Draft NSW MUSIC Modelling Guidelines

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Draft New South Wales MUSIC Modelling Guidelines

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Authors :	Tony Weber, Associate Professor Tim Fletcher
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1 INTRODUCTION

The Sydney Metropolitan Catchment Management Authority' (CMA) is very pleased to release the draft NSW MUSIC Modelling Guideline for comment and review, which is MUSIC Version 4 compliant.

Without exception, the Sydney Metropolitan CMA accepts no responsibility for the application of these draft guidelines and/or the derived modelling results, outcomes or outputs.

This draft document is a guide only, it is strongly recommended professional experience and judgement must still be applied to ensure the modelling is done in a logical fashion.

This document is a live version and will be updated as required to ensure the information is in accordance with NSW Government Policy and evolutions thereabouts. For further information about policy direction, development and delivery in this regard, please contact Peter Marczan, Manager Technical Advisory Unit (Water), Department of Environment, Climate Change and Water on (02) 9995 6059 or via peter.marczan@environment.nsw.gov.au.

This version was updated from a 2008 edition, public release was pending final approval of a Stream Erosion Index, which is currently being finalised by the NSW Department of Environment and Climate Change and Water.

In the absence of Stream Erosion Index (SEI) targets, the agreed process for evaluating the SEI using MUSIC has been included in the draft Guideline. Once approved and released, it is our intention to integrate these targets into the Guideline.

Similar, to the SEI Targets, preferred Stormwater Management Objectives are currently being finalised by the NSW Department of Environment and Climate Change and Water. In the interim, it is recommended that you refer to the Sydney Metropolitan Catchment Management Authority's WSUD Interim Reference Guideline for the South East Queensland Concept Design Guidelines for WSUD available at http://www.wsud.org/wp-content/uploads/WSUD-Interim-Reference-Guideline-Concept-Design-Guidelines-FINAL.pdf and which provides interim advice - identifying design objectives for water conservation and stormwater management.

The Sydney Metropolitan CMA released this document in draft format, in recognition of stakeholder feedback identifying its absence as a key barrier to the uptake of Water Sensitive Urban Design. Secondly, to provide an avenue to integrate industry and other stakeholder feedback into a final draft. Thirdly, it is our intention to integrate this feedback into a technial review of the document, which will be scheduled as soon as seed funding and additional funding partners can be located.

If you would like to provide feedback for inclusion in the draft Guideline's review, please refer to the Tools and Resources page of the WSUD Program's Website at http://www.wsud.org/tools-resources/

These MUSIC Modelling Guidelines have been developed to assist proponents when preparing MUSIC models to predict the impacts of proposed land use changes through urban and rural developments within New South Wales.

Typically, this land use change is associated with an increase in impervious area, resulting in both an increase in stormwater runoff, and associated pollutant loads. To manage these impacts, various management techniques such as wetlands, gross pollutant traps, biofiltration systems and rainwater tanks can be implemented as part of the development. In order to assess the performance of these systems, it is imperative that a consistent assessment methodology be put in place. This document forms part of that assessment methodology.

This guideline aims to show practitioners how to set up a MUSIC model that reflects the post development site layout, considering the site layout, drainage configuration, the climatic region in which it lies and the configuration of treatment measures. It is not intended as a detailed design tool and it also is not a substitute for knowledge and experience in catchment modelling and the application of Water Sensitive Urban Design (WSUD) principles. The overall aim of this and other documents relating to the management of water quality in New South Wales is to ensure that water quality flowing into receiving waters is effectively managed so that pre-determined targets are achieved. These guidelines are applicable to Version 4 of MUSIC and this version (or any subsequent updates) should be used as this version represents the current state of knowledge and science with respect to the modelling of stormwater quality improvement.

These guidelines do not take precedence over more locally specific MUSIC modelling guidelines. The user of this document should therefore check whether other locality specific guidelines are applicable in the region where MUSIC modelling is to be undertaken.

2 OVERVIEW OF MUSIC AND WHEN TO USE

2.1 What is MUSIC?

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) is a decision support tool for stormwater managers. It helps them to plan and design (to a conceptual level) appropriate stormwater management systems for catchments. The MUSIC modelling software was developed by researchers and practitioners of the former CRC for Catchment Hydrology and the current eWater CRC and represents an accumulation of the best available knowledge and research into urban stormwater management in Australia.

MUSIC estimates stormwater flow and pollution 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 quality improvement measures, MUSIC provides information on whether a proposed system conceptually would achieve flow and water quality targets.

2.2 When to use MUSIC

The use of MUSIC is related to the risk of a particular development impacting on water quality, and whether that risk needs to be estimated via a detailed decision support tool like MUSIC, or a more simplistic approach where the risk may be lower.

Consideration of the size of a development and the likely risk it poses to waterway health is required to assess where MUSIC modelling is warranted. As such, within NSW, MUSIC should be used for assessing impacts to stormwater flow and quality from a proposed development where the total impervious area of the proposed development, including future dwellings and associated works is greater than 2500 m^2.

In all other cases, a small scale stormwater quality model (the S3QM) is available that can be used to demonstrate and certify that stormwater quality management has been satisfactorily addressed for the proposed development.

Within highly pervious catchments the hydrology 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, evapotranspiration rates and infiltration rates may each have a significant influence on the hydrologic cycle and to different degrees between sites. Modelling of highly pervious catchments in MUSIC should be undertaken with care, with model results checked against gauged data (where available), expected volumetric runoff co-efficients, evapotranspiration losses and export loads.

2.3 What to Model with MUSIC

MUSIC is a conceptual modelling tool ideally suited to modelling the stormwater flows and loads in urban catchments. It can be used to assess a range of development and land use types through appropriate parameterisation and configuration of the model and is the preferred tool for the assessment of water sensitive urban design measures in the Australian context. MUSIC has traditionally been used to quantify pollutant loads and concentrations, however it also provides a useful framework to assess hydrologic objectives and a process to undertake this is outlined in these guidelines.

While MUSIC has been extensively used in the urban context, the underlying hydrologic and constituent generation models are very flexible and can be parameterised to represent a large range of land uses. The limitations of applying MUSIC to rural land uses are in the accurate prediction of nutrient export from catchments, especially phosphorus, as phosphorus stormflow concentrations within the model are correlated to suspended solids concentrations where stochastic generation is used. This limitation can be avoided by using the "mean" estimation method for generating nutrients and adjusting the parameters accordingly.

In addition, the treatment performance of some or all of the measures within MUSIC have not been rigorously tested in rural environments, and while it is expected that similar performance characteristics may be observed, care should be taken to consider the species of constituents coming from the catchment and the device's ability to effectively treat them. For example, if a considerable proportion of the Total Phosphorus load coming from an agricultural catchment is soluble, the effectiveness of a grassed swale in treating this would obviously be considerably different to an urban catchment where the majority of phosphorus is associated with particulate matter. The user should therefore make an assessment of this when analysing MUSIC outputs and appropriate caveats noted.

3 MODELLING THE TREATMENT TRAIN USING MUSIC

3.1 Background

To develop a MUSIC model that sufficiently represents the area likely to be developed, a series of steps need to be conducted, both within and outside the modelling environment. These guidelines provide the necessary detail to undertake these steps, however professional experience and judgement must still be applied to ensure the modelling is done in a logical fashion. Figure 3-1 outlines the steps for setting up and running a MUSIC model. Further guidance is provided in the following chapters for each of these steps.

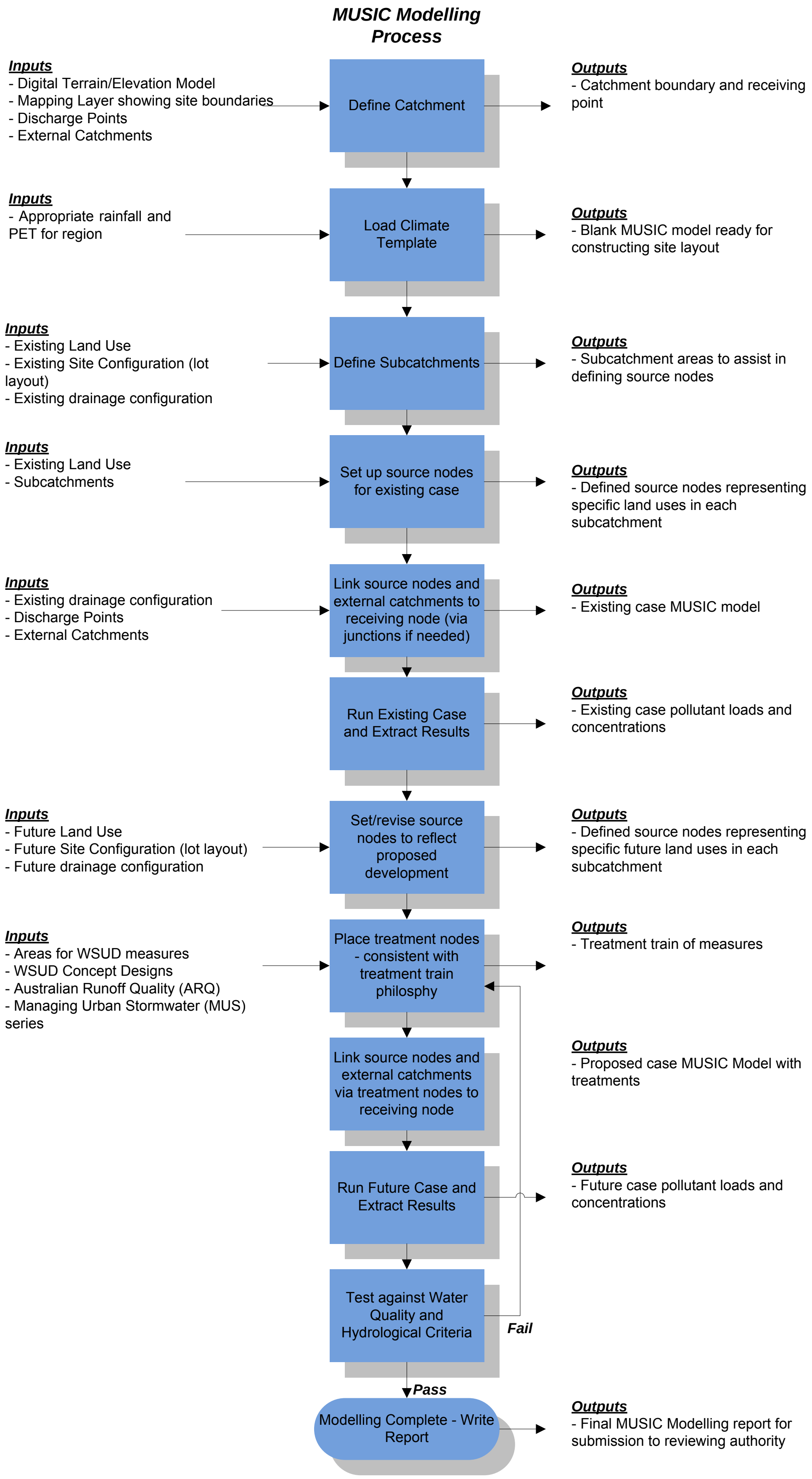


Figure 3-1 MUSIC Modelling Flow Chart

3.2 Define Catchment Area

To properly define the catchment area, firstly identify the boundary of the development. This can be done through examination of property records and overlaying these on GIS layers, or measuring out the site through survey. The underlying terrain needs to be defined so drainage paths and the overall contributing catchment area can be identified. This is very important, especially where external catchments may pass through the site, so that the impacts by the development itself can be quantified prior to any flows coming in from the external catchment (in other words, so as not to dilute the "dirty" water coming from the development).

Where a digital terrain model (DTM) or digital elevation model (DEM) are available, stream definitions and catchment boundaries can usually be created using automated methods, however this is sometimes unnecessarily complex for most urban developments. Boundaries may also be set arbitrarily based on different land uses, but some consideration of the topography, land uses, existing and/or future drainage networks should also be made. Once this is completed, it is then beneficial overlay this with the subcatchments defined in Section 3.5 to prepare a background bitmap for use as a modelling template.

3.3 Using the Notes Function

MUSIC provides the ability to add notes to any source or treatment node as a method of recording assumptions or other comments associated with that node. This can be an extremely useful method of capturing information on the model that then resides in the model itself and can be a suitable way of keeping a model "log". An example of the notes screen is provided below.

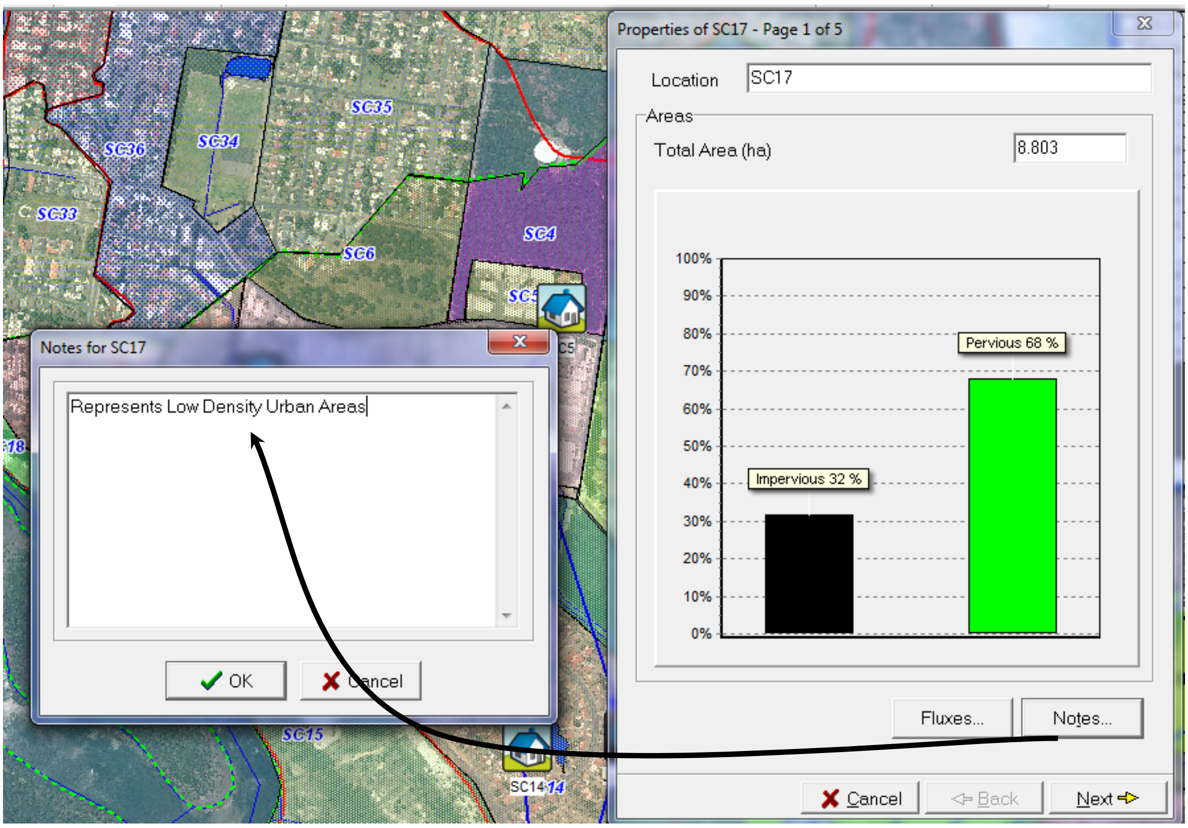


Figure 3-2 Notes Function

The note, once created, then appears as a rollover "hint" whenever the mouse is rolled over the relevant node (when the "catchment hints" option is turned on under Edit -> Preferences").

3.4 Selecting Climate Data

3.4.1 Using Predefined Climate Data

MUSIC uses rainfall and potential evapotranspiration data to generate runoff timeseries at each source node. The adopted climate template is then utilised for all source nodes in a particular MUSIC model. It is therefore necessary to select appropriate climatic data for the region being modelled to ensure that reasonable predictions of runoff can be made.

When installed, MUSIC contains a number rainfall stations and evapotranspiration data for locations across New South Wales, however these are not always the most appropriate for the region being modelled. From assessment of rainfall data for various regions across NSW, the following table outlines regions and rainfall stations where appropriate data is available. Note that not all of these stations are provided with MUSIC and the user may have to obtain these separately. For users of MUSIC Version 4 that have obtained premium support, these rainfall stations are available for direct download of data using the rainfall tool available from the MUSIC support website.

To select the most appropriate location, consult Table 3-1 for the region in which the area to be modelled lies, then select a rainfall station that is either closest to the area, and/or has a mean annual rainfall volume similar to the area (if known). The period of data shown represents that which was determined to contain the least amount of missing and/or accumulated data for the location. Modellers should aim to use the entire period listed for the location wherever possible.

Table 3-1 Suggested Climatic Data for MUSIC in NSW

Region	Suggested Rainfall Station	Period of Valid Data	Approx Mean Annual Rainfall Volume (mm)
Northern Coastal NSW	Coffs Harbour	1/1/1999 - 31/12/2003	1600
	Murwillumbah	6/2/1996 - 2/8/2001	1500
Central Coastal NSW	Chichester	8/9/1999 - 2/4/2006	1200
	Taree	1/1/1967 - 30/12/1975	1200
	Williamtown	1/1/2002 – 31/12/2006	1100
Central and Eastern Sydney	Sydney Meteorological Office	5/1/1962 - 31/12/1966	1300
Western Sydney	Penrith	1/1/1980 - 31/12/1990	700
South Coast NSW	Eden (Green Cape)	24/10/1969 - 6/9/1974	700
	Moruya	1/1/2000 - 31/12/2005	800
	Nowra	1/1/1964 - 31/12/1970	1000
Blue Mountains (outside SCA Region)*	Katoomba	1/1/1974 - 31/12/1980	1400
Southern Highlands (outside SCA region)*	Bowral	1/1/1995 - 31/12/1999	800
	Nerriga	1/1/2000 - 1/12/2005	650
Western NSW	Inverell	1/9/1996 - 30/4/2006	800
	Orange	13/8/1966 - 30/6/1973	1100
	Wellington	1/1/2000 - 31/12/2004	600
	Wagga Wagga	2/10/2000 - 30/4/2006	440

* for areas within Sydney Catchment Authority region, consult SCA's MUSIC Modelling Guidelines

A meteorological template includes the rainfall and areal potential evapotranspiration data. For the above locations, if PET data is not supplied by the BoM, the monthly average areal PET from the National Climatic Atlas of Australia should be used.

3.4.2 Choosing Locally Specific Data

As noted above, the Bureau of Meteorology has a large number of rainfall stations across NSW and all other states in Australia. The majority of these gauges have recorded daily rainfalls, however quite a number have also recorded pluviometer data at smaller timesteps suitable for use in MUSIC. In order to obtain this data, it is first necessary to identify a suitable rain gauge close to the location being modelled. To do this, a rainfall tool is available through the MUSIC Version 4 support pages as shown below.

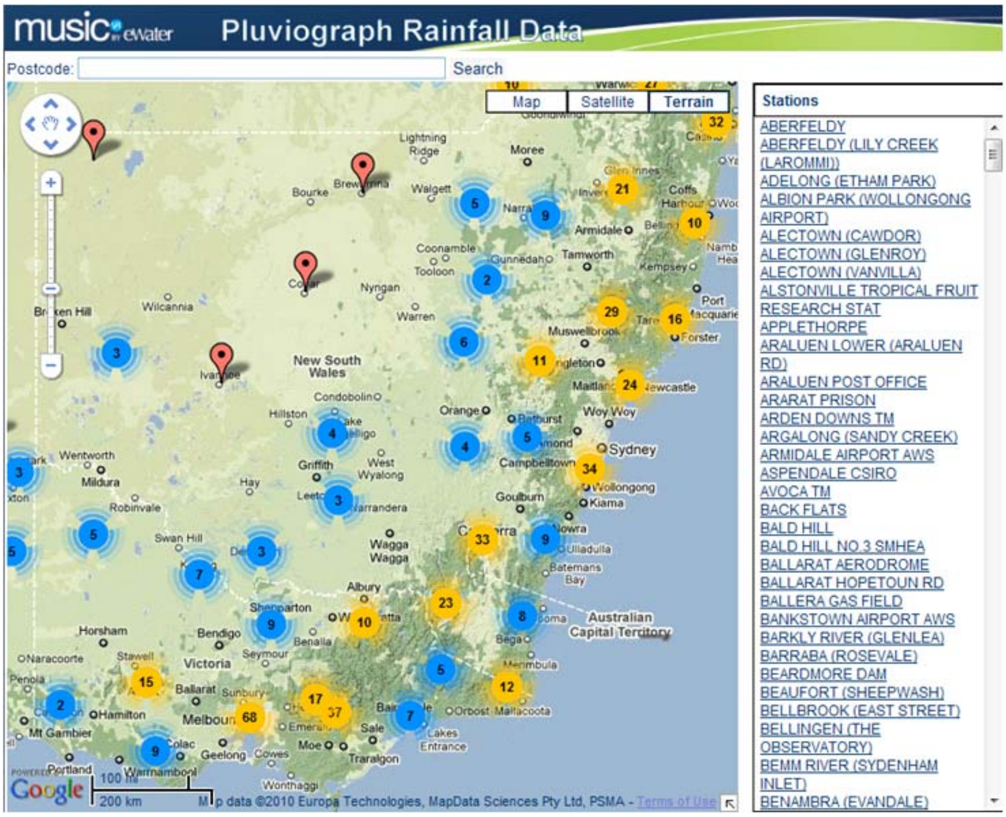


Figure 3-3 MUSIC Version 4 Rainfall Tool

The most suitable station can be selected then from the list available on the right, and when downloaded, this will be in a format suitable for direct use in MUSIC. Note that evapotranspiration values are not included with this data and therefore will need to be determined by consultation the National Climatic Atlas of Australia Evapotranspiration Maps (available from the Bureau of Meteorology).

