the January 2011 flood are shown in Figure 4-5 to Figure 4-7.

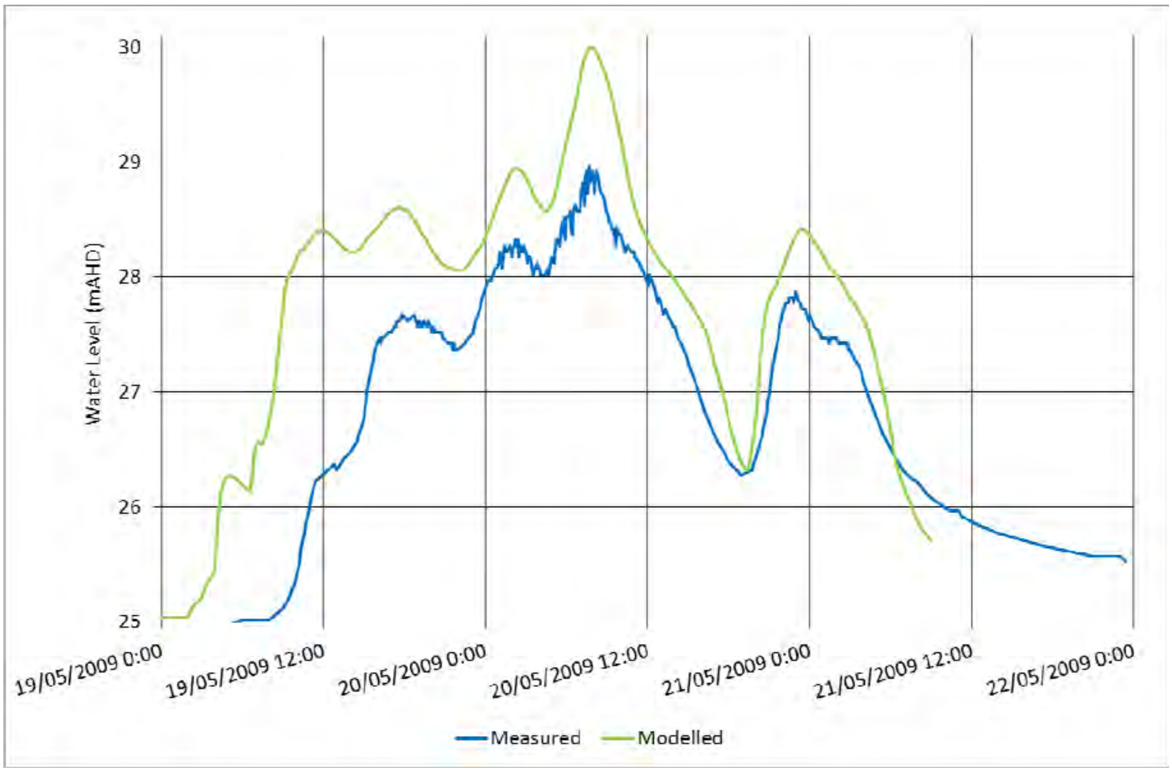

Figure 4-5 Flood Level Comparison at Wamuran Gauge for May 2009

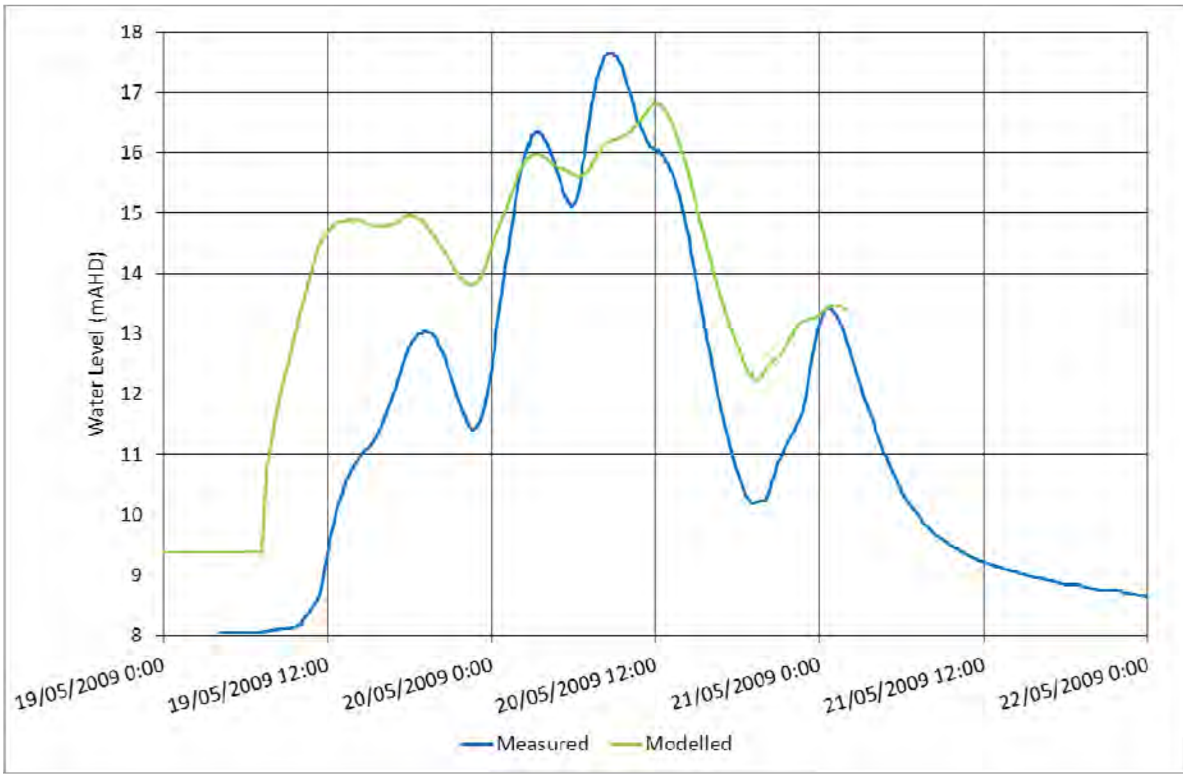

Figure 4-6 Flood Level Comparison at Upper Caboolture Gauge for May 2009

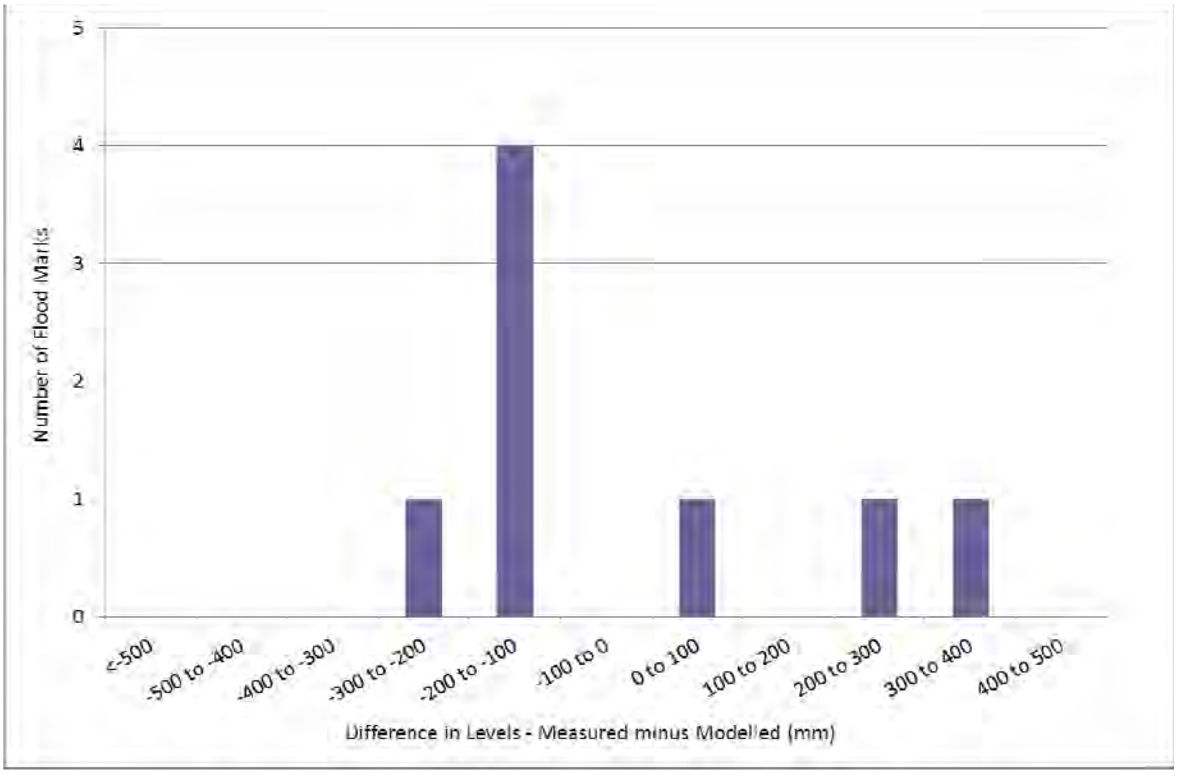

Figure 4-7 Flood Mark Histogram for May 2009 Flood

Of the 8 surveyed flood marks, 7 were within 0.3m of the modelled peak flood level. The model over predicted the peak flood level at Wamuran gauge by 0.98m and under predicted the peak flood level at the Upper Caboolture Gauge by 0.9m.

4.1.4 Conclusion

The model results indicate that the model replicates the historical flood behavior reasonably well. However there are some noticeable discrepancies. This may, in part, be due to insufficient data to enable the model to adequately capture the spatial distribution of rainfall patterns across the catchment. Inspection of radar data for the January 2012 event indicates that the location of the rain gauges (and rainfall interpolation between the gauges) ‘missed’ a zone of high rainfall in the western part of the catchment (as discussed in the model calibration report, Appendix C). Limitations in the model design may also have contributed to discrepancies between modelled and measured flood levels, particularly in upper parts of the catchment.

