CRC for Water Sensitive Cities

4th water sensitive cities conference

Australian Government
Department of Industry and Science

Business Cooperative Research Centres Programme

Assessing the research: tools to support decision making

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The University of Western Australia

Government of Western Australia
Department of Water

Overview:

- **Project aims**
- **Management need**
- **Decision support tools**
    - ➢ **RESTORE beta version**
    - ➢ **Waterway factsheets**
    - ➢ **Riparian guidelines**

Tools are online at the CRC website

Project aims:

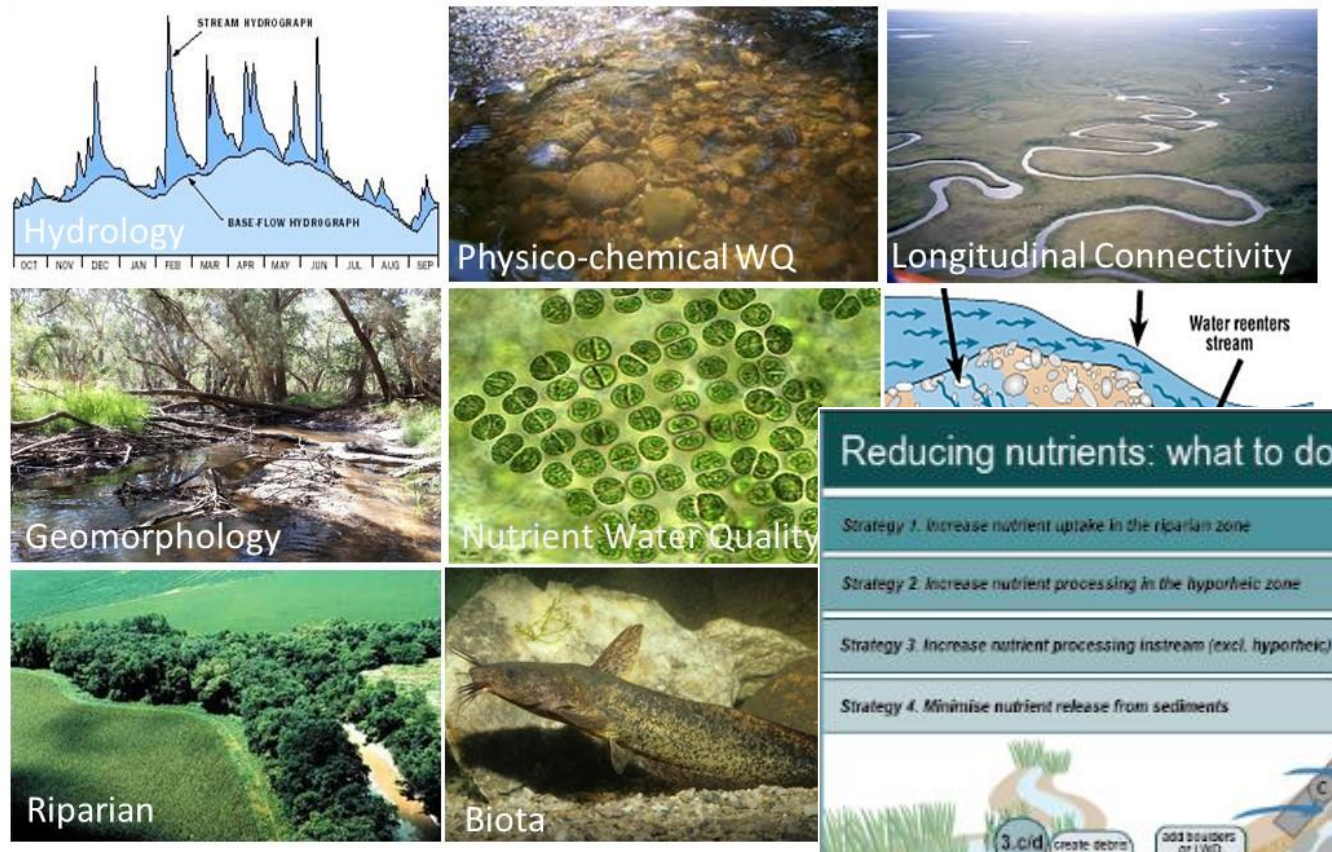
Project B2.2/3

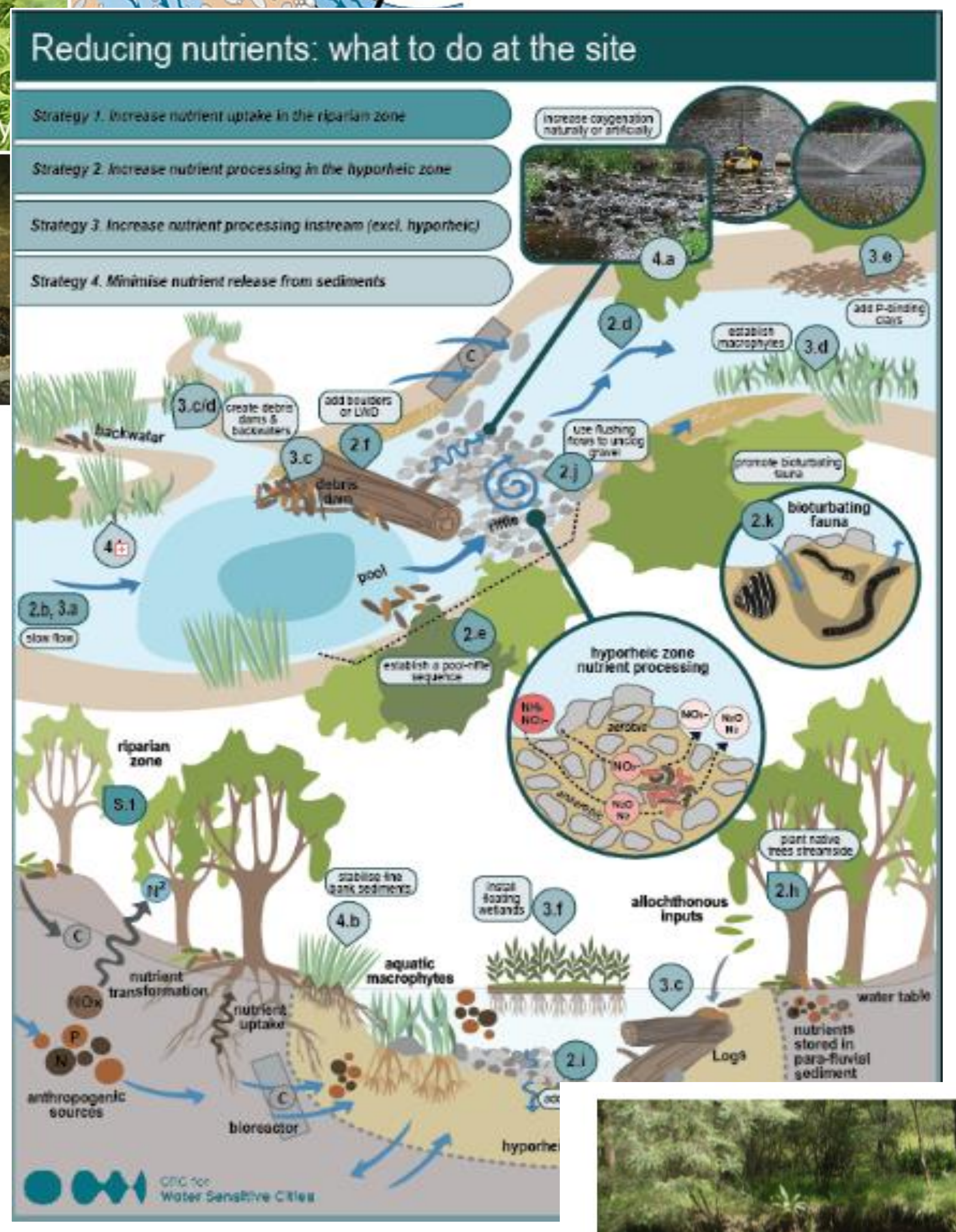
"Protection and restoration of urban freshwater ecosystems: informing management and planning "

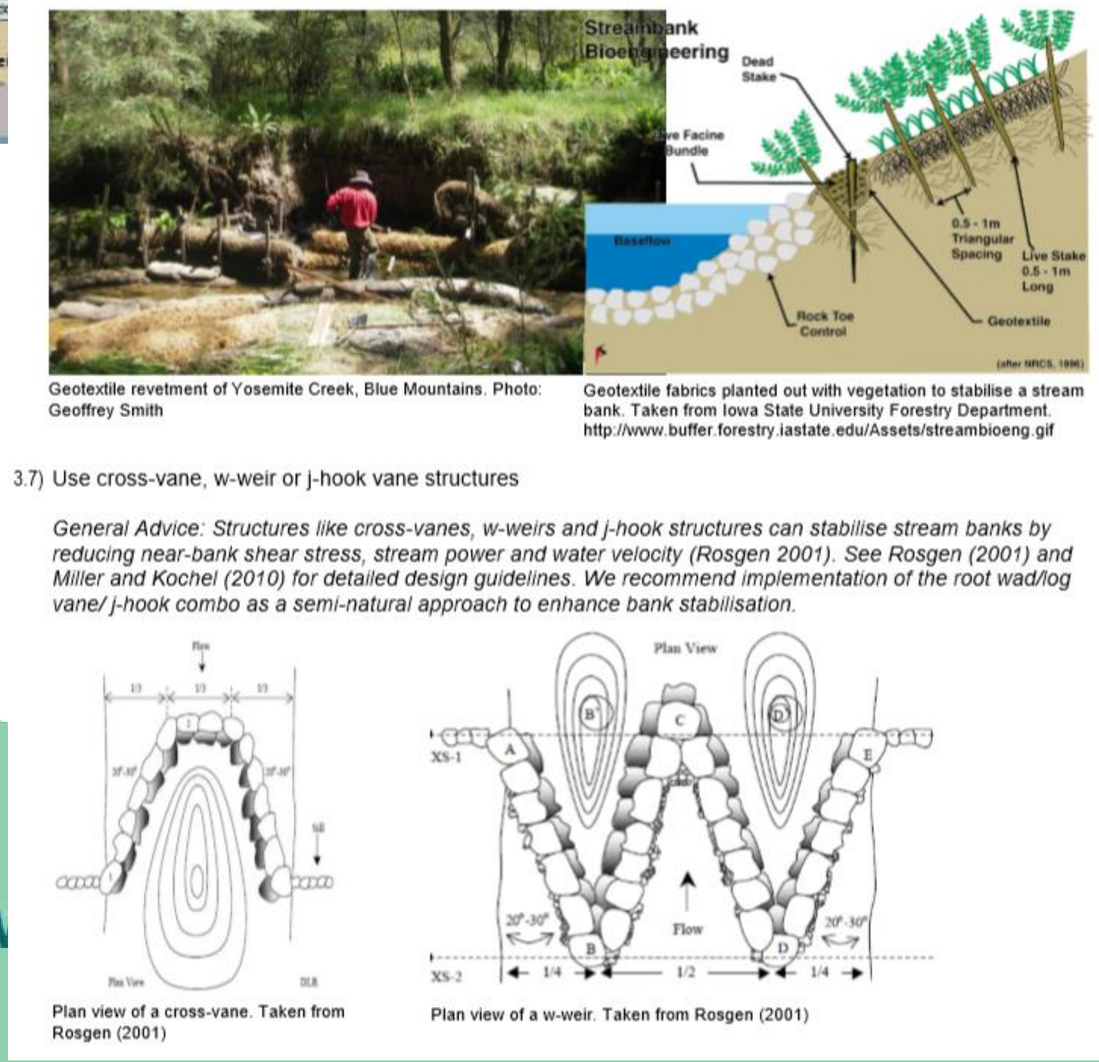
<u>Goals</u>

- To develop tools that support regional decisions to optimise the management and restoration of urban waterways over a range of scales
- To create a platform that houses knowledge and makes it available to practitioners

