Stormwater, Flooding and Servicing Report

for

Lake Munmorah

for Darkinjung Local Aboriginal Land Council

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Executive Summary

Northrop Consulting Engineers have been engaged by Darkinjung Local Aboriginal Land Council (DLALC) to prepare a servicing report to support the rezoning of Lot 642 DP1027231 (405-415 Pacific Highway, Lake Munmorah, 2259) and a part of Lot 100 DP1044282 (425 Pacific Highway, Crangan Bay, 2259). The report assesses the sites capacity to accommodate the proposed rezoning, outlining the availability of all necessary utility infrastructure including water, sewer, gas, electrical and communication services. The report also identifies the site requirements with respect to flooding and stormwater management such as stormwater quantity and quality controls.

The 55-hectare site is currently zoned as as E2 (Environmental Conservation) and E3 (Environmental Management) and is largely un-developed and predominantly vegetated with the exception of Chain Valley Bay Road and several trails which traverse the site. The application is seeking to rezone approximately 34.3 hectares of the site to R2 (Low Density Residential), R3 (Medium Density Residential) and RE1 (Public Recreation) with the remaining portions to remain E2 (Environmental Conservation) land-use.

Flooding constraints for the site have been reviewed with a two-dimensional XP-STORM model created to define the 1% AEP, 5% AEP, PMF and 1% AEP plus climate change scenarios. The flood extents have been used to ensure the proposed residential zones has been positioned outside the extent of the Flood Planning Area (i.e. the PMF).

A preliminary stormwater management strategy for the site has been considered to outline the measures required to mitigate the effects of future development in the residential zones on stormwater quantity and quality. Through hydrological and hydraulic modelling, it was determined that development in the proposed residential zones would result in increased peak flows which has the potential to create an adverse impact on downstream properties. Detention measures have therefore been proposed to attenuate runoff to pre-developed flow rates. It is anticipated that detention basins will be located within dedicated drainage reserves and designed to cater for the full contributing catchment once developed.

Through the adoption of Water Sensitive Urban Design (WSUD) principals, Council's water quality reduction targets were shown to be achievable for the future development of the residential zones. In accordance with Council's guidelines a treatment train approach could be implemented with rainwater tanks and an end-of-line gross pollutant trap to provide primary treatment and a wetland to provide secondary treatment.

The impact downstream of the proposed residential zones is therefore minimised through the introduction of the proposed stormwater quantity and quality management measures and the placement of the residential zones outside the extent of the Flood Planning Area.

Connection to existing potable water infrastructure with minor upgrades are expected to adequately service the residential zones. It is also anticipated that the construction of a new wastewater pump station and rising main will be required to service the future wastewater requirements.

Existing electrical and telecommunication utilities are located near to the site. Extension of these existing networks is considered feasible to service future residential development of the site.

Based on the assessment undertaken to date the site is recommended for rezoning on the grounds of stormwater, flooding and essential utility services.

Contents

Appendices

1. Introduction

Northrop Consulting Engineers have been engaged by Darkinjung Local Aboriginal Land Council (DLALC) to prepare a servicing report to support the rezoning of Lot 642 DP1027231 (405-415 Pacific Highway, Lake Munmorah, 2259) and part of Lot 100 DP1044282 (425 Pacific Highway, Crangan Bay, 2259), herein referred to as the “subject site”.

This report includes an overview of the flood management and drainage requirements for the proposed development as well as investigation into the availability of potable water, sewer, gas, electrical and communication infrastructure. The information contained herein has been prepared for the purpose of rezoning and to support the Planning Proposal submission to Central Coast Council. It is noted that further details will be provided at Development Application and Construction Certificate Stage.

1.1 Site Description

The subject site is located within the Central Coast Council region and spans across two suburbs namely, Lake Munmorah and Crangan Bay. As shown in the below Figure 1 the extent of DLALC owned land (shown by the yellow outline) consists of Lots 642 & 644 DP1027231 and Lot 100 DP1044282 while, the subject site (shown by the red outline) includes Lot 642 DP1027231 and part of Lot 100 DP1044282.

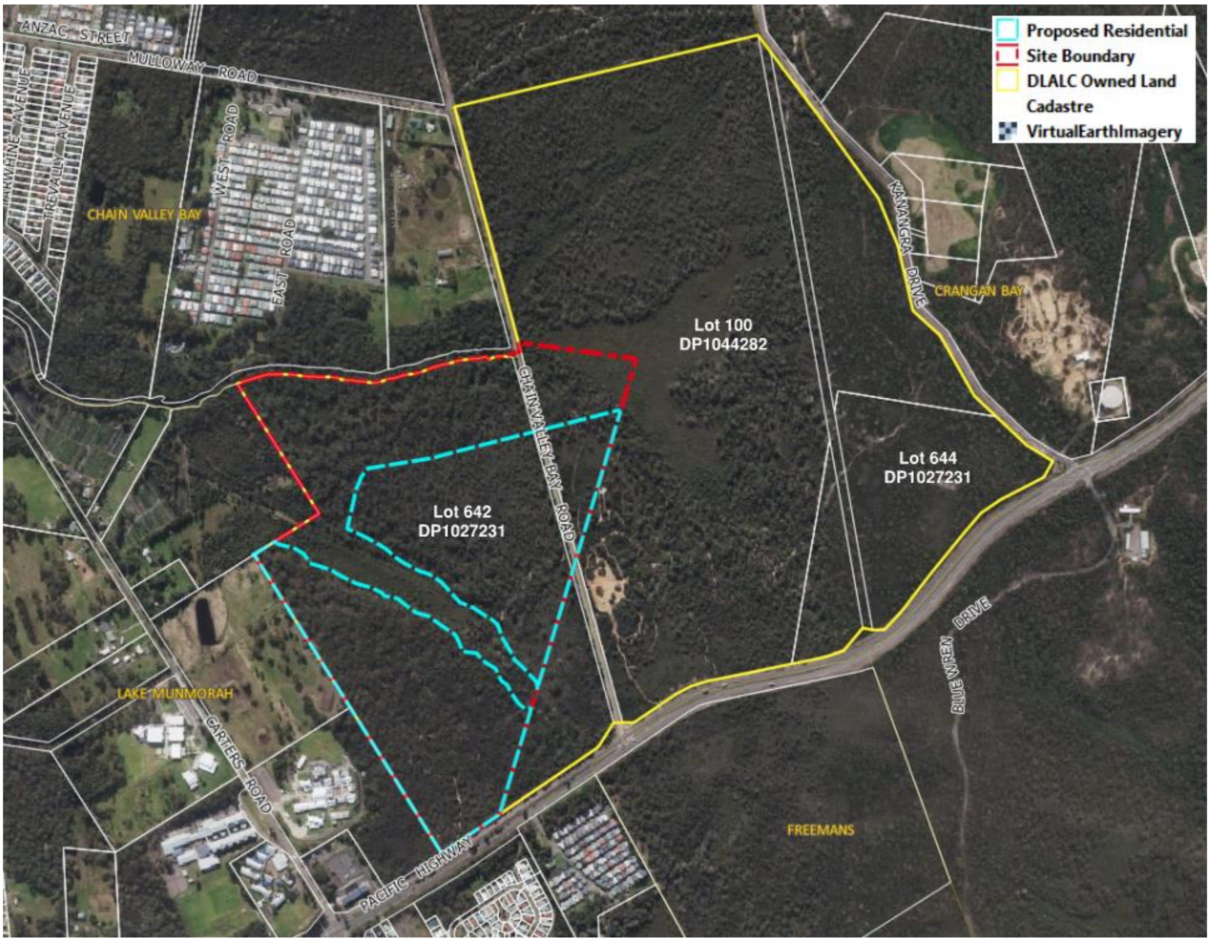


Figure 1 – Subject Site and Proposed Development

The subject site is bordered by Karignan Creek to the north, bushland to the east, a vacant lot and St Brendan's Catholic School to the west and the Pacific Highway to the south. Karignan Creek runs in a north-westerly direction, terminating at its confluence with Lake Macquarie approximately 900 metres north-west of the subject site.

The land use over the extent of the subject site is currently undeveloped and is predominantly vegetated with the exception of Chain Valley Bay Road and several trails which traverse the site. With a total area of approximately 55 Ha, the land is characterised by gently undulating slopes with grades in the order of 2 to 5 percent. The extent of the subject site is currently zoned as E2 (Environmental Conservation) and E3 (Environmental Management).

Surrounding land uses and current land zoning include the following:

- E1 – National Parks and Nature Reserves.
- E2 – Environmental Conservation.
- E3 – Environmental Management.
- RE1 – Public Recreation.
- RE2 – Private Recreation.
- RU6 – Transition.
- SP2 – Special Activities.
- W1 – Natural Waterways.

1.2 Planning Proposal

It is proposed to rezone the majority of Lot 642 DP1027231 and part of Lot 100 DP1044282 to enable residential development across the subject site. The objective of the proposal is to modify the zoning across the subject site to R2 (Low Density Residential), R3 (Medium Density Residential), RE1 (Public Recreation) and E2 (Environmental Conservation).

Approximately 36 hectares of land is proposed to be rezoned to residential as shown by the blue dashed line in the above Figure 1. A lot yield in the order of approximately 420 to 470 lots is anticipated with several different lot sizes ranging from 450m^2 to 650m^2 expected and a small component of smaller and larger lots

The intended outcome of the proposal is to enable future residential development of the subject site and appropriate protection of environmentally significant areas.

2. Flooding

2.1 Scope of Assessment

The primary aim of this desktop flooding investigation is to:

- Identify potential flood constraints with respect to the rezoning of the subject site.
- Define the existing case 5% AEP, 1% AEP flood and Probable Maximum Flood (PMF) extents within the extent of the proposed site.

Contained herein is a description of the contributing catchment, a brief description of previous studies as well as an outline of the modelling methodology and parameters used in preparation of the flood study.

2.2 Catchment Context

The subject site is located within the Karignan Creek catchment as shown in the attached Figures A1 and A2 of Appendix A. Karignan Creek is a tributary of Lake Macquarie with a total catchment area of approximately 4.2 km^2. The catchment is generally bound by the Pacific Highway to the south, Mulloway Road to the North, Kanangra Drive to the east and Tall Timbers Road to the west. A maximum elevation of approximately 55m AHD is observed with gentle to moderate slopes throughout the catchment ranging from 0% to 3%, increasing to 3% to 5% in the upstream sub-catchments.

The catchment land use is largely made up of forested areas with cleared agricultural land and small isolated residential and commercial sites throughout. Karignan Creek is classified as a third order watercourse under the Strahler system and has a relatively narrow floodplain with deep and well-defined channels and steep banks.

2.3 Previous Studies and Guidelines

The latest flood study covering the Karignan Creek catchment and the subject site is the Lake Macquarie Waterway Flood Study prepared by WMAwater in 2012. It is noted that the Lake Macquarie Waterway Flood Study (WMAwater, 2012) is strategic regional flood study for the Lake Macquarie catchment and utilised two-dimensional TUFLOW hydraulic modelling and adopted a model grid size of 40 metres by 40 metres.

It is understood the Lake Macquarie Waterway Flood Study (WMAwater, 2012) was not considered suitable for use for this study by Council and therefore, a localised flood model has been prepared.

This investigation has been prepared with consideration of the following documents:

- Australian Rainfall and Runoff 2019 (AR&R 2019).
- Civil Works Specification Design Guideline 2018 (Central Coast Council, 2019 Revision).
- Floodplain Risk Management Guide Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways (Office of Environment and Heritage, 2015).
- NSW Government Floodplain Development Manual (NSW Government, 2005).
- NSW Government Floodplain Risk Management Guide - Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways (OEH, 2015).
- Lake Macquarie Waterway Flood Study (WMAwater, 2012).
- Wyong Development Control Plan 2013 (WDCP 2013).

2.4 Modelling Methodology

A localised flood model has been prepared using the XP-STORM software which uses one-dimensional XP-RAFTS hydrology (Laurenson equation) and the one-dimensional XP-SWMM routing (St Venants equation) between sub-catchment nodes.

Two-dimensional hydraulic modelling for the Karignan creek floodplain has also been prepared using the TUFLOW hydrodynamic module to assesses flood flows over the Digital Terrain Model (DTM). The two-dimensional study enables the review of complex flow behaviour within the catchment with the potential for flow directions to change through the horizontal plane in response to the terrain.

This study has been undertaken generally in accordance with the following procedure:

- Desktop review of previous investigations and available information including but not limited to LiDAR survey, aerial imagery and cadastral data.
- Preparation of an “Existing Case” one-dimensional XP-STORM hydrological and hydraulic model to assist in the determination of the subject site critical durations.
- Conversion of the Existing Case one-dimensional XP-STORM hydrological and hydraulic model to a combined 1D/2D hydrological and hydraulic model.

The 1%, 5% AEP and PMF design storm events have been considered as part of the investigation. A worst-case climate change scenario has also been prepared which is based on a lake level increase of 0.9 metres and an increase in rainfall intensity by 30% for 1% AEP flood event.

2.5 Digital Terrain Model

Light Detection and Ranging (LiDAR) survey data was used to develop a high-resolution digital terrain model (DTM) of the subject site and vicinity. The LiDAR survey has been undertaken for the Lake Macquarie area in September 2014. Ground classified points were extracted from a LiDAR point cloud data and converted to 1 metre cell resolution raster to use for various stages flood modelling and data analysis.

Figure A1 of Appendix A presents the Digital Terrain Model used for this study. Note that, the “Proposed Residential” boundaries presented in Figure A1 represent the combined residential and recreation zones.

2.6 Hydrological Model

The Laurenson Hydrological model (XP-RAFTS), coupled with the Initial and Continuing Loss model has been used for this study. As per the latest ARR 2019 guidelines, initial loss, continuing loss, pre-burst rainfall and storm burst rainfall portions of the design storm events have been considered as part of this study as shown in the below Figure 2.1.

The XP-STORM hydrologic model was developed to serve the following purposes:

- Gain an understanding of rainfall-runoff and flood behaviour within the catchment.
- Determine flow hydrographs for input to the two-dimensional TUFLOW hydraulic model.
- Assess preliminary estimate of flood elevations to facilitate setup of the two-dimensional hydraulic model.

