Using MUSIC in Sydney Drinking Water Catchment

A WaterNSW Current Recommended Practice

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Using MUSIC in the Sydney Drinking Water Catchment

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1 INTRODUCTION

WaterNSW has developed *Using MUSIC in the Sydney Drinking Water Catchment* to help consultants prepare MUSIC stormwater quality models to demonstrate a neutral or beneficial effect on water quality can be achieved for proposed urban and rural land use developments. MUSIC stands for 'Model for Urban Stormwater Improvement Conceptualisation', which is a decision support system for simulating the performance of stormwater management measures. MUSIC is owned and distributed by the eWater Limited through the eWater Toolkit, https://ewater.org.au/products/music/.

Development in the Sydney drinking water catchment is regulated by the *State Environmental Planning Policy (Biodiversity and Conservation) 2021* (the B&C SEPP). Under the SEPP, proposed developments in the Sydney drinking water catchment that need consent under a council local environmental plan cannot be approved unless the consent authority is satisfied the development would have a neutral or beneficial effect (NorBE) on water quality.

For stormwater, NorBE is assessed by comparing the quality of runoff from the pre-development site with that from the post-development site including proposed stormwater treatment measures (such as water sensitive design elements) that may be needed to mitigate pollutant loads and concentrations resulting from the proposed land use change. This document, which is a standard under the SEPP, addresses the requirements for compliance with NorBE in relation to MUSIC modelling to assess stormwater quality impacts. More detailed aspects of compliance with NorBE are covered in WaterNSW's *Neutral or Beneficial Effect on Water Quality Assessment Guideline* [NorBE Guideline] (WaterNSW, 2022).

This manual focuses principally on stormwater quality. Where developments discharge into a Council stormwater drainage system or local waterways, particularly in urban areas, Councils will probably also require applicants to assess water quantity, especially peak flows and volumes. There is often a Council requirement to show that the post-development stormwater *quantity* does not exceed pre-development quantity.

This document is aimed at consultants who have completed MUSIC training and know the basic fundamentals of MUSIC modelling. The manual shows practitioners how to set up a MUSIC model for pre-development and post-development site layouts, considering the existing site characteristics, drainage configuration, the climatic region, and the configuration of post-development site layout and treatment measures in the context of NorBE. It is, however, not a substitute for the help file in MUSIC. It is also not intended to be a detailed design tool nor a substitute for knowledge and experience in catchment modelling and applying water sensitive design principles. The overall aim of this and other WaterNSW documents is about managing water quality in the Sydney drinking water catchment area and to protect the quality of water flowing into drinking water storages now and in the future.

This manual addresses modifications incorporated into version 6, and earlier versions of MUSIC, and WaterNSW will assess all submitted MUSIC models using version 6. Updates regarding the availability of a secondary drainage link (discussed in Section 2.4.6.1), and the performance of biofilters, particularly the use of submerged zones and associated model outputs, are addressed this version (see Section 2.4.6). WaterNSW strongly recommends that consultants upgrade to the latest version of MUSIC, which represents the best available science at the time, and undertake the additional MUSIC training associated with that version.

The manual is prescriptive; however, consultants can vary from it (at their own risk) where they provide suitable and well-substantiated alternatives or justifications that are acceptable to WaterNSW. This may, however, result in longer review and approval times.

This manual is one of a number of current recommended practices, performance standards and models that WaterNSW has either endorsed (where these have been developed externally) or has been developed by WaterNSW to meet a particular need. Two other documents of most relevance to stormwater management are WaterNSW's 'Water Sensitive Design Guide for Rural Residential Subdivisions' (WaterNSW, 2023a), and 'Developments in the Sydney Drinking Water Catchment – Water Quality Information Requirements' (WaterNSW, 2023). This manual and the above two

mentioned documents are available on WaterNSW's website at www.waternsw.com.au. The freely available Small-Scale Stormwater Quality Model (S3QM) to demonstrate NorBE for small scale developments where the use of MUSIC is not warranted (see Table 2.1) is also available direct from www.s3qm.com.au.

Sources of data and diagrams are acknowledged in tables and figures, however, where no acknowledgement is indicated, the data or figures were developed as part of the manual.

2 OVERVIEW OF MUSIC AND ITS APPLICATION TO NORBE

2.1 What is MUSIC?

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) is a water quality decision support tool for stormwater managers. It helps the planning and design (at a conceptual level) of appropriate stormwater treatment and management systems from an individual development to a catchment level. The MUSIC modelling software was developed by researchers and practitioners of the former Cooperative Research Centre (CRC) for Catchment Hydrology and eWater Limited, and represents an accumulation of the best available knowledge and research into urban and rural stormwater management in Australia.

MUSIC estimates stormwater pollutant generation and simulates the performance of stormwater treatment devices individually and as part of a treatment train (individual devices connected in series to improve overall treatment performance). By simulating the performance of stormwater treatment systems (stormwater quality improvement devices), MUSIC provides information on whether a proposed stormwater management system conceptually would achieve water quality targets, and in the Sydney drinking water catchment, whether the NorBE requirement is satisfied.

2.2 When to use MUSIC

The use of MUSIC is related to the potential impact of a development on water quality. Developments that have a high potential to impact on water quality should be estimated via a sophisticated decision support tool like MUSIC, whereas a simpler approach may be appropriate for a development with a lower risk to water quality.

Within the Sydney drinking water catchment, MUSIC modelling must be used to assess the impacts on water quality for a range of proposed developments, depending on the extent of development types and land use change. A summary of development types and land use changes that require MUSIC modelling in the Sydney drinking water catchment is listed in Table 2.1. If any of the criteria listed in Table 2.1 are exceeded, MUSIC modelling must be undertaken. For a high-risk site located in a sensitive area, such as a steep site entirely covered by native vegetation located adjacent to major watercourse, WaterNSW should be consulted to determine if MUSIC modelling would be required.

In cases where the trigger level to use MUSIC is not reached as per Table 2.1, the application of other suitable stormwater quality modelling tools, such as the Small-Scale Stormwater Quality Model (S3QM) assessment tool (which is based on regression analysis of MUSIC simulation outputs), is necessary to demonstrate and certify that NorBE has been achieved for stormwater quality for the development. WaterNSW's current recommended practice 'Development in the Sydney Drinking Water Catchment – Water Quality Information Requirements' (WaterNSW 2023) may also be relevant.

MUSIC was originally designed to simulate stormwater treatment and management systems in urban catchments; however, it can also be used for developments in rural catchments. The hydrology of highly pervious rural catchments is more complex than urban areas with high proportions of impervious surfaces. Factors including rainfall interception, rainfall intensity, catchment slopes, soil field capacity, soil drainage, interflow rates, groundwater recharge, evapo-transpiration rates and infiltration rates may each have a significant influence on the hydrologic cycle. These may be important to different degrees between sites. The modelling of highly pervious catchments in MUSIC must be undertaken with care and, where possible, model results should be checked against expected volumetric runoff coefficients, evapo-transpiration losses and export loads.

Table 2.1:   Trigger levels for MUSIC modelling in the Sydney drinking water catchment[1]

Nature of the development	Any Developments[2,3]
Increase of total impervious area	>2,500 m2 including new dwellings or buildings, alterations/additions to existing structures, access driveways, parking and hardstand areas, roads, rights-of-way and future dwellings
Sensitive areas[4]	Some sensitive areas may require MUSIC modelling below these thresholds - these will be determined on a case-by-case basis

[1] Other types of Stormwater Quality modelling may be required. Refer to Section 2.2 of this document for detailed stormwater modelling requirements or refer to Table A3 of Neutral or Beneficial Effect on Water Quality Assessment Guideline (WaterNSW, 2022) and Table 1 of Developments in the Sydney Drinking Water Catchment - Water Quality Information Requirements (WaterNSW, 2023).

[2] Industrial and commercial developments have significant levels of imperviousness associated with buildings, driveways, parking and hardstand areas. Appropriate assumptions for future development type at subdivision stage are required to conceptually identify the extent of stormwater management measures needed including the capacity of the site to contain such measures. Unless it can be specifically demonstrated otherwise, it should be assumed that all commercial / industrial developments are 80% impervious.

[3] For subdivisions, modelling is only required to demonstrate NorBE on water quality for the works required as part of the subdivision. Future dwellings or buildings can be included in the model where achieving a NorBE is reliant upon future stormwater quality improvements related to those dwellings, however reliance solely on lot-scale stormwater improvements may not be accepted.

[4] Sensitive areas may include (but are not limited to): areas of high erosion risk (poor or saline soils), existing sites with extensive gully erosion, or where the development proposes to clear a significant amount of native forest vegetation.

2.3 What and how to model with MUSIC

The following points provide a broad overview of the elements needed to model a proposed development with MUSIC:

- MUSIC assessments require two scenarios - a pre-development (or existing use) scenario and a post-development (future use) scenario. To demonstrate that NorBE is achieved, the pollutant loads and concentrations from the post-development scenario must be equal to or less than the pre-development scenario. WaterNSW requires the model to aim for a 10% improvement for total suspended solids, total phosphorus and total nitrogen loads on comparison of the pre- and post-development case to ensure the neutral or beneficial effect on water quality requirement can be met, given the uncertainty in the modelled outcomes. Details on comparing the pre- and post-development are outlined in Section 5.3.3.

- The pre-development scenario represents the condition of the site at the time the development application is to be lodged (that is before any work happens on the site). The post-development scenario represents the condition of the site after construction of all infrastructure (including buildings, roads, car parking areas). The total catchment area modelled should be equivalent for the pre- and post-development cases.

- For larger, rural residential type developments, it needs to be shown that NorBE is achieved on the part of a site that would be disturbed by the development. Parts of the site that would not be disturbed and do not drain to treatment measures must not be used to dilute the runoff quality from future developed areas.

- For subdivisions, modelling is only required to demonstrate NorBE for the proposed subdivision works. Future dwellings or buildings (and associated hard stand areas) can be included in the model where achieving NorBE is reliant on future stormwater quality improvement devices (SQIDs) related to those dwellings/buildings, or where the lots will drain to a communal SQID. Reliance solely on lot-scale SQIDs to achieve NorBE for the subdivision works may not be accepted. Any subsequent applications for dwellings and/or other developments on the proposed lots will be subject to the provisions of the SEPP and

will need to be assessed according to the NorBE test in relation to the potential effect of the development on water quality.

- Where the site drains to two or more separate catchments, it may be that one part of a site or catchment shows a slight deterioration in water quality whilst another part of the site shows an improvement in water quality as part of an overall achievement of NorBE for the whole site. Nevertheless, the aim should be to achieve, as much as possible, a uniform performance across the site, as a gross deterioration in water quality in one catchment, despite balancing improvement in another catchment, may in some circumstances not be considered an acceptable achievement of NorBE.

- For staged developments such as some subdivisions, NorBE is required to be achieved for each stage of the development. Where this requires MUSIC for the entire development, this will also require separate MUSIC models and analysis for each stage. This is due to the fact that subdivisions may be developed over long periods, may be changed or not proceed, or stages may be developed out of sync so it is important that each stage achieves NorBE in its own right, to ensure water quality risks are minimised.

- For developments that will result in greater than 70% of the subject land becoming impervious, the developer must allow sufficient space for suitably sized and designed SQIDs.

2.4 Determining NorBE

2.4.1 Context in the Sydney Drinking Water Catchment

Development in the Sydney drinking water catchment is regulated by chapter 6 of *State Environmental Planning Policy (Biodiversity and Conservation) 2021* (the B&C SEPP; formerly *State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011*). Under chapter 6, Part 6.5 of the B&C SEPP, any development in the Sydney drinking water catchment that need consent under a council's local environmental plan cannot be approved unless the consent authority is satisfied the development would have a neutral or beneficial effect (NorBE) on water quality.

A neutral or beneficial effect on water quality means development that:

- has no identifiable impact on water quality, or
- will contain any water quality impact on the development site and stop it from reaching any watercourse, waterbody or drainage depression on the site, or
- will transfer any water quality impact outside the site where it is treated and disposed of to standards approved by the consent authority.

In addition, the SEPP states that 'Development consent must not be granted to development on land in the Sydney Drinking Water Catchment unless the consent authority is satisfied the development is consistent with the NorBE Guideline'. The 'Neutral or Beneficial Effect on Water Quality Assessment Guideline' [NorBE Guideline] (WaterNSW, 2022) provides advice about the meaning of the neutral or beneficial effect, how to show it, and how to assess an application against the NorBE test. If you are unsure how to categorise your proposed development or activity, contact WaterNSW's Catchment Assessments team via environmental.assessments@waternsw.com.au.

It is a statutory requirement for all new developments in the Sydney drinking water catchment not to be approved unless the consent authority is satisfied the development would have a neutral or beneficial effect on water quality. WaterNSW will not concur with, and Council will not consent to any development application, which does not meet the NorBE requirement.

2.4.2 NorBE criteria and MUSIC modelling

To ensure that a development and its associated treatment systems (measures) achieve NorBE, it must meet the following criteria. The criteria are conservative to account for uncertainty in MUSIC predictions and to ensure NorBE is satisfied given this uncertainty. This can simply be done by comparing before and after development pollutant loads and concentrations:

- The mean annual pollutant loads for the post-development case (including mitigation measures) should aim for 10% less than the pre-development case for total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN). For gross pollutants, the post-development load only needs to be equal to or less than pre-development load.

- Pollutant concentrations for TP and TN for the post-development case (including mitigation measures) must be equal to or better compared to the pre-development case for between the 50th and 98th percentiles over the five-year modelling period when runoff occurs. Periods of zero flow are not accounted for in the statistical analysis as there is no downstream water quality impact. To demonstrate this, comparative cumulative frequency graphs, which use the Flow-Based Sub-Sample Threshold for both the pre- and post-development cases (see Section 5.3.3.2) must be provided. As meeting the pollutant percentile concentrations for TP generally also meets the requirements for TSS, cumulative frequency analysis is not required for TSS. Cumulative frequency is also not applied to gross pollutants.

2.4.3 Concept of developing a treatment train

To manage stormwater quality and, to a lesser extent, quantity, it is best to use stormwater treatment and management systems (water sensitive design measures) in a series where each measure focuses on one or more objectives or target pollutants. This 'treatment train' approach ensures that the selected measures operate most effectively in terms of their hydraulic and treatment capabilities.

It is important to understand the actual locations where treatment measures may be used in a development or existing area, so that the quantities of pollutants and flow likely to be received at each location are well understood. This should also consider the number, type and size of treatment measures that are appropriate for the type and scale of the development. WaterNSW strongly encourages developers to consider measures that are not over and above what is appropriate, having consideration for the future ownership and maintenance of such devices.

A sequence of treatments should be formulated that aim to treat specific size ranges of pollutants and over differing timescales, based on the areas available for siting treatment measures. For example, coarse sediment will settle out in a matter of minutes once the flow of water is stilled, however, removing nutrients can take several days or more. Further, a treatment measure that is effective at removing coarse sediment is invariably not the best measure to remove nutrients. It may also mean that a treatment measure designed to remove nutrients may need more frequent maintenance if it also has to remove coarse sediment. For details and examples see Section 5.1.2.

2.4.4 Modelling a treatment train using MUSIC

While the selection of a treatment train is an essential component of the overall design process, one or more elements may fail if there has not been proper consideration of how the overall water sensitive design strategy is to be implemented and maintained. To avoid this, it is necessary to follow a logical step-by-step approach to the development of the MUSIC model.

The process is based on a series of steps that help to characterise the site and identify key characteristics that may influence water sensitive design implementation. These steps are set out below and shown in Figure 2.1.

Step One	Site analysis
Step Two	Evaluate relevant documents, consult consent and reviewing authorities
Step Three	Select and load meteorological template
Step Four	Define areas for modelling
Step Five	Set up a pre-development MUSIC modelling scenario
Step Six	Set up a post-development MUSIC modelling scenario
Step Seven	NorBE analysis
Step Eight	Review, modify and finalise model and proposal
Step Nine	Write report

Inputs
- Digital Terrain/ Elevation Model
- Mapping Layer showing site boundaries
- Discharge points
- External Catchments

Define Catchment

Outputs
Catchment boundary and receiving point

Inputs
- Appropriate rainfall and PET for WaterNSW climate Region

Load Climate Template

Outputs
Blank MUSIC model ready for constructing site layout.

Inputs
- Existing Land Use
- Existing Site Configuration (lot layout)
- Existing drainage configuration

Define Sub-catchments

Outputs
Sub-catchment areas to assist in defining source nodes

Inputs
- Existing Land Use
- Sub-catchments

Set up source nodes for existing case

Outputs
Defined source nodes representing specific land uses in each sub-catchment

Inputs
- Existing drainage configuration
- Discharge Points
- External Catchments

Link source nodes and external catchments to receiving node (via junctions if needed)

Outputs
Existing case MUSIC model

Run Existing Case and Extract Results

Outputs
Existing case pollutant loads and concentrations

Inputs
- Future Land Use
- Future Site Configuration (lot layout)
- Future drainage configuration

Set/ revise source nodes to reflect proposed development

Outputs
Defined source nodes representing specific future land uses in each sub- catchment

Inputs
- Areas for WSUD measures
- WSUD Concept Designs
- Australian Runoff Quality (ARQ)
- Managing Urban Stormwater series

Place treatment nodes – consistent with treatment train philosophy

Outputs
Treatment train of measures

Link source nodes and external catchments via treatment nodes to receiving node

Outputs
Proposed case MUSIC Model with treatments

Run Future Case and Extract Results

Outputs
Future case pollutant loads and concentrations

Inputs
- WaterNSW NorBE Criteria

NorBE Analysis

Fail

Pass

Modelling Complete
- write report

Outputs
Inclusion of MUSIC modelling analysis and results within the Water Cycle Management Study for submission to the reviewing authority.

Figure 2.1:   MUSIC modelling process flow chart

In developing the treatment train and undertaking MUSIC modelling, it is essential to liaise with other professionals involved in developing the project so that the final adopted stormwater strategy integrates and is consistent with other discipline areas as much as possible. Other professionals include site planners, civil and hydraulic engineers, landscape designers, architects as well as council staff. It is particularly important that project managers, consultants and the developer/applicant consider council requirements when they develop stormwater and drainage management measures to avoid later amendments. It is also important that the developer or owner understands and agrees to the proposed stormwater treatment and management strategy, location of treatment measures, and associated costs and maintenance requirements to avoid needing to modify the strategy later. This also applies if it is proposed that council will take on the ownership and maintenance of the stormwater asset post-development, such as for subdivisions. Compromise will invariably be required in various areas, including the water sensitive design strategy, to finalise the overall site design.

2.4.5   Using the notes function in MUSIC

MUSIC provides the ability to add notes to any source or treatment node to record assumptions or other comments associated with that node. This can be an extremely useful method of capturing and keeping information in the model and can be a good way to keep a model 'log'. Figure 2.2 shows an example of the notes screen.
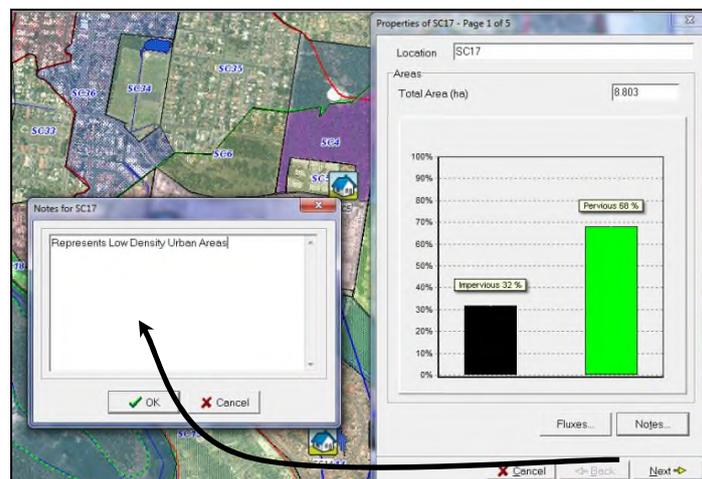
Figure 2.2:   Notes function*
*The note appears as a rollover 'hint' whenever the mouse is rolled over the relevant node (when the 'show notes on tooltip (hover over nodes)' option is turned on under Settings → Preferences).

2.4.6   Changes between MUSIC versions 5 and 6 and previous versions

The performance of biofiltration systems in MUSIC versions 5 and 6 has been modified to improve the modelling of submerged zones that include a carbon source. Such zones can significantly improve the removal of total nitrogen through denitrification processes; however, they can also result in leaching of total phosphorus where the reducing conditions in the submerged zones lead to organic and particulate bound phosphorus being converted to soluble forms. Version 4 of MUSIC considerably improved the modelling of these zones based on a number of laboratory and field based studies undertaken by the former Facility for Advancing Water Biofiltration (FAWB). These studies found that phosphorus leaching occurred when the submerged zone depths increased, and two discrete depths were used to indicate leaching. When the submerged zone was set to 0.3m or greater in version 4, a significant "step change" in phosphorus leaching was modelled, and again when the depth was 0.6m or greater, another "step change" in phosphorus leaching occurred. This was an approximation of what was observed in the laboratory and the field, and version 5 of MUSIC sought to correct this.

The research of FAWB (now Cooperative Research Centre for Water Sensitive Cities) also found that the nutrient content of the filter media itself was critical in determining nutrient removal

performance (as may be expected), so in versions 4 and 5, the option to choose the nutrient concentration in the filter media was added. Again, in version 4, this was only available through a selection of typical values, while in version 5, the modeller can select any value that is representative of the filter media. This leads to another critical point in the use of MUSIC. The MUSIC model must reflect what is to be built on the ground. It is inappropriate to artificially reduce or increase certain parameters to get the result in a model. The cost to rectify a system to meet NorBE once it is constructed will be far greater than that required to get the MUSIC model correctly set up.

MUSIC version 6 has included the option to select landuse zoning/surface type categories within the Urban Source Node, which automatically populates the base and storm flow pollutant concentrations of the node in accordance with this user guide. For example, selection of the "Residential" land use will result in the corresponding base flow (Table 4.6) and storm flow (Table 4.7) pollutant concentration parameters being applied. Note some default parameters (for eroded gullies, agricultural and forest nodes for baseflow and stormflow) are inconsistent with values in Tables 4.6 and 4.7. Until such times these values are corrected in a future version of MUSIC, manually enter the correct values.

When using MUSIC to address NorBE compliance in the Sydney drinking water catchment, the latest version of MUSIC will be used for assessment purposes. For the reasons outlined above, if the model has been set up and run in earlier versions of MUSIC, it is quite common that when run in version 6, different modelled outcomes may occur and result in NorBE compliance not being demonstrated. MUSIC Version 6 represents the best scientific understanding of the performance of stormwater quality treatment measures at this time, and WaterNSW have therefore adopted it as the standard of modelling required to demonstrate NorBE compliance for stormwater quality impacts.

2.4.6.1 Secondary drainage link

MUSIC version 6 has also included a 'secondary drainage link' option, which provides the opportunity to recapture exfiltrated water, overflows, high and low flow bypasses, pipe flow and/or evapotranspiration which may be "lost" within the MUSIC model. It can now be rerouted back into the model and provides the opportunity to demonstrate how this stormwater may undergo secondary treatment (for example, via filtration through naturally occurring soil as illustrated in Figure 2.3 below) and provides a more realistic representation of what may occur on the ground.
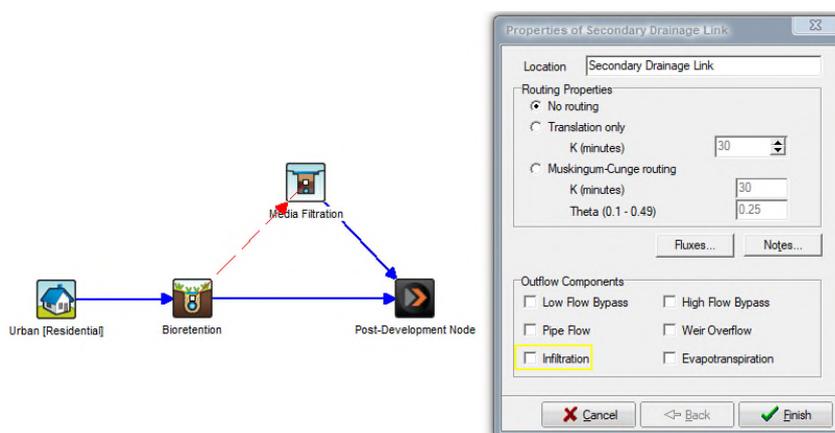
Figure 2.3: Use of secondary drainage link

The primary and secondary drainage links which connect the source, treatment, and junction nodes may represent pipes, open channels, or natural watercourses on the ground. To enable more accurate simulation, the routing properties of each link may be specified by the user.

Routing Properties: You may specify no routing, translation only, or full Muskingum-Cunge routing for any link in a treatment train. If you specify no routing, no further input is required. If you specify translation only, select an appropriate translation time K using the spinner arrows. Translation time will always be a multiple of the time-step for this catchment. If you select Muskingum-Cunge routing, enter appropriate values for the parameters K and Theta. K is equivalent to a translation time, while Theta measures the relative effect of inflow and outflow on the behaviour in a reach. For more information see [Routing Stormwater Using the Muskingum Cunge Method](#) (eWater Limited).

Outflow Components: The outflow components describe the types of outflow that may be captured and represented by the drainage link. If using a 'Primary' drainage link, the outflow components cannot be altered. However, if using a 'Secondary' drainage link, the outflow components can be updated by checking or unchecking the appropriate tick box. When modelling exfiltration using a secondary drainage link, you need to select 'Infiltration'.

2.4.6.2 Exfiltration

MUSIC allows the user to configure a value for exfiltration of water out of the treatment measure into surrounding soils. Where the management of hydrologic impacts from urbanisation is important, this exfiltration can be beneficial to reducing those impacts, however, unless configured using a secondary drainage link in MUSIC, infiltrated water is "lost" from the treatment train, and as such is shown as a pollutant loss. It is likely that in passing through the natural soil, some treatment of stormwater may occur, but as this is not accounted for in MUSIC, and the level of treatment is highly dependent on the characteristics of the soil, groundwater tables, proximity to watercourses and the like, the exfiltration value in any treatment node within MUSIC should be set to zero OR a secondary drainage link should be applied to return this 'lost' water to the post-development node – as per Figure 2.3.

This allows the amount of pollutants not treated directly by the treatment train to be adequately accounted for, such that the assessment agency can make a proper determination as to whether NorBE has been achieved without the uncertainty of what may or may not be treated via exfiltration into the surrounding soil.

Designer should ensure that all flows (high flow bypass, low flow bypass, and weir overflow, and exfiltration) should go to an appropriate node. For example, if the design of a sedimentation basin allows high flow bypass and not to be treated in the downstream treatment node such as a wetland. In such case sedimentation basin high flow bypass in the model should also bypass the wetland.

3 SETTING UP A MUSIC MODEL FOR A SITE

3.1 Step 1 – Understand all planning controls that apply to the site and the proposed development

Depending on the scale, type and complexity of the development, this may involve identifying, gathering, reviewing and understanding any documents and requirements relevant to the proposed development. This may include Council's Local Environmental Plan (LEP), Development Control Plan (DCP), Stormwater Management Strategy, the Government's BASIX requirements, as well as stormwater and hydraulic plans for the proposed development. For example, if a water cycle management study is prepared for a development in a business park without considering Council's stormwater management strategy for that business park, Council may, when assessing the development, require modifications to the proposed stormwater management measures to be consistent with the strategy. This can cause significant delays to the development and extra costs to the applicant. Also, if it is proposed to transfer responsibility of any stormwater treatment devices over to Council, it is important to reach agreement with Council for it to take on future maintenance and management responsibilities for such devices. Some council's do not accept responsibility for certain stormwater quality improvement devices so these should be discussed and agreed upon prior to submission of the proposal.

3.2 Step 2 – Site analysis

Identify current land uses – Gather information about current land use from the owner/developer, from existing maps and from any other available property information from Council and various agencies. It will also require a realistic assessment of the existing impervious areas associated with existing infrastructure, such as buildings, driveways and roads.

Identify catchment and sub-catchments – Undertake a site inspection to become familiar with the overall site characteristics and confirm that the information gathered is accurate, including current land use, topography, soils, and natural features such as stands of existing vegetation, flow pathways and waterways.

Identify drainage patterns – Understand the receiving environment and where the site will ultimately discharge to and if any runoff from external catchments enters the proposed site. This will also help identify appropriate locations for any stormwater treatment measures.

Identify site opportunities and constraints – Identify existing infrastructure, areas of open space, existing poorly drained areas that could be reconfigured into wetlands, flood risk, permeability issues, steep slopes, erodible soils, saline soils, natural vegetation.

Consider the proposed use – Analyse and evaluate the suitability of the proposed site and identify areas that need further investigation and consideration. WaterNSW's 'Water Sensitive Design Guide for Rural Residential Subdivisions' (WaterNSW, 2023a) may provide guidance for subdivision developments.

3.3 Step 3 – Consult relevant authorities

It is necessary to consult with consent and reviewing authorities to identify any issues that require their consideration. This may include a discussion of constraints and how they may potentially be addressed for large scale or complex developments, developments located in environmentally sensitive locations, or development that are potentially significant pollutant sources. It may also simply confirm where the assessment point for NorBE should be.

3.4 Step 4 – Select and load meteorological template

WaterNSW provides meteorological templates (music-climate-zone-key-maps) that include the rainfall and potential evapo-transpiration data for various catchment areas and which form the basis for the hydrologic calculations in MUSIC.

3.4.1   Select climate data and set up meteorological template

To identify the appropriate climate zone for the meteorological template file, first identify the sub-catchment where the proposed development will be located from Figure 3.1, then identify the relevant climatic zone from the key on the map. Where a development site straddles the boundary of two adjacent zones it is important to choose the sub-catchment with higher rainfall. It should be noted that rainfall Zone 1 has the lowest rainfall and Zone 9 has the highest rainfall.

> **MUSIC climate templates**
>
> The relevant MUSIC climate templates for each climate zone are provided by WaterNSW and can be downloaded from WaterNSW's website. They can be loaded directly into MUSIC simply by clicking on *New* then open template from a different directory, shown as a yellow file folder icon with a green arrow, and opening the climate template either directly or in another directory where the user may have saved them. A useful tip is to save them directly into the Program Files\MUSIC Version 6\Template directory on your computer. They will then be available in the same directory as the default climate templates supplied with MUSIC.

The rainfall files contain 6-minute time step data, over a period of five years, and which includes a range of wet and drier years to ensure conditions simulated are realistic. These climate templates must be used for MUSIC modelling in the Sydney drinking water catchment areas. Depending on the complexity of the model a longer time step, for example hourly, can be used to speed up runtimes while setting up the model, however, the submitted model and NorBE evaluation must use the 6-minute rainfall data supplied by WaterNSW.

Table 3.1:   WaterNSW sub-catchments (see locations in Figure 3.1)

No.	Name	No.	Name
1	Upper Shoalhaven River	15	Kangaroo River
2	Jerrabattagulla Creek	16	Wingecarribee River
3	Back & Round Mountain Creeks	17	Upper Nepean River
4	Braidwood	18	Nattai River
5	Mongarlowe River	19	Little River
6	Reedy Creek	20	Woronora River
7	Boro Creek	21	Werri Berri Creek
8	Mulwaree River	22	Lake Burragorang
9	Nerrimunga River	23	Kowmung River
10	Mid Shoalhaven River	24	Mid Coxs River
11	Endrick River	25	Lower Coxs River
12	Bungonia Creek	26	Grose River - Blue Mountains Catchments
13	Upper Wollondilly River	27	Upper Coxs River
14	Wollondilly River		
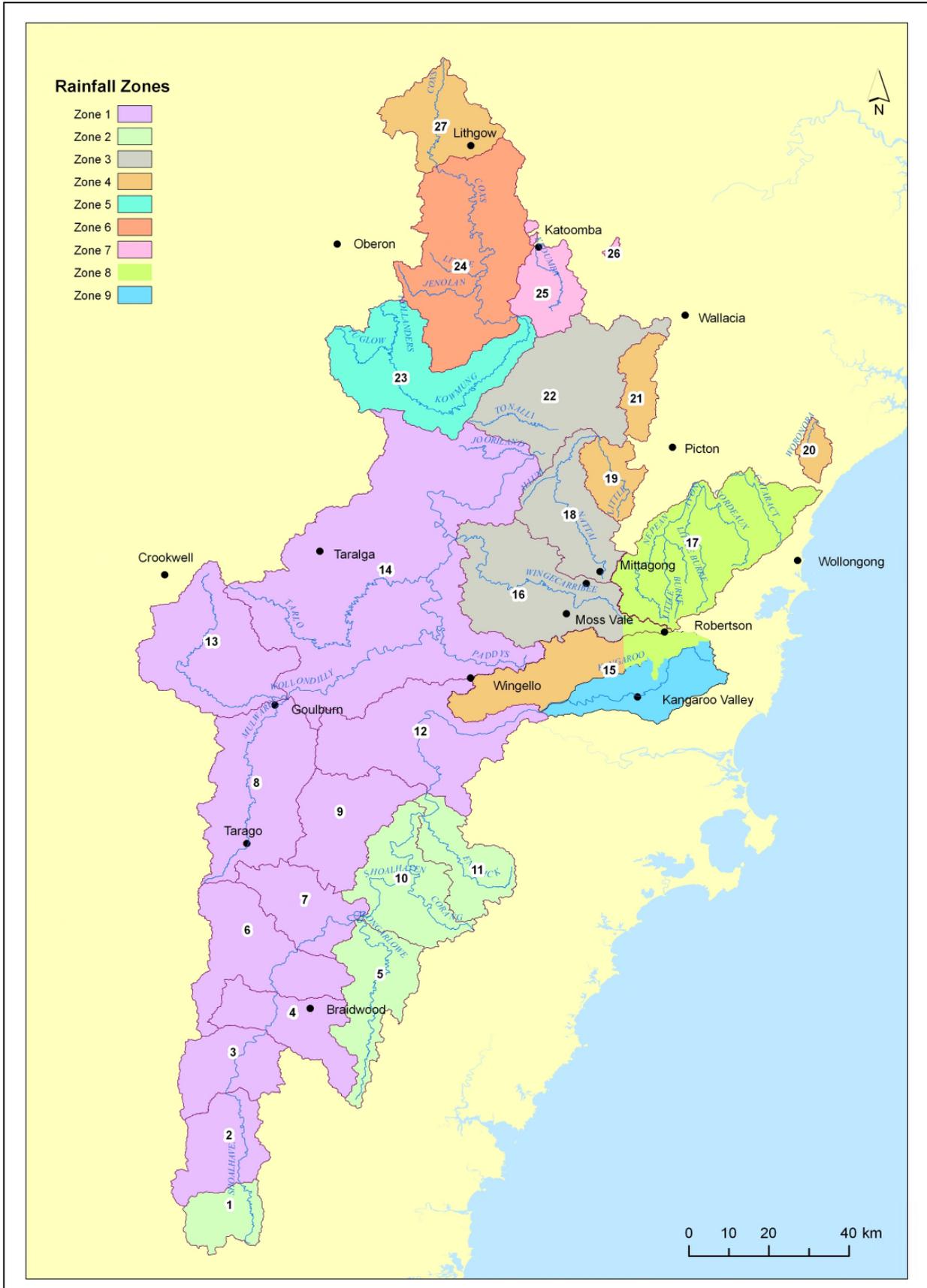
Figure 3.1: Sydney Drinking Water Catchment MUSIC climate zones
(see Table 3.1 for sub-catchment names)

3.5 Step 5 – Define areas for modelling

3.5.1 Define sub-catchment areas

To properly define the sub-catchment areas in a site, first identify the boundary of the development in relation to the drainage network and contours. This can be done through examination of property records and overlaying them on GIS layers, maps or delineating out the site through survey.