When obtaining pluviometer data, the minimum length of data should be at least 5 years of continuous rainfall, with a minimum of data gaps and accumulated data. MUSIC allows the viewing of this data (if in the appropriate BoM format) via the Meteorological template builder and areas of missing and accumulated data are shown as indicated in Figure 3-4 below.

As MUSIC is a continuous model, it is necessary to ensure that a representation of the typical climate experience in a region is selected. The guidance provided in the table below ensures that a reasonable amount of climate variability is represented and as such the mean annual loads obtained from MUSIC models using this climate data will represent wet, dry and average years and it should not be necessary to specify data and results being provided separately for these climatic years.

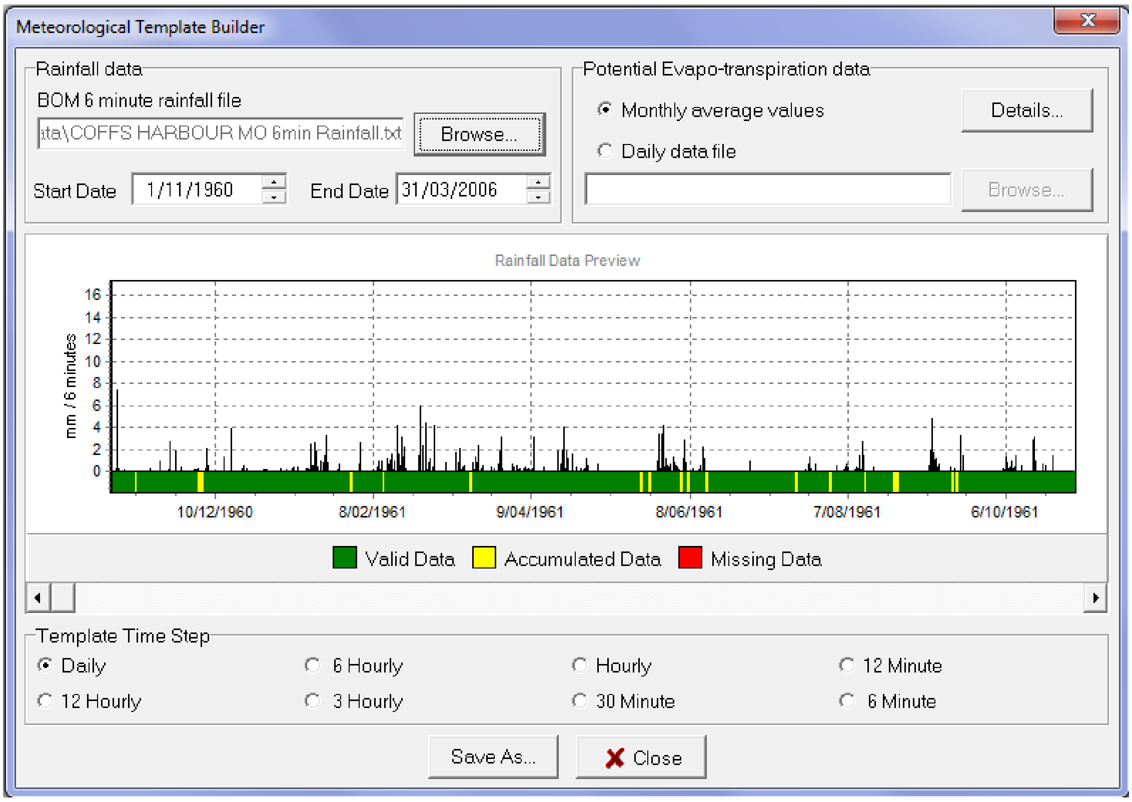


Figure 3-4 Meteorological Template Builder

Caution should also be taken in using this template builder to ensure that Potential Evapotranspiration (PET) data is also used when setting up rainfall data using either the data obtained from BoM (and usually included with the pluviometer data), or from the National PET Atlas, also available from BoM.

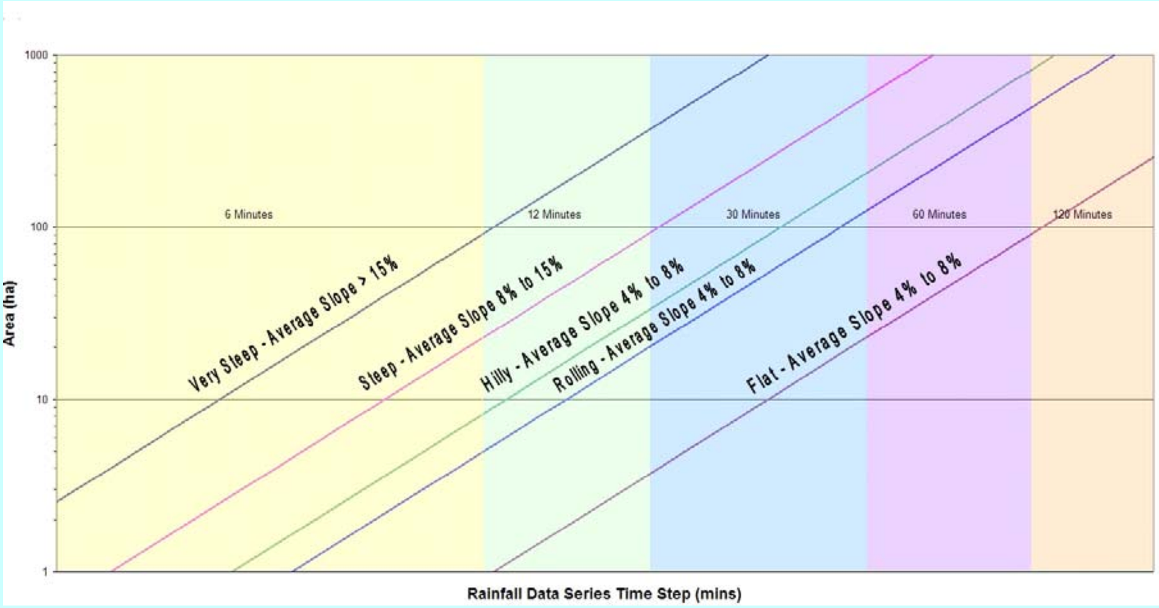
Where climatic data is required to assess wetland hydrology, considerably longer periods of rainfall data may be required. Up to 100 years of daily data required for the assessment of wetland hydrologic objectives. For this it may be necessary to use data from the National SILO climate database, once again, available from BoM.

3.4.3 Choice of Timestep

To choose an appropriate timestep, the modeller must consider the subcatchments and treatment measures being modelled. The timestep selected should reflect either the time of concentration of the smallest subcatchment, or the shortest residence time of any treatment measure. In the majority of cases, a 6 minute timestep provides suitable model results, and given current computing power, using this timestep will not result in onerous run times for most models.

Where a user wishes to determine an appropriate timestep based on the catchment and treatments being modelled, the suggested methodology for determining that timestep is shown below:

Step 1: Determine Timestep for <u>smallest</u> Source Node



Step 2: Determine Timestep for Treatment node(s)

1. Estimate detention time for treatment node(s)
   - Swales & buffer strips: typically 5-15 minutes (calculate using Manning's equation): **Recommendation: Use 6 minutes**
   - Bioretention & infiltration systems: typically 5-10 minutes for 'ponding component' (above-ground): **Recommendation: Use 6 minutes**
   - Ponds & wetlands: typically > 10 hours (calculate using T=0.278V/Q where T= time (hrs), V= extended detention volume (m^3), Q = discharge (L/sec): **Recommendation: Use 1 hour**
   - Rainwater tank: typically < 10 minute: (calculate using T=0.278V/Q where T= time (hrs), V= extended detention volume (m^3), Q = discharge (L/sec): **Recommendation: Use 6 min**
   - Gross pollutant traps: typically <5 minutes. Recommendation: **Use 6 min.**
2. **Select the <u>shortest</u> of these timesteps**

Step 3: Use the <u>shortest timestep</u> out of Step 1 and 2

3.5 Define Subcatchments

3.5.1 Overview

When defining subcatchments, it is critical to understand the site intimately. This is best done through a site visit and then reviewing areas that may flow to particular drainage points or may contain single land uses. Further information is usually required from survey data, lot layouts, aerial photography, digital elevation models and similar data sets

An example is shown below (Figure 3-5) where MUSIC subcatchments have been defined for a peri-urban area in coastal New South Wales. In this case, the boundaries were set based on three parameters, underlying land use (separating urban areas from rural and industrial areas), contours, and most importantly, existing drainage networks, both piped (as shown in blue), and overland flow paths (assumed from the contours).

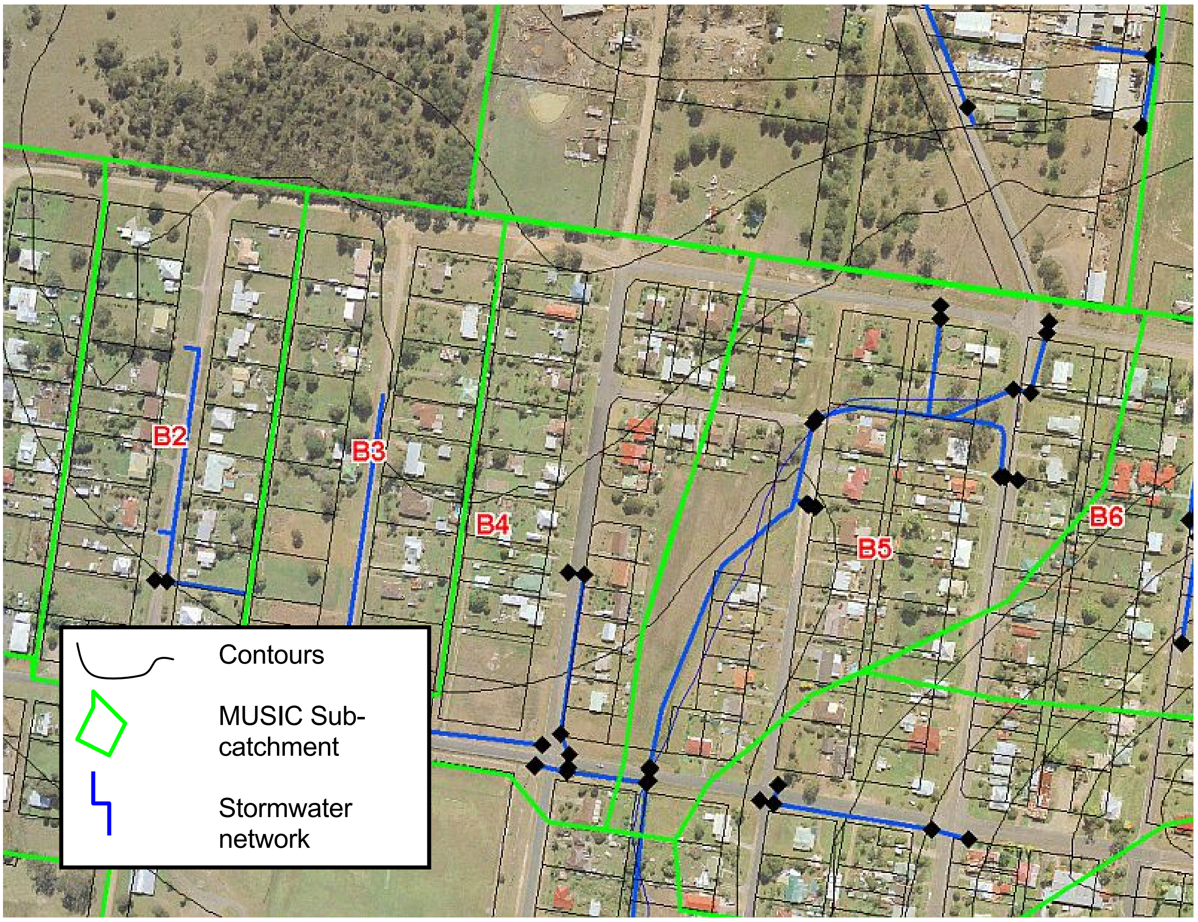


Figure 3-5 Subcatchment Delineation for MUSIC Modelling

The definition of subcatchments also comes down to some expert judgment and consideration of the final drainage layout of the site. It may also be necessary to create separate subcatchments wherever flow paths are separate. For example, in an allotment, roof areas may drain through a tank, whilst flow from surrounding impervious areas may flow directly to the drainage system, or through a (see Section 3.5.3.1). Impervious areas of the various subcatchments will then need to be calculated accordingly (see Section 3.6.4.1)

The above figure also shows the type of image that can be extremely useful as a background bitmap and serves as a template on which to build the MUSIC model. To do this, it is simply a matter of obtaining a screenshot (typically using the Print Screen or Prt Scr button) on the keyboard and pasting this into an image program (e.g. Windows Paint, Irfanview, etc) and saving it as a Windows bitmap (.bmp) format. In MUSIC, this can then be loaded as a background image by selecting Catchment from the toolbar, then Background Image. An example of a model built on a background bitmap is shown below.

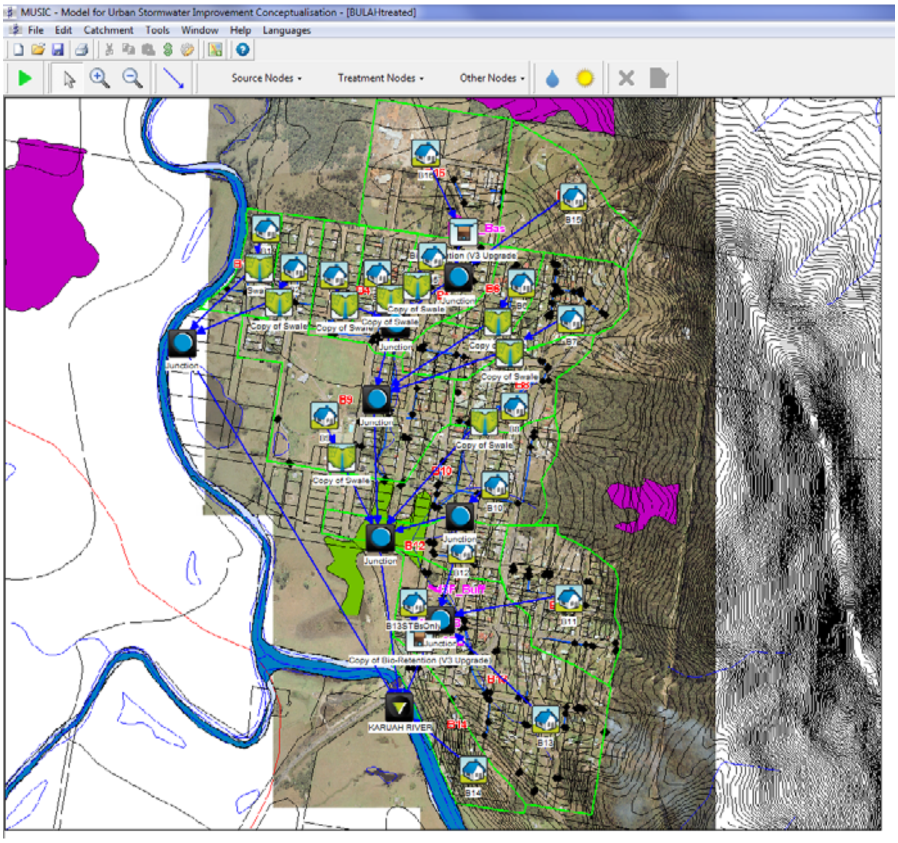


Figure 3-6 MUSIC Model with Background Bitmap

3.5.2 Location of Treatments – Offline or Online

A key issue to consider is whether the treatment measures would be positioned off-line (e.g. at source within lots, within road reserves, outside riparian zones adjacent to watercourses) or on-line (along watercourses that may also convey flow from catchment areas beyond the site extents). It is necessary to ensure that stormwater quality is treated appropriately before it enters any stream in order to prevent impacts on stream health and for that reason on-line treatment systems will not provide the necessary degree of protection required. For that reason, on-line treatments (i.e within a waterway or watercourse) are not recommended when setting up a treatment train to model in MUSIC.

3.5.3 Examples

Examples of some approaches that may be considered by the modeller when defining the subcatchment areas in MUSIC are shown in the following sections.

3.5.3.1 Individual Lot

Simulation of an individual lot in MUSIC can be achieved using a 1 node model that represents the average conditions of the land use being simulated (e.g. rural residential or urban residential). This approach is best applied when the proposed treatment measures will treat runoff from all the combined surfaces. When a measure is being proposed to treat runoff from a specific surface then this scenario can only be modelled appropriately by dividing the lot into different surfaces (according to their flow paths) as shown in Figure 3-7,(which shows splitting of an allotment according to roof and other areas) Figure 3-8 (which splits the roof area according ot the proportion which drains to the tank) and Figure 3-9 (which shows how tanks may be incorporated within non-residential allotments).

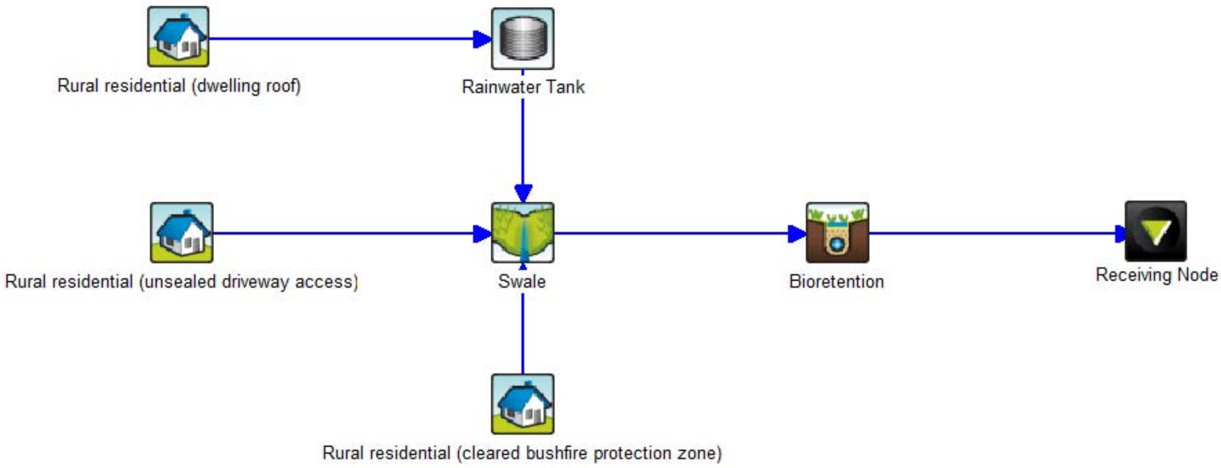


Figure 3-7 Catchment Areas for an Individual Rural Residential Lot (Disturbed Surfaces Only)

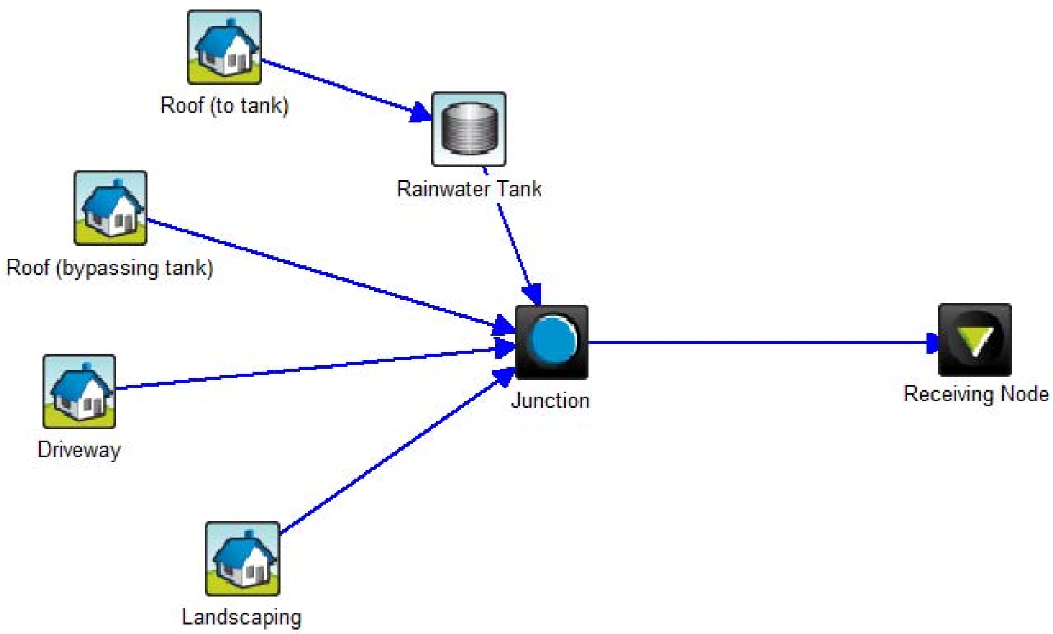


Figure 3-8 Catchment Areas for an Individual Low Density Urban Residential Lot (All Surfaces)

