Waterway and Channel Rehabilitation Guidelines

Ipswich City Council

Final V3

City of Ipswich

AECOM

Document Control Sheet

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Table of Contents

Purpose of Guidelines

This section of the guideline provides some background into why this guideline was developed and how to best use it to enhance ecological functioning of constructed waterways and channels within Ipswich.

How to use the Guidelines

Guidelines Framework

Purpose of Guidelines

AECOM was commissioned by Ipswich City Council (ICC) to develop a waterway and channel rehabilitation guideline. This document provides information on the retention or reinstatement of ecological functioning of waterways and channels, from design through to construction and maintenance. These solutions will increase habitat and water quality values associated with these waterways and channels as well as the aesthetic appeal and amenity of these public assets. Design solutions presented in the guidelines also aim to reduce maintenance requirements for these Council assets.

This guideline identifies key maintenance and waterway health issues and concerns within the city of Ipswich and provides drawings and supporting information to outline how these issues should be addressed for different waterway management situations, ranging from constructed swale systems to natural channels in developing catchments.

How to use the guideline

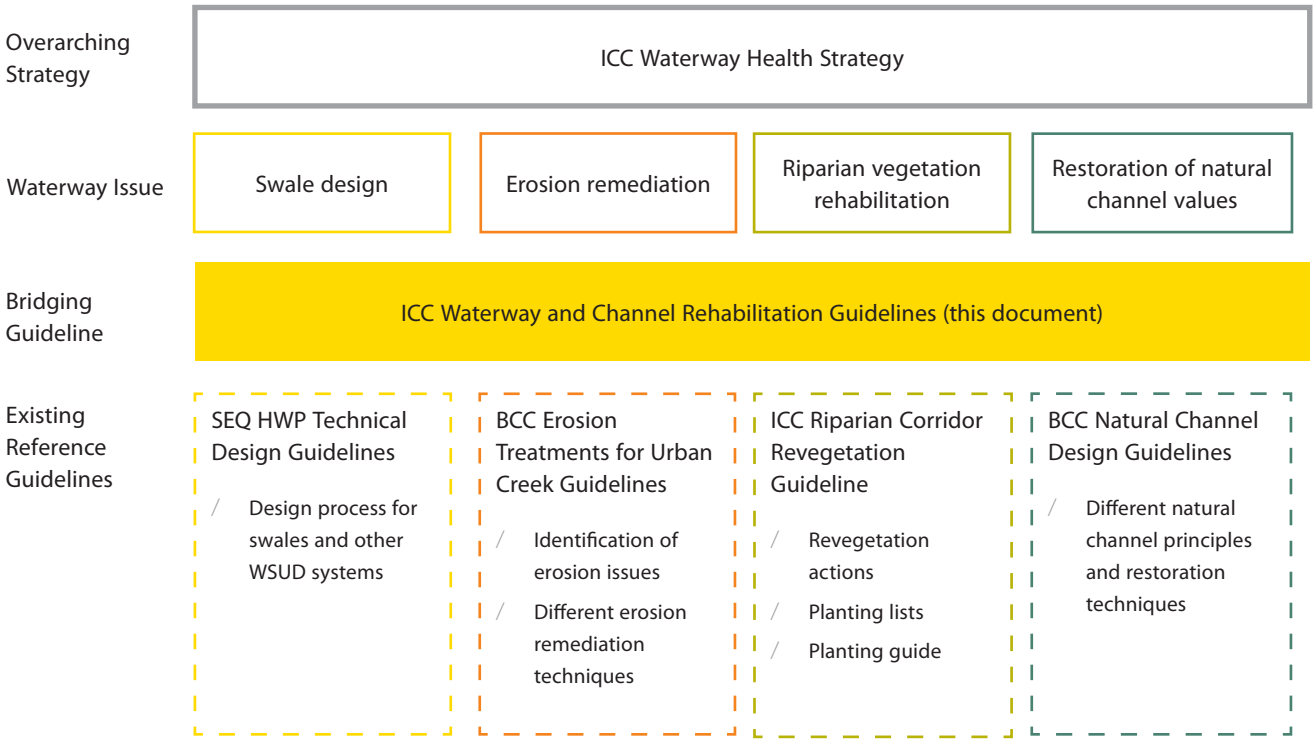
The guideline has been developed for use by Council staff to plan and deliver waterway and channel works which will successfully achieve cost-effective waterway enhancement outcomes and reduce future maintenance requirements. The guideline will also be an important reference for developers and designers involved in channel design to ensure that designs meet Council's requirements, minimise maintenance and maximise waterway health outcomes.

The focus of the guideline is primarily on urban waterways, but many of the principles outlined in this guideline could be adapted and applied to rural waterways.

There are a number of existing guidelines which are currently used by Council that provide detailed technical guidance on the design and treatments for different channels. This guideline does not replicate or replace these existing guidelines, rather it has been designed to act as a bridging document providing practical guidance to inform remediation, rehabilitation and restoration works for waterways within the city of Ipswich (see Guideline Framework).

Council also has a Waterway Health Strategy which was developed to assist with the management and enhancement of natural waterways within the City of Ipswich. It prescribes a change in current management practices to address waterway health improvement as an integral component of Total Water Cycle Management.

Guideline Framework



Waterway Characteristics

This section of the guideline introduces users to the typical characteristics of Ipswich waterways and channels.

Local Area

Waterway Management

Waterway Types

Waterway Characteristics

Local Area

The City of Ipswich lies within the 2,030 km^2 Bremer River Catchment which encompasses a diverse range of land uses including agriculture, mining, industry, commerce, natural areas and urban development. The Bremer River Catchment contains six major waterways, being the Bremer River, Bundamba Creek, Purga Creek, Reynolds Creek, Warrill Creek and Western Creek. The Bremer River Catchment also forms part of the Brisbane River Catchment, which is the largest river system in South East Queensland (ICC, 2010).

Much of the catchment is considered degraded due to overclearing of vegetation and inappropriate cropping and grazing practices. This land degradation coupled with the presence of erosive soils throughout the catchment means that erosion and sedimentation are serious issues in the Bremer River Catchment (ICC, 2010).

Ipswich is one of the fastest growing sub-regions of South-East Queensland. It is expected that the current population of 135,000 residents will almost double in the next 10 years (ICC, 2005). This increase in population will result in increased urbanisation, which has the potential to negatively impact waterways through increased flow volumes and velocities.

Ipswich has a history of flooding, with some small creeks in urban areas known to rise quickly during heavy rainfalls and also due to backwater flooding from the Brisbane and Bremer Rivers when they are in major flood (BOM, 2010).

Overall, most waterways have been significantly modified or altered from the pre-European state, with only a few waterways still maintaining aspects of the natural features, biodiversity and ecosystem functions representative of a waterway in a healthy natural state (ICC 2009).

Waterway Management

Waterway management initiatives should aim to meet suitable and achievable waterway conditions based on the current condition of the waterway and catchment. It is therefore important to classify the waterway type and to identify existing characteristics before determining waterway management initiatives.

Catchment development will increase catchment flows and as such, will modify the waterway condition. Identifying the stage of channel adjustment will influence the type of improvement works which will be required. For example, if the channel is in the process of adjusting to catchment urbanisation, works should be undertaken to increase channel capacity to ensure that increased catchment flows can be safely conveyed within the channel or designed over channel areas, decreasing erosion pressure within the waterway. Alternatively, if the catchment is fully developed and the channel adjustment has occurred, the channel just needs to be stabilised and rehabilitated.

Waterways in Ipswich can be classified according to their level of modification: from constructed open channels in developed catchments through to minimally impacted natural channels in developing catchments. All of these waterways remain a valuable asset, providing a number of environmental, landscape and social values (see Table 1).

Where waterway enhancement works are proposed the level of improvement and associated works should reflect the potential to reinstate the pre-developed waterway values. Rutherfurd et al. (2000) used the terminologies of waterway restoration, rehabilitation and remediation to distinguish between different recovery pathways and end points:

Restoration – Return the waterway to the pre-development waterway characteristics

Rehabilitation – Potential exists to re-create many waterway values but it may not be possible to fully restore the waterway to its original ecosystem condition due to catchment modifications.

Remediation – Due to the extent of catchment modification returning waterway health to the pre-developed condition is unlikely. It requires establishing a changed but nevertheless healthy waterway representing an ecosystem state that accommodates changes in the catchment conditions.

This guideline has been developed to focus on constructed drainage systems and waterways which will require either remediation (such as open channels in developed catchments) or rehabilitation (natural channels in developing catchments). Details around the more extensive works required for these remediation and rehabilitation efforts are provided in the Natural Channel Design Guidelines (BCC, 2000).

Plate 1: Drainage channel within Ipswich parkland (image: AECOM)

Table 1: Summary of waterway and channel types and values
(each of these are documented in more detail in Section 3: Waterway Management Scenarios)

Waterway Type		General Description	Ecosystem Function and Values
High maintenance swale system		Typically a shallow constructed open drainage channel located in road verges, central road medians or housing developments. Typically grass or vegetated with a regular cross section, designed to receive intermittent storm flows.	Moderate water quality function improvement (sediment trapping and nutrient transformations), low to moderate habitat values
Weedy open channel in grassed parkland		Small and shallow channel within a parkland which has regular base flows. Storm flows regularly exceed channel capacity and flow through parkland.	Moderate water quality function improvement (sediment trapping and nutrient transformations), low to moderate habitat values
Natural channel with headcut erosion - upper urban catchment		Natural waterway in urban catchment with deepening channel, typically with steep, unstable banks.	Limited ecosystem functioning in this section of the waterway (active erosion and sediment transport)
Natural channel with headcut erosion - upper rural catchment		Natural waterway in rural catchment with deepening channel, typically with steep, unstable banks.	Limited ecosystem function in this section of the waterway (active erosion and sediment transport)
Piped flows entering natural channel		Piped outfall entering waterway directly or via a swale system, causing localised erosion within the channel	Reduced ecosystem function in this section of the waterway (active erosion)
Channelised overland flow entering natural channel		Natural channel with sedimentation occurring on outer boundary of riparian zone (typically in rural catchments)	Moderate channel ecosystem function, however lateral in-flows are bypassing the riparian zone thus limiting transformation processes, such as, sediment trapping and nitrification and denitrification.
Natural channel in developing catchment		Natural channel with significant areas of remnant riparian vegetation within a developing catchment	Ecosystem function is being impacted by increased catchment flows causing bank erosion

Landscape and Social Values	Affect on Downstream Ecosystem Function	Remediation / Rehabilitation Potential	Waterway Management Situation Page Reference
Generally weedy and unaesthetic, generating complaints from local residents	Limited moderation of peak discharges, limited pollutant load reduction.	Potential to create a vegetated swale (with or without trees) providing some improvements to ecological, landscape and social values	Pages 10 to 11
Weedy and unaesthetic, generating complaints from park users and local residents	Limited moderation of peak discharges, limited pollutant load reduction.	Potential to create a broader riparian zone with a floodplain function providing moderate improvements to ecological function as well as landscape and social values	Pages 12 to 13
Steep and unstable banks typically accompany head cut erosion which impact on amenity and public safety	Bed and bank erosion result in sediments being transported downstream	Potential to establish grade control structures to prevent further erosion and stabilise bed and banks, improving ecological, social and landscape values	Pages 14 to 15
Steep and unstable banks typically accompany head cut erosion, mainly on private property, impacting any riparian vegetation and stock safety	Bed and bank erosion result in sediments being transported downstream	Potential to establish grade control structures and use other bank stabilisation techniques (such as stock fencing) to improve ecological, social and landscape values	Pages 16 to 17
Eroded banks and weedy swale systems impact landscape and amenity and public safety values	Localised erosion may result in downstream deposition	Use of a sediment pond or flow dissipation device will slow flows before they enter the channel, improving ecological, social and landscape values	Pages 18 to 21
Eroded riparian edge impacts landscape values (mainly on private property)	Channelised flows result in increased velocities at the confluence with the downstream waterway	Potential to create a series of discontinuous shallow swales to trap sediments and distribute flows through the riparian zone to improve ecological and landscape values.	Pages 22 to 25
Steep, eroded banks and a widening channel impact on neighbouring properties and public safety	Eroded sediments are transported downstream. Downstream areas are also impacted by increased catchment flows.	Potential to stabilise banks and provide increased channel cross sections to adapt to new catchment conditions.	Pages 26 to 27

Table 1 Cont.: Summary of waterway and channel types and values
(each of these are documented in more detail in Section 3: Waterway Management Scenarios)

Waterway Type		General Description	Ecosystem Function and Values
Channel bank erosion at culvert headwalls due to overland flows		Catchment overland flowpaths typically enter waterway at the same location as the piped network. If not designed for, these flows can cause erosion behind stormwater infrastructure along waterway banks, exposing pipes and compromising headwall stability.	Ecosystem function is being impacted by sediment transport associated with isolated bank erosion
Channel bank erosion due to overland sheetflow - parkland area		Overland sheetflow can enter waterways on broad fronts. In intense rainfall events, such flows can be considerable even from turfed parkland catchments. Waterway banks without sufficient riparian groundcover are susceptible to erosion under these conditions.	Reduced ecosystem function in this section of the waterway due to broad scale active erosion of banks, reduction in riparian zone ecosystem services and associated sediment transport
Channel with steep banks and / or undercutting		Widening of a waterway as a result of bank erosion due to undercutting at the toe of the bank. This situation is nearly always the result of either headward erosion creating steep unvegetated banks and exposing erodable / dispersive soils or constructed or enlarged channels being created with steep batters	Limited riparian in-stream ecosystem functioning in this section of the waterway (active erosion and sediment transport)

Landscape and Social Values	Affect on Downstream Ecosystem Function	Remediation / Rehabilitation Potential	Waterway Management Situation Page Reference
Exposed pipes and unstable headwalls can impact public safety as well as amenity	Bank erosion results in sediments being transported downstream	Potential to protect pipe infrastructure with rock in combination with management of catchment overland flows, improving ecological, social and landscape values	Pages 28 to 29
Unstable banks along parks can create a high public safety risk as well as reduce parkland amenity	Bank erosion results in sediments being transported downstream	Appropriate maintenance of riparian groundcover, ensuring herbicides are not used in this environment. Potential to direct catchment overland flows to discharge via a swale to a formalise rock chute within a revegetated bank, improving ecological, social and landscape values	Pages 30 to 31
Unstable banks can impact on amenity and public safety	Bank erosion results in sediments being transported downstream	Potential to establish grade control structures to raise bed level and establish bank stabilisation techniques to improve ecological, social and landscape values	Pages 32 to 33

Waterway Management Situations

The purpose of this section of the Guideline is to provide relevant information to enable users to undertake works to improve the existing waterway values of each different waterway type.

High Maintenance Swale System

Weedy and Unaesthetic Open Channel in Grassed Parkland

Natural Channel with Headcut Erosion - Upper Urban Catchment

Natural Channel with Headcut Erosion - Upper Rural Catchment

Piped Flows Entering Natural Channel

Channelised Overland Flow Entering Natural Channel

Natural Channel in Developing Catchment

Channel Bank Erosion at Culvert Headwalls due to Overland Flows

Channel Bank Erosion due to Overland Sheet flow - Parkland Area

Channel with Steep Banks and / or Undercutting

Waterway Management Situations

Council's Waterway Health Strategy identifies the vision for Ipswich waterways which is to have improved water quality and increased biodiversity values and that they are appreciated by the community for their amenity and recreational values. With this in mind, the primary objective of this Guideline is to create waterways which have the following characteristics:

- Riparian vegetation providing a clearly defined maintenance boundary between the natural asset and surrounding areas
- A riparian corridor linking public open space / vegetated areas
- Shade trees in the riparian zone to shade out weeds in the drainage system or waterway
- Stable bed and banks

This section of the Guideline provides templates for the possible remediation / rehabilitation of seven different waterway types which are typically encountered in Ipswich. To achieve the primary waterway objectives described above, it is important to undertake the following steps:

1. identify problem / issue
2. identify waterway type
3. understand natural processes underlying the problem / issue
4. redesign waterway addressing the degrading processes and to work to enhance natural processes

Site investigations of typical waterway types within Ipswich have been used to identify typical issues associated with each waterway type, and to gain an understanding of the processes underlying these problems. Information is provided for each waterway management situation to help the user identify the type of waterway they are dealing with (as represented in the 'existing waterway condition' image). Preferred design responses have been developed for each waterway type (as represented in the 'future waterway condition' image). Notes on the required design, construction, establishment and maintenance elements required to achieve these design responses are provided. Additional details for each of these elements is provided in Section 4 of this Guideline.

To achieve the vision of improved water quality and increased biodiversity for waterways, the focus of the design responses in this Guideline is for the use of soft rather than hard engineering structures where possible. This is due to a number of benefits that soft engineering solutions can provide including:

- self adjustment and movement of structures to respond to changes in the waterway (e.g. rock chutes and riffles)
- infiltration to support passive irrigation of riparian zone vegetation and encouraging denitrification and other soil nutrient cycling processes.
- reduced flow velocities
- natural habitat creation

Before undertaking rehabilitation / remediation works it is important that the following information is gathered for the site:

- Catchment condition - what stage of development is the catchment currently in?
- Soil type - are there dispersive, erosive or expansive soils present?
- Flow regimes - is flow management a management objective?
- Flooding - are there existing flooding issues?

This information will assist decisions around the type, extent and staging of works to be undertaken.

For example, if the catchment is fully urbanised and the channel adjustment has already occurred, the channel just needs to be stabilised and rehabilitated. On the other hand, if the catchment is currently being developed, channel adjustment may have only just begun. This situation may require a combination of works including flow retardation (particularly for the channel forming frequent flows 1.5 -2 year ARI flows), armouring of the channel or works to increase channel capacity all of which may be staged in response to development rates.