When defining sub-catchments, it is vital to fully understand the site, and this can only be achieved through a site visit. This enables the identification of specific land uses on the site, the underlying terrain and identification of drainage paths and the determination of contributing areas that flow to particular drainage points. The latter is important, where external catchments may drain through the site, so that the development impacts can be quantified separately from any flows coming in from the external catchments. The definition of sub-catchments also requires expert judgment and consideration of the final drainage layout of the post-development site. Large-scale developments often significantly alter natural drainage patterns, and some management measures may also divert drainage to other areas.

For larger rural residential type developments, the part of a site or sub-catchment that would be disturbed by the development footprint should be used.

Figure 3.2 below provides an example showing MUSIC sub-catchments that have been defined for a peri-urban area. In this case, the boundaries were based on three parameters - underlying land use (separating urban areas from rural and industrial areas), contours, and most importantly, existing drainage networks, both piped (shown in blue), and overland flow paths (assumed from the contours).
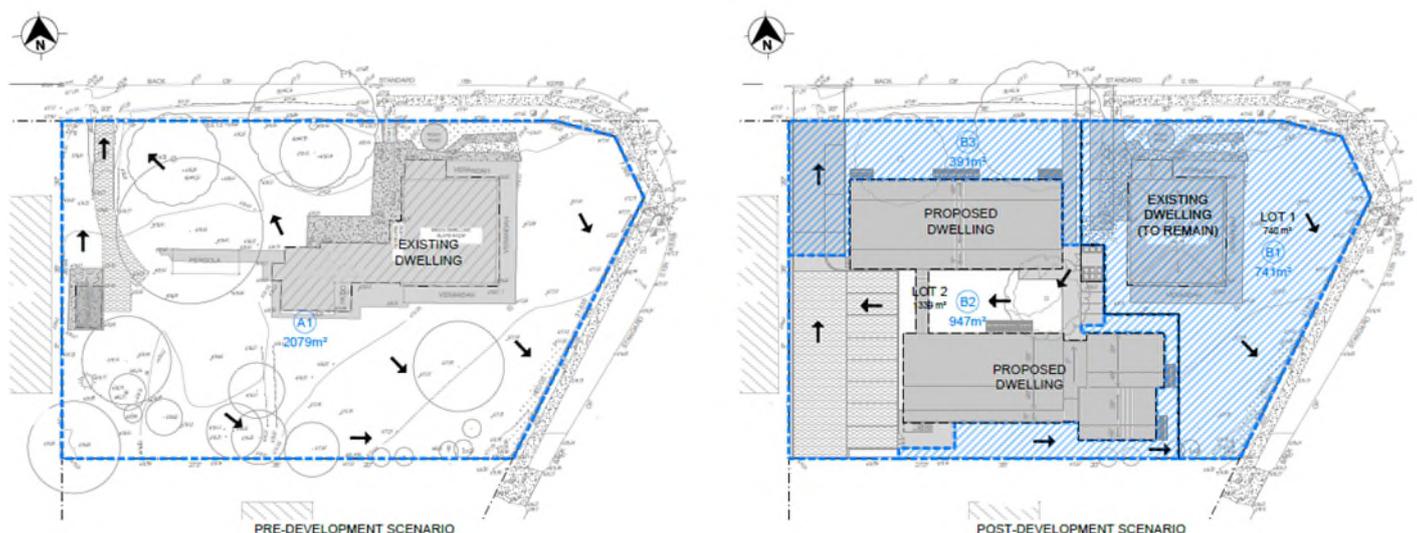
Figure 3.2: **An example of the delineation of sub-catchments for MUSIC modelling (only some sub-catchments are shown)**

3.5.2 Define location of treatment options

It is preferable and often more effective for all developments but particularly larger ones, to have source control, possibly integrated into landscaping, rather than relying on a single outlet or end-of-pipe treatment measures.

Another key issue to consider is whether the treatment measures would be positioned off-line or on-line. On-line refers to treatment measures located along or within natural drainage lines, dams or watercourses that may also convey flow from catchment areas beyond the site boundaries. Off-line refers to treatment measures that are not located in the natural drainage network and are located at or near the source, for example in lots, road reserves, or outside riparian zones adjacent to watercourses. WaterNSW generally requires treatment measures to be located off-line as the object of NorBE is to prevent pollutants reaching waterways, and to avoid impairment of treatment performance during high or flood flows. WaterNSW also prefers stormwater measures to be located above the 2% Annual Exceedance Probability (AEP) flood level to prevent impairment of longer-term treatment performance and avoid structural damage. Note that while an inundated swale may not be damaged, a bioretention system inundated by floodwater may be clogged with sediment and is likely to have to be substantially reconstructed. WaterNSW will consider the location of stormwater management structures on floodplains and near watercourses on a case-by-case basis.

For off-line measures, the catchment area input to MUSIC represents the proportion of area inside the development site boundary that would be disturbed by development activities. Areas that will not be disturbed in and upslope of the site should (where practical and appropriate) be diverted around the location of planned stormwater quality management measures to avoid overloading them with runoff or necessitating larger structures to deal with the greater hydraulic load.

In special circumstances, and on a case-by-case basis, WaterNSW may allow the use of on-line treatment measures. However, in such cases, the catchment area must either be quite small, or the greater percentage of the contributing catchment area (more than 80-90%) must be from the proposed development. Further, approvals for such on-line measures may also have to be obtained from government authorities, such as the Department of Planning and Environment – Water (DPE - Water) or the Natural Resources Access Regulator (NRAR) for controlled activities under the *Water Management Act 2000*. Any such on-line measure should be discussed with and agreed to by WaterNSW before it is formally proposed. Any on-line treatment measure must be sized to deal with the total hydraulic load regardless of its origin (including that derived from upstream of the site) to ensure satisfactory performance.

NorBE should be assessed for the proposed development site only. Estimated flows and pollutant loads from any external catchment area and undisturbed site area should be subtracted from the total pre- and post-development loads draining to the measure. By doing this, flow and pollutants from the unmodified catchment area do not mask or buffer any increased pollutant loads from developed areas.

3.5.3 Examples

Examples of some approaches a modeller may consider when defining site sub-catchment areas in MUSIC are shown in the following sections.

3.5.3.1 Individual building lot

Simulation of an individual building in MUSIC can be achieved using a 1-node model to represent the average conditions of the land use being simulated (such as rural residential or urban residential). This approach is best applied when the proposed treatment measures will treat runoff from all the combined surfaces. If a measure is proposed to treat runoff from a specific surface, this scenario can only be modelled appropriately by dividing the lot into different surfaces as shown in Figures 3.3 to 3.5.
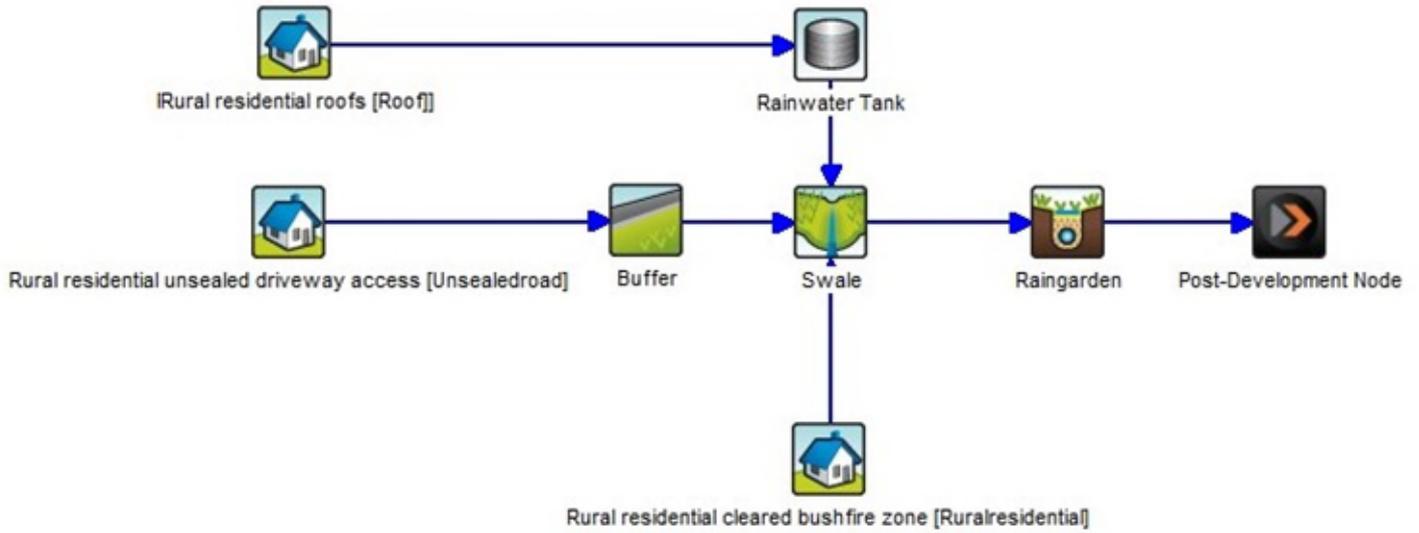
Figure 3.3: **Catchment areas for an individual rural-residential lot - disturbed areas only**
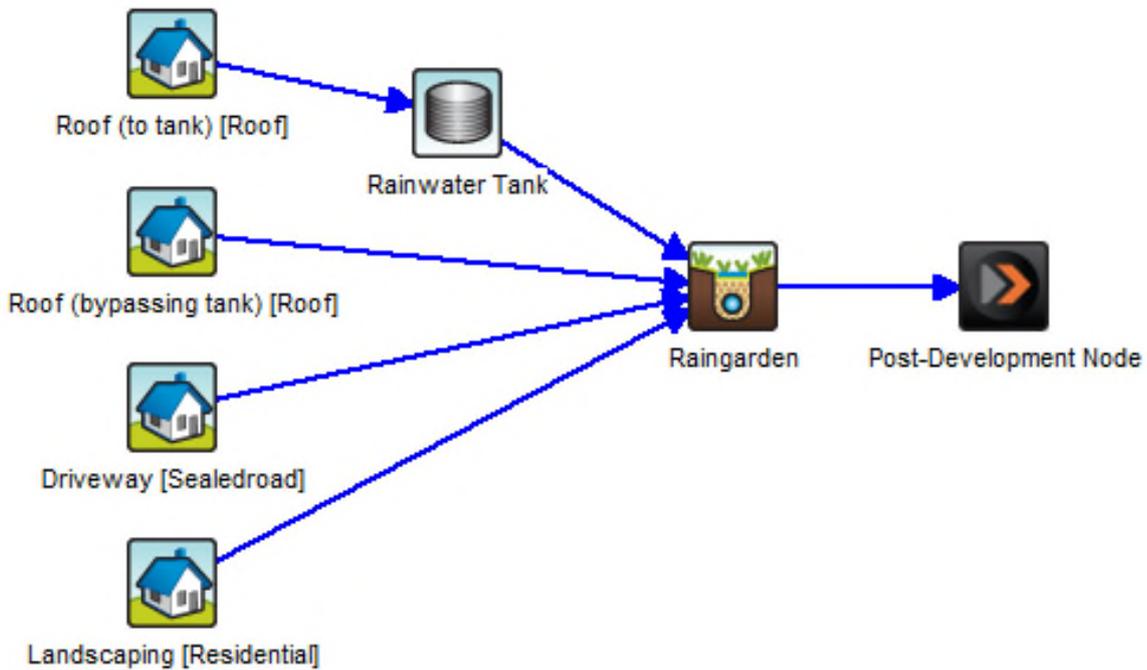
Figure 3.4: **Catchment areas for a single low-density residential lot - all surfaces**
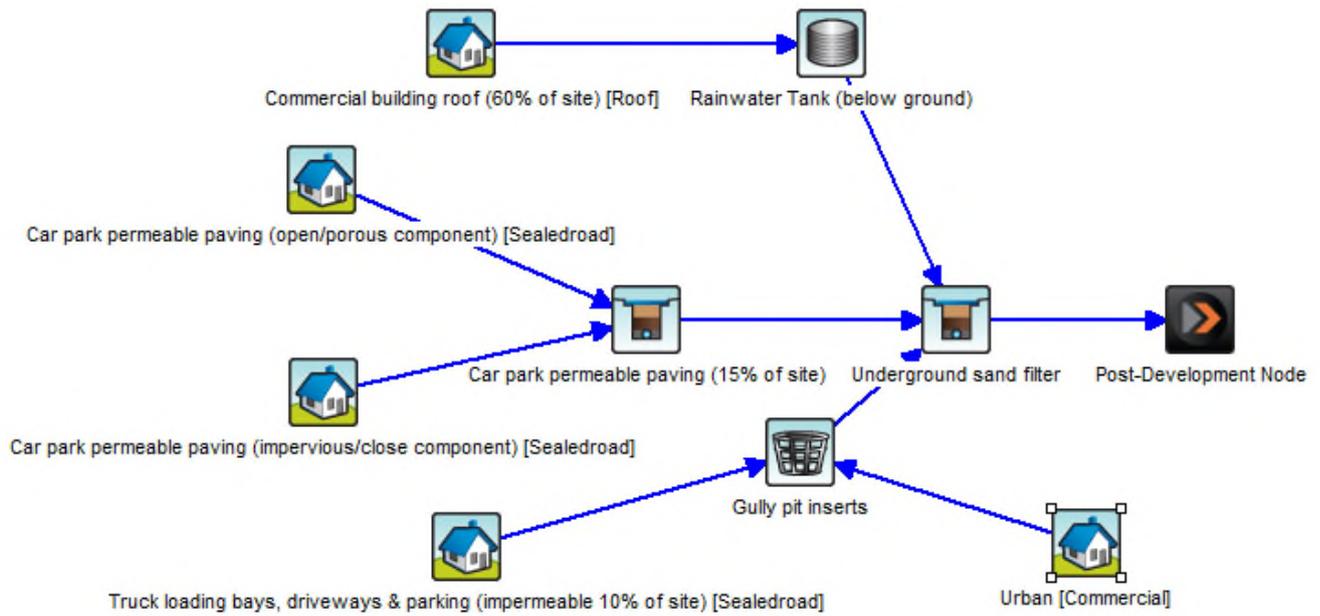
Figure 3.5: **Catchment areas for a commercial lot - all surfaces**

3.5.3.2 *Multiple lots or dwellings*

To simplify the model, the modeller should look to combine areas with similar characteristics (such as lot area, roof area, dwelling footprint, driveway area). The size of the treatment measures estimated using this modelling approach can then be disaggregated and proportioned within the site based on the actual size of each individual lot. When adopting this approach source nodes must be aggregated based on a similar series of treatment nodes and a common discharge location (Figure 3.6).

Alternatively, a conservative approach could be adopted by modelling the lot with the largest catchment/area of disturbance (or a range of individual lot scales) and using the modelled treatment measure size for all lots. This is only appropriate where treatment measures are entirely contained on each lot **and** all other environmental aspects for each lot that impact on modelled outcomes are similar.
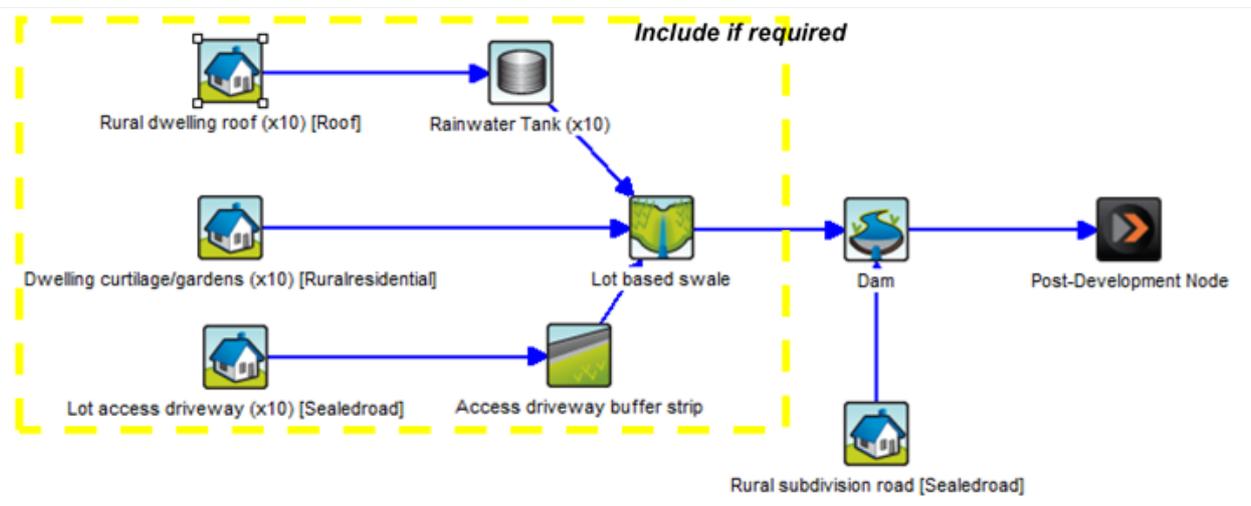
Figure 3.6: **Combined catchment areas for a 10-lot rural subdivision**

Where off-line treatment measures are to be positioned outside the lots in areas such as in road reserves or public open space, it may be possible to divide the site according to the areas draining to specific locations (Figure 3.7).
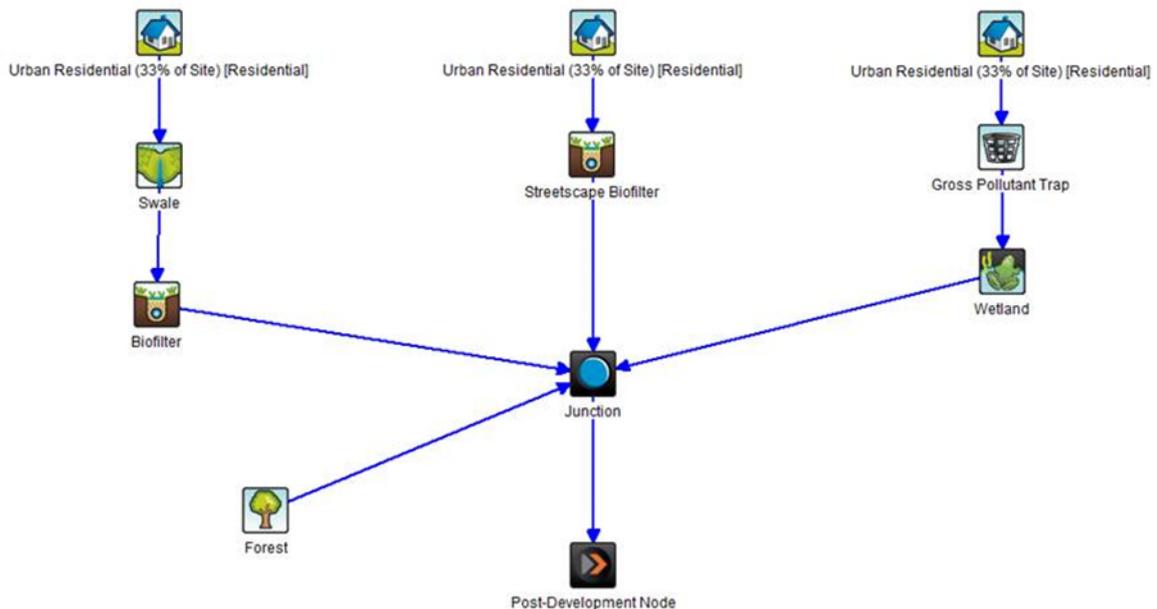
Figure 3.7:   Proportioning catchment areas

3.5.3.3   Large scale developments

Where the treatment nodes can and are to be concentrated near the catchment/site outlet, simplifying the catchment into broad land uses will probably provide a reasonable modelling approach. This large scale approach is shown in Figure 3.8.
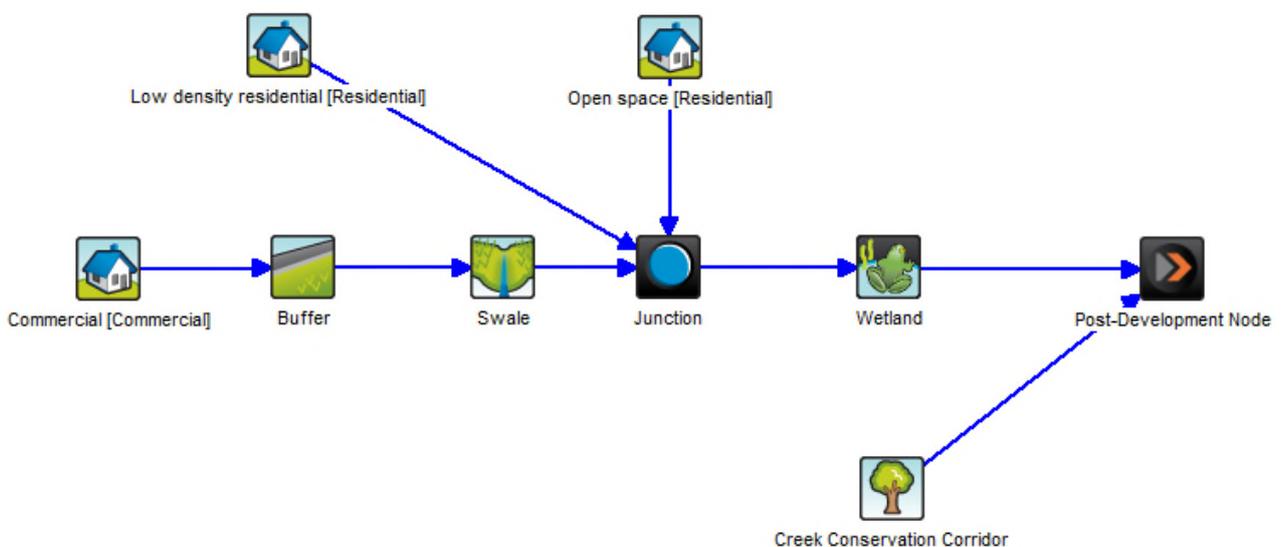
Figure 3.8:   Catchments defined according to broad land uses

4 DEVELOPING A PRE-DEVELOPMENT SCENARIO

4.1 Step 5 – Setting up a pre-development MUSIC model

4.1.1 Setting up source nodes

4.1.1.1 Source node types

The next step in creating a MUSIC model is to define source nodes that represent hydrologic sub-catchments. The information in this section applies equally well to existing and future scenario source nodes. The total catchment area modelled should be equivalent for the pre- and post-development.

MUSIC currently incorporates five source node types (urban, agricultural, forest, user defined and imported data). Modelling developments in the Sydney drinking water catchment should only use the urban, agricultural and forest nodes together with modified base flow and storm flow pollutant generation values as shown in Tables 4.6 and 4.7. The site's surface types and land use/zonings should be translated into MUSIC source nodes according to Table 4.1. It is noted that MUSIC version 6 includes Landuse Zoning/Surface Type categories within the 'Urban' node, consistent with those listed in Table 4.1 below. When selected, the base flow and storm flow pollutant values are automatically populated within the node with those values shown in Tables 4.6 and 4.7 of this guide. Note some default parameters (for eroded gullies, agricultural and forest nodes for both baseflow and stormflow) are inconsistent with values in Tables 4.6 and 4.7. Until such times these values are corrected in a future version of MUSIC, manually enter the correct values.

Users are urged to select the appropriate source node for the development for accuracy of modelling and consistency with this guide.

Table 4.1:   Translation of surface types and land use/zoning into MUSIC source nodes

Surface type or land use/zoning	Adopt parameters for
Surface type	
Roofs	Roofs
Unsealed/partially sealed roads	Unsealed roads
Sealed roads including rural sealed roads	Sealed roads
Private residential landscaping/gardens	Residential
Revegetated land	Rural
Land use/zoning	
All urban residential zones	Residential
All commercial zones	Commercial
All industrial zones	Industrial
Schools	Residential
Urban parks	Residential
National Park	Forest[1]
Protected land	Forest[1]
Rural residential	Rural residential
Rural grazing	Agriculture
Nurseries	Agriculture
Quarries	Unsealed roads

[1] Forest do occur on private land. Where private land has tree cover, thick mulch and permeable soil, adopt parameters for 'Forest Node' and where there is evidence of little or no mulch and hard surfaces, adopt parameters for 'Rural residential'.

4.1.2   Catchment area and impervious area

The total area and the proportion of effective impervious area need to be defined for each MUSIC source node. These values, together with the rainfall data and soil properties, define the runoff generated from the modelled catchment area. The effective impervious area (EIA) - referred to as imperviousness in MUSIC - is approximately equivalent to the directly connected impervious area and is expressed as a percentage of the total impervious area (TIA). It is a measure of the area of land that is directly connected to the stormwater or natural drainage system.

The effective impervious area shall be estimated from the values outlined for either of the two approaches in Table 4.2. The first approach based on surface types is typically used for smaller developments, and larger developments where measures are proposed to manage runoff from specific surfaces (such as rainwater tanks for roof runoff). For this approach, the effective impervious area should be determined directly from the site layout plan. For the post-development case, it should be confirmed that the effective impervious area values presented in the table are appropriate for the specific development layout being modelled. The broad land use or zoning approach should only be applied for larger catchments/developments where there is limited data on the connectivity of the drainage system and detailed site plans are not available, and where all stormwater management measures are proposed at the sub-catchment scale.

Table 4.2:   Default effective impervious area proportions

Surface type and land use/zoning	Effective impervious area[1]
Surface types approach	
Roofs	1.0 x TIA
Sealed roads[2]	1.0 x TIA
Permeable paving	1.0 x TIA
Unsealed roads	0.5 x TIA
Paved landscaping	0.5 x TIA
Vegetated landscaping (areas over a large scale)	0.05 x TIA
Revegetated land	0.00 x TIA
Land use or zoning approach	
Residential	0.55 x TIA
Commercial	0.80 x TIA
Industrial	0.90 x TIA
Rural residential	0.05 x TA
Agricultural / grazing	0.00 x TA
Native/plantation forest	0.00 x TA

TIA = Total impervious area; **TA** = Total site, catchment or surface area,

[1] Wherever available and possible use detailed site plans for effective impervious area calculations, otherwise use land use zoning approach.

[2] Rural sealed roads should include unsealed shoulders and should be modelled as 0.5 x TIA.

4.1.2.1   Calculating effective impervious area

From Table 4.2, when using the surface types approach, it is necessary to know the layout of the site with sufficient detail to estimate the areas of the different surface types. It also requires identification of impervious areas that will flow directly to the drainage network, including roadside kerbs, piped drainage, gully pits or inter-allotment drainage. These will be the areas that will be 'effective' in generating runoff and will deliver stormwater rapidly to the catchment outlet during a rainfall event.

In the Figure 4.1 example, assuming a total lot area of 800 m^2, the total impervious area would be the combined area of the driveway, patio, garage, house roof and shed, or 360 m^2, giving a total impervious percentage of 45%. To determine the effective impervious area, only consider the areas that are connected directly to the stormwater drainage network either into a pipe or via the kerb. Given that the free-standing shed is not connected and assuming that only 30 m^2 of the driveway discharges to the kerb, the effective impervious area is only the combined area of the house roof, the garage, and the proportion of the driveway that flows to the kerb. In this case (noting that the correction factors in Table 4.2 do not apply) the effective impervious area is 230 m^2, giving an effective impervious area percentage of 29%.
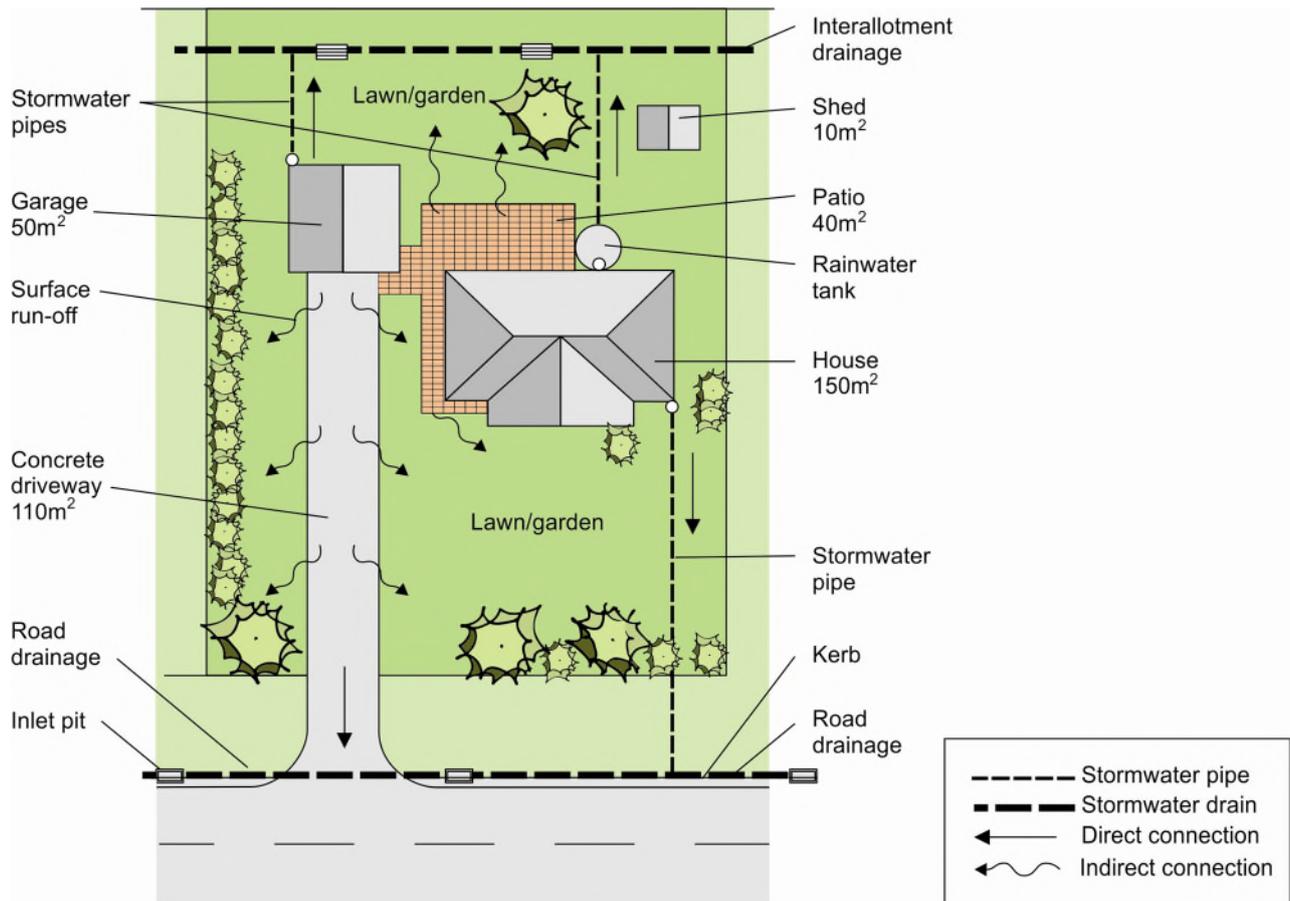
Figure 4.1: **Differences in directly connected and indirectly connected impervious areas for determining effective impervious area**

4.1.3 Rainfall-runoff parameters

4.1.3.1 Impervious area parameters

Table 4.3 provides the rainfall threshold values, above which runoff is generated, that should be adopted in MUSIC models.

4.1.3.2 Pervious area parameters

Appropriate parameters should be selected based on the dominant soil type and average soil depth of the root zone in the site. Where there is more than one soil type across the site, use the rainfall-runoff parameters for the soil type that results in a lower estimate of flow volume for the pre-development condition for the entire site. Soil texture should be determined from geotechnical soil information obtained for the development site. Care must be taken in appropriately modelling post-development soil characteristics, as they may be substantially changed from the pre-development case due to compaction, removal or replacement of topsoil, or the importing of fill.

Table 4.3:   Default rainfall threshold values

Surface type	Rainfall threshold (mm) [1]
Roofs	0.3
Sealed roads, driveways, paving, car parks and paths	1.5
Unsealed roads and car parks	1.5
Permeable paving (open proportion)[2]	0
Permeable paving (paved proportion)[1]	1.5
Land use zoning	
For all land uses (residential, rural residential etc.)	1.0

[1] Rainfall threshold is related to impervious areas only. Any changes to rainfall thresholds must be justified.

[2] Refer to Section 5.2.2.2 for further discussion on modelling permeable paving

To derive the pervious area parameters to use in MUSIC, the field texture of the soil and the soil depth of the root zone (see Macleod, 2008) are required. These are used to determine the soil storage capacity (the maximum water storage capacity in millimetres of pervious soils) and field capacity (the maximum water storage in the soil without gravity drainage to groundwater). This guide uses a soil depth of 0.5 m for the root zone as only a few vegetation types such as forests would have deeper root zones. As a result, evapo-transpiration is unlikely to be significant in predicting water loss from pervious areas below the adopted 0.5 m depth.

Table 4.4 should be consulted to determine the soil storage capacity and field capacity depending on the existing and likely future soil conditions. The remaining pervious area parameters to be used can then be selected from Table 4.5. Use the default MUSIC parameter values for initial storage (percentage of capacity) and initial depth (mm) for all soil types.

