Hydrological and Environmental Engineering

Wallacia Cemetery

Water Sensitive Urban Design Strategy

and

Storm Water Management Plan

11 October 2017

Report by: **Stormy Water Solutions**

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Contents

1. Introduction

This Wallacia 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 cemetery. 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 integration with the site drainage, catchment, landscape and ecological and riparian zone 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.

Stormy Water Solutions

The primary author of this report is Valerie Mag, principal of Stormy Water Solutions. Valerie is a hydrologist with the following educational qualifications:

- Bachelor of Civil Engineering, Monash University (1989)
- Master of Water Resources and Environmental Engineering, Monash University (1993)

Valerie has twenty eight 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,
- Safety 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 (22 wetlands were design to current best practice requirements in 2016 alone).

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 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 north eastern portion of the Wallacia township. The land is undulating, with some steep areas. Jerrys Creek and some smaller tributaries of the Nepean River traverse the site. The site has a total area of 44.2 ha.

The site is current used as a golf course. There are significant stands of vegetation is the site, especially in the Jerrys Creek riparian zone. However, largely the site consists of clears fairways and greens. This offers the opportunities to increase the environmental and ecological diversity of the site going forward.

It is understood that the site current utilises water rights at 9 ML/yr to water greens and tees.

It is the intention of this SWMP to provide flood flow retardation storage by constructing a naturalistic “wetland” 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 development catchment.

Key to the design is to use the drainage infrastructure as an opportunity to assist to the landscape and ecological diversity of the site.

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), 2016,
- The “ Penrith Development Control Plan 2014, Part C3 Water Management” document,
- 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 and 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 (Model for Urban Stormwater Improvement Conceptualisation) software developed for this study by Stormy Water Solutions 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 much 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, or reserve widths, buffers, ecological constraints etc.

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

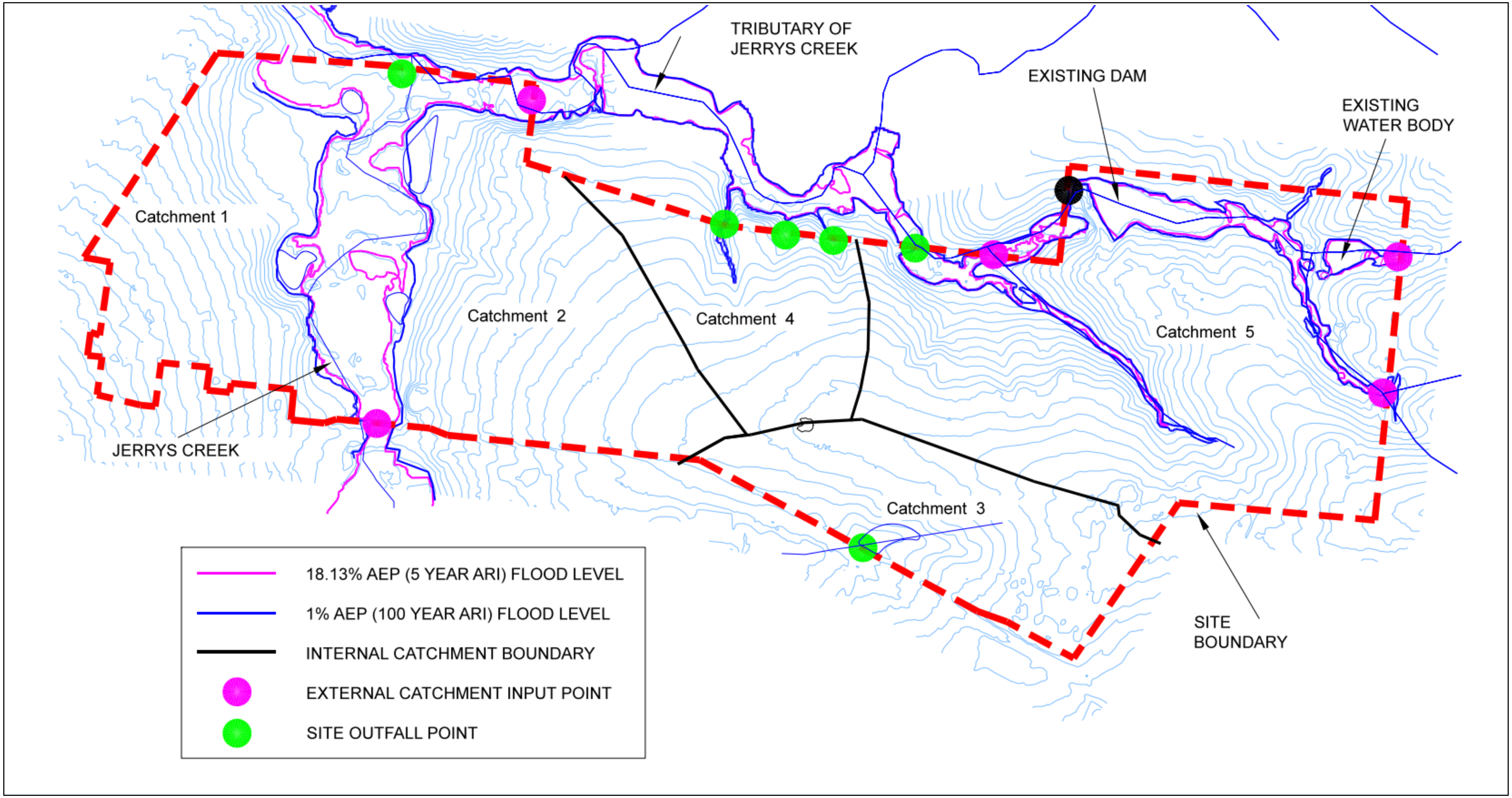

Figure 1 Subject Site

3. WSUD Strategy SWMP Objectives

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

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 takes into account 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

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;
- To rehabilitate existing riparian corridors and ensure that width, buffers to development, quality of landscape and diversity of vegetation to support principles of ecological sustainability are provided.

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.

All of the above requirements can met by the SWMP detailed in Section 4.

There are two WSUD elements proposed within the riparian zone of the second order stream located in the north eastern portion of the catchment in Catchment 5. These are Wetland 5 and Retarding Basin/Pond 5. Both these WSUD/Drainage elements will be utilising existing water features to perform the functions of the WSUD strategy and SWMP. However, works will be limited to "stormwater outlet structures and essential services" as defined in the first dot point above. The only works proposed on both systems are:

- Reconstruct the downstream embankments to current structural requirements to ensure the safety of downstream landowners,
- Ensure the outlet from both systems are designed and constructed to meet the WSUD and flood storage requirements as detailed in Appendices B and C, and
- Possibly 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 features on this second order stream will ensure it retains its function as a second order stream. TB&E has advised that the WSUD strategy and SWMP can retain both elements in their current form while constructing outlet works to ensure the functions required under the SWMP, without compromising the riparian corridor.

All other wetlands and retarding basins are proposed to be located away from, or within the 50% outer Vegetated Riparian Zone for affected waterways.

The only other impact on the riparian zone of waterways is the remodelling of some Stream Order 1 watercourses as vegetated swales. The swales affected are in Catchments 4 and 5. The form of these swales is as described in Appendix D. It is proposed to reconstruct these watercourses as a swales and, as such, the watercourses are assumed to be converted to drainage swale definition. This will require an offset elsewhere onsite.

It should be noted that Retarding Basin /Pond 5 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 simular designs are advocated in Australian Rainfall and Runoff: A Guide to Flood Estimation (2016, Book 9, Chapter 4, Table 9.4.4. Assumed General Suitability of Common Volume Management Design Solutions (indicative only)) and the Austroads Publication "Guide to Road Design Part 5A: Drainage – Road Surface, Networks, Basins and Subsurface (2013)". Basins of this type are seen as best practice examples of incorporating flood storage and WSUD objectives in one site, and should be supported as such. This is an opportunity for council to support such a design in line with current best practice.

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, Florence Jaquet Landscape Architects and Stormy Water Solutions have worked closely to ensure that drainage elements, such as wetland systems and swales, offer the opportunity to complement the landscape amenity and ecological diversity (especially of the riparian zones of the final landscape form). 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 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 C 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.
- Must be designed using a catchment wide approach (that is, consideration of the total catchment, and external site catchments must be undertaken), and

Appendices A and B detail the RORB modelling completed for the SWMP detailing that the above conditions have been met.

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 the clause is related to pollutants that could be hazardous to the watercourse and not the sediment or waterborne pollutants retained in a wetland system. Given the above wetlands (which also include a retarding basin function) are located between the 5 year (to be in line with Section 3.7, PDCP C3 for retarding basins) and 100 year flood line.

The pipes and swales specified in the SWMP shall be sized to convey a 1 in 20 year average recurrence interval (ARI) storm event without creating nuisance flows on the roads or beyond the extents of the easements. 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 site piped drainage system 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 9 ML/yr (in line with the current water rights) 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 9 ML/yr use of stormwater harvesting on site. If this use is eventually taken up, the stormwater pollutant reductions as specified in Appendix C will only increase.

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 pre developed duration of stream forming flows. The comparison of post development and pre development stream flows is commonly referred to as the Stream Erosion Index (SEI).

This is a condition that is typically met with retarding basins designed as per this SWMP. As such, detailed 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.

Handover of WSUD / Stormwater Treatment Assets to Council 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.

The above two conditions will be captured via the production of detailed inspection and maintenance schedules for all retarding basins, wetlands, swales and bioretention systems at the functional design stage of the project.

4. Storm Water Management Plan Description

The primary drainage elements proposed within the SWMP are detailed within SWS drainage set 1774/SWS/1-8. These drawings are reproduced in this section and discussed further below.

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.

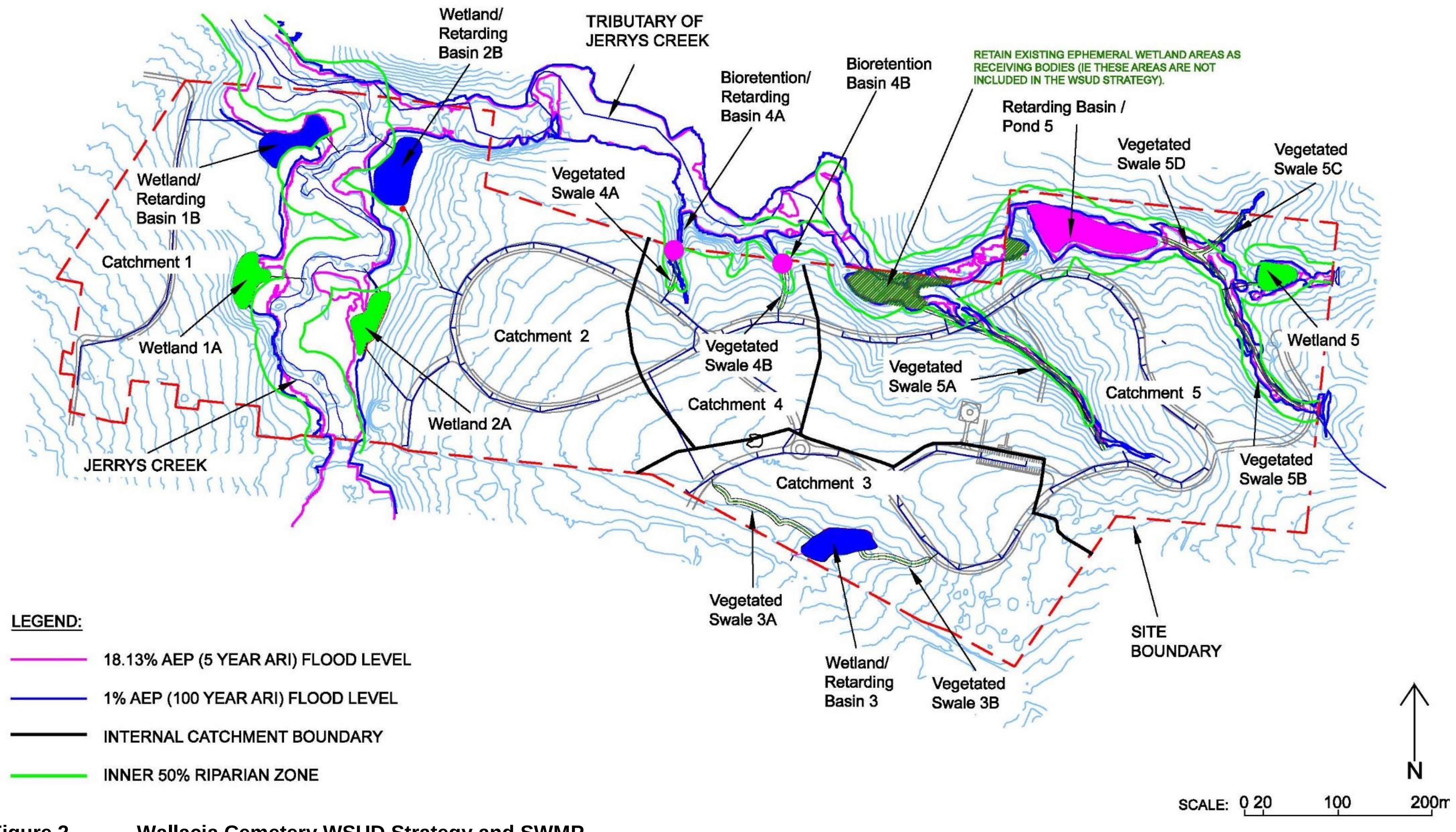

Figure 2 **Wallacia Cemetery WSUD Strategy and SWMP**
(See SWS Drawing 1774/SWS/1 for full detail)

4.1 Treatment of Development and Burial Areas – All Catchments

In regard to drainage impact, this development largely consist 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 outfall locations (as described above) for treatment of stormwater.

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 reasonable fraction imperviousness for areas which have burial areas (lawn and monumental) located within them is assumed to be 25% within the WSUD Strategy and 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 C of this report.

Essentially, this "buffer" treatment is the primary treatment element in the WSUD strategy treatment train definition for this site. Secondary and tertiary treatment occurs in the downstream swales, wetland and bioretention 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 drainage system.

4.2 Catchment 1

Catchment 1 is defined as the catchment out falling to the western bank of Jerrys Creek from the southern to northern portion of the site. In existing conditions, much of the outflow to this part of the creek is via sheet flow from fairways and greens to the creek in a distributive manner. As such, it is difficult to define a defined outfall point for this catchment. As detailed in the hydrological models (Appendices A. B and C), the WSUD strategy and SWMP for this catchment accounts for all flow from this catchment, but lumps all inputs together for this section of Jerrys Creek.

The formulation of the SWMP for this catchment has been undertaken in this way to clearly (and transparently) show that all the hydrological conditions relating to the discharge of flow from Catchment 1 to Jerrys Creek can be met.

WSUD strategy and SWMP elements proposed in Catchment 1 are:

- Buffer treatment of the imperious areas in burial areas,
- GPT1 on the pipe outfall just upstream of Wetland/ Retarding Basin W1B (Rocla 0708M type wet sump vortex systems (or equivalent)),
- Wetland 1A (stormwater treatment function only), and
- Wetland/Retarding Basin 1B (stormwater treatment and flood retardation function).

In regard to flood control the major element proposed is Wetland/Retarding Basin 1B. This element has been placed on the outfall from the main piped system in this catchment to ensure all “road and building” runoff is captured in this element. However, it has been oversized to ensure that the total flow from the whole of Catchment 1 is retarded to below predevelopment conditions. At this stage (as detailed in Appendix B) the all post development flows (10%, 5%, 2% and 1% AEP) are retarded to WELL BELOW the total predevelopment flow expected from Catchment 1.

The second objective is to provide stormwater treatment or at least best practice downstream of downstream of the subject site. Appendix C details the post-development modelling which shows the council requirement in relation to this issue can be met by the SWMP.

Figures 3 and 4 detail the concept design of Wetland 1A and Wetland/Retarding Basin 1B.

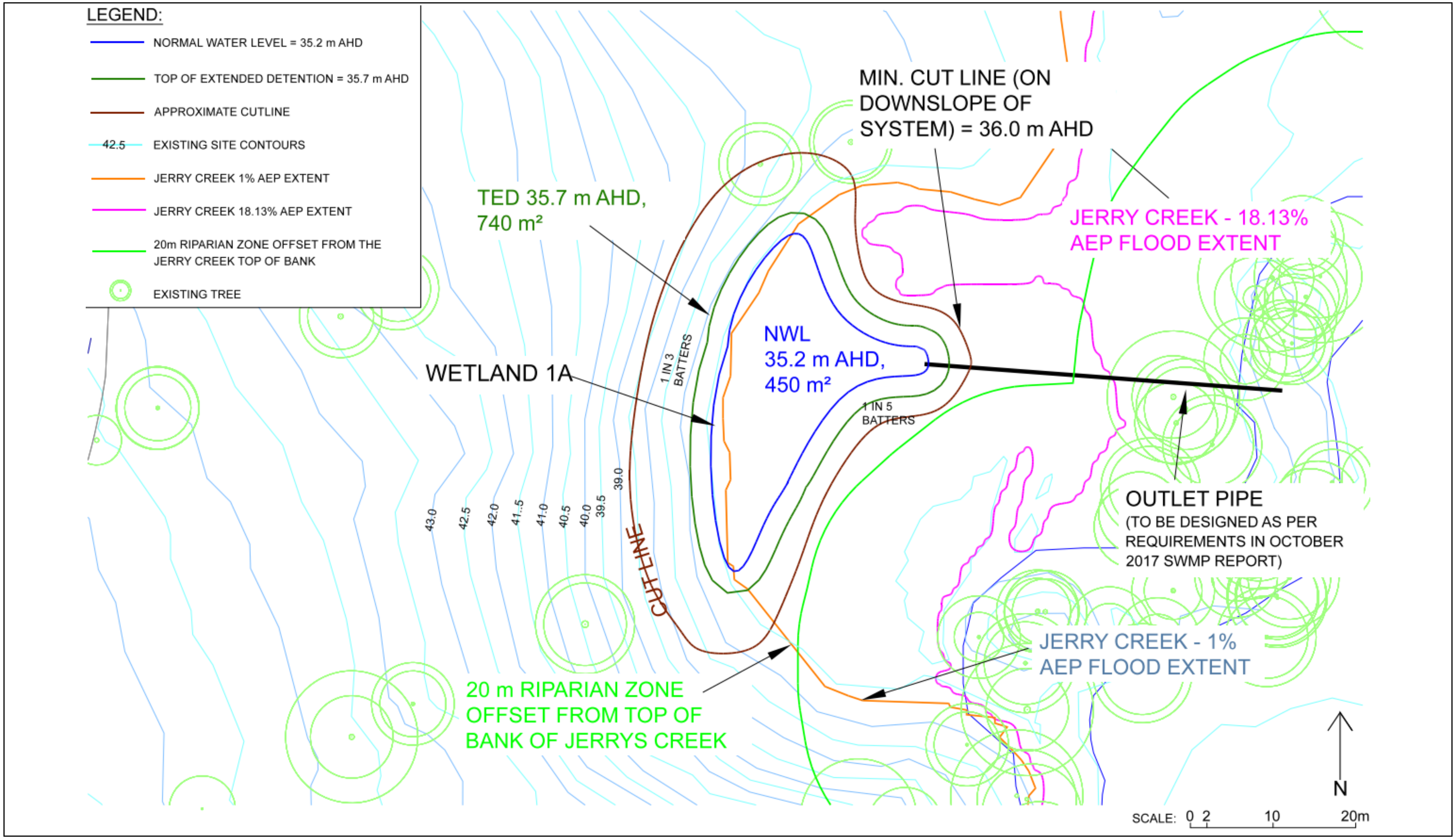

Figure 3 **Concept Design - Wetland 1A**
(See SWS Drawing 1774/SWS/2 for full detail)

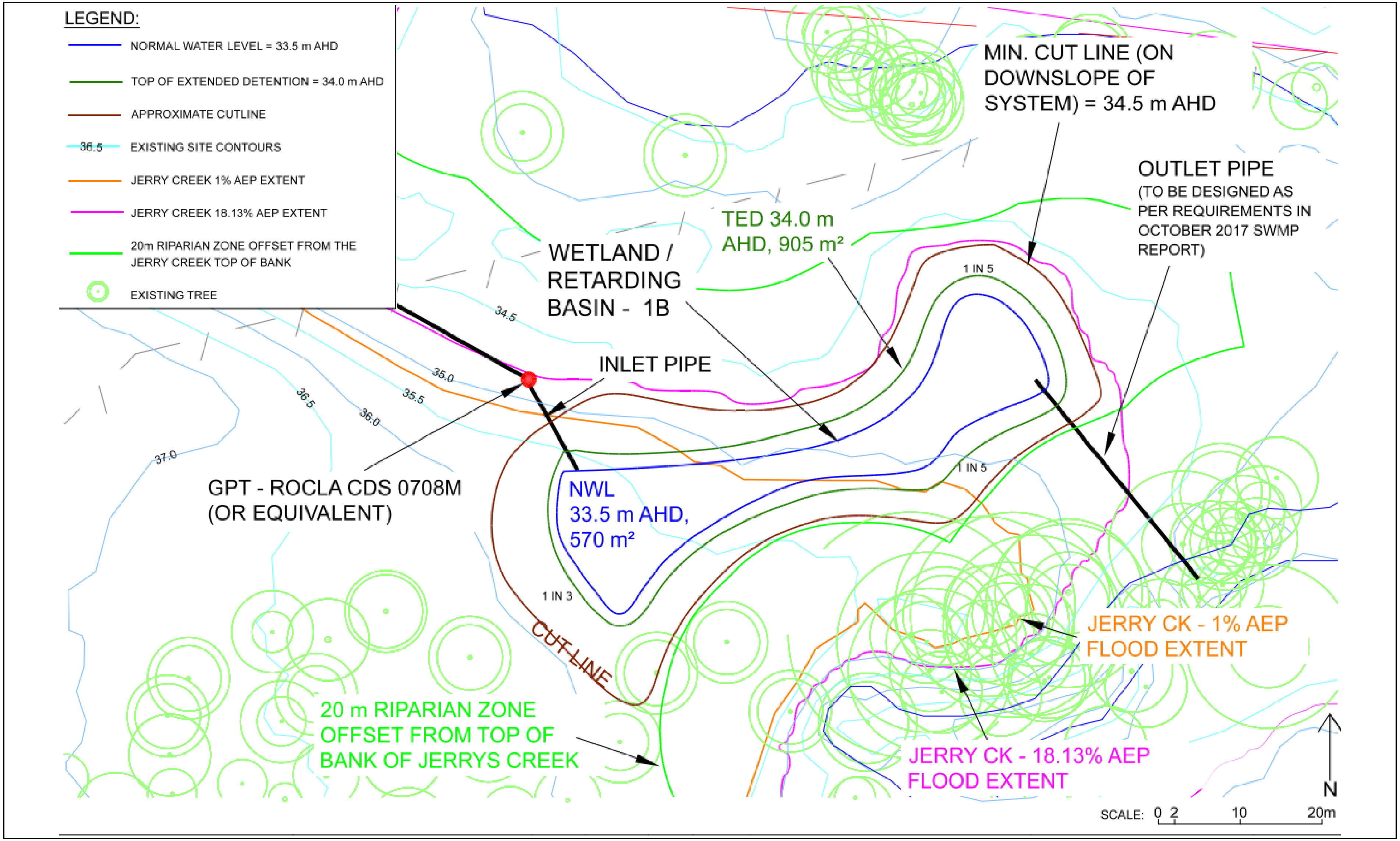

Figure 4 **Concept Design – Wetland/ Retarding Basin 1B**
(See SWS Drawing 1774/SWS/3 for full detail)

4.3 Catchment 2

Catchment 2 is defined as the catchment out falling to the eastern bank of Jerrys Creek from the southern to northern portion of the site. As with Catchment 1, in existing conditions, much of the outflow to this part of the creek is via sheet flow from fairways and greens to the creek in a distributive manner. Again, it is difficult to define a defined outfall point for this catchment. As detailed in the hydrological models (Appendices A, B and C), the WSUD strategy and SWMP for Catchment 2 accounts for all flow from this catchment, but lumps all inputs together for this section of Jerrys Creek.

