Hydrological and Environmental Engineering

Nepean Memorial Park

Water Sensitive Urban Design Strategy

and

Storm Water Management Plan

9 December 2019

Report by: **Stormy Water Solutions**

val.mag@stormywater.com.au, michael.mag@stormywater.com.au

www.stormywater.com.au

M 0412 436 021

Document Verification

Project Name	**Nepean Memorial Park**
Client Contact	David De Angelis, NettCorp Pty Ltd
SWS Project Number	1954
Document Name	Nepean Memorial Park, Water Sensitive Urban Design Strategy and Storm Water Management Plan, 9 December 2019

Document History

Issued To	Date	Version	Author	Reviewer
NettCorp **Florence Jaquet Landscape Architects** **Warren Smith and Partners**	1/10/19	Version 1	V. Mag	M. Mag
NettCorp **Florence Jaquet Landscape Architects** **Warren Smith and Partners** **Urbis**	9/12/19	Version 2		V. Mag

Accreditation

Michael Mag

- Bachelor of Engineering – Civil (Honours) 2016
- Bachelor of Science – Applied Mathematics 2016

Valerie Mag

- Bachelor of Engineering (Honours) 1989
- Master of Engineering Science 1993
- Registered as a Professional Engineer (Civil and Environmental Engineering), National Engineering Register (Engineers Australia).

Climate Change Statement

Unless otherwise stated, the information in this report does not take into consideration the current understanding of climate change and its consequences on our current engineering practices. This may lead to a under (or over) estimation of hydrological calculations and as such may result in under (or over) design of aspects of this design compared to a design in which climate change is considered.

Disclaimer

This report is prepared by Stormy Water Solutions for its clients' purposes only. The contents of this report are provided expressly for the named client for its own use. No responsibility is accepted for the use of or reliance upon this report in whole or in part by any third party. This report is prepared with information supplied by the client and possibly other stakeholders. While care is taken to ensure the veracity of information sources, no responsibility is accepted for information that is withheld, incorrect or that is inaccurate. This report has been compiled at the level of detail specified in the report and no responsibility is accepted for interpretations made at more detailed levels than so indicated.

Contents

1. Introduction

This Nepean Memorial Park Storm Water Management Plan (SWMP) has been prepared to complement the drainage design prepared by Warren Smith and Partners (WS&P). Stormy Water Solutions (SWS) has worked closely with WS&P, Florence Jaquet Landscape Architect (FJLA) and Travers Bushfire & Ecology (TB&E) to ensure an integrated approach to this unique site.

This SWMP report and associated plans specifically applies to the flood storage and Water Sensitive Urban Design (WSUD) requirements of the site once it is developed as a memorial park. The specific piped drainage network pertaining to individual catchments and roads are as developed by WS&P. Crucial to the development of the SWMP is the integration of the site drainage, catchment, landscape and ecological considerations. This has been achieved through an iterative process to ensure all objectives and constraints have been captured.

This report considers the major WSUD elements, retarding basin flood storage and water quality management issues within the subject site. The aim of the SWMP is to clearly define the potential land footprint requirements of major drainage assets so that the site can be developed as proposed without adverse downstream or upstream drainage impacts.

WS&P will be preparing documentation and plans relating the road and development piped network. Similarly, GRC Hydro have conducted a flood analysis of the waterways affecting the site which has been used a constraint in formulating this SWMP.

All assets detailed in this report are at the strategy development/concept design stage. As such, all proposals are subject to change as the planning and design process continues. Notwithstanding this, 0.5 metre Lidar information, ecological constraints, flooding constraints and the current details of the civil and landscape plans have been used to ensure all SWMP assets are realistic in regard to sizing and placement within the site.

The primary author of this report is Valerie Mag, principal of Stormy Water Solutions. Valerie has thirty years' experience and expertise in hydrologic and hydraulic engineering, particularly in the areas of:

- Preparing complex urban and rural flood plain strategies,
- Preparing Water Sensitive Urban Design Strategies,
- Major catchment analysis, including flood flow and flood level estimation,
- Planning and assessment of development within flood plain and overland flow path systems,
- Reviewing drainage strategies prepared by other consultants for Melbourne Water and various councils, and
- Regularly preparing and conducting training in drainage and WSUD for the Municipal Association of Victoria, Vic Roads, Melbourne Water, the Department of Tourism Arts and the Environment (Tasmania), ARRB Group (run twice in Sydney), Austroads and others.

Projects the Stormy Water Solutions team have completed include, but are not limited to, those listed below.

- Audits of drainage and WSUD elements, with a particular emphasis on clearly identifying ongoing maintenance issues and recommending cost effective remedial works,
- Development of WSUD maintenance schedules for bioretention systems, wetlands, sediment ponds and swales,
- Audits of pond and wetland systems,
- Hydraulic assessment and/or concept design of rock chutes, weirs, culverts, bridges, spillways and other hydraulic structures,
- Specialist advice on all aspects of Water Sensitive Urban Design,
- Pollutant modelling using the MUSIC model,
- Concept and functional design of best practice stormwater system elements such as retarding basins, wetlands, bioretention systems, swales, gross pollutant traps and rainwater storage tanks.

The Stormy Water Solutions team have used the above experience, together with the extensive knowledge within the consultant team for this project (WS&P, TB&E, GRC Hydro and FJLA and in particular), to ensure drainage concept designs are to best practice and to Council and state requirements.

2. Background

Figure 1 below details the subject site and the main drainage and waterway features located in and around the area of interest.

The subject land is located directly north of Park Road in the eastern portion of the existing golf course. The site is in the north eastern portion of the Wallacia township. The land is undulating, with some steep areas. Some small tributaries of Jerrys Creek traverse the site. Jerrys Creek is a tributary of the Nepean River.

The site is currently used as a golf course. There are significant stands of vegetation within the site. However, primarily, the site consists of cleared fairways and greens. This offers the opportunity to increase the environmental and ecological diversity of the site going forward.

It is understood that the golf course currently utilises water rights (9 ML/yr) to water greens and tees.

It is the intention of this SWMP to provide flood flow retardation storage by utilising naturalistic "wetland" and "pond" systems in the base of retarding basins. This will provide the additional flood storage on site to compensate for the increase in impervious areas within the cemetery.

<u>Key to the design is to use the drainage infrastructure as an opportunity to complement the landscape and ecological diversity of the site.</u>

In producing this WSUD strategy and SWMP SWS has used:

- Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019;
- Penrith Development Control Plan 2014, Part C3 Water Management;
- Penrith City Council Stormwater Drainage Guidelines for Building Developments, 28 November 2016;
- Penrith City Council Water Sensitive Urban Design (WSUD) Policy, 16 December 2013;
- Austroads Publication "Guide to Road Design Part 5A: Drainage – Road Surface, Networks, Basins and Subsurface" 2013;
- NSW Office of Water's "Guidelines for riparian corridors on waterfront land (July 2012)";

- 0.5 m contour information;

- Various working plans developed by WS&P, TB&E and FJLA in September/October 2017;

- The results of the TUFLOW modelling produced by GRC Hydro to define the 18.13% Annual Exceedance Probability (AEP) and 1% AEP flood extents on the property;

- The documented photos and notes from a site inspection conducted by WS&P in September 2017;

- A RORB model (an industry-standard Runoff Routing Model originally developed by Monash University (Laurenson EM and Mein RG)) developed for this study by SWS to estimate flood flows and provide flood storage capacity requirements;

- Various hydraulic formula (including Manning's formula) to estimate required swale dimensions; and

- A MUSIC Model V6.3.0 (Model for Urban Stormwater Improvement Conceptualisation) developed for this study by SWS to simulate runoff and pollutant load regimes and to design the Water Sensitive Urban Design (WSUD) elements on site. This modelling has including using the Penrith City Council MUSIC link data, requirements and checks.

All elements proposed as part of this drainage strategy have been fully considered in regard to their applicability. As far as possible actual invert levels, normal water levels, batter requirements etc. have been set at this stage to ensure all elements can be constructed and will not be constrained by outfall invert levels, buffers and ecological constraints.

Notwithstanding the above, all designs are at the concept design stage only and are subject to change during the design process.

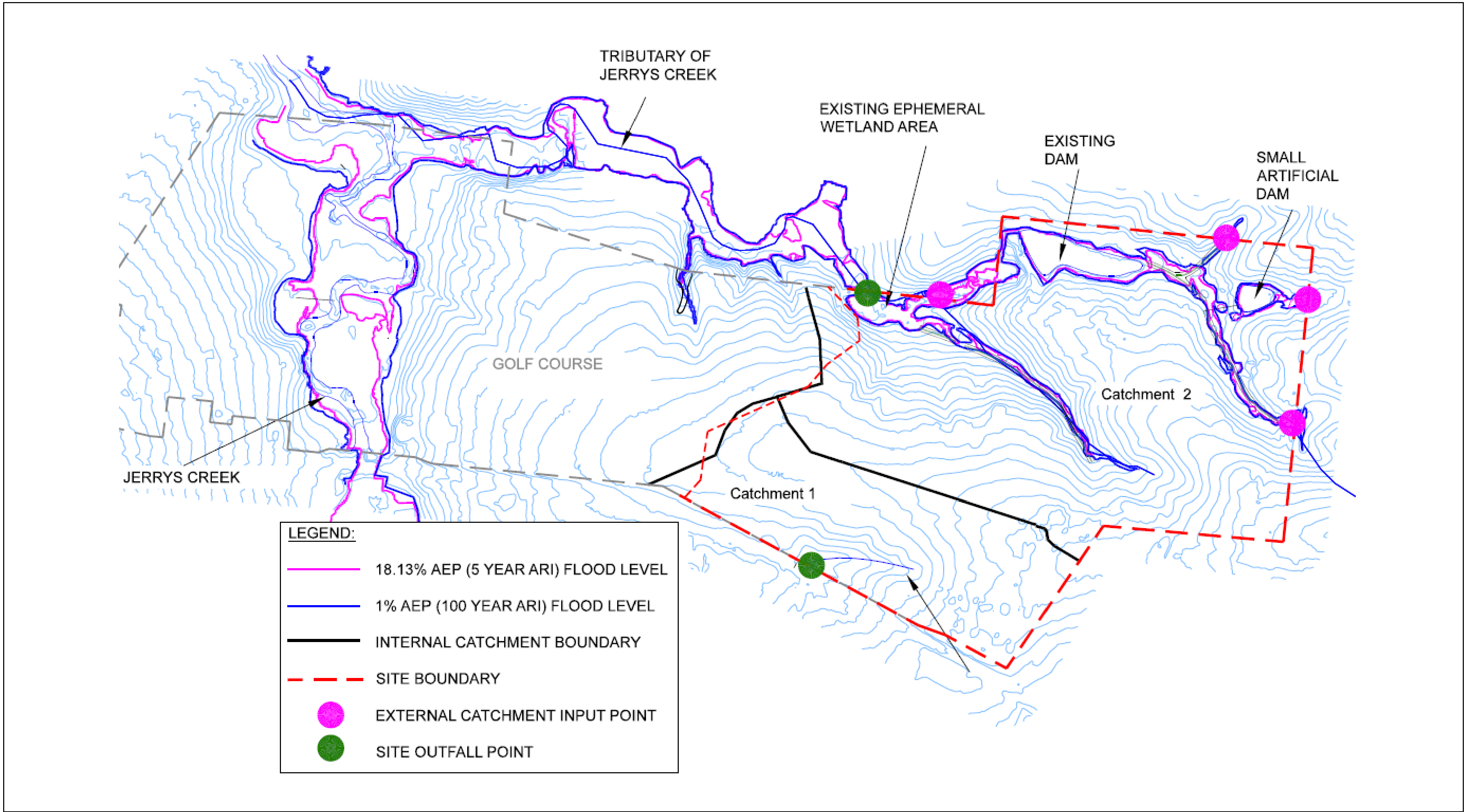


Figure 1 **Subject Site Locality**

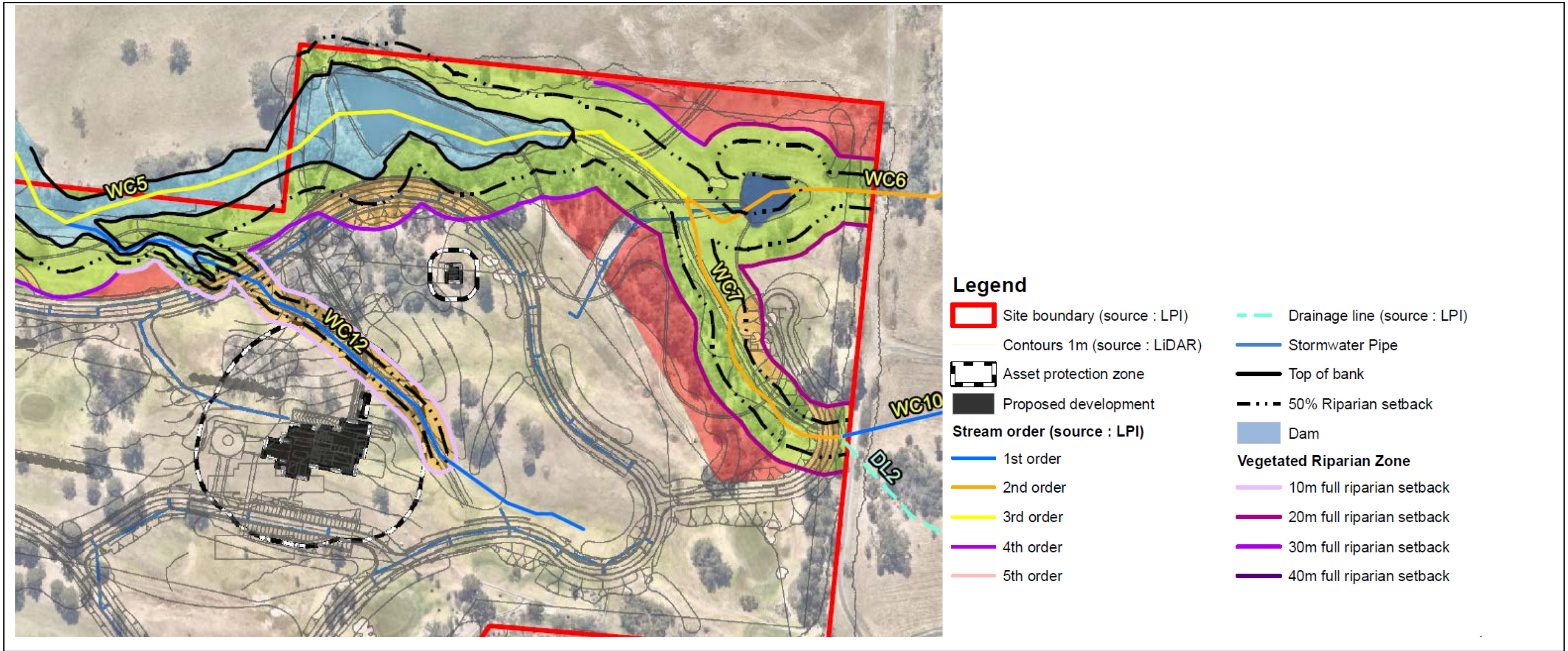


Figure 2 **Stream Orders AND Riparian Zones**
Source: TB&E Plan A17162-RIP002 dated 24/10/17

3. WSUD Strategy SWMP Objectives

All WSUD and SWMP elements referred to in this section are described in detailed Section 4 below and Appendix A of this report.

The drainage requirements applicable to this SWMP are as defined in the Penrith Development Control Plan 2014, Part C3 Water Management. This document is referred to at PDCP C3 in this report

The general objectives of the PDCP C3 are:

- To adopt an integrated approach that considers all aspects of the water cycle in determining impacts and enhancing water resources;
- To promote sustainable practices in relation to the use of water resources for human activities;
- To address water resources in terms of the entire water catchment;
- To protect water catchments and environmental systems from development pressures and potential pollution sources;
- To protect and enhance natural watercourses, riparian corridors, wetlands and groundwater dependent ecosystems;
- To protect, conserve and enhance surface and groundwater resources;
- To integrate water management with stormwater, drainage and flood conveyance requirements; and
- To utilise principles of Water Sensitive Urban Design in designing new developments or infill development in existing areas.

3.1 Watercourse and Riparian Corridor Protection

3.1.1 Requirements

The PDCP C3 document states the objectives in regard to existing riparian zones are:

- To protect water quality and terrestrial and aquatic life forms by identifying a riparian corridor along identified waterways and establishing specific planning controls for land within those corridors;
- To minimise disturbance and/or impacts on natural water bodies; and
- To rehabilitate existing riparian corridors and ensure that width, buffers to development, quality of landscape and diversity of vegetation support the principles of ecological sustainability.

In relation to activities within the vegetated riparian zone, such as cycle ways and paths, detention basins, stormwater management devices and essential services, compliance is required with the 'riparian corridor matrix' in the NSW Office of Water's "Guidelines for riparian corridors on waterfront land (July 2012)".

As defined in these 2012 guidelines, the riparian corridor matrix enables applicants to identify certain works and activities that can occur on waterfront land and in riparian corridors.

The Vegetated riparian zone (VRZ) is the required width of the VRZ measured from the top of the high bank on each side of the watercourse.

The riparian corridor matrix states:

1. Stormwater outlet structures and essential services can be proposed within the riparian zone waterways of stream orders 1 – 4,
2. Detention basins can be proposed only within 50% outer Vegetated Riparian Zone for waterways of stream orders 1 – 4,
3. Detention basins can be online to 1st and 2nd order streams,
4. Online basins must:
   - Be dry and vegetated,
   - Be for temporary flood detention only with no permanent water holding
   - Have an equivalent VRZ for the corresponding watercourse order, and
   - Not be used for water quality treatment purposes.

There are two WSUD elements proposed within the riparian zone of the third order stream located in the north eastern portion of the catchment in Catchment 1. These are Wetland 1 and Retarding Basin/Pond 1. These are discussed below.

3.1.2 Placement of RBP2 in a Riparian Zone

RBP2 will be utilising an existing water features (pond in an existing dam) to perform the functions of the WSUD strategy and SWMP. However, works will be limited to "stormwater outlet structures and essential services". The only works proposed on this system are to:

- Reconstruct the downstream embankment to current structural requirements to ensure the safety of downstream landowners,
- Ensure the outlet from the system is designed and constructed to meet the WSUD and flood storage requirements as detailed in Appendices C and D, and
- Remodel and revegetate the pond edges to ensure they meet current edge safety requirements in relation to "not inviting people to danger".

TB&E has advised that the above modifications to the existing water feature on this third order stream will ensure it retains its function as a third order stream. TB&E has advised that the WSUD strategy and SWMP can retain this element in its current form while constructing outlet works to ensure the functions required under the SWMP, without compromising the riparian corridor.

It should be noted that Retarding Basin /Pond2 (RBP2) will incorporate a pond within the base of the retarding basin. This does not meet the Council requirement that online basins must not hold permanent water. However, this is an existing pond with an existing downstream embankment.

Given that there is an existing water feature in the base of this system, it is considered in this case, that a “wet” retarding basin base is reasonable. It should be noted that similar designs are advocated in Australian Rainfall and Runoff: A Guide to Flood Estimation (2019, Book 9, Chapter 4, Table 9.4.4) and the Austroads Publication “Guide to Road Design Part 5A: Drainage – Road Surface, Networks, Basins and Subsurface Drainage(2013)”. Basins of this type are seen as best practice examples of incorporating flood storage and WSUD objectives in one location and should be supported as such. This is an opportunity for council to support such a design in line with current best practice.

Certainly, this is in line with the PDCP C3 document objective “to rehabilitate existing riparian corridors and ensure that width, buffers to development, quality of landscape and diversity of vegetation support the principles of ecological sustainability”.

3.1.3 Placement of Wetland W2 in a Riparian Zone

Wetland W2 is proposed to be placed on a Third Order stream just upstream of RBP2.

Wetland W2 is essentially a relocation of the small dam in the north eastern portion of the property. TB&E have advised that this existing dam can be removed because it has been artificially constructed.

Almost all of the upstream catchment will be retained in its current form or will be heavily revegetated in the future as part of the cemetery development. As such, there will be no impact on the frequent or extreme flow rates at the existing downstream dam (to be remodelled at RBP2). That is, the catchment hydrological response at RBP2 (and int the downstream ecological wetland) will not change. This, in addition to the proposed structural outlet works on RBP2, will ensure in no structural embankment issues at RBP2 and to the flow regimes in the ecological wetland downstream of RBP2.

In addition, the new Wetland W2 will be a completely “cut” construction. This essentially removes the structural integrity issues associated with the informal embankment currently incorporated into the dam it is replacing.

Further, W2 will be an ephemeral wetland placed where there is currently a golf course fairway. As such the proposal is also in line with the PDCP C3 document objective “to rehabilitate existing riparian corridors and ensure that width, buffers to development, quality of landscape and diversity of vegetation support the principles of ecological sustainability”.

As there will be no adverse impacts from the proposals, TB&E have advised that relocation of the existing small dam to the W2 location is acceptable and will result in net structural integrity and ecological benefits to the riparian zone in the site.

However, as W2 will be performing a water treatment function an offset somewhere else on site may be required.

3.1.4 Placement of Wetland/Retarding Basin WLRB1

Constructed wetland WLRB1 will be located in Catchment 1 and is proposed to be placed away from the identified Vegetated Riparian Zone on site.

3.1.5 Placement of Vegetated Swales

The only other impact on the riparian zone of waterways is the remodelling of some Stream Order 1 and 2 watercourses as vegetated swales in Catchments 1 and 2. The form of these swales is as described in Appendix E.

