Mackay Regional Council MUSIC Guidelines

Version 1.1 (September 2008)

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1 Introduction

Ensuring that stormwater runoff is managed to protect the environment and the community is a key priority for Mackay Regional Council (MRC). The *Stormwater Quality Management Plan for Mackay* (MRC) provides the framework for this by defining the key stormwater protection issues for the Mackay region and establishing stormwater treatment objectives for the region.

It is Council's position that all development, as defined in *Engineering Design Guidelines: Soil and Water Quality Management* (MRC), must achieve the stormwater treatment objectives. Developments that are considered "high risk" are to demonstrate the achievement of the objectives through the use of the MUSIC (Model for Urban Stormwater Improvement Conceptualisation) software. If the Applicant has any doubt regarding the level of stormwater quality modelling required, a pre-lodgement meeting should be held with Council's development assessment officers.

MUSIC is a tool that allows the simulation of both quantity and quality of runoff from different landuses and the effect of a range of treatment elements on the quantity and quality of runoff downstream

These Guidelines are provided to support the use of the MUSIC model in Mackay and ensure consultants, developers and Council have a consistent and uniform approach to stormwater quality modelling. Unless otherwise agreed with Council, all MUSIC models submitted to Council with Development Applications must be consistent with these guidelines.

1.1 Purpose of these guidelines

Council has developed these guidelines to:

- ensure consistency in the application and approval process for stormwater management in developments in the Mackay region
- provide advice on using MUSIC in the Mackay region
- provide guidance on parameters to be used when using MUSIC to assess compliance with Mackay Regional Council's stormwater management objectives

It is assumed that users of these guidelines will be familiar with using the MUSIC software. These guidelines should be read in conjunction with the MUSIC User Guide (MUSIC Development Team, 2005), which outlines all the definitions, assumptions and methodologies provided within the MUSIC package.

1.2 Structure of these guidelines

Section 1 provides an overview of Mackay's climatic and catchment conditions and an introduction to the MUSIC software.

Section 2 provides references to the most recent stormwater management objectives for the Mackay region and provides guidance on which of these can be assessed using the MUSIC software.

Section 3 describes a "pre-approved" modelling approach that can be used to develop a site based management plan without the need for justification. Section 3 also contains an outline of features of the software and advice for developing models that generate meaningful results.

The "pre-approved" parameters and approaches are highlighted in grey shaded boxes to differentiate them from the general modelling advice.

MUSIC templates with "pre-approved" meteorological and catchment parameters can be provided by Council or downloaded from the Council website.

1.3 Overview of MUSIC software

MUSIC is a conceptual design tool that can be used to predict catchment runoff, pollutant export and the performance of stormwater management systems. The software adopts continuous simulation using historical climate records or other user defined climate data across a range of timesteps (6 minutes to 24 hours). For the assessment of stormwater management systems at least 5 years of meteorological data, preferably 10 years, is used at a timestep of 6 minutes.

The magnitude of runoff and the loads of key pollutants are predicted by the model based on user defined rainfall-runoff and pollutant concentration input parameters. The flow of water through various treatment systems (e.g. wetlands and bioretention) and the reduction in pollutant loads are modelled enabling assessments to be made against quantitative stormwater management objectives. MUSIC can simulate the performance of a single treatment node or a group of stormwater management measures configured in series or parallel to form a "treatment train".

MUSIC was developed by the MUSIC Development Team of the CRC for Catchment Hydrology and was first released in May 2002. The software is available for download from www.toolkit.net.au. Users are able to subscribe to the email based "MUSIC e-group" through this website, a forum for discussing the product and its use among users.

1.4 Proposed updates to MUSIC (and this guideline)

At the time of writing this guideline, the current version of the MUSIC software was Version 3.01. eWater are in the process of developing MUSIC Version 4 which is expected to be released in mid 2009. It is anticipated the Mackay Regional Council MUSIC Guideline will be updated immediately following the release of MUSIC Version 4.

Further updates to the guideline will occur on a regular basis (every 1 – 2 years) in response to new research into stormwater quality and stormwater treatment.

2 Overview of local conditions

2.1 Climate

Mackay has a tropical climate, typically with hot wet summers and warm dry winters. The mean annual rainfall for the Mackay township is 1670 mm and the majority of this rain occurs between December to April, as illustrated in Figure 1 which also provides mean monthly potential evapotranspiration (from www.bom.gov.au).

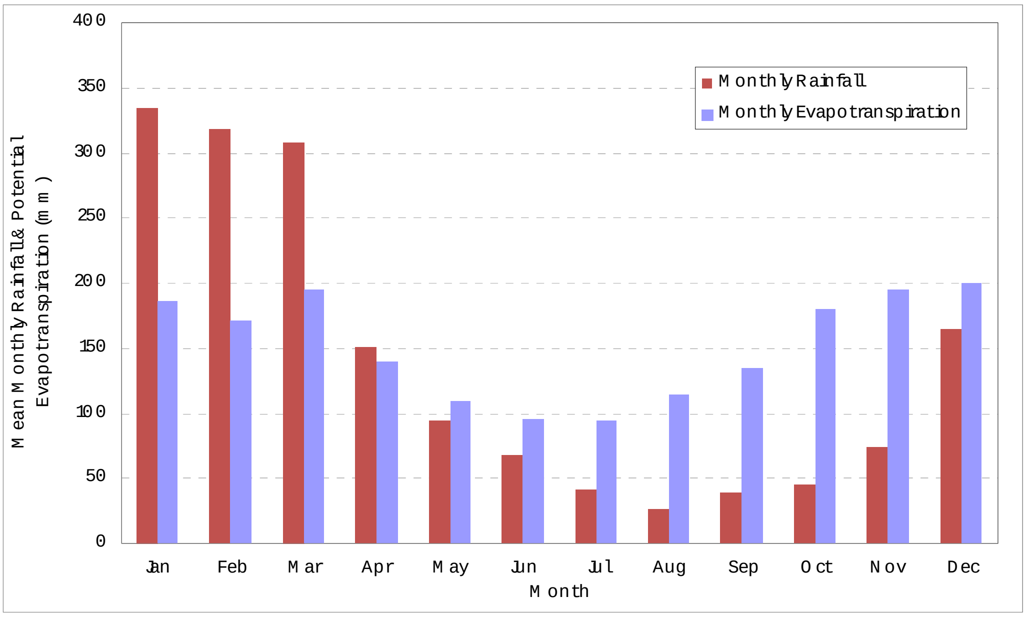


Figure 1 Mackay Post Office mean annual rainfall and evapotranspiration

The mean annual rainfall (MAR) varies across the Mackay Regional Council local government area and is generally highest along the coast and decreases further inland as shown in Figure 2.

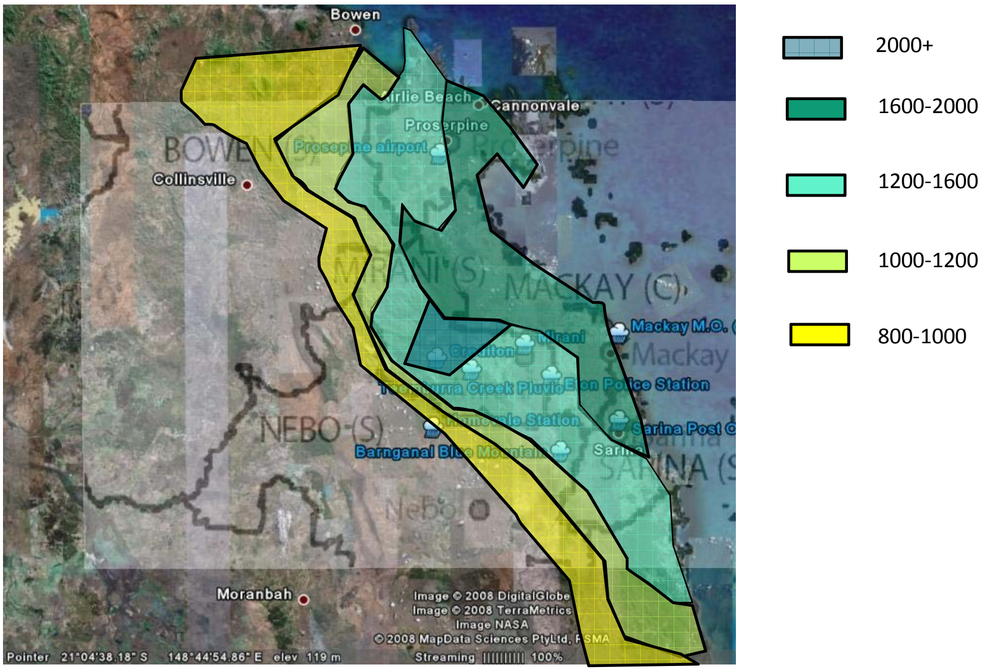


Figure 2 Mean annual rainfall (MAR) across Mackay Regional Council

2.2 Soil types

A map of the range of soil types found in the area surrounding Mackay is shown in Figure 3. A higher resolution of this plan can be downloaded from Councils website. It should be noted that this map does not cover the entire Mackay Regional Council area.

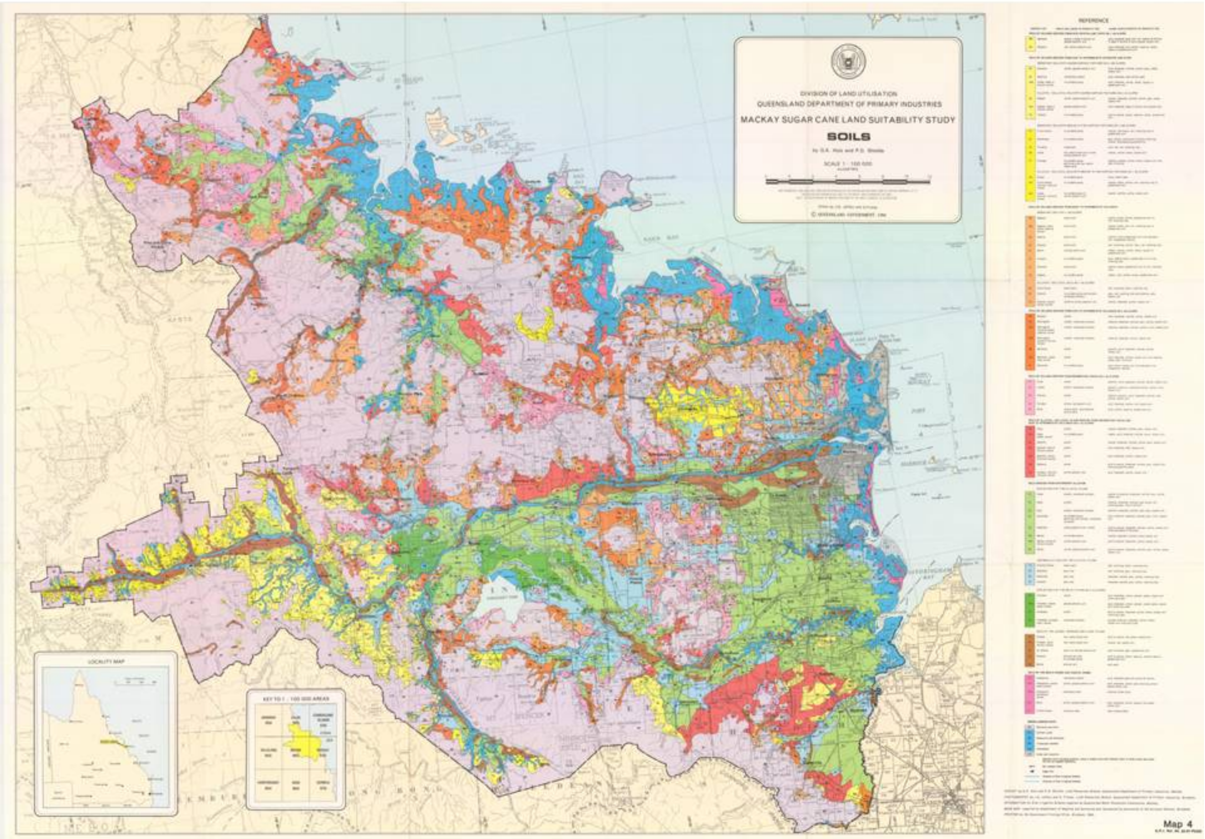


Figure 3 Soil types surrounding Mackay

3 Stormwater management objectives for developments in Mackay

In the Mackay region, MUSIC is to be used for the following:

- Stormwater Quality - assessing stormwater quality objectives based on a mean annual reduction in pollutant loads in stormwater runoff
- Constructed Lakes - providing catchment flows to water balance models for assessing constructed lake drawdown and turnover performance again Council lake objectives.