While urbanisation has an impact on both event and base flows, some waterway ecosystems will be highly sensitive to the increased peak flows. In these areas increasing channel capacity will not be an appropriate design response and stormwater capture within the catchment will be required to mange frequent flows.

Additional information is provided in Section 4: Design, Construction and Establishment to assist users to deliver waterway design templates provided in this section.

Plate 2: Use of rock chutes to improve waterway condition - Lilac Street waterway restoration (Image: AECOM)

High Maintenance Swale System

Typical Characteristics

- Constructed drainage channel designed to convey flows equivalent to the minor drainage system within urban development
- May be located in road verges, central road medians, housing developments or parklands
- Typically used at the upstream end of constructed drainage lines
- Can be designed as a grassed swale, rock lined swale or vegetated swale depending on slope and climate

This waterway situation is created when a grassed swale is poorly designed making maintenance difficult.

Typical Issues

- Flat swales (<2% grade) often don't drain creating wet or boggy inverts which cause maintenance difficulties.
- Steep swales (>5% grade) may be prone to erosion due to high velocities.
- Grassed swales can be difficult to maintain in wet-dry summer rainfall climates (can die-off in the dry season or become over-grown in the wet season).
- Rock lined swales can be prone to weed invasion.
- A lack of shade trees encourages weed growth in channel and on batters.
- Can become weedy and unaesthetic, generating complaints from local residents.
- Falls within park maintenance responsibility but often unable to employ typical terrestrial maintenance techniques such as mowing and strip herbicide applications.
- Maintenance can be difficult if the swale has steep banks.

Design Response

- Vegetated swales (with or without trees) are the preferred swale format for summer rainfall climate. This design response enables an 'as-required' bush-land regeneration maintenance approach rather than a regular parkland maintenance approach.
- For vegetated swales care needs to be taken in the selection of roughness factors for the sizing of swale cross-sections to ensure appropriate conveyance.
- Grassed swales may best be avoided in summer rainfall climates unless the design (access and dimensions) is such that the invert can be mown with a side or arm mounted slasher.
- If the intent is to keep the swale turfed (either short term or long term), flat swales (<2% grade) need underdrainage to allow sufficient drainage to enable mowing.
- Clear maintenance boundaries need to be created between drainage and waterway corridors and adjacent parkland areas. This can be achieved with formal edging designs (vegetated edge, plinths, boards, mowing edge, etc.) and/ or a tree canopy to create a clear maintenance boundary between mown open space areas and riparian vegetation.
- The establishment of riparian cover on swale batters will also shade out weeds in channel.
- Stepped cross-sections can also be employed to create more defined maintenance boundaries. This also increases the conveyance area to compensate for increased roughness.
- Steep swales with erosion potential requires surface and batter protection (e.g. rock armouring and vegetation) and may also require the construction of grade control structures to decrease the grade of the bed to reduce flow velocities.

Key Rehabilitation / Remediation Works

Typical works required to achieve a functional and low maintenance swale may include:

- Grade control
- Battering back banks
- Bank stabilisation
- Riparian revegetation

Please refer to Section 4: Construction and Establishment for more information for each of these and for other elements which may be required due to specific site characteristics.

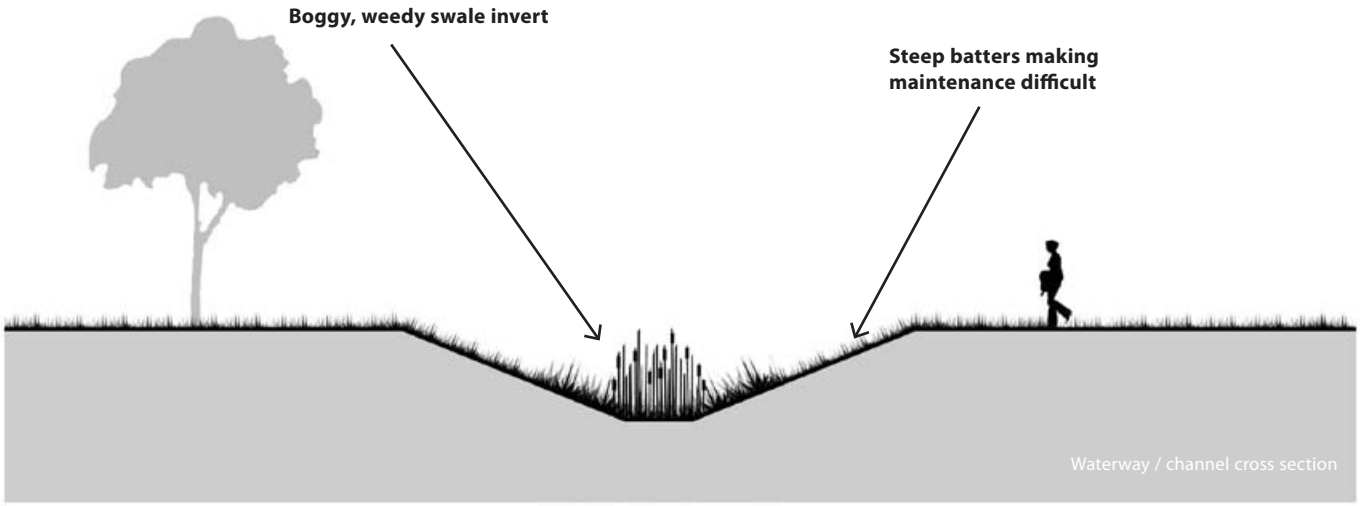
Maintenance

Maintenance requirements to ensure the successful establishment of these works could involve:

- Monitoring, watering and weeding of revegetated areas (as recommended in the ICC Riparian Corridor Revegetation Guideline)
- Regular inspection of the swale to identify areas of increased sediment deposition or scour of the swale invert or rill erosion on swale batters
- Removal, and where necessary replacement, of any bank protection material (e.g.: Jute Mat) that has been displaced

Existing Waterway Condition

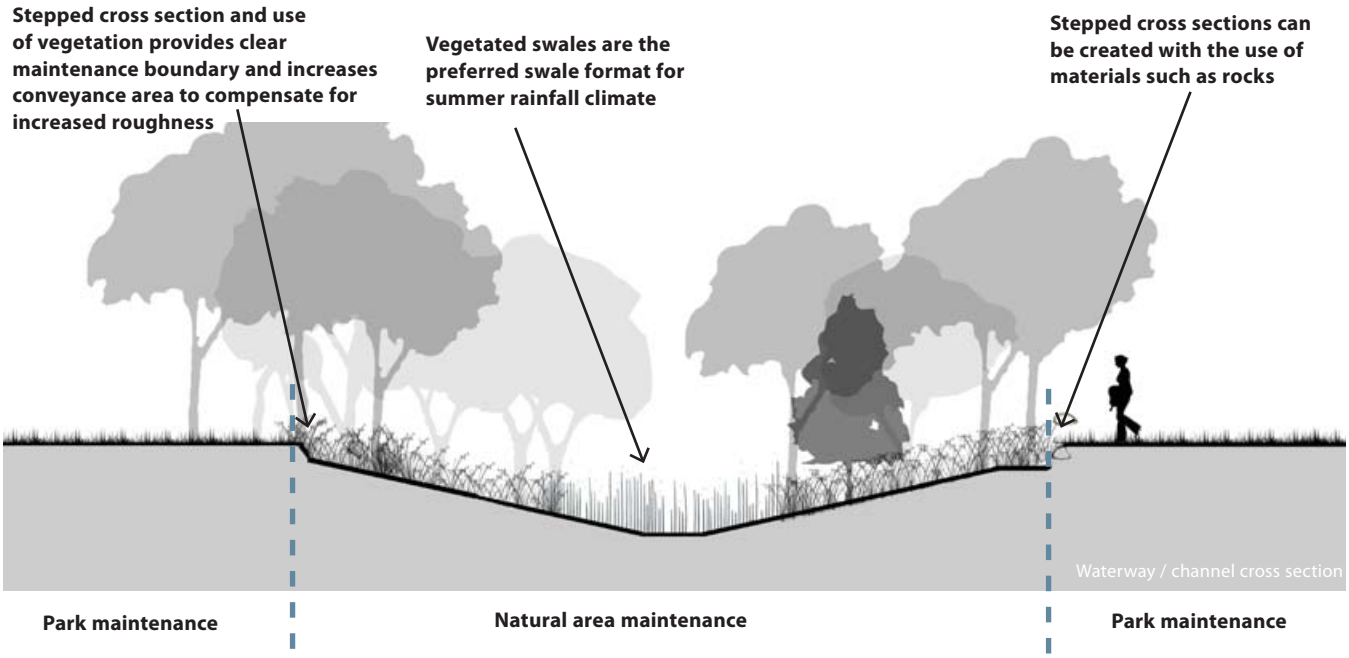
Weedy, open swale in public area; no shade cover on batters; difficult to maintain channel due to wet / boggy invert.



Park maintenance for entire area

Improved Waterway Condition

Low flow channel with vegetated batters; shade trees on batters to control weed growth; defined maintenance boundary created between the mown area / and the riparian vegetation.



Flow conveyance can be maintained by increasing the cross sectional area of the vegetated swale by battering back the banks.

Waterway Management Situations

Weedy Open Channel in Grassed Parkland

Typical Characteristics

- Small and shallow channel with regular base flows
- Flows regularly exceed the channel and move through mown open space / parkland area
- May have concrete low flow channel

Typical Issues

- Open channel often with wet or boggy invert creating maintenance difficulties.
- No shade trees allowing weed growth in channel and on batters.
- Weedy and unaesthetic, generating complaints from park users and local residents.
- Falls within park maintenance area but parkland maintenance techniques are unsuitable for drainage systems and waterways.
- Over bank flows engaging parkland.
- Bed and bank erosion.
- Creation of wheel ruts from slashers, particularly when slashing during wet or boggy conditions, provides areas for mosquito breeding, and compaction of soils.
- Differential resistance to flow across flow paths can result in erosion at the interface between resistant/rough surfaces and treatments and smoother and less resistant surfaces and treatments (examples include low flow concrete channel and the riparian vegetation and between the riparian vegetation and grassed parkland).

This waterway situation is created by a lack of defined interface between the parkland and channel. This results in a lack of management boundary.

Design Response

- If over-bank flows in the parkland, the flow paths should be considered, this includes: increasing drainage line capacity by inclusion of a broader riparian zone with a floodplain function, provision of additional or alternative overland flow paths, re-design/relocate park features and facilities to tolerate occasional flooding.
- Creation of a distinct riparian zone maintained using low frequency bushland techniques.
- Creation of riparian cover to shade out weeds in channel.
- Plant out a designated area with riparian vegetation (such as 1 year flood extent) to create a clear maintenance boundary between parks and natural areas.
- Where bed or bank erosion is evident it may be necessary to re-design the channel and re-enforce the bed and banks with appropriately sized rock stabilised with vegetation.
- Erosion at the interface of treatment surfaces across the flow path requires some interface treatment that recognises the stability and roughness differences. For example where concrete channel meets riparian zone vegetation a segment of vegetated structural soil intervenes to help stabilise the transition vegetation. Similarly where riparian zone vegetation meets parkland grass, the cut on parkland grass adjacent to the riparian zone needs to be longer and rougher to resist the potential increased velocities during infrequent events.
- Surface protection due to design velocity or redesign to reduce velocities.

Key Rehabilitation / Remediation Works

Typical works required to achieve an aesthetic and functional open channel in a grassed parkland may include:

- Battering back banks
- Bank stabilisation
- Riparian revegetation

Please refer to Section 4: Construction and Establishment for more information for each of these and for other elements which may be required due to specific site characteristics.

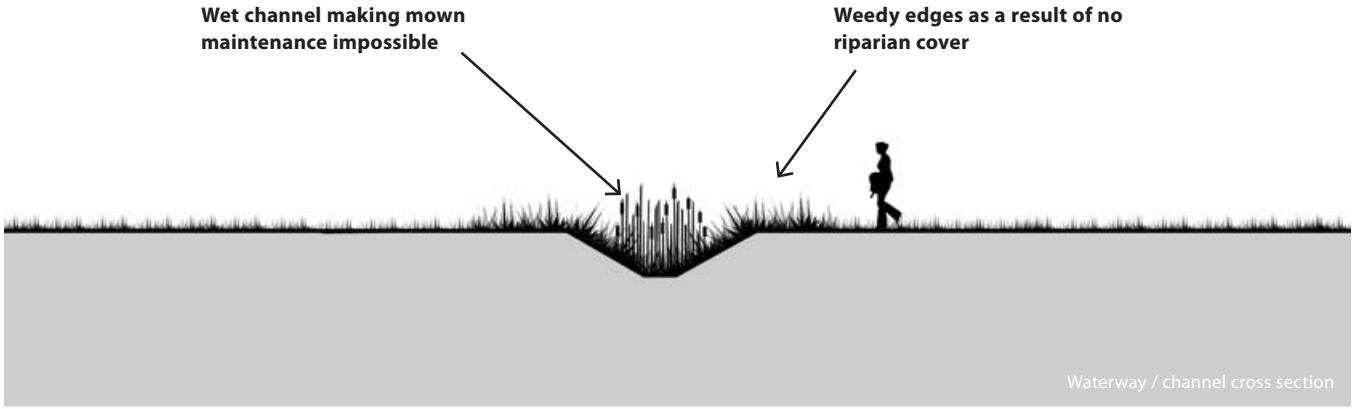
Maintenance

Maintenance requirements to ensure the successful establishment of these works could involve:

- Monitoring, watering and weeding of revegetated areas (as recommended in the ICC Riparian Corridor Revegetation Guideline)
- Inspection of channel banks to identify any erosion / scour zones
- Removal, and where necessary replacement, of any bank protection material (e.g.: Jute Mat) that has been displaced

Existing Waterway Condition

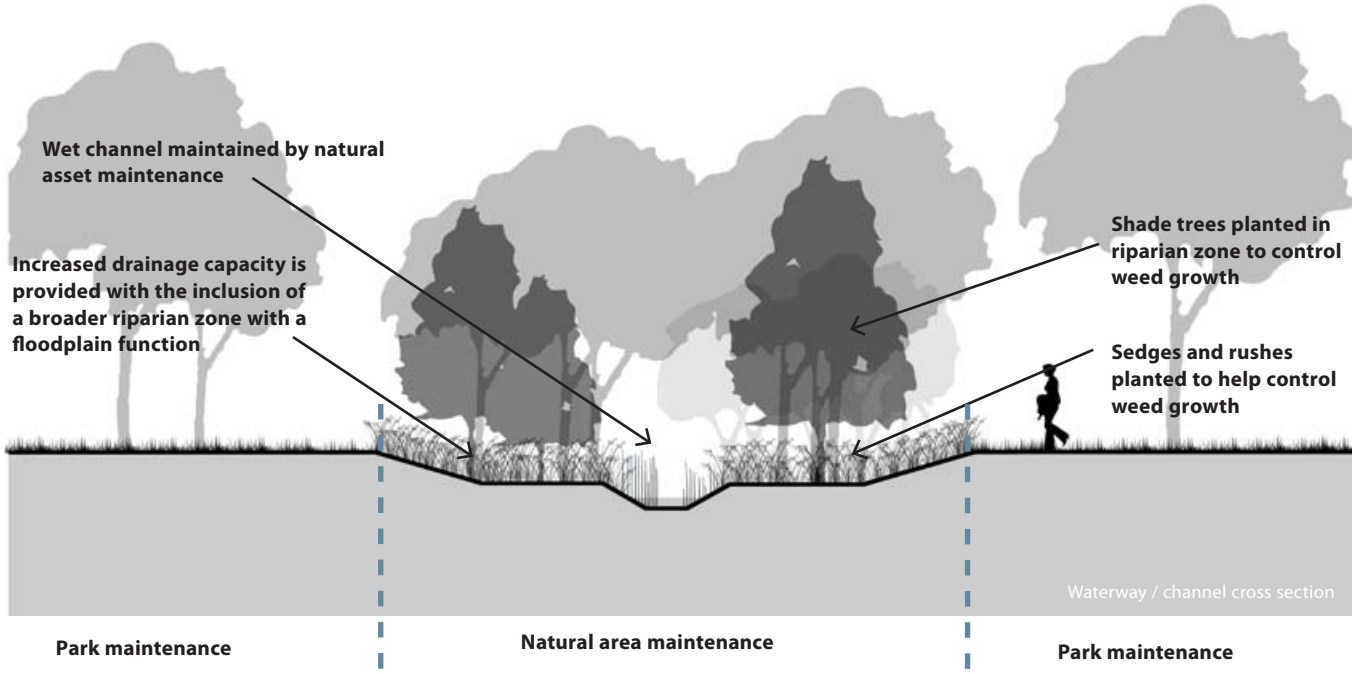
Weedy, open channel within grassed parkland area; no riparian cover; difficult to maintain waterway as part of parkland.



Park maintenance for entire area

Improved Waterway Condition

Low flow channel with vegetated riparian zone floodplain area within grassed parkland area; riparian shade trees control weed growth; defined maintenance boundary created between the mown park and the natural asset.



Flooding risk is reduced by increasing the cross sectional area of the channel by battering back banks to create a defined riparian floodplain area. This allows trees to be planted in this area without increasing flooding.

Natural Channel with Headcut Erosion - upper urban catchment

Typical Characteristics

- Natural waterway with deepening channel
- May have steep banks
- May be in a developing urban area

Typical Issues

- Deepening channel caused by an advancing erosion head in the upstream direction. This can cause steep, unstable banks.
- The leading edge of the headcut erosion can take the form of a small waterfall or steep section in the creek bed.
- The cause of the erosion may be due to a number of factors including development of the surrounding catchment or direct human modifications to the waterway caused by the creation of road culverts etc.
- Soil vulnerability in frequent flow events.
- Upstream control / mitigation of flows.
- Undercutting and destabilisation of banks (unstable toe of bank).

