CRC Water Sensitive Cities

Project B2.23 – Restoring urban freshwater ecosystems: Informing management and planning

Project Update – June 2016

Project Leader: Peter Davies & Mike Grace
There are two discrete projects within B2.23:

Project a) is led by Mike Grace and based out of Monash University in Melbourne looking into Nitrogen transformation processes in wetlands.

Project b) is led by Peter Davies based out of UWA in Albany developing an urban river restoration decision support tool.

Both projects finish December 2016
Using stable isotopes to unravel nitrogen processing in wetlands

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Constructed Wetlands

- Treat stormwater nitrogen loads
- Management of vegetation and sediment
- Monitoring – water quality

Denitrification

Assimilation
- Transformation will result in the enrichment of $\delta^{15}\text{N}$ and $\delta^{18}\text{O}$ of $\text{NO}_3^-$ in the residual pool

**Denitrification $\delta^{15}\text{N} \sim 2\%$**

**Assimilation $\delta^{15}\text{N} \sim 5-15\%$**

(Michener and Lajtha 2007, Kendell et al 2007)
Study Sites

Cascades on Clyde, Melbourne

Kelletts Drain, Melbourne

Anvil Way Compensation Basin, Perth

Perth

Melbourne
Study Sites

Cascades on Clyde, Melbourne

Turbid and poorly vegetated

Kelletts Drain, Melbourne

Low turbidity and established vegetation

Anvil Way Compensation Basin, Perth

Well vegetated, anoxic groundwater input
Hypotheses

Cascades on Clyde, Melbourne

**Denitrification**
*Low fractionation of N*

Kelletts Drain, Melbourne

**Assimilation**
*High fractionation of N*

Anvil Way Compensation Basin, Perth

**Denitrification and/or Assimilation**
Cascades on Clyde

![Graphs showing changes in [NO₃⁻] and δ¹⁵N-NO₃ before and after an event.]

- **[NO₃⁻]**
  - Concentration of nitrate (µmol/L) decreases with distance from the inlet.

- **δ¹⁵N-NO₃**
  - δ¹⁵N-NO₃ (%o) increases with distance from the inlet.
Cascades on Clyde

**NO$_3^-$ (µmol/L)**

**Distance from Inlet (m)**

**BEFORE EVENT**

1 Day AFTER

3 Days AFTER

**δ$^{15}$N-NO$_3^-$ (%)**

**Distance from Inlet (m)**

**BEFORE EVENT**

1 Day AFTER

3 Days AFTER
Cascades on Clyde

- **Nitrification** of ammonium is producing lighter $\text{NO}_3^-$ decreasing the $\delta^{15}\text{N-NO}_3^-$ in the ‘residual’ pool

- Moving toward the outlet $\text{NO}_3^-$ becomes more limited promoting $\text{N}_2$ **fixation** introducing lighter $\delta^{15}\text{N}$ into the system
Kelletts Drain

Graph showing the concentration of NO$_3^-$ (µmol/L) and δ$^{15}$N-NO$_3^-$ (%) across different distances from the inlet of the drain, before an event.
Kelletts Drain

NO$_3^-$ (µmol/L) vs. Distance from Inlet (m)

- BEFORE EVENT
- 1 Day AFTER
- 3 Days AFTER

δ$^{15}$N-NO$_3^-$ (%o) vs. Distance from Inlet (m)

- BEFORE EVENT
- 1 Day AFTER
- 3 Days AFTER
- The residual NO$_3^-$ gets heavier 3 days after the event which is consistent with assimilation
Anvil Way

**[NO₃⁻]**

- **BEFORE EVENT**
- **1 Day AFTER**

**δ¹⁵N-NO₃⁻**

- **BEFORE EVENT**
- **1 Day AFTER**
Anvil Way

[Graph showing changes in $\text{NO}_3^-$ and $\delta^{15}\text{N}-\text{NO}_3^-$ concentrations before and after an event at Anvil Way.]

- $\text{NO}_3^-$ (µmol/L)
- Distance from Inlet (m)
- $\delta^{15}\text{N}-\text{NO}_3^-$ (%)

- BEFORE EVENT
- 1 Day AFTER
- 3 Days AFTER
δ¹⁸O-NO₃⁻ vs δ¹⁵N-NO₃⁻

- **Mixing** with rainwater and no observed transformation
- The δ¹⁵N-NO₃⁻ moves back to the pre-event state
- δ¹⁵N-NO₃⁻ is heavy because most of the drainage from upstream is supplied from groundwater
What did we see?

