North Penrith Stages 2B-3B

Water Cycle Management Strategy Report Incorporating Water Sensitive Urban Design Techniques

Prepared for:

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NORTH PENRITH STAGES 2B-3B
WATER CYCLE MANAGEMENT STRATEGY INCORPORATING
WATER SENSITIVE URBAN DESIGN TECHNIQUES

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1 INTRODUCTION

The North Penrith development site is a former army barracks area and is located just to the north of Penrith's CBD. The total site consists of approximately 40 hectares of land which is being redeveloped as residential and commercial lots. Stage 1 of the development is currently under construction. An application has been lodged for development of Stage 2A. Landcom has engaged JWP to prepare a Water Cycle Management Strategy to support a development application for Stages 2B-3B (incorporating Stages 2B, 2C, 2D, 3A and 3B).

This report details the procedures used and presents the results of investigations undertaken by J. Wyndham Prince Pty Ltd in developing a Water Cycle Management Strategy that incorporates the principles of Water Sensitive Urban Design (WSUD) to integrate with and support a development application to the Department of Planning and Infrastructure for Stages 2B-3B.

The objective of this investigation is to identify the stormwater issues to be taken into account in the detailed planning, design and development of the North Penrith Stages 2B-3B site. The investigation builds on previous studies to confirm appropriate options and locations for the control of the quantity and quality of stormwater leaving the site, and to identify the land areas required to implement the recommended options. The investigation also includes a detailed water balance assessment to ensure that the proposed central water feature and wetland are viable from both a water quality and water reuse perspective.

This investigation addresses engineering considerations whilst placing a strong focus on creating enhanced bio-diversity, ecological health and positive water quality benefits within the proposed stormwater elements to provide an integrated natural resource for the incoming residents.

The investigation involved the following specific tasks:

- Liaise with the Landcom and Penrith City Council to determine their specific requirements for development of the site.
- Review the previous Stormwater Strategy prepared for the site and identify any modifications or enhancements required for the Stage 2B-3B site to achieve Landcom's vision for the development.
- Undertake a hydrologic analysis to determine the peak 2, 5, 20 and 100 year ARI pre development and post development flows.
- Determine the minimum detention storage requirements to restrict post development flows to pre development levels and the capacity of downstream stormwater infrastructure.
- Undertake a water quality analysis and determine the minimum treatment device areas required to achieve Office of Environment and Heritage water quality targets.
- Prepare preliminary engineering concept designs for any measures required to achieve the water quality and quantity objectives.
- Undertake a detailed water balance assessment to ensure that the central water feature and wetland are viable from both a water quality and water reuse perspective.
- Prepare a Water Cycle Management Concept Plan.
- Prepare a Water Cycle Management Strategy Report Incorporating Water Sensitive Urban Design Techniques to support the development application for the North Penrith Stage 2B-3B site, detailing the investigations, findings, calculations and design details.

2 PREVIOUS RELEVANT REPORTS

Two previous relevant reports have been prepared by Worley Parsons for the North Penrith development. These reports form part of the approved Concept Plan and are summarised below.

North Penrith – Drainage, Stormwater and Groundwater Management Report (Worley Parsons, 2011)

This report described the objectives and proposed strategies for managing stormwater within the North Penrith development and Stage 1. Stormwater drainage is addressed through provision of a piped network with a 5 year ARI capacity. Water quality is addressed through a treatment train approach, including gross pollutant traps, bioretention systems, ponds and wetlands. Water quantity is addressed through provision of a detention basin incorporated with the central water feature and main wetland.

North Penrith – Regional Flooding Assessment (Worley Parsons, 2010)

This report was prepared to establish how the proposed North Penrith development conforms to the NSW Government's Floodprone Land Policy, whether the development can integrate into the SES regional evacuation strategy and how the development will manage the structural damage risk. The report presented the regional flooding results for the 100, 200, 500 and 1000 year ARI and PMF events. The minimum habitable floor level for the North Penrith development was determined to be RL 25.9m AHD (100 year ARI flood level plus 0.5m freeboard).

An additional report was also prepared by Egis Consulting which is relevant to the North Penrith site and is summarised below.

North Penrith Stormwater Masterplan (Egis Consulting, 2002)

This report detailed a flood evacuation strategy and supporting plan which concluded that a residential development would have an acceptable evacuation plan for regional floods up to the PMF in consideration of the Hawkesbury/Nepean Floodplain Management Strategy.

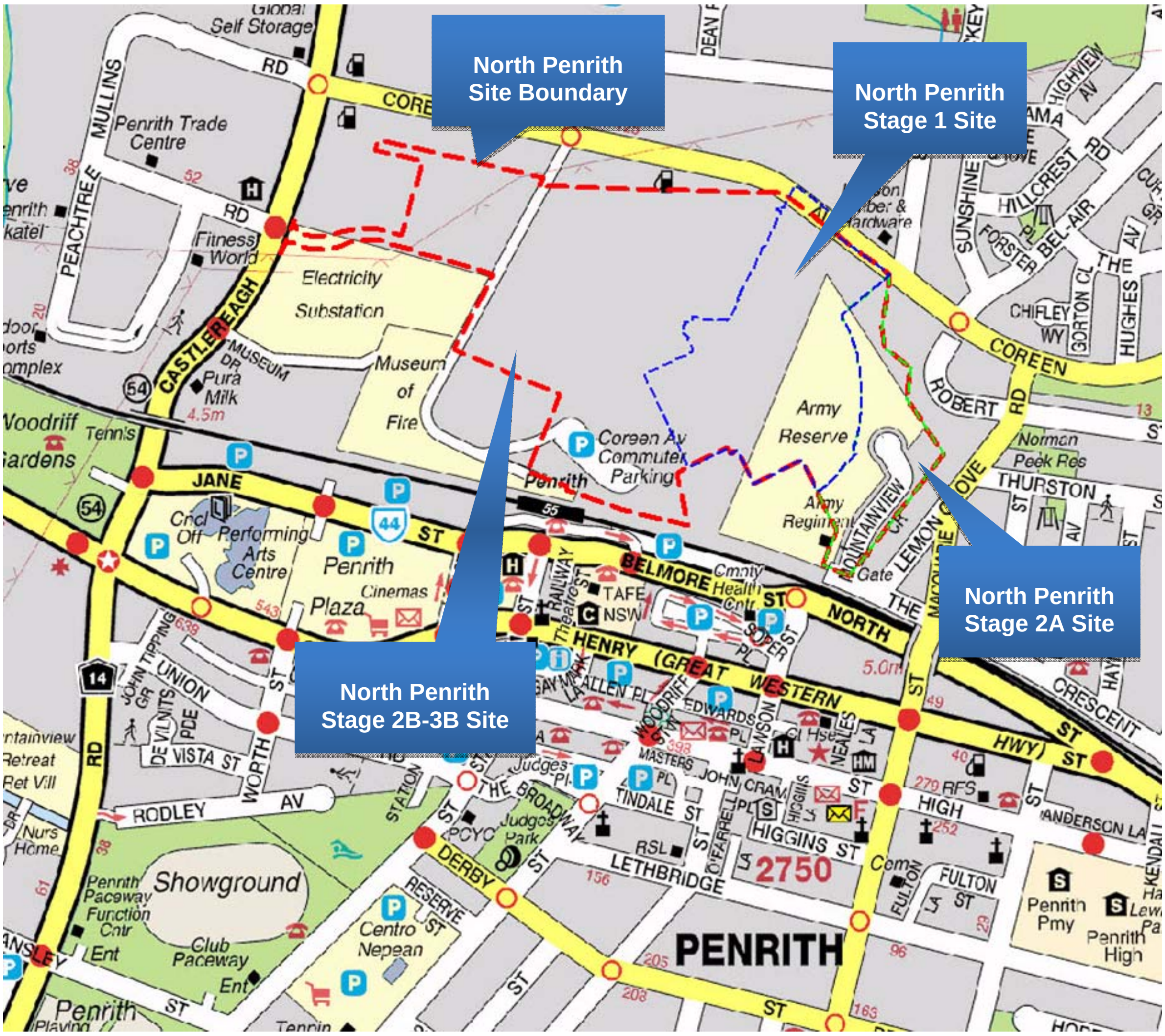
3 THE SITE

The North Penrith development, which totals approximately 40 hectares, is located immediately north of the Penrith CBD and western rail line. The site is bounded by Coreen Avenue to the north, existing residential development to the east and existing commercial and industrial development to the west. The main access to the development site is via Castlereagh Road and Coreen Avenue.

The site is a former army barracks. All former buildings have been removed and the Stage 1 and Stage 2A developments are currently under construction. The site is characterised by its very flat nature, with grades generally around or less than 1%.

The Stage 2B-3B site is approximately 24 hectares and forms the western portion of the North Penrith development site.

The location of the North Penrith site and the various stages is indicated on Plate 3.1 below and is shown in more detail on Figure 1.



(Source: UBD)

Plate 3.1 Location of the North Penrith Development Site

3.1 Existing Drainage Configuration

The North Penrith site is extremely flat but generally grades to the west and north-west. There are two discharge points from the site. The first is a 2 x 900mm diameter culvert under Coreen Avenue and the second is an existing open channel at the north-west boundary of the site, which discharges to Boundary Creek and then ultimately to the Nepean River.

The existing drainage configuration and flow directions within the North Penrith site are shown on Plate 3.2. The existing drainage catchments are shown on Figure 2.

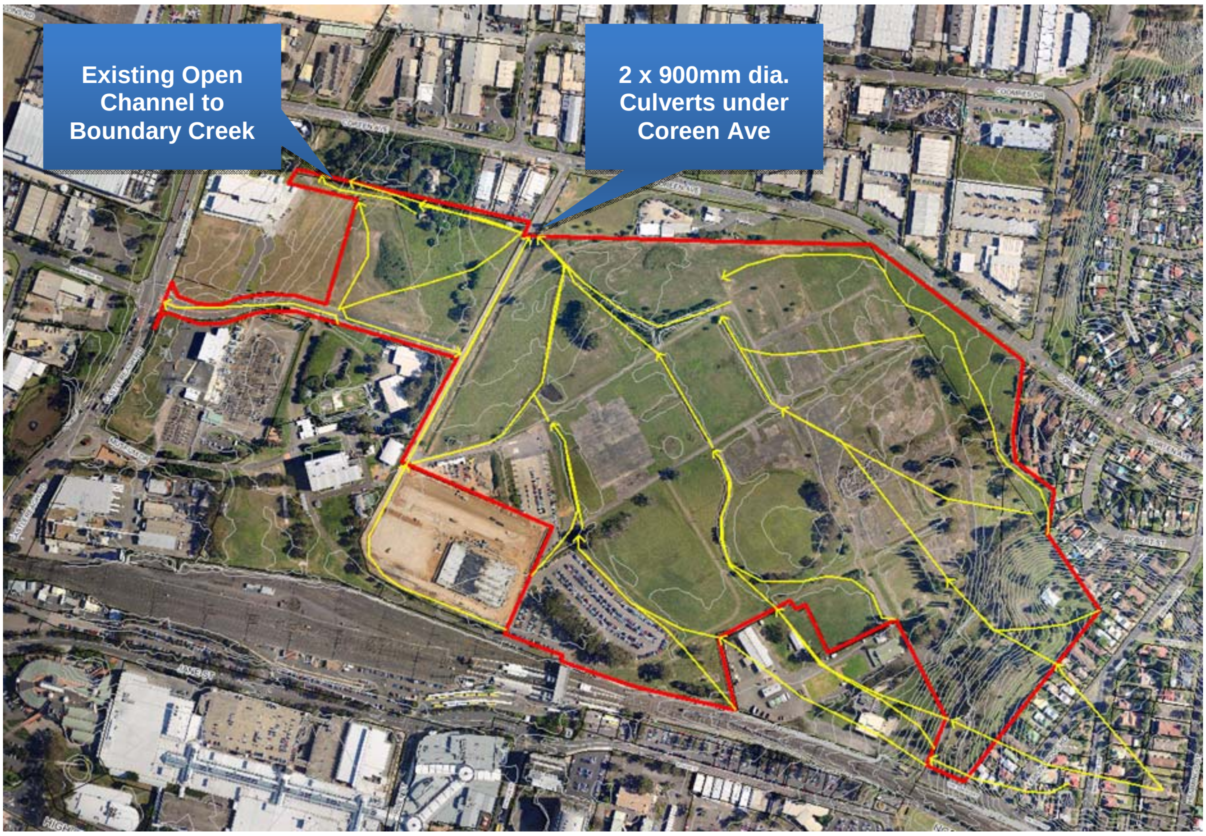


PLATE 3.2 DIRECTION OF FLOWS UNDER EXISTING CONDITIONS

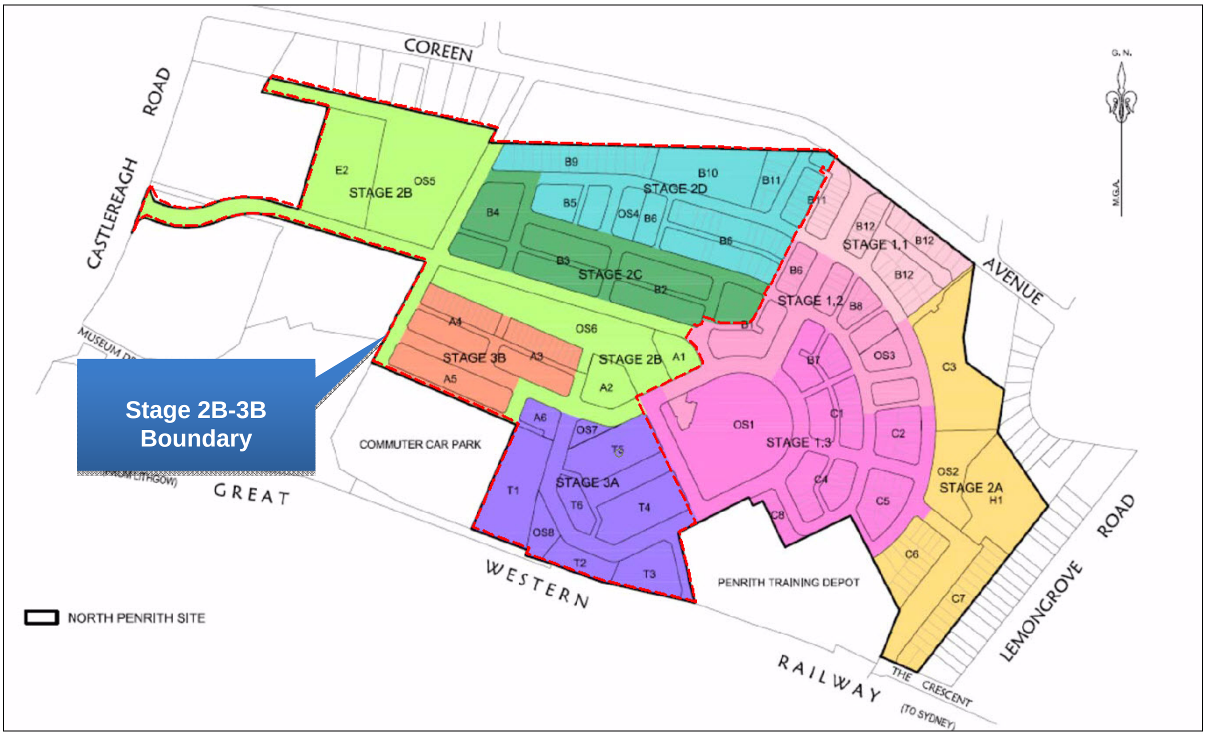
3.2 The Proposed Development

With an overall area of approximately 24 ha, the Stage 2B-3B subdivision of the North Penrith site by Landcom will involve the creation of approximately 800 residential allotments, the construction of a central water feature for water quality control, a combined water quantity control detention basin and water quality wetland and dedication of new roads.

