MUSIC (Model for Urban Stormwater Improvement Conceptualisation)

Guideline

October 2023

Melbourne Water
Enhancing Life and Liveability

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Acronyms and Abbreviations

Term	Definition
AEP	Annual exceedance probability
ARI	Annual recurrence interval
Baseflow	The component of streamflow supplied by groundwater discharge
BPEM	Best practice environmental management, specifically the *Best Practice Environmental Guidelines for Urban Stormwater* (Victorian Stormwater Committee, 1999)
Development	Includes construction or carrying out of works, including building and road construction
EDD	Extended detention depth
EPA	Environment Protection Authority (Victoria)
EPA SWMM	Environment Protection Authority (United States) Storm Water Management Model
Evapotranspiration	Water that is lost to the atmosphere via evaporation from land and water surfaces plus transpiration from vegetation
EY	Exceedances per year
Flow regime	The range of flows that a waterway experiences throughout the seasons and years, which may include baseflows, low flows, high flows, overbank flow and cease to flow (drying) events
Groundwater dependent ecosystem (GDE)	Natural ecosystems that require access to groundwater to meet all or some of their water requirements to maintain their ecological processes
Gross pollutants	Material that would be retained by a five-millimetre mesh screen
Harvest	Rain that is captured for potential use and prevented from entering a waterway
Hectare (ha)	Ten thousand square metres
Hydrologic regime	Changes with time in the rates of flow and in the levels and volumes of water in rivers, lakes, and WSUD assets; the hydrologic regime is closely related to seasonal changes in climate but is also influenced by catchment vegetation, soils and urban development
Impervious	Impermeable; sealed surfaces that do not allow water to infiltrate or be absorbed
Infiltrate/filter	Runoff from impervious surfaces that soaks into the ground (infiltrates) or is slowly (mimics the infiltration rates of the surrounding soil) released to the drainage system from a stormwater management asset (filter)

Term	Definition
Integrated water management	Integrated water management is a collaborative approach to planning that brings together organisations that influence all elements of the water cycle, including waterways and bays, wastewater management, alternative and potable water supply, stormwater management and water treatment. It considers environmental, social and economic benefits.
Low flow	Water that creates a continuous flow over the bottom of the waterway channel but does not fill the channel to any great depth. The term is most often used in relation to baseflows that occur over the drier periods of the year that are sustained for some period (weeks to months), due to short bursts of rain.
Nature-based solutions	The use of natural features and processes, such as earthen physical form combined with vegetation, to manage stormwater as applied through constructed wetlands or biofilters. Nature-based solutions are the preference of Melbourne Water within Development Services Schemes[1].
NWL	Normal water level
Overbank flows	Water that spills over the waterway channel onto the floodplain
Stormwater	Rainfall that runs off roofs, roads, and other urban surfaces into gutters, drains, creeks and rivers, and eventually into the sea
Treatment train	A sequence of stormwater treatment assets designed to manage potential impacts to downstream aquatic environments
Urban	Areas that are developed for residential, industrial, or commercial activities, including roads
Waterway	Has the same meaning as in the *Water Act 1989* and includes a river, creek, lake, or other body of water
WSUD	Water sensitive urban design – an approach to urban planning and design that aims to minimize the hydrologic impacts of urban development on the surrounding environment.

[1] https://www.melbournewater.com.au/building-and-works/developer-guides-and-resources/drainage-schemes-and-contribution-rates/find-your#/

1. Purpose

The purpose of this document is to provide guidance on modelling approaches and input parameters for MUSIC models that are submitted to Melbourne Water. This guideline is also useful for building a model.

> MUSIC is a software that simulates rainfall, stormwater runoff, flows and pollution. It also simulates pollutant removal and flow reduction through stormwater management assets such as sediment ponds, wetlands, bioretention and stormwater harvesting.

The *Best Practice Environmental Management Guidelines for Urban Stormwater* (Victoria Stormwater Committee, 1999)[2] (referred to as BPEM) set out objectives for stormwater management.

These objectives are to reduce typical urban stormwater pollutant loads by:

- 80% for Total Suspended Solids (TSS)
- 45% for Total Phosphorus (TP)
- 45% for Total Nitrogen (TN)
- 70% for Gross Pollutants

The objectives apply to Melbourne Water's management district, including both the Port Phillip Bay and Western Port catchments.

Melbourne Water, councils, the EPA, and other authorities have legal obligations to protect the beneficial uses of receiving waters and may at their discretion further require additional stormwater management levels depending on the receiving environment.

Designers must clearly document and explain the design intent for any treatment asset with Melbourne Water early in the concept design stage. It is usually expected that MUSIC will be used for the design of stormwater quality assets. Designers may alternately choose methods or models other than MUSIC (for example, EPA SWMM) to demonstrate performance targets are achieved. The intended approaches should be discussed and agreed with the relevant authority in advance. The acceptance of such methods may require additional review effort and time (which may include external review) and acceptance of alternatives is wholly at the discretion of the relevant authority.

The objectives of this guideline are to:

- ensure a consistent, fair, and evidence-based approach is applied to MUSIC models
- be specific to the climate and geology of the Melbourne region
- reduce the time taken to prepare and assess MUSIC models.

[2] The latest BPEM information is available via the CSIRO website: https://www.publish.csiro.au/book/2190/#details

2. Scope

This guideline is intended for use by members of the land development industry who submit MUSIC models to Melbourne Water for the design of stormwater treatment systems, for example in Development Services Schemes. Users should check the applicability of this guideline when preparing models for other needs. Other professionals working within the stormwater management and land development industry may also find this resource useful.

This document covers catchment model set-up, model configuration, input parameters for source and treatment nodes, and how to use MUSIC to evaluate stormwater objectives. It also includes Melbourne Water's submission requirements for MUSIC modelling and useful procedures for modelling. It does not cover design guidance or engineering standards. Users should read this document alongside appropriate design guidelines such as:

- *WSUD Engineering Procedures: Stormwater* (Melbourne Water, 2005)[3]
- *Wetland Design Manual* (Melbourne Water, 2020)[4]
- *Biofiltration systems in Development Services Schemes Guideline* (Melbourne Water, 2020)[5].

> Note, MUSIC can help predict potential flow volume and pollutant removal for a design but is not the only validation. MUSIC is not suitable for validating drainage design for flow conveyance and flood mitigation. Other referral authorities, including councils, may have their own additional MUSIC modelling requirements.

Version compatibility

This guideline was developed for use with MUSIC Version 6.3. However, the underlying science within MUSIC X is unchanged. The same guidance and recommendations apply for MUSIC X while the look of the interface and pathways to some functions may differ.

At the time of publication MUSIC X has a similar feature set to MUSIC Version 6.3 with some variations in the features and functions available to users. Certain features including some that may be referenced within the guideline have been hidden or removed while it is likely new features will be added over time. Users should refer to the MUSIC user manual for guidance on any new features.

Disclaimer

Melbourne Water and the guideline authors do not accept responsibility or liability for any use of, or reliance, on the guidelines by third parties.

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[3] https://www.publish.csiro.au/book/4974/
[4] https://www.melbournewater.com.au/building-and-works/developer-guides-and-resources/standards-and-specifications/constructed-wetlands
[5] https://www.melbournewater.com.au/media/14586/download

Updates to this guideline

This revision of the guideline includes new and updated guidance.

The following material is new:

- modelling high flow bypasses and overflows
- modelling wetlands with multiple inlets.

The following guidance has been updated:

- selected rainfall templates and regions including introduction of a new region
- source nodes including pollutant concentration data
- stand-alone sediment pond (basin) treatment
- modelling sediment ponds connected to wetlands
- wetlands online
- defining custom outflow and storage properties for wetlands
- application of hydrologic routing
- application of drainage links
- proprietary stormwater treatment devices.

3. Catchment model set-up

Climate data

Melbourne Water provides MUSIC rainfall templates for 10-year periods. Users can download these from Melbourne Water's website[6] under 'Tool Guidelines' and save them to a folder for ready access. All models submitted to Melbourne Water must use Melbourne Water's rainfall templates unless written permission is provided by Melbourne Water. To use the templates, click the 'Open template from a different directory' icon and navigate to the saved template location where the downloaded templates were saved (see Figure 1).

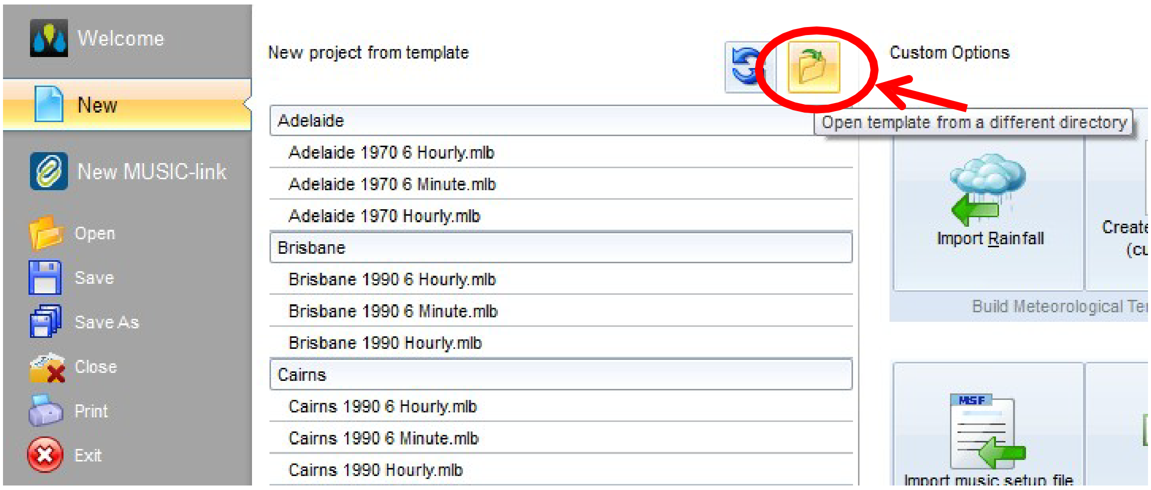

Figure 1 Step to select a Melbourne Water provided 10-year rainfall template

The rainfall distribution map (Figure 2) can be used to find the appropriate rainfall template and corresponding weather station for a site. The 'Tool Guidelines' website section provides a JPEG large-scale version of the map, ESRI and MapInfo layers, and the rainfall templates. A summary of the rainfall templates with mean annual rainfall and evapotranspiration is provided in Table 1.

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6 https://www.melbournewater.com.au/building-and-works/developer-guides-and-resources/guidelines-drawings-and-checklists/guidelines

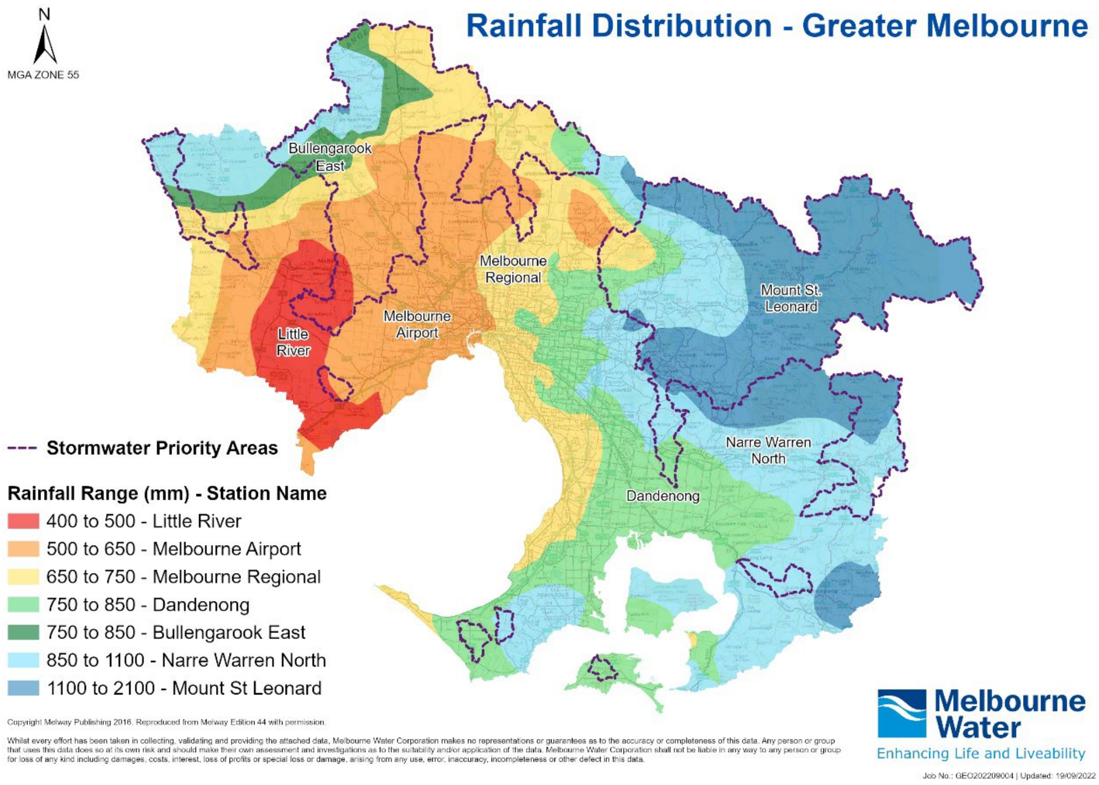

Figure 2 Rainfall template selection map

Table 1 Rainfall templates with mean annual rainfall and evapotranspiration

Rainfall band	Rainfall station	Period	Mean annual rainfall	Evapo-transpiration
400-500	87033 Little River	1992-2001	473	1067
500-650	86282 Melbourne Airport infilled	1987-1996	573	1041
650-750	86071 Melbourne Regional	1952-1961	707	995
750-850 West	87075 Bullengarook East	1990-1999	770	1046
750-850 East	86224 Dandenong	1967-1976	773	1027
850-1,100	86085 Narre Warren North	1984-1993	933	985
1,100-2,100	86142 Toolangi (Mount St Leonard DPI)	1995-2004	1,221	962

Climate data including rainfall and evapotranspiration are essential inputs to MUSIC. MUSIC is a continuous simulation model and requires an input time series of rainfall data.

Where alternate rainfall templates are proposed these should be discussed and confirmed with the relevant authority. These require additional effort and should generally only be proposed where there is a clear need or demonstrable change in outcomes. These may require additional review time and effort and acceptance of alternatives is wholly at the discretion of the relevant authority. If you intend to model using an alternate rainfall template, rainfall data is available from the Bureau of Meteorology at a 6-minute timestep for several gauges across Melbourne Water's service area[7]. The selection of a rainfall gauge and period should consider:

- Local rainfall patterns for the site of interest: This may include seasonal and annual variability. Check if the data pluviograph gauge and period chosen has a similar range of mean annual and mean monthly flows to the observed data from relevant daily gauges. Regions with more variable rainfall (such as arid areas) may warrant using a longer time series (e.g. 20 years) to ensure a representative range of conditions are modelled.
- Completeness of record: Check if the gauge chosen has significant missing or accumulated data. If so, can these be infilled with data from another gauge with a good statistical correlation to the gauge of interest? Some gaps are acceptable for stormwater quality assessment but for assessing yields and drying spells it is more important that these are filled in. The Bureau of Meteorology flags most missing and accumulated data. Some gaps during which stations are not recording may remain unflagged although these are usually a small proportion of most datasets. Care must be taken when infilling to not over infill periods of zero rainfall and inappropriately remove valid periods where no rainfall occurred.
- Representation of a range of conditions including wet and dry periods and a variety of storm events of varying size and antecedent dry periods: Does the period chosen include both wet and dry years and at least some storm events that are less frequent?
- Purpose of the model: A relatively short period (5-10 years) may be adequate for assessment of stormwater quality and percentage reductions in mean annual loads. At least 10 years is desirable for assessing rainwater or stormwater harvesting yields. Wetter or dryer periods may also be used as a sensitivity check. A longer period may be preferred for assessment of effects on downstream hydrology and flow duration curves.

