WYONG SHIRE COUNCIL

WATER SENSITIVE URBAN DESIGN TECHNICAL GUIDELINE

CONCEPT DESIGN TOOLS

November 2010

Document Control Sheet		
DRAFT	April 2008	For Exhibition
DRAFT	April 2009	Remove MUSIC help menus and other minor amendments.
DRAFT	Nov 2010	Amend for revised IWCM Strategy, NSW MUSIC Modelling Guidelines & WSC Deemed to Comply Provisions. For Exhibition.
FINAL	July 2012	Amended for inclusion as an appendix to the "Civil Works Design Guidelines.

Table of Contents

1.0 INTRODUCTION

This document contains the following three tools:

- Stormwater quality (MUSIC) modelling guidelines (Section 2);
- Stormwater storage design curves (Section 3);
- Stormwater storage modelling tool (Section 4).

These tools are relevant to the Development Application stage of the design and approval process. Other useful tools, relevant to the detailed design stage of the process, can be found in the Australian Runoff Quality (ARQ) by Engineers Australia.

This document expects a certain level of knowledge of the MUSIC program. Information and training is available on MUSIC. Go to www.ewater.com.au for further information.

Water quality modelling is required to demonstrate compliance with the stormwater quality objectives.

Section 2 details the stormwater quality modelling guidelines and includes the following sections:

- Sections 2.3 to 2.6 cover key inputs to the MUSIC model, including meteorological data, catchment details, rainfall runoff parameters and pollutant generation parameters. These sections guide the setup of the MUSIC model.
- Section 2.8 describes how to model stormwater treatment elements in MUSIC, including wetlands, sedimentation basins, infiltration basins, gross pollutant traps, buffer strips, bioretention systems, swales, bioretention swales and rainwater tanks.

Section 3 details the stormwater storage design curves for standard development applications. The stormwater storage design curves and associated modelling tool are designed to assist in demonstrating compliance with the wetland hydrology objectives and/or waterway stability objectives for broad, undefined drainage depressions. The stormwater storage design curves can be used for standard applications (e.g. typical detached dwellings, attached dwellings, multi-storey residential, commercial and industrial land uses) or for an initial estimate of stormwater storage requirements.

Section 4 details the stormwater storage design tool for non-standard development applications. Non-standard applications are when the design principles specified in Section 3 are not adhered to or site conditions and WSUD designs are non standard regional IWCM design parameters are not adhered to. It includes the following sections:

- Sections 4.1 describes how to use MUSIC to produce flow time series data for the pre- and post-development scenarios.
- Section 4.2 also describes how to model different types of stormwater storages, including: active storages, storages for reuse, detention storages.
- Section 4.3 describes the use of the post processing tool, which translates time series flow data into low and high flow duration frequency curves and low flow spells frequency curves.
- Section 4.4 describes how to check compliance with the wetland hydrology and waterway stability objectives.

THE GUIDELINES AND TOOLS WITHIN THIS DOCUMENT PROVIDE INFORMATION IN RELATION TO THE *MUSIC* MODELLING TOOL KIT. OTHER MODELLING TOOLS ARE ON THE MARKET AND CAN BE USED WITH PRIOR APPROVAL FROM COUNCIL.

2.0 STORMWATER QUALITY (MUSIC) MODELLING GUIDELINES

2.1 Introduction

Recent developments in urban stormwater quality modelling software have resulted in a significant advancement in the ability to simulate the pollutant removal efficiency of a range of stormwater treatment devices. Specifically, MUSIC (Model for Urban Stormwater Improvement Conceptualisation) developed by the Cooperative Research Centre for Catchment Hydrology (CRC-CH) now provides stormwater practitioners with a conceptual design tool that estimates stormwater pollutant generation and the performance of stormwater treatment measures. MUSIC is designed for use by a range of stormwater professionals who require a good understanding and knowledge of stormwater management principles. MUSIC can be used to:

- Undertake conceptual design of stormwater treatment elements;
- Undertake stormwater storage modelling to establish the size of stormwater storages. This is required if stormwater storage curves provided in Section 4 do not adequately represent the proposed harvesting strategy in a particular catchment.

These guidelines are provided to ensure consultants, developers and Council have a consistent and uniform approach to stormwater quality and harvesting modelling within the Wyong Shire region. The guidelines provide specific guidance on rainfall and evaporation inputs, source node selection, rainfall runoff parameters, pollutant generation parameters, stormwater treatment nodes and stormwater storage nodes. The use of parameters different to those listed in this document must be justified.

These guidelines should be read in combination with the *NSW MUSIC Modelling Guideline*[1] *s (BMT WBM 2010)* and the MUSIC User Guide, which outlines all the definitions, assumptions and methodologies provided within the MUSIC tool.

2.2 MUSIC Model Setup

A MUSIC model requires a significant amount of information during the model set-up stage. These steps include the selection and input of the following information:

- Appropriate meteorological data (rainfall and evaporation inputs);
- Defining catchment areas (source nodes) to be incorporated into the model;
- Appropriate soil properties (rainfall runoff properties); and
- Pollutant generation characteristics for selected source nodes.

These are discussed in further detail in sections 2.2 – 2.7.

[1] Guidelines are available for download from the *eWater* Toolkit – see http://www.ewatercrc.com.au/index.html

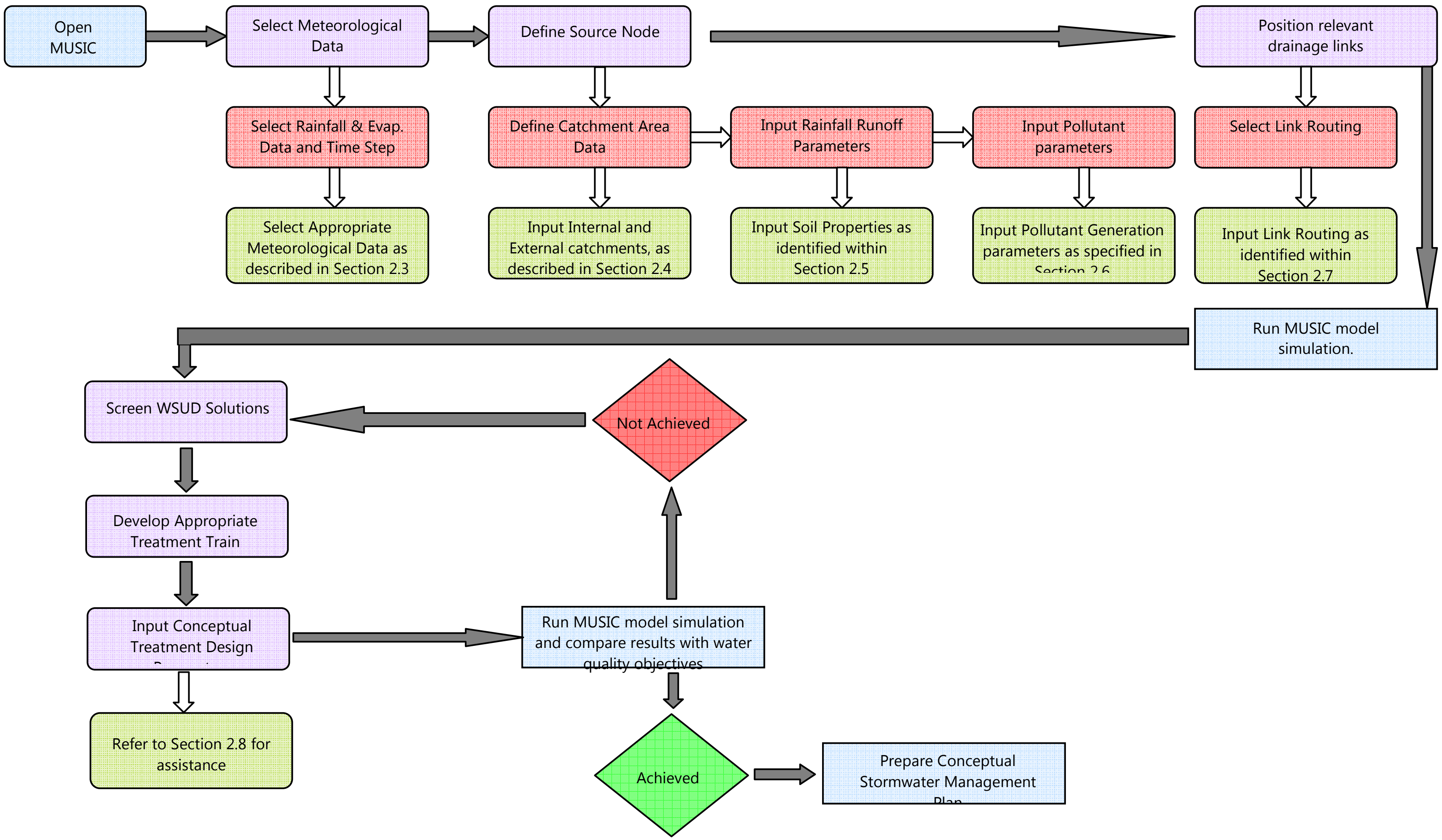


Figure 1 Schematic of MUSIC modelling process (as adapted from the Gold Coast City Council MUSIC Guidelines)

2.3 Rainfall and Evaporation Inputs

Stormwater runoff is represented as both surface runoff and baseflow in the MUSIC model. It 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). The following sections outline Council's preferred rainfall and evapotranspiration datasets to be used when undertaking stormwater quality designs and hydrologic investigations for stormwater harvesting.

2.3.1 Rainfall Data for Water Quality Modelling

Council requires the following approach to rainfall simulation be adopted for stormwater quality modelling:

- Continuous simulation of a minimum of 10 years; and
- A six (6) minute time step is to be utilised as this allows for the appropriate definition of storm hydrograph movement through small-scale stormwater treatment processes such as vegetated swales and bioretention systems.

To provide a consistent approach to stormwater modelling, Council has identified an appropriate rainfall station for the Shire, and periods of modelling to be utilised within the MUSIC model. Three 6 minute data stations were investigated for their suitability. These included rainfall stations at:

- Kulnurra (William Road), approximately 25km west of Wyong;
- Peats Ridge approximately 20 km west-southwest of Wyong;
- Sydney Observatory Hill, approximately 70-75 km south-southwest of Wyong.

Comparison of rainfall at various stations in Wyong Shire and Sydney Observatory Hill are shown below in Figure 2.

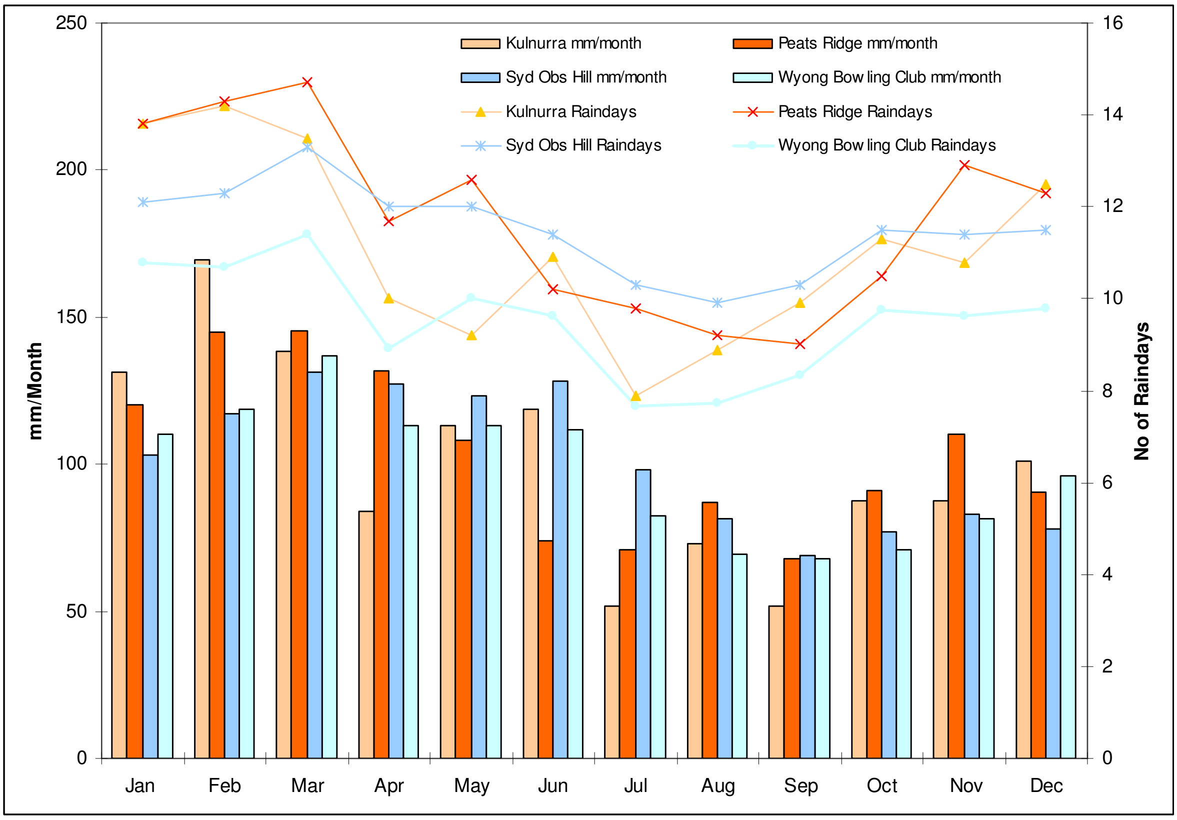


Figure 2 Minute Rainfall Station Comparison

Wyong Shire Council has identified that the 6 minute rainfall data at Sydney Observatory Hill is comparable to the rainfall experienced in the Wyong Shire, with the rainfall and number of raindays per month, when compared to Wyong Bowling Club rainfall records. It consistently has about one more rain day a month than Wyong, suggesting that rainfall at Wyong Bowling Club is more intense than at Sydney.