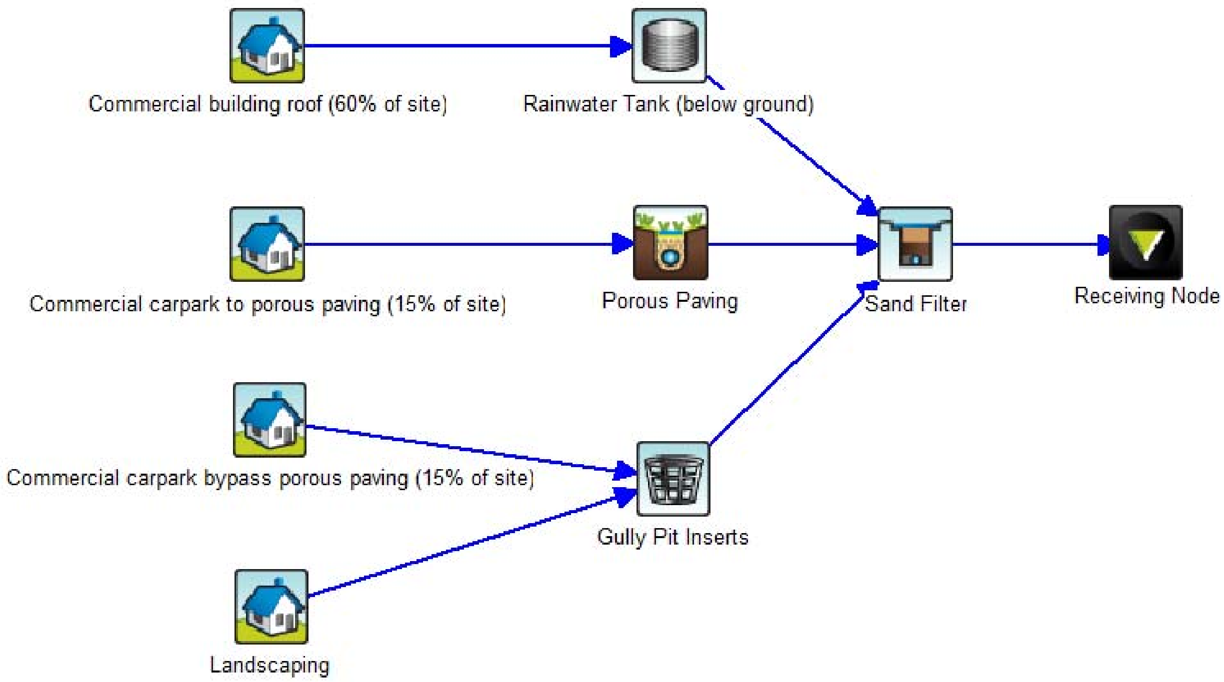


Figure 3-9 Catchment Areas for an Individual Commercial Lot (All Surfaces)

3.5.3.2 Multiple Lots

To simplify the model, the modeller should look to combine areas with similar characteristics, such as where a subdivision is proposed of similar lots. The individual lots do not need to be modelled separately, but can be aggregated, or "lumped" such that the source node used represents a number of lots of similar characteristics. The imperviousness used in this case should reflect the aggregated lots (i.e. it will need to reflect that there may be different driveway and outbuilding configurations in addition to varying roof areas). The size of the treatment measures estimated using this modelling approach can also be aggregated and proportioned within the site based upon the actual size any individual treatments on each individual lot. The example in Figure 3-1 shows an area being modelled where 10 lots are lumped into a single source node for each of surface types required. The rainwater tank node is also used to lump 10 rainwater tanks into a single treatment node.

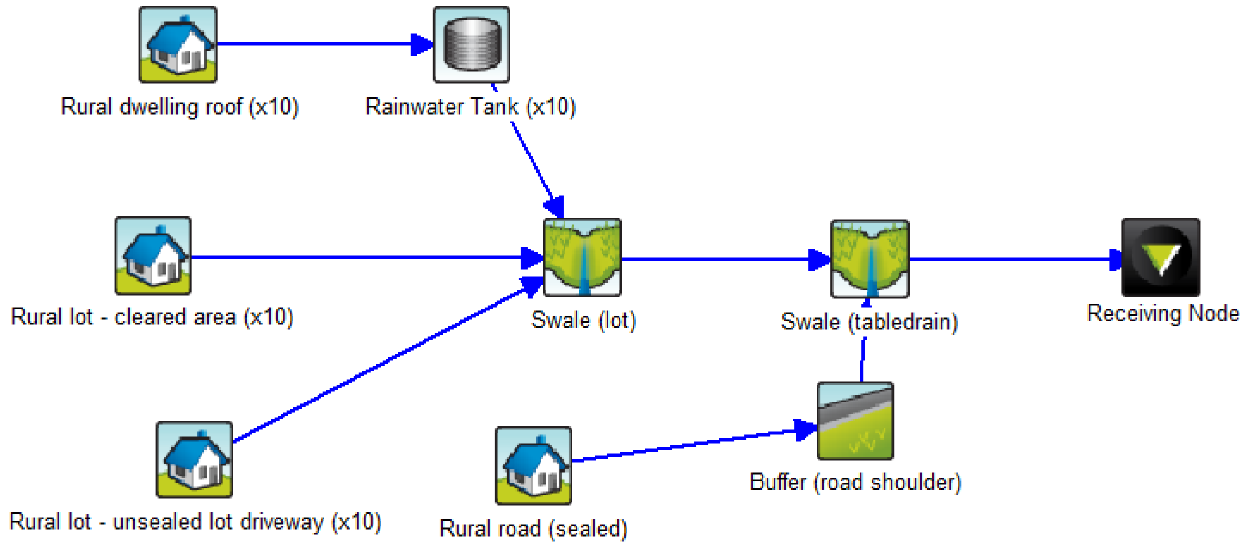


Figure 3-10 Combining Areas to Simplify MUSIC Modelling

In circumstances where the treatment measures are to be positioned outside the lots in areas such as off-line of watercourses, in road reserves or public open space it may be possible to divide the site according to the area draining to specific locations throughout the catchment.

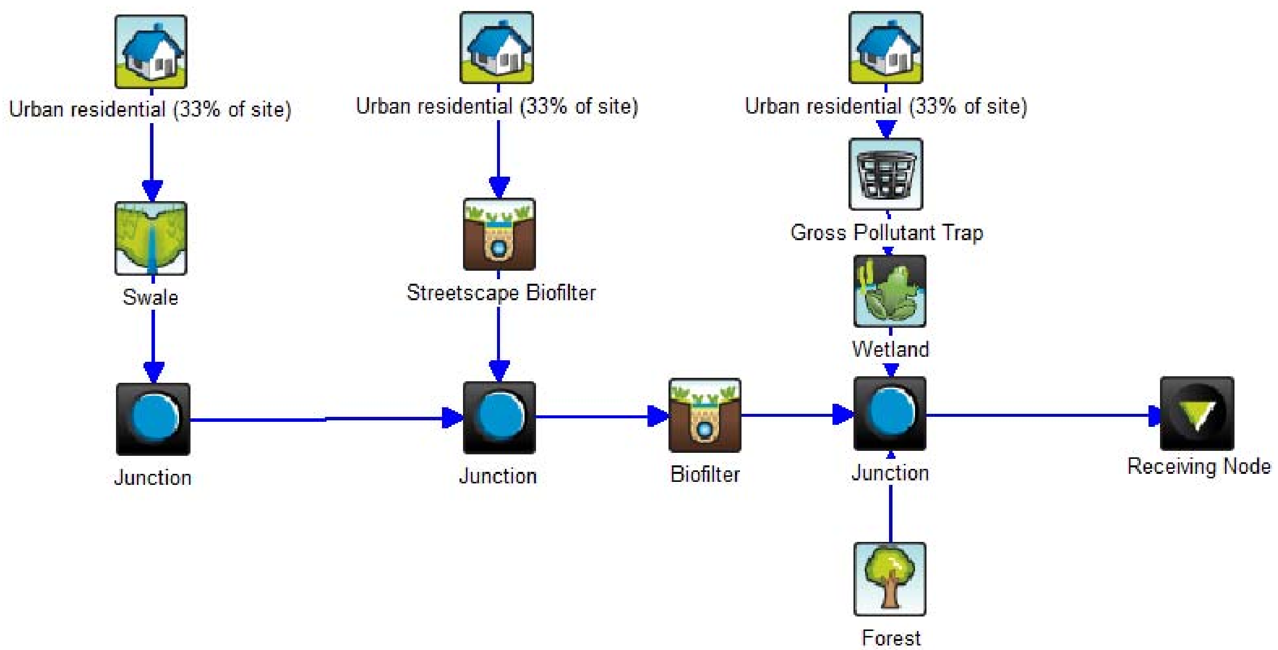


Figure 3-11 Proportioning Catchment Areas

3.5.3.3 Large Scale

In circumstances where the treatment nodes are to be concentrated near the catchment/site outlet, simplifying the catchment into broad land uses is likely to provide a reasonable modelling approach. This large scale approach is shown in **Figure 3-12**.

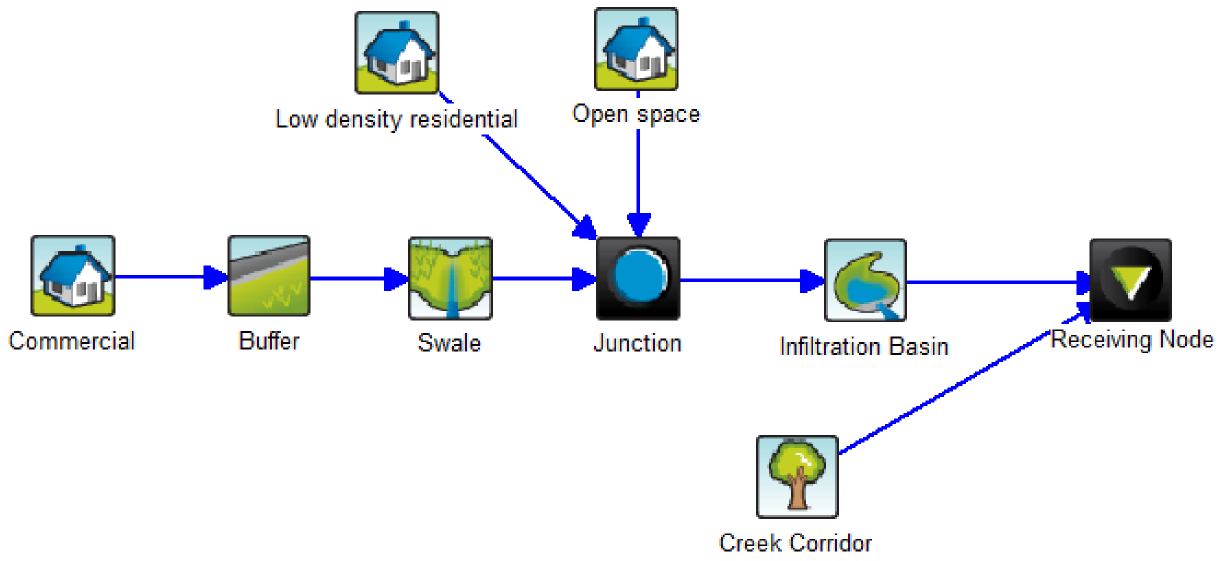


Figure 3-12 Catchments Defined Based on Broad Land Uses

3.6 Setting up Source Nodes

3.6.1 Source Node Types

The second step in creating a MUSIC model is to define Source Nodes that represent watershed sub-catchments. The notes in this section apply equally well to both the existing and future scenario source nodes.

MUSIC currently incorporates five default source node types (urban, agricultural, forest, user defined and imported data). Typically, the urban source node should be used to represent any urban residential development, including rural, low, medium and high density residential allotments. The percentage imperviousness can then be adjusted accordingly. Park areas within these urban developments can also be represented using the urban source node as shown in Table 3-2

For modelling purposes, land use/zonings and surface types should be translated into MUSIC source nodes according to Table 3-2, using the parameters provided in subsequent sections relevant to the recommended source node types.

Table 3-2 Translation of Land Use/Zoning and Surface Types into MUSIC Source Nodes

Land use/zoning and surface type	Adopt parameters for…
Land use/zoning	
All urban residential zones	Residential
All commercial zones	Commercial
All industrial zones	Industrial
Schools	Residential
Urban parks	Residential
National Park	Forest
Protected land	Forest
Rural residential	Rural residential
Rural grazing (horse paddocks)	Rural residential
Rural grazing (other stocked areas)	Agricultural
Nurseries	Agricultural
Surface type	
Roofs	Roofs
Unsealed/partially sealed roads	Unsealed roads
Sealed roads	Sealed roads
Private residential landscaping/gardens	Residential

3.6.2 Catchment Area and Impervious Area

Each MUSIC Source Node requires the total subcatchments area and **effective impervious area proportion** to be defined. 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 area (TA). It is a measure of the area of land that is effective in generating runoff that flows directly to the stormwater drainage system.

In developing a MUSIC model, the most sensitive parameter in dictating the volume of runoff from a particular source node is the percentage of effective impervious area as discussed above. From calibration studies in NSW, it has been assessed that once the effective impervious area percentage is >10%, the adjustment of soil parameters has little significance in improving runoff prediction. As such, it is imperative that the estimation of percentage effective impervious area is estimated using the techniques discussed below.

The source nodes in MUSIC should be parameterised according to one of two approaches. These approaches are dependent upon the areas used for the source nodes.

3.6.3 Approach 1 – Large Scale Catchments (Source Nodes >10ha)

For large scale catchments, where the majority of source nodes are likely to have areas >10ha, the estimated EIA exceeds 5% and the catchment is dominated by clay soil textures the following approach is considered appropriate:

- Determine EIA from the total source node area using values in Table 3-3

- All connected impervious areas must be included in the calculation of EIA, including those areas which may flow to WSUD treatments in the “treated case” model, as MUSIC will account for the effect of the WSUD treatments in achieving disconnection of these impervious areas.
- Adopt impervious rainfall threshold values as shown in **Table 3-6**.
- Adopt the averaged MUSIC pervious area parameters shown in **Table 3-4** unless parameters based upon local calibrated MUSIC models are available.
- Run MUSIC utilising the adopted pervious area parameters and EIA estimate.
- Output flow data from MUSIC and based on the estimated effective impervious area and average annual rainfall (for the period simulated) compare the modelled runoff fraction with the values shown on **Figure 3-13**.
- If the model results are within 0 to +10% (relative) of the estimate from **Figure 3-13** adopt the model as being reasonably representative of the urban catchment hydrology. If not,
- Modify the rainfall threshold within reasonable bounds (from 0 to 3.5mm is considered appropriate, based on calibration of MUSIC in NSW**)**. If the model results are still not within 0 to +10% of the estimate from Figure 3-13, modify the SSC and field capacity values (within reasonable bounds) keeping the ratio between these two parameters the same.
- If reasonable agreement cannot be reached with the expected values, consider using Approach 2.

The rainfall-runoff parameters outlined in Table 3-4 were determined considering primarily clay-based catchments in NSW. Where the site/catchment being modelled is dominated by sandy soils the approach outlined above should be undertaken along with the approach outlined in Section 3.6.4 and the results compared to confirm which parameters provide the most appropriate water balance estimate for the site (considering total modelled base flow, surface runoff and evapotranspiration volumes).

Table 3-3 Default EIA Proportions for MUSIC Models in NSW

Land Use Type	EIA Factor
Residential	0.55 x TIA
Commercial	0.80 x TIA
Rural residential	0.05 x SCA
Industrial	0.90 x TIA
Agricultural / grazing	0.00 x SCA
Native/plantation forest	0.00 x SCA

SCA = Subcatchment/surface area, TIA = Total Impervious Area, EIA = Effective impervious area

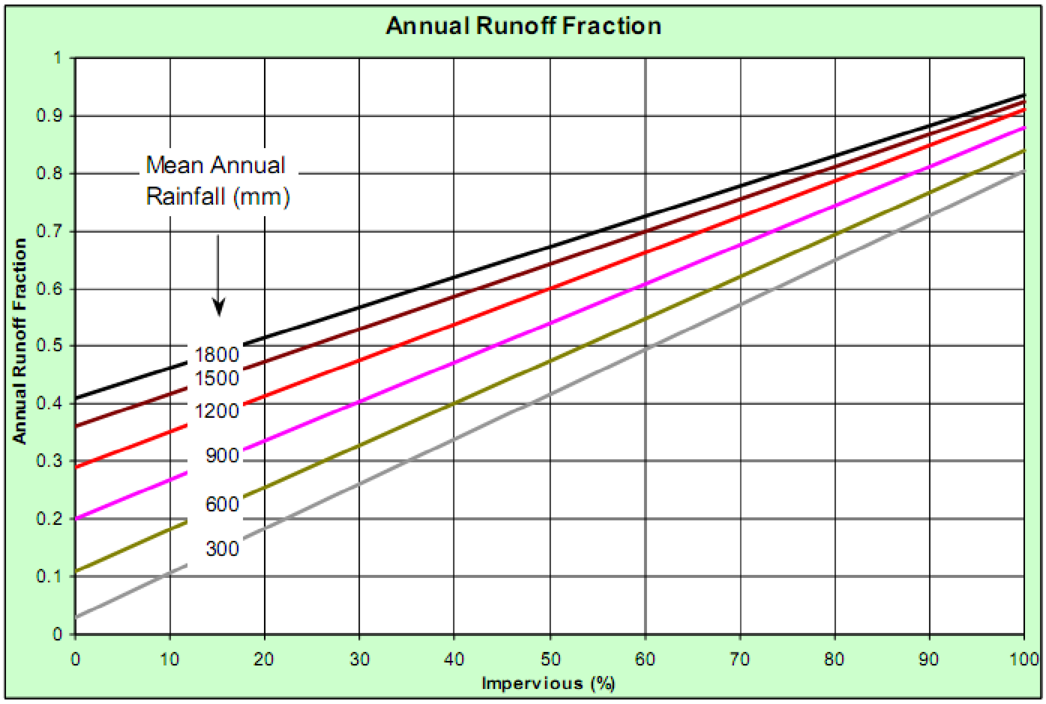


Figure 3-13 Annual Runoff Fraction (Fletcher et al, 2004)

Table 3-4 Pervious Area Parameters – For Source Nodes >10ha

	URBAN	NON-URBAN	
Parameter	**All MAR**	**MAR <1000mm**	**MAR >1000mm**
Pervious Area Parameters			
Soil Storage capacity (mm)	170	210	175
Initial Storage (% of capacity)	30	30	30
Field Capacity (mm)	70	80	55
Infiltration Capacity Coefficient – a	210	175	215
Infiltration Capacity Exponent - b	4.7	3.1	2.4
Groundwater Properties			
Initial depth (mm)	10	10	10
Daily Recharge Rate (%)	50	35	55
Daily Baseflow Rate (%)	5	20	10
Daily Deep Seepage Rate (%)*	0	0	0

* For any catchment, it may be necessary to set the Daily Deep Seepage Rate to some value other than 0, as there may be water that is lost in the system and does not reappear downstream. A method to determine this is shown below.

3.6.3.1 *Specifying Groundwater Behaviour (baseflow or seepage)*

The first parameter to specify (or to determine by calibration, see 3.6.3.2 below) is whether the catchment being modelled has baseflow or not. Baseflow should be specified in MUSIC (see Figure 3-14a) if there is a permanent stream within the catchment being modelled or where intermittent streams still have some residual baseflow after an event. This will normally be the case for a relatively large catchment.

In the case of a small catchment, where there is no permanent drainage line, all groundwater should be specified as being lost to deep seepage. For example, in most cases, where the "point of compliance" is at the outlet of a development (which may be a pipe, swale or outlet of another development-scale treatment device), the deep seepage option would be chosen (because there is no baseflow in a pipe or swale, and any groundwater returns as baseflow downstream of the outlet being assessed). In a case where a large regional treatment (e.g. wetland) is being considered, and there is permanent baseflow running into the wetland, then the baseflow option would be chosen. An example of each case is shown in Figure 3-14b. In most cases, a specification of either one or the other will suffice. Calibration (see Section 3.6.3.2) may be required in intermediate cases, where some of the groundwater contributes to baseflow, and some of it is lost as deep seepage (ie. it returns to baseflow below the point of compliance being modelled).

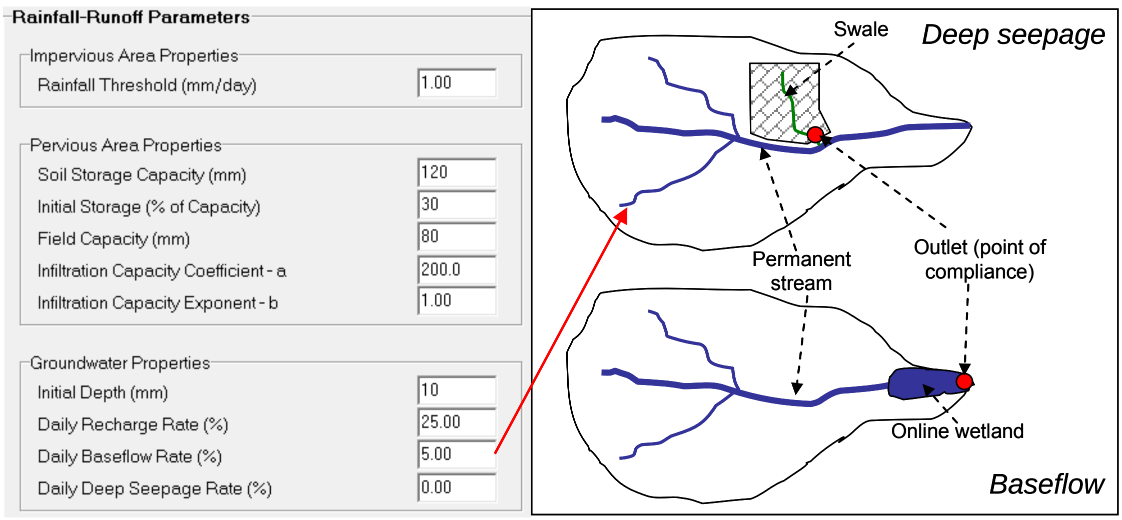


Figure 3-14 (a) MUSIC source node rainfall-runoff dialogue showing specification of what proportion of groundwater goes to baseflow and/or deep seepage and (b) illustration of where each would be specified.