Cascades on Clyde, Melbourne

Decrease $\delta^{15}$N-NO$_3^-$
Nitrification or N$_2$ fixation

Kelletts Drain, Melbourne

Increase $\delta^{15}$N-NO$_3^-$
Assimilation

Anvil Way Compensation Basin, Perth

Mixing
No transformation

Perth

Melbourne
Conclusions

- The use of $\delta^{15}N$ and $\delta^{18}O$ of NO$_3^-$ (and fractionation factors) for wetland components confirm the assimilation and denitrification enrichment trends observed in the literature.

- Wetlands do NOT behave uniformly – vegetation/turbidity and water flow paths greatly influence how (and if) nitrogen is removed.
Project B – Developing urban river restoration decision support system is led by Peter Davies and undertaken by Dr Leah Beesley in Albany.

The Department of Water River Health team were introduced as co-delivery partners in 2015.

The objective of the project is to develop a suite of decision support tools that can assist urban river managers to prioritise effective on ground activities that will repair or protect the important “drivers” of stream ecosystems.

What do we mean by “driver”? 

What do we mean by “driver”?

Components of the physical, chemical and biotic system that influence stream health.

Hydrology is the master driver of stream health....

But, if river managers are not in a position to alter the current state, what else can we do to still improve the ecological condition?
Can we do more in our urban stream than just ‘pretty them up’? Can we improve ecosystem function?

Much of the early work in this project focused on these drivers of stream health and exploring their capacity to recover from the stress of urbanisation. The reviews across multiple disciplines indicated that:

Management effort will yield greatest result when it targets ecosystem components that:

a) Exert significant influence on ecosystem function of a site,

b) Are highly altered from their aspired state, and

c) Have a good capacity to recover.
Project Background

Can we do more in our urban stream than just ‘pretty them up’? Can we improve ecosystem function?

Much of the early work in this project focused on these drivers of stream health and exploring their capacity to recover from the stress of urbanisation. The reviews across multiple disciplines indicated that:

*Management effort will yield greatest result when it targets ecosystem components that:*

  a) Exert significant influence on ecosystem function of a site,
  b) Are highly altered from their aspired state, and
  c) Have a good capacity to recover.

How does one figure this out?
Project Background

During the development of a River Action Plan or River Restoration Plan, a systems assessment and prioritisation process is undertaken.

When data has been complied from the systems assessment, it can be challenging deciding what is important in rehabilitating or protecting the site.

Identifying which suite of driver is important for a particular site is key.

Early work developing typologies for this project identified that depending if you are in a headwater environment or lowland environment, surface runoff or groundwater driven environment, the relative influence of each driver, is different.

Management actions at one site, may be more or less beneficial at another site depending on the relative influence of the driver that the particular action targets.
B2.23 is developing an Urban Water Restoration Framework that guides managers through the system assessment and prioritisation process when developing a River Action Plan, with urban specific tools and guidelines along the way.

These supporting tools include:

(i) ‘RESTORE’ - a tool that synthesizes multi-disciplinary current state of knowledge to guide the **prioritisation of important drivers and on-ground management actions**,  
(ii) the determination of multiple **biotic indicators** of stream condition to help managers evaluate the state of urban waterways and restoration success,  
(iii) an analytical framework that allow **site-specific reference condition to be predicted for biotic indicators**, and  
(iv) **guidelines** for determining appropriate **riparian buffers**.

1. **Exert significant influence on ecosystem function of a site**,  
2. **Are highly altered from their aspired state**,  
3. **Have a good capacity to recover**.
Restoration Framework...

Guiding managers along a restoration pathway

Background
Management need
Who should use this tool?
What does it do?
Instructions for use
Supporting documents
Scientific justification
What is the framework, & what does it do?

The Framework is a series of questions that directs managers to obtain the information required to assist them to make three key decisions.

Decision 1. which on-ground actions should be implemented to optimise ecological improvement or protection at their site, given urban constraints.

Decision 2. what ecological targets are being aimed for and what parameters (i.e., ecological indicators) should be monitored to assess the success of the intervention.

Decision 3. when and how should monitoring take place to evaluate the success of the restoration intervention.

The Framework uses knowledge from many sources to assist in the decision-making-process.
The Restoration Framework guides managers through 11 steps.

Step 1. Explicitly state the goal or aims of your restoration activity
Step 2. Use the RESTORE tool to determine which ecosystem components are management priorities
Step 3. Identify the ecological elements you want to improve/protect/create for the priority ecosystem components
Step 4. Identify an ecological indicator to describe each ecological element
Step 5. Determine the aspirational condition for each indicator
Step 6. Determine the current condition of each indicator this will reveal how much the indicator has departed from aspiration
Step 7. Set a realistic target for each indicator given your management intervention
Step 8. Create a list of on-ground actions that should improve the ecological elements of interest (see BMP table)
Step 9. Refine targets given on-ground actions
Step 10. Implement on-ground actions
Step 11. Monitor ecological indicators at the appropriate spatial-temporal scale to evaluate success.
The framework

START

Is ecological health (stream integrity) a primary goal?

