Water Cycle Management Strategy Report

Mirvac Homes (NSW) Pty Limited and
Vianello Holdings Pty Limited

Glenmore Park Stage 3 (GP3)

April 2022

J. WYNDHAM PRINCE
CONSULTING CIVIL INFRASTRUCTURE ENGINEERS
& PROJECT MANAGERS

Prepared by

J. Wyndham Prince
Contact: David Crompton
Phone: 02 4720 3300
Email: jwp@jwprince.com.au
ABN: 67 002 318 621

Prepared for

Mirvac Homes (NSW) Pty Limited and
Vianello Holdings Pty Limited
Contact: Justin Soto
Phone: 0423 303 408
Email: justin.soto@mirvac.com

Version control

Issue	Author	Reviewer	Approver	Date approved
A – First Issue	Troy McLeod / Francis Lane	David Crompton	David Crompton	23/12/2021
B – Second Issue	Troy McLeod	David Crompton	David Crompton	12/04/2022
C – Third Issue	Troy McLeod	David Crompton	David Crompton	13/04/2022

© Copyright: The information in this document is the property of J. Wyndham Prince Pty Ltd. Use of this document, or passing it on to others, or copying it, in part or in full, without the written permission of J. Wyndham Prince Pty Ltd, is infringement of copyright.

TABLE OF CONTENTS

PLATES

TABLES

APPENDICES

1. EXECUTIVE SUMMARY

J. Wyndham Prince has been engaged by Mirvac Homes (NSW) Pty Ltd (Mirvac) and Vianello Holdings Pty Ltd (Vianello) to prepare a Water Cycle Management Strategy Report in support of the proposed rezoning of a 205-ha parcel of land at The Northern Road, Mulgoa. The Glenmore Park Stage 3 (GP3) site is located within the Penrith Local Government Area (LGA). This report details the procedures used and presents the results of investigations to support the rezoning and future development applications to be submitted to Penrith City Council (Council).

This Water Cycle Management Strategy (WCMS) presents background and details of the planning proposal for the GP3 rezoning, hydrologic analysis, water quality analysis, riparian corridor assessment and ecological assessment. An initial WCMS was previously submitted to Council (JWP, 24 March 2020, ref: 110474-02-Rpt1_E) which resulted in a series of comments and requests for information that have subsequently been addressed in this revised report. Key updates include transitioning the hydrologic model to ARR 2019 methodologies, the preparation of a 1D/2D flood model of the site in TUFLOW, preparation of a detailed water quality model of the proposed development in MUSIC and the preparation of concept design plans for a selection of devices across the site. In addition to this, NSW Government's Cumberland Plain Conservation Plan (CPCP) has been considered to inform the GP3 Master Plan.

The revised modelling and overall Water Cycle Management Strategy is based on the revised Master Plan and preliminary gradings that have been undertaken by ADW Johnson (for the Mirvac landholdings) and J. Wyndham Prince (for the Vianello landholdings).

Results demonstrate that the proposed five (5) detention basins located throughout the site with a total storage of approximately 39,000 m³ will ensure that peak post-development discharges in storm events up to and including the 1% AEP are restricted to less than the pre-development levels at all key comparison locations. The strategy includes one (1) "dry" detention basin and four (4) "wet" detention basins co-located with open water bodies.

The Water Cycle Management Strategy also provides a flood impact assessment of the GP3 precinct. The assessment defines the flood behaviour within the Precinct providing information on the flood depths, levels, and hazards for 20% AEP, 1% AEP and PMF events. The flood impact maps show that in the 20% AEP and 1% AEP events, the development of GP3 results in some localised impacts within the Mulgoa Nature Reserve downstream which are restricted to the existing flood extents. Further investigations to reduce these impacts will be undertaken in the post exhibition phase of the rezoning.

Water quality will be managed by on-lot rainwater tanks, gross pollutant traps, raingardens and permanent ponds in order to deliver the required water quality outcomes for the site. A total of nine (9) raingardens and four (4) permanent ponds are proposed across the site. The anticipated total bio-retention raingarden area is 11,420 m² and the anticipated total pond surface area is 23,720 m².

Concept designs have been prepared for a selection of devices across the site to give an indication of the stormwater infrastructure design outcomes that can be expected. The concept designs are provided in Appendix A. For an overview of the Water Cycle Management Plan refer to Figure 1-1 in Appendix B.

The Water Cycle Management Strategy proposed for Glenmore Park Stage 3 is functional; delivers the required technical performance; lessens environmental degradation and pressure on downstream ecosystems and infrastructure and provides for a 'soft' sustainable solution for stormwater management within the precinct.

2. BACKGROUND

2.1. Site

The Glenmore Park Stage 3 site is located within the Penrith City Council Local Government area and consists of approximately 205 ha of land located at The Northern Road, Mulgoa. The site is bound to the north by the existing Glenmore Park Stage 2 development, The Northern Road to the east, Chain-O-Ponds Road to the south and Mulgoa Nature Reserve to the west.

The site includes a number of minor Mulgoa Creek tributaries that traverse the site before discharging to Mulgoa Nature Reserve as well as a number of existing farm dams. The site is predominantly used for agricultural purposes with an undulating terrain and variations in height from RL 91 m to RL 47 m.

Refer to Plate 2-1 below for further detail of the site.

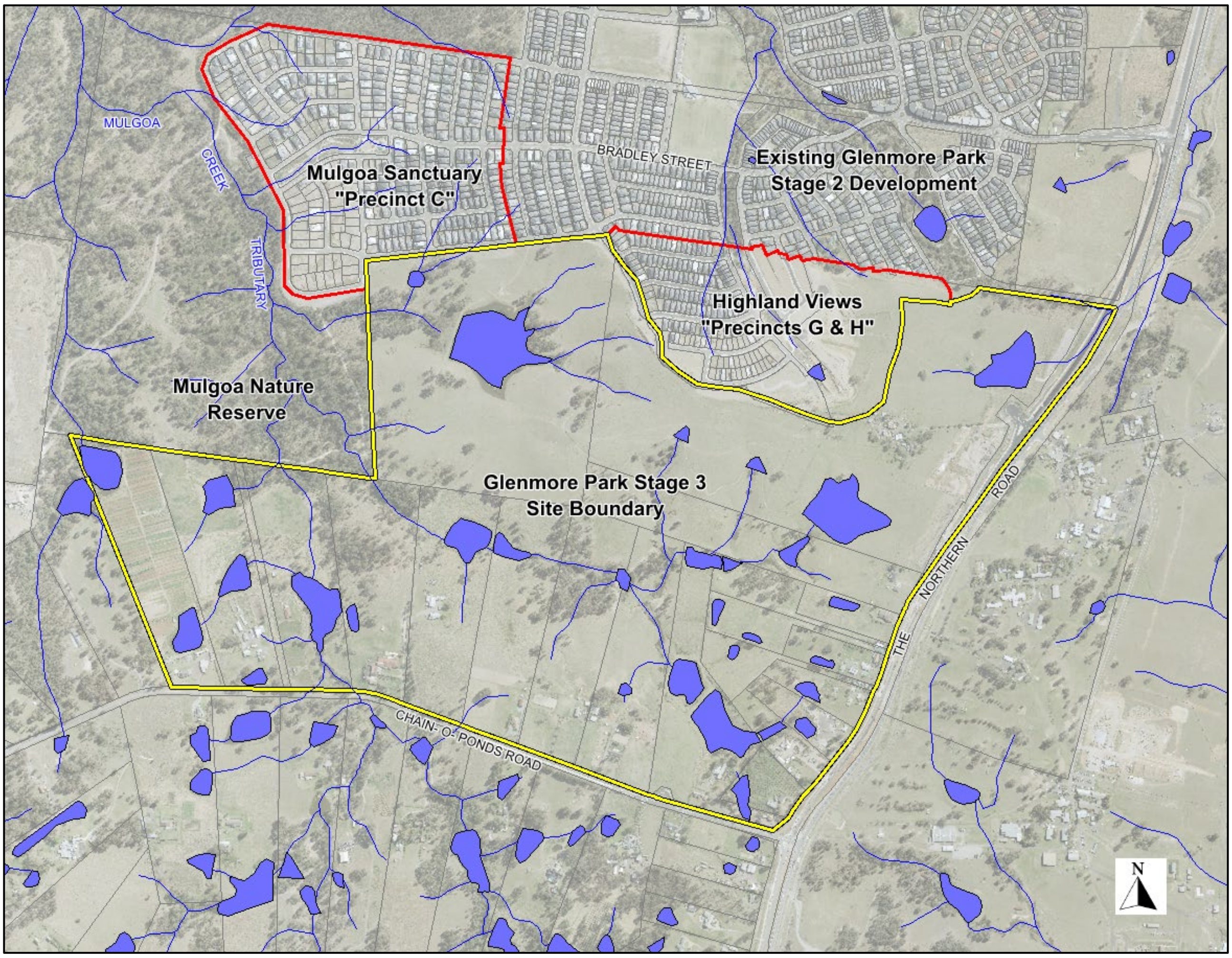

Plate 2-1 – Existing Site

There are a series of significant upstream catchments, ranging in size from 1 ha to 10 ha, that are conveyed via watercourses (unnamed tributaries) through the subject site before discharging to Mulgoa Creek along the northern boundary. It is proposed that a number of tributaries that traverse the site will be maintained as fully functional riparian corridors.

The Vianello portion of land is currently zoned as RU2 Rural Landscape under the Penrith Local Environmental Plan (2010), while the remaining portion of land under control of Mirvac and others is zoned RU2 Rural Landscape and E3 Environmental Management. Refer to Plate 2-2 below for details.

