STORM_CONSULTING

Mundamia Development

Water Cycle Management Report for proposed residential development of Lot 384 DP 755952 & Lot 3 DP568613

Report prepared for:
Twynam Property Group

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Project No. 1338

Prepared by:
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Alex Soovoroff	18/2/09	PDF	24/2/09	PDF	02/7/09	PDF
	Issue G		Issue H		Issue I	
Matt Philpott	18/2/09	PDF	22/2/12	PDF	8/3/12	PDF
	Issue J		Issue K			
Matt Philpott	30/5/12	PDF	20/8/2012	PDF		

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report comprises an updated version of a Water Cycle Management Plan, specifically, it addresses the requirements listed by the Director General of the Department of Planning. A summary of the Director General's Requirements relevant to this report and the how they have been addressed is summarised below.

6.7 Provide an assessment of any flood risk on site including the potential effects of sea level rise and an increase in rainfall intensity in consideration of any relevant provisions of the NSW Floodplain Development Manual (2005); NSW Government Sea Level Rise Policy Statement (DECCW, October 2009); Draft Coastal Risk Management Guide: Incorporating sea level rise benchmarks in flood risk assessment (DECCW, 2009); and NSW Coastal Planning Guideline: Adapting to Sea Level Rise (DoP, Aug 2010).

The site is on an escarpment above Flat Rock Creek, the lowest point on the development is 30 m AHD, which is well above the flood levels for Flat Rock Creek and the Shoalhaven River. Therefore no modelling of the effect of sea level rise on the development has been undertaken.

The critical peak flow from the 100-year ARI event through the northern (major) catchment is 6.7 m^3/s. A climate change scenario where an increase in rainfall intensity of 30% has also been assessed by calculating conveyance requirements for a peak flow of 8.74 m^3/s.

Based on a limiting slope of 2%, a typical road reserve cross section with a width of 10 m has been modelled using hydraulic software. Results show that 2 m^3/s can be conveyed in compliance with hazard limits. A 1200 mm diameter pipe is the minimum pipe diameter required to convey the remaining 4.7 m^3/s (100-year ARI scenario, no climate change) however this pipe will have additional capacity (up to 5.9 m^3/s) and therefore the system will be capable of conveying a total of up to 7.9 m^3/s, which partially addresses climate change. An additional 600 mm diameter pipe would be required to convey the total flow of 8.74 m^3/s (100-year peak flow, climate change scenario). If deemed necessary, it is recommended that pipe network augmentation occur at a later date when it can be established whether the additional capacity is required.

Flood Planning Levels can be generated in the detailed design stage, when a site grading plan is established and more accurate flood modelling through the road sections can be provided.

Flows within the development site are accommodated within swales and road reserves. A more detailed discussion on the impacts and the proposed mitigation measures are contained in Sections 4 and 5 of the report.

6.8 Consider the potential impacts of filling on the flood regime of the site and adjacent land.

Some filling is necessary to ensure that large flow events are confined to the proposed floodway through the site. A detailed site grading plan will be required to determine exact extents of cut and fill on site. An approximate area is shown in Appendix C.

Filling will not affect flood storage as the site well above both Shoalhaven River and Flat Bottom Creek.

The site has minor external catchments as it is located on a ridgeline plateau. Modelling has been undertaken to ensure that adequate space has been provided within critical road reserves to accommodate flows from the development. There are no impacts of site filling on flooding beyond the site boundaries.

7.1 Address and outline measures for integrated water cycle management (including stormwater) based on water sensitive urban design principles which address impacts on the surrounding environment, mitigate impacts on water quality downstream, drainage and water quality controls for the catchment, and erosion and sediment controls during construction and for the life of the proposal.

A stormwater management plan has been developed for the site and has been modelled to establish its effectiveness. The design includes water quality features including road swales, infiltration pits and rainwater harvesting systems. MUSIC modelling results show that water quality controls meet current best practice guidelines. Refer to Sections 3, 4, 5 and 6 for detail.

Council does not have on-site detention requirements for the proposed development.

Erosion and sediment controls for the construction phase are to be specified during detailed design, these are to adhere to the current edition of "Soils and Construction - Managing Urban Stormwater Handbook" (otherwise referred to as the "Blue Book"), Council and the approved Soil and Water Management Plan.

7.2 Assess the impacts of the proposal on surface and groundwater hydrology and quality during construction and occupation of the site.

Potential impacts from development on surface and groundwater hydrology have been investigated and mitigation measures recommended (see Appendix F Hydrogeological Assessment, Martens Consulting Engineers, 2011). These will include the use of distributed collection and dispersal systems (biotretention filters) throughout the site to allow surface flows to enter the soil profile. Stormwater discharge from most of the site is spread over a wide area to maintain wet habitats adjacent to the site and maintain diffuse discharge of runoff from the site.

Water quality control measures have been recommended that will ensure that water quality is contained within accepted EPA guidelines. Refer to Sections 3, 4, 5 and 6 for detail.

Where concentrated discharge occurs, energy dissipation measures will be implemented to ensure flow velocities are below scour velocities, these are to be provided at detailed design phase.

7.3 Address safeguards to mitigate any impacts upon water quality, including impacts downstream on Flat Rock Creek, Flat Rock Creek Dam and the Shoalhaven River. Provide details of proposed effluent management, effluent and wastewater reuse/recycling, stormwater, road drainage, alternatives to town water supply and water quality management for the site. For example description and locations of on-site wastewater systems, swales, water quality retention ponds, etc. Address the requirements, where relevant, of the Flat Rock Creek Notification Area under the *Mining Act 1992 (NSW)* and the *Dam Safety Act 1978* (NSW).

A stormwater management plan has been prepared which addresses water quality requirements and meets best practice objectives; refer to sections 3, 4, 5 and 6.

Sewage will flow to Councils sewerage system.

Refer to the Infrastructure Report authored by Allen, Price and Associates with respect to alternatives to town water supply.

There are no relevant requirements under the Mining Act1992, or the Dam Safety Act 1978.

7.4 Include consideration of any specific existing or draft Estuary management Plan and Coastline Management Plan.

The Shoalhaven River Estuary Management plan requires the consideration of stormwater effects of development on wetlands and the estuary. There are no specific quantitative, or qualitative requirements listed. The impacts of the development have been considered in the context of meeting current best practice guidelines for stormwater pollutant load reduction and water quality runoff from the site meets accepted EPA guidelines.

The following policy guidelines have been incorporated in the formulation of the Water Cycle Management Report:

- Water Quality Guidelines for the Protection of Aquatic Ecosystems for Upland Rivers (ANZECC, 2000)
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000)
- NSW Government Floodplain Development Manual – Management of Flood Liable Land (DIPNR, 2005)
- Practical Consideration of Climate Change – Floodplain Risk Management Guideline (DECC, October 2007)
- Managing Urban Stormwater: Soils and Construction (NSW Landcom, March 2004) – “The Blue Book”

1.0 INTRODUCTION

1.1. Background and context

STORM CONSULTING (STORM) has been engaged by Twynam Property Group to prepare a water cycle management report as part of an application for the residential development of Lot 384 DP 755952 and Lot 3 DP568613 at Mundamia, to the west of Nowra. This report addresses specific requirements raised in the Director-General's Environmental Assessment Requirements (DGEARs):

1.2. Scope and objective

The scope of this report includes the review of the development in relation to the impact of the development on water quality and quantity. Based on this review, water quality and quantity management strategies are developed to mitigate and control the potential impacts of the proposed development.

The objective is to outline, and where possible, quantify the potential water quality and quantity impacts and issues associated with the proposed development. Information is presented in the form of modelled water quality and quantity data as well as conceptual designs of management strategies to address the requirements raised in the DGEARs.

1.3. Proposal description

1.3.1. Locality

The proposed development is located at Mundamia, on the western side of Nowra. The development area is adjacent to the existing Wollongong University Campus off Jonsson Road. The eastern boundary adjoins land zoned 7a (ecology) (**Figure 1.1**).

1.3.2. Proposed works

The proposed development consists of 312 lots, 284 residential lots, 21 medium density lots, 7 dual occupancy lots, 1 rural lot (**Figure 1.2**). Residential lots range in size from approximately 550 to 800m^2 averaging around 600m^2. They are arranged in a standard grid pattern, modified slightly to fit with the landscape. Small areas of open space are incorporated through the southern half of the development.

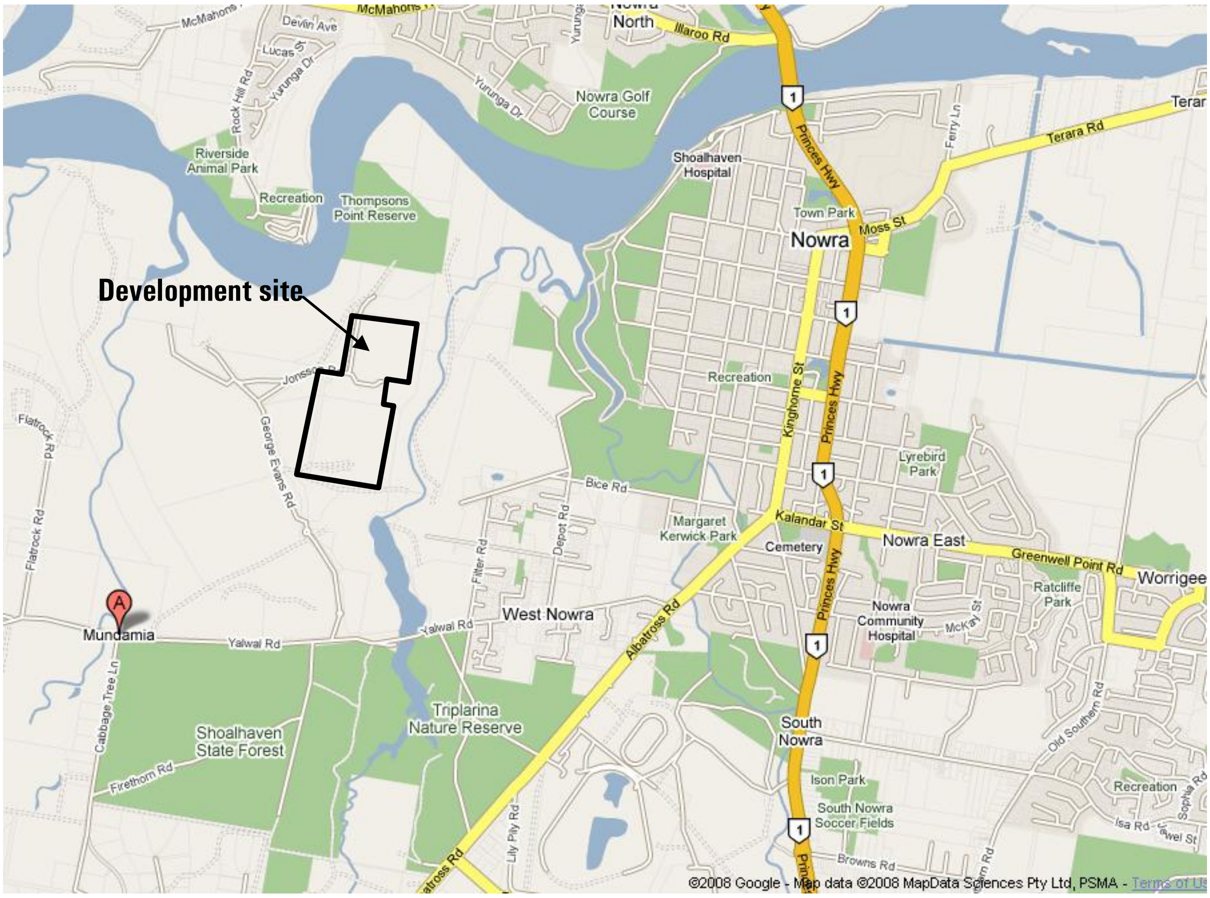


Figure 1.1: Site locality

Figure 1.2 Proposed development layout

Figure 1.2 shows two Environmental Conservation Zones (ECZs) along the eastern boundary of the site. An existing drainage depression runs through the northernmost ECZ.