YES

Are you interested in holistic (general) ecosystem condition?

YES

Use the RESTORE tool to prioritise ecosystem components for repair

Identify the ecological elements you want to improve/protect/create for the priority ecosystem components

Identify at least one ecological indicator to describe each ecological element

What is the aspirational goal of restoration?

Rehabilitation towards historic condition

Protection of current condition

Set targets for each indicator given your management intervention and aims

Iterative refinement of targets

Determine on-ground actions that will improve the ecological elements of interest

Implement on-ground management intervention

Monitor & evaluate indicators for recovery/maintenance/creation

NO, I know which ecosystem components I want to manage

This framework is not appropriate

Are you interested in holistic (general) ecosystem condition?

NO

Identify the ecological elements you want to improve/protect/create for the priority ecosystem components

Identify at least one ecological indicator to describe each ecological element

What is the aspirational goal of restoration?

Rehabilitation towards historic condition

Protection of current condition

Set targets for each indicator given your management intervention and aims

Iterative refinement of targets

Determine on-ground actions that will improve the ecological elements of interest

Implement on-ground management intervention

Monitor & evaluate indicators for recovery/maintenance/creation

Refine list of ecological elements and indicators if needed

START

YES

NO

This framework is not appropriate
Step 1. Setting the scene...

Provide information about your restoration activity and your goals.

**Question**

Are you wanting to protect, repair or create an urban waterway? ?

What is the aspirational goal for the site? ?

**Answer (select)**

- Rehabilitation

- Historical reference condition

*Go to RESTORE*
RESTORE...

Optimising ecological gains to urban stream sites by prioritising the natural ecosystem components for repair

Management need
Who should use this tool?
How does the tool work?
Instructions for use
Supporting documents
Restoration Framework
Scientific justification

Click here to begin
RESTORE is a conceptual tool that supports urban stream restoration.

The tool synthesizes existing knowledge from multiple disciplines and across multiple spatial scales of influence (site/reach → catchment/region) to determine *the ecological components that should be the focus of management attention*.

RESTORE’s premise is that management effort will yield the largest ecological return when it targets ecosystem components that:

(i) exert significant influence on the ecosystem function of the site,
(ii) are highly altered, and
(iii) have a good capacity for recovery.
How does the tool work?

There are 9 components important to stream health:

- biota
- hydrology
- riparian zone,
- physical water quality
- vertical connectivity.
- nutrients
- geomorphology
- longitudinal connectivity
- lateral connectivity

The tool ranks stream components according to three criteria:

Criterion 1. Importance to natural ecosystem function
Criterion 2. Severity of its departure from reference condition
Criterion 3. Potential for recovery

Prioritisation happens behind the scenes, all you need to do is answer a series of questions.

Click here to begin

Ecosystem components that receive a high score should be prioritised over components that receive a low score.
The three criteria are prioritised using information about the environmental characteristics both today (current) and in the past (e.g. historical condition) and by information about urban development.

**Large Scale Factors**
- Area of urban catchment
- Type of stormwater management
- Future development projections of catchment
- Fragmentation of river network by roads
- Dam or barriers in catchment

**Meso & Fine Scale Factors**
- Distance from stream to urban development
- Stormwater drains at site
- Groundwater pumping nearby
- Leaky water and wastewater infrastructure
- Barriers to fish passage
- Flow regulating structure upstream

**Environmental characteristics**

**Large Scale Factors**
- Climate
- Vegetation
- Geology
- Physiography
- Biogeography
- Prior agricultural land use

**Meso & Fine Scale Factors**
- Position in River Continuum
- Tributary effects
- Instream habitat attributes
- Etc.

**9 Ecosystem Components Driving Stream Function**

Criterion 1. Importance to natural ecosystem function
Criterion 2. Severity of stress due to urban development
Criterion 3. Potential for recovery
Questions need to be answered from different spatial scales & different perspectives...

You need to answer questions about the current characteristics of your site and your aspirational condition.

Current condition:
- 32 site questions
- 13 catchment questions

Click here

You need to answer questions about your site & the catchment it sits within.

Aspirational condition:
- 14 site questions
- 7 catchment questions

Click here
Current environmental attributes of the site...

Instructions. Answer the questions below using the current physical attributes of the site. A visit to the site or GIS mapping may assist.