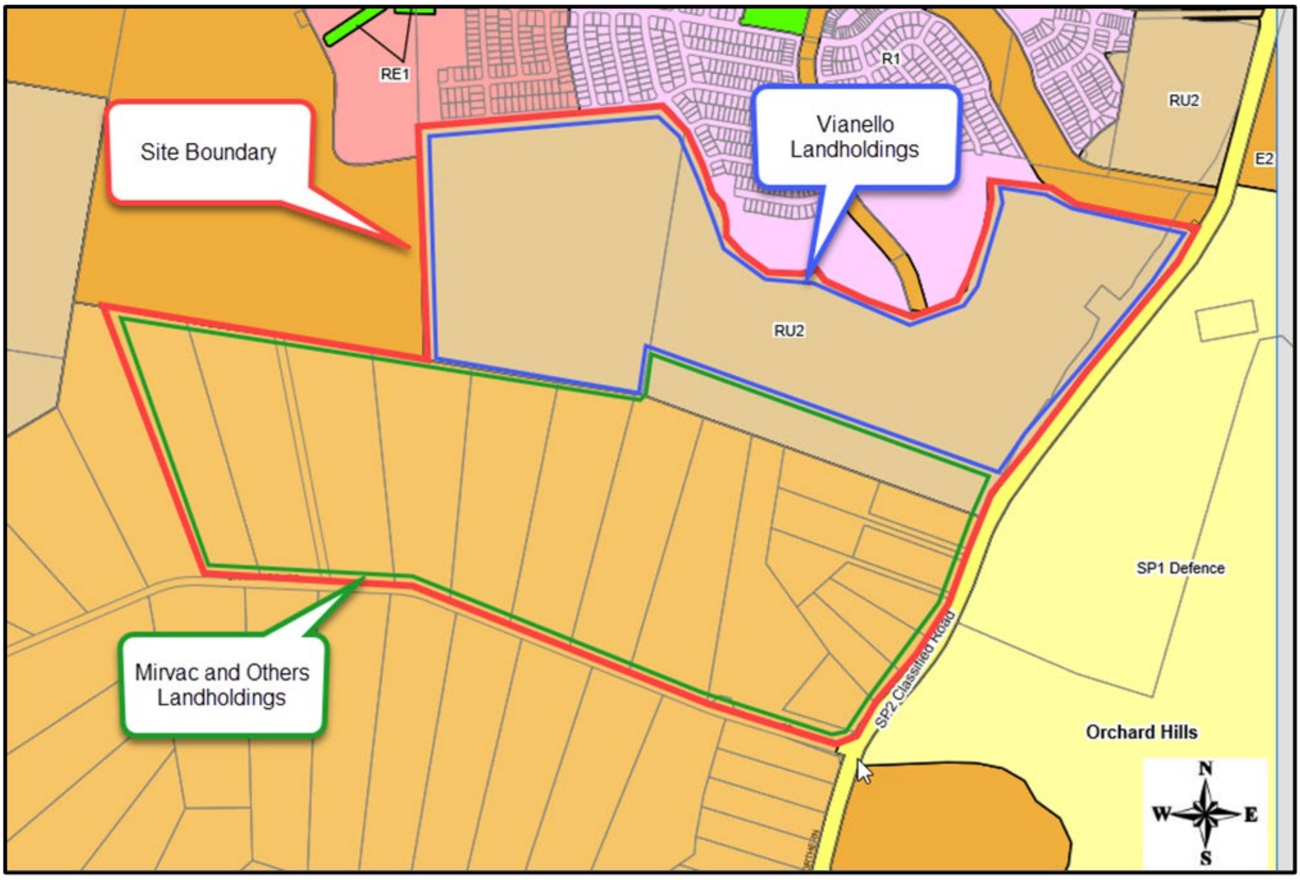

Plate 2-2 – Existing Zoning

2.2. Objective

The objective of this study is to support the rezoning application for GP3 by expanding on the previously submitted stormwater strategy, addressing the items raised by Council, and includes an assessment of flooding within and surrounding the subject site, water quality assessment and concept design preparation. This assessment will ensure compliance with Council's development standards and policies.

2.3. Proposed Development

The Planning Proposal submitted to Council on 21 May 2018 supports an amendment to the Penrith Local Environmental Plan (LEP) 2010 to rezone a 205-ha parcel of land at The Northern Road, Mulgoa to accommodate a new residential development.

The Planning Proposal is supported by a Masterplan, which represents the overall planning framework and preferred outcome for the Glenmore Park Stage 3. The Masterplan includes the following significant features:

- Residential development with associated road infrastructure
- School site
- Mixed use / commercial areas
- Passive / Active Open Space Area throughout the masterplan

Five (5) stormwater detention basins will be provided at strategic locations throughout the development to mitigate peak flows resulting from urbanisation of the catchment to less than (or equal to) existing conditions.

Some riparian corridors which bisect the site are proposed to be maintained and enhanced to be a functioning riparian corridor, while others are proposed to be removed with the support of Natural Resources Access Regulator (NRAR). The Cumberland Plain Conservation Plan is also a key constraint that has been considered in the proposed Master Plan. Various water quality devices are also proposed throughout the development to minimise the impact on the environment and deliver PCC's water quality objectives. Refer to Plate 2-3 for the Masterplan for the site.

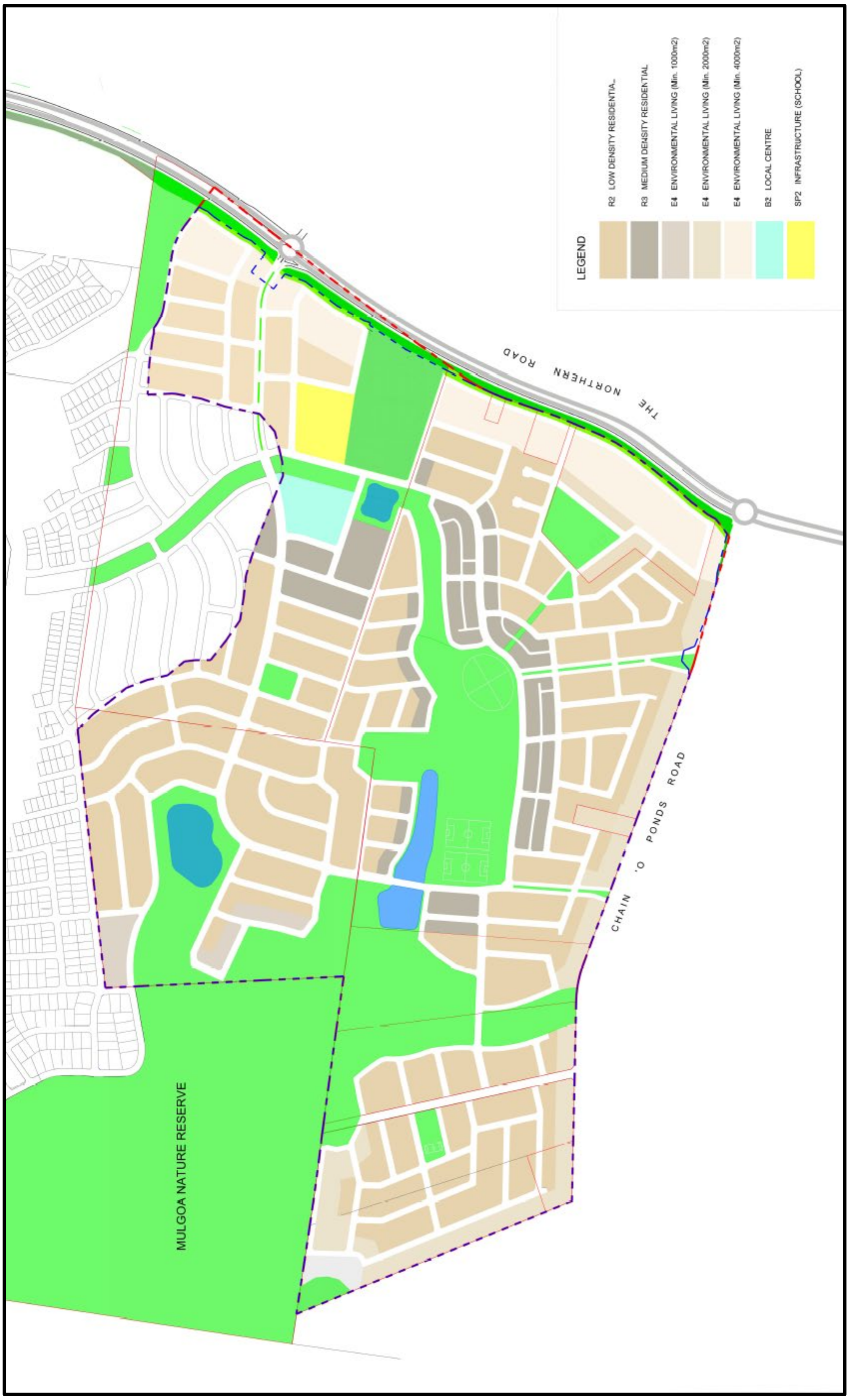

Plate 2-3 – GP3 Master Plan (Mirvac, 4 April 2022, Rev F)

3. PREVIOUS STUDIES

3.1. Stormwater Management Strategy – Glenmore Park Stage 2 (2005)

This report (JWP, 2005) was previously prepared to support the master planning and rezoning process and presents the results of the investigations undertaken in developing a Stormwater Management Strategy that incorporated the principles of Water Sensitive Urban Design (WSUD) to integrate with and support the development planning process for the Glenmore Park Stage 2 Release Area.

The water quality strategy proposed in this investigation allowed for the provision of bio-retention raingardens sized at 1% of the catchment area. The modelling also included rainwater tanks on each residential allotment; however, these were modelled as a pond node due to the rainwater tank node not being included in earlier versions of the MUSIC water quality modelling software. The results of the modelling showed that the treatment train was adequate to achieve the applicable water quality targets at the time, with scope to be refined in subsequent investigations.

The strategy also allowed for the provision of detention storage to restrict 1 EY (Exceedances per Year) post development peak flows to predevelopment levels for local catchments within Glenmore Park Stage 2 (consistent with the requirements of the Glenmore Park Stage 2 DCP). Detention incorporated within the existing Blue Hills Wetland provides adequate storage to restrict post development flows to predevelopment levels for all storms up to and including the 1% AEP storms for the Surveyors Creek catchment of Glenmore Park Stage 2.

Results of the strategy indicate that there is no net increase in stormwater discharge rates at the downstream end of the Mulgoa Creek Tributary, and therefore no detention storage has been provided for storm events in excess of the 1 EY.

3.2. Penrith Overland Flow Flood “Overview Study” (2006)

In August 2006, Cardno Lawson Treloar Pty Ltd (Cardno) prepared the Overland Flow Study for Penrith City Council. The study formed the first stage to inform a series of flood assessments across the LGA. It identified 40 creek systems and their catchment areas that will ultimately require further studies.

As part of the study, two-dimensional (2D) hydraulic (SOBEK) modelling was completed to determine flood behaviour for the entire LGA. This model was not informed by traditional methods of hydrological modelling. Instead, design rainfall time-series were applied directly on the model grid as input. The resulting flood extents were used to identify properties affected by overland flooding.

The 1% AEP flood extents defined in this study were used to identify the flooding constraints affecting the Glenmore Park Stage 3 site.

Plate 3-1 shows extracts of Council’s flood maps which shows the extents of 5% AEP (20-year ARI), 1% AEP (100 year ARI) and PMF overland flooding across the existing site.

