WINGECARRIBEE SHIRE COUNCIL

Nattai Ponds Flood Study

Final Report

VOLUME 1: Report and Appendices

Revision 3
July 2016

Catchment Simulation Solutions

Nattai Ponds Flood Study

Final Report

VOLUME 1: Report and Appendices

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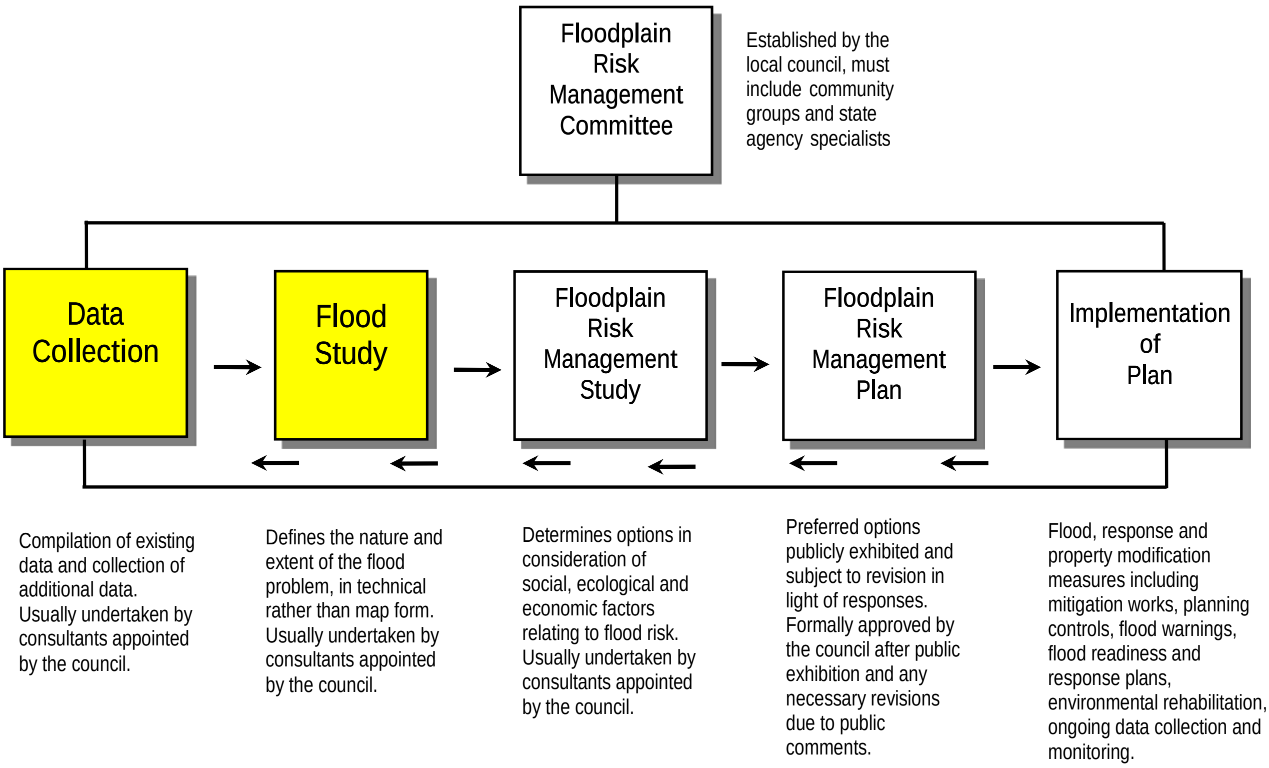
FOREWORD

The NSW Government's Flood Prone Land Policy is directed towards providing solutions to existing flooding problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas. The Policy is defined in the NSW Government's *Floodplain Development Manual* (NSW Government, 2005).

Under the Policy, the management of flood liable land remains the responsibility of Local Government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Local Government in its floodplain management responsibilities.

The Policy provides for technical and financial support by the State Government through the following stages:



The Nattai Ponds Flood Study represents stages one and two of the five stage process outlined above. The aim of the Nattai Ponds Flood Study is to produce information on flood discharges, levels, depths and velocities, for a range of flood events under existing topographic and development conditions. This information can then be used as a basis for identifying those areas where the greatest flood damage is likely to occur, thereby allowing a targeted assessment of where flood risk mitigation measures would be best implemented as part of the subsequent Floodplain Risk Management Study and Plan.

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF PLATES

1 INTRODUCTION

The “Nattai Ponds” catchment is located in the Southern Highlands of New South Wales and occupies a total area of 7.9 km^2. The extent of the catchment is shown in **Figure 1**.

The Nattai Ponds catchment originates near the intersection of Range Road and Old South Road at Mittagong and drains in a north-easterly direction through Renwick, Balaclava and Braemar. It continues to drain in a northerly direction beneath the Hume Highway and ultimately into Sheepwash Creek which, in turn, drains into the Nattai River. The eastern sections of Mittagong as well as the suburb of Willow Vale also falls within the Nattai Ponds catchment.

The main watercourse that drains through the catchment has no formal name according to the Geographical Names Board of NSW. Previous investigations have referred to it as the ‘Nattai Rivulet’ and ‘Nattai Ponds Creek’. For the purposes of this investigation, it shall be referred to as the main watercourse.

The catchment is drained primarily by natural watercourses. However, the urbanised sections of the catchment are also drained by a stormwater system which carries local catchment runoff into the watercourses via a network of stormwater pipes, pits, open channels and culverts.

During periods of heavy rainfall, there is potential for the capacity of the stormwater system to be exceeded and for water to overtop the banks of the natural watercourses and inundate the adjoining floodplain. Flooding has been experienced on several occasions in the past, particularly across properties fronting Inkerman Road and Braemar Avenue.

Although some flooding investigations have been completed at isolated locations across the catchment, a comprehensive flood study of the entire Nattai Ponds catchment has not previously been prepared. Therefore, with the exception of reports of flooding from residents, the extent of the existing flooding problem is not fully understood.

In recognition of this, Wingecarribee Shire Council resolved to prepare a Floodplain Risk Management Plan for the Nattai Ponds catchment. The first stage in the development of a Floodplain Risk Management Plan involves the preparation of a Flood Study. The Flood Study provides a technical assessment of flood behaviour.

This report forms the Flood Study for the Nattai Ponds catchment. It documents flood behaviour across the catchment for a range of design floods for existing topographic and development conditions. This includes information on peak discharges, flood levels, flood extents, flood depths and flow velocities for a range of design floods. It also provides provisional estimates of the flood hazard and hydraulic categories across the catchment.

2 Review of Available Information

2.1 Overview

A range of data were made available to assist with the preparation of the Nattai Ponds Flood Study. This included previous reports, hydrologic data and GIS data.

A description of each dataset along with a synopsis of its relevance to the flood study is summarised below.

2.2 Previous Reports and Investigations

2.2.1 Renwick Sustainable Village Project, Mittagong – Flood Study (2006)

The *'Renwick Sustainable Village Project, Mittagong - Flood Study'* (December 2006), was prepared by Bewsher Consulting for Landcom to quantify the potential hydrologic and hydraulic impacts associated with subdividing and developing the Renwick urban area for residential uses. The extent of the Renwick subdivision that was considered as part of the study is shown in **Figure 2**.

The study included the development of a hydrologic computer model of the catchment draining through the Renwick area. The hydrologic model was developed using the XP-RAFTS software (XP Software, 2009). A lack of stream flow and historic flooding information for the catchment meant that the model could not be calibrated. However, the XP-RAFTS model discharges were verified against peak 1% AEP Probabilistic Rational Method discharges.

The XP-RAFTS model was subsequently used to estimate peak design discharges at various locations across the catchment for the 1%, 5%, 20% and 100% AEP design storms, as well as the PMF for 'existing' conditions. A selection of peak design discharges were extracted from the report and are reproduced in **Table 1**.

Table 1 Peak design discharges extracted from "Renwick Sustainable Village Project, Mittagong - Flood Study" (2006)

Location	Peak Discharge (m^3/s)			
	20% AEP	5% AEP	1% AEP	PMF
Mary Street/Bong Bong Road intersection	3.9	5.6	7.1	25
Main crossing of Bong Bong Road	10.9	17.8	25.6	99.4
Downstream of Railway crossing	42.7	68.6	93.2	386

The XP-RAFTS model was subsequently updated to account for the proposed development. This included updates to impervious areas as well as the inclusion of detention basins to reduce the predicted increases in runoff from the developed areas. The hydrologic investigations determined that a detention basin located along the main watercourse would suitably attenuate design flows to 'pre-development' levels.

Flood behaviour was defined using a 2-dimensional hydraulic model. The hydraulic model was developed using the TUFLOW software and employed a 2.5m grid to describe the variation in topography and hydraulic roughness across the study area. The TUFLOW model extended from Bong Bong Road downstream to the main railway crossing.

The TUFLOW model was used to simulate a flood that occurred on 25th October 1999. Although no specific flood marks are provided for calibration purposes, the TUFLOW outputs for this event were shown to neighbouring properties who considered it provided a good approximation of the extent of inundation that was experienced during this event.

The TUFLOW model was then used to simulate the design 1%, 5%, 20% and 100% AEP design floods, as well as the PMF for existing topographic and development conditions. Flood maps were produced from the model outputs showing peak floodwater levels and depths across the study area. The extent of inundation for existing conditions for the 1% AEP flood is shown on **Figure 2**. The outputs from the TUFLOW model demonstrated considerable 2-dimensional flow behaviour across the area, particularly in the vicinity of Inkerman Road and Scarlett Street.

The TUFLOW model was subsequently updated to reflect "post-development" topographic and development conditions (i.e., including full development of the Renwick area) and was used to re-simulate each design flood. The TUFLOW model confirmed that a detention basin located midway along the main watercourse would suitably attenuate flows to pre-development levels.

It is noted that the Renwick subdivision is now partly completed. Accordingly, 'current' catchment conditions fall somewhere between the 'existing' and 'post-development' conditions documented in the report. It is also noted that a number of small detention basins have been implemented as part of the completed stages of work. The large on-line detention basin that was proposed as part of the assessment is yet to be implemented. However, it is understood that this will be implemented as part of future stages of the Renwick development.

2.2.2 Renwick Village Development, Renwick Drive, Renwick – Flood Hydraulic Assessment (2013)

The '*Renwick Village Development Flood Hydraulics Assessment'* was prepared by JMD Development Consultants (August 2013). The report was commissioned after a review of the '*Renwick Sustainable Village Project, Mittagong – Flood Study'* (Bewsher, 2006) determined that the proposed mitigation options proposed in the original report involved significant reshaping of the creek channel and loss of natural riparian vegetation. This was considered to be unacceptable. As a result, JMD coordinated with Urban Growth NSW, NSW Office of Water and Wingecarribee Shire Council to coordinate a more appropriate design for the creek system that would ensure stabilisation of the creek bed while retaining the existing creek environment and vegetation where possible.

This report states that the complexity of the previously used TUFLOW hydraulic model would not be required for this assessment. Therefore, a 1-dimensional HEC-RAS model was developed using the information extracted from the previous TUFLOW model. Design inflows to the HEC-RAS model were retained from the XP-RAFTS model developed as part of the 2006 study.

The report includes a considerable amount of information describing the HEC-RAS model inputs. This includes surveyed cross-sections and structure details that were extracted and used to assist in the development of the hydraulic model developed for the current study.

2.2.3 Flood Impact Assessment - Lot 117 DP 659149 and Lot 8 DP 1044854 Old Hume Highway, Braemar (2011)

Southeast Engineering and Environmental prepared the "Flood Impact Assessment - Lot 117 DP 659149 and Lot 8 DP 1044854 Old Hume Highway, Braemar" to quantify the potential flood impacts associated with the development of two lots located between the Old Hume Highway and railway line for residential purposes. The area is now referred to as the 'Nattai Ponds' subdivision and the extent of the subdivision is shown in **Figure 2**.

The study included the development of a hydrologic computer model of the catchment draining to the development site. The hydrologic model was developed using the XP-RAFTS software (XP Software, 2009). The XP-RAFTS model was subsequently used to estimate peak design discharges at various locations for the 1%, 5%, and 20% and 50% AEP design storms. A summary of peak discharges extracted from the report is provided in **Table 2**.

Table 2 Peak design discharges extracted from the Lot 8 and Lot 117 Old Hume Highway Flood Impact Assessment (2011)

Location	Peak Discharge (m^3/s)			
	50% AEP	20% AEP	5% AEP	1% AEP
Old Hume Highway Culverts	23.83	34.44	45.20	52.98
Boundary between Lot 8 and Lot 117	20.77	29.98	38.76	46.08
Downstream of Railway	20.30	29.02	36.93	44.15

Flood hydraulics in the vicinity of the development site was defined using a 1-dimensional HEC-RAS model. The model extends from the railway line downstream to the Old Hume Highway. The model was used to simulate the 1% AEP flood along the main watercourse draining through the site for existing as well as 'post-development' conditions (i.e., incorporating fill across the adjoining floodplain to accommodate residential development). The hydraulic analysis determined that development of the area would likely increase peak 1% AEP flood levels. However, these flood level impacts were contained within the development site and minimal impacts were predicted upstream and downstream of the site.

This report includes a detailed description of how water moves across the site, including the potential contribution of flows from a subcatchment located on the western side of the Old Hume Highway. However, it is noted that the hydrologic/hydraulic analysis completed as part of this study did not incorporate the contribution of flows from this subcatchment. This was later determined to be a limitation and a more detailed hydraulic assessment was requested by Council. This additional hydraulic assessment is discussed in more detail below.

2.2.4 Addendum - Flood Impact Assessment - Lot 117 DP 659149 and Lot 8 DP 1044854 Old Hume Highway, Braemar (2012)

An addendum to the "Flood Impact Assessment - Lot 117 DP 659149 and Lot 8 DP 1044854 Old Hume Highway, Braemar" was submitted by Southeast Engineering and Environment. The addendum was prepared to address concerns regarding the HEC-RAS modelling that was completed in the original report. More specifically, Council requested a 2-dimensional hydraulic model be prepared to better simulate the contribution of overland flows from the south and from the west of the site.

The revised assessment retained the hydrology from the original assessment, but included a new 2-dimensional hydraulic model of the area. The hydraulic model was developed using the TUFLOW software and utilised a 5 metre grid size to describe the variation in topography and hydraulic roughness across the site.

The TUFLOW model was used to simulate 'existing' and 'post-development' flood behaviour and the report includes figures showing peak 1% AEP floodwater depths, water levels and provisional hazard categories. The 1% AEP 'existing' conditions flood extent from this study is shown on **Figure 2**.

The TUFLOW modelling outputs confirm the complex flow patterns across this area, including the contribution of flows from the western side of Hume Highway.

The Nattai Ponds subdivision was partly constructed at the time the current study was being completed. Therefore, neither the 'existing' or 'post-development' scenarios included in this report reflect current topographic/development conditions. Therefore, it is considered that the hydraulic model outputs are of limited value for the current study. Nevertheless, peak flows as well as the details of major hydraulic structures (e.g., Railway Bridge, Old Hume Highway culverts) can be extracted and used to assist in the setup and verification of the hydrologic and hydraulic models developed for the current study.

2.2.5 Bowral Floodplain Risk Management Study and Plan (2005)

The *'Bowral Floodplain Risk Management Study and Plan'* (2005) was prepared by Bewsher Consulting for Wingecarribee Shire Council. The study was commissioned to investigate a range of options that could be potentially implemented to reduce flood damages within the Mittagong Creek catchment. The Mittagong Creek catchment is located approximately 5 km south-west of the Nattai Ponds catchment.

Although this report does not contain any specific flooding information for the Nattai Ponds catchment, it does incorporate newspaper clippings from 'The Bowral Free Press' documenting a large flood that occurred in March 1893. Photos are also provided showing flooding across different parts of Bowral on:

- January, 1915;
- March, 1975;
- March, 1978;
- November, 1985;
- August, 1986;
- April, 1988;

- October, 1999;
- February, 2005; and,
- June, 2007.

Given the proximity of the Nattai Ponds catchment to the Mittagong Creek catchment, flooding may have also been experienced in the Nattai Ponds catchment during each of these events. The community questionnaire responses confirmed that the June 2007 event was a significant flood within the Nattai Ponds catchment (refer **Plate 4** in Section 2.7.2).

2.3 Hydrologic Data

2.3.1 Historic Rainfall Data

A number of daily read and continuous (i.e., pluviometer) rainfall gauges are located within close proximity to the Nattai Ponds catchment. The location of each rain gauge is shown in **Figure 3** and key information for each gauge is summarised in **Table 3**.

The information provided in **Table 3** indicates that the majority of rain gauges have a limited record length. Nevertheless, the Mittagong (Alfred St) gauge has over 100 years of daily rainfall records. The Mittagong (Kia-Ora) gauge also provides over 100 years of daily rainfall records, however, the record is only 67% complete. **Table 3** also shows that no continuous rainfall data are available prior to January 1990.

A review of the available rainfall data was completed to identify when significant historic rainfall events have occurred and, consequently, when flooding may have been experienced in the catchment. The details of the top ten rainfall events are summarised in **Table 4**.

As shown in **Table 4**, the most significant rainfall event on record occurred in March 1893, where nearly 300 mm of rain fell within a 24-hour period. This concurs with a large reported flood documented in *'The Bowral Free Press'* (refer Section 2.2.5). However, the Nattai Ponds catchment was largely undeveloped at this time. Therefore, it is unlikely that significant flooding problems would have been reported.

The most significant contemporary rainfall events occurred in August 1986 and March 1978.

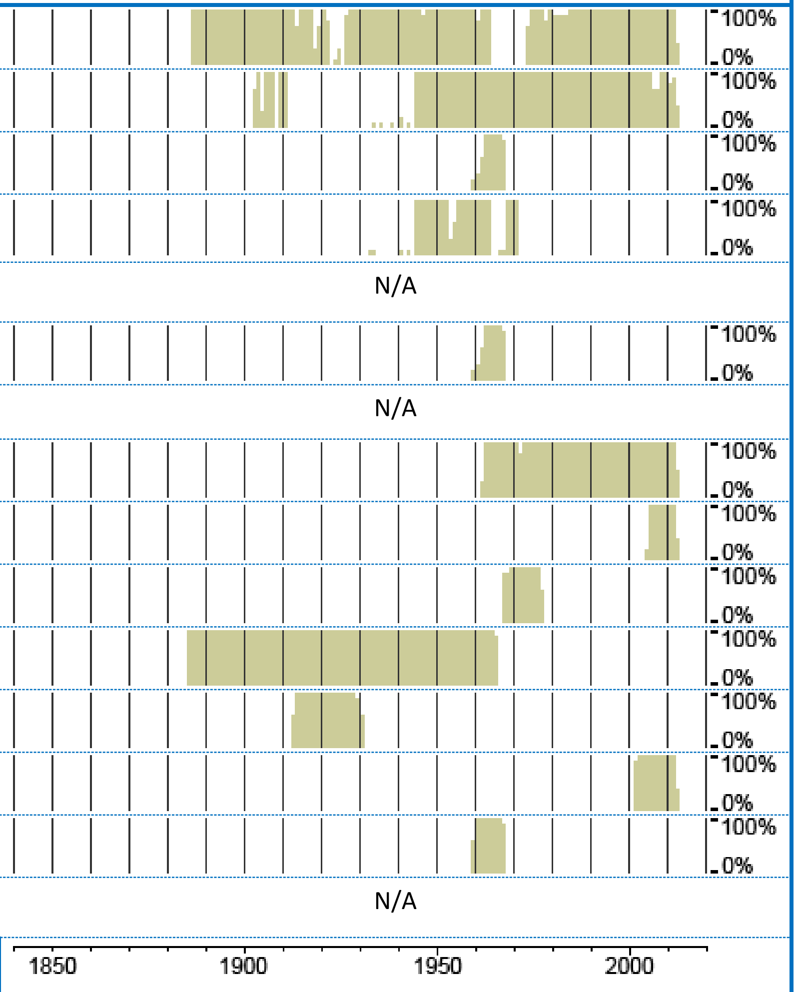
The rainfall information presented in **Table 4** also indicates that significant rainfall can occur throughout the year. However, most of the significant rainfall events tend to be concentrated in February/March and June/July/August. Significant rainfall events during the February/March period are most likely associated with short duration thunderstorms while rainfall in the June/July/August period is most likely associated with east coast lows.

2.3.2 Historic Stream Gauge Data

There are no stream gauges located within the Nattai Ponds catchment. Accordingly, no stream gauge information could be uncovered.

Table 3 Available rain gauges in the vicinity of the Nattai Ponds catchment

Gauge Number	Gauge Name	Gauge Type	Owner*	Period of Record	Distance From Catchment (km)	Temporal Availability and Percentage of Annual Record Complete
68044	Mittagong (Alfred St)	Daily	BOM	01/01/1886 -> present	1.6	
68033	Mittagong (Kia-Ora)	Daily	SCA	01/01/1902 -> present	2.5	
68087	Spring Hill (Warana)	Daily	BOM	01/01/1959->31/12/1968	2.6	
68040	Mittagong (Maguires Crossing)	Daily.	BOM	01/01/1928 -> 31/12/1970	6.5	
568054	Mittagong (Maguires Crossing)	Cont.	SCA	01/01/1990 -> present		N/A
68163	Mittagong (Leicester Park)	Daily	BOM	01/01/1957 -> 31/12/1970	7.4	
68102	Bowral (Parry Drive)	Cont.	BOM	30/11/1992 -> 28/06/2013	8.2	N/A
68102	Bowral (Parry Drive)	Daily	BOM	08/10/1961 -> present	8.2	
68255	Bowral (Orchard St)	Daily	BOM	09/01/2000 -> present	8.3	
68184	Bowral Centennial Road	Daily	BOM	01/01/1967 ->31/12/1977	8.7	
68005	Bowral Post Office	Daily	BOM	01/01/1885 -> 01/01/1965	9.3	
68157	Yarrow (Boural)	Daily	BOM	01/01/1912 -> 31/12/1930	9.3	
68239	Moss Vale AWS	Cont.	BOM	01/09/2001 -> present	10.3	
68092	Berrima (Hillview)	Daily	BOM	01/01/1959 -> 31/12/1967	10.8	
568165	Moss Vale (Berrima Junction)	Cont.	SCA	28/06/1990 -> present	14.1	N/A



NOTE: * BOM = Bureau of Meteorology, SCA = Sydney Catchment Authority

Table 4 Significant Historic Rainfall Events

Rank	Year	Day/Month	Rainfall in 24 hour Period (mm)	Rainfall in Preceding 24 Hour Period (mm)	Rainfall in Following 24 Hour Period (mm)
1	1893	5th March	297	15	4
2	1978	20th March	265	0	120
3	1914	30th December	184	1	1
4	1955	1st May	179	55	38
5	1898	14th February	175	26	62
6	1890	12th March	165	21	1
7	1986	6th August	164	54	72
8	1975	22nd June	152	3	92
9	1959	21st July	148	0	29
10	1956	25th July	147	27	2

NOTE: Significant rainfall was based on daily rainfall totals for Mittagong (Alfred St) & Mittagong (Kia Ora) rain gauges.

2.4 Topographic Data

2.4.1 LiDAR Data

Light Detection and Ranging (LiDAR) data was collected across the southern highlands area in April 2014 by the NSW Government's Land and Property Information department. The LiDAR has a stated absolute horizontal accuracy of better than 0.8 metres and an absolute vertical accuracy of better than 0.3 metres. It is considered that the vertical and horizontal accuracy provided by the LiDAR data is suitable for the study.

The LIDAR was used to develop a Digital Elevation Model (DEM) of the study area, which is provided in **Figure 4**. **Figure 4** shows that ground surface elevations vary between 750 mAHD near the intersection of Range Road and Old South Road down to 590 mAHD near the Hume Highway. Although the upstream sections of the catchment are quite steep, the topography 'flattens' considerably downstream of Bong Bong Road.

As the LiDAR was collected relatively recently, it is considered to provide a reliable representation of contemporary topographic conditions across most of the catchment. However, it is noted that the Renwick and Nattai Ponds subdivisions were still being developed when the LiDAR was collected. As a result, the topographic representation across these areas is unlikely to represent current topographic conditions.

In addition, LiDAR can provide a less reliable representation of the terrain in areas of high vegetation density. This is associated with the laser ground strikes often being restricted by the vegetation canopy. Errors can also arise if non-ground elevation points (e.g., vegetation canopy) are not correctly removed from the raw LiDAR dataset. Therefore, additional checks were completed across areas of dense vegetation to confirm if the terrain representation was reliable.

Plate 1 provides an example of the LiDAR point density in the vicinity of Willow Vale which includes significant vegetation cover. **Plate 1** shows a decrease in point density of LiDAR ground points in the vicinity of the dense tree/vegetation coverage. Therefore, it appears that non ground points have correctly been removed from the elevation information. However, this also means that the LiDAR provides more limited ground elevation points in the vicinity of dense vegetation. In addition, the LiDAR will not pick up the details of topographic and drainage features that are obscured from aerial survey techniques, such as culvert obvert elevations. Accordingly, it was considered necessary to supplement the LiDAR data with additional survey and topographic information to ensure a reliable representation of drainage features is provided across all areas of the catchment. Further information of the additional survey that was collected is provided in Section 2.8.

Plate 1 LiDAR data points (yellow crosses) in the vicinity of the vegetated channel in Willow Vale

2.5 Engineering Plans

A range of engineering plans were also provided by Council. The plans provided design details and work-as-executed survey for a range of drainage infrastructure (primarily stormwater pits and pipes) contained within the Nattai Ponds catchment including:

- "Stormwater Drainage Willow Street Willow Vale – Easement over properties 27 &27A" (Wingecarribee Shire Council, 2015)
- "Nattai Ponds Stage 1 – Stormwater management and cycle path" (Southeast engineering and environmental, 2013)
- "Nattai Ponds Stage 1 – Plans of Internal Civil Works" (Civil Development Solutions, 2013)
- "Renwick External Works – Inkerman Road Upgrade" (ARUP Consulting Engineers, 2009)
- "Renwick DA03 – Bong Bong Road, Mittagong" (JMD Development Consultants, 2009)
- "Renwick DA06 – Bong Bong Road, Mittagong" (JMD Development Consultants, 2011)

- "Plan of Proposed civil works associated with Renwick DA10 subdivision" (JMD Development Consultants, 2011)
- "Renwick DA07 – Renwick Village Development" (JMD Development Consultants, 2014)
- "Renwick DA11 – Bong Bong Road, Mittagong" (JMD Development Consultants, 2014)
- "Renwick Stage 8 – civil, roads, drainage, water and sewer works" (JMD Development Consultants, 2014)
- "Drainage Concept Plan for Proposed Residential Subdivision – Lots Cardigan Street Mittagong" (D&M Consulting, 2015)

2.6 GIS Data

A number of GIS data layers were also provided by Council to assist with the study. This included:

- Aerial Photography – provides 2013 ortho-rectified aerial imagery at a 0.5 metre pixel size;
- Cadastre – provides property boundary polygons;
- Stormwater Conduits – Provides alignments, lengths and diameters of stormwater pipes;
- Stormwater Nodes – Provides locations of stormwater pits/inlets;
- Bridges – Provides the location of designated bridges

The stormwater layers were reviewed in detail to determine if there was sufficient information contained in these layers to describe the stormwater system in the hydraulic computer model. The review determined that most of the information necessary to include the trunk stormwater drainage system was provided in these GIS layers. Nevertheless, some additional information including pit depths/invert elevations, pit types (e.g., kerb inlet, grated inlet) and culvert invert elevations are not available in these layers.

The extent of the stormwater network GIS layers is provided in **Figure 2**. As shown in **Figure 2**, there is only limited sub-surface stormwater infrastructure across the Nattai Ponds catchment. As a result, the majority of flow during significant storm events will travel overland across the catchment.

The bridges GIS layer showed that bridges are located at the following locations within the Nattai Ponds catchment:

- Railway Terrace, Willow Vale;
- Scarlet Street, Balaclava;
- Inkerman Road, Balaclava;
- Renwick Drive Railway Crossing, Renwick

All other stream crossings comprise pipe or box culverts.

2.7 Community Consultation

A key component of the flood study involves development and calibration of hydrologic and hydraulic computer models. Calibration involves using the computer models to replicate floods that have occurred in the past. Council holds minimal information on historic flooding across the Nattai Ponds catchment that can be used to assist with the calibration process.

However, it was considered that residents within the Nattai Ponds catchment may be able to provide information on past flood events. Accordingly, several community consultation devices were developed to inform the community about the study and to obtain information from the community about their past flooding experiences. Further information on each of these consultation devices is provided below.

2.7.1 Flood Study Website

A flood study website was established for the duration of the study. The website address was: http://www.nattaiponds.floodstudy.com.au/

The website was developed to provide the community with detailed information about the study and also provide a chance for the community to ask questions and complete an online questionnaire (this online questionnaire was identical to the questionnaire distributed to residents and business owners, as discussed in Section 2.7.2).

During the course of the study (until March 2016), the website was visited 1,940 times by 1,620 unique visitors.

2.7.2 Community Information Brochure and Questionnaire

A community information brochure and questionnaire was prepared and distributed to 414 households and businesses within the Nattai Ponds catchment. A copy of the brochure and questionnaire is included in **Appendix A**.

The questionnaire sought information from the community regarding whether they had experienced flooding, the nature of flood behaviour, if roads and houses were inundated and whether residents could identify any historic flood marks. A total of 68 questionnaire responses were received (10 online and 58 via mail), providing a questionnaire response rate of 16%. A summary of all questionnaire responses is provided in **Appendix A**. The spatial distribution of questionnaire respondents is shown in **Figure A1**, which is also enclosed in **Appendix A**.

The following information was gleaned from the responses to the questionnaire:

- The majority of respondents have lived in the Nattai Ponds catchment for over 15 years. The average length of residence was about 20 years.
- 36% of the respondents indicated that they have experienced some sort of flood impact (refer **Plate 2**).
- The flooding impacts were typically associated with inundation of front/back yards. However, 5 respondents indicated that they have had their house or business inundated during past floods (refer **Plate 3**).
- Flooding problems were reported in the vicinity of:
  - Biggera St
  - Bunya Close
  - Rush Lane
  - Railway Parade
  - Inkerman Road.
- A number of respondents indicated that Braemar Avenue experienced regular inundation. **Plate 4** shows a photograph of the 2007 flood taken at Braemar Avenue by a local resident.

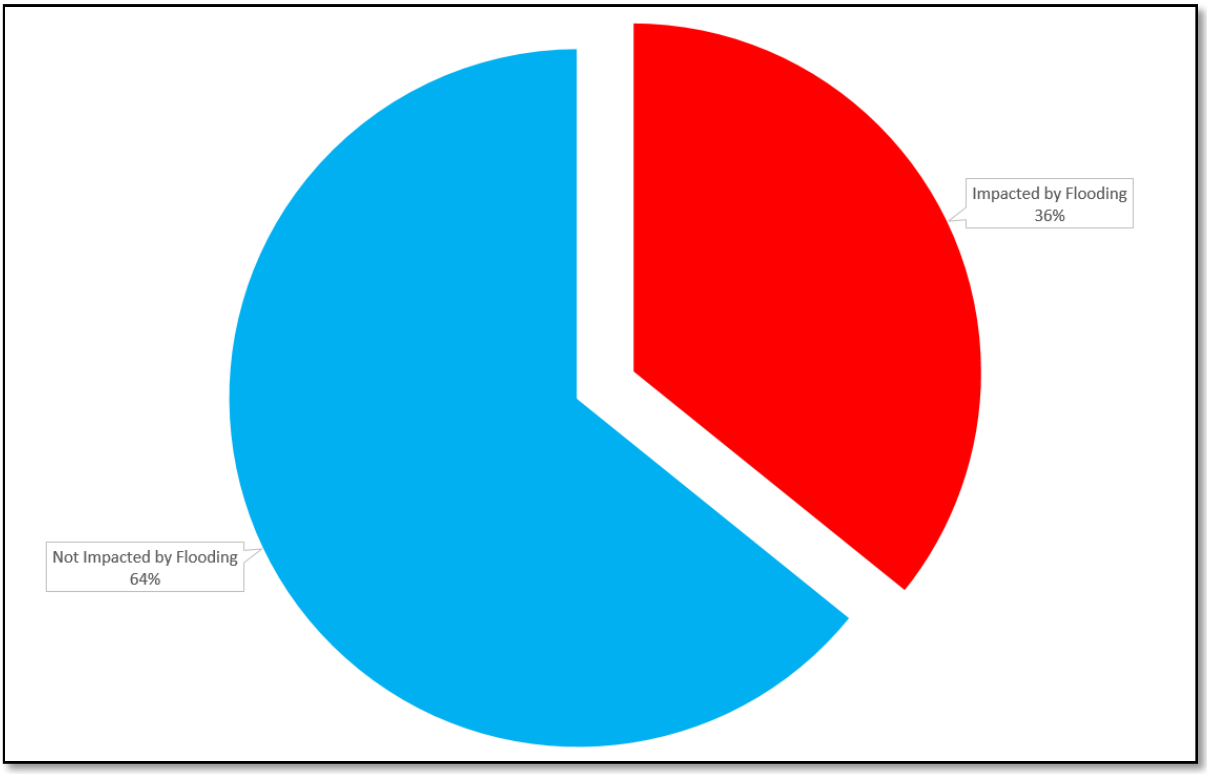


Plate 2 Proportion of questionnaire responses impacted by past flooding

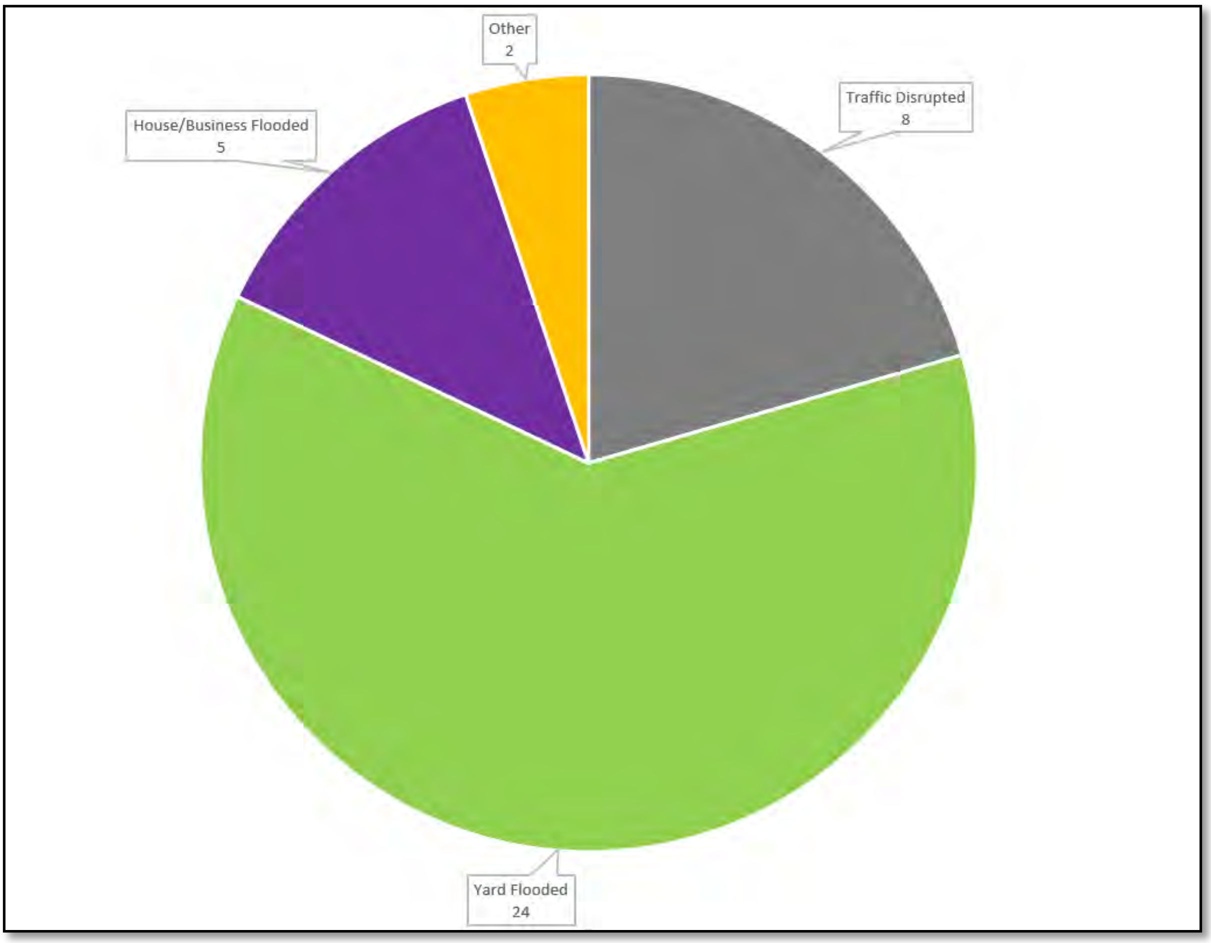


Plate 3 Types of flood impacts across the Nattai Ponds catchment

Plate 4 Water flowing over Braemar Avenue causing traffic disruption during the 2007 flood event

- The majority of respondents considered that the flooding problems are primarily associated with:
  -> lack of stormwater facilities (kerb & gutter, stormwater pits and pipes)
  -> existing drainage facilities having inadequate capacity
  -> increases in runoff from new developments (e.g., Renwick).

The spatial distribution of respondents that have experienced past flooding problems is shown by the red dots in **Figure A1**.

No specific flood mark information was provided by any of the respondents. However, several residents provided information on typical floodwater depths during past floods that could be used to assist in the verification of the hydrologic and hydraulic models. This included:

- Water depths of between 300 and 600mm were experienced on 26/08/2014 across the property at 62 Inkerman Road, Mittagong. **Plates 5** and **6** also shows the extent of inundation across this property during this event.
- On the 26/10/1999, both the house and garage at 4 Railway Parade, Braemar were inundated to a depth of 20mm above the floor level, causing damage to carpets and furniture.
- In 2007/2008, floodwaters almost reached the front and back door of 5/1 Biggera Street, Braemar and also inundated the front and back yards. This is most likely the June 2007 event (refer **Plate 4**).
- In 2013, water spilling from the creek flooded the back garden of 10 Bunya Close, Braemar to a depth of between 100-150mm. **Plate 7** shows the extent of inundation.
- Road access for residents at 15 Biggera Street, Braemar has been cut on a number of occasions by approximately 100mm of water extending across the Old Hume Highway

- The driveway and wooded land at 22 Scarlet Street, Balaclava have been inundated with over 300mm of water entering the property. **Plate 8** and **9** shows the extent of inundation across this property.

Plate 5 Water entering 62 Inkerman Street, Balaclava during the 2014 flood

Plate 6 Inundation across property at 62 Inkerman Street, Balaclava during the 2014 flood

Plate 7 View of the backyard of 10 Bunya Close, Braemar during the February 2013 flood event

Plate 8 View showing floodwaters entering Lot 8, Scarlet Street, Mittagong (date unknown)

Plate 9 View looking south from Scarlet Street down the driveway of Lot 8, Scarlet Street, Mittagong (date unknown)

2.8 Cross-Section and Structure Survey

To enable development of a hydraulic model capable of providing reliable estimates of flood behaviour within the study area it was necessary to collect additional survey information across the Nattai Ponds catchment. Consulting surveyors, Lawrence Group, collected the additional survey information.

The additional data collection comprised the survey of 12 creek cross-sections and 23 hydraulic structures (i.e., culverts and bridges). Additional cross-sections were also surveyed upstream and downstream of each structure. The location of cross-sections and structures that were surveyed is shown in **Figure 5**.

To assist in verifying the reliability of the LiDAR, the surveyed ground levels were also compared against the LiDAR elevations. The differences were subsequently subdivided based on land use and it was determined that in areas of high vegetation density (e.g., trees) the average difference between surveyed and LiDAR elevations was 0.17 metres. In areas of low vegetation density / open space (e.g., grass), the average difference between surveyed and LiDAR elevations was 0.09 metres. Accordingly, the LiDAR appears to afford a reasonable level of accuracy, particularly in areas of low vegetation density.

3 HYDROLOGIC MODEL

3.1 General

The most common method of quantifying flood flows (*i.e., discharges*) at a particular location in a catchment is via a hydrologic computer model. A hydrologic model is a mathematical representation of the various processes that transform rainfall into runoff. The model is developed so that it incorporates key hydrologic characteristics of the catchment such as area, slope, impervious proportion and roughness. The model can then be used to simulate the transformation of rainfall into runoff for either historic or statistically derived (i.e., design) rainfall.

The XP-RAFTS software was used to develop a hydrologic computer model of the Nattai Ponds catchment. XP-RAFTS is a lumped hydrologic computer model that is developed by XP Software (2009) and is used extensively across Australia for deriving discharge estimates. The following sections provide a summary of how the model was developed, the adopted input parameters and the outcomes of the model verification.

3.2 Hydrologic Model Development

3.2.1 Subcatchment Parameterisation

The Nattai Ponds catchment was subdivided into 209 subcatchments based on the alignment of major flow paths, key topographic divides and the location of stormwater pipes and pits. The subcatchments were delineated with the assistance of the CatchmentSIM software (Catchment Simulation Solutions, 2012) using a 2 metre Digital Elevation Model (DEM). The final subcatchment layout is presented in **Figure 6**.

The Nattai Ponds catchment includes some urban areas that are relatively impervious. Urbanisation effectively separates the catchment into two hydrologic systems, i.e.,:

- rapid rainfall response and low infiltration potential for impervious areas; and,
- slower rainfall response and high infiltration potential for pervious areas.

In recognition of the differing characteristics of the two hydrologic systems, each XP-RAFTS subcatchment was subdivided into two sub-areas. The first sub-area was used to represent the pervious sections of the subcatchment and the second sub-area was used to represent the impervious sections of the subcatchment. The division of each subcatchment into pervious and impervious sub-areas allows different loss rates and roughness coefficients to be specified, thereby providing a more realistic representation of rainfall-runoff processes from the two different hydrologic systems.

Key hydrologic properties including area, impervious proportion, roughness and average vectored slope were calculated automatically for each subcatchment using CatchmentSIM in conjunction with detailed land use information. The land use information was developed using an automated remote sensing approach that takes advantage of the full range of information collected by LiDAR, particularly multiple returns, LiDAR intensity as well as aerial imagery (Ryan, 2013).

The automated remote sensing approach provides a detailed spatial description (i.e., 1m grid size) of the variation in land use across the catchment. However, there were several misclassifications that were identified. These are primarily associated with shadowing effects and occasional misclassification of buildings. Therefore, some manual updates to the remote sensing outputs were completed to ensure a reliable description of land use was provided across the study area. The final land use mapping is shown in **Figures 10.1** to **10.9** inclusive.

Percentage impervious and Manning's 'n' roughness values were assigned to each land use (refer **Table 5**) and were used to calculate weighted average percentage impervious and 'n' values for each subcatchment. The adopted subcatchment parameters are provided in **Appendix B**.

Table 5 Adopted Impervious Percentage and Manning's 'n' Values for Hydrologic Model

Land Use Description	Manning's 'n'	Impervious (%)
Rural grasslands/Brush	0.045	0
Dense trees	0.100	0
Impervious areas (roads & concrete)	0.016	100
Water bodies	0.030	100
Buildings/roof area	0.025	100

3.2.2 Stream Routing

In addition to local subcatchment runoff, most subcatchments will also carry flow from upstream catchments along the main watercourses. The flow along the watercourses in XP-RAFTS is represented using a "link" between successive subcatchment "nodes".

For this study, time delay lag routing was employed to represent the routing of runoff along the main watercourses into downstream subcatchments. The time delay value for each subcatchment was calculated using a modified version of the Bransby-Williams formula (Queensland Government, 2007) and enforcing a minimum stream velocity of 0.8m/s to overcome unrealistically large lag times in very flat areas. The adopted lag value values for each link are summarised in **Appendix B**.

In addition to the time delay lag routing links, a diversion link was included in the model to represent the potential for runoff from Willowvale to bypass a culvert than runs beneath the railway embankment and into Railway Parade. This culvert was previously determined to have a capacity of 1.3 m^3/s (Southeast Engineering + Environmental, 2011). Accordingly, flows in excess of this capacity were assumed to travel along the western side of the embankment towards the industrial area on Braemar Avenue.

3.2.3 Rainfall Loss Model

During a typical rainfall event, not all of the rain falling on a catchment is converted to runoff. Some of the rainfall may be intercepted and stored by vegetation, some may be stored in small depression areas and some may infiltrate into the underlying soils.

To account for rainfall "losses" of this nature, the hydrologic model incorporates a rainfall loss model. For this study, the "Initial-Continuing" loss model was adopted, which is recommended in *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (Engineers Australia, 1987) for Eastern NSW.

This loss model assumes that a specified amount of rainfall is lost during the initial saturation/wetting of the catchment (referred to as the 'Initial Loss'). Further losses are applied at a constant rate to simulate infiltration/interception once the catchment is saturated (referred to as the 'Continuing Loss Rate'). The initial and continuing losses are effectively deducted from the total rainfall over the catchment, leaving the residual rainfall to be distributed across the catchment as runoff.

Initial and continuing losses were applied based on standard design values documented in *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (Engineers Australia, 1987). The losses were then refined as part of the model calibration process, which is discussed in Section 3.3.

3.2.4 Flood Detention Basins

A number of flood detention basins have been constructed across the catchment to offset potential increases in runoff associated with new development areas, most notably the Renwick and Nattai Ponds subdivisions. A total of seven basins were identified within the Renwick subdivision and two basins were identified within the Nattai Ponds subdivision. As these detention basins are designed to attenuate downstream flows during significant storm events, they were incorporated as flood storage basins in the XP-RAFTS model using storage and outflow pipe/spillway information contained in the design plans for each subdivision.

3.3 Hydrologic Model Calibration

3.3.1 General

Hydrologic computer models are typically developed using parameters that are not known with a high degree of certainty including rainfall loss rates and catchment roughness. Accordingly, the model should be calibrated using rainfall and stream flow data from historic flood events to ensure the adopted parameters are producing reliable estimates of rainfall-runoff behaviour. Calibration is typically completed by routing recorded rainfall through the hydrologic model. Simulated discharge hydrographs are extracted from the model results at locations where recorded stream flow records are available. Calibration is completed by adjusting model parameters to achieve the best match possible between recorded and model-generated hydrographs.

Unfortunately, no stream gauges are located within the catchment. The lack of stream flow data means that a comprehensive calibration of the hydrologic model could not be completed. Nevertheless, it is possible to complete a 'pseudo-calibration' by routing historic rainfall through the hydrologic model and then routing the resultant discharge hydrographs through the hydraulic model (refer Chapter 4). Peak flood extents and depths produced by the hydraulic model can then be compared against recorded flood extents / flood photographs to verify the combined performance of the hydrologic and hydraulic models. Calibration is achieved by jointly adjusting hydrologic and/or hydraulic inputs parameters until the recorded flood depths and extents are reproduced by the hydraulic model as closely as possible.

Some photographs and detailed descriptions of past floods were provided by residents as part of the responses to the community questionnaire. This included floods that occurred on 11th February 2007, 17th August 2014, and 26th August 2015. Accordingly, these events were selected for the purposes of model calibration / verification. In addition, a number of residents provided general descriptions of flood behaviour that can be used to further validate the performance of the computer models.

Further details of the hydrologic model calibration / verification process are provided below. As a joint calibration was performed using both the hydrologic and hydraulic models, the hydrologic model calibration should be read in conjunction with the hydraulic model calibration, which is documented in Section 4.3.

3.3.2 Rainfall Data

Continuous rainfall data are required to define the temporal (i.e., time-varying) distribution of rainfall in the hydrologic computer model for the nominated calibration / verification event. The following continuous rainfall gauges are located in close proximity to the Nattai Ponds catchment:

- 68102 Bowral (Parry Drive): November 1992 -> February 2011 (6 minute time step)
- 68239 Moss Vale AWS: September 2010 -> present (1 minute time step)
- 568054 Mittagong (Maguires Crossing): January 1990 -> present (60 minute time step)
- 568165 Moss Vale (Berrima Junction): June 1990 -> present (60 minute time step)

Continuous rainfall data are available for the February 2007 event (at a 6 minute temporal resolution), and for the August 2014 and August 2015 floods (at a 1 minute temporal resolution). This was considered to be suitable to describe the temporal variation in rainfall during each event.

There are also several daily read rainfall gauges located within or in close proximity to the catchment. The daily read rainfall records can be used to provide an indication of the spatial variation in rainfall during the historic event. Three daily read rainfall gauges were operational during the 2007 and 2015 event, and five were operational during the 2014 event. This provided sufficient information to describe the spatial variation in rainfall during all three events.

3.3.3 Results

February 2007 Simulation

A review of the rainfall records indicates that approximately 135 mm of rain fell over a 2-day period commencing on 10th February, 2007. Continuous rainfall data was extracted from the 'Bowral (Parry Drive)' gauge for the 2007 event and is enclosed in **Appendix C** as **Figure C2**. A comparison between intensity-frequency-duration data for the Nattai Ponds catchment with the continuous rainfall information from the Bowral (Parry Drive) gauge indicates that the 2007 event falls between a 50% and 20% AEP flood (refer **Figure C1** in **Appendix C**).

Accumulated daily rainfall totals for each gauge that was operational during the 2007 event are provided in **Figures 7.1** and **7.2**. The accumulated daily rainfall totals were used to develop a pair of rainfall isohyet maps, which are also included on **Figures 7.1** and **7.2**. The isohyet maps show that accumulated daily rainfall across the catchment varied between 36.5 mm and 37.9 mm on

10th February and 95 mm and 105 mm on 11th February. Accordingly, there was evidence of some spatial variation in rainfall across the catchment during the 2007 event. The rainfall isohyets presented in **Figures 7.1** and **7.2** were used to estimate the average rainfall depth across the catchment for the 2007 event. This rainfall depth was subsequently applied to each subcatchment in the XP-RAFTS model.

The 'Bowral (Parry Drive)' rainfall gauge was used to describe the temporal distribution of rainfall across the 36 hour period for the 2007 event. This gauge provides a detailed description of the temporal variation in rainfall during the 2007 event (i.e., 6 minute resolution).

A review of the daily read rainfall records indicates the February 2007 event was not preceded by any significant rainfall. Therefore, the catchment would have been relatively 'dry' at the start of the main storm event. Accordingly, an initial loss at the higher end of the range suggested in *'Australian Rainfall and Runoff'* (Engineers Australia, 1987) was applied to pervious areas. A summary of the adopted initial losses and continuing loss rates is provided in **Table 6**.

Table 6 Adopted XP-RAFTS Rainfall Losses for Calibration Simulations

Land Use Description	February 2007 Event		August 2014 Event		August 2015 Event	
	Initial Loss *(mm)*	Continuing Loss *(mm/hr)*	Initial Loss *(mm)*	Continuing Loss *(mm/hr)*	Initial Loss *(mm)*	Continuing Loss *(mm/hr)*
Pervious	20	2.5	10	2.5	20	2.5
Impervious	1	0	1	0	1	0

It was noted that a number of topographic and development modifications have occurred across the Nattai Ponds catchment since the 2007 event. Most notably, the Renwick, Braemar Gardens and Nattai Ponds subdivisions were not present when the 2007 event occurred (refer **Plate 10**). Therefore, a revised XP-RAFTS model was developed for the 2007 simulation to reflect historic catchment conditions. This included modifying subcatchment boundaries, roughness coefficients and impervious proportions across the Nattai Ponds, Braemar Gardens and Renwick development areas.

Once the model was modified to reflect historic conditions, it was used to simulate rainfall-runoff processes for the 2007 event. A summary of peak discharges that were generated by the XP-RAFTS model for the 2007 simulation is provided in **Appendix C**.

The discharges generated by the XP-RAFTS model were subsequently applied to the 2007 conditions TUFLOW hydraulic model to simulate the 2007 flood. Further information regarding the TUFLOW model setup and the outcomes of the 2007 flood simulation are provided in Section 4.3.3.

August 2014 Simulation

A review of rainfall records indicates that approximately 128 mm of rain fell over a 3-day period commencing on 16th August, 2014. Continuous rainfall data was extracted from the 'Moss Vale AWS' gauge for the 2014 event and is enclosed in **Appendix C** as **Figure C3**. A comparison between intensity-frequency-duration data for the Nattai Ponds catchment with the continuous rainfall information from the Moss Vale AWS gauge indicates that the 2014 event is slightly more severe than a 50% AEP flood (refer **Figure C1** in **Appendix C**).

Plate 10 Comparison between 2007 (top image) and 2015 (bottom image) aerials showing Renwick, Braemer Gardens and Nattai Ponds developments (Google, 2015).

Accumulated daily rainfall totals for each gauge that was operational during the 2014 event are provided in **Figures 8.1** and **8.2**. The accumulated daily rainfall totals were used to develop rainfall isohyet maps, which are also included on **Figures 8.1** and **8.2**. The isohyet maps show that accumulated daily rainfall across the catchment varied between 66 mm and 80 mm on 17th August and 43 mm and 51 mm on 18th August. The rainfall isohyets presented in **Figures 8.1** and **8.2** were used to estimate the average rainfall depth across the catchment for the 2014 event. This rainfall depth was subsequently applied to each subcatchment in the XP-RAFTS model.

The 'Moss Vale AWS' rainfall gauge was used to describe the temporal distribution of rainfall across the 72-hour period for the 2014 event. This gauge provides a detailed description of the temporal variation in rainfall during the 2014 event (i.e., a 1-minute resolution).

A review of the daily read rainfall records indicates the August 2014 event was preceded by approximately 20 mm of rainfall. Therefore, the catchment would have been relatively 'wet' at the start of the main storm event. Accordingly, an initial loss at the lower end of the suggested *'Australian Rainfall and Runoff'* (Engineers Australia, 1987) range was applied to pervious areas. A summary of the adopted initial losses and continuing loss rates is provided in **Table 6**.

A summary of peak discharges that were generated by the XP-RAFTS model for the 2014 simulation is provided in **Appendix C**.

The discharges generated by the XP-RAFTS model were subsequently input into the TUFLOW hydraulic model to simulate the 2014 flood. Further information regarding the TUFLOW model setup and the outcomes of the 2014 flood simulation are provided in Section 4.3.3.

August 2015 Simulation

Available rainfall records indicate that approximately 165 mm of rain fell over a 2-day period between 24th and 25st August 2015. A review of intensity-frequency-duration data indicates that this rainfall intensity is slightly more severe than a 50% AEP event (refer **Figure C1** in **Appendix C**). Continuous rainfall information from the Moss Vale AWS gauge for the 2015 event and is presented in **Figure C4** in **Appendix C**.

Accumulated daily rainfall totals for each gauge that was operational during the 2015 event are provided in **Figures 9.1** and **9.2**. The accumulated daily rainfall totals were used to develop rainfall isohyet maps, which are also included on **Figures 9.1** and **9.2**. The isohyet maps show that accumulated daily rainfall across the catchment varied between 63 mm and 68 mm on 24th August and 92 mm and 98 mm on 25th August. The rainfall isohyets presented in **Figures 9.1** and **9.2** were used to estimate the average rainfall depth across the catchment for the 2015 event. This rainfall depth was subsequently applied to each subcatchment in the XP-RAFTS model.

The Moss Vale AWS gauge was used to describe the temporal distribution of rainfall across the 48-hour period for the 2015 event.

A review of the daily read rainfall records indicates the August 2015 event was preceded by negligible rainfall (i.e., <5mm). Therefore, the catchment would have been relatively 'dry' at the start of the main storm event. Accordingly, an initial loss at the upper end of the suggested *'Australian Rainfall and Runoff'* (Engineers Australia, 1987) range was applied to pervious areas. A summary of the adopted initial losses and continuing loss rates is provided in **Table 6**.

A summary of peak discharges that were generated by the XP-RAFTS model for the 2015 simulation is provided in **Appendix C**.

The discharges generated by the XP-RAFTS model were subsequently input into the TUFLOW hydraulic model to simulate the distribution of flows during the 2015 event. Further information regarding the TUFLOW model setup and the outcomes of the 2015 flood simulation are provided in the following section.

4 HYDRAULIC MODEL

4.1 General

Hydraulic computer models are the most common method of simulating flood behaviour through a particular area of interest. They can be used to route discharge hydrographs generated by the hydrologic model across the study area and predict flood characteristics such as peak flood level and flow velocity. The results of the modelling can also be used to define the variation in flood hazard and hydraulic categories across the study area.

The TUFLOW software was used to develop a hydraulic computer model of the Nattai Ponds catchment. TUFLOW is a fully dynamic, 1D/2D finite difference model developed by BMT WBM (2013). It is used extensively across Australia to assist in defining flood behaviour.

The following sections describe the model development process as well as the outcomes of the model calibration and verification.

4.2 Hydraulic Model Development

4.2.1 Model Grid Size and Extent

A linked 1-dimensional/2-dimensional hydraulic model of the watercourses, floodplain, stormwater network and overland flow system was developed for the Nattai Ponds catchment using the TUFLOW software. The model extends across the full extent of the Nattai Ponds catchment draining to the Hume Highway. The extent of the hydraulic model is shown in **Figures 10.1** to **10.9** inclusive.

The TUFLOW software uses a uniform grid to define the spatial variation in topography and hydraulic properties (e.g., Manning's 'n') across the 2D model domain. A 2 metre grid size was adopted for this study. The 2 metre grid size is considered to provide a reasonable representation of the variation in terrain and hydraulic roughness across the catchment while keeping simulations times within reasonable limits.

A dynamically linked 1-dimensional (1D) network was embedded within the 2D domain to represent areas that would not be well represented by the 2 metre grid (e.g., narrow creek channels). The extent of the 1D and 2D model domains is shown in **Figures 10.1** to **10.9** inclusive.

4.2.2 Model Topography

Elevations were assigned to grid cells within the 2D domain based on the Digital Elevation Model derived from LiDAR data. As the LiDAR data was collected in 2014, the terrain representation in TUFLOW is indicative of topographic conditions at that time. That is, any topographic modifications completed since 2014 will not be reflected in the model. A review of recent aerial photography indicates there has been negligible large topographic modifications across the catchment since the LiDAR data was collected. Therefore, the LiDAR is considered to provide a reliable representation of contemporary topographic conditions across the majority of the catchment.

The elevations assigned to grid cells located within building footprints were elevated by 0.15 metres above the maximum level within the footprint based on the assumption that the floor level of houses will be elevated above the natural ground surface. The 0.15 metre value was adopted based upon Section 3.1.2.3(b) of the Building Code of Australia (2012), which states that the floor level of buildings in poorly drained areas or impervious areas that do not slope away from the building shall be elevated 0.15 metres above the finished ground level.

The topography within the 1D domain was defined using surveyed cross-sections (refer Section 2.8). This was also supplemented with cross-sections extracted from the LiDAR in areas that were not obstructed by vegetation.

4.2.3 Material Types / Manning's 'n' Roughness

The TUFLOW software employs material polygons to define the variation in hydraulic roughness (i.e., Manning's 'n' values) across the study area. As discussed in Section 3.2.1, remote sensing analysis was used to subdivide the catchment into different land uses. These classifications were also used to assign Manning's 'n' values to each material type. The spatial distribution of the different material types is shown in **Figures 10.1** to **10.9,** and the corresponding Manning's 'n' values are provided in **Table 7**.

1D cross-sections, pipes and culverts within the 1D domain of the TUFLOW model also require the specification of Manning's 'n' values. These values were defined based on field assessments, photography and inspection of 2013 aerial photography.

Table 7 Manning's 'n' Roughness Values

Material Description	Manning's 'n'
Grass	0.045
Trees	0.100
Paved Roads	0.016
Waterbodies	0.030
Buildings	2.000

4.2.4 Culverts/Bridges

Culverts and bridges can have a significant influence on flood behaviour. Therefore, all significant bridges and culverts located within the Nattai Ponds catchment were included within the TUFLOW model.

For circular or rectangular culverts, the physical dimensions and invert elevations of the structures were included as 1D elements in the TUFLOW model based on the survey information that was collected or work-as-executed plans. For irregular culverts (e.g., arch culverts), the shape of each crossing was defined using a flow height versus flow width relationship. Entry and exit loss coefficients were defined based on default values provided in the TUFLOW Manual (BMT WBM, 2010). Typically, an entry loss coefficient of 0.5 and an exit loss coefficient 1.0 was adopted for all culverts.

The catchment also includes a number of bridge crossings. The available waterway area beneath the bridge deck was specified using a surveyed cross-section. Energy losses were defined using a water height versus loss coefficient relationship that was developed based on procedures outlined in *'Hydraulics of Bridge Waterways'* (Bradley, 1978). The bridge loss calculations are included in **Appendix E**.

Bridge and Culvert Blockage

During a typical flood, sediment, vegetation and urban debris (e.g., litter) from the catchment can become mobilised leading to blockage of downstream culverts and bridges (refer **Plate 11**). Consequently, bridges and culverts will not operate at full efficiency during most floods. This can increase the severity of flooding across areas located adjacent to these structures.

Plate 11 Example of vegetation and silt partially blocking culvert at rear of property at 14 Evans Street, Mittagong.

In recognition of this, blockage factors were applied to all bridges and culverts. The blockage factors were applied based on guidelines contained in the Australian Rainfall & Runoff document titled 'Blockage of Hydraulic Structures' (Engineers Australia, 2015). This guideline requires an assessment of potential debris type, debris availability, debris mobility and debris transportability at each structure location. This assessment was completed using the land use information described in Section 3.2.1 as well the LiDAR information. The outcome of the blockage assessment is summarised in **Appendix D** for each culvert/bridge located within the catchment.

4.2.5 Detention Basins / Farm Dams

As discussed, the Renwick and Nattai Ponds subdivisions incorporate a number of detention basins that serve to attenuate downstream flows. In addition, the upper catchment includes a number of farm dams that also have the potential to store water and attenuate flows during floods. A representation of each basin and dam was included in the TUFLOW model.

The absence of any water level monitoring gauges within each basin/dam means that the normal operating water level (or range of operating water levels) of each storage is not known. In the absence of any water level information, it was assumed that all 'wet' water storages (e.g., farm dams) were full at the start of each simulated flood.

4.2.6 Stormwater System

The majority of the Nattai Ponds catchment is drained by a network of open creek channels. However, this is supplemented by a stormwater drainage system that is designed to capture runoff across the urban sections of the catchment during frequent rainfall events and convey it below ground and into the receiving waterway. Therefore, it was considered important to incorporate the conveyance provided by the stormwater system in the TUFLOW model to ensure the interaction between piped stormwater and overland flows across the urban sections of the catchment was represented.

A representation of the full stormwater system was included within the TUFLOW models as a dynamically linked 1-Dimensional (1D) network. This allowed representation of the conveyance of flows by the stormwater system below ground as well as simulation of overland flows in two dimensions once the capacity of the stormwater system is exceeded.

Where available, stormwater system information contained in work-as-executed and design plans was used to define the stormwater system. This was supplemented with information contained in Council's stormwater GIS layer. However, as discussed in Section 2.6, some key information describing the stormwater system (e.g., invert elevations, pit types) was not available for all pipes and pits. As a result, the GIS layers did not contain all of the information necessary to fully define the stormwater system in TUFLOW.

Therefore, the missing pit and pipe GIS information was estimated to ensure all required information describing the stormwater system was included in the TUFLOW model. The missing pipe information was estimated using the following approach:

- Where pipe diameter information was not available, the diameter was interpolated based upon inspection of the upstream and downstream pipe diameters;

The missing pit information was populated using the following approach:

- All stormwater pits without a type classification were assumed to comprise a grated kerb inlet with a lintel length of 1.8 metres.
- Pit invert elevations were linearly interpolated between known pit invert elevations. Where known pit information was not available to assist the interpolation, the pit inverts were estimated using the following equation:
  -> Invert elevation = Ground elevation – 1 metre

The estimated pit inverts were subsequently reviewed to ensure there were no adverse pipe grades across the catchment. This resulted in some modifications to the estimated pit invert elevations by hand.
The extent of the stormwater system included within the TUFLOW models is shown in **Figure 10**.

Once all pit types were defined across the catchment, inlet capacity curves were prepared to define the variation in pit inflow capacity with respect to water depth at each pit location. The 'Drains Generic Pit Spreadsheet' (Watercom Pty Ltd, July 2005), was used to develop the inlet capacity curves. The inlet capacity curves were developed to take account of:

- The different pit inlet types (e.g., sag inlets, grated inlets, kerb inlets, combination inlets); and,
- The different pit dimensions and lintel sizes.

A copy of the inlet capacity curves are provided in **Appendix F**.

Hydraulic 'losses' throughout the stormwater system were estimated using the Engelhund loss approach (BMT WBM, 2015). This loss approach automatically accounts for the following loss components for each stormwater pit for each model time step:

- Pit entrance loss
- Loss associated with a drop in elevation between inlet and outlet pipes
- Loss associated with a change in flow direction between the inlet and output pipes
- Pit exit loss

Stormwater inlets may also become blocked by debris during the course of a flood. As a result, most stormwater inlets will not operate at full efficiency during most floods. In recognition of this, a 50% blockage factor was also applied to all sag stormwater inlets and 20% blockage was applied to on-grade stormwater inlets.

4.2.7 Fences

Fences can also provide a significant impediment to flow in urbanised catchments. Therefore, it was also considered important to include a representation of fences within the TUFLOW model. An automated approach was employed to extract approximate fence alignments across urbanised sections of the floodplain based on information contained in cadastre, roadway and LEP GIS layers. The extent of fence lines that were generated based on this approach is shown in **Plate 12**.

A field review indicated a variety of different fence types across the catchment including Colorbond, paling, picket and wire mesh fencing. Accordingly, the degree of blockage afforded by each fence type is likely to vary considerably. Nevertheless, it was recognised that even relatively permeable fence types can become partially blocked during the course of a flood. For example, during the early stages of a flood, debris (e.g., leaves, branches) can be mobilised and conveyed down major flow paths until it reaches an obstruction whose aperture is too small to transmit the debris. Therefore, by the peak of the flood there is a significant probability that most fences will be at least partially blocked with debris. In recognition of this, all fences were implemented with a blockage of 50%. That is, a 50% reduction in conveyance capacity is provided through the fence lines. Although there is likely to be considerable variability in the degree of blockage provided by different fence types, a 50% blockage factor provided a realistic estimate of the average degree of blockage provided by all fence types across the Nattai Ponds catchment. It was also assumed that all fences were 1 metre high since the hydrodynamic forces associated with water depths over 1 metre was considered sufficient to cause failure of the fences.

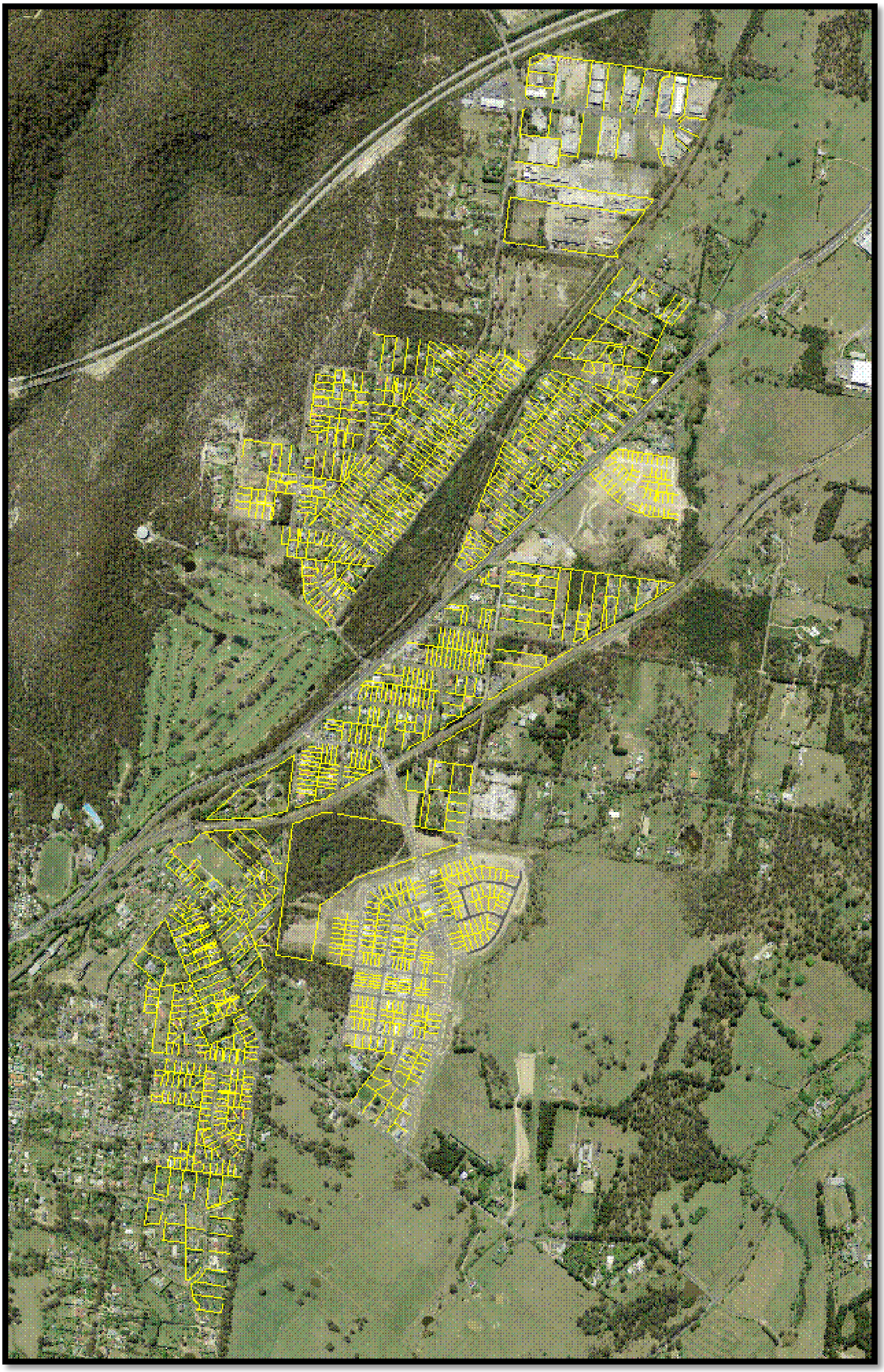


Plate 12 Extent of fences (yellow lines) extracted using cadastre, zoning and roadway GIS layers

4.3 Hydraulic Model Calibration

A full calibration of the XP-RAFTS hydrologic and TUFLOW hydraulic computer models could not be completed due to the lack of stream gauge(s) within the Nattai Ponds catchment. Nevertheless, a joint calibration of the hydrologic and hydraulic models was attempted to verify that the computer models were providing realistic reproductions of past flood events.

As discussed in Section 3.3.1, photographs and descriptions of floods that occurred in February 2007, August 2014 and August 2015 were provided by several residents (refer **Table 8**). Accordingly, these events were selected for the purposes of model calibration / verification. Further details of the hydraulic model calibration / verification process are provided below.

As a joint calibration was performed using the hydrologic and hydraulic models, the hydraulic model calibration should be read in conjunction with the hydrologic model calibration previously discussed in Section 3.3.

4.3.1 Model Boundary Conditions

Upstream Boundary Conditions

Upstream boundary conditions define the variation in flows with respect to time across the hydraulic model area during each historic flood. Inflows to the TUFLOW hydraulic model were defined using discharge hydrographs extracted from the XP-RAFTS hydrologic modelling (refer Section 3.3). Inflows were applied to the lowest point within each XP-RAFTS model subcatchment.

Downstream Boundary Conditions

Hydraulic computer models also require the adoption of a suitable downstream boundary condition in order to reliably define flood behaviour throughout the area of interest. The downstream boundary is typically defined as a known water surface elevation (i.e., stage).

As shown in **Figure 10.9**, the downstream boundary of the TUFLOW model is located downstream of the Hume Highway. Accordingly, water travelling along the main watercourse at this location can discharge freely downstream and there should be no 'backwater' effects from dams and other watercourses that may influence the water surface elevation in this area.

Accordingly, a 'normal depth' boundary was applied at the downstream end of the Nattai Ponds TUFLOW model. This approach assumes that the downstream water level is influenced only by the geometry, roughness and slope of the main waterway. Given the Hume Highway embankment and culvert is located upstream of the model boundary, it is considered that this culvert will have a greater influence on flood behaviour across the lower catchment. This is, any uncertainty associated with the downstream boundary definitions should not impact on flood behaviour across the "built up" sections of the catchment where historic flood information is available.

4.3.2 Modifications to Represent Historic Floodplain Conditions

February 2007

As discussed, the Renwick, Braemar Gardens and Nattai Ponds subdivisions were not present during the February 2007 flood event. Therefore, modifications to the TUFLOW hydraulic model were completed to provide a more reliable description of historic catchment conditions. More specifically, the following updates were completed to the 'existing' conditions TUFLOW model:

- 2010 ALS information was used to define topography across the Renwick, Braemar Gardens and Nattai Ponds subdivisions instead of the 2014 LiDAR data.
- Stormwater drainage and hydraulic structures were removed from across the Renwick, Braemar Gardens and Nattai Ponds development areas.
- Manning's 'n' values across the Renwick, Braemar Gardens and Nattai Ponds development areas were also altered to be representative of long grass.

August 2014
As the August 2014 event occurred relatively recently, no modifications were considered necessary to the "existing" conditions model to reflect 2014 conditions.

August 2015
As the August 2015 event occurred relatively recently, no modifications were considered necessary to the "existing" conditions model to reflect 2015 conditions.

4.3.3 Calibration Approach

Calibration of the TUFLOW model was completed by using the model to reproduce reports of historic flood behaviour that occurred during the 2007, 2014 and 2015 events. The descriptions of historic flood behaviour largely drew upon information provided as part of the community questionnaire responses. This included anecdotal descriptions of historic flood behaviour as well as photographs of these past floods.

The descriptions of historic flood behaviour and flood photographs were used to estimate historic water levels at each location. This was completed by combining the reported floodwater depths with ground surface elevations extracted from the available LiDAR information.

The historic water level estimates were compared against simulated water levels generated by the TUFLOW model. Adjustments were completed to the TUFLOW input parameters until a reasonable correlation between simulated water levels and historic flood mark elevations was achieved. The results of the model calibration for each specific flood event are presented below.

4.3.4 Calibration Results

February 2007 Simulation
Calibration of the TUFLOW hydraulic model was attempted based upon descriptions of inundation extents and water depths, as well as two photographs of the 2007 flood. The verification was completed by routing the discharge hydrographs generated by the XP-RAFTS model for the 2007 event through the TUFLOW model.

The simulated depths of inundation during the 2007 event are provided in **Figures 11.1** to **11.8** inclusive. **Figures 11.1** to **11.8** also incorporate velocity vector arrows, which show the direction and speed of floodwater movement.

The two photographs which were used as the basis for the model calibration are included in **Figure 11.7**. The coloured arrows that are included with each photo in **Figure 11.7** show the direction that each photo was taken.

The flood mark elevation that was estimated from the flood photographs is also included on **Figure 11.7** as well as in **Table 8**. The comparison provided in **Table 8** and **Figure 11.7** shows that the TUFLOW model is producing a flood level estimate that is within 20 mm of the historic flood mark elevation.

Table 8 Comparison between Recorded and Simulated Historic Flood Levels for 2007 event

Flood Photo	Description	Flood Mark Elevation# (mAHD)	Simulated Flood Level (mAHD)
2007A in **Figure 11.7**	View looking upstream from the Braemar Ave crossing of the Nattai Ponds Catchment main watercourse. Floodwater depth of 0.1metres above road surface estimated from photos.	593.35	**593.37**
2007B in **Figure 11.7**	View looking southeast from Braemar Ave towards Braemar Lodge. Floodwater depth of 0.1metres above road surface estimated from photos.		

NOTE: # Flood mark elevations are based upon interpretation of photographs and flood descriptions provided by residents. Therefore, they should be considered approximate only.

Photos 2007A and 2007B in **Figure 11.7** generally show relatively shallow depths of inundation in the vicinity of Braemar Avenue. This appears to be reproduced by the TUFLOW model with simulated floodwater depths in this area being less than 0.3 metres (with the exception of depths along the main watercourse).

Overall, the outcomes of the 2007 calibration show that the TUFLOW model is providing a reasonable reproduction of flood behaviour in the vicinity of Braemar Avenue.

August 2014 Simulation

The TUFLOW hydraulic model was also calibrated using flood marks that were estimated from historic descriptions of flood behaviour as well as two photographs of the August 2014 flood.

Peak floodwater depths and velocities generated by the TUFLOW model for the 2014 simulation are provided in **Figures 12.1** to **12.8** inclusive. The photographs of the 2014 flood are included as photos 2014A and 2014B in **Figures 12.3** and **12.5** and show inundation extents in the vicinity of 45 and 62 Inkerman Road.

A comparison between the recorded flood mark elevations derived from the flood photos and simulated flood levels for the 2014 flood is provided in **Table 9** as well as **Figures 12.3** and **12.5**. An additional flood mark was extracted based upon a description of flood behaviour provided as part of the questionnaire responses and is included on **Figure 12.7** (however, no photograph is available to support this flood mark).

The comparison provided in **Table 9** and **Figures 12.3**, **12.5** and **12.7** shows that the TUFLOW model is producing flood level estimates that are within 90 mm of anecdotal flood mark elevations. The extent and depth of inundation shown in the photographs on **Figures 12.3** and **12.5** also appears to be reasonably well produced by the TUFLOW model.

In general, the depths and extents of inundation produced by the TUFLOW model appear to provide a reasonable reproduction of reported flood levels and depths. Accordingly, the TUFLOW model is considered to be providing realistic estimates of historic flood behaviour for the 2014 event across these areas.

Table 9 Comparison between Recorded and Simulated Historic Flood Levels for 2014 event

Flood Photo	Description	Flood Mark Elevation# (mAHD)	Simulated Flood Level (mAHD)
2014A in **Figure 12.5**	View looking south from the rear of 45 Inkerman Rd. Questionnaire response stated that floodwater depths across rear of the property were typically less than 0.2 metres.	605.63	**605.54**
2014B in **Figure 12.5**	View looking West from 62 Inkerman Rd. Questionnaire response stated that water was between 0.3 and 0.6 metres deep.	603.47	**603.48**
No photo Available	Questionnaire response stated that water across Braemar Avenue was about 0.1 metres deep.	593.36	**593.32**

NOTE: # Flood mark elevations are based upon interpretation of photographs and flood descriptions provided by residents. Therefore, they should be considered approximate only.

August 2015 Simulation

The TUFLOW hydraulic model was also calibrated using flood marks that were estimated based upon five photographs of the August 2015 event. The photographs show floodwater depths and extents at 62 Inkerman Road, the rear of 5 Braemar Ave as well as adjoining the Renwick subdivision (refer flood photos on **Figures 13.3, 13.5** and **13.7**).

Peak floodwater depths and velocities generated by the TUFLOW model for the 2015 simulation are provided in **Figures 13.1** to **13.8** inclusive. A comparison between recorded flood mark elevations and simulated flood levels for the 2015 flood is also provided in **Table 10** as well as on **Figures 13.3, 13.5** and **13.8**.

Table 10 Comparison between Recorded and Simulated Historic Flood Levels for 2015 event

Flood Photo	Description	Flood Mark Elevation# (mAHD)	Simulated Flood Level (mAHD)
2015A in **Figure 13.3**	Looking North-West towards Cardigan St culverts. Floodwater depth of 0.3 metres estimated from photo.	607.58	**607.62**
2015B in **Figure 13.3**	Looking East from the corner of Mackellar Cct and Cardigan St. Floodwater depth of 0.3 metres estimated from photo.	607.22	**607.27**
2015C in **Figure 13.5**	Looking west from 62 Inkerman Rd. Questionnaire response stated that floodwater depths across the property were typically between 0.3 and 0.5 metres.	603.47	**603.48**
2015D in **Figure 13.5**	Looking north from the rear of 62 Inkerman Rd. Questionnaire response stated that floodwater depths across the property were typically between 0.3 and 0.5 metres.	602.72	**602.78**
2015E in **Figure 13.8**	View looking south from the rear of 5 Braemar Ave. Questionnaire response stated that photo was taken after the peak of the flood and that up to 1.5m of water flowed across the land.	591.86	**591.03**

NOTE: # Flood mark elevations are based upon interpretation of photographs and flood descriptions provided by residents. Therefore, they should be considered approximate only.

The comparison provided in **Table 10** and **Figures 13.3, 13.5** and **13.8** shows that the TUFLOW model is producing flood level estimates that are generally within 60 mm of the historic flood mark elevations. The only exception is a flood mark located downstream of Braemar Avenue, where the difference is over 0.8 m. It should be noted that this flood mark is based on a depth estimate where the community member had 'low' confidence in the depth estimate. It should also be noted that the extent and depth of inundation shown in flood photograph 2015E on **Figure 13.8** (upon which the flood mark is based) appears to be reasonably well reproduced by the TUFLOW model and does not appear to approach the reported 1.5 metre water depth.

In general, it is considered that the TUFLOW model is providing a reasonable reproduction of historic flood behaviour for the 2015 event.

4.3.5 Additional Validation

A number of community members provided flood photographs and anecdotal information for past floods that did not include specific information on the date of the flood. Therefore, it was not possible to use this information to assist with the calibration of the TUFLOW model.

However, this additional information was considered useful for determining whether the hydraulic model is providing realistic estimates of flood behaviour in areas away from the historic flood marks. The flood marks that were estimated from the additional (i.e., non-date specific) historic flood information is provided in **Table 11**. **Table 11** also includes the simulated flood levels that were generated by the TUFLOW model at each flood mark location for each historic flood simulation.

The comparisons provided in **Table 11** shows that the simulated flood levels generated by the TUFLOW model are typically within 150 mm of the estimated flood mark elevations. Given the relatively good correlation between the simulated flood levels and historic flood mark elevations, it is considered likely that the flood photographs and descriptions of flood behaviour correspond to either the 2007, 2014 or 2015 events.

4.3.6 Summary

A definitive calibration of the XP-RAFTS hydrologic model and TUFLOW hydraulic model could not be completed due to the lack of historic stream gauging data. Nevertheless, a pseudo calibration and validation of the models was attempted using historic rainfall data in conjunction with descriptions of past floods and flood photographs provided by the community.

The outcomes of the calibration and verification simulations indicate that the combination of the XP-RAFTS hydrologic model and TUFLOW hydraulic model provide a reliable reproduction of historic flood behaviour during the 2007, 2014 and 2015 events. Accordingly, it is considered that the XP-RAFTS and TUFLOW models are suitable for use in simulating design flood behaviour across the Nattai Ponds catchment.

It should be noted that no calibration data is available for large floods (i.e., > 20% AEP flood). Therefore, the reliability of the model performance during large floods could not be explicitly verified.

Table 11 Comparison between Recorded and Simulated Historic Flood Levels for Unknown Historic Events

Description	Flood Mark Elevation# (mAHD)	Simulated Flood Level (mAHD)
 View showing flood water entering Lot 8 Scarlet St	600.58	**2007** = 600.65 **2014** = 600.62 **2015** = 600.62
 Photo looking north-east from the rear of 5 Braemar Ave	590.93	**2007** = 591.02 **2014** = 590.79 **2015** = 591.78
10cm of water in front and backyards, almost up to front and back doors of 5/1 Biggera St, Braemar	611.07	**2007** = 611.07 **2014** = 611.05 **2015** = 611.04
Up to 20cm in the whole area from house to creek at 32 Balaclava Street, Balaclava	600.28	**2007** = 600.27 **2014** = 600.26 **2015** = 600.25

NOTE: # Flood mark elevations are based upon interpretation of photographs and flood descriptions provided by residents. Therefore, they should be considered approximate only.

5 Design Flood Simulations

5.1 General

Design floods are hypothetical floods that are commonly used for planning and floodplain management investigations. Design floods are based on statistical analysis of rainfall and flood records and are typically defined by their probability of exceedance. This is typically expressed as an Annual Exceedance Probability (AEP).

The AEP of a particular flood level or discharge at a specific location is the probability that the flood level/discharge will be equalled or exceeded in any one year. For example, a 1% AEP flood has a 1% chance of being equalled or exceeded in any one year.

Design floods are typically estimated by applying design rainfall to the hydrologic model to develop design flood hydrographs at various locations throughout the catchment. The design flood hydrographs are then routed through the hydraulic model to derive design flood level, depth and velocity estimates. The procedures employed in deriving design flood estimates for the Nattai Ponds catchment are outlined in the following sections.

5.2 Model Updates for Existing/Future Conditions

5.2.1 General

At the time this study was prepared, a number of areas were undergoing further urbanisation/expansion. As this flood study will serve as the baseline document for defining flood behaviour across the catchment for a number of years, it was felt important to include a full representation of these new development areas. Accordingly, the 'existing' conditions models were updated to reflect full development across these current and potentially imminent development areas.

5.2.2 Renwick DA07 and DA11

DA07 and DA11 of the Renwick subdivision includes channel works and a significant residential release area east of the main Nattai Ponds watercourse (JMD Development Consultants, 2014). Proposed topography and hydraulic structures across this area were extracted from design plans and included into the TUFLOW hydraulic model. Material types and corresponding Manning's "n" values were also updated to reflect the modified hydraulic roughness across the development area. The XP-RAFTS hydrologic model was also updated to reflect the increased impervious proportion and reduced Manning's "n" roughness across this section of the catchment. **Plate 13** shows the area modified from existing conditions to reflect the development that is, and will continue to occur as a result of the approved DA07 and DA11 plans.

As some elements of the development are yet to be fully constructed, detailed delineation of features such as buildings could not occur. As a result, the Manning's "n'" values and percentage impervious were altered slightly from other sections of the model to reflect "weighted average" values (refer **Table 12**).

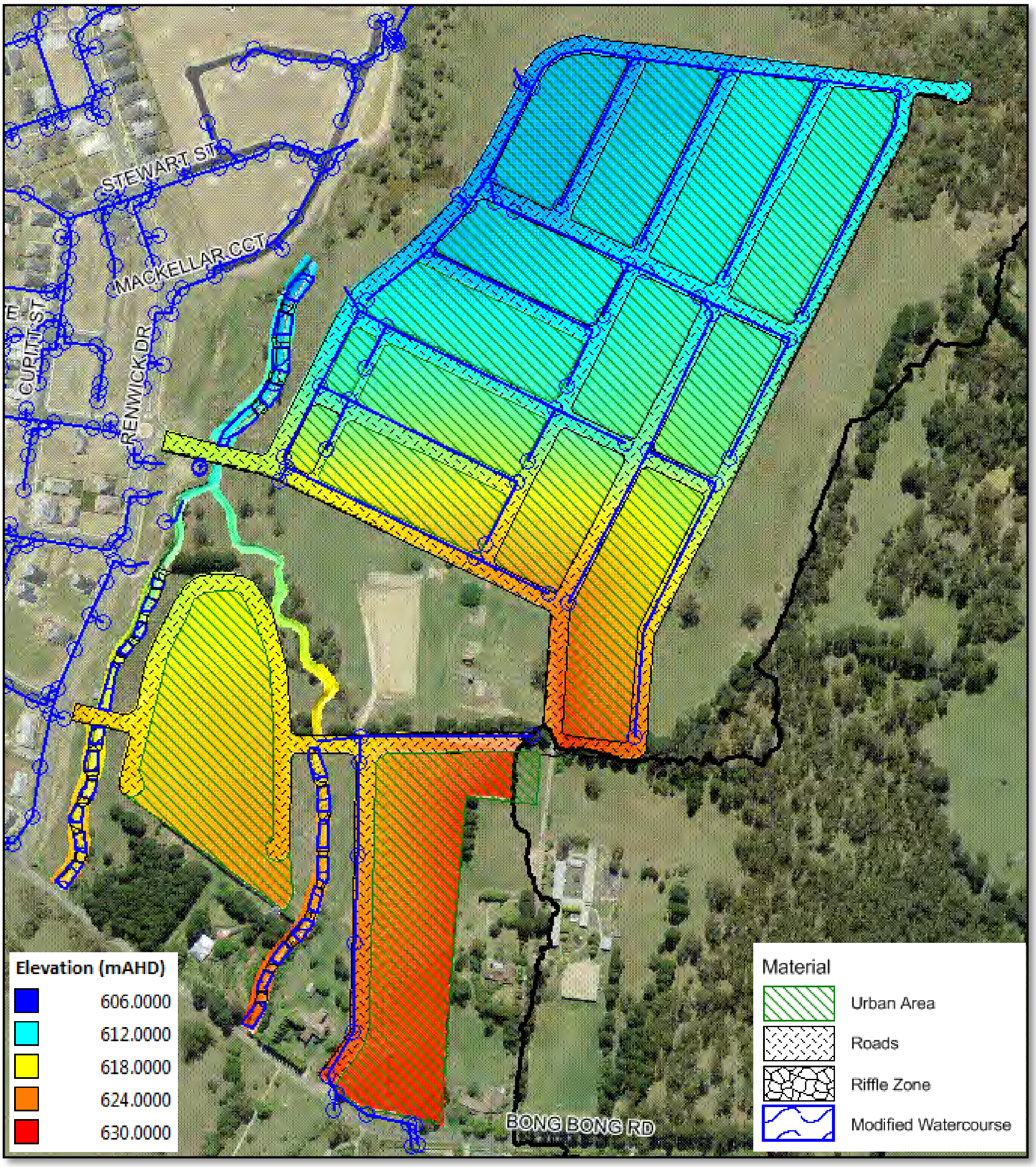


Plate 13 DA07 and DA11 urban release development areas and channel works included within the "design" model

Table 12 Adopted manning's 'n' roughness for future development areas

Land Use Description	Manning's 'n' roughness	Impervious Percentage (%)
Urban areas	0.028	60
Roads	0.016	100
Realigned watercourses	0.04	0
Riffles within watercourses	0.05	100

Additional hydraulic structures were also incorporated in the model. This includes culverts under Guthawah Way, a bebo arch culvert under Oldfield Rd and some small culverts under an emergency access road to the east of the development. A representation of the proposed stormwater network was also included in the hydraulic model.

5.2.3 Cardigan Street Development

A development application submitted to Wingecarribee Shire Council during the preparation of the flood study outlines the proposed subdivision of a parcel of land fronting Cardigan St at Balaclava (D&M Consulting, 2015). The development includes a number of residential lots, a new access roadway and additional existing stormwater pits and pipes. Accordingly, the Cardigan Street development was also included in the model representation. **Plate 14** shows the area modified from existing conditions to represent the proposed development.