The use of MUSIC is not to be used for estimating the magnitude of flood events or design storm peak flows or assessing the performance of management options (e.g. retarding basins).

3.1 Stormwater quality

Load based stormwater quality objectives for new development in Mackay are outlined in the *Stormwater Quality Management Plan for Mackay* which can be downloaded from the Council website (www.mackay.qld.gov.au/business/strategic_planning_services).

3.2 Lake management

Lake management objectives and guidance for using MUSIC to assess these objectives in the Mackay region are contained in *Engineering Design Guidelines – Constructed Lakes* (MRC) which can be downloaded from Council's website (www.mackay.qld.gov.au/business/city_planning_scheme/planning_scheme_policies2).

4 Modelling steps

The MUSIC modeling process can be broken down into four steps as shown in Figure 4. This section contains a summary of approved inputs into each of these steps that must be used for development approvals submitted to Council as well a description of the inputs and the use of MUSIC.

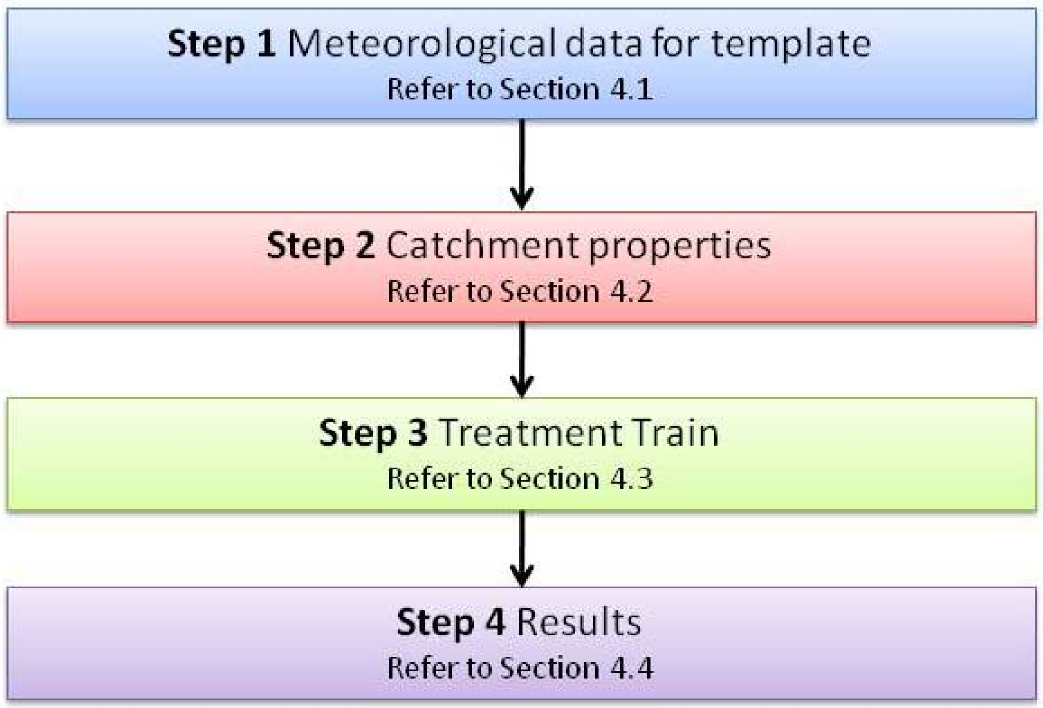


Figure 4 Four steps of MUSIC modelling

4.1 STEP 1: Meteorological data

This box describes the pre-approved meteorological data. Council will consider alternative modelling approaches, however, justification must be provided in the Site based stormwater management plan (SBSMP) with consideration of the methods described in the remainder of Section 4.1.

Rainfall

To provide a consistent approach to stormwater modelling, appropriate rainfall stations and periods of modelling have been identified which must be used for MUSIC modelling in Mackay. Figure 5 shows three rainfall zones for the Mackay Region and Table 1 shows the rainfall datasets that are approved for use in each of the rainfall zones. Where developments are located across the boundary of two zones, the rainfall data relating to the zone with the highest mean annual rainfall should be used.

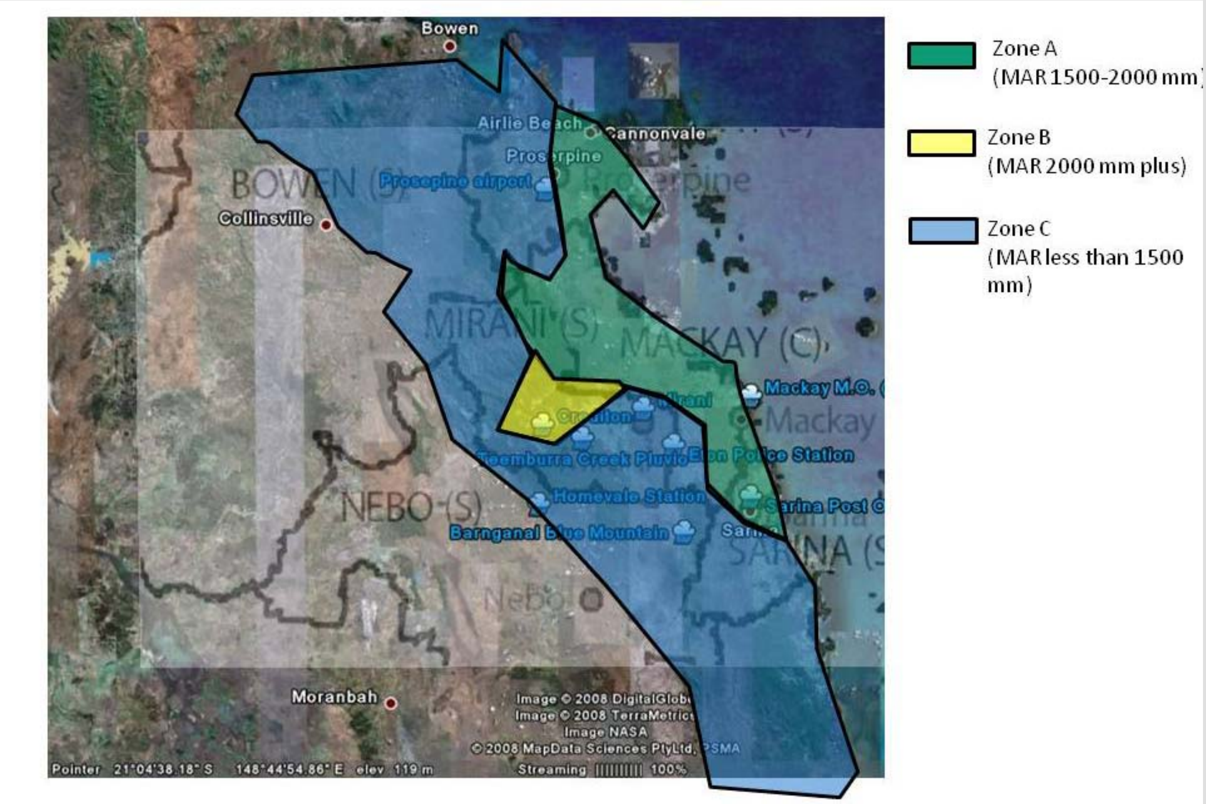


Figure 5 Rainfall zones – Mean Annual Rainfall (MAR) across Mackay Region

Table 1 Rainfall data to be used for assessing pollutant reductions

Rainfall Zone	Station name	MAR	Timestep	Period
Zone A (Eastern)	Mackay M.O.	1566mm	6 min	1990 – 1999
Zone B (Hinterland)	Crediton	2325mm	6 min	1972 - 1981
Zone C (Western)	Proserpine	1361mm	6 min	1990 – 1999

Evapotranspiration

The use of Mackay Monthly Aerial Evapotranspiration (provided with MUSIC software) is approved for the local government area for the Mackay Regional Council.

Stormwater runoff (represented as surface runoff and baseflow) is generated in MUSIC through the interaction of rainfall, evapotranspiration and the MUSIC Rainfall-Runoff Model (see MUSIC User Manual for full description of Rainfall-Runoff Model).

4.1.1 Rainfall

Historical rainfall data, available from the Bureau of Meteorology is generally used in MUSIC models. Some rainfall data (1959-2000) for the Mackay M.O. (station # 33119) is provided with the MUSIC software. Mackay Regional Council has purchased available rainfall for all local suitable pluviographic stations and these data are available for download on Council's website. A summary of the available data is shown in Table 2.

Table 2 Pluviographic data available on Council's website

Station #	Station name	Start	End
33021	Eton Police station	Oct 1970	Jul 1986
33067	Sarina Post Office	Nov 1986	Jan 2000
33087	Barnganal Blue Mountain	Jul 1963	Present
33099	Teemburra Creek Pluvio	Jul 1962	April 1985
33119	Mackay M.O.	Sep 1959	Present
33146	Homevale Station	Nov 1970	Jul 1998
33152	Mirani	Oct 1970	May 2000
33172	Crediton	Apr 1972	Present
33247	Proserpine Airport	Dec 1988	Present

Many of these data sets have significant gaps in the time series and care should be taken when using this data in MUSIC. Review of the data has been completed to identify which of the rainfall stations provide suitable data for MUSIC assessments in Mackay considering the following requirements:

- Continuous simulation of a minimum of 10 years. While a shorter "representative" meteorological record can be used for initial modelling runs, it is recommended that at least 10 years of data are used to assess the performance of a stormwater treatment train.
- 6 minute timestep as this allow for appropriate definition of storm hydrograph movement through stormwater treatment systems.

Figure 5 shows three rainfall zones for the Mackay Region and Table 1 shows the rainfall datasets that are approved for use in each of the rainfall zones.

4.1.2 Potential Evapotranspiration

The measured mean annual potential evapotransipration for Mackay M.O (station # 33119) is provided with the MUSIC software and is shown in Table 3. Potential evaporation has less spatial variation than rainfall and the Mackay M.O. data is considered suitable for modelling catchments anywhere within Mackay Regional Council local government area. Data can also be derived from the *Climatic Atlas of Australia – Evapotranspiration (BoM 2001).*

Table 3 Monthly Evapotranspiration

Month	J	F	M	A	M	J	J	A	S	O	N	D
Evapotranspiration (mm)	190	152	150	105	75	60	65	80	107	150	175	190

4.2 STEP 2: Catchment properties

Once the meteorological data has been input into the model the user must then define the source nodes to reflect the details of the contributing catchments. This involves:

- Establishing the type of landuse and source nodes
- Defining the catchments
- Splitting the catchments into land types (roof, road, ground level) where required
- Inserting rainfall runoff parameters
- Inserting pollutant export parameters

4.2.1 Types of source nodes (Landuse)

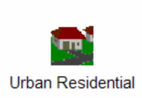
This box describes the pre-approved approach for selecting source nodes. Council will consider alternative modelling approaches, however, justification must be provided in the SBSMP with consideration of the methods described in the remainder of Section 4.2.1.

The following landuses should be used with the pre-approved input parameters described in Section 3.2.2 to 3.2.6:

- Urban Residential
- Industrial
- Commercial
- Rural Residential
- Forest
- Agriculture

MUSIC currently has five land uses, these being; forest, agricultural, urban, user defined and imported data. Stormwater data collected around Australia, in particular Brisbane City Council's Stormwater Quality Monitoring Program, has allowed for the calibration of additional source nodes namely industrial and commercial. The landuses and sources which apply to the Mackay Region are described below.

For these sources nodes, MUSIC generates runoff (volume and quality) based on the rainfall data defined in the template and rainfall-runoff/pollutant parameters defined within the node properties. The rainfall-runoff and pollutant parameters vary between source nodes.



The Urban Residential source node is used to describe residential areas including activities servicing local neighbourhood needs. While such areas will typically comprise of a mix of land uses, including, for example, small nodes of commercial use, the majority of these areas will consist of residential dwellings together with all associated facilities such as roads, parks and school grounds.