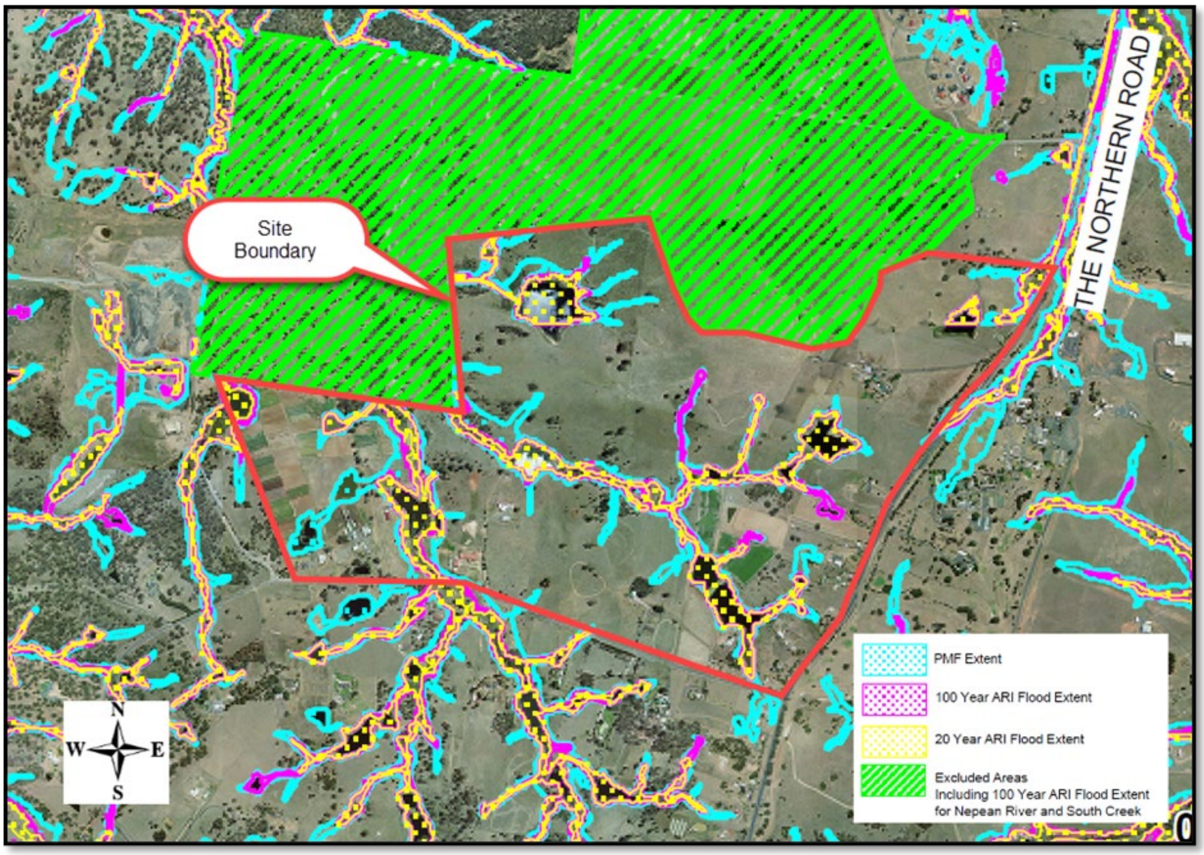

Plate 3-1 – Flooding Across GP3 Site (Cardno, 2006)

3.3. Glenmore Park Stage 2 – Stormwater Management Strategy Addendum Report – Revised Water Quality Modelling & Stream Erosion Index Assessment (2010)

In 2010, J. Wyndham Prince completed the "Glenmore Park Stage 2 – Stormwater Management Strategy Addendum Report – Revised Water Quality Modelling & Stream Erosion Index Assessment" (Addendum Report) for the Landowners Group. This assessment revised the previous strategy for the Glenmore Park Stage 2 Release Area (JWP, 2005) to address updates to the development layout, PCC's design requirements and MUSIC modelling software.

Results of this investigation showed that the provision of Gross Pollutant Traps (GPTs) and raingardens within the development will ensure that the post development stormwater discharges will meet the DCP's water quality objectives for Glenmore Park Stage 2. The inclusion of rainwater tanks as an additional node in the new MUSIC model has allowed raingarden areas derived in the 2005 study to be reduced from 1% to 0.55% relative to the catchments they service.

3.4. Glenmore Park Stage 2 Precinct C – Stormwater Management Strategy (2017)

This report (JWP 2017) was prepared to support Development Applications for bulk earthworks, subdivision and development within Precinct C at Glenmore Park Stage 2. The strategy has been prepared to conform with the statutory requirements and industry best practice for stormwater management.

The Stormwater Management Strategy comprises of a treatment train consisting of on lot treatment, street level treatment and subdivision/development treatment measures. The structural elements proposed for the development include proprietary GPT units, three (3) detention basins and three (3) bio-retention systems (raingardens). Refer to Plate 3-2 below.

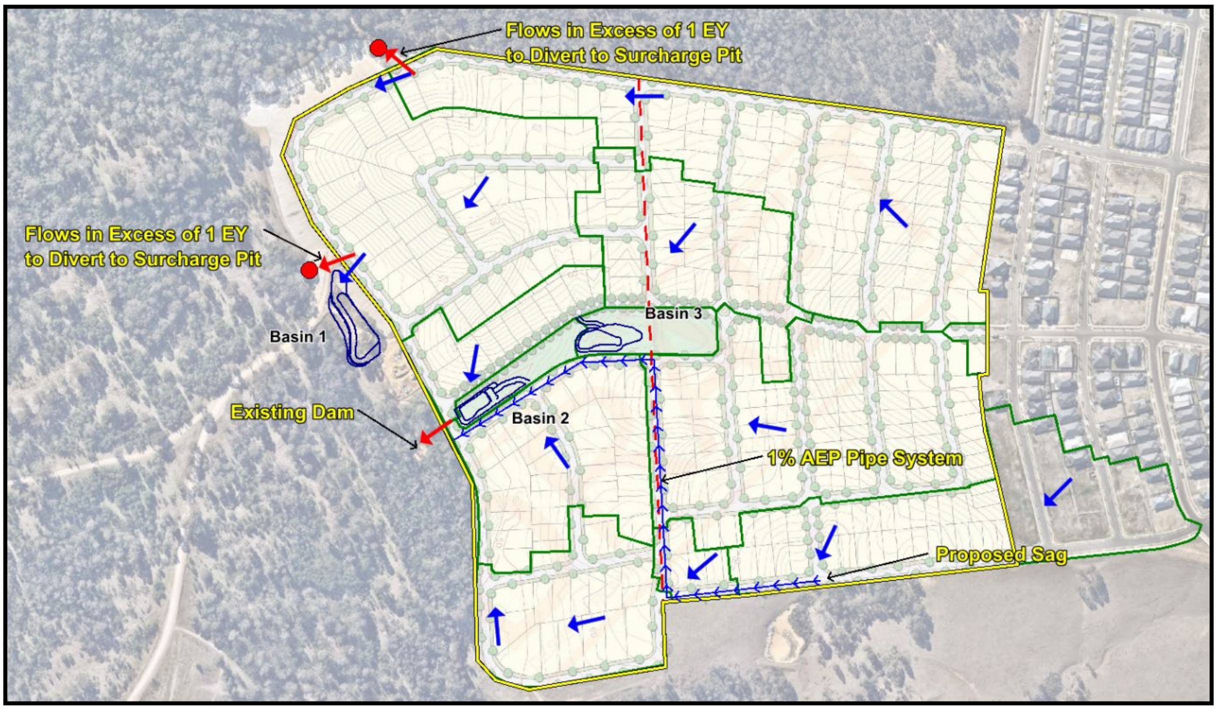

Plate 3-2 – Stormwater Management Strategy – Precinct C

The proposed strategy for the developed site provides a basis for the detailed design and development of the site to ensure that the environmental, urban amenity, engineering and economic objectives for stormwater management and site are achieved.

4. DEVELOPMENT GUIDELINES AND CONSTRAINTS

The following guidelines were considered in developing the Water Cycle Management Strategy for the Glenmore Park Extension Planning Proposal site.

4.1. Penrith City Council Water Sensitive Urban Design Policy (2017)

Penrith City Council's WSUD Policy (PCC, adopted 2013, reviewed 2017) identifies the following objectives for consideration with regard to stormwater management:

- Protect and enhance natural water systems such as creeks and rivers in the Penrith LGA.
- Treat urban stormwater to meet water quality objectives for reuse and/or discharge to receiving waters.
- Match the natural water runoff regime as closely as possible (where appropriate).
- Reduce potable water demand through water efficient fittings and appliances, rainwater harvesting and water reuse.
- Minimise wastewater generation and treatment of wastewater to a standard suitable for effluent reuse opportunities.
- Integrate stormwater management into the landscape so as to maximise the visual and recreational amenity of urban development.
- Provide objectives and controls for specific WSUD elements including water conservation, stormwater quality and waterway stability management.

This document nominates the pollutant load reductions as follows:

- **Gross Pollutants:** 90% reduction in the post development mean annual load greater than 5mm
- **Total Suspended Solids:** 85% reduction in the post development mean annual load
- **Total Phosphorus:** 60% reduction in the post development mean annual load
- **Total Nitrogen:** 45% reduction in the post development mean annual load

This policy is supported by Penrith City Council's "WSUD Technical Guidelines" (PCC, 2015), which sets out the key parameters that are required to be used in sizing all Stormwater Treatment Measures in MUSIC.

4.2. Penrith City Council Development Control Plan (2014)

The Penrith City Council Development Control Plan (Part C3 – Water Management) (PCC, 2014) identifies the following objectives for consideration with regard to water management:

- Adopt an integrated approach that takes into account all aspects of the water cycle in determining impacts and enhancing water resources;
- Promote sustainable practices in relation to the use of water resources for human activities;
- Minimise water consumption for human uses by using best practice site planning, design and water efficient appliances;
- Address water resources in terms of the entire water catchment;
- Protect water catchments and environmental systems from development pressures and potential pollution sources;
- Protect and enhance natural watercourses, riparian corridors and wetlands;
- Integrate water management with stormwater, drainage and flood conveyance requirements; and
- Utilise principles of Water Sensitive Urban Design in designing new developments or infill development in existing areas.

4.3. Cooling the City Strategy (2015)

Penrith City Council has developed the Cooling the City Strategy, in 2015 that identifies strategies to cool the city and region in a way that improves liveability and prioritises protection from heat for people and communities based on the research undertaken within Penrith LGA. This strategy identified a range of opportunities that could be considered to cool the city to have the greatest impact and includes:

- Green Infrastructure;
- Water Sensitive Urban Design (WSUD);
- Increased Albedo / Reflectivity;
- Policy & Planning
- Community Engagement.

The research also demonstrated water either on the surface or stored in the soil profile, tree cover, and ground cover that is permeable and grassed are significantly cooler than others. The foundation of urban heat mitigation is the retention of water in the landscape. WSUD includes technologies such as water efficient fittings and appliances, rainwater tanks to reduce potable water consumption and costs, bio retention systems (rain gardens), swales, wetlands, proprietary devices and other approved site-specific measures to reduce pollution from stormwater entering local waterways which together can influence air temperature and surface temperature.

4.4. Penrith City Council Stormwater Drainage Guidelines for Building Developments (2020)

The Penrith City Council Stormwater Drainage Guidelines for Building Developments (PCC, adopted 2016, reviewed 2020) identifies the following objectives for consideration with regard to stormwater drainage:

- Minimise any adverse impacts and prevent damage to the built and natural environment as a result of stormwater runoff from building developments;
- Manage the quantity of stormwater runoff generated by building developments;
- Protect the existing public stormwater drainage assets;
- Minimise the impacts of flooding (mainstream and local) to the built and natural environment;
- Manage risk to lives and property from the impacts of stormwater and flooding;
- Ensure the design and construction of the stormwater drainage systems for building developments can be economically maintained;
- Provide uniform specification and technical requirements in design and construction of stormwater drainage systems for building developments within the Penrith City Council Local Government Area (LGA); and
- Have uniform approach and ensure consistency in the assessment of stormwater drainage systems for building developments.

4.5. Guidelines for controlled activities on waterfront land – Riparian corridors (NRAR, 2018)

In May 2018, the Natural Resources Access Regulator (NRAR) released guidelines for riparian corridors on waterfront land. New rules regarding controlled activities within riparian corridors have been established that provide more flexibility in how riparian corridors can be used. These guidelines have been adopted in developing the riparian corridor strategy for the Glenmore Park Stage 3 Planning Proposal.

As part of the guidelines, water courses orders have been classified under the Strahler System using current 1:25,000 topographic maps. The Strahler System classification methodology, corresponding riparian corridor widths and riparian corridor matrix are shown on Plate 4-1, Table 4-1 and 4-2, respectively.