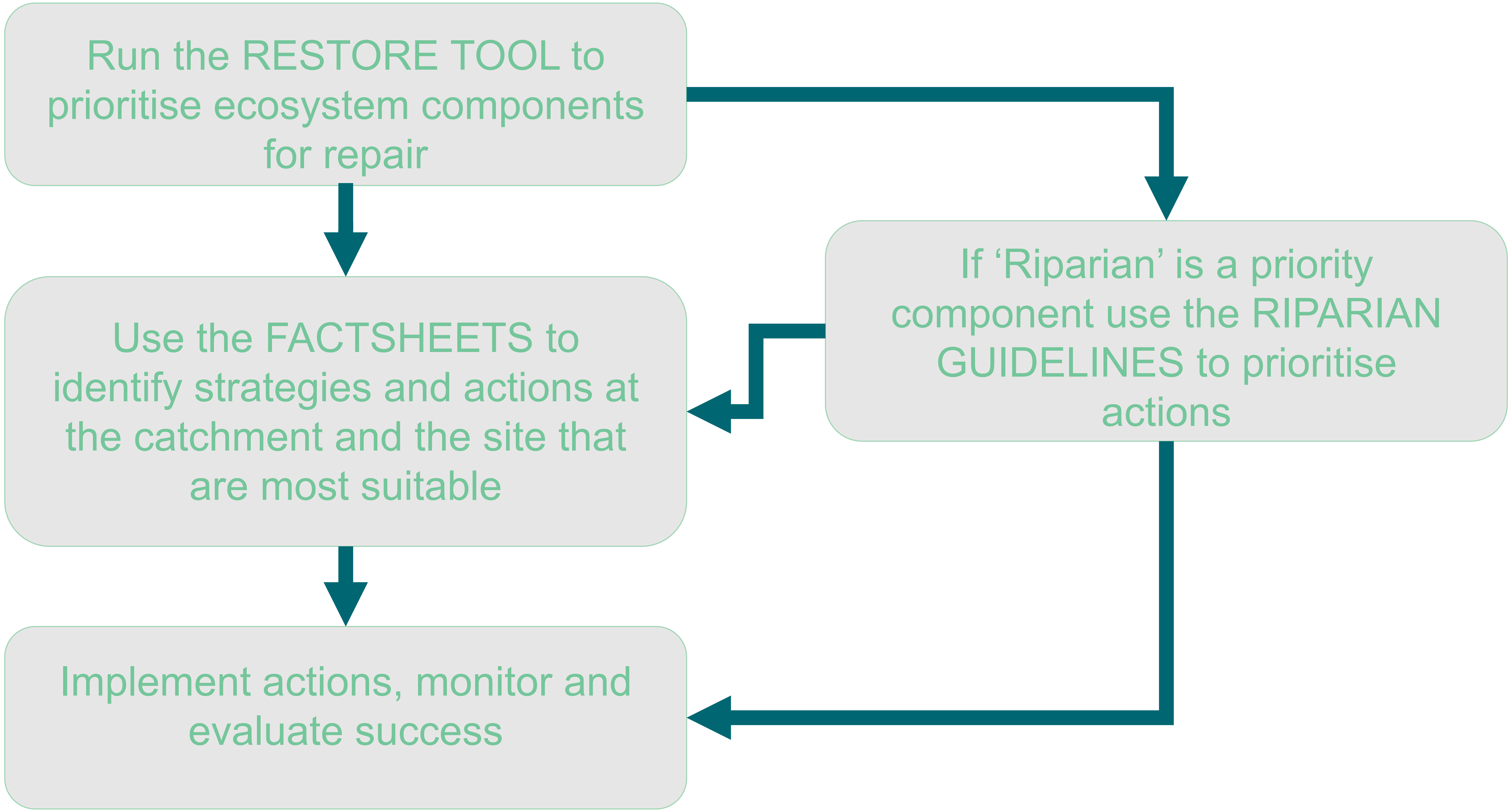
RESTORE... *Optimising ecological gains to urban waterways by prioritising the natural ecosystem components for repair*







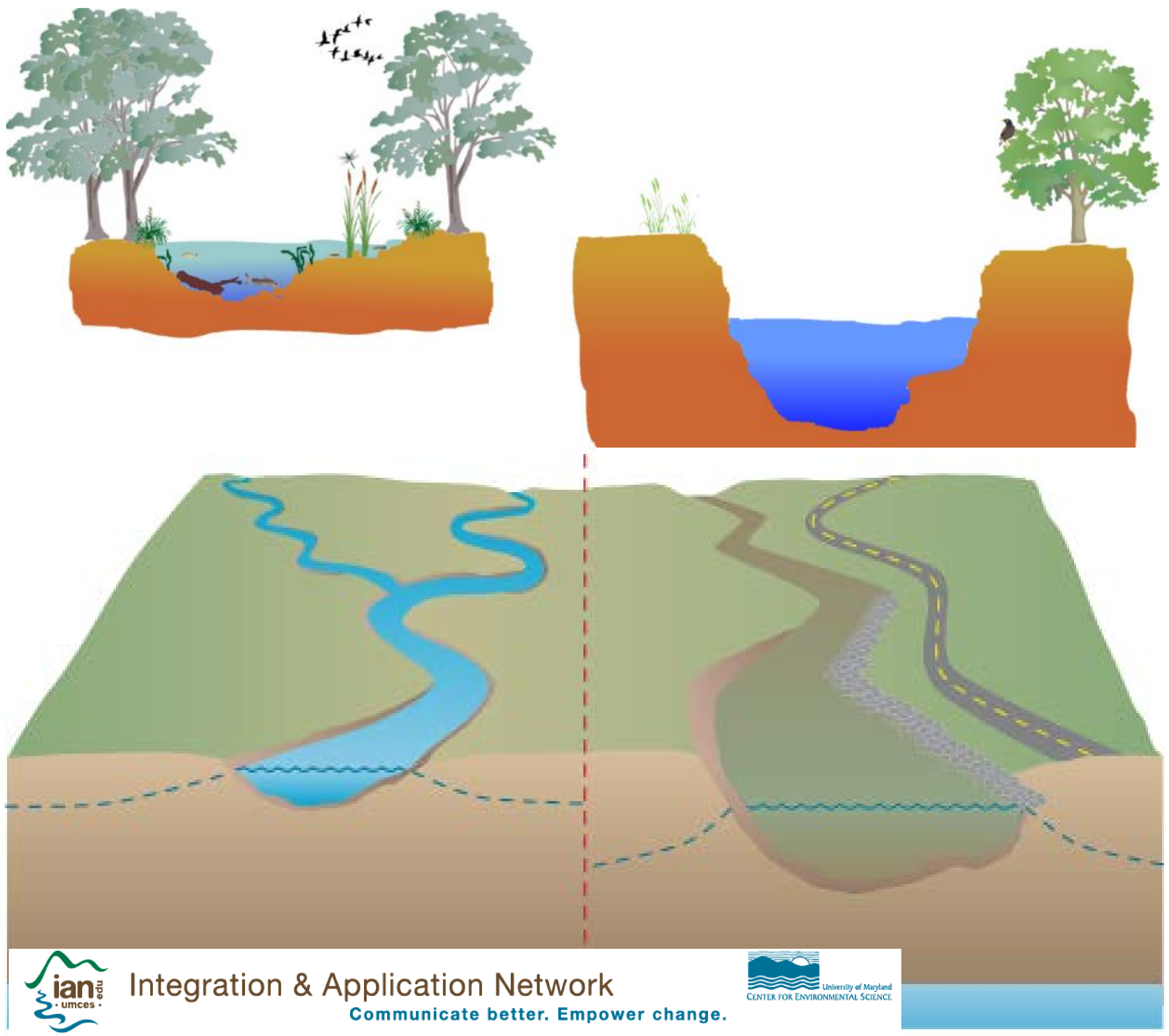
The tools connect:



Background:

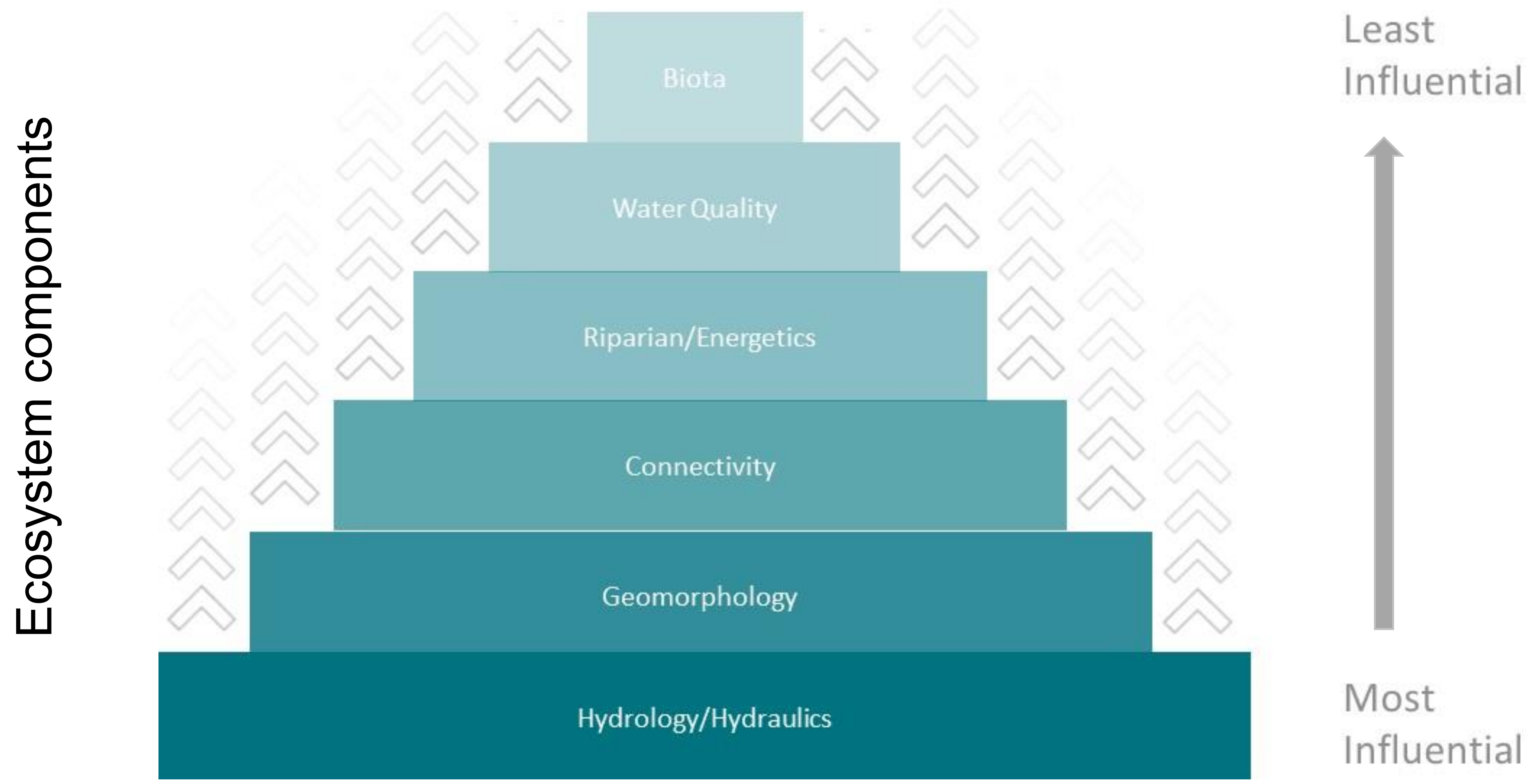
Urban Stream Syndrome

Flashy scouring flows
Increased flow volume
High water temperature
High nutrient & pollutant levels
Eroded channel
Decline in retention of organic matter
Low biodiversity particularly sensitive species