The combined wetland / detention basin, which is designed to retard peak post development, flows up to the 100 year ARI to pre development levels. The combined wetland / detention basin is located to the north-west of the Stage 2B-3B site.

A water recirculation system will be incorporated within the North Penrith development, which pumps water from a sand filter, located immediately downstream of the wetland / detention basin, back to the top of the central water feature. The recirculation system is integral to the development's overall water quality system and also assists in reducing the risk of algal problems. A detailed description of the wetland / central water feature and recirculation system operation is included in Section 5.

The proposed North Penrith Stage 2B-3B development is shown below in Plate 3.3. The developed case catchment boundaries are shown on Figure 3.



(Source: Landcom)

PLATE 3.3 PROPOSED NORTH PENRITH DEVELOPMENT LAYOUT PLAN (INCLUDING STAGES 2B – 3B)

4 WATER CYCLE MANAGEMENT STRATEGY CONCEPT

The Water Cycle Management Strategy proposed for the North Penrith development focuses on minimising the impacts of the development on the total water cycle and maximising the environmental, social and economic benefits achievable by utilising responsible and sustainable stormwater management practices. The Water Cycle Management Strategy has been prepared with consideration of the following documents and guidelines:

- Engineering Guide for Development (Penrith City Council, 1997)
- North Penrith Design Guidelines 2012
- Australian Runoff Quality (Engineers Australia, 2005)
- Australian Rainfall and Runoff (Institution Of Engineers Australia, 1987)
- Draft NSW MUSIC Modelling Guidelines (Sydney Metropolitan Catchment Management Authority, 2010)

Managing Urban Stormwater (Draft) (Office of Environment and Heritage (Former Department of Environment and Climate Change, 2007)To maintain stormwater quality at the required levels, a "treatment train" approach is proposed where various types of pollutants are removed by a number of devices acting in series. The stormwater management treatment train will consist of the following elements.

Implementation of water efficient fittings and appliances in all dwellings (dual flush toilet, AAA shower heads, water efficient taps and plumbing).

- Minimisation of impervious areas through acceptable development controls.
- The provision of rainwater tanks on each allotment, along with implementation of the above water efficient devices, will satisfy the requirements of BASIX and connection of the water tank for internal uses (toilet flushing) will ensure any requirements are met and additional benefits are realised.

4.1 Water Efficiency

4.1.1 *On Lot Treatment*

- Implementation of water efficient fittings and appliances in all dwellings (dual flush toilet, AAA shower heads, water efficient taps and plumbing).
- Minimisation of impervious areas through acceptable development controls.
- The provision of rainwater tanks on each allotment, along with implementation of the above water efficient devices, will satisfy the requirements of BASIX and connection of the water tank for internal uses (toilet flushing) will ensure any requirements are met and additional benefits are realised.

4.2 Water Quality

4.2.1 *Street Level Treatment*

Gross Pollutant Traps (GPTs) to remove litter, vegetative matter, free oils and grease and coarse sediments prior to discharge to a downstream treatment device. GPTs will be located at all discharge points to the central water feature and wetland to not only form an important part of the water quality treatment train but to also reduce the visual impacts that gross pollutants will have on the central water feature / wetland features.

4.2.2 *Subdivision / Development Treatment*

Subdivision scale treatment measures will be incorporated within the development to reduce the total suspended solids and nutrient loads generated from the site and include:

- Central water feature ponds and feature Wetlands
- Main Wetland
- Sand Filter

A detailed description of the central water feature and wetland system operation is included in Section 5.

Refer to Appendix A for a detailed description of the water quality elements listed above and the assumptions used in the water quality modelling. The proposed water cycle management strategy plan is shown on Figure 4.

4.3 Water Quantity

4.3.1 *Subdivision / Development Treatment*

Peak storm flow attenuation up to the 100 year ARI event is addressed through the provision of a detention basin, incorporated with the main wetland and central water feature, to restrict peak post development flows to pre development levels for storm events up to the 100 year ARI.

4.4 Key Features

Key features of the proposed water cycle management strategy for the North Penrith site are as follows:

Social:

- Integration of a constructed wetland and central water feature with the overall landscape strategy for the estate to create an integrated-natural resource for the incoming and wider community.
- Enhanced visual amenity.
- Flood affectation and public safety issues identified and controlled.
- Provision of aesthetic soft design forms that enhance urban and environmental amenity.

Environmental:

- Limited downstream and in-channel discharge peaks and velocities to avoid scouring, siltation and flora and fauna impacts
- Enhanced ecological health and biodiversity within the central water feature and wetland.
- Provision of gross pollutant traps, central water feature ponds, constructed wetlands and sand filter to achieve water quality targets.
- Provision of ponds and wetlands capable of sustaining aquatic ecosystems.

- Limitation of frequent wetting flows and peak velocities to avoid creek bed/bank erosion and sedimentation. Peak storm flow attenuation is addressed through provision of a local detention basin located within the North Penrith site.

- A holistic and interdisciplinary approach to the management of urban salinity, using an approach to construction, stormwater management, building and landscaping practices, consistent with the WSROC Western Sydney Salinity Code of Practice.

- Provision of extensive deep rooted vegetation in strategic areas to intercept ground water flows and generate natural groundwater discharge processes (evapotranspiration).

- Extensive revegetation of allotments, streetscapes, central water feature and the constructed wetland to manage urban salinity and provide habitat.

- Provision of BASIX compliant rainwater tanks within the development to reduce reliance on potable water supplies by using recycled water as a resource.

Economic:

- Minimisation of land take consistent with the achievement of environmental and social objectives.

- Proposed water quality improvement measures that keep recurrent maintenance tasks and costs to a minimum.

The water cycle management strategy proposed for the North Penrith development site is functional; delivers the required technical performance; lessens environmental degradation and pressure on downstream ecosystems and infrastructure; and provides for a 'soft' sustainable solution for stormwater management within the release area. The water cycle management concept is illustrated on Figure 4.

4.5 Construction Stage

Erosion and sediment control measures are to be implemented during the construction phase in accordance with the requirements of Penrith City Council and the guidelines set out by Landcom (the "Blue Book" Ref. 9).

As the operation of constructed wetland and pond water quality treatment systems are sensitive to the impact of sedimentation, these controls should generally be maintained until the majority of site building works are complete. Alternatively, a very high level of at source control on individual allotments during the building and site landscaping works, which is regularly inspected by either Landcom or Council officers, would be required.

4.6 Interim Treatment Measures

The constructed wetlands and ponds should be protected as much as practical throughout the civil and housing construction phases of the development.

Before the commencement of construction activity, silt fence should be installed on the upslope of the wetland and adjacent to the drainage paths that lead to the wetland. Damaged silt fence should be replaced or repaired immediately.

Stockpiling of materials adjacent to the wetlands and ponds should be avoided as much as practical. Any stockpiled material should be protected with silt fencing. Stockpiled material should be seeded or covered to help prevent erosion.

At Construction Certificate stage a detailed management strategy which details how the wetland and central water feature will be protected during the civil and housing construction stages should be prepared.

4.7 Long Term Management

Regular maintenance of the stormwater quality treatment devices is required to control weeds, remove rubbish, and monitor plant establishment and health.

Proper management and maintenance of the water quality control systems will ensure long-term, functional stormwater treatment. A separate site-specific Operation and Maintenance (O & M) Manual will be prepared for the system. The O & M Manual will provide information on the Best Management Practices (BMP's) for the long-term operation of the treatment devices. The manual will provide site-specific management procedures for:

Maintenance of the GPT structures including rubbish and sediment removal.

Management of the ponds and wetlands including plant monitoring, replanting guidelines, monitoring and replacement of the filtration media and general maintenance (i.e. weed control, sediment removal).

An overview of the contents and structure of the O&M Manual is included in Section 6.

4.8 Stormwater Monitoring Programme

A stormwater monitoring programme should be implemented to ensure the water quality wetland continues to operate as efficiently as possible. The monitoring programme developed for the site will be included in the Operation and Maintenance Manual.

5 WETLAND AND CENTRAL WATER FEATURE SYSTEM DESIGN OVERVIEW

The proposed Wetland and Central Water Feature system at North Penrith services both the total water quality and quantity requirements for the for the North Penrith residential development (51 ha including upstream catchment).

The system will also provide passive recreation, aesthetic vistas and an environment for the colonisation of native flora (aquatic and terrestrial) and fauna into the local area.

5.1 Water Quality Functions

The central water feature receives piped stormwater flows up to the 5 year ARI event. The piped flows are passed through proprietary GPTs before discharging into the central water feature at various points. A twin GPT structure at the head of the central water feature has been built as part of Stage 1. All other GPT's as located on JWP Plan No's 9470 DA 16-20 are proposed to be built in Stages 2A and 2B.

The stormwater flows discharged into the central water feature via the GPT's flow in a westerly direction towards Combewood Drive.

The conveyed flows would have velocities of less than 1 m/s. The stormwater is then passed via twin 3300 x 2400 RCBC units under Combewood Drive and discharged into the wetlands area. Flows up to the 3 month ARI event are diverted to the east and west perimeter macrophyte channel. These channels have been designed to maximise macrophyte growth and maximise contact time with the stormwater flow. Both channels direct stormwater to the north and then discharge into the wetland deep water zone.

The wetland and eastern section of the central water feature have been designed to have 300 mm of extended detention for water quality, before flows exit through the discharge control structures. The system is designed to have a three (3) days residence time and this is achieved by an appropriately sized orifice and pipe located in the north western weir device.

As noted in Section 9, a single pass through the central water feature / wetland system falls short of providing the required nutrient and suspended solids removal from the developed catchment. This shortfall has been addressed by recirculating stormwater via a pump and rising main to the head of the central water feature. This then provides a second pass through the wetland and central water feature system. The second pass, when modelled, meets the nutrient and suspended solids removal requirements for the developed catchment. The recirculation is via a pipe with an intake situated at the southern end of the deep water zone within the wetland. The pipe intake is set at RL 21.3. The wetland Static Water Level is 23.67, thus a 2.37m drawdown of the wetland is possible to replenish flows in the central water feature and create recirculation of the entire system. Before flows are pumped to the head of the central water feature, stormwater from the wetland is the passed via a sized pipe into the 210 m^2 sand filter with a base level of RL 21.0. Flows between the wetland and sandfilter are controlled via an automated solenoid valve. The size of the sand filter has been optimised to provide a minimum 50 L/s of flow to the pump well.

A pump capable of delivering 50 L/s to the top of the central water feature will be contained within the well and controlling switches will be housed in a cabinet beside the well. The rising main from the pump will discharge into the two (2) pond cells at the start of the central water feature. Discharging 10 L/s, both sides of the highest pond cell and a further 15 L/s both sides of the second highest pond cell. Discharges into the pond will be via directional jets to produce current (water movement) within the pond cells.

5.2 Water Quantity Functions

The central water feature receives, via the road network, major flows up to the 100 year ARI event. The flows are conveyed to the west via twin 3300 x 2400 RCBC units under Combewood Drive and into the wetland. All stormwater flows up to and including the 100 year ARI local event are detained by outlet structures within the wetland .The storage volume required is provided within the footprint of the in the wetland / central water feature system. Controlled flows leaving the site are via two (2) outlet systems. The first stage outlet pit begins operation at RL 24.0 and is situated on the north eastern edge of the wetland. Flows are conveyed via twin 900 dia. pipes to Coreen Avenue.

The second stage outlet is located in the North Western corner of the wetland and begins operation at RL 24.2. Flows are controlled by a 14 m long weir structure. Stormwater flows are then passed through the downstream channel and continue onto Coreen Avenue. The required detention storage for the site is 12,000m3, however the detention provided within the system has been designed to meet downstream flow constraints and thus a larger storage volume in excess of 20,000 m3 has been provided (refer to Section 6).

5.3 Algae Risk

Open water bodies such as the wetland and central water feature, are subject to the risk of algae blooms. This risk is highest from spring to autumn. The contributing factors include high water temperature, nutrient loads, turbidity of the water column, long periods without storm flushing flows, extended periods of sunlight and still wind conditions.

The proposed wetland and central water feature system has been designed with the following strategies to limit algae blooms:

- The central water feature and wetland have been designed with deep water areas. Up to 3.9m within the wetland and up to 3.3 m within the central water feature. This will aid in keeping water temperatures lower in summer than if shallow wetland and central water feature designs were proposed. When the colder water located at the base of the central water feature is mixed with warmer surface water, a lower homogenous water column temperature will be attained.

- To further cool water temperature within the wetland and central water feature water bodies, water is drawn from the deepest section within the wetland and passed through a sand filter. The sand filter would provide further cooling of the recirculated water, before being discharged at the head of the system. Aerating the water through the designed pond level changes will also cool the water.

- Water movement through the system is provided by the pumped flows. The discharging rising mains will be nozzled to provide directional current. Additionally, directional current and aeration of the main central water feature will be achieved by aerator/pumps located near the pedestrian bridge.

- The amount of macrophyte vegetation within a pond has a direct relationship with the available nutrients suspended within the water column for algae growth. 80% of the wetland surface area has been designed for macrophyte vegetation. Most of the northern side of the central water feature and a few designated areas on the south will have fringing macrophyte vegetation. With a large foot print of vegetation, fewer nutrients will be available for algae growth.

- All recirculated flows will be via the sand filter. The sand filter has been designed to have alternating wet and dry periods. The sand filter will provide reduction of algae being transported from the wetlands to the central water feature via filtration through the sands. Algae rafts accumulating on the surface of the sand filter will be exposed to drying, desiccation and eventually will die.

- Shading of the central water feature by appropriate tree planting on the northern edge of the central water feature will further aid in controlling algae proliferation.

5.4 Conclusion

The proposed central water feature and wetland system have been designed to provide the total solution for water quality and quantity requirements for the North Penrith development. As part of the design process involving Penrith City Council, structures and access points for the ongoing maintenance of the system have been included. The control of conditions that favour algae bloom in open water bodies has also been considered and designed into the proposal. The system will not only provide functional infrastructure, but will provide a valuable environmental and aesthetic feature for the inhabitants and broader community of North Penrith.

6 OPERATION AND MAINTENANCE

6.1 Introduction

The management of stormwater discharges relies on a number of different Stormwater Treatment Measures (STMs) arranged in series (sometimes referred to as a "Treatment Train") to control both the quantity and quality of stormwater entering the receiving environment. At the North Penrith site these STMs consist of:

i. Gross Pollutant Traps
ii. Wet Ponds;
iii. Constructed Wetlands;
iv. Sand Filter.

Stormwater entering STMs (particularly ii. and iv. above) must be pre-treated to remove coarse sediment and gross pollutants as these contaminants are capable of impairing their performance and increasing their maintenance liability. This pre-treatment is provided by Gross Pollutant Traps (i.e. STM i.). Each of the four (4) STM practices referred to above rely on physical, chemical and biological mechanisms, in varying degrees, to achieve their design objectives.