As with the development of the Catchment 1 strategy, the formulation of the SWMP for Catchment 2 has been undertaken in this way to clearly (and transparently) show that all the hydrological conditions relating to the discharge of flow from Catchment 2 to Jerrys Creek can be met.

WSUD strategy and SWMP elements proposed in Catchment 2 are:

- Buffer treatment of the imperious areas in burial areas,
- GPT2 on the pipe outfall just upstream of Wetland / Retarding Basin W2B (Rocla 0708M type wet sump vortex systems (or equivalent)),
- Wetland 2A (stormwater treatment function only), and
- Wetland/Retarding Basin 2B (stormwater treatment and flood retardation function).

In regard to flood control the major element proposed is Wetland/Retarding Basin 2B. This element has been placed on the outfall from the largest piped system in this catchment to ensure most “road and building” runoff is captured in this element. However, it has been oversized to ensure that the total flow from the whole of Catchment 2 is retarded to below predevelopment conditions. At this stage (as detailed in Appendix B) the all post development flows (10%, 5%, 2% and 1% AEP) are retarded to <u>WELL BELOW</u> the total predevelopment flow expected in Catchment 2.

Appendix C details the post-development MUSIC modelling which shows the council requirement in relation to stormwater treatment requirements issue can be met by the SWMP.

Figures 5 and 6 detail the concept design of Wetland 2A and Wetland/Retarding Basin 2B.

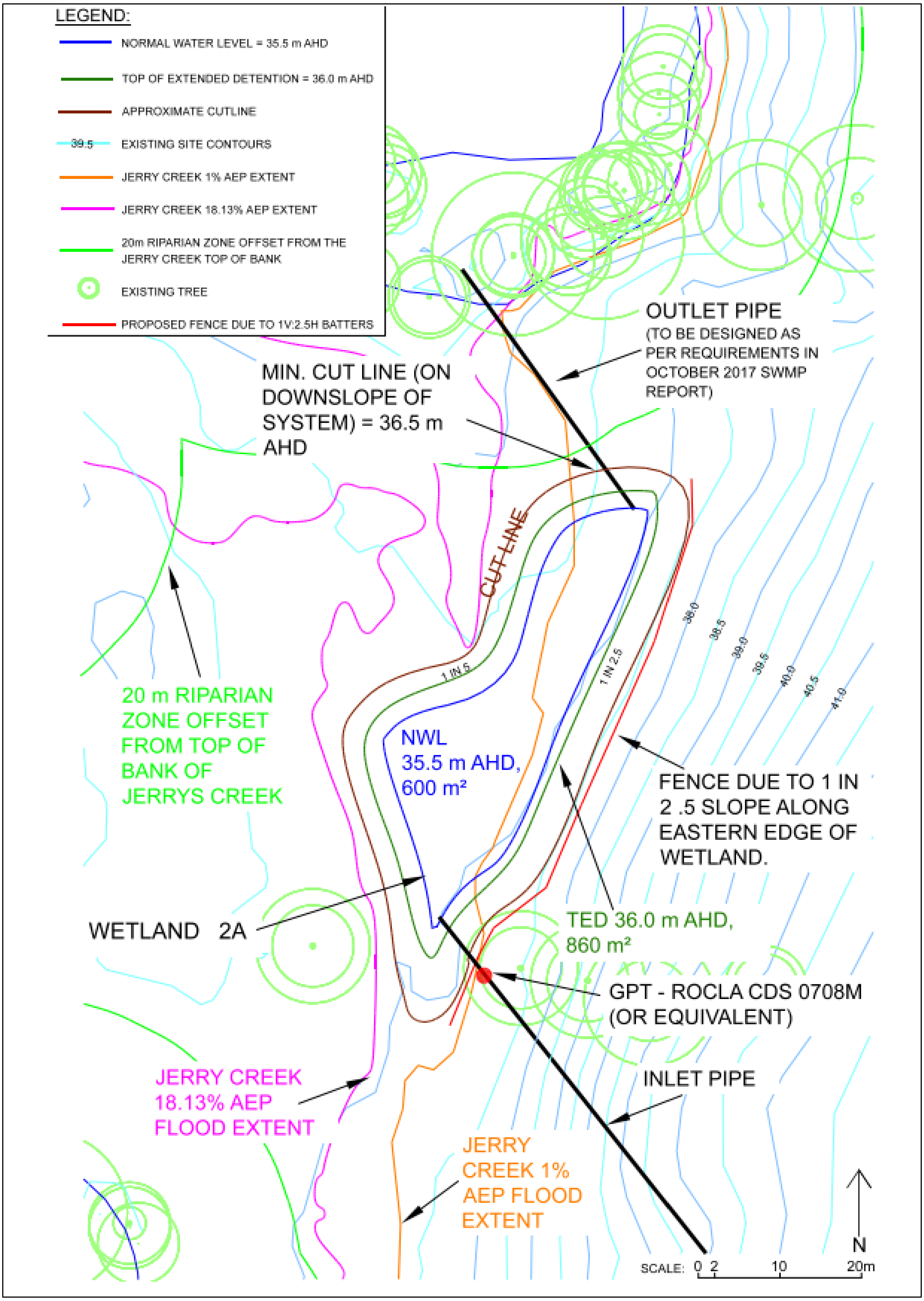

Figure 5 **Concept Design - Wetland 2A**
(See SWS Drawing 1774/SWS/4 for full detail)

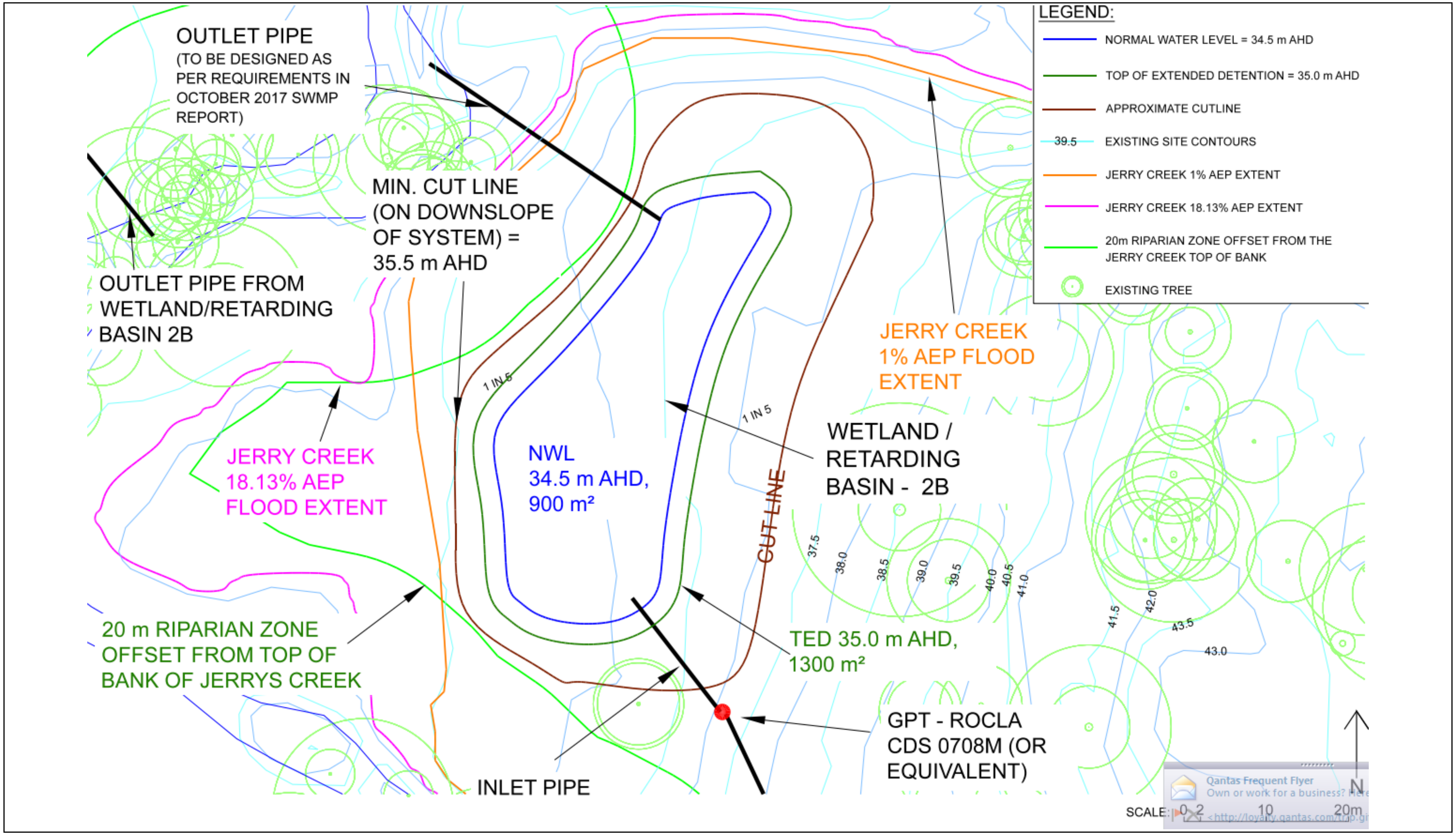

Figure 6 Concept Design – Wetland/Retarding Basin 2B
(See SWS Drawing 1774/SWS/5 for full detail)

4.4 Catchment 3

Catchment 3 is defined as the catchment out falling to Park Road at the southern site outfall point.

WSUD strategy and SWMP elements proposed in Catchment 3 are:

- Buffer treatment of the imperious areas in burial areas,
- Vegetated Swales 3A and 3B providing secondary treatment from piped outfall points to Wetland/Retarding Basin 3, and
- Wetland/Retarding Basin 3 (stormwater treatment and flood retardation function).

It should be noted that the Vegetated Swales 3A and 3B 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 significant 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 B), 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 3. 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 3.

Appendix C details the post-development MUSIC modelling which shows the council requirement in relation to stormwater treatment requirements issue can be met by the SWMP.

Figures 7 and 8 details the concept design of Wetland 3 and Vegetated Swales 3A and 3B.

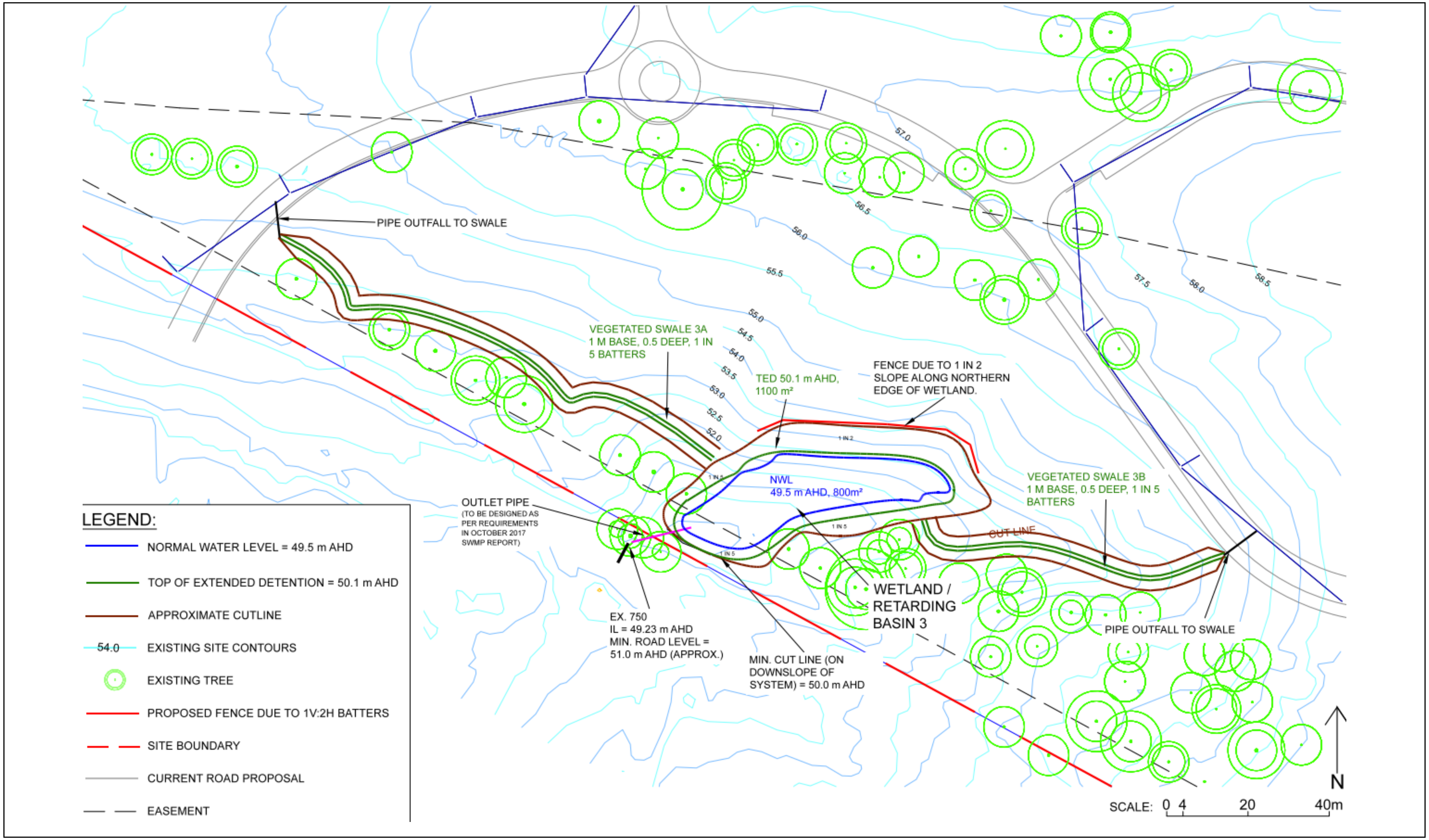

Figure 7 **Concept Design - Vegetated Swales 3A, 3B and Wetland/Retarding Basin 3**
(See SWS Drawing 1774/SWS/6 for full detail)

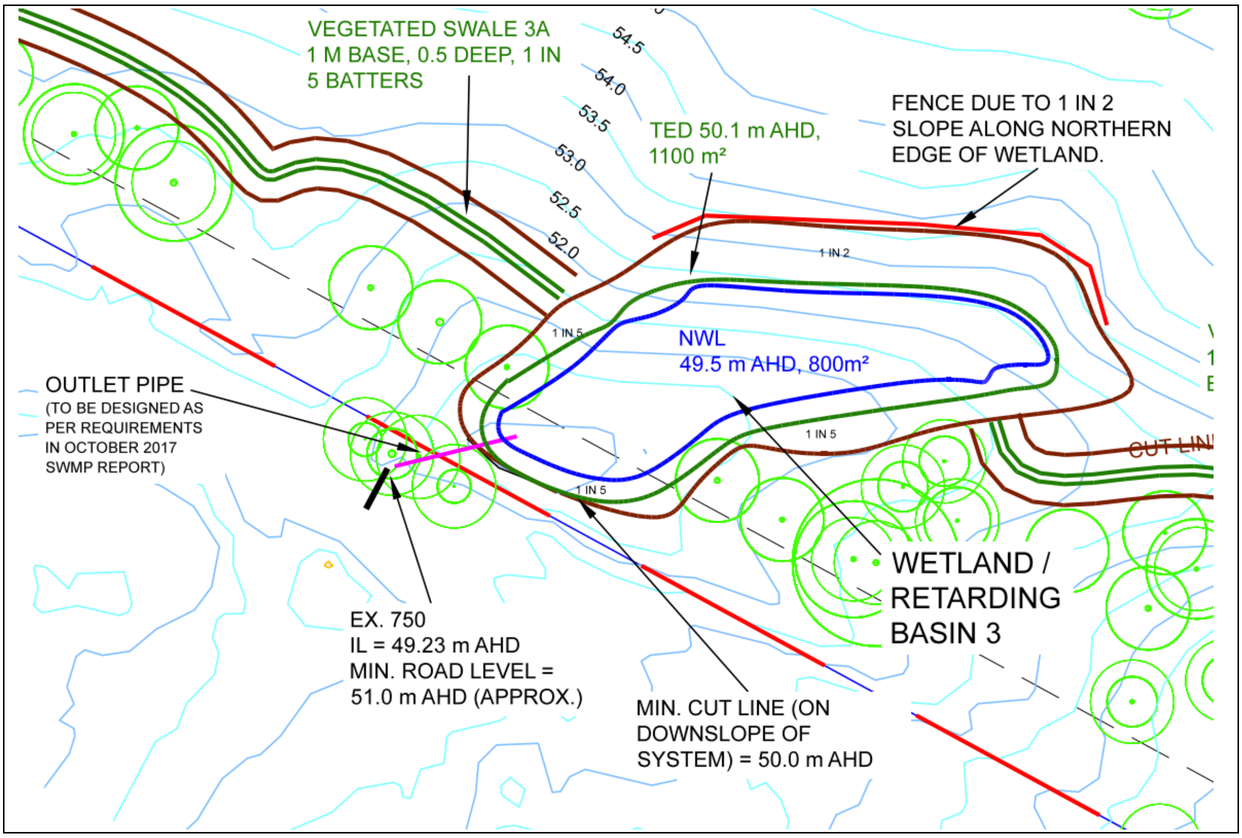

Figure 8 **Concept Design – Wetland/Retarding Basin 3**
(See SWS Drawing 1774/SWS/6 for full detail)

4.5 Catchment 4

Catchment 4 is defined as the catchment out falling from three small watercourses to the north portion of the site, and into a tributary of Jerrys Creek located north of the subject site.

As with Catchments 1 and 2, in existing conditions, much of the outflow to this part of the creek is via sheet flow from fairways and greens to the three small gullies. As detailed in the hydrological models (Appendix A, B and C), the WSUD strategy and SWMP for this catchment accounts for all flow from this catchment, but lumps all inputs together for this section of Jerrys Creek.

As with the development of the Catchment 1 and 2 strategies, the formulation of the SWMP for Catchment 4 has been undertaken in this way to clearly (and transparently) show that all the hydrological conditions relating to the discharge of flow from Catchment 4 to Jerrys Creek tributary can be met.

WSUD strategy and SWMP elements proposed in Catchment 4 are:

- Buffer treatment of the imperious areas in burial areas,
- Vegetated Swales 4A and 4B,
- Bioretention System /Retarding Basin 4A (stormwater treatment and flood retardation function), and

- Bioretention System 4B (stormwater treatment function only).

Again, Vegetated Swales 4A and 4B not only contribute to stormwater treatment, but they aid in the flood retardation strategy. This has been captured in the hydrological RORB modelling (Appendix B), 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 bioretention systems 4A. The combination of these elements indicates that, at this stage (as detailed in Appendix C) the all post development flows (10%, 5%, and 1% AEP) are retarded to BELOW the total predevelopment flow expected in Catchment 3. The 2% flow is just above this requirement. However, considering the significant reduction in flows from all other catchments (especially Catchment 5), this is seen (at this concept design stage) as acceptable.

The description of the vegetated swale form and design is detailed in Appendix D.

Appendix C details the post-development MUSIC modelling which shows the council requirement in relation to stormwater treatment requirements issue can be met by the SWMP.

Figures 9 details the concept design of the Catchment 4 WSUD and drainage elements.

Due to the steep nature of these gully’s, it is anticipated that the “filter of the bioretention systems will be formed (in a simple sense) by filling the gully. In this way, site outfall pipes at these locations can outfall to the existing natural surface, and not be required to have a drain cut downstream of the site at these locations. A retarding wall located at least 3 metres upstream of the site boundary will form the structural element retarding the bioretention filter, and the water stored for treatment and flood retardation. The hydraulic controls will be designed to outfall though this retaining wall to the existing drainage line as described above.

Catchment 4 required 2 Stream Order 1 watercourses to act as vegetated swales. The form of these swales is as described in Appendix D. It is proposed to vegetate the existing watercourses for use as swales and, as such, the watercourses are assumed to be converted to drainage swale definition. This will require an offset elsewhere onsite.

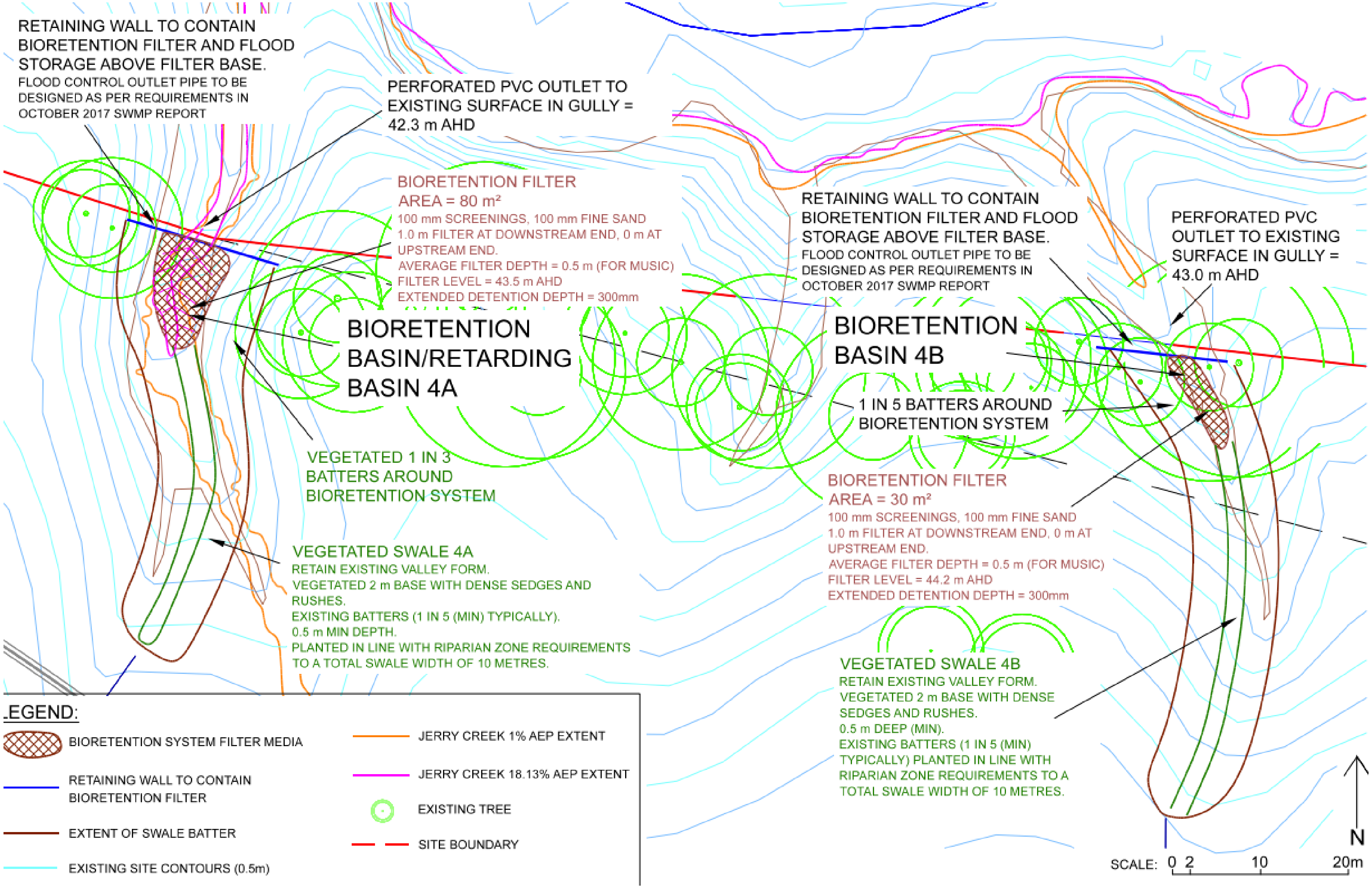

Figure 9 **Concept Design, Vegetated Swale 4A, and Biorention System/Retarding Basin 4A**
(See SWS Drawing 1774/SWS/7 for full detail)

4.6 Catchment 5

Catchment 5 is the largest catchment in the strategy. It incorporates a significant external catchment.

WSUD strategy and SWMP elements proposed in Catchment 5 are:

- Buffer treatment of the imperious areas in burial areas,
- Vegetated Swales 5A, 5B, 5C, 5D and 5E,
- Pond/Retarding Basin 5 (stormwater treatment and flood retardation function), and
- Wetland 5 (stormwater treatment function only).