The **Industrial** source node should be used for areas consisting of light and general industry. These will typically include activities associated with the manufacture and/or distribution of goods (e.g. heavy machinery). The area of the Industrial node will include building envelopes, parking areas, adjacent roads and road reserves. Industrial areas are typified by a high percentage of total impervious area. For individual industrial allotments it is suggested that the site is split into land types as outlined in Section 4.2.3. Extractive industry cannot be modelled using this source node.

The Commercial source node should be used for areas consisting mainly of retail and commercial enterprises not generating manufacturing wastes. Such areas will typically include associated activities such as offices and restaurants. The area of the Commercial node will include building envelopes, parking areas, adjacent roads and road reserves. Special Purpose or Multipurpose Centres such as hospitals, major educational facilities, Shopping Centres and Community Centres should be modelled using this type of Source Node. Commercial areas are typified by a high percentage of total impervious area. For individual commercial allotments it is suggested that the site is split into land types as outlined in Section 4.2.3.

Rural Residential

The **Rural Residential** source node largely applies to residential blocks on large allotments, with a high proportion of unpaved open space. Source nodes of this type will also include associated activities servicing local needs, such as schools and parklands. Areas of broad hectare low intensity farming activities (where soils are not exposed) and semi-natural broad hectare land may also be included. These nodes will typically have less than 15% total impervious area.

Forest

The **Forest** source node is to be used for natural bushland areas. It is anticipated this node will not be regularly used in the Mackay Region. Where the modeller proposes to use the Forest Source Node, Council should be consulted to confirm the suitability of it application.

Agricultural

The **Agricultural** source node refers to areas of large scale cropping or grazing that contain exposed soils. Only areas supported with recent (past 6 months) photography of animal wash down/dip areas or crops are to use this Source Node. If these cannot be provided then a Rural Residential node is to be utilised.

User-defined Source

The **User Defined** source node is similar to the catchment nodes described above in that MUSIC generates runoff based on defined rainfall-runoff and pollutant parameters. However, the default parameters for the user defined node cannot be altered and changes must be made manually for each new node.

Imported Data Node

The **Imported Data** Source Node allows the use of known runoff/flow data (rather than using MUSIC to generate flows from the rainfall template and catchment parameters). This node can be used with data from an external source e.g. stream gauge or from data generated from a previous MUSIC run (refer to Section 4.4.6 for information on exporting data from MUSIC). Refer to Section 3.5 of the MUSIC Users Manual for information on using the imported data node.

Guidance on defining catchments and subcatchments along with Specific rainfall runoff and pollutant parameters are available for the sources nodes in Mackay are provided in the following sections.

4.2.2 Catchment definition & split

This box describes the pre-approved approach for defining and splitting catchments for MUSIC modelling. Council will consider alternative modelling approaches, however, justification must be provided in the SBSMP .

The MUSIC model must include all surfaces within a development area including any surfaces within a development area that do not receive any treatment (i.e. areas where runoff is discharged from the site without interaction with a treatment measure). Catchments for MUSIC modelling must be divided into subcatchments in response to the following:

- As dictated by topography. For development situations the subcatchments must reflect the final road levels, earthworks levels and proposed stormwater drainage system.
- Different soil types exist for various pervious areas within a catchment (Upland, Lowland or Sandy refer to Section 4.2.5).
- Different parts of the catchment are directed to different treatments (e.g. road runoff is directed to bioretention pods and the remainder of runoff is directed into a wetland)
- Runoff from parts of the development area are directed straight to receiving waters (i.e. not treated)

The catchment area for each subcatchment area must be established from development plans preferably digitally (i.e. ACAD or MapInfo) and inserted in the relevant source node in hectares. The location and extent of the subcatchments that relate to the MUSIC must be clearly depicted in the Site Based Stormwater Management Plan.

Runoff volume and pollutant loads generated for a catchment node by MUSIC are proportional to the total catchment area. For example, the total output from ten one hectare catchment nodes would be equal to the output from one ten hectare node with identical percentage impervious, rainfall-runoff and pollutant parameters. This means that identical catchment nodes that are directed to a common downstream node (i.e. treatment system) can be lumped together without and loss of accuracy to reduce the number of modelling iterations and hence the model run time.

The user can enter a catchment area from 0.001 hectares (10 m^2) to 10,000 hectares. This means there is flexibility to model all stormwater scenarios from small lots or streets through to Greenfield developments across large catchments.

The split of catchment source nodes and the area associated with those source nodes is defined by the catchment characteristics and the location of the stormwater treatment systems. The scenarios list above in the pre-approved approaches dictate when catchments should be split into subcatchments in Mackay.

The catchment area for each subcatchment area must be established development plans preferably digitally (i.e. ACAD or MapInfo) and inserted in the relevant source node in hectares. The location and extent of the subcatchments that relate to the MUSIC must be clearly depicted in the Site Based Stormwater Management Plan.

4.2.3 Surface type split

This box describes the pre-approved approach for splitting surface types. Council will consider alternative modelling approaches, however, justification must be provided in the SBSMP .

Catchments and subcatchments in MUSIC must be split into various surface types (roof, road reserve and ground level) in the following situations:

- Where roof runoff is directed to rainwater tanks. In this case, assuming the ratio of roof area to tank volume/reuse demand are constant, all roof areas can be lumped together and directed to lumped tank node.
- Single allotment including residential, industrial or commercial
- Single street including allotments

The catchment area for each land type must be established from development plans preferably digitally (i.e. ACAD or MapInfo) and inserted in the relevant source node in hectares. The location and extent of the subcatchments that relate to the MUSIC must be clearly depicted in the Site Based Stormwater Management Plan.

Specific percentage imperviousness and pollutant parameters are available for the various catchment portions (roof, road, ground level) are provided in the following sections.

4.2.4 Percentage Imperviousness

This box describes the pre-approved approach for setting percentage impervious. Council will consider alternative modelling approaches, however, justification must be provided in the SBSMP.

The MUSIC model must include all surfaces within the development boundary including any surfaces within a development area that do not receive any treatment (i.e. areas where runoff is discharged from the site without interaction with a treatment measure). . Percentage pollutant reductions are to be reported using the entire area.

The overall percentage impervious for various development types should be established from plans and/or aerial photos of similar development areas and should be within the ranges shown in Tables 4 and 5 below.

The percentage impervious inserted into MUSIC is the total impervious area measured from the development plans (for the purposes of MUSIC modelling in Mackay total impervious = directly connected imperviousness).

The total area and percentage impervious must be defined for all catchment nodes. The user can alter the percentage by dragging the columns representing the pervious and impervious area up or down. The percentage of impervious surfaces (e.g. roads, roofs and paving) within the catchment influence the volume and pollutants loads of runoff. In the Mackay region, the mean annual runoff from pervious areas is approximately half that of impervious areas.

The percentage impervious for a new development can be measured from development plans or estimated from aerial photos of similar development types. Table 4 provides typical percentage impervious ranges for different landuses in Mackay.

Table 5 shows typical split of surface types and percentages impervious for development in Mackay.

Table 4 Typical percentage imperviousness for different landuses in Mackay (lumped landuse)

Landuse	% impervious
Urban Residential	40 - 70%
Industrial	70 - 90%
Commercial	80 - 100%
Rural Residential	5 - 20%

Table 5 Typical percentage imperviousness when splitting land types

Land use category	Residential		Industrial		Commercial	
	% overall catchment	% impervious	% overall catchment	% impervious	% overall catchment	% impervious
Roof	35%	100%	60%	100%	60%	100%
Road reserve	25%	70%	25%	70%	30%	80%
Remainder	40%	19%	15%	17%	10%	60%
Overall	100%	60%	100%	80%	100%	90%

4.2.5

4.2.6 Rainfall runoff parameters

This box describes the pre-approved approach for setting rainfall runoff parameters. Council will consider alternative modelling approaches, however, justification must be provided in the SBSMP with consideration of the methods described in the remainder of Section 4.2.6

Rainfall runoff parameters are influenced by soil type. The soil category for a catchment area should be determined using Table 6 and Figure 3. For development sites outside the boundaries of Figure 3, the soil category that is thought to represent the local soils should be selected and a short justification for this choice provided in the SBSMP. If in doubt, the upland category should be selected.

Table 6 Soil category for MUSIC modelling

Soil category to be adopted for selecting MUSIC rainfall runoff parameters	Description on Figure 3 (Section 2.2)	Colours on Figure 5
Upland	- Soils of uplands derived from acid crystalline tuffs on 1-4% slope - Soils of uplands derived from acid to intermediate intrusive and dykes - Soils of uplands derived from basic to intermediate volcanos on 2-8% slopes - Soils of uplands derived from sedimentary rocks on 2-8% slopes	Light yellow, dark yellow, light brown, orange, light pink, purple
Lowland	- Soils types not covered by other two soil categories	Red, light green, light blue, green, dark brown, dark blue, grey
Sandy	- Soils of the beach ridges and coastal dunes	Dark pink

The rainfall runoff parameters to be used for each soil category are shown in Table 7.

Table 7 MUSIC Rainfall runoff parameters

	Soil Typology		
Parameter	**Upland**	**Lowland**	**Sandy**
Rainfall Threshold (mm)	1	1	1
Soil Capacity (mm)	200	250	250
Initial Storage (%)	30	30	5
Field Capacity	80	100	100
Infiltration Capacity Coefficient a	200	200	200
Infiltration Capacity Coefficient b	1	1	1
Initial Depth (mm)	10	10	0
Daily Recharge Rate (%)	0.5	4	25
Daily Baseflow Rate (%)	0.16	2	0
Deep Seepage (%)	2	0.4	0

Stormwater runoff (represented as storm flow and baseflow) is generated in MUSIC through the interaction of rainfall, evapotranspiration and the MUSIC Rainfall-Runoff Model. A full description of the MUSIC rainfall-runoff model is provided in the MUSIC User Manual. If the reader of this document has no MUSIC modelling experience they should review Appendix A of the User Manual before reading below.

The rainfall runoff parameters of a catchment node influence the runoff quantity and patterns. The only rainfall-runoff parameter that relates to the impervious portion of the catchment is the Rainfall Threshold (mm/day) which is the depth of rainfall that wets the surface but does not runoff. All daily rainfall onto impervious surfaces, in excess of the threshold, is converted to runoff. In MUSIC, runoff from impervious areas does not interact with the soil or groundwater and so does contribute to base flow.

The remaining nine rainfall-runoff parameters relate to the pervious portion of the catchment. When rain falls on a pervious surface, some is absorbed into the soil profile, some enters groundwater and is subsequently released into the drainage system as “baseflow”, some enters groundwater and stays there and some runs directly off from the surface as “stormflow”. The distribution of runoff between these pathways is influenced by rainfall patterns (frequency, intensity and duration) and soil/groundwater properties. Together the nine rainfall runoff parameters in MUSIC simulate the behaviour of the soil and groundwater profile of a catchment. These are not parameters that can be individually measured in the field; they are best defined by calibrating flow patterns generated by MUSIC with local rainfall runoff data. Continuous rainfall runoff data at an urban development scale that are suitable for calibration are generally not available. Therefore, adopting parameters based on regional soil types is recommended. Refer to Section 2.2 for a description of three soil type categories for the Mackay Region.

A proposed drainage layout will determine whether it is suitable for baseflow to be considered when modelling urban systems. Treatment nodes only supplied by piped drainage, are unlikely to receive base flows whereas treatment nodes supplied by open waterways would.

4.2.7 Pollutant export parameters

This box describes the pre-approved approach for setting pollutant parameters. Council will consider alternative modelling approaches, however, justification must be provided in the SBSMP with consideration of the methods described in the remainder of Section 4.2.7

The pollutant export parameters to be adopted in Mackay for each landuse when the catchments are "lumped" are provided in Table 8.

The specific pollutant export parameters for the split land types (roof, road reserves and ground level) are provided in Table 9. These parameters are to be used when the land types are split as described in Section 4.2.3.

Pollutant export estimation method must be set to "stochastic generated".