It is proposed to reconstruct these watercourses as swales. As such, the watercourses are assumed to be converted to drainage swale definition. This will require an offset elsewhere onsite.

3.1.6 Use of Riparian Zones in Formulating the SWMP

The importance of considering the management objectives, landscape values and community aspirations is a fundamental part of developing an integrated design solution. To this end, TB&E, WS&P, FJLA and SWS have worked closely to ensure that drainage elements (such as wetlands and swales) offer the opportunity to complement the landscape amenity and ecological diversity within the site (especially in the identified riparian zones). This is in line with best practice application of WSUD in drainage strategies.

In particular, provision of existing and future habitat corridors along existing watercourses and future swales has been seen as a major objective, particularly in terms of providing future habitat links for local fauna.

3.2 Water Quality Requirements

Stormwater quality requirements for all development types identified in Table C3.1 of the PDCP C3 document are:

a) Pollution load reductions:

- 90% reduction in the post development mean annual load of total gross pollutant (greater than 5mm);
- 85% reduction in the post development mean annual load of Total Suspended Solids (TSS);
- 60% reduction in the post development mean annual load of Total Phosphorus (TP);

- 45% reduction in the post development mean annual load of Total Nitrogen (TN);
- 90% Free Oils and Grease with no visible discharge.

b) Modelling for the determination of the mean annual loads of land uses must be undertaken in MUSIC and in accordance with the associated WSUD Technical Guidelines.

Appendix D details the MUSIC modelling completed for the SWMP production. At this stage, the strategy aims to retain stormwater pollutants to the above requirements. However, the MUSIC modelling to date indicates this objective can be exceeded (especially if consideration of other benefits, such as onsite harvesting of stormwater for site irrigation, are considered).

The PDCP C3 also requires that any changes to the flow rate and flow duration within the receiving watercourses as a result of the development shall be limited as far as practicable. Natural flow paths, discharge point and runoff volumes from the site should also be retained and maintained as far as practicable. As detailed in the SWMP drawings this is proposed to occur through,

- Vegetating existing mown (fairway) depressions with sedges rushes (and small trees on the banks), thus significantly increasing the ecological diversity of the drainage line, while slowing water down within the site in line with the above objective, and
- Minimising directly connected areas to the drainage system via using swales to disconnect pipe systems from the WSUD elements at the site outfalls etc.

In addition, the PDCP C3 requires impervious areas directly connected to the stormwater system to be minimised. This has been achieved via FJLA specifying (as far as possible) burial areas which direct runoff from headstones etc. onto grass and other landscaped areas designed to accept such flows.

3.3 Flood Storage Requirements

As detailed in the PDCP C3 document, On-Site Stormwater Detention (OSD) or retarding basins (as OSD's are referred to in this report) must be designed and constructed to ensure that:

- For all rainwater events up to and including the 1:100 Average Recurrence Interval (ARI) event, new developments and redevelopments do not increase stormwater peak flows in any downstream areas;
- They are located at a level that is above the 1:5 ARI flood level; and
- Must be designed using a catchment wide approach (that is, consideration of the total catchment, and external site catchments must be undertaken).

This SWMP proposes two assets to provide flood retardation functions on site. These are RBP2 and WLRB1. Appendix B, C and F detail the RORB modelling and completed "Penrith City Catchment Stormwater Drainage Guidelines for Building Developments 2016 Checklist". These show that the above conditions have been met by the flood retardation assets proposed in this SWMP.

3.4 Flood Protection Requirements

All cemetery development will be located outside the 1% AEP flood extent of the local waterways as defined by GRC Hydro.

Section 12 of PDCP C3 states onsite water treatment facilities should be located above the 1% AEP flood line. At this stage it is assumed that this clause is related to pollutants that could be hazardous to the watercourse and not the stormwater sediment or nutrients retained in a wetland system. Given the above Wetland W2 (which also includes a retarding basin function) is located inside the defined 1% AEP flood line.

The pipes and swales specified in the SWMP shall be sized to convey a 5% Annual Exceedance Probability (AEP = 1 in 20-year average recurrence interval (ARI)) storm event without creating nuisance flows on the roads or burial areas. These drainage elements will satisfy the minor flow requirements of the development and be sympathetic with the landscape.

The above is in line with the PDCP C3 document requirement that the drainage system is to be designed to control:

- Minor stormwater flows under normal operating conditions for an ARI of 5 years, and
- Major stormwater flows under normal operating conditions for an ARI of 100 years.

3.5 Stormwater Harvesting

At this stage it is assumed that at least part of the 9 ML/yr (in line with the current water rights of the Golf course) can be used for stormwater harvesting on site for garden beds etc.

As detailed in the PDCP C3 document, the NSW Farm Dams Policy (harvestable right dams' policy) allows rural landholders to harvest a basic volume of water (10% of runoff), store and use that water for any purpose without the need to obtain a licence under the Water Management Act 2000. Any take of water over and above 10% runoff would require a water access licence and an approval.

At this stage the SWMP has been formulated without accounting for the potential use of stormwater harvesting on site. If this use is eventually taken up, the stormwater pollutant reductions as specified in Appendix D will only improve.

3.6 Stormwater Quantity – Stream Forming Flows

The development of the site has the potential to increase surface runoff flow rates and volumes leading to impacts on steam stability, receiving water ecology and flooding in Jerrys Creek and other receiving waters.

The PDCP C3 document objectives in regard to this issue are to manage the volume and duration of stormwater flows entering local waterways so as to protect the geomorphic values of those waterways.

It is required that the post development duration of stream forming flows shall be no greater than 3.5 times the predeveloped duration of stream forming flows. The comparison of post development and predevelopment stream flows is commonly referred to as the Stream Erosion Index (SEI).

This is a condition that is typically met with retarding basins and vegetated swales aiming to mitigate the response time of the development by mimicking the predevelopment response times.

The retardation benefits of WLRB1 and RBP2 are detailed in Appendix C. The results clearly show that, at this stage, both sites are over-designed for all events of greater magnitude than the 10% AEP storm. As such, there should be adequate additional flood storage in both assets to ensure the above objectives can be met going forward. Low flow outlets will be designed, and hydrographs will be produced at the detailed design stage of the project to show this condition can be met.

3.7 System Maintenance

The PDCP C3 document requires that retarding basins have a maintenance program in place and be placed on the title of the relevant allotment/property to ensure their retention and maintenance.

Council ‘s prefers WSUD measures to be located on private land under the maintenance of the owner or occupier. If there is a need to hand assets over to Council, arrangements will be made prior to the approval of a Development Application.

At this stage it is assumed the Memorial Park will be responsible for the maintenance of all WSUD assets proposed.

The above two conditions are captured in the draft inspection and maintenance schedules for all retarding basins, wetlands and swales on site as per Appendix G of this report.

4. Storm Water Management Plan Description

The primary drainage elements proposed within the SWMP are detailed within SWS drainage set **1954/SWS/1-4**. These drawings are reproduced in **Appendix A** and discussed further below.

The WSUD elements detailed in the SWMP complement the piped drainage design proposed by WS&P. The WSUD elements are detailed in Table 1 below.

Table 1 Nepean MP WSUD Assets

SWS Asset Number	Asset Name	Primary Asset Type	Secondary Asset Type	Asset Dimensions and WSUD Properties
WLRB1	Wetland/Retarding Basin 1	Retarding Basin	Treatment Wetland	Ephemeral Base = 920 m^2 Base level = 49.50 m AHD TED = 1230 m^2 Detention time = 48 hours Extended Detention Depth = 600 mm
VS1A	Vegetated Swale	Stormwater Conveyance	Treatment Swale	Base = 1 metre 1 in 5 Batters 0.5 m deep 1/60 slope Length = 125 m
VS1B	Vegetated Swale	Stormwater Conveyance	Treatment Swale	Base = 1 metre, 1 in 5 Batters 0.5 m deep, 1/25 slope Length = 60 m
VS1C	Vegetated Swale	Stormwater Conveyance	Treatment Swale	Base = 1 metre, 1 in 5 Batters 0.3 m deep, 1/100 slope Length = 130
W2	Wetland	Treatment Wetland		Ephemeral Base = 1040 m^2 Base level = 50.50 m AHD TED = 1480 m^2 Detention time = 48 hours Extended Detention Depth = 500 mm
RBP2	Retarding Basin/Pond	Retarding Basin	Landscape Pond	3750 m^2 at NWL. NWL = 49.50 m AHD
VS2A	Vegetated Swale	Stormwater Conveyance	Treatment Swale	Base = 2 metre, 1 in 8 Batters 0.5 m deep, 1/25 slope Length = 190 m
VS2B	Vegetated Swale	Stormwater Conveyance	Treatment Swale	Base = 2 metre, 1 in 8 Batters 0.5 m deep, 1/25 slope Length = 185 m
VS2C	Vegetated Swale	Stormwater Conveyance	Treatment Swale	Base = 1 metre, 1 in 5 Batters 0.5 m deep, 1/25 slope Length = 40 m
VS2D	Vegetated Swale	Stormwater Conveyance	Treatment Swale	Base = 2 metre, 1 in 8 Batters 0.5 m deep, 1/25 slope Length = 100 m
VS2E	Vegetated Swale	Stormwater Conveyance	Treatment Swale	Base = 2 metre, 1 in 8 Batters 1.0 m deep, 1/100 slope Length = 30 m
VS2F	Two Vegetated Swales	Stormwater Conveyance	Treatment Swale	Base = 1 metre, 1 in 5 Batters 0.5 m deep, 1/100 slope Length = 45 m (each swale)
VS2G	Vegetated Swale	Stormwater Conveyance	Treatment Swale	Base = 1 metre, 1 in 5 Batters 0.3 m deep, 1/100 slope Length = 65 m

To achieve the requirements detailed in Section 3 above, the developed SWMP must achieve multiple objectives. This can be achieved by providing drainage elements:

- Which act together to achieve specific objectives, and
- Incorporate dual functions within each site (if possible).

For example, a retarding basin (flood storage function) can contain a wetland (WSUD function) and also ensure landscape enhancement and increase site ecological diversity. This is WSUD at its best. The industry is well beyond the time when drainage elements only perform engineering functions alone.

The developed SWMP is aimed at achieving all of the above objectives detailed in Section 3. Specific requirements and the SWMP proposed in the SWMP to address these issues are detailed below.

4.1 Treatment of Development and Burial Areas – All Catchments

In regard to drainage impact, this development largely consists of two types of development being:

- Development resulting in 100 % imperviousness areas (roads, car parks, roofs etc), and
- Burial areas.

100% impervious areas (such as roads, car parks and roofs) have been designed by WS&P to drain directly to pipes drainage systems which outfall into the swales, wetlands and/or retarding basin/wetland systems aligned to site outfall locations (as described above).

The reminder of the site will largely be “Burial” areas. FJLA estimates that:

- 20% of total “Burial” areas could (in some cases) be full monumental (100% impervious), and
- The remainder will be lawn with a concrete beam (0.40 m wide on average concrete beams, running parallel every 5.1 m) This results in a fraction imperviousness in these areas of 8%.

Of course, the total site will not be defined burial areas, As such, a conservative fraction imperviousness for areas which have burial areas (lawn and monumental) located within them is assumed to be 25% within this SWMP.

Burial areas (catchments), have one additional treatment source in addition to those defined above. All burial areas are assumed to shed stormwater from their impervious areas directly into the surrounding grass, where it eventually makes its way to a local pipe or an outfall treatment element. This shedding of water into surrounding grass can be defined a “buffer” treatment in the MUSIC model and this has been accounted for in the MUSIC models detailed in Appendix D of this report.

Essentially, this "buffer" treatment is the primary (i.e. first) treatment element in the WSUD strategy treatment train definition for this site. Secondary and tertiary treatment occurs in the downstream swales and wetland systems as applicable (see below).

In catchments where there are some roads, roofs etc., up to 20% of the catchment may be directly connected to a pipe. In this situation it is assumed that 80% of the catchment is buffered and the buffer area is assumed to be 50% of the upstream impervious area. In catchments only exhibiting burials, none of the catchment will be directly connected to a pipe system, and as such 100 % of the catchment is assumed to be buffered and the buffer area is assumed to be 50% of the upstream impervious area. Both of these assumptions are considered conservative in this application in regard to accounting for burial areas being disconnected from the piped drainage system.

4.2 Catchment 1

Catchment 1 is defined as the catchment out falling to Park Road at the southern site outfall point.

WSUD strategy and SWMP elements proposed in Catchment 1 are:

- Buffer treatment of the imperious areas in burial areas,
- Vegetated Swales VS1A, VS1B and VS1C providing secondary treatment from piped outfall points to Wetland/Retarding Basin WLRB1,
- Vegetated Swale VS1C providing secondary treatment from burial areas and diverting the catchment west of the administration building and access road to Swale VS1A (i.e. away from the golf course), and
- Wetland/Retarding Basin WLRB1 providing a stormwater treatment and flood retardation function.

It should be noted that the Vegetated Swales 1A, 1B and 1C not only contribute to stormwater treatment, but they aid in the flood retardation strategy as well. By vegetating the systems, the velocity of the flow is significantly reduced. This increases the reaction time of the catchment to runoff and reduces flood flows (from those expected from piped catchments). This is valid assumption and has been captured in the hydrological RORB modelling (Appendix C), by specifying vegetated swale reaches as "natural" reaches. This is in line with the definition of this type of reach in the RORB manual.

The vegetated swales are supplemented by Wetland/Retarding Basin WLRB1. The combination of these elements indicates that, at this stage (as detailed in Appendix C) the all post development flows (10%, 5%, 2% and 1% AEP) are retarded to BELOW the total predevelopment flow expected in Catchment 1.

Appendix D details the post-development MUSIC modelling which shows the council requirements in relation to stormwater treatment can be met by the SWMP. See SWS Drawing 1954/SWS/1, 2 and 4 (Appendix A) for full Catchment 1 WSUD element details.

4.3 Catchment 2

Catchment 2 is the largest catchment in the strategy. It incorporates a significant external catchment.

WSUD strategy and SWMP elements proposed in Catchment 2 are:

- Buffer treatment of the imperious areas in burial areas,
- Vegetated Swales VS2A, VS2B, VS2C, VS2D, VS2E, VS2F and VS5G,
- Pond/Retarding Basin RBP2 (stormwater treatment and flood retardation function), and
- Wetland W2 (stormwater treatment function only).

The pond RBP2 is an existing asset modified to suit the drainage functions required under the SWMP (see Section 3 above).

Wetland W2 is a new wetland placed in a depression which currently incorporates mown golf course land. This wetland replaces the existing artificial asset located upstream. This existing wetland has been removed as to reduce the risk associated with structural collapse of its informal earthen batter. TB&E have advised that this asset can be removed as it is an artificial dam on a first order steam. Wetland W2 is a totally cut construction which completely negates the risk of embankment collapse. Wetland W2 will be an ephemeral system, with no permanent water present in the system between rainfall events. This has been proposed to complement the open water body located directly downstream (RBP2) and thus maximise the ecological diversity of site.

The swales proposed in all the existing drainage lines will be planted with dense sedges and rushes to achieve stormwater treatment and flood storage functions (see Section 3 and Appendix D).

Vegetated Swales VS2B, VS2C, VS2D, Pond RBP2 and Wetland W2 all treat external catchments. This external catchment treatment does not occur currently due to:

- All drainage lines incorporating short mown grass with very little pollutant retention capacity, and
- The existing artificial dam in the north eastern portion of the site not incorporating hydraulic controls to detain stormwater for treatment over 48 hours.

Once the swales are vegetated (and the hydraulic controls on Pond RBP2 and Wetland W2 are constructed) the operation of the system will change. These changes will ensure, not only treatment of the subject site flows, but of the currently untreated external catchments as well. This has been captured in the MUSIC modelling detailed in Appendix D.

Again, all proposed Vegetated Swales not only contribute to stormwater treatment, but they aid in the flood retardation strategy. This has been captured in the hydrological RORB modelling (Appendix C), by specifying vegetated swale reaches as "natural" reaches. Again, this is in line with the definition of this type of reach in the RORB manual.

The vegetated swales are supplemented by the flood storage provision above Pond RBP2. The combination of these elements indicates that, at this stage (as detailed in Appendix C) the all post development flows (10%, 5%, 2% and 1% AEP) are retarded to BELOW the total predevelopment flow expected in Catchment 2.

Appendix A (Drawings 1954/SWS/1, 3 and 4) detail the concept design of the Catchment 2 WSUD and drainage elements.

Note that the existing informal ephemeral wetland area just upstream of the northern site outfall is not part of the WSUD strategy. This informal, naturalistic wetland area will be retained as a functioning riparian zone area. As such, it is treated as a "receiving body" in this strategy, with all stormwater treatment occurring before outfall of flows into this area.

5. Conclusions

The stormwater drainage system proposed for the Nepean Memorial Park represents a strategy development covering all requirements of best practice floodplain and catchment management. In addition, the WSUD strategy and SWMP meets all the requirements of the Penrith Development Control Plan 2014, Part C3 Water Management document.

The WSUD strategy and SWMP has been formulated with full integration with:

- The 1% AEP flood lines as defined by GRC Hydro,
- The landscape proposals (developed by FJLA),
- Ecological constraints (defined by TB&E), and
- Internal development drainage proposals (developed by WS&P).

The SWMP plans clearly show there is enough space allocated on site to incorporate all drainage and WSUD elements to ensure the requirements of the SWMP are met.

The assumptions in regard SWMP elements may change over time. However, it is considered at this stage, that the work presented has defined realistic and adequate land footprints required for major drainage assets going forward.

6. Abbreviations and Definitions

The following table lists some common abbreviations and drainage system descriptions and their definitions which are referred to in this report.

Abbreviation / Descriptions	Definition
AEP – Annual Exceedance Probability	The probability of an event being equalled or exceeded within a year.
AHD - Australian Height Datum	Common base for all survey levels in Australia. Height in metres above mean sea level.
ARI - Average Recurrence Interval.	The average length of time in years between two floods of a given size or larger
AR&R 2019	Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019
BoM	Bureau of Meteorology
Evapotranspiration	The loss of water to the atmosphere by means of evaporation from free water surfaces (e.g. wetlands) or by transpiration by plants
FJLA	Florence Jaquet Landscape Architect
Groundwater	All water stored or flowing below the ground surface level
Hectare (ha)	10,000 square metres
Hec Ras	A one dimensional, steady state hydraulic model which uses the Standard Step Method to calculate flood levels and flood extents
Kilometre (km)	1000 metres
m^3/s -cubic metre/second	Unit of discharge usually referring to a design flood flow along a stormwater conveyance system
Megalitre (ML) (1000 cubic metres)	1,000,000 litres = 1000 cubic metres Often a unit of water body (e.g. pond) size
MUSIC	Hydrologic computer program used to calculate stormwater pollutant generation in a catchment and the amount of treatment which can be attributed to the WSUD elements placed in that catchment. Can also be used to calculate water body turnover period and wetland draw downs etc.
NWL	Normal Water Level – invert level of lowest outflow control from a wetland or pond.
PDCP C3	Penrith Development Control Plan 2014, Part C3 Water Management.
PET	Potential Evapotranspiration – potential loss of water to the atmosphere by means of evaporation or transpiration from wetland or pond systems.
Retarding Basin	Drainage element used to retard flood flows to limit flood impacts downstream of a development. Can include complementary WSUD and ecological site benefits if wetland incorporated within the site.
RORB	Hydrologic computer program used to calculate flood flows (m^3/s) and size retarding basins
Surface water	All water stored or flowing above the ground surface level
SWMP	Storm Water Management Plan
TED	Top of Extended Detention – Level to which stormwater is temporarily stored for treatment in a wetland or pond (above NWL).
TB&E	Travers Bushfire & Ecology
TSS	Total Suspended Solids – a term for a particular stormwater pollutant parameter
TP	Total Phosphorus – a term for a particular stormwater pollutant parameter
TN	Total Nitrogen – a term for a particular stormwater pollutant parameter
WS&P	Warren Smith and Partners
Wetland	WSUD elements which is used to collect TSS, TP and TN. Either permanently or periodically inundated with shallow water and either permanently or periodically supports the growth of aquatic macrophyte

7. References

Allison, R. A., T. Walker, F. H. S. Chiew, I. C. O'Neill and T. A. McMahon (1998). *From roads to rivers: gross pollutant removal from urban waterways (Technical Report No. 98/6)*. Melbourne, Cooperative Research Centre for Catchment Hydrology.

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019, *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia.

Penrith Development Control Plan 2014, Part C3 Water Management" document,

Penrith City Council Stormwater Drainage Guidelines for Building Developments, 28 November 2016

Penrith City Council Water Sensitive Urban Design (WSUD) Policy, 16 December 2013

Austroads Publication "Guide to Road Design Part 5A: Drainage, Road Surface, Networks, Basins and Subsurface" 2013;

NSW Office of Water's "Guidelines for riparian corridors on waterfront land (July 2012)";

Concrete Pipe Association of Australasia (2012), *Hydraulics of Precast Concrete Conduits, Pipe and Box Culverts*, CPAA Design Manual.

CSIRO (1999). "*Urban Stormwater Best Practice Environmental Management Guidelines*." CSIRO PUBLISHING, Melbourne.