1.4. Site Description.

1.4.1. Land Use

The site is almost completely cleared (**Figure 1.3**), apart from; remnant native vegetation along a drainage depression running north east through the northern half of the property; native vegetation in the northern sector of the site (**Figure 1.4**); and a strip of native vegetation along the eastern boundary, where exposed rock and steeper slopes have precluded this area from rural use. The remainder of the site is used for "hobby farm" style grazing, with a small number of horses, sheep and cattle on the site.

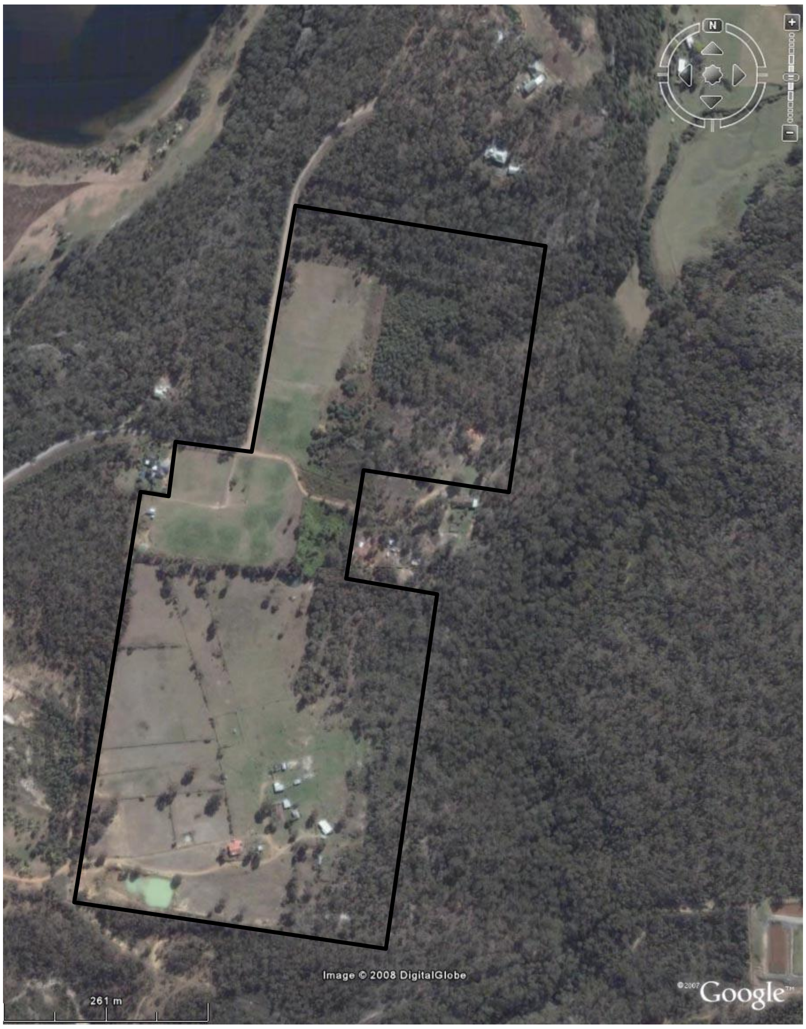


Figure 1.3 Aerial photo of site

1.4.2. Topography

The site is located on a sandstone plateau that slopes gradually to the north and west above an escarpment along Flat Rock Creek. The site has flat to moderate slopes over most of the development area. Slopes close to the edge of the plateau on the eastern edge are significantly steeper as an escarpment drops down to Flat Rock Creek.

1.4.3. Soils

Soils on the site are characterised by Nowra Sandstones generally consisting of shallow yellowish brown sand or hard setting gravelly massive yellowish brown clayey sand topsoils overlaying 0.5m to 1m of brown podzolic soils (clay loams and light clays) overlaying sandstone bedrock (**Figure 1.5**). Numerous areas of exposed bedrock were noted during a site visit, particularly in, and close to drainage depressions and close to the edge of the plateau. A more detailed hydrogeological assessment was performed by Martens (2011) and is included as Appendix F.

1.4.4. Drainage

The most significant drainage feature on the site is a drainage depression which runs for approximately half of the length of the site (**Figure 1.4, Figure 1.6**). Some modifications have been carried out including crossings, small dams and some clearing of riparian vegetation. Base-flows were observed during a site visit which are likely to be a combination of extended rainfall and shallow soils and bedrock forcing flows to the surface.

In the south-west corner of the site there is a large excavation, partially filled with water which is a remnant of previous quarrying activities.

Runoff that does not make its way to the central drainage depression runs off the site via small depressions leading to Flat Rock Creek to the east (**Figure 1.7**).

The shallow soils on the site mean that the surface and sub-surface / groundwater are closely interlinked, having implications for vegetation species over the site.

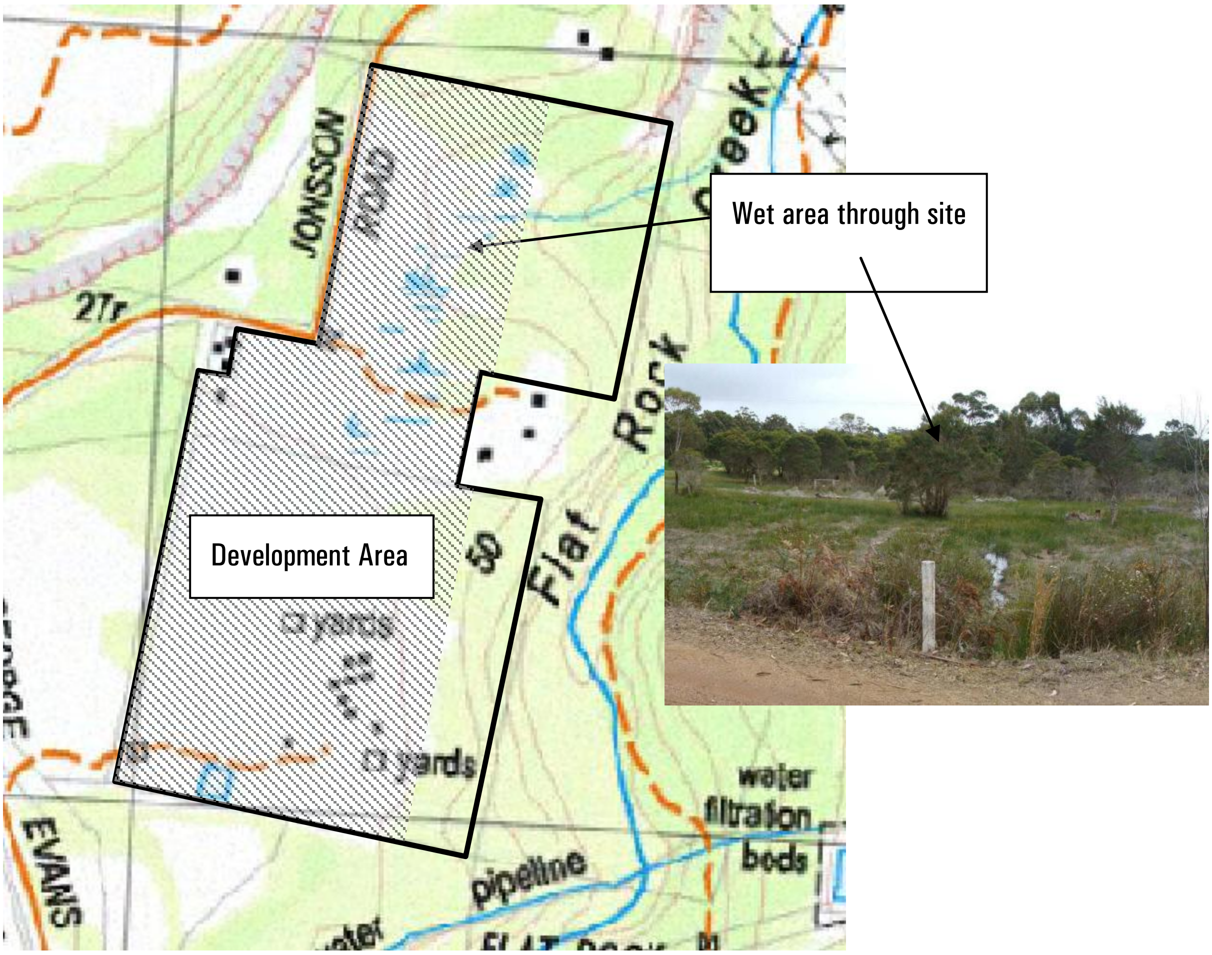


Figure 1.4 Site topography and drainage depressions (Dept. Lands SIX Viewer – Topographic Maps, 2007)

1.4.5. Vegetation

The cleared area of the site consists of exotic dominated pasture grasses including Couch and Kikuyu, with scattered remnant/regrowth paddock trees.

Remnant vegetation consists mainly of tall open forest with typical Nowra sandstone species composition. The over story is dominated by mixed eucalypts including Scribbly Gum (*Eucalyptus sclerophylla*), Thin-leaved Stringybark (*E. eugenioides*), Red Bloodwood (*E. gummnifera*) and Forest Oak (*Allocasuarina torelosa*). The understorey is dominated by Tea-tree (*Leptospermum* spp.), Hairpin Banksia (*Banksia spinulosa*) and Pine-leaf geebung *(Persoonia pinifolia)* and mixed native grasses. Depressions/drainage lines are dominated by Paperbark (*Melaleuca* spp.) and Tea-tree (*Leptospermum* spp.).

The threatened species *Triplarina nowraensis* has been recorded at the site on slopes as well as in poorly drained and riparian areas (Dominic Fanning, SLR). In developing water cycle management designs for the proposed development, STORM has provided details to manage the hydrological regime, particularly at stormwater discharge points, required for this species, as described further in Sections 3 and 4.

Figure 1.5 Soil profile in western non-waterlogged area

Figure 1.6 Main drainage depression

Figure 1.7 Typical seepage area on eastern side of the site

Figure 1.8 Remnant tall open forest (on higher ground)

Figure 1.9 Typical view of cleared areas

2.0 ASSESSMENT METHODOLOGY

2.1. Planning context

In addition to the relevant DGEARs, background research of Shoalhaven City Council planning documentation identified the following:

Shoalhaven City Council LEP

The receiving waters for runoff are zoned 7(a). The intention of this zone is the "Protection and maintenance of the natural environment, endangered species areas of high biodiversity and water quality". This zone will change to zone E2 in the new LEP which is Environmental Conservation with environmental protection works permitted with consent.

