Brighton Creek Flood Study

Volume 1 of 2

BRISBANE CITY

Brighton Creek Flood Study

Volume 1 of 2

Prepared by Jacobs
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Executive Summary

Introduction

Brighton Creek is located within the suburb of Brighton 19 km north of Brisbane CBD. The creek is a small tidally influenced creek with a catchment of only 2.9 km^2 draining directly to Bramble Bay within Moreton Bay. The catchment features generally low-density residential land use with substantial open-space and conservation areas surrounding the creek. The creek is highly modified as the area was originally coastal dunes and lagoons which have been channelised. The creek is characterised by narrow channels running through wetland areas providing detention storage. The channel is predominantly vegetated with the exception of two concrete sections.

The most recent flood study for the Brighton Creek catchment was undertaken by Council in 2014. Since this previous flood study was completed, there have been significant changes in standard flood modelling practice with the publication of Australian Rainfall and Runoff 2019 and advances in hydrodynamic modelling software. These changes have prompted Brisbane City Council (Council) to undertake an update to the flood study.

Since completion of the previous flood study in 2014, Council has installed five Maximum Height Gauges within the catchment which have captured flood levels in four recent events. The February 2022 flood event caused wide-spread flooding within the catchment with properties inundated. This additional dataset provides additional information to inform the flood study update.

Project Objectives

The purpose of this flood study update for the Brighton Catchment is to improve the accuracy and confidence in the understanding of flooding in Brighton Creek by updating the model calibration and adopting design flood estimation methods consistent with AR&R 2019.

Project Elements

The following project elements have been completed as part of this study:

- Develop an URBS hydrologic model of the catchment to replace the previous XP-RAFTS model.
- Update the existing TUFLOW model to TUFLOW HPC and SGS incorporating 2019 LiDAR data
- Undertake a joint calibration of the URBS and TUFLOW models for the December 2019, February 2020 and February 2022 events.
- Simulate Existing catchment condition (Scenario 1) design events in accordance with Australian Rainfall and Runoff (Ball, et al., 2019) and Council's Flood Study Procedure (Version 9) for events from the 50% AEP to PMF, with and without allowance for climate change.
- Simulate Ultimate catchment condition (Scenario 3) design events for the 50% AEP to 0.2% AEP with allowance for climate change, by incorporating the Minimum Riparian Corridor (MC) and floodplain development outside the Flood Corridor.
- Produce flood extent mapping for Scenario 1 with climate change.
- Produce Hydraulic Structure Reference Sheets (HSRS) to capture the flooding and hydraulic characteristics of major hydraulic structures for the 50% AEP to 0.05% AEP for the Existing catchment condition (Scenario 1) without climate change.

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Glossary of Terms

Term	Definition
2014 ALS Data	This dataset is part of the SEQ 2014 LiDAR capture project and covers an area of approximately 1392 km^2 over Brisbane City. This project was undertaken by Fugro Spatial Solutions Pty Ltd on behalf of the Queensland Government.
2019 ALS Data	This dataset is part of the Brisbane-Ipswich LiDAR 2019 Project, acquired by Aerometrex Pty Ltd on behalf of the Queensland Government.
AHD	Australian Height Datum (AHD) is the reference level for defining reduced levels adopted by the National Mapping Council of Australia. The level of 0.0 mAHD is approximately mean sea level.
Annual Exceedance Probability (AEP)	The probability that a given rainfall total or flood flow will be exceeded in any one year.
AR&R Data Hub	The Australian Rainfall and Runoff Data Hub is a tool that allows for easy access to the design inputs required to undertake flood estimation in Australia. Background on the development and use of this data can be found in Australian Rainfall and Runoff (2019).
Brisbane Bar	Location at the mouth of the Brisbane River
Catchment	The area of land draining through the main stream (as well as tributary streams) to a particular site. It always relates to an area above a specific location.
Digital Elevation Model (DEM)	A three-dimensional model of the ground surface elevation.
Design Event, Design Storm	A hypothetical flood / storm representing a specific likelihood of occurrence (for example the 1% AEP).
ESTRY	ESTRY is the 1d hydrodynamic solver used by TUFLOW.
Flood Classification (BOM Definition)	Minor - Causes inconvenience. Low-lying areas next to water courses are inundated. Minor roads may be closed and low-level bridges submerged. In urban areas inundation may affect some backyards and buildings below the floor level as well as bicycle and pedestrian paths. In rural areas removal of stock and equipment may be required. Moderate - In addition to the above, the area of inundation is more substantial. Main traffic routes may be affected. Some buildings may be affected above the floor level. Evacuation of flood affected areas may be required. In rural areas removal of stock is required. Major - This causes inundation of large areas, isolating towns and cities. Major disruptions occur to road and rail links. Evacuation of many houses and business premises may be required. In rural areas widespread flooding of farmland is likely.

Glossary of Terms (continued)

Term	Definition
Flood Planning Area (FPA)	Flood Overlay Code development control mechanism that recognises the susceptibility of flooding in terms of frequency, flow velocity and flood depth. There are five FPAs (1 to 5), where FPA1 is subject to the most stringent development assessment requirements.
HEC-RAS	Hydraulic modelling software package developed by USACE
Hydrograph	A graph showing how the discharge or stage / flood level at a particular location varies with time during a flood.
Manning's 'n'	The Gauckler–Manning coefficient, used to represent hydraulic roughness in 1d / 2d flow equations.
Minimum Riparian Corridor (MRC)	An area where future revegetation of the creek riparian zone has been assumed for modelling purposes. Modelled as dense vegetation (nominal Manning's n=0.15) and typically extending for a maximum of 15 m on either side of the low-flow channel.
Modelled Flood Corridor	The "Modelled Flood Corridor" is the greater extent of the Waterway Corridor (WC) and Flood Planning Areas (FPAs) 1, 2 & 3 which represents an assumed zone of no filling.
Probable Maximum Flood (PMF)	An extreme flood deemed to be the largest flood that could conceivably occur at a specific location.
Probable Maximum Precipitation (PMP)	The theoretical greatest depth of precipitation that is physically possible over a particular catchment
Probable Maximum Precipitation Flood (PMPF)	The flood derived from the PMP under "AEP neutral" assumptions.
Storm Injector	Software Interface to define AR&R design storms for simulation within hydrologic modelling software packages including URBS
TIN	Series of non-overlapping triangles from which the 3d vertices (x,y,z) are used as an approximation of the 3d surface.
TUFLOW	Hydraulic modelling software package developed by BMT
URBS	Hydrologic modelling software package developed by D.G. Carroll

List of Abbreviations

Abbreviation	Definition
1d	One dimensional, in the context of hydraulic modelling
2d	Two dimensional, in the context of hydraulic modelling
AMTD	Adopted Middle Thread Distance
ALS	Airborne Laser Scanning
AR&R 1987	Australian Rainfall and Runoff (1987)
AR&R 2019	Australian Rainfall and Runoff (2019)
BCC	Brisbane City Council
CBD	Central Business District
CL	Continuing rainfall loss (mm/hr)
DEA AR&R 1987	Design Event Approach Australian Rainfall and Runoff (1987)
DEA AR&R 2019	Design Event Approach Australian Rainfall and Runoff (2019)
DTMR	Department of Transport and Main Roads (Queensland)
FPA	Flood Planning Area
FSPV9	Flood Study Procedure Volume 9 (BCC 2020)
HSRS	Hydraulic Structure Reference Sheets
ICC	Ipswich City Council
IFD	Intensity Frequency Duration
IL	Initial rainfall loss (mm)
IL_s	Initial loss for the rainfall event (mm)
IL_b	Initial loss for the rainfall burst (mm)
IWL	Initial Water Level (mAHD)
LCC	Logan City Council
mAHD	metres above AHD
MBRC	Moreton Bay Regional Council
MHG	Maximum Height Gauge
MRC	Minimum Riparian Corridor
MSQ	Maritime Safety Queensland
POT	Peak Over Threshold
RCBC	Reinforced Concrete Box Culvert

Abbreviation	Definition
RCP	Reinforced Concrete Pipe
RCP4.5	Representative Concentration Pathway 4.5
RCP8.5	Representative Concentration Pathway 8.5
QUDM	Queensland Urban Drainage Manual
SQID	Stormwater Quality Improvement Device
TIN	Triangular Irregular Network
WC	Waterway Corridor
WQA	Water Quantity Assessment

1.0 Introduction

1.1 Catchment Overview

Brighton Creek is a small tidally-influenced creek located within the suburb of Brighton 19 km north of the Brisbane CBD. The catchment covers an area of 2.9 km^2. Figure 1-1 presents the locality of the Brighton Creek catchment.

It is understood that much of the catchment has been heavily modified, with the creek consisting of a series of constructed channels which flow through large, vegetated flood storage areas. The catchment includes three wetland areas which drain to Bramble Bay through a concrete trapezoidal channel. The three wetlands are maintained as wooded parkland by Council: Main Wetland (Pimelea Woods), South Wetland (Goodenia Woods), and North Wetland (Dianella Woods).

The lower reaches of the creek, particularly the channels within the Main wetland and South wetland are tidal. The catchment is bounded by the Bald Hills Creek catchment to the west and local Bramble Bay catchments to the north and south. Land use outside the wetland areas is primarily low density residential.

1.2 Study Background

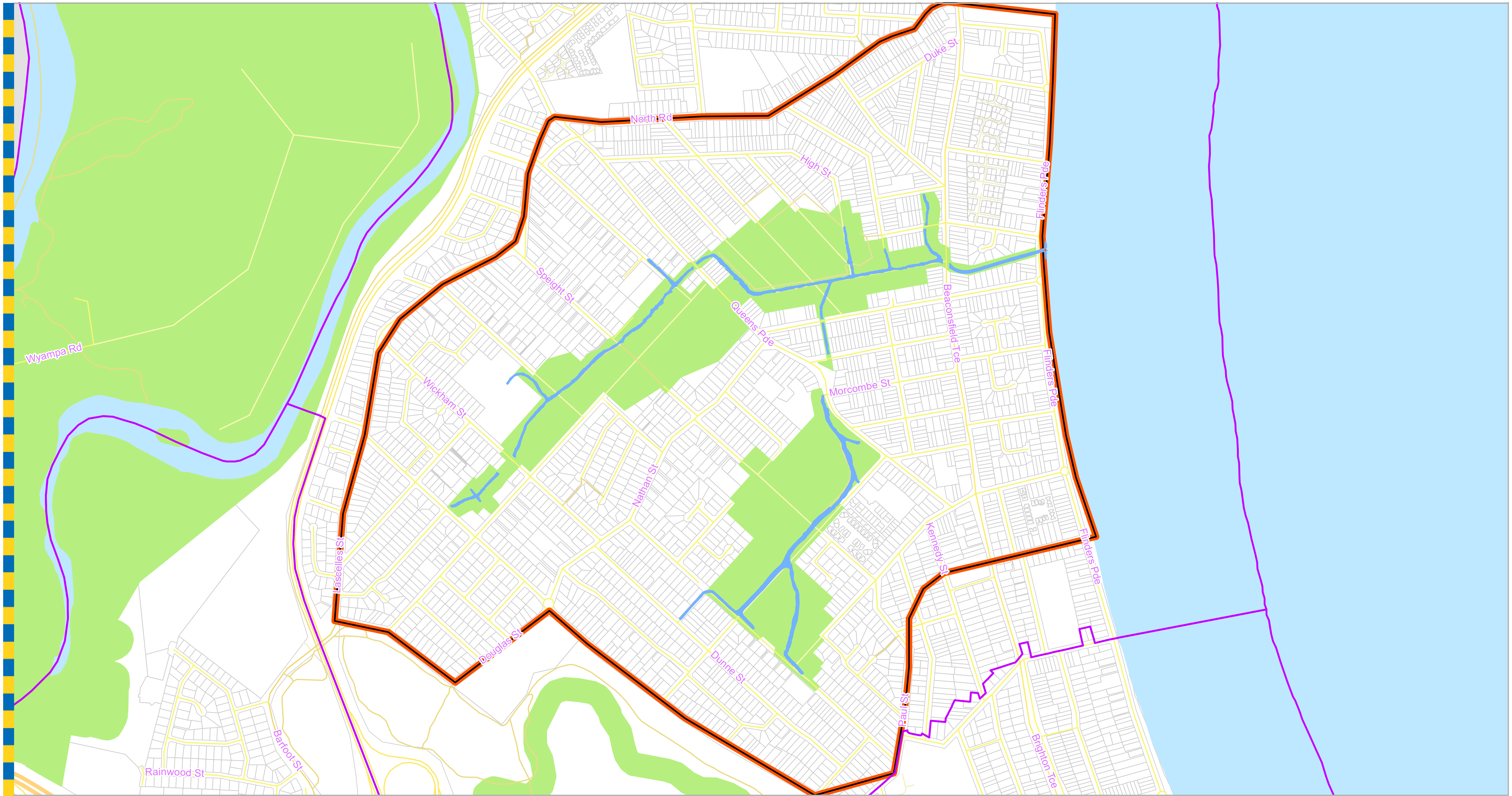
As part of BCC's Maintain and Enhance Program, flood studies are periodically updated to capture recent changes in the catchment; updates to planning and policy documents as well as the acquisition of more recent data.

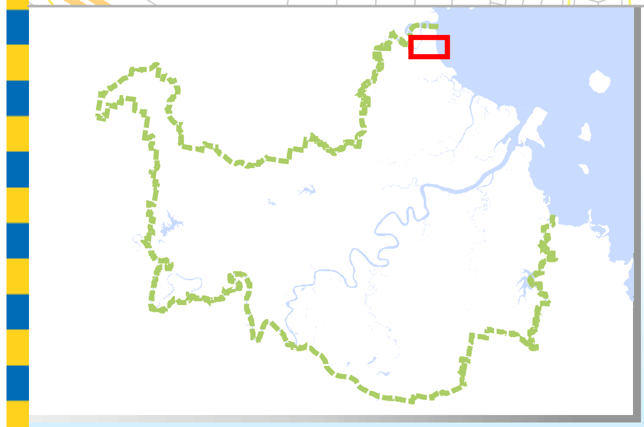
The most recent BCC flood study of Brighton Creek was completed in 2014. Previous flood studies had also been undertaken in 1997 and 1974. In this report, the previous flood study is termed the 2014 Flood Study. The 2014 Flood Study utilised XP-RAFTS (Version 2009) and TUFLOW (Version 2012-05-AE) models for the catchment. Limited verification of the models was undertaken to debris marks surveyed after the January 1974 event.

Since the 2014 Flood Study, Council has installed several Maximum Height Gauges with recorded peak levels now available for several flood events of varying magnitude. The catchment experienced significant flooding during the February 2022 event with a number of properties inundated, prompting community requests for further investigation of flooding within the catchment.

Additionally, there have been significant changes to standard industry practices in relation to design flood estimation since 2014, with the publication of Australian Rainfall and Runoff 2019 (AR&R 2019).

The purpose of this flood study update for the Brighton Catchment is to improve confidence in the understanding of flooding in Brighton Creek by updating the model calibration and adopting methods consistent with AR&R 2019.





Legend

- Creek
- Suburb Boundary
- Brighton Creek Catchment Area
- Waterway/Waterbody
- Parks

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Figure 1-1: Locality Plan

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1.3 Scope of the Flood Study

The update of the Brighton Creek Flood Study has been undertaken in accordance with the current BCC Flood Study Procedure document1 (FSPV9).

A summary of the scope is outlined below:

- Develop an URBS hydrologic model of the catchment to replace the previous XP-RAFTS model.
- Update the existing TUFLOW model to TUFLOW HPC and SGS incorporating the 2019 LiDAR data
- Undertake a joint calibration of the URBS and TUFLOW models for the December 2019, February 2020 and February 2022 events.
- Simulate Existing catchment condition (Scenario 1) design events in accordance with Australian Rainfall and Runoff (Ball, et al., 2019) and Flood Study Procedure Version 9 (FSPV9) for events from the 50% AEP to PMF, with and without allowance for climate change.
- Simulate Ultimate catchment condition (Scenario 3) design events for the 50% AEP to 0.2% AEP with allowance for climate change, by incorporating the Minimum Riparian Corridor (MRC) and floodplain development outside the Flood Corridor.
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1.4 Study Limitations

This report has been prepared based on the results of the hydrologic and hydraulic models developed for this study in accordance with Council's Flood Study Procedure Version 9. It is important to be aware of the inherent limitations of these models which include (but are not limited to) the following:

- The models have been "calibrated" using only Maximum Height Gauge (MHG) records for a very small number of events. This should be considered when using the model outputs, particularly for areas of the model distant from the MHGs, for events smaller or larger than the calibration events, and for purposes where timing of flooding is important.
- The models were developed for the purpose of simulating creek flows, and do not include representation of the stormwater network or local overland flow. For a catchment of this size and nature, it is highly likely that there is a high degree of interaction between flows within the stormwater network, overland flows and creek flows. It is important to note that in some areas of the catchment, the stormwater network and overland flows do not outlet to the same part of the creek. Additionally, areas of the coastal flats between Beaconsfield Terrace and Flinders Parade are directly connected to Bramble Bay via the stormwater network which is not represented in the flood model.

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[1] Brisbane City Council - *Creek Flood Study Procedure Document Version 9.0, 2022.*

- The 2019 LiDAR data has been used as the basis for the hydraulic model terrain. No site survey was available to ground-truth the accuracy of this data. It has been assumed that the 2019 LiDAR is representative and “fit for purpose”.
- Terrain modifications were included in TUFLOW to enforce the channel inverts where the raw LiDAR captured standing water or was influenced by thick vegetation. This was based on visual inspection during the site visit but has not been verified by survey. To understand the impacts of this limitation, a sensitivity test was undertaken for a single representative 1% AEP temporal pattern. The results indicated that the terrain modification and hence the introduction of additional conveyance makes little/no difference to the maximum water levels in large flood events. Smaller, more frequent events will be more heavily influenced by the assumed terrain modifications.
- Flood behaviour in the wetlands is highly sensitive to conditions at the outlet structure (tailwater). For the North and South Wetlands, this is the conditions in the Main Wetland. For the Main Wetland, this is influenced by the flood levels in the coastal flats area between Beaconsfield Terrace and Flinders Parade. Discharge curves for the wetlands are therefore highly dependent on downstream flood levels which can be variable. This behaviour is not simple to represent within the URBS model. As a result, the URBS model has been developed as a tool to derive local hydrographs for simulation within the TUFLOW model and should not be used as a stand-alone tool for assessment of flows throughout the catchment.
- Recent survey information was not available for the hydraulic structures within the catchment. Representation of inverts and sizes was adopted based on previous modelling where available, or where not previously modelled visual observations in the field.

2.0 Catchment Description

2.1 Catchment and Waterway Characteristics

The Brighton Creek catchment is located in the northern suburbs of Brisbane and has an area of 2.91 km^2. The catchment drains in an easterly direction and ultimately discharges into Bramble Bay (part of Moreton Bay). The catchment area is relatively flat with a maximum slope less than 5%.

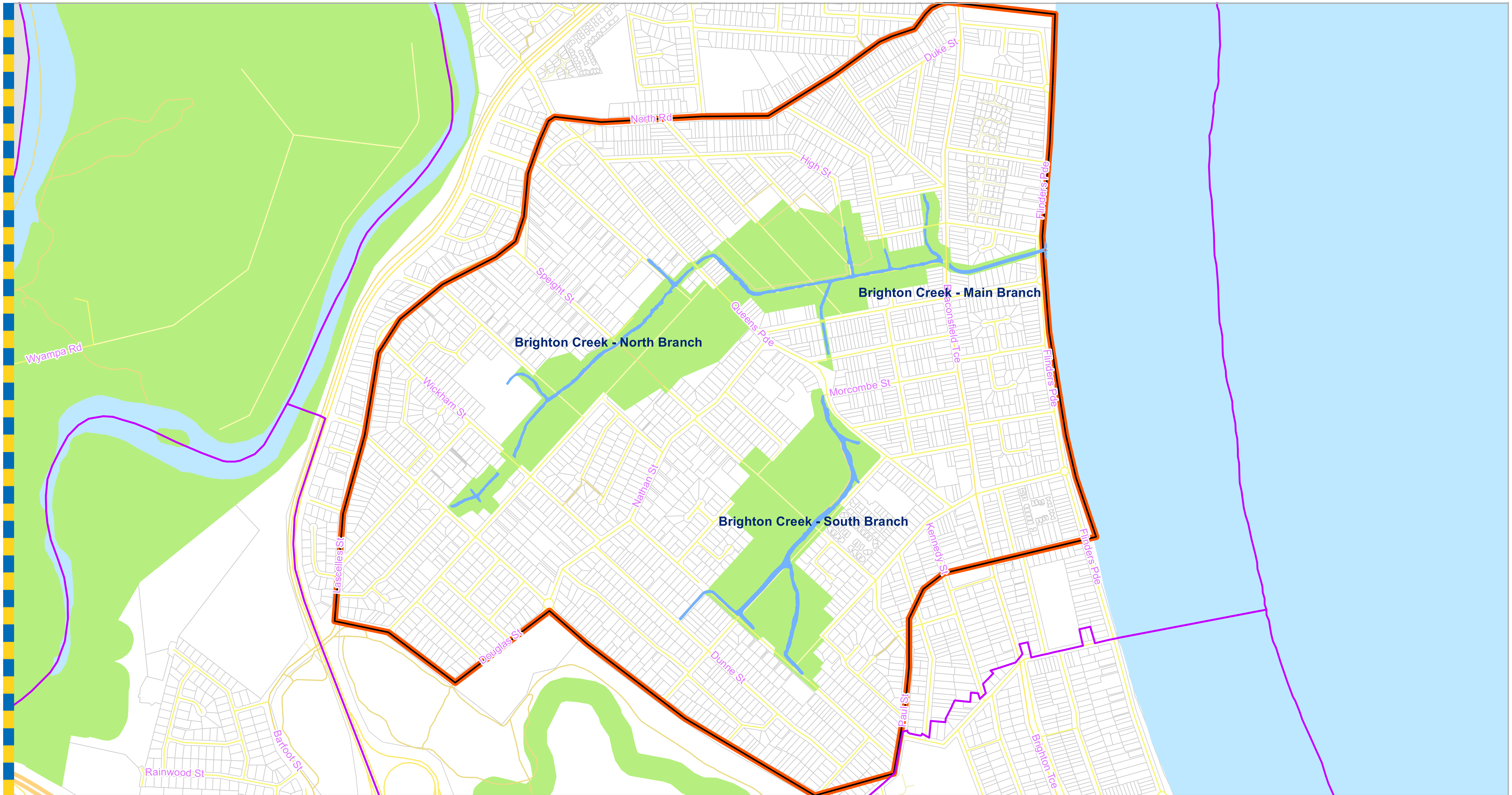
The catchment is bounded by Bald Hills Creek catchment on the west and Moreton Bay to the east. The roads - Lascelles Street, Douglas Street and Baskerville Street are on the ridge, and form the periphery of the model domain.

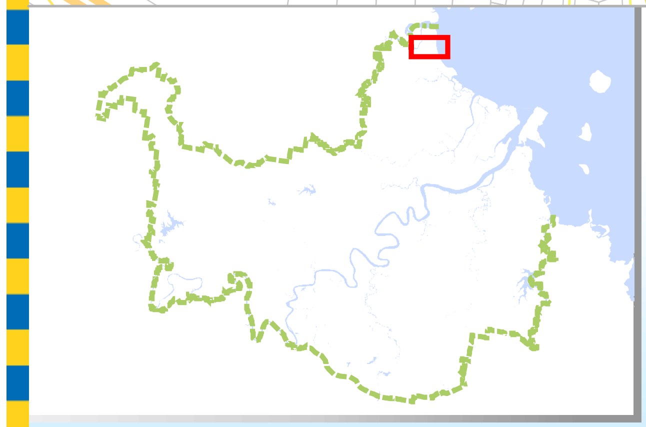
The catchment is drained by two main branches: the North branch and the South branch. The part of the watercourse after the confluence is identified as Main branch. Figure 2-2 presents the Brighton Creek catchment and these branches. There are wetland areas on each of these branches, similarly named: North Wetland, South Wetland and Main Wetland. These are maintained by Council as conservation areas, named: Dianella Woods, Goodenia Woods and Pimelea Woods, respectively.

The catchment is heavily modified with much of the watercourses within the catchment being constructed channels bounded by open space. Two sections of the channel are concreted: a 90 m section of the South Branch upstream of Townsend Street, and the 270 m length of the Main Branch downstream of Beaconsfield Terrace to the outlet. The lower reaches that are not concreted are dominated by mangroves.

The concrete-lined reach between Beaconsfield Terrace and Flinders Parade is the only discharge point for the catchment, as sea walls have been constructed along the shorefront preventing out of bank flows entering the ocean directly. Aerial imagery from 1949 shows a series of lagoons in the coastal flat areas on either side of this concrete channel which was already in place.

Figure 2-1: Brighton Catchment 1946 and 2021





Legend

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Brighton Creek Flood Study

Figure 2-2: Major Creeks and Tributaries

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The wetland areas provide storage during flood events with wetland discharge controlled by structure capacity, road elevations and flood levels downstream of the outlet structure (tailwater). Historically, the catchment also had a fourth detention area.

The South Wetland is located on the South Branch upstream of Queens Parade and drains through long sections of pipelines to a concrete channel downstream of Seaview Street. In larger events, the wetland overtops Queens Parade with flows travelling overland north to the Townsend Street channel and east to the coastal flats behind the sea wall. The channel within the South Wetland is tidal.

The North Wetland is located on the North Branch upstream of Queens Parade. Flow enters the North Wetland through a pipeline under the Tiny Legends Child Care Centre. At the downstream end, the wetland drains through a culvert under Queens Parade with larger event flows broadly overtopping Queens Parade further to the south. The North Wetland is not significantly tidal.

The Main Wetland is located downstream of the North and South Wetlands upstream of Beaconsfield Terrace. In small events flow exits the wetland through the culverts under Beaconsfield Terrace. In larger events, flows exit the wetlands via Townsend Street, with the control around Bayview Road.

There are a number of roads that cross the watercourses within the catchment, with key structures at: Flinders Parade, Beaconsfield Terrace, Townsend Street, Queens Parade and Wickham Street. Full details of the structures within the catchment are included in the Hydraulic Structure Reference Sheets (HSRS) included in Appendix J: Hydraulic Structure Reference Sheets.

2.2 Land Use

Table 2-1 provides a detailed split of the different land use zones within the catchment as per the City Plan 2014. The Brighton Creek catchment primarily consists of low-density residential areas (60%) and environmental conservation areas around the wetlands (11%). Roads including verges (23%) occupy a significant proportion of the catchment.

It is noted that Emerging Community designated land accounts for only 2% of the catchment, so there is little scope for further development without zoning changes to allow for densification.

Table 2-1: Land use/land cover in the Brighton Creek catchment

Land use / Land cover	**Catchment Percentage**
Neighbourhood centre	< 1%
Community facilities	< 1%
Emerging communities	2%
Environmental management and conservation	11%
General residential	60%
Recreation and open space	1%
Special purpose	< 1%
Sport and recreation	2%
Roads and footpaths	23%

3.0 Available Data

3.1 Previous Studies

As described in Section 2.0, flood studies for the Brighton Creek catchment had previously been undertaken in 1974, 1997 and 2014. The 2014 Flood Study developed XP-RAFTS and TUFLOW models for the catchment, with a full range of design events simulated.

3.2 Topographic Survey Data

3.2.1 LiDAR

LiDAR captured in 2019 was used within this study. It is understood that this was captured as part of the Brisbane-Ipswich LiDAR 2019 Project, undertaken by the Queensland Government. The stated vertical accuracy is understood to be 0.3 m vertical and 0.8 m horizontal.

Visual inspection of the 2019 LiDAR shows that it appears to have been captured at low tide and provides a reasonable representation of tidal channel areas. Levels within some parts of the wetlands do appear to be influenced by thick vegetation and may not be fully representative.

3.2.2 Field Survey

Field survey was captured in 1997 as part of the 1997 flood study for Brighton Creek. Comparison of the 1997 cross-sections and 2019 LiDAR, with site inspection observations identified that the 1997 channel sections appeared to significantly over-estimate the width and depth of channels through the wetland areas. This data was not adopted for use within this study.

3.2.3 Aerial Imagery

Aerial imagery from 2019, 2020 and 2021 was used to inform this study. 2014 aerial imagery was also accessed through Google Earth Pro to assist in understanding the adopted catchment representation in the 2014 Flood Study.

3.2.4 Site Visit

A site visit was undertaken on 21 December 2022 to assess the catchment condition and inspect the key hydraulic structures. During this site visit, five minor hydraulic structures were identified that were not previously represented within the model. Structure sizings were visually estimated while on site.

It was also identified during the site visit that there was some degree of re-growth within the channels throughout the catchment consistent with that visible in the 2019/2020/2021 aerial imagery but greater than that visible in historic imagery from around 2014.

3.3 Existing Hydraulic Models

The 2014 Flood Study TUFLOW model was adopted as the basis for the model update undertaken as part of this study. This model was a 1D-2D linked hydrodynamic model developed using TUFLOW (Version 2012-05-AE). The model was developed by Council.

Limited verification of this model to debris marks surveyed after the January 1974 event was undertaken. The Maximum Height Gauges within the catchment were installed after this study was completed.

3.4 Hydrometric Data and Storm Selection

3.4.1 Selection of Historical Storm Events

No streamflow or river level gauges are located within the Brighton Creek catchment. Five (5) Maximum Height Gauges were installed following completion of the 2014 Flood Study.

Joint calibration of the URBS and TUFLOW models was requested by Council for the following events:

- February 2020
- February 2022
- December 2019

Model verification was requested using the following event:

- December 2021

3.4.2 Availability of Historical Data for Selected Storms

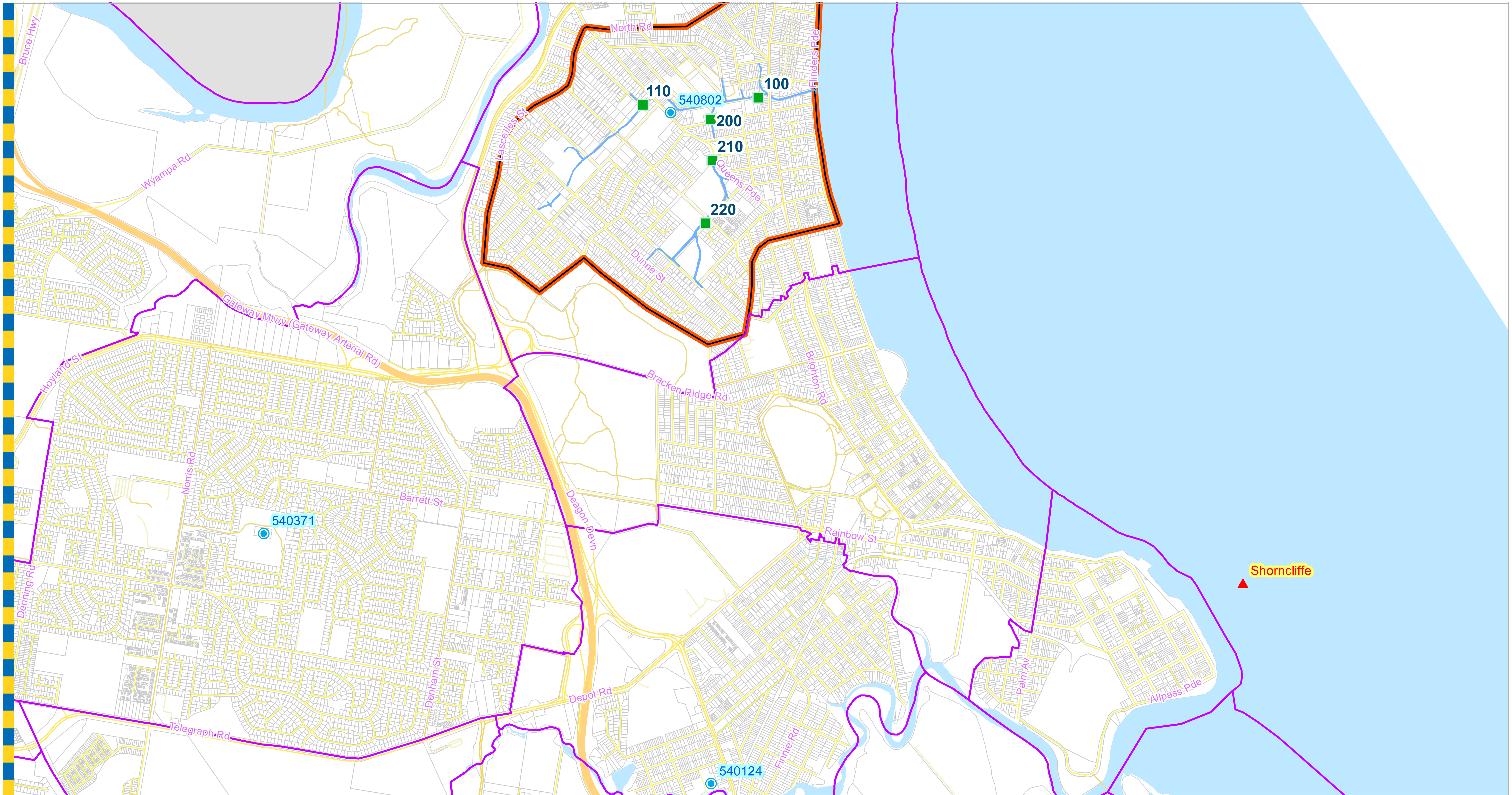
A pluviograph rainfall station, GS 540802, is located in the centre of the Brighton Catchment with data for all of the selected historical events.

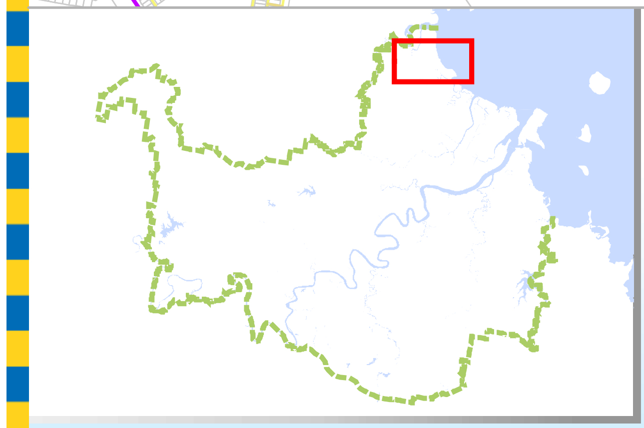
Table 3-1 presents the availability of the Maximum Height Gauge data while Figure 3-1 presents the location of all the gauges within the catchment. No debris levels were available for any of these events.

Table 3-1: Maximum Height Gauge Data Availability

Gauge ID	Location	Dec 2019	Feb 2020	Dec 2021	Feb 2022
MHG100	Main Wetland US Beaconsfield Tce	x	✓	x	✓
MHG110	North Branch US Queens Pde	✓	✓	✓	✓
MHG200	South Branch DS Townsend St	x	x	x	✓
MHG210	South Wetland US Queens Pde	x	x	x	✓
MHG220	South Wetland at Northcote St	✓	✓	✓	✓

Tidal data was available for the Brisbane Bar, Scarborough Boat Harbour and Shorncliffe stations. Analysis of the three datasets showed that the datasets displayed similar timing of high and low tides and high tide levels within 100mm. The Brisbane Bar dataset deviates towards the end of the February 2022 event where it is influenced by the elevated Brisbane River catchment flows.





Legend

- Tidal Gauge
- Pluviograph Station
- Maximum Height Gauge
- Creek
- Suburb Boundary
- Brighton Creek Catchment Area
- Waterway/Waterbody

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Figure 3-1: Hydrometric Gauges

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3.4.3 Characteristics of Historical Events

December 2019 Event

The December 2019 event is the smallest recorded event since the Maximum Height Gauges were installed. The event was a very short storm, with 60 mm recorded in around 40 minutes. BoM radar records for the event show that it was an intense small storm that passed over the Brighton catchment before quickly heading out to sea.

This event occurred during an otherwise dry summer characterised across the state by drought and bushfire conditions. While timing information is not available for the recorded peak flood levels, the rainfall fell around low tide.

Figure 3-2 presents a comparison of the event rainfall with the Brighton IFD curve, demonstrating that the rainfall was likely in the order of a 5% AEP event for the 45 min duration.

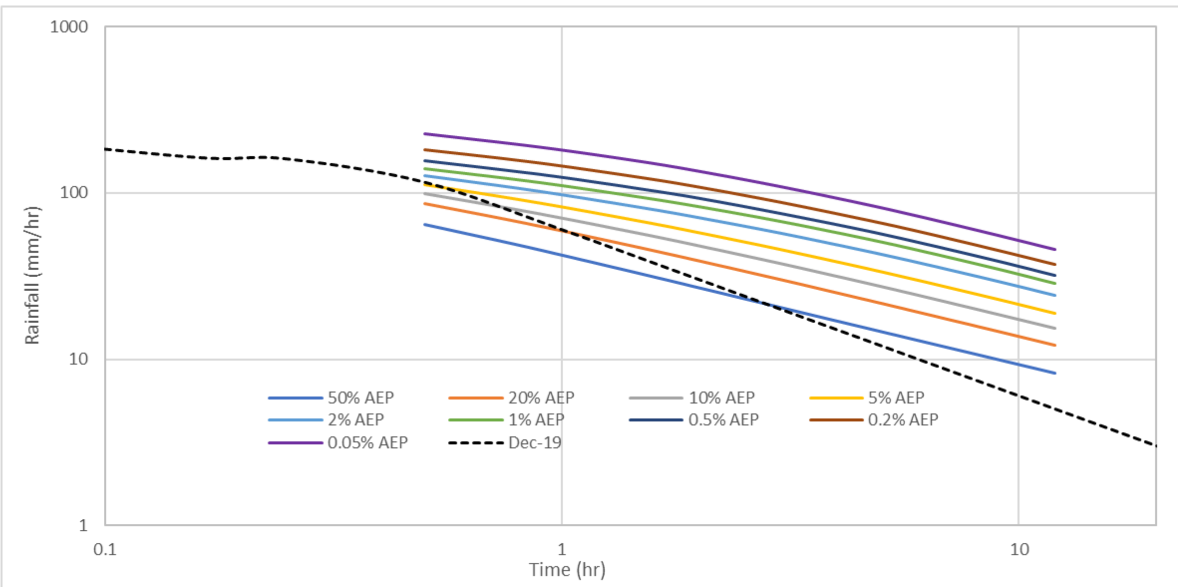


Figure 3-2: IFD Curve for December 2019 Event

February 2020 Event

Recorded peak levels for the February 2020 and December 2021 events are very similar.

The February 2020 event consisted of intermittent rainfall over 2 days. The total recorded rainfall depth was 196 mm with 133 mm in the first 24 hours.

This event happened just 2 months after the December 2019 event. It is likely that the catchment was fully saturated prior to the event.

Figure 3-3 presents a comparison of the event rainfall with the Brighton IFD curve, demonstrating that the rainfall was consistently just smaller than a 50% AEP event for durations from 30 min to 12 hours.

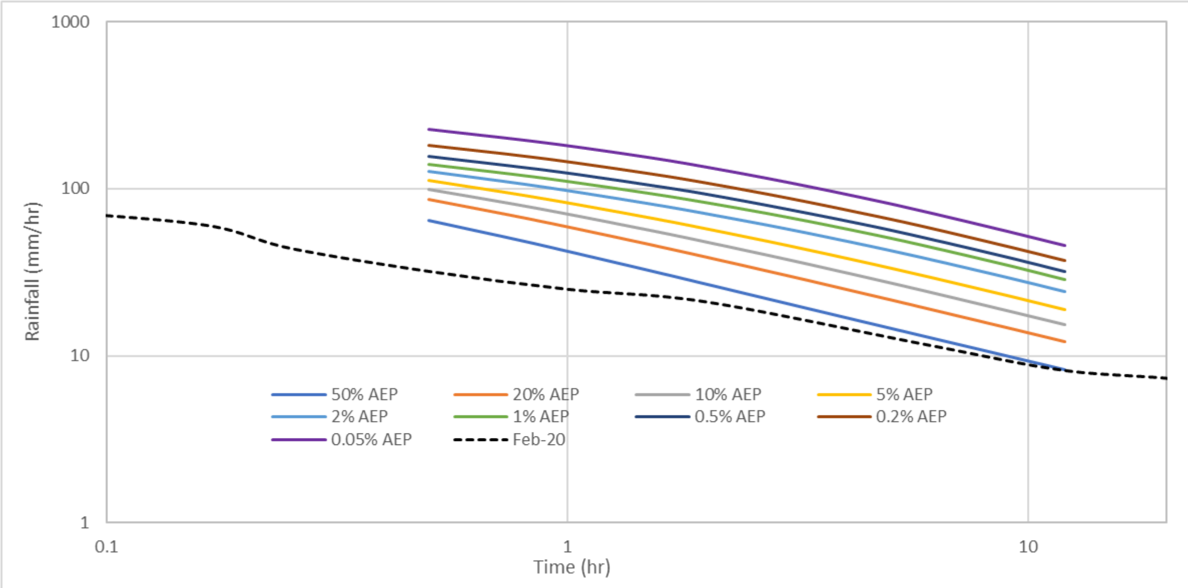


Figure 3-3: IFD Curve for February 2020 Event

December 2021 Event

Recorded peak levels for the February 2020 and December 2021 events are very similar.

The December 2021 event was characterised by two rainfall bursts approximately 1 day apart, with rainfall in both bursts falling just after high tide. As it is unknown which rainfall burst caused the recorded peak levels at the Maximum Height Gauge, the full duration including both bursts was included in the simulation. The total recorded rainfall depth over the two bursts was 133 mm with 48 mm in the first burst and 85 mm in the second burst.

Figure 3-4 presents a comparison of the event rainfall with the Brighton IFD curve, demonstrating that the rainfall was consistently in the order of a 50% AEP event for durations from 30 min to 12 hours.

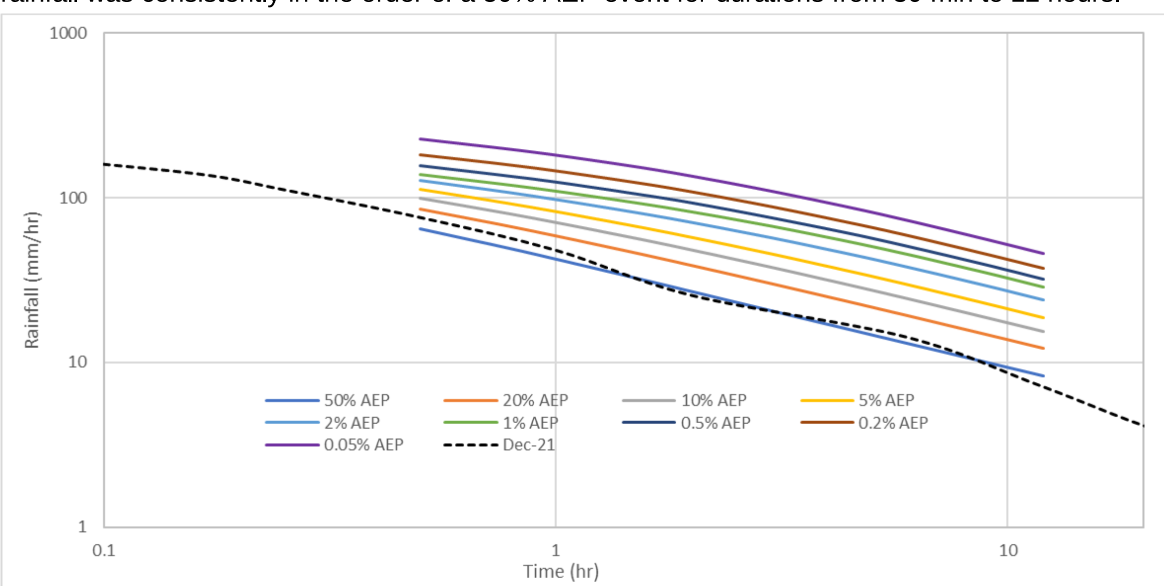


Figure 3-4: IFD Curve for December 2021 Event

February 2022 Event

This event is the largest on record for the Brighton Creek catchment with a number of residents reporting flood waters entering their homes.

The event lasted for several days with rainfall starting in the early morning of 25 February and finishing at night on 27 February. Rainfall was constant throughout the event with larger bursts on the last day. A total of 1006 mm fell over the duration of the event.

This event happened during a significant La Nina event with frequent rainfall in the preceding months, and just 2 months after the December 2021 event. It is expected that the catchment was fully saturated prior to the event.

Figure 3-5 presents a comparison of the event rainfall with the Brighton IFD curve, demonstrating that the rainfall was more extreme for longer duration events and was in excess of a 1 in 500 AEP event for durations greater than 12 hours.