Table 8 Pollutant parameters for "lumped" landuses

Land-use category		Log10 TSS (mg/L)		Log10 TP (mg/L)		Log10 TN (mg/L)	
		Base Flow	Storm Flow	Base Flow	Storm Flow	Base Flow	Storm Flow
Urban Residential[1]	Mean	1.0	2.18	-0.97	-0.47	0.20	0.26
	Std Dev	0.34	0.39	0.31	0.31	0.20	0.23
Industrial[1]	Mean	0.78	1.92	-1.11	-0.59	0.14	0.25
	Std Dev	0.45	0.44	0.48	0.36	0.20	0.32
Commercial[1]	Mean	0.78	2.16	-0.60	-0.39	0.32	0.37
	Std Dev	0.39	0.38	0.50	0.34	0.30	0.34
Rural Residential[1]	Mean	0.53	2.26	-1.54	-0.56	-0.52	0.32
	Std Dev	0.24	0.51	0.38	0.28	0.39	0.30
Forest[1]	Mean	0.51	1.90	-1.79	-1.10	-0.59	-0.075
	Std Dev	0.28	0.20	0.28	0.22	0.22	0.24
Agriculture[2]	Mean	1.40	2.30	-0.88	-0.27	0.074	0.59
	Std Dev	0.13	0.31	0.13	0.30	0.13	0.26

1 – Guidelines for Pollutant Export Modelling in Brisbane Version 7)
2 – MUSIC User Guide

Table 9 Pollutant parameters for "split" land types

Land Use	Log10 TSS (mg/L)		Log10 TP (mg/L)		Log10 TN (mg/L)	
	Base Flow	Storm Flow	Base Flow	Storm Flow	Base Flow	Storm Flow
Urban Residential						
Road	1.0	2.43	-0.97	-0.30	0.20	0.26
Roof	-	1.30	-	-0.89	-	0.26
Ground Level	1.0	2.18	-0.97	-0.47	0.20	0.26
Industrial						
Roads (including parking)	0.78	2.43	-1.11	-0.30	0.14	0.25
Roofs	-	1.30	-	-0.89	-	0.25
Ground level	0.78	1.92	-1.11	-0.59	0.14	0.25
Commercial						
Roads (including parking)	0.78	2.43	-0.60	-0.30	0.32	0.37
Roof	-	1.30	-	-0.89	-	0.37
Ground Level	0.78	2.16	-0.60	-0.39	0.32	0.37

NOTE: Std Dev for each landuse land type is provided in Table 8

As outlined in the MUSIC User Manual, a comprehensive review of stormwater quality in urban catchments was undertaken by Duncan (1999) and this review forms the basis for the default values of event mean concentrations in MUSIC for total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN). Further investigation by the CRC for Catchment Hydrology and Brisbane City Council of the extensive stormwater quality database for a range of Brisbane catchments has further refined these event mean concentrations for both storm runoff (i.e. surface flows) and baseflow conditions (refer to Brisbane City Council document Guidelines for Pollutant Export Modelling in Brisbane Version 7). More recently Fletcher et al (2004/5) has updated the values provided in Duncan (1999) and specifically provides guidance on appropriate land type breakdown.

Lumped Landuse

Table 8 provides the pollutant export parameters to be adopted in Mackay for each landuse when the catchments are "lumped". The basis of these parameters is the Event Mean Concentrations (EMC) and Dry Weather (i.e. baseflow) Concentrations (DWC) as provided by Brisbane City Council. The BCC information is considered to reflect the best available data for Queensland.

Split Land Types

Analysis of stormwater pollutant load data from various urban surfaces by Duncan (1999) and Fletcher et al (2004) shows that:

- Suspended solids and total phosphorus loads for roads are generally higher than the average load across all urban surfaces.
- Suspended solid loads and total phosphorous loads from rooves are generally lower than the average load across all urban surfaces.
- Total nitrogen loads are reasonably consistent across urban surfaces which is a reflection of the uniform nature of atmospheric deposition of nitrogen.

Where the applicant proposes to split the land types as described in Section 4.2.3, Council provides the pollutant export parameters in Table 9. These values are based on those adopted for the Gold Coast City Council MUSIC Guideline which reference the following:

- Brisbane City Council's *Guidelines for Pollutant Export Modelling in Brisbane Version 7 – Draft*.
- Duncan, H.P. 1999. *Urban Stormwater Quality: A Statistical Overview.* CRC for Catchment Hydrology Report 99/3.
- Fletcher, T. et al. 2004. *Stormwater Flow and Quality, and the Effectiveness of Non-Proprietary Stormwater Treatment Measures – A Review and Gap Analysis*. CRC for Catchment Hydrology Report 04/8.

Stochastic Generation

Runoff pollutant concentrations can be generated stochastically from a defined mean and standard deviation or by adopting a constant mean concentration. The stochastic option must be used for modelling stormwater runoff and treatment in Mackay.

4.2.8 Tips for model setup

4.2.8.1 Background image

A "bitmap" file can be displayed as the background to a MUSIC model to depict the approximate location of source node(s) and treatment node(s). This can be a useful visual record of the way the various parts of a catchment are being treated and can assist assessing officers to quickly understand the way the model is set up. An example of a MUSIC model with a background image is shown in Figure 6. A background image is inserted from the "Catchment" drop down menu.

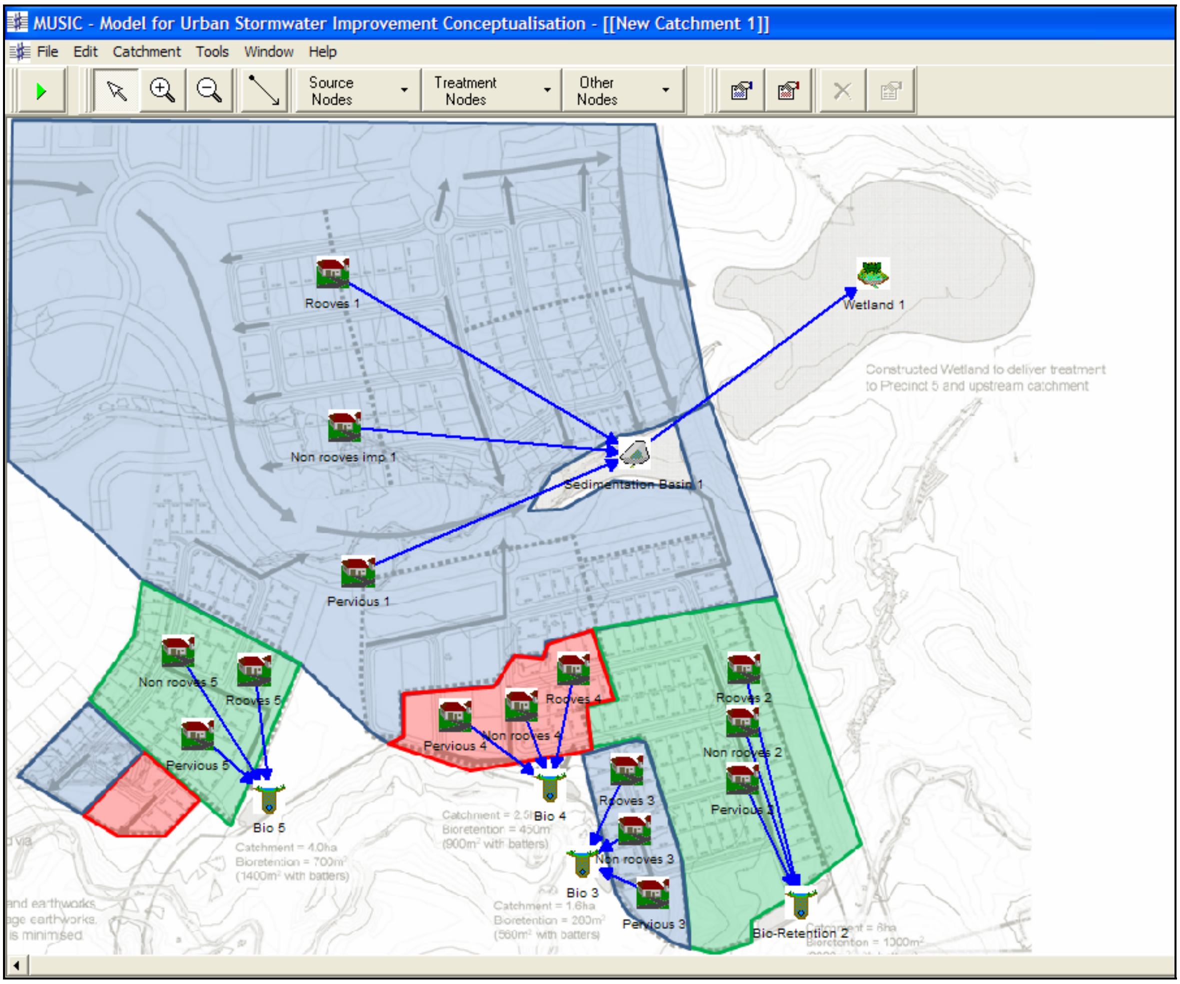


Figure 6 Example of MUSIC file with background image

4.2.8.2 Adding notes to nodes and links

Notes can be added to all MUSIC nodes and links and it is recommended that a summary of assumptions made (along with references if relevant) be recorded within the model. This feature is shown in Figure 7.

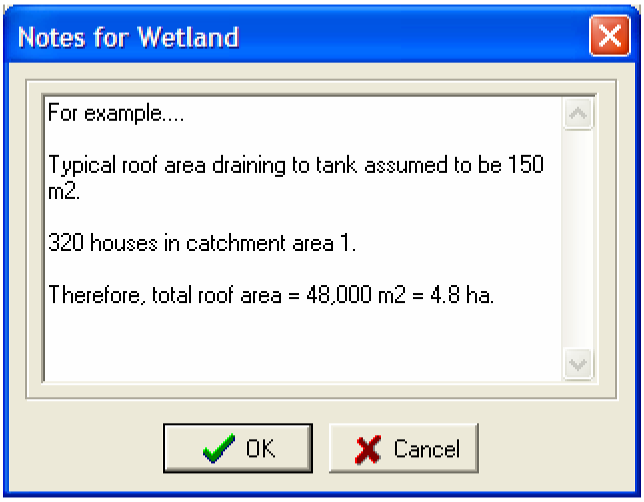


Figure 7 Example note in node

4.2.8.3 Using junction nodes and labels

To add notes to a model that can be viewed without opening any of the nodes or links, it is suggested that junction nodes are used as shown in Figure 8.

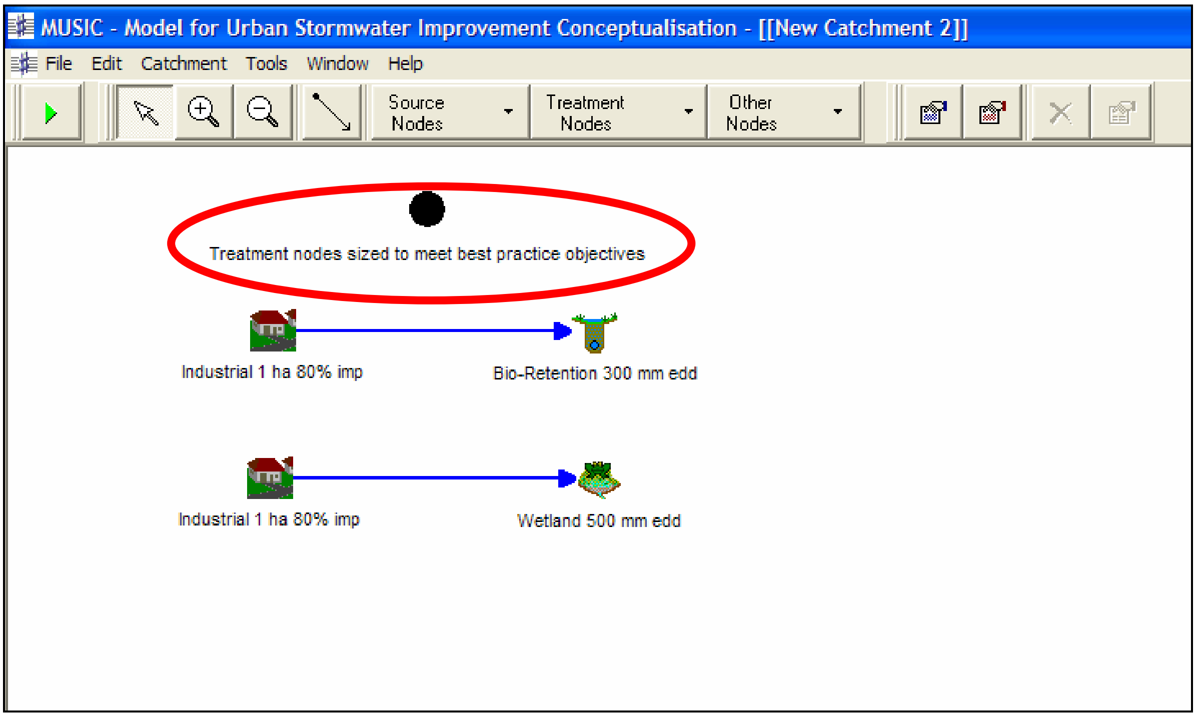


Figure 8 Example of using junction node as a label

4.3 STEP 3: Stormwater treatment

Following establishment of the catchment properties, a treatment train is developed based on site constraints and opportunities. The user is able to define the physical configuration of treatment systems as well as parameters relating to the removal of pollutants e.g. k, c* for the universal stormwater treatment model (USTM) (refer Section 5 of the MUSIC Users Manual). The default parameters in MUSIC for the first order decay K c* model used to define the treatment efficiency of each treatment device should be used unless local relevant treatment performance monitoring can be used as reasonable justification for modification of the default parameters.