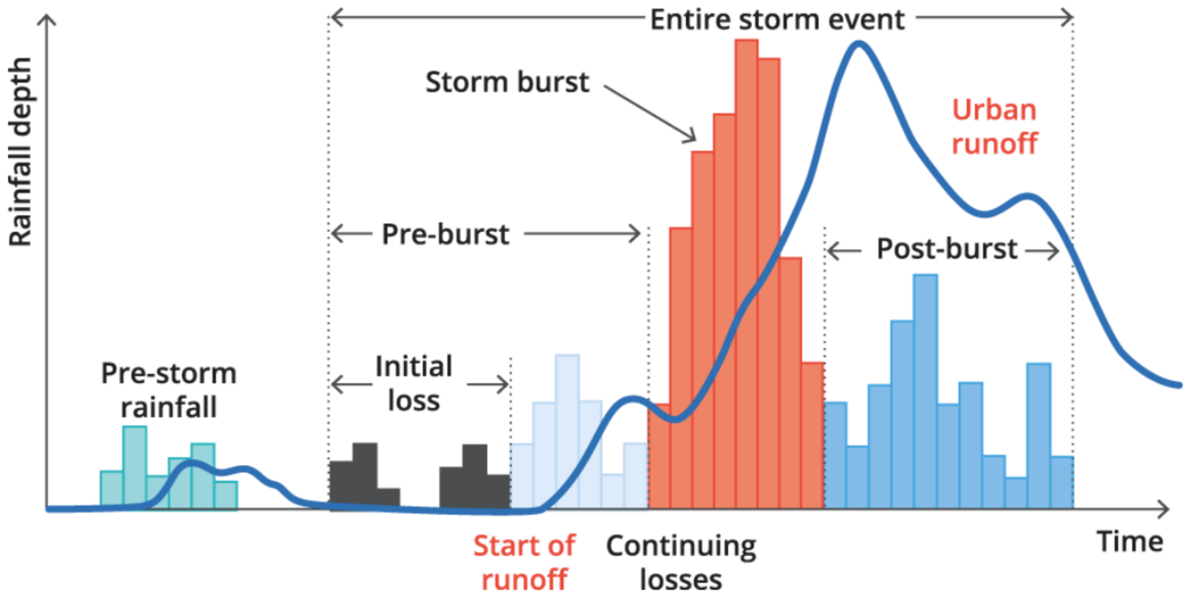


Figure 2.1 - Rainfall and Runoff in Urban Catchments (ARR 2019 Figure 9.6.4)

The key parameters used in XP-STORM hydrological model are outlined below.

2.6.1 Sub-Catchment Properties

Sub-catchments have been digitised using a combination of LiDAR, cadastre and aerial imagery. Sub-catchments are shown in Figure A2 of Appendix A with the sub-catchment properties presented in the below Table 2.1. Note that, the "Proposed Residential" boundaries presented in the Figure A2 represent the combined residential and recreation zones.

Table 2.1 Sub-Catchment Properties

Catchment Reference	Area (ha)	Impervious (%)	Slope (%)
C01	44.88	22	3.9
C02	1.42	0	1.4
C03	16.48	46	3.9
C04	10.19	74	4.1
C05	6.41	4	3.9
C06	26.94	1	5.6
C07	69.69	16	4.2
C08	11.85	51	3.8
C09	23.17	0	3.9
C10	9.81	3	4.4
C11	2.97	0	2.6
C12	33.62	8	4.7

Catchment Reference	Area (ha)	Impervious (%)	Slope (%)
C13	25.92	10	5.4
C14	16.9	0	5.1
C15	9.94	0	5.6
C16	15.19	7	3.5
C17	20.06	4	4
C18	15.63	5	4.1
C19	3.5	23	3.8
C20	23.69	50	3.8
C21	25.42	3	4.3
C22	29.52	11	3.8
C23	39.06	11	3.5

2.6.2 Routing Method

The Laurenson equation is a time-area routing function for the simulation of catchment runoff. It has been adopted in various hydrological models, including RORB, RAFTS, RSWM, as well as XP-STORM. The function works by subdividing a catchment into numerous sub-areas that sequentially discharge into the downstream catchment. The storage of each of these sub-areas is related to the discharge according to the equation:

$$S = BQ^{n+1}$$

Where S is the volume of storage (hours.m^3/s), Q is the discharge (m^3/s), B is a storage delay time coefficient and n is a storage non-linearity exponent. The default value of n is 0.285, which is used throughout this investigation. The value of B is determined by XP-STORM based on the catchment area, urbanised (impervious) fraction and catchment slope.

2.6.3 Design Rainfall

Australian Rainfall and Runoff 2019 (AR&R 2019) provides guidance on design storm events which are defined in terms of Intensity, Frequency and Duration (IFD) and rainfall temporal patterns. AR&R 2019 recommends the use of the storm ensemble method using 10 temporal patterns for each storm duration. For this investigation, storm durations including the; 10, 15, 20, 25, 30, 45 minute and 1, 1.5, 2, 3, 4.5, 6, 9, 12,18, 24, 36, 48, 72 hours were assessed.

The Probable Maximum Precipitation (PMP) design storm event rainfall depths and temporal patterns were estimated using the Generalised Short-Duration Method (GSDM) for durations up to 6 hours. The durations 15, 30, 45 minutes and 1, 1.5, 2, 2.5, 3, 4, 5, 6 hours were modelled to define PMF.

Rainfall depths obtained from the Bureau of Meteorology and used for this study are provided in Appendix D.

2.6.4 Infiltration Losses and Roughness

The Initial and Continuing Loss model was used for this study with the latest AR&R 2019 storm losses obtained from the AR&R Data Hub for a location over the subject site and presented in the below Table 2.2. The Initial and Continuing Loss method simulates catchment storage as an initial loss in rainfall followed by a constant rate (continuing loss). The ARR Data Hub data, including the storm losses, is provided herein as Appendix D.

Similarly, typical hydrological roughness values have been used for the impervious and pervious portions of the catchment. A roughness of 0.014 has been used for impervious areas which is consistent with a concrete surface while a roughness of 0.060 has been adopted as an average for pervious areas which is represents thick grass/ low to medium density bushland and the small amount of pervious residential areas (grass, garden beds etc).

Table 2.2 Adopted Infiltration Loss Rates

Landuse	Initial Loss (mm/hr)	Continuous Loss (mm/hr)	Roughness (Manning's)
Pervious Areas	49.0	2.4	0.060
Impervious Areas	1.5	0.0	0.014

2.6.5 Pre-Burst Rainfall

The Median Pre-Burst depths have been added to the design rainfall events and distributed evenly over three timesteps prior to the burst of the design storm events. The ARR Data Hub data, including the Median Pre-Burst Rainfall and ARR Data Hub data has been provided herein as Appendix D.

As recommended by the latest ARR 2019 guidelines, the 60min pre-burst depths have been used for storm durations that are less than 60 minutes.

The ARR Data Hub provides Median Pre-Burst rainfall which in XP-STORM, is added to each storm event over several timesteps prior to the burst. Resultant burst rainfall losses are then determined by the difference between the pre-burst rainfall and the Storm Losses provided by the ARR Data Hub, (raw data provided in Appendix D). This calculation is summarised below.

Burst Initial Loss = Storm Initial Loss - Pre-burst Rainfall

For example, the Median Burst Initial Loss for the 1% AEP - 60-minute storm duration is applied in XP-STORM to Rural Pervious catchments through the below calculation.

8.7mm (Rural Median IL) = 49mm (Rural Storm Loss) – 40.3mm (Median Pre-Burst)

Through this methodology, the Median Burst Initial Losses have been adopted as part of this study.

2.7 Hydraulic Model

The XP-STORM hydraulic model is made up of two parts:

- The one-dimensional hydraulic model including routing through the creek sections. This model has been used to determine critical durations to pass to two-dimensional model.
- The two-dimensional TUFLOW hydrodynamic model which has been used to define the flood and development extents.

2.7.1 Boundary Conditions

In 2015 the NSW Office of Environment and Heritage (NSW OEH) published the *Floodplain Risk Management Guide – Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways*. This guideline provides advice on approaches that can be used to derive ocean boundary conditions and design flood levels for flood investigations in coastal waterways considering the interaction of catchment flooding and oceanic inundation for the various classes of estuary waterways found in NSW and likely corresponding ocean boundary conditions.

The procedure for modelling ocean level interactions is dependent on the waterway type and location. For Karignan creek, the waterway entrance type is defined as “Waterway Entrance Type A, Group 3 tide dominated estuaries” and located south of Crowdy Head. This entrance type results in little ocean tide attenuation and negligible wave set-up. Based on this waterway entrance type and location the combinations of catchment flooding and oceanic inundation peak levels presented in the below Table 2.3 were adopted.

Table 2.3 Combinations of Catchment Flooding and Oceanic Inundation Peak Level

Design AEP Peak Level	Catchment Flood Scenario	Ocean Water Level Boundary Scenario	Ocean Inundation Peak Level
5% AEP	5% AEP	HHWS(SS)	Dynamic hydrograph, peak level 1.05 metres AHD
1% AEP	1% AEP	5% AEP	Dynamic hydrograph, peak level 1.4 metres AHD
1% AEP Climate Change 2100	1% AEP + 30% Rainfall Increase	5% AEP + 0.9m Sea Level Rise	Dynamic hydrograph, peak level 2.3 metres AHD
PMF	PMF	1% AEP	Dynamic hydrograph, peak level 1.45 metres AHD

2.7.2 Manning's Roughness (1D)

The one-dimensional manning's roughness accounts for the influence that the surface roughness has on the flow through the creek bed and banks. Surface roughness values used in this investigation range from 0.045 for in-channel flow to 0.06 for overbank flow. These values are based on review of hydraulic literature and review of aerial imagery.

2.7.3 Manning's Roughness (2D)

The below Table 2.4 presents the Manning's surface roughness categories adopted for two-dimensional TUFLOW model. The attached Figure A3 of Appendix A presents the extent of roughness values used across the study area.

Table 2.4 TUFLOW Manning's n Values

Land Use	Manning's n
Bushland	0.060
Low Vegetation / Grassed Areas	0.045
Creek	0.040
Residential Areas	0.055
Water Bodies	0.020
Roads / Hardstand	0.015

2.7.4 Two-Dimensional Grid Size

A grid size of 5 metres per 5 metres was adopted for the two-dimensional model which was considered to provide an adequate representation of the creek profile and to define flows through the creek lines and overland flow paths. The two-dimensional TUFLOW grid extent is presented in Figure A2 of Appendix A.

2.8 Results

2.8.1 Critical Storm Durations

To determine the critical storm duration for the areas adjacent to the subject site, the guidance provided in the latest AR&R 2019 guidelines was considered as summarised below:

- Classification of the average value of the ten temporal patterns for each storm duration.
- Selection of the duration that produces the maximum average value for each return interval.

The one-dimensional XP-STORM model was used to classify three critical storm durations to be passed into the two-dimensional TUFLOW model. These were based on a review of the Box and Whisker plots presented in Appendix E.

The below Table 2.5 summarises the storm ensembles that were passed into the two-dimensional TUFLOW model.

Table 2.5 Storm Ensembles passed to the two-dimensional model

Return Interval	Event 1	Event 2	Event 3
5% AEP	3hr	4.5hr	6hr
1% AEP	1.5hr	2hr	3hr
1% AEP + CC	1.5hr	2hr	3hr

All events ranging from the 15-minute to the 2-hour storm duration were passed into the two-dimensional TUFLOW model for the PMF design storm event.

Figures B1, B2, B3 and B4 of Appendix A demonstrates which storm events were critical in the two-dimensional model throughout the catchment for the 1% AEP, 5% AEP, PMF and 1% AEP climate change scenarios respectively. Note that, the “Proposed Residential” boundaries presented in the aforementioned figures represent the combined residential and recreation zones.

2.8.2 Peak Flow

Central Coast Council Civil Works Guidelines suggests that for catchment areas greater than 50 hectares a second peak flow estimation method should be prepared for comparative purposes.

For comparison purposes, two locations have been chosen with the peak flow during the 1% AEP and 5% AEP design storm events presented in the following Table 2.6. These peak flow rates have been extracted from the two-dimensional model.

Table 2.6 Predicted Peak Flow Rates

Cross Section Location	Flood Event	Critical Duration	Peak Flow (m^3/s)
Location A: 200 metres upstream of 2D model outlet	1% AEP	3 hours	65
	5% AEP	4.5 hours	40
Location B: 800 metres upstream of 2D model outlet, downstream the proposed development	1% AEP	3 hours	34
	5% AEP	4.5 and 6 hours	21

The Regional Flood Frequency Estimation (RFFE) tool has been used for the comparison at a location generally commensurate with Location A as defined in Table 2.6 above. The 1% AEP and 5% AEP peak flow results provided by the RFFE are presented in the below Table 2.7.

Table 2.7 Regional Flood Frequency Estimation Tool Results

Flood Event	Discharge (m^3/s)	Lower Confidence Limit 5% (m^3/s)	Upper Confidence Limit 95% (m^3/s)
1% AEP	145	62.7	338
5% AEP	72.3	32.1	163

Review of the above Table 2.6 and Table 2.7 suggests that, although the results are towards the lower bounds, the modelled peak flow rates are within the RFFE model confidence limits.

2.8.3 Flood Depth

The flood depth results for the 1% AEP and 5% AEP design storm events are presented in Figures C1 and C4 of Appendix A respectively. During the 1% AEP and 5% AEP design storm events, flood depths are generally greater than 700mm within Karignan creek and downstream areas. Given their low-lying nature, the downstream areas are expected to be dominated by the flood levels in Lake Macquarie. Flood depths in the other areas of the floodplain are typically less than 0.7 metres.

Similar results are observed in the climate change scenario (Figure C10 of Appendix A) with the exception of the downstream areas which show greater depths in the downstream areas which are generally greater than 2 metres. These changes are expected with the 900mm increase in tailwater levels during the climate change scenario.

During the PMF event Figure C7 of Appendix A demonstrates maximum flood depths within Karignan creek and downstream areas that are also greater than 2 metres while other areas of the floodplain have depths that are generally less than 900mm.

2.8.4 Flood Velocity

Figures C2, C5 and C11 of Appendix A present the maximum flow velocities for the 1% AEP, 5% AEP and 1% AEP + Climate Change events respectively. The results suggest that for all three events, flood velocities within Karignan creek generally range between approximately 0.40 to 1.80 m/s.

During the PMF event, Figure C8 of Appendix A presents the maximum flow velocities within the upper reaches of the Karignan Creek channel are generally greater than 1.8 m/s.

2.8.5 Flood Hazard

Flood hazard for the 1% AEP, 5% AEP, PMF and 1% AEP + Climate Change scenarios are presented in Figures C3, C6, C09 and C12 and of Appendix A respectively. Flood hazard classifications have been based on the NSW Government's *'Floodplain Development Manual'* (2005) and have been defined in accordance with the hydraulic behaviour shown in the below Figure 2.2.