The pond and wetland are existing assets modified to suit the drainage functions required under the SWMP (see Section 3 above). The swales are almost all the existing drainage lines planted to achieve stormwater treatment and flood storage functions (see Section 3 and Appendix D).

Vegetated Swales 5B, 5C, 5D, Pond 5 and Wetland 5 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
- Pond 5 and Wetland 5 not incorporating hydraulic controls to detain stormwater for treatment over 48 to 72 hours.

Once the swales are vegetated, and the hydraulic control of Pond 5 and Wetland 5 are 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 in Appendix C.

Again, all 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 B), 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 5. 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 3.

Figures 10 details the concept design of the Catchment 5 WSUD and drainage elements.

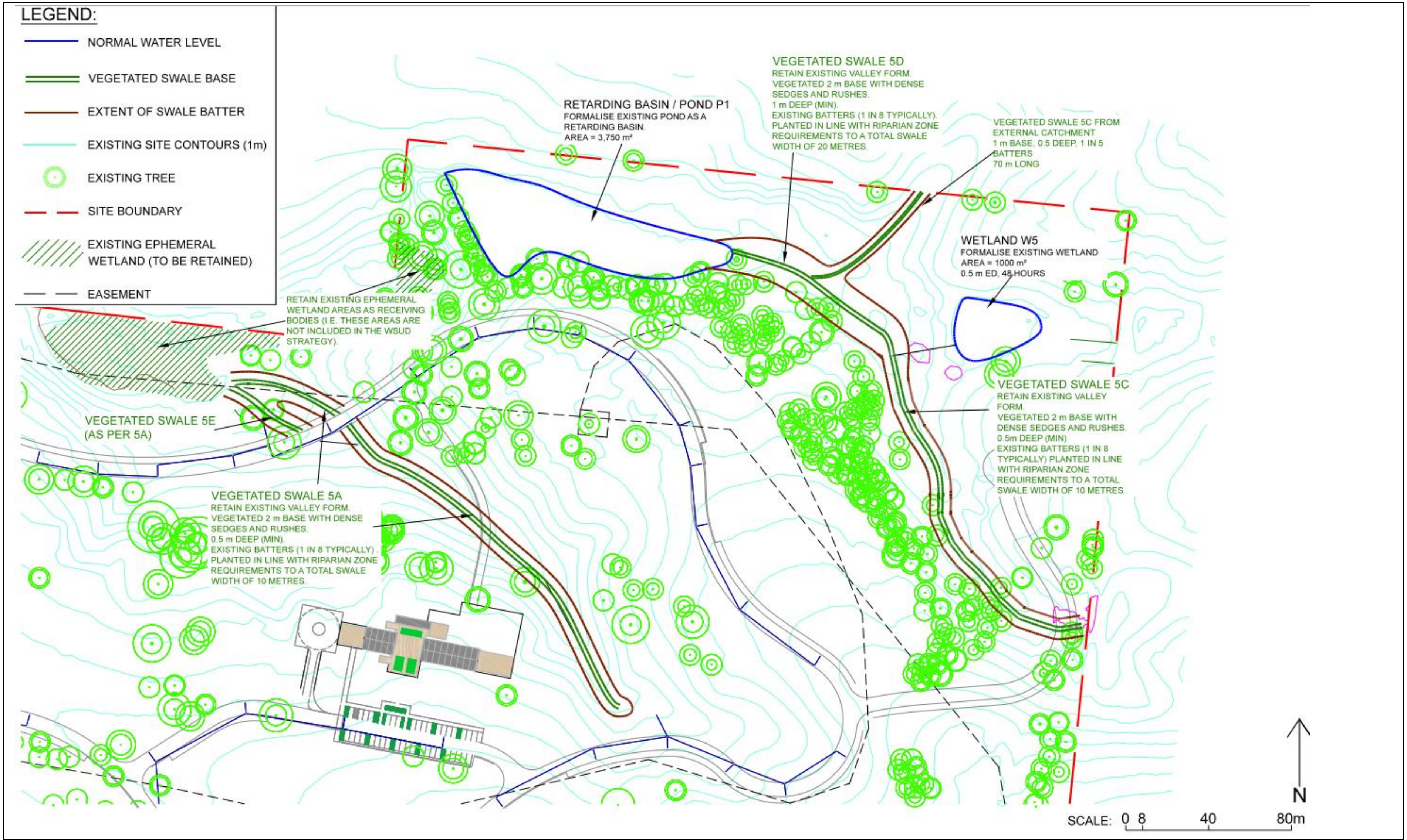

Figure 10 **Concept Design, Catchment 5 Drainage Elements**
(See SWS Drawing 1774/SWS/8 for full detail)

5. Conclusions

The stormwater drainage system proposed for the Wallacia Estate 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 landscape proposals (developed by FJLA), ecological constraints (defined by TB&E) and internal development drainage proposals (developed by WS&P). As such, the plans clearly show there is ensuring space allocated on further work required going forward in the design process to ensure all drainage requirements can be met.

It should be noted that the assumptions in regard to WSUD strategy and SWMP elements may change over time. However, it is considered at this stage, that the work presented has defined realistic and adequate potential land footprints required by major drainage assets for the development required for the Wallacia cemetery.

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 2016	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), 2016
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

APPENDIX A Pre-development Hydrological Model

The RORB Runoff Routing Program (Version 6.31) 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.

A.1 Model Description

Five separate RORB pre-development RORB models have been constructed of the subject site as shown in Figure A.1. Each model has been described in detail below.

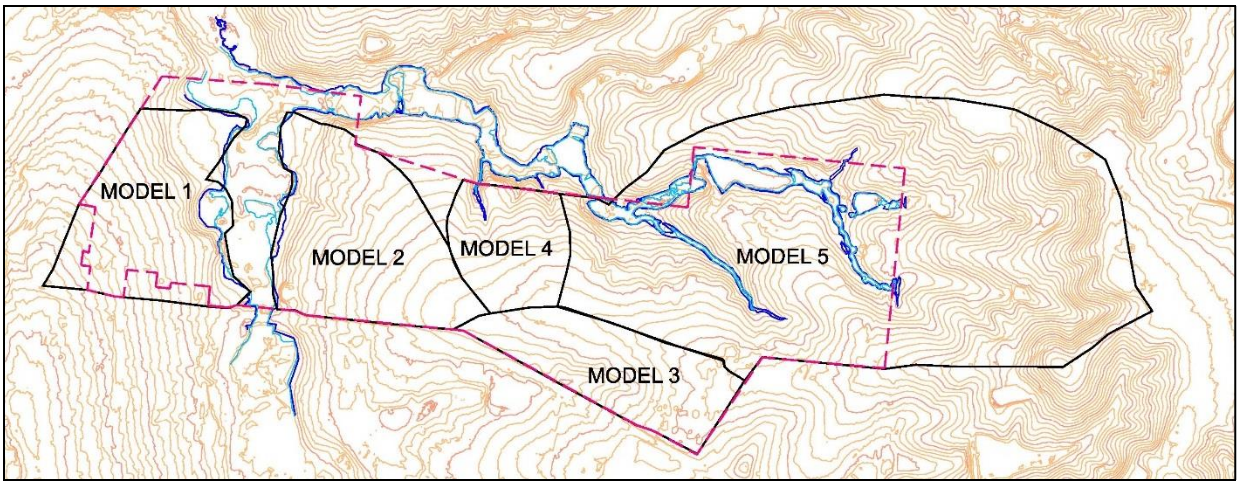

Figure A.1 Pre-development RORB models

Models 3 and 5 are able to print hydrographs at defined outlet locations. As the catchments represented in Models 1, 2 and 4 have no defined outlet location (from the subject site to Jerrys Creek) in the pre-development scenario (i.e. currently the 1% AEP event would be sheet flow over the surface), representative hydrographs have been produced for the total outflow flow from these catchments.

It should be noted, different reach types in RORB effect the K_r parameter described in Section A.2. Each of the four reach types effect the relative delay time of a reach. A “DROWNED” reach type in RORB indicates instantaneous routing from the reach, (i.e. no change to the hydrograph) and is appropriate to use for adding multiple smaller catchment outlets into one large representative catchment outlet.

Generally, flow across fairways is modelled as “Excavated/Unlined” reaches. This represents flow over short mown grass.

“Natural” reaches are largely used for creeks in their natural state.

A.1.1 Model 1

Figure A.2 below details the RORB model's setup. The RORB model's layout has been based on 0.5m LiDAR survey. Tables A.1 and A.2 detail the tabulation of the RORB model inputs.

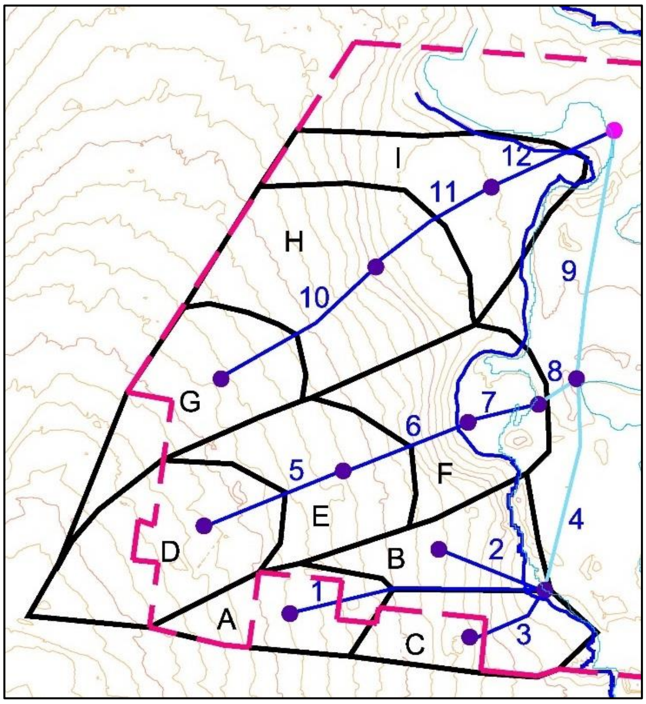

Figure A.2 RORB Model 1 Setup

Table A.1 Model 1 sub-catchment definition

Sub Area	Area (ha)	Area (km^2)	Fraction Imperviousness Pre
A	0.51	0.0051	0.80
B	0.54	0.0054	0.10
C	0.59	0.0059	0.10
D	1.01	0.0101	0.80
E	0.79	0.0079	0.10
F	0.92	0.0092	0.10
G	0.82	0.0082	0.25
H	1.39	0.0139	0.10
I	0.92	0.0092	0.10
TOTAL	**7.5**	0.0749	0.26

Table A.2 Model 1 reach definition

Reach	Length (km)	Slope %	Reach Type Pre
1	0.157	7.6%	EX/UNLINED
2	0.067	9.7%	EX/UNLINED
3	0.055	10.0%	EX/UNLINED
4	0.129	0.0%	DROWNED
5	0.089	6.2%	EX/UNLINED
6	0.082	11.6%	EX/UNLINED
7	0.045	1.1%	EX/UNLINED
8	0.026	0.0%	DROWNED
9	0.150	0.0%	DROWNED
10	0.115	7.8%	EX/UNLINED
11	0.085	4.1%	EX/UNLINED
12	0.083	1.8%	EX/UNLINED

A.1.2 Model 2

Figure A.3 below details the RORB model's setup. The RORB model's layout has been based on 0.5m LiDAR survey. Tables A.3 and A.4 detail the tabulation of the RORB model inputs.

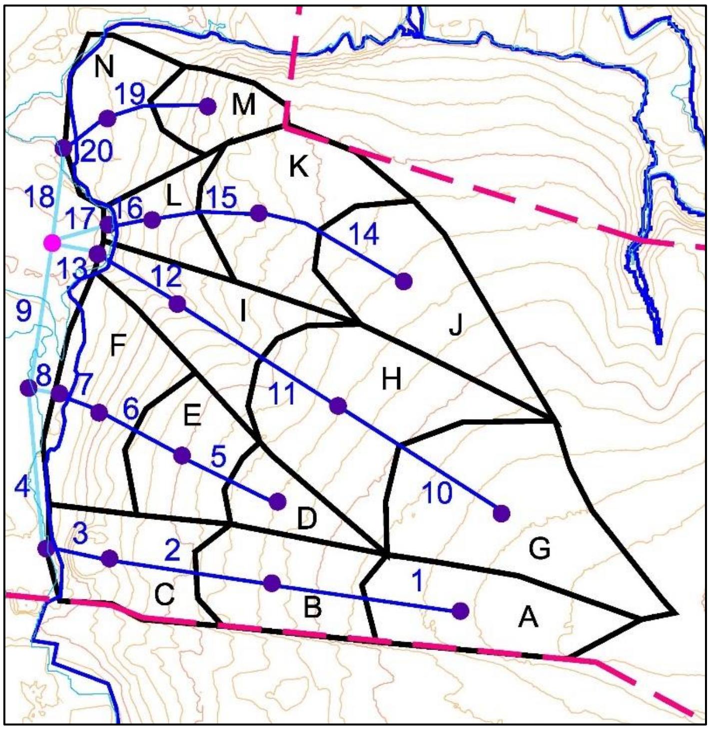

Figure A.3 RORB Model 2 Setup

Table A.3 Model 2 sub-catchment definition

Sub Area	Area (ha)	Area (km²)	Fraction Imperviousness Pre
A	0.61	0.0061	0.10
B	0.53	0.0053	0.10
C	0.50	0.0050	0.10
D	0.25	0.0025	0.10
E	0.43	0.0043	0.10
F	0.67	0.0067	0.10
G	1.06	0.0106	0.10
H	1.01	0.0101	0.10
I	0.55	0.0055	0.10
J	0.73	0.0073	0.10
K	0.72	0.0072	0.10
L	0.28	0.0028	0.10
M	0.26	0.0026	0.10
N	0.49	0.0049	0.10
TOTAL	**8.1**	0.0808	0.10

Table A.4 Model 2 reach definition

Reach	Length (km)	slope %	Reach Type Pre
1	0.109	3.7%	EX/UNLINED
2	0.095	6.3%	EX/UNLINED
3	0.036	12.6%	EX/UNLINED
4	0.092	0.0%	DROWNED
5	0.061	4.9%	EX/UNLINED
6	0.052	10.6%	EX/UNLINED
7	0.026	9.6%	EX/UNLINED
8	0.017	0.0%	DROWNED
9	0.083	0.0%	DROWNED
10	0.113	4.0%	EX/UNLINED
11	0.110	6.8%	EX/UNLINED
12	0.054	8.3%	EX/UNLINED
13	0.030	0.0%	DROWNED
14	0.093	4.8%	EX/UNLINED
15	0.061	7.4%	EX/UNLINED
16	0.028	10.9%	EX/UNLINED
17	0.034	0.0%	DROWNED
18	0.056	0.0%	DROWNED
19	0.059	8.5%	EX/UNLINED
20	0.030	3.4%	EX/UNLINED

A.1.3 Model 3

Figure A.4 below details the RORB model's setup. The RORB model's layout has been based on 0.5m LiDAR survey. Tables A.5 and A.6 detail the tabulation of the RORB model inputs.

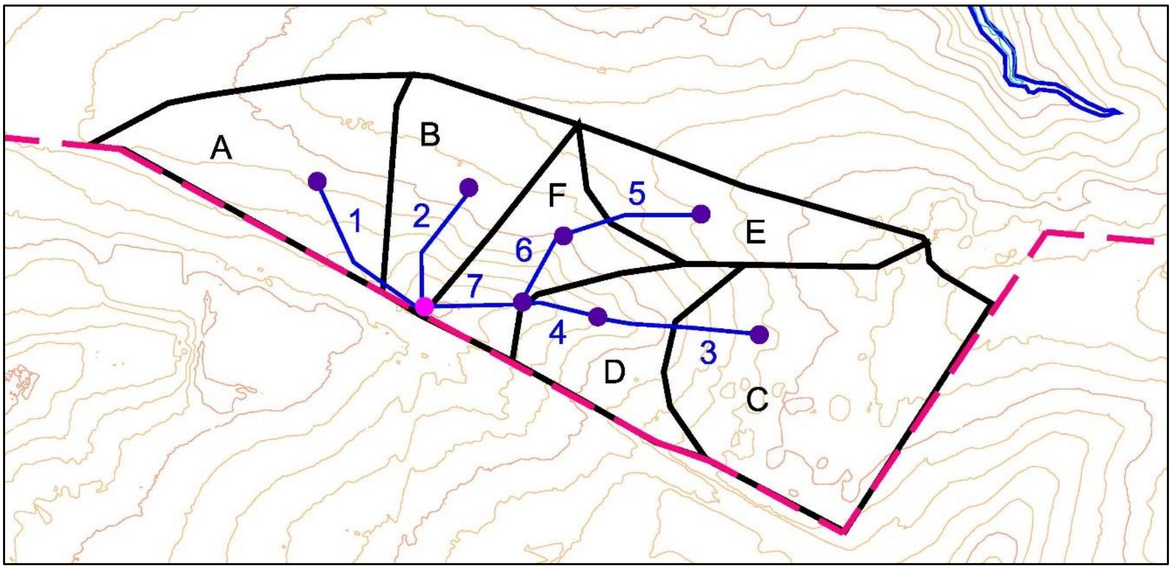

Figure A.4 RORB Model 3 Setup

Table A.5 Model 3 sub-catchment definition

Sub Area	Area (ha)	Area (km^2)	Fraction
			Imperviousness
			Pre
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	**5.3**	0.0528	0.10

Table A.6 Model 3 reach definition

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

A.1.4 Model 4

Figure A.5 below details the RORB model's setup. The RORB model's layout has been based on 0.5m LiDAR survey. Tables A.7 and A.8 detail the tabulation of the RORB model inputs.

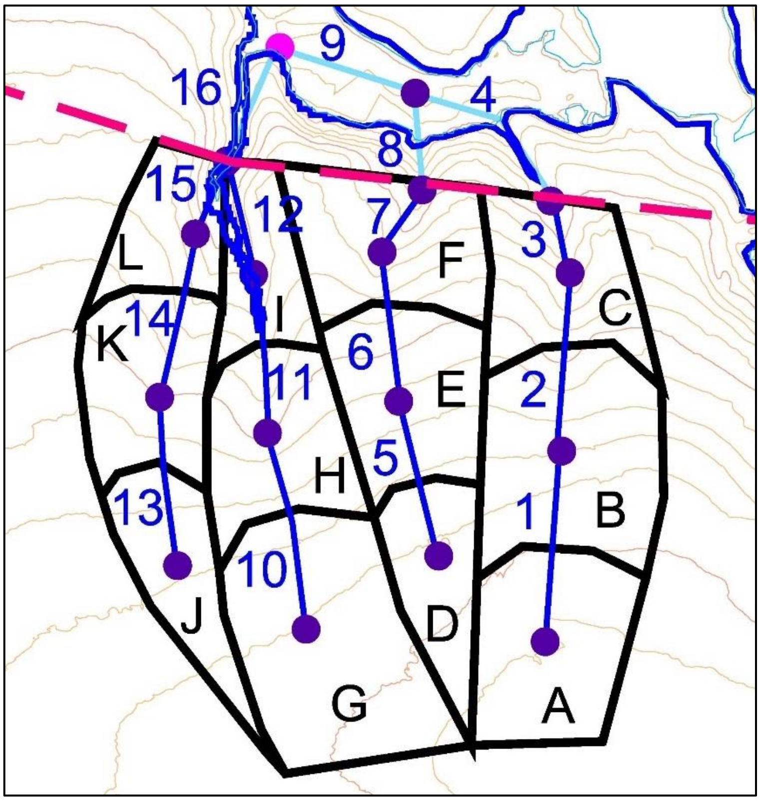

Figure A.5 RORB Model 4 Setup

Table A.7 Model 4 sub-catchment definition

Sub Area	Area (ha)	Area (km^2)	Fraction Imperviousness Pre
A	0.34	0.0034	0.10
B	0.44	0.0044	0.10
C	0.28	0.0028	0.10
D	0.21	0.0021	0.10
E	0.31	0.0031	0.10
F	0.32	0.0032	0.10
G	0.53	0.0053	0.10
H	0.29	0.0029	0.10
I	0.18	0.0018	0.10
J	0.22	0.0022	0.10
K	0.28	0.0028	0.10
L	0.19	0.0019	0.10
TOTAL	**3.6**	0.0359	0.10

Table A.8 Model 4 reach definition

Reach	Length (km)	slope %	Reach Type Pre
1	0.065	4.6%	EX/UNLINED
2	0.063	9.5%	EX/UNLINED
3	0.028	10.7%	EX/UNLINED
4	0.064	0.0%	DROWNED
5	0.056	4.5%	EX/UNLINED
6	0.053	9.4%	EX/UNLINED
7	0.027	9.4%	EX/UNLINED
8	0.032	0.0%	DROWNED
9	0.049	0.0%	DROWNED
10	0.070	5.0%	EX/UNLINED
11	0.057	7.9%	EX/UNLINED
12	0.041	7.4%	EX/UNLINED
13	0.061	4.9%	EX/UNLINED
14	0.058	6.9%	EX/UNLINED
15	0.028	8.9%	EX/UNLINED
16	0.042	0.0%	DROWNED

A.1.5 Model 5

Figure A.6 below details the RORB model's setup. The RORB model's layout has been based on 0.5m LiDAR survey. Tables A.9 and A.10 detail the tabulation of the RORB model inputs.

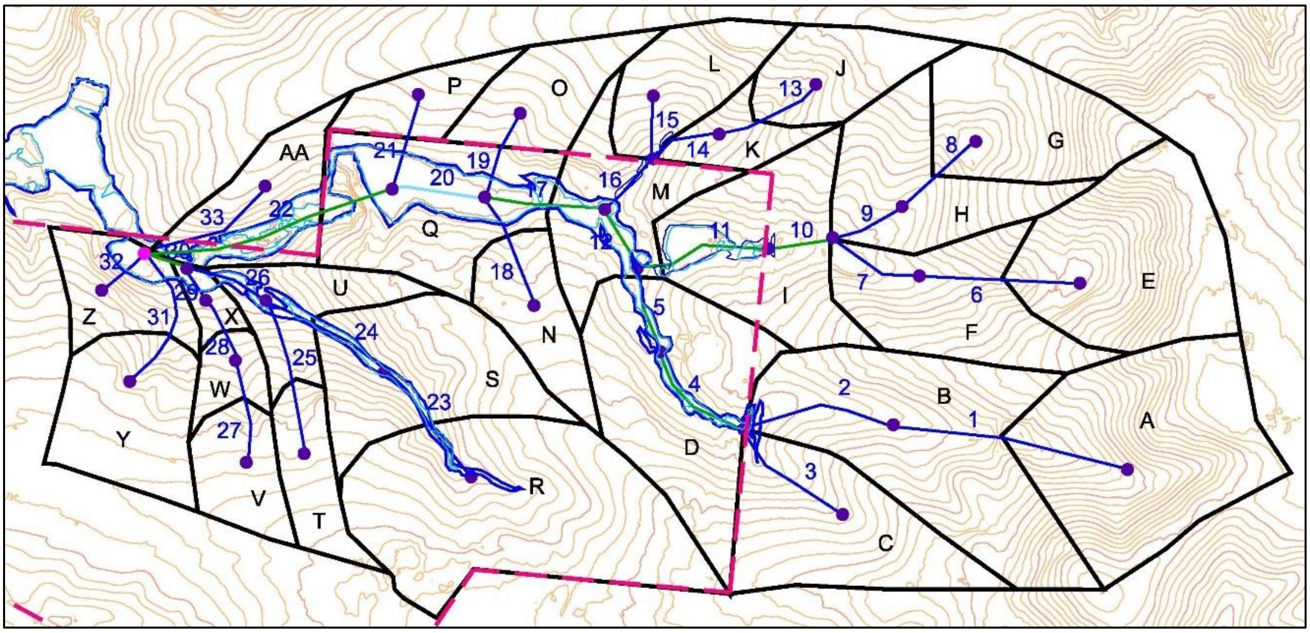

Figure A.6 RORB Model 5 Setup

Table A.9 Model 5 sub-catchment definition

Sub Area	Area (ha)	Area (km²)	Fraction Imperviousness Pre
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
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 A.10 Model 5 reach definition

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

A.2 Model Parameters

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

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

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 (AR&R). 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 2016) 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 the current catchment development is largely pervious, the use of a CL rather than a pervious area runoff coefficient is appropriate. IL and CL values have been obtained from the AR&R datahub for the location 33.86583 S, 150.646315 E as shown below.