The following sections provide guidance on modelling of the following treatment systems in MUSIC and provide pre approved parameters:

- Rainwater tanks
- Wetlands
- Bioretention
- Swales
- Bioretention Swales
- Gross Pollutant Traps
- Sedimentation Basins
- Ponds
- Infiltration

Wetlands and bioretention systems are generally the most significant components of a stormwater treatment train designed to meet stormwater treatment objectives and therefore more detailed advice is provided for these systems.

Additionally, guidance is provided for the following:

- Reuse from treatment notes
- Generic Nodes
- Junction Nodes
- Receiving Water Nodes
- Linking catchment nodes to treatment nodes

4.3.1 Rainwater tanks

This box contains the pre-approved approach for modelling rainwater tanks. Council will consider alternative modelling approaches, however, justification must be provided in the SBSMP with consideration of the methods described in the remainder of Section 4.3.1.

Inlet properties		
High Flow By-Pass (cubic metres per sec)	100	
Low Flow By-Pass (cubic metres per sec)	0	
Storage properties		
Volume below overflow pipe (kL)	User defined (must be greater than or equal to five times the maximum daily demand)	
Depth above overflow (m)	User defined	
Surface area (m^2)	User defined (Unless tank being designed to provide retardation of peak flows, make surface area (m^2) equal to storage volume (kL) i.e. tank is one meter deep.)	
Outlet properties		
Overflow pipe diameter (mm)	User defined (unless tank being designed to provide retardation of peak flows, make pipe area equal to the surface area divided by 10.)	
Reuse parameters		
Annual Demand (kL/day)	User defined irrigation demand (see below)	
Daily demand (kL/day)	User defined indoor demand (see below)	
Monthly distribution of Annual Demand (kL/yr)	0	
Advanced parameters		
	k	C*
Total Suspended Solids	400	12
Total Phosphorous	300	0.13
Total Nitrogen	40	1.4

As required by Part MP 4.2 (Water Savings Targets) of the Queensland Development Code (QDC; November 2007) residential development in Mackay is to adopt and implement strategies to reduce potable water consumption. This will involve demand management and installation of rainwater tanks where recycled water is not available.

Rainwater tanks must be connected to one outdoor tap, laundry cold tap and toilets on all residential allotments. Tanks must be sized in accordance with below:

- Minimum 5,000L for all detached dwellings
- Minimum 3,000L for attached dwellings

For all other situations and landuses the rainwater tanks will be established by the proponent in consultation with Council.

The residential demands shown in Table 10 and Table 11 should be used for modelling rainwater tanks. Note that sensitivity testing has been undertaken on the outdoor demand and has found this demand has very little influence on the potential size of treatment system downstream because this demand occurs during the dryer months of the year.

Consideration must be given to tank catchment areas. For example, often not all downpipes are connected to a tank and so it only receives runoff from a proportion of the roof area. The minimum roof area as required by Part MP 4.2 (Water Savings Targets) of the Queensland Development Code (QDC; November 2007) will need to be plumbed to the tanks.

Table 10 Household water demands

Demand	L/household/day	Annual distribution
Toilet flushing	125	Constant
Cold laundry	50	Constant
Outdoor	65*	Refer table below

* Equivalent to 20% of the typical outdoor demand in Mackay. This allows for water restrictions.

Table 11 Monthly outdoor demand distribution

Month	% Annual demand	Month	% Annual demand
January	1	**July**	10
February	1	**August**	12
March	1	**September**	17
April	11	**October**	18
May	3	**November**	14
June	6	**December**	6

4.3.1.1 General

The parameters that can be defined for the rainwater tank node are described in Section 3.3.9 of the MUSIC Users Manual.

Rainwater tanks can enable potable water demands to be reduced as well as contributing to a reduction in pollutant discharge through treatment that occurs in the tank (e.g. settlement of solids) and through the removal of pollutants from the stormwater stream through the use of water from the tank.

The “Depth above overflow”, “Surface area” and ”Overflow pipe diameter” parameters are only important when the effects of tanks on providing retardation of peak flows is being considered.

When modelling rainwater tanks only, a coarser time-step (e.g. daily) can be used than when modelling stormwater treatment elements such as wetland and bioretention systems.

MUSIC assumes that the daily demand can be met by the sum of the water in the tank from the previous time-step and the daily inflows. This means that the amount of water that is reused can be overestimated when the daily demand is large compared to the tank size. The impact of diurnal reuse demand patterns is also more significant where the size of the tank is small compared to the daily demand. MUSIC is not considered to be a suitable tool for modelling scenarios where maximum daily demand is greater than five time tank volume.

4.3.1.2 Residential Tanks

For tanks in residential developments the catchments must be split into ‘roof’, ‘road’ and ‘ground level’ as illustrated in Figure 9. This partitioning is necessary to accommodate the roof to rainwater tank systems and to more accurately simulate the pollutant load generation from these different surfaces. The following assumptions will generally apply for residential tank applications:

- For **detached dwellings**, roof areas are approximately 225-250m^2 per allotment and 100% impervious. 150m^2 of the roof enters the rainwater tank with the remaining not entering the tanks to reflect the difficulty is delivering all roof area to tanks.
- For **attached dwellings**, roof areas are approximately 125-150m^2 per allotment and set to 100% impervious. 100m^2 of the roof enters the rainwater tanks with the remaining not entering the tanks to reflect the difficulty is delivering all roof area to tanks.

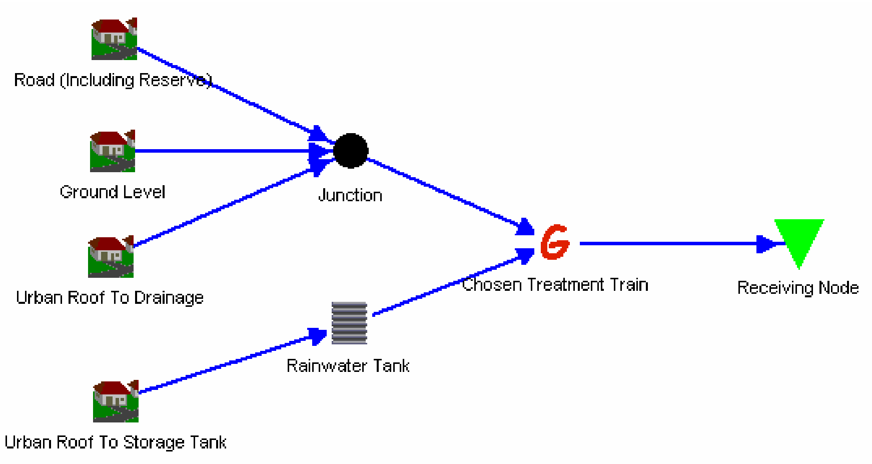


Figure 9 Example of rainwater tanks in residential MUSIC model

4.3.2 Wetlands

This box contains the pre-approved approach for modelling wetlands. Council will consider alternative modelling approaches, however, justification must be provided in the SBSMP with consideration of the methods described in the remainder of Section 4.3.2.

Inlet properties			
Low Flow By-Pass (cubic metres per sec)	0		
High Flow By-Pass(cubic metres per sec)	100		
Inlet pond volume (cubic meters)	Sized to remove coarse sediment (>125um) during 1yr ARI storm (typically 5 – 10% macrophyte area)		
Storage properties			
Surface area (square meters)	User defined		
Extended detention (meters)	0.3-0.6 (preferably 0.5m)		
Permanent pool volume (cubic meters)	0.3*Surface area		
Seepage loss (mm/hr)	0		
Evaporative Loss as % of PET	125		
Outlet properties			
Equivalent pipe diameter (mm)	Sized so that notional detention time is as close to 36 - 48 hrs as possible		
Overflow weir width (meters)	Greater than or equal to surface area (m^2)/10		
Notional Detention Time (hrs)	As close to 36 – 48 hrs as possible		
Advanced properties			
Orifice discharge coefficient	0.6		
Weir coefficient	1.7		
Number of CSTR cells	5		
	k	C*	C**
Total Suspended Solids	1500	6.000	6.000
Total Phosphorous	1000	0.060	0.060
Total Nitrogen	150	1.000	1.000

The wetland node incorporates an inlet pond for initial sediment collection followed by a macrophyte zone where finer sediment particles and the majority of dissolved nutrients are removed. The parameters that can be defined for the wetland node are shown in table above and are described in Section 3.3.3 of the MUSIC Users Manual.

4.3.2.1 Inlet properties

MUSIC is not a suitable tool for sizing wetland inlet ponds (refer to SEQ Tech Guidelines for recommended method). The inlet pond volume specified in a MUSIC model (to allow sizing of the macrophyte zone) should be sized to give the equivalent sediment removal of a correctly sized inlet pond (i.e. as determined from the method in the *Water Sensitive Urban Design Guidelines for South East Queensland (MBWCP, 2006)*. To size the inlet pond volume in the model, the pond should be at least 1.5 m deep and have a surface area suitable to promote remove of coarse sediment during the 1 yr ARI storm event (typically 5 – 10% of the macrphyte zone for a wetland design to meet best practice in Mackay). If the user is not aiming to size the wetland to meet best practice objectives, it is still recommended that an inlet pond be size in accordance with the method in the *Water Sensitive Urban Design Guidelines for South East Queensland (MBWCP, 2006)* i.e. the inlet pond should not be smaller than this.

4.3.2.2 Storage properties (macrophyte zone)

Version 3.01 (current at time of writing) does not allow the user to specify a stage-storage relationship for the permanent pool or the extended detention area. Constructed wetlands generally do not have vertical edges and so the area at the base of the permanent pool is usually significantly smaller than the area at the top of the extended detention. The "*surface area*" specified in the wetland model should be equal to the **average** of surface area at the top of the permanent pool (commonly referred to as the "normal water level") and the top of the extended detention (commonly referred to as "top water level"). This will simulate the extended detention volume in the model to be approximately equal to the actual volume. This approach to setting the surface area means that the surface area of the permanent pool and hence the evaporation rate and drawn down between rainfall events is overestimated.

The extended detention default value in MUSIC is one metre which is above what is considered the optimum range for plant health. An extended detention greater than 0.6 m significantly reduces the number of plant species suitable for the macrophyte zone. The preferred extended detention depth for wetland in Mackay is 0.5m.

As discussed above, MUSIC assumes the permanent pool volume is a constant depth, whereas constructed wetlands generally have a range of depths including ephemeral areas (i.e. no permanent pool). An average depth of 0.2-0.3 m is common for well performing constructed wetlands. A depth of 0.3m can be used to calculate the permanent pool volume of the wetland zone.

When modelling to assess reduction in pollutant loads, the seepage parameter should be set to zero. If a wetland is modelled with seepage, pollutant loads in the water that is lost to seepage are included in the reduction in pollutant loads achieved across the treatment node. Stormwater pollutant reduction objectives relate to all runoff leaving the site including that seeping to groundwater. An example of when the seepage function would be useful is when estimating the volume of water available for reuse at the downstream end of a wetland that is known to lose water to seepage.

4.3.2.3 Outlet properties

The equivalent pipe diameter of the wetland outlet is used to set the notional detention time. The notional detention time is equal to the extended detention volume (surface area * extended detention depth) divided by the flow rate through a circular orifice (equal to the equivalent pipe diameter) with a head equal to the extended detention depth. The equivalent pipe diameter should be set so that the notional detention time is between 36 and 48 hours (preferably 48 hours).

The actual time taken for the wetland to draw down from the top of extended detention to the permanent pool level will be greater than the notional detention time as the discharge rate will decrease as the water level and hence head of water acting on the orifice decreases.