3.6.3.2 *Local Calibration*

In any modelling exercise, calibration to local data should be undertaken wherever possible and where good quality data sets are available. This calibration can be completed within MUSIC, using either the observed data option to visually perform calibrations, or more quantitatively through extraction of data into a spreadsheet and comparison with observed data to obtain optimised parameters based on objective functions such as coefficient of efficiency (Nash-Sutcliffe) calculations, sum of least squares or others. A useful tool for undertaking calibrations of the pervious area parameters in MUSIC is to utilise the Rainfall Runoff Library (RRL) tool available on the eWater

CRC's Toolkit website (see www.toolkit.net.au). This allows the dynamic calibration of a number of rainfall runoff models, one of which is SimHyd, the basis for the rainfall runoff model in MUSIC. Parameters used in SimHyd correlate to those used in the MUSIC rainfall runoff model.

3.6.4 Approach 2 – Small Scale Subcatchments (Source Nodes <10 ha) and Rural Catchments

For developments where source nodes are likely to be <10ha, or those which contain <5% EIA (i.e. non-urban), the EIA estimate should be calculated directly from the site layout plan. For the developed scenario, the modeller should confirm that the EIA values presented in Table 3-5 are appropriate for the specific development layout being modelled.

Table 3-5 Surface Type EIA Factors (for Source Nodes <10 ha)

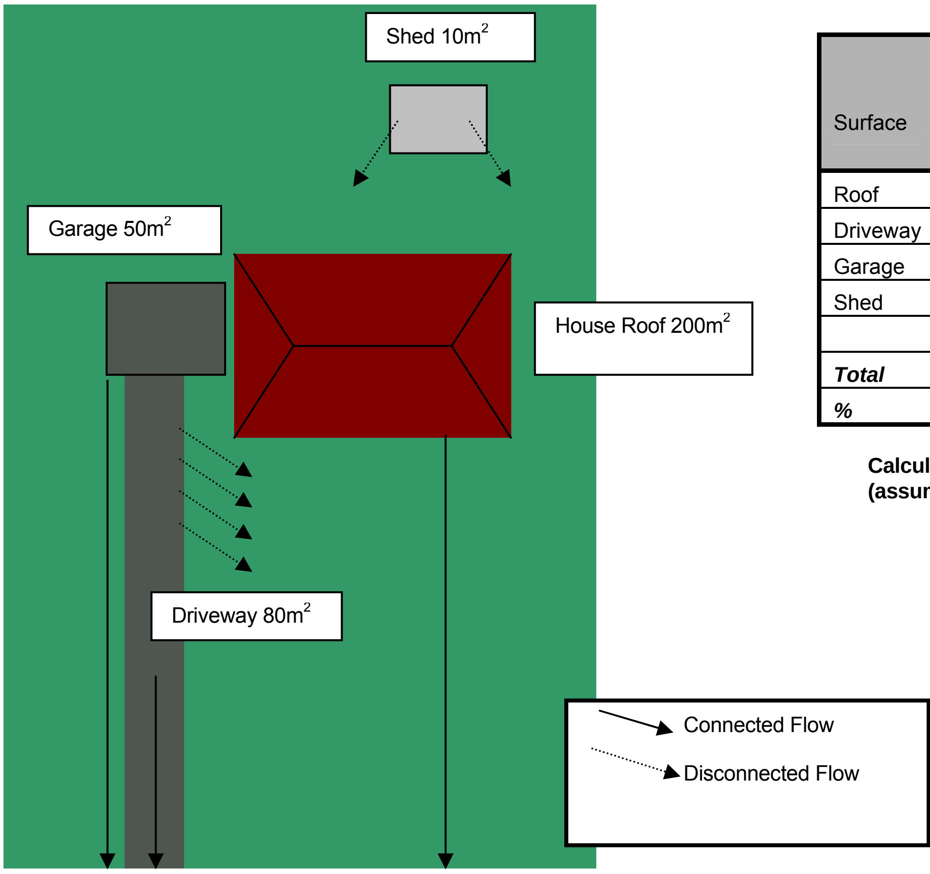
Surface types	EIA Factor
Roofs	1.0 x TA
Sealed roads	1.0 x TA
Permeable paving	1.0 x TA
Unsealed roads	0.5 x TA
Paved landscaping	0.5 x TA
Vegetated landscaping	0.05 x TA
Other pervious areas (yards, grassed verges	0 x TA

TA = Total site/catchment/surface area, EIA = Effective impervious area

3.6.4.1 Calculating Effective Impervious Area (<10ha)

From the above table, when using the surface types approach, it is necessary to have some indication of the layout of the site, which should have sufficient detail to allow estimates of areas of the different surface types outlined above. To complete this, the user needs to identify those impervious areas which will flow directly to the drainage network, whether this is the roadside kerb, piped drainage, gully pit or interallotment drainage. These will be the areas which will be "effective" in generating runoff which will be delivered rapidly at the catchment outlet during a rainfall event.

An example of how this can be determined is shown in the figure below. *Note that this is indicative only and would need to be calculated for several lot types in the development and lumped up accordingly.*



Surface	Total Impervious Area (m^2)	Directly Connected Impervious Area (m^2)
Roof	200	200
Driveway	80	30
Garage	50	50
Shed	10	0
Total	***340***	***280***
%	***42.5***	***35***

Calculations of % Imperviousness (assuming total area of 800m^2)

3-15 Calculating Effective Impervious Areas

In the above example, the total impervious area would be the combined area of the driveway, garage, house roof and shed, however when considering those areas which are connected directly to the drainage network (either into a pipe or via the kerb), the effective impervious area is only the combined area of the roof, garage, and the proportion of the driveway that flows to the kerb.

3.6.4.2 Impervious Area Parameters

In addition to the correct definition of effective impervious area, the rainfall threshold (the volume of rain required before runoff occurs) needs to be defined. This represents the amount of rain required to "wet" the surface before runoff is generated. MUSIC subtracts this amount from the overall rainfall for each day, with the remainder being converted directly into runoff. The rainfall threshold is "emptied" each day, such that rainfall on subsequent days will also be subject to this initial loss.

The following rainfall threshold values should be adopted.

Table 3-6 Default Rainfall Threshold Values (RT)

	RT
Land Use Zoning	
For all land uses (residential, rural residential….etc)	1.0mm
Surface Type	
Roofs	0.3mm
Sealed roads, driveways, paving and paths	1.5mm
Unsealed roads	1.5mm
Permeable paving (opening proportion)[1]	0mm
Permeable paving (paved proportion)[1]	1.5mm

1. Refer to Section 3.8.2.2 for further discussion on modelling permeable paving

3.6.4.3 Pervious Area Parameters

The derivation of pervious area parameters within MUSIC is usually undertaken by calibration of gauged catchments in a particular climatic region, with the resultant calibrated parameters then being utilised in ungauged catchments with similar characteristics. This method typically produces values that are suitable for describing large subcatchments (e.g. >10ha) as described in Approach 1, where small scale effects (e.g. localised storage) become less significant in predicting runoff. For smaller catchments, or those where effective impervious areas are <5% it may be more appropriate to use parameters which reflect local soil conditions.

To derive the pervious area parameters for use in MUSIC, the field texture of the soil is required as is a determination of the depth of the root zone (Macleod 2008). From this, the Soil Storage Capacity and Field Capacity can then be determined. To assist in determining the field texture from sieve analysis, Figure 3-16 shows a soil texture triangle which may be of assistance, however this reflects US conditions and more appropriate reference may be available on pg 171 in Charman and Murphy (eds), 2007. Soils: Their Properties and Management, Third Edition. Oxford University Press. Note that a maximum soil depth for the rooting zone is 1.0m. Rarely would the rooting zone be deeper than this, and as such, evapotranspiration is not likely to be significant in predicting water loss from pervious areas below this depth. As such, the modeler needs to first consult Table 3-7 to determine the Soil Storage Capacity and Field Capacity dependent on the existing and likely future soil conditions. The remaining pervious area parameters to be adopted can then be selected from Table 3-8. The default parameter values for initial storage (% of capacity) and initial depth (mm) should be adopted for all soil types.

Table 3-7 Pervious Area Soil Storage Capacity and Field Capacity (from Macleod 2008)

Dominant Soil Description	0.5m root zone		1.0m root zone	
	SSC*	FC*	SSC*	FC*
Sand	175	74	350	144
Loamy sand	139	69	279	134
Clayey sand	107	75	214	145
Sandy loam	98	70	195	135
Loam	97	79	194	154
Silty clay loam	100	87	200	167
Sandy clay loam	108	73	217	138
Clay loam	119	99	238	189
Clay loam (sandy)	133	89	267	169
Silty clay loam	88	70	175	133
Sandy clay	142	94	283	179
Silty clay	54	51	108	96
Clays	93	68	187	127

*** SSC – Soil Storage Capacity**

*** FC – Field Capacity**

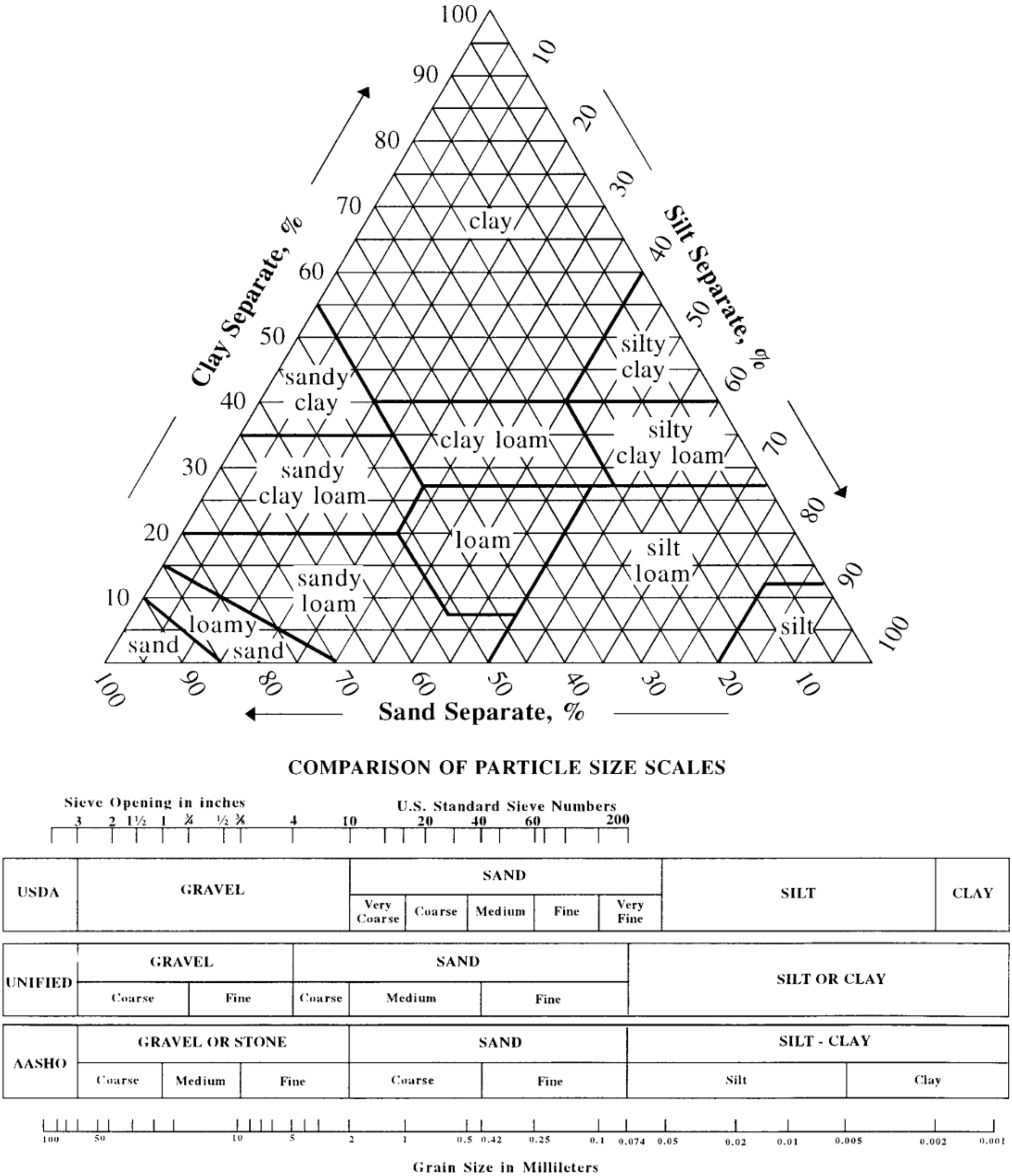


Figure 3-16 Soil Texture Triangle (http://soils.usda.gov/technical/handbook/images)

Table 3-8 Remaining Pervious Surface MUSIC Rainfall Runoff Parameters (adapted from Macleod 2008)

	MUSIC rainfall-runoff parameters				
Dominant soil description	**Inf "a" (mm/d)**	**Inf "b"**	**DRR (%)**	**DBR (%)**	**DSR (%)**
Sand, loamy sand	360	0.5	100%	50%	0%
Clayey sand, sandy loam, loam, silty clay loam, sandy clay loam	250	1.3	60%	45%	0%
Clay loam, clay loam (sandy), silty clay loam, sandy clay, silty clay	180	3.0	25%	25%	0%
Clays	135	4.0	10%	10%	0%

MUSIC rainfall-runoff parameter definitions – SSC=Soil Storage Capacity, FC=Field Capacity, Inf "a" = Infiltration capacity co-efficient a, Inf "b"=Infiltration capacity exponent b, DRR=Daily Recharge Rate, DBR=Daily Baseflow Rate, DSR=Daily Deep Seepage Rate.

1. These parameter estimates are based on soil properties only and do not incorporate allowance for rainfall losses associated with depression storage, mulch/ vegetation interception and other non-soil sources of water storage within a catchment.

3.6.5 Stormwater Pollutant Input Parameters

The stormwater pollutant input parameters to be used for each land use/zoning and surface type for base flow and storm flow are presented in Table 3-9 and

Table 3-10. The base flow parameters are applied to groundwater flow, whilst the storm flow parameters are applied to surface runoff. **In all cases, the stochastic generation option for pollutant generation should be selected.**

The parameters to be used out of each table should be consistent with the approach used to set up the source nodes, such that if "Approach 1" (see Section 3.6.3) is used, the Base Flow and Storm Flow paremeters for the Land use/zoning types should be used, whereas if "Approach 2" (see Section 3.6.4) is used, then the parameters for the particular surface types used in the source nodes should be adopted.

Table 3-9 Base Flow Concentration Parameters for NSW (Fletcher et al, 2004)

	Concentration (mg/L-log_{10})					
	TSS		TP		TN	
	mean	std. dev	mean	std. dev	mean	std. dev
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
Surface type						
Roofs	n/a	n/a	n/a	n/a	n/a	n/a
Sealed roads (if contains a pervious fraction e.g. verge)	1.20	0.17	-0.85	0.19	0.11	0.12
Unsealed roads[1]	1.20	0.17	-0.85	0.19	0.11	0.12
Eroding gullies[1]	1.20	0.17	-0.85	0.19	0.11	0.12

Table 3-10 Storm Flow Concentration Parameters for NSW (Fletcher et al, 2004)

Concentration (mg/L-$\log_{10}$)						
	TSS		TP		TN	
	mean	std. dev	mean	std. dev	mean	std. dev
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
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[1]	3.00	0.32	-0.30	0.25	0.34	0.19
Eroding gullies[1]	3.00	0.32	-0.30	0.25	0.34	0.19

1. Additional surface type not included in Fletcher et al (2004).

3.7 Building the Model Network

3.7.1 Joining Nodes

Once the source nodes have been properly defined, they should be joined up consistent with the overall drainage pattern of the site. To assist this, it is useful to use the Junction Nodes in MUSIC to provide a visual reference that is similar to the overall network.

When the network has been completed, the modeller should consider whether routing of links is to be incorporated within the model.

3.7.2 Link Routing

MUSIC uses Drainage Links to join together source, treatment and junction nodes. These drainage links may represent pipes, open channels or a natural watercourse. To enable more accurate simulation the user may specify the routing properties of each link.

3.7.2.1 Routing Properties (from BCC 2005)

There are three options for hydrologic routing along a link in MUSIC:

1. **No Routing** - has no attenuation or delay of the peak flows between the source node and the receiving node. Generally suitable when catchment source nodes are of similar travel distance from the receiving node. Using this option will typically generate conservative

peak flow values. Where insufficient information is available on the anticipated runoff and drainage network characteristics, it is recommended that users adopt the **No Routing** option for the simulated links between source and receiving nodes (i.e. channels, pipes and natural watercourses).

2. **Translation Only** - will not account for attenuation of the flow hydrographs (refer **Figure 3-17**) but will delay flow peaks from different source nodes (refer **Figure 3-18).** This option is generally suitable when the travel distance from catchment source nodes to common receiving nodes is anticipated to be considerably different. The translation value K (mins), which can be thought of roughly as the time of concentration, will need to be supported by a hydrologic model or similar calculations.

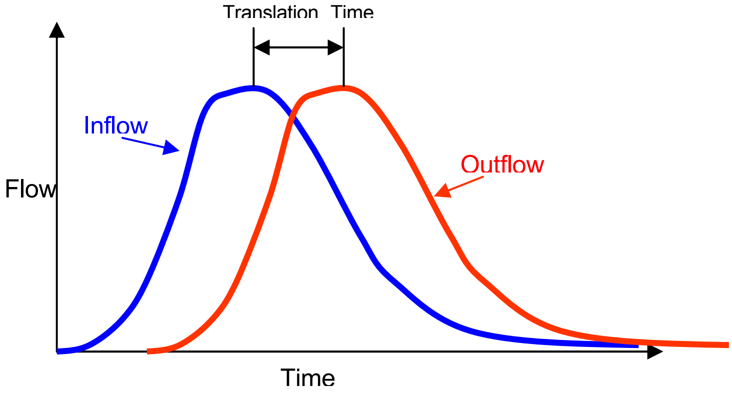


Figure 3-17 Hydrograph Translation Only

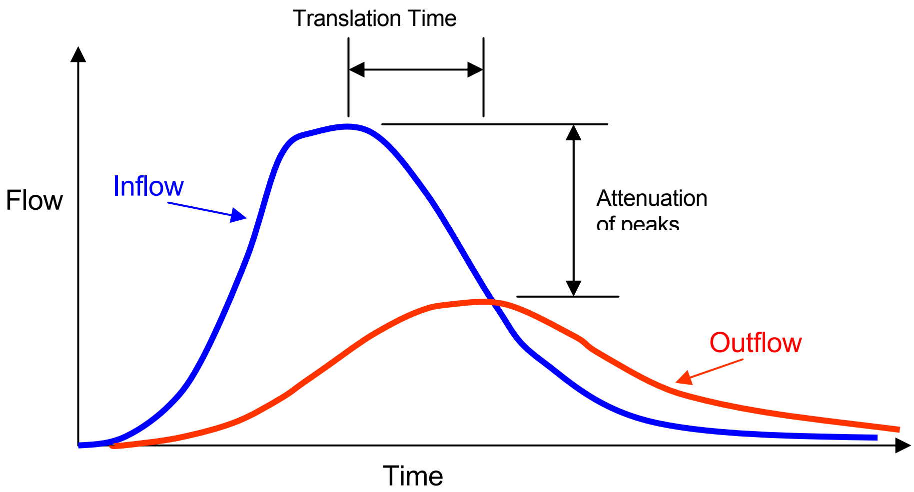


Figure 3-18 Hydrograph Attenuation

3. **Muskingum-Cunge** – routing analysis is based upon the known relationship of a storage wedge existing between the inflow and outflow hydrographs of a flood wave. The relationship states that during the advance of the flood wave the inflow will exceed the

outflow and during the recession, outflow will exceed the inflow. The storage wedge is the instantaneous difference between the inflow and outflow values over a known reach length, as shown on **Figure 3-19**. The translation value K (mins) and Theta θ will need to be supported by a hydrologic model (such as RORB) or similar calculations. In lieu of recorded flow data for calibration and selection of K and θ values, users who choose Muskingum-Cunge routing should undertake a sensitivity analysis to demonstrate the influence of varying K and θ within reasonable limits.