The choice of meteorological data is a balance between the level of accuracy required and the time and effort required for modelling. The templates Melbourne Water provides represent the rainfall variations across metropolitan Melbourne.

[7] http://www.bom.gov.au/climate/data/stations/

The following periods are recommended for different applications:

≥10 years

- all Development Services Scheme designs and precinct-scale integrated water management strategies
- modelling of areas including significant areas of pre-development, rural or pervious land
- analysis of flow frequency objectives such as number of flow days, stream erosion index and flow frequency curves.

20+ years (optional)

- Regional and catchment-scale integrated water management strategies
- waterway flow analyses
- analysis of large pervious catchments (>100 ha).

Timestep

All models must be run at a 6-minute timestep where possible. Using longer timesteps (particularly daily) can result in significant errors and increase the variability of the results. Where a different timestep is adopted, it must comply with the following:

The timestep must be equal to or less than:

- the time of concentration of the smallest sub-catchment
- the shortest detention time (under design flows) of the treatment measures being modelled.

Circumstances where a different modelling timestep may be appropriate include:

- concept level modelling of systems that have long times of concentration and detention times, such as rivers or lakes, where no representative 6-minute data is available
- where a larger timestep is required to interface with another model and allow consistent rainfall to be used. Usually, it is preferred to run MUSIC at a 6-minute timestep and export results at an appropriate longer timestep.

Catchments and source nodes

Source node selection

For most catchment modelling purposes, urban land uses, and surface types can be lumped together and represented with a single set of pollutant concentration data.

The following nodes are recommended for representation of catchments:

- urban node with "mixed" zoning/surface type for most modelling purposes to represent existing and new urban areas (including a mix of residential, commercial, industrial, parkland and other land uses within an urban area)
- forest nodes should be used only for representing catchments that are mostly old growth or well-established forested areas
- agricultural nodes for actively farmed rural areas which may have elevated nutrient concentrations.

Pollutant concentrations are significantly different for road and roof surface types and some stormwater management responses focus strongly on one or both surface types. For this reason, separate source nodes representing different surface types should preferably be adopted to provide more representative outcomes when modelling:

- roof water harvesting (roof runoff to rainwater tanks)
- direct streetscape treatments treating only roads and not a mix of surface types
- catchments with a mix of surface types that is very different to a typical urban area (for example, mostly roof or mostly road).

For guidance on representing pollutant concentrations for these surface types refer to *Pollutant concentration data* within this document.

Impervious fraction

Total impervious area

The impervious fraction is the proportion of a catchment that is impervious to rainfall and produces significant amounts of surface runoff. This impervious area is commonly referred to as total impervious area (TIA).

Directly connected imperviousness

Directly connected imperviousness (DCI) is the proportion of the impervious surface that is directly connected to a stream through conventional drainage. The directly connected impervious area may be lower than the total impervious area due to impervious areas discharging over adjacent pervious and vegetated areas, leakage from drains, channels and waterways, and other factors.

The TIA must be used for all water quality modelling in MUSIC including sizing of stormwater quality treatment assets and development planning applications. This will help to reduce the potential for under-sizing of stormwater quality assets.

New development

In new development areas, the total impervious fraction is typically relatively high. This means that the corresponding pervious or permeable surface area, which provides potential opportunity for disconnection to occur is much less. Modern construction approaches are also more likely to provide effective drainage for most impervious surfaces. As a general principle for new development, the total impervious area should initially be assumed to be directly connected impervious area and modelled as such. This helps ensure that stormwater quality treatment assets are adequately sized to treat all of their likely catchment.

Existing urban areas and stormwater harvesting

Existing urban areas and stormwater harvesting: In existing urban areas, the directly connected impervious area, as estimated through flow calibration may be significantly less than the total impervious area due to both intentional and incidental disconnection of impervious areas as well as leakage from existing drainage. This may be due to some structures being identifiable as impervious but not connected to drainage, rainwater tanks and intentional disconnections as well as leakage through the drainage system.

Total impervious area may over-estimate flow volumes and harvesting yields from existing urban areas. Specifically, for the design and estimation of yield for retrofit stormwater harvesting schemes within existing urban areas, stormwater reuse volumes should be estimated using directly connected imperviousness.

To estimate directly connected imperviousness in existing urban areas, Melbourne Water may be able to supply impervious area mapping for a catchment of interest upon request. Alternatively, users can assume directly connected imperviousness makes up two-thirds of total imperviousness. This assumption is based on previous mapping of total and directly connected imperviousness by Melbourne Water, which suggest that on average DCI in existing areas makes up around two-thirds of total imperviousness, although this can also vary widely.

At-source WSUD and disconnection responses

The total impervious areas draining to any recognised WSUD asset such as a raingarden should be represented in the model as impervious areas.

If an impervious area is to be intentionally 'disconnected' through drainage over a vegetated pervious surface of a substantial relative size (such as at least half the size of the impervious area), the proposed disconnection may be explicitly designed and modelled with the pervious area represented using a modified bioretention, buffer or swale node as appropriate. This may be used to represent a 'downspout disconnection' where a roof drains to a garden or a driveway drains via sheet flow over an adjacent lawn area. In these cases, the ownership and assurance of ongoing retention and maintenance arrangements for the vegetated pervious area should be confirmed.

General guidance

Use Table 2 to estimate the total impervious area for different land uses in new development areas. Any significant deviation from the figures in Table 2 must be supported by a rationale and relevant information such as plans and description of proposed urban form or alternately a model calibrated to long-term (ideally at least 5 years) flow data as described below in the section on how to *Determine directly connected imperviousness through calibration*.

Users may adopt an alternative approach subject to agreement with Melbourne Water of undertaking a detailed assessment of proposed and potential future effective impervious fractions where the proposed and likely future impervious areas can be identified with a high degree of confidence, see example below in Detailed calculation of effective impervious fraction.

MUSIC does not directly represent rainfall onto a treatment node. Rather, it is assumed the area of the treatment is included within an upstream catchment area. Since all rainfall falling on a WSUD asset will enter it, the area should be represented as a 100% impervious surface area to ensure a correct water balance with all direct rainfall becoming inflow.

Table 2 Total impervious fractions for source nodes by land use (continues over page)

Zone	Zone code	Brief description and examples	Normal range	Typical value
Residential zones				
Residential growth zone, general residential zone, and neighbourhood residential zone	RGZ, GRZ and NRZ	Large residential (allotment size 601m^2 to 1000m^2)	0.50 – 0.80	0.60
		Standard densities (allotment size 300m^2 to 600m^2)	0.70 – 0.80	0.75
		High densities (allotment size <300m^2)	0.80 – 0.95	0.85
Low density residential zone	LDRZ	Allotment size >1000m^2	0.10 – 0.30	0.20
Mixed use zone	MUZ	Mix of residential, commercial, industrial and hospitals.	0.6 – 0.90	0.75
Township zone	TZ	Small townships with no specific zoning structures	0.40 – 0.70	0.55
Industrial zones				
Industrial 1 zone	IN1Z	Main zone to be applied in most industrial areas	0.70 – 0.95	0.90
Industrial 2 zone	IN2Z	Large industrial zones away from residential areas	0.70 – 0.95	0.90
Industrial 3 zone	IN3Z	Buffer between zone 1 and zone 3	0.70 – 0.95	0.90
		For garden suppliers/nurseries	0.30 – 0.60	0.50
		For quarries	0.10 – 0.30	0.20
Commercial zones				
Commercial 1 zone	C1Z	Main zone to be applied in most commercial areas	0.70 – 0.95	0.90
Commercial 2 zone	C2Z	Offices, manufacturing industries and associated uses	0.70 – 0.95	0.90
Rural zones				
Farming zone	FZ	Main zone to be applied in most rural areas	0.05 – 0.20	0.10
Rural activity zone	RAZ	Agriculture and other compatible uses	0.10 – 0.30	0.20
Rural living zone	RLZ	Main residential use in rural areas	0.10 – 0.30	0.20
Public land zones				
Education	PU2Z	Schools and universities	0.60 – 0.80	0.70
Service and Utility	PU1Z	Power lines, pipe tracks and retarding basins	0.00 – 0.10	0.05
		Reservoirs	0.40 – 0.60	0.50
Health and community	PU3Z	Hospitals	0.80 – 0.90	0.85
Transport	PU4Z	Railways and tramways	0.60 – 0.80	0.70

Zone	Zone code	Brief description and examples	Normal range	Typical value
Cemetery or crematorium	PU5Z	Cemeteries and crematoriums	0.50 – 0.70	0.60
Local government	PU6Z	Libraries, sports complexes, and offices/depots	0.50 – 0.90	0.70
Other public use	PU7Z	Museums	0.50 – 0.80	0.60
Public park and recreation zone	PPRZ	Main zone for public open space, including golf courses	0.00 – 0.20	0.10
Public conservation and resource zone	PCRZ	Protection of natural environment or resources	0.00 – 0.05	0.00
Road zone, category 1	RDZ1	Major roads and freeways	0.60 – 0.90	0.70
Road zone, category 2	RDZ2	Secondary and local roads	0.50 – 0.80	0.60
Special purpose zones				
Special use zone	SUZn	Development for specific purposes	0.50 – 0.80	0.60
Comprehensive development zone	CDZn	Large and complex developments – residential	0.40 – 0.80	n/a
Urban floodway zone	UFZ	Land identified as part of an active floodway	0.00 – 0.05	0.00
Capital city zone	CCZn	Special use zone for land in Melbourne’s central city	0.70 – 0.90	0.80
Docklands zone	DZn	Special use Zone for land in Docklands area	0.70 – 0.90	0.80
Commonwealth land	CA	Army Barracks, CSIRO	0.50 – 0.80	0.60

Note: values included in this table are impervious fractions, not runoff coefficients and should not be used as runoff coefficients for flood modelling.

Detailed calculation of directly connected imperviousness

An alternative method is to determine the directly connected impervious area and corresponding directly connected impervious fraction. This is done by mapping all impervious surfaces and determining which of these are effectively connected to the drainage system using detailed data. This approach may be used for small developing or developed catchments up to 10 ha where accurate details of the existing or proposed drainage system, land-uses and lot layouts are known. However, it is considered most appropriate for use with existing urban areas where the impervious surfaces are likely to be fairly stable with limited change.

For an area to be considered not part of the directly connected impervious area, it must drain to a permeable vegetated area that is nominally at least half as large as the impervious area and certain to remain both permeable and vegetated for the foreseeable future.

A reasonable allowance must be made for potential future changes by landowners to replace permeable vegetated areas with other surfaces such as decks, patios and paving except where there are covenants or similar restrictions explicitly protecting the retention of permeable vegetated areas.

An example estimate of directly connected imperviousness for a small catchment is shown in Figure 3 and Table 3.

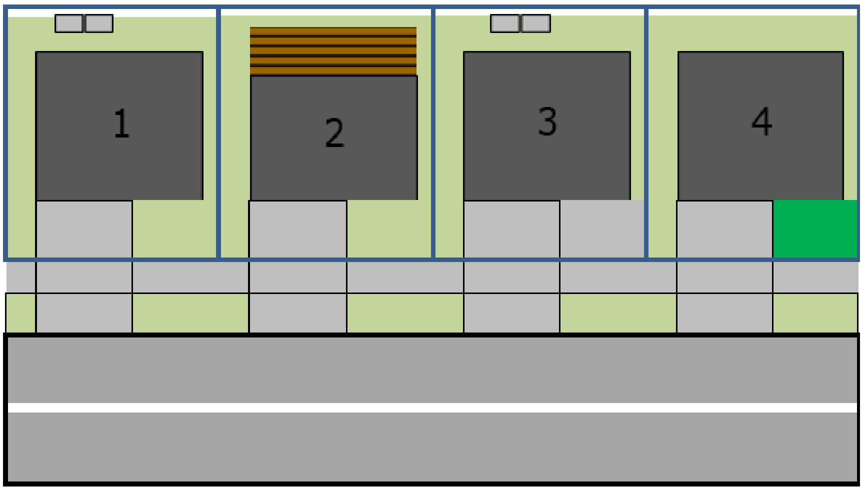

Figure 3 Directly connected imperviousness example

Property 1 has a 20m² paved area in the backyard that drains to an equivalent area of surrounding grass, not directly connected to the drainage system.

Property 2 has a wooden deck in the back yard with limited surrounding vegetation and an overflow pit to manage any stormwater excess. Decks, patios and similar structures are to be considered an impervious surface.

Property 3 has additional paved area in the front yard connected to the drainage system and a 20m² paved area in the backyard that drains to an equivalent area of surrounding grass, not directly connected to the drainage system.

Property 4 has synthetic grass in the front yard that connects to the drainage system.

Table 3 Directly connected imperviousness calculation example

Surface area	Area (m^2)
Directly connected impervious area	
All roofs	750
Road	920
Driveways	390
Footpath	100
House 1 deck	20
House 3 additional front yard paving	40
House 4 synthetic turf	40
Impervious area not directly connected	
House 1 and 3 backyard paving	40
Pervious area	
Lawn and gardens	700
Total area	3000
Total impervious fraction = (750 + 920 + 390 + 100 + 20 + 40 + 40) / 3000	77%
Directly connected imperviousness (may be used in MUSIC) = (750 + 920 + 390 + 100 + 40 + 40) / 3000	75%

Note: all impervious areas that drain to WSUD features, such as the raingarden and rainwater tank in this example, must be counted as impervious area for calculating the directly connected imperviousness since they are explicitly represented.

Determine directly connected imperviousness through calibration

If the catchment of interest is fully developed, directly connected imperviousness may be determined through calibration using rainfall and flow data for a drain or waterway[8]. This is most relevant for use in the design of stormwater harvesting systems for existing urban areas where flow data may exist or be collected to support design.

Soil parameters

In MUSIC, the pervious area soil properties must be altered to reflect properties recommended for use in Melbourne. Any proposed deviation from the Melbourne parameters listed here should be described in the report provided with the model. Supporting evidence must be provided.

[8] For an example of calibrating directly connected imperviousness through calibration, see *Analysis of parameter uncertainty of a flow and quality stormwater model* (Dotto, et al., 2009)

The soil input parameters recommended here are based on a review of twelve catchment calibrations undertaken for Melbourne catchments in recent years.

Soil storage capacity = 120 mm, Field capacity = 50 mm

Pollutant concentration data

Stormwater pollutant concentrations were estimated for use in MUSIC based on a study of worldwide data (Duncan, 1999) and these as well as minor updates, drawing on Fletcher et al. (2005) provide the basis for the default parameters recommended below.

The default parameters for TSS, TP and TN concentrations for the urban (mixed surface type/land use), agricultural, and forest nodes must be used unless the split surface type approach is used with the concentrations as set out in Table 4 below or written permission is provided by Melbourne Water to use alternative inputs. Where the split surface types are adopted, these should be consistently used to represent all urban catchment areas and not mixed within the same model with nodes using the urban (mixed surface type/land use).