Table 6.1 links operational mechanisms, common to most STMs, with the pollutant specifically targeted by that mechanism. Consequently, the maintenance goal for any STM is to promote its operational mechanisms such that the control of the target pollutant is optimised.

TABLE 6.1 OPERATIONAL MECHANISMS AND TARGET POLLUTANTS (USEPA 1997)

Target Pollutant	Operational Mechanisms of the STM
All	• Increased Hydraulic Residence Time (HRT) • Low turbulence • Fine, dense herbaceous plants • Medium-fine textured media
Phosphorus	• High soil exchangeable aluminium (Al) and/or iron (Fe) content • Addition of precipitating agents
Nitrogen	• Alternating aerobic and anaerobic conditions • Low levels of toxicants • Circumneutral pH (around 7)
Metals	• High soil organic content • High soil Cation Exchange Capacity (CEC) • Circumneutral pH (around 7)
Organic Matter (OM)	• Aerobic conditions • High light • High soil organic content • Low levels of toxicants • Circumneutral pH (around 7)

Thorough and consistent maintenance of each of the operational mechanisms of an STM must be carried out routinely in order for them to achieve their pollutant control objective. A detailed Operation and Maintenance Manual should be prepared prior to completion of the STM construction works. The Manual will include descriptions of each of these operational mechanisms and provide field orientated Inspection Checklists which should be used as the basis for a Work Instruction to effect repairs and cleaning, as required.

The following sections provide an overview of the Operation and Maintenance tasks that will be outlined in more detail in the comprehensive manual.

6.2 Gross Pollutant Traps (GPTs)

Gross Pollutant Traps are the first element in the "Treatment Train" of STMs. They remove the light litter and, by default, much of the coarse sediment from the runoff. In so doing they protect the integrity of the larger vegetative and media filtration practices from high sediment loads and light litter.

They can be specifically designed to fit with site specific constraints or they can be purchased as proprietary devices modified to fit the location. Most GPTs use either a centrifugal (e.g. CDS) or direct screening (e.g. Baramy) technologies to remove the bed load or positively buoyant pollutants. Once the solid pollutants are separated from the liquid portion of the runoff they are stored in either a wet sump (e.g. CDS) or dry sump (e.g. Baramy) Separation Chamber.

6.2.1 *Operation*

"The descriptions of GPTs and sediment traps are divided into five operating types:

- **drainage entrance treatments:** grate entrance systems, side entry pits and gully pit traps
- **direct screening devices:** litter collection baskets, release nets, trash racks, return flow litter baskets, and channel nets
- **non-clogging screens:** circular and downwardly inclined screens
- **floating traps:** flexible floating booms, floating debris traps
- **sediment traps:** sediment settling basins and ponds, circular settling tanks, hydrodynamic separators."

(Engineers Australia, 2005)

PLATE 6.1 EMPTYING THE BASKET CONTAINING THE SOLIDS IN A WET SUMP GPT

6.2.2 *Maintenance*

GPTs rely on their screens being clean and the separation chamber having sufficient capacity to capture and retain the solid pollution contained within the design flow. Consequently Maintenance can be referred to as either:

Routine Cleaning

- Wet Sump – decant supernatant and dispose of at a licensed liquid waste facility;
- Dry Sump and Wet Sump – remove solid waste in accordance with the manufacturers guidelines;
- Dispose of solid waste to a licensed solid waste facility or recycling centre;
- Fill in the Gross Pollutant Trap Cleaning Report and provide copies to the owner and other relevant authorities.

Corrective Maintenance

- Repair access ramps;
- Repair any damage to inlet and outlet structures;
- Repair any visible erosion especially if it represents "piping";
- Repair all damage to infrastructure including fencing, gates, grates, lids, locks and security systems.

Maintenance Considerations (Engineers Australia, 2005)

- Special equipment such as cranes, tip trucks, eduction;
- Specialised equipment/training necessary to check device e.g. Confined Spaces;
- Trade waste licence;
- Overhead restrictions e.g. power, obstructions;
- Liquid waste removal;
- Isolation of device e.g. tidal or backwater affectation;
- Traffic control;
- Road load limits;
- Draining of solid waste before removal to land fill;
- Odour management;
- Occupational health and safety;
- Insects and vermin living in device;
- Trapped animals.

6.3 Wet Ponds

Generally referred to as a Wet Detention Pond as they often incorporate a temporary storage Extended Detention Zone (EDZ) on top of a permanent storage volume.

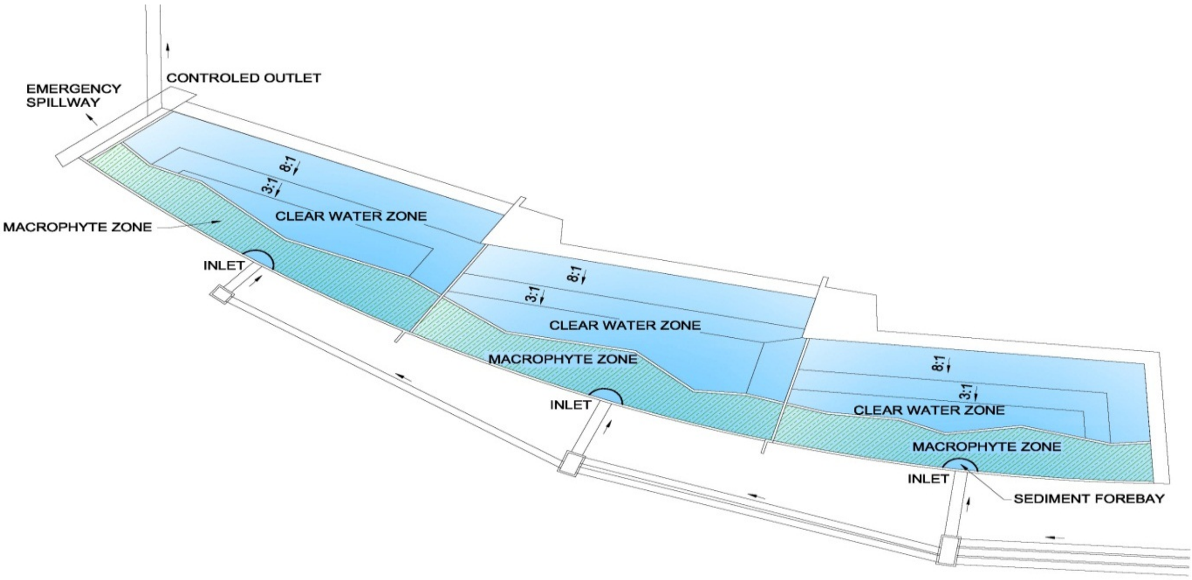


PLATE 6.2 TYPICAL SCHEMATIC OF A WET POND

These STMs retain water permanently and often have a recreational component associated with their installation e.g. visual, wildlife habitat, boating. The maintenance of the recreational elements of these systems would not be dealt with in Operation and Maintenance Manual. They are dominated by open water and may have a narrow littoral zone of fringing vegetation.

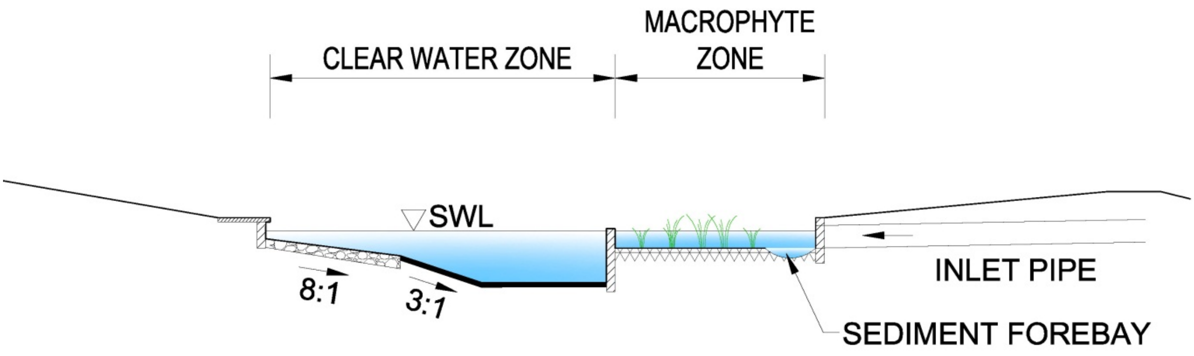


PLATE 6.3 TYPICAL SECTION THROUGH A WET POND

6.3.1 *Operation*

Wet Ponds are designed to have a permanent water storage that promotes a Hydraulic Residence Time (HRT) of sufficient length to promote the appropriate pollutant removal mechanisms.

Consequently they have at least two (2) and generally three (3) outlets:

i. Permanent water level control set at the Static Water Level (SWL) to maintain the desired storage volume;
ii. Detention water level control set at a water level equivalent to the top of the EDZ to provide control over rainfall event of a specific design frequency, often referred to as Average Recurrence Interval (ARI).
iii. Top water level control defined as an emergency spillway to allow stormwater runoff in excess of the design ARI to flow through the STM without being detained and without causing catastrophic failure to the structure.

Fringing vegetation may be planted or develop over time. This vegetation can help promote the Pollutant Removal Mechanisms described above, differentiate between the water and inhibit public access to the deeper water.

Often the water stored in these systems is seen as a source of water for irrigation of the terrestrial landscape. The infrastructure associated with the use of this water will include pumps, pipes and valves involve a disinfection system if the risk to human health from contact with the irrigated water is identified as high.

Fountains, aerators and mixers are often incorporated as underwater infrastructure to assist with control of Blue Green Algae and thermal stratification of the water column.

6.3.2 *Maintenance*

Routine Maintenance Activities

- Grass mowing of embankments;
- Removal of tree and shrubs from embankments and repair of any animal burrows;
- Replace vegetation where coverage has diminished and bare earth has become visible;
- Removal and dispose of light litter and debris, especially from structures;
- Weed removal;
- Replanting of littoral zone as needed;
- Report on any nuisance insects especially mosquitoes;
- Remove sediment accumulated in inlet zones;
- Repair visible erosion hazards;
- Report on the operation of any pumping, fountains and aeration systems;
- Repair any damage that threatens the integrity of any of the Public and Operational Safety and Security systems;
- Check and report on static water level.

Corrective Maintenance Activities

- Pond dewatering to remove accumulated sediment (generally when the permanent water storage volume has been reduce by 20%);
- Repair any damage to inlet and outlet structures as well as pumps and aerators used for irrigation and aeration;
- Repair any visible erosion especially if it represents “piping” or preferential seepage along any pipes that cross through the embankments;
- Repair all damage to infrastructure including fencing, gates, grates, lids, locks and security systems;

- Check for and repair any leaks if water levels reported in Routine Maintenance Inspections continually fall (in excess of evapo-transpiration estimates) between rainfall events.

6.4 Constructed Wetlands

Constructed wetlands are shallow water storages that are dominated by hydrophytic (emergent aquatic plants or macrophytes). They are sometimes referred to as Wetland Treatment Systems (WTS) due to the variety of different natural processes that occur within them.

PLATE 6.4 CONSTRUCTED WETLAND (FOREBAY, MARSH AND OPEN POND)

They generally have a small open pond at the inlet that acts as sediment basin or forebay, followed by a shallow (300 mm to 600 mm deep) marsh system and sometimes a clear water zone near the outlet. Macrophytes generally occupy in excess of 50% of the surface area and the complete system and the water level is controlled in manageable increments (generally less than 150 mm).

6.5 Operation

WTS are designed to have a permanent open pond with fringing macrophytes, similar to a wet pond. However the most obvious difference between the two (2) systems is the shallow marsh systems that dominate the WTS. The permanent water storage promotes a Hydraulic Residence Time (HRT) of sufficient length to promote physical settlement of particulate matter and the shallow marsh promotes the biological process that are very efficient at removing the fine particulates and many of the soluble pollutants from the water column.

Consequently they have at least two (2) and generally three (3) outlets:

Permanent water level control set at the Static Water Level (SWL) to maintain the desired storage volume;

Detention water level control set at a water level equivalent to the top of the EDZ to provide control over rainfall event of a specific design frequency, often referred to as Average Recurrence Interval (ARI).

Top water level control defined as an emergency spillway to allow stormwater runoff in excess of the design ARI to flow through the STM without being detained and without causing catastrophic failure to the structure.

Often the water stored in the open pond is seen as a source of water for irrigation of the terrestrial landscape. The infrastructure associated with the use of this water will include pumps, pipes and valves involve a disinfection system if the risk to human health from contact with the irrigated water is identified as high. Fountains, aerators and mixers are often incorporated into the open pond as underwater infrastructure to assist with control of Blue Green Algae and thermal stratification of the water column.

6.5.1 Maintenance

Routine Maintenance Activities

- Grass mowing of embankments;
- Removal of tree and shrubs from embankments and repair of any animal burrows;
- Replace vegetation where coverage has diminished and bare earth has become visible;
- Removal and dispose of light litter and debris, especially from structures;
- Weed removal;
- Replanting of littoral zone and marsh zones as needed;
- Report on any nuisance insects especially mosquitoes;
- Remove sediment accumulated in inlet zones;
- Repair visible erosion hazards;
- Report on the operation of any pumping, fountains and aeration systems;
- Repair any damage that threatens the integrity of any of the Public and Operational Safety and Security systems.

Corrective Maintenance Activities

- Dewatering of the marsh systems to remove accumulated sediment (generally when the permanent water storage volume has been reduce by 20%);
- Repair any damage to inlet and outlet structures as well as pumps and aerators used for irrigation and aeration;
- Repair any visible erosion especially if it represents “piping” or preferential seepage along any pipes that cross through the embankments;
- Repair all damage to infrastructure including fencing, gates, grates, lids, locks and security systems.

6.6 Sand Filter

Sand filters are depressed (generally 300mm to 600mm) flat media beds with a temporary water storage component. Sand filters are effective in removing several common pollutants from storm water runoff. They consist of a sand or gravel bed which provides very limited flow rate control (i.e. high flow rates) and rely on the stormwater moving vertically downward through the media. Sand filters are able to achieve high removal efficiencies for sediment, biochemical oxygen demand (BOD) and fecal coliform bacteria. They also assist in removing a low amount of nutrients.

PLATE 6.5 SAND FILTER

6.6.1 *Operation*

Sand filters are intended to temporarily store stormwater during and immediately following rainfall. The filter material is designed to have a permeability that allows the stormwater to percolate through to the lower drainage layer and under drains, from where it can either be recirculated back to the central water feature or discharged to the local drainage network. Sand filters operate by capturing particulates on the surface of the sand or gravel media layer. As water flows through the media, the particulates can be captured through direct collision, surface charge attraction or diffusion.

6.6.2 *Maintenance*

Routine Maintenance Activities

- Grass mowing of embankments;
- Removal of tree and shrubs from embankments and repair of any animal burrows;
- Removal and dispose of light litter and debris, especially from structures;
- Weed removal;
- Report on any nuisance insects especially mosquitoes;
- Remove sediment accumulated in inlet zones;
- Repair visible erosion hazards;
- Report on the operation of any pumping systems;
- Repair any damage that threatens the integrity of any of the Public and Operational Safety and Security systems.