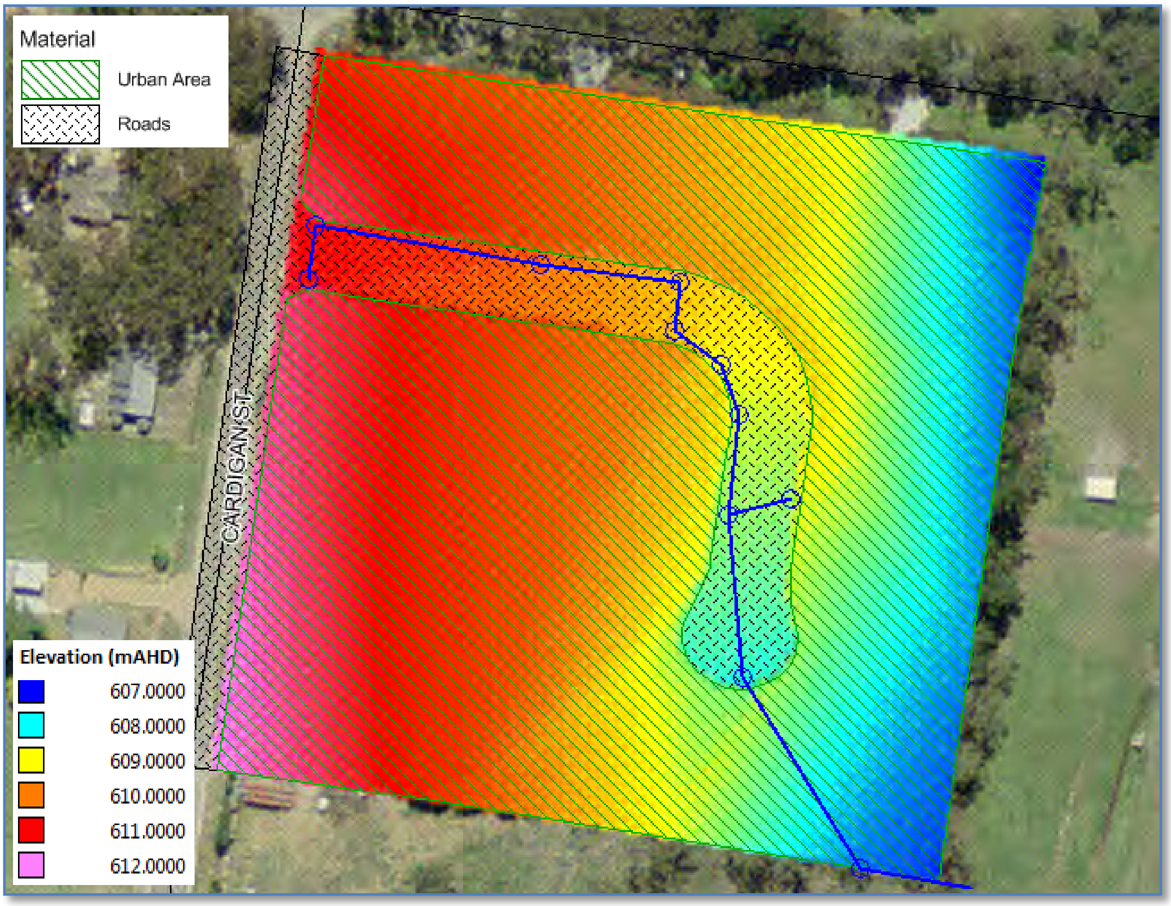


Plate 14 Cardigan Street subdivision included within the model

Manning's "n" roughness and percentage impervious across the proposed subdivision were specified as per **Table 12**. The TUFLOW hydraulic model was also updated to include the altered topography, material types and Manning's "n" roughness across the site.

5.2.4 Nattai Ponds (Lot 117 and Lot 8, Old Hume Highway, Braemar) Development

The Nattai Ponds subdivision was partly constructed at the time this study was prepared. Plans of the proposed subdivision layout were provided by Council for the current and future release areas and included roadway and residential block alignments (Southeast Engineering + Environmental, 2013).

Manning's 'n' roughness and percentage impervious for the area were updated in the XP-RAFTS model in accordance with the parameter values included in **Table 12**. The TUFLOW hydraulic model was also updated to include the proposed topography and Manning's "n" roughness across the proposed development.

An additional bank of culverts was included in the TUFLOW model at the location of a new roadway crossing and an indicative stormwater network was also included within the development site. **Plate 15** shows the area modified from existing conditions to represent the proposed development.

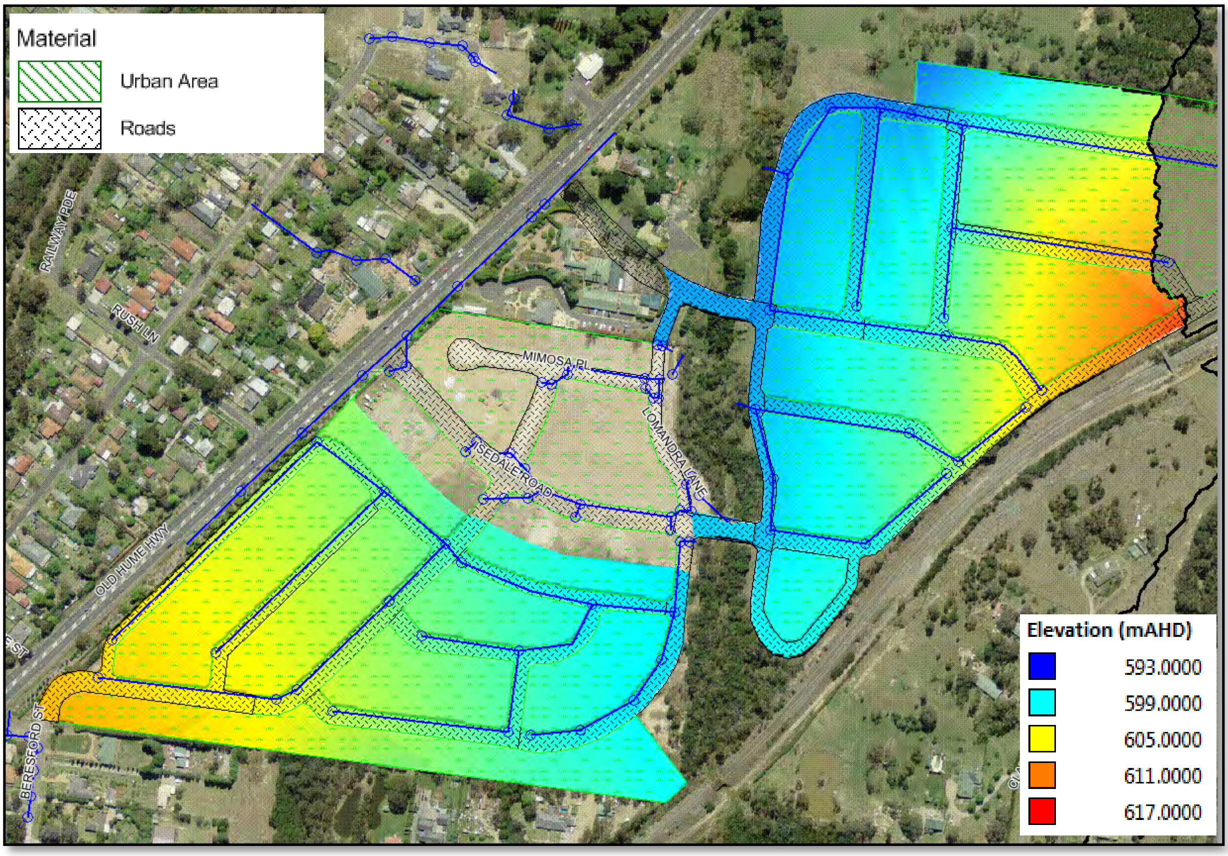


Plate 15 Nattai Ponds subdivision included within the 'design' model

5.3 Hydrology

5.3.1 Design Rainfall

Design rainfall for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events were derived using standard procedures outlined in *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (Engineers Australia, 1987). This involved extracting base design intensity-frequency-duration values at the centroid of the Nattai Ponds catchment (refer **Table 13**). This base design rainfall information was used to interpolate design rainfall for other design rainfall frequencies and durations. Adopted rainfall intensities for each design storm and duration are summarised in **Table 14**. The resulting intensity-frequency-duration (IFD) curves for the Nattai Ponds catchment are also provided in **Appendix C**.

The resulting design rainfall information was also verified against design rainfall extracted using the Bureau of Meteorology's Computerised Design IFD Rainfall System and was found to be consistent.

Table 13 Design IFD Parameters

Parameter	Value
$^{2}I_{1}$	32.28
$^{2}I_{12}$	6.82
$^{2}I_{72}$	2.29
F2	4.74
F50	14.40
Skew	0.02

Table 14 Design Rainfall Intensities

Duration	Rainfall Intensity (mm/hr)						
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	PMP
5 mins	134.4	152.2	175.6	206.4	230.0	N/A	N/A
6 mins	126.1	142.8	164.8	193.7	215.9	N/A	N/A
10 mins	103.3	117.1	135.3	159.1	177.4	196.6	N/A
20 mins	75.54	85.73	99.1	116.7	130.3	144.4	N/A
30 mins	61.55	69.90	80.88	95.32	106.4	118.1	420
60 mins	41.93	47.70	55.28	65.25	72.93	81.25	320
90 mins	32.96	37.54	43.56	51.48	57.58	64.09	273
2 hours	27.63	31.51	36.59	43.30	48.46	53.97	240
3 hours	21.45	24.51	28.50	33.78	37.85	42.24	190
4.5 hours	16.62	19.02	22.15	26.31	29.51	33.03	144
6 hours	13.88	15.90	18.54	22.04	24.75	27.74	128
9 hours	10.81	12.40	14.47	17.23	19.36	21.71	N/A
12 hours	9.08	10.42	12.17	14.50	16.29	18.25	N/A
24 hours	6.04	6.93	8.08	9.62	10.80	12.13	N/A
48 hours	3.97	4.55	5.30	6.29	7.05	7.87	N/A
72 hours	3.01	3.45	4.01	4.76	5.33	5.96	N/A

NOTE: N/A indicates a design rainfall is not applicable for this duration

For all design storms up to and including the 0.5% AEP event, the design rainfall was uniformly distributed across the entire study area. That is, there was no spatial variation in design rainfall across the study area. However, the design rainfalls listed in **Table 14** are only applicable at a point and it is unrealistic to assume that these intensities can be maintained across geographic areas in excess of 4km^2, such as the Nattai Ponds catchment. Therefore, it is necessary to apply areal reduction factors to the point rainfall intensities before applying them to the computer model. Accordingly, areal reduction factors where extracted from Figure 1.6 of *'Australian*

Rainfall and Runoff – A Guide to Flood Estimation' (Engineers Australia, 1987). The adopted reduction factors are summarised in **Table 15**.

Table 15 Areal Reduction Factors

Storm Duration	Rainfall Reduction Factor
10 mins	0.99
15 mins	0.99
30 mins	0.99
1 hour	0.99
1.5 hours	0.99
2 hours	0.99
3 hours	0.99
6 hours	0.99
9 hours	0.99
12 hours	0.99
24 hours	0.99

The areal reduced design rainfall estimates were used in conjunction with standard design temporal patterns to describe how the design rainfall varies with respect to time throughout each design storm.

5.3.2 Probable Maximum Precipitation (PMP)

As part of the flood study it was also necessary to define flood characteristics for the Probable Maximum Flood (PMF). The PMF is considered to be the largest flood that could conceivably occur across a particular area.

The PMF is estimated by routing the Probable Maximum Precipitation (PMP) through the computer model. The PMP is defined as the greatest depth of rainfall that is meteorologically possible at a specific location.

PMP depths were derived for the Nattai Ponds catchment for a range of storm durations up to and including the 6-hour event based on procedures set out in the Bureau of Meteorology's *'Generalised Short Duration Method'* (GSDM) (Bureau of Meteorology, 2003). The PMP estimates were varied spatially and temporally based on the GSDM approach before application to the XP-RAFTS. The GSDM PMP calculations are included in **Appendix G**. The PMP rainfall intensities are also summarised in **Table 14**.

5.3.3 Rainfall Loss Model

As discussed in Section 3.2.3, the "Initial-Continuing" loss model was adopted in the XP-RAFTS model to represent rainfall loses across the catchment. The rainfall losses that were adopted for the design flood simulations are summarised in **Table 16.** The adopted rainfall losses for all design events were applied based on the design ranges documented in *"Australian Rainfall and Runoff – A Guide to Flood Estimation"* (Engineers Australia, 1987).

Table 16 Adopted XP-RAFTS Design Rainfall Losses

Land Use Description	Initial Loss *(mm)*	Continuing Loss *(mm/hr)*
Pervious	10	2.5
Impervious	1	0

5.3.4 Peak Discharges

The XP-RAFTS model was used to simulate the 20%, 10%, 5%, 2%, 1% and 0.5% AEP design floods as well as the PMF.

A range of storm durations were modelled for each design storm to establish the critical storm duration for each subcatchment within the Nattai Ponds catchment. Peak discharges were extracted from the XP-RAFTS model for each storm duration and are provided in **Appendix H**. Peak discharges at key locations throughout the catchment are also summarised in **Table 17**.

The results of the design simulations indicate that the critical storm duration for the majority of subcatchments varies between 1.5 and 2 hours. However, during the PMF the critical duration drops to between 15 and 90 minutes.

5.3.5 Verification of Design Discharges

Past Studies

To help verify the XP-RAFTS model results, peak design discharges generated by the XP-RAFTS model were compared against peak design discharges documented in previous flood investigations. This included:

- 'Renwick Sustainable Village Project, Mittagong Flood Study' (**Table 18**); and
- 'Lot 8 and Lot 117 Old Hume Highway Flood Impact Assessment' (**Table 19**).

The comparison provided in **Table 18** shows that the peak discharges generated by the XP-RAFTS model generally compare well with peak discharges documented in the *'Renwick Sustainable Village'* (Bewsher, 2006) in the immediate vicinity of the Renwick subdivision. However, there are some more significant differences away from the Renwick subdivision, with the Bewsher peak discharges generally being between 15% and 20% higher those generated by the XP-RAFTS model. The higher discharges generated by the Bewsher model can most likely be attributed to:

- The Bewsher model utilised a Bx factor of 0.8 which will provide less attenuation/storage relative to the default Bx factor of 1.0 that was adopted for the current study. It is noted that this Bx factor was adopted based on the Bewsher model being "calibrated" against Probabilistic Rational Method discharges while the current model and Bx factor was pseudo-calibrated against historic flood information. Overall, it is considered that the adoption of a Bx factor of 1.0 is reasonable.
- The Bewsher model did not include any of the detention basins that are now constructed within the Renwick development site, which serve to reduce peak flows from the site.

Table 17 Peak Design Discharges for Existing Conditions

Location (XP-RAFTS ID)		Peak Discharge (m³/s)						
		20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	PMF
Bong Bong Road *(1.05)*	Nattai Ponds Creek	9.35	11.53	14.70	17.75	20.83	23.84	40.71
Bong Bong Road *(6.05)*	Unnamed Tributary	6.57	8.17	10.37	12.60	14.88	17.31	32.33
Renwick Drive *(19.07)*	Unnamed Tributary	6.77	8.25	10.58	12.96	15.34	17.80	40.73
Inkerman Road *(19.11)*	Nattai Ponds Creek	3.50	3.89	4.44	5.02	5.49	5.94	15.14
Inkerman Road *(Junc_38)*	Unnamed Tributary	25.53	31.28	39.37	47.83	55.71	63.56	136.31
Scarlet Street *(Junc_44)*	Nattai Ponds Creek	4.02	4.53	5.26	5.98	6.59	7.19	19.81
Main Southern Railway *(US_Rail)*	Nattai Ponds Creek	33.68	41.16	51.43	62.52	72.69	82.82	193.53
Old Hume Highway *(US_OHH)*	Nattai Ponds Creek	37.82	45.97	57.09	69.35	80.40	91.43	227.02
Braemar Avenue *(Junc_80)*	Nattai Ponds Creek	41.18	49.72	61.34	74.29	85.82	97.29	244.31
Hume Highway *(1.26)*	Nattai Ponds Creek	55.20	66.55	81.99	99.72	114.93	131.05	360.10

Table 18 Peak design discharges extracted from "Renwick Sustainable Village Project, Mittagong - Flood Study" (2006)

Location	Peak Discharge (m³/s)							
	20% AEP		5% AEP		1% AEP		PMF	
	Current Study	Bewsher, 2006	Current Study	Bewsher, 2006	Current Study	Bewsher, 2006	Current Study	Bewsher, 2006
Upstream of Renwick Basin	12.7	13.1	19.6	20.9	28.2	29.9	133	121
Downstream of Renwick Development	21.6	22.3	33.7	35.5	47.9	47.9	239.	214
Upstream of Railway	32.7	35.7	49.9	58.2	70.5	77.7	346	328
Downstream of Mary St	5.4	7.0	8.6	10.2	12.3	13.3	63.3	47.7

Table 19 Peak design discharges extracted from the Lot 8 and Lot 117 Old Hume Highway Flood Impact Assessment (2011)

Location	Peak Discharge (m³/s)					
	20% AEP		5% AEP		1% AEP	
	Current Study	Southeast, 2011	Current Study	Southeast, 2011	Current Study	Southeast, 2011
Old Hume Highway Culverts	37.8	34.4	57.1	45.2	80.4	53.0
Boundary between Lot 8 and Lot 117	36.6	30.0	55.3	38.8	78.1	46.1
Downstream of Railway	34.0	29.0	51.9	36.9	73.3	44.2

Table 19 shows that the current XP-RAFTS model is predicting higher peak discharges relative to the peak discharges documented in the 'Lot 8 and Lot 117 Old Hume Highway Flood Impact Assessment' (Southeaster Engineering + Environmental, 2011). More specifically, differences of up to 18% are predicted during the 20% AEP event increasing to over 40% during the 1% AEP event. This is most likely associated with the Southeast model not accounting for any development across the upstream catchment (e.g., Renwick). As noted in Section 5.2, the model developed for the current study assumed full development across Renwick.

Probabilistic Rational Method

Additional verification of the peak design discharges generated by the XP-RAFTS model was completed by comparing peak 1% AEP XP-RAFTS discharges against peak discharges calculated using the Probabilistic Rational Method (PRM). The outcomes of the comparison are provided in **Table 20** at selected locations across the Nattai Ponds catchment. A complete listing of PRM and XP-RAFTS discharges for each subcatchment is provided in **Appendix I**.

Table 20 XP-RAFTS Verification against Probabilistic Rational Method and Regional Flood Frequency Approach

Location	Peak 1% AEP Discharge (m³/s)				
	Current XP-RAFTS	PRM	Regional Flood Frequency		
			5% Confidence	Design Discharge	95% Confidence
Nattai Ponds @ Catchment Outlet	115	93.2	29.3	81.3	228
Nattai Ponds @ Old Hume Highway	80.4	67.8	21.9	60.6	170
Nattai Ponds @ Railway	72.7	61.0	23.4	64.9	182
Nattai Ponds @ Bong Bong Rd	20.8	15.0	4.8	13.4	37.7

In general, the XP-RAFTS and PRM discharges show a reasonable correlation, particularly across the upper sections of the catchment, which are largely undeveloped. The level of agreement starts to diverge further down the catchment where more significant urbanisation is evident. This is not unexpected as the PRM is designed for application in rural catchments so it fails to account for the increased runoff potential across impervious sections of the catchment.

Overall, the XP-RAFTS model produces 1% AEP peak discharges that are, on average, 10% higher than the PRM.

Regional Flood Frequency

Project 5 of the Australian Rainfall & Runoff revision process has included the development of a regional flood frequency (RFF) approach that enables peak design discharges to be estimated for ungauged catchments. Accordingly, peak discharges were established using the RFF approach at a selection of locations across the Nattai Ponds catchment based upon the procedures set out by Engineers Australia (2015). The 1% AEP RFF discharge estimates are provided in **Table 20** (the corresponding 1% AEP XP-RAFTS discharges are also provided for comparison). The regional flood frequency approach acknowledges that there is uncertainty associated with regional approaches. Accordingly, the approach also provides confidence intervals so that an appreciation of the uncertainty in the discharge estimates can be gained.

The comparison provided in **Table 20** shows that the XP-RAFTS generally produces higher discharges relative to the RFF approach. This difference is most likely associated with the RFF approach not accounting for the increase in runoff potential across urbanised sections of the catchment. However, in all cases the XP-RAFTS peak discharges fall well within the RFF confidence limits at each location.

5.4 Hydraulics

5.4.1 General

The TUFLOW hydraulic model was used to simulate design flood behaviour across the Nattai Ponds catchment for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events as well as the Probable Maximum Flood (PMF).

The procedures employed in developing the design flood estimates are outlined in the following sections.

5.4.2 Model Boundary Conditions

Flow Boundary Conditions

Inflows to the TUFLOW hydraulic model were defined using 'local' discharge hydrographs (representing flows from the local subcatchments only) extracted from the XP-RAFTS hydrologic modelling.

Downstream Boundary Conditions

Downstream boundary conditions for the Nattai Ponds TUFLOW model were defined using a "normal depth" calculation. That is, the downstream stage was defined based on the stream geometry and slope as well as the total discharge at the downstream model boundary.

5.4.3 Critical Duration

The XP-RAFTS and TUFLOW models were used to simulate design flood behaviour across the Nattai Ponds catchment for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events as well as the PMF.

It was recognised that a single storm duration will not necessarily produce the "critical" flood behaviour across all sections of the catchment. Therefore, the XP-RAFTS and TUFLOW models were used to simulate flood behaviour across the Nattai catchment for a range of different durations for each design storm (i.e., 60 minutes up to 9 hours). The results from the 1% AEP design flood simulations were subsequently interrogated to determine the "critical" storm duration or durations across the catchment. The outcomes from this assessment are shown graphically in **Plate 16** and are also tabulated in **Table 21**.

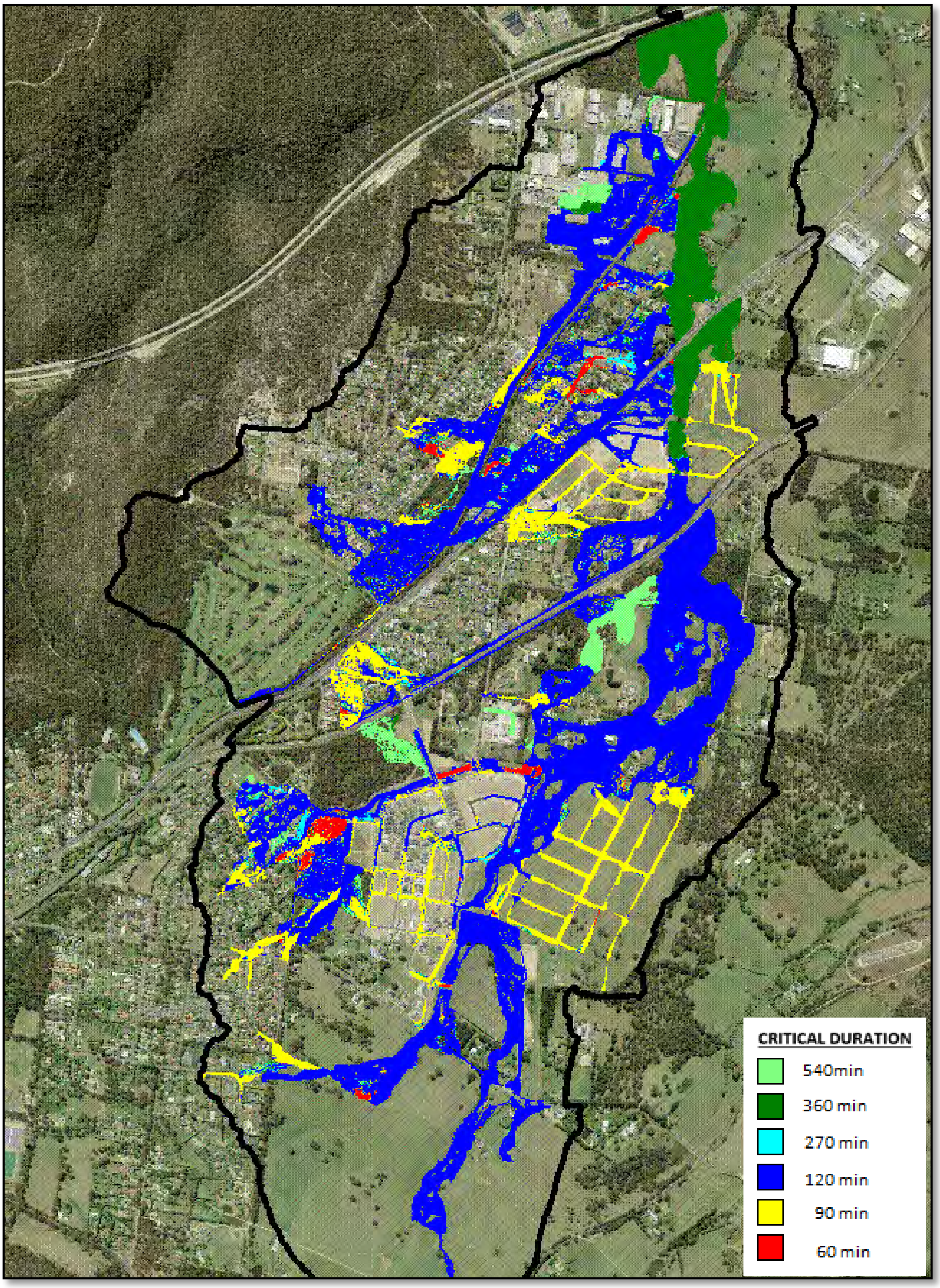


Plate 16 Spatial Variation in Critical Duration for the 1% AEP Flood

The information contained in **Plate 16** and **Table 21** show that the 120-minute storm duration produces the highest 1% AEP flood levels across the majority of the catchment. The 90-minute storm generally dominates in urbanised areas while the 360-minute storm duration dominates along the downstream sections of the catchment.

Table 21 Summary of Critical Storm Durations for 1% AEP flood level

Storm Duration (hours)	Percentage of Flooded Area Where Storm Duration is Critical	Rank
540	4.9%	4
360	13.3%	3
270	2.7%	5
120	63.8%	1
90	13.7%	2
60	1.5%	6

A review of the XP-RAFTS hydrologic model results for the 1% AEP flood was also completed and indicates that the 90-minute and 120-minute storm durations generate the highest peak discharges for the majority of the subcatchments across the Nattai Ponds catchment. That is, the 90-minute and 120-minute storms generate the highest peak discharges as well as the highest peak flood levels across the majority of the catchment.

5.4.4 Design Blockage

As described in Section 4.2.4, blockage factors were applied to each hydraulic structure for each design flood based on guidelines contained in 'Blockage of Hydraulic Structures' (Engineers Australia, 2015). However, it was noted that application of partial blockage to each hydraulic structure effectively creates a number of small storages across the catchment that serve to attenuate flows and reduce water levels downstream of each structure.

In recognition of the potential attenuation effects provided by the blockage factors and the understanding that structure blockage can be highly variable, each design flood was also simulated with no structure blockage. This was completed to ensure the flood risk downstream of each hydraulic structure was not underrepresented.

5.4.5 Design Flood Envelope

As discussed, a range of different storm durations were simulated for each design flood (ranging from the 60-minute storm up to the 9-hour storm). In addition, simulations were completed with partial blockage as well as no blockage of hydraulic structures. As a result, a range of results were generated as part of the design flood modelling.

Therefore, the results from each of the individual simulations (i.e., different storm durations and blockage scenarios) were subsequently merged to form a "flood envelope" for each design flood. This involved extracting and comparing peak flood levels, depths and velocities at each TUFLOW grid cell and adopting the highest depth, level and velocity at each grid cell. It is this design flood envelope, comprising the critical depths, velocities and levels at each grid cell that forms the basis for the results documented in the following sections.

5.4.6 Design Floodwater Depths, Levels and Velocities

Peak flood levels, depths and velocities for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events as well as the Probable Maximum Flood (PMF) were extracted from the results of the TUFLOW model. Peak floodwater depths, levels and velocity vectors are presented in **Figures 14.1** to **20.8** inclusive.

Peak flood levels were also extracted from the results of the modelling and are presented in **Table 23** at key locations throughout the Nattai Ponds catchment. The location identification (ID) numbers can also be referenced by the yellow points in **Figure 10.1** to **10.9** inclusive.

Peak floodwater surface profiles for the main watercourses within the Nattai Ponds study area for each design flood are also provided in **Figure 21.0** to **21.3** inclusive**.**

It should be noted that the primary objective of the flood study is to define the nature and extent of the flooding problem across the Nattai Ponds catchment. Therefore, there is a need to distinguish between areas of significant inundation depth / flood hazard and those areas subject to negligible inundation. In this regard, only areas exposed to an inundation depth of greater than 0.1 metres are shown in **Figures 14.1** to **20.8** inclusive. In some cases, this can result in a discontinuous inundation surface. However, it needs to be recognised that these isolated "puddles" are linked by areas of shallow flow.

5.4.7 Verification of Design Flood Levels

Verification of the results generated by the TUFLOW model was completed by comparing peak 1% AEP TUFLOW water level results with peak 1% AEP water level results documented in the *'Renwick Sustainable Village'* (Bewsher Consulting, 2006) and the '*Lot 8 and Lot 117, Old Hume Highway*' (Southeast Engineering, 2011). The comparison is provided in **Table 22.**

Table 22 TUFLOW Verification against Past Studies

Design Event	Location	Peak Water Level (mAHD)		
		Current TUFLOW	Past Studies	
			TUFLOW (Renwick Sustainable Village)	TUFLOW (Lot 8 and Lot 117, Old Hume Highway)
1% AEP	Nattai Ponds D/S Bong Bong Rd (Eastern Tributary)	626.0	626.0	
	Nattai Ponds D/S Oldfield Rd	613.4	613.5	
	Nattai Ponds D/S boundary of Renwick	606.5	606.5	
	Nattai Ponds U/S Inkerman Rd	604.7	604.6	
	Nattai Ponds D/S Railway	599.4		599.0
	D/S Braemar Garden World access road and main culvert	596.0		596.0

As shown in **Table 22** the TUFLOW model produces peak 1% AEP water levels that are generally within 0.1m of the two past studies. The most significant difference is 0.4m and occurs downstream of the railway culvert near the Nattai Ponds subdivision. It is considered that the differences at this location may be associated with the lower 1% AEP flows that were adopted as part of the Southeast report and potentially differences in assumptions regarding the future development layout across the Nattai Ponds subdivision. Nevertheless, the verification indicates the TUFLOW model developed as part of this study is producing flood level estimates that are generally comparable with past studies.

Table 23 Peak Design Water Level

ID	Location	Peak Water Level *(mAHD)*						
		20% AEP	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**	**PMF**
1	U/S Bong Bong Rd Channel 55	628.01	628.06	628.12	628.17	628.20	628.27	628.71
2	U/S Bong Bong Rd Channel 54	622.56	622.62	622.67	622.72	622.74	622.79	623.29
3	U/S Guthawah Way	619.13	619.15	619.21	619.20	619.22	619.34	619.86
4	U/S Emergency Access Channel 55	620.42	620.47	620.51	620.54	620.58	620.60	620.95
5	U/S Oldfield Rd	614.97	615.30	615.64	616.00	616.34	616.69	617.37
6	U/S Renwick Footbridge	614.43	614.48	614.53	614.58	614.61	614.64	615.33
7	U/S Renwick Dr	609.50	609.57	609.65	609.74	609.79	609.88	611.63
8	U/S Cardigan St	608.32	608.37	608.49	608.51	608.59	608.63	609.93
9	U/S Inkerman Rd	604.51	604.58	604.65	604.70	604.71	604.77	605.51
10	U/S Inkerman Rd Tributary	603.46	603.51	603.58	603.64	603.65	603.71	604.54
11	U/S Scarlet St	600.71	600.73	600.75	600.78	600.79	600.82	603.12
12	U/S Railway	599.20	599.28	599.38	599.50	599.55	599.64	603.03
13	U/S Railway Culvert Braemar	615.34	615.38	615.46	615.52	615.57	615.62	615.96
14	U/S Biggera St	611.37	611.37	611.38	611.40	611.42	611.47	611.93
15	U/S Isedale Rd	596.83	597.00	597.19	597.42	597.64	597.93	599.17
16	U/S Lot 117 Access	595.53	595.67	595.86	596.09	596.29	596.55	598.04
17	U/S Old Hume Highway	594.50	594.66	594.90	595.17	595.37	595.48	596.88
18	U/S Braemar Av	593.63	593.66	593.70	593.72	593.77	593.79	594.83
19	U/S Braemar Av, Willowvale	597.88	597.92	597.97	598.01	598.03	598.08	598.60
20	U/S Hume Highway	587.52	587.71	587.90	588.14	588.40	588.65	594.78

refer to Figure 10 for Location ID

6 Flood Hazard and Hydraulic Categorisation

6.1 Provisional Flood Hazard Categories

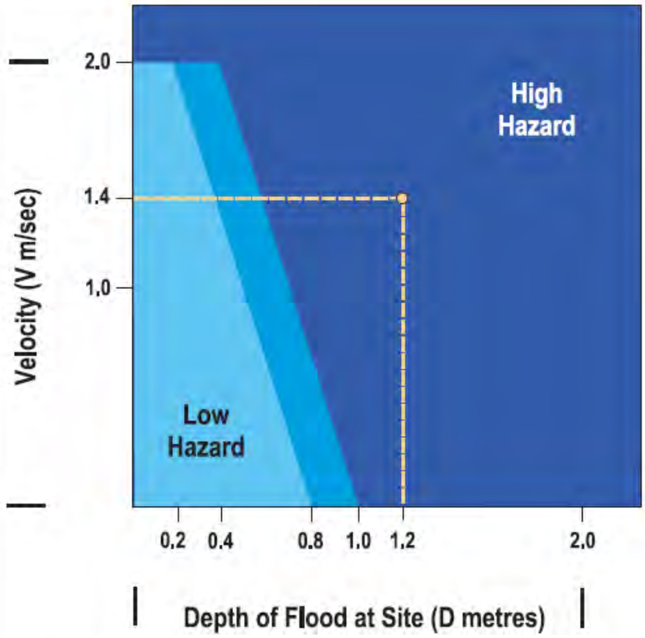
Flood hazard effectively defines the impact that flooding will have on development and people across different sections of the floodplain.

The determination of flood hazard at a particular location requires consideration of a number of factors, including (NSW Government, 2005):

- depth and velocity of floodwaters;
- size of the flood;
- effective warning time;
- flood awareness;
- rate of rise of floodwaters;
- duration of flooding; and
- potential for evacuation.

Consideration of all of the above items is generally completed as part of the Floodplain Risk Management Study. The scope of the Flood Study typically only requires a provisional estimate of the flood hazard to be determined. The provisional flood hazard is based solely on the depth and velocity of floodwaters.

The provisional flood hazard at a particular area of a floodplain can be established from **Figure L2** of the *'Floodplain Development Manual'* (NSW Government, 2005). This figure is reproduced on the right.



Notes

The degree of hazard may be either -

- reduced by establishment of an effective flood evacuation procedure.
- increased if evacuation difficulties exist.

In the transition zone highlight by the median colour, the degree of hazard is dependant on site conditions and the nature of the proposed development.

Example:

If the depth of flood water is **1.2 m**
and the velocity of floodwater is **1.4 m/sec**
then the provisional hazard is **high**

FIGURE L2 - Provisional Hydraulic Hazard Categories

As shown in **Figure L2**, the *'Floodplain Development Manual'* (NSW Government, 2005) divides hazard into two categories, namely high and low. It also includes a "transition zone" between the low and high hazard categories. Sections of the floodplain located in the "transition zone" may be classified as either high or low depending on site conditions or the nature of any proposed development.

6.1.1 Provisional Flood Hazard

The TUFLOW hydraulic software was used to automatically calculate the variation in provisional flood hazard across the Nattai Ponds catchment based on the criteria shown in Figure L2. The hazard categories for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events as well as the PMF are shown in **Figures 22.1** to **28.8** inclusive.

It needs to be reinforced that the hazard represented in this mapping is provisional only. This is because it is based only on an interpretation of the flood hydraulics and does not reflect the effects of other factors that influence flood hazard.

Accordingly, modification of the hazard categories presented in **Figures 22.1** to **28.8** inclusive may occur as part of investigations to be carried out during the subsequent Floodplain Risk Management Study.

6.2 Hydraulic Categories

The NSW Government's *'Floodplain Development Manual'* (NSW Government, 2005) also characterises flood prone areas according to the hydraulic categories presented in **Table 24**. The hydraulic categories provide an indication of the potential for development across different sections of the floodplain to impact on existing flood behaviour and highlights areas that should be retained for the conveyance and storage of floodwaters.

6.2.1 Adopted Hydraulic Categories

Unlike provisional hazard categories, the *'Floodplain Development Manual'* (NSW Government, 2005) does not provide explicit quantitative criteria for defining hydraulic categories. This is because the extent of floodway, flood storage and flood fringe areas are typically specific to a particular catchment.

However, the *'Floodplain Development Manual'* (NSW Government, 2005) does provide qualitative guidelines to assist in the delineation of hydraulic categories. The *'Floodway Definition'* guideline (Department of Environment and Climate Change, 2007) also provides additional guidance for the definition of floodway extents. These qualitative guidelines are also summarised in **Table 24**.

The results of the design flood simulations were interrogated to assess the potential extent of floodway, flood storage and flood fringe areas based on the qualitative guidelines listed in **Table 24**. Preliminary hydraulic category boundaries were delineated by hand across different areas of the Nattai Ponds catchment. The extent of each preliminary hydraulic category boundary was superimposed on peak depth, flow velocity and velocity-depth product values to determine if the hydraulic categories could be defined numerically. The results of this assessment determined that the depth, velocity and velocity-depth product values listed in the third column of **Table 24** could be used to automate the delineation of hydraulic categories for the Nattai Ponds catchment. Some additional post processing of the hydraulic categories was completed to ensure continuity of floodways and to remove small, isolated categories.

Table 24 Qualitative and Quantitative Criteria for Hydraulic Categories

Hydraulic Category	Qualitative Description	Adopted Criteria*
Floodway	• those areas where a significant volume of water flows during floods • often aligned with obvious natural channels and drainage depressions • they are areas that, even if only partially blocked, would have a significant impact on upstream water levels and/or would divert water from existing flowpaths resulting in the development of new flowpaths. • they are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.	• V x D > 0.25 m^2/s
Flood Storage	• those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood • if the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. • substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.	• Not floodway and depth ≥0.15 m
Flood Fringe	• the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. • development (e.g., filling) in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.	• Not floodway and depth <0.15 m

NOTES: V = Velocity, D = Depth
Hydraulic categories were only applied to areas subject to inundation (i.e., D > 0.1m)
**The adopted criteria were developed specifically for the Nattai River Catchment only and may not be appropriate for any other areas.*

Flood storage areas were then defined as those areas located outside of floodways but where the depth of inundation was greater than 0.15 metres. This aimed to identify areas where a significant amount of flow was not necessarily conveyed, however, the depths of water indicate a significant amount of storage capacity was being provided.

The resulting hydraulic category maps for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events as well as the PMF are shown in **Figures 29.1** to **35.8** inclusive.

6.2.2 Verification of Hydraulic Categories

Floodway

In order to verify the suitability of the delineated floodways, additional checks were performed in accordance with recommendations outlined in the DECC *'Floodway Definition'* guideline. This involved partial blockage of the delineated floodways and quantifying the impact that this encroachment had on peak flood levels (through the preparation of flood level difference mapping) as well as the distribution of floodwaters in the vicinity of the encroachment. The outcomes of this assessment are presented in **Plates 17, 18** and **19**.

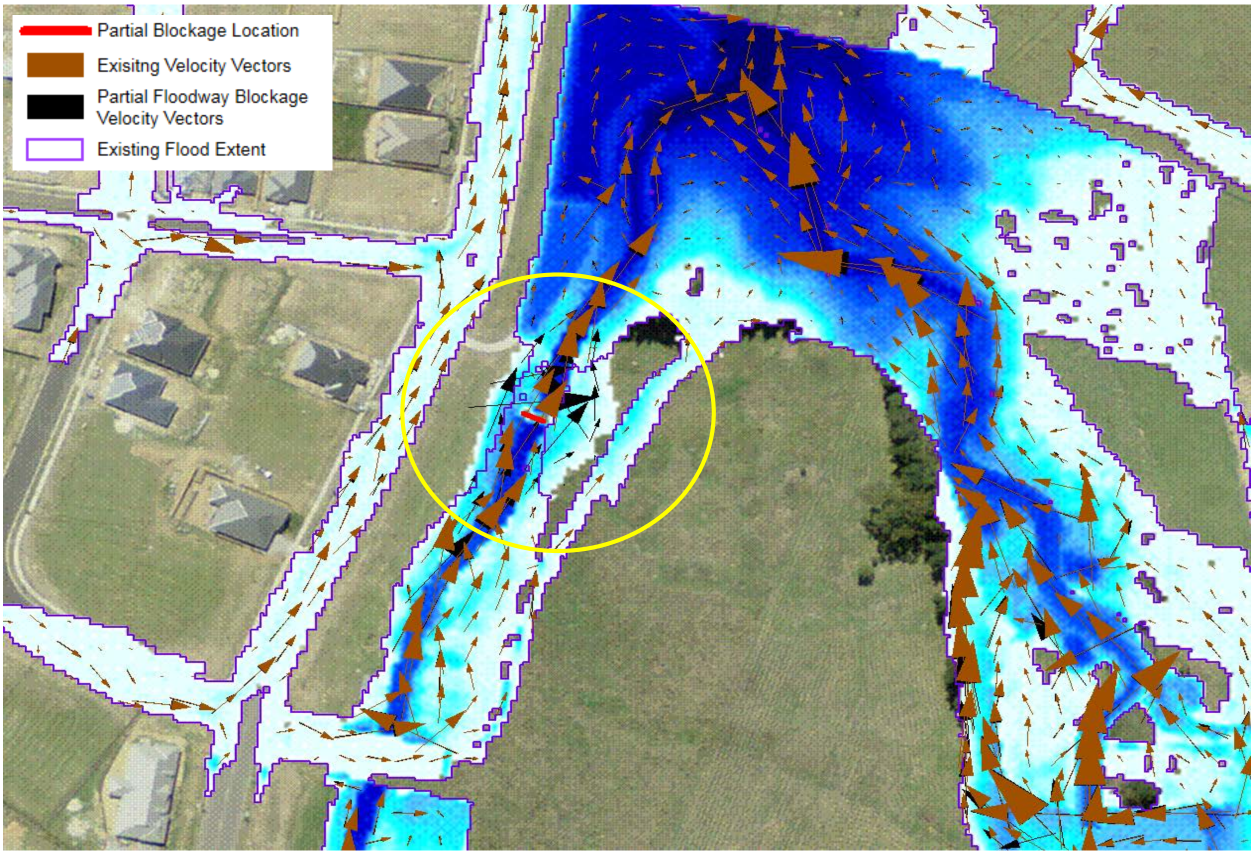


Plate 17 Predicted Peak 1% AEP Flood Depth and Velocities with Partial Blockage of Floodway. Blockage location is highlighted by yellow circle.

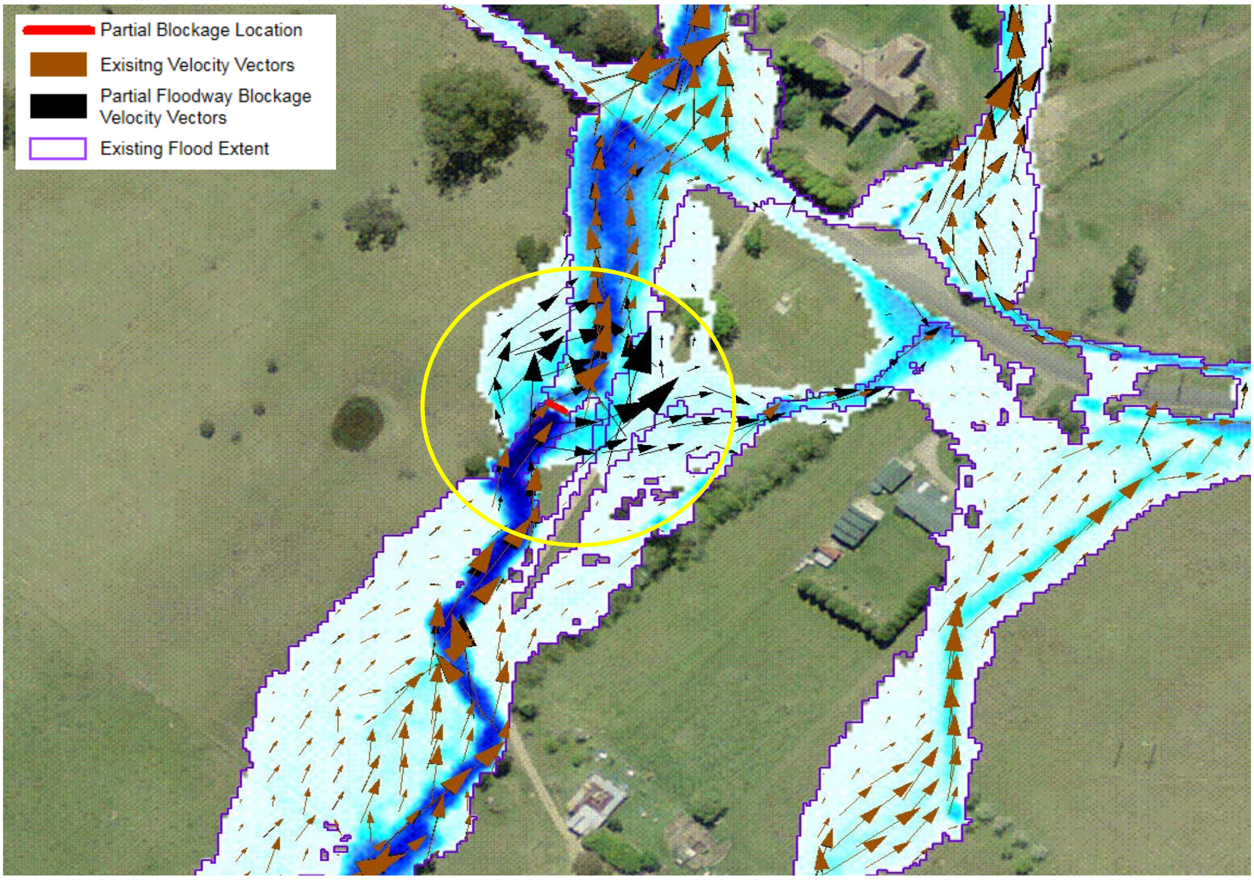


Plate 18 Predicted Peak 1% AEP Flood Depth and Velocities with Partial Blockage of Floodway. Blockage location is highlighted by yellow circle.

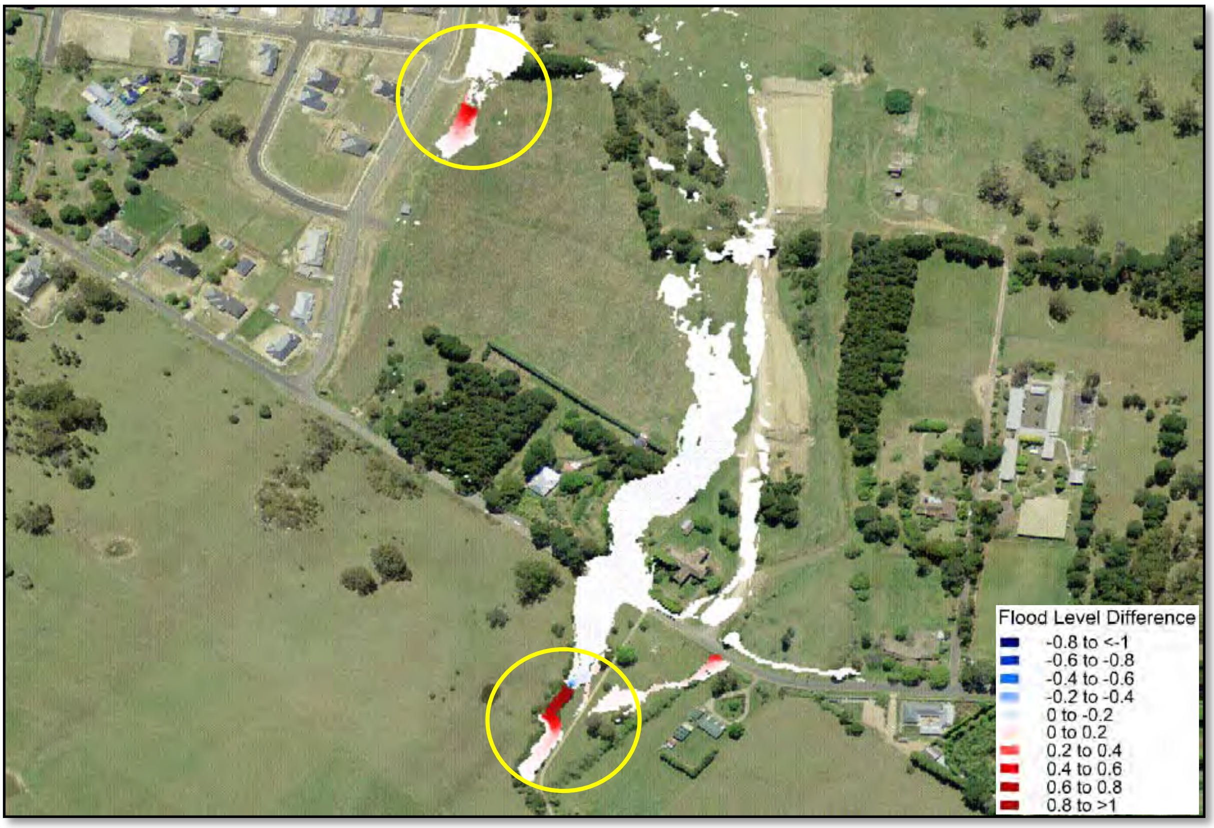


Plate 19 Predicted Change in Peak 1% AEP Flood Levels with Partial Blockage of Floodways (blockage locations highlighted by yellow circles)

The flood level difference mapping presented in **Plate 19** shows that partial encroachment of the delineated floodway extents would increase peak flood levels in the vicinity of the encroachment by over 0.5 metres in the immediate vicinity of the blockage. This is considered to be a "significant impact" on upstream water levels.

Plates 17 and **18** also show that the encroachment would cause a significant redistribution of floodwaters (refer velocity vectors). That is, a significant proportion of floodwaters would be forced into areas that were not previously conveying a significant amount of the total flow.

The results shown in **Plates 17, 18** and **19** are considered to be consistent with the qualitative floodway descriptions outlined in the *'Floodway Definition'* guideline and indicate that the delineated floodway extents are reasonable.

Flood Storage/Flood Fringe

The *"Floodplain Development Manual"* (NSW Government, 2005) states that flood storage and flood fringe areas are those that are important for the temporary storage of water during the passage of a flood. Therefore, they are areas that are typically exposed to slow moving water.

The suitability of the delineated flood storage and flood fringe areas was verified by increasing the Manning's "n" value assigned to storage/fringe areas ("n" = 0.2) and re-simulating the 1% AEP flood. The results of the simulations were then reviewed to determine if the increases in Manning's' "n" produced an unacceptable increase in 1% AEP flood level. This was quantified by preparing flood level difference mapping, which is presented in **Plates 20** and **21** at select locations across the Nattai Ponds catchment.

Plate 20 Predicted Change in Peak 1% AEP Flood Levels with increase in Manning's 'n' across flood storage/fringe areas (hatched) in the upper area of the Renwick development

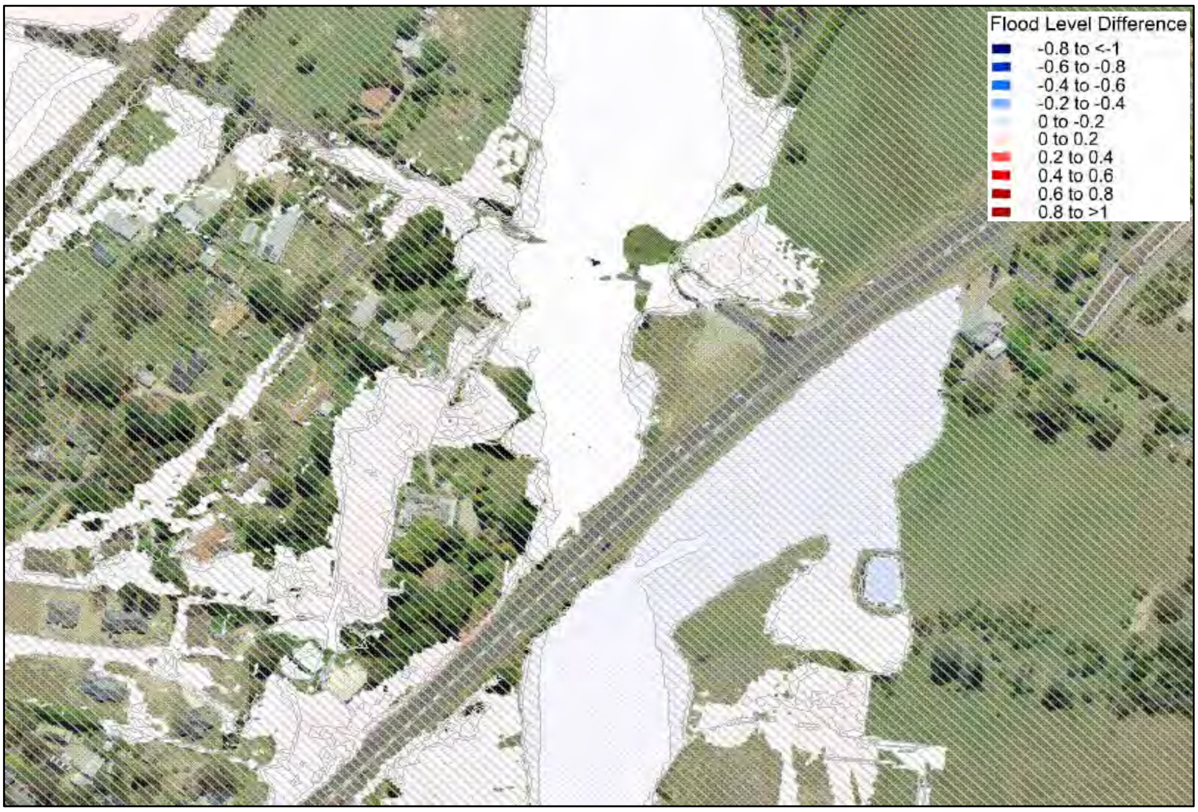


Plate 21 Predicted Change in Peak 1% AEP Flood Levels with increase in Manning's 'n' across flood storage/fringe areas (hatched) in vicinity of the Old Hume Highway

The difference mapping indicates that increasing the roughness of all flood storage as well as flood fringe areas will increase peak 1% AEP flood levels by less than 0.3 metres. In most cases, the increases in peak 1% AEP flood level are around 0.1 metres. Given the significant increase in Manning's 'n' across the flood storage/fringe areas, it is considered that increases in peak flood level of this magnitude are reasonable. Accordingly, it is suggested the extent of the food storage and flood fringe areas is appropriate.

6.3 Flood Risk Precincts

Wingecarribee Shire Council's Development Control Plan (DCP) No. 34, titled *'Managing our Flood Risks'*, outlines Council's requirements for development on all floodplains within the Local Government Area. This includes the floodplain of the Nattai Ponds catchment.

Section 2.3 of the DCP, introduces the concept of "Flood Risk Precincts", which subdivides the floodplain accordingly to the potential flood hazard/risk. This flood risk precinct classification, in turn, determines which development controls are applicable for a particular parcel of land. The four flood risk precincts that are documented in the DCP are summarised in **Table 25**.

Table 25 Flood Risk Precinct Definitions

Flood Risk Precinct	Description
High	This Precinct contains that land below the 1% AEP flood that is either subject to a high hydraulic hazard or where there are significant evacuation difficulties. The high flood risk precinct is where high flood damages, potential risk to life, and evacuation problems would be anticipated or development would significantly and adversely affect flood behaviour. Most development should be restricted in this precinct. In this precinct, there would be a significant risk of flood damages without compliance with flood related building and planning controls.
Medium	This Precinct contains that land below the 1% AEP flood that is not subject to a high hydraulic hazard and where there are no significant evacuation difficulties. In this precinct there would still be a significant risk of flood damage, but these damages can be minimised by the application of appropriate development controls.
Fringe-Low	This Precinct contains that land between the extents of the 1% AEP flood and the 1% AEP flood plus 0.5m in elevation (being a freeboard). In this precinct there would still be a significant risk of flood damage, but these damages can be minimised by the application of appropriate development controls.
Low	This Precinct contains that land within the floodplain (i.e. within the extent of the probable maximum flood) but not identified within any of the above Flood Risk Precincts. The Low Flood Risk Precinct is where risk of damages is low for most land uses and most land uses would be unrestricted within this precinct.

To aid Council in defining the spatial variation in flood risk precincts across the Nattai Ponds catchment, a Flood Risk Precinct map was prepared based on the outcomes of the design flood simulations and provisional hazard mapping and is shown in **Figures 36.1** to **36.8** inclusive.

7 Climate Change Assessment

7.1 General

Climate change refers to a significant and lasting change in weather patterns arising from both natural and human induced processes. The Office of Environment and Heritage's (formerly Department of Environment, Climate Change and Water) *'Practical Consideration of Climate Change'* states that climate change is expected to have adverse impacts on sea levels and rainfall intensities in the future.

Although increases in sea level are not predicted to have an impact on flood behaviour across the Nattai Ponds catchment, increases in rainfall intensities would produce increases in runoff volumes across the catchment. This, in turn, would likely produce an increase in the depth, extent and velocity of floodwaters.

This flood study will form the basis for defining flood behaviour for a number of years into the future. It will also form the basis for the future Floodplain Risk Management Study, where a range of flood risk mitigation measures will be evaluated. Therefore, it is important that potential climate change impacts are quantified so that development decisions and the robustness of flood risk mitigation measures can be assessed in an informed manner.

The following sections describe the process that was employed to quantify climate change impacts on flooding across the Nattai Ponds Catchment.

7.2 Hydrology

7.2.1 General

The *'Practical Consideration of Climate Change'* (Department of Environment and Climate Change, 2007) guideline states that rainfall intensities are predicted to increase in the future. The NSW Government's *'Climate Change in the Sydney Metropolitan Catchments'* (CSIRO, 2007) elaborates on this further and suggests that annual rainfall is likely to decrease, however, extreme rainfall events are likely to more intense. It is anticipated that extreme rainfall intensities could increase by between 2% and 24% by 2070 (Department of Environment and Climate Change, 2007).

Due to the wide potential variability of future rainfall intensities, the *'Practical Consideration of Climate Change'* (Department of Environment and Climate Change, 2007) provides guidelines for quantifying the potential impacts of these changes. The guideline states that additional simulations should be completed with 10%, 20% and 30% increases in rainfall intensities to quantify the potential impacts associated with climate change.

7.2.2 Results

The XP-RAFTS model was used to perform additional simulations incorporating increases in 1% AEP rainfall intensity of 10%, 20% and 30% in accordance with the OEH guideline. Peak discharges were extracted from the results of each climate change simulation and are summarised in **Appendix J**. XP-RAFTS discharges for "existing" conditions are also included in **Appendix J** for comparison.

The results provided in **Appendix J** show that a 10% increase in peak 1% AEP design rainfall intensities will increase peak 1% AEP discharges by 13%, on average. The results also show that a 20% and 30% increase in design rainfall intensities will increase average peak 1% AEP discharges by about 27% and 40% respectively. Accordingly, increases in rainfall intensity of this magnitude have the potential to cause significant increases in flood discharges across the catchment.

7.3 Hydraulics

7.3.1 Results

The revised 1% AEP flows were also applied to the TUFLOW model to determine the impact that the rainfall intensity increases may have on peak 1% AEP flood levels. The revised 1% AEP water levels were extracted from the results of the modelling and were compared against peak flood levels for "base" design conditions to develop flood level difference mapping. The flood level difference mapping is provided in **Plates 22**, **23** and **24**.

The difference mapping was also statistically analysed to determine the magnitude of changes in peak 1% AEP water levels across the catchment and these are presented in **Table 26**. As shown in **Table 26**, the flood level differences are reported as a series of percentiles. For example, the 10% increase in rainfall 90th percentile value of 0.16 metres indicates that 90% of the inundated areas are predicted to be exposed to changes in existing 1% AEP flood level of less than or equal to 0.16 metres.

The results show that a 10% increase in peak 100 year ARI design rainfall intensities will typically increase peak 1% AEP flood levels by less than 0.04 metres (50th percentile value), although some localised increases in excess of 0.24 metres (99th percentile) are predicted at some locations.

The results also show that 20% and 30% increases in design rainfall intensities are predicted to increase median 1% AEP flood levels by 0.13 metres and 0.19 metres respectively. The 30% increase in rainfall intensity scenario also has the potential to increase flood levels by over 0.8 metres at some locations. As shown in **Plates 23** and **24** the most significant changes in flood level are concentrated upstream of structures (i.e., bridges and culverts).

Accordingly, it can be concluded that while extreme increases in rainfall intensity could be expected to have significant impacts on flood severity across much of the catchment, the impacts of modest increases in intensity are likely to lie within the typical freeboard allowance made for them

Table 26 Impact of Rainfall Intensity Increases on 1% AEP Flood Levels

Climate Change Scenario	Percentile Change in "Design" 1% AEP Flood Levels (metres)								
	1st	5th	10th	25th	50th	75%	90th	95th	99th
10% Increase in Rainfall	0.00	0.01	0.01	0.02	0.04	0.07	0.16	0.22	0.24
20% Increase in Rainfall	0.01	0.02	0.02	0.04	0.09	0.14	0.32	0.49	0.51
30% Increase in Rainfall	0.01	0.02	0.03	0.06	0.13	0.22	0.53	0.79	0.82

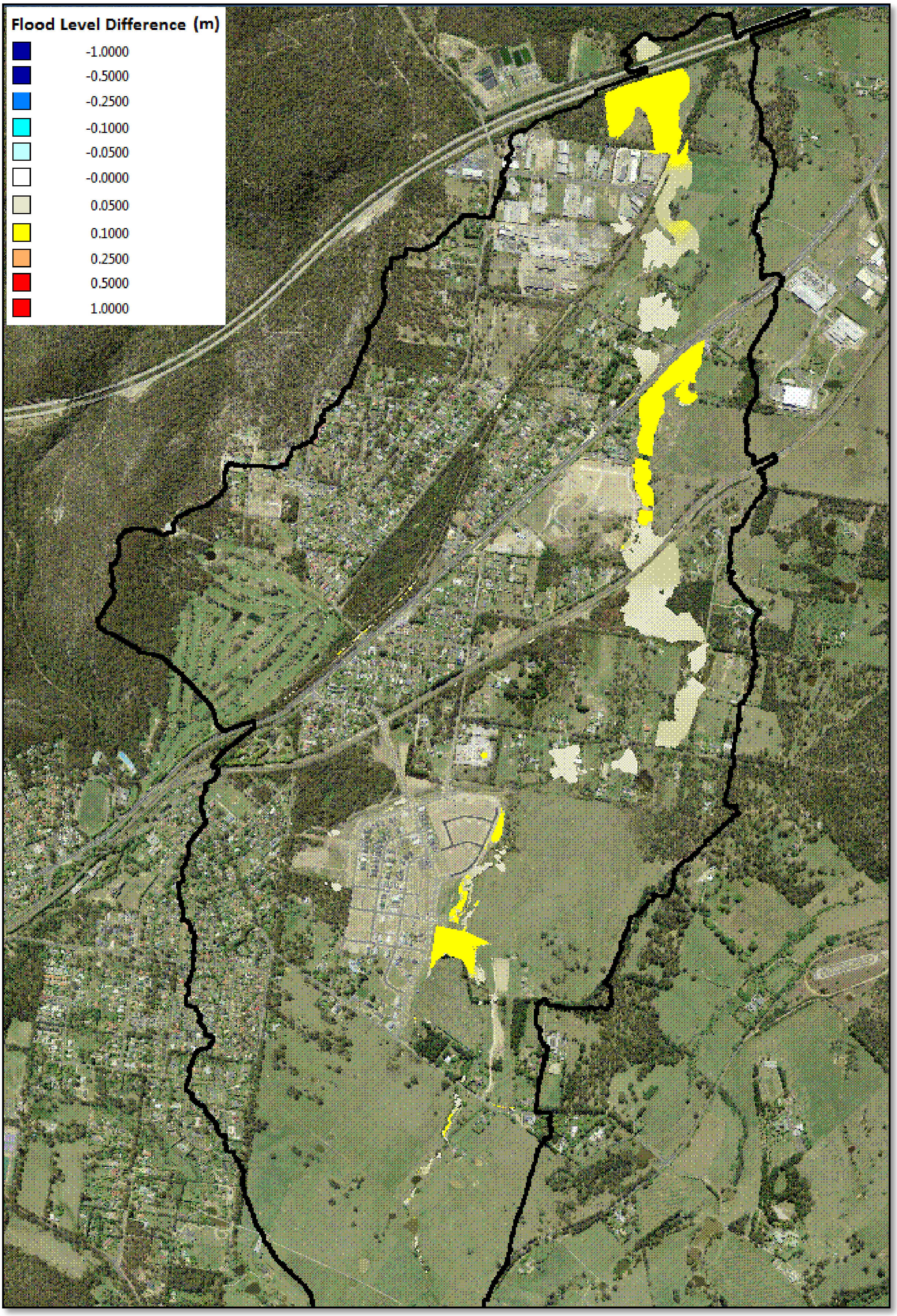


Plate 22 Flood level difference map with 10% Increase in Rainfall Intensity

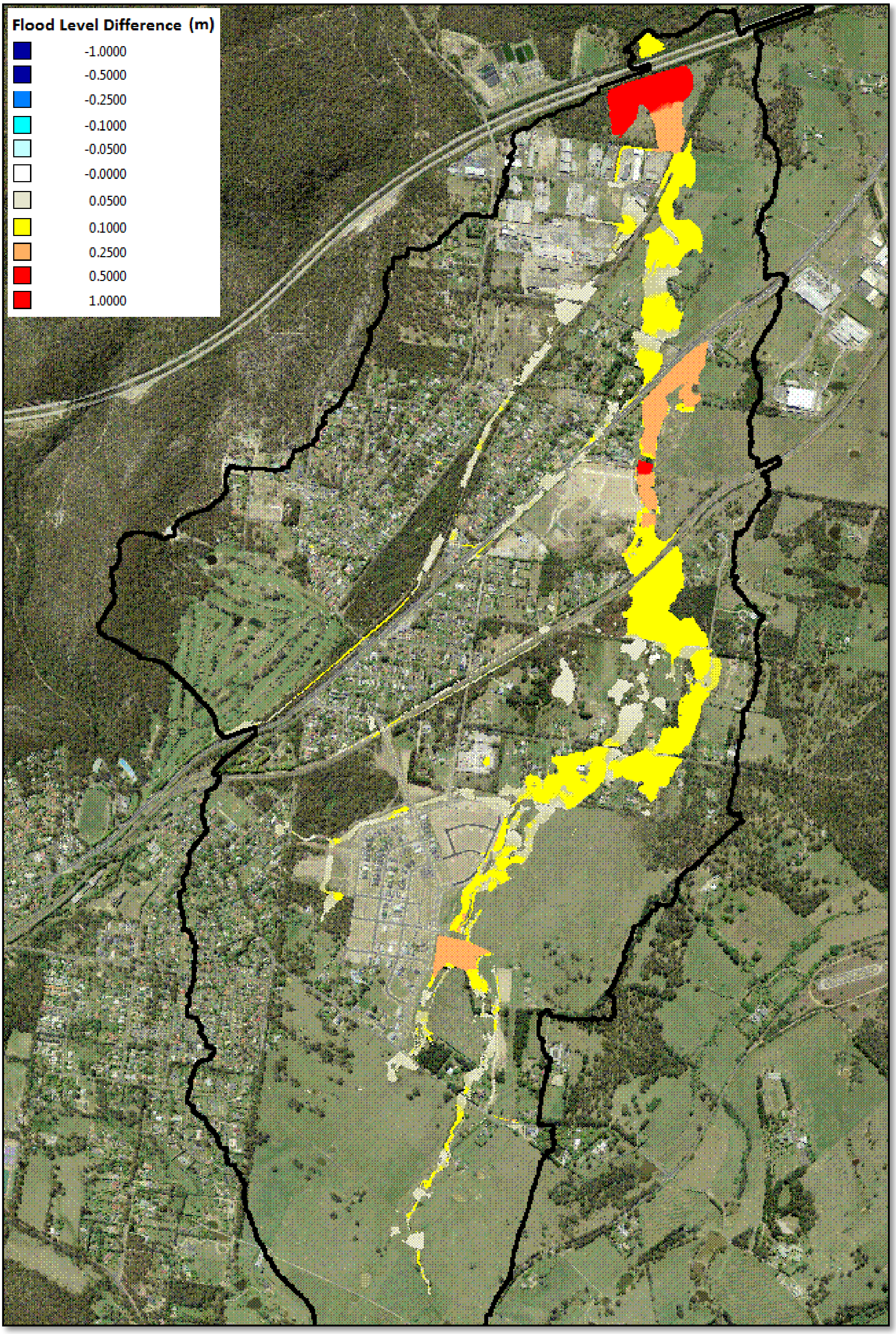


Plate 23 Flood level difference map with 20% Increase in Rainfall Intensity

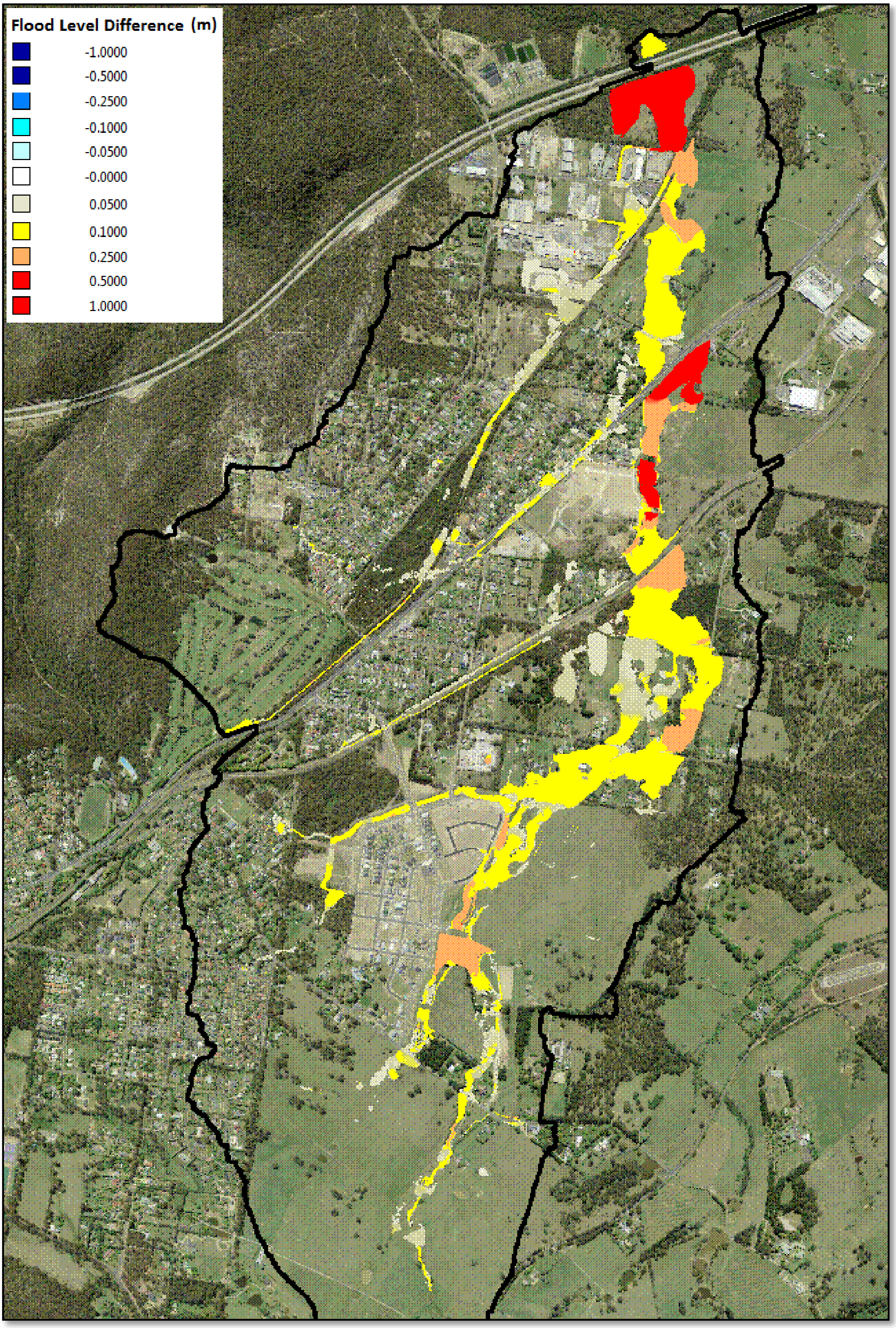


Plate 24 Flood level difference map with 30% Increase in Rainfall Intensity

8 SENSITIVITY ANALYSIS

8.1 General

Hydrologic and hydraulic computer models require the estimation of several parameters that are not necessarily known with a high degree of certainty. Each of these parameters can impact on the results generated by the model.

Typically, hydrologic and hydraulic computer models are calibrated using recorded rainfall, stream flow and/or flood mark information. Calibration is achieved by adjusting the parameters that are not known with a high degree of certainty until the computer models reproduce the recorded flood information.

As discussed in Sections 3.3 and 4.3, the XP-RAFTS hydrologic and TUFLOW hydraulic models developed for this study could not be comprehensively calibrated as there was insufficient recorded stream flow information. However, the models were verified against floods that occurred in 2007, 2014 and 2015 and were found to provide a reasonable description of historic flood behaviour.

Nevertheless, it is important to understand how any uncertainties in model input parameters may impact on the results produced by the model. Therefore, a sensitivity analysis was undertaken to establish the sensitivity of the results generated by the computer model to changes in model input parameter values. The outcomes of the sensitivity analysis are provided below.

8.2 Model Parameter Sensitivity

8.2.1 Initial Loss / Antecedent Conditions

An analysis was undertaken for the 1% AEP storm to assess the sensitivity of the results generated by the XP-RAFTS model to variations in antecedent wetness conditions (i.e., the dryness or wetness of the land within the catchment prior to the design storm event). A catchment that has been saturated prior to a major storm will have less capacity to absorb rainfall. Therefore, under wet antecedent conditions, there will be less "loss" of rainfall and consequently more runoff.

The variation in antecedent wetness conditions was represented by modifying the adopted initial rainfall losses in the XP-RAFTS model. Specifically, initial losses were changed from the "design" values of 10mm/1mm (for pervious/impervious areas respectively) to:

- <u>"Wet" catchment</u>: 0mm for pervious and impervious areas; and,
- <u>"Dry" catchment</u>: 20mm for pervious areas and 2mm for impervious areas

The XP-RAFTS model was used to re-simulate the 1% AEP event with the modified initial losses. Peak 1% AEP discharges were extracted from the results of the updated model runs and are summarised in **Appendix K**.

The results of the initial loss sensitivity analysis show that decreasing the initial losses would increase the peak 1% AEP discharges generated by 11%, on average. Increasing the initial loss would decrease peak discharge by 14% (on average).

The revised 1% AEP flows were also applied to the TUFLOW model to determine the impact that changes to the initial losses would have on "design" 1% AEP flood levels/depths. Accordingly, the TUFLOW model with the modified flows was used to re-simulate the 1% AEP flood. Water levels were extracted from the results of the revised modelling and were compared against peak water flood levels for "base" design conditions. This allowed water level difference mapping to be prepared showing the magnitude of any change in water levels/depths associated with the change in initial loss values.

The difference mapping is presented in **Plate 25** and **26** for the "dry" and "wet" catchment scenarios respectively. Decreases in 1% AEP "design" flood levels are shown in shades of blue and increases in 1% AEP flood levels are shown in shades of yellow/red.

The difference mapping was also statistically analysed to determine the magnitude of changes in peak 1% AEP water levels across the catchment. The outcomes of this statistical assessment are provided in **Table 27**.

Table 27 Impact of Changes to TUFLOW Model Input Parameters on 1% AEP Flood Level

Sensitivity Analysis		**Percentile Change in "Design" 1% AEP Flood Levels** (metres)								
		1st	**5th**	**10th**	**25th**	**50th**	**75%**	**90th**	**95th**	**99th**
Initial Loss	Perv IL = 0 mm Imperv. IL = 0 mm	0.00	0.01	0.01	0.02	0.03	0.06	0.13	0.19	0.20
	Perv IL = 20 mm Imperv. IL = 2 mm	-0.47	-0.16	-0.13	-0.05	-0.03	-0.01	-0.01	0.00	0.00
Continuing Loss Rate	Perv CL = 1.5 mm/hr Imperv. CL = 0 mm/hr	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.03
	Perv CL = 3.5 mm/hr Imperv. CL = 1.0 mm/hr	-0.04	-0.03	-0.03	-0.01	0.00	0.00	0.00	0.00	0.00
Manning's 'n'	-20%	-0.18	-0.10	-0.08	-0.06	-0.03	-0.01	0.00	0.05	0.06
	+20%	-0.04	-0.03	0.00	0.01	0.02	0.05	0.07	0.08	0.13
Riparian Corridor Rehabilitation		-0.04	-0.03	-0.01	0.00	0.00	0.01	0.05	0.11	0.23
Stormwater & Structure Blockage	No Blockage	-0.17	-0.05	-0.02	-0.01	0.00	0.01	0.02	0.02	0.04
	Complete Blockage	-0.62	-0.21	-0.04	0.00	0.05	0.71	2.13	2.43	3.33
Downstream Boundary	-20%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
	+20%	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The difference mapping shows that a lower initial loss value will produce increases in 1% AEP flood levels that are primarily concentrated along the main creek lines and areas where a significant volume of floodwater is stored. Conversely, the higher initial loss values will generate decreases in 1% AEP water levels that are again concentrated along the main creek lines, and major storage areas. The magnitude of the differences is typically less than 0.05 metres with the median (i.e., 50^{th} percentile) difference being ±0.03 metres. The most significant differences are predicted to occur in the vicinity of major bridges and culverts.

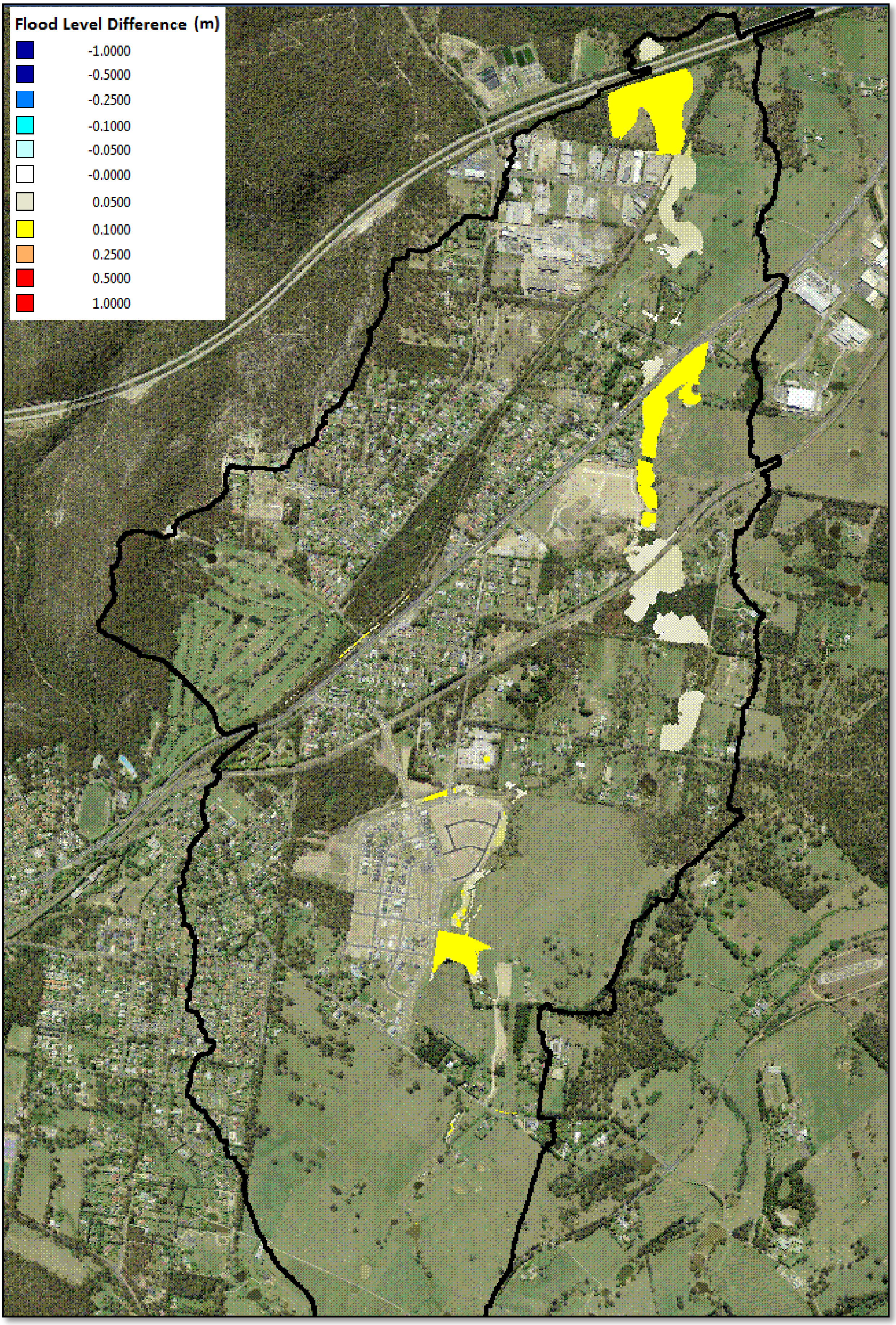


Plate 25 Flood level difference map for the “wet” catchment sensitivity simulation

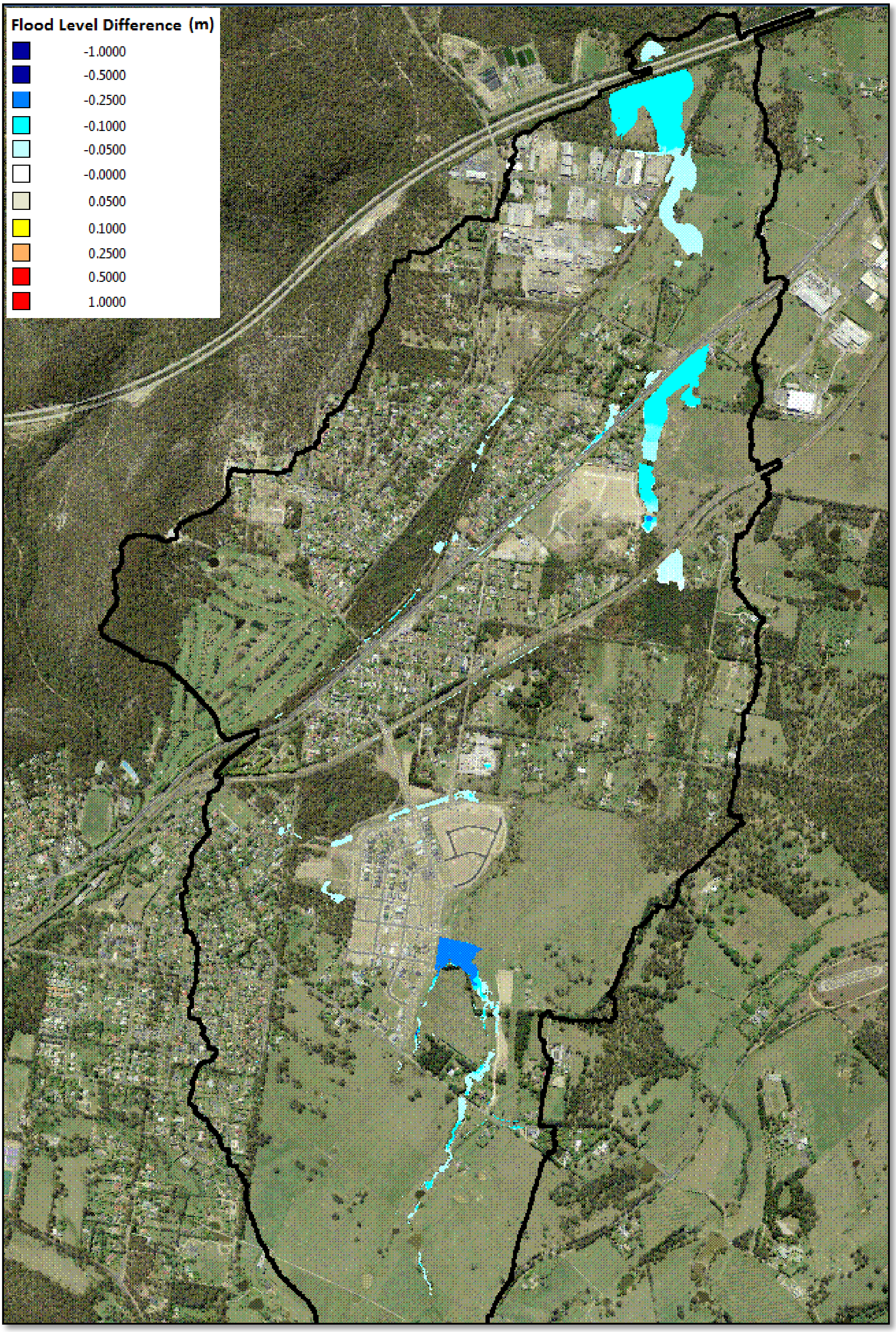


Plate 26 Flood level difference map for the “dry” catchment sensitivity simulation

Overall, it can be concluded that the model is somewhat sensitive to changes in the adopted initial losses. *'Australian Rainfall & Runoff'* (Engineers Australia, 1987) suggests adopting an initial loss of between 10 mm and 30 mm for design flood estimation. The adopted initial loss of 10 mm is at the lower end of the suggested range and would, therefore, provide reasonably conservative design flood level estimates.

8.2.2 Continuing Loss Rate

An analysis was also undertaken to assess the sensitivity of the results generated by the XP-RAFTS and TUFLOW models to variations in the adopted continuing loss rates. Accordingly, the continuing loss rates within the models were changed from the “design” values of 2.5 mm/hr (pervious areas) and 0 mm/hr (impervious areas) to:

- Increased Continuing Loss Rates: 3.5mm/hr for pervious areas and 1mm/hr for impervious areas.
- Decreased Continuing Loss Rates: 1.5mm/hr for pervious areas and 0mm/hr for impervious areas.

The XP-RAFTS model was used to re-simulate the 1% AEP event with the modified continuing losses. Peak 1% AEP discharges were extracted from the results of the updated model runs and are summarised in **Appendix K**.

The results presented in **Appendix K** shows that increasing the continuing loss rates will decrease peak 1% AEP flows by 1% (on average) and decreasing the initial loss rates will increase peak 1% AEP flows by 1% (on average). Accordingly, the XP-RAFTS model appears to be relatively insensitive to changes in continuing loss rates.

The revised flow estimates were also applied to the TUFLOW model was used to re-simulate the 1% AEP flood. Peak flood levels were extracted from the results of the modelling and were used to prepare flood level difference mapping, which were statistically analysed and the outcomes of the analysis are presented in **Table 27**.

The results of the sensitivity analysis show that the TUFLOW model is relatively insensitive to changes in continuing loss rates. More specifically, only relatively small changes in 1% AEP flood levels are predicted with the modified continuing loss rates. In all cases, the 99th percentile change in 1% AEP flood levels are predicted to be less than 0.05 metres.

Therefore, it can be concluded that any uncertainties associated with the adopted continuing loss rates are not predicted to have a significant impact on the results generated by the XP-RAFTS or TUFLOW models.

8.2.3 Manning’s ‘n’

Manning’s’ ‘n’ roughness coefficients are one of the primary hydraulic model inputs and calibration parameters. They are used to describe the resistance to flow afforded by different land uses / surfaces across the catchment. However, they can be subject to considerable variability (e.g., vegetation density in the summer would typically be higher than the winter leading to higher Manning’s ‘n’ values). Therefore, additional analyses were completed to quantify the impact that any uncertainties associated with Manning’s ‘n’ roughness values may have on predicted design flood behaviour.

The TUFLOW model was updated to reflect a 20% increase and a 20% decrease in the adopted design Manning's 'n' values and additional 1% AEP simulations were completed with the modified 'n' values. Flood level difference mapping was prepared based on the results of the revised simulations and are presented in **Plate 27** and **Plate 28**.

The difference maps were also statistically analysed and the outcomes of the analysis are presented in **Table 27**.

The results listed in **Table 27** show that increasing the Manning's 'n' values by 20% will increase peak 1% AEP flood levels by 0.02 metres (median difference), although some changes in excess of 0.13 metres (99th percentile) are predicted at isolated locations. Decreasing the Manning's 'n' values by 20% will decrease peak 1% AEP flood levels by an average of 0.03 metres, although some changes in excess of 0.18 metres (1st percentile) are predicted at isolated locations. In general, increasing the Manning's "n" values will increase peak 1% AEP flood levels and decreasing the "n" value will decrease the peak 1% AEP flood levels.

In general, it is considered that the model is relatively insensitive to changes in Manning's 'n' values.

Riparian Corridor Revegetation

Wingecarribee Shire Council's Environment and Sustainability section are planning to rehabilitate existing creek corridors across the local government area. This potentially includes those falling within the Nattai Ponds catchment. Accordingly, Council was interested in gaining an understanding of the potential impact that rehabilitation/revegetation of the creek lines may have on existing flood behaviour. Accordingly, an additional sensitivity analysis was completed to determine the potential impact of the creek rehabilitation on peak 1% AEP flood levels.

The Wingecarribee Local Environmental Plan (Wingecarribee Shire Council, 2010) outlines riparian buffer zones along each of the major watercourses draining through the Nattai Ponds catchment (refer **Plate 29**). The buffer zones are typically contained 10 metres either side of the main creek banks, although the buffer increases to 30 metres either side of the banks in areas between Gantry Place and the Hume Highway, Braemar. Information provided by Council staff indicates that these riparian buffer zones serve as a guide for revegetation along creeks and rivers on private land (under Council's private land conservation programs) and would serve as a suitable basis for defining the likely extent of future creek rehabilitation works.

Accordingly, the TUFLOW model was updated to reflect rehabilitation of all areas located within the riparian buffer zones where suitable riparian vegetation is not already established. To assist in defining suitable Manning's "n" roughness coefficients for the rehabilitated areas, it was assumed that the rehabilitated creeks would ultimately take a form similar to that shown in **Plate 30**. **Plate 30** shows a main channel with rocks, long grass, reeds and shrubs with an overbank/floodplain comprising dense vegetation / trees. Therefore, the TUFLOW model was updated so that grassed areas along the main channel (defined as the area from top of bank to top of bank) was assigned a "n" value of 0.06 (corresponding to shrubs/reeds) and grassed overbank areas (representing the area from the top of creek bank to the extent of the riparian buffer zone) were assigned an "n" value of 0.1 (reflecting trees). Those creek channels where riparian vegetation is already established were not altered from "existing" conditions.