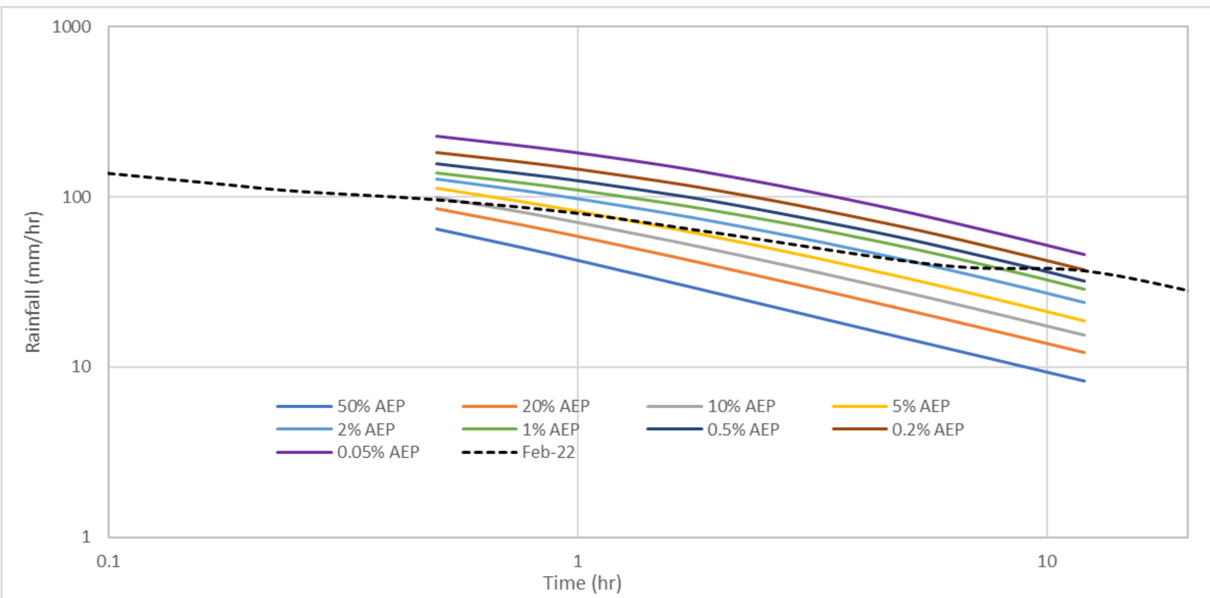


Figure 3-5: IFD Curve for February 2022 Event

4.0 Hydrologic Model Development and Calibration

4.1 Overview

The 2014 Brighton Creek Flood Study included an XP-RAFTS hydrologic model with design hydrology based on AR&R 1987 Guidelines. However, as the XP-RAFTS is no longer supported by the software developer and as per the scope of services, an updated hydrologic model has been developed using URBS software. Details of the URBS model schematization, parameters, input data, and calibration are provided in the subsequent sections.

The URBS model has been developed using the "Split" modelling approach where sub-catchment routing is undertaken separately to the channel routing. For further details on this modelling approach refer to the URBS User Manual.[2]

4.2 URBS Sub-catchment Data

4.2.1 General

This section details the sub-catchment information used within the URBS model. For this study, the following URBS parameters were utilised:

- Area: Sub-catchment area (mandatory)
- CS: Catchment Slope
- I: Impervious Fraction

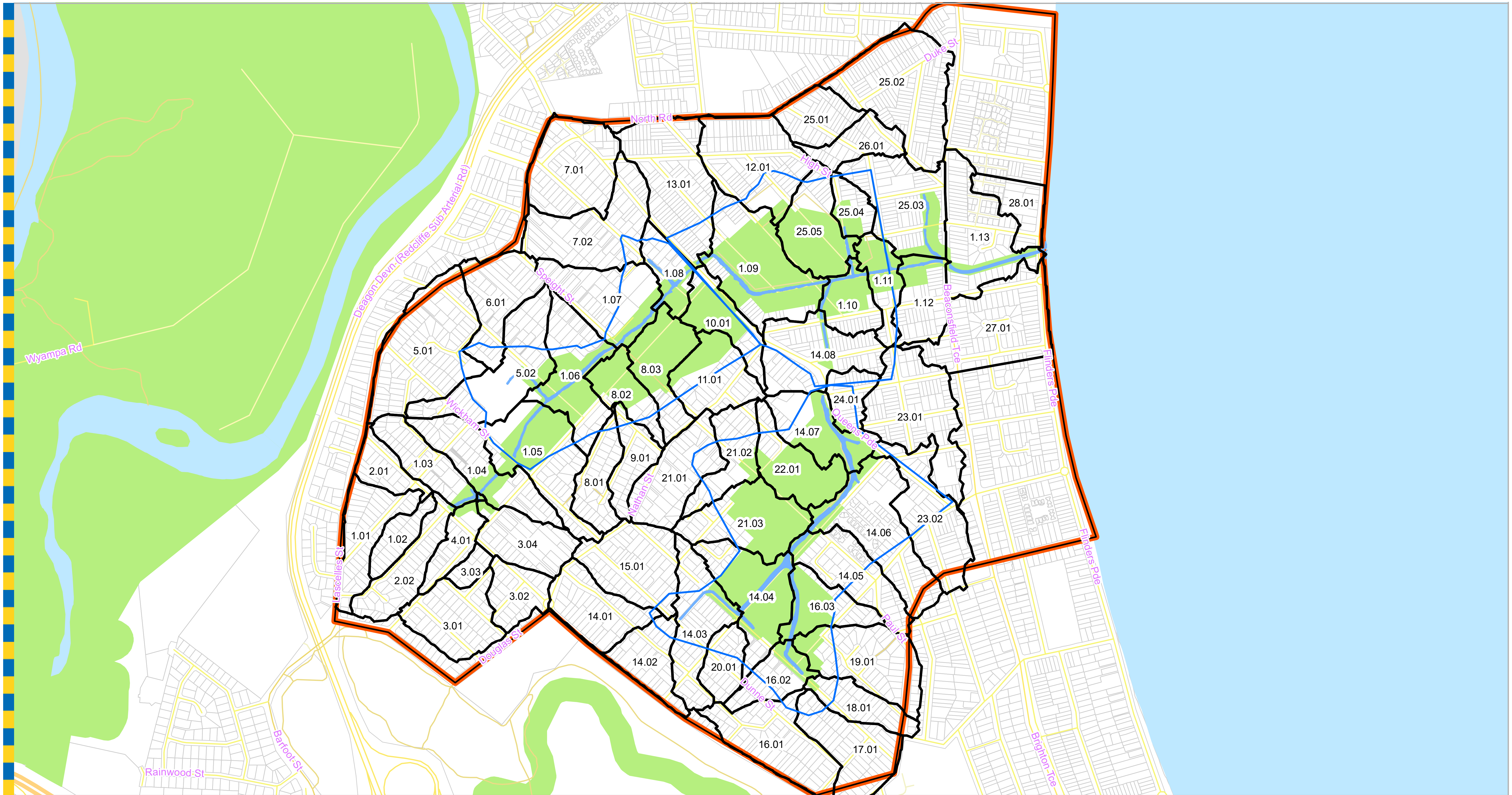
The input data (.cat and .vec files) required for the URBS hydrologic model have been prepared using CatchmentSIM software with minor modifications to align with TUFLOW inflow locations.

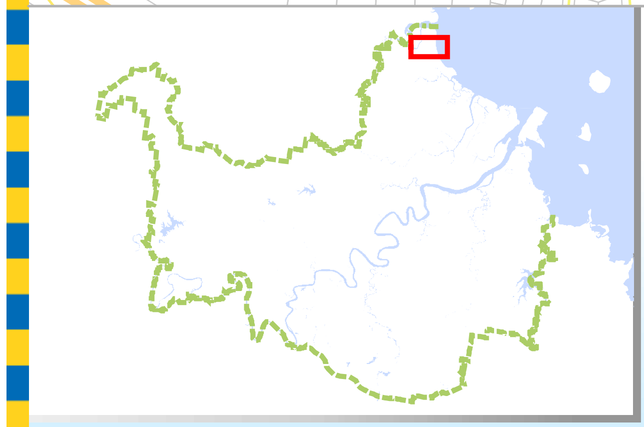
4.2.2 Sub-catchment Delineation

The sub-catchments (18) used in the 2014 study generally represented the catchment sufficiently within the XP-RAFTS model, given XP-RAFTS' ability to internally route hydrographs. Further sub-catchment refinement was required to produce an appropriate URBS model.

To achieve the required catchment discretisation, the 1m LiDAR data (2019) was resampled to a 5m grid within CatchmentSIM. The study area was split into a sufficient number of sub-catchments to ensure that there are multiple sub-catchments draining to each upstream inflow location to be used in the TUFLOW model, and consistency of sub-catchment size is maintained across the model. The sub-catchments have been delineated primarily based on the topographical divides, and further modified to account for major storm water drains and roads. The sub-catchments and stream network for the study area is shown in Figure 4-1.

[2] DG Carroll 2016 - *URBS A Rainfall Runoff Routing Model for Flood Forecasting and Design Version 6.00*





Legend

- Wetland Storages
- Subcatchments
- Brighton Creek Study Area
- Creek
- Waterway/Waterbody
- Parks

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Revision : 1
Publication Date : 12 Jun 2023
Project Number : IW286200

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Figure 4-1: URBS Schematisation

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The delineation resulted in 64 sub-catchments, with the smallest having an area of 1ha and the largest having an area of 8ha. The study area is very flat, and the mean slope for the sub-catchments varies between 2 and 5%.

4.2.3 Land Use and Impervious Area

The land use/land cover in the Brighton Creek catchment consists of low- to medium-density residential buildings, medium-density vegetation and other community use areas and infrastructure (roads, parks etc). The catchment slope (CS) and impervious fraction (I) for all the sub-catchments have been calculated within GIS. The percentage impervious for the Ultimate Conditions was developed based on the City Plan 2014 Land Use and QUDM guidance on fraction impervious for varying land use.

The percentage impervious was then modified for Existing Catchment Conditions based on review of aerial imagery from 2019, 2020 and 2021. Limited differences were observed between the aerial imagery for the three years.

Given the limited scope for further development within the catchment under City Plan 2014, there is very little difference between the adopted Existing Conditions and Ultimate Conditions percentage impervious. The percentage impervious has been included in the ".cat" file within the URBS model. The Ultimate Conditions .cat file parameters are presented in Appendix B: URBS Model Parameters. A figure showing the City Plan 2014 land use areas is included within Appendix C: Adopted Land Use.

4.3 URBS Channel Data

The channel lengths (L) estimated by CatchmentSIM have been adopted within the URBS model. The lengths have been re-calculated where minor modifications to sub-catchments have been undertaken outside CatchmentSIM to account for stormwater network and TUFLOW inflow locations, that could not be considered in CatchmentSIM.

Given the extremely flat nature of the catchment, the channel slope (Sc) has not been used in the URBS model for the study.

4.4 Event Rainfall

As noted in Section 3.4, rainfall data for the station 540802 has been used for hydrologic modelling of the historical events for the Brighton Creek catchment. Review of the locations of the closest rainfall gauges outside the catchment identified that Thiessen polygons for these gauges would be located outside the catchment. Therefore, data from station 540802 has been adopted uniformly across the catchment for all events.

4.4.1 Observed Rainfall

For the station 540802, observed rainfall data is available for all the 4 events considered for the calibration of the flood models. The rainfall data was provided in Excel format post-processed to 5 minute interval. Table 4-2 identifies the start and end dates for the provided data.

Table 4-1: Data availability for the rainfall events

Event	Start date/time	End date/time
December 2019	13/12/2019 12:00:00 AM	14/12/2019 12:00:00 AM
February 2020	6/02/2020 12:00:00 AM	8/02/2020 12:00:00 AM
December 2021	8/12/2021 12:00:00 AM	10/12/2021 12:00:00 AM
February 2022	25/02/2022 12:00:00 AM	28/02/2022 12:00:00 AM

For the URBS model, the above data have been used to prepare .rf and .r files for each event.

4.4.2 Rainfall Losses

The Initial and Continuing loss model has been used for the study area. This model assumes that there is an initial loss before any rainfall becomes effective. After this, a continuing loss is applied to the rainfall.

As a starting point for the calibration losses, the AR&R datahub (http://data.arr-software.org/) losses were reviewed and are presented in Table 4-2.

Table 4-2: AR&R Data Hub losses for Brighton Creek catchment

ID	Loss
Storm Initial Losses (mm)	20.0
Storm Continuing Losses (mm/h)	2.4

For the calibration events, the losses have been further adjusted as mentioned below:

- The initial loss for the December 2019 event (very dry period with bushfires across the state) has been set to 50.0 mm.
- For all other events, the initial loss has been set to 0.0 mm, as each event was preceded by another flood event or an extended wet period.

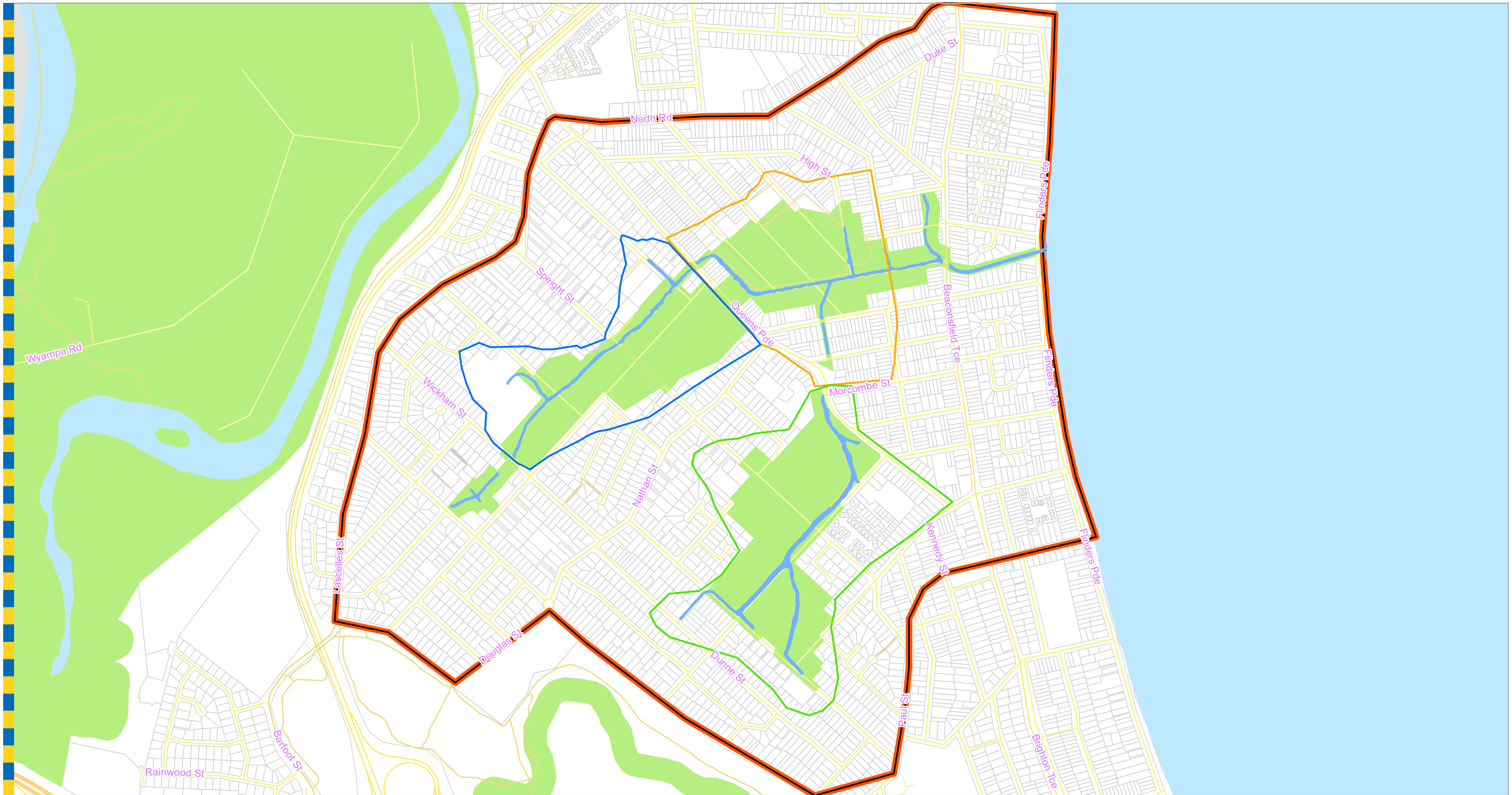
A review of the long-term Brighton rainfall record showed that the three month antecedent rainfall prior to the December 2019 event was only 111 mm in comparison to 352 mm, 478 mm and 634 mm variously for the other events, supporting the use of low (zero) initial losses for 2020, 2021 and 2022 and high initial losses for 2019.

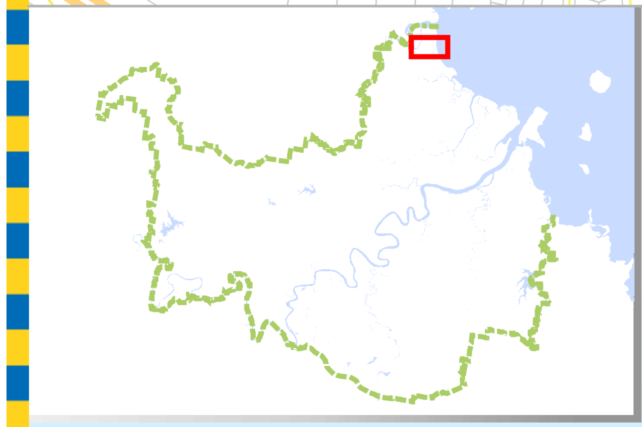
The continuing loss was set at 2.4 mm/hr consistent with the suggested continuing losses within the datahub, with reasonable agreement to the recorded peak levels. A sensitivity analysis was undertaken with the continuing losses reduced to 1.1 mm/hr. This resulted in changes in peak level of 10 mm in the Main Wetland. With no further data to inform the selection of continuing loss, the DataHub loss of 2.4 mm/hr was adopted for both the Calibration and Design events.

4.5 Wetland Storages

There are three wetlands within the study area (Figure 4-2) which store and attenuate flooding within the catchment. Each of the three wetlands were represented as a “special storage” within the URBS model, represented by a Storage Volume – Discharge (S-Q) relationship derived from:

- Stage-storage curves derived via GIS using the 2019 LiDAR data (Figure 4-3)
- Stage-discharge curves derived from the February 2022 TUFLOW hydrodynamic model





Legend

- North Wetland
- South Wetland
- Main Wetland
- Brighton Creek Study Area
- Creek
- Waterway/Waterbody
- Parks

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Figure 4-2: Wetland Storage Areas

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Figure 4-3: Wetland Stage-Storage Curves

The focus of this study was to develop a calibrated TUFLOW model to produce flood surfaces for use in floodplain planning. The URBS model provides routed inflows at the upstream extents of the TUFLOW model and local sub-catchment inflows throughout the remainder of the model including the areas of all the wetland storages. The accuracy of the representation of the wetland storages within URBS does not influence the outputs of the TUFLOW hydrodynamic model, as the wetland storages and outflow structures are explicitly represented within TUFLOW.

The objective of incorporation of the wetland storages into the URBS model was to produce consistency between the URBS and TUFLOW models. This would then allow the URBS model to be used as a proxy for the hydraulic model for confirmation of critical duration events and potential flood forecasting.

However, through a series of TUFLOW simulations it was identified that the discharge behaviour of each of the wetlands varies significantly depending on the magnitude of the event and the spatial variation of the rainfall in the event, as there are significant hydraulic controls at the outlet of each of the wetlands where the downstream (tailwater) conditions for the structure determines the outflow from the wetland.

Figure 4-4 presents an example for the North Wetland showing the range of ratings developed from TUFLOW scenarios with varying inflow contributions upstream and downstream of the wetland control.

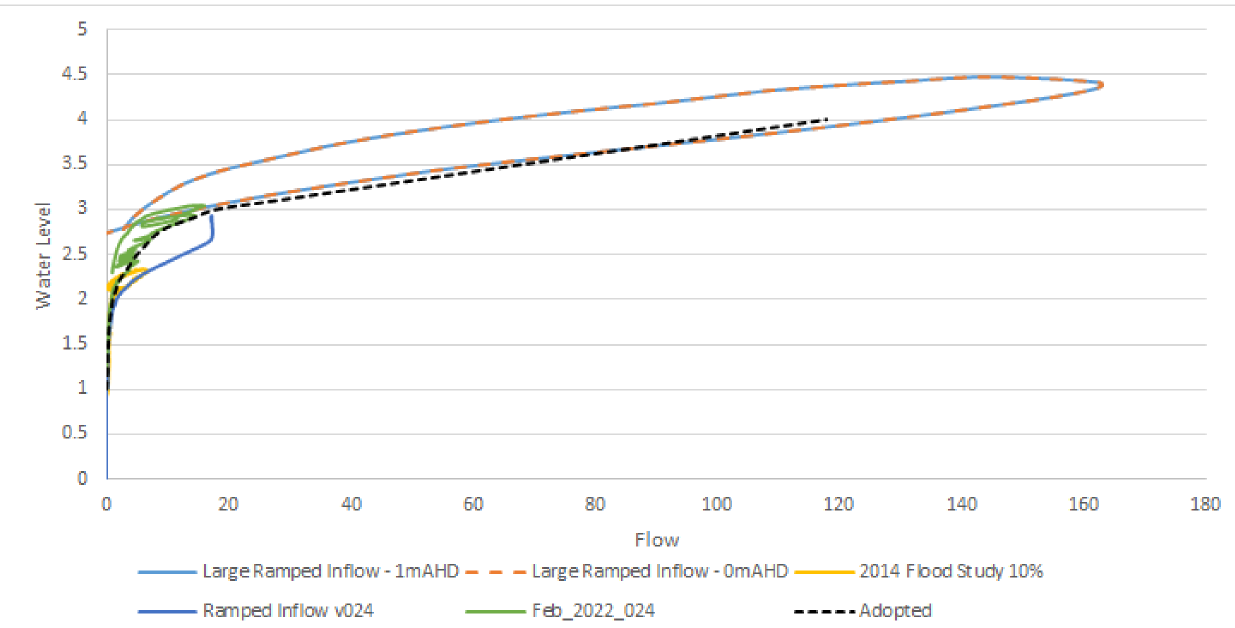


Figure 4-4: Variability of Wetland Discharge Rating Curves

Given this variability, it was not possible to sufficiently represent the wetland behaviour within URBS without deriving a library of tailwater-dependent discharge curves. The URBS model should therefore only be used in tandem with the TUFLOW model, not as a stand-alone tool, without further investigation.

Smoothed rating curves based on the rising limb of the February 2022 event TUFLOW model were adopted for the URBS model. This produced a reasonable fit between URBS and TUFLOW for the February 2022 event but not for other events.

In the URBS model, the parameter VBF (volume before full) is required to represent the volume available within the storage which must be filled before discharge will occur. For the events considered for the study, VBF at each of the storage areas was estimated by considering the tidal level at the beginning of the simulation as the south and main wetland's storage are influenced by the tidal levels. The North Wetland was started full for all events.

Table 4-3: VBF for calibration events

Wetland	VBF (ML)	
	Dec 2021	Other events
North	0.0	0.0
South	0.52	0.52
Main	0.175	1.65

4.6 Calibration and Verification Procedure

4.6.1 General

A joint calibration of the hydrologic and hydraulic models has been undertaken as there are no continuous stream gauge records in the catchment that would support hydrologic model calibration.

Joint calibration generally includes comparison of flow hydrographs between hydrologic and hydraulic models to ensure that there is consistency in the catchment behaviour i.e., the hydrograph peak, timing and shape are similar between the two models.

4.6.2 Tolerances

Council's FSPV9 details various model performance criteria (peak flow ratio, volume ratio, and Nash-Sutcliffe coefficient) to evaluate the performance of hydrologic models. However, as no flow recordings are available in the Brighton Creek catchment, the URBS model performance could not be evaluated against those criteria.

The URBS model results are however compared with TUFLOW results to ensure that the hydrologic and hydraulic models are consistent in simulating the catchment behaviour.

4.6.3 Methodology

Out of the 4 events with data available, 3 events (February 2022, February 2020, and December 2019) were chosen for calibration and one event for verification (December 2021). This selection ensures that the calibration is undertaken on a broad range of catchment conditions (wet-dry), which improves confidence in the model.

Given the February 2022 event was the largest available and is considered to be the flood of record for the catchment, a high emphasis was placed on this event in the calibration. Noting the commentary in Section 4.5, and the absence of any streamflow data for calibration, it was necessary to undertake a joint calibration of the URBS and TUFLOW models with the emphasis on achieving the calibration targets for peak levels at the Maximum Height Gauges. The methodology applied to the calibration of the URBS model is provided below.

- Input the February 2022 observed rainfall data for the catchment and run the calibration events through the URBS and TUFLOW models with standard parameters.
- Compare the URBS simulated hydrographs with the TUFLOW model outputs.
- Extract wetland rating curves from the TUFLOW model, input to URBS and re-assess the URBS-TUFLOW comparison.
- Iteratively adjust the model parameters (as required) and re-run the model to achieve the best possible fit with the hydraulic model outputs for February 2022.
- The predominant model parameters adjusted were the channel lag parameter (α) to match timing between URBS and TUFLOW, and the catchment lag parameter (β) to match observed peaks. Losses were maintained at 0mm (saturated catchment) and 2.4mm/hr (DataHub average continuing loss).
- Once a reasonable calibration was achieved for the February 2022 event, the parameters were transferred to the other calibration events to assess the overall reasonable-ness of the adopted parameters. The aim was to produce a reasonable calibration for all events with a single combination of CL, α, β and m.
- Adjust the initial loss (as required) to represent the event specific rainfall loss at the start of the events
- Repeat the above steps as necessary, until the TUFLOW model results meet the calibration targets as listed in Section 5.3.1.
- Run the verification event through the calibrated URBS and TUFLOW models.

4.7 Simulation Parameters

The model parameters used in the calibration/verification are shown in the table below. The initial loss for the December 2019 event has been selected as 50 mm, as the flood event followed a very dry season.

Alpha and beta have been iteratively tested, and the final selection is based on the matching of the time of peak with the hydraulic model.

Table 4-4: URBS calibration parameters

Event	alpha	m	beta	IL	CL
Dec 2019	0.2	0.8	2.0	50.0	2.4
All other events	0.2	0.8	2.0	0.0	2.4

4.8 Hydrologic Model Calibration Results

As no recorded stream flow data is available for the study area, the URBS results were compared with TUFLOW model results.

4.8.1 February 2022 event

The plots comparing flow hydrographs between URBS and TUFLOW models are presented in Figure 4-5. From the analysis of February 2022 results, it can be noted that:

- There is a reasonable match between the hydrologic and hydraulic models, with the general shape of the flow hydrographs matching well.
- The timing of the peak in the URBS model is matching reasonably well with the TUFLOW peaks, although generally a little later in URBS. This means the routing and attenuation within the wetland storage areas is reasonable for this event.
- Peaks are generally higher in the TUFLOW model.

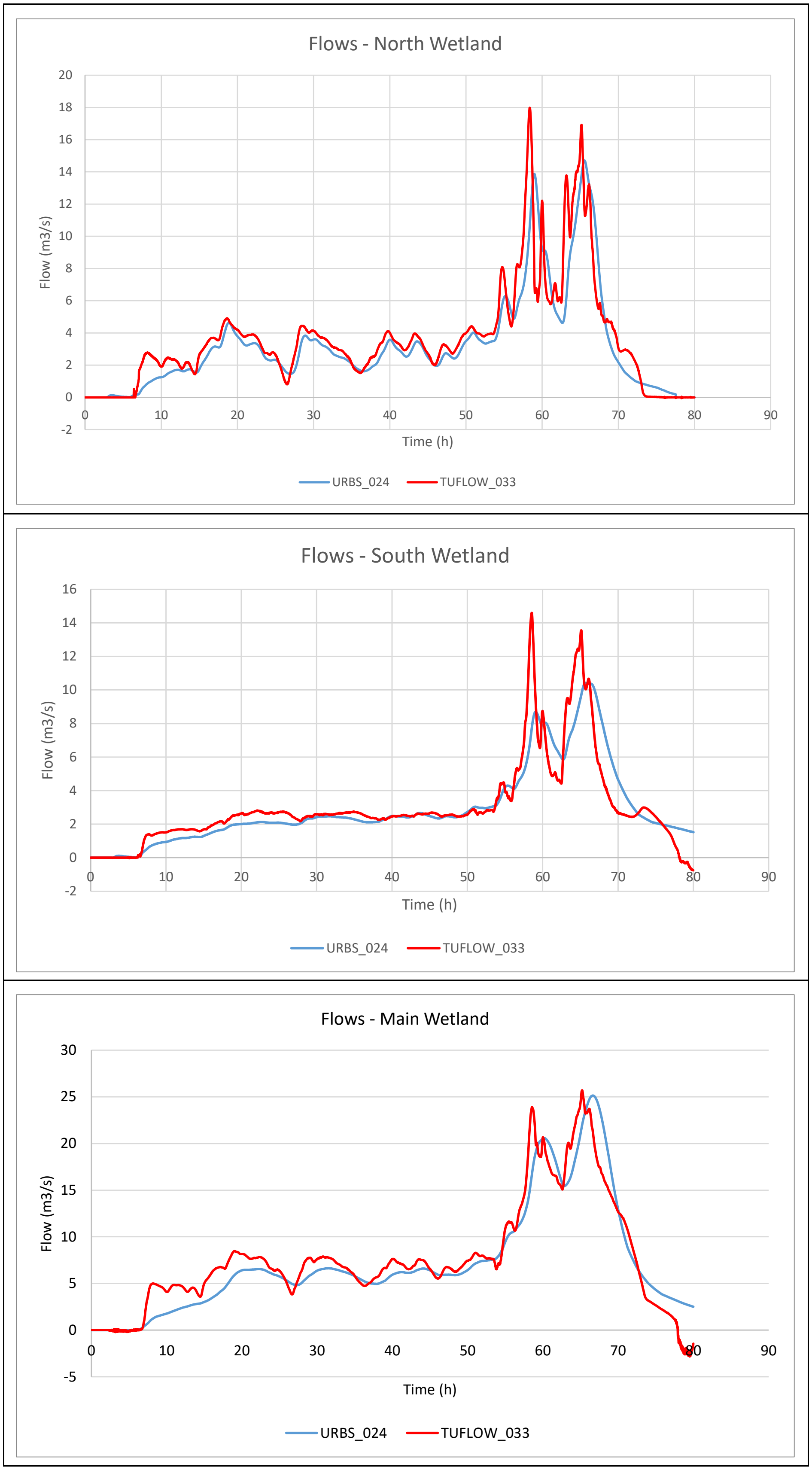


Figure 4-5: February 2022 event – flow hydrographs

4.8.2 February 2020 event

The February 2020 event was a much smaller event compared to February 2022. It was comprised of multiple bursts of rainfall, resulting in multi-peaked hydrographs. The plots comparing flow hydrographs between URBS and TUFLOW models are presented in Figure 4-6. From the flow hydrographs comparison, it can be noted that:

- The timing of the flood peaks for the north and south wetlands are matching reasonably well . However, the magnitude of the peaks and shapes of the hydrographs are different between the hydrologic and hydraulic models.
- Review of the hydraulic behaviour identified that the wetland storage rating curves are heavily dependent on the conditions downstream of the wetlands. That is the South Wetland discharge is highly sensitive to conditions within the Main Wetland and the Main Wetland discharge is highly sensitive to the conditions within the coast flats between Beaconsfield Terrace and Flinders Parade. The North Wetland is less sensitive to downstream conditions and shows better agreement.
- This smaller event appears to be significantly tidally influenced within the TUFLOW model with URBS peak flows maintained over low tide periods where TUFLOW flows dramatically reduce (and even result in negative or upstream flows) due to the dynamic downstream tidal condition.
- There is some instability at structures in TUFLOW at low/negative flows but this is not influencing the flood behaviour at the peak.

4.8.3 December 2019 event

The December 2019 flood event followed a significant dry period; hence an initial loss of 50 mm has been applied in the URBS model. All other parameters remain the same as the other calibration events.

The plots comparing flow hydrographs between URBS and TUFLOW models are presented in Figure 4-7.

From the analysis of December 2019 results, it can be noted that:

- The URBS and TUFLOW timing of the onset of flooding shows very good agreement although the shape and peak is not represented well.
- For the Main Wetland this is likely partially due to the tidal influence in this smaller event with peaks exacerbated by coincidence with high tide and duration of flooding reduced with the outgoing tide.
- The Main Wetland timing matches well for the onset of flooding but does not produce the peak or shape, given it is more heavily influenced by the attenuation in the North and South Wetlands which is clearly not represented well in this model.
- There is some instability at structures in TUFLOW at low/negative flows but this is not influencing the flood behaviour at the peak.

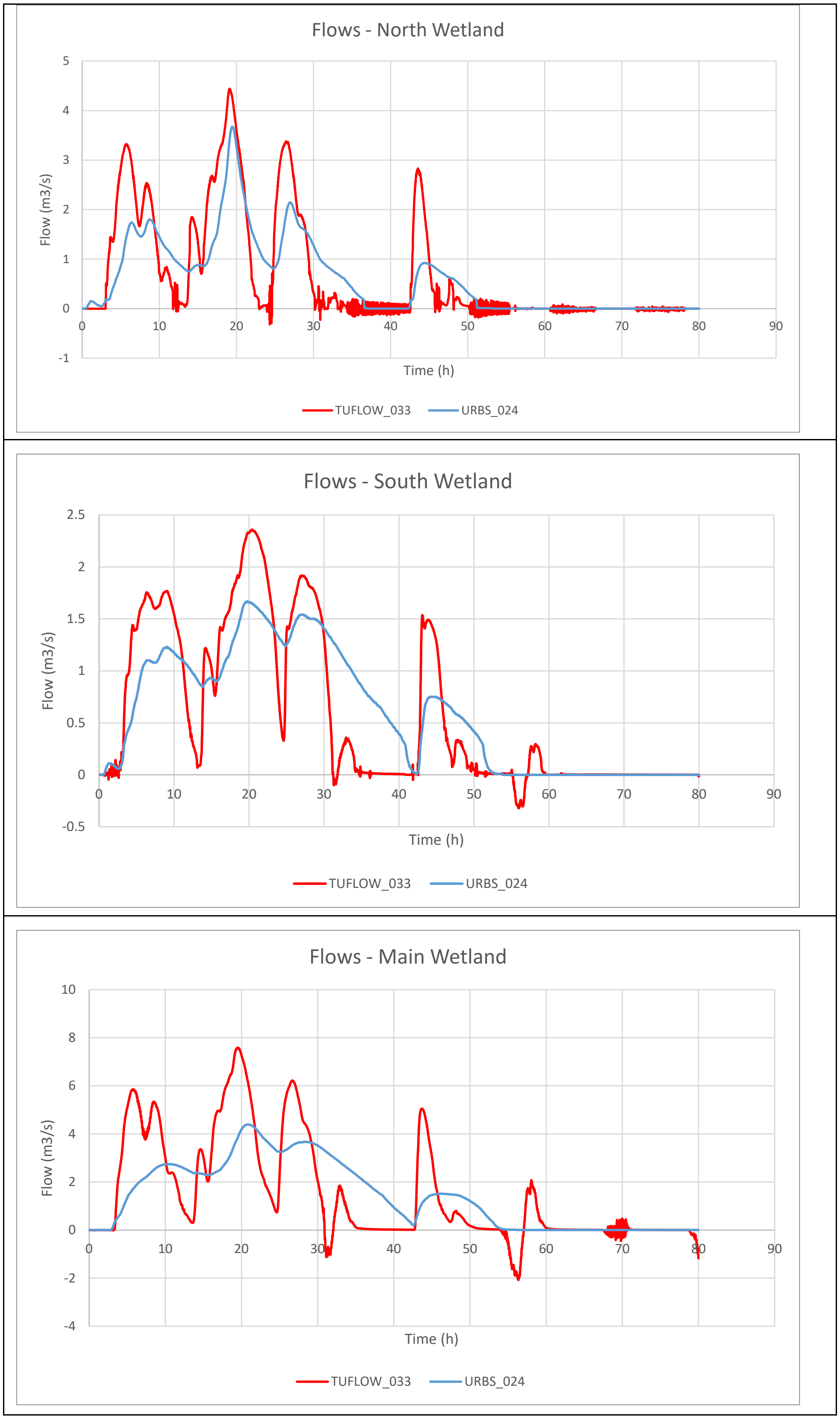


Figure 4-6: February 2020 event – flow hydrographs

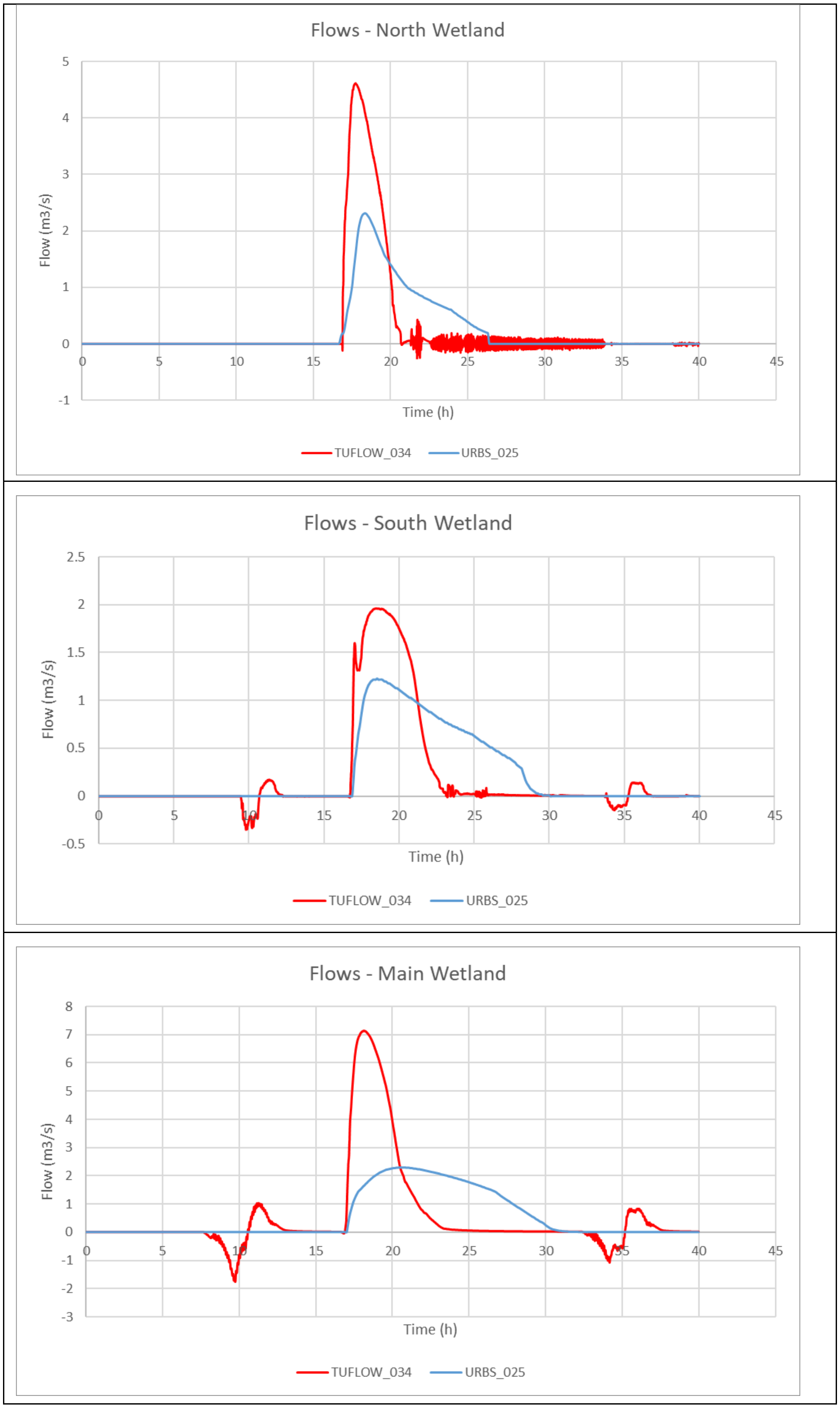


Figure 4-7: December 2019 event – flow hydrographs

4.9 Discussion on the URBS Model Calibration Results

- The calibration events consist of very large rainfall during a wet period (February 2022), and smaller events during both wet (February 2021) and dry (December 2019) periods.
- The URBS model results have indicated that, in general, there is some level of a coherence between all calibration events in terms of matching the timing of the flow hydrographs between URBS and TUFLOW.
- The URBS and TUFLOW model results match more fully for the February 2022 from which the Wetland rating curves were derived. Adoption of rating curves from smaller events with less volume stored within the coastal flats would likely improve the TUFLOW-URBS match for the other smaller events. However, there will still be some tidal influence on the hydrographs, particularly for the Main Wetland.
- The match across all events is better for the Northern Wetland which is less affected by the downstream tailwater conditions.
- The choice of URBS model parameters has resulted in peak flood levels in TUFLOW that match observed levels well across a range of events. See Section 6. On this basis, the adopted URBS parameters are considered appropriate for adoption.
- However, the URBS model results alone do not reasonably represent these peak flood levels for any event apart from the February 2022 event.
- Without significant further work to derive and incorporate a library of tailwater dependent rating curves for the wetlands, the URBS model should not be used as a standalone tool. Rather it is appropriate for use to derive inflows for simulation within TUFLOW.
- Peak flood levels, depths, velocities and flows should all be extracted from the TUFLOW model, not the URBS model.

4.10 Hydrologic Model Verification Results

The flood event of December 2021 has been chosen as the verification event. There were two bursts of rainfall resulting in two-peaked hydrographs in the URBS model.

The URBS model has also been updated for the volume before full (VBF) for the main wetland based on the tailwater level at the beginning of the simulation.

The URBS model has been simulated, and the plots comparing flow hydrographs for December 2021 event are presented in Figure 4-8.

The verification results show that:

- The flood onset for each burst matches very well for all locations, with peak timing matching well for the North and South wetlands, although the peak is higher in the TUFLOW model and not sustained as long as in the URBS model.
- The shape and peak of the Main Wetland does not match particularly well with the URBS model predicting a more sustained hydrograph with a lower peak, likely due to the cumulative effects in the differences upstream combined with the tidal boundary influence in the Main Wetland.

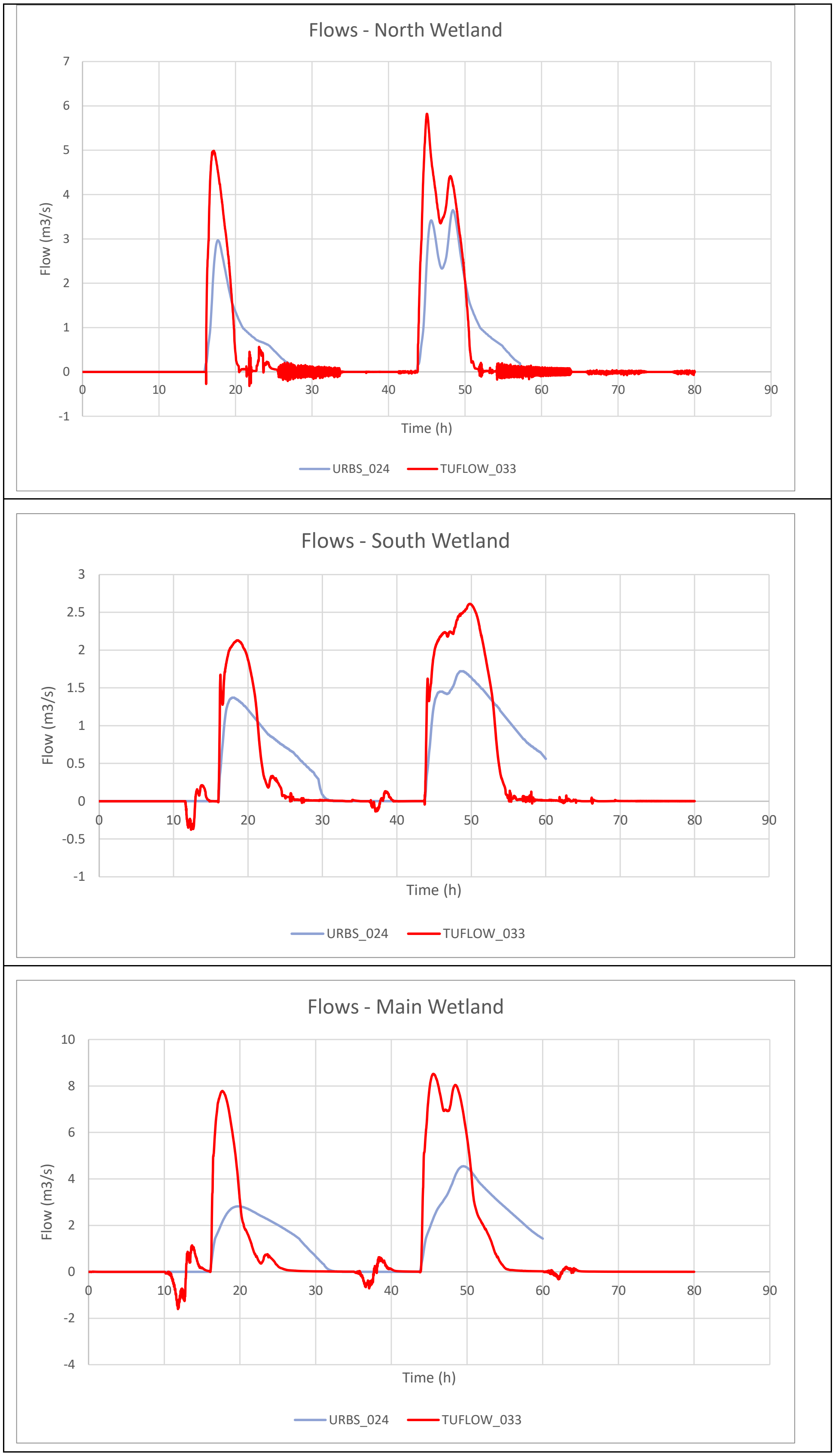


Figure 4-8: December 2021 event – flow hydrographs

5.0 Hydraulic Model Development and Calibration

5.1 Overview

The previous model for the Brighton Creek catchment (2014) represented the channels and floodplains in 2D, and culverts in 1D ESTRY. The model incorporated the North, South and Main branches of the Brighton Creek catchment. Surveyed bed levels from the 1997 survey were used to represent the channel profiles. A 2D cell size of 2m was applied to represent the floodplains.