Given the above, Council requires all stormwater quality modelling in MUSIC to be undertaken using the Sydney Observatory Hill rainfall data and the modelling period between 1973-1993 (refer Table 1).

Table 1: Recommended 6 Minute Rainfall Station

Rainfall Station	Modelling Period	Annual Rainfall (mm)
Sydney Observatory Hill (station 066062)	1973-1993	1273

2.3.2 Rainfall Data for Hydrologic Modelling

The following approach is to be undertaken for hydrologic assessment modelling. That is, modelling required for stormwater harvesting and stormwater storage design in response to wetland hydrology and waterway stability objectives.

Continuous simulation of a minimum of 20 years should be used, including:

- Daily time step is to be utilised for simulating stormwater storage sizes where the pump rate drains the storage over three days or greater;
- minute to hourly time step is to be utilised for storages where the pump rate drains the storage in less than three days;
- The rainfall data contains a wet, dry and average rainfall year.

Wyong Shire Council has identified two appropriate daily rainfall stations to be utilised within the MUSIC model for hydrologic modelling. Sydney Observatory Hill is the preferred rainfall station (refer section 2.3.1). However, if daily rainfall data is required, then the Wyong Bowling Club rainfall records can be used.

Table 2: Recommended Daily Rainfall Station

Rainfall Station	Modelling Period [2]	Mean Annual Rainfall (mm)
Sydney Observatory Hill **(preferred)**	1963-1993	1222
Wyong Bowling Club	1918-1965	1184

2.3.4 Evapotranspiration Data

Wyong Shire Council found that Sydney evaporation data closely matches that from the Wyong Shire region (although slightly higher) and is therefore suitable for use in MUSIC modelling for water quality and hydrology. The monthly evapotranspiration values for Sydney are shown in Table 3and the comparison with Peats Ridge and Kulnura is illustrated in Figure 3.

[2] Select a period that has minimal gaps in the data

Table 3: Evapotranspiration Values

Month	J	F	M	A	M	J	J	A	S	O	N	D
Evapotranspiration(mm)	180	135	128	85	58	43	43	58	88	127	152	163

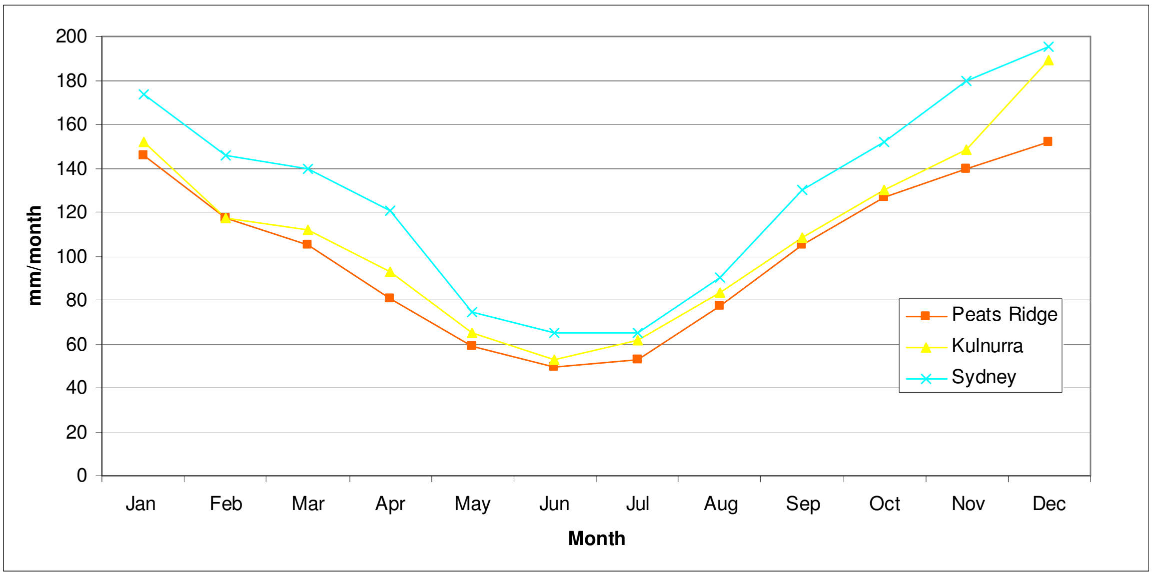


Figure 3 Comparison of evaporation data for Sydney and Wyong regions

2.4 MUSIC Source Nodes

The source nodes must be defined to reflect the details of the contributing catchments of the development. Source Nodes for Wyong Shire catchments are defined below:

- The Urban Source Node in MUSIC is used to describe low to high density residential, commercial and industrial areas. These land uses include lots with all associated facilities, such as roads and parks;
- The Agricultural Source Node refers to areas of large scale cropping or grazing. This node should be only be used for low density rural areas situated in predominantly agricultural settings;
- The Forested Source Node is to be used for natural bushland areas. This node is to be utilised in areas where canopy densities are greater than 50%;
- The Imported Data Source Node is to be utilised in the regional storage and harvesting scenario modelling. This setup is explained in further detail in Section 0.

Each individual Source Node, with the exception of the Imported Data Node, requires the total area and impervious percentage of the site to be defined.

An initial estimate of percentage impervious for each particular land use should be based on the ultimate zoning of the area, reflecting the ultimate land use of the catchment. Building density controls for urban areas must also be considered, including elements such as minimum soft landscaping area, maximum building envelopes, floor space ratios and road design guidelines. These estimates should also be compared to aerial photos of similar recent housing developments in the vicinity of the proposed development.Where differences between the estimates and the on ground impervious area are significant then estimates should be revised or the differences justified. Consult Part 10 – STORMWATER DRAINAGE DESIGN of the Civil Works Design Guideline for further information on determining development impervious areas.

2.4.1 Urban Land Use Split

The urban node must be split into the various land use types (i.e. road reserve, roof, ground level pervious and impervious) when the following proposed developments are modelled:

- a single lot (including commercial and industrial);
- a single street (including multiple lots);
- the influence of rainwater tanks within a development (regardless of the size of development).

When utilising this approach:

- Roof areas are to be modelled as 100% impervious;
- Road reserve areas include the road and adjacent landscaping and footpaths contained within the road reserve. Imperviousness of this node should be approximately 70%; and
- Remaining ground areas can be further split into pervious and impervious areas when required.

An example of an urban land-use split in MUSIC is shown below:

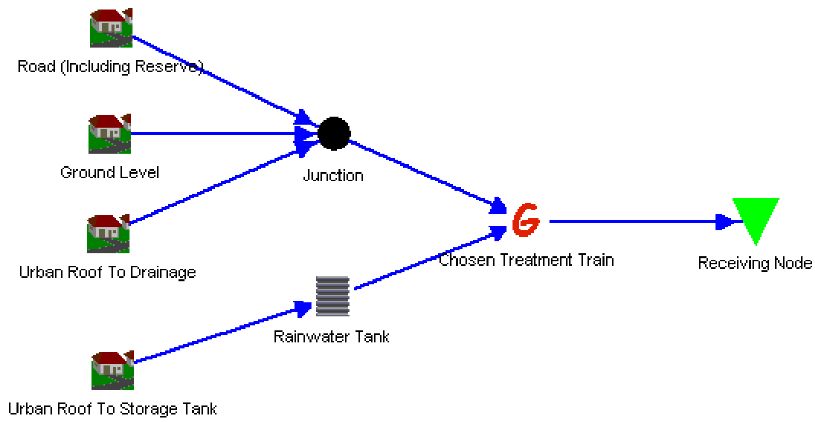


Figure 4 Example MUSIC model setup including a rainwater tank

2.5 Rainfall Runoff Parameters

Stormwater runoff (represented as storm flow and baseflow) is generated in MUSIC through the interaction of rainfall, evapotranspiration and the MUSIC Rainfall-Runoff Model[3].

MUSIC rainfall-runoff parameters were derived for the Wyong Shire region through a calibration process to stream information for Jilliby - Jilliby Creek (upstream tributary of Wyong River). Details of this calibration process is provided in the *DRAFT Discussion Paper Modelling Rationale for the Porters Creek Stormwater Harvesting Strategy (Ecological Engineering 2006)*.

Based on the calibration to stream flow data at Jilliby - Jilliby Creek two general pervious source nodes were developed, an 'upland' and 'lowland' node, based on the following catchment geography:

- Upland nodes are areas within the catchment where slopes are generally greater than 5%., and are typically found in the headwaters of the catchments;

[3] A full description of the MUSIC Rainfall-Runoff Model is provided in the MUSIC User Manual.

- Lowland nodes are areas with slopes generally less than 5% and are typically found in the floodplain zone of unconfined valleys of a higher order creek.

Pervious areas must be modelled as upland or lowland area depending on the location of the development within Wyong Shire.

Section 2.5.1 outlines the way to determine whether a development is in an upland or lowland catchment. Section 2.5.2 outlines the steps to inputting this data into the MUSIC Source Node Parameters.

2.5.1 Defining Upland and Lowland Areas

To delineate between upland and lowland areas, the following steps should be undertaken:

a Obtain the best available contour data for the catchments of interest.

b Make an initial visual assessment of the contour information based on obvious changes in slope and topography for a rough estimation of upland and lowland areas.

c Calculate ground slopes (%) for the area of interest. A Digital Elevation Model may be of assistance in delineating upland and lowland areas for larger catchments.

d Analyse slope data to identify areas greater than and less than approximately 5% slope. **Slopes <5% are considered lowland and slopes >5% are considered upland.** Note: It may be necessary to repeat this step with slopes of 2-6% in order to achieve a reasonable delineation between upland and lowland areas.

e Perform a manual check and edit anomalies. Common anomalies include relatively flat areas in the upper part of the catchment (e.g. gently sloping hill tops). These areas should be modelled as upland to reflect the likely soil properties.

A site-specific assessment should be performed for most developments, to generate more detailed information at a scale appropriate to the individual development.

2.5.2 Rainfall – Runoff Parameters for Upland and Lowland Areas

The following soil characteristics are to be used in the rainfall-runoff parameters of upland and lowland areas:

Table 4: Soil Characteristics

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

Note: The above rainfall threshold values are an average value for the various land-use types. Refer to the NSW MUSIC Modelling Guidelines [4] for specific threshold values relating to roofs, roads etc.

2.6 Pollutant Generation

The recommended model defaults for various land use categories is based on research by Fletcher et al. (2004). These are to be as per the guidelines listed in *NSW MUSIC Modelling Guidelines*.

Note: For all simulations the MUSIC model must be run with pollutant export estimation method set to "stochastic generated".

2.7 Link Routing

Routing may be used to reflect the travel time for flood wave propagation through the catchment. For all MUSIC model simulations it is recommended that the channel routing option in MUSIC be set to "No Routing" as this is the most conservative modelling scenario.

If the routing option is used in the model, suitable justification is required to be submitted with the concept design. Translation only method or Muskingham-Cunge method are to be used if the routing option is chosen. The user is referred to the MUSIC User Manual for further details.

[4] Guidelines are available for download from the *eWater* Toolkit – see http://www.ewatercrc.com.au/index.html

2.8 Stormwater Quality Treatment Nodes

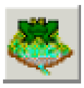
Several stormwater treatment elements are available in MUSIC as shown adjacent. Once the WSUD objectives have been determined for a site, an appropriate treatment train can be modelled in MUSIC.