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer (select)</th>
<th>Question</th>
<th>Answer (select)</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the stream order of the site?</td>
<td>3</td>
<td>What is the dominant geomorphic unit?</td>
<td>run</td>
</tr>
<tr>
<td>What is the orientation of the stream channel?</td>
<td>East-west</td>
<td>Is there much spatial complexity in geomorphic units?</td>
<td>Low complexity</td>
</tr>
<tr>
<td>What is channel sinuosity?</td>
<td>meandering</td>
<td>What is the soil pH of the channel bank?</td>
<td>unknown</td>
</tr>
<tr>
<td>What is the material of the channel bed</td>
<td>Sand and gravel</td>
<td>Is the site upstream of a knick point?</td>
<td>no</td>
</tr>
<tr>
<td>What is the width of the riparian buffer?</td>
<td>10 – 50 m</td>
<td>What % of the riparian veg. has been cleared?</td>
<td>&gt;50%</td>
</tr>
<tr>
<td>Is the riparian zone trees, shrubs or grass?</td>
<td>forested</td>
<td>What % of the riparian veg. is non-native?</td>
<td>&gt;75-100%</td>
</tr>
<tr>
<td>What is the dominant soil type of the riparian zone?</td>
<td>sand</td>
<td>What season does most leaf litter fall?</td>
<td>autumn</td>
</tr>
<tr>
<td>What is the slope of the riparian zone?</td>
<td>&lt; 10%</td>
<td>How much organic matter is there in the soil?</td>
<td>low</td>
</tr>
<tr>
<td>Is flow perennial or intermittent?</td>
<td>perennial</td>
<td>What is the min. depth to groundwater during the year?</td>
<td>2-4 m</td>
</tr>
<tr>
<td>Does the site experience protracted periods of low flow?</td>
<td>yes</td>
<td>Is the site connected downstream of a flow regulating structure?</td>
<td>no</td>
</tr>
<tr>
<td>Do low flows occur during warm months?</td>
<td>yes</td>
<td>How stained (coloured) is the water?</td>
<td>Deeply tannin stained</td>
</tr>
<tr>
<td>Does the site experience high velocity scouring flows?</td>
<td>unknown</td>
<td>Is baseflow falling or rising?</td>
<td>rising</td>
</tr>
<tr>
<td>Is the site near a tributary?</td>
<td>&gt; 100 m from tributary</td>
<td>Is the site connected to a floodplain?</td>
<td>Not connected</td>
</tr>
<tr>
<td>How much LWD is there in the channel?</td>
<td>&lt; 1 piece per 10m</td>
<td>Is there a natural recharge area nearby?</td>
<td>NA</td>
</tr>
<tr>
<td>Has past agriculture led to elevated salinity?</td>
<td>yes</td>
<td>Are there threatened or endangered species at the site?</td>
<td>Not at site, but in system</td>
</tr>
<tr>
<td>Are there ASS at the site or nearby upstream?</td>
<td>no</td>
<td>How far is the site to a refuge?</td>
<td>&lt; 1 km</td>
</tr>
</tbody>
</table>
**Instructions. Answer the questions below using the current urban attributes of the site. A visit to the site or GIS mapping may assist.**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer (select)</th>
</tr>
</thead>
<tbody>
<tr>
<td>How close to the stream is urban development?</td>
<td>50-100 m</td>
</tr>
<tr>
<td>Do stormwater drains feed into the site or upstream?</td>
<td>At the site</td>
</tr>
<tr>
<td>Do subsurface drains feed into the site or upstream?</td>
<td>&lt; 1 km upstream</td>
</tr>
<tr>
<td>Is groundwater pumped within 100m of the site?</td>
<td>Yes – residential bores</td>
</tr>
<tr>
<td>Do underground water mains and sewage infrastructure leak?</td>
<td>None or little leakage</td>
</tr>
<tr>
<td>Are there barriers to fish passage at the site?</td>
<td>Yes – a culvert</td>
</tr>
<tr>
<td>Has the stream channel been revetted?</td>
<td>Rock lining in places</td>
</tr>
<tr>
<td>Could channel redesign cause a flood risk to people or infrastructure?</td>
<td>Highly unlikely</td>
</tr>
<tr>
<td>Is the site connected downstream of a flow regulating structure?</td>
<td>Yes, downstream of detention basin</td>
</tr>
<tr>
<td>Is the site close to an artificial aerator?</td>
<td>no</td>
</tr>
<tr>
<td>Are there levees or regulating structures preventing floodplain inundation?</td>
<td>no</td>
</tr>
<tr>
<td>Is there a point source WQ pollution occurring at the site or in the upstream reach?</td>
<td>Yes, industrial discharge</td>
</tr>
<tr>
<td>Is there a non-point source WQ pollution occurring at the site or in the upstream reach?</td>
<td>Yes, residential use of herb/pesticides</td>
</tr>
</tbody>
</table>
Current environmental attributes of the catchment...