There have been advances in the TUFLOW software since the previous study, with HPC GPU currently the preferred solver over TUFLOW Classic. The HPC solver has advantages and offers advanced functionalities including faster model run times and Sub-Grid Sampling (SGS). SGS functionality uses stage-storage curves representing the topography inside a TUFLOW grid cell to improve model resolution.

For the present study, TUFLOW 2020-10-AB has been used with the HPC solver and SGS option.

5.2 Model Development

5.2.1 Model Extents

The model extent, inflow locations, modelled watercourses, culverts and bridges are shown in the Figure 5-1.

5.2.2 Base Terrain Data

LiDAR data of 1m resolution (2019) has been used as the base data for the TUFLOW model.

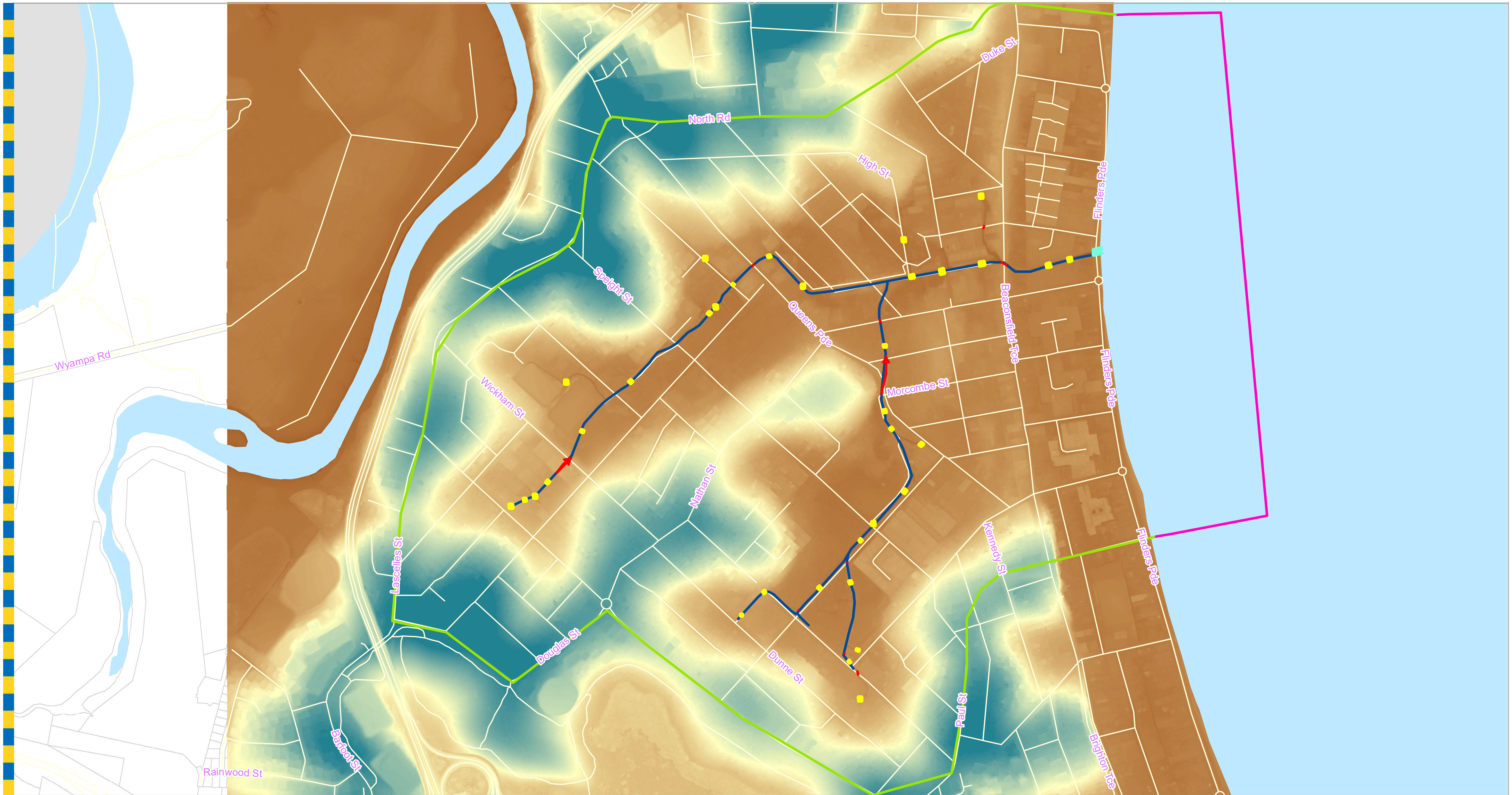
The TUFLOW grid size has been set to 2m, which is sufficient to represent the details of the floodplain. The SGS option has been enabled, with the sample frequency set to 3, to incorporate the aspects of the more detailed underlying LiDAR of 1 m resolution.

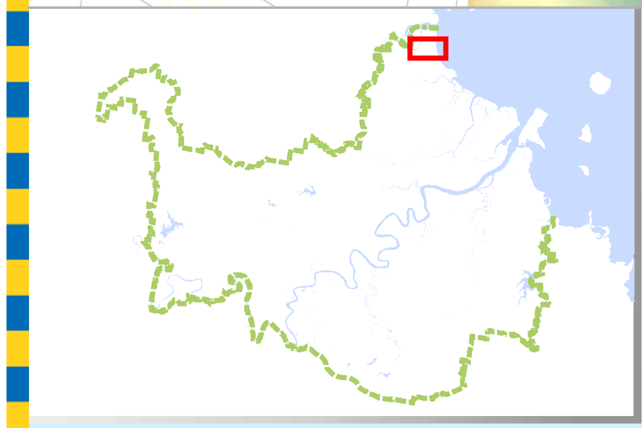
5.2.3 Open Channels

The study area consists of two major branches of Brighton Creek, the North branch and the South branch. The combined watercourse after the confluence is named as the Main branch. There are small tributaries for all the branches (Figure 5-1).

The open channels were previously represented by ~2m wide Zshape in the 2014 study. However, as the present study used SGS approach, the channel profiles and conveyance are represented in more detail through the base 1m LiDAR. Hence, Zlines have only been used within the North and South Wetland channels and Sheppard Street tributary to reinforce the channel invert to ensure a falling gradient in the downstream direction. Figure 5-2 presents representative cross-sections through these areas.

A separate ASCII grid created using 12D has been applied to represent the channel under the Flinders Parade bridge, based on the LiDAR captured, upstream channel width and visual observation of the unchanged section through the bridge (no piers/abutments). This bridge has been represented using a layered flow constriction.





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Prepared : PA
Checked : SW
Revision : 1
Publication Date : 12 Jun 2023
Project Number : IW286200

Legend

- 2d Inflow Locations
- Downstream Boundary
- 1d Piped Drainage
- 2D Structure
- Brighton Creek Centreline
- Model Boundary

Elevation

Value

High : 30

Low : 1

DATA INFORMATION

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Brighton Creek Flood Study

Figure 5-1: TUFLOW Model Schematisation

GIM - 100001 - 001

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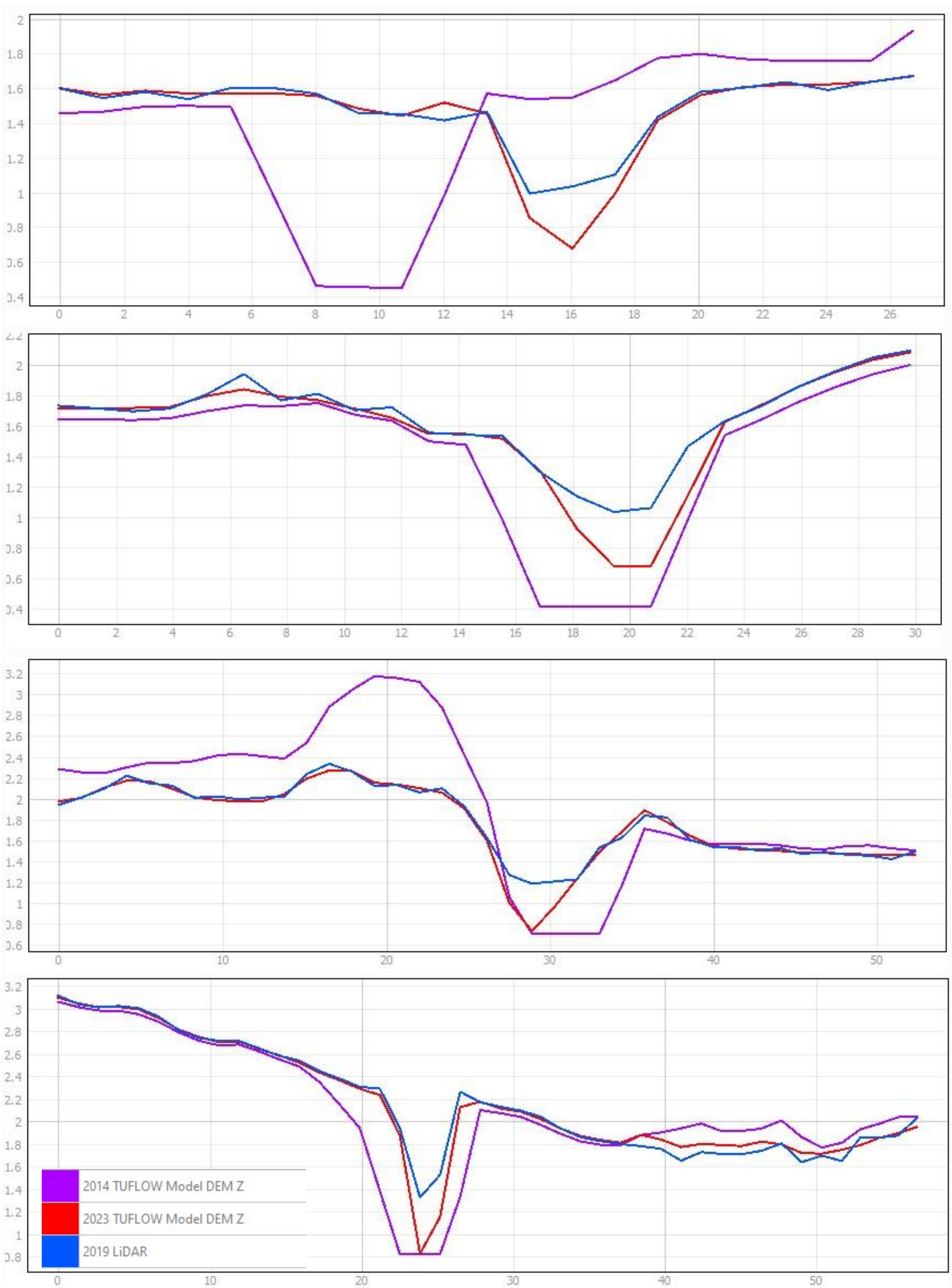


Figure 5-2: Comparative cross-sections in North and South Wetlands

The conveyance through the downstream concrete channel is very important as it is the only discharge point for flows within the channel, as flows are trapped behind the sea-wall along the remainder of the length of the catchment. The previous model represented this channel and structure based on the previous 1997 survey which appears to have significantly over-represented the channel size through this section. Figure 5-3 and Figure 5-4 present comparative sections along and through the reach demonstrating the reduced width of channel, and decreased slope compared to the previous study.

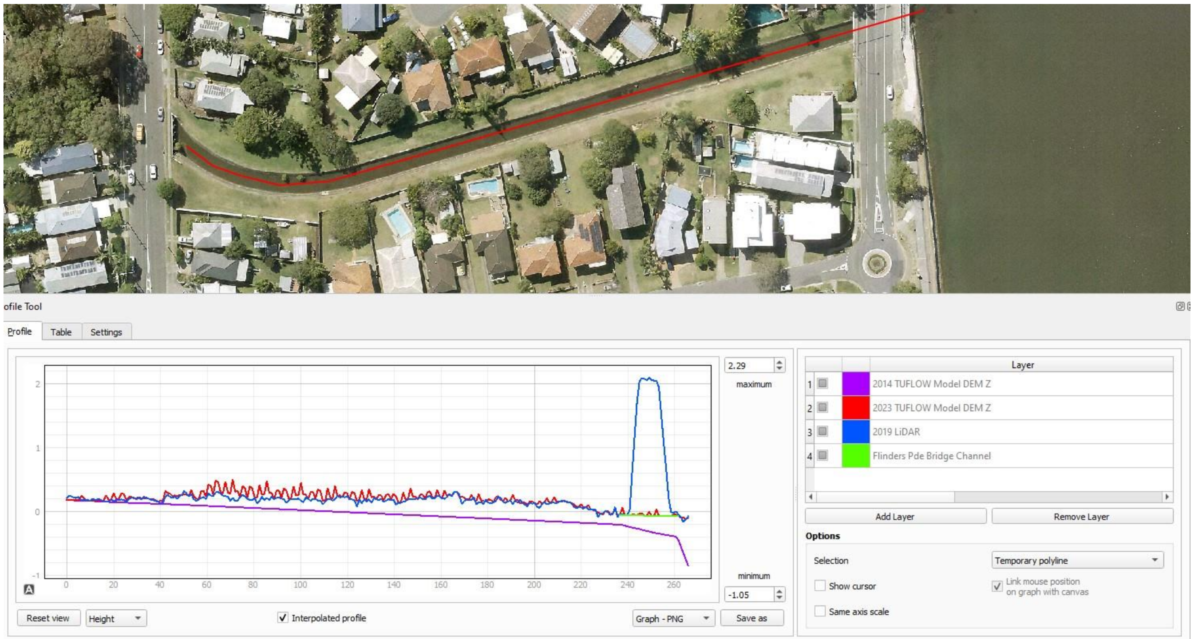


Figure 5-3: Comparative longsection along downstream concrete reach

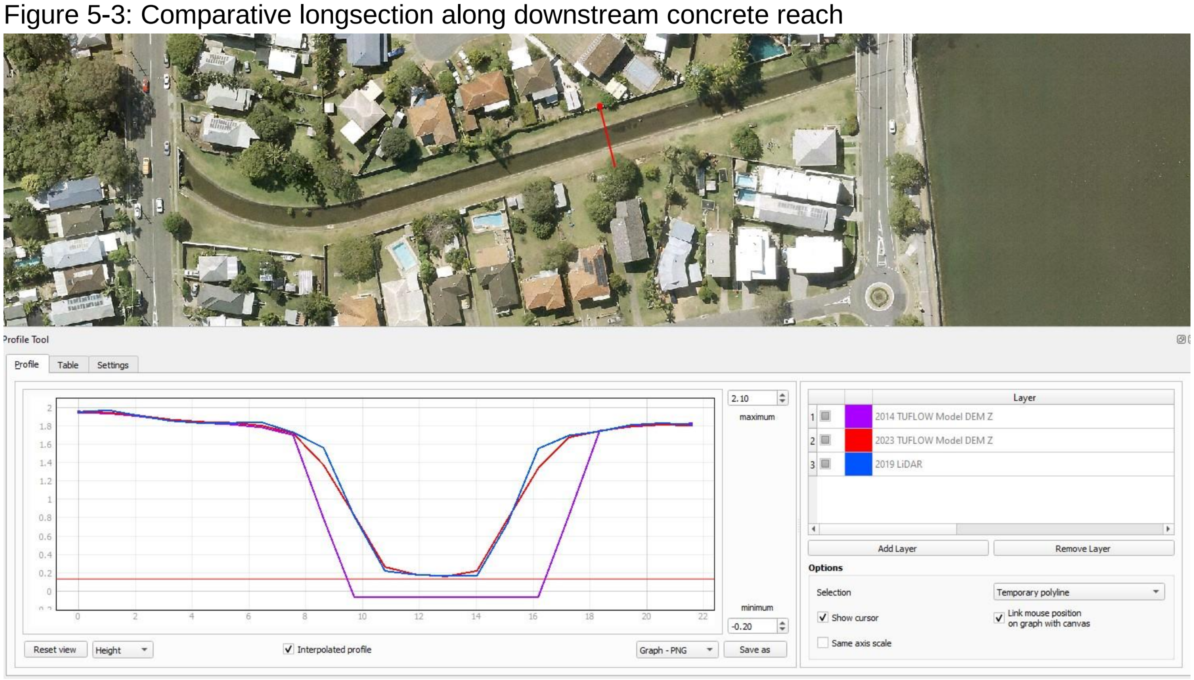


Figure 5-4: Comparative cross-section along downstream concrete reach

5.2.4 Land Use and Hydraulic Roughness

The TUFLOW materials layer from the 2014 Flood Study was reviewed and generally adopted for use within this study. Further refinement was undertaken to define the hydraulic roughness categories around Brighton Hotel, Dickson Street, and Eleventh Avenue. The Manning's roughness for various land use/land cover categories have been assigned based on the aerial images, relevant hydraulic literature, and standard practices.

A series of sensitivity tests were undertaken as part of the calibration to assess the sensitivity of flood levels throughout the model to the adopted roughness of the concrete channel at the downstream end of the model. The model was found to have some sensitivity to the adopted values. Roughness values of 0.018 and 0.020 have been tested, with 0.018 adopted to produce the best match to recorded levels across the three calibration events.

Table 5-1: Manning's 'n' roughness values for different land use/land cover categories

Land use/land cover	**Manning's n**
Verge/Footpath/Driveway to property (default layer)	0.03
Community Use Area Community Facilities	0.1
Community Use Area Education Purposes	0.1
Community Use Area Emergency Services	0.15
Community Use Area Health Care Purposes	0.15
Community Use Area Railway	0.04
Community Use Area Utility Services	0.04
Emerging Communities	0.06
High Density Residential	0.15
Light Industrial	0.15
Low Density Residential	0.12
Low-Medium Density Residential	0.15
Medium Density Residential	0.15
Multi-Purpose Centre Convenience Centre	0.15
Multi-Purpose Centre Suburban Centre	0.15
Park Land	0.04
Sports and Recreation	0.04
Conservation Environmental Protection	0.08
Channel - Concrete	0.015
Roads	0.02
Channel - Smooth	0.025
Little or no vegetation (grass)	0.035
Channel - Medium / Light density vegetation	0.05
Channel - Rough	0.075
Medium density vegetation	0.08
Medium to high density vegetation	0.12
High density vegetation	0.15
Flinders Pde Channel	0.018

5.2.5 Hydraulic Structures

Major culverts in the study area have been included in the TUFLOW model as shown in Figure 5-1.

The structure at Flinders Parade has been modelled using a layered flow constriction approach to accurately represent the conveyance of the channel and blockage due to railings. There are 11 other structures modelled in 1D ESTRY. Details of the structures have been taken from the 2014 model, and from the site visit on 16th December 2022. The structure at the Speight Street crossing on the North branch has been excluded from the model given it is drowned out in very small events and caused model stability issues.

A full listing of the hydraulic structures in the model is presented in Appendix L.

5.2.6 Piped Drainage

No piped drainage has been included in the model.[3] Only major culverts in the main channel, North branch and South branch.

5.2.7 Boundary Conditions

Inflow Boundaries

The inflows to the hydraulic model are represented using discharge versus time timeseries data, applied at SA polygons at the locations shown in Figure 5-1. These inflows have been derived from the URBS model. The locations have been adopted based on the 2014 model, and further development of the URBS model.

Downstream Boundary

A time varying water level boundary has been applied at the downstream boundary of the model for the calibration events based on recorded tide levels for each event. Initially the Brisbane Bar record was used before data was available for the Shorncliffe gauge which is significantly closer to Brighton. A sensitivity analysis was undertaken which demonstrated that there was limited difference between the recorded levels and timing of the tidal series from the different gauges and that the peak flood levels were not sensitive to the adopted tide gauge.

For stability reasons and to avoid the location of the boundary near the modelled structures, the boundary is applied away from the shore as shown in Figure 5-1.

5.2.8 Run Parameters

The 2D timestep has been set to 1 second as per the standard rule considering 2m grid size of the model, however this is used only for the initial timestep, as the HPC solution scheme uses adaptive timesteps.

[3] A sensitivity test was undertaken to assess the impact of the piped drains to the east of Beaconsfield Terrace and south of the main watercourse. The model results indicated negligible impact due to the pipes for the February 2022 event. None of the other calibration events have breakout flows into these areas. Design event modelling shows that breakout flows impact these areas with piped drainage only in events greater than the 5% AEP under existing conditions.

5.3 Calibration Procedure

5.3.1 Tolerances

Council flood studies aim to achieve the following tolerances for the hydraulic model calibration / verification:

1. Continuous recording stream gauges - within ± 0.15 m of the peak flood level
2. MHGs - within ± 0.30 m of the peak flood level
3. Debris marks - within ± 0.40 m of the peak flood level
4. Good replication of the timing of peaks and troughs.

Since only maximum height gauge levels are available for the Brighton Creek catchment, a target of ± 0.3m was adopted for the calibration in the present study.

5.3.2 Methodology

The procedure adopted for the calibration and verification of the Brighton Creek model is given below.

1. Using the flow inputs from the URBS model, run the calibration events through the TUFLOW model and compare the simulated maximum water levels with the MHGs data.
2. Iteratively adjust the TUFLOW model parameters and re-run the calibration events to achieve a good match with the recorded data.
3. Adopt the model parameters based on the calibration (Manning's n is the only parameter that has been adjusted during the calibration exercise).
4. Using the flow inputs from the URBS model, run the verification events through the TUFLOW model and compare the simulated maximum water levels with the MHGs data.

For calibration, February 2022, February 2020, and December 2019 events have been chosen. For verification, December 2021 event has been chosen. This selection ensures that the calibration is undertaken on a broad range of catchment conditions (wet-dry), which improves confidence in the model.

The calibration exercise has been primarily done on the February 2022 event, as it had the maximum number of MHG recordings. The locations of MHGs are shown in Figure 3-1.

5.4 Hydraulic Model Calibration Results

5.4.1 February 2022 event

The TUFLOW model has been simulated for 80 hours, from 00:00 hrs of 25/02/2022 to 08:00 hrs of 28/02/2022. The rainfall was continuous throughout the event, with the peak occurring around 60 hours from the start (i.e., 12:00 hrs on 27/02/2022). For the February 2022 event, maximum height gauge recordings are available at all the 5 locations within the catchment. The comparison of the model simulated maximum levels with the recorded data is provided in Table 5-2 below.

Table 5-2: Comparison of maximum water levels for February 2022 event

Gauge ID	Recorded (mAHD)	TUFLOW (mAHD)	Difference (m)
100	2.42	2.53	0.11
110	2.61	2.56	-0.05
200	2.55	2.56	0.01
210	2.78	2.57	-0.21
220	2.71	2.57	-0.14

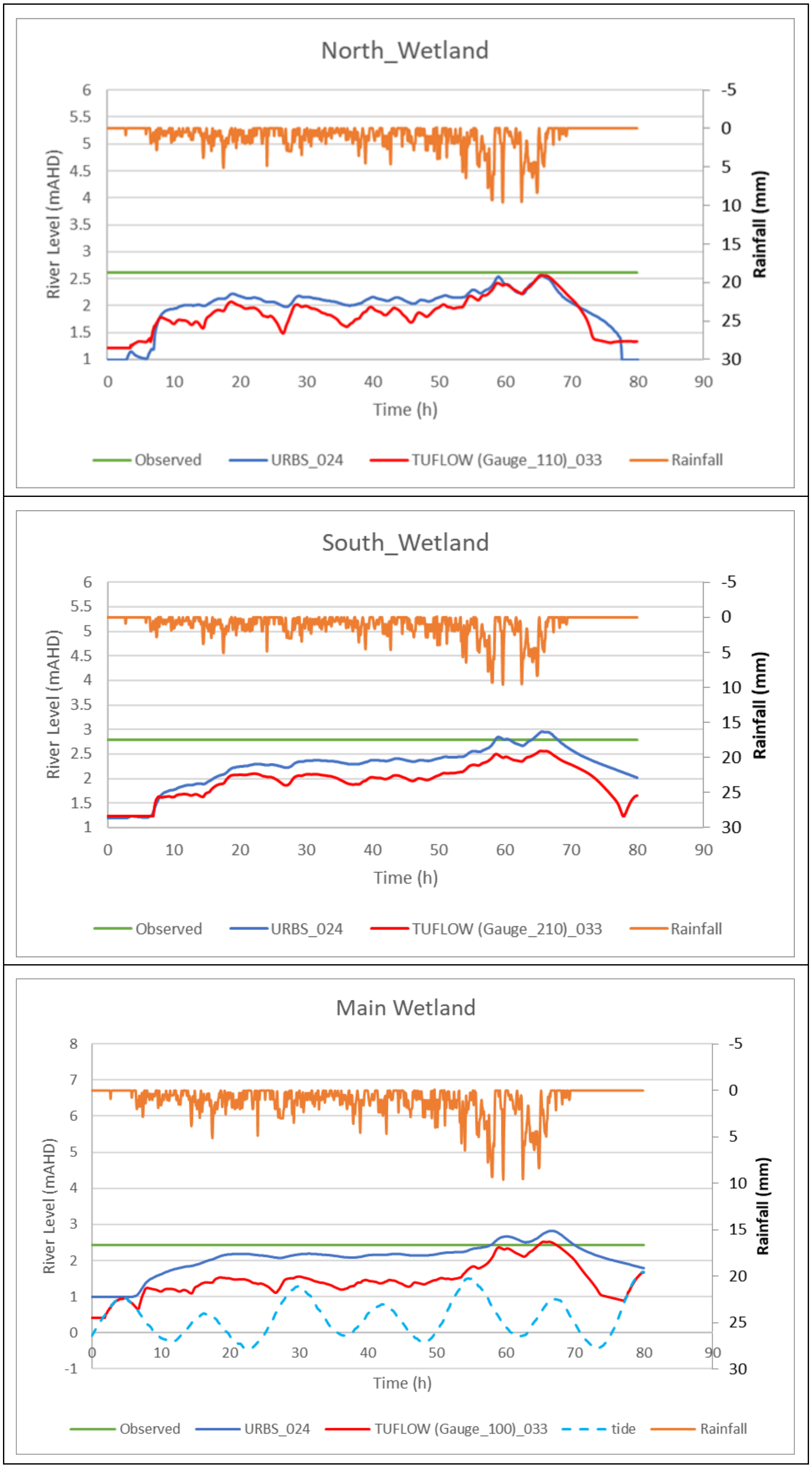


Figure 5-5: February 2022 – TUFLOW comparison to observed peak

The differences between the model simulated values and the recorded data show that the model is able to predict the peak water levels very well, within the tolerance specified by Council (± 0.30 m for MHGs).

A comparison of the TUFLOW stage hydrograph with the URBS outputs and MHG data has been provided for the gauges at each wetland storage area in Figure 5-6. Analysis of the results indicate that:

1. The TUFLOW model is able to predict the maximum water level at the downstream end of the north wetland and main wetland relatively more accurately than the south wetland.
2. The peak water levels are influenced by the tailwater conditions – the second peak of the stage hydrograph is around the peak of the tide. The tailwater conditions impact the water levels in the main and south wetlands.
3. Before and after the rainfall event (0-7 hours and 76-80 hours in the simulation), the water level in the downstream channel follows the tidal cycle (see the plot for main wetland). This indicates that emptying of the whole catchment depends on the tailwater level.

A comparison of the timing of the peak water level has also been done with anecdotal evidence (Capital Expenditure Proposal Report). For the February 2022 event, the timing of the peak matches accurately with the anecdotal evidence (i.e., peak at 07:00 pm on 27th February 2022).

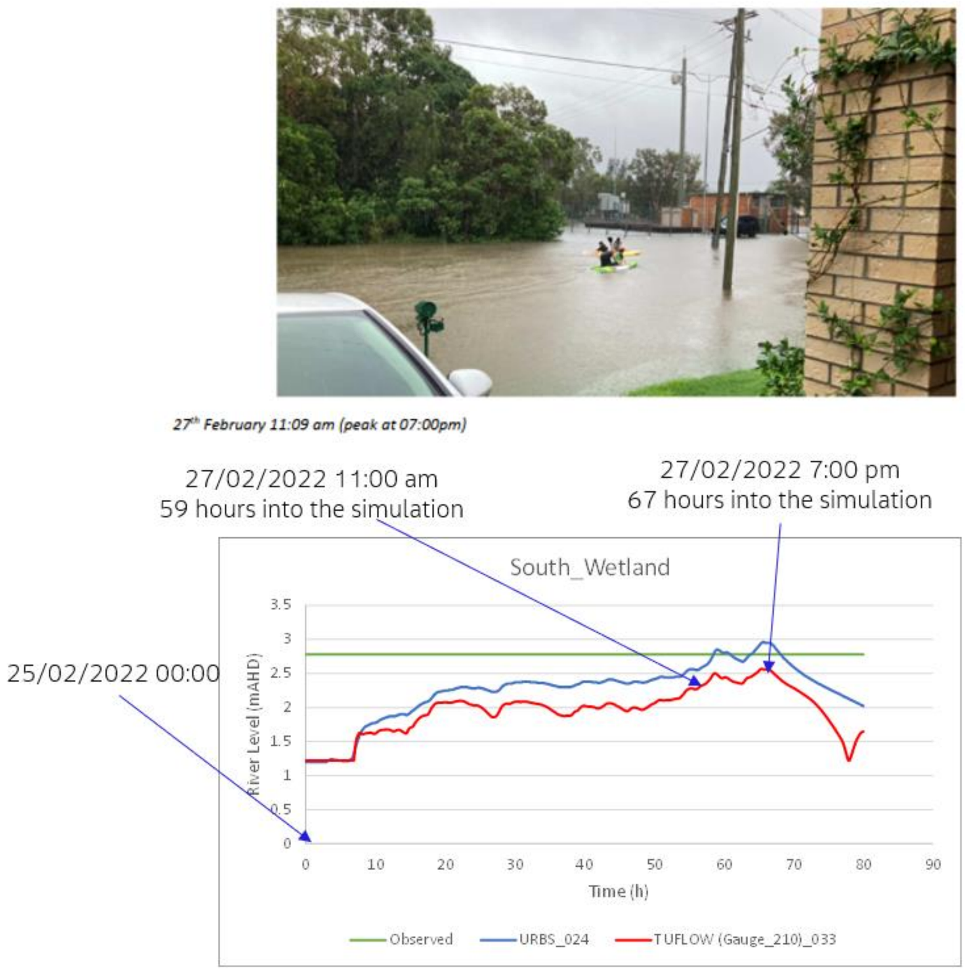


Figure 5-6: February 2022 - anecdotal evidence of flooding

5.4.2 December 2019 event

The TUFLOW model has been simulated for 40 hours, from 00:00 hrs of 13/12/2019 to 16:00 hrs of 14/12/2019. A single short burst of rainfall occurred (< 1 hour) with peak rainfall around 16 hours into the simulation (i.e., 16:00 hrs on 13/12/2019).

For the December 2019 event, the MHG data is available only at gauges 110 and 220, which are located far upstream in the catchment. The model simulated maximum water level has been compared with MHG data and tabulated in Table 5-3 below.

Table 5-3: Comparison of maximum water levels for December 2019 event

Gauge ID	Recorded (mAHD)	TUFLOW (mAHD)	Difference (m)
110	1.65	2.02	0.37
220	1.69	1.87	0.18

The TUFLOW model is able to simulate the maximum water level for the gauge 220 within the tolerance of ± 0.30 m, however for the gauge 110, the model is overestimating the level.

The stage hydrographs from the TUFLOW model along with the URBS results and MHG data are provided in the figure below.

From the analysis of stage hydrographs for the December 2019 event, the below points are noted:

- There is a good match in the peak timings between the TUFLOW and URBS models
- The shapes of the stage hydrographs are different, as the URBS model does not consider the tailwater conditions
- The main wetland is majorly influenced by the tailwater conditions. The water levels in the main channel around this storage area closely follow the tidal cycle if there are no additional fluvial flows/flooding.

5.4.3 February 2020 event

For the February 2020 event, the TUFLOW model has been simulated for 60 hours, from 00:00 hrs of 6/02/2020 to 12:00 hrs of 8/02/2020. There were 4 bursts of rainfall during the event. There are 3 MHGs that recorded the levels for the flood event. TUFLOW model has been simulated with the inflows derived from the URBS model for the event, and the TUFLOW simulated maximum water levels are compared with the observed data in table below.

Table 5-4: Comparison of maximum water levels for February 2020 event

Gauge ID	Recorded (mAHD)	TUFLOW (mAHD)	Difference (m)
100	1.84	1.52	-0.32
110	1.98	2.01	0.03
220	1.86	1.96	0.10

There is a good fit between the modelled and observed maximum levels at the gauges 110 and 220 for the 2020 event. The maximum water level is underpredicted at the gauge 110, and the difference is slightly off the acceptable tolerance.

There could be a chance that the downstream culvert at the Queens Parade had a blockage during the flood event increasing the water levels in the upstream. However, further evidence is needed to confirm this.

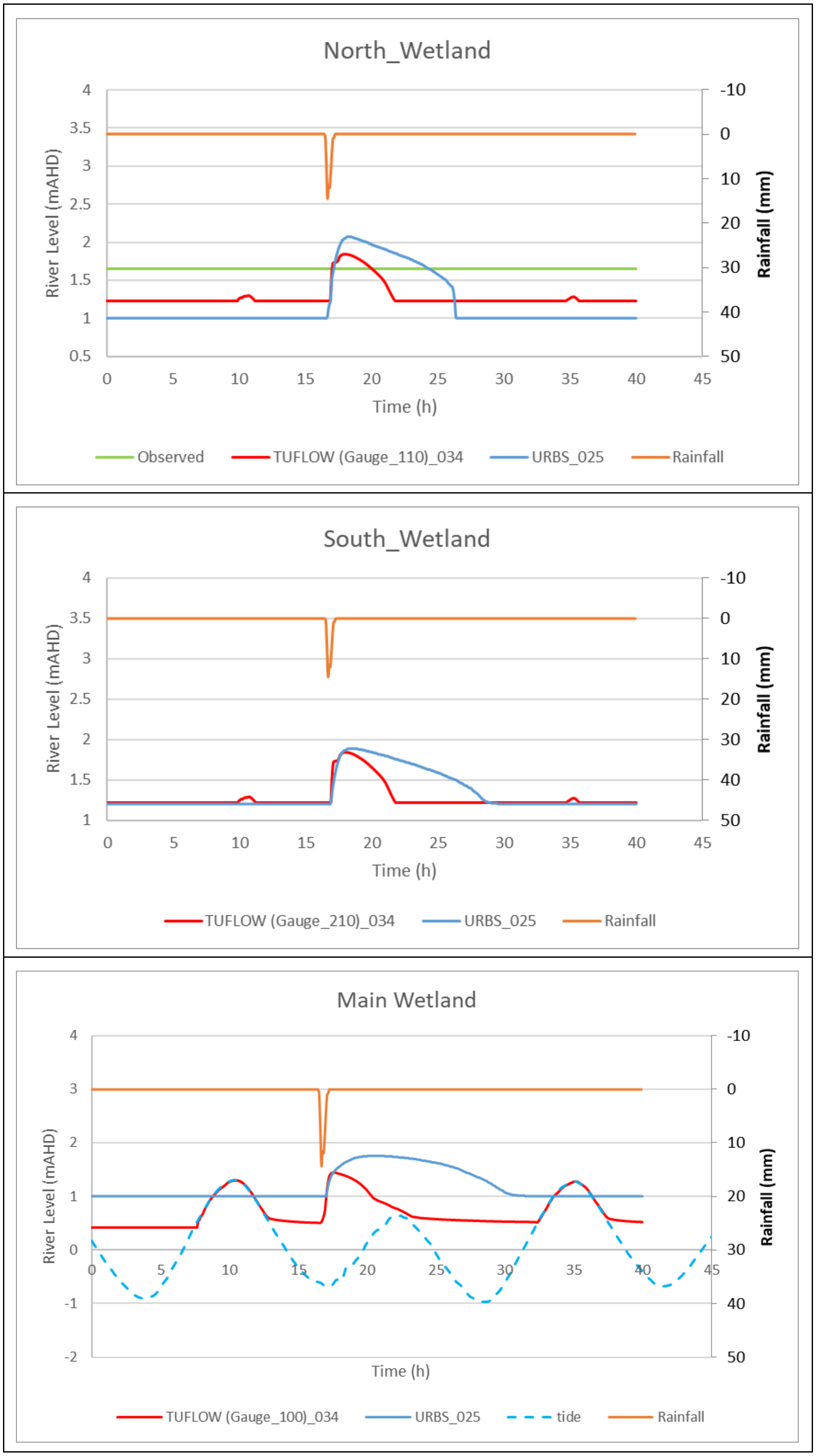


Figure 5-7: December 2019 event – stage hydrographs

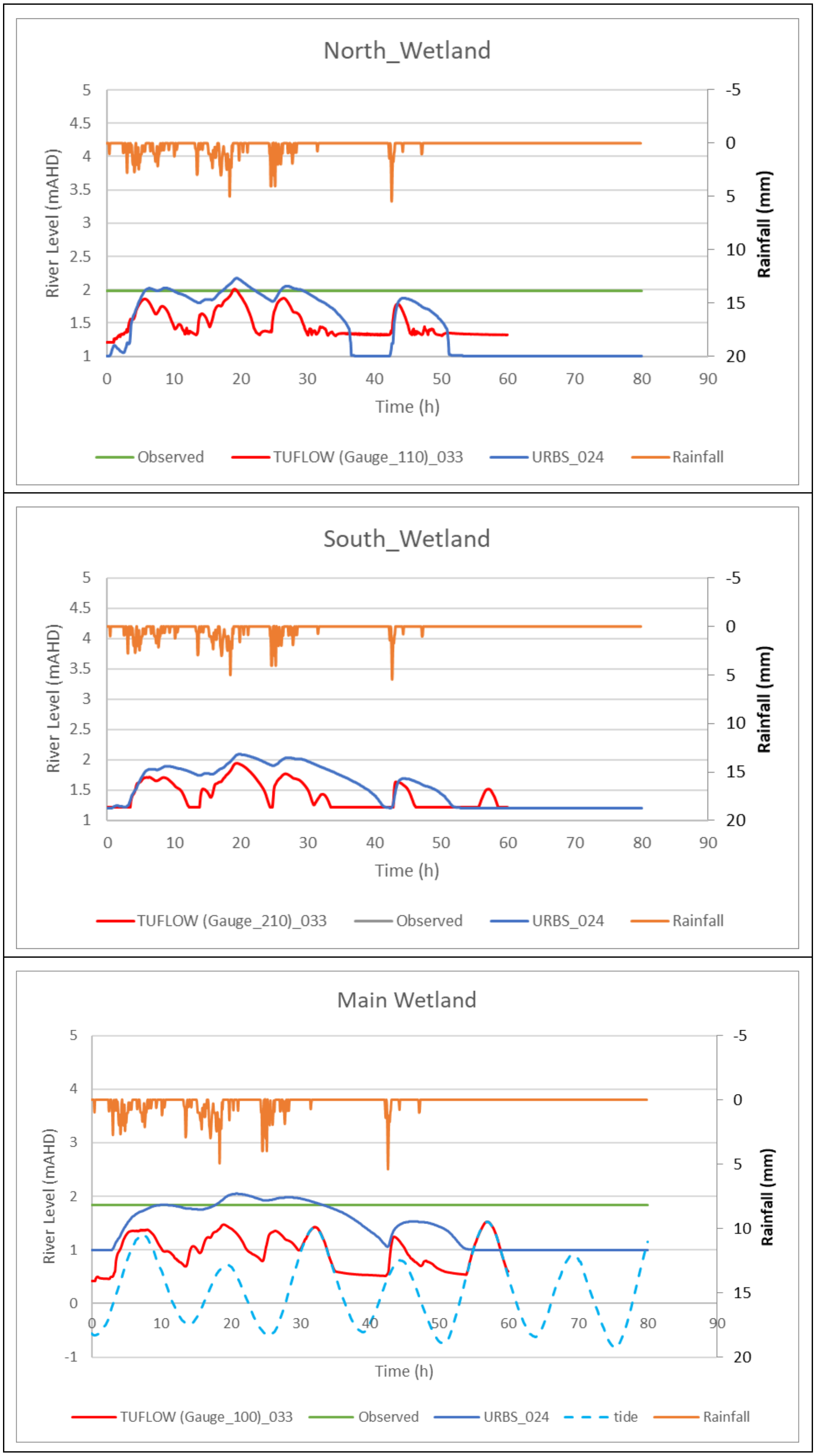


Figure 5-8: February 2020 event – stage hydrographs

The 2020 event stage hydrographs from the TUFLOW model along with the URBS results and MHG data are provided in Figure 5-8. The analysis of the TUFLOW results show that:

- The flooding is due to a combination of fluvial flows due to heavy rainfall and high tides occurring around the same time.
- The timing of the peaks is matched reasonably well between TUFLOW and URBS models.
- The water level in the main wetland is controlled by the tailwater conditions when there is no fluvial flooding. Hence, emptying of this storage system is dependent on the tidal levels downstream.

5.5 Hydraulic Model Verification Results

The model has been verified for the December 2021 event. The TUFLOW model has been simulated for 60 hours, from 00:00 hrs of 8/12/2021 to 12:00 hrs of 10/12/2021. There are two MHG recordings available for the event, and the model simulated maximum water levels are compared to these in table below.

Table 5-5: Comparison of maximum water levels for December 2021 event

Gauge ID	Recorded (mAHD)	TUFLOW (mAHD)	Difference (m)
110	2.06	2.11	0.05
220	1.85	2.05	0.20

There is a very good match between the model predicted and recorded maximum water levels for the verification event. The model overestimates the levels; however, the differences are within the acceptable tolerance.

From the stage hydrographs, it can be implied that:

- The two peaks are similar in terms of magnitude. As there is no recording of the timing of the maximum height, the highest of the two has been compared with the MHG data for the gauge 110 (north wetland). The model prediction is within the acceptable tolerance.
- The peaks match well between the TUFLOW and URBS models, except for the main wetland which is governed by the tailwater levels.
- The parameters chosen for calibration have given a good model prediction during the verification event.

A summary of maximum water levels predicted by the TUFLOW model and recorded data is provided in Table 5-6, indicating that the majority of the model simulated levels are in the allowable tolerance (± 300 mm), thus demonstrating a good calibration.