Table 4 Pollutant concentration data for source nodes where surface types are split (Fletcher, 2007)

Pollutant	Surface type	Storm flow (log mg/L)		Baseflow (log mg/L)	
		Mean	SD	Mean	SD
TSS	Roof	1.301	0.333	n/a*	n/a
	Road	2.431	0.333	n/a	n/a
	All other urban areas	1.882	0.333	0.96	0.401
TP	Roof	-0.886	0.242	n/a	n/a
	Road	-0.301	0.242	n/a	n/a
	All other urban areas	-0.680	0.242	-0.731	0.360
TN	Roof	0.301	0.205	n/a	n/a
	Road	0.342	0.205	n/a	n/a
	All other urban areas	0.224	0.205	0.346	0.309

* n/a indicates that baseflow does not occur from these surfaces

Serial correlation

The serial correlation (R squared) must be zero for all pollutants for analysis of stormwater quality treatment performance.

Stochastic versus mean generated data

MUSIC allows stormwater pollutant concentrations to be predicted in one of two ways:

Mean pollutant concentrations: use a single mean concentration.

Stochastic pollutant generation: predicts a new pollutant concentration for each timestep using a mean and standard deviation to produce a distribution of concentrations that is consistent with the input parameters of the model, which are in turn based on monitored data.

Stochastically generated pollutant concentrations must be used.

Subject to agreement, Melbourne Water may allow the use of mean concentrations for specific purposes, such as examining behaviour for a particular storm event or set of operating conditions, but not general stormwater treatment design.

Routing and drainage links

Water will flow through a catchment into drains, stormwater treatment assets and receiving waterways. In MUSIC, drainage links are used to direct water flows to and from each node.

Routing

Drainage links can also be used to set how long water will take to travel through a link and describe the links behaviour, which is defined as routing.

A link may represent either:

Catchment time of concentration: Water flows from the furthest upstream point in a catchment to its outlet or the point at which flows reach a confluence with flows from other catchments. The longest time it takes water to reach the outlet is called the time of concentration of the catchment. It depends on the size and shape of the catchment and the corresponding length and slope of the longest flow path within it. It may also be influenced by whether flows will occur along natural depressions and waterways or piped drainage. The time of concentration is represented using the first link downstream of a catchment node.

Travel time: Water flows from one point to another which may be a confluence, treatment asset or other point of interest. Routing in this instance represents the travel time between these points.

The time in drainage links may be set to reflect the time of concentration of the catchment, using the first link from a catchment node, and travel times within the drainage network from one location or asset to another using other links. Routing times may be estimated using standard methods for drainage design and input into MUSIC (MUSIC does not calculate these).

When should routing be used?

- Routing may be omitted for most MUSIC models for the design of stormwater treatment assets as well as for small catchments. This simplifies the model and is usually conservative for stormwater quality models. Routing is unlikely to have much effect in small catchments where the time of concentration is less than 10 minutes given that times are rounded to the nearest modelling timestep interval which is usually 6-minute increments.
- Routing is recommended for analyses that are sensitive to peak flows. These include flow rate diversions (for example, wetland high flow bypasses and pumping to stormwater harvesting assets).

If routing is used, it must be calculated and applied consistently across a model to ensure timing of peak flows and possible coincident peaks are modelled appropriately.

In MUSIC, three types of routing are available:

1. Select 'no routing' for simple models where routing is to be omitted. This assumes water flows instantaneously from one point to another.
2. Select 'translation only' for flows in pipes and concrete channels. This assumes water flows through the reach with no or minimal attenuation.
3. Select 'Muskingum Cunge' for overland flows and flows in natural channels and waterways where attenuation would be expected (typically theta = 0.25 is adopted unless informed by further analysis or calibration).

Routing through drainage links can be specified via double click to access the properties dialogue box, see Figure 4.

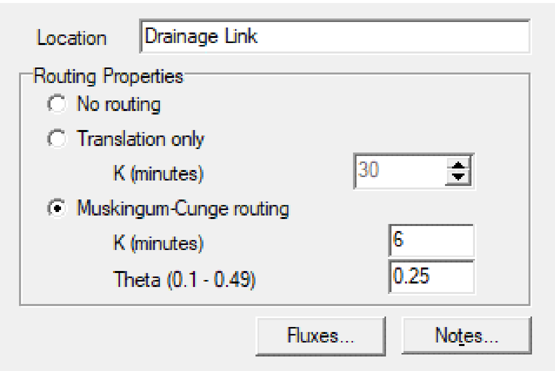

Figure 4 Setting routing parameters in MUSIC

Primary and secondary drainage links

In MUSIC both primary and secondary links may be defined.

A primary drainage link from a node must be used first. Secondary links may then optionally be used to direct selected flows to another destination.

Primary drainage links

When only a primary drainage link is used, all flows from the node are directed through that link. For primary links from source nodes (catchments), this includes by default:

- baseflow
- pervious storm flow
- impervious storm flow.

MUSIC assumes deep seepage and evapotranspiration are directed out of the model as losses.

MUSIC assumes that flows diverted around a treatment and those passing through it are *recombined at the outlet from the asset*. Primary drainage links (see Figure 5) from a treatment by default include:

- low flow bypass
- high flow bypass
- pipe flow
- weir overflow.

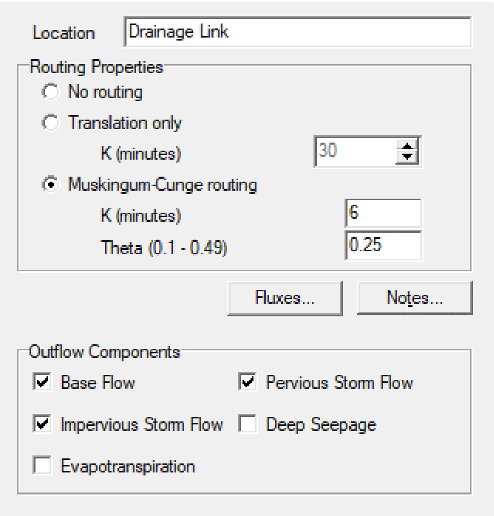

Figure 5 Primary drainage link parameters in MUSIC

Secondary drainage links

Secondary drainage links may be used to divert and redirect flows from source nodes and treatment nodes in MUSIC to a different point than the primary link. This is useful for separating and directing specific components of the total flow to or around downstream treatment nodes.

Secondary links must be used to more realistically represent actual conditions where flows are split or diverted.

Secondary drainage links from source nodes

Secondary drainage links separate and redirect flows from source nodes that are otherwise combined. Available flow components to be redirected include:

- baseflow
- pervious storm flow
- impervious storm flow
- deep seepage
- evapotranspiration.

For example, surface flows may be directed through a treatment asset while baseflows may infiltrate to groundwater and discharge directly into the receiving water. This can be modelled by adding a secondary link to a catchment node and routing it around the treatment to the receiving node (Figure 6).

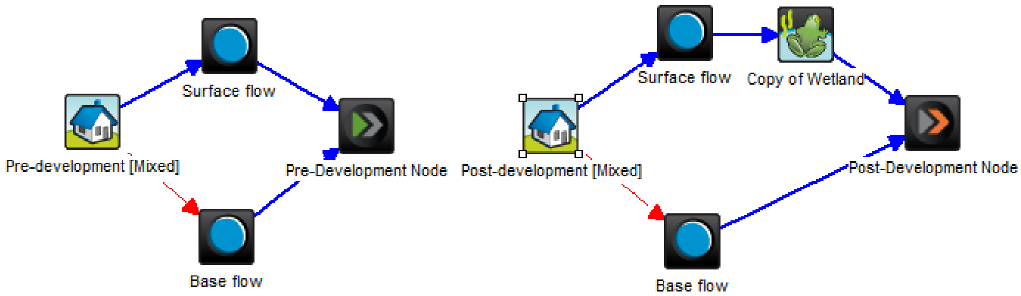

Figure 6 Directing only surface flows to treatment while baseflows are assumed to infiltrate and enter the waterway via groundwater

Secondary drainage links from treatment nodes

Secondary drainage links can separate and redirect flows from a treatment node and this can be particularly useful for representing different treatment and outlet configurations.

The range of outflow components depends on the type of treatment node and may include:

- outflow (pipe outflow)
- overflow (weir overflow)
- low flow bypass
- high flow bypass
- reuse
- infiltration
- evapotranspiration.

Some examples of the use of secondary links include:

- Routing overflows or bypass flows from a treatment asset around a downstream asset. For example, diversion of 'Weir Overflow' and 'High Flow Bypass' flows from a sediment pond around the macrophyte zone of a wetland. This is needed when a separate sediment basin node is used upstream of a wetland node. Refer to Figure 7.
- Routing flows from a treatment into or around a downstream stormwater reuse storage so that only treated flows are captured for reuse.
- Representing pumped flows using a constant reuse demand in the model and directing the resulting reuse flows to a different treatment or storage. See Figure 8 for an example.
- Representing the high flow bypass for a typical constructed wetland

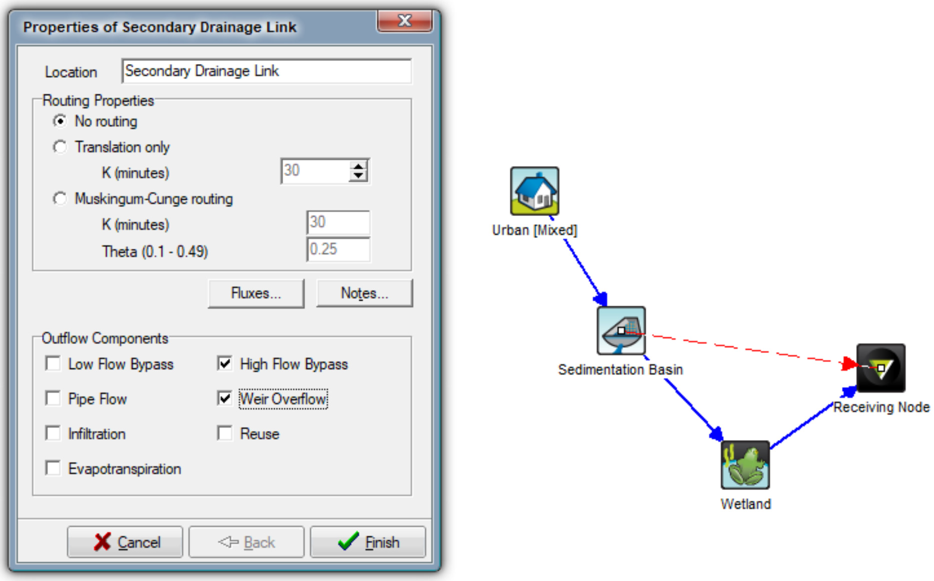

Figure 7 A MUSIC model containing a secondary link redirecting overflows and high flow bypass around a downstream wetland

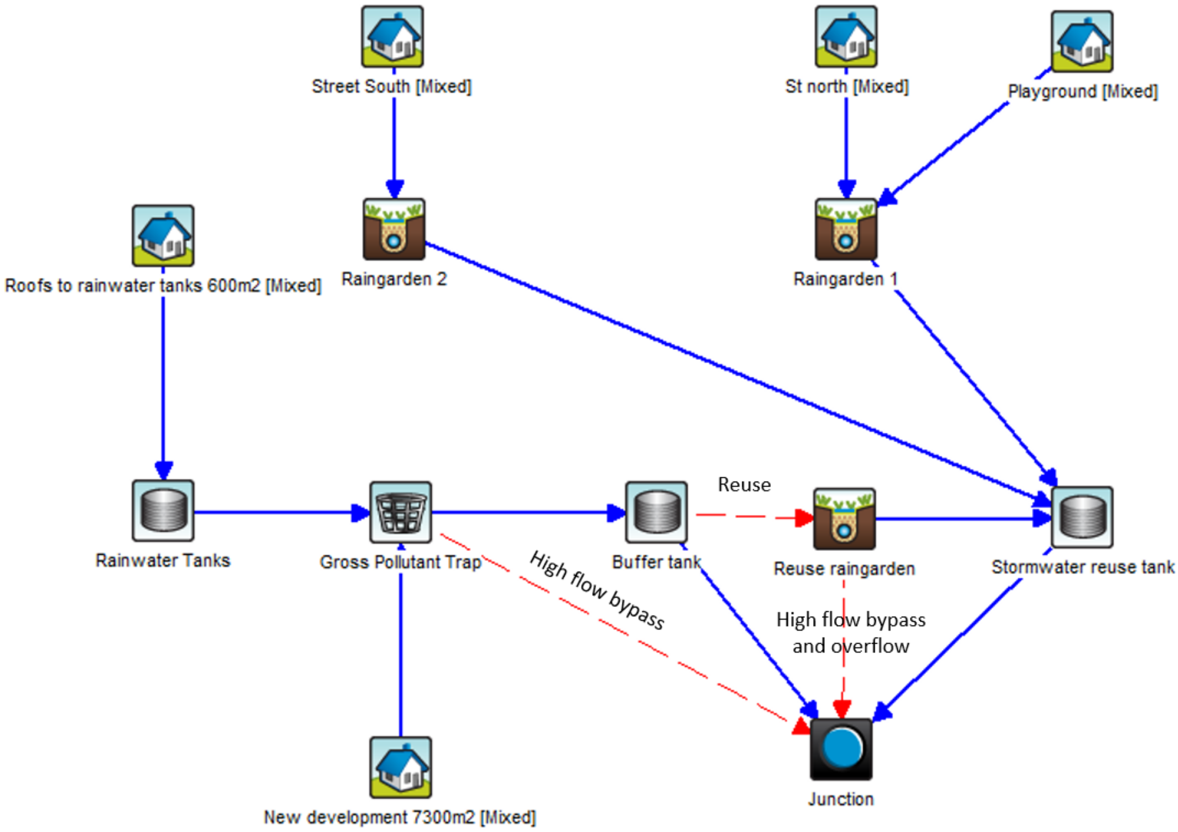

Figure 8 Directing high flow bypasses and overflows to outlet, pumped reuse from a buffer to a raingarden and outflows to a stormwater reuse storage

It is important when using secondary links to ensure that flows are directed back into the final receiving node before reporting to ensure flows are not lost.

Tip: If the treatment train effectiveness is to be used, users must ensure all flows normally routed within primary drainage links are redirected back into the model before the point where treatment train effectiveness is assessed. For source nodes these are baseflow, pervious storm flow, impervious storm flow, and for treatment nodes these are low flow bypass, high flow bypass, pipe flow and weir overflow.

If users do not direct these flows back into the model, treatment train effectiveness results will not be available.

4. Treatment nodes

General notes

K, C*, C**

The default k and C* values must not be adjusted without prior written approval from Melbourne Water. An exception to this is the nitrogen k value for stand-alone sediment ponds as these should be excluded from nitrogen treatment performance reporting (refer also to *Sediment ponds (labelled "sediment basin" in MUSIC)* within this document). In this instance the nitrogen k value for stand-alone sediment ponds should be set to zero, reflecting that these assets on their own are not viable systems for temporary or long-term nitrogen removal.

In addition to requiring written approval from Melbourne Water, any data used to modify these parameters must be peer-reviewed publications and/or research that has been undertaken according to scientific and ethical norms (for example, Australian Code for the Responsible Conduct of Research) and be appropriate for the circumstances being modelled.