Shoalhaven City Council Subdivision DCP

Requires interception and treatment of pollutants through the use of appropriate water quality control measures prior to discharge to receiving waters, including wetlands, lakes and ponds.

The site is not identified as within the 1% Flood Zone on Council's Online Interactive Draft SLEP webmap.

The following State and National Policies have been reviewed in the development of the Water Cycle Management Report:

- Water Quality Guidelines for the Protection of Aquatic Ecosystems for Upland Rivers (ANZECC, 2000)
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000)
- NSW Government Floodplain Development Manual – Management of Flood Liable Land (DIPNR, 2005)
- Practical Consideration of Climate Change – Floodplain Risk Management Guideline (DECC, October 2007)
- Managing Urban Stormwater: Soils and Construction (NSW Landcom, March 2004) – "The Blue Book"

2.2. Water quality and quantity objectives

The proposed development will change an existing, predominantly rural landscape to a low density residential site. Broadly, the impacts on water quality and quantity will be:

- Changes to suspended solid and nutrient loads and concentrations leaving the site
- Increased runoff volume, peak flows and runoff frequency, altered catchment pervious %.

These changes can have impacts on receiving waters through increased sediment loads, increased nutrient loads and changes to catchment hydrology/hydrogeology.

Stormwater management measures proposed for this development and outlined in section 3.2 are designed to manage these changes.

Water Quality

In order to determine the form, shape and size of these management measures we have assumed benchmarks based on current best practice guidelines as outlined in *"Stormwater Treatment Techniques – Environmental Targets"* (DECC, 2007). Stormwater quality benchmarks require Total Suspended Solids (TSS), Total Phosphorous (TP) and Total Nitrogen (TN) loads to be reduced by 85%, 65% and 45% respectively from the development. In addition to this, we will also report against existing pollutant loads to appreciate what changes may occur post development.

Water Quantity

As is currently the case, once developed, the majority of the site will drain north and outfall to the main drainage depression that runs through the site. An assessment of the peak flow rates and overland flow path widths within this area is contained in this report.

Shoalhaven Council do not have requirements for on-site detention for the subject development.

Bioretention infiltration systems within lots and in public areas were sized to match existing infiltration so that the groundwater hydrology is maintained and there is minimal impact to the habitat of the Spring Tiny Greenhood Orchid and Nowra Heath Myrtle.

3.0 PROPOSED STORMWATER MANAGEMENT STRATEGY

3.1. Construction period controls

During the construction period there is potential for high levels of stormwater pollution to occur, particularly suspended solids. As part of the detailed design, a Soil and Water Management Plan will be required in accordance with the *Managing Urban Stormwater: Soils & Construction, Version 4* (Landcom, 2004).

3.2. Operational stormwater management

Preface

Historically, stormwater management has focussed on conveyance of stormwater from impervious surfaces directly into pits and pipes and subsequently to receiving waters. This approach increases the frequency, rate and volume of runoff to receiving waters. The current approach is to intercept stormwater runoff as close to the source as possible, and treat and infiltrate the runoff within the urban landscape. This is commonly known as Water Sensitive Urban Design (WSUD). WSUD also encourages the better use of water resources.

WSUD Approach

Existing site conditions show opportunities for WSUD, including low to moderate gradient, a predominantly cleared site and moderately permeable soils. Constraints to WSUD include shallow soils and exposed bedrock which restricts treatment opportunities and areas for infiltration. Shallow soils over the site, and bedrock close to the surface give rise to a close link between surface and groundwater. Vegetation on the site, exposed bedrock and surface water ponding over the site suggests that a large amount of water flows through the soil profile.

The site has a low to moderate gradient lending itself to at-source controls where possible. However, many of the flatter areas of the site have been nominated for house lots or roads, which makes economic sense. There are some small areas of open space within the development envelope that present opportunities for stormwater management systems. The remaining open space exists on the steeper portions of the site. These have been identified as significant water management areas, particularly as they are located at the lower end of the catchments.

The lack of large areas of flat space precludes such systems as wetlands and ponds which have specific sizing ratios and necessitate large flat expanses. Bioretention systems have been identified as the primary water quality treatment system at a lot level and in public areas due to their versatility in terms of size and shape, high treatment efficiencies and the fact that they can remain waterlogged for a period and promote infiltration. Additionally, they can be designed with shallow filter systems. In this case, a filter depth of 0.4m has been assumed with no underdrain. Bioretention units within lots have an extended detention depth and volume of at least 0.24m and 2 m^3 respectively, with a minimum filter area of 4.6m^2. Bioretention units within public areas are of variable size and have an extended detention of 0.3m, with 1 in 4 side slopes (Appendix B). A total of 5,000 m^2 of public area/road reserve bioretention swale has been specified MUSIC modelling and 5 kL rainwater tanks on residences which are plumbed to supply hot water and laundry demands.

As discussed, the landscape is characterised by shallow soils over bedrock which leads to naturally waterlogged areas and numerous shallow watercourses and wet depressions throughout the site. The use of a shallow bioretention trenches will promote, where locations of assets allow, stormwater to be distributed into these existing wet areas as water percolates out of these systems at low points. Where bioretention systems are proposed across slopes, particularly at the northern boundary diffuse discharge of collected stormwater for small events is encouraged. The bioretention trench along the northern boundary acts much like an interception drain which will infiltrate and direct stormwater to existing wet low points.

Design information, typical details, photos and background information on these systems are contained in Appendix B. Appendix A contains schematic plans outlining the stormwater management strategy for the site.

Site stormwater management configuration

The proposed development is divided into 6 main sub-catchments: A, B, C, D, E and F based on feasible stormwater drainage through the site and linking catchments with available areas to install water quality control structures. Details on the location and size are included in Appendix B.

Catchment A

This catchment drains the far southern component of the development. There are two bioretention areas, that may be linked, that would run along the edge of the northern boundary road, where road runoff would be diverted directly (as surface flow) into the bioretention area. A minimum total bioretention surface area of 420m^2 is required for this catchment.

Catchment B

This catchment drains a large portion of the southern half of the proposed development. A large road easement allows for the construction of a bioretention swale on the western side of the road. Area is also available along the northern boundary. Catchments B1 and B2 require a total bioretention surface area of 1005 m^2. Catchments B3 and B4 require bioretention surface areas of 270m^2 each. As for catchment A, where possible, road drainage should be diverted directly (as surface flow) to the bioretention systems.

Catchments C and D

These catchments drains the central portion of the site. Subcatchment C1 and C2 drain into subcatchment D and into a bioretention area located along the eastern boundary of the Site that has a minimum surface area of 2100m^2. Subcatchment C3 drains to the east into a bioretention system that has a minimum surface area of 150m^2.

Catchment E

Catchment E drains the northern portion of the site. Treatment is identified as a bioretention system (450m^2) that would sit at the base of the catchment. This would be located off-line from the existing drainage depression in that area.

Catchment F

Catchment F is a relatively small catchment on the eastern edge of the site. A linear bioretention system (420m^2) is proposed along the length of the eastern boundary road.

4.0 WATER QUALITY AND QUANTITY

4.1. Introduction

A change in landscape from rural to urban will have an impact on pollutant types and concentrations in runoff, and the increase in effective impervious area will modify the local hydrology. The purpose of this section is to assess what these impacts may be and outline what mitigating measures may be necessary to meet relevant guidelines and provide an acceptable level of protection. The Model for Urban stormwater Improvement Conceptualisation (MUSIC) has been used to assess both the impacts of the change in landscape and the effect of proposed mitigation measures.

4.2. MUSIC model assumptions and stormwater treatment measures

4.2.1. Climate Information

The closest continuous rainfall data gauge (6 minute) is located at Nowra (Bureau of Meteorology station no. 68076). The longest continuous record of 6min data available, 1964 to 1983, was used with an average annual rainfall from this period of 981 mm. The average over the entire period for that station is 1110 mm. The data set used in the model presents a slightly drier period than average. However, it was the longest continuous set of data available at the time.

4.2.2. Soil Information

The MUSIC model uses an impervious store, pervious store and groundwater store to calculate surface runoff and base flow (interflow). Inputs into the model were based on soil types and depths consistent with the site Hydrogeological Assessment (Appendix F) and consistent with Draft NSW MUSIC modelling guidelines (SMCMA 2010).

4.2.3. Model Configuration

Details of the proposed stormwater management strategy are contained in Appendix A and B. Specific details of the configuration within each sub-catchment are discussed in Section 3.2. Model configuration and details for each catchment are contained in Appendix C.

4.3. Pollutant loads and concentrations

Table 4.1 Pollutant Load (kg/annum) for development with and without treatment

	No Treatment	With Treatment	Benchmark (minimum)	% Load Reduction	Meets Criteria, Y/N
Total Suspended Solids (kg/y)	36000	5640	85%	84.3%	N
Total Phosphorus (kg/y)	67.7	19.8	65%	70.8%	Y
Total Nitrogen (kg/y)	558	212	45%	62.1%	Y

4.3.1. Summary

MUSIC model results show that the proposed treatment systems for the development meet the benchmark of 65% removal of Total Phosphorus load and 45% removal of Total Nitrogen load. TSS reduction of 84.3% is slightly below the benchmark removal of 85%, but is considered conservatively low as the bioretention systems will also include adjacent vegetated areas which have not been modelled which will increase TSS removal.

4.4. Water quantity results

Water quantity reporting is based on all catchments combined. Pre- and post-development conditions have been compared to demonstrate the impact of the change in land use on flows, and the mitigating impacts of the stormwater management system. MUSIC modelling results show a total pre-development flow from the site of 56.2 ML/yr and post development flow of 110 ML/yr. The cumulative flow frequency graphs exported from the MUSIC model (and **Figure 4.2**) indicate that the average flow rate from the site will be similar following development.

The MUSIC results also show that from installing bioretention across the site consistent with that shown in Appendix B, an annual supplementary infiltration of 111 ML/yr can be achieved. This is equal to the total supplementary recharge required to ensure minimal impacts to flora, consistent with recommendations in the Hydrogeological Assessment by Martens et al(2011).

Flora Impacts

The threatened Nowra Heath-myrtle Triplarina nowraensis has been recorded on the subject land (SLR Consulting 2012) in a variety of circumstances, including on slopes to the north of the development area, in areas of high soil moisture (particularly associated with the drainage line in the northeastern part of the subject land) and amongst Tick Bush heathland in the eastern part of the site. Although the species does occur in areas of moist soils and poor drainage, some of the stands of the Nowra Heath-myrtle on the subject site occurs in more xeric environments (particularly those in the Tick Bush heathland and to the north of the proposed development).

Development of the subject site will involve localised increases in runoff volumes and runoff frequencies, particularly associated with the drainage line in the northeastern part of the subject site, and to some extent along the eastern boundary of the development area. These areas (in patches at least) already have high levels of soil moisture and poor drainage due to the proximity of bedrock.