Table 4.4: **Soil storage capacity and field capacity for a 0.5 m root-zone depth**
Source: Macleod, 2008

Dominant soil description	Root zone soil depth (0.5 m)	
	Soil storage capacity (mm)	Field capacity (mm)
Sand	175	74
Loamy sand	139	69
Clayey sand	107	75
Sandy loam	98	70
Loam	97	79
Silty loam	100	87
Sandy clay loam	108	73
Clay loam	119	99
Clay loam, sandy	133	89
Silty clay loam	88	70
Sandy clay	142	94
Silty clay	54	51
Light clay	98	73
Light-medium clay	90	67
Medium clay	94	70
Medium-heavy clay	94	70
Heavy clay	90	58

Table 4.5: **Other soil rainfall-runoff parameters for a 0.5 m root-zone depth**
(adapted from Macleod, 2008)

Dominant soil description	Soil rainfall-runoff parameters[1]				
	Infiltration capacity coefficient-a (mm/d)	Infiltration capacity exponent-b	Daily recharge rate (%)	Daily baseflow rate (%)	Daily seepage rate (%)
Sand, loamy sand	360	0.5	100	50	0
Clayey sand, sandy loam, loam, silty loam, sandy clay loam	250	1.3	60	45	0
Clay loam, sandy clay loam, silty clay loam, sandy clay, silty clay	180	3.0	25	25	0
Light clay, light medium clay, medium clay, medium heavy clay, heavy clay	135	4.0	10	10	0

[1] These parameter estimates are based on soil properties only. There is no allowance for rainfall losses associated with depression storage, mulch, vegetation interception and other non-soil sources of water storage in a catchment.

4.1.4   Stormwater pollutant input parameters

Tables 4.6 and 4.7 show the stormwater pollutant input parameters to be used for each surface type and land use or zoning for base flow and storm flow. Strong justification must be provided where alternative pollutant input values are used. Base flow parameters are applied to groundwater flow, and storm flow parameters are applied to surface runoff. In all cases, the stochastic generation option for pollutant generation must be selected.

Table 4.6:   Base flow pollutant concentration parameters[1] (based on Fletcher _et al_., 2004)

Concentration (mg/L-log$_{10}$)	Total suspended solids		Total phosphorus		Total nitrogen	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Surface type						
Roofs[2]	-	-	-	-	-	-
Sealed roads[3]	1.20	0.17	-0.85	0.19	0.11	0.12
Unsealed roads[4]	1.20	0.17	-0.85	0.19	0.11	0.12
Eroding gullies[4]	1.20	0.17	-0.85	0.19	0.11	0.12
Revegetated land[4, 5]	1.15	0.17	-1.22	0.19	-0.05	0.12
Quarries[4]	1.20	0.17	-0.85	0.19	0.11	0.12
Land use/zoning						
Residential	1.20	0.17	-0.85	0.19	0.11	0.12
Commercial	1.20	0.17	-0.85	0.19	0.11	0.12
Industrial	1.20	0.17	-0.85	0.19	0.11	0.12
Rural residential	1.15	0.17	-1.22	0.19	-0.05	0.12
Agricultural	1.30	0.13	-1.05	0.13	0.04	0.13
Forest	0.78	0.13	-1.52	0.13	-0.52	0.13

[1] Derived for NSW.

[2] Roofs have no base flow.

[3] Most urban sealed roads are fully sealed to a gutter or concrete edge and thus have no baseflow, whereas rural sealed roads invariably include unsealed shoulders, which do generate baseflow. Rural sealed roads should therefore be modelled with the shoulders and given a 50% impervious value – see footnote Table 4.2.

[4] Additional surface types not included in Fletcher et al. (2004).

[5] Revegetated land means cleared land that has been replanted with trees and shrubs and fenced-off from livestock.

Table 4.7:   Storm flow pollutant concentration parameters[1] (based on Fletcher _et al_., 2004)

Concentration (mg/L-log$_{10}$)	Total suspended solids		Total phosphorus		Total nitrogen	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Surface type						
Roofs	1.30	0.32	-0.89	0.25	0.30	0.19
Sealed roads	2.43	0.32	-0.30	0.25	0.34	0.19
Unsealed roads[2]	3.00	0.32	-0.30	0.25	0.34	0.19
Eroding gullies[2]	3.00	0.32	-0.30	0.25	0.34	0.19
Revegetated land[2, 3]	1.95	0.32	-0.66	0.25	0.30	0.19
Quarries[2]	3.00	0.32	-0.30	0.25	0.34	0.19

Land use/zoning						
Residential	2.15	0.32	-0.60	0.25	0.30	0.19
Commercial	2.15	0.32	-0.60	0.25	0.30	0.19
Industrial	2.15	0.32	-0.60	0.25	0.30	0.19
Rural residential	1.95	0.32	-0.66	0.25	0.30	0.19
Agricultural	2.15	0.31	-0.22	0.30	0.48	0.26
Forest	1.60	0.20	-1.10	0.22	-0.05	0.24

[1] Derived for NSW.

[2] Additional surface types not included in Fletcher et al. (2004).

[3] Revegetated land means cleared land that has been replanted with trees and shrubs and fenced-off.

4.1.5   Serial correlation

MUSIC version 6 allows manual input of serial correlation values between pollutant concentrations in source nodes. It was introduced because there can be strong correlations for key pollutants, particularly stormflow total suspended solids and total phosphorus concentrations, which can be used to create more realistic 'pollutographs' (cumulative frequency graphs for pollutant concentrations - see Section 5.3.2). However, using serial correlation makes stochastically modelled outcomes more variable. This makes it harder to assess models in relation to the required 10% improvement in modelled pollutant loads needed to meet NorBE. As a result, the default serial correlation value, which varies with time step, should be zero, which is the default value of MUSIC version 6. The estimation method should be 'Stochastically generated'.

4.1.6   Existing treatment nodes

The presence of existing treatment nodes on the development site such as farm dams, ponds, wetlands, swales, and rainwater tanks must be included in the pre-development node to account for water quality improvements that these measures provide to the predevelopment site. If these existing water quality improvement measures will be retained in the post development case, then they should be included in the post development modelling case. Where these water quality improvements measures are to be retained, a statement should be included in the water cycle management study stating that they are to be retained. This will be captured in conditions of consent.

4.1.7   Joining source nodes and running a pre-development model

Once the source nodes have been properly defined, they should be joined up in a manner that is consistent with the overall drainage pattern of the site. It is useful to use Junction nodes in MUSIC to provide a visual reference that reflects the overall drainage network. When the network is completed, the pre-development MUSIC model should be simulated for subsequent comparison with the post-development case. Note that in MUSIC version 6, both pre- and post-development models ending in pre-development and post-development nodes can be developed and run in the same file.

5 DEVELOPING A POST-DEVELOPMENT SCENARIO

5.1 Step 6 – Setting up a post-development MUSIC model

A second MUSIC model (often a modified version of the pre-development) must be prepared to simulate the post-development case. The pre- and post-development cases should be included in one MUSIC file. In MUSIC version 6, pre-development and post-development nodes should be used as these will enable easy comparison of pollutant loads and concentrations (see Section 5.3.3).

The new source nodes relevant to post-development land uses and site layout are set up in a similar way as were set up for pre-development case as per Sections 4.1.1 to 4.1.5. The total catchment area modelled should be equivalent for the pre- and post-development cases.

In addition to new source nodes, treatment measures need to be selected to address the changes in pollutant loads and concentrations caused by the development. The following sections provide guidance on developing a treatment train, considering treatment processes, selecting site and development-specific treatment measures, and simulating the performance of treatment measures.

5.1.1 Developing a water quality treatment train

Developing a stormwater quality treatment system, or strategy to treat stormwater runoff though water sensitive design (WSD) measures (as discussed in Section 2.4.3), should be a series of 'fit for purpose' treatment measures placed sequentially to form a treatment train. As single treatment measure may not adequately address the full range of pollutants generated from a development site, a treatment train consisting of a connected series of individual treatment measures must be developed. This should consider the best operating environment for each treatment measure and must take into account the hydraulic and treatment capabilities of the treatment measures.

The treatment train should be suitable for the site and development type. It may include treatment from primary through to tertiary that specifically aims to treat stormwater for the target pollutants.

5.1.2 Treatment processes

As discussed above, each treatment measure operates over particular hydraulic loading rates (that is the quantity of water able to pass through a given surface area of the treatment measure) and pollutant size ranges. The pollutants typically targeted for removal by water sensitive design measures (such as sediment, nutrients, and litter) can have very large size ranges, as shown in Figure 5.1. The figure shows that a single treatment measure may not be suitable to treat certain pollutants. For example, while a vegetated swale may remove some nutrients, it will not be effective for the colloidal and dissolved material that a wetland will treat more efficiently. A swale could become a pre-treatment measure for a wetland, and so creates a treatment train.

Figure 5.1 also shows that to remove gross pollutants and coarse sediment, the hydraulic loading rate can be very high, whereas a much smaller hydraulic loading rate is necessary to effectively remove nutrients or metals. To remove nutrients either less water can be treated, or a larger treatment measure is required to treat an equivalent amount of water.

For this reason, treatment trains should focus on treating gross particulates first (such as larger organic matter and litter), then coarse particulates (sediment) and finally fine, colloidal and dissolved material. Configuring the treatment train this way also provides a pre-treatment or protection function to downstream treatment measures. Treatment devices sized to treat gross pollutants and coarse sediment will ensure that downstream devices are not damaged or impaired by excessive quantities of pollutants that they are not designed to treat. For example, a bioretention basin located downstream of a development site may become clogged with coarse sediment very quickly if no upstream sediment treatment measure has been provided.

Size range (µm)	Pollutant					Treatment mechanism
	Litter	Sediment	Nutrients	Organics	Metals	
>5000 (gross solids)						Screening
5000–125 (coarse)						Sedimentation
125–10 (fine)						Enhanced sedimentation
10–0.45 (colloidal)						Adhesion and filtration
<0.45 (dissolved)						Biological uptake

Size range (µm)	Treatment					Hydraulic loading rate - inflow/ surface area (m³/m²/yr)
	Gross pollutant traps	Sediment basins	Swales and buffer strips	Constructed wetlands	Biofilters	
>5000 (gross solids)						1,000,000 - 100,000
5000–125 (coarse)						50,000 - 5,000
125–10 (fine)						2,500 - 1,000
10–0.45 (colloidal)						500 - 50
<0.45 (dissolved)						10

Figure 5.1:   Relationship of pollutant type and particle size to treatment measure effectiveness and hydraulic loading (after MUSIC Version 6 Documentation)
https://wiki.ewater.org.au/display/MD6/MUSIC+v6+Documentation+and+Help+Home

5.1.3 Choosing optimal water sensitive design measures

A list of possible water sensitive design measures or devices should be selected to develop a series of alternative treatment trains for the proposed development based on the interpreted site conditions and site opportunities and constraints. Any selection should consider primary treatment measures mainly to remove gross pollutants and coarse sediments, secondary measures mainly to treat finer materials, and tertiary measures to treat colloidal and dissolved materials. Other issues that should be considered to choose the best and most appropriate treatment measures include:

- the site and development-specific nature of proposed measures - for example, low-density subdivisions generally have larger allotments. Landscaped water sensitive design elements, such as swales and buffer strips, can be incorporated into road reserves, and wetlands incorporated into natural depressions. In high density developments water sensitive design elements may need to be incorporated into courtyards and roof areas (as per Figures 5.2 and 5.3)

- the use of a distributed versus a 'bottom-of-catchment' or 'end of pipe' approach - a distributed approach can give improved removal efficiencies as the flow volumes and velocities are lower, however, capital and maintenance costs may be higher

- integration with urban design, including road and lot layouts (for example clustering houses to use a central stormwater treatment measure, reducing road widths to decrease impervious area and allow the incorporation of grassed roadside swales

- the environmental suitability of measures (for example existing native woodland or forest vegetation should be kept where possible)

- the appropriateness of some water sensitive design measures in certain more rural locations (for example bioretention systems may not be suitable along rural subdivision roads)

- the cost-to-benefit ratio of the number of treatment devices (capital and maintenance costs) against the water quality outcome achieved

- the life cycle costs and ongoing maintenance requirements and resources (for example if a device is to be handed over to Council it needs to be on the basis that Council will be committed to maintaining the devices)

- the workplace health and safety issues for maintenance crews (for example maintenance should not require direct contact with pollutants and other trapped materials, and avoid the need to enter confined spaces)

- the ease and practicality of ongoing management and maintenance of stormwater treatment devices (this includes access to devices)

- general public amenity and safety (for example consider and address risks associated with open water bodies and water ponds), and

- the reduction in the treatment effectiveness of stormwater management measures over the short and longer term where they are not properly maintained – this could be a lack of regular cleaning of a proprietary stormwater quality improvement device or the slow deterioration of a bioretention system over time where there is no periodic maintenance.

Figure 5.2: **Wetland in a low-density development**

Figure 5.3: **Bioretention basin for urban development**

A number of factors must be considered when choosing the final treatment train for the site. These factors should be considered alongside the opportunities and constraints identified at the site, and the opportunities to layout the development to respond to water sensitive design principles. Tables 5.1 and 5.2 outline the scales of application of particular treatment measure types and some of the constraints to consider. More guidance is provided in Australian Runoff Quality (Wong, 2006) and other stormwater guidelines.

Table 5.1: General suitability of water sensitive design applications at various scales

Water sensitive design measure	Allotment scale[1]	Street scale	Regional scale	Suitability for rural development[1]
Primary treatment measures				
Rainwater tanks	S	N/A	N/A	S
Buffer strips	S	S	N/A	NS
Gross pollutant traps	S	S	S	P
Sedimentation basins	NS	S	S	S
Secondary treatment measures				
Infiltration measures	S	S	S	S
Permeable paving	S	S	NS	NS
Vegetated swales	S	S	S	S
Sand filters	S	S	S	NS
Mitre drains	NS	S	S	S
Rehabilitation of eroded gullies	S	S	S	S
Ponds	NS	P	S	S
Proprietary Filtration Devices[2]	S	P	NS	NS
Tertiary treatment measures				
Constructed/Floating wetlands	NS	P	S	S
Bioretention measures	S	S	NS	NS

S - Suitable; **NS** - Not Suitable; **P** - Possible; **N/A** - Not Applicable

[1] On some larger rural lots some of the measures indicated as not suitable may be appropriate and vice versa. For example in unsewered peri-urban areas open vegetated swales may conflict with required setback distances to on-site wastewater management areas.

[2] Proprietary filtration devices are generally used where space is constrained e.g. commercial, industrial and multi-dwelling and developments.

Table 5.2: Site constraints for water sensitive design measures (adapted from Moreton Bay Waterways and Catchments Partnership, 2006)

Water sensitive design measure	Steep site	Shallow bedrock	Low permeability soil (eg clay)	High permeability soil (eg sand)	High water table	High sediment input	Land availability
Primary treatment measures							
Rainwater tanks	✓	✓	✓	✓	✓	✓	✓
Buffer strips	C	D	✓	✓	D	D	C
Gross pollutant traps	D	D	✓	✓	D	✓	✓
Sedimentation basins	C	✓	✓	✓	D	✓	C
Secondary treatment measures							
Infiltration measures	C	C	C	✓	C	C	C
Permeable paving	C	✓	✓	✓	✓	C	✓
Vegetated swales	C	D	✓	✓	D	D	C
Sand filters	D	✓	✓	✓	D	C	✓
Mitre drains	D	D	✓	✓	✓	D	✓
Rehabilitation of eroded gullies	NA	NA	NA	NA	NA	NA	NA
Ponds	C	D	✓	D	D	D	C
Proprietary Filtration Devices[2]	✓	✓	✓	✓	✓	✓	✓
Tertiary treatment measures							
Constructed/Floating wetlands	C	D	✓	D	D	D	C
Bioretention measures	C	C/D[1]	✓	✓	C	C/D[1]	C

C – Constraint may preclude use; **D** – Constraint may be overcome through appropriate design; ✓ - Generally not a constraint; **NA** – Not applicable

[1] For bioretention swales or basins constraint may preclude use; however, such constraint may be overcome through appropriate design.

[2] The performance of Proprietary devices is subject to large variation depending upon treatment methods and design.

5.2 Treatment node input data

The following sections provide guidance on the input parameter values to be used to simulate the performance of the various treatment measures. This is not intended to be a comprehensive review of the performance of these measures, and further guidance is available in a range of documents listed in the reference section.

5.2.1 Primary treatment measures

5.2.1.1 Rainwater tanks

Rainwater tanks shall be simulated considering the physical constraints of the roof drainage system. Where the tank is located above ground and services a single level building in an urban setting, gravity drainage of the entire roof area to the tank may not be possible. Where the tank is

underground, it may be feasible to drain the entire roof area to the tank. Figures 5.4 and 5.5 show configurations of these situations.

In a rural setting, it is common to seek to drain the entire roof area to rainwater tanks positioned above ground using charged systems or other mechanisms. In an urban setting, some allowance for a proportion of the roof area to bypass the tank should be considered. The modeller should specify for the particular development the proportion of the roof area that can reasonably be drained to a rainwater tank, and the proportion of roof area that would bypass the tank. Rainwater collection and reuse systems should always attempt to incorporate the majority of the roof draining to the tank wherever possible; however, the maximum roof area that can realistically be configured for capture in a rainwater tank is 80%. To ensure a reasonable water quality benefit, rainwater collection and reuse systems should be configured such that at least 50% of the roof area drains to a tank.

Most modern urban rainwater collection systems also incorporate a first flush diversion device to prevent accumulated litter and some dry fallout (dust) from entering the tank. Although from a modelling perspective this first flush diversion represents rainwater tank bypass, this does not need to be considered or modelled in MUSIC as the rainfall threshold for roofs includes an allowance for water lost through first flush diverters.

> ### Why treat rainwater?
>
> In many situations, nitrogen is the pollutant that limits the size of stormwater treatment systems. A significant amount, if not most, of the nitrogen in stormwater comes from the atmosphere via rainfall and dry fallout (dust). Nitrogen concentrations in roof runoff are typically as high as those in ground surface runoff (Fletcher *et al.* 2004). Due to the levels of nitrogen in roof runoff, it is best to ensure that roof runoff is treated through rainwater tanks with re-use in combination with other measures, such as bioretention systems, that effectively remove nitrogen. If roof water is not treated, treatment measures designed to treat stormwater runoff from the remaining site surface areas will need to be oversized to compensate for the roof area that is not being treated. Treating roof runoff is generally more cost effective than over-sizing other treatment measures.

When developing a treatment train, the size of the rainwater tank should be realistic for the type and scale of the development. In the past, WaterNSW have assessed models proposing rainwater tanks with volumes well above what is necessary for residential developments and recommend the values outlined in Table 5.3 be considered when preparing a treatment train that is suitable for the type and scale of your development.

Table 5.3:   Recommended sizing of rainwater tanks for residential developments

Lot size	Rainwater tank size
Less than 500 square metres	2,000 litres
500 to 749 square metres	3,000 litres
750 to 999 square metres	5,000 litres
1,000 to 2,000 square metres	10,000 litres
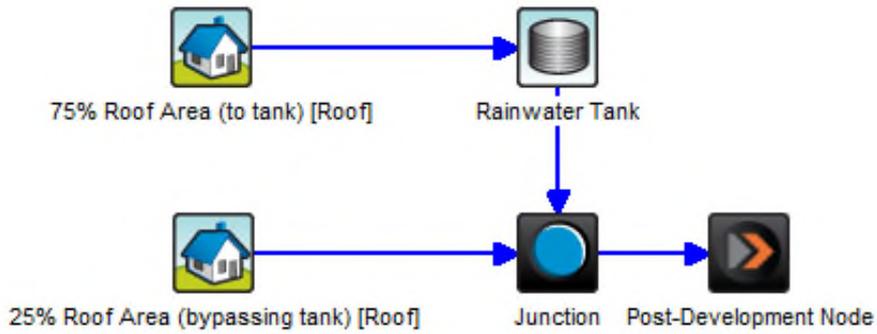
Figure 5.4:   Rainwater tank (urban setting) – roof drained to an above-ground tank

Figure 5.5:   Rainwater tank – roof drained to a below-ground tank

To configure a rainwater tank, the MUSIC model needs several parameters. The representation of rainwater tanks in MUSIC is shown in the conceptual diagram (Figure 5.6).
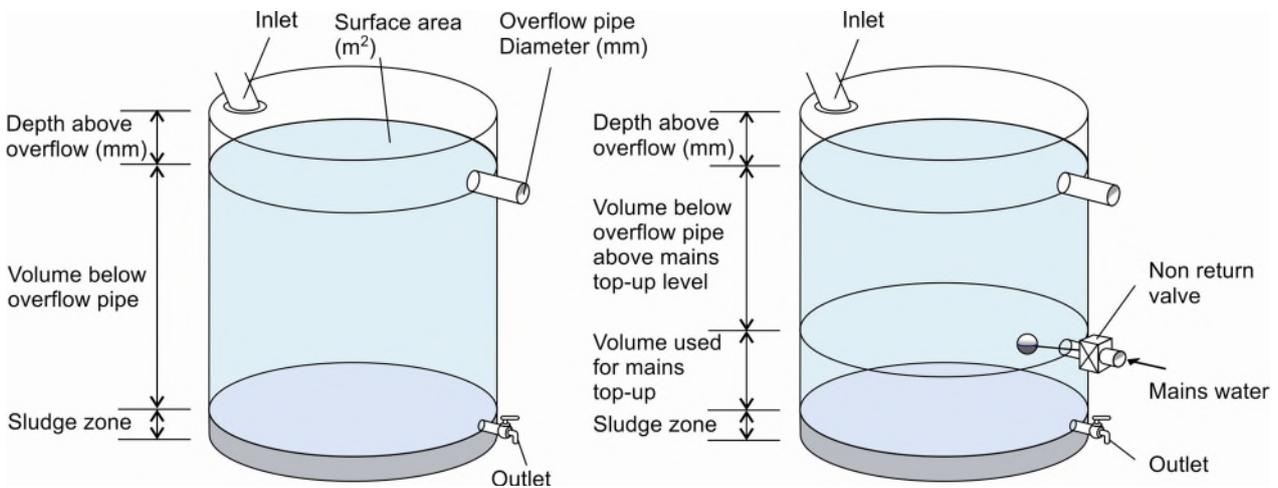
Figure 5.6:   Rainwater tank conceptual diagrams: a standard tank and a tank including mains top-up

Estimate residential demands for rainwater re-use based on the values in Table 5.4. The external demands represent typical urban residential demands. Where an additional external demand (for example irrigation) for rural residential development is identified, demand estimates may be increased where provided information supports the revised estimates.

Table 5.4: Water demands for rural and urban dwellings (adapted from Coombes *et al.* 2003)

	Rural dwelling rainwater tank sole water supply				Urban dwelling reticulated water supply			
	Annual internal use in kilolitres (kL/yr/dwelling)							
No. of bedrooms[1]	**1 to 2**	**3**	**4**	**5**	**1 to 2**	**3**	**4**	**5**
Toilet (25%)	31	44	57	71	46	66	86	106
Toilet + laundry (50%)	60	88	115	142	91	131	172	212
Toilet + laundry + hot water (90%)	110	159	206	256	164	237	309	384
Toilet + laundry + hot water + other (100%)	122	175	230	283	183	263	343	424
	Daily internal use in kilolitres (kL/day/dwelling)							
No. of bedrooms[1]	**1**	**2**	**3**	**4**	**1 to 2**	**3**	**4**	**5**
Toilet (25%)	0.085	0.120	0.155	0.195	0.125	0.180	0.235	0.290
Toilet + laundry (50%)	0.165	0.240	0.315	0.390	0.250	0.360	0.470	0.580
Toilet + laundry + hot water (90%)	0.300	0.435	0.565	0.700	0.450	0.650	0.845	1.045
Toilet + laundry + hot water + other (100%)	0.335	0.480	0.630	0.775	0.500	0.720	0.940	1.160
	External and commercial / industrial use							
External residential use eg gardens	For a typical urban lot - 0.15 kL/day/dwelling or 55 kL/yr/dwelling							
Commercial / Industrial Use	Indicative 0.1 kL/day/1000 m^2 of roof area (internal use) & 20 kL/yr/1000 m^2 (external use) - Development-specific data may provide better reuse values							

[1] Note - Where the number of bedrooms is unknown as for subdivisions, assume 4 bedrooms per dwelling

Key Points – Rainwater tanks

- The roof area draining to a rainwater tank shall be realistic considering downpipe locations, reasonable roof gutter gradients and the relevant land use and no more than 80% in an urban setting.

- Low flow bypass shall be set at 0 m^3/s - the rainfall threshold for roofs shown in Table 4.3 includes an allowance for the volume lost through first flush diverters.

- High flow bypass shall be based on the lesser of roof gutter capacity and the tank inlet capacity. A value of 0.005 m^3/s is considered a reasonable high flow bypass value for a typical detached residential dwelling.

- The 'volume below overflow pipe' shall not include the temporary detention, sediment storage zone, and mains top-up volumes. Assuming no detention or mains top-up, only a maximum of 80% of the physical tank volume should be modelled. The volume and surface area of a single rainwater tank node representing combined multiple tanks is determined by the multiple of the single tank. The 'depth above overflow' value for the combined tank node is identical to a single tank.

- The overflow pipe from individual tanks shall be modelled as a typical 90 or 100 mm diameter pipe. For simulating combined multiple tanks via an individual rainwater tank node, the overflow pipe diameter for a single tank is multiplied by the square root of the number of tanks. For example, if the diameter of the single overflow pipe is 90 mm and the combined tank node represent 30 tanks, then the overflow pipe diameter for the combined tank node is given by 90 mm x 5.477 (the square root of 30) and is equal to 492 mm.

- External re-use shall be modelled as an annual demand scaled by potential evapo-transpiration (PET).

- Internal use shall be modelled as an average daily demand.

- Urban residential sites - internal uses can include toilet flushing, laundry and hot water.

- Rural residential sites with no mains water – all internal uses.

- Other land uses – determine demands based on a case-by-case situation.

5.2.1.2 Buffer strips

Buffer strips are grassed or otherwise vegetated areas formed to filter sheet flow runoff from the impervious proportion of a source node. Buffer strips are mainly used to remove coarse matter that may otherwise overload a downstream measure. A typical example of this treatment node would be where road pavement runoff is allowed to flow across a vegetated roadside strip before draining into a roadside swale or bioretention system (Figure 5.7).

Where a buffer is proposed in the modelling, the site plans and/or stormwater drainage plans must show where the proposed buffer area will be located.

Road, roof + landscaping [Residential]   Buffer   Swale   Post-Development Node

Figure 5.7:   Example of buffer strip node application in MUSIC

Key points – Buffer strips

- Buffer strips are only effective immediately downstream of a source node that incorporates impervious area.
- Buffer strips are only appropriate to simulate situations where flow is not concentrated. If flow is concentrated, use a modified swale treatment node to model the system.
- Where a buffer is proposed in the modelling, the site plans and/or stormwater drainage plans must show where the buffer area is to be located.
- A buffer zone immediately adjacent to an outlet from a stormwater drainage system discharging into existing natural vegetation shall be simulated as a wide swale. Refer to Section 5.2.2.1 for guidance.
- Ensure the percentage of upstream area buffered is based on the **impervious area only**. For example, if a source node represents a combination of equal areas of road (100% impervious), roof (100% impervious) and grassed (0% impervious) areas, and if only the road will be buffered, then 50% of the total impervious area (representing road and roof) would be the figure used.
- Exfiltration shall be 0 millimetres per hour unless 'lost' water is returned to the model via a secondary drainage link or it can be demonstrated that infiltrated runoff would not contribute to observed flows downstream either through surface runoff, seepage into drainage lines, interflow or groundwater (for example deep sandy soils).

5.2.1.3   *Gross pollutant traps*

Gross pollutant traps are typically provided to remove litter, organic debris and medium to coarse sediment that may otherwise overload other treatment measures provided to manage fine particulates and nutrients.

Gross pollutant traps are usually modelled at the sub-catchment scale in MUSIC as pre-treatment for a pond, constructed wetland, bioretention system or stormwater filtration device (Figure 5.8). Lot-scale management of stormwater quality may include screening measures such as first flush diverters (for rainwater tanks) or stormwater pits with inclined outlet screens (for infiltration measures) to minimise the potential for the treatment mechanism of the device to be impeded. Street scale measures typically may have stormwater pits with flush grates that effectively remove larger gross pollutants (typically greater than 20 mm in size). Pit insert gross pollutant traps may also be provided within stormwater pits. Do not model nets in MUSIC.

Urban [Residential]   Gross Pollutant Trap   Wetland   Post-Development Node
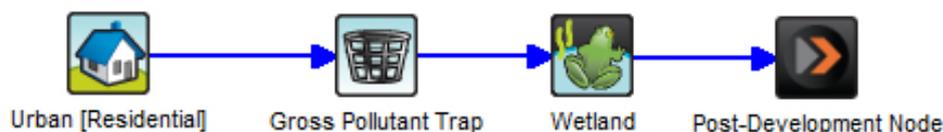
Figure 5.8:   Example of a gross pollutant trap node application in MUSIC

Where a gross pollutant trap is needed, it should be selected or designed to achieve the minimum performance criteria outlined in Table 5.5. If alternative performance data is to be relied upon to estimate the performance of a gross pollutant trap, this data must be from an independent source and not simply based on proprietor-supplied data. The source document (not just the reference) for the data should be included with the MUSIC model report so as to enable a review.

Table 5.5:   **Gross pollutant trap treatment node calibration inputs (adapted from Alison *et al.,* 1998)**

GPT default treatment node inputs (based on a CDS GPT)		
	Inlet properties	
Low flow bypass	0	
High flow bypass	50% of peak 63.2% AEP[1]	
	Input (mg/L)	**Output (mg/L)**
TSS	0	0
	75	75
	1000	350
TP	0.00	0.00
	0.50	0.50
	1.00	0.85
TN	0.0	0.0
	0.5	0.5
	5.0	4.3
Gross pollutants	0	0
	15	1.5

[1] 63.2% AEP (Annual Exceedance Probability) is equivalent to the 1 year ARI = Average Recurrence Interval (Australian Rainfall and Run-Off, Ball *et al.* 2016)

Key points – Gross pollutant traps

- Gross pollutant traps are sometimes used as a standalone measure for commercial developments with potentially high litter loads but invariably other treatment measures will also be necessary to achieve NorBE.

- Gross pollutant traps can be used as a pre-treatment measure for sites where large sub-catchment scale measures are proposed, such as water quality control ponds, bioretention basins, constructed wetlands or stormwater filtration devices.

- Gross pollutant traps are generally not needed at the lot and street scale level where stormwater quality is generally managed using measures such as rainwater tanks, buffer strips, grassed swales and raingardens. Other appropriate pre-filtering options such as inlet basins, that perform similar functions to gross pollutant traps, may be used to reduce future maintenance.

- Use the treatable flow rate to set the high flow bypass in the gross pollutant trap node (typically 50% of the 1 EY (events per year) flow) as outlined in *Australian Rainfall and Runoff* (Ball *et al*, 2016) to estimate peak discharges in urban and rural catchments (whichever is most appropriate). If an alternate treatable flow rate is proposed, this should be justified in the report.

- All MUSIC models must specify the type and size of any gross pollutant trap.

5.2.1.4 Proprietary stormwater treatment devices

Most proprietary stormwater treatment devices fit into one of the following categories:

(i) nets and in-stream measures – devices installed in a watercourse or at the end of a stormwater pipe to catch large and floating gross pollutants

(ii) pit inserts – source control measures installed in stormwater pits to catch gross pollutants and coarse sediment

(iii) in-line gross pollutant traps – devices installed along a stormwater drainage line to filter stormwater to remove gross pollutants and coarse sediment

(iv) end-of-line gross pollutant traps – devices installed at the end of a piped drainage system to filter stormwater to remove gross pollutants and coarse sediment

(v) media filtration devices - source control measures installed to capture fine sediment, some fine particulate pollutants and, depending on the nature of the media, may also absorb dissolved pollutants including nutrients. These are typically rechargeable/replaceable cartridges filled with perlite, zeolite, granular activated carbon, activated alumina or a mixture of these materials., and

(vi) oil and sediment separators – source control measures installed to capture oil, coarse sediment and some fine sediment.

Note: Do not simulate proprietary devices corresponding to category (i) above in MUSIC.

For proprietary stormwater treatment devices (PSTD) that fit into categories (ii), (iii) and (iv) above, the default treatment performance values shown in Table 5.4 should be used. If alternative performance values are used, independent performance evaluation and accepted pollutant removal efficiency claims consistent with national stormwater quality improvement device evaluation protocol (SQIDEP) must be submitted with the MUSIC report to support their use.

PSTDs that correspond to category (v) above can be modelled using the GPT or generic node and appropriate treatment node inputs and outputs should be applied for the specific device. Performance claims for category (v) devices shall be based on performance evaluation as required by the SQIDEP and must be provided with the MUSIC report to support their use. Consultants should contact WaterNSW to confirm the acceptable values for various proprietary media filtration devices.

In addition to national stormwater quality field testing protocol SQIDEP, WaterNSW has developed its own performance evaluation criteria (including independence, method and location, rigour and recommended maintenance schedule) for assessing performance claims of PSTDs in the Sydney drinking water catchment. Further information on WaterNSW's performance evaluation criteria can be obtained via environmental.assessments@waternsw.com.au. Information provided by manufacturers of some PSTD may not adequately address all of WaterNSW's evaluation criteria for performance claims. WaterNSW applies conservative values to the pollutant removal efficiencies of PSTDs in the Sydney drinking water catchment, and as such, WaterNSW may not accept the pollutant removal efficiency values stated in individual MUSIC nodes provided by the proprietor or available through MUSICLink.

PSTDs that correspond to category (vi) above are specialized devices that should be used where oil is a key pollutant source, such as service station forecourts. They can be modelled as a single stand-alone device or, in some circumstances, may incorporate an upstream primary gross pollutant traps in the form of pit inserts or an in-line gross pollutant trap. Such devices should be modelled as a gross pollutant trap with treatment performance values for total suspended solids, total phosphorus and total nitrogen as outlined in Table 5.4. Where alternative performance values are used, independent performance evaluation and accepted pollutant removal efficiency claims consistent with SQIDEP must be provided with the MUSIC report to support their use. Oil cannot be modelled in MUSIC.

WaterNSW notes there are a number of proprietary Floating Treatment Wetlands available for stormwater treatment in the market. These should be modelled using the wetland node. See Section 5.2.3.1 for more detail.

5.2.1.5 Sedimentation basins (and detention basins)

Sedimentation basins are mainly used to remove fine and coarse sediment from stormwater, however, they may also be designed to act as a gross pollutant trap if an appropriate trash rack or similar is incorporated into their design. Sedimentation basins can be used during the construction and post-development phases for a site. It is important to note the key differences between these two phases. In MUSIC, post construction large open detention basins and sediment basins node are modelled identically, so in theory any one of these nodes could be used, though for convenience and to reflect what may be constructed, the sediment basin node should be used primarily where the system is to remove fine sediments and have sufficient detention times. Note that the model assumes that the sediment basin is maintained, and accumulated sediment is removed as required.

