PART E: DESIGN TOOLS AND RESOURCES

E1. DESIGN TOOLS

This section equips the user with the necessary tools required for waterway design. The information is provided in support of Part D and should be consulted in tandem with design procedures therein.

Part E includes detailed guidance regarding the application of the following design tools:

- Hydrologic modelling - RORB
- Terrain modelling – 12d Model
- Hydraulic modelling – HEC-RAS
- Methods for reducing shear stress in the design waterway

There are other tools available to design waterways, but these tools are considered the baseline package of tools.

Part E also includes key resources required as part of the design process:

- Geology and soil resources
- Constructed Waterway Types
- Healthy Waterways Visions (vegetation, stream form)
- Waterway Protection and Rehabilitation
- Waterway Maintenance Requirements
- Useful Guidelines

Where the waterway designer is using hydrologic and hydraulic modelling software, Melbourne Water requires the waterway designer to use RORB and HEC-RAS.

Various terrain modelling packages are available and widely used across the industry and are therefore acceptable to Melbourne Water. It is Melbourne Water's preference that a software package such as 12d is used.

E1.1 Hydrologic Modelling

The catchment hydrology can be estimated using RORB runoff routing software. ARR2019 should be followed. The ARR2019 website includes guidelines (ARR2019 – A guide to flood estimation), software and a data hub for all hydrologic inputs for the modelling (including links to the latest 2016 BoM IFD data).

The Melbourne Water recommended RORB modelling procedure includes:

- Set-up the undiverted RORB model
- Calibrate the undiverted RORB model
- Use the calibrated undiverted RORB model as basis for modelling future scenario/s

Terminology

Two approaches are used when describing the probabilities of flood events. The definitions of these as per ARR2019 are shown below:

- Annual Exceedance Probability (AEP) - the probability of an event being equalled or exceeded within a year. Typically the AEP is estimated by extracting the annual maximum in each year to produce an Annual Maxima Series (AMS);
- Average Recurrence Interval (ARI) - the average time period between occurrences equalling or exceeding a given value. Usually the ARI is derived from a Peak over Threshold series (PoTS) where every value over a chosen threshold is extracted from the period of record.

The terminology adopted in this manual is shown in Figure 66 below. In general, the 20% AEP design flood is used in place of the 5-year ARI design flood even though these are not exactly equivalent (20% AEP corresponds to 4.5 years ARI and 5-years ARI corresponds to 18.13% AEP). Similarly, the 10% AEP is used to describe the 10 year ARI.

FREQUENCY DESCRIPTOR	EY	AEP (%)	AEP (1 IN X)	ARI
Very frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	20
	0.02	2	50	50
	0.01	1	100	100
Very rare	0.005	0.5	200	200
	0.002	0.2	500	500
	0.001	0.1	1000	1000
	0.0005	0.05	2000	2000
Extreme	0.0002	0.02	5000	5000
			↓ PMP / PMPDF	

Figure 66 - Australian Rainfall and Runoff Preferred Terminology (ARR2019: A Guide to Flood Estimation). Dark blue outline shows acceptable terminology.

Modelling scenarios

Hydrological modelling of existing and proposed conditions is required. Modelling of the existing condition is to be based on the current planning zones (or historical if current zone is Urban Growth) and should only consider existing topography and infrastructure. Modelling of future conditions is to be based on the proposed planning zone and include all infrastructure (drainage, storage, etc.) and any changes to topography.

The full suite of design events required for the design of waterways must be modelled. Generally, this includes (but is not limited to): the 3 month flow, the 1EY, 40% AEP, 20% AEP, 10% AEP, 5% AEP, 2% AEP and 1% AEP flows. For all events the full range of storm durations from 10 minutes to 72 hours will need to be run in order to adequately capture and hydraulically model the rainfall event that leads to the maximum flood level.

A climate change scenario should also be modelled to reflect a 19.5% increase in rainfall intensity (predicted under a 2100 climate scenario). The 2016 IFD values are to be increased by a factor that scales rainfall intensity. The increased peak flow for the 1% AEP will be used as an input to the hydraulic modelling to test the sensitivity of the model to this flow (i.e. does the climate scenario 1% AEP flood level still fall within the 600mm freeboard to building floor levels).

See ARR2019 Book 1 Chapter 6 for more details.

Delineation of RORB catchment and sub-catchment boundaries, nodes and reach alignments

The Developer must take note of the following requirements in relation to the delineation (or review) of RORB sub-catchment areas, nodes and reach alignments:

- Catchment boundary must match adjoining catchment boundaries that have been provided by Melbourne Water.
- Sub-catchments to be delineated as most appropriate for the 1% AEP event.
- Sub-catchments, nodes and reaches to be named/numbered as recommended by Melbourne Water
- Nodes to be located where required and also at the downstream end of each sub-catchment.
- Where relevant, the local Council drainage systems should be considered when delineating sub-catchments.
- In order to ensure adequate routing for upstream locations where design flows are required for hydraulic modelling, a sufficient number of sub catchments are required, e.g. minimum of 5.

The final sub-catchment boundaries must be provided to Melbourne Water in the structure of the final MapInfo table deliverables.

Fraction impervious methodology

The fraction impervious must be determined using the existing planning zones (as per the Planning Schemes Zones MapInfo table provided by Melbourne Water) as a starting point. The Developer must then assess the fraction impervious for each zone in a sub-catchment.

The fraction impervious must be reported in table format detailing the fraction impervious for each zone within a sub-catchment as well as the overall fraction impervious for the sub-catchment. This must be reported as part of submissions made to Melbourne Water.

RORB model calibration

The undiverted RORB model must be reconciled to an estimated flow. Past practice has included the reconciliation of RORB models to peak flow estimates based on the urban rational method. This approach is no longer supported. Instead, alternative approaches can be used as discussed below.

In cases where simple RORB models are used to generate rainfall excess hydrographs for input to hydraulic models, and no routing is used, the choice of kc value is not important. However, where RORB is used to model design flows, routing parameters must be selected.

The value of kc should be based on local data, knowledge or experience if possible. Regional methods can be used to guide selection of initial values of kc (Table 28). If there are reliable kc values from nearby catchments, these can be scaled to the catchment of interest. kc is approximately proportional to dav or the square root of the catchment area (Pearse et al., 2002; Laurenson et al., 2010). Selected values then need to be refined by calibration, or sanity checking, of model outputs.

Table 28 - Regional equations for RORB routing parameter kc (sourced from Melbourne Water's Flood Mapping Projects Guidelines and Technical Specifications)

NO.	REGIONAL EQUATION	APPLICATION	SOURCE
1	$k_c = 0.49 \times A^{0.65}$	Areas with annual rainfall < 800mm	ARR2016 Book 7, Chapter 6.2.1.3
2	$k_c = 2.57 \times A^{0.45}$	Areas with annual rainfall < 800mm	ARR2016 Book 7, Chapter 6.2.1.3
3	$k_c = 2.2 \times A^{0.5}$	General	RORB V6 User Manual Equation 2-5
4	$k_c = 1.25 \times d_{av}$	Victoria	Pearse et al. (2002)
5	$k_c = 1.19 \times A^{0.56}$	Yarra and Maribyrnong areas	Melbourne Water
6	$k_c = 1.53 \times A^{0.555}$	South East areas. The area that was formerly managed by the Dandenong Valley Authority	Melbourne Water

An undiverted RORB model can be defined as a model:

- Without special storages;
- Without diversions to separately route multiple flow paths (i.e. overland flows and underground asset flows); and
- With a structure and reach types consistent with the regional equations.

Calibration at multiple locations within the catchment will be required when:

- the topography varies significantly across the catchment; and/or
- the land use varies (i.e. urban vs rural) across different parts of the catchment; and/or
- the size of the catchment is larger than 20km2 and/or
- the Developer considers it necessary

As a minimum the calibration checks must occur at the upstream end of the Melbourne Water drainage system but some projects may require calibration at the upstream end of the modelled council drainage system, the catchment outlet and/or at confluences of drainage systems.

Calibration/validation should focus on large events such as the 1% AEP flood. which is the design event for planning purposes.

Sanity checks can also be undertaken by comparing results to approximate methods that include:

- Nikoloau/vont Steen equations
- For definitions of the Nikoloau/vont Steen equations see Grayson, R. B. et al. (2006) Hydrological Recipes, page 108. For catchment area in square kilometers. Approximate 1% AEP floods are as follows.
- For rural catchments Q 1% = 4.67A 0.763
- For urban catchments Q 1% = 10.29A 0.71
- RFFE (Regional Flood Frequency Estimation tool see http://rffe.arr-software.org/

Undiverted RORB model

The following parameters should be adopted for the calibration and analysis process:

- IFD data is to cover storm durations from 10 minutes to 72 hours and be calculated at appropriate intervals.

Specifically relating to RORB:

- A value of 0.8 must be assigned to the exponent *m* unless the Developer believes this is inappropriate, in which case the recommended value is to be discussed with Melbourne Water prior to proceeding with this part of the work;
- k_c must be adjusted so the flow from the undiverted RORB model matches the regional equation estimated flow and is validated from checks detailed above;
- AR&R method must be used for the Areal Reduction Factor. These are obtained from the ARR2019 Data Hub;
- Initial loss values. These are obtained from the ARR Data Hub.
- Temporal patterns must be fully filtered.
- Runoff coefficients for RORB model – the runoff coefficients for an urban catchment of 0.6 for the 1% AEP event is to be used as a guide. If the Developer proposes to use other values (e.g. for interim development conditions), the rationale for adopting other values must be discussed and agreed with Melbourne Water prior to undertaking this part of the work. For rural catchments, the Developer is to propose an approach to be used regarding the use of a Runoff Coefficient versus Initial loss/Continuous loss.

RORB *model* data

The *.catg files of all scenarios modelling, along with parameter files and IFD parameters and data must be provided to Melbourne Water as part of carrying out the project.

Please note, all RORB reach alignments, node locations, sub-catchment and catchment boundaries are to be populated with appropriate descriptions, slopes, lengths to correspond with the RORB model code.

E1.2 Terrain Modelling

Terrain modelling software allows the designer to represent, in three-dimensional computer space, the existing terrain surface (such as the whole catchment) and to build the constructed waterway surface within it. The 'terrain' model is made up of a digital elevation model (DEM).

The digital elevation model (DEM)

A DEM is a representation of a topographic surface by a regular array of elevation values. In raw form it is a text or ASCII file containing a grid of elevation values (for example easting, northing and elevation, or X, Y, and Z values).

For the purpose of constructed waterway design a DEM is used to represent the design waterway surface to enable the designer to build a hydraulic model. The DEM is manipulated through various means to build different waterway configurations and then test these in a hydraulic model.

