Repairing water quality: what to do in the catchment

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Strategy 1. Keep water cool

Suitability of strategy: most suitable for small streams with naturally cool water. Most likely to be effective where a small portion of the catchment is impervious and where a sizeable tract of the upstream waterway is still relatively intact. Less achievable when the urban area is anticipating marked increases in temperature associated with climate change.

Action	Explanation	Conditions where action is most likely to be suitable andeffective	Other references recommending action	Guidelines for implementation
1a. Revegetate riparian land upstream of the site	Shading upstream of the site affects water temperature at the site. Ensuring the riparian zone is vegetated for the upstream 1 km will keep water cool at the site.	Where the channel is narrow (< 10 m wide). Where the upstream vegetation has been largely cleared. Where the buffer is wide enough to allow the establishment of two to three tree widths back from the channel.	[1-3]	[4]
1b. Manage the release of wastewater effluent into waterways	Wastewater effluent is typically several degrees warmer than stream water and can markedly increase instream water temperature. Wastewater should be held in shaded bioretention ponds until it cools (before release to waterways).	Where wastewater plants discharge effluent into waterways, particularly where the effluent makes up a large fraction of stream flow – e.g. where water is discharged into intermittent or low-flow streams. Where management actions cool effluent so that its temperature is similar (<0.5C of stream water) or slightly cooler than instream water. Use caution – this approach could exacerbate nutrient and pollution issues instream	[5, 6]	
1c. Use bioretention basins (biofiltration wetlands, raingardens, vegetated swales) to cool stormwater	Stormwater which runs off over hot paved surfaces should be held in bioretention basins and allowed to cool before being slowly released to waterways.	Most areas, particularly where rainfall and runoff from impervious surfaces occurs during the warmer months of the year. Most effective where the biorention area is large relative to the size of the catchment it is filtering.	[7, 8]	[8] Also see biofiltration guidelines
1d. Run stormwater through vegetated filter strips / riparian land	Stormwater should not be directly piped to waterways, instead it should be allowed to flow through vegetated filter strips or riparian land where it can cool before entering the stream via surface or sub-surface pathways.	Where the riparian land is shaded by trees. Where the vegetated buffer that the stormwater passes through is > 10 m wide.	[9]	[9]

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Action	Explanation	Conditions where action is most likely to be suitable andeffective	Other references recommending action	Guidelines for implementation
1e. Cold-water release from base of dam	The release of cold water from the base of dams may be used to reduce the temperature of downstream urban waterways.	Where the capacity to shade the urban waterway is very limited. Where short-term weather forecasts predict upcoming severe hot weather. Where the addition of cold water will not create thermal shock for native species. Where environmental water allocations are available. Where dams have the capacity to release water from their hypolimnion. This action should be monitored and used with caution.	[3, 10]	Little information, but see [10] for a discussion of the pros and cons
1f. Environmental water release from alternative non-dam sources	Releasing water from non-dam water infrastructure (e.g. pipelines, fire hydrants) treatment facilities) can increase the volume of water in urban waterways, therefore reducing their susceptibility to changes in temperature.	Where environmental water allocations are available. Where instream flows are very low, such that the added water contributes a significant portion of flow or water in refuge pools.	[11]	
1g. Maintain baseflow See *Repairing flow: what to do in the catchment* factsheet, actions 5a to h	Water temperatures typically increase as waterways dry down. Maintaining flow and water volume in waterways assists to reduce temperature extremes.	Where urbanisation has caused baseflow to fall.	[3]	See associated factsheet
1h. Promote groundwater upwelling See *Repairing vertical connectivity: what to do at the site and in the catchment* factsheet, all Strategies	Groundwater is typically considerably cooler than surface water, hence actions that improve the flow of groundwater into the waterway help moderate elevated temperatures.	Where the site would naturally receive a significant proportion of its flow from groundwater – i.e. highly permeable bed sediment (gravel, coarse sand) and has a shallow watertable (< 4m deep). Not appropriate if the groundwater is contaminated with pollutants (nutrient or non-nutrient).	[3, 12, 13]	See associated factsheet

Strategy 2. Keep oxygen levels high

Suitability of strategy: most suitable where the waterway has protracted periods of low flow, particularly during the warmer months.