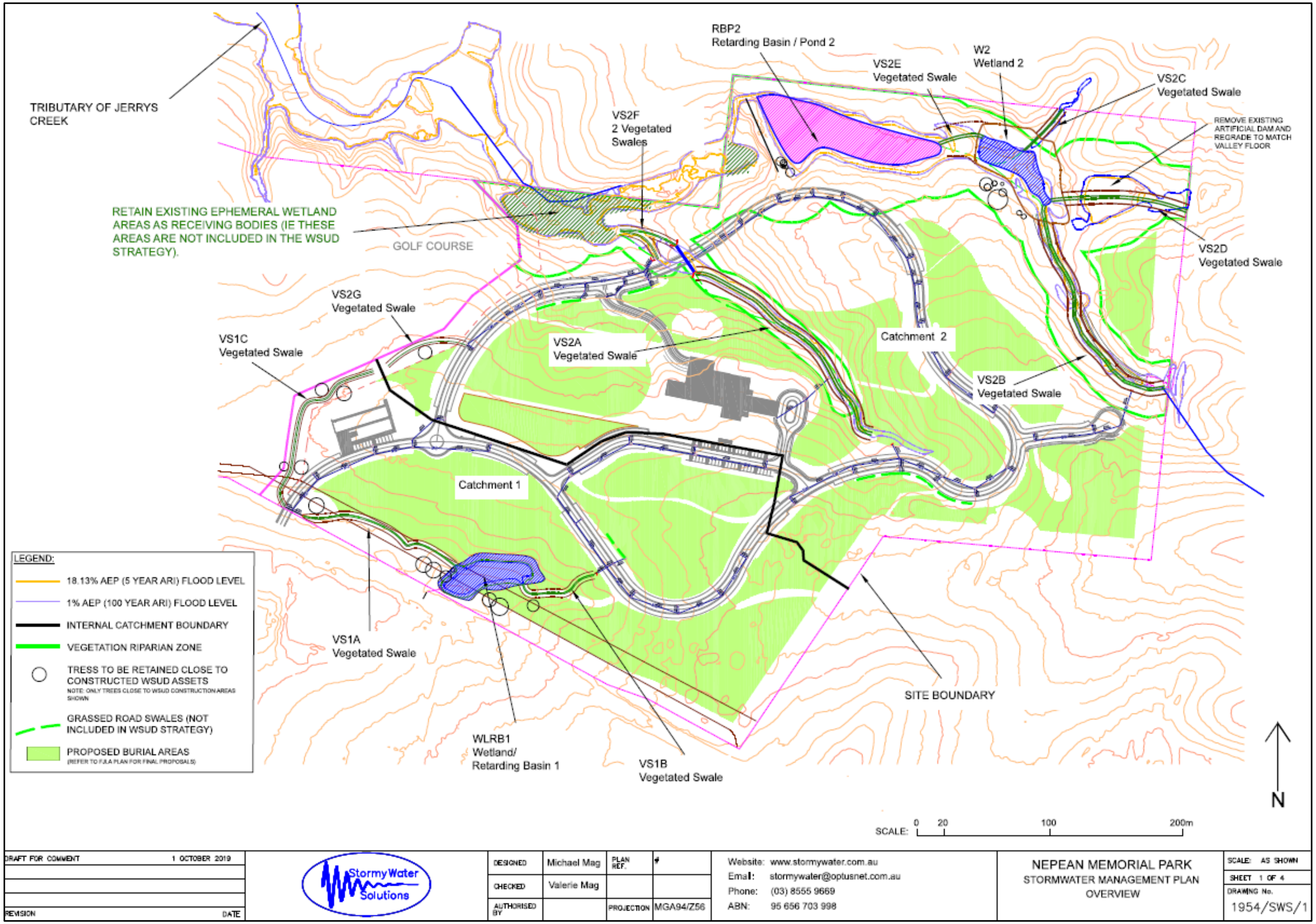
Department of Environment, Land, Water and Planning (DELWP) (2019), "*Guidelines for Development in Flood Affected Areas"*, February 2019, The State of Victoria.

Melbourne Water (2005). "*WSUD Engineering Procedures: Stormwater Melbourne"*, CSIRO Publishing.
Melbourne Water (2008). "*Guidelines for Development in Flood-prone Areas*", October 2008, Melbourne Water

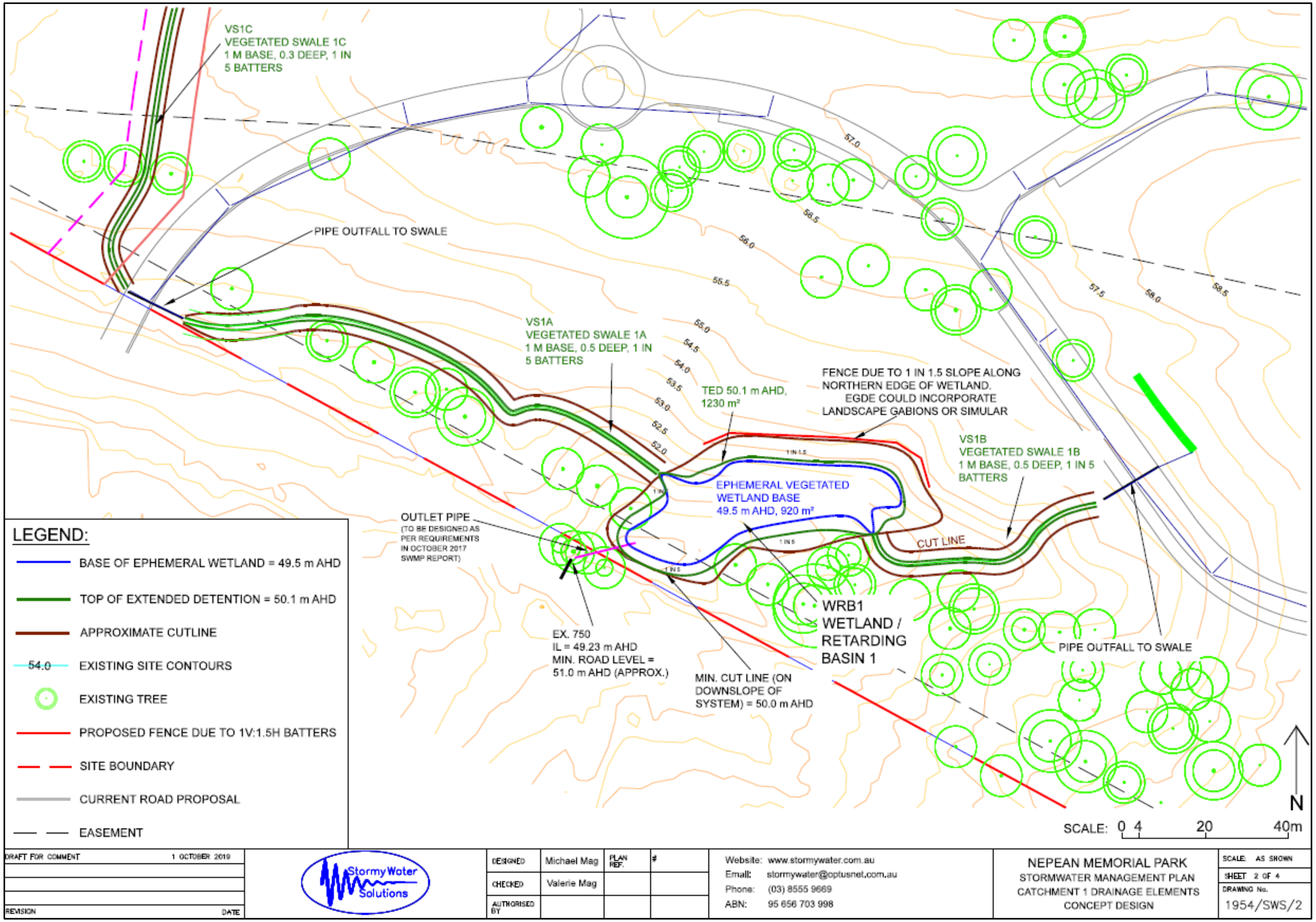
Melbourne Water (2018a). *"Melbourne Water Corporation Flood Mapping Projects Guidelines and Technical Specifications Version 9: Final"*, November 2018, Melbourne Water

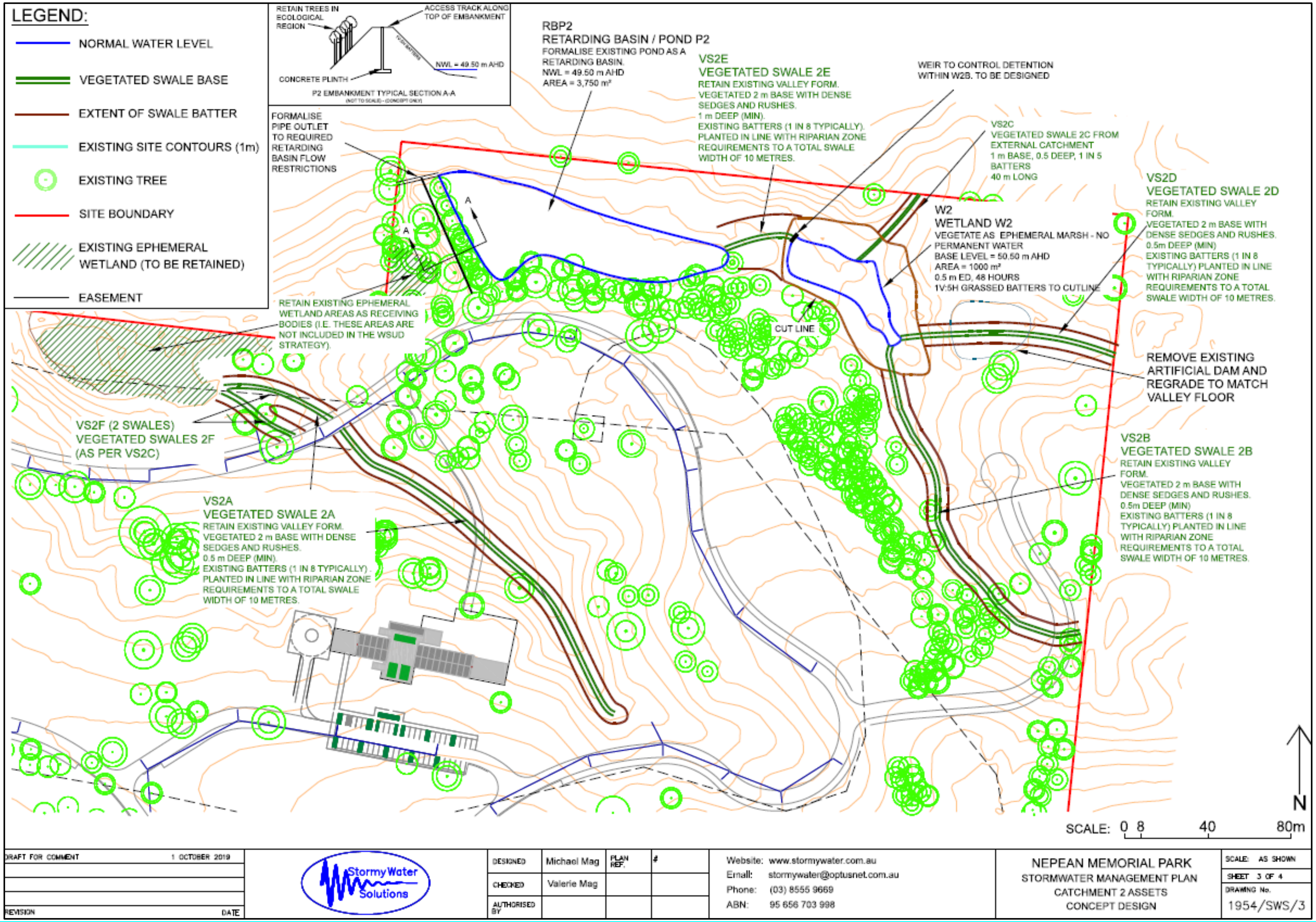
Nearmap 2019. *Areal imagery for locations and dates shown on Figures where applicable*.

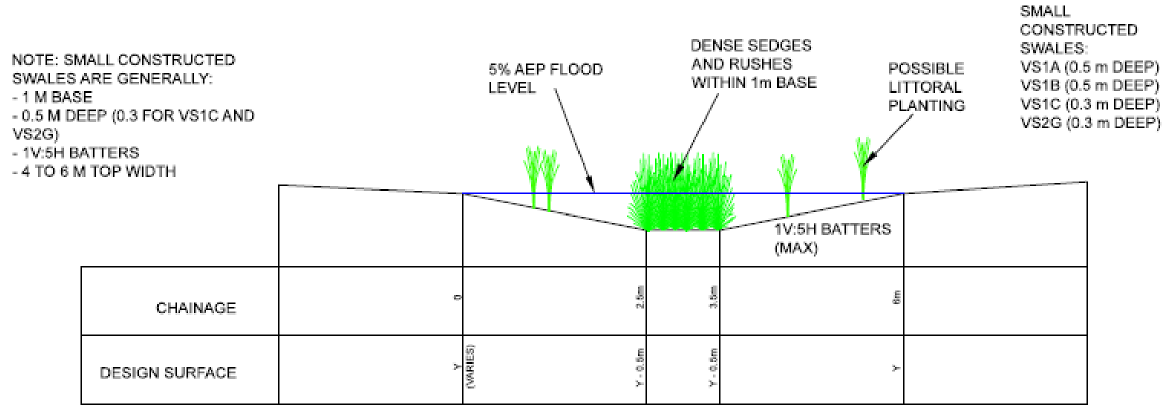
Appendix A Design Drawings



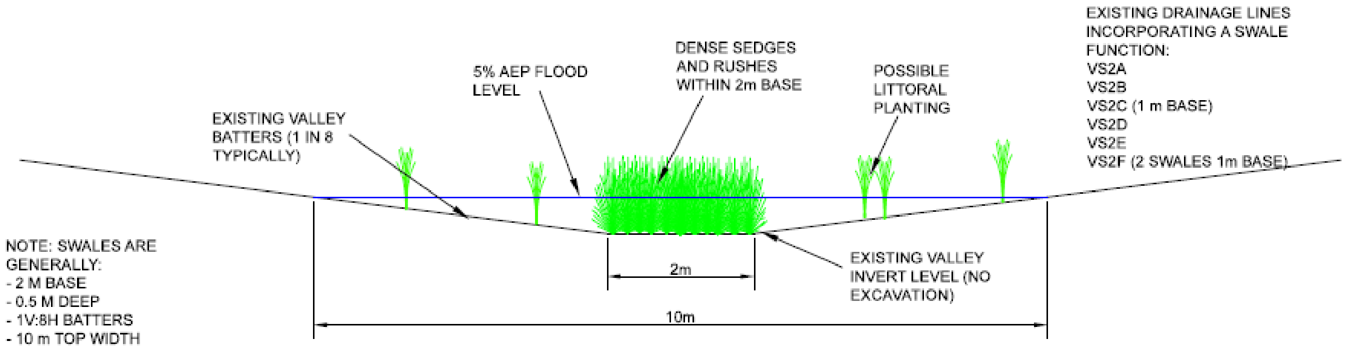
TRIBUTARY OF JERRYS CREEK
RETAIN EXISTING EPHEMERAL WETLAND AREAS AS RECEIVING BODIES (IE THESE AREAS ARE NOT INCLUDED IN THE WSUD STRATEGY).
GOLF COURSE
VS2F 2 Vegetated Swales
RBP2 Retarding Basin / Pond 2
VS2E Vegetated Swale
W2 Wetland 2
VS2C Vegetated Swale
REMOVE EXISTING ARTIFICIAL DAM AND REGRADE TO MATCH VALLEY FLOOR
VS2D Vegetated Swale
VS2G Vegetated Swale
VS1C Vegetated Swale
VS2A Vegetated Swale
Catchment 2
VS2B Vegetated Swale
Catchment 1
LEGEND:
18.13% AEP (5 YEAR ARI) FLOOD LEVEL
1% AEP (100 YEAR ARI) FLOOD LEVEL
INTERNAL CATCHMENT BOUNDARY
VEGETATION RIPARIAN ZONE
TRESS TO BE RETAINED CLOSE TO CONSTRUCTED WSUD ASSETS
NOTE: ONLY TREES CLOSE TO WSUD CONSTRUCTION AREAS SHOWN
GRASSED ROAD SWALES (NOT INCLUDED IN WSUD STRATEGY)
PROPOSED BURIAL AREAS
(REFER TO FJLA PLAN FOR FINAL PROPOSALS)
VS1A Vegetated Swale
WLRB1 Wetland/ Retarding Basin 1
VS1B Vegetated Swale
SITE BOUNDARY
N
SCALE: 0 20 100 200m
DRAFT FOR COMMENT 1 OCTOBER 2019
REVISION DATE
Stormy Water Solutions
DESIGNED Michael Mag
CHECKED Valerie Mag
AUTHORISED BY
PLAN REF. #
PROJECTION MGA94/Z56
Website: www.stormywater.com.au
Email: stormywater@optusnet.com.au
Phone: (03) 8555 9669
ABN: 95 656 703 998
NEPEAN MEMORIAL PARK
STORMWATER MANAGEMENT PLAN
OVERVIEW
SCALE: AS SHOWN
SHEET 1 OF 4
DRAWING No. 1954/SWS/1


VS1C
VEGETATED SWALE 1C
1 M BASE, 0.3 DEEP, 1 IN 5 BATTERS
PIPE OUTFALL TO SWALE
VS1A
VEGETATED SWALE 1A
1 M BASE, 0.5 DEEP, 1 IN 5 BATTERS
TED 50.1 m AHD, 1230 m²
FENCE DUE TO 1 IN 1.5 SLOPE ALONG NORTHERN EDGE OF WETLAND. EGDE COULD INCORPORATE LANDSCAPE GABIONS OR SIMULAR
VS1B
VEGETATED SWALE 1B
1 M BASE, 0.5 DEEP, 1 IN 5 BATTERS
EPHEMERAL VEGETATED WETLAND BASE
49.5 m AHD, 920 m²
CUT LINE
OUTLET PIPE
(TO BE DESIGNED AS PER REQUIREMENTS IN OCTOBER 2017 SWMP REPORT)
EX. 750
IL = 49.23 m AHD
MIN. ROAD LEVEL = 51.0 m AHD (APPROX.)
MIN. CUT LINE (ON DOWNSLOPE OF SYSTEM) = 50.0 m AHD
WRB1
WETLAND / RETARDING BASIN 1
PIPE OUTFALL TO SWALE
LEGEND:
BASE OF EPHEMERAL WETLAND = 49.5 m AHD
TOP OF EXTENDED DETENTION = 50.1 m AHD
APPROXIMATE CUTLINE
54.0 EXISTING SITE CONTOURS
EXISTING TREE
PROPOSED FENCE DUE TO 1V:1.5H BATTERS
SITE BOUNDARY
CURRENT ROAD PROPOSAL
EASEMENT
SCALE: 0 4 20 40m
N
DRAFT FOR COMMENT 1 OCTOBER 2019
REVISION DATE
Stormy Water Solutions
DESIGNED Michael Mag
CHECKED Valerie Mag
AUTHORISED BY
PLAN REF. #
Website: www.stormywater.com.au
Email: stormywater@optusnet.com.au
Phone: (03) 8555 9669
ABN: 95 656 703 998
NEPEAN MEMORIAL PARK
STORMWATER MANAGEMENT PLAN
CATCHMENT 1 DRAINAGE ELEMENTS
CONCEPT DESIGN
SCALE: AS SHOWN
SHEET 2 OF 4
DRAWING No. 1954/SWS/2