Table 5-6: Comparison of maximum water levels

	13/12/2019			6/02/2020			9/12/2021			27/02/2022		
Gauge ID	Recorded	TUFLOW	Difference	Recorded	TUFLOW	Difference	Recorded	TUFLOW	Difference	Recorded	TUFLOW	Difference
100				1.84	1.52	-0.32				2.42	2.53	0.11
110	1.65	2.02	0.37	1.98	2.01	0.03	2.06	2.11	0.05	2.61	2.56	-0.05
200										2.55	2.556	0.01
210										2.78	2.57	-0.21
220	1.69	1.87	0.18	1.86	1.96	0.10	1.85	2.05	0.20	2.71	2.57	-0.14

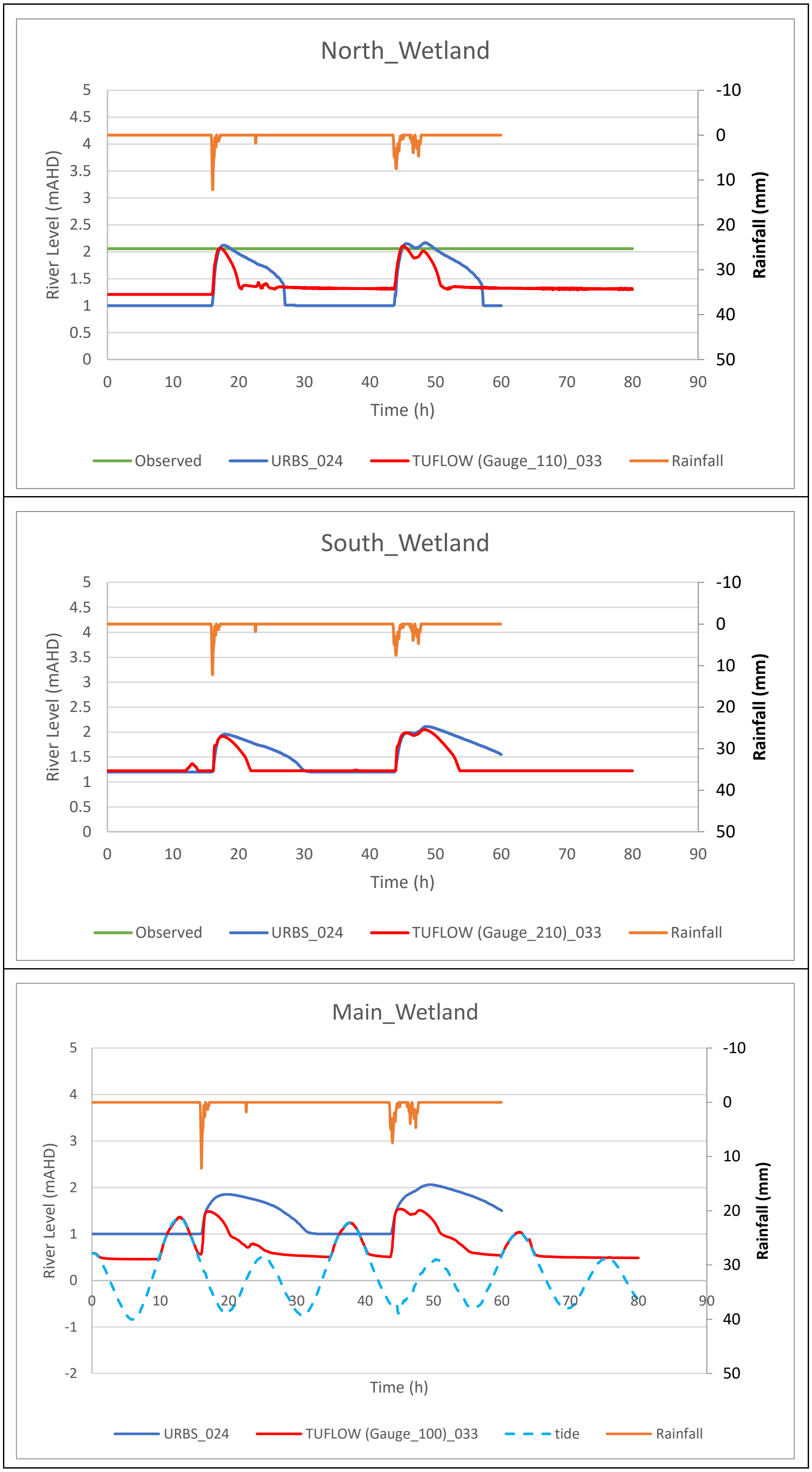


Figure 5-9: December 2021 event – stage hydrographs

5.6 Hydraulic Structure Verification

5.6.1 Bridge Head-loss Checks

It is a standard practice in Council flood studies to validate structure head-losses to gain confidence in the model representation and the results. Also, the TUFLOW manual recommends confirming the head-loss at the structures using other approaches/calculations/tools.

An assessment of the head-loss at two key structures has been undertaken as a part of this study. HEC-RAS has been chosen for validating the head-loss calculated in the TUFLOW model. The two structures selected for the exercise are the Beaconsfield Terrace culverts and the Flinders Parade Bridge.

It has been claimed by the local residents that the hydraulic headloss at the Beaconsfield Terrace culverts and Flinders Parade bridge have contributed to the inundation of properties in the upstream of the culverts during the historical flood events. Hence these two structures are important. Other structures within the catchment are located in volume dominant areas where significant 2D effects are present. Most of these structures are minor and submerged during all but the smallest of flood events.

For the smaller events, flow within the concrete channel is supercritical transitioning to subcritical at the exit of the channel downstream of Flinders Parade where the channel opens out into the MHWS level in Moreton Bay, resulting in a hydraulic jump at the exit of the Flinders Pde structure. At the reporting locations, this results in a minor negative headloss across the structure in HEC-RAS and a minor positive headloss in TUFLOW for flows less than 10m^3/s. Figure 5-10 shows the hydraulic jump at the Flinders Pde structure.

Table 5-7 and Table 5-8 present the simulated head-losses in TUFLOW and HEC-RAS at Beaconsfield Terrace and Flinders Parade, respectively.

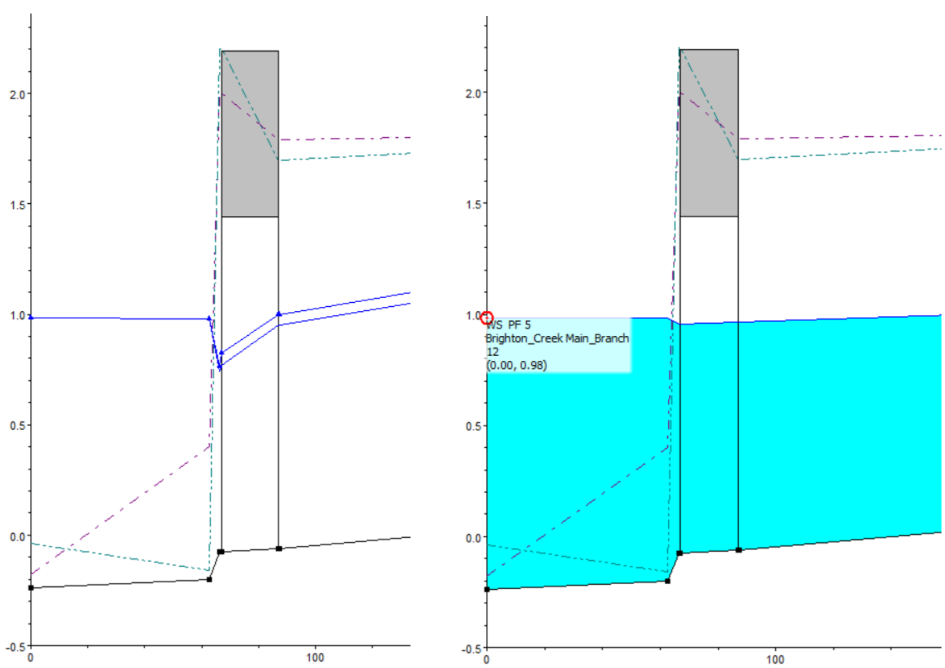


Figure 5-10: Hydraulic jump at Flinders Pde exit showing (L) flows below 12m^3/s and (R) 12m^3/s

Table 5-7: Headloss comparison at Beaconsfield Terrace

Flow (m^3/s)	TUFLOW headloss (m)	HEC RAS headloss (m)	Difference (m)
5	0.05	0.06	0.01
6	0.06	0.07	0.01
7	0.07	0.08	0.01
8	0.08	0.09	0.02
9	0.09	0.10	0.01
10	0.10	0.11	0.01
11	0.11	0.12	0.01
12	0.12	0.12	0.00
13	0.13	0.13	0.00
14	0.14	0.14	-0.00
15	0.15	0.15	-0.01
16	0.17	0.16	-0.01
17	0.18	0.17	-0.01
18	0.20	0.18	-0.02
19	0.22	0.20	-0.03
20	0.24	0.21	-0.03
21	0.26	0.25	-0.01
22	0.28	0.32	0.04
23	0.30	0.38	0.08
24	0.32	0.45	0.13
25	0.34	0.59	0.18

Table 5-8: Headloss comparison at Flinders Pde

Flow (m^3/s)	TUFLOW headloss (m)	HEC RAS headloss (m)	Difference (m)
5	0.01	-0.02	-0.03
6	0.02	-0.02	-0.04
7	0.02	-0.03	-0.05
8	0.03	-0.04	-0.08
9	0.04	-0.05	-0.10
10	0.06	-0.06	-0.12
11	0.08	-0.06	-0.14
12	0.12	-0.03	-0.15
13	0.16	0.02	-0.14
14	0.19	0.07	-0.13
15	0.23	0.11	-0.12
16	0.28	0.15	-0.13
17	0.32	0.20	-0.13
18	0.36	0.24	-0.12
19	0.40	0.28	-0.12
20	0.44	0.32	-0.12

Flow (m^3/s)	TUFLOW headloss (m)	HEC RAS headloss (m)	Difference (m)
5	0.01	-0.02	-0.03
21	0.47	0.36	-0.11
22	0.50	0.39	-0.11
23	0.54	0.43	-0.11
24	0.59	0.54	-0.05
25	0.66	0.58	-0.08

The TUFLOW and HEC RAS models have been simulated for a range of flows from 5 to 25 m^3/s with a constant tailwater of 0.98 mAHD (MHWS for Brisbane Bar). At flows greater than 24 m^3/s, Beaconsfield Terrace is overtopped, introducing 2D behaviour which cannot be accurately modelled in the 1D HEC-RAS model. The head-loss is higher at high flows.

In general, the differences in the head-losses are within the acceptable tolerance limits of +/- 0.3m for the range of flows considered. This is considered as a good result and provides confidence in the calculated head-losses in the TUFLOW model.

It is noted that the head-losses predicted by both TUFLOW and HEC-RAS are significantly higher for this Study than those predicted in the 2014 Study. This is expected given the following key changes that have been incorporated into the current hydrodynamic models:

- The conveyance of the trapezoidal concrete channel between Beaconsfield Terrace and Flinders Parade was over-represented in the 2014 models. It was represented as a Z-shape based on the 1997 survey which showed a base-width of more than 6 m compared to the current 2019 LiDAR which shows a base-width of less than 4 m.
- The waterway opening at Flinders Parade Bridge was similarly over-represented consistent with the channel representation.
- The 2014 model also assumed a steep drop-off from the Flinders Parade bridge to the ocean whereas the 2019 LiDAR shows the mudflats extend out to sea at a very low grade.

The updated TUFLOW model is considered a much more accurate representation of the constriction of outflows through the Flinders Parade bridge.

5.7 Hydrologic-Hydraulic Model Consistency Checks (Historical Events)

Consistency checks between the URBS and TUFLOW models were carried out during the calibration exercise. Comparison plots are presented for all events throughout Section 4.8.

As outlined within this section, there is a reasonable agreement between the URBS and TUFLOW models for the February 2022 event from which the URBS wetland rating curves were derived. There is limited agreement between the model results for other events. This is due to the discharge from the wetlands being controlled by the tailwater downstream of the discharge points.

It has therefore been concluded that the URBS model should not be used stand-alone but rather as a tool to derive inflows to the TUFLOW model which can then be used to extract flow hydrographs.

5.8 Discussion on Calibration and Verification

Calibration and further verification have been undertaken for the TUFLOW model for the Brighton Creek catchment. From the analysis of the results, below points can be noted.

- The TUFLOW model has been able to predict the maximum water levels at the gauges within the acceptable limits for most of the calibration/verification events. This demonstrates the confidence in the hydraulic and hydrological models developed for the Brighton Creek catchment.
- Manning's n has been calibrated for the catchment, and further used in the verification event. The selection has given satisfactory results (i.e., maximum water levels).
- Recordings of time varying water levels is not available for the catchment; hence only maximum water levels have been compared. However, it has been noted that the water levels in the watercourses for the majority of the catchment (south and main wetland) is governed by the tailwater conditions.
- As the Flinders Parade Bridge is the only element in the system to discharge floodwaters, and its proximity to the ocean, it acts as the bottleneck.
- A sensitivity of the calibration events to the adopted tidal conditions was undertaken which demonstrated that for all events, modelled peak levels had limited sensitivity to the adoption of static MHWS tidal conditions rather than the observed tidal hydrograph, but high sensitivity to the adoption of static HAT conditions.
- While the current model is not significantly sensitive to the adopted tidal conditions, this is likely due to the Flinders Parade Bridge being inlet-controlled for the majority of simulated events. If Flinders Parade Bridge and/or the channel between Flinders Parade and Beaconsfield Terrace are updated, the system may become more sensitive to the tidal conditions.

6.0 Design Event Analysis

6.1 Design Event Scenarios

Table 6-1 indicates the two scenarios utilised in the modelling of the design events, noting that all design event scenarios were modelled using ultimate catchment hydrological conditions.

For the purpose of this report, the term "design events" refers to the following events:

- Frequent: 50% AEP and 20% AEP, and
- Intermediate: 10% AEP and 5% AEP, and
- Rare: 2% AEP and 1% AEP

Table 6-1: Design Event Scenarios

Event	Scenario 1 (without climate change)	Scenario 1 (including climate change)	Scenario 3 (including climate change)
50% AEP	✓	✓	✓
20% AEP	✓	✓	✓
10% AEP	✓	✓	✓
5% AEP	✓	✓	✓
2% AEP	✓	✓	✓
1% AEP	✓	✓	✓

The following describes the design event scenarios:

Scenario 1: Existing Waterway Conditions

Scenario 1 is based on the current waterway conditions.

Scenario 3: Filling to the Modelled Flood Corridor + Minimum Riparian Corridor (MRC)

Scenario 3 includes an allowance for a riparian corridor along the edge of the channel. Council reviewed the existing vegetation and land-use adjacent to the channel to determine an appropriate Manning's 'n' roughness value for the riparian corridor.

In most locations the default value of n = 0.15 was used. For the maintained section on either side of the concrete trapezoidal channel between Beaconsfield Terrace and Flinders Parade, a value of n = 0.08 was adopted.

A 30 m wide corridor (15m wide each side from the low flow channel) was defined through a new 2d materials layer within the TUFLOW model. In areas where the 15 m width was not available, the MRC was set to the maximum possible width (i.e. up to 15 m) up to the boundary of the "Modelled Flood Corridor."

The "Modelled Flood Corridor" is the greater extent of the Waterway Corridor (WC) and Flood Planning Areas (FPAs) 1, 2 and 3. Roads and parks have also been included in the flood corridor. Figure 6-1 indicates the "Modelled Flood Corridor" adopted for the catchment. Scenario 3 assumes filling to the "Modelled Flood Corridor" boundary to represent potential development. In the design events, 50% AEP to 1% AEP, the filling acts as a barrier and the "Modelled Flood Corridor" was modelled simplistically by restricting the TUFLOW model code boundary to the Flood Corridor. This is a simple and conservative assumption used to develop design planning levels up to the 1% AEP. It does not necessarily reflect allowable development assumptions under BCC City Plan.

6.2 Design Event Hydrology

This study utilises the AR&R 2019 approach for design flood estimation, detailed in the following sections.

6.2.1 Flood Frequency Analysis (FFA)

No at site Flood Frequency Analysis was possible for this location as only Maximum Height Gauges with a very short period of record (less than 5 years) are located within this catchment. No event gaugings have been undertaken at these locations to provide rating curve information.

The Regional Flood Frequency Estimation (RFFE) method groups flood frequency analyses for gauged catchments with similar characteristics such that FFA characteristics can be transferred to nearby catchments. However, this method was developed based on data from rural catchments and cannot be applied to urban catchments like Brighton.

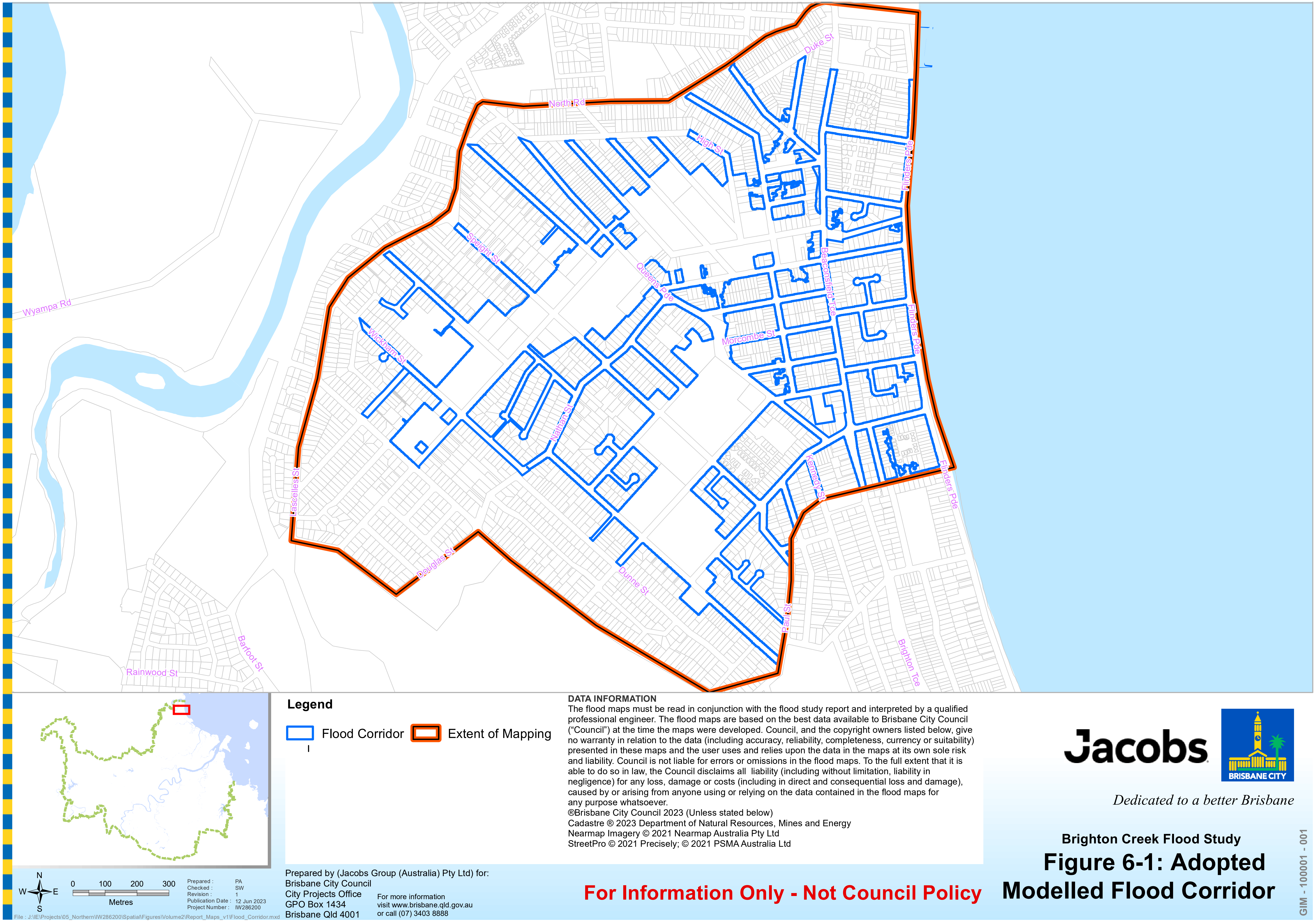
6.2.2 Adopted Methodology for the DEA AR&R 2019

In accordance with Council's FSPV9 document, the AR&R 2019 Ensemble Design Event Approach (DEA AR&R 2019) was adopted. This approach involves simulating 10 temporal patterns for each duration, with the critical duration identified by the maximum of the Rank 6 estimates (peak immediately larger than the Median) for each duration.

Storm Injector, a proprietary Software Interface used to define AR&R design storms for simulation within hydrologic modelling software packages, was used to run the design event URBS models with the parameters described in the following sections.

6.2.3 URBS Model Set-up

The URBS model developed through the joint calibration exercise was used to simulate the design event hydrology. The following describes the parameters adopted and modifications to the calibration model undertaken for design event simulation.



Legend

Flood Corridor
Extent of Mapping

Prepared : PA
Checked : SW
Revision : 1
Publication Date : 12 Jun 2023
Project Number : IW286200

File : J:\IE\Projects\05_Northern\IW286200\Spatial\Figures\Volume2\Report_Maps_v1\Flood_Corridor.mxd

DATA INFORMATION

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Brighton Creek Flood Study

Figure 6-1: Adopted Modelled Flood Corridor

GIM - 100001 - 001

Catchment Development

The design events were modelled based on Ultimate catchment hydrologic conditions with the level of development based on the BCC City Plan (2014) zoning to establish ultimate land use. The Impervious Fraction was modified within the URBS model to account for future land use changes. Given the current development level within Brighton, the average impervious percentage increased from 54.5% under existing conditions to 55.7% under Ultimate Conditions. Appendix B presents the adopted URBS parameters for the design event model with the adopted land use for the ultimate catchment development shown on a catchment map in Appendix C.

Design IFDs

Council (along with other SEQ Local Councils) recently commissioned a study to review and update IFD values for SEQ. The LIMB 2022 IFD values have been used within this study. Due to the small size of the Brighton Catchment, no spatial variation or Areal Reduction Factor have been applied.

Table 6-2 presents the adopted design rainfalls for Existing Climate Conditions.

The potential effects of climate change have been simulated in accordance with Council's FSPV9 by the application of a 9.8% increase in rainfall depth. This increase is based on Representative Climate Pathway (RCP) 4.5 for climate conditions in 2100, based on extrapolation of the AR&R DataHub estimates for 2080 and 2090.

Table 6-2: Adopted Design Event IFD Data – Existing Climate

Duration (minutes)	Rainfall Depth (mm) (1)					
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
Brighton Catchment						
30	32	43	50	56	64	69
45	38	52	61	70	82	91
60	42	59	71	82	98	110
90	49	70	85	100	122	140
120	54	78	96	115	142	165
180	62	91	113	137	172	202
270	71	105	132	161	204	242
360	78	116	146	179	229	272

(1) The values presented do not include any allowance for climate change rainfall increases.

Losses

For pervious areas, the Burst Initial Loss (**(**IL_b) was simulated based on the following approach with the Burst Initial Loss set to zero where the Median Pre-burst rainfall exceeded the Storm Initial Loss:

Burst Initial Loss (ILb) = Storm Initial Loss (ILs) – Median Pre-burst rainfall

For impervious areas, the Burst Initial Loss was set as zero. For pervious areas, the Storm Initial Loss was set to 20 mm based on the AR&R Data Hub.

Median Pre-burst rainfalls, which vary by AEP and duration, were extracted from the AR&R Data Hub for standard durations and AEPs up to 1% AEP. Median Pre-burst rainfalls for non-standard durations were interpolated from the Data Hub values and 1% AEP values adopted for rare events.

For larger and longer duration events Median Pre-burst rainfalls are quite large for Brighton resulting in Burst Initial losses of zero for larger events. This is quite consistent with the calibration losses as a zero initial loss was adopted for the larger, longer duration events (i.e., Feb 2022) while an initial loss of 50 mm was adopted for the smaller, shorter duration December 2019 event which followed an extensive dry period.

The pervious Continuing Loss was set at 2.4 mm/hr based on the AR&R Data Hub while the impervious Continuing Loss was set at 0 mm/hr.

Table 6-3 presents the adopted loss values while Table 6-4 presents the applied losses with Pre-Burst accounted for.

Table 6-3: Adopted Losses

	Adopted Losses	
	Storm Initial Loss (mm)	**Continuing Loss (mm/hr)**
Pervious	20	2.4
Impervious	0	0

Table 6-4: Adopted Burst Initial Loss (Storm Loss – Pre-Burst Rainfall)

Duration	AEP					
	50%	**20%**	**10%**	**5%**	**2%**	**1%**
60 min	17.3	14.2	12.1	10.1	11	11.6
90 min	18.1	10.4	5.3	0.4	4.9	8.3
120 min	18.1	10.4	5.4	0.6	2.0	3.0
180 min	14.8	5.0	0	0	0	0
360 min	13.4	5.9	0.9	0	0	0

Temporal Patterns

The ensemble of point temporal patterns for the East Coast North zone was applied for durations from 30 minutes to 6 hours.

Baseflow

Given the small tidal nature of the catchment, baseflow was not included in the design flow estimates.

6.3 Design Event Hydraulic Modelling

6.3.1 Overview

The TUFLOW model was used to determine design flows and flood levels for those scenarios as detailed in Table 6-1 for the 50% AEP to the 1% AEP events. These events were simulated for storm durations from 30 minutes to 6 hours using the DEA AR&R 2019 as discussed in the previous section.

6.3.2 Methodology

For each AEP and duration, 10 temporal patterns were simulated, with the critical duration for each AEP identified based on the maximum of the Rank 6 estimates (peak immediately larger than the Median) for each duration.

6.3.3 TUFLOW Model Set-up

TUFLOW model extents

The adopted model extent for the Scenario 1 TUFLOW model was the same as that developed for the calibration and verification events. The adopted model extent for the Scenario 3 TUFLOW model was limited to the Flood Corridor to represent infinite filling outside of the Flood Corridor.

TUFLOW model roughness

The hydraulic roughness in the calibrated TUFLOW model was updated for Scenario 3 to include the Minimum Riparian Corridor.

TUFLOW inflows

The design inflow hydrographs were taken from the URBS model for each simulated event. The inflow locations (SA polygons) were not modified from the TUFLOW model developed for the calibration and verification events.

Design Tailwater Boundary

The design event TUFLOW model utilised a static water level boundary as the downstream model boundary as follows:

- Current Climate Conditions: MHWS = 0.832mAHD
- Future Climate Change (Year 2100): MHWS + 0.8 m = 1.632 mAHD

These boundary tailwater levels are based on the Shorncliffe Tide Gauge.

6.4 Results and Mapping

6.4.1 Design Discharge Results

A full range of durations (30 minutes to 6 hours) were simulated for the 50% AEP to 1% AEP events. Table 6.6 provides design flow results at selected major waterway crossings for Scenario 1 under Existing Climate Conditions. This information is from the TUFLOW hydraulic model.

Table 6-5: Design Discharge at Major Crossings (Scenario 1 Existing Climate)

Location	Design Discharge (1) (m^3/s) (1)					
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
Queens Pde at South Wetland	2.2	2.5(2)	2.5(2)	2.4(2)	2.3(2)	2.3(2)
Wickham St - 1	2.8	4.4	5.3	6.0	6.4	7.0
Wickham St - 2	2.3	2.6	2.9	3.1	3.4	3.5
Queens Pde at North Wetland	5.0	5.6	5.8	5.8	5.8	5.8
Beaconsfield Tce	8.6	11.8	14.8	17.2	20.6(3)	23.4(3)
Flinders Pde	9.0	12.1	15.6	17.9	20.4(3)	22.8(3)

(1) Discharge through structure. Does not include overtopping flow.
(2) Culverts at Queens Pde at South Wetland are flowing full. Variation in flow is due to selection of critical duration and TP at culvert location.
(3) Flow breaks out of the concrete channel between Beaconsfield Tce and Flinders Pde, resulting in a lower peak flow through the Flinders Pde structure.

6.4.2 Design Flood Levels

Tabulated design flood level results for the 50% AEP to 1% AEP events are provided in Appendix D: Design Events (Scenario 1) - Peak Flood Levels and Appendix E: Design Events (Scenario 3) - Peak Flood Levels. The design flood levels are extracted along Council's AMTD line for the creek. The critical storm duration and Rank 6 ensemble for each location is provided in Appendix H: Design Events (Scenario 1) – Critical Duration and Median Ensemble.

6.4.3 Return Periods of Historic Events

Figure 6-2 provides an estimated flood level frequency curve at each of the Maximum Height Gauges. Based on this information, the magnitude of each of the historic events has been estimated in Table 6-6.

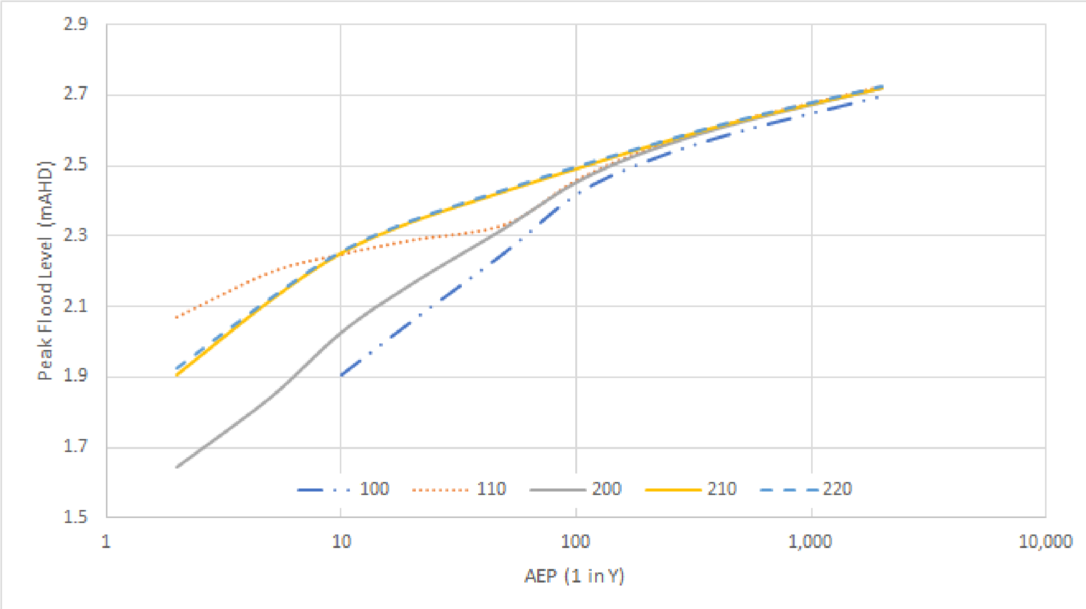


Figure 6-2: Flood Freqency Curve at Maximum Height Gauges

Table 6-6: Estimated Magnitude of Historic Events (AEP)

Gauge ID	Location	Dec 2019	Feb 2020	Dec 2021	Feb 2022
MHG100	Main Wetland US Beaconsfield Tce	*x*	<10%	*x*	1%
MHG110	North Branch US Queens Pde	<50%	<50%	50%	0.5%-0.2%
MHG200	South Branch DS Townsend St	*x*	*x*	*x*	0.5%-0.2%
MHG210	South Wetland US Queens Pde	*x*	*x*	*x*	>0.05%
MHG220	South Wetland at Northcote St	<50%	<50%	<50%	0.2%-0.05%

6.4.4 Rating Curves

Rating curves have not been derived for the Brighton Catchment as the outflow from each of the wetlands is highly tailwater dependent, i.e. discharge from each of the wetlands is heavily influenced by the volume stored within the downstream portion of the catchment. This will vary significantly depending on the magnitude of the event and spatial variability of the rainfall.

The Main Wetland outflows are sensitive to the conditions within the concrete channel between Beaconsfield Street and Flinders Parade and the coastal flats. The South and North Wetlands are sensitive to the conditions within the Main Wetland.

6.4.5 Hydrologic-Hydraulic Model Consistency Check (Design Events)

Consistency checks between the URBS and TUFLOW models were not undertaken for the design events due to the difficulty in representing the complex wetland discharge conditions within URBS, as outlined in Section 4.5. Due to the sensitivity of the wetland outflows to the flood levels downstream, the URBS model should only be used to generate inflows to inform the TUFLOW model.

6.4.6 Hydraulic Structure Reference Sheets

Details of the hydraulic structures, as well as the flood level and flow data derived from the hydraulic model at each of the structures, are summarised in the Hydraulic Structure Reference Sheets and included in Appendix J: Hydraulic Structure Reference Sheets. The flood levels and flow values are representative of present day catchment conditions and as such do not include future development filling and increases in rainfall intensity and sea-level rise due to projected climate variability effects.

6.4.7 Flood Mapping

Flood extent mapping for Scenario 1 with Climate Change is provided in Volume 2 for the 50% AEP to 1 % AEP events.

7.0 Very Rare and Extreme Event Analysis

7.1 Very Rare and Extreme Event Scenarios

Table 7.1 indicates the events and scenarios modelled as part of the Very Rare and Extreme event analysis. These scenarios have been previously described in Section 6.1. All Very Rare and Extreme event modelling was undertaken using ultimate hydrological conditions.

Table 7-1: Design Event Scenarios

Event	Scenario 1 (without climate change)	Scenario 1 (including climate change)	Scenario 3 (including climate change)
0.5% AEP	✓	✓	✓
0.2% AEP	✓	✓	✓
0.05% AEP	✓	✓	x
PMF	✓	*x*	*x*

For the modelling of the Scenario 3 events, the fill height outside of the “Modelled Flood Corridor” was set to the Scenario 3 1% AEP flood level plus an additional height allowance of 0.3 m.

The “1% AEP plus 0.3 m flood surface” was stretched to represent a developed floodplain consistent with City Plan requirements in accordance with the procedures set out in FSPV9 for very rare flood events (0.5% AEP and 0.2% AEP). A stretching buffer of 100 m and depth threshold of 0 m were adopted.

7.2 Extreme Event Terminology

In accordance with FSPV9, the term Probable Maximum Flood (PMF) has been used to define the flood event which is produced through the modelling of Council’s duration independent superstorm across the catchment.

This method does not fully align with the methods outlined in AR&R 2019 for derivation of extreme floods. However, the adoption of the “PMF” terminology provides consistency with the terminology used in recent BCC flood studies and City Plan 2014.

7.3 Very Rare Event Hydrology

As outlined in Section 6.2 for the Design Events, the DEA AR&R 2019 approach was adopted for the 0.5% AEP to 0.05% AEP events. Ten temporal patterns were simulated for each duration, with the critical duration identified by the maximum of the Rank 6 estimates (peak immediately larger than the Median) for each duration.

Storm Injector was used to run the Very Rare event URBS models with the parameters described in the following sections.

Design IFDs

Table 7-2 presents the adopted rare and very rare rainfalls for Existing Climate Conditions. These are based on the recently completed LIMB rainfall study undertaken by South East Queensland Councils. Due to the small size of the Brighton Catchment, no spatial variation or Areal Reduction Factor have been applied.

The potential effects of climate change have been simulated for rare and very rare events consistent with the approach outlined for design events.

Table 7-2: Adopted Rare and Very Rare Event IFD Data – Existing Climate

Duration (minutes)	Rainfall Depth (mm) (1)		
	0.5% AEP	0.2% AEP	0.05% AEP
Brighton Catchment			
30	78	91	113
45	103	121	149
60	124	145	180
90	158	185	230
120	186	217	269
180	226	264	327
270	271	315	389
360	304	353	434

(1) The values presented do not include any allowance for climate change rainfall increases.

Losses

The adopted losses for the design events were also adopted for the very rare events.

Temporal Patterns

The ensemble of point temporal patterns for the East Coast North zone was applied for durations from 30 minutes to 6 hours. The rare temporal patterns were applied for the rare and very rare events.

7.4 Extreme Event Hydrology

The PMF inflow hydrograph was derived based on simulation of Council's 6-hour super-storm across the catchment.

Losses

Table 7-3 presents the adopted loss values for the PMF event in accordance with AR&R 2019.

Table 7-3: Adopted Losses

	Adopted Losses	
	Burst Initial (mm)	**Continuing (mm/hr)**
Pervious	0	0
Impervious	0	0

7.5 Very Rare and Extreme Event Hydraulic Modelling

7.5.1 General

The TUFLOW model was used to simulate the scenarios as detailed in Section 7.1.

7.5.2 Methodology

Very Rare Events

The TUFLOW model was used to simulate the 0.5% AEP to 0.05% AEP events for durations from 30 minutes to 6 hours. For each AEP and duration, 10 temporal patterns were simulated, with the critical duration for each AEP identified based on the maximum of the Rank 6 estimates (peak immediately larger than the Median) for each duration.

Extreme Events

The TUFLOW model was used to simulate the 6 hour superstorm PMF event as outlined in Section 7.4.

7.5.3 TUFLOW Model Set-up

TUFLOW model extents

The adopted model extents for the Scenario 1 and Scenario 3 TUFLOW models were the same as that developed for the calibration and verification events.

TUFLOW model terrain

The adopted terrain for the Scenario 3 Very Rare events was updated to incorporate filling outside the Flood Corridor to a level equivalent to the 1% AEP Scenario 3 peak level + 300 mm.

TUFLOW model roughness

The hydraulic roughness in the calibrated TUFLOW model was updated for Scenario 3 to include the Minimum Riparian Corridor.

TUFLOW inflows

The design inflow hydrographs were taken from the URBS model for each simulated event. The inflow locations (SA polygons) were not modified from the TUFLOW model developed for the calibration and verification events.

Design Tailwater Boundary

The design event TUFLOW model utilised a static water level boundary as the downstream model boundary as follows:

- Current Conditions: HAT = 1.372 mAHD
- Future Climate Change (Year 2100): HAT + 0.8 m = 2.172 mAHD

These boundary tailwater levels are based on the Shorncliffe Tide Gauge.

7.5.4 Hydraulic Structures

No changes were made to the TUFLOW representation of the hydraulic structures for the Very Rare and Extreme events.

7.6 Results and Mapping

7.6.1 Design Discharge Results

A full range of durations (30 minutes to 6 hours) were simulated for the 0.5% AEP to 0.05% AEP events. Table 6.6 provides design flow results at selected major waterway crossings for Scenario 1 under Existing Climate Conditions. This information is extracted from the TUFLOW hydraulic model.

Table 7-4: Design Discharge at Major Crossings (Scenario 1 Existing Climate)

Location	Design Discharge (m^3/s) (1)			
	0.5% AEP	0.2% AEP	0.05% AEP	PMF
Queens Pde at South Wetland	2.3	2.3	2.3	2.3
Wickham St - 1	7.6	8.0	8.3	9.1
Wickham St - 2	3.7	3.7	3.8	4.0
Queens Pde at North Wetland	5.7	5.7	5.7	5.7
Beaconsfield Tce	24.8(2)	26.0	27.2	28.4
Flinders Pde	24.5(2)	26.5	30.0	49.2

(1) Discharge through structure. Does not include overtopping flow

(2) Flow breaks out of the concrete channel between Beaconsfield Tce and Flinders Pde, resulting in a lower peak flow through the Flinders Pde structure.

7.6.2 Design Flood Levels

Tabulated design flood level results for the Very Rare events are provided in the following appendices.

- Appendix F: Very Rare Events (Scenario 1) - Peak Flood Levels - 0.5% AEP to 0.05% AEP events

- Appendix G: Very Rare Events (Scenario 3) - Peak Flood Levels - 0.5% AEP and 0.2% AEP events

The design flood levels were extracted along Council's AMTD line for the creek. The critical storm duration and Rank 6 ensemble for each location are provided in Appendix I: Very Rare Events (Scenario 1) – Critical Duration and Median Ensemble.

7.6.3 Flood Mapping

Flood extent mapping for Scenario 1 with Climate Change is provided in Volume 2 for the 0.5% AEP to 0.05% AEP events.

8.0 Summary of Study Findings

This flood study report details the model development, calibration and verification, and simulation of design, very rare and extreme flood events for the Brighton Creek catchment.

A new URBS model has been developed for the catchment. The existing TUFLOW model has been updated using HPC and SGS methods, to consider the best available topographic data, and calibration to newly available Maximum Height Gauge Data.

A joint calibration of the URBS and TUFLOW models was undertaken for the February 2022, February 2020 and December 2019 events. The December 2021 event was used for verification. It is noted that only Maximum Height Gauge data is available within this catchment. No information on the timing or shape of hydrographs is available. This limitation of the calibration should be considered when interpreting the flood study results.

The URBS model was used to produce inflows for use in the TUFLOW model. Given the highly 2D nature of the catchment, the dependence of wetland storage outflows on variable downstream flood levels (tailwaters), and the lack of streamflow observations, it was not possible to create a stand-alone calibrated URBS model. The URBS model developed in this study should be used in tandem with the TUFLOW model, not alone.

Cross-checks of the TUFLOW hydraulic structure head-losses were undertaken at selected structures using the HEC-RAS software, with the representation found to be appropriate.

Design flood events were simulated for the full range of events from the 50% AEP to PMF. All design analyses assumed ultimate catchment development conditions, based on City Plan 2014, for determining inflow hydrographs.

Existing floodplain conditions (Scenario 1) has been simulated for both Existing Climate and Climate Change conditions.

Ultimate floodplain conditions (Scenario 3) have been simulated for Climate Change Conditions. Scenario 3 represents the floodplain with filling outside the Modelled Flood Corridor to simulate potential development in accordance with City Plan 2014, as well as an allowance for a densely vegetated riparian corridor along the edge of the channel.

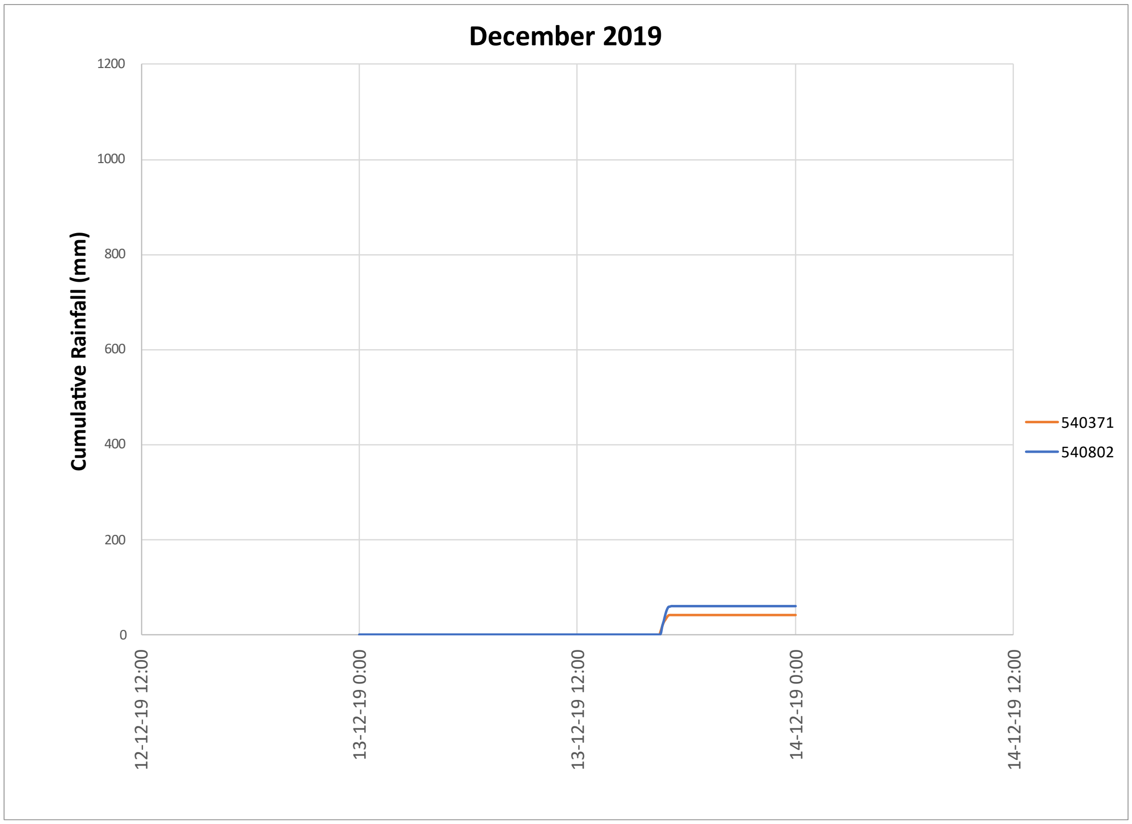
The following outputs have been derived from the TUFLOW model:

- Peak flood discharges
- Peak flood levels along the AMTD line
- Peak flood extent mapping (Scenario 1) - Volume 2

Hydraulic Structure Reference Sheets (HSRS) have been developed for key hydraulic structures including a structure description and hydraulic characteristics extracted from the TUFLOW model.