The information used to build a DEM comes in multiple formats. Melbourne Water usually provides information in text, grid or image format (Table 29)

Table 29 - Common DEM formats issued by Melbourne Water

FORMAT NAME	FILE EXTENSION	POINT DISTRIBUTION
ASCII XYZ	.xyz or.thn	Randomly distributed points Gridded DEM
ESRI GRID – ASCII format	.asc	Gridded DEM
ESRI GRID – binary format	.adf, .log and info folder	Gridded DEM
TIFF	.tiff	Gridded DEM

Terrain modelling

There are numerous terrain modelling software packages with the capability of establishing a design waterway surface for the purpose of hydraulic investigation. 12d Model is used widely in stream management and planning throughout Victoria. It is not the only product suitable for the task of constructed waterway design; however it has been used in this manual by way of example to demonstrate the use of terrain modelling software in waterway design.

Largely a civil engineering-based application, 12d Model enables users to construct a design surface such as a waterway. 12d Model interfaces with various hydraulic analysis software packages. Specifically, 12d Model's 'River Module' interfaces with HEC-RAS and works on a single stretch of river, or a complex system of branched rivers. The River Module is used to generate the waterway geometry, such as longitudinal and cross section detail, based on the underlying DEM. Additional hydraulic information such as hydraulic roughness and flow rate can be input from within the 12d Model river module.

Further information on 12d Model can be found at https://www.12d.com/ and, specific the river module, at https://www.12d.com/product/Rivers-Dams-Hydrology.html.

The process for establishing the waterway surface using 12d Model is outlined in this section. This information is considered essential for designing constructed waterways however it is not comprehensive or a substitute to referencing the 12d Model's user manual or seeking professional training.

Reading in raw spatial data

12d Model is capable of reading a wide range of input spatial information formats. For the most part spatial data will be provided in Ascii (XYZ) or Grid (DEM) format by Melbourne Water. These formats are easily imported to 12d Model using: (i) File I/O | Data input | xyz, and (ii) File I/O | Data input | DEM. As part of the import process the spatial information is assigned to a 'model' (this is sometimes known as a 'layer' in other spatial packages) specified by the user. This model (and the spatial information it contains) is then used to generate a Triangular Irregular Network (TIN). The TIN can be thought of as the terrain surface upon which the waterway information is layered.

Generating a TIN

A TIN is basically a three dimensional representation of a surface. TINs form the basis for designing the constructed waterway and generating the hydraulic model within 12d Model. A TIN is created by selecting Tins | Create | Triangulate Data. The input spatial data, TIN name and model are all assigned by the user.

Multiple TINs can be superimposed to make a new TIN, known as a supertin, in 12d Model. Supertins are particularly useful once the user has designed the waterway surface (detailed below) and wishes to amalgamate the two surfaces (Figure 67). A supertin is created from two or more separate TINs by selecting Tins | Create | Supertin.

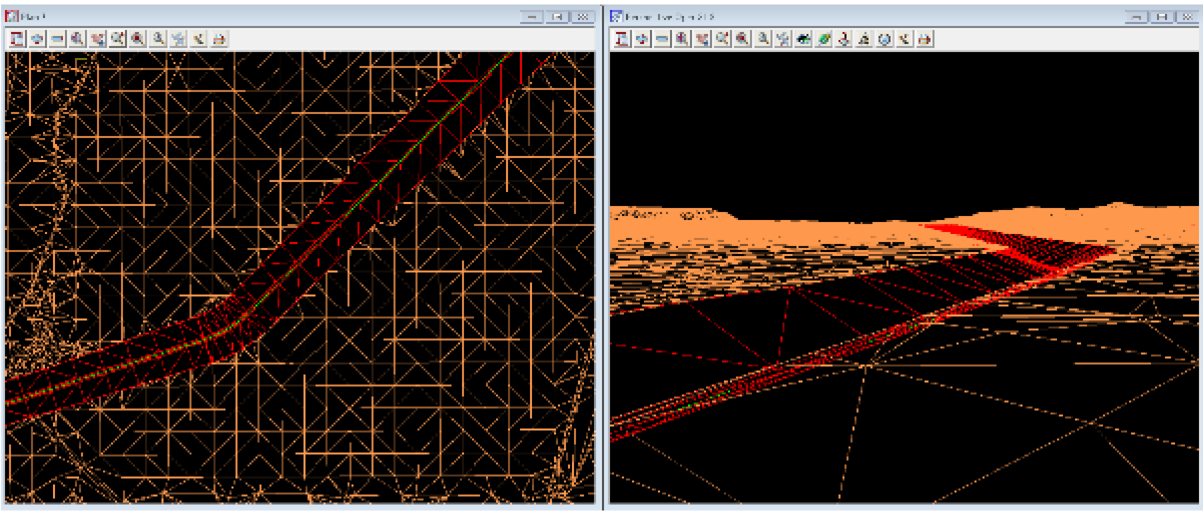

Figure 67 - Example supertin plan view (left) and isometric view (right)

Building the constructed waterway

12d Model enables the user to grade the designed waterway geometry into the existing terrain. There are numerous steps to this process and professional training is advised. The key steps involved include:

- Create a super alignment string (Strings | Create | Super Alignments) along the alignment of the design waterway. The super alignment string must be assigned both horizontal and vertical position information (for example the alignment may represent the centreline of the design waterway at its base).
- Create a grading template (Design | Templates | Create/edit). Templates are basically the cutting tool used to carve out the waterway shape along an alignment string. Templates are used to set desired widths, depths and batter slopes from the super alignment.
- Apply the grading template (Design | Apply | Apply many). In applying the template the user specifies the relationship between the underlying terrain (TIN), design waterway alignment (alignment string/s) and design template/s. The function is used to shape the constructed waterway any which way. For example the user can specify that the base width of the constructed waterway increases over a transition distance around the location of a contributing tributary so as to accommodate increased flows. Likewise, the outside bank angle may be steepened at the outside of a bend, or a mid-level bench appear at the inside of a bend, in accordance with the design intent. Importantly, the waterway surface TIN is generated by this function.
- Amalgamate the constructed waterway surface TIN and the existing surface TIN (as outlined earlier).
- The designer is required to represent the various waterway features in the hydraulic model. In the case of pools and riffles, benches and bars, it is best to achieve this by building the designed pools and riffles in to the terrain model. Pools and riffles are carved into the previously established terrain modelling using the same tools and methods as previously discussed.
- Use concept stage TIN of waterway
- Introduce cross-section variability to represent pools and riffles either by manipulating existing alignment strings and/or grading templates, or by creating new ones. That is:

  The designer may introduce longitudinal variability by changing the alignment string's 'vertical geometry'

  The designer may introduce cross-section variability using the modifier function when applying the grading template/s
- Again, generate a combined TIN of the waterway and existing terrain (to represent areas outside of the waterway itself)

Other features such as vegetation design and distribution, instream woody habitat structures, pile fields, and bed and bank stabilisation measures are more efficiently represented within the HEC-RAS model. More information is provided in the hydraulic modelling section below.

Building the hydraulic model

The 12d Model river module requires the 'river strings' and 'source strings' to be specified before the hydraulic model can be generated.

Three individual strings (left bank, centre line, and right bank) must be created for each reach to make up the river strings model. If the constructed waterway consists of a network of three reaches then the river strings model must contain nine individual strings with the appropriate labelling. Strings must be sketched in the upstream direction.

The source strings model must be populated with strings at the location of cross sections. Source strings must be sketched from left to right overbank when facing downstream, must be placed perpendicular to the direction of flow, and must intersect each river string (left bank, centre line, and right bank) only once (Figure 68).

Source string may be generated automatically using the river module, however this method is not recommended as the automatically generated source strings often break the rules of source string placement for one-dimensional hydraulic modelling.

The functional design stage is focussed on reach scale design. As such, a lower resolution of source strings is appropriate for this step. In the detailed design stage the resolution of cross sections must be increased to a suitable level for feature scale analysis and design. For example, 50m cross section spacing may be appropriate for the reach scale design of a one kilometre waterway. For the detailed design the spacing may be reduced around individual features of interest. For example the designer may place additional cross sections at the inlet, deepest point (bend apex), and outlet of a pool, or a bench, or any other feature of interest. This way the designer can be confident that the hydraulic model is estimating, to the best level of accuracy as can be expected in 1D modellings, the particular the hydraulic conditions around waterway features

Exporting the geometry

The river module is then used to generate a hydraulic model of the constructed waterway for use in HEC-RAS. After selecting *Design* | *Rivers* | *HEC-RAS interface* | *Create HEC-RAS project* the user must specify: (i) the river strings model, (ii) the source strings model, (iii) the cross section model (in the first instance this is a new model to be filled with cross section information generated by the river module), (iv) the surface tin, (v) the start-up data (Manning's *n*, discharge, zero chainage location and units), and (vi) the project file path and name.

Once the river module has processed the written geometry file can be read directly into HEC-RAS.

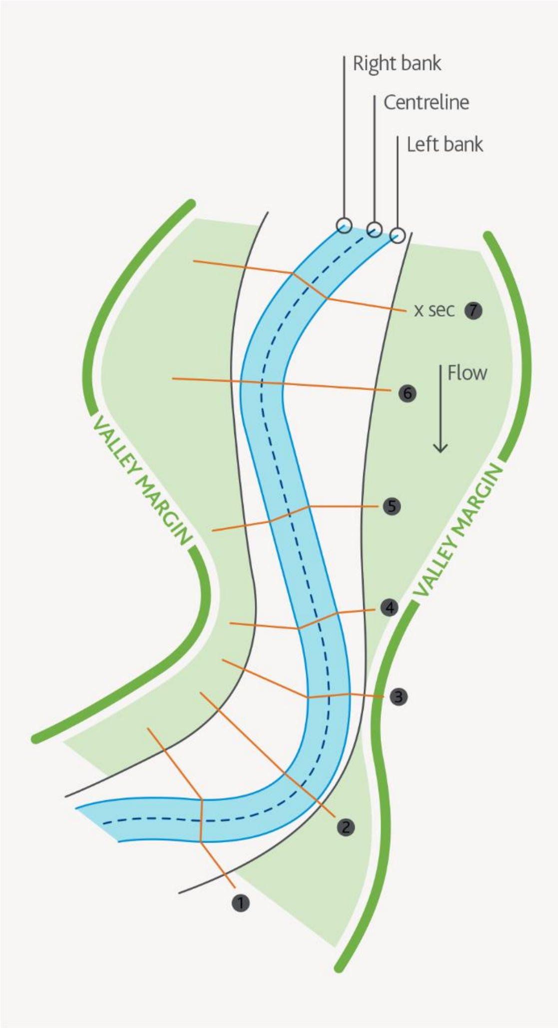

Figure 68 - Placement of source strings (cross sections) perpendicular to direction of flow

E1.3 Hydraulic Modelling

The Hydrologic Engineering Centre of the US Army Corps of Engineers developed the River Analysis System (HEC-RAS) software. The software allows the user to perform one-dimensional steady and unsteady river calculations (US Army Corps HEC RAS manual) through interaction with the graphical user interface.