The various watercourses within the existing site include 1st to 4th order water courses.

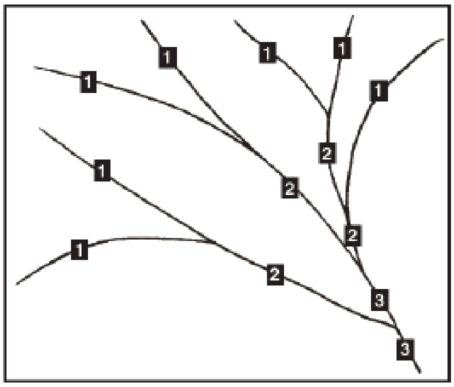

Plate 4-1 – The Strahler System (NRAR)

Table 4-1 – Recommended Riparian Corridor Widths (NRAR)

Watercourse type	VRZ width (each side of watercourse)	Total RC width
1st order	10 metres	20 metres + channel width
2nd order	20 metres	40 metres + channel width
3rd order	30 metres	60 metres + channel width
4th order and greater (includes estuaries, wetlands and parts of rivers influence by tidal waters)	40 metres	80 metres + channel width

Note: Where a watercourse does not exhibit the features of a defined channel with bed and banks, the NRAR may determinethat the watercourse is not waterfront land for the purposes of the WM Act.

Table 4-2 – Riparian Corridor Matrix (NRAR)

Stream order	Vegetated riparian zone(VRZ)	RC offsetting for non-RC users	Cycleways andpaths	Detention basins		Stormwater outlet structures and essential services	Stream realignment	Road crossings		
				Only within 50% outer VRZ	Online			Any	Culvert	Bridge
1st	10 m	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
2nd	20 m	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No
3rd	30 m	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes
4th	40 m	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes

4.6. Cumberland Plain Conservation Plan (DPIE, 2022)

As part of the NSW Government's commitment to providing the Western Parkland City, the Department of Planning, Industry and Environment has prepared a Cumberland Plain Conservation Plan (CPCP) in order to protect Western Sydney's biodiversity and support its growth to 2056 and beyond (NSW, Planning Portal, 2022).

The following future development areas are covered by the CPCP

- Greater Macarthur Growth Area

- Greater Penrith to Eastern Creek Investigation Area (GP3 forms part of this area)
- Western Sydney Aerotropolis
- Wilton Growth Area.

The full extent of the CPCP is provided below in Plate 4-2.

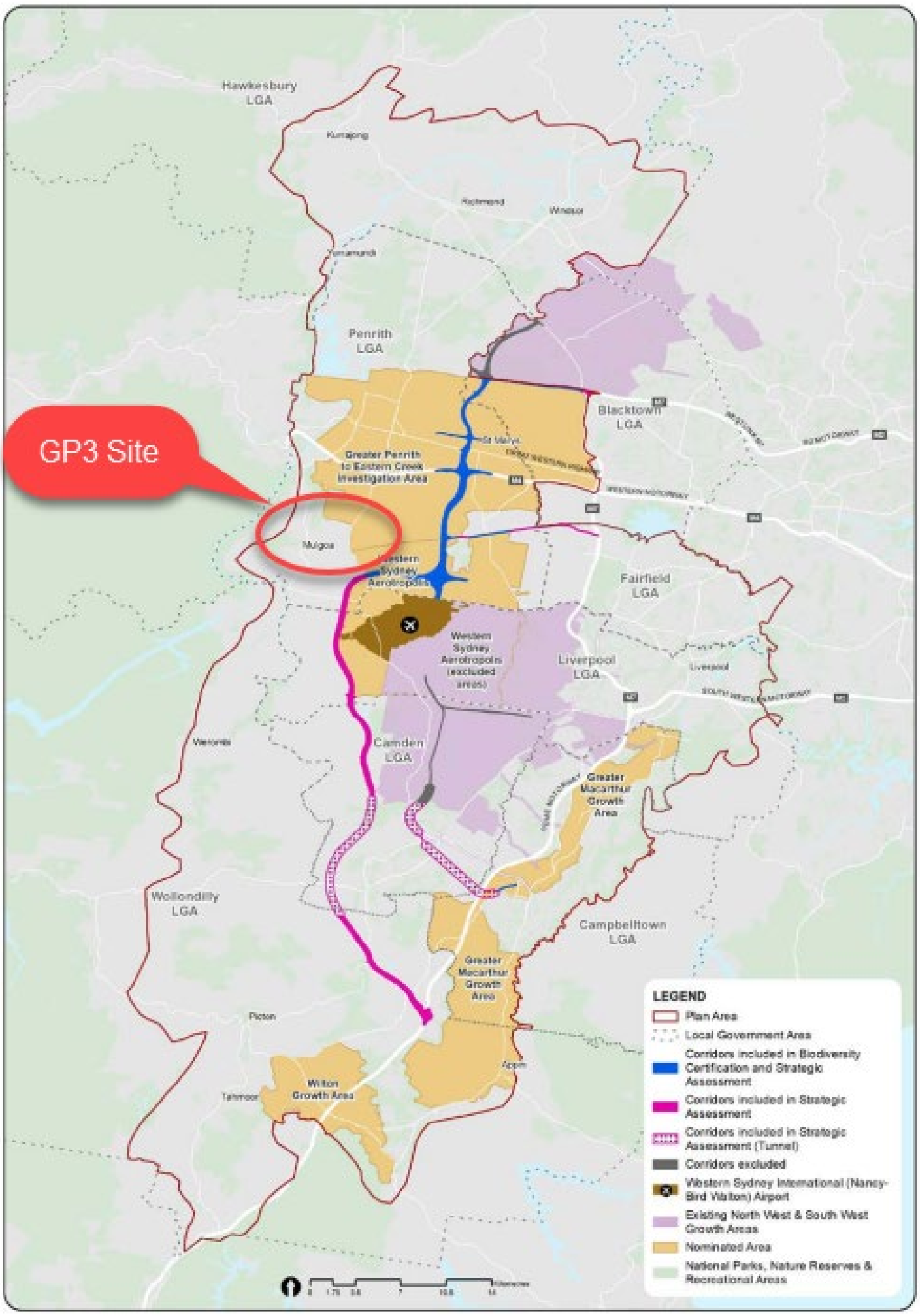

Plate 4-2 – Cumberland Plain Conservation Plan (DPIE)

The CPCP constraints within GP3 has been used to inform the masterplan development.

The CPCP will be a key constraint in developing GP3 and the required water management devices will need to consider the CPCP constraints and adjoining riparian corridors. Concept designs for the water quality devices adjoining these corridors will be undertaken post-exhibition.

5. HYDROLOGIC ASSESSMENT

The hydrologic analysis for the site at Glenmore Park Stage 3 was undertaken using the rainfall-runoff flood routing model XP-RAFTS (2018). This assessment has adopted the methodologies outlined in the Australian Rainfall and Runoff (ARR) 2019 guidelines (formerly ARR 2016).

In order to address these requirements, hydrologic modelling for the 20% AEP, 1% AEP and PMF storm events for a range of durations and temporal patterns has been undertaken and a basin strategy has been developed.

The details of the key stormwater infrastructure are shown on the concept plans in Appendix A.

5.1. Hydrologic Parameters

The ARR Data Hub provides guidance on the loss parameters for pervious catchments for this locality. The overall storm loss suggested by ARR Data Hub is 46 mm which has then been factored by 60% due to the urban nature of the surrounding catchment consistent with advice in ARR 2016 Book 5 section 3.5.3.2.1. Refer to Table 5-1 for details of the loss parameters used in the assessment.

Table 5-1 – Initial / Continuing Loss

Catchment Conditions	Initial Loss (mm)	Continuing Loss (mm/hr)
Pervious	27.6	2.5
Impervious	1	0

The Manning's roughness parameters used in this assessment are based on industry best practice and experience in similar catchments in the Penrith LGA. Refer to Table 5-2 for details of the Manning's roughness parameters used in the assessment.

Table 5-2 – Manning's Roughness 'n'

Conditions	Manning's Value
Existing (Rural) Pervious	0.040
Urban Pervious	0.025
Impervious	0.015

The rainfall data used in this assessment was adopted from the Bureau of Meteorology (BOM) 'Design Rainfall Data System' (downloaded on 9 November 2021). Details of the IFD data used in the XP-RAFTS modelling is provided in Appendix C along with the ARR Data Hub summary.

5.2. Existing Conditions

Sub-catchment areas contributing to the drainage system were established through a combination of LiDAR contour data obtained from the NSW Spatial Information Exchange, detailed site survey obtained for portions of the site and catchment information gathered from surrounding studies / developments.

The XP-RAFTS model includes catchments upstream of the site and extends approximately 500 m to the north-west of the site into Mulgoa Nature Reserve. The model also includes catchments to the east of the site adjacent to the new Northern Road alignment.

Model development of the "existing" site conditions included the following assumptions:

- Link lagging between sub-catchments was adopted throughout the hydrological model. Given the site and upstream catchment is largely pasture grass, the lag times adopted have been based on a flow velocity of 1 m/s. Following an initial run of the hydraulic model, the hydrologic lag links were then adjusted to the velocities from the hydraulic model at various points in the catchment. The hydraulic model shows that velocities are generally in the range of 1-1.5 m/s.

- Fraction impervious values for each catchment have been measured to reflect impervious surfaces such as buildings, pavement and permanent farm dams based on the available aerial imagery.

Refer to Plate 5-1 for the existing model layout and Figure 5-1 for the existing catchment plan.

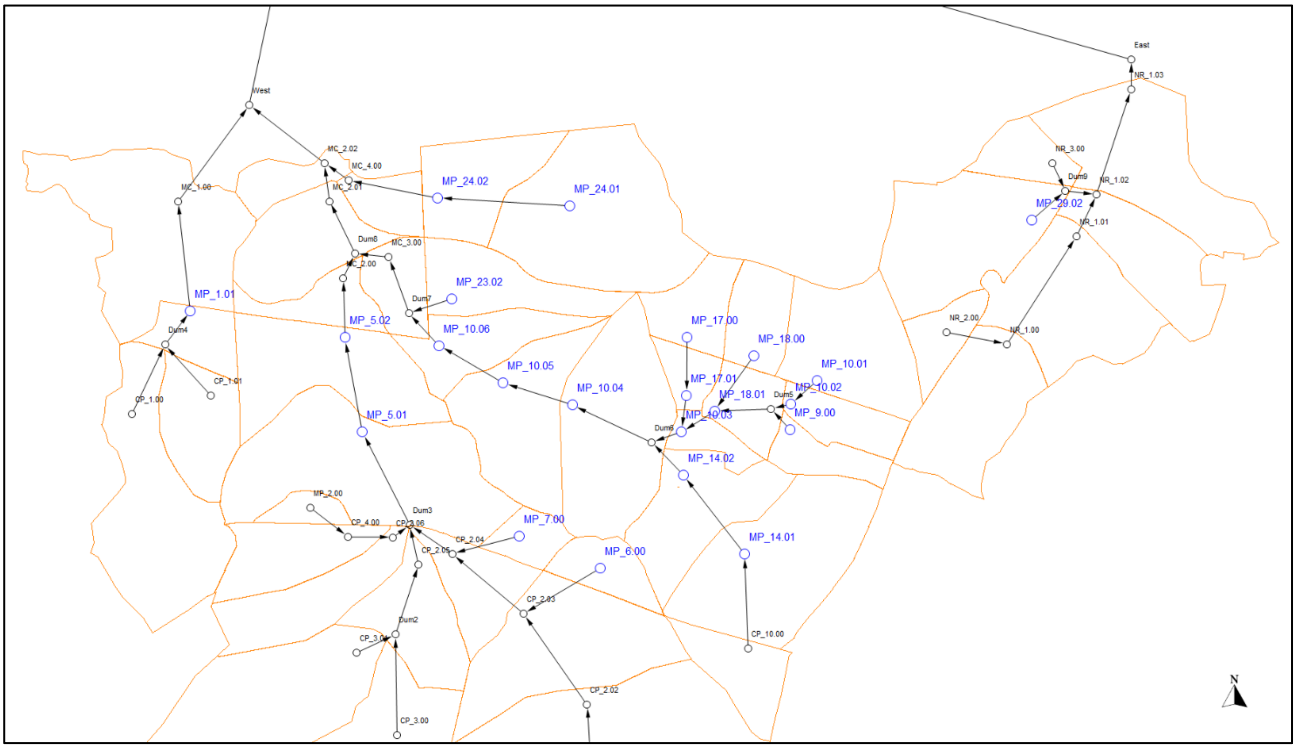

Plate 5-1 – Existing Conditions XP-Rafts Layout

(Ref: 110474_Ex_003.xp)

5.3. Developed Site Conditions

The developed case sub-catchment areas contributing to the drainage system were maintained to be the same as the existing case catchment boundaries outside the site. Developed catchment boundaries within the Glenmore Park Stage 3 site were adjusted to represent the proposed preliminary gradings.