Figure 2.2 – Flood Hazard Hydraulic Behaviour (FPDM, 2005)

Four hazard categories for the 1% AEP, 5% AEP, PMF and 1% AEP Climate change scenario are presented in Figures C3, C6, C12 and C15 of Appendix A respectively, which are based on the above Figure 2.2 and summarised below:

- Low Hazard - Vehicles are considered to be stable and wading is safe.
- Low Hazard - Vehicles unstable – vehicles are considered to be unstable, but wading is considered safe.
- High Hazard - Vehicles and wading are considered unsafe.
- High Hazard - Damage to light structures is possible.

2.8.6 Provisional Hydraulic Categories

The NSW Government's *'Floodplain Development Manual'* (2005) also characterises flood affected areas as hydraulic categories known as Floodways, Flood Storage and Flood Fringe. These are discussed in greater detail in the below Table 2.8.

Table 2.8 Hydraulic Categories - Description

Hydraulic Category	Description
Floodway	• Those areas where a significant volume of water flows during floods. • Often aligned with obvious natural channels. • They are areas that, even if only partially blocked, would cause a significant increase in flood levels and/ or a significant redistribution of flood flow, which may in turn adversely affect other areas. • They are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.
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.
Flood Fringe	• The remaining area of land affected by flooding, after floodway and flood storage areas have been defined. • Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

In the absence of explicit quantitative criteria for defining hydraulic categories, site specific criteria have been adopted for definition of hydraulic categories within the Karignan Creek catchment. The adopted criteria are based on analysis of the modelled flood hazard, velocity, depth and are summarised in Table 2.9 below.

Table 2.9 Hydraulic Categories - Description

Hydraulic Category	Adopted Criteria	Comment
Floodway	Depth > = 0.5 metres; and Velocity > 0.2 m/s; and Velocity x Depth > 0.25 m^2/s	Area conveying a significant proportion of flood flow
Flood Storage	Depth >= 0.5 metres; and Velocity =< 0.2 m/s; and Velocity x Depth =< 0.25m^2/s	Areas outside of floodway
Flood Fringe	Depth < = 0.5 metres; and Velocity < 0.2 m/s	The remaining area of land affected by flooding, after floodway and flood storage areas have been defined

The above criteria were applied to the 1% AEP design storm to produce the provisional hydraulic category map as presented in Figure C16 of Appendix A. The results presented in Figure C16 of Appendix A show that the proposed residential zones are located outside the extent of floodway.

2.8.7 Flood Planning Area

The Flood Planning Area (FPA) has been determined based on the PMF as an alternative to the 1% AEP + 500mm. The PMF has been used due to the difference in flood depth in the creek lines adjacent to the proposed urban footprint.

Figure C17 of Appendix A presents a comparison between the 1% AEP and PMF flood depths. A difference in flood depth of generally less than 300mm is observed in the creeks adjacent to the proposed urban footprint. Given the PMF is considered the worst-case flood event, the additional freeboard contained in the 1% AEP + 500mm is considered over conservative in this case. Preliminary discussions with DPIE and Central Coast Council representatives suggests this may be acceptable.

The resultant Flood Planning Area, based on the PMF is presented in Figure C18 of Appendix A along with the proposed Urban Zone Boundaries. The Urban Zone Boundaries presented in Figure C18 represent the combined residential and recreation zones.

2.9 Discussion

2.9.1 Karignan Creek Crossing

During initial discussions with Council and subsequent discussions with Department of Planning, Industry and Environment (DPIE), concern was raised with respect to how the Karignan creek crossing was included in the flood model. The Karignan creek Crossing is located approximately 1km downstream of Chain Valley Bay Road, within the boundaries of Lot 428 DP755266 and Lot 594 DP727722 and a photo of the structure is shown in the below Figure 2.3. The approximate location of the structure is presented in Figure A1 of Appendix A.

Figure 2.3 – Karignan Creek Crossing

The crossing represents a typical weir structure with observations made using aerial imagery of water ponding on both the upstream and downstream reaches of the creek. Review of LiDAR elevation data suggests the top elevation of the crossing is approximately 1.3m AHD with an invert that is less than approximately 0.25m AHD. This structure is included in the DTM of the two-dimensional model acting as an obstruction to flow. No culvert or hydraulic structure has been assumed.

With an obvert elevation of approximately 1.3m and a minimum modelled tailwater elevation of approximately 1.05-1.4m AHD, the structure is not expected to significantly alter the results of the flood assessment. Similarly, Figure A1 of Appendix A shows a minimum elevation across the proposed development in the order of 6.5m AHD. Given the elevated level of the development with respect to the weir obvert, it is not expected that the weir will significantly influence the flood planning levels or flood planning extent for the subject site.

2.10 Sensitivity Tests

Following consultation with DPIE, additional sensitivity tests have been performed on the catchment with respect to the assumed model parameters. This has been performed due to the absence of calibration data within the catchment.

The below 2.10 summarises the sensitivity tests performed while, the attached Figures D1 to D5 Appendix A present the results.

Table 2.10 Flood Model Sensitivity Tests (refer to Appendix A for Figures)

Sensitivity Test	Figure Reference	Summary of Results
Bushland Roughness increased from 0.060 to 0.080	Figure D1	Increases generally less than 20mm are observed in the creek adjacent to the proposed urban areas. It is noted that there was a preference from DPIE to update the bushland roughness to 0.080. However, given the relatively insignificant change in flood depth and extents presented in the results, bushland roughness has been unchanged.
Continuing Loss reduced from 2.4mm/hr to 0.96mm/hr (per latest OEH advice)	Figure D2	Relatively insignificant changes are observed with generally less than +/-10mm change in flood depth observed across the majority of the study area. DPIE suggested continuing loss should also be updated if a significant change was observed when testing its sensitivity. The results presented in Figure D2 of Appendix A suggest the catchment is not sensitive to continuing losses and therefore, this variable has not been modified.
Initial Loss reduced from 49mm to 25mm	Figure D3	Sensitivity to initial losses shows the greatest change in flood depth when compared to other sensitivity tests considered herein. Increases of up to 200mm are observed in Karignan Creek while increases, generally less than 30mm are also observed in the creek adjacent to the Urban Zone Boundaries. Although the flood depth differences are greatest in this scenario, still only minor changes in flood extents are observed.

Sensitivity Test	Figure Reference	Summary of Results
All manning's surface roughness values increased by 20%	Figure D4	Increases of up to approximately 150mm are observed in Karignan Creek along the northern boundary. Similarly, increases generally less than 20mm are observed in the creek running between the Urban Zone Boundaries.
All Manning's surface roughness values decreased by 20%	Figure D5	Decreases of up to approximately 150mm are observed in Karignan Creek along the northern boundary. Similarly, decreases generally less than 20mm are observed in the creek running between the Urban Zone Boundaries.

The sensitivity tests performed herein suggest only minor changes to flood depth are expected in the creeks adjacent to the Urban Zone Boundaries. The greatest changes were observed in Karignan Creek however, review of Figure A1 suggests the Urban Zone Boundaries closest to the Creek are approximately 10m above the invert of the creek. As such, changes in Karignan Creek are not expected to significantly change the proposed Urban Zone Boundaries.

The results of the sensitivity test conclude the proposed development is relatively insensitive to the assumed model parameters. Further modelling is expected at Development Application phase once a layout is determined with an opportunity to update the model parameters during this phase as required.

3. Stormwater Drainage

The introduction of an urban environment typically results in a significant modification to soils, topography, impervious percentages and vegetation when compared to the pre-developed state. Surface water runoff volumes and pollutant concentrations from un-mitigated urban catchments are typically above pre-developed conditions and without appropriate mitigation measures have the potential to convey increased runoff volumes and pollutant loads into downstream receiving waters. To mitigate the potentially detrimental effects of urbanisation upon the environment stormwater runoff needs to be managed appropriately as part of any future development of the subject site.

3.1 Stormwater Management Objectives

The Central Coast Council (CCC) currently has two operational Development Control Plans (DCPs). Situated within the old Wyong Local Government Area (LGA) the proposed rezoning will need to consider the 2013 Wyong DCP. In accordance with the DCP a stormwater management strategy is to be prepared for all subdivision development which will generally comply with the following:

- All land is to be adequately drained so as not to impact on adjacent sites.
- Development will not contribute to drainage or flooding problems elsewhere.
- Prevent erosion and sedimentation through incorporation of adequate soil stability measures.
- Promote water sensitive urban development and provide a more integrated approach to urban water cycle management.
- Ensure conservation of water and reduction in mains water consumption by utilising stormwater as a natural water resource for larger subdivisions.
- Protect sensitive ecosystems and to maintain hydrological regimes to downstream environments.

The specific design requirements for stormwater quantity and quality management are outlined in Section 10 of the CCC's 2018 Civil Works Specification. Under this guideline the following design objectives are applicable:

- Post-development peak flow from the outlet point(s) of the site to the downstream public drainage system or receiving water shall not exceed the pre-development peak flow for both the minor and major system design storm AEP.
- Development shall mitigate the impacts of urban development on stormwater quality through adoption of Water Sensitive Urban Design Principles to reach the nominated pollutant load reduction targets.

3.2 Stormwater Management Strategy

A concept stormwater management strategy illustrating compliance with the design objectives outlined in **Section 3.1** above will need to be prepared to support any subsequent development applications following rezoning.

Considered pertinent to assessing the feasibility of the rezoning application, the sections below outline a preliminary strategy for the stormwater detention and water quality measures required to mitigate the effects of future development. It is anticipated that details of the minor and major conveyance infrastructure will be provided once lot layouts have been determined during the Development Application and Detailed Design phase.

3.3 Sub-Catchments

The proposed development site includes six proposed residential areas as shown in Figure 3 of Appendix A. Each of the proposed residential areas forms a sub-catchment that has been considered to independently address the objectives outlined above. In accordance with Table 10.2 of CCC's Civil Works Specification and the proposed residential land use, a gross impervious fraction of 80% has been assumed for the preliminary strategy.

3.4 Stormwater Detention

Preliminary hydrological modelling has been undertaken to assess the contributing catchment in both the pre and post developed scenarios. The model was then used to develop mitigation measures which have been designed to ensure no net increase in peak flows for a range of events from the 20% AEP to the 1% AEP over a range of durations from the 10 minutes to 72 hours. This range of events was considered appropriate for the site with water quality treatment devices expected to effectively attenuate more frequent flows.

3.4.1 Hydrologic Model Setup

The one-dimensional XP-STORM model used to derive the flood extents was modified to include the proposed development including the proposed stormwater detention measures.

Similar to the setup for the flood model, the latest rainfall depths have been obtained from the Bureau of Meteorology (BOM) for a location over the catchment while the losses presented in the above have been used. Transformational pre-burst depths have been added to the design rainfall events and distributed evenly over six timesteps prior to the burst of the design storm events. The 60min pre-burst depths have been used for storm durations that are less than 60 minutes.

Additional details of the modelling hydrological model parameters are described in **Section 2.5** of this report.

3.4.2 Results

The modelling results for three scenarios including the pre-developed, post-developed and post-developed with detention are summarised below in Table 3.1. A comparison between the results of the pre-developed and post-developed scenarios suggests the proposed development will increase peak flows within each sub-catchment over the full range of return intervals considered.

It is noted that the results for the post-developed scenario with integrated detention basins are approximate only and are based on post-developed catchments with the highly conservative effective impervious area percentage of 80%. Further detailed modelling will be required at Development Application and Construction Certificate stage to fully determine the development characteristics (road layout, percentage impervious, latest guidelines etc.). The below values have therefore been provided as a guide to display how detention may be located and incorporated within future development.

Table 3.1: Stormwater Detention Peak Flow Comparison

ID, Area and Average Slope	Storm Event AEP %	Pre-developed		Post-developed		Post-developed with Detention		Basin Volume (m³)
		Peak Flow Rate (m³/s)	Critical Duration	Peak Flow Rate (m³/s)	Critical Duration	Peak Flow Rate (m³/s)	Critical Duration	
1 6.85 ha 4.7%	20	**0.55**	1.5 hr	**3.59**	45 min	**0.54**	1 hr	4078
	5	**0.99**	1 hr	**5.26**	30 min	**0.98**	1 hr	
	1	**1.63**	1 hr	**7.78**	25 min	**1.63**	1 hr	
2 4.86 ha 3.9%	20	**0.39**	1.5 hr	**2.54**	45 min	**0.36**	1 hr	2900
	5	**0.69**	1 hr	**3.70**	30 min	**0.68**	1 hr	
	1	**1.15**	1 hr	**5.47**	25 min	**1.13**	1 hr	
3 9.80 ha 4.5%	20	**0.73**	1.5 hr	**4.92**	45 min	**0.69**	1 hr	5244
	5	**1.27**	1 hr	**7.05**	45 min	**1.26**	1 hr	
	1	**2.17**	1 hr	**10.45**	30 min	**2.13**	1 hr	
4 4.28 ha 3.7%	20	**0.34**	1.5 hr	**2.24**	45 min	**0.31**	1 hr	2416
	5	**0.61**	1 hr	**3.26**	30 min	**0.60**	1 hr	
	1	**1.01**	1 hr	**4.83**	25 min	**1.00**	1 hr	
5 7.24 ha 4.3%	20	**0.56**	1.5 hr	**3.71**	45 min	**0.53**	1 hr	4660
	5	**0.99**	1 hr	**5.34**	45 min	**0.97**	1 hr	
	1	**1.66**	1 hr	**7.92**	30 min	**1.64**	1 hr	
6 4.10 ha 3.8%	20	**0.33**	1.5 hr	**2.16**	45 min	**0.30**	1 hr	2415
	5	**0.60**	1 hr	**3.18**	30 min	**0.60**	1 hr	
	1	**0.98**	1 hr	**4.70**	25 min	**0.97**	1 hr	

As summarised in the above Table 3.1 the proposed detention basins effectively attenuate runoff from the development sites for events up to and including the 1% AEP.

It is anticipated stormwater detention will be further refined during future detailed design to suit the development layout more appropriately. This is expected to occur at both the Development Application and Construction Certificate stages.

3.5 Stormwater Quality Treatment

In accordance with the DCP the development is to incorporate the principles of Water Sensitive Urban Design (WSUD). WSUD is a philosophy that incorporates urban water cycle management into the urban design process. The philosophy considers options to integrate urban water management infrastructure within the natural environment. It aims to protect the health of aquatic ecosystems and minimise negative impacts on the natural water cycle.