HEC-RAS comprises four river analysis components: (i) steady flow water surface profiles, (ii) unsteady flow simulation, (iii) sediment transport/movable boundary computations, and (iv) water quality analysis. For the purpose of waterway design it is important to be familiar with the steady flow water surface profile component only.

Getting started

The HEC-RAS software and supporting resources (user's manual, applications guide and the hydraulic reference manual) is freely available at https://www.hec.usace.army.mil/software/hec-ras/.

The user's manual is a guide to using HEC-RAS and provides an overview of installation, getting started, entering and editing geometric and flow input data, modelling components and processes, and using the output results. The user's manual also contains simple example applications.

The hydraulic reference manual provides the background theory (equations, assumptions, and modelling approaches) to HEC-RAS.

The applications guide contains a series of examples to demonstrate the various modelling aspects (data requirements and modelling approach) with supporting illustrations.

This manual assumes that the user is familiar with the steps required to set-up a basic steady flow simulation project in HEC-RAS. The user must be familiar with:

- The install/uninstall procedure
- Starting a new HEC-RAS project
- Data management and storage (project file, plan/s, geometry file, and flow file)
- Entering geometric data (river reach and cross section information)
- Entering flow data and boundary conditions (steady flow only)
- Performing hydraulic computations (steady flow only, and mixed flow regime)
- Viewing and printing results (cross section, longitudinal section, and X-Y-Z perspective plotters)

The information below is specifically related to HEC-RAS modelling for constructed waterways in the Melbourne region. There is particular focus toward assimilation with terrain modelling software (12d Model) for the design and analysis of the waterway.

The geometry file

Starting with a new HEC-RAS project and empty geometry file, the user can then (i) import the geometry file, (ii) add detail to the waterway geometry file to property represent the proposed design surface. Importantly, this step is used to:

- Import geometric data (geometry exported from terrain modelling package)
- Specify the waterway's hydraulic roughness (Manning's *n*)
- Where applicable, specify bridge/culvert, inline and lateral structure information

Importing geometric data

HEC-RAS can import geometric data in several different formats (GIS, HEC-RAS, and others). The HEC-RAS format may be used when importing geometric data from 12d Model.

- From 12d Model (HEC-RAS format). Geometric data created in 12d Model is imported to HEC-RAS in HEC-RAS format by selecting *File* | *Import geometry Data* | *HEC-RAS Format* from within the geometric data editor window. The HEC-RAS user's manual (pp. 6-131 to 6-137) provides supporting information for the process.
- Alternatively, cross sections can be created directly in the RAS mapper function of HEC-RAS, where terrain can be imported and cross sections draped across this data.

Top of bank markers

Top of bank markers are used to differentiate between the low flow channel and the main channel (or floodplain). They are placed at the top of the low flow waterway bank (Figure 69). There are multiple ways to shift the top of bank markers in HEC-RAS. The recommended method is to use the graphical cross section editor (*Tools* | *Graphical Cross Section Edit* from the geometry data window) and the various bank station tools therein.

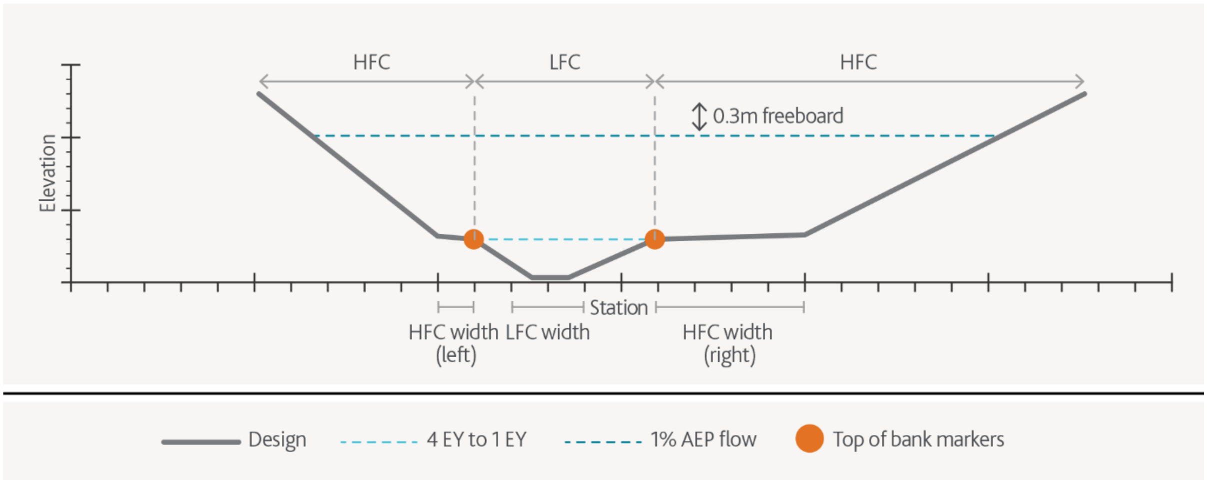

Figure 69 - Markers placed at top of bank to differentiate between low flow channel and main channel (floodplain)

Hydraulic roughness

A waterways hydraulic roughness determines the amount of energy lost by water as it flows through the waterway. Densely vegetated waterways flow more slowly than concrete lined channels. This is because the hydraulic roughness of the relatively smooth concrete is much lower than the vegetated channel. Greater energy loss gives rise to slower flow. It is important to correctly estimate the hydraulic roughness of the waterway at the various stages of its lifetime. For example, the waterway in the immediate post-construction phase is likely to be largely a bare earth surface. At 3 months, it is likely to be planted down with some vegetation that is not well established. At 10 years, the waterway is likely to be populated by an array of both mature and establishing vegetation species with variation between the floodplain, banks and bed of the waterway.

The user must select the appropriate hydraulic roughness to best represent the waterway at various time scales. There are numerous references for hydraulic roughness values for typical waterways.

- For the post-construction period the recommended Manning's n values for the low flow waterway and the main waterway include:
- Earth, straight and uniform (low sinuosity reaches) 0.018 (min 0.016, max 0.020)
- Earth, winding and sluggish (sinuous reaches) 0.025 (min 0.023, max 0.030)
- Bedrock cuts, jagged and irregular 0.040 (min 0.035, max 0.050)

Once vegetation is established the hydraulic roughness must change accordingly. All vegetation in the corridor will influence hydraulic conditions to some extent depending where it is located, and how much flow resistance it offers. The nature of this effect varies with plant species and flow depth. The following table presents a summary of the nominal Manning's *n* values for different waterway types.

Table 30 - Typical hydraulic roughness values for the different waterway types

MATERIAL	LFC	HFC
Compound	0.05 (min. 0.045 max. 0.06)	0.05 (min. 0.045 max. 0.06)
Bedrock	0.040 (min 0.035, max 0.050)	As above unless bedrock extends to 1% AEP flood level.
Linear pools	0.035 (predominately open water) (min 0.03, max 0.040) 0.05 (predominantly marsh)	0.05 (min. 0.045 max. 0.06)

Some parts of the corridor may be lined with rock or other bank strengthening materials. A list of potential bank linings and their associated hydraulic roughness are included in Table 15 and Table 31.

Table 31 - Typical hydraulic roughness values for rock and other bank protection material

MATERIAL	MANNING'S *n*
Rock 250 mm	0.030
Rock 450 mm	0.035
Other bank strengthening fabrics (jute matting, ecomat, etc.)	0.025

Additional resources

The following references provide information on the selection of Manning's roughness (Queensland Urban Drainage Manual 2007):

- The HEC-RAS user's manual provides a concise summary of some of the more common waterway types (Table 3-1 from pp 3-14 to 3-16, refer table from HEC-RAS manual).
- Tables relating channel type and surface conditions, to recommended roughness coefficients, e.g. Argue (1986) Table 6.1, Books 7 & 8 of ARR (1998), Henderson (1966) Table 4.2, Chow (1959) Table 5.6.
- Photographs and descriptions of channels with known roughness coefficients, e.g. Brisbane City Council (2000), Chow (1959), Barnes (1967), French (1985), Hicks & Mason (1991) and Arcement & Schneider (1989). Caution: Hicks & Mason (1991) provide roughness values usually relating to low-flow conditions, not to bankfull or overbank conditions presented in the photos. Arcement & Schneider (1989) provide roughness values for vegetated floodplains in the USA; however, the supplied photos show the vegetation in winter conditions (i.e. low leaf matter) even though the roughness values refer to summer conditions (i.e. dense leaf and vine matter).
- Equations to derive estimates of channel roughness and which incorporate modifying factors representing the individual components of the effective Manning's roughness coefficient, e.g. Brisbane City Council (2000), Book 7 of ARR (1998), Chow (1959) Table 5.5 and French (1985).

The designer should use an appropriate reference to estimate hydraulic roughness, such as those suggested above and include justification of the selection of roughness in the functional design report.

Representing the true waterway geometry

It is important to understand the interaction between the waterway and any intersecting bridges or culverts. Bridges and culverts must be modelled in accordance with the guidance notes in the HEC-RAS user manual (pp. 6-25 to 6-58). Other structures that may be required to be modelled include:

- Inline structures such as weirs or gates.
- Lateral structures to model connection to offline structure (wetland, retention basin, etc.)
- Levees, ineffective areas and blocked obstructions

The flow file

Once peak flows have been estimated at the appropriate location/s along the waterway we can input these directly to HEC-RAS for steady flow simulation.

The steady flow file allows the user to specify the flow rate at any location in the model (including changes to flows along the reach length). In order for the simulation to run, the flow rate must be specified at the top of every reach in the model. The user then has the option of specifying any amount of variation to the flow rate along the reach length. Note that HEC-RAS will automatically combine two flows at the junction of two or more contributing streams. This does not have to be entered manually by the user.

Boundary conditions

The steady flow file requires that hydraulic boundary conditions be specified at the top and bottom of every reach (when running missed flow regime). Boundary conditions are necessary to determine the starting water surface at each end of the waterway to begin the simulation. The downstream boundary condition is required when modelling all flow regimes while the upstream boundary condition is only required for super-critical (or mixed) flow regime.