As the Nowra Heath-myrtle is adapted to (albeit not confined to) areas of high soil moisture and poor drainage, the increased flows associated with the proposed development are not likely to adversely affect that species (F Dominic Fanning - SLR Consulting pers comm). It is also to be noted that investigations have demonstrated that adult plants of the Nowra Heath-myrtle are highly tolerant of elevated nutrient levels, although seedlings are more sensitive (Hogbin 2002). The proposed stormwater discharge regime will not involve significant elevations in nutrient levels or (for most of the distribution of the Nowra Heath-myrtle on the subject site) any increases in water volume.

In general, development has the potential to redirect, and concentrate flows away from existing wet, or moist areas. To protect existing wet areas outside of the development footprint, stormwater discharge will be diffuse and arranged such that water can make its way to existing low points. The proposed bioretention system will ensure that there is minimal impact to the existing groundwater hydrology. Diffuse distribution of runoff will be achieved by arranging bioretention trenches along most of the northern boundary road, where upslope catchments have been modified. The road shall have, where possible, a 1 way cross-fall to divert runoff directly to treatment systems, and distribute flows at, or close to their current areas (Appendix B). In most cases the longitudinal road grading will automatically divert bioretention flows to existing low points. Where diversion is necessary, cut-off walls should be installed within the bioretention trenches at key points to block flows and divert them into the local soil profile. Piped flows from upper catchments shall discharge into these trenched, preferably at the surface. Refer to the typical section in Appendix B for more detail.

Water quality treatment is incorporated into the proposed development and Nitrogen and Phosphorus loads are reduced by 62% and 71% respectively as compared to a site with no WSUD.

Flat Rock Creek

The Flat Rock Creek catchment is approximately 1,000 Ha. The development area accounts for about 33 Ha (3%) of this so the increase in flows associated with the development will have a negligible impact on the hydrology within Flat Rock Creek. This is particularly true, as the developed sub-catchment is at the lower end of the catchment, i.e. the site will discharge well before the runoff peak from the entire catchment.

On-Site Detention / Retention

Shoalhaven Council do not have on-site detention requirements for the proposed development within their Council policies. This has been confirmed through discussion with Council.

Two properties exist close to the confluence of Flat Rock Creek and the Shoalhaven River, downstream of the development. The site drainage flows into a natural creek line, the small increase to flows means that downstream infrastructure or assets will not be adversely affected.

Although there is an average increase in flows over the year, advice from the ecologist is that as long as the flow regime is maintained (i.e. flows are not cut-off from downstream habitats and measures ensure diffuse distribution) and exit velocities are controlled to less than scour velocity, then there will be no adverse impacts on downstream habitats. Exit velocities can be controlled through placement of appropriate energy dissipation material (with high roughness) at locations where stormwater leaves site.

The shallow soil profile also leads to the surface/groundwater table being closely linked and therefore, as long as WSUD principles are employed and diffuse distribution allows infiltration there should be no net loss of water to the system and the total water balance to the downstream habitats will be maintained.

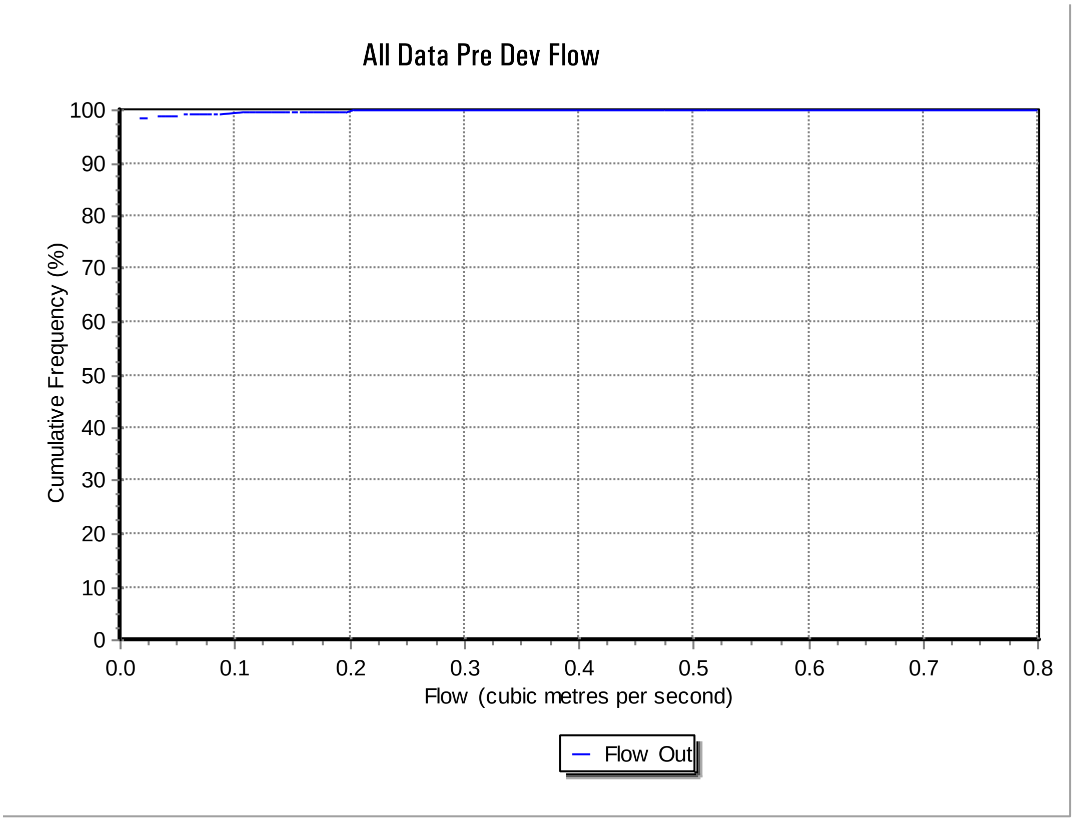


Figure 4.1 Pre-development cumulative flow frequency

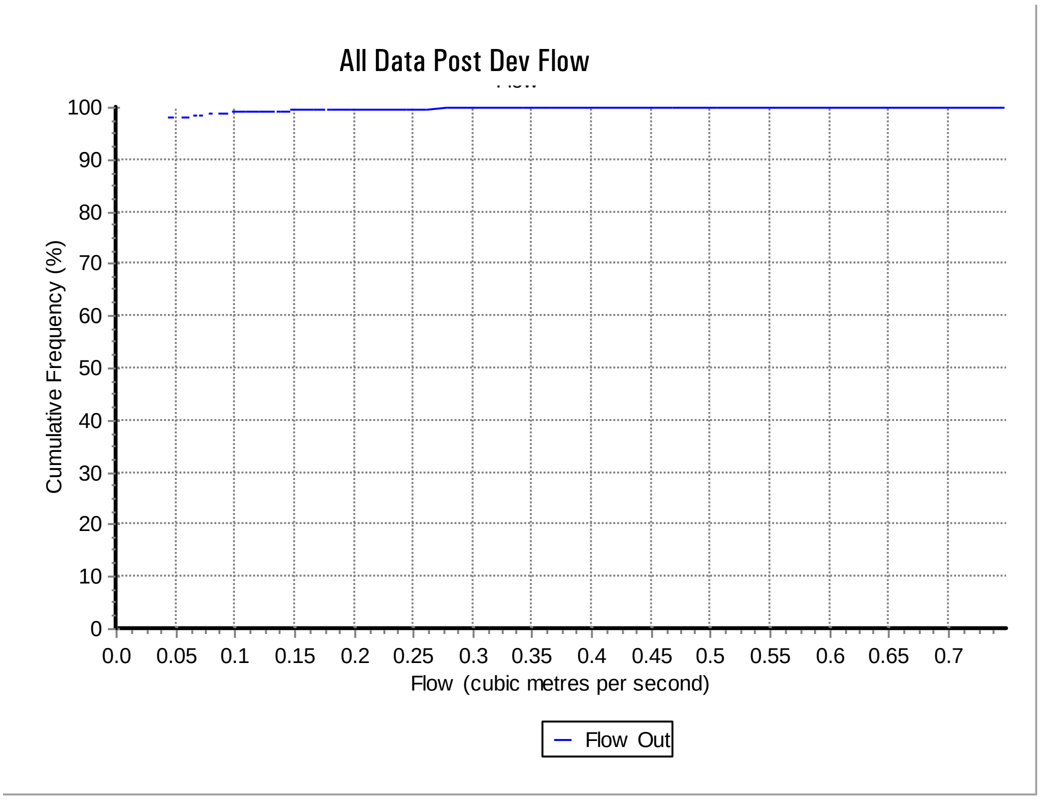


Figure 4.2 Post-development cumulative flow frequency

5.0 OVERLAND FLOW ASSESSMENT

5.1. Description

The drainage depression running through the northern half of the site collects the majority of runoff from the site. Smaller depressions drain local runoff over the escarpment on the southeastern boundary. Development is proposed over the upper section of the drainage depression and flows would be conveyed within pipes and the road reserve.

The purpose of this assessment is to determine the peak flowrate that will travel down the proposed roadway which will act as the main floodway and estimate approximate road easement widths and pipe diameters. The main floodway is the pink area shown in the drawing in Appendix C.

Drainage shall be configured so that piped flows drain catchments that currently drain to the north and north-east will now drain to the east. Stormwater drainage has been configured in this way to convey stormwater to the proposed water quality treatment systems which are proposed along the eastern boundary, this will maximise water quality benefits. Larger overland flows (100 year ARI flows) will continue to approximately follow the existing drainage depression route.

In order to use the roadway as the main overland flow path, some re-shaping of the landscape will be necessary. An area of cut is required in the southern portion of the development to allow stormwater to drain to the east. An area of fill is required in the northern part of the site where blocks are proposed over the existing drainage depression. Refer to appendix C for the location of these areas.

5.2. Hydrology

The hydrologic model RAFTS was used to estimate peak flows. Refer to appendix E for details on catchment areas, flow paths and hydrologic model configuration.

The 100 year flow to the hatched area is calculated as the 100 year flow from catchments 2, 3 and 4a minus piped flows from the eastern half of catchments 3 and 4a which direct flows to treatment systems along the eastern boundary. It is assumed that the pipes network will convey the 5 year ARI event peak flow.

5.3. Climate change impacts

The DGEARs recommend that the impacts of Climate Change, namely sea level rise and an increase in rainfall intensity be considered. The Floodplain Risk Management Guideline for the Practical consideration of Climate Change (DECC, 2007) suggests that, in lieu of detailed information a worst case sensitivity analysis of an increase in rainfall intensity of 30% be assessed. For the purposes of this report, we have assumed a proportional relationship between rainfall intensity and peak flow. Subsequently, we have assumed peak flows increase by 30% sometime into the future.

With respect to sea level rise, the lowest point on the development is at 30m AHD. The maximum predicted sea level rise by 2100 is about 0.9m. Increase flooding of the Shoalhaven River, and Flatrock Creek, combined with predicted maximum sea level rise would have no impact on this development.