Instructions. Answer the questions below using the current physical attributes of the site. A visit to the site or GIS mapping may assist.

**Question**

Is the catchment flat or steeply sloped?
- Very flat (<1% slope)
- Sand, high permeability

Is the soil permeability of the catchment low or high?
- Sand, high permeability

Can rainfall intensity be high?
- yes

What is the flow class of your site?
- Stable winter baseflow

What is the min. depth to groundwater during the year?
- 2-4 m

Is the climate drying?
- markedly

Is the aquatic food web of river system reliant on the migration of fish from the ocean/estuary?
- unlikely

Do biota of interest have a high capacity for dispersal?
- unknown

Are non-native aquatic species present downstream but not at your site?
- yes

**Answer (select)**

- More information about the question
- How does this affect stream function?

**Stream Function:** Catchment slope affects how much rain flows over the surface (i.e., runoff) of the land, hence it affects stream flow. Flatter landscapes experience lower runoff than sloped landscapes.

**Susceptibility to Urban Stress:** Studies have found that flat landscapes experience reduced peak discharges than sloped landscapes after urbanisation (Utz et al. 2011, Hopkins 2015); therefore, sloped landscapes are more susceptible to urban flow stress.
Instructions. Answer the questions below using the current urban attributes of the site. A visit to the site or GIS mapping may assist.

### Question

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer (select)</th>
</tr>
</thead>
<tbody>
<tr>
<td>What % of the catchment is impervious?</td>
<td>10-30%</td>
</tr>
<tr>
<td>How large is the catchment's urban area?</td>
<td>&lt;5km²</td>
</tr>
<tr>
<td>What is the dominant type of stormwater management?</td>
<td>Stormwater piped to drainage lines</td>
</tr>
<tr>
<td>What is the drainage density?</td>
<td>0.41 – 0.89 km²</td>
</tr>
<tr>
<td>What % of natural vegetation has been cleared</td>
<td>75-100%</td>
</tr>
<tr>
<td>Could channel redesign cause a flood risk to people or infrastructure?</td>
<td>Highly unlikely</td>
</tr>
<tr>
<td>Is there currently, or likely to be, urban development in the upstream catchment?</td>
<td>No</td>
</tr>
<tr>
<td>Is there likely to be coarse sediment (sand, gravel) running into drainage lines associated with ongoing urban development?</td>
<td>NA</td>
</tr>
<tr>
<td>Is there likely to be fine sediment (silt) running into drainage lines associated with ongoing urban development or agriculture?</td>
<td>unknown</td>
</tr>
<tr>
<td>Is the river network upstream of the site highly fragmented by roads and other urban development?</td>
<td>Yes, &gt; 10 road crossings</td>
</tr>
<tr>
<td>Is much of the upstream river network buried?</td>
<td>yes, 10-50% is piped</td>
</tr>
<tr>
<td>Is there a dam upstream that is affecting the thermal or oxygen regime of the site?</td>
<td>no</td>
</tr>
<tr>
<td>Are there barriers upstream or downstream preventing the ingress of important species (e.g. native fish)?</td>
<td>Yes, effect on fish unclear</td>
</tr>
</tbody>
</table>
Prioritisation output...

The natural ecosystem components prioritised for repair at your restoration site
Using the output of RESTORE, provide information about the ecosystem components for management attention.

### Question

Which ecosystem components are considered to be a management priority for your site? List in descending order of importance.

### Answer (select)

<table>
<thead>
<tr>
<th>Component</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrology (flow)</td>
<td>Priority 1</td>
</tr>
<tr>
<td>Nutrients, Water Quality</td>
<td>Priority 2</td>
</tr>
<tr>
<td>Riparian</td>
<td>Priority 3</td>
</tr>
<tr>
<td>Vertical Connectivity</td>
<td>Priority 4</td>
</tr>
<tr>
<td>Physico-chemical, Water Quality</td>
<td>Priority 5</td>
</tr>
<tr>
<td>Geomorphology</td>
<td>Priority 6</td>
</tr>
<tr>
<td>Lateral Connectivity</td>
<td>Priority 7</td>
</tr>
<tr>
<td>Longitudinal Connectivity</td>
<td>Priority 8</td>
</tr>
<tr>
<td>Biota</td>
<td>Priority 9</td>
</tr>
</tbody>
</table>

Go to next step
Step 3.

Ecological elements for repair or protection...