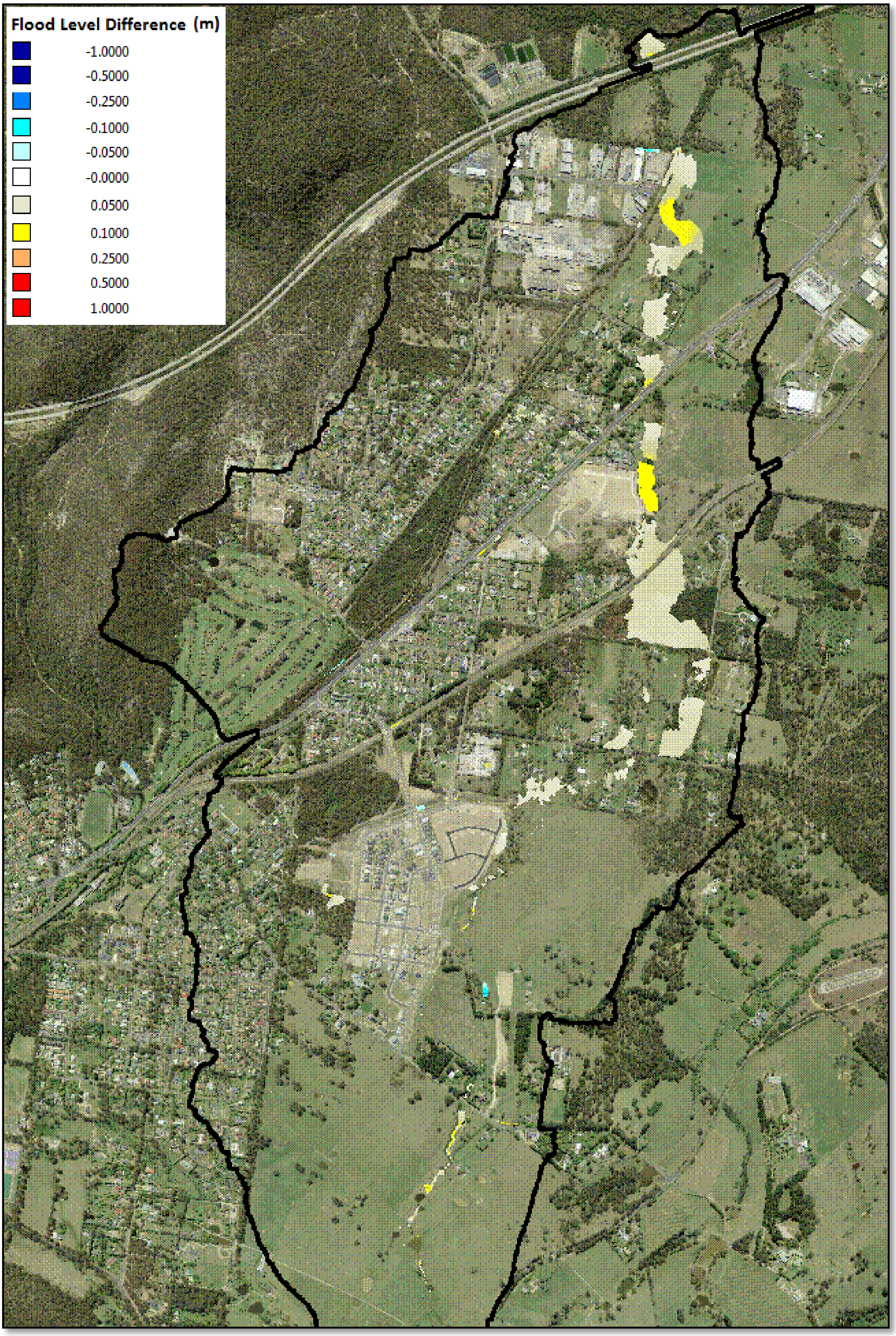


Plate 27 Flood level difference map with increased Manning's "n" roughness values

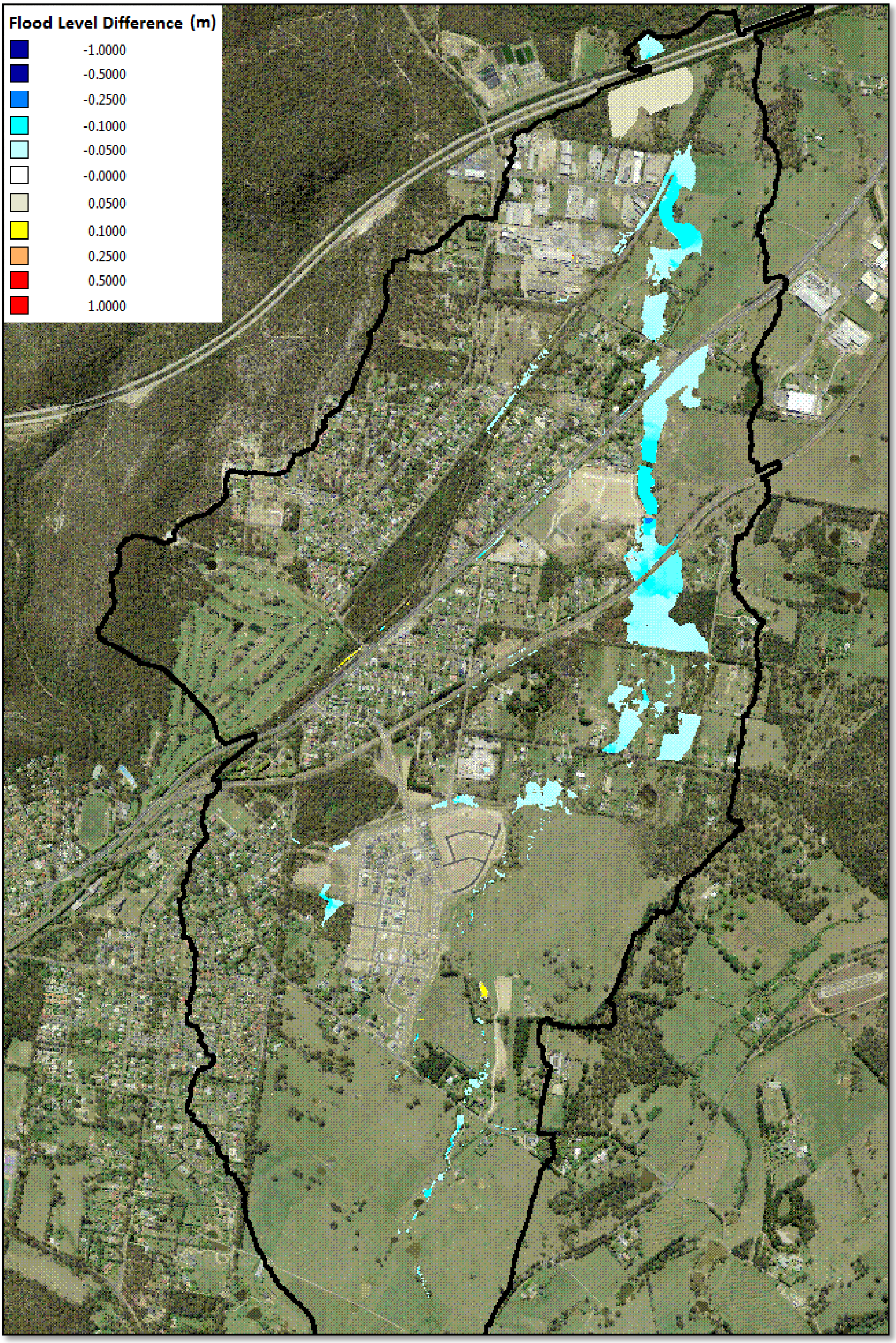


Plate 28 Flood level difference map with decreased Manning's "n" roughness values

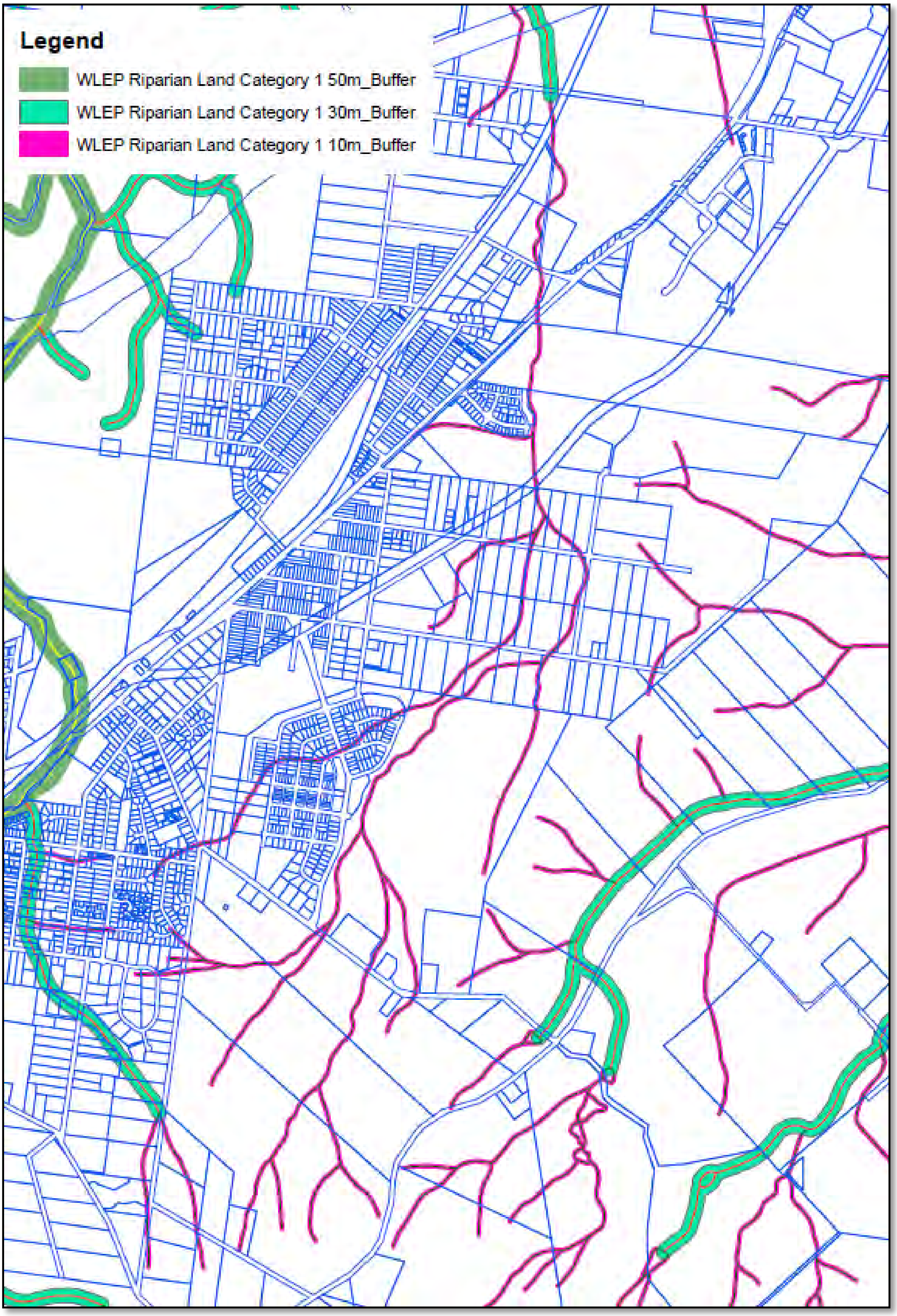


Plate 29 Extract from Local Environmental Plan showing riparian corridors

Plate 30 Image showing rehabilitated channel with established vegetation along the main channel and overbanks (photos courtesy of Catchments & Creeks Pty Ltd).

The updated model was used to re-simulate the 1% AEP flood for post-rehabilitation conditions. Flood level difference mapping was prepared based on the results of the revised simulation and is presented in **Plate 31**. The differences were also statistically analysed and the outcomes of the assessment are included in **Table 27**.

The results indicate that the creek rehabilitation will generate some very small reductions in 1% AEP flood levels across some sections of the catchment. However, for the most part, the rehabilitation is predicted to increase existing 1% AEP flood levels. In general, the increases in flood level are contained within the riparian buffer and are predicted to be less than 0.1 metres. However, the 1% AEP flood level increases are predicted to exceed 0.3 metres in the area east of the Braemar Industrial Area where the riparian corridor width is more significant.

Overall, the rehabilitation of the creeks within the Nattai Ponds catchment has the potential to increase peak 1% AEP flood levels. Although the increases in flood levels are predicted to be less than 0.10 metres across the majority of the catchment, care will need to be exercised during any planned rehabilitation works to ensure that the rehabilitation does not increase the flood liability of existing residential properties. Therefore, it is recommended that a detailed hydraulic assessment is completed in particularly sensitive areas once a final rehabilitation plan is established.

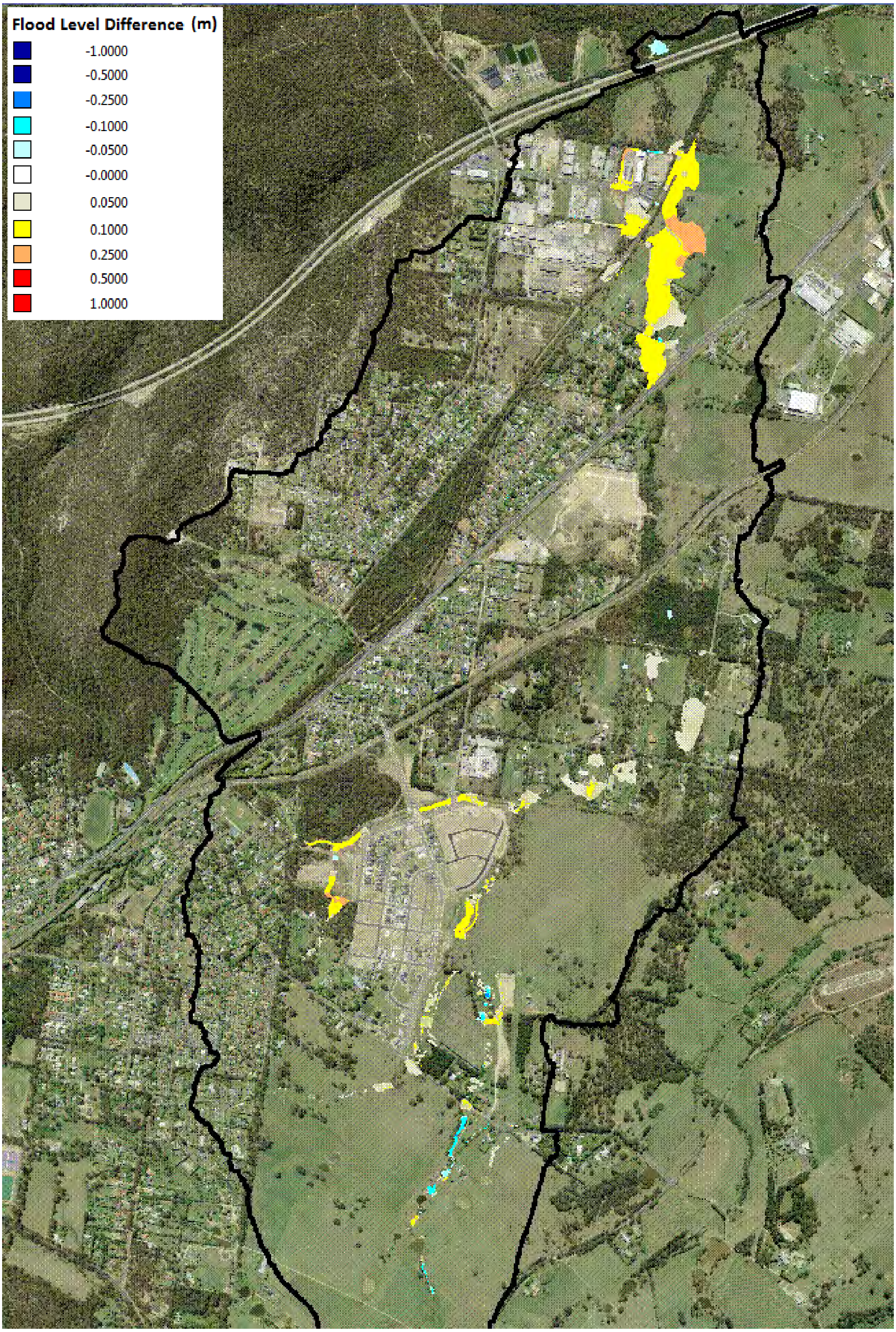


Plate 31 Flood level difference map with riparian corridor rehabilitation

8.2.4 Hydraulic Structure Blockage

As discussed in Section 4.2.4, blockage factors ranging between 0% and 100% were applied to all bridges, culverts and stormwater inlets as part of the design flood simulations. Additional simulations were also completed with no blockage and the results were combined to form the final design flood envelope. However, as it is not known which structures will be subject to what percentage of blockage during any particular flood, additional 1% AEP TUFLOW simulations were completed to determine the impact that alternate blockage scenarios would have on simulated flood behaviour. Specifically, additional simulations were undertaken with no blockage as well as complete blockage of all stormwater inlets, bridges and culverts. Flood level difference mapping was also prepared and is presented in **Plate 32** and **Plate 33**.

The difference maps were also statistically analysed and the outcomes of the analysis are presented in **Table 27**.

Peak floodwater depths and velocity vectors were extracted from the results of the modelling and are presented in **Figures 37.1** to **38.8** inclusive. The predicted extent of inundation for "baseline" conditions is superimposed on **Figures 37.1** to **38.8** for comparison.

Plate 31 shows that no blockage will generally decrease water levels upstream of major hydraulic structures and increase water levels downstream of major hydraulic structures. In general, decreases in 1% AEP flood level are predicted to be less than 0.17 metres (1^{st} percentile) and increases in 1% AEP flood levels are predicted to be less than 0.04 metres (99^{th} percentile).

Plate 32 shows that complete blockage will cause some significant changes to 1% AEP flood levels. 1% AEP flood levels are predicted to increase by over 3.3 metres (99^{th} percentile). There are predicted to be some commensurate decreases in water level downstream of these significant embankments structure and are associated with the “damming” effect provided by the embankment. **Figures 38.5, 38.7** and **38.8** show that the structures most sensitive to blockage include the main railway bridge, the Old Hume Highway culvert and the Hume Highway culvert.

In general, changes to stormwater inlet blockage are not predicted to have a significant impact on 1% AEP water levels across the majority of the urban areas. This is likely associated with the stormwater system only having sufficient capacity to carry a relatively small proportion of the overall flow during a large storm event (such as the 1% AEP flood). Consequently, changes to stormwater inlet blockage generally do not result in a large change in the amount of water travelling overland.

Overall, it is considered that the TUFLOW model is not particularly sensitive to stormwater inlet blockage. However, it should be noted that the stormwater system will convey a significant proportion of flow during more frequent rainfall events. Therefore, it is still important for the stormwater system to be well maintained to ensure it is capable of carrying the majority of flows during these more frequent events.

The results of the blockage sensitivity analysis also show that the model results are sensitive to variations in blockage in the immediate vicinity of major structures, particularly if complete blockage of structures occurs. This outcome emphasises the need to ensure key drainage infrastructure and bridges/culverts are well maintained (i.e., debris is removed on a regular basis).

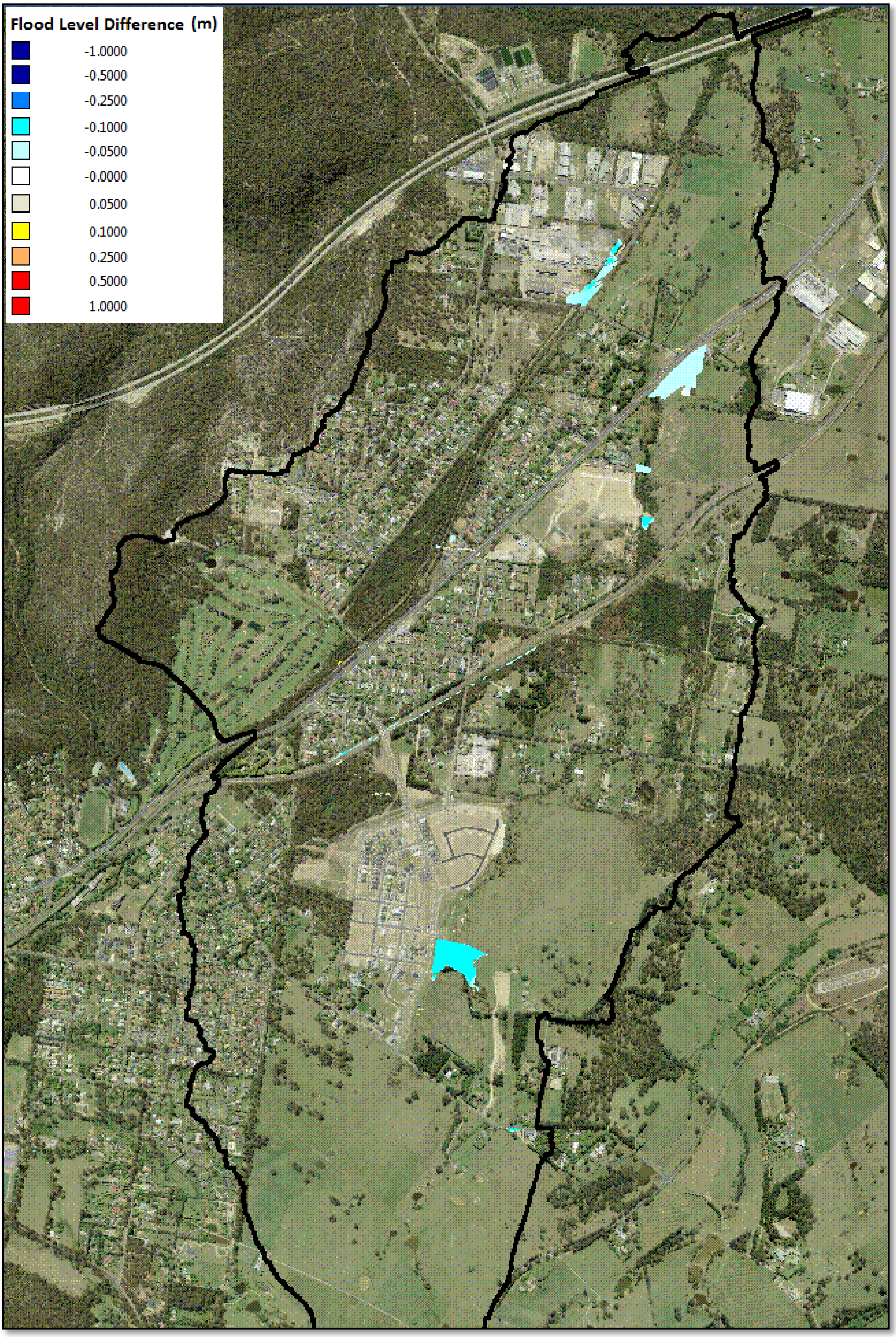


Plate 32 Flood level difference map with no blockage of hydraulic structures

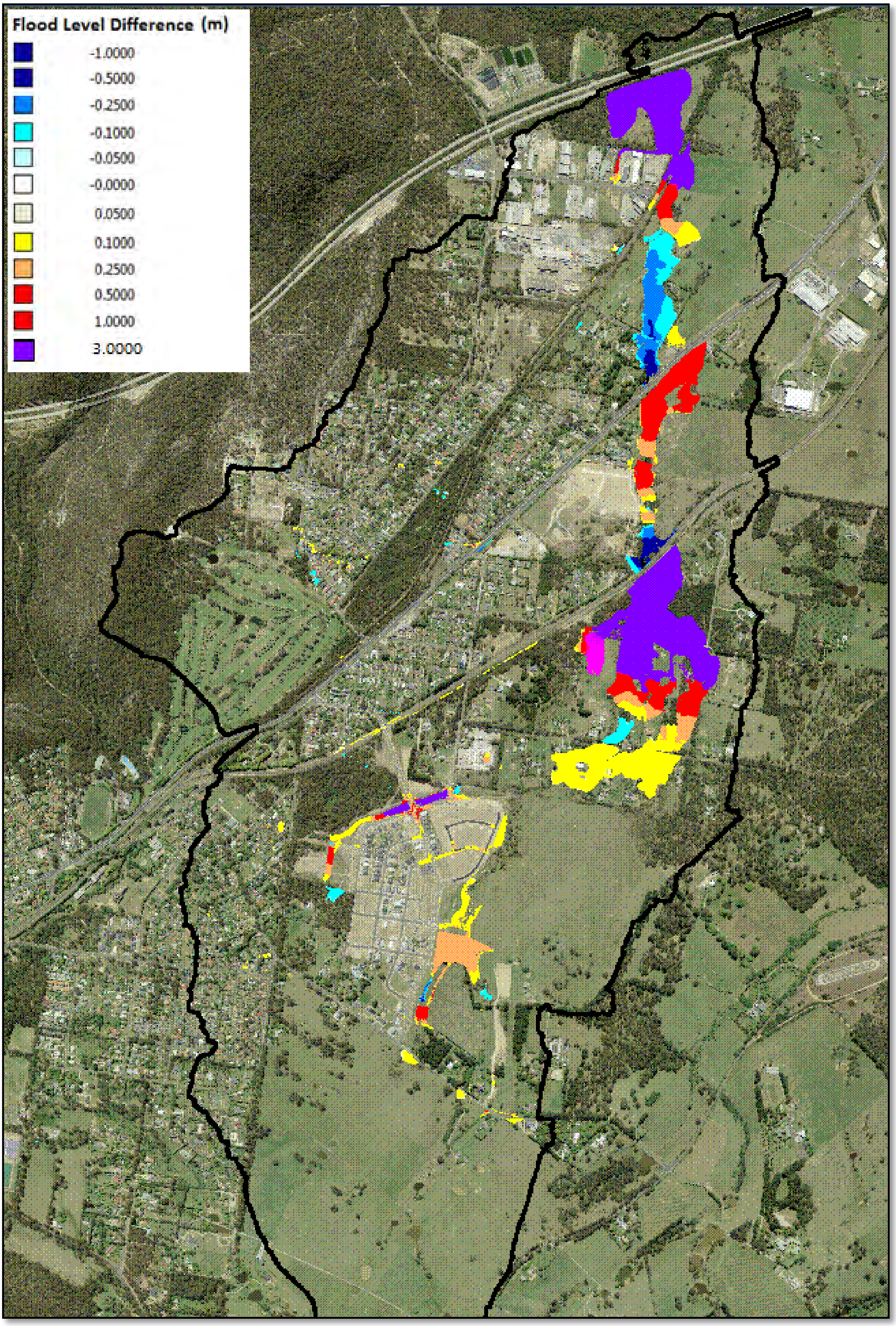


Plate 33 Flood level difference map with complete blockage of hydraulic structures

8.2.5 Downstream Boundary Condition

As discussed in Section 4.3.1, the downstream boundary condition was defined using a 'normal depth' calculation. This requires the specification of a channel slope at the downstream model boundary. Therefore, additional sensitivity simulations were completed to see how variations in the downstream channel slope may impact on model results.

The TUFLOW model was updated to reflect a 20% increase and a 20% decrease in the adopted design downstream boundary slope and additional 1% AEP simulations were completed with the modified values. Flood level difference mapping was also prepared. The statistical analysis of the difference mapping is provided in **Table 27**. The statistics presented in **Table 27** show that increasing or decreasing the downstream boundary slope by 20% will typically alter peak 1% AEP flood levels by less than 0.01 metres (1st/99th percentiles). The difference mapping also showed that no changes in flood level are predicted upstream of the Hume Highway.

Therefore, the results of this analysis indicate that the model is insensitive to changes in downstream boundary.

8.3 Computer Model Confidence Limits

As discussed, the development of computer models requires the estimation of parameters that are not always known with a high degree of certainty. The computer models that were created as part of this study were developed based upon best estimates of model parameters. The models were subsequently shown to produce realistic results relative to the limited amount of historic flood information that is available. Accordingly, the computer models are considered to provide a reasonable estimate of design flood behaviour across the catchment.

However, the outcomes of the climate change assessment and sensitivity analysis indicate that the design flood level estimates may be subject to variations if one or more of the input variables change (e.g., blockage, rainfall losses, hydraulic roughness). Accordingly, the model input parameters and design flood level estimates presented in this report are subject to some uncertainty.

In recognition of this uncertainty, additional statistical analyses were completed based upon the outcomes of the various sensitivity and climate change analyses in an attempt to assign "confidence limits" to the peak 1% AEP flood level estimates. In order to reliably define confidence limits to the 1% AEP results, it would be necessary to undertake thousands (potentially tens of thousands) of simulations to reflect the numerous combinations/permutations of potential parameter estimates and provide a sufficiently large population to enable meaningful statistical analysis. Unfortunately, the long simulation times only permit a limited number of parameter scenarios to be investigated.

In instances where a sufficiently large "population" of results is not available, it is still possible to derive confidence limits using the Student's t-test (Zhang, 2013). This approach involves interrogating peak flood level estimates from all 1% AEP simulations at each TUFLOW grid cell. This information is used to calculate a mean water level and standard deviation at each grid cell. This information can then be combined with the population size (i.e., number of different 1% AEP simulations) to develop 95% confidence limit estimates at each TUFLOW grid cell.

The resulting "95% Confidence Limit" grid is shown in **Plate 34**. Green/aqua colours indicate small confidence limits (i.e., more confidence in results) and yellow-red colours indicate higher confidence limits (i.e., less confidence in results).

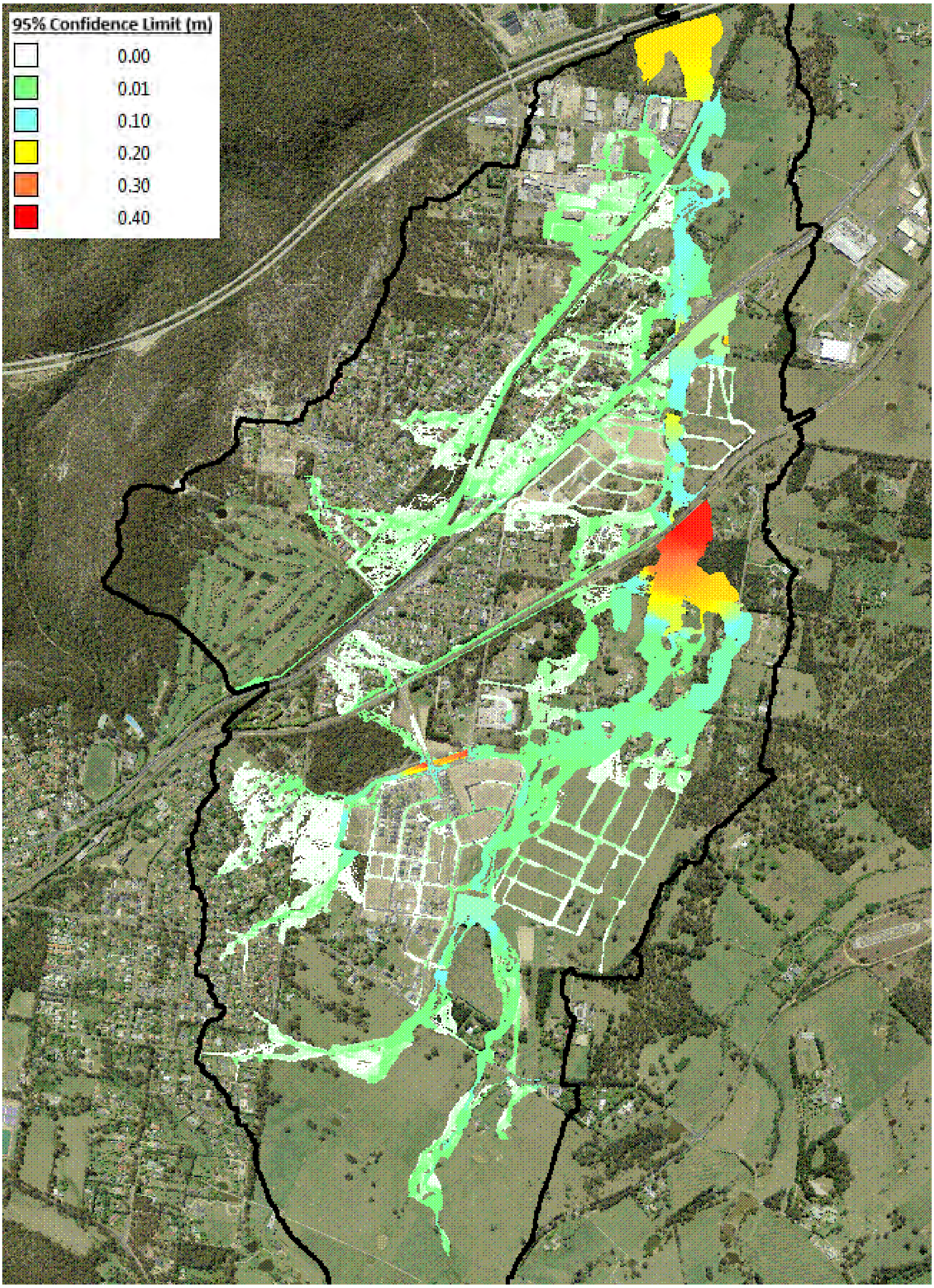


Plate 34 95% Confidence Interval Grid Developed Based Upon Student's t-test

The confidence limit grid shows that across the majority of the catchment, we can be confident that the "correct" 1% AEP flood levels will be contained within 0.1 metres of the design flood levels shown in **Figures 18.1** to **18.8** and **Table 23** (refer aqua/green areas in **Plate 34**). However, there is less confidence in 1% AEP flood level estimates across some areas, most notably upstream of the railway bridge where the 95% confidence interval is around 0.4 metres. The uncertainty at this location is driven primarily by the sensitivity of the results at this location to blockage.

8.4 Freeboard

Freeboard is a factor of safety that is used to account for uncertainties in computer modelling results. The freeboard is typically used in conjunction with 1% AEP flood level estimates to derive the flood planning level for a particular location.

To assist in the selection of an appropriate freeboard, the 95% confidence limit grid was interrogated. The confidence limit grid (refer **Plate 34**) shows that the model confidence limits across most of the study area is low (i.e. <0.1 metres), indicating a relatively high degree of confidence in the model results. However, confidence limits in the vicinity of major culverts and bridges are higher (i.e., >0.2 metres) indicating reduced confidence in the model results. Therefore, there is a significant amount of spatial variability in the model confidence limits.

Council's current freeboard requirement is 0.5 metres. The 95% confidence interval grid is not predicted to exceed 0.4 metres at any location. Accordingly, the adoption of a 0.5 metre freeboard would make an allowance for modelling uncertainty of up to 0.4 metres and at least a 0.1 metre allowance for areas of "other" uncertainty that cannot be explicitly represented in the modelling (e.g., wind and wave action). Therefore, it is considered that the 0.5 metre freeboard is suitable for application across areas subject to mainstream flooding.

The confidence interval across areas subject to overland flooding (e.g., across the urban areas of the catchment) is generally much lower than along major watercourses and at major hydraulic structures. More specifically, the confidence interval across all urban areas is not predicted to exceed 0.2 metres. This is primarily associated with the comparatively shallow flow depths across most of the urban areas relative to the mainstream areas. Accordingly, a reduced freeboard of 0.3 metres may be suitable across the urban areas of the Nattai Ponds catchment. This will provide a 0.2 metre allowance for modelling uncertainty plus a minimum of a 0.1 metre allowance for other uncertainties.

9 DISCUSSION

9.1 General

The results of the design flood modelling show that:

- Flood behaviour across the Nattai Ponds catchment is typically characterised by relatively shallow depths of inundation (i.e., < 0.3 metres). However, more significant depths are predicted along and immediately adjacent to designated waterways.
- The relatively shallow depths of inundation result in the majority of the floodplain being exposed to a low provisional flood hazard.
- However, several sections of the catchment are predicted to be exposed to more significant floodwater depths and velocities and, consequently, a high provisional flood hazard during large events. This includes:
  - Braemar Avenue (adjacent to the Old Hume Highway and Railway Loop Line)
  - Inkerman Road
  - Scarlet Street

Further detailed discussion on the impact of flooding on key infrastructure and transportation routes is provided below.

9.2 Impact of Flooding on Key Facilities

9.2.1 Key Infrastructure

There is some significant infrastructure located within the Nattai Ponds catchment that can play a key role in emergency response management during floods. As such, it was considered important to assess the impact of flooding on these facilities to determine their suitability for use / evacuation during floods.

Such infrastructure includes:

- **Schools:**
  - ***Tangara* School** (Bong Bong Road, Renwick): the school buildings are not predicted to be inundated during any design flood up to and including the PMF. However, access to and from the school may be cut for a period during large floods due to overtopping of Bong Bong Road.
  - ***Highlands School*** (Bong Bong Road, Mittagong): The school lies on the catchment boundary. It is not predicted to be inundated during any of the design floods up to and including the PMF.
- **Fire Stations**: There are no fire stations located within the catchment;
- **Police Stations**: There are no police stations located within the catchment;
- **State Emergency Service**: There are no SES buildings located within the catchment;
- **Ambulance Stations**: There are no ambulance stations located within the catchment;
- **Hospitals**: There are no hospitals located within the catchment;

- **Aged Care Facilities:** There are no aged care facilities located within the catchment;
- **Other Facilities:** There are no other applicable facilities within the catchment

The outcomes of this assessment are also summarised in **Table 28**.

Table 28 Impact of Flooding on Key Infrastructure

<table>
<tr><th colspan="2" rowspan="2">Key Infrastructure</th><th colspan="2">1% AEP Flood</th><th colspan="2">PMF</th></tr>
<tr><th>Inundated?</th><th>Access Cut?</th><th>Inundated?</th><th>Access Cut?</th></tr>
<tr><td>Fire Stations</td><td></td><td colspan="4">There are no fire stations located within the catchment</td></tr>
<tr><td>Police Stations</td><td></td><td colspan="4">There are no police stations located within the catchment</td></tr>
<tr><td>State Emergency Service</td><td></td><td colspan="4">There are no SES buildings located within the catchment</td></tr>
<tr><td>Ambulance Stations</td><td></td><td colspan="4">There are no ambulance stations located within the catchment</td></tr>
<tr><td>Hospitals</td><td></td><td colspan="4">There are no hospitals located within the catchment</td></tr>
<tr><td>Aged Care Facilities</td><td></td><td colspan="4">There are no aged care facilities located within the catchment</td></tr>
<tr><td rowspan="2">Schools</td><td>Tangara
(Bong Bong Road, Renwick)</td><td></td><td>☑</td><td></td><td>☑</td></tr>
<tr><td>Highlands School
(Bong Bong Road, Mittagong)</td><td></td><td></td><td></td><td></td></tr>
</table>

9.2.2 Transportation Links

There are several major roadways within the Nattai Ponds Catchment which may be required for evacuation or emergency services access during floods. It is important to have an understanding of the impacts of flooding on these roads so that appropriate emergency planning can occur.

- ***Bong Bong Road:*** Bong Bong Road is predicted to experience inundation during all of the design floods. This ranges from 0.1m during the 20% AEP flood and 0.25m during the 1% AEP flood to more than 0.5 metres during the PMF. Accordingly, the road would likely remain trafficable during smaller events but access would be cut during events greater than the 1% AEP flood.
- ***Inkerman Road:*** Inkerman Road is predicted to be inundated during all of the simulated design floods. Depths of inundation are predicted to range from 0.2m during the 20% AEP event to ~1.3 m during the PMF. Accordingly, it is unlikely that vehicular access along Inkerman Road would be possible during events greater than the 20% AEP event. This is likely to results in a number of rural residential properties becoming isolated.
- ***Scarlet Street:*** Scarlet Street is predicted to be inundated during all of the simulated design floods. Depths of inundation are predicted to range from 0.25m during the 20% AEP event, 0.4m in the 1% AEP event, and ~2.8 m during the PMF. Accordingly, it is unlikely that vehicular access along Scarlet Street would be possible during events more severe than the 20% AEP event. This would result in a number of rural residential properties becoming isolated.

- ***Old Hume Highway***: The Old Hume Highway is predicted to experience inundation from local overland flow in the vicinity of Rush Lane and Isedale Road. Depths along the Northbound carriageway vary from less than 0.1m in the 20% AEP event to 0.2m in the 1% AEP event and 0.8m in the PMF. The highway would remain trafficable in events up to and including the 1% AEP. The PMF is predicted to overtop the Old Hume Highway adjacent to Braemar Avenue with depths across the roadway being about 1 metre.
- ***Braemar Avenue:*** Braemar Avenue is predicted to experience inundation at two locations. Adjacent to the Old Hume Highway, inundation of 0.35m is predicted during the 20% AEP event increasing to over 1.7m during the PMF. Accordingly, it is unlikely that vehicular access along Braemar Avenue would be possible during any of the simulated design floods. Adjacent to the Braemar Avenue industrial area depths of 0.3m are predicted in the 1% AEP event with almost 0.8m of water extending across the roadway during in the PMF. Therefore, this section of Braemar Avenue is predicted to be cut during events in excess of the 2% AEP event.
- ***Hume Highway***: The Hume Highway is predicted to remain "flood free" during all events except the PMF. Depths across the highway during the PMF are predicted to exceed 0.5 metres. Accordingly, the Hume Highway would only be cut during very large floods.

The outcomes of this assessment are also summarised in **Table 29**. It should be noted that under no circumstances should vehicles attempt to drive through floodwaters.

Table 29 Impact of Flooding on Key Transportation Links

Roadway	Access Cut During 20% AEP Flood?	Access Cut During 1% AEP Flood?	Access Cut During PMF?
Bong Bong Road			☑
Inkerman Road		☑	☑
Scarlet Street		☑	☑
Old Hume Highway (northbound carriageway)		☑	☑
Braemar Avenue	☑	☑	☑
Hume Highway			☑

10 Public Exhibition Of Draft Flood Study

The Draft Flood Study Report was exhibited from 6 May 2016 to 15 June 2016 at Wingecarribee Shire Council Civic Centre, Moss Vale Public Library, Bowral Public Library, and Mittagong Public Library. The public exhibition was also advertised on the flood study website, where a digital version of the draft flood study was available (http://www.nattaiponds.floodstudy.com.au). The flood study website was visited 108 times during the public exhibition period by 94 unique visitors.

A total of 23 owner occupiers, landlords and tenants who had indicated they had experienced past flooding problems (as part of the community consultation stage of the study) were also notified via letter as well as email regarding the public exhibition to provide opportunities to comment.

One submission was received from the public during the public exhibition period. The submission primarily related to the inadequacy of the Braemar Avenue culverts. The submission went on to request that no further development occur in the upstream catchment until actions were taken to rectify the problems at the Braemar Avenue culverts.

The submission was reviewed and it was determined that no changes to the Nattai Ponds Flood Study were considered necessary. However, this comment should be noted and incorporated into the future Floodplain Risk Management Study for the catchment.

11 CONCLUSION

This report documents the outcomes of investigations to quantify contemporary flood behaviour across the Nattai Ponds catchment for a full range of design floods. It provides information on design flood discharges, levels, depths and velocities as well as hydraulic and flood hazard categories.

Flood behaviour across the study area was defined using a hydrologic computer model of the Nattai Ponds catchment as well as a two-dimensional hydraulic model. The hydrologic computer model was developed using the XP-RAFTS software and the hydraulic model was developed using the TUFLOW software.

The computer models were calibrated/verified using rainfall data and reports of flooding received from the community for floods that occurred in 2007, 2014 and 2015. In general, the models provided a reasonable reproduction of historic flood depths and extents that were reported by the community.

The models were subsequently used to simulate a range of design floods including the 20%, 10%, 5%, 2%, 1% and 0.5% AEP floods as well as the PMF. The following conclusions can be drawn from the results of the design flood simulations:

- Flooding across the Nattai Ponds catchment can occur as a result of major watercourses overtopping their banks as well as from overland flooding when the capacity of the stormwater system is exceeded.
- Flooding can occur as a result of a variety of different storm durations. However, a storm duration of 2 hours typically produces the critical flood conditions across most of the catchment.
- A number of properties are predicted to be inundated during the 1% AEP flood. These are mainly limited to rural residential land, however, some urban properties in the Willow Vale/Braemar areas are impacted. The Braemar industrial area is also predicted to be impacted at the peak of the 1% AEP flood.
- A number of roadways are predicted to be overtopped during the 1% AEP flood. This would typically render the roadways impassable for at least 2 hours. This includes Inkerman Road, Scarlet Street, the Old Hume Highway and Braemar Avenue. Braemar Avenue is predicted to be cut during events as frequent as the 20% AEP flood.
- The catchment incorporates a number of bridges and culverts. The results of a blockage sensitivity analysis show that the severity of flooding upstream of these structures can be significantly increased due to blockage. This highlights the importance of routine maintenance on this infrastructure, particularly immediately after a flood.

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GLOSSARY

acid sulphate soils	are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
annual exceedance probability (AEP)	the chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. Eg, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger events occurring in any one year (see ARI).
Australian Height Datum (AHD)	a common national surface level datum approximately corresponding to mean sea level.
average annual damage (AAD)	depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
average recurrence interval (ARI)	the long-term average number of years between the occurrence of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the Local Governments Act.
catchment	the land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	the council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the council, however legislation or an EPI may specify

development	is defined in Part 4 of the Environmental Planning and Assessment Act (*EP&A Act*). <u>infill development:</u> refers to development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. <u>new development:</u> refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. <u>redevelopment:</u> refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
disaster plan (DISPLAN)	a step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	the rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
ESD	Ecologically Sustainable Development (ESD) using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act, 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice of an impending flood and before floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	a range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a

	watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	the remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	is synonymous with flood prone land, i.e., land susceptible to flooding by the PMF event. Note that the term flood liable land covers the whole floodplain, not just that part below the FPL (see flood planning area).
flood mitigation standard	the average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	the measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	a management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at state, division and local levels. Local flood plans are prepared under the leadership of the SES.
flood planning area	the area of land below the FPL and thus subject to flood related development controls.
flood planning levels (FPLs)	are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans.
flood proofing	a combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.

flood prone land
land susceptible to flooding by the PMF event. Flood prone land is synonymous with flood liable land.

flood readiness
Readiness is an ability to react within the effective warning time.

flood risk
potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below.

<u>existing flood risk</u>**:** the risk a community is exposed to as a result of its location on the floodplain.

<u>future flood risk</u>: the risk a community may be exposed to as a result of new development on the floodplain.

<u>continuing flood risk</u>: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.

flood storage areas
those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.

floodway areas
those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.

freeboard
provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.

hazard
a source of potential harm or a situation with a potential to cause loss. In relation to this study the hazard is flooding which has the potential to cause damage to the community.

Definitions of high and low hazard categories are provided in Appendix L of the *Floodplain Development Manual* (*2005*).

historical flood
a flood which has actually occurred.

hydraulics
term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.

hydrograph a graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.

hydrology term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.

local overland flooding inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.

local drainage smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.

mainstream flooding inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.

major drainage councils have discretion in determining whether urban drainage problems are associated with major or local drainage. Major drainage involves:

- the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or
- water depths generally in excess of 0.3m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or
- major overland flowpaths through developed areas outside of defined drainage reserves; and/or
- the potential to affect a number of buildings along the major flow path.

mathematical / computer models the mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

merit approach the merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well-being of the State's rivers and floodplains.

The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into council plans, policy, and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local flood risk management policy and EPIs.

minor, moderate and major flooding

Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood.

minor flooding: Causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.

moderate flooding: Low lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.

major flooding: Appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

modification measures

measures that modify either the flood, the property or the response to flooding.

peak discharge

the maximum discharge occurring during a flood event.

probable maximum flood (PMF)

the PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.

probable maximum precipitation (PMP)

the PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.

probability

A statistical measure of the expected chance of flooding (*see annual exceedance probability*).

risk

chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.

runoff

the amount of rainfall which actually ends up as streamflow, also known as rainfall excess.

stage

equivalent to water level (both measured with reference to a specified datum).

stage hydrograph	a graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	a plan prepared by a registered surveyor.
TUFLOW	is a 1-dimensional and 2-dimensional flood simulation software. It simulates the complex movement of floodwaters across a particular area of interest using mathematical approximations to derive information on floodwater depths, velocities and levels.
velocity	the speed or rate of motion (*distance per unit of time, e.g., metres per second*) in a specific direction at which the flood waters are moving.
water surface profile	a graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	the horizontal distance in the direction of wind over which wind waves are generated.
XP-RAFTS	is a non-linear runoff routing software. It incorporates subcatchment information such as area, slope, roughness and percentage impervious and is used to simulate the transformation of historic or design rainfall into runoff (i.e., discharge hydrographs).

Appendix A

Community Consultation

Why Do We Need to Prepare a Flood Study?

Flooding is the most costly natural disaster in Australia, causing an estimated $314 million worth of damage each year. Over 2,000 people have also lost their lives due to floods in Australia. Accordingly, flooding can impose significant financial burdens and place lives at risk.

The preparation of a flood study will help Wingecarribee Shire Council to understand the existing flooding problem within the Nattai Ponds catchment. It will also help to identify where flood damage reduction measures may be best implemented to reduce the cost of flooding to the community, assist with emergency management and evacuation processes and guide future development / re-development in a way that is compatible with the flood risk.

How *you* can help...

The flood study will include the development of computer models to simulate flood behaviour across the catchment. To ensure the computer models are providing reliable descriptions of flood behaviour they will be calibrated so they reproduce floods that have occurred in the past.

Enclosed with this brochure is a questionnaire that aims to collect as much historic flood information as possible to assist with the computer model calibration. If you have information on past floods you are encouraged to complete the questionnaire and return it by **14th August 2015**. Alternatively, the questionnaire can be completed online via the flood study website:

www.nattaiponds.floodstudy.com.au

Further Information

To obtain further information on the Nattai Ponds Flood Study or to submit any information that you think may be valuable to the study, please contact:

David Tetley
Catchment Simulation Solutions
Suite 2.01, 210 George Street
Sydney NSW 2000
(02) 9247 4882
dtetley@csse.com.au

....

Sha Prodhan
Wingecarribee Shire Council
PO Box 141
Moss Vale NSW 2577
(02) 4868 0798
sha.prodhan@wsc.nsw.gov.au

Alternatively, you can visit the flood study website, which provides additional information and contact details:
www.nattaiponds.floodstudy.com.au

Your contribution to this study is greatly appreciated!

Nattai Ponds Flood Study

Community Information Brochure

WINGECARRIBEE SHIRE COUNCIL

Introduction

Wingecarribee Shire Council is in the initial stages of preparing a flood study for the Nattai Ponds catchment. The extent of the catchment is shown in the image on the right.

During most rainfall events across the catchment, runoff is carried by the stormwater system into one of the many creeks located within the catchment. But during periods of heavy rainfall there is potential for the capacity of the stormwater system to be exceeded leading to overland flooding. There is also potential for water to overtop the banks of the creek and inundated the adjoining floodplain.

Flooding across the catchment can cut roadways and also has the potential to inundate adjoining properties. This can result in damage to garages, sheds and homes. It can also place lives at risk during particularly rare floods.

In recognition of these issues, Wingecarribee Shire Council has decided to prepare a flood study for the Nattai Ponds catchment. The flood study is the first step in assisting Council to better understand, plan and manage the risk of flooding across the catchment.

The flood study is being completed as part of Council's Floodplain Risk Management Program, which aims to reduce the impact of flooding on the community.

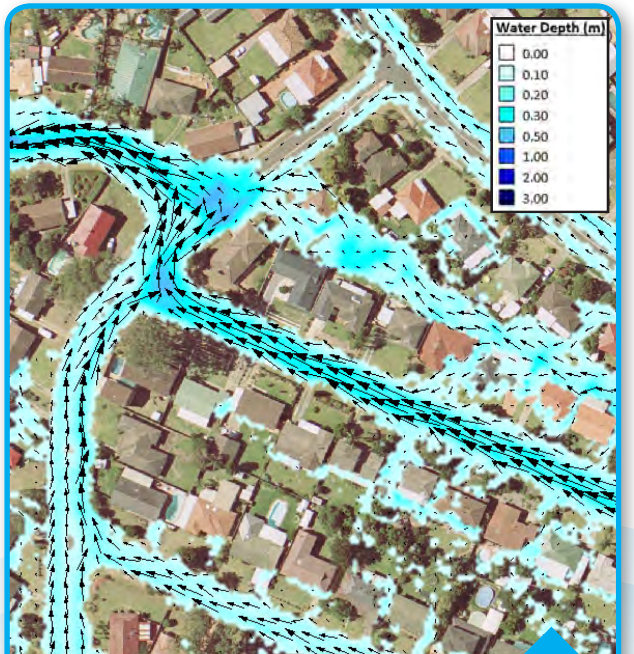
Extent of the Natta Ponds Catchment

The information generated as part of the flood study will be used as the basis for prepapring a floodplain risk management study for the catchment. This study will allow Council to identify where flood mitigation measures (e.g., stormwater pipe upgrades) may be best implemented to reduce the impact of flooding on property owners across the catchment. It will also assist the SES with emergency response planning and will allow Council to ensure that future development across the catchment is compatible with the flood risk.

What is a Flood Study?

The primary objective of the flood study is to identify the nature and extent of the existing flooding problem. This will be primarily achieved through the development of a computer flood model, which will be used to quantify how rainfall is converted into runoff and how that runoff would move across the catchment. An example of a floodwater depth and velocity map that is produced by a computer flood model is shown below.

Council has commissioned specialist flood consultants, Catchment Simulation Solutions, to prepare the flood study.



Sample floodwater depth and velocity output from flood model

Thank you for taking the time to complete this questionnaire!

The questionnaire can be returned without a postage stamp or scanned and emailled to: dtetley@csse.com.au by 14 August 2015. Flood photos and videos can also be sent to this email address or posted to:

Catchment Simulation Solutions
Suite 2.01, 210 George Street
Sydney, NSW 2000

Catchment Simulation Solutions will analyse the community responses and report back to Council. If you would like to have items returned please note this and the items will be returned at the conclusion of the study.

Fold Here

How to send back this questionnaire...

Please fold this questionnaire using the 'Fold Here' lines as a guide to form a business sized evelope with the address on the front and this text box on the back. Seal the folded pages with a piece of tape to help maintain privacy and then post it back.

Fold Here

Delivery Address:
PO Box 141
MOSS VALE NSW 2577

No stamp required if posted in Australia

WSC
Reply Paid 141
MOSS VALE NSW 2577

Attn: Mr Sha Prodhan
Nattai Ponds Flood Study

Nattai Ponds Flood Study

Community Questionnaire

Wingecarribee Shire Council is completing a flood study for the Nattai Ponds catchment. The flood study is the first step in assisting Council to better understand, plan and manage the risk of flooding across the catchment.

The information that you provide in the following questionnaire will prove invaluable in the calibration of computer models that are being developed as part of the Flood Study. It will also provide Council with an understanding of existing flooding problems and areas where flood damage reduction measures should be investigated in the future.

The following questionnaire should only take around 10 minutes to complete. Try to answer as many questions as you can and give as much detail as possible (attach additional pages if necessary). Once complete, please return the questionnaire via email or mail (no postage stamp required) by **14 August 2015**. Alternatively, if you have internet access, an online version of the questionnaire can be completed at: www.nattaiponds.floodstudy.com.au

If you have any questions or require any further information please contact:

Catchment Simulation Solutions
David Tetley
Catchment Simulation Solutions
(02) 9223 0882
dtetley@csse.com.au

Wingecarribee Shire Council
Sha Prodam
Wingecarribee Shire Council
(02) 4868 0798
sha.prodhan@wsc.nsw.gov.au

CONTACT DETAILS

Can you please provide the following contact details in case we need to contact you for additional information? If you do provide contact details, this information will remain confidential at all times and will not be published.

Name: ____________________

Address: ____________________

____

Phone No. ____________________

Email: ____________________

1. WHAT TYPE OF PROPERTY DO YOU LIVE IN / OWN?

☐ Residential
☐ Commerical
☐ Industrial
☐ Vacant Land
☐ Other (Please specify:____________________)

2. WHAT IS THE OCCUPIER STATUS OF THIS PROPERTY?

☐ Owner occupied

☐ Rental property

☐ Business

☐ Other (Please specify:____)

3. HOW LONG HAVE YOU LIVED / WORKED IN THE AREA?

(a) At this address? ____

(b) In the Natta Ponds / Mittagong area? ____________________________

4. HAS YOUR PROPERTY EVER BEEN AFFECTED BY FLOODING?

☐ Yes

☐ No (If you answered No, please go to Question 10)

5. HOW WAS YOUR PROPERTY AFFECTED BY FLOODING?

☐ Roadway was cut by water

☐ My front / back yard was flooded

☐ My garage was flooded

☐ My house was flooded

☐ Other (Please specify: ____)

6. CAN YOU PROVIDE ADDITIONAL INFORMATION ON THESE PAST FLOODS?

Date of flood(s)		
Flood depth / height & location		
How confident are you with the height / depth of the flood?	☐ High (exact) ☐ Medium (within 10cm) ☐ Low (within 50cm)	☐ High (exact) ☐ Medium (within 10cm) ☐ Low (within 50cm)

7. DO YOU HAVE ANY PHOTOGRAPHS OR VIDEOS OF THESE FLOODS?

☐ Yes ☐ No

If you answered Yes, can you provide a copy of these photos/videos to assist with the computer flood model calibration?

☐ Yes ☐ No

8. WAS YOUR PROPERTY DAMAGED BY FLOODWATERS?

☐ Yes ☐ No

If 'Yes', please provide details: ____

____

____

____

____

9. IN YOUR OPINION, WHAT WAS THE MAIN CAUSE OF FLOODING?

____

____

____

____

____

____

10. DO YOU HAVE ANY SUGGESTIONS ON WAYS OF REDUCING THE FLOODING PROBLEMS?

____

____

____

____

____

____

11. DO YOU HAVE ANY OTHER COMMENTS, SUGGESTIONS OR INFORMATION THAT YOU THINK MAY ASSIST THE STUDY?

____

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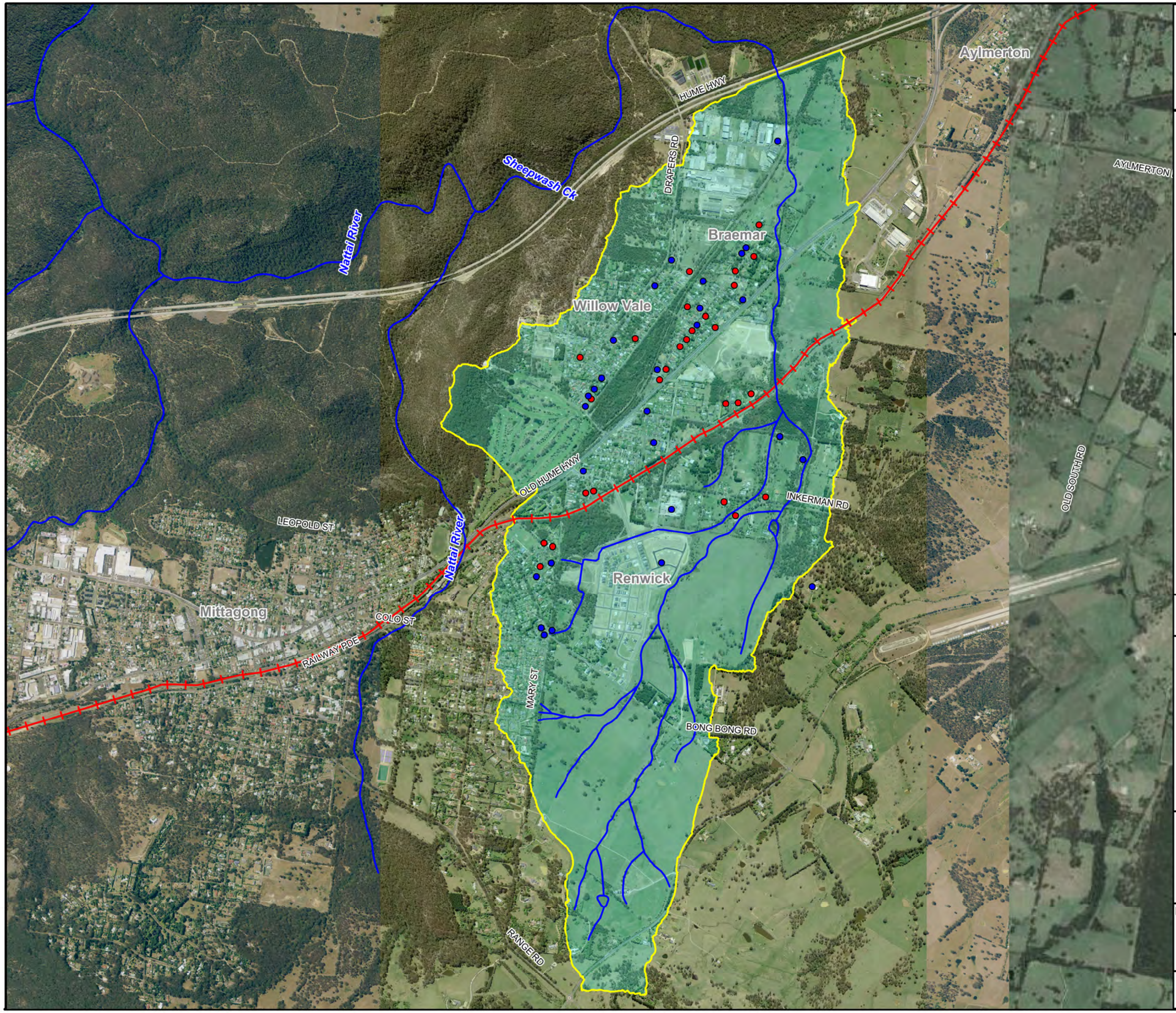
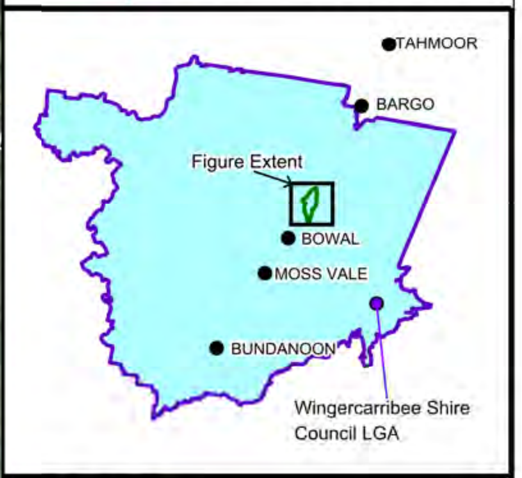


WINGECARRIBEE SHIRE COUNCIL



LEGEND

- Nattai Ponds Catchment
- Railway

Questionnaire Response Locations
Has flooding been experienced?

- No
- Yes

Notes:
Aerial photograph date: May 2014

N W E S

Scale 1:22,000 (at A3)
0 0.5 1.0
Km

Figure A1: Spatial Distribution of Questionnaire Responses

Prepared By:
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File Name: Fig A1 - Spatial Distribution of Questionnaire Responses.wor

Community Questionnaire Responses - Nattai Ponds Flood Study

#	Property Type	Occupier Status	How long have your lived in area?				Have you been affected by flooding in the past?						Can you provide additional information on these past floods			Additional Flood Information				
			Current Address		In the Nattai Ponds/Mittagong area		Roadway was cut by water	My front/back yard was flooded	My garage was flooded	My house was flooded	Other	Description	Date of Floods	Flood Depth / Height & Location	Confidence Level	Photo/Video	Was your property damaged by floodwaters, if yes please provide details	In your opinion, what was the main Cause of Flooding?	Do you have any suggestions on ways of reducing the flooding problems?	Do you have any other comments, suggestions or information that you think may assist the study?
1	Residential	Owner Occupied	6.5	Years	11.5	Years		Yes				Fences were knocked over due to debris. Chicken/duck pends damaged	26/08/2014	62 Inkerman Road. Depth between 1-2feet	Medium	Yes	Yes, Fences were knocked over due to debris. Chicken/duck pends damaged			Flooding was caused by Renwick development. We have had a lot more 'flood' type ocuurence in last two years
2	Residential	Owner Occupied	4	Years	4	Years		Yes					18/08/2014	less than 20cm at the far southern end of our property	Medium	Yes	No	lack of stormwater capacity	Improvement to the efficency of existing retention areas in Renwick and/or additional capacity of retention areas between our property and to the south towards Bong Bong Road.	A "creek"/stormwater channel/easement travels across our property from SW to NE. it used to be the case (when we first moved in nearly 4 years ago), that it could rain heavily for hours and there would be no appreciable change to the water level in the creek. It would take several hours or sometimes the next day for the creek level to rise. In the last 12 months the effect from heavy rain is seen much quicker and appears with more of a surge. In addition, surface water from up the hill towards Bong Bong road appears to now last for weeks rather than days. This is my observation but I cannot offer an explanation for the reason why this is now occurring.
													10/08/2015	less than 20cm at the far southern end of our property	Medium					
3	Residential	Owner Occupied	20	Years	20	Years		Yes	Yes	Yes			26/10/1999	House 2cm above floor level, Garage 2cm above floor level	High	No	Yes, when the house was flooded, carpets and some furniture needed replacing. When the garage floods we keep anything that could be water damaged above flood level.	Lack of stormwater capacity	Pits and pipes along our street. Also a detention basin in the railway land adjacent to the Mittagong Picton Railway and ensuring stormwater is channeled along western side of railway all the way to Braemar Ave. At the moment there are some culverts under the railway that allow it to flow into the residential area at Braemar and they should be closed up.	I recorded 120mm in my rain gauge on the day our house flooded. The storm lasted 2 hours.
5	Residential	Rental Property	5	Years	5	Years	Yes	Yes		Yes	Yes	Sub Floor Flooding (Constant Dampness)	After downpour	70mm approx	Low	No	Yes, Mouldy Carpet	Lack of Stormwater Capacity Building Next door has built up forcing water to my property	Install efficient stormwater system	Do not release any subdivision approvals without ensuring that the block will be adequately drained
6	Residential	Owner Occupied	12	Years	12	Years		Yes			Yes	Garage does flood in very heavy rain but it is only run-off from the driveway. There is a dam at the rear of the property that would have been part of the original agricultural landscape. It over-tops in very heavy rain each year and creates shallow flooding in the garden alongside.Less than 20 cm	Every year in very heavy rain	Less than 20 cm		Yes	No	Natural drainage of the whole area into the low ground.	We have seen a Council proposal for an open concrete lined drain to run along the boundary of the new Nattai Ponds development at the end of our block. It is essential that this drain allows our dam to overflow freely. At present the residual water is not flowing away and appears to have been backed up by the excavation / fill works now being undertaken.	
7	Residential	Owner Occupied	31	Years	6	Years						Property not affected							At the moment all the water that comes down the eastern side of Railway Parade Braemar runs in a pipe under my driveway and sits on the vacant block next door. It should have been directed under the road into the drain on the Western side of Railway Parade which is what we were told at the time.	It would help if kerb and guttering was put in Railway parade Braemar and the water redirected as mentioned above.
8	Residential	Owner Occupied	3.5	Years	3.5	Years		Yes	Yes			Under the house was flooded	Whenever it rains	Front Yard 1 - 2 inches	High	No	No	Lack of storm water capacity, no street gutters or culverts, poor infrastructure.	All water runs off the road onto the property. Installation of street gutters/culverts would help fix this issue	
													Whenever it rains	Backyard 2-3 inches	High					
													Whenever it rains	under the house 1-2 inches	High					
9	Residential	Owner Occupied	6	Years																
10	Residential	Owner Occupied	64	Years															No	
11	Residential	Owner Occupied	8	Years				Yes					Early July 2015	2-3 Times too much detail to put on paper you would have to come to site to understand			No	We had a lot of rain, however we believe the new development renwich has contributed to more water than usual	I would like to think the experts can come up with a solution	As I mentioned in our situation it would be a useul exercise if somebody came and looked at our problem
12	Residential	Owner Occupied	7	Years	7	Years	Yes	Yes					Several during my time here		Low		Yes, open basements runs through the Braemar Garden Estate. Water has come into my back garden only causing damage to plants	Excess drainage from willow vale, No underground drains have been put in place by council	There is no stormwater drainage too many low ditches expected to take rain water run off causing flood back up	Rush lane is the only access to 150 homes. When it is not safe for travel people on foot have serious concerns. Pot holes have to be repaired on a regualr basis.
13	Other, Rural/Farming	Owner Occupied	10	Years	13	Years													All new housing should have water tanks less water on the ground more captured	
14	Residential	Owner Occupied	15	Years	15	Years														
15	Residential	Owner Occupied	2	Years															No	No
16	Residential	Owner Occupied	28	Years	28	Years										Yes			No	Here are a few photos of Braemar at the Crossway and Draper Road Sheepwash Creek. All photos a day after the rain stopped
17	Residential	Owner Occupied	16	Years			Yes	Yes	Yes				Roadway in late 1999	Roadway		No	No	Heavy Rains continual for days		
													Whenever heavy consistent rain occurs	Garage, Backyard						
18	Residential	Owner Occupied	13	Years	41	Years		Yes			Yes	Driveway washed away/ Trees drowned	Backyard		Low	No	Yes, Driveway washed away, trees drowned	Increased development without proper drainage planning	Council could listen to resident concerns. Place conditions on deelopers to upgrade existing drainage infrastructure. So existing dwellings do not get flooded	It is great that this study is been untaken but the subdivision of development is there.
19	Residential	Owner Occupied	12	Years				Yes				No access into property by foot whenever it rains					No	Poor Drainage (None at the moment)	Reconstructing end of crane st at railway line	
20	Residential	Owner Occupied	16	Years	20	Years														
21	Residential	Owner Occupied	20	Years	20	Years													Council could keep gulleys arround Braemar clean & clear of vegetation	Money needs to be spent on proper drainage in rush lane/Biggera Street. At time of heavy rain I cannot go out of my front gate due to water.
22	Residential	Rental Property	30	Years	30	Years													No	There is a stormwater Drain in an Easement adjoining our property. I notice from your computer model that drain has the highest volume/flow in the catchment area. Suggest council ensure drain id adequate to cope with 1 in 100 year Flood

#	Property Type	Occupier Status	How long have your lived in area?				Have you been affected by flooding in the past?						Can you provide additional information on these past floods			Additional Flood Information				
			Current Address		In the Nattai Ponds/Mittagong area		Roadway was cut by water	My front/back yard was flooded	My garage was flooded	My house was flooded	Other	Description	Date of Floods	Flood Depth / Height & Location	Confidence Level	Photo/Video	Was your property damaged by floodwaters, if yes please provide details	In your opinion, what was the main Cause of Flooding?	Do you have any suggestions on ways of reducing the flooding problems?	Do you have any other comments, suggestions or information that you think may assist the study?
23	Residential	Owner Occupied	8.5	Years	8.5	Years		Yes					2007/2008	10cm water in front + backyard almost up to front and back doors	Medium	Yes, can be provided	No	Ineffective drainage arround Braemar Gardens, particularly between railway and houses on Willow Vale side and also at Mittagong end of Braemar Gardens	After 2012 flooding, council did some improvements to drainage. This needs to be maintained to be effective.	Water through Braemar Gardens seems to come from Willow Vale Direction
													2012	10cm water in backyard flowing from yard of No.7	High					
24	Residential	Owner Occupied	16	Years																
25	Residential	Owner Occupied	14.5	Years	14.5	Years													No	No
26	Vacant Land	Owner Occupied										Bit hold up water railway bridge				No	No		Senes Renwick	
27	Residential	Owner Occupied	3	Years	3	Years			Yes				Maybe 2014	3 inches	Low	No	No, not the house but the garage	Don't know, but neighbours had their garages flooded and water coming into their house	No, other than regular gutter cleaning to remove leaves, branche, rubbish etc.	Gutters need regular cleaning from branches, leaves etc as getting jammed in drain which is located next door
28	Residential	Owner Occupied	59	Years	59	Years		Yes				Driveways backyard flooded by water from road gutter run off from further up the street	Whenever there is long rainfall	50-75mm Deep	Medium	No	No	Runoff from the bushland in which runs onto the road also water from a drain in Braemar Garden Subdivision where there was a creek which ran out to the old hume highway. The council let the developer cover in so much of the run off comes down the road down my driveway	Council get there act together, and down some kerbs guttering and drain forming.	The creek in Braemar Gardens has always flooded even prior to that development. It used to back up and go across the highway to Natai Ponds. This creek starts back in the bush in Wallow Vale
29	Residential	Owner Occupied	2.5	Years			Yes						Last heavy rain	4cm front foot path	Low	No	No	Being at the bottom of railway Terrace and water from houses on L/H/Side of road + water from the telstra box runs across our paths	Better control of water from the telstra boxes and better direction of rain water	
30	Residential	Owner Occupied	2.5	Years															No	No
31	Residential	Owner Occupied	2.5	Years	2.5	Years			Yes				Approx 18 months ago	Not deep but covered 75% of a 3 cm can	Medium	No	No, stored carpet ruined plus water damage to garage items- not surely this is a yes to property damage	Heavy rain + ingress from properties on higher ground	Perhaps better water retention along golf course boundary. Path along golf course at Mittagong often leveled with water after rain	
32	Residential	Owner Occupied	4	Years	4	Years		Yes				But I have stormwater easement going through my backyard	Earlier this year 2015 and every year since I have live here since 2011 - 2015			Yes	No	Flow down from railway line and trees near my house		We need another acess to the main road as our only entry/ exit is through rush lane
33	Residential	Rental Property	4	Years				Yes				Pockets of water in backyard and side of the house	For the last 5 years at least once a year			No	Yes, The yard ground became very soft to make it hard for vehicles to be parked	Flow from behind railway line		The area road on the corner needs to be filled as they are full of holes. Houses on corner block therfore rainwater accumilates there.
34	Residential	Owner Occupied	1.5	Years				Yes						10 cm front yard close to driveway section	Medium	No	No	Heavy rain	unblock 250 mm drainage tube	severe blue algae last summer, twice needed medical attention
														Back up to 20 cm the whole area from house to water (creek) Easement	Medium					
35	Industrial	Business	15	Years																
36	Residential	Owner Occupied	27	Years	48	Years		Yes					Increasing problems in approx last 2 - 3 years 2012	Back/ side of property 5 - 20 cm	Medium	Yes, attached	Yes, actual building structure of house not damaged but shed (large/lined/concrete base) has been damaged by water	Inadequate drainage and stormwater drain problems in properties adjoining the back of my property. i.e. properties fronting on to bong bong road	improved drains (maybe of various types) to carry water into drainage system rather than allowing excessive run-off to flood lower lying properties	Yes, see attached correspondence, note highlighted sections as particularly relevant. Thorough inspection and assesment of drainage
37	Residential	Owner Occupied	12	Years	12	Years	Yes	Yes					25/02/2013	100mm to 150 mm Back Garden Braemar Ave (Creek overflow)	High	Yes, photos provided	Water has entered the air spaces in the brickwork of our house, if there is damage under our house it cannot be seen	The raising of the vacant land at the rear of our property (for development). The water channel along the fenceline is not deep enough and is not being kept clear. The creek through Braemar lodge is overgrown and should be cleaned out	The water channel along the fenceline is not deep enough and is not being kept clear. The creek through Braemar lodge is overgrown and should be cleaned out	Yes, as mentioned earlier
													Several Times	Back Garden Braemar Ave see photos	High					
38	Residential	Owner Occupied	13	Years	13	Years		Yes						12 - 14 cms through front yard under veranda and foundations into backyard has occurred 3 times	Medium	No	Yes, the loss of garden plants possilbe movement of foundations.	Stormwater drains are not capable of handling the water flow during heavy rain.	Clean out the drains install suitable size pipes and close out what are now open drains.	Install drainage pipes close to the top of the rise on either side of hume highway
39	Residential	Owner Occupied	22	Years																
40	Residential	Owner Occupied	28	Years			Yes	Yes								No	No	Renwick, before renwick, sydeny water would open flood gates and stop the flooding	Better drainage, new pipes	Clean all the pipes and let water flow
41	Residential	Owner Occupied	7	Years	57	Years													The creek at lower old hume highway braemar ave area is over grown with weeds of blackberry. Clean it our	It has to rain pretty hard for it to flood arround here.
42	Residential	Owner Occupied	16	Years	16	Years		Yes					No sure 2- 3 years ago	Approx 5 cm	Medium	No	No	Told it was blockage in Mary Street Mittagong overflow of drain.		
43	Residential	Owner Occupied	1	Year	38	Years													A lot of water comes down from Willow Vale and drains under the loop line railway. The area on either side of the line becomes quite swampy	More effective drainage is required

#	Property Type	Occupier Status	How long have your lived in area?				Have you been affected by flooding in the past?						Can you provide additional information on these past floods			Additional Flood Information				
			Current Address		In the Nattai Ponds/Mittagong area		Roadway was cut by water	My front/back yard was flooded	My garage was flooded	My house was flooded	Other	Description	Date of Floods	Flood Depth / Height & Location	Confidence Level	Photo/Video	Was your property damaged by floodwaters, if yes please provide details	In your opinion, what was the main Cause of Flooding?	Do you have any suggestions on ways of reducing the flooding problems?	Do you have any other comments, suggestions or information that you think may assist the study?
44	Residential	Owner Occupied	6	Years															The runoff from the road causes some problems. Reported this as it was particularly bad after. There is no guttering along parts of orient st near draper road so the water tends to flow where it likes.	
45	Residential	Owner Occupied	35	Years	35	Years											No			
46	Residential	Owner Occupied	15	Years	20	Years													No	No
47	Residential	Owner Occupied	0.417	Years	0.417	Years													It would appear after the moths of rain we have had the drainage and spillways arround Renwich are sufficient to avoid flooding	
48	Residential	Owner Occupied	16	Years				Yes						Numerous occasions following continued heavy rain	Medium	No	Yes, water flows from Gascoyne St raod reserve and washes away gravel from the driveway	Lack of drainage to deal with run off	Probably needs a storm drain but as the house is not affected this cannot be rated a high priority	
49	Residential	Owner Occupied	17	Years															None. I have never being affected by flooding	
50	Residential	Owner Occupied	18	Years	25	Years														
51	Residential	Owner Occupied	10	Years	25	Years		Yes								No	No	Being at the end of crane st. The water ends up sitting in my block thus meaning all cars have to be parked out front. The open drainage is an issue in crane st	Lay pipes and close open drains	
52	Residential	Owner Occupied	16	Years	34	Years														No
53	Residential	Owner Occupied	14	Years	61	Years					Yes	Couldn't get out of driveway at old hume highway		100mm over old hume highway	Medium	No	No	Water coming from Willow Vale and Mittagong golf course. Drains from willow vale havent been cleaned		Water now runs parallel with railway line as drains under railway have very little water runnign through.
54	Residential	Owner Occupied	1	Year	3	Years												Not enough drainage	Proper drainage of stormwater	
55	Residential	Owner Occupied	6	Years	6	Years		Yes											The last 18 months extremely wet and muddy. Is this caused by drainage changes in Renwick?	The first 4 years we had no water problem but it is steadily getting worse. Water is now continously beside the railway line.
56		Owner Occupied	12	Years	23	Years										No	Yes, Driveway washed away	Slope of backyard	Check drains	No
57	Residential	Owner Occupied	25	Years	25	Years	Yes					Part of drive flooded		up to 12 inches, spreads over north side of land and drains away usually over few days	Medium	Yes	No	Poor drainage on scarlett street, Renwick development creted run off into our creeks	The main ditch at the end of scarlett street should have been on the north side of the street since all the houses are on the south side.	
58	Industrial	Owner Occupied	14	Years																
59	Residential	Owner Occupied	14	Years			Yes						2 to 3 times this has happened over last 12 - 18 months	Over the creek at Braemar Avenue depth over road under a metre	Medium	No	No	The creek is over grown and needs to be cleaned of debris. Maybe widened to take the extra flow of water	As above	In bunya Close, we are now experiencing constant water over the road which I believe comes from the new lots of Biggera St area, drainage seems to be directed down towards bunya rather than the stormwater channel

APPENDIX B

XP-RAFTS MODEL INPUT PARAMETERS

XP-RAFTS INPUT PARAMETERS - Nattai Ponds

Existing Conditions

Subcatchment ID	Sub-Area	Area [ha]	Catchment Slope [%]	Percentage Impervious [%]	Mannings 'n'
1.01	1	8.78	6.82	0	0.066
	2	0.28	6.82	100	0.015
1.02	1	5.78	11.10	0	0.045
	2	0.71	11.10	100	0.015
1.03	1	8.71	3.64	0	0.045
	2	0.30	3.64	100	0.015
1.04	1	1.27	2.61	0	0.047
	2	0.11	2.61	100	0.015
1.05	1	12.03	2.61	0	0.048
	2	0.19	2.61	100	0.015
1.06	1	2.75	1.70	0	0.064
	2	0.07	1.70	100	0.015
1.07	1	5.14	2.01	0	0.056
	2	0.04	2.01	100	0.015
1.08	1	3.27	1.24	0	0.048
	2	0.05	1.24	100	0.015
1.09	1	3.59	2.77	0	0.048
	2	0.02	2.77	100	0.015
1.1	1	9.43	0.66	0	0.054
	2	0.38	0.66	100	0.015
1.11	1	4.64	2.11	0	0.066
	2	0.47	2.11	100	0.015
1.12	1	5.17	1.70	0	0.062
	2	0.43	1.70	100	0.015
1.13	1	3.36	1.15	0	0.067
	2	0.09	1.15	100	0.015
1.14	1	5.23	0.83	0	0.080
	2	0.40	0.83	100	0.015
1.15	1	2.76	2.05	0	0.065
	2	0.35	2.05	100	0.015
1.16	1	0.78	1.92	0	0.089
	2	0.02	1.92	100	0.015
1.17	1	0.59	4.27	0	0.061
	2	0.07	4.27	100	0.015
1.18	1	2.91	1.82	0	0.062
	2	0.12	1.82	100	0.015
1.19	1	7.09	1.16	0	0.057
	2	0.25	1.16	100	0.015
1.2	1	0.70	3.66	0	0.062
	2	0.10	3.66	100	0.015
1.21	1	2.12	1.46	0	0.066
	2	0.13	1.46	100	0.015

Subcatchment ID	Sub-Area	Area [ha]	Catchment Slope [%]	Percentage Impervious [%]	Mannings 'n'
1.22	1	9.93	1.05	0	0.059
	2	0.27	1.05	100	0.015
1.23	1	12.23	1.16	0	0.051
	2	0.21	1.16	100	0.015
1.24	1	0.06	4.00	0	0.056
	2	0.03	4.00	100	0.015
1.25	1	0.60	2.25	0	0.075
	2	0.03	2.25	100	0.015
1.26	1	16.79	1.60	0	0.062
	2	1.97	1.60	100	0.015
2.01	1	1.65	10.47	0	0.058
	2	0.08	10.47	100	0.015
2.02	1	5.06	9.89	0	0.047
	2	0.48	9.89	100	0.015
3.01	1	4.03	7.69	0	0.056
	2	0.66	7.69	100	0.015
3.02	1	9.25	6.46	0	0.049
	2	0.24	6.46	100	0.015
3.03	1	6.61	5.07	0	0.045
	2	0.35	5.07	100	0.015
4.01	1	8.39	10.77	0	0.059
	2	0.54	10.77	100	0.015
5.01	1	7.73	4.35	0	0.045
	2	0.22	4.35	100	0.015
5.02	1	9.25	3.24	0	0.049
	2	0.23	3.24	100	0.015
5.03	1	10.38	1.55	0	0.057
	2	0.97	1.55	100	0.015
6.01	1	14.29	5.21	0	0.046
	2	0.29	5.21	100	0.015
6.02	1	4.56	4.30	0	0.045
	2	0.05	4.30	100	0.015
6.03	1	3.02	3.86	0	0.045
	2	0.00	3.86	100	0.015
6.04	1	0.34	1.37	0	0.074
	2	0.01	1.37	100	0.015
6.05	1	3.02	4.09	0	0.051
	2	0.06	4.09	100	0.015
6.06	1	5.07	1.83	0	0.059
	2	0.28	1.83	100	0.015
6.07	1	0.51	1.40	0	0.060
	2	0.00	1.40	100	0.015
7.01	1	6.43	4.48	0	0.052
	2	0.18	4.48	100	0.015
8.01	1	2.29	5.85	0	0.052

Subcatchment ID	Sub-Area	Area [ha]	Catchment Slope [%]	Percentage Impervious [%]	Mannings 'n'
8.01	2	0.62	5.85	100	0.015
8.02	1	5.89	4.98	0	0.056
	2	0.62	4.98	100	0.015
8.03	1	5.33	3.62	0	0.053
	2	0.07	3.62	100	0.015
9.01	1	3.42	6.03	0	0.057
	2	1.21	6.03	100	0.015
10.01	1	5.11	4.20	0	0.055
	2	0.18	4.20	100	0.015
11.01	1	4.27	1.80	0	0.044
	2	1.11	1.80	100	0.015
11.02	1	0.43	1.99	0	0.045
	2	0.00	1.99	100	0.015
12.01	1	2.27	1.38	0	0.041
	2	0.88	1.38	100	0.015
13.01	1	1.37	3.09	0	0.042
	2	0.67	3.09	100	0.015
14.01	1	7.69	1.34	0	0.045
	2	0.15	1.34	100	0.015
15.01	1	12.44	2.11	0	0.052
	2	0.01	2.11	100	0.015
15.02	1	6.35	1.70	0	0.058
	2	0.00	1.70	100	0.015
15.03	1	2.69	3.54	0	0.073
	2	0.37	3.54	100	0.015
15.04	1	2.62	2.86	0	0.073
	2	0.19	2.86	100	0.015
16.01	1	9.12	0.97	0	0.047
	2	0.00	0.97	100	0.015
17.01	1	3.91	3.36	0	0.089
	2	0.01	3.36	100	0.015
18.01	1	2.03	3.91	0	0.079
	2	0.04	3.91	100	0.015
19.01	1	2.68	5.29	0	0.052
	2	1.52	5.29	100	0.015
19.02	1	1.76	4.59	0	0.060
	2	0.56	4.59	100	0.015
19.03	1	1.90	5.52	0	0.071
	2	0.18	5.52	100	0.015
19.04	1	7.08	3.04	0	0.071
	2	0.20	3.04	100	0.015
19.05	1	2.64	3.38	0	0.057
	2	0.55	3.38	100	0.015
19.06	1	2.38	2.98	0	0.082
	2	0.02	2.98	100	0.015

Subcatchment ID	Sub-Area	Area [ha]	Catchment Slope [%]	Percentage Impervious [%]	Mannings 'n'
19.07	1	3.58	2.08	0	0.082
	2	0.08	2.08	100	0.015
19.08	1	0.37	1.51	0	0.045
	2	0.03	1.51	100	0.015
19.09	1	1.55	1.33	0	0.040
	2	0.33	1.33	100	0.015
19.1	1	4.59	0.75	0	0.063
	2	0.09	0.75	100	0.015
19.11	1	1.11	1.84	0	0.064
	2	0.12	1.84	100	0.015
19.12	1	5.48	0.92	0	0.062
	2	0.36	0.92	100	0.015
20.01	1	1.08	7.09	0	0.052
	2	0.58	7.09	100	0.015
21.01	1	1.45	6.16	0	0.059
	2	0.65	6.16	100	0.015
22.01	1	3.11	4.53	0	0.058
	2	0.12	4.53	100	0.015
23.01	1	0.94	4.36	0	0.064
	2	0.21	4.36	100	0.015
24.01	1	2.20	3.28	0	0.064
	2	0.56	3.28	100	0.015
24.02	1	0.36	3.04	0	0.054
	2	0.19	3.04	100	0.015
24.03	1	0.52	2.96	0	0.052
	2	0.30	2.96	100	0.015
24.04	1	2.07	1.81	0	0.064
	2	0.60	1.81	100	0.015
24.05	1	0.65	2.59	0	0.083
	2	0.05	2.59	100	0.015
25.01	1	2.87	1.48	0	0.056
	2	0.36	1.48	100	0.015
26.01	1	2.17	5.03	0	0.058
	2	0.69	5.03	100	0.015
26.02	1	1.08	3.47	0	0.060
	2	0.24	3.47	100	0.015
27.01	1	2.23	6.45	0	0.066
	2	0.42	6.45	100	0.015
28.01	1	2.58	2.97	0	0.069
	2	0.52	2.97	100	0.015
29.01	1	0.77	2.04	0	0.060
	2	0.22	2.04	100	0.015
30.01	1	3.83	1.73	0	0.044
	2	1.19	1.73	100	0.015
31.01	1	1.99	2.21	0	0.059

Subcatchment ID	Sub-Area	Area [ha]	Catchment Slope [%]	Percentage Impervious [%]	Mannings 'n'
31.01	2	0.63	2.21	100	0.015
31.02	1	5.23	1.56	0	0.063
	2	1.14	1.56	100	0.015
31.03	1	6.19	1.37	0	0.078
	2	0.41	1.37	100	0.015
32.01	1	1.64	1.70	0	0.038
	2	1.05	1.70	100	0.015
33.01	1	1.13	1.70	0	0.036
	2	0.82	1.70	100	0.015
34.01	1	2.77	3.33	0	0.053
	2	0.37	3.33	100	0.015
35.01	1	1.00	1.98	0	0.039
	2	0.31	1.98	100	0.015
35.02	1	0.52	2.58	0	0.041
	2	0.15	2.58	100	0.015
35.03	1	1.26	1.56	0	0.038
	2	0.55	1.56	100	0.015
35.04	1	3.28	1.20	0	0.041
	2	0.57	1.20	100	0.015
35.05	1	0.42	0.66	0	0.043
	2	0.04	0.66	100	0.015
35.06	1	0.40	4.11	0	0.043
	2	0.05	4.11	100	0.015
36.01	1	0.94	2.91	0	0.037
	2	0.69	2.91	100	0.015
37.01	1	0.43	0.84	0	0.039
	2	0.29	0.84	100	0.015
38.01	1	1.64	1.42	0	0.041
	2	0.25	1.42	100	0.015
39.01	1	6.47	1.28	0	0.057
	2	0.37	1.28	100	0.015
40.01	1	0.64	2.25	0	0.053
	2	0.40	2.25	100	0.015
40.02	1	1.14	1.80	0	0.057
	2	0.42	1.80	100	0.015
40.03	1	4.70	2.38	0	0.057
	2	1.52	2.38	100	0.015
40.04	1	1.29	1.86	0	0.056
	2	0.38	1.86	100	0.015
40.05	1	3.68	0.55	0	0.054
	2	0.71	0.55	100	0.015
40.06	1	1.25	1.44	0	0.067
	2	0.45	1.44	100	0.015
41.01	1	1.89	3.35	0	0.054
	2	0.78	3.35	100	0.015

Subcatchment ID	Sub-Area	Area [ha]	Catchment Slope [%]	Percentage Impervious [%]	Mannings 'n'
42.01	1	2.72	2.60	0	0.051
	2	0.99	2.60	100	0.015
43.01	1	1.03	1.09	0	0.063
	2	0.28	1.09	100	0.015
44.01	1	2.80	1.08	0	0.060
	2	0.30	1.08	100	0.015
44.02	1	0.74	1.35	0	0.062
	2	0.16	1.35	100	0.015
44.03	1	2.47	1.74	0	0.061
	2	0.12	1.74	100	0.015
44.04	1	8.78	0.85	0	0.074
	2	0.46	0.85	100	0.015
45.01	1	1.15	1.40	0	0.066
	2	0.32	1.40	100	0.015
46.01	1	4.04	0.71	0	0.060
	2	0.15	0.71	100	0.015
47.01	1	1.94	0.94	0	0.051
	2	0.10	0.94	100	0.015
48.01	1	6.49	0.72	0	0.078
	2	0.40	0.72	100	0.015
48.02	1	0.43	1.62	0	0.095
	2	0.00	1.62	100	0.015
49.01	1	4.29	2.52	0	0.070
	2	0.42	2.52	100	0.015
50.01	1	5.69	1.58	0	0.056
	2	0.49	1.58	100	0.015
51.01	1	1.37	1.07	0	0.061
	2	0.26	1.07	100	0.015
52.01	1	6.68	1.32	0	0.061
	2	1.02	1.32	100	0.015
52.02	1	2.68	0.89	0	0.058
	2	0.04	0.89	100	0.015
53.01	1	1.45	1.85	0	0.050
	2	0.09	1.85	100	0.015
53.02	1	3.22	1.38	0	0.043
	2	0.43	1.38	100	0.015
53.03	1	1.93	1.32	0	0.049
	2	0.00	1.32	100	0.015
54.01	1	1.54	2.36	0	0.037
	2	0.57	2.36	100	0.015
55.01	1	1.39	2.74	0	0.040
	2	0.37	2.74	100	0.015
56.01	1	1.70	1.34	0	0.054
	2	0.53	1.34	100	0.015
57.01	1	3.21	2.34	0	0.055

Subcatchment ID	Sub-Area	Area [ha]	Catchment Slope [%]	Percentage Impervious [%]	Mannings 'n'
57.01	2	1.45	2.34	100	0.015
57.02	1	0.75	0.86	0	0.040
	2	0.57	0.86	100	0.015
57.03	1	0.53	1.92	0	0.037
	2	0.46	1.92	100	0.015
58.01	1	11.60	5.11	0	0.074
	2	0.02	5.11	100	0.015
58.02	1	2.36	5.48	0	0.056
	2	0.19	5.48	100	0.015
58.03	1	3.41	3.37	0	0.060
	2	0.16	3.37	100	0.015
58.04	1	2.52	4.28	0	0.063
	2	0.17	4.28	100	0.015
58.05	1	1.89	2.36	0	0.081
	2	0.28	2.36	100	0.015
58.06	1	0.20	1.74	0	0.072
	2	0.07	1.74	100	0.015
58.07	1	0.33	0.76	0	0.083
	2	0.06	0.76	100	0.015
58.08	1	0.97	2.30	0	0.060
	2	0.37	2.30	100	0.015
58.09	1	2.00	1.69	0	0.060
	2	0.59	1.69	100	0.015
58.1	1	1.43	1.26	0	0.062
	2	0.37	1.26	100	0.015
58.11	1	0.59	3.02	0	0.065
	2	0.13	3.02	100	0.015
59.01	1	7.70	6.71	0	0.078
	2	0.33	6.71	100	0.015
59.02	1	5.02	3.81	0	0.057
	2	0.05	3.81	100	0.015
60.01	1	4.05	10.32	0	0.088
	2	0.17	10.32	100	0.015
60.02	1	8.70	3.47	0	0.061
	2	0.08	3.47	100	0.015
61.01	1	2.07	7.69	0	0.076
	2	0.31	7.69	100	0.015
61.02	1	1.31	4.48	0	0.058
	2	0.39	4.48	100	0.015
61.03	1	2.19	4.24	0	0.059
	2	0.67	4.24	100	0.015
61.04	1	4.47	2.04	0	0.092
	2	0.13	2.04	100	0.015
62.01	1	3.24	5.10	0	0.053
	2	0.37	5.10	100	0.015