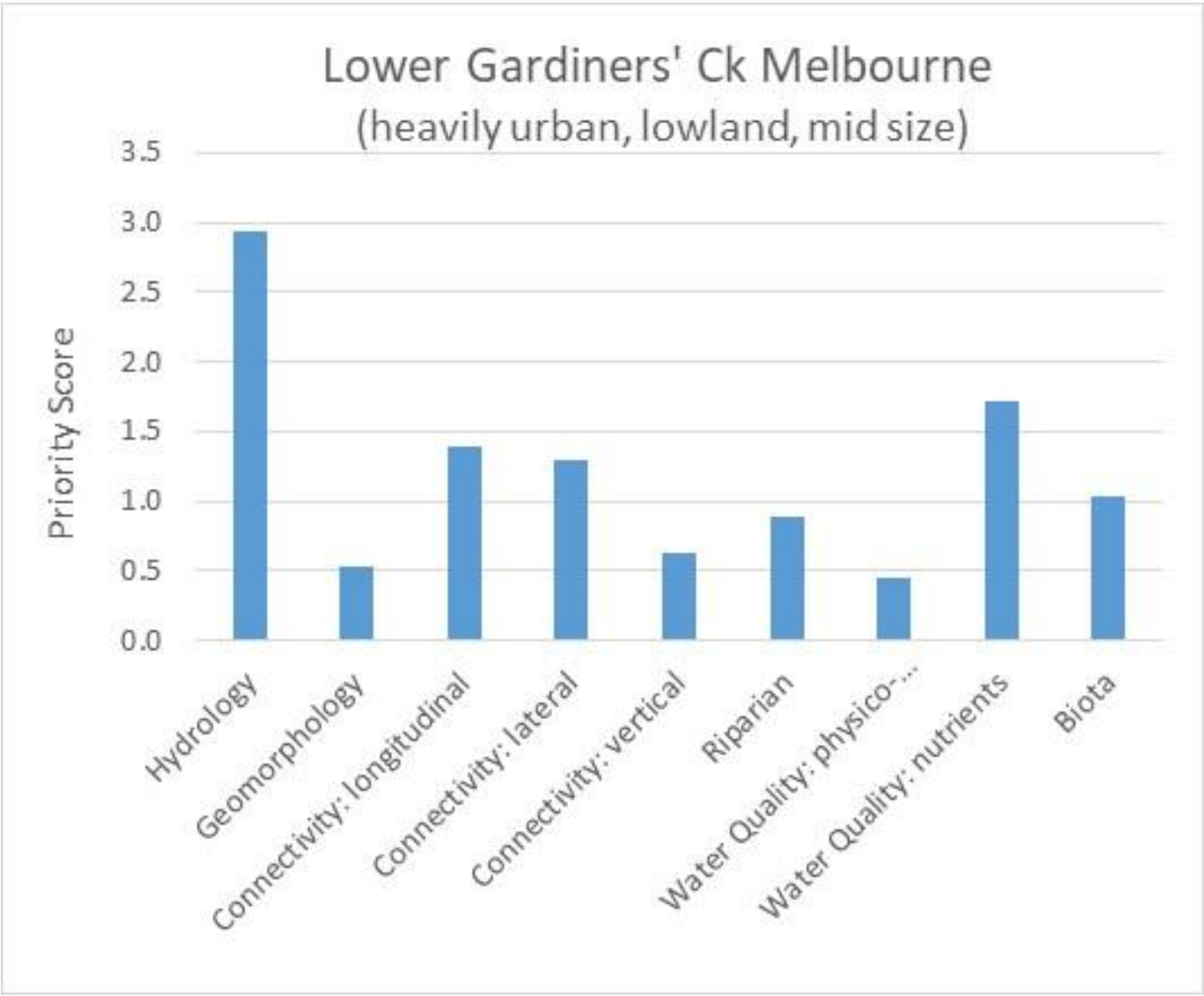
Generic management:

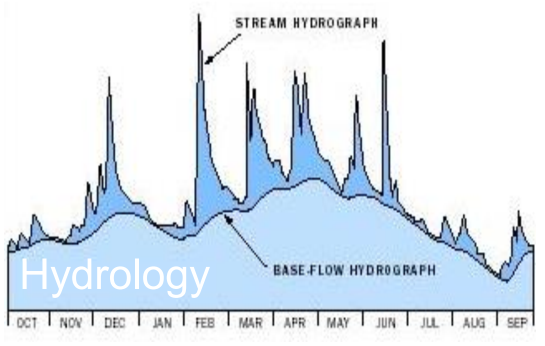
- Stream restoration is typically generic

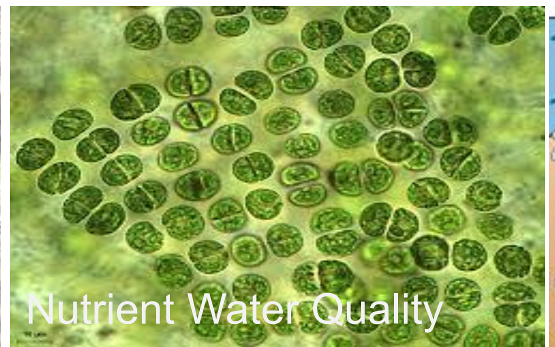


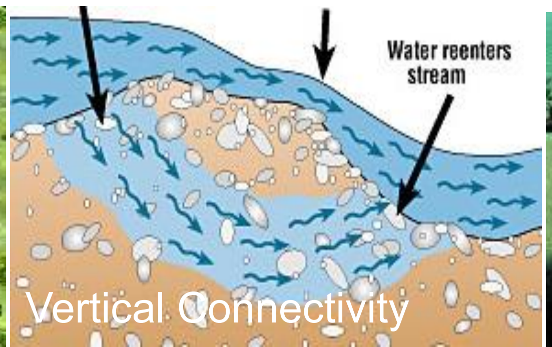
Tailored management:

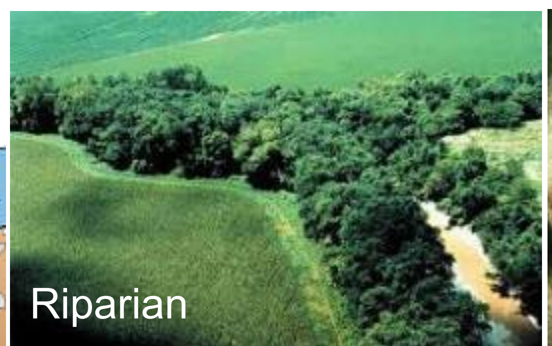
- Position along the river continuum
- Regional setting
- Urban constraints and practices now and into the future