Corrective Maintenance Activities

- Removal and replacement of the top layers of sand, gravel and/or filter fabric that has become clogged;
- Repair any damage to inlet and outlet structures;
- Repair any visible erosion especially if it represents "piping" or preferential seepage along any pipes that cross through the embankments;
- Repair all damage to infrastructure including fencing, gates, grates, lids, locks and security systems.

6.7 Recirculation and Aeration System

The central water feature and wetland system, as designed, has little natural water movement apart from that generated by major inflows during storm events. Water will be recirculated via a pump and rising main to the head of the central water feature. The pump, capable of delivering a flow rate of 50 litres per second, will be contained within a well and the controlling switches will be housed in a cabinet beside the well. Two aerators are also incorporated in the system to assist in maintaining a constant water temperature throughout the water column.

6.7.1 *Maintenance*

Routine Maintenance Activities

- Run pump and aerators for at least the minimum time recommended by the manufacturer every month;
- Inspect pump and aerators for any leaks and vibrations;
- Check aerators for electricity leakage in accordance with the manufacturers specification.

Corrective Maintenance Activities

- Remove and service pump and aerators as required.

7 WATER QUANTITY MANAGEMENT

7.1 Hydrological Analysis

Water quantity management for this study is undertaken using XP-RAFTS modelling software package. XP-RAFTS is a non-linear runoff routing model that generates runoff hydrographs from rainfall data.

XP-RAFTS modelling has been undertaken in this study to establish the peak flows considering both existing and developed conditions of North Penrith site and to determine the size of mitigation measures required to restrict developed case flows to existing levels. Details and discussion of this modelling are included in Sections 7.2 to 7.6 below.

7.2 Catchments

A 3D digital terrain model (DTM) was developed based on Airborne Laser Survey (ALS) provided for existing conditions. The upstream existing catchment was defined based on aerial contours derived from existing ALS data, while consideration was also given to the existing road and pipe networks. The catchment delineation was found to be generally consistent with the previous report (Worley Parsons, 2011), with a total upstream catchment area of 51 Ha. The overall existing catchment was then further divided in twenty (20) sub-catchments which range in size from 0.3 to 6 Ha.

The proposed development area has been divided into twenty six (26) sub-catchments based on design contours and the design road and pipe networks. Developed sub-catchment sizes range from 0.2 to 3.3 ha, the details are included in Appendix B.

Existing and developed case catchment layouts are shown on Figures 2 and 3, respectively.

The existing and developed XP-RAFTS model layouts are illustrated in Plate 7.1 and 7.2.

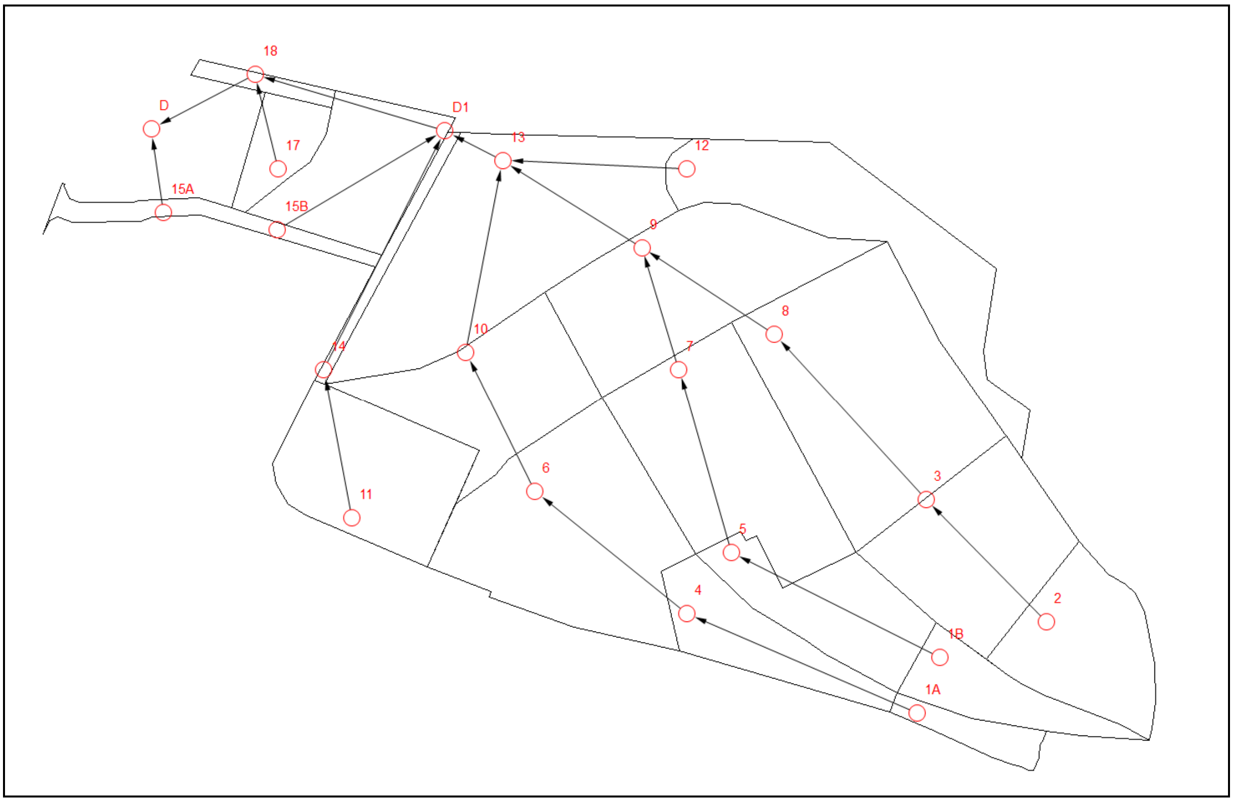


PLATE 7.1 XP-RAFTS EXISTING CASE MODEL LAYOUT

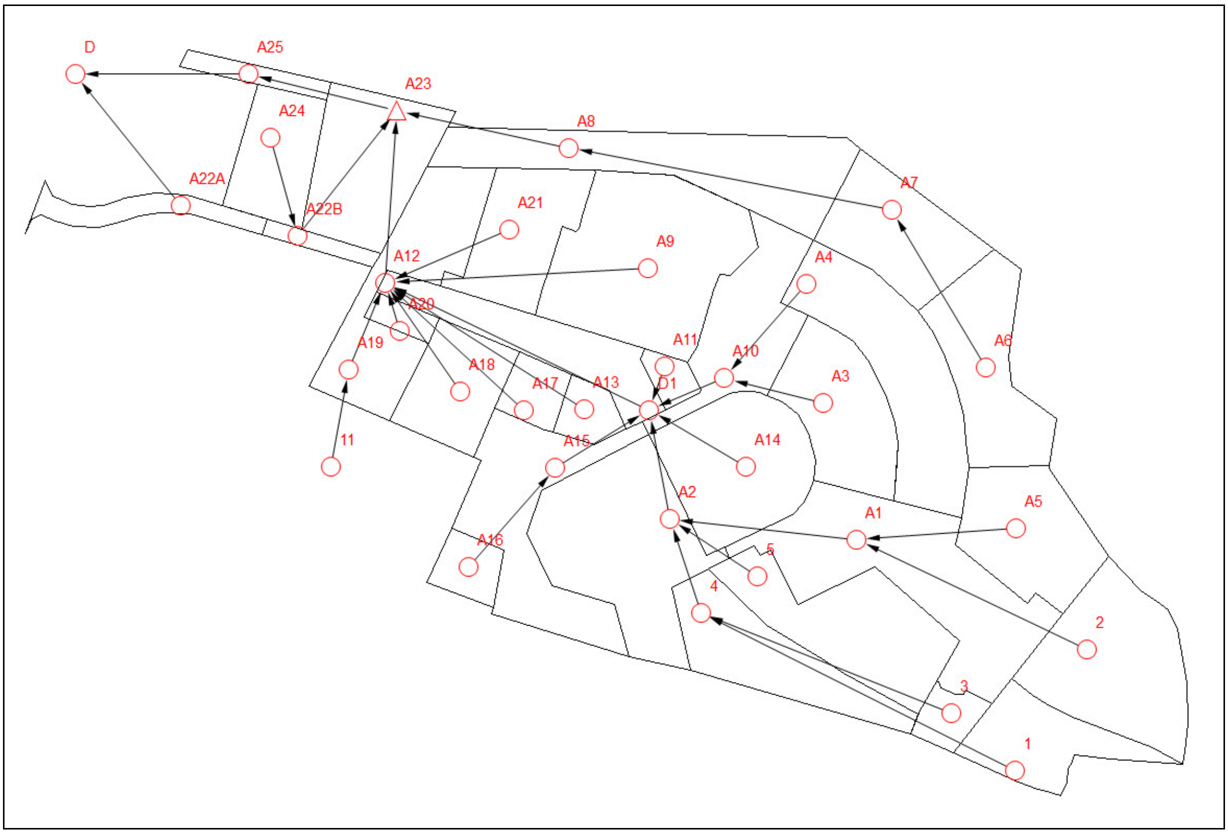


PLATE 7.2 XP-RAFTS DEVELOPED CASE MODEL LAYOUT

7.3 Modelling Parameters

As part of the XP-RAFTS modelling for the North Penrith site the following parameters were adopted:

Design rainfall intensity-frequency-duration (IFD) has been adopted as per Council guidelines (Penrith City Council, 2010). Refer to summary Table B-1 in **Appendix B**.

Rainfall Loss Parameters - The initial and continuing loss method was applied in accordance with Australian Rainfall and Runoff (IE Aust, 1987). Rainfall loss parameters were adopted based on previous experience on similar projects in the Penrith areas. The adopted parameters are included in Table B-2 in **Appendix B**.

Slope - Catchment slopes have been estimated from existing survey contours (for the existing model) and design contours (for developed model) and range from 0.1 % to 6.5 %. The majority of catchment slopes determined for both scenarios is less than 1% as the whole site is very flat. A detailed summary of catchment slopes is provided in Tables B-4a and B-4b in **Appendix B.**

Area - Catchment areas were measured digitally in MapInfo software package and are summarised in Tables B-4a and B-4b in **Appendix B**.

Fraction Impervious – Fraction impervious parameters were applied to various land uses across the overall catchment. These were applied in accordance with Council guidelines (Penrith City Council, 2010) and assigned based on aerial imagery, Land and Property Management Authority (LPMA) data and the proposed development. Refer to Table B-3 in **Appendix B**.

Manning's PERN value – The type of land use has an effect on the runoff by providing some "resistance" to the flow. The "resistance" effect in XP-RAFTS is simulated by a storage delay coefficient called "Pern". Table B-5 in **Appendix B** lists the standard Pern (n) values used in the model.

Lag Links – Durations of lag links were based on velocities along flowpaths, which were estimated at 1 to 1.5 m/s. Refer to Table B-6a and B-6b in **Appendix B**.

7.4 Basin Discharge Control Structure Design

In order to restrict post development flows back to existing levels for events up to the 100 year ARI storm, a detention basin is proposed to be incorporated with the wetland area to manage the flows.

There are two discharge points available adjacent to the proposed basin/wetland. The basin can discharge into the existing culverts (2 x 900mm dia pipes) under Coreen Avenue as well as to an existing open channel to the north-west of the site, which discharges into Boundary Creek.

A complex multi-staged outlet control structure is proposed for the detention basin. Modelling of the outlet structure is beyond the capability of XP-RAFTS. The hydraulic software package XP-STORM was therefore used to model the basin outlet arrangements. A stage / discharge relationship was determined by assessing a series of discharges through the system and calculating the headwater required to force a certain flow rate through the system.

The detention basin and outlet configuration was designed not only to adequately detain discharges for the developed site but also so that peak post development discharges do not to exceed the current capacity of the existing downstream infrastructure (open channel and culverts under Coreen Avenue).

The proposed wetland / detention basin will manage discharges up to the 100 year ARI event. For details of the wetland / detention basin arrangements refer to JWP engineering plans Ref 9470 DA16-20.

7.5 Tailwater Effects

The North Penrith site is affected by regional flooding from the Nepean River. When regional flooding occurs in conjunction with local storm events at the site, the basin performance will also be affected. In order to properly assess the detention basin performance, the tailwater impact needs to be incorporated into the modelling. The hydraulic performance of the outlet arrangement for the basin, including tailwater effects, has been modelled in XP-STORM.

Based on North Penrith Urban Area – Redundant Defence Lands Stormwater Masterplan (Egis, 2002) flow / discharge relationships were applied as tailwater conditions at the two existing discharge points: the culverts under Coreen Avenue and the open channel to Boundary Creek (refer to Tables B-7a and B-7b in Appendix B). These relationships were derived from the 5 year, 20 year and 100 year ARI flood levels determined at these two locations.

7.6 Discharge Estimates and Basin Performance

The proposed basin was designed to have a maximum storage of 24,340 m3 (RL 25.2m) and its 100 year ARI local top water level (TWL) is RL 24.94 m (see Table 7-2). The detention basin is incorporated with the water quality wetland, with the detention volume component located above the wetland static water level and extended detention zone (RL 24.0 m). Due to the size of the wetland required to meet the water quality targets, the basin storage volume provided is subsequently larger than is required to restrict 100 year ARI peak post development flows to existing levels. Refer to JWP engineering plans 9470 DA16-20 for concept design drawings of the proposed basin / wetland system.

Discharge estimates were derived for the existing and developed catchments for storms with Average Recurrence Intervals (A.R.I.'s) of 2, 5, 20 and 100 years. The discharges from the basin have been designed not to exceed the capacity of the open channel and existing culverts under Coreen Avenue. A range of storm durations from 15 minutes to 24 hours were analysed to determine the critical storm duration for each sub-catchment.

XP-RAFTS modelling was undertaken to determine the estimated peak discharges exiting the North Penrith site from the upstream catchments for the pre and post development conditions. These peak discharges are shown in Table 7.1 below:

TABLE 7.1 PRE & POST DEVELOPMENT PEAK DISCHARGES

ARI Storm Event	Pre-development		Post-development		Post/Pre Development Ratio
	Peak Inflow (m^3/s)	Storm Duration (min)	Peak Inflow (m^3/s)	Storm Duration (min)	
2 year ARI	4.10	120	2.02	120	0.5
5 year ARI	5.90	120	2.37	120	0.4
20 year ARI	8.50	120	3.56	120	0.4
100 year ARI	11.4	120	5.14	120	0.5

The performance of the proposed detention basin system is illustrated in the following Table 7.2:

TABLE 7.2 DETENTION BASIN PERFORMANCE

ARI Storm Event	Peak Inflow (m^3/s)	Storm Duration (min)	Peak Outflow (m^3/s)	Storm Duration (min)	Storage used (m^3)	Stage used RL (m)
2 year ARI	7.03	20	1.99	120	5708	24.31
5 year ARI	9.33	20	2.35	120	9828	24.52
20 year ARI	12.5	20	3.54	120	14003	24.73
100 year ARI	16.2	20	5.10	120	18578	24.94

7.7 Discussion of Modelling Results

The results of the hydrologic modelling for the North Penrith site, as summarised in Tables 7.1 and 7.2, show that:

- The proposed detention basin is adequate to restrict peak post development discharges to below existing levels.
- Approximately 18,580m3 (76%) of the available 24,340m3 of storage capacity in the basin is used in the peak 100 year ARI event.