This waterway situation is due to an erosion head deepening the waterway channel in an upstream direction.

Design Response

- Construction of grade control structures to prevent bed deepening from progressing further upstream and establishment of a more stable channel slope within the reach where headcuts have already passed through by slowing flows and allowing material to drop out into the channel, reducing the potential for bed deepening.
- Bank stabilisation may also be required if banks are very steep and unstable. In most situations where bed erosion has been active, bank stabilisation works such as laying back the batters and rock armouring will be required to achieve a stable environment.
- Riparian revegetation will be required in association with any bank stabilisation work. Riparian revegetation needs to be carefully matched to bank stabilisation works. Vegetation palettes need to be adjusted for the use of rock or geotextile materials as the bank stabilisation approach.
- As for simple open channels, the interface of conditions and treatments across the flow-path is important in the stability of natural waterway channels. The boundary conditions around any rock stabilisation structure needs to be carefully designed and vegetated to ensure stability.

Key Rehabilitation / Remediation Works

Typical works required to achieve a stable waterway may include:

- Grade control
- Bank stabilisation
- Riparian revegetation

Please refer to Section 4: Construction and Establishment for more information for each of these and for other elements which may be required due to specific site characteristics.

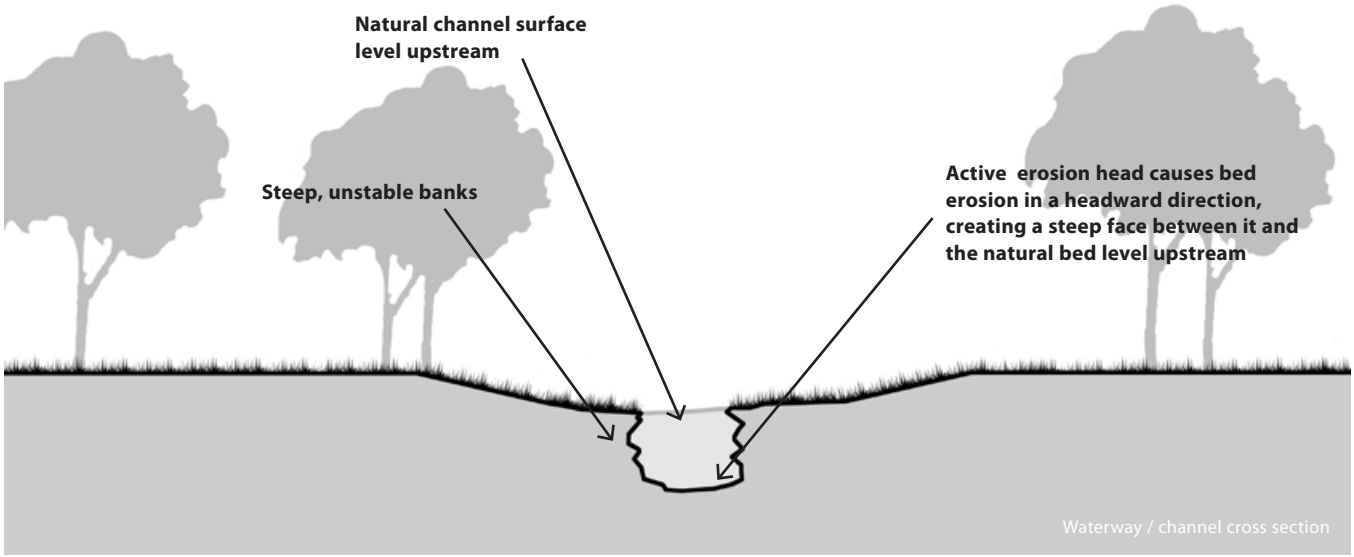
Maintenance

Maintenance requirements to ensure the successful establishment of these works will involve:

- Monitoring, watering and weeding of revegetated areas (as recommended in the ICC Riparian Corridor Revegetation Guideline)
- Inspection of channel banks to identify any erosion / scour zones
- Inspection of chutes to check for dislodgement of rock protection or the presence of weeds
- Removal, and where necessary replacement, of any bank protection material (e.g.: Jute Mat) that has been displaced

Existing Waterway Condition

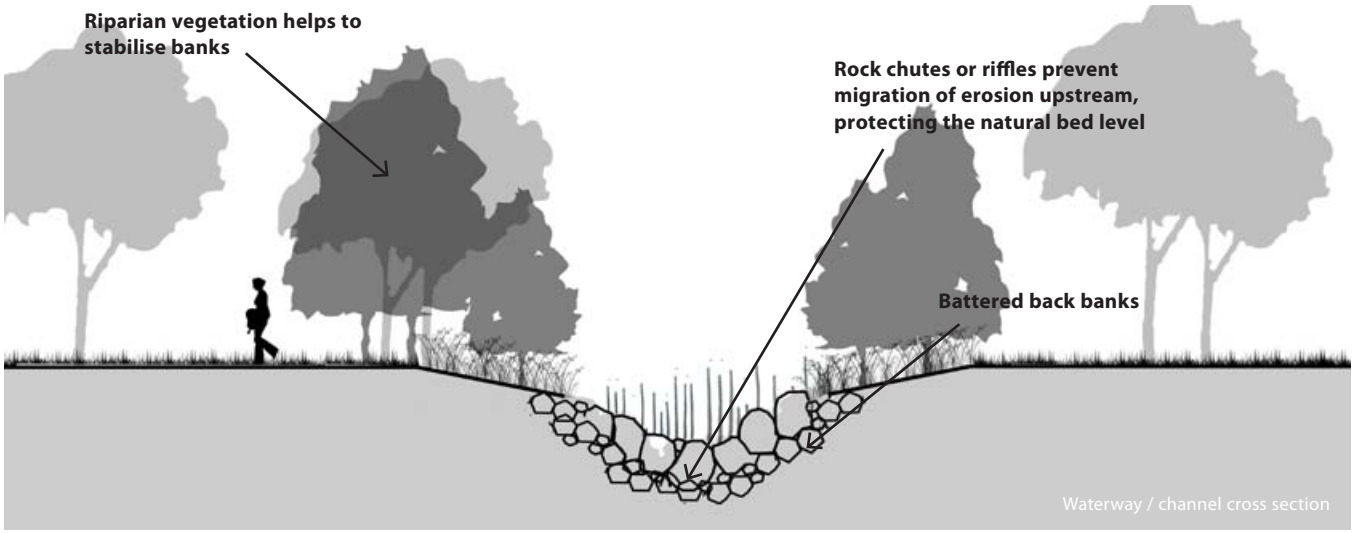
Deepening channel caused by erosion head moving upstream leaving steep, unstable banks.



*Refer to 'Natural Channel with Headcut Erosion - upper rural catchment' for long section view of rock chutes

Improved Waterway Condition

Grade control structures preventing progression of erosion moving further upstream as well as increasing bed level and stabilising banks downstream.



*Refer to 'Natural Channel with Headcut Erosion - upper rural catchment' for long section view of rock chutes

Grade control structures are designed to slow velocities in the waterway which could result in localised flooding. The cross section of the waterway could be increased by battering back banks to reduce this risk.

Natural Channel with Headcut Erosion - upper rural catchment

Typical Characteristics

- Natural waterway with deepening channel
- May have steep banks
- Located in a rural catchment

Typical Issues

- Deepening channel caused by an advancing erosion head in the upstream direction. This can cause steep, unstable banks.
- The leading edge of the headcut erosion can take the form of a small waterfall or steep section in the creek bed.
- The cause of the erosion may be due to a number of factors including clearing of the catchment, loss of riparian vegetation, stock access, or installation of road culverts.

Design Response

- Construction of grade control structures to prevent bed deepening from progressing further upstream and to establish a more stable channel slope within the reach where head-cuts have already passed through by slowing flows and allowing bed material to deposit in the channel, reducing the potential for further bed deepening.
- Bank stabilisation may also be required if banks are very steep and unstable. In most situations where bed erosion has been active, bank stabilisation works such as laying back the batters and rock armouring will be required to achieve a stable environment for bank revegetation.
- Riparian revegetation will be required in association with any bank stabilisation work. Riparian revegetation needs to be carefully matched to bank stabilisation works. Vegetation palettes need to be adjusted depending on the use of rock or geotextile materials as the bank stabilisation approach.
- Depending on the size of the channel and severity of the bank erosion, once the bed has been stabilised, an alternative bank stabilisation approach may be to fence the waterway and re-vegetate the banks without any significant bank works. This approach can be suitable where: the channel is small and bank damage is limited, remnant riparian vegetation exists and can be enhanced and built-on, there is no immediate down-stream waterway that needs immediate protection.
- As for simple open channels, the interface of conditions and treatments across the flow-path is important in the stability of natural waterway channels. The boundary conditions around any rock stabilisation structure needs to be carefully designed and vegetated to ensure stability.

This waterway situation is due to an erosion head deepening the waterway channel in an upstream direction.

Key Rehabilitation / Remediation Works

Typical works required to achieve a stable waterway may include:

- Grade control
- Bank stabilisation
- Riparian revegetation

Please refer to Section 4: Construction and Establishment for more information for each of these and for other elements which may be required due to specific site characteristics.

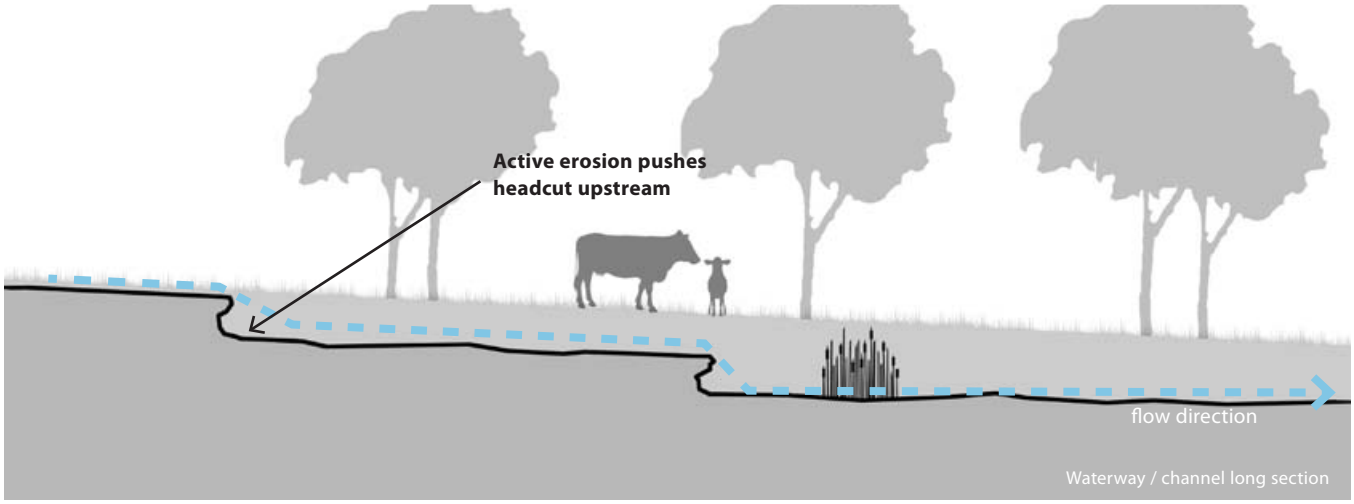
Maintenance

Maintenance requirements to ensure the successful establishment of these works will involve:

- Monitoring, watering and weeding of revegetated areas (as recommended in the ICC Riparian Corridor Revegetation Guideline)
- Inspection of channel banks to identify any erosion / scour zones
- Inspection of chutes to check for dislodgement of rock protection or the presence of weeds
- Removal, and where necessary replacement, of any bank protection material (e.g.: Jute Mat) that has been displaced

Existing Waterway Condition

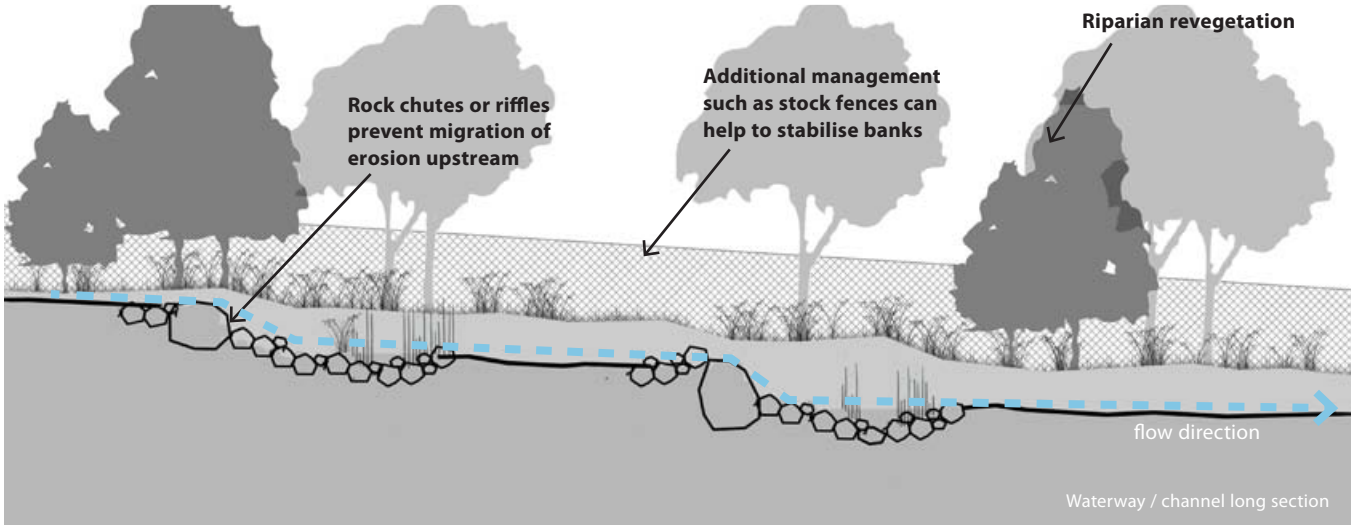
Deepening channel caused by erosion head moving upstream leaving steep, unstable banks.



*Refer to 'Natural Channel with Headcut Erosion - upper urban catchment' for cross section view of rock chutes

Improved Waterway Condition

Grade control structures preventing progression of erosion moving further upstream as well as increasing bed level and stabilising banks downstream.



*Refer to 'Natural Channel with Headcut Erosion - upper urban catchment' for cross section view of rock chutes

Grade control structures are designed to slow velocities in the waterway which could result in localised flooding. The cross section of the waterway could be increased by battering back banks to reduce this risk.

Piped Flows Entering Natural Channel

Typical Characteristics

- Pipe outfall may be discharging directly into waterway
- Pipe outfall may also be discharging to waterway via a swale system, typically in a linear mown parkland area.

Typical Issues

- Piped outfalls to waterways can result in localised erosion to both bed and banks.
- Piped outfalls to waterways can also result in the deposition of gravel and sediment.
- Where piped outfalls occur at the start of a natural channel erosion impacts may dissipate with distance downstream where depositional impacts will become evident.
- Where piped outfalls enter a waterway laterally, high velocity inflows may result in both local bed and bank impacts and also initiation of head-ward erosion which could propagate up-stream. Depositional impacts may also become evident down-stream.
- Where piped flows enter the waterway from the top of steep banks, high velocity flows may result in significant localised bank and bed erosion. This vertical drop may be due to bed erosion within the channel.
- Swale systems conveying piped flows are often rock lined, which can become weedy once sediments settle out in the swale system generating complaints from park users and local residents.

This waterway situation is created by high velocity piped catchment flows entering the waterway, causing localised erosion.

Design Response

- Creation of flow dissipater device between piped flows and waterway. This may be a sediment pond or rock transitional area.
- The retrofit of a sediment basin will help to capture sediments as well as the detain and slow flows before they enter the channel.
- The rock transitional area should be designed to spread flows and to control any grade changes between the pipe and the channel. This structure could be a riffle system or a rock chute depending on the grade change.
- Where piped flows enter the waterway from the top of a steep bank, a rock chute may be required to address the bank erosion. An alternative solution is to construct a pit and discharge the flows into the base of the waterway. For either of these designs to be successful, the cause of the vertical drop needs to be addresses (e.g. address headcut erosion).
- Where piped discharges are conveyed to the waterway by a swale system, the swale should be protected from high flows and sediment loads by either a pond or a rock transitional/deposition zone, vegetated with riparian species, including trees, to inhibit weed invasion.

Key Rehabilitation / Remediation Works

Typical works required to achieve a stable waterway may include:

- Grade control / riffle systems
- Bank stabilisation

Please refer to Section 4: Construction and Establishment for more information for each of these and for other elements which may be required due to specific site characteristics.

To find more information about the design of a sediment basin, please refer to the SEQ WSUD Technical Design Guidelines (HWP 2006).

