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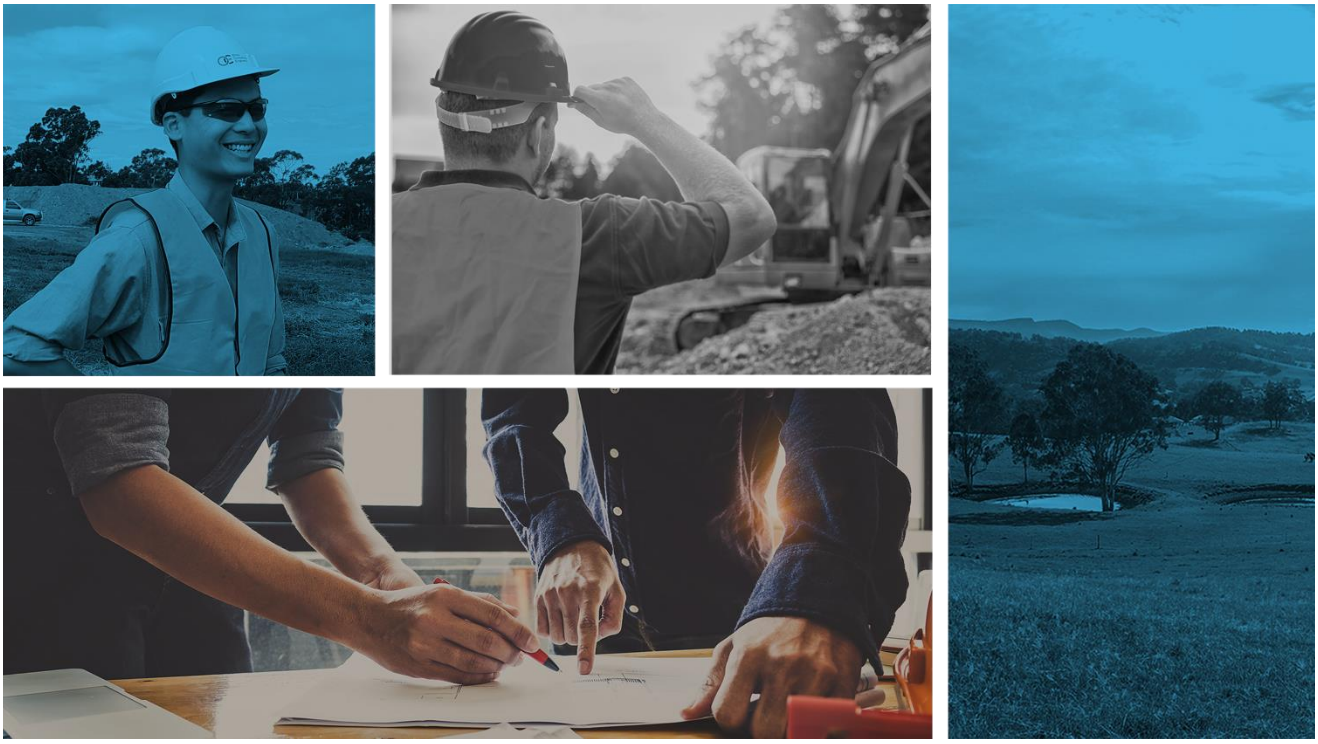
Aoyuan
building a healthy lifestyle

Integrated Water Cycle Management Report

Coomungie and Chelsea Gardens - Moss Vale



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Executive Summary

This report has been prepared by Orion Consulting (Orion) for Aoyuan International (Aoyuan) to support the site-specific development control plan for the development known as the Coomungie and Chelsea Gardens located just south of the Moss Vale township. Orion has been engaged to provide new updates and design input into the current underlying integrated water cycle management strategy, coordinating with the landscaping, open space and urban design strategy proposed by Arterra and Aoyuan as well as integrating with an informed earthworks and civil design strategy for the masterplanned community.

This report demonstrates that the current proposed integrated water cycle management strategy meets the flooding, stormwater management and water sensitive urban design requirements as specified by Wingcarribee Shire Council and other regulating authorities.

Glossary of Terms

As compiled from the NSW Government Floodplain Development Manual 2005 unless otherwise noted.

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. For example, if a peak flood discharge of 500 m3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m3/s or larger event 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.

A note on terminology:
The following conversion table as extracted from Australian Rainfall and Runoff 2019, book1, chapter 2 section 2.5.5 below provides a guide to convert ARI to AEP. ARI terminology is noted as being generally the accepted terminology under Australian Rainfall and Runoff 1987 guidelines whiles AEP terminology is noted as being the accepted terminology under Australian Rainfall and Runoff 2016 - 2019 guidelines and onwards.

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	19.5
	0.02	2	50	49.5
	0.01	1	100	99.5
Very Rare	0.005	0.5	200	199.5
	0.002	0.2	500	499.5
	0.001	0.1	1000	999.5
Extreme	0.0005	0.05	2000	1999.5
	0.0002	0.02	5000	4999.5
			↓	
			PMP/ PMP Flood	

Bio-retention system	A well-vegetated, retention cell or pond designed to enhance water filtration through a specially prepared sub-surface sand filter. Bio-retention cells may be incorporated into grass or vegetated swales or may be a stand-alone treatment system. The system incorporates vegetation with medium-term stormwater retention and sub-surface filtration/infiltration. Also known as bio-filtration systems or biofilters. (QDUM 2013)
Bypass flow	That portion of the flow on a road or in a channel which is not collected by a gully inlet or field inlet, and which is redirected out of the system or to another inlet in the system. (QDUM 2013)
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 a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
Detention basin	A large, open, free draining basin that temporarily detains collected stormwater runoff. These basins are normally maintained in a dry condition between storm events. (QDUM 2013)
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). infill development: refers to the 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. new development: 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. redevelopment: 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 (m3/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).
effective warning time	The time available after receiving advice of an impending flood and before the 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.
Extended detention	A stormwater detention basin or tank designed to drain over a period of days rather than hours to enhance its pollution retention and solar treatment while minimising the adverse effects of coincident flooding downstream of the basin. (QDUM 2013)
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	Flood 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 probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (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.
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 State Emergency Service. flood planning area The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the "flood liable land" concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPL's 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. FPLs supersede the "standard flood event" in the 1986 manual.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
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 readiness	Flood 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. existing flood risk: the risk a community is exposed to as a result of its location on the floodplain. future flood risk: the risk a community may be exposed to as a result of new development on the floodplain. continuing flood risk: 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.
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.
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 flows, or a significant increase in flood levels.
freeboard	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.
GPTs	Trash rack and/or sediment collection sump usually located at or near the end of a stormwater pipe. (QDUM 2013 in part)
Grass swale	Shallow, low-gradient, grass-lined overland flow path used primarily for stormwater treatment. (QDUM 2013)
habitable room	in a residential situation: a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. in an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
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.
Intensity-frequency-duration data (IFD)	Basic rainfall data used in the calculation of rainfall runoff rates. (QDUM 2013)
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam. local drainage Are 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 design storm	The rainfall event for the AEP chosen for the design of the Major Drainage System. (QDUM 2013)
Major drainage system	That part of the overall drainage system which conveys flows greater than those conveyed by the Minor Drainage System and up to and including flows from the Major Design Storm. (QDUM 2013)
Major overland flow path	An overland flow path that drains water from more than one property, has no suitable flow bypass, and has a water depth in excess of 75mm during the major design storms; or is an overland flow path recognised as significant by the local government. (QDUM 2013)
Manning's roughness coefficient	A measure of the surface roughness of a conduit or channel to be applied in the Manning's equation. (QDUM 2013)
mathematical/computer models (TUFLOW, WBNM)	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.
Minor design storm	The rainfall event for the AEP chosen for the design of the Minor Drainage System. (QDUM 2013)
Minor drainage system	That part of the overall drainage system which controls flows from the Minor Design Storm e.g. kerbs and channels, inlets, underground drainage etc. for the purpose of providing pedestrian safety and convenience, and vehicle access. (QDUM 2013)
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. Examples are indicated in Table 2.1 with further discussion in the Manual.
peak discharge	The maximum discharge occurring during a flood event.
probability	A statistical measure of the expected chance of flooding (see AEP).
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.
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 are 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.
Water Sensitive Urban Design (WSUD)	A set of design elements and on-ground solutions that aim to minimise impacts on the water cycle from the built urban environment. It offers a simplified and integrated approach to land and water planning by dealing with the urban water cycle in a decentralised manner consistent with natural hydrological and ecological processes. (QDUM 2013)
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
WSC	Wingcarribee Shire Council

1 Introduction

1.1 Site Description

Located within the Wingecarribee Shire Council LGA and approximately 1.5km South of the Moss Vale town centre, the Coomungie and Chelsea Gardens Urban Release Area is a new masterplanned community lead by Aoyuan International. The site comprises approximately 125 hectares in area over Lot 3 in DP706194 and Lot 12 in DP866036 and known as 141 Yarrawa Road and No. 32 Lovelle Street in Moss Vale NSW (the site). The site extents are shown in the below figure.

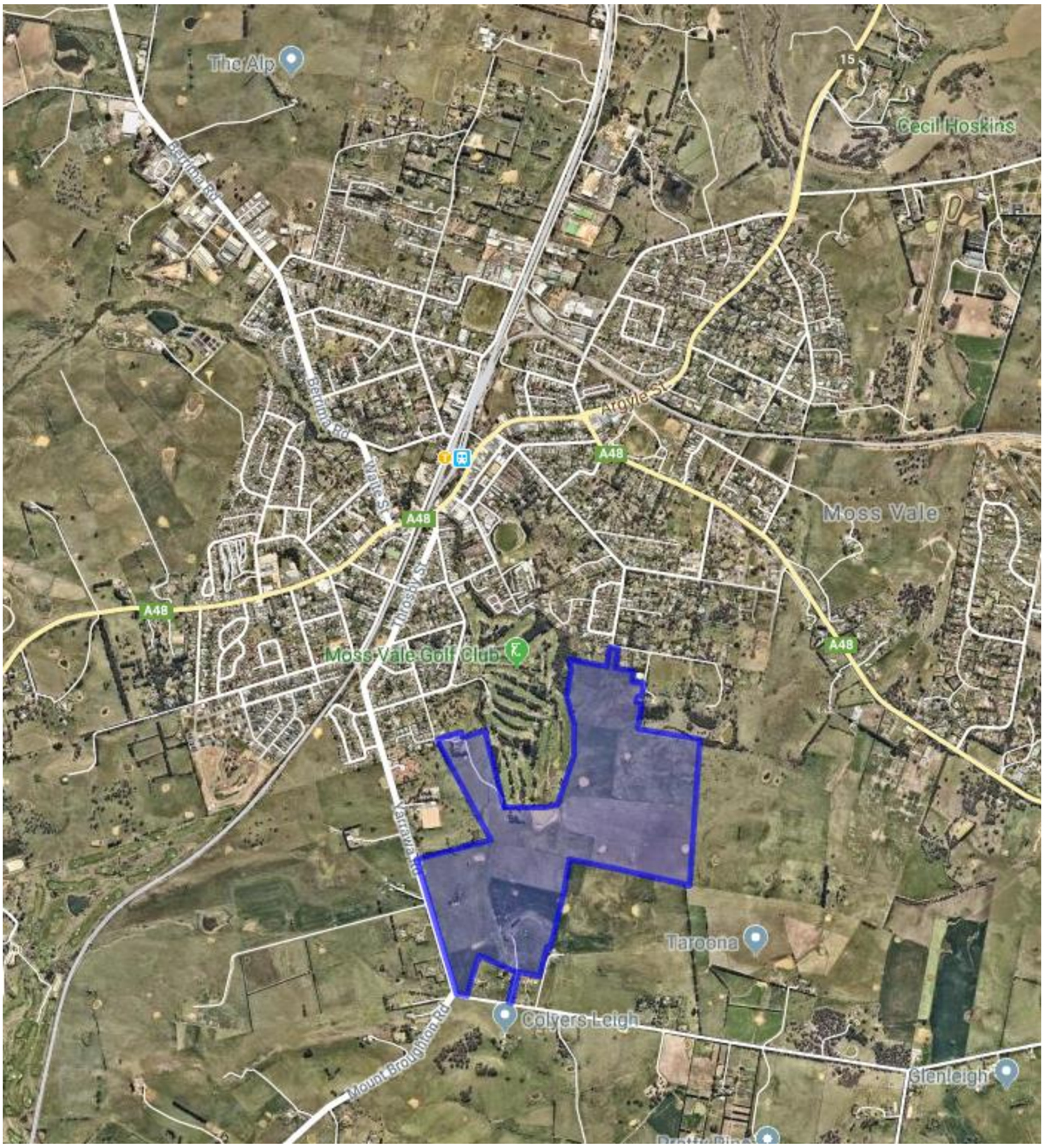

Figure 1 - Coomungie Chelsea Gardens Site Locality (Imagery courtesy of Nearmap ©)

In late October 2017 the site was rezoned for development comprising of R2 (Low Density Residential), R5 (Large Lot Residential), RE1 (Public Recreation) and B1 (Neighbourhood Centre). The site is primarily lightly vegetated rural farmland generally used for livestock farming.

The site is bordered by Yarrawa Road to the West, Harper Entertainment Distribution Services (No. 37 Yarrawa Road) and the Harbison Aged Care accommodation (No. 34 Yarrawa Road) to the North West, the Moss Vale Golf Club to the North and existing rural farmland to the East.

The site generally grades towards several defined outlets, which drain to Moss Vale Golf Club across the common boundary, ultimately converging into Whites Creek which flows through the Golf Club before running adjacent to Moss Vale town centre under the Illawarra Highway/Argyle Street. A defined ridge line with steep grades (10-15%) is located in the Eastern portion of the site which delineates an independent catchment discharging to the east towards Kellys Creek; this is the only catchment that does not ultimately discharge through the Golf Club or Moss Vale town centre further downstream. Both catchments form part of the Sydney drinking water catchment and as such this development and masterplan is subject to Water NSW Sydney Catchment Authority regulations and guidelines for water quality controls (Neutral or Beneficial Effect on Water Quality Assessment Guideline 2015).

Whilst the majority of the site is moderately graded (2-10%) the northern reaches of the site under the existing water reservoirs adjacent to Hill Road feature extremely steep grades (40-50%) and a significant landslip area with visible evidence of slumping. Site pedology is predominantly highly erodible silts and clays of the Moss Vale soil landscape with localised areas of uncontrolled fill and colluvium. Site lithology is predominantly underlying Bringelly Shale comprised of low to medium strength shales and siltstones, igneous bedrocks to the south western portion of the site and dolerite (sometimes exposed) in the area of steep grades in the northern portion of the site.

It is noted that further geotechnical investigation and engagement is to be completed through subsequent stages of Development Assessment.

Refer to the figure overleaf for extract of the overall site plan, contained in full in Appendix A.

Figure 2 - Moss Vale Master Plan Extract

1.2 The Proposed Development

Aoyuan International are aiming to provide a balanced masterplanned community with a core focus on integrating and maximising open green and community spaces throughout the development. To aid in this vision Arterra Design Pty Ltd (Arterra) are a core project collaborator for the urban and landscaping design of the community. The current masterplan comprises of the following:

- 5 Local Parks
- Central Village Hub and Early Learning Centre
- Central Lakes, wetlands and dining/cafe
- Mix of lot sizes broken down in the following:

450-600m^2	circa 289 Lots -	13.9 ha
600-2000m^2	circa 712 Lots -	46.5 ha
2000m^2	circa 66 Lots -	14.7 ha

- Central collector ring-road facilitating bus connection

1.3 Objectives

The purpose of this report and assessment is to design, establish and present the full integrated water cycle management strategy for the proposed masterplan considering:

- Stormwater management controls that meet the intent of Wingcarribee Shire Council's (WSC) Moss Vale Development Control Plan (hereinafter referred to as 'the DCP')

- Stormwater management controls that do not adversely impact and ideally *improve* conditions downstream of the subject site. Of most importance is the assessment of Whites Creek, which traverses the Golf Club and intersection under the Illawarra Highway, the railway and Lackey Road. This approach is to mitigate any risks associated with flood hazard to people and property by the proposed development.