5.4. Flood flow conveyance

The peak 100 year ARI flow in at the lower end of the proposed floodway is 6.72m^3/s. The shallowest road longitudinal slope (worst case scenario) along the proposed floodway is about 2%. Flow depths in the roadway must not exceed 200mm depth and have a velocity depth multiple of no greater than 0.4. Approximately 2m^3/s can be safely conveyed in the roadway (10m wide pavement width, flow depth 0.2m, velocity 1.24m/s, VD multiple 0.25) (Figure 5.1).

The remaining 4.72m^3/s must be conveyed as pipe flow. At 2% grade this would require a single 1200mm diameter pipe based on the Colebrook White Equation (k value of 0.6). The 1200 mm diameter pipe can convey up to 5.9 m^3/s, however a 1050 mm diameter pipe has a capacity of 4.2 m^3/s, therefore the 1200 mm diameter pipe is required to provide sufficient capacity below the roadway.

The upper recommended assessment of a 30% increase in rainfall intensity associated with climate change increases the peak 100 year flow to 8.74m^3/s. The roadway can only safely convey 2m^3/s and a 1200 mm diameter pipe would convey 5.9 m^3/s at full capacity (total 7.9 m^3/s). The combination of a 10 m road width and 1200 mm diameter pipe conveys the majority of flow under a climate change scenario. An additional 600 mm diameter pipe would be required to convey the additional 0.8 m^3/s for a total a peak flow of 8.7 m^3/s.

8.74m^3/s is at the upper range of potential increases to rainfall intensity, due to the uncertain nature of climate change impacts, and the timeframe for their occurrence, it is not recommended that the additional pipe be constructed at this stage. A more cost effective and prudent approach may be to design the road pavement width to 10m and utilise a 1200 mm diameter pipe below the roadway, which would provide a system capacity of about 7.9m^3/s. This would provide for the majority of the predicted increase in flows associated with Climate Change and some leeway in the timing of any drainage upgrades that may be necessary.

Both the current and climate change examples do not consider hydraulic losses associated with pits, bends and junctions, and therefore pipe sizes are likely to be larger. Conveying this flow in pipes assumes that inlet structures are designed with sufficient redundancy so that even with blockage, sufficient stormwater flows are intercepted and conveyed into pipes.

The design of fail-safe and low risk conveyance of flows within the road reserve requires detailed assessment and modelling. A high level of redundancy for all design components is recommended and the assessment of worst case scenarios such as 100% blockage of inlets should be considered.

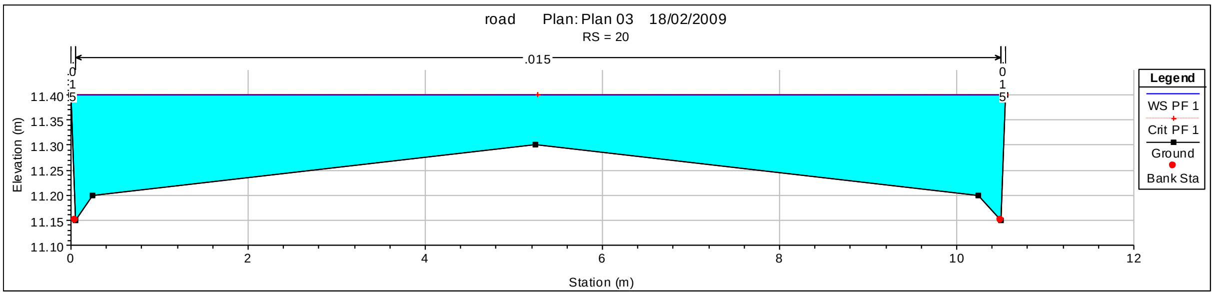


Figure 5.1 Road cross section at 2m^3/s

5.5. Impact of filling on flood regime

As discussed, filling will be required on the site associated with reshaping the landscape to accommodate new roads. Major areas of cut and fill are shown in Appendix C. Part of an area that currently conveys flows is proposed to be filled and overland flows conveyed in the adjacent roadway.

The site has minor external catchments as it is located on a ridgeline plateau. Modelling has been undertaken to ensure that flow paths within the development site can be designed to accommodate major flows.

During detailed design phase, the design will need to ensure that there is sufficient freeboard to ensure that flows do not encroach on adjacent properties.

Any design should comply with council subdivision design guidelines relating to overland flow paths, and the guidelines outlined in the NSW Floodplain Management Manual. Filling of the site will not affect flood storage as the site well above both Shoalhaven River and Flat Bottom Creek.

6.0 PLANNING SUMMARY

Table 6.1 summarises the impact of the development against the relevant planning controls and relevant DGEARs.

Table 6.1 Cross reference planning objectives

Planning Document	**Relevant Clause**	**Comment**
Shoalhaven City Council LEP	• Protection and maintenance of the natural environment, endangered species, areas of high biodiversity and water quality	Best management practice guidelines for pollutant removal have been applied for TP and TN being 65% and 45% respectively. TSS reduction of 84.3% is slightly below the benchmark removal of 85%, but is considered conservatively low as the bioretention systems will also include adjacent vegetated areas which have not been modelled which will increase TSS removal.
Shoalhaven City Council Subdivision DCP	• ...interception and treatment of pollutants through the use of appropriate water quality control measures prior to discharge to receiving waters, including wetlands, lakes and ponds.	A WSUD strategy is proposed for the site that includes rainwater tanks and bioretention.
DGEARs	6.7 Provide an assessment of any flood risk on site including the potential effects of sea level rise and an increase in rainfall intensity in consideration of any relevant provisions of the NSW Floodplain Development Manual (2005); NSW Government Sea Level Rise Policy Statement (DECCW, October 2009); Draft Coastal Risk Management Guide: Incorporating sea level rise benchmarks in flood risk assessment (DECCW, 2009); and NSW Coastal Planning Guideline: Adapting to Sea Level Rise (DoP, Aug 2010).	Sea level rise has no impact on the development as the lowest proposed developed area is RL30m AHD. Flood risk is due to local flooding only as the development is on a ridgeline. Conceptual sizing of drainage infrastructure has been undertaken through the floodway for the major flowpath which provides some capacity for increased peak flows from climate change. Further detailed design of stormwater infrastructure will be necessary in the detailed design phase.
	6.8 Consider the potential impacts of filling on the flood regime of the site and adjacent land	Some filling is necessary to ensure that large flow events are confined to the proposed floodway through the site. A detailed site grading plan will be required to determine exact extents of cut and fill on site. An approximate area is shown in Appendix C.

		Filling will not affect flood storage as the site well above both Shoalhaven River and Flat Bottom Creek. There are no impacts of site filling on flooding beyond the site boundaries.
	7.1 Address and outline measures for integrated water cycle management (including stormwater) based on water sensitive urban design principles which address impacts on the surrounding environment, mitigate impacts on water quality downstream, drainage and water quality controls for the catchment, and erosion and sediment controls during construction and for the life of the proposal	A stormwater management plan has been developed for the site and has been modelled to establish its effectiveness. The design includes water quality features including road swales, infiltration pits and rainwater harvesting systems. MUSIC modelling results show that water quality benchmarks of 65% and 45% removal of TP and TN respectively are met based on conceptual water quality modelling. TSS reduction of 84.3% is slightly below the benchmark removal of 85%, but is considered conservatively low as the bioretention systems will also include adjacent vegetated areas which have not been modelled which will increase TSS removal. Council does not require detention of flows from the proposed development. The site has minor external catchments as it is located on a ridgeline plateau. Modelling has been undertaken to ensure that adequate space has been provided within critical road reserves to accommodate flows from the development. Erosion and sediment controls for the construction phase are to be specified during detailed design, these are to adhere to the current edition of "Soils and Construction - Managing Urban Stormwater Handbook" (otherwise referred to as the "Blue Book"), Council and the approved Soil and Water Management Plan.
	7.2 Assess the impacts of the proposal on surface and groundwater hydrology and quality during construction and occupation of the site.	Potential impacts from development on surface and groundwater hydrology have been investigated and mitigation measures recommended (see Appendix F Hydrogeological Assessment, Martens Consulting Engineers, 2011). These will include the use of distributed collection and dispersal systems (biotretention filters) throughout the site to allow surface flows to enter the soil profile. Stormwater discharge from most of the site is spread over a

		wide area to maintain wet habitats adjacent to the site and maintain diffuse discharge of runoff from the site.
	7.3 Address safeguards to mitigate any impacts upon water quality, including impacts downstream on Flat Rock Creek, Flat Rock Creek Dam and the Shoalhaven River. Provide details of proposed effluent management, effluent and wastewater reuse/recycling, stormwater, road drainage, alternatives to town water supply and water quality management for the site. For example description and locations of on-site wastewater systems, swales, water quality retention ponds, etc. Address the requirements, where relevant, of the Flat Rock Creek Notification Area under the *Mining Act 1992 (NSW)* and the *Dam Safety Act 1978* (NSW).	A WSUD approach is proposed. Rainwater tanks and bioretention systems are proposed throughout the site. Water quality benchmarks of 65% and 45% removal of TP and TN respectively are met based on conceptual water quality modelling. TSS reduction of 84.3% is slightly below the benchmark removal of 85%, but is considered conservatively low as the bioretention systems will also include adjacent vegetated areas which have not been modelled which will increase TSS removal. The purpose of the Flat Rock Creek Notification Area is to ensure that dam areas are not affected by mining claims or mining works. As the development only involves surface works, no notification or further assessment is necessary. Sewage will flow to Councils sewerage system. Refer to the Infrastructure Report authored by Allen, Price and Associates with respect to alternatives to town water supply.
	7.4 Include consideration of any specific existing or draft Estuary Management Plan and Coastline Management Plan.	The proposed development site ultimately drains to Zone 2 of the Shoalhaven River, as identified in the Shoalhaven River Estuary Management Plan. This area has been identified as Significant Protection and Healthy Modified. Of particular relevance to this site is the requirement that the development must take into consideration potential stormwater impacts on the estuary and wetlands. This has been addressed through the preparation of a stormwater management plan and demonstrated through the use of water quality modelling showing that the proposal will meet BMP guidelines for water quality management.

7.0 CONCLUSIONS & RECOMMENDATIONS

The Water Cycle Management Plan has specified a WSUD approach to mimic existing hydrology through incorporation bioretention and rainwater harvesting and re-use. The following measures are recommended:

- 5kL rainwater harvesting tanks to be plumbed in to the proposed houses to supply hot water and laundry demands
- Infiltration pits with a minimum filter area of 4.6 m^2 per lot
- A total swale area of 5,000 m^2 on roadsides and public spaces (see Appendix B for proposed swale locations)

Stormwater discharged from the site is treated to the current best practice guideline of 65% removal of Total Phosphorus and 45% of Total Nitrogen from the proposed development. TSS reduction of 84.3% is slightly below the benchmark removal of 85%, but is considered conservatively low as the bioretention systems will also include adjacent vegetated areas which have not been modelled which will increase TSS removal.

The use of bioretention trenches along the northern perimeter of the development provides a diffuse means for stormwater discharge from the site. The bioretention trenches will ensure that the groundwater hydrology remains similar to existing conditions. These trenches will also allow runoff from smaller storm events to migrate to natural low points and maintain the moist areas that currently support the threatened species *Triplarina nowraensis.*

A high-level site analysis shows that a relatively small area of cut and fill is required within the site to define flowpaths and confine major flows to roadways. The full extent of cut and fill is to be identified in the detailed design phase with the preparation of a grading plan and development of flood planning levels throughout the site. Appropriate energy dissipation structures to mitigate scour are to be designed in this phase, as there will be more certainty on specific road grades and therefore flow velocities through the development.