Action	Explanation	Conditions where action is most likely to be suitable andeffective	Other references recommending action	Guidelines for implementation
2a. Reduce nutrients (N,P) concentrations See *Repairing nutrients: what to do in the catchment* factsheets, all Strategies	High levels of nutrients, particularly phosphorous, promote the development of algal blooms. The decomposition of these algal blooms by microbes causes high demand for oxygen – causing instream oxygen levels to fall.	Where nutrient levels are high. This is typically lowland rivers, but it can also be small urban waterways if they are adjacent to nutrient-rich landuse or if they receive water from wastewater treatment plants.	[14, 15]	See associated factsheet
2b. Reduce unnatural inputs of dissolved organic carbon by phasing out septic tanks and repairing leaky sewage networks	High levels of dissaolved organic carbon (DOC) fron septic tanks, and leaks in sewer networks, increase microbial demand for oxygen - causing instream oxygen levels to fall.	Where there are point source inputs of DOC that can be managed.		
2c. Keep the water as cool as possible – as per Strategy 1 this factsheet	The solubility of oxygen in water decreases as water temperature increases, therefore efforts to cool instream water will also improve oxygen levels.	Most suitable for small streams with naturally cool water. Most likely to be effective where a small portion of the catchment is impervious and where a sizeable tract of the upstream waterway is still relatively intact. Less suitable when the urban area is anticipating marked increases in temperature associated with climate change.		As per Strategy 1 this factsheet
2d. Maintain baseflow See *Repairing flow: what to do in the catchment* factsheet, actions 5a to h	Flow promotes the oxygenation of water. When flows cease, oxygen levels fall.	Where urbanisation has caused baseflow to fall.	[16, 17]	See associated factsheet

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Action	Explanation	Conditions where action is most likely to be suitable andeffective	Other references recommending action	Guidelines for implementation
2e. Environmental water release to maintain flow	Releasing water from water infrastructure (e.g. weir/dam, pipelines, fire hydrants) can keep flow moving in waterways that would otherwise stop flowing. Maintaining flow promotes surface oxygenation, while slowing stratification and the establishment of algal blooms – all of which reduce the likelihood of an oxygen crash.	Where environmental water allocations are available. Where instream flows are very low, such that the added water contributes a significant portion of flow or water in refuge pools. This action is particularly important during years of drought and to protect high value assets (e.g. refuge pools). Care should be taken if water is released from the base of the dam (hypolimnion) as it may be low in oxygen. Caution should also be used where pools have already stratified (i.e. contain thermal layers) because high flow mixing could exacerbate low oxygen issues - seek expert guidance.	[11, 18, 19]	Little information about oxygen, but see [19] for general guidance

Strategy 3. Reduce non-nutrient pollutants (i.e. heavy metals, hydrocarbons, PCBs, pharmaceuticals and other personal care products)

Suitability of strategy: most suitable where the restoration site has large quantities of fine sediments, given fine sediments bond to contaminants and increase the exposure of the site to pollutants. Most appropriate for catchments that include industrial landuse.

Action	Explanation	Conditions where action is most likely to be suitable andeffective	Other references recommending action	Guidelines for implementation
3a. Install gross pollutant traps (GPTs)	GPTs catch plastic and other rubbish in stormwater drains.	All areas.	WSUD manuals	[20]
3b. Relocate pre-exsisting industrial land use and strategic planning of industrial land use	Industrial land use creates significantly higher inputs of pollutants than residential land use. Polluting land uses should be strategically located or relocated to areas remote from waterways and WSUD elements such as biofiltration wetlands (constructed or natural).	Most urban areas. This action is best suited to new developments for inclusion in town planning.	[21]	
3c. Discourage pesticide/ herbicide use adjacent to the waterway and promote the use of lower risk chemicals	The use of pesticides and herbicides close to waterways should be discouraged, as these chemicals can make their way to the stream/river via overland or subsurface flow paths.	Where the riparian land is being actively managed for weeds. Where residential property is close to the waterway (< 30 m). Where residents grow vegetables on riparian land – more relevant to Asia than Australia.	[22]	