- Water Sensitive Urban Design (WSUD) to meet the requirements of the DCP. It is noted that WSUD controls are to generally consider both the Neutral or Beneficial Effect on Water Quality (NorBE) assessment criteria as specified by WaterNSW and the post-development percentage reduction targets for total suspended solids, phosphorus, nitrogen and gross pollutants. The most conservative treatment train will be adopted such that the requirements of both standards will be met.

- Provide adequate detail for the hydraulic arrangement of proposed controls for the detailed design phases in the future such that the IWCM strategy presented in this report is maintained.

- Implementation of structured water quality treatment trains to minimise pollutant loads to the permanent water bodies within the development and to minimise total number of smaller permanent water bodies to simplify long-term maintenance requirements and to activate more useable open parkland for the community.

- Strategic design of water management controls to fully integrate into the proposed landscape and open space vision for the site. This has incorporated the utilisation of a mix of water quantity and quality management strategies for each of the uniquely designed parks and water management facilities.

1.4 Study Methodology

The study methodology is in two distinct components; water quantity and overland flow assessment that includes the design of on-site stormwater detention (OSD) and flood mitigation controls and, water quality or WSUD controls in the form of designing and integrating gross pollutant traps (GPT's), bioretention systems, sediment basins and engineered wetlands.

1.4.1 Water Quantity Methodology

- Development of overall catchment plans encompassing the whole study area with clear structure for a suitable rainfall-runoff-routing hydrologic model.

- Development of a WBNM (Watershed Bounded Network Model) rainfall-runoff-routing hydrologic model for both pre-developed and post-developed scenarios for assessment. It is noted that ARR1987 design methodologies and rainfall data has been adopted to maintain continuity and consistency with the current assessment guidelines and other historical flood studies of the area.

- Development of a fully combined conceptual civil design model of the site to inform road grades and levels, particularly around the proposed parks, basins and open space areas. Preliminary design and grading of basins and lakes creating a design feedback loop into the post developed WBNM model to provide informed sizing and water staged-storage relationships for the proposed controls.

- Development of a 2D TUFLOW hydraulic model for both pre-developed and post developed scenarios for detailed hydraulic assessment. 2D TUFLOW model set-up within 12D model software to combine both GIS and civil design information in a coordinated environment. The 2D model is to combine inflow hydrograph data from the WBNM model for the upper model reaches and rainfall-on-grid for the downstream extents of the model domain.

WBNM is an industry standard runoff routing model originally developed in Wollongong in the mid 1970's. It is widely adopted for hydrological modelling for natural or partially developed urban catchments in South East NSW and is well documented and referenced in engineering research literature. It is noted that this model has been developed from primarily statistical data from coastal catchments on the South Coast of NSW and has been utilised by other consultants in previous reporting for this site.

TUFLOW (classic) is a finite difference second order implicit solver resolving 2D continuity and momentum, depth averaged shallow water equations and is specifically designed for calculating floodplain hydraulics. TUFLOW is an industry adopted standard both domestically and internationally backed by an active development team, extensive research and benchmark studies.

1.4.2 Water Quality Methodology

- Development of a detailed catchment plan encompassing a breakdown of total lots and proposed land use by sub-catchment.

- Development of a MUSIC Model (Model for Urban Stormwater Improvement Conceptualisation) for pre and post developed cases; assessment of both NorBE and percentage reduction target requirements for isolation of critical design requirements. Design feedback loop into the 12D civil design model and water storage relationships for water quantity controls.

2 Adopted Information

2.1 Pre-Existing Flood Studies and Water Cycle Management Plans

2.1.1 Water Cycle Management Study - Cardno, 2019

A core referencing document that this report is extending is the Water Cycle Management Study *Moss Vale Project* (reference 82018221-01) as prepared by Cardno NSW/ACT Pty Ltd (Cardno) and dated 31 January 2019. It is noted that the Cardno study forms the original water cycle management report submitted to support the site-specific Draft Development Control Plan for the proposed development. This report by Orion, is to be considered for the proposed development unless replaced by future revisions or additional reporting.

Some key points for this study are as follows:

- Adoption of a WBNM hydrological model and a complementing 2D TUFLOW Hydraulic model over the study area.
- Australian Rainfall and Runoff 1987 rainfall data and modelling guidelines adopted.
- Calibration with existing/historical regional flood studies.
- Proposed water management strategy generally met both water quality and flood management control targets.

2.2 Survey Data

2.2.1 Detailed Survey Data

Original detailed survey data was provided by Cardno and dated 1st August 2018. The scope of this survey incorporated all lands within the subject site and survey works over portions of Yarrawa Road, the intersection of Villers Road and Hill Road and the intersection of Daylesford Drive and Lovelle Street.

Additional survey data over Whites Creek, the Moss Vale Golf Club and Harper Entertainment Distribution Services site was collected by Keatley Surveyors and received on 27th May 2019 as a fully combined and coordinated file via Civil Development Solutions.

2.2.2 ALS / LiDAR Survey Data

For areas of the study outside the scope of the detailed survey data, Aerial Laser or LiDAR Scanning data was obtained from the ELVIS - Elevation and Depth Foundation Spatial Data website. The following ALS data has been adopted:

- 1m DEM (digital elevation model) data as published by NSW Land Registry Services (ex LPI) and dated May 2014.
- 2m DEM data as published by NSW Land Registry Services (LRS) and dated May 2018. It is noted that the 2m grid resolution DEM data was only adopted where 1m data was unavailable; this is primarily isolated to the far upstream reaches of the catchment, outside of the site to the west of Yarrawa Road.

2.2.3 Aerial Imagery

Historical and recent aerial imagery of the site was obtained through NearMap for documentation purposes.

2.2.4 Cadastral Data

Cadastral data of the surrounding lot boundaries was obtained through NSW LRS Spatial Information Exchange 'Clip & Ship' data service.

2.3 Landscape Masterplan and Lot Layout

In developing the integrated water cycle management strategy key consideration and coordination with the current landscaping masterplan (July 2019) as prepared by Arterra Design Pty Ltd (Arterra) was adopted in order to develop a fully integrated and informed design. This has allowed for:

- Minimisation of water control device footprints.
- Simplification of the catchment layout, proposed treatment train and proposed stormwater drainage network (anticipating and allowing for locations of splitter pit locations and high flow bypass routes relative to the 12D civil design model).
- Proposed controls to be 'multi-use' - targeting place making and water quality control objectives.
- Maximisation of open space for recreational use.
- Minimisation of long-term maintenance requirements for the proposed controls.
- Staged or modular treatment train design and allowing flexibility in future design stages to facilitate new proprietary technologies and control facilities. This will assist in leveraging further economic and community benefits to the project.

2.4 Preliminary Geotechnical Investigation

A Report on Preliminary Geotechnical Investigation was prepared by Douglas Partners (reference 40494.01, dated February 2019) based off the site analysis and geotechnical investigations performed in September 2018. Some key points include:

- Primarily dispersive and highly dispersive soils of the Moss Vale erosional soil landscape over primarily Bringelly Shale lithological group.
- Concentrated areas of extreme erosion potential will require extensive staged soil and erosion and sediment management during construction.
- Concentrated areas of visible landslip regions and areas of soil creep in steeper areas of the site.
- A concentrated area of approximately 40-50% in grade underneath Hill Road will present a requirement for a coordinated design approach between the masterplan arrangement of the collector road, civil road grading and earthworks design and geotechnical slope stability and earth retaining options.

In order to minimise risks associated with the future staging strategy, further geotechnical investigations with deeper test pits in areas of anticipated cut will be performed for future approvals in order to identify and classify rock strengths by depths.

3 Hydrology - WBNM Model

3.1 Catchment Delineation

In order to develop a hydrological model the available survey data was combined to form a 'master' existing survey model used to delineate sub-catchments within the study area. It is noted that in order to maintain continuity with existing studies and minimise extensive re-assessment, the pre-developed 'existing' catchment plan as provided by Cardno (2019) was adopted as a base and adjusted to suit future hydraulic modelling considerations.

The figure below shows an extract of the pre-developed scenario catchment plan and can be found in full in Appendix B.

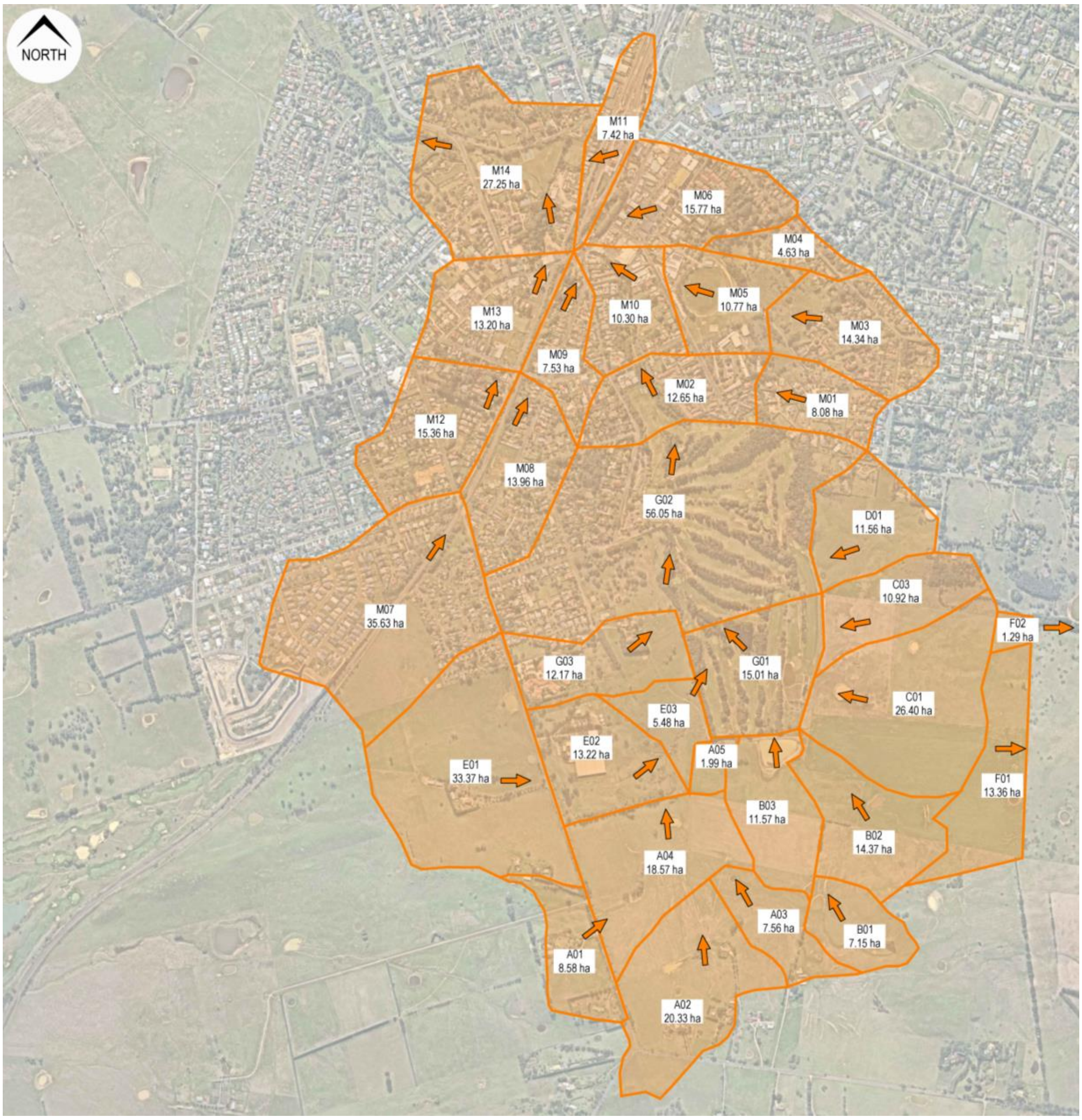

Figure 3 - Pre-Developed Scenario Catchment Plan

In order to inform the post developed scenario and ongoing strategic earthworks staging strategies a preliminary civil design model has been established for the entire site. While this civil model and grading strategy is not part of the scope of this report, it significantly aids in informing the probable post developed sub-catchment delineation and anticipated future stormwater network drainage strategy to be incorporated.

The figure below shows an extract of the post developed scenario catchment plan that can be found in full in Appendix B. Like the pre-developed scenario catchment plan, post-developed catchment delineation has been prepared with consideration of the hydrologic and hydraulic modelling steps to follow.

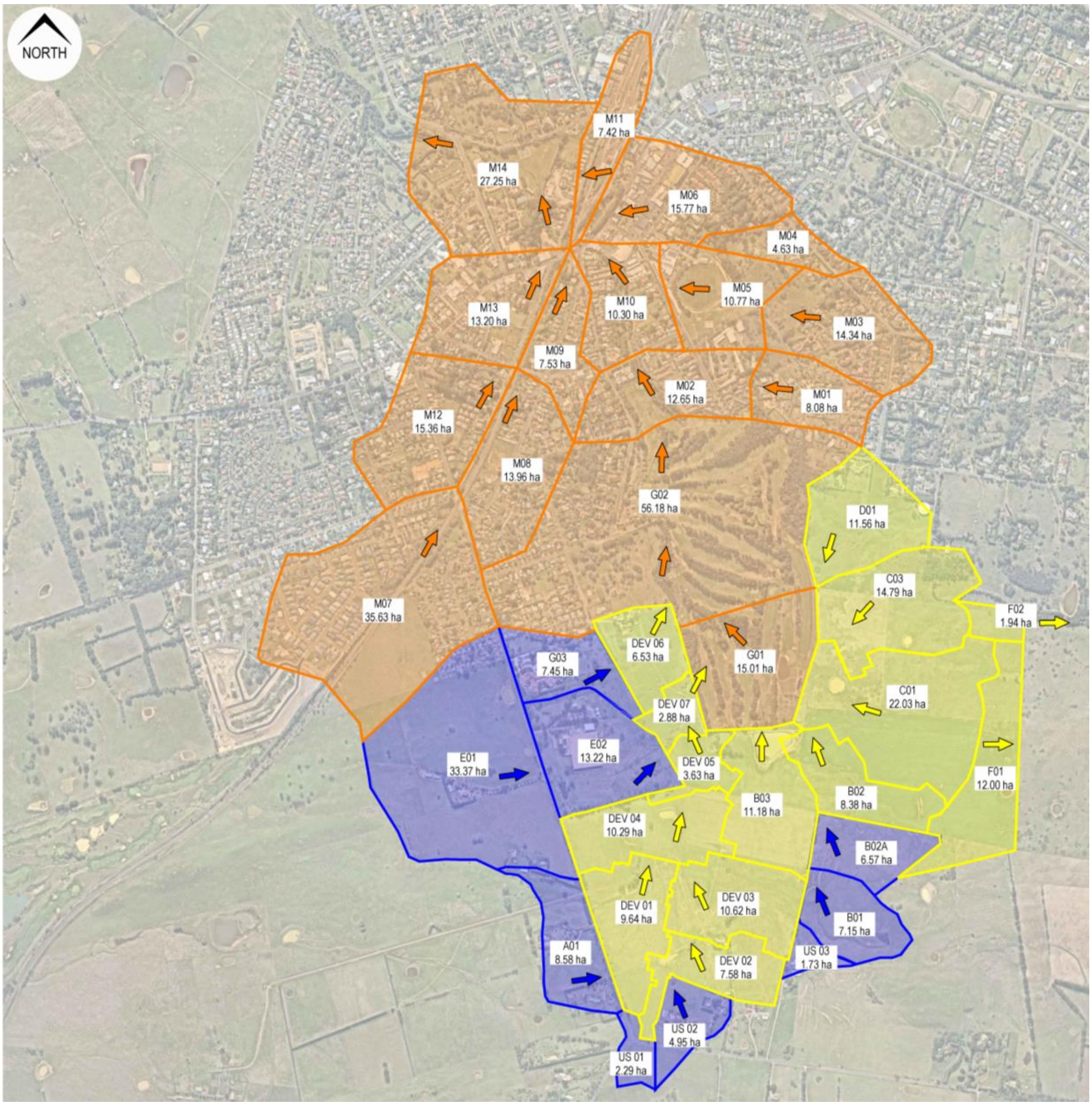

Figure 4 - Post-Developed Scenario Catchment Plan

3.2 WBNM Modelling Parameters

3.2.1 Rainfall Data

ARR1987 Rainfall data for the Moss Vale township was extracted from the Bureau of Meteorology website. The coefficients adopted for rainfall and storm event generation are shown in Table 1 below:

Table 1 - ARR1987 Rainfall Data Coefficients

Coefficient	Value
2 Year ARI, 1 Hour Intensity	31.7 mm/hr
2 Year ARI, 12 Hour Intensity	7.00 mm/hr
2 Year ARI, 72 Hour Intensity	2.40 mm/hr
50 Year ARI, 1 Hour Intensity	63.6 mm/hr
50 Year ARI, 12 Hour Intensity	14.5 mm/hr
50 Year ARI, 72 Hour Intensity	4.6 mm/hr
F2 Factor	4.28
F50 Factor	15.74
Skew	0.00

3.2.2 Soil Loss Model

To account for soil infiltration losses an Initial Loss - Continuing Loss (ILCL) model was adopted across both the WBNM and 2D TUFLOW models with the parameters shown in Table 2 below:

Table 2 - Soil Loss Model Parameters

Parameter	Loss
Initial Loss (pervious)	10 mm
Continuing Loss (pervious)	2.5 mm/hr
Initial Loss (impervious)	1.0 mm
Continuing Loss (impervious)	0 mm/hr

It is noted that while antecedent moisture conditions will most likely result in an initially 'wet' catchment for large or major storm events, the adopted initial loss is minor in comparison to total rainfall depth for the identified critical duration major 2-hour event. There are many shallow depth trapped low points within the flood model, the Initial Loss will allow the storage within these trapped low points to be effectively modelled without the need for a detailed assessment of each of these low points.

3.2.3 Lag Parameters and Model Calibration

To validate industry standard lag parameters and stream lag factors natively used on WBNM models for catchments on the East Coast of Australia, direct 'rainfall-on-grid' was applied to a 2D TUFLOW pre-developed scenario hydraulic model as a test case. It is understood that while the adoption of a rainfall-on-grid (all or in part) significantly increases the TUFLOW model calculation time, a significantly higher level of modelling fidelity is achieved as the entire topographic landform is captured within the model domain.

The primary objective by adopting this method was to validate the catchment and sub catchment reaction time and associated downstream outlet hydrographs due to the significantly varying grades and levels of urbanisation scattered throughout the catchment. Due to the site-specific topography, surface characteristics and the adopted rainfall-on-grid methodology, iterative adjustment to the WBNM model was undertaken to ensure that peak flow results were conservative but also generally consistent with the TUFLOW modelling results.

The detailed survey data indicates that both the subject and neighbouring sites that are predominantly agricultural feature distinct well-defined man-made flow paths linking internal farm dams together in series. With this in mind it is evident that the initial 'default' Lag Parameter and Stream Lag Factors selected within WBNM were not suitable to accurately represent the catchment, with rainfall, runoff and routing occurring much faster in time due to distinct catchment characteristics. As such, the Lag Parameter and Stream Lag Factor values were adjusted accordingly resulting in a much greater parity between the TUFLOW and WBNM results after calibration.

The table below summarises the selected parameters accordingly:

Table 3 - WBNM Runoff and Routing Parameters for Natural and Semi-Urban Catchments

	Lag Parameter	**Stream Lag Factor**
Initial / Recommended Values	1.6	1
Adopted / Calibrated Values	1.3 (steep catchments / upper reaches) 1.6 (flatter catchments / lower reaches)	0.8-0.5 (varies based on level of urbanisation)

A note for the reader: The 'Lag Parameter' is a measure of how fast rainfall is converted to runoff for any given pervious fraction of a sub-catchment. Generally, the smaller the number the more rapid rainfall is converted to runoff increasing peak downstream flows. The 'Stream Lag Factor' is a measure of how fast stream flow is routed through a sub-catchment. Again, generally smaller values represent distinct urbanisation or channelisation of a given sub-catchment increasing flow conveyance speed through a sub-catchment. The 'Stream Lag Factor' is only applied to catchments that route water from upstream (the top) to downstream (the bottom/outlet).

3.3 Post Developed Scenario Management Strategy

In order to reduce post developed flows back to or improve on the pre-developed scenario a series of on-site stormwater detention systems are proposed to be provided throughout the development, integrated into the open space and combined water cycle management strategy.

The on-site stormwater detention (OSD) strategy has been designed to cater for post developed flows discharging from the following locations within the development:

- Outlet 01 - Whites Creek Park ; outlet into the top of Whites Creek
- Outlet 02 - Northern Catchment; outlet into the Golf Club adjacent to Seymour Park
- Outlet 03 - Windbreak Park; outlet into the top (Southernmost) boundary of the Golf Club
- Outlet 04 - Central Lakes; primary outlet along the Eastern common boundary with the Golf Club
- Outlet 05 - Eastern View Park; outlet to existing farmland at the top of the Kellys Creek catchment

The figure below shows the general arrangement of the Parklands as extracted from the Landscape Master Plan Report (Arterra, 2019):

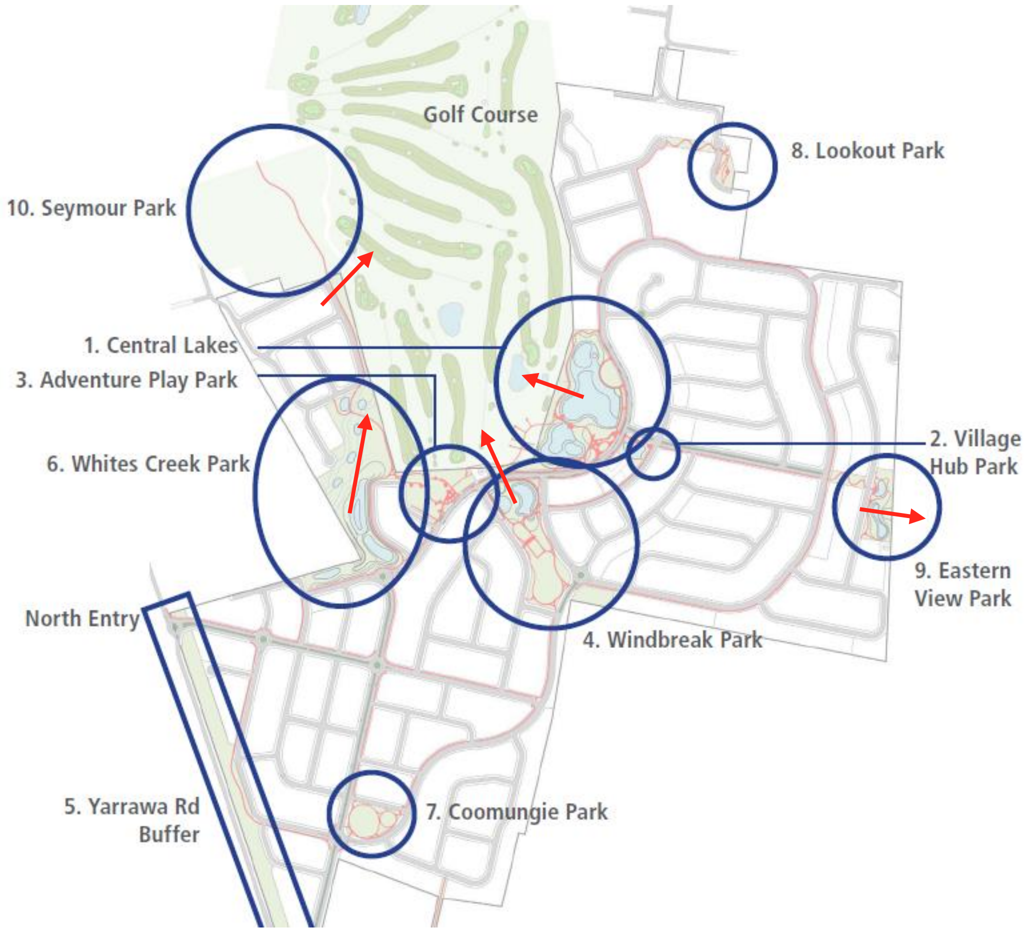

Figure 5 - Proposed Parklands and Open Space Areas

3.3.1 On-Site Stormwater Detention Arrangement

The following table below summaries the proposed OSD storage structures and bypass catchments

Table 4 - On-Site Stormwater Detention Facilities

Outlet / Catchment	Control Measures	Comments
Outlet 01 - Whites Creek Park, outlet into top of Whites Creek	OSD Facility 01 - active storage above permanent water body	Caters to offset peak flows discharging to the Golf Club adjacent to Seymour Park as well as detaining flows from its direct upstream developed catchment. Effective storage to 100 Year ARI = 14,710 m^3
Outlet 02 - Northern Catchment, outlet into Golf Club adjacent to Seymour Park	Catchment bypasses OSD facility	No OSD required. Offset by controls provided in Whites Creek Park. Local grading strategy to outlet to achieve balanced earthworks providing a level interface to Seymour Park to facilitate pedestrian connection.
Outlet 03 - Windbreak Park West	Catchment bypasses OSD facility	No OSD required. Offset by controls provided in the Central Lakes active storage zone. Local grading strategy to lower critical sag levels and reduce local import/fill requirement.
Outlet 03 - Central Lakes	OSD and flood mitigation Facility 02 - active storage above permanent water body	Effective storage to 100 Year ARI = 31,260 m^3
Outlet 04 - Windbreak Park East	Discharges to Central Lakes	
Outlet 05 - Eastern View Park	OSD Facility 03 - active storage above permanent water body	Effective storage to 100 Year ARI = 2,960 m^3

The following figures show general arrangement schematic plans for the proposed water cycle management facilities integrated within the open spaces and parkland of the development. A full set of schematic plans can be found in Appendix C.