$IL = 46\ mm,$

$CL = 3.4\ mm/hr$

AR&R 2016 Data hub (Lat: 33.86583 S, Lon: 150.646315 E, accessed: 22 September 2017) rainfall depths, rainfall temporal patterns and areal reduction factors have been used in the model.

A summary of the key parameters for all models is shown below in Table A.11. It should be noted, unlike previous area runoff coefficients, CL values are independent of AEP and should not be varied with AEP (ARR 2016, Book 5, Chapter 3.7.1). As such, the parameters quoted in Table A.11 apply for all AEP with only the rainfall depths and temporal patterns changing with AEP.

Table A.11 RORB Pre-development Parameter Set (All AEP events)

Model	Area (km^2)	K_c	m	IL (mm)	CL (mm/hr)
1	0.0749	0.35	0.80	46	3.4
2	0.0808	0.36	0.80	46	3.4
3	0.0528	0.30	0.80	46	3.4
4	0.0359	0.25	0.80	46	3.4
5	0.3472	0.72	0.80	46	3.4

A.3 Model Verification

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 are compared against other flow computational methods.

The flows were compared to the flows calculated by WS&P for predevelopment catchment conditions and found to be within the same order of magnitude. RORB flows were slightly less than those calculated by WS&P (using the ILSAX model). ILSAX is appropriate for use on small urban catchments and uses the time-area method to calculate hydrographs. RORB is a physically based model that is able to route the flow (which attenuates the hydrograph shape as part of storages within the catchment). As such, RORB should better represent expected flows from the catchments, and the small discrepancies between the two modelling approaches are expected due to the reach catchment and reach storages effects modelled within RORB.

A.4 Model Results

As ARR 2016 recommends the use of ensemble simulations, 10 temporal patterns have been simulated for each duration and AEP. As recommended in AR&R (Book 2, Chapter 5.9.2), it is appropriate to take the median hydrograph as the design flows for each duration. As such, Table A.12 is reported with the temporal pattern number as obtained from the ARR 2016 data hub. Example box and whisker plots of all the temporal patterns simulated for the 1% AEP flow for each model at the outflow (or equivalent outflow) location have been produced.

Table A.12 Pre-development RORB Model Results

Model	1% AEP			2% AEP			5% AEP			10% AEP		
	Q (m^3/s)	Duration	TP	Q (m^3/s)	Duration	TP	Q (m^3/s)	Duration	TP	Q (m^3/s)	Duration	TP
1	1.9	45-minute	26	1.4	45-minute	27	1.0	2-hour	14	0.7	2-hour	16
2	1.9	45-minute	26	1.3	45-minute	30	1.0	2-hour	14	0.7	2-hour	16
3	1.1	45-minute	27	0.8	2-hour	25	0.6	2-hour	15	0.4	2-hour	16
4	0.9	45-minute	26	0.6	2-hour	29	0.5	2-hour	14	0.4	2-hour	16
5	3.4	1.5-hour	29	2.8	2-hour	25	1.7	9-hour	18	1.4	9-hour	11

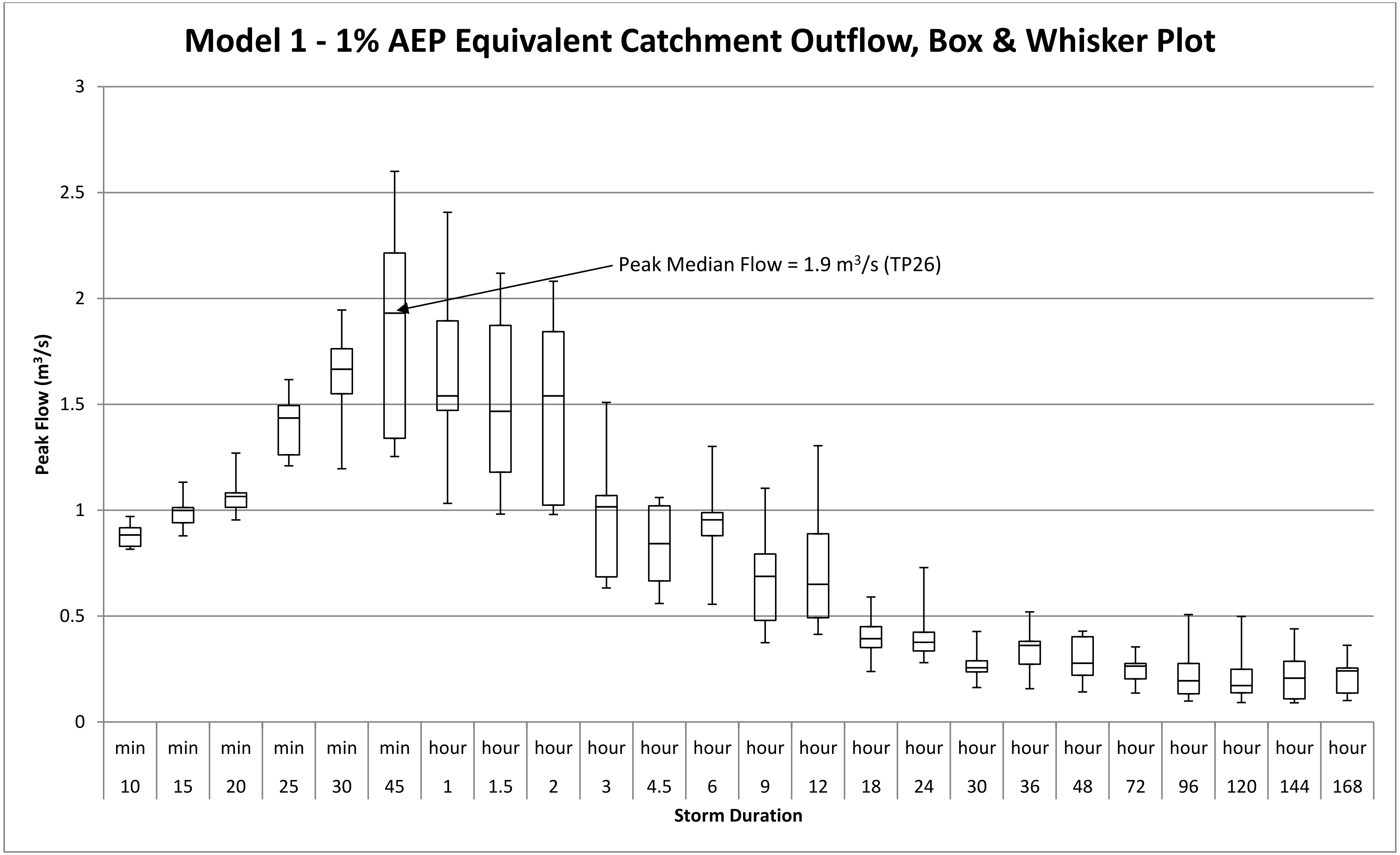

Figure A.7 **Box and Whisker Plot of all 240 1% AEP simulations run for Model 1.**
Note: quoted value from Table A.12 highlighted

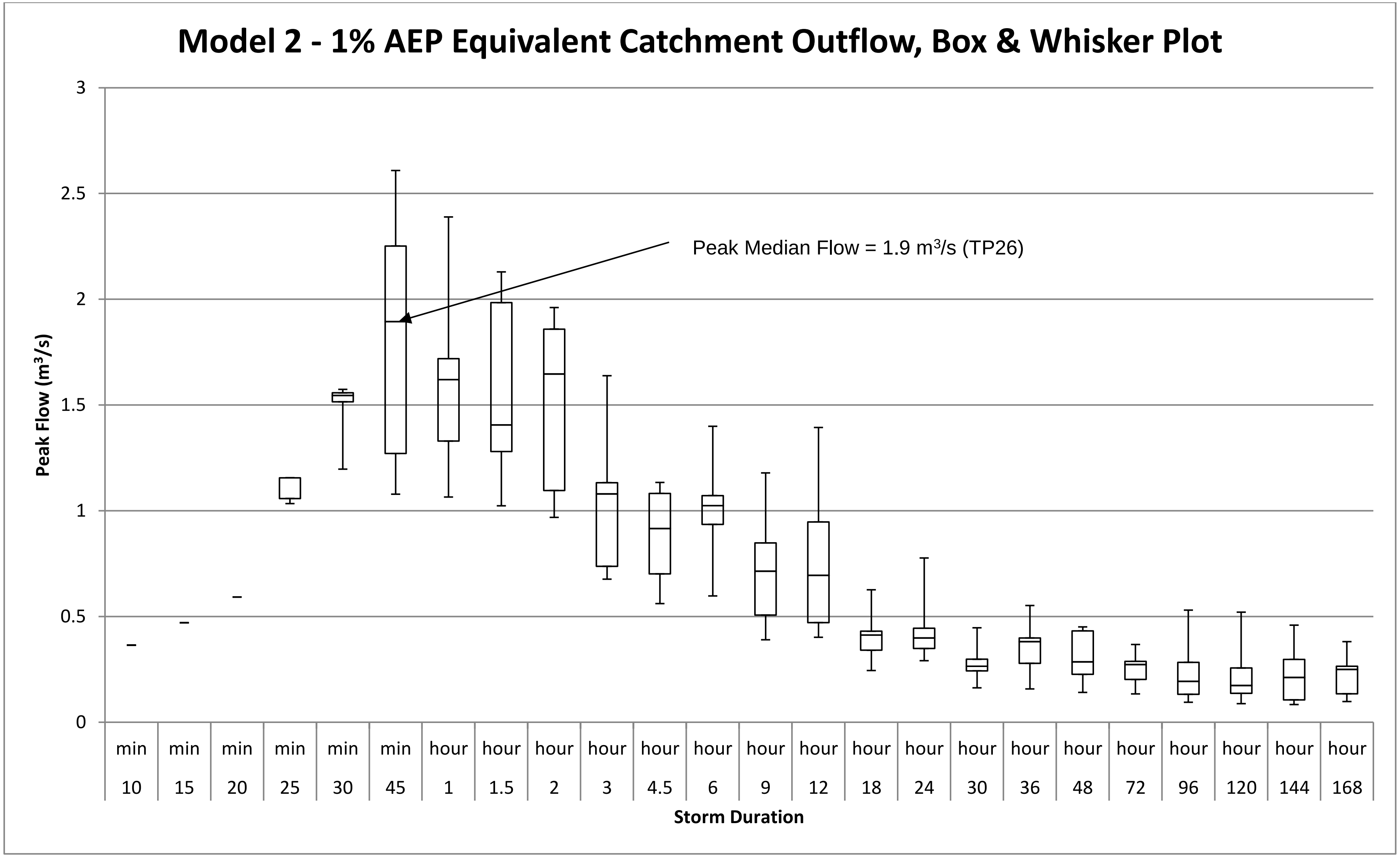

Figure A.8 **Box and Whisker Plot of all 240 1% AEP simulations run for Model 2.**
Note: quoted value from Table A.12 highlighted

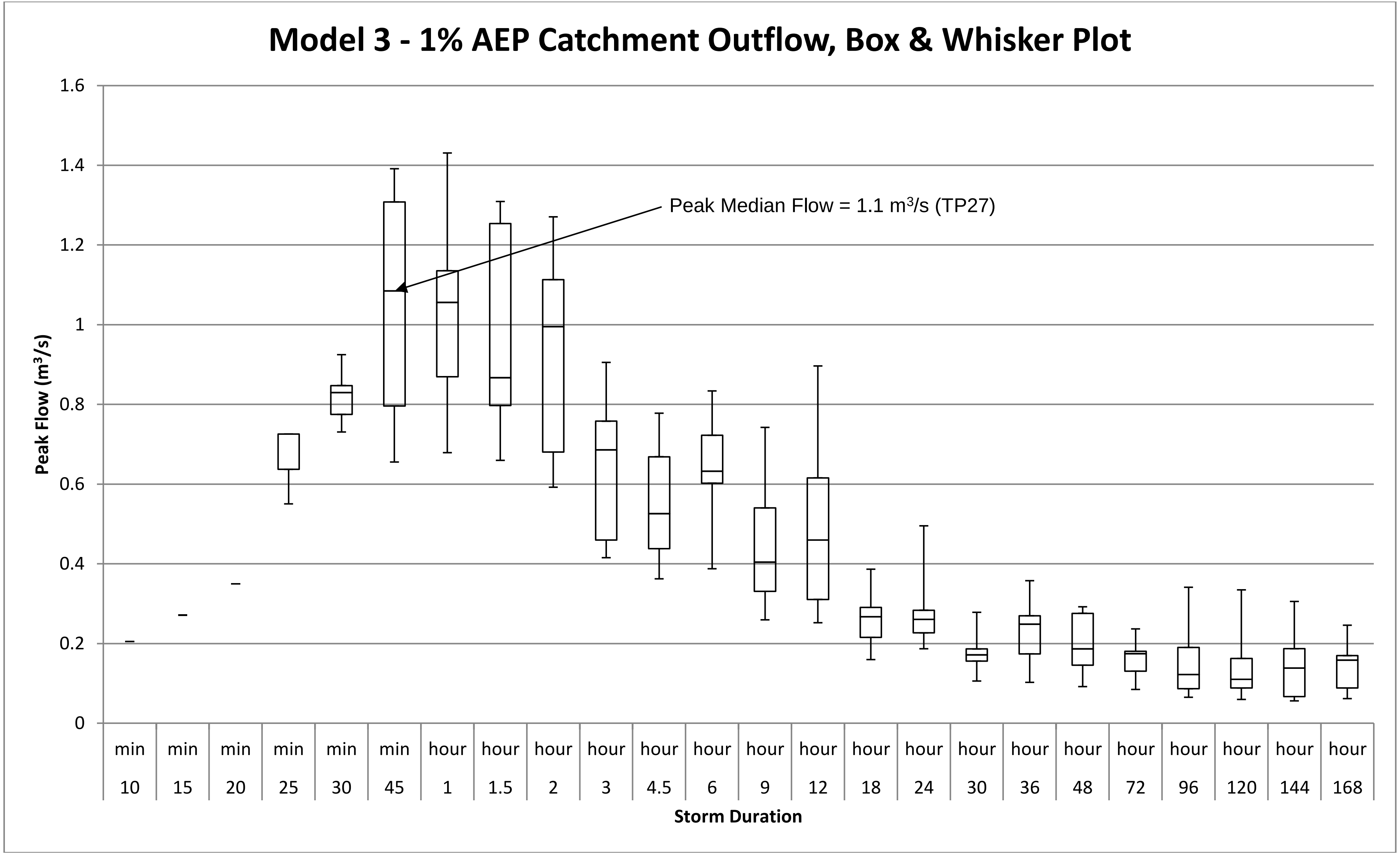

Figure A.9 **Box and Whisker Plot of all 240 1% AEP simulations run for Model 3.**
Note: quoted value from Table A.12 highlighted

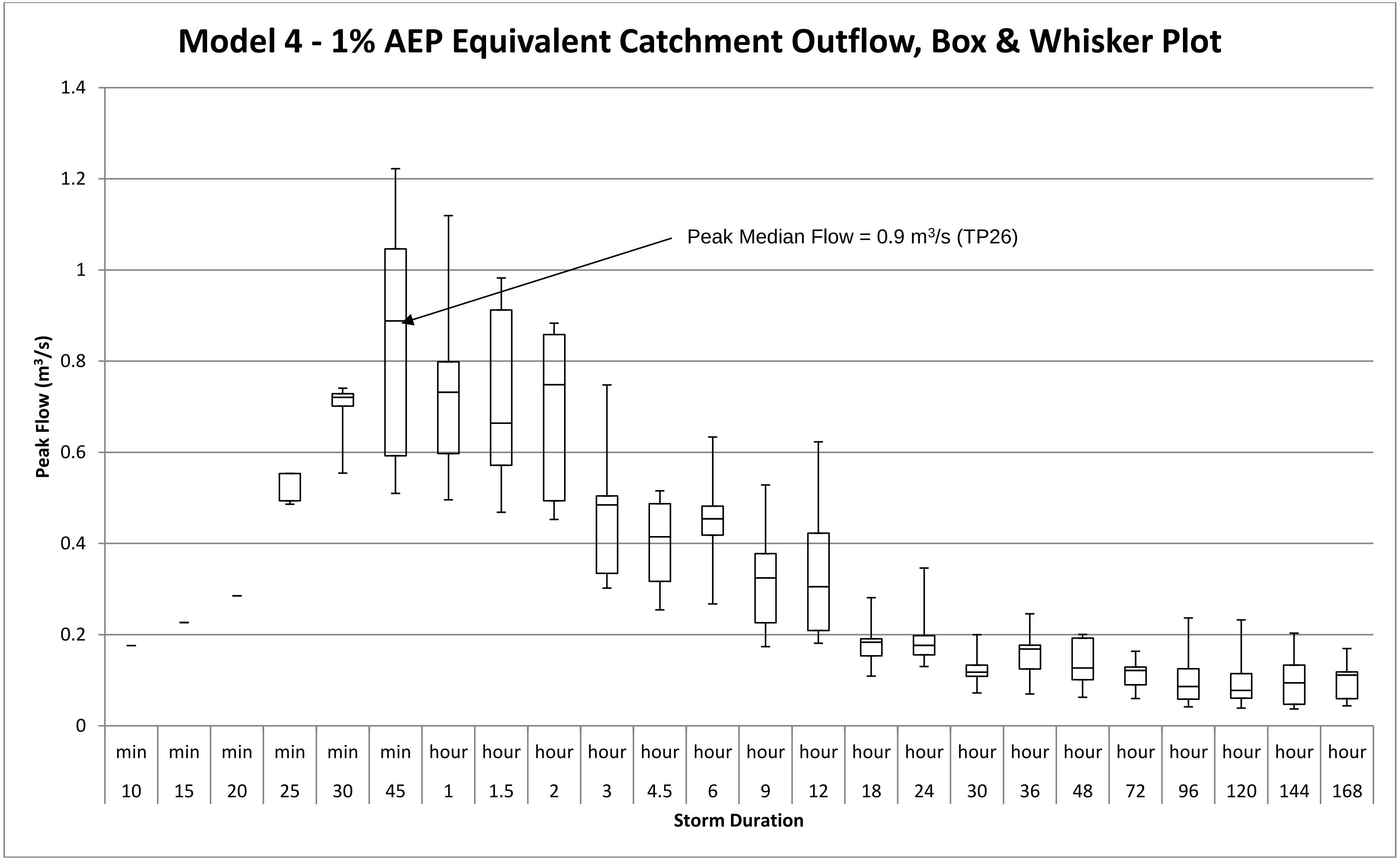

Figure A.10 **Box and Whisker Plot of all 240 1% AEP simulations run for Model 4.**
Note: quoted value from Table A.12 highlighted

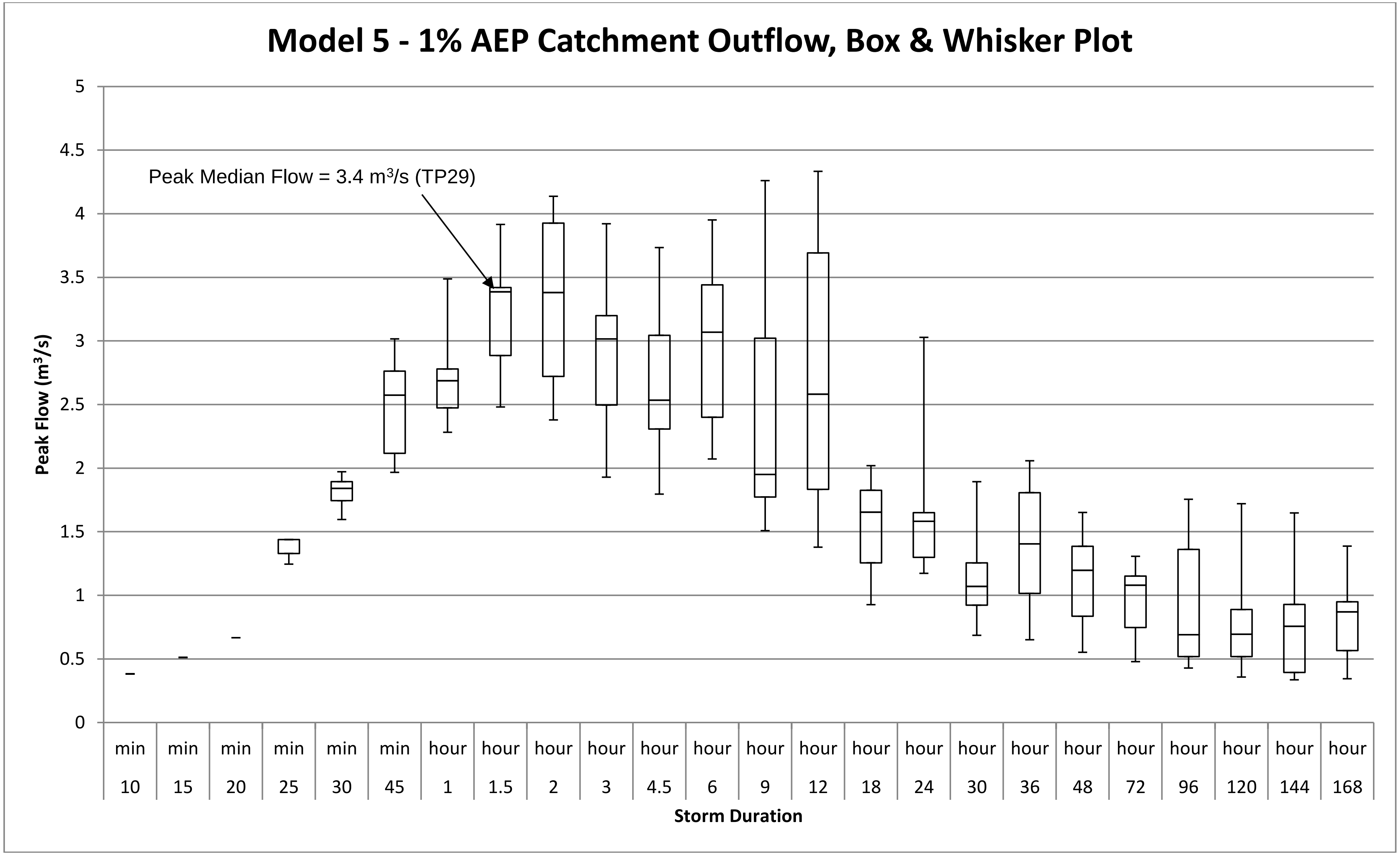

Figure A.11 **Box and Whisker Plot of all 240 1% AEP simulations run for Model 5.**
Note: quoted value from Table A.12 highlighted

Appendix B Post Development Hydrologic Model

The RORB Runoff Routing Program (Version 6.31) was used to determine the 10, 5, 2 and 1% AEP (10, 20, 50 and 100-year ARI) post-development design flows originating from the subject site with the proposed future retarding basins.

B.1 Model Description

Similar to the pre-development modelling, five separate RORB models have been constructed for each of the five catchments shown in Figure B.1.