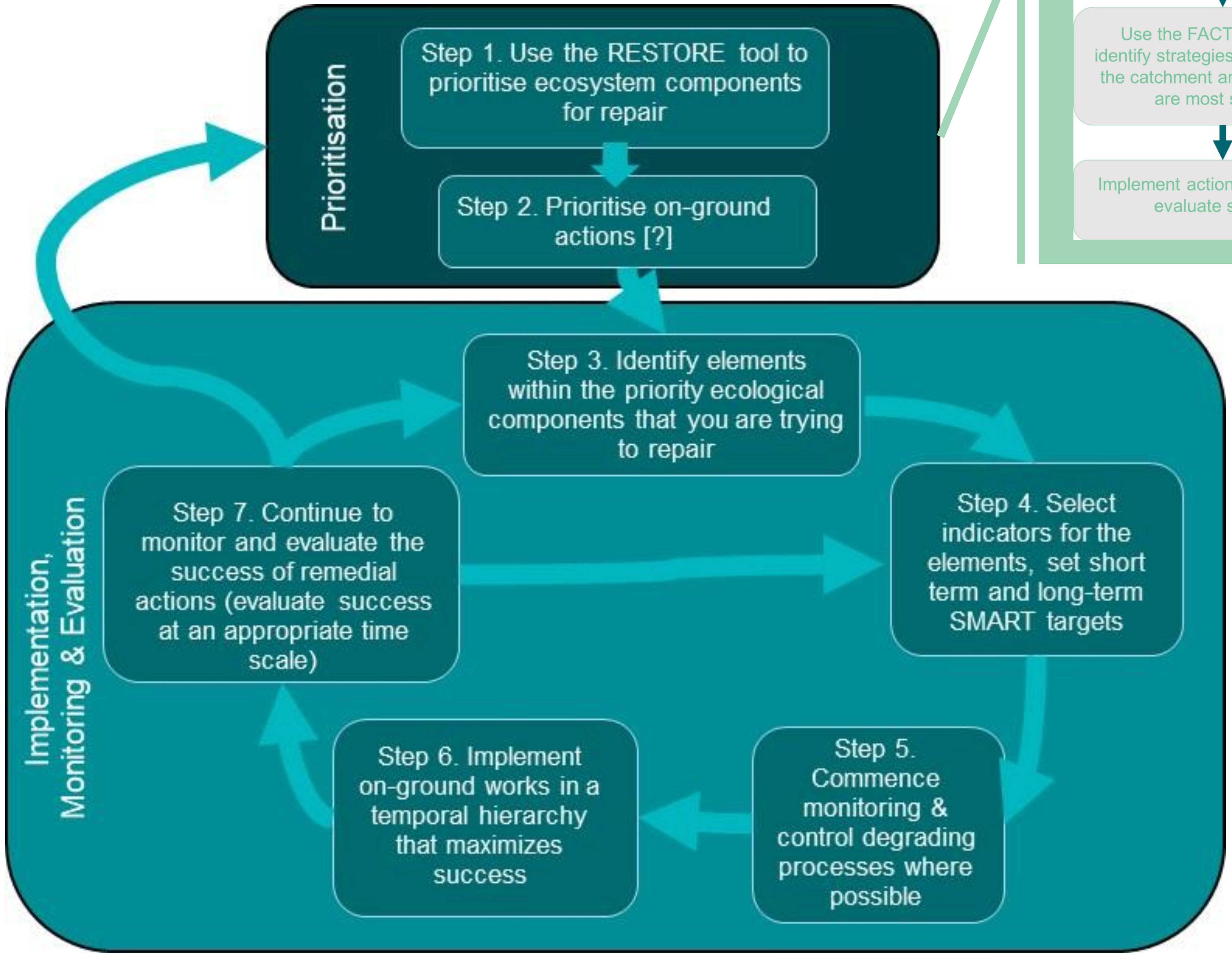


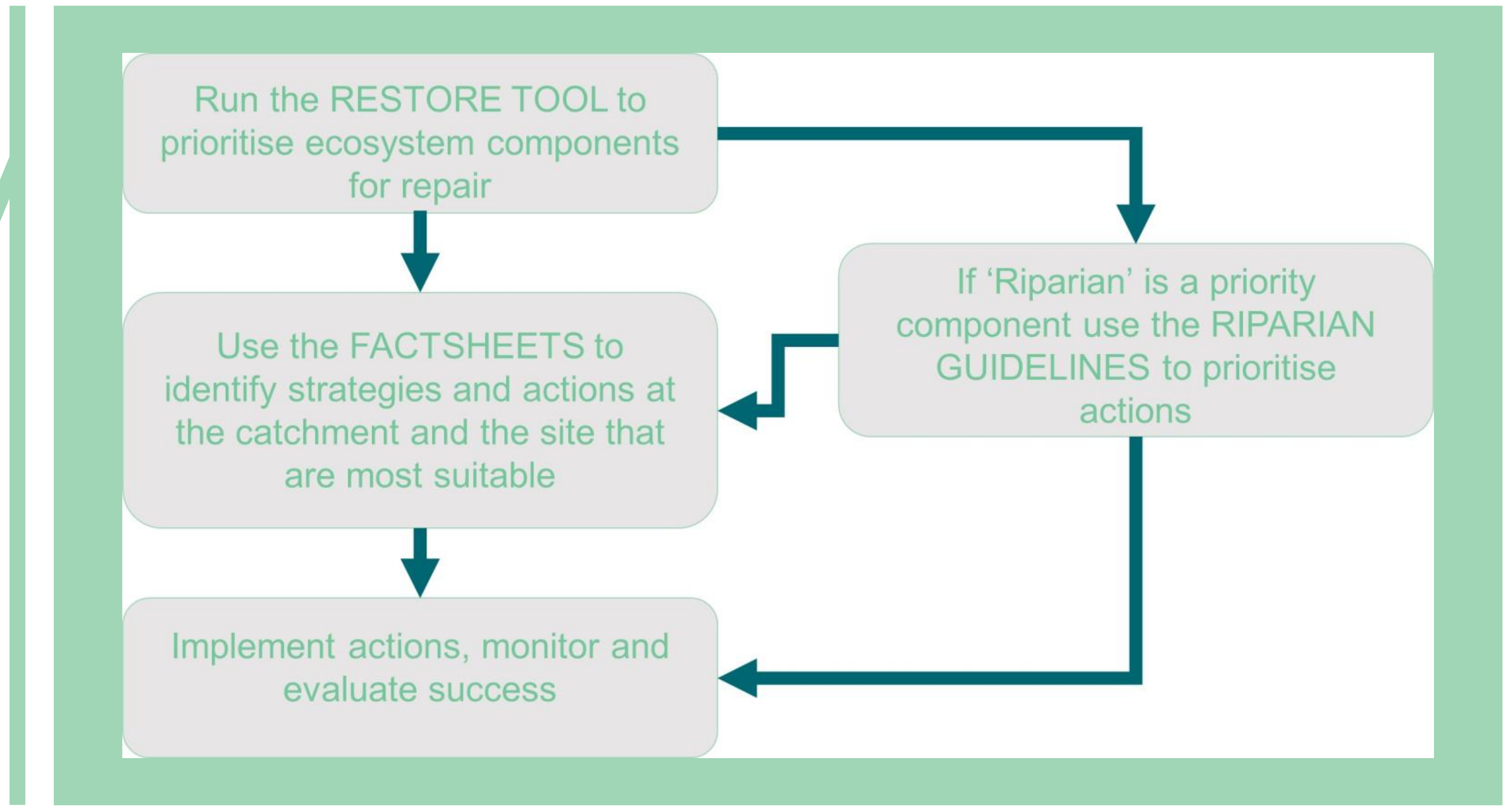




Framework:

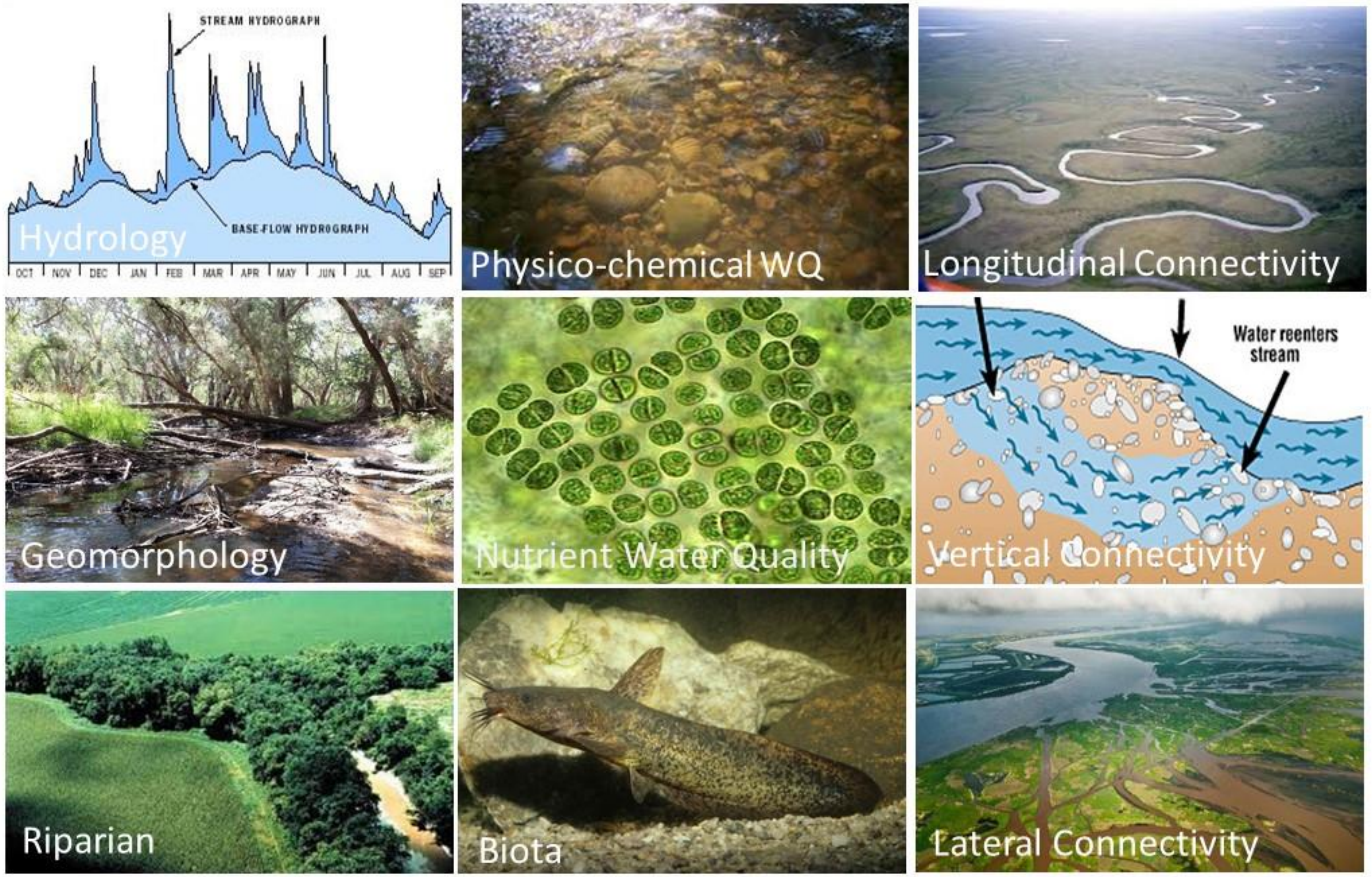
Management goal includes 'holistic repair'





RESTORE...