**Of your priority ecosystem components, choose elements are you interested in repairing, protecting or creating?**

<table>
<thead>
<tr>
<th>Ecosystem Components</th>
<th>Element 1</th>
<th>Element 2</th>
<th>Element 3</th>
<th>Element 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Priority 1</td>
<td>Hydrology (flow)</td>
<td>Flow volume</td>
<td>Flow permanence</td>
<td>Rate of rise and fall</td>
</tr>
<tr>
<td>Priority 2</td>
<td>Nutrients, Water Quality</td>
<td>Nitrate</td>
<td>Phosphorus</td>
<td><strong>select</strong></td>
</tr>
<tr>
<td>Priority 3</td>
<td>Riparian</td>
<td>Stream shading</td>
<td>Instream habitat creation</td>
<td><strong>select</strong></td>
</tr>
<tr>
<td>Priority 4</td>
<td>Vertical Connectivity</td>
<td>Baseflow</td>
<td>Channel unit complexity</td>
<td><strong>select</strong></td>
</tr>
<tr>
<td>Priority 5</td>
<td>Physico-chemical, Water Quality</td>
<td>Temperature</td>
<td>Salinity</td>
<td><strong>select</strong></td>
</tr>
<tr>
<td>Priority 6</td>
<td>Geomorphology</td>
<td>Channel unit complexity</td>
<td>Bank stability</td>
<td><strong>select</strong></td>
</tr>
<tr>
<td>Priority 7</td>
<td>Lateral Connectivity</td>
<td>select</td>
<td>select</td>
<td><strong>select</strong></td>
</tr>
<tr>
<td>Priority 8</td>
<td>Longitudinal Connectivity</td>
<td>select</td>
<td>select</td>
<td><strong>select</strong></td>
</tr>
<tr>
<td>Priority 9</td>
<td>Biota</td>
<td>select</td>
<td>select</td>
<td>select</td>
</tr>
</tbody>
</table>

*Element selection should reflect ecosystem component priorities. That is, you should select more elements for the ecosystem components considered to be a priority. The exception may be biota, which itself may not exert a marked influence on general stream function, it can provide a holistic description of stream condition (i.e. biota can synthesise improvement in multiple physical factors).*
For each of your priority elements, the tool automatically generates a list of potential ecological indicators. Select the ecological indicators that are relevant to your urban region.

<table>
<thead>
<tr>
<th>Priority Elements</th>
<th>Ecological indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow volume</td>
<td>Discharge (ML/d, ML/yr)</td>
</tr>
<tr>
<td>Flow permanence</td>
<td># days no flow per year</td>
</tr>
<tr>
<td>Flow velocity</td>
<td>select</td>
</tr>
<tr>
<td>Rate of rise and fall</td>
<td>select</td>
</tr>
<tr>
<td>Nitrate</td>
<td>NOX</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Soluble Reactive P</td>
</tr>
<tr>
<td>Organic nitrogen</td>
<td>Total organic N (mg/L)</td>
</tr>
<tr>
<td>Stream shading</td>
<td>select</td>
</tr>
<tr>
<td>Instream habitat creation</td>
<td>select</td>
</tr>
<tr>
<td>Vegetation nativeness</td>
<td>select</td>
</tr>
<tr>
<td>Upstream continuity</td>
<td>select</td>
</tr>
<tr>
<td>Baseflow</td>
<td>Baseflow index</td>
</tr>
</tbody>
</table>

**Biodiversity ecological indicators**

- **Macroinvertebrates**
  SIGNAL. Suitable for south-eastern Australia, but not WA. Macroinvertebrate family richness, suitable for all states.

- **Fish**
  Total native species richness. Suitable for all states.
Step 5.

Aspirational condition...

If your goal is to Protect the health of a waterway not improve it skip to step 6.  

If your goal is to create a novel living stream, e.g. a stream in an area where there has never been one (new development) skip to step 7.

For each of your ecological indicators use the site-specific Historical Condition Applications, Reference Typology or other tools to determine your aspirational condition, and use field measurements to describe current condition. Models (i.e. apps) generating predictions that are site-specific should be used in preference to generic typologies where data permits.

**Ecological indicator** | **Tool** | **Aspirational condition**
---|---|---
Discharge (ML/d, ML/yr) | [Reference typology](#) | enter
# days no flow per year | [Reference typology](#) | enter
select | [Reference typology](#) | enter
select | [Reference typology](#) | enter
Nitrate, Nitrite (NOX) | [Historical condition application](#) | enter
Soluble Reactive P | [Historical condition application](#) | enter
Total organic N (mg/L) | [Historical condition application](#) | enter
select | [Historical condition application](#) | enter
select | [Historical condition application](#) | enter
select | [Historical condition application](#) | enter
Baseflow index | [Historical condition application](#) | enter
Native fish sp richness | [Historical condition application](#) | enter

*Go to next step*
Next, you need to determine the current condition of the ecological indicators at your site. This can be achieved by field measurements or data recently collected from your site. Once the current condition is entered, the departure from reference will be automatically generated. NB. Departure from Aspiration will only be generated if your goal is rehabilitation.