Final catchment boundaries and areas contributing to each detention basin and water quality device will be updated and confirmed as part of future development applications. However, preliminary developed case catchment extents are shown on Figure 5-2.

Model development of the “developed” site conditions included the following assumptions:

- Sub-catchments within the site boundary were updated based on the indicative road network and anticipated regrading of the site.
- In accordance with Council guidelines, a fraction impervious of 80% impervious has been applied to each developed condition catchment across GP3. This is consistent with the fraction impervious for residential development including half road as outlined in Councils ‘Design Guidelines for Engineering Works for Subdivisions and Developments’ (2013). Riparian corridors have been assumed to be 5% impervious and external catchments have been left consistent with existing conditions assumptions.
- Developed lag links have generally been kept consistent with existing lag assumptions in the creek lines. An increase flow velocity of 1.5 – 2.5 m/s dependant on the grade of the sub-catchment has been applied for developed subdivision catchments.

It is noted that portions of the northern Vianello catchments have been diverted to the east, along the internal landholder boundary, to be managed in consolidated detention basin VB4. This allows for the delivery of total flow from these catchments to be at or below existing conditions levels at the site, corridor and landholder boundaries. To achieve this, minor (piped) flows are proposed to be delivered south across the landholder boundary into Mirvac's portions of the development at existing flowrates up to the likely street drainage capacity. All flows in excess of the existing condition flow regime are diverted for detention management.

A catchment diversion has also been adopted at the southern boundary of the site and involves diverting catchments MP_6.00 and MP_7.00 (see Figure 5-2) to the corridor to the west. The proposed culvert in this area will be required to cater for approximately 4-5 m³/s of flow and will be in the order of a 1.5 m x 1.2 m box culvert. Further details of this arrangement and hydraulic modelling can be provided at the detailed design stages of the development.

Refer to Plate 5-2 for the developed model layout.

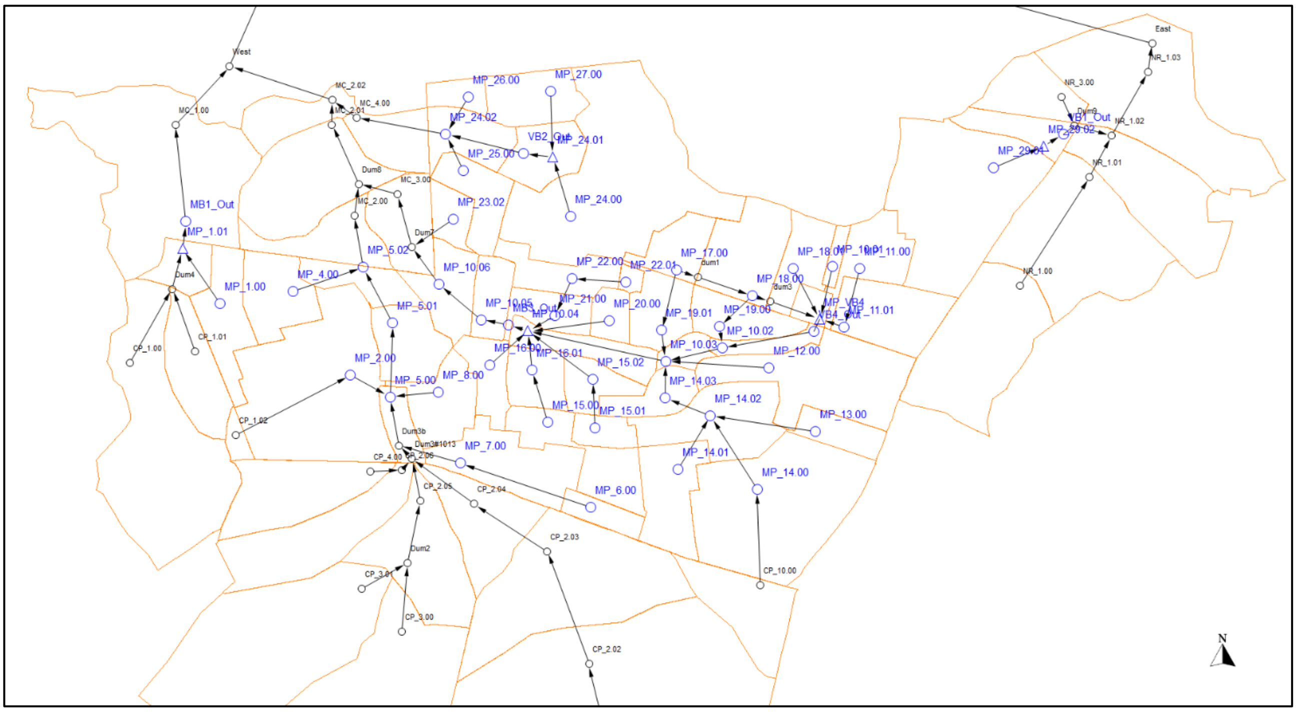

Plate 5-2 – Developed Conditions XP-Rafts Layout

(Ref: 110474_Dev_004.xp)

5.4. Proposed Detention Basins

Five (5) detention basins are proposed within the Glenmore Park Stage 3 Planning Proposal development to attenuate stormwater runoff discharging from the site. The proposed detention basins will adopt outlet arrangements suitable to ensure that at the discharge locations from the site, peak flows under developed conditions are equal to or less than existing conditions for both the 20% and 1% AEP storm events.

For the proposed locations of the detention basins and the flow comparison locations, refer to Plate 5-3. For further detail of the indicative arrangement of the basins refer to the Water Cycle Management Plan, (Figure 1-1) or the concept plans in Appendix A.

Four (4) detention basins are proposed to be "wet" detention basins located over permanent waterbodies within the site to enhance the local amenity and assist in the management of the "urban heat effect". The other (1) "dry-bed" detention basin is proposed as part of the Water Cycle Management Strategy and will provide passive open space for the community.

It is also noted that the surrounding road drainage network will be required to be designed to allow for minor (piped) flows and major (overland) flows to drain to the basins.

Basins that have been concept designed have been represented in the model using stage-storage relationships derived from 12d design modelling. Basins without concept designs have been represented using a storage applied at a maximum detention depth of 1-1.5 m for the 1% AEP storm event. Custom stage-discharge relationships have been derived for each basin to ensure flow management is achieved.

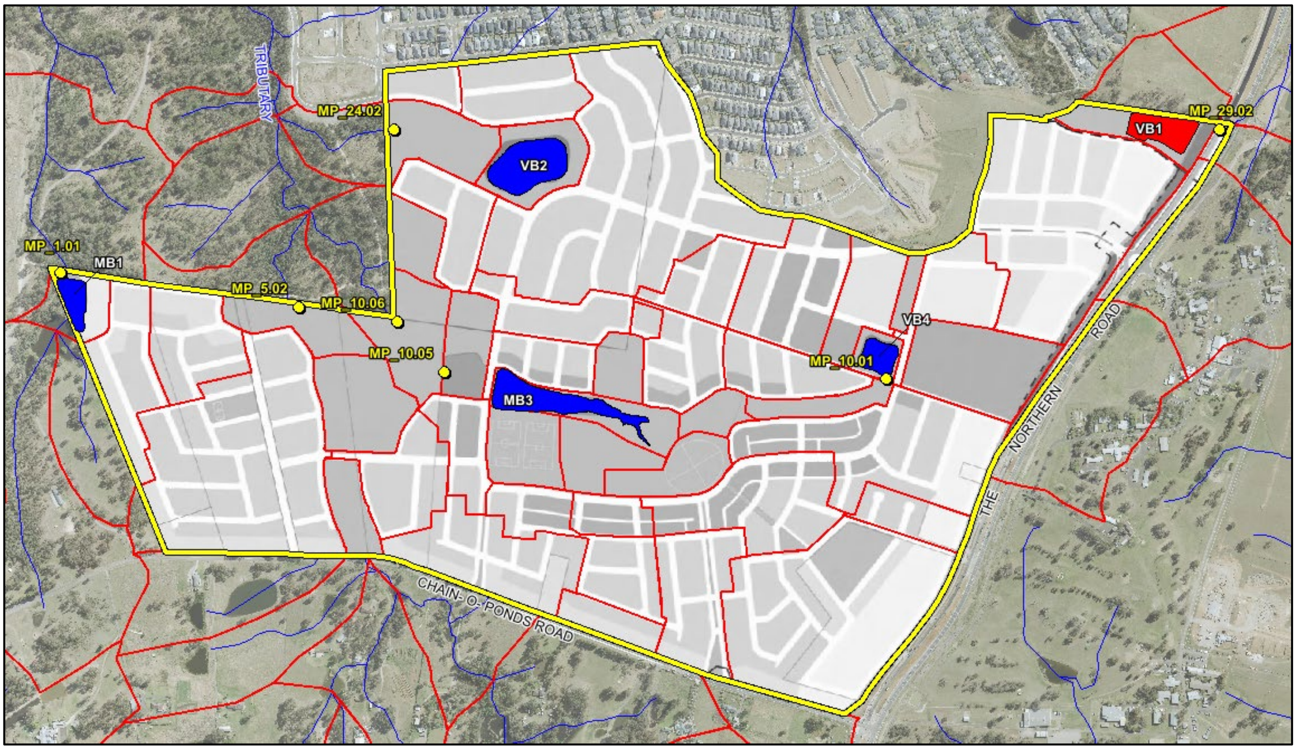

Plate 5-3 – XP-Rafts Comparison Locations

5.5. Results

Discharge estimates were derived for both the “existing” and “developed” catchments for the 20% AEP and 1% AEP events. A range of storm durations from 10 minutes to 24 hours were analysed to determine the peak mean duration/temporal pattern consistent with ARR 19 methodologies. Table 5-3 below shows a comparison between “existing” and “developed” peak flows at each of the key comparison locations shown on Plate 5-3.