APPENDICES

Appendix A: Rainfall Distribution



December 2019
Cumulative Rainfall (mm)
1200
1000
800
600
400
200
0
12-12-19 12:00
13-12-19 0:00
13-12-19 12:00
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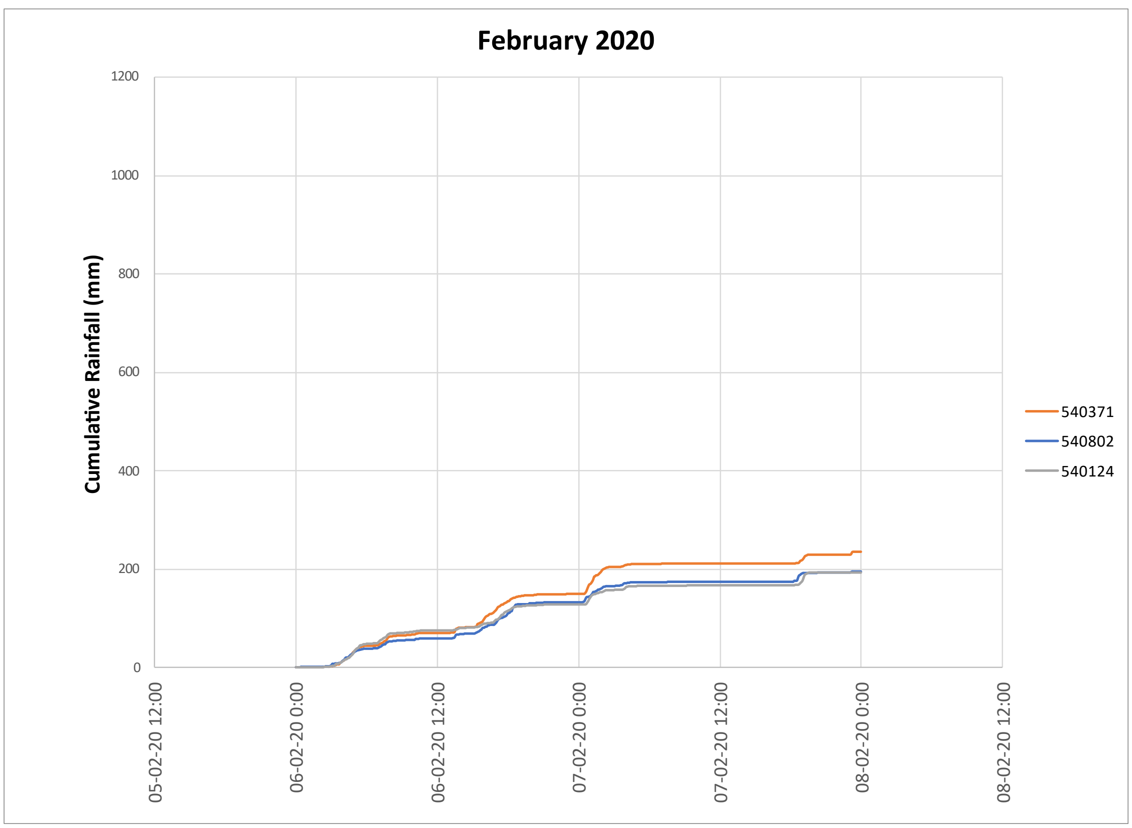
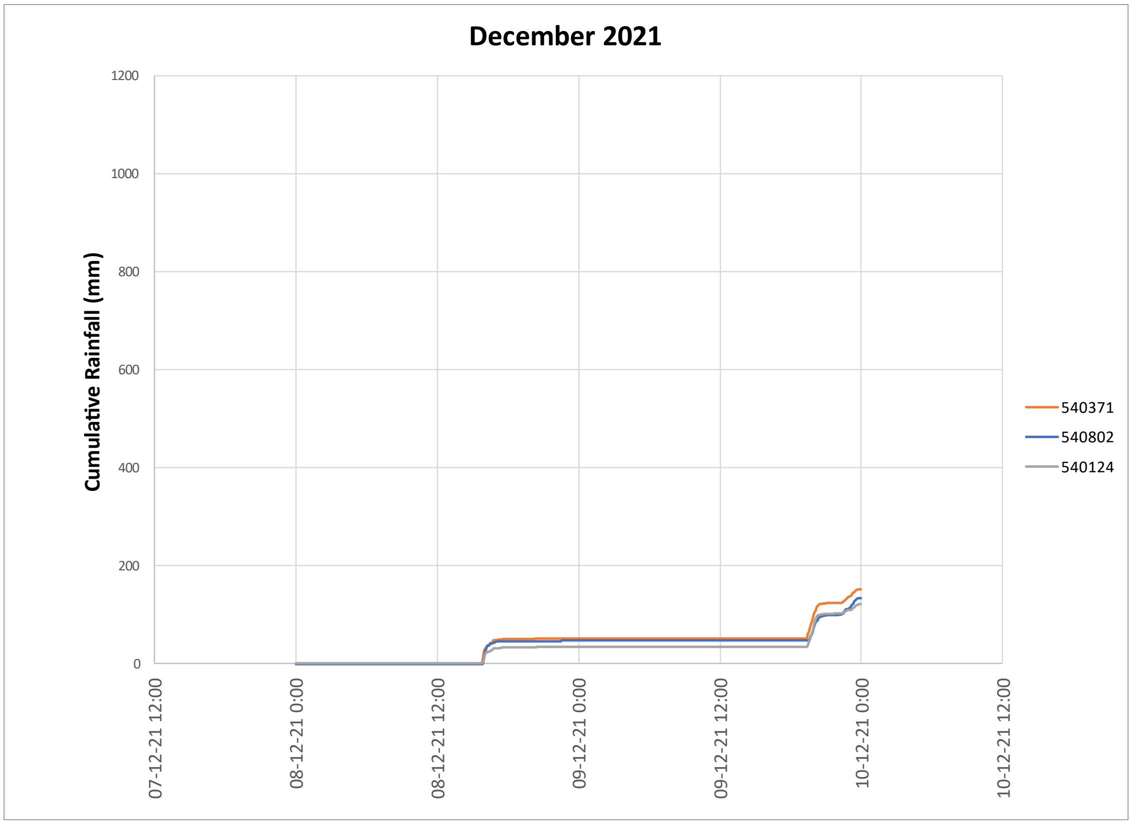
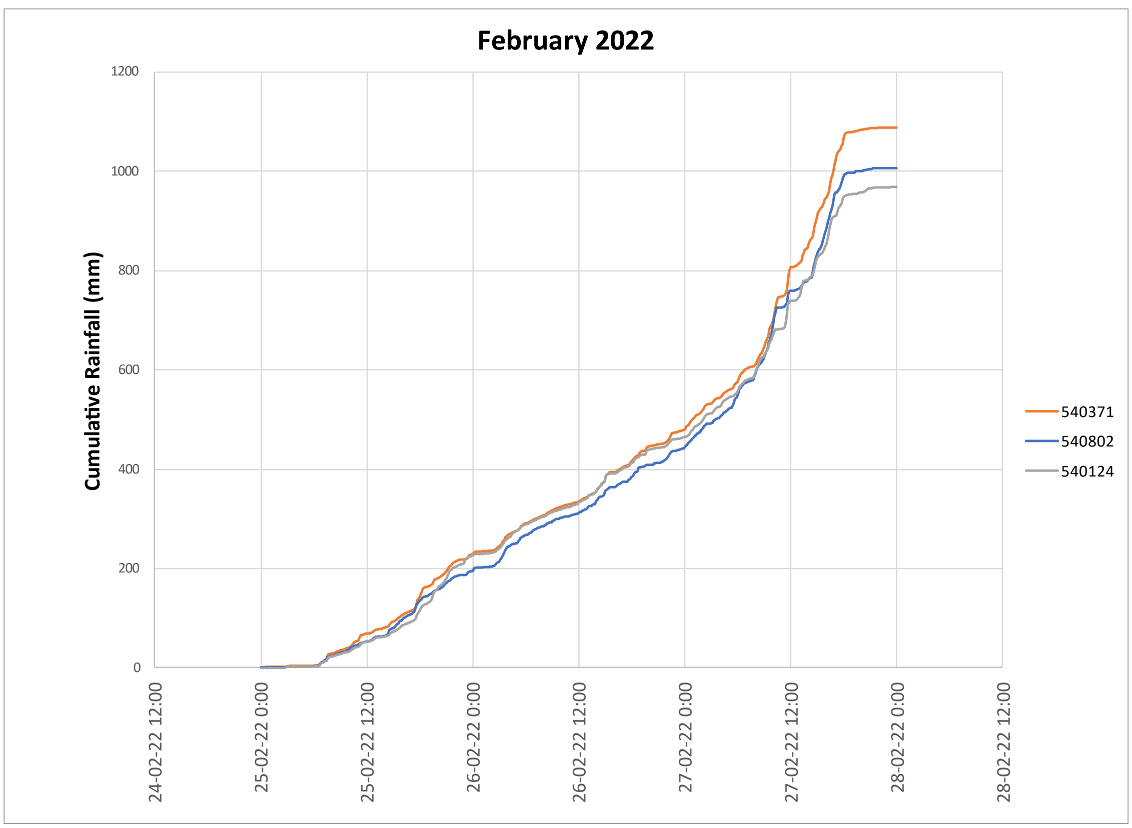
14-12-19 12:00
540371
540802



February 2020
Cumulative Rainfall (mm)
1200
1000
800
600
400
200
0
05-02-20 12:00
06-02-20 0:00
06-02-20 12:00
07-02-20 0:00
07-02-20 12:00
08-02-20 0:00
08-02-20 12:00
540371
540802
540124


December 2021
Cumulative Rainfall (mm)
1200
1000
800
600
400
200
0
07-12-21 12:00
08-12-21 0:00
08-12-21 12:00
09-12-21 0:00
09-12-21 12:00
10-12-21 0:00
10-12-21 12:00
540371
540802
540124

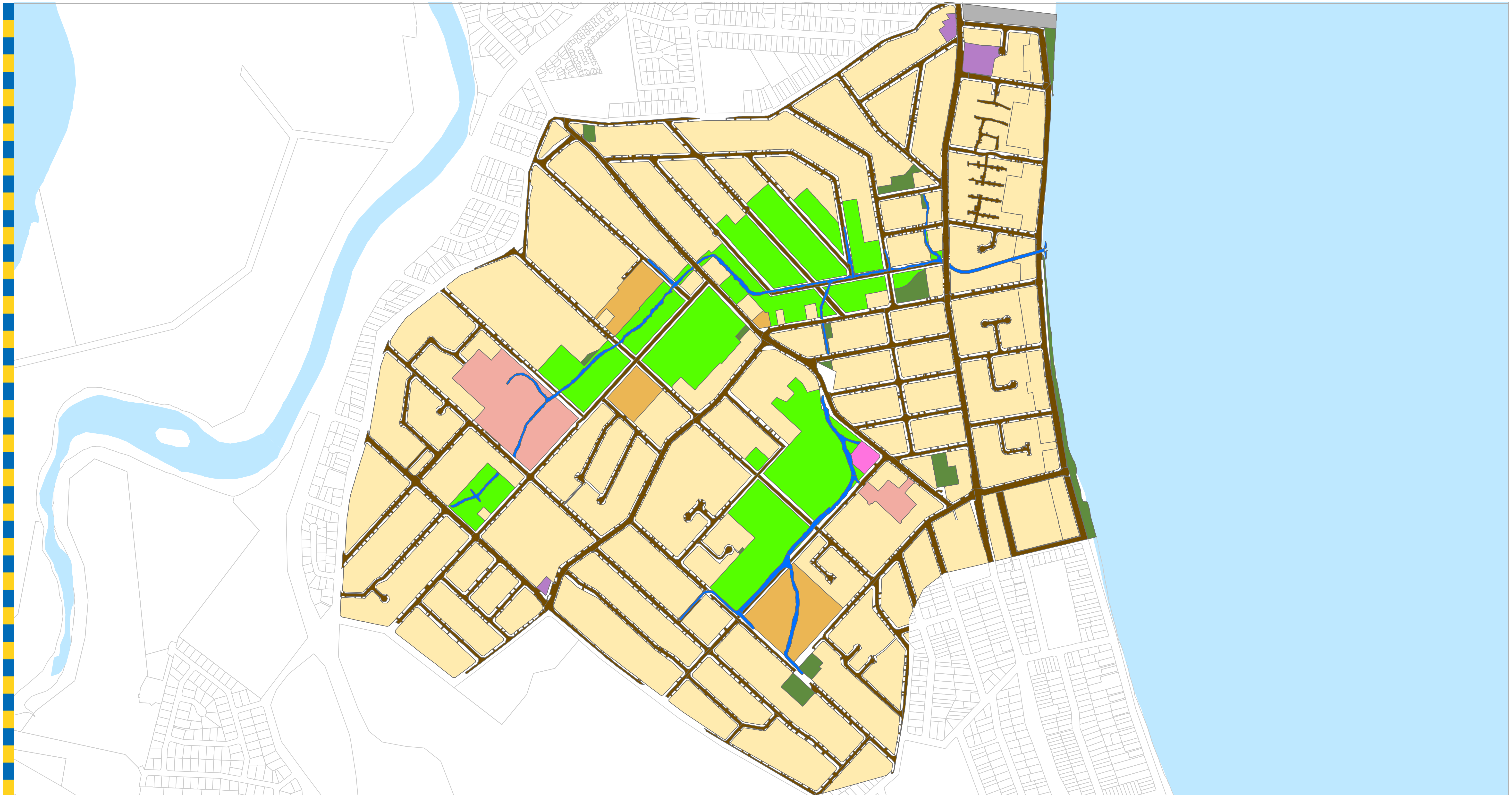

February 2022
Cumulative Rainfall (mm)
1200
1000
800
600
400
200
0
24-02-22 12:00
25-02-22 0:00
25-02-22 12:00
26-02-22 0:00
26-02-22 12:00
27-02-22 0:00
27-02-22 12:00
28-02-22 0:00
28-02-22 12:00
540371
540802
540124

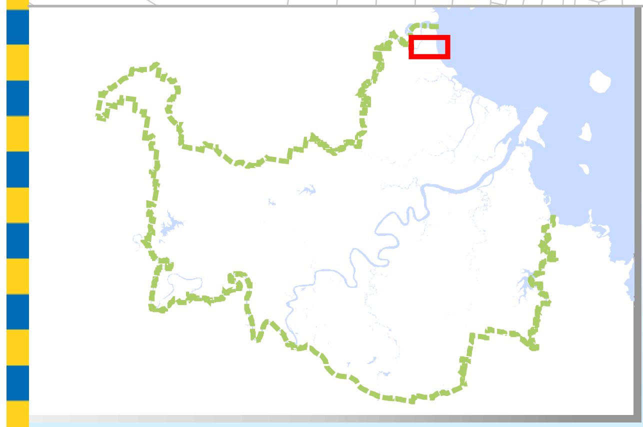
Appendix B: URBS Model Parameters

URBS Sub-catchment Parameters – Brighton			
S/C	**Area (ha)**	**CS**	**I**
1	2.54	0.0034	0.67
2	2.13	0.0024	0.68
3	7.55	0.003	0.68
4	5.55	0.003	0.645
5	5.60	0.0046	0.68
6	6.04	0.0038	0.62
7	1.44	0.0039	0.40
8	4.05	0.0029	0.12
9	2.19	0.0025	0.68
10	6.65	0.0034	0.69
11	5.70	0.0032	0.67
12	5.87	0.0044	0.65
13	2.06	0.0038	0.34
14	3.03	0.003	0.50
15	6.88	0.0023	0.70
16	2.16	0.0035	0.29
17	2.36	0.0035	0.26
18	7.07	0.0036	0.17
19	3.53	0.0025	0.23
20	4.83	0.0044	0.55
21	5.14	0.0031	0.67
22	2.84	0.0027	0.33
23	3.83	0.0033	0.43
24	4.96	0.0042	0.28
25	2.41	0.0027	0.34
26	7.73	0.0039	0.66
27	4.01	0.0043	0.61
28	5.63	0.0038	0.39
29	3.56	0.0043	0.21
30	2.57	0.004	0.67
31	2.19	0.0035	0.70
32	5.58	0.0029	0.42

URBS Sub-catchment Parameters – Brighton			
S/C	**Area (ha)**	**CS**	**I**
33	1.66	0.002	0.70
34	5.00	0.0032	0.71
35	6.51	0.0023	0.64
36	4.33	0.0038	0.66
37	6.36	0.0032	0.59
38	4.33	0.0034	0.53
39	3.03	0.004	0.582
40	3.59	0.0033	0.69
41	1.82	0.0039	0.72
42	3.27	0.0042	0.68
43	1.94	0.0039	0.567
44	3.58	0.003	0.15
45	1.56	0.004	0.63
46	2.86	0.0038	0.62
47	3.43	0.0036	0.61
48	4.84	0.0032	0.24
49	0.78	0.0044	0.61
50	4.15	0.0035	0.65
51	5.02	0.0035	0.38
52	2.34	0.0042	0.71
53	4.15	0.0035	0.70
54	2.86	0.0038	0.59
55	4.66	0.0038	0.66
56	4.97	0.0038	0.69
57	3.78	0.0035	0.68
58	2.92	0.0032	0.67
59	1.92	0.0034	0.68
60	5.31	0.0039	0.65
61	2.27	0.0035	0.50
62	2.39	0.004	0.66
63	5.37	0.0037	0.68
64	4.51	0.0038	0.64

Appendix C: Adopted Land Use





Legend

LVL1_ZONE

- Centre
- Community facilities
- Emerging communities
- Environmental management and conservation
- General residential
- Recreation and open space
- Roads
- Special purpose
- Sport and recreation
- Watercourse

DATA INFORMATION

The flood maps must be read in conjunction with the flood study report and interpreted by a qualified professional engineer. The flood maps are based on the best data available to Brisbane City Council ("Council") at the time the maps were developed. Council, and the copyright owners listed below, give no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) presented in these maps and the user uses and relies upon the data in the maps at its own sole risk and liability. Council is not liable for errors or omissions in the flood maps. To the full extent that it is able to do so in law, the Council disclaims all liability (including without limitation, liability in negligence) for any loss, damage or costs (including in direct and consequential loss and damage), caused by or arising from anyone using or relying on the data contained in the flood maps for any purpose whatsoever.

Jacobs

BRISBANE CITY

Dedicated to a better Brisbane

Brighton Creek Flood Study

Future Landuse

GIM - 100001 - 001

N W E S

0 100 200 300
Metres

Prepared :	PA
Checked :	SW
Revision :	1
Publication Date :	12 Jun 2023
Project Number :	IW286200

File : J:\IE\Projects\05_Northern\IW286200\Spatial\Figures\Volume2\Report_Maps_v1\Future_Landuse.mxd

Prepared by (Jacobs Group (Australia) Pty Ltd) for:
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Appendix D: Design Events (Scenario 1) - Peak Flood Levels

The flood level data presented in this Appendix has been extracted (in part) from the results of a 2-dimensional flood model. Levels presented have been extracted generally at selected points along the centreline of the waterway with the intent of demonstrating general flood characteristics. The applicability of this data to locations on the floodplains adjacent should be determined by a suitably qualified professional. It is recommended for any detailed assessment of flood risk associated with the waterway that complete flood model results be accessed and interrogated.

AMTD (m)	Design Events – Scenario 1 (Existing Waterway Conditions) Peak Water Levels (mAHD)					
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
Brighton Creek						
CH 0(3)	1.76	1.76	1.76	1.76	1.76	1.76
CH 100	1.72(4)	1.72	1.73	1.77	1.89	2.00
CH 200	1.73	1.77	1.83	1.89	1.99	2.06
CH 300	1.78	1.95	2.10	2.22	2.40	2.52
CH 400	1.80	1.97	2.12	2.24	2.41	2.53
CH 500	1.82	2.02	2.17	2.29	2.44	2.55
CH 600	1.83	2.02	2.17	2.29	2.44	2.55
CH 700	1.85	2.03	2.17	2.29	2.44	2.55
CH 800	1.87	2.05	2.18	2.29	2.44	2.55
CH 900	1.87	2.05	2.18	2.29	2.44	2.55
CH 1000	1.92	2.07	2.18	2.29	2.44	2.55
CH 1100	2.10	2.24	2.28	2.31	2.44	2.55
CH 1200	2.11	2.24	2.28	2.32	2.44	2.55
CH 1300	2.11	2.24	2.28	2.32	2.44	2.55
CH 1400	2.12	2.25	2.29	2.33	2.44	2.55
CH 1500	2.13	2.26	2.31	2.35	2.45	2.56
CH 1600	2.30	2.40	2.44	2.46	2.49	2.56
CH 1700	2.39	2.48	2.52	2.54	2.56	2.58
Brighton Tributary A						
CH 0	1.82	2.02	2.17	2.29	2.44	2.55
CH 100	1.84	2.02	2.17	2.29	2.44	2.55
CH 200	1.87	2.04	2.18	2.29	2.44	2.55
CH 300	N/R	2.14	2.23	2.31	2.44	2.55
CH 400	2.05	2.22	2.34	2.40	2.48	2.56
CH 500	2.05	2.23	2.34	2.40	2.48	2.56
CH 600	2.05	2.23	2.34	2.40	2.48	2.56
CH 700	2.05	2.23	2.34	2.40	2.48	2.56
CH 800	2.05	2.23	2.34	2.40	2.48	2.56
CH 900	2.05	2.23	2.34	2.40	2.48	2.56
CH 1000	2.05	2.23	2.34	2.40	2.48	2.56
CH 1100	2.08	2.26	2.38	2.44	2.52	2.60

(1) N/R = no result, typically because the AMTD line does not intersect the flood surface.
(2) Flood levels are inclusive of a 9.8% increase in rainfall intensity and a 0.8m increase above MHWS, due to projected climate variability effects.
(3) CH 0 downstream of Brighton Creek is tidally influenced and downstream of a hydraulic jump within the Flinders Parade Bridge Structure.
(4) Hydraulic jump occurring within structure resulting in lower peak water level at CH 100 when compared to CH 0.

Appendix E: Design Events (Scenario 3) - Peak Flood Levels

The flood level data presented in this Appendix has been extracted (in part) from the results of a 2-dimensional flood model. Levels presented have been extracted generally at selected points along the centreline of the waterway with the intent of demonstrating general flood characteristics. The applicability of this data to locations on the floodplains adjacent should be determined by a suitably qualified professional. It is recommended for any detailed assessment of flood risk associated with the waterway that complete flood model results be accessed and interrogated.

AMTD (m)	Design Events – Scenario 3 (Ultimate Waterway Conditions) Peak Water Levels (mAHD)					
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
Brighton Creek						
CH 0	1.76	1.76	1.76	1.76	1.76	1.76
CH 100	1.72(3)	1.72	1.74	1.78	1.84	1.95
CH 200	1.73	1.77	1.84	1.93	2.03	2.13
CH 300	1.79	1.95	2.11	2.25	2.42	2.59
CH 400	1.80	1.98	2.13	2.27	2.44	2.60
CH 500	1.82	2.02	2.18	2.31	2.46	2.62
CH 600	1.83	2.02	2.18	2.31	2.47	2.62
CH 700	1.85	2.03	2.19	2.31	2.47	2.62
CH 800	1.87	2.05	2.19	2.31	2.47	2.62
CH 900	1.87	2.05	2.19	2.31	2.47	2.62
CH 1000	1.92	2.07	2.19	2.31	2.47	2.62
CH 1100	2.10	2.24	2.28	2.33	2.47	2.62
CH 1200	2.11	2.24	2.29	2.33	2.47	2.62
CH 1300	2.11	2.24	2.29	2.33	2.47	2.62
CH 1400	2.12	2.25	2.30	2.34	2.47	2.62
CH 1500	2.13	2.27	2.31	2.35	2.47	2.63
CH 1600	2.30	2.40	2.44	2.46	2.49	2.63
CH 1700	2.40	2.48	2.52	2.54	2.56	2.64
Brighton Tributary A						
CH 0	1.82	2.02	2.18	2.31	2.47	2.62
CH 100	1.84	2.02	2.18	2.31	2.47	2.62
CH 200	1.87	2.04	2.19	2.31	2.46	2.62
CH 300	N/R	2.24	2.37	2.43	2.51	2.63
CH 400	2.05	2.24	2.40	2.50	2.61	2.68
CH 500	2.05	2.24	2.40	2.50	2.61	2.68
CH 600	2.05	2.24	2.40	2.50	2.61	2.68
CH 700	2.05	2.24	2.40	2.50	2.61	2.68
CH 800	2.05	2.24	2.40	2.50	2.61	2.68
CH 900	2.05	2.25	2.40	2.51	2.61	2.68
CH 1000	2.05	2.24	2.40	2.50	2.61	2.68
CH 1100	2.07	2.27	2.42	2.55	2.65	2.73

(1) N/R = no result, typically because the AMTD line does not intersect the flood surface.

(2) Flood levels are inclusive of a 9.8% increase in rainfall intensity and a 0.8m increase above MHWS, due to projected climate variability effects.

(3) Hydraulic jump occurring within structure resulting in lower peak water level at CH 100 when compared to CH 0.

Appendix F: Very Rare Events (Scenario 1) - Peak Flood Levels

The flood level data presented in this Appendix has been extracted (in part) from the results of a 2-dimensional flood model. Levels presented have been extracted generally at selected points along the centreline of the waterway with the intent of demonstrating general flood characteristics. The applicability of this data to locations on the floodplains adjacent should be determined by a suitably qualified professional. It is recommended for any detailed assessment of flood risk associated with the waterway that complete flood model results be accessed and interrogated.

AMTD (m)	Scenario 1 (Existing Waterway Conditions) Peak Water Levels (mAHD) (2)		
	0.5% AEP	0.2% AEP	0.05% AEP
BRIGHTON CREEK			
CH 0	2.17	2.17	2.17
CH 100	2.46	2.49	2.55
CH 200	2.46	2.5	2.55
CH 300	2.69	2.74	2.81
CH 400	2.69	2.74	2.81
CH 500	2.71	2.75	2.83
CH 600	2.71	2.75	2.83
CH 700	2.71	2.75	2.83
CH 800	2.71	2.75	2.83
CH 900	2.71	2.76	2.83
CH 1000	2.71	2.76	2.83
CH 1100	2.71	2.76	2.84
CH 1200	2.71	2.76	2.84
CH 1300	2.71	2.76	2.83
CH 1400	2.71	2.76	2.84
CH 1500	2.72	2.76	2.84
CH 1600	2.72	2.77	2.84
CH 1700	2.73	2.77	2.85
BRIGHTON TRIBUTARY A			
CH 0	2.71	2.75	2.83
CH 100	2.71	2.75	2.83
CH 200	2.71	2.75	2.83
CH 300	2.71	2.75	2.83
CH 400	2.71	2.75	2.83
CH 500	2.71	2.75	2.83
CH 600	2.71	2.75	2.83
CH 700	2.71	2.75	2.83
CH 800	2.71	2.75	2.83
CH 900	2.71	2.76	2.83
CH 1000	2.71	2.75	2.83
CH 1100	2.73	2.78	2.86

(1) N/R = no result, typically because the AMTD line does not intersect the flood surface

(2) Flood levels are inclusive of a 9.8% increase in rainfall intensity and a 0.8m increase above HAT, due to projected climate variability effects.

Appendix G: Very Rare Events (Scenario 3) - Peak Flood Levels

The flood level data presented in this Appendix has been extracted (in part) from the results of a 2-dimensional flood model. Levels presented have been extracted generally at selected points along the centreline of the waterway with the intent of demonstrating general flood characteristics. The applicability of this data to locations on the floodplains adjacent should be determined by a suitably qualified professional. It is recommended for any detailed assessment of flood risk associated with the waterway that complete flood model results be accessed and interrogated.

AMTD (m)	Scenario 3 (Ultimate Waterway Conditions) Peak Water Levels (mAHD) (2)	
	0.5% AEP	0.2% AEP
BRIGHTON CREEK		
CH 0	2.17	2.17
CH 100	2.47	2.52
CH 200	2.51	2.56
CH 300	2.84	2.92
CH 400	2.85	2.93
CH 500	2.86	2.93
CH 600	2.86	2.93
CH 700	2.86	2.93
CH 800	2.86	2.93
CH 900	2.86	2.94
CH 1000	2.86	2.94
CH 1100	2.87	2.94
CH 1200	2.87	2.94
CH 1300	2.87	2.94
CH 1400	2.87	2.94
CH 1500	2.87	2.94
CH 1600	2.87	2.94
CH 1700	2.88	2.94
BRIGHTON TRIBUTARY A		
CH 0	2.86	2.93
CH 100	2.86	2.93
CH 200	2.86	2.93
CH 300	2.86	2.94
CH 400	2.87	2.94
CH 500	2.87	2.94
CH 600	2.87	2.94
CH 700	2.87	2.94
CH 800	2.87	2.94
CH 900	2.87	2.94
CH 1000	2.87	2.94
CH 1100	2.90	2.97

(1) N/R = no result, typically because the AMTD line does not intersect the flood surface.

(2) Flood levels are inclusive of a 9.8% increase in rainfall intensity and a 0.8m increase above HAT, due to projected climate variability effects.

Appendix H: Design Events (Scenario 1) – Critical Duration and Median Ensemble

AMTD (m)	Design Events – Scenario 1 (Existing Waterway Conditions) (2)					
	50% AEP		20% AEP		10% AEP	
	Critical Duration	Median Ensemble	Critical Duration	Median Ensemble	Critical Duration	Median Ensemble
Brighton Creek						
CH 0	30 min	6	30 min	6	30 min	6
CH 100	30 min	6	30 min	6	180 min	8
CH 200	30 min	6	180 min	1	180 min	4
CH 300	270 min	8	180 min	6	180 min	4
CH 400	270 min	8	180 min	6	180 min	4
CH 500	270 min	8	180 min	6	180 min	4
CH 600	270 min	8	180 min	6	180 min	4
CH 700	270 min	8	180 min	6	180 min	4
CH 800	270 min	8	180 min	6	180 min	4
CH 900	270 min	8	180 min	6	180 min	4
CH 1000	270 min	8	180 min	6	180 min	4
CH 1100	120 min	7	180 min	1	120 min	5
CH 1200	120 min	7	180 min	1	120 min	5
CH 1300	120 min	7	180 min	1	120 min	5
CH 1400	120 min	7	180 min	1	120 min	5
CH 1500	180 min	1	180 min	1	120 min	5
CH 1600	45 min	4	45 min	7	45 min	6
CH 1700	45 min	4	45 min	7	45 min	6
Brighton Tributary A						
CH 0	270 min	8	180 min	6	180 min	4
CH 100	270 min	8	180 min	6	180 min	4
CH 200	270 min	8	180 min	6	180 min	4
CH 300	N/R	N/R	270 min	4	360 min	10
CH 400	270 min	4	270 min	4	360 min	1
CH 500	270 min	4	270 min	4	360 min	1
CH 600	270 min	4	270 min	4	360 min	1
CH 700	270 min	4	270 min	4	360 min	1
CH 800	270 min	4	270 min	4	360 min	1
CH 900	270 min	4	270 min	5	360 min	10
CH 1000	270 min	4	270 min	4	360 min	1
CH 1100	270 min	8	270 min	5	360 min	1

(1) N/R = no result, typically because the AMTD line does not intersect the flood surface.
(2) Inclusive of a 9.8% increase in rainfall intensity and a 0.8m increase above HAT, due to projected climate variability effects.

AMTD (m)	Design Events – Scenario 1 (Existing Waterway Conditions) (2)					
	5% AEP		2% AEP		1% AEP	
	Critical Duration	Median Ensemble	Critical Duration	Median Ensemble	Critical Duration	Median Ensemble
Brighton Creek						
CH 0	30 min	6	30 min	6	30 min	6
CH 100	180 min	4	270 min	3	270 min	9
CH 200	360 min	10	270 min	3	270 min	9
CH 300	360 min	10	270 min	9	270 min	2
CH 400	360 min	10	270 min	9	270 min	2
CH 500	360 min	10	270 min	9	270 min	2
CH 600	360 min	10	270 min	9	270 min	2
CH 700	360 min	10	270 min	9	270 min	2
CH 800	360 min	10	270 min	9	270 min	2
CH 900	360 min	10	270 min	9	270 min	2
CH 1000	180 min	4	270 min	9	270 min	2
CH 1100	180 min	6	270 min	9	270 min	2
CH 1200	120 min	5	270 min	9	270 min	2
CH 1300	120 min	5	270 min	9	270 min	2
CH 1400	120 min	5	270 min	9	270 min	2
CH 1500	120 min	5	270 min	9	270 min	2
CH 1600	120 min	10	90 min	3	270 min	2
CH 1700	90 min	6	90 min	3	120 min	1
Brighton Tributary A						
CH 0	360 min	10	270 min	9	270 min	2
CH 100	360 min	10	270 min	9	270 min	2
CH 200	360 min	10	270 min	9	270 min	2
CH 300	360 min	10	270 min	9	270 min	2
CH 400	270 min	6	270 min	2	270 min	2
CH 500	270 min	6	270 min	2	270 min	9
CH 600	270 min	6	270 min	2	270 min	9
CH 700	270 min	6	270 min	2	270 min	9
CH 800	270 min	6	270 min	2	270 min	9
CH 900	270 min	8	270 min	2	270 min	2
CH 1000	270 min	7	270 min	2	270 min	9
CH 1100	180 min	3	180 min	6	270 min	1

(1) N/R = no result, typically because the AMTD line does not intersect the flood surface.
(2) Inclusive of a 9.8% increase in rainfall intensity and a 0.8m increase above HAT, due to projected climate variability effects.

Appendix I: Very Rare Events (Scenario 1) – Critical Duration and Median Ensemble

AMTD (m)	Very Rare Events – Scenario 1 (Existing Waterway Conditions) [(2)]					
	0.5% AEP		0.2% AEP		0.05% AEP	
	Critical Duration	Median Ensemble	Critical Duration	Median Ensemble	Critical Duration	Median Ensemble
Brighton Creek						
CH 0	30 min	8	30 min	8	30 min	8
CH 100	270 min	2	270 min	2	270 min	2
CH 200	270 min	2	270 min	2	270 min	2
CH 300	270 min	2	270 min	2	120 min	8
CH 400	270 min	2	270 min	2	120 min	8
CH 500	270 min	2	270 min	2	120 min	8
CH 600	270 min	2	270 min	2	120 min	8
CH 700	270 min	2	270 min	2	120 min	8
CH 800	270 min	2	270 min	2	120 min	8
CH 900	270 min	2	270 min	2	120 min	8
CH 1000	270 min	2	270 min	2	120 min	8
CH 1100	270 min	2	270 min	2	120 min	8
CH 1200	270 min	2	270 min	2	120 min	8
CH 1300	270 min	2	270 min	2	120 min	8
CH 1400	270 min	2	270 min	2	120 min	8
CH 1500	270 min	2	270 min	2	120 min	8
CH 1600	270 min	2	270 min	2	120 min	8
CH 1700	270 min	2	270 min	2	120 min	8
Brighton Tributary A						
CH 0	270 min	2	270 min	2	120 min	8
CH 100	270 min	2	270 min	2	120 min	8
CH 200	270 min	2	270 min	2	120 min	8
CH 300	270 min	2	270 min	2	120 min	8
CH 400	270 min	2	270 min	2	120 min	8
CH 500	270 min	2	270 min	2	120 min	8
CH 600	270 min	2	270 min	2	120 min	8
CH 700	270 min	2	270 min	2	120 min	8
CH 800	270 min	2	270 min	2	120 min	8
CH 900	270 min	2	270 min	2	120 min	8
CH 1000	270 min	2	270 min	2	120 min	8
CH 1100	270 min	2	270 min	2	120 min	2

(1) N/R = no result, typically because the AMTD line does not intersect the flood surface.
(2) Inclusive of a 9.8% increase in rainfall intensity and a 0.8m increase above HAT, due to projected climate variability effects.

Appendix J: Hydraulic Structure Reference Sheets

The hydraulic structure reference sheets provide an overview of the hydraulic characteristics and performance of the waterway structure for the current catchment and climate conditions. They have been compiled from the best available data for the waterway structure.

Peak flood levels and structure flood immunity have typically been extracted from the design flood surface grids at the structure location, while the overtopping level of the weir / road have been derived from the existing ground surface at the low point of the road alignment in the vicinity of the structure (and not necessarily at the structure).

Flooding characteristics at waterway structures can be complex and it is recommended that the hydraulic structure reference sheets be read in conjunction with the results of the TUFLOW model.

Waterway	Structure ID	AMTD	Structure location	Structure details	Modelled structure representation	Origin of Structure Coding	HSRS
Brighton Creek	Flinders Pde	CH 0	Flinders Parade	Bridge	Layered flow constriction	2014 Flood Study	Y
Brighton Creek	C_Beacon	CH 300	Beaconsfield Terrace	5 / 1.8 RCP	1D Circular culvert	2014 Flood Study	Y
Brighton Creek	C_NS02	CH 900	Goodenia Woods	1 / 2.4 x 1.5 RCBC	1D Rectangular culvert	Site Observation	Y
Brighton Creek	C_Queens	CH 1030	Queens Parade	2 / 2.1 x 1.15 RCBC	1D Rectangular culvert	2014 Flood Study	Y
Brighton Creek	C_Wickham_1	CH 1700	Upstream of Wickham St	2 / 1.35 RCP	1D Circular culvert	2014 Flood Study	Y
Brighton Creek	C_Wickham_2	CH 1700	Upstream of Wickham St	1 / 1.2 RCP	1D Circular culvert	2014 Flood Study	Y
Brighton Creek Tributary	C_Townsend	CH 200	Townsend Street	2 / 1.22 RCP	1D Circular culvert	2014 Flood Study	Y
Brighton Creek Tributary	C_Qpde_South	CH 400	Queens Parade	2 / 1.22 RCP	1D Circular culvert	2014 Flood Study	Y
Brighton Creek	C_NS03	CH 1100	Saul Street	1 / 3.3 x 0.88 RCBC	1D Rectangular culvert	Site Observation	Y
Unnamed Tributary	C_OS_01	N/A	Saul Street Park	1 / 0.75 RCP	1D Circular culvert	Site Observation	Y

Hydraulic Structure Reference Sheet

Brighton Creek Flood Study
Flinders Parade

BCC Asset ID	B0770/B9422	Tributary Name	Brighton Creek
Owner	BCC	AMTD (m)	CH 0
Year of Construction	July 1977	Coordinates (GDA94)	506381, 6980593
Year of Significant Modification		Hydraulic Model ID	FlindersPde
Source of Structure Information	Site Visit / LiDAR	Flood Model Representation	Layered flow constriction
Link to Data Source			

Structure Description		Bridge	
Bridges		**Culverts**	
Number of Spans	1	Number of Barrels	NA
Number of Piers in Waterway	0	Dimensions (m)	NA
Pier shape and Width (m)	NA	Upstream Invert (m AHD)	NA
Bridge Invert Level (m AHD)	-0.06	Downstream Invert (m AHD)	NA
Structure Length (m) (in direction of flow)		18	
Span Length (m)		8	
Lowest Level of Deck Soffit (m AHD)		1.5	
Overtopping Level of Weir/Road (m AHD) (not including handrail)		2.25	
Average Handrail Height (m)		1.47	

Image Description	Looking upstream (IMG_1333)
Date	12/16/2022
Source	Site Visit

Image Description	Looking downstream (IMG_1343)
Date	12/16/2022
Source	Site Visit

Link to Flood Model Results	\TUFLOW\Design\results\
Model Version Number	BCFS_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_052.tcf
Model Scenario	SCENARIO 1 DESIGN EXISTING CLIMATE (DES_S1_EC) / SCENARIO 1 EXTREME EXISTING CLIMATE (EXT_S1_EC)

Structure Flood Immunity (immunity of lowest point of weir above structure)				0.2% AEP				
AEP (%)	Total Discharge (m^3/s)	Discharge through Structure (m^3/s)[1]	U/S Peak Water Level (m AHD)[2]	D/S Peak Water Level (m AHD)[2]	Afflux (m)[3]	Structure Velocity (m/s)[4&6]	Weir Velocity (m/s)[5&6]	Critical Storm Duration (hrs)[7] & Ensemble
20	12.1	N/A	1.03	0.83	0.20	N/A	N/A	3.0/E7
10	15.6	N/A	1.20	0.83	0.37	N/A	N/A	3.0/E4
5	17.9	N/A	1.30	0.83	0.47	N/A	N/A	3.0/E4
2	20.4	N/A	1.41	0.83	0.58	N/A	N/A	4.5/E3
1	22.8	N/A	1.52	0.83	0.69	N/A	N/A	4.5/E3
0.50	24.5	N/A	1.62	1.37	0.25	N/A	N/A	4.5/E9
0.20	26.5	N/A	1.92	1.37	0.55	N/A	N/A	6.0/E6
0.05	30.0	N/A	2.30	1.37	0.93	N/A	N/A	4.5/E9

[1]Flow underneath the road and only for 1D structures
[2]Measured at centre-span of bridge or at centre of culvert
[3]This is afflux at peak water level
[4](i) Only for 1D structures. (ii) This is the peak of the depth/width averaged velocity within the structure opening
[5](i) Only for 1D structures (ii) This is the peak of the depth/width averaged velocity across the 1D weir section of the model
[6]Velocities provided here are approximate only and the model should be interrogated for design purposes.
[7]Based on peak water level
[(b)]Backwater affected value

Hydraulic Structure Reference Sheet

Brighton Creek Flood Study
Beaconsfield Terrace

BCC Asset ID	C0120P	Tributary Name	Brighton Creek
Owner	BCC	AMTD (m)	CH 300
Year of Construction	1970 February	Coordinates (GDA94)	506108.0, 6980562.0
Year of Significant Modification		Hydraulic Model ID	C_Beacon
Source of Structure Information	2014 TUFLOW model	Flood Model Representation	1D culverts / 2D weir
Link to Data Source			

Structure Description		Reinforced concrete pipe culverts	
Bridges		**Culverts**	
Number of Spans	NA	Number of Barrels	5
Number of Piers in Waterway	NA	Dimensions (m)	1.8
Pier shape and Width (m)	NA	Upstream Invert (m AHD)	0.34
Bridge Invert Level (m AHD)	NA	Downstream Invert (m AHD)	0.19
Structure Length (m) (in direction of flow)		20	
Span Length (m)		NA	
Lowest Level of Deck Soffit (m AHD)		1.99	
Overtopping Level of Weir/Road (m AHD) (not including handrail)		2.77	
Average Handrail Height (m)		0.90	

Image Description	Looking upstream (IMG_1352)
Date	12/16/2022
Source	Site Visit

Image Description	Mangroves and siltation upstream (IMG_1348)
Date	12/16/2022
Source	Site Visit

Link to Flood Model Results	\TUFLOW\Design\results\
Model Version Number	BCFS_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_052.tcf
Model Scenario	SCENARIO 1 DESIGN EXISTING CLIMATE (DES_S1_EC) / SCENARIO 1 EXTREME EXISTING CLIMATE (EXT_S1_EC)

Structure Flood Immunity (immunity of lowest point of weir above structure)				0.05% AEP				
AEP (%)	Total Discharge (m^3/s)	Discharge through Structure (m^3/s)[1]	U/S Peak Water Level (m AHD)[2]	D/S Peak Water Level (m AHD)[2]	Afflux (m)[3]	Structure Velocity (m/s)[4&6]	Weir Velocity (m/s)[5&6]	Critical Storm Duration (hrs)[7] & Ensemble
20	11.8	11.8	1.70	1.59	0.11	1.08	N/A	3.0/E1
10	14.8	14.8	1.92	1.78	0.15	1.24	N/A	3.0/E4
5	17.2	17.2	2.07	1.88	0.18	1.39	N/A	3.0/E4
2	20.6	20.6	2.25	1.99	0.26	1.62	N/A	4.5/E9
1	23.4	23.4	2.40	2.06	0.34	1.84	N/A	4.5/E9
0.50	26.8	24.8	2.49	2.11	0.38	1.95	N/A	4.5/E9
0.20	32.9	26.0	2.58	2.21	0.38	2.04	N/A	4.5/E2
0.05	44.8	27.2	2.69	2.42	0.27	2.13	N/A	4.5/E2

[1]Flow underneath the road and only for 1D structures
[2]Measured at centre-span of bridge or at centre of culvert
[3]This is afflux at peak water level
[4](i) Only for 1D structures. (ii) This is the peak of the depth/width averaged velocity within the structure opening
[5](i) Only for 1D structures (ii) This is the peak of the depth/width averaged velocity across the 1D weir section of the model
[6]Velocities provided here are approximate only and the model should be interrogated for design purposes.
[7]Based on peak water level
[(b)]Backwater affected value

Hydraulic Structure Reference Sheet

Brighton Creek Flood Study
Goodenia Woods – Walkway 3

BCC Asset ID	NA	Tributary Name	Brighton Creek
Owner		AMTD (m)	CH 900
Year of Construction	Unknown	Coordinates (GDA94)	505690.43, 6979739.67
Year of Significant Modification		Hydraulic Model ID	C_NS02
Source of Structure Information	Site visit	Flood Model Representation	1D culvert/ 2D weir
Link to Data Source			

Structure Description		Reinforced Concrete Box Culvert	
Bridges		**Culverts**	
Number of Spans	NA	Number of Barrels	1
Number of Piers in Waterway	NA	Dimensions (m)	2.4 x 1.5
Pier shape and Width (m)	NA	Upstream Invert (m AHD)	0.616
Bridge Invert Level (m AHD)	NA	Downstream Invert (m AHD)	0.616
Structure Length (m) (in direction of flow)		3.6	
Span Length (m)		NA	
Lowest Level of Deck Soffit (m AHD)		2.12	
Overtopping Level of Weir/Road (m AHD) (not including handrail)		2.10	
Average Handrail Height (m)		Unknown	

Image Description	Looking downstream (IMG_1406)
Date	12/16/2022
Source	Site Visit

Image Description	
Date	
Source	

Link to Flood Model Results	\TUFLOW\Design\results\
Model Version Number	BCFS_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_052.tcf
Model Scenario	SCENARIO 1 DESIGN EXISTING CLIMATE (DES_S1_EC) / SCENARIO 1 EXTREME EXISTING CLIMATE (EXT_S1_EC)

Structure Flood Immunity (immunity of lowest point of weir above structure)				<50% AEP				
AEP (%)	Total Discharge (m^3/s)[8]	Discharge through Structure (m^3/s)[1]	U/S Peak Water Level (m AHD)[2]	D/S Peak Water Level (m AHD)[2]	Afflux (m)[3]	Structure Velocity (m/s)[4&6]	Weir Velocity (m/s)[5&6]	Critical Storm Duration (hrs)[7] & Ensemble
20	N/A	2.3	2.12	2.11	0.00	0.95	N/A	4.5/E4
10	N/A	2.5	2.26	2.26	0.00	0.96	N/A	6.0/E8
5	N/A	2.7	2.35	2.35	0.00	1.05	N/A	6.0/E1
2	N/A	2.8	2.44	2.44	0.00	1.12	N/A	4.5/E2
1	N/A	2.8	2.50	2.50	0.00	1.12	N/A	4.5/E3
0.50	N/A	2.8	2.56	2.56	0.00	0.93	N/A	4.5/E3
0.20	N/A	2.9	2.63	2.63	0.00	0.97	N/A	4.5/E2
0.05	N/A	3.2	2.72	2.72	0.00	1.02	N/A	4.5/E2

[1]*Flow underneath the road and only for 1D structures*
[2]*Measured at centre-span of bridge or at centre of culvert*
[3]*This is afflux at peak water level*
[4]*(i) Only for 1D structures. (ii) This is the peak of the depth/width averaged velocity within the structure opening*
[5]*(i) Only for 1D structures (ii) This is the peak of the depth/width averaged velocity across the 1D weir section of the model*
[6]*Velocities provided here are approximate only and the model should be interrogated for design purposes.*
[7]*Based on peak water level*
[(b)]*Backwater affected value*
[8]*Structure located within South Wetland inundation, not possible to define overtopping flow.*