Plant survival

MUSIC cannot model plant death due to long dry periods, or more commonly, excessive water depth. Further analysis and input from practitioners with knowledge of aquatic ecology are needed to make sure the plants selected will survive and contribute to pollutant removal over the life of the treatment node if non-standard designs are used. Melbourne Water's *Biofiltration systems in Development Services Schemes Guideline* (Melbourne Water, 2020) and *Wetland Design Manual* (Melbourne Water, 2020) provide guidance on appropriate plant selection. Designers may also use the wetland analysis tool on the MUSIC Auditor website as an initial screen to identify obvious risks to plant survival based on inundation frequency patterns.

Number of CSTR cells

The CSTR input parameter in MUSIC represents the hydrodynamics or hydraulic mixing behaviour of treatment nodes. The default number of CSTR cells for a treatment node can be changed through the 'More' button. The number of CSTR cells for sediment ponds can also be changed through the 'Estimate Parameters' button.

These are usually only changed to more accurately represent sediment ponds of a given shape. The length to width ratios for the shapes used to estimate the number of CSTR cells is listed in Figure 9 below.

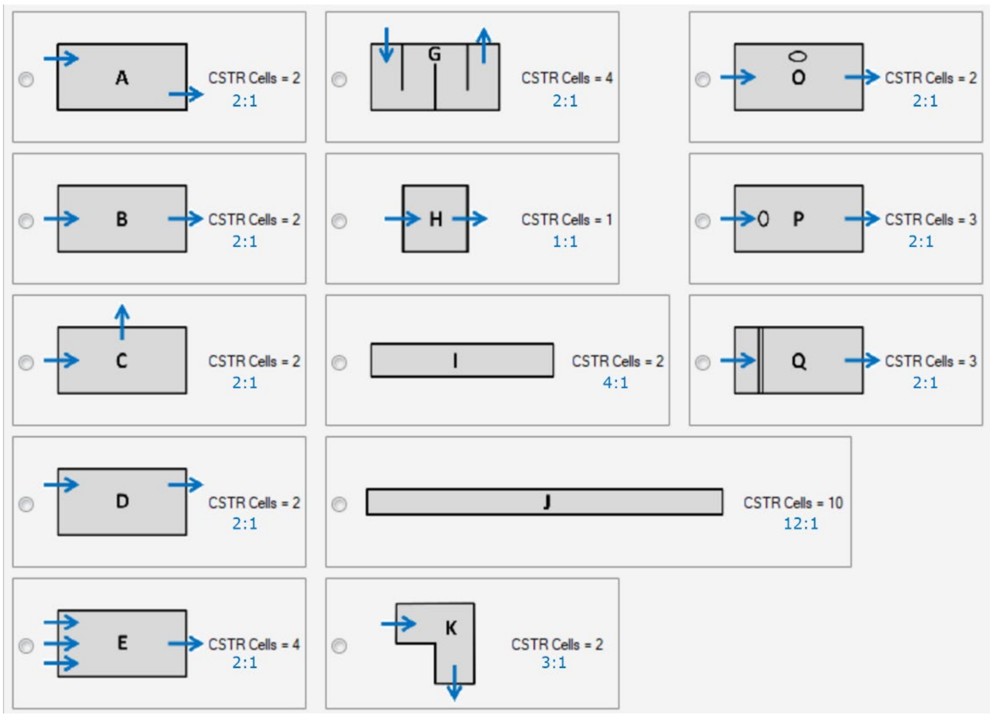

Figure 9 Treatment node shapes and length to width ratio to determine the number of CSTR cells (Persson, 2000). P contains an island blocking the central flow path and Q contains a structure to distribute the flows evenly.

Treatment trains

Treatment nodes within a MUSIC model must be linked in an appropriate order (see example in Figure 10), with primary treatment devices first, followed by secondary treatment devices and tertiary treatment devices last (if present).

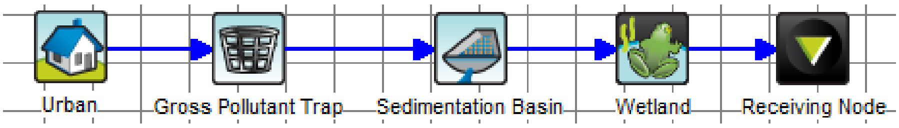

Figure 10 Example treatment train

Infiltration into surrounding soils (exfiltration rate)

Infiltration into surrounding soils is represented in MUSIC using the 'Exfiltration rate'. Generally, this should be set to zero where available information is limited.

Where an exfiltration rate of greater than 0 mm/hour is proposed this should be supported by relevant geotechnical testing for the site or requested. At a minimum, it must be based on representative rates for the underlying soil types for incidental infiltration. The use of infiltration shall be subject to agreement by the relevant authority.

Where infiltration is used, all pollutant loads infiltrated must be counted as contributing towards outflow pollutant loads.

Instream works and waterways

Do not include constructed or natural waterways, natural wetlands or grassed retarding basins as treatment nodes.

Stormwater harvesting or reuse

Developers will need to apply for a stormwater harvesting licence if you connect to new or modified stormwater drains, watercourse or open channel or harvest any quantity of stormwater from a waterway controlled by Melbourne Water. Details on Melbourne Water's process for stormwater harvesting can be found on Melbourne Water's website[9].

For large scale stormwater harvesting, a reuse master plan must be provided which is to be signed off by all relevant authorities (Local Government, Retail Water Company, Melbourne Water). Calculations should be provided to support estimated volumes of harvested stormwater. All harvested stormwater should be treated to a fit-for-purpose standard that also supports the long-term sustainability of the reuse infrastructure (including irrigation infrastructure).

Guidelines on quality of harvested stormwater and treatment for public health can be found online by searching for "Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2) Stormwater Harvesting and Reuse".

Rainwater or stormwater harvesting may contribute to treatment train performance if the demands are reliable (for example, toilet flushing at 20 litres per person per day and laundry at 80 litres per household per day). Irrigation of residential blocks is encouraged, although it is not considered a reliable demand. On-site treatment claims on the *Stormwater Quality Offset Contribution Form* cannot include residential irrigation.

For stormwater harvesting to be accepted as part of a MUSIC model, there needs to be a suitable agreement for construction and operation of the scheme between the relevant stakeholders.

A minimum of ten years of six-minute rainfall data (which is included in the provided rainfall templates) must be used to model all stages of a design that includes stormwater harvesting.

Modelling high flow bypasses and overflows

The following guidance is relevant to all treatment nodes, except buffers and swales. It is intended to provide greater clarity on this topic, in addition to guidance available from the MUSIC help menu.

There are three main possible configurations for high flow bypasses and overflows:

1. no flow rate based high-flow bypass (Figure 11 and Figure 12)
2. high-flow bypass occurs upstream of the treatment asset represented by a single node (Figure 13 and Figure 14)
3. high-flow bypass occurs at an asset and bypasses other treatment asset(s) downstream (Figure 15 and Figure 16).

No flow rate based high-flow bypass

How to model: Set high flow bypass to default of 100 m^3/s (or an arbitrary large number greater than all flows).

[9] https://www.melbournewater.com.au/building-and-works/stormwater-management/stormwater-harvesting/stormwater-harvesting-licence

All inflows flow into the asset. High flows exceeding the outlet capacity spill over an overflow weir after treatment (for example, a small streetscape raingarden with internal overflow pit).

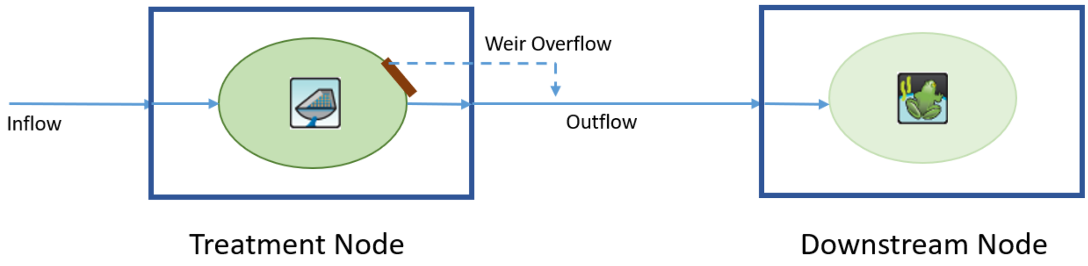

Figure 11 Behaviour of treatment nodes with no high flow bypass rate set and weir overflows from downstream end for most treatment nodes

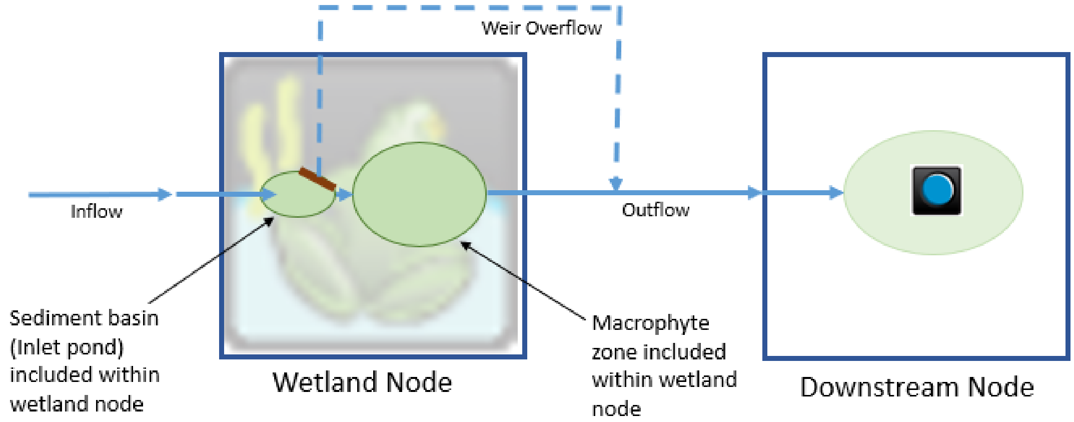

Figure 12 Behaviour of wetland node with no high flow bypass set and weir overflows from sedimentation basin

High-flow bypass occurs upstream of treatment asset represented by a single node

How to model: Set high flow bypass to design bypass flow rate for asset.

Bypassed flows are directed untreated to the immediate downstream node.

This configuration applies for example to treatment nodes that are sized to fit into a given area rather than sized to treat their full upstream catchment.

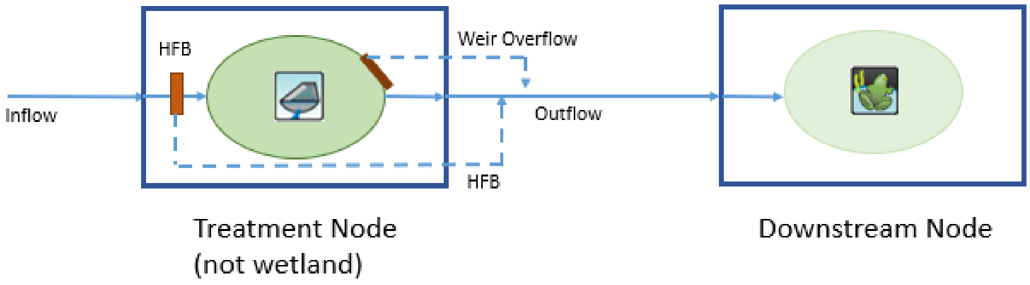

Figure 13 Behaviour of most treatment nodes with high flow bypass upstream (HFB) and weir overflows from downstream end for most treatment nodes

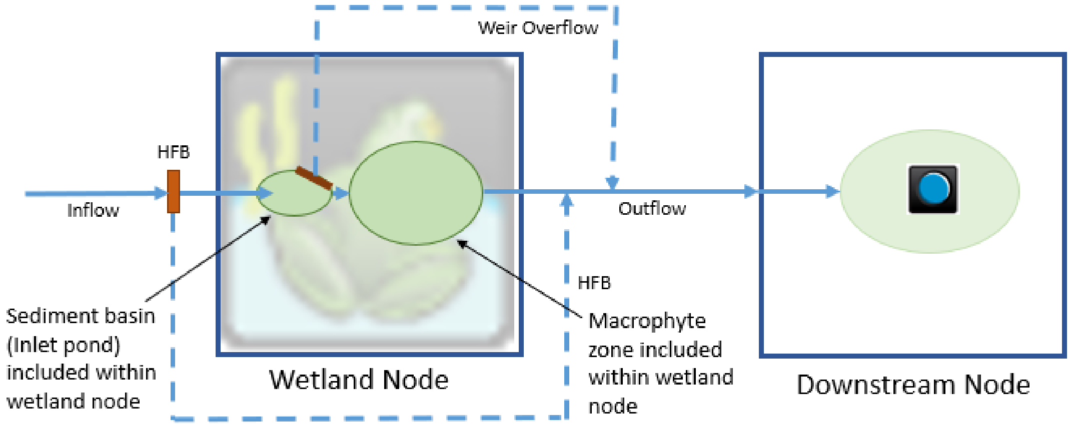

Figure 14 Behaviour for wetland with high flow bypass upstream (HFB) and weir overflows from downstream end of macrophyte zone for a single wetland node

High-flow bypass occurs at an asset and bypasses other treatment asset(s) downstream

How to model: Set high flow bypass to design flow rate for asset and use secondary link to direct bypassed flows around treatment assets as required to represent design.

The bypassed flow will be directed to a node downstream of the treatment node via the secondary link. This is useful when flows are bypassed upstream of an asset then continue to be bypassed for downstream assets (e.g. high flow bypass upstream of a sediment pond and wetland or sediment pond and bioretention).

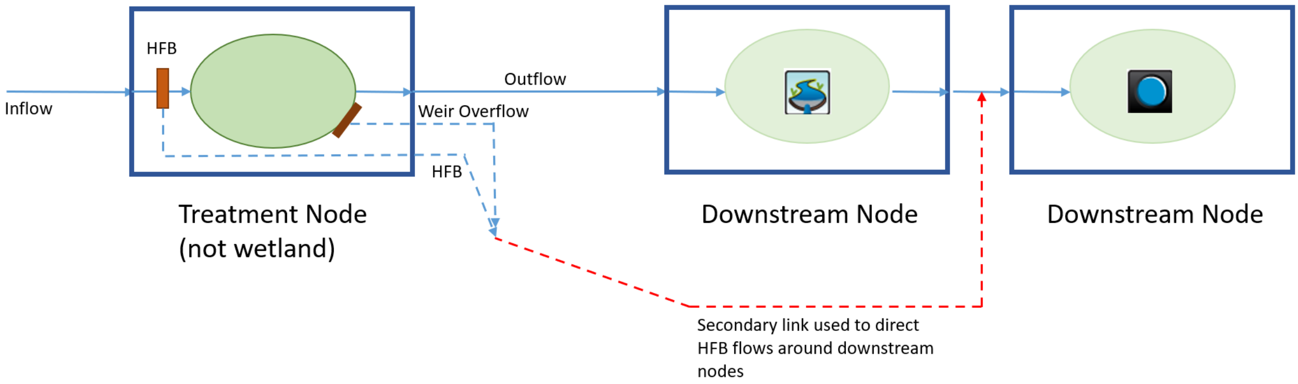

Figure 15 Behaviour of most treatment nodes with high flow bypass directed around both a treatment node and downstream node(s)

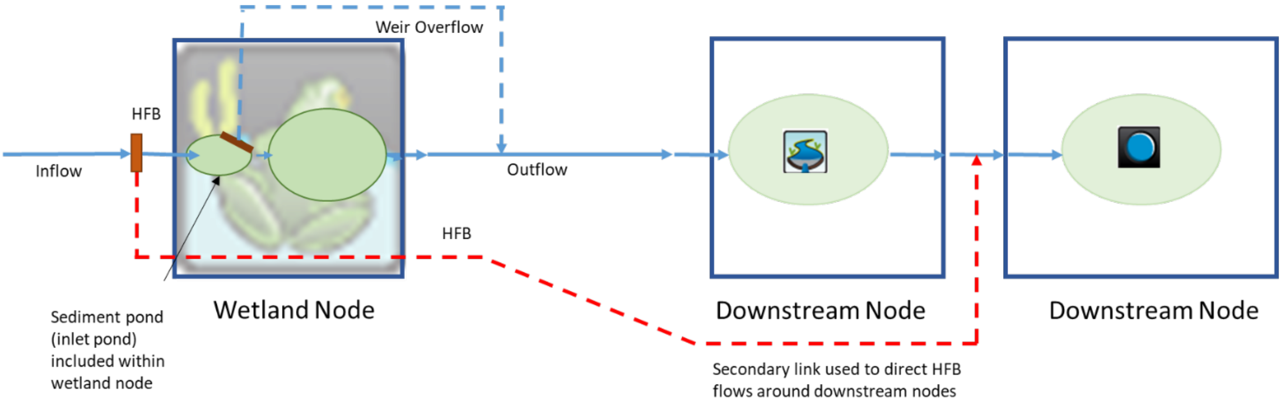

Figure 16 Behaviour of wetland with high flow bypass directed around both wetland node and downstream node(s)

Similar approaches may be adopted for weir overflows as appropriate.