Subcatchment ID	Sub-Area	Area [ha]	Catchment Slope [%]	Percentage Impervious [%]	Mannings 'n'
63.01	1	2.40	4.96	0	0.072
	2	0.16	4.96	100	0.015
64.01	1	0.75	2.82	0	0.053
	2	0.10	2.82	100	0.015
65.01	1	1.70	2.84	0	0.063
	2	0.37	2.84	100	0.015
65.02	1	0.78	3.01	0	0.058
	2	0.33	3.01	100	0.015
66.01	1	0.12	4.54	0	0.050
	2	0.03	4.54	100	0.015
67.01	1	2.63	1.74	0	0.056
	2	0.98	1.74	100	0.015
68.01	1	1.72	1.92	0	0.067
	2	0.49	1.92	100	0.015
69.01	1	1.03	1.73	0	0.051
	2	0.54	1.73	100	0.015
69.02	1	0.96	1.25	0	0.064
	2	0.33	1.25	100	0.015
70.01	1	2.61	1.11	0	0.053
	2	0.87	1.11	100	0.015
71.01	1	10.82	1.37	0	0.051
	2	0.01	1.37	100	0.015
71.02	1	0.80	1.06	0	0.047
	2	0.14	1.06	100	0.015
72.01	1	5.54	1.68	0	0.053
	2	0.89	1.68	100	0.015
73.01	1	1.82	1.34	0	0.064
	2	0.41	1.34	100	0.015
73.02	1	2.57	1.30	0	0.065
	2	0.46	1.30	100	0.015
73.03	1	3.35	1.16	0	0.069
	2	0.47	1.16	100	0.015
74.01	1	1.55	1.50	0	0.061
	2	0.17	1.50	100	0.015
75.01	1	0.87	1.38	0	0.074
	2	0.18	1.38	100	0.015
76.01	1	8.60	2.09	0	0.049
	2	0.32	2.09	100	0.015
77.01	1	11.65	1.99	0	0.062
	2	0.14	1.99	100	0.015
78.01	1	0.61	4.90	0	0.050
	2	0.31	4.90	100	0.015
78.02	1	2.44	1.73	0	0.092
	2	0.16	1.73	100	0.015
78.03	1	0.67	2.27	0	0.085

Subcatchment ID	Sub-Area	Area [ha]	Catchment Slope [%]	Percentage Impervious [%]	Mannings 'n'
78.03	2	0.12	2.27	100	0.015
78.04	1	0.80	1.20	0	0.072
	2	0.25	1.20	100	0.015
78.05	1	1.88	1.75	0	0.070
	2	0.19	1.75	100	0.015
78.06	1	1.50	0.74	0	0.056
	2	0.66	0.74	100	0.015
78.07	1	1.06	1.29	0	0.045
	2	0.78	1.29	100	0.015
79.01	1	2.63	6.90	0	0.059
	2	0.72	6.90	100	0.015
79.02	1	0.70	3.43	0	0.069
	2	0.20	3.43	100	0.015
79.03	1	1.75	4.56	0	0.065
	2	0.53	4.56	100	0.015
80.01	1	1.76	6.22	0	0.066
	2	0.45	6.22	100	0.015
81.01	1	0.51	6.53	0	0.060
	2	0.15	6.53	100	0.015
82.01	1	1.80	7.32	0	0.053
	2	0.73	7.32	100	0.015
82.02	1	1.85	4.60	0	0.068
	2	0.49	4.60	100	0.015
82.03	1	1.22	1.58	0	0.088
	2	0.14	1.58	100	0.015
83.01	1	1.91	5.42	0	0.057
	2	0.65	5.42	100	0.015
84.01	1	1.63	3.87	0	0.069
	2	0.52	3.87	100	0.015
84.02	1	1.33	2.66	0	0.060
	2	0.47	2.66	100	0.015
85.01	1	0.89	4.50	0	0.061
	2	0.33	4.50	100	0.015
86.01	1	0.07	3.08	0	0.068
	2	0.03	3.08	100	0.015
86.02	1	1.21	2.26	0	0.053
	2	0.58	2.26	100	0.015
87.01	1	0.58	3.20	0	0.058
	2	0.09	3.20	100	0.015
88.01	1	2.91	4.92	0	0.061
	2	1.00	4.92	100	0.015
88.02	1	2.32	4.96	0	0.074
	2	0.36	4.96	100	0.015
88.03	1	9.10	3.64	0	0.080
	2	0.45	3.64	100	0.015

Subcatchment ID	Sub-Area	Area [ha]	Catchment Slope [%]	Percentage Impervious [%]	Mannings 'n'
88.04	1	7.59	1.81	0	0.057
	2	0.26	1.81	100	0.015
89.01	1	5.03	4.62	0	0.075
	2	0.20	4.62	100	0.015
89.02	1	5.54	0.85	0	0.048
	2	2.45	0.85	100	0.015
89.03	1	2.95	1.44	0	0.051
	2	0.57	1.44	100	0.015
90.01	1	5.47	3.10	0	0.070
	2	0.25	3.10	100	0.015
91.01	1	3.40	1.34	0	0.047
	2	1.28	1.34	100	0.015
92.01	1	3.53	1.63	0	0.043
	2	1.53	1.63	100	0.015
92.02	1	2.66	1.22	0	0.054
	2	0.91	1.22	100	0.015

XP-RAFTS INPUT PARAMETERS - Nattai Ponds

2007 Historic Conditions

Subcatchment ID	Sub-Area	Area [ha]	Catchment Slope [%]	Percentage Impervious [%]	Mannings 'n'
1.01	1	8.78	6.82	0	0.066
	2	0.28	6.82	100	0.015
1.02	1	5.78	11.10	0	0.045
	2	0.71	11.10	100	0.015
1.03	1	8.71	3.64	0	0.045
	2	0.30	3.64	100	0.015
1.04	1	1.27	2.61	0	0.047
	2	0.11	2.61	100	0.015
1.05	1	12.03	2.61	0	0.048
	2	0.19	2.61	100	0.015
1.06	1	2.75	1.68	0	0.060
	2	0.07	1.68	100	0.015
1.07	1	6.55	2.10	0	0.046
	2	0.03	2.10	100	0.015
1.08	1	4.44	1.34	0	0.045
	2	0.00	1.34	100	0.015
1.09	1	3.68	2.62	0	0.045
	2	0.00	2.62	100	0.015
1.1	1	3.95	1.33	0	0.045
	2	0.00	1.33	100	0.015
1.11	1	5.48	0.74	0	0.061
	2	0.37	0.74	100	0.015
1.12	1	4.64	2.11	0	0.066
	2	0.47	2.11	100	0.015
1.13	1	5.17	1.70	0	0.062
	2	0.43	1.70	100	0.015
1.14	1	3.36	1.15	0	0.067
	2	0.09	1.15	100	0.015
1.15	1	5.23	0.83	0	0.080
	2	0.40	0.83	100	0.015
1.16	1	3.69	1.85	0	0.062
	2	0.36	1.85	100	0.015
1.17	1	1.58	1.69	0	0.071
	2	0.11	1.69	100	0.015
1.18	1	3.39	1.91	0	0.060
	2	0.09	1.91	100	0.015
1.19	1	7.85	0.98	0	0.056
	2	0.25	0.98	100	0.015
1.2	1	0.70	3.66	0	0.062
	2	0.10	3.66	100	0.015
1.21	1	2.12	1.46	0	0.066
	2	0.13	1.46	100	0.015

Subcatchment ID	Sub-Area	Area [ha]	Catchment Slope [%]	Percentage Impervious [%]	Mannings 'n'
1.22	1	9.93	1.05	0	0.059
	2	0.27	1.05	100	0.015
1.23	1	12.23	1.16	0	0.051
	2	0.21	1.16	100	0.015
1.24	1	0.06	4.00	0	0.056
	2	0.03	4.00	100	0.015
1.25	1	0.60	2.25	0	0.075
	2	0.03	2.25	100	0.015
1.26	1	16.93	1.74	0	0.062
	2	1.99	1.74	100	0.015
2.01	1	1.65	10.47	0	0.058
	2	0.08	10.47	100	0.015
2.02	1	5.06	9.89	0	0.047
	2	0.48	9.89	100	0.015
3.01	1	4.04	7.69	0	0.056
	2	0.66	7.69	100	0.015
3.02	1	9.33	6.84	0	0.049
	2	0.24	6.84	100	0.015
3.03	1	6.61	5.07	0	0.045
	2	0.35	5.07	100	0.015
4.01	1	8.39	10.77	0	0.059
	2	0.54	10.77	100	0.015
5.01	1	7.73	4.35	0	0.045
	2	0.22	4.35	100	0.015
5.02	1	9.25	3.24	0	0.049
	2	0.23	3.24	100	0.015
5.03	1	10.57	1.27	0	0.058
	2	0.80	1.27	100	0.015
6.01	1	14.13	5.13	0	0.046
	2	0.28	5.13	100	0.015
6.02	1	4.56	4.30	0	0.045
	2	0.05	4.30	100	0.015
6.03	1	3.02	3.86	0	0.045
	2	0.00	3.86	100	0.015
6.04	1	0.34	1.37	0	0.074
	2	0.01	1.37	100	0.015
6.05	1	3.02	4.09	0	0.051
	2	0.06	4.09	100	0.015
6.06	1	10.68	2.40	0	0.051
	2	0.38	2.40	100	0.015
6.07	1	3.60	3.88	0	0.046
	2	0.09	3.88	100	0.015
7.01	1	6.43	4.46	0	0.052
	2	0.18	4.46	100	0.015
8.01	1	2.32	5.92	0	0.052

Subcatchment ID	Sub-Area	Area [ha]	Catchment Slope [%]	Percentage Impervious [%]	Mannings 'n'
8.01	2	0.62	5.92	100	0.015
8.02	1	5.89	4.98	0	0.056
	2	0.62	4.98	100	0.015
8.03	1	5.33	3.62	0	0.053
	2	0.07	3.62	100	0.015
9.01	1	3.45	5.94	0	0.057
	2	1.21	5.94	100	0.015
10.01	1	5.18	4.20	0	0.049
	2	0.10	4.20	100	0.015
11.01	1	6.41	1.43	0	0.045
	2	0.00	1.43	100	0.015
12.01	1	12.45	2.11	0	0.048
	2	0.00	2.11	100	0.015
12.02	1	6.35	1.70	0	0.055
	2	0.00	1.70	100	0.015
12.03	1	2.69	3.54	0	0.073
	2	0.37	3.54	100	0.015
12.04	1	2.62	2.86	0	0.073
	2	0.19	2.86	100	0.015
13.01	1	9.13	0.97	0	0.047
	2	0.00	0.97	100	0.015
14.01	1	3.91	3.36	0	0.089
	2	0.01	3.36	100	0.015
15.01	1	2.03	3.91	0	0.079
	2	0.04	3.91	100	0.015
16.01	1	2.62	5.28	0	0.052
	2	1.47	5.28	100	0.015
16.02	1	1.76	4.59	0	0.060
	2	0.56	4.59	100	0.015
16.03	1	1.90	5.49	0	0.071
	2	0.18	5.49	100	0.015
16.04	1	7.88	3.39	0	0.068
	2	0.28	3.39	100	0.015
16.05	1	4.35	1.53	0	0.057
	2	0.11	1.53	100	0.015
16.06	1	0.88	1.29	0	0.094
	2	0.00	1.29	100	0.015
16.07	1	1.64	1.09	0	0.065
	2	0.00	1.09	100	0.015
16.08	1	1.58	1.10	0	0.054
	2	0.00	1.10	100	0.015
16.09	1	0.49	1.63	0	0.047
	2	0.00	1.63	100	0.015
16.1	1	2.67	0.69	0	0.065
	2	0.09	0.69	100	0.015

Subcatchment ID	Sub-Area	Area [ha]	Catchment Slope [%]	Percentage Impervious [%]	Mannings 'n'
16.11	1	1.11	1.62	0	0.064
	2	0.12	1.62	100	0.015
16.12	1	5.48	0.92	0	0.062
	2	0.36	0.92	100	0.015
17.01	1	1.08	7.09	0	0.052
	2	0.58	7.09	100	0.015
18.01	1	1.45	6.16	0	0.059
	2	0.65	6.16	100	0.015
19.01	1	3.11	4.53	0	0.058
	2	0.12	4.53	100	0.015
20.01	1	0.94	4.35	0	0.064
	2	0.21	4.35	100	0.015
21.01	1	2.64	3.17	0	0.061
	2	0.64	3.17	100	0.015
21.02	1	0.36	3.04	0	0.054
	2	0.19	3.04	100	0.015
21.03	1	0.52	2.96	0	0.052
	2	0.30	2.96	100	0.015
21.04	1	2.08	1.91	0	0.064
	2	0.61	1.91	100	0.015
21.05	1	2.59	3.11	0	0.069
	2	0.53	3.11	100	0.015
21.06	1	3.01	1.42	0	0.092
	2	0.11	1.42	100	0.015
22.01	1	2.86	1.50	0	0.056
	2	0.35	1.50	100	0.015
23.01	1	2.17	4.88	0	0.058
	2	0.69	4.88	100	0.015
23.02	1	1.08	3.47	0	0.060
	2	0.24	3.47	100	0.015
24.01	1	2.24	6.51	0	0.066
	2	0.42	6.51	100	0.015
25.01	1	0.77	2.04	0	0.060
	2	0.22	2.04	100	0.015
26.01	1	4.97	2.38	0	0.045
	2	0.01	2.38	100	0.015
27.01	1	3.44	2.23	0	0.045
	2	0.00	2.23	100	0.015
28.01	1	1.26	1.02	0	0.095
	2	0.00	1.02	100	0.015
29.01	1	5.20	1.53	0	0.045
	2	0.00	1.53	100	0.015
30.01	1	0.67	2.60	0	0.051
	2	0.43	2.60	100	0.015
30.02	1	3.01	1.62	0	0.058

Subcatchment ID	Sub-Area	Area [ha]	Catchment Slope [%]	Percentage Impervious [%]	Mannings 'n'
30.02	2	1.01	1.62	100	0.015
30.03	1	5.22	1.57	0	0.064
	2	1.13	1.57	100	0.015
30.04	1	6.25	1.30	0	0.081
	2	0.34	1.30	100	0.015
30.05	1	2.71	1.25	0	0.081
	2	0.16	1.25	100	0.015
30.06	1	2.56	1.21	0	0.091
	2	0.00	1.21	100	0.015
31.01	1	4.63	2.06	0	0.096
	2	0.03	2.06	100	0.015
32.01	1	1.63	0.83	0	0.045
	2	0.00	0.83	100	0.015
33.01	1	6.57	1.30	0	0.057
	2	0.37	1.30	100	0.015
34.01	1	4.77	2.46	0	0.058
	2	1.51	2.46	100	0.015
34.02	1	1.29	1.86	0	0.056
	2	0.38	1.86	100	0.015
34.03	1	3.68	0.55	0	0.054
	2	0.71	0.55	100	0.015
34.04	1	1.25	1.44	0	0.067
	2	0.45	1.44	100	0.015
35.01	1	1.89	3.35	0	0.054
	2	0.78	3.35	100	0.015
36.01	1	2.72	2.60	0	0.051
	2	0.99	2.60	100	0.015
37.01	1	1.42	1.14	0	0.062
	2	0.33	1.14	100	0.015
38.01	1	3.18	1.03	0	0.059
	2	0.30	1.03	100	0.015
38.02	1	0.74	1.35	0	0.062
	2	0.16	1.35	100	0.015
38.03	1	2.47	1.74	0	0.061
	2	0.12	1.74	100	0.015
38.04	1	8.78	0.85	0	0.074
	2	0.46	0.85	100	0.015
39.01	1	1.15	1.40	0	0.066
	2	0.32	1.40	100	0.015
40.01	1	4.04	0.71	0	0.060
	2	0.15	0.71	100	0.015
41.01	1	1.94	0.94	0	0.051
	2	0.10	0.94	100	0.015
42.01	1	6.49	0.72	0	0.078
	2	0.40	0.72	100	0.015

Subcatchment ID	Sub-Area	Area [ha]	Catchment Slope [%]	Percentage Impervious [%]	Mannings 'n'
42.02	1	0.43	1.62	0	0.095
	2	0.00	1.62	100	0.015
43.01	1	4.29	2.52	0	0.070
	2	0.42	2.52	100	0.015
44.01	1	5.69	1.58	0	0.056
	2	0.49	1.58	100	0.015
45.01	1	1.31	1.14	0	0.061
	2	0.26	1.14	100	0.015
46.01	1	3.21	2.38	0	0.055
	2	1.45	2.38	100	0.015
46.02	1	0.90	0.85	0	0.043
	2	0.57	0.85	100	0.015
46.03	1	1.85	0.98	0	0.040
	2	0.44	0.98	100	0.015
47.01	1	1.56	1.82	0	0.046
	2	0.18	1.82	100	0.015
47.02	1	2.07	0.96	0	0.044
	2	0.15	0.96	100	0.015
48.01	1	5.85	1.27	0	0.063
	2	0.71	1.27	100	0.015
48.02	1	1.47	0.96	0	0.065
	2	0.02	0.96	100	0.015
48.03	1	0.17	1.79	0	0.046
	2	0.00	1.79	100	0.015
49.01	1	0.76	1.32	0	0.055
	2	0.21	1.32	100	0.015
50.01	1	0.73	0.52	0	0.054
	2	0.00	0.52	100	0.015
50.02	1	1.58	1.55	0	0.045
	2	0.06	1.55	100	0.015
51.01	1	1.65	2.09	0	0.045
	2	0.01	2.09	100	0.015
52.01	1	1.20	1.16	0	0.055
	2	0.50	1.16	100	0.015
53.01	1	0.50	1.92	0	0.035
	2	0.44	1.92	100	0.015
54.01	1	11.68	5.14	0	0.074
	2	0.02	5.14	100	0.015
54.02	1	2.36	5.47	0	0.056
	2	0.19	5.47	100	0.015
54.03	1	3.41	3.37	0	0.060
	2	0.16	3.37	100	0.015
54.04	1	2.52	4.28	0	0.063
	2	0.17	4.28	100	0.015
54.05	1	1.89	2.36	0	0.081

Subcatchment ID	Sub-Area	Area [ha]	Catchment Slope [%]	Percentage Impervious [%]	Mannings 'n'
54.05	2	0.28	2.36	100	0.015
54.06	1	0.20	1.74	0	0.072
	2	0.07	1.74	100	0.015
54.07	1	0.33	0.76	0	0.083
	2	0.06	0.76	100	0.015
54.08	1	0.97	2.30	0	0.060
	2	0.37	2.30	100	0.015
54.09	1	2.00	1.69	0	0.060
	2	0.59	1.69	100	0.015
54.1	1	1.43	1.26	0	0.062
	2	0.37	1.26	100	0.015
54.11	1	0.68	2.67	0	0.065
	2	0.13	2.67	100	0.015
55.01	1	7.70	6.71	0	0.078
	2	0.33	6.71	100	0.015
55.02	1	5.02	3.81	0	0.057
	2	0.05	3.81	100	0.015
56.01	1	4.05	10.32	0	0.088
	2	0.17	10.32	100	0.015
56.02	1	8.70	3.47	0	0.061
	2	0.08	3.47	100	0.015
57.01	1	2.07	7.69	0	0.076
	2	0.31	7.69	100	0.015
57.02	1	1.31	4.48	0	0.058
	2	0.39	4.48	100	0.015
57.03	1	2.19	4.24	0	0.059
	2	0.67	4.24	100	0.015
57.04	1	4.47	2.04	0	0.092
	2	0.13	2.04	100	0.015
58.01	1	3.24	5.10	0	0.053
	2	0.37	5.10	100	0.015
59.01	1	2.40	4.96	0	0.072
	2	0.16	4.96	100	0.015
60.01	1	0.75	2.82	0	0.053
	2	0.10	2.82	100	0.015
61.01	1	1.70	2.84	0	0.063
	2	0.37	2.84	100	0.015
61.02	1	0.78	3.01	0	0.058
	2	0.33	3.01	100	0.015
62.01	1	0.12	4.54	0	0.050
	2	0.03	4.54	100	0.015
63.01	1	2.63	1.74	0	0.056
	2	0.98	1.74	100	0.015
64.01	1	1.72	1.92	0	0.067
	2	0.49	1.92	100	0.015

Subcatchment ID	Sub-Area	Area [ha]	Catchment Slope [%]	Percentage Impervious [%]	Mannings 'n'
65.01	1	1.03	1.73	0	0.051
	2	0.54	1.73	100	0.015
65.02	1	0.96	1.25	0	0.064
	2	0.33	1.25	100	0.015
66.01	1	10.82	1.37	0	0.051
	2	0.01	1.37	100	0.015
66.02	1	0.80	1.06	0	0.047
	2	0.14	1.06	100	0.015
67.01	1	5.54	1.68	0	0.053
	2	0.89	1.68	100	0.015
68.01	1	3.77	1.28	0	0.057
	2	1.17	1.28	100	0.015
68.02	1	3.91	1.15	0	0.068
	2	0.57	1.15	100	0.015
69.01	1	2.59	1.30	0	0.065
	2	0.46	1.30	100	0.015
70.01	1	1.55	1.50	0	0.061
	2	0.17	1.50	100	0.015
71.01	1	0.87	1.38	0	0.074
	2	0.18	1.38	100	0.015
72.01	1	8.60	2.09	0	0.049
	2	0.32	2.09	100	0.015
73.01	1	11.65	1.99	0	0.062
	2	0.14	1.99	100	0.015
74.01	1	0.61	4.90	0	0.050
	2	0.31	4.90	100	0.015
74.02	1	2.44	1.73	0	0.092
	2	0.16	1.73	100	0.015
74.03	1	0.67	2.27	0	0.085
	2	0.12	2.27	100	0.015
74.04	1	0.80	1.20	0	0.072
	2	0.25	1.20	100	0.015
74.05	1	1.85	1.77	0	0.070
	2	0.19	1.77	100	0.015
74.06	1	1.50	0.73	0	0.056
	2	0.66	0.73	100	0.015
74.07	1	1.06	1.29	0	0.045
	2	0.78	1.29	100	0.015
75.01	1	2.63	6.90	0	0.059
	2	0.72	6.90	100	0.015
75.02	1	0.70	3.43	0	0.069
	2	0.20	3.43	100	0.015
75.03	1	1.75	4.56	0	0.065
	2	0.53	4.56	100	0.015
76.01	1	1.76	6.22	0	0.066

Subcatchment ID	Sub-Area	Area [ha]	Catchment Slope [%]	Percentage Impervious [%]	Mannings 'n'
	2	0.45	6.22	100	0.015
77.01	1	0.51	6.53	0	0.060
	2	0.15	6.53	100	0.015
78.01	1	1.80	7.32	0	0.053
	2	0.73	7.32	100	0.015
78.02	1	1.85	4.60	0	0.068
	2	0.49	4.60	100	0.015
78.03	1	1.22	1.58	0	0.088
	2	0.14	1.58	100	0.015
79.01	1	1.91	5.42	0	0.057
	2	0.65	5.42	100	0.015
80.01	1	1.63	3.87	0	0.069
	2	0.52	3.87	100	0.015
80.02	1	1.33	2.66	0	0.060
	2	0.47	2.66	100	0.015
81.01	1	0.89	4.50	0	0.061
	2	0.33	4.50	100	0.015
82.01	1	0.07	3.08	0	0.068
	2	0.03	3.08	100	0.015
82.02	1	1.21	2.26	0	0.053
	2	0.58	2.26	100	0.015
83.01	1	0.58	3.20	0	0.058
	2	0.09	3.20	100	0.015
84.01	1	2.91	4.92	0	0.061
	2	1.00	4.92	100	0.015
84.02	1	2.32	4.96	0	0.074
	2	0.36	4.96	100	0.015
84.03	1	9.10	3.64	0	0.080
	2	0.45	3.64	100	0.015
84.04	1	7.62	1.47	0	0.057
	2	0.26	1.47	100	0.015
85.01	1	2.86	1.57	0	0.051
	2	0.55	1.57	100	0.015
86.01	1	5.03	4.62	0	0.075
	2	0.20	4.62	100	0.015
86.02	1	5.62	1.04	0	0.048
	2	2.46	1.04	100	0.015
86.03	1	3.36	1.32	0	0.047
	2	1.28	1.32	100	0.015
86.04	1	3.48	1.60	0	0.043
	2	1.53	1.60	100	0.015
86.05	1	2.62	1.10	0	0.054
	2	0.90	1.10	100	0.015
87.01	1	5.47	3.10	0	0.070
	2	0.25	3.10	100	0.015

Link ID	Hydrograph lag (Existing) [mins]
Link 1	1.2
Link 10	2.8
Link 100	0
Link 101	0
Link 102	0
Link 103	0
Link 104	0
Link 105	5
Link 106	2.4
Link 107	0
Link 108	0
Link 109	0
Link 11	1.3
Link 110	0
Link 111	0
Link 112	0
Link 113	5.1
Link 114	0
Link 115	0
Link 116	3.4
Link 117	2
Link 118	0
Link 119	0
Link 12	1.2
Link 120	2.2
Link 121	0.3
Link 122	0.9
Link 123	0.4
Link 124	1.3
Link 125	2
Link 126	2.1
Link 127	2.3
Link 128	1.4
Link 129	1.4
Link 13	2.5
Link 130	1.5
Link 131	2.4
Link 132	0.7
Link 133	0.2
Link 134	1.5
Link 135	0.2
Link 136	0.3
Link 137	1.5
Link 138	0.3
Link 139	1.5

Link 14	1.5
Link 140	1.4
Link 141	1.4
Link 142	1.2
Link 143	1.8
Link 144	0
Link 145	0
Link 146	1.3
Link 147	1.3
Link 148	2
Link 149	2.1
Link 15	1.2
Link 150	0.4
Link 151	3.2
Link 152	0
Link 153	0
Link 154	2
Link 155	0
Link 156	0
Link 157	0
Link 158	0
Link 159	1.5
Link 16	0.9
Link 160	1.5
Link 161	1.4
Link 162	0
Link 163	0
Link 164	0.9
Link 165	1.2
Link 166	0
Link 167	0
Link 168	0.6
Link 169	0
Link 17	0.8
Link 170	0
Link 171	0
Link 172	0
Link 173	1.6
Link 174	0
Link 175	0
Link 176	1.3
Link 177	1.5
Link 178	1.5
Link 179	0
Link 18	2.3
Link 180	0
Link 181	1.2

Link 182	0.9
Link 183	3.1
Link 184	2.9
Link 185	3
Link 186	2
Link 187	2.4
Link 188	0
Link 189	0
Link 19	0
Link 190	0
Link 191	1.8
Link 192	3.4
Link 193	0
Link 194	1.9
Link 195	4.1
Link 196	0
Link 197	2.5
Link 198	0
Link 199	0
Link 2	1.4
Link 20	0
Link 200	1.8
Link 202	4
Link 203	0
Link 204	0
Link 205	2.4
Link 206	1.3
Link 207	0.9
Link 208	1.6
Link 209	0
Link 21	0.9
Link 22	0
Link 23	1.6
Link 24	0
Link 25	1.1
Link 26	0.9
Link 27	1.2
Link 28	5.6
Link 29	0.9
Link 3	1.7
Link 30	0
Link 31	0
Link 32	0
Link 33	0
Link 34	0
Link 35	0
Link 36	0.5

Link 37	0
Link 38	0
Link 39	3
Link 4	2.1
Link 40	2.9
Link 41	1.8
Link 42	0.9
Link 43	0
Link 44	0
Link 45	0
Link 46	0
Link 47	1.6
Link 48	0
Link 49	0
Link 5	1.8
Link 50	0
Link 51	0
Link 52	0
Link 53	0
Link 54	2.2
Link 55	0
Link 56	0
Link 57	2.7
Link 58	2.6
Link 59	0
Link 6	2.5
Link 60	0
Link 61	1.7
Link 62	2.5
Link 63	0
Link 64	0
Link 65	0
Link 66	2.4
Link 67	0.4
Link 68	2.9
Link 69	2.8
Link 7	1.4
Link 70	1.5
Link 71	3
Link 72	4.3
Link 73	0
Link 74	0
Link 75	0.6
Link 76	0.5
Link 77	1.9
Link 78	1.3
Link 79	0

Link 8	1.2
Link 80	0
Link 81	1.3
Link 82	1.4
Link 83	0
Link 84	0
Link 85	0
Link 86	3.6
Link 87	0
Link 88	0
Link 89	0
Link 9	1.5
Link 90	0
Link 91	2.5
Link 92	1.3
Link 93	0
Link 94	0
Link 95	1.4
Link 96	0
Link 97	0
Link 98	0.4
Link 99	0
Link J_116	0.4
Link J_123	1.6
Link J_125	4.3
Link J_126	0.1
Link J_130	0.2
Link J_133	1
Link J_135	0.6
Link J_136	0.9
Link J_138	1.4
Link J_142	1.4
Link J_150	0.9
Link J_151	1.3
Link J_158	1.2
Link J_162	1.6
Link J_19	1
Link J_21	3.1
Link J_28	1.1
Link J_29	0.6
Link J_30	1.3
Link J_32	0.5
Link J_37	1.3
Link J_38	2
Link J_40	1.7
Link J_41	1.5
Link J_42	4.4

Link J_44	2.6
Link J_47	3.4
Link J_50	1.2
Link J_59	0.9
Link J_64	2.3
Link J_68	1.8
Link J_69	2.4
Link J_71	1.8
Link J_74	1.8
Link J_76	0.6
Link J_80	3.4
Link J_81	0.7
Link J_84	0.3
Link J_85	1.1
Link J_86	2.5
Link J_88	3.6
Link J_91	2.9
Link 1	0.6
Link 2	1.8

Link ID	Hydrograph lag (Historic) [mins]
Link 1	1.2
Link 10	3.1
Link 100	0
Link 101	2.2
Link 102	1.1
Link 103	2
Link 104	2.1
Link 105	2.3
Link 106	1.4
Link 107	1.4
Link 108	1.5
Link 109	2.7
Link 11	1.3
Link 110	0.7
Link 111	1.4
Link 112	1.2
Link 113	1.8
Link 114	0
Link 115	0
Link 116	1.3
Link 117	1.3
Link 118	2
Link 119	2.1
Link 12	1.2
Link 120	0.4
Link 121	3.2
Link 122	0
Link 123	0
Link 124	0
Link 125	0
Link 126	0
Link 127	0
Link 128	1.5
Link 129	1.5
Link 13	2.5
Link 130	1.4
Link 131	0
Link 132	0
Link 133	0.9
Link 134	1.2
Link 135	0
Link 136	0
Link 137	0
Link 138	0
Link 139	1.3

Link 14	1.5
Link 140	1.5
Link 141	1.5
Link 142	1.6
Link 143	0.1
Link 144	1.2
Link 145	0.9
Link 146	3.1
Link 147	2.9
Link 148	3
Link 149	2.3
Link 15	1.2
Link 150	2.4
Link 151	0
Link 152	0
Link 153	0
Link 154	1.8
Link 155	3.4
Link 156	0
Link 157	1.9
Link 158	4.1
Link 159	0
Link 16	0.9
Link 160	2.5
Link 161	0
Link 162	0
Link 164	4
Link 165	0
Link 166	0
Link 167	3
Link 168	2.6
Link 169	0.9
Link 17	0.8
Link 170	0
Link 171	1.6
Link 172	0
Link 173	1
Link 174	2.6
Link 175	0
Link 176	1.6
Link 177	1.5
Link 178	1.5
Link 179	0
Link 18	2.1
Link 180	0
Link 181	0
Link 182	0

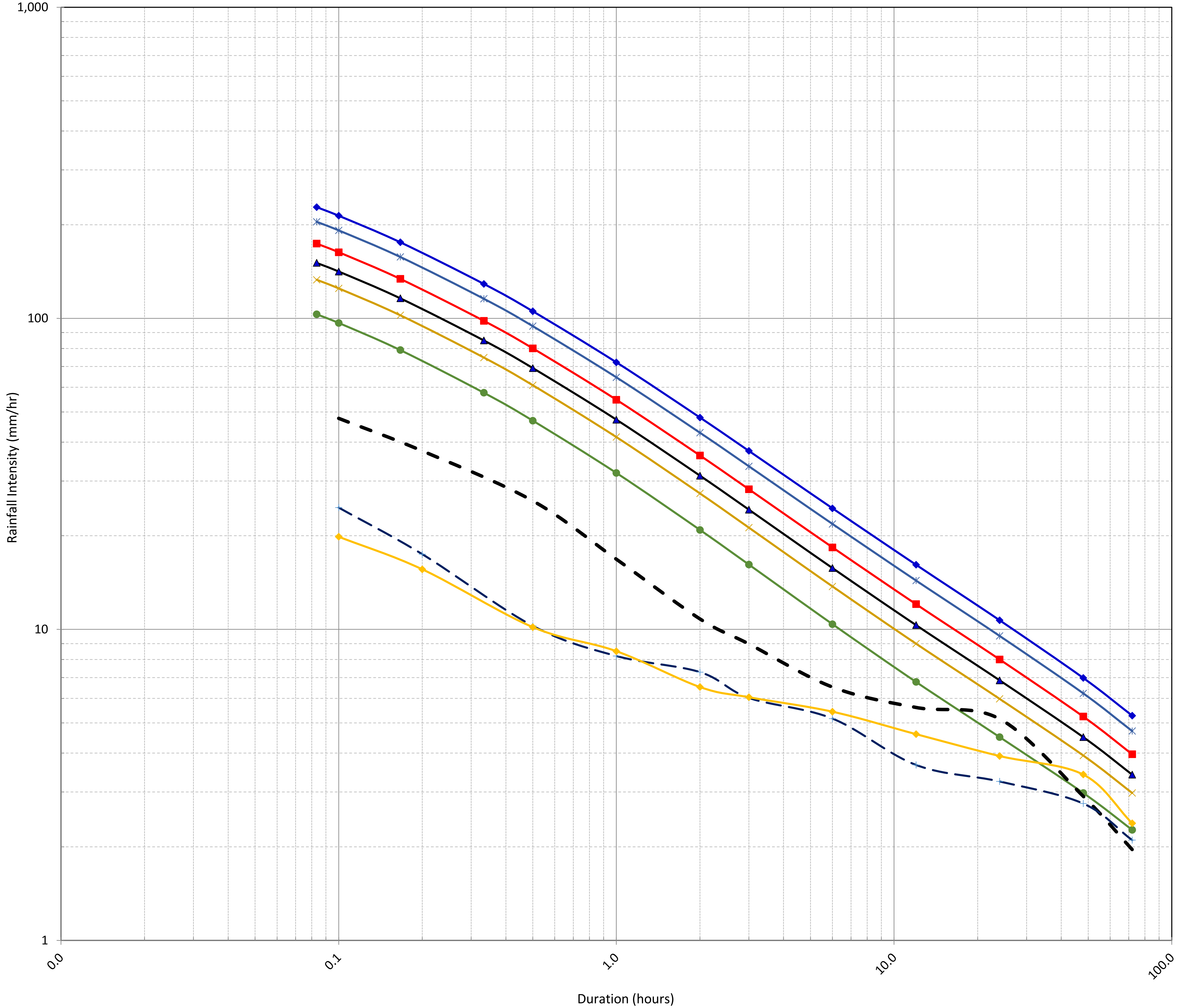
Link 183	1.3
Link 184	0
Link 185	1.6
Link 186	2.3
Link 187	3.5
Link 188	2.6
Link 189	1.5
Link 19	0
Link 190	0
Link 191	3.6
Link 192	0.5
Link 193	0.6
Link 194	1.3
Link 195	1.8
Link 196	0
Link 197	1.2
Link 198	2.3
Link 199	2.4
Link 2	1.4
Link 20	0
Link 200	1.9
Link 201	0
Link 21	0.9
Link 22	0
Link 23	1.5
Link 24	0.9
Link 25	0.9
Link 26	0
Link 27	0
Link 28	2.6
Link 29	0.1
Link 3	1.7
Link 30	0
Link 31	0
Link 32	0.9
Link 33	1.3
Link 34	0
Link 35	0
Link 36	0
Link 37	0
Link 38	0
Link 39	0
Link 4	2.1
Link 40	0
Link 41	0
Link 42	2.2
Link 43	0

Link 44	0
Link 45	2.7
Link 46	2.6
Link 47	0
Link 48	0
Link 49	1.7
Link 5	1.8
Link 50	2.5
Link 51	0
Link 52	0
Link 53	0
Link 54	2.4
Link 55	0.4
Link 56	2.4
Link 57	2.8
Link 58	1.5
Link 59	3
Link 6	2.5
Link 60	4.3
Link 61	1.4
Link 62	1.9
Link 63	0
Link 64	0
Link 65	0
Link 66	1.4
Link 67	0
Link 68	0
Link 69	2.3
Link 7	1.4
Link 70	0
Link 71	0
Link 72	0
Link 73	2.5
Link 74	1.3
Link 75	1.8
Link 76	1.4
Link 77	0
Link 78	0
Link 79	0.4
Link 8	1.2
Link 80	0
Link 81	0
Link 82	0
Link 83	0
Link 84	0
Link 85	0
Link 86	4.8

Link 87	2.5
Link 88	0
Link 89	0
Link 9	1.5
Link 90	0
Link 91	0
Link 92	0
Link 93	0
Link 94	4.9
Link 95	0
Link 96	0
Link 97	3.4
Link 98	2.1
Link 99	0
Link J_100	1.6
Link J_101	4.3
Link J_102	0.1
Link J_106	0.2
Link J_109	1
Link J_110	1.4
Link J_123	0.9
Link J_131	1.2
Link J_134	1.6
Link J_139	1.5
Link J_142	2.5
Link J_146	1.2
Link J_147	0.9
Link J_19	1
Link J_21	2.8
Link J_25	0.6
Link J_28	0.5
Link J_31	2
Link J_32	1.7
Link J_33	1.5
Link J_34	4.4
Link J_36	2.6
Link J_39	3.4
Link J_42	1.2
Link J_53	2.3
Link J_54	0.9
Link J_57	1.8
Link J_59	1.8
Link J_64	0.6
Link J_68	3.4
Link J_69	0.6
Link J_72	0.3
Link J_73	1.1

Appendix C

XP-RAFTS Model Results for Historic Simulations



LEGEND:

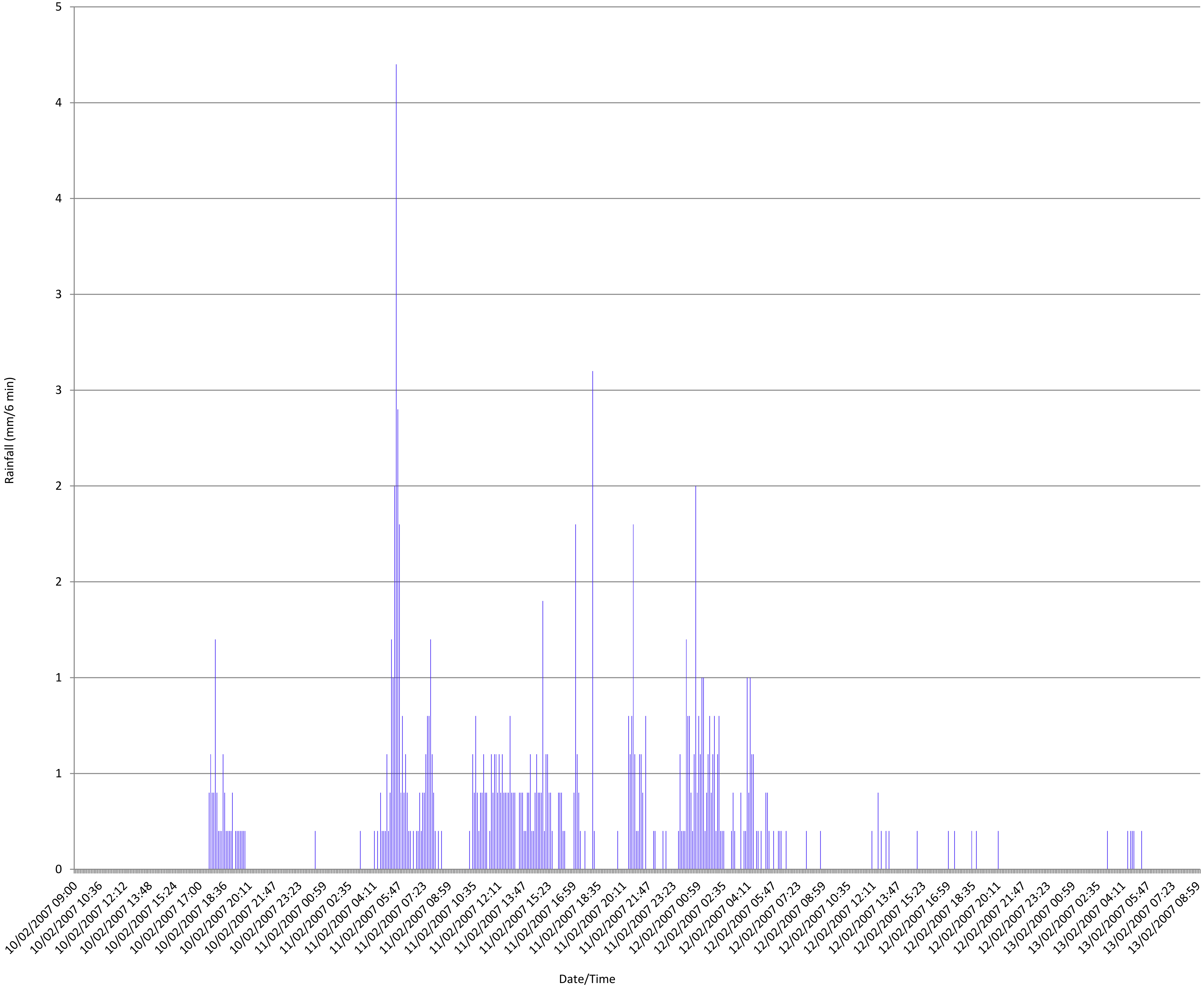
- 1% AEP
- 2% AEP
- 5% AEP
- 10% AEP
- 20% AEP
- 50% AEP
- Factored Parry Drive February 2007 Rainfall
- Factored Moss Vale AWS August 2014 Rainfall
- Factored Moss Vale AWS August 2015 Rainfall

Notes:
The IFD Curves shown incorporate appropriate Aerial reduction Factors

Figure C1: Design Intensity - Frequency - Duration Curves Vs Historic Rainfall

Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George Street
Sydney, NSW, 2000

File Name: Nattai Ponds Catchment IFD Curves.xlsx



WINGECARRIBEE SHIRE COUNCIL

LEGEND:

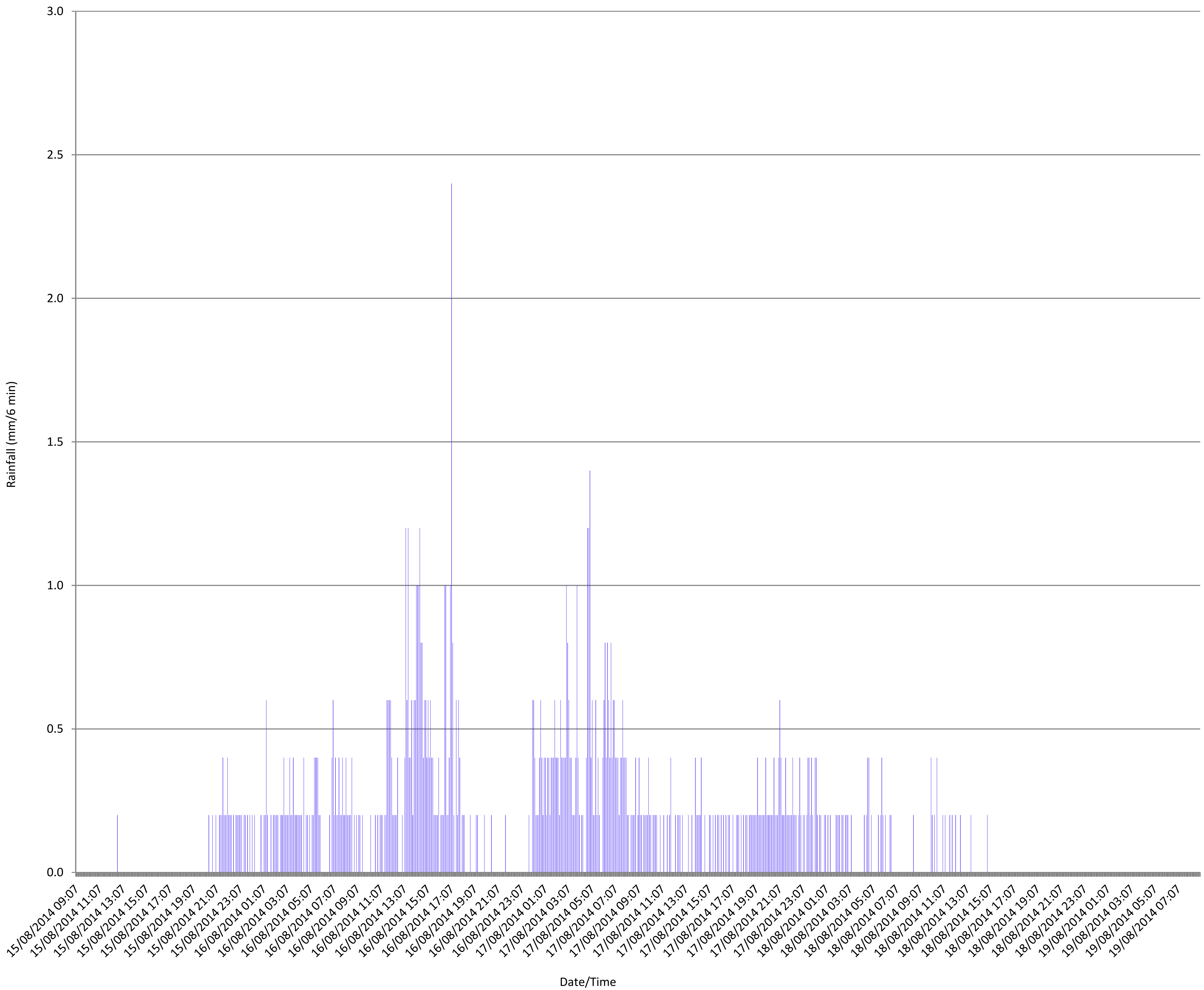
Parry Dr Pluviograph

Notes:

Figure C2: Continuous Rainfall Data for the February 2007 Event

Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George Street
Sydney, NSW, 2000

File Name: Nattai_Pluviographs.xlsx



LEGEND:

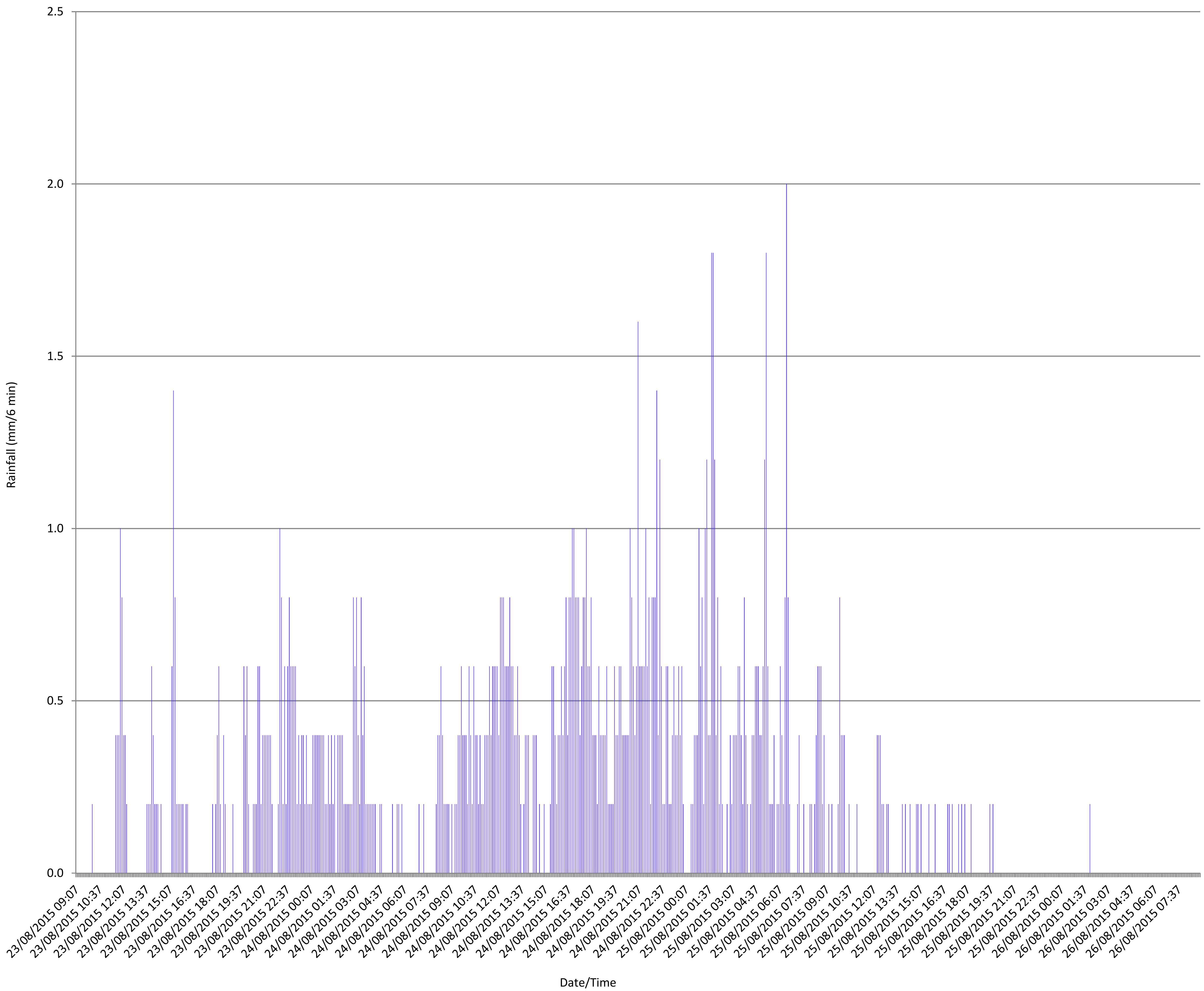
Moss Vale AWS

Notes:

Figure C3:
Continuous Rainfall Data for the August 2014 Event

Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George Street
Sydney, NSW, 2000

File Name: Nattai_Pluviographs.xlsx



WINGECARRIBEE SHIRE COUNCIL

LEGEND:

Moss Vale AWS

Notes:

Figure C4: Continuous Rainfall Data for the August 2015 Event

Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George Street
Sydney, NSW, 2000

File Name: Nattai_Pluviographs.xlsx

PEAK DESIGN FLOOD DISCHARGES - Calibration Events

#The XP-RAFTS model subcatchment layout was modified for the 2007 calibration event to replicate historic topography.

	Peak Discharge (m3/s)		Peak Discharge (m3/s)	Peak Discharge (m3/s)
2007# Calibration Event Subcatchment ID	February 2007	2014/15 Calibration Event Subcatchment ID	August 2014	August 2015
1.01	0.25	1.01	0.15	0.13
1.02	0.46	1.02	0.28	0.27
1.03	0.94	1.03	0.58	0.55
1.04	1.90	1.04	1.11	1.12
1.05	2.18	1.05	1.27	1.26
1.06	2.24	1.06	1.30	1.29
1.07	3.04	1.07	1.77	1.71
1.08	5.17	1.08	2.95	2.80
1.09	5.41	1.09	3.10	2.92
1.1	5.50	1.10	3.16	3.01
1.11	5.58	1.11	3.67	3.45
1.12	6.49	1.12	3.72	3.50
1.13	6.60	1.13	3.75	3.53
1.14	6.65	1.14	5.37	5.15
1.15	10.48	1.15	5.59	5.37
1.16	10.92	1.16	5.70	5.47
1.17	11.49	1.17	5.80	5.56
1.18	11.56	1.18	5.86	5.62
1.19	11.77	1.19	5.98	5.74
1.2	11.81	1.20	6.10	5.86
1.21	13.78	1.21	7.54	7.18
1.22	14.22	1.22	7.76	7.38
1.23	14.62	1.23	8.00	7.59
1.24	14.84	1.24	8.14	7.70
1.25	16.61	1.25	9.33	8.76
1.26	17.62	1.26	9.64	9.02
2.01	0.06	2.01	0.03	0.03
2.02	0.23	2.02	0.16	0.16
3.01	0.16	3.01	0.08	0.08
3.02	0.71	3.02	0.41	0.41
3.03	0.92	3.03	0.53	0.54
4.01	0.28	4.01	0.16	0.17
5.01	0.23	5.01	0.13	0.13
5.02	0.48	5.02	0.28	0.25
5.03	0.66	5.03	0.41	0.38
6.01	0.40	6.01	0.23	0.21
6.02	0.53	6.02	0.30	0.28
6.03	0.81	6.03	0.46	0.42
6.04	1.43	6.04	0.78	0.73
6.05	1.67	6.05	0.91	0.85
6.06	1.92	6.06	0.97	0.91
6.07	2.03	6.07	1.15	1.08
7.01	0.19	7.01	0.11	0.10
8.01	0.10	8.01	0.06	0.06
8.02	0.46	8.02	0.26	0.25
8.03	0.61	8.03	0.32	0.30

	Peak Discharge (m3/s)		Peak Discharge (m3/s)	Peak Discharge (m3/s)
2007# Calibration Event Subcatchment ID	**February 2007**	**2014/15 Calibration Event Subcatchment ID**	**August 2014**	**August 2015**
9.01	0.17	9.01	0.11	0.10
10.01	0.15	10.01	0.08	0.08
11.01	0.14	11.01	0.10	0.09
12.01	0.27	11.02	0.24	0.20
12.02	0.40	12.01	0.07	0.06
12.03	0.73	13.01	0.06	0.05
12.04	0.79	14.01	0.09	0.09
13.01	0.18	15.01	0.15	0.15
14.01	0.08	15.02	0.22	0.21
15.01	0.05	15.03	0.40	0.37
16.01	0.20	15.04	0.43	0.41
16.02	0.35	16.01	0.11	0.09
16.03	0.56	17.01	0.04	0.04
16.04	0.75	18.01	0.03	0.03
16.05	0.84	19.01	0.13	0.10
16.06	1.67	19.02	0.23	0.20
16.07	1.81	19.03	0.38	0.34
16.08	1.96	19.04	0.46	0.40
16.09	2.52	19.05	0.51	0.45
16.1	2.59	19.06	0.95	0.84
16.11	2.76	19.07	1.32	1.16
16.12	2.84	19.08	1.42	1.21
17.01	0.08	19.09	0.78	0.74
18.01	0.09	19.10	0.98	0.94
19.01	0.10	19.11	1.06	1.01
20.01	0.04	19.12	1.11	1.06
21.01	0.10	20.01	0.05	0.04
21.02	0.12	21.01	0.06	0.05
21.03	0.22	22.01	0.05	0.05
21.04	0.55	23.01	0.03	0.02
21.05	0.64	24.01	0.05	0.05
21.06	0.69	24.02	0.07	0.06
22.01	0.07	24.03	0.14	0.12
23.01	0.10	24.04	0.33	0.30
23.02	0.23	24.05	0.42	0.37
24.01	0.09	25.01	0.04	0.04
25.01	0.03	26.01	0.07	0.06
26.01	0.13	26.02	0.14	0.13
27.01	0.10	27.01	0.05	0.05
28.01	0.02	28.01	0.05	0.05
29.01	0.12	29.01	0.02	0.02
30.01	0.06	30.01	0.10	0.09
30.02	0.19	31.01	0.06	0.05
30.03	0.33	31.02	0.17	0.14
30.04	0.40	31.03	0.25	0.20
30.05	0.54	32.01	0.08	0.07
30.06	0.58	33.01	0.06	0.05
31.01	0.09	34.01	0.05	0.05
32.01	0.04	35.01	0.03	0.03

	Peak Discharge (m3/s)		Peak Discharge (m3/s)	Peak Discharge (m3/s)
2007# Calibration Event Subcatchment ID	**February 2007**	**2014/15 Calibration Event Subcatchment ID**	**August 2014**	**August 2015**
33.01	0.14	35.02	0.11	0.09
34.01	0.20	35.03	0.17	0.15
34.02	0.35	35.04	0.23	0.20
34.03	0.55	35.05	0.24	0.21
34.04	0.64	35.06	0.20	0.19
35.01	0.10	36.01	0.06	0.05
36.01	0.13	37.01	0.02	0.02
37.01	0.04	38.01	0.03	0.03
38.01	0.07	39.01	0.08	0.07
38.02	0.13	40.01	0.03	0.03
38.03	0.19	40.02	0.07	0.06
38.04	0.33	40.03	0.20	0.17
39.01	0.04	40.04	0.31	0.26
40.01	0.08	40.05	0.46	0.38
41.01	0.04	40.06	0.52	0.43
42.01	0.12	41.01	0.07	0.06
42.02	0.23	42.01	0.09	0.07
43.01	0.12	43.01	0.03	0.02
44.01	0.14	44.01	0.04	0.03
45.01	0.04	44.02	0.09	0.07
46.01	0.19	44.03	0.12	0.10
46.02	0.25	44.04	0.22	0.19
46.03	0.33	45.01	0.03	0.03
47.01	0.05	46.01	0.04	0.04
47.02	0.10	47.01	0.02	0.02
48.01	0.14	48.01	0.07	0.07
48.02	0.19	48.02	0.14	0.12
48.03	0.19	49.01	0.06	0.06
49.01	0.03	50.01	0.08	0.07
50.01	0.02	51.01	0.03	0.03
50.02	0.06	52.01	0.12	0.10
51.01	0.04	52.02	0.14	0.12
52.01	0.06	53.01	0.02	0.02
53.01	0.06	53.02	0.07	0.07
54.01	0.27	53.03	0.10	0.09
54.02	0.34	54.01	0.05	0.05
54.03	0.44	55.01	0.04	0.04
54.04	0.86	56.01	0.05	0.04
54.05	1.24	57.01	0.12	0.10
54.06	1.25	57.02	0.15	0.12
54.07	1.88	57.03	0.16	0.14
54.08	1.32	58.01	0.16	0.15
54.09	1.55	58.02	0.20	0.19
54.1	1.69	58.03	0.25	0.23
54.11	1.71	58.04	0.48	0.46
55.01	0.22	58.05	0.70	0.66
55.02	0.35	58.06	0.71	0.66
56.01	0.12	58.07	1.04	0.98

	Peak Discharge (m3/s)		Peak Discharge (m3/s)	Peak Discharge (m3/s)
2007# Calibration Event Subcatchment ID	February 2007	2014/15 Calibration Event Subcatchment ID	August 2014	August 2015
56.02	0.33	58.08	1.06	1.01
57.01	0.08	58.09	1.18	1.13
57.02	0.25	58.10	1.25	1.20
57.03	0.44	58.11	1.31	1.26
57.04	0.62	59.01	0.13	0.12
58.01	0.12	59.02	0.20	0.18
59.01	0.07	60.01	0.07	0.06
60.01	0.03	60.02	0.19	0.18
61.01	0.06	61.01	0.04	0.04
61.02	0.11	61.02	0.14	0.13
62.01	0.01	61.03	0.24	0.23
63.01	0.13	61.04	0.36	0.33
64.01	0.06	62.01	0.06	0.06
65.01	0.07	63.01	0.04	0.04
65.02	0.11	64.01	0.02	0.02
66.01	0.22	65.01	0.04	0.03
66.02	0.38	65.02	0.07	0.06
67.01	0.16	66.01	0.00	0.00
68.01	0.15	67.01	0.08	0.07
68.02	0.30	68.01	0.04	0.04
69.01	0.07	69.01	0.04	0.04
70.01	0.04	69.02	0.07	0.06
71.01	0.03	70.01	0.07	0.06
72.01	0.20	71.01	0.12	0.11
73.01	0.24	71.02	0.22	0.21
74.01	0.04	72.01	0.10	0.08
74.02	0.68	73.01	0.04	0.03
74.03	1.31	73.02	0.09	0.07
74.04	1.51	73.03	0.17	0.14
74.05	1.63	74.01	0.02	0.02
74.06	2.13	75.01	0.02	0.02
74.07	2.23	76.01	0.12	0.12
75.01	0.12	77.01	0.13	0.13
75.02	0.24	78.01	0.03	0.03
75.03	0.32	78.02	0.06	0.05
76.01	0.07	78.03	0.46	0.42
77.01	0.03	78.04	0.61	0.54
78.01	0.10	78.05	0.70	0.62
78.02	0.17	78.06	1.04	0.92
78.03	0.29	78.07	1.31	1.24
79.01	0.09	79.01	0.07	0.07
80.01	0.07	79.02	0.16	0.14
80.02	0.17	79.03	0.21	0.19
81.01	0.05	80.01	0.05	0.04
82.01	0.00	81.01	0.02	0.02
82.02	0.08	82.01	0.07	0.06
83.01	0.02	82.02	0.12	0.10
84.01	0.13	82.03	0.20	0.18
84.02	0.21	83.01	0.06	0.05

	Peak Discharge (m3/s)		Peak Discharge (m3/s)	Peak Discharge (m3/s)
2007# Calibration Event Subcatchment ID	**February 2007**	**2014/15 Calibration Event Subcatchment ID**	**August 2014**	**August 2015**
84.03	0.41	84.01	0.05	0.04
84.04	0.56	84.02	0.12	0.11
85.01	0.09	85.01	0.03	0.03
86.01	0.14	86.01	0.00	0.00
86.02	0.47	86.02	0.05	0.04
86.03	0.60	87.01	0.01	0.01
86.04	0.76	88.01	0.09	0.08
86.05	0.84	88.02	0.13	0.12
87.01	0.14	88.03	0.24	0.22
_junc_100	0.36	88.04	0.33	0.31
_junc_101	14.42	89.01	0.07	0.07
_junc_102	0.37	89.02	0.27	0.25
_junc_106	1.58	89.03	0.43	0.38
_junc_109	0.46	90.01	0.07	0.07
_junc_110	0.57	91.01	0.10	0.09
_junc_123	0.97	92.01	0.12	0.10
_junc_131	0.22	92.02	0.20	0.17
_junc_134	0.10	_junc_116	0.10	0.10
_junc_139	1.53	_junc_123	0.21	0.19
_junc_142	1.69	_junc_125	7.88	7.47
_junc_146	1.93	_junc_126	0.21	0.18
_junc_147	2.51	_junc_130	0.86	0.80
_junc_19	0.27	_junc_133	0.32	0.27
_junc_21	5.06	_junc_135	0.09	0.07
_junc_25	0.45	_junc_136	0.13	0.11
_junc_28	0.19	_junc_138	0.31	0.29
_junc_31	6.38	_junc_142	0.37	0.33
_junc_32	0.30	_junc_150	0.24	0.22
_junc_33	0.79	_junc_151	0.36	0.32
_junc_34	0.48	_junc_158	0.13	0.12
_junc_36	2.90	_junc_162	0.05	0.05
_junc_39	0.90	_junc_19	0.18	0.15
_junc_42	0.07	_junc_21	2.92	2.77
_junc_53	1.42	_junc_28	0.93	0.82
_junc_54	0.38	_junc_29	0.28	0.25
_junc_57	0.14	_junc_30	0.05	0.05
_junc_59	1.64	_junc_32	0.11	0.10
_junc_64	11.79	_junc_37	1.04	0.99
_junc_68	14.04	_junc_38	3.61	3.40
_junc_69	0.11	_junc_40	0.27	0.22
_junc_72	14.84	_junc_41	0.44	0.42
_junc_73	16.59	_junc_42	0.39	0.33
_junc_74	17.31	_junc_44	1.14	1.09
_junc_76	2.10	_junc_47	0.73	0.61
_junc_79	2.20	_junc_50	0.04	0.04
_junc_93	0.19	_junc_59	5.69	5.46
US_OHH	12.16	_junc_64	1.11	1.06
US_Rail	10.81	_junc_68	0.09	0.08
		_junc_69	5.89	5.65

	Peak Discharge (m3/s)		Peak Discharge (m3/s)	Peak Discharge (m3/s)
2007# Calibration Event Subcatchment ID	**February 2007**	**2014/15 Calibration Event Subcatchment ID**	**August 2014**	**August 2015**
		_junc_71	1.22	1.17
		_junc_74	1.29	1.25
		_junc_76	6.09	5.84
		_junc_80	7.66	7.28
		_junc_81	0.11	0.10
		_junc_84	8.14	7.70
		_junc_85	9.32	8.75
		_junc_86	9.45	8.85
		_junc_88	1.02	0.90
		_junc_91	1.29	1.21
		US_OHH	6.31	6.04
		US_Rail	5.53	5.32

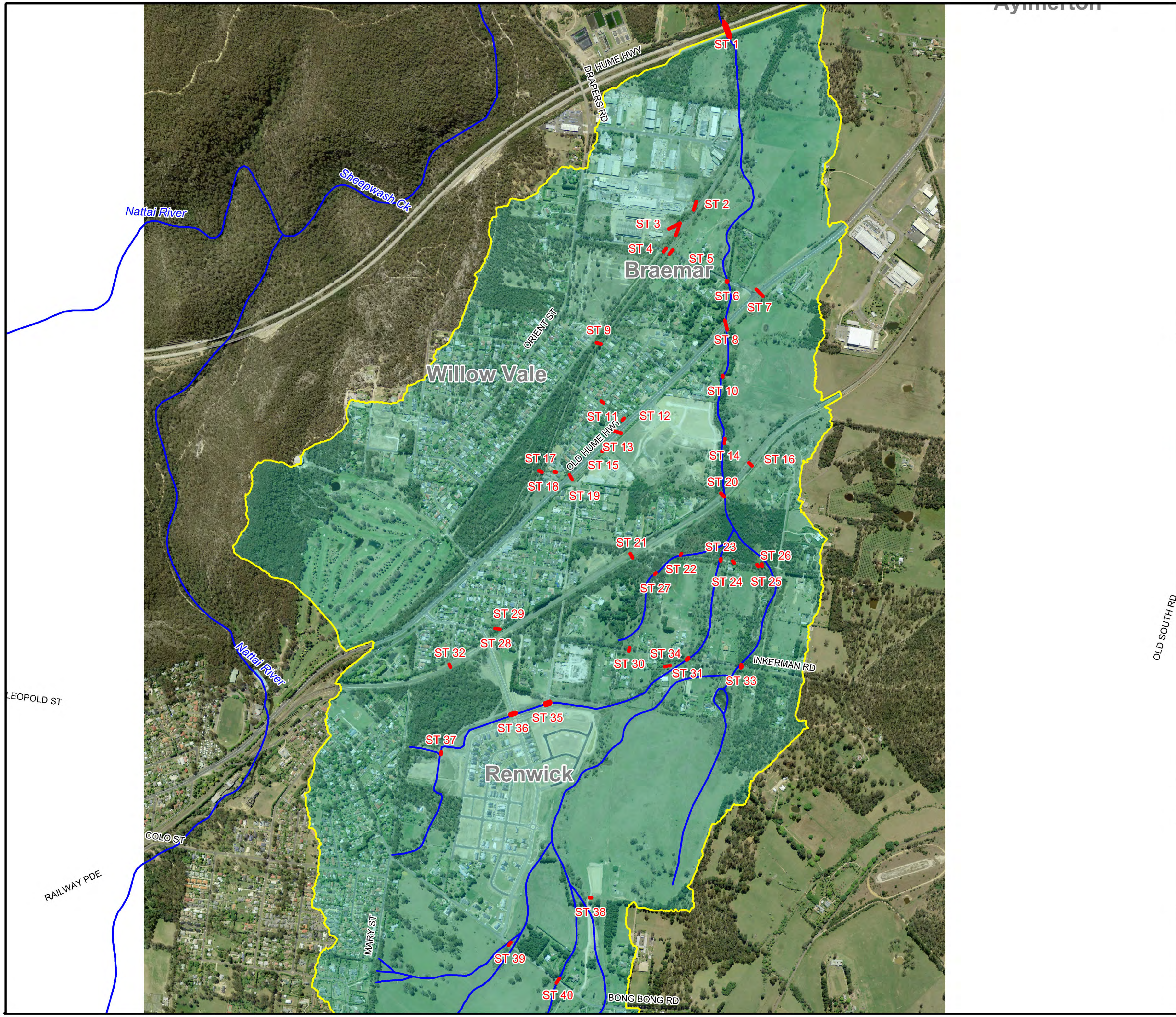
APPENDIX D

STRUCTURE BLOCKAGE CALCULATIONS

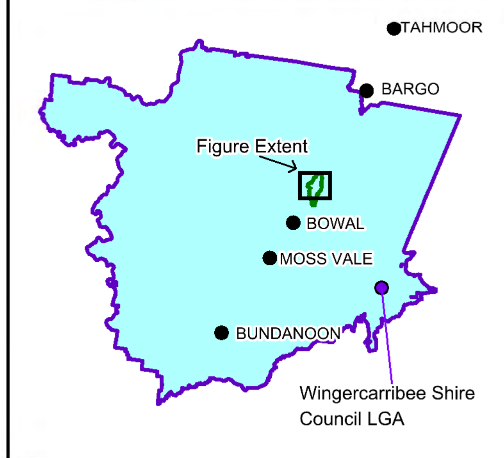
STRUCTURE BLOCKAGE ASSESSMENT

Nattai Ponds Flood Study

Structure ID	Roadway	Waterway	Structure Type	Structure Dimensions			Land Use Across Upstream Catchment	Max. L10 (m)	Control Dimension	Main Stream Slope (%)	Debris Availability (L, M, H)	Debris Mobility (L, M, H)	Debris Transportability (L, M, H)	Debris Potential	Debris Potential at Structure	Adjustment for AEP			Design Blockage Level		
				Dia/Width/Span	Height	Cells / Spans										AEP >5%	AEP 5%-0.5%	AEP < 0.5%	AEP >5%	AEP 5%-0.5%	AEP < 0.5%
ST 1	Hume Highway	Nattai Rivulet	Culvert	3.1	0	1	61% Grass, 28% Trees, 5% Roads, 6% Buildings	3.00	L<W<3L	0.39	M	M	L	**MML**	Low	Low	Low	Medium	10%	10%	10%
ST 2	Industrial Railway	Unnamed Tributary	Culvert	1.2	0	0	43% Trees, 35% Grass, 22% Roads	3.00	W<L	0.81	M	M	L	**MML**	Low	Low	Low	Medium	50%	50%	50%
ST 3	Industrial Railway	Unnamed Tributary	Culvert	1.5	0	0	37% Grass, 29% Trees, 20% Roads, 14% Buildings	3.00	W<L	2.27	M	M	M	**MMM**	Medium	Low	Medium	High	50%	50%	100%
ST 4	Braemar Ave	Unnamed Tributary	Culvert	0.45	0	0	42% Grass, 4% Roads, 47% Trees, 7% Buildings	3.00	W<L	2.82	M	M	M	**MMM**	Medium	Low	Medium	High	50%	50%	100%
ST 5	Braemar Ave	Unnamed Tributary	Culvert	0.45	0	0	14% Roads, 62% Trees, 20% Grass, 4% Buildings	3.00	W<L	1.31	M	M	M	**MMM**	Medium	Low	Medium	High	50%	50%	100%
ST 6	Braemar Ave	Nattai Rivulet	Culvert	0.6	0	1	43% Trees, 4% Roads, 45% Grass, 8% Buildings	3.00	W<L	0.55	M	M	L	**MML**	Low	Low	Low	Medium	50%	50%	50%
ST 7	Old Hume Highway	Nattai Rivulet	Culvert	0.6	0	0	63% Grass, 21% Trees, 12% Roads, 4% Buildings	3.00	W<L	2.43	M	M	M	**MMM**	Medium	Low	Medium	High	50%	50%	100%
ST 8	Old Hume Highway	Nattai Rivulet	Box Culvert	2.6	3	4	63% Grass, 6% Roads, 23% Trees, 7% Buildings	3.00	W<L	0.38	M	M	L	**MML**	Low	Low	Low	Medium	50%	50%	50%
ST 9	Railway	Unnamed Tributary	Irregular Culvert	0.93	0	0	14% Buildings, 30% Grass, 7% Roads, 49% Trees	3.00	W<L	2.54	M	M	M	**MMM**	Medium	Low	Medium	High	50%	50%	100%
ST 10	Causeway	Nattai Rivulet	Culvert	0.375	0	3	69% Grass, 22% Trees, 7% Roads, 3% Buildings	3.00	W<L	0.37	M	M	L	**MML**	Low	Low	Low	Medium	50%	50%	50%
ST 11	Biggera St	Street Drainage	Culvert	0.45	0	0	9% Roads, 33% Grass, 45% Trees, 13% Buildings	3.00	W<L	1.92	M	M	M	**MMM**	Medium	Low	Medium	High	50%	50%	100%
ST 12	Rush Lane	Street Drainage	Culvert	0.3	0	2	31% Grass, 47% Trees, 14% Buildings, 8% Roads	3.00	W<L	0.96	M	M	L	**MML**	Low	Low	Low	Medium	50%	50%	50%
ST 13	Old Hume Highway	Street Drainage	Culvert	0.6	0	0	31% Grass, 39% Trees, 16% Buildings, 13% Roads	3.00	W<L	0.33	M	M	L	**MML**	Low	Low	Low	Medium	50%	50%	50%
ST 14	Nattai Ponds Access Rd	Nattai Rivulet	Box Culvert	3.35	1.8	4	62% Grass, 7% Roads, 27% Trees, 1% Water, 4% Buildings	3.00	L<W<3L	1.06	M	M	M	**MMM**	Medium	Low	Medium	High	10%	10%	20%
ST 15	Old Hume Highway	Street Drainage	Culvert	0.9	0	2	41% Roads, 41% Grass, 18% Trees	3.00	W<L	1.69	M	M	M	**MMM**	Medium	Low	Medium	High	50%	50%	100%
ST 16	Railway	Nattai Rivulet	Irregular Culvert	2.45	0	1	66% Grass, 25% Trees, 7% Roads, 1% Buildings	3.00	W<L	1.56	M	M	M	**MMM**	Medium	Low	Medium	High	50%	50%	100%
ST 17	Link Line Railway	Unnamed Tributary	Irregular Culvert	0.8	0	0	46% Grass, 47% Trees, 3% Roads, 3% Buildings, 1% Water	3.00	W<L	1.98	M	M	M	**MMM**	Medium	Low	Medium	High	50%	50%	100%
ST 18	Biggera St	Unnamed Tributary	Box Culvert	0.95	0.45	0	14% Roads, 16% Buildings, 27% Trees, 43% Grass	3.00	W<L	3.08	M	M	H	**MMH**	Medium	Low	Medium	High	50%	50%	100%
ST 19	Old Hume Highway	Unnamed Tributary	Box Culvert	2.8	0.8	0	18% Roads, 11% Buildings, 34% Trees, 38% Grass	3.00	W<L	6.56	M	M	H	**MMH**	Medium	Low	Medium	High	50%	50%	100%
ST 20	Railway	Nattai Rivulet	Bridge	15	0	0	35% Grass, 59% Trees, 2% Buildings, 4% Roads, 1% Water	3.00	W>3L	0.29	M	M	L	**MML**	Low	Low	Low	Medium	0%	0%	0%
ST 21	Railway	Unnamed Tributary	Irregular Culvert	1.22	0	0	12% Roads, 45% Grass, 31% Trees, 12% Buildings	3.00	W<L	1.13	M	M	M	**MMM**	Medium	Low	Medium	High	50%	50%	100%
ST 22	Scarlet St	Unnamed Tributary	Culvert	0.375	0	0	58% Grass, 6% Roads, 34% Trees, 1% Water	3.00	W<L	2.23	M	M	M	**MMM**	Medium	Low	Medium	High	50%	50%	100%
ST 23	Scarlet St	Nattai Rivulet	Bridge	4.5	0	1	1% Roads, 32% Trees, 63% Grass, 2% Water, 2% Buildings	3.00	L<W<3L	0.49	M	M	L	**MML**	Low	Low	Low	Medium	10%	10%	10%
ST 24	Scarlet St	Nattai Rivulet	Culvert	0.525	0	1	23% Trees, 74% Grass, 1% Roads, 2% Buildings	3.00	W<L	0.05	M	M	L	**MML**	Low	Low	Low	Medium	50%	50%	50%
ST 25	Scarlet St	Nattai Rivulet	Culvert	0.6	0	1	40% Grass, 54% Trees, 6% Roads	3.00	W<L	0.27	M	M	L	**MML**	Low	Low	Low	Medium	50%	50%	50%
ST 26	Scarlet St	Nattai Rivulet	Culvert	0.6	0	1	42% Trees, 2% Roads, 50% Grass, 3% Water, 3% Buildings	3.00	W<L	0.31	M	M	L	**MML**	Low	Low	Low	Medium	50%	50%	50%
ST 27	Private Access	Unnamed Tributary	Culvert	0.6	0	0	47% Trees, 4% Roads, 46% Grass, 3% Buildings	3.00	W<L	0.37	M	M	L	**MML**	Low	Low	Low	Medium	50%	50%	50%
ST 28	Sebastopol Lane	Unnamed Tributary	Box Culvert	1.2	0.3	0	35% Trees, 34% Grass, 22% Roads, 8% Buildings	3.00	W<L	2.28	M	M	M	**MMM**	Medium	Low	Medium	High	50%	50%	100%
ST 29	Sebastopol Lane	Unnamed Tributary	Box Culvert	0.9	0.3	0	75% Trees, 25% Grass	3.00	W<L	2.28	M	M	M	**MMM**	Medium	Low	Medium	High	50%	50%	100%
ST 30	Inkerman Rd	Nattai Rivulet	Box Culvert	0.8	0.3	0	45% Grass, 21% Trees, 34% Roads	3.00	W<L	0.65	M	M	L	**MML**	Low	Low	Low	Medium	50%	50%	50%
ST 31	Inkerman Rd	Nattai Rivulet	Box Culvert	2.3	1.2	1	2% Buildings, 55% Grass, 32% Trees, 11% Roads	3.00	W<L	0.8	M	M	L	**MML**	Low	Low	Low	Medium	50%	50%	50%
ST 32	Railway	Unnamed Tributary	Irregular Culvert	0.93	0	0	12% Roads, 38% Grass, 41% Trees, 8% Buildings	3.00	W<L	1.49	M	M	M	**MMM**	Medium	Low	Medium	High	50%	50%	100%
ST 33	Inkerman Rd	Nattai Rivulet	Culvert	0.4	0	0	21% Trees, 74% Grass, 2% Buildings, 2% Roads, 1% Water	3.00	W<L	0.77	M	M	L	**MML**	Low	Low	Low	Medium	50%	50%	50%
ST 34	Private Access	Nattai Rivulet	Bridge	2.9	0	0	15% Trees, 71% Grass, 5% Buildings, 8% Roads	3.00	W<L	0.47	M	M	L	**MML**	Low	Low	Low	Medium	50%	50%	50%
ST 35	Cardigan St	Unnamed Tributary	Box Culvert	3.6	1.8	4	61% Grass, 14% Roads, 3% Trees, 22% Buildings	3.00	L<W<3L	0.92	M	M	L	**MML**	Low	Low	Low	Medium	10%	10%	10%
ST 36	Renwick Dr	Unnamed Tributary	Box Culvert	3.6	2.1	1	42% Trees, 41% Grass, 6% Roads, 10% Buildings	3.00	L<W<3L	1.11	M	M	M	**MMM**	Medium	Low	Medium	High	10%	10%	20%
ST 37	Renwick Pedestrian Bridge	Unnamed Tributary	Bridge	21	0	0	39% Trees, 7% Roads, 45% Grass, 10% Buildings	3.00	W>3L	2.72	M	M	M	**MMM**	Medium	Low	Medium	High	0%	0%	10%
ST 38	Private Access	Unnamed Tributary	Culvert	0.6	0	0	82% Grass, 14% Trees, 1% Buildings, 2% Roads, 1% Water	3.00	W<L	2.71	M	M	M	**MMM**	Medium	Low	Medium	High	50%	50%	100%
ST 39	Bong Bong Rd	Nattai Rivulet	Culvert	1.2	0	2	80% Grass, 3% Roads, 3% Buildings, 14% Trees	3.00	W<L	3.09	M	M	H	**MMH**	Medium	Low	Medium	High	50%	50%	100%
ST 40	Bong Bong Rd	Nattai Rivulet	Culvert	1.2	0	2	15% Trees, 80% Grass, 3% Roads, 2% Water	3.00	W<L	4.86	M	M	H	**MMH**	Medium	Low	Medium	High	50%	50%	100%



WINGECARRIBEE SHIRE COUNCIL



LEGEND

- Nattai Ponds Catchment
- Watercourse
- ST 1 Structures

Notes:
Aerial photograph date: May 2014

N
W E
S

Scale 1:15,000 (at A3)
0 0.5 1.0
Km

Figure D1: Structure Locations

Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: FigD1 - Structure Locations.wor

APPENDIX E

BRIDGE LOSS CALCULATIONS

Representation of Bridges in TUFLOW

TUFLOW does not explicitly allow inclusion of bridge structure details, such as abutments or piers like other software, such as HEC-RAS. Therefore, the variation in energy losses that can be expected through a bridge opening must be defined using a height varying loss coefficent.

This requires calculation of suitable loss coefficient values from the channel invert up to the elevation of the underside of the culvert/bridge deck.

The following pages present the calculations that were completed to determine appropriate bridge loss coefficients.

All calculations were completed in accordance with procedures detailed in the 'TUFLOW User Manual' (BMT WBM, 2010) and 'Hydraulics of Bridge Waterways' (Bradley, 1978).

Representation of Bridges in TUFLOW

Prepared by: D. Fedczyna | **Date:** 1/10/2015
Checked by: | **Date:**

Reference: 'Hydraulics of Bridge Waterways: HDS 1' (Bradley, March 1978)

The total backwater (i.e., energy loss) coefficient is calculated as:
$K^* = K_b + K_p + K_e + K_s$

Bridge modelling approach = 1D

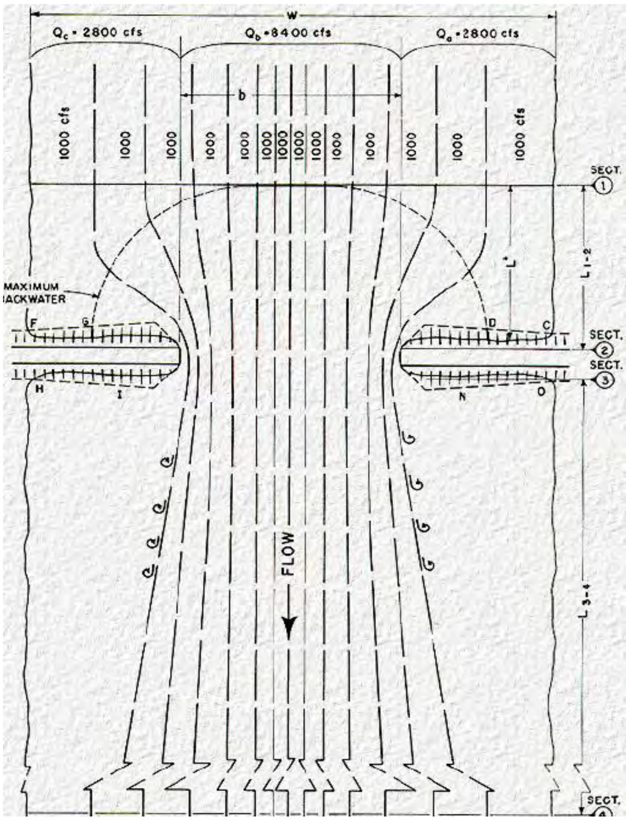
K_b (base coefficient)

First need to calculate the Bridge Opening Ratio (M)

M = Unimpeded Flow / Total Flow

$M = Q_b / (Q_a + Q_b + Q_c)$

Unimpeded Flow =	22.7	m^3/s
Total Flow=	23.1	m^3/s
M =	0.98	



Abutment Type = 90o Wingwall

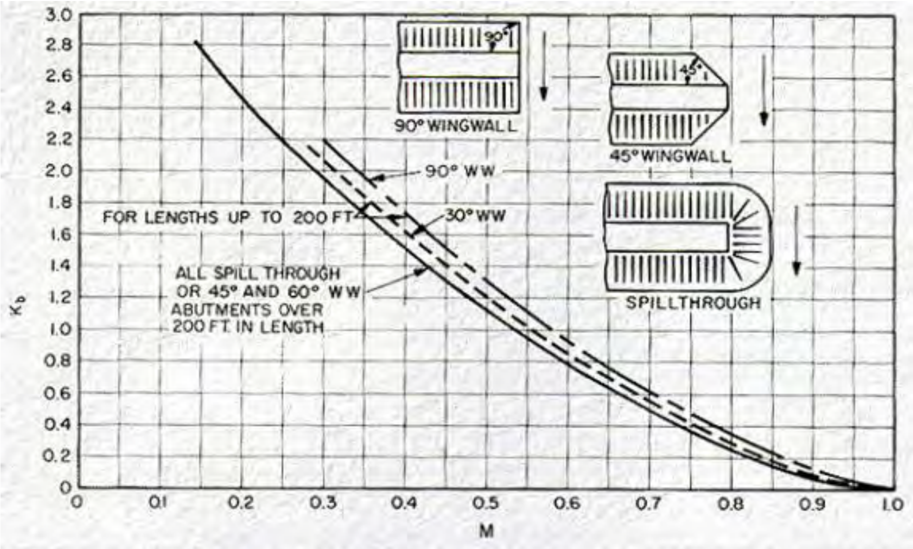


Figure 6. Backwater coefficient base curves (subcritical flow).

K_b = 0.03

K_p (Pier Coefficient)

Assume fences abstruct flow similar to pier

Ratio of gross waterway area to pier area

$J = A_p / A_{n3}$

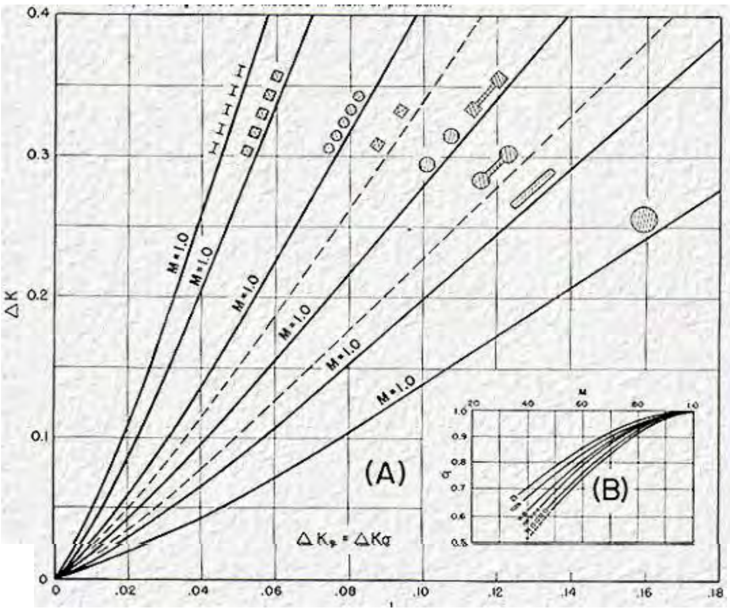
A_p = 0 m^2

A_{n2} = 23.1 m^2

J = 0

J = 0%

Pier Type: Single Rectangular Pier



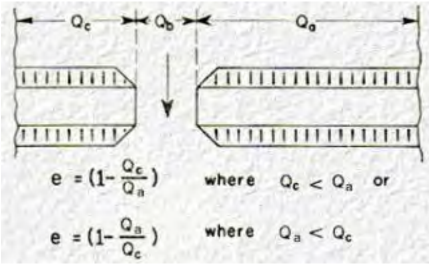
σ = 1.00

ΔK = 0.00

$K_p = \sigma\Delta K$

K_p = 0.00

K_e (Eccentricity Coefficient)



Q_c = 1	m^3/s
Q_a = 1	m^3/s

e = 0.00

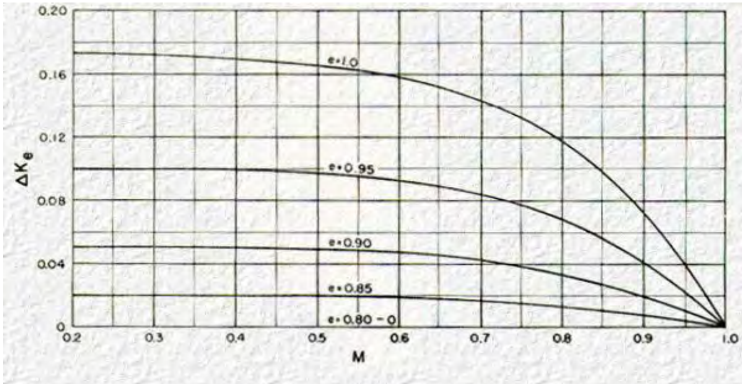


Figure 8. Incremental backwater coefficient for eccentricity.

K_e = 0.00

K_s (Skew Coefficient)

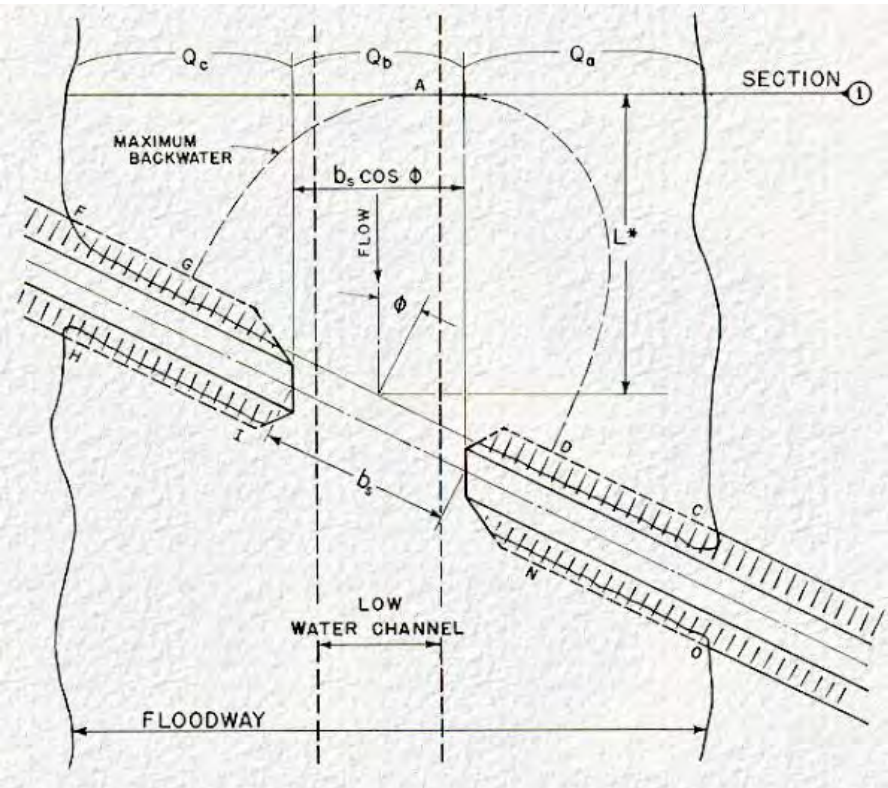


Figure 9. Skewed crossings.