It is noted that a number of local sub-catchments in the Glenmore Park Stage 3 site will discharge undetained across the site boundary into Mulgoa Nature Reserve land. Although this will increase local sub-catchment flows, peak flows at the discharge locations of the site to Mulgoa Creek Tributary will not increase.

Table 5-3 – Peak Mean Flow Estimates

Comparison Node	ARR 2019					
	20% AEP			1% AEP		
	Existing Flow (m³/s)	Developed Flow (m³/s)	Dev/Ex	Existing Flow (m³/s)	Developed Flow (m³/s)	Dev/Ex
MP_1.01	1.81	1.52	0.84	6.02	6.00	1.00
MP_5.02	13.63	11.69	0.86	36.58	34.93	0.95
MP_10.01	0.86	0.83	0.97	2.49	2.46	0.99
MP_10.05	6.03	6.05	1.00	19.45	19.02	0.98
MP_10.06	6.29	6.17	0.98	20.99	19.22	0.92
MP_24.02	2.01	1.95	0.97	6.41	6.19	0.97
MP_29.02	0.91	0.84	0.93	3.08	2.90	0.94

Table 5-4 below includes a summary of the detention volumes required at each basin to ensure that developed flows do not exceed existing flows. Refer to Plate 5-3 for basin locations.

Table 5-4 – Summary of Detention Volumes

Basin	Storage Required (m³)	Stage Used (m)
MB1	2,140	1.03
MB3	15,620	1.56
VB1	4,960	1.10
VB2	9,890	0.99
VB4	6,140	1.02

Further detailed modelling of these basins will be undertaken to support any future Development Application (DA) to Council.

5.6. Discussion of Modelling Results

Results of the hydrological modelling show that the proposed five (5) detention basins within the development site will ensure that post-development flows do not exceed existing flows at the key comparison locations for events up to and including the 1% AEP storm event.

The modelling, therefore, demonstrates that the proposed stormwater management strategy supports the proposed planning proposal and will ensure that there are no adverse impacts upon surrounding properties. The modelling of the basin outlets will be optimised at the future detailed design stages to provide more efficient water quantity management outcomes while still achieving pre-post flow targets.

6. HYDRAULIC MODELLING

A fully dynamic one and two dimensional (1D/2D) hydraulic model has been prepared to inform the flood impact assessment for Glenmore Park Stage 3. The TUFLOW modelling is used to confirm the basin performance of the "online" basin MB3 and ensure there are no impacts of the proposed development to the neighbouring environment. The 20% AEP, 1% AEP and PMF events were modelled for the critical peak mean storm durations as determined in the hydrological model.

6.1. Available Data

The following data was used to inform the modelling:

- Hydrology models (XP-Rafts) prepared for this Water Cycle Management Strategy using ARR 2019 methodologies;
- Digital Elevation Model (DEM) obtained from the NSW Government Spatial Services website;
- Detailed site survey for the existing creeks within the Mirvac portion of the site;
- Design information for the RMS upgrade of the Northern Road, including culvert crossing sizes and DEM;
- Approximate road crossing information at Chain O Ponds Road obtained via ground truthing during a site inspection;
- Preliminary gradings prepared by ADW Johnson (for the Mirvac landholdings) and J. Wyndham Prince (for the Vianello landholdings);
- Concept designs for key stormwater infrastructure within the site;
- Aerial imagery for the site recorded by MetroMap, 2021.

6.2. TUFLOW Model Development

The hydraulic (TUFLOW) model has been developed to assess the behaviour and extent of flooding in the vicinity of GP3. A map showing the main features adopted in the TUFLOW model is provided in Figures 6-1 (existing conditions) and 6-2 (developed conditions) in Appendix B. The assessment has been undertaken using the 2020-10-AB TUFLOW build using the heavily parallelised computation (HPC) methodology.

6.2.1 Model Domain

The model extent encompasses the development and contributing catchments to the south and extends into Mulgoa Nature Reserve in the west and beyond The Northern Road in the east where the subject site discharges.

6.2.2 Grid Size

A grid size of 3 m x 3 m was adopted for the purpose of this assessment. This resolution of the model grid provides a balance between an accurate definition of the catchment and minimises model run times. Given the intent of the flood modelling, a 3 m x 3 m cell size is considered fit for purpose for this rezoning assessment.

6.2.3 Terrain

The underlying digital elevation model (DEM) is based on LiDAR data captured in 2019 by NSW Government Spatial Services and detailed site survey obtained for the creeks and dams within Mirvac's landholdings. This was combined with design data of the RMS The Northern Road upgrade, forming the 'existing surface'.

The preliminary design surfaces and concept designs were added to the 'existing surface' to form the 'design surface'.

6.2.4 Material Roughness

Material roughness parameters have been set up in the model based on cadastral boundary information in the catchment and aerial imagery. Pervious open space areas have been divided based on the density of vegetation present and farm dams have been assumed to contain permanent water to the spillway levels. Rural buildings have also been represented with a higher manning's to reflect the obstructions to flow.

Under developed conditions, the urban residential areas have been divided into lots and road corridors to provide the level of detail necessary for the purposes of this assessment. For details of the adopted roughness values refer to Table 6-1 below. A map showing materials roughness adopted in the TUFLOW model is provided in Figure 6-3 and 6-4 in Appendix B.

Table 6-1 – Material Roughness, 'n', Parameters

Mannings Roughness, n	Landuse
0.3	Residential areas – high density
0.1	Residential areas – low density
0.3	Industrial/commercial
0.035	Open pervious areas, minimal vegetation (grassed)
0.06	Open pervious areas, moderate vegetation(shrubs)
0.1	Open pervious areas, thick vegetation (trees)
0.03	Waterways/channels – minimal vegetation
0.045	Waterways/channels – vegetated
0.015	Concrete lined channels
0.02	Paved roads/car park/driveways
0.02	Lakes (no emergent vegetation)
0.06	Wetlands (emergent vegetation)
0.02	Estuaries/Oceans

6.2.5 Flow Hydrographs and Boundary Conditions

Flow hydrographs extracted from the XP-RAFTS hydrological model were applied to represent flows entering the model from local catchments within the model extent. The peak mean flows at critical locations throughout the site have been examined to determine a suitable suite of durations and temporal patterns to assess in the model. The adopted durations and temporal patterns are summarised in Table 6-2 below.

Table 6-2 – Modelled Events, Durations and Temporal Patterns

Event	Duration	Temporal Pattern
20% AEP	60 min	8
	120 min	6
	120 min	8
	360 min	10
1% AEP	45 min	6
	45 min	8
	60 min	2
	60 min	8
PMF	15 min	GSDM method adopted
	30 min	
	45 min	
	60 min	

Flow hydrographs have been applied as "Source Area" (SA) inputs and flow versus time (QT) inflow boundaries.

Under existing conditions, it should be noted that total hydrographs have been applied in the creek upstream of basin MB3 and in the creek downstream of basin MB1. This is to remove the influence of passive storages and attenuation that the large existing farm dams provide in both the south eastern portion of the site (downstream of Chain O Ponds Road) and in the western corner of the site (at MB1).

Under developed conditions, basin outflows are applied downstream of each basin to reflect the attenuation that has been modelled in the hydrological model. The exception to this is basin MB3 which has been modelled in the TUFLOW model with an appropriately sized outlet arrangement. A total hydrograph has also been used to represent the delivery of flows to the main corridor to the west of catchments MP_6.00 and MP_7.00 via a culvert arrangement as detailed in Section 5.3.

A water level versus flow (HQ) downstream boundary with a 1% slope was used as the downstream boundary of the model.

6.2.6 Initial Water Level

Farm dams throughout the model extent have been assumed to be at full supply level at the beginning of the storm events to reflect antecedent rainfall in the catchment.

6.2.7 Pipe (1D) Networks

1D Pipe Networks have been used within the model to reflect the various road crossings at Chain O Ponds Road and The Northern Road. Culvert sizes at Chain O Ponds Road have been obtained via ground truthing during a site visit while culvert sizes at The Northern Road have been obtained from RMS design plans (GHD, 2017).

In addition to road crossings, the basin MB1 and MB3 outlets (in the developed conditions) have been modelled using a 1D network arrangement and has been sized to match the outlet that informed the hydrology modelling. A 1D network has also been used to convey flows from catchment CP_10.00 (see Figure 5-2) through the proposed development.

6.3. Discussion of Results

6.3.1 Existing Scenario Flood Behaviour

The existing condition flood depth and level results for the 20% AEP, 1% AEP and PMF event are shown on Figures 6-5, 6-8 and 6-11 in Appendix B respectively. The 20% and 1% AEP flood extents are generally similar, with flows appearing well contained within the existing well-defined watercourses.

In 20% AEP event (Figure 6-5), flood depths within the watercourses both within and upstream of the site are generally in the order of 0.5 m to 1.0 m, and greater than 2 m within existing farm dams online to the main watercourses. In the lower reaches, flood depths generally up to 1.0 m are observed in the main water courses in the 20% AEP event, with isolated pockets of flood depth greater than 2.0 m.

In 1% AEP event (Figure 6-8), flood depths within the watercourses both within and upstream of the site are generally similar to the 20% AEP event, however isolated of flood depths in the order of 1.0 m to 2.0 m are now observed. In the lower reaches, flood depths generally up to 2.0 m are observed in the main water courses, increasing to greater than 2.0 m toward the model outlet.

Based on site observations and available lidar data, it appears that the existing 2 x 1800 mm RCP crossing of Chain of Ponds Road (upstream of the future western channel) hold permanent water due to the embankment of a downstream dam being higher than the culvert inverts.

The PMF flood extents shown in (Figure 6-11) are much broader than the 1% AEP event, however it is noted that flows are contained within well-defined watercourses. Broadscale flood depths in the order of 1.0 to 2.0 m occur in the upper reaches, and greater than 2.0 m in the lower reaches which are to be expected in this extreme event.

6.3.2 Developed Scenario Flood Behaviour

The developed conditions flood depth and level results for the 20% AEP, 1% AEP and PMF event are shown on Figures 6-6, 6-9 and 6-12 in Appendix B respectively. Flood extents external to the site are generally consistent with existing conditions.

In 20% AEP event (Figure 6-6), flood depths within the channel in the western portion of the site are generally in the order of 0.5 m to 1.0 m, with isolated pockets of flood depth greater than 1.0 m. Flood depths in the main corridor upstream of Basin MB3 range from 0.1 m to 2.0 m in deeper existing pools.

In 1% AEP event (Figure 6-9), flood depths within the channel in the western portion of the site are generally in the order of 1.5 m. Flood depths in the main corridor upstream of Basin MB3 are generally similar to the 20% AEP event, however the extent of deeper water is slightly increased. A pipe system reflects flow from upstream catchments to the south of the site safely conveyed through the development to the main corridor, with no overland flow observed.

In the PMF event (Figure 6-12), flood depths greater than 2.0 m are observed within the main corridor and western channel, with some encroachment on perimeter roads and lots evident. It is noted that the preliminary trunk pipe system (2 x 1200 mm RCPs) through the south-eastern portion of the site appears to have PMF capacity, as no flows are evident on the subdivision. However, the future drainage design will need to carefully consider the practicality of pit depths and capacities. A balance may need to be found between managing some PMF flow in a pipe and some safe overland flow through the street drainage network in the south eastern portion of the site to the main corridor.