Localised model adjustments may have resulted in better “fit” between the measured and modelled results. However such a course of action would be counter to Council’s objective for a regionally consistent model library. Localised model adjustments may also mask underlying modelling uncertainties and input data limitations. The adopted parameter set was therefore considered on-balance to be appropriate to this model. It is also noted that this decision was reached by Council having regard to similar calibration and verification exercises in adjoining catchments. These results therefore need to be considered in the context of a regional calibration approach across multiple model domains.

4.2 Design Flood Behaviour

4.2.1 Model Results

The following data were output by the model at 30 minutes intervals as well as the peak values recorded during each simulation:

1. Flood Levels (H flag);
2. Flood Depth (D flag);
3. Flood Velocity (V flag);
4. Depth Velocity Product (Z0 flag);
5. Flood Hazard based on NSW Floodplain Development Manual (DIPNR, 2005) (Z1 flag);
6. Stream Power (SP flag); and
7. Inundation Times (no flag required).

The maximum velocity was used in combination with a ‘Maximum Velocity Cutoff Depth’ of 0.1m. Consequently, the model result files plot the maximum velocity for depths greater than 0.1m; for depths of less than 0.1m the velocity at the peak level is recorded in TUFLOW’s output file. This approach is recommended so as to exclude any high velocities that can occur as an artefact of the modelling during the wetting and drying process.

TUFLOW can provide output relevant to the timing of inundation. In particular:

- The time that a cell first experiences a depth greater than the depth(s) specified; and
- The duration of time that a cell is inundated above the depth(s) specified.