Councils DCP outlines a number of acceptable strategies for achieving the principles of WSUD including:

- Utilisation of water quality control ponds (WQCP) or constructed wetlands, as physical and biological treatment systems, upstream of urban lakes.
- Incorporation of gross pollutant traps (GPTs) on inlets to urban lakes and WQCPs to intercept trash and debris and the coarser fractions of sediment.
- Incorporation of 'off-stream' sediment interception ponds (SIP) in land development works to intercept and treat runoff prior to its discharge to the stormwater system.

3.5.1 Pollution Load Reduction Targets

Water quality is proposed to be managed through a treatment train approach to meet pollutant removal efficiency targets specified within Council's DCP. The relevant targets have been reproduced in Table 3.2 below.

Table 3.2: Pollutant Removal Efficiency Targets

Pollutant	Treatment Efficiency Target
Total Suspended Solids (TSS)	80% reduction in mean annual load
Total Nitrogen (TN)	45% reduction in mean annual load
Total Phosphorous (TP)	45% reduction in mean annual load
Gross Pollutant (GP)	90% reduction in mean annual load (for pollutants greater than 5mm in diameter)

3.5.2 MUSIC Modelling

The performance of the proposed stormwater management strategy has been assessed using the conceptual computer software MUSIC (Version 6.3). MUSIC serves as a planning and decision support system that is used to estimate the efficiency of Stormwater Quality Improvement Devices (SQIDs) at capturing common stormwater pollutants including Total Suspended Solids, Total Nitrogen, Total Phosphorous and Gross Pollutants from stormwater runoff. Modelling involves the use of historical or synthesized long-term rainfall data and algorithms that can simulate the performance of stormwater treatment measures to determine stormwater pollution control.

CCC's MUSIC-Link for low land development has been utilised for all rainfall and source node pollutant data inputs. Source nodes were classified as one of three land use categories being roof, sealed road or residential areas. For the purpose of the water quality study the roof area was conservatively estimated as 32% of the site. The estimate is based on statistical calculations of ten random samples of typical medium sized residential lot with average area approximately of 700 square metres.

3.5.3 Proposed Treatment Train

Treatment trains consisting of the following devices have been proposed for each sub-catchment:

- Reuse Tanks – Individual 4000 litres rainwater harvesting tanks have been proposed for future lots. All tanks are to be fitted with proprietary first flush devices as minimum treatment prior to onsite reuse. By capturing the first portion of runoff from the roof areas the first flush devices will effectively remove course sediment and attached nutrients from the system.

- GPTs – End of line proprietary gross pollutant traps have been proposed to provide primary treatment. The devices are designed to remove litter, debris and course sediment from runoff to protect downstream treatment measures.
- Wetlands – Constructed wetlands have been proposed as end of line tertiary treatment measures. Constructed wetland systems are shallow, extensively vegetated water bodies that use enhanced sedimentation, fine filtration and biological uptake processes to remove pollutants from stormwater. The proposed wetlands will generally consist of an inlet zone, macrophyte zone and a high flow bypass channel. Detailed design of the wetlands will need to show consideration to the landscape, plant species section, nominal detention time and hydrodynamic basin function. At this stage the wetlands have been conservatively estimated to have a surface area of approximately 5-7% of the contributing catchment area.

3.5.4 Results

The estimated pollutant load reductions modelled in MUSIC are presented in Table 3.3. The resultant MUSIC-Link report has been provided in Appendix B.

Table 3.3: Stormwater Quality Results

Sub-Catchment	Parameter (kg/yr)	Source Load	Residual Load	% Reduction
1	TSS	8090	1400	**82.7**
	TP	16.3	6.42	**60.6**
	TN	149	81.7	**45.1**
	GP	1740	1.83	**99.9**
2	TSS	4890	852	**82.6**
	TP	9.8	3.89	**60.4**
	TN	89.6	49.2	**45.1**
	GP	1050	1.2	**99.9**
3	TSS	10100	1740	**82.7**
	TP	20.2	7.92	**60.7**
	TN	186	102	**45.2**
	GP	2180	2.62	**99.9**
4	TSS	4900	849	**82.6**
	TP	9.84	3.89	**60.4**
	TN	90.7	49.8	**45.1**
	GP	1060	1.22	**99.9**
5	TSS	10200	1780	**82.6**
	TP	20.4	8.07	**60.5**
	TN	188	103	**45.0**
	GP	2210	2.8	**99.9**
6	TSS	4540	781	**82.8**

Sub-Catchment	Parameter (kg/yr)	Source Load	Residual Load	% Reduction
	TP	9.6	3.61	**60.6**
	TN	84.4	46.3	**45.1**
	GP	989	1.25	**99.9**

As summarised in Table 3.3, the proposed treatment train will effectively meet all residual pollutant load reduction targets as recommended by the DCP. Detailed design to confirm the device sizes and inlet configurations is to be undertaken at subsequent Development Application and Construction Certificate stages. It is anticipated that the constructed wetlands will be located within dedicated drainage reserves upstream of the proposed stormwater detention basins within each sub-stage of the development.

3.6 Erosion and Sediment Control

In addition to the long-term impacts of urbanisation, significant impacts on stormwater quality can result during construction. Construction activities involve the removal of vegetation and exposure of large areas of bare soil which increases the risk of erosion. Sediment runoff during construction is considered a significant contributor to high nutrient levels in wet weather conditions.

Whilst detailed erosion and sediment control plans are not considered pertinent to the rezoning application, concept plans will be required to support any subsequent development applications. There are various best practice guidelines which assist in preparing management plans with Landcom's Managing Urban Stormwater: Soils and Construction (the 'Blue Book') considered the most relevant and comprehensive guideline in NSW. In accordance with Council's DCP the Blue Book' is expected to form the basis for the preparation of the stage specific erosion and sediment control designs. Consideration should also be given to CCC's Civil Work and Construction Specifications when preparing detailed design plans.

4. Potable Water

4.1 Points of Connection and Available Capacity

The subject site is currently fronted along the southern boundary by an existing DN375 water main along the northern side of the Pacific Highway. There is also an existing DN200 water main which branches off this DN375 water main and runs along the western side of Chain Valley Bay Road. CCC has confirmed connection will be possible to these mains.

A plan showing the location of existing water infrastructure is included in Appendix C.

4.2 Estimated Water Demand

Water demands for the proposed development have been estimated in accordance with the Water Supply Code of Australia, Hunter Water Edition, incorporating CCC's modified water demands. Estimated water demands are provided in Table 4.1.

Table4.1: Design Water Demands.

Land Use Category	Residential
Average Annual Demand Basis	
Development Footprint	470 lots
Average Day Demand	264 kL/day
Average Day Demand	3.1 L/s
Peak Day Demand	9.5 L/s
Peak Hour Demand	19.1 L/s
Extreme Day Demand	10.9 L/s
95^{th} Percentile Peak Hour Demand	15.3 L/s
Firefighting Allowance	10 L/s (residential)
95^{th} Percentile Peak Hour Demand + Firefighting Allowance	25.3 L/s

4.3 Proposed Servicing

The proposed the site is to be serviced via connections to the existing surrounding infrastructure. These connections include two connections to the existing DN375 trunk main to the south along the Pacific Highway and two connections to the existing DN200 trunk main along the western side of Chain Valley Bay Road. In addition to connection to this existing infrastructure, a DN200 cross connection will be required between Carter Road and Chain Valley Bay Road. The internal reticulation network within the development will comprise of mains approximately DN100-DN200.

An indicative layout of the proposed servicing layout can be seen in Appendix C. Detailed design of this network is to be undertaken at a later stage.

5. Sewer

5.1 Points of Connection and Available Capacity

The subject site is not currently serviced by sewer infrastructure. The surrounding areas are serviced by a network of gravity mains leading to sewer pump stations that ultimately discharge to Mannering Park Wastewater Treatment Plant (WWTP). The existing pump stations do not have capacity to service the proposed development.

A plan showing the location of existing sewer infrastructure is included in Appendix C.

5.2 Estimated Sewer Loading

Sewer loadings for the proposed development have been estimated in accordance with the CCC's adopted average dry weather flow of 0.0067 L/s/ET.

The estimated sewer loadings are summarised in Table 5.1 below.

Table 5.1: Sewer Loading.

Catchment	ET	ADWF (L/s)	PDWF (L/s)	PWWF (L/s)
36 ha	470	3.15	8.04	35.30

5.3 Proposed Servicing

It is proposed to service the development by the way of constructing a gravity network throughout the site along with a new sewer pump station (SPS) and rising main. The gravity network will direct flows from the development to the new SPS which will then transfer wastewater via the rising main directly to the Mannering Park WWTP.

The rising main is expected be approximately 3.8km long and the route is likely to require crossing three (3) intermediate high points before discharging the Mannering Park WWTP inlet works at approximately RL17m. From the new SPS constructed in the low point of the site, it is anticipated the rising main will be directed south-west until Carters Road, then continue north-west via road corridors and easements towards Mannering Park WWTP.

An indicative layout of the proposed sewer servicing layout can be seen in Appendix C. Detailed design of this network is to be undertaken at a later stage.

6. Service Infrastructure

6.1 Electricity

Electrical infrastructure currently exists to the south along the Pacific Highway and to the east along Chain Valley Bay Road. Given the number and nature of the proposed future development it is expected that this system will have capacity to service the site. Further detailed investigations and liaison will be undertaken at Development Application Phase of the development.

6.2 Telecommunications

Based on information obtained from the Dial Before You Dig (DBYD) service, the site is located in proximity to existing communications infrastructure which services the surrounding schools to the west and residential dwellings to the south. It is anticipated that the subject site can be serviced with telecommunications by extending and upgrading this existing network.

6.3 Gas

Based on discussions with Jemena, there is no gas available to service the proposed development. Extending the gas network to this area has previously been investigated and was not considered viable. It has been advised that extension of this existing gas network is possible but would require significant contributions from the developer.

7. Conclusion

Based on the assessment undertaken to date the site is recommended for planning proposal on the grounds of stormwater flooding and essential services. As outlined above the site is considered to have sufficient capacity to accommodate the proposed rezoning with further investigations required to support the detailed design of the subdivision application.

The outcomes of the preliminary stormwater management strategy indicate that detention measures can be adopted to attenuate post developed flows to pre-developed rates. In addition to this, through the adoption of WSUD principals, water quality reduction targets can be achieved.

Future servicing for the site is feasible and would be subject to an application to each authority at the time of development application. Augmentation to existing infrastructure would be undertaken by the developer in conjunction with local servicing authorities and neighbouring developments.

Appendix A – Flooding and Stormwater Figures

Appendix B – MUSIC-Link Reports

Appendix C – Services Drawings

Appendix D – Hydrological Model Data

Results - ARR Data Hub

[STARTTXT]

Input Data Information

[INPUTDATA]

Latitude,-33.179000

Longitude,151.577000

[END_INPUTDATA]

River Region

[RIVREG]

Division,South East Coast (NSW)

River Number,11

River Name,Macquarie-Tuggerah Lakes

[RIVREG_META]

Time Accessed,21 October 2019 10:03AM

Version,2016_v1

[END_RIVREG]

ARF Parameters

[LONGARF]

Zone,SE Coast

a,0.06

b,0.361

c,0.0

d,0.317

e,8.11e-05

f,0.651

g,0.0

h,0.0

i,0.0

[LONGARF_META]

Time Accessed,21 October 2019 10:03AM

Version,2016_v1

[END_LONGARF]

Storm Losses

[LOSSES]

ID,30834.0

Storm Initial Losses (mm),49.0

Storm Continuing Losses (mm/h),2.4

[LOSSES_META]

Time Accessed,21 October 2019 10:03AM

Version,2016_v1

[END_LOSSES]

Temporal Patterns

[TP]

code,ECsouth

Label,East Coast South

[TP_META]

Time Accessed,21 October 2019 10:03AM

Version,2016_v2

[END_TP]

Areal Temporal Patterns

[ATP]

code,ECsouth

arealabel,East Coast South

[ATP_META]

Time Accessed,21 October 2019 10:03AM

Version,2016_v2

[END_ATP]

Median Preburst Depths and Ratios

[PREBURST]

min (h)\AEP(%),50,20,10,5,2,1

60 (1.0),32.8 (1.038),38 (0.844),38 (0.688),37.5 (0.567),37.2 (0.454),40.3 (0.422)

90 (1.5),32.8 (0.896),36.7 (0.704),36.6 (0.573),36.1 (0.473),36.4 (0.385),40.4 (0.367)

120 (2.0),32.9 (0.81),36.7 (0.636),36.7 (0.519),37 (0.438),36.1 (0.347),42 (0.347)

180 (3.0),31.2 (0.662),35.7 (0.534),35.9 (0.44),37.2 (0.382),37.8 (0.315),43.4 (0.312)

360 (6.0),34.8 (0.567),38.9 (0.449),39 (0.368),39.9 (0.319),38.1 (0.247),45.5 (0.256)

720 (12.0),29.3 (0.362),33.3 (0.292),34 (0.245),36.1 (0.22),34.9 (0.174),45.5 (0.196)

1080 (18.0),27.9 (0.294),32.9 (0.246),32.9 (0.202),35.6 (0.184),33.8 (0.143),44.7 (0.164)

1440 (24.0),26.5 (0.25),30.7 (0.205),30.7 (0.169),32.6 (0.151),32.5 (0.122),42.4 (0.138)

2160 (36.0),21.2 (0.174),27.5 (0.158),28.5 (0.134),30.6 (0.121),28.7 (0.093),39.2 (0.109)

2880 (48.0),19.2 (0.143),23.7 (0.124),24.7 (0.106),21 (0.075),26.7 (0.078),38.2 (0.096)

4320 (72.0),15 (0.1),19.9 (0.093),20.6 (0.078),17.5 (0.055),24.4 (0.063),32.5 (0.073)

[PREBURST_META]

Time Accessed,21 October 2019 10:03AM

Version,2018_v1

Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

[END_PREBURST]

10% Preburst Depths

[PREBURST10]

min (h)\AEP(%),50,20,10,5,2,1

60 (1.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

90 (1.5),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

120 (2.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

180 (3.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

360 (6.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

720 (12.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

1080 (18.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

1440 (24.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

2160 (36.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

2880 (48.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

[PREBURST10_META]

Time Accessed,21 October 2019 10:03AM

Version,2018_v1

Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

[END_PREBURST10]