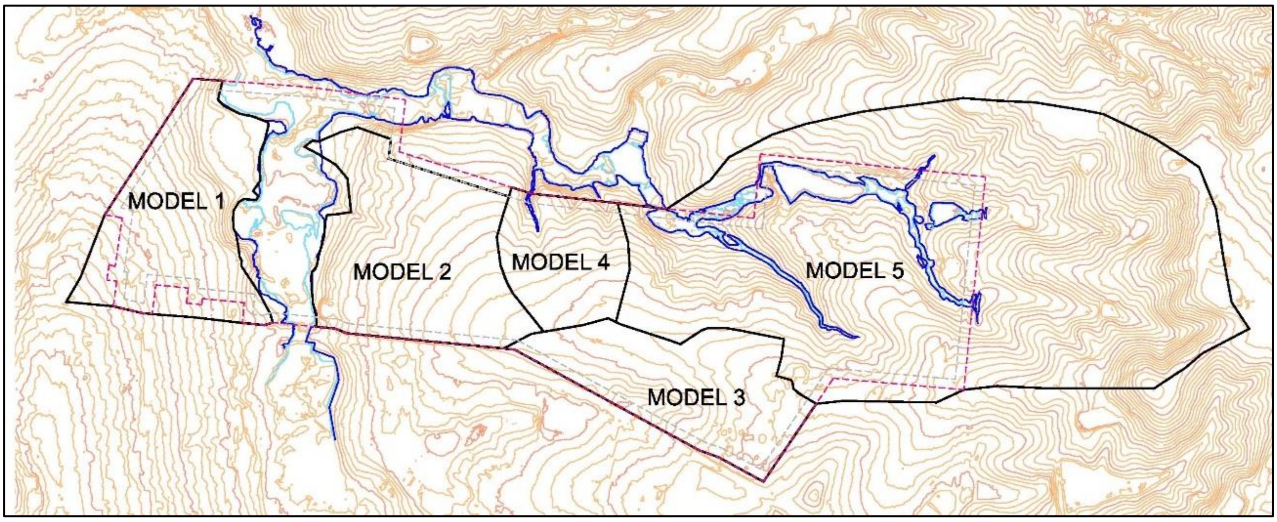

Figure B.1 Post-development RORB Model delineation

Models 3 and 5 are able to print hydrographs at defined outlet locations as per the pre-development scenario. As the catchments represented in Models 1, 2 and 4 have no defined outlet location (from the subject site to Jerrys Creek) in the pre-development scenario (i.e. currently the 1% AEP event would be sheet flow over the surface), representative hydrographs have been produced for the total outflow flow from these catchments for the post-development scenario to compare with the pre-development results.

All models have been formulated assuming the October 2017 proposed site layout and are subject to change given the final development layout.

As in the pre development models, a “DROWNED” reach type in RORB indicates instantaneous routing from the reach, (i.e. no change to the hydrograph) and is appropriate to use for adding multiple smaller catchment outlets into one large representative catchment outlet.

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 heavily vegetated swale system (as per the WSUD strategy).

B.1.1 Model 1

Figure B.2 below details the RORB model's setup. The RORB model's layout has been based on 0.5m LiDAR survey. Tables B.1 and B.2 detail the tabulation of the RORB model inputs.

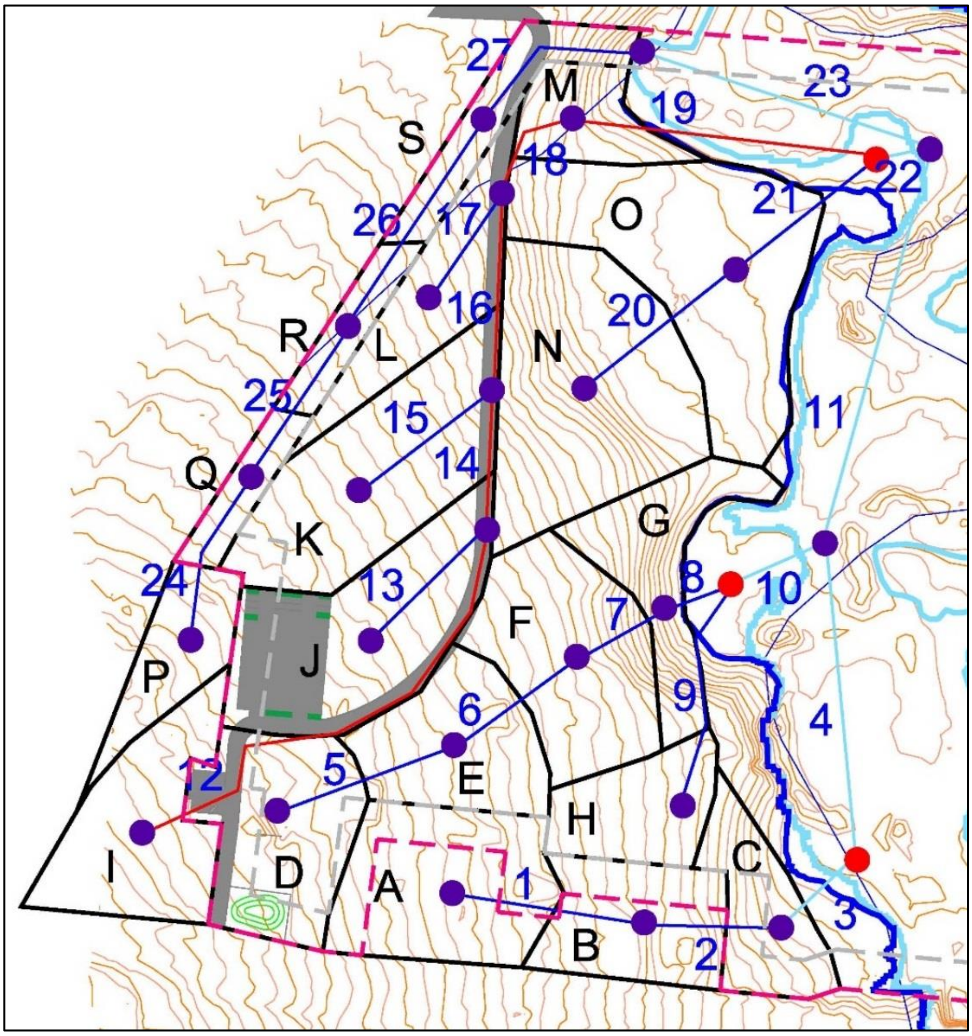

Figure B.2 RORB Model 1 Setup

Table B.1 Model 1 sub-catchment definition

Sub Area	Area (ha)	Area (km^2)	Fraction Imperviousness Post
A	0.47	0.0047	0.80
B	0.33	0.0033	0.25
C	0.25	0.0025	0.20
D	0.44	0.0044	0.80
E	0.35	0.0035	0.25
F	0.49	0.0049	0.25
G	0.32	0.0032	0.25
H	0.25	0.0025	0.25
I	0.42	0.0042	0.80
J	0.58	0.0058	0.63
K	0.60	0.0060	0.25
L	0.31	0.0031	0.25
M	0.19	0.0019	0.25
N	0.74	0.0074	0.25
O	0.75	0.0075	0.25
P	0.21	0.0021	0.80
Q	0.10	0.0010	0.00
R	0.12	0.0012	0.00
S	0.20	0.0020	0.00
TOTAL	7.1	0.0711	0.38

Table B.2 Model 1 reach definition

Reach	Length (km)	Slope %	Reach Type Post (10/20/50/100)
1	0.075	6.0%	EX/UNLINED
2	0.055	10.0%	EX/UNLINED
3	0.039		DROWNED
4	0.123		DROWNED
5	0.075	4.7%	EX/UNLINED
6	0.057	7.0%	EX/UNLINED
7	0.038	17.1%	EX/UNLINED
8	0.027	1.9%	EX/UNLINED
9	0.091	6.6%	EX/UNLINED
10	0.039		DROWNED
11	0.160		DROWNED
12	0.197	4.6%	PIPED
13	0.062	4.8%	EX/UNLINED
14	0.053	3.8%	PIPED
15	0.062	7.3%	EX/UNLINED
16	0.076	3.3%	PIPED
17	0.050	8.0%	EX/UNLINED
18	0.044	5.7%	PIPED
19	0.118	2.1%	PIPED
20	0.075	4.0%	EX/UNLINED
21	0.070	1.4%	EX/UNLINED
22	0.022		DROWNED
23	0.118		DROWNED
24	0.068	5.1%	EX/UNLINED
25	0.070	4.3%	EX/UNLINED
26	0.095	4.7%	EX/UNLINED
27	0.074	8.8%	EX/UNLINED

B.1.2 Model 2

Figure B.3 below details the RORB model's setup. The RORB model's layout has been based on 0.5m LiDAR survey. Tables B.3 and B.4 detail the tabulation of the RORB model inputs.

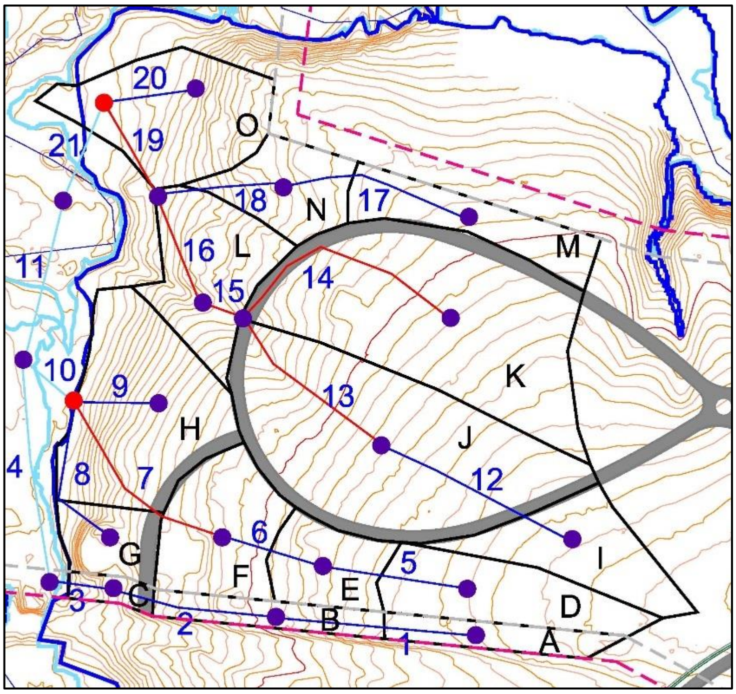

Figure B.3 RORB Model 2 Setup

Table B.3 Model 2 sub-catchment definition

Sub Area	Area (ha)	Area (km^2)	Fraction
			Imperviousness
			Post
A	0.19	0.0019	0.00
B	0.20	0.0020	0.00
C	0.07	0.0007	0.17
D	0.46	0.0046	0.25
E	0.28	0.0028	0.25
F	0.47	0.0047	0.25
G	0.21	0.0021	0.39
H	0.84	0.0084	0.29
I	0.44	0.0044	0.25
J	1.49	0.0149	0.35
K	1.44	0.0144	0.33
L	0.51	0.0051	0.25
M	0.35	0.0035	0.25
N	0.32	0.0032	0.25
O	0.64	0.0064	0.25
TOTAL	**7.9**	0.0792	0.28

Table B.4 Model 2 reach definition

Reach	Length (km)	slope %	Reach Type
			Post (10/20/50/100)
1	0.115	3.9%	EX/UNLINED
2	0.180	3.6%	EX/UNLINED
3	0.033	12.1%	EX/UNLINED
4	0.125		DROWNED
5	0.081	3.7%	EX/UNLINED
6	0.060	5.0%	EX/UNLINED
7	0.120	7.1%	PIPED
8	0.089	6.7%	EX/UNLINED
9	0.048	12.5%	EX/UNLINED
10	0.035		DROWNED
11	0.091		DROWNED
12	0.118	3.4%	EX/UNLINED
13	0.106	7.1%	PIPED
14	0.142	4.6%	PIPED
15	0.024	4.2%	PIPED
16	0.065	4.6%	PIPED
17	0.108	3.2%	EX/UNLINED
18	0.070	7.9%	EX/UNLINED
19	0.059	4.2%	PIPED
20	0.052	4.8%	EX/UNLINED
21	0.061		DROWNED

B.13 Model 3

Figure B.4 below details the RORB model's setup. The RORB model's layout has been based on 0.5m LiDAR survey. Tables B.5 and B.6 detail the tabulation of the RORB model inputs.

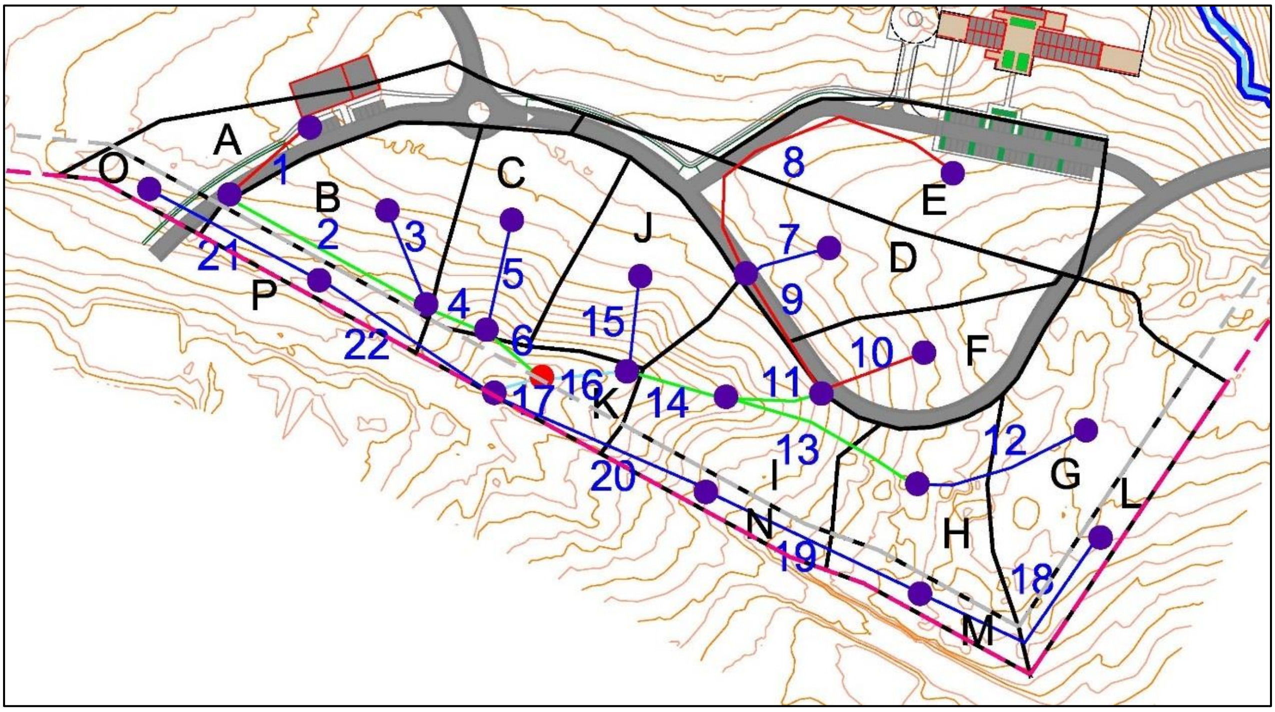

Figure B.4 RORB Model 3 Setup

Table B.5 Model 3 sub-catchment definition

Sub Area	Area (ha)	Area (km^2)	Fraction Imperviousness Post
A	0.43	0.0043	0.56
B	0.47	0.0047	0.25
C	0.47	0.0047	0.25
D	0.61	0.0061	0.38
E	0.70	0.0070	0.48
F	0.42	0.0042	0.46
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	0.14	0.0014	0.00
N	0.15	0.0015	0.00
O	0.09	0.0009	0.00
P	0.15	0.0015	0.00
TOTAL	**6.0**	0.0603	0.26

Table B.6 Model 3 reach definition

Reach	Length (km)	slope %	Reach Type Post (10/20/50/100)
1	0.043	3.5%	PIPED
2	0.093		NATURAL
3	0.043	4.7%	EX/UNLINED
4	0.026		NATURAL
5	0.047	8.5%	EX/UNLINED
6	0.026		NATURAL
7	0.037	4.1%	EX/UNLINED
8	0.150	1.7%	PIPED
9	0.055	0.4%	PIPED
10	0.044	6.8%	PIPED
11	0.043		NATURAL
12	0.073	2.7%	EX/UNLINED
13	0.086		NATURAL
14	0.041		NATURAL
15	0.039	10.3%	EX/UNLINED
16	0.034		DROWNED
17	0.021		DROWNED
18	0.101	1.0%	EX/UNLINED
19	0.099	4.0%	EX/UNLINED
20	0.098	5.6%	EX/UNLINED
21	0.081	1.8%	EX/UNLINED
22	0.084	3.0%	EX/UNLINED

B.1.4 Model 4

Figure B.5 below details the RORB model's setup. The RORB model's layout has been based on 0.5m LiDAR survey. Tables B.7 and B.8 detail the tabulation of the RORB model inputs.

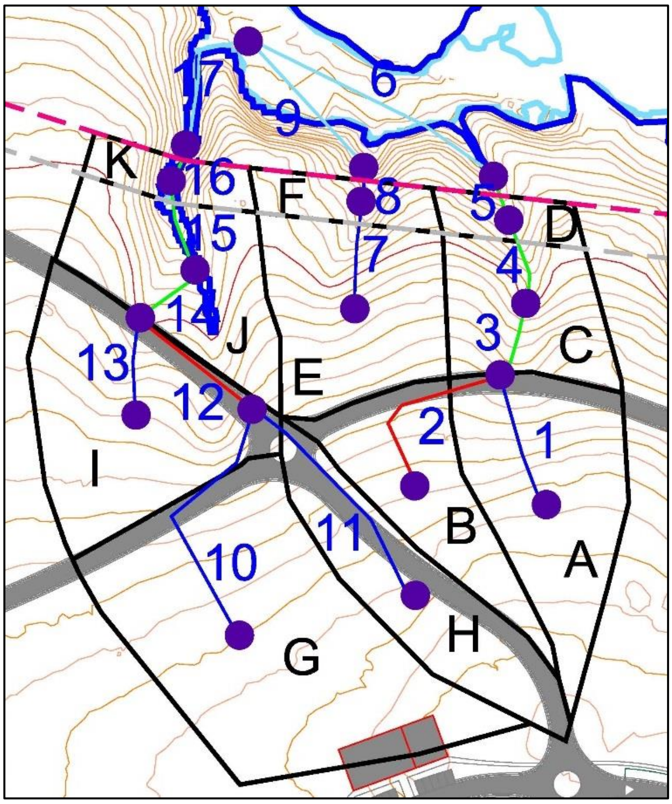

Figure B.5 RORB Model 4 Setup

Table B.7 Model 4 sub-catchment definition

Sub Area	Area (ha)	Area (km^2)	Fraction Imperviousness Post
A	0.42	0.0042	0.34
B	0.28	0.0028	0.36
C	0.25	0.0025	0.25
D	0.07	0.0007	0.00
E	0.36	0.0036	0.25
F	0.10	0.0010	0.00
G	0.84	0.0084	0.30
H	0.33	0.0033	0.56
I	0.49	0.0049	0.37
J	0.34	0.0034	0.25
K	0.09	0.0009	0.00
TOTAL	3.57	0.0357	0.31

Table B.8 Model 4 reach definition

Reach	Length (km)	slope %	Reach Type Post (10/20/50/100)
1	0.046	8.7%	EX/UNLINED
2	0.070	4.3%	PIPED
3	0.028		NATURAL
4	0.029		NATURAL
5	0.016		NATURAL
6	0.097		DROWNED
7	0.036	12.5%	EX/UNLINED
8	0.011	9.1%	EX/UNLINED
9	0.060		DROWNED
10	0.094	3.7%	EX/UNLINED
11	0.086	5.2%	EX/UNLINED
12	0.050	6.0%	PIPED
13	0.033	9.1%	EX/UNLINED
14	0.026		NATURAL
15	0.030		NATURAL
16	0.014		NATURAL
17	0.050		DROWNED

B.1.5 Model 5

Figure B.6 below details the RORB model's setup. The RORB model's layout has been based on 0.5m LiDAR survey. Tables B.9 and B.10 detail the tabulation of the RORB model inputs.

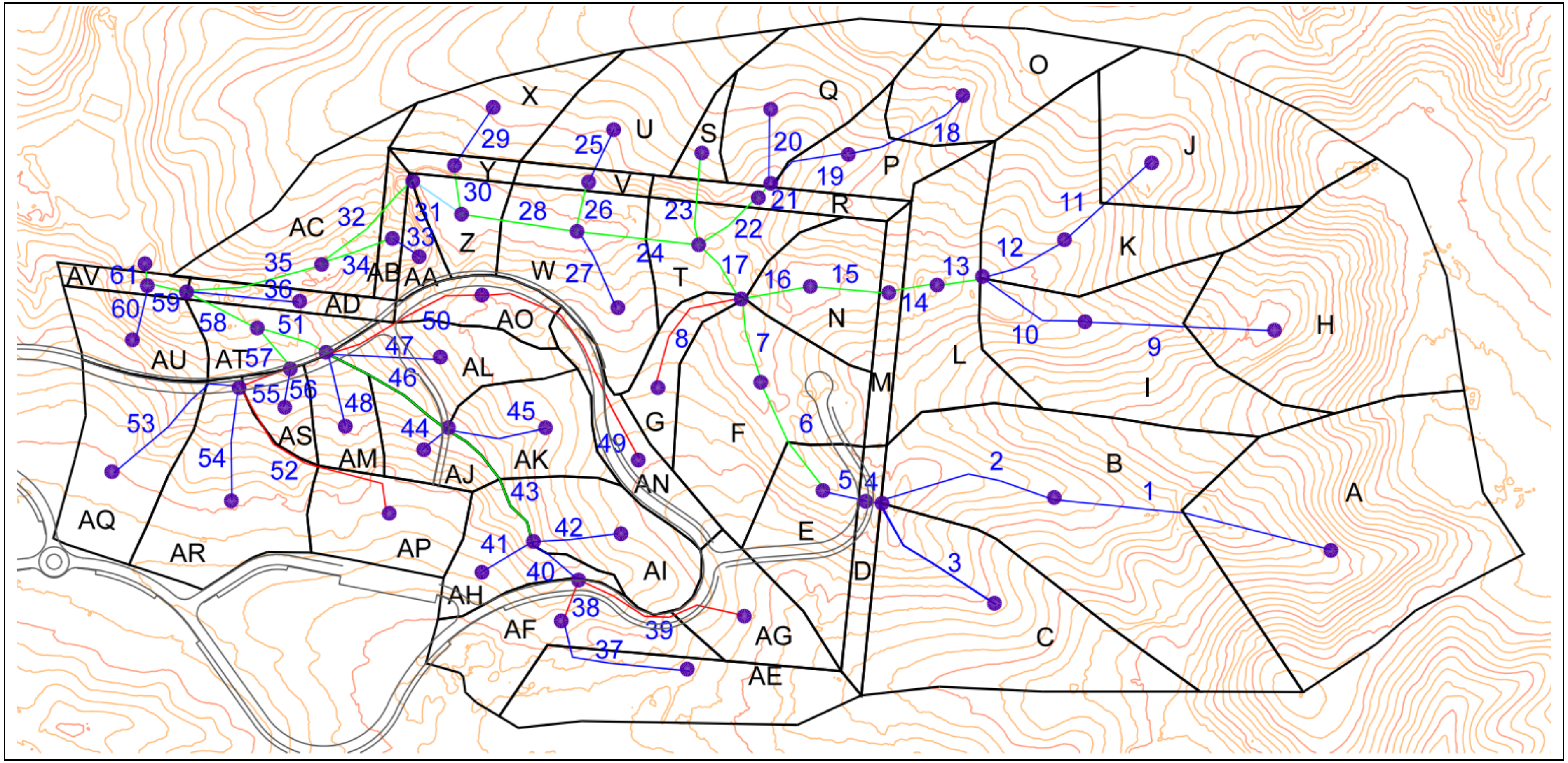

Figure B.6 **RORB Model 5 Setup**

Note: Swale conveyance 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 flows produced in this model will be considered conservative (that is, higher) than will ultimately occur.