A ‘Time Output Cutoff Depths’ of 0.1m, 0.3m and 1m, were selected. This selection provides further flood information in the catchment; e.g.:

- Establishing when areas are inundated with shallow depths of 0.1m;
- Considering pedestrian and vehicle safety (flood depth between 0.1 and 0.3m); and
- The duration and/or time of inundation for significant flood depths of 1m and more throughout the catchment.

This information can assist in emergency planning by highlighting which areas of the catchment are inundated early in the flood event and also highlighting which regions may be isolated for long durations.

The model results were used to prepare a set of design flood maps, including inundation maps, peak flow velocity maps, hazard maps and stream power maps for the 100 year ARI flood event. The flood conditions on these maps were derived using the envelope (maximum) of all storm durations used in the critical duration analysis. Flood maps are only provided for the 100 year ARI design event because the focus of this project is on digital data, rather than the provision of flood maps. A description of the digital data provided to MBRC for incorporation into their RFD is summarised in Section 4.2.2. The flood maps of the 100 year ARI design storm event are presented in Appendix E.

4.2.2 Digital Data Provision

The Regional Floodplain Database is focused on structuring model input and output data in a GIS database. Therefore, all model input and output are being provided to MBRC at the completion of the study. The data includes all model files for the design events (for each storm duration) and sensitivity analyses.