There are several options for specifying boundary conditions: a known stage-discharge relationship, critical flow depth, or normal flow depth. Specifying the normal flow depth is the simplest and most common approach for constructed waterway design. The normal water depth is the longitudinal slope of the water surface at the boundary in question and can be estimated by the longitudinal slope of the waterway base.

The longitudinal slope is established by sampling the waterway base (at its lowest point) for a nominal distance at the boundary. For example, the user may employ terrain modelling software, Excel, or even HEC-RAS to determine the bed level fall over an appropriate distance. The slope (fall divided by distance) is then input as the boundary condition in the steady flow file (Figure 70).

When a network of waterways is modelled HEC-RAS will automatically specify the boundary conditions at junctions.

Figure 70 - Example longitudinal section profile showing boundary conditions

Steady flow analysis

Water surface profiles for steady flow are calculated for a single reach or a full network of reaches. Where flow is gradually varied, calculation is based on the solution to the one-dimensional energy equation with frictional and expansion/contraction losses estimated. For rapidly varied flow (hydraulic jumps, at bridges, or at confluences) the momentum equation is used to calculate the water surface profile. Refer Chapter 7 of the HEC-RAS user's manual for guidance through the steady flow analysis procedure.

- Once the geometry file has been exported from 12d Model the designer is ready to set-up and run the revised hydraulic model to check its hydraulic performance and the proposed feature configuration. The tools and methods required in this process are all detailed in Part D of this manual, but in summary, include:
- Open the concept stage HEC-RAS project
- Use either the existing geometry file, or start a new one, and import the geometry information from 12d Model export
- Revise the flow file if required
- Revise any flow constriction if required (reminder that these include culverts and bridges) in the geometry file
- Revise the hydraulic roughness values (Manning's n) consistent with the vegetation design, and feature-scale design of the waterway.
- Run the model in steady flow analysis mode, using the mixed flow regime.

Interrogate the model and export the hydraulic performance for further analysis or presentation to Melbourne Water (once the waterway is optimised).

Methods for reducing shear stress

Managing shear stress within the waterway can be achieved in a variety of ways. The below techniques can be used in isolation or in combination and apply to both the low flow and high flow channels equally. For the compound type the main advantage of the low flow channel is that sinuosity can be used as a tool to manage shear stress. For example, increasing the sinuosity increases the length of the low flow channel, reducing its bed slope/grade and therefore shear stress.

Melbourne Water requires flow energy management design options to be fully explored rather than resort directly to artificial armouring of the waterway to cope with increased flow energy. High shear stress should be managed in the following sequence:

- Alter the waterway geometry to the fullest extent possible within the bounds of the available waterway corridor (see methods below)
- Explore the use of alternative vegetation species and distributions to provide additional protection where required (subject to the ecological requirements of the waterway). Also consider the use of long-stemming or tubestock with larger root system so that they can be planted deeper
- Explore the use of soft engineering protective materials such as jute matting and coir logs. Note that these products generally have a limited design life, however can often be used successfully to protect the waterway boundary for the vegetation establishment period
- Explore options for relocating assets further from the waterway to reduce the consequences of erosion
- Where the above options are exhausted explore the use of rock protection. Melbourne Water requires that shear stress be managed as the first priority before extensive armouring of the bed and banks is introduced. Armouring should only be used as a last resort where no other technique or combination of techniques has been able to produce the desired effect.

Methods to reduce shear stress in the design waterway may be reduced either by lengthening the waterway, or by increasing the resistance to flow. Specifically, bed shear stress can be reduced by:

- Altering the width of the channel to increase its capacity and reduce flow depth. Some iteration will be required here to ensure that flow depths at higher flows now contained within the wider channel do not generate shear stresses of concern for channel stability. If this is the case, channel depth will need to be reduced to create a wider shallow channel. If this is the required design response, then consideration should be given to incorporating benches within the channel cross section (see below);
- Creating a series of benches within the channel at different flow levels to increase flow extents and reduced flow depths. This can be done on both sides of the low flow channel or on one or other side, to create either symmetrical or asymmetrical cross sections using benches;
- Altering the roughness (Manning's 'n') of the channel by modifying any vegetation, in-channel structures, rock work etc., which is generating roughness to either increase or decrease roughness to achieve a reduction in shear stress;
- Altering the longitudinal grade of the channel to reduce its steepness.

Bank shear stress can be reduced by:

- Creating a series of benches within the channel at different flow levels to increase flow extents and reduced flow depths. This can be done adjacent to one or other or both banks, depending on which bank is subject to high shear stresses.

Bend shear stress can be reduced by:

- Reducing the sharpness (Rc/W) of the bend, by modifying the bend radius and/or channel width;
- Creating a series of benches within the channel at different flow levels to increase flow extents and reduced flow depths. This can be done adjacent to one or other or both banks, depending on which bank is subject to high shear stresses.

E2. DESIGN RESOURCES

The following design resources are provided to assist the waterways designer through the concept and functional design phases:

- Geology and soil – used in site analysis and concept design phases
- Constructed waterway types – used in concept design phase
- Healthy Waterways Visions – used in concept/functional design phases
- Waterway protection and rehabilitation
- Waterway and associated asset maintenance requirements
- Useful Guidelines

Image 3 – Dandenong Creek at Jells Park

E2.1 Geology and Soil

The design of waterways must consider the local soil type and rock type because of the potential impact they may have on the civil and landscape design of the waterway. This is particularly important for properties with dispersive soils as it can jeopardise the stability of the waterway.

This manual references the following information on the geology and soils of the Melbourne region:

- Geological information (ref http://dpistore.efirst.com.au/categories.asp?cID=4)

  1:250,000 Geological Map Series: Melbourne SJ 55-5 (Edition 2, May 1997)

  1:250,000 Geological Map Series: Queenscliff SJ 55-9 (Edition 2, May 1997)

- Soil information

  Australian Soil Classification (ref http://www.clw.csiro.au/aclep/asc_re_on_line/soilhome.htm)

  Australian Soil Resource Information System (ASRIS) (ref http://www.asris.csiro.au/themes/Atlas.html)

  Victorian Data Online (ref

  https://www.data.vic.gov.au/)

  Landcare Note – Melbourne Soils (ref http://agriculture.vic.gov.au/agriculture/farm-management/soil-and-water/soils/melbourne-soils)

From the available mapping across the Melbourne region, there appear to be the following broad groupings of rock types and soils within the developing areas around Melbourne:

- Quaternary Extrusive basalts "Newer Volcanics" (Qvn) from the extensive lava flows of the Victorian Volcanic Plains, with overlying heavy clay soils of varying character (e.g. Vertosols, Ferrosols). Occurrence is extensive, covering most of the major growth corridors (developing areas) to the west, north west and north of Melbourne;
- Ordovician Marine Sedimentary deposits (Our/Ou) with overlying dispersive clay soils (e.g. Sodosols). Occurrence is mostly in pockets to the north west and north of Melbourne, particularly the developing areas around Sunbury and Diggers Rest;
- Silurian Marine Sedimentary deposits "Dargile formation" with overlying dispersive clay soils (e.g. Sodosols). Occurrence is mostly to the north east of Melbourne in the developing areas around Whittlesea;
- Quaternary Fluvial Sedimentary deposits (Qra) with overlying alluvial soils (e.g. Stratic to Fluvic Clastic Rudosols). Occurrence is extensive in the developing areas to the south east of Melbourne, particularly in the area to the north of Westernport Bay;
- Quaternary Aeolian Sedimentary deposits (Qpd) with overlying lightly acidic sandy top soils and alkaline sub soils (e.g. Lutic Rudosols). Occurrence is mostly restricted to the developing areas around Cranbourne; to the south-east of Melbourne;
- Quaternary Paludal Sedimentary deposits (Qrm) with overlying silty-clay organic rich soils (e.g. semi-aquic and aquic Podosols). Occurrence is extensive in the developing areas to the south east of Melbourne, particularly in the area to the north of Westernport Bay;
- Tertiary Fluvial Sedimentary deposits "Brighton Group" (Tpb/Tpx) with overlying alluvial soils (e.g. Stratic to Fluvic Clastic Rudosols). Occurrence is extensive in the developing areas to the south east of Melbourne, particularly in the area to the north west of Westernport Bay;

Some of the broad soil types typical of the Melbourne region are presented below. Of particular note are the characteristics of those soil types that can be problematic for waterway design.

Table 32 - Design considerations of the main Melbourne area soil types
http://www.clw.csiro.au/aclep/asc_re_on_line/

SOIL	DESCRIPTION	DESIGN CONSIDERATION
Ferrosol	Soils with B2 horizons which are high in free iron oxide, and which lack strong texture contrast between A and B horizons. These soils are almost entirely formed on either basic or ultrabasic igneous rocks, their metamorphic equivalents, or alluvium derived therefrom.	These soils are friable, which means they are very crumbly when dry and most, and can become soft when wet. They are therefore prone to erosion by water if left exposed.
Vertosol	Clay soils with shrink-swell properties that exhibit strong cracking when dry and at depth have slickensides and/or lenticular structural aggregates. Many such soils exhibit gilgai micro relief. Clay context is >35%.	These soils are reactive and prone to expansion/swelling when wet and shrinkage/cracking when dry. This presents issues for: • vegetation establishment and survival, due to the highly variable moisture contents and physical disturbance to the roots of establishing plants; and • can contribute to erosion of the soil surface by water on slopes, due to the increased effectiveness of sub-aerial weathering during dry periods causing crusts to be easily removed, and water to penetrate the deep cracks, dislodging material.
Sodosol	Sodosols have an abrupt clay increase down the profile (strong texture contrast between A horizons and B horizons) and high sodium content (ESP > 6) in the sodic B horizon, which are not strongly acid.	These soils are usually very hard when dry and are prone to crust formation. The dispersive subsoil makes them prone to clay dispersion and instability when wet, which frequently results in tunnel and gully erosion. Seasonally perched water tables are common because of the subsoil structure.
Podosol	Usually infertile sandy soils with B horizons dominated by the accumulation of compounds of organic matter, aluminium and/or iron. Typically slightly acidic.	Due to the coastal and floodplain landscapes to the south-east of Melbourne where the large majority of these soils occur, high groundwater tables are common and they are prone to seasonal inundation. Poor drainage.
Rudosol	These soils are typically free draining and poorly structured. The Lutic Rudosols are prone to wind erosion. Due to the floodplain landscape to the south-east of Melbourne where the large majority of the Fluvic Rudosols occur, they are prone to seasonal inundation. (Note – some Rudosols may be Tenosols).	These soils are typically free draining and poorly structured. The Lutic Rudosols are prone to wind erosion. Due to the floodplain landscape to the south-east of Melbourne where the large majority of the Fluvic Rudosols occur, they are prone to seasonal inundation. (Note – some Rudosols may be Tenosols).