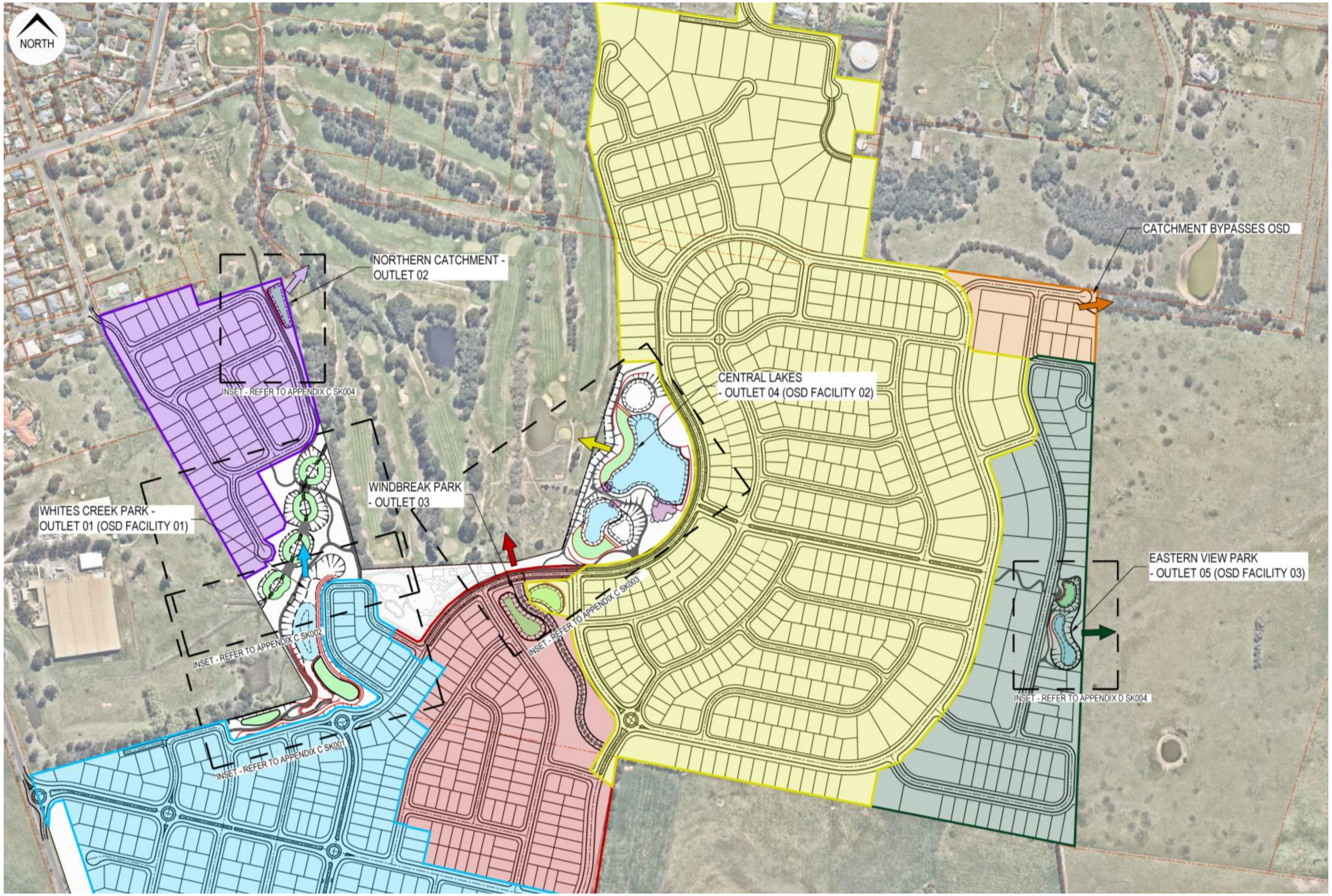

Figure 6 - OSD and Outlet Location Key Plan

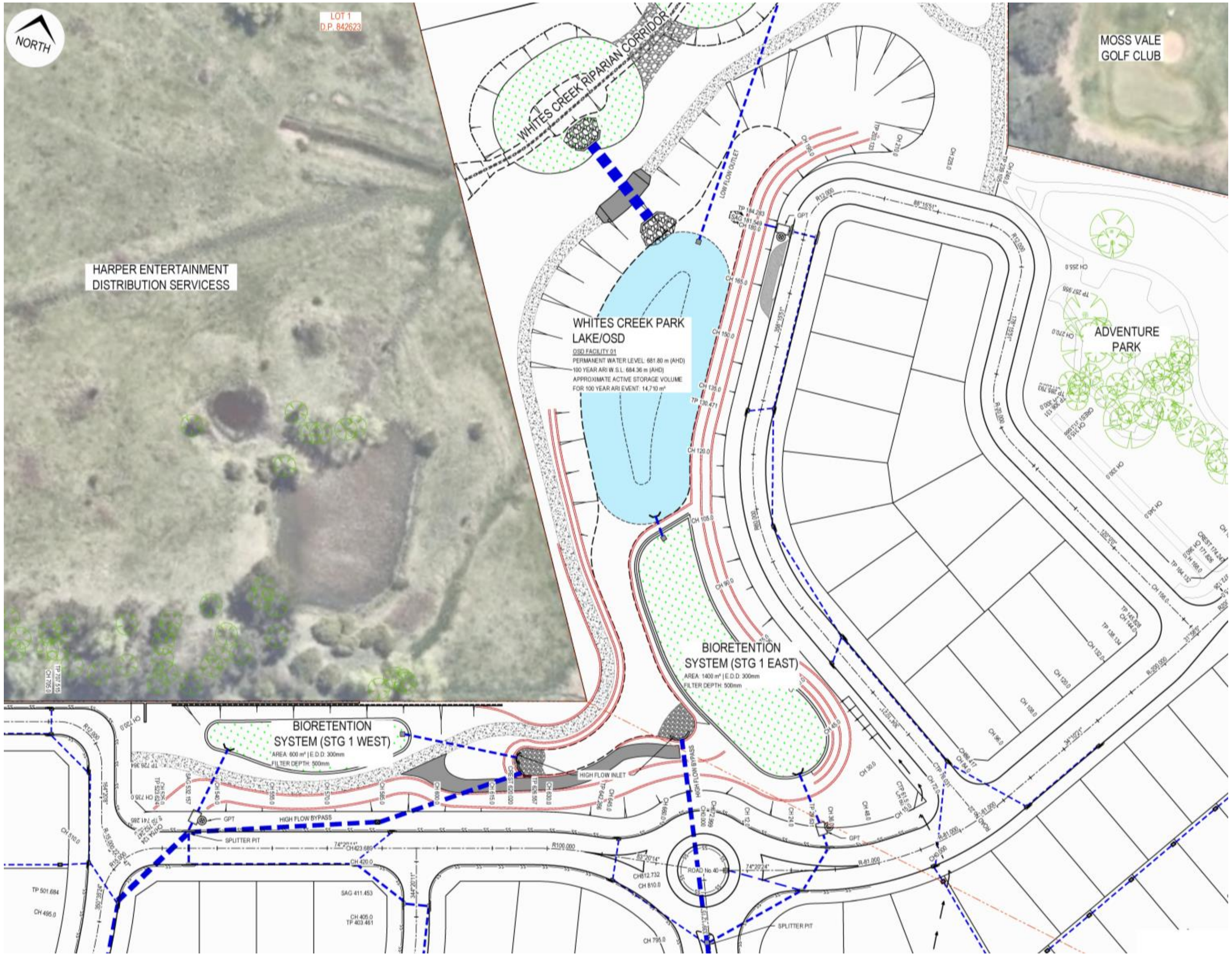

Figure 7 - Whites Creek Park Control Facilities Plan Extract

Figure 8 - Whites Creek Riparian Corridor Plan Extract

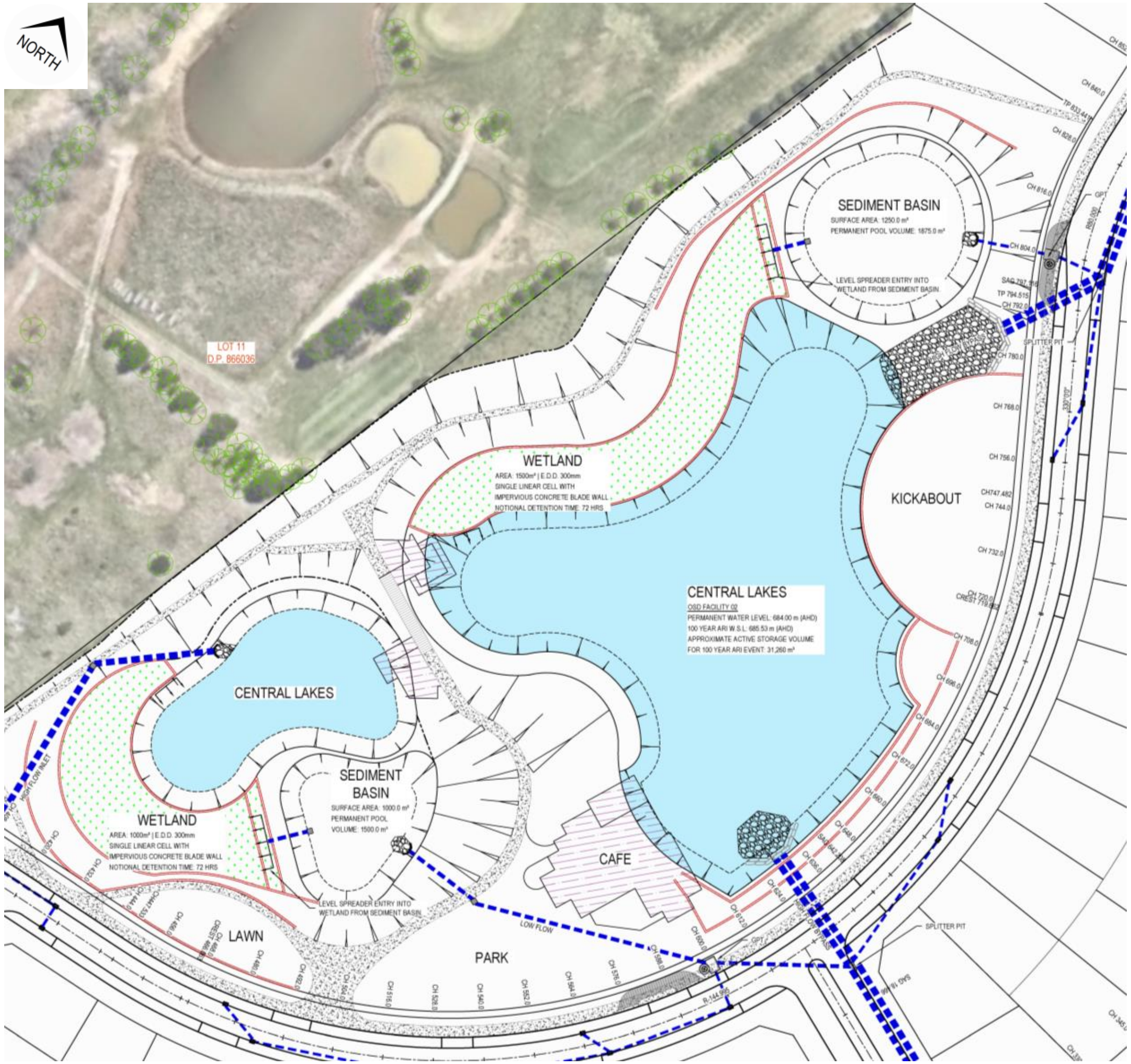

Figure 9 - Central Lakes Control Facilities Plan Extract

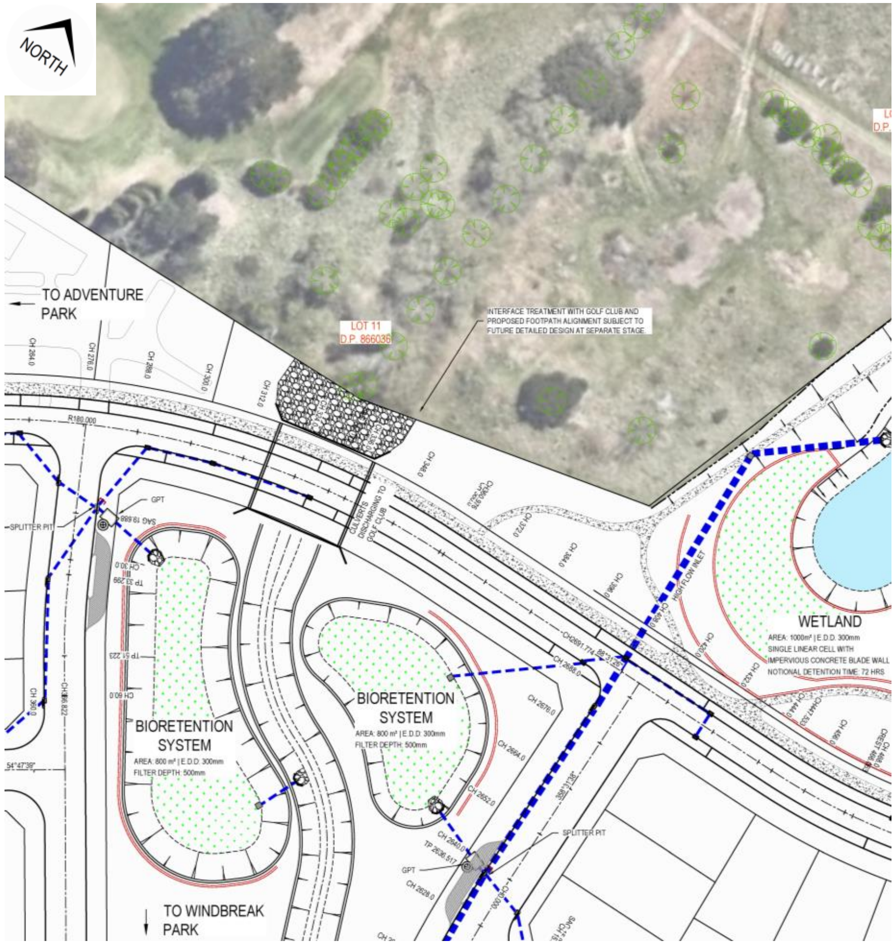

Figure 10 - Windbreak Park Control Facilities Plan Extract

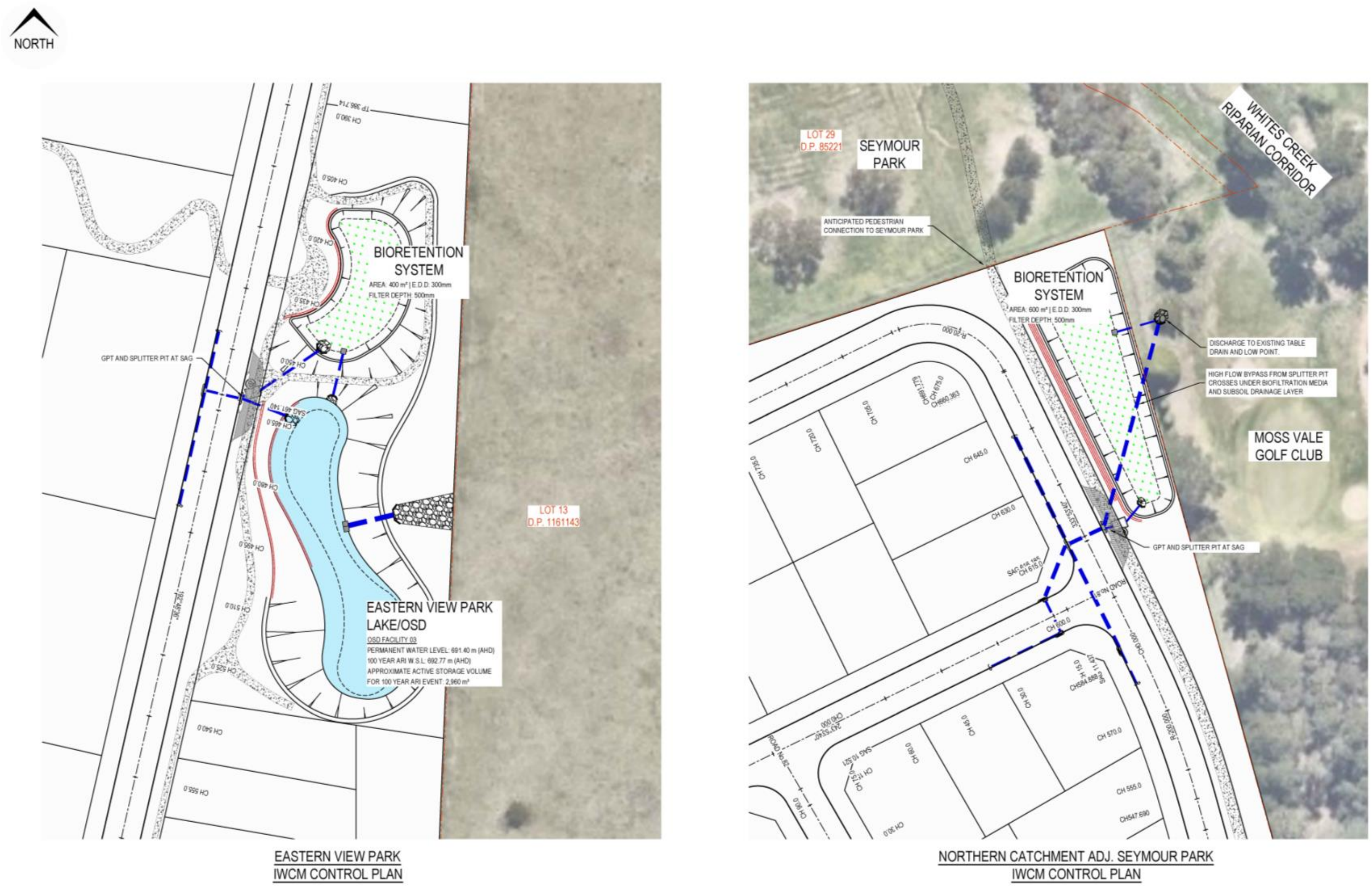

Figure 11 - Eastern View Park and Northern Catchment Control Facilities Plan Extract

3.3.1 On-Site Stormwater Detention Performance

OSD performance has been measured for the 2, 5, 10, 20, 50 and 100 Year ARI critical duration event at each location to ensure compliant design across the whole range of storm frequencies. It is noted that while attenuation of the minor 2 year ARI storm is not explicitly required, adopting this event duration for design will aim to cater for and reduce nuisance flows and stream erosion downstream. To measure the performance of the proposed OSD strategy, the WBNM model compares peak flows at the following locations between the pre-developed and post-developed model scenarios:

i. Flows entering the top boundary of the Golf Course (WBNM location 'G01 top'); Directly measuring the performance from flows entering the downstream catchment from Whites Creek Park, Windbreak Park and the Central Lakes

ii. Flows at the mid-point of the Golf Course (WBNM location 'G02 top');
Directly measuring the performance of all catchments discharging to the Whites Creek catchment.

iii. Flows at the downstream boundary of the model domain near Waite Street (WBNM location 'M14 bottom'); Validating model performance and reduction in peak flows for the post-developed scenario downstream of the Moss Vale township for the entire Whites Creek sub-catchment.

iv. Flows crossing the Eastern boundary from Eastern View Park into the Kellys Creek catchment (WBNM location 'F_OUT bottom'); Directly measuring Eastern View Park OSD performance *including* the minor bypass catchment.