The detention basin will provide a benefit to Penrith Council as it assists in reducing peak flows to the capacity of existing infrastructure.

8 FLOODING

The following sections have been provided to address Clause C6 of the Concept Plan approval, which states the following:

C6 Flooding

Prior to the determination of any development approval for infrastructure works in Stage 2, the proponent shall submit a further assessment of flooding behaviour that includes:

1) *An assessment of the impact of filling on site on flood levels at adjoining properties; and*
2) *An assessment of the impact of climate change on flooding behaviour, changes to temperature, rainfall and evaporation and the impact this may have on flood levels on and adjoining the site and the stormwater management strategy.*

8.1 Local Flooding

The North Penrith development site has very little upstream catchment draining to it. Local flooding is therefore primarily limited to stormwater runoff from the development site only. Flows up to the 5 year ARI will be conveyed through the site via the stormwater pipe network. Flows in excess of the 5 year ARI (up to the 100 year ARI) will be conveyed by an overland flow network, which includes the roads and central water feature. The overland flow network will be designed to ensure that flows are conveyed safely in accordance with the Floodplain Development Manual (2005) and Penrith City Council requirements.

The development incorporates a detention basin to reduce peak post development flows to existing levels or the capacity of the downstream drainage infrastructure. Therefore, peak flows at the downstream boundary of the site will not increase as a result of the development and, hence, there will be no significant adverse impact on flood levels downstream of the site as a result of the development.

8.2 Regional Flooding

The site is partially affected by regional flooding from the Nepean River. The 100 year ARI regional flood (R.L. 25.4) affects only a small portion to the north west of the site, while the regional PMF (R.L. 31.0) affects the majority of the site.

In order to provide sufficient grade to drain the site and reduce the flood hazard for extreme events some filling is required. A Regional Flood Assessment was undertaken by Worley Parsons (2010). The assessment concluded that:

- The minimum habitable floor level was to be the 100 year ARI plus 0.5m freeboard (R.L. 25.9m AHD).
- The north western area of the site to be filled up to 1.5m in the lower areas to ensure the flood risk in floods rarer than the 100 year ARI would reduce the risk of substantial property damage to socially acceptable and sustainable levels.
- The proposed filling will meet Council's criteria by not causing any significant changes to flood behaviour, no potential for cumulative flood impacts, no significant adverse impacts on surrounding development and local drainage problems.

The filling works for Stages 2B-3B are generally consistent with the previous assessment undertaken by Worley Parsons (2010) and, hence, will not have significant adverse impacts on surrounding development.

8.3 Climate Change

The potential impacts of climate change are outlined in a document titled Impacts of Climate Change on Urban Stormwater Infrastructure in Metropolitan Sydney, Sydney Metropolitan Catchment Management Authority (January 2011). In summary the impacts are:

Summer runoff depths are expected to increase by a maximum of 26%.

The 40-year 24-hour duration rainfall intensity is expected to increase by a maximum of 12%.

The net average annual runoff is expected to fluctuate with an overall minor increase.

Part of the standard freeboard requirement includes a component to account for climate variability. It is anticipated that any increases in flood levels as a result of climate change can be accommodated in the minimum 0.5m freeboard allowance to the dwelling floor levels.

9 WATER BALANCE

9.1 Introduction

One of the main objectives of the North Penrith development is the provision of a central water feature and wetland. As part of the design of stages 2B-3B, J. Wyndham Prince undertook a detailed water balance assessment to ensure that both the central water feature and wetland were viable from both a water quality and water reuse perspective.

Algae risk in open water bodies is an ongoing concern and as part of the design process best management practices and techniques have been incorporated into the design of the water bodies to provide the best possible management of algae blooms during the warmer months of the year (see Section 9.3).

The viability of the central water feature and wetland will be influenced by the volume of rain runoff generated from the catchment. An important component of the runoff volume generated from the development is the inclusion of rainwater tanks within each proposed lot.

9.2 Assumptions and Considerations

As part of the concept approval, a detailed investigation has been completed by Worley Parsons titled “North Penrith – Drainage, Stormwater and Groundwater Management Report” (Worley Parsons, 2011).

This report provided a number of critical input variables to this current assessment. Details of the elements of the Worley Parsons report, together with the details of our assumptions and considerations are provided below.

- Runoff from precipitation falling on the 43.7 ha catchment (Worley Parsons Table 11, p.31) has been assumed as the only source of inflow.
- Daily rainfall and monthly evaporation data provided by the Bureau of Meteorology (BOM), for the Proposed Reservoir Station (No. 067019) for the period between 2nd February 1887 and 22nd January, 2008.
- Full development of the site (60% Pervious Urban Catchment) using a volumetric runoff coefficient of 0.57 (Worley Parsons Table 7, p. 25).
- Evaporation has been based on the Bureau of Meteorology (BOM) information for Prospect Reservoir, adjusted seasonally to account for climate change projections as recommended by the Office of Environment and Heritage (OEH). Daily rainfall values for Prospect Reservoir between 2 Feb, 1887 and 22 Jan, 2008 have been adopted.
- Reuse estimates have been based on a permanent population within the development of 2,430 people (900 dwelling x 2.7 person per dwelling) and the use of rainwater, to flush toilets only, at 40L/day/person. Total usage equal to 97,200 L/day.
- Unless otherwise specified, all of the following modelling results have been carried out on the assumption that the wetland and central water feature are on continuous water body. Consequently, the drawdown of the top water level (TWL), as a result of evaporation and/or reuse, refers to the anticipated decrease in TWL of the combined water bodies.

9.3 Algae Risk

The design and formation of the wetland and central water feature, that formed part of the Worley Parsons design (Worley Parsons, 2011), is in our opinion too shallow and is likely to be subjected to significant algal risks (both blue-green and filamentous). The engineering design presented on the DA plans has been configured to assist in minimising the algal risk.

Notwithstanding the possibility of algae blooms, we have assessed the likely management tools required to provide best practice management of the water bodies to reduce the likelihood of their occurrence and provide an acceptable level of control. Regardless of these tools a comprehensive algal risk management plan which is informed by a comprehensive monitoring strategy for the system will most likely be required by Penrith City Council.

The general criteria used to indicate the possibility of an impending blue-green algal bloom relate to: Warm water temperatures; Low dissolved oxygen; and an alkaline pH. Other criteria include nutrient levels in excess of the ANZECC 2000 guidelines and extended periods of sunlight with mild to still wind conditions.

Strategies that have been used to limit algal blooms in the design are:

- Continual water movement through the system – this would involve the use of pumps to move water from the wetland up to the head of each of the central water feature cells. See JWP engineering plan 9470 DA16-20 for details of the recirculation system.
- Destratification – mechanical infrastructure used to mix the upper and lower layers of the water column and provide a homogenous water body with similar temperature, dissolved oxygen, pH and nutrient levels throughout.
- Shading – restrict extended periods of sunlight through the use of strategically placed vegetation and structures to provide shade, especially in spring and summer. Care should be taken to ensure that these shade structures do not present a windbreak.

9.4 Water Balance Assessment

The Water Balance Assessment has been undertaken using rainfall data from 2 Feb, 1887 to 22 Jan, 2008 or 121 years of rainfall for the Prospect Reservoir. As mentioned previously, the water balance assessment included rainwater tanks and reuse.

To enable the reuse and the impacts that the rainwater tanks will have on the Water Balance Assessment, we have simplified the assessment with the volume of the rainwater tanks and the potential reuse of this captured stormwater for toilet flushing into a daily loss rate. The assumption that approximately 2,430 people (2.7 people, per 900 proposed dwellings estimated) would use an upper limit of 40 L/day/person which results in an estimated loss rate to reuse of 97,200 L/day.

Considering this use and the runoff from 121 years of rainfall the water balance assessment has concluded that:

- The wetlands and central water feature could be expected to be close to full on average 69% of the days each year.
- There is a 0.1% probability that a maximum drawdown of 0.85 m across both water bodies (wetland and central water feature) would occur within a 12-month period.
- There is a 50% probability that a drawdown, across both water bodies, in excess of 0.6 m could be expected to occur within any 12-month period for a maximum duration of about three (3) weeks. Spring and summer are the seasons within which a drawdown of this magnitude would most likely occur. Longest period of continual drawdown in excess of 0.2 m was approximately 30-weeks.
- There is a 100% probability that a maximum drawdown, across both water bodies, in excess of 0.5 m could be expected to occur within any 12-month period. Spring and summer are the seasons within which a drawdown of this magnitude would most likely occur. However, numerous instances where drawdowns of this magnitude were identified during autumn and winter. Longest period of continual drawdown of between 0.5 m and 0.6 m was approximately 30-weeks whilst periods in excess of 3-weeks were not uncommon.

- On average approximately 157,000 m^3/yr of runoff from the site can be expected to be discharged directly into Boundary Creek during rainfall events.
- If the wetland were to provide “top up” water for the central water feature, i.e. the stored water within the wetland is used to maintain the TWL in the central water feature regardless of the impact on the TWL within the wetland, then the TWL in the wetland could be expected to draw down by between 1.5 m and 2 m whilst the central water feature would remain full. The probability of this level of drawdown in any 12-month period could be expected to be as high as 50% whilst the probability that it would draw down by 1 m in any 12-month period could be expected to be 100%.

Evaporation from the surface of both water bodies was based on the BOM seasonal Potential Evaporation values for Prospect Reservoir, modified to account for the seasonal variations projected by OEH attributed to their Climate Change projections. Evaporation was not calculated for those days on which rainfall had been recorded. Evaporation from the water bodies was based on the TWL surface area and no account was taken of the reduction in total volume evaporated as the surface area of the water bodies reduced i.e. shallow water is likely to evaporate at a greater rate than deeper water (as the TWL decreases with evaporation so does the surface area of the water body which in turn reduces the surface area from which evaporation can occur).

9.4.1 *Comments and Conclusion*

The investigation have identified that a drawdown of up to 1.5 m (worst case scenario) in the wetland is possible and has been confirmed as an acceptable management tool to ensure the viability of the central water feature. The water balance has concluded that there is sufficient stormwater runoff from within the North Penrith development site to maintain the TWLs.

The system can operate and be viable with only stormwater runoff from the site.

9.5 Impacts Of Climate Change

Accounting for climate change in water balance calculations is a complex process which requires the extrapolation of projections of changes to seasonal precipitation and potential evapotranspiration (PET) to be scaled down to a daily time step. At present the algorithms to account for this have not been developed. DECCW (2010/171) “NSW Climate Change Impact Profile” does provide some guidance on projected changes to both seasonal precipitation and evaporation, and these have been adopted for this assessment. The only decrease projected for total precipitation is in winter months whilst only summer and spring evaporation are anticipated to increase by up to 20%.

Consequently for the purposes of this water balance assessment the existing BOM daily precipitation has been adopted and BOM PET values for Spring and Summer have been increased by 20%. It is anticipated that this adjustment will provide an over estimation of the draw down that may be experienced within the wetland / central water feature system, based on the 2050 Climate Change projections.

This assessment has been based on the current OEH projections for Climate Change Impacts on rainfall / runoff volumes and evaporation rates. It is subject to change as more confidence in the projections becomes available. However, it is our opinion that the values adopted in this assessment represent a considered approach to addressing Climate Change impacts on the proposed water bodies within this development and provide an insight into the possible fluctuations in TWLs which may be expected within the proposed water bodies.

10 WATER QUALITY ANALYSIS

The water quality analysis for this study was undertaken using the model MUSIC (Model for Urban Stormwater Improvement Conceptualisation) Version 5 (CRCCH - 2005). This water quality modelling software was developed by the Cooperative Research Centre (CRC) for Catchment Hydrology, which is based at Monash University and was first released in July 2002.

The model provides a number of features relevant for the development:

- It is able to model the potential nutrient reduction benefits of gross pollutant traps, constructed wetlands, grass swales, bio-retention systems, sedimentation basins, infiltration systems and it incorporates mechanisms to model stormwater re-use as a treatment technique;
- It provides mechanisms to evaluate the attainment of water quality objectives;

The MUSIC modelling was undertaken to demonstrate that the water cycle management system proposed for the North Penrith site will result in a reduction in overall post-development pollutant loads.

10.1 Catchments

A MUSIC model was established for the proposed stormwater management system for the North Penrith Precinct. The proposed catchment is 40 ha and is split into urban, industrial / commercial and drainage reserve areas to represent each post development subcatchment within the Precinct. The general arrangement of the MUSIC model is shown in Appendix A.

The assumed catchment densities for the Precinct are detailed in Table 10.1:

TABLE 10.1 CATCHMENT DENSITIES ASSUMPTIONS

Adopted Average No. of Lots per Hectare	20 lots
Population per Dwelling	2.7 persons
Average Percentage Impervious of the Lots	90%
Average Roof Area per Dwelling	200 m^2

The majority of the catchment will discharge to the water quality elements prior to discharge to the central water feature and the wetland.

As with any computer model, a number of standard parameters are used in the establishment of the modelling components. Rainwater tanks, GPTs, wetlands, ponds and a sand filter were used as water quality elements in the treatment train to achieve the target reductions of pollutants. Details of the standard parameters used in this study are presented in Appendix A. The technical parameters associated with the MUSIC model node elements together with soil/groundwater assumptions are also presented in Appendix A.

10.2 MUSIC Modelling Philosophy and Parameters

Rainwater tanks are proposed to be provided for each household and industrial/commercial development capturing roof water for re-use within the Precinct and there are to be GPT's as primary treatment devices located throughout the development prior to discharging stormwater flows into all ponds or wetlands to ensure gross pollutants do not impact the operation of the secondary devices prior to discharge to the downstream drainage system.

The central water feature forms the basis of the fringe wetlands and ponds capturing the majority of the site prior to discharging into the wetland at the downstream of the site drainage system. To prevent stagnation in the central water features, a pump system is proposed to recirculate the water through the central water feature ponds again, which also provides for additional treatment of flows. Prior to recirculation, the pumped flows will pass through a sand filter, which will provide further treatment. The recirculation system is proposed to operate at 50 l/s for a continuous period of 6 hours/day 7 days/week during the summer months (October through to April), a solenoid will control the recirculation flows during the rest of the year, essentially whenever storm flows are discharging through the system. The MUSIC model was set up to simulate the site treatment system, including a single recirculation cycle, with a second pass through the central water feature system to the main wetland, then discharging from the site.

The contributing catchments to each device within the Precinct are shown in Appendix A.

10.3 Rainfall Data

The MUSIC model is able to utilise rainfall data based on 6 minute, hourly, 6 hourly and daily time steps. A 6 minute time step was used in the analysis which was chosen in accordance with the recommendations for selecting a time step within the MUSIC Users Manual.

The nearest rainfall station to the site with a reasonable period of 6 minute rainfall data for a suitably representative period of rainfall for the site was:

Station No	Location	Years of Record	Type of Data
67033	Richmond RAAF	1980 - 1990	6 minute

The mean annual rainfall in the data set is 831mm, while the mean annual rainfall available from the Bureau of Meteorology's long term data for the station closest to the site (Orchard Hills) is 812mm.

10.4 Rainwater Tanks

For the purpose of this water quality assessment, it is assumed that the developments will have a reasonable demand for reuse, for things such as toilet flushing, irrigation of landscaped areas, vehicular washing and other appropriate uses, 3 kL rainwater tanks are being adopted for all individual residential lots throughout the Precinct. The rainwater tank parameters adopted in the assessment are provided in Appendix A.