Table B.9 Model 5 sub-catchment definition

Sub Area	Area (ha)	Area (km²)	Fraction
			Imperviousness
			Post
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	0.46
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	0.27
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	0.25
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
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	0.38
AG	0.53	0.0053	0.32
AH	0.44	0.0044	0.28
AI	0.69	0.0069	0.25
AJ	0.32	0.0032	0.25
AK	0.55	0.0055	0.25
AL	0.59	0.0059	0.29
AM	0.31	0.0031	0.28
AN	0.45	0.0045	0.55
AO	0.33	0.0033	0.43
AP	0.60	0.0060	0.90
AQ	0.82	0.0082	0.30
AR	1.01	0.0101	0.29
AS	0.21	0.0021	0.37
AT	0.40	0.0040	0.25
AU	0.45	0.0045	0.25
AV	0.13	0.0013	0.00
TOTAL	**34.6**	0.3464	0.18

Table B.10 Model 5 reach definition

Reach	Length (km)	slope %	Reach Type
			Post (10/20/50/100)
1	0.189	5.3%	EX/UNLINED
2	0.124	4.0%	EX/UNLINED
3	0.107	7.5%	EX/UNLINED
4	0.009	5.6%	EX/UNLINED
5	0.029	3.4%	EX/UNLINED
6	0.083		NATURAL
7	0.057		NATURAL
8	0.092	7.1%	PIPED
9	0.124	6.5%	EX/UNLINED
10	0.078	3.8%	EX/UNLINED
11	0.080	7.5%	EX/UNLINED
12	0.056	5.4%	EX/UNLINED
13	0.032		NATURAL
14	0.030		NATURAL
15	0.049		NATURAL
16	0.044		NATURAL
17	0.045		NATURAL
18	0.090	7.8%	EX/UNLINED
19	0.056	6.3%	EX/UNLINED
20	0.048	10.4%	EX/UNLINED
21	0.010		NATURAL
22	0.051		NATURAL
23	0.062		NATURAL
24	0.080		NATURAL
25	0.040	10.0%	EX/UNLINED
26	0.034		NATURAL
27	0.057	7.0%	EX/UNLINED
28	0.078		NATURAL
29	0.048	8.3%	EX/UNLINED
30	0.034		NATURAL
31	0.041		DROWNED
32	0.083		NATURAL
33	0.023	13.0%	EX/UNLINED
34	0.050		NATURAL
35	0.095		NATURAL
36	0.076	2.6%	EX/UNLINED
37	0.103	3.4%	EX/UNLINED
38	0.029	5.2%	PIPED
39	0.120	6.7%	PIPED
40	0.040	7.5%	EX/UNLINED
41	0.041	11.0%	EX/UNLINED
42	0.058	10.3%	EX/UNLINED
43	0.097		NATURAL
44	0.021	11.9%	EX/UNLINED
45	0.068	8.8%	EX/UNLINED
46	0.094		NATURAL
47	0.074	9.5%	EX/UNLINED
48	0.050	9.0%	EX/UNLINED
49	0.166	2.7%	PIPED
50	0.113	8.4%	PIPED
51	0.050		NATURAL
52	0.138	6.5%	PIPED
53	0.106	7.5%	EX/UNLINED
54	0.076	9.9%	EX/UNLINED
55	0.037	4.1%	PIPED
56	0.027	11.1%	EX/UNLINED
57	0.034		NATURAL
58	0.054		NATURAL
59	0.025		NATURAL
60	0.037	18.9%	EX/UNLINED
61	0.014		NATURAL

B.2 Model Parameters

The same parameter set detail in Appendix A.2 for the pre-development modelling has been used in the post-development scenario. The only variation is in the K_c values that have minor changes with the slight changes in catchment delineation. The resultant adopted parameter set adopted for all simulations is shown below in Table B.11.

Table B.11 RORB Post-Development Parameter Set (All AEP events)

Model	Area (km^2)	K_c	m	IL (mm)	CL (mm/hr)
1	0.0711	0.34	0.80	46	3.4
2	0.0792	0.36	0.80	46	3.4
3	0.0603	0.32	0.80	46	3.4
4	0.0357	0.25	0.80	46	3.4
5	0.3464	0.72	0.80	46	3.4

B.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 design for each catchment. All basins are intended to be dual purpose assets which also provide water quality and/or landscape benefits.

The location of the basin within each catchment is 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 B.12 – B.16 as much as possible.

Table B.12 Wetland/Retarding Basin 1B SSD relationship

Stage (m AHD)	Storage (m^3)	Discharge (m^3/s)
33.50	0	0
34.00	368	0.002
34.30	673	0.15
34.35	730	0.18
34.50	914	0.25
34.60	1046	0.40
34.75	1261	0.70

Table B.13 Wetland/Retarding Basin 2B SSD relationship

Stage (m AHD)	Storage (m^3)	Discharge (m^3/s)
34.50	0	0
35.00	550	0.003
35.10	684	0.25
35.20	827	0.40
35.35	1057	0.50
35.45	1222	0.55
35.50	1308	1.20

Table B.14 Wetland/Retarding Basin 3 SSD relationship

Stage (m AHD)	Storage (m^3)	Discharge (m^3/s)
49.50	0	0
50.00	465	0.003
50.20	694	0.21
50.30	820	0.30
50.40	955	0.42
50.60	1252	0.75

Table B.15 Bioretention/Retarding Basin 4A SSD relationship

Stage (m AHD)	Storage (m^3)	Discharge (m^3/s)
43.50	0	0.00
43.55	9	0.05
43.60	19	0.15
43.65	32	0.27
43.70	47	0.40
43.75	64	0.55
43.80	74	1.00

Table B.16 Retarding Basin/Pond 5 SSD relationship

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

B.4 Model Results

Similar to the pre-development modelling scenario, the peak median flow has been reported as the design flow for each AEP for each catchment. Box and whisker plots have not been reproduced in this report for the post-development scenario as the general concept in obtaining the design flow for the post-development flow was identical to the pre-development scenario method. All results presented below include the detention basin relationships detailed in Section B.3.

Table B.17 Post and Pre-development RORB Results for Catchment 1

AEP	ARI	Catchment 1 - Total Equivalent Outflow					
		Pre-development			Post-development		
		Q (m^3/s)	Duration	TP	Q (m^3/s)	Duration	TP
10%	10-Year	0.72	2-hour	16	0.61	20-minute	14
5%	20-Year	0.97	2-hour	14	0.72	15-minute	16
2%	50-Year	1.37	45-minute	27	0.88	15-minute	30
1%	100-Year	1.93	45-minute	26	1.10	30-minute	27

Table B.18 Post and Pre-development RORB Results for Catchment 2

AEP	ARI	Catchment 2 - Total Equivalent Outflow					
		Pre-development			Post-development		
		Q (m^3/s)	Duration	TP	Q (m^3/s)	Duration	TP
10%	10-Year	0.74	2-hour	16	0.41	6-hour	6
5%	20-Year	1.01	2-hour	14	0.73	2-hour	12
2%	50-Year	1.29	45-minute	30	0.87	2-hour	14
1%	100-Year	1.89	45-minute	26	1.05	2-hour	25

Table B.19 Post and Pre-development RORB Results for Catchment 3

AEP	ARI	Catchment 3 - Total Outflow					
		Pre-development			Post-development		
		Q (m^3/s)	Duration	TP	Q (m^3/s)	Duration	TP
10%	10-Year	0.41	2-hour	16	0.25	9-hour	18
5%	20-Year	0.6	2-hour	15	0.34	2-hour	17
2%	50-Year	0.81	2-hour	25	0.52	1.5-hour	28
1%	100-Year	1.08	45-minutes	27	0.68	1.5-hour	28

Note: Duration = Critical Storm Duration
TP = Applicable temporal pattern for each critical duration and AEP

Table B.20 Post and Pre-development RORB Results for Catchment 4

AEP	ARI	Catchment 4 - Total Equivalent Outflow					
		Pre-development			Post-development		
		Q (m^3/s)	Duration	TP	Q (m^3/s)	Duration	TP
10%	10-Year	0.35	2-hour	16	0.35	45-minute	17
5%	20-Year	0.47	2-hour	14	0.43	1-hour	13
2%	50-Year	0.61	2-hour	29	0.66	45-minute	27
1%	100-Year	0.89	45-minute	26	0.85	45-minute	26

Table B.21 Post and Pre-development RORB Results for Catchment 5

AEP	ARI	Catchment 5 - Total Outflow					
		Pre-development			Post-development		
		Q (m^3/s)	Duration	TP	Q (m^3/s)	Duration	TP
10%	10-Year	1.39	9-hour	11	1.23	9-hour	18
5%	20-Year	1.72	9-hour	18	1.49	9-hour	18
2%	50-Year	2.77	2-hour	25	2.00	12-hour	28
1%	100-Year	3.39	1.5-hour	29	2.63	2-hour	26

Note: Duration = Critical Storm Duration
TP = Applicable temporal pattern for each critical duration and AEP

As can be seen from the above, the proposed detention basin concepts are able to retard almost all peak post-development flows to well below the peak pre-development flow rates for the 10, 5, 2 and 1% AEP events. The only instance where the post-development design flow is greater than the pre-development design flow is the 2% AEP (50-year ARI) simulation for catchment 4. The increase in this simulation is only 0.05 m^3/s (50 L/s). Considering the upstream catchment 5 retardation of the main drainage branch by 0.77 m^3/s, the overall effect expected at the equivalent outfall from catchment 4 at the drainage line is expected to be less than the pre-development flow rate.

Optimisation of the retardation basin design 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 B.22 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 B.22 have been produced at each detention basin. These levels are conceptual only and may change as the design progresses.

Table B.22 Conceptual flood levels with detention basins.

Location	1% AEP Level (m AHD)	5% AEP Level (m AHD)
Wetland/Retarding Basin 1B	34.60	34.35
Wetland/Retarding Basin 2B	35.45	35.20
Wetland/Retarding Basin 3	50.50	50.30
Bioretention/Retarding Basin 4A	43.95	43.80
Retarding Basin/Pond 5	50.80	50.45

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. These flows are detailed in Appendix D.

B.5 RORB Control Vectors

The post development RORB control vectors (the code used to model each individual catchment) are documented below. This will enable Council (or an independent reviewer) to easily replicate the models used in this SWMP (if required).

B.5.1 Catchment 1 Control Vector

```
WALLACIA MODEL 1 POST
C RORB MODEL DEVELOPED BY MICHAEL MAG
C Project Engineer, Stormy Water Solutions
C POST-DEVELOPMENT MODEL
C DATE: 5/10/17
C AREA TOTAL = 0.0711 km^2
C kc FROM EQN 7.6.11 AR&R
C Kc = 0.34 = 1.18*(AREA)^0.47
C m = 0.8
C IL AND CL FROM AR&R DATAHUB
C Initial loss = 46 mm
C CL = 3.4 mm/hr
C IFD Data location: 33.8625(S),150.6375(E)
0
1,2,0.075,6.0,-99     1    A
2,2,0.055,10.0,-99    2    B
2,4,0.039,-99         3    C
7
FP1
5,4,0.123,-99         4
3
1,2,0.075,4.7,-99     5    D
2,2,0.057,7.0,-99     6    E
2,2,0.038,17.1,-99    7    F
2,2,0.027,1.9,-99     8    G
3
1,2,0.091,6.6,-99     9    H
4
7
FP2
5,4,0.039,-99         10
4
5,4,0.160,-99         11
3
1,3,0.197,4.6,-99     12   I
3
1,2,0.062,4.8,-99     13   J
4
5,3,0.053,3.8,-99     14
3
1,2,0.062,7.3,-99     15   K
4
5,3,0.076,3.3,-99     16
3
1,2,0.050,8.0,-99     17   L
4
5,3,0.044,5.7,-99     18
2,3,0.118,2.1,-99     19   M
3
1,2,0.075,4.0,-99     20   N
2,2,0.070,1.4,-99     21   O
4
16
FP3
1,0,7,
0,0,368,0.002,673,0.15,
730,0.18,914,0.25,1046,0.40,
1261,0.7,-99
1,7,
33.5,0,34.0,368,34.3,673,
34.35,730,34.5,914,34.60,1046,
34.75,1261,-99
5,4,0.022,-99         22
4
5,4,0.118,-99         23
3
1,2,0.068,5.1,-99     24   P
2,2,0.070,4.3,-99     25   Q
2,2,0.095,4.7,-99     26   R
2,2,0.074,8.8,-99     27   S
4
7
TOTAL MODEL 1
0
C SUB-CATCHMENT AREAS (KM^2)
0.0047,0.0033,0.0025,0.0044,0.0035,
0.0049,0.0032,0.0025,0.0042,0.0058,
0.0060,0.0031,0.0019,0.0074,0.0075,
0.0021,0.0010,0.0012,0.0020,-99
C IMPERVIOUS FRACTION
1,0.80,0.25,0.20,0.80,0.25,
0.25,0.25,0.25,0.80,0.63,
0.25,0.25,0.25,0.25,0.25,
0.80,0.00,0.00,0.00,-99
```

B.5.2 Catchment 2 Control Vector

```
WALLACIA MODEL 2 POST
C RORB MODEL DEVELOPED BY MICHAEL MAG
C Project Engineer, Stormy Water Solutions
C POST-DEVELOPMENT MODEL
C DATE: 6/10/17
C AREA TOTAL = 0.0792 km^2
C kc FROM EQN 7.6.11 AR&R
C Kc = 0.36 = 1.18*(AREA)^0.47
C m = 0.8
C IL AND CL FROM AR&R DATAHUB
C Initial loss = 46 mm
C CL = 3.4 mm/hr
C IFD Data location: 33.8625(S),150.6375(E)
0
1,2,0.115,3.9,-99   1    A
2,2,0.180,3.6,-99   2    B
2,2,0.033,12.1,-99  3    C
7
FP1
5,4,0.125,-99       4
3
1,2,0.081,3.7,-99   5    D
2,2,0.060,5.0,-99   6    E
2,3,0.120,7.1,-99   7    F
3
1,2,0.089,6.7,-99   8    G
4
3
1,2,0.048,12.5,-99  9    H
4
7
SOUTHERN WETLAND
5,4,0.035,-99       10
4
5,4,0.091,-99       11
3
1,2,0.118,3.4,-99   12   I
2,3,0.106,7.1,-99   13   J
3
1,3,0.142,4.6,-99   14   K
4
5,3,0.024,4.2,-99   15
2,3,0.065,4.6,-99   16   L
3
1,2,0.108,3.2,-99   17   M
2,2,0.070,7.9,-99   18   N
4
5,3,0.059,4.2,-99   19
3
1,2,0.052,4.8,-99   20   O
4
16
NORTHERN WETLAND/RB
1,0,7,
0,0,550,0.003,684,0.25,
827,0.40,1057,0.50,1222,0.55,
1308,1.2,-99
1,7,
34.50,0,35.00,550,35.10,684,
35.20,827,35.35,1057,35.45,1222,
35.50,1308,-99
5,4,0.061,-99       21
4
7
TOTAL MODEL 2
0
C SUB-CATCHMENT AREAS (KM^2)
0.0019,0.0020,0.0007,0.0046,0.0028,
0.0047,0.0021,0.0084,0.0044,0.0149,
0.0144,0.0051,0.0035,0.0032,0.0064,-99
C IMPERVIOUS FRACTION
1,0.00,0.00,0.17,0.25,0.25,
0.25,0.39,0.29,0.25,0.35,
0.33,0.25,0.25,0.25,0.25,-99
```

B.5.3 Catchment 3 Control Vector

```
WALLACIA MODEL 3 POST
C RORB MODEL DEVELOPED BY MICHAEL MAG
C Project Engineer, Stormy Water Solutions
C POST-DEVELOPMENT MODEL
C DATE: 5/10/17
C AREA TOTAL = 0.0603 km^2
C kc FROM EQN 7.6.11 AR&R
C Kc = 0.32 = 1.18*(AREA)^0.47
C m = 0.8
C IL AND CL FROM AR&R DATAHUB
C Initial loss = 46 mm
C CL = 3.4 mm/hr
C IFD Data location: 33.8625(S),150.6375(E)
0
1,3,0.043,3.5,-99    1     A
5,1,0.093,-99        2
3
1,2,0.043,4.7,-99    3     B
4
5,1,0.026,-99        4
3
1,2,0.047,8.5,-99    5     C
4
5,1,0.026,-99        6
3
1,2,0.037,4.1,-99    7     D
3
1,3,0.150,1.7,-99    8     E
4
5,3,0.055,0.4,-99    9
3
1,3,0.044,6.8,-99    10    F
4
5,1,0.043,-99        11
3
1,2,0.073,2.7,-99    12    G
2,1,0.086,-99        13    H
4
2,1,0.041,-99        14    I
3
1,2,0.039,10.3,-99   15    J
4
5,4,0.034,-99        16
4
2,4,0.021,-99        17    K
16
RB
1,0,6,
0,0,465,0.003,694,0.21,
820,0.30,955,0.42,1250,0.75,-99
1,6,
49.50,0,50.00,465,50.2,694,
50.30,820,50.40,955,50.60,1250,-99
3
1,2,0.101,1.0,-99    18    L
2,2,0.099,4.0,-99    19    M
2,2,0.098,5.6,-99    20    N
3
1,2,0.081,1.8,-99    21    O
2,2,0.084,3.0,-99    22    P
4
7
15m OFFSET
4
7
TOTAL MODEL 3
0
C SUB-CATCHMENT AREAS (KM^2)
0.0043,0.0047,0.0047,0.0061,0.0070,
0.0042,0.0063,0.0040,0.0053,0.0041,
0.0024,0.0021,0.0014,0.0015,0.0009,
0.0015,-99
C IMPERVIOUS FRACTION
1,0.56,0.25,0.25,0.38,0.48,
0.46,0.25,0.25,0.25,0.25,
0.25,0.00,0.00,0.00,0.00,
0.00,-99
```

B.5.4 Catchment 4 Control Vector

```
WALLACIA MODEL 4 POST
C RORB MODEL DEVELOPED BY MICHAEL MAG
C Project Engineer, Stormy Water Solutions
C POST-DEVELOPMENT MODEL
C DATE: 6/10/17
C AREA TOTAL = 0.0357 km^2
C kc FROM EQN 7.6.11 AR&R
C Kc = 0.25 = 1.18*(AREA)^0.47
C m = 0.8
C IL AND CL FROM AR&R DATAHUB
C Initial loss = 46 mm
C CL = 3.4 mm/hr
C IFD Data location: 33.8625(S),150.6375(E)
0
1,2,0.046,8.7,-99    1    A
3
1,3,0.070,4.3,-99    2    B
4
5,1,0.028,-99        3
2,1,0.029,-99        4    C
2,1,0.016,-99        5    D
7
FP1
5,4,0.097,-99        6
3
1,2,0.036,12.5,-99   7    E
2,2,0.011,9.1,-99    8    F
7
FP2
5,4,0.060,-99        9
4
3
1,2,0.094,3.7,-99    10   G
3
1,2,0.086,5.2,-99    11   H
4
5,3,0.050,6.0,-99    12
3
1,2,0.033,9.1,-99    13   I
4
5,1,0.026,-99        14
2,1,0.030,-99        15   J
2,1,0.014,-99        16   K
16
FP3
1,0,12,
,0.00,4,0.02,9,0.05,
14,0.10,19,0.15,25,0.21,
32,0.27,39,0.34,47,0.40,
55,0.48,64,0.55,74,1.00,-99
1,12,
43.50,0,43.55,4,43.60,9,
43.65,14,43.70,19,43.75,25,
43.80,32,43.85,39,43.90,47,
43.95,55,44.00,64,44.05,74,-99
5,4,0.050,-99        77
4
7
TOTAL MODEL 4
0
C SUB-CATCHMENT AREAS (KM^2)
0.0042,0.0028,0.0025,0.0007,0.0036,
0.0010,0.0084,0.0033,0.0049,0.0034,
0.0009,-99
C IMPERVIOUS FRACTION
1,0.34,0.36,0.25,0.00,0.25,
0.00,0.30,0.56,0.37,0.25,
0.00,-99
```

B.5.5 Catchment 5 Control Vector

```
WALLACIA MODEL 5 POST
C RORB MODEL DEVELOPED BY MICHAEL MAG
C Project Engineer, Stormy Water Solutions
C POST-DEVELOPMENT MODEL
C DATE: 6/10/17
C AREA TOTAL = 0.3464 km^2
C kc FROM EQN 7.6.11 AR&R
C Kc = 0.72 = 1.18*(AREA)^0.47
C m = 0.8
C IL AND CL FROM AR&R DATAHUB
C Initial loss = 46 mm
C CL = 3.4 mm/hr
C IFD Data location: 33.8625(S),150.6375(E)
0
1,2,0.189,5.3,-99      1     A
2,2,0.124,4.0,-99      2     B
3
1,2,0.107,7.5,-99      3     C
4
5,2,0.009,5.6,-99      4
2,2,0.029,3.4,-99      5     D
2,1,0.083,-99          6     E
2,1,0.057,-99          7     F
7
SOUTHERN SWALE
3
1,3,0.092,7.1,-99      8     G
4
3
1,2,0.124,6.5,-99      9     H
2,2,0.078,3.8,-99      10    I
3
1,2,0.080,7.5,-99      11    J
2,2,0.056,5.4,-99      12    K
4
5,1,0.032,-99          13
2,1,0.030,-99          14    L
2,1,0.049,-99          15    M
2,1,0.044,-99          16    N
7
NORTH EAST POND
4
5,1,0.045,-99          17
3
1,2,0.090,7.8,-99      18    O
2,2,0.056,6.3,-99      19    P
3
1,2,0.048,10.4,-99     20    Q
4
5,1,0.010,-99          21
2,1,0.051,-99          22    R
3
1,1,0.062,-99          23    S
4
4
2,1,0.080,-99          24    T
3
1,2,0.040,10.0,-99     25    U
2,1,0.034,-99          26    V
4
3
1,2,0.057,7.0,-99      27    W
4
5,1,0.078,-99          28
3
1,2,0.048,8.3,-99      29    X
2,1,0.034,-99          30    Y
4
2,4,0.041,-99          31    Z
16
RETARDING BASIN LOCATION
1,0,5,
0,0,999,0.41,2101,1.13,
3059,2.01,4355,3.00,-99
1,5,
50.00,0,50.25,999,50.50,2101,
50.75,3059,51.00,4355,-99
5,1,0.083,-99          32
3
1,2,0.023,13.0,-99     33    AA
2,1,0.050,-99          34    AB
4
2,1,0.095,-99          35    AC
3
1,2,0.076,2.6,-99      36    AD
4
3
1,2,0.103,3.4,-99      37    AE
2,3,0.029,5.2,-99      38    AF
3
1,3,0.120,6.7,-99      39    AG
4
5,2,0.040,7.5,-99      40
3
1,2,0.041,11.0,-99     41    AH
4
3
1,2,0.058,10.3,-99     42    AI
4
5,1,0.097,-99          43
3
1,2,0.021,11.9,-99     44    AJ
4
3
1,2,0.068,8.8,-99      45    AK
4
5,1,0.094,-99          46
3
1,2,0.074,9.5,-99      47    AL
4
3
1,2,0.050,9.0,-99      48    AM
4
7
MIDDLE SWALE
3
1,3,0.166,2.7,-99      49    AN
2,3,0.113,8.4,-99      50    AO
4
5,1,0.050,-99          51
3
1,3,0.138,6.5,-99      52    AP
3
1,2,0.106,7.5,-99      53    AQ
3
1,2,0.076,9.9,-99      54    AR
4
4
5,3,0.037,4.1,-99      55
3
1,2,0.027,11.1,-99     56    AS
4
5,1,0.034,-99          57
4
2,1,0.054,-99          58    AT
4
5,1,0.025,-99          59
3
1,2,0.037,18.9,-99     60    AU
4
2,1,0.014,-99          61    AV
7
TOTAL MODEL 5
0
```

```
C SUB-CATCHMENT AREAS (KM^2)
0.0265,0.0276,0.0166,0.0024,0.0072,
0.0125,0.0030,0.0208,0.0147,0.0139,
0.0135,0.0097,0.0024,0.0062,0.0085,
0.0044,0.0090,0.0025,0.0013,0.0056,
0.0084,0.0014,0.0094,0.0054,0.0012,
0.0032,0.0015,0.0014,0.0087,0.0021,
0.0094,0.0080,0.0053,0.0044,0.0069,
0.0032,0.0055,0.0059,0.0031,0.0045,
0.0033,0.0060,0.0082,0.0101,0.0021,
0.0040,0.0045,0.0013,-99
```

```
C IMPERVIOUS FRACTION
1,0.10,0.10,0.10,0.00,0.25,
0.25,0.46,0.10,0.10,0.10,
0.10,0.10,0.00,0.27,0.10,
0.10,0.10,0.00,0.10,0.25,
0.10,0.00,0.20,0.10,0.00,
0.20,0.25,0.00,0.10,0.00,
0.10,0.38,0.32,0.28,0.25,
0.25,0.25,0.29,0.28,0.55,
0.43,0.90,0.30,0.29,0.37,
0.25,0.25,0.00,-99
```

Appendix C 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);

C.1 MUSIC Model Description

The performance in regard to stormwater pollutant retention of the wetland system was analysed using the MUSIC model, Version 6.04.