Where post construction small underground detention basins designed to remove some sediments and have low detention times are proposed for a development, these should be modelled using the rainwater tank or pond node. But for convenience and to reflect high turbulence likely in small detention storages (i.e. they are not likely to simulate plug flow in them like a bigger sediment basin would) the rainwater tank node should be used. For storage properties of rainwater tanks, the volume below overflow pipe should be the detention volume of the tank and the depth above overflow should be the equivalent of the height between the top of the overflow weir and the roof of the structure. Water re-use can be modelled in these nodes based on realistic assumptions (see Table 5.3 for guidance on water re-use modelling).

A conceptual sedimentation basin as represented in MUSIC is shown in Figure 5.9.
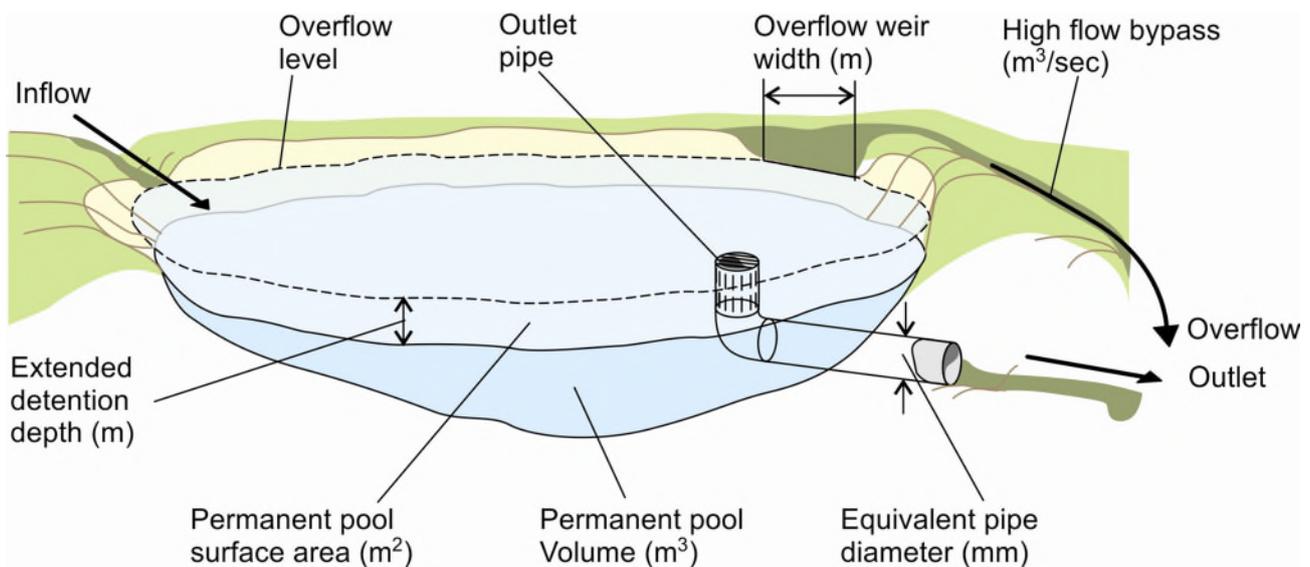
Figure 5.9:   A perspective view of a sedimentation basin

During construction, sedimentation basins are used to catch and enable settling of coarse and/or fine sediment particles that erode from surfaces exposed during construction. The basin size is typically based on a specific design event (typically a 75th percentile five-day rainfall depth) and should be determined using the approaches outlined in Managing Urban Stormwater: Soils and Construction – Volume 1 the "Blue Book" (Landcom, 2004). Sedimentation basins should not be simulated in MUSIC for the construction phase.

Construction-phase sedimentation basins can be modified to function as another stormwater management measure such as a pond or wetland for the post-development phase. For the post-development-phase the sedimentation pond treatment node should only be used to simulate sites where unvegetated and exposed soil forms a significant part of post-development conditions, for example quarries, landscape supply developments, unsealed roads, intensive horticulture or erosion gullies (see Figure 5.10). The size of the basin is typically based on continuous simulation modelling of a range of events and MUSIC can be used for appropriate sizing using notional detention time.

Unsealed road [Unsealedroad]   Sedimentation Basin   Post-Development Node
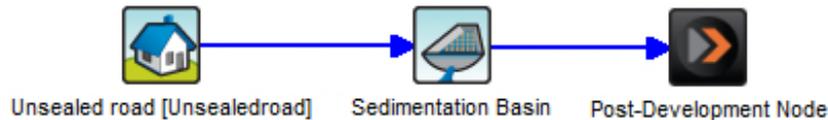
Figure 5.10: **Example of a sedimentation basin node application in MUSIC**

The detention basin node in MUSIC is identical to the sediment basin node (except that there is no permanent pool volume in a detention basin), and can be used to represent a detention basin, but only where that detention basin is designed as part of an overall stormwater quality treatment train. For example, a dry detention basin, which has no allowance for storage of trapped material will still show some treatment in MUSIC, however in real life, any material trapped in one event would be scoured out in the next and therefore the device would not provide any significant degree of treatment. If this is the case, the detention basin node should not be used.

> ### *Key points – Sedimentation basins*
>
> - Construction-phase sedimentation basins should be sized using the methods in Managing Urban Stormwater: Soils and Construction – Volume 1 (Landcom, 2004).
> - Post-development phase sedimentation basins should be modelled to remove the coarser range of total suspended solids particles.
> - Only use sedimentation basins in sites where unvegetated areas with exposed soils are part of the post-development site conditions (such as quarries, landscape supply developments, unsealed roads, intensive horticulture or erosion gullies).
> - The storm flow total suspended solids concentration for areas that are unvegetated in the post-development state should be set at 1000 mg/L. Set total phosphorus and total nitrogen concentrations to the same values as for unsealed roads as per Tables 4.6 and 4.7. In addition, the k and C* values for total suspended solids in the sediment node shall be adjusted to 15,000 and 90 mg/L respectively.
> - Use a maximum detention time of less than eight hours (preferably four to five hours) to size a sediment basin, assuming an average settling zone or permanent pool volume depth of one metre to target coarser particles. Where it is desired to remove finer particles, such as clays or colloids, an alternative treatment measure such as a pond or wetland incorporating vegetation should be proposed and modelled. This will ensure that captured nutrients associated with finer material can be removed biologically. Increasing the detention time of a sedimentation basin may simply result in other water quality issues such as excessive algal growth.
> - Provide an appropriate high flow bypass to minimise the chance of scouring the basin (typically 50% of the 1 EY (events per year) flow) as outlined in *Australian Rainfall and Runoff* (Ball *et al*, 2016) to estimate peak discharges in urban and rural catchments.
> - Sedimentation basin design involves a number of key factors including length to width ratio, particle size, storage depth, depth for sediment settlement. Typical sediment basin design incorporates an overall depth of around two metres including a 0.5 to 1 metre extended detention depth. The permanent pool volume can be calculated as being the overall depth (without the extended detention depth) multiplied by the surface area. Thus, where the overall depth is 2 metres and the extended detention depth is 1 metres the volume would be the surface area expressed as cubic metres (ie permanent pool volume in cubic metres = depth of 1 metre x surface area in square metres.
> - The evaporative loss should be the default value of 75 percent of the relevant potential evapo-transpiration (PET) value except where the basin is designed as an underground type (eg an underground detention basin). In that case the evaporative loss should be set to 0 percent.

5.2.1.6 Revegetation of cleared land

Where part of a rural development is proposed to be revegetated with trees and shrubs, and fenced off from livestock, the concentration parameters for the post-development model should be the 'revegetated lands' parameters given in Tables 4.6 and 4.7. Do not use the parameters for 'forest' as it takes more than 15 years for a revegetated site to return to the equivalent water quality functioning and performance of a "fully forested" state. The pre-development use of that part of the development can be modelled as agricultural land.

5.2.2 Secondary treatment measures

5.2.2.1 Vegetated swales

Vegetated swales are typically trapezoidal or dish-shaped open channels provided to convey and filter stormwater runoff through vegetation to remove coarse sediment and total suspended solids. The performance of these measures in MUSIC depends largely on the vegetation height, and the gradient and length of the swale (see Figure 5.11).
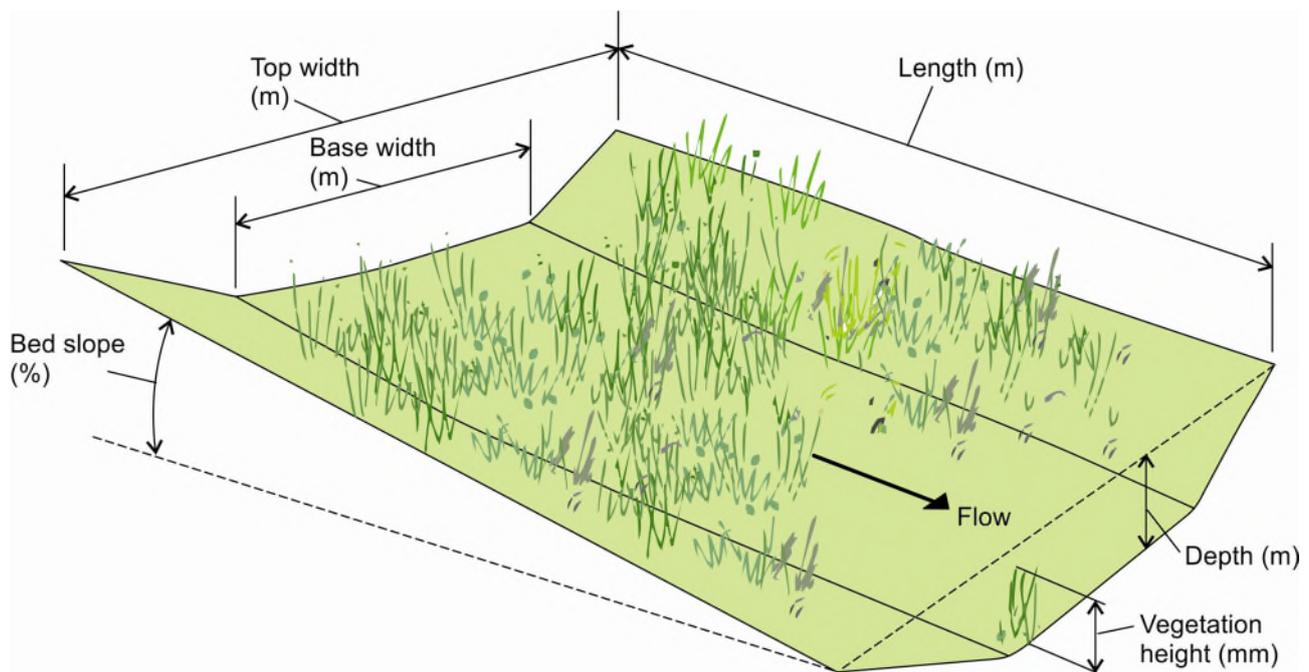
Figure 5.11:   A perspective view of a swale as used in MUSIC
(https://wiki.ewater.org.au/display/MD6/Vegetated+Swales)

Choose the swale length to reflect the physical configuration of the development. It is important to consider whether the swales should be modelled in series or parallel. Where the constructed swale will be relatively long and linear with individual allotment drainage entering it, the swale can be modelled as several sections representing the individual lot flows into the swale. Figure 5.12 shows the configuration of this approach.
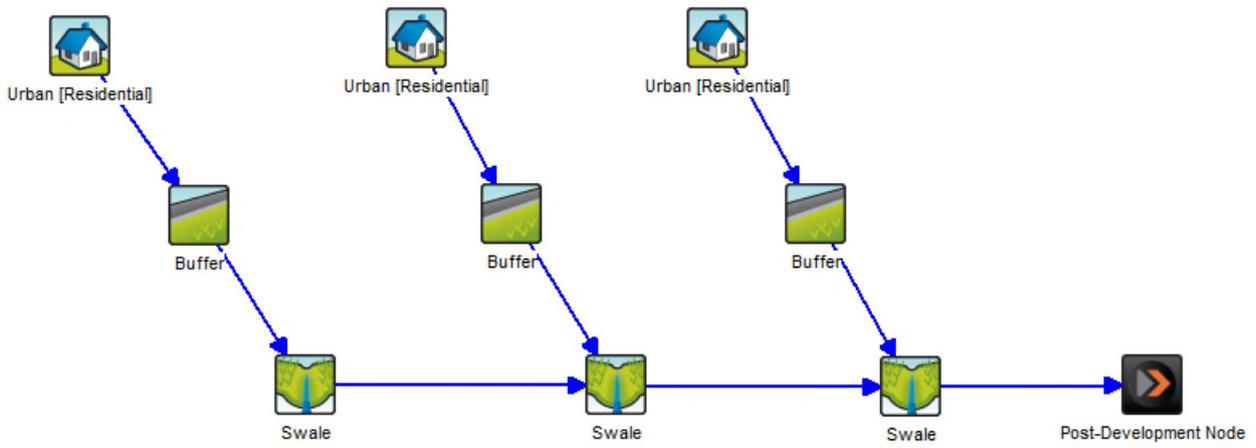
Figure 5.12:   Vegetated swales in series

Where a swale has lot drainage (or similar) inlets positioned along its length, but each one of the swale lengths has an associated overflow pit, then the approach as illustrated in Figure 5.12 is not appropriate. The source node catchment area for each swale length should be estimated based on the proposed location of drainage inlets. This approach assumes that all flows will not bypass a drainage inlet and is useful to simulate where the length of a swale discharges into underground drainage. Figure 5.13 shows the recommended configuration of this approach.
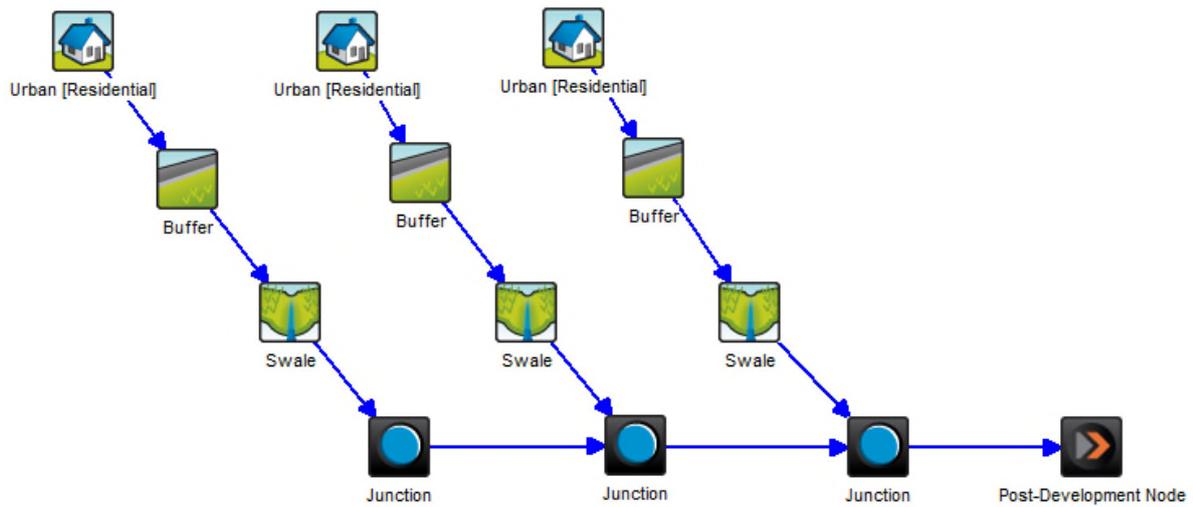
Figure 5.13   Vegetated swales in parallel

> ### *Key points – Swales*
>
> - Do not model table drains with drainage as a main function as grassed swales.
> - Confirm Council's engineering standards to define appropriate swale characteristics.
> - The background concentration (C*) for a swale is relatively high, so ensure that swales are correctly positioned in the treatment series so that modelled concentrations do not increase by passing through them.
> - Consider if the swales are more appropriately modelled as a series of segments.
> - The low flow bypass should usually be set to 0 m³/s. This should only be modified where it is clear that runoff draining to the swale would bypass it during low flow events, such as through a below-ground piped system.
> - The longitudinal bed slope of the swale should be within 1 to 4%. For gradients of 1 to 2%, swales with sub-soil drainage may be appropriate. Slopes of less than 1% should not be used due to the risk of ponded water caused by poor construction or simply settlement over time. For steeper locations with slopes greater than 4%, check-dams along the length of the swales may be used to ensure that swales between the check-dams fall within the 1 to 4% slope range. Where swales exceed 4% slope and do not incorporate check-dams they should be considered as table drains and not modelled.
> - If the swale has a non-linear shape (for example curved profile), top and base widths should be selected that best represent the swale dimensions.
> - Swale depths in most road reserves should optimally be between 0.15 m and 0.30 m to achieve suitable side slopes. For local streets swales should be modelled with a depth closer to 0.15 m where it can be demonstrated that the swale has sufficient flow capacity to minimize the chance of nuisance flooding, however, swale depths closer to 0.30 m are generally best. Swale depths outside the road reserve (for example in open space areas) may be deeper if it is practical to implement.
> - Vegetation height should be realistic for available species. For swales in rural areas, use two-thirds of the swale depth up to a maximum of 0.25 m. For swales in urban areas, decrease vegetation height to about 0.05 m, as residents are likely to mow regularly.
> - Exfiltration should be 0 millimetres per hour unless 'lost' water is returned to the model via a secondary drainage link or it can be demonstrated that infiltrated runoff would not contribute to observed flows downstream either through surface runoff, seepage into drainage lines, interflow or groundwater (for example deep sandy soils).

5.2.2.2 *Permeable paving*

Permeable paving is a paving material specifically designed to allow runoff to drain through an open pavement and infiltrate to the underlying base-course. Water typically drains through the sand and gravel of the basecourse and is collected by a subsoil drain (Figure 5.14). Particulates and some dissolved pollutants are removed by being filtered and absorbed by the filter media. Using porous paving instead of conventional paving reduces the amount of directly connected impervious area and reduces the volume of untreated runoff reaching the outlet.

Permeable paving is usually provided at the lot scale for surfaces including driveways (Figures 5.15 and 5.16). Most permeable paving is unsuitable for large-scale developments because it cannot withstand heavy-vehicle traffic loads. High sediment loads can also clog the paving and reduce its effectiveness.

Porous or pervious pavers or concrete should be treated the same as permeable paving provided it is laid on an appropriate depth of basecourse that acts as a filter and is constructed with an underdrain. The 'open' area, which represents the filter area, will vary according to the nature of the porous material and ranges from about 10% for porous asphalt, porous concrete pavers or porous concrete to an upper value of 40% for resin-bound pavers or surfaces. A conservative value based

on the product specifications should be adopted for modelling. An example of the representation of permeable paving in MUSIC is shown in Figure 5.17.
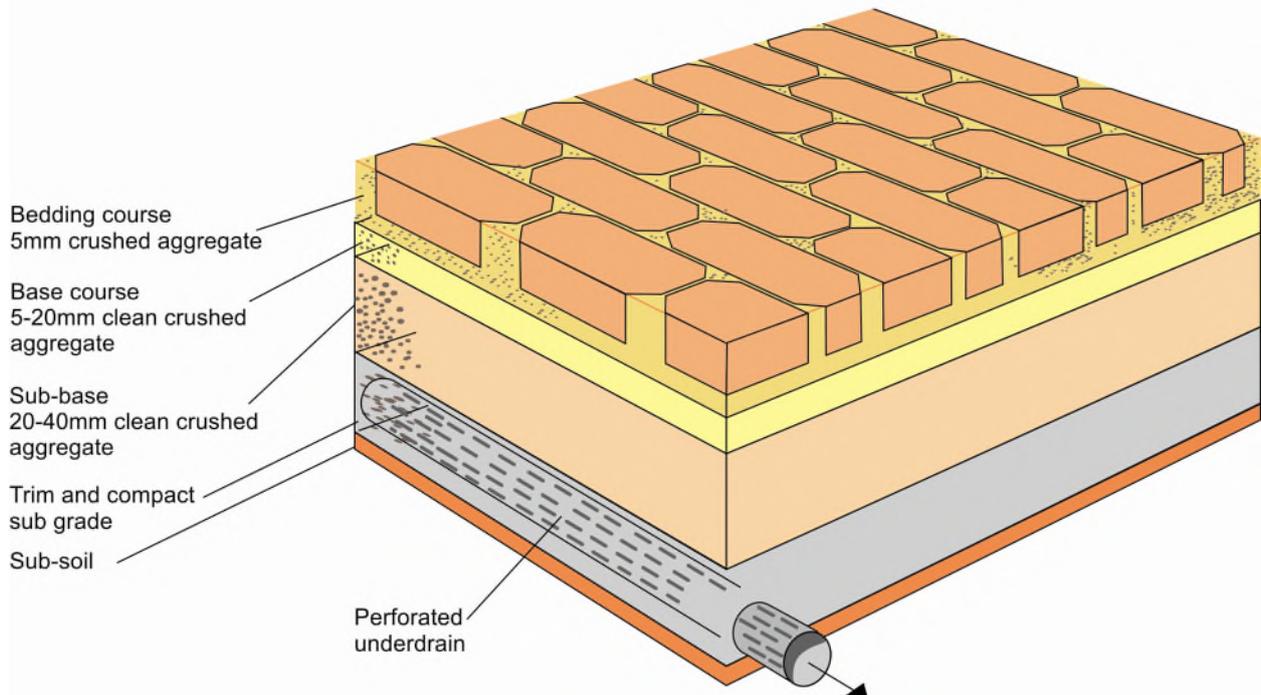
Figure 5.14:   A typical cross-section of permeable paving with an underdrain

Figure 5.15:   An example of the use of permeable paving in a car park

Figure 5.16: **A close up view of permeable paving showing closed and open components**
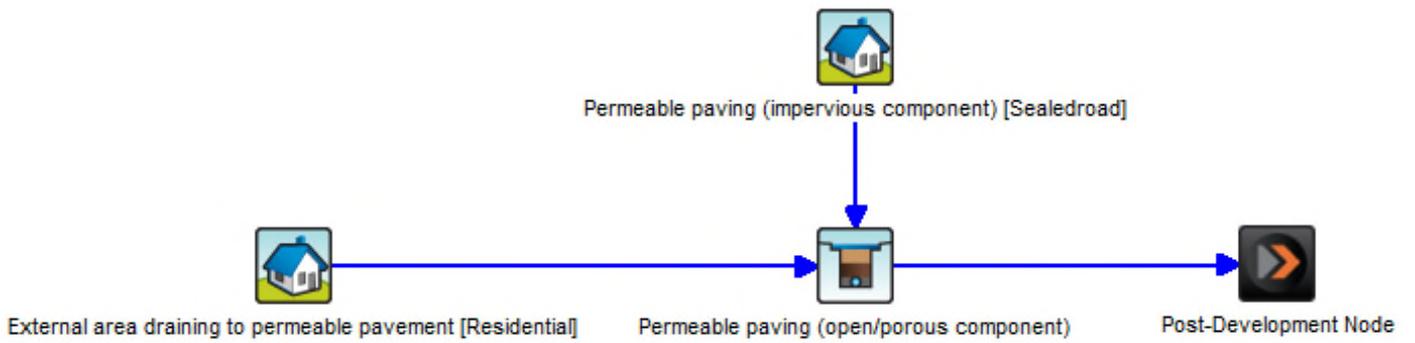
Figure 5.17: **Example of permeable paving application in MUSIC**

> ***Key points – Permeable paving***
>
> - Use the Media filtration system node in MUSIC to model permeable or porous paving.
> - The 'open' or permeable part of the permeable pavement (not the total surface area) should be input as the filter area. This should be estimated from the product specifications. The 'open' space for porous pavers or pavement should be based on a conservative value derived from product specifications (see comment above).
> - Separate the catchment draining to the permeable paving treatment node into two or more source nodes. One node should represent external surface flow from surrounding impervious areas (including down pipes from roofs) to the permeable pavement. The other node represents the direct rainfall on the impervious component of the permeable pavement.
> - Set the extended detention depth of the treatment node to zero unless the design specifically intends to allow regular ponding above the pavement.
> - Determine the saturated hydraulic conductivity to represent the smallest median aggregate (D_{50}) in the permeable paving base and sub-base layers. This value should be factored by 0.4 to allow for a reduction in permeability over the life of the pavement.
> - The filter depth should represent the total depth of the basecourse (and sub-base course if applicable), but should not include the transition and drainage layers, which are usually coarser material that provides negligible treatment capacity.
> - It is generally better to drain the filtered runoff away from the pavement subgrade. For this situation assume that the depth below underdrain is 0% and that exfiltration is zero. Where there is potential for exfiltration to occur within the permeable paving, set the exfiltration rate appropriately and apply the secondary drainage link to a junction node.

5.2.2.3   Sand filters

Sand filters work in a similar way to bioretention systems (refer 5.2.3.2), except that stormwater passes through a filter media (typically sand) that has no vegetation growing on the surface (Figure 5.18).
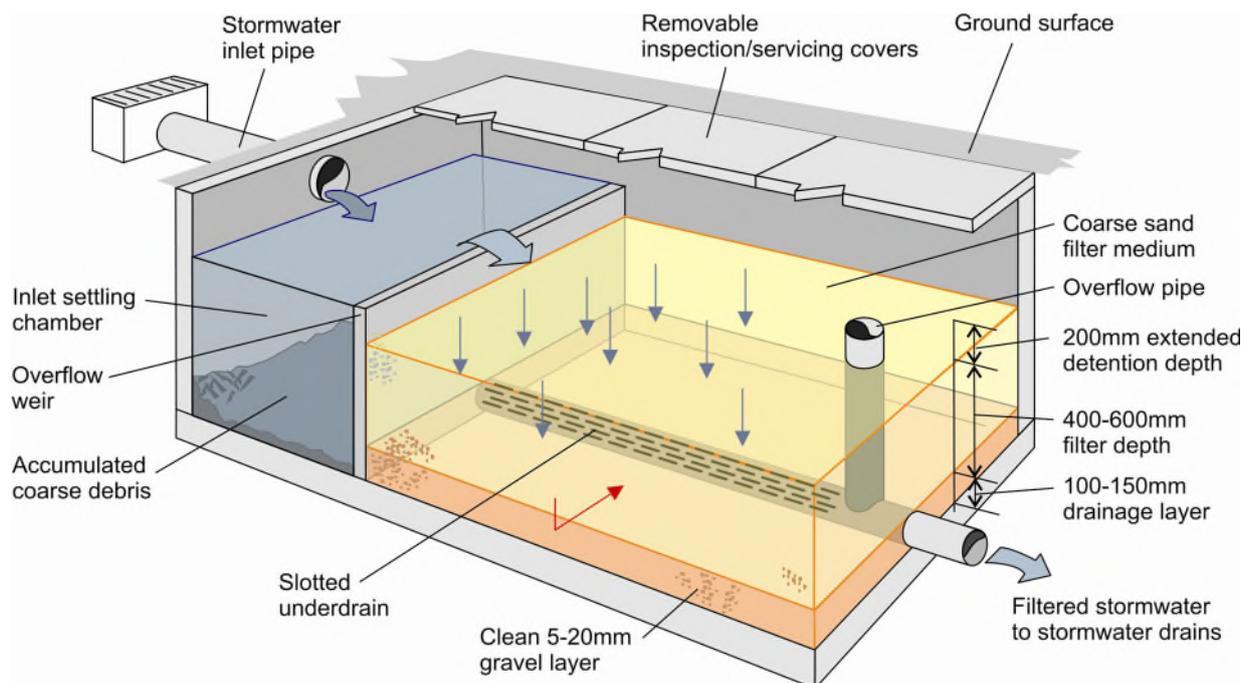
Figure 5.18:   Conceptual section view of a ground-level sand filter

Sand filters do not incorporate vegetation because they do not retain enough moisture to grow plants and they are often installed underground where there is no light for plant growth.

Sand filters require pre-treatment, typically with a gross pollutant trap, to reduce the risk of clogging the filter and to extend the life of the system (Figure 5.19). Above ground sand filters can include exfiltration which can managed via secondary drainage link as per sections 2.4.6.1 and 5.2.2.8.
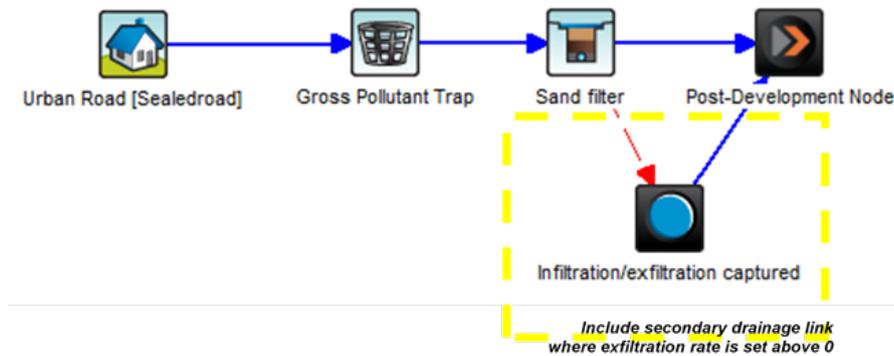
Figure 5.19:   Example of sand filter application in MUSIC

Key points – Sand filters

- Use the Media filtration system node in MUSIC to model sand filters.

- For all sand filters, the extended detention depth should represent the depth available above the filter media for temporary storage before filtering, based on the level of the overflow/bypass weir.

- For all sand filters, design the overflow weir to control and discharge the peak design AEP flow relevant to the minor drainage system.

- For all sand filters, base the saturated hydraulic conductivity on the smallest D_{50} of the media layers in the filter (refer Table 5.8). Reduce the saturated hydraulic conductivity by multiplying it by 0.4 to allow for a reduction in permeability over the life of the filter media **except** where routine maintenance is possible **and** proposed.

- The different input factors for sand filters with below ground and above ground extended detention storages must be considered. Where the extended detention storage is below ground, the filter area is typically equivalent to the surface area and the seepage loss and depth below underdrain pipe is generally zero (assuming the sand filter is completely contained within the tank). Where the extended detention storage is above ground, the surface area of the extended detention storage will be the surface area at approximately two-thirds of the proposed maximum extended detention depth. The depth below the underdrain pipe should not be more than 50 mm.

- There must be no seepage loss and this parameter should be set to 0 mm/hr for all underground sand filters.

- For above-ground sand filters, the exfiltration should be 0 millimetres per hour unless 'lost' water is returned to the model via a secondary drainage link or it can be demonstrated that infiltrated runoff would not contribute to observed flows downstream either through surface runoff, seepage into drainage lines, interflow or groundwater (for example deep sandy soils).

5.2.2.4   Mitre drains

Mitre drains (also called turnout or tailout drains) are common along unsealed roads and tracks in rural areas. They intercept concentrated flow moving down a swale or table drain and fan it out onto a level vegetated area as sheet flow (Figure 5.21). The lower velocity of the sheet flow causes coarser sediment to drop out and associated vegetation filters finer sediments. Mitre drains provide a small reduction in phosphorus levels but negligible reduction in nitrogen levels. These measures are invariably positioned adjacent to a roadside runoff discharge point. Figure 5.20 shows the representation of mitre drains in MUSIC.

Figure 5.20:   Example of mitre drain application in MUSIC
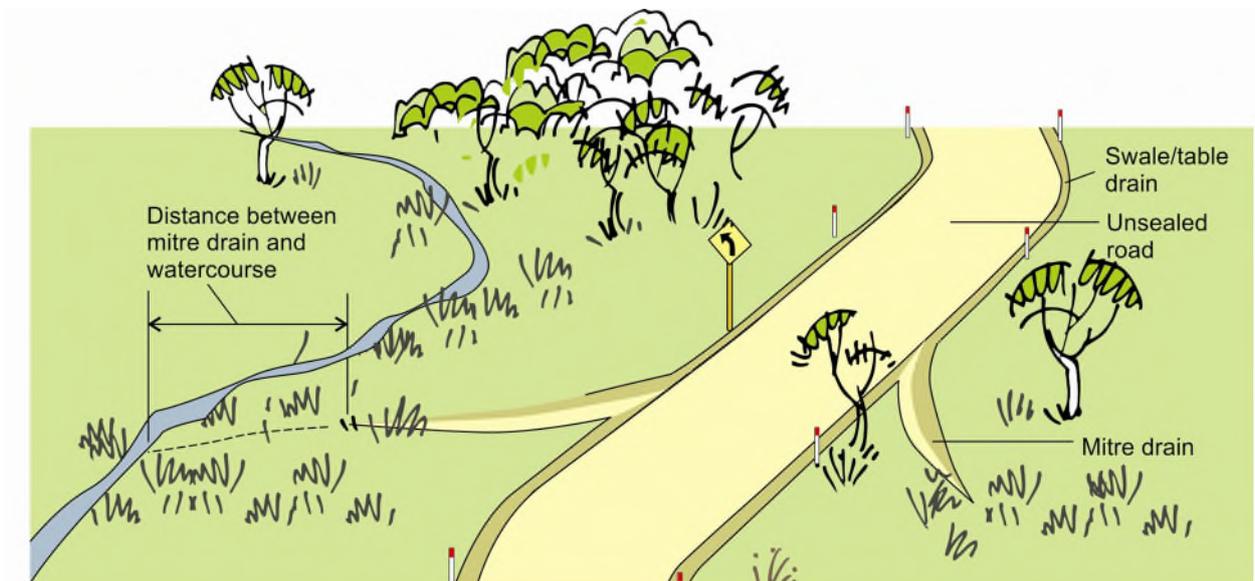
Figure 5.21:   Unsealed crowned road with typical mitre drains

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Key points – Mitre drains

- Mitre drains work by having a flat/level section that causes sediment to fall out, with further filtering of this clarified stormwater as it passes through the vegetation at the end of, or after, the mitre drain. The swale treatment node should be used to model mitre drains. Distances greater than 20m should be justified from the downslope end of the mitre drain to either the nearest watercourse (gully, creek or drainage depression), or to a flat surface, and should be taken as the length of a wide swale.

- The dimensions of the swale representing each mitre drain should be limited to a length of 20 m, a base width of 0.5 m, a depth of 0.3 m, and a slope of between 1 and 3% depending on the site.

- Mitre drains should be modelled in multiples for each site sub-catchment and not individually to show that there is sufficient treatment. The average length of "swales" representing mitre drains (nominal top and base width of 1.5 m and 0.5 m, and depth of 0.3 m) should be multiplied by the number of mitre drains for the length of road.

- High flow by-pass should be modelled using a secondary drainage link.

- Mitre drain spacing is dependent on 1) steepness and length of slope and 2) soil type and erodibility, 3) as well as rainfall and the location of natural drainage lines. A reasonable starting point for determining the **maximum** spacing of mitre drains is by the relationship: *300 divided by slope (expressed as a percentage)*

- WaterNSW's 'Water Sensitive Design Guide for Rural Residential Subdivisions' (WaterNSW, 2023a) or the DECC's 'Soils and Construction Volume 2C: Unsealed Roads' (DECC, 2008) provide more detail for determining mitre drain spacing, taking into account other factors.