The tables below show a summary of pre-developed and post-developed peak flows for the 4 locations as listed above:

Table 5 - Pre-Developed Scenario Flow Summary

Event	Q_{PRE} G01 top	Q_{PRE} G02 top	Q_{PRE} M14 out	Q_{PRE} F_OUT
ARI (duration)	cu.m/s	cu.m/s	cu.m/s	cu.m/s
2 (2hr)	11.84	13.05	21.57	1.32
5 (2hr)	18.251	20.26	32.27	2.01
10 (2hr)	22.38	24.86	38.79	2.42
20 (2hr)	27.7	30.75	47.26	2.95
50 (2hr)	33.02	36.87	57.37	3.47
100 (2hr)	38.23	42.84	66.18	3.98

Table 6 - Post-Developed Scenario Flow Summary

Event	Q_{POST} G01 top	Q_{POST} G02 top	Q_{POST} M14 out	Q_{POST} F_OUT
ARI (duration)	cu.m/s	cu.m/s	cu.m/s	cu.m/s
2 (2hr)	8.91	10.30	20.53	1.23
5 (2hr)	13.00	14.69	29.49	1.74
10 (2hr)	15.31	17.53	34.97	2.07
20 (2hr)	18.19	21.29	42.27	2.59
50 (2hr)	22.29	25.6	50.92	3.17
100 (2hr)	27.60	31.00	58.84	3.74

Table 7 - Pre Vs Post Flow Difference Summary

Event	ΔQ G01 top	ΔQ G02 top	ΔQ M14 out	ΔQ F_OUT
ARI (duration)	cu.m/s	cu.m/s	cu.m/s	cu.m/s
2 (2hr)	2.93	2.75	1.04	0.09
5 (2hr)	5.25	5.57	2.78	0.27
10 (2hr)	7.07	7.33	3.82	0.35
20 (2hr)	9.51	9.46	4.99	0.36
50 (2hr)	10.73	11.27	6.45	0.30
100 (2hr)	10.63	11.84	7.34	0.24

Note: Table 7 above represents the difference between the pre-developed scenario and post developed scenario flows at the respective nominated locations i.e. 5 (2hr) 11.84 - 8.91 = 2.93 cu.m/s.

We note that while the 90-minute storm is explicitly the critical duration storm for the local F01 and F02 catchments combined, the difference in pre-developed flows between the 90 minute and 2-hour storm events is only 1-3%. For model simplicity and continuity, the 2-hour storm event has been isolated as the critical design storm for modelling purposes for both the Whites Creek and Kellys Creek Catchments.

In all cases the proposed design reduces the post developed flows to below the modelled pre-developed flow rates both immediately downstream of the subject site at all site outlets and further downstream near Waite Street, North-West of the Moss Vale Township. By assessing the flows at both the site outlet locations and downstream of the Moss Vale Township the post developed model has been validated by cross checking the impact of the proposed development at both the site outlets and against the entire catchment upstream of Moss Vale.

A full copy of the pre and post developed WBNM models can be found in Appendix D.

Table 8 - OSD Storage Facility Water Level Summary

	OSD Facility 01 Whites Creek Park Basin		OSD Facility 02 Central Lakes		OSD Facility 03 Eastern View Park Basin	
	m(AHD)	Volume m^3	m(AHD)	Volume m^3	m(AHD)	Volume m^3
Initial Water Level	681.8		684		691.4	
2 Year ARI 2hr)	683.67	6403	684.9	17354	692.26	1420
5 Year ARI (2hr)	683.75	9165	685.2	23353	692.43	1911
10 Year ARI (2hr)	683.96	10954	685.27	25262	692.52	2177
20 Year ARI (2hr)	684.13	12452	685.36	27281	692.62	2499
50 Year ARI (2hr)	684.28	13819	685.46	29615	692.7	2742
100 Year ARI (2hr)	684.36	14709	685.53	31263	692.77	2956
Top of Bank (Max.) RL	684.8		686		693	

4 Hydraulics - TUFLOW Model

To determine the extent of flood affected land downstream of the development in the pre-development scenario as well as to validate the WBNM modelling, proposed flood mitigation and on-site stormwater detention strategy, a fully integrated 1D-2D linked TUFLOW Hydraulic model was developed over the study area. Key features of the model include:

- Primarily focusing on rainfall-on-grid modelling methodology to better reflect the catchment characteristics.
- 2D Domain extending just past Waite Street, North West of the Moss Vale Town Centre in order to present a fully integrated model that both validates the design proposed at critical locations within the domain to address external stakeholder considerations.
- Modelling of major 1D culverts and pipe systems linked with the 2D model domain. This is critically required due to the crossings near the Town Centre under the Illawarra Highway/Argyle Street, the railway line and Lackey Road.
- Hydrograph inflows as extracted from the respective critical duration storms from the WBNM model inserted into the 2D domain generally along the common boundary between the subject site and the discharge locations.
- Consideration of farm dams and water bodies within the 2D domain as completely full at the start of the storm.

An extract of the 2D model domain is shown overleaf and provided in full in Appendix E.

4.1 Materials and Impervious Area Mapping

The following table below presents the materials Mannings 'n' roughness coefficients and impervious area fractions adopted within the hydraulic model.

Table 9 - Materials Properties

Material	Manning's n Roughness Coefficient	Impervious Fraction
Pasture/Open Farmland/Grass	0.05	0
Road Corridors	0.02	1
Rail Corridors	0.04	0.85
Low Density Residential Lots	0.1	0.6
High Density Residential Lots/Commercial	0.2	1
Solid Buildings	0.035	1
Trees	0.075	0
Riparian Corridor - Low Density Vegetation	0.06	0
Riparian Corridor - High Density Vegetation	0.085	0
Water Bodies & Wetlands	0.04	0

An extract of the materials mapping is shown overleaf and provided in full in Appendix E.

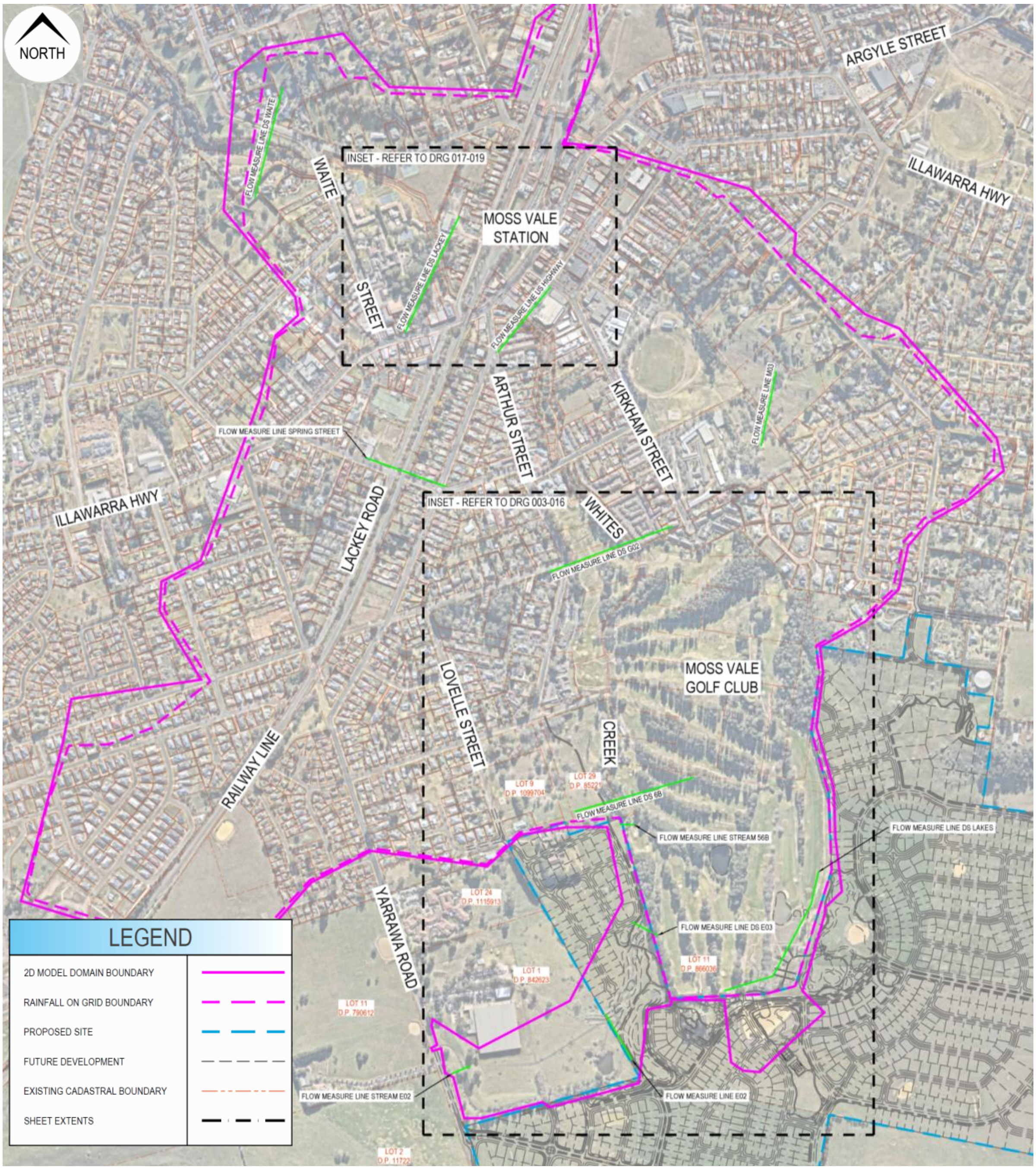

Figure 12 - 2D Model Domain Plan

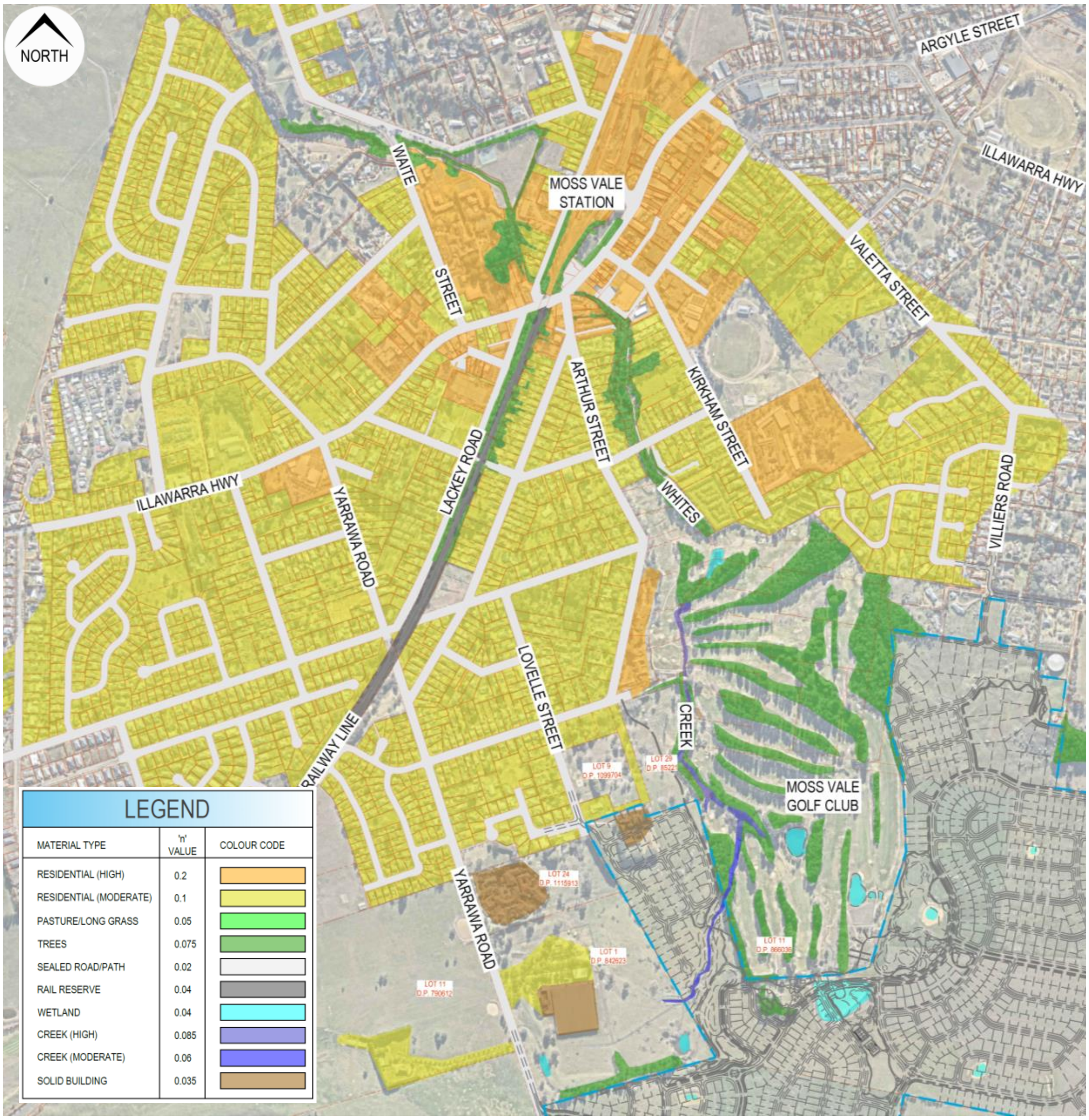

Figure 13 - Pre-Developed Materials Map

4.2 Primary 1D Model Elements

To understand the influence of the existing constrictions and creek crossings within the study area, the following structures were added into the model domain.

Table 10 - 1D hydraulic structures

Location	Size	Source
Mack Street Crossing	8.1m wide x 1.5m high RCBC	URS (2012) Floodplain Risk Management Study and Plan in Cardno 2019
Argyle Street Culvert	3.4m wide x 2.05 high RCBC	URS (2012) Floodplain Risk Management Study and Plan in Cardno 2019
Railway Crossing	2 x 2.4m dia RCP	URS (2012) Floodplain Risk Management Study and Plan in Cardno 2019
Lackey Road Bridge	7.6m wide x 2.6m high RCBC	URS (2012) Floodplain Risk Management Study and Plan in Cardno 2019
Wait Street Crossing	9.15m wide x 2.1 high RCBC	URS (2012) Floodplain Risk Management Study and Plan in Cardno 2019
Mid-point of Golf Course Crossing	3 x 1050 dia RCP	Cardno 2019

No blockage factors were applied within the pre or post developed model scenarios. Assessment and performance of existing hydraulic structures downstream of the subject site is not part of the scope of this study with the 2D TUFLOW Hydraulic model aiming to validate the proposed subject site stormwater management strategy. No blockage of the hydraulic structures listed above was consistently applied for both the pre-developed and post-developed modelling scenario ensuring validity of the pre-developed versus post-developed flood impact assessment.