25% Preburst Depths

[PREBURST25]

min (h)\AEP(%),50,20,10,5,2,1

60 (1.0),0.2 (0.006),0.1 (0.002),0.1 (0.001),0.0 (0.000),0.0 (0.000),0.0 (0.000)

90 (1.5),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

120 (2.0),0.5 (0.012),0.3 (0.005),0.1 (0.002),0.0 (0.000),0.0 (0.000),0.0 (0.000)

180 (3.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

360 (6.0),2.0 (0.032),2.1 (0.024),2.2 (0.021),2.3 (0.019),1.0 (0.006),0.0 (0.000)

720 (12.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.5 (0.003),0.9 (0.004)

1080 (18.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),3.2 (0.014),5.7 (0.021)

1440 (24.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),1.3 (0.005),2.3 (0.008)

2160 (36.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

2880 (48.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

[PREBURST25_META]

Time Accessed,21 October 2019 10:03AM

Version,2018_v1

Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

[END_PREBURST25]

75% Preburst Depths

[PREBURST75]

min (h)\AEP(%),50,20,10,5,2,1

60 (1.0),39.2 (1.241),39.2 (0.870),39.2 (0.709),39.1 (0.592),33.4 (0.408),29.2 (0.305)

90 (1.5),33.9 (0.925),34.9 (0.670),35.6 (0.557),36.3 (0.475),34.7 (0.367),33.5 (0.305)

120 (2.0),36.6 (0.901),40.0 (0.693),42.3 (0.599),44.5 (0.527),46.4 (0.445),47.9 (0.396)

180 (3.0),37.6 (0.799),47.3 (0.707),53.6 (0.657),59.8 (0.614),76.1 (0.634),88.3 (0.636)

360 (6.0),45.1 (0.735),69.9 (0.806),86.3 (0.817),102.0 (0.814),118.9 (0.772),131.6 (0.741)

720 (12.0),29.5 (0.365),44.5 (0.391),54.5 (0.393),64.0 (0.390),83.7 (0.415),98.4 (0.424)

1080 (18.0),27.3 (0.288),42.2 (0.315),52.0 (0.319),61.4 (0.318),76.3 (0.322),87.5 (0.320)

1440 (24.0),19.4 (0.184),33.6 (0.224),43.0 (0.236),52.0 (0.240),66.2 (0.249),76.9 (0.251)

2160 (36.0),10.3 (0.085),24.7 (0.142),34.2 (0.161),43.3 (0.171),49.3 (0.159),53.9 (0.150)

2880 (48.0),6.4 (0.048),9.7 (0.051),11.8 (0.051),13.9 (0.050),24.1 (0.070),31.8 (0.080)

4320 (72.0),0.0 (0.000),3.5 (0.016),5.8 (0.022),8.1 (0.026),21.8 (0.056),32.0 (0.072)

[PREBURST75_META]

Time Accessed,21 October 2019 10:03AM

Version,2018_v1

Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

[END_PREBURST75]

90% Preburst Depths

[PREBURST90]

min (h)\AEP(%),50,20,10,5,2,1

60 (1.0),89.1 (2.817),119.3 (2.648),139.2 (2.520),158.3 (2.394),160.6 (1.957),162.2 (1.699)

90 (1.5),63.4 (1.730),81.3 (1.560),93.2 (1.459),104.5 (1.368),135.2 (1.430),158.2 (1.441)

120 (2.0),73.7 (1.813),101.1 (1.751),119.3 (1.687),136.7 (1.619),143.3 (1.374),148.2 (1.225)

180 (3.0),89.1 (1.891),129.2 (1.933),155.7 (1.907),181.2 (1.861),195.8 (1.633),206.8 (1.490)

360 (6.0),76.3 (1.243),106.7 (1.231),126.9 (1.202),146.2 (1.166),187.8 (1.220),218.9 (1.232)

720 (12.0),65.8 (0.814),77.8 (0.682),85.7 (0.619),93.3 (0.568),148.7 (0.738),190.3 (0.819)

1080 (18.0),65.9 (0.695),88.3 (0.659),103.1 (0.633),117.3 (0.608),144.3 (0.609),164.5 (0.602)

1440 (24.0),47.0 (0.444),70.1 (0.468),85.4 (0.468),100.1 (0.463),122.2 (0.460),138.8 (0.453)

2160 (36.0),39.1 (0.320),61.9 (0.356),76.9 (0.363),91.4 (0.362),103.0 (0.332),111.7 (0.312)

2880 (48.0),20.6 (0.154),43.2 (0.226),58.1 (0.248),72.4 (0.259),93.0 (0.271),108.4 (0.274)

4320 (72.0),6.3 (0.042),21.1 (0.098),30.9 (0.117),40.3 (0.128),64.7 (0.167),83.0 (0.186)

[PREBURST90_META]

Time Accessed,21 October 2019 10:03AM

Version,2018_v1

Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

[END_PREBURST90]

Interim Climate Change Factors

[CCF]

,RCP 4.5,RCP6,RCP 8.5

2030,0.869 (4.3%),0.783 (3.9%),0.983 (4.9%)

2040,1.057 (5.3%),1.014 (5.1%),1.349 (6.8%)

2050,1.272 (6.4%),1.236 (6.2%),1.773 (9.0%)

2060,1.488 (7.5%),1.458 (7.4%),2.237 (11.5%)

2070,1.676 (8.5%),1.691 (8.6%),2.722 (14.2%)

2080,1.810 (9.2%),1.944 (9.9%),3.209 (16.9%)

2090,1.862 (9.5%),2.227 (11.5%),3.679 (19.7%)

[CCF_META]

Time Accessed,21 October 2019 10:03AM

Version,2019_v1

Note,ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

[END_CCF]

Probability Neutral Burst Initial Loss

[BURSTIL]

min (h)\AEP(%),50,20,10,5,2,1

60 (1.0),16.6,11.4,11.4,11.9,12.2,9.1

90 (1.5),16.6,12.7,12.8,13.3,13.0,9.0

120 (2.0),16.5,12.7,12.7,12.4,13.3,7.4

180 (3.0),18.2,13.7,13.5,12.2,11.6,6.0

360 (6.0),14.6,10.5,10.4,9.5,11.3,3.9

720 (12.0),20.1,16.1,15.4,13.3,14.5,3.9

1080 (18.0),21.5,16.5,16.5,13.8,15.6,4.7

1440 (24.0),22.9,18.7,18.7,16.8,16.9,7.0

2160 (36.0),28.2,21.9,20.9,18.8,20.7,10.2

2880 (48.0),30.2,25.7,24.7,28.4,22.7,11.2

4320 (72.0),34.4,29.5,28.8,31.9,25.0,16.9

[BURSTIL_META]

Time Accessed,21 October 2019 10:03AM

Version,2018_v1

Note,As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

[END_BURSTIL]Transformational Pre-burst Rainfall

[PREBURST_TRANS]

min (h)\AEP(%),50,20,10,5,2,1

60 (1.0),32.8,38.0,38.0,37.5,37.2,40.3

90 (1.5),32.8,36.7,36.6,36.1,36.4,40.4

120 (2.0),32.9,36.7,36.7,37.0,36.1,42.0

180 (3.0),31.2,35.7,35.9,37.2,37.8,43.4

360 (6.0),34.8,38.9,39.0,39.9,38.1,45.5

720 (12.0),29.3,33.3,34.0,36.1,34.9,45.5

1080 (18.0),27.9,32.9,32.9,35.6,33.8,44.7

1440 (24.0),26.5,30.7,30.7,32.6,32.5,42.4

2160 (36.0),21.2,27.5,28.5,30.6,28.7,39.2

2880 (48.0),19.2,23.7,24.7,21.0,26.7,38.2

4320 (72.0),15.0,19.9,20.6,17.5,24.4,32.5

[PREBURST_TRANS_META]

The tranformational pre-burst is intended for software suppliers in the NSW area and is simply the Initial Loss - Burst Initial Loss. It is not appropriate to use these values if considering a calibrated initial loss.

[END_PREBURST_TRANS]

IFD Design Rainfall Depth (mm)

Issued:,21 October 2019

Location Label:,

Requested coordinate:,Latitude,-33.179,Longitude,151.577

Nearest grid cell:,Latitude,33.1875 (S),Longitude,151.5875 (E)

,,Annual Exceedance Probability (AEP)

Duration,Duration in min,63.2%,50%,20%,10%,5%,2%,1%

1 min,1,2.26,2.58,3.65,4.47,5.35,6.64,7.74

2 min,2,3.80,4.34,6.18,7.59,9.09,11.2,13.0

3 min,3,5.28,6.02,8.56,10.5,12.6,15.5,18.0

4 min,4,6.61,7.53,10.7,13.1,15.7,19.4,22.5

5 min,5,7.81,8.89,12.6,15.4,18.5,22.9,26.6

10 min,10,12.4,14.0,19.9,24.4,29.1,36.2,42.2

15 min,15,15.4,17.6,24.9,30.5,36.5,45.4,53.0

20 min,20,17.8,20.2,28.7,35.2,42.1,52.4,61.1

25 min,25,19.7,22.4,31.8,39.0,46.7,58.1,67.7

30 min,30,21.2,24.2,34.4,42.2,50.5,62.8,73.3

45 min,45,24.9,28.4,40.4,49.6,59.4,73.8,86.0

1 hour,60,27.7,31.6,45.0,55.2,66.1,82.0,95.5

1.5 hour,90,32.1,36.6,52.1,63.9,76.4,94.5,110

2 hour,120,35.6,40.6,57.7,70.7,84.4,104,121

3 hour,180,41.3,47.1,66.8,81.6,97.3,120,139

4.5 hour,270,48.2,54.9,77.7,94.7,113,138,160

6 hour,360,53.9,61.4,86.7,106,125,154,178

9 hour,540,63.3,72.1,102,124,147,180,207

12 hour,720,71.0,80.9,114,139,164,201,232

18 hour,1080,83.2,94.8,134,163,193,237,273

24 hour,1440,92.6,106,150,182,216,266,307

30 hour,1800,100,115,163,198,236,290,334

36 hour,2160,107,122,174,212,252,310,358

48 hour,2880,117,134,191,234,279,343,396

72 hour,4320,131,150,215,264,316,388,446

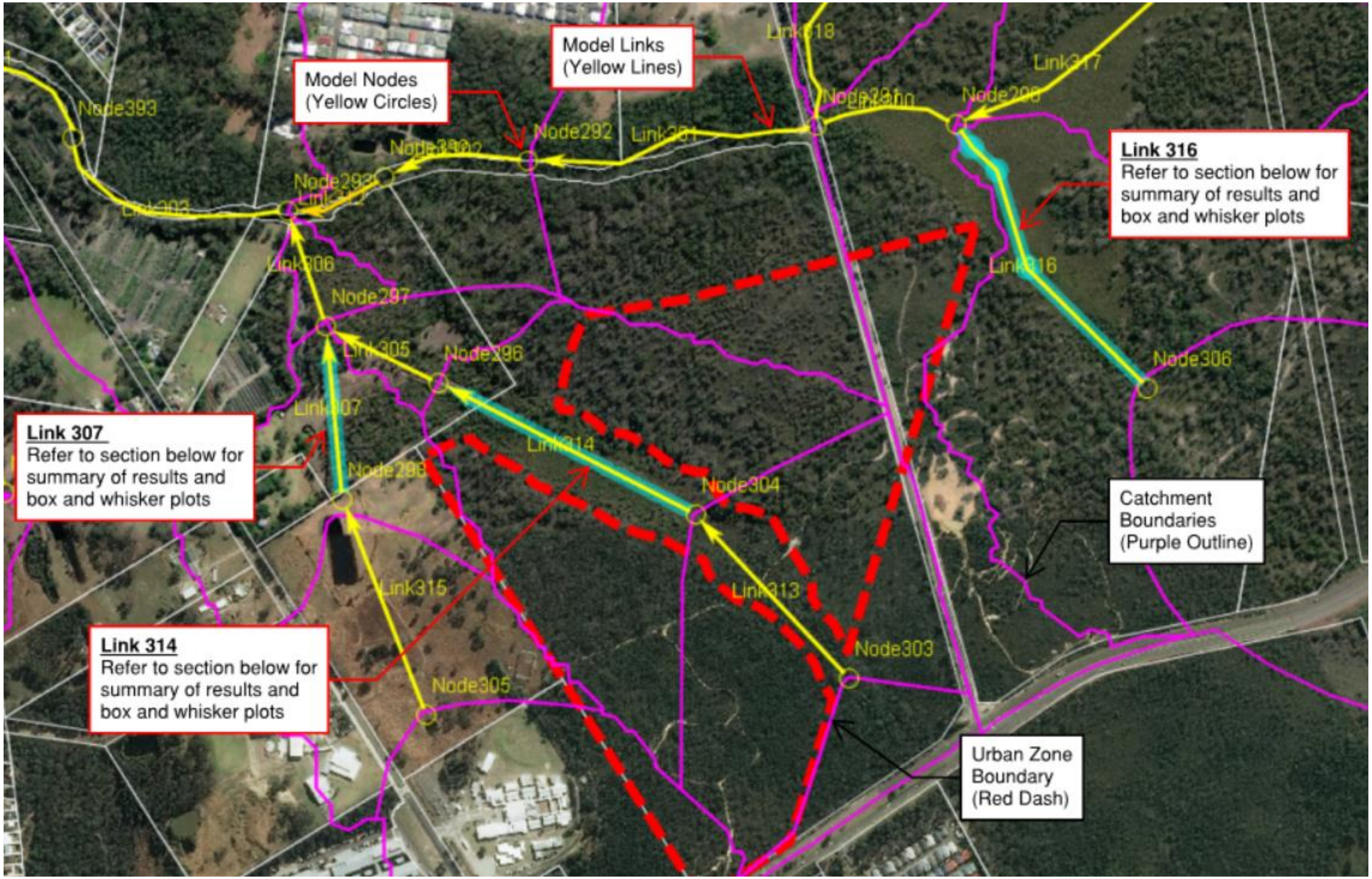
96 hour,5760,140,160,231,283,339,415,475