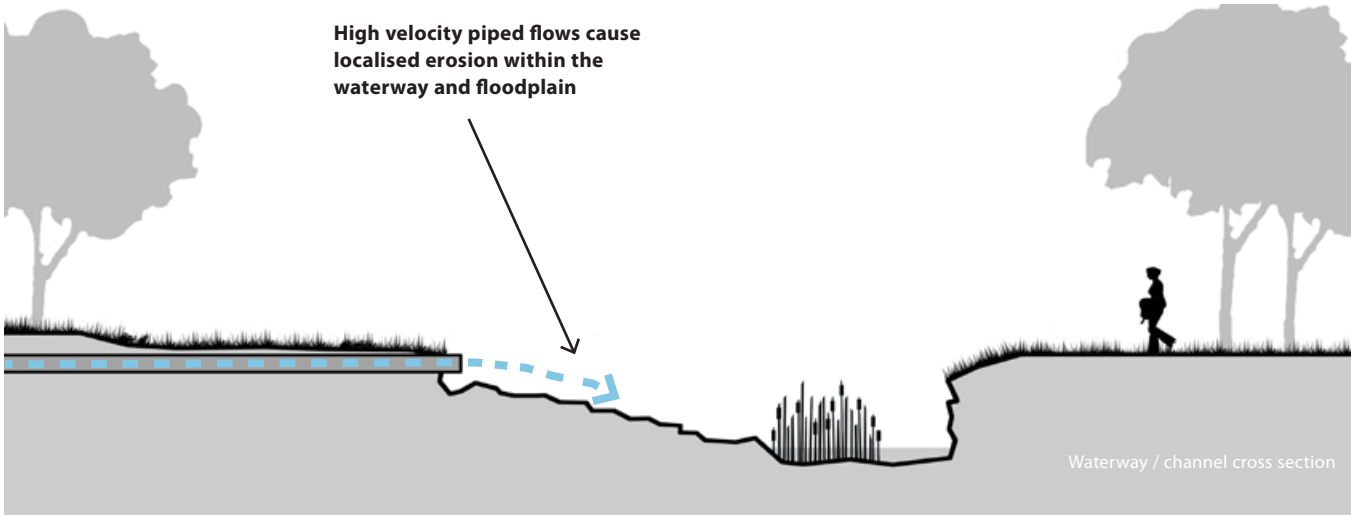
Maintenance

Maintenance requirements to ensure the successful establishment of these works will involve:

- Monitoring, watering and weeding of revegetated areas (as recommended in the ICC Riparian Corridor Revegetation Guideline)
- Inspection of channel banks to identify any erosion / scour zones
- Inspection for dislodgement of rock protection or the presence of weeds or accumulated sediment

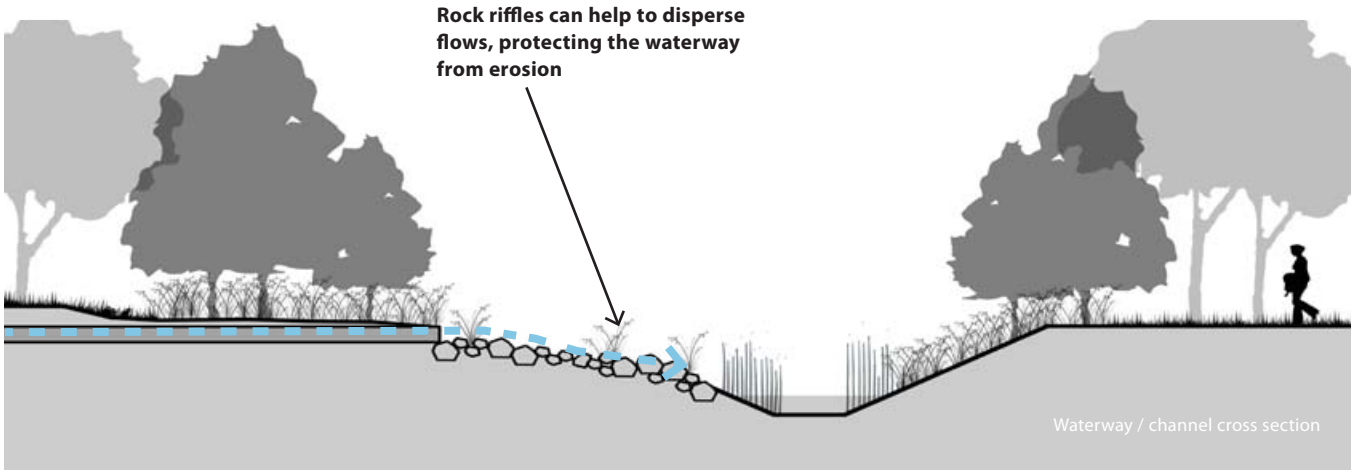
Existing Waterway Condition - Example #1

Erosion present at pipe outlets due to high velocity flows entering the waterway



Improved Waterway Condition - Example #1

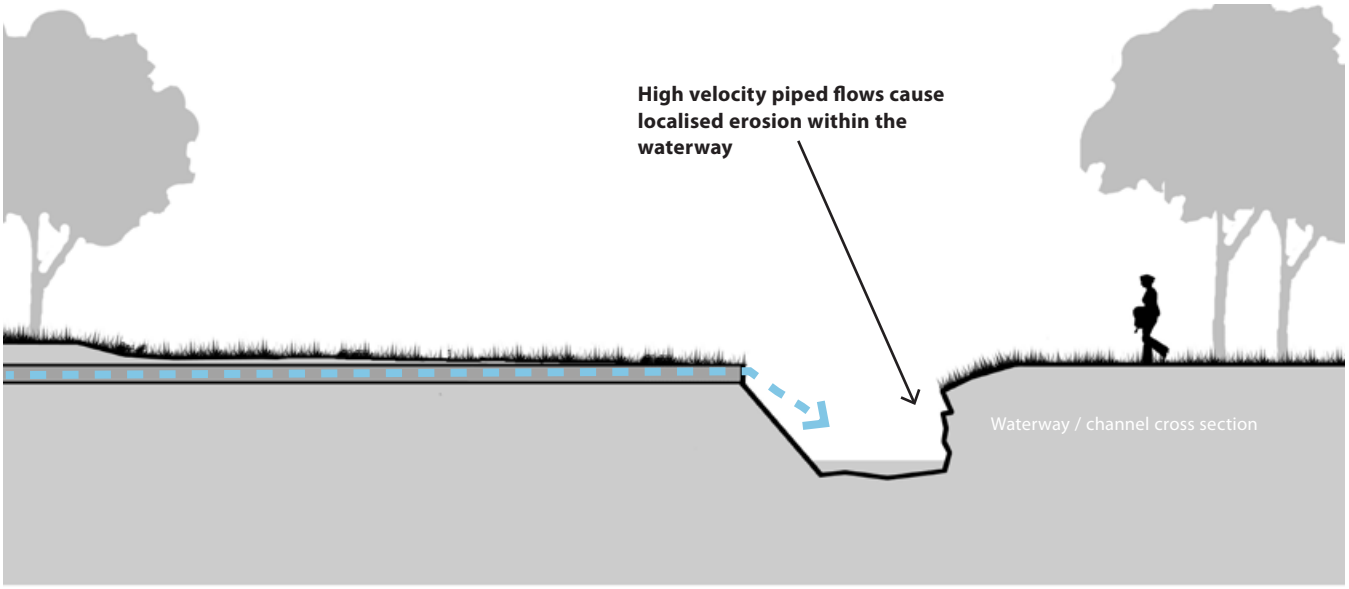
Piped flows are dispersed, reducing velocities and the receiving environment is protected from scour.



Slowing the velocity of water at the pipe outfall could increase risk of localised flooding. The flow dissipater device or sediment pond should be sized to ensure that flooding risk is reduced.

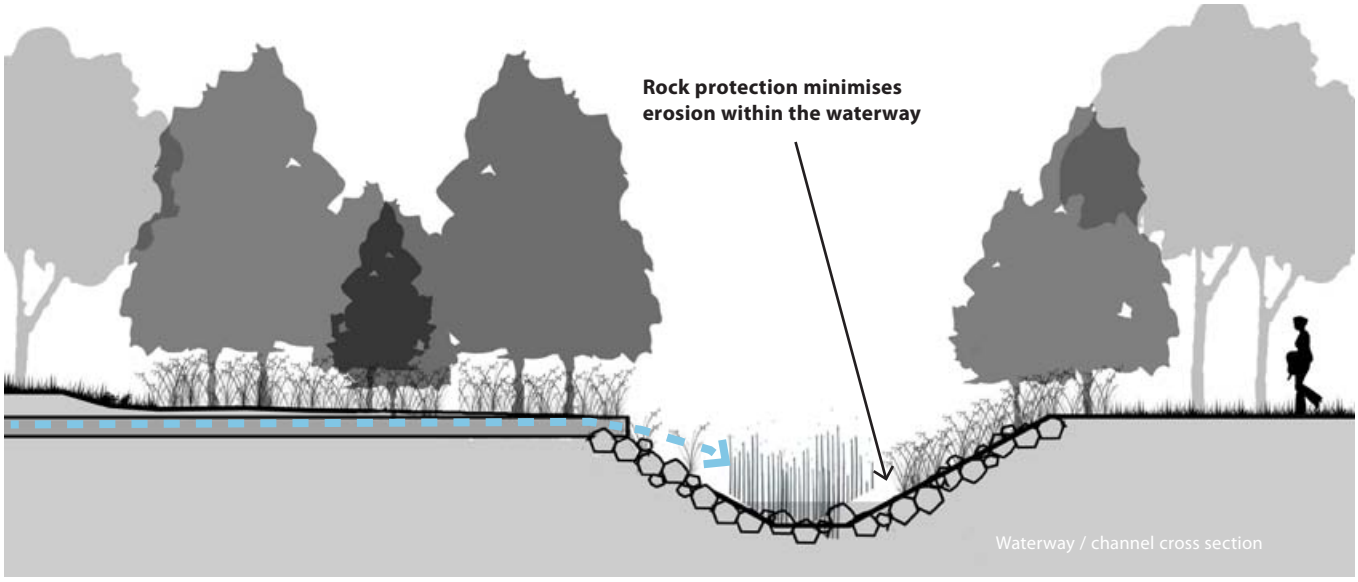
Existing Waterway Condition - Example #2

Erosion present at pipe outlets due to high velocity flows entering the waterway



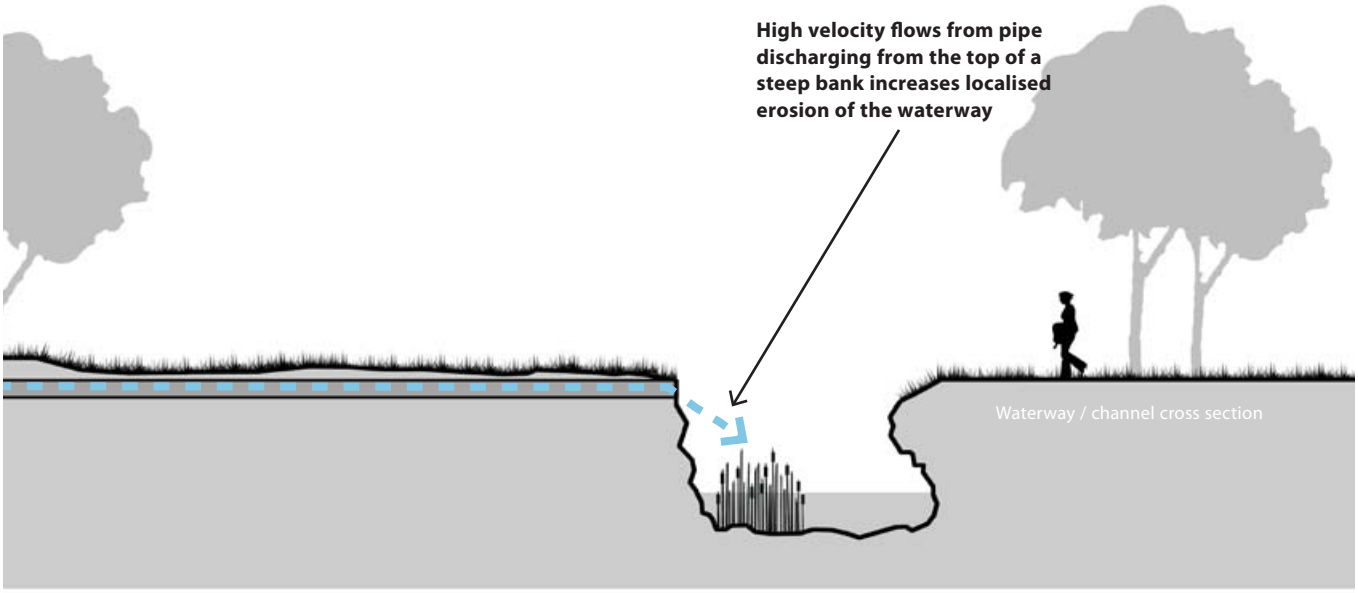
Improved Waterway Condition - Example #2

Receiving environment is protected from scour.



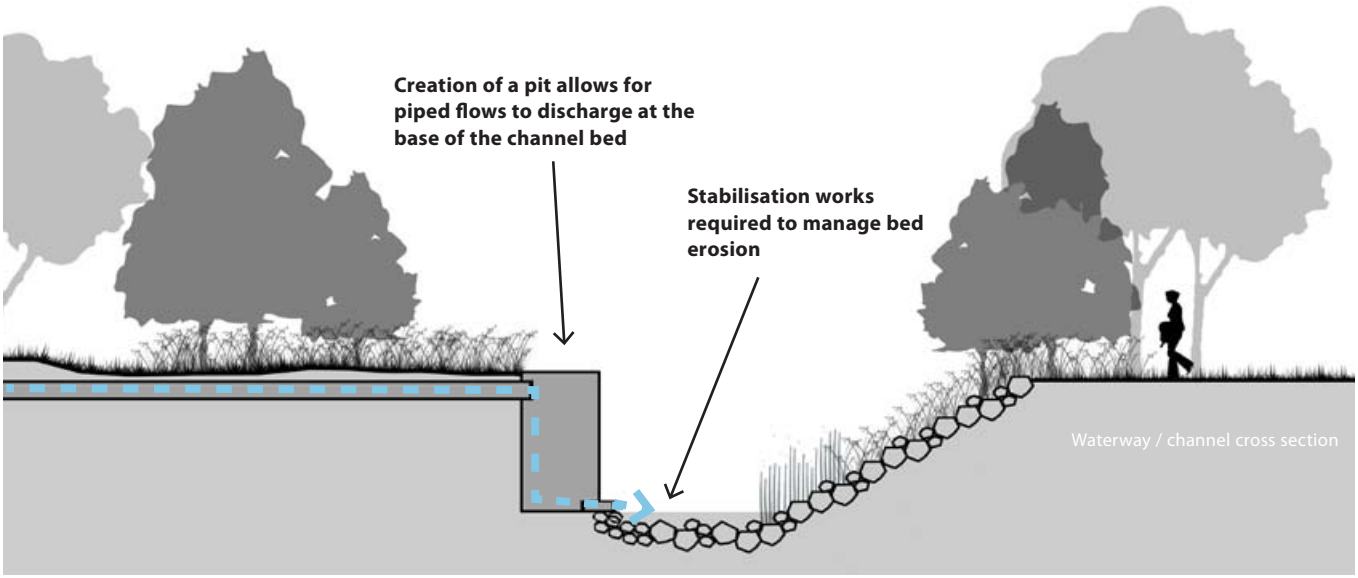
Existing Waterway Condition - Example #3

Erosion present at elevated pipe outlets due to high velocity flows entering the waterway



Improved Waterway Condition - Example #3

Piped flows are delivered from the base of the bank into a stable receiving environment



Channelised Overland Flow Entering Natural Channel - rural catchment

Typical Characteristics

- Natural channel with vegetated riparian zone
- Typically located in a rural catchment with cropping or grazing landuse
- Build-up of sediment on the outer boundary of the riparian zone due to deposition of sediments from sheet and rill erosion of rural paddocks / catchments with limited groundcover

Typical Issues

- Regularly disturbed soil surface in the contributing rural catchment.
- Overland flows paths from the rural catchment slow when they meet the vegetated riparian zone, causing sediments to drop out along its edge.
- This build up of sediment causes flows to be directed parallel to the waterway, bypassing the riparian zone.
- These channelised flows have increased velocity, causing erosion along the flowpath created on the edge of the riparian zone and also on the banks when the flows eventually enter the waterway.

This waterway situation is created by sediment dropping out of overland flows when they meet the vegetated riparian zone

Design Response

- Encourage protection/revegetation of on-farm overland flow paths.
- Create a linear sediment trap in the form of a series of discontinuous shallow swales to trap sediments and distribute flows.
- Stabilise depressions and banks where overland flows have been channelised and caused erosion.
- Revegetation of the banks will be required as part of bank stabilisation works.

Key Rehabilitation / Remediation Works

Typical works required to achieve a functional and low maintenance swale may include:

- Bank stabilisation
- Riparian revegetation

Please refer to Section 4: Construction and Establishment for more information for each of these and for other elements which may be required due to specific site characteristics.