4.3 Input Data

The rainfall hyetograph for the 10 Year ARI and 100 Year ARI adopted for the rainfall-on-grid model is shown below in Figure 14 as extracted from the WBNM result files:

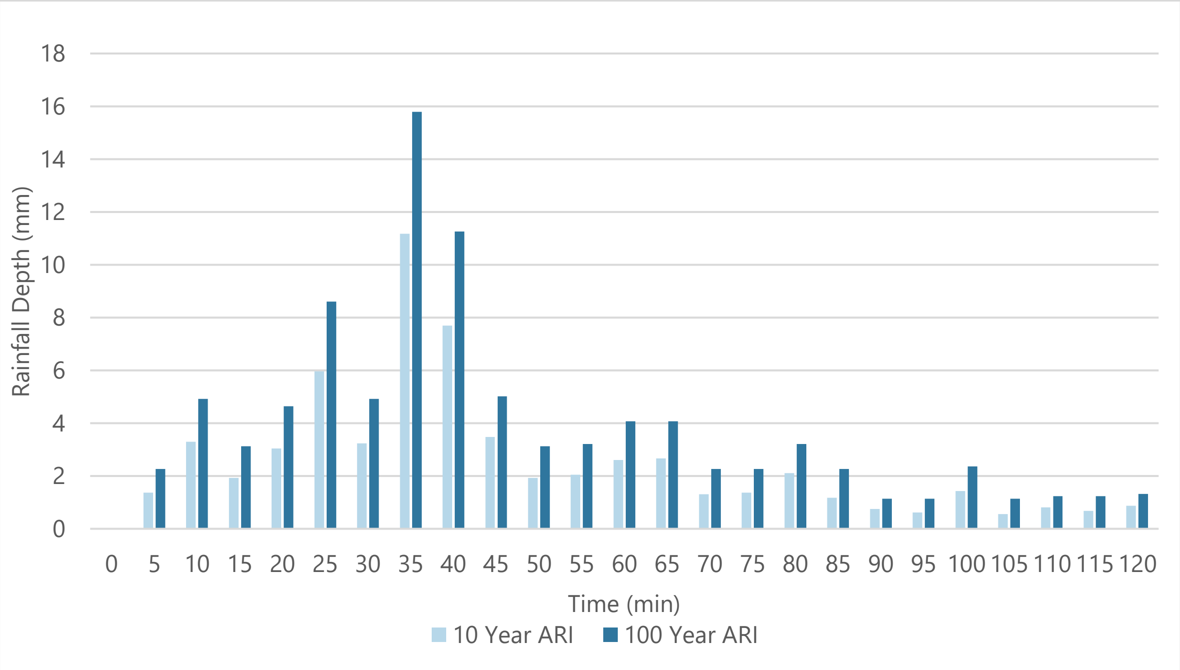

Figure 14 - Rainfall Hyetograph

For both the pre and post-developed scenario model cases inflow hydrographs have been extracted from the respective WBNM model. For the post developed scenario, inflow hydrographs were overlayed on the fully modelled OSD/active storage facilities as detailed and documented within the WBNM model. A full set of the TUFLOW inflow boundary hydrographs are presented in table form in Appendix I and Appendix J for each respective pre-developed and post developed scenario models.

1D weir and culvert elements were added to represent the staged discharge control of the proposed on-site stormwater detention facilities. The modelled staged discharge control elements are summarised in the table below:

Table 11 - Post-Developed Scenario OSD Discharge Controls

Storage Facility	Structure	Comment
Whites Creek Park - OSD Facility 01	375mm Dia. RCP	Low flow - not modelled within 2D domain
	1.8m wide x 0.9m high RCBC Inv. 682.2 m (AHD)	Box culvert modelled and linked
	15m Weir, Elev. R.L. 684.0 m (AHD)	Weir modelled and linked
Central Lakes - OSD Facility 02	375mm Dia. RCP	Low flow not modelled within 2D domain
	10m Weir, Elev. R.L. 685.1	Primary site discharge weir and flood mitigation control modelled and linked
Eastern View Park - OSD Facility 03	600mm Dia. RCP	Not within 2D model domain
	2.4m Weir, Elev. R.L. 692.3 m (AHD)	Not within 2D model domain
	4.0m Weir, Elev. R.L. 692.6 m (AHD)	Not within 2D model domain

4.4 Results Analysis

The 10 Year ARI and 100 Year ARI 2-hour critical storm events were run for both the pre and post developed scenarios with a 2-metre grid resolution for the full duration of the storm event.

4.4.1 Pre-Developed Scenario

Key points observed for the pre-developed scenario include:

- Primarily minor or minimal overbank flooding for the majority of the Whites Creek Riparian Corridor immediately inside and downstream of the subject site.
- Significant overland sheet flow leading from the existing farm dams located within the subject site through the Golf Course to the Whites Creek channel.
- A defined channel is located along the common southern boundary of the Harper Entertainment Distribution Services site. This localised stream flow regime transitions to sheet flow around the online dam at the top of the Whites Creek riparian corridor (also within the Harper Entertainment Distribution Services Site).
- Localised overbank flooding into residential and commercial lots around culvert crossing locations in both the minor and major storm event cases.

- Generally minor and negligible overbank flooding within the subject site. We note that the model domain extents only consider a small portion of the subject site and this observation is limited in nature.

- Flooding over roads:

  i. Illawarra Highway/Argyle Street railway underpass; experiencing approximately 800mm of ponding in the 10 Year ARI event and 1.2m of ponding in the 100 Year ARI event. This is deemed as a high flood hazard; unsafe and untrafficable for all people and vehicle types with a Hazard Vulnerability Classification of between H4 and H5 as defined by Smith *et al.* in Australian Rainfall & Runoff 2019 (AR&R19), Book 6, Chapter 7 section 7.2.7 . The Hazard Vulnerability Classification and flood hazard curves are discussed in section 4.4.3 of this report below.

  ii. Mack Street culvert crossing; experiencing approximately 200-250mm of ponding in the 10 Year ARI event and 500-600mm of ponding in the 100 Year ARI event. This is deemed unsafe for all vehicles and pedestrians in the major (100 Year ARI) storm event given the corresponding water velocity and depth profile. In the major case this is classified with a Hazard Vulnerability Classification of H4.

A full set of pre-developed scenario flood maps are provided in appendix E.

4.4.2 Post-Developed Scenario

Key points observed for the post-developed scenario and flood difference maps include:

- Post Developed Flood Depths within Whites Creek have been reduced downstream of the site in all modelled storm events, inclusive of reductions in flooding over the Illawarra Highway and Argyle Street crossing.

- Minor local increase in concentrated flows entering the Golf Club across the Southern common boundary by locally increasing flows in the existing table drain by approximately 400mm in depth. This is attributed to the minor local concentration of flows through Windbreak Park in lieu of the existing sheet flow regime discharging from the farm dam currently located inside the subject site boundary. An extract of the 10 Year ARI flooded depths is shown below in the following figure.

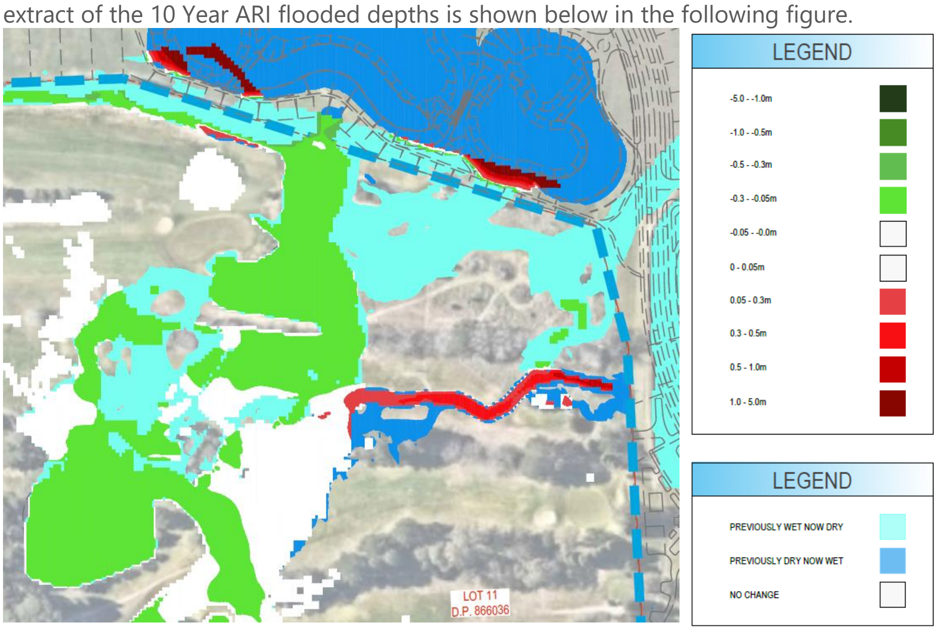

Figure 15 - 10 Year ARI Post Developed Flooded Depths Extract

- Due to the proposed Central Lakes OSD system the post-developed scenario will generally reduce minor overland sheet flows entering the common boundary with the Golf Club.

- The Illawarra Highway/Argyle Street crossing depths have been reduced in the post developed scenario, improving safety. However given the depth of flooding present the reductions do not improve the categorisation of the risks.

A full set of post-developed scenario flood maps are provided in Appendix F and a full set of the difference maps are provided in Appendix G.

An additional flood map inset has been provided to measure the flood depth and hazard for the critical pinch-point at the railway - Illawarra Highway/Argyle Street crossing. These maps are provided in full in Appendix H.

4.4.3 Flood Risk

In order to quantify and classify the flood risk hazard to people and property the flood risk hazard curves and associated Hazard Vulnerability Classifications were adopted from the Flood Hazard technical report prepared by Smith *et al.* 2014 and as generally suggested by Australian Rainfall and Runoff 2019, Book 6, Chapter 7 Section 7.2.7. It is noted that these flood hazard curves incorporate new stability curves for different vehicle classes and pedestrian age groups with defined limiting conditions for both velocity and depth profiles.

The following figure below shows the general flood hazard curves adopted:

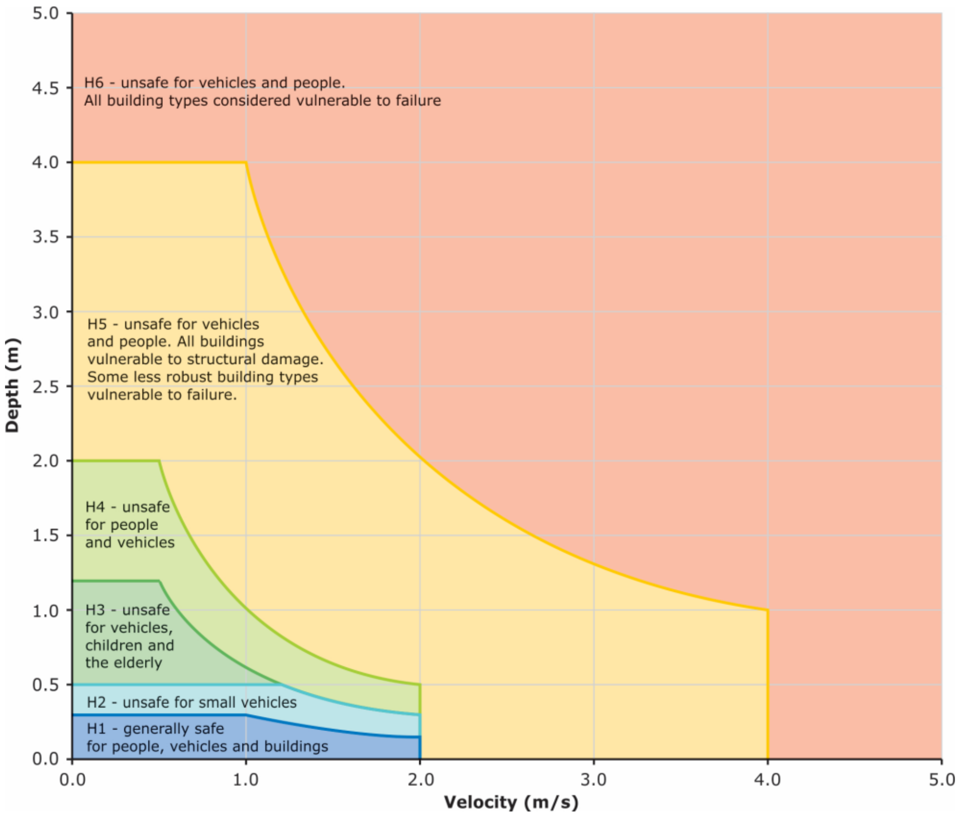

Figure 16 - General Flood Hazard Curves (Smith *et al.* 2014)

The following tables below identifies the Hazard Vulnerability Classifications and the limiting conditions:

Table 12 - Hazard Vulnerability Classifications

Hazard Vulnerability Classification	Description
H1	Generally safe for vehicles, people and buildings.
H2	Unsafe for small vehicles.
H3	Unsafe for vehicles. children and the elderly.
H4	Unsafe for vehicles and people.
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

Table 13 - Hazard Vulnerability Classification Limiting Conditions

Hazard Vulnerability Classification	Classification Limit (D and V in combination)	Limiting Still Water Depth (D)	Limiting Velocity (V)
H1	D*V ≤ 0.3	0.3	2.0
H2	D*V ≤ 0.6	0.5	2.0
H3	D*V ≤ 0.6	1.2	2.0
H4	D*V ≤ 1.0	2.0	2.0
H5	D*V ≤ 4.0	4.0	4.0
H6	D*V > 4.0	-	-

As a reference, flood risk maps have also been provided showing standard velocity depth dot product relationships.

4.4.4 Pre-Developed versus Post-Developed Scenario Flood Difference

In order to validate the improved performance of the post developed scenario hydraulic model over the pre-developed case water levels were extracted at the following locations for water difference comparison:

i. Downstream of the proposed development adjacent to Seymour Park at TUFLOW flow measure line "DS S6B"

ii. Upstream of the first culvert crossing at the junction of Whites Creek and the Illawarra Highway/Argyle Street at TUFLOW flow measure line 'US HWY"

iii. Downstream of Waite Street at TUFLOW flow measure line "DS WAITE"

A full plan detailing all TUFLOW flow measure line locations can be found on sheet 001 in Appendix E.

The following tables below identify the extracted water surface levels and flood depth differences at each respective location:

Table 14 - 10 Year ARI Flood Differences

	DS S6B	US HWY	DS WAITE
Pre Developed (mAHD)	676.42	668.28	663.16
Post Developed (mAHD)	676.17	668.16	663.09
Difference (m)	-0.25	-0.12	-0.07

Table 15 - 100 Year ARI Flood Differences

	DS S6B	US HWY	DS WAITE
Pre Developed (mAHD)	676.86	668.64	663.45
Post Developed (mAHD)	676.61	668.49	663.36
Difference (m)	-0.25	-0.15	-0.09

The water level differences shown in Tables 9 and 10 demonstrate the proposed post-developed model scenario improving flood depths from the pre-developed case.

The hydraulic modelling results further demonstrate the effectiveness of the proposed detention measures in effectively matching or lowering all post development outflows.

A full set of flood difference maps can be found in Appendix G.

4.5 Model Performance

The performance of the TUFLOW model, peak flows were extracted at the following locations for comparison with the WBNM model:

- Flow measure line 'DS Waite' - Located at the downstream edge of the model domain; to be measured against the downstream outlet of sub-catchment M14 from the WBNM model.
- Flow measure line 'DS S6B' - Located at the approximate mid-point of the Golf Club adjacent to Seymour Park; to be measured against the top of stream for sub-catchment G02 from the WBNM model.

Refer to Appendix E, sheet 001 for a complete plan of the flow measure line locations inserted within the 2D TUFLOW model domain for flow hydrograph extraction.

The tables below compare the respective pre and post developed scenario results between the WBNM and TUFLOW models.

Table 16 - Pre-Developed Scenario TUFLOW vs WBNM Performance

	10 Year ARI, 2hr DS Waite / M14 Out	10 Year ARI, 2hr DS S6B / G02 top	100 Year ARI, 2hr DS Waite / M14 Out	100 Year ARI, 2hr DS S6B / G02 top
TUFLOW (cu.m/s)	36.38	21.69	64.27	38.77
WBNM (cu.m/s)	39.79	24.86	66.18	42.84
Absolute Difference (cu.m/s)	3.41	3.17	1.91	4.07
% Difference	8.95	13.62	2.93	9.97

Table 17 - Post-Developed Scenario TUFLOW vs WBNM Performance

	10 Year ARI, 2hr DS Waite / M14 Out	10 Year ARI, 2hr DS S6B / G02 top	100 Year ARI, 2hr DS Waite / M14 Out	100 Year ARI, 2hr DS S6B / G02 top
TUFLOW (cu.m/s)	31.46	14.9	55.11	28.14
WBNM (cu.m/s)	34.97	17.53	58.84	31
Absolute Difference (cu.m/s)	3.51	2.63	3.73	2.86
% Difference	10.57	16.22	6.55	9.67

From the results above it can be seen that both the TUFLOW and WBNM models are performing generally consistently. It is expected that given the two completely different modelling and calculation methods that minor differences will exist in peak flow rates at set locations. This modelling difference allowance is allowed for and hence the reason for freeboard limits on flood planning levels.