C.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.

C.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 just greater than 48 hours (to be consistent with the Council MUSIC requirements).

The GPT's were modelled as Rocla 0708M type wet sump vortex systems. This structure is as described by Rocla as applicable to catchments of the size delineated.

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.

C.1.3 Catchment Models

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

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 C.1 to C.5 detail the MUSIC models developed.

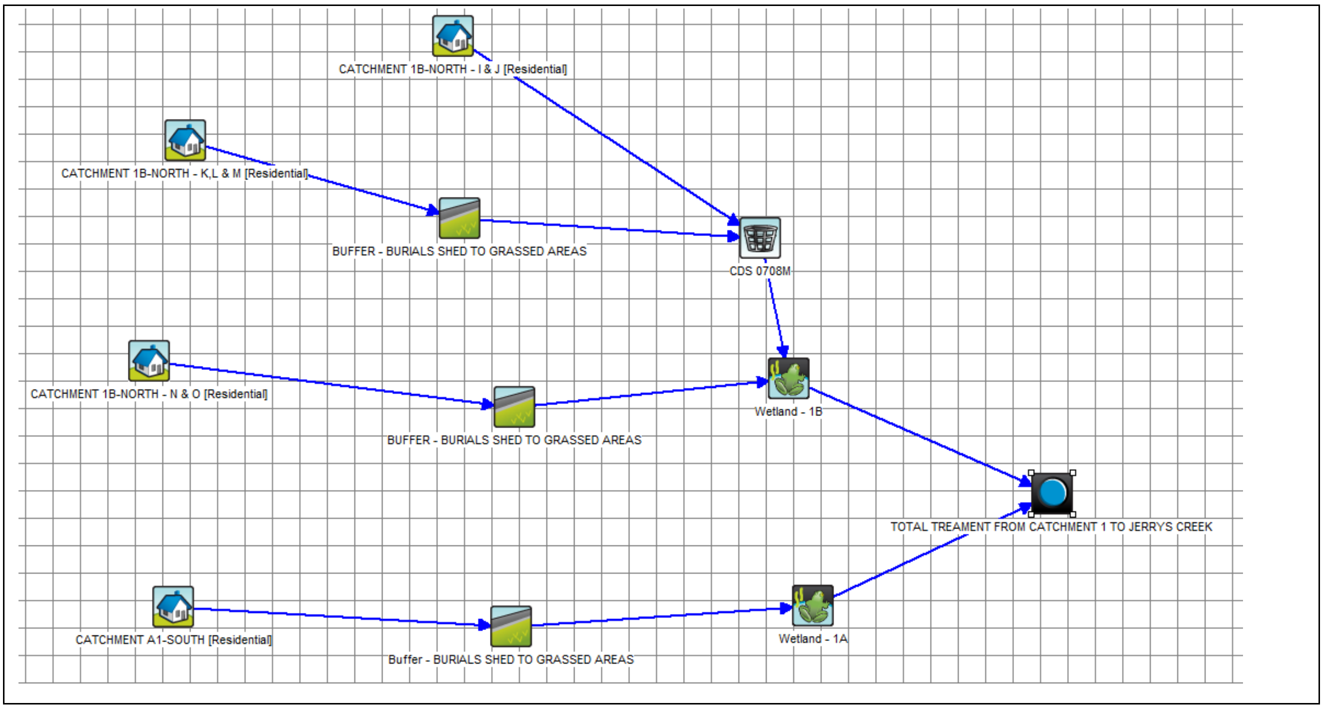

Figure C.1 MUSIC Model Catchment 1

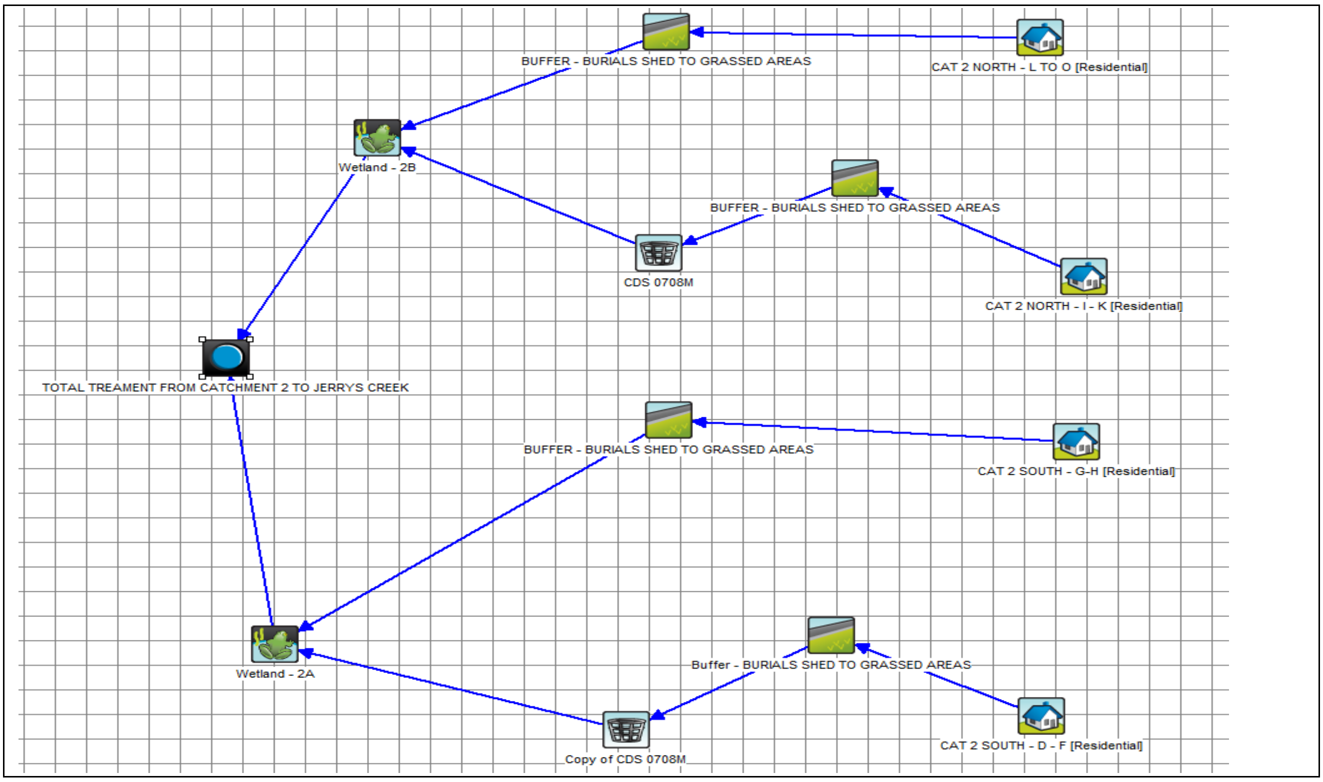

Figure C.2 MUSIC Model Catchment 2

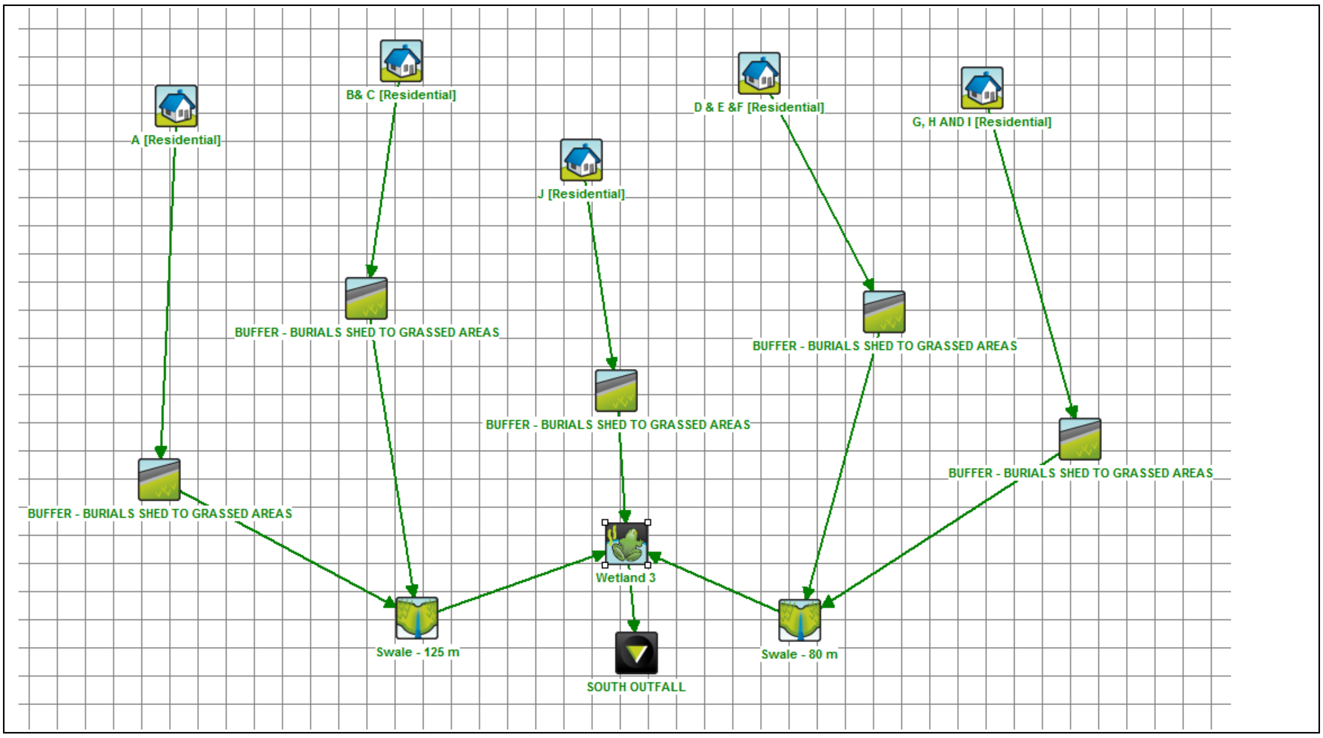

Figure C.3 MUSIC Model Catchment 3

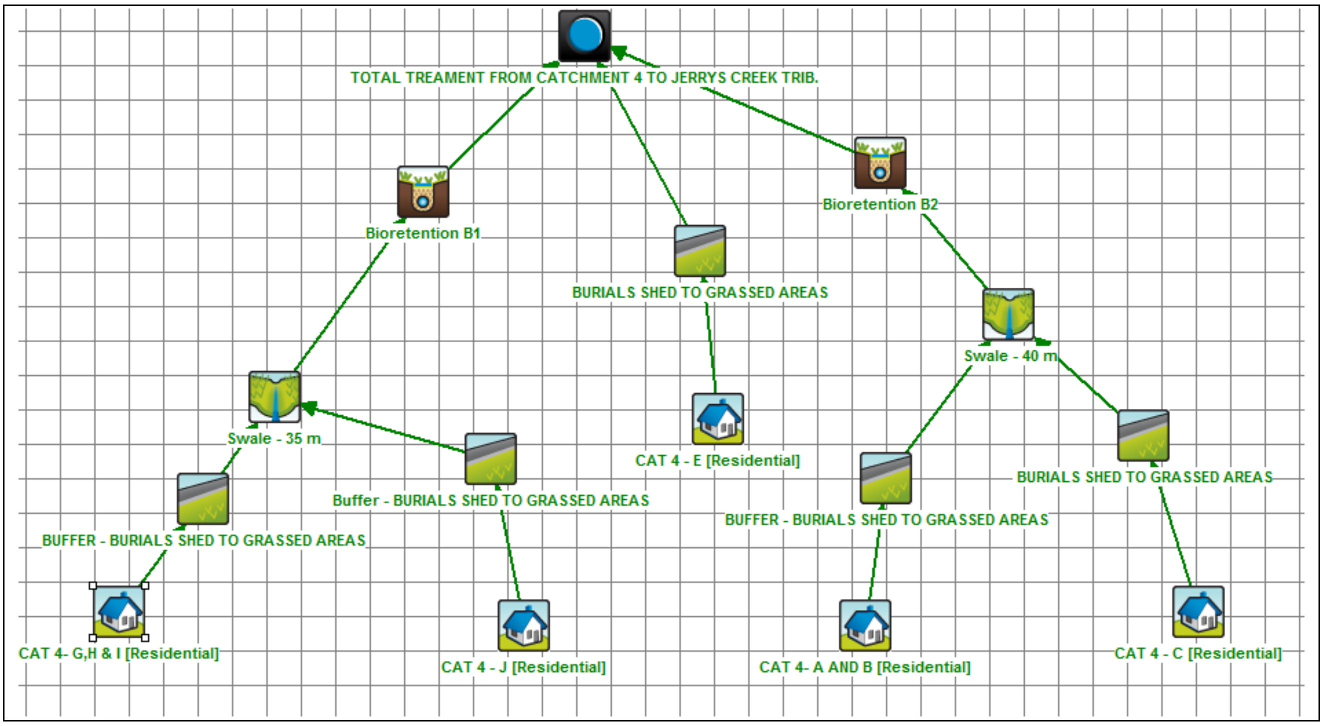

Figure C.4 MUSIC Model Catchment 4

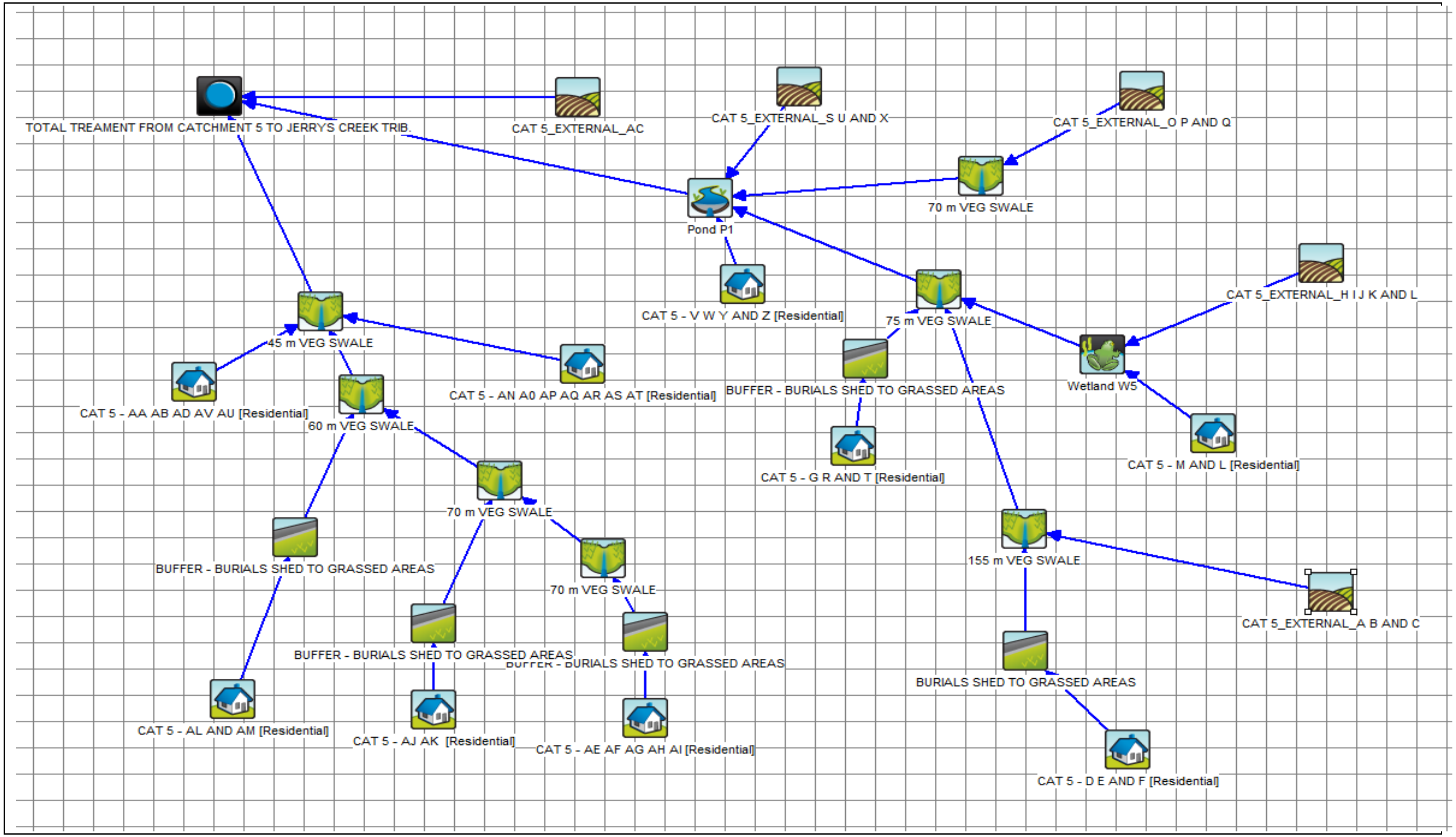

Figure C.5 MUSIC Model Catchment 5

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, less) than will ultimately occur.

C.2 MUSIC Pollutant Modelling Results.

C.2.1 Catchment 1 MUSIC Results

The catchment 1 MUSIC results are detailed below.

	Sources	Residual Load	% Reduction
Flow (ML/yr)	15.4	13.5	12.2
Total Suspended Solids (kg/yr)	2700	281	89.6
Total Phosphorus (kg/yr)	4.45	1.34	70
Total Nitrogen (kg/yr)	33.4	18.3	45.3
Gross Pollutants (kg/yr)	510	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.

C.2.2 Catchment 2 MUSIC Results

The catchment 2 MUSIC results are detailed below.

	Sources	Residual Load	% Reduction
Flow (ML/yr)	17.9	15.4	14.4
Total Suspended Solids (kg/yr)	3130	285	90.9
Total Phosphorus (kg/yr)	5.1	1.42	72.2
Total Nitrogen (kg/yr)	38.1	20.1	47.2
Gross Pollutants (kg/yr)	606	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 2.

C.2.3 Catchment 3 MUSIC Results

The catchment 3 MUSIC results are detailed below.

	Sources	Residual Load	% Reduction
Flow (ML/yr)	13.5	12.1	9.9
Total Suspended Solids (kg/yr)	2380	160	93.3
Total Phosphorus (kg/yr)	3.85	1.06	72.4
Total Nitrogen (kg/yr)	28.9	15.6	45.8
Gross Pollutants (kg/yr)	451	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 3.

C.2.4 Catchment 4 MUSIC Results

The catchment 4 MUSIC results are detailed below.

	Sources	Residual Load	% Reduction
Flow (ML/yr)	8.64	8.42	2.6
Total Suspended Solids (kg/yr)	1500	148	90.2
Total Phosphorus (kg/yr)	2.5	0.871	65.1
Total Nitrogen (kg/yr)	18.6	9.83	47.1
Gross Pollutants (kg/yr)	294	26.3	91

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 4.

C.2.5 Catchment 5 MUSIC Results

The catchment 5 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 5B, 5C, 5D , Pond 5 and Wetland 5 all treatment 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
- Pond 5 and Wetland 5 not incorporating hydraulic controls to detail stormwater for treatment over 48 hours.

Once the swales are vegetated, and the hydraulic control of Pond 5 and Wetland 5 are 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 in Appendix C.

MUSIC Output - total treatment train at Catchment 5 Outlet to Jerrys Creek	Source	Residual Load
Flow (ML/yr)	64	59.7
Total Suspended Solids (kg/yr)	10700	2490.0
Total Phosphorus (kg/yr)	18	8.7
Total Nitrogen (kg/yr)	135	98.7
Gross Pollutants (kg/yr)	1780	27.2

MUSIC Output - External Catchment Pollutant Load Generation	Source
Flow (ML/yr)	28
Total Suspended Solids (kg/yr)	4440
Total Phosphorus (kg/yr)	8
Total Nitrogen (kg/yr)	58
Gross Pollutants (kg/yr)	590

	Pollutant Generated in total Catchment 5 Area	Pollutants at receiving node to Tributary of Jerrys Creek
Total Suspended Solids (kg/yr)	10700	2490
Total Phosphorus (kg/yr)	18.0	8.7
Total Nitrogen (kg/yr)	135	99
Gross Pollutants (kg/yr)	1780	27
Pollutant Generated in External Catchments		
Total Suspended Solids (kg/yr)	4440	
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)	6260	
Total Phosphorus (kg/yr)	10.4	
Total Nitrogen (kg/yr)	78	
Gross Pollutants (kg/yr)	1190	
Amount of Pollutants Retained in Catchment 5 WSUD strategy		
Total Suspended Solids (kg/yr)	8210	
Total Phosphorus (kg/yr)	9.3	
Total Nitrogen (kg/yr)	36	
Gross Pollutants (kg/yr)	1753	
% Reduction Compared to Pollutants Generated in the Subject Site		
Total Suspended Solids (%)	131%	
Total Phosphorus (%)	90%	
Total Nitrogen (%)	47%	
Gross Pollutants (%)	147%	

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 5. In fact, the treatment of external flows (current not treated) ensures that TSS generated on site is treated to the equivalent of over 100%.

C.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.