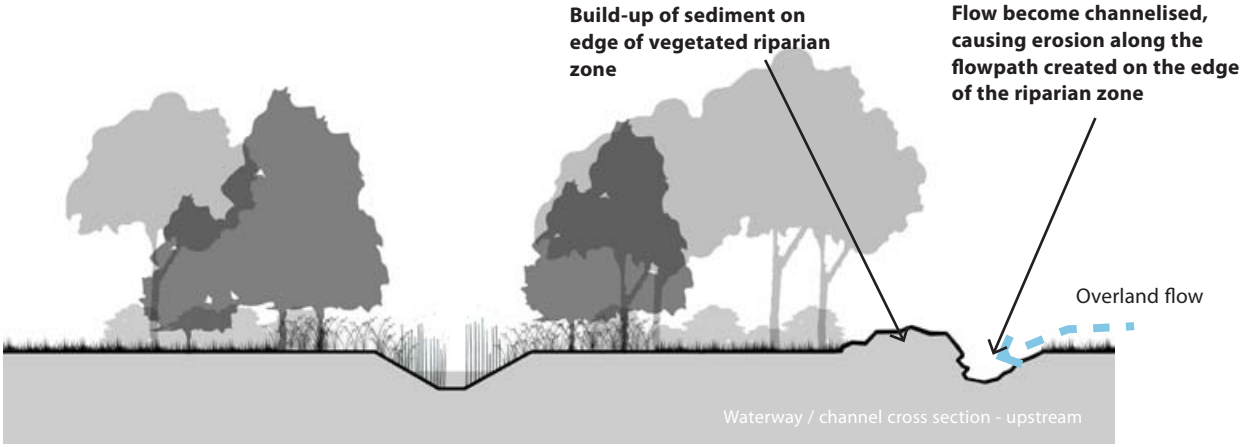
Maintenance

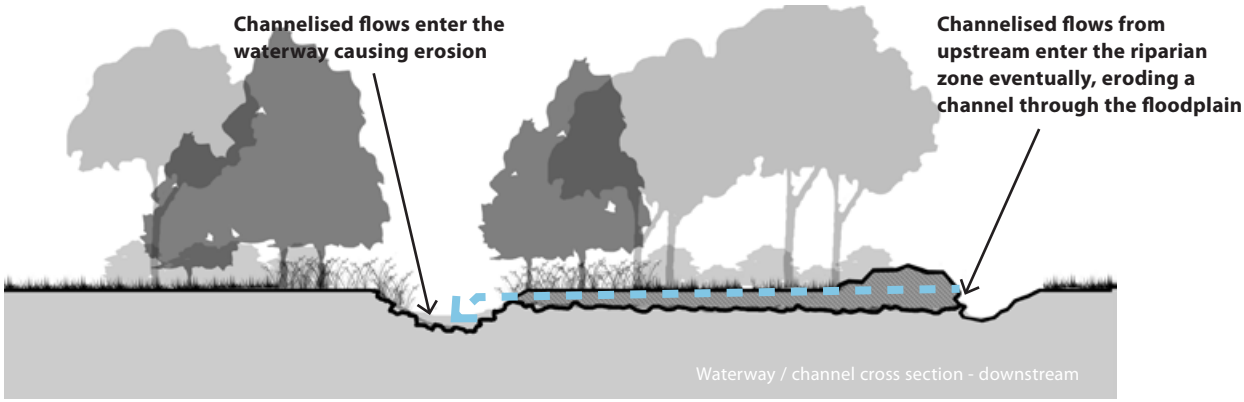
Typical works required to achieve a stable waterway may include:

- Monitoring, watering and weeding of revegetated areas (as recommended in the ICC Riparian Corridor Revegetation Guideline)
- Regular inspection of the shallow swales to identify areas of increased sediment deposition or scour of the swale invert or rill erosion on swale batters

Existing Waterway Condition - Cross Section Examples

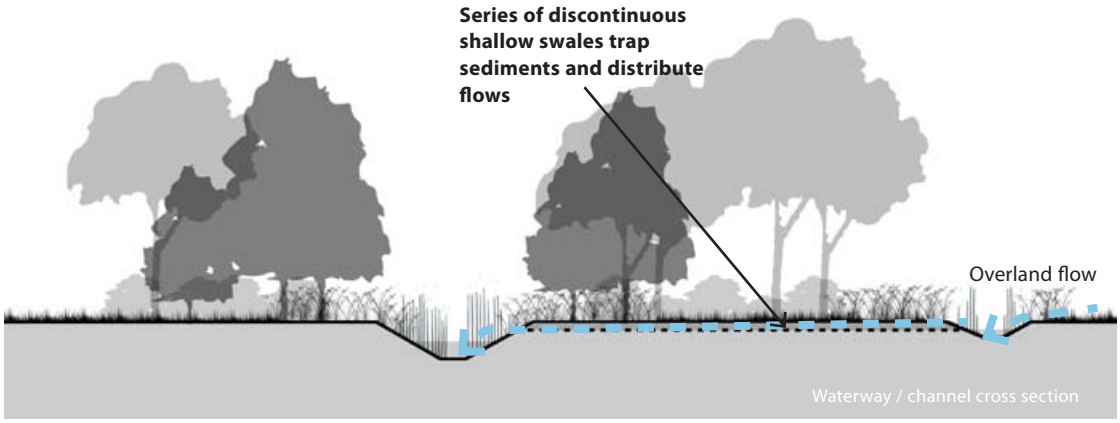
Natural channel with vegetated riparian zone, overland flow from disturbed catchments drop out sediment when they meet the riparian edge which causes flows to channelise and bypass the vegetation.





Improved Waterway Condition

Linear sediment traps (in the form of a series of discontinuous shallow swales) trap sediments and distribute flows through the riparian zone.

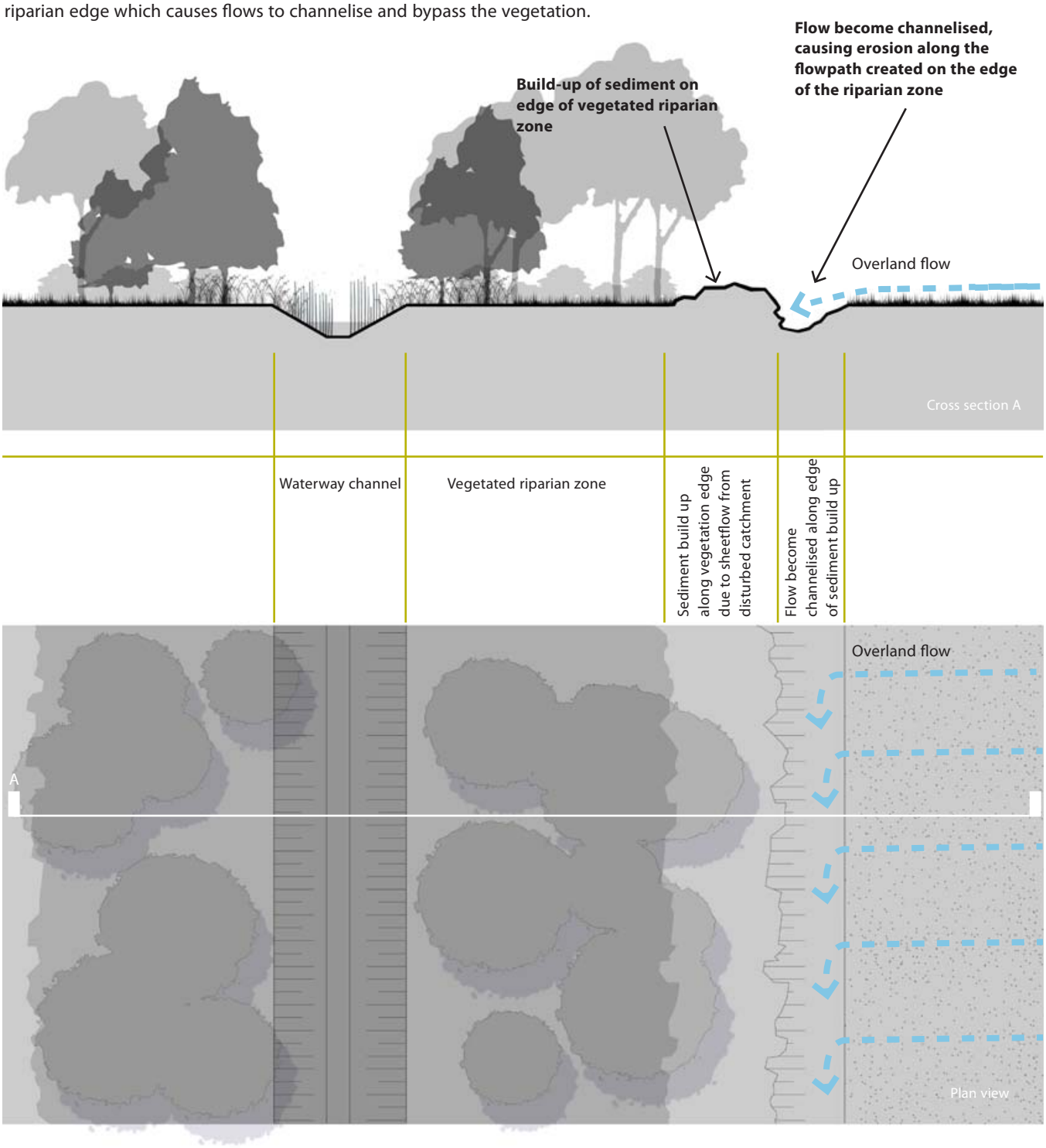


These conditions are shown in more detail on the following pages

Creation of the swale systems does not impact on flooding, allowing flows to evenly distribute through the riparian zone.

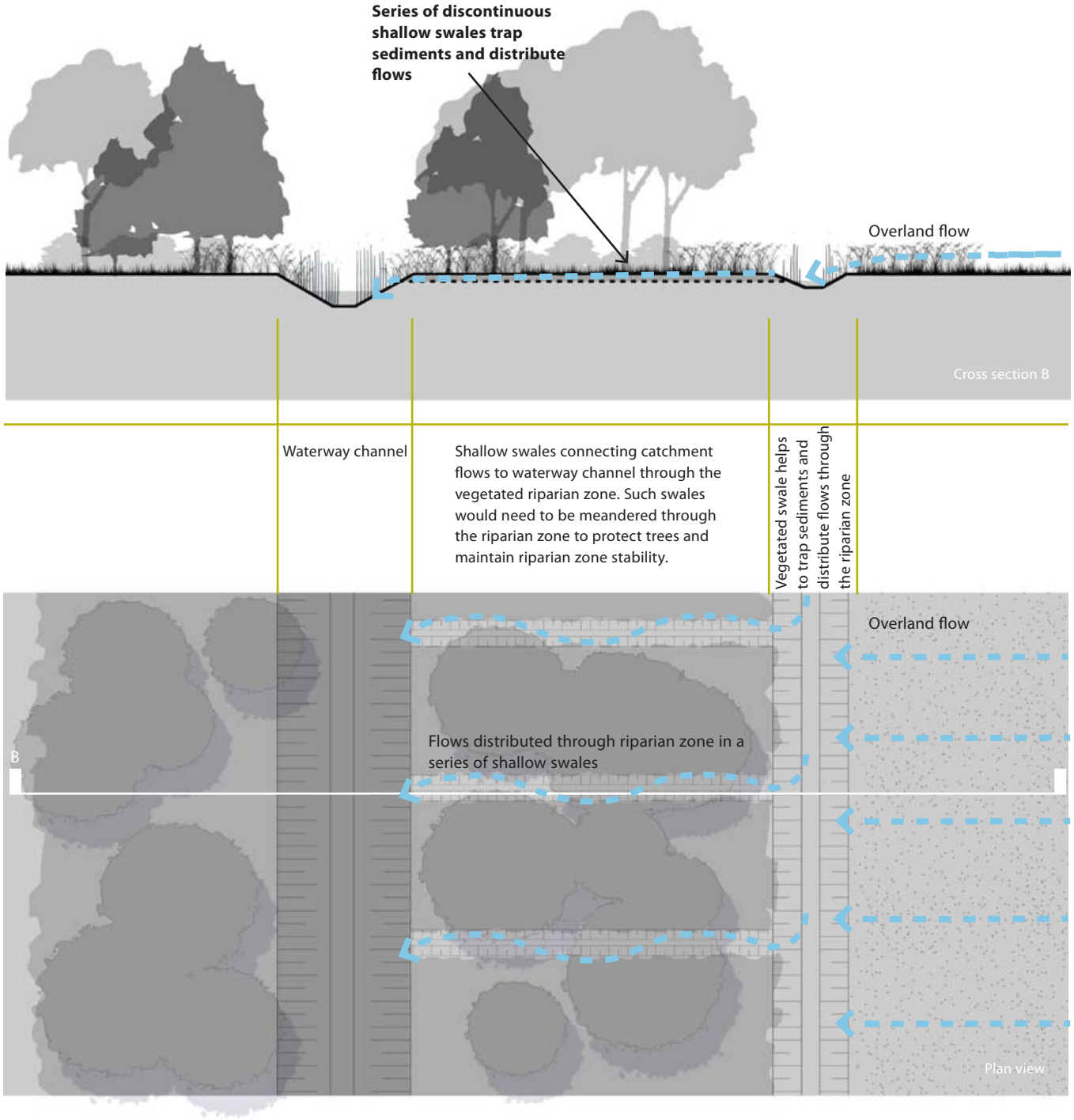
Existing Waterway Condition - Plan and Cross Section

Natural channel with vegetated riparian zone, overland flow from disturbed catchments drop out sediment when they meet the riparian edge which causes flows to channelise and bypass the vegetation.



Improved Waterway Condition - Plan and Cross Section

Linear sediment traps (in the form of a series of discontinuous shallow swales) trap sediments and distribute flows through the riparian zone.



Natural Channel in Developing Catchment

Typical Characteristics

- Natural channel with upstream developing catchment
- Significant areas of remnant riparian vegetation
- The natural condition of the channel may be an ephemeral system which during the dry, only has permanent water in pools

Typical Issues

- Rapidly increasing flows because of catchment development.
- Steep eroded banks, particularly on outside bends.
- Widened channel caused by increased flows.
- Sand slugs in channel due to channel adjustment and upstream erosion.
- Past catchment development, when not addressed adequately at the time, has the risk of creating on-going issues for waterways and adjacent properties.

This waterway situation is created by an increase in catchment flows entering natural waterways.

Design Response

- Stabilise steep banks on outer side on meanders.
- Lay-back the inner banks of the meanders to increase channel capacity to better cope with increased catchment flows.
- Create strategically placed deposition zones to enable easy removal of sand slugs (this activity will only be required for the period of channel adjustment).
- Ensure there is significant riparian cover to shade out weeds in channel, stabilise banks and to create a clear maintenance boundary between mown parks and natural areas.

Key Rehabilitation / Remediation Works

Typical works required to achieve a stable waterway may include:

- Bank stabilisation
- Battering back banks
- Riparian revegetation

Please refer to Section 4: Construction and Establishment for more information for each of these and for other elements which may be required due to specific site characteristics.

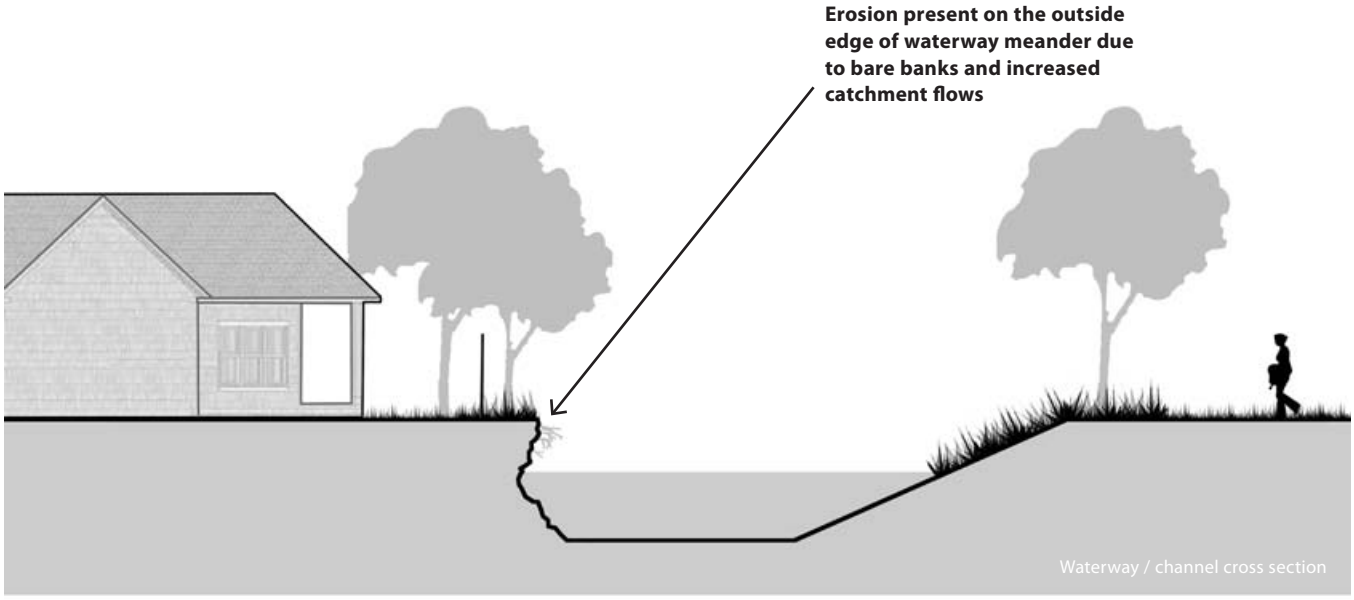
Maintenance

Maintenance requirements to ensure the successful establishment of these works will involve:

- Monitoring, watering and weeding of revegetated areas (as recommended in the ICC Riparian Corridor Revegetation Guideline)
- Inspection for dislodgement of rock protection or the presence of weeds
- Inspection of channel banks to identify any erosion / scour zones

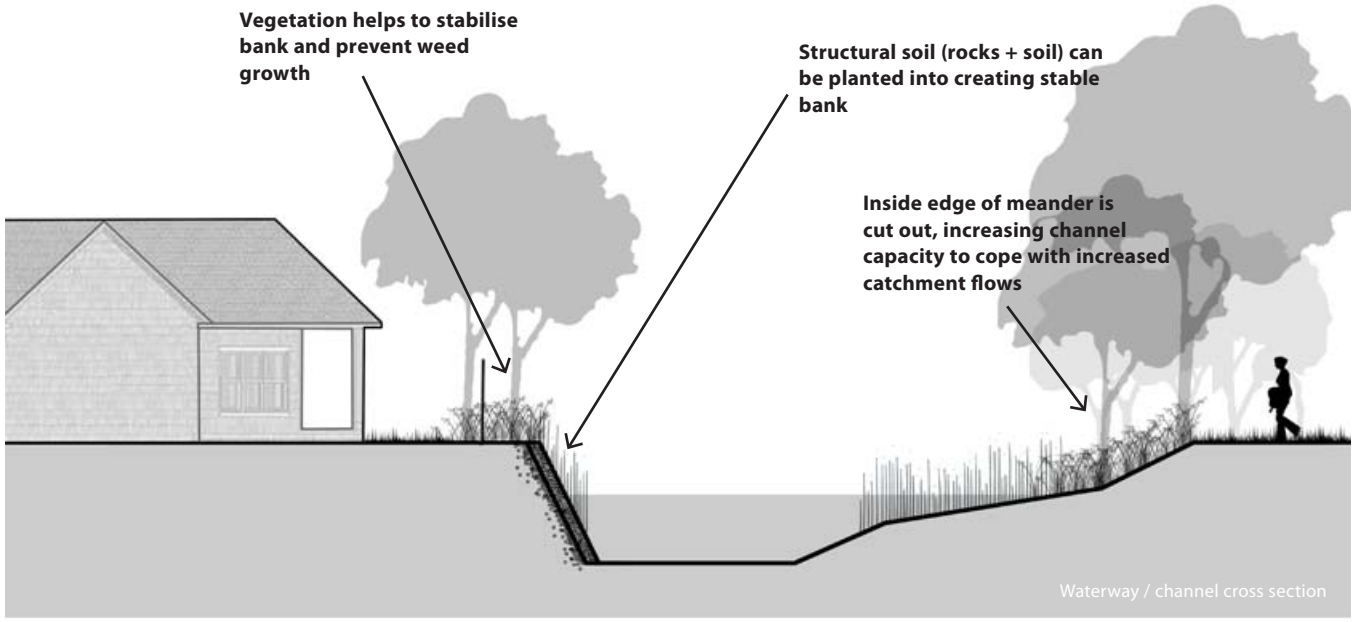
Existing Waterway Condition

Widened channel with eroded banks due to increased catchment flows



Improved Waterway Condition

Wide channel with stabilised banks.