<table>
<thead>
<tr>
<th>Ecological indicator</th>
<th>Current condition</th>
<th>Departure from Aspiration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge (ML/d, ML/yr)</td>
<td>enter</td>
<td>To be generated</td>
</tr>
<tr>
<td># days no flow per year</td>
<td>enter</td>
<td>To be generated</td>
</tr>
<tr>
<td>Nitrate, Nitrite (NOX)</td>
<td>enter</td>
<td>To be generated</td>
</tr>
<tr>
<td>Soluble Reactive P</td>
<td>enter</td>
<td>To be generated</td>
</tr>
<tr>
<td>Total organic N (mg/L)</td>
<td>enter</td>
<td>To be generated</td>
</tr>
<tr>
<td>Baseflow index</td>
<td>enter</td>
<td>To be generated</td>
</tr>
<tr>
<td>Native fish sp richness</td>
<td>enter</td>
<td>To be generated</td>
</tr>
</tbody>
</table>

Consider removing this parameter from your ecological indicator list unless future development is likely to cause stress to base flow.
Next, you need to set realistic targets for each of your ecological indicators. These should be values you believe are attainable given your management interventions. Mathematical models may be able to assist you in creating realistic targets.

There are several factors you should consider when setting your target.

1. Whether the ecological indicator is shaped by small (e.g., site) or large (e.g., catchment) scale ecological processes
   If small-scale processes are dominant, large improvements in the indicator can be achieved by on-ground actions at the site (e.g., stream shading) and targets can be ambitious. If large-scale processes are dominant, large improvements in the indicator are only possible if on-ground actions occur across the catchment. This may be very difficult to achieve, unless the catchment is very small. Consequently, targets for these indicators (e.g., flow) should be more conservative.

2. The scale of management intervention
   If a management intervention is controlled by large-scale processes (e.g., catchment) then the greater the spatial scale of the intervention the more ambitious the target can be. Note that exceptions occur. For example, if an upstream weir can be controlled to manage flow to the stream site, then an ambitious target for flow could be set even though the spatial scale of influence is small (e.g. the weir).

3. The type of management intervention
   Not all management interventions have the same capacity to deliver ecosystem improvements. If interventions are likely to have a strong direct effect on the indicator then targets can be ambitious, if interventions are likely to have a weak or indirect effect on the indicator then targets should be conservative.

4. Temporal aspects of recovery
   Most ecological components are interdependent, and some are dominant, e.g., flow strongly affects geomorphology. Thus it may not be appropriate to set an ambitious target for certain indicators if influential components of the stream ecosystem have not already been repaired.

5. Future urban development
   Future development within a restoration site’s catchment will increase stress to many ecological indicators, particularly if they are related to catchment-scale processes (e.g., flow). In such instances a target of ‘maintaining current condition’ may be more appropriate than an ‘improvement in condition’.

6. Legacies
   Past land use change can leave long-lasting effects on stream ecosystems, which can make certain targets difficult to achieve. For example, agriculture can cause nutrient levels in soils and streams to remain elevated for decades. In such instances, targets must be adjusted down or the time-frame of achievement needs to be extended.
Step 8.

Create a list of suitable on-ground actions...

Next, you need to create a list of the management actions that can repair your ecological indicators (ecological elements). Use the dropdown menu to identify the ecosystem component and ecological element that describe each ecological indicator. A list of management actions will appear. You must then choose the management actions that can be implemented given fiscal and urban constraints. Drag and drop your list of on-ground actions to your cart.

### Ecosystem Component
- **Nitrate**

### Priority Element
- **Nutrient Water Quality**

### Management objective
- **Reduction**

#### Management strategies
- Reduce nutrient input by people
- Reduce the volume of stormwater
- Clean stormwater prior to it reaching the stream network
- Slow and reduce the transport of nutrient-rich groundwater
- Increase nutrient processing and uptake in the riparian zone
- Increase nutrient processing and uptake instream