Low flow bypasses may be configured and managed similar to high-flow bypasses where they are relevant, such as for diversions and bypassing of low flows to ensure baseflows are maintained.

Swales

Suggested vegetation heights:

- Grass swale (mowed) height range: 10 to 100 millimetres
- Vegetation (not mowed): 100 to 400 millimetres

In the case where unmown vegetation is being used, the proponent should identify what type of vegetation is proposed, and how it will be managed within the landscape and maintenance requirements of the development. Waterways within developments cannot be deemed as swales and shall not be included in the treatment train model.

Sediment ponds (labelled "sediment basin" in MUSIC)

Sediment pond sizing

Calculate the modelled sediment pond volume from halfway up the sediment accumulation zone to the normal water level, as illustrated in Figure 17.

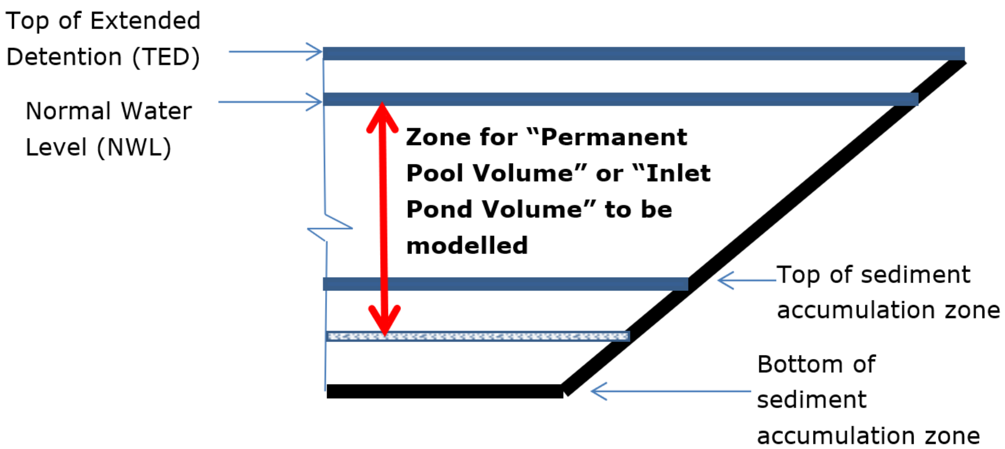

Figure 17 Calculate the modelled sediment pond volume from halfway up the sediment accumulation zone to the normal water level

Do not design the size of the sediment pond with MUSIC alone. Sediment ponds must be designed to meet the sediment pond requirements of Melbourne Water's *Wetland Design Manual* (Melbourne Water, 2020).

Do not use the 'Estimate Inlet Volume' or 'Estimate Storage Properties' function in MUSIC as it is not set up for Melbourne Water's requirements.

Stand-alone sediment pond treatment

Sediment ponds are primary treatment measures in a stormwater treatment train that remove (via settling) coarse to medium-sized sediments (≥ 125 µm). Their function is to protect and operate in conjunction with downstream secondary or tertiary measures such as wetlands or biofilters that use enhanced sedimentation, fine filtration and pollutant uptake processes to remove pollutants such as phosphorus and nitrogen and fine sediments from stormwater. The removal of coarse sediments prior to secondary and tertiary treatment measures is crucial for their effective operation. There is insufficient evidence to confirm that temporary or permanent nitrogen removal is facilitated by sediment ponds. This is due to research findings that nitrogen removal declines with the age of sediment ponds, coupled with a lack of reliable long-term data. To take a conservative approach to minimise the risks to human health and the environment based on the current state of knowledge, Melbourne Water does not accept nitrogen removal modelled for stand-alone sediment ponds when these do not form part of a treatment system that includes downstream secondary or tertiary treatment (refer also to *K, C*, C*** within this document). To be considered part of a treatment system, the sediment pond must be directly connected to the downstream secondary or tertiary treatment measure to form part of the system's overall treatment process.

Modelling sediment ponds connected to wetlands

Sediment ponds must be modelled either as part of the wetland node or as a separate upstream sediment basin node depending on whether the pond outlet flow is influenced by the water level in the wetland macrophyte zone. If the sediment pond is likely to be influenced by the water level within the wetland, then a single wetland node with an inlet pond should be used to represent the sediment pond and wetland.

Guidance on determining whether the wetland water level is likely to significantly influence the outlet flow in the sediment pond is shown in Figure 18 and described below.

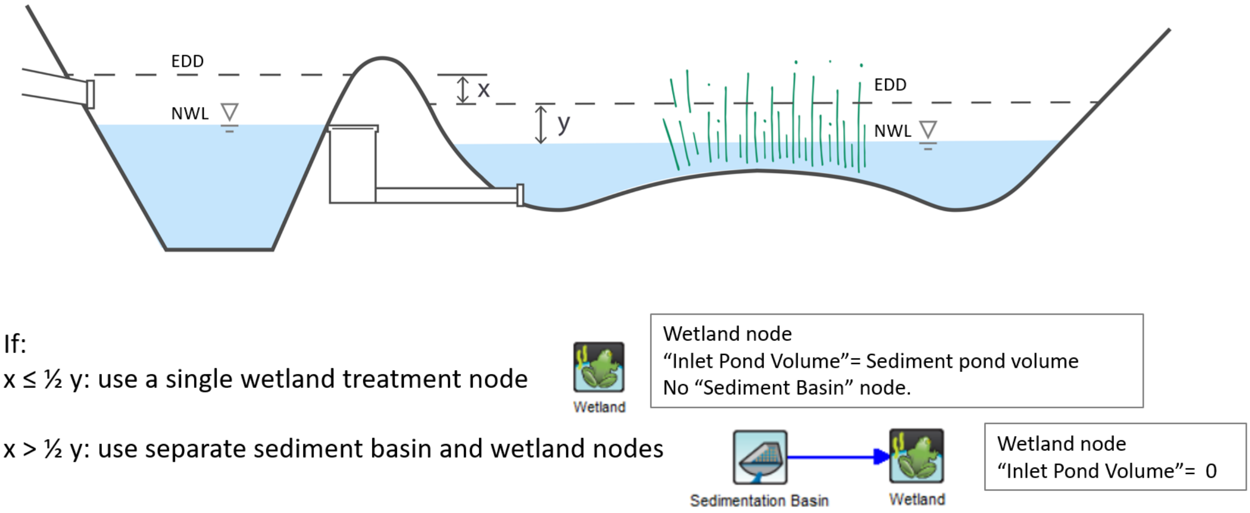

Figure 18 Sediment pond and wetland extended detention levels

Choosing whether to use a single wetland node or separate sediment pond and wetland nodes:

A single wetland node must be used where the difference between the sediment pond and wetland macrophyte zone extended detention levels (x) is less than half of the total EDD of the macrophyte zone (y) or where there is uncertainty as to whether the sediment pond outflow may be significantly influenced by the wetland water level.

Separate sediment basin and wetland nodes must be used where the difference between the sediment pond and wetland macrophyte zone extended detention levels (x) is greater than half the wetland macrophyte zone EDD (y).

Where separate sediment basin and wetland nodes are used:

- Set the wetland node ‘Inlet Pond Volume’ to zero.
- The sediment basin node weir overflow must be directed around the wetland node using a secondary drainage link (refer to *Modelling high flow bypasses and overflows* in this guide).
- The sediment basin node equivalent pipe diameter must reflect the hydraulic control between the sediment pond and wetland macrophyte zone (this is likely to need to be defined using the custom outflow function).

Melbourne Water’s Deemed to Comply Criteria in the *Wetland Design Manual* (Melbourne Water, 2020) require the sediment pond normal water level (NWL) to be a minimum 100 mm higher than the macrophyte zone NWL and sediment pond and the macrophyte zone extended detention depth (EDD) less than or equal to 350 mm. The single wetland treatment node approach would apply under these conditions.

A more detailed approach is as follows:

- Model the sediment pond and wetland using a single wetland node.

- Obtain an inundation frequency curve.
- Assess the level of interaction using the inundation frequency curve for the wetland.

Where the inundation frequency curve indicates that the water levels will spend a significant proportion of time above the sediment NWL, this would indicate significant interaction. Where the water levels are mostly below the sediment pond NWL most of the time, the interaction is less significant. It is recommended that the water levels should not be above the sediment pond NWL for more than 15% of the time to justify use of a separate sediment pond. Ideally this should be zero, however a small level of interaction has been allowed for practicality as this would not have a significant impact on outcomes.

Worked example 1 for detailed approach

A typical inundation frequency curve for a wetland is shown in Figure 19. In this example the sediment pond NWL is 200 mm above the wetland NWL and that both have an independent EDD of 350 millimetres. y = 350 mm and x = 200 mm.

$x > ½ y$

Figure 19 shows that the wetland water levels would only exceed the NWL of the sediment pond and interact with those in the sediment pond for 8% of the time. This is within the acceptable range. The water level interactions and impact on hydraulics and treatment performance are likely to be relatively minimal. This asset may be modelled as a separate sediment pond and wetland.

Worked example 2 for detailed approach

A typical inundation frequency curve for a wetland is shown in Figure 20. In this example the sediment pond NWL is 100 mm above the wetland NWL and that both have an independent EDD of 350 millimetres. y = 350 mm and x = 100 mm.

$x < ½ y$

Figure 20 shows that the wetland water levels would exceed the NWL of the sediment pond and interact with those in the sediment pond for 25% of the time. This exceeds the acceptable range. The water level interactions and impact on hydraulics and treatment performance may be significant. This asset should be modelled as a combined sediment pond and wetland.

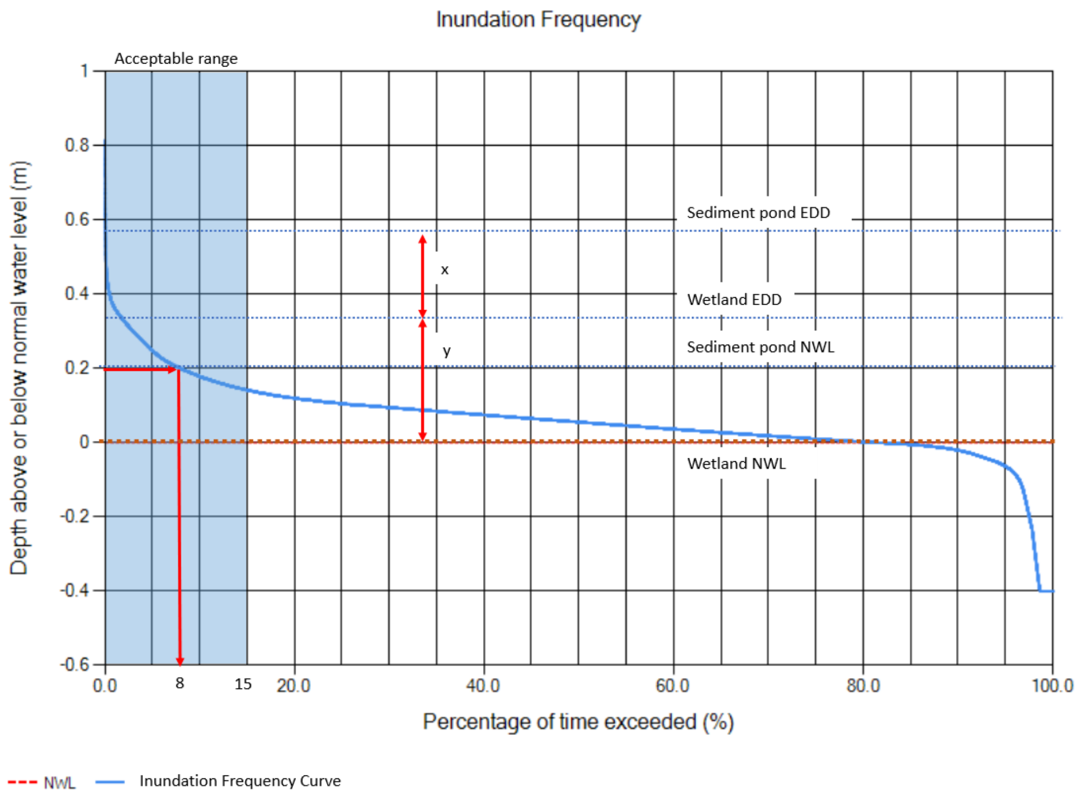

Figure 19 Typical inundation frequency curve for a wetland (sediment pond NWL and EDD 200 mm above wetland NWL and EDD). Separate sediment pond and wetland

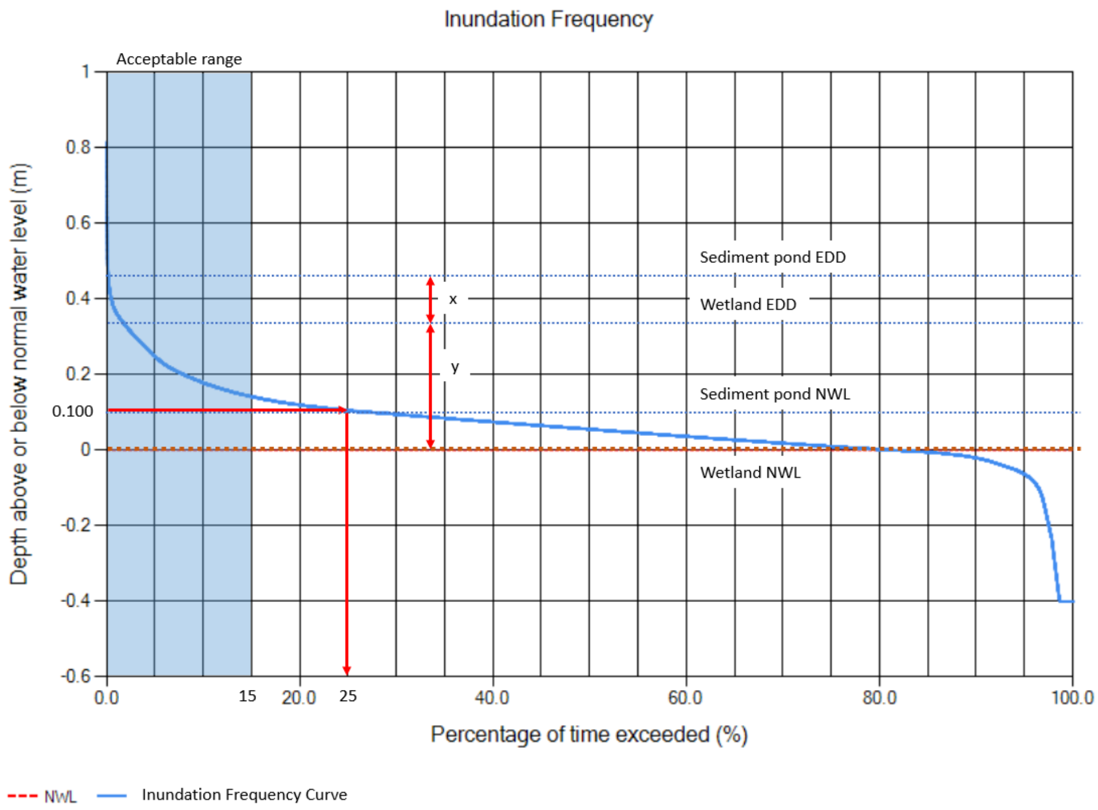

Figure 20: Typical inundation frequency curve for a wetland with sediment pond NWL and EDD 100 mm above wetland NWL and EDD). Combined sediment pond and wetland

Wetlands

Constructed wetland assets must be designed in accordance with Melbourne Water's *Wetland Design Manual* (Melbourne Water, 2020)[10].