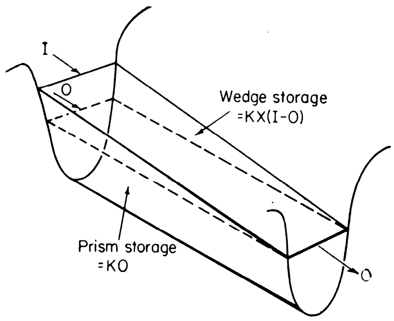


Figure 3-19 Flow Prism – Muskingum-Cunge Routing

3.8 Treatment Node Input Data

In addition to new source nodes, treatment measures need to be selected to address the changes in pollutant loads and concentrations from the development. The following sections provide guidance on the input parameter values to be used to simulate the performance of the various treatment measures. Note, this is not intended to be a complete guide and further guidance is available in a range of documents, such as the MUSIC User Manual, as shown in the References section.

3.8.1 Primary Treatment Measures

3.8.1.1 Rainwater Tanks and On-site Stormwater Detention Tanks

Rainwater tanks and on-site stormwater drainage (OSD) tanks should 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 it is likely that gravity drainage of the entire roof area to the tank would be impractical. Where the tank is underground, draining of the entire roof area to the tank may be feasible. Example configurations of these situations are shown in Figure 3-20 and Figure 3-21. For on-site detention, this should not be modelled as a treatment measure, however the impacts of OSD will need to be accounted for within Stream Erosion Index calculations.

In the rural setting, it is common for the entire roof area to drain to rainwater tanks positioned above ground. Whilst in an urban setting, some allowance for a proportion of the roof area to bypass the tank should be considered. The MUSIC modeller should confirm for their particular development (and Council area) a reasonable proportion of the roof area that can be drained to a rainwater tank and what proportion would bypass. In the majority of greenfield developments, it is expected that the amount of roof area draining to the tank should be 100%, however in retrofit contexts, this may not always be possible, hence the guidance below.

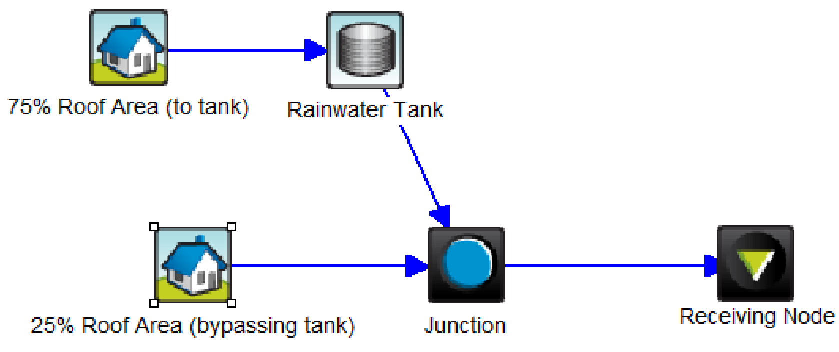


Figure 3-20 Rainwater Tank (Urban Setting) – Roof Drained to Above Ground Tank

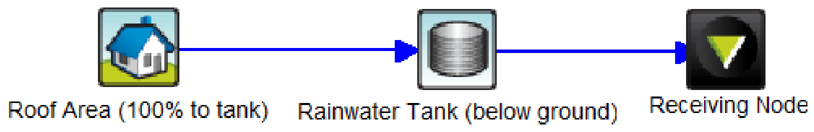


Figure 3-21 Rainwater Tank – Roof Drained to Below Ground Tank

In configuring the rainwater tank, several parameters are required by the MUSIC model. The representation of a rainwater tank in MUSIC is shown in the conceptual diagram below.

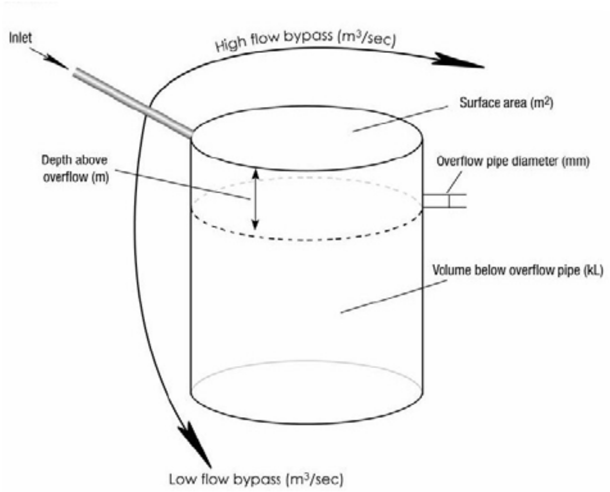


Figure 3-22 Rainwater Tank Conceptual Diagram (as used in MUSIC v4)

It is suggested that residential demands can be estimated based on the values presented in Table 3-12, however local demand data should be used wherever possible. Where data is available on potable water demands in the area being modelled, it may also be necessary to determine internal end use dependant demands as these may vary according to local regulations. If this data is not available, the ratios suggested in Table 3-11 may be used for derivation of them for use in MUSIC. Note that the external demands shown in Table 3-12 represent typical urban residential demands. If additional external demand (i.e. irrigation) is identified for rural residential development these demand estimates may be increased provided information is provided to support the estimates.

Table 3-11 Suggested Internal End Use Ratios

End Use	% of Total Potable Water Use (approx)
toilet	25%
toliet+laundry	50%
toilet+laundry+hot water	90%
toilet + laundry + hot water + other	100%

For locations where on-site stormwater detention is required, the rainwater tank node in MUSIC can be used to simulate this. The rainwater tank should be parameterised with the depth above overflow pipe set to the storage depth of the tank, and the volume below overflow set to 0. No reuse should be allowed.

Table 3-12 Water Demands for Rural and Urban Dwellings (adapted from Coombes et al, 2003)

	RURAL DWELLING solely reliant on rainwater tanks				URBAN DWELLING mains water supply is reticulated			
End Use	***Annual* Internal Use in Kilolitres (kL/yr/dwelling)**							
No. of occupants	**1 to 2**	**3**	**4**	**5**	**1 to 2**	**3**	**4**	**5**
toilet	31	44	57	71	46	66	86	106
toliet+laundry	60	88	115	142	91	131	172	212
toilet+laundry+hot water	110	159	206	256	164	237	309	384
toilet + laundry + hot water + other	122	175	230	283	183	263	343	424
End Use (% of total potable water use)	***Daily* Internal Use in Kilolitres (kL/day/dwelling)**							
No. of occupants	**1**	**2**	**3**	**4**	**1 to 2**	**3**	**4**	**5**
toilet	0.085	0.120	0.155	0.195	0.125	0.180	0.235	0.290
toliet+laundry	0.165	0.240	0.315	0.390	0.250	0.360	0.470	0.580
toilet+laundry+hot water	0.300	0.435	0.565	0.700	0.450	0.650	0.845	1.045
toilet + laundry + hot water + other	0.335	0.480	0.630	0.775	0.500	0.720	0.940	1.160
Daily External Use (eg, gardens)	0.31 kL/day/dwelling or 112 kL/yr/dwelling							

- The roof area draining to a tank should be realistic considering downpipe locations, reasonable roof gutter gradients and the relevant land use.
- Low flow bypass should be 0m^3/s. For rainwater tanks, first flush diversion is included within the rainfall threshold for roofs shown in **Table 3-6**.
- High flow bypass should be estimated based on the roof gutter capacity and the tank inlet capacity. The lesser of these two controls should be used. Note, 0.005m^3/s per dwelling is considered reasonable for a typical detached residential dwelling and the Building Code specifies that guttering should have a capacity to convey rainfall intensities of 100 mm/hr.
- The volume below the overflow pipe should not include the temporary detention, sediment storage zone and top up volumes. A maximum of 80% of the physical rainwater tank volume should be adopted for modelling.
- The overflow pipe from individual tanks should be modelled as a typical 90 or 100 mm diameter pipe. Overflow pipes for an individual rainwater tank node simulating combined multiple tanks should have an equivalent area as the total area of the overflows from the individual tanks.
- For on-site detention tanks, the depth above overflow should be set to the storage depth of the tank and volume below overflow should be set to 0 with no reuse allowed.
- For rainwater tanks, external re-use should be modelled using the annual demand scaled by daily PET-Rain option in the re-use box.
- The efficiency of the tank can be estimated by using the Node Water Balance option in the statistics output.
- For rainwater tanks, internal use should be modelled as an average daily demand.
- Urban residential sites - internal uses include toilet flushing, laundry and hot water.
- Rural residential sites (no mains water) – all internal uses
- Other land uses – determine demands based on a case-by-case situation.

3.8.1.2 Buffer Strips

Buffer strips essentially are grassed or otherwise vegetated areas formed to filter sheet flow runoff from the impervious proportion of a source node. Buffers are provided primarily to remove coarse matter that may otherwise overload a downstream measure. A typical application of this treatment node would be where road pavement runoff is allowed to flow across a vegetated roadside strip prior to draining into a roadside swale or bioretention system.

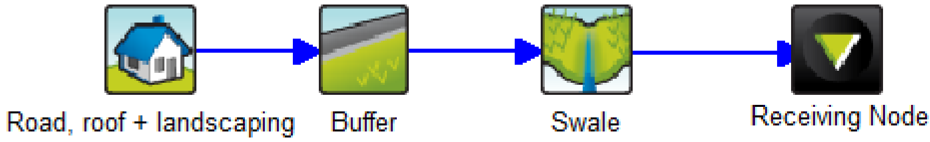


Figure 3-23 Example of Buffers Strip Node Application in MUSIC

Key points – Buffer strips

- Only effective immediately downstream of a source node that incorporates impervious area.
- Only appropriate for simulating situations where flow is not concentrated. If flow is concentrated, model this situation using a modified swale treatment node.
- Ensure the percentage of upstream area buffered is based on the **IMPERVIOUS AREA ONLY**. For example, if the node essentially represents the combination of equivalent road (100% impervious), roof (100% impervious) and grassed (0% impervious) areas and if only the road is to be buffered, 50% would be the adopted figure (i.e. 33% / 66%).
- A maximum seepage loss of 0.1mm/hr may be adopted unless it can be demonstrated that infiltrated runoff would not contribute to observed flows downstream either through seepage into drainage lines, interflow or groundwater discharge.
- The maximum recommended seepage loss rate is approximately equivalent to the average PET rate and represents the loss of water due to evapotranspiration from the buffer strip.
- A buffer zone immediately adjacent to an outlet from a stormwater drainage system discharging into existing natural vegetation should be simulated as a wide swale. Refer to **Section 3.8.2.3** for further guidance.

3.8.1.3 Gross Pollutant Traps

Gross pollutant traps (GPTs) are typically provided to remove litter, organic debris and coarse sediment that may otherwise overload measures provided to manage fine particulates and nutrients. GPTs are also often installed as a standalone measure at specific hotspots to trap gross pollutants.

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

GPTs are usually modelled at the sub-catchment scale in MUSIC as pre-treatment for a pond, constructed wetland or bioretention system, however, at the lot scale, management of gross pollutants may still be necessary and could 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.

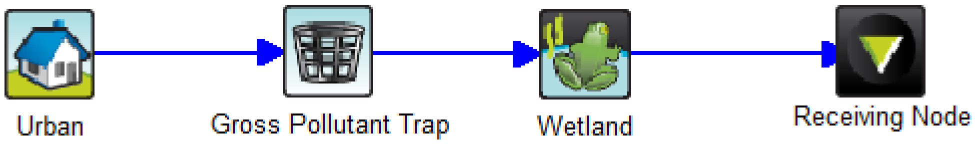


Figure 3-24 Example of GPT Node Application in MUSIC

Where a GPT is necessary and this GPT is designed to remove sediment in addition to gross pollutants, it shall be selected or designed to achieve the minimum performance criteria outlined in Table 3-13. If alternative data is to be relied upon for estimating the performance of the GPT, this shall be included in the report for review with the MUSIC model. This data should be derived from an independent, published source (i.e. not simply based on proprietor supplied data).

Where a GPT is to be implemented only for gross pollutant capture (e.g. a trash rack or pipe net), then only the gross pollutant removal component as shown in Table 3-13 shall be used (i.e. no sediment or nutrient removal is to be attributed to the device). If a proprietary device is noted as being and oil and grit/sediment separator, ***no*** gross pollutant removal is to be attributed to the device, nor should it be used for this purpose.

Table 3-13 GPT treatment node inputs (adapted from Alison et al 1998)

GPT default treatment node inputs		
	Inlet properties	
Low flow bypass	0	
High flow bypass	50% of peak 1yr ARI	
	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

3.8.1.4 Proprietary Stormwater Treatment Devices

The majority of proprietary stormwater treatment devices fit into one of the following categories-:

1. Pit inserts – Source control measures installed within stormwater pits to capture gross pollutants and coarse sediment;
2. Oil and sediment separators – Source control measures installed to capture oil, coarse sediment and some fine sediment;
3. In-line GPTs – Devices installed along a stormwater drainage line to filter stormwater to remove gross pollutants and coarse sediment;
4. End of line GPTs – Devices installed at the end of a piped drainage system to filter stormwater to remove gross pollutants and coarse sediment; and
5. In-stream measures – Devices installed within a watercourse to intercept floating gross pollutants.

As noted above, the modeller shall ensure that proprietary devices that fit into Category 2 listed above are not utilised as gross pollutant trapping devices. If these devices are modelled as a component of the treatment strategy, an additional GPT shall be proposed/modelled upstream of the device. The treatment performance values for TSS, TP and TN outlined in Table 3-13 may be adopted. If alternative performance values are adopted by the modeller, independent testing data shall be provided to support the alternative values.

For proprietary stormwater treatment devices that fit into Categories 1, 3 and 4, the modeller may adopt the treatment performance values shown in Table 3-13. If alternative performance values are adopted by the modeller, independent testing data shall be provided to support the alternative values. Proprietary devices in Category 5 should not be simulated in MUSIC.

Key points – GPTs

- Only required as a standalone measure for commercial development with potentially high litter loads
- Provide as a pre-treatment measure for sites where large sub-catchment scale measures are proposed (e.g. water quality control ponds, bioretention basins, constructed wetlands).
- GPTs generally will not be necessary where stormwater quality is managed using lot and street scale measures (e.g. rainwater tanks, grassed swales, bioretention swales). Other appropriate pre-filtering options shall be provided for these measures to reduce future maintenance. As an alternative, consider using inlet basins to perform a similar function as a GPT.
- The treatable flow rate should be used to set the high flow bypass in the GPT node (typically 50% of the 1 year Average Recurrence Interval (ARI) flow). The modeller shall estimate the high flow bypass rate applying the methods outlined in Australian Rainfall and Runoff, Volume 1, 2001 for estimating 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.

3.8.1.5 Sedimentation Basins

Sedimentation basins are primarily used to target the removal of coarse and medium sediment from stormwater. Sedimentation basins may also be designed to incorporate a gross pollutant trapping function. Sedimentation basins are measures that can be utilised during the construction and post development phases for a site. It is important to note the key differences between these two phases.

A sediment basin is represented conceptual in MUSIC as shown below

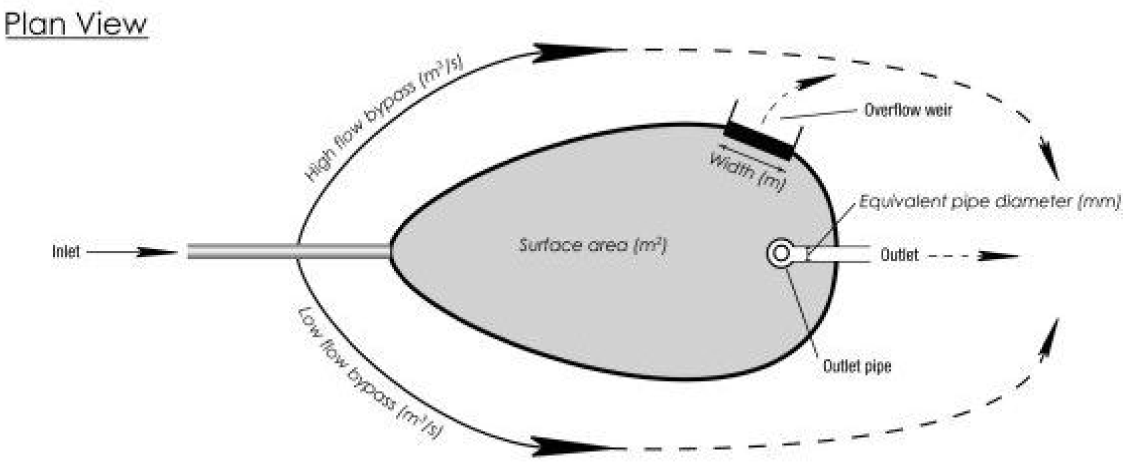


Figure 3-25 Conceptual Plan View of Sediment Basin (as used in MUSIC v4)

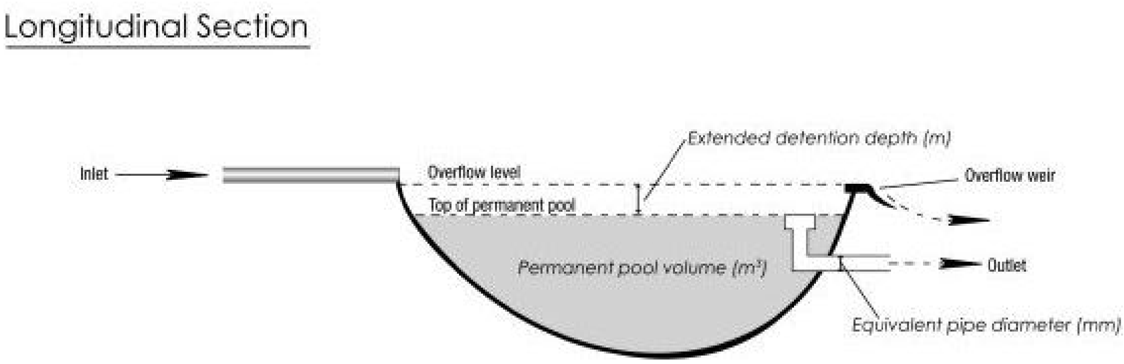


Figure 3-26 Conceptual Cross Sectional View of Sediment Basin (as used in MUSIC v4)

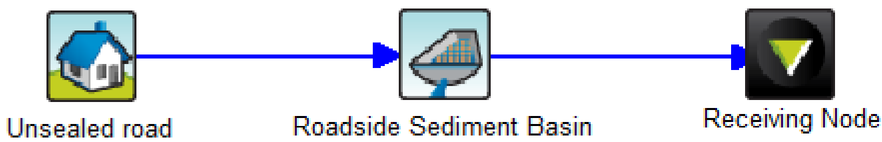


Figure 3-27 Example of Sedimentation Basin Node Application in MUSIC

During the **construction phase**, sedimentation basins are provided to capture and enable settling of coarse and/or fine sediment particles generated from erosion of exposed surfaces during construction. The basin sizing is typically **based on a specific design event** and should be undertaken applying the approaches outlined in the current version of Managing Urban Stormwater: Soils and Construction – Volumes 1 and 2 (the "Blue Book"). <u>Construction phase sediment basins should not be simulated using MUSIC</u>.

Construction phase sediment basins can be modified to function as other measures (e.g. pond, wetland) during the post development phase. During the **post development phase** this treatment node should only be used when simulating catchments where unvegetated/exposed soils form a significant part of post development conditions (e.g. unsealed roads). The basin sizing is typically **based on continuous simulation modelling of a range of events** and MUSIC can be used for appropriate sizing.

Key points – Sediment basins

- Construction phase sediment basins should be sized applying the methods in the "Blue Book".
- Post development phase sediment basins should be modelled to remove the coarser range of TSS particles.
- Sediment basins should only be applied within sites where unvegetated areas with exposed soils form a component of the post development site conditions (e.g. coal mine, pasture, unsealed road).
- Basins should be designed to having a length to width rations of at least 3:1 and be at least 0.6m deep to reduce the risk of scouring previously settled sediments.
- MUSIC currently assumes that the extended detention storage has vertical sides. Therefore, if the system modelled does not have vertical sides an estimate of surface area needs to be calculated. If the system modelled has a trapezoidal shaped extended detention storage, the surface area should be calculated as the detention depth when it is at 1/2 of the maximum extended detention depth.
- The storm flow TSS concentration for areas that are unvegetated in the post development state (e.g. coal mines, pastures, unsealed roads) should be set at 1000mg/L. In addition k and C* must be adjusted to 15,000 and 90mg/L respectively.
- A maximum notional detention time of 8 hours should be adopted for sizing a sediment basin (assuming an average settling zone depth of 1m) to target coarser particles. If a longer detention time is desirable, an alternative treatment measure incorporating vegetation should be modelled to ensure that any captured nutrients are capable of being removed biologically otherwise water quality issues such as excessive algal growth may occur within the basin.
- Provide an appropriate high flow bypass to minimise the potential for scouring of the basin (50% of 1yr ARI flow).