Note 1*: The following devices are not to be modelled within the MUSIC program: natural waterways, natural wetlands, naturalised channel systems, environmental buffers and natural lake/pond systems. The following Sections 2.8.1 to 2.8.10 briefly outline each treatment element available in MUSIC, and parameters to be used, if applicable. Further reference should be made to the MUSIC user manual.*

Note 2*: MUSIC is a conceptual comparison tool only, not a design tool. It is essential that devices included in a model are achievable within the modelled catchment. The designer should carry out preliminary calculations to ensure that devices included can be drained and adequate allowance had been made for batters in restricted areas.*

A summary of modelling guidelines is provided below.For further details and modelling requirements for rainwater reuse, pervious pavements and other treatment measures refer to the *NSW MUSIC Modelling Guidelines*.

2.8.1 Wetland



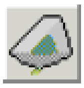
Constructed wetland systems use enhanced sedimentation, fine filtration and pollutant uptake processes to remove pollutants from stormwater. Constructed wetland systems consist of:

- an inlet zone (sediment basin to remove coarse sediments);
- a macrophyte zone (a shallow heavily vegetated area to remove fine particulates and uptake of soluble pollutants); and
- a high flow bypass channel (to protect the macrophyte zone).

The following parameters are to be included when modelling a wetland:

- Extended detention depth of between 0.25 - 0.75m;
- Seepage losses set to zero unless geotechnical soil testing indicates otherwise;
- Adjust the pipe diameter or orifice size to ensure the device has adequate detention time (a notional detention time of 48 hours to 72 hrs is required) . Sizes less than 100mm diameter are to consider appropriate screening to prevent blockage.

2.8.2 Sedimentation Basin



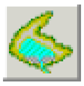
Sediment basins are used to retain coarse sediments from runoff. They operate by reducing flow velocities and encouraging sediments to settle out of the water column.

They are frequently used for trapping sediment in runoff during construction activities and for pre-treatment to measures such as wetlands and are sized according to the design storm discharge and the target particle size for trapping (generally 0.125 mm). These devices can be utilised as pre-treatment devices upstream of bioretention devices to allow for a diversion of flows above recommended scour velocities.

The following parameters are to be included when modelling a sedimentation basin:

- Seepage losses set to zero unless soil testing indicates otherwise;
- Adjust the pipe diameter to ensure the device has a detention time of approximately 48 - 72 hours.

2.8.3 Infiltration Basin



Infiltration measures encourage stormwater to infiltrate into surrounding soils. Infiltration measures are highly dependent on local soil characteristics and are best suited to sandy and sandy clay soils with deep groundwater. Generally geotechnical assessment is to be undertaken before infiltration is considered at a particular site.

Note: Infilltration measures are not treatment systems and suitable pre-treatment of stormwater is required prior to entering the infiltration measure. When assessing pollutant removal performance in MUSIC, the water quality objectives should be met upstream of any infiltration system.

The following parameters are to be included when modelling an infiltration basin:

- Establish the infiltration rate based on findings from a geotechnical engineering report or soil percolation test to determine the likely infiltration rate from the device to the surrounding soils.

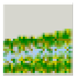
2.8.4 Gross Pollutant Trap

Gross Pollutant Traps (GPT's) typically remove rubbish, sediment and hydrocarbons from stormwater runoff. GPT's can be very effective at removal of solids conveyed within stormwater which are typically larger than 5mm in size.

There are no specific input parameters for GPT's.

Pollutant removal efficiency of gross pollutant devices will have to be adequately demonstrated by independent testing. Pollutant removal efficiencies claimed by manufacturers of proprietary devices are not considered sufficient. Manufacturer's claims must be supported by independent testing comprising continuous monitoring of the product for a time frame of three months after an initial storm event. [5].

[5] Typically independent testing would be carried out over a minimum three month period. The test results should include various documented design events (and include typical stormwater runoff from the chosen land use). No pollutants are to be removed from the device during the assessment of the device to mimic the actual maintenance regime of GPT's within the Wyong Shire.

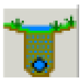
2.8.5 Buffer 

Buffer or filter strips, in the context of urban stormwater, are grassed or vegetated areas over which stormwater runoff from adjoining impervious catchments traverses enroute to the stormwater drainage system or receiving environment. Buffer strips are intended to provide discontinuity between impervious surfaces and the drainage system. Buffer strips receive water from impervious surfaces in a distributed manner, promoting uniform flows while enabling minor filtration of sediments and coarse pollutants. The most important component of a buffer strip is its ability to distribute flows over a wide vegetated area. They also provide a minor detention role to slow flows down. The buffer design in MUSIC must be a realistic representation of the post-construction scenario for incoming flow discharge points.

The following parameters are to be included when modelling a buffer area:

- The seepage losses set to zero.

***Note**: Utilise buffer devices upstream of other treatment devices to assist in sediment drop out prior to stormwater entering secondary treatment devices i.e. swales.*

2.8.6 Bioretention 

Bioretention systems (also known as biofiltration trenches) are a combination of vegetation and filter substrate that provides treatment of stormwater through filtration, extended detention and some biological uptake.

The following parameters are to be included when modelling a bioretention area:

- Ponding depths of 0.1 to 0.30 metres are recommended for plant sustainability and adequate draining times. Depths greater than 0.40 metres not recommended;
- Minimum depth within the device: > 0.5 m for rushes and shrubs and > 0.8 m for tree species;
- The seepage losses set to zero.

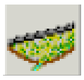
a Provide the proposed depth of filter media within the device. The following depths are recommended as a minimum within the device: > 0.5 m for rushes and shrubs and > 0.8 m for tree species proposed to ensure adequate area for root growth are provided within the device. This depth does not include the drainage layer;

b Identify the type of filter media proposed based upon particle size and hydraulic conductivity. A sandy-loam mixture is recommended to provide adequate organic material for vegetation/root yet still has sufficient drainage characteristics;

c The depth below underdrain pipe is the percentage of filter below the slotted drainage pipe;

d The default k-c* values for the bioretention system must not be adjusted without appropriate confirmation from Council.

***Note**: When locating bioretention devices ensure the ability of the devices to drain adequately has been assessed. Also ensure the device has sufficient pre treatment bypass flows or contains structures to ensure flows within the device are kept below the scour velocity of the chosen filter media.*

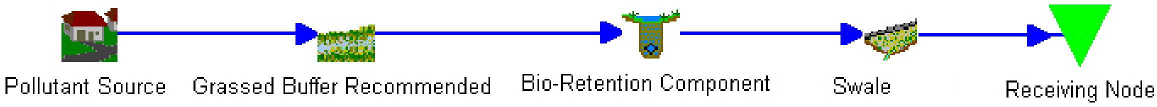
2.8.7 Swale 

Vegetated swales are open vegetated channels that can be used as an alternative stormwater conveyance system to pipes or can be used in conjunction with a pipe system. The interaction of surface flows with the vegetation in a swale facilitates an even distribution and slowing of flows thus encouraging particulate pollutant settlement. Swales can be incorporated into streetscape designs and can add to the aesthetic character of an area.

The following parameters are to be included when modelling a swale area:

- The seepage set to zero;
- Swales with a bed slope greater than 5% and less than 2% are not recommended;
- Swales with bed slopes less than 2% must incorporate a low-flow drainage line;
- Ensure side batters are a minimum of 1 (vertical) : 4 (horizontal).

2.8.8 Bioretention Swales



In order to model the proposed treatment efficiency of a bioretention swale within a treatment train, the bioretention swale should be split into its various components. These are the bioretention filter surface and battered slopes of the grassed channel. The image above depicts a standard layout for incorporating a bioretention swale within a treatment train.

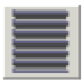
The following parameters are to be included when modelling a bioretention swale:

Bioretention Component:

- The device should have no extended detention depth as runoff is anticipated to be conveyed through the device and not ponded to a design depth;
- Seepage set to zero;
- The filter media used is to be a sandy-loam material to ensure vegetation can establish on the surface of the filter media.

Swale Component:

- Ensure that the bed slope of the swale is not less than 2% and does not exceed 5%.
- Seepage set to zero.

2.8.9 Rainwater Tank 

In order to appropriately model the treatment efficiency of a rainwater tank within an urban development, the rainwater tank that is entered into MUSIC must comply with any BASIX certificate for that residential site.

The following parameters are to be included when modelling rainwater tanks:

- Relatively constant demands such as toilet flushing should be entered as a daily demand in kL/day;

- Seasonal demands such as irrigation should be entered as an annual demand in ML/year, and should be scaled according to 5 inSection 4.2.3;
- End Use demands should be verified with demands from BASIX calculated water demands.

Where rainwater tanks are included in a particular stormwater strategy the various "land types" need to be delineated in the MUSIC model to ensure the pollutant export and treatment processes are appropriately considered (i.e. less TSS and TP is exported from roof areas so rainwater tanks play only a small role in the management of these pollutants).

A generic node is also provided at the end this Section (Section 2.8.11) which models Council's Deemed to Comply Provisions for small scale residential development – this makes allowance for an average size rainwater tank.

2.8.10 Generic Node 

This node allows the user to simulate the treatment performance of devices not listed within the default parameters. This use of this device is similar to the processes identified for a Gross Pollutant Trap with the exception of a Flow transfer function to replicate any flow attenuation produced by the proposed device.
The Generic Node is also to be used to represent application of Deemed to Comply Provisions on individual allotments in a residential subdivision as described in Section 2.4.1

***Note 1**: This node is used to model Wyong Council's Deemed to Comply Provisions. See Section 2.8.11 for further details.*

***Note 2**: Not withstanding the above the use of the Generic Node shall only be permitted if sufficient justification can be provided and where Council support this information. Typically Wyong Shire Council discourage the use of this node, and if this node is utilised the user is to justify the treatment efficiency along with any additional supporting information to Councils requirements.*

2.8.11 Modelling for Deemed To Comply Provisions

For the purpose of devising a WSUD Strategy for subdivisions or similar then certain assumptions are needed in relation to expected treatment measures and this is outlined below.

Residential single allotments should be modelled as an urban node with <u>70 % impervious area</u> . Figure 5 shows a simplified subdivision model which should be amended to suit each project. Road reserves, community facilities and open space should be provided with separate nodes reflecting each of these uses.

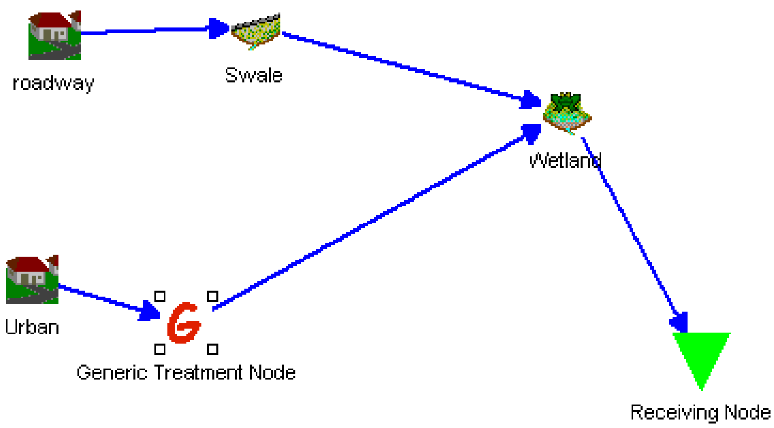


Figure: 5 Example of a simplified MUSIC model for subdivision using single node for allotments and generic node for Deemed to Comply Provisions

The WSUD Deemed to Comply Provision for treatment on individual allotments is to be modelled using a generic treatment node with the following parameters:

- Flow Reduction 25%[6];
- TSS reduction 50%;
- Phosphorus reduction 40%;
- Nitrogen reduction 40%;
- Gross Pollutants reduction 80%.

These parameters take into account a combination of treatment and flow reduction measures including rainwater tanks, rain gardens and pervious pavement or reduced hardstand. No further credit may be claimed for allotment treatment where the deemed to comply solution is adopted.

A screen capture from the MUSIC program is illustrated in Figure 5b over the page. This shows the input parameters for the generic treatment node. The high flow bypass for the generic node should be set at 0.01 per allotment and scaled for the total number of allotments in the subdivision. The generic nodes shown are for 10 allotments.