Designers should establish soil characteristics through the engagement of soil assessment studies.

- Soil needs to be tested for dispersivity (pinhole or Emerson Class). This should be informed by geotechnical advice.
- Soils might need treatment to manage dispersivity (e.g. gypsum) which should be informed by geotechnical recommendations.
- Soil amelioration should be considered to ensure ideal plant growth conditions (e.g. if topsoil not being imported or cultivation of subsoils is required). This should be informed by soil science/ agronomist advice.
- Clay to be considered also.
- Refer to Melbourne Water's topsoil specification.

E2.2 Waterway Types

The manual has introduced the concept of waterway types to assist the designer tailor their design to the predominant landscape characteristics. This is to ensure the design responds to site opportunities and constraints, and to assist in achieving the design objectives.

Urban waterways can be grouped by landscape setting and boundary material.

There are three broad waterway types prescribed for constructed waterways in the Port Phillip and Westernport catchments, as described below.

- Bedrock waterway type
- Linear pools type
- Compound waterway type

These waterway types are broad and flexible – the waterway designer can select and modify a wide range of design parameters with each of these types to develop a design that provides the required outcomes for the waterway and the site.

Waterway type decision criteria

The criteria that distinguish between the three waterway types: presence of bedrock close to the surface of the site and longitudinal bed slope (i.e. slope in a downstream direction). The criteria are used to select an appropriate waterway type using a decision tree (

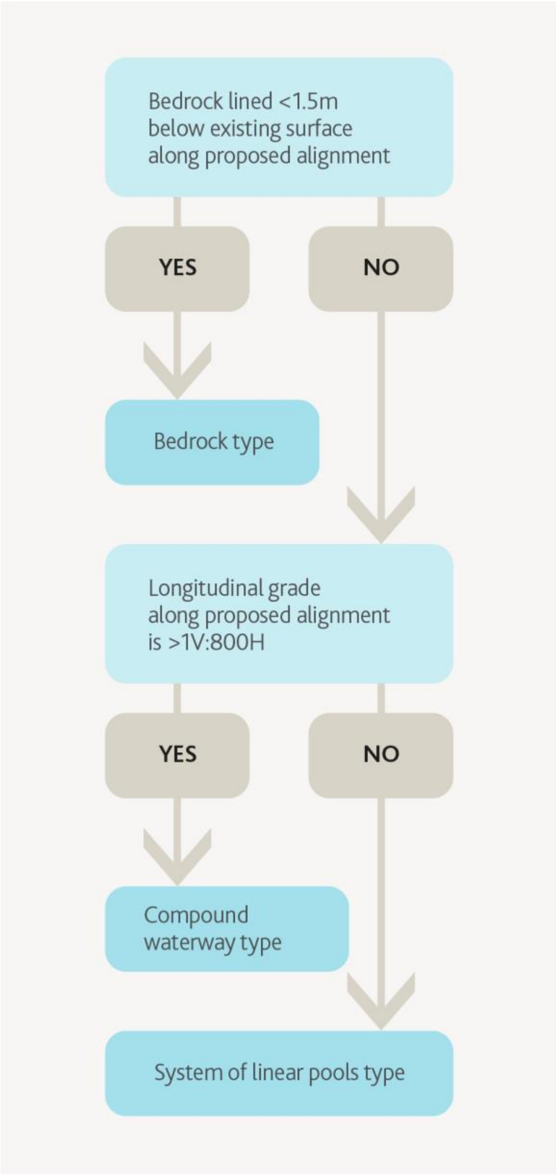

Figure 71) by answering these questions:

- Is the bedrock lined with bedrock at a depth not greater than 1.5m?
- Is the longitudinal grade of the proposed alignment greater or less than 1V:800H?

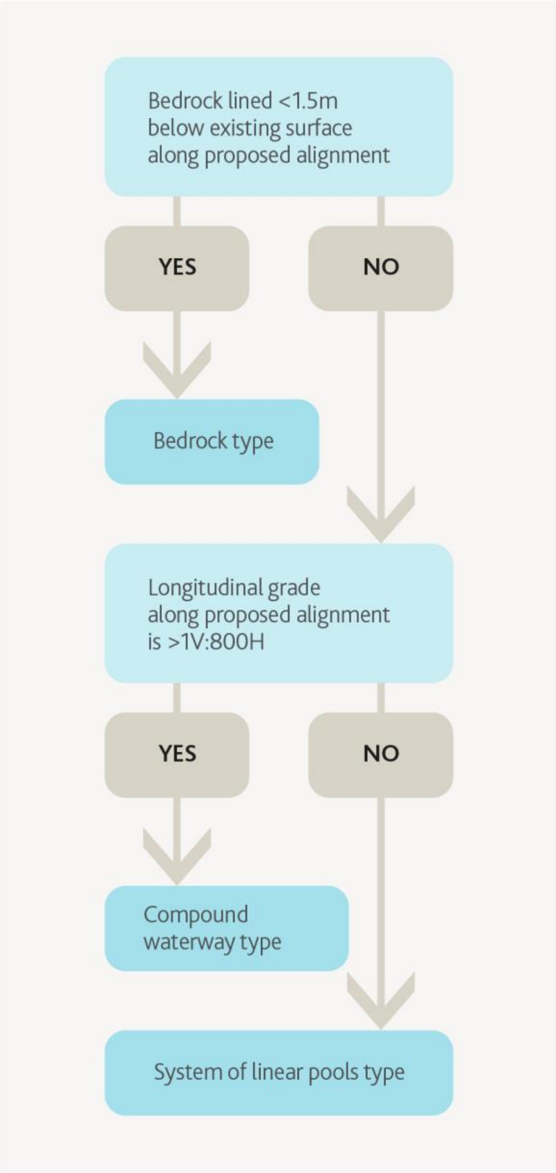

Figure 71 - Constructed waterway type decision tree

Bedrock type

Waterways constructed into corridors lined with bedrock have different design considerations to the more typical waterway set within erodible sediments such as clay, silt and sand. The geotechnical survey carried out as part of the concept design stage will determine the presence or otherwise of bedrock material. The geotechnical survey must indicate the presence of bedrock between existing surface and 1.5m (min) below existing surface or design invert level.

Compared with the more common alluvial lined types (detailed below) bedrock is inherently more stable, and therefore allows for the construction of a waterway with greater resilience to velocity and shear stress.

An indicative form for the bedrock type is shown below (Figure 72). There is no prescribed cross-section geometry, longitudinal profile, or planform for this type. Instead, the designer must demonstrate than the proposed form meets the required design outcomes for waterway as set out in Part A. At the same time, the designer must utilise, where possible, the natural features and form of the bedrock boundary. For example, using natural riffles and freefall sections where they appear in the existing bedrock boundary.

For the bedrock type the design must minimise construction effort and ensure the design objectives are met.

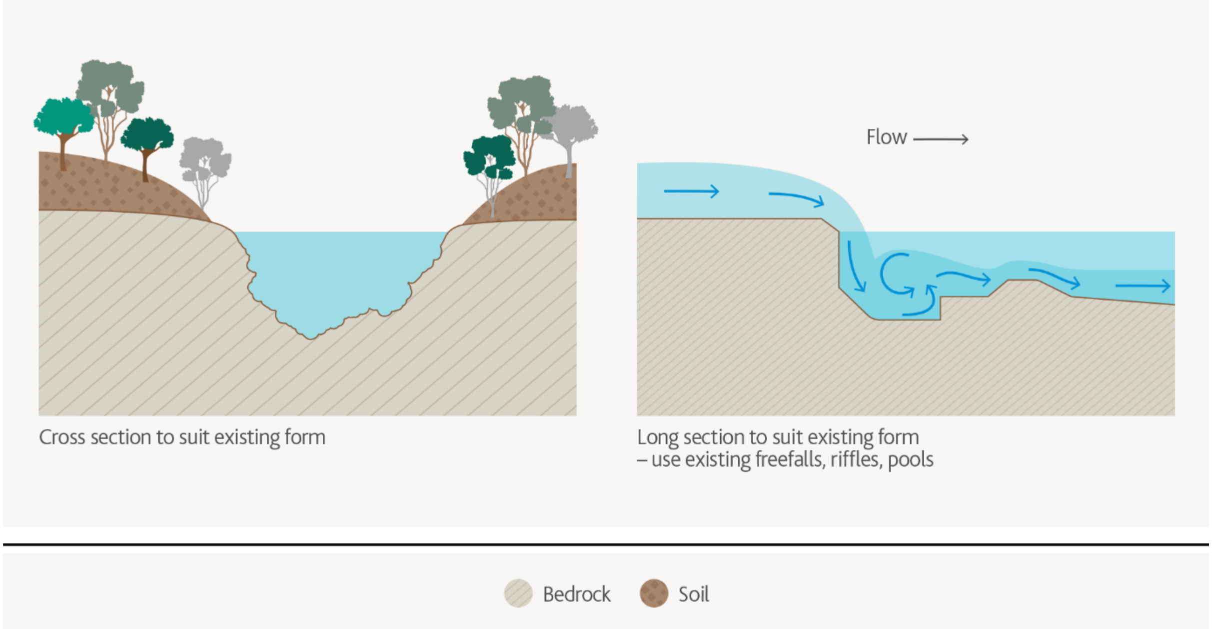

Figure 72 - Bedrock type indicative cross section and longitudinal section profile and planform

Although bedrock is generally much more resistant to erosion by flowing water, there are some instances where fractured or heavily weathered basalt may be encountered. When this type of rock is encountered during the geotechnical investigation or excavation, additional consultation with Melbourne Water in the design process may be required to ensure the required outcomes are achieved.

System of linear pools type

In very flat sites it may be necessary to construct a system of connected pools in order for surrounding development to drain efficiently. An inherent problem associated with waterway with very low longitudinal bed slopes is the base of the waterway does not drain effectively, leading to areas of the channel system that consistently hold shallow water. Depending on the required landscape / amenity outcomes this can lead to problems.

By designing the waterway as a series of pools, the designer can:

- Reduce the overall reach grade by providing flat water sections linked with waterway at a reasonable grade (Type 1, Figure 73) and / or
- Reduce the overall grade by providing flat water sections linked with a crest graded waterway, this is where sections of the floodway grade to pools, whilst a net grade is achieved (Type 2, Figure 73).

It is important to recognise that these pools in a waterway are not designed to serve a water quality objective. Designers need to ensure that scour velocities can be achieved across the pools to ensure that sediment transfer occurs and long-term maintenance requirements are not overly onerous.