120 hour,7200,146,168,241,296,354,430,491

144 hour,8640,152,174,248,304,363,438,498

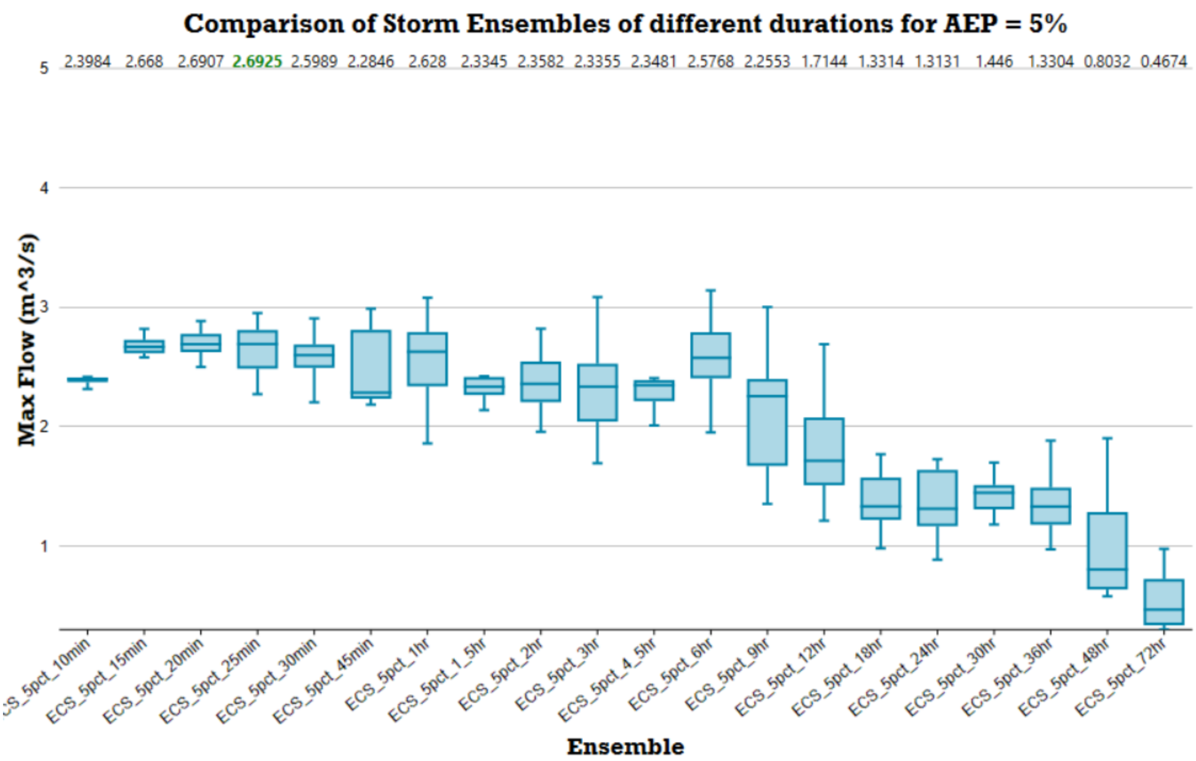
168 hour,10080,156,178,253,309,368,441,499

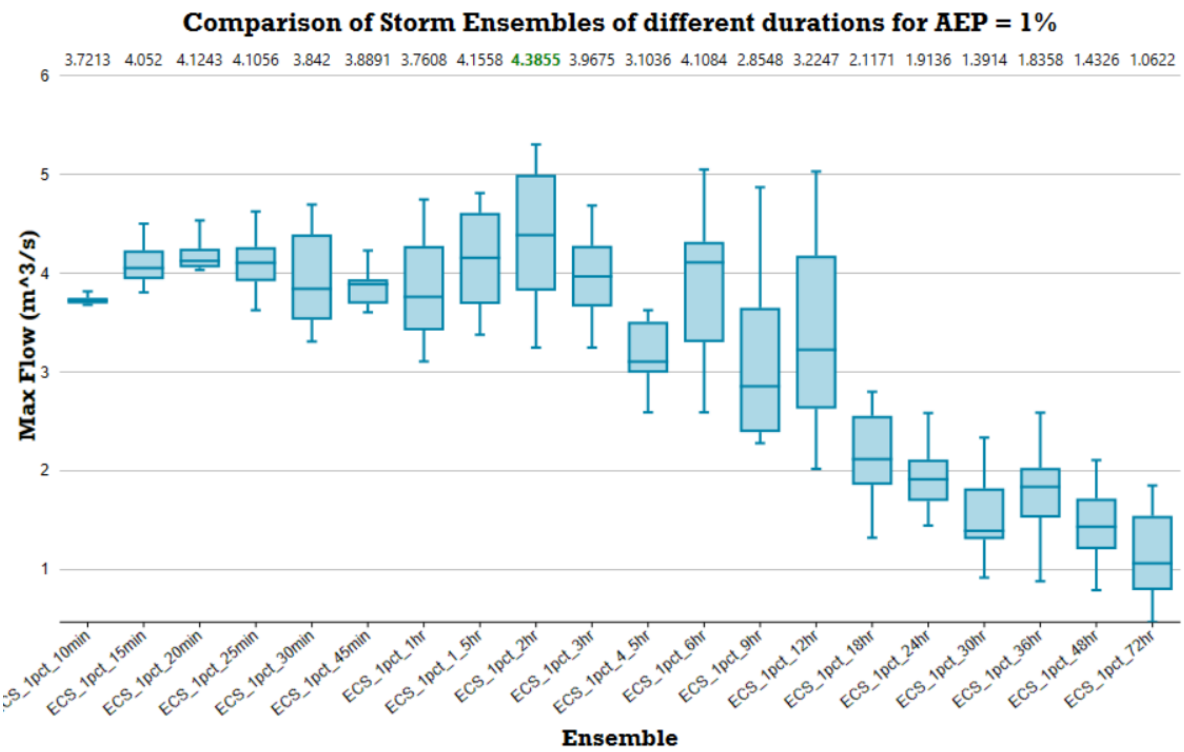
Appendix E – Critical Storm Box and Whisker Plots



Link 307 Peak Flow

	Ensemble Name	AEP	Mean	Mean Storm	Median	Median Storm	Min	Min Storm	Max	Max Storm
1	ECS_5pct_10min	5%	2.38623	ECS_5pct_10min_4	2.39839	ECS_5pct_10min_5	2.31506	ECS_5pct_10min_1	2.41702	ECS_5pct_10min_3
2	ECS_5pct_15min	5%	2.67992	ECS_5pct_15min_10	2.66794	ECS_5pct_15min_10	2.58032	ECS_5pct_15min_5	2.81898	ECS_5pct_15min_4
3	ECS_5pct_20min	5%	2.67391	ECS_5pct_20min_8	2.69069	ECS_5pct_20min_7	2.33397	ECS_5pct_20min_3	2.88420	ECS_5pct_20min_4
4	ECS_5pct_25min	5%	2.64856	ECS_5pct_25min_2	2.69244	ECS_5pct_25min_9	2.27223	ECS_5pct_25min_7	2.95132	ECS_5pct_25min_10
5	ECS_5pct_30min	5%	2.59457	ECS_5pct_30min_6	2.59890	ECS_5pct_30min_6	2.20330	ECS_5pct_30min_2	2.90639	ECS_5pct_30min_9
6	ECS_5pct_45min	5%	2.48606	ECS_5pct_45min_1	2.28457	ECS_5pct_45min_4	2.18406	ECS_5pct_45min_5	2.98781	ECS_5pct_45min_9
7	ECS_5pct_1hr	5%	2.56409	ECS_5pct_1hr_7	2.62799	ECS_5pct_1hr_6	1.85961	ECS_5pct_1hr_4	3.07912	ECS_5pct_1hr_9
8	ECS_5pct_1_5hr	5%	2.39545	ECS_5pct_1_5hr_2	2.33450	ECS_5pct_1_5hr_7	2.13758	ECS_5pct_1_5hr_3	3.12996	ECS_5pct_1_5hr_9
9	ECS_5pct_2hr	5%	2.41121	ECS_5pct_2hr_1	2.35819	ECS_5pct_2hr_5	1.95733	ECS_5pct_2hr_8	3.21177	ECS_5pct_2hr_10
10	ECS_5pct_3hr	5%	2.30851	ECS_5pct_3hr_6	2.33542	ECS_5pct_3hr_6	1.69362	ECS_5pct_3hr_2	3.08519	ECS_5pct_3hr_10
11	ECS_5pct_4_5hr	5%	2.47319	ECS_5pct_4_5hr_10	2.34806	ECS_5pct_4_5hr_3	2.00971	ECS_5pct_4_5hr_4	4.34344	ECS_5pct_4_5hr_10
12	ECS_5pct_6hr	5%	2.56083	ECS_5pct_6hr_2	2.57677	ECS_5pct_6hr_4	1.95144	ECS_5pct_6hr_7	3.14115	ECS_5pct_6hr_1
13	ECS_5pct_9hr	5%	2.13712	ECS_5pct_9hr_5	2.25528	ECS_5pct_9hr_5	1.35237	ECS_5pct_9hr_6	3.00098	ECS_5pct_9hr_2
14	ECS_5pct_12hr	5%	1.82650	ECS_5pct_12hr_3	1.71439	ECS_5pct_12hr_7	1.21220	ECS_5pct_12hr_4	2.69062	ECS_5pct_12hr_8
15	ECS_5pct_18hr	5%	1.51003	ECS_5pct_18hr_4	1.33139	ECS_5pct_18hr_5	0.98070	ECS_5pct_18hr_7	2.96472	ECS_5pct_18hr_10
16	ECS_5pct_24hr	5%	1.43004	ECS_5pct_24hr_7	1.31308	ECS_5pct_24hr_6	0.88588	ECS_5pct_24hr_5	2.39900	ECS_5pct_24hr_9
17	ECS_5pct_30hr	5%	1.40299	ECS_5pct_30hr_10	1.44601	ECS_5pct_30hr_4	0.87421	ECS_5pct_30hr_2	1.69931	ECS_5pct_30hr_3
18	ECS_5pct_36hr	5%	1.37511	ECS_5pct_36hr_2	1.33036	ECS_5pct_36hr_2	0.97184	ECS_5pct_36hr_3	1.88301	ECS_5pct_36hr_8
19	ECS_5pct_48hr	5%	0.97846	ECS_5pct_48hr_6	0.80319	ECS_5pct_48hr_4	0.57861	ECS_5pct_48hr_1	1.90288	ECS_5pct_48hr_10
20	ECS_5pct_72hr	5%	0.55638	ECS_5pct_72hr_3	0.46735	ECS_5pct_72hr_4	0.29942	ECS_5pct_72hr_10	0.97587	ECS_5pct_72hr_6
21	ECS_1pct_10min	1%	3.72449	ECS_1pct_10min_7	3.72125	ECS_1pct_10min_7	3.67934	ECS_1pct_10min_2	3.81513	ECS_1pct_10min_9
22	ECS_1pct_15min	1%	4.10096	ECS_1pct_15min_7	4.05200	ECS_1pct_15min_8	3.80449	ECS_1pct_15min_4	4.50034	ECS_1pct_15min_9
23	ECS_1pct_20min	1%	4.17068	ECS_1pct_20min_4	4.12427	ECS_1pct_20min_2	3.60353	ECS_1pct_20min_3	4.70704	ECS_1pct_20min_9
24	ECS_1pct_25min	1%	4.09924	ECS_1pct_25min_1	4.10558	ECS_1pct_25min_3	3.62440	ECS_1pct_25min_2	4.62371	ECS_1pct_25min_10
25	ECS_1pct_30min	1%	3.96369	ECS_1pct_30min_9	3.84199	ECS_1pct_30min_4	3.30829	ECS_1pct_30min_2	4.69462	ECS_1pct_30min_10
26	ECS_1pct_45min	1%	3.83021	ECS_1pct_45min_1	3.88912	ECS_1pct_45min_8	3.31360	ECS_1pct_45min_7	4.22925	ECS_1pct_45min_10
27	ECS_1pct_1hr	1%	3.82586	ECS_1pct_1hr_6	3.76080	ECS_1pct_1hr_8	3.10615	ECS_1pct_1hr_4	4.74626	ECS_1pct_1hr_1
28	ECS_1pct_1_5hr	1%	4.12775	ECS_1pct_1_5hr_9	4.15580	ECS_1pct_1_5hr_9	3.37665	ECS_1pct_1_5hr_2	4.81135	ECS_1pct_1_5hr_6
29	ECS_1pct_2hr	1%	4.33130	ECS_1pct_2hr_4	4.38551	ECS_1pct_2hr_4	3.24587	ECS_1pct_2hr_3	5.30346	ECS_1pct_2hr_10
30	ECS_1pct_3hr	1%	3.96127	ECS_1pct_3hr_8	3.96749	ECS_1pct_3hr_8	2.58063	ECS_1pct_3hr_1	5.27229	ECS_1pct_3hr_10
31	ECS_1pct_4_5hr	1%	3.34578	ECS_1pct_4_5hr_8	3.10356	ECS_1pct_4_5hr_9	2.58961	ECS_1pct_4_5hr_5	4.59081	ECS_1pct_4_5hr_2
32	ECS_1pct_6hr	1%	3.87632	ECS_1pct_6hr_1	4.10838	ECS_1pct_6hr_5	2.59112	ECS_1pct_6hr_4	5.05026	ECS_1pct_6hr_6
33	ECS_1pct_9hr	1%	3.09587	ECS_1pct_9hr_1	2.85476	ECS_1pct_9hr_1	2.27891	ECS_1pct_9hr_6	4.86945	ECS_1pct_9hr_9
34	ECS_1pct_12hr	1%	3.42585	ECS_1pct_12hr_6	3.22467	ECS_1pct_12hr_1	2.01792	ECS_1pct_12hr_7	5.02974	ECS_1pct_12hr_5
35	ECS_1pct_18hr	1%	2.14514	ECS_1pct_18hr_3	2.11704	ECS_1pct_18hr_3	1.32017	ECS_1pct_18hr_8	2.79829	ECS_1pct_18hr_1
36	ECS_1pct_24hr	1%	2.05087	ECS_1pct_24hr_4	1.91356	ECS_1pct_24hr_3	1.44429	ECS_1pct_24hr_10	3.46989	ECS_1pct_24hr_2
37	ECS_1pct_30hr	1%	1.59659	ECS_1pct_30hr_3	1.39132	ECS_1pct_30hr_8	0.91665	ECS_1pct_30hr_10	2.60674	ECS_1pct_30hr_2
38	ECS_1pct_36hr	1%	1.78452	ECS_1pct_36hr_4	1.83584	ECS_1pct_36hr_10	0.88024	ECS_1pct_36hr_7	2.58772	ECS_1pct_36hr_9
39	ECS_1pct_48hr	1%	1.47727	ECS_1pct_48hr_6	1.43260	ECS_1pct_48hr_2	0.78923	ECS_1pct_48hr_8	2.10690	ECS_1pct_48hr_9
40	ECS_1pct_72hr	1%	1.15369	ECS_1pct_72hr_8	1.06219	ECS_1pct_72hr_1	0.46569	ECS_1pct_72hr_10	1.84882	ECS_1pct_72hr_3