Hydraulic Structure Reference Sheet

Brighton Creek Flood Study
Queens Parade (North Wetland)

BCC Asset ID	C0017B	Tributary Name	Brighton Creek
Owner	BCC	AMTD (m)	CH 1030
Year of Construction	1964 January	Coordinates (GDA94)	505429.86, 6980547.95
Year of Significant Modification		Hydraulic Model ID	C_Queens
Source of Structure Information	2014 TUFLOW model	Flood Model Representation	1D culvert/2D weir
Link to Data Source			

Structure Description		Reinforced Concrete Box Culvert	
Bridges		**Culverts**	
Number of Spans	NA	Number of Barrels	2
Number of Piers in Waterway	NA	Dimensions (m)	2.1 x 1.15
Pier shape and Width (m)	NA	Upstream Invert (m AHD)	0.67
Bridge Invert Level (m AHD)	NA	Downstream Invert (m AHD)	0.66
Structure Length (m) (in direction of flow)		12	
Span Length (m)		NA	
Lowest Level of Deck Soffit (m AHD)		1.81	
Overtopping Level of Weir/Road (m AHD) (not including handrail)		2.13	
Average Handrail Height (m)		0.90	

Image Description	Upstream face (IMG_1465)
Date	12/16/2022
Source	Site Visit

Image Description	Upstream face (IMG_8881)
Date	30/04/2016
Source	Council – Assessment Management Maintenance Record

Link to Flood Model Results	\TUFLOW\Design\results\
Model Version Number	BCFS_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_052.tcf
Model Scenario	SCENARIO 1 DESIGN EXISTING CLIMATE (DES_S1_EC) / SCENARIO 1 EXTREME EXISTING CLIMATE (EXT_S1_EC)

Structure Flood Immunity (immunity of lowest point of weir above structure)				50% AEP				
AEP (%)	Total Discharge (m^3/s)[8]	Discharge through Structure (m^3/s)[1]	U/S Peak Water Level (m AHD)[2]	D/S Peak Water Level (m AHD)[2]	Afflux (m)[3]	Structure Velocity (m/s)[4&6]	Weir Velocity (m/s)[5&6]	Critical Storm Duration (hrs)[7] & Ensemble
20	9.5	5.6	2.13	2.02	0.11	1.16	N/A	3.0/E1
10	13.1	5.8	2.21	2.12	0.09	1.18	N/A	3.0/E6
5	17.0	5.8	2.26	2.19	0.07	1.20	N/A	3.0/E6
2	20.7	5.8	2.34	2.33	0.01	1.20	N/A	4.5/E9
1	23.6	5.8	2.46	2.46	0.00	1.20	N/A	4.5/E9
0.50	26.8	5.7	2.55	2.54	0.00	1.19	N/A	4.5/E2
0.20	31.9	5.7	2.63	2.63	0.00	1.18	N/A	4.5/E2
0.05	41.3	5.6	2.73	2.72	0.00	1.17	N/A	4.5/E3

[1]Flow underneath the road and only for 1D structures
[2]Measured at centre-span of bridge or at centre of culvert
[3]This is afflux at peak water level
[4](i) Only for 1D structures. (ii) This is the peak of the depth/width averaged velocity within the structure opening
[5](i) Only for 1D structures (ii) This is the peak of the depth/width averaged velocity across the 1D weir section of the model
[6]Velocities provided here are approximate only and the model should be interrogated for design purposes.
[7]Based on peak water level
[(b)]Backwater affected value
[8]Broad overtopping of Queens Parade not just at structure

Hydraulic Structure Reference Sheet Brighton Creek Flood Study Wickham Street

BCC Asset ID	B17000056	Tributary Name	Brighton Creek
Owner	BCC	AMTD (m)	CH 1700
Year of Construction	1981 October	Coordinates (GDA94)	504898, 6979986.00
Year of Significant Modification	2003 January	Hydraulic Model ID	C_Wickham_1 C_Wickham_2
Source of Structure Information	2014 TUFLOW model	Flood Model Representation	1D culvert/2D weir
Link to Data Source			

Structure Description		Reinforced concrete pipe culverts	
Bridges		**Culverts**	
Number of Spans	NA	Number of Barrels	2 / 1
Number of Piers in Waterway	NA	Dimensions (m)	1.35 / 1.2
Pier shape and Width (m)	NA	Upstream Invert (m AHD)	2.3 / 1.88
Bridge Invert Level (m AHD)	NA	Downstream Invert (m AHD)	2.1 / 1.6
Structure Length (m) (in direction of flow)		62	
Span Length (m)		NA	
Lowest Level of Deck Soffit (m AHD)		3.45 / 2.80	
Overtopping Level of Weir/Road (m AHD) (not including handrail)		4.40	
Average Handrail Height (m)		1.00	

Image Description	Upstream face (IMG_1550)
Date	12/16/2022
Source	Site Visit

Image Description	
Date	
Source	

Link to Flood Model Results	\TUFLOW\Design\results\
Model Version Number	BCFS_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_052.tcf
Model Scenario	SCENARIO 1 DESIGN EXISTING CLIMATE (DES_S1_EC) / SCENARIO 1 EXTREME EXISTING CLIMATE (EXT_S1_EC)

Structure Flood Immunity (immunity of lowest point of weir above structure)				0.5% AEP				
AEP (%)	Total Discharge (m^3/s)	Discharge through Structure (m^3/s)[1]	U/S Peak Water Level (m AHD)[2]	D/S Peak Water Level (m AHD)[2]	Afflux (m)[3]	Structure Velocity (m/s)[4&6]	Weir Velocity (m/s)[5&6]	Critical Storm Duration (hrs)[7] & Ensemble
20	7.0	7.0	3.52	2.60	0.92	2.22 / 2.45	N/A	0.75/E7
10	8.2	8.2	3.72	2.67	1.05	2.41 / 2.51	N/A	0.75/E5
5	9.1	9.1	3.86	2.72	1.14	2.54 / 2.7	N/A	0.75/E5
2	9.8	9.8	4.12	2.76	1.36	2.59 / 3.01	N/A	1.5/E3
1	10.5	10.5	4.25	2.83	1.41	2.59 / 3.11	N/A	1.5/E3
0.50	11.2	11.2	4.39	2.87	1.52	2.63 / 3.23	N/A	1.5/E3
0.20	14.1	11.7	4.51	2.96	1.55	2.8 / 3.3	2.4	1.5/E5
0.05	19.6	12.1	4.60	3.00	1.60	2.9 / 3.38	7.5	2.0/E3

[1]*Flow underneath the road and only for 1D structures*
[2]*Measured at centre-span of bridge or at centre of culvert*
[3]*This is afflux at peak water level*
[4]*(i) Only for 1D structures. (ii) This is the peak of the depth/width averaged velocity within the structure opening*
[5]*(i) Only for 1D structures (ii) This is the peak of the depth/width averaged velocity across the 1D weir section of the model*
[6]*Velocities provided here are approximate only and the model should be interrogated for design purposes.*
[7]*Based on peak water level*
[(b)]*Backwater affected value*

Hydraulic Structure Reference Sheet

Brighton Creek Flood Study
Townsend Street

BCC Asset ID	C0188P	Tributary Name	Brighton Creek Tributary
Owner	BCC	AMTD (m)	CH 200
Year of Construction	1964 January	Coordinates (GDA94)	505782.0, 6980394.0
Year of Significant Modification		Hydraulic Model ID	C_Townsend
Source of Structure Information	2014 TUFLOW model	Flood Model Representation	1D culvert/2D weir
Link to Data Source			

Structure Description		Reinforced concrete pipe culverts	
Bridges		**Culverts**	
Number of Spans	NA	Number of Barrels	2
Number of Piers in Waterway	NA	Dimensions (m)	1.22
Pier shape and Width (m)	NA	Upstream Invert (m AHD)	0.48
Bridge Invert Level (m AHD)	NA	Downstream Invert (m AHD)	0.36
Structure Length (m) (in direction of flow)		12	
Span Length (m)		NA	
Lowest Level of Deck Soffit (m AHD)		1.58	
Overtopping Level of Weir/Road (m AHD) (not including handrail)		2.06	
Average Handrail Height (m)		1.00	

Image Description	Upstream face (IMG_1449)
Date	12/16/2022
Source	Site Visit

Image Description	Downstream dace (IMG_9069)
Date	01/05/2014
Source	Council – Asset Management Maintenance Record

Link to Flood Model Results	\TUFLOW\Design\results\
Model Version Number	BCFS_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_052.tcf
Model Scenario	SCENARIO 1 DESIGN EXISTING CLIMATE (DES_S1_EC) / SCENARIO 1 EXTREME EXISTING CLIMATE (EXT_S1_EC)

Structure Flood Immunity (immunity of lowest point of weir above structure)				10% AEP				
AEP (%)	Total Discharge (m^3/s)[8]	Discharge through Structure (m^3/s)[1]	U/S Peak Water Level (m AHD)[2]	D/S Peak Water Level (m AHD)[2]	Afflux (m)[3]	Structure Velocity (m/s)[4&6]	Weir Velocity (m/s)[5&6]	Critical Storm Duration (hrs)[7] & Ensemble
20	2.8	2.8	1.87	1.82	0.05	1.23	N/A	3.0/E8
10	3.7	3.0	2.04	2.03	0.01	1.30	N/A	3.0/E4
5	5.4	2.9	2.17	2.16	0.00	1.24	N/A	3.0/E8
2	8.4	2.8	2.33	2.32	0.00	1.25	N/A	4.5/E9
1	9.6	2.8	2.45	2.45	0.00	1.26	N/A	4.5/E9
0.50	9.8	2.5	2.54	2.54	0.00	1.06	N/A	4.5/E9
0.20	10.1	2.5	2.62	2.62	0.00	1.09	N/A	4.5/E2
0.05	10.6	2.6	2.72	2.72	0.00	1.14	N/A	4.5/E3

[1]*Flow underneath the road and only for 1D structures*
[2]*Measured at centre-span of bridge or at centre of culvert*
[3]*This is afflux at peak water level*
[4]*(i) Only for 1D structures. (ii) This is the peak of the depth/width averaged velocity within the structure opening*
[5]*(i) Only for 1D structures (ii) This is the peak of the depth/width averaged velocity across the 1D weir section of the model*
[6]*Velocities provided here are approximate only and the model should be interrogated for design purposes.*
[7]*Based on peak water level*
[(b)]*Backwater affected value*
[8]*Road at structure is highest point. Broad overtopping of Townsend St before structure is overtopped.*

Hydraulic Structure Reference Sheet

Brighton Creek Flood Study
Queens Parade (South Wetland)

BCC Asset ID	C4031P	Tributary Name	Brighton Creek Tributary
Owner	BCC	AMTD (m)	CH 400
Year of Construction	1964 January	Coordinates (GDA94)	505782, 6980200.0
Year of Significant Modification		Hydraulic Model ID	C_Qpde_South
Source of Structure Information	2014 TUFLOW model	Flood Model Representation	1D culvert/2D weir
Link to Data Source			

Structure Description		Reinforced concrete pipe culverts	
Bridges		**Culverts**	
Number of Spans	NA	Number of Barrels	2
Number of Piers in Waterway	NA	Dimensions (m)	1.22
Pier shape and Width (m)	NA	Upstream Invert (m AHD)	0.68
Bridge Invert Level (m AHD)	NA	Downstream Invert (m AHD)	0.48
Structure Length (m) (in direction of flow)		115	
Span Length (m)		NA	
Lowest Level of Deck Soffit (m AHD)		1.7	
Overtopping Level of Weir/Road (m AHD) (not including handrail)		2.81	
Average Handrail Height (m)		1.00	

Image Description	Queens Parade culvert South looking downstream (IMG_1428)
Date	12/16/2022
Source	Site Visit

Image Description	Queens Parade culvert South looking downstream
Date	
Source	2014 report

Link to Flood Model Results	\TUFLOW\Design\results\
Model Version Number	BCFS_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_052.tcf
Model Scenario	SCENARIO 1 DESIGN EXISTING CLIMATE (DES_S1_EC) / SCENARIO 1 EXTREME EXISTING CLIMATE (EXT_S1_EC)

Structure Flood Immunity (immunity of lowest point of weir above structure)				20% AEP[8]				
AEP (%)	Total Discharge (m^3/s)[8]	Discharge through Structure (m^3/s)[1]	U/S Peak Water Level (m AHD)[2]	D/S Peak Water Level (m AHD)[2]	Afflux (m)[3]	Structure Velocity (m/s)[4&6]	Weir Velocity (m/s)[5&6]	Critical Storm Duration (hrs)[7] & Ensemble
20	2.8	2.8	2.10	1.88	0.22	1.20	N/A	4.5/E4
10	3.7	3.0	2.24	2.04	0.21	1.27	N/A	6.0/E10
5	5.5	2.9	2.33	2.16	0.17	1.25	N/A	6.0/E7
2	9.1	2.9	2.43	2.31	0.11	1.22	N/A	4.5/E2
1	10.8	2.6	2.49	2.45	0.04	1.12	N/A	4.5/E2
0.50	11.1	2.3	2.55	2.54	0.01	1.02	N/A	4.5/E9
0.20	12.0	2.3	2.63	2.62	0.01	1.00	N/A	4.5/E2
0.05	12.6	2.4	2.72	2.72	0.00	1.02	N/A	4.5/E2

[1]Flow underneath the road and only for 1D structures
[2]Measured at centre-span of bridge or at centre of culvert
[3]This is afflux at peak water level
[4](i) Only for 1D structures. (ii) This is the peak of the depth/width averaged velocity within the structure opening
[5](i) Only for 1D structures (ii) This is the peak of the depth/width averaged velocity across the 1D weir section of the model
[6]Velocities provided here are approximate only and the model should be interrogated for design purposes.
[7]Based on peak water level
[(b)]Backwater affected value
[8] Queens Pde is affected by broad overtopping in 20% AEP. Discharge towards Main Wetland.

Hydraulic Structure Reference Sheet Brighton Creek Flood Study Goodenia Woods – Walkway 2

BCC Asset ID	NA	Tributary Name	Brighton Creek
Owner		AMTD (m)	CH 1100
Year of Construction	Unknown	Coordinates (GDA94)	505556.85, 6979610.95
Year of Significant Modification		Hydraulic Model ID	C_NS03
Source of Structure Information	Site visit	Flood Model Representation	1D culvert/2D weir
Link to Data Source			

Structure Description		Reinforced Concrete Box Culvert	
Bridges		**Culverts**	
Number of Spans	NA	Number of Barrels	1
Number of Piers in Waterway	NA	Dimensions (m)	3.3 x 0.88
Pier shape and Width (m)	NA	Upstream Invert (m AHD)	1.429
Bridge Invert Level (m AHD)	NA	Downstream Invert (m AHD)	1.305
Structure Length (m) (in direction of flow)		3.6	
Span Length (m)		NA	
Lowest Level of Deck Soffit (m AHD)		2.13	
Overtopping Level of Weir/Road (m AHD) (not including handrail)		2.18	
Average Handrail Height (m)		Unknown	

Image Description	Looking upstream (IMG_1398)
Date	12/16/2022
Source	Site Visit

Image Description	
Date	
Source	

Link to Flood Model Results	\TUFLOW\Design\results\
Model Version Number	BCFS_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_052.tcf
Model Scenario	SCENARIO 1 DESIGN EXISTING CLIMATE (DES_S1_EC) / SCENARIO 1 EXTREME EXISTING CLIMATE (EXT_S1_EC)

Structure Flood Immunity (immunity of lowest point of weir above structure)				20% AEP				
AEP (%)	Total Discharge (m^3/s)[8]	Discharge through Structure (m^3/s)[1]	U/S Peak Water Level (m AHD)[2]	D/S Peak Water Level (m AHD)[2]	Afflux (m)[3]	Structure Velocity (m/s)[4&6]	Weir Velocity (m/s)[5&6]	Critical Storm Duration (hrs)[7] & Ensemble
20	N/A	2.2	2.13	2.13	0.00	1.85	N/A	4.5/E9
10	N/A	2.5	2.26	2.27	-0.01	1.86	N/A	6.0/E10
5	N/A	2.8	2.35	2.37	-0.02	1.88	N/A	6.0/E3
2	N/A	2.8	2.44	2.46	-0.01	1.95	N/A	4.5/E2
1	N/A	2.9	2.50	2.51	-0.01	1.97	N/A	4.5/E8
0.50	N/A	3.0	2.56	2.57	-0.01	1.88	N/A	4.5/E3
0.20	N/A	3.1	2.63	2.64	-0.01	1.91	N/A	4.5/E2
0.05	N/A	3.2	2.73	2.74	-0.01	1.98	N/A	4.5/E3

[1]Flow underneath the road and only for 1D structures
[2]Measured at centre-span of bridge or at centre of culvert
[3]This is afflux at peak water level
[4](i) Only for 1D structures. (ii) This is the peak of the depth/width averaged velocity within the structure opening
[5](i) Only for 1D structures (ii) This is the peak of the depth/width averaged velocity across the 1D weir section of the model
[6]Velocities provided here are approximate only and the model should be interrogated for design purposes.
[7]Based on peak water level
[(b)]Backwater affected value
[8]Structure located within South Wetland inundation, not possible to define overtopping flow.

Hydraulic Structure Reference Sheet

Brighton Creek Flood Study
Saul Street Park

BCC Asset ID	NA	Tributary Name	Unnamed Tributary
Owner		AMTD (m)	N/A
Year of Construction	Unknown	Coordinates (GDA94)	505720.7, 6979434.3
Year of Significant Modification		Hydraulic Model ID	C_OS_01
Source of Structure Information	Site visit	Flood Model Representation	1D culvert/2D weir
Link to Data Source			

Structure Description		Reinforced concrete pipe culvert	
Bridges		**Culverts**	
Number of Spans	NA	Number of Barrels	1
Number of Piers in Waterway	NA	Dimensions (m)	0.75
Pier shape and Width (m)	NA	Upstream Invert (m AHD)	1.721
Bridge Invert Level (m AHD)	NA	Downstream Invert (m AHD)	1.671
Structure Length (m) (in direction of flow)		15	
Span Length (m)		NA	
Lowest Level of Deck Soffit (m AHD)		2.42	
Overtopping Level of Weir/Road (m AHD) (not including handrail)		3.04	
Average Handrail Height (m)		Unknown	

Image Description	
Date	
Source	

Image Description	
Date	
Source	

Link to Flood Model Results	\TUFLOW\Design\results\
Model Version Number	BCFS_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_052.tcf
Model Scenario	SCENARIO 1 DESIGN EXISTING CLIMATE (DES_S1_EC) / SCENARIO 1 EXTREME EXISTING CLIMATE (EXT_S1_EC)

Structure Flood Immunity (immunity of lowest point of weir above structure)				<20% AEP				
AEP (%)	Total Discharge (m^3/s)[8]	Discharge through Structure (m^3/s)[1]	U/S Peak Water Level (m AHD)[2]	D/S Peak Water Level (m AHD)[2]	Afflux (m)[3]	Structure Velocity (m/s)[4&6]	Weir Velocity (m/s)[5&6]	Critical Storm Duration (hrs)[7] & Ensemble
20	N/A	1.1	3.08	2.52	0.56	2.41	N/A	0.75/E7
10	N/A	1.1	3.12	2.58	0.54	2.50	N/A	0.75/E6
5	N/A	1.1	3.14	2.60	0.54	2.53	N/A	0.75/E5
2	N/A	1.1	3.17	2.64	0.53	2.52	N/A	1.5/E3
1	N/A	1.1	3.18	2.70	0.48	2.52	N/A	1.5/E3
0.50	N/A	1.1	3.20	2.75	0.45	2.52	N/A	1.5/E3
0.20	N/A	1.1	3.23	2.81	0.42	2.51	N/A	1.5/E3
0.05	N/A	1.1	3.26	2.89	0.37	2.50	N/A	1.5/E3

[1]Flow underneath the road and only for 1D structures
[2]Measured at centre-span of bridge or at centre of culvert
[3]This is afflux at peak water level
[4](i) Only for 1D structures. (ii) This is the peak of the depth/width averaged velocity within the structure opening
[5](i) Only for 1D structures (ii) This is the peak of the depth/width averaged velocity across the 1D weir section of the model
[6]Velocities provided here are approximate only and the model should be interrogated for design purposes.
[7]Based on peak water level
[(b)]Backwater affected value
[8]Structure located within South Wetland inundation, not possible to define overtopping flow.

Hydraulic Structure Reference Sheet

Brighton Creek Flood Study
Goodenia Woods – Walkway 1

BCC Asset ID	NA	Tributary Name	Unnamed Tributary
Owner		AMTD (m)	N/A
Year of Construction	Unknown	Coordinates (GDA94)	505680.9, 6979491.7
Year of Significant Modification		Hydraulic Model ID	C_NS01
Source of Structure Information	Site visit	Flood Model Representation	1D culvert/2D weir
Link to Data Source			

Structure Description		Reinforced Concrete Box Culvert	
Bridges		**Culverts**	
Number of Spans	NA	Number of Barrels	1
Number of Piers in Waterway	NA	Dimensions (m)	1.5 x 1.5
Pier shape and Width (m)	NA	Upstream Invert (m AHD)	1.056
Bridge Invert Level (m AHD)	NA	Downstream Invert (m AHD)	1
Structure Length (m) (in direction of flow)		4.8	
Span Length (m)		NA	
Lowest Level of Deck Soffit (m AHD)		2.5	
Overtopping Level of Weir/Road (m AHD) (not including handrail)		2.72	
Average Handrail Height (m)		Unknown	

Image Description	Looking downstream (IMG_1407)
Date	12/16/2022
Source	Site Visit

Image Description	
Date	
Source	

Link to Flood Model Results	\TUFLOW\Design\results\
Model Version Number	BCFS_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_052.tcf
Model Scenario	SCENARIO 1 DESIGN EXISTING CLIMATE (DES_S1_EC) / SCENARIO 1 EXTREME EXISTING CLIMATE (EXT_S1_EC)

Structure Flood Immunity (immunity of lowest point of weir above structure)				0.5% AEP				
AEP (%)	Total Discharge (m^3/s)[8]	Discharge through Structure (m^3/s)[1]	U/S Peak Water Level (m AHD)[2]	D/S Peak Water Level (m AHD)[2]	Afflux (m)[3]	Structure Velocity (m/s)[4&6]	Weir Velocity (m/s)[5&6]	Critical Storm Duration (hrs)[7] & Ensemble
20	N/A	2.2	2.23	2.14	0.09	1.29	N/A	3.0/E9
10	N/A	3.1	2.33	2.27	0.06	1.50	N/A	0.75/E6
5	N/A	3.2	2.45	2.36	0.09	1.76	N/A	0.75/E6
2	N/A	3.5	2.55	2.45	0.10	1.77	N/A	1.5/E3
1	N/A	3.7	2.62	2.50	0.12	1.84	N/A	2.0/E6
0.50	N/A	3.9	2.67	2.56	0.11	1.90	N/A	2.0/E5
0.20	N/A	4.1	2.72	2.63	0.09	1.95	N/A	2.0/E5
0.05	N/A	4.3	2.79	2.74	0.05	2.00	N/A	2.0/E5

[1]*Flow underneath the road and only for 1D structures*
[2]*Measured at centre-span of bridge or at centre of culvert*
[3]*This is afflux at peak water level*
[4]*(i) Only for 1D structures. (ii) This is the peak of the depth/width averaged velocity within the structure opening*
[5]*(i) Only for 1D structures (ii) This is the peak of the depth/width averaged velocity across the 1D weir section of the model*
[6]*Velocities provided here are approximate only and the model should be interrogated for design purposes.*
[7]*Based on peak water level*
[(b)]*Backwater affected value*
[8]*Structure located within South Wetland inundation, not possible to define overtopping flow.*

Hydraulic Structure Reference Sheet

Brighton Creek Flood Study
Shepherd Street

BCC Asset ID	C0684B	Tributary Name	Unnamed Tributary
Owner	BCC	AMTD (m)	
Year of Construction	1980 May	Coordinates (GDA94)	506064, 6980662.0
Year of Significant Modification		Hydraulic Model ID	C_Sheppard
Source of Structure Information	2014 TUFLOW model	Flood Model Representation	1D culvert/2D weir
Link to Data Source			

Structure Description		Reinforced Concrete Box Culvert	
Bridges		**Culverts**	
Number of Spans	NA	Number of Barrels	1
Number of Piers in Waterway	NA	Dimensions (m)	3 x 1.2
Pier shape and Width (m)	NA	Upstream Invert (m AHD)	0.55
Bridge Invert Level (m AHD)	NA	Downstream Invert (m AHD)	0.5
Structure Length (m) (in direction of flow)		12.2	
Span Length (m)		NA	
Lowest Level of Deck Soffit (m AHD)		1.7	
Overtopping Level of Weir/Road (m AHD) (not including handrail)		2.26	
Average Handrail Height (m)		1.00	

Image Description	Downstream face (IMG_1588)
Date	12/16/2022
Source	Site Visit

Image Description	Downstream face (IMG_9036)
Date	01/05/2014
Source	Council – Assessment Management Maintenance Record

Link to Flood Model Results	\TUFLOW\Design\results\
Model Version Number	BCFS_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_052.tcf
Model Scenario	SCENARIO 1 DESIGN EXISTING CLIMATE (DES_S1_EC) / SCENARIO 1 EXTREME EXISTING CLIMATE (EXT_S1_EC)

Structure Flood Immunity (immunity of lowest point of weir above structure)				5% AEP				
AEP (%)	Total Discharge (m^3/s)[8]	Discharge through Structure (m^3/s)[1]	U/S Peak Water Level (m AHD)[2]	D/S Peak Water Level (m AHD)[2]	Afflux (m)[3]	Structure Velocity (m/s)[4&6]	Weir Velocity (m/s)[5&6]	Critical Storm Duration (hrs)[7] & Ensemble
20	2.9	2.9	1.75	1.72	0.04	0.82	N/A	3.0/E8
10	3.3	3.3	1.98	1.95	0.04	0.89	N/A	3.0/E8
5	3.9	3.9	2.11	2.07	0.03	1.04	N/A	3.0/E4
2	N/A	4.3	2.30	2.27	0.03	1.17	N/A	4.5/E9
1	N/A	4.7	2.45	2.44	0.01	1.27	N/A	4.5/E9
0.50	N/A	5.0	2.54	2.53	0.01	1.38	N/A	4.5/E3
0.20	N/A	5.4	2.62	2.62	0.00	1.50	N/A	4.5/E2
0.05	N/A	5.7	2.73	2.72	0.00	1.59	N/A	4.5/E3

[1] *Flow underneath the road and only for 1D structures*
[2] *Measured at centre-span of bridge or at centre of culvert*
[3] *This is afflux at peak water level*
[4] *(i) Only for 1D structures. (ii) This is the peak of the depth/width averaged velocity within the structure opening*
[5] *(i) Only for 1D structures (ii) This is the peak of the depth/width averaged velocity across the 1D weir section of the model*
[6] *Velocities provided here are approximate only and the model should be interrogated for design purposes.*
[7] *Based on peak water level*
(b) *Backwater affected value*
[8] *Affected by broad inundation within Main Wetland for events greater than 5% AEP*

Appendix K: External Peer Review Documentation

ARUP

Technical Note

Project title	Brighton Creek Flood Study
Job number	293481-02
File reference	Peer Review Phase 1 Technical Note – Calibration Performance
cc	Hanieh.Zolfaghari@brisbane.qld.gov.au
Prepared by	Cecile Peille, Brian Sexton
Date	02 March 2023
Subject	Flood Model Review

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t +61 7 3023 6000 d +61 4 34 877 807
arup.com

1. Introduction

1.1 The Project

Brisbane City Council (BCC) is currently undertaking an update of the 2014 Brighton Creek Flood Study. Following on from the February 2022 flood event, complaints were received from residents stating that ongoing catchment development contributed to further inundation of the lower reach of Brighton Creek, and that the hydraulic performance of the Beaconsfield Terrace culverts and Flinders Parade bridge had impacted on upstream flooding during the event. Therefore, BCC has commissioned Jacobs to update the Brighton Creek Flood Study to current standards in order to better understand flooding conditions within the catchment and investigate potential mitigation options to alleviate flooding (the Project). This Project will be delivered in 2 stages:

- Stage 1: Brighton Creek Flood Study Update
- Stage 2: Potential Flood Mitigation Options for Lower Brighton Creek

The project is currently in Stage 1.

1.2 Document purpose

Arup has been commissioned by BCC to undertake a peer peer review of the project at key phases of Stage 1, specifically:

- Peer Review Phase 1: Brighton Creek Flood Study Calibration performance.
- Peer Review Phase 2: Brighton Creek Flood Study Design events.

This technical note documents the peer review process and review findings associated with the Brighton Creek Flood Study Update for Phase 1 (Calibration performance).

1.3 Review guidelines

This technical review has been undertaken in line with the following documents:

- Flood Study Procedure Document, City Projects Office Brisbane Infrastructure, Version 9.0 (September 2022).
- Australian Rainfall and Runoff (ARR) 2019
- URBS User Manual, Version 6.6 (September 2021)
- TUFLOW User Manual (March 2018) and subsequent releases notes.

2. Review Method

2.1 Methodology

Each element of review is included in the QA form attached at the end of this technical note. For clarity, only the elements of review that require further clarification are listed in this technical note. These are also summarised in Section 6.

2.2 Files provided

2.2.1 Hydrological model files

The following files were provided for review:

GIS layers:

- 'Brighton Catchment" v014
- 'Brighton Sub-Catchment" v014
- 'Brighton stream" v014
  - This layer reflects the two main creek / canal flowpaths
- 'Brighton main stream" v014
  - This layer reflects flowpaths across sub-catchments
- 'Brighton Long FP" v014
  - This layer reflects the longest flow path within each sub-catchments (i.e from upstream to downstream oh)
- 'Brighton Synthetic stream" v014
  - This layer reflects all sub catchments local flowpaths
- 'Brighton Nodal Link" v014
  - This layer reflects the schematical URBS sub-catchment linkage
- 'Brighton Routing distance" v014
  - This layer reflects the routing distance for each flowpath between each node URBS

URBS Model:

- Catchment file, Vector File, and associated results for the following events:
  - December 2019
  - February 2020
  - December 2021
  - February 2022
- Ratings curves for3 basins within the catchment

2.2.2 Hydraulic model files

- TUFLOW Control files provided for Run 033 (relating to calibration events 2020, 2021 and 2022)
- TUFLOW Control files provided for Run 034 (relating to calibration event 2019)
- All associated TUFLOW model input files
- All associated TUFLOW model results
- Check and model log files

2.2.3 Report

No report was provided for this review. A PowerPoint document titled 'Brighton Calibration Summary' was provided.

The document includes calibration performance figures.

3. Hydrological Model Review

3.1 Catchment definition review

Sub-catchments appear to be delineated through Catchment SIM software (or similar). It is generally recommended to delineate small urban sub-catchments with consideration being given to the underground drainage layout.

BCC Flood Study Procedure Document states that *"modelling of the underground pipe network is not required unless it forms the major flow path, connecting open waterways"*. As such the work conducted by Jacobs appears in accordance with BCC Procedure.

- It is still recommended to verify the appropriateness of the sub-catchment plan delineation in contrasting it against the major/trunk underground drainage network to ensure there are no major issues / anomalies that may otherwise affect the accuracy of the flood model (where pipes are above a nominal minimum diameter, say).

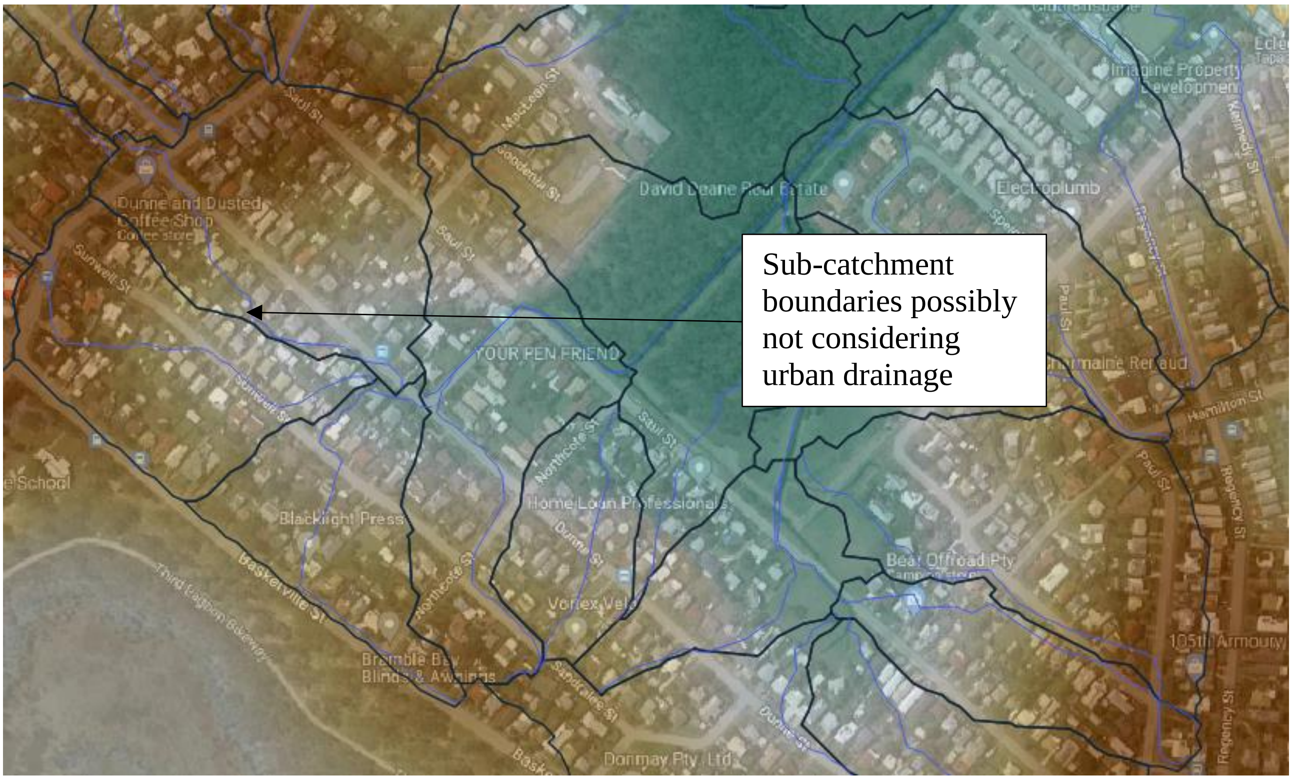


Figure 1: Sub-catchment plan review

3.2 Catchment and stream properties

All sub-catchments are attributed a fraction of catchment impervious. Spot checks have been made with recent aerial imagery and appear correct. However, all impervious fractions are the same across all calibration events (2019, 2020, 2021 and 2022).

- Jacobs to confirm that there has been no major development in the area between 2019 and 2022.
- Jacobs to confirm that the BCC ultimate development landuse plan shall be used for the design events, i.e. it is anticipated that the impervious fraction will be the same or greater than calibration events.

3.3 Losses and coefficients

The URBS Loss method of uniform continuing has been applied. Initial Loss and Continuing Loss (IL / CL) were specified in the batch file for each event. These values match Jacobs reported values and are consistent across the 2020, 2021, and 2022 events:

- IL = 0mm, except the 2019 flood event which has an IL = 50mm
- CL = 1.104mm/hr.

A specific set of losses was required to target a suitable calibration performance for the 2019 event.

The calibration performance for the 2019 event was still found to be outside the preferred BCC tolerance at Gauge ID 110, with modelled peak level below the recorded level by 0.374m.

The 2019 flood event pluviograph was reviewed and found to be a very short-duration storm (~half an hour, and approximately a 5% AEP rainfall event) as shown in Figure 2 (which compares it against 2020 rainfall event for context).

The short, intense, and possibly localised nature of the 2019 rainfall event implies that there may be limitations with how well able the flood modelling can be calibrated to it. Accordingly, it would likely be reasonable to place less weight on this calibration event in comparison to the three other historic events.

- ➢ Jacobs to review the 2019 event (particularly if any historic radar imagery is available e.g. https://theweatherchaser.com) with regard to potential limitations associated with the calibration – any such findings should be documented in its formal reporting

Overall, the rainfall losses used in the calibration exercise appear reasonable, and are supported by the validation outcomes. The fact that they are generally consistent (and not overly dissimilar to the ARR Datahub losses) supports their use for the flood model calibration exercise.

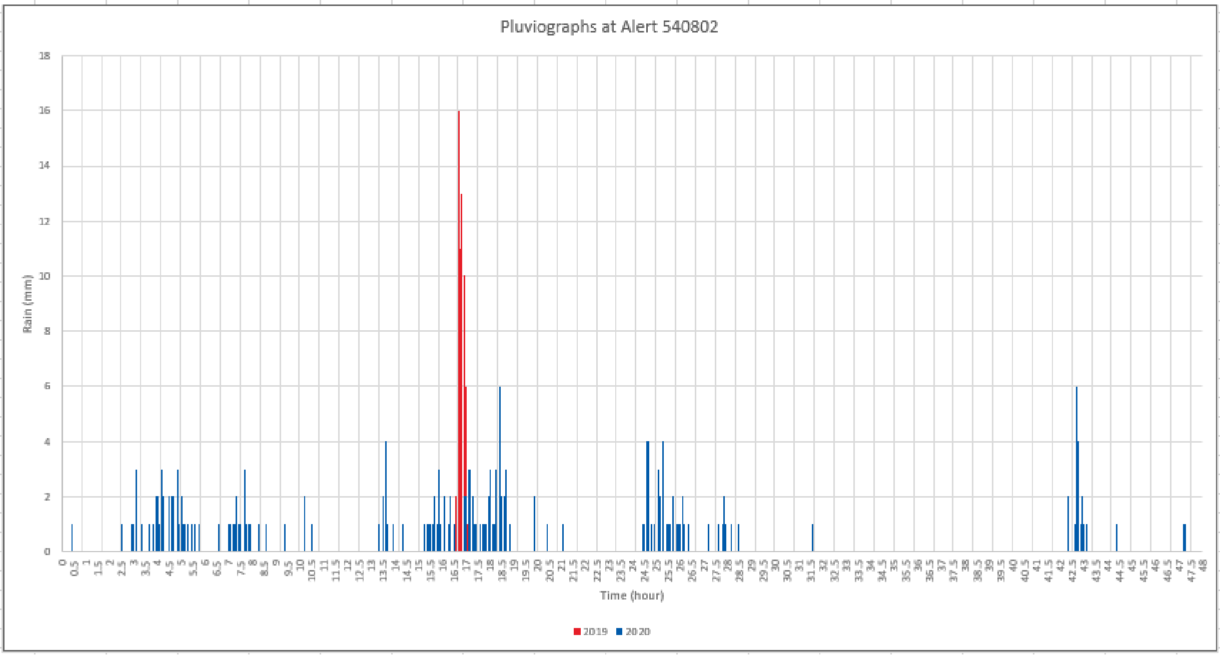


Figure 2: 2019 Pluviograph

As a note, and by way of comparison, the ARR Datahub losses are IL = 31mm and CL = 2.5mm/hr.

- It is recommended to draw upon the IL/CL outcomes obtained for the 2020, 2021 and 2022 calibration/validation modelling in defining design event losses (noting the fact they are lower, and therefore marginally more conservative than ARR datahub).
- When modelling the design event scenarios, it may be beneficial to undertake sensitivity testing with the ARR datahub losses and the calibration values to assess their impact on design event flood levels results (for next phase e.g. 1% AEP flood event).
- Ahead of defining design event rainfall losses, and the potential to draw upon the calibrated rainfall losses in this regard, it is also suggested that Jacobs conduct a cursory check of the antecedent catchment rainfall (i.e. to gain an appreciation of the level of catchment saturation) across these three historic events, to ensure any decisions are targeted towards obtaining probability-neutral outcomes for the flood study's design event modelling.

4. Hydraulic Model Review

4.1 Model extent and boundaries

Model Extent

The hydraulic model code covers the entire catchment as shown in Figure 3.

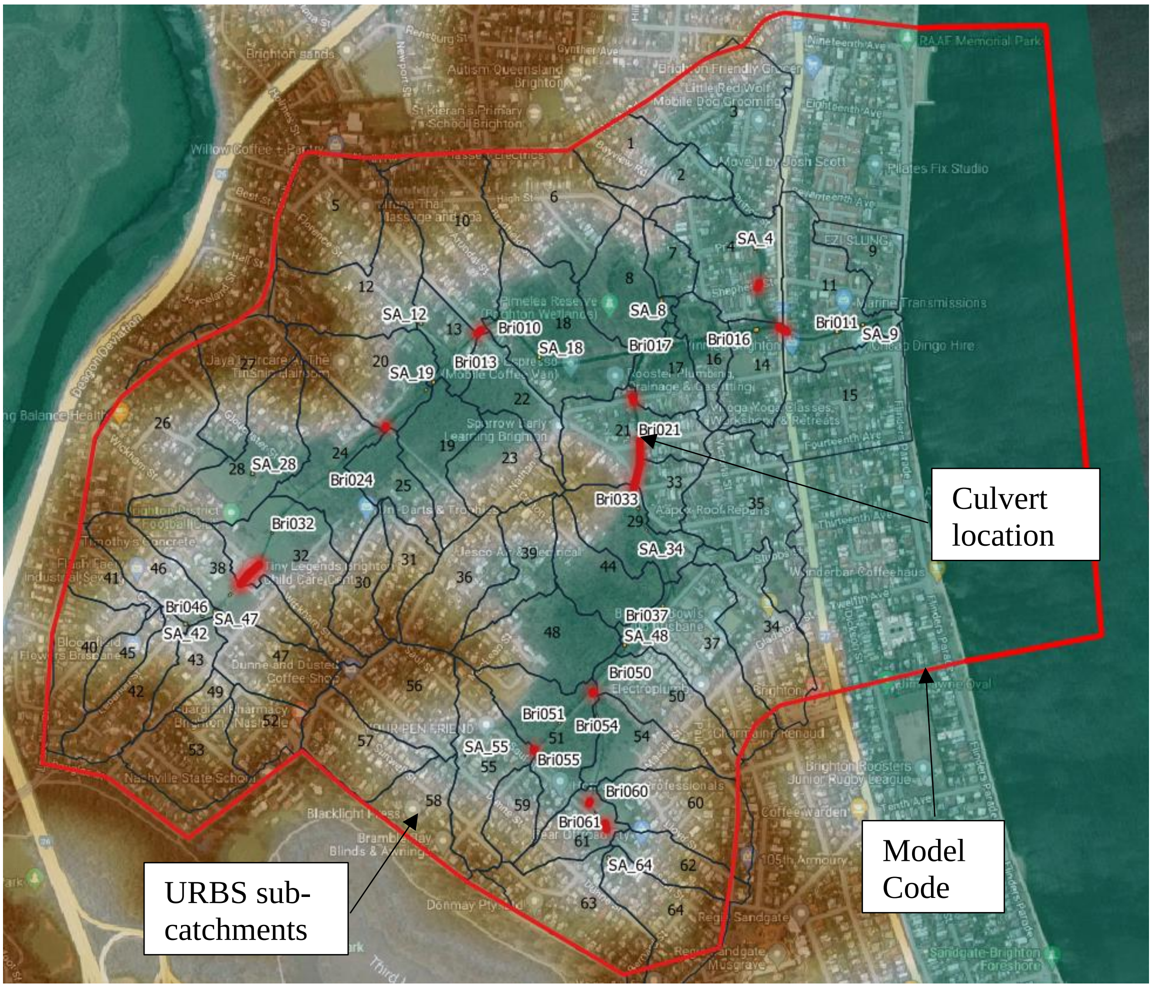


Figure 3: TUFLOW Model Layout review

Downstream boundary condition

The model is highly dependent on downstream boundary conditions applied due to the tidal nature of the Brisbane River. The recorded tidal levels from the Brisbane Bar have been applied for calibration events.

- Jacobs to confirm the location of the recorded level gauge and adjustment made (if any) to suit the model downstream boundary location. This recognises that the recorded tide level at a gauge could be appreciably different to the actual tide level at the project focus area (i.e. the creek mouth) if the spatial distance between them is significant – adjustments or interpolation may therefore need to be applied to define appropriate tidal tailwater levels, noting the potential sensitivity of the lower floodplain to the downstream boundary condition. This aspect of the modelling is likely more important looking ahead to the design event simulations.

Model inflows

The routed URBS total flows have been applied at some of the upstream parts of the model, for example Catchment SA_42 as shown in Figure 4 below (this means that not all local catchments are routed in TUFLOW). This comment is for information only and does not constitute a departure from BCC guidelines.

All wetlands basins are represented (i.e. routed) in TUFLOW which is appropriate.

Inconsistencies are noted in the application of the local catchment flows (labelled Bri0xx) and catchment total flows (labelled SA_xx), with some hydrographs applied at catchment centroids and others applied at catchment outlets. Whilst it is anticipated to have minimal effects onto results overall, it is recommended to review the application of flows for consistency.