10.5 Treatment Device Performance

The location and indicative sizes of the proposed treatment devices are shown on Figure 4. A summary of the proposed treatment devices sizes and respective total catchment areas are presented in Table10.2 below.

TABLE 10.2 TREATMENT DEVICE SIZES

Stormwater Treatment Device	Sandfilter	Wetlands		Ponds	
	Filter Bed Area (m²)	Wetland Area (m²)	Volume (m³)	Pond Area (m²)	Volume (m³)
Central Water Feature Wetland		1480	740		
Pond 1				805	1280
Pond 2				1125	1785
Pond 3				5820	9240
Main Wetland		9400	10000		
Recirc Sandfilter	210				
Total	**210**	**10880**	**10740**	**7750**	**12305**

10.6 Pollutant Load Estimates

The pollutant loads at the discharge points from the wetland/detention basin after the initial treatment run is shown in Table 10.3.

TABLE 10.3 ESTIMATED MEAN ANNUAL POLLUTANT LOADS AND REDUCTIONS - MAIN WETLAND AFTER INITIAL PASS

Pollutant	Total Developed Source Nodes (kg/yr)	Minimum Reduction Required (kg/yr)	Total Residual Load from Site (kg/yr)	Total Reduction Achieved (kg/yr)	Total Reduction Achieved (%)
TSS	50,600	43,010	14,100	36,500	**72.1%**
TP	95.8	62.3	38.3	57.5	**60.0%**
TN	615	277	361	254	**41.3%**
Gross Pollutants	7,640	6,876	0.0	7,640	**100.0%**

The results of pollutant removal performance through the sand filter for the recirculated flows (up to 50 l/s) is shown in Table 10.4, and the resulting pollutant removal performance through one full cycle of recirculation (at 50 l/s) through the central water feature system and wetland at the discharge point from the site is shown in Table 10.5.

TABLE 10.4 ESTIMATED MEAN ANNUAL POLLUTANT LOADS AND REDUCTIONS - RECIRCULATION FLOWS THROUGH SAND FILTER

Pollutant	Total Developed Source Nodes (kg/yr)	Minimum Reduction Required (kg/yr)	Total Residual Load from Site (kg/yr)	Total Reduction Achieved (kg/yr)	Total Reduction Achieved (%)
TSS	50,600	43,010	10,100	40,500	**80.0%**
TP	95.8	62.3	29.3	66.5	**69.4%**
TN	615	277	307	308	**50.1%**
Gross Pollutants	7,640	6,876	0.0	7,640	**100.0%**

Locations of junctions within the Precinct are shown in the layout plan in Appendix A.

TABLE 10.5 ESTMATED MEAN ANNUAL POLLUTANT LOADS/REDUCTIONS RECIRCULATION FLOWS THROUGH CENTRAL WATER FEATURE AND WETLAND SYSTEM TO SITE DISCHARGE POINT (ONE CYCLE)

Pollutant	Total Developed Source Nodes (kg/yr)	Minimum Reduction Required (kg/yr)	Total Residual Load from Site (kg/yr)	Total Reduction Achieved (kg/yr)	Total Reduction Achieved (%)
TSS	50,700	43,095	7,400	43,300	**85.4%**
TP	96.0	62.4	24.9	71.1	**74.1%**
TN	617	278	264	353	**57.2%**
Gross Pollutants	7,670	6,903	35.8	7,634	**99.5%**

10.7 Discussion of Modelling

The performance of the proposed water quality management strategy for the North Penrith Defence Lands Precinct shows that the treatment train proposed will meet the requirements specified within OEH's water quality objectives (OEH, 2009) after one recirculation pass through the treatment system.

The expectation is that the system will be continually subject to recirculation and that a considerable portion of the stormwater flows will be repeatedly retreated by the central water feature-wetland system, providing a higher level of treatment performance than is reported.

11 SUMMARY & CONCLUSION

The Water Cycle Management Strategy incorporating WSUD techniques has been prepared for the North Penrith Stage 2B-3B development to support the DA process for the site. The strategy has been prepared to conform with the statutory requirements and industry best practice for stormwater management in this catchment.

The Water Cycle Management Strategy consists of a treatment train consisting of on lot treatment, street level treatment and subdivision / development treatment measures. The structural elements proposed for the development consists of:

- 3,000 litre rainwater tanks on each allotment.
- Proprietary GPT units at each stormwater discharge point.
- A central water feature consisting of macrophyte zones of total approximate area 1,480m^2 and three ponds of total area 7,750m^3 .
- A constructed wetland of total area 9,400m^2.
- A sandfilter of total area 210m^2.
- A detention basin of approximate total volume 24,340m^3.

Provision of the proposed detention basin within the development will ensure that peak post development discharges are restricted to less than the pre development levels.

The results of the water balance and water quality investigations identify that the wetland and central water feature are sustainable with stormwater runoff generated from the site and do not require an external top up source of water supply.

The wetland and central water feature will be subject to the risk of algal blooms, particularly from spring to autumn. The engineering design incorporates the following best management practices and initiatives to address the algal risk:

- Incorporation of deep water areas will aid in keeping water temperatures lower in summer.
- Installation of a mechanical recirculation system to allow water to be recirculated from the sand filter to the central water feature.
- Water movement through the system, which is provided by the pumped flows.
- An aeration system is to be incorporated which assists in keeping the water temperature lower and circulation.
- The wetland has been designed with 80% coverage of macrophyte vegetation.

Provision of the proposed water quality treatment devices within the development will ensure that the post development stormwater discharges will meet the Office of Environment and Heritage's and Landcom's water quality objectives for the North Penrith development.

The provision of WSUD elements within the North Penrith development will assist in minimising the impact of urbanisation on the waterway stability of the downstream waterways.

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

12 REFERENCES

- CRC For Catchment Hydrology (2009). MUSIC Model for Urban Stormwater Improvement Conceptualisation – User Guide
- Egis (2002). North Penrith Urban Area – Redundant Defence Lands Stormwater Masterplan
- Engineers Australia (2006). Australian Runoff Quality – A Guide To Water Sensitive Urban Design
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- Landcom (2004). Managing Urban Stormwater – Soils and Construction – 4th Edition
- Office of Environment and Heritage (Formerly the Department of Environment and Climate Change (2007). Managing Urban Stormwater
- Penrith City Council (1997). Engineering Guide for Development
- Sydney Metropolitan Catchment Management Authority (2010). Draft NSW MUSIC Modelling Guidelines
- Sydney Metropolitan Catchment Management Authority (2011). Impacts of Climate Change on Urban Stormwater Infrastructure in Metropolitan Sydney
- Willing & Partners Pty. Ltd. (1994). Runoff Analysis & Flow Training Simulation. Detailed Documentation and User Manual, Version 4.0
- Willing & Partners Pty. Ltd. (1996). Runoff Analysis & Flow Training Simulation. Addendum, Version 5.0
- WSROC (2003). Western Sydney Salinity Code of Practice

APPENDIX A – MUSIC WATER QUALITY RESULTS AND DETAILS

MUSIC MODELLING LANDUSE PARAMETERS

Details of the soil / groundwater parameters adopted for the MUSIC modelling undertaken for this development are presented in Table A1 below. The adopted Annual Pollutant event mean concentrations are also presented in Table A2 below:

Table A1 ADOPTED SOIL / GROUNDWATER PARAMETERS FOR THE SITE [1]

	Units	Parks & Landscaped	Urban
Impervious Area Parameters			
Rainfall threshold (Road 1, Roofs 0.5)	mm/day	1.4	1.4
Pervious Area Parameters			
Soil storage capacity	mm	210	170
Initial storage	% of capacity	30	30
Field capacity	mm	80	70
Infiltration capacity coefficient - a		175	210
Infiltration capacity coefficient - b		3.1	4.7
Groundwater Properties			
Initial depth	mm	10	10
Daily recharge rate	%	35	50
Daily baseflow rate	%	20	4
Daily deep seepage rate	%	0	0

* Roofed and Road catchments have been assumed to be 100% impervious

Table A2 ADOPTED ANNUAL POLLUTANT EVENT MEAN CONCENTRATIONS [2]

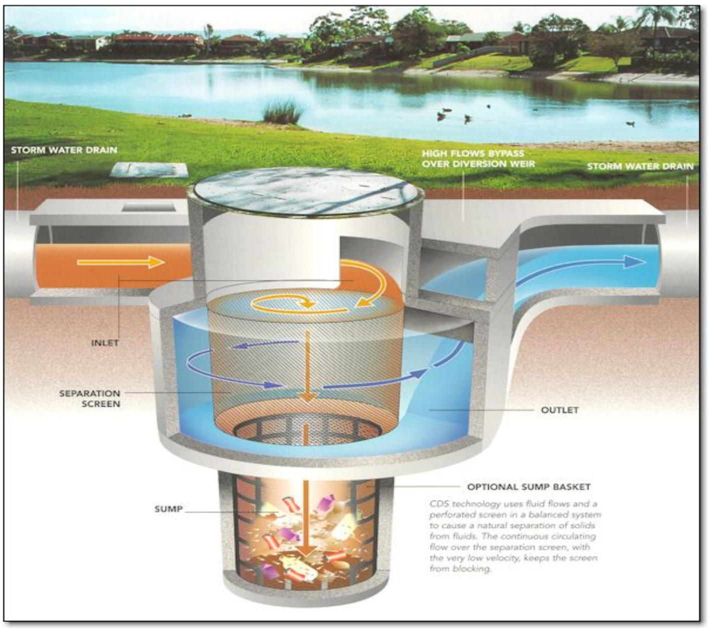
Pollutant	Roofed*		Road*		Remaining Urban		Parks & Landscaped	
	Base Flow (mg/l)	Storm Flow (mg/l)	Base Flow (mg/l)	Storm Flow (mg/l)	Base Flow (mg/l)	Storm Flow (mg/l)	Base Flow (mg/l)	Storm Flow (mg/l)
TSS	0	20	0	270	16	141.2	6	40
TP	0	0.13	0	0.5	0.14	0.18	0.03	0.08
TN	0	2	0	2.2	1.3	1.68	3.3	0.9

* Roofed and Road catchments have been assumed to be 100% impervious

1 CRC for Catchment Hydrology (2005). MUSIC Model for Urban Stormwater Improvement Conceptualisation – User Guide Version 3

2 Department of Environment and Climate Change. Technical Note – Interim Recommended Parameters for Stormwater Modelling – North-West and South-West Growth Centres

GROSS POLLUTANT TRAPS (GPT'S)



GPT devices are typically provided at the outlet to stormwater pipes. These systems operate as a primary treatment to remove litter, vegetative matter, free oils and grease and course sediments prior to discharge to a downstream (Secondary and Tertiary) treatment devices. They can take the form of trash screens or litter control pits, filter pit inserts and wet sump gross pollutant traps. Council approved GPT units are to be provided at the end of stormwater pipes servicing urbanised catchments prior to discharging to the receiving waters.

Gross pollutant traps are available in various sizes and the performances of these devices vary substantially. To ensure flexibility in the detailed design phase of any development project, J. Wyndham Prince adopt a generic GPT node in its Water Quality Modelling.

Music Modelling Parameters

Within MUSIC transfer functions are used to calculate the stormwater effluent concentration of the stormwater flowing into the device, using a simple graphical relationship between the inflow and outflow concentration. MUSIC allows the user to describe the performance of the generic node by using a graphically based transfer function editor, for each of the pollutant types – Gross Pollutants (GP), Total Suspended Solids (TSS), Total Phosphorus (TP) and Total Nitrogen (TN). The adopted values for modelling of GPT's for this development are presented in Table A3 below.

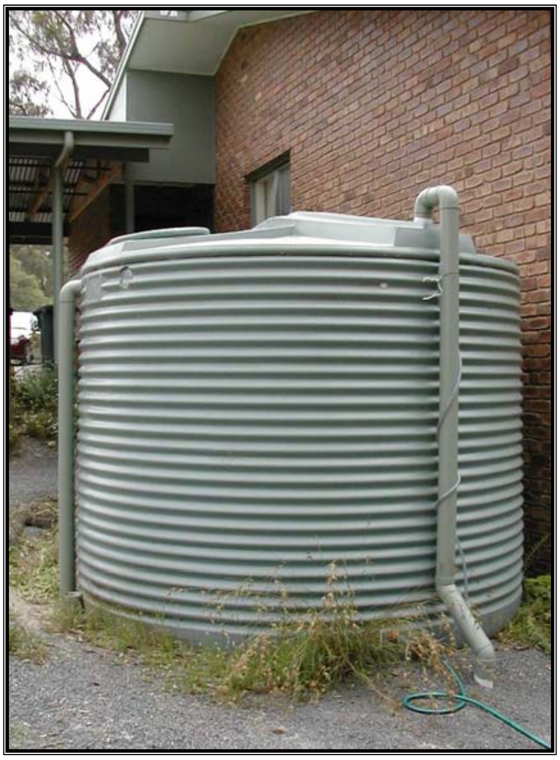
As the there is currently no adopted Australian method of measuring comparable performance of various GPT devices, and the products can range from basic trash screens to sophisticated proprietary devices, the TSS and nutrient removal performance of the systems has been conservatively adopted as zero. Individual products may achieve substantially improved performance over these adopted targets.

Table A3 ADOPTED GPT PERFORMANCE PARAMETERS

Pollutant Type	Remove Efficiency
GP	90%
TSS	0%
TP	0%
TN	0%

RAINWATER TANKS

Rainwater tanks are sealed tanks designed to contain rainwater collected from roofs. Rainwater tanks provide the following main functions:



- Allow the reuse of collected rainwater as a substitute for mains water supply, for use for toilet flushing, laundry, or garden watering (facilitate attainment of BASIX compliance).
- Provide some on-site detention, thus reducing peak flows and reducing downstream velocities; (when designed with additional storage capacity above the overflow);
- Provide captured stormwater for internal hot water supply (in some instances).

The water collected can be reused as a substitute for mains water supply either indoors (toilet flushing and laundry) or outdoors (garden watering). Rainwater tanks can be either above ground or underground. Above ground tanks can be placed on stands to prevent the need of installing a pump to distribute the water. Such systems are referred to as gravity systems. Pressure systems require a pump and can be either above or below ground tanks.

Tanks can be constructed of various materials such as Colorbond, galvanised iron, polymer or concrete.

Music Modelling Performance Criteria

The expected sediment and nutrient removal performance of the proposed devices was determined using the default equations and parameters provided in the MUSIC model. The water quality reduction mechanisms in MUSIC are based on an exponential decay equation referred to as the k -C* curve. The adopted MUSIC modelling parameters for Rainwater tanks are presented in Table A4.

Table A4 ADOPTED RAINWATER TANK PERFORMANCE PARAMETERS

	Rainwater Tanks	
Pollutant	**k (m/yr)**	**C* (mg/L)**
TSS	400	12.000
TP	300	0.130
TN	40	1.400

Re use Assumptions

Residential water demand is estimated based on the values presented in Draft NSW MUSIC Modelling Guidelines by BMT WBM and CMA (2010). The external and internal usage for typical rural and urban residential households is indicated in Table A5 below.