MUSIC can predict the potential pollutant removal outcomes of a design.

The recommendations for modelling with an inlet pond or separate sediment basin node are provided in the *Sediment ponds (labelled "sediment basin" in MUSIC)* section of this guide.

For functional and detailed design stages, the stage-storage-discharge relationships of the wetland extended detention must be represented using MUSIC's custom outflow and storage relationship function. Where the wetland is within a retarding basin, the MUSIC model must also reflect the stage-storage-discharge relationship of the retarding basin (when the water level exceeds top of extended detention).

In MUSIC the surface area and permanent pool volume of the wetland are provided as inputs.

> In MUSIC, the average permanent pool depth is assumed to be the permanent pool volume divided by the surface area (unless a custom stage storage discharge relationship is used).

This should consider Deemed to Comply Criteria MZ1 in the *Wetland Design Manual* (Melbourne Water, 2020). This will usually not be more than 400 millimetres in complying designs.

Wetland user defined outlet

Usually it is sufficient to model a notional detention time of 72 hours for concept designs, however for functional and detailed designs the wetland outlet properties must use custom outflow and storage relationships. These may be defined externally and the process to bring these into MUSIC is described in *Defining custom outflow and storage properties* in this guide.

Modelling wetlands with multiple inlets

The MUSIC modelling software was developed assuming the wetland treatment node represents a single inlet pond feeding flows to a macrophyte zone. Wetlands with multiple inlets where inflows are split between multiple sediment ponds before flowing through the attached macrophyte zone require special consideration. This type of wetland configuration can be difficult to reasonably represent in MUSIC.

The flow path length through the macrophyte zone must also be sized proportional to the volume entering the system. The macrophyte zone surface area at NWL, planting zone distribution and macrophyte coverage must also be proportional.

> The design of each inlet pond should be generally in proportion to stormwater runoff volumes entering from its direct catchment.

To model a wetland treatment with multiple inlets in MUSIC, the following approach must be applied (with reference to *Modelling sediment ponds connected to wetlands*):

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[10] https://www.melbournewater.com.au/building-and-works/developer-guides-and-resources/standards-and-specifications/constructed-wetlands

If the wetland is represented by a single treatment node, the 'inlet pond volume' entered in the wetland treatment node must equal to the sum of the volume of all associated sediment ponds up to NWL.

If the wetland is represented by separate wetland and sediment basin nodes, a sediment basin node must be provided for each (inlet) sediment pond consistent with its design. Each of these should be sized in proportion to the flows entering at that inlet. For example, if 60% of flows enter at inlet A and 40% at inlet B, then 60% of the total sediment pond volume should be provided at inlet A and 40% at inlet B.

Wetland analysis tool

The wetland analysis tool on the MUSIC Auditor website should be used to check the appropriateness of the design response. The tool provides the following checks:

- Effective water depth does not exceed half plant height more than 20% of the time
- Average water level is not more than 50 mm above normal water level
- The 90th percentile residence time should be 72 hours (3 days). A lower detention time of not less than 48 hours may be considered in retrofit circumstances to achieve the plant inundation frequency criteria.
- Shallow marsh plants are unlikely to persist with water levels 300 millimetres above NWL for greater than 10 days occurring. A check is made that no more than one spell of 10 days or more occurs where water levels are greater than 300 mm above normal water level in 10 years (see spells example in Figure 21).

The following should also be checked:

- Relevant velocity checks should be undertaken as indicated in the *Wetland Design Manual* (Melbourne Water, 2020).
- Check the frequency and periods of drawdown below normal water level (resulting in drying of large areas of planted macrophyte zone) are acceptable with respect to plant health and potential for mosquito breeding.

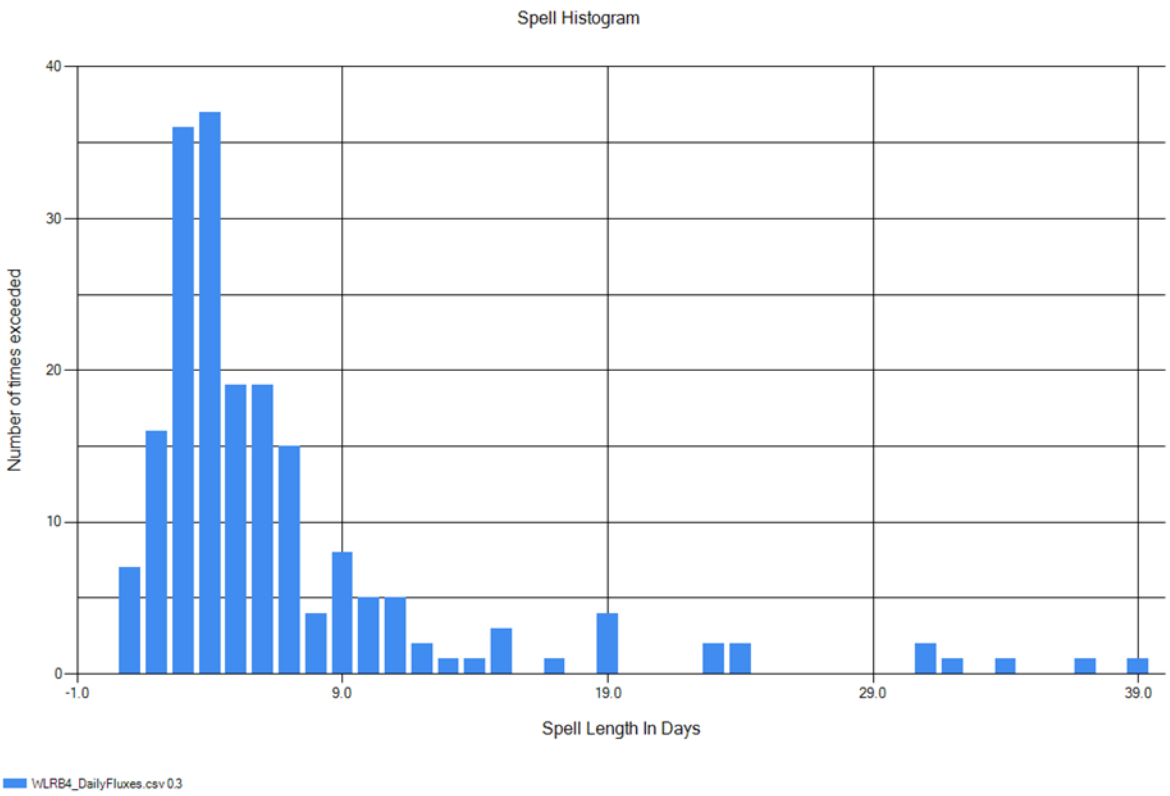


Figure 21 Spells where water level is greater than 300 millimetres above NWL in a wetland where the planting is likely to be compromised. In this non-complying example, spells of 10 days occur five times and longer spells also occur multiple times in the analysis period.

Online wetlands

Melbourne Water does not provide MUSIC guidance for online wetlands. For Melbourne Water's position on online wetlands please see the *Wetland Design Manual Part A2: Deemed to Comply Design Criteria* (Melbourne Water, 2020), Deemed to Comply Criteria MZ3 and the *Wetland Design Manual Part A3: Design Considerations for Wetlands Manual* (Melbourne Water, 2020), Section 3.4.

Ponds

MUSIC is not a suitable model for in-lake processes, other than water balance assessments. Guidance on this topic can be found in Melbourne Water's *Constructed Shallow Lake Systems: Design Guidelines for Developers* (Melbourne Water, 2005)[11]. Ponds will not be accepted as treatment nodes.

Bioretention (raingardens, biofilters)

Bioretention assets must be modelled in accordance with Melbourne Water's *Biofiltration systems in Development Services Schemes Guideline* (Melbourne Water, 2020) which provides guidance on appropriate design ranges for various parameters. Designers should familiarise themselves with and consider the Deemed to Comply Criteria in Part B of the guideline. References to these criteria are made throughout this section of the modelling guide.

[11] https://www.melbournewater.com.au/media/607/download

Note, MUSIC models must reflect the design and expected behaviour of the asset (refer to Deemed to Comply Criteria GN4).

Inlet properties

The high flow bypass in MUSIC must be configured based on the inlet capacity and Deemed to Comply Criteria BR2.

Infiltration properties

The exfiltration rate applies to the underlying soil (not the filter media) and Deemed to Comply Criteria BR8. Where an exfiltration rate of greater than 0 mm/hour is proposed this should be supported by relevant geotechnical testing for the site or requested. At a minimum, it must be based on representative rates for the underlying soil types for incidental infiltration. The use of infiltration shall be subject to agreement by the relevant authority. Where infiltration is used, all pollutant loads infiltrated must be counted as contributing towards outflow pollutant loads.

Filter media properties

Default values for nitrogen and orthophosphate content of the filter media must be used. Lower orthophosphate concentrations may be used, as low as 20 milligrams per kilogram, provided evidence for concentrations at or below this is provided in the filter media sign-off form as part of the construction documentation.

Outlet properties

The overflow weir width must be based on the designed length for the overflow weir or pit crest and in accordance with Deemed to Comply Criteria GN5.

Sediment removal

All coarse sediment removal pre-treatment assets must be designed and sized in accordance with Deemed to Comply Criteria CS1 and CS6.

Filter media

An acceptable design range for the design hydraulic conductivity of a biofilter is 100 to 300 millimetres per hour as recommended in the *Adoption Guidelines for Stormwater Biofiltration Systems* (Payne, et al., 2015)[12].

The modelled hydraulic conductivity of the filter media must either match the design specification or preferably be a conservatively low figure. A maximum of 100 millimetres per hour is recommended for all typical assets and 150 millimetres per hour for high priority and reliably maintained assets such as stormwater reuse biofilters only. These are based on the recognition that some sediment clogging of the surface is likely to occur as well as plant perturbation meaning higher infiltration rates may not be reliably sustained, irrespective of initial hydraulic conductivity.

12 https://watersensitivecities.org.au/content/stormwater-biofilter-design/

Submerged zone

A Submerged zones with a minimum depth of 300 mm is recommended and preferred where site conditions permit, refer to Deemed to Comply Criteria BR7.

The filter media depth in MUSIC should include the filter media from the surface to the base of the filter media, or the invert level of the outlet pipe if this is higher. It must not include the transition or drainage layers.

If a submerged zone is used, the submerged zone depth in MUSIC may include the drainage and transition layers below the invert of the outlet pipe.

Plant species selection

The *Biofiltration systems in Development Services Schemes Guideline* (Melbourne Water, 2020) identifies specific plant species to be used including plants that provide effective nutrient removal. If 'effective nutrient removal plants' are selected under 'Vegetation Properties' (recommended), the planting specification must support this with at least the minimum numbers of plant species, proportion effective for nutrient removal and densities as set out in VG2 to VG6.

The design must provide sufficient soil moisture to sustain plants. This can be achieved through:

- a minimum filter media depth of 400 millimetres (500 millimetres preferred)
- a submerged zone
- no underdrain (where underlying soils have adequate infiltration rates)
- appropriate size treatment area relative to the catchment (generally 20 to 100 times the area of the bioretention system)
- a reliable source of irrigation to be used occasionally during extended dry periods.

Extended detention depth

The user should set an extended detention depth taking into consideration climatic conditions and likely wetting and drying behaviour and that is safe for construction, operation and maintenance of the system and the public. Bioretention assets with a longitudinal slope will not have a uniform extended detention depth and in these cases an average depth must be adopted.

The extended detention depth for Melbourne's different climatic regions must be in accordance with that advised in the *Biofiltration systems in Development Services Schemes Guideline* (Melbourne Water, 2020), see Table 5 and refer to Deemed to Comply Criteria BR4.

Table 5 Recommended biofilter extended detention depth ranges (adapted from *Biofiltration systems in Development Services Schemes Guideline* to reflect updated rainfall regions*)*

Rainfall region	Extended detention depth (mm)
Melbourne City	100 to 300[13]

[13] Based on *Adoption Guidelines for Biofiltration Systems* (CRC for Water Sensitive Cities, 2015).

Rainfall region	Extended detention depth (mm)
Dandenong Bullengarook East Narre Warren North Toolangi (Mt St Leonard)	
Little River Melbourne Airport	100 to 500[14]

[14] Based on *Bioretention in the West – Phase 1, Design for Sustained Health of Plants through Consideration of Soil Moisture Behaviour* (E2DesignLab, 2013).

Permeable or porous paving

Permeable paving allows runoff to drain through or between a paved surface and infiltrate the underlying media. It can provide some degree of stormwater treatment but more importantly increases the pervious area of the developed catchment that can infiltrate into the soil. An example of a typical permeable pavement cross-section is shown in Figure 22. Permeable paving is considered a type of unvegetated filter and may be modelled using the media filtration node.

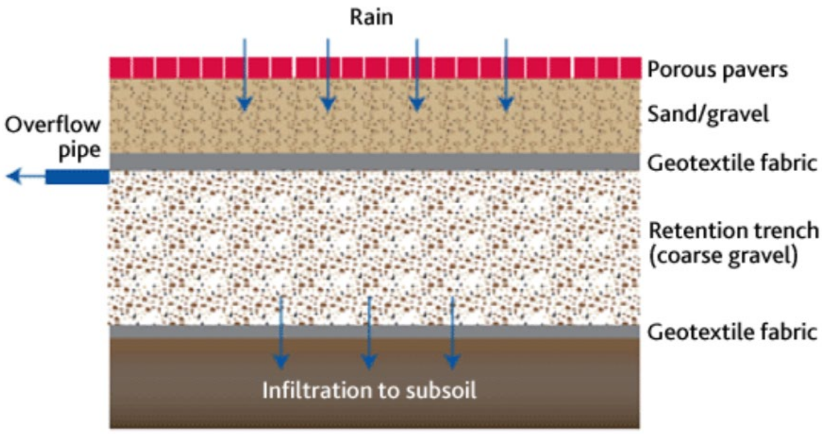


Figure 22 A typical permeable pavement cross section

Permeable paving must be modelled taking the following approaches and relevant manufacturer's guidelines into account. Users should use the permeable pavement treatment input parameters for the media filtration node described in Table 6.