Flooding risk is reduced by increasing the cross sectional area of the channel by battering back banks on the inside of the channel meanders. This allows trees to be planted in this area without increasing flooding.

Channel Bank Erosion at Culvert Headwalls due to Overland Flow

Typical Characteristics

- Natural channel with piped upstream urban catchment
- Stormwater pipes discharge directly into waterway, typically within urban parkland areas
- Overland flow pathway follows piped drainage network

Typical Issues

- When the stormwater pipe networks are exceeded, overland flows enter the waterway at the same location as the stormwater pipes.
- Overland flows can cause erosion around the stormwater infrastructure, exposing pipes and compromising headwall stability.

This waterway situation is created by overland flows entering waterway in the same location as the piped stormwater network

Design Response

- Rock placement is required around the pipe and the headwall to stabilise this infrastructure.
- The headwall can be redesigned to act as a weir, spreading overland flows prior to entering the waterway.
- The design of overland flow discharge points needs to be considered as a part of the minor drainage system design. This may require the rock on either side of the headwall to be filled with some concrete.

Key Rehabilitation / Remediation Works

Typical works required to achieve a stable waterway may include:

- Bank stabilisation / reinforcement
- Riparian revegetation

Please refer to Section 4: Construction and Establishment for more information for each of these and for other elements which may be required due to specific site characteristics.

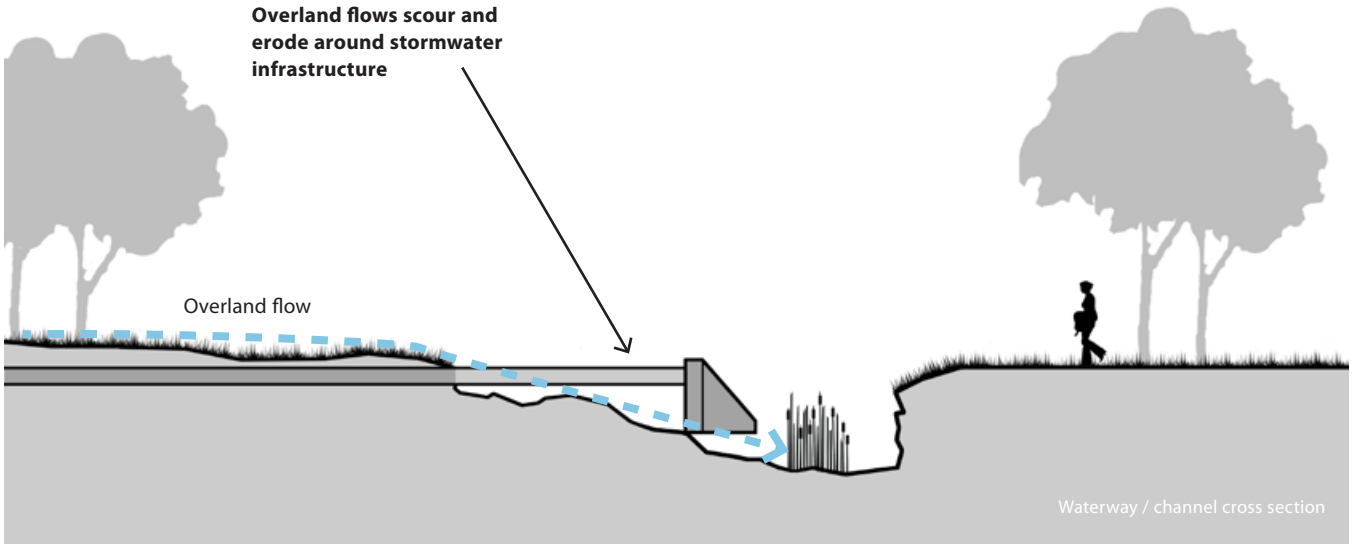
Maintenance

Maintenance requirements to ensure the successful establishment of these works will involve:

- Monitoring, watering and weeding of revegetated areas (as recommended in the ICC Riparian Corridor Revegetation Guideline)
- Inspection of reinforcement works for stability of structures or the presence of weeds

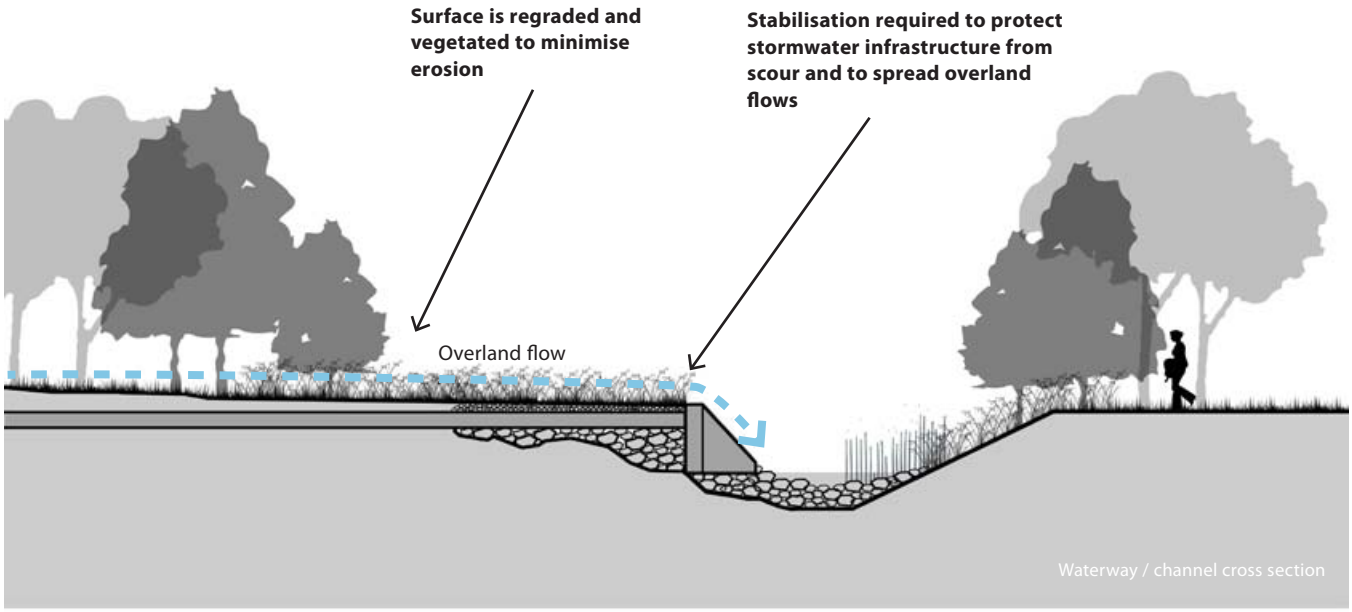
Existing Waterway Condition

Overland flow causing erosion and exposure of stormwater infrastructure



Improved Waterway Condition

Stabilised banks and stormwater infrastructure



Flooding should not be impacted as long as the overland flow paths are not significantly altered as part of the design response

Channel Bank Erosion due to Overland Sheet fbw - Parkland Area

Typical Characteristics

- Channel with an adjacent parkland area
- Pathways typically located near top of waterway bank
- Bank maintenance resulting in limited riparian groundcover
- Dispersive soils may also be present

Typical Issues

- Under high intensity rainfall events local riparian catchments will result in sheet overland flow, even in turfed parkland environments.
- Some natural concentration of sheetflow will usually occur close to the waterway as a result of natural topography or collection and redirection by paved pathways.
- Where riparian groundcover vegetation has been disturbed by weed management activities, such as herbicide applications, overland flows cause erosion on the exposed banks where they enter the waterway, typically undermining the pathway infrastructure.

This waterway situation is created by overland flows causing erosion on exposed waterway

Design Response

- The overland flows should be addressed as a priority as they are the main cause of the erosion. This can be achieved by designing and constructing specific drainage lines to control the flows (these can be in the form of vegetated swales).
- These drainage lines should be designed to discharge at controlled inflow points along the waterway edge. These inflow points could be protected and managed with the design and construction of rock chutes.
- Existing erosion should be dealt with by placing rock (300mm diameter) and backfilling with soil into the eroded area.
- The riparian zone should also be revegetated to protect the soils for future erosion. The vegetation used in the revegetation should be chosen to ensure adequate ground cover and shade, but should allow for clear view lines to the waterway.

Key Rehabilitation / Remediation Works

Typical works required to achieve stable waterway banks may include:

- Grade control / rock chutes
- Bank stabilisation
- Riparian revegetation

Please refer to Section 4: Construction and Establishment for more information for each of these and for other elements which may be required due to specific site characteristics.

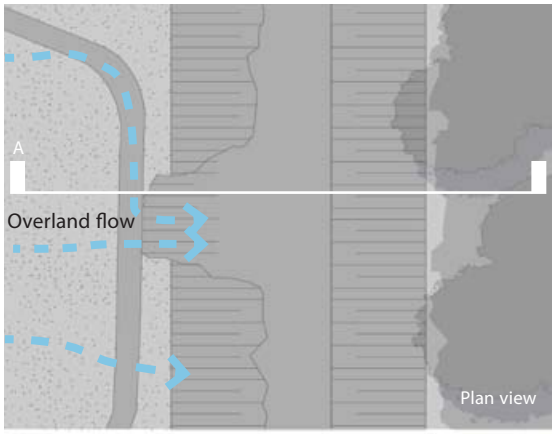
Maintenance

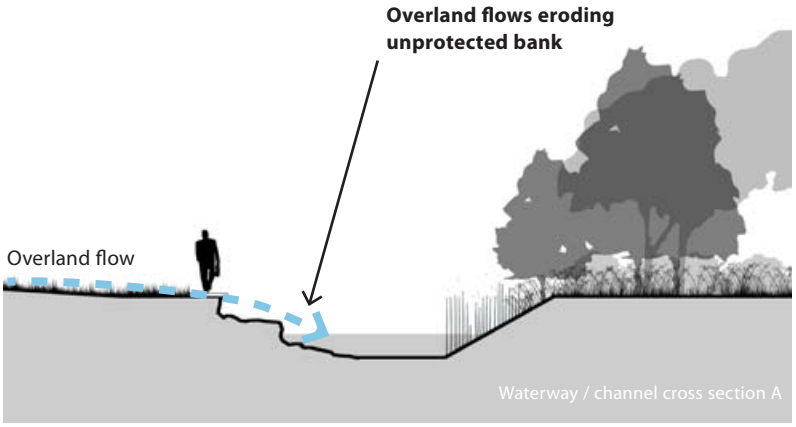
Maintenance requirements to ensure the successful establishment of these works will involve:

- Monitoring, watering and weeding of revegetated areas (as recommended in the ICC Riparian Corridor Revegetation Guideline)
- Inspection of channel banks to identify any erosion / scour zones
- Inspection of chutes to check for dislodgement of rock protection or the presence of weeds
- Removal, and where necessary replacement, of any bank protection material (e.g.: Jute Mat) that has been displaced

Existing Waterway Condition

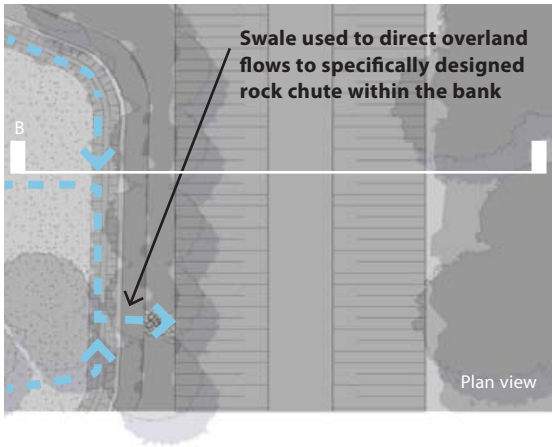
Erosion of exposed banks due to channelised overland flows

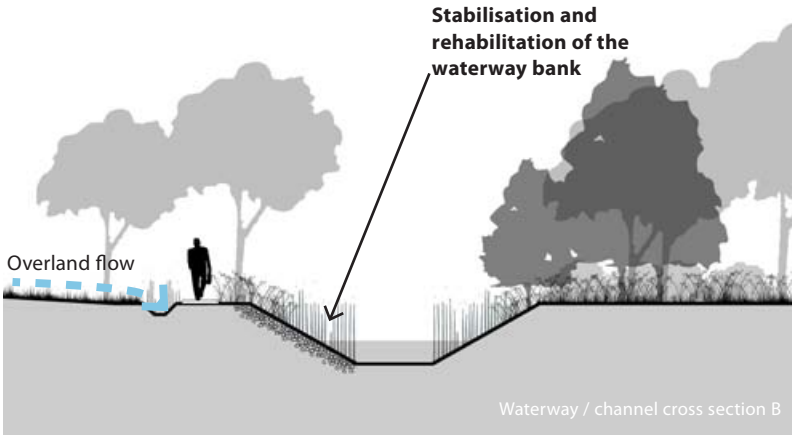




Improved Waterway Condition

Overland flows managed with vegetated swales and rock chutes





Flooding risk can be managed by ensuring channel capacity is not impacted by riparian revegetation

Channel with Steep Banks and / or Undercutting

Typical Characteristics

- Channel with steep banks and a deep incised bed level
- This condition may be the result of headward erosion as a result of downstream activities or as a result of increase flow and stream power as a result of increased catchment runoff
- The bank may also experience undercutting and widening as a result of the bed erosion creating steep unvegetated banks and exposing erodable / dispersive soils
- Parklands or built infrastructure may be located adjacent the waterway

Typical Issues

- Steep banks can often be unstable, presenting a risk to the public as well as any adjacent private or public assets.
- Difficult to gain access to construct improvement works or maintain channel.

Deep incised channels may be a result of past headcut erosion events, resulting in steep unstable banks

Design Response

- The design needs to respond to the existing conditions of the waterway.
- If active erosion is still occurring in the bed and banks, works need to be undertaken to control the erosion and stabilise and fill the steep, deep eroded channel.
- Initial works need to focus on bed stabilisation. Bank stabilisation can only occur once the bed is stable.
- Protection/stabilisation of dispersive soils (refer page 40)
- Channel stabilisation can be achieved with the use of rock chutes. However, this may not address the safety issues associated with a deeply incised channel.
- To improve safety, the channel bed may need to be lifted and the banks battered back.
- If there is sedimentation occurring in the area due to the erosion of upstream sediments, the rock chutes can be designed to capture sediments behind the chutes, raising the channel bed level.
- If there is limited sedimentation occurring (stable developed upstream catchment) the channel may need to be backfilled with a series of rock wedges as the stable catchment is not likely to produce enough sediment to back fill the channel behind a traditional rock chute in a reasonable time.
- In this case, rock placement is used to lift the bed level. This rock could be relatively small (D50 ~ 300mm) and simply strategically tipped into the channel to form a series of wedges behind grade control chutes.
- Lifting the bed level allows the batters to be strategically flattened where existing vegetation permits without requiring major works.

Key Rehabilitation / Remediation Works

Typical works required to achieve a stable waterway may include:

- Grade control (rock chutes + rock placement)
- Battering back banks
- Bank stabilisation
- Riparian revegetation

Please refer to Section 4: Construction and Establishment for more information for each of these and for other elements which may be required due to specific site characteristics.