A RAFTS model was schematised to calculate peak 100-year ARI flow through the northern section of the development (which conveys the majority of site runoff), the results showed a peak flow of 6.7 m^3/s.

It is recommended that a road width of 10 m be adopted through the critical area which discharges to the northern drain as marked in pink in Appendix C, this is to be combined with a pipe network with a minimum diameter of 1200 mm. This design is compliant with hazard requirements to convey major flows and provides capacity of up to 7.9 m^3/s which allows for some increase in future peak flows from climate change (a 30% increase in the peak 100-year ARI is 8.74 m^3/s). These calculations are to be refined in he detailed design phase and are based on a limiting slope of 2%.

The potential climate change effect of increases in sea level have not been incorporated into the design as the development is located on a ridgeline plateau, above the Shoalhaven River and Flat Rock Creek. The lowest point on the development is 30 m AHD and it is therefore not necessary to incorporate the effects of sea level rise on the development.

There are no requirements for on-site detention, as per Shoalhaven Council policy. Sewage will flow to Councils sewerage system .

It is recommended that erosion and sediment controls for the construction phase are to be specified during detailed design, these are to adhere to the current edition of "Soils and Construction - Managing Urban Stormwater Handbook" (otherwise referred to as the "Blue Book"), Council and the approved Soil and Water Management Plan.

Additional studies which support this report are provided in Appendix F *Hydrogeological Assessment* (Martens Consulting Engineers) and also in the Infrastructure Report (Allen Price and Associates) which addresses alternatives to town water supply.

Further design of stormwater drainage system will need to incorporate limitations of the site due to the presence of shallow bedrock.

REFERENCES

Bannerman and Hazleton (1993). *Soil Landscapes of the Kiama 1:100 000 Sheet Report*, Department of Conservation and Land Management, Sydney.

Department of Environment and Climate Change (2007), *Guideline for the practical consideration of climate change, NSW Floodplain Management Manual.*

Engineers Australia (2006), *Australian Runoff Quality*, Engineers Australia, Sydney.

Environmental Protection Authority (2004), *Managing Urban Stormwater: Treatment Techniques,* Department of Environment and Conservation

Hogbin, P. (2002) *The impact of elevated nutrient levels on the growth and survival of the Endangereed plant Triplarina nowrensis.* NSW NPWS.

Landcom (2004), *Managing Urban Stormwater, Soils and Construction, Vers 4*

Macleod (2008), *MUSIC Calibration based on soil conditions,* NSW and QLD SIA Conference, 2008.

Martens Consulting Engineers (2011), *Hydrogeological Assessment: Proposed Sub-division, Mundamia Release Area, Mundamia NSW*.

Sydney Metropolitan Catchment Management Authority (2010), *Draft NSW MUSIC Modelling Guidelines*.

Water Quality Guidelines for the Protection of Aquatic Ecosystems for Upland Rivers (ANZECC, 2000)Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000)

NSW Government Floodplain Development Manual – Management of Flood Liable Land (DIPNR, 2005)

Practical Consideration of Climate Change – Floodplain Risk Management Guideline (DECC, October 2007)

Managing Urban Stormwater: Soils and Construction (NSW Landcom, March 2004) – “The Blue Book”

APPENDIX A

Stormwater management measures

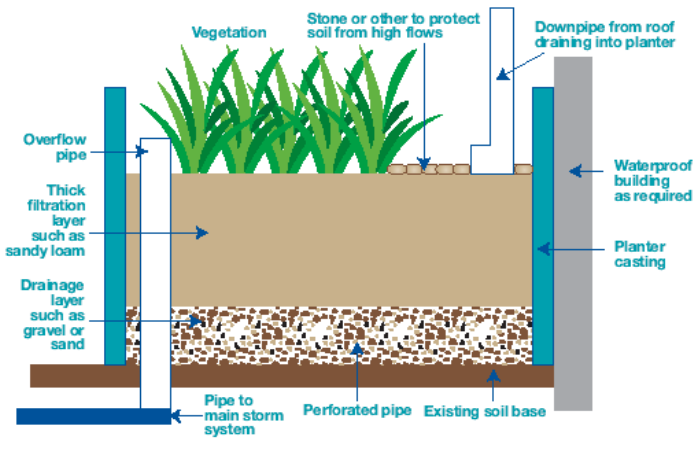
Rainwater Tanks

It is recommended that a minimum 5 KL rainwater tank be installed on each house with a minimum of 80% of the roof area draining to it. The tank should be plumbed to supply the hot water and laundry demands to regularly draw down the storage in the tank to retain runoff from the site.

Typical Rainwater tank installation

Lot Level Bioretention and Infiltration

Infiltration is recommended for all lots. Rainwater tank overflow, runoff from lot impervious surfaces and general backyard runoff should be collected and infiltrated. A bioretention system with an extended detention volume of 2 m^3 and a filter area of 4.6 m^2 within each lot is required to infiltrate frequent runoff. A conceptual infiltration area configuration is shown on the Stormwater Master Plan drawing (Appendix C). Promoting infiltration will assist with the maintenance of interflow (water flow through the soil profile, rather than the surface) thus helping to maintain the existing hydrological regime after development.



Examples of a Bioretention infiltration system

(http://library.melbournewater.com.au/content/wsud/sustainable_urban_design/Raingardens.pdf and http://www.rtbg.tas.gov.au/raingarden.html)

Street Side Bioretention and Infiltration

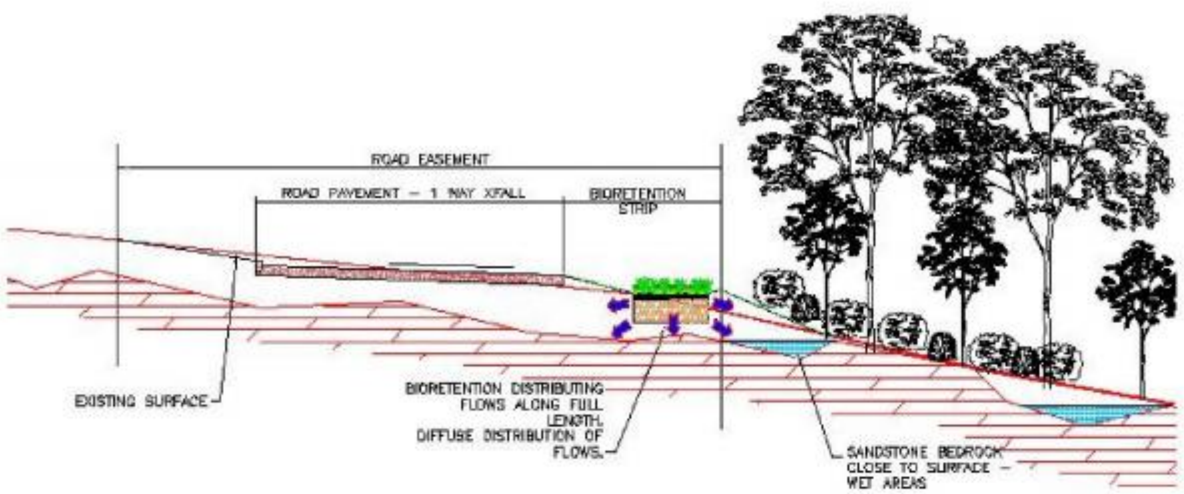
Bioretetion areas and locations are shown in Appendix B. These trenches will collect surface runoff from roads as well as piped runoff. Piped runoff should undergo some level of pre treatment before entering the biofiltration area. This could occur either through a stilling basin, via collection baskets/bags at stormwater pits, or through a permeable pipe/surcharge system.

Bioretention trenches should be adopted to promote infiltration and interflow into the EEC area through the soil profile to maintain moisture to this sensitive community. See below for an example of a typical roadside bioretention system.