Documentation supporting the modelling must be submitted for review.

Table 6 Input parameters for permeable paving

Parameter	Guidance and discussion
Extended detention	Usually set to 0 millimetres (or a nominal depth, for example, 10 millimetres) if water overflows freely from the permeable pavement. It may be set higher if there is a specific design intent to allow frequent ponding above the paving
Exfiltration rate	The exfiltration rate applies to the underlying soil (not the filter media). Designs including infiltration must consider site suitability as well as constraints for infiltration such as reactive clay soils, bedrock, groundwater, slope, soil contamination and nearby infrastructure.
Surface area	The total surface area of the permeable pavement. This includes both pavers and permeable openings for permeable interlocking pavers or similar.
Filter area	For permeable interlocking pavers or similar with openings to allow infiltration, the opening area of the permeable pavement (not the total surface area) should be set as the filter area. This must be estimated based on the product specifications.
Filter depth	Set the filter depth to represent the depth of the treatment zone, nominally the depth of permeable pavement and underlying sand and gravel supporting layers including the base course, see Figure 22.
Filter median particle diameter	Set to median particle size, such as 2 millimetres (a range of 1 to 5 millimetres depending on design is acceptable).
Saturated hydraulic conductivity	A value within the range 100 to 200 millimetres per hour must be used as a reasonable approximation to allow for clogging of the pavement surface over time and representative long-term performance. Permeable pavement specifications will detail high infiltration rates, commonly thousands of millimetres per hour, however these can be expected to decline exponentially over time. An infiltration rate of 100 to 200 millimetres per hour represents a well performing established asset more realistically. This assumes that maintenance will be undertaken if performance falls significantly below these levels.
Depth below underdrain pipe (% of filter depth)	Set to zero per cent if no submerged zone below underdrainage. Set to an appropriate percentage where underdrainage is provided to encourage additional infiltration.

Source Node Set Up

While most treatment assets are a small proportion of their catchment, permeable pavements are usually a large portion of their catchment.

MUSIC does not directly represent rainfall onto a treatment node. Rather, it is assumed the area of the treatment is included within an upstream catchment area. For assets like permeable pavement where the treatment asset will be a significant part of its catchment (10% or more), it becomes important that this treatment area is represented. Direct rainfall on the permeable paving may comprise a significant portion (or all) of the total flow treated and therefore has an influence on treatment outcomes. Since all rainfall falling on a WSUD asset will enter it, the area should be represented as a 100% impervious surface area to ensure a correct water balance with all direct rainfall becoming inflow. A 'road' surface type should usually be adopted as the best approximation of pollutant concentrations. Justification must be provided where a different surface type is proposed (for example, 'all other urban' surface concentrations for a pedestrian area with permeable paving).

For clarity in the model setup it is recommended to separate the catchment draining to the permeable paving into two (or more) nodes: one node to represent any surface flows from external areas to the permeable paving and the other to represent the direct rainfall on the permeable pavement.

Imported data nodes

Supporting documentation will be required to justify and explain the use of any imported data nodes in models.

Generic treatment nodes

A generic treatment node can be used to simulate a pump, by setting the flow rate passing through the node (the high flow bypass rate) to the maximum pump flow rate. Flows exceeding the pump flow rate must then be accounted for using a secondary link to direct the high flows above the high flow bypass rate to an appropriate downstream node.

Generic nodes can be used to simulate the splitting of flows and are most useful where a flow rate-based diversion is used. Appropriate documentation and calculations must be provided to justify the split of flows where generic nodes are used for this purpose. Many flow splits can more easily modelled using a secondary link to split flows from a catchment or treatment outlet.

For generic nodes, the outflows or pollutant concentrations out of a transfer curve must not exceed the inflows or pollutant concentrations in. The pollutant balance should be checked using Mean Annual Loads for the node to ensure pollutants are not created or lost, as generic treatment node outputs can easily be misinterpreted.

5. Proprietary stormwater treatment devices

Proprietary stormwater treatment devices are manufactured products aimed at improving stormwater quality.

Most of these devices fit into the following categories:

- gross pollutant/litter traps
- sedimentation devices
- oil separators
- man-made floating wetlands
- media filtration devices.

Melbourne Water is not a proprietary stormwater treatment device regulator and does not undertake reviews or provide endorsements of proprietary stormwater treatment devices and their performance. Proprietary manufactured devices may not be considered a replacement of nature-based solutions in Development Services Schemes.

Outside of Development Services Schemes the selection and adoption of proprietary stormwater treatment devices is to be discussed and agreed upon with the relevant responsible body, for example, councils, road authorities, body corporates, golf courses etc.

In circumstances that require alternative solutions, Melbourne Water may investigate or accept the implementation of a proprietary stormwater treatment device, however this does not constitute endorsement of the device.

OFFICIAL

6. Submission requirements for MUSIC modelling

All submissions

All submissions must include:

1. A copy of the MUSIC model
2. A report from the MUSIC Auditor.
3. A copy of any non-standard rainfall template (*.mlb) file.
4. A copy of any background images to support interpretation of the model

Constructed wetlands

Melbourne Water's submission requirements for constructed wetlands are in Part B of the *Wetland Design Manual* (Melbourne Water, 2020). An excerpt of the submission requirements that directly relate to MUSIC modelling are provided below.

Wetland concept design

The submission requirements for a wetland concept design include:

- summary of MUSIC (or alternative model), including:
  - version of MUSIC or model used
  - meteorological data used
  - map outlining catchment areas and direction of flows
  - justification for choice of source node impervious percentage and any routing used
  - treatment node parameters
  - any modelling parameters that are not in accordance with Melbourne Water's *MUSIC Guideline* (this document)
  - pollutant reduction results
- drawings of the treatment system, including placements, which match the model.

Wetland functional design

The submission requirements for a wetland functional design include:

- a description of the updated MUSIC (or alternative model), including:
  - the inlet pond volume in MUSIC to the sediment pond volume shown on plans (from halfway up the sediment accumulation zone)
  - the permanent pool volume to the proposed bathymetry (using the user defined stage-storage relationship)
  - the high flow bypass configuration to the design
  - the extended detention-controlled outlet configuration to the design (using the user defined stage-storage relationship)
- an inundation frequency analysis of water levels in the macrophyte zone showing that it meets target thresholds for plant survivability (the wetland analysis tool on the MUSIC Auditor website may be used)

- the 90th percentile residence time in the macrophyte zone (the *Wetland Analysis Tool* on the MUSIC Auditor website may be used)
- drawings of the treatment system, including placements, which match the model.

Other treatment devices

In general, the functional design report should incorporate the following information for assets (other than wetlands) modelled in MUSIC:

- description of the function and intent of the treatment system
- description of how fraction impervious was calculated (what figures were used for different zonings)
- drawings of the treatment system, including placements, which match the model
- specification for the treatment system, including any soil or filter media
- vegetation specification for bioretention systems
- description of any updates to the MUSIC model at each stage of the design
- summary of MUSIC modelling (or alternative model), including:
  - version of MUSIC or model used
  - meteorological data used
  - catchment areas with impervious percentage
  - any routing used
  - treatment node parameters
  - any modelling parameters that are not in accordance with Melbourne Water's *MUSIC Guideline* (this document).

Custom outflow and storage relationships

For custom outflow and storage relationships, the following information must be provided for review and comment as part of the design submission:

- output from earthworks modelling software of stage-storage relationship
- stage-storage-discharge relationships for treatment used in MUSIC (table and graph)
- area and volume at normal water level and extended detention
- calculations used for stage-discharge relationship for both outflows and overflows
- maximum water level reached for the design storm event (such as 4 EY) and maximum flows through treatment as per design.

7. Useful procedures

Defining custom outflow and storage properties

MUSIC requires the following three relationships for wetland and other waterbody outflow and residence time calculations:

- stage-storage (how water storage volume varies with depth)
- stage-discharge for outlet (how outlet rate varies with depth)
- stage-discharge for overflow (how overflow rate varies with depth).

Where:

- stage (metres): height or depth of water in the wetland
- storage (cubic metres): water storage volume for a given stage
- discharge (cubic metres per second): outflow rate (for outflow pipe or weir and for overflow pipe or weir).

When the standard input parameters are used, MUSIC automatically estimates the stage-storage-discharge relationships using the permanent pool volume, surface area, extended detention depth, outlet pipe diameter, and overflow weir length.

The default approach is generally acceptable for concept level design.

MUSIC by default assumes the wetland or other treatment has vertical sides. If that is not a reasonable assumption for the design, it needs to be changed using the custom storage properties.

Melbourne Water's *Wetland Design Manual* (Melbourne Water, 2020) requires that the stage-storage-discharge relationships are defined by the user to provide greater accuracy for functional and detailed design of wetlands. This is especially important for understanding inundation frequency and duration patterns and residence time of a wetland.

> Wetland outlet and storage properties must be defined using custom outflow and storage relationships for functional and detailed designs.

Defining and submitting stage-storage relationships

The stage-storage relationship of a treatments custom outflow and storage function is used to define the physical topographic conditions of the proposed asset. The values entered in the model must be consistent with the submitted design.

Where a 3D earthworks model of the treatment is available, designers can use a design package to calculate the stage-storage relationship above NWL. Generally, the data exported from a design model will be heights above a vertical site datum such as Australian Height Datum (AHD) or reduced level (RL). These must be converted to heights above NWL where zero metres represents NWL. To make this conversion, the NWL (RL) is subtracted from the height (RL) at each stage. See Figure 23 for an example output from an earthworks model and Figure 24 for the corresponding MUSIC input.

PANEL SETTINGS

Tin	DESN
Minimum height	56.500
Maximum height	58.000
Height increment	0.100
Fence name	STG1C D WETLAND
Fence model	STG1C D WETLAND

Height	Delta height	Volume to height	Delta volume	Plan area	Delta plan	Slope area	Delta slope
58.000	0.100	1739.201	365.648	4184.814	1005.813	4234.260	1009.685
57.900	0.100	1373.553	275.939	3179.002	786.264	3224.575	789.695
57.800	0.100	1097.614	204.761	2392.738	647.809	2434.880	650.748
57.700	0.100	892.853	151.460	1744.928	446.834	1784.132	450.228
57.600	0.100	741.393	112.877	1298.095	484.060	1333.903	487.944
57.500	0.100	628.515	79.408	814.035	39.751	845.959	43.374
57.400	0.100	549.107	75.480	774.284	38.815	802.585	42.345
57.300	0.100	473.627	71.645	735.469	37.879	760.240	41.315
57.200	0.100	401.982	67.904	697.590	36.944	718.925	40.286
57.100	0.100	334.078	64.256	660.646	36.012	678.639	39.257
57.000	0.100	269.822	60.702	624.634	35.081	639.382	38.228
56.900	0.100	209.120	57.240	589.553	34.150	601.154	37.199
56.800	0.100	151.880	53.872	555.403	33.221	563.955	36.171
56.700	0.100	98.009	50.596	522.182	32.293	527.784	35.144
56.600	0.100	47.413	47.413	489.889	489.889	492.640	492.640
56.500	11.739	0.000	0.000	0.000	0.000	0.000	0.000

Figure 23 Example output from earthworks model

Height (m)	Storage Volume (m^3)
0 (NWL)	1000.000
0.1	1147.413
0.2	1198.009
0.3	2151.880
0.4	2209.120
0.5	2268.822
0.6	2334.078
0.7	2401.982
0.8	2473.627
0.9	2549.107
1.0	2628.515
1.1	2741.393
1.2	2892.853
1.3	3097.614
1.4	3373.553
1.5	3739.201
2.35	5108.008

Permanent pool volume

Extrapolated storage volume

Figure 24 Corresponding MUSIC input based on earthworks model output

The data output from an earthworks model can be imported into MUSIC using the open button (note 2, Figure 25) or copied to the clipboard and pasted using the paste button (note 3, Figure 25). This data must be saved with a *.csv file extension and opened in a text editor to ensure it does not contain additional formatting or formulas. The data must be presented in the following format before input into the MUSIC model:

- no header line
- comma or space delineated
- height increments of 100 millimetres to 4 decimal places (to avoid rounding errors) (note 1, Figure 25)
- stage-storage relationship must extend at least two metres above the extended detention level (rounded up to the nearest 100 millimetres)
- standard number format for .csv (MUSIC will convert these to scientific format)
- starting height = zero metres (represents NWL of the wetland)
- starting volume = storage below NWL (permanent pool volume)

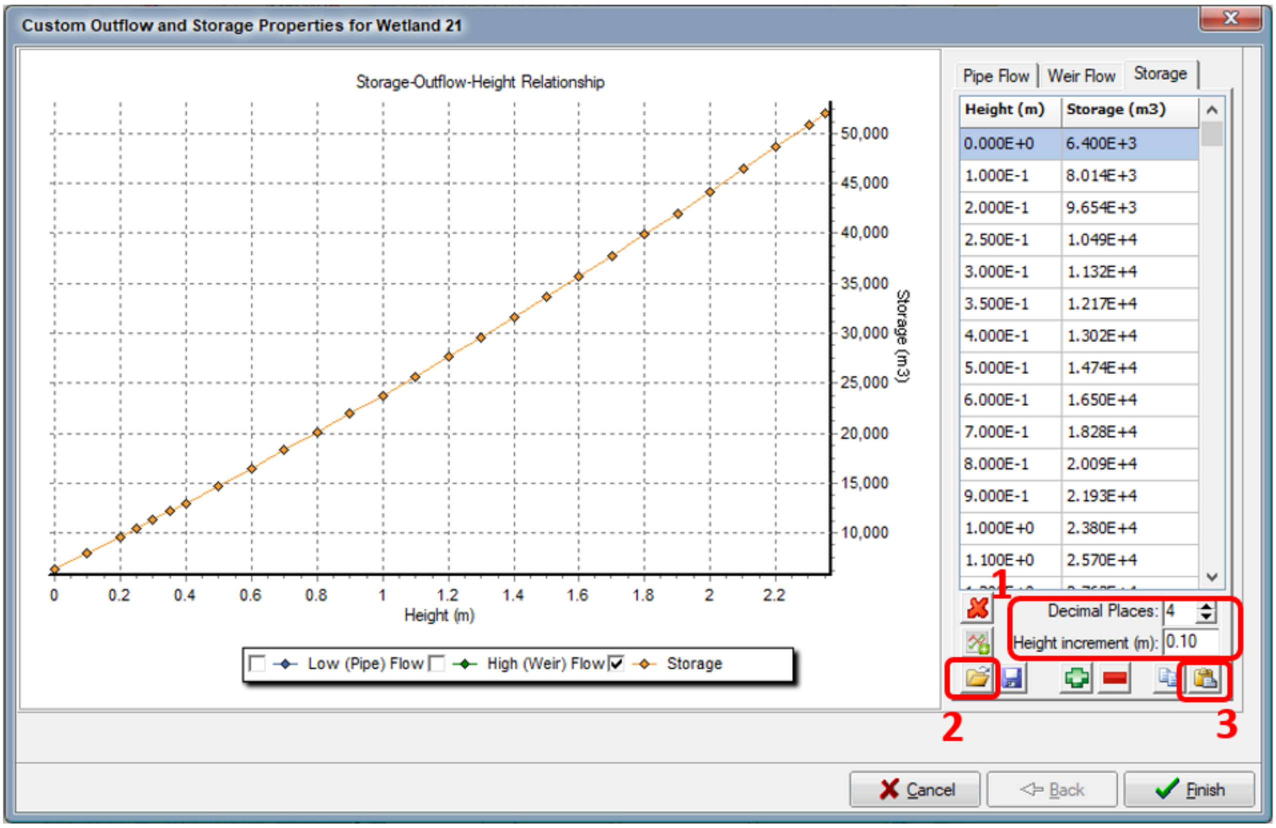


Figure 25 Example stage-storage relationship

When creating a new custom stage-storage relationship:

- Enter the correct EDD in the treatment properties dialogue before entering the custom stage-storage relationship dialogue.
- Enter the stage-storage relationship prior to defining the stage-discharge relationships.
- Set 100 millimetres increments at a maximum to 4 decimal places to avoid rounding errors (note 1, Figure 25), before pasting or importing the data.
- Represent the wetland permanent pond volume at the stage value of zero (NWL).
- Provide values in the stage-storage-discharge relationships for at least two meters above the EDD value (specified prior to selecting 'Use custom outflow and storage relationship'). Where these cannot be derived from the earthworks model (where the wetland is not located in a retarding basin), the stage-storage curve must be extrapolated linearly based on the slope of the curve from the last two data points from the earthworks model. *Failure to adhere to this may result in the model not running.*

Defining stage-discharge relationship

The stage-discharge relationships of a treatments custom discharge function are used to define the outflow and overflow behaviour of the proposed asset.