LEGEND:
NORMAL WATER LEVEL
VEGETATED SWALE BASE
EXTENT OF SWALE BATTER
EXISTING SITE CONTOURS (1m)
EXISTING TREE
SITE BOUNDARY
EXISTING EPHEMERAL WETLAND (TO BE RETAINED)
EASEMENT
RETAIN TREES IN ECOLOGICAL REGION
ACCESS TRACK ALONG TOP OF EMBANKMENT
NWL = 49.50 m AHD
CONCRETE PLINTH
P2 EMBANKMENT TYPICAL SECTION A-A
FORMALISE PIPE OUTLET TO REQUIRED RETARDING BASIN FLOW RESTRICTIONS
RBP2
RETARDING BASIN / POND P2
FORMALISE EXISTING POND AS A RETARDING BASIN.
NWL = 49.50 m AHD
AREA = 3,750 m²
VS2E
VEGETATED SWALE 2E
RETAIN EXISTING VALLEY FORM.
VEGETATED 2 m BASE WITH DENSE SEDGES AND RUSHES.
1 m DEEP (MIN).
EXISTING BATTERS (1 IN 8 TYPICALLY).
PLANTED IN LINE WITH RIPARIAN ZONE REQUIREMENTS TO A TOTAL SWALE WIDTH OF 10 METRES.
WEIR TO CONTROL DETENTION WITHIN W2B. TO BE DESIGNED
VS2C
VEGETATED SWALE 2C FROM EXTERNAL CATCHMENT
1 m BASE, 0.5 DEEP, 1 IN 5 BATTERS
40 m LONG
VS2D
VEGETATED SWALE 2D
RETAIN EXISTING VALLEY FORM.
VEGETATED 2 m BASE WITH DENSE SEDGES AND RUSHES.
0.5m DEEP (MIN)
EXISTING BATTERS (1 IN 8 TYPICALLY) PLANTED IN LINE WITH RIPARIAN ZONE REQUIREMENTS TO A TOTAL SWALE WIDTH OF 10 METRES.
W2
WETLAND W2
VEGETATE AS EPHEMERAL MARSH - NO PERMANENT WATER
BASE LEVEL = 50.50 m AHD
AREA = 1000 m²
0.5 m ED, 48 HOURS
1V:5H GRASSED BATTERS TO CUTLINE
CUT LINE
RETAIN EXISTING EPHEMERAL WETLAND AREAS AS RECEIVING BODIES (I.E. THESE AREAS ARE NOT INCLUDED IN THE WSUD STRATEGY).
REMOVE EXISTING ARTIFICIAL DAM AND REGRADE TO MATCH VALLEY FLOOR
VS2F (2 SWALES)
VEGETATED SWALES 2F (AS PER VS2C)
VS2A
VEGETATED SWALE 2A
RETAIN EXISTING VALLEY FORM.
VEGETATED 2 m BASE WITH DENSE SEDGES AND RUSHES.
0.5 m DEEP (MIN).
EXISTING BATTERS (1 IN 8 TYPICALLY). PLANTED IN LINE WITH RIPARIAN ZONE REQUIREMENTS TO A TOTAL SWALE WIDTH OF 10 METRES.
VS2B
VEGETATED SWALE 2B
RETAIN EXISTING VALLEY FORM.
VEGETATED 2 m BASE WITH DENSE SEDGES AND RUSHES.
0.5m DEEP (MIN)
EXISTING BATTERS (1 IN 8 TYPICALLY) PLANTED IN LINE WITH RIPARIAN ZONE REQUIREMENTS TO A TOTAL SWALE WIDTH OF 10 METRES.
N
SCALE: 0 8 40 80m
DRAFT FOR COMMENT 1 OCTOBER 2019
REVISION DATE
Stormy Water Solutions
DESIGNED Michael Mag
CHECKED Valerie Mag
AUTHORISED BY
PLAN REF. #
Website: www.stormywater.com.au
Email: stormywater@optusnet.com.au
Phone: (03) 8555 9669
ABN: 95 656 703 998
NEPEAN MEMORIAL PARK
STORMWATER MANAGEMENT PLAN
CATCHMENT 2 ASSETS
CONCEPT DESIGN
SCALE: AS SHOWN
SHEET 3 OF 4
DRAWING No. 1954/SWS/3



TYPICAL SWALE SECTION FOR SMALL CONSTRUCTED SWALES



TYPICAL SWALE SECTION FOR EXISTING DRAINAGE LINES INCORPORATING A SWALE FUNCTION

AFT FOR COMMENT 1 OCTOBER 2019
EVISION DATE

Stormy Water Solutions

DESIGNED	Michael Mag	PLAN REF.	#
CHECKED	Valerie Mag		
AUTHORISED BY			

Website: www.stormywater.com.au
Email: stormywater@optusnet.com.au
Phone: (03) 8555 9669
ABN: 95 656 703 998

NEPEAN MEMORIAL PARK
STORMWATER MANAGEMENT PLAN
TYPICAL SWALE
CROSS SECTIONS

SCALE: AS SHOWN
SHEET 4 OF 4
DRAWING No. 1954/SWS/4

Appendix B Pre-development Hydrologic Modelling

The RORB Runoff Routing Program (Version 6.45) was used to determine the 10, 5, 2 and 1% AEP (10, 20, 50 and 100-year ARI) pre-development design flows originating from the subject site. RORB is a general runoff and stream flow routing program used to calculate flood hydrographs from rainfall and other channel inputs. It subtracts losses from rainfall to produce rainfall excess and routes this through catchment storage to produce the hydrograph.

B.1 Model Descriptions

Two separate RORB models have been developed, one for catchment C1 and one for catchment C2 as defined within Figure B.1.

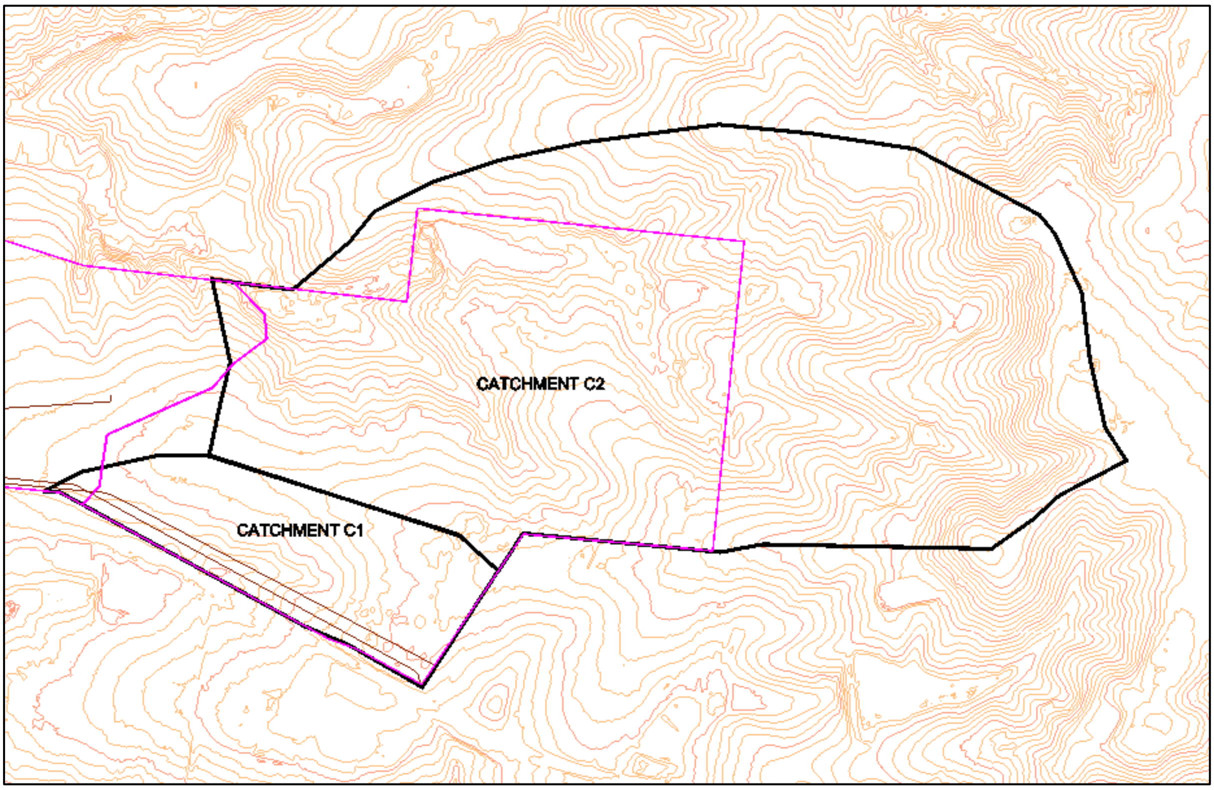


Figure B.1 General Catchment/Model Delineations

Pre-developed catchment delineations are based on 1 m Contour information.

Both Pre-development models use a variety of reach type definitions within RORB. Different reach types in RORB effect the K_r parameter described in Section B.2. Each of the four reach types effect the relative delay time of a reach. A "Drowned" reach type (Type 4) in RORB indicates instantaneous routing from the reach, (i.e. no change to the hydrograph). Generally, flow across fairways is modelled as "Excavated/Unlined" (Type 2) reaches. This represents flow over short mown grass. "Natural" (Type 1) reaches are largely used for creeks in their natural state and vegetated systems. "Piped" (Type 3) are not used within the pre-development models.

B.1.1 Catchment C1

Figure B.2 details the RORB model for the pre-development conditions and Tables B.1 and B.2 detail the tabulation of the RORB model setup (i.e. catchment area, fraction imperviousness, reach lengths, etc).

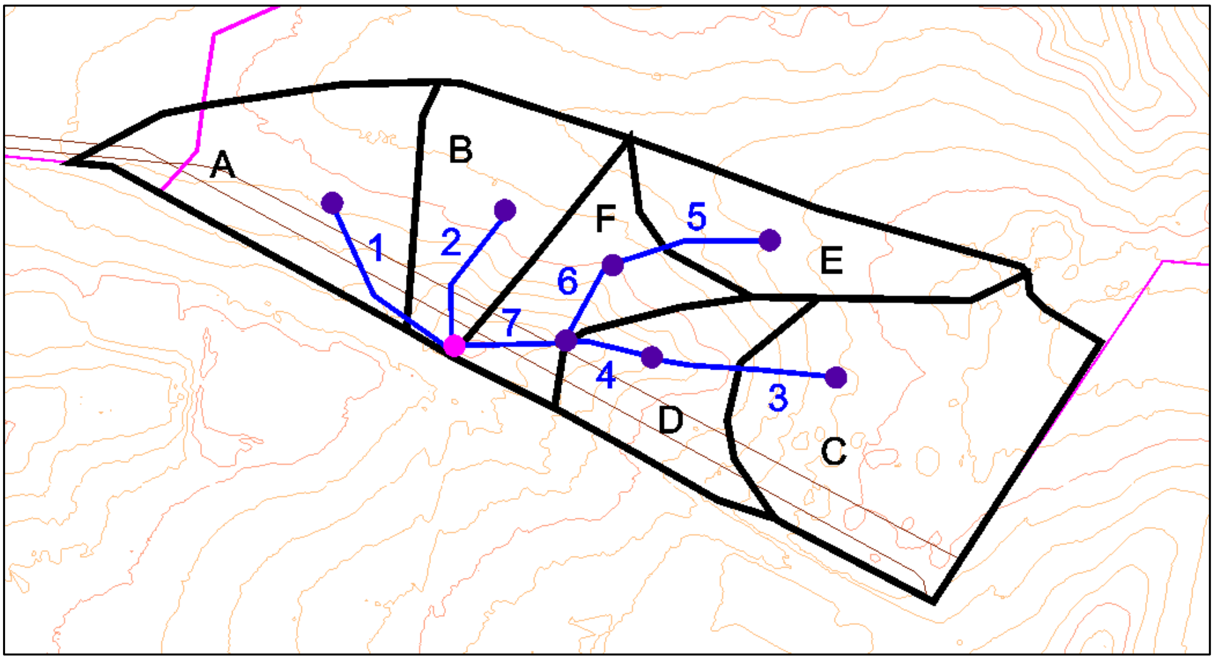


Figure B.2 Pre-development RORB model schematic for Catchment C1

Table B.1 Pre-development C1 sub-catchment definition

Sub Area	Area (ha)	Area (km²)	F_{imp} - Pre-development
A	1.02	0.0102	0.10
B	0.75	0.0075	0.10
C	1.64	0.0164	0.10
D	0.63	0.0063	0.10
E	0.67	0.0067	0.10
F	0.58	0.0058	0.10
TOTAL	**5.28**	**0.0528**	**0.10**

Table B.2 Pre-development C1 reach definitions

Reach	Length (km)	Slope (%)	Reach Type
1	0.092	4.3%	2
2	0.072	7.6%	2
3	0.087	6.9%	2
4	0.047	3.2%	2
5	0.070	4.3%	2
6	0.043	4.7%	2
7	0.055	2.7%	2

Note: RORB reach type numbers correspond to:

1 = Natural Reach

2 = Ex/Unlined Reach (mown grass)

3 = Piped Reach

4 = Drowned Reach

B.1.2 Catchment C2

Figure B.3 details the RORB model for the pre-development conditions and Tables B.3 and B.4 detail the tabulation of the RORB model setup (i.e. catchment area, fraction imperviousness, reach lengths, etc).

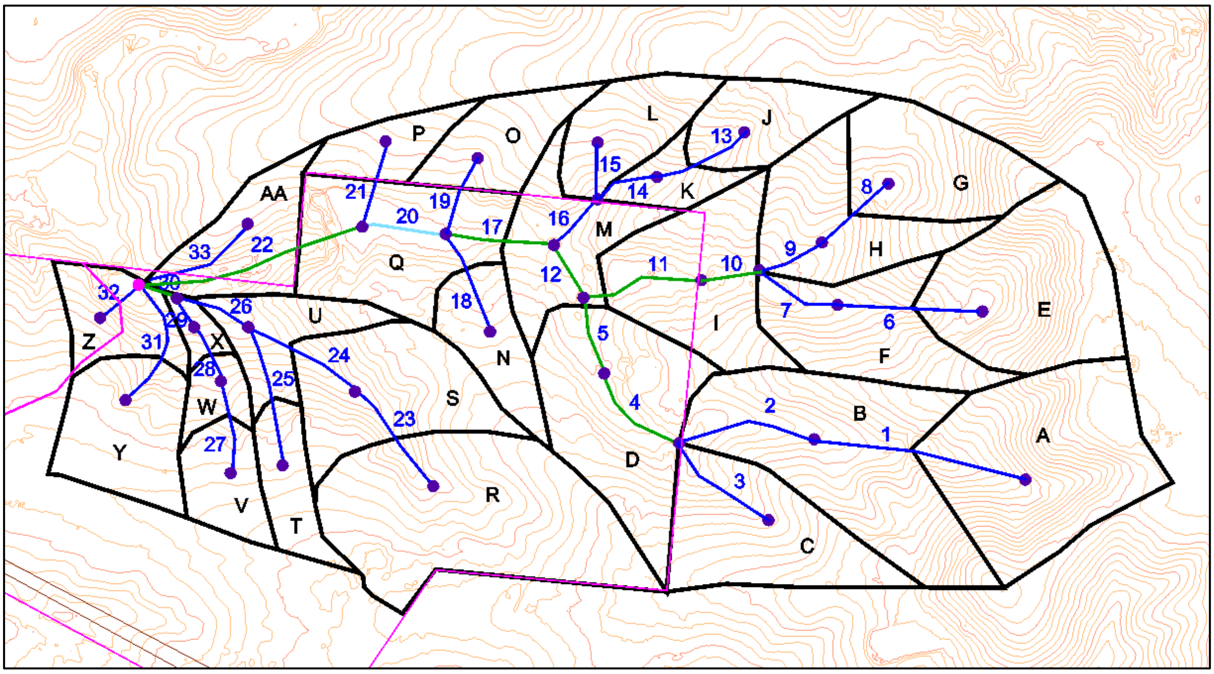


Figure B.2 Pre-development RORB model schematic for Catchment C2

Table B.3 Pre-development C2 sub-catchment definition

Sub Area	Area (ha)	Area (km^2)	F_{imp} - Pre-development
A	2.65	0.0265	0.10
B	2.76	0.0276	0.10
C	1.66	0.0166	0.10
D	2.14	0.0214	0.10
E	2.08	0.0208	0.10
F	1.47	0.0147	0.10
G	1.39	0.0139	0.10
H	1.35	0.0135	0.10
I	1.67	0.0167	0.10
J	0.85	0.0085	0.10
K	0.42	0.0042	0.10
L	0.89	0.0089	0.10
M	1.15	0.0115	0.10
N	0.78	0.0078	0.10

Sub Area	Area (ha)	Area (km^2)	F_{imp} - Pre-development
O	0.83	0.0083	0.10
P	0.55	0.0055	0.10
Q	1.79	0.0179	0.10
R	3.10	0.0310	0.10
S	1.65	0.0165	0.10
T	0.61	0.0061	0.10
U	0.78	0.0078	0.10
V	0.65	0.0065	0.10
W	0.33	0.0033	0.10
X	0.19	0.0019	0.10
Y	1.24	0.0124	0.10
Z	0.75	0.0075	0.10
AA	1.00	0.0100	0.10
TOTAL	**34.7**	**0.3472**	**0.10**

Table B.4 Pre-development C2 reach definition

Reach	Length (km)	Slope (%)	Reach Type
1	0.189	5.3%	2
2	0.124	4.0%	2
3	0.107	7.5%	2
4	0.093	3.2%	1
5	0.067	3.0%	1
6	0.124	6.5%	2
7	0.078	3.8%	2
8	0.080	7.5%	2
9	0.056	5.4%	2
10	0.054	3.7%	1
11	0.110	3.6%	1
12	0.054	1.8%	1
13	0.090	7.8%	2
14	0.056	5.3%	2
15	0.048	10.4%	2
16	0.056	5.4%	2
17	0.093	2.1%	1
18	0.094	6.4%	2
19	0.073	6.9%	2
20	0.073	0.0%	4
21	0.077	6.5%	2
22	0.204	3.9%	1
23	0.106	5.7%	2
24	0.110	3.6%	2
25	0.127	8.7%	2
26	0.070	2.9%	2
27	0.084	8.3%	2
28	0.051	9.8%	2
29	0.030	3.3%	2
30	0.033	3.0%	1
31	0.124	8.1%	2
32	0.045	15.6%	2
33	0.111	6.3%	2

Note: RORB reach type numbers correspond to:

1 = Natural Reach (natural creek or vegetated systems)

2 = Ex/Unlined Reach (mown grass/paddocks)

3 = Piped Reach

4 = Drowned Reach (Existing Dam)

B.2 Model Parameters

RORB is based on the following equation relating storage (S) and discharge (Q) of a watercourse:

$S = k \times Q^m$ where $k = K_c \times K_r$

The values of K_c and m are parameters that can be obtained by calibration of the model using corresponding sets of data on rainfall for selected historical flows. If historical flows are unknown, values can be estimated from regional analysis or by values suggested by Australian Rainfall & Runoff (ARR). The value of k_r is a physical parameter related to the reach type chosen by the modeller which is automatically calculated by RORB.

In this case, flow gauging information was not available. However, a regional parameter set (recommended by AR&R 2019) is applicable. The K_c parameter for each used is as detailed in AR&R, Book 7, Chapter 6, Equation 7.6.11 for New South Wales catchments east of the Great Dividing Range.

$K_c = 1.18 \times A^{0.47}$

$m \ = 0.8$

Other parameters of RORB are the initial loss (IL) and the continuing loss (CL). IL is the amount of rainfall needed before runoff occurs. As much of the existing is pervious, the use of a CL rather than a pervious area runoff coefficient is appropriate. IL and CL values obtained from the ARR 2019 datahub for the location 33.866 S, 150.653 E are:

- $IL_{storm} = 46\ mm$
- $CL_{storm} = 3.4\ mm \ \times 40\% = 1.36\ \mathrm{mm/hr}$

The ARR 2019 data hub (location: 33.866S, 150.653 E) accessed: 16th September 2019 was also used to extract rainfall depths, burst rainfall temporal patterns (for 24 durations ranging from 10-minutes to 168-hours) and areal reduction factors which have been used in the modelling.

Following the methodology of 'NSW specific data' in the ARR2019 datahub, this modelling exercise falls into Approach 5. That is, the ARR2019 losses, with a factor of 40% applied to the CL and the probability natural pre-bursts applied to the IL will be utilised. The probability natural pre-bursts for each AEP vary with duration. However, for simplicity in the modelling, and given the expected critical durations within the catchments, being representative probability neutral pre-burst of a 90-minute storm has been used (across all durations). Thus, the utilised model Initial loss parameters are detailed in Table B.5 below.

Table B.5 Adopted Initial Loss Parameters

AEP:	10%	5%	2%	1%
IL_{Storm} (mm) =	46.0	46.0	46.0	46.0
$IL_{pre\text{-}burst}$ (mm) =	14.3	15.0	14.4	13.3
Adopted IL_{burst} (mm) = IL_{Storm} - $IL_{pre\text{-}burst}$ =	**31.7**	**31.0**	**31.6**	**32.7**
Adopted IL_{burst} (mm)[1.]	**31.0**			

Note: [1.] Given all values are similar, the most conservative value has been adopted.

The effective impervious area (EIA) and indirectly connected area (ICA) surface type splitting's recommended in ARR 2019 have not been used. In both the pre and post-development modelling, the land use is relatively consistent. The EIA and ICA concepts introduce an additional complexity into the modelling, which given the many uncertainties with these estimates, may not produce better final design outcomes. Modelling without EIA and ICA (and modelling all impervious areas as directly connected) will likely produce conservative results (i.e. higher flows and volumes) (Chapter 5.3.4.1.2, Book 5, ARR 2019).

B.3 Model Sensitivity

To check whether the assumption of applying the 90-minute probability neutral pre-bursts to all durations is valid, a sensitivity check has been performed. Typically, the probability neutral pre-bursts between the 60-minute duration and the 180-minute durations vary between ± 2 mm of the 90-minute value.

As such, a sensitivity analysis has been conducted on the 1% AEP and 10% AEP flow estimates. It was found that varying the $IL_{pre\text{-}burst}$ by ± 2 mm had negligible effects on the flows calculated, only varying the flows by typically ± 0.1 m^3/s. Given the significantly larger uncertainties in flow estimation associated with the temporal patterns and rainfall, the $IL_{pre\text{-}burst}$ assumption is deemed appropriate.

B.4 Model Validation

It is required to check the estimated flows against other flow calculation methods to ensure the RORB model developed is valid for application. To achieve this check design flows have been compared to flows generated by the Probabilistic Rational Method (utilising the 2019 IFD's). The Probabilistic Rational Method has been chosen as the validation model given the catchment size is too small for use within the RFFE (i.e. less than 1 km^2). The comparison of the methods for both catchments is provided in Tables B.6 and B.7 below. Overall, the RORB model is providing a reasonable estimate of the flows.

Table B.6 C1 RORB Model Validation

AEP	10%	5%	2%	1%
RORB	0.7	1.0	1.2	1.5
Rational[1.]	0.5	0.6	0.8	0.9

Note: [1.] C_5 of 0.25, t_c of 10 min

Table B.7 C2 RORB Model Validation

AEP	10%	5%	2%	1%
RORB	2.1	2.8	3.7	4.5
Rational[1.]	2.2	2.8	3.6	4.3

Note: 1. C_5 of 0.25, t_c of 20 min

B.4 Model Results

The models have been simulated for the 1% AEP, 2% AEP, 5% AEP and 10% AEP storm events using the full ensembles of 240 temporal patterns as required in ARR 2019. The calculated flows at the catchment outlet from these simulations are provided in Table B.8.