[6] The flow reduction is intended for use in the water quality MUSIC model. However it can also be used in the Hydrological modelling which is used to assess performance of the wetland hydrology

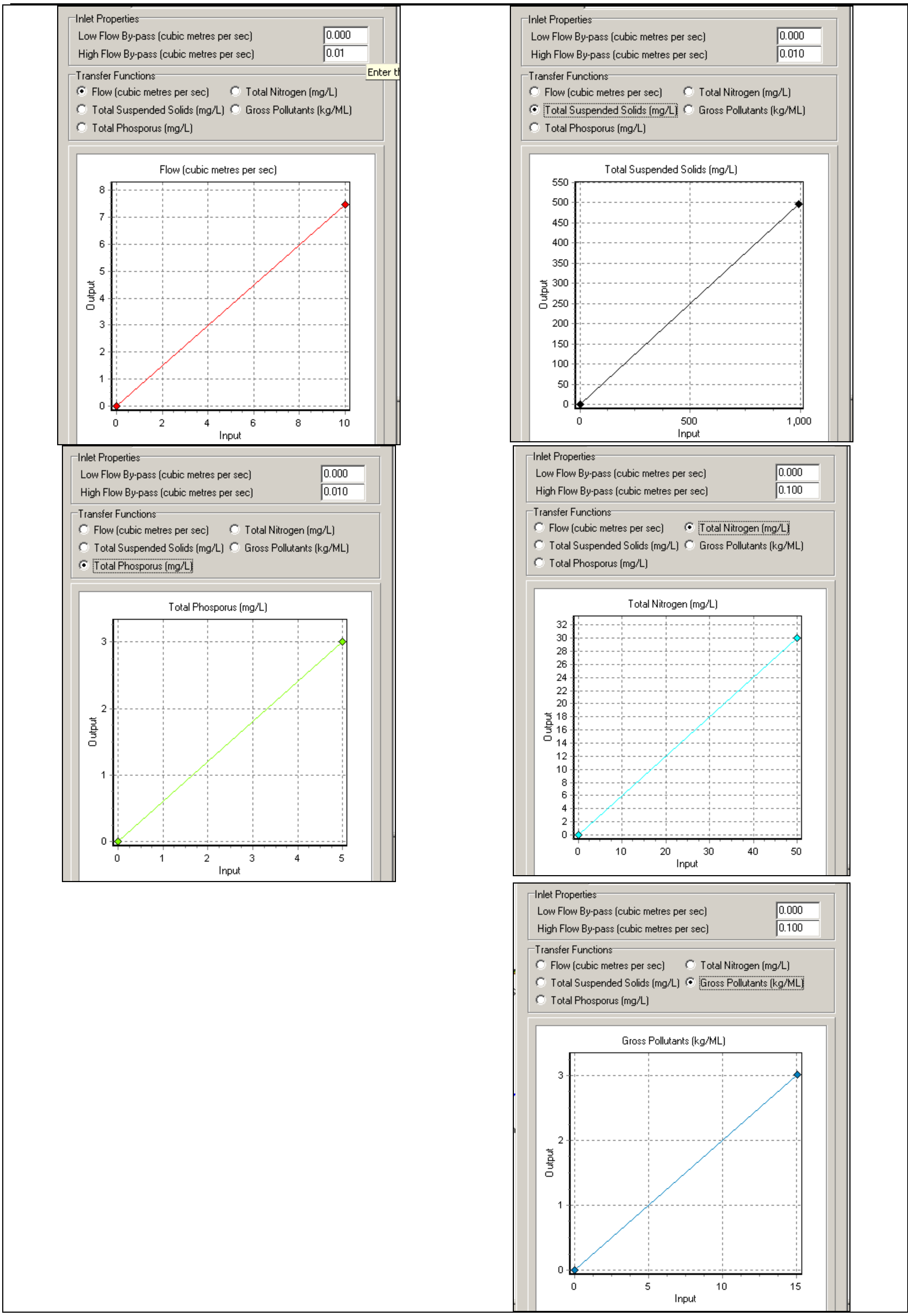


Figure 6 **Deemed to Comply Node – input parameters for Flow, TSS, TP, TN and Gross pollutants**

2.8.12 Modelling for Regional Wetlands

For areas where there is an IWCM Scheme the development will drain to a regional wetland/storage basin which is generally identified in the relevant Contributions Plan. . It is proposed that the WSUD Strategy will include stormwater treatment in the street-scape via buffer strips, raingardens or grass swales. The contribution of the regional wetland may be modelled using the music parameters detailed in Figure 6. The parameters shown in the table below are for a 1 hectare site, areas and volumes should be scaled to suit. Note: the extended detention depth is not to be scaled.

Outlet pipe size should be adjusted to achieve approximately 48 hours – 72 hours detention time to reflect detention times achieved in the regional wetland..

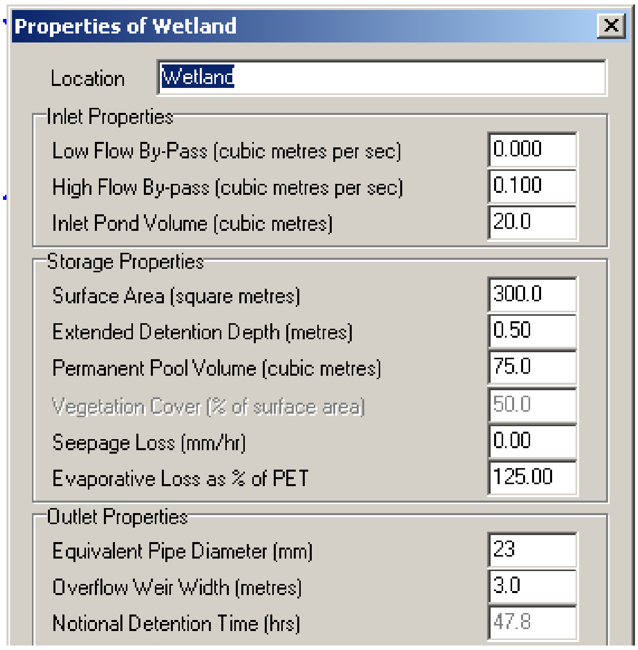


Figure 7 Wetland treatment node input parameters (for 1 hectare size wetland)

3.0 STORMWATER STORAGE DESIGN CURVES (STANDARD APPLICATIONS)

Urban development increases the volume and frequency of runoff, which changes the natural hydrology of an area. These changes can have a major impact on natural wetlands, lakes and salt marshes. There are a number of management measures to mitigate these impacts on wetlands including using stormwater storages with associated re-use.

In order to assess the effectiveness a detention and/or harvesting and reuse strategy for its effectiveness in meeting the wetland hydrology and waterway stability objectives, the stormwater storage modelling tool can be used.

The stormwater storage design curves can be used:

- to size active stormwater storages for standard applications (including typical detached dwellings, attached dwellings, multi-storey residential, commercial and industrial development).

The hydrologic modelling tools described in Section 2 have been used to derive a standard set of 'stormwater storage design curves'. The curves allow initial sizing of the stormwater storage designs , once the final landuse is established, without the need to undertake detailed hydrology modelling.

Stormwater storage design curves have been generated for two wetland hydrologic objectives:

- Freshwater wetlands;
- Undefined drainage depressions;
- Standard design curves have not been produced to meet the objectives for estuarine lakes (7-day high flow duration frequency curve). This objective is generally easier to meet than the above two.

A set of standard design curves have been produced for typical developments, including:

- detached and attached dwellings;
- multi-storey residential;
- commercial and industrial land uses.

The stormwater storage modelling tool of Section 4 should only be used in non-standard situations where:

a The landuse and percentage impervious assumptions vary significantly from those presented in the standard application Stormwater Storage Design Curves (standard applications) Tool; AND

b The Stormwater Storage Design Curves do not adequately represent the proposed WSUD and stormwater harvesting solution. It is anticipated the stormwater storage design curves will apply to most WSUD and stormwater harvesting solutions in Wyong Shire.

The following sections include:

- Section 3.1 discusses the development of the curves;
- Section 3.2 presents the curves themselves;
- Section 3.3 provides an illustrative application of the curves.

3.1 Development of the Stormwater Storage Design Curves

Numerous scenarios were assessed to define the stormwater storage design curves, utilising the modelling tool detailed in Section 4. A range of development types were considered, including detached dwellings, multi-storey residential and commercial development. Each development type was modelled with and without rainwater tanks and with a range of percentage impervious areas, as currently found throughout Wyong Shire. The optimal stormwater storage size for each land use percentage impervious was established by comparing the pre and post development low flow durations, high flow durations and low flow spells.

Importantly, modelling determined that stormwater storage requirements were not reduced enough with the inclusion of a rainwater tank, as required by BASIX. The demand on rainwater tanks under a typical BASIX scenario is more than an order of magnitude smaller than a pump rate of 50 kL/day/ha applied to the active stormwater storage. As such, rainwater tanks under a typical BASIX scenario play only a very minor role in achieving the wetland hydrology and waterway stability objectives.

It should be noted that rainwater tanks may be more effective in reducing overall stormwater storage sizes if developments include rainwater tanks larger than those typically required for BASIX and if they are plumbed into additional constant daily uses these required by BASIX, such as washing machines and hot water systems.

3.2 Stormwater Storage Design Curves

This section presents standard stormwater storage design curves for typical development in Wyong Shire. Note that in producing these curves, a pump rate of 38 kL/day/ha has been assumed. This is the pump rate adopted in the Porters Creek IWCM Strategy area in order to satisfy the objectives that serve to protect Porters Creek wetland. If a different pump rate is used, the Stormwater Storage Modelling Tool should be used instead of the standard design curves .

It can be concluded that active stormwater storage size is directly related to the impervious fraction of the catchment and that rainwater harvesting under a typical BASIX scenario within the development does not have great impact in reducing stormwater runoff in a volume sense.

Figure 8indicates the derived stormwater storage design curves, from modelling numerous scenarios across the full range of impervious fractions, for both 30 day and 14 day reference durations. The curves define the volume of “active storage” required to deliver the relevant hydrologic objectives across a range of catchment impervious fractions. These curves are to be used by designers, developers and Council to define the size of the active stormwater storage volume once the final landuse (and associated impervious fraction) is established.

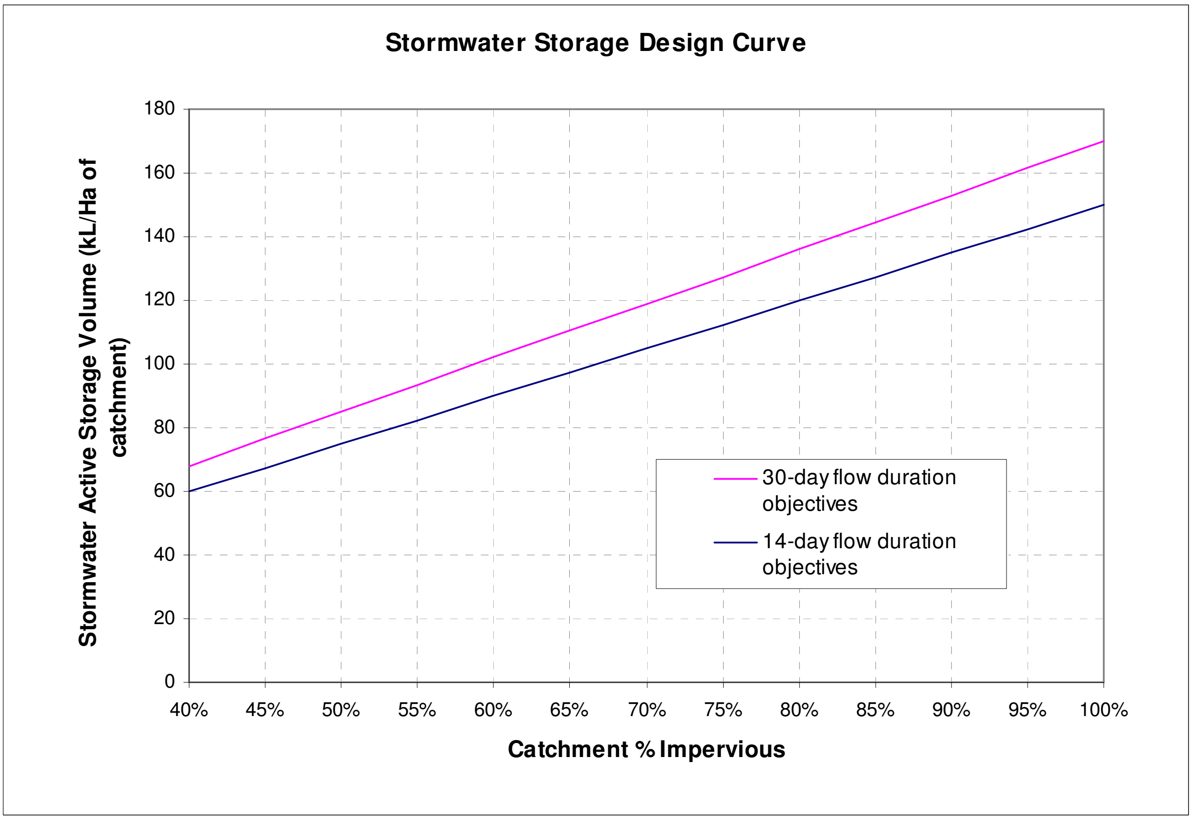


Figure 8 Storage design curves (sizing the active storage volume)

Interpretation of the curves provided in Figure 5indicates that for the protection of downstream freshwater wetlands (30-day reference duration) the following design principles apply:

- **Standard active storage pump rate = 38kL/day/ha;**
- **Active stormwater storage volume = Impervious Area (ha) x 170 (kL/ha);**
- To satisfy the Waterway stability targets for undefined drainage depressions, **active stormwater storage volume = Impervious Area (ha) x 150 (kL/ha).**

3.3 Stormwater Storage Example

A catchment within Warnervale Town Centre is 15.5Ha and is to be developed as a residential estate with an estimated 65% impervious fraction. This area naturally drains to Porters Creek Wetland and therefore the following objectives apply:

- 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.