ϕ = 0

Abutment Type =	(B)-Straight

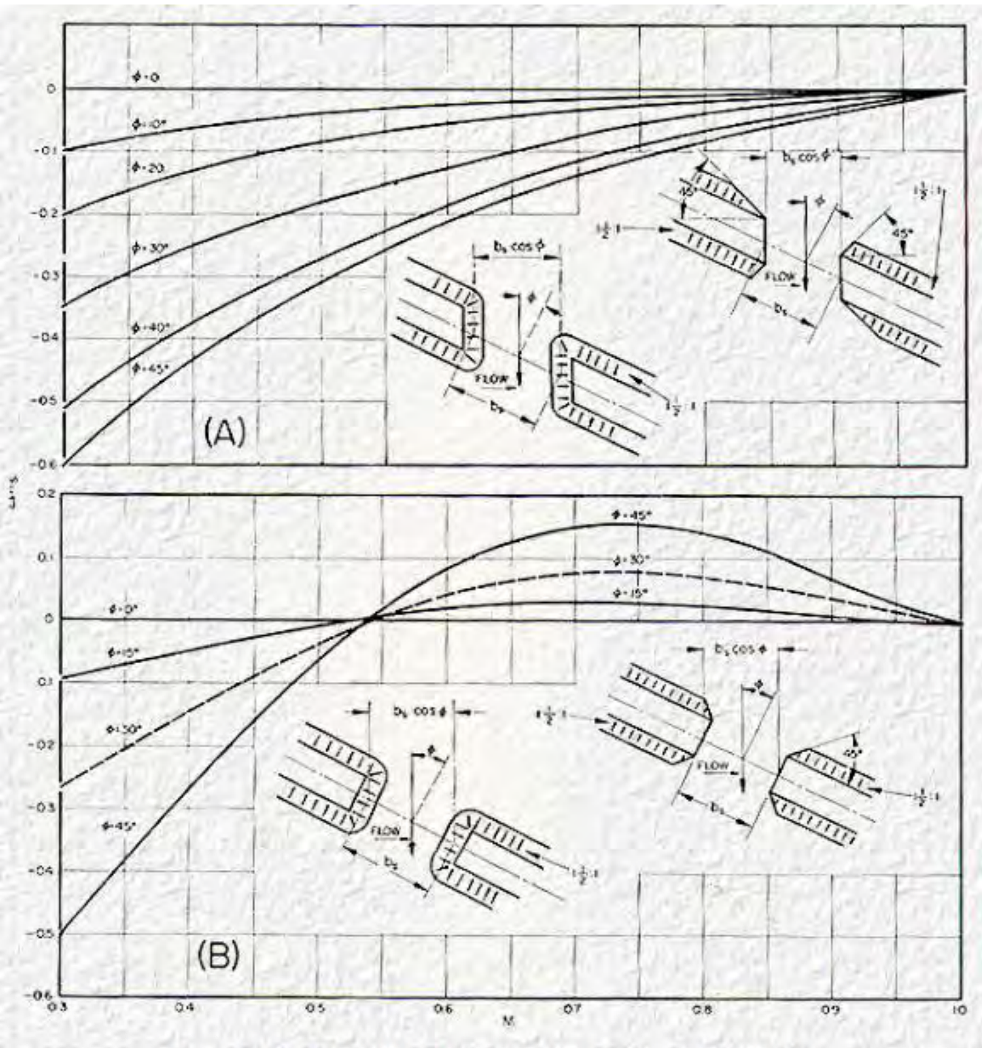


Figure 10. Incremental backwater coefficient for skew.

K_s = 0.00

(K*) Total Backwater Coefficient

$K^* = K_b + K_p + K_e + K_s$

K* = 0.03

Notes

K* = 0.03 from 597.73 to 599.65 (from bottom to half bank full).

Representation of Bridges in TUFLOW

Prepared by: D. Fedczyna	**Date:** 1/10/2015
Checked by:	**Date:**

Reference: 'Hydraulics of Bridge Waterways: HDS 1' (Bradley, March 1978)

The total backwater (i.e., energy loss) coefficient is calculated as:

$K^* = K_b + K_p + K_e + K_s$

Bridge modelling approach = 1D

K_b (base coefficient)

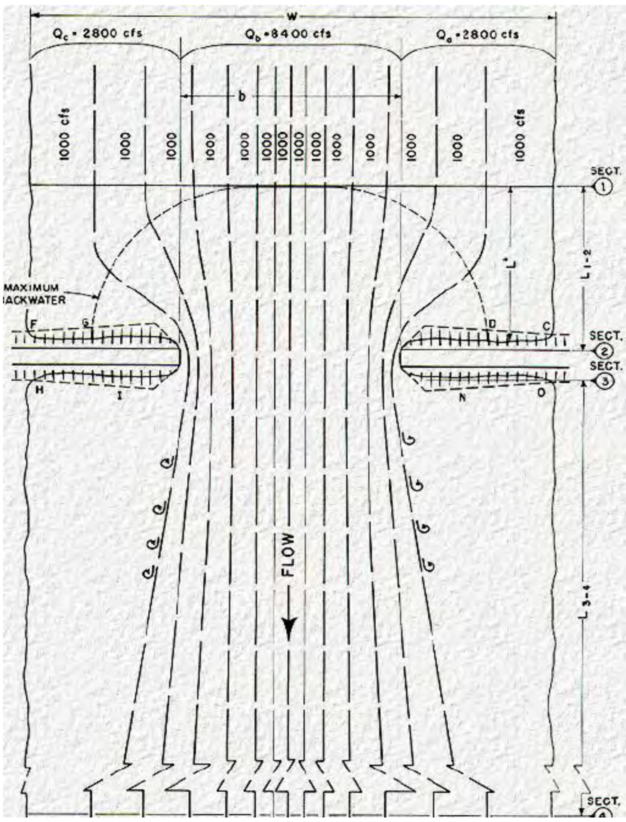
First need to calculate the Bridge Opening Ratio (M)

M = Unimpeded Flow / Total Flow

$M = Q_b / (Q_a + Q_b + Q_c)$

All flow contained in channel

Unimpeded Flow =	44	m^3/s
Total Flow=	46	m^3/s
M = 0.96		



Catchment Simulation Solutions

Abutment Type = 90o Wingwall

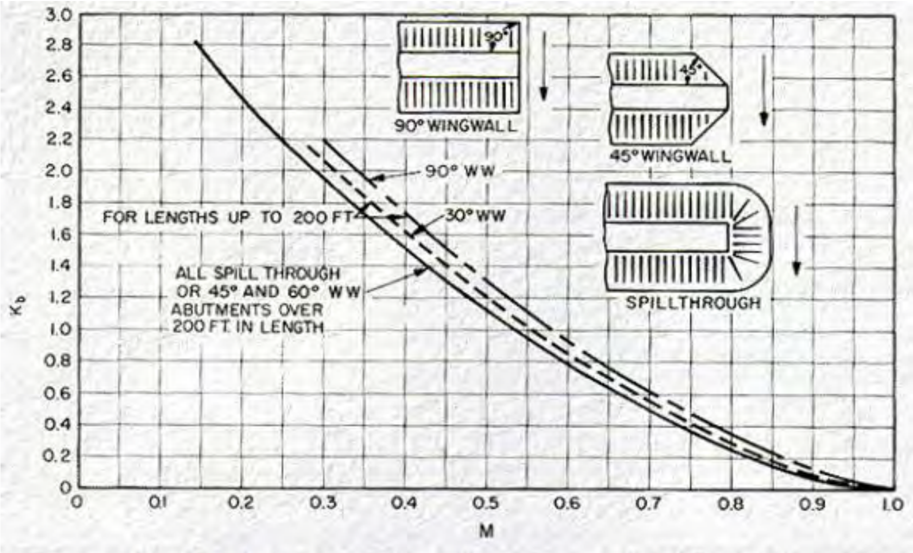


Figure 6. Backwater coefficient base curves (subcritical flow).

K_b = 0.07

K_p (Pier Coefficient)

Assume fences abstruct flow similar to pier

Ratio of gross waterway area to pier area

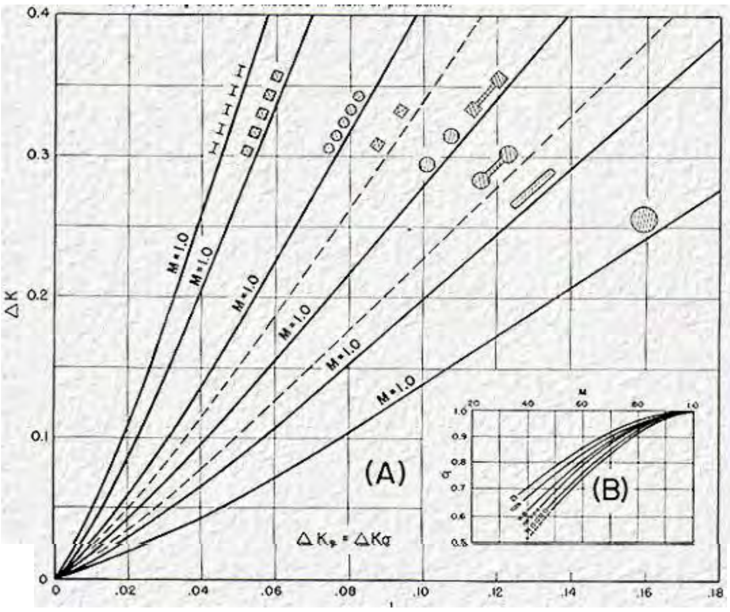
$J = A_p / A_{n3}$

A_p = 0 m^2

A_{n2} = 11.12 m^2

J = 0
J = 0%

Pier Type: Single Rectangular Pier



σ = 0.99

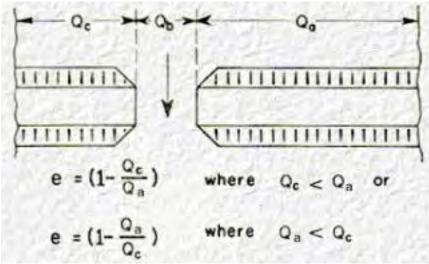
ΔK = 0.00

$K_p = \sigma \Delta K$

K_p = 0.00

Catchment Simulation Solutions

K_e (Eccentricity Coefficient)



Q_c = 1	m^3/s
Q_a = 1	m^3/s

e = 0.00

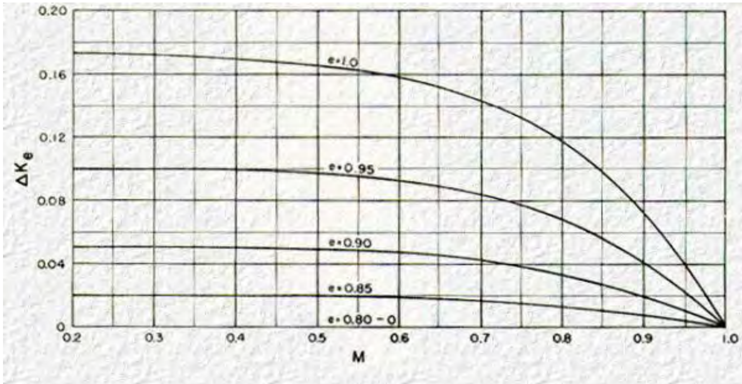


Figure 8. Incremental backwater coefficient for eccentricity.

K_e = 0.00

K_s (Skew Coefficient)

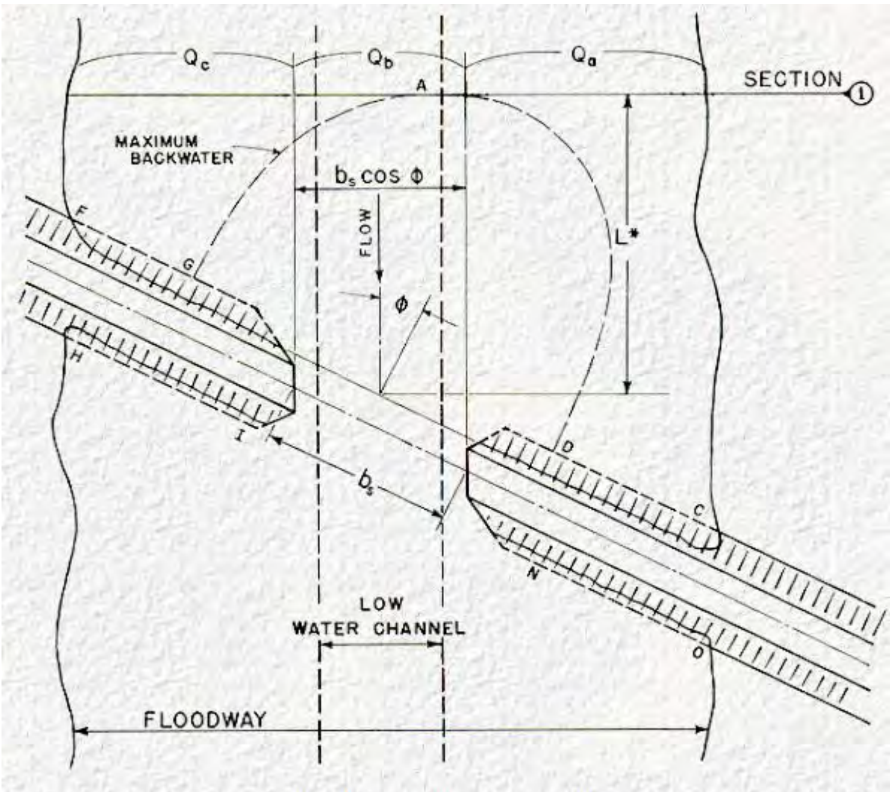


Figure 9. Skewed crossings.

ϕ = 0

Abutment Type =	(B)-Straight

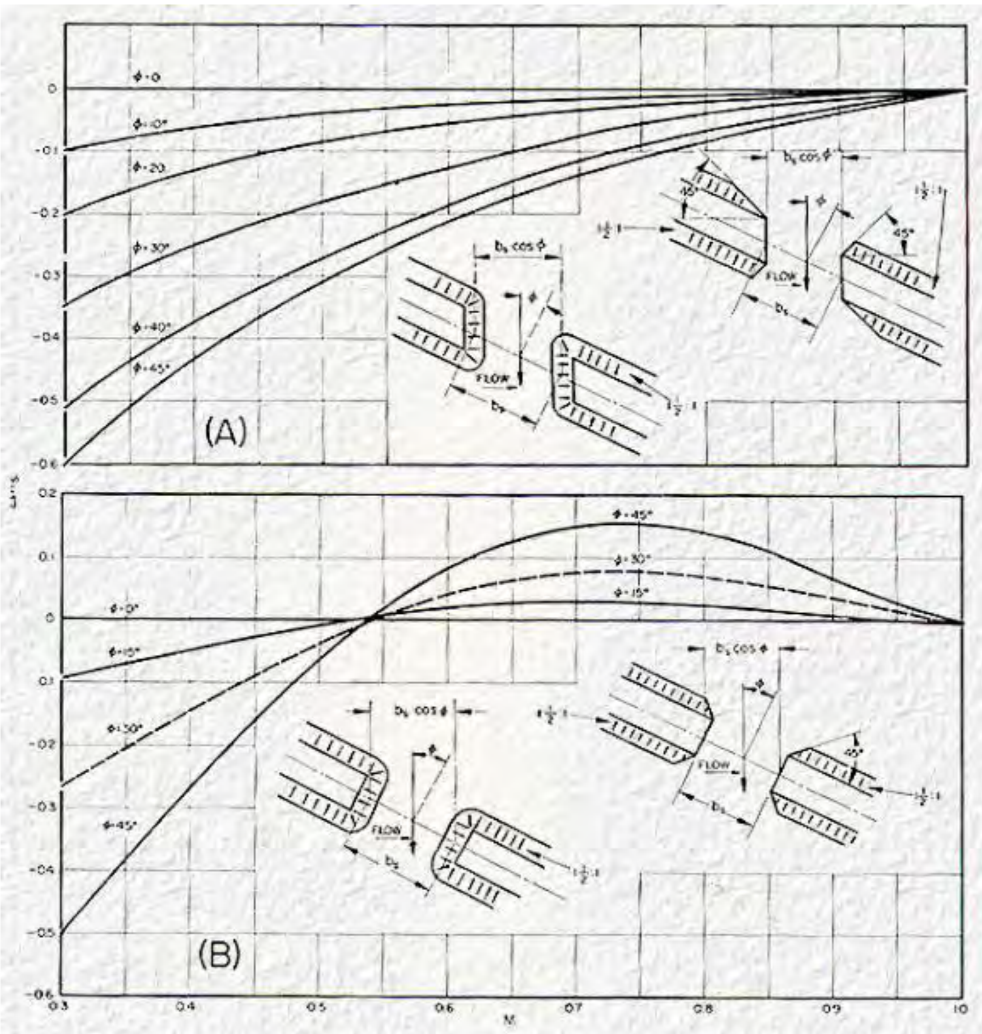


Figure 10. Incremental backwater coefficient for skew.

K_s = 0.00

(K*) Total Backwater Coefficient

$K^* = K_b + K_p + K_e + K_s$

K^* = 0.07

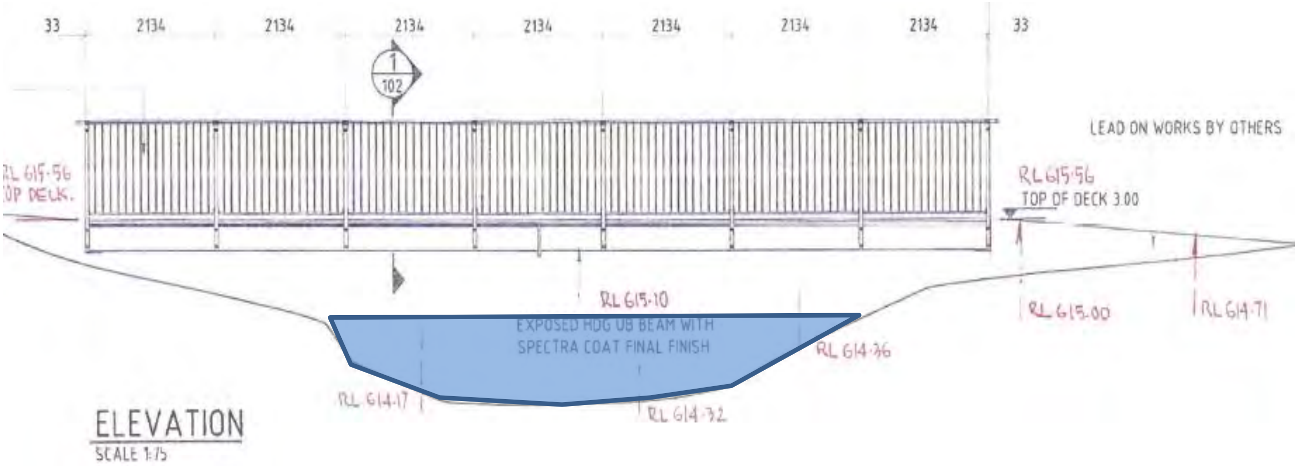
Notes

K* = 0.07 from 599.65 to 601.58 (bank full at invert of deck).

Representation of Bridges in TUFLOW

Prepared by: D. Fedczyna **Date:** 1/10/2015
Checked by: **Date:**

Reference: 'Hydraulics of Bridge Waterways: HDS 1' (Bradley, March 1978)



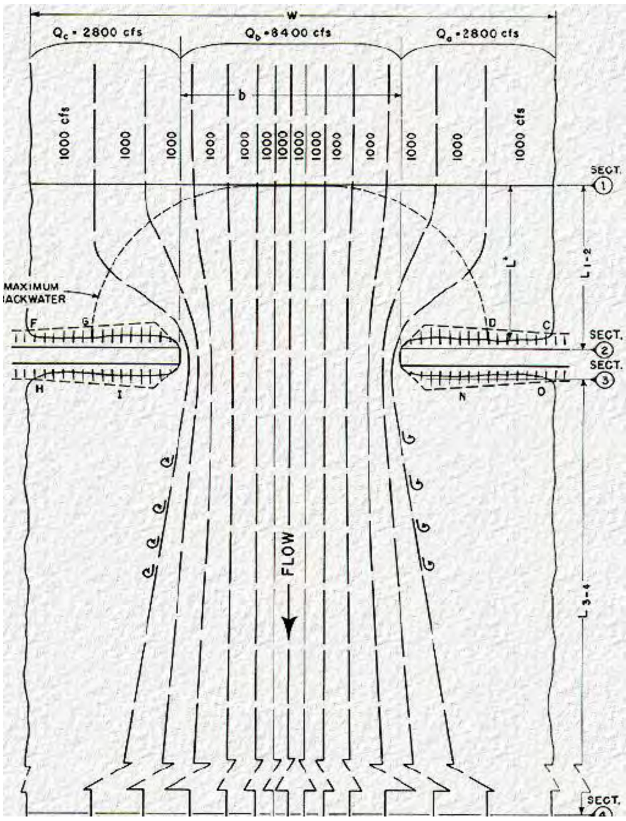
The total backwater (i.e., energy loss) coefficient is calculated as:
$K^* = K_b + K_p + K_e + K_s$

Bridge modelling approach = 2D

K_b (base coefficient)

First need to calculate the Bridge Opening Ratio (M)
M = Unimpeded Flow / Total Flow
$M = Q_b / (Q_a + Q_b + Q_c)$

All flow contained in channel
Unimpeded Flow = 1.7 m^3/s
Total Flow= 1.7 m^3/s
M = 1.00



Catchment Simulation Solutions

Abutment Type = 90o Wingwall

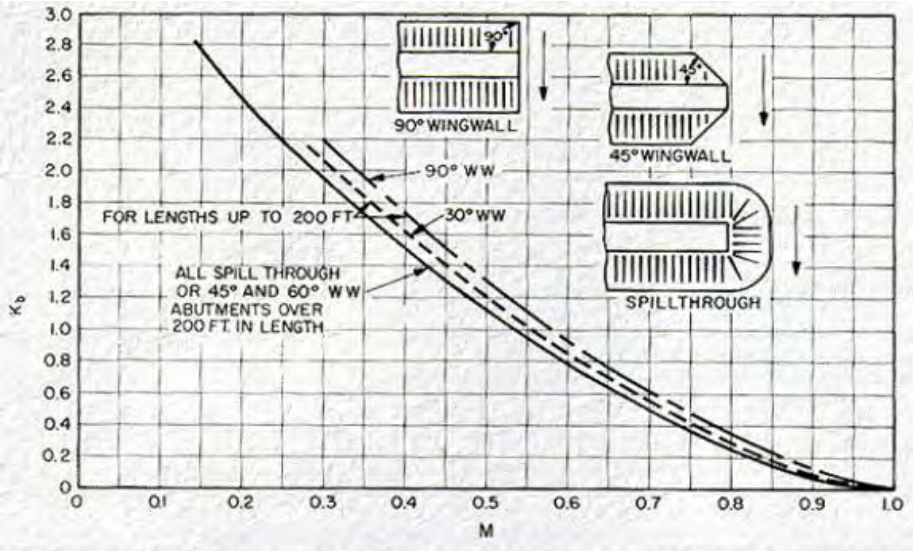


Figure 6. Backwater coefficient base curves (subcritical flow).

K_b = 0.00

K_p (Pier Coefficient)

Assume fences abstruct flow similar to pier

Ratio of gross waterway area to pier area

$J = A_p / A_{n3}$

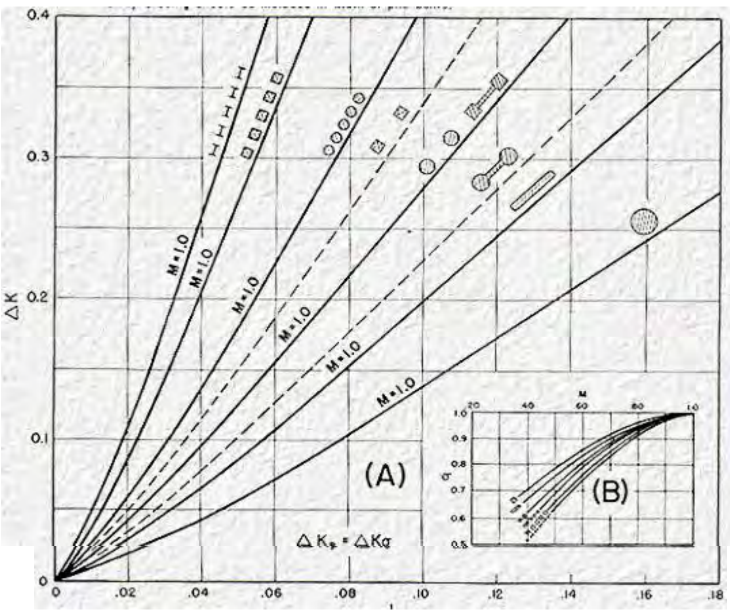
A_p = 0 m^2

A_{n2} = 1.7 m^2

J = 0

J = 0%

Pier Type: Single Rectangular Pier



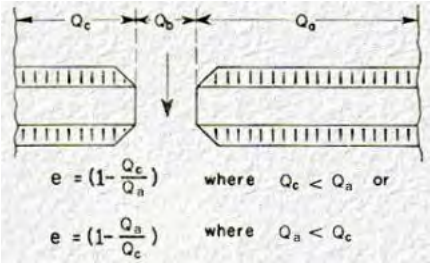
σ = 1.00

ΔK = 0.00

$K_p = \sigma\Delta K$

K_p = 0.00

K_e (Eccentricity Coefficient)



Q_c = 1	m^3/s
Q_a = 1	m^3/s

e = 0.00

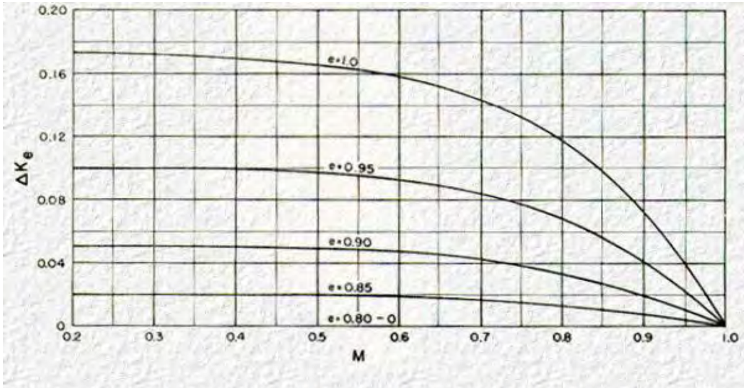


Figure 8. Incremental backwater coefficient for eccentricity.

K_e = 0.00

K_s (Skew Coefficient)

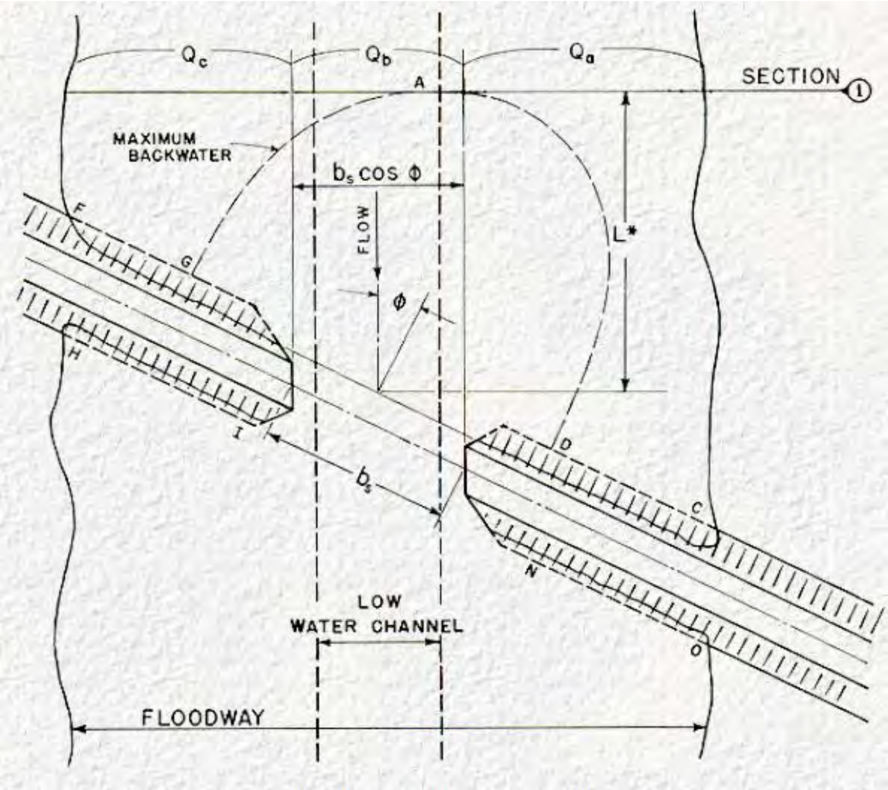


Figure 9. Skewed crossings.

ϕ = 0

Abutment Type = (B)-Straight

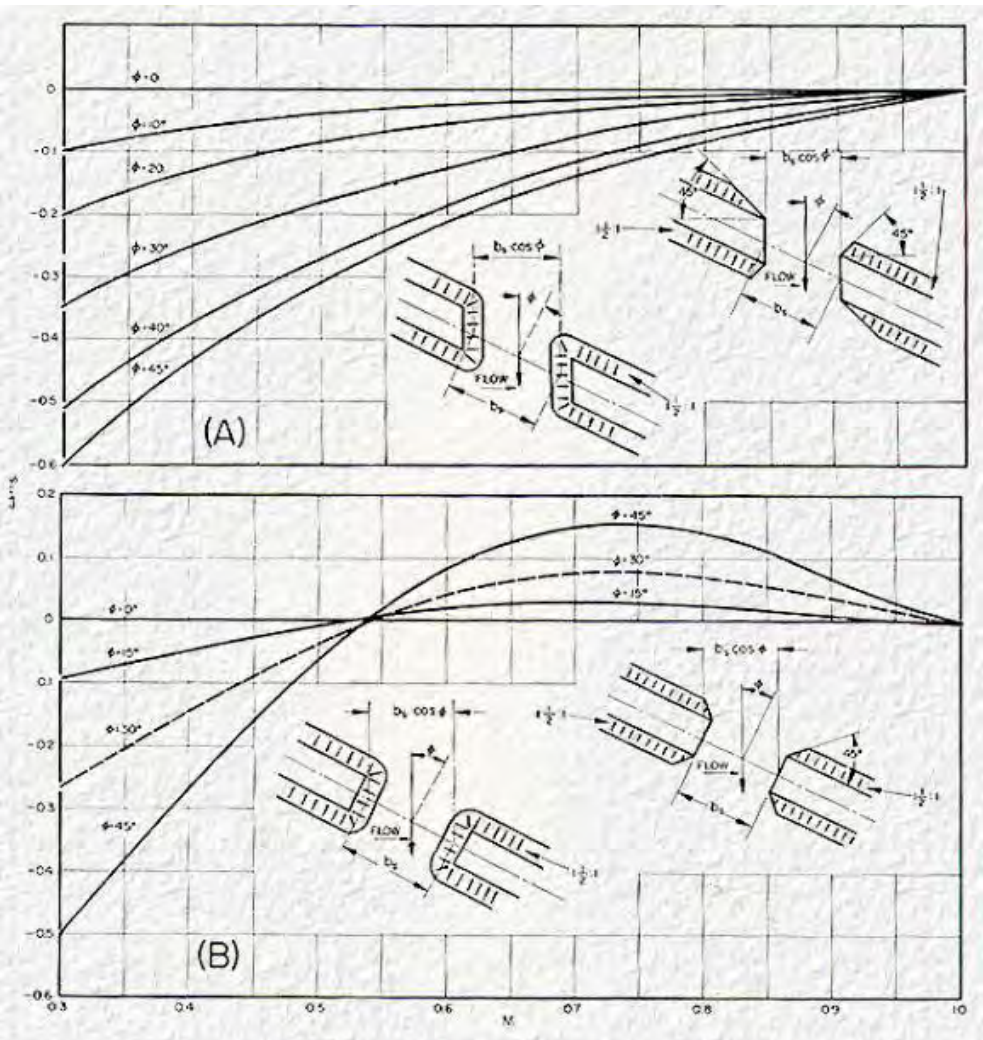


Figure 10. Incremental backwater coefficient for skew.

K_s = 0.00

(K*) Total Backwater Coefficient

$K^* = K_b + K_p + K_e + K_s$

K^* = 0.00

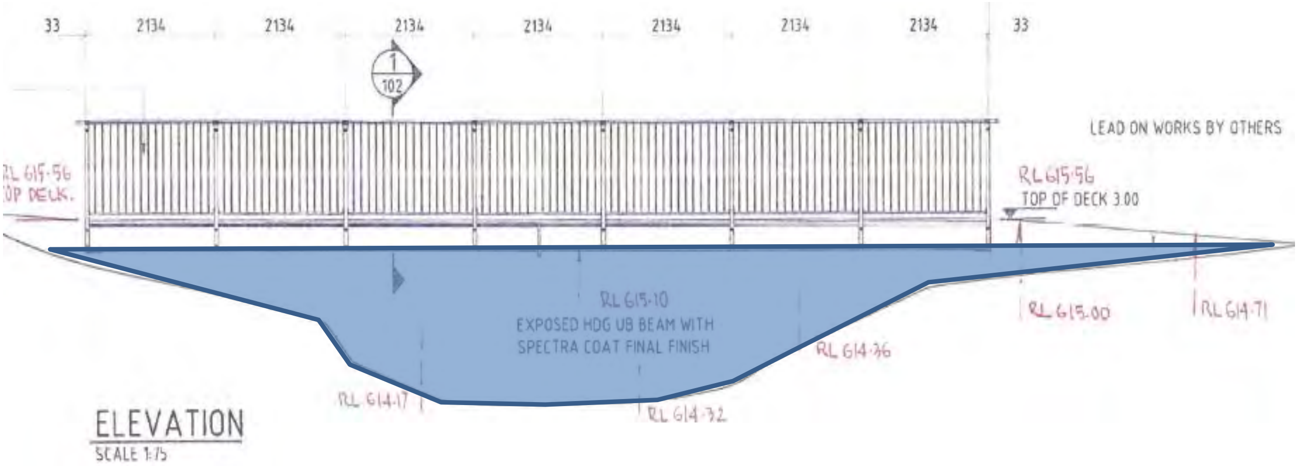
Notes

K* = 0.00 from 614.17 to 614.45 (from bottom to half bank full).

Representation of Bridges in TUFLOW

Prepared by: D. Fedczyna **Date:** 1/10/2015
Checked by: **Date:**

Reference: 'Hydraulics of Bridge Waterways: HDS 1' (Bradley, March 1978)



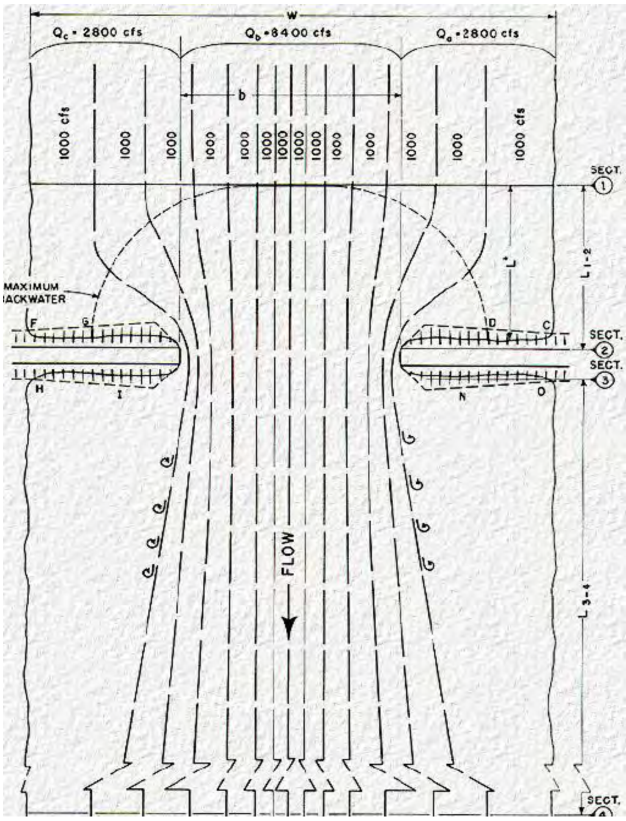
The total backwater (i.e., energy loss) coefficient is calculated as:
$K^* = K_b + K_p + K_e + K_s$

Bridge modelling approach = 2D

K_b (base coefficient)

First need to calculate the Bridge Opening Ratio (M)
M = Unimpeded Flow / Total Flow
$M = Q_b / (Q_a + Q_b + Q_c)$

All flow contained in channel
Unimpeded Flow = 11 m^3/s
Total Flow= 11.09 m^3/s
M = 0.99



Abutment Type = 90o Wingwall

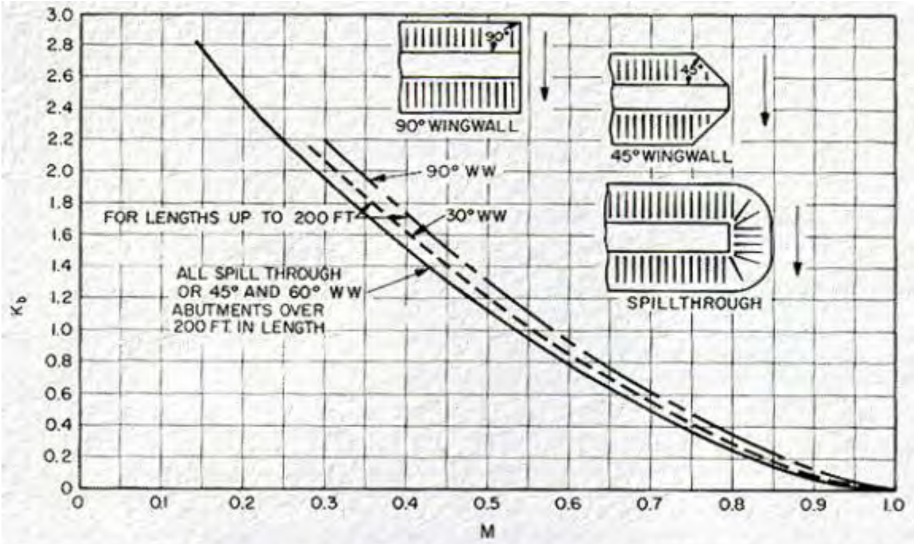


Figure 6. Backwater coefficient base curves (subcritical flow).

K_b = 0.01

K_p (Pier Coefficient)

Assume fences abstruct flow similar to pier

Ratio of gross waterway area to pier area

$J = A_p / A_{n3}$

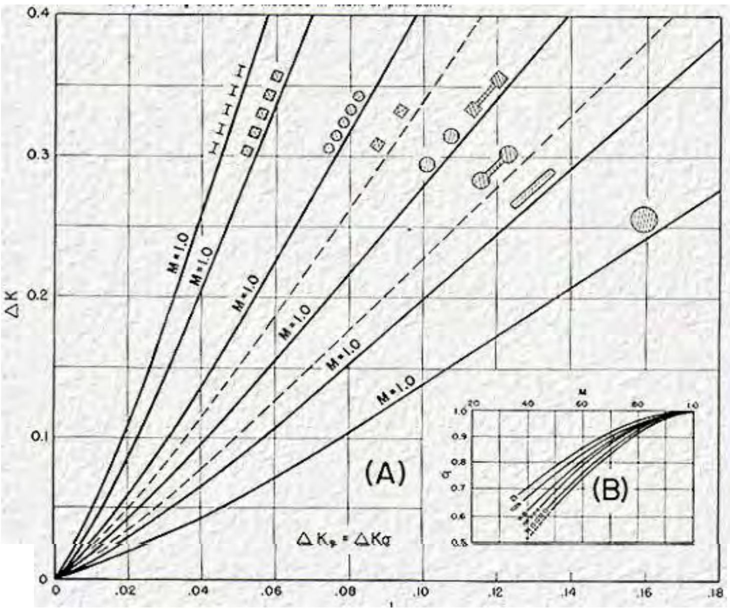
A_p = 0 m^2

A_{n2} = 11.12 m^2

J = 0

J = 0%

Pier Type: Single Rectangular Pier



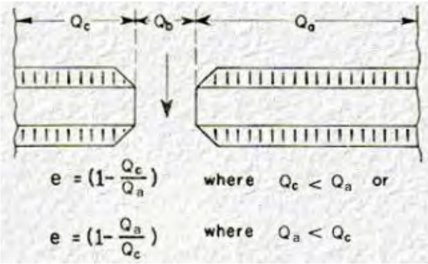
σ = 1.00

ΔK = 0.00

$K_p = \sigma\Delta K$

K_p = 0.00

K_e (Eccentricity Coefficient)



Q_c = 1	m^3/s
Q_a = 1	m^3/s

e = 0.00

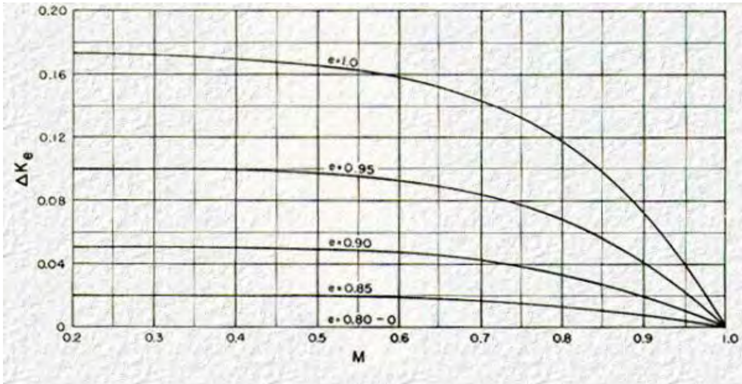


Figure 8. Incremental backwater coefficient for eccentricity.

K_e = 0.00

K_s (Skew Coefficient)

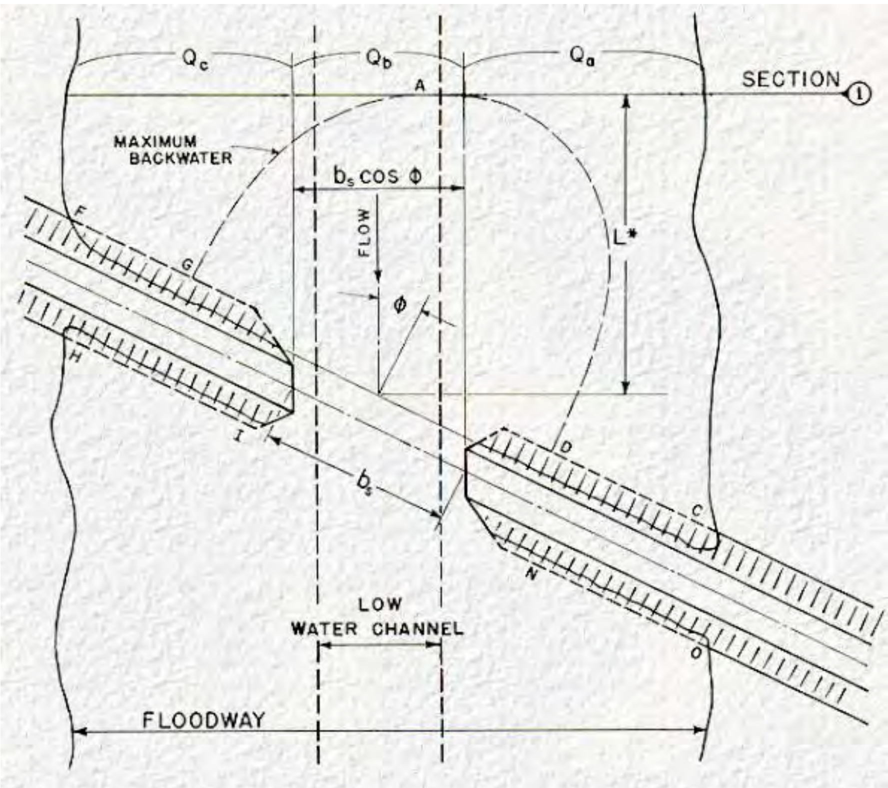


Figure 9. Skewed crossings.

ϕ = 0

Abutment Type =	(B)-Straight

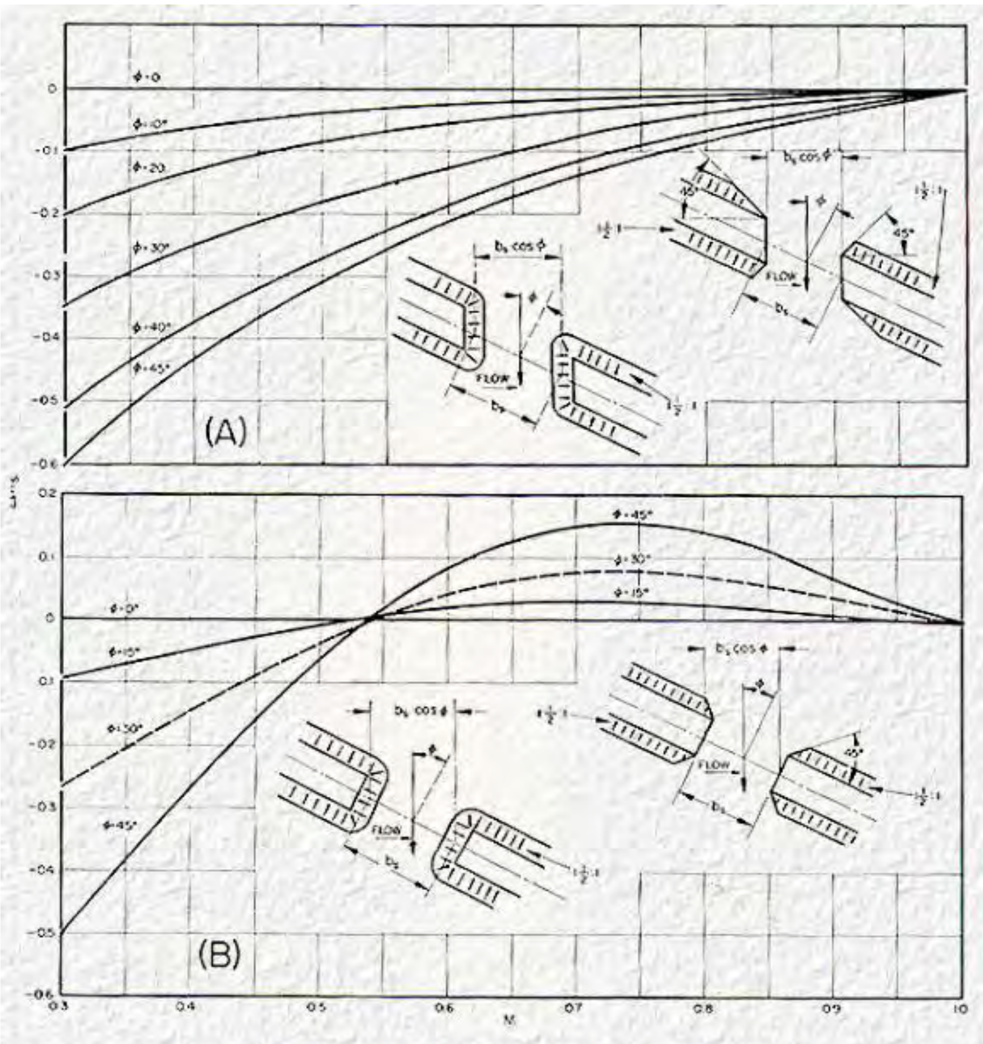


Figure 10. Incremental backwater coefficient for skew.

K_s = 0.00

(K*) Total Backwater Coefficient

$K^* = K_b + K_p + K_e + K_s$

K* = 0.01

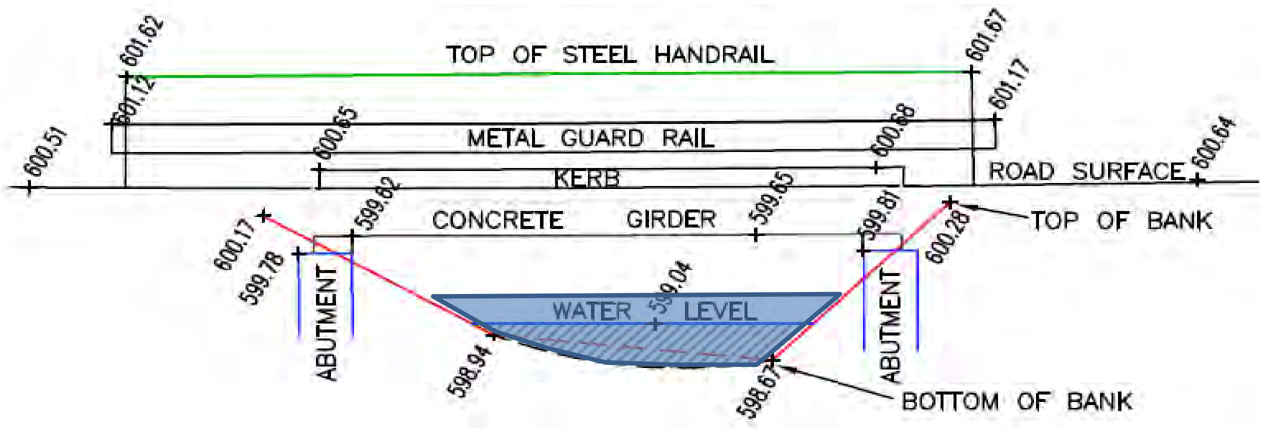
Notes

K* = 0.01 from 614.45 to 615.10 (bank full at invert of deck).

Representation of Bridges in TUFLOW

Prepared by: D. Fedczyna **Date:** 1/10/2015
Checked by: **Date:**

Reference: 'Hydraulics of Bridge Waterways: HDS 1' (Bradley, March 1978)



The total backwater (i.e., energy loss) coefficient is calculated as:
$K^* = K_b + K_p + K_e + K_s$

Bridge modelling approach = 2D/1D

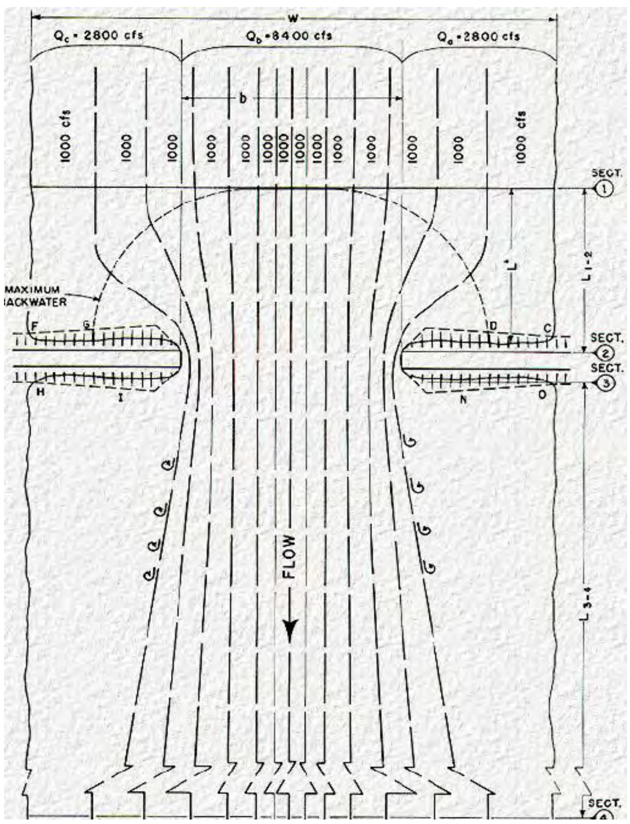
K_b (base coefficient)

First need to calculate the Bridge Opening Ratio (M)

M = Unimpeded Flow / Total Flow

$M = Q_b / (Q_a + Q_b + Q_c)$

Unimpeded Flow =	1.5	m^3/s
Total Flow=	1.5	m^3/s
M = 1.00		



Abutment Type = 90o Wingwall

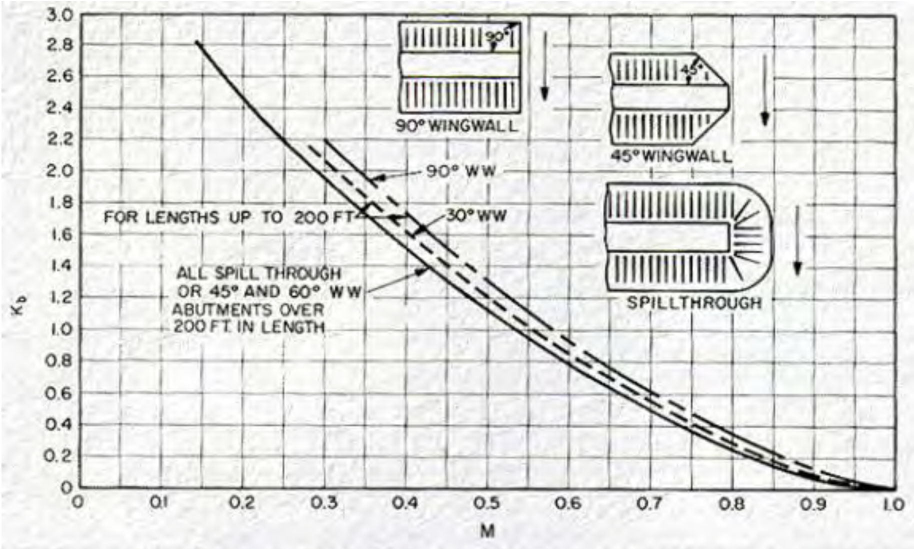


Figure 6. Backwater coefficient base curves (subcritical flow).

K_b = 0.00

K_p (Pier Coefficient)

Assume fences abstruct flow similar to pier

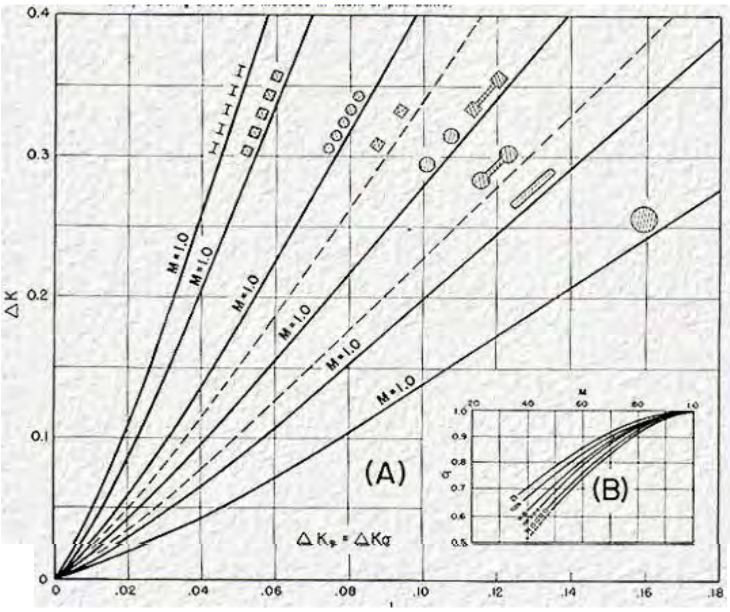
Ratio of gross waterway area to pier area

$J = A_p / A_{n3}$

A_p = 0 m^2

A_{n2} = 1.5 m^2

J = 0
J = 0%



Pier Type: Single Rectangular Pier

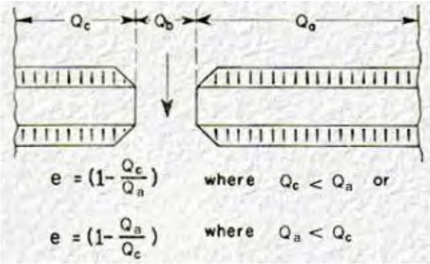
σ = 1.00

ΔK = 0.00

$K_p = \sigma \Delta K$

K_p = 0.00

K_e (Eccentricity Coefficient)



Q_c = 1	m^3/s
Q_a = 1	m^3/s

e = 0.00

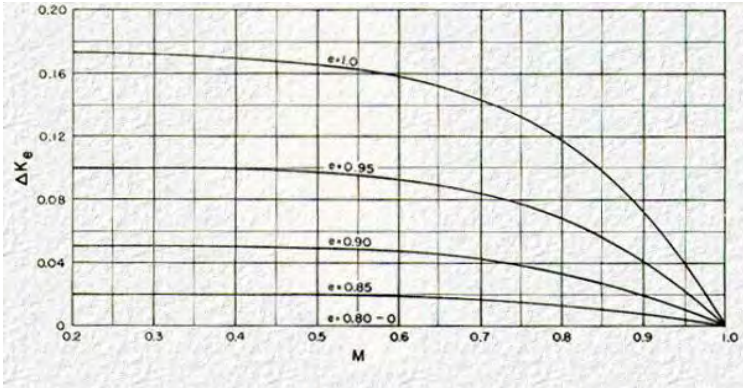


Figure 8. Incremental backwater coefficient for eccentricity.

K_e = 0.00

K_s (Skew Coefficient)

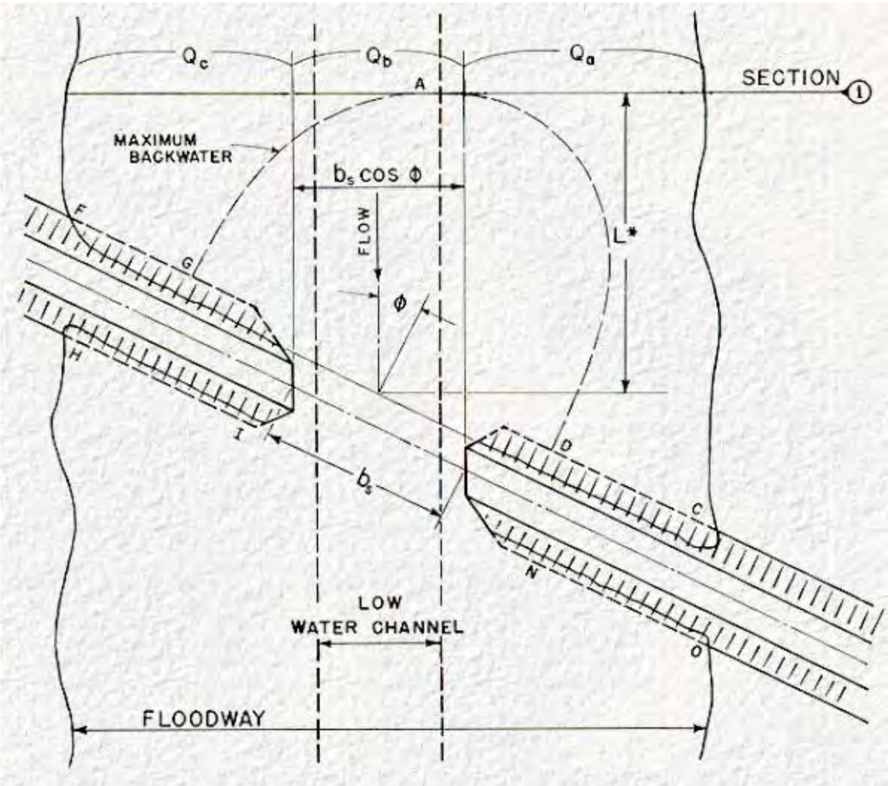


Figure 9. Skewed crossings.

ϕ = 0

Abutment Type = (B)-Straight

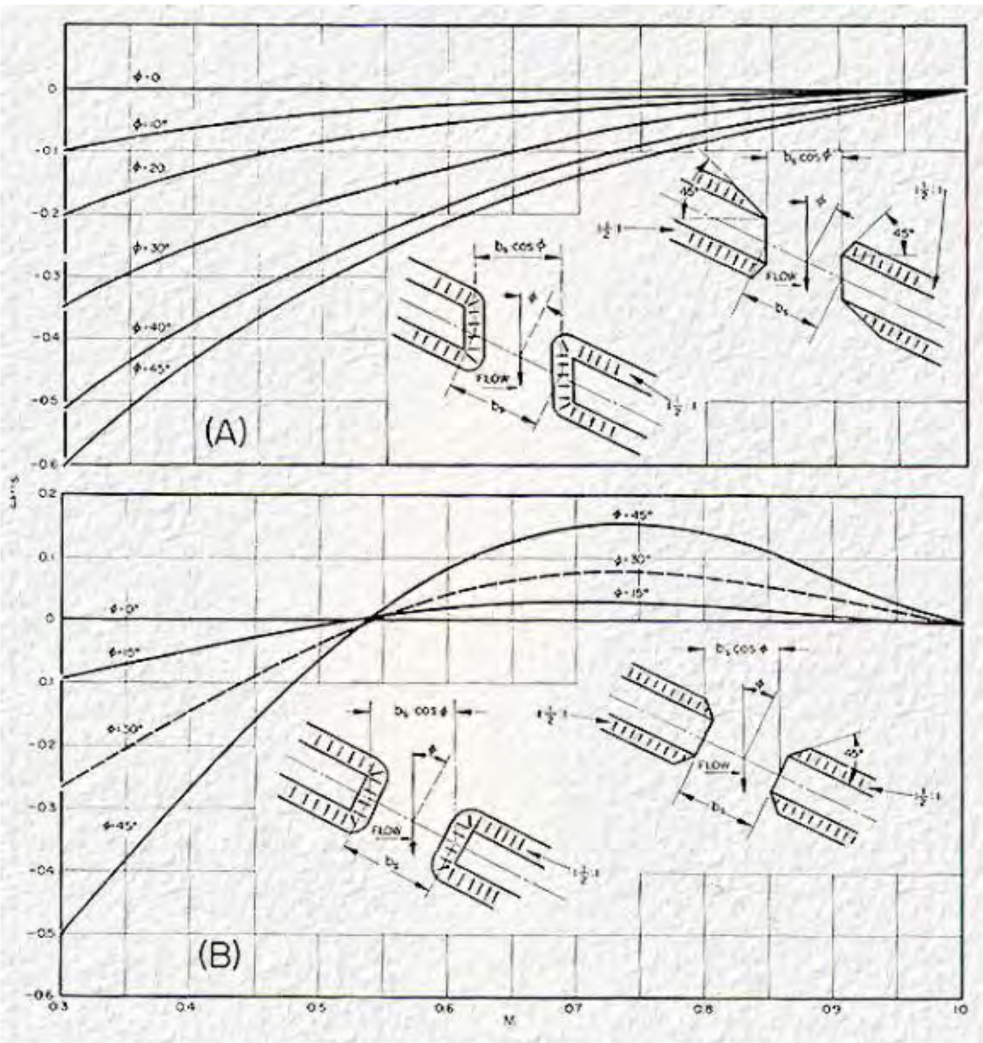


Figure 10. Incremental backwater coefficient for skew.

K_s = 0.00

(K*) Total Backwater Coefficient

$K^* = K_b + K_p + K_e + K_s$

K^* = 0.00

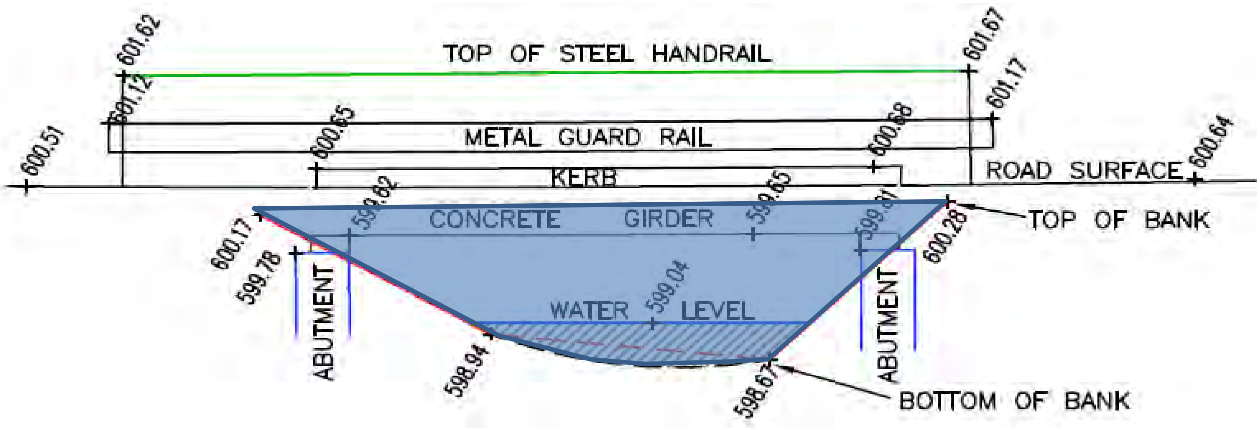
Notes

K* = 0.00 from 598.67 to 599.10 (from bottom to half bank full).

Representation of Bridges in TUFLOW

Prepared by: D. Fedczyna | **Date:** 1/10/2015
Checked by: | **Date:**

Reference: 'Hydraulics of Bridge Waterways: HDS 1' (Bradley, March 1978)



The total backwater (i.e., energy loss) coefficient is calculated as:
$K^* = K_b + K_p + K_e + K_s$

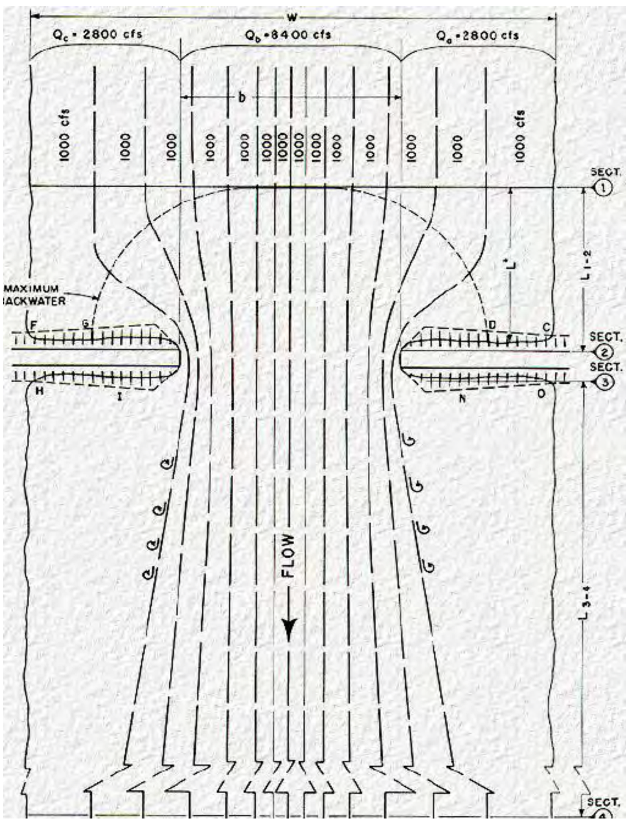
Bridge modelling approach = 2D/1D

K_b (base coefficient)

First need to calculate the Bridge Opening Ratio (M)
M = Unimpeded Flow / Total Flow
$M = Q_b / (Q_a + Q_b + Q_c)$

All flow contained in channel

Unimpeded Flow =	7.8	m^3/s
Total Flow=	8.3	m^3/s
	M = 0.94	



Abutment Type = 90o Wingwall

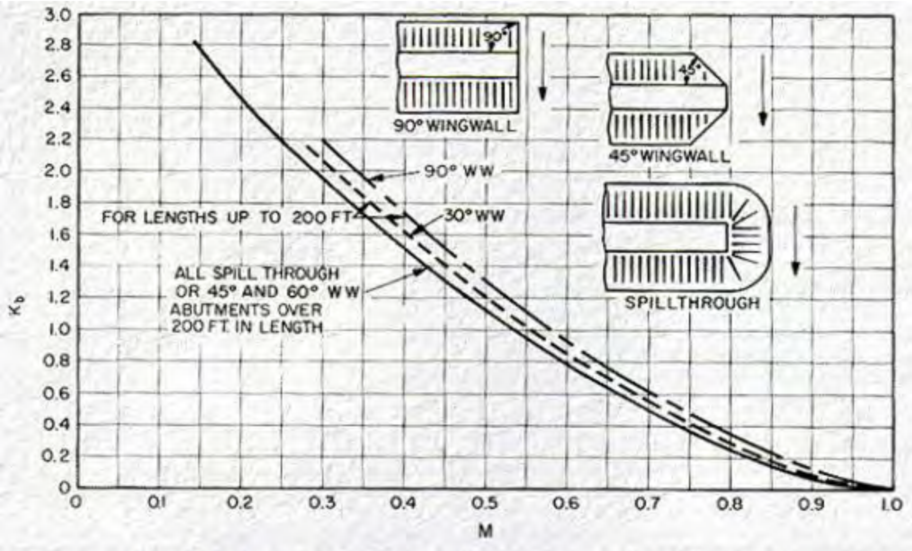


Figure 6. Backwater coefficient base curves (subcritical flow).

K_b = 0.09

K_p (Pier Coefficient)

Assume fences abstruct flow similar to pier

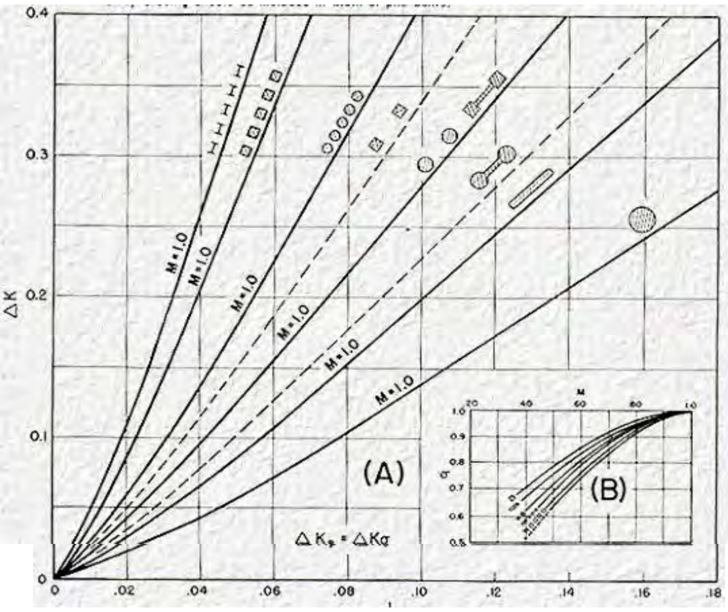
Ratio of gross waterway area to pier area

$J = A_p / A_{n3}$

A_p = 0 m^2

A_{n2} = 8.3 m^2

J = 0
J = 0%



Pier Type: Single Rectangular Pier

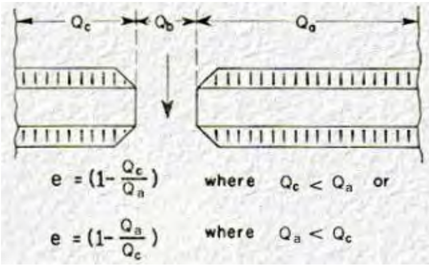
σ = 0.98

ΔK = 0.00

$K_p = \sigma\Delta K$

K_p = 0.00

K_e (Eccentricity Coefficient)



Q_c =	1	m^3/s
Q_a =	1	m^3/s

e = 0.00

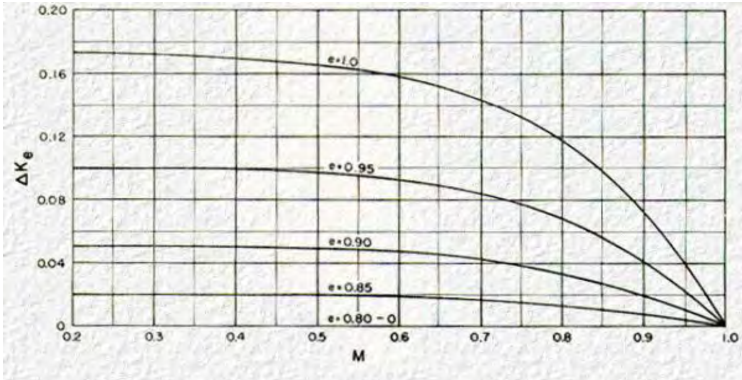


Figure 8. Incremental backwater coefficient for eccentricity.

K_e = **0.00**

K_s (Skew Coefficient)

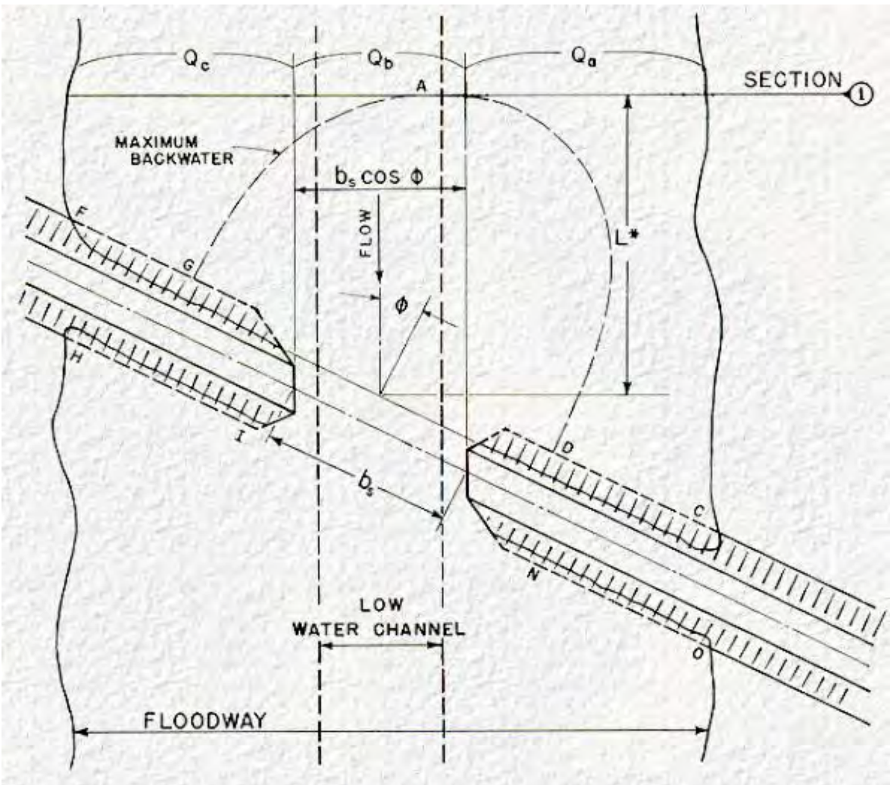


Figure 9. Skewed crossings.

ϕ =	0

Abutment Type =	(B)-Straight

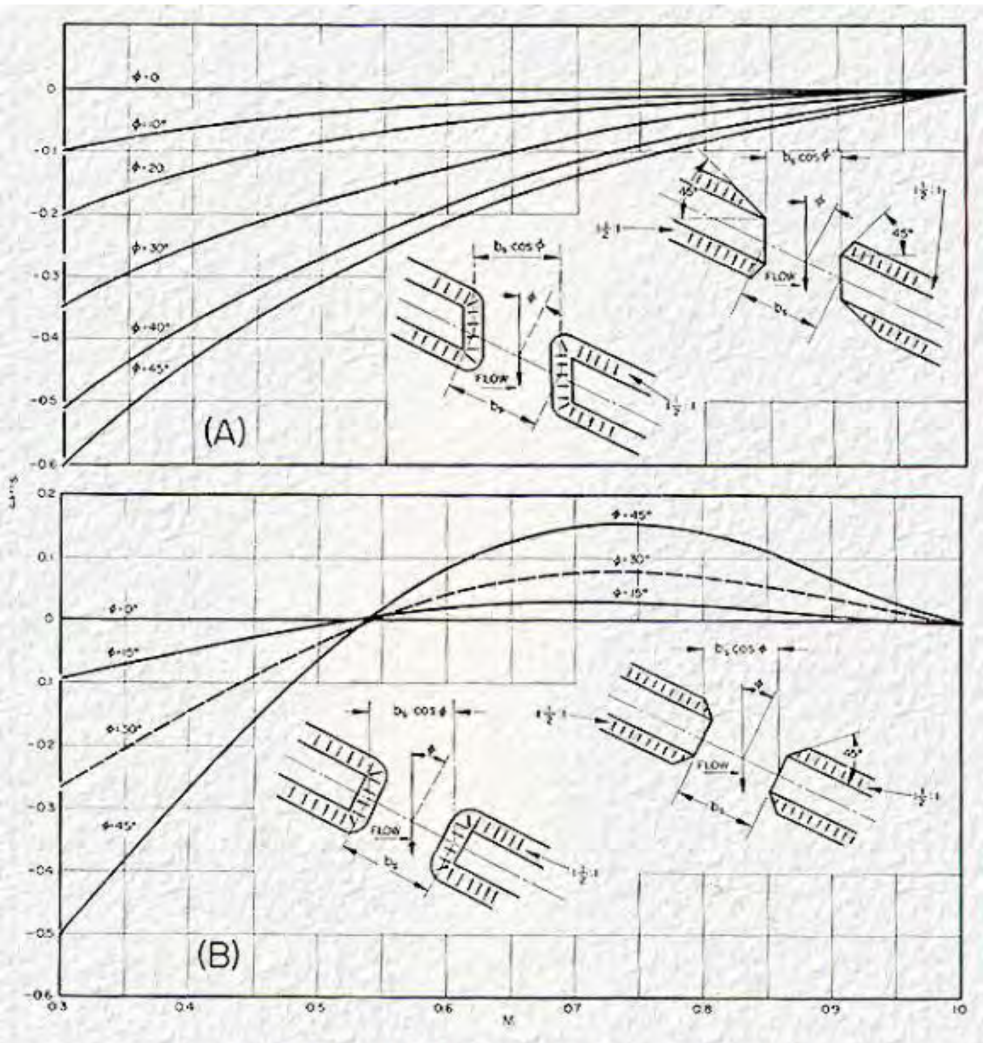


Figure 10. Incremental backwater coefficient for skew.

K_s = 0.00

(K*) Total Backwater Coefficient

$K^* = K_b + K_p + K_e + K_s$

K^* = 0.09

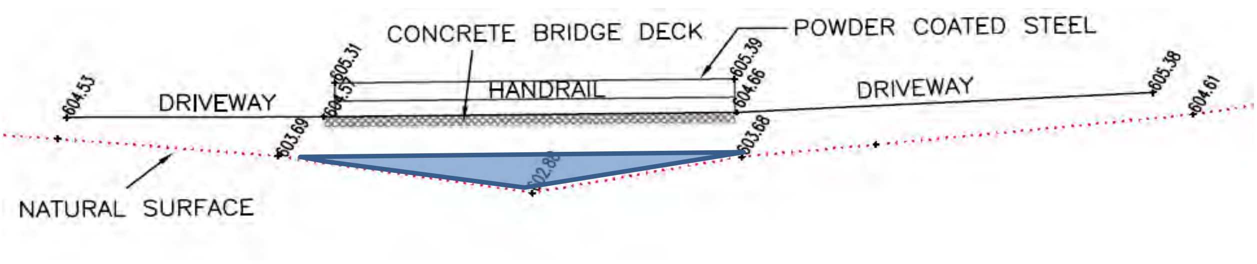
Notes

K* = 0.09 from 599.1 to 600.28 (bank full). Contact with deck, spill over Scarlet St is calculated in 2D

Representation of Bridges in TUFLOW

Prepared by: D. Fedczyna **Date:** 1/10/2015
Checked by: **Date:**

Reference: 'Hydraulics of Bridge Waterways: HDS 1' (Bradley, March 1978)



The total backwater (i.e., energy loss) coefficient is calculated as:
$K^* = K_b + K_p + K_e + K_s$

Bridge modelling approach = 1D/2D

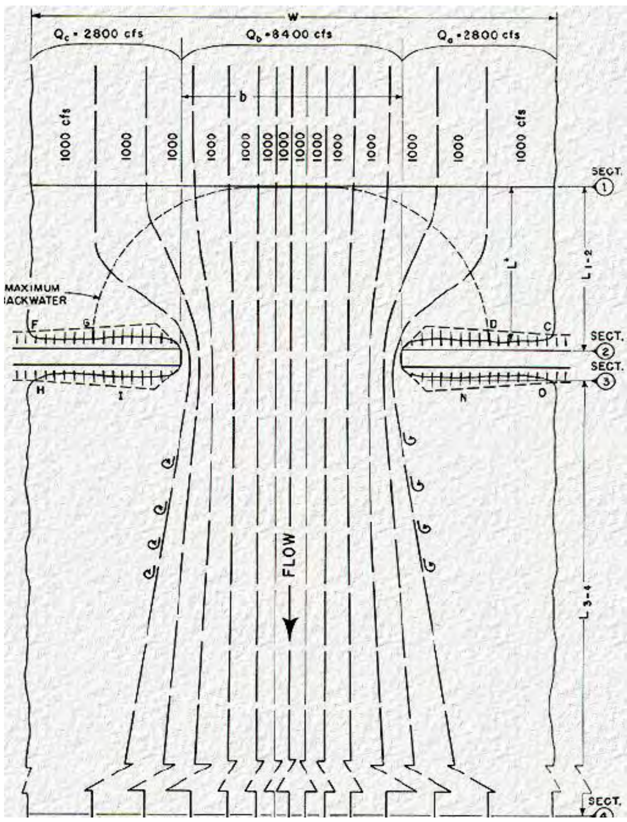
K_b (base coefficient)

First need to calculate the Bridge Opening Ratio (M)

M = Unimpeded Flow / Total Flow

$M = Q_b / (Q_a + Q_b + Q_c)$

Unimpeded Flow =	6.24	m^3/s
Total Flow=	6.24	m^3/s
M = 1.00		



Catchment Simulation Solutions

Abutment Type = 90o Wingwall

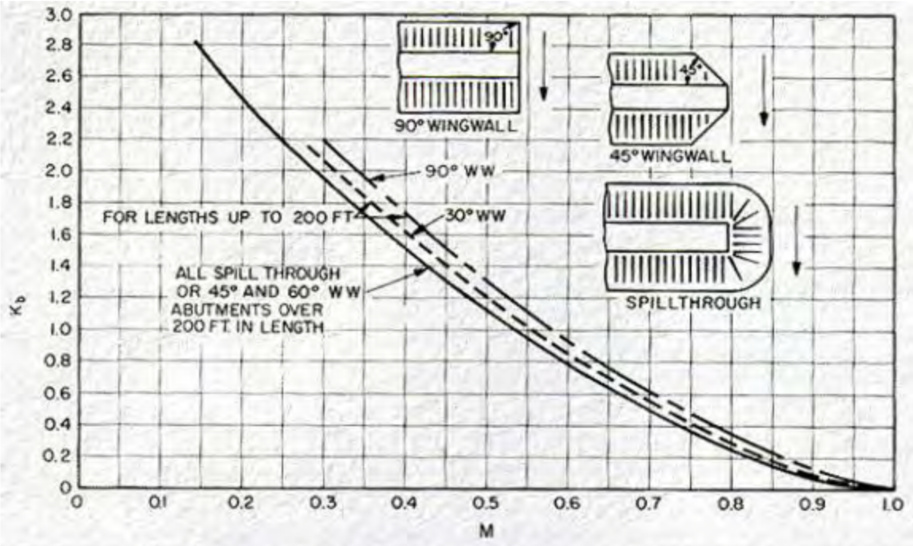


Figure 6. Backwater coefficient base curves (subcritical flow).

K_b = 0.00

K_p (Pier Coefficient)

Assume fences abstruct flow similar to pier

Ratio of gross waterway area to pier area

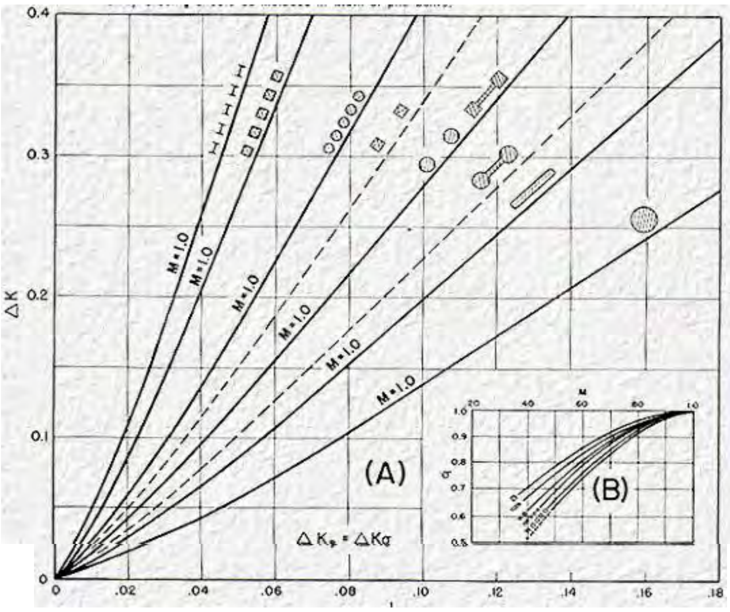
$J = A_p / A_{n3}$

A_p = 0 m^2

A_{n2} = 6.24 m^2

J = 0
J = 0%

Pier Type: Single Rectangular Pier



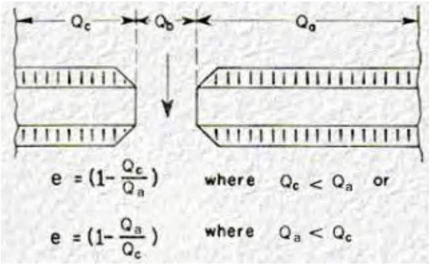
σ = 1.00

ΔK = 0.00

$K_p = \sigma \Delta K$

K_p = 0.00

K_e (Eccentricity Coefficient)



Q_c = 1	m^3/s
Q_a = 1	m^3/s

e = 0.00

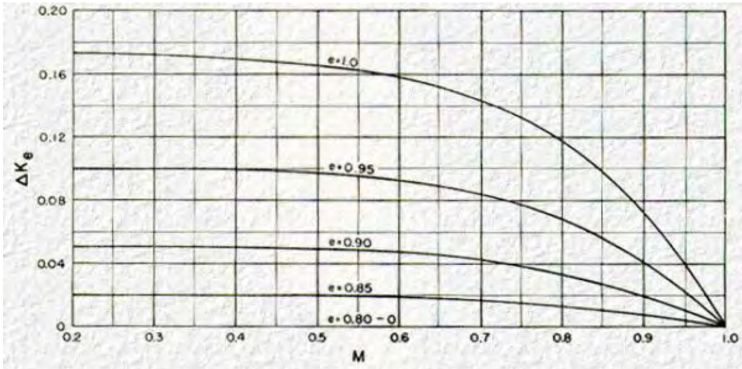


Figure 8. Incremental backwater coefficient for eccentricity.

K_e = 0.00

K_s (Skew Coefficient)

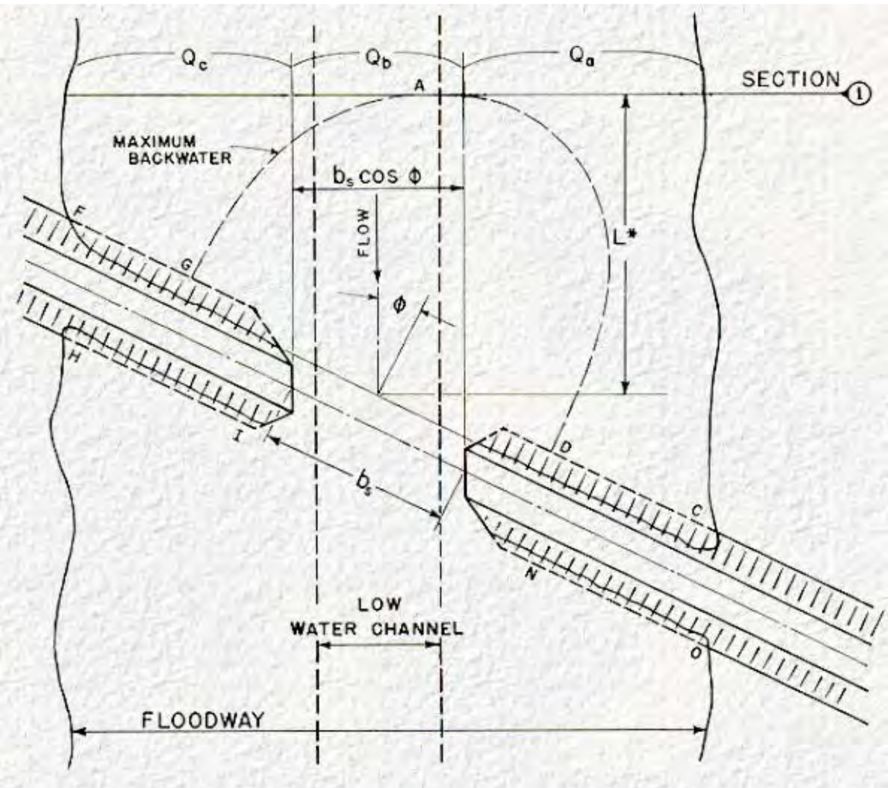


Figure 9. Skewed crossings.

ϕ = 0

Abutment Type =	(B)-Straight

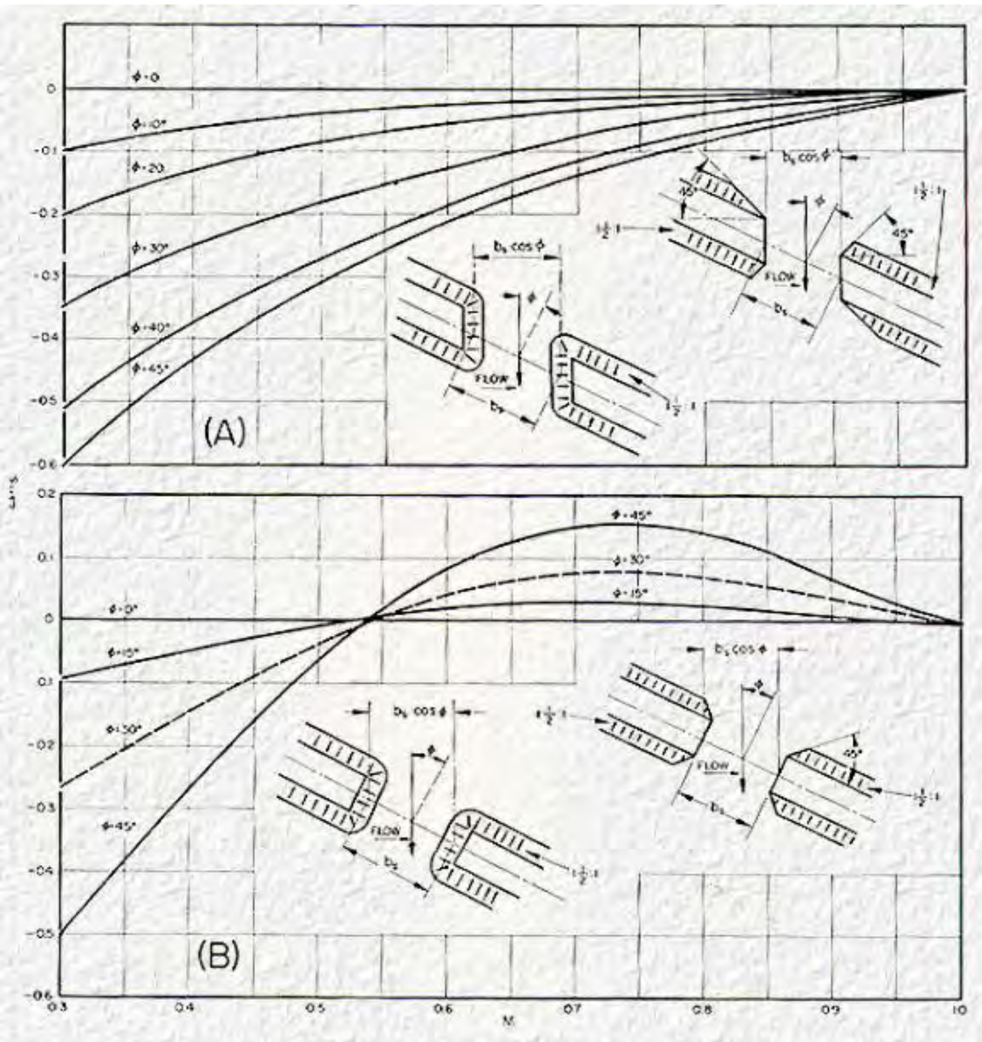


Figure 10. Incremental backwater coefficient for skew.