Table B.8 Pre-Development RORB Flow Estimates

AEP	Catchment C1		Catchment C2	
	Q[1.] (m^3/s)	Critical Duration	Q[1.] (m^3/s)	Critical Duration
10%	0.7	1-hour	2.1	2-hour
5%	1.0	1-hour	2.8	2-hour
2%	1.2	45-minute	3.7	1.5-hour
1%	1.5	25-minute	4.5	1.5-hour

Notes: 1. Taken as the peak average flow for the ensembles of temporal patterns.

Appendix C Post-Development Hydrologic Modelling

C.1 Model Descriptions

The same general catchment ID's (C1 and C2) as per Appendix B (specifically relating Figure B.1) are retained in the post-development models.

Catchment areas vary slightly from predevelopment conditions given:

- The proposed road and drainage layout proposed by WS&P, and
- The fact that the catchment for Model 1 is increased slightly due to Swale 1C capturing burial areas draining towards the golf course and bring this flow back into Catchment 1.

All models have been formulated assuming the September 2019 proposed site layout formulated by the project team and is subject to change given the final development layout.

Generally, flow across burial areas are modelled as "Excavated/Unlined" reaches. This represents flow over short mown grass. "Piped" Reaches are used in areas where WS&P have allocated pipe system conveyance. "Natural" reaches are largely used for creeks in their natural state, and or proposed heavily vegetated swale system (as per the WSUD strategy).

C.1.1 Catchment C1

Figure C.1 details the RORB model for the post-development conditions and Tables C.1 and C.2 detail the tabulation of the RORB model setup (i.e. catchment area, fraction imperviousness, reach lengths, etc).

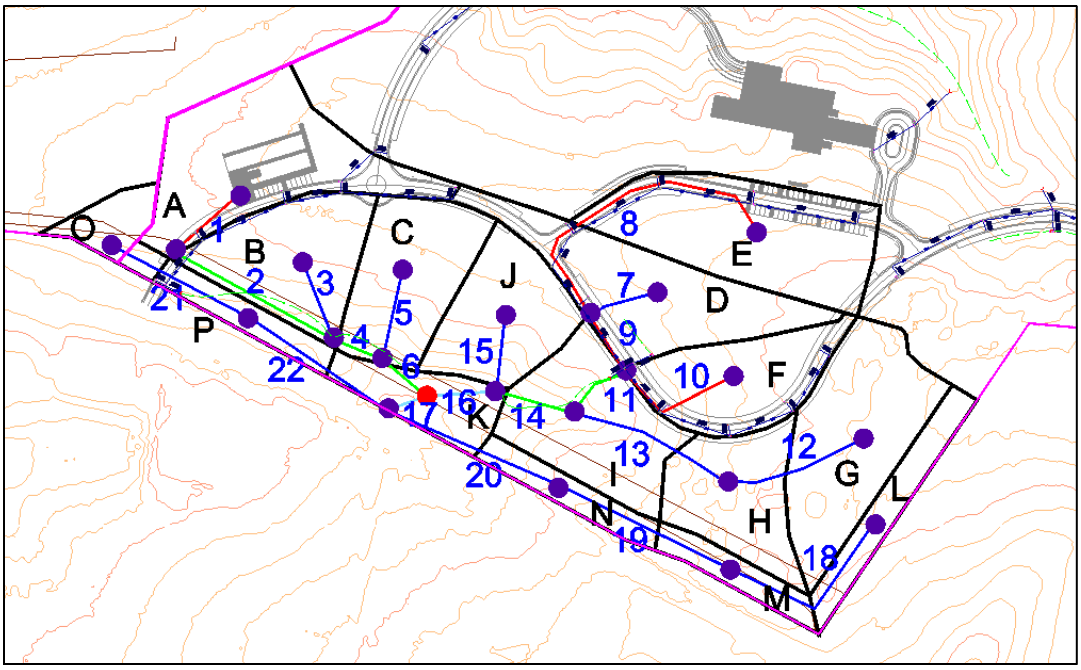


Figure C.1 Post-development RORB model schematic for Catchment C1

Table C.1 Post-development C1 sub-catchment definition

Sub Area	Area (ha)	Area (km^2)	F_{imp} - Post-development
A	0.71	0.0071	0.45
B	0.47	0.0047	0.25
C	0.46	0.0046	0.25
D	0.61	0.0061	0.45
E	0.69	0.0069	0.45
F	0.42	0.0042	0.52
G	0.63	0.0063	0.25
H	0.40	0.0040	0.25
I	0.53	0.0053	0.25
J	0.41	0.0041	0.25
K	0.24	0.0024	0.25
L	0.21	0.0021	0.00
M	0.13	0.0013	0.00
N	0.15	0.0015	0.00
O	0.15	0.0015	0.00
P	0.15	0.0015	0.00
TOTAL	**6.35**	**0.0635**	**0.30**

Table C.2 Post-development C1 reach definitions

Reach	Length (km)	Slope (%)	Reach Type
1	0.043	3.5%	3
2	0.093		1
3	0.043	4.7%	2
4	0.026		1
5	0.047	8.5%	2
6	0.029		1
7	0.037	4.1%	2
8	0.170	1.5%	3
9	0.033	0.6%	3
10	0.069	4.3%	3
11	0.036		1
12	0.073	2.7%	2
13	0.086	7.0%	2
14	0.041		1
15	0.039	10.3%	2
16	0.034		4
17	0.021		4
18	0.101	1.0%	2
19	0.099	4.0%	2
20	0.098	5.6%	2
21	0.081	1.8%	2
22	0.084	3.0%	2

Note: RORB reach type numbers correspond to:

1 = Natural Reach (vegetated swales)

2 = Ex/Unlined Reach (sheet flow from burial areas)

3 = Piped Reach (WS&P pipes)

4 = Drowned Reach (proposed pond RBP1)

C.1.2 Catchment C2

Figure C.2 details the RORB model for the post-development conditions and Tables C.3 and C.4 detail the tabulation of the RORB model setup (i.e. catchment area, fraction imperviousness, reach lengths, etc).

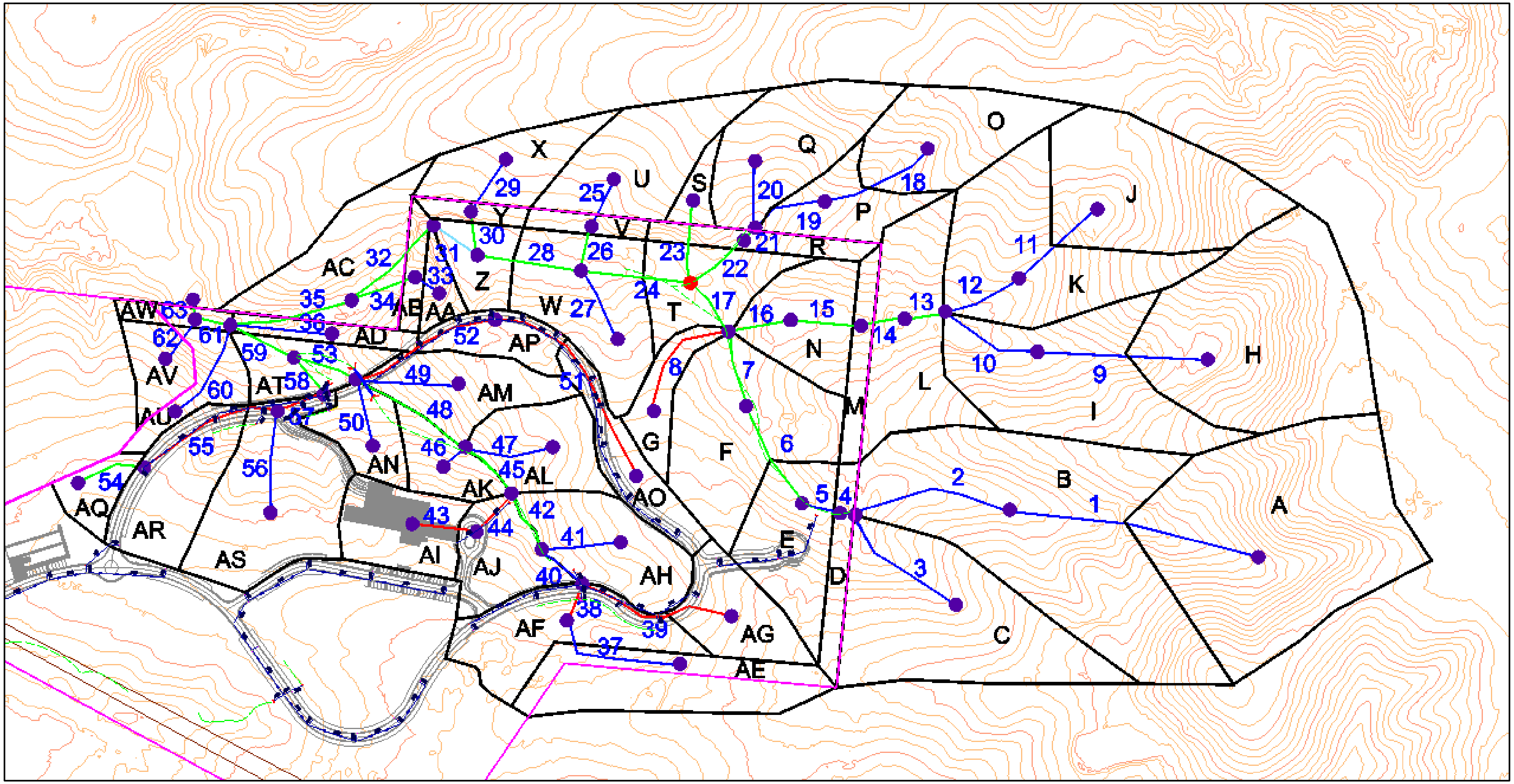


Figure C.2 **Post-development RORB model schematic for Catchment C2**

Table C.1 Post-development C1 sub-catchment definition

Sub Area	Area (ha)	Area (km^2)	F_{imp} - Post-development
A	2.65	0.0265	0.10
B	2.76	0.0276	0.10
C	1.66	0.0166	0.10
D	0.24	0.0024	0.00
E	0.72	0.0072	0.25
F	1.25	0.0125	0.25
G	0.30	0.0030	0.25
H	2.08	0.0208	0.10
I	1.47	0.0147	0.10
J	1.39	0.0139	0.10
K	1.35	0.0135	0.10
L	0.97	0.0097	0.10
M	0.24	0.0024	0.00
N	0.62	0.0062	0.25
O	0.85	0.0085	0.10
P	0.44	0.0044	0.10
Q	0.90	0.0090	0.10
R	0.25	0.0025	0.00
S	0.13	0.0013	0.10
T	0.56	0.0056	0.10
U	0.84	0.0084	0.10
V	0.14	0.0014	0.00
W	0.94	0.0094	0.20
X	0.54	0.0054	0.10
Y	0.12	0.0012	0.00

Sub Area	Area (ha)	Area (km^2)	F_{imp} - Post-development
Z	0.32	0.0032	0.20
AA	0.15	0.0015	0.25
AB	0.14	0.0014	0.00
AC	0.87	0.0087	0.10
AD	0.21	0.0021	0.00
AE	0.94	0.0094	0.10
AF	0.80	0.0080	0.39
AG	0.53	0.0053	0.31
AH	0.73	0.0073	0.25
AI	0.55	0.0055	0.90
AJ	0.48	0.0048	0.47
AK	0.32	0.0032	0.25
AL	0.55	0.0055	0.25
AM	0.59	0.0059	0.10
AN	0.15	0.0015	0.31
AO	0.45	0.0045	0.51
AP	0.33	0.0033	0.25
AQ	0.22	0.0022	0.15
AR	0.71	0.0071	0.45
AS	1.17	0.0117	0.33
AT	0.40	0.0040	0.00
AU	0.32	0.0032	0.10
AV	0.28	0.0028	0.00
AW	0.13	0.0013	0.00
TOTAL	**34.7**	**0.3471**	**0.17**

Table C.2 Post-development C1 reach definitions

Reach	Length (km)	Slope (%)	Reach Type
1	0.189	5.3%	2
2	0.124	4.0%	2
3	0.107	7.5%	2
4	0.009	5.6%	2
5	0.029	3.4%	2
6	0.083		1
7	0.057		1
8	0.092	7.1%	3
9	0.124	6.5%	2
10	0.078	3.8%	2
11	0.080	7.5%	2
12	0.056	5.4%	2
13	0.032		1
14	0.030		1
15	0.049		1
16	0.044		1
17	0.045		1
18	0.090	7.8%	2
19	0.056	6.3%	2
20	0.048	10.4%	2
21	0.010		1
22	0.051		1
23	0.062		1
24	0.080		1
25	0.040	10.0%	2
26	0.034		1
27	0.057	7.0%	2
28	0.078		1
29	0.048	8.3%	2
30	0.034		1
31	0.041		4
32	0.083		1

Reach	Length (km)	Slope (%)	Reach Type
33	0.023	13.0%	2
34	0.050		1
35	0.095		1
36	0.076	2.6%	2
37	0.103	3.4%	2
38	0.029	5.2%	3
39	0.120	6.7%	3
40	0.040	7.5%	2
41	0.058	10.3%	2
42	0.048		1
43	0.048	2.1%	3
44	0.040	12.5%	3
45	0.047		1
46	0.021	11.9%	2
47	0.068	8.8%	2
48	0.094		1
49	0.074	9.5%	2
50	0.050	9.0%	2
51	0.166	2.7%	3
52	0.113	8.4%	3
53	0.065		1
54	0.049		1
55	0.110	7.3%	3
56	0.076	9.9%	2
57	0.037	4.1%	3
58	0.034		1
59	0.054		1
60	0.080	12.5%	2
61	0.025		1
62	0.032	18.8%	2
63	0.014		1

Note: RORB reach type numbers correspond to:

1 = Natural Reach (vegetated swales)

2 = Ex/Unlined Reach (sheet flow from burial areas)

3 = Piped Reach (WS&P pipes)

4 = Drowned Reach (proposed pond RBP1)

C.2 Model Parameters

The same parameters as per Appendix B.2 have been utilised, however, to ensure consistency between the model comparisons, the K_c values in the post-development models have been scaled to ensure that the ratio of K_c/d_{av} for both scenarios is consistent. This is as recommended in the RORB manual for the same catchment modelled with different reach types and lengths). Table C.5 below details the adopted parameter set.

Table C.5 Adopted Post-development Parameter set

Model	K_c - Pre	d_{av} - Pre (km)	d_{av} - Post (km)	K_c - Post	m	IL_{burst} (mm)	CL (mm/hr)
C1	0.30	0.13	0.18	0.41	0.8	31	1.36
C2	0.72	0.48	0.55	0.82	0.8	31	1.36

C.3 Model Retarding Basin/Detention Basins

In order to retard to the peak post-development 10, 5, 2 and 1% AEP (10, 20, 50 and 100-year ARI) flows to less than the peak pre-development flow rates, one detention (retarding) basin has been designed for each catchment. The two retarding basins are WLRB1 and RBP2. Both basins are intended to be dual purpose assets which also provide water quality and/or landscape benefits.

The location of WLRB1 and RBP2 are as shown in the SWMP drawings.

As the design progresses (and the outlets to each basin designed), care should be taken to reflect the below stage vs storage vs discharge (SSD) relationships in Tables C.6 and C.7 as much as possible. That is, the detailed design process should incorporate outlet culvert systems which ensure the outflows as the stated heads occur in each system.

Table C.6 Wetland/Retarding Basin 1 (C1) SSD relationship for WLRB1

Stage (m AHD)	Storage (m^3)	Discharge (m^3/s)
49.50	0	0
50.10	705	0.003
50.20	853	0.21
50.30	1010	0.30
50.40	1177	0.42
50.60	1540	0.75
51.00	2385	1.00

Table C.7 Wetland/Retarding Basin 2 (C2) SSD relationship for RBP!

Stage (m AHD)	Storage (m^3)	Discharge (m^3/s)
50.00	0	0.00
50.25	999	0.41
50.50	2101	1.13
50.75	3059	2.01
51.00	4355	3.00
51.25	5999	4.05

C.4 Model Results

The models have been simulated for the 1% AEP, 2% AEP, 5% AEP and 10% AEP storm events using the full ensembles of 240 temporal patterns as required in ARR 2019. The calculated flows at the catchment outlet from these simulations are provided in Table C.8 and C.9.

Table C.8 Post and Pre-development RORB Results for Catchment C1 at WLRB1 Outlet

AEP	ARI	Pre-development		Post-development	
		Q[1.] (m^3/s)	Duration	Q[1.] (m^3/s)	Duration
10%	**10-Year**	0.7	1-hour	0.35	2-hour
5%	**20-Year**	1.0	1-hour	0.50	2-hour
2%	**50-Year**	1.2	45-minute	0.65	1.5-hour
1%	**100-Year**	1.5	25-minute	0.80	1.5-hour

Notes: [1.] Taken as the peak average flow for the ensembles of temporal patterns rounded up to the nearest 0.05 m^3/s for the post-development scenario.

Table C.9 Post and Pre-development RORB Results for Catchment C2 at Site Outlet

AEP	ARI	Pre-development		Post-development	
		Q[1.] (m^3/s)	Duration	Q[1.] (m^3/s)	Duration
10%	**10-Year**	2.1	2-hour	1.55	4.5-hour
5%	**20-Year**	2.8	2-hour	2.00	3-hour
2%	**50-Year**	3.7	1.5-hour	2.70	2-hour
1%	**100-Year**	4.5	1.5-hour	3.30	2-hour

Notes: [1.] Taken as the peak average flow for the ensembles of temporal patterns rounded up to the nearest 0.05 m^3/s for the post-development scenario.

As can be seen from the above, WLRB1 and RBP2 are able to retard all peak post-development flows to well below the peak pre-development flow rates for the 10, 5, 2 and 1% AEP events.

Optimisation of the retardation basin designs has not occurred, as the system sizes are generally required to ensure the WSUD stormwater treatment objectives can be met. That is, the system footprint is set by the wetland requirement within the site, not the flood storage requirement.

Table C.10 has been provided to assist WS&P with their internal drainage system design in regard to understanding flood levels at the pipe outfall points. The 1% AEP and 5% AEP conceptual flood levels shown in Table C.10 have been produced at each detention basin. These levels are conceptual only and may change as the design progresses.

Detention Basin	Flood Level Estimate[1] (m AHD)	
	1% AEP	5% AEP
WLRB1n	50.55	50.40
RBP1	50.90	50.70

Table C.10 Conceptual flood level estimates within the detention basins.

Notes: [1] All flood levels are estimates only and have been rounded up to the nearest 0.05 m AHD.

In addition to the above 5% AEP (20-year ARI) flows have been produced at critical swale locations to ensure the vegetated swales have sufficient capacity. The locations of these flows are shown in Figure C.2, with the associated flows reported in Table C.11.

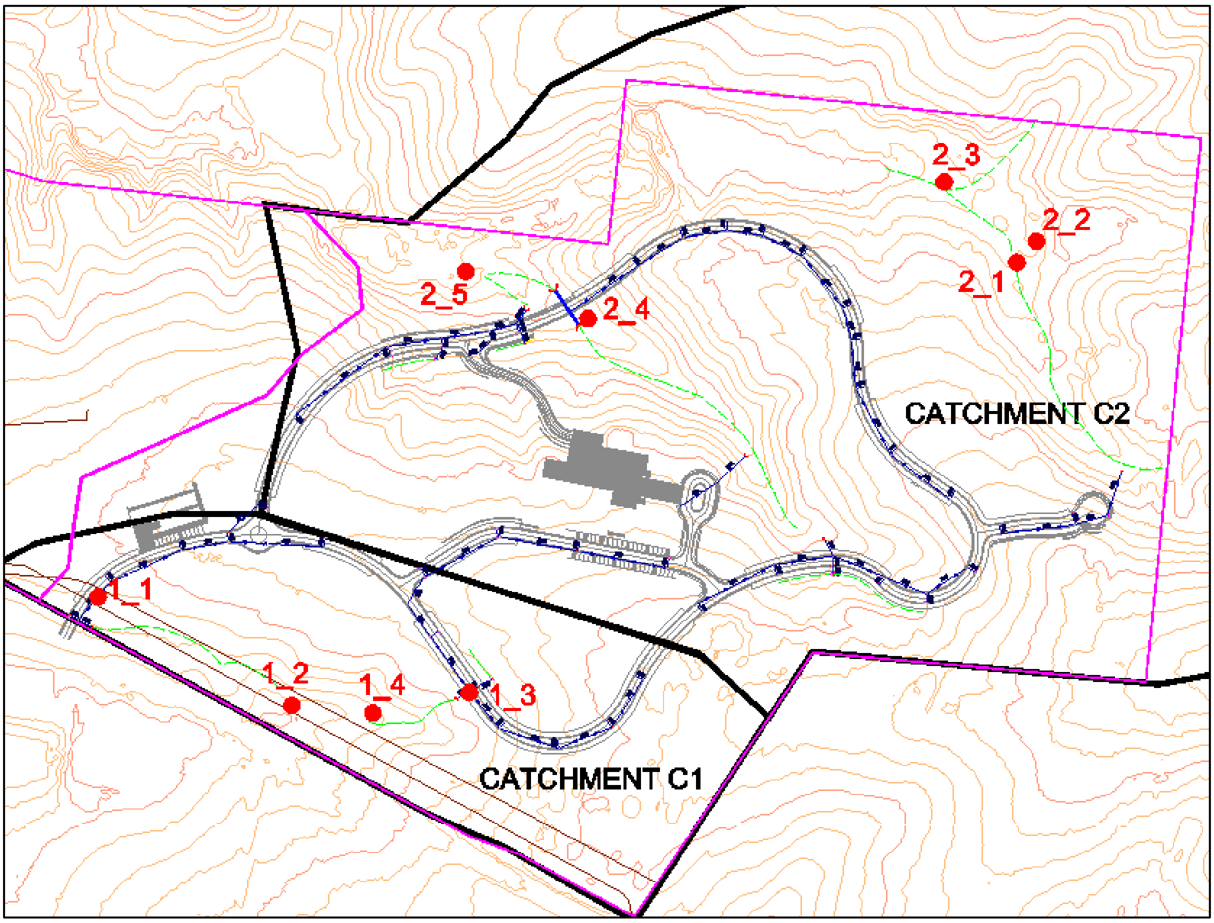


Figure C.2 Swale Flow Point ID's Locations

Table C.11 5% AEP Swale Flows

Flow ID	$Q_{5\%AEP}$[1.] (m^3/s)	Critical Duration
1_1	0.25	20-minute
1_2	0.25	1-hour
1_3	0.50	20-minute
1_4	0.60	1-hour
2_1	1.15	1-hour
2_2	1.10	1-hour
2_3	2.40	1-hour
2_4	0.65	1-hour
2_5	1.05	1-hour

Notes: [1.] Taken as the peak average flow for the ensembles of temporal patterns rounded up to the nearest 0.05 m^3/s for the post-development scenario.