For the current assessment, rainwater tanks are assumed to store sufficient water for toilet and laundry (internal use) and all external uses. A total of **2.7** occupants per dwelling has been adopted. A maximum of 80% of the physical rainwater tank volume is adopted for modelling in order to allow for top up from Sydney Water supply during dry periods. A summary of the parameters adopted in the MUSIC modelling undertaken for the site are presented in Table A6. We have conservatively adopted re-use rates lower than that suggested by the CMA in the modelling, which result in lower pollutant removal efficiencies.

TABLE A5 RESIDENTIAL WATER USAGE FOR VARIOUS OCCUPANCY AND END USE SCENARIOS[3]

	RURAL DWELLING solely reliant on rainwater tanks				URBAN DWELLING mains water supply is reticulated			
End Use	**Annual Internal Use in Kilolitres (kL/yr/dwelling)**							
No of Occupants	1 to 2	3	4	5	1 to 2	3	4	5
Toilet	31	44	57	71	46	66	86	106
Toilet + Laundry	60	88	115	142	91	131	172	212
Toilet + Laundry + Hot Water	110	159	206	256	164	237	309	384
Toilet + Laundry + Hot Water + Other	122	175	230	283	183	263	343	424
End Use	**Daily Internal Use in Kilolitres (kL/day/dwelling)**							
Toilet	0.085	0.120	0.155	0.195	0.125	0.180	0.235	0.290
Toilet + Laundry	0.165	0.240	0.315	0.390	0.250	0.360	0.470	0.580
Toilet + Laundry + Hot Water	0.300	0.435	0.565	0.700	0.450	0.650	0.845	1.045
Toilet + Laundry + Hot Water + Other	0.335	0.480	0.630	0.775	0.500	0.720	0.940	1.160
Annual External Use	112 kL/year/dwelling							

TABLE A6 ADOPTED RESIDENTIAL WATER USAGE

Contributing Catchment to Rainwater Tank (33% of Average Roof Area, m^2)	67
Active Storage Volume (m^3)	2.4
Rainwater Tank Top Up	Below 20% capacity
Internal Reuse Rate (Laundry + Toilets), kL/day/dwelling	0.25
External Reuse Rate, kL/year/dwelling	50
Rainwater Tank Bypass (m^3/s)	0.002

[3] Catchment Management Authority & BMT WBM, Sydney (2010). Draft NSW MUSIC Modelling Guidelines

A summary of the parameters adopted in the MUSIC modelling undertaken for each allotment in the site site are presented in Table A7, the resulting parameters adopted for each catchment are presented in Table A8.

TABLE A7 ADOPTED RAINWATER TANK PARAMETERS (PER LOT)

Parameter	Amount	Unit
Low level Overflow	0	l/s
High level Overflow (per Dwelling)	2	l/s
Active Storage Volume	2.4	m^3
Depth Above Overflow	0.2	m^3
Surface Area	1.6	m^2
Overflow Pipe Diameter	50	mm
Residential Dwellings per Hectare	20	houses/ha
Daily Re-Use (Interior)	0.25	kl/day
Annual Re-Use (Exterior)	50	kl/year

TABLE A8 ADOPTED RAINWATER TANK PARAMETERS (EACH CATCHMENT)

Catchment Designation	Dwellings (No.)	Total Roofed Area (ha)	Roof Area Captured for Re-Use (ha)	High Level Bypass (m^3/s)	Tank Volume (m^3)	Tank Area (m^2)	Overflow Pipe Diameter (mm)	Annual Demand (kL/yr)	Daily Demand (kL/day)
C1	35	0.70	0.233	0.070	84	56	296	1750	8.75
C4	40	0.80	0.267	0.080	96	64	316	2000	10.00
C4a	10	0.20	0.067	0.020	24	16	158	500	2.50
C5	25	0.50	0.167	0.050	60	40	250	1250	6.25
C6	55	1.10	0.367	0.110	132	88	371	2750	13.75
C7	135	2.70	0.900	0.270	324	216	581	6750	33.75
C9	5	0.10	0.033	0.010	12	8	112	250	1.25
C12	20	0.40	0.133	0.040	48	32	224	1000	5.00
C13	65	1.30	0.433	0.130	156	104	403	3250	16.25
C14	105	2.10	0.700	0.210	252	168	512	5250	26.25
C15	50	1.00	0.333	0.100	120	80	354	2500	12.50
C16	30	0.60	0.200	0.060	72	48	274	1500	7.50

CENTRAL WATER FEATURE PONDS

The Central Water Feature Ponds consists of an open water body with an extended detention zone typically from 100-300 mm deep designed to detain and treat first flush flows from the upstream catchment. Ornamental ponds are generally provided as an aesthetic amenity for the community and are typically located within focal open space areas. The overall depth of ornamental ponds are typically 1.5 – 2.5 m deep.

Music Modelling Parameters

The general feature and standard configuration of ornamental ponds are shown in Table A9 below:

Table A9 ADOPTED POND SYSTEM MUSIC FEATURES

	Ponds
Storage	
Surface Area (m^2)	various
Extended Detention Depth	0.3
Evaporative Loss as % of PET	100
Outlet	
Equivalent Pipe Diameter (mm)	50
Overflow Weir Width (m)	5
Notional Detention Time (hrs)	78.4

Performance Criteria

The expected sediment and nutrient removal performance of the proposed devices was determined using the default equations and parameters provided in the MUSIC model. The water quality reduction mechanisms in MUSIC are based on an exponential decay equation referred to as the k - C* curve and the adopted values are presented in Table A10.

Table A10 ADOPTED POND PERFORMANCE PARAMETERS

	Pond	
Pollutant	**k (m/yr)**	**C* (mg/L)**
TSS	400	12.000
TP	300	0.090
TN	40	1.000

WETLAND

The Wetland consists of an open water body with a specified area of macrophyte plants along a shallow fringe and an extended detention zone typically from 100 to 300 mm deep designed to detain and treat first flush flows from the upstream catchment. Wetlands are generally provided as an aesthetic amenity for the community and are typically located within focal open space areas. The deep water zones of wetlands are typically 1.5 – 2.5 m deep, with shallow fringes to allow the proliferation of macrophyte vegetation.

Music Modelling Parameters

The general feature and standard configuration of wetlands are shown in Table A11 below:

Table A11 ADOPTED WETLAND SYSTEM MUSIC FEATURES

	Canal Wetlands	Main Wetland
Storage		
Surface Area (m^2)	varies	6800
Extended Detention Depth (m)	Varies, generally 0.3	0.3
Permanent Pool Volume (m^3)	varies	10000
Evaporative Loss as % of PET	100	100
Outlet		
Equivalent Pipe Diameter (mm)	60	210
Overflow Weir Width (m)	3	5
Notional Detention Time (hrs)	4	10

Performance Criteria

The expected sediment and nutrient removal performance of the proposed devices was determined using the default equations and parameters provided in the MUSIC model. The water quality reduction mechanisms in MUSIC are based on an exponential decay equation referred to as the k - C* curve and the adopted values are presented in Table A12.

Table A12 ADOPTED WETLAND PERFORMANCE PARAMETERS

	Wetland	
Pollutant	k (m/yr)	C* (mg/L)
TSS	1500	6.000
TP	100	0.060
TN	150	1.000

SAND FILTER

A Sand Filter is proposed to be located immediately downstream of the main Wetland accepting discharges for the recirculation system prior to being pumped to the head of the canal system. The device will form part of the treatment train and will be appropriately sized to help achieve the required OEH Stormwater treatment targets. Discharges through the sand filter will be controlled by the pump system at 0.05 m³/s

Music Modelling Parameters

The general feature and standard configuration of ornamental pond are shown in Table A13 below:

Table A13 ADOPTED SAND FILTER SYSTEM MUSIC FEATURES

	Sand Filter
Storage	
Extended Detention Depth	0.3
Infiltration	
Filter Area (m^2)	210
Filter Depth (m)	0.5
Filter Particle Effective Diameter (mm)	0.60
Saturated Hydraulic Conductivity (mm/h)	1200
Outlet	
Overflow Weir Width (m)	2

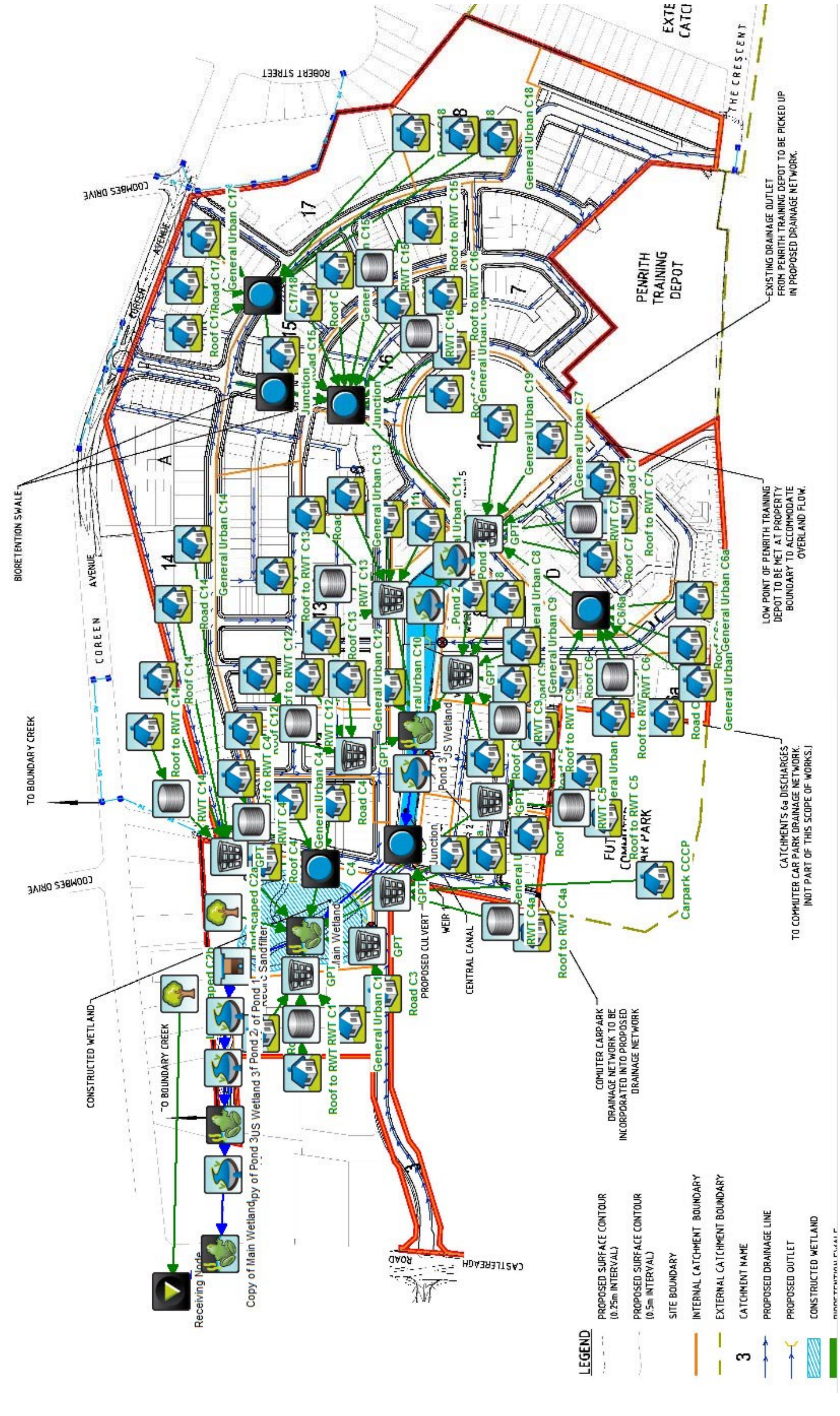
Performance Criteria

The expected sediment and nutrient removal performance of the proposed devices was determined using the default equations and parameters provided in the MUSIC model. The water quality reduction mechanisms in MUSIC are based on an exponential decay equation referred to as the k - C* curve and the adopted values are presented in Table A14.

Table A14 ADOPTED SAND FILTER PERFORMANCE PARAMETERS

	Sand Filter	
Pollutant	**k (m/yr)**	**C* (mg/L)**
TSS	8000	20.000
TP	6000	0.130
TN	500	1.400

MUSIC MODEL LAYOUT



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MUSIC MODEL CATCHMENTS

The adopted catchment areas and assumed percentage imperviousness used for the source nodes are presented below in Table A15.

Table A15 ADOPTED MUSIC MODEL CATCHMENT PARAMETERS

						MUSIC INPUTS					
Catchment Designation	Total Catchment Area (ha)	Assumed %Impervous (%)	Impervious Area (ha)	Pervious Area (ha)	Roofed Area (ha)	Roof to Tank for Re-Use (ha)	Roof Bypassing Tank (ha)	Roads (ha)	General Urban (ha)	General Urban Imperviousness (%)	Landscaped (ha)
C1	1.2	96%	1.15	0.05	0.70	0.233	0.467		0.50	90%	
C2a	1.3	10%	0.13	1.17							1.30
C2b	1.0	10%	0.10	0.90							1.0
C3	0.8	100%	0.80	0.00				0.80			
C4	2.1	91%	1.92	0.18	0.80	0.267	0.533	0.80	0.50	64%	
C4a	0.3	88%	0.26	0.04	0.20	0.067	0.133		0.10	64%	
CCCP	3.0	100%	3.00	0.00				3.00			
C5	1.2	94%	1.12	0.08	0.50	0.167	0.333	0.40	0.30	74%	
C6	3.1	96%	2.98	0.12	1.10	0.367	0.733	1.30	0.70	83%	
C6a	0.4	95%	0.38	0.02	0.20		0.200		0.20	90%	
C7	7.3	95%	6.90	0.40	2.70	0.900	1.800	2.80	1.80	78%	
C8	0.4	96%	0.38	0.02	0.20		0.200		0.20	92%	
C9	0.4	90%	0.36	0.04	0.10	0.033	0.067	0.20	0.10	60%	
C10	1.5	40%	0.60	0.90					1.50	40%	
C11	0.3	97%	0.29	0.01	0.20		0.200		0.10	90%	
C12	1.0	92%	0.92	0.08	0.40	0.133	0.267	0.40	0.20	60%	
C13	3.8	86%	3.26	0.54	1.30	0.433	0.867	1.40	1.10	51%	
C14	4.4	90%	3.98	0.42	2.10	0.700	1.400	0.90	1.40	70%	
C15	2.9	88%	2.54	0.36	1.00	0.333	0.667	1.00	0.90	60%	
C16	1.7	93%	1.58	0.12	0.60	0.200	0.400	0.80	0.30	60%	
C17	1.9	85%	1.62	0.28	0.90		0.900	0.30	0.70	60%	
C18	1.8	29%	0.52	1.28	0.10		0.100	0.10	1.60	20%	
Totals	41.8	83%	34.81	6.99	13.10	3.833	9.267	14.20	12.20		2.30

APPENDIX B – XP-RAFTS PARAMETERS

Table B-1 IFD Rainfall Intensity

Duration (minutes)	100 Year ARI Rainfall Intensity (mm/hour)
10	168
15	140
20	122
30	99
45	79
60	67
90	53
120	44.4
180	34.8
270	27.2
360	22.8
540	17.9
720	15
1080	12
1440	10.2
2160	8.09
2880	6.8
4320	5.24