The use of online wetland systems (which are generally deemed inappropriate) within a waterway may achieve a similar objective, however the designer needs to meet additional criteria set out in the wetlands design manual and consult with Melbourne Water for acceptance of this proposed design response, before proceeding.

Design of the linear pool waterway type needs to consider:

- Constructed shallow lake systems design guidelines
- Constructed wetlands manual (with reference to safety criteria for edge treatments).

These waterway types are particularly vulnerable to sediment loading during the construction phase of the associated subdivision / housing; as such, when designing these systems it is important to identify ways of preventing high sediment loads from entering the waterway and / or identify additional maintenance requirements during the defects liability period. Designers should consider offline sediment traps, gross pollutant traps and / or sediment pits.

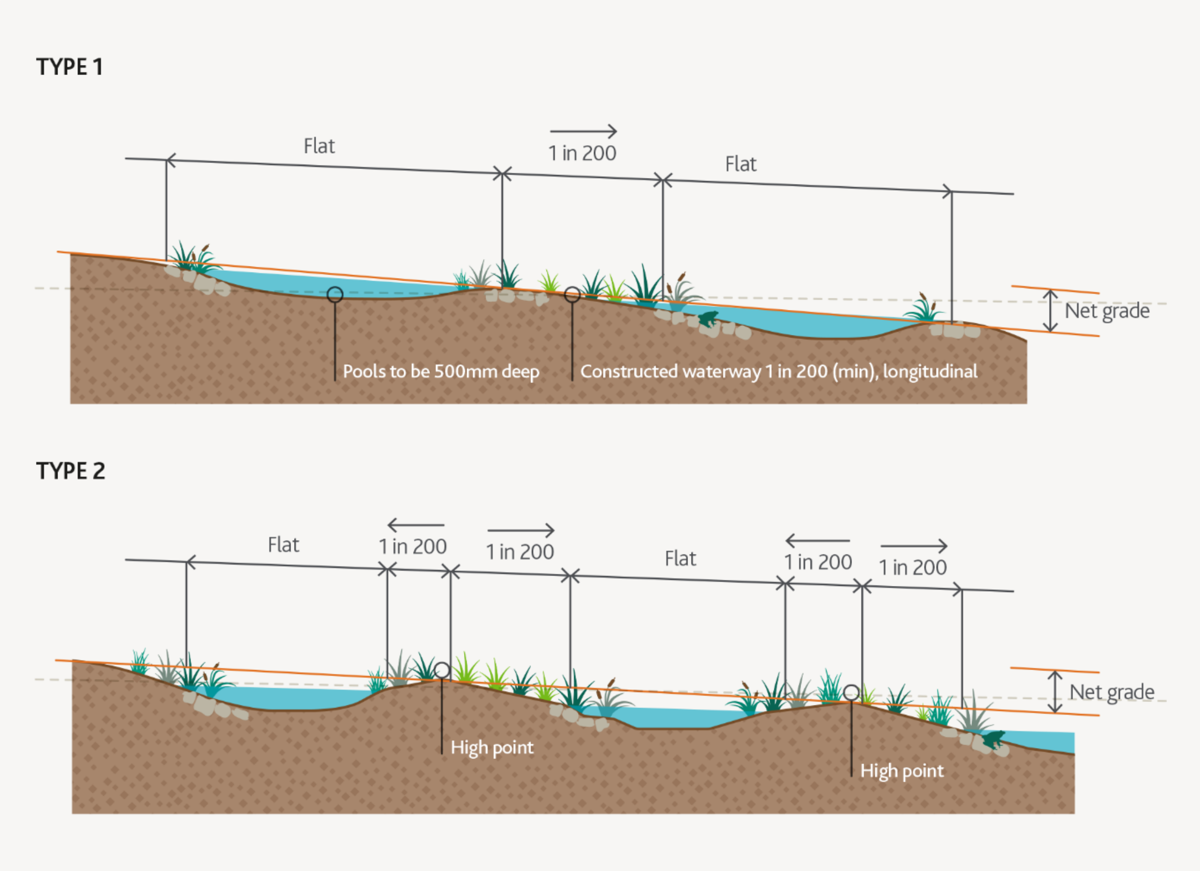

Figure 73 - Types of linear pools types in constructed waterways

Compound waterway type

Waterways constructed in erodible sediments are the most common form of constructed waterway in the Melbourne Water region. This is due to the broad range of landscape settings that this basic type can be applied to. For example, the boundary material can range from stable clays through to silts, sands and gravels. Even though the basic form of the waterway is the same for all of these boundaries, the relative size and alignment will be different due to the inherent strength of the boundary material itself as well as the vegetation community able to be supported by the material.

The ***compound*** waterway type is one with a high flow channel that conveys the 1% AEP flow (with freeboard), and a sinuous low flow channel that conveys flows between the 4EY and 1EY flows. The compound waterway type can contain a variety of features, such as pools and riffles and typically includes a variety of batter slopes and bench levels. An example of a typical cross-section is shown below (Figure 74).

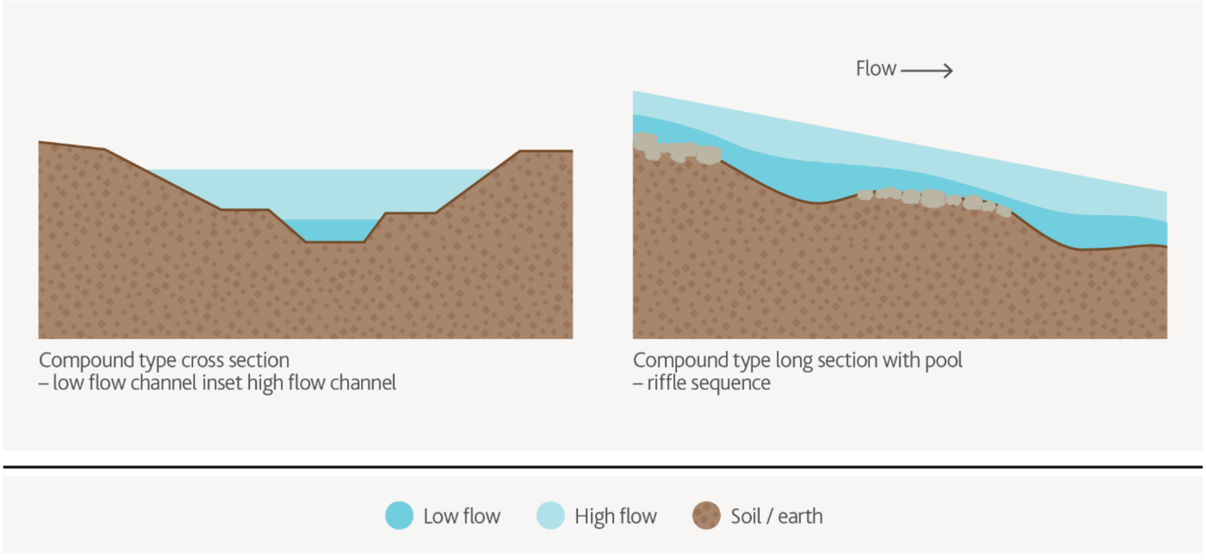

Figure 74 - Compound waterway type indicative cross section and longitudinal section profile and planform

There are obvious differences in the approach to implementing the compound waterway type in areas of highly erosive boundary material, compared with its stable equivalent. For example, in very erosive soils the designer may implement a design which is much more reliant on grade control structures to establish a suitable bed grade for the boundary material. Conversely, for the same waterway in a stable setting there is no need for a grade control-based strategy to be implemented.

Grassed floodway

Grassed floodways have historically been used within urban developments, however they are no longer acceptable within developments where catchment areas exceed 60 Ha. Grassed floodways will now be associated with conveyance of overland flow to an adjoining waterway and these systems will typically be owned and maintained by the respective local council.

E2.3 Healthy Waterways Visions

Melbourne Water has produced a range of 'Healthy Waterways Visions' which communicate aspirations Melbourne Water has for the waterways in Port Phillip and Westernport. Visions have been developed for the following waterway attributes:

- Stream form
- Vegetation quality and species
- Water quality
- Flow

The Healthy Waterway Visions for **vegetation quality and species,** and **stream form** are an integral component of constructed waterway design method. An overview of these visions is provided below.

Vegetation quality and species

The vegetation community is a critical component of the vegetation design for the site, and also has implications for the hydraulic roughness of juvenile and mature vegetation, which will influence flood conveyance and erosion resistance.

The Healthy Waterways vegetation visions communicate Melbourne Water's longer-term vision for riparian and aquatic vegetation across the Port Phillip and Westernport catchments, including constructed waterways. Two vegetation visions were developed: vegetation quality (which indicates the riparian vegetation quality to be achieved and maintained along Melbourne Water's waterways) and vegetation species (which identifies an appropriate range of species at any location in the Port Phillip and Westernport region.

Vegetation quality is rated from 1 (very low) to 5 (very high). Each vegetation quality level describes a number of waterway characteristics such as vegetation structure, species composition, instream vegetation, continuity and connectivity, and suitable vegetation management techniques (Figure 75). The minimum vegetation quality in constructed waterways is 3, so the vegetation quality and species vision templates can be used to identify the appropriate list of species for a constructed waterway at any site in Port Phillip and Westernport.

The vegetation species visions are based on Ecological Vegetation Classes (EVCs), which are spatially explicit representations of a vision for riparian and aquatic vegetation species across the Port Phillip and Westernport catchments. The vegetation species visions provide species lists for each of the five vegetation quality levels set out in the vegetation quality visions (Figure 76).

The vegetation visions for the waterway will be provided by Melbourne Water as part of the Scheme Servicing Advice in the Concept Design stage of the project.