- Mitre drains should not be used in urban areas.

- Exfiltration should be 0 millimetres per hour unless 'lost' water is returned to the model via a secondary drainage link or it can be demonstrated that infiltrated runoff would not contribute to observed flows downstream either through surface runoff, seepage into drainage lines, interflow or groundwater (for example deep sandy soils).

- Case study A4.4 provides an example of its application.

5.2.2.5 *Media filtration devices*

The MUSIC media filtration node can be used for filtration systems (non-proprietary) that operate in a way that is not properly represented by other MUSIC treatment nodes outlined in this guideline. A
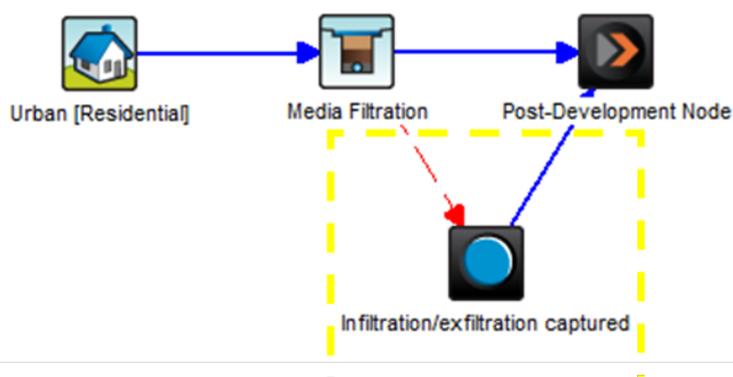
typical configuration is shown in Figure 5.22 below.

Figure 5.22: Example of a media filtration node in MUSIC

WaterNSW will not accept models using this node unless it has been demonstrated that the proposed treatment measure cannot be represented using one of the other MUSIC treatment nodes. Guidance regarding use of this treatment note with regards to existing soil conditions and properties can be found in Section 5.2.2.8 below.

5.2.2.6 Rehabilitation of eroded gullies

Rehabilitation of eroded gullies is often a key measure used on rural sites to offset the impacts of a proposed development, and involves stabilizing the eroding gully through some combination of reshaping, revegetating and fencing off from livestock. It is represented by a generic treatment node.
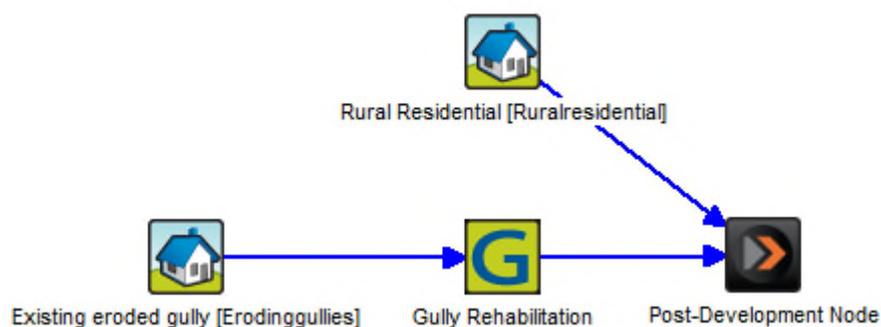
Figure 5.23: Example of gully rehabilitation in MUSIC

Table 5.6: Pollutant generation reductions associated with gully rehabilitation (WaterNSW)

Degree of rehabilitation[1]	Total suspended sediment (%)	Total phosphorus (%)	Total nitrogen (%)
Permanent fencing off from livestock	50	35	0
Revegetation and fencing off	60	45	5
Reshaping a gully to a more stable profile, revegetation and fencing off	75	55	10

[1] Rehabilitation of gully from livestock along the full extent of gully within the development site

> **Key points – Rehabilitation of eroded gullies**
> - The gully area on the site that is proposed to be rehabilitated must be defined as a separate source node in MUSIC (see 'Urban' source node), and the impact of the gully rehabilitation must be assessed using the generic treatment node in MUSIC (see Figure 5.23).
> - Use baseflow and stormflow pollutant concentration values from Tables 4.6 and 4.7 to calibrate the gully source node. Use soil characteristics parameters as per **original** soils.
> - When simulating the impact of the gully rehabilitation, the actual area of the gully should be the only area draining to the treatment node. It should be assumed that runoff from the development site will not have any further treatment by passing through the rehabilitated gully.
> - Table 5.6 gives the pollutant reduction rates for gully rehabilitation that should be used to define the transfer functions in the generic treatment node.
> - Where alternative pollutant reduction values are used, detailed information that supports these values must be provided with the model.

5.2.2.7 Ponds

A pond is essentially a basin with a permanent water storage component. Ponds usually have an average depth of more than 1.5 m to minimize emergent plant growth and are mainly used for aesthetic reasons. A pond is represented conceptually in MUSIC in the same way as a sedimentation basin (refer to Section 5.2.1.5). MUSIC uses a default vegetation coverage of 10% for ponds that represents a predominantly open water pond with fringing vegetation, which is different than a constructed wetland (Figure 5.24).

The impact of direct rainfall onto the pond may also need to be considered, particularly for larger ponds exceeding 500 square metres. In this case, the area of the pond should be modelled as a separate node linked to the wetland node, and the rainfall threshold should be set to "0".

A pre-treatment device is usually required to reduce gross pollutants and coarse sediments entering the pond to maintain functionality, reduce maintenance and prolong the life of the pond (Figure 5.25).
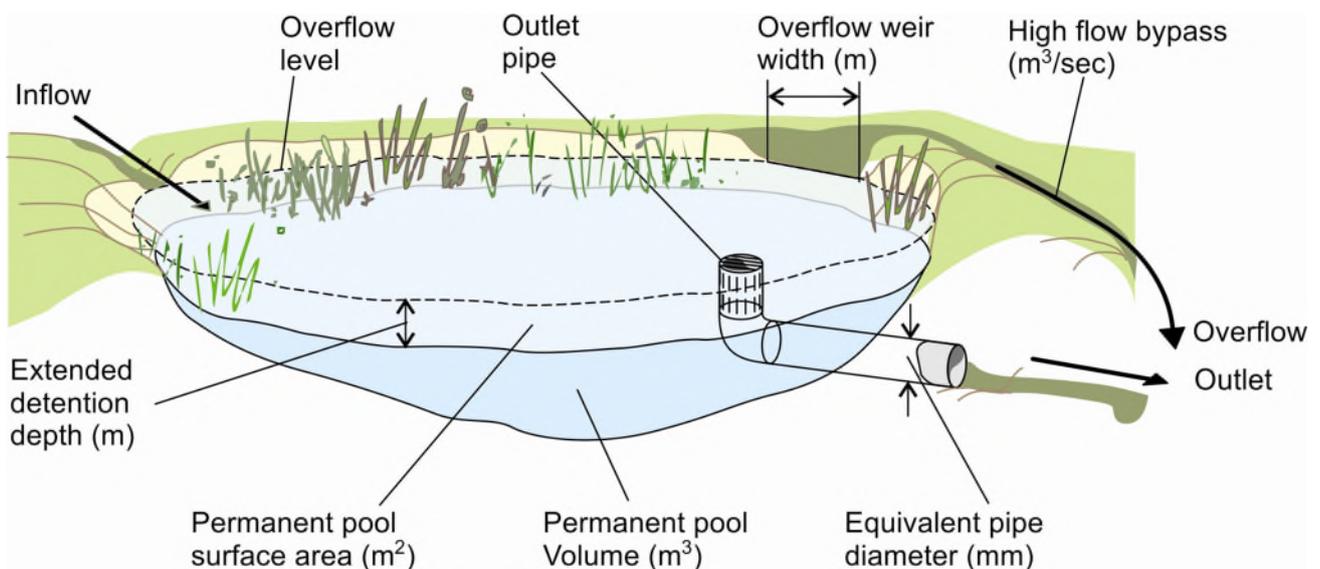
Figure 5.24:   Conceptual diagram of a pond
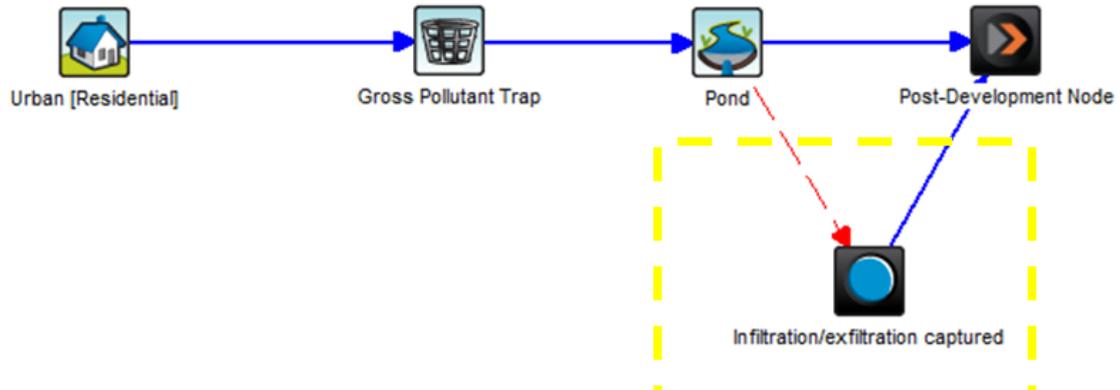
Figure 5.25:   Example of pond node application in MUSIC

> **Key points – Ponds**
>
> - The use of ponds for stormwater management in urban areas is generally not preferred, as other water quality issues such as algal blooms can happen in ponds that have limited vegetation coverage. Additional biological treatment for these issues can outweigh the other water quality benefit that ponds provide.
> - A gross pollutant trap must be incorporated into the model when a pond is utilised in urban areas to remove coarse sediment and gross pollutants. Preferably, ponds should only be used to target the removal of medium to coarse grained particles. The hydraulic residence time should be appropriate to minimise the capture of fine grained particles and nutrients that can lead to high maintenance requirements where there is not enough aquatic vegetation to prevent issues like algal growth.
> - The pond node should be used to model farm dams in rural areas where they are used to treat runoff and sediment from unsealed roads. Locate ponds to capture runoff from roadside swales, which will also remove coarse sediments and gross pollutants. Such ponds or dams will generally be small, for example 100 to 200 m^2 of surface area, and may be combined into a single node where appropriate in the model.
> - If a pond spillway or high-flow bypass is to be located near the inlet, model the pond treatment measure as a constructed wetland and adjust the C* and k parameters to the values for a pond. This is because the overflow from a typical pond is normally assumed to be located at the downstream end of the pond. Spills from the pond are assumed to be partially treated, which is not true if the high-flow bypass is near the inlet.
> - The notional detention time should typically be more than 48 hours to ensure the best treatment of nutrients.

5.2.2.8   Infiltration measures

Infiltration systems reduce flow volumes and help to offset increased runoff resulting from additional impervious surface area after a site is developed. The infiltration measure treats stormwater by infiltrating it into the surrounding soil and to groundwater. The performance and suitability of these measures is highly dependent on-site soil characteristics. Site specific soil investigations for soil type, soil texture and soil depth should be confirmed for the modelling purposes.

Table 5.7:   Infiltration soil conditions and separation distances (adapted from ARQ, 2005)

Soil type	Minimum hydraulic conductivity (mm/hr)	Minimum separation distance (for footings and other infrastructure) (m)
Deep sands (confined or unconfined)	180	2
Sandstone (overlain by shallow soil)	3.6	2
Sandy Clays	36	2
Medium Clay	3.6	4
Heavy Clay	0.036	5
Constructed Clay	0.0004	5

Infiltration measures are suited to permeable soil types with deep groundwater and are not suited to clayey soils with low to imperfect drainage. Care should be taken using infiltration systems in soils with high acidity and/or salinity, especially sodic soils and areas of high acid-sulphate soil potential.

It is also important to consider the separation distances of infiltration systems for various soil types to avoid seepage and adverse impacts on adjacent infrastructure that is downslope on the hydraulic gradient. Tables 5.7 and 5.8 provide some guidance about separation distances and hydraulic conductivities.

Table 5.8: Soil type, mean particle size, typical hydraulic conductivity and suitability for infiltration (adapted from various published data)

Soil type	Mean particle size (d$_{50}$) mm	Typical or indicative hydraulic conductivity (mm/hr)	Suitability for infiltration
Gravel	2	36000	No
Coarse sand	1	3600	No
Sand	0.7	360	No
Sandy loam	0.45	200	Yes
Loam	0.25	90	Yes
Silty clay loams	0.10	36	Yes
Sandy clays	0.01	20	Possibly[1]
Medium clay	0.004	2	No
Heavy clay	<0.002	0.2	No
Constructed clay	<0.002	0.0	No

[1] Only for sandy clays at the top of the hydraulic conductivity range

In MUSIC, care needs to be taken to ensure that pollutant loads assumed to be removed using an infiltration node. Losses via infiltration can result in unrealistically high pollutant load removals when high exfiltration rates are used in the model, that are not representative of the overall treatment performance of an infiltration system. To account for these losses, a secondary treatment node should be used. See section 2.4.6.1 for more information on this.

Where other stormwater treatment measures included in the model have an exfiltration rate set above 0, infiltration through naturally occurring soil at the site can be modelled using the secondary drainage link connected to a media filtration or infiltration node, see Figure 5.26 below. As outlined above, this is not recommended at sites with medium to heavy clays, or sandy soils with a shallow groundwater table.

Table 5.9 provides guidance of the maximum area that can be claimed when modelling in-situ soils for pollutant removal. The area of the media filtration/infiltration node will also depend on the size of upstream treatment node to ensure there is sufficient flow into media filtration/infiltration node. For example, 5 square metre bioretention system cannot claim very large media filtration/infiltration area.

Table 5.9: Media filtration/infiltration node area

Slope	Soil type	Media filtration area sizing
0-2%	Light clay	50 square metres
	Clay loam, sandy clay loam, silty clay loam, sandy clay, silty clay	80 square metres
	Clayey sand, sandy loam, loam, silty loam	120 square metres
3-4%	Light clay	70 square metres
	Clay loam, sandy clay loam, silty clay loam, sandy clay, silty clay	100 square metres
	Clayey sand, sandy loam, loam, silty loam	150 square metres

[1] Surfaces with greater than 5% slope are not suitable for infiltration modelled though the media filtration or infiltration node.

[2] The area of naturally occurring soils modelled using the media filtration or infiltration node should be available on the ground, otherwise the node area should be reduced to reflect the actual area available.
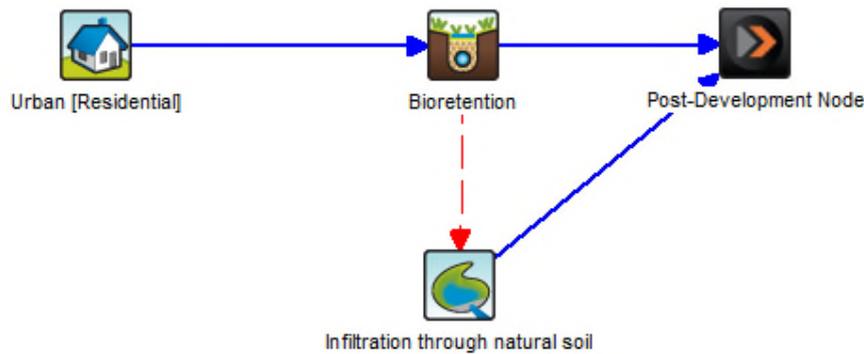
Figure 5.26: **Example of modelling infiltration through naturally occurring soil**

If the infiltration measure is part of a treatment train, then the mass load leaving the infiltration system will need to be added to the total residual load at the end of the treatment train and the reduction percentage calculated manually, similar to the above.

Infiltration systems require pre-treatment, usually in the form of a gross pollutant trap, to reduce the risk of clogging soil pores and to extend the life of the system (Figure 5.27).
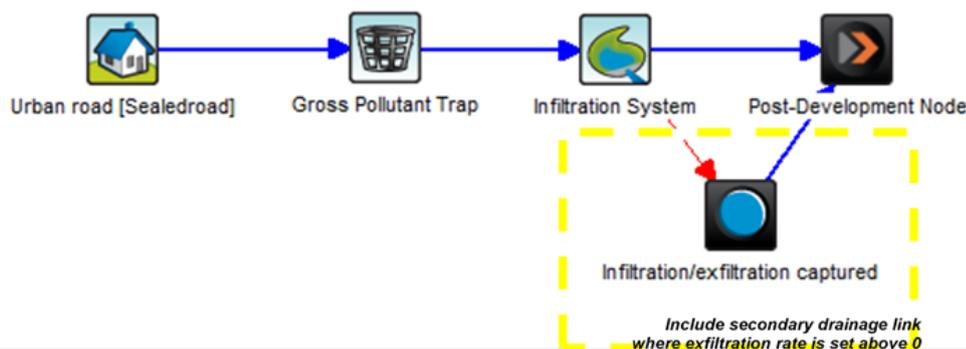
Figure 5.27: **Example of infiltration node application in MUSIC**

Key points – Infiltration measure

- Do not use this treatment node for developments in the Sydney drinking water catchment unless it can be clearly shown that infiltrated flow will exfiltrate into the surrounding soil and will not reappear in either a constructed drainage system or as groundwater discharge or in natural stream downstream of the infiltration point.

- Do not use or model infiltration measures for developments on sites with medium to heavy clay or compacted soils where drainage rates are low, or for sandy soils where drainage rates are very high and the infiltrated stormwater is likely to reappear elsewhere.

- Modelling infiltration through naturally occurring soils should not occur on sites with 5% or greater slope.

5.2.3 Tertiary treatment measures

5.2.3.1 Constructed or Floating Treatment wetlands

Constructed wetlands are artificial systems that mimic functions of natural wetlands in reducing fine particulate sediments and associated pollutants such as nutrients, metals and toxicants, including those in soluble forms. They are simulated in MUSIC as surface wetlands with permanent or ephemeral water bodies in the upstream inlet (sediment) pond and main wetland (macrophyte) zone. Figure 5.28 shows how they are conceptually represented in MUSIC.

Constructed wetlands have a higher proportion of shallow water zones than ponds, and aquatic vegetation is distributed more widely across the wetland (in ponds vegetation is mainly limited to the edges of the pond). Constructed wetlands include low flow and high flow bypass channels. The low-flow bypass channel offtake is located upstream of the wetland zone, while the high flow bypass offtake is located in the inlet pond and operates when the wetland (macrophyte) zone is full.

The impact of direct rainfall onto the wetland may also need to be considered, particularly for larger wetlands exceeding 500 square metres. In this case, the area of the wetland should be modelled as a separate node linked to the wetland node and the rainfall threshold should be set to "0".

Proprietary floating treatment wetlands (FTW) should be modelled as per constructed wetlands. Given the vegetation cover (set as 50% of the surface area) cannot be changed within the wetland node, the surface area of the wetland should be set to double the area of the FTW modules, and not the total area of the pond/basin containing the modules.
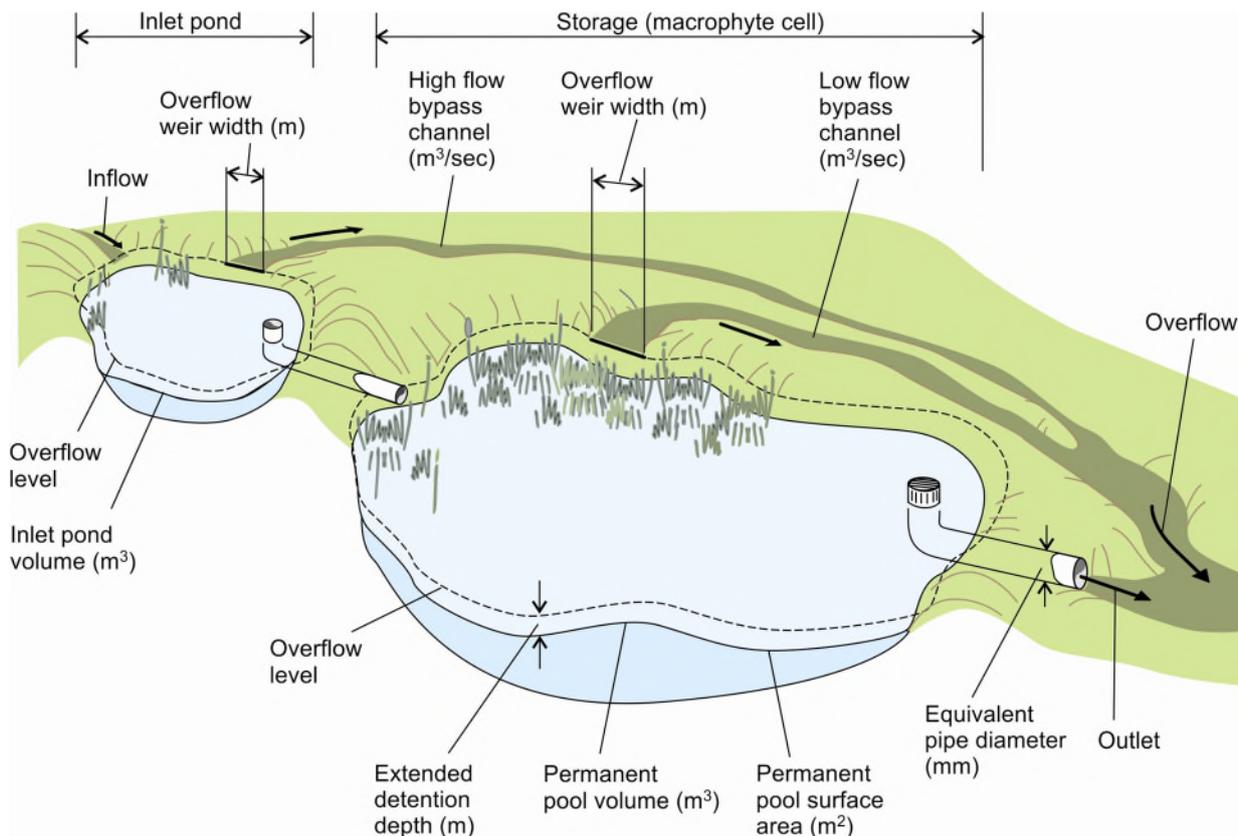
Figure 5.28: Conceptual perspective of a wetland with an inlet pond as used in MUSIC

A pre-treatment device such as a gross pollutant trap is typically required to reduce gross pollutants and coarse sediments from entering the wetland to maintain functionality, reduce maintenance and prolong the life of the system (Figure 5.29). If a gross pollutant trap is not provided, design and model the wetland with an inlet pond.
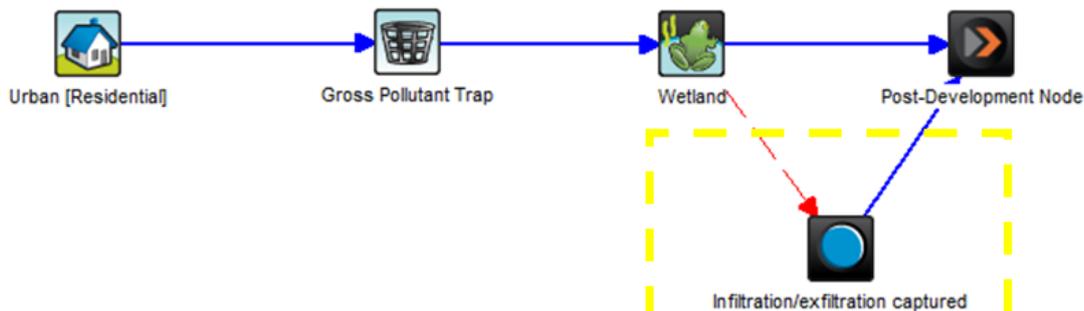
Figure 5.29: Example of a constructed wetland node application in MUSIC

Key points – Constructed wetlands

- The weir overflow from a constructed wetland should be located at the inlet, with the high-flow bypass value estimated by using 50% of the peak one-year average recurrence interval flow.

- If the high flow bypass is located at the outlet, model the wetland as a pond with k and C* parameters in the pond node adjusted to be equivalent to the corresponding wetland parameters.

- Calculate the surface area input for this treatment node when the water level is approximately half of the extended detention depth. This assumes trapezoidal banks for the wetland. If the wetland is surrounded by vertical or near vertical walls, the surface area will probably be almost equivalent to the surface area when the permanent storage is full.

- In situations where a gross pollutant trap is not provided for, pre-treatment using an inlet pond will be required. The constructed wetland should then be modelled with an inlet pond with a volume more than 10% of the wetland's permanent pool volume.

- A fixed default of 50% vegetation coverage applies to the constructed wetland node. If less vegetation is proposed, the constructed wetland node k and C* values should be modified to pond node values to represent a lower level of treatment.

- Extended detention should not exceed 0.5 m unless it can be shown that a higher depth is achievable without flooding impacts.

- The permanent pool volume in the constructed wetland should not exceed the surface area (at permanent pool level) multiplied by one metre unless more detailed information is provided of the wetland configuration.

- Exfiltration shall be 0 millimetres per hour unless 'lost' water is returned to the model via a secondary drainage link or it can be demonstrated that infiltrated runoff would not contribute to observed flows downstream either through surface runoff, seepage into drainage lines, interflow or groundwater (for example deep sandy soils).

- The evaporative loss shall be the default value of 125% of the relevant potential evapo-transpiration (PET) value.

- The notional detention time of the wetland should typically be between 48 to 72 hours to ensure optimal treatment of nutrients. The value of the equivalent pipe diameter should be reflected by appropriate design. The actual value of the equivalent pipe diameter is not important, it is just the way to set the detention time in MUSIC. This notional detention time must be used as the basis for the design of the overflow culvert structure of the basin. Note that in Version 6, alternative outflow structures, such as riser outlets can be modelled more accurately using the custom outflow and storage option in the wetland dialog box.

5.2.3.2 Bioretention systems

Bioretention systems include bioretention swales, bioretention basins and raingardens. Bioretention swales are typically used on median strips or along footpaths in the road reserve and may also provide a flow conveyance function. Raingardens are typically small bioretention basins distributed in lots, a road reserve or open space areas to catch and treat flow at a specific location and are often vertically sided. Bioretention basins are typically larger basins provided in large open space areas to manage stormwater quality at the sub-catchment scale. These measures are represented as one node in MUSIC as shown in Figures 5.30 and 5.31.
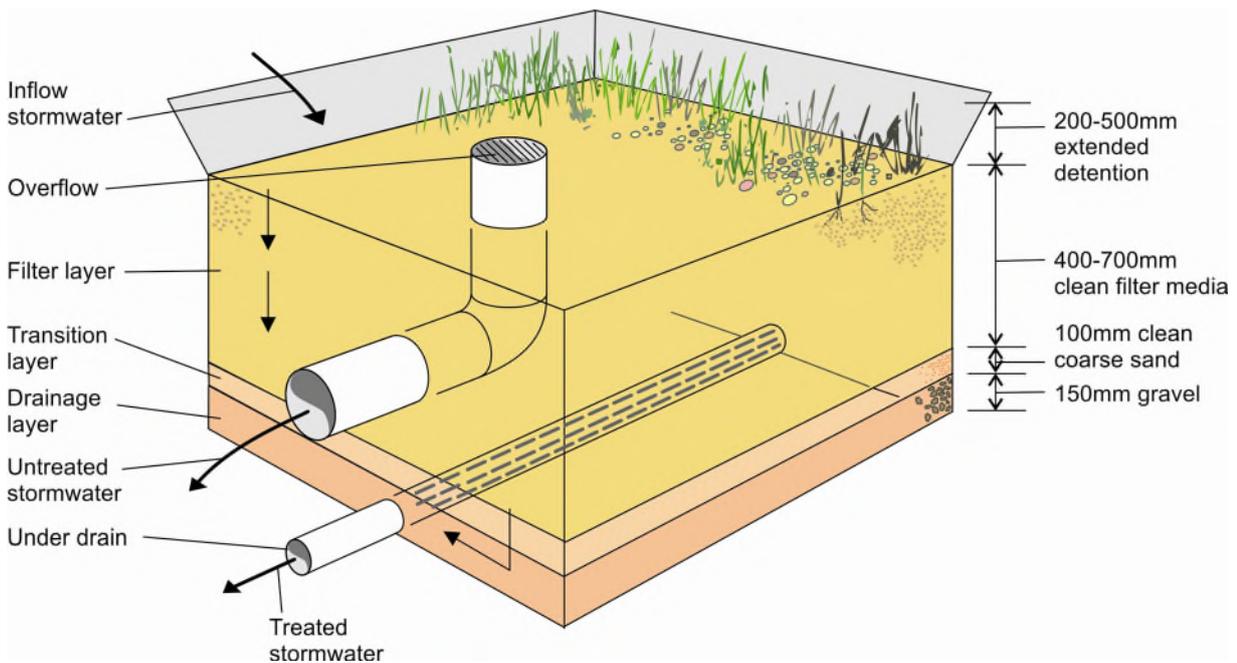
Figure 5.30: Perspective view of a standard bioretention basin (adapted from FAWB, 2015)
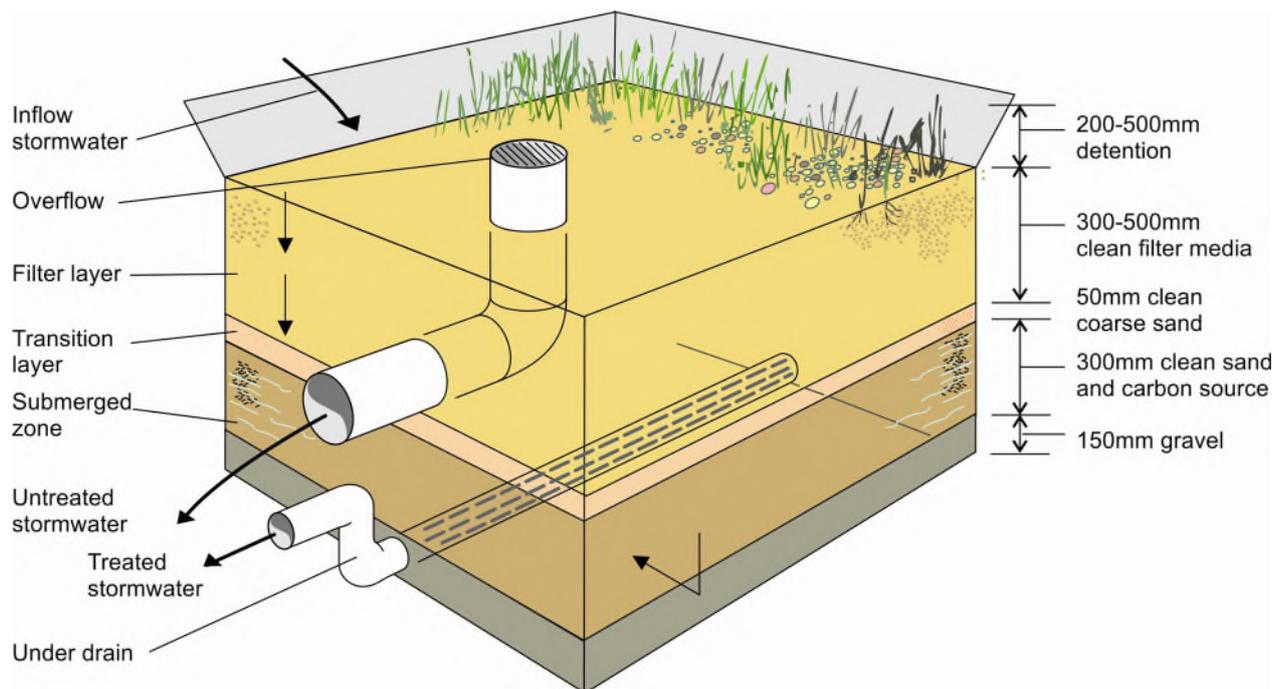
Figure 5.31: Perspective view of an advanced bioretention basin with a saturated zone
(adapted from Payne *et al* 2015)
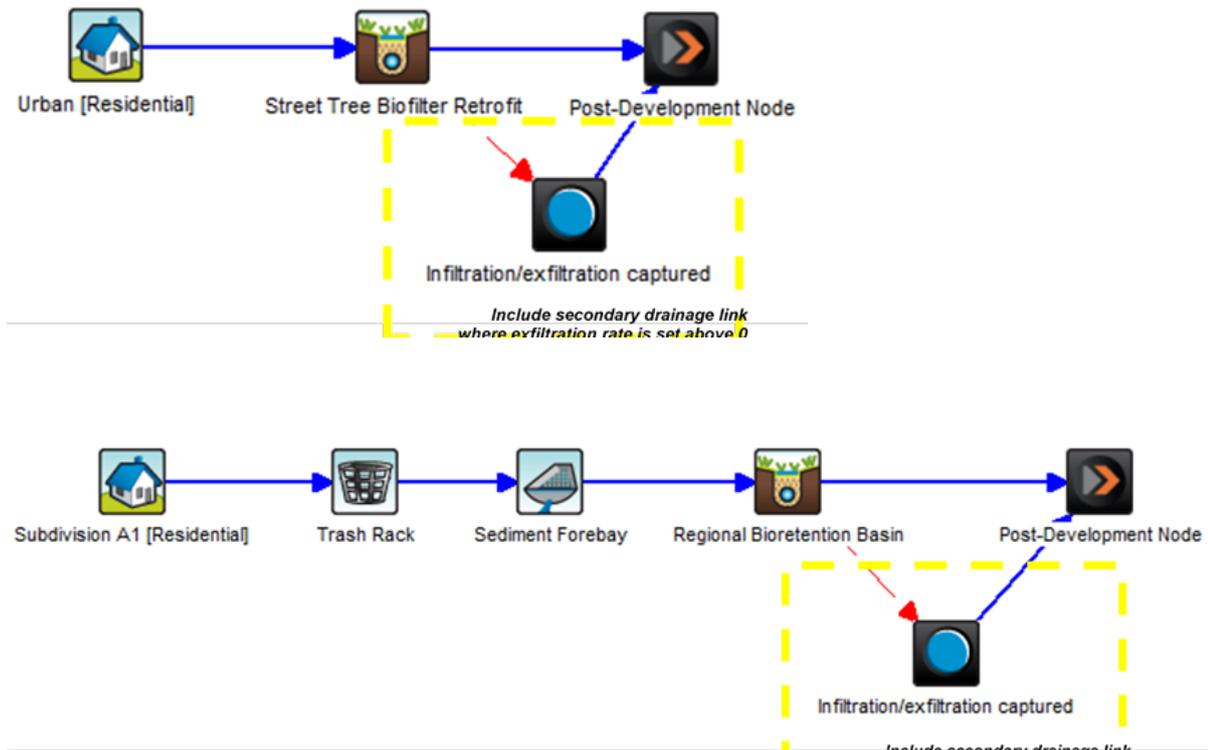
Figure 5.32:   Examples of bioretention node application in MUSIC

Bioretention swales:

Bioretention swales need to be treated slightly differently to other bioretention systems because after most rainfall events there is only minimal ponding above the surface of bioretention swales. As a result, such treatment systems need to be modelled as a bioretention system with an extended detention depth of less than 0.05 m followed by a swale of the same length with a low flow bypass set to the infiltration rate of the filter area. For a 50 m long bioretention swale with a filter media width of 0.8 m and a saturated hydraulic conductivity of 200 mm/h, the low flow bypass for the following swale node is 50 x 0.8 x 200 / 1000 / 3600 or 0.0022 m^3/s, where the last two values represent the conversion from millimetres to metres and from per hour to per second. The other parameters for the bioretention swale and swale nodes should be set in accordance with information provided elsewhere in this guide. If the filter media component is not planted with effective nutrient-removal plants, but instead relies on grass or turf or where no planting is used, the 'Vegetated with Ineffective Nutrient Removal Plants' or 'Unvegetated' parameter must be selected in the biofiltration node. Figure 5.33 shows the appropriate MUSIC layout for a bioretention swale.