3.8.2 Secondary Treatment Measures

3.8.2.1 Infiltration Measures

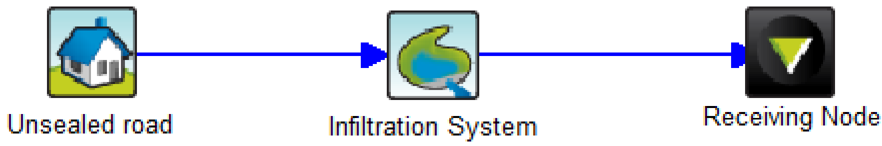


Figure 3-28 Example of Infiltration Node Application in MUSIC

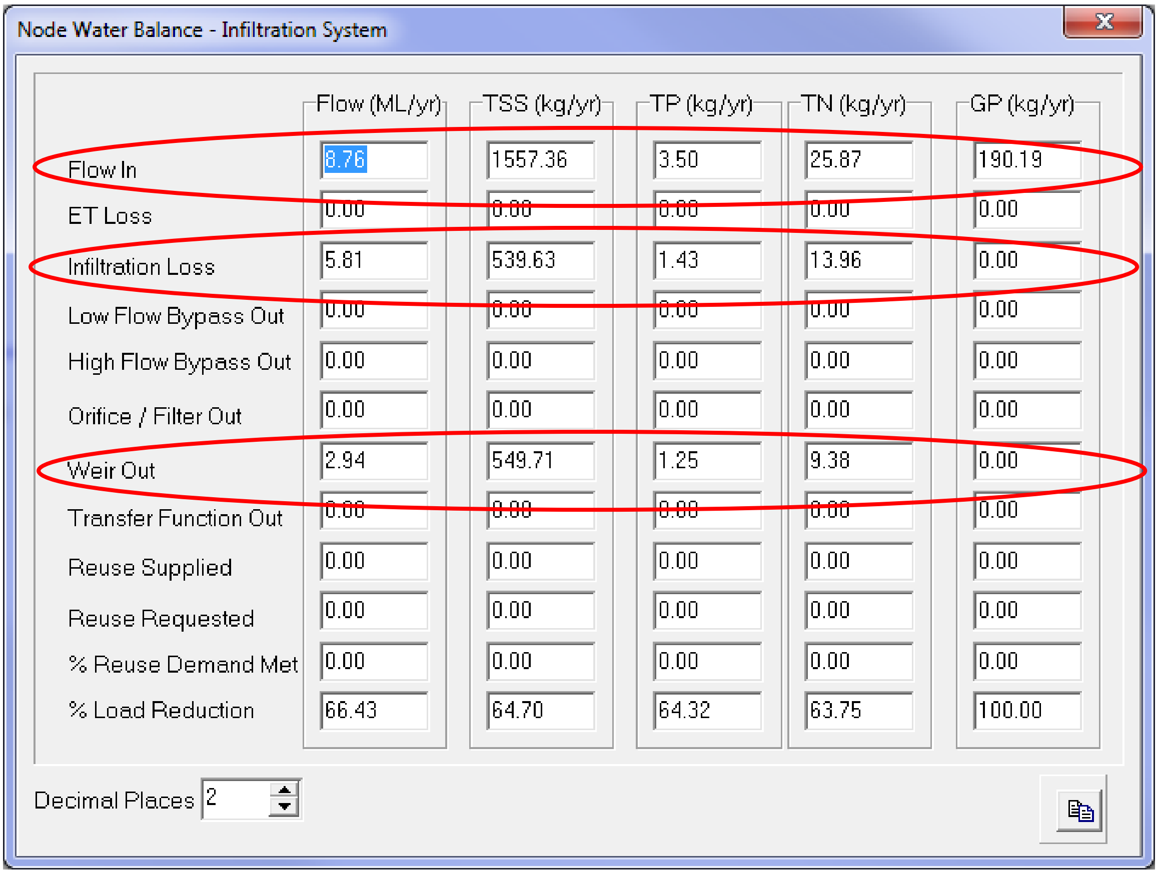
The use of infiltration systems within Australia is increasing due to their ability to assist in managing hydrologic objectives and they are one of the few measures which can lead to a significant reduction in flow volumes for smaller rainfall events and therefore lead to reductions in overall flow frequencies from urbanized catchments. Several guidance documents exist which specify how the application of infiltration systems can be introduced into the WSUD treatment train. Care needs to be taken with their adoption such that consideration is given to separation distances, soil characteristics (e.g. hydraulic conductivity and downslope nuisance (ie. seepage adjoining properties that lie downslope in regards to the hydrologic gradient). For soil characteristics and separation distances, Table 3-14 below provides some guidance as to both the hydraulic conductivities that may be suitable for use in MUSIC and the likely separation distances required. Note that these are for homogeneous soils. Care also needs to be taken about the use of infiltration systems in soil types with high acidity and/or salinity, especially sodic soils and areas known to have high acid sulfate soil potential.

Table 3-14 Infiltration Soil Conditions and Separation Distances (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
Sandy Clays	36	2
Medium Clay	3.6	4
Heavy Clay	0.036	5
Constructed Clay	0.0004	5
Sandstone (overlain by shallow soil)	3.6	2

Within MUSIC, care needs to be taken to ensure that the loads assumed to be removed using an infiltration node are accounted for. The losses via infiltration can result in apparently high load removals when higher seepage rates are used in the model and are not representative of the overall treatment performance of systems where losses through infiltration may occur. To account for these losses, MUSIC Version 4 has a Node Water Balance table available through the statistics result output. When using the infiltration node, the amount of pollutants lost via infiltration needs to be accounted for, as while this is theoretically lost from the treated surface water flows, there will still be pollutants associated with the infiltrated water. While some further treatment may be expected within the subsoil, this has the potential for contaminating groundwater supplies and therefore needs to be accounted for.

To do this, simply use the Node Water Balance to determine the Infiltration Loss and the amount being overflowed via the Weir Out figures. Add these two figures together to determine the total amount of pollutants leaving the system (i.e. that which hasn't been treated by the infiltration media) and subtract these from the Flow In numbers. The result of that calculation can then be divided by the Flow In number to determine the amount removed as shown below.


Node Water Balance - Infiltration System

	Flow (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	GP (kg/yr)
Flow In	8.76	1557.36	3.50	25.87	190.19
ET Loss	0.00	0.00	0.00	0.00	0.00
Infiltration Loss	5.81	539.63	1.43	13.96	0.00
Low Flow Bypass Out	0.00	0.00	0.00	0.00	0.00
High Flow Bypass Out	0.00	0.00	0.00	0.00	0.00
Orifice / Filter Out	0.00	0.00	0.00	0.00	0.00
Weir Out	2.94	549.71	1.25	9.38	0.00
Transfer Function Out	0.00	0.00	0.00	0.00	0.00
Reuse Supplied	0.00	0.00	0.00	0.00	0.00
Reuse Requested	0.00	0.00	0.00	0.00	0.00
% Reuse Demand Met	0.00	0.00	0.00	0.00	0.00
% Load Reduction	66.43	64.70	64.32	63.75	100.00

Decimal Places 2

Figure 3-29 Example Node Water Balance

Table 3-15 Load Lost via Infiltration

Consider the example
Node Water Balance above

Parameters

TN Infiltration Loss + Weir Out = 13.96+9.38 = 23.24 kg/yr

Inflow TN = 25.87 kg/yr

Calculation

TN % removal = (25.87-23.24) / 25.87 * 100%

= 9.8%

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.

3.8.2.2 Permeable Paving

Permeable paving allows runoff to drain through an open pavement and infiltrate to the underlying soil. Removal of particulates and some dissolved pollutants is achieved through filtration and adsorption on to soil particles.

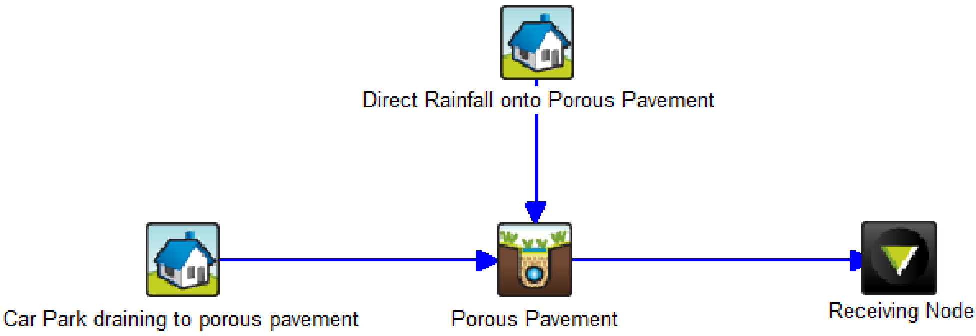


Figure 3-30 Example of Permeable Paving Application in MUSIC

Porous (or pervious) pavements are an alternative to conventional impermeable pavements with many stormwater management benefits. These surfaces allow stormwater to be filtered by a coarse sub-base, and may allow infiltration to the underlying soil. Porous pavements can also be provided with an underground tank in appropriate locations to collect filtered stormwater, which can then be used for other purposes.

A number of porous (or pervious) pavement products are available and usually consists of monolithic material (i.e. a single continuous porous medium), or individual paving blocks. These are available as commercial products including:

- Pavements made from special asphalts or concrete containing minimal fine materials
- Concrete grid pavements
- Concrete, ceramic or plastic modular pavements

Porous (or pervious) pavement can be utilised to promote a variety of water management objectives, including:

- Reduced (or even zero) peak stormwater discharges from paved areas;
- Increased groundwater recharge;
- Ability to store stormwater;
- Improved stormwater quality; and

- Reduced area of land dedicated solely for stormwater management.

The treatment zone for porous pavement systems can either be underneath the drainage layer, or adjacent to it. Care needs to be taken in setting up the bioretention node to represent the treatment zone only, not the drainage layer, as this is usually established as coarse material with little or no treatment capacity.

Key points – Permeable paving

- Permeable paving should be modelled using the bioretention node with the "Unvegetated" option selected in the Vegetation Properties field.
- The opening area in the permeable paving (not the total surface area) should be input as the filter area. This should be estimated from the product specifications.
- The catchment draining to the permeable paving should be separated into 2 or more nodes. One node should represent the surface flow to the paving and the other the direct rainfall on the paving. For the source node representing the actual area of the pavement, adopt 100% impervious and proportion the rainfall threshold based upon the ratio of paved areas/ (paved area + opening area) (refer to **Table 3-6**).
- The saturated hydraulic conductivity should be determined to be representative of 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 reduction in permeability during the pavement lifecycle. If the permeable paving is slightly depressed, allow for this by including a small extended detention depth.
- The filter depth should represent the total depth of the basecourse (and sub-base course if applicable).
- It will generally be preferable to drain the filtered runoff away from the pavement subgrade. For this situation assume that the depth below underdrain is 0% and that the seepage loss is zero.

3.8.2.3 Vegetated Swales

Vegetated swales are typically trapezoidal shaped open channels provided to convey stormwater runoff and filter this runoff through vegetation to assist in the removal of coarse sediment and TSS. The performance of these measures in MUSIC is largely dependent on the vegetation density and height, and the gradient/length of the swale.

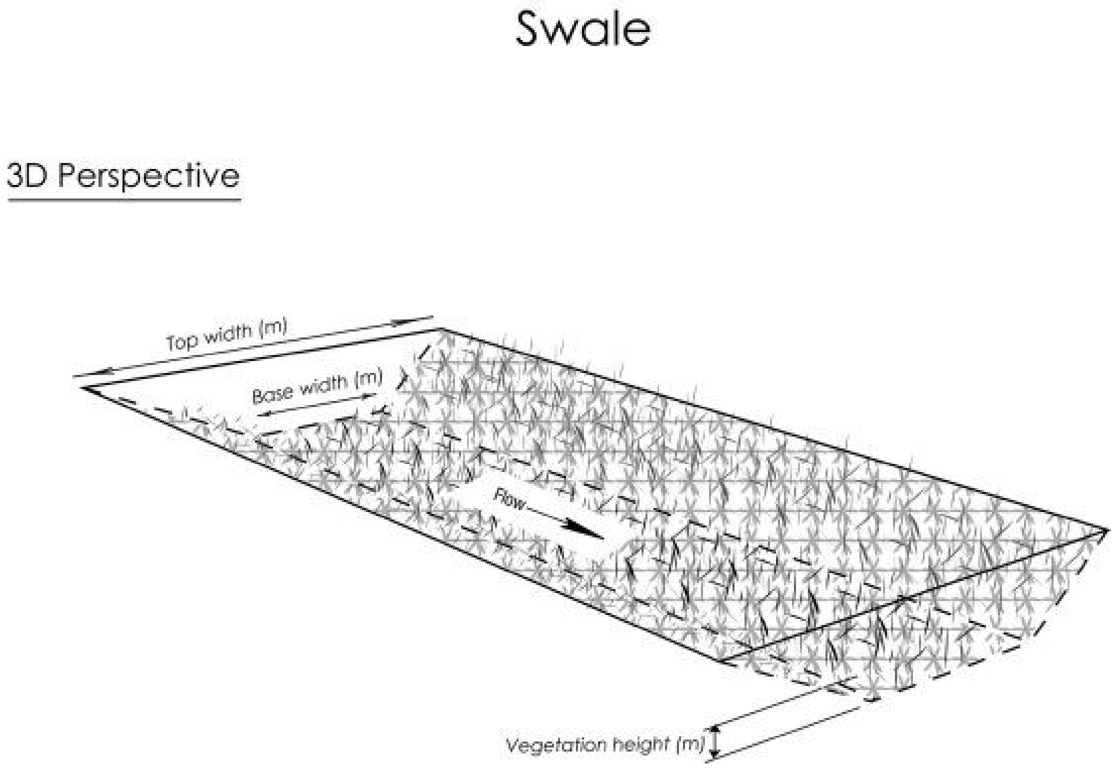


Figure 3-31 Conceptual Diagram of Swale (as used in MUSIC v4)

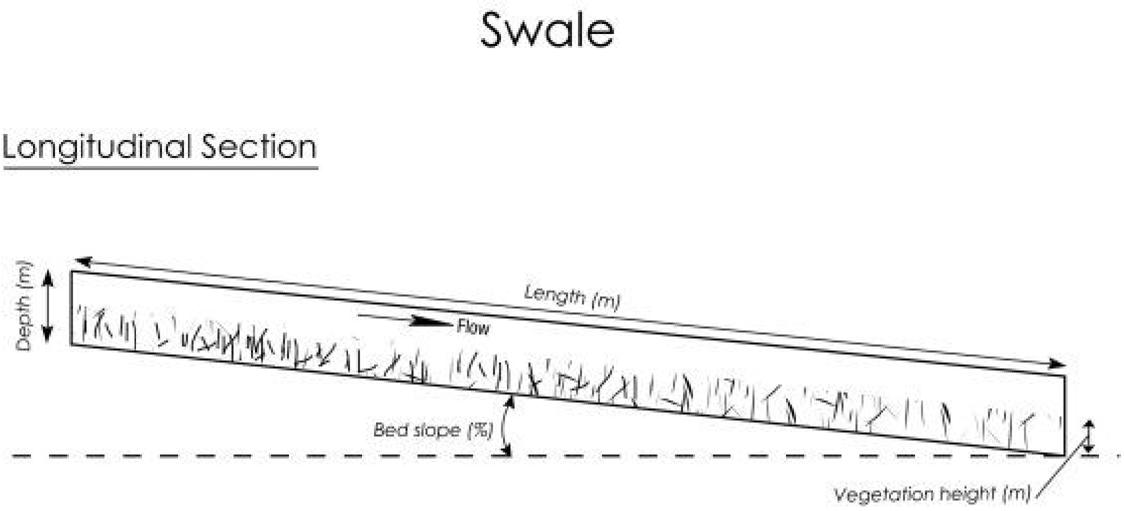


Figure 3-32 Conceptual Cross Section of Swale (as used in MUSIC v4)

The swale length should be selected 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 the swale, it can be modelled as several sections representing the individual lot flows into the swale. The configuration of this approach is shown in **Figure 3-33**.

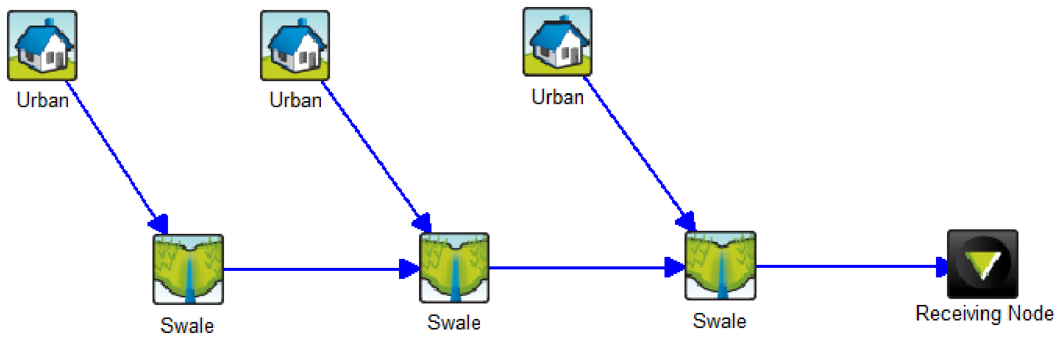


Figure 3-33 Vegetated Swales in Series

Where a swale has lot drainage (or similar) inlets positioned along its length, but each one of these swale lengths has an associated overflow pit, then the above approach is no longer appropriate. The source node catchment area for each swale 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. The configuration of this approach is shown in **Figure 3-34**.

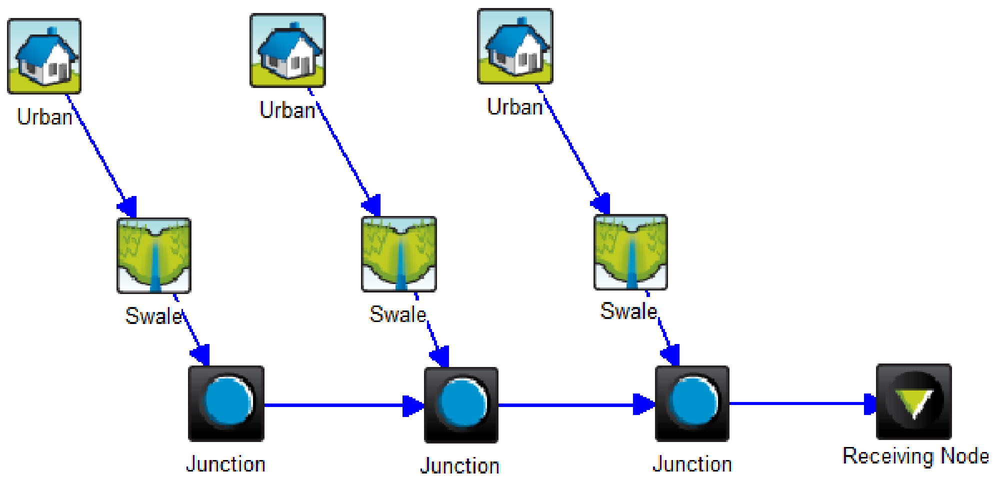


Figure 3-34 Vegetated Swales in Parallel

Key points – Swales

- Table drains with a primary drainage function should not be modelled as grassed swales.
- The local council's engineering standards should be confirmed to define appropriate swale characteristics.
- Ensure that swales are correctly positioned in the treatment train to ensure that modelled concentrations do not increase, as the background concentration (C*) for a swale is relatively high.
- Consider if the swales are best modelled as a series of segments or as parallel measures.
- In most circumstances the low flow bypass should be set to $0m^3/s$. This should only be modified where it is clear that runoff draining to the swale would bypass during low flow events, either by a below ground piped system or similar system.
- An average slope for swales with varying gradients should be estimated using the equal area method. The longitudinal bed slope should be within 1 to 4%. For gradients of 1-2%, swales with sub-soil drainage may be appropriate.
- If the swale is of a non-linear shape (e.g. curved profile), the modeller should select top and base widths that provide an appropriate simplified representation of the swale dimensions.
- Swale depths in the road reserves should typically be within the 0.15m to 0.30m range to achieve suitable side slopes. This range of depths is typically most feasible for measures positioned within the road reserve. Swales with a depth closer to 0.15m should only be modelled for local streets where it can be demonstrated that the swale has sufficient flow capacity to minimize the potential for nuisance flooding to occur. Swale depths closer to 0.30m are preferred wherever possible. Swale depths outside the road reserve (e.g. open space areas) may be deeper where appropriate, although this must be clearly demonstrated as being achievable within the proposal and appropriate safety factors considered.
- Vegetation height should be should consider appropriate available species.
- Seepage loss should be 0mm/hr unless a separate node representing direct rainfall on the measure is created in which case a seepage loss of 0.1mm/hr which is broadly representative of average PET conditions can be adopted. If a site is modelled to generate regular base flow a relatively small seepage rate (<1mm/hr) is all that is required to remove a high proportion of the base flow (and entrained pollutants) discharged into the swale.

3.8.2.4 Sand Filters

Sand filters operate in a similar manner to bioretention systems, with the exception that stormwater passes through a filter media (typically sand) that has no vegetation growing on the surface. Sand filters do not incorporate vegetation because the filter media does not retain sufficient moisture to support plant growth and they are often installed underground, therefore light limits plant growth.

Figure 3-35 Example of Sand Filter Application in MUSIC

Key points – Sand filters

- Sand filters should be modelled using the bioretention node with the Unvegetated option selected in the Vegetation Properties field.
- For all sand filters, the extended detention depth should represent the depth available above the filter media for temporary storage prior to filtration (should be based on the level of the overflow/bypass weir).
- For all sand filters, the overflow weir should be designed to control and discharge the peak design ARI flow relevant to the minor drainage system.
- For all sand filters, the saturated hydraulic conductivity should be based upon the smallest D_{50} of the media layers in the filter. The saturated hydraulic conductivity should be factored by 0.4 for sand filters where access to the filter media for maintenance is limited.
- The modeller should consider the different input considerations for sand filters with below ground and above ground extended detention storages.
- 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 should generally be zero (assuming the sand filter is completely contained within the tank).
- Where the extended detention storage is above ground, the surface area input where the extended detention storage is above ground should be the surface area at approximately 2/3 of the proposed maximum extended detention depth. And the depth below underdrain pipe should not be greater than 50mm.
- Seepage loss should be 0mm/hr for all underground sand filters.