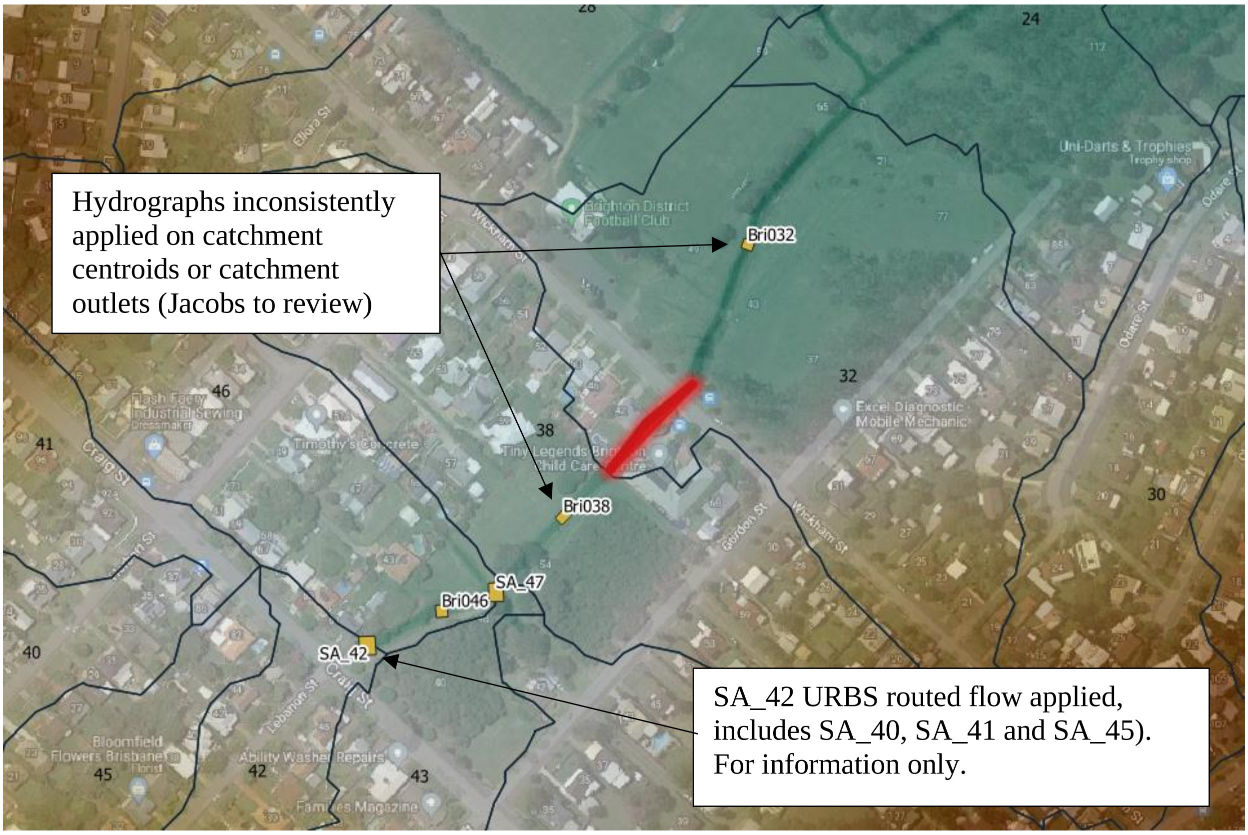


Figure 4: TUFLOW inflows application review

4.2 Hydraulic structures

One bridge was identified at Flinders Parade and represented within the model as 2d_lfcsh polygon element. No form loss coefficient was applied.

- Jacobs to confirm that there are no supporting piers to the bridge (this seems to be the case from aerials)

Culverts appeared to be correctly represented within the model. As a note, blockage factor allowance shall be included in the design scenario modelling (not assessed as part of the calibration review).

No underground drainage network (apart from cross-drainage culverts) was included in the model which appears to be in line with BCC Flood Study Procedure Document.

4.3 Model Topography

Channel gullies have been enforced via “2d_zsh” elements and significant conveyance capacity has therefore been added to channels. Whilst it is possible that the vegetation may have resulted in a inaccurate LiDAR at location (i.e. LiDAR not picking up bottom of the channel) and that manual adjustments are required, it is recommended that this major enforcement be verified through comparison with survey information, along with site observations where possible, as it could potentially affect design flood level results appreciably.

- Jacobs to confirm the rationale/supporting information behind the enforced deepening of channels

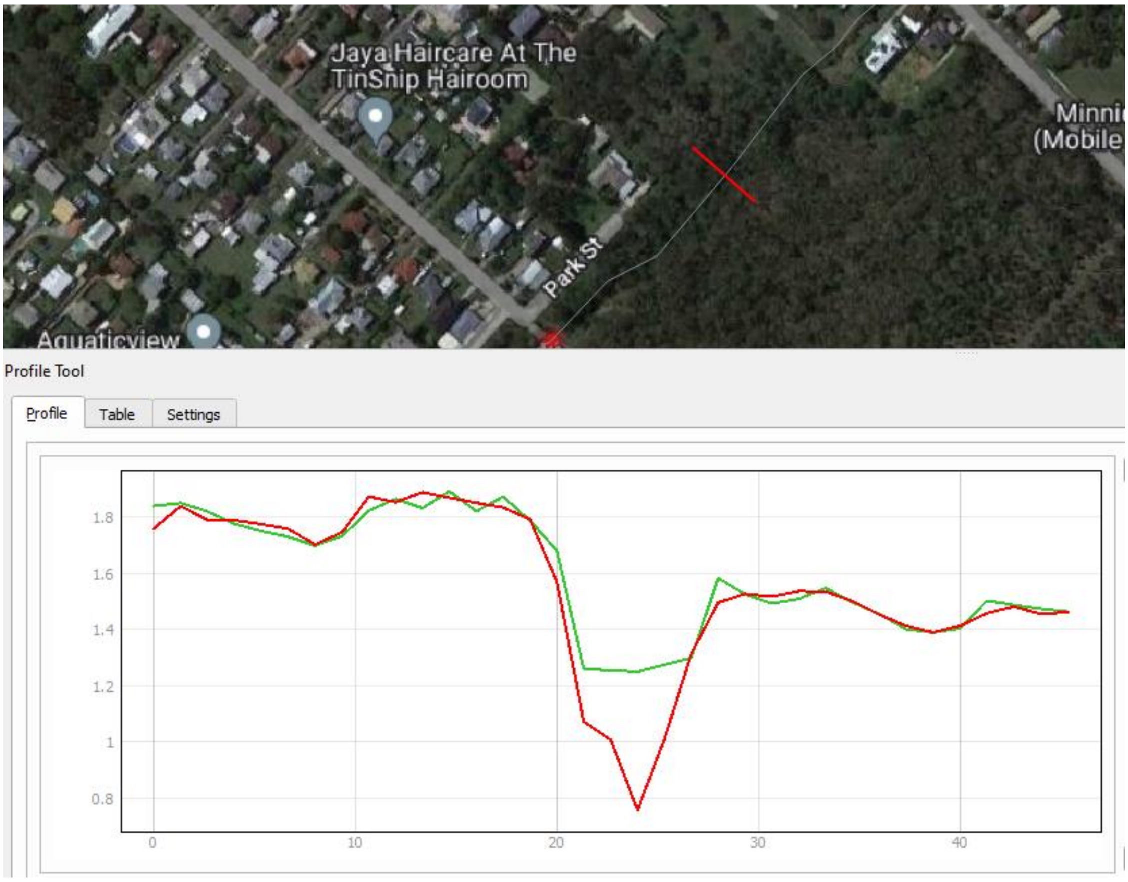


Figure 5: Gully channel enforcement example

5. Calibration Performance

5.1 URBS model calibration

The URBS model was not calibrated for flows. In the brief it is stated that *"The 2014 Flood Study models were not calibrated due to insufficient historical data at the time the study was undertaken. Since the completion of the Study, five new Maximum Height Gauges (MHGs) have been installed within the catchment".* It is therefore interpreted to mean there are no continuous water level gauges in the catchment. On that basis the calibration of the model with regard to timing, volume, and shape is not possible – it can only be calibrated to flood levels.

5.2 TUFLOW model calibration

The TUFLOW model peak flood level results were compared to maximum height gauge levels recorded at 5 locations (refer Figure 6). The calibration performance is well within the BCC preferred range for these gauge types, i.e. within +/-300mm difference, except for the 2019 flood event at Gauge ID 110 (refer to discussion in Section 3.3) and for the 2020 flood event at Gauge ID 100, where local deviation could be accepted considering it is only 0.016m beyond target criteria and also considering the good calibration performance achieved elsewhere.

Comparison of recorded and model simulated levels

(all units in mAHD)

	13/12/2019			6/02/2020			27/02/2022			9/12/2021		
Gauge ID	Recorded	TUFLOW	diff	Recorded	TUFLOW	diff	Recorded	TUFLOW	diff	Recorded	TUFLOW	diff
100				1.840	1.524	-0.316	2.420	2.532	0.112			
110	1.650	2.024	0.374	1.980	2.005	0.025	2.610	2.561	-0.049	2.060	2.111	0.051
200							2.550	2.556	0.006			
210							2.780	2.568	-0.212			
220	1.690	1.866	0.176	1.860	1.959	0.099	2.710	2.569	-0.141	1.850	2.054	0.204

Calibration Validation

Figure 6: TUFLOW peak level calibration

5.3 URBS / TUFLOW joint calibration

The flow hydrographs comparison between URBS and TUFLOW were provided by Jacobs for the 2022 flood event at the three wetlands and found to compare well for this event, both in terms of timing and amplitude.

The level hydrographs were also compared at the wetlands (note: rating curve was used to derive levels from flows in URBS) and these were found to deviate appreciably, as shown in Figure 7 for the main wetland. This deviation was also observed for other events, with URBS predicting higher levels than TUFLOW.

Jacobs mentioned that the system is tidal at these locations, which cannot be replicated within URBS.

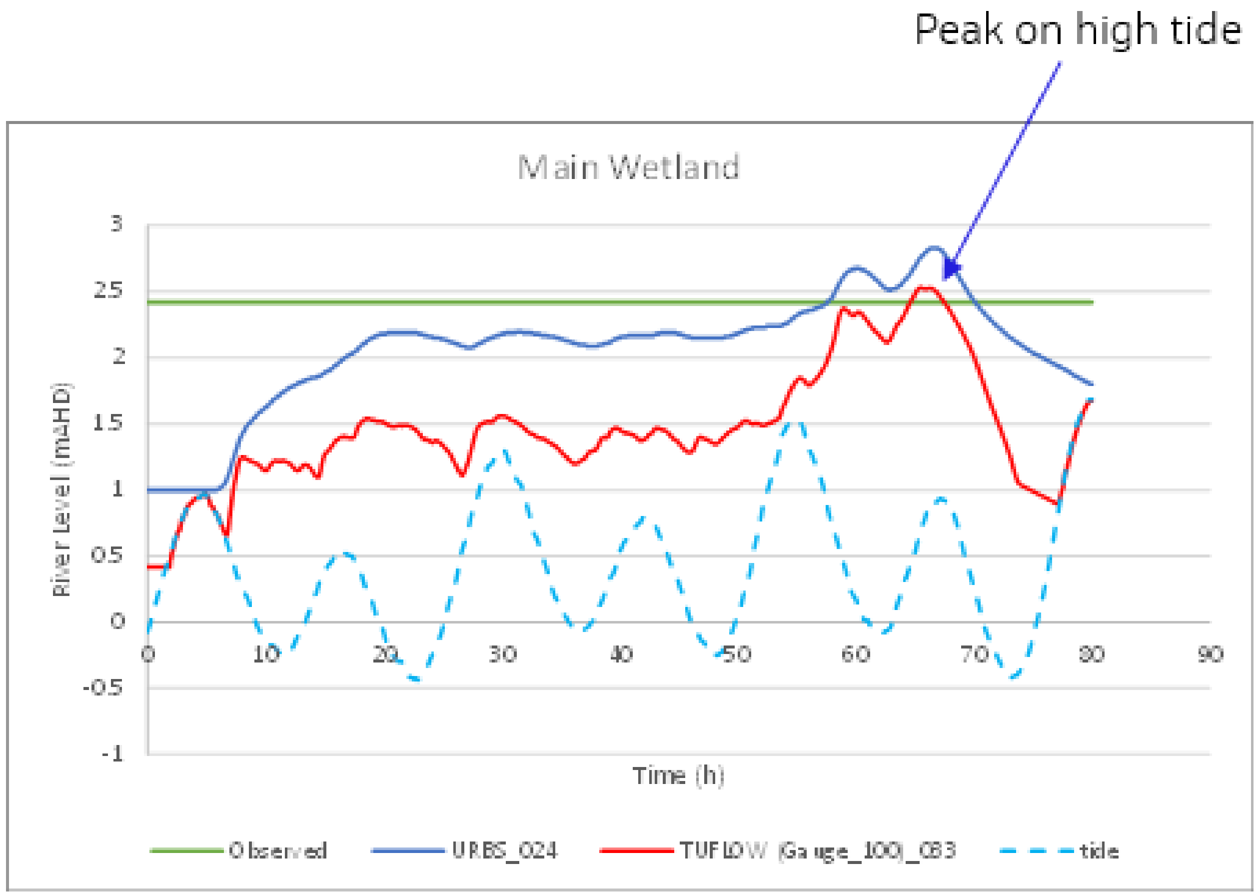


Figure 7: TUFLOW / URBS peak level comparison at main wetland

As noted by Jacobs, a joint calibration exercise can be complex in a tidal environment where TUFLOW is more suited than URBS due to the time-varying tail-water levels, and the subsequent effect this may have on discharge. The purpose of URBS is to derive inflows to TUFLOW, where the flood mechanics of tides can then be represented.

It is understood that BCC requires a reliable hydrology model as it may be used for flood forecasting. It is recommended that further discussions be held between BCC and Jacobs (Arup happy to partake if required) to better understand how the hydrology outputs are being used for flood forecasting and to define a strategy for the catchment.

Arup agrees with Jacobs that URBS will not be able to replicate the mechanisms of a tidal environment. It is also recommended to verify the joint calibration with a design event (e.g. 1% AEP, with a fixed tailwater level) to assess how URBS and TUFLOW compare in a non-tidal scenario.

6. Review Recommendations Summary

Arup has undertaken a comprehensive Phase 1 Peer Review of the hydrologic and hydraulic models associated with the Brighton Creek Flood Study in line with BCC project brief requirements. Overall, the models and methodology were found to be sound and in line with current best industry practices.

The following items were raised as part of this Peer Review:

Table 1: Project interfaces

Item	Review Comment / Recommendation	Criticality
1	Sub-catchment plan not delineated in accordance with urban drainage layout. BCC Flood Study Procedure Document states that *"modelling of the underground pipe network is not required unless it forms the major flow path, connecting open waterways"*. As such the work conducted by Jacobs is in accordance with BCC Procedure. It is still recommended to verify the appropriateness of the sub-catchment plan delineation in contrasting it against the major/trunk underground drainage network to ensure there are no major issues / anomalies that may otherwise affect the accuracy of the flood model (where pipes are above a nominal minimum diameter, say)	Low
2	Impervious fractions are the same across all calibration events (2019, 2020, 2021 and 2022). Jacobs to confirm that there has been no major development in the area between 2019 and 2022.	Low
3	The short, intense, and possibly localised nature of the 2019 rainfall event implies that there may be limitations with how well able the flood modelling can be calibrated to it. Accordingly, it would likely be reasonable to place less weight on this calibration event in comparison to the three other historic events. Jacobs to review 2019 event (particularly if any historic radar imagery is available e.g. https://theweatherchaser.com) with regard to potential limitations associated with the calibration – any such findings should be documented in its formal reporting	Low
4	It is recommended to draw upon the IL/CL outcomes obtained for the 2020, 2021 and 2022 calibration/validation modelling in defining design event losses (noting the fact they are lower, and therefore marginally more conservative than ARR datahub). When modelling the design event scenarios, it may be beneficial to undertake sensitivity testing with the ARR datahub losses and the calibration values to assess their impact on design event flood levels results (for next phase e.g. 1% AEP flood event). Ahead of defining design event rainfall losses, and the potential to draw upon the calibrated rainfall losses in this regard, it is also suggested that Jacobs conduct a cursory check of the antecedent catchment rainfall (i.e. to gain an appreciation of the level of catchment saturation) across these three historic events, to ensure any	Low

Item	Review Comment / Recommendation	Criticality
	decisions are targeted towards obtaining probability-neutral outcomes for the flood study's design event modelling.	
4	The model is highly dependent on downstream boundary conditions applied due to the tidal nature of the Brisbane River. The recorded tidal levels from the Brisbane Bar have been applied for calibration events. Jacobs to confirm the location of the recorded level gauge and adjustment made (if any) to suit the model downstream boundary location. This recognises that the recorded tide level at a gauge could be appreciably different to the actual tide level at the project focus area (i.e. the creek mouth) if the spatial distance between them is significant – adjustments or interpolation may therefore need to be applied to define appropriate tidal tailwater levels, noting the potential sensitivity of the lower floodplain to the downstream boundary condition. This aspect of the modelling is likely more important looking ahead to the design event simulations.	Medium
5	Inconsistencies are noted in the application of the local catchment flows, with some hydrographs applied at catchment centroids and others applied at catchment outlets. Whilst it is anticipated to have minimal effects onto results overall, it is recommended to review the application of flows for consistency.	Low
6	Jacobs to confirm that there are no supporting piers to the Flinders Parade bridge.	Low
7	Channel gullies have been enforced via "2d_zsh" elements and significant conveyance capacity has therefore been added to channels. Whilst it is possible that the vegetation may have resulted in a inaccurate LiDAR at location (i.e. LiDAR not picking up bottom of the channel) and that manual adjustments are required, it is recommended that this major enforcement be verified through comparison with survey information, along with site observations where possible, as it could potentially affect design flood level results appreciably.	High
8	It is understood that BCC requires a reliable hydrology model as it is used for flood forecasting. It is recommended that further discussions be held between BCC, Jacobs and Arup to better understand how the hydrology outputs are being used for flood forecasting and to define a strategy for the catchment. Arup agrees with Jacobs that URBS will not be able to replicate the mechanisms of a tidal environment. It is also recommended to verify the joint calibration with a design event (e.g. 1% AEP, fixed tailwater level) to assess how URBS and TUFLOW compare in a non-tidal scenario.	Medium

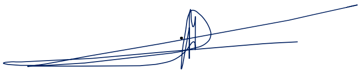
7. Reliance Statement

The sole purpose of this technical note the associated services performed by Arup is in accordance with the scope of services set out in the contract between Arup and BCC for the Project. In preparing this technical note, Arup has relied upon, and presumed accurate, information provided by BCC and Jacobs. Except as otherwise stated in this technical note, Arup has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Arup has undertaken this peer review in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures, and practices at the date of issue of this technical note. For the reasons outlined above however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in the technical note, to the extent permitted by law.

This assessment has been prepared on behalf of, and for the exclusive use of, BCC, and is subject to, and issued in accordance with, the provisions of the contract between Arup and BCC. Arup accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this technical note and flood modelling by any third party.

DOCUMENT CHECKING

	Prepared by	Checked by	Approved by
Name	Cecile Peille	Brian Sexton	Brian Sexton
Signature			

Attached: QA review form

Technical Note

Project title	Brighton Creek Flood Study
Job number	293481-02
File reference	Peer Review Phase 2 Technical Note – Design Events
cc	Hanieh.Zolfaghari@brisbane.qld.gov.au
Prepared by	Cecile Peille, Brian Sexton
Date	19 April 2023
Subject	Flood Model Review

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1. Introduction

1.1 The Project

Brisbane City Council (BCC) is currently undertaking an update of the 2014 Brighton Creek Flood Study. Following on from the February 2022 flood event, complaints were received from residents stating that ongoing catchment development contributed to further inundation of the lower reach of Brighton Creek, and that the hydraulic performance of the Beaconsfield Terrace culverts and Flinders Parade bridge had impacted on upstream flooding during the event. Therefore, BCC has commissioned Jacobs to update the Brighton Creek Flood Study to current standards in order to better understand flooding conditions within the catchment and investigate potential mitigation options to alleviate flooding (the Project). This Project will be delivered in 2 stages:

- Stage 1: Brighton Creek Flood Study Update
- Stage 2: Potential Flood Mitigation Options for Lower Brighton Creek

The project is currently in Stage 1.

1.2 Document purpose

Arup has been commissioned by BCC to undertake a peer review of the project at key phases of Stage 1, specifically:

- Peer Review Phase 1: Brighton Creek Flood Study Calibration performance.
- Peer Review Phase 2: Brighton Creek Flood Study Design events.

This technical note documents the peer review process and review findings associated with the Brighton Creek Flood Study Update for Phase 2 (Design Events).

1.3 Review guidelines

This technical review has been undertaken in line with the following documents:

- Flood Study Procedure Document, City Projects Office Brisbane Infrastructure, Version 9.0 (September 2022), FSPV9 document
- Australian Rainfall and Runoff (ARR) 2019
- URBS User Manual, Version 6.6 (September 2021)
- TUFLOW User Manual (March 2018) and subsequent releases notes.

2. Review Method

2.1 Methodology

The supplied design event modelling package was reviewed against Council's FSPV9 procedure. It is understood that no changes to the flood model were performed since the calibration review phase except those listed in the attached QA form. As such the model was not re-verified for all items. Refer to the Peer review Phase 1 technical note for previous review outcome.

For clarity, only the elements of review that require further clarification are listed in this technical note.

2.2 Files provided

2.2.1 Hydrological model files

The following files were provided for review:

- URBS catchment file, vector File, and associated results for the following events:
  - 50% AEP, 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP and 200yr ARI, 500yr ARI, 2000yr ARI events with and without Climate Change.
  - Each event has been simulated for a range of storm durations from 30min to 720min.
  - PMP provided for a 360min 'superstorm'.
  - note: nomenclature for extreme events is in ARI as per provided files.

2.2.2 Hydraulic model files

- TUFLOW Control files and model inputs for Run 045
- Full sets of raw TUFLOW results for the 10% AEP, 1% AEP and 2000yr ARI extreme event (scenario S1)
- Processed results (envelope) for all events and <u>all scenarios</u>
- Check and model log files

2.2.3 Report

- IW286200-JAC-BC-00-RPT-HY-0001 - FloodStudy_v0.pdf
- IW286200-JAC-BC-00-RPT-HY-0002 - Volume2_v0.pdf

3. Hydrological Model Review

3.1 Design Events URBS parameters

The following parameters were found appropriate and in line with Council's FSPV9 procedure:

- Updated IFD's specifically developed for the Brisbane LGA have been used.
- ARF of 1 is appropriate for the catchment.
- Storm injector used to derive all events and run ensemble storms
- Point Temporal Patterns used (East Coast North)
- Pervious Burst Initial Loss (IL) of 0mm, ascertained through calibration (refer to the 2020, 2021 and 2022 events)
- Pervious continuing loss (CL) of 2.4mm/hr applied, consistent with ARR Datahub
- Zero (0mm) Initial Burst Loss / Continuing Loss for impervious surfaces

The third-last point above means that the study has adopted a Burst Initial Loss of 0mm regardless of the pre-burst depth. As stated in Council's FSPV9 procedure the burst Initial Loss is calculated as:

Burst Initial Loss (ILb) = Storm Initial Loss (ILs) – pre-burst rainfall

Accordingly, the adopted method appears to have been to exclude pre-burst rainfall, unless mistaken. However ARR 2019 (Book 5 Chapter 3, Sn 3.3.2) does state that “The failure to recognise the rainfall prior to design rainfall bursts has the potential to significantly underestimate the design flood.” Council’s FSPV9 procedure appears unclear as to the preferred method for the application of (excess) pre-burst rainfall, but does discuss the topic generally (and provides the above equation, which is consistent with ARR 2019).

In the particular case of the Brighton Creek flood study, applying the pre-burst rainfall to the model could potentially fill some the wetland storage volumes before the main storm burst, and could therefore result in higher design event flood levels. Considering the flooding behaviour is likely sensitive to the wetland conditions, it is recommended that BCC and the consultant discuss this particular aspect to confirm direction with regard to pre-burst rainfall.

3.2 URBS model application

It is understood that BCC requires a hydrology model that can be used for flood forecasting.

As stated by Jacobs, *“There is not good agreement between the TUFLOW and URBS models […] which is primarily due to the outlet structure tailwater dependence of each of the wetland outflows.*

The URBS/TUFLOW combination is calibrated to provide appropriate flood levels within the catchment. However, we would not recommend using the URBS model for any other purpose than producing inflows for the TUFLOW model.

To use the URBS model alone for flood forecasting, a body of work would be required to develop TW dependent rating curves for each of the three wetlands. The rating curves would need to vary based on the magnitude of the event but also based on the distribution of rainfall across the catchment which may drive variable structure tailwater levels.

Note also with the catchment being as small as it is, it is (relatively speaking) quite responsive with comparatively short critical durations across the floodplain. Accordingly, this may potentially limit the ability to undertake flood forecasting on this catchment, owing to the nature of the storm events that will usually lead to flooding, and the limitations this places on the subsequent issuing of warnings to the community (and the communities subsequent ability to react to any such warnings given the timeframes in question). This statement is not a conclusive finding nor a recommendation, but may be worth factoring into any further discussions between BCC and Jacobs on this topic. BCC may also be able to draw on any experience of flood forecasting on similar catchments within its jurisdiction. BCC to advise on final position with regard to this matter.

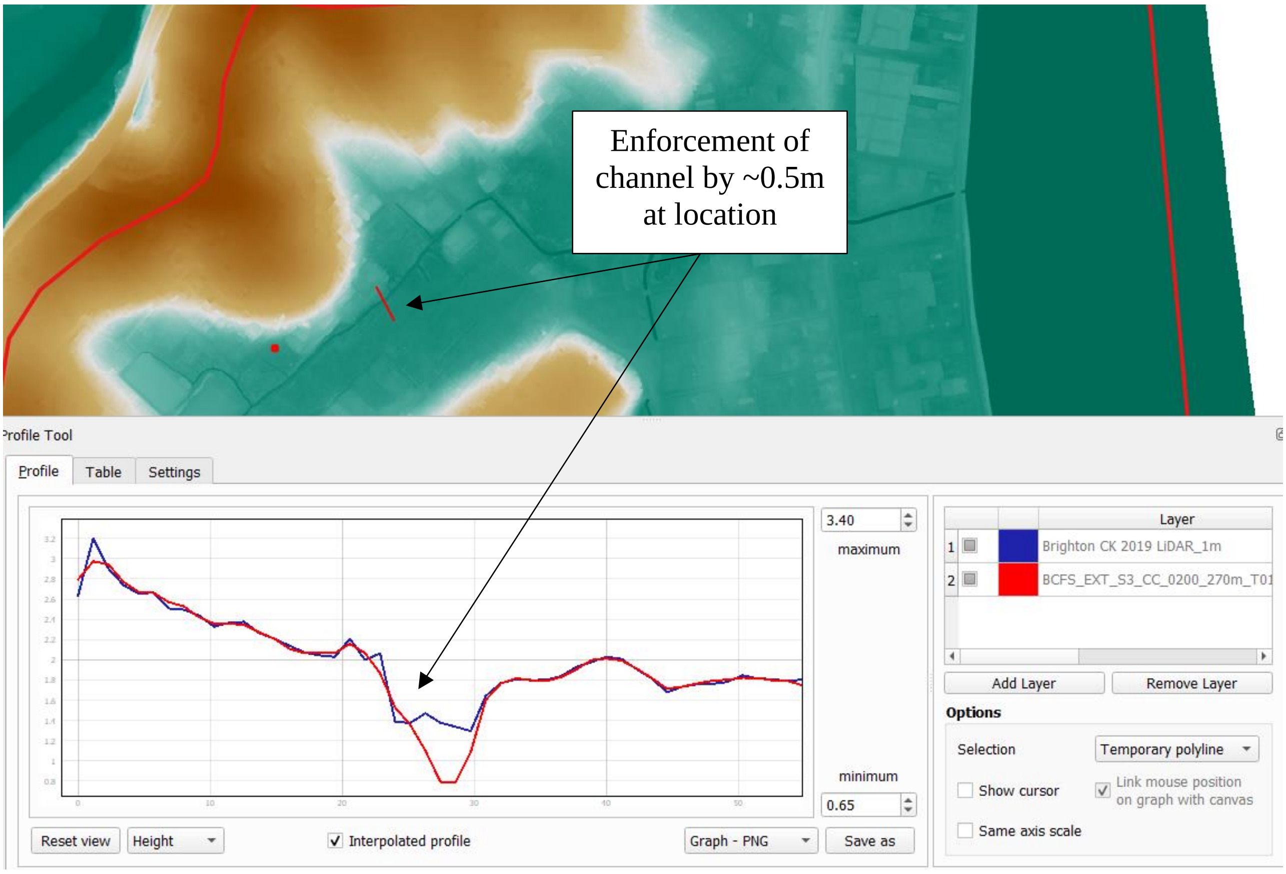
4. Hydraulic Model Review

4.1 Model Topography

Channel gullies have been enforced via “2d_zsh” elements and additional conveyance capacity has therefore been added to channels. Although the extent It is noted that there are some areas where the model topography is significantly different to the supplied LiDAR.

It is possible that the vegetation may have resulted in an inaccurate LiDAR at locations (i.e. LiDAR not picking up bottom of the channel) and that manual adjustments are required, however it is recommended that this enforcement be verified through comparison with survey information as it could potentially affect design flood level results appreciably. Site observation may also assist, but survey will be the most reliable form of comparison. Alternatively, it could be beneficial to undertake a sensitivity test (e.g. with no channel enforcement) to understand what effect this has on flood levels, and the sensitivity of the flood levels to this adjustment (which may inform on whether or not survey is needed / critical). BCC to advise on final position with regard to this matter, and whether the model build can be accepted as is (i.e. without the need for survey comparison).

Figure 1: Gully channel enforcement example



4.2 Blockage assessment

A preliminary blockage assessment as per the BCC Creek Flood Study Procedure document for key structures should be undertaken for the 1% AEP existing development condition (Scenario 1) for the following situations: as per AR&R 2019 requirements, as per QUDM 2016 requirements, and a 'Worst Case' scenario. There currently appears to be no blockage assessment included in the reporting or provided files.

4.3 Scenario S3

Spot checks were performed on the definition of scenario S3 and it was found that filling appears in line with BCC procedure. However, a detailed review of the development of the flood corridor envelope or any flood extent stretching has not been performed by Arup. It is understood that this aspect is reviewed internally by Council (BCC to confirm).

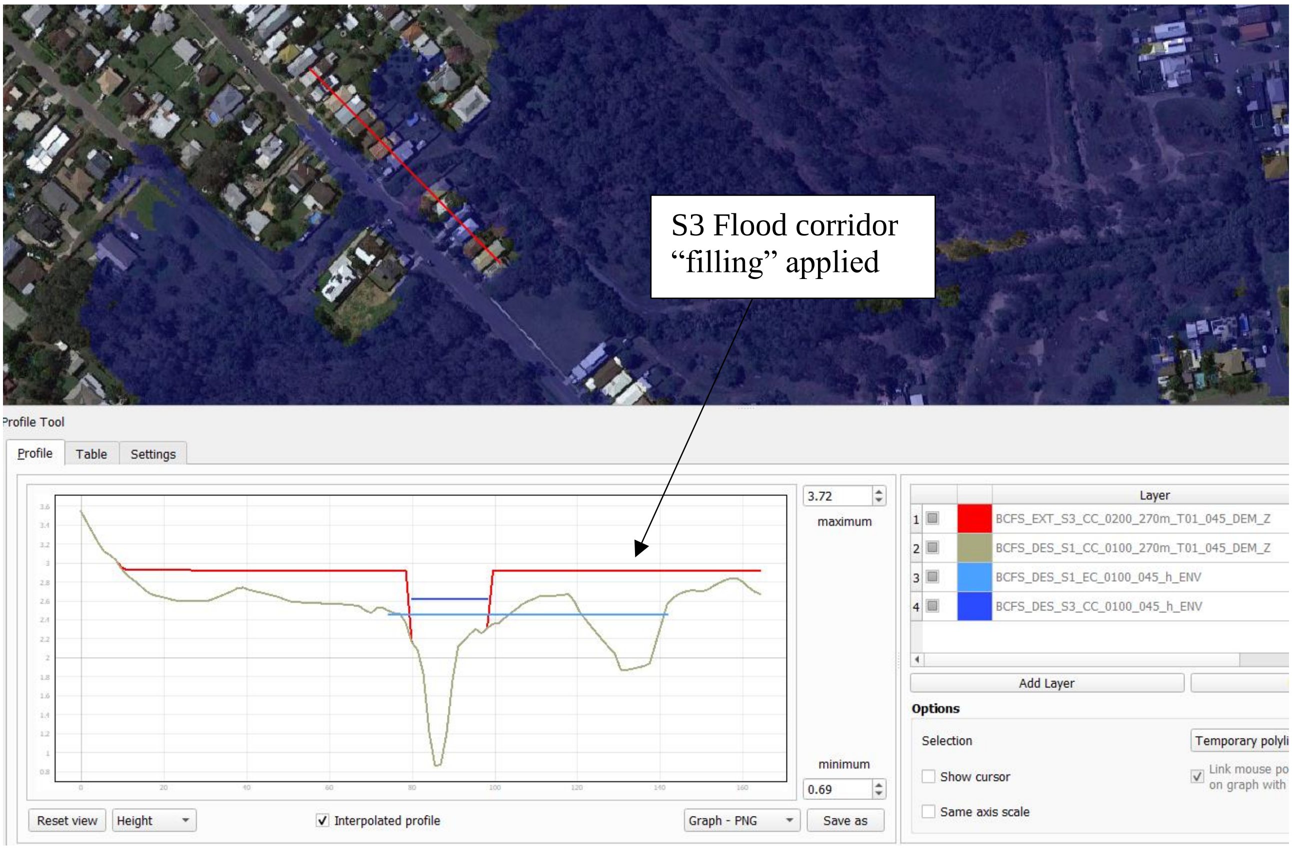


Figure 2: Scenario S3 “Flood Corridor”

4.4 Additional verifications

In line with the flood study brief the following verifications should be made:

- *Afflux maps should be generated for the 50% and 20%, 20% and 10%, 10% and 5%, 5% and 2%, 2% and 1%, 1% and 0.5%, 0.5% and 0.2%, 0.2% and 0.05% AEP events to ensure the flood model generates sound outcomes and model instabilities are identified (if there are any).*
    - ➢ Arup has performed this check for one event and no model instabilities were found. Jacobs to confirm that “afflux” maps were generated for all events.
- *The flood extents should also be compared between the above events to ensure that the extents of the smaller flood events are contained within the larger event extents.*
    - ➢ This check has been done by Arup and is confirmed correct.

5. Reporting and mapping

At the time of review the following elements were still missing from the report (understood to be being prepared in parallel):

- Report Figures missing
- Flood Mapping volume incomplete
- Appendix L: Hydraulic Structure Reference Sheets

Please see also comments relating to report as per the attached document: "IW286200-JAC-BC-00-RPT-HY-0001 - FloodStudy_v0 [Arup].docx". These are all generally minor in nature.

6. Review Recommendations Summary

Arup has undertaken a comprehensive Phase 2 Peer Review of the hydrologic and hydraulic models associated with the Brighton Creek Flood Study in line with BCC project brief requirements. Overall, the models and methodology were found to be sound and in line with current best industry practices.

The following items were raised as part of this Peer Review:

Table 1: Review recommendations

Item	Review Comment / Recommendation	Criticality
1	The adopted method appears to have been to exclude pre-burst rainfall, unless mistaken. However ARR 2019 (Book 5 Chapter 3, Sn 3.3.2) does state that "The failure to recognise the rainfall prior to design rainfall bursts has the potential to significantly underestimate the design flood." Council's FSPV9 procedure appears unclear as to the preferred method for the application of (excess) pre-burst rainfall, but does discuss the topic generally (and provides the above equation, which is consistent with ARR 2019). In the particular case of the Brighton Creek flood study, applying the pre-burst rainfall to the model could potentially fill some the wetland storage volumes before the main storm burst, and could therefore result in higher design event flood levels. Considering the flooding behaviour is likely sensitive to the wetland conditions, it is recommended that BCC and the consultant discuss this particular aspect to confirm direction with regard to pre-burst rainfall.	Medium
2	It is understood that BCC requires a hydrology model that can be used for flood forecasting. As stated by Jacobs, *"There is not good agreement between the TUFLOW and URBS models […] which is primarily due to the outlet structure tailwater dependence of each of the wetland outflows.* *The URBS/TUFLOW combination is calibrated to provide appropriate flood levels within the catchment. However, we would not recommend using the URBS model for any other purpose than producing inflows for the TUFLOW model.* *To use the URBS model alone for flood forecasting, a body of work would be required to develop TW dependent rating curves for each of the three wetlands. The rating curves would need to vary based on the magnitude of the event but also based on the distribution of rainfall across the catchment which may drive variable structure tailwater levels.* With the catchment being as small as it is, it is (relatively speaking) quite responsive with comparatively short critical durations across the floodplain. Accordingly, this may potentially limit the ability to undertake flood forecasting on this catchment, owing to the nature of the storm events that will usually lead to flooding, and the limitations this places on the subsequent issuing of warnings to the community (and	Low

Item	Review Comment / Recommendation	Criticality
	the communities subsequent ability to react to any such warnings given the timeframes in question). This statement is not a conclusive finding nor a recommendation, but may be worth factoring into any further discussions between BCC and Jacobs on this topic. BCC may also be able to draw on any experience of flood forecasting on similar catchments within its jurisdiction. BCC to advise on final position with regard to this matter.	
3	Channel gullies have been enforced via “2d_zsh” elements and additional conveyance capacity has therefore been added to channels. It is noted that there are some areas where the model topography is significantly different to the supplied LiDAR. It is possible that the vegetation may have resulted in an inaccurate LiDAR at locations (i.e. LiDAR not picking up bottom of the channel) and that manual adjustments are required, however it is recommended that this enforcement be verified through comparison with survey information as it could potentially affect design flood level results appreciably. Site observation may also assist, but survey will be the most reliable form of comparison. Alternatively, it could be beneficial to undertake a sensitivity test (e.g. with no channel enforcement) to understand what effect this has on flood levels, and the sensitivity of the flood levels to this adjustment (which may inform on whether or not survey is needed / critical). BCC to advise on final position with regard to this matter, and whether the model build can be accepted as is (i.e. without the need for survey comparison)	High
4	A preliminary blockage assessment as per the BCC Creek Flood Study Procedure document for key structures should be undertaken for the 1% AEP existing development condition (Scenario 1) for the following situations: as per AR&R 2019 requirements, as per QUDM 2016 requirements, and a ‘Worst Case’ scenario.	Medium

7. Reliance Statement

The sole purpose of this technical note the associated services performed by Arup is in accordance with the scope of services set out in the contract between Arup and BCC for the Project. In preparing this technical note, Arup has relied upon, and presumed accurate, information provided by BCC and Jacobs. Except as otherwise stated in this technical note, Arup has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

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DOCUMENT CHECKING

	Prepared by	Checked by	Approved by
Name	Cecile Peille	Brian Sexton	Brian Sexton
Signature			

Attached: QA review form

Subject	Flood Model Review Checklist		
Date	7 July 2023	Doc Ref	DRN-CHK-BNE

Flood Assessment Model Checklist			
Project Name	Brighton Creek Flood Study	**Date**	07/07/2023
Project Stage	Phase 1 – Calibration events Phase 2 – Design event modelling	**Project Review** Finalisation of review	Phase 1 + 2 – Finalisation of review

DESIGNER			
Company / Staff	**Jacobs**	Samantha Watt	Section Leader Water Resources

REVIEWER			
Company / Staff	**Arup**	Cecile Peille	Senior Flooding Engineer

Notes:

- This checklist is a tool to be used by modellers as a QA mechanism.
- This checklist is a general overview of typical design elements.
- This checklist is to be used for all phases of design. It is to be completed and included at each formal review phase of the project. It is best employed as a living document during the execution of a project.