Table B-2 Loss Parameters

Pervious		Impervious	
Initial Loss (mm)	Continuous Loss (mm/ hr.)	Initial Loss (mm)	Continuous Loss (mm/ hr.)
10	2.5	1	0

Table B-3 Fraction Impervious for Runoff Coefficients

Land Use	f
Public Recreation Areas/ Open Space	0.5
Residential Lot Only	0.85
Water bodies	1
Half Width Road Reserve	0.95
Industrial Areas/ Commercial Areas	0.95

Table B-4a Catchment Breakup for Existing Condition

EXISTING CONDITION					
Catchment ID	Area	Percent Impervious	Pervious Area	Impervious Area	Slope
	(Ha)	(%)	(Ha)	(Ha)	(%)
1A	0.6	70	0.18	0.42	6.5
1B	1.3	65	0.46	0.85	4.4
2	2.5	75	0.63	1.88	1.9
3	3.3	20	2.64	0.66	5.6
4	1.7	85	0.26	1.45	2.2
5	2.2	50	1.10	1.10	2.4
6	5	50	2.50	2.50	0.3
7	4.3	15	3.66	0.65	0.3
8	5.8	80	1.16	4.64	1.2
9	4	20	3.20	0.80	0.7
10	2.9	70	0.87	2.03	0.5
11	3	25	2.25	0.75	0.3
12	3.8	5	3.61	0.19	0.8
13	6	5	5.70	0.30	0.2
14	0.4	90	0.04	0.36	0.5
15A	0.5	90	0.05	0.45	0.2
15B	0.3	90	0.03	0.27	0.6
16	2.3	5	2.19	0.12	0.1
17	0.8	5	0.76	0.04	0.3
18	0.3	5	0.29	0.02	1.1

Table B-4b Catchment Breakup for Proposed Condition

DEVELOPED CONDITION					
Catchment ID	Area	Percent Impervious	Pervious Area	Impervious Area	Slope
	(Ha)	(%)	(Ha)	(Ha)	(%)
A1	4	85	0.6	3.4	3.0
A10	1.7	85	0.3	1.4	0.9
A11	0.2	85	0.0	0.2	1.0
A12	1.4	55	0.6	0.8	1.0
A13	0.4	85	0.1	0.3	0.8
A14	2.1	5	2.0	0.1	1.0
A15	2.2	80	0.4	1.8	0.3
A16	0.5	85	0.1	0.4	1.0
A17	0.4	85	0.1	0.3	0.8
A18	1.2	85	0.2	1.0	0.6
A19	2.1	85	0.3	1.8	0.6
A2	2.9	85	0.4	2.5	0.4
A20	0.2	85	0.0	0.2	0.6
A21	1.5	85	0.2	1.3	0.5
A22A	0.5	90	0.1	0.5	0.4
A22B	0.2	90	0.0	0.2	0.7
A23	1.9	55	0.9	1.0	0.3
A24	1.2	90	0.1	1.1	1.0
A25	0.3	5	0.3	0.0	1.1
A3	1.7	85	0.3	1.4	0.8
A4	2.5	85	0.4	2.1	0.6
A5	1.8	10	1.6	0.2	5.1
A6	1.9	90	0.2	1.7	0.7
A7	1.7	85	0.3	1.4	0.9
A8	2.7	85	0.4	2.3	0.9
A9	3.3	80	0.7	2.6	0.8

Table B-5 Manning's PERN Values

Parameter	Catchment Condition	Adopted Value
PERN	Pervious	0.025
PERN	Impervious	0.015

Table B-6a Summary of Links – Existing Condition

EXISTING CONDITION			
Lag Link	Flow path Length (m)	Assumed Velocity (m/s)	Lag Time (min)
1B-5	264	1.5	2.9
9-13	211	1.0	3.5
3-8	305	1.0	5.1
2-3	173	2.0	1.4
1A-4	306	1.5	3.4
5-7	234	1.0	3.9
4-6	232	1.0	3.9
7-9	137	1.0	2.3
15-14	169	1.0	2.8
11-14	326	1.0	5.4
6-10	141	1.0	2.3
8-9	141	1.0	2.4
10-13	287	1.0	4.8
12-13	256	1.0	4.3
d1-16	235	1.0	3.9
d1-18	134	1.5	1.5
17-18	70	1.5	0.8

Table B-6b Summary of Links – Proposed Condition

DEVELOPED CONDITION			
Lag Link	Flow path Length (m)	Assumed Velocity (m/s)	Lag Time (min)
24-22B	134	1.0	2.2
22B-23	174	1.0	2.9
23-25	147	1.0	2.5
CROSS A12	339	1.0	5.7
A16-A15	255	1.0	4.3
A4-A10	311	1.0	5.2
A3-A10	206	1.0	3.4
A1-A2	195	1.0	3.3

Table B-7a: Tailwater condition at Coreen Avenue discharge point

Flow(m^3/s)	Stage (m)
0	22.85
5.24	24.62
5.65	24.69
6.38	24.84

Table B-7b: Tailwater condition at Boundary Creek discharge point

Flow(m^3/s)	Stage (m)
0	23.4
5.5	24.84
7	25

FIGURES

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LEGEND

- NORTH PENRITH SITE BOUNDARY
- NORTH PENRITH STAGE 1 SITE BOUNDARY
- NORTH PENRITH STAGE 2A SITE BOUNDARY
- NORTH PENRITH STAGES 2B-3B SITE BOUNDARY

Aerial Photograph Date: 2012 (supplied courtesy of NearMap Pty Ltd)

Notes:

N
W E
S

Scale 1: 4,000

100 0 100 m

Figure 1

North Penrith Stages 2B-3B

Site Layout and Staging Plan

File Name: 9470Fig1_Site Layout Plan
Date : 7/9/12 Issue A

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LEGEND

- NORTH PENRITH SITE BOUNDARY
- 0.5m INTERVAL EXISTING CONTOUR
- EXISTING CATCHMENT BOUNDARY

N W E S

Scale 1: 4,000

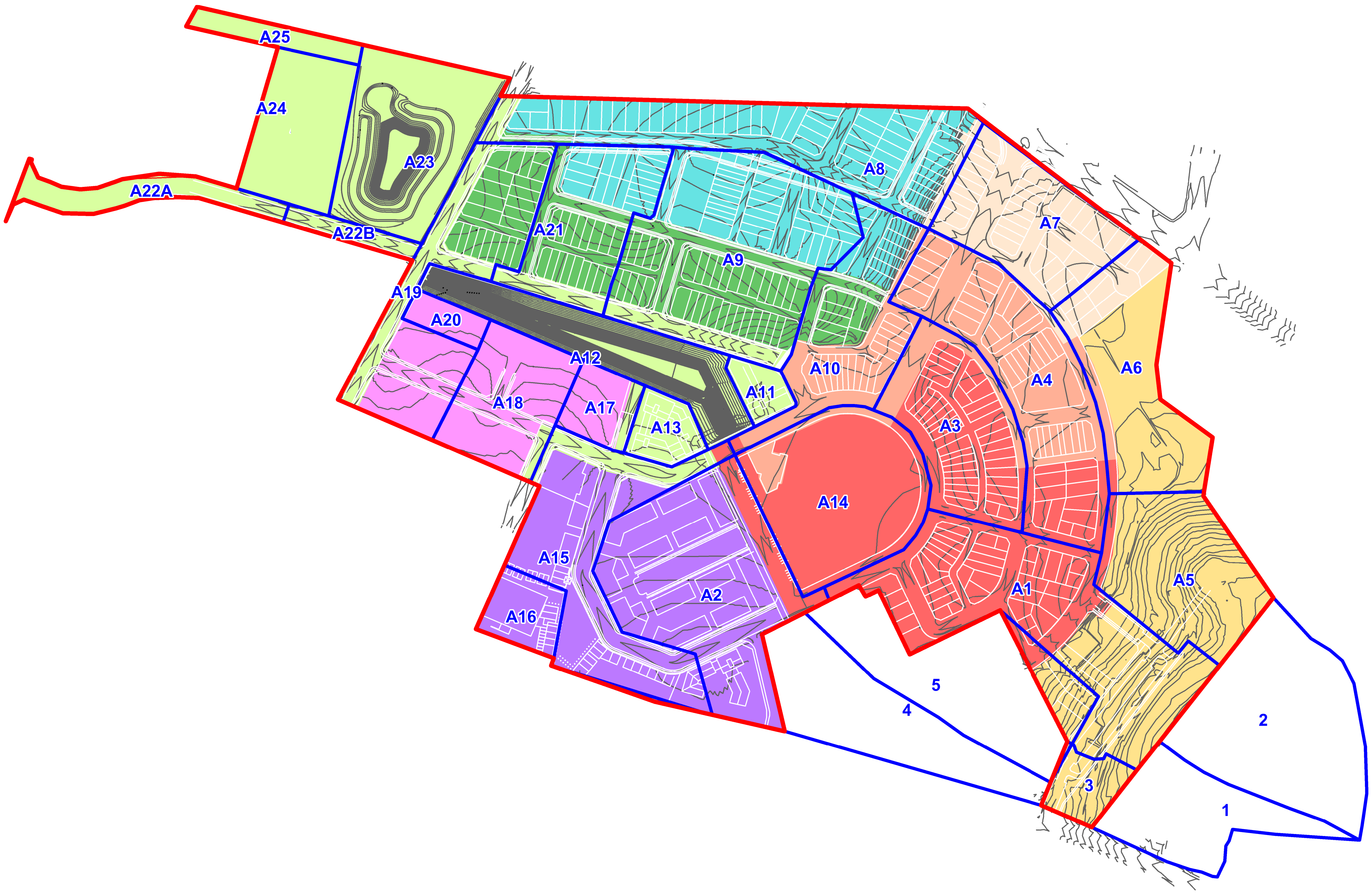
100 0 100 m

Figure 2

North Penrith Stages 2B - 3B

Existing Catchment Plan

File Name: 8470Fig2_Ext Catchment Plan
Date : 03/09/2012 Issue : A



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LEGEND

NORTH PENRITH SITE BOUNDARY

0.25m INTERVAL CONTOUR

DEVELOPED CATCHMENT BOUNDARY

N W E S

Scale 1: 4,000 @ A3

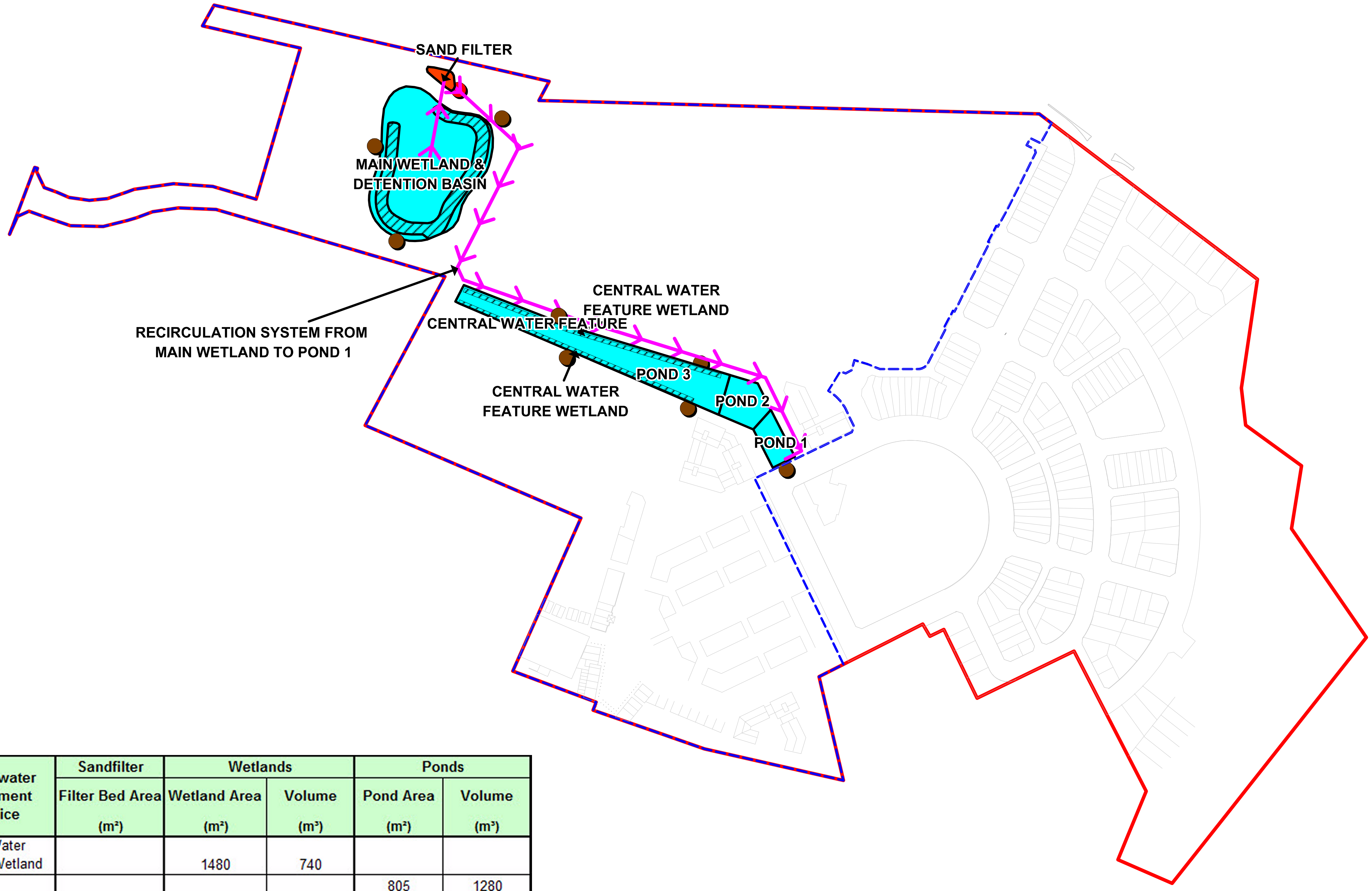
100 0 100 m

Figure 3

North Penrith Stages 2B - 3B

Developed Catchment Plan

File Name: 9470Fig3_Dev_Catchment_Plan
Date : 10/09/2012 Issue : B



Stormwater Treatment Device	Sandfilter	Wetlands		Ponds	
	Filter Bed Area (m²)	Wetland Area (m²)	Volume (m³)	Pond Area (m²)	Volume (m³)
Central Water Feature Wetland		1480	740		
Pond 1				805	1280
Pond 2				1125	1785
Pond 3				5820	9240
Main Wetland		9400	10000		
Recirc Sandfilter	210				
Total	**210**	**10880**	**10740**	**7750**	**12305**

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LEGEND

- NORTH PENRITH SITE BOUNDARY
- STAGE 2B - 3B SITE BOUNDARY
- INDICATIVE LOCATION OF GROSS POLLUTANT TRAP
- POND
- WETLAND
- SAND FILTER
- RECIRCULATION CONDUIT FROM SAND FILTER TO HEAD OF CANAL

N
W E
S

Scale 1: 4,000 @ A3

100 0 100 m

Figure 4

North Penrith Stages 2B - 3B

Proposed Water Cycle Management Plan

File Name: 9470Fig4_WCMP
Date : 03/09/2012
Issue : B