Action	Explanation	Conditions where action is most likely to be suitable andeffective	Other references recommending action	Guidelines for implementation
3d. Disconnect and infiltrate stormwater See *Repairing flow: what to do in the catchment* factsheet, actions 1b–1e.	Most chemical pollutants, such as heavy metals and hydrocarbons, are sourced from urban impervious surfaces (e.g. roads) and transported to streams via conventional stormwater drainage. Disconnecting and infiltrating stormwater will reduce the load of pollutants transported to urban waterways.	Most areas, particularly where stormwater drains roads or industrial land use. Where pollutant loads in the stormwater are high.	[7, 22]	See associated factsheet
3e. Direct stormwater through biofiltration basins See *Repairing flow: what to do in the catchment* factsheet, actions 1f and 1g	Wetland biofiltration basins and other specially designed biofiltration media adsorb or transform chemical pollutants – reducing the concentration of pollutants in stormwater.	Most areas, particularly where enough space exists to install biofiltration basins. Most effective when the appropriate biofiltration media is used and when biofiltration basins are strategically placed in areas of the catchment that receive the largest loads of pollutant-rich water.	[22-25]	See biofiltration guidelines
3f. Remove fine sediments in GPTs but allow coarse sediments to pass	Most pollutants bond to fine sediments (medium sand and smaller particles). Removing fine sediments from gross pollutant traps and transporting them to landfill can reduce the influx of pollutants to urban waterways.	If heavy metal contamination is a problem - where GPTs contain large quantities of fine sediment (< 500 µm). If PAHs are a problem – where GPTs contain large quantities of very fine particles (< 250 µm).	[26] but see [27] for a conflicting opinion	[26] Coarse sediments should be retained and returned to the urban waterway
3g. Improve practices on polluting land uses	Changes in behaviour, or the industrial process, can reduce the amount of pollutants released into the stormwater network or into the ground. Tackling illegal connections of industrial sewage to the stormwater network is key.	All areas		See best management practice guidelines
3h. Improve the treatment of wastewater	Wastewater is high in pollutants. Many treatment plants focus only on cleaning out nutrients and heavy metals, paying little attention to removing pharmaceuticals, such as hormones, anti-depressants and antibiotics. Updating onsite cleaning processes so that pharmaceuticals are also removed will reduce chemical stress to waterways.	Where wastewater plants discharge effluent into waterways, particularly where the effluent makes up a large fraction of streamflow – e.g. where water is discharged into intermittent or low-flow streams.	[5]	As per state and federal best management practice

Action	Explanation	Conditions where action is most likely to be suitable andeffective	Other references recommending action	Guidelines for implementation
3i. Keep oxygen levels high – see Strategy 2 this factsheet	The biodegradation of many pharmaceuticals and most trace organic contaminants is accelerated under aerobic conditions.	See actions 2a–2c this factsheet.	[28]	As per Strategy 2 this factsheet
3j. Promote hyporheic exchange See *Repairing vertical connectivity* factsheet, Strategy 2	The hyporheic zone is a biogeochemically active hotspot where many pollutants are broken down. Slowing streamflow by harvesting, infiltrating and disconnecting stormwater, or by using weirs, increases the likelihood that downwelling of surface water into the hyporheic zone will occur.	Where the catchment has waterways with permeable bed substrate. Where flashy urban flows have been managed.	[28]	See associated factsheet
3k. Prevent extreme low flows using environmental flow releases	Low flows increase contact between biota and sediment-bound pollutants. They also increase the concentration of water-borne pollutants. Releasing environmental water from weirs, dams, pipelines or fire hydrants may combat low-flow conditions that stress biota.	Where the climate and/or river regulation creates periods of protracted low flows.	[11, 29]	
3l. Disconnect or manage wetlands affected by acid sulfate soils (ASS)	Wetlands with pyritic soils (sulfide-rich sediments) that become exposed to air create sulfuric acid upon rewetting. This low pH environment promotes the release of heavy metals from sediments – increasing their availability in the waterway.	Where ASS-affected wetlands exist (note these may be pre-existing freshwater or coastal wetlands or constructed wetlands in new urban developments). Where ASS soils are likely to become exposed to air – i.e. either due to a falling watertable associated with urbanisation or due to climate change. Where the wetland inputs a large volume of low pH water into the receiving waterway.	[30]	[30]

Strategy 4. Maintain normal salinity and pH levels

Suitability of strategy: virtually all sites, except those that have naturally evolved under high conductivity, salinity or pH (likely to be very few places in Australia).

Action	Explanation	Conditions where action is most likely to be suitable andeffective	Other references recommending action	Guidelines for implementation
4a. Disconnect and infiltrate stormwater	Disconnecting stormwater pipes from waterways prevents the transfer of charged particles (metals, nutrients) from the built environment (roads, buildings) to waterways.	All areas.	[31]	See associated factsheet
4b. See *Repairing flow: what to do in the catchment* factsheet, actions 1b–1e.	Wetland biofiltration basins and other specially designed biofiltration media adsorb or transform ionised metals, repairing the ionic level of the receiving water.	Most areas, particularly where biofiltration basins are serially aligned along the drainage network to create a cumulative improvement in water quality.	[32]	See biofiltration guidelines
4c. Direct stormwater through biofiltration basins See *Repairing flow: what to do in the catchment* factsheet, actions 1f and 1g	In Australia, particularly in the south-west, agricultural clearing has caused the watertable to rise – bringing salt with it. If salt-affected land is developed it can cause salt to be transported by urban drainage to waterways.	In regions of south-western Australia that were formerly agricultural and now have a high soil salt content. Where the watertable is shallow (< 4 m) such that subsurface drainage will be used to prevent flooding of houses and other urban infrastructure.	[33]	
4d. Avoid development on agricultural land with a legacy of high soil salt levels	Urban development can accelerate the creation of ASS if the soils are highly pyritic because aggressive dewatering and stockpiling of peat soils allows oxygenation of the pyrite – priming the system for sulfuric acid creation upon rewetting. Subsurface drains can then mobilise low pH water from ASS-affected soils and transport this acidic water to urban waterways.	Where the catchment contains pyritic soils (e.g. parts of Perth) and where subsurface drainage has been installed. This action is particularly relevant where ASS soils are likely to become exposed to air – i.e. either due to construction, a falling watertable associated with urbanisation or climate change. Where the receiving waterway gets a large portion of its water from the subsurface drains (i.e. where dilution by water in the channel cannot overcome acidic inputs).	[30, 34]	[30]