5 Water Quality

The water quality or water sensitive urban design strategy for the proposed development has been determined through the adoption and implementation of a MUSIC model. MUSIC is an industry standard modelling tool to design and size water quality controls subject to a number of water quality assessment criteria.

5.1 Assessment Metrics

The WSC Moss Vale Township DCP 2019 Section A4.7 identifies the following assessment criteria for water sensitive urban design:

One of the following, which ever provides the greatest treatment of water:

Percentage reduction targets:

- Total Suspended Solids (TSS) 85%
- Total Phosphorus (TP) 65%
- Total Nitrogen (TN) 45%
- Gross Pollutants (GP) 90%

Or

Compliance with the Neutral or Beneficial Effect (NorBE) guidelines as governed by WaterNSW Sydney Catchment Authority. Compliance under NorBE guidelines is specified as a 10% improvement in TSS, TP, and TN from the pre-developed scenario and concentrations curves of TN and TP to be below existing 55 and 98 cumulative percentiles.

It is noted that due to the current agricultural land use and current nutrient loading that the existing site is imposing on the catchment, the percentage reduction targets will offer the greatest treatment of water and not NorBE. Fundamentally, adopting the percentage reduction targets presents a more conservative modelling approach and aids in reducing nutrient loads released into the catchment. This in turn reduces the risk of algal blooms and long-term maintenance requirements on the proposed permanent water bodies and lakes within the proposed development. It is also noted that while the Moss Vale Township DCP 2019 does not specifically relate to the subject site (covered under its own DCP), the above assessment metrics provide a quantifiable and conservative set of targets for any proposed Water Sensitive Urban Design (WSUD).

5.2 Treatment Train Strategy

The following water quality control assets are proposed for implementation:

i. Proprietary gross pollutant trap (GPT) - for removal of coarse sediment and large debris reducing maintenance obligations and pollutant load on the tertiary treatment controls. (Noting that this modelling will not adopt generic GPT parameters). Sized generally for the 6 month flow (approximated as 50% of the 1 Year ARI flow rate).

ii. Bioretention systems - for capture of finer sediments and nutrients.

iii. Engineered wetlands - for capture of finer sediments and nutrients - promotes aquaculture around permanent place making water bodies.

iv. Sediment basins - for removal of fine and coarse sediments for larger sub catchments with sediment storage zone for ease of maintenance. Reduces pollutant loads passing further down the treatment train.

v. Vegetated Swales - utilised for sediment and nutrient removal where upstream and adjacent catchments flow through established riffle zones and planted pool zones.

vi. Rainwater tanks - generally required in order to meet BASIX requirements and provides a starting point for pollutant capture and removal as well as reduction in runoff from the site due to the provided storage. A nominal 4,000 Litre tank has been allowed for each lot with 100mm dia. uPVC outlet and a re-use drawdown of 470 Litres, per lot, per day.

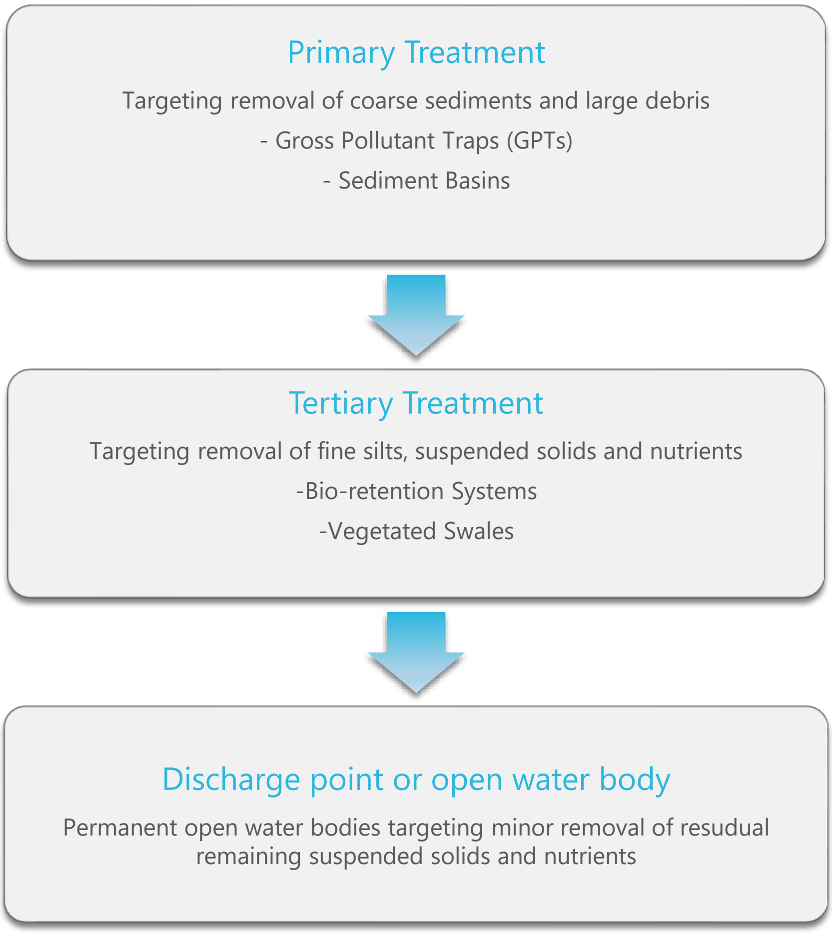

Figure 17 - Water Quality Treatment Train

It is noted that permanent lakes or water bodies are not proposed to form an integral part of the treatment train in order to improve and maintain long term lake health and minimising ongoing maintenance obligations. While the central lakes and permanent water bodies will provide additional water quality control benefits prior to discharge, it is a core design objective to minimise sediment and nutrient loads entering the lakes in the initial instance by utilising the proposed Stormwater Quality Improvement Devices (SQUIDs) located upstream of the lakes.

The table below summaries the proposed treatment train strategy for the different stormwater outlets for the proposed development:

Table 18 - Water Quality Control Treatment Train Strategy

Outlet / Catchment	Control Measures	Comments
Whites Creek Park, outlet into top of Whites Creek	3 x GPT, 2 x bioretention systems into lake and OSD facility	Two (>14ha) sub catchments each draining to a low flow splitter structures and then in-line treatment train consisting of a GPT and bioretention system. High flows discharge directly into Whites Creek Park OSD Facility 01. Minor sub catchment unable to discharge to bioretention systems treated by single GPT before discharge OSD Facility 01.
Northern Catchment, outlet into Golf Club, Stage 6B	1 x GPT and bioretention system	Stage 6B sub catchment to grade to the north east to the low flow splitter that directs treatable flows to the to GPT and bioretention system prior to discharge directly to a Whites Creek sub-tributary within the Golf Club.
Windbreak Park East and West, outlet into top of Golf Club	1 x GPT and 1 x bioretention system (each sub catchment)	Two (≈8ha) sub catchments drain to Windbreak Park each draining to a low flow splitter structures and then in-line treatment train consisting of a GPT and bioretention system. Eastern sub catchment from Windbreak Park to discharge into Central Lakes OSD Facility 02. Western and upstream external sub catchments bypasses OSD control via a central open channel and discharges into the top (southern edge) of the Gold Club.
Central Lakes, primary outlet to Golf Club	1 x GPT, Sediment basin and engineered wetland (each sub catchment)	Large (>20ha) sub catchments each draining to a low flow splitter structures and then in-line treatment train consisting of GPT, sediment basin and wetland. High flows discharge directly into Central Lakes OSD Facility 02. It is anticipated that due to high inlet flows in major events rock armour and scour protection around lake inlets will require detailed design and assessment at detail design stage.
Eastern Catchment, outlet to existing farmland	1 x GPT and bioretention system	Low flow splitter directing treatable flows to GPT and bioretention system prior to discharge into lake and OSD storage.

5.3 Modelling Input Data

The site has been identified to lie within Climate Zone 3 as provided by the Water NSW Sydney Catchment Authority. The relevant MUSIC .mlb database file was downloaded and implemented for rainfall and evapotranspiration data from the 1997 to 2001 inclusive.

Due to only 5 years of data being available within this WaterNSW standard MUSIC model database file it is noted that during the future detailed design phases an water balance with a greater range of rainfall data will be required to assess the proposed permanent water bodies (to establish average residence time and recharge rates).

5.3.1 Catchment Delineation

The post-developed scenario catchment delineation that was adopted for the hydrological modelling has been further refined and is shown in greater detail in Appendix B.

5.3.2 Sub-Catchment Breakdown

To apply both a conservative and accurate modelling approach sub-catchments and adopted impervious areas were defined by the following method:

i. Calculation of total number of lots and corresponding total lot areas for each sub-catchment;

ii. Breakdown of the total lot areas into both roof area and supplementary (garden, driveway) areas. Supplementary areas were modelled as 50% impervious for the 450-600 m^2 lots and 25% impervious for the larger 1000-2000 m^2 lots;

iii. An estimate of 275 m^2 roof area was allowed for each individual lot with 50% of the roof area to drain to a rainwater tank. All roof areas were modelled as 100% impervious;

iv. Total area of road corridors were calculated for each sub-catchment and assumed to be 95% impervious; and

v. Local park impervious areas estimated based on future use; It is anticipated that the Adventure Park (50% impervious) will have a higher percentage of hardstand area than Coomungie or Windbreak Parks (35% impervious).

These allowances for impervious area proportions are area conservative estimates based upon proposed masterplan lot layout and sizes from previous subdivision design experience and have been adjusted to account for anticipated larger dwellings given the number of larger 600+ square metre lots proposed within this development.

5.3.3 Catchment Areas Summary

The tables below summarise the adopted sub-catchment areas and breakdown of land use:

Table 19 - MUSIC Sub-Catchment Summary (1 of 3)

	Stage 1 West Catchment	Stage 1 East Catchment	Stage 1 Bypass	Stage 6B - NW Catchment	Windbreak Park West
Total Lots	147	213	30	65	108
Lot Area (ha)	9.52	13.43	1.44	4.24	5.23
Roof Area (ha)	4.04	5.86	0.83	1.79	2.97
Lot Sup. Area (ha)	5.48	7.58	0.62	2.45	2.26
Roads (ha)	4.57	7.21	0.64	2.59	2.94
Parks (ha)	0.00	0.55	0.00	0.00	0.43
Total Area (ha)	14.09	21.20	2.08	6.83	8.60

Table 20 - MUSIC Sub-Catchment Summary (2 of 3)

	Windbreak Park East	North Central Catchment	Northern Escarpment	Eastern View Park	Eastern View Park Bypass
Total Lots	74	189	169	70	12
Lot Area (ha)	4.85	13.36	15.58	7.31	1.22
Roof Area (ha)	2.04	5.20	5.92	1.93	0.33
Lot Sup. Area (ha)	2.81	8.17	9.66	5.39	0.89
Roads (ha)	2.75	5.89	5.91	2.16	0.72
Parks (ha)	0.32	0.00	0.00	0.71	0.00
Total Area (ha)	7.91	19.25	21.49	10.18	1.94

Table 21 - MUSIC Sub-Catchment Summary (3 of 3) - Parks and Open Space

Whites Creek Park (ha)	2.06
Central Lakes (ha)	3.45
Whites Creek Riparian Corridor (ha)	1.86
Adventure Park (ha)	1.05
Windbreak Park Central Corridor (ha)	1.4
TOTAL MUSIC MODEL AREA (ha)	**123.39**

5.3.4 Pollutant and Soil Input Parameters

Soil storage and pollutant concentration parameters for each of the respective source nodes were extracted from section 4.1.4 of the Water NSW 'Using MUSIC in the Sydney Drinking Water Catchment' guideline and are summarised in the following tables:

Table 22 - Soil Storage Capacity Parameters

Rainfall Threshold Values	
Roofs	0.3 mm
Sealed Roads	1.5 mm
All land uses	1.0 mm
Soil Storage Capacity and Rainfall-Runoff Parameters	
Soil Storage Capacity	54 mm
Field Capacity	51 mm
Infiltration Capacity Coeff. A	180 mm/d
Infiltration Capacity Coeff. B	3.0 mm/d
Daily Recharge Rate	25%
Daily Baseflow Rate	25%
Daily Seepage Rate	0%

Table 23 - Base Flow Pollutant Concentration Parameters

(mg/L-log_{10})	TSS		TP		TN	
Surface Type	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Roofs	0	0	0	0	0	0
Sealed Roads	1.2	0.17	-0.85	0.19	0.11	0.12
Revegetated Land	1.15	0.17	-1.22	0.19	-0.05	0.12
Land use						
Residential	1.2	0.17	-0.85	0.19	0.11	0.12
Agricultural	1.3	0.13	-1.05	0.13	0.04	0.13

Table 24 - Storm Flow Pollutant Concentration Parameters

(mg/L-log_{10})	TSS		TP		TN	
Surface Type	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Roofs	1.3	0.32	-0.89	0.25	0.3	0.19
Sealed Roads	2.43	0.32	-0.3	0.25	0.34	0.19
Revegetated Land	1.95	0.32	-0.66	0.25	0.3	0.19
Land use						
Residential	2.15	0.32	-0.6	0.25	0.3	0.19
Agricultural	2.15	0.31	-0.22	0.3	0.48	0.26

5.3.5 Model Layout

The figures following show the MUSIC model layout and breakdown and can be reviewed in full in the provided modelling file (.sqz). The proposed treatment trains for each of the respective quality control facilities are presented in Appendix D.