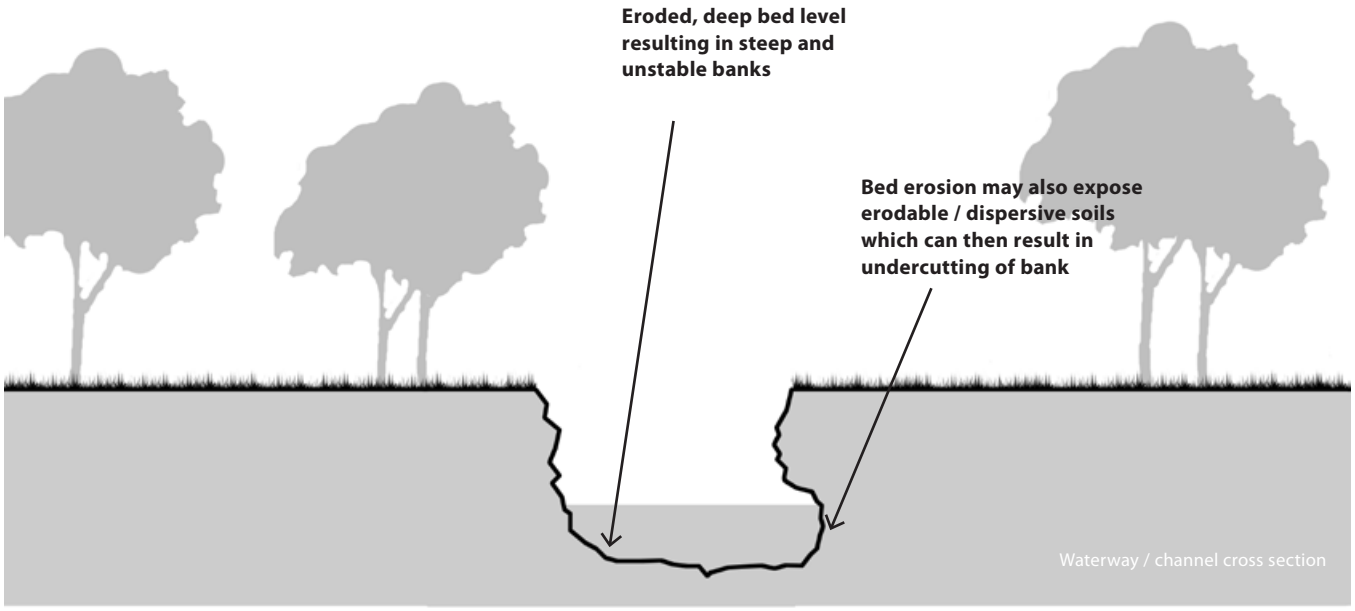
Maintenance

Maintenance requirements to ensure the successful establishment of these works will involve:

- Monitoring, watering and weeding of revegetated areas (as recommended in the ICC Riparian Corridor Revegetation Guideline)
- Inspection of channel banks to identify any erosion / scour zones
- Inspection of chutes and rock placement to check for dislodgement of rock protection or the presence of weeds

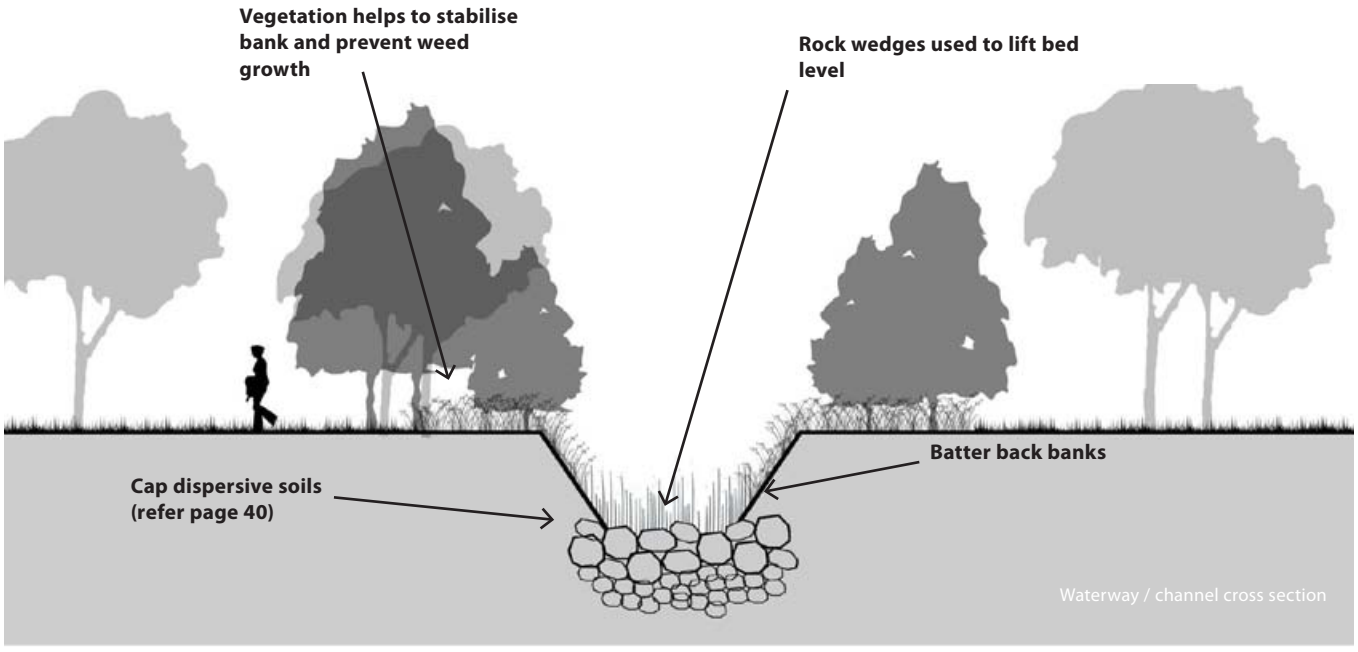
Existing Waterway Condition

Deep channel with eroded banks due to past bed erosion



Improved Waterway Condition

Shallow channel with stabilised banks.



Raising the bed level of the waterway decreases the conveyance capacity of the waterway. Battering back the banks will help to maintain the cross sectional area of the channel.

Design, Construction and Establishment

This section of the Guideline provides additional information to assist users to undertake remediation / rehabilitation works to achieve outcomes proposed in Section 3: Waterway Management Situations.

Project Management

Design Considerations

Design Details

Construction and Establishment

Maintenance

Design, Construction and Establishment

Project Management

Before undertaking any rehabilitation or remediation works, it is important that the project manager has a clear understanding of the waterway / channel issues which requires addressing. To gain an appreciation of the issue, why it has occurred and how to best address it, the project manger will need to consider a number of different elements such as site context and waterway values. These are discussed in more detailed in 'Design Considerations' below.

It is also important that the project manager is familiar with the design opportunities available to best address the waterway / channel issue. These opportunities are presented in Section 3: Waterway Management Situations. They must also be familiar with the design requirements and materials that are needed to achieve these design solutions. This information is provided in 'Design Details' on page 24.

Design Considerations

This section provides additional site specific information which is important to consider when designing the rehabilitation or remediation of waterways and channel works. This information should be used to modify design responses outlined in Section 3: Waterway Management Situations to address local conditions.

Initial data collection

To ensure that the waterway works will operate as planned, it is important that the design, construction and establishment period of works are well managed.

Initial data collection, site visit or assessments are required in order to gather the following specific information for the site:

- Catchment details
- Soil type
- Channel gradient
- Channel form (e.g. pools + riffles)
- Flow regimes

This information will help you modify the design solution for each waterway management situation (as presented in Section 3: Waterway Management Situations) to ensure the design response adequately addresses site specific characteristics (as summarised in Table 2).

It is especially important that soils assessments are undertaken at the start of any works and soil type and erosivity will play a critical role in the design and construction of waterway works.

Table 2: Site specific issues and associated design response required

Site characteristics / observations	Design, construction and establishment response
Weedy channel	Riparian revegetation
Steep channel with erosion / scour present	Grade control structures may be required
Dispersive or sodic soils	Surface treatments and choice of vegetation
Flat channel grade with wet or boggy inverts	Subsurface drainage (if wanting to maintain the channel as a mown turf)
Developing catchment	Increase channel capacity by battering back banks
Steep and / or unstable banks	Battering back banks and / or bank protection
Localised flooding issues	Increase channel capacity by battering back banks and / or provision of shade to decrease roughness associated with weeds

Maintaining / enhancing waterway values

As previously discussed, waterways provide a number of values. The purpose of this guideline is to ensure that these values are maintained or enhanced as a part of waterway management works within Ipswich.

Identifying key existing waterway features is important before undertaking any waterway management works as these should be retained as part of the design, construction and establishment process. These include:

- identifying the stage of channel adjustment relative to catchment development (i.e. is the channel just starting to adjust to catchment urbanisation or has adjustment occurred and the channel just needs to be stabilised and rehabilitated)
- identifying existing vegetation that should be retained
- identifying channel forms (such as pool and riffles and natural controls such as rock bars, etc) which should be retained

There may be a number of waterway values and features that could be enhanced as part of waterway management works. These should also be identified early in the design, construction and establishment process to ensure the scope of works allows for these improvements. This may include:

- enhanced habitat values by vegetating waterway edges and providing pool / riffle systems along the waterway
- enhanced water quality with the use of shade trees, stabilising channel bed and providing stable, vegetated banks
- enhanced recreational/social values by improving waterway aesthetics by controlling weeds with appropriate width riparian zones, shade trees, appropriate management of edges and improving water quality

Design details

This section provides additional information on how to successfully design waterway rehabilitation and remediation works to respond to common waterway conditions in Ipswich. This information should be used in conjunction with existing Guidelines to achieve the design responses outlined in Section 3: Waterway Management Situations.

Riparian revegetation

To ensure that riparian revegetation establishes successfully, there are a number of key design elements that need to be considered. These include

- bank orientation
- inundation tolerance / bank position
- use of topsoil
- type of vegetation
- plant structure and channel conveyance

More information is provided on each of these factors below.

Bank Orientation

Plant establishment in the riparian zone is closely related to the orientation of the waterway. Vegetation on the south side of an east-west section of waterway can be exposed to the sun for most of the day while the northern side could be more sheltered depending on the topography north of the site. This difference in exposure to the sun means that special attention needs to be provided for the plant selection on these 2 banks, ensuring that more heat tolerant species are specified for the southern bank. Trees on the south side will not cast shade on the water. Along a north-south section of waterway trees on both banks will be exposed to sunlight for half of the day, so no difference in species selection is required for the 2 banks.

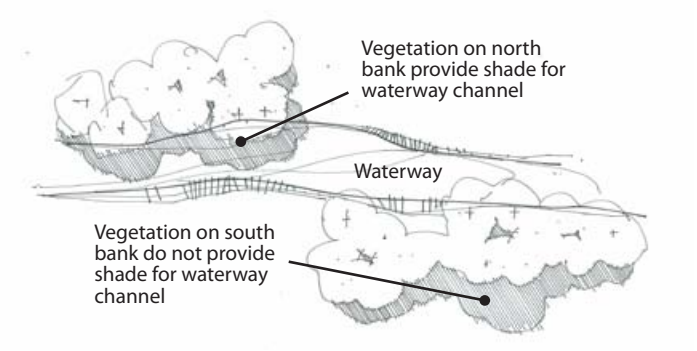


Figure 1: Shading on a East-West orientated waterway

Inundation Tolerance / Bank Position

Different plant species have different inundation tolerances. In riparian revegetation designs it is important to clearly distinguish between species that may occur in the channel (as aquatic or semi-aquatic) and those that occur in the riparian zone and may only be inundated briefly during runoff events. Typically it is adequate to distinguish between lower bank and upper bank species. Lower bank species are typically more restricted and generally only occur on moist soils or in locations that are inundated during most runoff events. Upper bank species generally have a wider distribution and would also typically occur in broader gully line and valley vegetation communities.

The planting selection within the riparian zone planting zones should also reflect the function of the vegetation along the waterway bank to ensure structural integrity and protection of the banks. The ICC Riparian Corridor Revegetation Guideline suggests that dense plantings of mat rushes and sedges with root systems and flexible branches to protect the bank from undercutting and scour should be used in the channel / lower bank while fast growing, hardy trees and shrubs with deep root systems to provide structure should be used on the upper bank. A recommended species list is also provided in the Guideline which provides information on recommended bank position for each species.

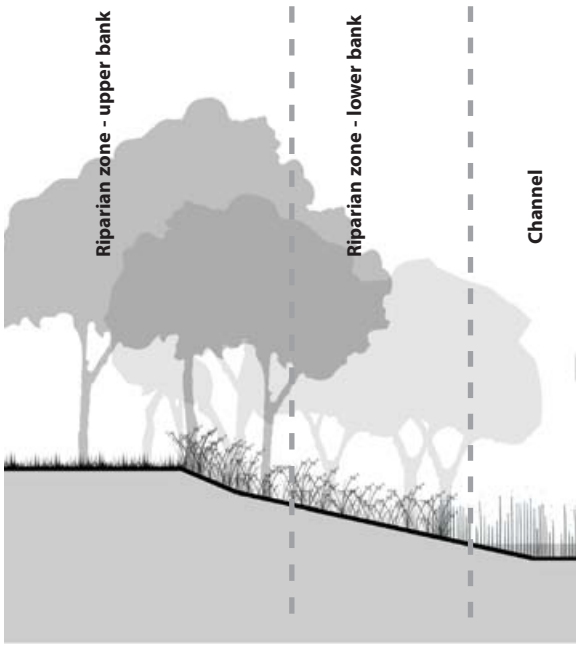


Figure 2: Cross section of a waterway channel showing riparian revegetation planting zones.

Use of Topsoil

All plants require suitable top-soil for successful establishment and good growth. In revegetation exercises where topsoil has been lost, such as in many bank erosion situations, it will be necessary to introduce a suitable soil. Where soils need to be introduced to channel banks and batters it will be necessary to provide an anchoring system for the soil. The simplest anchoring and stabilisation system is rock lining where the spaces between the rock can be filled with soil. Planting can occur into the soil filled voids between the rocks. The soil doesn't necessarily have to be particularly high quality but needs to be:

- able to support plant growth,
- free of weeds
- non-dispersive.

In areas of saline or sodic soils it will be crucial to have adequate topsoil cover for successful revegetation.

Geotextile materials can also be used to protect topsoil while areas are being re-vegetated. While the use of geotextiles can be very successful at protecting topsoils from erosion, careful consideration of plant selection, planting density and longevity of the geotextile is required to obtain a good long-term result.

For example without appropriate maintenance and selection of matting, geotextiles can inhibit the spread of rhizomatous or suckering species. The successful use of geotextiles with spreading species needs selection of short field life materials and regular adjustment of planting holes as the plants establish and start to spread.

Plate 3: Geotextile materials require planting holes to be cut and regularly adjusted to allow vegetation to establish successfully.

Type of vegetation

Before revegetating your site, it is important to gain an understanding of the local indigenous species that are either present or are known to have existed in the local area. The design of waterway and riparian vegetation needs to balance the pragmatic requirements of creating a stable waterway channel while respecting the relative Regional Ecosystem for the site in question. In general revegetation species should be drawn from a relevant Regional Ecosystem mapped community. For example Regional Ecosystem 12.3.3c: Floodplain (other than floodplain wetlands) is described as: "*Melaleuca irbyana* low open-forest or thicket. Emergent trees may be present e.g. *Eucalyptus moluccana, E. crebra, E. tereticornis* and *Corymbia citriodora. Casuarina glauca* or *Acacia harpophylla* occasionally present. Occurs on Quaternary alluvial plains". This community could form the basis for the riparian zone - upper bank community and general riparian corridor. The understorey for this area could consist of Lomandra spp., whereas the lower bank could support *Carex appressa* or *Poa* spp. and the channel *Schoenoplectus validus.*

It is also important that fast growing native species that provide quick coverage for weed suppression and protection of the bank are chosen. The ICC Riparian Corridor Revegetation Guideline provides a list of fast growing plants that are commonly available from local and regional stockists.

Plant structure and channel conveyance

In areas where flooding is a concern it is important to consider the plant structure of any species specified for the channel or floodplain and how the channel and riparian vegetation may influence the conveyance capacity of the waterway. Appendix C of the Natural Channel Design Guidelines (BCC, 2000) outlines a range of recommended Manning's N values for a range of waterway types and vegetation conditions. It is important to recognise that the roughness of in-stream and riparian vegetation will change over time as the community establishes, develops and matures. Roughness is likely to increase as revegetation establishes and may start to decline over time as the riparian community matures and trees start to control the density and size of ground cover.

Crime Prevention Through Environmental Design (CPTED)

When revegetating the waterway riparian zone, it is important to consider the use of the surrounding area. If the waterway falls within a public open space area, plant selection should ensure that public safety is not adversely affected by the revegetation works. This can be done by choosing groundcovers which do not grow taller than 0.6m and shade trees which can have their lower branches easily pruned.

Other Key References:

- Natural Channel Design Guidelines (BCC, 2000)
  - Section 4: Revegetation
  - Appendix C: Mannings Roughness
- Riparian Corridor Revegetation Guideline (ICC) - details on plant selection, weed control and planting guide

Battering banks

Battering back banks involves the excavation of the bank to decrease its steepness. Battering back banks can provide a number of waterway benefits including increasing channel capacity, stabilising steep banks and can create clear maintenance boundaries. Undertaking bank works can expose soils within the waterway channel and should be undertaken with an appropriate design and construction and establishment plan to minimise risk of bank erosion.