Appendix D Stormwater Pollutant Modelling

The water quality objectives are detailed below.

- 90% reduction in the post development mean annual load total gross pollutant (greater than 5mm);
- 85% reduction in the post development mean annual load of Total Suspended Solids (TSS);
- 60% reduction in the post development mean annual load of Total Phosphorus (TP);
- 45% reduction in the post development mean annual load of Total Nitrogen (TN);

D.1 MUSIC Model Description

The performance in regard to stormwater pollutant retention of the wetland system was analysed using the MUSIC model, Version 6.3.0.

D.1.1 Rainfall and Evaporation Data

Bureau of Meteorology rainfall and evaporation data as required under the MUSIC-link requirements for Penrith have been used (Penrith rainfall and evaporation 1999 – 2008 at 6-minute intervals). This data set resulted in an annual rainfall of 691 mm/yr and an average annual evaporation of 1158 mm/yr.

D.1.2 Treatment Element Models

The modelled wetland elements are as detailed in Section 4 of this report. The concept design drawings were used to estimate the swale lengths, wetland normal water level areas and wetland top of extended detention level areas. The "average" area used to model "water stored for treatment" was taken as the average of the normal water level (NWL) and top of extended detention (TED). All wetlands incorporate an extended detention period of greater than 48 hours (to be consistent with the Council MUSIC requirements).

Buffers are modelled as described in Section 4 of this report. In catchments where there are some roads, roofs etc., up to 20% of the catchment may be directly connected to a pipe. In this situation it is assumed that 80% of the catchment is buffered and the buffer area is assumed to be 50% of the upstream impervious area. In catchments only exhibiting burials, none of the catchment will be directly connected to a pipe system, and as such 100% of the catchment is assumed to be buffered and the buffer area is assumed to be 50% of the upstream impervious area. Both of these assumptions are considered conservative in this application in regard to accounting for burial areas being disconnected from the drainage system.

D.1.3 Catchment Models

Subareas and fraction imperviousness are as detailed in the post development RORB Model (Appendix C).

Sub areas are subject to change given the final development layout, however, provided the criteria of directing as much catchment as possible to (or close to) the defined inlet locations is adhered to, the final MUSIC results are not expected to change significantly. Figures D.1 and D.2 detail the MUSIC models developed.

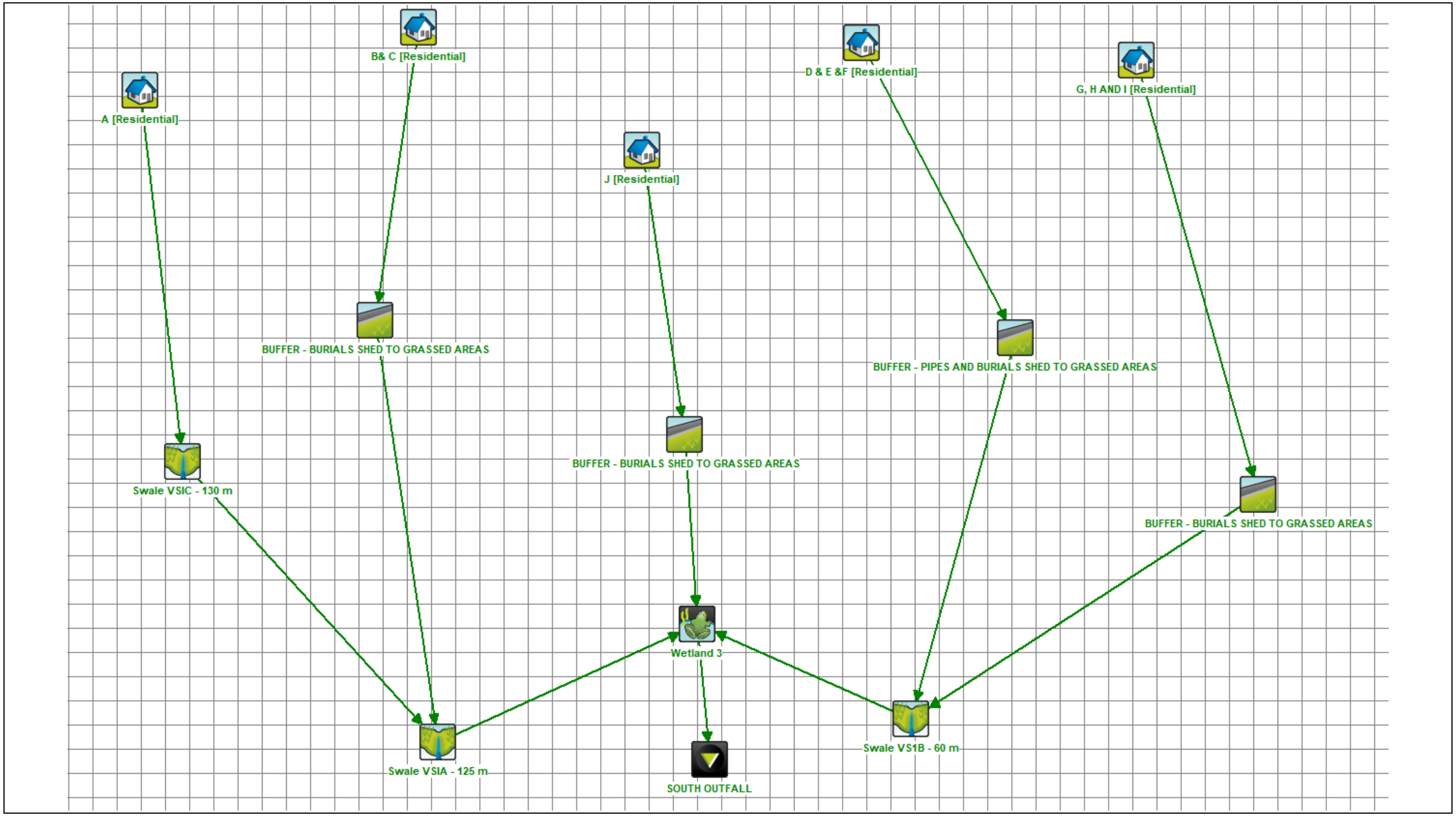


Figure D.1 MUSIC Model Catchment 1

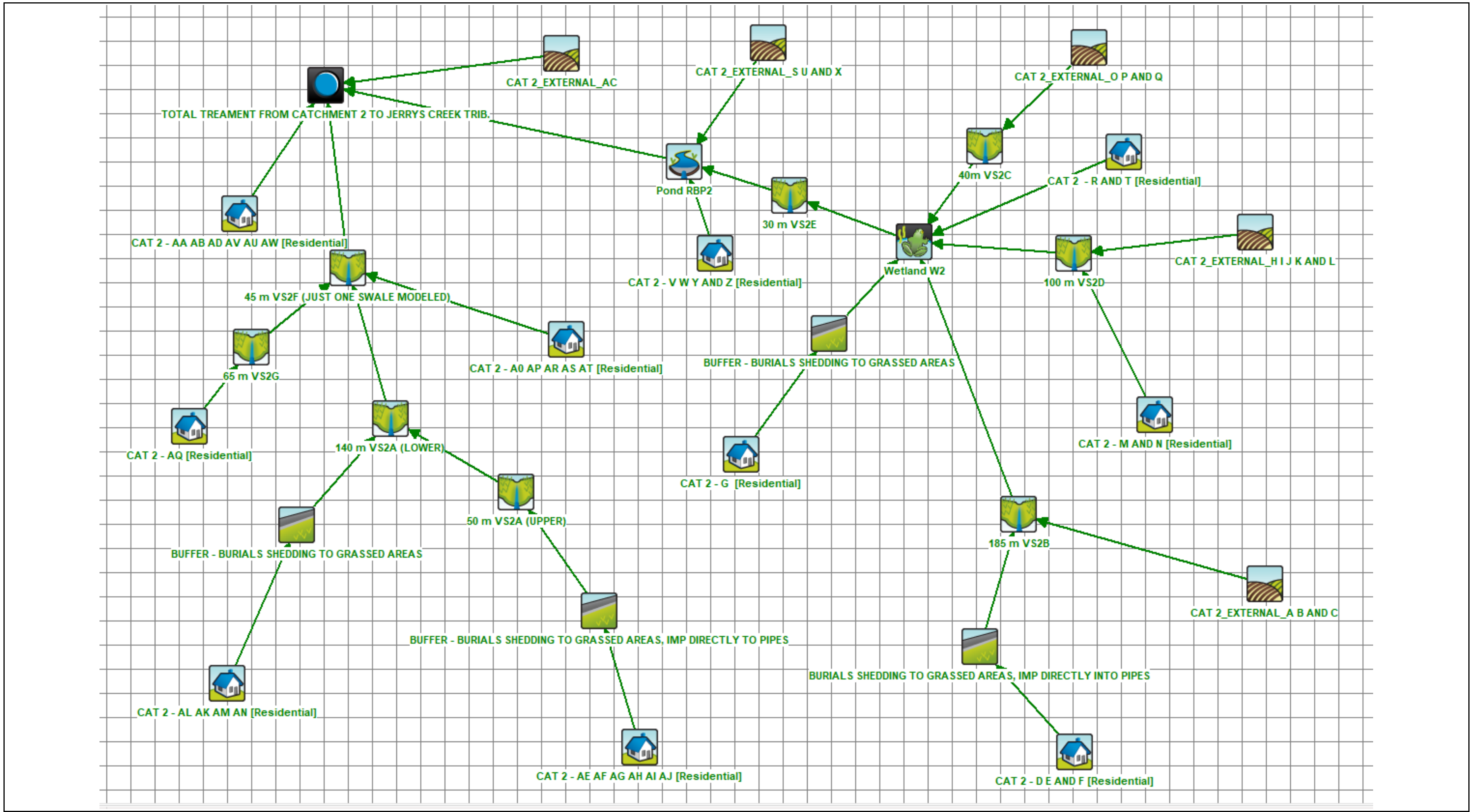


Figure D.2 **MUSIC Model Catchment 2**

Note: Swale treatment may be underestimated in this model. That is, more flow may ultimately be conveyed in swales than has been modelled. If this is the case, then the overall system stormwater treatment in this model will be considered conservative (that is, more treatment will ultimately occur.

D.2 MUSIC Pollutant Modelling Results.

D.2.1 Catchment 1 MUSIC Results

The catchment 1 MUSIC results are detailed below.

	Sources	Residual Load	% Reduction
Flow (ML/yr)	14.2	12.8	9.7
Total Suspended Solids (kg/yr)	2500	162	93.5
Total Phosphorus (kg/yr)	4.05	1.1	72.8
Total Nitrogen (kg/yr)	30.5	16.8	45
Gross Pollutants (kg/yr)	476	0	100

As detailed, the current best practice requirements of 90% gross pollutants, 85% TSS, 60% TP and 45% TN retention can be met by the proposed WSUD initiatives in Catchment 1.

D.2.2 Catchment 2 MUSIC Results

The catchment 2 MUSIC results are detailed below. It should be noted that the MUSIC results were exported into excel to determine the equivalent treatment of the subject development area. The Vegetated Swales VS2B, VS2C, VS2D, VS2E, Pond RBP2 and Wetland W2 all treat external catchments. This external catchment treatment does not occur currently due to:

- All drainage lines incorporating short mown grass with very little pollutant retention capacity, and
- The existing dams not incorporating hydraulic controls to detail stormwater for treatment over 48 hours.

Once the swales are vegetated, and the hydraulic control of and Wetland W2 is constructed, the operation of the system will change. These changes will ensure, not only treatment of the subject site flows, but of the external catchments as well. This has been captured in the MUSIC modelling detailed.

Catchment 2 MUSIC Results		
	Pollutant Generated in total Catchment Area	**Pollutants at receiving node to Tributary of Jerrys Creek**
Total Suspended Solids (kg/yr)	10500	2290
Total Phosphorus (kg/yr)	17.7	8.4
Total Nitrogen (kg/yr)	133	95
Gross Pollutants (kg/yr)	1710	47
Pollutant Generated in External Catchments		
Total Suspended Solids (kg/yr)	4540	
Total Phosphorus (kg/yr)	7.6	
Total Nitrogen (kg/yr)	58	
Gross Pollutants (kg/yr)	590	
Pollutant Generated in Subject Site		
Total Suspended Solids (kg/yr)	5960	
Total Phosphorus (kg/yr)	10.1	
Total Nitrogen (kg/yr)	75	
Gross Pollutants (kg/yr)	1120	
Amount of Pollutants Retained in Catchment 2 WSUD strategy		
Total Suspended Solids (kg/yr)	8210	
Total Phosphorus (kg/yr)	9.4	
Total Nitrogen (kg/yr)	38	
Gross Pollutants (kg/yr)	1663	
% Reduction Compared to Pollutants Generated in the Subject Site		
Total Suspended Solids (%)	138%	
Total Phosphorus (%)	92%	
Total Nitrogen (%)	51%	
Gross Pollutants (%)	148%	

As detailed, the current best practice requirements of 90% gross pollutants, 85% TSS, 60% TP and 45% TN retention can be met by the proposed WSUD initiatives in Catchment 2. In fact, the treatment of external flows (currently not treated) ensures that TSS generated on site is treated to the equivalent of over 100%.

D.3 MUSIC Link Reports.

MUSIC-Link was run for all the models above. In all cases parameters were within the values required by Council under the MUSIC Link checks. As required by Council, the resultant result files are reproduced below.

D.3.1 MUSIC-Link Report – Catchment 1

PENRITH CITY COUNCIL

music@link

MUSIC-*link* Report

Project Details		Company Details	
Project:	Nepean MP SWMP Catchment 1	**Company:**	Stormy Water Solutions
Report Export Date:	23/09/2019	**Contact:**	Valerie Mag
Catchment Name:	NEPEAN MP_CAT 1 _SEPT 2019	**Address:**	1.26 202 Jells Road, Wheelers Hill 3150
Catchment Area:	5.33ha	**Phone:**	0412 436 021
Impervious Area*:	33.96%	**Email:**	val.mag@stormywater.com.au
Rainfall Station:	67113 PENRITH		
Modelling Time-step:	6 Minutes		
Modelling Period:	1/01/1999 - 31/12/2008 11:54:00 PM		
Mean Annual Rainfall:	691mm		
Evapotranspiration:	1158mm		
MUSIC Version:	6.3.0		
MUSIC-link data Version:	6.32		
Study Area:	Penrith		
Scenario:	Penrith Development		

* takes into account area from all source nodes that link to the chosen reporting node, excluding Import Data Nodes

Treatment Train Effectiveness		Treatment Nodes		Source Nodes	
Node: SOUTH OUTFALL	**Reduction**	**Node Type**	**Number**	**Node Type**	**Number**
Flow	9.72%	Wetland Node	1	Urban Source Node	5
TSS	93.5%	Swale Node	3		
TP	72.8%	Buffer Node	4		
TN	45%				
GP	100%				

Comments

PENRITH CITY COUNCIL

music@link

Passing Parameters

Node Type	Node Name	Parameter	Min	Max	Actual
Receiving	SOUTH OUTFALL	% Load Reduction	None	None	9.72
Receiving	SOUTH OUTFALL	GP % Load Reduction	90	None	100
Receiving	SOUTH OUTFALL	TN % Load Reduction	45	None	45
Receiving	SOUTH OUTFALL	TP % Load Reduction	60	None	72.8
Receiving	SOUTH OUTFALL	TSS % Load Reduction	85	None	93.5
Swale	Swale VS1B - 60 m	Bed slope	0.01	0.05	0.04
Swale	Swale VSIA - 125 m	Bed slope	0.01	0.05	0.016
Swale	Swale VSIC - 130 m	Bed slope	0.01	0.05	0.01
Urban	A	Area Impervious (ha)	None	None	0.317
Urban	A	Area Pervious (ha)	None	None	0.392
Urban	A	Total Area (ha)	None	None	0.71
Urban	B& C	Area Impervious (ha)	None	None	0.230
Urban	B& C	Area Pervious (ha)	None	None	0.699
Urban	B& C	Total Area (ha)	None	None	0.93
Urban	D & E &F	Area Impervious (ha)	None	None	0.769
Urban	D & E &F	Area Pervious (ha)	None	None	0.950
Urban	D & E &F	Total Area (ha)	None	None	1.72
Urban	G_ H AND I	Area Impervious (ha)	None	None	0.391
Urban	G_ H AND I	Area Pervious (ha)	None	None	1.168
Urban	G_ H AND I	Total Area (ha)	None	None	1.56
Urban	J	Area Impervious (ha)	None	None	0.101
Urban	J	Area Pervious (ha)	None	None	0.308
Urban	J	Total Area (ha)	None	None	0.41

Only certain parameters are reported when they pass validation

D.3.2 MUSIC-Link Report – Catchment 2

PENRITH
CITY COUNCIL

music@link

MUSIC-*link* Report

Project Details		Company Details	
Project:	Nepean MP - Catchment 2	**Company:**	Stormy Water Solutions
Report Export Date:	25/09/2019	**Contact:**	Valerie Mag
Catchment Name:	NEPEAN MP_CAT 2 _SEPT 2019	**Address:**	1.26 202 Jells Road, Wheelers Hill 3150
Catchment Area:	34.71ha	**Phone:**	0412 436 021
Impervious Area*:	17.10%	**Email:**	val/mag@stormywater.com.au
Rainfall Station:	67113 PENRITH		
Modelling Time-step:	6 Minutes		
Modelling Period:	1/01/1999 - 31/12/2008 11:54:00 PM		
Mean Annual Rainfall:	691mm		
Evapotranspiration:	1158mm		
MUSIC Version:	6.2.1		
MUSIC-link data Version:	6.22		
Study Area:	Penrith		
Scenario:	Penrith Development		

* takes into account area from all source nodes that link to the chosen reporting node, excluding Import Data Nodes

Treatment Train Effectiveness

Node: TOTAL TREAMENT FROM CATCHMENT 2 TO JERRYS CREEK TRIB.	Reduction
Flow	7.79%
TSS	78.1%
TP	52.8%
TN	28.6%
GP	97.2%