If the bioretention swale is adjacent to the road and the bioretention component is along the entire length of the road, then the runoff entering from the edge of the road at the higher end of the bioretention swale will receive 100% treatment, but water that enters at the lower end of the bioretention swale will receive little or no treatment. As a result, only 50% of the bioretention area should be modelled to provide an accurate representation of the level of treatment that occurs to the runoff from the road surface. It should also be noted that bioretention swales are not feasible for stormwater management where slopes exceed 5%.
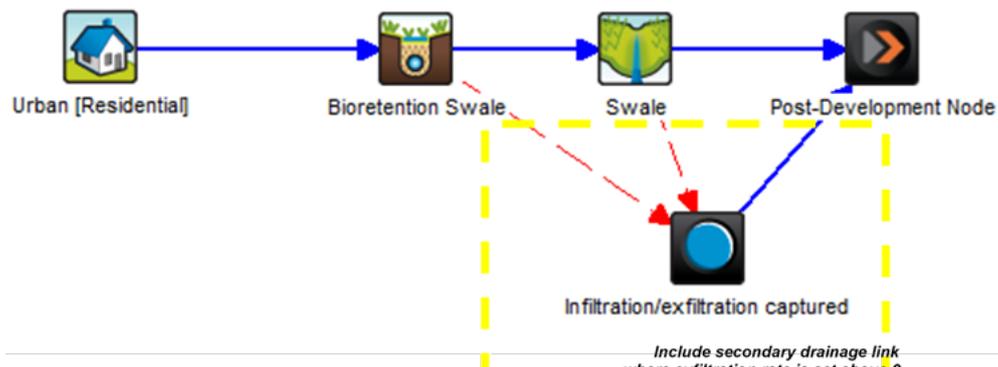
Figure 5.33: **Example of a bioretention swale representation in MUSIC**

Key Bioretention Treatment Node parameters:

Low Flow By-pass (cubic metres/second): This should be set to zero m³/s.

High Flow By-pass (cubic metres/second): The high flow bypass value can be estimated by using 50% of the 63.2% AEP peak flow. Where there is potential for treatment of the high flow by-pass, this can be modelled using a secondary drainage link to a treatment node.

Filter Area (square metres): The filter area depends on the scenario and is set as the area of the bioretention filter media.

Unlined Filter Media Perimeter (metres): The parameters for an unlined filter media perimeter depend on the scenario. Where an exfiltration rate of 0 mm/h is used, set the unlined perimeter to as close to zero as possible. If the unlined perimeter is not known, a useful general rule to use is four times the square root of the surface area.

Saturated Hydraulic Conductivity (mm/hr): It is usually best to use a loamy sand as the filter media for bioretention systems, with an effective particle diameter of around 0.45 mm and a hydraulic conductivity of 200 mm/hr. Given compaction and the accumulation of fine sediment particles in bioretention systems over time, the hydraulic conductivity value adopted for modelling should be set at half of the typical hydraulic conductivity (ie 90 mm/hr instead of the indicated 180 mm/hr for sandy loam media).

Filter Depth (metres): The recommended bioretention filter depth is between 0.4 m and 1 m. The depth depends on the available depth based on the inlet and outlet levels and the plant species being used. For particularly flat sites where streetscape bioretention pods are used, it may be possible to limit the filter depth to 0.3 m. For any filter media depth more than 0.8 m, the planting of deep-rooted plants such as trees is necessary. If a filter media depth of more than 0.8 m is proposed, obtain expert advice from a landscape architect or ecologist study that provides adequate justification for plant selection. Such advice should be lodged with the water cycle management plan. Do not model the depth of the intermediate transition layer or the drainage layer as part of the filter depth.

TN Content of Filter Media (mg/kg): Where the total nitrogen content in the filter media is unknown, use a value of 400 mg/kg. The total nitrogen content is the amount of nitrogen available within the filter media consistent with the Guidelines for Soil filter Media in Bioretention Systems (FAWB, 2009). Ideally the filter media used in bioretention systems and raingardens should be tested from NATA accredited laboratory and accurate figures based on locally-sourced filter media should be used where available and justification provided in the report.

Orthophosphate Content of Filter Media (mg/kg): Where the orthophosphate content of the filter media is unknown, use a value of 40 mg/kg. This is the amount of phosphorus available within the filter media defined by testing consistent with the Guidelines for Soil filter Media in Bioretention Systems (FAWB (2009). Accurate figures based on locally-sourced filter media should be used where available and justification provided in the report.

Exfiltration Rate (mm/hr): If a bioretention system is modelled with exfiltration, the pollutant loads in the water that is lost to exfiltration are included in the reduction of pollutant loads achieved across the treatment node (as shown by the mean annual loads and treatment train effectiveness statistics). NorBE and water quality objectives to reduce stormwater pollutants relate to all runoff leaving the site, including runoff exfiltrating to groundwater. Therefore, exfiltration shall be 0 millimetres per hour unless 'lost' water is returned to the model via a secondary drainage link or it can be demonstrated that infiltrated runoff would not contribute to observed flows downstream either through surface runoff, seepage into drainage lines, interflow or groundwater (for example deep sandy soils).

Where exfiltration is used the rate must be justified through in-situ soil testing relevant to the depth of exfiltration, and that the in-situ soils will not be compacted during earthworks and construction. If a system is designed and modelled to exfiltrate, the lining of the sides of the bioretention system is required to ensure that stormwater is properly treated through the filter before it enters the receiving environment. Exfiltration should only happen either at the level of the drainage layer or through the base of the bioretention system. The secondary link is to be used to capture this water for treatment in a media filtration node. The media filtration node is then connected to the next downstream node or the post treatment node.

Lining Properties: If the bioretention system is lined, tick 'Yes' to show that the base is lined and ensure the Exfiltration Rate is set to 0 mm/hr to comply with NorBE and water quality objectives. On steep (more than 25%) or constrained sites (for example, where the basin is located close to building footings), bioretention systems should be lined and/or should incorporate a suitably designed retaining wall (Water by Design, 2014).

Vegetation Properties: Plant types have a significant impact on reducing nutrient loads. Root morphology and associated physiochemical processes are key factors (Read *et al.,* 2009). Bioretention systems perform best with deep-rooting plants and they should be modelled using the option 'Vegetated with Effective Nutrient Removal Plants'. If the vegetation in the bioretention system is proposed to be turf, for example, use the 'Vegetated with Ineffective Nutrient Removal Plants' option.

Overflow Weir Width (metres): The length of the overflow weir controls the discharge rate when the water level in the bioretention system exceeds the top of extended detention. If the overflow weir is too small it can cause water to back up, effectively adding additional extended detention. To avoid this, set the overflow weir length (metres) as the surface area (square metres) divided by 10 m. Where there is potential for treatment of the overflow weir discharge, this can be modelled using a secondary drainage link to an appropriate treatment node.

Underdrain present? (Yes/No): As bioretention systems are generally configured with underdrain collection pipes the 'Yes' option should be ticked. If the proposed system does not include an underdrain, then the Infiltration System node should be used to model the system.

Submerged Zone with Carbon Present? (if Yes; Depth (metres)): If the system is proposed to include a submerged (or saturated) zone this option should be ticked. Submerged zones improve the potential for microbial denitrification, and provide more permanent storage of water for plants, which can be important during dry periods. Where practical, a submerged zone should be included below the underdrain. The submerged zone typically has a depth of between 0.2 m and 0.4 m, and consists of medium to coarse sand, or fine gravel, combined with a carbon source (usually 5% by volume of hardwood chips) to provide a permanent pool of water to support plants and to enhance microbial nitrogen removal.

Mulch: Organic mulch is not considered suitable due to risk of floating and clogging outlets and removal via wind. Gravel mulch can be useful to decrease the ponding depth for safety reasons and prevent scouring, but it may increase stress on plants due to heat retention and impede removal of accumulated sediment. Using a high planting density and care during seedling establishment is recommended to quickly develop high plant cover. Use of trees to shade the surface can also reduce drying.

Optimising bioretention systems to remove nitrogen and phosphorus

Designing a stormwater treatment system to reduce nitrogen and phosphorus loads, is best achieved through using either wetlands or bioretention systems. The following are some points to configuring a bioretention node for optimal nutrient removal.

Optimising a bioretention system is firstly about ensuring that the size is large enough to treat a significant proportion of the flow, but that it also drains quickly enough so that it is ready to capture the next event. Sizing a bioretention system is important and ideally should be around 2% of the upstream *impervious* catchment area. Anything greater than this 2% is going to be somewhat inefficient. Hydraulic conductivity should be set to half of the hydraulic conductivity for the filter media proposed to be used.

The optimal removal of nitrogen is dependent on the initial total nitrogen content of the filter media itself, and whether any submerged zone is used. Start with a value of between 400-500 mg/kg for the total nitrogen content for the filter media. If total nitrogen removal is not high enough consider employing a submerged zone. The submerged zone promotes denitrification under anoxic conditions, and thus provides greater nitrogen removal efficiency, but this will also cause phosphorus to leach out of the bioretention system and may impact on phosphorus removal efficiency.

Phosphorus removal is optimised by several methods. Firstly, ensure that the extended detention depth drains effectively as noted above, so that the system is ready for the next event, as some phosphorus is removed through sedimentation on the surface. Secondly, set the orthophosphate content of the filter media to between 40-50 mg/kg to reduce the potential for phosphorus leaching from the system. Where a submerged zone in a bioretention system, the depth of that zone should be less than 300 mm as greater depths will lead to higher phosphorus leaching.

Finally, tick the Vegetated with Effective Nutrient Removal Plants box in the bioretention node, and ensure that appropriate deep-rooted moisture-tolerant plants are used in the design.

Note that changing filter media and other parameters in the bioretention node in the model **must** reflect the design of the bioretention system, the availability of suitable filter media with the modelled nutrient content, and that which is constructed on- ground.

The maintenance of bioretention systems, particularly regular removal of accumulated litter, fine sediment and debris, and ensuring that plants are healthy will assist in ensuring high nutrient removal efficiency.

> ### *Key points – Bioretention systems*
>
> - The extended detention depth (EDD) for bioretention systems within lots or road reserves should be between 0.15 m and 0.30 m. While this depth range is feasible for most bioretention systems located in a road reserve, bioretention with a depth closer to 0.15 m should only be modelled for local streets where the system has sufficient flow capacity to minimize potential for nuisance flooding. It is better to have depths closer to 0.30 m wherever possible.
>
> - The EDD for bioretention systems outside lots and road reserves (for example, open space areas) may be deeper than 0.30m and up to 0.5 m, although this must be clearly demonstrated as being achievable and that the chosen vegetation is suitable for inundation at greater depths for prolonged periods. EDDs greater than 0.5 m will not be accepted.
>
> - For a raingarden or bioretention basin, the longitudinal gradient is likely to be close to 0% across the system, whilst a bioretention swale may have a gradient typically up to 2% and as a result the storage depth along the swale will vary. This should be accounted for when estimating the extended detention depth. Bioretention swales should be limited to locations where a longitudinal gradient less than 4% can be achieved.
>
> - MUSIC currently assumes that the extended detention storage has vertical sides. If the proposed system does not have vertical sides the surface area needs to be determined. For a trapezoidal shaped extended detention storage, the surface area should be calculated at half of the maximum extended detention depth.
>
> - The base of the bioretention system should be within soil and not recessed into rock, and should also be located at least 0.5 m above the seasonal high groundwater table to ensure that the media is not periodically saturated by groundwater. Where parts of a bioretention system are recessed into rock or lined with concrete (some raingardens), they must have a sufficient media depth for the proposed deep-rooted vegetation and must incorporate an underdrain.
>
> - Choosing plants for a bioretention system is critical to ensure best performance in terms of removing nutrients and maintaining saturated hydraulic conductivity. The best deep rooting plants to remove nutrients include Carex sp, Melaleuca ericfolia, M, inacana, M lateritia, Juncus sp., Goodenia ovata, Baume and Ficinia (Payne et al., 2015). Grass and turf are not effective plants for removing nutrients from the full filter media depth, and this should be shown as such in the Bioretention node. Plant selection depends on a number of factors including habitat, amenity, microclimate, safety and biodiversity.
>
> - The vertical structure of the bioretention media - particularly the transition layer, which consists of medium to coarse sand below the filter media - is important to prevent filter media from washing into the drainage layer and the drainage pipe. The drainage layer, which typically consists of fine 5 mm gravel conveys filtered water to and holds the perforated collection pipe.
>
> - For systems where the filtered flow will be collected in a sub-soil drain near the base of the bioretention filter and directed to a constructed drainage system, it should be confirmed that the sub-soil drain is not below the base of the stormwater pit that it would connect into. Choose an appropriate soil media considering the Adoption Guidelines for Stormwater Biofiltration Systems (Payne et al., 2015).
>
> - Where bioretention systems are located downstream of a large source area and unsealed area, pre-treatment, such as a buffer strip or gross pollutant trap, should be installed to reduce the risk of clogging filter media and to prolong the life of the system (see Figure 5.32).
>
> - Exfiltration shall be 0 millimetres per hour unless 'lost' water is returned to the model via a secondary drainage link or it can be demonstrated that infiltrated runoff would not contribute to observed flows downstream either through surface runoff, seepage into drainage lines, interflow or groundwater (for example deep sandy soils).
>
> - Bioretention systems should incorporate a surface mulch layer, consisting of coarse gravel, cobbles or rock, to prevent scouring and prolong the system's effectiveness and life.

5.2.4   Join source and treatment nodes and run post-development model

Once post-development source nodes and treatment nodes have been properly defined, they should be joined up consistent with the overall post-development site layout and drainage pattern of the site. It is useful to use junction nodes in MUSIC to provide a visual reference that is similar to the overall stormwater drainage and treatment network. When the network has been completed, the MUSIC model representing the post-development case should be simulated and the results extracted for comparison with the pre-development case.

5.3 Step 7 - NorBE analysis

There are two measures of pollutant levels with respect to water quality that are relevant to NorBE - pollutant load and pollutant concentration. Loads are generally a more suitable measure for still waters whereas concentration is generally more suitable for moving water. Both measures must be considered in an acceptable NorBE analysis. Additionally, NorBE must be shown at all times including particularly during wet weather.

5.3.1   Pollutant loads

All models have inherent uncertainties arising from assumptions and approximations associated with the algorithms used in the model, as well as input data such as rainfall parameters. As a result, to ensure NorBE is achieved, the modelled pollutant loads for the developed case should aim to achieve 10% less than the pre-development case for total suspended solids, total phosphorus and total nitrogen. For gross pollutants, the modelled post-development load only needs to be equal to or less than pre-development load.

These levels have been set conservatively to account for potential uncertainty in MUSIC predictions and to ensure that NorBE is satisfied despite this uncertainty. This can simply be achieved by comparing the mean annual pollutant loads of the existing and developed cases.

5.3.2   Pollutant concentration

To meet NorBE the concentration of pollutants for the post-development case should always be equal to or less than the concentration for the pre-development case. This is impractical for a risk-based approach and the natural variability of rainfall events. As a result, NorBE will be deemed to be met if the post-development case pollutant concentrations are equal to or less than the pre-development case concentrations between the 50th and 98th frequency percentiles when runoff occurs. This can be demonstrated by comparing the cumulative frequency graphs of pollutant concentrations (typically in milligrams per litre) for the pre- and post-development cases. Due to the background pollutant concentrations (C*) for a number of treatment measures, sometimes it is not possible to show that post-development concentrations are equal to or less than pre-development levels at very low pollutant concentrations below the 20th percentile. The real challenge of this NorBE test, however, is at the higher concentration end of the frequency spectrum, where these concentrations also potentially have the greatest impact on water quality. Invariably, meeting this NorBE test for the 50th to 98th percentile range will generally also show NorBE for the 20th to 50th percentile range.

5.3.3   Step 8 - Comparing pre- and post-development nodes in MUSIC

MUSIC includes two nodes to represent the end point of pre- or post-development to assist in evaluating whether NorBE has been achieved. These nodes allow a user to model both the pre- and post-development situations in the one model and compare the results directly on the screen.
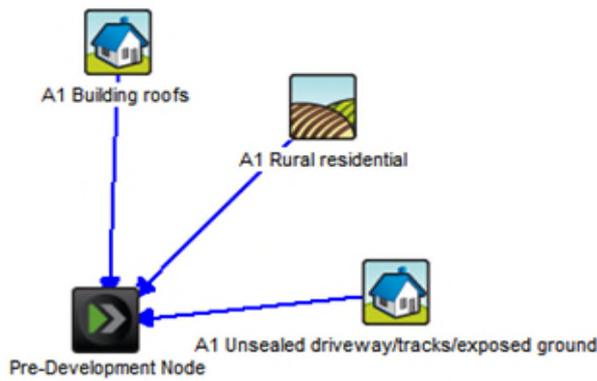
Figure 5.34:   Pre-development model

Once the pre-development model is completed, build the post-development model within the same MUSIC model page with the model finishing at the post-development node as shown in Figure 5.35. For auditing purposes, similar nodes in the pre- and post-development scenarios should have unique names as demonstrated in Figure 5.35 below.
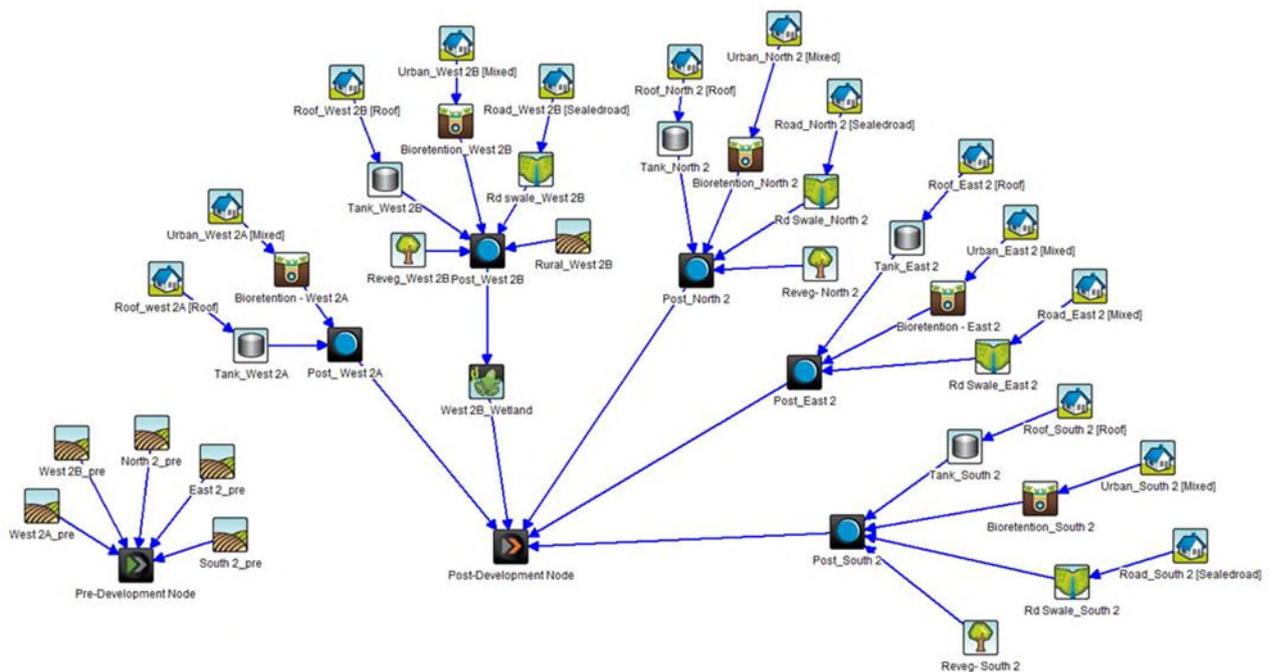
Figure 5.35:   Pre- and post-development models

5.3.3.1 Comparing pollutant loads

From this point, NorBE for pollutant loads can be assessed by simply right clicking on either the Pre- or Post-Development Node and display the mean annual loads through the Statistics -> Mean Annual Loads option and ticking the "Include Pre- (or Post-) Development" box as shown in Figure 5.36. When this is ticked, the other development node results are displayed next to the current one so that a direct comparison can be made. This can then be used to determine whether the post-development results are in compliance with this part of the NorBE requirement.

Figure 5.36:   Mean annual loads comparison

The Node Water Balance can be used to identify effectiveness of proposed treatment measures and assist in refinement of the treatment train design. It also helps to determine whether water, and associated nutrients, are being "lost" from the treatment train resulting in an unrealistic water quality benefit. For example, it identifies infiltration loss where an exfiltration rate has been set above '0' and a secondary drainage link hasn't been applied. See Figure 5.37 below.

Figure 5.37: Node Water Balance

5.3.3.2   Comparing pollutant concentrations

In MUSIC, Advanced Charts can be used to directly compare cumulative frequency graphs of pollutants. As an assessment of NorBE only applies to pollutant concentrations when runoff occurs, the times when there is no runoff must be removed as these can unduly influence the cumulative frequency chart and make it difficult to achieve NorBE. To remove these no-flow periods, click on the Post-Development node, then select the Flow-Based Sub-Sample Bounds option as shown in Figure 5.38. This provides the option of setting a lower or upper threshold for MUSIC to compile results with. To eliminate periods of no flow set the Lower Flow Threshold to zero as shown below. Repeat the process for the Pre-Development node.
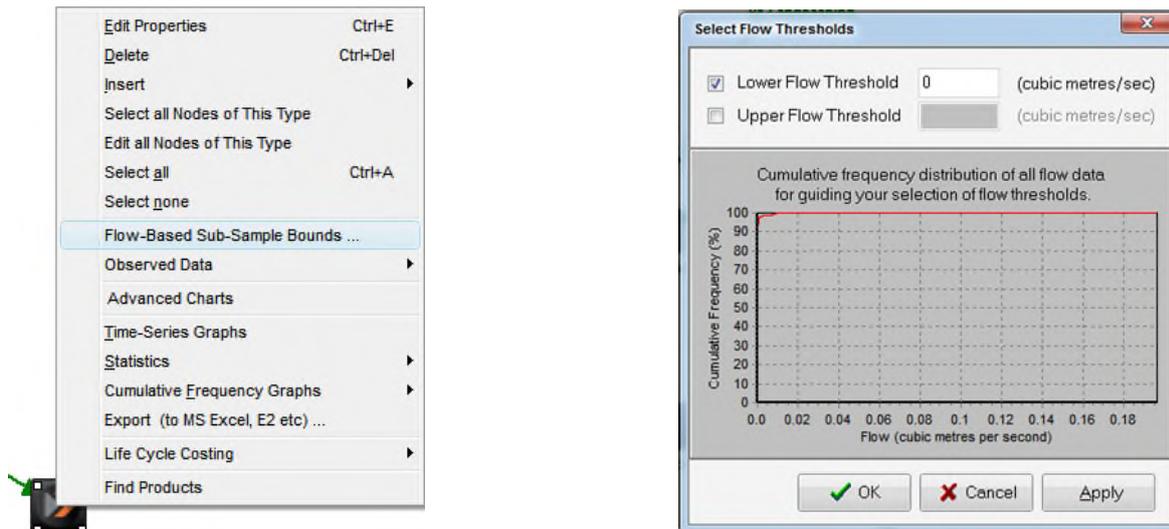
Figure 5.38:   Select Flow-Based Sub-Sample Bounds and set Low Flow Threshold to zero

Once the low flow thresholds have been set to zero, use the Advanced Charts to display both the Pre- and Post-Development nodes on the one chart. To do this, right click on the Post Development Node and select Advanced Charts as shown in Figure 5.39. The first chart to display is the Flow chart as a Time Series.
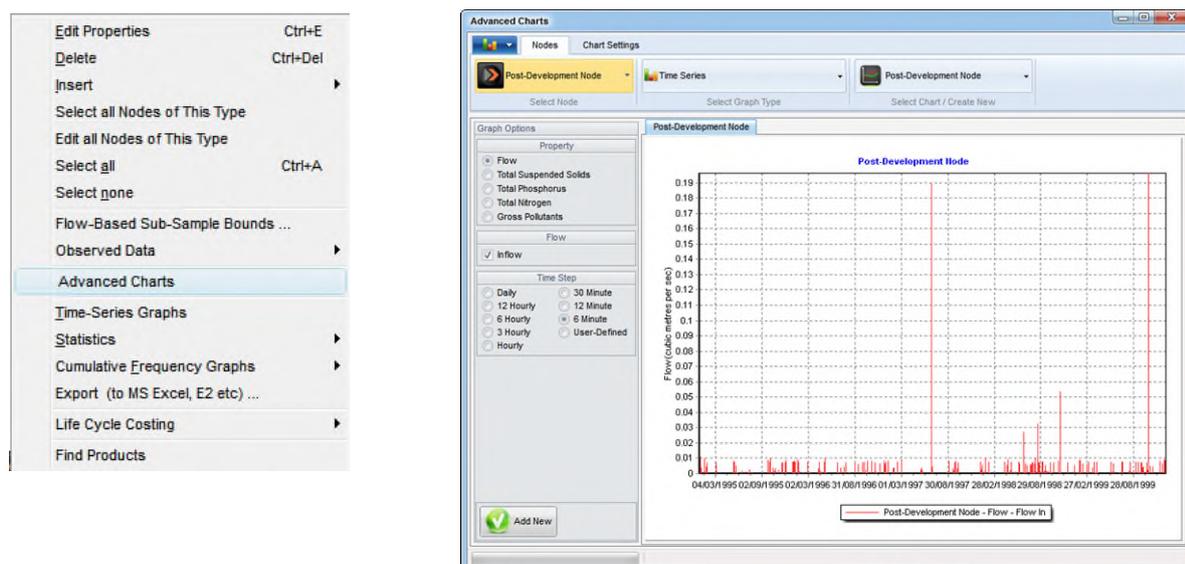
Figure 5.39:   Select Advanced Charts and then select Time Series

From this chart, change the Graph Type to Cumulative Frequency – Flow-Based Sub-Sample using the Select Graph Type button in the centre of the top tool bar as shown below.
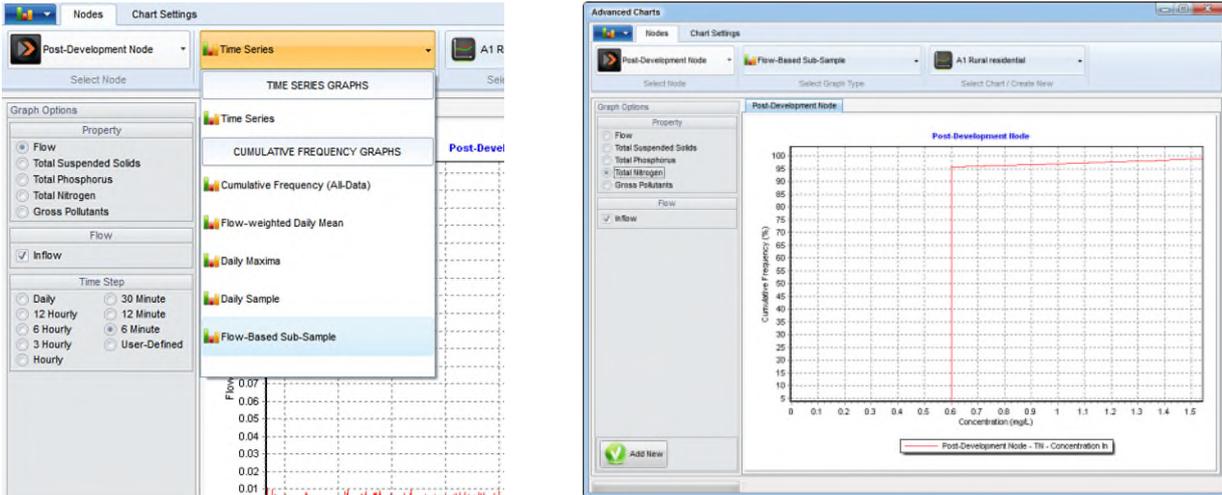
Figure 5.40:   Select Flow-Based Sub-Sample and then choose pollutant (eg Total Nitrogen)

Once the data has been processed, select the pollutant of interest, eg Total Nitrogen, from the Graph Options – Property box on the left hand side of the chart window. This will display the flow-based sub-sample cumulative frequency chart for Total Nitrogen for the node as shown in Figure 5.40.

Once this has displayed, a second cumulative frequency chart can be added by clicking on the Add New button in the bottom left hand corner of the chart window, then selecting the second node, in this case the Pre-Development Node. This will display the Total Nitrogen Flow-Based Sub-Sample Cumulative Frequency graphs for both the Pre- and Post-Development Nodes on the same screen as shown in Figure 5.41. From this combined graph, a visual assessment can be undertaken to check whether the post-development concentration is equal to or less than the pre-development level between the 50th and 98th percentiles as part of the NorBE test. The example shown below indicates that post-development total nitrogen concentrations are less than the pre-development concentrations for the entire frequency range indicating that this aspect of NorBE is met in this case. The case studies in Section 6 indicate that this pre- and post-development comparison is not always as clear as indicated in Figure 5.41.
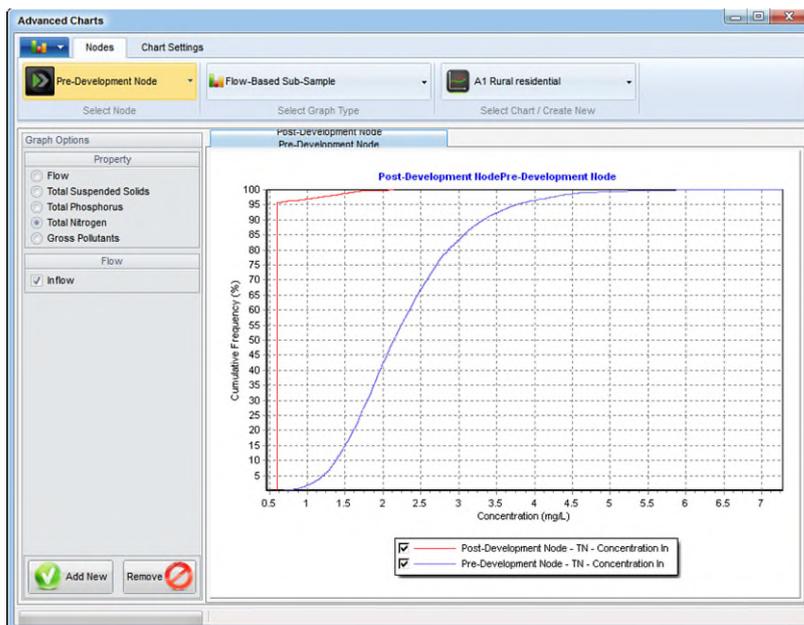
Figure 5.41:   Pre- and post-development cumulative frequency plots for total nitrogen concentration

5.3.4 Review, modify and finalise model and proposal

If the NorBE criteria in Sections 5.3.1 and 5.3.2 are not satisfied, it is important to identify the reasons before modifying the model. This may require including extra or alternative stormwater treatment measures and/or to increase the size of the proposed measures. Once the model is revised, it should be rerun and tested against the NorBE criteria. Continue this process until NorBE is satisfied. Sometimes it may be necessary to reduce the scale of the development to meet NorBE, particularly for some extensive and intensive commercial and industrial proposals. To revise and modify the application may necessitate liaison and consultation with the owner/developer, other consultants or engineers, Council or WaterNSW. At all times ensure that what is modelled and proposed is agreed by the developer and is reflected in the final stormwater plan for the development.

5.4 Step 9 - Write report

The MUSIC modelling report is part of a water cycle management study for the proposed development that shows that the proposed development can achieve a sustainable neutral or beneficial effect on water quality including during periods of wet weather. It should contain and consider the following information and issues:

5.4.1 Site and development details

5.4.1.1 Description of the proposed development

- A clear and complete description of the proposed development including the likely nature of any future uses that may result from it.

- Site plans at a suitable scale in the context of the site constraints.

5.4.1.2 Site details

- Lot and DP numbers, land use, total area and area proposed to be developed.

- Site characteristics - topography, soil information, climate, native vegetation, surface and subsurface hydrology including the presence of any watercourses, any flooding potential, drainage networks, poor drainage areas, existing erosion control structures, existing erosion problems such as gullies, salt affected areas, and any constraints or opportunities for water cycle management.

- Where necessary information about surrounding land uses, particularly where this can effect stormwater management (including stormwater inflows from surrounding catchments, or where the surrounding natural vegetated, riparian or aquatic environment is pristine or has a high water quality, biodiversity or habitat value.

- Defined sub-catchments and an accurate representation of the existing situation, including identifying how existing drainage on the site is managed (that is where the water flows) in relation to existing contours or topography.

5.4.1.3 Site land use changes

- Defined sub-catchments for the future scenario, including an accurate representation of the changes resulting from the development such as the construction of buildings, car parks, roads, driveways, vegetation clearing and hardstand areas.

- An accurate representation of the location, size and imperviousness of each land use change. Identification of how future drainage will be configured, including final site topography after any site regrading, and the location of discharges off the site (that is where NorBE will be determined).

- The location of all proposed water management structures, devices and flow lines, including landscaping and any other information that may affect or relate to stormwater management. This should include any offset measures such as revegetation or erosion gully rehabilitation.

- Identify any potential future water quality or quantity issues including impacts on watercourses, rivers, and riparian zones.

5.4.2 Proposed stormwater management and offset measures

5.4.2.1 Proposed stormwater management measures

- The report should identify the proposed stormwater management measures that are appropriate for the site and soil, and the scale and nature of the development. It should also clearly identify the location of these measures to ensure that the maximum volume of stormwater from the site is treated.

- It should detail the specific design elements of the proposed stormwater management measures, including the hydraulic basis for their sizing based on the size of the contributing catchment area and proposed land uses. They must be able to treat most of the runoff from the site before any discharge off-site or to a watercourse. In some circumstances it may necessitate being able to accommodate off-site hydraulic loads that flow onto the development.