In addition, post processing batch files were provided. The batch files were used to:

- Envelope (derive the maximum of) the critical duration runs and combine these into one file; and
- Convert the envelope file into ESRI readable acii grids (*.asc).

4.3 Sensitivity Analysis

The 100 year Embedded Design Storm (100 year ARI 15 minute in 270 minute) was used as a base case for the sensitivity analysis. The results of the sensitivity analysis are mapped in Appendix F. A comparison of the EDS event with the 100 year design flood event with selected critical durations (3, 6 and 12 hour) is shown in Figure F1. The results indicate that peak flood levels for the EDS is up to 500mm lower than the envelope of selected critical durations, predominantly in the downstream part of the catchment. Therefore, it is recommended that future sensitivity analyses undertaken during model upgrades use the selected critical duration design events rather than the EDS event in order to eliminate these under predictions.

4.3.1 Future Landuse Analysis

The Caboolture catchment is generally insensitive to changes in vegetation throughout most of the catchment, with some areas of increased sensitivity in the upstream catchment. Furthermore, the catchment is highly insensitive to increases in residential development. These results reflect what would be expected, as the catchment is highly vegetated, particularly around the watercourses.

Increases in peak flood levels through the catchment as a result of the changes to vegetation are in the order of 500mm in some of the upper reaches of the catchment. There is a localised decrease in flood levels of up to 500mm upstream of Wamuran.

An increase in residential development has no significant impact on peak flood levels across the floodplain.

4.3.2 Hydraulic Roughness Analysis

Increasing Manning's 'n' by 20% has resulted in no changes in peak flood level of more than 100mm across most of the floodplain, apart from some areas of dense vegetation in the upper catchment where the impact is approximately 400mm.

4.3.3 Structure Blockage Analysis

As expected, the structure blockage analysis has shown that structure blockages cause an increase in peak flood levels in the vicinity of the blocked structures, and in some areas there has been a decrease in flood levels downstream of a structure. These flood level increases are significant in some places, being over 0.5m.

4.3.4 Climate Change and Downstream Boundary Conditions Analysis

Climate change has a significant impact on flood levels throughout the catchment for all the different scenarios modelled.

An increase in rainfall through the catchment has a significant impact on flood levels within the upper catchment, with increases often greater than 500mm. In the downstream catchment, the impact of the increase in rainfall is in the range of 100mm to 500mm.

Increasing the downstream boundary to simulate the effects of sea level rise causes increases of generally up to 500mm in the downstream part of the catchment. At the entrance of the Caboolture River the increase in levels is more significant, with impacts greater than 500mm. There is also a localised decrease in levels in the water bodies near Bayside Drive in Godwin Beach.

The impacts outlined in the two scenarios above are exacerbated for the combined climate change scenario. Impacts within the middle of the catchment are particularly impacted, with an increase of impacts of up between 100mm to 500mm.

The catchment is also sensitive to high tidal surges, with tidal surge peak flood levels being higher than the EDS event by 500mm through most of the downstream catchment, decreasing to a difference of between 100mm to 500mm towards the middle of the catchment. However, much of this area is undeveloped. These differences are further exacerbated when combined with an increase in rainfall intensity and sea level rise, with increases of greater than 500mm throughout most of the downstream catchment.

Therefore, it can be concluded that the catchment is sensitive to climate change and high tidal surges.

4.4 Model Limitations

Watercourses within the Caboolture catchment were represented in the 2D domain, for which the grid resolution is limited to either 5mor 10m. This may not allow adequate representation of the channel conveyance, particularly for smaller, more frequent flood events. In some instances this limitation may lead to the model over or underestimating conveyance in the watercourses. The extent of this over or underestimation will vary according to local topographic factors.

5 CONCLUSION

Two TUFLOW models of the Caboolture catchment were developed:

i. A 5m grid resolution model for events smaller than the 100 year ARI event; and

ii. A 10m grid resolution model for events larger than the 100 year ARI event (including sensitivity runs).

The model was set up in a manner prescribed by MBRC specifically for the RFD project to ensure a consistent approach across the whole LGA and to enable the model and model outputs to be integrated into MBRC's Regional Floodplain Database. The main focus of the project is delivery of the model and its outputs in digital format, therefore only a selection of results have been presented in this report. The outcomes of this work will be used in stage 3 of the RFD to analyse and assist with managing flood risk in the Caboolture catchment.

6 REFERENCES

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