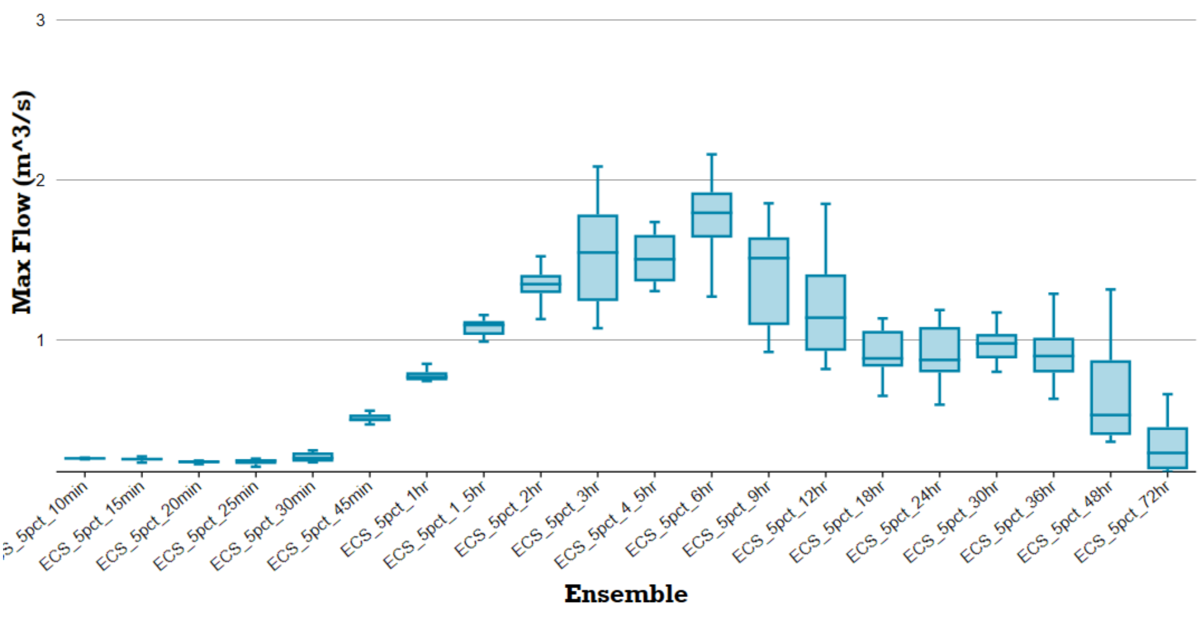
Comparison of Storm Ensembles of different durations for AEP = 1%
3.7213 4.052 4.1243 4.1056 3.842 3.8891 3.7608 4.1558 4.3855 3.9675 3.1036 4.1084 2.8548 3.2247 2.1171 1.9136 1.3914 1.8358 1.4326 1.0622
Max Flow (m^3/s)
6
5
4
3
2
1
ECS_1pct_15min
ECS_1pct_20min
ECS_1pct_25min
ECS_1pct_30min
ECS_1pct_45min
ECS_1pct_1hr
ECS_1pct_1_5hr
ECS_1pct_2hr
ECS_1pct_3hr
ECS_1pct_4_5hr
ECS_1pct_6hr
ECS_1pct_9hr
ECS_1pct_12hr
ECS_1pct_18hr
ECS_1pct_24hr
ECS_1pct_30hr
ECS_1pct_36hr
ECS_1pct_48hr
ECS_1pct_72hr
Ensemble

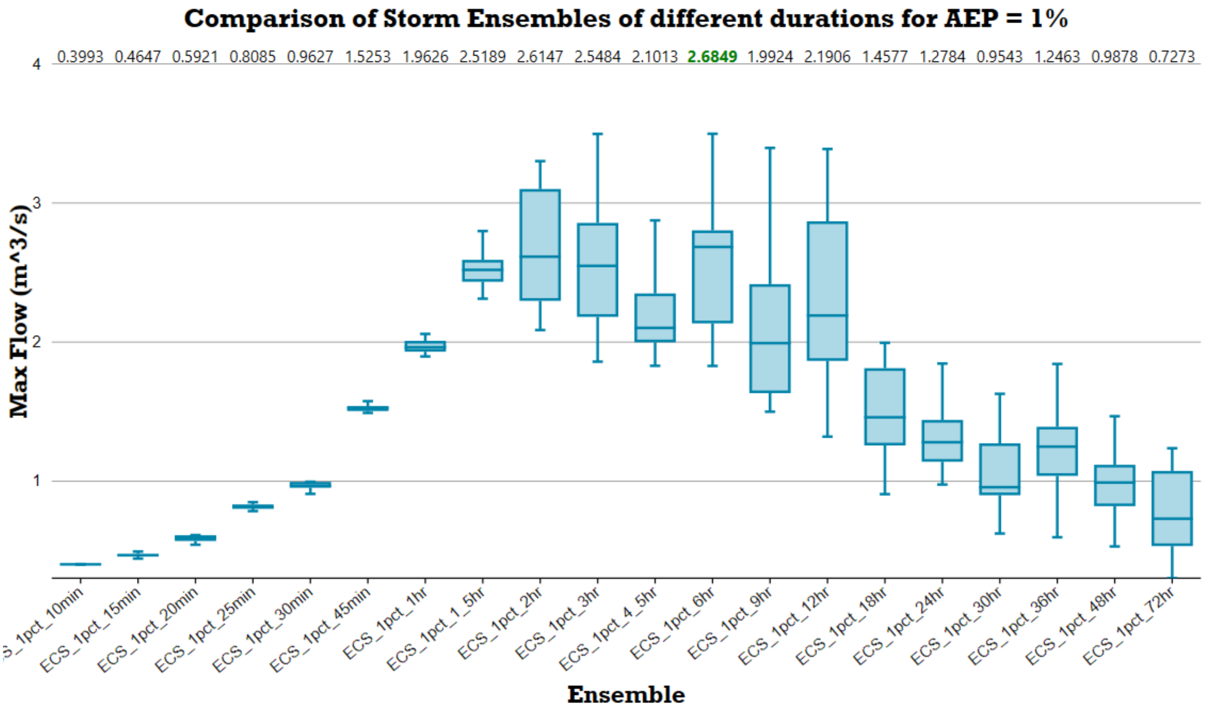
Link314 Peak Flow

	Ensemble Name	AEP	Mean	Mean Storm	Median	Median Storm	Min	Min Storm	Max	Max Storm
1	ECS_5pct_10min	5%	0.26130	ECS_5pct_10min_9	0.26161	ECS_5pct_10min_9	0.25658	ECS_5pct_10min_5	0.26578	ECS_5pct_10min_4
2	ECS_5pct_15min	5%	0.25656	ECS_5pct_15min_6	0.25763	ECS_5pct_15min_6	0.23588	ECS_5pct_15min_5	0.27373	ECS_5pct_15min_7
3	ECS_5pct_20min	5%	0.24162	ECS_5pct_20min_9	0.24204	ECS_5pct_20min_9	0.22559	ECS_5pct_20min_3	0.27478	ECS_5pct_20min_2
4	ECS_5pct_25min	5%	0.24142	ECS_5pct_25min_6	0.24723	ECS_5pct_25min_2	0.20913	ECS_5pct_25min_5	0.26041	ECS_5pct_25min_1
5	ECS_5pct_30min	5%	0.27036	ECS_5pct_30min_5	0.26384	ECS_5pct_30min_5	0.23688	ECS_5pct_30min_3	0.31194	ECS_5pct_30min_9
6	ECS_5pct_45min	5%	0.51853	ECS_5pct_45min_6	0.50190	ECS_5pct_45min_7	0.47440	ECS_5pct_45min_1	0.61467	ECS_5pct_45min_9
7	ECS_5pct_1hr	5%	0.78058	ECS_5pct_1hr_7	0.77023	ECS_5pct_1hr_1	0.74459	ECS_5pct_1hr_4	0.85230	ECS_5pct_1hr_9
8	ECS_5pct_1_5hr	5%	1.08267	ECS_5pct_1_5hr_5	1.09472	ECS_5pct_1_5hr_6	0.99089	ECS_5pct_1_5hr_1	1.15677	ECS_5pct_1_5hr_9
9	ECS_5pct_2hr	5%	1.34972	ECS_5pct_2hr_1	1.35020	ECS_5pct_2hr_1	1.13132	ECS_5pct_2hr_3	1.52358	ECS_5pct_2hr_10
10	ECS_5pct_3hr	5%	1.53504	ECS_5pct_3hr_6	1.54769	ECS_5pct_3hr_6	1.07487	ECS_5pct_3hr_2	2.08395	ECS_5pct_3hr_10
11	ECS_5pct_4_5hr	5%	1.63947	ECS_5pct_4_5hr_9	1.50547	ECS_5pct_4_5hr_3	1.30669	ECS_5pct_4_5hr_8	2.98232	ECS_5pct_4_5hr_10
12	ECS_5pct_6hr	5%	1.74569	ECS_5pct_6hr_10	1.79543	ECS_5pct_6hr_4	1.27227	ECS_5pct_6hr_8	2.15996	ECS_5pct_6hr_1
13	ECS_5pct_9hr	5%	1.41719	ECS_5pct_9hr_1	1.51209	ECS_5pct_9hr_5	0.92645	ECS_5pct_9hr_6	1.85452	ECS_5pct_9hr_3
14	ECS_5pct_12hr	5%	1.20368	ECS_5pct_12hr_3	1.14028	ECS_5pct_12hr_10	0.81959	ECS_5pct_12hr_4	1.85146	ECS_5pct_12hr_8
15	ECS_5pct_18hr	5%	1.01755	ECS_5pct_18hr_4	0.88640	ECS_5pct_18hr_5	0.65200	ECS_5pct_18hr_7	2.05566	ECS_5pct_18hr_10
16	ECS_5pct_24hr	5%	0.95992	ECS_5pct_24hr_7	0.87670	ECS_5pct_24hr_3	0.59665	ECS_5pct_24hr_5	1.62688	ECS_5pct_24hr_9
17	ECS_5pct_30hr	5%	0.95695	ECS_5pct_30hr_4	0.97943	ECS_5pct_30hr_4	0.58313	ECS_5pct_30hr_2	1.17290	ECS_5pct_30hr_3
18	ECS_5pct_36hr	5%	0.93426	ECS_5pct_36hr_2	0.90138	ECS_5pct_36hr_7	0.63338	ECS_5pct_36hr_3	1.29000	ECS_5pct_36hr_8
19	ECS_5pct_48hr	5%	0.65542	ECS_5pct_48hr_6	0.53249	ECS_5pct_48hr_4	0.36550	ECS_5pct_48hr_1	1.31691	ECS_5pct_48hr_10
20	ECS_5pct_72hr	5%	0.34846	ECS_5pct_72hr_3	0.29552	ECS_5pct_72hr_4	0.17802	ECS_5pct_72hr_10	0.66292	ECS_5pct_72hr_6
21	ECS_1pct_10min	1%	0.39938	ECS_1pct_10min_9	0.39928	ECS_1pct_10min_9	0.39702	ECS_1pct_10min_3	0.40119	ECS_1pct_10min_2
22	ECS_1pct_15min	1%	0.47057	ECS_1pct_15min_8	0.46466	ECS_1pct_15min_2	0.44060	ECS_1pct_15min_6	0.51975	ECS_1pct_15min_9
23	ECS_1pct_20min	1%	0.59318	ECS_1pct_20min_5	0.59209	ECS_1pct_20min_5	0.54041	ECS_1pct_20min_3	0.68899	ECS_1pct_20min_9
24	ECS_1pct_25min	1%	0.81090	ECS_1pct_25min_8	0.80841	ECS_1pct_25min_8	0.73456	ECS_1pct_25min_2	0.87181	ECS_1pct_25min_10
25	ECS_1pct_30min	1%	0.98131	ECS_1pct_30min_3	0.96268	ECS_1pct_30min_9	0.90604	ECS_1pct_30min_2	1.09365	ECS_1pct_30min_10
26	ECS_1pct_45min	1%	1.52456	ECS_1pct_45min_1	1.52523	ECS_1pct_45min_1	1.48969	ECS_1pct_45min_4	1.57405	ECS_1pct_45min_5
27	ECS_1pct_1hr	1%	1.97032	ECS_1pct_1hr_9	1.96257	ECS_1pct_1hr_9	1.89542	ECS_1pct_1hr_5	2.05807	ECS_1pct_1hr_10
28	ECS_1pct_1_5hr	1%	2.50983	ECS_1pct_1_5hr_10	2.51892	ECS_1pct_1_5hr_5	2.18068	ECS_1pct_1_5hr_2	2.79838	ECS_1pct_1_5hr_6
29	ECS_1pct_2hr	1%	2.68242	ECS_1pct_2hr_9	2.61469	ECS_1pct_2hr_6	2.08588	ECS_1pct_2hr_4	3.30231	ECS_1pct_2hr_10
30	ECS_1pct_3hr	1%	2.54867	ECS_1pct_3hr_9	2.54839	ECS_1pct_3hr_9	1.85848	ECS_1pct_3hr_1	3.49814	ECS_1pct_3hr_10
31	ECS_1pct_4_5hr	1%	2.26566	ECS_1pct_4_5hr_8	2.10127	ECS_1pct_4_5hr_9	1.82834	ECS_1pct_4_5hr_5	3.13741	ECS_1pct_4_5hr_2
32	ECS_1pct_6hr	1%	2.59168	ECS_1pct_6hr_1	2.68487	ECS_1pct_6hr_5	1.82777	ECS_1pct_6hr_4	3.49933	ECS_1pct_6hr_6
33	ECS_1pct_9hr	1%	2.10447	ECS_1pct_9hr_1	1.99236	ECS_1pct_9hr_1	1.49834	ECS_1pct_9hr_6	3.39773	ECS_1pct_9hr_9
34	ECS_1pct_12hr	1%	2.31923	ECS_1pct_12hr_6	2.19061	ECS_1pct_12hr_1	1.31858	ECS_1pct_12hr_7	3.38999	ECS_1pct_12hr_9
35	ECS_1pct_18hr	1%	1.49759	ECS_1pct_18hr_5	1.45767	ECS_1pct_18hr_3	0.90444	ECS_1pct_18hr_8	1.99409	ECS_1pct_18hr_1
36	ECS_1pct_24hr	1%	1.40265	ECS_1pct_24hr_4	1.27840	ECS_1pct_24hr_3	0.97363	ECS_1pct_24hr_10	2.39710	ECS_1pct_24hr_2
37	ECS_1pct_30hr	1%	1.10951	ECS_1pct_30hr_3	0.95425	ECS_1pct_30hr_8	0.62061	ECS_1pct_30hr_10	1.87507	ECS_1pct_30hr_2
38	ECS_1pct_36hr	1%	1.22575	ECS_1pct_36hr_2	1.24626	ECS_1pct_36hr_4	0.59411	ECS_1pct_36hr_7	1.84197	ECS_1pct_36hr_9
39	ECS_1pct_48hr	1%	1.00152	ECS_1pct_48hr_2	0.98780	ECS_1pct_48hr_2	0.52730	ECS_1pct_48hr_8	1.46557	ECS_1pct_48hr_9
40	ECS_1pct_72hr	1%	0.78127	ECS_1pct_72hr_8	0.72726	ECS_1pct_72hr_1	0.29925	ECS_1pct_72hr_10	1.23458	ECS_1pct_72hr_7