To achieve these hydrologic objectives, the following active storage parameters would apply:

- Active storage volume = 110 kL/ha (8). Total volume required = 110 kL/ha x 15.5 ha = 1,710 kL
- Pump rate = 38 kL/day/ha x 15.5 ha = 598 kL/day.

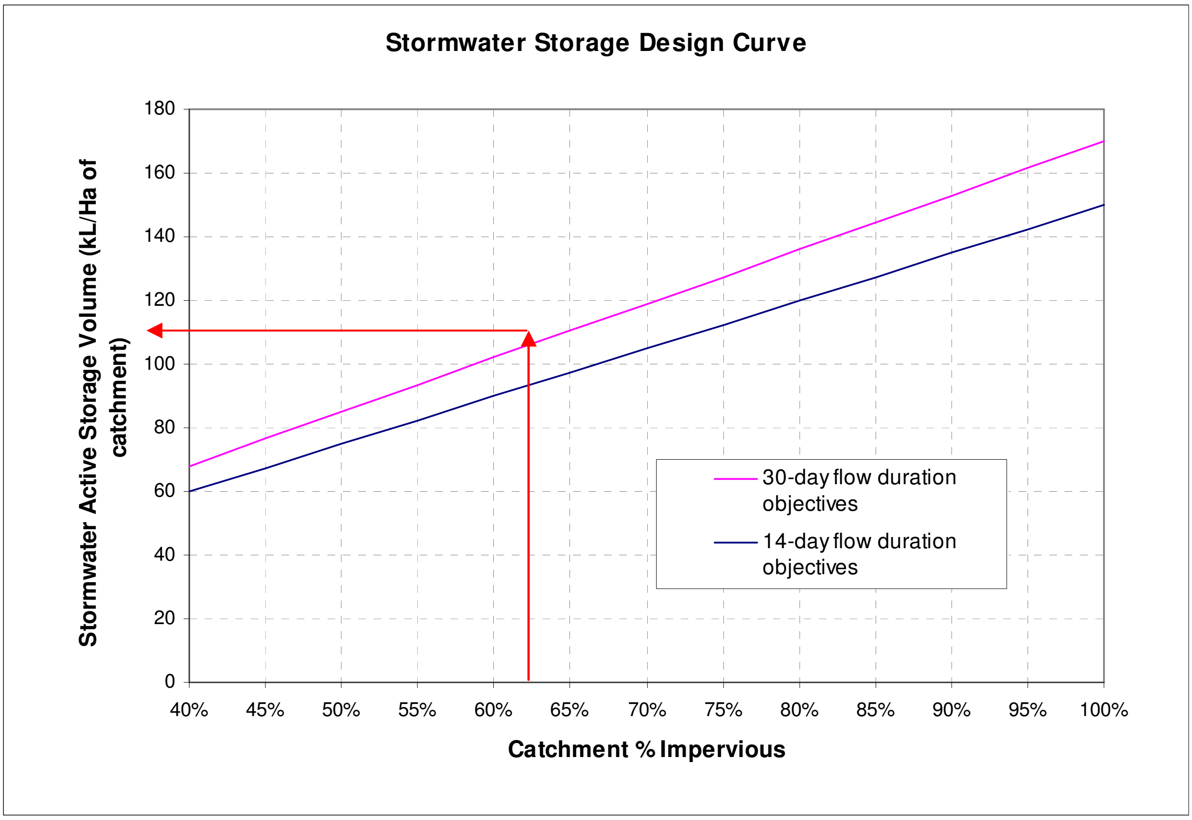


Figure 9 Example use of the storage curves

4.0 STORMWATER STORAGE MODELLING TOOL (NON-STANDARD APPLICATIONS)

Non-standard applications are when the design principles specified in Section 3 are not adhered to or when other issues complicate the analysis e.g. development crosses separate catchment boundaries etc.

To size stormwater storages and demonstrate compliance with the hydrologic objectives for non-standard developments, the following section details the methodology to comply with the following objectives:

- Low flow duration frequency curve for the dry season (October to January);
- High flow duration frequency curve for the whole year (July to June);
- Low flow spells frequency curve for the dry season (October to January).

There are four main steps in applying the non-standard *Stormwater Storage Modelling Tool*:

- Section 4.1 - Using MUSIC, produce a time series of pre-development flows;
- Section 4.2 - Using MUSIC, produce a time series of post-development flows, including mitigation measures;
- Section 4.3 - Analyse each time series to produce the three hydrologic indices – the low and high flow duration frequency curves and the low flow spells frequency curve. MUSIC does not have the capability to generate these hydrologic indices; therefore a specific post processing tool has been developed for this task. Results from the MUSIC model are inputted into the post-processing tool, which then produces the appropriate hydrologic objective indices;
- Section 4.4 - Compare the pre- and post-developed hydrologic indices' to ensure compliance with their respective objectives.

The post processing tool is available from Council and comprises an excel spread sheet with in-built macros that permit the imported MUSIC model data files to be processed and presented as frequency duration curves.

Council staff can provide examples of such analysis if required. This is helpful to familiarise the user with the methods and ensure the correct steps and procedures are included in the modelling.

4.1 Pre-Development

To establish the hydrology of the site prior to development (i.e. no impervious areas) a pre-development MUSIC model must be created. The simulated flows are then exported from the MUSIC model and analysed using the post processing tool.

Set-up an existing MUSIC model for the site, as indicated in Section 2;

Place a flux file on the outlet node, and run the model;

Export the results files.

4.2 Post-Development with WSUD Strategy

Following the simulation of pre-development hydrologic conditions, MUSIC is used to simulate post-development conditions and configure the WSUD treatment train. The key features of a MUSIC model used for post-development hydrology assessment are:

- The setup of imported nodes to separate baseflows and surface flows from pervious areas;
- The inclusion of stormwater storages to represent the stormwater detention, harvesting and reuse and/or diversion scheme.

The recommended model setup for the post development hydrology regime is described in Sections 4.2.1 to 4.2.6.

Rainwater tanks to harvest roof runoff may be included in this *hydrologic* MUSIC model however tanks of the size required to satisfy BASIX requirements have been found to have minimal impact on post development hydrology. Where rainwater tanks are used in the model their size and reuse characteristics must be demonstrated to be applicable to the development under consideration. Generally most water quality WSUD elements have negligible effect on the hydrologic objectives. As such, they do not have to be included in the *hydrologic* MUSIC model.

4.2.1 Baseflow Separation Using Imported Data Nodes

The post-development MUSIC model should be set up in accordance with Section 2, ensuring appropriate delineation of nodes and impervious areas.

Pervious areas generate both surface runoff and baseflow. To assess the impact of the post development scenario on stormwater flow regimes, it is necessary to separate surface flows that would flow into treatment and storage systems, from baseflow, which would not enter treatment or storage systems at all.

Baseflow can be separated from the stormwater storage catchment by use of an imported "base flow only" node. An example of a MUSIC model setup including baseflow is indicated in Figure . Note that the use of imported data nodes is only required for the modelling of the post development model hydrologic regime.

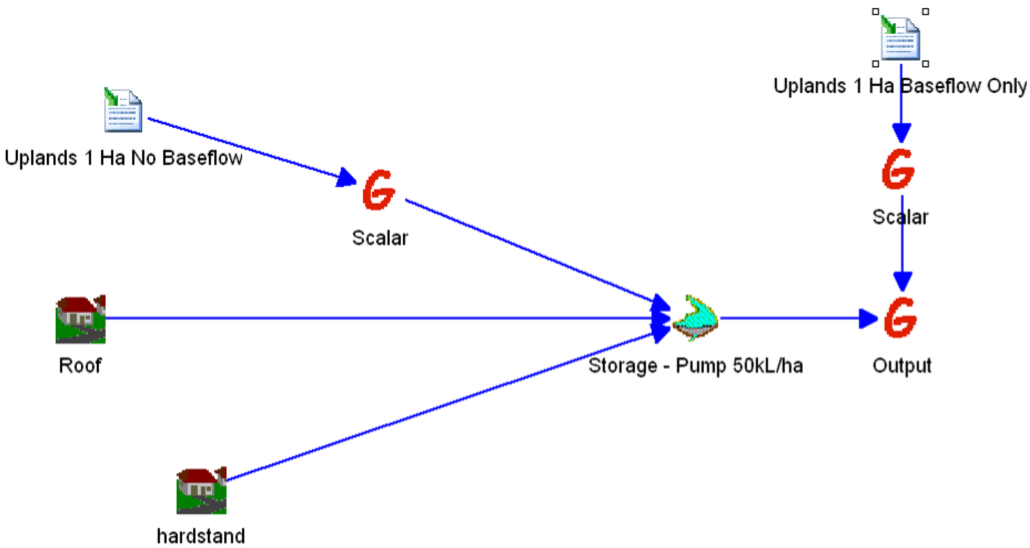


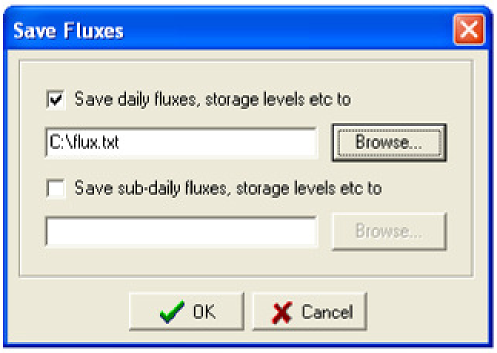
Figure 10 Recommended MUSIC model setup for post-development hydrology modelling

The imported nodes need to be created for a specific pervious catchment (upland or lowland) and for specific rainfall conditions. Standard pervious nodes have been developed for the Wyong Shire so that they can be automatically imported, for the following specific conditions:

- upland pervious areas;
- Sydney Observatory Hill rainfall for 70 years of daily data from 1921 to 1990;
- general urban water quality pollutant generation parameters – specified in Section 2.0.

If different rainfall data, different time step, or pervious node runoff or pollutant parameters are required the imported nodes will need to be created. The creation of these nodes requires the following:

Step 1: Run a 1 hectare 100% pervious upland or lowland node, as appropriate for the catchment and selected rainfall data, with a daily flux file on the source node (not the node downstream), as shown on the right. For sub-daily time steps the second box will need to be selected as the flux file.



Step 2: Open the flux file in a spreadsheet package and convert the "Pervious area surface runoff (mm)" and "baseflow (mm)" outputs into m^3/s (for daily time steps this requires dividing the value in the flux file by 8640).

Step 3: Using the spreadsheet package, set up a new file for the baseflow. Column 1 should contain exactly the same dates (and timesteps if sub-daily) as the selected rainfall file. Column 2 should contain the baseflows in m^3/s (as calculated in Step 2).

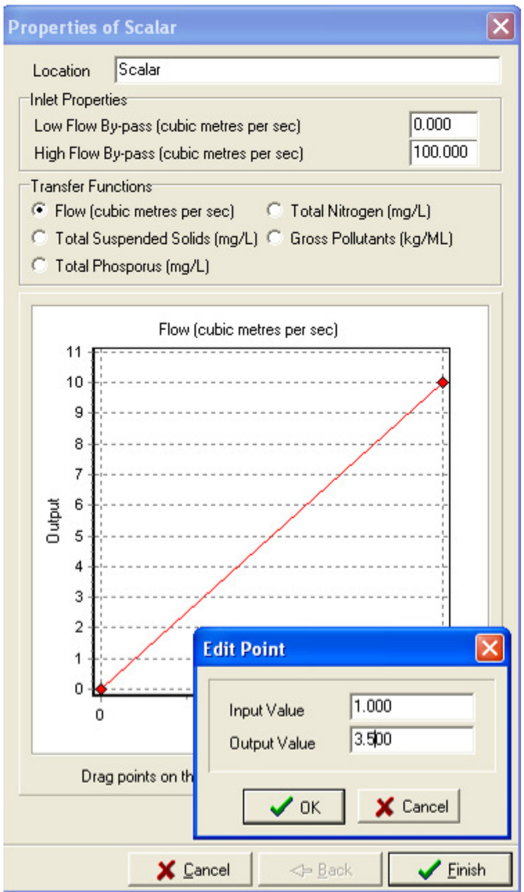
Step 4: In the same file as Step 3, Columns 3-5 should contain the TSS, TP and TN concentrations in mg/L. Copy the baseflow concentrations in mg/L from the flux file into the new baseflow file for TSS, TP and TN. Create a Column 6 for Gross Pollutants and set to 0 for all timesteps. Save the file as a text file (tab or comma delimited recommended).