Treatment Nodes

Node Type	Number
Buffer Node	4
Swale Node	8
Wetland Node	1
Pond Node	1

Source Nodes

Node Type	Number
Urban Source Node	10
Agricultural Source Node	10

Passing Parameters

Node Type	Node Name	Parameter	Min	Max	Actual
Agricultural	CAT 2_EXTERNAL_AB AND C	Area Impervious (ha)	None	None	0.709
Agricultural	CAT 2_EXTERNAL_AB AND C	Area Pervious (ha)	None	None	6.350
Agricultural	CAT 2_EXTERNAL_AB AND C	Total Area (ha)	None	None	7.06
Agricultural	CAT 2_EXTERNAL_AC	Area Impervious (ha)	None	None	0.087
Agricultural	CAT 2_EXTERNAL_AC	Area Pervious (ha)	None	None	0.782
Agricultural	CAT 2_EXTERNAL_AC	Total Area (ha)	None	None	0.87
Agricultural	CAT 2_EXTERNAL_HIJK AND L	Area Impervious (ha)	None	None	0.729
Agricultural	CAT 2_EXTERNAL_HIJK AND L	Area Pervious (ha)	None	None	6.530
Agricultural	CAT 2_EXTERNAL_HIJK AND L	Total Area (ha)	None	None	7.26
Agricultural	CAT 2_EXTERNAL_OP AND Q	Area Impervious (ha)	None	None	0.220
Agricultural	CAT 2_EXTERNAL_OP AND Q	Area Pervious (ha)	None	None	1.969
Agricultural	CAT 2_EXTERNAL_OP AND Q	Total Area (ha)	None	None	2.19
Agricultural	CAT 2_EXTERNAL_SU AND X	Area Impervious (ha)	None	None	0.150
Agricultural	CAT 2_EXTERNAL_SU AND X	Area Pervious (ha)	None	None	1.349
Agricultural	CAT 2_EXTERNAL_SU AND X	Total Area (ha)	None	None	1.5
Agricultural	Copy of CAT 2_EXTERNAL_AB AND C	Area Impervious (ha)	None	None	0.709
Agricultural	Copy of CAT 2_EXTERNAL_AB AND C	Area Pervious (ha)	None	None	6.350
Agricultural	Copy of CAT 2_EXTERNAL_AB AND C	Total Area (ha)	None	None	7.06
Agricultural	Copy of CAT 2_EXTERNAL_AC	Area Impervious (ha)	None	None	0.087
Agricultural	Copy of CAT 2_EXTERNAL_AC	Area Pervious (ha)	None	None	0.782
Agricultural	Copy of CAT 2_EXTERNAL_AC	Total Area (ha)	None	None	0.87
Agricultural	Copy of CAT 2_EXTERNAL_HIJK AND L	Area Impervious (ha)	None	None	0.729
Agricultural	Copy of CAT 2_EXTERNAL_HIJK AND L	Area Pervious (ha)	None	None	6.530
Agricultural	Copy of CAT 2_EXTERNAL_HIJK AND L	Total Area (ha)	None	None	7.26
Agricultural	Copy of CAT 2_EXTERNAL_OP AND Q	Area Impervious (ha)	None	None	0.220
Agricultural	Copy of CAT 2_EXTERNAL_OP AND Q	Area Pervious (ha)	None	None	1.969
Agricultural	Copy of CAT 2_EXTERNAL_OP AND Q	Total Area (ha)	None	None	2.19
Agricultural	Copy of CAT 2_EXTERNAL_SU AND X	Area Impervious (ha)	None	None	0.150
Agricultural	Copy of CAT 2_EXTERNAL_SU AND X	Area Pervious (ha)	None	None	1.349
Agricultural	Copy of CAT 2_EXTERNAL_SU AND X	Total Area (ha)	None	None	1.5
Pond	Pond RBP2	% Reuse Demand Met	None	None	0
Swale	100 m VS2D	Bed slope	0.01	0.05	0.04
Swale	140 m VS2A (LOWER)	Bed slope	0.01	0.05	0.04
Swale	185 m VS2B	Bed slope	0.01	0.05	0.04
Swale	30 m VS2E	Bed slope	0.01	0.05	0.01
Swale	40m VS2C	Bed slope	0.01	0.05	0.04
Swale	45 m VS2F (JUST ONE SWALE MODELED)	Bed slope	0.01	0.05	0.02
Swale	50 m VS2A (UPPER)	Bed slope	0.01	0.05	0.04
Swale	65 m VS2G	Bed slope	0.01	0.05	0.01
Urban	CAT 2 - R AND T	Area Impervious (ha)	None	None	0.057

Only certain parameters are reported when they pass validation

PENRITH CITY COUNCIL

music link

Node Type	Node Name	Parameter	Min	Max	Actual
Urban	CAT 2 - R AND T	Area Pervious (ha)	None	None	0.752
Urban	CAT 2 - R AND T	Total Area (ha)	None	None	0.81
Urban	CAT 2 - AO AP AR AS AT	Area Impervious (ha)	None	None	1.053
Urban	CAT 2 - AO AP AR AS AT	Area Pervious (ha)	None	None	1.996
Urban	CAT 2 - AO AP AR AS AT	Total Area (ha)	None	None	3.05
Urban	CAT 2 - AA AB AD AV AU AW	Area Impervious (ha)	None	None	0.072
Urban	CAT 2 - AA AB AD AV AU AW	Area Pervious (ha)	None	None	1.147
Urban	CAT 2 - AA AB AD AV AU AW	Total Area (ha)	None	None	1.22
Urban	CAT 2 - AE AF AG AH AI AJ	Area Impervious (ha)	None	None	1.498
Urban	CAT 2 - AE AF AG AH AI AJ	Area Pervious (ha)	None	None	2.531
Urban	CAT 2 - AE AF AG AH AI AJ	Total Area (ha)	None	None	4.03
Urban	CAT 2 - AL AK AM AN	Area Impervious (ha)	None	None	0.327
Urban	CAT 2 - AL AK AM AN	Area Pervious (ha)	None	None	1.292
Urban	CAT 2 - AL AK AM AN	Total Area (ha)	None	None	1.62
Urban	CAT 2 - AQ	Area Impervious (ha)	None	None	0.044
Urban	CAT 2 - AQ	Area Pervious (ha)	None	None	0.175
Urban	CAT 2 - AQ	Total Area (ha)	None	None	0.22
Urban	CAT 2 - D E AND F	Area Impervious (ha)	None	None	0.497
Urban	CAT 2 - D E AND F	Area Pervious (ha)	None	None	1.712
Urban	CAT 2 - D E AND F	Total Area (ha)	None	None	2.21
Urban	CAT 2 - G	Area Impervious (ha)	None	None	0.075
Urban	CAT 2 - G	Area Pervious (ha)	None	None	0.224
Urban	CAT 2 - G	Total Area (ha)	None	None	0.3
Urban	CAT 2 - M AND N	Area Impervious (ha)	None	None	0.154
Urban	CAT 2 - M AND N	Area Pervious (ha)	None	None	0.705
Urban	CAT 2 - M AND N	Total Area (ha)	None	None	0.86
Urban	CAT 2 - V W Y AND Z	Area Impervious (ha)	None	None	0.259
Urban	CAT 2 - V W Y AND Z	Area Pervious (ha)	None	None	1.250
Urban	CAT 2 - V W Y AND Z	Total Area (ha)	None	None	1.51

Only certain parameters are reported when they pass validation

Appendix E Vegetated Swale Design

E.1 Vegetated Swale Form

As detailed below all swales are capable of containing the 5% AEP (20 Year ARI) flow. Crucial to the strategy is to ensure the base of all swales are planted out with dense sedges and rushes. This is crucial to ensuring the flow velocities do not cause erosion of the drainage lines in this relatively steep slope.

The detailed design phase of the project may also consider strategic placement of pools and riffles to minimise swale slope in some locations. However, provided planting occurs as described above, this rockwork is not specifically required in the design.

E.1.1 Small Constructed Vegetated Swales

Vegetated swales VS1A, VS1B, VS1C and VS2G will be small constructed vegetated swales and are proposed to incorporate the following parameters:

- Base width = 1 metre (fully vegetated with sedges and rushes)
- Side Batters = 1(vertical) to 5(horizontal)
- Depth = 0.5 m (0.3 for VS1C and VS2G)
- Top Width = 4 - 6 m
- Longitudinal slope = 1/20 to 1/60 (generally following natural surface slope along the swale).

The typical envisaged form of the small vegetated swales is shown in Figure E.1 below.

Figure E.1 Typical form of a small vegetated swale
Note the Nepean Memorial Park SWMP calls for a 1 in 5 vegetated batter

E.1.2 Vegetated Swales Placed in Existing Small Watercourses

Vegetated swales VS2A, VS2B, VS2D, VS2E, and VS2F incorporate the existing form of the gully topography along the existing defined drainage lines in line with the riparian zone requirements. As it is proposed to remodel these watercourses as swales, the watercourses are assumed to be converted to drainage swale definition. This will require offsets elsewhere onsite.

The primary requirement in regard to the drainage requirements of the existing design lines incorporated as swales is that the base of each swale is required to be planted with dense sedges and rushed over 2 metres. This dense planting forms the flood storage and pollutant reduction function as detailed in this WSUD strategy and SWMP. The typical envisaged form of a vegetated swale placed in an existing depression is shown in Figure E.2 below.

Based on typical cross sections determined from the Lidar data, these assets will generally incorporate the following parameters:

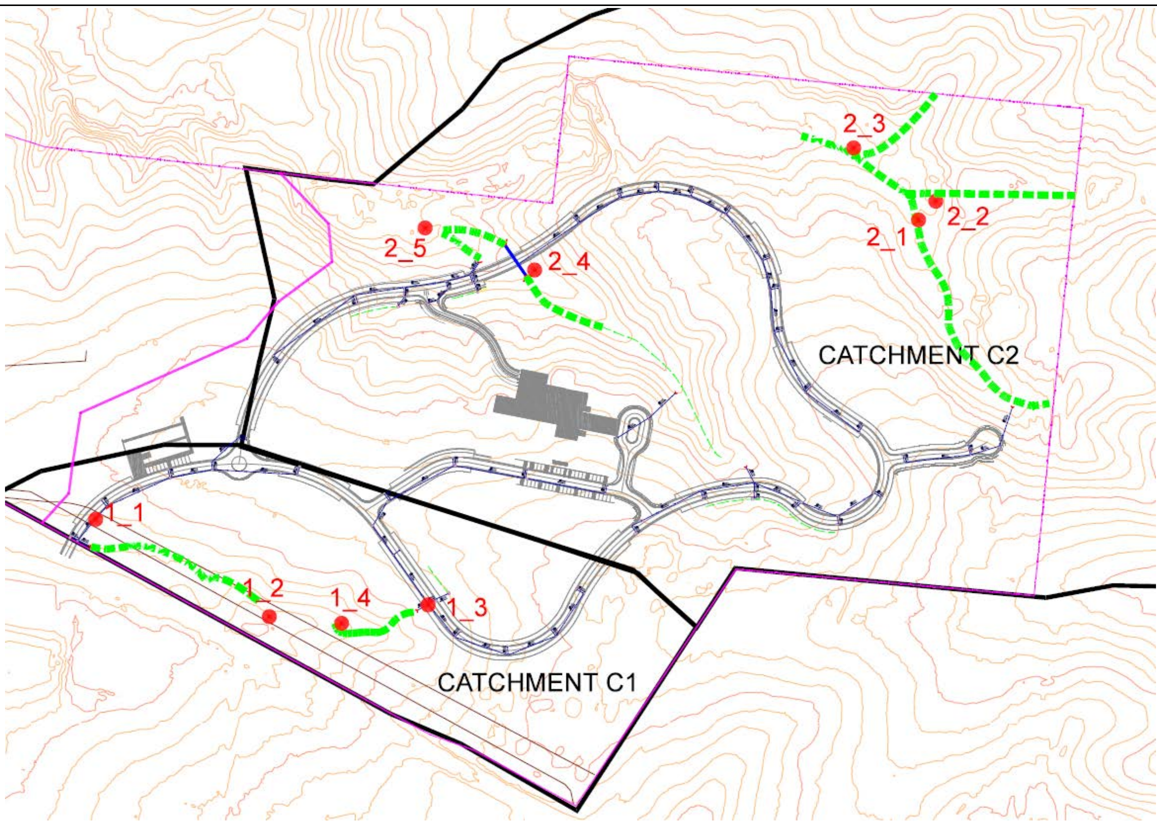
- Base width = 2 metres (fully vegetated with sedges and rushes)
- Side Batters = 1(vertical) to 8(horizontal), typical based on Lidar information
- Depth = 0.5 m (generally)
- Top Width = 10 m (generally, which is consistent with the required riparian offset)
- Longitudinal slope = 1/10 to 1/25 (generally following natural surface slope along the swale), and other dimensions as per the table below.

Figure E.2 Typical form of a vegetated swale in Catchment 2

E.2 Vegetated Swale Design Flows

The post development RORB models detailed in Appendix B were used to calculate the 5% AEP (20 Year ARI) flood flows at critical locations on the vegetated swale system. Figure E.3 below details these flows.

It should be noted that swale conveyance may be underestimated in the RORB model. That is, less flow may ultimately be conveyed in swales than has been modelled. If this is the case, then the flows detailed will be considered conservative (that is, higher) than will ultimately occur.



Flow ID	$Q_{5\%AEP}$[1.] (m^3/s)	Critical Duration
1_1	0.25	20-minute
1_2	0.25	1-hour
1_3	0.50	20-minute
1_4	0.60	1-hour
2_1	1.15	1-hour
2_2	1.10	1-hour
2_3	2.40	1-hour
2_4	0.65	1-hour
2_5	1.05	1-hour

Figure E.3 5% AEP (20 Year ARI) flood flows at critical locations on the vegetated swale system

E.3 Vegetated Swale Design Capacity

As detailed below all swales are capable of containing the 5% AEP flow. Crucial to the strategy is to ensure the base of all swales are planted out with dense sedges and rushes. This is essential in ensuring the flow velocities do not cause erosion of the drainage lines in this relatively steep slope. Note that all 5% AEP velocities are less than 0.4 m/s

Table E.1 Swale Capacity Calculations

Swale	Swale Depth (m)	Base width (m)	Longitudinal Slope	Batters (1 in X)	Mannings n (Heavily Vegetated)	Flow Area (m^2)	P (m)	R (m)	Velocity (m/s)	Capacity (m^3/s)	5% AEP Design Flow		Note
VS1A	0.5	1	0.017	5	0.25	1.75	6.10	0.29	0.22	0.39	0.25	OK	
VS1B	0.5	1	0.040	5	0.25	1.75	6.10	0.29	0.35	0.61	0.6	OK	
VS1C	0.3	1	0.010	5	0.25	0.75	4.06	0.18	0.13	0.10	0.08	OK	(Approx. Flow)
VS2A	0.5	2	0.040	8	0.25	3	10.06	0.30	0.36	1.07	0.65	OK	
VS2B	0.5	2	0.040	8	0.25	3.2032	10.38	0.31	0.37	1.17	1.15	OK	
VS2C	0.5	1	0.040	5	0.25	1.75	6.10	0.29	0.35	0.61	0.25	OK	(Approx. Flow)
VS2D	0.5	2	0.040	8	0.25	3	10.06	0.30	0.36	1.1	1.1	OK	
VS2E	1	2	0.010	8	0.25	10	18.12	0.55	0.27	2.69	2.4	OK	1 m depth is approximately at the 1% flood line
VS2F	0.5	1	0.040	5	0.25	1.75	6.10	0.29	0.35	0.61	0.525	OK	2 swales - Total Flow = 1.05 m^3/s
VS2G	0.3	1	0.010	5	0.25	0.75	4.06	0.18	0.13	0.10	0.08	OK	(Approx. Flow)

Appendix F Penrith City Council Stormwater Drainage Guidelines for Building Developments, 28 November 2016 Checklist

Notes:

- All elements proposed as part of this drainage strategy have been fully considered in regard to their applicability. As far as possible actual invert levels, normal water levels, batter requirements etc. have been set at this stage to ensure all elements can be constructed and will not be constrained by outfall invert levels, buffers and ecological constraints.
- There are no OSD systems proposed in this strategy. However, retarding basins (in line with the usual requirements of catchments of this size) are proposed (WLRB1 and RBP2). As such, many of the OSD requirements are not applicable in this case.

Information	Yes	No	N/A	Comments
1. Site boundaries	Yes			See SWS Drawing 1954/SWS/1 – Appendix A
2. North point	Yes			See SWS Drawing 1954/SWS/1 – Appendix A
3. Services within the public footway			N/A	Not applicable for a memorial park
4. Site features, including tree, structures, depressions	Yes			See SWS Drawings 1954/SWS/1, 2 and 3 – Appendix A
5. Contours at 0.1m for flat sites ranging to 0.5m for steep sites and extending 10m into adjoining properties	Yes			See SWS Drawing 1954/SWS/1 – Based on 0.5 m lidar information
6. Top of kerb levels	Yes			Refer to WS&P Road civil drawings
7. Boundary levels	Yes			See SWS Drawing 1954/SWS/1 – Based on 0.5 m lidar information
8. Benchmarks	Yes			Refer to WS&P Road civil drawings
9. Levels to AHD where site is affected by overland flow, flooding or where works on Council's drainage network are required	Yes			
General	**Yes**	**No**	**N/A**	**Comments**
1. Plans to scale of 1:100 or 1:200	Yes			Refer to WS&P Road civil drawings. WSUD concept plans to scale as required to delineate design intent.
2. Designer's name, qualifications, contact details provided	Yes			See SWS Drawing 1954/SWS/1-4, Appendix A
3. Design report, including details of any variations provided	Yes			Refer to this report
4. Plan number and date of issue shown	Yes			See SWS Drawing 1954/SWS/1-4, Appendix A
5. Consistency between stormwater, architectural and landscape plans	Yes			See SWS Drawing 1954/SWS/1-4 consistent with WS&P civil drawing set and FJLA landscape drawing set
6. 1% AEP overland flow extents shown	Yes			See SWS Drawing 1954/SWS/1 – Appendix A
7. Development layout, building envelope and	Yes			See SWS Drawing 1954/SWS/1 – Appendix A

proposed driveway locations shown				
8. Drainage calculations to support the proposed design submitted	Yes			See Appendix B, C and D of this report and WS&P pipe system design
9. Proposed finished floor, garage and ground surface	Yes			Refer to Architectural Drawings for administration building and chapel
10. Compliance with freeboard requirements	Yes			All building well outside of (and above) 1% AEP flood line
11. Location and level of proposed retaining walls indicated	Yes			See SWS Drawing 1954/SWS/2 for retaining wall proposed on WLRB1 – Appendix A
12. Appropriate tail water selected	Yes			Refer to GRC Hydro 1% Flood Level analysis
13. No adverse impact on other properties or the stormwater network	Yes			See Appendix B and C of this report
14. Mainstream flood / local overland flow flood report (if any)	Yes			Refer to GRC Hydro 1% Flood Level analysis
Drainage Layout	**Yes**	**No**	**N/A**	**Comments**
1. Pipe size, grade and invert level indicated	Yes			Refer to WS&P Road civil drawings. WSUD concept plans also detail actual swale and wetland levels and grades as required.
2. Pit location, size, invert level and surface level indicated	Yes			Refer to WS&P Road civil drawings.
3. Proposed connection point to Council's stormwater system	Yes			See SWS Drawing 1954/SWS/1 – Appendix A
OSD	**Yes**	**No**	**N/A**	**Comments**
1. A catchment plan showing areas draining to the OSD system.	Yes			See Appendix B of this report
2. Location and size of OSD system and WSUD measures shown	Yes			See Appendix B of this report and Drawings 1954/SWS/1, 2 and 3.
3. Location and level of OSD discharge points shown	Yes			See Appendix B of this report and Drawings 1954/SWS/1, 2 and 3.
4. Compliance with detention volume required	Yes			See Appendix B of this report and Drawings 1954/SWS/1, 2 and 3.
5. Compliance with less than 15% of site area bypassing OSD system	Yes			See Appendix B of this report and Drawings 1954/SWS/1, 2 and 3. 100% of Catchment 1 captured. Capture of external catchment essentially compensates for more than 15% of Catchment 2 not entering RBP2.
6. Compliance with the Permissible Site Discharge (PSD) requirements	Yes			See Appendix B of this report
7. Compliance with OSD storage depths			N/A	The SWMP details retarding basin design in line with best practice to sites of this size and scale. OSD not appropriate in this instance.
8. Overland flows clear from the OSD system			N/A	Retarding basins placed as per best practice under total catchment management procedures applicable to a site of this size. No OSD facilities proposed.
9. OSD storage located within common areas, clear of private courtyards and accessible from the street			N/A	Not applicable for a memorial park
10. Overflow weir provided and shown			N/A at SWMP stage	Retarding basin concept designs only. Stage/Storage/Discharge relationship formulated based on predevelopment flow requirements. Stage/Storage

			of the project	relationship is set based on concept design and site constraints (e.g. outlet invert level etc). Functional and detailed design development to ensure outlet and spillway details meet the requirements of the Stage /Discharge relationship detailed in Appendix B.
11. Details of discharge control pit shown			N/A at SWMP stage of the project	Retarding basin concept designs only. Stage/Storage/Discharge relationship formulated based on predevelopment flow requirements. Stage/Storage relationship is set based on concept design and site constraints (e.g. outlet invert level etc). Functional and detailed design development to ensure outlet and spillway details meet the requirements of the Stage /Discharge relationship detailed in Appendix B.
12. Orifice details and calculations shown			N/A at SWMP stage of the project	Retarding basin concept designs only. Stage/Storage/Discharge relationship formulated based on predevelopment flow requirements. Stage/Storage relationship is set based on concept design and site constraints (e.g. outlet invert level etc). Functional and detailed design development to ensure outlet and spillway details meet the requirements of the Stage /Discharge relationship detailed in Appendix B.
13. Typical sections of OSD storage, including basin invert level, centreline level of outlet orifice, top water level, finished surface levels provided	Yes			Concept designs specify pond NWL, ephemeral wetland base level, 1% AEP flood levels etc. Given the detailed design stage/discharge relationship will be in line with the relationship in Appendix B, these levels are not expected to change. That is, both retarding basins have been “designed” to site” given existing site attributes and constraints.
14. Provision of design certification of the OSD system in accordance with this policy			N/A	Not applicable for a memorial park
Others	**Yes**	**No**	**N/A**	**Comments**
1. Location of Council’s drainage easements, private inter-allotment easements shown (if any)			N/A	Not applicable for a memorial park
2. Location and details of basement pump-out system provided (if any)			N/A	No pumps proposed
3. Location and details of overland flow path shown (if any)	Yes			Overland flow paths as per 1% flood line as defined by GRC Hydro.

Appendix G WSUD Inspection and Maintenance Schedules

Nepean Memorial Park

Inspection and Maintenance of WSUD Assets

VEGETEATED SWALES, RETARDNG BASINS, WETLANDS AND PONDS

Draft

September 2019

Contents

1. Introduction

Inspection and maintenance schedules are essential to ensure the ongoing sustainability of the WSUD systems within the Nepean Memorial Park. These systems have been designed specifically to treat development runoff generated within the subject site.