It is important to note that a climate change assessment has not been undertaken at this stage. However, given that the PMF is generally well contained within the corridor, it is anticipated that a 1% AEP climate change scenario is unlikely to affect the proposed lots greater than PMF event affectation.

6.3.3 Flood Impact Assessment

Flood difference mapping for the 20% and 1% AEP event are shown on Figures 6-7 and 6-10 in Appendix B respectively.

Generally, there are no flood impacts external to the site in the 20% and 1% AEP events. There are some minor localised flood level increases (within the existing extents of flooding) that can be seen downstream of basin VB2 in the 20% AEP event. There are also some minor flood impacts downstream of basin MB3 in the 1% AEP event which stretch into the Mulgoa Nature Reserve downstream of the site. In both situations, the flood level increases are in the order of 20-40mm and dissipate once the flows reach the confluence with the main Mulgoa Creek Tributary. Further modelling will need to be undertaken during the post exhibition / development application phase of the project to ensure that these minor impacts are mitigated.

Local flood level increases due to the proposed development upstream of basins within the site are to be expected, as are areas along the western channel where existing flooded areas are now lifted and still wet (i.e., the design flood depths are appropriate, the flood level increase is due to a surface amendment).

6.3.4 Flood Hazard

The 20% AEP existing and developed flood hazard mapping shown of Figures 6-13 to 6-18 indicate that there are no adverse changes in Flood Hazard external to the site in all modelled events. Within the site, high hazard up to a H6 category (unsafe for people, vehicles and buildings) are evident within the watercourses and basins, which is to be expected. Appropriate flood warning signage will need to be provided in these areas as part of the future construction designs of these areas/devices.

7. WATER QUALITY ASSESSMENT

7.1. Modelling Inputs and Assumptions

MUSIC modelling for GP3 has been undertaken using MUSIC 6.3. The modelling has considered the Penrith City Council WSUD Technical Guidelines (PCC, 2020) and Council Standard Engineering Guidelines.

The MUSIC model catchments have been split into various source nodes (i.e. roof, road, urban pervious and impervious) and the details on the catchment area and land use assumptions are provided in Appendix D.

The pollutant reduction targets for this development are detailed in Table 7-1 below as depicted in PCC's WSUD Technical Guidelines.

Table 7-1 – Pollutant Reduction Targets

Pollutant	Reduction Targets
Gross Pollutants	90%
Total Suspended Solids (TSS)	85%
Total Phosphorus (TP)	60%
Total Nitrogen (TN)	45%

The MUSIC modelling has assumed the following in the determination of the results:

- The proposed development has a lot mix of normal and medium density residential. As outlined in PCC's Standard Engineering Guidelines, these lot types have an overall impervious percentage of 75% and 85% respectively.
- Roof areas for normal lots are assumed to cover 60% of the lot area.
- Roof areas for medium density lots are assumed to cover 75% of the lot area.
- Commercial areas - 100% impervious.
- Road reserve - 95% impervious.
- Riparian corridor - 5% impervious.
- Active open space - 50% impervious.
- Passive open space - 10% impervious.
- School - 75%.
- It is understood that the average R2 lot size across GP3 is approximately 400 m². As such, it has been assumed that all R2 lots will have rainwater tanks. It is understood that the average R3 lot size will be only 200 m², therefore, rainwater tanks have not been modelled for the R3 lots.
- Normal lots that have rainwater tanks are assumed to capture 50% of the roof area with the other 50% to bypass.
- It is assumed that commercial areas will provide on-lot treatment which has been modelled using a generic treatment node set to achieve reduction targets locally. The ultimate treatment train can be determined as part of a future development application.

Further details on the assumed parameters are provided in Appendix D.

7.2. Water Quality Management Measures

It is proposed that stormwater quality in the GP3 precinct be managed using a treatment train approach. A proposed treatment train of water quality devices has been identified to achieve the target pollutant removals. This includes a combined system of rainwater tanks, Gross Pollutant Traps (GPT), bio-retention raingardens and permanent water bodies (ponds). The proposed treatment train consists of:

- Rainwater harvesting and re-use of residential roof runoff of by utilising on-lot rainwater tanks;

- Rainwater harvesting and re-use of catchment flows discharging to the proposed sporting fields;
- On-lot treatment for commercial lots;
- Gross Pollutant Traps (GPT) to pre-treat runoff prior to discharge into bioretention raingardens and ponds;
- Bioretention Raingarden which will receive flows from the GPTs; and
- Permanent water bodies (ponds) which will receive flows from the GPTs.

The indicative location of bioretention raingardens, ponds and other key devices are shown in Figure 7-1 in Appendix B.

7.2.1 Rainwater Tanks

On-lot rainwater tanks were modelled for the development based on the following design assumptions:

- All normal residential (R2) lots are assumed to have a rainwater tank;
- 50% of the roof areas from these lots will be captured by the rainwater tanks;
- 3.0kL rainwater tanks will be provided on each lot, with 2.4kL re-usable storage above top-up.
- Rainwater tank re-use of 0.10kL/day internal use and 50kL/year as PET-Rain (in accordance with PCC WSUD Technical Guidelines, 2020).

Additional details on the rainwater tank sizing are provided in Appendix D. It is noted that any OSD that the rainwater tanks may provide have been ignored in the formal OSD modelling assessment detailed in Section 5.

A rainwater storage tank is also proposed to be located at the proposed sporting fields to capture stormwater runoff to be reused for irrigation. This tank assumed the following design assumptions:

- 1000 kL storage capacity;
- 25 mm/week irrigation demand.

7.2.2 Gross Pollutant Traps

The GPTs have been provided to filter stormwater prior to discharge into the drainage system, bioretention raingarden devices and ponds. The expected pollutant removal rates adopted within the model is provided in Table 7-2. A generic vortex style GPT node has been adopted in MUSIC to provide flexibility in the detailed design and allow for a specific product to be selected at a later stage. The GPT node has adopted a reduction in gross pollutants, total phosphorus (TP), total suspended solids (TSS) and no additional removal of total nitrogen (TN). For the purposes of achieving the water quality targets, it has been assumed in the MUSIC model that the GPTs are located upstream of the bioretention raingarden and ponds.

Table 7-2 - GPT Input Parameters

Pollutant	Input	Output
TSS (mg/L)	0	0
	75	75
	1000	300
TP (mg/L)	0	0
	0.5	0.5
	10	7
TN (mg/L)	0	0
	50	50
Gross Pollutant (kg/ML)	0	0
	100	2

7.2.3 Ponds

Permanent water bodies (ponds) are designed to have permanent water storage that promotes a Hydraulic Residence Time (HRT) of sufficient length to promote the appropriate pollutant removal mechanisms. The ponds are to receive flows having firstly being treated by the GPTs and/or raingarden devices. The design parameters adopted for the ponds are shown in Table 7-3.

Table 7-3 - Pond Input Parameters

Parameters	Permanent Pond ID			
	MB1	VB2	VB4	MB3
Surface Area(sq.m)	2,000	10,000	5,179	6,540
Extended Detention Depth (m)	0.3	0.3	0.3	0.3
Permanent pool volume (cu.m)	2,000	37,000	7,200	7,830
Initial Volume (cu.m)	2,000	37,000	7,200	7,830
Exfiltration Rate (mm/hr)	0.03	0.03	0.03	0.03

7.2.4 Bioretention Raingardens

The bioretention raingardens are to receive and treat the run-off flows through the filter media bed after being firstly treated by the GPT. Numerous bioretention raingardens have been proposed across the development in order to achieve the pollutant reduction targets outlined in PCC's WSUD Technical Guidelines (PCC, 2020). The devices will also attenuate first flush flows to reduce the risk of stream erosion within the watercourse. The design parameters adopted for the bioretention raingardens are shown in Table 7-4.

Table 7-4 - Bioretention Raingarden Input Parameters

Parameters	Raingarden ID								
	RG A	RG B	RG C	RG D	RG E	RG F	RG G	RG H	RG J
Low flow by-pass (cu.m/s)	0	0	0	0	0	0	0	0	0
High Flow by-pass (cu.m/s)	100	100	100	100	100	100	100	100	100
Extended Detention Depth (m)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Filter Area (sq.m)	400	200	2,000	1,100	4,000	720	500	1,000	1,500
Saturated Hydraulic Conductivity (mm/hr)	125	125	125	125	125	125	125	125	125
Filter Depth (m)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
TN Content (mg/kg)	800	800	800	800	800	800	800	800	800
Orthophosphate Content (mg/kg)	40	40	40	40	40	40	40	40	40
Exfiltration Rate (mm/hr)	0	0	0	0	0	0	0	0	0
Base Lined	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Underdrain Present	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Submerged Zone	No	No	No	No	No	No	No	No	No

7.3. Modelling Results

The proposed treatment train devices have ensured the pollutant reduction targets that are detailed in PCC's WSUD Technical Guidelines (PCC, 2020) have been achieved. A summary of the MUSIC model results at the total receiving node of the model are provided in Table 7-5.

Table 7-5 - Summary of MUSIC Model Results

Pollutant	Total Developed Source Loads	Total Residual Load from Site	Total Reduction Achieved	Target Reduction Required	Total Reduction Achieved
	(kg/yr)	(kg/yr)	(kg/yr)	(%)	(%)
TSS	135000	18900	116100	85.0%	86.0%
TP	266	83.9	182	60.0%	68.5%
TN	1880	869	1011	45.0%	53.8%
Gross Pollutants	22400	208	22192	90.0%	99.1%

(Ref: 110474-02-MU02.sqz)

Key reporting locations have also been assessed at the discharge points of the site to ensure that pollutant reduction targets are being achieved downstream of each treatment train. Further details of these results can be found in Appendix D. Refer to Plate 7-1 for context of MUSIC reporting locations, raingardens and catchments and Figure 7-1 in Appendix B for further detail.