### On-ground action

<table>
<thead>
<tr>
<th>On-ground action</th>
<th>Scale</th>
<th>Mechanism</th>
<th>Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construct rain gardens</td>
<td>Street</td>
<td>Nutrients are reduced by filtering and trapping stormwater in sediment and plant media.</td>
<td>High – sediment and vegetation need to...</td>
</tr>
<tr>
<td>Construct vegetated swales</td>
<td>Street</td>
<td>Nutrients are reduced by trapping stormwater.</td>
<td>High – sediment and vegetation need to...</td>
</tr>
<tr>
<td>Construct wetland biofilters</td>
<td>Precinct</td>
<td>Nutrient uptake is enhanced by slowing the flow of water and creating areas rich in macrophytes.</td>
<td>High – sediment and vegetation need to...</td>
</tr>
</tbody>
</table>

### On-ground action

<table>
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<th>Mechanism</th>
<th>Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase stormwater infiltration by various mechanisms.</td>
<td>Catchment</td>
<td>Increasing stormwater infiltration raises the water table which creates more anoxic soil in the riparian zone and improves denitrification.</td>
<td>See STORMWATER INFILTRATION</td>
</tr>
<tr>
<td>Plant native deep-rooted vegetation in riparian zone</td>
<td>Site</td>
<td>Deep-rooted vegetation increases the carbon content of riparian soils. It also increases the depth of the microbial active zone. Trees/shrubs will also uptake nutrients, particularly if fast growing.</td>
<td>Low – none required</td>
</tr>
<tr>
<td>Increase width of riparian buffer</td>
<td>Site</td>
<td></td>
<td>Low – trees bordering roads and paths...</td>
</tr>
<tr>
<td>Create trenches filled with sawdust</td>
<td>Site</td>
<td>Localised reduction in nitrate on other side of trench.</td>
<td></td>
</tr>
</tbody>
</table>
Refine targets given management actions...

Next, revisit your targets for each ecological indicator in light of the management actions you will implement. Targets may need to be refined.

- **Making Targets More Ambitious**
  - If this tool has revealed there are management actions that you were not aware of that are highly effective, you may be able to make your targets more ambitious.

- **Making Targets Less Ambitious**
  - If this tool has revealed that management actions you expected to implement are likely to have poor efficiency given your physiographic setting, you may decide not to implement them and may need to make your targets more conservative.
Next, implement your on-ground management actions.

BUT before you do... consider if the timing of different actions can improve your chance of success.

**Useful tips**

1. Channel reconfiguration is more likely to last if flow has already been fixed
2. Replanting of native understory vegetation is more likely to be successful if weeds have been removed and overstorey vegetation is present to shade seedlings
3. Implement destructive actions (e.g. channel modification) before you implement other actions
Step 10. Monitoring and evaluation...

Finally, you need to monitor your ecological indicators to evaluate if you have reached your restoration/protection or creation target.

To do this you need to monitor at the appropriate spatio-temporal scale, i.e. in the appropriate locations at the appropriate times.

Where to sample?
You need to decide if you only need to sample at the site or at other ‘control’ sites as well. This will depend on how you plan to analyse your data.

To know when to sample you need to know:
1) How much your indicator naturally changes through time unrelated to your management intervention (e.g. seasonally)
2) How much time it will take for intervention to cause a change in your indicator

You also need to decide how you place your sampling effort at the site. This will be determined by how variable the indicator is over fine scale (i.e. within your site). If the indicator is relatively constant across the site then it can be measured at one location.

When to sample?
To answer point 1 you need to understand to what extent your indicator changes hourly, daily, monthly, yearly. If change is considerable you need to standardise sampling so that you can control for these changes.

To answer point 2 you need to have some understanding of how long recovery will take. Some indicators may change relatively quickly (e.g. days to months), whereas others may take years or decades to recover. Resources should not be wasted measuring indicators that have not had sufficient time to respond.
B2.23 developed a urban water restoration framework that guides managers through the system assessment and prioritisation process when developing a River Action Plan, with tools and guidelines along the way.

These supporting tools include:

(i) ‘RESTORE’ - a tool that synthesizes multi-disciplinary current state of knowledge to guide the prioritisation of important drivers and on-ground management actions,

(ii) the determination of multiple Biotic indicators of stream condition to help managers evaluate the state of urban waterways and restoration success,

(iii) an analytical framework that allow site-specific reference condition to be predicted for biotic indicators, and

(iv) guidelines for determining appropriate riparian buffers.
Through the RESTORE tool, the restoration team can identify the important ecosystem components to repair at a site and optimise on-ground works.

Monitoring can be optimised by identifying the most appropriate biotic indicators.

Has the capacity to model reference conditions to support site restoration in areas with little or no data.

Has guidelines regarding effective design dimensions for riparian buffers.
By December 31 – the framework and the restore tool will be embedded into literature and a suite of paper products. 5 papers to date have been submitted to journals.

The models will be held by Department of Water.

There is still a lot of work to undertake.
Thank you.

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&
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