Step 5: Select an imported data node in MUSIC and "Import" the text file that was created in Steps 3-4.

Step 6: Repeat steps 3 to 5 for pervious surface runoff, using the surface runoff flow values in m^3/s, and concentrations for pollutants including gross pollutants.

Step 7: Run the MUSIC file with the two imported nodes and confirm that the sum of the baseflow and surface runoff nodes is equal to the original 1 hectare node for runoff volumes and pollutant loads.

Step 8: Steps 1-7 created two imported nodes representing pervious area baseflow and surface runoff. The imported nodes are generic 1 hectare upland or lowland nodes. The final step involves scaling flows from the 1 ha catchment to the size of the actual pervious area. This is done using a Generic Node, as shown on the right.



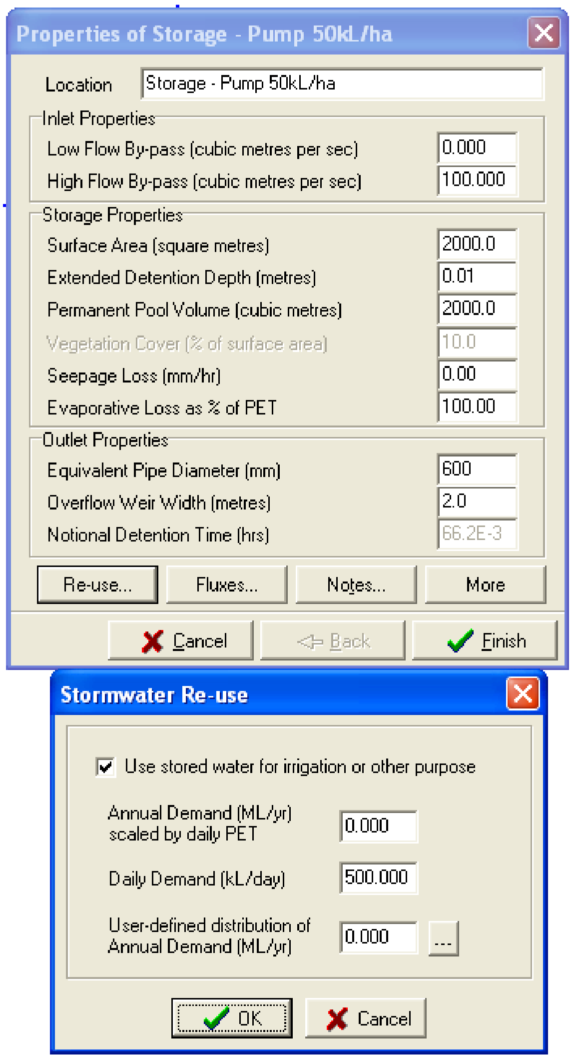
Step 9: Run the MUSIC file with the two scaled nodes and confirm that the sum of the pre and post developed base flow is equal (see example below).

For example, if there was 3.5 hectares of pervious area in the development then the generic scalar would be 3.5. In the Generic Node, only the flows should be scaled; not any of the pollutant concentrations. This is done by editing the point on the flow curve to an output value of 3.5 for an input value of 1 (as shown above). Note that this MUST be done for both baseflow AND surface flow by the same scalar factor. It is recommended that the scalar be clearly labelled to identify this.

These imported (baseflow and surface runoff nodes) and the associated scalars are combined with the 100% impervious nodes (roof, hardstand, road) to create the source nodes for the post development model, as indicted on Figure 10.

4.2.2 Modelling Active Stormwater Storages

The active stormwater storage node is the key element of the post-development hydrology model. The active stormwater storage requires a specific treatment node in MUSIC due to its specific design requirements. The node is shown on the right. The "pond" treatment node in MUSIC is used to model the storage.



The key feature is that only the active storage zone is modelled and this is represented by the permanent pool volume in the MUSIC model. There is no extended detention. Evaporative loss should only be included if the storage is open.

The active stormwater storage and re-use is modelled this way in MUSIC due to the constant draw-down the re-use demand generates. If the "extended detention depth" option is chosen, then the rate of outflow will vary with the depth of the detention volume. The constant draw-down the pump generates will remove the stormwater from the system and it will not contribute to downstream flows.

This is achieved in MUSIC by specifying a "re-use" demand on the permanent pool. In MUSIC the re-use demand is set to equal the proposed pump rate. Reuse demands only applies to the permanent pool and not the extended detention, thus the active storage zone is modelled as the permanent pool volume in MUSIC.

Where rainwater tanks are used to harvest roof runoff, these can be included in the post-development hydrology model downstream of the roof areas where the hydrology objectives are based on a 7-day reference duration. Where the hydrology objectives are based on a 30 day or 14 day reference duration, rainwater tanks have negligible impact on the hydrologic indices.

Active Volume Storage and Area
The key parameter that is used to alleviate the impact of the post development hydrologic regime on Wyong Shires sensitive freshwater wetlands, estuarine lakes and undefined drainage depressions is the volume of the active storage (permanent pool volume in MUSIC). This parameter is varied until the post-developed dry season low flow duration and low flow spells frequency curves and the annual high flow duration frequency curve match the pre-development curves (see Section 0 and 0 for details). The storage area will also change accordingly, and the final storage volume must be aware of the actual area and topography available for the storage. It is recommended to use a standard 0.75 m depth for the active storage zone. If the storage is to be vegetated, 0.75m is a reasonable inundation depth for a variety of wetland plants.

Pump Rate
The pump rate (stormwater re-use demand in MUSIC) is the rate at which water is extracted from the active storage zone (permanent pool volume in MUSIC) and either diverted from the catchment or directed to secondary storages for beneficial reuse. A pump rate should be selected so that the active storage will be drawn down completely in no more than four days. For example, as part of the Porters Creek Wetland Stormwater Harvesting Strategy, a pump rate has been set at 38kL/day/ha. Hence for a 10 hectare catchment the pump rate (reuse demand) is set to 380 kL/day. The pump rate has been set based on a number of different factors including the rate required to effectively draw down the storage, pumping costs, yield from the storages and regional infrastructure provision. For more information on the setting of this pump rate refer to the Porters Creek Regional IWCM Technical Paper (Wyong Shire Council, 2010).

Other Parameters
While the storage volume and area are varied to determine the optimum storage size, all other parameters, including extended detention, equivalent pipe diameter and overflow weir must not be changed from the settings in the model.

4.2.3 Modelling Stormwater Storages for Harvesting and Reuse

Stormwater storages can also be designed to retain water for reuse. These types of stormwater storages will not be as effective at meeting the hydrology objectives; however they may still contribute as part of an overall scheme.

In order to model a storage designed for reuse, the principles are similar to the active storage modelling described above, where there is no extended detention and the permanent pool is the storage volume. Evaporative loss should only be included if the storage is open. However in this case the demand should be the total water demands (e.g. irrigation, toilet flushing) and should be specified as follows:

- Relatively constant demands such as toilet flushing should be entered as a daily demand in kL/day;
- Seasonal demands such as irrigation should be entered as an annual demand in ML/year, and should be scaled according to Table 5 below.

Table 5: Typical annual distribution of irrigation demand for Wyong Shire

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
17%	9%	6%	1%	0%	0%	0%	5%	11%	14%	16%	21%

It is typical to size stormwater storages for harvesting and reuse on the basis of a storage reliability curve. An example is shown inFigure 11. For a given demand, a range of storage sizes are modelled in MUSIC and their ability to meet the reuse demand is expressed as a percentage of demand met.

To determine how much of the demand is met by stormwater re-use, the following steps can be taken:

- Set up a MUSIC model to represent the catchment, storage and demand;
- Run the MUSIC model at a daily time step;
- Query the Mean Annual Loads for the storage pond, and compare Inflow to Outflow. The difference is the total annual volume extracted from the storage pond;
- Divide this volume by the total annual demand and convert to a percentage.

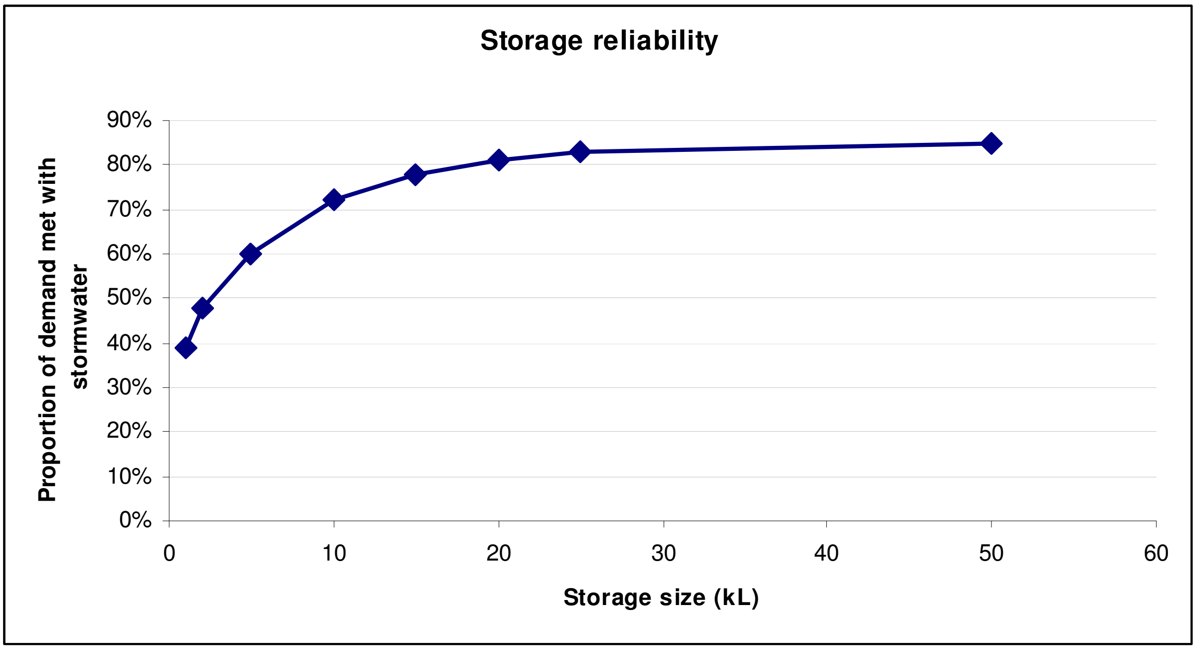
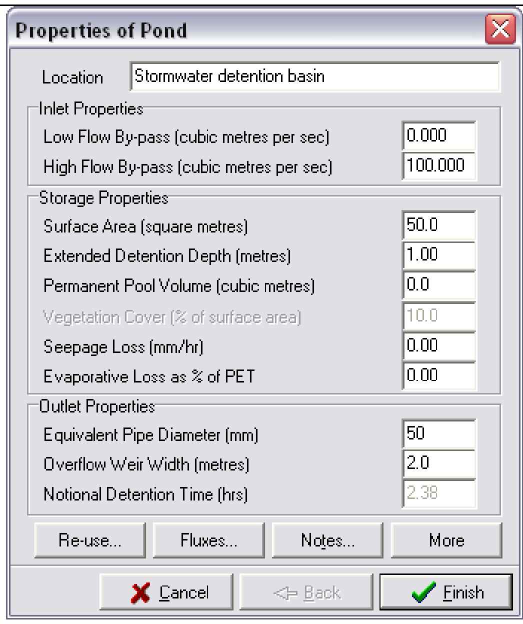


Figure 11 Example storage reliability curve

4.2.4 Modelling Stormwater Storages for Detention

Detention reduces high flows by capturing stormwater, storing it temporarily and releasing it slowly at a controlled rate. In some cases it may be feasible to meet the hydrology objective for estuarine lakes (preservation of the pre-development 7 day high flow duration frequency curve) with the use of stormwater detention. Stormwater detention designed to meet the 2 year ARI flow objective for waterways may also contribute to meeting the hydrology objectives and could be included in the MUSIC model for the post-development case.