- It should consider whether the proposed treatment measures can be practically implemented at the proposed location in the development site. It should also be demonstrated that there is adequate space to implement the treatment measures, and that they are appropriately located in the development (for example water will flow into them as intended) so that they can capture runoff from the modelled catchment areas. The treatment measures should not adversely impact upon, or be impacted on, by the operation of the site. The operation of the site must not affect the ability to maintain the treatment measures. Proposed roadside treatment measures must be practical and acceptable considering potential use of the road reserve for the location of council utilities.

- It should show appropriate design parameters to ensure the proposed treatment measures are hydraulically sound with regard to size and function. It should also show that they can convey the design event/s where they are in the overall drainage network, and their detention times are appropriate for the performance required. For example, if a wetland is proposed for nutrient removal, it should be shown using hydraulic calculations that the feasible detention time for the configuration is consistent with MUSIC's 48 to 72 hour detention time.

- The report should clearly specify and justify any variations to the recommendations, requirements or specifications of this standard.

- It should identify the life span, the practicalities of ongoing management, and the maintenance cost requirements of proposed treatment measures to ensure that they will not be an inordinate and unrealistic maintenance burden on those responsible for on-going management. For example the stormwater management structures such as gross pollutant trap media filtration devices in road and public reserves as part of a subdivision where such structures are often dedicated to councils.

- The report should identify any specific measures needed to protect the proposed stormwater management measures including appropriate signage.

5.4.2.2 Proposed offset measures

- The report should identify the nature, magnitude and location of any proposed offset measures such as revegetation of pasture land or riparian zones, or erosion gully rehabilitation, when these measures will be implemented, and how the success of these measures is ensured, for example the survival rate of plants in revegetated areas.

- The report should identify any specific measures needed to maintain and protect the offset measures.

5.4.3 MUSIC modelling

The MUSIC model needs to show that the proposed development can achieve a sustainable neutral or beneficial effect on water quality including during wet weather and should include:

5.4.3.1 Climate data

- The model must use climate data provided by WaterNSW relevant to the location of the development. Climate data available on WaterNSW's website. Where this is not available an acceptable alternative may be to use five years of six-minute rainfall data for a nearby location that has at least 20 years of records. The five years should include a number of average years as well as the wettest year on record.

5.4.3.2 Modelling assumptions, representation and configuration

- The report needs to include a statement of all assumptions that have been adopted in the MUSIC model and the implications for NorBE. This may include notional dwelling sizes and associated impervious or other impacted areas for a subdivision where NorBE is reliant on such measures. Note: Reliance on only future lot-scale stormwater quality measures for subdivisions is not acceptable.

- Identify key assumptions relating to land use change such as the retention of existing native vegetation and regrowth, or the retention of existing erosion control works structures on site for ongoing water quality management.

- The model needs to realistically represent the site in the pre- and post-development cases and must be supported by detailed site plans.

- The model must use appropriate source nodes for the land uses being simulated including default pollutant concentrations, and realistic impervious area percentages for pre- and post-development cases.

- The NorBE model comparison must ensure the same total catchment area is modelled for the pre- and post-development cases.

- Appropriate treatment nodes for proposed stormwater management structures must be used for the post-development case.

- The model must use design parameters for treatment nodes based on appropriate hydraulic sizing and treatment effectiveness.

- A clear and strong justification must be provided for the use of any non-default or non-specified parameters in the model – it is suggested that modellers consult WaterNSW where they propose to use any non-default parameters.

5.4.3.3 Modelling results and NorBE demonstration

- The modelling results must compare pre- and post-development annual pollutant loads and should aim for an improvement of least 10% for nutrients and suspended sediments to ensure NorBE can be met given the uncertainty in the modelled outcomes.

- The modelling results must compare pre- and post-development cumulative frequency curves of pollutant concentrations and should show that post-development concentrations are better than or equal to pre-development concentrations between the 50th and 98th frequency percentiles.

- An electronic copy of the MUSIC model must be provided to the consent authority for assessment.

5.4.3.4 Other water cycle management study requirements

- The water cycle management study must also identify which WaterNSW current recommended practices will be used during construction and post construction phases of the development, or

identify alternative best management practices where it can be demonstrated they will achieve at least the same water quality outcome.

- The study must incorporate an overall conclusion that should include a specific conclusion about the nature, extent and duration of any stormwater quality and quantity impacts on any receiving waters and drainage network, and also a specific conclusion about the sustainable achievement of NorBE at all stages of the proposed development.

- It must include or have attached a stormwater drainage plan that shows the location, size and nature of each stormwater treatment measure including a section view or relative levels. The drainage plan must reflect MUSIC model requirements and management measures.

- It should also include a detailed list of all references used.

- The water cycle management study may also include a section on lifecycle cost analysis, where councils require such cost-benefit analysis of stormwater management works that are to be dedicated to council. In such a case the study should include the overall life cycle costs for all elements in the treatment train split into total acquisition, typical annual maintenance and renewal/adaptation costs. In most cases, a decommissioning cost should not be included and this should be set to the same value as the typical annual maintenance cost.

6 CASE STUDIES

These case studies show how MUSIC models apply to particular development types by applying this manual in order to meet compliance with the neutral or beneficial effect test on water quality. They are based on real developments in Sydney drinking water catchment area, although locations and/or configurations have been changed slightly where appropriate so as to not identify any particular development. The case studies are just one example of how to model the development types, not the only or the definitive method.

6.1 Case study 1: Small scale peri-urban residential subdivision

6.1.1   Site and development summary

This case study is a fourteen-lot subdivision in a sewered area on the outskirts of Goulburn and involves creating residential lots with lot sizes ranging from 700 m^2 to 1,520 m^2. The site has access to a reticulated town water supply and sewer.

The site characteristics for this fourteen-lot residential subdivision are summarized in Table 6.1 with the site plan shown in Figure 6.1.

Table 6.1:   Case study 1: Site characteristics

Site characteristics	Detail
Site location:	Goulburn
Drinking water catchment:	No. 14 – Wollondilly River
Rainfall and PET zone:	No. 1
Total site area:	1.3 ha
Total catchment area:	1.3 ha
Total disturbed area:	0.927 ha
Pre-development site gradient:	2 - 5%
Soil landscape:	Sooley – light to medium clay dominant soil type
Existing watercourses?	No – Wollondilly River approximately 120 metres south of site
Overland flow draining onto the site?	Minimal
Soils suitable for infiltration?	Limited potential
Pre-development	**Description**
Existing development characteristics:	Residue land on an existing hospital site
Existing land uses and areas:	Small hospital site with approximately 66% of site vacant comprising open grassland with no tree coverage
Post-Development	**Description**
Proposed development characteristics:	14-lot urban residential subdivision, lot sizes between 700 m2 and 1,520 m^2, a new sealed subdivision road and access driveway. Existing cottages on site will remain.

6.1.2   Catchment details and representation

6.1.2.1   Pre- and post-development catchment detail

The site is partially developed with two thirds of the site vacant, open grassland. The site grades at 2 to 5% from the location of the proposed subdivision road and access driveway, generally towards the Wollondilly River located directly south, approximately 120 metres from the site.

Catchment areas have been defined primarily considering the drainage flow paths, the locations of proposed treatment measures, and the distribution of surface types. The site has been defined as one catchment for the pre-development case (A1) and four sub-catchments for the post-development case (B1, B2, B3 and B4) representing urban lots and/or subdivision road and access driveway (Table 6.2).

Figure 6.1:   Case study 1: Site plan – existing (left) and post-development (right)

Table 6.2:   Case study 1: Development summary for the site

Land use / surface type	Total area* (ha)	Sub-catchment areas (ha)			
Pre-development		**A1**			
Residential	0.926	0.926			
Total	**0.926**	0.926			
Post-development		**B1**	**B2**	**B3**	**B4**
Residential (undeveloped)	0.784	0.320		0.464	
Subdivision roads/ access roads	0.142	0.098	0.020		0.024
Total	**0.927**	0.418	0.020	0.464	0.024

*Note: only the disturbed area of the proposed subdivision has been included in the model.

6.1.2.2   *Source nodes and parameters for pre- and post-development cases*

As the NorBE assessment only applies to the current proposal, being the construction of the subdivision road, access driveway and intra-allotment drainage for the proposed lots, future dwellings and associated hardstand areas are not considered in the MUSIC modelling. WaterNSW considers that any subsequent applications for dwellings and/or other developments on the proposed lots will be subject to the provisions of State Environmental Planning Policy (Biodiversity and Conservation) 2021 and will need to be assessed according to the NorBE test in relation to the potential effect of that development on water quality. Therefore, modelling of the lots using the Urban [Residential] selection applied 100 percent perviousness.

For the pre-development case, given the developed portion of the site will remain unchanged as the cottages will be retained, only the disturbed area of the site was modelled with one source node representing the defined surface type as per Table 4.1. For the post-development case, the site was divided into five nodes including subdivision road, access driveway and undeveloped residential lot areas.

Rainfall-runoff parameters for the impervious surfaces (rainfall threshold) were determined for each surface from Table 4.3. Pervious surface parameters (see Tables 4.4 and 4.5) were determined from those for a silty clay loam derived from geotechnical data for the site. The base flow and storm flow pollutant concentration parameters for the pre- and post-development nodes were automatically populated with the values from Tables 4.6 and 4.7 as the appropriate zoning/surface type was selected for each node. Note some default parameters (for eroded gullies, agricultural and forest nodes both for baseflow and stormflow) are inconsistent with values in Tables 4.6 and 4.7. Until such times these values are corrected in the future version of MUSIC, manually enter the correct values.

6.1.3   Proposed treatment measures for post-development case

6.1.3.1   *Bioretention Basin*

A 40 m^2 bioretention basin was provided beside and at the low end of the subdivision road to manage road runoff and runoff from proposed lots 1 to 4. The node was constructed according to the details outlined in section 5.2.3.2.

The following were required for the bioretention basin:

- be designed consistent with Adoption Guidelines for Stormwater Biofiltration Systems Version 2 (Payne *et al*, 2015, CRC for Water Sensitive Cities Ltd.)
- be planted with appropriate deep-rooted, moisture-tolerant vegetation protected by rock mulch (grass and turf is not appropriate vegetation and organic mulch is not suitable)

- be permanently protected from vehicular damage by bollards, fences, castellated kerbs or similar structures, with a sign to be erected to advise of its nature and purpose in water quality management, and
- be protected by sediment and erosion control measures during any construction and post-construction phase until the ground surface is revegetated or stabilised.

An instrument created under Section 88E of the *Conveyancing Act 1919* was also required over proposed Lot 5 requiring the bioretention basin be retained, protected and maintained in accordance with the required Operational Environmental Management Plan, and that no development take place within one metre of the structure.

6.1.3.2 Permeable paving

Permeable paving is proposed for the entire length of the access driveway to proposed Lot 10. The subdivision road, which may be subject to heavy-vehicles would be concrete or bitumen-sealed.

The access driveway node was modelled with 15 percent perviousness, with the zoning/surface type of sealed road selected.

Section 5.2.2.2 and Table 4.3 were used to determine the configuration of the node, including rainfall threshold for the permeable pavement. A void open to close ratio of 15% was used to estimate the rainfall threshold for the permeable paving.

6.1.3.3 Buffer strips

A buffer strip was provided along the access driveway to proposed Lot 11 to filter runoff before discharge to council's stormwater system.

- It was assumed that 100% of the impervious access driveway would be buffered.
- The supplied plans showed the driveway would be 4 m wide and that buffer strip with a width of 1 m (that is 30 % of the upstream impervious area) would be located beside the driveway.
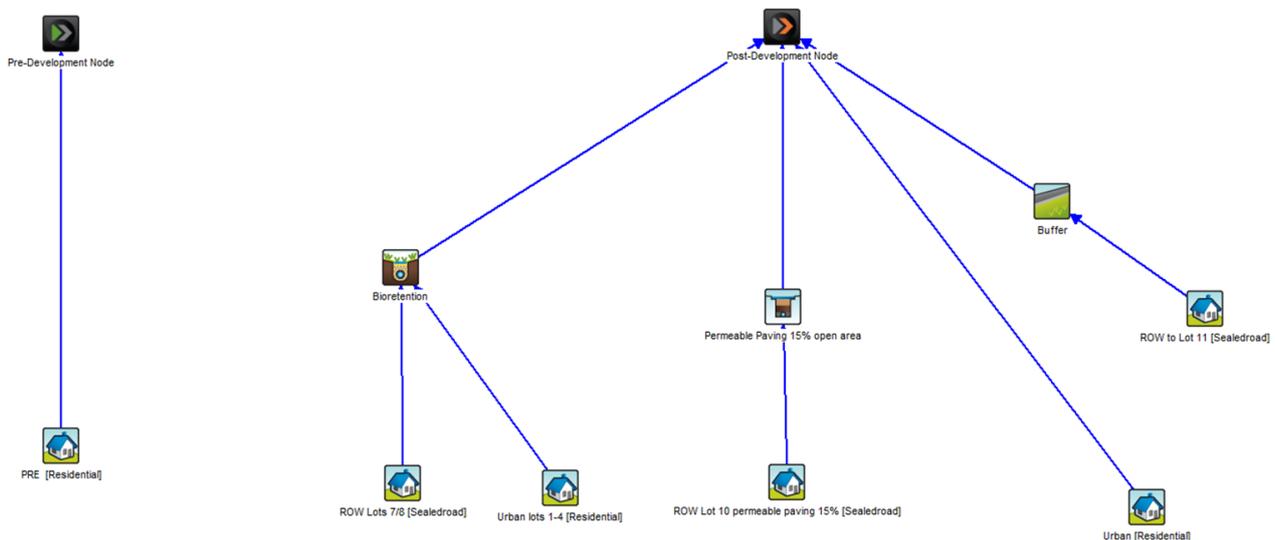
Figure 6.2:   Case study 1: Pre- and post-development MUSIC models

6.1.4 Model results

The MUSIC models for the site are shown in Figure 6.2, the model results for annual pollutant loads are presented in Table 6.3 below, and the comparative cumulative frequency curves for pollutant concentration (phosphorus and nitrogen) are provided in Figure 6.3.

Table 6.3: Case study 1: MUSIC modelling pollutant load results

Scenario/catchment	Annual pollutant loading (kg/yr)			
	TSS	TP	TN	GP
Pre-development (1)	110	0.231	1.77	4.46
Post-development (with measures) (2)	65.5	0.179	1.59	3
Difference (3) = (1) – (2)	44.5	0.052	0.18	1.46
% Improvement = (3) / (1) *100	40%	23%	10%	33%
Neutral or beneficial effect? (Y/N)	Y	Y	Y	Y
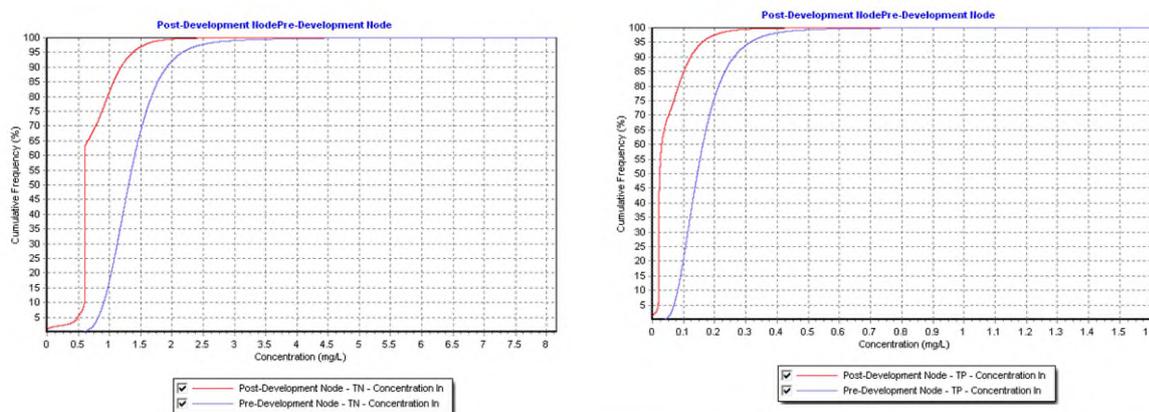
Figure 6.3: Case study 1: Pre- and post-development cumulative frequency graphs for nutrient concentrations

6.1.5 Conclusions

- The modelled post-development total suspended solids, total phosphorus, total nitrogen and gross pollutant loads with the proposed stormwater management measures in place are all 10% less than pre-development conditions.

- The total suspended solids, total phosphorus and total nitrogen runoff concentrations for the post-development scenario are lower than or equal to the pre-development conditions between the 50th and 98th percentiles. For phosphorus concentrations the cumulative frequency crossover between pre- and post-development at the 45th percentile just meets the NorBE requirement.

- The MUSIC model results have conceptually shown that NorBE would be achieved for the 14-lot urban residential development on the site with the proposed management measures.

- The sustainable achievement of NorBE will require stormwater management measures consisting of:
  - a 40 square metre bioretention basin to treat runoff from the subdivision road
  - permeable paving for 100% of the access driveway to proposed Lot 10, and
  - buffer strips along the access driveway to proposed Lot 11.

- Although this example of a NorBE analysis covers the subdivision works only, subsequent applications for dwellings and/or other developments on the proposed lots will need to be assessed according to the NorBE test in relation to the potential effect of those developments on water quality.
- The bioretention basin constructed for the subdivision works would need to be protected from siltation during construction activities for future dwellings on the lots using suitable erosion and sediment control measures.

6.2 Case study 2: Medium-density urban residential development

This case study for applying MUSIC is for a staged 70-unit seniors living development that includes communal buildings and communal areas, as well as a central road, access roads, driveways and parking areas on a 3.2 hectare site on the outskirts of Braidwood. The site will be sewered and connected to reticulated water supply. The site is cleared and there are no major constraints and no drainage features other than an existing dam near the bottom of the site i.e. to the south. Most of the site slopes gently towards a road to the east, which has a roadside drain draining to a nearby watercourse. Neither the soils nor the climate are major constraints, however, the intensity of the development may provide challenges for locating the stormwater management measures.

6.2.1 Site and development summary

The site characteristics for this 70-unit medium density residential development are summarized in Table 6.4, with a post-development site plan for Stage-1 (only) shown in Figure 6.4.

Table 6.4: **Case study 2: Site characteristics**

Site characteristics	Detail
Site location:	Braidwood
Drinking water catchment:	No. 4 - Braidwood
Rainfall and PET zone:	No. 1
Total site area:	3.2 ha
Total catchment area:	3.2 ha
Pre-development site gradient:	1 - 3%
Soil landscape:	Braidwood – sandy clay predominant soil type
Existing watercourses through the site?	No - but roadside drain located along eastern boundary draining to a nearby watercourse.
Overland flow draining onto the site?	No
Soils suitable for infiltration?	No
Pre-development	**Description**
Existing development characteristics:	Rural residential lot
Existing land uses and areas:	Rural cleared land – just one dwelling, two large sheds, a driveway, large hardstand areas, and a farm dam, but virtually no trees.
Post-development	**Description**
Proposed development characteristics:	Staged Strata title, 70 residential Seniors Living units, one main communal building, a central access road, shared driveways, parking, hard and soft landscaping. External and internal re-use of rainwater.

6.2.2 Catchment details and representation

6.2.2.1 Pre- and post-development catchment detail

Catchment areas were defined mainly considering the drainage flowpaths, locations of proposed treatment measures and distribution of surface types. The site has been defined as one catchment for the pre-development case (A1) and three sub-catchments for the post-development case (B1, B2 and B3) (Table 6.5). These sub-catchments were further divided based on surface types and to define direct runoff and rainfall on treatment measures (such as permeable paving). As the whole development eventually drains to one point on the site and the lowest section was to be developed first as Stage-1. NorBE needs to be shown for all stages of a development, but in this example is only shown for Stage-1 of the development.

Table 6.5: Case study 2: Development summary for the site

Land use / surface type	Total area (ha)	Sub-catchment areas (ha)		
Pre-development		**A1**		
Cleared rural land	3.00	3.00		
Unsealed driveway and hardstand areas	0.10	0.10		
Dwelling and shed roofs	0.10	0.10		
Total	**3.20**	3.20		
Post-development		**B1**	**B2**	**B3**
Residential roofs	0.70	0.45	0.25	
Access driveways (75% permeable paving)	0.338	0.225	0.113	
Access driveways and footpaths (25% impermeable)	0.112	0.075	0.037	
Communal building roof	0.07	0.07		
Central access road	0.08			0.08
Hard/soft landscaping	1.90	0.60	1.30	
Total	**3.20**	1.42	1.70	0.08

6.2.2.2 Source nodes and parameters for pre- and post-development cases

For the pre-development case it was reasonably determined that the site was entirely pervious except for a single dwelling, several large sheds, an unsealed driveway and various tracks and hardstand areas. As there was a detailed site plan for the development site it was easy to determine the various land surface types for the post-development case, and the effective impervious areas were determined by using the parameters in Table 4.2. All roofs and the central access road were assumed to be 100% effective impervious area. Twenty five percent of the access driveways to the units were sealed with bitumen while the other 75% were constructed of permeable paving with a void ratio of 13%. It was assumed that 10% of the landscaped area on the site would be impervious, and based on Table 4.2, 50% of this impervious landscaped area would be effective impervious area (that is 5% of the total landscaped area).

Rainfall-runoff parameters for the impervious surfaces (rainfall threshold) were determined for each surface type from Table 4.3. Pervious surface soil parameters (see Tables 4.4 and 4.5) were based on a sandy clay loam, which is the dominant soil type based on geotechnical data for the site. The base flow and storm flow pollutant concentration parameters for the pre- and post-development cases were taken from Tables 4.6 and 4.7 for the various surface types for each case (see Table 4.1).

The pre-development case was modelled as one catchment with three separate nodes, while the post-development scenario was modelled by separating the site into six individual surfaces (Table 6.5) notionally separated into three sub-catchments, although they could all drain to the same outlet to the east.

Permeable paved road
Internal sealed road
Concrete path
Communal landscape area
Private landscape area

Figure 6.4:   Case study 2: Site plan for Stage-1 of the seniors living development

6.2.3   Proposed treatment measures for post-development case

6.2.3.1   Rainwater tanks

As with all developments involving dwellings, rainwater tanks are proposed to catch and re-use roof runoff. The minimum tank size for a development may be specified by BASIX or discussions with the local authority, however, for these small units with a roof area of approximately 100 m², rainwater tanks with a capacity of 4 kL were required. For the larger communal building a rainwater tank with a capacity of 10 kL was needed. In addition, the following representations, configurations and assumptions were used for rainwater tanks and water use:

- The roof areas, rainwater tanks and water demand were aggregated for all lots to simplify modelling.
- All roofs are 100% impervious and the appropriate rainfall threshold for roofs was adopted from Table 4.3.

- It was assumed that 80% of 4 kL rainwater tank capacity was available to harvest, and the other 20% of capacity was configured for mains top-up.

- It was assumed that all of the relatively small 100 m^2 dwelling roof area could be configured to direct all runoff to a rainwater tank.

- As the development incorporates aged care housing, it was assumed that up to 50% of the internal domestic water demand (toilets and laundry) would be sourced from the rainwater tanks, and that 100% of external water use for landscape watering was also sourced from the tanks (see Table 5.3).

- The estimated water use demands were based on a dwelling occupancy of two people. Total water demand for each unit was based on the values provided in Table 5.3.

- It may be assumed that each dwelling and the communal building would have individual rainwater tanks. However, one or more larger underground tanks of equivalent capacity that can capture the roof runoff from all units and be plumbed for toilet and laundry re-use in all units would be equally acceptable.

6.2.3.2 Permeable paving

Permeable paving was proposed for 75% of the shared access roads, driveways and parking areas. The remaining 25% would be bitumen sealed. The following representations, configurations and assumptions were used for the shared access driveway area.

- The shared access driveway and parking areas were aggregated for each sub-catchment to simplify modelling.

- The shared driveways were split into two nodes for each sub-catchment to represent the 75% permeable paving and 25% sealed pavement.

- An effective imperviousness of 100% was used for both the permeable and sealed pavements. The rainfall thresholds for the open and paved portions of permeable paving and the sealed pavement were determined from Table 4.3.

- A 'void' or 'open to closed' paved area ratio of 13% was adopted for the permeable paving (see 5.2.2.2).

6.2.3.3 Buffer strips

Buffer strips would be provided beside the impervious pathways and walkways in the landscaped areas of the site to filter runoff before discharge to constructed drainage lines that direct runoff to a bioretention basin.

- It was assumed that 75% of the impervious pathways and walkways would be buffered.

- It was also assumed that the pathways and walkways would be 1.5 m wide and that buffer strips with a width of 0.75 m (that is 50% of the upstream impervious area) would be located beside the pathway.

6.2.3.4 Gross pollutant trap

All constructed stormwater drainage lines and other surface runoff is to be directed to a gross pollutant trap located upstream of the bioretention basin. The purpose of the gross pollutant trap is to remove litter, organic debris and sediment, and to protect the bioretention basin from being overloaded and prevent its longer-term performance being impaired by such material.

6.2.3.5 Bioretention basin

A large bioretention basin with a surface and filter area of 100 m^2 was proposed to capture and treat most of the site runoff. Drainage lines would need to be constructed to ensure that all runoff from the three sub-catchments was directed via the gross pollutant trap to the bioretention basin. The optimal size of the basin to ensure that NorBE would be achieved for the development was determined by

iteration. The discharge and overflow from the basin would be directed via a pipe and stabilised outlet to the ornamental pond.

6.2.3.6 Ornamental pond

The existing farm dam was converted to a small shallow ornamental pond able to receive the discharge from the bioretention basin. It could arguably be considered part of the treatment train. However, it was not modelled in MUSIC as the pond would provide minimal improvement of filtered water being discharged from the bioretention system. The ornamental pond, which already contained some submerged and emergent aquatic vegetation, discharged to the adjoining roadside drain via an armoured and stabilised outlet.

6.2.4 Model results

The pre- and post-development MUSIC models are shown in Figure 6.5, the model results for annual pollutant loads are shown in Table 6.6, and the comparative cumulative frequency curves for nutrient concentrations are shown in Figure 6.6.

Table 6.6: Case study 2: MUSIC modelling pollutant load results

Scenario/catchment	Annual pollutant loading (kg/yr)			
	TSS	TP	TN	GP
Pre-development (1)	612	1.160	7.37	34.1
Post-development (with measures) (2)	74.5	0.612	5.32	0
Difference (3) = (1) – (2)	537.5	0.548	2.05	31.9
% Improvement = (3) / (1) * 100	88%	47%	28%	100%
Neutral or beneficial effect? (Y/N)	Y	Y	Y	Y
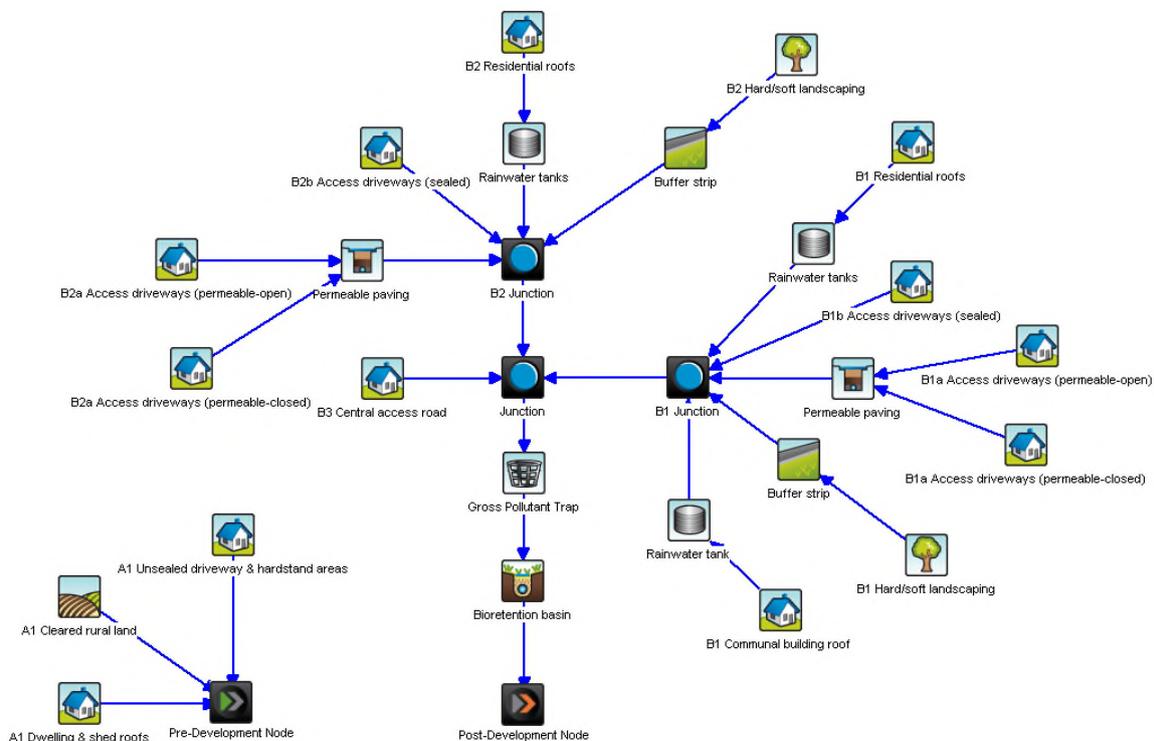
Figure 6.5: Case study 2: Pre- and post-development MUSIC models

Figure 6.6: Case study 2: Pre- and post-development cumulative frequency graphs for nutrient concentrations

6.2.5 Conclusions

- The modelled post-development total suspended solids, total phosphorus, total nitrogen and gross pollutant loads with the proposed stormwater management measures in place are all more than 10% lower than pre-development conditions.

- The total suspended solids, total phosphorus and total nitrogen concentrations in runoff for the post-development scenario are lower than or equal to the pre-development conditions between the 50th and 98th percentiles.

- The MUSIC model results conceptually show that NorBE would be achieved for Stage-1 of this 70 unit senior living development using the proposed management measures.

- Achievement of an overall sustainable neutral or beneficial effect on water quality for the development will require stormwater management measures consisting of:
  - o 4kL rainwater tanks for each unit and a 10 kL tank for the communal dwelling. Due to space constraints on the site, the developer chose a single large underground rainwater tank with the same overall capacity, located to capture all roof runoff and plumbed back to the dwellings
  - o all roofs designed to maximise capture of runoff into the tank
  - o plumbing to ensure rainwater is re-used for toilets and laundry for each dwelling, and external use for landscape watering
  - o plumbing to ensure no more than 20% of tank capacity is used for mains top-up
  - o buffer strips along pathways and walkways in the landscaped areas of the site
  - o permeable paving for 75% of the shared access roads, driveways and parking areas
  - o constructed stormwater drainage lines that direct all stormwater to a gross pollutant trap, and
  - o a 100 square metre bioretention basin to treat all surface runoff from the site before discharge to an ornamental pond.

- Although this example of a NorBE analysis covers Stage-1 of the development, separate NorBE analyses would be needed for each additional stage of the development.

- The bioretention basin constructed to achieve NorBE for Stage-1 of the development would need to be protected from siltation from future construction activity using suitable erosion and sediment control measures.

6.3 Case study 3: Commercial retail centre

This MUSIC example is for a large retail hardware warehouse on the outskirts of Mittagong that includes an outdoor plant nursery, extensive car parking areas, and a separate bulky goods shop building. The development will result in a significant percentage of imperviousness over the site. The site will be sewered and connected to a reticulated water supply. The major constraints are the slope of the site, which will need significant cut and fill, and the limited area available to manage stormwater on the site.

6.3.1 Site and development summary

Table 6.7 summarises the site characteristics for this bulky goods warehouse development, while Figure 6.7 shows the post-development site plan.

Table 6.7:   Case study 3: Site characteristics

Site characteristics	Detail
Site location:	Braemar (near Mittagong)
Drinking water catchment:	No. 18 - Nattai River
Rainfall and PET zone:	No. 3
Total site area:	2.5 ha
Total catchment area:	2.5 ha
Pre-development site gradient:	2 - 10%
Post-development site gradient:	1 – 3%
Soil landscape:	Lower Mittagong - light-medium clay soils – the site will be extensively reshaped and modified by cut and fill
Existing watercourses through the site?	No
Overland flow draining onto the site?	No, diverted by dish drain along high side boundary
Soils suitable for infiltration?	Limited potential following cut/fill earthworks and compaction
Pre-development	**Description**
Existing development characteristics:	Vacant cleared land, fill stockpiles, unsealed access track
Existing land uses and areas:	Previously cleared for grazing with a few isolated trees, unsealed access road, no buildings or other infrastructure
Post-development	**Description**
Proposed development characteristics:	Bulky goods retail warehouse, outdoor nursery, smaller separate bulky goods retail building, car parking, access driveways, landscaping. It will involve external and internal rainwater re-use

6.3.2 Catchment details and representation

6.3.2.1 Pre- and post-development catchment detail

The site grades at 2 to 10% from the rear of the site to the eastern road frontage. There are moderately steep slopes on the northern and southern sides of the undeveloped site. Site gradients are lower at the front. The site is currently grassed and was previously cleared of all except a couple of isolated trees. The site is bounded on three sides by roads, and there is a watercourse about 50 m to the southeast of the site.

Catchment areas were defined primarily considering the drainage flowpaths, the reshaped site and the location of proposed stormwater structures and treatment measures. The pre-development case was defined as one sub-catchment (A1), and for the post-development case as three sub-catchments (B1, B2 and B3) (Table 6.8). Sub-catchment B1 represents the western part of the site, B2 represents the eastern part of the site and B3 represents landscaped fill batters around the edge of the site that drain untreated to the nearby creek. These sub-catchments were further sub-divided based on surface types and locations of proposed treatment measures.

Values in Tables 4.1 and 4.2 were used to determine the impervious areas input to MUSIC for the site. For the pre-development scenario, the site was divided into two nodes representing each defined surface type (Figure 6.8). For the post-development case it was assumed that the roof and road areas were 100% effective impervious area. It was assumed that 10% of landscaped areas would be paved and 50% of the paved area was assumed to be effective impervious area. This would represent 5% of the total landscaped area.

Rainfall-runoff parameters for the impervious surfaces (rainfall threshold) were determined for each surface type from Table 4.3. Pervious surface parameters for the landscaped areas were determined from Tables 4.4 and 4.5, based on a medium-clay soil profile derived from geotechnical data for the original site and considering the planned soil replacement of these areas.

6.3.2.2 Source nodes and parameters for pre- and post-development cases

For the pre-development case, two thirds of the site was modelled as a rural grazing land, and the other third, consisting of fill stockpiles/unsealed roads, was modelled as unsealed road. The post-development case was modelled by separating the site sub-catchments into individual surfaces. Tables 4.6 and 4.7 were used to set base flow and storm flow pollutant levels.