1 Hydrologic Modelling Checklist

Check Item	Reviewer Comments (Arup)	Designer Response (Jacobs)	Reviewer Closeout
Catchment Definition			
Catchment boundary drawn correctly	Yes, appears to follow ridges.		Closed
Sub-catchment boundaries drawn correctly	Sub-catchments appear to be delineated through Catchment SIM software (or similar). It is recommended to verify the appropriateness of the sub-catchment plan delineation in contrasting it against the major/trunk underground drainage network to ensure there are no major issues / anomalies that may otherwise affect the accuracy of the flood model (where pipes are above a nominal minimum diameter, say).	Sub-catchments delineated through CatchmentSIM software and manually adjusted where necessary to accommodate TUFLOW inflow locations. The trunk drainage locations were reviewed as part of this delineation. In most areas the overland flowpath and trunk drainage catchments are similar. In one or two areas the trunk drainage does not follow the overlying topography. In these areas, the overland flowpath has been prioritised given the small capacity of the drainage and the need for the URBS and TUFLOW models to simulate events where the drainage capacity is exceeded.	Closed
Network structure is correct	Spot checks of the vector file has been made and network structure (i.e. sub-catchment ordering, ‘store’, ‘rain’, ‘add rain’, ‘routh thru” and ‘get’ functions) are correct. The ‘nodal link’ GIS file provided appears off at junction points (probably due to its automatic output) however the vector file is correct.		Closed
Subareas, reaches and nodes names appropriate	Subareas names follow good practice file structure and naming conventions.		Closed
Output locations are consistent with project goals	Local sub-catchment outflows all printed correctly.		Closed

Subject Flood Model Review Checklist

Date 7 July 2023 Job No/Ref DRN-CHK-BNE

Check Item	Reviewer Comments (Arup)	Designer Response (Jacobs)	Reviewer Closeout
Catchment and stream properties			
Areas have been entered correctly	Spot checks have been made and areas appear correct.		Closed
Surface type division is appropriate and correct (i.e. URBS fractions UL, UM, etc.)	All sub-catchments are attributed a fraction of catchment impervious, i.e. direct pervious / impervious loss method is used. Whilst ARR recommends the use of effective impervious area (EIA), this method is not yet coded in URBS therefore a pervious / impervious method is considered appropriate.		Closed
Impervious fractions have been entered correctly	Spot checks have been made with recent aerials and appears correct. However, it is noted that all impervious fractions are the same across all calibration events. Jacobs to confirm that there has been no major development in the area between 2019 and 2022. Note: the BCC ultimate development plan shall be used for design events, i.e. it is anticipated that the impervious fraction will be the same or greater than calibration events.	The calibration events range from Dec 2019 through to Feb 2022. Aerial imagery shows very little change in landuse over this period. As such we have used the same Impervious fractions for all calibration events.	Closed
Slope calculations are appropriate and correct	Spot checks have been made and slopes appear correct.		Closed
Routing distances are correct	Spot checks have been made and appear correct. Half-length of longest catchment flowpath has been used (appropriate)		Closed
Special elements have been entered correctly	Rating curves have been entered for 3 basins (.rat file) to represent storage.		Closed

Subject Flood Model Review Checklist

Date 7 July 2023 Job No/Ref DRN-CHK-BNE

Check Item	Reviewer Comments (Arup)	Designer Response (Jacobs)	Reviewer Closeout
Rainfall			
IFD method and parameters are correct	Updated IFD's specifically developed for the Brisbane LGA have been used in line with BCC requirements.		Closed
Storm duration and method	The AR&R 2019 Ensemble Design Event Approach (DEA AR&R 2019) was adopted in line with BCC requirements. Storm Injector was used to run the design event URBS models.		Closed
Temporal patterns and zones are correct	East Coast North used		Closed
Areal Reduction Factor	ARF = 1 (OK for this catchment)		Closed
Pre-burst application is appropriate	The adopted method appears to have been to exclude pre-burst rainfall, unless mistaken. However ARR 2019 (Book 5 Chapter 3, Sn 3.3.2) does state that "The failure to recognise the rainfall prior to design rainfall bursts has the potential to significantly underestimate the design flood." Council's FSPV9 procedure appears unclear as to the preferred method for the application of (excess) pre-burst rainfall, but does discuss the topic generally (and provides the above equation, which is consistent with ARR 2019). In the particular case of the Brighton Creek flood study, applying the pre-burst rainfall to the model could potentially fill some the wetland storage volumes before the main storm burst, and could therefore result in higher design event flood levels. Considering the flooding behaviour is likely sensitive to the wetland conditions, it is recommended that BCC and the consultant discuss this particular aspect to confirm direction with regard to pre-burst rainfall.		Closed, based on reporting provided by Jacobs
Extreme events rainfall / PMF	PMP provided for a 360mn 'superstorm'. Extreme events as per BCC procedure.		Closed

Check Item	Reviewer Comments (Arup)	Designer Response (Jacobs)	Reviewer Closeout
Climate Change scenario	The climate change scenario has been simulated in accordance with Council's FSPV9 by the application of a 9.8% increase in rainfall depth. This increase is based on Representative Climate Pathway (RCP) 4.5 for climate conditions in 2100, based on extrapolation of the AR&R DataHub estimates for 2080 and 2090.		Closed
Historical events are representative of the catchment and representative for calibration	4 events used for calibration / verification (good coverage).		Closed
Calibration Rainfall data	Jacobs to review the 2019 event (particularly if any historic radar imagery is available e.g. https://theweatherchaser.com) with regard to potential limitations associated with the calibration – any such findings should be documented in its formal reporting	Radar rainfall from December 2019 reviewed. Visually rainfall over the catchment occurs in one brief burst between 4-5pm consistent with the recorded gauge rainfall. A reference to this has been added to the report.	Closed
Losses and coefficients			
Loss method is appropriate	Loss method: uniform continuing. Appropriate.		Closed
Loss values adopted for calibration are appropriate for location	IL / CL specified in the batch file. These match Jacobs reported values. These are consistent across events (IL = 0mm and CL = 1.104mm/hr) except the 2019 flood event which has IL = 50mm. It is recommended to draw upon the IL/CL outcomes obtained for the 2020, 2021 and 2022 calibration/validation modelling in defining design event losses (noting the fact they are lower, and therefore marginally more conservative than ARR datahub). When modelling the design event scenarios, it may be beneficial to undertake sensitivity testing with the ARR datahub losses and the calibration values to assess their	Antecedent rainfalls for the calibration events have been reviewed. Rainfall in the 3 months prior to December 2019 totalled 111 mm compared to 352, 478 and 634mm in the other calibration events. The 1.1mm continuing loss adopted in the calibration events was based on the ARR2019 Datahub recommended continuing loss of 2.4mm reduced pro-rata based on the percentage impervious within	Closed

Check Item	Reviewer Comments (Arup)	Designer Response (Jacobs)	Reviewer Closeout
	impact on design event flood levels results (for next phase e.g. 1% AEP flood event). Ahead of defining design event rainfall losses, and the potential to draw upon the calibrated rainfall losses in this regard, it is also suggested that Jacobs conduct a cursory check of the antecedent catchment rainfall (i.e. to gain an appreciation of the level of catchment saturation) across these three historic events, to ensure any decisions are targeted towards obtaining probability-neutral outcomes for the flood study's design event modelling.	the catchment, as the "USES: I" was not turned on in the URBS vector file. A further mass balance check has identified that URBS applies the standard 0mm/hr continuing loss for impervious areas even when USES: I was not implemented. The calibration events have been further checked with USES: I on and off and 1.1mm/hr and 2.4mm/hr continuing losses adopted. The model results showed limited sensitivity to the adopted continuing loss. For the Feb 2022 event, the peak level decreases by less than 10mm with the increased loss. Report has adopted 2.4mm/h for the calibration and design events.	
Loss values adopted for design events are appropriate for location and AEP	IL / CL in line with calibration values.		Closed
URBS Parameters			
Run time step and duration are appropriate	Time increment = 5mn (appropriate)		Closed
URBS key parameters Alpha, m Beta	Coefficients included in the batch file (i.e. overwriting these specified in the vector filed). All consistent across calibration events and within URBS manual typical range.		Closed

2 Hydraulic Modelling Checklist

Check Item	Reviewer Comments	Designer Response	Reviewer Closeout
Model Extents and Boundaries			
Extents are consistent with project requirements	TUFLOW model code covers the entire catchment.		Closed
Area of interest is removed from boundary effects	The model is highly dependent on downstream boundary conditions applied due to the tidal nature of the Brisbane River. The recorded tidal levels from the Brisbane Bar have been applied for calibration events. Jacobs to confirm the location of the recorded level gauge and adjustment made (if any) to suit the model downstream boundary location. This recognises that the recorded tide level at a gauge could be appreciably different to the actual tide level at the project focus area (i.e. the creek mouth) if the spatial distance between them is significant – adjustments or interpolation may therefore need to be applied to define appropriate tidal tailwater levels, noting the potential sensitivity of the lower floodplain to the downstream boundary condition. This aspect of the modelling is likely more important looking ahead to the design event simulations. It is recommended to perform sensitivity testing on the downstream boundary condition in the next phase of the model	The Brighton Creek drains directly to Moreton Bay, not to the Brisbane River. The Brisbane Bar tidal record was used in the calibration as it was the closest available record from MSQ. BCC has now supplied Shorncliffe tidal data which is very similar to the Brisbane Bar data (+/-200mm), with the exception of the drain down of the 2022 event when the Brisbane Bar levels are clearly influenced by outflows from the Brisbane River catchment. The existing conditions hydraulic model is not highly sensitive to the downstream boundary tidal condition due to high headloss and constrained conveyance through the Flinders Ave bridge. However, the assessment of potential flood mitigation options that may include increasing the conveyance through this area are likely to be highly sensitive to the adopted tidal boundary condition. Conditions within the Main, North and South Wetlands are driven by the outlet structures tailwater, due to the reach capacity between the Beaconsfield	Closed

Check Item	Reviewer Comments	Designer Response	Reviewer Closeout
		Terrace and Flinders Ave, which are controlled by the Flinders Ave bridge.	
Downstream boundary condition is appropriate	MHWS has been adopted as tailwater boundary condition for design events up to the 1% AEP event and HAT has been adopted for the extreme events (0.5%, 0.2%, 0.05% AEP and PMF). Climate Change scenario includes a +0.8m increase in tailwater boundary condition.		Closed
Initial conditions are appropriate and correct	IWL appropriately defined in the .tef for each calibration event.		Closed
Model rainfall and inflows are correct	Inconsistencies are noted in the application of the local catchment flows (labelled Bri0xx) and catchment total flows (labelled SA_xx), with some hydrographs applied at catchment centroids and others applied at catchment outlets. Whilst it is anticipated to have minimal effects onto results overall, it is recommended to review the application of flows for consistency.	Hydrograph inflow locations have been checked and minor adjustments made. Local catchment inflows have been placed at the closest main channel location to the centroid, given BCC's preference that all inflows are placed in the creek. With the small catchment sizes these shifts are unlikely to overly influence peak levels. Total flows (SA_xx) are applied at the routed point where they are printed within the URBS model. This is generally at a catchment outlet but is sometimes at a specific junction.	Closed
Model topography			
Resolution is appropriate	2m grid cell size appropriate		Closed
Topography has been entered correctly	2019 LiDAR is appropriate Flinders ave bridge DEM is appropriate and tie-in well with LiDAR		Closed

Check Item	Reviewer Comments	Designer Response	Reviewer Closeout
Key features have been identified	Local adjustments to culverts entrances / exit generally appropriate. Warning 2118: please check that entrance / exit topography at culverts is aligned with topography. Adjustments > 0.5m should be addressed, for example culvert C_Speights.	Consistency of culvert inverts and topography has been checked.	Closed
Model enforcements	Channel gullies have been enforced via “2d_zsh” elements and significant conveyance capacity has therefore been added to channels. Whilst it is possible that the vegetation may have resulted in inaccurate LiDAR levels at locations (i.e. LiDAR not picking up bottom of the channel) and that manual adjustments are required, it is recommended that this major enforcement be verified through comparison with survey information, and along with site observations where possible, as it could potentially affect design flood level results appreciably. Jacobs to confirm the rationale/supporting information behind the enforced deepening of channels. 14/04/2023: It is possible that the vegetation may have resulted in an inaccurate LiDAR at locations (i.e. LiDAR not picking up bottom of the channel) and that manual adjustments are required, however it is recommended that this enforcement be verified through comparison with survey information as it could potentially affect design flood level results appreciably. Site observation may also assist, but survey will be the most reliable form of comparison. Alternatively, it could be beneficial to undertake a sensitivity test (e.g. with no channel enforcement) to understand what effect this has on flood levels, and the	The previous BCC model extensively used Zshapes to enforce the channels based on 1997 survey. Visual inspection of the channels, aerial imagery and 2019 LiDAR identified that these Zshapes appeared to create channels significantly larger than those observed. The previous Zshapes were removed from the model with the 2019 LiDAR generally used to define the channel. However, some areas with heavy vegetation did require some channel reinforcement. No recent survey was available for these areas. Thus, the adopted Zshapes have been produced based on comparison of the 1997 survey and site visit observations. There would be benefit in some localised survey in these areas to improve confidence in the model. Cross-section comparisons in these areas have been included in the report.	Closed, based on email from BCC, 07/07/2023

Check Item	Reviewer Comments	Designer Response	Reviewer Closeout
	sensitivity of the flood levels to this adjustment (which may inform on whether or not survey is needed / critical). BCC to advise on final position with regard to this matter, and whether the model build can be accepted as is (i.e. without the need for survey comparison)		
Hydraulic Structures			
Bridges identified and represented	One bridge (Flinders Parade) identified and represented within the model as 2d_lfcsh polygon element. No form loss coefficient applied, Jacobs to confirm that there are no supporting piers to the bridge (this seems to be the case from aerials)	There are no piers within the Flinders Pde Bridge.	Closed
Culvert identified and represented	No BCC data was provided for comparison however check with aerials was performed and culverts within model appear to be represented.		Closed
Culvert losses are appropriate	Losses for R type and C type as per TUFLOW recommended values.		Closed
Culvert configuration / size has been entered correctly	No BCC data was provided for comparison however check with DEM was performed and culverts appear to be correctly represented.		Closed
Culvert Manning's are consistent	All culverts have a manning's of 0.015 applied which is within standard values, except culvert ID C_Beacon which has a manning's of 0.02. Jacobs to confirm this higher value is on purpose.	The Beaconsfield culvert Mannings has been chosen consistent with the adopted channel mannings upstream and downstream. This area has a high degree of mangrove roots upstream and some siltation downstream.	Closed
1d/2d Links have been entered correctly	Links correctly digitised and aligned with channels.		Closed
Roughness and materials			

Check Item	Reviewer Comments	Designer Response	Reviewer Closeout
Roughness values are appropriate	Roughness values defined in the .tmf file appear consistent with industry standards and BCC guidelines.		Closed
Spatial delineation of roughness is correct	Order of landuse hierarchy is: 1. Verges/footpath/driveway to properties 2. City Plan 3. Vegetation 4. Roads 5. Channel Review of landuse against aerials was performed and found suitable. Majority of urban zones are 'low density residential' with Manning's n = 0.12 which is appropriate. Buidlings footprints not represented (not required by BCC).		Closed
Model runs parameters			
Run time step and duration are appropriate	HPC solver used (N.A.). Storm end time duration appropriate.		Closed
Specific commands that have the potential to mask model errors or instability (additional storage etc.)	No specific commands used.		Closed
Model Results and stability			
Results are stable and consistent	Flow hydrographs through culverts appear stable. MB < 0.5% Model Stable		Closed
TUFLOW Messages output (warnings and checks) have been addressed	Warning 2118: please check that entrance / exit topography at culverts is aligned with topography. Adjustments > 0.5m should be addressed, for example culvert C_Speights outlets to a local lower ground (i.e. topography is increasing in a downstream direction).	Warnings checked. All layers are being read as intended. Minor modifications undertaken to minimise warnings. However, some remain due to handling issues with shapefile types.	Closed

Check Item	Reviewer Comments	Designer Response	Reviewer Closeout
	Warning 2073: null shape object ignored. Check that all layers objects are read as intended.		
Model output and interval consistent with projects objectives	Map Output Data Types == q h V d MB1 MB2 Z0 dt (appropriate for flood study) Output interval every 5mn (appropriate)		Closed
Blockage assessment	A preliminary blockage assessment as per the BCC Creek Flood Study Procedure document for key structures should be undertaken for the 1% AEP existing development condition (Scenario 1) for the following situations: as per AR&R 2019 requirements, as per QUDM 2016 requirements, and a ‘Worst Case’ scenario. There currently appears to be no blockage assessment included in the reporting or provided files		Closed - blockage sensitivity testing in the brief relates to Stage 2, which is not part of the peer review remit

3 Calibration Performance Checklist

Check Item	Reviewer Comments	Designer Response	Reviewer Closeout
URBS calibration			
Flow hydrographs have been calibrated at gauges in terms of both timing and amplitude.	The URBS model was not calibrated for flows. There are no gauge records within the model to verify flows hydrographs (timing and amplitude).		Closed
TUFLOW Calibration			
Level hydrographs have been calibrated at gauges in terms of both timing and amplitude.	The TUFLOW model peak level results were compared to gauge levels recorded at 5 locations. The calibration performance is well within BCC target for these gauge types, i.e. within +/-300mm difference, except for the		Closed

Check Item	Reviewer Comments	Designer Response	Reviewer Closeout
	2019 flood event (refer comment in 'rainfall' section) and for the 2020 flood event at Gauge ID 100, where local deviation can be accepted considering it is only 0.016m beyond target criteria and also considering the good calibration performance achieved elsewhere. The TUFLOW model was not calibrated against gauge recorded levels hydrographs. There are no continuous gauge records within the model to verify level hydrographs (timing and amplitude).		
TUFLOW / URBS joint calibration			
TUFLOW / URBS compare well at key model locations.	The level hydrographs were compared at the wetlands and were found to deviate significantly, with URBS generally predicting higher levels than TUFLOW. Jacobs mentioned that the system is tidal at these locations, which cannot be replicated in URBS. It is understood that BCC requires a reliable hydrology model as it may be used for flood forecasting. It is recommended that further discussions be held between BCC and Jacobs (Arup happy to partake if required) to better understand how the hydrology outputs are being used for flood forecasting and to define a strategy for the catchment. Arup agrees with Jacobs that URBS will not be able to replicate the mechanisms of a tidal environment. It is also recommended to verify the joint calibration with a design event (e.g. 1% AEP, with a fixed tailwater level) to assess how URBS and TUFLOW compare in a non-tidal scenario. 14/03/2023: It is understood that BCC requires a hydrology model that can be used for flood forecasting. As stated by Jacobs, "*There is no good agreement between the TUFLOW and URBS models […] which is*	We agree that there is not good agreement between the TUFLOW and URBS models. While there is some tidal influence in this mismatch, it is primarily due to the outlet structure tailwater dependence of each of the wetland outflows. The URBS/TUFLOW combination is calibrated to provide appropriate flood levels within the catchment. However, we would not recommend using the URBS model for any other purpose than producing inflows for the TUFLOW model. To use the URBS model alone for flood forecasting, a body of work would be required to develop TW dependent rating curves for each of the three wetlands. The rating curves would need to vary based on the magnitude of the event but also based on the distribution of rainfall across the	Closed, based on email from BCC, 07/07/2023

Check Item	Reviewer Comments	Designer Response	Reviewer Closeout
	primarily due to the outlet structure tailwater dependence of each of the wetland outflows. *The URBS/TUFLOW combination is calibrated to provide appropriate flood levels within the catchment. However, we would not recommend using the URBS model for any other purpose than producing inflows for the TUFLOW model.* *To use the URBS model alone for flood forecasting, a body of work would be required to develop TW dependent rating curves for each of the three wetlands. The rating curves would need to vary based on the magnitude of the event but also based on the distribution of rainfall across the catchment which may drive variable structure tailwater levels."* With the catchment being as small as it is, it is (relatively speaking) quite responsive with comparatively short critical durations across the floodplain. Accordingly, this may potentially limit the ability to undertake flood forecasting on this catchment, owing to the nature of the storm events that will usually lead to flooding, and the limitations this places on the subsequent issuing of warnings to the community (and the communities subsequent ability to react to any such warnings given the timeframes in question). This statement is not a conclusive finding nor a recommendation, but may be worth factoring into any further discussions between BCC and Jacobs on this topic. BCC may also be able to draw on any experience of flood forecasting on similar catchments within its jurisdiction. BCC to advise on final position with regard to this matter.	catchment which may drive variable structure tailwater levels.	

Appendix L: Modelling User Guide

Dedicated to a better Brisbane

Brighton Creek Flood Study

Model User Guide

Prepared by Jacobs
Prepared for Brisbane City Council

July 2023

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1.0 Introduction

1.1 Brighton Creek Flood Study (2023)

This document is to be read in conjunction with Brighton Creek Flood Study – Volume 1 (2023).

The Brighton Creek Flood Study (2023) incorporates the calibration and verification of the hydrologic and hydraulic models as well as design event and very rare / extreme event modelling. Hydrologic and hydraulic models have been developed using the URBS and TUFLOW modelling software respectively.

Calibration of the URBS and TUFLOW models have been undertaken using 3 historical flood events: December 2019, February 2020, and February 2022. The December 2021 event has been used for the verification of the calibrated URBS and TUFLOW models.

Design and extreme flood magnitudes were estimated for the full range of events from 50% AEP to PMF. These analyses assumed hydrologic ultimate catchment development conditions in accordance with the current version of BCC City Plan.

Two waterway scenarios were considered, as follows:

- Scenario 1 – Existing Waterway Conditions: Based on the current waterway conditions. Some minor modifications were made to the TUFLOW model developed as part of the calibration / verification phase. This scenario was run for both (i) current and (ii) projected future climate conditions.
- Scenario 3 – Ultimate Conditions: Includes an allowance for the minimum riparian corridor along the edge of the channel, and also assumes development infill to the boundary of the "Modelled Flood Corridor" in order to simulate potential development. This scenario was run for only projected future climate conditions.

1.2 Scope of this Document

This document is intended to provide guidelines to the users of the URBS hydrologic and TUFLOW hydraulic models that were developed as a part of the study.

2.0 Hydrologic and Hydraulic Models

2.1 Hydrologic Models

2.1.1 General

The hydrologic model was developed using URBS32 Ver. 6.35 (beta). The simulations were performed using batch files for calibration and Storm Injector was used for design events. Further details are provided in the following sections.

The Brighton Catchment includes three large wetland storages. Flood behaviour in the wetlands is highly sensitive to conditions at the outlet structure (tailwater). For the North and South Wetlands, this is the conditions in the Main Wetland. For the Main Wetland, this is influenced by the flood levels in the coastal flats area between Beaconsfield Terrace and Flinders Parade. Discharge curves for the wetlands are therefore highly dependent on downstream flood levels which can be variable.

This behaviour is not simple to represent within the URBS model. As a result, the URBS model has been developed as a tool to derive local hydrographs for simulation within the TUFLOW model and should not be used as a stand-alone tool for assessment of flows throughout the catchment.

2.1.2 Calibration and Verification Models

Separate URBS models were developed for each of the calibration and verification events. Details on the model parameters has been discussed in the Brighton Creek Flood Study – Volume 1 (2023) report.

Below is the typical batch file used for calibration and verification URBS models.

February 2022 Event

```
rem Single Event Batch File
J:
PATH=J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\URBS_2016
del J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\Feb_2022\urbserr.log
del J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\Feb_2022\urbsout.log
del J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\Feb_2022\counter
set URBS_LOGF=TRUE
set URBS_LOGD=J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\Feb_2022\
set URBS_RAIN=J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\Feb_2022\data
set URBS_RETS=J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\Feb_2022\results
set URBS_RATS=J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\ratings\
del J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\Feb_2022\results\Brighton_Calib_Feb_2022_024_?.csv
set URBS_TFLW=TRUE
set URBS_DATE=25/02/2022
set URBS_TIME=00:00:00
cd J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\Feb_2022
J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\URBS_2016\urbs32.exe Brighton_019.vec data\Calibration_Feb_2022.rf Brighton_Calib_Feb_2022_024 0.2 0.8 2 0 1.104
pause
```

February 2020 Event

```
rem Single Event Batch File
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del J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\Feb_2020\urbsout.log
del J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\Feb_2020\counter
set URBS_LOGF=TRUE
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set URBS_RAIN=J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\Feb_2020\data
set URBS_RETS=
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set URBS_RATS=J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\ratings\
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alib_Feb_2020_024_?.csv
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set URBS_DATE=06/02/2020
set URBS_TIME=00:00:00
cd J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\Feb_2020
J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\URBS_2016\urbs32.exe
Brighton_019.vec data\Calibration_Feb_2020.rf Brighton_Calib_Feb_2020_024 0.2 0.8 2 0 1.104
pause
```

December 2019 Event

```
rem Single Event Batch File
J:
PATH=J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\URBS_2016
del J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\Dec_2019\urbserr.log
del J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\Dec_2019\urbsout.log
del J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\Dec_2019\counter
set URBS_LOGF=TRUE
set URBS_LOGD=J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\Dec_2019\
set URBS_RAIN=J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\Dec_2019\data
set URBS_RETS=
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set URBS_RATS=J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\ratings\
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alib_Dec_2019_025_?.csv
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set URBS_TIME=00:00:00
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pause
```

February 2021 Event

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rem Single Event Batch File
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del J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\Dec_2021\urbsout.log
del J:\IE\Projects\05_Northern\IW286200\06_Technical\Hydrology\Brighton_URBS\calib\Dec_2021\counter
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alib_Dec_2021_024_?.csv
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Brighton_019_Dec21.vec data\Calibration_Dec_2021.rf Brighton_Calib_Dec_2021_024 0.2 0.8 2 0 1.104
pause
```

2.1.3 Design and Extreme Models

Three separate setups have been developed in Storm Injector as follows:

- Design Events (0002, 0005, 0010, 0020, 0050, 0100)
- Very Rare Events (0200, 0500, 2000)
- PMF

Storm Injector software was used to derive the flows for the Design, Extreme and PMF events. General settings used in the generation of design/extreme flows for the study are shown in Figure 1. The temporal pattern for the PMF is also shown in this figure (BCC-DIS).

BOM IFDs were imported initially into the Storm Injector to setup the project, and the data was modified further using BCC IFDs for the specific events in the study, including the climate change events.

Figure 2 presents the settings used for Existing Climate Design Events. Figure 3 presents the settings used for Design Events under Future Climate Conditions.

Figure 4 presents the settings used for Existing Climate Very Rare Events. Figure 5 presents the settings used for Very Rare Events under Future Climate Conditions.

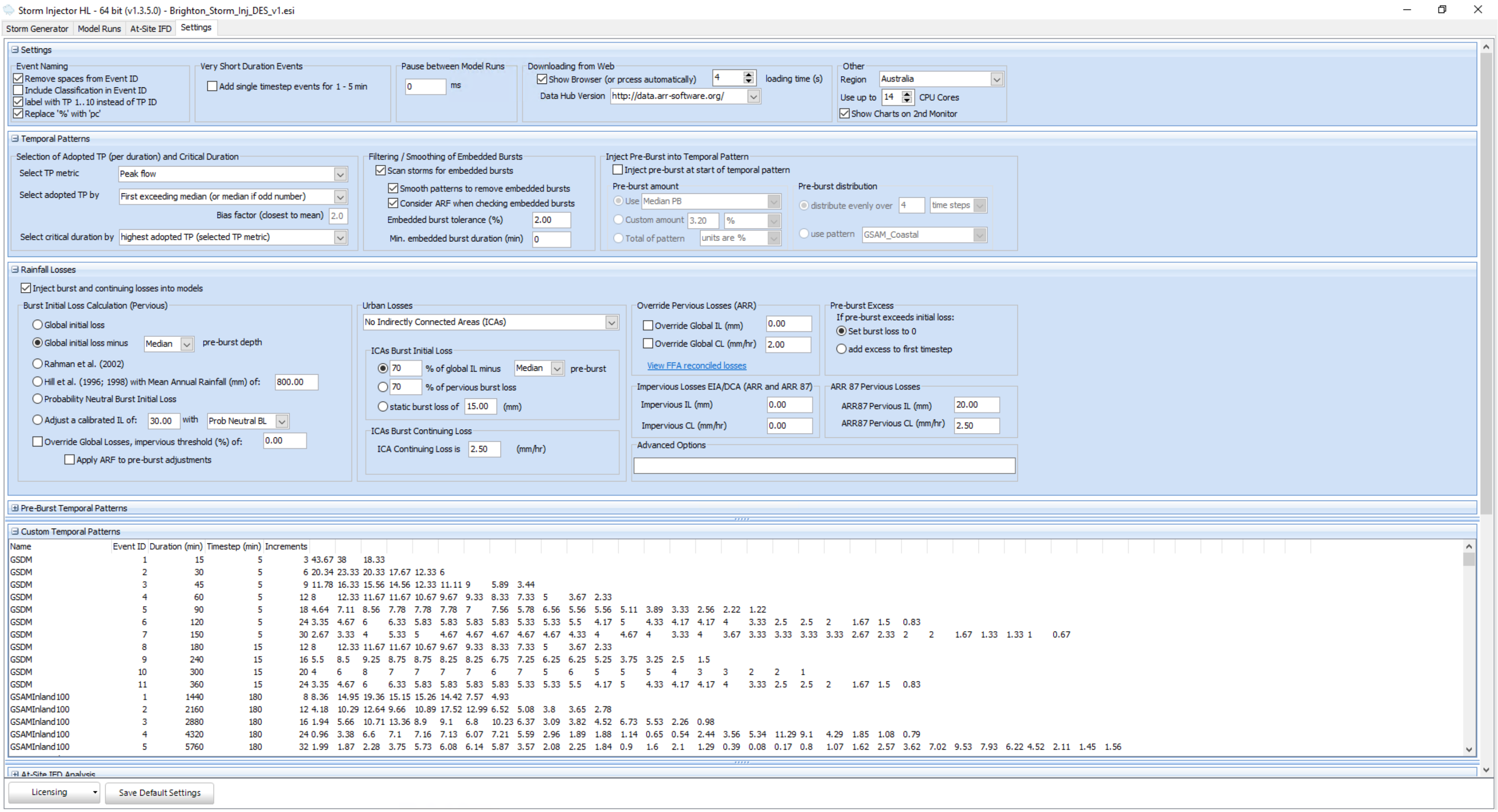

Figure 1 General Settings

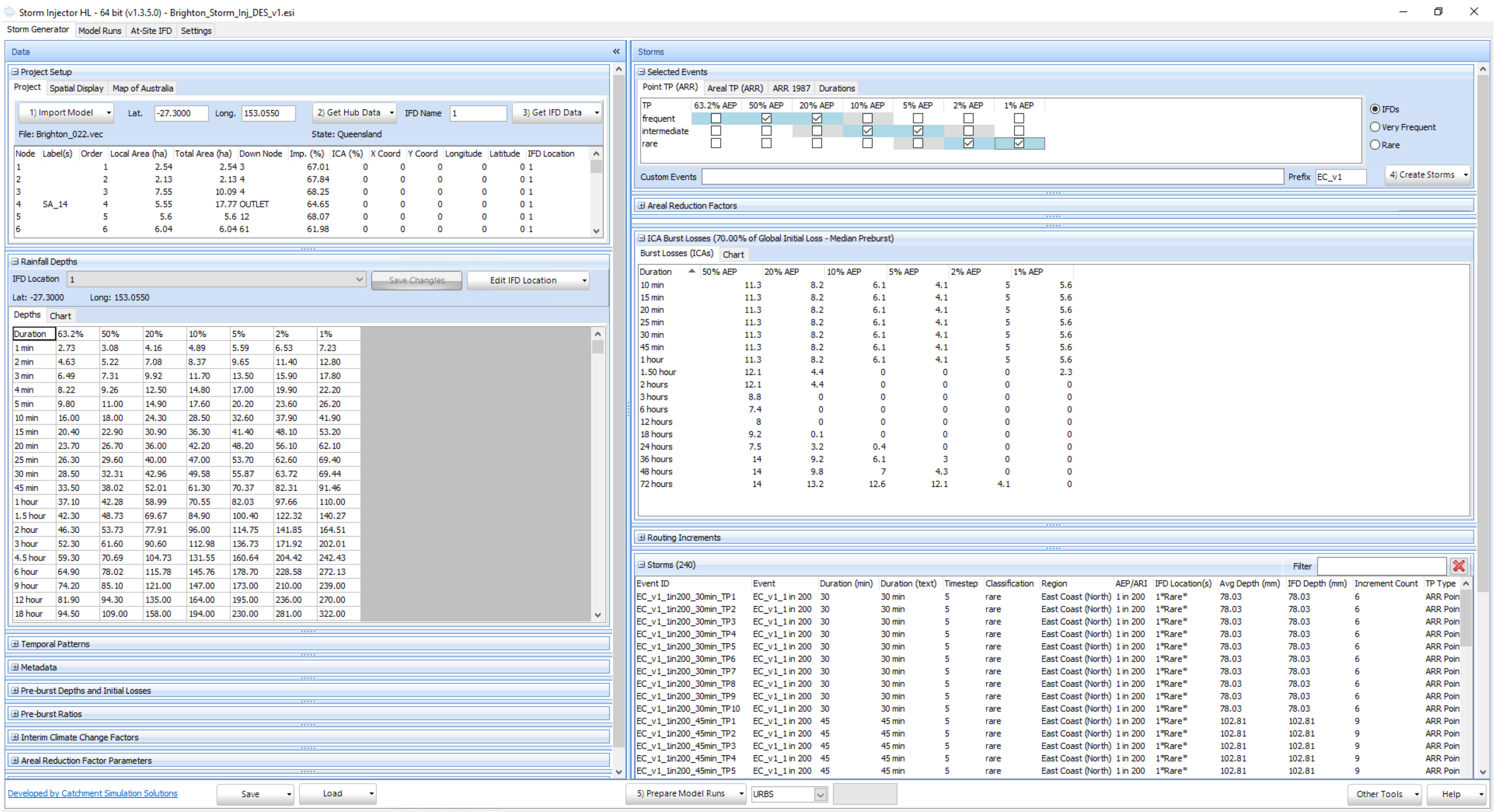

Figure 2 Settings for Design events

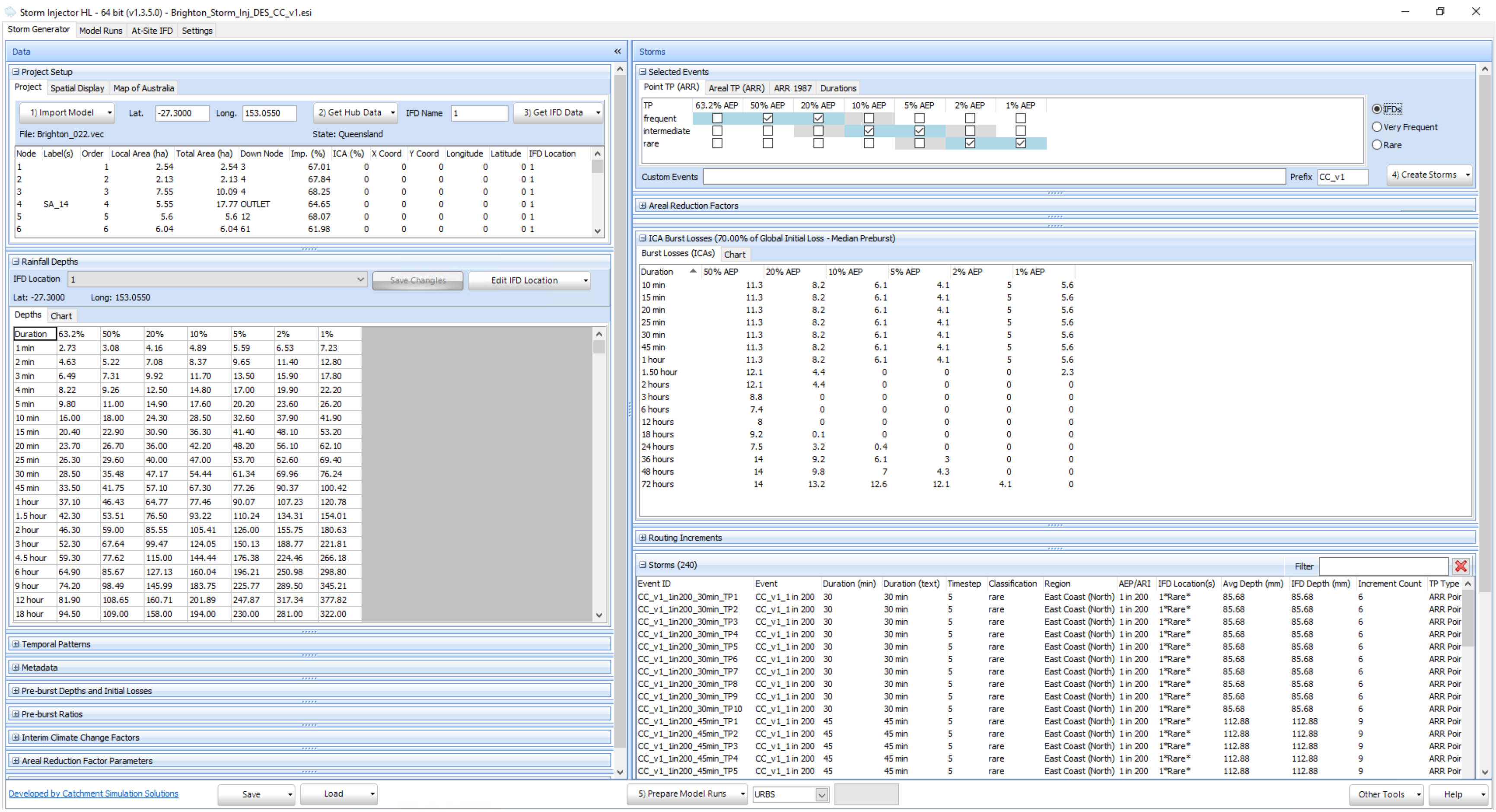

Figure 3 Settings for Design events with climate change

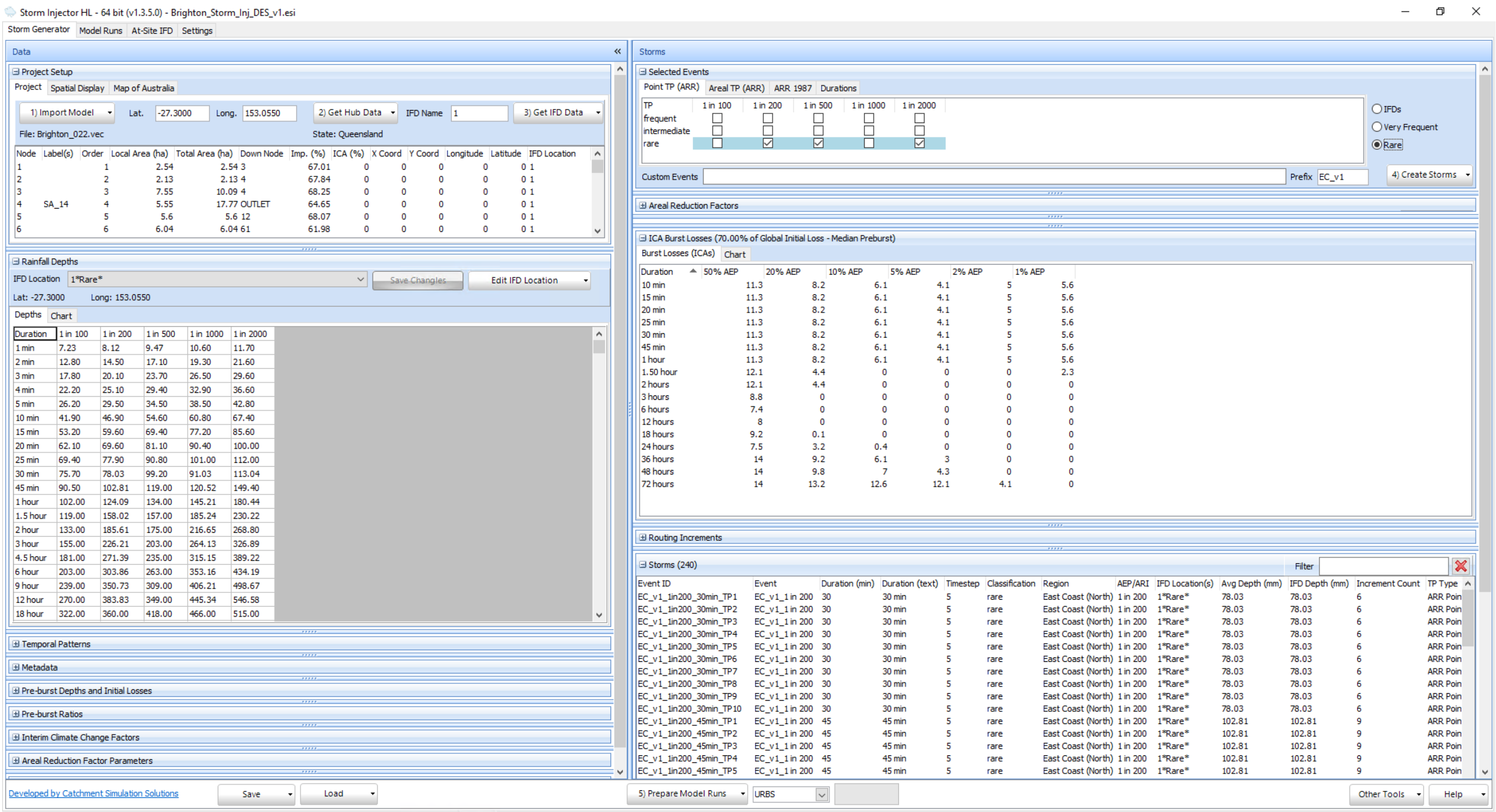

Figure 4 Settings for Extreme events

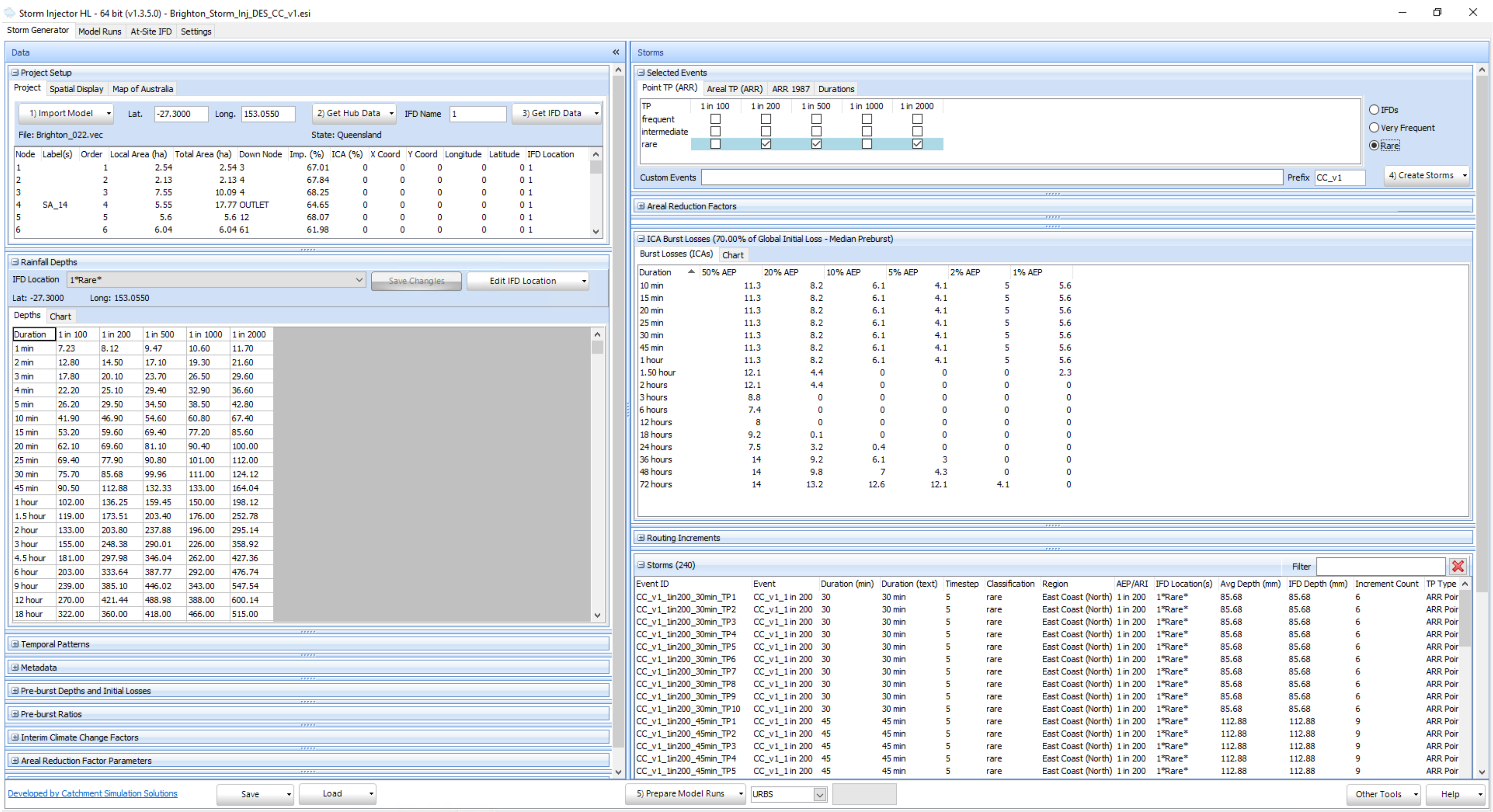

Figure 5 Settings for Extreme events with climate change

2.2 Hydraulic Models

2.2.1 General

TUFLOW modelling was undertaken in TUFLOW HPC using build: 2020-10-AB-iSP-w64

2.2.2 TUFLOW Calibration and Verification Models

TUFLOW simulations were undertaken for all four historical events.

The TUFLOW modelling was undertaken using two TUFLOW Control Files (TCF) for the calibration and validation events. For the February 2020, December 2021, and February 2022 events, the TCF file was named BCFS_CAL~e1~033.tcf. For the December 2019 event TCF was named BCFS_CAL~e1~034.tcf. For the December 2019 model, 50mm initial loss specific to the event was applied.

The TUFLOW model is essentially the same for all the calibration and verification events with the exception of the boundary conditions. Table 2-1 indicates the scenario and event codes to be used inside the TUFLOW batchfile.

Table 2-1 TUFLOW Calibration and Verification Batch Codes

Simulation	TCF	Event 1 ~e1~
December 2019	BCFS_CAL~e1~034.tcf	Dec_2019
February 2020	BCFS_CAL~e1~033.tcf	Feb_2020
December 2021	BCFS_CAL~e1~033.tcf	Dec_2021
February 2022	BCFS_CAL~e1~033.tcf	Feb_2022

As an example, the batchfile command for the February 2022 event would be as follows:

TUFLOW_iSP_w64.exe -b -e1 Feb_2022 BCFS_CAL~e1~033.tcf.

2.2.1 TUFLOW Design Event Models

The TUFLOW modelling was undertaken using a single TUFLOW Control File (TCF) for all the design events, which was named: BCFS_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_052.tcf

TUFLOW simulations were undertaken for all Scenario 1 and Scenario 3 design events up to and including the 1 % AEP event. Scenario 1 was simulated for both Existing Climate and Climate Change Conditions. Scenario 3 was simulated only for Climate Change Conditions.

If statements within the TCF file modified the CODE for the Scenario 3 events to the Flood Corridor.

Table 2-2 indicates the scenario and event codes to be used inside the TUFLOW batch file.

Table 2-2 TUFLOW Design Event Batch Codes

Simulation	Scenario 1 ~s1~	Scenario 2 ~s2~	Scenario 3 ~s3~	Event 1 ~e1~	Event 2 ~e2~	Event 3 ~e3~
Design Events (Scenario 1) Without Climate Change	DES	S1	EC	0002 0005 0010 0020 0050 0100	030m 045m 060m 090m 120m 180m 270m 360m	T01 T02 T03 T04 T05 T06 T07 T08 T09 T10
Design Events (Scenario 1 and 3) With Climate Change	DES	S1 S3	CC	0002 0005 0010 0020 0050 0100	030m 045m 060m 090m 120m 180m 270m 360m	T01 T02 T03 T04 T05 T06 T07 T08 T09 T10

As an example, the batchfile command for the Scenario 1% AEP (with climate change) 270 minute Temporal Pattern 9 event would be as follows:

TUFLOW_iSP_w64.exe -b -s1 EXT -s2 S1 -s3 CC -e1 0100 -e2 0270m -e3 T09 BCFS_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_052.tcf

2.2.1 TUFLOW Very Rare and Extreme Event Batch Codes

TUFLOW simulations were undertaken for Scenario 1 very rare/extreme events up to the PMF. TUFLOW simulations were undertaken for Scenario 3 very rare events up to the 0.2% AEP event.

If statements within the TCF file modified the terrain for the Scenario 3 events to incorporate filling to the 1% AEP + 500mm level outside the Flood Corridor.

Table 2-3 indicates the scenario and event codes to be used inside the TUFLOW batch file.

Table 2-3 TUFLOW Very Rare and Extreme Event Batch Codes

Simulation	Scenario 1 ~s1~	Scenario 2 ~s2~	Scenario 3 ~s3~	Event 1 ~e1~	Event 2 ~e2~	Event 3 ~e3~
Very Rare Events (Scenario 1) Without Climate Change	EXT	S1	EC	0200 0500 2000	030m 045m 060m 090m 120m 180m 270m 360m	T01 T02 T03 T04 T05 T06 T07 T08 T09 T10
Extreme Event (Scenario 1) Without Climate Change	EXT	S1	EC	PMF	360m	T01
Very Rare Events (Scenario 1) With Climate Change	EXT	S1	CC	0200 0500 2000	030m 045m 060m 090m 120m 180m 270m 360m	T01 T02 T03 T04 T05 T06 T07 T08 T09 T10
Very Rare Events (Scenario 3) With Climate Change	EXT	S3	CC	0200 0500	030m 045m 060m 090m 120m 180m 270m 360m	T01 T02 T03 T04 T05 T06 T07 T08 T09 T10

As an example, the batchfile command for the Scenario 1 0.5% AEP (with climate change) 270 minute Temporal Pattern 2 event would be as follows:

TUFLOW_iSP_w64.exe -b -s1 EXT -s2 S1 -s3 CC -e1 0200 -e2 0270m -e3 T02 BCFS_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_052.tcf

Similarly, the batch file command for Scenario 1 PMF 360-minute simulation would be as follows:

TUFLOW_iSP_w64.exe -b -s1 EXT -s2 S1 -s3 EC -e1 PMF -e2 0360m -e3 T01 BCFS_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_052.tcf