Comparison of Storm Ensembles of different durations for AEP = 5%

0.2616 0.2576 0.2421 0.2473 0.2638 0.5019 0.7703 1.0948 1.3502 1.5477 1.5055 **1.7955** 1.5121 1.1403 0.8864 0.8767 0.9795 0.9014 0.5325 0.2956





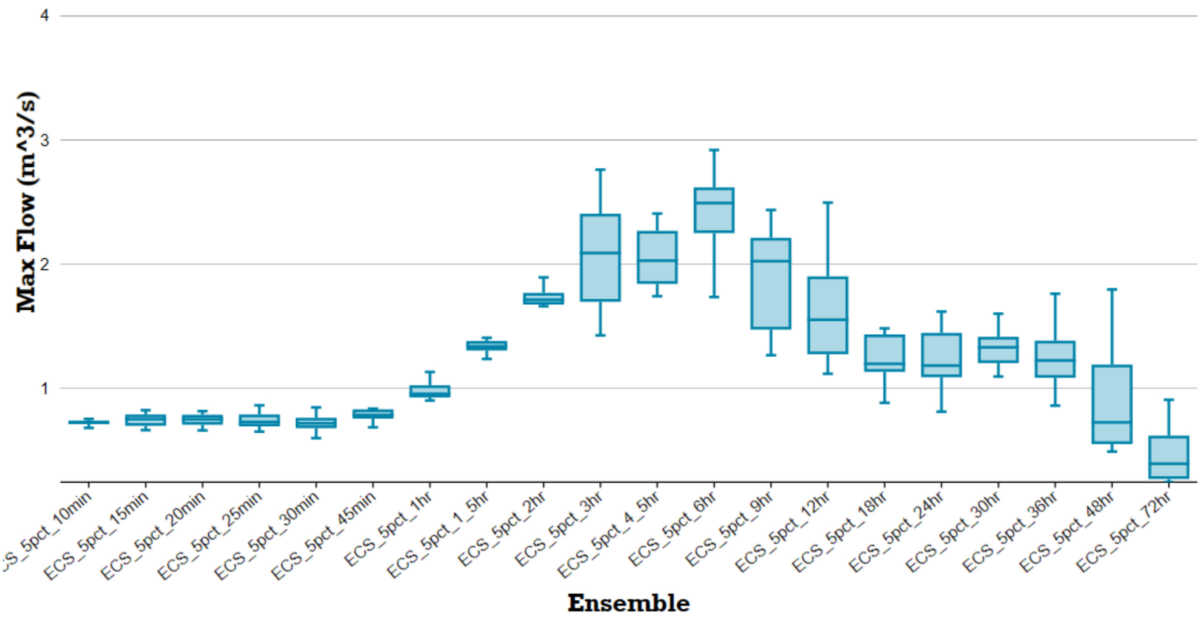
Comparison of Storm Ensembles of different durations for AEP = 1%
0.3993 0.4647 0.5921 0.8085 0.9627 1.5253 1.9626 2.5189 2.6147 2.5484 2.1013 2.6849 1.9924 2.1906 1.4577 1.2784 0.9543 1.2463 0.9878 0.7273
Max Flow (m^3/s)
4
3
2
1
S_1pct_10min
ECS_1pct_15min
ECS_1pct_20min
ECS_1pct_25min
ECS_1pct_30min
ECS_1pct_45min
ECS_1pct_1hr
ECS_1pct_1_5hr
ECS_1pct_2hr
ECS_1pct_3hr
ECS_1pct_4_5hr
ECS_1pct_6hr
ECS_1pct_9hr
ECS_1pct_12hr
ECS_1pct_18hr
ECS_1pct_24hr
ECS_1pct_30hr
ECS_1pct_36hr
ECS_1pct_48hr
ECS_1pct_72hr
Ensemble

Link316 Peak Flow

	Ensemble Name	AEP	Mean	Mean Storm	Median	Median Storm	Min	Min Storm	Max	Max Storm
1	ECS_5pct_10min	5%	0.72313	ECS_5pct_10min_3	0.72926	ECS_5pct_10min_7	0.68082	ECS_5pct_10min_2	0.75333	ECS_5pct_10min_4
2	ECS_5pct_15min	5%	0.74709	ECS_5pct_15min_7	0.75137	ECS_5pct_15min_7	0.66280	ECS_5pct_15min_3	0.82377	ECS_5pct_15min_10
3	ECS_5pct_20min	5%	0.75380	ECS_5pct_20min_4	0.75011	ECS_5pct_20min_4	0.66047	ECS_5pct_20min_1	0.91585	ECS_5pct_20min_9
4	ECS_5pct_25min	5%	0.74620	ECS_5pct_25min_4	0.72940	ECS_5pct_25min_1	0.65118	ECS_5pct_25min_5	0.86334	ECS_5pct_25min_9
5	ECS_5pct_30min	5%	0.72510	ECS_5pct_30min_4	0.71795	ECS_5pct_30min_4	0.59825	ECS_5pct_30min_2	0.84637	ECS_5pct_30min_10
6	ECS_5pct_45min	5%	0.80737	ECS_5pct_45min_2	0.78432	ECS_5pct_45min_6	0.68545	ECS_5pct_45min_4	0.98470	ECS_5pct_45min_9
7	ECS_5pct_1hr	5%	0.98230	ECS_5pct_1hr_7	0.95579	ECS_5pct_1hr_1	0.90152	ECS_5pct_1hr_4	1.13154	ECS_5pct_1hr_9
8	ECS_5pct_1_5hr	5%	1.33276	ECS_5pct_1_5hr_7	1.33795	ECS_5pct_1_5hr_7	1.23669	ECS_5pct_1_5hr_1	1.40651	ECS_5pct_1_5hr_9
9	ECS_5pct_2hr	5%	1.72602	ECS_5pct_2hr_2	1.71379	ECS_5pct_2hr_2	1.53013	ECS_5pct_2hr_3	1.89276	ECS_5pct_2hr_9
10	ECS_5pct_3hr	5%	2.05314	ECS_5pct_3hr_6	2.08947	ECS_5pct_3hr_6	1.42618	ECS_5pct_3hr_2	2.75983	ECS_5pct_3hr_10
11	ECS_5pct_4_5hr	5%	2.21720	ECS_5pct_4_5hr_9	2.02781	ECS_5pct_4_5hr_3	1.74068	ECS_5pct_4_5hr_8	4.00187	ECS_5pct_4_5hr_10
12	ECS_5pct_6hr	5%	2.38113	ECS_5pct_6hr_4	2.49124	ECS_5pct_6hr_2	1.73492	ECS_5pct_6hr_8	2.91871	ECS_5pct_6hr_1
13	ECS_5pct_9hr	5%	1.88927	ECS_5pct_9hr_1	2.02269	ECS_5pct_9hr_5	1.26625	ECS_5pct_9hr_6	2.43564	ECS_5pct_9hr_3
14	ECS_5pct_12hr	5%	1.62684	ECS_5pct_12hr_3	1.55208	ECS_5pct_12hr_10	1.11729	ECS_5pct_12hr_4	2.49497	ECS_5pct_12hr_8
15	ECS_5pct_18hr	5%	1.37545	ECS_5pct_18hr_6	1.19697	ECS_5pct_18hr_1	0.88251	ECS_5pct_18hr_7	2.81814	ECS_5pct_18hr_10
16	ECS_5pct_24hr	5%	1.29615	ECS_5pct_24hr_7	1.18283	ECS_5pct_24hr_3	0.81100	ECS_5pct_24hr_5	2.20605	ECS_5pct_24hr_9
17	ECS_5pct_30hr	5%	1.30165	ECS_5pct_30hr_4	1.32965	ECS_5pct_30hr_4	0.79283	ECS_5pct_30hr_2	1.60065	ECS_5pct_30hr_3
18	ECS_5pct_36hr	5%	1.27197	ECS_5pct_36hr_2	1.22395	ECS_5pct_36hr_7	0.86034	ECS_5pct_36hr_3	1.76119	ECS_5pct_36hr_8
19	ECS_5pct_48hr	5%	0.89169	ECS_5pct_48hr_6	0.72577	ECS_5pct_48hr_4	0.48999	ECS_5pct_48hr_1	1.79542	ECS_5pct_48hr_10
20	ECS_5pct_72hr	5%	0.47280	ECS_5pct_72hr_2	0.39248	ECS_5pct_72hr_3	0.24417	ECS_5pct_72hr_5	0.90717	ECS_5pct_72hr_6
21	ECS_1pct_10min	1%	1.10160	ECS_1pct_10min_4	1.09731	ECS_1pct_10min_7	1.05512	ECS_1pct_10min_2	1.18677	ECS_1pct_10min_9
22	ECS_1pct_15min	1%	1.14598	ECS_1pct_15min_7	1.10368	ECS_1pct_15min_8	1.04166	ECS_1pct_15min_3	1.36287	ECS_1pct_15min_9
23	ECS_1pct_20min	1%	1.26200	ECS_1pct_20min_5	1.22722	ECS_1pct_20min_10	1.14614	ECS_1pct_20min_2	1.52480	ECS_1pct_20min_9
24	ECS_1pct_25min	1%	1.33578	ECS_1pct_25min_5	1.33601	ECS_1pct_25min_5	1.19493	ECS_1pct_25min_2	1.55223	ECS_1pct_25min_10
25	ECS_1pct_30min	1%	1.42363	ECS_1pct_30min_9	1.38500	ECS_1pct_30min_6	1.31070	ECS_1pct_30min_2	1.65993	ECS_1pct_30min_10
26	ECS_1pct_45min	1%	1.95688	ECS_1pct_45min_10	1.93823	ECS_1pct_45min_6	1.87169	ECS_1pct_45min_4	2.06657	ECS_1pct_45min_5
27	ECS_1pct_1hr	1%	2.52917	ECS_1pct_1hr_9	2.52048	ECS_1pct_1hr_9	2.45120	ECS_1pct_1hr_5	2.63971	ECS_1pct_1hr_10
28	ECS_1pct_1_5hr	1%	3.37121	ECS_1pct_1_5hr_10	3.40665	ECS_1pct_1_5hr_5	3.00337	ECS_1pct_1_5hr_2	3.65006	ECS_1pct_1_5hr_8
29	ECS_1pct_2hr	1%	3.64374	ECS_1pct_2hr_6	3.63814	ECS_1pct_2hr_6	2.95521	ECS_1pct_2hr_4	4.39291	ECS_1pct_2hr_10
30	ECS_1pct_3hr	1%	3.49332	ECS_1pct_3hr_9	3.53690	ECS_1pct_3hr_9	2.48543	ECS_1pct_3hr_1	4.78070	ECS_1pct_3hr_10
31	ECS_1pct_4_5hr	1%	3.08411	ECS_1pct_4_5hr_8	2.84883	ECS_1pct_4_5hr_9	2.45143	ECS_1pct_4_5hr_5	4.24481	ECS_1pct_4_5hr_2
32	ECS_1pct_6hr	1%	3.51821	ECS_1pct_6hr_1	3.66052	ECS_1pct_6hr_5	2.47223	ECS_1pct_6hr_8	4.75434	ECS_1pct_6hr_6
33	ECS_1pct_9hr	1%	2.87184	ECS_1pct_9hr_1	2.69695	ECS_1pct_9hr_1	2.03627	ECS_1pct_9hr_6	4.60643	ECS_1pct_9hr_9
34	ECS_1pct_12hr	1%	3.12163	ECS_1pct_12hr_6	2.98364	ECS_1pct_12hr_1	1.80097	ECS_1pct_12hr_7	4.55878	ECS_1pct_12hr_9
35	ECS_1pct_18hr	1%	2.03574	ECS_1pct_18hr_5	1.98245	ECS_1pct_18hr_3	1.23192	ECS_1pct_18hr_8	2.71319	ECS_1pct_18hr_1
36	ECS_1pct_24hr	1%	1.89998	ECS_1pct_24hr_4	1.73285	ECS_1pct_24hr_3	1.31635	ECS_1pct_24hr_10	3.24940	ECS_1pct_24hr_2
37	ECS_1pct_30hr	1%	1.51232	ECS_1pct_30hr_3	1.29947	ECS_1pct_30hr_8	0.84959	ECS_1pct_30hr_10	2.54365	ECS_1pct_30hr_2
38	ECS_1pct_36hr	1%	1.66347	ECS_1pct_36hr_4	1.66138	ECS_1pct_36hr_4	0.81321	ECS_1pct_36hr_7	2.51013	ECS_1pct_36hr_9
39	ECS_1pct_48hr	1%	1.35543	ECS_1pct_48hr_2	1.32725	ECS_1pct_48hr_4	0.72175	ECS_1pct_48hr_8	1.99822	ECS_1pct_48hr_9
40	ECS_1pct_72hr	1%	1.06256	ECS_1pct_72hr_8	0.99546	ECS_1pct_72hr_1	0.41493	ECS_1pct_72hr_10	1.68313	ECS_1pct_72hr_7

Comparison of Storm Ensembles of different durations for AEP = 5%

0.7293 0.7514 0.7501 0.7294 0.718 0.7843 0.9558 1.338 1.7138 2.0895 2.0278 **2.4912** 2.0227 1.5521 1.197 1.1829 1.3297 1.224 0.7258 0.3925



Comparison of Storm Ensembles of different durations for AEP = 1%