Table 6.8:   Case study 3: Development summary for the site

| Land use / surface type	Total area (ha)	Sub-catchment areas (ha)		
Pre-development		A1		
Cleared rural land	1.65	1.65		
Fill stockpile areas and unsealed access track	0.85	0.85		
Total	**2.50**	2.50		
Post-development		B1	B2	B3
Warehouse roof	0.80	0.80		
Smaller building roof	0.20		0.20	
Nursery	0.20	0.20		
Car parking (permeable paving)	0.112	0.112		
Driveways, access lanes & loading bays (sealed)	0.688	0.448	0.240	
Landscaping	0.50	0.30	0.15	0.05
Total	**2.50**	1.86	0.59	0.05
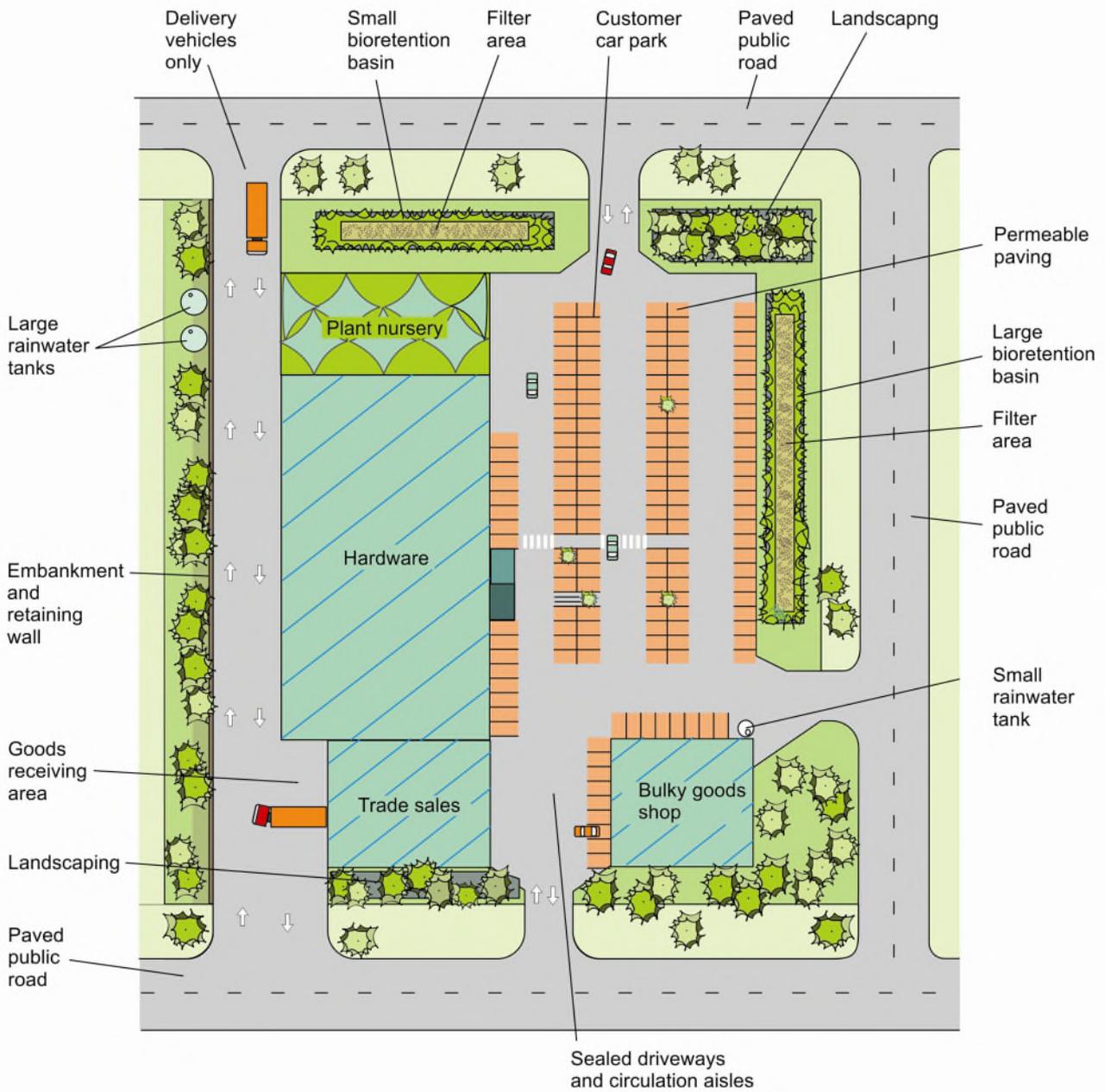
Figure 6.7:   Case study 3: Post-development site plan

6.3.3 Proposed treatment measures for post-development case

6.3.3.1 Rainwater tanks

Rainwater tanks are proposed to capture roof runoff for the warehouse and smaller building. The appropriate size of the tanks was estimated by iteration based on the anticipated water demands for toilet flushing, nursery irrigation supply and landscape area irrigation. Tank sizes of 120 kL (total capacity) and 15 kL for the main warehouse and smaller building respectively are proposed. The following assumptions were used:

- The warehouse rainwater tanks would be underground and the smaller building tank would be above ground.
- An imperviousness of 100% was used for the roofs, and the appropriate rainfall threshold for roofs was used from Table 4.3.
- Stormwater pollutant concentrations for the roofs were used from Table 4.7 (as the source node is 100% impervious, there is no base flow as only storm flow concentrations are relevant).
- The volume available for rainwater harvesting is 80% of the tank capacity.

6.3.3.2 Permeable paving

Permeable paving is proposed for all car parking spaces and the plant nursery. Other car park areas such as circulation aisles, driveway entrances and areas subject to heavy-vehicles and loading bays would be concrete or bitumen-sealed.

The car parking, driveway and loading areas were split into two nodes for each sub-catchment – one to represent the permeable paving (12%) and the other the impervious pavement (88%). All impervious concrete or bitumen-sealed driveways, loading bays and car park areas were aggregated for each sub-catchment to simplify modelling.

An imperviousness of 100% was used for the sealed pavement and closed part of the permeable pavement. Table 4.3 was used to determine the rainfall threshold for the permeable pavement and sealed pavement. A void ratio of 10% was used to estimate the rainfall threshold for the permeable paving.

6.3.3.3 Pit inserts

Pit inserts are proposed in all stormwater pits in the car parking area to pre-treat runoff draining to bioretention basins. Conservatively these were not modelled for areas draining to permeable paving.

6.3.3.4 Bioretention basins

Two bioretention basins would be provided to manage stormwater separately from the northern and eastern drainage systems for the building and car parking areas.

A bioretention basin with modelled surface and filter areas of 400 m^2 and 200 m^2 would be provided along the eastern boundary of the site to; treat runoff from the main car park areas, the nursery permeable paving, as well as overflow from the smaller building rainwater tank. A bioretention basin with modelled surface and filter area of 200 m^2 and 100 m^2 would be provided along the northern boundary of the site to treat runoff from the delivery vehicle driveways, parking areas and loading bays, as well as overflow from the warehouse rainwater tank. Both basins would have an extended detention depth of 0.3 m and a filter media depth of 0.6 m.
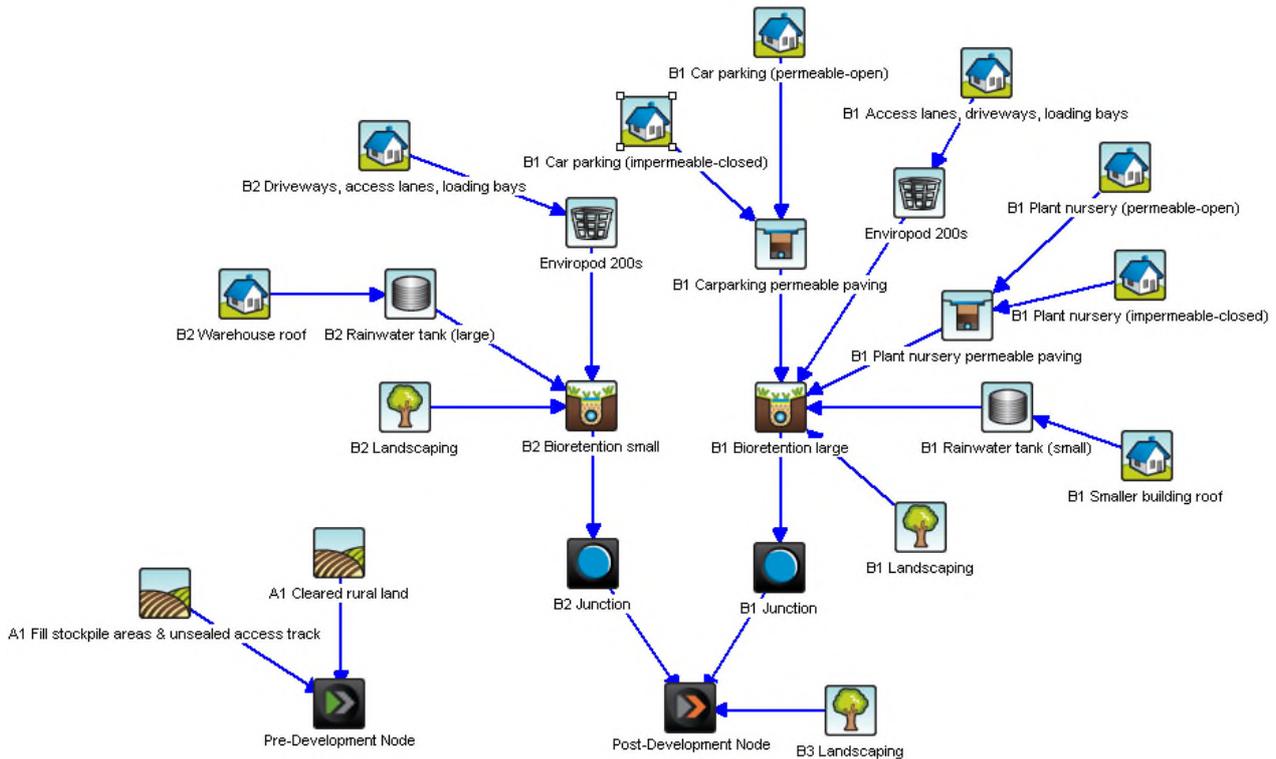
Figure 6.8:   Case study 3: Pre- and post-development MUSIC models

6.3.4   Model results

The pre- and post-development MUSIC models for the site are shown in Figure 6.8, the model results for annual pollutant loads are presented in Table 6.9, and the comparative cumulative frequency curves for nutrient concentrations are shown in Figure 6.9.

Table 6.9:   Case study 3: MUSIC modelling pollutant load results

Scenario/catchment	Annual pollutant loading (kg/yr)			
	TSS	TP	TN	GP
Pre-development (1)	4060	3.95	17.0	72.0
Post-development (with measures) (2)	169	1.36	15.1	1.8
Difference (3) = (1) – (2)	3891	2.59	1.9	61.7
% Improvement = (3) / (2) * 100	96%	66%	11%	98%
Neutral or beneficial effect? (Y/N)	Y	Y	Y	Y
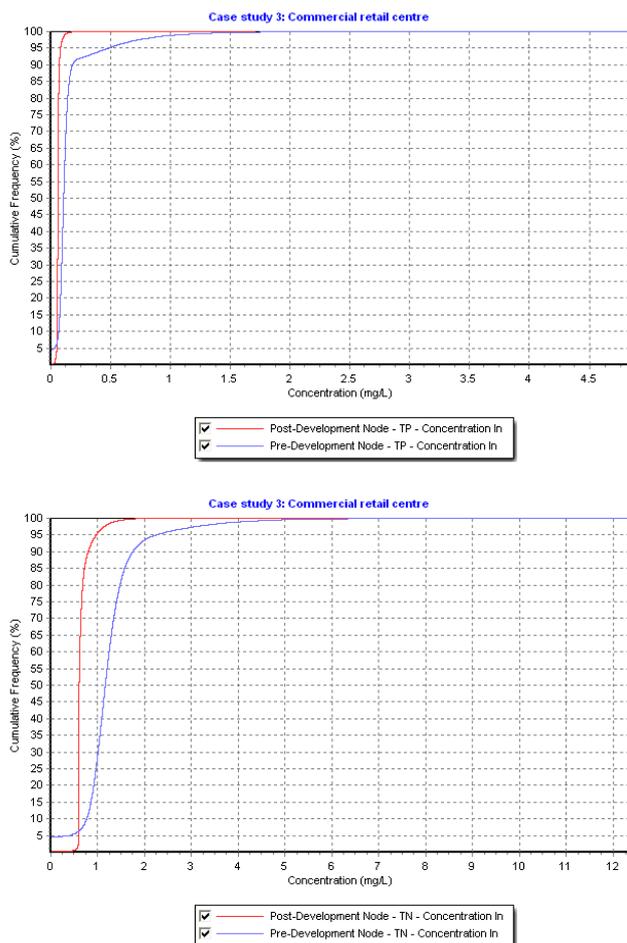
Figure 6.9:   Case study 3: Pre- and Post-development cumulative frequency graphs for nutrient concentrations

6.3.5   Conclusions

The MUSIC model results conceptually show that NorBE criteria would be achieved for the site.

The modelled post-development total suspended solids, total phosphorus, total nitrogen and gross pollutant loads are all 10% less than pre-development conditions.

The 50th to 98th percentiles of total suspended solids, total phosphorus and total nitrogen concentrations for the post-development scenario are all lower than the pre-development conditions (Figure 6.9 shows total nitrogen and phosphorus).

Achievement of an overall sustainable neutral or beneficial effect on water quality for the development will require stormwater management measures consisting of:

- installing two 60 kL rainwater tank for the main building with extensive re-use in a plant nursery, as well as re-use in toilets, showers and for general landscape watering
- installing a 15 kL rainwater tank plumbed for toilet and shower re-use in the smaller building
- designing all roofs to ensure maximum capture of runoff into the rainwater tanks
- using permeable paving in car parking areas representing 12% of all external impervious areas
- using permeable paving for the plant nursery
- building stormwater drainage lines to direct all stormwater into one of two bioretention basins via pit inserts (the latter were not modelled in MUSIC)

- building two large bioretention basins (200 m^2 and 100 m^2 filter areas) to capture, treat and hold all stormwater runoff from the site before discharge to a natural watercourse off-site, and

- landscaping parts of the site will provide some minor water quality benefits, however, landscaping the streetscape outside of the site was not modelled in MUSIC as these areas were outside of the development site.

Nitrogen for this case study was clearly the limiting pollutant in terms of annual loads, and in ensuring that NorBE was met for nitrogen there was an associated very large improvement in phosphorus loads. Subject to hydraulic sizing it is possible that NorBE could have been achieved with a smaller sized *advanced* bioretention basin, which has greater nitrogen removal efficiency, although a lower phosphorus removal efficiency.

6.4 Case study 4: Large scale residential subdivision

This MUSIC case study is for a large residential subdivision, comprising 134 lots where most lots have an area of between 800 m^2 and 1,665 m^2. The site has access to reticulated town water supply and sewer. Major constraints for the site are the significant run-on from existing development upslope of the site, steep and highly erodible soils, and is bounded by a watercourse to the northeast. The subdivision will entail several new roads and a residual lot (marked for future development) has a creek draining through the middle of it.

While the light clay soils of the area have a relatively high erosion risk, this can be managed and neither the soils nor the climate constitute major constraints.

6.4.1 Site and development summary

The site characteristics for this large residential subdivision are summarised in Table 6.10, with the post-development site plan shown in Figure 6.10.

Table 6.10:   Case study 4: Site characteristics

Site characteristics	Detail
Site location:	Lithgow
Drinking water catchment:	No. 27 – Upper Coxs River
Rainfall and PET zone:	No. 4
Total site area:	20.9 ha
Total catchment area:	20.9 ha
Total disturbed area:	13.228 ha
Existing site gradient:	1 to >20% towards watercourse
Soil landscape:	Marrangaroo – light clays with a high erosion risk
Existing watercourses through the site?	Yes, site is bounded by Good Luck Creek which falls within the residual lot marked for future development
Overland flow draining onto the site?	Yes, however, proposed to divert upslope run-on so only areas of disturbance being modelled
Soils suitable for infiltration?	No
Pre-development details	**Description**
Existing development characteristics:	Large areas of cleared rural land
Existing land uses and areas:	Agricultural - grazing
Post-development details	**Description**
Proposed development characteristics:	134-lot residential subdivision with lot sizes between 800 m^2 and 1,665 m^2. Construction of new roads

6.4.2 Catchment details and representation

6.4.2.1   Pre- and post-development catchment detail

Consistent with Sections 2.3 and 3.4, catchment areas were defined as those areas likely to be disturbed as part of the subdivision development, specifically by road construction, and not all of the site was modelled. A portion of the un-modelled part of the site is open vacant grassland, and a key assumption is that these areas will remain unchanged until future developments commence, at which time NorBE will be assessed to manage those impacts.

To define the sub-catchments for the pre-development case, it is necessary to calculate the area of disturbance for the post-development case (that is the area of building envelopes, access ways and future roads).

Figure 6.10: Case study 4: Post-development subdivision site layout plan

Table 6.11: Case study 4: Development summary for the site - only disturbed areas shown

Land use / surface type	Total area (ha)	Sub-catchment areas (ha)	
Pre-development		**A1**	
Agricultural land (area that will be disturbed by road construction and building envelopes)	13.228	13.228	
Total	**13.228**	13.228	
Post-development		**B1**	**B2**
Lot areas draining to bioretention basins	11.445	4.455	6.99
Sealed roads	1.783	0.659	1.124
Total	**13.228**	5.114	8.114

6.4.2.2 Source nodes and parameters for pre- and post-development cases

Vegetation clearing was not intended or required as future development would only occur on areas already cleared for agriculture, so the pre-development case was modelled as rural grazing (Figure 6.11). As the NorBE assessment only applied to the current proposal, being the construction of the subdivision roads and intra-allotment drainage. Future dwellings and associated hardstand areas were therefore not considered in the MUSIC modelling. WaterNSW considers that any subsequent applications for dwellings and/or other developments on the proposed lots will be subject to the provisions of The B&C SEPP and will need to be assessed according to the NorBE test in relation to the potential effect of that development on water quality. Therefore, modelling of the lots was undertaken using the Urban [Residential] selection and applying 70 percent perviousness, as explained below.

The post-development case was modelled by separating the site into sub-catchments, based on the areas draining to bioretention basins, including the sealed subdivision roads. The proposed lot areas were included with 30 percent imperviousness, given they will be draining to the sub-catchment scale bioretention basins which need to be sized to account for likely pollutant loads.

Site Plans and field inspections were also needed to determine the length of sealed subdivision roads for each sub-catchment, and the most appropriate location of bioretention basins. When considering treatment and management options to achieve NorBE for this development, it was important to identify the sources of the key pollutants – in particular, nitrogen – so that the most appropriate and cost-effective measures and locations are identified.

Rainfall-runoff parameters for the impervious surfaces (rainfall threshold) were determined for each surface from Table 4.3. Pervious surface parameters (see Tables 4.4 and 4.5) were based on light clay, as identified by the geotechnical data for the site. The base flow and storm flow pollutant concentration parameters for the pre- and post-development nodes were automatically populated with the values from Tables 4.6 and 4.7 as the appropriate zoning/surface type was selected for each node. Note some parameters (for eroded gullies, agricultural and forest nodes both for baseflow and stormflow) are inconsistent with values in Tables 4.6 and 4.7. Until such times these values are corrected in the future version of MUSIC, manually enter the correct values.

6.4.3 Proposed treatment measures for post-development case

6.4.3.1 Bioretention Basins

Two bioretention basins with filter areas of 90 m^2 and 36 m^2 were proposed at the lowest point for both sub-catchments, to capture and treat runoff from the subdivision roads and developed lot areas. The nodes were constructed according to the details outlined in section 5.2.3.2.

The following were required for the bioretention basins:

- be designed consistent with Adoption Guidelines for Stormwater Biofiltration Systems Version 2 (Payne *et al*, 2015, CRC for Water Sensitive Cities Ltd)

- be planted with appropriate deep-rooted, moisture-tolerant vegetation protected by rock mulch (grass and turf is not appropriate vegetation and organic mulch is not suitable)

- be permanently protected from vehicular damage by bollards, fences, castellated kerbs or similar structures, with a sign to be erected to advise of its nature and purpose in water quality management, and

- be protected by sediment and erosion control measures during any construction and post-construction phase until the ground surface is revegetated or stabilised.

Figure 6.11: Case study 4: Pre- and post-development MUSIC models

6.4.4   Model Results

The pre- and post-development MUSIC models for the site are shown in Figure 6.11. The model results for annual pollutant loads are shown in Table 6.12, while the comparative cumulative frequency curves for nutrient concentration are shown in Figure 6.12.

Table 6.12:   Case study 4: MUSIC modelling pollutant load results

Scenario/catchment	Annual pollutant loading (kg/yr)			
	TSS	TP	TN	GP
Pre-development (1)	5360	23	115	0
Post-development (with measures) (2)	4750	11.3	92.9	0
Difference (3) = (1) – (2)	610	11.7	22.1	0
% Improvement = (3) / (1) * 100	11%	51%	19%	0%
Neutral or beneficial effect? (Y/N)	Y	Y	Y	Y

Figure 6.12: **Case study 4: Pre- and post-development cumulative frequency graphs for nutrient concentrations**

As can be seen, there is a significant reduction in total phosphorous due to the change in land-use from agricultural to residential. The NorBE requirements for pollutant loads is achieved in this example for total nitrogen, total phosphorus, and total suspended solids.

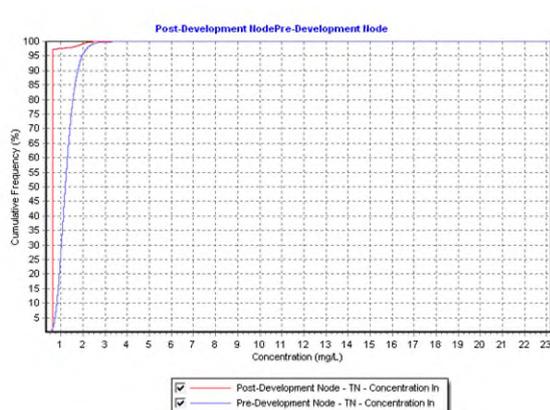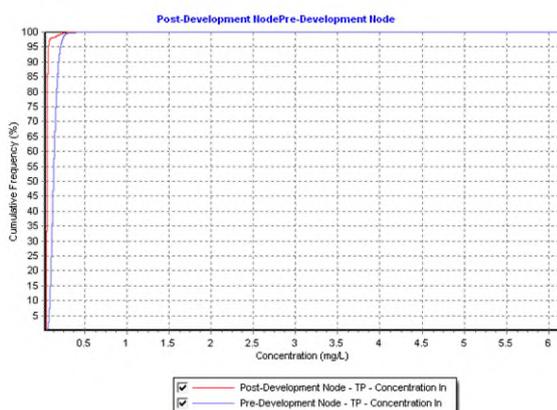The 50th to 98th percentile pollutant concentrations were assessed for the pre- and post-development cases. The post-development 50th to 98th percentile concentration was less than the pre-development case for all parameters, so the proposed stormwater treatment strategy is also shown to comply with this NorBE requirement.

6.4.5   Conclusions

This case study shows how MUSIC can be configured to address the NorBE requirement for stormwater for a large residential development, where only a proportion of each lot will be disturbed. If more information were to become available as part of the development process, for example a detailed stormwater plan with relative levels or a hydraulic assessment or relocation of the bioretention basins, the model may need to be reconfigured to more accurately represent them. The above model is an example of how such a large residential development may be modelled in MUSIC and should not be taken as the 'definitive way' to model these types of development.

Critical NorBE modelling issues were:

- to realistically represent only the areas likely to be disturbed, and
- to accurately identify and represent those areas of the site that will drain to the bioretention basins.

The MUSIC model results conceptually show that NorBE criteria would be achieved for the site. The modelled post-development total suspended solids, total phosphorus, total nitrogen and gross pollutant loads are all 10% less than pre-development conditions.

The 50th to 98th percentiles of total suspended solids, total phosphorus and total nitrogen concentrations for the post-development scenario are lower than the pre-development conditions.

Achievement of an overall sustainable neutral or beneficial effect on water quality for the development will require stormwater management measures consisting of:

- Two bioretention basins with filter areas of 90 m^2 and 36 m^2 and larger surface areas to account for on-site detention
- The use of an extensive pit and pipe network to drain various parts of the sub-catchments to the relevant bioretention basin, and
- Appropriately designed and sized under road drainage to convey stormwater from the southwest portion of the site to the treatment measures in the northeast portion of the site.

Although this example of a NorBE analysis covers the subdivision works only, subsequent applications for dwellings and/or other developments on the proposed lots will need to be assessed according to the NorBE test in relation to the potential effect of those developments on water quality.

The bioretention basins constructed for the subdivision works would need to be protected from siltation during construction activities for future dwellings on the lots using suitable erosion and sediment control measures.

7 GLOSSARY

TERM	DEFINITION
BASIX	BASIX or the Building Sustainability Index is a NSW Government online program that ensures new homes are designed to be water and energy efficient. Information about the location, size, building materials, and insulation etc, of a dwelling is entered into the online BASIX tool, which analyses the data and determines if the proposed dwelling meets the minimum water reduction and re-use and energy efficiency targets, and issues a BASIX Certificate (see https://www.planningportal.nsw.gov.au/basix).
Biodiversity	The variability among living organisms and the ecosystems of which those organisms are a part and includes the following — (a) diversity within native species and between native species; (b) diversity of ecosystems; (c) diversity of other biodiversity components. Biodiversity is a measure of the health of an ecosystem. Healthy ecosystems have greater variety and variation in plant and animal life than unhealthy ones.
Catchment	A hydrological catchment or area of land where surface waters drain by a network of drainage lines and streams to a single outlet.
sub-catchment	A smaller component of a larger catchment where surface water drains to a single outlet.
Current Recommended Practice (CRP)	Current recommended practice's and guidelines accepted or adopted by industry and natural resource management agencies to manage an aspect of the operation or development to ensure all activities are performed in a way that best protects the environment and water quality. A WaterNSW endorsed CRP provides particular measures that ensure water quality is protected.
	As per the B&C SEPP NorBE requirements, endorsed CRPs are to be used for developments or activities unless it can be shown that alternative measures will have equal or better water quality outcomes. A best management practice guideline is similar in concept to a CRP.
Concurrence	Concurrence is agreement from a government agency in relation to a development proposal in light of the agency's specialised functions and policies. Invariably the provision of concurrence to a consent authority will be subject to conditions. WaterNSW has a concurrence role in relation to proposed developments in the Sydney drinking water catchment (except those where the Minister for Planning is the consent authority).
Consent authority	The consent authority is the body responsible for the approval (or otherwise) of all development applications required to be submitted under the EP&A Act.
	The consent authority for most developments is usually council or Planning Panels. However, development that is important to the State for economic, environmental or social reasons can be classified a State significant development (SSD) or State significant infrastructure (SSI). This development requires the approval of the Minister for Planning or Independent Planning Commission before it may proceed.
Denitrification	The reduction of simple inorganic nitrogen compounds such as nitrates (NO_3^-) or nitrites (NO_2^-) by heterotrophic denitrifying soil bacteria to gaseous nitrogen forms such as N_2, which is returned to the atmosphere. Denitrification occurs in low oxygen or anoxic environments, such as the saturated zone of a bioretention system.
Development	Has the same meaning as in Part 5 of the EP&A Act
	(a) the use of land,
	(b) the subdivision of land,
	(c) the erection of a building,
	(d) the carrying out of a work,
	(e) the demolition of a building or work, and
	(f) any other act, matter or thing that may be controlled by an environmental planning instrument.

Development application	An application for consent under Part 4 of the EP&A Act to carry out development.
Drainage depression	A low point that carries water during rainfall events but dries out quickly once rainfall has ceased. A gully or incised drainage depression is considered to constitute a watercourse.
EP&A Act	The *Environmental Planning and Assessment Act 1979* provides the planning framework for NSW. It covers environmental planning instruments including state environmental planning policies, local environmental plans, development control plans, assessment of major projects by the Independent Planning Commission. It includes environmental assessment procedures for Part 4 developments that require consent, environmental assessment procedures for Part 5 developments and activities such as infrastructure by public authorities, and some activities, such as mining exploration, that do not require development consent.
Groundwater	Means water occurring in saturated layers of soil, sediment or porous rock below the land surface as aquifers. Aquifers in geological formations are permeable enough to allow water to move into them and enable discharge or extraction.
Gully erosion	A form of erosion involving the formation of deep sided channels or gullies usually due to the removal of riparian vegetation.
Module	The characterisation of development activities into similar groupings according to risk that are used to determine NorBE as indicated in WaterNSW's NorBE Assessment Guideline.
MUSIC	Model for Urban Stormwater Improvement Conceptualisation is a stormwater quality modelling tool that estimates stormwater pollutant generation and the performance of stormwater treatments from proposed land development. It is the required model for stormwater modelling to determine NorBE in the Sydney drinking water catchment.
NorBE	NorBE is an abbreviation for the neutral or beneficial effect on water quality test as required by the State Environmental Planning Policy. All proposed developments under Part 4 of the Environmental Planning and Assessment Act 1979 requiring consent must be able to demonstrate that they will have a neutral or beneficial effect on water quality, whereas all Part 5 activities must consider NorBE. NorBE is demonstrated if a proposed development: • has no identifiable potential impact on water quality, or • can contain any such impact on the site of the development **and** prevent it from reaching any watercourse, waterbody or drainage depression on the site, or • can transfer any such impact outside the site by treatment in a facility that will treat water to a required standard.
NorBE Assessment Guideline	A guideline produced by WaterNSW which collates relevant information and provides a clear direction as to what is meant by a neutral or beneficial effect (NorBE) on water quality, how to demonstrate it, and how to assess an application against the NorBE test. It also brings together relevant supporting information. The guideline is available at www.waternsw.com.au. Development consent will not be granted to development on land in the Sydney Drinking Water Catchment unless the consent authority is satisfied the development is consistent with the NorBE Guideline.
NorBE Tool	The NorBE Tool is a Windows-based GIS software application that guides the user to enter information derived from the information accompanying the development application e.g. the impervious area or the slope. Other data is automatically generated by the tool e.g. rainfall. The tool helps councils determine a neutral or beneficial effect or a WaterNSW concurrence role and records the decision process for each development application.
Nutrients	Substances such as phosphorus and nitrogen that are essential for life. In excess they may stimulate the growth of plants, algae and cyanobacteria (blue-green algae).
Pathogen	A biological agent or organism such as a virus, bacterium, protozoan or other microorganism that causes disease or illness to its host.

Permeability	The characteristic of a soil texture, structure and particle size and that governs the rate at which water moves through it. Sandy soils have a high permeability; clay soils generally have a low permeability.
Raingarden	A small bioretention system with vertical sides typically located on residential lots that cleans stormwater runoff from the lot by the filtering action of a special soil and plants growing in the raingarden. It reduces nitrogen, phosphorus and sediment levels in the treated stormwater discharged from the garden to an external stormwater drainage system.
Rainfall erosivity	A calculated climatic factor that links the potential for soil erosion to the intensity and duration of rainfall events – that is the potential for soil to wash off from disturbed and denuded sites during rainstorm events.
Riparian zone	Any land and associated vegetation immediately adjoining a creek or river, and areas around lakes and wetlands. Riparian also refers to anything connected with or immediately adjacent to the banks of a stream such as riparian access.
Rural residential development	A subdivision and development of larger rural and agricultural land holdings into smaller lots for rural residential use.
Site area	The area of land on which a development is proposed to be carried out, which may include the whole or part of a lot, or lots.
Soil depth	The vertical depth of soil from the soil surface to the top of the C horizon (weathered rock), the parent rock or to the water table (periodic or permanent). This does not include the C horizon consisting of weathered rock.
State Environmental Planning Policy (SEPP)	A State Environmental Planning Policy (SEPP) is a policy proposed by the Minister and approved by the Governor under the Environmental Planning and Assessment Act 1979 that deals with environmental planning matters involving several local authorities.
Suspended solids	Means fine clay or silt particles suspended in the water as a result of the motion of water or as colloids, resulting in turbidity.
Waterbody	A natural or artificial body of water, whether perennial or intermittent, fresh, brackish or saline, including a lake, wetland, river, stream, constructed waterway, canal, dam, lake or artificial wetland, but does not include a dry detention basin or other stormwater management structure that is only intended to hold water intermittently.
Watercourse	Means any river, creek, stream or chain of ponds, whether artificially modified or not, in which water usually flows, either continuously or intermittently, in a defined bed or channel, but does not include a waterbody (artificial).
Water Cycle Management Study (WCMS)	A study that addresses the management of stormwater, wastewater, site and development specific pollutants or contaminants, and erosion and sediment control for a specific development proposal. In the context of the Sydney drinking water catchment the WCMS needs to show that the proposed development and management measures can achieve a sustainable NorBE, including during wet weather. Details and specific information requirements for a WCMS is specified in WaterNSW's standard Developments in the Sydney Drinking Water Catchment: Water Quality Information Requirements, which can be found on WaterNSW's website <www.waternsw.com.au>.
Wetland	An area of land where soil is inundated or saturated with salt, fresh, or brackish water, either permanently, seasonally or periodically, and which is characterised by specialised vegetation and animal communities. A wetland is typically natural but may also be artificial.

8 ACRONYMS

AEP	Annual Exceedance Probability
CRC	Cooperative Research Centre
CRP	Current Recommended Practice
C*	background event concentration, applies at higher flows such as when the extended detention storage is used
C**	the baseflow background concentration for flows largely confined to a low-flow channel
D$_{50}$	the grain diameter at which 50% of the sand sample is larger and 50% is smaller than the nominated value
DPE	Department of Planning and Environment
DPE - Water	Department of Planning and Environment - Water
ha	hectare
k	k is the rate constant in m/yr of a 1st order kinetic (k- C*) stormwater treatment model that reflects the settling velocity of the targeted sediment size
kg/yr	kilograms per year
kL	kilolitre
kL/day	kilolitres per day
kL/yr	kilolitres per year
m	metres
m^2	square metres
m^3/s	cubic metres per second
mg/kg	milligrams per kilogram
mg/L	milligrams per litre
ML/yr	megalitres per year
mm	millimetres
mm/d	millimetres per day
mm/hr	millimetres per hour
N/A	not applicable
NRAR	Natural Resources Access Regulator
PET	Potential Evapo-Transpiration
%	Percent
RL	Relative levels
TN	Total nitrogen
TP	Total phosphorus
WSD	Water sensitive design

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