K_s = 0.00

(K*) Total Backwater Coefficient

$K^* = K_b + K_p + K_e + K_s$

K^* = 0.00

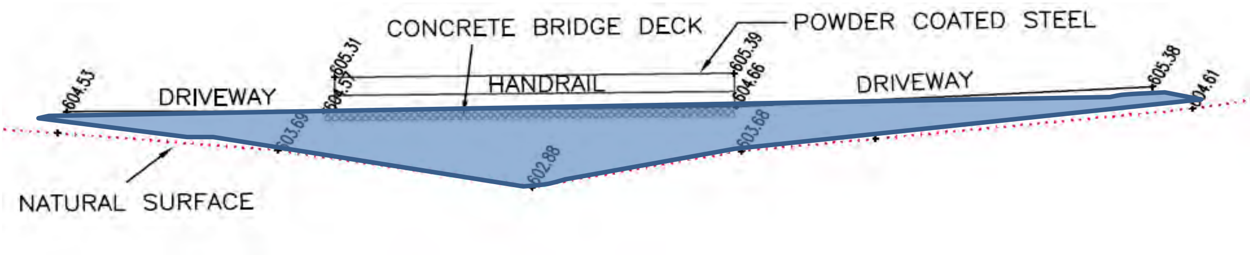
Notes

K* = 0.00 from 602.88 to 603.68 (from bottom to half bank full).

Representation of Bridges in TUFLOW

Prepared by: D. Fedczyna **Date:** 1/10/2015
Checked by: **Date:**

Reference: 'Hydraulics of Bridge Waterways: HDS 1' (Bradley, March 1978)

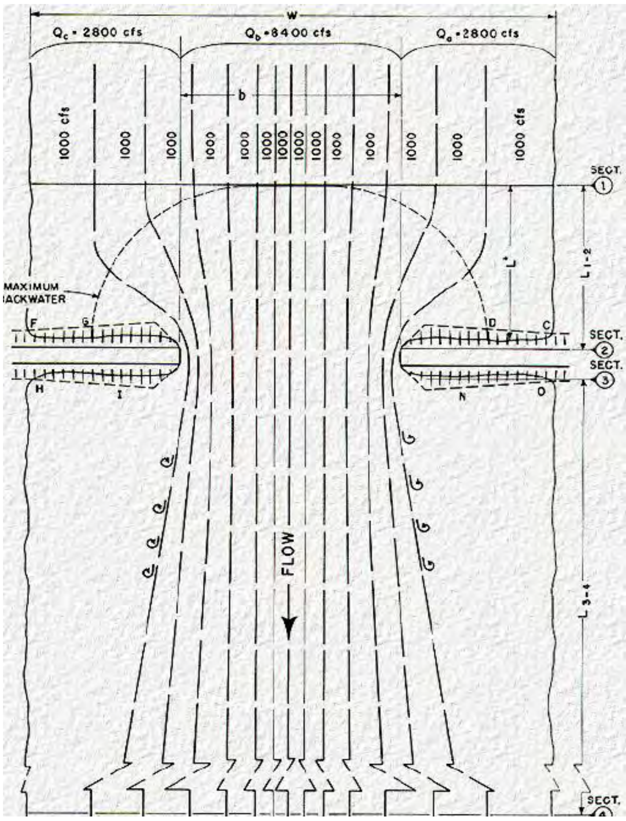


The total backwater (i.e., energy loss) coefficient is calculated as:
$K^* = K_b + K_p + K_e + K_s$

Bridge modelling approach = 1D/2D

K_b (base coefficient)

First need to calculate the Bridge Opening Ratio (M)
M = Unimpeded Flow / Total Flow
$M = Q_b / (Q_a + Q_b + Q_c)$



All flow contained in channel
Unimpeded Flow = 49.4 m^3/s
Total Flow= 49.83 m^3/s
M = 0.99

Abutment Type = 90o Wingwall

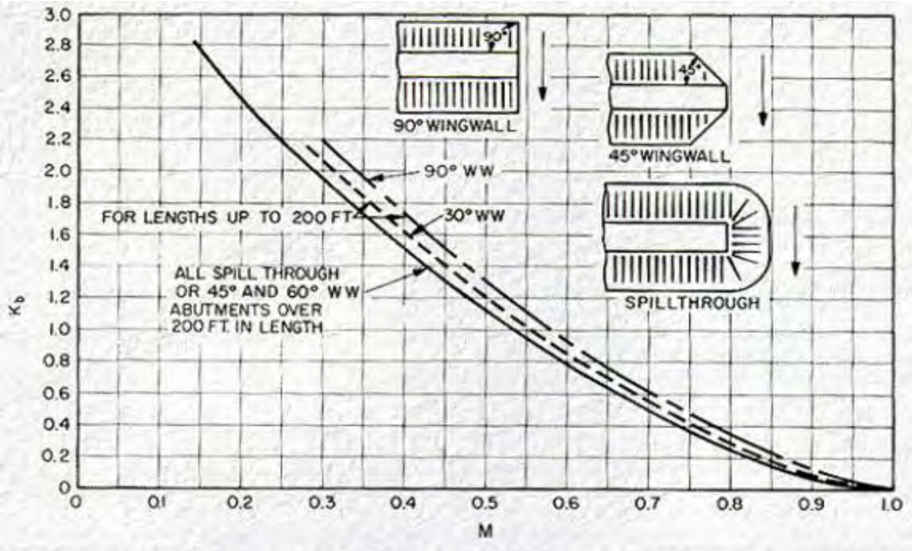


Figure 6. Backwater coefficient base curves (subcritical flow).

K_b = 0.01

K_p (Pier Coefficient)

Assume fences abstruct flow similar to pier

Ratio of gross waterway area to pier area

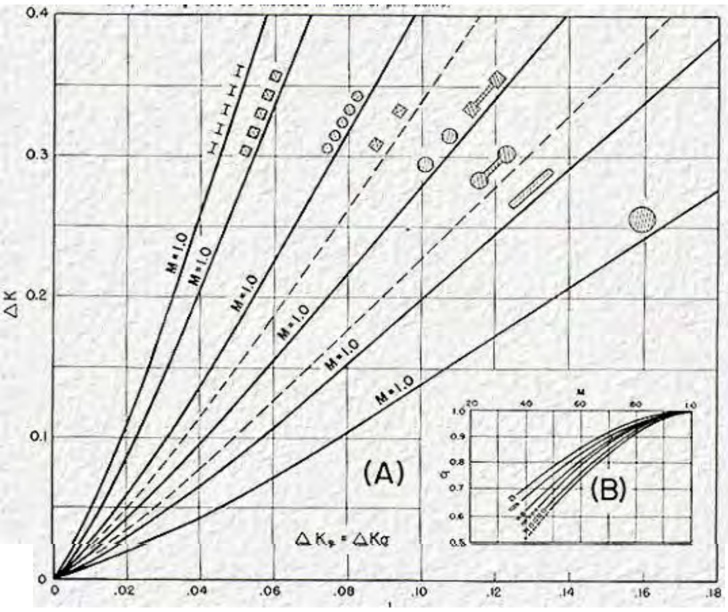
$J = A_p / A_{n3}$

J = 0
J = 0%

A_p = 0 m^2

A_{n2} = 49.83 m^2

Pier Type: Single Rectangular Pier



σ = 1.00

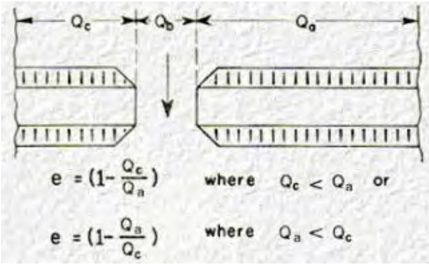
ΔK = 0.00

$K_p = \sigma\Delta K$

K_p = 0.00

Catchment Simulation Solutions

K_e (Eccentricity Coefficient)



Q_c = 1	m^3/s
Q_a = 1	m^3/s

e = 0.00

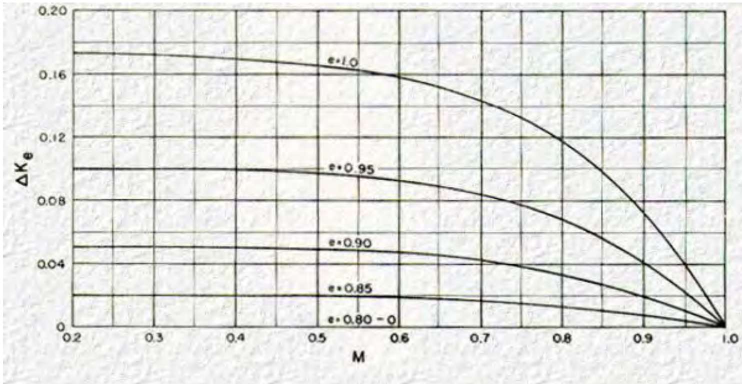


Figure 8. Incremental backwater coefficient for eccentricity.

K_e = 0.00

K_s (Skew Coefficient)

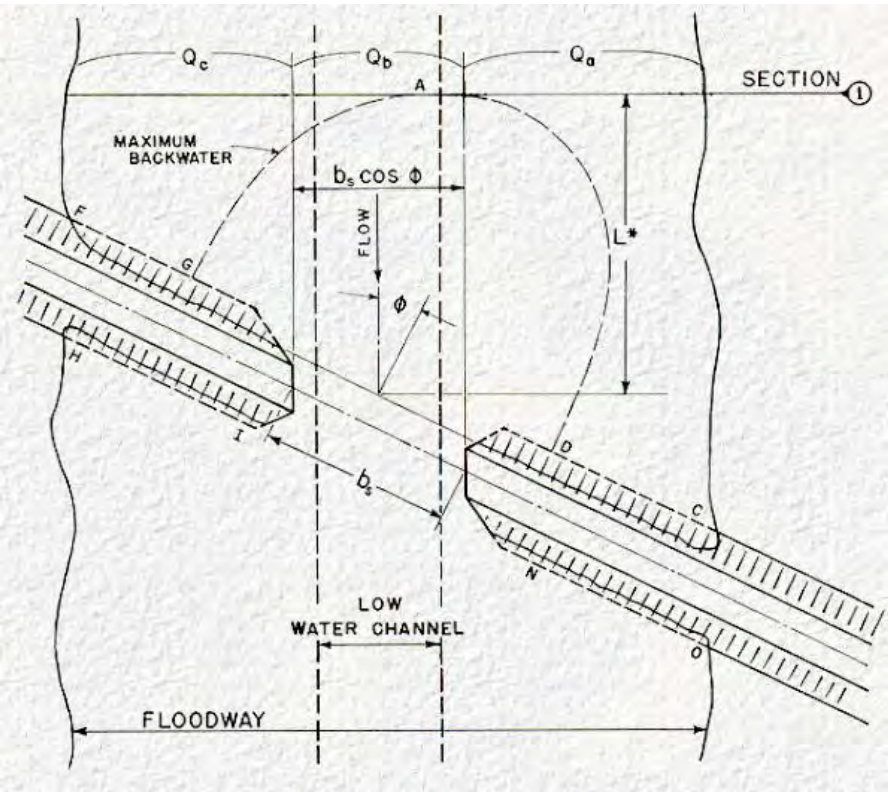


Figure 9. Skewed crossings.

ϕ = 0

Abutment Type =	(B)-Straight

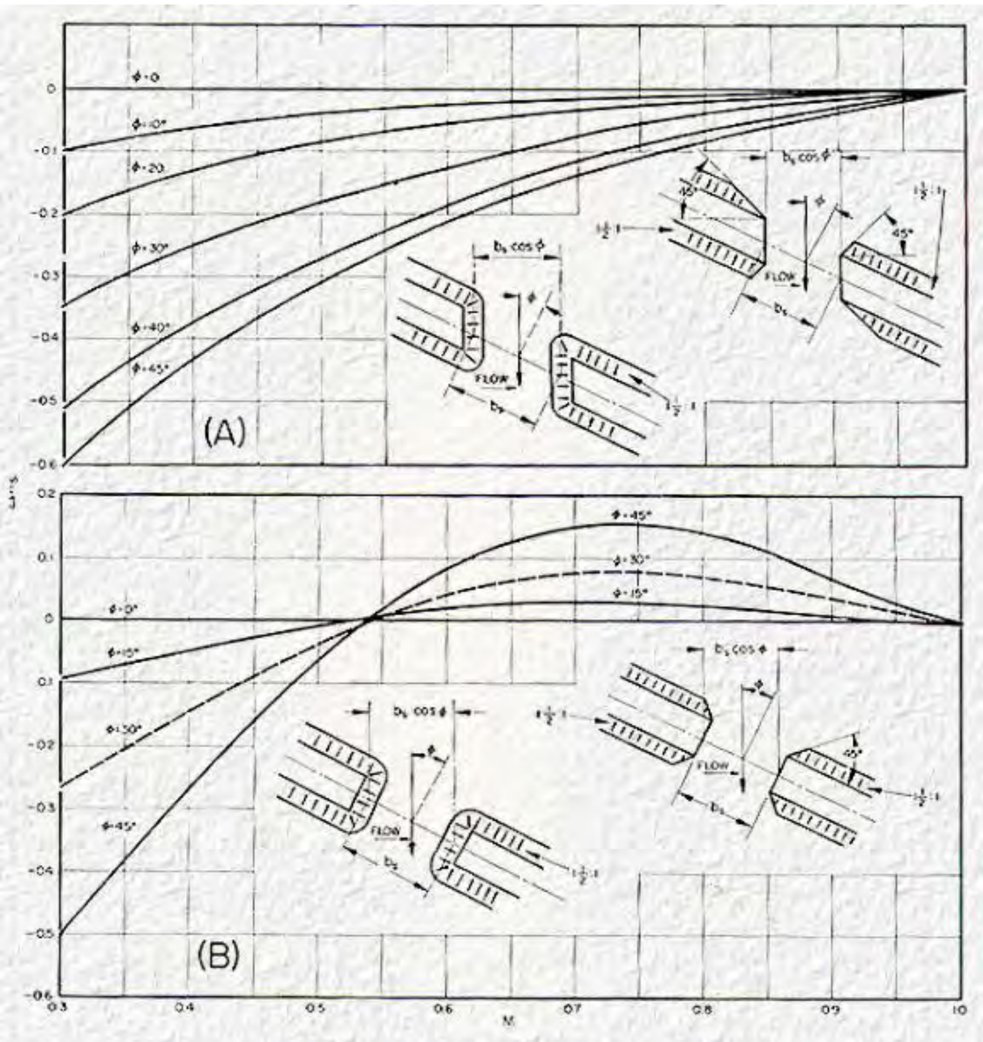


Figure 10. Incremental backwater coefficient for skew.

K_s = 0.00

(K*) Total Backwater Coefficient

$K^* = K_b + K_p + K_e + K_s$

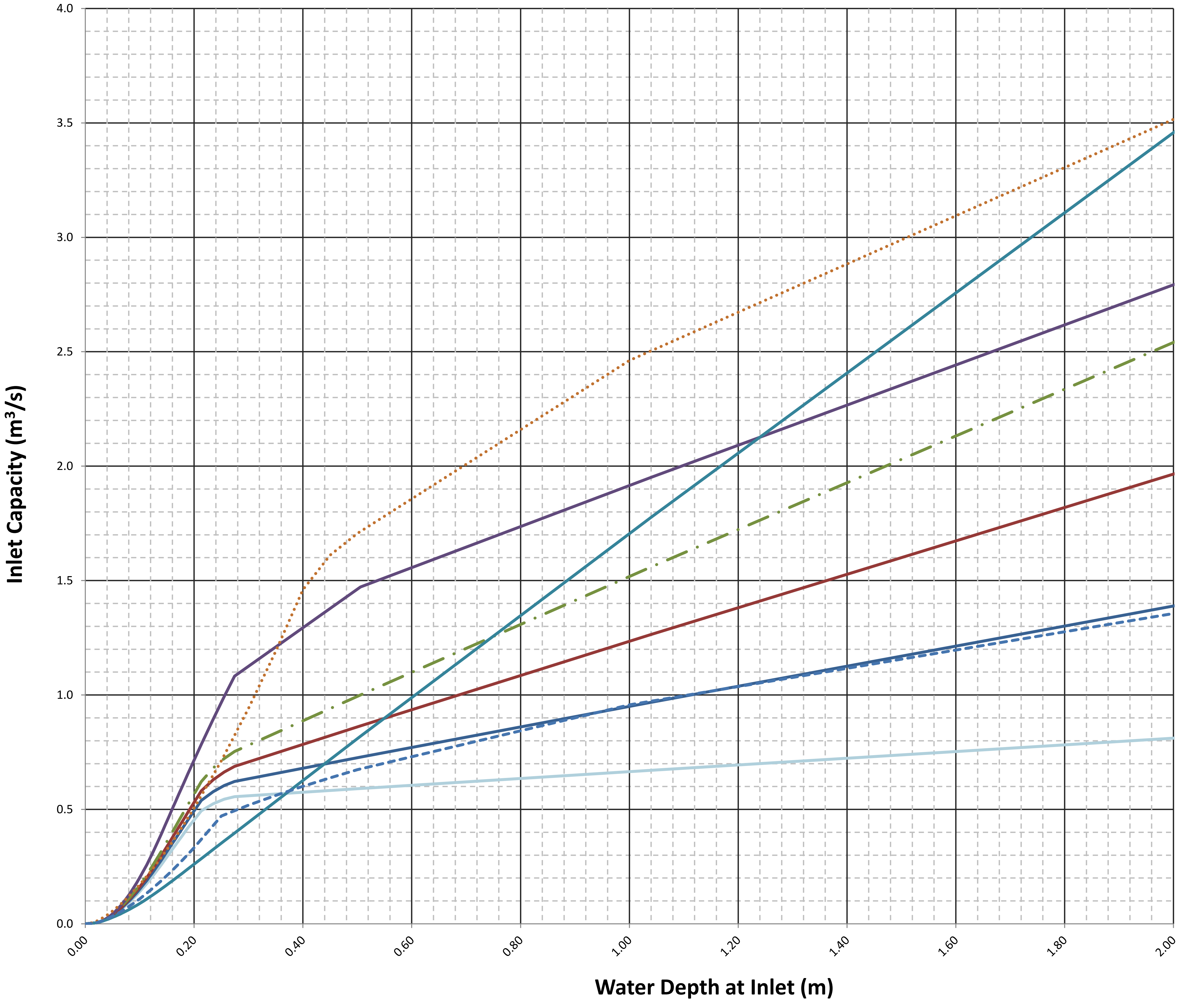
K* = 0.01

Notes

K* = 0.01 from 603.68 to 604.53 (bank full at invert of deck). Flow/loss above deck invert calculated in 2D

APPENDIX F

STORMWATER INLET CAPACITY CURVES



WINGECARRIBEE SHIRE COUNCIL

LEGEND

- On-Grade Combination inlet with 1.2m lintel & 0.9x0.6m grate
- On-Grade Combination inlet with 1.8m lintel & 0.9x0.6m grate
- On-Grade Combination inlet with 2.4m lintel & 0.9x0.6m grate
- On-Grade Combination inlet with 3m lintel & 0.9x0.6m grate
- On-Grade Combination inlet with 3.6m lintel & 0.9x0.6m grate
- On-Grade Inlet with 0.36m2 grate on Kerb
- Sag Combination inlet with 2.4m lintel & 0.9x0.6m grate
- Sag Inlet with 0.6m x 0.6m grate

Notes:

Inlet capacity curves do not consider blockage.

Figure F1: Inlet Capacity Curves

Prepared By:

Catchment Simulation Solutions
Suite 2.01, 210 George Street
Sydney, NSW, 2000

File Name: Inlet Capcacity Curves.xls

APPENDIX G

PMP CALCULATIONS

GSDM CALCULATION SHEET

LOCATION INFORMATION

Catchment Nattai Ponds
Area 7.83 km^2

State New South Wales
Duration Limit 6.0 hrs

Latitude 34.4432^0S
Longitude 150.4739^0E

Portion of Area Considered:

Smooth, **S** = 0.00 (0.0 - 1.0)
Rough, **R** = 1.00 (0.0 - 1.0)

ELEVATION ADJUSTMENT FACTOR (EAF)

Mean Elevation 625 m

Adjustment for Elevation (-0.05 per 300m above 1500m) 0.00

EAF = **1.00** (0.85 – 1.00)

MOISTURE ADJUSTMENT FACTOR (MAF)

MAF = **0.68** (0.40-1.00)

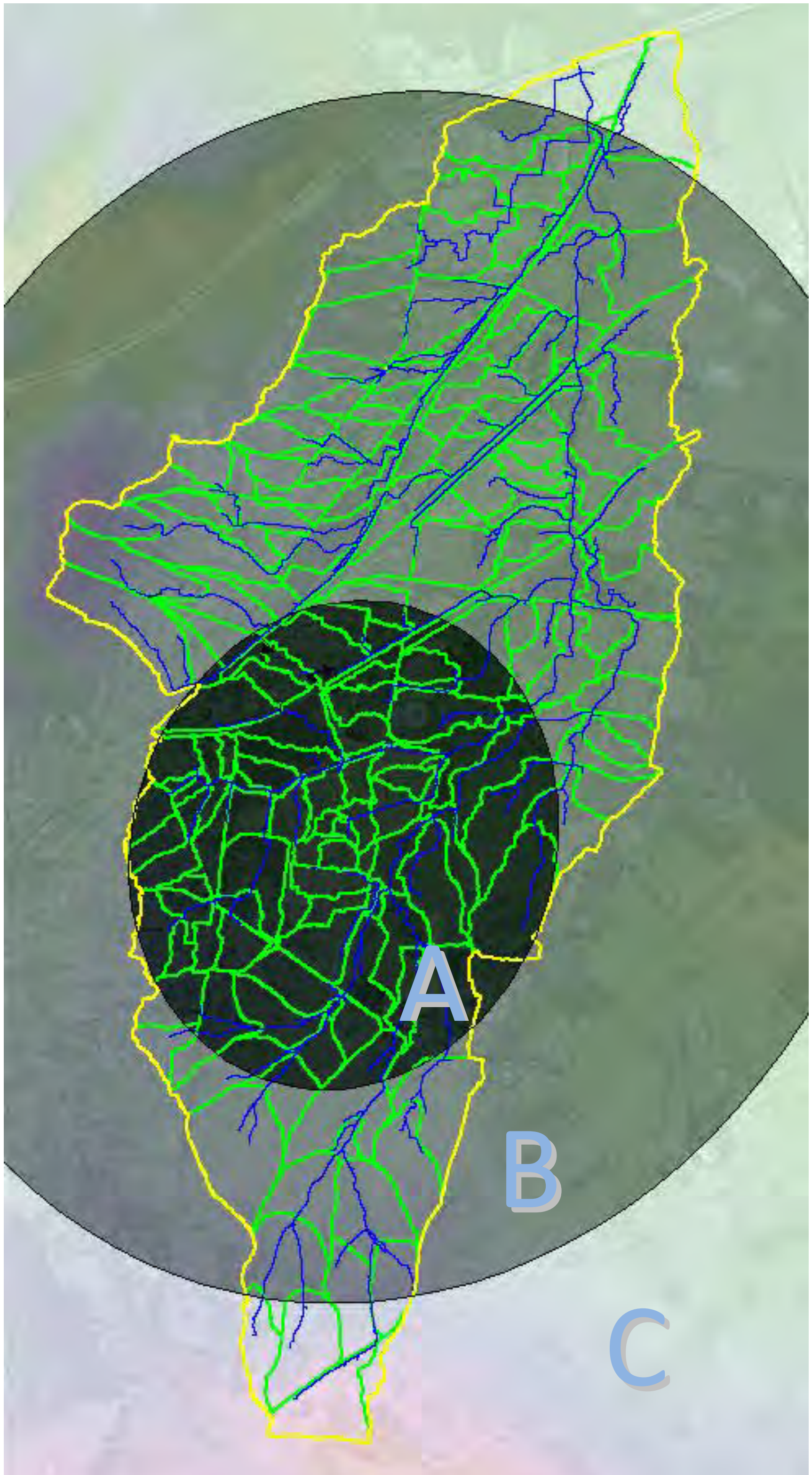
PMP VALUES (mm)

Duration (hours)	Initial Depth -Smooth (D_S)	Initial Depth -Rough (D_R)	PMP Estimate = (D_SxS + D_RxR) x MAF x EAF	Rounded PMP Estimate (nearest 10 mm)
0.25	215	215	145	150
0.50	317	317	214	210
0.75	403	403	272	270
1.00	469	469	316	320
1.50	536	601	406	410
2.00	599	704	475	480
2.50	638	775	523	520
3.00	670	849	573	570
4.00	738	973	657	660
5.00	794	1070	722	720
6.00	840	1137	767	770

Prepared By D. Fedczyna
Date 30/11/2015

Checked By D. Tetley
Date 06/01/2016

GSDM SPATIAL DISTRIBUTION



GSDM SPATIAL DISTRIBUTION

DURATION = 0.25 Hours

Ellipse	Catchment Area Between Ellipse (km^2)	Catchment Area Enclosed by Ellipse (km^2)	Initial Mean Rainfall Depth (mm)	Adjusted Mean Rainfall Depth (mm)	Rainfall Volume enclosed by Ellipse ($mm.km^2$)	Rainfall Volume between Ellipses ($mm.km^2$)	Mean Rainfall Depth between ellipses (mm)
A	2.55	2.55	232	157	400	400	157
B	4.79	7.34	216	146	1072	672	140
C	0.49	7.83	215	145	1139	67	135
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

DURATION = 0.50 Hours

Ellipse	Catchment Area Between Ellipse (km^2)	Catchment Area Enclosed by Ellipse (km^2)	Initial Mean Rainfall Depth (mm)	Adjusted Mean Rainfall Depth (mm)	Rainfall Volume enclosed by Ellipse ($mm.km^2$)	Rainfall Volume between Ellipses ($mm.km^2$)	Mean Rainfall Depth between ellipses (mm)
A	2.55	2.55	336	227	580	580	227
B	4.79	7.34	318	215	1576	996	208
C	0.49	7.83	317	214	1673	98	199
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

GSDM SPATIAL DISTRIBUTION (continued)

DURATION = 0.75 Hours							
Ellipse	Catchment Area Between Ellipse (km²)	Catchment Area Enclosed by Ellipse (km²)	Initial Mean Rainfall Depth (mm)	Adjusted Mean Rainfall Depth (mm)	Rainfall Volume enclosed by Ellipse (mm.km²)	Rainfall Volume between Ellipses (mm.km²)	Mean Rainfall Depth between ellipses (mm)
A	2.55	2.55	425	287	733	733	287
B	4.79	7.34	404	273	2002	1269	265
C	0.49	7.83	403	272	2128	126	257
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

DURATION = 1.0 Hours							
Ellipse	Catchment Area Between Ellipse (km²)	Catchment Area Enclosed by Ellipse (km²)	Initial Mean Rainfall Depth (mm)	Adjusted Mean Rainfall Depth (mm)	Rainfall Volume enclosed by Ellipse (mm.km²)	Rainfall Volume between Ellipses (mm.km²)	Mean Rainfall Depth between ellipses (mm)
A	2.55	2.55	493	333	851	851	333
B	4.79	7.34	471	318	2332	1482	309
C	0.49	7.83	469	316	2478	146	297
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

GSDM SPATIAL DISTRIBUTION (continued)

DURATION = 1.5 Hours							
Ellipse	Catchment Area Between Ellipse (km^2)	Catchment Area Enclosed by Ellipse (km^2)	Initial Mean Rainfall Depth (mm)	Adjusted Mean Rainfall Depth (mm)	Rainfall Volume enclosed by Ellipse ($mm.km^2$)	Rainfall Volume between Ellipses ($mm.km^2$)	Mean Rainfall Depth between ellipses (mm)
A	2.55	2.55	637	430	1098	1098	430
B	4.79	7.34	603	407	2990	1892	395
C	0.49	7.83	601	406	3177	187	381
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

DURATION = 2.0 Hours							
Ellipse	Catchment Area Between Ellipse (km^2)	Catchment Area Enclosed by Ellipse (km^2)	Initial Mean Rainfall Depth (mm)	Adjusted Mean Rainfall Depth (mm)	Rainfall Volume enclosed by Ellipse ($mm.km^2$)	Rainfall Volume between Ellipses ($mm.km^2$)	Mean Rainfall Depth between ellipses (mm)
A	2.55	2.55	745	503	1284	1284	503
B	4.79	7.34	707	477	3503	2220	464
C	0.49	7.83	704	475	3722	219	445
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

GSDM SPATIAL DISTRIBUTION (continued)

DURATION = 2.5 Hours							
Ellipse	Catchment Area Between Ellipse (km^2)	Catchment Area Enclosed by Ellipse (km^2)	Initial Mean Rainfall Depth (mm)	Adjusted Mean Rainfall Depth (mm)	Rainfall Volume enclosed by Ellipse ($mm.km^2$)	Rainfall Volume between Ellipses ($mm.km^2$)	Mean Rainfall Depth between ellipses (mm)
A	2.55	2.55	822	555	1417	1417	555
B	4.79	7.34	779	526	3859	2442	510
C	0.49	7.83	775	523	4099	240	489
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

DURATION = 3.0 Hours							
Ellipse	Catchment Area Between Ellipse (km^2)	Catchment Area Enclosed by Ellipse (km^2)	Initial Mean Rainfall Depth (mm)	Adjusted Mean Rainfall Depth (mm)	Rainfall Volume enclosed by Ellipse ($mm.km^2$)	Rainfall Volume between Ellipses ($mm.km^2$)	Mean Rainfall Depth between ellipses (mm)
A	2.55	2.55	902	609	1555	1555	609
B	4.79	7.34	853	576	4225	2670	558
C	0.49	7.83	849	573	4490	265	538
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

GSDM SPATIAL DISTRIBUTION (continued)

DURATION = 4.0 Hours							
Ellipse	**Catchment Area Between Ellipse (km^2)**	**Catchment Area Enclosed by Ellipse (km^2)**	**Initial Mean Rainfall Depth (mm)**	**Adjusted Mean Rainfall Depth (mm)**	**Rainfall Volume enclosed by Ellipse ($mm.km^2$)**	**Rainfall Volume between Ellipses ($mm.km^2$)**	**Mean Rainfall Depth between ellipses (mm)**
A	2.55	2.55	1031	696	1777	1777	696
B	4.79	7.34	977	660	4843	3066	640
C	0.49	7.83	973	657	5146	303	617
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

DURATION = 5.0 Hours							
Ellipse	**Catchment Area Between Ellipse (km^2)**	**Catchment Area Enclosed by Ellipse (km^2)**	**Initial Mean Rainfall Depth (mm)**	**Adjusted Mean Rainfall Depth (mm)**	**Rainfall Volume enclosed by Ellipse ($mm.km^2$)**	**Rainfall Volume between Ellipses ($mm.km^2$)**	**Mean Rainfall Depth between ellipses (mm)**
A	2.55	2.55	1136	767	1959	1959	767
B	4.79	7.34	1074	725	5322	3363	703
C	0.49	7.83	1070	722	5655	333	677
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

GSDM SPATIAL DISTRIBUTION (continued)

DURATION = 6.0 Hours							
Ellipse	**Catchment Area Between Ellipse (km^2)**	**Catchment Area Enclosed by Ellipse (km^2)**	**Initial Mean Rainfall Depth (mm)**	**Adjusted Mean Rainfall Depth (mm)**	**Rainfall Volume enclosed by Ellipse (mm.km^2)**	**Rainfall Volume between Ellipses (mm.km^2)**	**Mean Rainfall Depth between ellipses (mm)**
A	2.55	2.55	1201	811	2071	2071	811
B	4.79	7.34	1141	770	5654	3583	748
C	0.49	7.83	1137	767	6009	355	723
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Appendix H

XP-RAFTS Model Results for Design Flood Simulations

PEAK DESIGN FLOOD DISCHARGES - 20% AEP

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
1.01	0.30	0.62	0.80	0.91	0.93	0.95	0.79	**0.98**	0.83	0.73
1.02	0.83	1.38	1.54	1.80	1.88	**2.01**	1.62	1.72	1.52	1.32
1.03	1.63	2.87	3.23	3.78	3.87	**4.20**	3.34	3.54	3.14	2.73
1.04	3.08	5.77	6.64	7.70	7.82	**8.46**	6.67	7.24	6.35	5.50
1.05	3.33	6.34	7.43	8.55	8.71	**9.35**	7.36	8.26	7.29	6.35
1.06	3.37	6.46	7.61	8.77	8.92	**9.58**	7.55	8.48	7.52	6.56
1.07	4.14	8.15	10.06	11.61	11.81	**12.61**	9.96	11.47	10.35	9.15
1.08	6.55	13.29	16.78	19.28	19.58	**20.65**	16.54	19.50	17.23	15.33
1.09	6.74	13.60	17.42	20.02	20.46	**21.64**	17.50	20.27	18.14	16.20
1.1	6.80	13.75	17.63	20.34	20.85	**22.08**	17.95	20.65	18.62	16.76
1.11	8.10	15.16	19.70	23.22	24.36	**25.88**	21.57	23.72	22.15	20.11
1.12	8.17	15.33	19.93	23.51	24.71	**26.24**	21.91	24.06	22.55	20.50
1.13	8.20	15.41	20.06	23.67	24.88	**26.43**	22.10	24.24	22.77	20.72
1.14	10.18	18.88	24.54	29.05	30.91	**32.70**	28.28	30.16	29.44	27.83
1.15	10.45	19.42	25.29	29.97	32.10	**33.99**	29.56	31.30	30.81	29.20
1.16	10.57	19.65	25.61	30.37	32.68	**34.61**	30.20	31.83	31.53	29.90
1.17	10.71	19.70	25.69	30.46	33.01	**35.01**	30.65	32.08	32.05	30.38
1.18	10.79	19.76	25.76	30.55	33.26	**35.33**	30.97	32.27	32.33	30.65
1.19	10.92	19.93	25.98	30.82	33.83	**36.05**	31.66	32.75	32.94	31.22
1.2	11.06	20.11	26.24	31.13	34.30	**36.57**	32.19	33.16	33.51	31.75
1.21	12.89	22.30	28.76	33.94	37.86	**40.52**	36.01	36.46	37.57	35.64
1.22	13.11	22.77	29.42	34.78	38.96	**41.75**	37.23	37.53	38.89	36.96
1.23	13.42	23.31	30.12	35.66	40.10	**43.01**	38.50	38.68	40.26	38.29
1.24	13.57	23.60	30.51	36.18	40.75	**43.72**	39.21	39.34	41.03	39.02
1.25	16.06	27.37	36.23	43.99	49.99	**53.83**	49.16	48.56	51.57	49.02
1.26	16.34	27.96	36.96	44.97	51.27	**55.20**	50.63	49.93	53.13	50.54
2.01	0.15	0.23	0.24	0.29	0.31	**0.34**	0.26	0.23	0.19	0.17
2.02	0.53	0.91	1.00	1.16	1.23	**1.34**	1.06	0.95	0.80	0.69
3.01	0.35	0.48	0.55	0.64	0.71	**0.72**	0.58	0.56	0.50	0.43
3.02	1.12	2.17	2.56	2.93	2.97	**3.22**	2.50	2.73	2.40	2.05
3.03	1.40	2.79	3.29	3.76	3.83	**4.11**	3.20	3.54	3.08	2.66
4.01	0.48	0.88	1.02	1.18	1.20	**1.30**	1.01	1.07	0.94	0.81
5.01	0.30	0.64	0.78	0.88	0.90	**0.93**	0.74	0.90	0.77	0.66
5.02	0.55	1.19	1.51	1.68	1.73	1.78	1.47	**1.82**	1.56	1.38
5.03	1.68	1.80	2.17	2.45	2.50	2.65	2.36	**2.79**	2.40	2.20
6.01	0.53	1.07	1.36	1.52	1.56	**1.61**	1.30	1.61	1.37	1.19
6.02	0.72	1.48	1.82	2.06	2.09	**2.20**	1.73	2.13	1.83	1.58
6.03	1.08	2.24	2.76	3.11	3.16	**3.32**	2.61	3.19	2.76	2.38
6.04	1.99	3.76	4.61	5.23	5.31	**5.62**	4.38	5.39	4.70	4.05
6.05	2.30	4.35	5.38	6.12	6.23	**6.57**	5.12	6.29	5.48	4.74
6.06	2.43	4.53	5.69	6.49	6.60	**6.94**	5.46	6.67	5.88	5.11
6.07	2.98	5.20	6.56	7.47	7.59	**7.93**	6.38	7.83	6.84	5.98

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
7.01	0.23	0.51	0.63	0.70	0.71	**0.73**	0.58	0.73	0.63	0.54
8.01	0.28	0.35	0.35	0.40	**0.49**	0.47	0.38	0.36	0.31	0.27
8.02	1.06	1.29	1.40	1.63	**1.87**	1.82	1.47	1.61	1.43	1.23
8.03	1.18	1.53	1.84	2.14	2.29	**2.33**	1.86	2.17	1.92	1.65
9.01	0.50	0.58	0.49	0.63	**0.75**	0.68	0.55	0.54	0.49	0.42
10.01	0.19	0.36	0.48	0.54	0.55	0.57	0.46	**0.58**	0.50	0.42
11.01	0.44	0.50	0.38	0.53	**0.61**	0.53	0.45	0.52	0.45	0.41
11.02	1.06	1.16	0.93	1.24	**1.47**	1.27	1.03	1.13	1.01	0.89
12.01	0.34	0.35	0.29	0.38	**0.44**	0.38	0.29	0.32	0.29	0.26
13.01	0.28	0.30	0.25	0.34	**0.40**	0.34	0.28	0.26	0.22	0.19
14.01	1.33	1.32	1.11	1.32	**1.47**	1.35	0.89	0.84	0.77	0.68
15.01	2.12	2.11	1.78	2.12	**2.39**	2.16	1.46	1.39	1.26	1.10
15.02	2.81	2.81	2.39	2.86	**3.19**	2.94	1.93	1.92	1.76	1.57
15.03	5.07	5.07	4.33	5.18	**5.76**	5.34	3.51	3.46	3.19	2.86
15.04	5.13	5.15	4.40	5.32	**5.92**	5.50	3.66	3.69	3.40	3.05
16.01	2.05	1.99	1.74	1.96	**2.13**	2.01	1.20	1.11	0.93	0.82
17.01	0.10	0.17	0.22	0.26	0.28	**0.30**	0.28	0.29	0.30	0.28
18.01	0.05	0.13	0.16	0.18	0.19	0.20	0.17	**0.20**	0.18	0.16
19.01	0.61	0.67	0.51	0.70	**0.82**	0.72	0.56	0.52	0.45	0.39
19.02	1.05	1.16	0.97	1.29	**1.52**	1.34	1.07	1.01	0.88	0.77
19.03	1.59	1.87	1.82	2.15	**2.63**	2.42	1.97	1.94	1.75	1.52
19.04	1.72	2.04	2.13	2.43	**2.94**	2.79	2.27	2.48	2.22	1.96
19.05	1.85	2.22	2.40	2.73	**3.22**	3.10	2.51	2.81	2.50	2.22
19.06	3.26	3.66	4.26	4.82	**5.44**	5.37	4.35	5.17	4.55	4.07
19.07	4.05	4.63	5.56	6.20	6.69	**6.77**	5.69	6.73	6.01	5.61
19.08	4.26	4.82	5.78	6.45	6.95	**7.04**	5.88	6.97	6.23	5.80
19.09	0.92	1.31	1.53	1.67	1.84	1.94	2.01	2.01	2.07	**2.18**
19.1	1.27	1.89	2.23	2.47	2.70	2.84	2.89	2.86	2.97	**3.10**
19.11	1.39	2.13	2.54	2.80	3.05	3.21	3.24	3.22	3.33	**3.50**
19.12	1.44	2.25	2.70	3.00	3.30	3.48	3.52	3.50	3.63	**3.80**
20.01	0.25	0.29	0.24	0.33	**0.39**	0.34	0.27	0.24	0.19	0.16
21.01	0.27	0.31	0.26	0.35	**0.41**	0.37	0.30	0.27	0.23	0.20
22.01	0.13	0.25	0.31	0.35	0.36	**0.37**	0.30	0.36	0.31	0.27
23.01	0.10	0.11	0.13	0.15	**0.18**	0.17	0.14	0.14	0.12	0.10
24.01	0.23	0.25	0.23	0.29	**0.35**	0.30	0.25	0.29	0.26	0.23
24.02	0.30	0.32	0.29	0.37	**0.43**	0.39	0.31	0.35	0.31	0.27
24.03	0.55	0.59	0.55	0.65	**0.80**	0.73	0.59	0.69	0.62	0.56
24.04	1.29	1.41	1.43	1.61	**2.00**	1.84	1.51	1.71	1.53	1.36
24.05	1.62	1.75	1.75	1.97	**2.40**	2.23	1.84	2.17	1.92	1.71
25.01	0.15	0.17	0.18	0.21	**0.25**	0.25	0.24	0.25	0.25	0.24
26.01	0.29	0.35	0.31	0.38	**0.46**	0.40	0.34	0.33	0.30	0.26
26.02	0.56	0.70	0.72	0.82	**0.99**	0.93	0.77	0.80	0.71	0.61
27.01	0.19	0.26	0.28	0.32	**0.37**	0.36	0.29	0.31	0.28	0.24

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
28.01	0.22	0.23	0.22	0.27	**0.33**	0.28	0.26	0.29	0.26	0.24
29.01	0.09	0.10	0.08	0.10	**0.12**	0.11	0.09	0.11	0.09	0.08
30.01	0.47	0.51	0.39	0.53	**0.62**	0.54	0.42	0.49	0.43	0.39
31.01	0.25	0.26	0.21	0.28	**0.34**	0.28	0.23	0.26	0.23	0.21
31.02	0.68	0.70	0.57	0.75	**0.88**	0.76	0.61	0.67	0.65	0.63
31.03	0.83	0.85	0.71	0.92	**1.09**	0.97	0.88	0.93	0.99	1.01
32.01	0.41	0.41	0.34	0.43	**0.51**	0.45	0.33	0.31	0.28	0.24
33.01	0.32	0.32	0.27	0.34	**0.40**	0.34	0.26	0.25	0.21	0.19
34.01	0.17	0.24	0.29	0.31	0.34	0.33	0.28	**0.35**	0.30	0.26
35.01	0.13	0.15	0.15	0.17	**0.22**	0.20	0.16	0.16	0.14	0.12
35.02	0.47	0.51	0.46	0.57	**0.71**	0.62	0.50	0.47	0.39	0.34
35.03	0.77	0.81	0.71	0.86	**1.06**	0.94	0.76	0.73	0.65	0.56
35.04	0.93	0.99	0.93	1.10	**1.30**	1.23	0.98	1.04	0.94	0.83
35.05	0.94	1.01	0.96	1.13	**1.32**	1.26	1.00	1.08	0.97	0.86
35.06	0.49	0.74	0.90	0.99	1.02	**1.05**	0.94	1.02	0.97	0.92
36.01	0.28	0.29	0.23	0.32	**0.38**	0.34	0.25	0.23	0.18	0.16
37.01	0.11	0.11	0.09	0.11	**0.13**	0.12	0.08	0.08	0.07	0.06
38.01	0.11	0.13	0.16	0.18	0.20	0.19	0.16	**0.20**	0.18	0.15
39.01	0.18	0.25	0.33	0.40	0.46	0.49	0.47	0.47	**0.51**	0.49
40.01	0.16	0.16	0.13	0.17	**0.19**	0.17	0.12	0.12	0.11	0.09
40.02	0.32	0.33	0.27	0.34	**0.39**	0.35	0.26	0.28	0.26	0.22
40.03	0.90	0.94	0.76	0.98	**1.12**	1.00	0.73	0.85	0.75	0.67
40.04	1.28	1.36	1.13	1.46	**1.67**	1.53	1.14	1.30	1.17	1.04
40.05	1.75	1.80	1.57	1.93	**2.21**	2.14	1.60	1.87	1.68	1.56
40.06	1.91	1.96	1.75	2.14	**2.40**	2.35	1.81	2.08	1.89	1.76
41.01	0.31	0.34	0.28	0.37	**0.43**	0.38	0.30	0.31	0.28	0.24
42.01	0.39	0.42	0.33	0.46	**0.53**	0.47	0.36	0.40	0.35	0.31
43.01	0.11	0.11	0.09	0.11	**0.13**	0.12	0.09	0.10	0.10	0.09
44.01	0.13	0.14	0.14	0.16	0.19	0.20	0.19	0.19	**0.22**	0.21
44.02	0.30	0.32	0.28	0.34	0.39	0.39	0.37	0.39	**0.40**	0.38
44.03	0.36	0.40	0.44	0.49	0.55	0.60	0.56	0.59	**0.60**	0.57
44.04	0.46	0.51	0.63	0.71	0.81	0.86	0.83	0.84	0.94	**1.03**
45.01	0.13	0.13	0.10	0.13	**0.15**	0.14	0.11	0.13	0.11	0.11
46.01	0.07	0.09	0.13	0.15	0.18	0.20	0.21	0.21	0.22	**0.24**
47.01	0.05	0.07	0.11	0.13	0.14	0.15	0.14	0.15	**0.15**	0.15
48.01	0.16	0.17	0.15	0.18	0.21	0.23	0.25	0.26	0.27	**0.32**
48.02	0.35	0.40	0.43	0.48	0.56	0.59	0.57	0.58	0.64	**0.69**
49.01	0.19	0.22	0.25	0.29	0.34	0.36	0.34	0.35	**0.36**	0.34
50.01	0.21	0.26	0.29	0.35	0.39	0.43	0.41	0.40	**0.46**	0.43
51.01	0.12	0.12	0.10	0.13	**0.15**	0.13	0.12	0.14	0.12	0.12
52.01	0.42	0.44	0.36	0.48	**0.55**	0.49	0.44	0.44	0.51	0.51
52.02	1.05	1.02	0.87	1.02	**1.16**	1.03	0.72	0.72	0.70	0.70
53.01	0.41	0.41	0.35	0.41	**0.46**	0.41	0.26	0.23	0.18	0.15

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
53.02	1.34	1.31	1.14	1.31	**1.46**	1.35	0.85	0.76	0.59	0.52
53.03	1.75	1.71	1.50	1.67	**1.87**	1.74	1.14	1.03	0.81	0.71
54.01	0.58	0.57	0.48	0.60	**0.66**	0.61	0.37	0.33	0.24	0.21
55.01	0.47	0.47	0.40	0.49	**0.55**	0.50	0.31	0.27	0.20	0.18
56.01	0.42	0.41	0.36	0.41	**0.46**	0.42	0.27	0.26	0.24	0.20
57.01	0.56	0.57	0.47	0.61	**0.69**	0.62	0.44	0.46	0.42	0.37
57.02	0.71	0.69	0.63	0.72	**0.83**	0.79	0.54	0.57	0.52	0.47
57.03	0.80	0.77	0.76	0.85	0.95	**0.95**	0.63	0.66	0.60	0.55
58.01	0.24	0.55	0.76	0.85	0.92	**1.00**	0.90	0.97	0.93	0.86
58.02	0.36	0.77	0.99	1.10	1.14	1.22	1.10	**1.25**	1.14	1.05
58.03	0.47	0.99	1.27	1.41	1.46	1.56	1.39	**1.59**	1.44	1.32
58.04	0.93	1.98	2.55	2.88	2.94	3.07	2.69	**3.16**	2.80	2.55
58.05	1.30	2.79	3.66	4.15	4.23	4.44	3.89	**4.53**	4.05	3.69
58.06	1.31	2.81	3.67	4.17	4.26	4.46	3.91	**4.56**	4.08	3.71
58.07	1.92	4.03	5.26	6.00	6.11	**6.40**	5.55	6.39	5.82	5.35
58.08	1.35	1.37	1.38	1.40	**1.46**	1.43	1.40	1.42	1.40	1.38
58.09	1.70	1.89	1.96	2.04	**2.36**	2.20	2.05	2.16	2.07	2.00
58.1	1.94	2.22	2.26	2.36	**2.81**	2.61	2.41	2.57	2.45	2.34
58.11	2.11	2.39	2.53	2.64	**3.07**	2.94	2.71	2.90	2.74	2.64
59.01	0.23	0.48	0.62	0.72	0.73	0.77	0.67	**0.79**	0.69	0.62
59.02	0.38	0.80	1.05	1.20	1.22	1.27	1.10	**1.31**	1.14	1.02
60.01	0.17	0.33	0.41	0.47	0.47	**0.51**	0.38	0.48	0.41	0.35
60.02	0.36	0.75	1.00	1.13	1.14	1.19	1.05	**1.23**	1.09	0.99
61.01	0.15	0.21	0.25	0.28	**0.31**	0.30	0.25	0.28	0.25	0.21
61.02	0.51	0.70	0.82	0.94	**1.03**	1.02	0.84	0.90	0.80	0.69
61.03	0.79	1.17	1.40	1.59	1.63	**1.71**	1.37	1.60	1.39	1.20
61.04	1.13	1.53	1.84	2.08	2.14	**2.24**	1.79	2.17	1.90	1.71
62.01	0.19	0.32	0.38	0.44	0.44	**0.49**	0.37	0.42	0.37	0.32
63.01	0.09	0.19	0.23	0.26	0.27	0.27	0.23	**0.28**	0.24	0.21
64.01	0.05	0.07	0.09	0.11	0.11	**0.12**	0.09	0.10	0.09	0.07
65.01	0.16	0.17	0.18	0.19	**0.25**	0.22	0.18	0.22	0.19	0.17
65.02	0.30	0.33	0.30	0.36	**0.44**	0.41	0.33	0.36	0.32	0.28
66.01	0.02	0.03	0.02	0.03	**0.04**	0.03	0.03	0.02	0.02	0.01
67.01	0.38	0.38	0.32	0.40	**0.47**	0.41	0.30	0.33	0.30	0.27
68.01	0.20	0.20	0.17	0.21	**0.24**	0.22	0.17	0.20	0.18	0.17
69.01	0.21	0.21	0.18	0.22	**0.25**	0.23	0.16	0.17	0.16	0.13
69.02	0.33	0.34	0.28	0.34	**0.39**	0.35	0.25	0.28	0.25	0.22
70.01	0.33	0.33	0.28	0.34	**0.40**	0.34	0.26	0.27	0.26	0.25
71.01	1.73	1.71	1.47	1.70	**1.88**	1.73	1.10	1.05	0.97	0.87
71.02	2.13	2.16	1.81	2.19	**2.45**	2.23	1.52	1.61	1.46	1.35
72.01	0.36	0.41	0.35	0.44	**0.52**	0.48	0.46	0.49	0.49	0.46
73.01	0.16	0.17	0.14	0.18	**0.20**	0.18	0.16	0.18	0.17	0.16
73.02	0.34	0.35	0.29	0.36	**0.42**	0.37	0.36	0.38	0.39	0.37

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
73.03	0.58	0.61	0.54	0.64	0.75	0.72	0.69	0.73	**0.76**	0.74
74.01	0.08	0.09	0.11	0.12	0.13	0.14	0.13	**0.15**	0.14	0.13
75.01	0.07	0.08	0.06	0.08	**0.09**	0.08	0.07	0.08	0.08	0.07
76.01	0.21	0.37	0.54	0.63	0.68	**0.73**	0.68	0.71	0.70	0.65
77.01	0.16	0.33	0.50	0.61	0.69	0.76	0.73	0.70	**0.80**	0.78
78.01	0.13	0.15	0.13	0.17	**0.22**	0.19	0.15	0.13	0.10	0.09
78.02	0.72	2.86	4.15	4.92	5.05	**5.35**	4.50	5.33	4.78	4.31
78.03	1.80	4.04	5.63	6.61	6.73	**7.15**	5.94	7.09	6.36	5.75
78.04	2.18	4.35	6.07	7.09	7.24	**7.71**	6.40	7.60	6.86	6.21
78.05	2.36	4.56	6.35	7.43	7.61	**8.11**	6.73	7.96	7.23	6.56
78.06	3.19	5.58	7.78	9.13	9.46	**10.09**	8.58	9.83	9.16	8.41
78.07	3.95	6.57	9.12	10.89	11.44	**12.27**	10.55	11.77	11.32	10.50
79.01	0.32	0.39	0.39	0.45	**0.55**	0.52	0.42	0.40	0.36	0.31
79.02	0.62	0.75	0.80	0.91	**1.08**	1.05	0.84	0.84	0.75	0.65
79.03	0.83	0.93	1.02	1.17	**1.36**	1.31	1.07	1.10	0.98	0.85
80.01	0.20	0.24	0.25	0.29	**0.35**	0.32	0.27	0.26	0.23	0.20
81.01	0.07	0.09	0.09	0.10	**0.14**	0.14	0.10	0.09	0.07	0.06
82.01	0.32	0.38	0.34	0.43	**0.52**	0.47	0.37	0.34	0.28	0.24
82.02	0.50	0.59	0.56	0.68	**0.81**	0.74	0.61	0.57	0.51	0.45
82.03	0.80	0.93	0.91	1.08	**1.29**	1.17	0.97	0.95	0.86	0.76
83.01	0.28	0.33	0.29	0.36	**0.44**	0.39	0.32	0.31	0.27	0.24
84.01	0.22	0.22	0.20	0.25	**0.31**	0.27	0.22	0.24	0.21	0.19
84.02	0.53	0.56	0.51	0.60	**0.77**	0.68	0.56	0.58	0.52	0.45
85.01	0.14	0.15	0.15	0.17	**0.23**	0.20	0.17	0.16	0.13	0.11
86.01	0.01	0.02	0.01	0.02	**0.02**	0.02	0.02	0.01	0.01	0.01
86.02	0.24	0.25	0.20	0.26	**0.32**	0.27	0.22	0.21	0.19	0.17
87.01	0.05	0.06	0.07	0.08	0.09	**0.09**	0.07	0.08	0.07	0.06
88.01	0.41	0.47	0.39	0.50	**0.58**	0.51	0.41	0.44	0.40	0.34
88.02	0.57	0.66	0.61	0.74	**0.88**	0.79	0.65	0.73	0.65	0.56
88.03	0.73	0.88	1.07	1.21	1.27	1.32	1.21	**1.38**	1.23	1.17
88.04	0.87	1.09	1.43	1.64	1.74	1.87	1.73	**1.90**	1.80	1.72
89.01	0.15	0.27	0.37	0.43	0.45	0.48	0.43	**0.50**	0.43	0.40
89.02	1.02	1.02	1.00	1.15	1.30	**1.41**	1.32	1.37	1.40	1.35
89.03	1.72	1.73	1.51	1.83	**2.14**	2.07	1.95	2.06	2.04	1.95
90.01	0.14	0.25	0.33	0.39	0.43	**0.47**	0.43	0.46	0.45	0.42
91.01	0.49	0.50	0.41	0.53	**0.60**	0.54	0.38	0.41	0.37	0.35
92.01	0.59	0.61	0.50	0.64	**0.72**	0.65	0.47	0.50	0.45	0.40
92.02	0.92	0.92	0.78	0.95	**1.11**	0.97	0.71	0.77	0.70	0.65
_junc_116	0.34	0.53	0.63	0.72	0.75	**0.79**	0.62	0.70	0.62	0.53
_junc_123	2.09	2.12	1.76	2.13	**2.40**	2.16	1.47	1.53	1.39	1.28
_junc_125	13.29	23.03	29.74	35.17	39.47	**42.32**	37.81	38.02	39.51	37.55
_junc_126	0.54	0.62	0.71	0.83	0.94	1.02	0.97	0.97	1.09	**1.12**
_junc_130	2.16	4.10	5.07	5.77	5.87	**6.19**	4.83	5.95	5.19	4.48

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
_junc_133	1.42	1.58	1.36	1.77	**2.12**	1.87	1.51	1.42	1.24	1.07
_junc_135	0.41	0.44	0.37	0.49	**0.60**	0.51	0.42	0.39	0.32	0.28
_junc_136	0.57	0.61	0.53	0.66	**0.81**	0.72	0.58	0.54	0.47	0.40
_junc_138	4.86	4.80	4.12	4.81	**5.31**	4.93	3.13	2.96	2.70	2.39
_junc_142	1.51	1.52	1.29	1.59	**1.87**	1.79	1.68	1.78	1.76	1.70
_junc_150	1.07	3.36	4.81	5.65	5.77	**6.13**	5.15	6.11	5.48	4.96
_junc_151	1.38	1.49	1.51	1.69	**2.10**	1.93	1.59	1.82	1.61	1.44
_junc_158	0.35	0.38	0.40	0.45	0.54	0.56	0.54	0.55	0.60	**0.66**
_junc_162	0.14	0.26	0.32	0.36	0.36	**0.39**	0.30	0.38	0.33	0.28
_junc_19	0.86	0.96	0.74	1.03	**1.21**	1.05	0.82	0.76	0.64	0.56
_junc_21	6.50	13.16	16.58	19.05	19.35	**20.38**	16.30	19.25	16.97	15.09
_junc_28	3.23	3.61	4.12	4.67	**5.31**	5.22	4.23	4.98	4.38	3.90
_junc_29	1.11	1.27	1.27	1.44	**1.79**	1.65	1.36	1.49	1.32	1.17
_junc_30	0.22	0.23	0.22	0.27	**0.33**	0.28	0.26	0.29	0.26	0.24
_junc_32	0.45	0.49	0.46	0.54	**0.69**	0.61	0.52	0.60	0.53	0.49
_junc_37	1.37	2.09	2.49	2.75	3.00	3.15	3.19	3.16	3.27	**3.44**
_junc_38	8.02	14.99	19.47	22.93	24.02	**25.53**	21.22	23.38	21.78	19.76
_junc_40	1.22	1.28	1.02	1.35	**1.55**	1.38	1.03	1.15	1.03	0.91
_junc_41	0.84	1.79	2.31	2.61	2.67	2.80	2.48	**2.89**	2.56	2.34
_junc_42	1.62	1.69	1.39	1.77	**2.06**	1.92	1.47	1.70	1.50	1.33
_junc_44	1.47	2.33	2.82	3.14	3.48	3.67	3.72	3.70	3.85	**4.02**
_junc_47	2.35	2.43	2.23	2.76	**3.12**	3.02	2.64	2.91	2.73	2.77
_junc_50	0.17	0.20	0.19	0.22	**0.28**	0.25	0.21	0.24	0.21	0.18
_junc_59	10.56	19.63	25.58	30.32	32.62	**34.55**	30.15	31.78	31.48	29.85
_junc_64	1.52	1.60	1.66	1.72	**1.94**	1.80	1.70	1.74	1.70	1.65
_junc_68	0.39	0.48	0.48	0.55	**0.69**	0.66	0.52	0.49	0.43	0.37
_junc_69	10.82	19.77	25.76	30.56	33.33	**35.44**	31.06	32.32	32.41	30.72
_junc_71	1.87	2.15	2.17	2.26	**2.71**	2.51	2.28	2.44	2.32	2.22
_junc_74	2.07	2.35	2.46	2.58	**3.00**	2.87	2.66	2.83	2.67	2.59
_junc_76	11.04	20.10	26.22	31.10	34.26	**36.52**	32.14	33.12	33.46	31.70
_junc_80	13.01	22.55	29.10	34.38	38.45	**41.18**	36.66	37.01	38.26	36.32
_junc_81	0.41	0.43	0.38	0.46	**0.54**	0.51	0.49	0.53	0.52	0.50
_junc_84	13.57	23.60	30.51	36.18	40.75	**43.71**	39.21	39.34	41.02	39.02
_junc_85	16.04	27.35	36.21	43.96	49.95	**53.80**	49.12	48.53	51.53	48.99
_junc_86	16.17	27.60	36.45	44.32	50.42	**54.29**	49.67	49.01	52.08	49.51
_junc_88	3.16	5.54	7.73	9.03	9.33	**9.96**	8.45	9.71	9.01	8.26
_junc_91	3.92	6.51	9.06	10.80	11.34	**12.15**	10.43	11.66	11.18	10.36
US_OHH	11.31	20.55	26.81	31.81	35.35	**37.82**	33.37	34.07	34.76	32.91
US_Rail	10.38	19.32	25.16	29.80	31.83	**33.68**	29.25	31.06	30.50	28.92

PEAK DESIGN FLOOD DISCHARGES - 10% AEP

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
1.01	0.40	0.79	0.99	1.12	1.13	**1.18**	0.95	1.15	0.99	0.85
1.02	1.07	1.70	1.87	2.19	2.31	**2.48**	1.98	2.00	1.80	1.54
1.03	2.20	3.56	3.93	4.61	4.77	**5.20**	4.11	4.15	3.69	3.18
1.04	4.21	7.24	8.09	9.43	9.57	**10.42**	8.31	8.46	7.42	6.43
1.05	4.53	7.98	9.04	10.52	10.67	**11.53**	9.19	9.73	8.56	7.44
1.06	4.59	8.12	9.28	10.78	10.94	**11.80**	9.42	9.99	8.83	7.69
1.07	5.60	10.27	12.40	14.28	14.53	**15.49**	12.43	13.73	12.16	10.71
1.08	8.80	16.80	20.77	23.67	24.13	**25.52**	20.47	23.34	20.26	17.92
1.09	9.03	17.19	21.57	24.57	25.11	**26.65**	21.51	24.24	21.32	18.93
1.1	9.12	17.37	21.83	24.97	25.60	**27.19**	22.02	24.71	21.91	19.61
1.11	10.04	19.15	24.36	28.41	29.81	**31.74**	26.24	28.34	26.04	23.50
1.12	10.16	19.37	24.66	28.79	30.24	**32.20**	26.67	28.76	26.51	23.95
1.13	10.20	19.49	24.82	28.98	30.46	**32.43**	26.89	28.99	26.77	24.21
1.14	12.68	23.68	30.07	35.32	37.53	**39.97**	33.99	35.98	34.51	32.39
1.15	13.04	24.36	31.00	36.47	38.98	**41.52**	35.54	37.33	36.19	34.00
1.16	13.20	24.65	31.40	36.99	39.67	**42.27**	36.33	38.00	37.09	34.83
1.17	13.24	24.71	31.48	37.15	40.05	**42.68**	36.88	38.29	37.68	35.42
1.18	13.30	24.77	31.56	37.30	40.34	**43.04**	37.26	38.52	38.05	35.72
1.19	13.40	24.98	31.83	37.65	41.01	**43.90**	38.09	39.06	38.83	36.38
1.2	13.52	25.21	32.14	38.09	41.55	**44.50**	38.76	39.58	39.49	36.99
1.21	15.46	27.69	34.94	41.30	45.53	**48.89**	43.14	43.36	44.04	41.41
1.22	15.77	28.29	35.78	42.35	46.89	**50.42**	44.64	44.70	45.63	42.96
1.23	16.14	28.96	36.65	43.47	48.29	**51.96**	46.22	46.10	47.24	44.50
1.24	16.33	29.33	37.17	44.11	49.07	**52.83**	47.09	46.89	48.15	45.36
1.25	20.01	34.49	44.70	53.92	60.63	**64.90**	59.38	58.60	60.69	57.22
1.26	20.40	35.15	45.69	55.11	62.19	**66.55**	61.16	60.25	62.55	59.00
2.01	0.19	0.28	0.29	0.35	0.39	**0.41**	0.31	0.27	0.22	0.19
2.02	0.75	1.12	1.19	1.40	1.54	**1.63**	1.28	1.11	0.92	0.80
3.01	0.42	0.61	0.68	0.77	0.88	**0.88**	0.72	0.66	0.58	0.50
3.02	1.55	2.78	3.11	3.60	3.63	**3.95**	3.16	3.18	2.79	2.41
3.03	1.94	3.54	4.00	4.63	4.68	**5.06**	4.03	4.12	3.59	3.11
4.01	0.65	1.11	1.24	1.44	1.46	**1.59**	1.28	1.25	1.09	0.94
5.01	0.41	0.79	0.95	1.08	1.10	**1.17**	0.91	1.05	0.91	0.78
5.02	0.72	1.50	1.86	2.09	2.14	**2.21**	1.77	2.17	1.86	1.62
5.03	1.93	2.15	2.71	3.03	3.10	3.20	2.78	**3.35**	2.89	2.57
6.01	0.68	1.38	1.67	1.87	1.91	**2.03**	1.59	1.90	1.62	1.39
6.02	0.94	1.89	2.25	2.54	2.59	**2.78**	2.15	2.51	2.17	1.85
6.03	1.40	2.85	3.38	3.82	3.89	**4.17**	3.25	3.76	3.25	2.79
6.04	2.57	4.78	5.70	6.40	6.53	**7.00**	5.52	6.34	5.52	4.76
6.05	2.97	5.55	6.67	7.51	7.64	**8.17**	6.44	7.41	6.44	5.56
6.06	3.10	5.84	7.08	7.96	8.11	**8.62**	6.81	7.92	6.92	6.00
6.07	3.74	6.69	8.17	9.19	9.35	**9.86**	7.82	9.33	8.05	7.02

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
7.01	0.29	0.64	0.76	0.85	0.87	**0.91**	0.73	0.86	0.74	0.63
8.01	0.34	0.42	0.43	0.49	**0.61**	0.59	0.46	0.42	0.36	0.32
8.02	1.28	1.55	1.76	2.00	**2.32**	2.27	1.85	1.87	1.67	1.44
8.03	1.47	1.97	2.30	2.64	2.88	**2.90**	2.38	2.55	2.25	1.94
9.01	0.61	0.68	0.64	0.76	**0.94**	0.85	0.69	0.64	0.57	0.49
10.01	0.24	0.48	0.60	0.67	0.68	**0.70**	0.57	0.68	0.59	0.51
11.01	0.52	0.58	0.48	0.62	**0.72**	0.63	0.53	0.64	0.55	0.48
11.02	1.24	1.38	1.13	1.50	**1.75**	1.54	1.24	1.35	1.20	1.04
12.01	0.40	0.42	0.33	0.46	**0.53**	0.47	0.35	0.38	0.34	0.30
13.01	0.32	0.38	0.30	0.41	**0.47**	0.41	0.33	0.31	0.26	0.22
14.01	1.52	1.52	1.27	1.53	**1.72**	1.56	1.05	1.00	0.91	0.79
15.01	2.44	2.43	2.06	2.47	**2.80**	2.51	1.75	1.65	1.46	1.28
15.02	3.21	3.23	2.73	3.29	**3.70**	3.40	2.33	2.29	2.08	1.82
15.03	5.79	5.87	4.94	5.96	**6.67**	6.16	4.21	4.13	3.78	3.33
15.04	5.87	5.99	5.03	6.13	**6.88**	6.36	4.40	4.41	4.03	3.55
16.01	2.33	2.27	1.98	2.23	**2.44**	2.30	1.40	1.30	1.09	0.95
17.01	0.12	0.20	0.27	0.31	0.34	**0.37**	0.35	0.36	0.35	0.33
18.01	0.07	0.16	0.20	0.23	0.23	0.24	0.21	**0.24**	0.21	0.19
19.01	0.72	0.78	0.60	0.83	**0.99**	0.85	0.68	0.62	0.53	0.46
19.02	1.22	1.41	1.17	1.53	**1.79**	1.60	1.29	1.19	1.02	0.89
19.03	1.87	2.29	2.23	2.58	**3.13**	2.96	2.40	2.27	2.03	1.76
19.04	2.04	2.52	2.64	3.03	**3.55**	3.47	2.78	2.92	2.62	2.31
19.05	2.23	2.74	2.97	3.40	**3.88**	3.86	3.08	3.31	2.95	2.60
19.06	3.83	4.53	5.24	5.97	6.57	**6.69**	5.35	6.11	5.40	4.77
19.07	4.75	5.73	6.74	7.52	8.08	**8.25**	6.71	8.00	7.06	6.50
19.08	4.98	5.97	7.00	7.81	8.37	**8.55**	6.97	8.27	7.31	6.73
19.09	1.05	1.47	1.71	1.86	2.02	2.13	2.23	2.26	2.30	**2.44**
19.1	1.48	2.16	2.51	2.73	2.99	3.15	3.20	3.19	3.29	**3.44**
19.11	1.65	2.45	2.82	3.11	3.42	3.59	3.64	3.59	3.74	**3.89**
19.12	1.72	2.60	3.02	3.36	3.73	3.93	3.99	3.92	4.09	**4.25**
20.01	0.29	0.36	0.29	0.39	**0.46**	0.40	0.31	0.27	0.21	0.19
21.01	0.32	0.37	0.32	0.41	**0.49**	0.44	0.35	0.32	0.27	0.23
22.01	0.18	0.31	0.39	0.43	0.45	**0.48**	0.37	0.43	0.37	0.31
23.01	0.11	0.14	0.16	0.18	**0.21**	0.21	0.17	0.16	0.14	0.12
24.01	0.27	0.31	0.27	0.34	**0.41**	0.36	0.30	0.34	0.30	0.26
24.02	0.34	0.38	0.35	0.43	**0.51**	0.46	0.38	0.42	0.37	0.32
24.03	0.64	0.69	0.67	0.81	**0.95**	0.89	0.72	0.82	0.73	0.65
24.04	1.50	1.72	1.75	1.98	**2.38**	2.26	1.84	2.02	1.79	1.59
24.05	1.88	2.09	2.14	2.43	**2.92**	2.75	2.26	2.58	2.28	2.00
25.01	0.18	0.20	0.23	0.26	0.30	**0.31**	0.29	0.30	0.29	0.27
26.01	0.34	0.41	0.38	0.45	**0.54**	0.51	0.41	0.39	0.35	0.30
26.02	0.67	0.84	0.89	1.01	**1.18**	1.16	0.94	0.93	0.82	0.71
27.01	0.24	0.31	0.34	0.40	0.45	**0.45**	0.36	0.36	0.32	0.28

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
28.01	0.25	0.28	0.27	0.33	**0.39**	0.34	0.30	0.35	0.31	0.27
29.01	0.11	0.11	0.10	0.12	**0.15**	0.14	0.11	0.13	0.11	0.09
30.01	0.54	0.60	0.46	0.62	**0.72**	0.65	0.51	0.59	0.52	0.45
31.01	0.29	0.31	0.25	0.35	**0.40**	0.36	0.28	0.31	0.28	0.24
31.02	0.79	0.84	0.66	0.88	**1.04**	0.90	0.75	0.83	0.77	0.74
31.03	0.95	0.99	0.85	1.10	**1.29**	1.15	1.09	1.15	1.21	1.20
32.01	0.47	0.48	0.39	0.52	**0.59**	0.53	0.39	0.37	0.33	0.28
33.01	0.36	0.38	0.31	0.42	**0.47**	0.42	0.31	0.29	0.24	0.21
34.01	0.21	0.29	0.35	0.39	0.42	**0.43**	0.34	0.41	0.35	0.30
35.01	0.16	0.18	0.18	0.21	**0.27**	0.23	0.20	0.19	0.16	0.14
35.02	0.54	0.61	0.54	0.71	**0.86**	0.75	0.60	0.55	0.45	0.40
35.03	0.88	0.95	0.84	1.06	**1.28**	1.14	0.93	0.86	0.75	0.66
35.04	1.08	1.18	1.12	1.33	**1.59**	1.49	1.19	1.23	1.10	0.97
35.05	1.10	1.20	1.15	1.37	**1.62**	1.53	1.22	1.28	1.14	1.00
35.06	0.59	0.90	1.06	1.14	1.18	**1.20**	1.09	1.16	1.11	1.05
36.01	0.32	0.36	0.27	0.39	**0.45**	0.40	0.30	0.26	0.21	0.18
37.01	0.13	0.13	0.11	0.13	**0.15**	0.14	0.09	0.09	0.08	0.07
38.01	0.13	0.16	0.20	0.21	**0.24**	0.24	0.19	0.24	0.21	0.18
39.01	0.22	0.32	0.43	0.52	0.57	**0.62**	0.58	0.61	0.60	0.57
40.01	0.18	0.19	0.16	0.20	**0.23**	0.20	0.15	0.14	0.13	0.11
40.02	0.37	0.38	0.31	0.40	**0.47**	0.41	0.32	0.33	0.30	0.26
40.03	1.04	1.10	0.87	1.14	**1.32**	1.18	0.88	1.03	0.91	0.80
40.04	1.49	1.60	1.30	1.73	**1.99**	1.83	1.39	1.57	1.40	1.23
40.05	2.02	2.13	1.82	2.29	**2.64**	2.56	1.95	2.25	2.02	1.83
40.06	2.20	2.30	2.03	2.53	**2.88**	2.82	2.16	2.52	2.27	2.07
41.01	0.36	0.42	0.33	0.45	**0.52**	0.45	0.37	0.35	0.32	0.28
42.01	0.46	0.51	0.39	0.54	**0.63**	0.55	0.44	0.47	0.42	0.36
43.01	0.13	0.13	0.11	0.13	**0.16**	0.14	0.12	0.13	0.12	0.11
44.01	0.15	0.16	0.18	0.20	0.24	0.25	0.24	0.24	**0.26**	0.25
44.02	0.35	0.37	0.36	0.40	0.49	0.47	0.45	**0.49**	0.47	0.45
44.03	0.42	0.48	0.55	0.62	0.67	0.73	0.69	**0.74**	0.70	0.67
44.04	0.55	0.63	0.78	0.89	0.99	1.06	1.02	1.05	1.15	**1.22**
45.01	0.15	0.15	0.12	0.16	**0.18**	0.16	0.14	0.16	0.14	0.12
46.01	0.08	0.12	0.16	0.19	0.22	0.24	0.25	0.25	0.27	**0.29**
47.01	0.06	0.11	0.14	0.16	0.17	**0.19**	0.17	0.18	0.18	0.17
48.01	0.19	0.20	0.18	0.22	0.27	0.28	0.32	0.32	0.33	**0.39**
48.02	0.41	0.49	0.53	0.60	0.68	0.73	0.70	0.73	0.76	**0.82**
49.01	0.22	0.28	0.33	0.37	0.41	**0.45**	0.42	0.44	0.42	0.40
50.01	0.26	0.32	0.36	0.43	0.50	**0.54**	0.51	0.53	0.54	0.51
51.01	0.14	0.15	0.12	0.15	**0.18**	0.16	0.15	0.16	0.15	0.14
52.01	0.49	0.54	0.41	0.56	**0.64**	0.58	0.55	0.56	0.62	0.60
52.02	1.19	1.17	1.00	1.19	**1.37**	1.21	0.87	0.87	0.84	0.83
53.01	0.47	0.47	0.40	0.48	**0.54**	0.49	0.31	0.27	0.20	0.18

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
53.02	1.52	1.51	1.29	1.52	**1.68**	1.56	0.99	0.88	0.68	0.60
53.03	1.99	1.96	1.71	1.95	**2.16**	2.04	1.34	1.19	0.93	0.81
54.01	0.66	0.68	0.56	0.70	**0.76**	0.71	0.43	0.38	0.28	0.24
55.01	0.54	0.56	0.45	0.58	**0.63**	0.58	0.36	0.31	0.23	0.20
56.01	0.48	0.47	0.41	0.48	**0.55**	0.49	0.34	0.32	0.27	0.24
57.01	0.65	0.68	0.54	0.70	**0.80**	0.72	0.52	0.55	0.50	0.44
57.02	0.80	0.79	0.72	0.85	**0.96**	0.92	0.64	0.69	0.62	0.55
57.03	0.91	0.90	0.88	1.01	1.10	**1.13**	0.75	0.79	0.72	0.64
58.01	0.29	0.70	0.95	1.07	1.14	**1.20**	1.09	1.19	1.10	1.01
58.02	0.46	0.97	1.23	1.37	1.41	1.46	1.32	**1.51**	1.35	1.23
58.03	0.60	1.25	1.58	1.76	1.81	1.86	1.66	**1.92**	1.71	1.55
58.04	1.21	2.52	3.18	3.56	3.64	3.74	3.20	**3.81**	3.33	2.98
58.05	1.71	3.60	4.55	5.11	5.24	5.40	4.64	**5.47**	4.81	4.32
58.06	1.72	3.61	4.57	5.14	5.27	5.43	4.66	**5.50**	4.84	4.34
58.07	2.59	5.18	6.52	7.33	7.50	**7.82**	6.61	7.74	6.94	6.26
58.08	1.36	1.41	1.42	1.46	**1.51**	1.48	1.44	1.44	1.43	1.41
58.09	1.88	2.20	2.12	2.38	**2.61**	2.42	2.20	2.34	2.23	2.13
58.1	2.25	2.58	2.50	2.80	**3.19**	2.96	2.62	2.83	2.69	2.54
58.11	2.45	2.77	2.83	3.14	**3.64**	3.44	2.98	3.23	3.04	2.87
59.01	0.30	0.62	0.79	0.88	0.90	0.93	0.80	**0.96**	0.82	0.73
59.02	0.50	1.04	1.32	1.48	1.51	1.55	1.30	**1.57**	1.36	1.19
60.01	0.23	0.43	0.52	0.58	0.59	**0.63**	0.49	0.56	0.49	0.41
60.02	0.47	0.98	1.23	1.39	1.42	1.46	1.24	**1.49**	1.29	1.16
61.01	0.18	0.27	0.31	0.35	0.37	**0.39**	0.32	0.32	0.29	0.25
61.02	0.64	0.88	1.01	1.17	1.27	**1.30**	1.05	1.05	0.93	0.80
61.03	0.97	1.47	1.71	1.97	2.02	**2.12**	1.73	1.86	1.63	1.41
61.04	1.35	1.92	2.26	2.57	2.63	**2.78**	2.26	2.55	2.25	2.00
62.01	0.26	0.40	0.47	0.55	0.56	**0.60**	0.48	0.49	0.43	0.37
63.01	0.14	0.23	0.29	0.32	0.32	**0.33**	0.27	0.33	0.28	0.24
64.01	0.06	0.10	0.12	0.13	**0.15**	0.15	0.13	0.12	0.10	0.09
65.01	0.18	0.20	0.21	0.25	**0.30**	0.27	0.23	0.26	0.23	0.20
65.02	0.35	0.39	0.38	0.43	**0.56**	0.51	0.42	0.42	0.38	0.33
66.01	0.02	0.03	0.03	0.04	**0.04**	0.04	0.03	0.03	0.02	0.02
67.01	0.44	0.45	0.37	0.48	**0.55**	0.49	0.36	0.39	0.35	0.32
68.01	0.23	0.23	0.19	0.25	**0.31**	0.26	0.21	0.24	0.22	0.19
69.01	0.24	0.25	0.20	0.26	**0.31**	0.27	0.21	0.20	0.19	0.16
69.02	0.38	0.39	0.32	0.40	**0.47**	0.41	0.31	0.34	0.30	0.27
70.01	0.38	0.39	0.32	0.40	**0.47**	0.41	0.31	0.33	0.31	0.29
71.01	1.98	1.97	1.67	1.96	**2.17**	2.01	1.30	1.24	1.16	1.03
71.02	2.44	2.50	2.08	2.55	**2.86**	2.62	1.82	1.96	1.78	1.60
72.01	0.42	0.49	0.44	0.52	0.62	0.61	0.58	**0.63**	0.57	0.54
73.01	0.19	0.19	0.16	0.21	**0.25**	0.21	0.19	0.21	0.20	0.19
73.02	0.39	0.40	0.34	0.43	**0.52**	0.45	0.43	0.46	0.46	0.43

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
73.03	0.68	0.72	0.66	0.76	**0.92**	0.88	0.84	0.89	0.90	0.87
74.01	0.09	0.10	0.14	0.15	0.16	0.18	0.16	**0.18**	0.16	0.15
75.01	0.09	0.09	0.07	0.10	**0.11**	0.10	0.09	0.10	0.09	0.09
76.01	0.26	0.51	0.69	0.78	0.84	**0.90**	0.82	0.89	0.83	0.76
77.01	0.21	0.44	0.64	0.75	0.84	0.92	0.88	0.87	**0.98**	0.93
78.01	0.16	0.18	0.15	0.22	**0.26**	0.22	0.18	0.15	0.12	0.10
78.02	1.40	4.05	5.46	6.29	6.46	**6.80**	5.60	6.73	5.93	5.26
78.03	2.24	5.50	7.25	8.32	8.54	**8.96**	7.32	8.84	7.80	6.94
78.04	2.62	5.86	7.78	8.89	9.17	**9.63**	7.87	9.43	8.39	7.49
78.05	2.81	6.12	8.15	9.30	9.62	**10.11**	8.28	9.86	8.81	7.89
78.06	3.71	7.40	9.96	11.41	11.83	**12.49**	10.49	12.12	11.11	10.05
78.07	4.68	8.64	11.65	13.60	14.30	**15.14**	12.95	14.54	13.66	12.48
79.01	0.39	0.47	0.48	0.55	**0.67**	0.65	0.52	0.47	0.42	0.36
79.02	0.74	0.91	0.98	1.11	**1.34**	1.30	1.05	0.98	0.87	0.75
79.03	0.96	1.18	1.25	1.42	**1.66**	1.62	1.32	1.28	1.14	0.99
80.01	0.24	0.30	0.30	0.34	**0.41**	0.39	0.32	0.30	0.27	0.24
81.01	0.09	0.11	0.11	0.14	**0.18**	0.16	0.13	0.11	0.08	0.07
82.01	0.38	0.46	0.41	0.52	**0.62**	0.57	0.45	0.40	0.32	0.28
82.02	0.59	0.73	0.68	0.81	**0.98**	0.90	0.73	0.68	0.59	0.52
82.03	0.95	1.16	1.10	1.29	**1.55**	1.44	1.17	1.12	1.00	0.89
83.01	0.33	0.40	0.36	0.44	**0.52**	0.49	0.39	0.37	0.32	0.28
84.01	0.25	0.27	0.24	0.31	**0.37**	0.32	0.27	0.28	0.25	0.22
84.02	0.61	0.66	0.62	0.75	**0.92**	0.81	0.68	0.67	0.61	0.53
85.01	0.16	0.19	0.18	0.22	**0.27**	0.24	0.20	0.18	0.15	0.13
86.01	0.02	0.02	0.02	0.02	**0.03**	0.02	0.02	0.02	0.01	0.01
86.02	0.28	0.29	0.23	0.31	**0.38**	0.32	0.26	0.25	0.23	0.20
87.01	0.06	0.07	0.09	0.11	0.12	**0.13**	0.09	0.09	0.08	0.07
88.01	0.48	0.55	0.48	0.59	**0.71**	0.63	0.51	0.52	0.46	0.40
88.02	0.67	0.80	0.75	0.88	**1.07**	0.97	0.80	0.86	0.76	0.66
88.03	0.87	1.08	1.34	1.48	1.57	1.57	1.44	**1.67**	1.46	1.36
88.04	1.05	1.37	1.83	2.03	2.11	2.24	2.07	**2.30**	2.13	2.00
89.01	0.19	0.35	0.48	0.55	0.55	0.58	0.51	**0.60**	0.52	0.46
89.02	1.17	1.20	1.27	1.47	1.59	1.73	1.62	**1.74**	1.65	1.58
89.03	1.97	2.03	1.87	2.15	2.53	2.53	2.37	**2.57**	2.39	2.28
90.01	0.18	0.31	0.42	0.50	0.53	0.58	0.53	**0.58**	0.53	0.49
91.01	0.57	0.59	0.47	0.61	**0.69**	0.62	0.45	0.49	0.44	0.40
92.01	0.68	0.72	0.57	0.74	**0.85**	0.76	0.55	0.60	0.54	0.47
92.02	1.06	1.06	0.89	1.12	**1.29**	1.15	0.84	0.93	0.84	0.75
_junc_116	0.44	0.67	0.78	0.90	0.93	**0.99**	0.80	0.81	0.72	0.62
_junc_123	2.40	2.45	2.02	2.48	**2.79**	2.53	1.75	1.87	1.69	1.52
_junc_125	15.96	28.61	36.16	42.84	47.51	**51.11**	45.37	45.31	46.34	43.63
_junc_126	0.64	0.76	0.89	1.03	1.17	1.27	1.20	1.25	1.30	**1.33**
_junc_130	2.80	5.23	6.30	7.07	7.21	**7.71**	6.08	7.01	6.09	5.26

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
_junc_133	1.65	1.92	1.64	2.10	**2.49**	2.25	1.81	1.67	1.43	1.24
_junc_135	0.48	0.53	0.44	0.60	**0.72**	0.62	0.50	0.45	0.37	0.33
_junc_136	0.67	0.72	0.62	0.81	**0.99**	0.86	0.70	0.63	0.54	0.47
_junc_138	5.54	5.51	4.69	5.51	**6.13**	5.68	3.74	3.53	3.17	2.77
_junc_142	1.72	1.79	1.61	1.86	2.19	2.19	2.05	**2.23**	2.07	1.98
_junc_150	1.78	4.67	6.24	7.19	7.38	**7.77**	6.39	7.68	6.78	6.02
_junc_151	1.60	1.80	1.85	2.09	**2.50**	2.38	1.94	2.14	1.90	1.68
_junc_158	0.41	0.48	0.51	0.57	0.65	0.69	0.66	0.69	0.72	**0.79**
_junc_162	0.19	0.33	0.39	0.44	0.44	**0.48**	0.39	0.44	0.39	0.33
_junc_19	1.01	1.14	0.88	1.22	**1.44**	1.25	0.99	0.89	0.74	0.64
_junc_21	8.72	16.63	20.52	23.39	23.83	**25.21**	20.21	23.03	19.96	17.64
_junc_28	3.78	4.43	5.07	5.78	6.40	**6.50**	5.19	5.87	5.19	4.57
_junc_29	1.30	1.52	1.56	1.79	**2.14**	2.04	1.66	1.74	1.55	1.37
_junc_30	0.25	0.28	0.27	0.33	**0.39**	0.34	0.30	0.35	0.31	0.27
_junc_32	0.52	0.58	0.56	0.68	**0.81**	0.73	0.61	0.72	0.64	0.57
_junc_37	1.62	2.41	2.78	3.06	3.36	3.53	3.58	3.53	3.67	**3.82**
_junc_38	9.93	18.94	24.07	28.04	29.39	**31.28**	25.83	27.92	25.59	23.08
_junc_40	1.41	1.51	1.18	1.59	**1.83**	1.63	1.25	1.38	1.23	1.07
_junc_41	1.08	2.29	2.90	3.24	3.32	3.40	2.94	**3.49**	3.05	2.73
_junc_42	1.88	1.99	1.62	2.09	**2.44**	2.29	1.79	2.04	1.80	1.57
_junc_44	1.76	2.71	3.17	3.54	3.95	4.17	4.24	4.17	4.36	**4.53**
_junc_47	2.72	2.91	2.76	3.31	**3.76**	3.66	3.17	3.56	3.23	3.25
_junc_50	0.21	0.24	0.23	0.29	**0.34**	0.31	0.26	0.28	0.25	0.21
_junc_59	13.18	24.62	31.36	36.94	39.61	**42.20**	36.26	37.94	37.02	34.77
_junc_64	1.57	1.86	1.74	1.94	**2.06**	1.92	1.80	1.84	1.78	1.72
_junc_68	0.48	0.58	0.59	0.67	**0.85**	0.81	0.64	0.58	0.50	0.43
_junc_69	13.30	24.77	31.57	37.31	40.43	**43.16**	37.38	38.58	38.17	35.81
_junc_71	2.16	2.50	2.39	2.68	**3.08**	2.79	2.51	2.68	2.53	2.39
_junc_74	2.40	2.72	2.74	3.06	**3.55**	3.33	2.92	3.15	2.96	2.80
_junc_76	13.51	25.19	32.11	38.05	41.50	**44.44**	38.70	39.54	39.44	36.93
_junc_80	15.62	28.00	35.38	41.86	46.25	**49.72**	43.94	44.06	44.87	42.19
_junc_81	0.48	0.51	0.48	0.55	**0.68**	0.62	0.59	0.64	0.61	0.58
_junc_84	16.33	29.33	37.17	44.11	49.07	**52.82**	47.09	46.89	48.14	45.35
_junc_85	19.99	34.47	44.67	53.88	60.59	**64.86**	59.34	58.56	60.64	57.17
_junc_86	20.18	34.71	45.02	54.30	61.14	**65.43**	59.99	59.12	61.28	57.78
_junc_88	3.67	7.35	9.88	11.28	11.67	**12.32**	10.34	11.98	10.93	9.88
_junc_91	4.64	8.58	11.58	13.50	14.15	**15.02**	12.81	14.41	13.50	12.32
US_OHH	13.83	25.77	32.81	38.93	42.77	**45.97**	40.19	40.69	40.99	38.43
US_Rail	12.96	24.24	30.84	36.25	38.65	**41.16**	35.16	37.05	35.81	33.68

PEAK DESIGN FLOOD DISCHARGES - 5% AEP

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
1.01	0.58	1.06	1.25	1.41	1.44	**1.51**	1.21	1.39	1.19	1.02
1.02	1.51	2.15	2.36	2.72	2.98	**3.12**	2.51	2.40	2.14	1.86
1.03	3.07	4.54	4.97	5.73	6.16	**6.53**	5.22	4.98	4.39	3.82
1.04	5.89	9.25	10.23	11.77	12.33	**13.26**	10.58	10.12	8.82	7.69
1.05	6.37	10.24	11.45	13.14	13.62	**14.70**	11.74	11.72	10.21	8.91
1.06	6.47	10.43	11.76	13.48	13.96	**15.04**	12.03	12.03	10.53	9.20
1.07	7.93	13.28	15.76	17.89	18.45	**19.64**	15.87	16.70	14.54	12.82
1.08	12.45	21.72	26.33	29.61	30.62	**32.35**	26.07	28.36	24.36	21.43
1.09	12.75	22.25	27.31	30.74	31.95	**33.69**	27.26	29.43	25.62	22.62
1.1	12.88	22.51	27.66	31.28	32.58	**34.41**	27.91	30.06	26.38	23.43
1.11	14.17	24.97	30.96	35.80	37.51	**39.95**	33.06	34.52	31.32	28.05
1.12	14.32	25.25	31.34	36.29	38.07	**40.54**	33.62	35.07	31.90	28.60
1.13	14.39	25.40	31.54	36.54	38.34	**40.83**	33.90	35.36	32.22	28.91
1.14	17.57	30.54	38.01	44.43	46.99	**49.94**	42.48	43.91	41.40	38.56
1.15	18.05	31.44	39.20	45.96	48.83	**51.87**	44.41	45.68	43.47	40.54
1.16	18.27	31.81	39.73	46.66	49.71	**52.79**	45.41	46.54	44.56	41.57
1.17	18.32	31.89	39.84	46.88	50.16	**53.26**	46.11	46.91	45.33	42.25
1.18	18.37	31.96	39.99	47.06	50.52	**53.65**	46.56	47.21	45.81	42.62
1.19	18.53	32.22	40.33	47.46	51.31	**54.65**	47.54	47.86	46.76	43.48
1.2	18.71	32.52	40.72	47.96	51.98	**55.34**	48.35	48.46	47.53	44.22
1.21	20.84	35.26	43.99	51.57	56.63	**60.33**	53.37	52.84	52.75	49.19
1.22	21.26	36.05	45.09	52.94	58.38	**62.23**	55.24	54.56	54.71	51.07
1.23	21.75	36.87	46.27	54.33	60.14	**64.09**	57.17	56.30	56.67	52.93
1.24	22.01	37.33	46.94	55.11	61.13	**65.15**	58.26	57.28	57.77	53.96
1.25	25.84	44.30	56.93	67.94	75.40	**79.97**	73.28	72.09	73.10	68.26
1.26	26.38	45.20	58.15	69.42	77.32	**81.99**	75.44	74.07	75.36	70.40
2.01	0.26	0.35	0.36	0.43	0.50	**0.51**	0.38	0.32	0.26	0.23
2.02	1.01	1.41	1.46	1.75	1.94	**2.01**	1.56	1.32	1.08	0.95
3.01	0.53	0.76	0.85	0.96	1.12	**1.12**	0.90	0.79	0.69	0.60
3.02	2.13	3.54	3.93	4.51	4.61	**5.03**	4.02	3.79	3.30	2.87
3.03	2.71	4.53	5.06	5.80	5.91	**6.46**	5.15	4.92	4.25	3.71
4.01	0.89	1.43	1.57	1.80	1.85	**2.02**	1.62	1.49	1.29	1.13
5.01	0.59	1.04	1.20	1.36	1.39	**1.49**	1.18	1.25	1.09	0.94
5.02	1.06	1.98	2.36	2.64	2.69	**2.81**	2.27	2.62	2.26	1.94
5.03	2.30	2.79	3.46	3.80	3.90	3.96	3.39	**4.09**	3.53	3.07
6.01	0.97	1.80	2.12	2.37	2.42	**2.56**	2.05	2.27	1.97	1.68
6.02	1.34	2.45	2.86	3.21	3.28	**3.50**	2.79	3.00	2.62	2.24
6.03	2.01	3.68	4.28	4.85	4.93	**5.27**	4.20	4.50	3.90	3.36
6.04	3.57	6.20	7.19	8.19	8.25	**8.88**	7.21	7.59	6.63	5.71
6.05	4.12	7.25	8.40	9.59	9.65	**10.37**	8.41	8.89	7.73	6.68
6.06	4.29	7.62	8.95	10.17	10.25	**10.97**	8.88	9.58	8.32	7.21
6.07	5.00	8.71	10.34	11.70	11.80	**12.53**	10.18	11.27	9.68	8.44