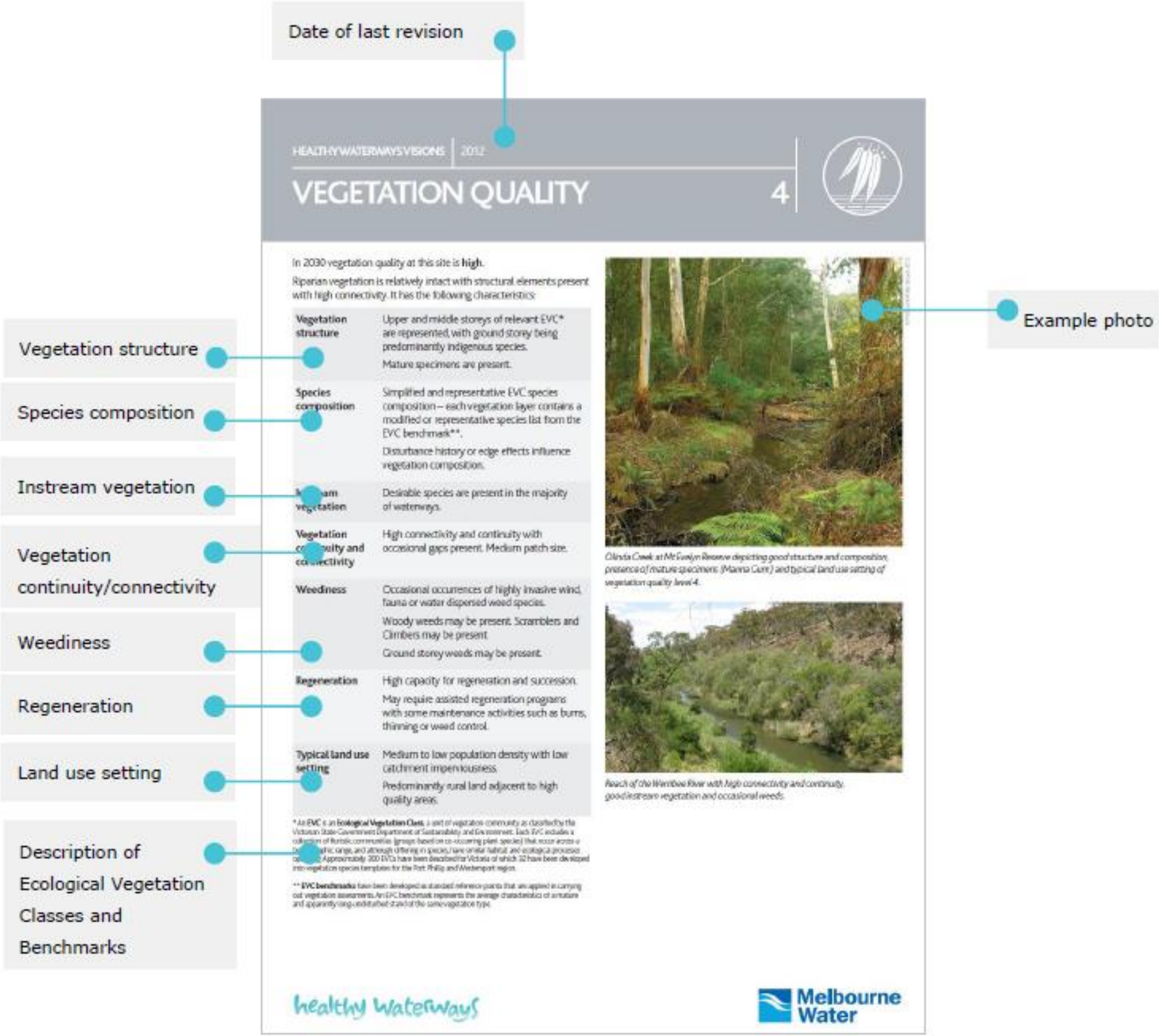

Figure 75 - Example vegetation quality templates for use in constructed waterway design

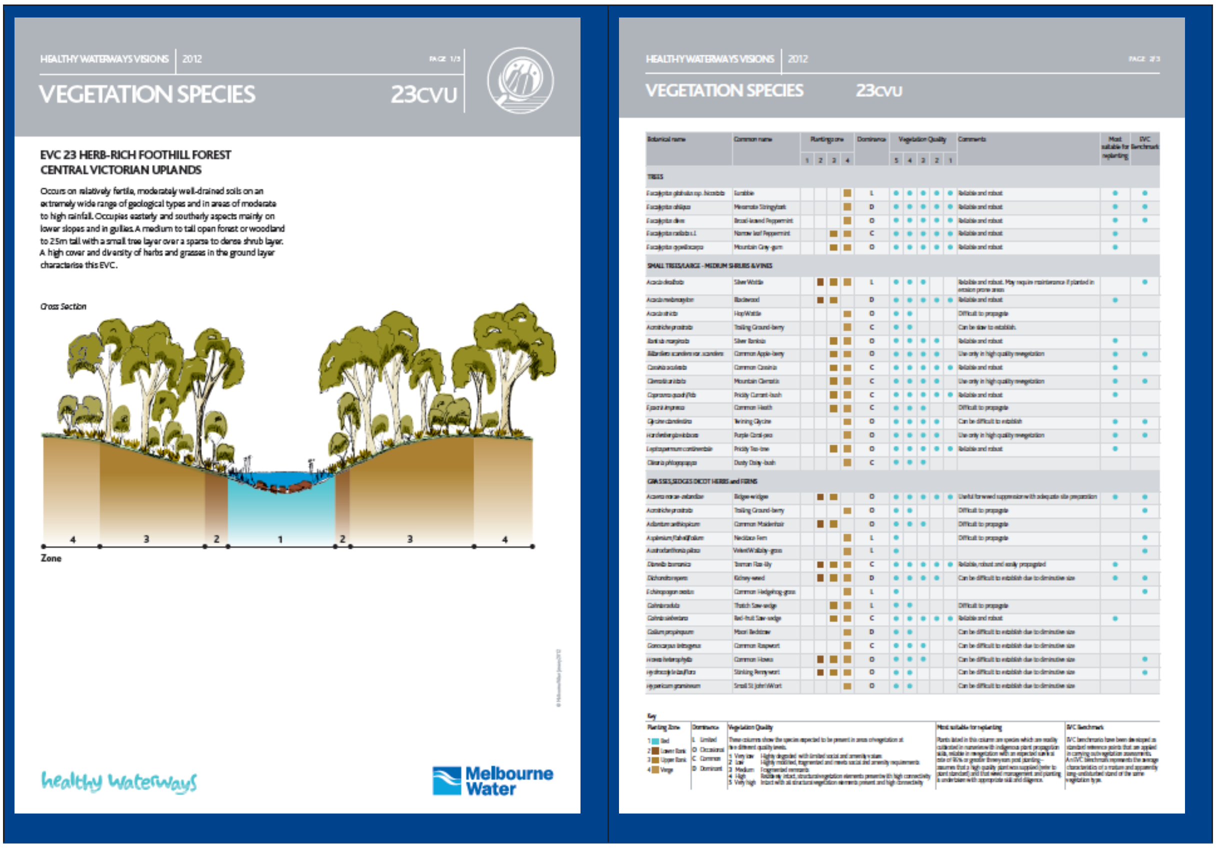

Figure 76 - *Example vegetation species templates for use in constructed waterway design*

Stream form

The Healthy Waterways vegetation stream form visions describe the important aspects of stream form and function, including providing the physical basis for biotic processes in streams (faunal and floral), describing and quantifying channel stability, and describing the relationship between the channel and its floodplain.

The stream form visions outline the physical form and expected ongoing physical processes occurring within the waterway. The visions include a description of channel character (valley abutment, sinuosity, and hydrology), behaviour (stability and timescales of adjustment) and geomorphic features (e.g. pools, riffles, benches).

The stream form visions are an integral component of describing the waterway type that must be selected for each site (as discussed in the previous section). An example stream form vision is presented below (Figure 77 and **Error! Reference source not found.**).

HEALTHY WATERWAYS VISIONS | 2012

STREAM FORM 15

Man-made channel – urban vegetated

The waterway in this reach in 2030 has a single channel with a relatively straight course interspersed by gentle bends. The waterway is likely to have been previously modified to improve drainage of the surrounding floodplain. The channel does not come into contact with the hillslopes at the side of the valley and flow will fill the channel and flow onto the floodplain during relatively large flow events.

The course of the channel is likely to be becoming more winding over time through bank erosion and sediment deposition on the inside of bends. There is likely to be some erosion and deposition during low to medium size events, but the large-scale channel change will occur slowly due to active bank management that will be undertaken to protect urban development and infrastructure that may be in the vicinity of the waterway.

A range of geomorphic features may be present in the channel, although not necessarily all are present in every location. In-channel features could include pools, runs and benches; these features are likely to be actively forming over periods of years.

In some locations the channel may have previously incised, leading to deepening of the bed and widening of the channel. The channel is larger and flooding occurs less frequently. A smaller channel forms in the base of the large channel with a similar range of geomorphic features as described above.

Where incision has occurred bed stabilisation works and revegetation works may be carried out. The banks of the incised channel are often steep. The natural recovery of the waterway to a stable, diverse system should be encouraged to reduce the frequency and magnitude of bank erosion and enhance in-channel habitat.

An example of this type of stream form. Note the surrounding land use may differ from that shown.