When stormwater detention is included in the MUSIC model, the model should be set up as per 10 so that pervious area surface runoff enters the detention system, while baseflows bypass the detention system. Stormwater detention can be modelled as a pond with the following parameters:



- No permanent pool.
- The total detention volume should be entered as the extended detention surface area and depth in MUSIC.
- Evaporative losses set to zero unless the detention system is an open basin.
- The equivalent pipe diameter is set to achieve the desired outflow rate.
- Where detention times are small the detention basin should be modelled at a 6 minute time step, as it will often fill and empty again within one day.

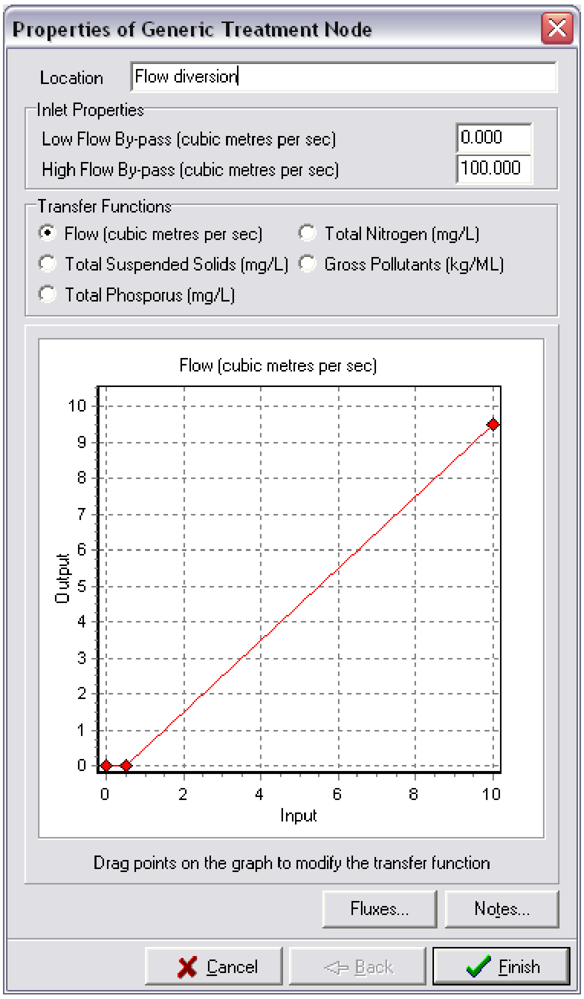
4.2.5 Modelling a Bypass Scheme (e.g. for salt marsh protection)

The most straightforward way to meet the hydrology objectives for salt marshes is to bypass excess stormwater flows around the salt marsh area. Salt marshes often occur in a narrow zone around the foreshore of the estuarine lakes, and in these situations it should be relatively straightforward to divert flows up to a certain rate in a defined open channel or pipe through the foreshore area.

Note: The music modelling must be a true representation of what is achievable on the site.

A bypass system can be represented in MUSIC using a generic node. The example to the right shows a generic node for diversion of all flows up to 0.5 m^3/s. Flows up to this value are stripped in the generic node. Pollutant concentrations should not be modified.

The stormwater diversion generic node should be located as per the stormwater storage inFigure 10, so that pervious area baseflows would bypass such a system.



4.2.6 Summary of Post Development Model Setup

The following is the summary of the steps involved in setting up the post development MUSIC model:

Step 1: Set up the imported nodes as described in Section 4.2.1. If upland areas are to be used, with the recommended Wyong Bowls Club or Sydney daily rainfall period of 1920 to 1990, then the 'template' post development MUSIC model imported source nodes can be used.

Step 2: Determine the area of impervious and pervious surfaces in the development.

Step 3: Enter the impervious area values directly into the impervious source nodes, as 100% impervious.

Step 4: Enter the pervious area values using the generic scalar nodes. It is important that the generic same value scalar node is used for both the baseflow and pervious surface runoff.

Step 5: Add treatment measures to the model, including stormwater storage and reuse systems (Section 0), stormwater detention systems (Section 3.2.4) and/or stormwater diversion systems (Section 4.2.5). Rainwater tanks and other stormwater treatment, harvesting and reuse measures can also be included in the model at this stage if desired.

Step 6: For all daily time step models place a flux file on the output generic node and run the model. For sub-daily time steps run the model and export the flow data at a daily timestep.

4.3 Post processing tool

MUSIC does not have the capability to generate flow duration curves and low flow spells curves. To overcome this gap a specific post processing tool was developed for this task. The tool automates the process of accessing MUSIC model results and developing the respective hydrologic indices, thus ensuring efficient and accurate post processing of model results.

The post processing tool utilises an Excel macro to generate low flow duration frequency curves, high flow duration frequency curves and low flow spells frequency curves. The use of this tool ensures that the post processing can be automated and also that there is a consistent post processing analysis procedure.
The basic steps included in the post processing tool are shown in the flow charts inFigure 11.

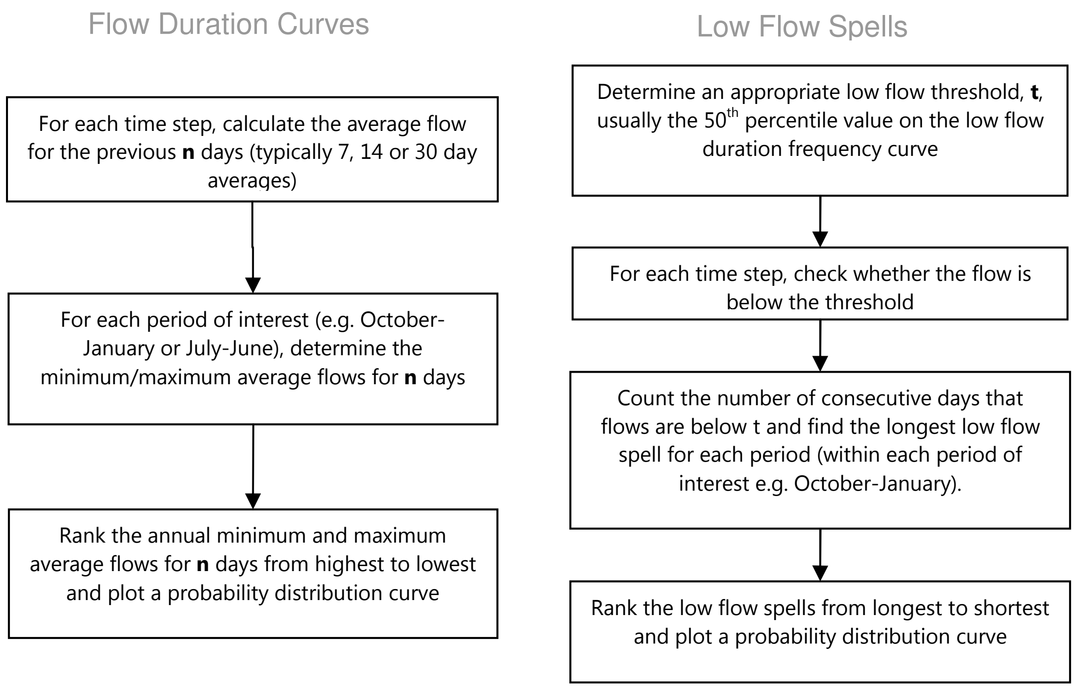


Figure 11 Steps included in the post-processing tool

The tool has two main sections, pre and post development. The only difference between the two sections is where the final data is copied to. This is important to ensure that the pre-development curve is represented separately from the post development curve on the Excel chart.

This section focuses on how to use the post processing tool and outlines the steps that are required to take the outputs from MUSIC and generate the relevant curves to analyse pre and post development hydrology.

Note: The post-processing tool (Excel file) that reflects the WSUD Strategy needs to be submitted to Council.

4.3.1 Definition of Terms

The key parameters for the user to select are the rainfall year, the critical drying period, the reference duration (n), and the low flow threshold (t). These are defined as follows:

Rainfall Year: The rainfall year is a continuous period of 12 months from a selected reference point (for Wyong - 1st July). The designation of a rainfall year is to ensure that critical periods, such as the summer drying period from October to January, are considered in the hydrologic assessment.

Critical Drying Period: The critical drying period is the period of interest for low flow analysis, for both low flow duration and low flow spells. The critical drying period is important for many key biological and chemical processes in natural wetlands. The critical drying period is determined by the period when the wetland is most likely to dry out and can be determined by analysing the evapotranspiration compared to rainfall. When evapotranspiration is higher than rainfall the wetland is likely to dry out. This period has been determined for wetlands in the Wyong Shire as October to January (refer to Figure 1 in WSUD Technical Guideline No1).

Reference Duration, (n): The number of days over which to average the flows for low and high flow duration analysis is directly related to the hydrologic regime of the downstream aquatic environment. Different natural wetlands and aquatic environments are sensitive to different lengths of wetting and drying periods. Freshwater wetlands are sensitive to wetting and drying periods of months in duration, and a reference duration of 30 days is used. Ecosystems in the estuarine lakes are sensitive to shorter periods of high freshwater inflows and reference duration of 7 days is used.

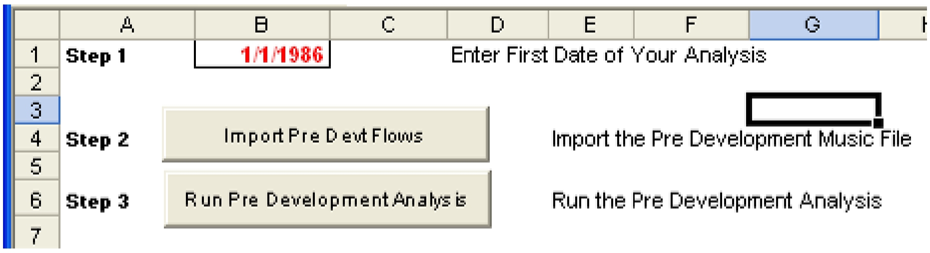
Low Flow Threshold, (t): Low flow spells are another hydrologic indicator available to determine hydrologic changes as a result of development. Low flow spells indicate drying processes within a wetland (i.e. drying out of a wetland is expected to occur during low flow periods). A measure of these low flow periods is to determine the number of consecutive days the flows into the wetland are below a daily flow threshold. As the drying period is concerned primarily with low flows the threshold is determined by taking the 50th percentile daily flow rate from the low flow duration curve. Thus the low flow threshold is defined as the median low flow during the critical drying period.

For more information on these terms, definitions and the importance of these to the hydrology of natural wetlands, see the *DRAFT Discussion Paper Modelling Rationale for the Porters Creek Stormwater Harvesting Strategy* (Ecological Engineering, 2006) and *Water Sensitive Urban Design Solutions for Catchments above Wetlands* (Ecological Engineering, 2005) reports prepared for Wyong Shire Council.

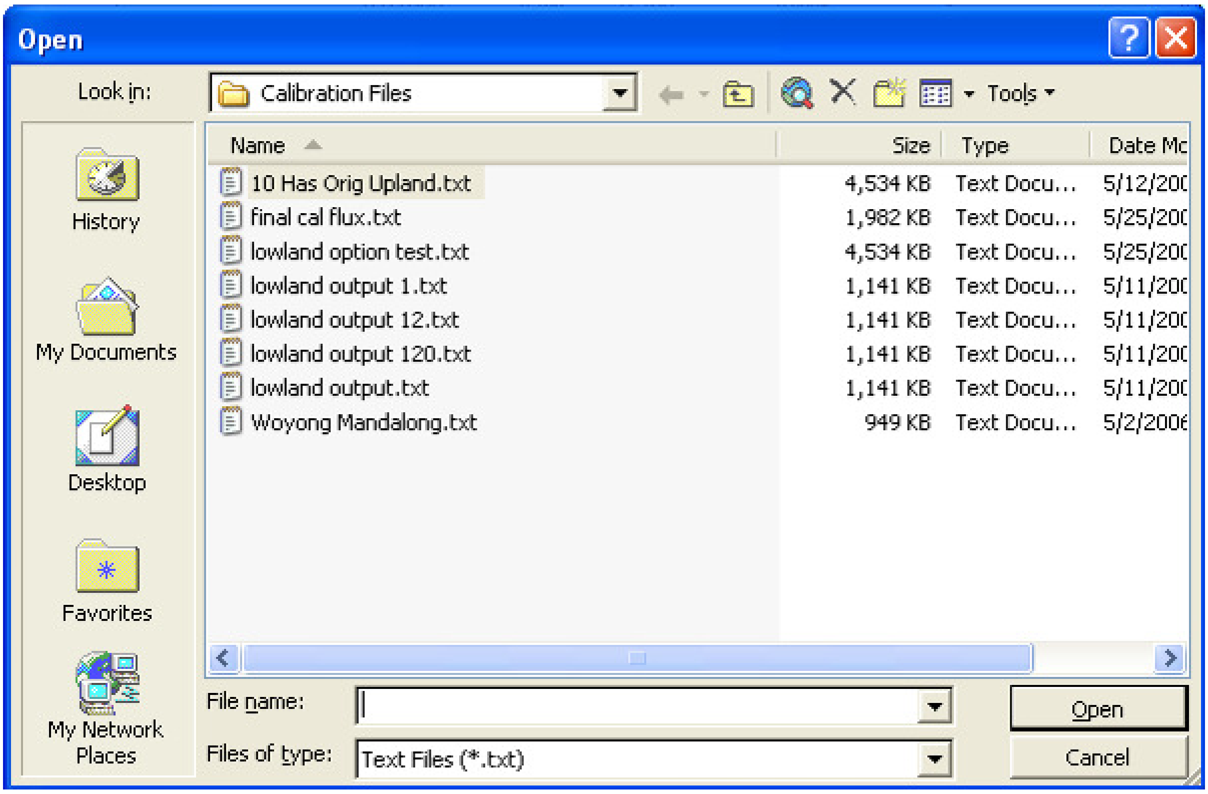
4.3.2 Using the Post Processing Tool

The use of the post processing tool is described in the following five steps. (NOTE: post processing tools only work with daily rainfall data.)