This document applies to:

- Wetland/Retarding Basin 1 (WLRB1)
- Wetland 2 (W2)
- Retarding Basin/Pond 2 (RBP2), and
- Vegetated Swales (VS) being:
- VS1A, VS1B, VS1C, VS2A, VS2B, VS2C, VS2D, VS2E, VS2F and VS2G.

For background information relating to the design of all WSUD assets refer to "Nepean Memorial Park, Water Sensitive Urban Design Strategy and Storm Water Management Plan, Stormy Water Solutions, October 2019". This is referred to the **Nepean 2019 SWMP** on this schedule.

General maintenance works of WSUD systems include:

- Replanting,
- Weed control,
- Mowing of grassed areas and slashing of sedges and rushes,
- Reseeding or returfing of grassed areas,
- Pest and disease control,
- Re-mulching,
- Pruning,
- Erosion repair,
- Rock protection inspection and repair if necessary,
- Weir inspection and repair if necessary and
- Inlet and outlet system inspection and repair if necessary.

1.1 Data sheets and Site Plans

Site plans can be reproduced from Appendix A of the Nepean 2019 SWMP. These can be attached to the Inspection Forms and Maintenance Forms to clearly show where inspections, maintenance and monitoring activities are required or have been performed.

2. Information Section

This schedule applies to the following assets. Applicable site plans are as per those produced in Appendix A of the Nepean SWMP.

SWS Asset Number	Asset Name	Primary Asset Type	Secondary Asset Type	Asset Dimensions and WSUD Properties
WLRB1	Wetland/Retarding Basin 1	Retarding Basin	Treatment Wetland	Ephemeral Base = 920 m^2 TED = 1230 m^2 Detention time = 48 hours Extended Detention Depth = 600 mm
VS1A	Vegetated Swale	Stormwater Conveyance	Treatment Swale	Base = 1 metre 1 in 5 Batters 0.5 m deep 1/60 slope Length = 125 m
VS1B	Vegetated Swale	Stormwater Conveyance	Treatment Swale	Base = 1 metre, 1 in 5 Batters 0.5 m deep, 1/25 slope Length = 60 m
VS1C	Vegetated Swale	Stormwater Conveyance	Treatment Swale	Base = 1 metre, 1 in 5 Batters 0.3 m deep, 1/100 slope Length = 130
W2	Wetland	Treatment Wetland		Ephemeral Base = 1040 m^2 TED = 1480 m^2 Detention time = 48 hours Extended Detention Depth = 500 mm
RBP2	Retarding Basin/Pond	Retarding Basin	Landscape Pond	3750 m^2 at NWL.
VS2A,	Vegetated Swale	Stormwater Conveyance	Treatment Swale	Base = 2 metre, 1 in 8 Batters 0.5 m deep, 1/25 slope Length = 190 m
VS2B	Vegetated Swale	Stormwater Conveyance	Treatment Swale	Base = 2 metre, 1 in 8 Batters 0.5 m deep, 1/25 slope Length = 185 m
VS2C	Vegetated Swale	Stormwater Conveyance	Treatment Swale	Base = 1 metre, 1 in 5 Batters 0.5 m deep, 1/25 slope Length = 40 m
VS2D	Vegetated Swale	Stormwater Conveyance	Treatment Swale	Base = 2 metre, 1 in 8 Batters 0.5 m deep, 1/25 slope Length = 100 m
VS2E	Vegetated Swale	Stormwater Conveyance	Treatment Swale	Base = 1 metre, 1 in 5 Batters 1.0 m deep, 1/100 slope Length = 30 m
VS2F	Two Vegetated Swales	Stormwater Conveyance	Treatment Swale	Base = 1 metre, 1 in 5 Batters 0.5 m deep, 1/100 slope Length = 45 m (each swale)
VS2G	Vegetated Swale	Stormwater Conveyance	Treatment Swale	Base = 1 metre, 1 in 5 Batters 0.3 m deep, 1/100 slope Length = 65 m

2.1 Vegetated Swales

Vegetated swales are small trapezoidal drainage systems, typically planted out for with sedges and rushes. Their primary design intent is to provide pre-treatment of storm flow prior to entry into the downstream ponds and wetlands. Swales have a dual flood conveyance and stormwater quality retention function. They are very simple, cost effective systems. No underlying drainage system is present in the Nepean Memorial Park swale systems.

Maintenance of swales systems is primarily concerned with:

- Maintenance of flow to and through the systems,
- Maintaining the flow conveyance capacity,
- Removal of accumulated sediments and litter and debris including dead leaves and grass clippings.
- Maintaining vegetation including:
    - Fertilising plants (if required),
    - Removal of noxious plants or weeds,
    - Re-establishment of plants that die, and/or
    - mowing of grassed swales

Sediment and leaf litter removal will be required in and around the swales. If not removed this is a risk in regard to not meeting the pollutant removal objectives, increasing local nuisance flooding and bypassing flow flows around the system. Removal of sediment and leaf litter should be done regularly and whenever it is it observed.

2.2 Wetlands

Wetlands typically incorporate:

- A wetland area being a vegetated and landscaped feature providing treatment of flows, and
- Various wetland inlet and outlet structures associated with movement of stormwater though the system (from upstream to downstream).

The primary functions of the wetland are treatment of storm flows prior to discharge to the downstream creek systems. As such, maintenance of these element is extremely crucial.

The two wetlands detailed in the 2019 SWMP are ephemeral systems. As such, shallow ponding will occur after storm events, with the system being dry between storm events. The systems will be planted with ephemeral sedges and rushes.

When runoff occurs, low flows enter the wetland systems. Flow is temporarily impounded in the wetland for a period of 2 days in the extended detention range (the vertical distance 0.5 – 0.6 metres above ephemeral base level of the wetland (typically)). Flooding above this level may occur in rarer events (e.g. 5 Year ARI event, 100 Year ARI event etc). The original functional design drawings should be assessed if information is required regarding a particular wetland operation requirement regarding both small events (for stormwater treatment) and large events (for flood management).

The vegetation in the wetlands is crucial to the treatment process. It is very important that plant densities are maintained, litter is removed, and weeds are kept under control to ensure the wetland systems operate to their optimum performance. Ideally a wetland area should have at least 80% vegetation coverage. Minor water areas should be located immediately downstream of inlet pipes and immediately upstream of outlet systems to ensure dissipation of flows into and out of the system.

Debris removal around the inlet and outlet systems is considered a priority to ensure no impact on flood levels during extreme flow events.

Large scale sediment removal should not be required given the upstream buffer and vegetated swale pre-treatment in the Nepean Memorial Park. Wetland resetting should not be required over its engineering life (30 – 50 years) if the sediment removal in the entry points of the swale systems occurs regularly. If sediment removal is not performed well, wetland resetting may be required at more frequent intervals.

Self-sustaining, dense native sedges, rushed and marsh vegetation in the wetland areas is acceptable provided this does not impede flood flow movement or block structures etc.

2.3 Ponds

Ponds are like wetlands except vegetation is limited within the pond to edge treatment. Edge vegetation is required to restrict public access to the water and meet safety requirements. Ideally the pond area should have at less than 20% vegetation coverage. Open water areas should be located immediately downstream of inlet pipes and immediately upstream of outlet systems.

Pond issues regarding vegetation are primarily concerned with ensuring the public are not invited to danger by provision of slight batters to the water (1 in 5 max) and vegetating the pond edge to a width of at least 2 – 3 metres. If the public has unrestricted access to the water, remedial edge planting of appropriate sedges and rushes should be initiated.

Ponds also may have water quality issues characterised by odour and/or algal growth. If blue green algae are identified, the public must be notified via a sign on site and notifications in local papers. Algae removal should be initiated. If required, pond modifications, upstream treatment options and/or diverting more stormwater to the pond could be considered as long-term solutions.

2.4 Retarding Basins

In two of the WSUD systems in the Nepean Memorial Park (WLRB1 and RBP2), the pond or wetland functions are complemented by a retarding basin function. The normal water level (NWL) of the pond, or the ephemeral base level of the wetland, forms the base of the retarding basin. The “retarding basin” forms no part of the WSUD function of the asset, but the outlet structures will form duel functions for water quality and flood retardation and must always be in working order and clear of debris.

Regarding the retarding basin wetland and pond, it is imperative that the location of all inlets and outlets are known, and that these structures are kept clear of debris and are always operational. Common potential problems associated with vegetated systems as a result of poor maintenance include:

- Decreased aesthetic amenity;
- Sediment build up restricting inflows (possibly causing flooding problems upstream),
- Debris and sediment build up in the outlet system restricting outflows which can cause a high normal water level (NWL) through the system, often drowning out the upstream pipes system (which may cause pipe and flooding problems), and
- Public health and safety risks.

The embankments of the two retarding basins will be designed to ensure adequate structural strength and batter requirements in line with current engineering standards.

2.5 General Issues and Maintenance Requirements

Issues commonly identified and requiring action (in all WSUD Assets) are listed below.

2.5.1 Sediment Removal

It is common that sediment loads into the vegetated swales may be relatively high. Most sediment will be caught at the first point a catchment discharges into a system.

Nepean Memorial Park staff should regularly check the swale system surface and system pipe entry points and remove sediment as required. It is expected that, over time, the operations staff will become familiar with the required interval of cleanout regimes for course sediment.

If caught early, maintenance may just require removal of sediment from the entry areas with a spade etc.

2.5.2 Blockage and Damage of Drainage Structures

The condition of all drainage structures on site (e.g. overflow pits etc.) should be inspected to assess whether damage or blockage has been caused by leaf litter build-up, blockage/covering by sediment, vandalism or storm damage.

This inspection of all structures identified as being crucial for flood flow conveyance (as opposed to stormwater treatment) should occur routinely.

2.5.3 Vegetation Issues

It is imperative that the vegetated swales and ephemeral wetland systems exhibit a robust density of sedges and rushes within the system base to meet their water quality objectives. Weed species must be controlled within the base of the swales and ephemeral wetlands for both water quality performance and landscape integrity.

In addition, it is imperative that the vegetation pond system is robust and healthy to:

- Ensure an adequate “safety” barrier between burial areas and the water body,
- Ensure the landscape integrity of the system is maintained, and
- Ensure adequate water quality treatment occurs.

Threats to desired system plants include:

- The presence of invasive species,
- The presence of weeds,
- The occurrence of disease, and
- Pest infection.

If weed removal is required, ensure that any flowering plants are removed before they can set seed. All weed vegetative matter should be disposed of at a waste disposal facility.

Do not use herbicide to control weed species within system unless they are registered near waterways. Always apply herbicides according to label specifications. Appropriate herbicide treatment can be used in terrestrial areas provided assessment is made of the problem and that best practice is employed.

Remove any diseased plants. Dead plants may need to be periodically removed. The accumulation of decaying vegetation can create mosquito breeding habitats and inhibit seasonal growth of plants. Ensure that the bed of the swale systems is free draining (i.e. stagnant pools of water cannot form during water level fluctuations) as a result of the removal of vegetation.

2.5.4 Litter

Litter is visually unappealing and the incidence of litter (or gross pollutants) can degrade the water quality in the WSUD systems. Remove and dispose of litter that may be visible in and around the system. Contact with sharp objects, including hypodermic needles is a risk when removing litter. All workers must be made aware of this risk, wear appropriate protective gear and use caution.

2.5.5 Erosion Issues

All site works should be in a stable condition. Erosion should not be threatening the integrity of the system or establishment and health of vegetation. A judgment call may need to be made to assess the severity of erosion.

If severe erosion is evident undertake remediation measures including overland flow inception, velocity reduction, dispersal, surface reinforcement and planting. Repairs to infrastructure or rock protection areas may be required.

If the erosion is assessed as mild, monitor the site in the short term (e.g. 3-6 months) to assess the need for remediation. Consider stabilizing the site using revegetation techniques.

If the erosion is assessed as minor, monitor the site in the long term (e.g. 6-12 months) and address if required.

2.6 Incident Inspection

2.6.1 Storm Event

An inspection is required following significant storm events. Inspection may detect minor damage to the site that should be repaired. This may include blockage of overflow system and/or erosion within the swale systems.

Damage and requested repairs should be noted on the incident inspection checklist.

Refer to the above information to assist in interpreting the severity of observed damage and appropriate action response.

2.6.2 Complaints

Complaints from visitors and staff need to be inspected and recorded on the incident inspection checklist.

Complaints could include observations of accumulated sediment in bubble up pits causing backwater issues in the site, nuisance ponding, litter, mosquitoes, snakes, odour or other water quality issues.

Refer to the above information to assist in interpreting the severity of observed damage and appropriate action response.

3. Inspection, Maintenance and Monitoring Calendar

The schedule detailed below is a guide only. Routine maintenance may be scheduled based on the outcome of routine inspections, after an extreme storm event or as a result of an algal bloom.

3.1 Inspections

Routine inspections should occur in **February, May and October** each year to address and/or identify any problems which may have developed within the previous 4 months. Inspections should also occur after major storm events (events greater than the 20% AEP (5 Year ARI storm).

It is anticipated that all asset inspections associated with this schedule will occur over one day to optimise staff time and provide consistent responses across assets.

3.2 Maintenance

Routine maintenance of the WSUD assets should occur in **March and November** each year to remove any litter and debris which may have collected during the previous 6 months, especially at the upstream pipe outfall location in all vegetated swale systems.

4. Inspection, Maintenance and Monitoring Forms

The following forms are provided:

WSUD Inspection and Maintenance – Inspection Form

WSUD Inspection and Maintenance - Maintenance Form

The forms below should be used:

- Whenever routine inspections of the systems are undertaken,
- Whenever routine maintenance of the systems is undertaken,
- To record any inspection or maintenance activity which is required as result of algal bloom or water quality issues, and
- To record any inspection or maintenance activity which is performed as result of a flood event or water quality complaint.

These forms should form part of an overall quality assurance program to ensure:

- A complete and thorough record of all issues and maintenance activities,
- Records of actions undertaken as a result of floods, algal blooms or other unforeseen events, and
- No loss of maintenance and asset knowledge over time which can ensure ongoing improvement of WSUD asset maintenance practices.

It is the responsibility of Nepean Memorial Park to ensure routine inspection and maintenance inspections are undertaken in line with the Inspection and Maintenance Calendar (Section 3 above).

All completed Inspection and Maintenance Schedule forms must be filed in the appropriate file for future reference. Again, this is the responsibility of Nepean Memorial Park.

It is the responsibility of Nepean Memorial Park to ensure any issues are actioned appropriately.

4.1 WSUD Inspection and Maintenance FORM – INSPECTION FORM

Nepean Memorial Park

WSUD Inspection and Maintenance

Vegetated Swales, Wetlands and Ponds

INSPECTION FORM

Additional copies to be photocopied if required

Asset Description

- Systems as defined below (See applicable plans in Appendix A of the Nepean 2019 SWMP for data sheets)
- Associated inlet and outlet structures
- Associated grassed batters (if applicable)

SWS Asset Number	Asset Name	Has the Site been inspected?
WLRB1	Wetland/Retarding Basin 1	
W2	Wetland	
RBP2	Retarding Basin/Pond	
VS1A	Vegetated Swale	
VS1B	Vegetated Swale	
VS1C	Vegetated Swale	
VS2A	Vegetated Swale	
VS2B	Vegetated Swale	
VS2C	Vegetated Swale	
VS2D	Vegetated Swale	
VS2E	Vegetated Swale	
VS2F	Vegetated Swale	
VS2G	Vegetated Swale	

Site Visit Date

Site Visit By

Weather

Document Set ID: 8966035
Version: 1, Version Date: 17/12/2019

Provide general detail of sediment or blockage issues.	**WLRB1**	**W2**	**RBP2**	**VS1A**	**VS1B**	**VS1C**	**VS2A**	**VS2B**	**VS2C**	**VS2D**	**VS2E**	**VS2F**	**VS2G**
Flooding issues?													
Entry points blocked with sediment and/or leaf litter build-up?													
Blockage undermining the water quality treatment function of the system (i.e. water not being able to enter the system and/or bypass occurring)?													
Is blockage forming a barrier to flood flow conveyance to the receiving body in a storm event?													
Assets requiring maintenance for Sediment issues.													

Vegetation Issues

Swales and Wetland/Pond Banks and Littoral Zones	**WLRB1**	**W2**	**RBP2**	**VS1A**	**VS1B**	**VS1C**	**VS2A**	**VS2B**	**VS2C**	**VS2D**	**VS2E**	**VS2F**	**VS2G**
Weed issues?													
Signs of plant disease?													
Signs of pest infection or stunted plant growth?													
Desired plant species which have thrived?													
Dead plants?													
Bare areas?													
Need to replant any sections of the system?													
Need to weed any parts of the system?													
Assets requiring maintenance for Vegetation issues.													

Aquatic Water Plants (Emergent and shallow marsh)	**WLRB1**	**W2**	**RBP2**
Problems with emergent or submergent plant species?			
Areas becoming too dense with submergent species?			
Require replanting or supplementary planting within the water?			
Is removal of excess algae or undesirable species required?			
Assets requiring maintenance for Aquatic Vegetation issues.			

Provide general detail of the health of systems.	**WLRB1**	**W2**	**RBP2**	**VS1A**	**VS1B**	**VS1C**	**VS2A**	**VS2B**	**VS2C**	**VS2D**	**VS2E**	**VS2F**	**VS2G**
Can an odour be detected? (Avoid contact with skin)													
Is there any sludge build-up on the surface of the system													
Structures/pits blocked or damaged and restricting passage of flood flows													
Large flood flows are not dissipating adequately after rainfall events													
Flooding Issues?													
Evidence of settling or erosion of batters of base													
Evidence of dumping (building waste, oils etc.)													
Assets requiring general maintenance.													

Pond Issues

Water Quality	**RBP2**
Obvious substances which produce undesirable colour, odour or foaming?	
Obvious undesirable aquatic life such as algal blooms, dense growth, insects or invertebrates?	
Employee or visitor complained about algal or water quality issues?	
Water appears stagnant and/or smell?	
Have any water quality teats been carried out?	
Are water quality tests required to confirm issues?	
Is Pond Maintenance Required?	

Structures	**WLRB1**	**W2**	**RBP2**	**VS1A**	**VS1B**	**VS1C**	**VS2A**	**VS2B**	**VS2C**	**VS2D**	**VS2E**	**VS2F**	**VS2G**
Inlet pipes are required to be cleaned out?													
Outlet system not operating effectively in both high and low flows?													
Damage, blockage or vandalism to any weir or spillway structure?													
Structural integrity of any structures is not satisfactory?													
Assets requiring maintenance for asset structure issues.													

Inspection Summary

Summary of assets requiring attention.

Which systems(s) and location(s)?

If maintenance is required, this must be actioned by the Nepean Memorial Park Manager. A Maintenance Form must be filled out and appropriately filed.

Nepean Memorial Park

WSUD Inspection and Maintenance

Vegetated Swales, Wetlands and Ponds

MAINTENANCE FORM

Additional copies to be photocopied if required

Asset Description	• Systems as defined below (See applicable plans in Appendix A of the Nepean 2019 SWMP for data sheets) • Associated inlet and outlet structures • Associated grassed batters (if applicable)

SWS Asset Number	Asset Name	Has the site been maintained?
WLRB1	Wetland/Retarding Basin 1	
W2	Wetland	
RBP2	Retarding Basin/Pond	
VS1A	Vegetated Swale	
VS1B	Vegetated Swale	
VS1C	Vegetated Swale	
VS2A	Vegetated Swale	
VS2B	Vegetated Swale	
VS2C	Vegetated Swale	
VS2D	Vegetated Swale	
VS2E	Vegetated Swale	
VS2F	Vegetated Swale	

Date: Weather:

Site visit by:

ROUNTINE MAINTENANCE – CALENDER

- Routine maintenance of the sediment ponds and wetlands should occur in **March and November** each year in response to any issues identified in the inspection form
- Maintenance should occur following any major flood event or water quality complaint, and completion of an Inspection Form.

Water Quality Maintenance - Pond RBP1

Have any water quality issues been identified? **YES/NO**

Have council staff and visitors been notified? **YES/NO**

Method of notification?

Has removal of algae been undertaken? **YES/NO**

Location? – Note sites where activities have occurred

Method? (Physical removal, use of chemicals or enzymes?)

Ease of extraction?

Approximate cost.

Vegetation Maintenance

Was there any planting of littoral, emergent or submerged plant species undertaken? YES/NO

Was edge planting undertaken to address areas/batters where the public can access the water body in an unsafe manner (i.e. edge planting/safety provisions are inadequate)?

YES/NO

Location? – note where sites where activities have occurred

Provide detail on location, species type and number required and approximate cost.

Was removal/harvesting of aquatic plant species or troublesome species removal undertaken? YES/NO

Location? Note where sites where activities have occurred

Species type?

Manual or conveyor belt boat extraction?

Ease of extraction?

Approximate cost.

Were any weeds removed from the invert of the wetlands or swales or associated bank/batter areas? YES/NO

Location?

Provide detail on location, species type, removal technique and approximate cost.

General Maintenance

Were any inlet or outlet pipes cleaned out? YES/NO

Was restoration of structure required? YES/NO

Provide detail on location, damage addressed, construction technique and approximate cost.

Location?

Was any hard rubbish (i.e. dumped rubbish, building waste, oils etc) removed from site? YES/NO

Provide detail on location, rubbish type, removal technique and approximate cost.

Location?

Additional Comments