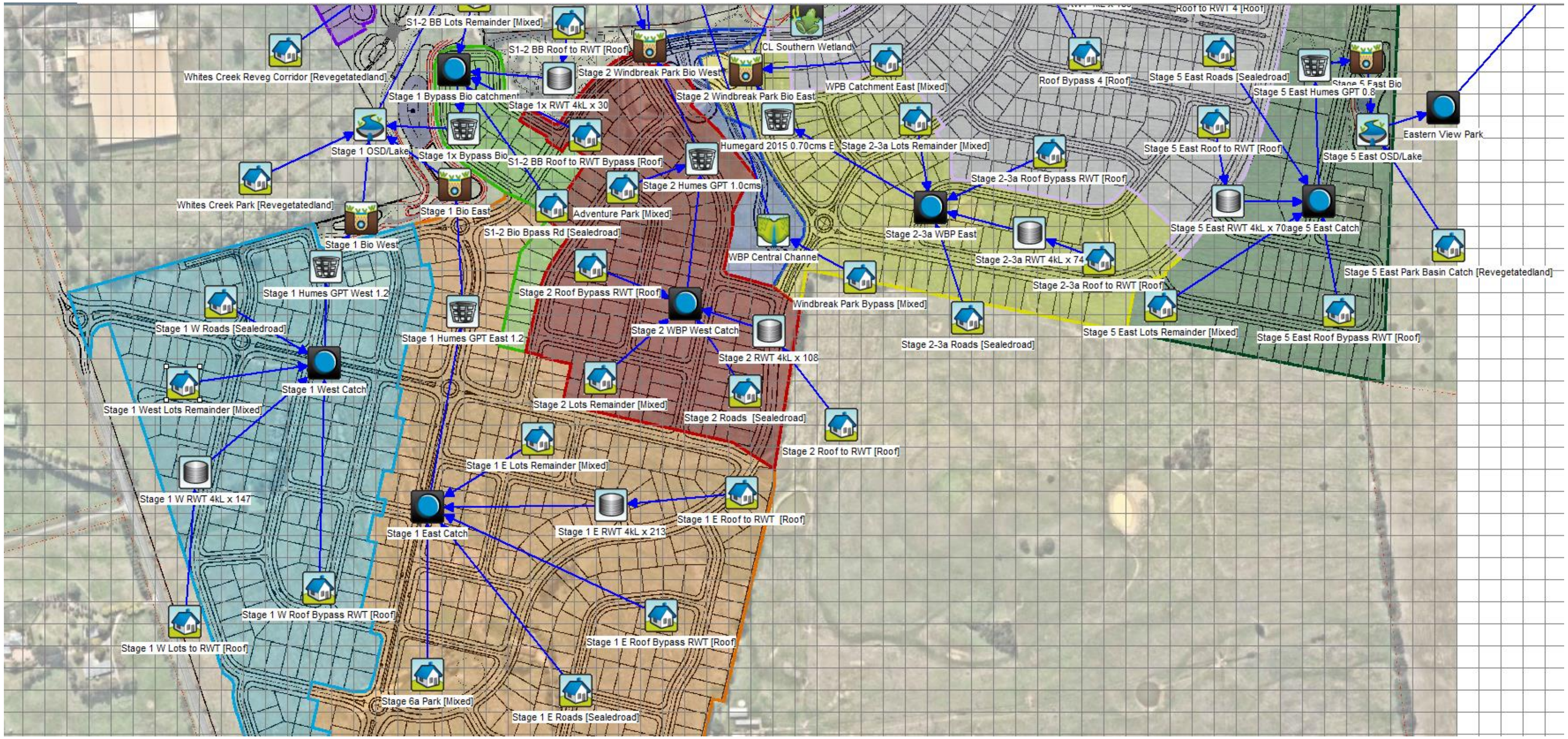

Figure 18 - MUSIC Model Layout - Part 1

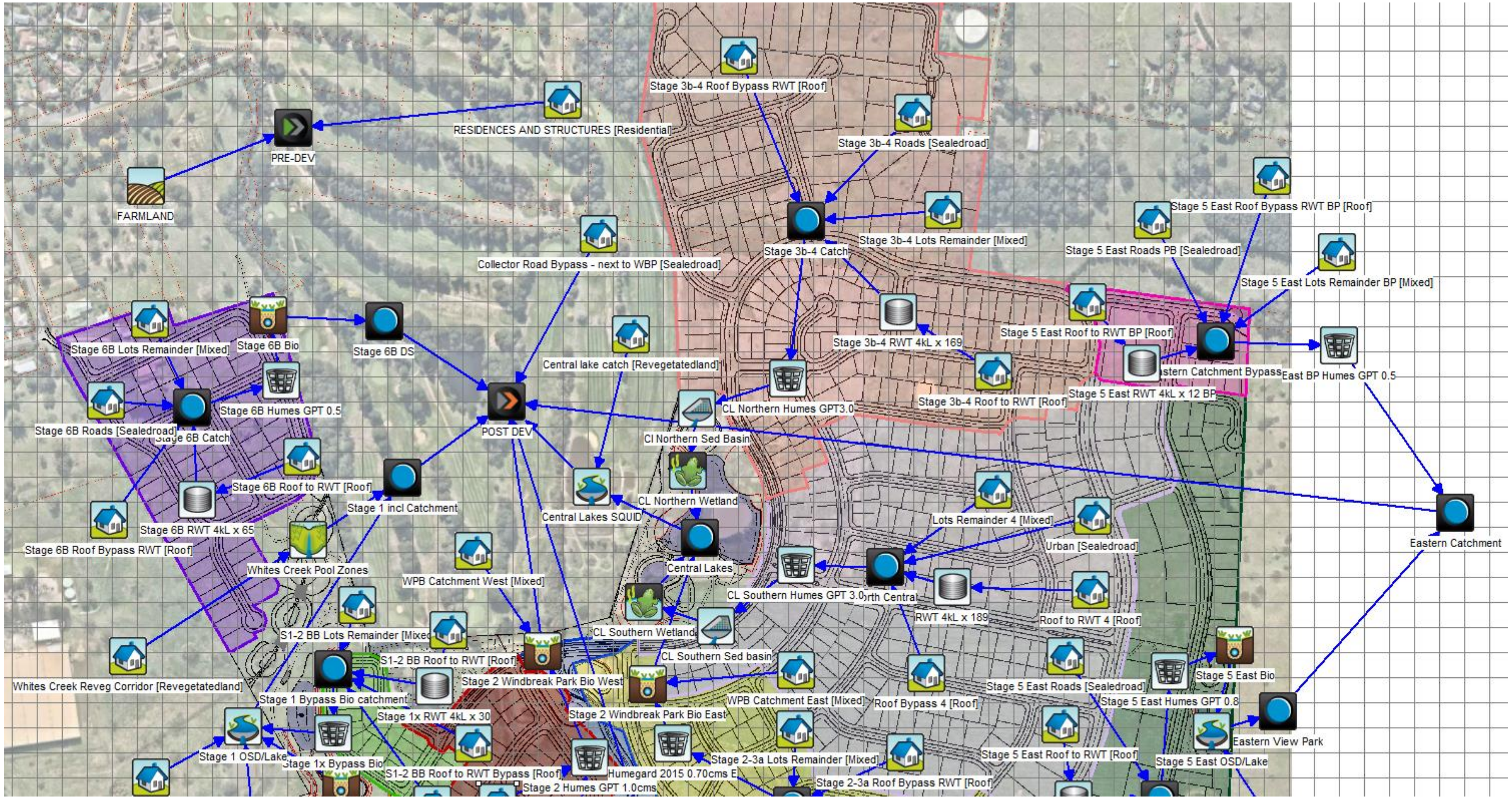

Figure 19 - MUSIC Model Layout - Part 2

5.4 Modelling Results

The Table 20 below summarises the pre-developed and post-developed scenario source and residual pollutant loads as well as the percentage reduction results.

Table 25 - Treatment Train Effectiveness

	Sources		Residual Load		% Reduction
	Pre	Post	Pre	Post	Post
TSS (kg/yr)	59400.00	142000.00	59400.00	21100.00	85.10
TP (kg/yr)	237	265	237	80.2	69.7
TN (kg/yr)	1170.00	1740.00	1170.00	789.00	54.70
Gross Pollutants (kg/yr)	114	19900.00	114	98.1	99.5

The above table demonstrates that both the 10% reduction in pre-developed sources (NorBE requirement) and the percentage reduction targets are achieved with the proposed treatment train and water quality management strategy.

The following figures show the cumulative frequency curves for total phosphorous and total nitrogen concentrations respectively for both the pre-developed scenario and post-developed scenario cases.

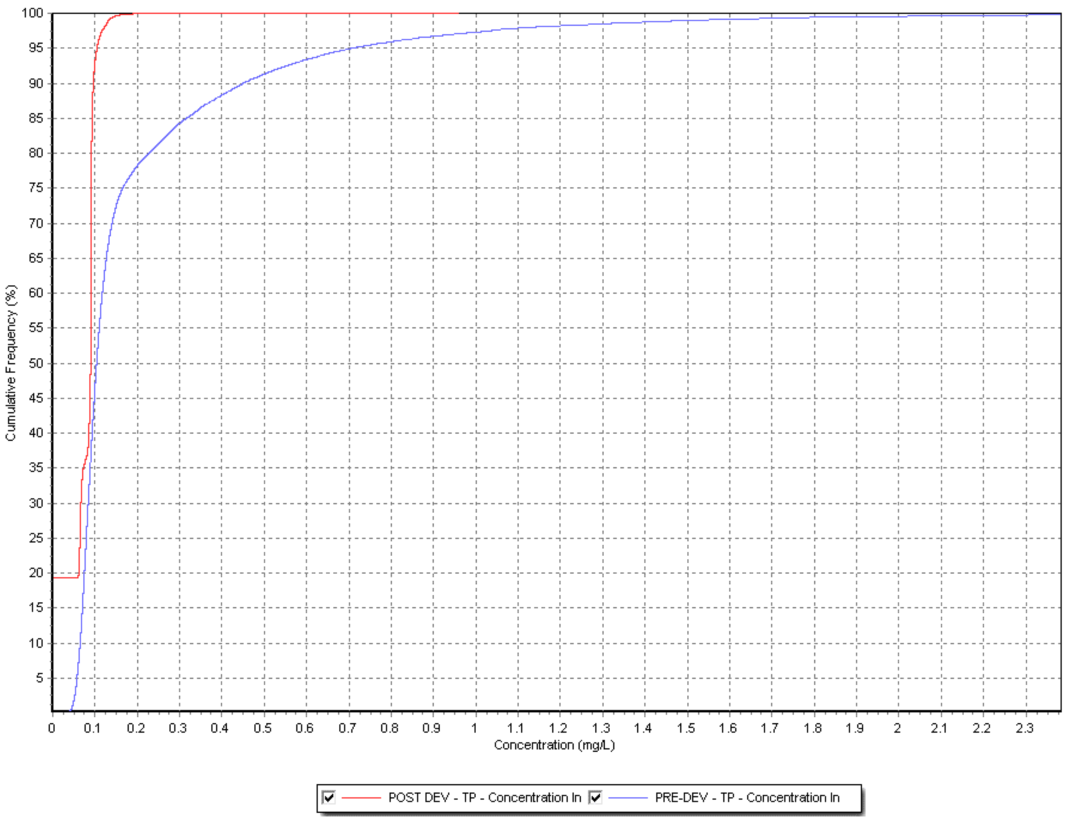

Figure 20 - Total Phosphorus Cumulative Frequency Plot (Flow Based Sub-Sample)

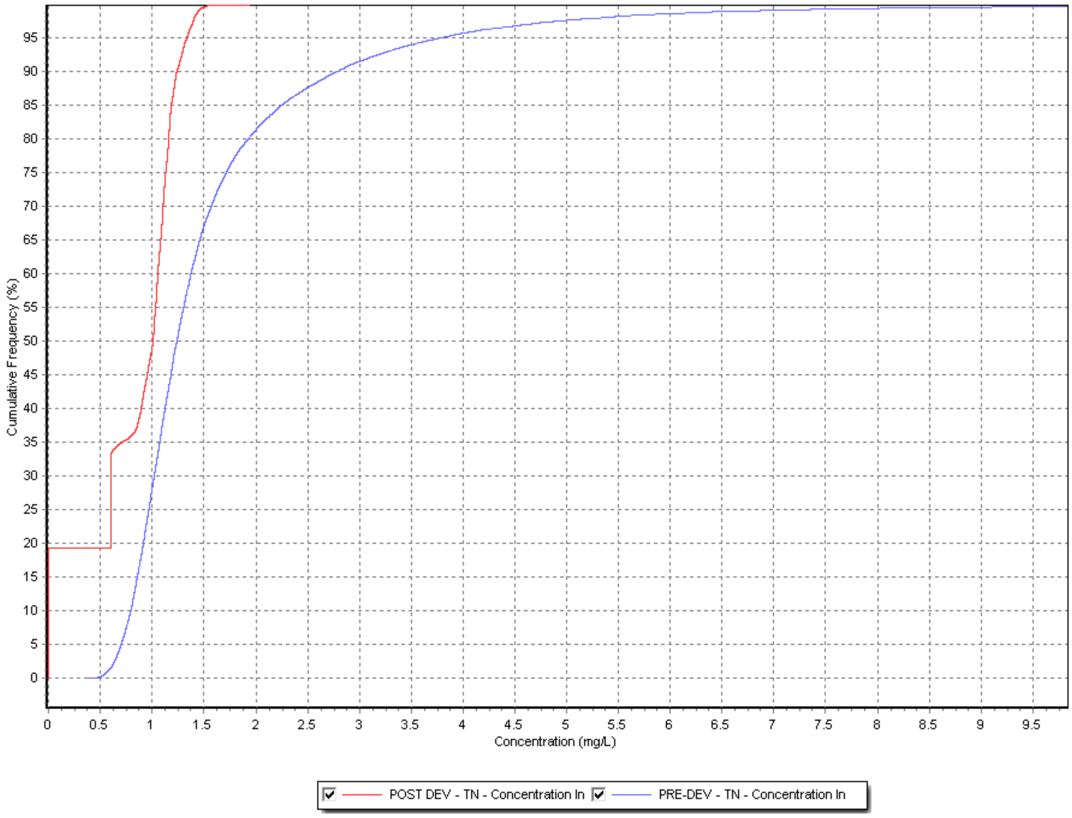

Figure 21 - Total Nitrogen Cumulative Frequency Plot (Flow Based Sub-Sample)

As observed above in all cases for total phosphorous and total nitrogen, the post-developed pollutant concentrations are lower than the pre-developed pollutant concentrations for all percentiles including the 50th Percentile and 98th Percentile demonstrating full compliance with the NorBE assessment guidelines.

5.5 Future Considerations

It is noted that with on-going research and development by a number of industry leading providers of proprietary water sensitive urban design solutions, new and more efficient stormwater control methods are constantly being developed. While fundamentally conservative in nature given the proposed standard treatment nodes, this design and geometric layout has been structured in a way to leverage new bioretention systems and engineered wetland solutions at future design stages subject to client, council and Water NSW requirements.

A key example of these new proprietary SQUIDs includes highly engineered filter media in lieu of the standard bioretention system adopted for this report:

- Significantly increased treatment rates thus significantly reducing required plan footprint
- Engineered media and sacrificial mulch layer forms primary form of nutrient removal not the plants, this allows for more native vegetation to be planted increasing resilience to drought conditions.
- Smaller footprint and number of plants reduces maintenance requirements.
- Installed and certified and optionally maintained by provider ensuring compliance.

6 Conclusions and Recommendations

For both water quantity, floodplain management and water quality the report demonstrates that the proposed management strategies reduce downstream peak flows and flooded depths and meet the relevant regulatory requirements for water quality targets. As such we conclude that this integrated water cycle management strategy is suitable to support the development proposal.

A summary of key findings is provided below:

i. The water quantity and flood mitigation strategy proposes 2 key on-site detention storage facilities located on the Whites Creek catchment and 1 on-site detention storage facility on the Eastern, Kellys Creek Catchment, these basins reduce peak flows to below pre-developed flows in all modelled events and reduce downstream flood affectation;

ii. Flooding at the Argyle Street/Illawarra Highway Crossing has been reduced, improving safety however the flood affection in this area still exhibits unsafe flooding characteristics that exceed minimum requirements for pedestrian and vehicle safety under the new ARR2016 and Australian Emergency Management Institute guidelines;

iii. The modelling of the proposed development does not indicate any increase in flood hazard or flood affectation for storms up to the 100 Year ARI event;

iv. The proposed treatment train considers splitting treatable flows. The geometric arrangement of the integrated water quantity/water quality controls considers the requirement for significant high-flow bypass routes; and

v. The proposed treatment train comprising of rainwater tanks, GPTs, sediment basins, engineered wetlands and bioretention gardens meets both the Moss Vale DCP and Water NSW water quality targets, *including* consideration of offsetting any bypass catchments as required.

We note that the modelling and reporting of this strategy is concept in nature and future stages, under separate approvals will be subject to further review as more detailed design of the proposed management methodology is performed.

7 References

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