In reality, wetland outlets are not always configured as a single orifice and so the stage discharge relationship would be different to that simulated in MUSIC. It is envisaged that in future versions of MUSIC, the stage storage relationship will be able to be set.

The length of the overflow weir controls the discharge rate when the water level in the wetland exceeds the top of extended detention. An undersized overflow weir will result in water “backing up” behind it, effectively adding additional extended detention. It is recommended that, as a starting point, the overflow weir length (m) is set at the surface area (m^2) divided by 10 m.

4.3.2.4 General

It is recommended that the wetland parameters not specifically described in this section are left as the default values for modelling typical stormwater treatment wetlands.

4.3.3 Bioretention basins

This section relates to modelling bioretention systems with a horizontal base, commonly called bioretention basins. For guidance on modelling bioretention systems with a sloping base, commonly called bioretention swales, refer to Section 4.3.5.

This box contains the pre-approved approach for modelling bioretention basins. Council will consider alternative modelling approaches, however, justification must be provided in the SBSMP with consideration of the methods described in the remainder of Section 4.3.3.

Inlet properties		
Low Flow By-Pass (cubic meters per sec)	0	
High Flow By-Pass(cubic metres per sec)	100	
Storage properties		
Surface area (square meters)	User defined (no greater than average of areas of top & bottom of extended detention)	
Extended detention (meters)	0.1-0.4 (preferably 0.3m)	
Seepage loss (mm/hr)	0	
Infiltration properties		
Filter area (square meters)	User defined	
Filter depth (meters)	0.4-1.0	
Filter median particle diameter (mm)	0.45	
Saturated Hydraulic Conductivity (mm/hr)	180	
Depth below underdrain pipe (% filter depth)	0	
Outlet properties		
Overflow weir width (meters)	Greater than or equal to surface area (m^2)/10	
Advanced properties		
Weir coefficient	1.7	
Voids ratio	0.3	
Number of CSTR cells	3	
	k	C*
Total Suspended Solids	8000	20.000
Total Phosphorous	6000	0.130
Total Nitrogen	500	1.400

The parameters that can be defined for the bioretention node are shown in the table above and are described in Section 3.3.6 of the MUSIC Users Manual.

4.3.3.1 Storage properties

Version 3.01 (current at time of writing) does not allow the user to specify a stage-storage relationship for the extended detention area of a bioretention basin. Where basins do not have vertical edges, the area at the surface of the basin is smaller than the area at the top of the extended detention. The “surface area” parameter in MUSIC represents the area that water can pond in and it is set to be equal to the average of the area at the surface of the filter media and area at the top of the extended detention (commonly referred to as “top water level”). Therefore, the extended detention volume in the model is approximately equal to the actual volume. This approach to setting the surface area means that the ponding depth and hence infiltration rate (determined by MUSIC using Darcy’s Law) will be underestimated when the basin is less than half full and overestimated when it is more than half full.

The extended detention default value in MUSIC is one metre which is above what is considered the optimum range for plant health. An extended detention of 0.3 m is preferred with depths less than 0.3m considered appropriate. Depths of greater than 0.3m starts to influence the viability of the plants and a suitable investigation into inundation periods is required prior to adopting these depths.

When modelling to assess reduction in pollutant loads, the seepage parameter should be set to zero. If a bioretention basin is modelled with seepage, the pollutant loads in the water that is lost to seepage are included in the reduction in pollutant loads achieved across the treatment node. Stormwater pollutant reduction objectives relate to all runoff leaving the site including that seeping to groundwater. An example of when the seepage function would be useful is when estimating the volume of water available for reuse at the downstream end of a bioretention basin that will lose water to seepage.

4.3.3.2 Infiltration properties

Bioretention filter depth generally ranges from 0.4 to 1.0 metre and is often controlled by the height of the discharge point relative to the height of the inlet.

The filter particle effective diameter should correlate to the saturated hydraulic conductivity. Section 10.5 of *Australian Runoff Quality* (Engineers Australia, 2006) provides guidance on typical particle sizes and hydraulic conductivities for a range of soil types. Sandy loam soil is generally adopted as the filter media for bioretention basins and has a effective particle diameter of around 0.45 mm and a hydraulic conductivity of around 180 mm/hr. The default MUSIC filter particle effective diameter of five millimetres is equivalent to coarse gravel which is not suitable for bioretention basin filter media.

4.3.3.3 Outlet properties

The length of the overflow weir controls the discharge rate when the water level in the bioretention basin exceeds the top of extended detention. An undersized overflow weir will result in water "backing up" behind it, effectively adding additional extended detention. It is recommended that, as a starting point, the overflow weir length (m) is set at the surface area (m^2) divided by ten.

4.3.3.4 General

The universal stormwater treatment model (USTM), which uses the specified values of k and c*, only applies to the treatment that occurs within the extended detention part of a bioretention basin. Different algorithms are used to predict the treatment that occurs in the filter media.

It is recommended that the bioretention parameters not specifically described in this section are left as the default values for modelling typical stormwater treatment bioretention basins.

4.3.3.5 Bioretention in series

MUSIC uses independent calculations to determine the pollutant reductions in two components of bioretention systems:

- Extended detention
- Filter media

The pollutant reduction in the extended detention component is based on the specified k, c* parameters so reductions in this component will plateau as incoming concentrations are at or below c*.

The pollutant reductions in the filter media component are calculated using the equations in Appendix D.3 of the MUSIC manual. The percentage reduction achieved is calculated as a function of detention time and particle size only. It does not take into account the incoming pollutant concentrations. The equations are based on observed relationships derived from monitoring data which would assumedly be from single bioretention systems accepting untreated stormwater, not treated stormwater.

It is for this reason that when modelling bioretention basins in series MUSIC over-estimates the treatment performance of bioretention basins and as a result there has been an increasing propensity among consultants in Queensland to model bioretention basins in series (to reduce bioretention footprint).

<u>Bioretention basins should not be modelled in series in MUSIC. MUSIC is not calibrated to simulate bioretention basins in series and therefore results in enhanced and artificially high load reduction effectiveness.</u>

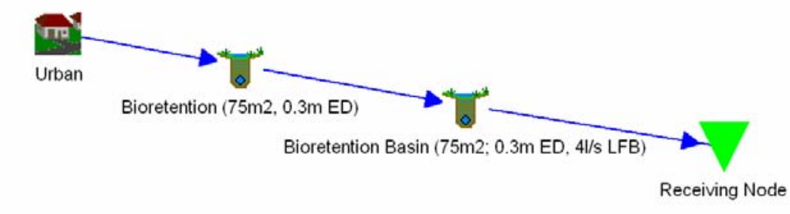
The following is suggested as an interim approach for modelling bioretention basins in series in MUSIC.

The preferred design philosophy for designing bioretention basin in series is to ensure the treated flow that passes through the filter media and discharges from the base of the first bioretention basin does not enter the downstream basin. There is no point treating stormwater that has already passed through the filter media of a bioretention basin because no additional treatment will occur. Only the stormwater that overtops the first bioretention basin (either via the overflow pit or weir) should enter the second basin. This requires a separate drainage system to keep the treated and untreated stormwater separate between the basins.

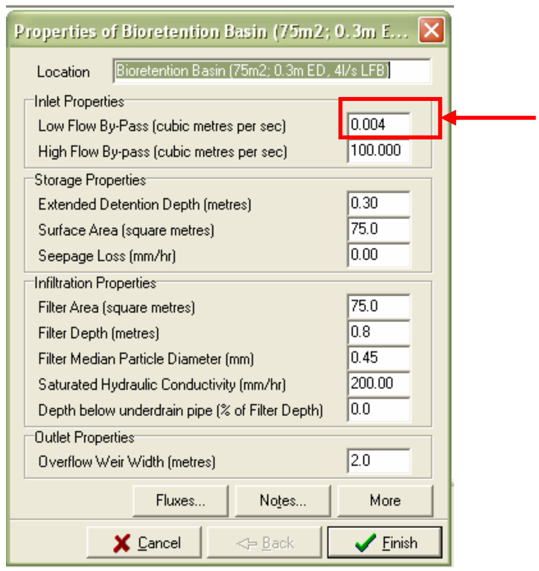
While it is not possible to simulate this exact scenario using standard nodes, a low flow bypass can be inserted in the bioretention basin node to bypass treated flows. This bypass should be set at the filtration rate of the upstream bioretention basin(s) = Filter Media Area x hydraulic conductivity. This ensures larger overflows from the upstream basin enter the downstream basin but treated flows are bypassed (some untreated stormwater will also bypass but this is small in the context of the total stormwater volume).

For example, according to best practice, urban developments in Mackay will require bioretention basins at approximately 1.5% of the development area to achieve the target load reductions for Mackay (assuming rainwater tanks and the other assumptions in this guideline). For simplicity, a MUSIC model is shown in figure below depicting two bioretention basins, each with 75 m^2 filter media area (total 150 m^2, or 1.5% of the catchment area).

While the first bioretention basin is modelled according to the parameters previously described in this guideline, the second (any subsequent) bioretention basin(s) are modelled with the low (predominantly treated) flows from the previous basin bypassing to the receiving node. In this example, the saturated hydraulic conductivity of the initial bioretention basin is 200 mm/hr (equating to 200L/m^2/hr, or 0.055m^3/ m^2/s) and the area is 75m^2, equating to a filtered flow rate of 4.2L/s or 0.004m^3/s (Figure 3).



MUSIC model depicting bioretention basins in series



4.3.4 Swales

This box contains the pre-approved approach for modelling swales. Council will consider alternative modelling approaches, however, justification must be provided in the SBSMP with consideration of the methods described in the remainder of Section 4.3.4.

Inlet properties			
Low Flow By-Pass (cubic metres per sec)	0		
Storage properties			
Length (meters)	User defined		
Bed slope (%)	User defined (less than 4%)		
Base width (meters)	User defined		
Top width (meters)	User defined (max side slopes 1:4 for mowing)		
Depth (meters)	User defined		
Vegetation height (meters)	User defined		
Seepage loss (mm/hr)	0		
Advanced properties			
Number of CSTR cells	10		
	k	C*	C**
Total Suspended Solids	8000	20.000	14.000
Total Phosphorous	6000	0.130	0.130
Total Nitrogen	500	1.400	1.400

The parameters that can be defined for the swale node are shown in table above and are described in Section 3.3.5 of the MUSIC Users Manual.

When modelling to assess reduction in pollutant loads, the seepage parameter should be set to zero.

4.3.5 Bioretention swales

This section relates to modelling bioretention systems with a sloping base, commonly called bioretention swales. For guidance on modelling bioretention systems with a horizontal base, commonly called bioretention basins, refer to Section 4.3.3.

This box contains the pre-approved approach for modelling bioretention swales. Council will consider alternative modelling approaches, however, justification must be provided in the SBSMP with consideration of the methods described in the remainder of Section 4.3.5.

Bioretention swales must be modelled as a bioretention with no extended detention followed by a swale with a low flow bypass set to the infiltration rate of the filter area (see Figure 9)

Bioretention component

Inlet properties		
Low Flow By-Pass (cubic metres per sec)	0	
High Flow By-Pass(cubic metres per sec)	100	
Storage properties		
Surface area (square meters)	Length of swale multiplied by the average width of the filter media in the base of the swale	
Extended detention (meters)	0	
Seepage loss (mm/hr)	0	
Infiltration properties		
Filter area (square meters)	Length of swale multiplied by the average width of the filter media in the base of the swale	
Filter depth (meters)	0.4 - 1.0	
Filter median particle diameter (mm)	0.45	
Saturated Hydraulic Conductivity (mm/hr)	180	
Depth below underdrain pipe (% filter depth)	0	
Outlet properties		
Overflow weir width (meters)	Greater than or equal to surface area (m^2)/10	
Advanced properties		
Weir coefficient	1.7	
Voids ratio	0.3	
Number of CSTR cells	3	
	k	C*
Total Suspended Solids	8000	20.000
Total Phosphorous	6000	0.130
Total Nitrogen	500	1.400

Swale component

Inlet properties			
Low Flow By-Pass (cubic metres per sec)	Infiltration rate of surface (length (m) x base width (m) x hydraulic conductivity (mm/hr)/3600/1000		
Storage properties			
Length (meters)	User defined		
Bed slope (%)	User defined (less than 4%)		
Base width (meters)	User defined		
Top width (meters)	User defined (max side slopes 1:4 for mowing)		
Depth (meters)	User defined		
Vegetation height (meters)	User defined		
Seepage loss (mm/hr)	0		
Advanced properties			
Number of CSTR cells	10		
	k	C*	C**
Total Suspended Solids	8000	20.000	14.000
Total Phosphorous	6000	0.130	0.130
Total Nitrogen	500	1.400	1.400

To model pollutant reductions associated with a bioretention swale, it is recommended that the treatment system is separated into its various components;

- batter slopes (where inflows reach the base of the swale by flowing through a buffer strip perpendicular to the main flow path (e.g. roadside swale)
- Filter component
- Surface swale component.