Typical bioretention trench

APPENDIX B

Stormwater management configuration

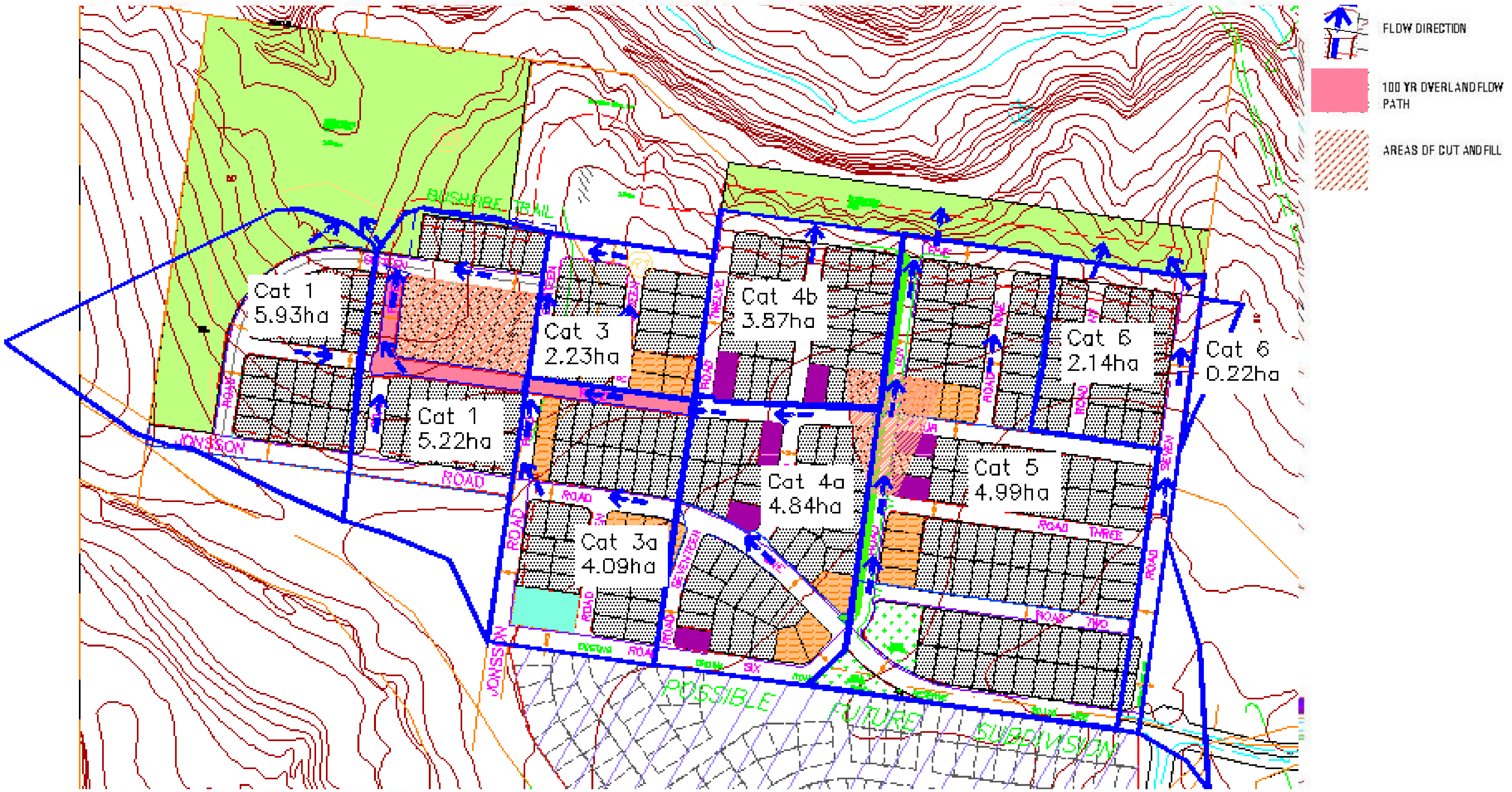


SECTION A - TYPICAL BIORETENTION CROSS-SECTION

STORM_CONSULTING

APPENDIX C

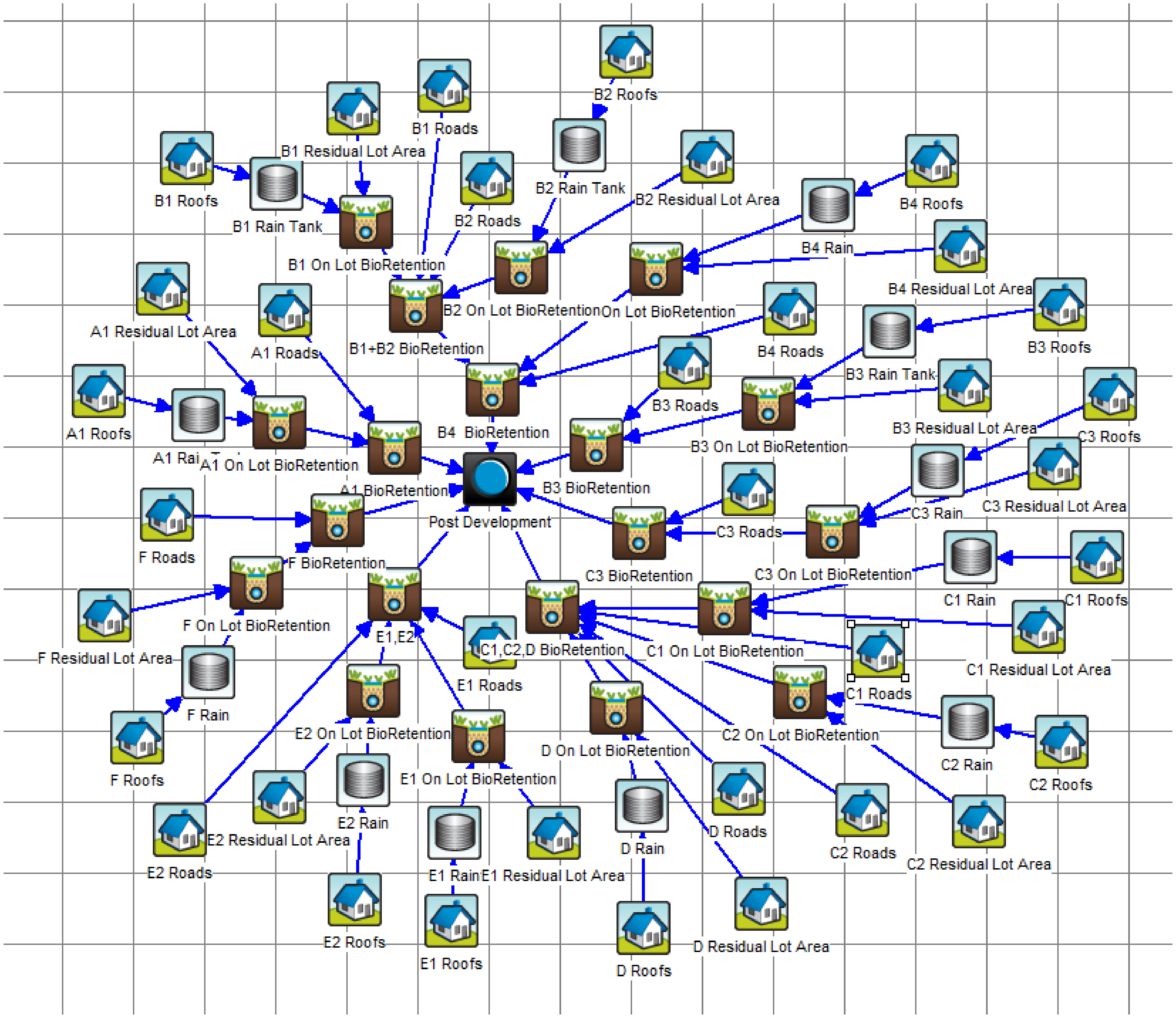
Catchment configuration



Drainage Flow Paths

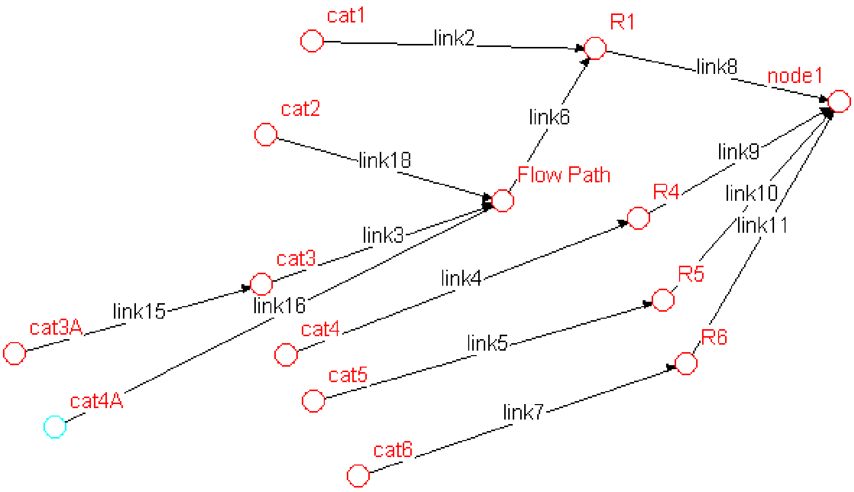
APPENDIX D

MUSIC model configuration and assumptions


B2 Roofs
B1 Roads
B1 Residual Lot Area
B1 Roofs
B1 Rain Tank
B2 Rain Tank
B2 Residual Lot Area
B4 Roofs
B2 Roads
B1 On Lot BioRetention
B4 Rain
B2 On Lot BioRetention
On Lot BioRetention
B4 Residual Lot Area
A1 Residual Lot Area
A1 Roads
B1+B2 BioRetention
B4 Roads
B3 Roofs
B3 Rain Tank
B3 Roads
A1 Roofs
B4 BioRetention
B3 Residual Lot Area
C3 Roofs
A1 Rai
A1 On Lot BioRetention
B3 On Lot BioRetention
A1 BioRetention
B3 BioRetention
C3 Residual Lot Area
C3 Rain
Post Development
F Roads
C3 Roads
F BioRetention
C3 BioRetention
C3 On Lot BioRetention
C1 Rain
C1 Roofs
F On Lot BioRetention
E1,E2
C1,C2,D BioRetention
C1 On Lot BioRetention
F Residual Lot Area
C1 Residual Lot Area
E1 Roads
C1 Roads
F Rain
E2 On Lot BioRetention
D On Lot BioRetention
C2 On Lot BioRetention
C2 Rain
C2 Roofs
F Roofs
E1 On Lot BioRetention
E2 Rain
D Roads
E2 Residual Lot Area
D Rain
C2 Roads
C2 Residual Lot Area
E2 Roads
E1 Rain
E1 Residual Lot Area
E2 Roofs
D Residual Lot Area
E1 Roofs
D Roofs

APPENDIX E

Hydrology model configuration and assumptions


cat1
link2
R1
link8
node1
cat2
link6
link18
Flow Path
link9
R4
link10
link3
link11
cat3
link4
R5
cat3A
link15
link16
cat4
link5
R6
cat5
cat4A
link7
cat6

Run started at: 30th May 2012 15:45:40

##

RUNTIME RESULTS

##

Max. no. of links allowed = 1500

Max. no. of routng increments allowed = 250000

Max. no. of rating curve points = 250000

Max. no. of storm temporal points = 250000

Max. no. of channel subreaches = 25

Max link stack level = 50

Input Version number = 800

LINK cat3A 1.000

ESTIMATED VOLUME (CU METRES*10**3) = 2.503
ESTIMATED PEAK FLOW (CUMECS) = 1.6
ESTIMATED TIME TO PEAK (MINS) = 30.00

LINK cat3 1.000

ESTIMATED VOLUME (CU METRES*10**3) = 5.005
ESTIMATED PEAK FLOW (CUMECS) = 3.1
ESTIMATED TIME TO PEAK (MINS) = 30.00

LINK cat4A 1.000

ESTIMATED VOLUME (CU METRES*10**3) = 6.566
ESTIMATED PEAK FLOW (CUMECS) = 3.7

ESTIMATED TIME TO PEAK (MINS) = 30.00

LINK cat2 1.000

ESTIMATED VOLUME (CU METRES*10**3) = 4.134

ESTIMATED PEAK FLOW (CUMECS) = 2.5

ESTIMATED TIME TO PEAK (MINS) = 30.00

LINK Flow Path 1.000

ESTIMATED VOLUME (CU METRES*10**3) = 15.71

ESTIMATED PEAK FLOW (CUMECS) = 9.3

ESTIMATED TIME TO PEAK (MINS) = 32.00

LINK cat1 1.000

ESTIMATED VOLUME (CU METRES*10**3) = 4.670

ESTIMATED PEAK FLOW (CUMECS) = 3.0

ESTIMATED TIME TO PEAK (MINS) = 30.00

LINK R1 1.000

ESTIMATED VOLUME (CU METRES*10**3) = 20.38

ESTIMATED PEAK FLOW (CUMECS) = 12.

ESTIMATED TIME TO PEAK (MINS) = 33.00

LINK cat4 1.000

ESTIMATED VOLUME (CU METRES*10**3) = 2.938

ESTIMATED PEAK FLOW (CUMECS) = 1.8

ESTIMATED TIME TO PEAK (MINS) = 30.00

LINK R4 1.000

ESTIMATED VOLUME (CU METRES*10**3) = 2.938

ESTIMATED PEAK FLOW (CUMECS) = 1.8

ESTIMATED TIME TO PEAK (MINS) = 32.00

LINK cat5 1.000

ESTIMATED VOLUME (CU METRES*10**3) = 3.994

ESTIMATED PEAK FLOW (CUMECS) = 2.5

ESTIMATED TIME TO PEAK (MINS) = 30.00

LINK R5 1.000

ESTIMATED VOLUME (CU METRES*10**3) = 3.994

ESTIMATED PEAK FLOW (CUMECS) = 2.5

ESTIMATED TIME TO PEAK (MINS) = 35.00

LINK cat6 1.000

ESTIMATED VOLUME (CU METRES*10**3) = 1.920

ESTIMATED PEAK FLOW (CUMECS) = 1.2

ESTIMATED TIME TO PEAK (MINS) = 30.00

LINK R6 1.000

ESTIMATED VOLUME (CU METRES*10**3) = 1.920

ESTIMATED PEAK FLOW (CUMECS) = 1.2

ESTIMATED TIME TO PEAK (MINS) = 35.00

LINK node1 1.000

ESTIMATED VOLUME (CU METRES*10**3) = 29.23

ESTIMATED PEAK FLOW (CUMECS) = 17.