Action	Explanation	Conditions where action is most likely to be suitable andeffective	Other references recommending action	Guidelines for implementation
4e. Avoid urban development in areas with significant risk of Acid Sulfate Soils (ASS) and shallow groundwater	Urban or agricultural drains (surface or subsurface) that are cut into historically water-logged pyritic soils are likely to leach sulfuric acid into the drain and then into the receiving waterway. Lining portions of these drains with soils high in lime (e.g. limestone) can neutralise the acidic water. Alternatively, shallow drains should be constructed so that ASS materials are not intersected. Permeable reactive barriers containing organic matter or iron filings can also be used to treat acidic water exiting from sub-surface drains before it reaches waterways.	Where the catchment contains ASS. Where the receiving waterway gets a large portion of its water from acid-affected drains (i.e. where dilution by water in the channel cannot overcome acidic inputs).	[30]	[30]
4f. Disconnect wetlands with ASS	Wetlands with pyritic soils (sulfide-rich sediments) that become exposed to air create sulfuric acid upon rewetting, which can compromise the pH of receiving waters.	Where ASS-affected wetlands exist (note these may be pre-existing freshwater or coastal wetlands or constructed wetlands in new urban developments). Where ASS soils are likely to become exposed to air – i.e. either due to a falling watertable associated with urbanisation or due to climate change. Where the wetland inputs a large volume of low pH water into the receiving waterway (i.e. where dilution by water in the channel cannot overcome acidic inputs from the wetland).	[30]	[30]
4g. Do not use salt to de-ice roads	Salt lowers the freezing point of water and is used in many countries, particularly in the northern hemisphere, to make roads more driveable. However, the salt makes its way via stormwater to urban waterways and creates severe salinity stress to these freshwater systems.	Where roads freeze over during winter and where salt is used as a de-icer. This does not occur anywhere in Australia.	[35]	Not relevant for Australia
4h. Prevent extreme low flows using environmental flow releases	Low flows, particularly drought conditions, increase daily fluctuations in pH. Maintaining flow can mitigate against extreme pH conditions.	Where the pH of the catchment is at the edge or beyond what is considered acceptable for water quality guidelines.	[36]	

Strategy 5. Improve water clarity

Suitability of strategy: suitable for most sites, particularly those with large quantities of fine sediments (e.g. clay, silt). May not be appropriate if improved water clarity will cause nuisance algal growth.

Action	Explanation	Conditions where action is most likely to be suitable andeffective	Other references recommending action	Guidelines for implementation
5a. Slow the flow of water See *Repairing flow: what to do at the catchment scale* factsheet, Strategy 2, all actions	As flow velocity increases so does its ability to suspend particles in the water column and increase turbidity. Slowing the flow of water allows fine particles to drop out of suspension and improve water clarity.	Where the substrate of the site is fine sediment (e.g. silt, clay).	[37]	See associated factsheet
5b. Ensure that construction sites use sediment control measures	Urban construction can cause instream sedimentation to increase three-fold. Ensuring that developers put measures in place (e.g. sediment traps) to reduce sediment runoff from construction sites into stormwater drains will improve waterway turbidity.	Where considerable construction activity is occurring in the upstream catchment. Where roadside stormwater drains are directly connected to the waterway.	WSUD manuals	[38, 39] And WSUD manuals
5c. Run stormwater though biofiltration basins/media	Biofiltration basins that detain stormwater and allow sediment to settle out will reduce the load of fine sediments into the receiving waterway and improve water clarity.	Where catchment and waterway soils (bed and bank sediments) have a high clay or silt content.		See biofiltration guidelines

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Repairing water quality: what to do in the catchment

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- **Strategy 1. Keep water cool**
- **Strategy 2. Keep oxygen levels high**
- **Strategy 3. Reduce non-nutrient pollutants**
- **Strategy 4. Maintain normal ionic & pH levels**
- **Strategy 5. Improve water clarity**