healthy waterways

Melbourne Water

Figure 77 - Example stream form vision for use in constructed waterway design

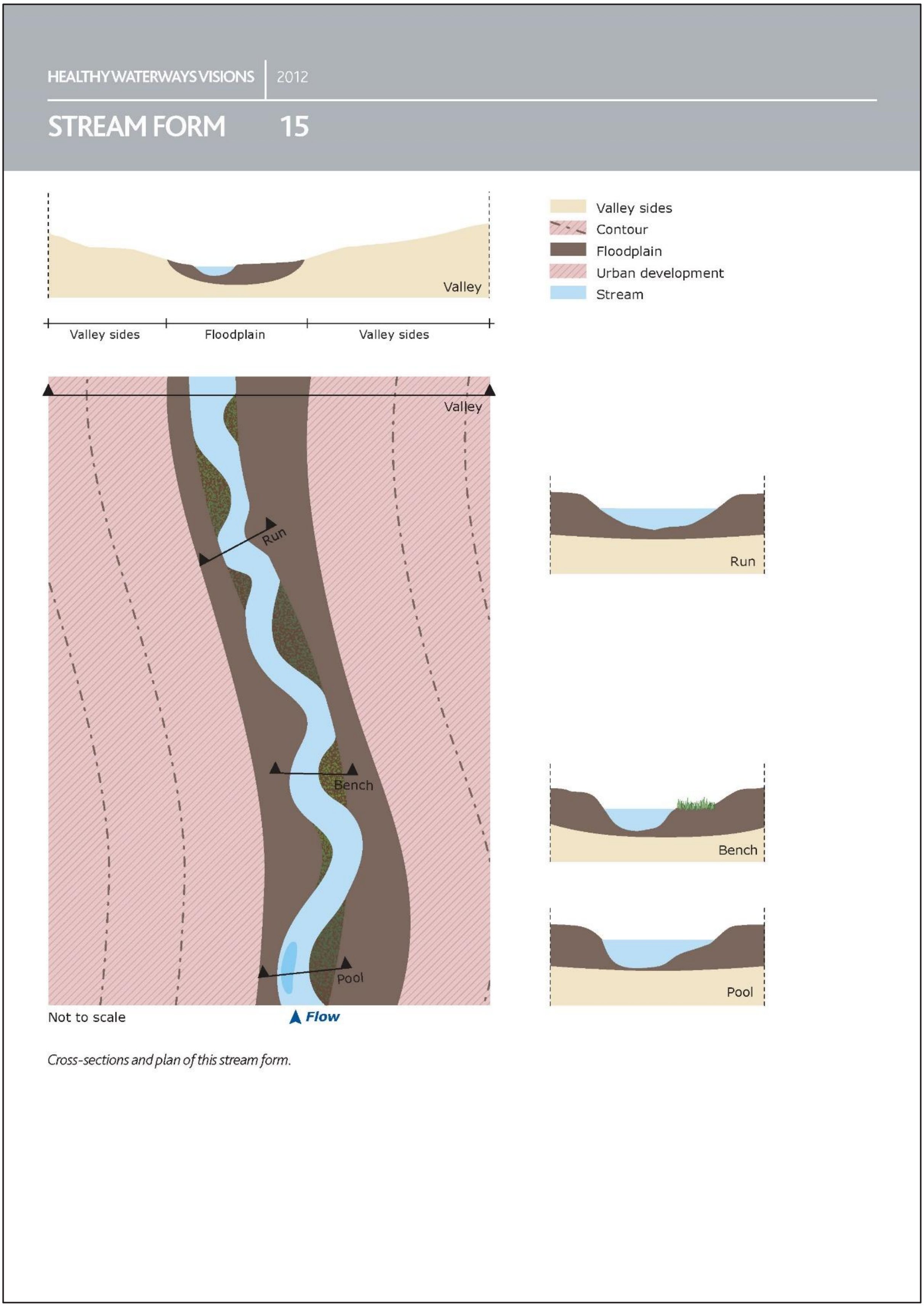

Figure 78 – Example Stream Form vision plan view for use in waterway design

E2.4 Waterway Protection & Rehabilitation

Protecting existing valued waterway form

If an existing waterway or drainage line on the site has cultural heritage, flora and fauna, or geomorphic values that must be retained, innovative solutions may be required to enable the existing waterway to perform the function of drainage outfall and conveyance.

Although not covered specifically in this manual some typical types are:

- **Type 1**. The existing waterway **is deep enoug**h to provide outfall and the waterway characteristics (width / grade) allow 1% AEP flow to be conveyed without detrimental impact to the existing values (Base case). No works are required within the waterway however the impact of urban hydrology on waterway values (physical form and ecology) should be assessed to inform the design of stormwater treatment systems across the catchment as part of adjacent developments. Flow and shear stress mitigation for higher volume and more frequent flows may be required.
- **Type 2.** The existing waterway **is deep enough** to provide outfall and the waterway characteristics (width / grade) **do not allow** 1% AEP **flow to be conveyed** without detrimental impact to the existing values. Works to create additional conveyance by enhancing high flow channel capacity in areas where the existing values are not at risk should be considered.
- **Type 3** The existing waterway **is not deep enough** to provide outfall however the waterway characteristics (width / grade) **allow 1% AEP flow to be conveyed** without detrimental impact to the existing values. A low flow pipe and / or surcharge system should be considered in order to avoid deepening the system and protect existing values. Note that Melbourne Water and Council do not accept submerged pipes.
- **Type 4** The existing waterway **is not deep enough** to provide outfall and the waterway characteristics (width / grade) **do not allow 1% AEP flow to be conveyed** without detrimental impact to the existing values. A low flow pipe and / or surcharge system along with additional conveyance (high flow channel capacity) could be considered.

The location of the existing values to be protected will influence the need for low flow pipe and / or additional conveyance and their subsequent location within the cross section and plan form. The designer may also need to consider the use of localised filling to adjacent land holdings to achieve a similar or complementary outcome. Melbourne Water will only consider allowing low flow pipes when the imperative is to protect the existing waterway values from physical and hydraulic disturbance.

Rehabilitating existing waterways

Melbourne Water is sometimes faced with the task of designing major works along a degraded reach of existing waterway within rural and existing urban land uses. Whilst the design principles and approach underpinning this manual are in many ways still applicable, the works delivery, design and acceptance processes are different to a constructed urban waterway.

Where the waterway designer encounters a site for a proposed waterway (or existing waterway that requires major rehabilitation works) with longitudinal grades steeper than 1-in-200 then the designer is encouraged to base their initial design response on a grade control program, then determine what additional design components can be added to this design response that will contribute to meeting the design objectives. Melbourne Water should be consulted at an early stage in the design process for these situations.

For further guidance regarding design philosophy and techniques for major waterway rehabilitation works, including grade control programs, the waterway designer is advised to refer to the *Technical Guidelines for Waterway Management* (DSE, 2007).

E2.5 Waterway maintenance requirements

Maintenance access

Direct maintenance access is required along both sides of the waterway (min 4m wide). The maintenance tracks should be offset from the top of any adjacent batter, to provide safe run off areas for maintenance vehicles. This access can often be incorporated with public amenity objectives via shared paths.

Careful planning of maintenance access and paths can limit vehicular disturbance that leads to damaged riparian vegetation and weed invasion.

The design for access should also consider:

- suitable materials for vehicle loadings, especially at cross-over points along the path network (i.e. where the Melbourne Water maintenance track for heavy machinery access to the waterway crosses over the public pathway)
- the prevention of non-authorised vehicle access (e.g. double-lock bollards/gates for Melbourne Water and Council).

Particular features in or near waterways such as large culverts, sediment basins, and pools that are designed to trap sediment or have access for de-silting purposes rather than only provide habitat, and wetlands will require specific design considerations in relation to maintenance needs, including:

- de-silting
- machinery sizes
- turning circles
- lifting distances.

Batter slopes

Batters on approaches to waterways, particularly areas with permanent water such as pools, must have suitable grades and must reflect these landscape constraints and current safety standards:

- the edge of any deep, open water should not be hidden or obscured by embankments or terrestrial planting, unless measures preventing access are provided
- approaches to batter slopes should be no steeper than 1:5 Vertical to Horizontal (V:H) unless there is special landscape edge treatment that will provide appropriate safety measures/fencing
- the safety bench must be densely planted with emergent macrophytes so that casual entry will be difficult.

Safety measures such as permanent fencing or combined fencing and densely vegetated buffer zones should be used in the following circumstances:

- adjacent to zones of deep water (greater than 350 mm at normal water level)
- adjacent to potentially unsafe structures
- where high velocities may be encountered (refer Melbourne Water's Land Development Manual floodway safety criteria)
- where batters are 1V:3H or steeper.

Maintenance access areas should be fenced and gated to discourage access where the basic safety measures described above are not met. Non-maintenance access to the top of weirs, orifice pits and outlet structures must be restricted by appropriate safety fences and other barriers.

If any part of the water body is deeper than 350 mm, interim fencing may be required between the periods of construction and the establishment of vegetation. For further safety design details for pools, refer to Melbourne Water's Wetlands Design Manual.

When preparing the concept design package the designer must demonstrate that maintenance access requirements for the proposed features within each of the options has been considered.

Maintenance responsibilities

The responsibility for maintenance falls to both Melbourne Water and council for features within the waterway corridor. To ensure clarity of future asset management and maintenance considerations the designer must highlight waterway features falling under the responsibility of each.

E2.6 Useful Guidelines

Melbourne Water guidelines

Melbourne Water has produced the following range of guidelines which may be of use or further interest to the waterway designer.

Healthy Waterways Strategy
https://www.melbournewater.com.au/media/6976/download

Stormwater Strategy
https://www.melbournewater.com.au/sites/default/files/2017-10/Stormwater-strategy_0.pdf

Waterway Corridor Guidelines
https://www.melbournewater.com.au/sites/default/files/Waterway-corridors-Greenfield-development-guidelines.pdf

Waterway Crossings Guidelines
https://www.melbournewater.com.au/sites/default/files/Constructing-waterway-crossings-guidelines.pdf

Stormwater connections
https://www.melbournewater.com.au/planning-and-building/work-or-build-near-our-assets-or-easements/stormwater-connection-guidelines

Shared Path Guidelines
http://www.melbournewater.com.au/Planning-and-building/Forms-guidelines-and-standard-drawings/Documents/Shared-pathways-guidelines.pdf

Jetties Guidelines
http://www.melbournewater.com.au/Planning-and-building/Forms-guidelines-and-standard-drawings/Documents/Jetties-approval-guidelines.pdf

Guidelines for development in flood prone areas
https://www.melbournewater.com.au/media/580

Constructed Wetlands Design Manual
https://www.melbournewater.com.au/planning-and-building/developer-guides-and-resources/standards-and-specifications/constructed-0

MUSIC Guidelines
https://www.melbournewater.com.au/planning-and-building/developer-guides-and-resources/guidelines-drawings-and-checklists/guidelines

Constructed Shallow Lake Systems – Design Guidelines for Developers
https://www.melbournewater.com.au/planning-and-building/developer-guides-and-resources/guidelines-drawings-and-checklists/guidelines

Topsoil specifications
https://www.melbournewater.com.au/media/624/download

Jute mat specifications
https://www.melbournewater.com.au/planning-and-building/developer-guides-and-resources/guidelines-drawings-and-checklists/guidelines#vegetation

Vegetation supply and installation standards
https://www.melbournewater.com.au/planning-and-building/developer-guides-and-resources/guidelines-drawings-and-checklists/guidelines#vegetation

Security and retention for developer instigated works
https://www.melbournewater.com.au/media/6746/download

Stormwater harvesting guidelines
https://www.melbournewater.com.au/media/619/download

Melbourne Water standard drawings
https://www.melbournewater.com.au/planning-and-building/developer-guides-and-resources/guidelines-drawings-and-checklists/drawings

Other guidelines

WSUD Engineering Procedures – Stormwater (CSIRO, 2005)
http://www.publish.csiro.au/pid/4974.htm

Technical Guidelines for Waterway Management (DSE, 2007)
(Soft copy available from Melbourne Water upon request).

Australian Rainfall and Runoff (AR&R; 2019)
http://arr.ga.gov.au/arr-guideline

Urban Stormwater: Best Practice Environmental Management Guidelines
http://www.publish.csiro.au/book/2190

Arthur Rylah Institute – Fishways and fish movement
https://www.ari.vic.gov.au/research/rivers-and-estuaries/fishways-and-fish-movement

Growling Grass Frog Crossing Design Standards (DELWP 2017)
https://www.msa.vic.gov.au/__data/assets/pdf_file/0020/73415/Growling-Grass-Frog-Crossing-Design-Standards_March2017.pdf

Factsheets about improving the ecological function of urban waterways

https://watersensitivecities.org.au/content/improving-the-ecological-function-of-urban-waterways-a-compendium-of-factsheets/

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