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
7.01	0.43	0.82	0.96	1.09	1.11	**1.17**	0.93	1.03	0.89	0.76
8.01	0.43	0.53	0.54	0.62	**0.78**	0.73	0.59	0.51	0.43	0.37
8.02	1.60	1.97	2.24	2.52	**2.97**	2.90	2.36	2.22	1.99	1.72
8.03	1.87	2.56	2.93	3.33	3.70	**3.73**	3.04	3.04	2.69	2.32
9.01	0.75	0.84	0.80	0.96	**1.17**	1.06	0.87	0.79	0.68	0.59
10.01	0.33	0.63	0.74	0.84	0.86	**0.90**	0.72	0.82	0.70	0.61
11.01	0.65	0.70	0.63	0.76	**0.91**	0.81	0.67	0.77	0.69	0.58
11.02	1.51	1.67	1.43	1.82	**2.17**	1.93	1.57	1.62	1.46	1.25
12.01	0.47	0.51	0.40	0.54	**0.63**	0.55	0.43	0.46	0.41	0.36
13.01	0.39	0.45	0.37	0.49	**0.58**	0.51	0.41	0.36	0.30	0.27
14.01	1.80	1.80	1.52	1.83	**2.09**	1.86	1.31	1.25	1.09	0.95
15.01	2.86	2.88	2.42	2.98	**3.36**	3.04	2.12	2.01	1.75	1.51
15.02	3.80	3.81	3.20	3.93	**4.47**	4.06	2.83	2.75	2.52	2.18
15.03	6.87	6.94	5.81	7.12	**8.05**	7.35	5.12	5.00	4.59	3.97
15.04	6.97	7.10	5.94	7.34	**8.31**	7.60	5.36	5.36	4.90	4.25
16.01	2.73	2.66	2.31	2.63	**2.88**	2.71	1.68	1.55	1.30	1.13
17.01	0.16	0.27	0.36	0.41	0.44	**0.48**	0.43	0.48	0.43	0.39
18.01	0.11	0.21	0.26	0.29	0.29	**0.30**	0.25	0.30	0.25	0.22
19.01	0.86	0.94	0.76	1.02	**1.24**	1.04	0.85	0.75	0.62	0.54
19.02	1.50	1.70	1.46	1.88	**2.23**	1.99	1.60	1.43	1.20	1.05
19.03	2.37	2.84	2.82	3.21	**3.95**	3.74	3.03	2.76	2.41	2.09
19.04	2.60	3.16	3.39	3.81	**4.53**	4.40	3.58	3.51	3.15	2.75
19.05	2.83	3.45	3.81	4.29	**4.98**	4.92	3.98	4.00	3.54	3.11
19.06	4.71	5.82	6.72	7.54	8.40	**8.55**	6.88	7.40	6.52	5.70
19.07	5.86	7.30	8.49	9.55	10.21	**10.58**	8.48	9.84	8.67	7.80
19.08	6.11	7.58	8.80	9.87	10.54	**10.91**	8.78	10.14	8.96	8.06
19.09	1.24	1.68	1.91	2.06	2.25	2.37	2.48	2.53	2.59	**2.73**
19.1	1.78	2.48	2.83	3.10	3.38	3.51	3.60	3.60	3.67	**3.87**
19.11	2.00	2.78	3.25	3.62	3.94	4.11	4.11	4.06	4.24	**4.44**
19.12	2.10	2.97	3.51	3.96	4.34	4.56	4.53	4.48	4.71	**4.92**
20.01	0.37	0.44	0.36	0.48	**0.55**	0.49	0.37	0.32	0.25	0.22
21.01	0.40	0.46	0.39	0.51	**0.60**	0.54	0.43	0.38	0.31	0.27
22.01	0.24	0.42	0.49	0.56	0.57	**0.61**	0.48	0.51	0.45	0.38
23.01	0.14	0.18	0.20	0.22	**0.27**	0.26	0.21	0.19	0.17	0.15
24.01	0.33	0.39	0.35	0.43	**0.50**	0.46	0.38	0.42	0.37	0.31
24.02	0.41	0.49	0.44	0.54	**0.64**	0.59	0.48	0.50	0.44	0.38
24.03	0.76	0.88	0.85	1.01	**1.19**	1.12	0.91	1.01	0.89	0.78
24.04	1.81	2.13	2.23	2.48	**3.00**	2.87	2.34	2.44	2.16	1.89
24.05	2.25	2.61	2.74	3.07	**3.66**	3.50	2.89	3.12	2.76	2.40
25.01	0.22	0.27	0.29	0.33	0.37	0.39	0.36	**0.39**	0.35	0.33
26.01	0.44	0.50	0.49	0.56	**0.69**	0.64	0.52	0.47	0.41	0.36
26.02	0.88	1.05	1.14	1.27	**1.51**	1.48	1.20	1.10	0.98	0.85
27.01	0.32	0.39	0.44	0.50	**0.58**	0.58	0.47	0.43	0.38	0.33

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
28.01	0.30	0.36	0.35	0.40	**0.47**	0.43	0.37	0.44	0.38	0.33
29.01	0.13	0.14	0.14	0.15	**0.20**	0.18	0.15	0.15	0.14	0.12
30.01	0.67	0.72	0.58	0.76	**0.90**	0.78	0.63	0.73	0.65	0.55
31.01	0.34	0.39	0.31	0.42	**0.49**	0.43	0.35	0.38	0.34	0.29
31.02	0.94	1.01	0.79	1.09	**1.25**	1.11	0.95	1.06	0.93	0.89
31.03	1.13	1.22	1.07	1.33	**1.57**	1.47	1.41	1.49	1.50	1.45
32.01	0.55	0.59	0.47	0.62	**0.71**	0.63	0.47	0.45	0.39	0.34
33.01	0.43	0.48	0.37	0.50	**0.57**	0.51	0.38	0.35	0.29	0.25
34.01	0.29	0.38	0.45	0.51	0.54	**0.56**	0.45	0.49	0.43	0.37
35.01	0.19	0.23	0.23	0.27	**0.32**	0.29	0.24	0.22	0.19	0.17
35.02	0.65	0.79	0.66	0.90	**1.03**	0.92	0.73	0.65	0.54	0.47
35.03	1.05	1.17	1.05	1.34	**1.56**	1.39	1.14	1.04	0.89	0.78
35.04	1.31	1.43	1.40	1.68	**1.97**	1.85	1.47	1.49	1.33	1.15
35.05	1.34	1.46	1.44	1.73	**2.02**	1.90	1.52	1.55	1.38	1.20
35.06	0.75	1.08	1.23	1.34	1.37	**1.40**	1.28	1.34	1.30	1.19
36.01	0.38	0.45	0.34	0.47	**0.54**	0.48	0.36	0.31	0.25	0.22
37.01	0.15	0.16	0.13	0.16	**0.18**	0.16	0.12	0.11	0.10	0.09
38.01	0.16	0.22	0.25	0.27	**0.31**	0.29	0.25	0.29	0.25	0.21
39.01	0.31	0.42	0.59	0.67	0.72	**0.77**	0.72	0.76	0.73	0.68
40.01	0.22	0.22	0.18	0.24	**0.30**	0.25	0.20	0.18	0.15	0.13
40.02	0.44	0.46	0.38	0.49	**0.60**	0.51	0.43	0.40	0.36	0.31
40.03	1.26	1.30	1.05	1.38	**1.63**	1.42	1.14	1.25	1.12	0.97
40.04	1.79	1.92	1.63	2.10	**2.46**	2.21	1.78	1.89	1.70	1.47
40.05	2.39	2.59	2.31	2.81	**3.21**	3.12	2.46	2.72	2.46	2.20
40.06	2.60	2.81	2.58	3.11	**3.52**	3.45	2.73	3.07	2.79	2.49
41.01	0.44	0.50	0.41	0.54	**0.63**	0.55	0.46	0.43	0.38	0.33
42.01	0.55	0.62	0.49	0.65	**0.76**	0.67	0.55	0.56	0.50	0.43
43.01	0.15	0.16	0.13	0.16	**0.19**	0.17	0.14	0.17	0.15	0.13
44.01	0.18	0.20	0.22	0.25	0.29	0.31	0.29	0.30	**0.32**	0.30
44.02	0.41	0.44	0.47	0.52	**0.61**	0.58	0.55	0.61	0.56	0.54
44.03	0.51	0.59	0.71	0.79	0.84	0.90	0.84	**0.93**	0.85	0.80
44.04	0.67	0.79	1.03	1.15	1.26	1.36	1.30	1.34	1.44	**1.48**
45.01	0.17	0.18	0.15	0.19	**0.23**	0.20	0.16	0.19	0.17	0.15
46.01	0.10	0.15	0.20	0.24	0.29	0.31	0.31	0.31	0.34	**0.35**
47.01	0.08	0.14	0.18	0.20	0.22	**0.23**	0.22	0.23	0.22	0.20
48.01	0.22	0.24	0.23	0.28	0.33	0.37	0.41	0.41	0.43	**0.49**
48.02	0.51	0.60	0.69	0.78	0.86	0.93	0.88	0.94	0.94	**1.00**
49.01	0.28	0.34	0.43	0.49	0.53	0.56	0.53	**0.58**	0.51	0.48
50.01	0.32	0.40	0.50	0.58	0.63	**0.68**	0.65	0.68	0.65	0.61
51.01	0.16	0.17	0.15	0.19	**0.23**	0.20	0.18	0.20	0.18	0.16
52.01	0.59	0.63	0.51	0.67	**0.79**	0.71	0.70	0.73	0.76	0.72
52.02	1.39	1.38	1.18	1.46	**1.64**	1.50	1.05	1.11	1.02	0.99
53.01	0.55	0.56	0.47	0.58	**0.64**	0.59	0.36	0.32	0.24	0.21

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
53.02	1.78	1.79	1.51	1.79	**1.99**	1.83	1.17	1.04	0.79	0.70
53.03	2.33	2.32	2.00	2.31	**2.55**	2.44	1.59	1.41	1.09	0.96
54.01	0.78	0.81	0.66	0.82	**0.89**	0.83	0.50	0.44	0.32	0.29
55.01	0.64	0.68	0.54	0.68	**0.74**	0.69	0.42	0.37	0.27	0.24
56.01	0.56	0.56	0.48	0.59	**0.66**	0.60	0.41	0.38	0.32	0.28
57.01	0.77	0.81	0.65	0.84	**0.97**	0.87	0.64	0.68	0.61	0.52
57.02	0.94	0.94	0.85	1.02	**1.15**	1.13	0.78	0.85	0.76	0.66
57.03	1.08	1.08	1.04	1.23	1.33	**1.38**	0.91	0.97	0.88	0.76
58.01	0.45	0.93	1.23	1.37	1.42	1.50	1.33	**1.50**	1.33	1.20
58.02	0.67	1.27	1.56	1.72	1.75	1.81	1.60	**1.88**	1.64	1.47
58.03	0.86	1.63	2.01	2.21	2.26	2.36	2.01	**2.38**	2.07	1.85
58.04	1.71	3.29	4.05	4.49	4.58	**4.76**	3.89	4.67	4.06	3.57
58.05	2.42	4.71	5.83	6.47	6.62	**6.87**	5.64	6.72	5.87	5.17
58.06	2.43	4.73	5.85	6.51	6.66	**6.91**	5.67	6.75	5.90	5.20
58.07	3.67	6.77	8.31	9.31	9.54	**9.98**	8.10	9.54	8.43	7.49
58.08	1.39	1.49	1.46	1.52	**1.57**	1.53	1.49	1.48	1.46	1.43
58.09	2.20	2.52	2.33	2.66	**2.91**	2.77	2.44	2.58	2.44	2.30
58.1	2.67	3.04	2.84	3.29	**3.65**	3.46	2.99	3.19	3.00	2.79
58.11	2.92	3.32	3.24	3.78	**4.20**	4.05	3.40	3.68	3.44	3.19
59.01	0.43	0.80	1.02	1.12	1.15	**1.18**	0.97	1.17	1.00	0.87
59.02	0.70	1.36	1.69	1.87	1.92	**1.97**	1.61	1.92	1.65	1.43
60.01	0.31	0.56	0.65	0.73	0.75	**0.80**	0.63	0.67	0.59	0.51
60.02	0.66	1.29	1.59	1.77	1.82	**1.89**	1.53	1.83	1.59	1.39
61.01	0.25	0.35	0.39	0.45	0.49	**0.50**	0.41	0.38	0.34	0.29
61.02	0.83	1.16	1.30	1.46	**1.66**	1.65	1.36	1.24	1.11	0.96
61.03	1.28	1.93	2.18	2.47	2.62	**2.73**	2.23	2.21	1.95	1.68
61.04	1.70	2.50	2.86	3.23	3.41	**3.54**	2.91	3.06	2.71	2.40
62.01	0.34	0.55	0.61	0.69	0.75	**0.76**	0.64	0.58	0.52	0.45
63.01	0.18	0.30	0.36	0.40	0.41	**0.44**	0.34	0.40	0.34	0.29
64.01	0.08	0.13	0.15	0.16	**0.19**	0.18	0.16	0.14	0.12	0.11
65.01	0.22	0.27	0.26	0.31	**0.37**	0.34	0.28	0.31	0.27	0.24
65.02	0.42	0.48	0.47	0.57	**0.68**	0.62	0.52	0.50	0.46	0.39
66.01	0.03	0.04	0.04	0.05	**0.05**	0.05	0.03	0.03	0.02	0.02
67.01	0.51	0.55	0.44	0.58	**0.66**	0.59	0.45	0.49	0.43	0.38
68.01	0.27	0.28	0.23	0.32	**0.37**	0.33	0.26	0.29	0.26	0.23
69.01	0.29	0.30	0.24	0.32	**0.38**	0.33	0.26	0.25	0.22	0.19
69.02	0.45	0.46	0.38	0.49	**0.58**	0.50	0.40	0.41	0.38	0.32
70.01	0.45	0.47	0.38	0.50	**0.57**	0.51	0.37	0.41	0.37	0.35
71.01	2.34	2.31	1.98	2.32	**2.63**	2.37	1.63	1.54	1.39	1.22
71.02	2.92	2.96	2.48	3.05	**3.50**	3.13	2.29	2.40	2.20	1.94
72.01	0.53	0.59	0.60	0.65	0.76	0.75	0.70	**0.78**	0.69	0.65
73.01	0.22	0.24	0.20	0.26	**0.32**	0.27	0.24	0.26	0.24	0.22
73.02	0.46	0.49	0.42	0.54	**0.64**	0.56	0.54	0.57	0.55	0.52

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
73.03	0.80	0.86	0.83	0.96	**1.16**	1.10	1.05	1.11	1.10	1.04
74.01	0.11	0.14	0.17	0.20	0.21	0.22	0.19	**0.22**	0.19	0.18
75.01	0.10	0.11	0.09	0.11	0.13	0.12	0.12	**0.13**	0.11	0.10
76.01	0.36	0.66	0.88	1.01	1.05	1.12	1.01	**1.13**	1.00	0.91
77.01	0.29	0.60	0.83	0.99	1.09	1.15	1.11	1.11	**1.19**	1.12
78.01	0.19	0.24	0.20	0.27	**0.31**	0.27	0.21	0.18	0.14	0.12
78.02	2.50	5.69	7.30	8.33	8.56	**9.00**	7.12	8.60	7.48	6.54
78.03	3.65	7.55	9.52	10.82	11.17	**11.68**	9.32	11.17	9.69	8.57
78.04	3.90	8.06	10.18	11.55	11.98	**12.52**	10.01	11.90	10.39	9.22
78.05	4.07	8.41	10.62	12.05	12.52	**13.09**	10.52	12.42	10.90	9.70
78.06	5.01	10.21	12.92	14.70	15.32	**15.98**	13.22	15.35	13.70	12.29
78.07	5.89	11.89	15.14	17.52	18.43	**19.33**	16.32	18.37	16.79	15.19
79.01	0.48	0.59	0.62	0.68	**0.87**	0.81	0.67	0.58	0.49	0.43
79.02	0.94	1.14	1.25	1.39	**1.70**	1.65	1.34	1.20	1.03	0.90
79.03	1.17	1.46	1.58	1.79	**2.10**	2.08	1.68	1.54	1.36	1.18
80.01	0.30	0.37	0.38	0.42	**0.52**	0.50	0.41	0.37	0.32	0.28
81.01	0.11	0.15	0.13	0.19	**0.21**	0.20	0.15	0.13	0.10	0.09
82.01	0.48	0.57	0.50	0.65	**0.78**	0.71	0.55	0.47	0.38	0.33
82.02	0.74	0.89	0.83	1.01	**1.21**	1.13	0.90	0.82	0.70	0.61
82.03	1.17	1.41	1.37	1.60	**1.94**	1.83	1.47	1.35	1.21	1.06
83.01	0.42	0.48	0.46	0.53	**0.66**	0.61	0.49	0.44	0.37	0.33
84.01	0.30	0.35	0.30	0.38	**0.45**	0.40	0.33	0.33	0.30	0.26
84.02	0.73	0.82	0.77	0.95	**1.12**	1.01	0.83	0.80	0.72	0.63
85.01	0.20	0.24	0.22	0.28	**0.33**	0.30	0.24	0.22	0.18	0.16
86.01	0.02	0.03	0.02	0.03	**0.03**	0.03	0.02	0.02	0.02	0.01
86.02	0.33	0.36	0.29	0.39	**0.46**	0.41	0.32	0.30	0.27	0.23
87.01	0.07	0.11	0.12	0.13	**0.16**	0.16	0.13	0.11	0.10	0.08
88.01	0.60	0.66	0.60	0.73	**0.89**	0.82	0.66	0.62	0.56	0.48
88.02	0.85	0.97	0.95	1.09	**1.34**	1.26	1.03	1.02	0.92	0.79
88.03	1.10	1.39	1.69	1.86	2.00	2.02	1.76	**2.08**	1.81	1.63
88.04	1.34	1.84	2.31	2.56	2.62	2.77	2.55	**2.89**	2.58	2.40
89.01	0.26	0.50	0.62	0.69	0.71	0.72	0.61	**0.74**	0.63	0.56
89.02	1.36	1.45	1.69	1.90	2.03	2.20	2.01	**2.20**	2.01	1.88
89.03	2.30	2.46	2.48	2.77	3.09	3.18	2.93	**3.25**	2.91	2.72
90.01	0.24	0.42	0.57	0.65	0.67	0.71	0.64	**0.72**	0.64	0.58
91.01	0.67	0.71	0.56	0.74	**0.84**	0.76	0.56	0.62	0.55	0.48
92.01	0.82	0.86	0.68	0.90	**1.04**	0.92	0.70	0.74	0.66	0.56
92.02	1.24	1.30	1.05	1.37	**1.56**	1.40	1.05	1.16	1.03	0.90
_junc_116	0.59	0.89	1.00	1.13	1.24	**1.26**	1.04	0.97	0.86	0.74
_junc_123	2.87	2.90	2.42	2.96	**3.39**	3.02	2.20	2.28	2.08	1.84
_junc_125	21.51	36.41	45.60	53.54	59.16	**63.04**	56.11	55.32	55.56	51.88
_junc_126	0.79	0.95	1.18	1.36	1.49	1.61	1.52	1.60	1.58	**1.61**
_junc_130	3.89	6.82	7.94	9.04	9.11	**9.78**	7.92	8.40	7.32	6.31

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
_junc_133	2.02	2.35	2.05	2.58	**3.08**	2.79	2.25	2.00	1.68	1.47
_junc_135	0.57	0.68	0.54	0.74	**0.86**	0.76	0.60	0.53	0.44	0.38
_junc_136	0.79	0.91	0.76	1.02	**1.19**	1.06	0.85	0.76	0.63	0.55
_junc_138	6.53	6.47	5.50	6.55	**7.36**	6.73	4.50	4.29	3.82	3.31
_junc_142	2.03	2.16	2.15	2.40	2.69	2.76	2.54	**2.82**	2.52	2.36
_junc_150	3.03	6.51	8.29	9.47	9.73	**10.19**	8.10	9.78	8.49	7.46
_junc_151	1.92	2.23	2.36	2.62	**3.16**	3.02	2.48	2.59	2.29	2.00
_junc_158	0.50	0.58	0.65	0.74	0.81	0.88	0.84	0.89	0.89	**0.96**
_junc_162	0.26	0.42	0.49	0.55	0.57	**0.62**	0.49	0.53	0.47	0.40
_junc_19	1.24	1.38	1.09	1.50	**1.79**	1.53	1.22	1.07	0.87	0.76
_junc_21	12.33	21.50	26.01	29.26	30.25	**31.97**	25.75	27.98	23.99	21.09
_junc_28	4.62	5.65	6.50	7.30	8.17	**8.31**	6.68	7.10	6.27	5.47
_junc_29	1.62	1.93	1.99	2.23	**2.70**	2.59	2.11	2.09	1.87	1.63
_junc_30	0.30	0.36	0.35	0.40	**0.47**	0.43	0.37	0.44	0.38	0.33
_junc_32	0.63	0.76	0.71	0.84	**1.01**	0.93	0.76	0.89	0.78	0.68
_junc_37	1.97	2.74	3.18	3.54	3.85	4.02	4.03	3.99	4.15	**4.36**
_junc_38	14.02	24.69	30.58	35.31	36.96	**39.37**	32.53	33.98	30.77	27.54
_junc_40	1.70	1.80	1.43	1.92	**2.26**	1.97	1.60	1.66	1.50	1.29
_junc_41	1.54	3.00	3.70	4.09	4.18	**4.32**	3.57	4.30	3.71	3.27
_junc_42	2.22	2.42	2.07	2.55	**2.97**	2.81	2.26	2.46	2.19	1.88
_junc_44	2.16	3.12	3.70	4.20	4.63	4.88	4.84	4.78	5.04	**5.26**
_junc_47	3.27	3.58	3.57	4.10	**4.64**	4.59	3.88	4.41	4.00	3.88
_junc_50	0.25	0.31	0.29	0.35	**0.42**	0.38	0.32	0.33	0.30	0.26
_junc_59	18.24	31.77	39.67	46.60	49.63	**52.71**	45.33	46.47	44.48	41.49
_junc_64	1.80	2.04	1.86	2.10	**2.23**	2.12	1.93	1.96	1.89	1.81
_junc_68	0.59	0.74	0.75	0.86	**1.08**	1.01	0.82	0.70	0.59	0.51
_junc_69	18.38	31.97	40.00	47.08	50.61	**53.79**	46.69	47.28	45.95	42.73
_junc_71	2.57	2.94	2.68	3.15	**3.49**	3.23	2.84	2.99	2.81	2.62
_junc_74	2.86	3.25	3.13	3.68	**4.08**	3.91	3.30	3.60	3.34	3.11
_junc_76	18.70	32.50	40.69	47.92	51.93	**55.28**	48.28	48.41	47.47	44.16
_junc_80	21.06	35.67	44.57	52.28	57.56	**61.34**	54.36	53.75	53.77	50.15
_junc_81	0.57	0.62	0.60	0.70	**0.84**	0.78	0.73	0.79	0.74	0.69
_junc_84	22.01	37.33	46.94	55.11	61.13	**65.15**	58.26	57.27	57.77	53.96
_junc_85	25.81	44.27	56.90	67.90	75.36	**79.93**	73.22	72.04	73.05	68.21
_junc_86	26.07	44.59	57.31	68.38	76.00	**80.59**	73.98	72.69	73.81	68.92
_junc_88	4.98	10.13	12.80	14.53	15.12	**15.76**	13.02	15.17	13.48	12.08
_junc_91	5.84	11.82	15.06	17.37	18.24	**19.14**	16.15	18.21	16.60	15.00
US_OHH	19.12	33.19	41.58	48.97	53.52	**57.09**	50.07	49.80	49.34	45.90
US_Rail	17.96	31.28	38.98	45.65	48.41	**51.43**	43.95	45.30	42.97	40.14

PEAK DESIGN FLOOD DISCHARGES - 2% AEP

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
1.01	0.77	1.40	1.60	1.76	1.77	**1.86**	1.46	1.59	1.35	1.16
1.02	2.07	2.71	2.94	3.29	3.58	**3.75**	2.94	2.76	2.42	2.09
1.03	4.23	5.69	6.17	6.94	7.45	**7.86**	6.13	5.71	4.95	4.30
1.04	8.24	11.78	12.84	14.35	15.11	**15.92**	12.53	11.54	9.92	8.65
1.05	8.93	13.10	14.45	16.15	16.78	**17.75**	13.99	13.42	11.54	10.06
1.06	9.07	13.35	14.86	16.58	17.20	**18.17**	14.34	13.84	11.91	10.40
1.07	11.12	17.10	20.01	22.19	22.81	**23.88**	19.01	19.33	16.48	14.52
1.08	17.55	28.33	33.40	36.89	37.75	**39.37**	31.23	32.68	27.66	24.27
1.09	17.97	29.13	34.73	38.51	39.36	**40.97**	32.65	33.99	29.10	25.62
1.1	18.15	29.47	35.26	39.22	40.18	**41.85**	33.46	34.76	30.01	26.56
1.11	19.92	32.67	39.60	44.98	46.33	**48.55**	39.54	40.19	35.63	31.81
1.12	20.12	33.04	40.13	45.63	47.03	**49.27**	40.22	40.86	36.30	32.43
1.13	20.24	33.25	40.41	45.97	47.39	**49.66**	40.56	41.22	36.68	32.80
1.14	24.34	39.69	48.71	55.76	57.97	**60.65**	50.71	51.31	47.36	43.84
1.15	25.00	40.86	50.34	57.72	60.28	**63.05**	53.06	53.44	49.78	46.17
1.16	25.28	41.35	51.03	58.63	61.40	**64.22**	54.28	54.48	51.06	47.36
1.17	25.33	41.44	51.16	58.89	61.98	**64.82**	55.11	54.94	51.93	48.17
1.18	25.39	41.55	51.34	59.11	62.43	**65.30**	55.64	55.31	52.48	48.62
1.19	25.60	41.86	51.73	59.59	63.42	**66.45**	56.80	56.14	53.61	49.64
1.2	25.83	42.22	52.19	60.20	64.23	**67.27**	57.75	56.89	54.49	50.48
1.21	28.20	45.33	55.97	64.50	69.68	**73.02**	63.47	62.09	60.29	56.01
1.22	28.75	46.39	57.44	66.33	71.91	**75.43**	65.77	64.19	62.60	58.19
1.23	29.38	47.49	58.89	68.19	74.15	**77.75**	68.09	66.30	64.86	60.32
1.24	29.72	48.14	59.72	69.25	75.42	**79.07**	69.40	67.49	66.13	61.51
1.25	34.23	57.32	73.02	85.75	93.30	**97.24**	87.41	85.16	84.02	78.00
1.26	34.85	58.48	74.60	87.61	95.72	**99.72**	90.08	87.53	86.66	80.47
2.01	0.36	0.43	0.44	0.53	**0.59**	0.58	0.43	0.36	0.29	0.25
2.02	1.43	1.73	1.78	2.09	2.32	**2.36**	1.78	1.50	1.20	1.06
3.01	0.73	0.98	1.07	1.16	**1.35**	1.35	1.06	0.90	0.77	0.67
3.02	3.06	4.55	4.98	5.54	5.76	**6.04**	4.82	4.30	3.70	3.23
3.03	3.85	5.84	6.40	7.11	7.36	**7.76**	6.15	5.58	4.77	4.17
4.01	1.26	1.83	1.99	2.19	2.32	**2.43**	1.94	1.68	1.45	1.26
5.01	0.81	1.36	1.52	1.71	1.69	**1.82**	1.41	1.43	1.23	1.06
5.02	1.48	2.61	3.00	3.31	3.32	**3.49**	2.74	3.02	2.57	2.21
5.03	2.65	3.74	4.45	4.80	4.82	**4.90**	4.05	4.76	4.07	3.50
6.01	1.37	2.40	2.68	2.93	2.95	**3.10**	2.47	2.58	2.22	1.91
6.02	1.93	3.24	3.59	3.97	3.98	**4.22**	3.36	3.41	2.95	2.54
6.03	2.90	4.87	5.40	5.98	6.00	**6.37**	5.08	5.12	4.40	3.81
6.04	5.17	8.15	9.07	10.14	10.08	**10.75**	8.76	8.63	7.48	6.47
6.05	5.97	9.55	10.62	11.86	11.80	**12.60**	10.21	10.11	8.73	7.57
6.06	6.19	10.09	11.34	12.63	12.55	**13.36**	10.82	10.96	9.41	8.18
6.07	6.92	11.61	13.12	14.55	14.45	**15.39**	12.39	12.90	10.97	9.58

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
7.01	0.63	1.10	1.22	1.34	1.35	**1.42**	1.12	1.17	1.01	0.86
8.01	0.51	0.62	0.67	0.77	**0.92**	0.87	0.68	0.58	0.48	0.42
8.02	1.95	2.55	2.83	3.09	**3.56**	3.51	2.82	2.56	2.24	1.94
8.03	2.32	3.34	3.73	4.12	4.50	**4.57**	3.66	3.46	3.03	2.62
9.01	0.87	0.96	0.99	1.17	**1.39**	1.28	1.02	0.89	0.76	0.66
10.01	0.50	0.84	0.95	1.06	1.06	**1.12**	0.87	0.93	0.80	0.69
11.01	0.75	0.78	0.80	0.90	**1.10**	0.99	0.82	0.89	0.78	0.68
11.02	1.77	1.88	1.83	2.15	**2.59**	2.33	1.89	1.86	1.65	1.43
12.01	0.55	0.57	0.49	0.64	**0.73**	0.64	0.52	0.53	0.47	0.40
13.01	0.47	0.51	0.46	0.57	**0.67**	0.60	0.47	0.41	0.34	0.30
14.01	2.03	1.98	1.73	2.11	**2.37**	2.14	1.52	1.44	1.23	1.07
15.01	3.23	3.21	2.75	3.40	**3.83**	3.47	2.48	2.33	1.97	1.71
15.02	4.27	4.17	3.68	4.53	**5.12**	4.65	3.35	3.22	2.86	2.48
15.03	7.77	7.62	6.71	8.18	**9.24**	8.38	6.06	5.84	5.24	4.52
15.04	7.94	7.81	6.89	8.46	**9.57**	8.70	6.36	6.20	5.61	4.84
16.01	3.04	2.88	2.61	2.95	**3.26**	3.01	1.93	1.79	1.47	1.27
17.01	0.22	0.37	0.49	0.54	0.55	**0.57**	0.52	0.57	0.49	0.45
18.01	0.16	0.28	0.33	0.36	0.36	**0.37**	0.30	0.35	0.29	0.25
19.01	1.00	1.06	0.94	1.23	**1.43**	1.25	0.98	0.86	0.69	0.61
19.02	1.76	1.93	1.80	2.26	**2.60**	2.36	1.86	1.63	1.35	1.17
19.03	2.84	3.27	3.54	3.89	**4.69**	4.50	3.58	3.17	2.71	2.35
19.04	3.14	3.87	4.29	4.67	**5.42**	5.34	4.25	4.04	3.59	3.12
19.05	3.47	4.37	4.85	5.28	**6.00**	5.98	4.74	4.60	4.04	3.52
19.06	5.93	7.68	8.60	9.39	10.22	**10.42**	8.30	8.55	7.47	6.48
19.07	7.43	9.65	10.92	11.98	12.50	**12.96**	10.31	11.48	10.08	8.96
19.08	7.71	9.96	11.26	12.33	12.86	**13.32**	10.63	11.81	10.39	9.24
19.09	1.45	1.90	2.15	2.34	2.54	2.68	2.79	2.85	2.89	**3.05**
19.1	2.12	2.83	3.25	3.49	3.75	3.88	3.96	3.96	3.99	**4.24**
19.11	2.41	3.23	3.82	4.27	4.53	4.69	4.58	4.50	4.72	**5.02**
19.12	2.55	3.50	4.18	4.73	5.08	5.29	5.13	4.99	5.31	**5.58**
20.01	0.43	0.50	0.44	0.56	**0.63**	0.56	0.42	0.36	0.28	0.25
21.01	0.47	0.53	0.48	0.60	**0.70**	0.64	0.50	0.43	0.35	0.31
22.01	0.33	0.57	0.63	0.70	0.70	**0.75**	0.59	0.58	0.51	0.43
23.01	0.17	0.23	0.25	0.27	**0.31**	0.31	0.25	0.22	0.19	0.16
24.01	0.40	0.44	0.45	0.50	**0.59**	0.56	0.45	0.48	0.42	0.36
24.02	0.49	0.55	0.57	0.64	**0.76**	0.71	0.57	0.57	0.50	0.43
24.03	0.88	1.01	1.06	1.19	**1.41**	1.34	1.08	1.18	1.03	0.89
24.04	2.18	2.52	2.82	3.07	**3.57**	3.48	2.80	2.80	2.47	2.14
24.05	2.64	3.11	3.50	3.85	**4.34**	4.29	3.46	3.60	3.16	2.73
25.01	0.26	0.31	0.38	0.43	0.45	**0.47**	0.43	0.47	0.40	0.37
26.01	0.52	0.57	0.62	0.68	**0.83**	0.78	0.62	0.54	0.46	0.40
26.02	1.05	1.29	1.44	1.57	**1.85**	1.81	1.44	1.27	1.10	0.95
27.01	0.38	0.51	0.57	0.62	**0.73**	0.71	0.57	0.49	0.43	0.37

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
28.01	0.37	0.41	0.45	0.49	**0.56**	0.52	0.43	0.51	0.44	0.37
29.01	0.15	0.16	0.18	0.19	**0.24**	0.22	0.18	0.17	0.15	0.13
30.01	0.76	0.80	0.77	0.90	**1.08**	0.96	0.79	0.83	0.74	0.63
31.01	0.40	0.44	0.39	0.49	**0.57**	0.50	0.41	0.44	0.38	0.33
31.02	1.10	1.14	1.04	1.25	**1.45**	1.29	1.12	1.25	1.11	1.01
31.03	1.30	1.37	1.47	1.61	1.82	**1.82**	1.71	1.81	1.75	1.67
32.01	0.64	0.65	0.54	0.72	**0.82**	0.73	0.56	0.51	0.43	0.38
33.01	0.50	0.53	0.42	0.57	**0.65**	0.58	0.44	0.39	0.32	0.28
34.01	0.34	0.52	0.58	0.64	0.68	**0.69**	0.57	0.55	0.49	0.42
35.01	0.23	0.27	0.28	0.33	**0.38**	0.36	0.29	0.25	0.21	0.19
35.02	0.79	0.92	0.81	1.06	**1.19**	1.08	0.84	0.74	0.60	0.52
35.03	1.22	1.36	1.29	1.58	**1.81**	1.67	1.32	1.19	1.00	0.87
35.04	1.53	1.67	1.76	2.01	**2.31**	2.22	1.75	1.71	1.52	1.30
35.05	1.56	1.71	1.82	2.06	**2.37**	2.29	1.80	1.78	1.58	1.36
35.06	0.93	1.28	1.45	1.54	1.55	**1.59**	1.45	1.50	1.43	1.35
36.01	0.46	0.50	0.41	0.55	**0.61**	0.55	0.40	0.35	0.27	0.24
37.01	0.17	0.17	0.15	0.18	**0.21**	0.19	0.14	0.13	0.11	0.10
38.01	0.20	0.28	0.31	0.34	**0.36**	0.36	0.30	0.33	0.28	0.24
39.01	0.37	0.61	0.77	0.86	0.91	**0.96**	0.87	0.93	0.84	0.78
40.01	0.24	0.25	0.22	0.30	**0.34**	0.31	0.23	0.21	0.17	0.15
40.02	0.50	0.51	0.47	0.59	**0.70**	0.62	0.50	0.47	0.41	0.35
40.03	1.43	1.44	1.32	1.61	**1.93**	1.69	1.39	1.44	1.28	1.11
40.04	2.09	2.16	2.09	2.46	**2.90**	2.63	2.15	2.18	1.94	1.68
40.05	2.78	2.96	2.98	3.33	**3.78**	3.76	2.96	3.16	2.83	2.52
40.06	3.06	3.23	3.34	3.69	4.16	**4.18**	3.30	3.59	3.21	2.86
41.01	0.53	0.56	0.52	0.63	**0.74**	0.67	0.54	0.49	0.43	0.37
42.01	0.65	0.69	0.64	0.77	**0.91**	0.84	0.67	0.64	0.57	0.49
43.01	0.17	0.17	0.16	0.19	**0.23**	0.21	0.17	0.19	0.17	0.15
44.01	0.21	0.25	0.29	0.34	0.37	**0.39**	0.36	0.37	0.37	0.34
44.02	0.48	0.52	0.61	0.66	**0.76**	0.73	0.67	0.73	0.65	0.61
44.03	0.61	0.76	0.94	1.03	1.06	**1.12**	1.01	1.11	0.98	0.91
44.04	0.85	1.08	1.37	1.52	1.64	1.71	1.60	1.66	1.70	**1.72**
45.01	0.20	0.20	0.19	0.23	**0.28**	0.24	0.20	0.23	0.20	0.17
46.01	0.14	0.21	0.27	0.32	0.37	0.40	0.39	0.38	**0.42**	0.41
47.01	0.11	0.18	0.23	0.26	0.27	**0.29**	0.26	0.27	0.25	0.23
48.01	0.26	0.29	0.29	0.34	0.44	0.49	0.53	0.53	0.53	**0.59**
48.02	0.62	0.72	0.92	1.01	1.08	1.15	1.06	1.13	1.13	**1.17**
49.01	0.34	0.44	0.58	0.64	0.66	**0.69**	0.62	0.69	0.60	0.54
50.01	0.39	0.55	0.68	0.75	0.79	**0.85**	0.77	0.82	0.75	0.70
51.01	0.19	0.19	0.20	0.23	**0.28**	0.24	0.21	0.24	0.21	0.19
52.01	0.69	0.71	0.68	0.78	**0.92**	0.89	0.85	0.88	0.89	0.83
52.02	1.55	1.55	1.33	1.65	**1.85**	1.70	1.22	1.31	1.20	1.13
53.01	0.63	0.63	0.53	0.66	**0.71**	0.66	0.40	0.36	0.26	0.23

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
53.02	2.02	1.95	1.71	2.05	**2.23**	2.07	1.31	1.16	0.88	0.78
53.03	2.62	2.58	2.27	2.64	**2.90**	2.76	1.79	1.57	1.21	1.06
54.01	0.90	0.89	0.75	0.92	**0.98**	0.93	0.55	0.49	0.36	0.32
55.01	0.74	0.74	0.62	0.77	**0.82**	0.77	0.46	0.41	0.30	0.26
56.01	0.64	0.63	0.54	0.67	**0.74**	0.68	0.47	0.43	0.36	0.31
57.01	0.89	0.89	0.76	0.98	**1.13**	1.00	0.77	0.78	0.70	0.59
57.02	1.07	1.06	1.00	1.21	**1.34**	1.32	0.94	0.99	0.87	0.75
57.03	1.25	1.25	1.20	1.44	1.54	**1.58**	1.09	1.14	1.00	0.87
58.01	0.66	1.26	1.61	1.78	1.77	**1.83**	1.58	1.79	1.53	1.37
58.02	0.97	1.68	2.01	2.19	2.19	**2.26**	1.90	2.22	1.90	1.67
58.03	1.23	2.18	2.58	2.82	2.82	**2.94**	2.38	2.80	2.41	2.11
58.04	2.45	4.41	5.17	5.65	5.65	**5.91**	4.71	5.44	4.68	4.07
58.05	3.53	6.33	7.45	8.15	8.16	**8.49**	6.81	7.84	6.77	5.89
58.06	3.55	6.36	7.49	8.19	8.20	**8.53**	6.85	7.88	6.80	5.93
58.07	5.23	9.02	10.65	11.69	11.69	**12.19**	9.84	11.17	9.71	8.55
58.08	1.51	1.52	1.51	1.57	**1.62**	1.58	1.52	1.51	1.48	1.45
58.09	2.60	2.73	2.61	2.90	**3.17**	3.01	2.64	2.81	2.62	2.44
58.1	3.20	3.36	3.26	3.67	**4.04**	3.83	3.30	3.52	3.26	3.00
58.11	3.56	3.76	3.76	4.26	**4.71**	4.53	3.79	4.10	3.78	3.46
59.01	0.64	1.11	1.30	1.40	1.40	**1.45**	1.17	1.36	1.15	0.99
59.02	1.03	1.85	2.16	2.35	2.34	**2.44**	1.96	2.22	1.89	1.63
60.01	0.44	0.73	0.81	0.92	0.91	**0.97**	0.77	0.76	0.66	0.57
60.02	0.98	1.74	2.04	2.22	2.23	**2.30**	1.86	2.13	1.83	1.58
61.01	0.30	0.45	0.50	0.55	0.61	**0.63**	0.50	0.43	0.38	0.33
61.02	1.02	1.48	1.63	1.80	2.00	**2.03**	1.62	1.42	1.24	1.08
61.03	1.62	2.50	2.77	3.10	3.21	**3.37**	2.69	2.52	2.20	1.90
61.04	2.14	3.27	3.62	4.08	4.13	**4.38**	3.51	3.54	3.10	2.73
62.01	0.46	0.69	0.76	0.85	0.90	**0.93**	0.75	0.66	0.58	0.51
63.01	0.24	0.41	0.46	0.52	0.51	**0.55**	0.43	0.45	0.39	0.33
64.01	0.12	0.17	0.18	0.20	0.22	**0.22**	0.18	0.16	0.14	0.12
65.01	0.26	0.31	0.34	0.37	**0.43**	0.41	0.34	0.36	0.31	0.27
65.02	0.49	0.58	0.59	0.68	**0.79**	0.74	0.61	0.58	0.51	0.45
66.01	0.04	0.05	0.04	0.05	**0.06**	0.05	0.04	0.03	0.03	0.02
67.01	0.59	0.61	0.50	0.66	**0.76**	0.68	0.52	0.57	0.50	0.43
68.01	0.30	0.33	0.29	0.37	**0.42**	0.37	0.30	0.35	0.30	0.26
69.01	0.33	0.34	0.29	0.38	**0.44**	0.39	0.30	0.29	0.25	0.21
69.02	0.51	0.51	0.46	0.58	**0.68**	0.60	0.48	0.47	0.43	0.37
70.01	0.51	0.53	0.44	0.57	**0.65**	0.58	0.45	0.49	0.44	0.40
71.01	2.63	2.53	2.23	2.66	**2.97**	2.71	1.86	1.78	1.60	1.38
71.02	3.30	3.27	2.84	3.55	**4.05**	3.63	2.72	2.81	2.53	2.20
72.01	0.61	0.66	0.77	0.85	**0.94**	0.92	0.84	0.93	0.81	0.74
73.01	0.25	0.27	0.25	0.31	**0.36**	0.32	0.29	0.31	0.28	0.25
73.02	0.53	0.56	0.55	0.63	**0.75**	0.70	0.65	0.69	0.63	0.59

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
73.03	0.92	0.99	1.07	1.18	**1.38**	1.38	1.28	1.34	1.27	1.20
74.01	0.13	0.18	0.22	0.25	0.25	**0.27**	0.23	0.26	0.23	0.20
75.01	0.12	0.12	0.13	0.14	**0.16**	0.16	0.14	0.16	0.14	0.12
76.01	0.52	0.90	1.16	1.29	1.32	**1.37**	1.19	1.33	1.16	1.04
77.01	0.42	0.82	1.12	1.29	1.38	**1.44**	1.35	1.34	1.39	1.29
78.01	0.23	0.28	0.25	0.32	**0.35**	0.31	0.23	0.20	0.15	0.14
78.02	4.09	7.98	9.71	10.78	10.78	**11.28**	8.88	10.31	8.81	7.64
78.03	5.59	10.35	12.52	13.80	13.92	**14.49**	11.59	13.26	11.32	9.95
78.04	5.94	11.01	13.38	14.77	14.94	**15.50**	12.43	14.12	12.12	10.69
78.05	6.16	11.44	13.95	15.41	15.62	**16.19**	13.02	14.73	12.71	11.24
78.06	7.36	13.81	16.96	18.87	19.14	**19.79**	16.07	18.28	15.95	14.20
78.07	8.53	16.12	19.95	22.55	23.05	**23.90**	19.74	21.86	19.51	17.51
79.01	0.57	0.70	0.76	0.86	**1.02**	0.97	0.77	0.66	0.55	0.48
79.02	1.12	1.42	1.55	1.71	**2.03**	1.98	1.57	1.37	1.16	1.01
79.03	1.43	1.82	2.00	2.19	**2.52**	2.50	2.00	1.77	1.52	1.32
80.01	0.37	0.43	0.48	0.52	**0.62**	0.61	0.48	0.42	0.36	0.31
81.01	0.15	0.19	0.17	0.22	**0.24**	0.23	0.17	0.14	0.11	0.10
82.01	0.57	0.66	0.60	0.79	**0.91**	0.82	0.63	0.53	0.42	0.37
82.02	0.90	1.02	1.03	1.21	**1.46**	1.35	1.06	0.93	0.79	0.69
82.03	1.44	1.62	1.72	1.96	**2.34**	2.22	1.74	1.56	1.36	1.19
83.01	0.49	0.55	0.57	0.65	**0.79**	0.74	0.58	0.50	0.42	0.37
84.01	0.35	0.39	0.38	0.44	**0.52**	0.48	0.39	0.38	0.33	0.29
84.02	0.85	0.98	0.96	1.11	**1.30**	1.21	0.98	0.92	0.81	0.70
85.01	0.24	0.28	0.27	0.33	**0.38**	0.35	0.28	0.24	0.20	0.18
86.01	0.02	0.03	0.03	0.03	**0.04**	0.03	0.02	0.02	0.02	0.01
86.02	0.38	0.42	0.36	0.46	**0.53**	0.46	0.37	0.35	0.30	0.26
87.01	0.09	0.13	0.15	0.16	0.19	**0.19**	0.15	0.13	0.11	0.09
88.01	0.70	0.75	0.78	0.88	**1.07**	0.99	0.80	0.73	0.63	0.54
88.02	1.01	1.10	1.23	1.35	**1.61**	1.55	1.25	1.16	1.04	0.89
88.03	1.35	1.87	2.19	2.37	2.44	**2.53**	2.07	2.43	2.13	1.86
88.04	1.68	2.50	3.02	3.29	3.28	3.38	3.05	**3.44**	3.02	2.74
89.01	0.35	0.67	0.81	0.88	0.88	**0.90**	0.73	0.86	0.73	0.64
89.02	1.56	1.80	2.24	2.45	2.55	**2.68**	2.39	2.62	2.33	2.15
89.03	2.66	2.75	3.28	3.59	3.70	**3.87**	3.49	3.87	3.36	3.10
90.01	0.33	0.60	0.74	0.82	0.84	**0.87**	0.76	0.86	0.74	0.67
91.01	0.78	0.78	0.65	0.84	**0.97**	0.86	0.65	0.73	0.65	0.55
92.01	0.94	0.95	0.81	1.04	**1.20**	1.06	0.83	0.84	0.76	0.65
92.02	1.40	1.44	1.20	1.57	**1.78**	1.60	1.23	1.35	1.20	1.03
_junc_116	0.76	1.15	1.26	1.40	1.51	**1.56**	1.25	1.10	0.96	0.84
_junc_123	3.24	3.19	2.76	3.43	**3.91**	3.48	2.59	2.67	2.40	2.09
_junc_125	29.05	46.85	58.06	67.13	72.88	**76.42**	66.79	65.09	63.56	59.10
_junc_126	0.95	1.25	1.60	1.75	1.87	**1.99**	1.83	1.93	1.87	1.87
_junc_130	5.64	8.99	10.02	11.19	11.12	**11.85**	9.63	9.56	8.26	7.16

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
_junc_133	2.40	2.67	2.53	3.06	**3.61**	3.31	2.61	2.27	1.88	1.64
_junc_135	0.69	0.77	0.66	0.87	**0.99**	0.88	0.69	0.60	0.49	0.43
_junc_136	0.92	1.05	0.94	1.20	**1.38**	1.26	0.98	0.86	0.71	0.62
_junc_138	7.32	7.06	6.29	7.49	**8.38**	7.65	5.28	5.01	4.33	3.75
_junc_142	2.33	2.41	2.83	3.10	3.20	3.35	3.02	**3.36**	2.91	2.69
_junc_150	4.78	8.99	10.97	12.16	12.17	**12.68**	10.11	11.66	9.97	8.70
_junc_151	2.29	2.67	2.99	3.26	**3.76**	3.69	2.97	2.97	2.62	2.27
_junc_158	0.60	0.69	0.88	0.95	1.02	1.09	1.01	1.07	1.08	**1.12**
_junc_162	0.37	0.57	0.63	0.72	0.70	**0.76**	0.61	0.60	0.53	0.45
_junc_19	1.43	1.56	1.33	1.80	**2.05**	1.80	1.40	1.22	0.97	0.85
_junc_21	17.39	28.04	32.98	36.40	37.26	**38.88**	30.83	32.22	27.23	23.89
_junc_28	5.79	7.44	8.31	9.07	9.94	**10.10**	8.04	8.19	7.17	6.21
_junc_29	1.93	2.24	2.51	2.72	**3.26**	3.14	2.52	2.40	2.13	1.85
_junc_30	0.37	0.41	0.45	0.49	**0.56**	0.52	0.43	0.51	0.44	0.37
_junc_32	0.74	0.86	0.92	0.99	**1.19**	1.12	0.91	1.04	0.90	0.78
_junc_37	2.37	3.16	3.75	4.14	4.42	4.57	4.49	4.41	4.58	**4.89**
_junc_38	19.71	32.30	39.08	44.35	45.65	**47.83**	38.91	39.55	35.00	31.23
_junc_40	1.96	2.00	1.84	2.24	**2.67**	2.36	1.92	1.91	1.71	1.48
_junc_41	2.22	4.03	4.74	5.17	5.16	**5.38**	4.30	5.02	4.29	3.73
_junc_42	2.55	2.73	2.69	3.01	**3.49**	3.44	2.71	2.83	2.50	2.15
_junc_44	2.65	3.69	4.44	5.03	5.45	5.69	5.51	5.36	5.72	**5.98**
_junc_47	3.91	4.17	4.63	5.02	5.57	**5.64**	4.65	5.23	4.71	4.45
_junc_50	0.30	0.36	0.36	0.41	**0.49**	0.46	0.38	0.38	0.34	0.29
_junc_59	25.25	41.30	50.97	58.55	61.31	**64.13**	54.18	54.40	50.96	47.28
_junc_64	2.10	2.13	2.00	2.23	**2.38**	2.26	2.04	2.08	1.98	1.89
_junc_68	0.70	0.87	0.91	1.08	**1.26**	1.20	0.94	0.81	0.66	0.58
_junc_69	25.40	41.55	51.35	59.14	62.56	**65.45**	55.80	55.40	52.65	48.78
_junc_71	3.06	3.24	3.05	3.48	**3.85**	3.57	3.12	3.28	3.05	2.81
_junc_74	3.48	3.67	3.62	4.11	**4.55**	4.35	3.66	4.00	3.68	3.37
_junc_76	25.81	42.19	52.16	60.16	64.16	**67.19**	57.67	56.83	54.41	50.41
_junc_80	28.49	45.88	56.73	65.47	70.86	**74.29**	64.68	63.19	61.47	57.11
_junc_81	0.66	0.71	0.77	0.84	**0.99**	0.96	0.88	0.95	0.85	0.79
_junc_84	29.72	48.14	59.72	69.24	75.41	**79.06**	69.39	67.48	66.12	61.50
_junc_85	34.21	57.29	72.98	85.71	93.25	**97.18**	87.35	85.10	83.96	77.95
_junc_86	34.43	57.68	73.48	86.27	94.03	**97.96**	88.27	85.87	84.82	78.76
_junc_88	7.31	13.70	16.81	18.66	18.89	**19.53**	15.82	18.06	15.70	13.96
_junc_91	8.47	16.01	19.82	22.35	22.81	**23.64**	19.50	21.67	19.29	17.30
US_OHH	26.35	43.00	53.28	61.54	66.13	**69.35**	59.79	58.62	56.59	52.42
US_Rail	24.88	40.65	50.01	57.34	59.77	**62.52**	52.51	53.00	49.21	45.69

PEAK DESIGN FLOOD DISCHARGES - 1% AEP

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
1.01	1.01	1.69	1.90	2.10	2.08	**2.21**	1.73	1.80	1.55	1.33
1.02	2.54	3.17	3.43	3.85	4.22	**4.42**	3.46	3.16	2.75	2.38
1.03	5.25	6.68	7.21	8.14	8.82	**9.23**	7.18	6.54	5.62	4.89
1.04	10.15	13.88	14.94	16.74	17.78	**18.64**	14.68	13.17	11.27	9.84
1.05	11.01	15.52	16.92	18.87	19.84	**20.83**	16.45	15.31	13.13	11.46
1.06	11.18	15.82	17.39	19.37	20.35	**21.32**	16.87	15.84	13.55	11.84
1.07	13.79	20.41	23.42	25.95	26.96	**28.07**	22.37	22.18	18.77	16.54
1.08	21.66	34.09	39.01	43.33	44.39	**46.08**	36.58	37.39	31.53	27.66
1.09	22.16	35.00	40.51	45.19	46.24	**47.88**	38.19	39.10	33.16	29.19
1.1	22.38	35.45	41.13	46.04	47.18	**48.91**	39.15	40.00	34.23	30.27
1.11	24.55	39.21	46.68	52.62	54.24	**56.55**	46.10	46.17	40.61	36.22
1.12	24.80	39.65	47.32	53.38	55.07	**57.41**	46.89	46.94	41.38	36.93
1.13	24.94	39.90	47.65	53.79	55.51	**57.87**	47.31	47.37	41.83	37.35
1.14	29.67	47.37	57.25	65.07	67.65	**70.49**	58.97	58.94	54.02	49.77
1.15	30.47	48.74	59.17	67.46	70.35	**73.29**	61.69	61.47	56.81	52.47
1.16	30.81	49.36	59.98	68.55	71.69	**74.65**	63.12	62.75	58.28	53.85
1.17	30.86	49.45	60.12	68.91	72.39	**75.33**	64.04	63.37	59.25	54.77
1.18	30.93	49.59	60.32	69.16	72.88	**75.86**	64.64	63.82	59.89	55.34
1.19	31.17	49.93	60.74	69.70	74.00	**77.16**	65.95	64.77	61.19	56.50
1.2	31.42	50.32	61.22	70.45	74.93	**78.06**	67.00	65.62	62.17	57.46
1.21	33.98	53.74	65.37	75.62	80.96	**84.37**	73.34	71.37	68.58	63.58
1.22	34.67	55.05	67.11	77.76	83.57	**87.16**	76.01	73.82	71.23	66.08
1.23	35.39	56.33	68.81	79.91	86.13	**89.81**	78.70	76.24	73.87	68.51
1.24	35.79	57.07	69.79	81.15	87.57	**91.30**	80.21	77.60	75.35	69.85
1.25	41.42	68.11	85.56	100.10	107.91	**112.04**	101.06	97.98	95.76	88.80
1.26	42.21	69.48	87.37	102.20	110.63	**114.93**	104.16	100.66	98.80	91.62
2.01	0.46	0.53	0.53	0.62	**0.67**	0.66	0.49	0.41	0.32	0.28
2.02	1.75	2.02	2.07	2.44	2.70	**2.71**	2.02	1.70	1.36	1.20
3.01	0.88	1.15	1.22	1.34	**1.57**	1.56	1.23	1.03	0.87	0.76
3.02	3.71	5.40	5.77	6.39	6.72	**7.03**	5.66	4.89	4.20	3.67
3.03	4.71	6.92	7.42	8.24	8.61	**9.03**	7.21	6.35	5.42	4.74
4.01	1.52	2.15	2.30	2.54	2.70	**2.82**	2.27	1.91	1.64	1.43
5.01	1.03	1.62	1.79	2.03	2.00	**2.14**	1.70	1.62	1.40	1.21
5.02	1.87	3.16	3.53	3.93	3.90	**4.16**	3.25	3.44	2.94	2.53
5.03	3.07	4.53	5.22	5.69	5.64	**5.86**	4.71	5.46	4.67	4.00
6.01	1.67	2.83	3.10	3.44	3.43	**3.63**	2.90	2.93	2.52	2.19
6.02	2.35	3.81	4.15	4.66	4.64	**4.94**	3.96	3.87	3.35	2.90
6.03	3.58	5.73	6.24	7.01	7.00	**7.45**	5.98	5.82	5.01	4.36
6.04	6.36	9.68	10.56	11.86	11.95	**12.70**	10.33	9.81	8.51	7.39
6.05	7.37	11.35	12.40	13.88	13.97	**14.88**	12.05	11.50	9.93	8.64
6.06	7.65	12.01	13.23	14.78	14.82	**15.79**	12.78	12.48	10.71	9.34
6.07	8.52	13.84	15.34	17.02	17.07	**18.19**	14.62	14.69	12.48	10.94

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
7.01	0.78	1.30	1.41	1.58	1.57	**1.69**	1.34	1.33	1.15	0.99
8.01	0.61	0.74	0.76	0.91	**1.07**	1.00	0.78	0.67	0.54	0.48
8.02	2.32	3.00	3.28	3.60	**4.17**	4.12	3.29	2.94	2.54	2.21
8.03	2.79	3.97	4.37	4.82	5.30	**5.37**	4.31	3.94	3.45	3.00
9.01	1.00	1.17	1.16	1.37	**1.61**	1.49	1.18	1.02	0.86	0.75
10.01	0.60	1.02	1.13	1.24	1.24	**1.31**	1.05	1.06	0.91	0.78
11.01	0.85	0.91	0.94	1.06	**1.27**	1.18	0.96	1.02	0.89	0.77
11.02	2.03	2.19	2.14	2.55	**3.00**	2.75	2.21	2.12	1.88	1.63
12.01	0.64	0.66	0.58	0.73	**0.86**	0.76	0.62	0.61	0.54	0.46
13.01	0.55	0.59	0.53	0.68	**0.78**	0.70	0.54	0.47	0.38	0.33
14.01	2.29	2.24	1.94	2.42	**2.71**	2.46	1.76	1.65	1.39	1.21
15.01	3.65	3.64	3.11	3.89	**4.38**	3.99	2.87	2.65	2.23	1.95
15.02	4.82	4.76	4.16	5.18	**5.89**	5.33	3.91	3.70	3.25	2.82
15.03	8.78	8.67	7.61	9.37	**10.67**	9.64	7.09	6.76	5.97	5.17
15.04	8.97	8.90	7.82	9.69	**11.07**	10.02	7.46	7.17	6.39	5.54
16.01	3.42	3.25	2.94	3.35	**3.70**	3.42	2.22	2.04	1.66	1.45
17.01	0.26	0.47	0.59	0.64	0.65	**0.67**	0.59	0.67	0.57	0.51
18.01	0.20	0.34	0.39	0.43	0.43	**0.45**	0.35	0.40	0.34	0.29
19.01	1.15	1.24	1.07	1.42	**1.64**	1.45	1.12	0.97	0.79	0.69
19.02	2.05	2.25	2.08	2.64	**3.03**	2.74	2.15	1.85	1.52	1.33
19.03	3.33	3.82	4.11	4.66	**5.55**	5.28	4.16	3.62	3.07	2.68
19.04	3.72	4.52	4.99	5.43	**6.44**	6.29	4.99	4.60	4.10	3.57
19.05	4.11	5.11	5.65	6.13	**7.13**	7.05	5.58	5.23	4.61	4.03
19.06	7.00	9.06	10.08	11.06	12.14	**12.33**	9.83	9.77	8.57	7.41
19.07	8.70	11.42	12.85	14.08	14.87	**15.34**	12.26	13.21	11.61	10.25
19.08	9.00	11.76	13.22	14.46	15.26	**15.72**	12.61	13.56	11.94	10.56
19.09	1.60	2.05	2.34	2.53	2.76	2.91	3.03	3.08	3.14	**3.33**
19.1	2.36	3.10	3.48	3.73	4.02	4.16	4.24	4.23	4.27	**4.55**
19.11	2.66	3.63	4.25	4.74	4.95	5.12	4.98	4.90	5.16	**5.49**
19.12	2.83	3.95	4.69	5.29	5.60	5.81	5.64	5.53	5.84	**6.13**
20.01	0.51	0.58	0.52	0.66	**0.72**	0.63	0.47	0.41	0.31	0.28
21.01	0.55	0.60	0.55	0.71	**0.83**	0.75	0.57	0.49	0.39	0.35
22.01	0.42	0.66	0.73	0.82	0.82	**0.87**	0.70	0.66	0.58	0.50
23.01	0.20	0.26	0.29	0.31	**0.37**	0.36	0.29	0.25	0.21	0.19
24.01	0.46	0.51	0.55	0.61	**0.71**	0.68	0.55	0.54	0.48	0.41
24.02	0.57	0.64	0.68	0.76	**0.89**	0.86	0.68	0.65	0.57	0.49
24.03	1.06	1.20	1.26	1.41	**1.65**	1.59	1.28	1.36	1.19	1.02
24.04	2.52	2.98	3.31	3.61	**4.21**	4.08	3.32	3.21	2.83	2.45
24.05	3.08	3.70	4.14	4.56	**5.14**	5.07	4.14	4.12	3.62	3.12
25.01	0.32	0.38	0.47	0.53	0.52	0.55	0.49	**0.56**	0.47	0.42
26.01	0.59	0.67	0.72	0.80	**0.98**	0.91	0.73	0.62	0.53	0.46
26.02	1.21	1.53	1.68	1.80	**2.16**	2.10	1.68	1.46	1.25	1.09
27.01	0.43	0.61	0.66	0.71	**0.84**	0.83	0.67	0.57	0.49	0.42

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
28.01	0.43	0.48	0.54	0.60	**0.66**	0.64	0.52	0.59	0.51	0.43
29.01	0.17	0.19	0.21	0.24	**0.28**	0.25	0.21	0.20	0.18	0.15
30.01	0.88	0.92	0.90	1.06	**1.27**	1.13	0.94	0.95	0.84	0.73
31.01	0.48	0.50	0.46	0.56	**0.66**	0.59	0.48	0.50	0.44	0.38
31.02	1.24	1.31	1.22	1.45	**1.70**	1.53	1.29	1.45	1.28	1.15
31.03	1.50	1.58	1.76	1.91	2.12	2.12	1.99	**2.12**	2.01	1.90
32.01	0.75	0.75	0.63	0.83	**0.95**	0.84	0.65	0.58	0.49	0.43
33.01	0.58	0.60	0.48	0.65	**0.74**	0.66	0.50	0.44	0.36	0.32
34.01	0.40	0.61	0.68	0.75	0.81	**0.81**	0.68	0.63	0.56	0.48
35.01	0.27	0.32	0.32	0.37	**0.44**	0.41	0.33	0.29	0.24	0.21
35.02	0.93	1.06	0.93	1.22	**1.37**	1.23	0.96	0.84	0.67	0.59
35.03	1.41	1.59	1.48	1.82	**2.09**	1.92	1.53	1.35	1.13	0.99
35.04	1.74	1.96	2.08	2.34	**2.70**	2.59	2.06	1.97	1.73	1.49
35.05	1.78	2.00	2.16	2.41	**2.77**	2.68	2.13	2.04	1.80	1.55
35.06	1.06	1.43	1.60	1.69	1.70	**1.73**	1.60	1.66	1.57	1.48
36.01	0.53	0.57	0.48	0.63	**0.70**	0.62	0.46	0.39	0.31	0.27
37.01	0.20	0.19	0.17	0.21	**0.25**	0.22	0.17	0.15	0.13	0.11
38.01	0.24	0.33	0.36	0.40	**0.43**	0.43	0.35	0.37	0.32	0.28
39.01	0.42	0.73	0.93	1.02	1.07	**1.13**	1.01	1.10	0.97	0.89
40.01	0.28	0.30	0.26	0.34	**0.39**	0.35	0.27	0.24	0.19	0.17
40.02	0.57	0.61	0.55	0.70	**0.79**	0.71	0.57	0.53	0.46	0.40
40.03	1.61	1.66	1.56	1.89	**2.22**	1.96	1.61	1.66	1.46	1.26
40.04	2.39	2.49	2.47	2.89	**3.37**	3.09	2.51	2.50	2.21	1.92
40.05	3.21	3.38	3.53	3.93	**4.45**	4.40	3.53	3.64	3.25	2.88
40.06	3.53	3.71	3.95	4.36	**4.90**	4.88	3.92	4.13	3.69	3.27
41.01	0.61	0.64	0.62	0.74	**0.87**	0.81	0.64	0.56	0.48	0.42
42.01	0.75	0.78	0.77	0.90	**1.09**	0.98	0.81	0.74	0.66	0.56
43.01	0.19	0.20	0.19	0.23	**0.28**	0.24	0.20	0.23	0.20	0.17
44.01	0.24	0.29	0.35	0.40	0.43	**0.47**	0.43	0.45	0.42	0.39
44.02	0.54	0.61	0.72	0.79	**0.87**	0.86	0.78	0.86	0.76	0.70
44.03	0.70	0.92	1.11	1.23	1.24	**1.31**	1.17	1.31	1.13	1.04
44.04	0.99	1.31	1.65	1.83	1.93	**2.03**	1.88	1.96	1.97	1.97
45.01	0.23	0.23	0.22	0.28	**0.32**	0.29	0.23	0.26	0.23	0.20
46.01	0.16	0.24	0.32	0.39	0.45	0.50	0.47	0.44	**0.50**	0.48
47.01	0.14	0.22	0.28	0.31	0.32	**0.34**	0.30	0.32	0.29	0.26
48.01	0.30	0.33	0.35	0.43	0.54	0.60	0.62	0.61	0.63	**0.68**
48.02	0.72	0.90	1.11	1.22	1.29	**1.38**	1.25	1.34	1.32	1.34
49.01	0.40	0.57	0.70	0.76	0.77	**0.81**	0.71	0.80	0.69	0.62
50.01	0.46	0.65	0.81	0.89	0.94	**1.00**	0.90	0.97	0.86	0.80
51.01	0.22	0.23	0.23	0.27	**0.31**	0.28	0.24	0.27	0.24	0.21
52.01	0.79	0.81	0.82	0.92	**1.12**	1.06	1.01	1.04	1.02	0.95
52.02	1.75	1.76	1.51	1.89	**2.12**	1.94	1.43	1.52	1.39	1.29
53.01	0.71	0.72	0.60	0.75	**0.80**	0.75	0.45	0.40	0.30	0.26

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
53.02	2.28	2.22	1.95	2.32	**2.53**	2.34	1.48	1.30	0.99	0.88
53.03	2.95	2.91	2.56	3.00	**3.27**	3.12	2.02	1.77	1.36	1.20
54.01	1.02	1.01	0.88	1.03	**1.10**	1.04	0.62	0.55	0.40	0.36
55.01	0.85	0.84	0.73	0.87	**0.92**	0.86	0.52	0.46	0.34	0.30
56.01	0.72	0.72	0.61	0.76	**0.85**	0.78	0.53	0.49	0.41	0.36
57.01	1.02	1.01	0.88	1.12	**1.34**	1.16	0.94	0.89	0.80	0.68
57.02	1.24	1.24	1.17	1.41	**1.60**	1.55	1.14	1.15	1.01	0.86
57.03	1.46	1.46	1.42	1.67	1.82	**1.85**	1.28	1.34	1.16	1.00
58.01	0.82	1.55	1.92	2.12	2.10	**2.14**	1.82	2.09	1.76	1.56
58.02	1.22	2.03	2.37	2.61	2.61	**2.73**	2.18	2.58	2.20	1.91
58.03	1.53	2.62	3.06	3.37	3.38	**3.53**	2.78	3.24	2.78	2.41
58.04	3.08	5.27	6.07	6.71	6.71	**7.07**	5.58	6.27	5.37	4.65
58.05	4.39	7.54	8.76	9.68	9.67	**10.16**	8.04	9.05	7.77	6.74
58.06	4.41	7.58	8.81	9.72	9.72	**10.21**	8.09	9.09	7.81	6.78
58.07	6.51	10.76	12.46	13.76	13.77	**14.46**	11.61	12.91	11.14	9.78
58.08	1.54	1.58	1.55	1.61	**1.67**	1.63	1.56	1.54	1.51	1.48
58.09	2.83	2.95	2.84	3.16	**3.45**	3.28	2.87	3.05	2.82	2.60
58.1	3.53	3.70	3.60	4.05	**4.47**	4.25	3.64	3.86	3.56	3.25
58.11	3.96	4.27	4.18	4.76	**5.24**	5.06	4.22	4.56	4.16	3.77
59.01	0.77	1.33	1.51	1.66	1.65	**1.72**	1.38	1.55	1.32	1.13
59.02	1.30	2.21	2.52	2.77	2.76	**2.91**	2.31	2.54	2.16	1.86
60.01	0.57	0.87	0.96	1.08	1.07	**1.14**	0.92	0.86	0.75	0.65
60.02	1.20	2.06	2.39	2.64	2.64	**2.77**	2.19	2.46	2.09	1.81
61.01	0.38	0.54	0.59	0.64	**0.74**	0.73	0.59	0.50	0.43	0.38
61.02	1.30	1.76	1.91	2.09	2.38	**2.39**	1.91	1.63	1.41	1.23
61.03	2.04	2.97	3.28	3.61	3.87	**3.99**	3.19	2.87	2.50	2.17
61.04	2.64	3.89	4.30	4.77	4.96	**5.18**	4.18	4.05	3.57	3.14
62.01	0.61	0.82	0.89	0.99	1.06	**1.11**	0.88	0.76	0.66	0.58
63.01	0.30	0.49	0.55	0.61	0.61	**0.64**	0.53	0.51	0.45	0.38
64.01	0.15	0.20	0.21	0.23	0.26	**0.26**	0.21	0.18	0.16	0.14
65.01	0.32	0.36	0.40	0.43	**0.50**	0.48	0.40	0.41	0.35	0.30
65.02	0.57	0.68	0.69	0.78	**0.92**	0.86	0.70	0.65	0.58	0.51
66.01	0.05	0.06	0.05	0.06	**0.06**	0.06	0.04	0.04	0.03	0.02
67.01	0.70	0.70	0.58	0.76	**0.88**	0.78	0.61	0.66	0.58	0.50
68.01	0.35	0.38	0.35	0.43	**0.49**	0.44	0.36	0.40	0.35	0.30
69.01	0.37	0.40	0.33	0.44	**0.50**	0.44	0.35	0.33	0.28	0.24
69.02	0.58	0.59	0.53	0.67	**0.79**	0.70	0.56	0.54	0.48	0.42
70.01	0.58	0.60	0.49	0.65	**0.74**	0.67	0.52	0.58	0.51	0.45
71.01	2.96	2.87	2.52	3.04	**3.40**	3.09	2.16	2.07	1.83	1.58
71.02	3.74	3.74	3.22	4.09	**4.67**	4.19	3.17	3.24	2.91	2.52
72.01	0.71	0.77	0.92	1.00	**1.11**	1.07	0.97	1.09	0.94	0.84
73.01	0.29	0.32	0.30	0.36	**0.42**	0.37	0.33	0.37	0.32	0.29
73.02	0.60	0.64	0.65	0.75	**0.86**	0.83	0.76	0.81	0.72	0.67

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
73.03	1.06	1.16	1.29	1.42	1.58	**1.64**	1.50	1.59	1.46	1.37
74.01	0.15	0.22	0.27	0.29	0.29	**0.31**	0.27	0.30	0.26	0.23
75.01	0.13	0.14	0.16	0.17	**0.21**	0.19	0.16	0.18	0.16	0.14
76.01	0.64	1.13	1.39	1.53	1.53	**1.59**	1.37	1.56	1.33	1.19
77.01	0.55	1.01	1.35	1.54	1.63	**1.73**	1.58	1.60	1.59	1.48
78.01	0.28	0.32	0.28	0.36	**0.39**	0.36	0.26	0.23	0.17	0.15
78.02	5.41	9.76	11.59	12.92	12.94	**13.62**	10.70	12.13	10.31	8.92
78.03	7.15	12.62	14.81	16.35	16.61	**17.24**	13.76	15.52	13.14	11.54
78.04	7.58	13.39	15.79	17.47	17.80	**18.41**	14.72	16.51	14.05	12.38
78.05	7.88	13.89	16.45	18.25	18.60	**19.21**	15.40	17.21	14.72	13.00
78.06	9.42	16.78	20.07	22.31	22.72	**23.44**	18.97	21.37	18.44	16.38
78.07	10.85	19.57	23.80	26.65	27.27	**28.21**	23.17	25.54	22.53	20.15
79.01	0.68	0.83	0.87	1.00	**1.18**	1.13	0.88	0.75	0.62	0.55
79.02	1.32	1.67	1.81	2.01	**2.38**	2.31	1.81	1.57	1.31	1.15
79.03	1.68	2.14	2.34	2.54	**2.98**	2.94	2.33	2.02	1.73	1.51
80.01	0.43	0.51	0.56	0.61	**0.76**	0.72	0.56	0.48	0.41	0.36
81.01	0.17	0.22	0.20	0.25	**0.27**	0.26	0.19	0.16	0.12	0.11
82.01	0.66	0.79	0.71	0.94	**1.04**	0.93	0.71	0.61	0.48	0.42
82.02	1.04	1.20	1.20	1.44	**1.70**	1.58	1.24	1.07	0.89	0.78
82.03	1.66	1.89	2.00	2.33	**2.76**	2.59	2.05	1.79	1.55	1.35
83.01	0.56	0.64	0.66	0.78	**0.93**	0.86	0.68	0.57	0.47	0.42
84.01	0.42	0.45	0.46	0.52	**0.61**	0.57	0.46	0.43	0.38	0.33
84.02	0.98	1.13	1.12	1.29	**1.51**	1.41	1.15	1.05	0.92	0.80
85.01	0.28	0.33	0.31	0.38	**0.44**	0.41	0.32	0.28	0.23	0.20
86.01	0.03	0.03	0.03	0.04	**0.04**	0.04	0.03	0.02	0.02	0.02
86.02	0.43	0.48	0.42	0.53	**0.61**	0.54	0.44	0.40	0.34	0.30
87.01	0.13	0.16	0.17	0.19	**0.22**	0.22	0.17	0.15	0.12	0.11
88.01	0.81	0.87	0.91	1.06	**1.25**	1.15	0.93	0.83	0.71	0.62
88.02	1.17	1.30	1.47	1.60	**1.93**	1.84	1.49	1.34	1.18	1.02
88.03	1.61	2.26	2.58	2.81	2.94	**3.02**	2.47	2.82	2.45	2.14
88.04	2.02	3.01	3.58	3.88	3.87	**4.02**	3.50	4.00	3.51	3.12
89.01	0.45	0.80	0.94	1.03	1.04	**1.06**	0.86	0.99	0.84	0.73
89.02	1.75	2.15	2.65	2.91	2.98	**3.11**	2.77	3.07	2.67	2.45
89.03	3.01	3.18	3.91	4.26	4.31	4.49	4.01	**4.50**	3.91	3.53
90.01	0.39	0.72	0.89	0.98	0.98	**1.02**	0.88	1.01	0.85	0.76
91.01	0.88	0.89	0.76	0.97	**1.13**	0.99	0.78	0.84	0.75	0.64
92.01	1.07	1.08	0.95	1.20	**1.41**	1.24	0.99	0.96	0.86	0.75
92.02	1.60	1.63	1.41	1.80	**2.05**	1.85	1.46	1.56	1.38	1.19
_junc_116	0.99	1.36	1.49	1.63	1.80	**1.84**	1.47	1.25	1.09	0.95
_junc_123	3.66	3.64	3.12	3.94	**4.50**	4.01	3.02	3.08	2.77	2.38
_junc_125	34.99	55.58	67.82	78.67	84.66	**88.28**	77.18	74.85	72.36	67.12
_junc_126	1.12	1.53	1.91	2.11	2.23	**2.37**	2.14	2.29	2.16	2.14
_junc_130	6.95	10.69	11.68	13.10	13.14	**14.01**	11.37	10.87	9.40	8.17

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
_junc_133	2.80	3.10	2.92	3.62	**4.22**	3.85	3.00	2.58	2.13	1.86
_junc_135	0.80	0.89	0.76	1.01	**1.14**	1.00	0.79	0.68	0.55	0.48
_junc_136	1.08	1.23	1.08	1.39	**1.59**	1.45	1.13	0.98	0.80	0.70
_junc_138	8.24	8.00	7.09	8.53	**9.59**	8.75	6.13	5.74	4.91	4.27
_junc_142	2.63	2.78	3.37	3.67	3.73	3.89	3.48	**3.91**	3.38	3.07
_junc_150	6.20	11.01	13.03	14.47	14.55	**15.21**	12.11	13.67	11.61	10.13
_junc_151	2.64	3.15	3.51	3.83	**4.44**	4.32	3.51	3.40	3.00	2.60
_junc_158	0.70	0.85	1.05	1.16	1.22	**1.30**	1.19	1.27	1.26	1.29
_junc_162	0.45	0.67	0.75	0.84	0.86	**0.90**	0.74	0.69	0.60	0.52
_junc_19	1.66	1.82	1.59	2.08	**2.36**	2.08	1.59	1.37	1.10	0.97
_junc_21	21.46	33.72	38.51	42.75	43.81	**45.50**	36.10	36.86	31.05	27.22
_junc_28	6.84	8.76	9.75	10.68	11.80	**11.94**	9.51	9.35	8.22	7.11
_junc_29	2.27	2.66	2.95	3.20	**3.81**	3.69	2.97	2.73	2.43	2.11
_junc_30	0.43	0.48	0.54	0.60	**0.66**	0.64	0.52	0.59	0.51	0.43
_junc_32	0.89	1.00	1.10	1.21	**1.40**	1.34	1.09	1.21	1.05	0.89
_junc_37	2.62	3.56	4.14	4.58	4.81	4.98	4.84	4.76	5.00	**5.33**
_junc_38	24.30	38.76	46.04	51.87	53.43	**55.71**	45.36	45.43	39.88	35.55
_junc_40	2.22	2.30	2.18	2.63	**3.10**	2.77	2.25	2.19	1.95	1.68
_junc_41	2.79	4.83	5.57	6.14	6.14	**6.44**	5.09	5.78	4.93	4.27
_junc_42	2.93	3.12	3.18	3.56	**4.11**	4.03	3.23	3.23	2.85	2.46
_junc_44	2.96	4.18	5.00	5.67	6.05	6.30	6.10	5.96	6.33	**6.59**
_junc_47	4.52	4.83	5.48	5.95	6.56	**6.63**	5.36	6.08	5.46	5.08
_junc_50	0.36	0.42	0.43	0.48	**0.57**	0.54	0.44	0.43	0.38	0.33
_junc_59	30.77	49.30	59.91	68.47	71.58	**74.54**	63.00	62.65	58.17	53.75
_junc_64	2.24	2.28	2.13	2.38	**2.55**	2.40	2.18	2.20	2.09	1.97
_junc_68	0.84	1.05	1.04	1.26	**1.46**	1.38	1.07	0.92	0.75	0.66
_junc_69	30.93	49.59	60.33	69.19	73.02	**76.02**	64.82	63.93	60.11	55.52
_junc_71	3.36	3.54	3.35	3.83	**4.24**	3.93	3.43	3.59	3.31	3.02
_junc_74	3.85	4.14	4.02	4.59	**5.06**	4.86	4.07	4.44	4.04	3.67
_junc_76	31.41	50.29	61.18	70.40	74.86	**77.98**	66.91	65.55	62.08	57.37
_junc_80	34.33	54.41	66.27	76.74	82.32	**85.82**	74.73	72.63	69.92	64.84
_junc_81	0.75	0.84	0.92	1.01	**1.14**	1.13	1.02	1.12	0.97	0.90
_junc_84	35.79	57.07	69.79	81.15	87.57	**91.30**	80.20	77.59	75.34	69.85
_junc_85	41.40	68.08	85.52	100.05	107.85	**111.98**	100.99	97.92	95.70	88.74
_junc_86	41.67	68.50	86.06	100.65	108.70	**112.88**	102.04	98.77	96.67	89.66
_junc_88	9.35	16.64	19.89	22.06	22.44	**23.13**	18.69	21.11	18.15	16.11
_junc_91	10.79	19.43	23.63	26.41	27.00	**27.91**	22.90	25.32	22.28	19.91
US_OHH	32.02	51.23	62.47	72.10	77.09	**80.40**	69.31	67.62	64.56	59.68
US_Rail	30.34	48.47	58.80	67.01	69.77	**72.69**	61.07	60.92	56.18	51.91

PEAK DESIGN FLOOD DISCHARGES - 0.5% AEP

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
1.01	1.18	1.98	2.18	2.39	2.39	**2.54**	2.07	2.03	1.75	1.50
1.02	3.05	3.66	3.94	4.44	4.87	**5.04**	4.00	3.58	3.09	2.68
1.03	6.27	7.71	8.24	9.35	10.14	**10.52**	8.30	7.41	6.31	5.51
1.04	12.16	15.96	17.05	19.19	20.50	**21.28**	16.83	14.89	12.66	11.07
1.05	13.22	17.93	19.35	21.61	22.89	**23.84**	18.96	17.26	14.77	12.91
1.06	13.43	18.28	19.90	22.20	23.48	**24.41**	19.45	17.86	15.23	13.34
1.07	16.54	23.67	26.85	29.81	31.15	**32.17**	25.78	25.09	21.11	18.62
1.08	26.01	39.89	44.82	49.89	51.25	**52.72**	42.08	42.23	35.50	31.16
1.09	26.57	40.93	46.54	51.96	53.40	**54.73**	43.86	44.28	37.32	32.87
1.1	26.84	41.47	47.27	52.96	54.48	**55.95**	44.95	45.36	38.56	34.10
1.11	29.38	45.89	54.15	60.56	62.45	**64.53**	52.77	52.28	45.72	40.77
1.12	29.67	46.46	54.89	61.44	63.40	**65.51**	53.68	53.16	46.59	41.57
1.13	29.83	46.75	55.27	61.92	63.93	**66.05**	54.18	53.65	47.11	42.05
1.14	35.18	55.28	66.25	74.70	77.69	**80.31**	67.38	66.94	60.73	55.84
1.15	36.10	56.90	68.48	77.50	80.83	**83.49**	70.53	69.93	63.88	58.89
1.16	36.48	57.62	69.44	78.88	82.38	**85.07**	72.18	71.40	65.54	60.46
1.17	36.54	57.71	69.59	79.47	83.15	**85.83**	73.28	72.09	66.63	61.53
1.18	36.61	57.86	69.81	79.85	83.69	**86.40**	73.94	72.60	67.37	62.19
1.19	36.87	58.23	70.29	80.61	84.93	**87.81**	75.41	73.72	68.81	63.52
1.2	37.15	58.65	70.84	81.50	85.99	**88.85**	76.59	74.69	69.91	64.58
1.21	39.89	62.37	75.36	87.21	92.53	**95.67**	83.53	80.93	76.97	71.30
1.22	40.71	63.87	77.35	89.72	95.50	**98.83**	86.59	83.71	80.12	74.12
1.23	41.52	65.30	79.37	92.18	98.38	**101.84**	89.63	86.42	83.09	76.84
1.24	42.01	66.12	80.54	93.55	99.98	**103.51**	91.35	87.93	84.73	78.34
1.25	49.06	78.85	98.78	114.78	122.74	**127.56**	114.99	111.03	107.74	99.82
1.26	50.00	80.43	100.81	117.11	125.83	**131.05**	118.59	114.13	111.15	103.00
2.01	0.55	0.62	0.61	0.71	**0.76**	0.75	0.55	0.47	0.36	0.32
2.02	2.09	2.37	2.40	2.83	**3.07**	3.04	2.26	1.92	1.52	1.34
3.01	1.05	1.30	1.39	1.54	**1.81**	1.77	1.39	1.17	0.97	0.85
3.02	4.51	6.17	6.58	7.33	7.77	**8.02**	6.44	5.53	4.72	4.13
3.03	5.67	7.92	8.46	9.46	9.95	**10.32**	8.20	7.16	6.09	5.33
4.01	1.88	2.46	2.61	2.91	3.11	**3.22**	2.57	2.17	1.84	1.61
5.01	1.19	1.90	2.07	2.31	2.30	**2.44**	2.01	1.82	1.58	1.37
5.02	2.23	3.66	4.10	4.51	4.51	**4.78**	3.85	3.86	3.32	2.86
5.03	3.49	5.30	6.01	6.56	6.57	**6.81**	5.52	6.17	5.28	4.52
6.01	2.11	3.25	3.58	3.98	3.95	**4.20**	3.36	3.28	2.83	2.46
6.02	2.94	4.38	4.80	5.37	5.35	**5.70**	4.58	4.35	3.76	3.27
6.03	4.45	6.59	7.24	8.08	8.09	**8.62**	6.91	6.54	5.63	4.91
6.04	7.77	11.21	12.31	13.69	14.04	**14.80**	11.93	11.02	9.55	8.33
6.05	8.99	13.14	14.42	15.99	16.40	**17.31**	13.90	12.92	11.15	9.74
6.06	9.32	13.91	15.40	17.05	17.40	**18.37**	14.75	14.03	12.04	10.53
6.07	10.38	16.07	17.84	19.62	20.04	**21.14**	16.88	16.52	14.03	12.33

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
7.01	0.96	1.49	1.65	1.85	1.83	**1.95**	1.56	1.50	1.29	1.12
8.01	0.69	0.88	0.87	1.07	**1.22**	1.14	0.88	0.75	0.61	0.53
8.02	2.69	3.46	3.79	4.12	**4.84**	4.74	3.78	3.31	2.85	2.49
8.03	3.29	4.60	5.05	5.53	6.16	**6.21**	4.96	4.45	3.87	3.38
9.01	1.16	1.34	1.32	1.58	**1.85**	1.70	1.35	1.15	0.96	0.84
10.01	0.73	1.18	1.29	1.44	1.43	**1.52**	1.22	1.19	1.03	0.89
11.01	0.96	1.06	1.10	1.25	**1.47**	1.37	1.13	1.15	1.01	0.87
11.02	2.30	2.52	2.49	2.94	**3.46**	3.20	2.57	2.38	2.12	1.83
12.01	0.73	0.75	0.69	0.83	**1.00**	0.90	0.72	0.68	0.61	0.52
13.01	0.61	0.68	0.60	0.78	**0.91**	0.80	0.62	0.52	0.43	0.37
14.01	2.55	2.55	2.19	2.73	**3.09**	2.77	2.02	1.87	1.56	1.36
15.01	4.12	4.09	3.51	4.40	**4.97**	4.51	3.27	2.99	2.50	2.18
15.02	5.39	5.38	4.65	5.88	**6.66**	6.06	4.46	4.19	3.65	3.17
15.03	9.83	9.78	8.50	10.68	**12.09**	11.00	8.14	7.70	6.71	5.83
15.04	10.06	10.07	8.74	11.07	**12.59**	11.46	8.60	8.20	7.20	6.24
16.01	3.81	3.62	3.25	3.78	**4.14**	3.85	2.50	2.30	1.85	1.62
17.01	0.32	0.57	0.69	0.75	0.74	**0.78**	0.67	0.76	0.65	0.58
18.01	0.22	0.40	0.46	0.50	0.50	**0.53**	0.41	0.45	0.38	0.33
19.01	1.29	1.44	1.23	1.63	**1.87**	1.65	1.26	1.08	0.88	0.77
19.02	2.30	2.61	2.36	3.06	**3.47**	3.12	2.44	2.08	1.70	1.50
19.03	3.79	4.46	4.71	5.44	**6.40**	6.04	4.76	4.09	3.43	3.01
19.04	4.25	5.26	5.79	6.34	**7.48**	7.24	5.78	5.22	4.61	4.03
19.05	4.73	5.94	6.54	7.13	**8.29**	8.11	6.46	5.91	5.19	4.55
19.06	8.10	10.52	11.70	12.79	14.17	**14.28**	11.42	11.02	9.69	8.38
19.07	9.95	13.28	14.95	16.24	17.38	**17.80**	14.30	14.97	13.16	11.60
19.08	10.28	13.64	15.35	16.64	17.79	**18.20**	14.67	15.34	13.51	11.92
19.09	1.73	2.22	2.52	2.72	2.96	3.12	3.26	3.33	3.37	**3.59**
19.1	2.56	3.34	3.71	3.99	4.30	4.44	4.50	4.50	4.55	**4.86**
19.11	2.90	4.00	4.67	5.20	5.41	5.54	5.39	5.34	5.59	**5.94**
19.12	3.10	4.39	5.23	5.88	6.15	6.33	6.14	6.07	6.37	**6.67**
20.01	0.58	0.67	0.59	0.76	**0.82**	0.72	0.53	0.46	0.35	0.31
21.01	0.62	0.69	0.62	0.84	**0.95**	0.84	0.65	0.55	0.44	0.39
22.01	0.52	0.78	0.85	0.96	0.95	**1.01**	0.82	0.74	0.65	0.56
23.01	0.26	0.30	0.33	0.36	**0.42**	0.41	0.33	0.28	0.24	0.21
24.01	0.53	0.58	0.64	0.70	**0.84**	0.80	0.65	0.61	0.54	0.46
24.02	0.66	0.73	0.79	0.87	**1.04**	1.00	0.80	0.74	0.65	0.56
24.03	1.22	1.37	1.48	1.64	**1.91**	1.87	1.49	1.54	1.35	1.16
24.04	2.92	3.44	3.82	4.18	**4.84**	4.75	3.83	3.61	3.20	2.77
24.05	3.54	4.29	4.80	5.29	**5.95**	5.90	4.79	4.64	4.11	3.53
25.01	0.36	0.45	0.57	0.61	0.61	0.63	0.55	**0.64**	0.55	0.48
26.01	0.67	0.79	0.81	0.95	**1.11**	1.04	0.83	0.71	0.59	0.52
26.02	1.41	1.76	1.91	2.11	**2.48**	2.41	1.91	1.66	1.40	1.22
27.01	0.53	0.70	0.75	0.82	**0.97**	0.96	0.76	0.65	0.55	0.48