3.8.2.5 Media Filtration Devices

The media filtration node has been set up to account for filtration systems (proprietary and non-proprietary) which operate in such a way that they are not properly represented by other MUSIC treatment nodes outlined in this manual. A typical configuration is shown below.

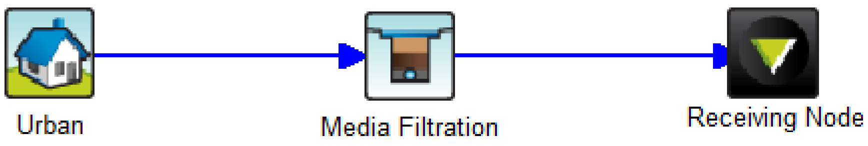


Figure 3-36 Example of a Media Filtration Node in MUSIC

This node requires the user to specify the pollutant removal efficiency and therefore users should express caution in adopting reliable pollutant reduction rates. Similarly, assessment authorities should not accept models using this node unless the applicant has demonstrated that:

- the proposed treatment measure operates in a manner which cannot be represented using one of the other MUSIC treatment nodes
- the proposed reduction efficiencies are justified by rigorous scientific testing and results are published in an credible engineering/scientific journal
- the modelled pollutant reduction efficiency reflect the published figures.

3.8.2.6 Tailout Drains

A tailout drain, (also called a turnout drain or mitre drain), intercepts concentrated flow moving down a culvert or table drain and fans it out into a vegetated area more as sheet flow.

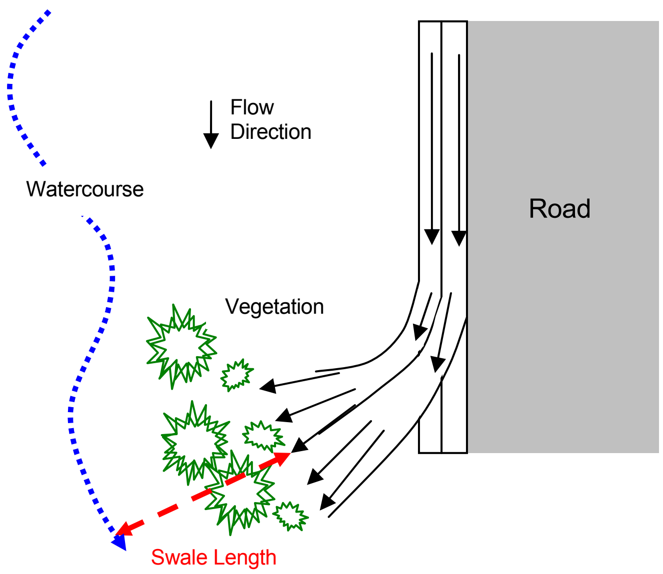


Figure 3-37 Typical Tailout Drain

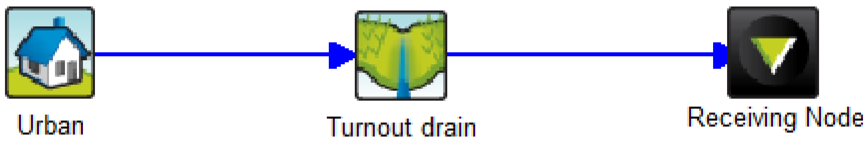


Figure 3-38 Example of Tailout Drain Application in MUSIC

These measures are typically positioned adjacent to a discharge point into the receiving environment.

Key points – Tailout drains

- These measures should be modelled using the swale treatment node, where the distance from the edge of the turnout drain to the nearest watercourse (gully, creek etc) be used as the swale length as shown in the figure above.
- The surface area of the measure should be modelled by reducing the available area by 50% to allow for less treatment during the vegetation establishment phase.

3.8.2.7 Pond

Figure 3-39 Example of Pond Node Application in MUSIC

A pond is essentially a basin with a permanent water storage component. These measures typically have an average depth greater than 1.5m to minimize the growth of emergent plant species and are primarily incorporated into a development configuration for aesthetics. MUSIC adopts a default vegetation coverage of 10% for ponds which essentially represents a predominantly open water pond with fringing vegetation. A pond is represented conceptually in MUSIC identically to sediment basins (refer Figure 3-25).

Key points – Ponds

- It is preferred that the pond treatment node is not used in MUSIC. It is considered that the potential for water quality issues to occur in ponds which have limited vegetation coverage/biological treatment exceeds the benefit of providing these measures. If ponds are modelled in MUSIC the modelled performance should be confirmed utilising a more detailed pond/lake model (e.g. DYRESM-CAEDYM) and the modeller should demonstrate that appropriate pre-treatment measures would be provided to minimise organic and nutrient loading on the pond.
- A GPT and a vegetated treatment node should be incorporated into the model to ensure that water quality entering a pond will minimise potential problems. .
- If the weir overflow or high flow bypass for a pond is to be located near the inlet, the measure should be modelled as a constructed wetland and the C* and k parameters adjusted to the default MUSIC values for a pond. This is because the weir overflow from a pond is assumed to be located at the downstream end of the pond and therefore spills from the pond are assumed to be partially treated (which is not the case for this scenario).
- MUSIC currently assumes that the extended detention storage has vertical sides. Therefore, if the system modelled does not have vertical sides an estimate of surface area needs to be calculated. If the system modelled has a trapezoidal shaped extended detention storage, the surface area should be calculated as the detention depth when it is at 1/2 of the maximum extended detention depth.

3.8.3 Tertiary Treatment Measures

3.8.3.1 Constructed Wetlands

Constructed wetlands are artificial systems that mimic functions of natural wetlands in reducing fine particulates and associated contaminates (including metals, nutrients and toxicants), and soluble contaminants. 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. The diagram below shows how they are conceptually represented within MUSIC.

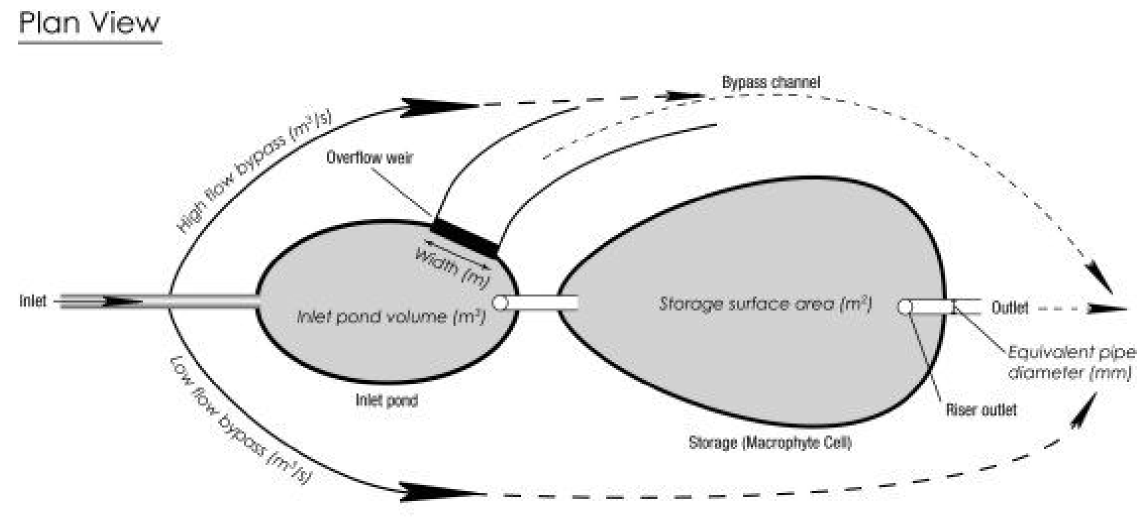


Figure 3-40 Conceptual Plan View of Wetland (as used in MUSIC v4)

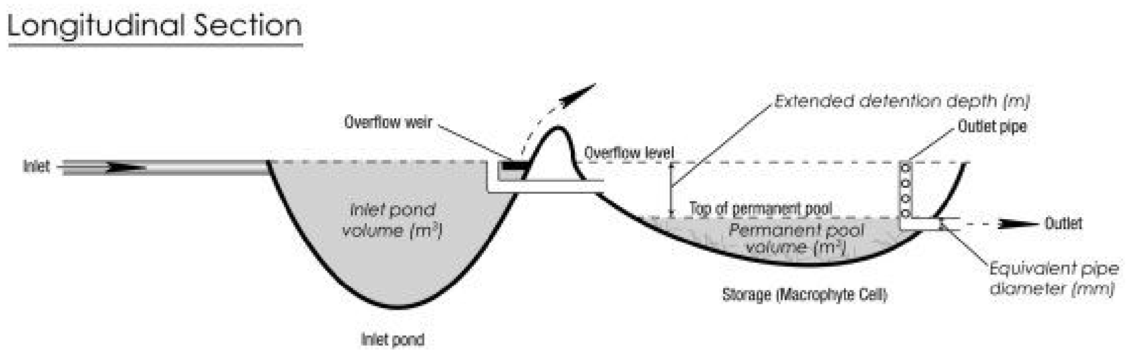


Figure 3-41 Conceptual Cross Section of Wetland (as used in MUSIC v4)

Constructed wetlands have a higher proportion of shallow water zones when compared to ponds, and aquatic vegetation is distributed more widely across the wetland (within ponds vegetation is primarily limited to the fringes of the pond). They also 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 within the inlet pond and operates when the wetland (macrophyte) zone is full.

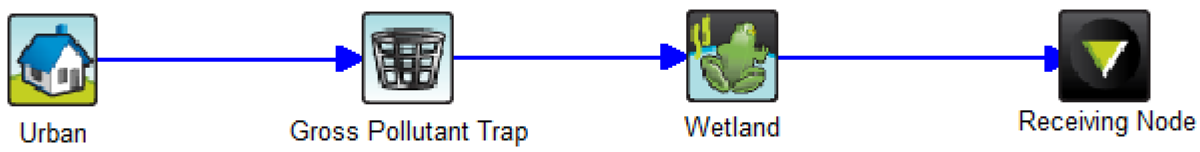


Figure 3-42 Example of Constructed Wetland Node Application in MUSIC

- **Key point – Constructed wetlands**

- The weir overflow from a constructed wetland is located at the inlet. The high flow bypass value can be estimated by adopting 50% of the peak 1 yr ARI flow.
- If the high flow bypass is located at the outlet the measure should be modelled as a pond and k and C* parameters in the pond node adjusted to be equivalent to the corresponding wetland parameters.
- Calculate the surface area of input for this treatment node when the water level is approximately ½ 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 is likely to be almost equivalent to the surface area when the permanent storage is full.
- In situations where a GPT is not provided for pre-treatment, a constructed wetland should be modelled with an inlet pond with a volume not less than 10% of the permanent pool volume.
- A fixed default 50% coverage of vegetation applies to the constructed wetland node. If less vegetation is proposed, the constructed wetland node k and C* values should be modified to the pond node values to represent a lower level of treatment.
- Extended detention should typically not exceed 0.50m unless it can be demonstrated that a higher depth is achievable without flooding impacts.
- The permanent pool in the constructed volume should not exceed the surface area (at permanent pool level) multiplied by 1m unless more detailed information is provided of the wetland configuration.
- The seepage loss should be 0mm/hr unless 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.
- The evaporative loss should be the default value of 125% of PET.
- The notional detention time should typically be between 48 to 72 hours to ensure optimal treatment of nutrient species. The value can be set by adjusting the equivalent pipe diameter, as this is simply a way of controlling the nominal outlet size.

3.8.3.2 Bioretention Systems

Bioretention systems include bioretention swales, raingardens and bioretention basins. Raingardens are typically small basins distributed within lots, the road reserve or open space areas to capture and treat flow at a specific location. Bioretention basins are typically large basins provided in large open space areas to manage stormwater quality at the sub-catchment scale. Bioretention swales are typically provided within medians or footpaths within the road reserve and these may also provide a minor flow conveyance function.

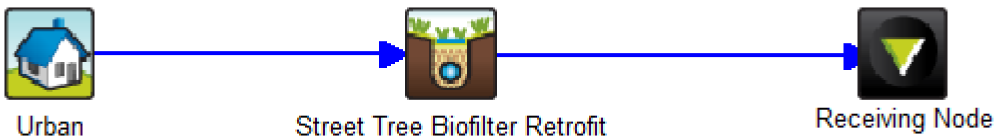


Figure 3-43 Example of Bioretention Node Application in MUSIC

These measures can be represented as one node in MUSIC as shown in the following diagrams.

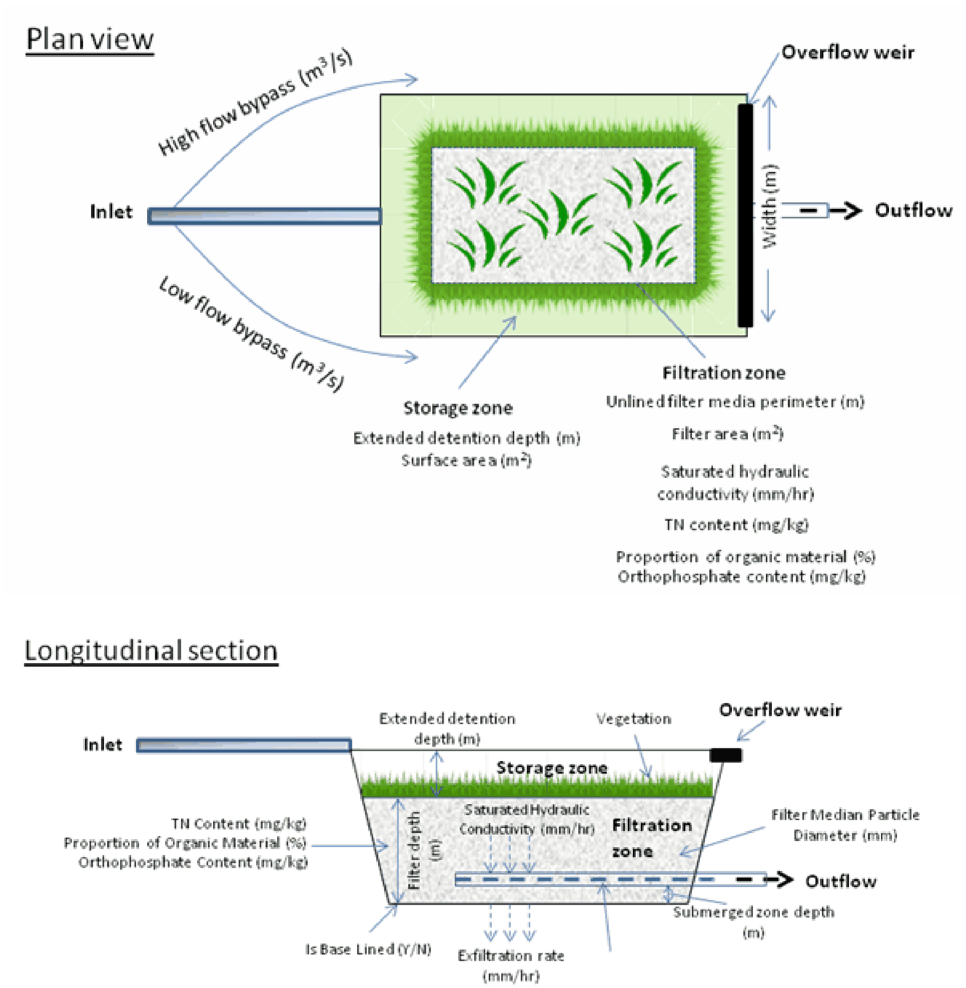


Figure 3-44 Conceptual View of Bioretention System (as used in MUSIC v4)

MUSIC Version 4 includes significant revisions to the bioretention node to reflect the recent studies undertaken by the Facility for Advancing Water Biofiltration (FAWB). This has also resulted in significant changes to the parameters needed to model these systems in MUSIC. The key parameters which have changed are related to the filter media properties and any exfiltration. These parameters are summarised below.

Filter area (m2): The filter area is scenario-dependant and is set as the area of the bioretention filter media.

Unlined filter media perimeter (m): The parameters for an unlined filter media perimeter are scenario-dependent. If an exfiltration rate of 0 mm/hr is used, set the unlined perimeter to zero. If the unlined perimeter is unknown, a useful rule-of-thumb 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. For sensitivity testing, simulate the bioretention system in MUSIC using a hydraulic conductivity of 50 mm/hr. **The final bioretention size should be based on the larger area of the two simulations**.

Filter depth (m2): The recommended bioretention filter depth is 0.4–1.0 m. The depth depends on the available depth based on the inlet and outlet levels and the species of plants being used. For particularly flat sites where streetscape bioretention pods are used the filter depth can be limited to 0.3m. Any filter media depth greater than 0.8m will require the planting of deep-rooted plants. If a filter media depth greater than 0.8 m is proposed expert advice from a landscape architect or ecologist is required at the conceptual design stage with adequate justification for plant selection lodged with development applications.

Do not model the depth of the drainage layer or intermediate layer as part of the filter media depth.

TN content in the filter media (mg/kg): Where this is unknown, use the default value of <800 mg/kg. The TN content is the amount of nitrogen available within the filter media consistent with the Facility for Advancing Water Biofiltration's (FAWB) current Guidelines for Soil Filter Media in Bioretention Systems (— Version 2.01 March 2008 or later).

Proportion of organic matter in the filter media (%): Where this is unknown, use a value of <5%. While some organic matter in filter media is desirable, excessive amounts can cause leaching of nutrients.

Orthophosphate content of filter media (mg/kg): Where this is unknown, use a value of range <55 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 — Version 2.01 (Facility for Advancing Water Biofiltration, 2008).

Other properties

Lining properties: Is the base of the bioretention system lined?: When demonstrating compliance with water quality objectives, it is necessary to tick "Yes" to indicate that the base is lined and then set the exfiltration rate (mm/hr) to zero.

Vegetation properties: Plant types have a significant impact on reducing nutrient loads with root morphology and associated physiochemical processes being key factors (Reed et. al. 2008). Bioretention systems perform best with deep-rooting plants and these are to be modelled using the option 'Vegetated with Effective Nutrient Removal Plants'. Where the vegetation in the bioretention system is turf for example, then the 'Vegetated with Ineffective Nutrient Removal Plants' option must be used.

Infiltration and outlet properties

- ***Overflow weir width (m):*** The length of the overflow weir controls the discharge rate when the water level in the bioretention system exceeds the top of extended detention. An undersized overflow weir results in water backing up, effectively adding additional extended detention. To avoid this, it is recommended that, as a starting point, the overflow weir length (m) is set as the surface area (m2) divided by 10 m.
- ***Exfiltration rate (mm/hr):*** If a bioretention system is modelled with exfiltration, the pollutant loads in the water 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). Objectives for reducing stormwater pollutants relate to all runoff leaving the site, including that exfiltrating to groundwater. Where an exfiltration rate is set greater than 0 mm/hr, sum all losses at any node that has exfiltration (using the node water balance statistics option at each node) as per the guidance provided in the Infiltration Node section, and add them to the total pollutant loads reported leaving the site when demonstrating compliance with stormwater pollutant load reduction objectives.

  If exfiltration is used the rate must be justified through in-situ soil testing. The applicant must suitably demonstrate that in-situ soils will not be compacted during earthworks.

  When a system is designed and modelled to exfiltrate, lining is still required to the sides of the bioretention filter media to ensure that that stormwater is properly treated through the filter before it enters the receiving environment i.e. exfiltration should only occur either at the level of the drainage layer or through the base of the bioretention.

Underdrain present?: Usually the 'Yes' option as Bioretention systems in are generally configured with collection pipes. If not, then the infiltration node should be used to model the system.

Submerged zone with carbon present (depth (m))?: To improve the potential for denitrification in bioretention systems, and to provide a moisture storage for the plants, where practicable include a zone below the underdrain.

Key points – Bioretention measures

- The high flow bypass value can be estimated by adopting 50% of the 1yr ARI peak flow. Extended detention for measures within lots or road reserve should be between 0.15 and 0.30m. This range of depths is typically most feasible for measures positioned within the road reserve. Bioretention with a depth closer to 0.15m should only be modelled for local streets where it can be demonstrated that the measure has sufficient flow capacity to minimize the potential for nuisance flooding to occur. Depths closer to 0.30m are preferred wherever possible.
- The extended detention depth for areas outside lots and road reserves (e.g. open space areas) may be deeper than 0.30m, although this must be clearly demonstrated as being achievable and the vegetation selected suitable for inundation at greater depths for prolonged periods.
- For a raingarden or bioretention basin, the longitudinal gradient is likely to be close to 0% across the measure, whilst a bioretention swale may have a gradient typically up to 2% and consequently 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 <4% is achievable.
- MUSIC currently assumes that the extended detention storage has vertical sides. Therefore, if the system modelled does not have vertical sides an estimate of surface area needs to be calculated. If the system modelled has a trapezoidal shaped extended detention storage, the surface area should be calculated as the detention depth when it is at 1/2 of the maximum extended detention depth.The filter area should not be greater than 70% of the surface area unless specific calculations are provided to indicate otherwise.
- It should be demonstrated that the base of the bioretention system will be located within soil and not recessed into rock. The base of the bioretention measure should also be located 0.5m minimum above the seasonal high groundwater table to ensure that the media is not frequently saturated by groundwater.
- For systems where the filtered flow is to be collected in a sub-soil drain near the base of the bioretention filter and directed to a constructed drainage system, the modeller should confirm that the sub-soil drain is not below the base of the stormwater pit that the subsoil drain would connect into. Determine an appropriate soil media considering the Facility for Advancing Water Biofiltration (FAWB) "Stormwater Biofiltration Systems Adoption Guideline".