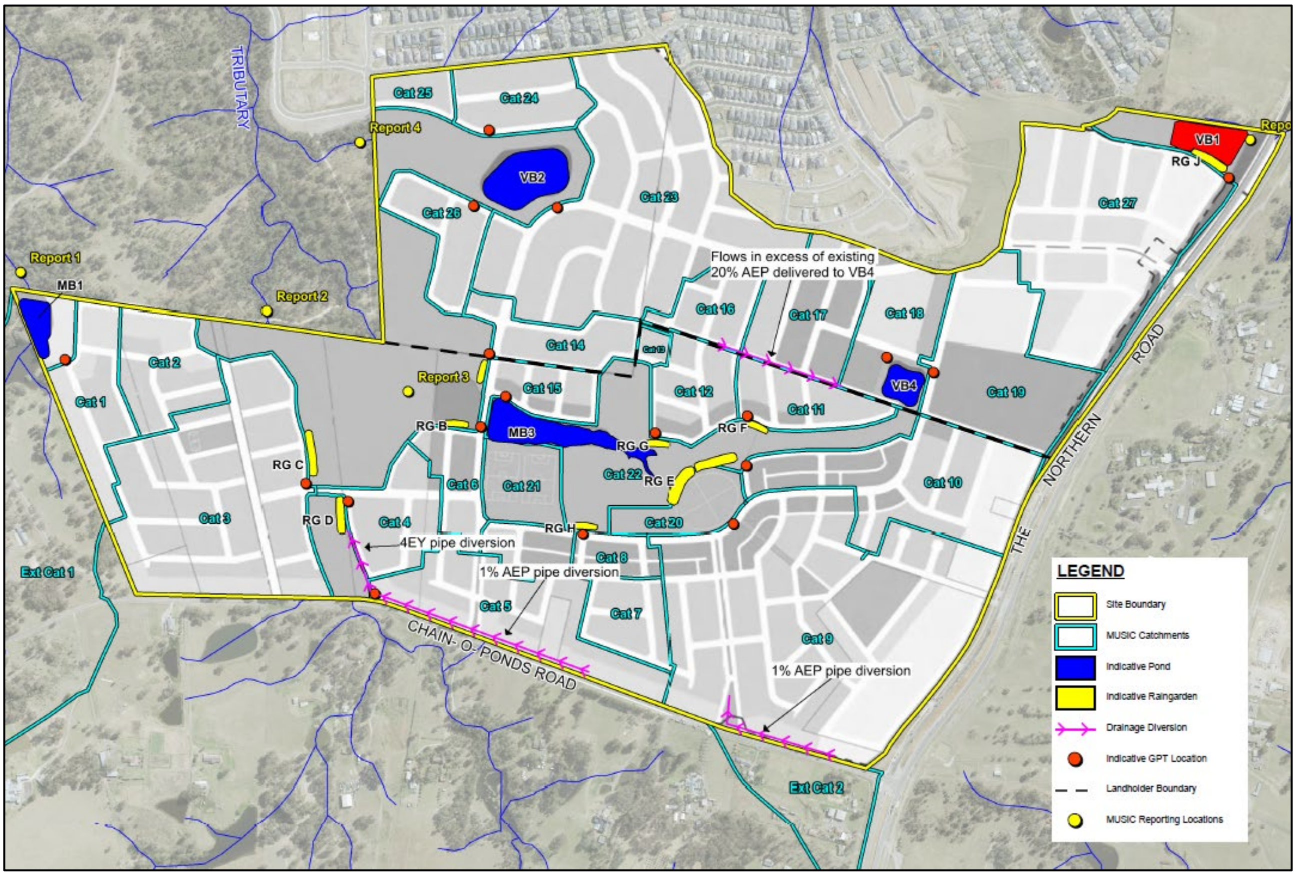

Plate 7-1 – MUSIC Catchments and Reporting Locations

7.4. Stream Erosion Index

The stream erosion index (SEI) assessment has been undertaken as outlined in PCC's WSUD Technical Guidelines (PCC, 2020). The SEI assessment is to ensure that the duration of post-development stream forming flows are no greater than 3.5 times the duration of the pre-development stream forming flows. The methodology to determine the SEI complies with the NSW MUSIC Modelling Guidelines (2015).

A rural residential source node has been used to represent the site under existing conditions. The flows for the existing and developed conditions have been calculated (refer to Table 7-6) and a SEI at each discharge location was determined. A summary of the SEI assessment and results are provided in Table 7-7.

Table 7-6 – Determination of Stream Forming Flow

	Determination of Critical Flow						
Assessment Location	Area (km^2)	$t_c = 0.76A^{0.38}$ (hour)	t_c (minutes)	I_2 (mm/hr)	C_2	Q_2 (m^3/s)	Q_{crit} (m^3/s)
Report 1	0.29	0.48	29	44.0	0.44	1.58	0.79
Report 2	0.33	0.50	30	43.5	0.44	1.75	0.87
Report 3	1.03	0.77	46	35.2	0.44	4.47	2.24
Report 4	0.29	0.47	28	44.0	0.44	1.57	0.79
Report 5	0.15	0.37	22	51.1	0.44	0.97	0.48

Table 7-7 – SEI Results Summary

Assessment Location	Stream Erosion Index		
	Pre Dev Outflow (ML/yr)	Post Dev Outflow (ML/yr)	SEI
Report 1	5.03	4.90	1.0
Report 2	5.71	13.50	2.4
Report 3	21.60	23.80	1.1
Report 4	4.98	5.21	1.0
Report 5	2.29	5.08	2.2

7.5. Permanent Water Body Management Strategy

The concept design plans in Appendix A, which include permanent water bodies (ponds) MB1, MB3 and VB4, have been designed to consider the Royal Life Saving Guidelines (2004) and should ensure the safety of anyone who may enter them.

Algal management is a key consideration to ensure the pond water remains clean, clear and healthy. Waterbodies particularly throughout Western Sydney can become thermally stratified when two (2) distinct temperature layers form. In the summer months, algal blooms often occur in the warm stable conditions of the upper layer. Increasing the movement of water that circulates between the shallower and deeper layers of the pond reduces the difference in temperature, oxygen and nutrients between the two layers. An aerator can be used within the pond to achieve the required water circulation and can also add an additional aesthetic appeal to the area. The high pumping rate/circulation rate of an aerator breaks down the thermal stratification, mixing the cooler deep-water layer with the warmer surface water layer. This in turn distributes oxygen to all parts of the lake which assists in the breakdown of the algae chain. To determine the recommended number of aeration units for a pond, the general sizing guideline is 1.5HP per 4000m^2 is suggested.

A depiction of a water aeration device that can be used within each pond is provided in Plate 7-1.

Plate 7-2 - Aeration Device

Source: www.otterbineaustralia.com.au

7.6. Construction Stage

Erosion and sediment control measures are to be implemented during the construction phase and to be in accordance with the requirements of PCC and the guidelines set out by Landcom (also known as the “Blue Book”, dated 2004).

Bioretention raingardens are well known to be sensitive to the impact of sedimentation. Hence, various sediment control devices and basins will need to be implemented during the construction phase. The bioretention raingardens should only be constructed when the majority of the works (approximately 80%) are complete.

7.7. Long Term Management

Regular maintenance of the stormwater quality treatment devices is required to control weeds, remove rubbish and monitor plant establishment and health. Some sediment build-up may occur on the surface of the raingardens and may require removal to maintain the high standard of stormwater treatment. Regular management and maintenance of the water quality control systems will ensure long-term functional stormwater treatment. It is recommended that a site-specific operation and maintenance manual is prepared for the long-term management of the treatment devices. The manual will provide site specific management procedures for:

- Management of the bioretention raingarden including the plant monitoring, replanting guidelines, monitoring and replacement of the filtration media and general maintenance (i.e. weed control, sediment removal).
- Management of permanent water systems including replanting guidelines. A separate algal control strategy may be needed in order to ensure the long-term viability of the waterbodies.
- Maintenance of the GPT devices including rubbish and sediment removal.
- Indicative costing of maintenance over the life of the device.

8. GLOSSARY

Term	Definition
Airborne Laser Survey (ALS)	Is a technique for obtaining a definition of the surface elevation (ground, buildings, power lines, trees, etc.) by pulsing a laser beam at the ground from an airborne vehicle (generally a plane) and measuring the time taken for the laser beam to return to a scanning device fixed to the plane. The time taken is a measure of the distance which, when ground-truthed, is generally accurate to ± 150mm.
Annual Exceedance Probability (AEP)	The chance or probability of a natural hazard event (usually a rainfall or flooding event) occurring annually. Normally expressed as a percentage.
Australian Rainfall and Runoff (AR&R)	Refers to the current edition of Australian Rainfall and Runoff published by the Institution of Engineers, Australia.
Dam Crest Flood (DCF)	The flood event where a dam embankment is first overtopped.
Dam Safety Committee (DSC)	A NSW statutory body aligned with Department of Primary Industries. Its function is to ensure the safety of dams within NSW.
Digital Terrain Model (DTM)	Is a spatially referenced three-dimensional (3D) representation of the ground surface represented as discrete point elevations where each cell in the grid represents an elevation above an established datum.
Exceedances per Year (EY)	The number of times a year that statistically a storm flow is exceeded.
Floodplain Planning Level (FPL)	The FPL is a height used to set floor levels for property development in flood-prone areas. It is generally defined as the 1% AEP flood level plus 0.5m freeboard.
Floodplain Development Manual (FDM) and Guidelines (April 2005)	The FDM is a document issued by the Department of Environment Climate Change and Water (DECCW) that provides a strategic approach to floodplain management. The guidelines have been issued by the NSW Department of Planning (DoP) to clarify issues regarding the setting of FPL's. This document is also the framework for the development of Floodplain Risk Management Studies and Plans.
Floodplain Storage Areas	Parts of a floodplain that are important for the temporary storage of floodwaters during the passage of a flood. Loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation.
Floodway	The areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
Hyetograph	The distribution of rainfall over time.
Hydrograph	Is a graph that shows how the stormwater discharge changes with time at any particular location.

Term	Definition
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
J. Wyndham Prince Pty Ltd (JWP)	Consulting Civil Infrastructure Engineers and Project Managers undertaking these investigations
MUSIC	A modelling package designed to help urban stormwater professionals visualise possible strategies to tackle urban stormwater hydrology and pollution impacts. MUSIC stands for Model for Urban Stormwater Improvement Conceptualisation and has been developed by the Cooperative Research Centre (CRC),
Peak Discharge	Is the maximum stormwater runoff that occurs during a flood event
Potential Loss of Life (PLL)	Potential Loss of Life assessment
Population at Risk (PAR)	Population at risk assessment
Probable Maximum Flood (PMF)	The greatest depth of precipitation for a given duration meteorologically possible for 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.
Triangular Irregular Network (TIN)	A technique used in the created DTM by developing a mass of interconnected triangles. For each triangle, the ground level is defined at each of the three vertices, thereby defining a plane surface over the area of the triangle
TUFLOW	A computer program that provides two-dimensional (2D) and one dimensional (1D) solutions of the free surface flow equations to simulate flood and tidal wave propagation. It is specifically beneficial where the hydrodynamic behaviour, estuaries, rivers, floodplains and urban drainage environments have complex 2D flow patterns that would be awkward to represent using traditional 1D network models.
XP-RAFTS	Is a runoff routing model that uses the Laurenson non-linear runoff routing procedure to develop a sub catchment stormwater runoff hydrograph from either an actual event (recorded rainfall time series) or a design storm utilising Intensity-Frequency-Duration data together with dimensionless storm temporal patterns as well as standard AR&R 1987 data.

9. REFERENCES

Australian Rainfall and Runoff (ARR, 1987)

Australian Rainfall and Runoff (ARR, 2019)

BMT WBM TUFLOW Manual 2018

J. Wyndham Prince, 2005, ‘Glenmore Park Stage 2 Stormwater Management Strategy’

J. Wyndham Prince, 2017, ‘Glenmore Park Stage 2 Precinct C – Stormwater Management Strategy’

Natural Resource Access Regulator (NRAR), 2018, ‘Guidelines for Controlled Activities on Waterfront Land – Riparian Corridors’

Penrith City Council, 2006, ‘Penrith Overland Flow Flood “Overview Study”’

Penrith City Council, 2013, ‘Design Guidelines for Engineering Works’

Penrith City Council, 2017, ‘Water Sensitive Urban Design (WSUD) Policy’

Penrith City Council, 2020, ‘WSUD Technical Guidelines’

Penrith City Council, 2015, ‘Cooling the City Strategy’

Penrith City Council, 2014, ‘Development Control Plan – Section C3 Water Management’

Penrith City Council, 2020, ‘Stormwater Drainage Guidelines for Building Developments’