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
28.01	0.49	0.55	0.63	0.69	**0.79**	0.76	0.63	0.66	0.58	0.49
29.01	0.19	0.23	0.24	0.27	**0.32**	0.29	0.24	0.22	0.20	0.17
30.01	1.00	1.06	1.03	1.24	**1.45**	1.30	1.08	1.08	0.95	0.82
31.01	0.54	0.57	0.55	0.64	**0.75**	0.69	0.56	0.56	0.50	0.43
31.02	1.41	1.48	1.42	1.66	**1.96**	1.77	1.47	1.67	1.47	1.29
31.03	1.70	1.82	2.06	2.21	**2.48**	2.45	2.29	2.45	2.28	2.15
32.01	0.84	0.85	0.71	0.94	**1.10**	0.96	0.75	0.65	0.55	0.48
33.01	0.66	0.68	0.57	0.74	**0.85**	0.75	0.57	0.50	0.40	0.36
34.01	0.49	0.71	0.79	0.87	0.93	**0.95**	0.78	0.71	0.63	0.55
35.01	0.32	0.36	0.37	0.43	**0.50**	0.47	0.37	0.32	0.27	0.24
35.02	1.10	1.20	1.06	1.38	**1.55**	1.39	1.08	0.93	0.75	0.66
35.03	1.63	1.79	1.70	2.08	**2.39**	2.19	1.75	1.52	1.26	1.11
35.04	2.01	2.22	2.38	2.72	**3.10**	2.98	2.39	2.23	1.95	1.69
35.05	2.06	2.27	2.48	2.80	**3.19**	3.09	2.47	2.32	2.03	1.76
35.06	1.18	1.57	1.75	1.84	1.85	**1.88**	1.75	1.81	1.71	1.62
36.01	0.61	0.64	0.54	0.71	**0.79**	0.70	0.51	0.44	0.34	0.30
37.01	0.22	0.22	0.19	0.24	**0.29**	0.25	0.20	0.18	0.15	0.13
38.01	0.29	0.38	0.43	0.48	0.50	**0.51**	0.42	0.42	0.36	0.31
39.01	0.52	0.87	1.09	1.19	1.23	**1.29**	1.15	1.27	1.10	1.00
40.01	0.31	0.35	0.29	0.38	**0.44**	0.39	0.30	0.26	0.22	0.19
40.02	0.64	0.70	0.63	0.79	**0.90**	0.80	0.65	0.60	0.52	0.45
40.03	1.82	1.90	1.80	2.18	**2.53**	2.26	1.86	1.87	1.65	1.42
40.04	2.70	2.86	2.86	3.33	**3.87**	3.55	2.91	2.82	2.49	2.16
40.05	3.62	3.85	4.08	4.56	**5.13**	5.08	4.09	4.15	3.69	3.26
40.06	4.01	4.24	4.57	5.06	5.64	**5.64**	4.54	4.70	4.18	3.70
41.01	0.68	0.74	0.72	0.85	**1.02**	0.92	0.75	0.64	0.54	0.47
42.01	0.84	0.90	0.89	1.06	**1.25**	1.13	0.93	0.84	0.74	0.64
43.01	0.22	0.23	0.22	0.28	**0.32**	0.29	0.23	0.26	0.23	0.20
44.01	0.29	0.34	0.42	0.48	0.51	**0.54**	0.50	0.53	0.47	0.44
44.02	0.63	0.71	0.84	0.93	**1.00**	0.99	0.89	1.00	0.87	0.78
44.03	0.82	1.06	1.30	1.44	1.44	1.50	1.34	**1.52**	1.30	1.17
44.04	1.15	1.53	1.94	2.13	2.23	**2.34**	2.16	2.30	2.26	2.24
45.01	0.25	0.27	0.25	0.32	**0.36**	0.33	0.27	0.30	0.26	0.22
46.01	0.19	0.29	0.39	0.48	0.53	0.57	0.55	0.52	**0.58**	0.54
47.01	0.16	0.26	0.32	0.36	0.37	**0.39**	0.34	0.38	0.33	0.30
48.01	0.34	0.38	0.42	0.53	0.63	0.69	0.72	0.70	0.72	**0.77**
48.02	0.81	1.06	1.30	1.44	1.52	**1.59**	1.46	1.58	1.50	1.52
49.01	0.45	0.68	0.82	0.88	0.89	**0.92**	0.81	0.92	0.79	0.70
50.01	0.53	0.75	0.94	1.05	1.10	**1.14**	1.03	1.13	0.98	0.90
51.01	0.24	0.26	0.27	0.31	**0.36**	0.32	0.28	0.31	0.27	0.24
52.01	0.88	0.93	0.96	1.07	**1.27**	1.24	1.17	1.23	1.15	1.08
52.02	1.96	1.97	1.68	2.12	**2.39**	2.19	1.66	1.75	1.59	1.46
53.01	0.82	0.80	0.68	0.83	**0.88**	0.83	0.50	0.44	0.33	0.29

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
53.02	2.54	2.48	2.18	2.60	**2.83**	2.61	1.66	1.45	1.10	0.98
53.03	3.30	3.24	2.89	3.36	**3.66**	3.48	2.26	1.97	1.51	1.34
54.01	1.14	1.12	0.97	1.15	**1.22**	1.15	0.69	0.61	0.45	0.40
55.01	0.95	0.94	0.81	0.96	**1.02**	0.96	0.57	0.51	0.38	0.33
56.01	0.81	0.80	0.69	0.86	**0.95**	0.88	0.61	0.55	0.46	0.40
57.01	1.13	1.16	1.01	1.30	**1.51**	1.34	1.07	1.01	0.90	0.78
57.02	1.36	1.39	1.29	1.61	**1.80**	1.76	1.30	1.29	1.13	0.98
57.03	1.59	1.66	1.56	1.91	**2.06**	2.05	1.47	1.51	1.29	1.13
58.01	1.01	1.82	2.23	2.42	2.43	**2.47**	2.06	2.36	2.01	1.76
58.02	1.49	2.36	2.75	2.99	3.01	**3.15**	2.55	2.91	2.51	2.16
58.03	1.90	3.05	3.54	3.86	3.89	**4.07**	3.29	3.67	3.17	2.73
58.04	3.77	6.15	7.07	7.74	7.80	**8.20**	6.56	7.09	6.10	5.26
58.05	5.37	8.83	10.20	11.21	11.27	**11.82**	9.45	10.25	8.81	7.62
58.06	5.39	8.86	10.25	11.27	11.32	**11.88**	9.50	10.29	8.86	7.67
58.07	7.91	12.52	14.48	15.99	16.10	**16.84**	13.56	14.68	12.61	11.06
58.08	1.58	1.62	1.59	1.66	**1.72**	1.68	1.60	1.58	1.54	1.50
58.09	3.04	3.19	3.11	3.42	**3.76**	3.57	3.13	3.29	3.03	2.78
58.1	3.85	4.07	3.97	4.44	**4.90**	4.66	4.02	4.22	3.86	3.50
58.11	4.37	4.69	4.66	5.25	**5.78**	5.59	4.68	5.02	4.55	4.09
59.01	0.93	1.55	1.76	1.93	1.94	**2.03**	1.61	1.75	1.49	1.28
59.02	1.56	2.58	2.93	3.22	3.23	**3.41**	2.69	2.87	2.45	2.10
60.01	0.68	1.02	1.10	1.24	1.23	**1.32**	1.08	0.97	0.84	0.73
60.02	1.47	2.44	2.78	3.07	3.08	**3.24**	2.57	2.79	2.37	2.05
61.01	0.46	0.62	0.67	0.74	**0.85**	0.84	0.67	0.57	0.49	0.43
61.02	1.55	2.02	2.17	2.38	**2.78**	2.75	2.18	1.85	1.58	1.38
61.03	2.43	3.46	3.75	4.14	4.52	**4.60**	3.67	3.24	2.81	2.45
61.04	3.15	4.53	4.97	5.52	5.81	**6.03**	4.85	4.56	4.05	3.55
62.01	0.72	0.95	1.02	1.12	1.25	**1.27**	1.01	0.86	0.74	0.65
63.01	0.35	0.58	0.63	0.71	0.70	**0.74**	0.62	0.57	0.51	0.43
64.01	0.18	0.23	0.24	0.27	0.29	**0.30**	0.24	0.21	0.17	0.15
65.01	0.37	0.41	0.47	0.52	**0.58**	0.57	0.47	0.46	0.40	0.34
65.02	0.67	0.78	0.80	0.89	**1.05**	1.00	0.81	0.74	0.66	0.57
66.01	0.05	0.07	0.06	0.07	**0.07**	0.07	0.05	0.04	0.03	0.03
67.01	0.77	0.79	0.69	0.87	**1.02**	0.90	0.72	0.75	0.66	0.56
68.01	0.40	0.43	0.40	0.49	**0.56**	0.50	0.42	0.45	0.39	0.34
69.01	0.42	0.45	0.38	0.50	**0.57**	0.51	0.40	0.37	0.31	0.27
69.02	0.65	0.69	0.60	0.78	**0.89**	0.79	0.64	0.61	0.54	0.47
70.01	0.68	0.68	0.56	0.74	**0.85**	0.75	0.59	0.67	0.59	0.50
71.01	3.28	3.24	2.82	3.44	**3.85**	3.50	2.47	2.36	2.06	1.78
71.02	4.19	4.26	3.62	4.68	**5.32**	4.79	3.65	3.68	3.30	2.84
72.01	0.81	0.89	1.07	1.17	**1.27**	1.22	1.10	1.25	1.08	0.95
73.01	0.33	0.37	0.35	0.41	**0.47**	0.43	0.38	0.42	0.37	0.33
73.02	0.68	0.73	0.76	0.85	**0.98**	0.95	0.87	0.95	0.82	0.76

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
73.03	1.20	1.34	1.50	1.69	1.81	**1.89**	1.74	1.86	1.65	1.54
74.01	0.18	0.26	0.31	0.34	0.34	**0.35**	0.30	0.35	0.29	0.26
75.01	0.15	0.16	0.18	0.19	**0.24**	0.22	0.18	0.21	0.18	0.16
76.01	0.77	1.33	1.63	1.79	1.79	**1.82**	1.56	1.79	1.50	1.34
77.01	0.66	1.20	1.57	1.79	1.91	**2.03**	1.85	1.90	1.80	1.67
78.01	0.32	0.36	0.33	0.41	**0.44**	0.40	0.29	0.25	0.19	0.17
78.02	6.83	11.59	13.67	15.22	15.34	**16.09**	12.73	13.98	11.84	10.25
78.03	8.78	14.88	17.28	19.03	19.49	**20.19**	16.14	17.83	15.01	13.18
78.04	9.31	15.84	18.39	20.31	20.82	**21.49**	17.22	18.96	16.07	14.12
78.05	9.67	16.47	19.13	21.20	21.74	**22.41**	17.99	19.77	16.83	14.81
78.06	11.47	19.99	23.34	25.92	26.56	**27.30**	22.10	24.54	21.04	18.62
78.07	13.19	23.32	27.73	30.94	31.79	**32.79**	26.90	29.33	25.65	22.86
79.01	0.78	0.98	0.98	1.17	**1.37**	1.29	1.00	0.84	0.70	0.61
79.02	1.54	1.93	2.05	2.36	**2.73**	2.64	2.06	1.76	1.47	1.29
79.03	1.93	2.49	2.68	2.95	**3.43**	3.38	2.68	2.28	1.93	1.69
80.01	0.49	0.59	0.64	0.74	**0.87**	0.82	0.65	0.54	0.46	0.40
81.01	0.21	0.25	0.24	0.28	**0.30**	0.29	0.21	0.18	0.14	0.12
82.01	0.75	0.93	0.85	1.08	**1.18**	1.05	0.80	0.68	0.53	0.47
82.02	1.18	1.38	1.37	1.68	**1.95**	1.81	1.41	1.21	1.00	0.88
82.03	1.89	2.23	2.28	2.74	**3.16**	2.96	2.34	2.04	1.73	1.52
83.01	0.65	0.76	0.74	0.92	**1.06**	0.97	0.77	0.65	0.53	0.47
84.01	0.47	0.52	0.54	0.59	**0.71**	0.67	0.54	0.48	0.43	0.37
84.02	1.16	1.28	1.31	1.47	**1.74**	1.63	1.32	1.18	1.03	0.90
85.01	0.33	0.37	0.36	0.43	**0.50**	0.46	0.36	0.31	0.25	0.22
86.01	0.03	0.04	0.03	0.04	**0.05**	0.04	0.03	0.03	0.02	0.02
86.02	0.52	0.54	0.48	0.60	**0.70**	0.61	0.50	0.45	0.38	0.33
87.01	0.15	0.18	0.19	0.22	0.25	**0.25**	0.20	0.17	0.14	0.12
88.01	0.91	1.03	1.05	1.22	**1.44**	1.33	1.06	0.93	0.80	0.70
88.02	1.32	1.53	1.70	1.84	**2.23**	2.12	1.72	1.53	1.33	1.15
88.03	1.86	2.65	2.97	3.26	3.45	**3.52**	2.90	3.22	2.79	2.42
88.04	2.35	3.58	4.15	4.49	4.53	**4.70**	3.96	4.58	4.00	3.50
89.01	0.56	0.95	1.10	1.20	1.20	**1.23**	1.00	1.12	0.95	0.82
89.02	1.97	2.55	3.12	3.41	3.44	**3.58**	3.14	3.53	3.03	2.76
89.03	3.39	3.78	4.58	4.97	4.98	**5.18**	4.54	5.16	4.47	3.97
90.01	0.49	0.86	1.06	1.15	1.14	**1.18**	1.00	1.15	0.97	0.86
91.01	1.00	1.01	0.88	1.11	**1.31**	1.15	0.93	0.96	0.85	0.73
92.01	1.20	1.22	1.08	1.40	**1.62**	1.44	1.14	1.09	0.97	0.84
92.02	1.83	1.84	1.61	2.03	**2.38**	2.12	1.70	1.78	1.56	1.35
_junc_116	1.18	1.57	1.69	1.86	2.11	**2.11**	1.69	1.43	1.22	1.07
_junc_123	4.09	4.13	3.51	4.50	**5.12**	4.58	3.48	3.50	3.13	2.70
_junc_125	41.06	64.45	78.17	90.76	96.71	**100.08**	87.89	84.85	81.38	75.28
_junc_126	1.27	1.79	2.24	2.49	2.61	**2.73**	2.49	2.68	2.45	2.41
_junc_130	8.48	12.38	13.60	15.11	15.44	**16.31**	13.13	12.21	10.56	9.21

Subcatchment ID	Peak Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min
_junc_133	3.18	3.56	3.30	4.20	**4.84**	4.37	3.41	2.90	2.38	2.09
_junc_135	0.93	1.00	0.86	1.14	**1.30**	1.14	0.89	0.76	0.61	0.54
_junc_136	1.27	1.38	1.23	1.59	**1.82**	1.64	1.28	1.11	0.90	0.79
_junc_138	9.20	9.00	7.90	9.66	**10.80**	9.92	6.96	6.49	5.50	4.79
_junc_142	2.96	3.28	3.95	4.29	4.31	4.48	3.93	**4.49**	3.86	3.45
_junc_150	7.73	12.98	15.29	16.93	17.16	**17.92**	14.29	15.73	13.30	11.60
_junc_151	3.07	3.64	4.05	4.43	**5.10**	5.03	4.05	3.83	3.40	2.93
_junc_158	0.79	1.00	1.23	1.36	1.44	**1.51**	1.39	1.50	1.43	1.46
_junc_162	0.52	0.80	0.87	0.97	0.99	**1.04**	0.86	0.77	0.68	0.59
_junc_19	1.87	2.10	1.82	2.39	**2.69**	2.37	1.79	1.54	1.23	1.08
_junc_21	25.76	39.45	44.23	49.22	50.58	**52.05**	41.52	41.62	34.94	30.66
_junc_28	7.91	10.17	11.29	12.33	13.75	**13.79**	11.04	10.53	9.28	8.04
_junc_29	2.63	3.06	3.39	3.73	**4.39**	4.28	3.41	3.11	2.75	2.38
_junc_30	0.49	0.55	0.63	0.69	**0.79**	0.76	0.63	0.66	0.58	0.49
_junc_32	1.02	1.14	1.29	1.42	**1.63**	1.59	1.28	1.36	1.20	1.02
_junc_37	2.85	3.90	4.51	5.01	5.20	5.37	5.23	5.16	5.41	**5.77**
_junc_38	29.09	45.32	53.41	59.69	61.51	**63.56**	51.92	51.44	44.90	40.02
_junc_40	2.50	2.64	2.52	3.02	**3.55**	3.18	2.61	2.47	2.19	1.90
_junc_41	3.41	5.63	6.46	7.07	7.12	**7.47**	5.98	6.54	5.60	4.83
_junc_42	3.31	3.55	3.68	4.14	**4.73**	4.64	3.74	3.63	3.21	2.77
_junc_44	3.25	4.65	5.61	6.35	6.68	6.90	6.68	6.58	6.93	**7.19**
_junc_47	5.16	5.53	6.37	6.91	7.61	**7.70**	6.22	6.98	6.23	5.73
_junc_50	0.42	0.48	0.51	0.56	**0.66**	0.64	0.52	0.49	0.43	0.37
_junc_59	36.44	57.56	69.36	78.76	82.25	**84.95**	72.06	71.28	65.42	60.35
_junc_64	2.35	2.41	2.28	2.53	**2.74**	2.58	2.32	2.32	2.20	2.07
_junc_68	0.99	1.24	1.18	1.45	**1.67**	1.58	1.21	1.03	0.84	0.74
_junc_69	36.61	57.87	69.83	79.91	83.84	**86.57**	74.15	72.73	67.61	62.40
_junc_71	3.66	3.89	3.69	4.19	**4.64**	4.30	3.77	3.90	3.57	3.25
_junc_74	4.23	4.55	4.49	5.05	**5.57**	5.36	4.51	4.89	4.41	3.97
_junc_76	37.13	58.62	70.80	81.45	85.90	**88.76**	76.49	74.61	69.81	64.49
_junc_80	40.31	63.14	76.39	88.49	94.05	**97.29**	85.11	82.33	78.59	72.71
_junc_81	0.86	0.96	1.07	1.19	**1.31**	1.29	1.17	1.30	1.11	1.01
_junc_84	42.01	66.12	80.54	93.55	99.98	**103.51**	91.34	87.93	84.73	78.33
_junc_85	49.03	78.82	98.74	114.73	122.68	**127.49**	114.91	110.96	107.67	99.75
_junc_86	49.34	79.27	99.31	115.37	123.60	**128.60**	116.13	111.91	108.74	100.77
_junc_88	11.39	19.83	23.13	25.62	26.22	**26.94**	21.77	24.24	20.72	18.32
_junc_91	13.13	23.16	27.55	30.68	31.46	**32.45**	26.58	29.08	25.37	22.60
US_OHH	37.81	59.71	72.26	83.34	88.38	**91.43**	79.19	76.91	72.61	67.09
US_Rail	35.95	56.59	68.07	76.95	80.17	**82.82**	69.83	69.30	63.17	58.25

PEAK DESIGN FLOOD DISCHARGES - PMF

Subcatchment ID	Peak Discharge (m^3/s)										
	15 min	30 min	45 min	60 min	90 min	120 min	150 min	180 min	240 min	300 min	360 min
1.01	8.21	10.42	**10.45**	9.76	8.96	8.16	7.18	6.63	5.79	5.17	4.67
1.02	17.02	**18.36**	18.17	17.17	15.64	14.14	12.45	11.44	10.00	9.05	8.24
1.03	36.84	**39.05**	37.88	35.80	32.51	29.27	25.80	23.67	20.83	18.87	17.13
1.04	74.08	**80.43**	77.83	72.29	65.22	58.33	51.40	47.39	41.90	37.90	34.30
1.05	82.38	**93.02**	90.87	85.26	77.45	69.59	61.65	56.54	49.76	44.87	40.71
1.06	83.95	**95.71**	94.27	88.36	80.43	72.31	64.13	58.86	51.76	46.66	42.30
1.07	105.40	129.72	**133.23**	125.01	115.52	104.28	93.14	85.50	74.81	67.16	60.71
1.08	171.64	222.89	**228.61**	214.57	198.83	179.14	160.55	147.31	128.74	115.59	104.00
1.09	174.91	228.88	**238.95**	226.49	209.61	190.21	170.40	156.76	136.87	122.80	110.38
1.1	177.34	232.92	**245.47**	233.96	217.51	197.70	177.43	163.53	142.53	127.73	114.91
1.11	190.48	255.17	**281.88**	278.39	261.15	240.00	214.18	198.81	173.02	154.74	138.92
1.12	192.21	258.11	**285.82**	283.21	266.11	244.68	218.45	202.84	176.62	157.91	141.77
1.13	193.28	259.80	**288.25**	286.10	269.11	247.53	221.06	205.29	178.79	159.81	143.48
1.14	217.89	298.53	345.93	**352.55**	338.48	314.11	284.20	263.70	231.52	206.00	185.22
1.15	222.38	306.43	358.02	**367.63**	356.24	331.42	299.85	278.88	245.12	218.04	195.93
1.16	224.73	310.32	363.80	**375.35**	365.62	340.63	307.93	286.89	252.27	224.37	201.56
1.17	224.83	310.57	364.62	**378.61**	371.47	346.76	313.02	292.56	257.22	228.81	205.50
1.18	225.07	310.93	365.43	**380.62**	375.02	350.52	316.62	296.34	260.32	231.74	208.11
1.19	225.78	312.09	367.45	**385.16**	382.90	358.75	324.67	304.63	267.24	238.21	213.85
1.2	226.62	313.53	370.20	**389.80**	389.04	364.94	330.08	310.16	272.22	242.64	217.79
1.21	232.97	322.88	385.80	412.33	**420.49**	396.28	359.86	339.74	298.72	266.16	238.85
1.22	237.24	329.44	395.83	425.20	**437.75**	413.36	375.98	355.04	312.49	278.59	249.91
1.23	240.79	334.68	403.98	436.61	**453.47**	429.54	391.64	369.51	325.72	290.69	260.66
1.24	242.80	337.68	408.23	442.65	**461.80**	438.20	400.04	377.27	332.85	297.22	266.47
1.25	269.82	392.09	499.72	561.69	**595.26**	567.09	522.82	490.29	434.50	387.24	346.48
1.26	273.21	397.74	509.00	573.57	**613.91**	587.10	542.21	508.16	451.12	402.56	360.10
2.01	**2.78**	2.56	2.34	2.08	1.81	1.62	1.45	1.36	1.20	1.07	0.96
2.02	**11.38**	10.67	9.88	8.93	7.71	6.90	6.16	5.74	5.10	4.56	4.08
3.01	5.97	**6.24**	6.10	5.48	4.84	4.28	3.79	3.53	3.13	2.84	2.55
3.02	28.24	**30.52**	29.49	27.03	24.13	21.31	18.89	17.50	15.46	13.96	12.61
3.03	35.83	**39.75**	38.33	35.01	31.46	27.87	24.71	22.87	20.18	18.19	16.41
4.01	11.11	**11.74**	11.42	10.35	9.22	8.14	7.21	6.71	5.93	5.36	4.83
5.01	8.60	**10.24**	9.89	9.33	8.37	7.48	6.61	6.07	5.34	4.78	4.32
5.02	16.21	**20.73**	20.50	19.38	17.83	16.27	14.41	13.17	11.50	10.28	9.28
5.03	21.51	31.43	**33.26**	31.83	29.97	27.14	24.47	22.41	19.41	17.28	15.49
6.01	14.69	**18.23**	17.79	16.82	15.17	13.70	12.09	11.09	9.73	8.70	7.87
6.02	20.39	**24.47**	23.74	22.41	20.19	18.17	16.04	14.73	12.94	11.60	10.50
6.03	31.14	**37.18**	36.02	33.92	30.74	27.67	24.46	22.47	19.72	17.69	15.99
6.04	54.29	**64.04**	61.88	58.34	52.73	47.35	41.88	38.50	33.75	30.29	27.41
6.05	63.76	**75.32**	72.78	68.51	62.15	55.87	49.44	45.46	39.83	35.77	32.33
6.06	66.80	**80.79**	79.01	74.57	67.82	61.07	54.18	49.77	43.54	39.09	35.30
6.07	74.97	**93.57**	92.98	88.09	80.48	72.67	64.54	59.25	51.74	46.43	41.87
7.01	7.18	**8.72**	8.41	7.94	7.17	6.44	5.70	5.24	4.59	4.11	3.69
8.01	3.95	**4.17**	3.98	3.58	3.13	2.78	2.47	2.28	2.06	1.85	1.66
8.02	17.26	**19.37**	18.65	17.48	15.61	13.84	12.26	11.30	9.90	9.02	8.14
8.03	23.16	**26.61**	25.42	24.02	21.67	19.34	17.12	15.76	13.79	12.47	11.26

Subcatchment ID	Peak Discharge (m^3/s)										
	15 min	30 min	45 min	60 min	90 min	120 min	150 min	180 min	240 min	300 min	360 min
9.01	6.13	**6.62**	6.48	5.93	5.22	4.61	4.09	3.78	3.37	3.06	2.74
10.01	6.06	**7.27**	7.02	6.57	6.00	5.40	4.78	4.40	3.84	3.45	3.09
11.01	4.85	6.45	**6.52**	6.30	6.02	5.41	4.84	4.44	3.83	3.42	3.05
11.02	11.97	**13.81**	13.71	13.13	12.34	11.12	9.91	9.07	7.84	7.00	6.38
12.01	3.32	3.90	**3.95**	3.78	3.55	3.20	2.84	2.60	2.26	2.01	1.83
13.01	**3.23**	3.19	3.06	2.70	2.38	2.10	1.87	1.75	1.57	1.42	1.26
14.01	**10.26**	10.07	10.08	9.85	8.93	7.97	7.07	6.48	5.59	5.14	4.65
15.01	**16.24**	16.20	16.15	15.76	14.15	12.65	11.19	10.26	8.88	8.19	7.37
15.02	21.58	22.63	**22.84**	22.06	20.76	18.54	16.55	15.14	13.08	11.68	10.66
15.03	38.81	40.21	**40.46**	39.41	37.85	33.94	30.42	27.88	24.05	21.36	19.49
15.04	40.22	43.03	**43.47**	42.19	40.59	36.48	32.72	30.00	25.88	22.98	20.90
16.01	**15.88**	12.12	11.90	11.48	10.44	9.25	8.21	7.52	6.59	6.10	5.48
17.01	2.31	3.49	**3.98**	3.91	3.75	3.52	3.15	2.93	2.54	2.24	2.01
18.01	1.76	2.38	**2.40**	2.28	2.12	1.93	1.71	1.56	1.36	1.22	1.10
19.01	6.16	**6.33**	6.14	5.52	4.85	4.27	3.80	3.53	3.19	2.88	2.56
19.02	**12.45**	12.41	11.91	10.66	9.48	8.35	7.44	6.91	6.24	5.61	5.00
19.03	23.90	**24.71**	23.69	21.68	19.37	17.09	15.19	14.05	12.55	11.38	10.16
19.04	28.55	**31.15**	30.12	28.58	26.27	23.90	21.43	19.70	16.92	15.20	13.85
19.05	31.66	**35.26**	34.32	32.41	29.63	27.02	24.28	22.32	19.18	17.27	15.70
19.06	56.48	**64.81**	63.30	59.91	55.86	50.97	45.80	42.08	36.20	32.42	29.33
19.07	67.32	81.32	**82.42**	78.25	75.17	69.33	63.17	59.09	51.67	45.96	40.73
19.08	68.12	82.28	**83.44**	79.26	76.17	70.29	64.08	60.00	52.55	46.80	41.55
19.09	4.15	5.15	5.98	6.47	7.34	7.89	8.19	8.51	8.95	9.24	**9.32**
19.1	6.38	8.56	10.18	10.98	12.03	**12.22**	12.07	12.04	11.97	11.93	11.75
19.11	10.57	16.06	18.18	18.80	**19.28**	18.75	17.93	17.54	16.66	15.92	15.14
19.12	12.25	18.99	22.19	23.28	**24.02**	23.33	22.10	21.53	20.15	18.98	17.84
20.01	**3.15**	2.88	2.55	2.25	1.96	1.75	1.61	1.51	1.32	1.17	1.04
21.01	**3.43**	3.34	3.16	2.81	2.45	2.17	1.94	1.82	1.63	1.47	1.30
22.01	4.07	**4.64**	4.39	4.11	3.71	3.30	2.93	2.70	2.37	2.14	1.93
23.01	1.67	**1.73**	1.66	1.51	1.34	1.18	1.05	0.98	0.87	0.79	0.70
24.01	2.91	**3.56**	3.55	3.38	3.09	2.80	2.48	2.28	1.98	1.77	1.61
24.02	3.77	**4.31**	4.25	4.08	3.71	3.36	2.98	2.73	2.37	2.14	1.94
24.03	7.15	8.47	**8.60**	8.27	8.02	7.23	6.56	6.04	5.19	4.62	4.12
24.04	18.52	**21.19**	20.73	19.75	18.53	16.80	15.08	13.85	11.91	10.66	9.66
24.05	23.01	**26.98**	26.56	25.19	23.85	21.60	19.39	17.79	15.33	13.72	12.36
25.01	2.28	3.22	**3.61**	3.48	3.42	3.16	2.85	2.65	2.28	2.02	1.80
26.01	3.94	**4.22**	4.10	3.76	3.33	2.93	2.61	2.41	2.15	1.95	1.74
26.02	9.34	**10.03**	9.70	8.90	7.94	7.00	6.24	5.77	5.10	4.63	4.14
27.01	3.66	**3.92**	3.77	3.46	3.08	2.71	2.42	2.24	1.98	1.80	1.61
28.01	2.80	3.62	**3.77**	3.61	3.45	3.11	2.79	2.56	2.21	1.97	1.76
29.01	1.10	**1.34**	1.31	1.26	1.13	1.01	0.89	0.82	0.71	0.65	0.58
30.01	4.75	5.99	**6.08**	5.88	5.62	5.05	4.52	4.14	3.58	3.19	2.86
31.01	2.59	3.22	**3.24**	3.11	2.94	2.66	2.36	2.16	1.87	1.67	1.51
31.02	6.61	8.24	**9.38**	9.17	9.14	8.70	7.80	7.26	6.32	5.58	4.94
31.03	9.08	11.81	14.08	14.57	**14.61**	14.06	13.12	12.25	10.79	9.64	8.50
32.01	3.61	**3.78**	3.77	3.52	3.12	2.75	2.44	2.24	1.99	1.83	1.64
33.01	2.87	**2.90**	2.85	2.59	2.27	2.00	1.78	1.64	1.48	1.34	1.20
34.01	3.62	**4.36**	4.21	3.96	3.59	3.21	2.84	2.62	2.29	2.06	1.86

Subcatchment ID	Peak Discharge (m^3/s)										
	15 min	30 min	45 min	60 min	90 min	120 min	150 min	180 min	240 min	300 min	360 min
35.01	1.89	**1.97**	1.90	1.72	1.53	1.35	1.20	1.11	0.99	0.90	0.80
35.02	**5.85**	5.63	5.35	4.77	4.21	3.72	3.32	3.11	2.78	2.50	2.23
35.03	9.04	**9.11**	8.68	7.94	7.13	6.28	5.58	5.15	4.62	4.18	3.74
35.04	12.06	**13.17**	12.78	11.99	11.02	10.07	8.98	8.23	7.12	6.48	5.85
35.05	12.46	**13.75**	13.35	12.53	11.52	10.53	9.39	8.61	7.45	6.77	6.11
35.06	4.23	5.11	**5.24**	5.09	5.08	5.01	4.90	4.84	4.71	4.57	4.39
36.01	**2.86**	2.69	2.48	2.20	1.91	1.70	1.54	1.46	1.28	1.15	1.01
37.01	0.90	0.98	**0.99**	0.93	0.83	0.74	0.65	0.60	0.52	0.48	0.43
38.01	2.02	**2.52**	2.46	2.34	2.13	1.93	1.70	1.57	1.36	1.22	1.11
39.01	3.97	6.37	**7.26**	7.23	7.00	6.64	5.94	5.58	4.83	4.28	3.79
40.01	1.45	**1.52**	1.50	1.38	1.21	1.07	0.94	0.87	0.78	0.71	0.63
40.02	3.11	**3.46**	3.40	3.25	2.94	2.65	2.35	2.15	1.87	1.71	1.54
40.03	8.33	10.35	**10.54**	10.06	9.80	8.82	7.93	7.27	6.26	5.58	4.97
40.04	13.43	**16.05**	15.99	15.23	14.54	13.18	11.81	10.83	9.33	8.33	7.51
40.05	18.35	22.74	**23.31**	22.25	21.54	19.65	17.85	16.61	14.54	12.88	11.37
40.06	20.14	25.51	**26.52**	25.37	24.53	22.34	20.37	18.99	16.60	14.69	12.97
41.01	3.45	**3.74**	3.69	3.47	3.08	2.72	2.41	2.22	1.95	1.79	1.61
42.01	3.85	**4.61**	4.60	4.42	4.01	3.62	3.20	2.93	2.55	2.30	2.09
43.01	1.03	1.31	**1.47**	1.41	1.40	1.29	1.16	1.08	0.93	0.82	0.73
44.01	1.69	2.58	3.03	**3.14**	3.09	2.95	2.68	2.50	2.18	1.93	1.71
44.02	3.70	5.06	**5.71**	5.63	5.51	5.24	4.73	4.43	3.85	3.40	3.02
44.03	5.57	7.81	**8.68**	8.45	8.24	7.78	6.99	6.56	5.68	5.02	4.45
44.04	7.65	11.31	13.29	13.89	**14.28**	13.79	12.92	12.49	11.31	10.22	9.18
45.01	1.21	1.54	**1.69**	1.62	1.60	1.45	1.31	1.21	1.04	0.92	0.82
46.01	1.24	2.20	2.88	3.17	**3.43**	3.29	3.07	2.95	2.62	2.37	2.12
47.01	1.09	1.74	**2.04**	2.02	1.93	1.83	1.63	1.52	1.32	1.17	1.05
48.01	1.53	2.33	3.14	3.73	4.52	**4.78**	4.52	4.36	4.06	3.73	3.34
48.02	4.41	6.83	8.08	8.40	**8.69**	8.49	8.06	7.74	7.24	6.50	5.90
49.01	2.71	4.13	**4.77**	4.68	4.52	4.25	3.79	3.53	3.06	2.70	2.42
50.01	3.03	4.89	5.81	**5.94**	5.74	5.50	4.93	4.58	4.00	3.52	3.15
51.01	1.05	1.41	**1.64**	1.60	1.58	1.48	1.32	1.23	1.06	0.93	0.83
52.01	3.67	4.85	6.19	6.69	**6.70**	6.49	6.05	5.61	4.96	4.38	3.90
52.02	7.05	7.58	8.46	8.93	**9.00**	8.78	8.19	7.60	6.71	5.93	5.27
53.01	**2.83**	2.46	2.21	1.94	1.70	1.58	1.42	1.31	1.14	1.00	0.89
53.02	**9.01**	7.81	7.17	6.48	5.58	5.05	4.60	4.32	3.79	3.36	2.99
53.03	**12.15**	10.54	9.64	8.86	7.65	6.84	6.25	5.85	5.16	4.59	4.10
54.01	**4.00**	3.42	3.04	2.67	2.42	2.20	1.97	1.81	1.57	1.38	1.22
55.01	**3.34**	2.88	2.53	2.22	2.03	1.84	1.64	1.51	1.31	1.15	1.02
56.01	**2.83**	2.73	2.80	2.69	2.36	2.11	1.86	1.70	1.50	1.38	1.25
57.01	4.27	4.99	**5.18**	5.04	4.81	4.32	3.86	3.52	3.05	2.71	2.46
57.02	5.50	6.27	**6.64**	6.39	6.00	5.48	4.94	4.52	3.92	3.47	3.14
57.03	6.53	7.09	**7.57**	7.37	6.90	6.36	5.73	5.27	4.56	4.04	3.66
58.01	7.60	11.45	**12.51**	12.00	11.47	10.49	9.50	8.74	7.56	6.69	6.01
58.02	10.49	14.24	**15.30**	14.68	14.05	12.80	11.63	10.70	9.24	8.18	7.34
58.03	13.54	18.20	**19.28**	18.52	17.62	16.07	14.59	13.44	11.61	10.28	9.24
58.04	26.70	35.93	**37.17**	35.51	33.52	30.59	27.59	25.34	21.93	19.48	17.55
58.05	38.15	51.92	**53.77**	51.47	48.50	44.34	39.97	36.73	31.81	28.26	25.46
58.06	38.28	52.10	**54.01**	51.73	48.75	44.58	40.18	36.93	31.99	28.42	25.60

Subcatchment ID	Peak Discharge (m^3/s)										
	15 min	30 min	45 min	60 min	90 min	120 min	150 min	180 min	240 min	300 min	360 min
58.07	51.94	71.74	**75.99**	73.15	68.96	63.88	57.64	53.37	46.24	40.92	36.85
58.08	2.60	**2.91**	2.90	2.85	2.68	2.53	2.38	2.29	2.16	2.08	2.00
58.09	8.98	11.13	**11.73**	11.47	11.13	10.16	9.29	8.62	7.63	6.90	6.32
58.1	12.63	15.76	**16.65**	16.21	15.71	14.35	13.08	12.13	10.66	9.58	8.71
58.11	15.38	19.30	**20.67**	20.20	19.52	18.10	16.44	15.27	13.38	11.96	10.85
59.01	6.49	9.02	**9.22**	8.78	8.21	7.46	6.64	6.06	5.28	4.70	4.23
59.02	10.89	14.95	**15.12**	14.34	13.37	12.17	10.83	9.90	8.63	7.69	6.92
60.01	4.52	**5.47**	5.26	4.98	4.45	3.97	3.51	3.23	2.84	2.55	2.31
60.02	10.43	14.34	**14.64**	13.89	13.08	11.91	10.70	9.79	8.48	7.56	6.81
61.01	2.86	**3.20**	3.07	2.87	2.54	2.25	2.00	1.84	1.62	1.47	1.33
61.02	9.24	**10.37**	9.96	9.30	8.21	7.26	6.45	5.95	5.25	4.78	4.30
61.03	15.70	**18.23**	17.46	16.48	14.75	13.14	11.64	10.71	9.43	8.52	7.70
61.04	20.58	**24.86**	24.21	23.00	21.16	19.27	17.46	16.18	14.13	12.42	11.14
62.01	4.27	**4.87**	4.64	4.35	3.85	3.41	3.02	2.79	2.46	2.24	2.01
63.01	2.56	**3.18**	3.12	2.95	2.67	2.41	2.13	1.95	1.71	1.53	1.38
64.01	1.06	**1.16**	1.12	1.03	0.91	0.80	0.71	0.66	0.58	0.53	0.47
65.01	1.85	**2.46**	2.46	2.36	2.14	1.94	1.71	1.57	1.37	1.22	1.11
65.02	3.40	**4.07**	4.00	3.85	3.45	3.13	2.76	2.52	2.20	1.99	1.81
66.01	**0.28**	0.24	0.22	0.19	0.17	0.15	0.14	0.13	0.11	0.10	0.09
67.01	2.89	3.58	**3.85**	3.77	3.64	3.30	2.97	2.72	2.35	2.08	1.87
68.01	1.63	2.16	**2.39**	2.31	2.23	2.02	1.82	1.67	1.44	1.28	1.14
69.01	1.62	1.89	**1.89**	1.85	1.64	1.48	1.30	1.19	1.04	0.95	0.86
69.02	2.59	3.10	**3.17**	3.08	2.93	2.64	2.36	2.16	1.86	1.65	1.50
70.01	2.45	3.00	**3.40**	3.35	3.33	3.15	2.80	2.61	2.26	1.99	1.78
71.01	**11.97**	11.04	11.43	11.33	11.06	9.98	8.93	8.18	7.06	6.23	5.58
71.02	15.29	17.28	**18.81**	18.48	18.09	16.59	14.86	13.69	11.83	10.43	9.33
72.01	3.75	5.51	**6.41**	6.32	6.16	5.82	5.17	4.81	4.17	3.68	3.29
73.01	1.38	1.86	**2.22**	2.18	2.14	2.02	1.79	1.67	1.45	1.28	1.14
73.02	2.97	4.17	4.97	**5.03**	4.88	4.68	4.20	3.91	3.41	3.00	2.68
73.03	5.62	8.22	9.74	**9.99**	9.77	9.37	8.53	7.89	6.98	6.14	5.46
74.01	1.10	1.65	**1.85**	1.77	1.71	1.56	1.41	1.30	1.12	0.99	0.89
75.01	0.65	0.94	**1.08**	1.04	1.03	0.95	0.85	0.79	0.68	0.60	0.54
76.01	5.35	8.45	**9.37**	9.07	8.72	8.05	7.26	6.70	5.80	5.14	4.60
77.01	4.52	8.00	9.83	**10.21**	10.12	9.60	8.88	8.25	7.35	6.48	5.78
78.01	**1.51**	1.44	1.30	1.16	0.99	0.89	0.81	0.76	0.67	0.59	0.53
78.02	51.92	72.79	**77.72**	75.02	70.76	65.61	59.00	54.63	47.22	41.58	37.28
78.03	60.62	87.74	**95.56**	93.26	88.27	82.51	73.97	68.72	59.52	52.38	46.93
78.04	63.18	92.14	**101.07**	99.23	93.98	87.74	78.80	73.22	63.56	55.92	50.11
78.05	65.08	95.11	**105.06**	103.53	98.29	91.55	82.39	76.54	66.55	58.56	52.47
78.06	77.08	114.90	**128.73**	128.25	122.42	114.26	102.84	95.74	83.46	73.47	65.77
78.07	88.92	133.46	152.43	**153.22**	148.32	138.54	125.75	116.55	102.14	89.96	80.51
79.01	4.32	**4.67**	4.51	4.09	3.59	3.18	2.83	2.61	2.34	2.11	1.89
79.02	9.18	**9.83**	9.41	8.59	7.62	6.74	5.99	5.52	4.94	4.45	4.00
79.03	11.70	**12.72**	12.21	11.27	10.04	8.89	7.88	7.26	6.46	5.83	5.27
80.01	2.80	**3.02**	2.94	2.69	2.37	2.09	1.86	1.71	1.53	1.39	1.25
81.01	**1.10**	1.03	0.93	0.83	0.71	0.64	0.58	0.54	0.48	0.43	0.38
82.01	**3.86**	3.78	3.53	3.17	2.73	2.43	2.17	2.05	1.82	1.62	1.45
82.02	6.38	**6.63**	6.39	5.85	5.20	4.59	4.06	3.74	3.36	3.04	2.74

Subcatchment ID	Peak Discharge (m^3/s)										
	15 min	30 min	45 min	60 min	90 min	120 min	150 min	180 min	240 min	300 min	360 min
82.03	10.37	**11.03**	10.71	9.97	8.92	8.09	7.21	6.61	5.70	5.24	4.77
83.01	3.34	**3.55**	3.46	3.13	2.74	2.43	2.16	1.99	1.78	1.61	1.45
84.01	2.14	**2.68**	2.63	2.54	2.26	2.02	1.79	1.64	1.43	1.30	1.18
84.02	5.56	**6.51**	6.35	6.11	5.43	4.87	4.29	3.94	3.44	3.14	2.85
85.01	1.64	**1.72**	1.66	1.49	1.31	1.16	1.03	0.95	0.86	0.77	0.69
86.01	**0.17**	0.16	0.14	0.13	0.11	0.10	0.09	0.08	0.07	0.06	0.06
86.02	2.11	**2.36**	2.32	2.25	2.00	1.78	1.57	1.44	1.26	1.15	1.04
87.01	0.87	**0.93**	0.89	0.81	0.72	0.64	0.56	0.52	0.46	0.42	0.38
88.01	4.22	**5.00**	4.85	4.69	4.14	3.69	3.26	2.99	2.63	2.40	2.17
88.02	6.77	**8.27**	8.10	7.78	6.94	6.20	5.48	5.02	4.40	3.99	3.62
88.03	11.36	15.62	**16.58**	16.09	15.54	14.43	12.97	12.06	10.46	9.20	8.23
88.04	15.01	21.83	**23.98**	23.44	22.61	21.28	19.10	17.85	15.54	13.67	12.21
89.01	3.84	5.64	**5.89**	5.63	5.32	4.82	4.31	3.94	3.42	3.04	2.74
89.02	9.44	15.64	17.94	**18.31**	17.68	16.64	14.99	13.94	12.25	10.77	9.62
89.03	14.60	22.64	26.25	**26.40**	25.46	24.03	21.52	20.10	17.56	15.45	13.81
90.01	3.39	5.43	**6.01**	5.81	5.60	5.18	4.66	4.30	3.72	3.29	2.95
91.01	3.68	4.40	**4.89**	4.76	4.67	4.28	3.83	3.53	3.05	2.69	2.41
92.01	4.56	5.41	**5.61**	5.47	5.21	4.69	4.19	3.82	3.31	2.94	2.67
92.02	6.94	8.49	**9.11**	8.85	8.66	7.87	7.07	6.50	5.61	4.96	4.44
_junc_116	7.12	**8.07**	7.70	7.23	6.39	5.66	5.02	4.63	4.08	3.71	3.34
_junc_123	14.66	16.25	**17.80**	17.48	17.16	15.79	14.10	12.99	11.22	9.90	8.85
_junc_125	238.35	331.11	398.84	429.70	**444.24**	420.04	382.48	361.09	318.03	283.65	254.40
_junc_126	7.41	11.72	13.90	**14.29**	14.05	13.54	12.75	12.20	11.06	9.91	9.00
_junc_130	59.92	**71.10**	68.75	64.75	58.67	52.73	46.66	42.90	37.58	33.74	30.50
_junc_133	**17.53**	17.38	16.57	14.91	13.26	11.70	10.42	9.67	8.73	7.87	7.00
_junc_135	**4.71**	4.57	4.38	3.89	3.43	3.03	2.70	2.53	2.26	2.04	1.81
_junc_136	**6.73**	6.61	6.31	5.65	5.04	4.43	3.94	3.66	3.30	2.98	2.65
_junc_138	**36.15**	33.69	33.59	32.96	31.07	27.79	24.76	22.66	19.56	17.65	16.10
_junc_142	12.30	19.51	22.65	**22.90**	22.11	20.92	18.75	17.47	15.28	13.44	12.01
_junc_150	55.90	79.59	**85.95**	83.41	78.79	73.50	65.92	61.17	52.92	46.58	41.74
_junc_151	19.59	**22.48**	21.98	20.94	19.64	17.80	15.98	14.66	12.62	11.30	10.23
_junc_158	4.19	6.44	7.64	7.98	**8.33**	8.18	7.76	7.43	6.98	6.27	5.69
_junc_162	3.61	**4.31**	4.20	3.97	3.58	3.21	2.83	2.60	2.28	2.04	1.86
_junc_19	**9.27**	9.03	8.66	7.71	6.78	5.98	5.33	5.04	4.51	4.05	3.60
_junc_21	169.77	219.86	**224.98**	210.92	195.38	175.95	157.66	144.59	126.39	113.49	102.14
_junc_28	54.60	**62.21**	60.52	57.30	53.29	48.62	43.66	40.11	34.50	30.93	28.02
_junc_29	16.50	**18.34**	17.78	16.98	15.65	14.19	12.70	11.65	10.03	9.01	8.21
_junc_30	2.80	3.62	**3.77**	3.61	3.45	3.11	2.79	2.56	2.21	1.97	1.76
_junc_32	5.99	7.42	**7.67**	7.35	7.12	6.42	5.83	5.36	4.61	4.10	3.66
_junc_37	9.84	14.85	16.95	17.63	**18.22**	17.71	17.02	16.62	15.86	15.22	14.51
_junc_38	188.75	252.20	**277.79**	273.72	256.51	235.63	210.10	195.07	169.72	151.82	136.31
_junc_40	11.78	**14.02**	13.92	13.32	12.78	11.53	10.32	9.45	8.14	7.27	6.56
_junc_41	24.39	33.02	**34.23**	32.69	30.90	28.15	25.41	23.32	20.17	17.92	16.13
_junc_42	17.07	**20.51**	20.41	19.36	18.52	16.76	15.00	13.74	11.86	10.59	9.55
_junc_44	13.43	21.13	25.07	26.44	**27.45**	26.62	25.13	24.42	22.69	21.22	19.81
_junc_47	27.76	36.78	**39.42**	38.61	37.74	35.79	32.90	30.99	27.62	24.91	22.16
_junc_50	2.09	**2.66**	2.64	2.54	2.29	2.08	1.84	1.68	1.47	1.31	1.20
_junc_59	224.56	310.06	363.41	**374.81**	364.96	339.97	307.36	286.31	251.76	223.92	201.16

Subcatchment ID	Peak Discharge (m^3/s)										
	15 min	30 min	45 min	60 min	90 min	120 min	150 min	180 min	240 min	300 min	360 min
_junc_64	5.49	6.47	**6.64**	6.53	6.30	5.81	5.35	5.00	4.50	4.13	3.83
_junc_68	5.38	**5.66**	5.43	4.89	4.30	3.80	3.38	3.12	2.82	2.54	2.27
_junc_69	225.07	310.95	365.48	**381.14**	376.15	351.73	317.85	297.66	261.39	232.75	209.00
_junc_71	11.54	14.20	**14.86**	14.46	14.06	12.77	11.65	10.78	9.49	8.55	7.79
_junc_74	14.63	18.59	**19.96**	19.49	18.85	17.50	15.87	14.74	12.91	11.55	10.48
_junc_76	226.59	313.48	370.06	**389.49**	388.49	364.36	329.53	309.61	271.73	242.19	217.39
_junc_80	234.83	325.76	390.46	418.42	**429.05**	404.67	367.83	347.33	305.54	272.30	244.31
_junc_81	4.04	5.81	**6.77**	6.76	6.53	6.24	5.57	5.20	4.53	3.98	3.56
_junc_84	242.80	337.68	408.23	442.65	**461.75**	438.14	399.98	377.22	332.80	297.16	266.43
_junc_85	269.79	392.04	499.58	561.47	**594.86**	566.65	522.38	489.89	434.13	386.89	346.17
_junc_86	270.37	393.04	501.68	564.43	**600.80**	573.28	529.00	495.73	439.67	392.15	350.84
_junc_88	76.44	113.90	**127.25**	126.55	120.56	112.45	101.11	94.23	82.09	72.23	64.68
_junc_91	88.60	132.98	151.65	**152.02**	146.82	137.05	124.33	115.23	101.02	88.91	79.58
US_OHH	228.93	317.19	376.44	399.22	**402.70**	378.75	343.13	323.47	284.02	253.01	227.02
US_Rail	221.83	305.50	356.24	**364.80**	352.40	327.62	296.49	275.44	242.22	215.34	193.53

APPENDIX I

PROBABILISTIC RATIONAL METHOD/REGIONAL FLOOD FREQUENCY ESTIMATION RESULTS

PROBABILISTIC RATIONAL METHOD
PEAK DESIGN FLOOD DISCHARGES - 1% AEP

C10 = 0.79
FFy= 1.50
Cy= 1.185

Subcatchment ID	Contributing Catchment Area (Ha)	Tc (min)	Design Intensity (mm/hr)	PRM Discharge (m3/s)	XP-RAFTS Discharge (m3/s)
1.01	9.1	18	135.9	2.7	2.2
1.02	15.6	19	134.3	2.9	4.4
1.03	31.8	29	107.4	7.5	9.2
1.04	63.3	38	93.6	13.0	18.6
1.05	75.5	41	90.2	15.0	20.8
1.06	78.3	41	89.8	15.2	21.3
1.07	112.3	48	83.0	20.5	28.1
1.08	189.5	58	74.3	30.9	46.1
1.09	200.9	59	73.3	32.3	47.9
1.10	210.7	61	72.6	33.6	48.9
1.11	255.6	65	69.6	39.0	56.6
1.12	261.2	66	69.2	39.7	57.4
1.13	264.6	66	69.0	40.1	57.9
1.14	435.0	80	61.8	59.1	70.5
1.15	458.0	81	61.1	61.5	73.3
1.16	469.2	82	60.8	62.7	74.7
1.17	477.0	83	60.6	63.5	75.3
1.18	482.1	83	60.4	64.0	75.9
1.19	493.4	84	60.1	65.2	77.2
1.20	501.2	84	59.9	66.0	78.1
1.21	611.5	91	57.3	69.9	84.4
1.22	633.5	92	56.8	72.1	87.2
1.23	654.9	93	56.4	73.6	89.8
1.24	666.8	94	56.2	75.4	91.3
1.25	755.9	98	54.6	90.7	112.0
1.26	783.3	100	54.2	93.2	114.9
2.01	1.7	10	179.3	0.7	0.7
2.02	7.3	13	159.0	1.3	2.7
3.01	4.7	14	152.5	1.6	1.6
3.02	23.1	26	114.6	5.7	7.0
3.03	30.1	28	110.1	6.8	9.0
4.01	8.9	18	138.3	2.5	2.8
5.01	7.9	17	139.2	2.4	2.1
5.02	17.4	23	120.5	4.6	4.2
5.03	28.8	27	111.6	6.4	5.9
6.01	14.6	21	126.4	3.7	3.6
6.02	19.2	24	119.5	4.8	4.9
6.03	28.8	28	109.7	6.9	7.5
6.04	48.6	35	98.7	10.5	12.7
6.05	57.0	37	95.6	12.0	14.9

Subcatchment ID	Contributing Catchment Area (Ha)	Tc (min)	Design Intensity (mm/hr)	PRM Discharge (m3/s)	XP-RAFTS Discharge (m3/s)
6.06	62.4	38	93.8	12.8	15.8
6.07	73.9	41	90.6	14.7	18.2
7.01	6.6	13	158.1	1.3	1.7
8.01	2.9	12	166.7	1.0	1.1
8.02	14.0	22	125.5	3.9	4.2
8.03	19.5	24	118.1	5.0	5.4
9.01	4.6	11	173.4	0.8	1.6
10.01	5.3	15	149.4	1.7	1.3
11.01	5.4	15	148.9	1.7	1.3
11.02	11.0	20	131.2	3.2	3.0
12.01	3.1	12	162.8	1.1	0.9
13.01	2.0	10	174.6	0.8	0.8
14.01	7.8	17	139.7	2.4	2.7
15.01	12.5	21	128.4	3.5	4.4
15.02	18.8	24	118.9	4.9	5.9
15.03	34.9	30	106.7	7.7	10.7
15.04	37.7	31	103.8	8.6	11.1
16.01	9.1	18	135.7	2.7	3.7
17.01	3.9	13	157.2	1.3	0.7
18.01	2.1	10	174.4	0.8	0.4
19.01	4.2	14	155.7	1.4	1.6
19.02	8.2	17	139.9	2.4	3.0
19.03	16.7	23	122.8	4.2	5.5
19.04	24.0	27	113.4	6.0	6.4
19.05	27.2	28	110.8	6.6	7.1
19.06	51.2	35	97.6	11.0	12.3
19.07	78.2	42	89.6	15.4	15.3
19.08	80.5	42	89.0	15.7	15.7
19.09	85.6	43	87.9	16.5	3.3
19.10	103.0	46	84.6	19.1	4.5
19.11	111.1	47	83.2	20.3	5.5
19.12	117.0	48	82.4	21.1	6.1
20.01	1.7	9	181.5	0.6	0.7
21.01	2.1	11	173.9	0.8	0.8
22.01	3.2	12	164.0	1.1	0.9
23.01	1.2	8	190.7	0.4	0.4
24.01	2.8	12	167.0	1.0	0.7
24.02	3.3	12	162.0	1.2	0.9
24.03	7.4	18	137.6	2.6	1.7
24.04	16.9	23	122.4	4.3	4.2
24.05	21.7	25	115.7	5.5	5.1
25.01	3.2	12	162.4	1.1	0.6
26.01	2.9	12	165.5	1.0	1.0
26.02	6.8	15	147.9	1.8	2.2
27.01	2.7	7	201.2	0.4	0.8
28.01	3.1	12	163.4	1.1	0.7

Subcatchment ID	Contributing Catchment Area (Ha)	Tc (min)	Design Intensity (mm/hr)	PRM Discharge (m3/s)	XP-RAFTS Discharge (m3/s)
29.01	1.0	6	214.6	0.2	0.3
30.01	5.0	15	150.7	1.7	1.3
31.01	2.6	10	177.8	0.7	0.7
31.02	9.0	18	136.1	2.7	1.7
31.03	15.6	22	123.1	4.2	2.1
32.01	2.7	12	167.1	1.0	1.0
33.01	1.9	10	176.1	0.7	0.7
34.01	3.1	12	163.0	1.1	0.8
35.01	1.3	9	184.5	0.6	0.4
35.02	3.6	13	159.3	1.3	1.4
35.03	6.1	16	145.5	2.0	2.1
35.04	10.0	19	133.5	2.5	2.7
35.05	10.5	19	132.4	3.0	2.8
35.06	12.8	21	127.7	3.6	1.7
36.01	1.6	9	183.1	0.6	0.7
37.01	0.7	7	204.4	0.3	0.2
38.01	1.9	10	176.8	0.7	0.4
39.01	6.8	16	142.8	2.1	1.1
40.01	1.0	8	194.4	0.4	0.4
40.02	2.6	11	168.0	0.9	0.8
40.03	8.8	18	136.5	2.6	2.2
40.04	13.1	21	127.0	3.7	3.4
40.05	21.2	25	116.1	5.4	4.5
40.06	24.3	27	113.2	6.0	4.9
41.01	2.7	11	167.8	1.0	0.9
42.01	3.7	13	158.8	1.3	1.1
43.01	1.3	8	192.1	0.5	0.3
44.01	3.1	12	163.3	1.1	0.5
44.02	5.5	15	149.7	1.7	0.9
44.03	8.1	12	165.5	1.0	1.3
44.04	17.3	23	120.7	4.6	2.0
45.01	1.5	9	188.7	0.5	0.3
46.01	4.2	14	155.5	1.4	0.5
47.01	2.0	10	174.8	0.8	0.3
48.01	6.9	16	142.6	2.2	0.7
48.02	12.0	20	129.1	3.4	1.4
49.01	4.7	14	152.4	1.6	0.8
50.01	6.2	16	145.4	2.0	1.0
51.01	1.6	9	182.6	0.6	0.3
52.01	7.7	15	148.6	1.8	1.1
52.02	10.4	19	132.6	3.0	2.1
53.01	1.5	7	209.0	0.3	0.8
53.02	5.2	15	149.8	1.7	2.5
53.03	7.1	17	141.8	2.2	3.3
54.01	2.1	11	173.9	0.8	1.1
55.01	1.8	10	178.9	0.7	0.9

Subcatchment ID	Contributing Catchment Area (Ha)	Tc (min)	Design Intensity (mm/hr)	PRM Discharge (m3/s)	XP-RAFTS Discharge (m3/s)
56.01	2.2	11	173.1	0.8	0.8
57.01	4.7	14	152.9	1.5	1.3
57.02	6.0	16	146.7	1.9	1.6
57.03	7.0	17	142.5	2.2	1.9
58.01	11.6	20	129.9	3.3	2.1
58.02	14.2	22	125.3	3.9	2.7
58.03	17.7	24	120.1	4.7	3.5
58.04	33.5	30	106.3	7.8	7.1
58.05	48.7	31	104.6	7.9	10.2
58.06	49.0	31	104.4	8.4	10.2
58.07	71.2	40	91.2	14.4	14.5
58.08	72.6	40	90.8	0.5	1.7
58.09	81.0	42	88.8	2.8	3.4
58.10	85.6	43	87.8	3.9	4.5
58.11	89.8	44	86.9	4.9	5.2
59.01	8.0	17	141.5	2.2	1.7
59.02	13.1	21	127.1	3.1	2.9
60.01	4.2	14	155.2	1.4	1.1
60.02	13.0	21	128.5	3.5	2.8
61.01	2.4	11	172.6	0.8	0.7
61.02	7.7	16	144.6	2.0	2.4
61.03	13.9	21	126.6	3.7	4.0
61.04	21.9	31	105.5	8.1	5.2
62.01	3.6	11	172.9	0.8	1.1
63.01	2.6	11	168.5	0.9	0.6
64.01	0.9	17	141.5	0.2	0.3
65.01	2.1	10	175.6	0.8	0.5
65.02	3.3	23	122.9	0.8	0.9
66.01	0.2	21	128.2	0.0	0.1
67.01	3.6	13	159.6	1.2	0.9
68.01	2.2	8	197.2	0.4	0.5
69.01	1.6	9	181.8	0.6	0.5
69.02	2.9	12	164.5	1.0	0.8
70.01	3.5	13	160.6	1.2	0.7
71.01	10.8	20	131.6	3.1	3.4
71.02	18.2	24	119.5	4.8	4.7
72.01	6.4	16	144.4	2.0	1.1
73.01	2.2	11	172.2	0.8	0.4
73.02	5.3	15	149.4	1.7	0.9
73.03	10.8	20	131.7	3.1	1.6
74.01	1.7	10	179.4	0.7	0.3
75.01	1.1	8	193.1	0.4	0.2
76.01	8.9	18	136.5	2.6	1.6
77.01	11.8	20	130.1	3.3	1.7
78.01	0.9	6	213.9	0.2	0.4
78.02	3.5	15	150.0	15.2	13.6

Subcatchment ID	Contributing Catchment Area (Ha)	Tc (min)	Design Intensity (mm/hr)	PRM Discharge (m3/s)	XP-RAFTS Discharge (m3/s)
78.03	22.5	25	115.8	17.7	17.2
78.04	28.7	27	111.6	18.4	18.4
78.05	33.3	32	103.0	20.3	19.2
78.06	59.5	37	94.9	23.1	23.4
78.07	88.5	43	87.4	27.0	28.2
79.01	3.3	13	161.4	1.2	1.2
79.02	7.1	17	142.3	2.2	2.4
79.03	9.4	9	183.5	0.6	3.0
80.01	2.2	9	182.1	0.6	0.8
81.01	0.7	8	190.5	0.5	0.3
82.01	2.5	11	171.9	0.5	1.0
82.02	4.9	14	151.5	1.6	1.7
82.03	8.8	22	125.3	3.9	2.8
83.01	2.6	8	196.2	0.4	0.9
84.01	2.1	9	181.2	0.6	0.6
84.02	5.2	10	177.4	0.7	1.5
85.01	1.2	9	189.1	0.3	0.4
86.01	0.1	11	171.0	0.0	0.0
86.02	1.9	14	156.0	0.5	0.6
87.01	0.7	16	142.7	0.1	0.2
88.01	3.9	13	157.2	1.3	1.3
88.02	6.6	16	144.3	2.0	1.9
88.03	16.1	17	141.2	2.3	3.0
88.04	24.0	24	120.4	4.6	4.0
89.01	5.2	12	163.8	1.1	1.1
89.02	19.0	24	118.7	4.9	3.1
89.03	27.2	28	110.7	6.6	4.5
90.01	5.7	15	147.3	1.9	1.0
91.01	4.7	14	153.0	1.5	1.1
92.01	5.1	26	113.7	1.2	1.4
92.02	8.6	18	137.9	2.5	2.0

APPENDIX J

XP-RAFTS MODEL RESULTS FOR CLIMATE CHANGE ASSESSMENT

CLIMATE CHANGE ASSESSMENT SUMMARY - 1% AEP

Subcatchment ID	Peak Discharge (m^3/s)			
	Existing	10% Increase in Rainfall Intensity	20% Increase in Rainfall Intensity	30% Increase in Rainfall Intensity
1.01	2.21	2.51	2.81	3.12
1.02	4.42	4.99	5.55	6.13
1.03	9.23	10.42	11.59	12.78
1.04	18.64	21.06	23.46	25.91
1.05	20.83	23.57	26.32	29.12
1.06	21.32	24.14	26.96	29.83
1.07	28.07	31.80	35.55	39.35
1.08	46.08	52.14	58.20	64.43
1.09	47.88	54.13	60.40	66.82
1.10	48.91	55.33	61.76	68.33
1.11	56.55	63.82	71.15	78.57
1.12	57.41	64.79	72.25	79.79
1.13	57.87	65.33	72.86	80.47
1.14	70.49	79.45	88.44	97.47
1.15	73.29	82.59	91.93	101.29
1.16	74.65	84.15	93.68	103.22
1.17	75.33	84.90	94.50	104.11
1.18	75.86	85.47	95.11	104.76
1.19	77.16	86.88	96.62	106.39
1.20	78.06	87.89	97.75	107.62
1.21	84.37	94.68	104.99	115.34
1.22	87.16	97.81	108.48	119.17
1.23	89.81	100.77	111.74	122.72
1.24	91.30	102.44	113.55	124.78
1.25	112.04	126.18	140.40	154.75
1.26	114.93	129.64	144.22	158.93
2.01	0.67	0.75	0.83	0.91
2.02	2.71	3.05	3.36	3.66
3.01	1.57	1.79	2.00	2.23
3.02	7.03	7.94	8.86	9.82
3.03	9.03	10.21	11.40	12.60
4.01	2.82	3.18	3.54	3.91
5.01	2.14	2.42	2.69	2.99
5.02	4.16	4.72	5.30	5.88
5.03	5.86	6.72	7.60	8.49
6.01	3.63	4.16	4.69	5.26
6.02	4.94	5.63	6.35	7.15
6.03	7.45	8.51	9.64	10.79
6.04	12.70	14.62	16.57	18.54
6.05	14.88	17.10	19.37	21.63
6.06	15.79	18.15	20.56	22.97
6.07	18.19	20.89	23.62	26.36

Subcatchment ID	Peak Discharge (m^3/s)			
	Existing	10% Increase in Rainfall Intensity	20% Increase in Rainfall Intensity	30% Increase in Rainfall Intensity
7.01	1.69	1.93	2.17	2.40
8.01	1.07	1.21	1.35	1.48
8.02	4.17	4.79	5.38	6.02
8.03	5.37	6.14	6.92	7.73
9.01	1.61	1.83	2.05	2.25
10.01	1.31	1.50	1.69	1.88
11.01	1.27	1.45	1.65	1.84
11.02	3.00	3.41	3.87	4.29
12.01	0.86	0.98	1.13	1.25
13.01	0.78	0.90	1.00	1.10
14.01	2.71	3.06	3.39	3.74
15.01	4.38	4.92	5.44	6.06
15.02	5.89	6.60	7.29	8.04
15.03	10.67	11.99	13.29	14.62
15.04	11.07	12.48	13.87	15.28
16.01	3.70	4.11	4.52	4.94
17.01	0.67	0.77	0.87	0.96
18.01	0.45	0.52	0.60	0.67
19.01	1.64	1.85	2.06	2.25
19.02	3.03	3.43	3.84	4.23
19.03	5.55	6.33	7.10	7.87
19.04	6.44	7.40	8.30	9.25
19.05	7.13	8.20	9.21	10.27
19.06	12.33	14.11	15.90	17.71
19.07	15.34	17.59	19.83	22.08
19.08	15.72	17.99	20.26	22.54
19.09	3.33	3.56	3.79	4.01
19.10	4.55	4.83	5.10	5.37
19.11	5.49	5.89	6.28	6.67
19.12	6.13	6.60	7.07	7.54
20.01	0.72	0.81	0.90	0.98
21.01	0.83	0.94	1.04	1.14
22.01	0.87	1.00	1.13	1.26
23.01	0.37	0.42	0.47	0.53
24.01	0.71	0.83	0.94	1.04
24.02	0.89	1.03	1.17	1.30
24.03	1.65	1.89	2.17	2.42
24.04	4.21	4.78	5.42	6.05
24.05	5.14	5.87	6.64	7.42
25.01	0.56	0.63	0.70	0.79
26.01	0.98	1.11	1.24	1.37
26.02	2.16	2.45	2.77	3.08
27.01	0.84	0.96	1.09	1.21
28.01	0.66	0.78	0.89	0.99

Subcatchment ID	Peak Discharge (m^3/s)			
	Existing	10% Increase in Rainfall Intensity	20% Increase in Rainfall Intensity	30% Increase in Rainfall Intensity
29.01	0.28	0.32	0.35	0.39
30.01	1.27	1.44	1.62	1.79
31.01	0.66	0.75	0.86	0.97
31.02	1.70	1.94	2.19	2.44
31.03	2.12	2.45	2.79	3.11
32.01	0.95	1.09	1.24	1.36
33.01	0.74	0.84	0.94	1.05
34.01	0.81	0.94	1.07	1.21
35.01	0.44	0.50	0.56	0.63
35.02	1.37	1.53	1.70	1.89
35.03	2.09	2.36	2.63	2.93
35.04	2.70	3.06	3.45	3.83
35.05	2.77	3.15	3.57	3.96
35.06	1.73	1.87	1.99	2.11
36.01	0.70	0.78	0.87	0.96
37.01	0.25	0.29	0.32	0.35
38.01	0.43	0.50	0.59	0.67
39.01	1.13	1.27	1.42	1.58
40.01	0.39	0.43	0.48	0.53
40.02	0.79	0.89	1.00	1.10
40.03	2.22	2.51	2.83	3.12
40.04	3.37	3.83	4.33	4.79
40.05	4.45	5.07	5.73	6.35
40.06	4.90	5.57	6.29	6.99
41.01	0.87	1.01	1.14	1.26
42.01	1.09	1.24	1.38	1.54
43.01	0.28	0.31	0.35	0.38
44.01	0.47	0.54	0.60	0.66
44.02	0.87	0.99	1.11	1.25
44.03	1.31	1.50	1.68	1.85
44.04	2.03	2.31	2.63	2.94
45.01	0.32	0.36	0.40	0.44
46.01	0.50	0.57	0.64	0.71
47.01	0.34	0.38	0.43	0.47
48.01	0.68	0.76	0.85	0.93
48.02	1.38	1.57	1.76	1.96
49.01	0.81	0.91	1.02	1.14
50.01	1.00	1.13	1.27	1.40
51.01	0.31	0.35	0.40	0.43
52.01	1.12	1.26	1.41	1.58
52.02	2.12	2.37	2.65	2.95
53.01	0.80	0.88	0.96	1.04
53.02	2.53	2.80	3.08	3.37
53.03	3.27	3.63	3.98	4.34

Subcatchment ID	Peak Discharge (m^3/s)			
	Existing	10% Increase in Rainfall Intensity	20% Increase in Rainfall Intensity	30% Increase in Rainfall Intensity
54.01	1.10	1.21	1.32	1.43
55.01	0.92	1.01	1.10	1.19
56.01	0.85	0.95	1.05	1.15
57.01	1.34	1.49	1.66	1.85
57.02	1.60	1.78	1.98	2.20
57.03	1.85	2.03	2.27	2.49
58.01	2.14	2.44	2.76	3.08
58.02	2.73	3.10	3.51	3.91
58.03	3.53	4.02	4.54	5.06
58.04	7.07	8.10	9.12	10.14
58.05	10.16	11.67	13.16	14.65
58.06	10.21	11.73	13.22	14.72
58.07	14.46	16.63	18.81	20.93
58.08	1.67	1.72	1.77	1.82
58.09	3.45	3.73	4.02	4.33
58.10	4.47	4.86	5.28	5.72
58.11	5.24	5.73	6.24	6.79
59.01	1.72	2.01	2.26	2.52
59.02	2.91	3.36	3.78	4.20
60.01	1.14	1.30	1.46	1.63
60.02	2.77	3.20	3.60	4.02
61.01	0.74	0.84	0.95	1.05
61.02	2.39	2.75	3.12	3.44
61.03	3.99	4.55	5.11	5.66
61.04	5.18	5.95	6.73	7.46
62.01	1.11	1.26	1.41	1.55
63.01	0.64	0.74	0.83	0.93
64.01	0.26	0.30	0.33	0.36
65.01	0.50	0.58	0.67	0.77
65.02	0.92	1.04	1.18	1.32
66.01	0.06	0.07	0.08	0.09
67.01	0.88	1.01	1.14	1.28
68.01	0.49	0.55	0.62	0.69
69.01	0.50	0.56	0.63	0.69
69.02	0.79	0.88	0.98	1.07
70.01	0.74	0.84	0.93	1.05
71.01	3.40	3.82	4.21	4.61
71.02	4.67	5.27	5.85	6.45
72.01	1.11	1.26	1.43	1.59
73.01	0.42	0.47	0.53	0.58
73.02	0.86	0.97	1.08	1.21
73.03	1.64	1.87	2.08	2.30
74.01	0.31	0.35	0.39	0.43
75.01	0.21	0.23	0.26	0.29
76.01	1.59	1.80	2.04	2.27
77.01	1.73	2.00	2.24	2.49
78.01	0.39	0.44	0.48	0.53
78.02	13.62	15.87	18.12	20.32

Subcatchment ID	Peak Discharge (m^3/s)			
	Existing	10% Increase in Rainfall Intensity	20% Increase in Rainfall Intensity	30% Increase in Rainfall Intensity
78.03	17.24	19.91	22.72	25.42
78.04	18.41	21.20	24.13	26.95
78.05	19.21	22.11	25.13	28.04
78.06	23.44	26.94	30.58	34.08
78.07	28.21	32.36	36.66	40.82
79.01	1.18	1.35	1.51	1.67
79.02	2.38	2.70	3.02	3.34
79.03	2.98	3.39	3.81	4.22
80.01	0.76	0.86	0.96	1.06
81.01	0.27	0.30	0.33	0.36
82.01	1.04	1.17	1.29	1.41
82.02	1.70	1.93	2.16	2.37
82.03	2.76	3.13	3.50	3.84
83.01	0.93	1.05	1.17	1.29
84.01	0.61	0.71	0.80	0.91
84.02	1.51	1.73	1.94	2.20
85.01	0.44	0.50	0.56	0.62
86.01	0.04	0.05	0.05	0.05
86.02	0.61	0.69	0.77	0.86
87.01	0.22	0.24	0.27	0.30
88.01	1.25	1.43	1.60	1.78
88.02	1.93	2.21	2.49	2.78
88.03	3.02	3.47	3.95	4.44
88.04	4.02	4.64	5.29	5.97
89.01	1.06	1.22	1.38	1.55
89.02	3.11	3.53	3.98	4.42
89.03	4.50	5.11	5.76	6.38
90.01	1.02	1.16	1.31	1.45
91.01	1.13	1.30	1.45	1.59
92.01	1.41	1.60	1.79	1.98
92.02	2.05	2.36	2.63	2.91
_junc_116	1.84	2.09	2.35	2.60
_junc_123	4.50	5.08	5.64	6.20
_junc_125	88.28	99.04	109.84	120.61
_junc_126	2.37	2.70	3.01	3.33
_junc_130	14.01	16.11	18.26	20.41
_junc_133	4.22	4.79	5.35	5.90
_junc_135	1.14	1.28	1.43	1.59
_junc_136	1.59	1.80	2.00	2.21
_junc_138	9.59	10.71	11.81	12.98
_junc_142	3.91	4.43	4.98	5.52
_junc_150	15.21	17.67	20.18	22.64
_junc_151	4.44	5.04	5.70	6.37
_junc_158	1.30	1.49	1.67	1.85
_junc_162	0.90	1.03	1.16	1.29
_junc_19	2.36	2.66	2.96	3.23
_junc_21	45.50	51.47	57.45	63.60
_junc_28	11.94	13.63	15.35	17.12

Subcatchment ID	Peak Discharge (m^3/s)			
	Existing	10% Increase in Rainfall Intensity	20% Increase in Rainfall Intensity	30% Increase in Rainfall Intensity
_junc_29	3.81	4.34	4.94	5.50
_junc_30	0.66	0.78	0.89	0.99
_junc_32	1.40	1.61	1.86	2.08
_junc_37	5.33	5.72	6.09	6.47
_junc_38	55.71	62.86	70.08	77.39
_junc_40	3.10	3.52	3.96	4.38
_junc_41	6.44	7.37	8.32	9.26
_junc_42	4.11	4.67	5.28	5.84
_junc_44	6.59	7.12	7.65	8.17
_junc_47	6.63	7.61	8.60	9.64
_junc_50	0.57	0.65	0.75	0.86
_junc_59	74.54	84.02	93.54	103.06
_junc_64	2.55	2.73	2.91	3.10
_junc_68	1.46	1.65	1.84	2.03
_junc_69	76.02	85.63	95.29	104.95
_junc_71	4.24	4.61	5.00	5.41
_junc_74	5.06	5.52	6.01	6.53
_junc_76	77.98	87.80	97.66	107.51
_junc_80	85.82	96.29	106.77	117.26
_junc_81	1.14	1.30	1.46	1.62
_junc_84	91.30	102.43	113.54	124.77
_junc_85	111.98	126.10	140.32	154.66
_junc_86	112.88	127.21	141.52	155.95
_junc_88	23.13	26.59	30.19	33.65
_junc_91	27.91	32.03	36.30	40.43
US_OHH	80.40	90.46	100.50	110.60
US_Rail	72.69	81.93	91.22	100.52

APPENDIX K

XP-RAFTS MODEL RESULTS FOR SENSITIVITY ANALYSES

SENSITIVITY ASSESSMENT SUMMARY - 1% AEP

Subcatchment ID	Peak Discharge (m^3/s)				
	Existing	0mm/hr Pervious, 0mm/hr Impervious Initial Loss	20mm/hr Pervious, 2mm/hr Impervious Initial Loss	1.5mm/hr Pervious, 0mm/hr Impervious Continuing Loss	3.5mm/hr Pervious, 1mm/hr Impervious Continuing Loss
1.01	2.21	2.43	1.78	2.24	2.18
1.02	4.42	4.81	3.71	4.46	4.37
1.03	9.23	9.98	7.77	9.31	9.13
1.04	18.64	20.18	15.66	18.82	18.44
1.05	20.83	22.65	17.34	21.05	20.60
1.06	21.32	23.24	17.76	21.55	21.08
1.07	28.07	30.86	23.39	28.37	27.74
1.08	46.08	50.44	38.70	46.58	45.52
1.09	47.88	52.44	40.46	48.40	47.29
1.10	48.91	53.55	41.36	49.44	48.31
1.11	56.55	61.07	48.41	57.16	55.83
1.12	57.41	62.01	49.13	58.03	56.67
1.13	57.87	62.53	49.52	58.51	57.13
1.14	70.49	76.07	60.67	71.29	69.56
1.15	73.29	79.12	63.15	74.13	72.30
1.16	74.65	80.64	64.35	75.52	73.63
1.17	75.33	81.34	65.03	76.21	74.29
1.18	75.86	81.86	65.59	76.74	74.80
1.19	77.16	83.08	66.90	78.05	76.07
1.20	78.06	84.11	67.78	78.98	76.96
1.21	84.37	90.71	73.89	85.35	83.16
1.22	87.16	93.76	76.37	88.19	85.90
1.23	89.81	96.75	78.80	90.90	88.49
1.24	91.30	98.43	80.16	92.42	89.96
1.25	112.04	121.81	99.43	113.50	110.29
1.26	114.93	125.10	102.03	116.45	113.12
2.01	0.67	0.69	0.63	0.68	0.66
2.02	2.71	2.83	2.46	2.73	2.68
3.01	1.57	1.73	1.31	1.58	1.55
3.02	7.03	7.65	5.97	7.09	6.95
3.03	9.03	9.80	7.63	9.12	8.93
4.01	2.82	3.06	2.40	2.85	2.79
5.01	2.14	2.34	1.77	2.16	2.11
5.02	4.16	4.61	3.36	4.21	4.11
5.03	5.86	6.73	5.14	5.92	5.79
6.01	3.63	4.01	3.02	3.68	3.59
6.02	4.94	5.44	4.12	5.00	4.88
6.03	7.45	8.22	6.23	7.54	7.37
6.04	12.70	14.31	10.51	12.84	12.56
6.05	14.88	16.65	12.30	15.04	14.71
6.06	15.79	17.67	13.04	15.96	15.60
6.07	18.19	20.30	14.92	18.39	17.97
7.01	1.69	1.87	1.38	1.71	1.67
8.01	1.07	1.15	0.90	1.07	1.06
8.02	4.17	4.77	3.39	4.20	4.13
8.03	5.37	6.16	4.35	5.42	5.32
9.01	1.61	1.79	1.34	1.62	1.60
10.01	1.31	1.45	1.08	1.33	1.30
11.01	1.27	1.50	1.05	1.27	1.26
11.02	3.00	3.45	2.51	3.01	2.97
12.01	0.86	1.01	0.74	0.86	0.85
13.01	0.78	0.86	0.67	0.79	0.78
14.01	2.71	2.96	2.48	2.72	2.69
15.01	4.38	4.77	3.99	4.39	4.35
15.02	5.89	6.45	5.30	5.90	5.85
15.03	10.67	11.71	9.56	10.70	10.59
15.04	11.07	12.26	9.85	11.11	10.99
16.01	3.70	3.87	3.49	3.71	3.68
17.01	0.67	0.76	0.60	0.68	0.66
18.01	0.45	0.52	0.38	0.45	0.44
19.01	1.64	1.76	1.43	1.64	1.63
19.02	3.03	3.29	2.58	3.04	3.00
19.03	5.55	6.20	4.52	5.59	5.50
19.04	6.44	7.36	5.22	6.49	6.38
19.05	7.13	8.18	5.85	7.19	7.06

Subcatchment ID	Peak Discharge (m^3/s)				
	Existing	0mm/hr Pervious, 0mm/hr Impervious Initial Loss	20mm/hr Pervious, 2mm/hr Impervious Initial Loss	1.5mm/hr Pervious, 0mm/hr Impervious Continuing Loss	3.5mm/hr Pervious, 1mm/hr Impervious Continuing Loss
19.06	12.33	14.22	10.13	12.45	12.19
19.07	15.34	17.53	12.51	15.51	15.16
19.08	15.72	17.94	12.87	15.89	15.54
19.09	3.33	3.38	3.26	3.40	3.24
19.10	4.55	4.61	4.48	4.63	4.46
19.11	5.49	5.56	5.40	5.59	5.37
19.12	6.13	6.24	6.04	6.25	5.99
20.01	0.72	0.74	0.66	0.72	0.72
21.01	0.83	0.89	0.70	0.84	0.82
22.01	0.87	0.97	0.74	0.88	0.86
23.01	0.37	0.41	0.30	0.37	0.36
24.01	0.71	0.86	0.57	0.72	0.70
24.02	0.89	1.06	0.73	0.90	0.88
24.03	1.65	1.96	1.36	1.67	1.63
24.04	4.21	4.88	3.38	4.24	4.17
24.05	5.14	6.05	4.11	5.18	5.08
25.01	0.56	0.64	0.49	0.57	0.55
26.01	0.98	1.09	0.78	0.98	0.97
26.02	2.16	2.44	1.77	2.17	2.14
27.01	0.84	0.96	0.69	0.85	0.84
28.01	0.66	0.83	0.56	0.67	0.66
29.01	0.28	0.32	0.24	0.28	0.28
30.01	1.27	1.45	1.05	1.28	1.26
31.01	0.66	0.77	0.56	0.66	0.65
31.02	1.70	1.97	1.46	1.71	1.69
31.03	2.12	2.54	1.92	2.15	2.10
32.01	0.95	1.07	0.84	0.96	0.95
33.01	0.74	0.81	0.67	0.75	0.74
34.01	0.81	0.96	0.66	0.82	0.81
35.01	0.44	0.49	0.37	0.44	0.44
35.02	1.37	1.45	1.20	1.38	1.36
35.03	2.09	2.31	1.80	2.10	2.07
35.04	2.70	3.08	2.26	2.71	2.68
35.05	2.77	3.19	2.31	2.79	2.75
35.06	1.73	1.83	1.61	1.75	1.72
36.01	0.70	0.73	0.63	0.70	0.70
37.01	0.25	0.28	0.22	0.25	0.24
38.01	0.43	0.53	0.36	0.43	0.43
39.01	1.13	1.24	0.97	1.14	1.11
40.01	0.39	0.42	0.34	0.39	0.39
40.02	0.79	0.88	0.69	0.80	0.79
40.03	2.22	2.52	1.87	2.23	2.21
40.04	3.37	3.86	2.82	3.39	3.35
40.05	4.45	5.17	3.69	4.48	4.41
40.06	4.90	5.70	4.05	4.93	4.86
41.01	0.87	1.00	0.73	0.88	0.87
42.01	1.09	1.25	0.90	1.10	1.09
43.01	0.28	0.31	0.23	0.28	0.28
44.01	0.47	0.52	0.41	0.48	0.46
44.02	0.87	1.02	0.75	0.88	0.87
44.03	1.31	1.48	1.15	1.33	1.29
44.04	2.03	2.28	1.97	2.05	2.00
45.01	0.32	0.36	0.27	0.32	0.32
46.01	0.50	0.55	0.48	0.52	0.49
47.01	0.34	0.37	0.29	0.34	0.33
48.01	0.68	0.68	0.67	0.70	0.65
48.02	1.38	1.53	1.34	1.40	1.35
49.01	0.81	0.90	0.71	0.82	0.79
50.01	1.00	1.10	0.86	1.02	0.98
51.01	0.31	0.36	0.27	0.31	0.31
52.01	1.12	1.28	0.98	1.12	1.11
52.02	2.12	2.35	1.93	2.13	2.11
53.01	0.80	0.80	0.78	0.80	0.79
53.02	2.53	2.58	2.41	2.53	2.51
53.03	3.27	3.36	3.09	3.28	3.25
54.01	1.10	1.11	1.08	1.10	1.09
55.01	0.92	0.93	0.91	0.92	0.91

Subcatchment ID	Peak Discharge (m^3/s)				
	Existing	0mm/hr Pervious, 0mm/hr Impervious Initial Loss	20mm/hr Pervious, 2mm/hr Impervious Initial Loss	1.5mm/hr Pervious, 0mm/hr Impervious Continuing Loss	3.5mm/hr Pervious, 1mm/hr Impervious Continuing Loss
56.01	0.85	0.91	0.79	0.85	0.84
57.01	1.34	1.49	1.13	1.34	1.33
57.02	1.60	1.77	1.35	1.60	1.57
57.03	1.85	2.00	1.62	1.82	1.79
58.01	2.14	2.45	1.89	2.17	2.11
58.02	2.73	3.15	2.36	2.76	2.71
58.03	3.53	4.04	2.99	3.57	3.49
58.04	7.07	8.02	5.86	7.15	6.98
58.05	10.16	11.53	8.43	10.30	10.02
58.06	10.21	11.59	8.46	10.35	10.07
58.07	14.46	16.48	11.91	14.66	14.27
58.08	1.67	1.72	1.61	1.67	1.66
58.09	3.45	3.75	3.16	3.46	3.43
58.10	4.47	4.89	4.01	4.48	4.44
58.11	5.24	5.77	4.66	5.25	5.21
59.01	1.72	1.97	1.48	1.74	1.70
59.02	2.91	3.29	2.42	2.94	2.87
60.01	1.14	1.26	0.95	1.16	1.13
60.02	2.77	3.14	2.30	2.81	2.73
61.01	0.74	0.84	0.61	0.74	0.73
61.02	2.39	2.75	1.94	2.41	2.36
61.03	3.99	4.52	3.24	4.03	3.94
61.04	5.18	5.93	4.21	5.24	5.12
62.01	1.11	1.25	0.89	1.12	1.10
63.01	0.64	0.73	0.54	0.65	0.64
64.01	0.26	0.29	0.21	0.26	0.26
65.01	0.50	0.61	0.41	0.51	0.50
65.02	0.92	1.05	0.77	0.92	0.91
66.01	0.06	0.07	0.06	0.06	0.06
67.01	0.88	1.02	0.78	0.88	0.88
68.01	0.49	0.56	0.43	0.49	0.48
69.01	0.50	0.55	0.44	0.50	0.50
69.02	0.79	0.87	0.68	0.79	0.78
70.01	0.74	0.83	0.66	0.74	0.74
71.01	3.40	3.67	3.15	3.40	3.38
71.02	4.67	5.17	4.16	4.68	4.64
72.01	1.11	1.30	0.96	1.11	1.10
73.01	0.42	0.47	0.36	0.42	0.41
73.02	0.86	0.98	0.73	0.86	0.85
73.03	1.64	1.83	1.41	1.66	1.61
74.01	0.31	0.34	0.27	0.31	0.30
75.01	0.21	0.23	0.16	0.21	0.20
76.01	1.59	1.79	1.39	1.61	1.57
77.01	1.73	1.96	1.53	1.76	1.70
78.01	0.39	0.40	0.36	0.40	0.39
78.02	13.62	15.73	11.01	13.83	13.42
78.03	17.24	19.64	14.16	17.47	17.01
78.04	18.41	20.85	15.17	18.64	18.16
78.05	19.21	21.70	15.89	19.45	18.95
78.06	23.44	26.43	19.58	23.74	23.11
78.07	28.21	31.70	23.78	28.58	27.81
79.01	1.18	1.30	0.98	1.19	1.18
79.02	2.38	2.63	1.95	2.39	2.36
79.03	2.98	3.36	2.44	3.00	2.95
80.01	0.76	0.84	0.61	0.77	0.75
81.01	0.27	0.28	0.25	0.27	0.27
82.01	1.04	1.08	0.93	1.05	1.04
82.02	1.70	1.87	1.40	1.71	1.68
82.03	2.76	3.06	2.23	2.77	2.73
83.01	0.93	1.02	0.75	0.94	0.92
84.01	0.61	0.72	0.51	0.61	0.61
84.02	1.51	1.74	1.28	1.52	1.50
85.01	0.44	0.48	0.38	0.44	0.44
86.01	0.04	0.04	0.04	0.04	0.04
86.02	0.61	0.68	0.53	0.61	0.60
87.01	0.22	0.24	0.18	0.22	0.22
88.01	1.25	1.42	1.03	1.26	1.24
88.02	1.93	2.23	1.54	1.95	1.91
88.03	3.02	3.57	2.58	3.05	2.98
88.04	4.02	4.75	3.60	4.07	3.98
89.01	1.06	1.22	0.93	1.07	1.05
89.02	3.11	3.46	2.73	3.15	3.06
89.03	4.50	5.22	4.02	4.58	4.42

Subcatchment ID	Peak Discharge (m^3/s)				
	Existing	0mm/hr Pervious, 0mm/hr Impervious Initial Loss	20mm/hr Pervious, 2mm/hr Impervious Initial Loss	1.5mm/hr Pervious, 0mm/hr Impervious Continuing Loss	3.5mm/hr Pervious, 1mm/hr Impervious Continuing Loss
90.01	1.02	1.15	0.90	1.04	1.01
91.01	1.13	1.30	0.99	1.14	1.12
92.01	1.41	1.59	1.21	1.42	1.40
92.02	2.05	2.36	1.83	2.06	2.04
_junc_116	1.84	2.09	1.49	1.86	1.82
_junc_123	4.50	4.97	4.03	4.51	4.47
_junc_125	88.28	95.01	77.44	89.33	87.00
_junc_126	2.37	2.62	2.13	2.41	2.33
_junc_130	14.01	15.73	11.58	14.16	13.85
_junc_133	4.22	4.59	3.58	4.25	4.19
_junc_135	1.14	1.22	1.00	1.15	1.13
_junc_136	1.59	1.72	1.38	1.60	1.58
_junc_138	9.59	10.32	8.79	9.61	9.53
_junc_142	3.91	4.50	3.48	3.97	3.84
_junc_150	15.21	17.48	12.42	15.42	15.00
_junc_151	4.44	5.14	3.55	4.47	4.40
_junc_158	1.30	1.45	1.28	1.33	1.28
_junc_162	0.90	1.02	0.75	0.91	0.88
_junc_19	2.36	2.50	2.09	2.37	2.34
_junc_21	45.50	49.77	38.21	45.99	44.95
_junc_28	11.94	13.78	9.84	12.06	11.80
_junc_29	3.81	4.40	3.07	3.84	3.77
_junc_30	0.66	0.83	0.56	0.67	0.66
_junc_32	1.40	1.70	1.14	1.41	1.38
_junc_37	5.33	5.40	5.25	5.43	5.22
_junc_38	55.71	60.16	47.67	56.31	55.00
_junc_40	3.10	3.53	2.60	3.11	3.08
_junc_41	6.44	7.32	5.40	6.51	6.36
_junc_42	4.11	4.77	3.41	4.13	4.08
_junc_44	6.59	6.78	6.50	6.72	6.44
_junc_47	6.63	7.76	5.51	6.69	6.56
_junc_50	0.57	0.68	0.47	0.57	0.56
_junc_59	74.54	80.52	64.26	75.41	73.53
_junc_64	2.55	2.73	2.39	2.55	2.54
_junc_68	1.46	1.58	1.23	1.46	1.45
_junc_69	76.02	82.01	65.77	76.91	74.97
_junc_71	4.24	4.62	3.84	4.25	4.21
_junc_74	5.06	5.57	4.51	5.07	5.03
_junc_76	77.98	84.03	67.70	78.90	76.88
_junc_80	85.82	92.25	75.20	86.83	84.59
_junc_81	1.14	1.32	0.98	1.14	1.13
_junc_84	91.30	98.42	80.16	92.41	89.95
_junc_85	111.98	121.74	99.37	113.44	110.23
_junc_86	112.88	122.77	100.21	114.35	111.11
_junc_88	23.13	26.11	19.30	23.43	22.81
_junc_91	27.91	31.38	23.56	28.27	27.51
US_OHH	80.40	86.53	70.06	81.35	79.25
US_Rail	72.69	78.50	62.59	73.53	71.72