Cross-sectional design

There are a number of different design options when battering back banks. These include:

- creation of low flow channel within a symmetrical broader channel with floodplain
- creation of symmetrical broad channel
- creation of broad channel with meanders and differing slopes

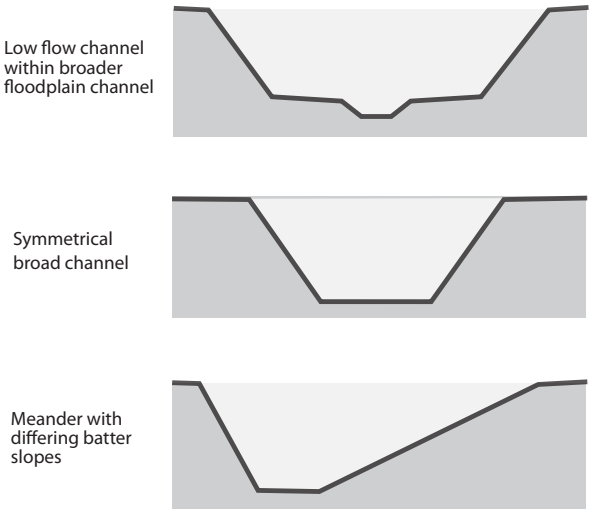


Figure 3: Cross sections of different batter design options

Cross-sectional design is intimately associated with plan-form (see 'meanders' discussion below). Cross-sectional design needs to consider the direction of bends and meanders and adjust cross-sectional geometry to limit flow velocities on outside bends. The consideration of cross-sectional variation should attempt to ensure that as flows increase the cross-sectional area increases and the flow path straightens (refer Figure 4).

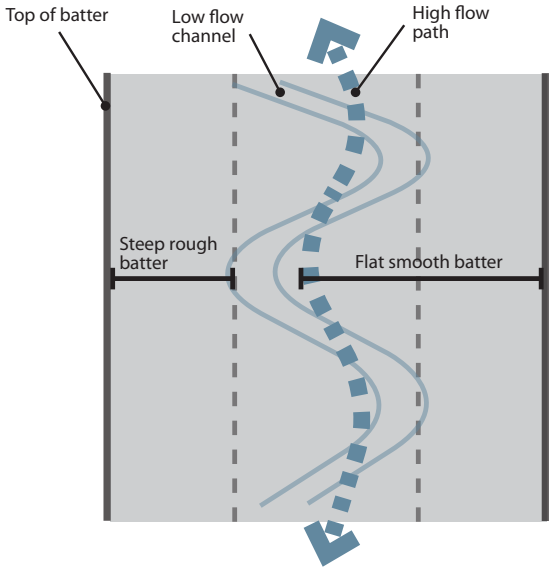


Figure 4: Plan section of meandering waterway channel showing the straightening of the flow path as flows increase.

Batter slopes

Batter slope design may alter depending on design objectives and site constraints. Site constraints include limited space available due to neighbouring private or public assets and bank condition / soil type. For example sandy soils should not have bank slopes greater than 1:4 while sandy-loam soil with groundcover vegetation may have a 1:3 batter (BCC, 2000).

Batter slopes greater than 1:5 provide safe public access to the waterway. This may be a design consideration if community engagement and access to the waterway is a desired objective for the waterway works. These slopes also allow for mowing which may be required if the banks are turfed.

Typically batters should not be steeper than 1:3. Constrained sites such limited available area and retaining existing trees may require steeper slopes. Any batters steeper than 1:3 will require bank stabilisation works, particular vegetation designs and consideration of cross-sectional compensation on the opposite bank.

Meanders

If a channel is to be rehabilitated, it is often desirable to introduce some channel meanders to improve aesthetics, habitat and channel diversity and also increase the effective channel length. Increasing channel length is one of the most effective ways of reducing the bankfull flow velocity (BCC, 2000).

The Natural Channel Design Guidelines (BCC, 2000) suggests that the meander radius is generally greater than three times the normal channel width. If a sharper meaner radius is required then it may be necessary to rock-line the outer bank of the meander.

Construction of meanders may involve 'flip-flopping' of batter slopes to create this visual affect (Figure 4). This will require bank stabilisation on the steep outside batter and may result in cutting back into the existing bank on the inside bank to create a flatter batter.

Channel capacity

Battering back existing steep slopes will increase the channel capacity. To ensure that the channel capacity is appropriate, initial data collection should identify the existing and proposed landuse in the contributing catchment. If development is being undertaken or is planned, the channel capacity should be increased to ensure that increased catchment flows can be safely conveyed within the channel or designed over channel areas.

Other Key References:

Natural Channel Design Guidelines (BCC, 2000)

- Section 3: Design Procedures - Steps 6 and 7

Erosion Treatments for Urban Creek Guidelines (BCC, 2004)

- Section A4 - Erosion Treatment Technique #T11

Bank stabilisation

There are a number of options available to stabilise banks, each with their own benefits, risk and preferred application with regards to waterway management. These are shown in Table 3.

Table 3: Bank stabilisation materials summary

Stabilisation material	Description	Risk of use	Preferred waterway management application
Rock and structural soil (with vegetation)	Layers of rocks (average diameter 250mm) backfilled with soil which can then be planted out (rock size will partly depend on the channel slope and flow velocities)	Any rock stabilisation techniques are only appropriate if the bed is stable. Bed instability will always create a risk for bank works	Steep slopes stabilisation (refer Figure 5 and Erosion Treatment Technique #T6 (BCC, 2004) for more information)
Jute matting	Biodegradable matting which can be cut and planted into	Can restrict plant growth. Needs to be carefully installed to ensure success. Needs to be maintained to ensure good plant growth and establishment.	Use when exposed soils are at high risk of eroding during channel works
Sterile rye grass	Grass seeds which establish quickly, stabilising exposed soils and can then be planted into	Need time to establish before banks are stabilised	Hydroseeding
Mulch	Many materials can be used as mulch, such as sugar cane and wood chips)	Most mulch materials float easily and therefore are washed away easily when used in waterways	Mulch should only be used on batters if netting is used to control mulch. Mulch is best applied at the top of the bank as part of riparian revegetation works
Coir logs	Coir netting filled with densley packed coir (coconut) fibre.	Should not be used in isolation of other stabilisation measures	Applied to toe of batter to provide short term protection as batter vegetation establishes

Other Key References:

Erosion Treatments for Urban Creek Guidelines (BCC, 2004)

- Section A4 - Erosion Treatment Technique #T6

Natural Channel Design Guidelines (BCC, 2000)

- Appendix A: Channel Features

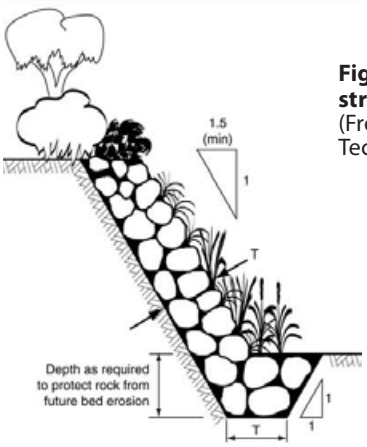


Figure 5: Vegetated rock and structural soil protection (From Erosion Treatment Technique #T6 (BCC, 2004))

Grade control structures

There are a number of techniques available to control erosion along the bed of a waterway. A summary of these techniques is provided in Table 4. More information on the construction of these techniques is documented in the Erosion Treatments for Urban Creek Guidelines (BCC, 2004).

Table 4: Grade control structures summary

Grade Control Structures	Description	Risk of use	Detailed construction Information*
Rock / log bed control	Involves using logs or rocks to create a retaining wall across the bed of the stream (acting as a weir-type structure)	- Logs will eventually rot - Can be seen as a fish movement barrier	Erosion treatment techniques #T1 and #T2 (refer Figure 6)
Rock chutes*	Rock used to form a rock chute which transfers stream from a higher to lower elevation without erosion	- Risk of failure related to appropriate selection of rock size	Erosion treatment technique #T3.
Boulder Plunge Pools	Large boulders used, placed in the creek bed and banks to control movement of erosion upstream.	- Can be seen as a fish movement barrier - Materials may not be readily available	Erosion treatment technique #T4

*This information can be found in Erosion Treatments for Urban Creek Guidelines (BCC, 2004)

**Under most circumstances an appropriately designed chute is often the preferred solution because of the long-term stability performance and revegetation potential and possibilities for fish passage and waterway connectivity.

It is important to integrate revegetation works with physical control structures. Without the soil protection ability of vegetation most physical works will fail. Vegetation provides a self repairing and adjusting system to augment the initial stability created by physical works.

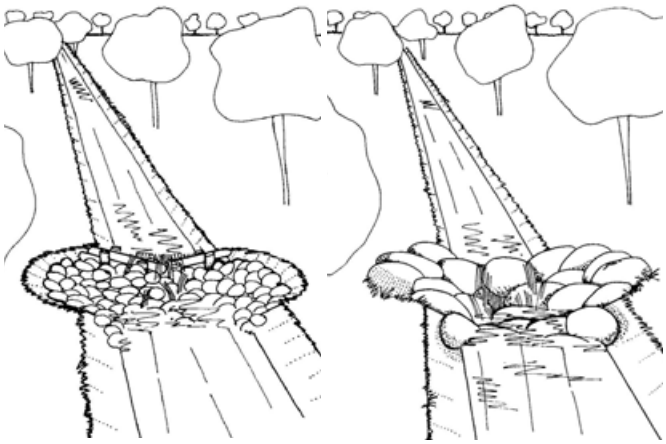


Figure 6: Example grade control structures: Log weir with rock bed control (left) and Boulder Plunge Pool (right) (From Erosion Treatment Techniques #T2 and #T4 (BCC, 2004))

Other Key References:

Erosion Treatments for Urban Creek Guidelines (BCC, 2004)

- Section A4 - Erosion Treatment Techniques #T1 to #T5
- Section B4 - Supplementary Information #B4

Managing dispersive and sodic soils

Understanding soil types and conditions is crucial for successful waterway management works. This is especially important in Ipswich due to extent of dispersive soils across the city.

Dispersive and sodic soils need careful management to ensure stable waterway conditions are achieved. Where dispersive or sodic soils are exposed, erosion risk is high. Exposed subsoils need to be covered with topsoil prior to revegetation or bank stability works (Figure 7). Any capping soil used should be classified as an engineering clay. Topsoil will need to be held in place with rock or geotextile materials until vegetation is established. In areas with sodic or saline subsoils the salinity tolerance of revegetation species needs to be considered.

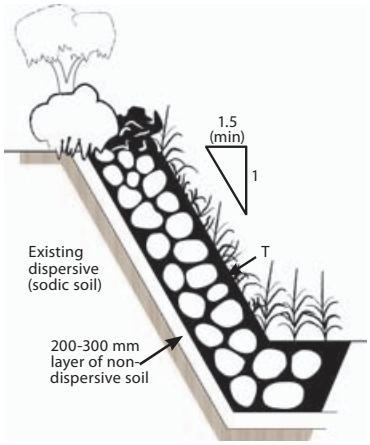


Figure 7: Vegetated rock and structural soil protection in an area with dispersive (sodic) soils (Adapted from Erosion Treatment Technique #T6 (BCC, 2004))

Construction and establishment

Waterway works can be problematic as they are undertaken in areas which flow regularly, resulting in risk of scour and erosion during construction and establishment. During this high risk stage of works, erosion and sediment control is a priority.

The timing of the works can help to reduce risk associated with construction within waterways. Typically, bulk earthworks should be undertaken in the dryer winter months.

The staging and sequencing of works can also reduce risk. Works should be staged from upstream to downstream locations, minimising the area of exposed 'transportable' sediment at any stage. Works can also be broken down into interim vs future works, reducing the timeframe and also the costs associated with each stage of works. Interim works can be undertaken immediately and within existing budgets to simplify existing maintenance of waterways. This work can involve weeding and mulching weedy riparian areas and also trying to control weeds in the channel. Future works can then be undertaken to create the 'Improved Water Condition' when timing (dry winter months) and budgets allow. When staging is necessary it is important to have a final rehabilitation plan to ensure the staged works will eventually sum to the desired outcome.

Figure 8: Risk trajectory of waterway works from construction to on-going maintenance

To reduce risk of failure during establishment, there are a number of activities which should be undertaken.

- Any rock structures should be monitored and reset if required.
- Regular watering is required for all vegetation to ensure successful establishment. Watering should be undertaken on an 'as needed basis" depending on climatic conditions (typically weekly for 4 weeks, fortnightly for 4-12 weeks and monthly watering for 3-6 months)
- Additional irrigation may be required for vegetation on exposed banks
- If jute matting is used, checks should be undertaken to ensure that it is not restricting plant growth. This may require additional cuts to be made in the matting. Checks should also be undertaken to ensure the jute matting does not become dislodged, which could result in the smothering of plants and / or erosion.
- Weed management is essential until plants are fully established and can suppress weed growth with their density and foliage cover.

Maintenance

Waterway rehabilitation /remediation solutions proposed in this guideline are designed to enhance the natural values of waterways within Ipswich City Council. Typically this will involve revegetation of the riparian zone. To ensure the success of these designs, maintenance needs to take in the following considerations:

- Timing of maintenance activities
- Responsibilities
- Maintenance requirements

Timing

Maintenance of waterway rehabilitation works will require an initial investment to be made to ensure the vegetation is established as designed, resulting in a more robust natural vegetation community. Once this landscape is established, the maintenance effort required to maintain the area will diminish, trending to a level of effort much less than is currently exercised for an equivalent open space area. This concept of diminishing maintenance burden is theoretically illustrated in Figure 9.

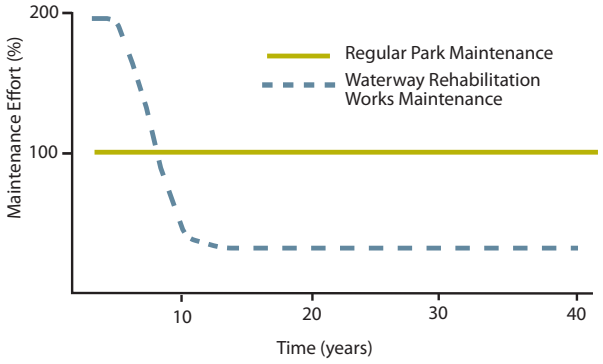


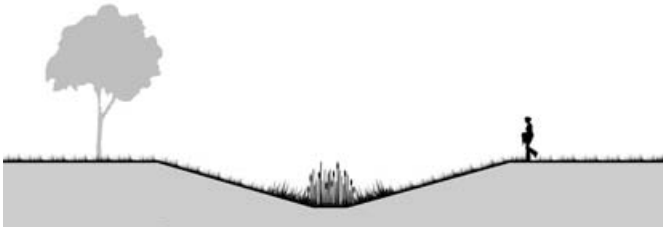
Figure 9: Maintenance effort associated with regular park maintenance and waterway rehabilitation works

This concept recognises that during the plant establishment period of waterway rehabilitation works (approximately 2 years), intensive maintenance will be required to control weeds, and to identify and replace unsuccessful plantings. After the establishment phase, the maintenance burden will taper off over the following four to five years as the vegetation community continues to mature. Beyond this time, maintenance requirements will continue to decrease as the vegetation community matures. It is envisaged that after 5-7 years the area should be incorporated into the regular natural asset maintenance program. Regular monitoring should be conducted to ensure that any new weed infestation is controlled and litter is removed.

Responsibility

Many channels and waterways are located within public open space areas. The waterway restoration solutions proposed in this guideline involve the establishment of riparian vegetation and in-stream works. Typical park maintenance such as mowing and strip herbicide applications is not appropriate for these areas. As such, the maintenance of these natural assets should be undertaken by the appropriate group within Council. This may result in a change of maintenance responsibilities within these parkland areas from predominately park maintenance to a mix of natural area and park maintenance (shown in Figure 10).

'Before' waterway works



Park maintenance for entire area

'After' waterway works

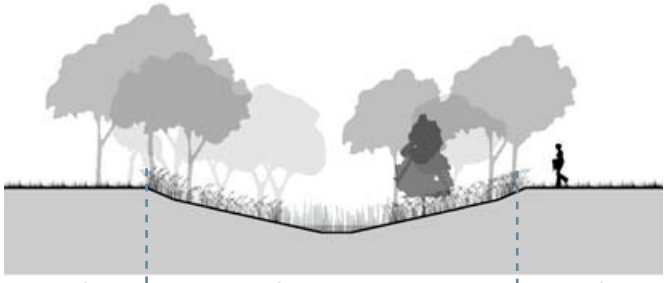


Figure 10: Maintenance responsibility before (top) and after (bottom) waterway rehabilitation works have been undertaken within a parkland area

Design Requirements

Design solutions proposed in this guideline recommend clear maintenance boundaries to be created to delineate between the drainage and waterway corridors and adjacent parkland areas. This can be achieved with formal edging designs (plinths, boards, mowing edge, etc.) and/or a tree canopy to create a clear maintenance boundary between mown and natural bush maintenance areas. Stepped cross-sections can also be employed to create more defined maintenance boundaries.

The boundary will delineate the areas which require regular park maintenance and natural asset maintenance (refer Figure 10). The requirements for both of these areas differ as highlighted below.

Regular park maintenance may involve:

- Litter collection
- Mowing
- Repair / replacement of structures such as decking, seats and bollards and paths

The intensity of this maintenance will remain relatively constant over time.

Natural asset maintenance will require initial investment to ensure works establish as designed. Maintenance requirements during this establishment phase will involve:

- Watering
- Weed removal
- Replacement of unsuccessful plantings
- Checks for erosion

Once the works are established, the maintenance of the area will reduce significantly and will require on-going monitoring to ensure that any new weed infestation, litter and erosion is controlled.

A case study on the maintenance costs of vegetated systems by the Cooperative Research Centre for Catchment Hydrology found that the cost of maintaining vegetated swales dropped from $9.00/m²/year to $1.50/m²/year (Lloyd et al. 2002).

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