3.8.4 Lifecycle Cost Analysis

The proponent should submit the overall life cycle costs for all elements in the treatment train and split these into Total Acquisition, Typical Annual Maintenance and Renewal/Adaptation Costs. In the majority of cases, a decommissioning cost should not be included and this should be set to the same value as the Typical Annual Maintenance cost.

Life cycle costing information in MUSIC is able to be extracted when setting up the life cycle costing properties at each node. To extract this information, the MUSIC model must have been run and individual node costing elements established. Once this is completed, the user needs to select the Results button on the life cycle costing entry dialog as shown below.

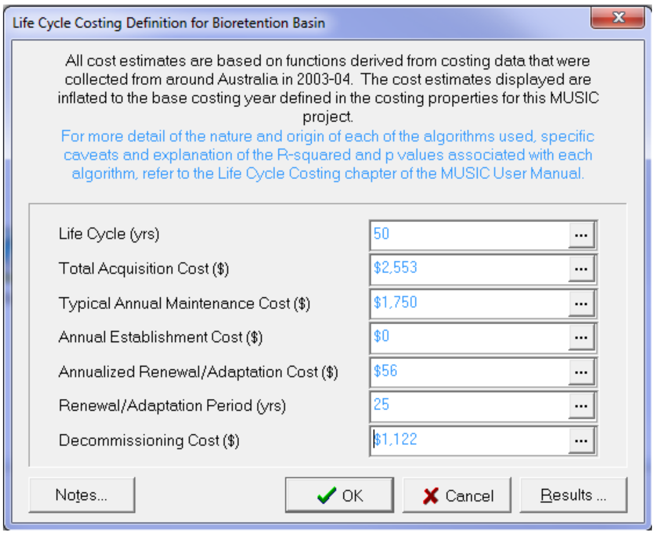


Figure 3-45 Life Cycle Costing Entry Dialog

While some of the individual costing elements are shown in this entry dialog, the results screen summarises these and also accounts for any renewal adaption period to present total costs for this element.

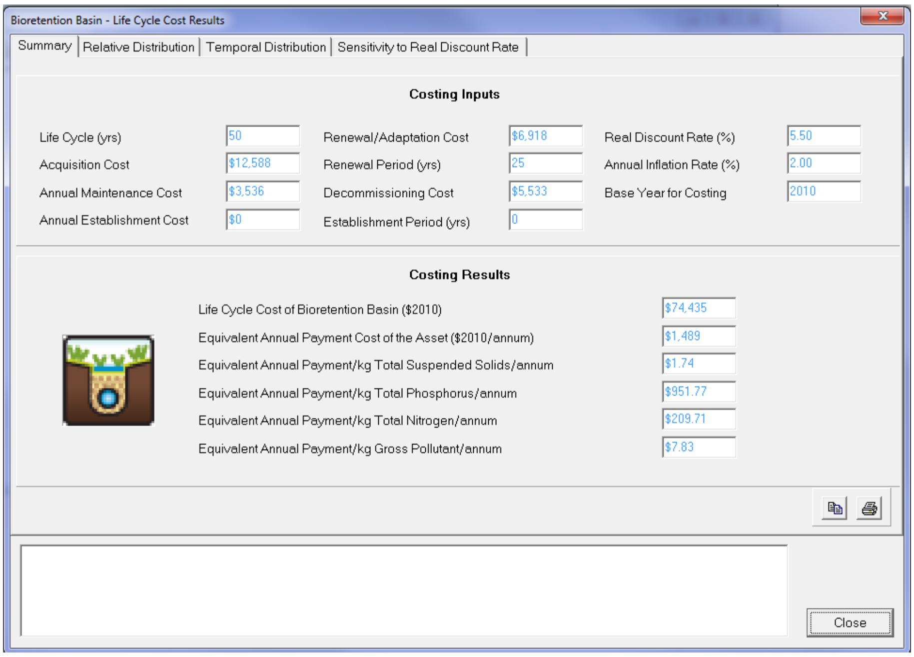


Figure 3-46 Final Costing Results (single node)

The user should treat the current life cycle costs as indicative only as the data used to develop the algorithms for this module are dated. MUSIC automatically adjusts the costs according the Base

Year for Costing (set in the Edit-> Costing Properties Dialogue). While these costs are indicative, they can be of assistance to local authorities in planning maintenance resources and expenditure for future contributed assets.

3.9 Calculation of Stream Erosion Index - adapted from Blackham, D. And Wettenhall, G. (2010)

3.9.1 How to estimate the stream erosion index for a development

Water Sensitive Urban Design (WSUD) strategies are typically modelled using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) developed by the Cooperative Research Centre for Catchment Hydrology (now eWater). MUSIC can be used to estimate the SEI for a development's stormwater management strategy to determine compliance with the SEI objective.

There are four steps in estimating SEI:

1. Estimate the critical flow for the receiving waterway above which mobilisation of bed material or shear erosion of bank material commences

2. Develop and run a calibrated MUSIC model of the area of interest for pre-development conditions

(i.e. current conditions) to estimate the mean annual runoff volume above the critical flow

3. Develop and run a MUSIC model for the developed scenario to estimate the mean annual runoff volume above the critical flow

4. Use the outputs from steps 3 and 4 to calculate SEI for the proposed scenario

These steps are described below.

3.9.2 Estimating the critical flow for the receiving waterway

The critical flow for a waterway is defined as the flow threshold below which no erosion is expected to occurwithin the waterway. This has been estimated (EarthTech, 2005) as a percentage of the

pre-development two year ARI peak flow at the location in question. The percentage varies from

10% to 50% depending on substrate in the waterway at that point.

The peak flow from the two year ARI storm event corresponding for pre-developed conditions should be estimated using either:

• Flood frequency analysis (where a sufficiently long period of local gauged flow data is available)

• The probabilistic rational method as described in Australian Rainfall and Runoff[1].

The pre-development two year ARI peak discharge should be estimated using the most appropriate of these methods and converted into a critical flow by applying the relevant percentage for the location in question.

3.9.3 Estimating mean annual flow for pre-development and post-development conditions

MUSIC should be used to estimate the mean annual runoff above the critical flow for both the predevelopment and post-development conditions. A six minute time step must be adopted for modelling SEI. The routing option MUSIC should be used to simulate the effect of catchment storage and lag time on peak flows generated as noted in the previous sections.

The data required for estimating SEI can be directly extracted from MUSIC by interrogating a generic node that is added to the treatment train immediately before flow from the development is discharged to the receiving waterway. The generic node in MUSIC provides a flow transfer function which can be simply defined to easily calculate the annual volume of flow above the critical flow. The generic node should be set up to convert all inflows at or below the critical flow to zero outflows. Flows above

[1] Pilgrim, D.H. (2001), Estimation of peak flows for small to medium sized rural catchments, Book 4, Section 1 in Pilgrim (ed.), Australian Rainfall and Runoff, ISBN 0 85825 744 0, Engineers Australia, 2001.

the critical flow will be passed through the node at the magnitude by which flow exceeds the critical flow, as described below:

$$Q_{out} = 0 \quad \text{if} \quad Q_{in} < Q_2 . x\%$$

$$Q_{out} = Q_{in} - \frac{Q_2}{x\%} \text{if} \quad Q_{in} = Q_{in} > Q_2 . x\%$$

Where x% is the percentage of the two year ARI peak flow that equates to critical flow in that location.

3.9.4 Pre-development modelling

Developing a realistic MUSIC model of pre-development conditions is important to ensure an accurate SEI is calculated for, as the pre-development scenario provides the base case. The following steps should be undertaken in developing the pre-development model.

In setting up the pre-development model, it is important to ensure the rainfall runoff relationship is as accurate as possible. Calibration of the pre-development MUSIC model using the following methods is recommended (listed in descending order of confidence):

a. Use recorded flow data from a gauging station on the stream in question if available

b. Use recorded flow from a gauging station on a nearby stream with similar catchment area, geology, network topological and land use

c. Use the parameters within this guideline

3.9.5 Post-development modelling

MUSIC modelling of the post-development conditions should accurately reflect the proposed development layout, density and other characteristics (which should have been undertaken for stormwater quality modelling).

Recommended pervious area parameters for post-development conditions should be consistent with those set for the predevelopment conditions. While the post-development soils may differ in hydrologic response due to replacement of topsoil, compaction, different vegetation, etc, retaining the same pervious area parameters will ensure consistency of the modelling. Further guidance may be available in future editions of this document regarding these parameters.

3.9.6 Calculating SEI

The generic nodes at the downstream end of the MUSIC models for pre-development and post-development conditions should be interrogated by:

1. Right clicking the generic node
2. Clicking on 'Statistics' then 'mean annual load'
3. Copying the flow ***output*** value

The SEI is calculated as the ratio of the output mean annual flow from the generic node for the post-developed model and the corresponding value for the pre-development model, as described in the main report:

$$SEI = \frac{\sum(Q_{post} - \mathrm{Q}_2.x\%)}{\sum(Q_{pre} - \mathrm{Q}_2.x\%)}$$

The SEI can be calculated for a range of flow management strategies or options in the post-development scenario and an optimal solution sought that meets the SEI objective.

3.10 Assessment of MUSIC Outputs

3.10.1 Water Quality

3.10.1.1 Objectives

For locations in NSW where load based targets have been established to assess the performance of water quality management measures, the modeller simply needs to establish the Treatment Train Effectiveness from the MUSIC model at the receiving node. Where concentration based targets are required to be achieved, the modeller should ensure that zero flows have been removed from the analysis. To accomplish this, the "flow based subsample threshold" within the assessment options (i.e when right clicking on a node in the model) should be used. The selection of this parameter can significantly affect the concentration results reported, however for consistency, the modeller should set the low flow threshold to 0 such that any results when no outflows are occurring are removed. The statistical analysis (mean, median, 10^{th} and 90^{th} percentiles) will then represent only those times when outflows are occurring.

3.10.1.2 Uncertainty

While no quantitative effort has yet been published on the uncertainty of models using MUSIC, usually as the uncertainty, variations and assumptions associated with the representation of a stormwater treatment strategy in MUSIC are significant, compared to that which is finally delivered on the ground. This means that a calculation of numerical uncertainty would have little value in expressing the true uncertainty of the ability of the model to represent that which is to finally occur. In presenting an assessment of the accuracy of the model if it did exactly represent the final adopted strategy, a value of 10% uncertainty in the model outputs was suggested as being reasonable when preparing Stormwater treatment curves used in Fletcher et al 2004.

3.10.2 Hydrology

3.10.2.1 Wetland Hydrology

The ability to assess compliance with hydrological objectives within MUSIC is limited. Recent studies in the Hunter and Central Coast Regions of NSW (HCCREMS 2007) have identified wetland types and their associated hydrologic management objectives. While reasonably specific to that region, these objectives can provide an indication of the water requirements of similar wetlands in the NSW coastal region and have therefore been included as a useful reference (see **Table 3-16**). Generally, this will require the following objectives to be achieved:

- Preserve the pre-development 30 day low flow duration frequency curve for the dry season (October to January).
- Preserve the low flow spells frequency curve for the dry season.
- Preserve the pre-development 30 day high flow duration frequency curve for all months.
- Maximise collection and reuse of stormwater in line with the above objectives.

For wetlands to be protected by 7 day flooding hydrology targets:

- Preserve the pre-development 7 day high flow duration frequency curve for all months.

Further guidance on this is provided in the assessment of hydrologic objectives (HCCREMS 2007 and the modeller is referred to those documents on developing suitable strategies and modelling them within MUSIC where wetland hydrologic objectives are to be achieved.

Where MUSIC is to be used to quantify hydrologic performance of management measures, a post-processing tool is used to generate flow duration curves and spells analyses. Within the Wyong Shire Council region, a tool has been developed and can be obtained from Council to assist in this purpose.

Table 3-16 Wetland Hydrologic Management Objectives

Wetland Category	Flooding Hydrology	Drying Hydrology		Reference Duration and Annual Exceedence Probability
	High Flow Duration Frequency Curve	Low Flow Duration Frequency Curve	Low Flow Spell Frequency	
1. Coastal Flats	✓			7 days – all AEPs
2. Inland Flats	✓	Isolate wetland from upstream catchment		7 days – all AEPs
3. Bogs	✓	✓	✓	7 days – all AEPs
4. Deep Marsh		✓	✓	30 days – events <50% AEPs
5. Fen	✓	✓	✓	30-60 days – events > 50% AEPs
6. Shallow Marsh		✓	✓	30 to 60 days – all AEPs
7. Salt Marsh	✓	✓	✓	7 days – all AEPs
8. Seagrass Beds	✓			7 days – all AEPs
9. Deep Salt Pans	✓	✓	✓	30-60 days – events > 50% AEPs
10. Deep Open Water	No hydrologic management objectives required			
11. Shallow Open Water		✓	✓	30 to 60 days – all AEPs
12. Wet Heath		✓	✓	30 to 60 days – all AEPs
13. Mangrove	✓			7 days – all AEPs
14. Scrub Swamp	✓	✓*	✓*	30 to 60 days – all AEPs
15. Forest Swamp - Wet		✓	✓	30-60 days – events <50% AEPs
16. Forest Swamp - Ephemeral		✓	✓	30 to 60 days – all AEPs
17. Forest Swamp - Dry	✓	✓*	✓*	30 to 60 days – all AEPs

Examples of the hydrologic curves showing minimum and maxium 30 day flow duration curves vs AEPs required to assess wetland hydrology objectives are shown below.

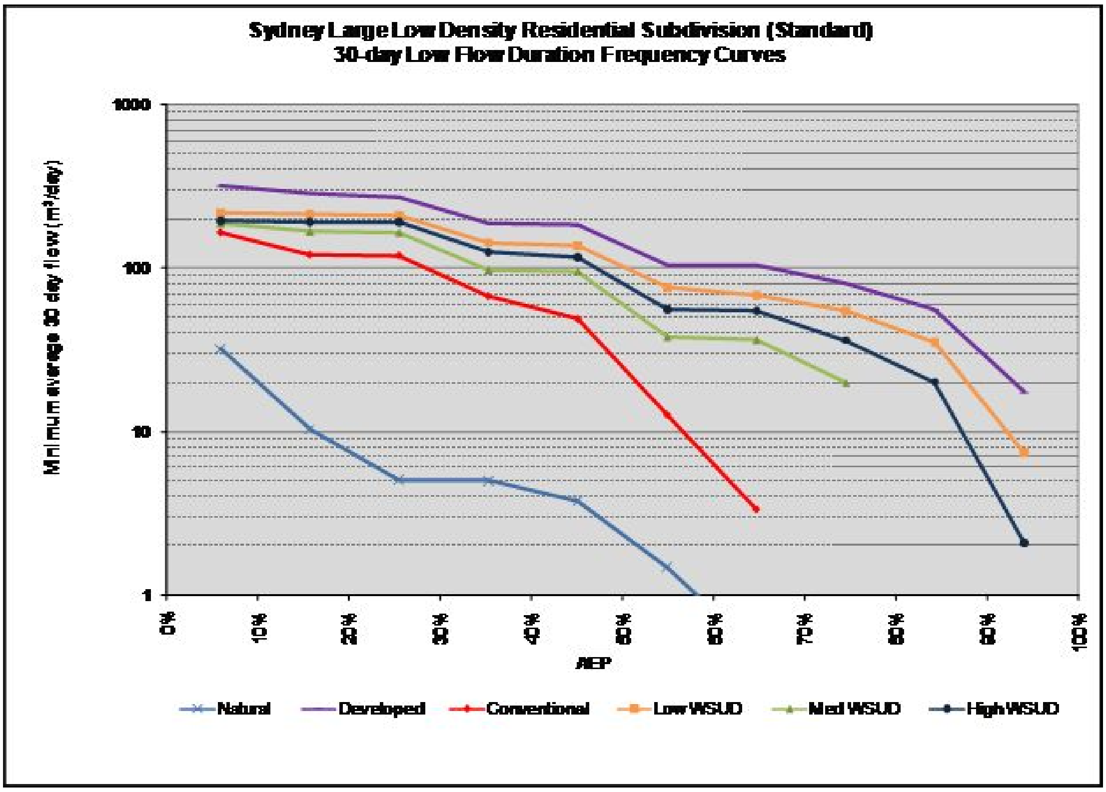


Figure 3-47 Minimum Average 30 day Flow vs Annual Exceedence Probabality for Sydney

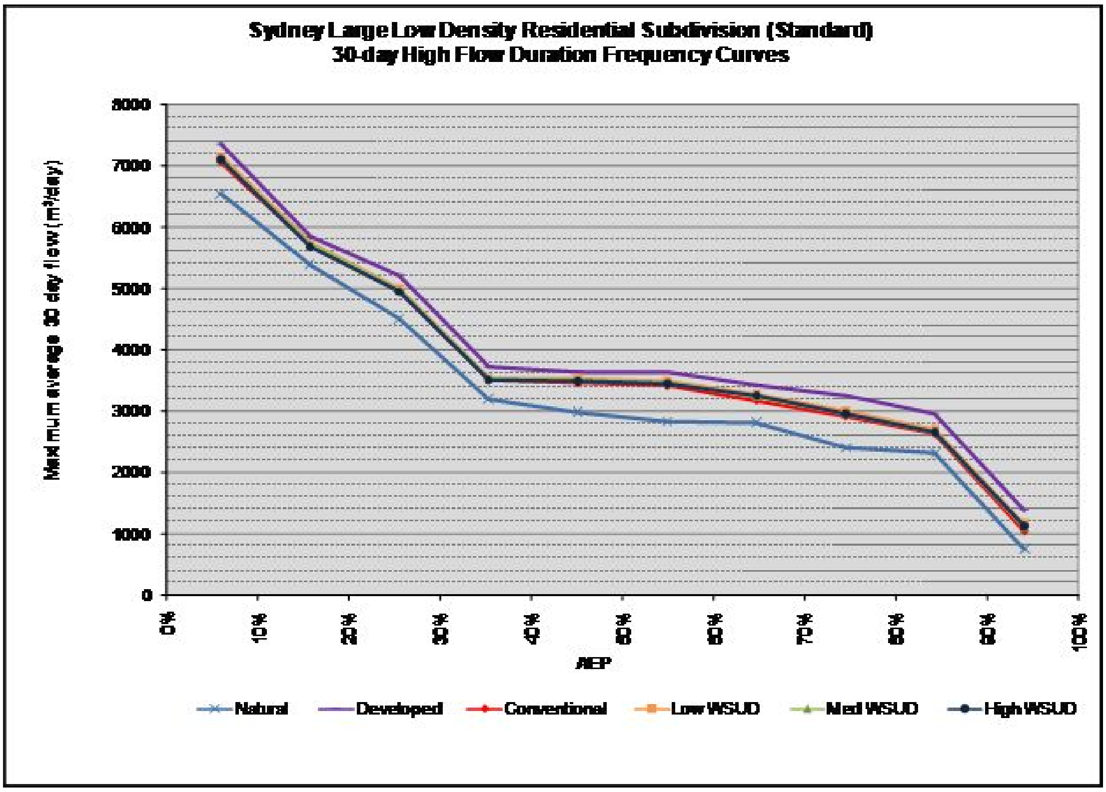


Figure 3-48 Maximum Average 30 day Flow vs Annual Exceedence Probability for Sydney

3.11 Submission Information Requirements

In order to provide a degree of confidence that the proposed MUSIC modelling suitably reflects that which is to be implemented as part of development, the modeller is required to prepare a report outlining the modelling undertaken and providing justification for any assumptions made. When preparing a report, the following notes should be considered/checked prior to submission:

(a) The representation of the site in MUSIC is reasonable for both the pre-development and post-development situations. This must be supported by site plans that show:

  (i) How existing drainage on the site is managed (i.e. where the water flows) including existing contours or topography;

  (ii) How future drainage is to be configured, including final site topography as a result of any site regrading;

  (iii) Defined subcatchments for both existing and future situations;

  (iv) The location of proposed treatment measures as modelled in MUSIC; and

  (v) Where discharges off site are to occur (i.e. where compliance with water quality targets are to be achieved.).

(b) The total catchment area modelled is equivalent for the existing and future conditions.

(c) The stormwater management measures are appropriate for the specific site / development scale and are sufficient to achieve the stormwater objectives and targets.

(d) The source nodes selected are appropriate for the land uses being simulated.

(e) The proposed treatment measures can be practically implemented within the development and maximise the area of impervious surface receiving treatment. The proponent should demonstrate that there is adequate room for their implementation, they are appropriately placed within the development (e.g. water will flow into them as intended) and they will not adversely impact upon the operation of the site or on the ability to maintain them.

(f) The proposed treatment measures are hydraulically sound in 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 (e.g. if a wetland node is being applied to simulate the removal of nutrients and MUSIC calculates the detention time to be 72 hours, the proponent should demonstrate using hydraulic calculations that this is feasible for the configuration proposed).

(g) The MUSIC modelling conducted is consistent with these guidelines in terms of climate data, source node parameters (e.g. % imperviousness for particular land uses) and treatment measure configuration. Where deviations are made, justification should be provided as to why these yield a better predictive output than using the guideline approach.

(h) The proposed treatment measures will have a sufficient life span and will not present an inordinate maintenance burden to those responsible for on-going management.

(i) A statement confirming that the proposed stormwater management strategy achieves compliance with the stormwater objectives and targets relevant to the site.

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