Figure 10 depicts a standard layout for modelling a bioretention swale.

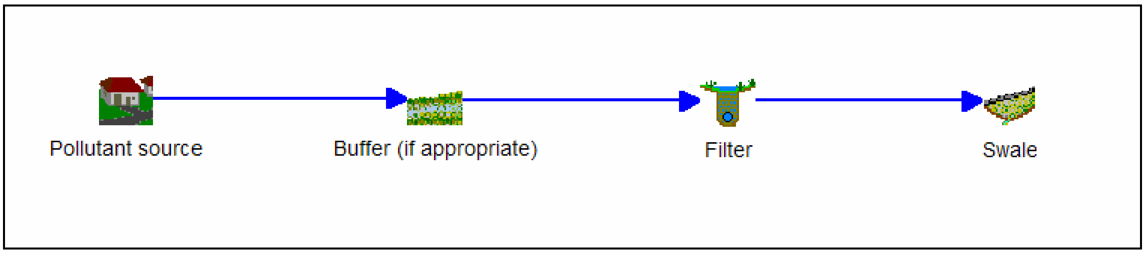


Figure 10 Standard bioretention swale model

There is typically only minimal ponding above the surface of bioretention swales for the majority of rainfall events and so the filter component should be modelled with no extended detention depth.

The other treatment train parameters should be set in accordance with the advice provided in the buffer, bioretention basin, and swale section of these guidelines (refer Section 4.3.3, 4.3.4 and 4.3.6).

4.3.6 Buffer strips

There are no pre-approved parameters for buffer strips.

The parameters that can be defined for the buffer node are shown in Figure 11 and are described in Section 3.3.4 of the MUSIC Users Manual. The buffer node can be used where stormwater runoff from an adjoining impervious surface traverses a vegetated area enroute to the stormwater drainage system or receiving environment.

Buffer nodes are generally located upstream of other stormwater treatment nodes. When modelling to assess reduction in pollutant loads, the seepage parameter should be set to zero.

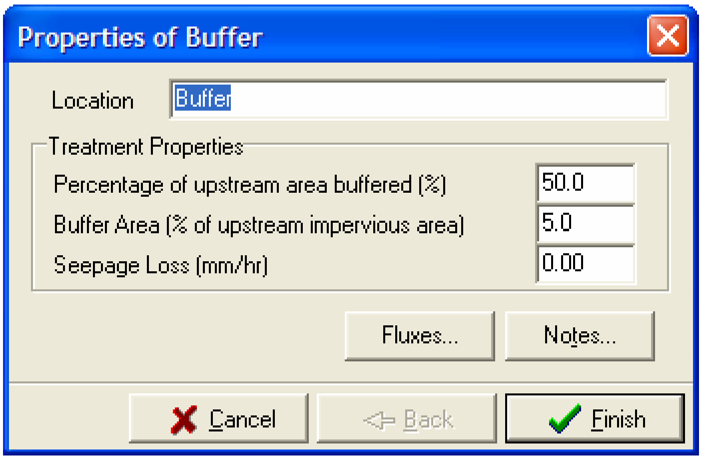


Figure 11 Buffer parameters

4.3.7 Ponds

Ponds and lakes, that is, waterbodies other than sediment basins that are not extensively vegetated, in the Mackay Region are considered receiving water bodies. Stormwater treatment must occur prior to entering these waterbodies and the waterbodies should not be considered as part of a stormwater treatment train. Refer *Engineering Design Guidelines – Constructed Lakes* (MRC) for details of Council requirements of pond and lakes.

4.3.8 Gross pollutant traps (GPTs) and other proprietary products

This box contains the pre-approved approach for modelling proprietary products such as gross pollutant. Council will consider alternative modelling approaches, however, justification must be provided in the SBSMP with consideration of the methods described in the remainder of 4.3.8.

Pollutant	Percentage reduction
Suspended solids	0
Total phosphorous	0
Total nitrogen	0

The parameters that can be defined for the GPT node are described in Section 3.3.2 of the MUSIC Users Manual. This node can also be used to model reductions in loads from other proprietary products.

While GPTs are typically designed to target solids larger 5 mm, they can also provide some reduction in loads of other finer pollutants. As outlined in *Australian Runoff Quality* (Engineers Australia, 2006), GPTs can operate:

- In isolation for primarily aesthetic reasons, to protect downstream waters from litter or to address specific problems such as syringes, or
- As the most upstream measure of a more comprehensive treatment system to protect the integrity of downstream treatments (such as wetlands) by removing the coarsest fraction of the contaminants.

GPTs cannot, in isolation, meet best practice stormwater treatment objectives for all pollutants. In particular, GPTs have only a minimal impact on total nitrogen reduction. Figure 12 below shows indicative upper limits of the amount of total phosphorous and total nitrogen that could be expected to be removed in a GPT relative to the amount of suspended solids that is removed.

If a GPT is designed to capture sediment, consideration should be given to the storage volume available and the acceptable clean out frequency. A clean out frequency of less than 3 months is not acceptable to Council. The density of sediment has been estimated to be approximately 2000 kg/m^3. The required sump volume can therefore be determined by dividing the suspended solids reduction across the GPT node by 2000 to give the annual sediment collection volume and then dividing the annual volume by four to get the three month storage volume. The sediment storage volume required is in addition to the gross pollutant storage volume.

GPTs are generally designed with a high flow bypass. It is important to enter the high flow bypass rate into the gross pollutant node in MUSIC so that no pollutant reductions are attributed to bypassed flows.

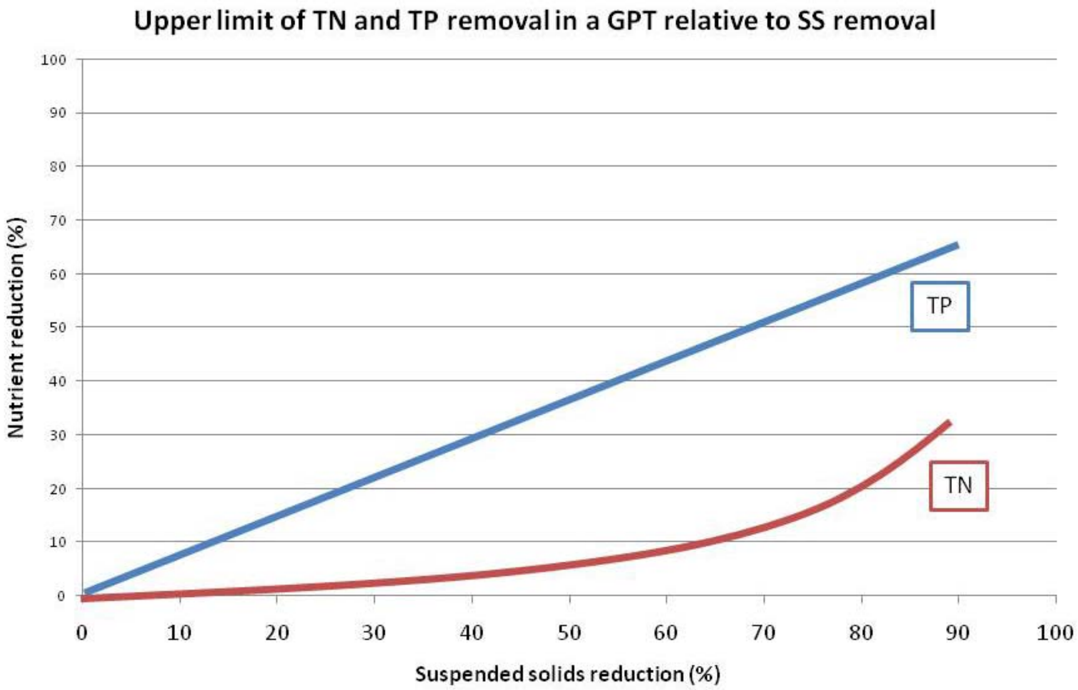


Figure 12 Upper limit of nutrient removal in a GPT relative to suspended solids removal

Where applicants wish to claim reductions for suspended solids or nutrients at GPTs or other proprietary products, they must provide:

1. Adopted pollutant reduction parameters that have been independently verified using a method suited to Mackay conditions;
2. Assumed high flow bypass rate and description of how this was determined; and
3. Calculations to show that GPT storage volume is large enough to contain 3 months of collected sediments and gross pollutants.

4.3.9 Sediment basin

The pre-approved approach for modelling sediment basins is to use the inlet pond of a wetland.

Sedimentation basins designed in isolation to other treatment systems should be designed in accordance with the guidance provided in Section 4.3.7 and the *Engineering Design Guidelines – Constructed Lakes* (MRC) .

The parameters that can be defined for the sediment basin node are described in Section 3.3.8 of the MUSIC Users Manual.

The performance of sediment basins is often simulated using the inlet pond setting integrated within the wetland node. Examples of when a separate sediment basin may be modelled are:

- where the user wishes to obtain information about sediment basin outflows independently from macrophyte zone outflows; and
- the user wishes to split sediment basin outflows between different downstream nodes.

The notional detention time in the sediment basin node is to be set to a short period (e.g. one hour) where there is no “choke” between a sediment basin and a downstream wetland for frequent flows (e.g. ≤ 3 month ARI). A short detention time can be achieved by setting a shallow extended detention depth and/or a large equivalent pipe diameter at the outlet. When modelling a sediment basin that has extended detention and receives “feedback” from the macrophyte zone water levels (i.e. water levels in the sediment basin are controlled by the macrophyte zone outlet) the extended detention volume located above the sediment basin should be included in the extended detention volume of the macrophyte zone node (i.e. make the surface area of the macrophyte zone equal to the total area of the sediment basin and macrophyte zone but ensure the permanent pool volume is set to only represent the permanent water in the macrophyte zone).

4.3.10 Infiltration

There are no pre-approved parameters for infiltration systems. Infiltration systems can be not used achieve stormwater treatment objectives. Stormwater must be treated to the best practice objectives prior to infiltration.

The parameters that can be defined for the infiltration node are described in Section 3.3.7 of the MUSIC Users Manual.

Infiltration nodes are used to simulate the discharge of water vertically from a site. The discharge of water and the associated pollutant loads into the groundwater receiving environment is not considered by Council to contribute to a stormwater treatment train. Stormwater must be trated prior to infiltration which could occur within a bioretention trench which has a leaky bottom to treat stormwater prior to infiltration.

4.3.11 Reuse from treatment nodes

The only pre-approved reuse parameters for reuse are from rainwater tanks (refer Section 4.3.1).

Reuse demand can be set for the following treatment nodes:

- Wetlands
- Ponds
- Sediment basins
- Infiltration basin
- Rainwater tanks.

Demands can be specified to be:

- Constant
- Distributed in proportion to evapotranspiration rates
- Distributed in proportion to a user defined monthly distribution.

Generally, indoor demands are constant whereas irrigation demands are highly seasonal. It should be noted that the units for the constant demand are kL/day whereas the seasonal demands are kL/yr.

4.3.12 Generic nodes

There are no pre-approved parameters for generic nodes.

The parameters that can be defined for the generic node are described in Section 3.3.10 of the MUSIC Users Manual.

The structure of the generic node is similar to the GPT node. The generic node can be used to define an input/output relationship for flow in addition to pollutant concentrations.

A common use of the generic node is to represent a flow split where low flows are directed to one downstream treatment node and high flows to another. Each generic node can only generate one of the split streams (e.g. low flows or high flows). To model multiple streams, the node(s) upstream of the generic node should be replicated.

Where a generic node is used to adjust the inflow/outflow relationship, the "treatment train effectiveness" results function will report differences in annual pollutant loads due to the reduction in increase in flow as well as any actual treatment within the upstream nodes.

Junction nodes

The use of the junction node is described in Section 2.3.4 of the MUSIC Users Manual.

A common use of junction nodes is where results for a group of source and treatment nodes are required.

Receiving water nodes

The use of the receiving water node is described in Section 2.3.4 of the MUSIC Users Manual.