C.3.1 MUSIC-Link Report – Catchment 1

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MUSIC-*link* Report

Project Details		Company Details	
Project:	WALLACIA CATCHMENT 1	**Company:**	STORMY WATER SOLUTIONS
Report Export Date:	10/10/2017	**Contact:**	VAL MAG
Catchment Name:	CAT 1 _PRELIM	**Address:**	1.26 202 JELLS ROAD WHEELERS HILL
Catchment Area:	5.44ha	**Phone:**	0412 436 021
Impervious Area*:	37.60%	**Email:**	stormywater@optusnet.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 1 TO JERRYS CREEK	Reduction
Flow	12.2%
TSS	89.6%
TP	70%
TN	45.3%
GP	100%

Treatment Nodes

Node Type	Number
Wetland Node	2
Buffer Node	3
GPT Node	1

Source Nodes

Node Type	Number
Urban Source Node	4

Comments

Passing Parameters

Node Type	Node Name	Parameter	Min	Max	Actual
GPT	CDS 0708M	Hi-flow bypass rate (cum/sec)	None	99	0.054
Urban	CATCHMENT 1B-NORTH - I & J	Area Impervious (ha)	None	None	0.699
Urban	CATCHMENT 1B-NORTH - I & J	Area Pervious (ha)	None	None	0.300
Urban	CATCHMENT 1B-NORTH - I & J	Total Area (ha)	None	None	1
Urban	CATCHMENT 1B-NORTH - K_L & M	Area Impervious (ha)	None	None	0.276
Urban	CATCHMENT 1B-NORTH - K_L & M	Area Pervious (ha)	None	None	0.823
Urban	CATCHMENT 1B-NORTH - K_L & M	Total Area (ha)	None	None	1.1
Urban	CATCHMENT 1B-NORTH - N & O	Area Impervious (ha)	None	None	0.374
Urban	CATCHMENT 1B-NORTH - N & O	Area Pervious (ha)	None	None	1.115
Urban	CATCHMENT 1B-NORTH - N & O	Total Area (ha)	None	None	1.49
Urban	CATCHMENT A1-SOUTH	Area Impervious (ha)	None	None	0.694
Urban	CATCHMENT A1-SOUTH	Area Pervious (ha)	None	None	1.155
Urban	CATCHMENT A1-SOUTH	Total Area (ha)	None	None	1.85

Only certain parameters are reported when they pass validation

C.3.2 MUSIC-Link Report – Catchment 2

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MUSIC-*link* Report

Project Details		Company Details	
Project:	WALLACIA CATCHMENT 2	**Company:**	STORMY WATER SOLUTIONS
Report Export Date:	10/10/2017	**Contact:**	VAL MAG
Catchment Name:	CAT 2 _PRELIM	**Address:**	1.26 202 JELLS ROAD WHEELERS HILL 3150
Catchment Area:	7.45ha	**Phone:**	0412 436 021
Impervious Area*:	28.76%	**Email:**	stormywater@optusnet.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	Reduction
Flow	14.4%
TSS	91.1%
TP	72.1%
TN	47.5%
GP	100%

Treatment Nodes

Node Type	Number
Wetland Node	2
Buffer Node	4
GPT Node	2

Source Nodes

Node Type	Number
Urban Source Node	4

Comments

Passing Parameters

Node Type	Node Name	Parameter	Min	Max	Actual
GPT	CDS 0708M	Hi-flow bypass rate (cum/sec)	None	99	0.054
GPT	Copy of CDS 0708M	Hi-flow bypass rate (cum/sec)	None	99	0.054
Urban	CAT 2 NORTH - I - K	Area Impervious (ha)	None	None	1.062
Urban	CAT 2 NORTH - I - K	Area Pervious (ha)	None	None	2.307
Urban	CAT 2 NORTH - I - K	Total Area (ha)	None	None	3.37
Urban	CAT 2 NORTH - L TO O	Area Impervious (ha)	None	None	0.457
Urban	CAT 2 NORTH - L TO O	Area Pervious (ha)	None	None	1.362
Urban	CAT 2 NORTH - L TO O	Total Area (ha)	None	None	1.82
Urban	CAT 2 SOUTH - D - F	Area Impervious (ha)	None	None	0.299
Urban	CAT 2 SOUTH - D - F	Area Pervious (ha)	None	None	0.910
Urban	CAT 2 SOUTH - D - F	Total Area (ha)	None	None	1.21
Urban	CAT 2 SOUTH - G-H	Area Impervious (ha)	None	None	0.323
Urban	CAT 2 SOUTH - G-H	Area Pervious (ha)	None	None	0.726
Urban	CAT 2 SOUTH - G-H	Total Area (ha)	None	None	1.05

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C.3.3 MUSIC-Link Report – Catchment 3

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MUSIC-*link* Report

Project Details		Company Details	
Project:	wallacia catchment 3	**Company:**	STORMY WATER SOLUTIONS
Report Export Date:	10/10/2017	**Contact:**	VAL MAG
Catchment Name:	CAT 3 _PRELIM	**Address:**	1.26 202 JELLS ROAD WHEELERS HILL 3150
Catchment Area:	5.07ha	**Phone:**	0412 436 021
Impervious Area*:	33.80%	**Email:**	stormywater@optusnet.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		Treatment Nodes		Source Nodes	
Node: SOUTH OUTFALL	**Reduction**	**Node Type**	**Number**	**Node Type**	**Number**
Flow	9.91%	Wetland Node	1	Urban Source Node	5
TSS	93.3%	Swale Node	2		
TP	72.4%	Buffer Node	5		
TN	45.8%				
GP	100%				

Comments

Passing Parameters

Node Type	Node Name	Parameter	Min	Max	Actual
Receiving	SOUTH OUTFALL	% Load Reduction	None	None	9.91
Receiving	SOUTH OUTFALL	GP % Load Reduction	90	None	100
Receiving	SOUTH OUTFALL	TN % Load Reduction	45	None	45.8
Receiving	SOUTH OUTFALL	TP % Load Reduction	60	None	72.4
Receiving	SOUTH OUTFALL	TSS % Load Reduction	85	None	93.3
Swale	Swale - 125 m	Bed slope	0.01	0.05	0.014
Swale	Swale - 80 m	Bed slope	0.01	0.05	0.04
Urban	A	Area Impervious (ha)	None	None	0.239
Urban	A	Area Pervious (ha)	None	None	0.190
Urban	A	Total Area (ha)	None	None	0.43
Urban	B& C	Area Impervious (ha)	None	None	0.232
Urban	B& C	Area Pervious (ha)	None	None	0.70735
Urban	B& C	Total Area (ha)	None	None	0.94
Urban	D & E &F	Area Impervious (ha)	None	None	0.754
Urban	D & E &F	Area Pervious (ha)	None	None	0.975
Urban	D & E &F	Total Area (ha)	None	None	1.73
Urban	G_ H AND I	Area Impervious (ha)	None	None	0.386
Urban	G_ H AND I	Area Pervious (ha)	None	None	1.1739
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

C.3.4 MUSIC-Link Report – Catchment 4

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MUSIC-*link* Report

Project Details		Company Details	
Project:	wallacia catchment 4	**Company:**	Stormy Water Solutions
Report Export Date:	6/10/2017	**Contact:**	Valerie Mag
Catchment Name:	CAT 4 _PRELIM	**Address:**	1.26 202 Jells Road Wheelers hill 3150
Catchment Area:	3.31ha	**Phone:**	0412 436 021
Impervious Area*:	33.21%	**Email:**	stormywater@optusnet.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 4 TO JERRYS CREEK TRIB.	Reduction
Flow	2.57%
TSS	90.2%
TP	64.5%
TN	46.6%
GP	91%

Treatment Nodes

Node Type	Number
Buffer Node	5
Swale Node	2
Bio Retention Node	2

Source Nodes

Node Type	Number
Urban Source Node	5

Comments

Passing Parameters

Node Type	Node Name	Parameter	Min	Max	Actual
Bio	Bioretention B1	Hi-flow bypass rate (cum/sec)	None	99	99
Bio	Bioretention B1	PET Scaling Factor	2.1	2.1	2.1
Bio	Bioretention B2	Hi-flow bypass rate (cum/sec)	None	99	99
Bio	Bioretention B2	PET Scaling Factor	2.1	2.1	2.1
Swale	Swale - 40 m	Bed slope	0.01	0.05	0.05
Swale	Swale - 35 m	Bed slope	0.01	0.05	0.05
Urban	CAT 4 - C	Area Impervious (ha)	None	None	0.061
Urban	CAT 4 - C	Area Pervious (ha)	None	None	0.188
Urban	CAT 4 - C	Total Area (ha)	None	None	0.25
Urban	CAT 4 - E	Area Impervious (ha)	None	None	0.0891
Urban	CAT 4 - E	Area Pervious (ha)	None	None	0.2709
Urban	CAT 4 - E	Total Area (ha)	None	None	0.36
Urban	CAT 4 - J	Area Impervious (ha)	None	None	0.084
Urban	CAT 4 - J	Area Pervious (ha)	None	None	0.25585
Urban	CAT 4 - J	Total Area (ha)	None	None	0.34
Urban	CAT 4- A AND B	Area Impervious (ha)	None	None	0.247
Urban	CAT 4- A AND B	Area Pervious (ha)	None	None	0.452
Urban	CAT 4- A AND B	Total Area (ha)	None	None	0.7
Urban	CAT 4- G_H & I	Area Impervious (ha)	None	None	0.617
Urban	CAT 4- G_H & I	Area Pervious (ha)	None	None	1.042
Urban	CAT 4- G_H & I	Total Area (ha)	None	None	1.66

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C.3.5 MUSIC-Link Report – Catchment 5

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MUSIC-*link* Report

Project Details		Company Details	
Project:	WALLACIA - CATCHMENT 5	**Company:**	STORMY WATER SOLUTIONS
Report Export Date:	6/10/2017	**Contact:**	VALERIE MAG
Catchment Name:	CAT 5 _PRELIM	**Address:**	1.26 202 JELLS ROAD WHEELERS HILL 3150
Catchment Area:	34.64ha	**Phone:**	0412 436 021
Impervious Area*:	17.89%	**Email:**	stormywater@optusnet.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 5 TO JERRYS CREEK TRIB.	Reduction
Flow	7.19%
TSS	76.8%
TP	51.8%
TN	27%
GP	98.5%

Treatment Nodes

Node Type	Number
Buffer Node	5
Swale Node	7
Wetland Node	1
Pond Node	1

Source Nodes

Node Type	Number
Urban Source Node	9
Agricultural Source Node	10

Comments

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Passing Parameters

Node Type	Node Name	Parameter	Min	Max	Actual
Agricultural	CAT 5_EXTERNAL_AB AND C	Area Impervious (ha)	None	None	0.709
Agricultural	CAT 5_EXTERNAL_AB AND C	Area Pervious (ha)	None	None	6.350
Agricultural	CAT 5_EXTERNAL_AB AND C	Total Area (ha)	None	None	7.06
Agricultural	CAT 5_EXTERNAL_AC	Area Impervious (ha)	None	None	0.087
Agricultural	CAT 5_EXTERNAL_AC	Area Pervious (ha)	None	None	0.782
Agricultural	CAT 5_EXTERNAL_AC	Total Area (ha)	None	None	0.87
Agricultural	CAT 5_EXTERNAL_H I J K AND L	Area Impervious (ha)	None	None	0.729
Agricultural	CAT 5_EXTERNAL_H I J K AND L	Area Pervious (ha)	None	None	6.530
Agricultural	CAT 5_EXTERNAL_H I J K AND L	Total Area (ha)	None	None	7.26
Agricultural	CAT 5_EXTERNAL_O P AND Q	Area Impervious (ha)	None	None	0.220
Agricultural	CAT 5_EXTERNAL_O P AND Q	Area Pervious (ha)	None	None	1.969
Agricultural	CAT 5_EXTERNAL_O P AND Q	Total Area (ha)	None	None	2.19
Agricultural	CAT 5_EXTERNAL_S U AND X	Area Impervious (ha)	None	None	0.150
Agricultural	CAT 5_EXTERNAL_S U AND X	Area Pervious (ha)	None	None	1.349
Agricultural	CAT 5_EXTERNAL_S U AND X	Total Area (ha)	None	None	1.5
Agricultural	Copy of CAT 5_EXTERNAL_AB AND C	Area Impervious (ha)	None	None	0.709
Agricultural	Copy of CAT 5_EXTERNAL_AB AND C	Area Pervious (ha)	None	None	6.350
Agricultural	Copy of CAT 5_EXTERNAL_AB AND C	Total Area (ha)	None	None	7.06
Agricultural	Copy of CAT 5_EXTERNAL_AC	Area Impervious (ha)	None	None	0.087
Agricultural	Copy of CAT 5_EXTERNAL_AC	Area Pervious (ha)	None	None	0.782
Agricultural	Copy of CAT 5_EXTERNAL_AC	Total Area (ha)	None	None	0.87
Agricultural	Copy of CAT 5_EXTERNAL_H I J K AND L	Area Impervious (ha)	None	None	0.729
Agricultural	Copy of CAT 5_EXTERNAL_H I J K AND L	Area Pervious (ha)	None	None	6.530
Agricultural	Copy of CAT 5_EXTERNAL_H I J K AND L	Total Area (ha)	None	None	7.26
Agricultural	Copy of CAT 5_EXTERNAL_O P AND Q	Area Impervious (ha)	None	None	0.220
Agricultural	Copy of CAT 5_EXTERNAL_O P AND Q	Area Pervious (ha)	None	None	1.969
Agricultural	Copy of CAT 5_EXTERNAL_O P AND Q	Total Area (ha)	None	None	2.19
Agricultural	Copy of CAT 5_EXTERNAL_S U AND X	Area Impervious (ha)	None	None	0.150
Agricultural	Copy of CAT 5_EXTERNAL_S U AND X	Area Pervious (ha)	None	None	1.349
Agricultural	Copy of CAT 5_EXTERNAL_S U AND X	Total Area (ha)	None	None	1.5
Pond	Pond P1	% Reuse Demand Met	None	None	0
Swale	155 m VEG SWALE	Bed slope	0.01	0.05	0.03
Swale	45 m VEG SWALE	Bed slope	0.01	0.05	0.04
Swale	60 m VEG SWALE	Bed slope	0.01	0.05	0.04
Swale	70 m VEG SWALE	Bed slope	0.01	0.05	0.035
Swale	70 m VEG SWALE	Bed slope	0.01	0.05	0.04
Swale	70 m VEG SWALE	Bed slope	0.01	0.05	0.04
Swale	75 m VEG SWALE	Bed slope	0.01	0.05	0.035
Urban	CAT 5 - AA AB AD AV AU	Area Impervious (ha)	None	None	0.149
Urban	CAT 5 - AA AB AD AV AU	Area Pervious (ha)	None	None	0.930

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Node Type	Node Name	Parameter	Min	Max	Actual
Urban	CAT 5 - AA AB AD AV AU	Total Area (ha)	None	None	1.08
Urban	CAT 5 - AE AF AG AH AI	Area Impervious (ha)	None	None	0.839
Urban	CAT 5 - AE AF AG AH AI	Area Pervious (ha)	None	None	2.550
Urban	CAT 5 - AE AF AG AH AI	Total Area (ha)	None	None	3.39
Urban	CAT 5 - AJ AK	Area Impervious (ha)	None	None	0.221
Urban	CAT 5 - AJ AK	Area Pervious (ha)	None	None	0.658
Urban	CAT 5 - AJ AK	Total Area (ha)	None	None	0.88
Urban	CAT 5 - AL AND AM	Area Impervious (ha)	None	None	0.256
Urban	CAT 5 - AL AND AM	Area Pervious (ha)	None	None	0.653
Urban	CAT 5 - AL AND AM	Total Area (ha)	None	None	0.91
Urban	CAT 5 - AN A0 AP AQ AR AS AT	Area Impervious (ha)	None	None	1.632
Urban	CAT 5 - AN A0 AP AQ AR AS AT	Area Pervious (ha)	None	None	2.177
Urban	CAT 5 - AN A0 AP AQ AR AS AT	Total Area (ha)	None	None	3.81
Urban	CAT 5 - D E AND F	Area Impervious (ha)	None	None	0.497
Urban	CAT 5 - D E AND F	Area Pervious (ha)	None	None	1.712
Urban	CAT 5 - D E AND F	Total Area (ha)	None	None	2.21
Urban	CAT 5 - G R AND T	Area Impervious (ha)	None	None	0.278
Urban	CAT 5 - G R AND T	Area Pervious (ha)	None	None	0.831
Urban	CAT 5 - G R AND T	Total Area (ha)	None	None	1.11
Urban	CAT 5 - M AND L	Area Impervious (ha)	None	None	0.167
Urban	CAT 5 - M AND L	Area Pervious (ha)	None	None	0.692
Urban	CAT 5 - M AND L	Total Area (ha)	None	None	0.86
Urban	CAT 5 - V W Y AND Z	Area Impervious (ha)	None	None	0.259
Urban	CAT 5 - V W Y AND Z	Area Pervious (ha)	None	None	1.250
Urban	CAT 5 - V W Y AND Z	Total Area (ha)	None	None	1.51

Only certain parameters are reported when they pass validation

Appendix D Vegetated Swale Design

D.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.

The vegetated swales in Catchment 3 will be constructed assets 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
- Top Width = 6 m
- Longitudinal slope = 1/20 to 1/60 (generally following natural surface slope along the swale).

The typical envisaged form of a vegetated swale in Catchment 3 is shown in Figure D.1 below.

Figure D.1 Typical form of a vegetated swale in Catchment 3
Note the Wallacia SWMP calls for a 1 in 5 vegetated batter

The vegetated swales in Catchments 4 and 5 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 a swales, the watercourse are assumed to be converted to drainage swale definition. This will require an offset elsewhere onsite.

The primary requirement in regard to the drainage requirements of the swales in Catchments 4 and 5 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.

Based on typical cross sections determined from the Lidar data, these assets will 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 (4A, 4B, 5A, 5B, 5C and 5E), 1 metre (5D)
- Top Width = 6 m (4A, 4B, 5A, 5B, 5C and 5E), 10 metre (5D)
- Longitudinal slope = 1/10 to 1/25 (generally following natural surface slope along the swale).

The typical envisaged form of a vegetated swale in Catchments 4 and 5 is shown in Figure D.2 below.

Figure D.1 Typical form of a vegetated swale in Catchment 3

D.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 D.3 below details these flows.

It should be noted that swale conveyance may be underestimated in the RORB model. That is, more flow may ultimately be conveyed in swales than has been modelled. If this is the case, then the flows detailed in Figure D.3 will be considered conservative (that is, higher) than will ultimately occur.

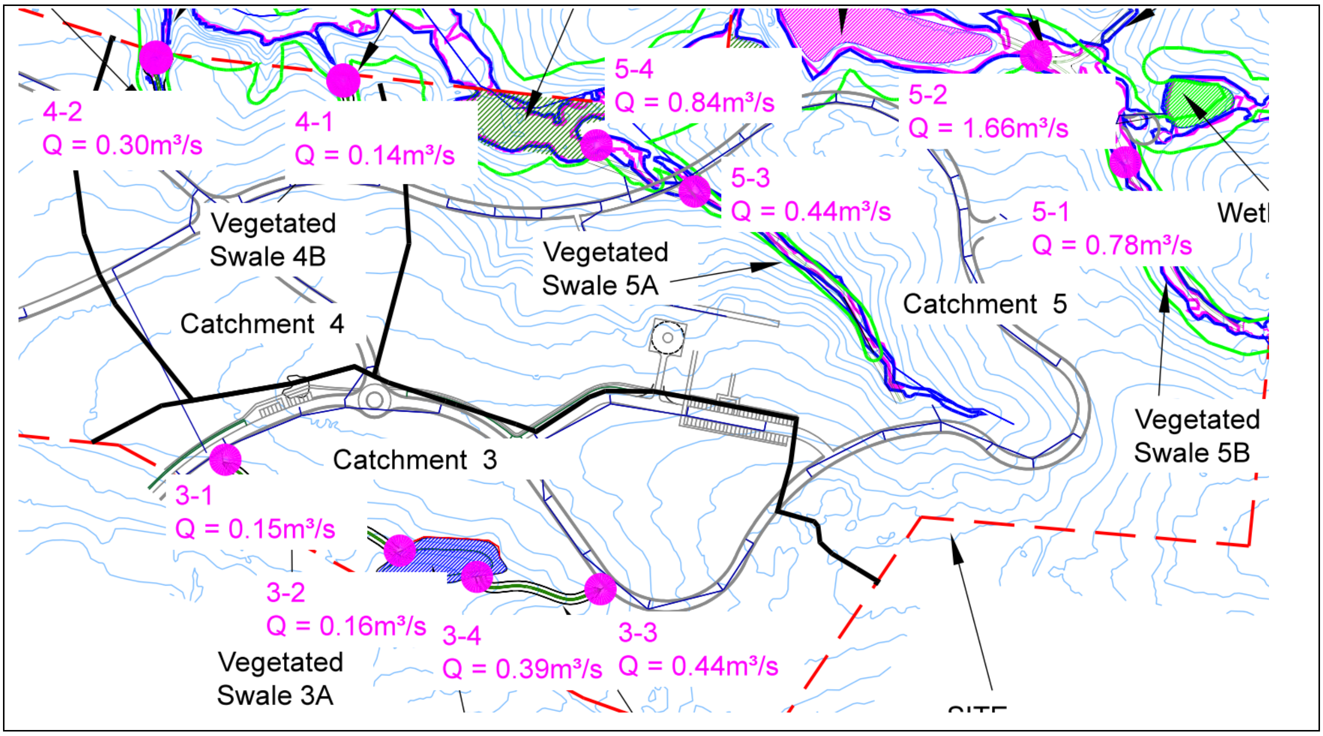

Figure D.3 **5% AEP (20 Year ARI) flood flows at critical locations on the vegetated swale system**

D.2 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.

Swale 3A				
5% AEP (20 Year ARI) Flow =	0.16	m^3/s	RORB Model	
Manning's calculation of capacity of a trapezoidal swale				
Water Depth	0.5	m	(6 m top width)	
Drain Base width	1	m		
Longitudinal Slope	0.016667	m/m	60	
side slope of batters	1 in	5		
Flow Area (A)	1.75	m^2		
ss length	2.55	m		
Wetted Perimeter (P)	6.10	m		
Hydraulic Radius (R)	0.29	m		
mannings n	0.300		Heavily Vegetated	
Capacity (Q)	0.33	m^3/s	**OK**	
Velocity (V)	0.19	m/s		

Swale 3B				
5% AEP (20 Year ARI) Flow =	0.44	m^3/s	RORB Model	
Manning's calculation of capacity of a trapezoidal swale				
Water Depth	0.5	m	(6 m top width)	
Drain Base width	1	m		
Longitudinal Slope	0.04	m/m	25	
side slope of batters	1 in	5		
Flow Area (A)	1.75	m^2		
ss length	2.55	m		
Wetted Perimeter (P)	6.10	m		
Hydraulic Radius (R)	0.29	m		
mannings n	0.300		Heavily Vegetated	
Capacity (Q)	0.51	m^3/s	**OK**	
Velocity (V)	0.29	m/s		

Swale 4A				
5% AEP (20 Year ARI) Flow =	0.3	m^3/s	RORB Model	
Manning's calculation of capacity of a trapezoidal swale				
Water Depth	0.5	m	(10 m top width)	
Drain Base width	2	m		
Longitudinal Slope	0.1	m/m	10	
side slope of batters	1 in	8		
Flow Area (A)	3	m^2		
ss length	4.03	m		
Wetted Perimeter (P)	10.06	m		
Hydraulic Radius (R)	0.30	m		
mannings n	0.300		Heavily Vegetated	
Capacity (Q)	1.41	m^3/s	**OK**	
Velocity (V)	0.47	m/s		

Swale 4B				
5% AEP (20 Year ARI) Flow =	0.14	m^3/s	RORB Model	
Manning's calculation of capacity of a trapezoidal swale				
Water Depth	0.5	m	(10 m top width)	
Drain Base width	2	m		
Longitudinal Slope	0.1	m/m	10	
side slope of batters	1 in	8		
Flow Area (A)	3	m^2		
ss length	4.03	m		
Wetted Perimeter (P)	10.06	m		
Hydraulic Radius (R)	0.30	m		
mannings n	0.300		Heavily Vegetated	
Capacity (Q)	1.41	m^3/s	**OK**	
Velocity (V)	0.47	m/s		

Swale 5A

5% AEP (20 Year ARI) Flow =	0.44	m^3/s	RORB Model

Manning's calculation of capacity of a trapezoidal swale

Water Depth	0.5	m	(10 m top width)
Drain Base width	2	m	
Longitudinal Slope	0.04	m/m	25
side slope of batters	1 in	8	
Flow Area (A)	3	m^2	
ss length	4.03	m	
Wetted Perimeter (P)	10.06	m	
Hydraulic Radius (R)	0.30	m	
mannings n	0.300		Heavily Vegetated
Capacity (Q)	0.89	m^3/s	**OK**
Velocity (V)	0.30	m/s	

Swale 5E

5% AEP (20 Year ARI) Flow =	0.84	m^3/s	RORB Model

Manning's calculation of capacity of a trapezoidal swale

Water Depth	0.5	m	(10 m top width)
Drain Base width	2	m	
Longitudinal Slope	0.04	m/m	25
side slope of batters	1 in	8	
Flow Area (A)	3	m^2	
ss length	4.03	m	
Wetted Perimeter (P)	10.06	m	
Hydraulic Radius (R)	0.30	m	
mannings n	0.300		Heavily Vegetated
Capacity (Q)	0.89	m^3/s	**OK**
Velocity (V)	0.30	m/s	

Swale 5B

5% AEP (20 Year ARI) Flow =	0.78	m^3/s	RORB Model

Manning's calculation of capacity of a trapezoidal swale

Water Depth	0.5	m	(10 m top width)
Drain Base width	2	m	
Longitudinal Slope	0.04	m/m	25
side slope of batters	1 in	8	
Flow Area (A)	3	m^2	
ss length	4.03	m	
Wetted Perimeter (P)	10.06	m	
Hydraulic Radius (R)	0.30	m	
mannings n	0.300		Heavily Vegetated
Capacity (Q)	0.89	m^3/s	**OK**
Velocity (V)	0.30	m/s	

Swale 5D

5% AEP (20 Year ARI) Flow =	1.66	m^3/s	RORB Model

Manning's calculation of capacity of a trapezoidal swale

Water Depth	1	m	(20 m top width)
Drain Base width	2	m	
Longitudinal Slope	0.04	m/m	25
side slope of batters	1 in	8	
Flow Area (A)	10	m^2	
ss length	8.06	m	
Wetted Perimeter (P)	18.12	m	
Hydraulic Radius (R)	0.55	m	
mannings n	0.300		Heavily Vegetated
Capacity (Q)	4.48	m^3/s	**OK**
Velocity (V)	0.45	m/s	