ESTIMATED TIME TO PEAK (MINS) = 33.00

###

100YR & 5YR

Results for period from 12: 0.0 1/ 1/2007

to 17: 0.0 1/ 1/2007

###

ROUTING INCREMENT (MINS) = 1.00

STORM DURATION (MINS) = 90.

RETURN PERIOD (YRS) = 100.

BX = 1.0000

TOTAL OF FIRST SUB-AREAS (ha) = 16.53

TOTAL OF SECOND SUB-AREAS (ha) = 20.14

TOTAL OF ALL SUB-AREAS (ha) = 36.67

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link	Catch. Area		Slope		% Impervious		Pern		B		Link
Label	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	No.
	(ha)		(%)		(%)						

cat3A	1.250	1.880	3.500	3.500	0.000	100.0	.025	.015	.0156	.0011	1.000
cat3	1.250	1.880	3.500	3.500	0.000	100.0	.025	.015	.0156	.0011	1.001
cat4A	3.280	4.910	1.600	1.600	0.000	100.0	.025	.015	.0381	.0027	2.000
cat2	2.880	2.350	4.900	4.900	0.000	100.0	.025	.015	.0204	.0011	3.000
Flow Path	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	1.002
cat1	3.450	2.480	8.300	8.300	0.000	100.0	.025	.015	.0172	.0008	4.000
R1	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	1.003
cat4	1.470	2.200	1.600	1.600	0.000	100.0	.025	.015	.0251	.0018	5.000
R4	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	5.001
cat5	1.850	3.130	2.300	2.300	0.000	100.0	.025	.025	.0236	.0036	6.000
R5	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	6.001
cat6	1.100	1.310	3.200	3.200	0.000	100.0	.025	.015	.0153	.0010	7.000
R6	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	7.001
node1	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	1.004

Link Label	Average Intensity (mm/h)	Init. Loss #1 (mm)	Init. Loss #2	Cont. Loss #1 (mm/h)	Cont. Loss #2	Excess Rain #1 (mm)	Excess Rain #2	Peak Inflow (m^3/s)	Time to Peak mins	Link Lag
cat3A	59.234	10.00	5.000	2.500	.5000	75.518	83.152	1.614	30.00	1.500
cat3	59.234	10.00	5.000	2.500	.5000	75.518	83.152	3.119	30.00	2.000
cat4A	59.234	10.00	5.000	2.500	.5000	75.518	83.152	3.722	30.00	2.000
cat2	59.234	10.00	5.000	2.500	.5000	75.518	83.152	2.546	30.00	2.900
Flow Path	59.234	10.00	0.000	2.500	0.000	75.518	0.000	9.281	32.00	1.700
cat1	59.234	10.00	5.000	2.500	.5000	75.518	83.152	2.964	30.00	2.800
R1	59.234	10.00	0.000	2.500	0.000	75.518	0.000	12.001	33.00	0.000
cat4	59.234	10.00	5.000	2.500	.5000	75.518	83.152	1.752	30.00	2.000
R4	59.234	10.00	0.000	2.500	0.000	75.518	0.000	1.752	32.00	0.000
cat5	59.234	10.00	5.000	2.500	.5000	75.518	83.152	2.458	30.00	5.100
R5	59.234	10.00	0.000	2.500	0.000	75.518	0.000	2.458	35.00	0.000
cat6	59.234	10.00	5.000	2.500	.5000	75.518	83.152	1.218	30.00	4.500
R6	59.234	10.00	0.000	2.500	0.000	75.518	0.000	1.218	35.00	0.000
node1	59.234	10.00	0.000	2.500	0.000	75.518	0.000	16.849	33.00	0.000

LINK cat3A 2.000

ESTIMATED VOLUME (CU METRES*10**3) = 1.365
ESTIMATED PEAK FLOW (CUMECS) = 0.97
ESTIMATED TIME TO PEAK (MINS) = 30.00

LINK cat3 2.000

ESTIMATED VOLUME (CU METRES*10**3) = 2.731
ESTIMATED PEAK FLOW (CUMECS) = 1.9
ESTIMATED TIME TO PEAK (MINS) = 30.00

LINK cat4A 2.000

ESTIMATED VOLUME (CU METRES*10**3) = 3.574

ESTIMATED PEAK FLOW (CUMECS) = 2.1

ESTIMATED TIME TO PEAK (MINS) = 30.00

LINK cat2 2.000

ESTIMATED VOLUME (CU METRES*10**3) = 2.222

ESTIMATED PEAK FLOW (CUMECS) = 1.5

ESTIMATED TIME TO PEAK (MINS) = 30.00

LINK Flow Path 2.000

ESTIMATED VOLUME (CU METRES*10**3) = 8.526

ESTIMATED PEAK FLOW (CUMECS) = 5.4

ESTIMATED TIME TO PEAK (MINS) = 32.00

LINK cat1 2.000

ESTIMATED VOLUME (CU METRES*10**3) = 2.505

ESTIMATED PEAK FLOW (CUMECS) = 1.8

ESTIMATED TIME TO PEAK (MINS) = 30.00

LINK R1 2.000

ESTIMATED VOLUME (CU METRES*10**3) = 11.03

ESTIMATED PEAK FLOW (CUMECS) = 7.0

ESTIMATED TIME TO PEAK (MINS) = 33.00

LINK cat4 2.000

ESTIMATED VOLUME (CU METRES*10**3) = 1.601

ESTIMATED PEAK FLOW (CUMECS) = 1.0

ESTIMATED TIME TO PEAK (MINS) = 30.00

LINK R4 2.000

ESTIMATED VOLUME (CU METRES*10**3) = 1.601

ESTIMATED PEAK FLOW (CUMECS) = 1.0

ESTIMATED TIME TO PEAK (MINS) = 32.00

LINK cat5 2.000

ESTIMATED VOLUME (CU METRES*10**3) = 2.183

ESTIMATED PEAK FLOW (CUMECS) = 1.4
ESTIMATED TIME TO PEAK (MINS) = 30.00

LINK R5 2.000

ESTIMATED VOLUME (CU METRES*10**3) = 2.183
ESTIMATED PEAK FLOW (CUMECS) = 1.4
ESTIMATED TIME TO PEAK (MINS) = 35.00

LINK cat6 2.000

ESTIMATED VOLUME (CU METRES*10**3) = 1.041
ESTIMATED PEAK FLOW (CUMECS) = 0.72
ESTIMATED TIME TO PEAK (MINS) = 30.00

LINK R6 2.000

ESTIMATED VOLUME (CU METRES*10**3) = 1.041
ESTIMATED PEAK FLOW (CUMECS) = 0.72
ESTIMATED TIME TO PEAK (MINS) = 35.00

LINK node1 2.000

ESTIMATED VOLUME (CU METRES*10**3) = 15.86
ESTIMATED PEAK FLOW (CUMECS) = 9.8
ESTIMATED TIME TO PEAK (MINS) = 33.00

###
100YR & 5YR

Results for period from 12: 0.0 1/ 1/2007
to 17: 0.0 1/ 1/2007
###

ROUTING INCREMENT (MINS) = 1.00
STORM DURATION (MINS) = 90.
RETURN PERIOD (YRS) = 5.
BX = 1.0000
TOTAL OF FIRST SUB-AREAS (ha) = 16.53
TOTAL OF SECOND SUB-AREAS (ha) = 20.14
TOTAL OF ALL SUB-AREAS (ha) = 36.67

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link Label	Catch. Area #1 (ha)	Catch. Area #2 (ha)	Slope #1 (%)	Slope #2 (%)	% Impervious #1 (%)	% Impervious #2 (%)	Pern #1	Pern #2	B #1	B #2	Link No.
cat3A	1.250	1.880	3.500	3.500	0.000	100.0	.025	.015	.0156	.0011	1.000
cat3	1.250	1.880	3.500	3.500	0.000	100.0	.025	.015	.0156	.0011	1.001
cat4A	3.280	4.910	1.600	1.600	0.000	100.0	.025	.015	.0381	.0027	2.000
cat2	2.880	2.350	4.900	4.900	0.000	100.0	.025	.015	.0204	.0011	3.000
Flow Path	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	1.002
cat1	3.450	2.480	8.300	8.300	0.000	100.0	.025	.015	.0172	.0008	4.000
R1	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	1.003
cat4	1.470	2.200	1.600	1.600	0.000	100.0	.025	.015	.0251	.0018	5.000
R4	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	5.001
cat5	1.850	3.130	2.300	2.300	0.000	100.0	.025	.025	.0236	.0036	6.000
R5	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	6.001
cat6	1.100	1.310	3.200	3.200	0.000	100.0	.025	.015	.0153	.0010	7.000
R6	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	7.001
node1	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	1.004

Link Label	Average Intensity (mm/h)	Init. Loss #1 (mm)	Init. Loss #2 (mm)	Cont. Loss #1 (mm/h)	Cont. Loss #2 (mm/h)	Excess Rain #1 (mm)	Excess Rain #2 (mm)	Peak Inflow (m^3/s)	Time to Peak	Link Lag mins
cat3A	34.869	10.00	5.000	2.500	.5000	39.095	46.637	0.9657	30.00	1.500
cat3	34.869	10.00	5.000	2.500	.5000	39.095	46.637	1.866	30.00	2.000
cat4A	34.869	10.00	5.000	2.500	.5000	39.095	46.637	2.123	30.00	2.000
cat2	34.869	10.00	5.000	2.500	.5000	39.095	46.637	1.504	30.00	2.900
Flow Path	34.869	10.00	0.000	2.500	0.000	39.095	0.000	5.402	32.00	1.700
cat1	34.869	10.00	5.000	2.500	.5000	39.095	46.637	1.801	30.00	2.800
R1	34.869	10.00	0.000	2.500	0.000	39.095	0.000	7.043	33.00	0.000
cat4	34.869	10.00	5.000	2.500	.5000	39.095	46.637	1.002	30.00	2.000
R4	34.869	10.00	0.000	2.500	0.000	39.095	0.000	1.002	32.00	0.000
cat5	34.869	10.00	5.000	2.500	.5000	39.095	46.637	1.429	30.00	5.100
R5	34.869	10.00	0.000	2.500	0.000	39.095	0.000	1.429	35.00	0.000
cat6	34.869	10.00	5.000	2.500	.5000	39.095	46.637	0.7152	30.00	4.500
R6	34.869	10.00	0.000	2.500	0.000	39.095	0.000	0.7152	35.00	0.000
node1	34.869	10.00	0.000	2.500	0.000	39.095	0.000	9.797	33.00	0.000

Run completed at: 30th May 2012 15:45:41

APPENDIX F

Hydrogeological Assessment - Martens Consulting Engineers (2011)