Step 1: In the top row enter the date that your analysis starts. This step is necessary as MUSIC does not save the date in the flux file. This can be determined by opening the MUSIC file and selecting Edit , then selecting Rainfall Data.



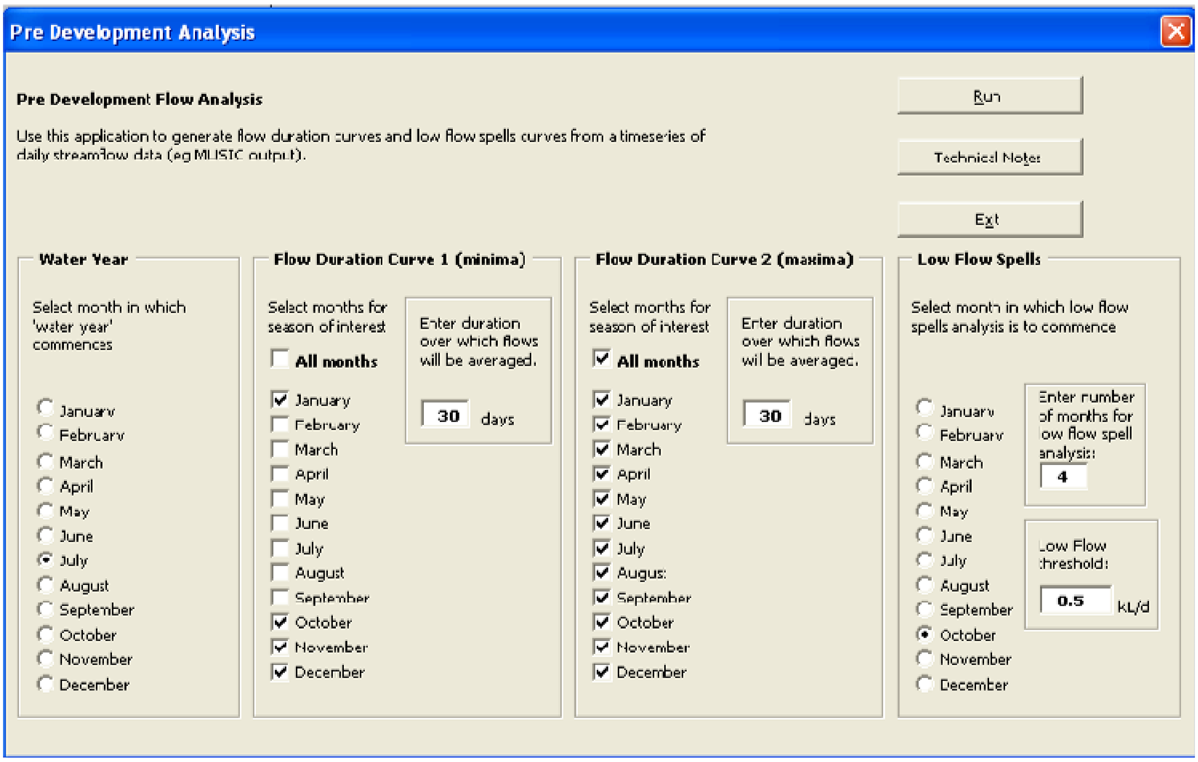
Step 2: Import the pre-development flux file, or exported daily flow file, using the command button "Import Pre Devt Flows". The "Open" dialogue box will appear and you can navigate to the appropriate file.



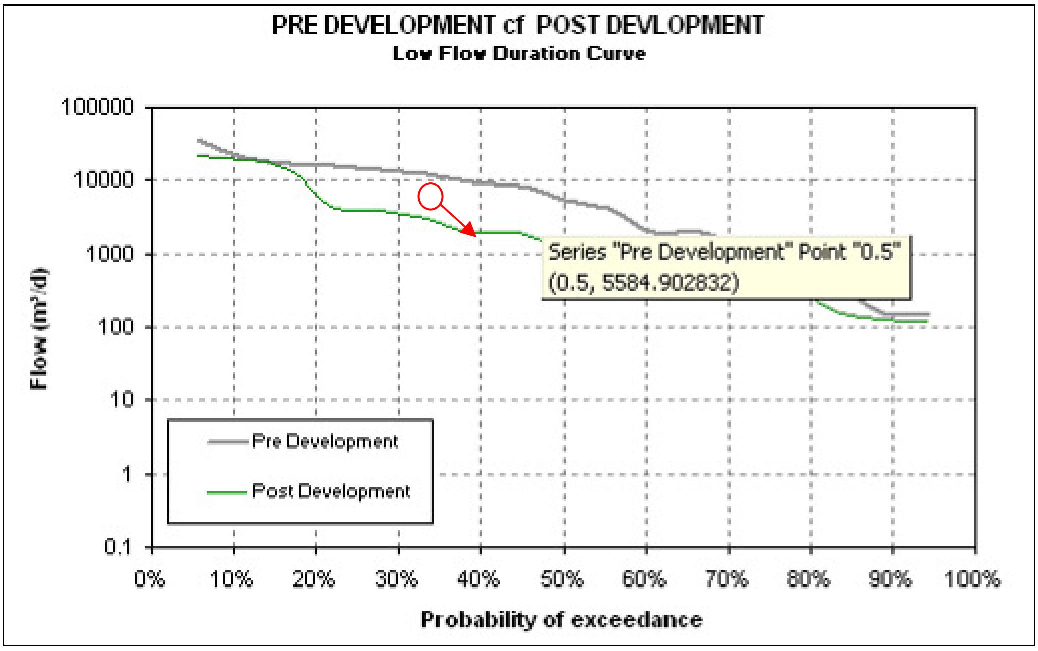
Step 3: Run the pre-development analysis by selecting the "Run Pre Development Analysis" button. A dialogue box will appear where you should enter the following parameters:

- Water year (July-June in Wyong);
- Critical drying period (October-January in Wyong);
- Reference duration (7, 14 or 30 days depending on the objectives that apply).

At this point it is not possible to determine the low flow threshold. Note that for Wyong Shire the high flow duration frequency curve should be produced for the whole water year, while the low flow duration frequency curve should be produced for the critical drying period.

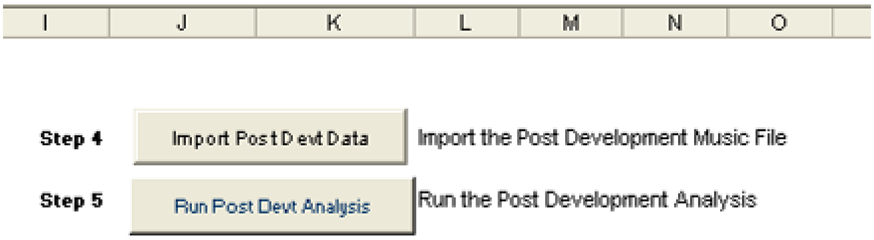


When the analysis is complete, the charts within the spreadsheet should be updated with the pre-development data. Read the 50th percentile value off the pre development low flow duration curve. In the example below this value is 5,585 kL/d.

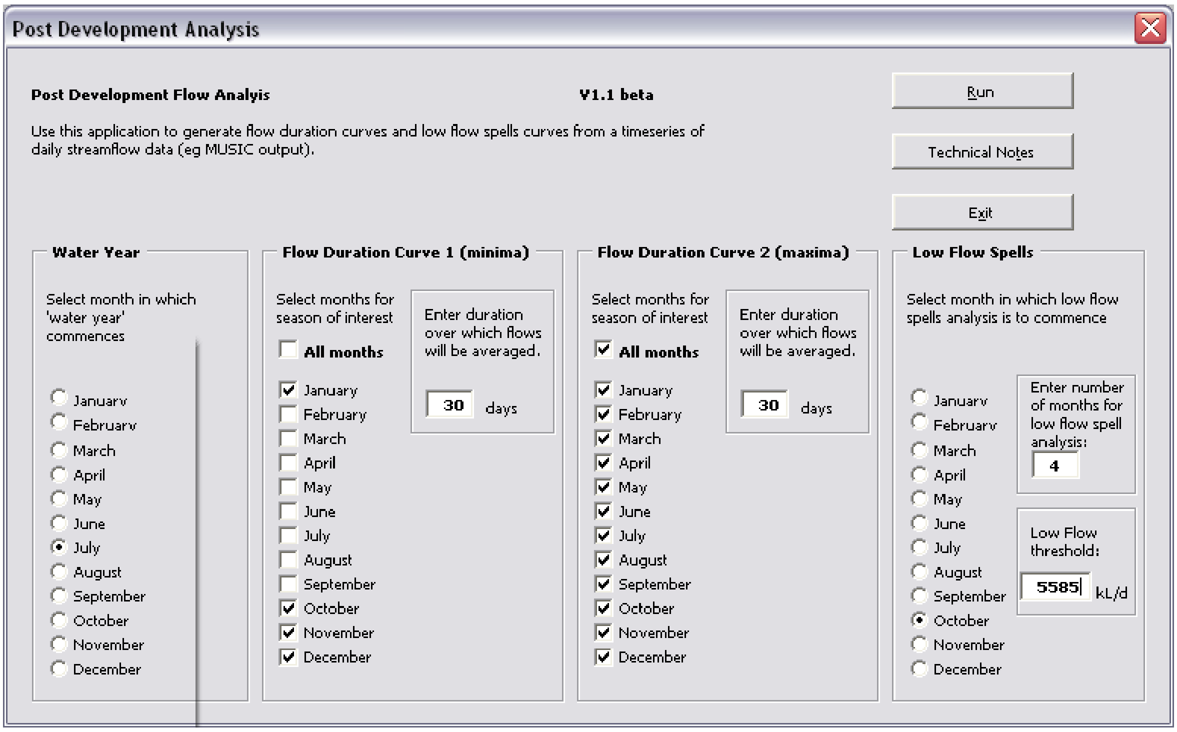


Re-run the pre-development analysis with the 50th percentile low flow value entered as the low flow spells threshold value. Keep all the other parameters the same as above.

Step 4: Import the post-development flows using the “Import Post Devt Data” command button.



Step 5: Run the post-development analysis by selecting the “Run Post Devt Analysis” button. Use the same values as in Step 3 for the water year, critical drying period, reference duration and low flow threshold.



At the completion of Step 5, the charts within the spreadsheet should be updated with the post-development data. It is now possible to compare the results for the pre and post development scenarios. Check the frequency curves for the low flow duration, high flow duration and low flow spells that have been generated in Excel.

4.4 Checking Compliance with the Objectives

Where the post development curves generally match the pre development curves, in particular between the probability exceedance of 20% and 80%, and achieve an R^2 greater than 0.8, the stormwater management strategy is considered appropriate. Where the post development curves do not match the pre development curves, in particular between the AEP of 20% and 80%, the stormwater management strategy will need to be adjusted. In particular, storage sizes may need to be adjusted in MUSIC and the above steps 1-5 repeated.

In some cases, it may be difficult to achieve simultaneous compliance with the low flow duration, high flow duration and low flow spells objectives, as there is effectively a trade off between meeting the low flow and high flow objectives. In these cases, discussion with Council is recommended in order to achieve a solution that balances the objectives.

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