It is not necessary to have a receiving water node at the downstream end of a model. Only one receiving water nodes can be used per MUSIC model.

4.3.13 Linking catchment nodes to treatment nodes

This box contains the pre-approved approach for modelling links between nodes. Council will consider alternative modelling approaches, however, justification must be provided in the SBSMP with consideration of the methods described in the remainder of Section 4.3.13.

No routing to be used.

The parameters that can be defined for links between nodes are described in Section 2.3.5 of the MUSIC Users Manual.

Each treatment node should be connected to at least one upstream source node. Each node can only be connected to one downstream node.

The routing and/or translation functions can be used to adjust the timing of flow arriving at a downstream node. The default setting of no translation or routing is a conservative approach for assessing treatment performance as the model assumes that flows and associated pollutants from all parts of a catchment arrive at a treatment node at the same time which means that MUSIC may over-predict the overflow volume. For small catchments where the time of concentration is not significantly longer that the modelling time-step, the use of routing is not recommended.

4.4 STEP 4: Results

There are many options for generating output from a MUSIC mode. The most suitable output format will be influenced by what the model is being used to assess.

A site based stormwater management plan (SBSMP) must specify the pollutant reductions achieved by the treatment train along with a summary of the model setup and any variation from the pre-approved approach. The minimum contents of a Site Based Stormwater Management Plan are listed in Appendix B. An examples plan for a residential and industrial site can be downloaded from Councils website.

4.4.1 Running models

MUSIC models are “run” by clicking the green triangle button located in the top left hand corner of the screen.

The model run time is a function of computer speed, the number of nodes in the model and number of time steps in the met data in the model template.

The running of MUSIC models is generally most stable if other applications are not used during the run time. The starting of a screen saver during a MUSIC modelling run should be avoided as it can sometimes cause problems.

If an open model has been run once, and adjustments made, subsequent model runs will only involve computations for nodes and links at or downstream of where adjustments have been made. This means that subsequent modelling runs are generally quicker than initial runs.

4.4.2 Catchment summary

The options for creating a catchment summary file are described in Section 4.10 of the MUSIC Users Manual.

This function generates a summary of the parameters defined in all nodes and links in the model. It does not include any information on modelling results outputs.

4.4.3 Graphical

The options for creating timeseries and cumulative frequency graphs are described in Section 4.3 and Section 4.5 of the MUSIC Users Manual. These outputs are useful to obtain a visual summary of the inputs and outputs of various nodes.

The flow based subsample feature can be used to generate cumulative frequency graphs for flows between an upper and lower threshold. This function is useful when

- considering cumulative frequencies of flows but excluding time periods where there is zero flow; and/or
- considering base flow independently to storm flow.

4.4.4 Statistics

The options for reporting statistics are described in Section 4.4 of the MUSIC Users Manual. These functions are useful to obtain a numerical summary of the inputs and outputs of various nodes.

The most commonly used statistical outputs for assessing compliance with stormwater treatment objectives are the “mean annual loads” (refer Figure 13) and “treatment train effectiveness” functions.

Figure 13 Example Mean Annual Loads and Treatment Train Effectiveness outputs

The mean annual load function reports the input, outputs and percentage reduction of flows (ML/yr), suspended solids (kg/yr), total phosphorous (kg/yr) and total nitrogen (kg/yr) across a single node. In comparison, the treatment train effectiveness function reports the inputs, output and reductions across the node that is being interrogated and all upstream nodes. As discussed in Section 4.3.12, the treatment train effectiveness function should not be used at or downstream of a generic treatment node that adjusts flow volumes.

4.4.5 Flux files

The method for generating flux files is described in Section 3.2.1 of the MUSIC Users Manual.

Flux files are text files containing all computer variables at a node for every time step in the meteorological template. They can be generated at any source or treatment node.

These files can be used to manually track the relationship between inflows and outflows and/or obtain information that is not available in other output options. For example, a flux file could be used to track water levels in a wetland.

The number of time steps in a model's meteorological template will determine the number of rows in a flux file. Where flux files are to be viewed/analysed in software programs that have row number limitations (e.g. Excel), consideration should be given to restricting the number of modelling time steps. Where there is a desire to consider more time steps than will fit in the software, the meteorological template can be "split" into multiple time periods that have an appropriate number of time steps.

4.4.6 Export files

The method for exporting files from treatment nodes is described in Section 4.8 of the MUSIC Users Manual.

This function allows the export of flow, pollutant concentration and or pollutant load data at a time step equal or coarser than the time step of the model's meteorological template. The main differences between "flux files" and "exported data files" are:

- Flux files can be generated at source nodes and treatment nodes whereas exported data files can only be produced for treatment nodes;
- Flux files contain the full range of computed variables for a particular node whereas exported files may only contain flow, pollutant concentration and or pollutant load data; and
- Flux files are generated at the same time-step as the model's meteorological template whereas exported data files can be generated for a coarser template.

4.4.7 Life cycle costing

For information of the life cycle costing function of MUSIC refer to Section 7 of the MUSIC Users Manual.

The life cycle function can be used to estimate acquisition (construction), typical maintenance, renewal/adaption and decommissioning costs. These estimates should be used as a guide only. More accurate estimates may be possible from more recent, specific and/or local cost data. The 'cost/size' relationships used in the model are based on real data collected from around Australia in 2002-04.

5 REFERENCES

Brisbane City Council, 2003, Guidelines for Pollutant Export Modelling in Brisbane, Version 7 – Draft

Engineers Australia, 2006, Australian Runoff Quality

Gold Coast City Council, 2006, MUSIC Modelling guidelines

Stormwater Quality Management Plan for Mackay (MRC 2006)

Water Corporation, 2007, MUSIC Guidelines for Perth, Draft Final Report

Moreton Bay Waterways and Catchments Partnership, 2006, Water Sensitive Urban Design Guidelines for South East Queensland

Wyong Shire Council, 2008, *Water Sensitive Urban Design Technical Guidelines #4 Concept Design Tools (DRAFT)*

APPENDIX A: Calibration of catchment nodes to local soil conditions

For each catchment node, MUSIC uses the percentage impervious of the catchment area and a series of user defined rainfall runoff parameters (e.g. rainfall threshold and soil storage capacity) to calculate the proportion of rainfall that is converted to runoff. This Appendix provides a summary of the method used to determine the three sets of parameters that are recommended for use in Section 3.2.4 of the Guidelines. These parameters have been defined so that the rainfall runoff relationship predicted by MUSIC for a given catchment is similar to the actual rainfall runoff relationship.

Impervious area parameters

The only rainfall runoff parameter that is used to calculated runoff from impervious surfaces is “rainfall threshold”. This parameter relates to the amount of water that it takes to wet a surface before runoff occurs. It is a function of the type of surface and is not region/site specific. For example, rougher surfaces are likely to have higher rainfall thresholds than smooth ones. The MUSIC default rainfall threshold of one millimetre per day is considered suitable for typical urban surface (roofs, footpaths, roads) and has therefore been adopted for Mackay.

Pervious area parameters

The proportion of rainfall falling on pervious surfaces that is converted to runoff is a function of the local soil and groundwater properties. The nine pervious area rainfall runoff parameters defined in MUSIC do not individually represent soil and groundwater properties that can be measured in the field, but together the set of parameters should ensure that the runoff time series predicted by MUSIC is representative of the actual flow.

Three soil categories were adopted; sandy, lowland and uplands as described in Section 0 of the guidelines. Therefore, to calibrate the nine pervious area rainfall runoff coefficients for each soil type, a corresponding rainfall and runoff timeseries for a catchment of a particular soil type are required. The longer the record and the smaller the timestep, the more accurate the calibration. Any storages and or extraction of runoff from the catchment above the gauging point affects the accuracy of the calibration. Ideally catchments used for calibration would contain only one soil type and be of a similar size to a typical urban development.

The only local flow timeseries that could be found were on the Natural Resources and Water website (www.nrw.qld.gov.au). Nine data sets were found for locations within or adjacent to the Mackay Regional Council boundary with catchment areas less than 1000 km^2. A summary of the datasets is shown in Table 12.

Table 12 Flow and rainfall gauging sites

Gauging station	Catchment Area (km^2)	Rainfall record	Runoff record
Andromache River @ Jochheims	230	1955 to 2006	1995 to 2006
O’Connell River @ Stafford’s Crossing	340	1989 to 2006	1969 to 2006
St Helens Creek @ Calen	118	1989 to 2006	1973 to 2006
Jolimont Creek @ Mt Roy	23	1998 to 2006	1998 to 2006
Finch Hatton Creek @ Dam site	506	1990 to 2006	1973 to 2006
Cattle Creek @ Gargett	326	None	1967 to 2006
Broken River @ Old racecourse	100	1991 to 2006	1969 to 2006
Sandy Creek @ Homebush	326	1905 to 2007	1966 to 2007
Black Creek @ Whiteford	506	1990 to 2006	1973 to 2006

The catchment areas were overlayed on the soils map (Figure 3). None of the gauging station catchments contain predominantly lowland or sandy soil types. The gauging station on Jolimont Creek at Mt Roy is the smallest catchments with predominantly upland soil types. The mean annual runoff coefficient for the Jolimont

Creek site is 0.28. While this timeseries is the best available, it is not ideal for calibration as the catchment area (23 km^2) is much larger than the area of a typical urban development.

In the absence of suitable local data for calibration, rainfall runoff parameters derived for similar soil types in other parts of Australia have been adopted for Mackay. Parameters derived for the lowland and upland soils in Wyong, NSW (Wyong Shire Council, 2008) were adopted as were parameters derived for sandy soil in Perth (Water Corporation, 2007). A summary of the source of adopted parameters and the corresponding mean annual runoff using Mackay rainfall data is shown in Table 13. It can be seen that the adopted upland parameters give the same mean annual runoff coefficient as the gauging station on Jolimont Creek at Mt Roy.

Table 13 Source of adopted rainfall runoff parameters

Soil type	Source	Mean annual runoff coefficient using Mackay rainfall data
Upland	Wyong City Council, 2008	0.28
Lowland	Wyong City Council, 2008	0.32
Sandy	Water Corporation, 2007	0.11

APPENDIX B: Site based stormwater management plan contents

For an example residential and industrial site based management plan please refer to Council's website.

1. Introduction

- Submission date
- Developer name
- Consultants name
- Current and proposed land use of development site
- Description of site location (including street directory reference)
- Reference to associated documents

2. Location Plan

- plan showing site location including major roads and landmarks in vicinity

3. Site plan (development plan)

- plan showing site boundary, drainage direction(s) receiving waters

4. Proposed landuses

Land type	Area (ha)	Assumed impervious area
Open space/parkland		
Low density residential		
Medium density residential		
High density residential		
Industrial		
Commercial		
TOTAL/OVERALL		

5. Location conditions

Rainfall zone	
Soil category	

6. Strategy description and plan

- Plan (with scale bar) showing sub catchment boundaries (including any untreated areas)
- Treatment area locations and indicative footprints (including allowance for batters)
- Description of how runoff will be conveyed to treatment systems
- Confirmation that treatment system can drain (i.e. outlet can freely drain)

7. Subcatchment table

Sub catchment code	Sub-catchment land use category	Treatment codes	Sub -catchment area (ha (% imp))
A	(refer to Table 4 of MUSIC Guidelines)	(include all if more than on in series)	
B			
TOTAL			

8. Treatment element table

Tank(s)

Treatment code	Number of houses	Total tank volume (kL)	Total tank constant demand (kL/day)	Total tank seasonal demand (kL/yr)

Bioretention system(s)

Treatment code	Surface area (m^2)	Filter area (m^2)	Extended detention (m)	Filter depth (m)

Swale(s)

Treatment code	Low flow bypass (m^3/s)	Length (m)	Slope (%)	Base/top width (m)	Depth (m)	Veg height (m)

Wetland(s)

Treatment code	Inlet pond volume (m^3)	Macrophyte zone area (m^2)	Extended detention (m)	Permanent pool volume (m^3)	Notional detention time (hrs)

9. Model setup

- Screen dump of MUSIC model
- record of version of MUSIC used

10. Results table

Treatment code		Inflows (kg/yr)	Outflows (kg/yr)	Reduction (kg/yr)	Reduction (%)
	SS TP TN				
TOTAL (ensure total inflows does not "double count" flows from catchments with a treatment train e.g. roof runoff)	**SS** **TP** **TN**				

- Confirmation that best practice objectives have been met