Note that MUSIC refers to pipe outflow and weir overflow. However, in practice both outflows and overflows or low and high flows may consist of either pipes or weirs.

MUSIC requires the stage (water level) and total discharge (the sum of pipe and weir flow at a given stage) inputs to have unique values. This enables MUSIC to interpolate from any given stage to a single total discharge and from any given total discharge to a single stage as needed. In effect, this means that the sum of the 'pipe flow' and 'weir flow' curves, and the storage curve must never be vertical or horizontal. For the same reason, there must be no negative slopes that will result in two or more points having the same value.

Figure 26 and Figure 27 show example stage-discharge curves for low ('pipe') flows and high ('weir') flows respectively.

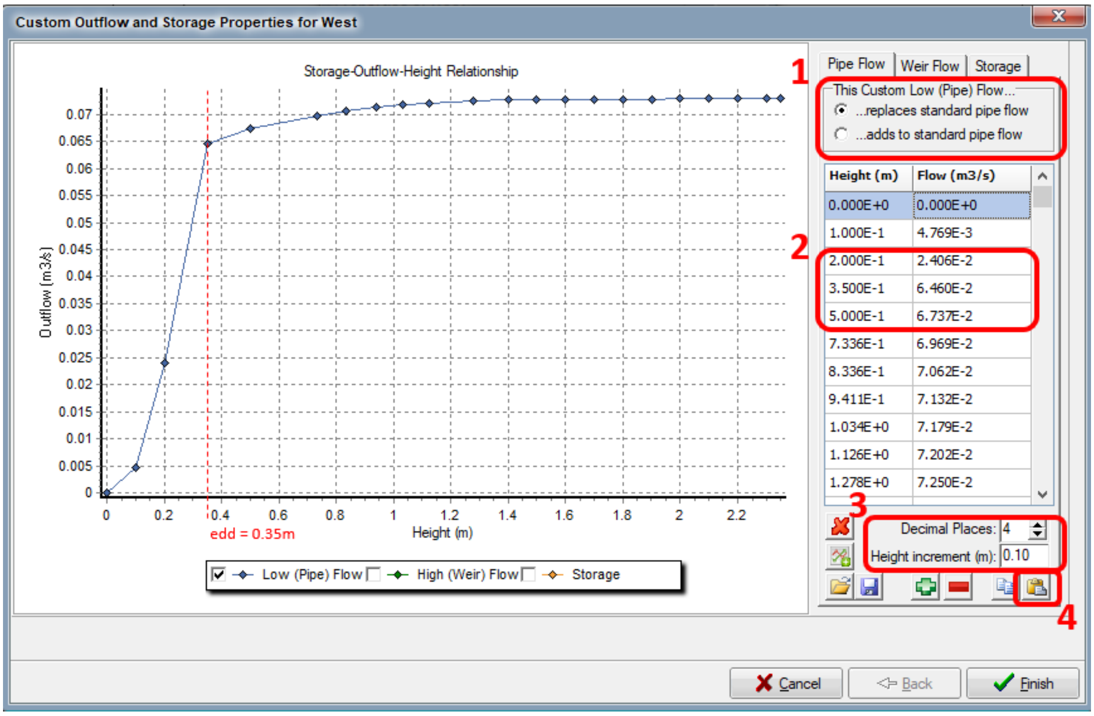


Figure 26 Example stage-discharge relationship for pipe flow

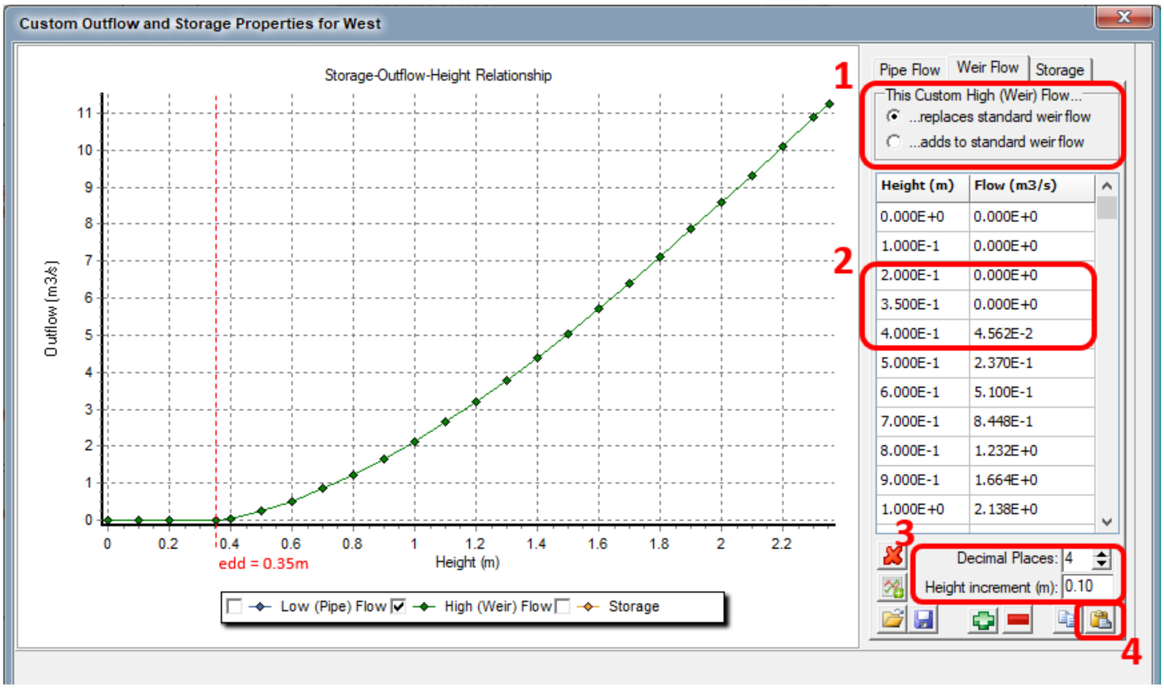


Figure 27 Example stage-discharge relationship for weir flow

Inputs for the stage-discharge curves must be calculated using standard and accepted equations for weir and orifice design as prescribed Part C of the *Wetland Design Manual* (Melbourne Water, 2020). The designer must consider the type of outlet structure and the resulting outflow behaviour and adopt the appropriate equations accordingly.

Note 1 in Figure 26 and Figure 27 must be set such that the calculated outflows replace standard flows.

The adopted relationships for low and high flows can be verified by observing the curves of the respective data and noting changes at the stage corresponding to the adopted EDD of the wetland (note 2, Figure 26 and Figure 27).

For the low (pipe) flow relationship, it is expected that outflows will increase up to and above EDD. The flow rates will typically be much lower than for weir flows. In most cases, the design will have a narrow slot weir plate instead of an orifice plate. The narrow slot weir outlet properties must be defined using custom outflow properties.

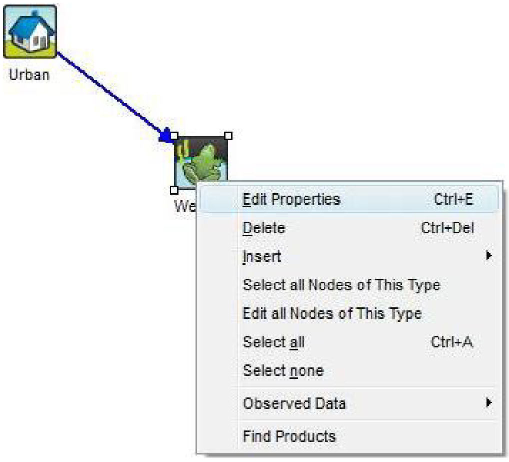
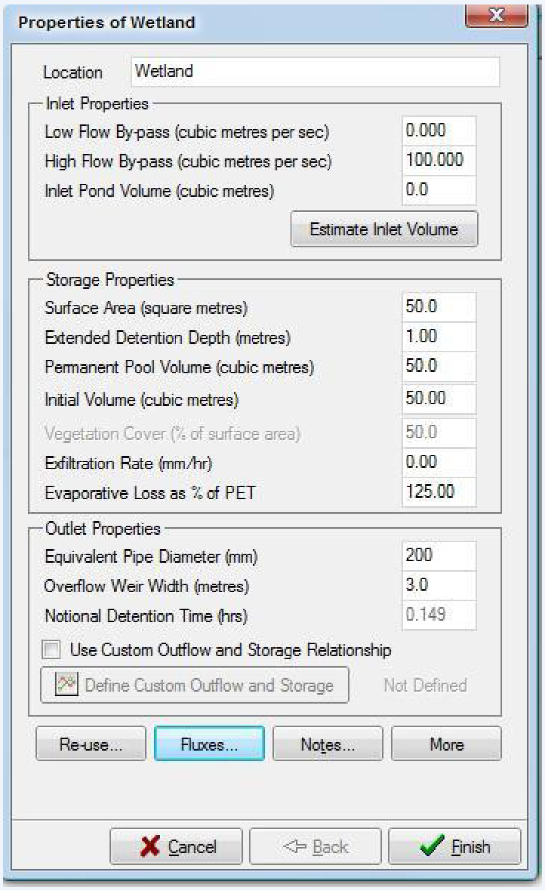
For the high (weir) flow relationship, outflows should be zero up to EDD, then increase with stage above the EDD level.

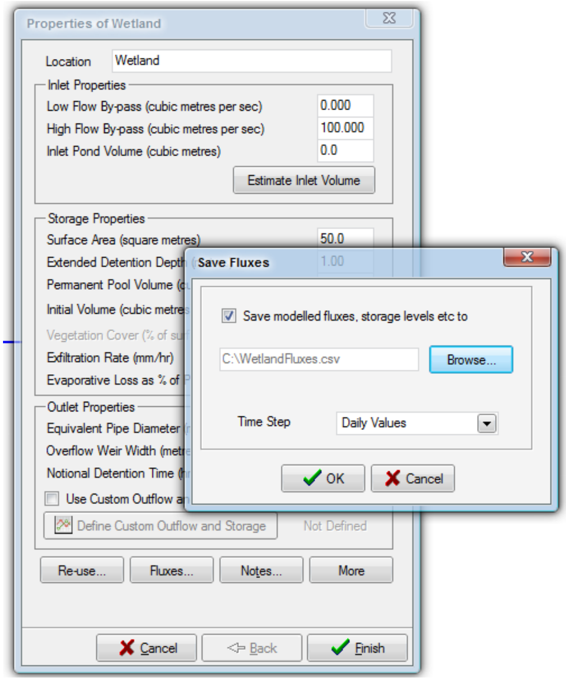
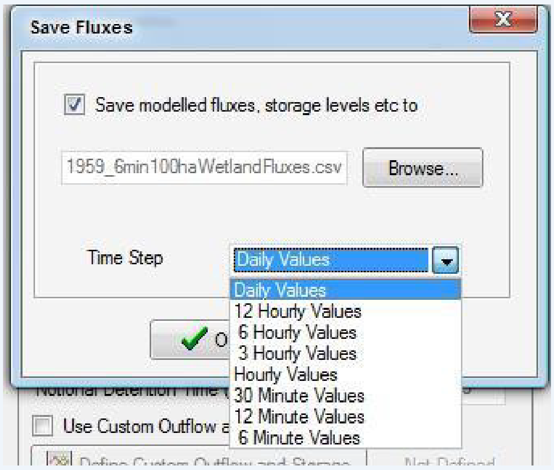
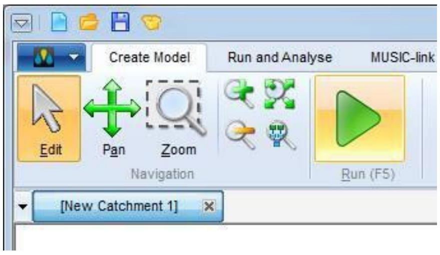
Creating a flux file for inundation frequency analyses

An inundation frequency curve illustrates the frequency with which certain depths are exceeded within a treatment system such as a wetland.

To undertake a frequency analysis, the treatment system depth data must be exported from MUSIC using the 'flux file'. Recent versions of MUSIC can export the data at an hourly or daily timestep that is easier to handle. The process for creating a flux file is shown in Table 7.

Table 7 Creating a flux file

Instruction	Example
Right click on wetland and select 'Edit properties'	
Click on 'Fluxes'	

Instruction	Example
Tick 'Save modelled fluxes' and set a filename	
Change the timestep to 'Daily' or 'Hourly' (Recommended)	
Run the MUSIC model	

Once the flux file is created, an inundation frequency curve can be created automatically from a flux file using the wetland analysis tool on the MUSIC Auditor website or manually in a spreadsheet following the guidance provided in Part D of the *Wetland Design Manual* (Melbourne Water, 2020).

Determining pipe flow rates for tanks

The pipe flow rate is determined by the equation $Q = C_d \sqrt{2gh}\, x\, \pi \frac{(d^2)}{4}$ (for a circular sharp-crested orifice), where:

C_d = orifice discharge coefficient

d = pipe diameter (m)

H = depth of orifice centre below free surface (nominally depth above overflow) (m)

g = gravitational acceleration (m/s^2)

Q = discharge (m^3/s)

8. References

Document title
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9. Document History

Date	Reviewed/ Actioned By	Version	Action
October 2023	Senior Stormwater Technical Advisor	2	
January 2023	Senior Stormwater Technical Advisor	2	Release A – final, incorporating industry feedback
May 2022	Senior Stormwater Technical Advisor	1	Release A – for industry review

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