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



RESTORE Scope:

The TOOL:

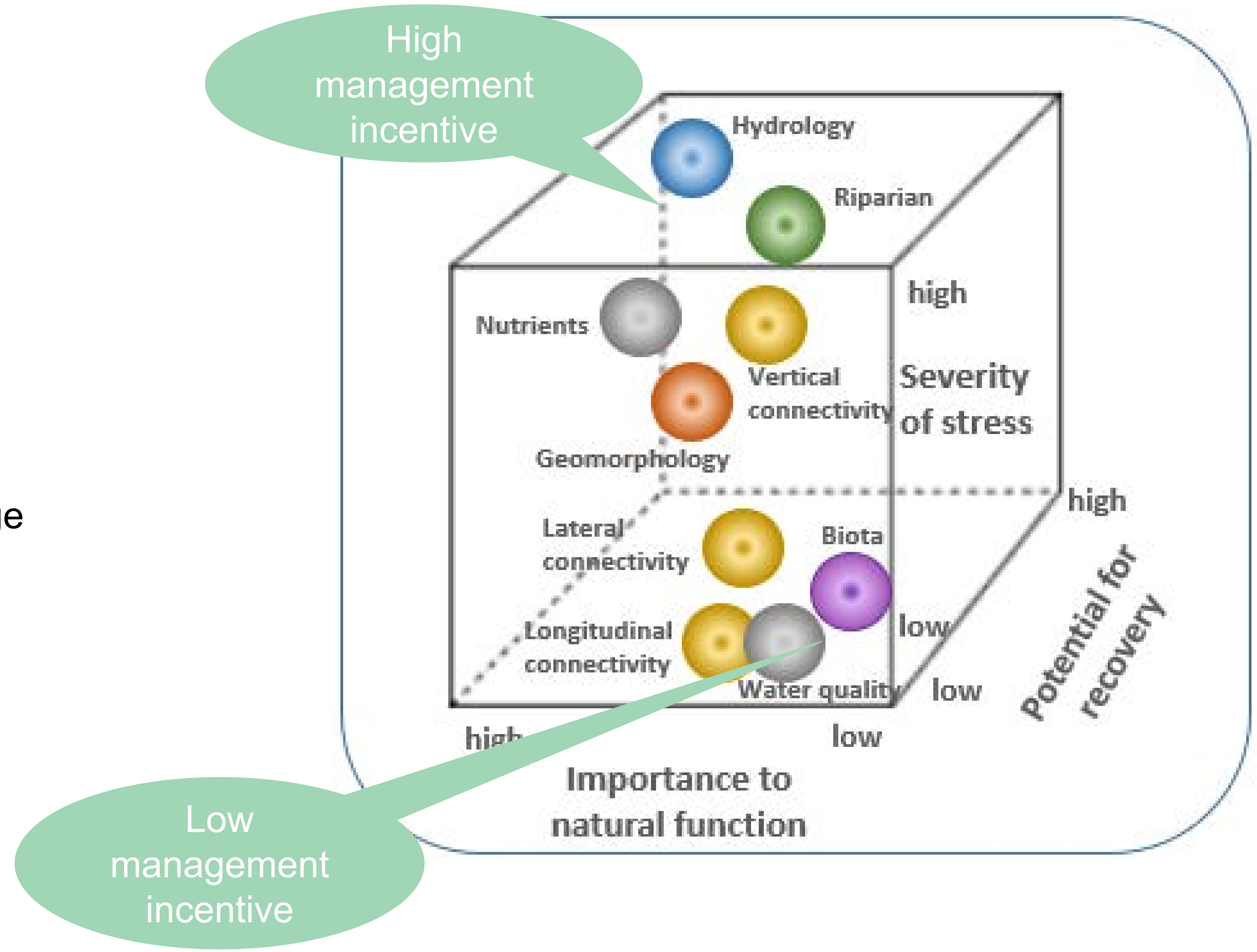
- assists managers to prioritise their on-ground effort once a restoration site has been identified
  "what type of restoration efforts are likely to deliver us the best ecological return for this site/reach?“
- assumes that stakeholders have agreed that ecological integrity is an aspirational goal for the site
- has been designed for flowing freshwaters
- has been designed for an urban and peri-urban context
- facilitates dialogue among stakeholders about the focus of on-ground actions
- creates a transparent platform to document why decisions were made
- is a repository of scientific evidence to broaden knowledge and build institutional capacity
- is simply that - a tool (assumptions, limitations)
- should be particularly helpful in data-limited situations and can identify knowledge gaps for future research

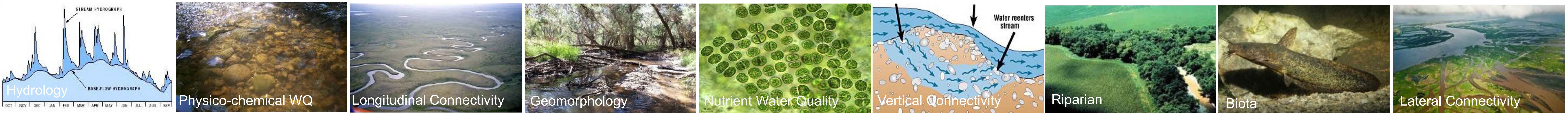
Prioritisation:

The tool prioritises the 9 ecosystem components using three criteria:

- Importance to natural ecosystem function
- Stress due to urbanisation / land use change
- Potential for recovery

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





Running the tool:

There are 126 questions in 4 tabs
Fill in blue cells

- 2-3hrs for 4 case studies (40min each)
- Questions grouped
- Useful resources (GIS layers) and staff
- Document decisions

CATCHMENT URBAN CONDITIONS

Question Type	Qu #	Questio
Urban Development	1	What p
Urban Development	2	How wi
Urban Development	3	Is there
Urban Development	4	Is urba
Urban Development	5	How fra
Urban Infrastructure	6	What is
Urban Infrastructure	7	Has sto
Urban Infrastructure	8	Are resi
Urban Infrastructure	9	Is wate
Urban Infrastructure	10	Are sep
Urban Infrastructure	11	Can ins
Urban Infrastructure	12	Current
Urban Practices	13	Current
Urban Practices	14	Is there
Urban Practices	15	Does th
Urban Practices	16	Is salt

SITE/REACH URBAN CON

Question Type	Qu #	Q
Urban Infrastructure	17	Is
Urban Infrastructure	18	Ar
Urban Infrastructure	19	Is
Urban Infrastructure	20	Ar
Urban Infrastructure	21	Is
Urban Infrastructure	22	If
Urban Infrastructure	23	W
Urban Infrastructure	24	Ar
Urban Infrastructure	25	Is
Riparian Buffer	26	Cu
Riparian Buffer	27	Lo
Riparian Buffer	28	Is
Riparian Buffer	29	At
Physical Alteration	30	Ha
Physical Alteration	31	De

CATCHMENT ENVIRONMENTAL CO

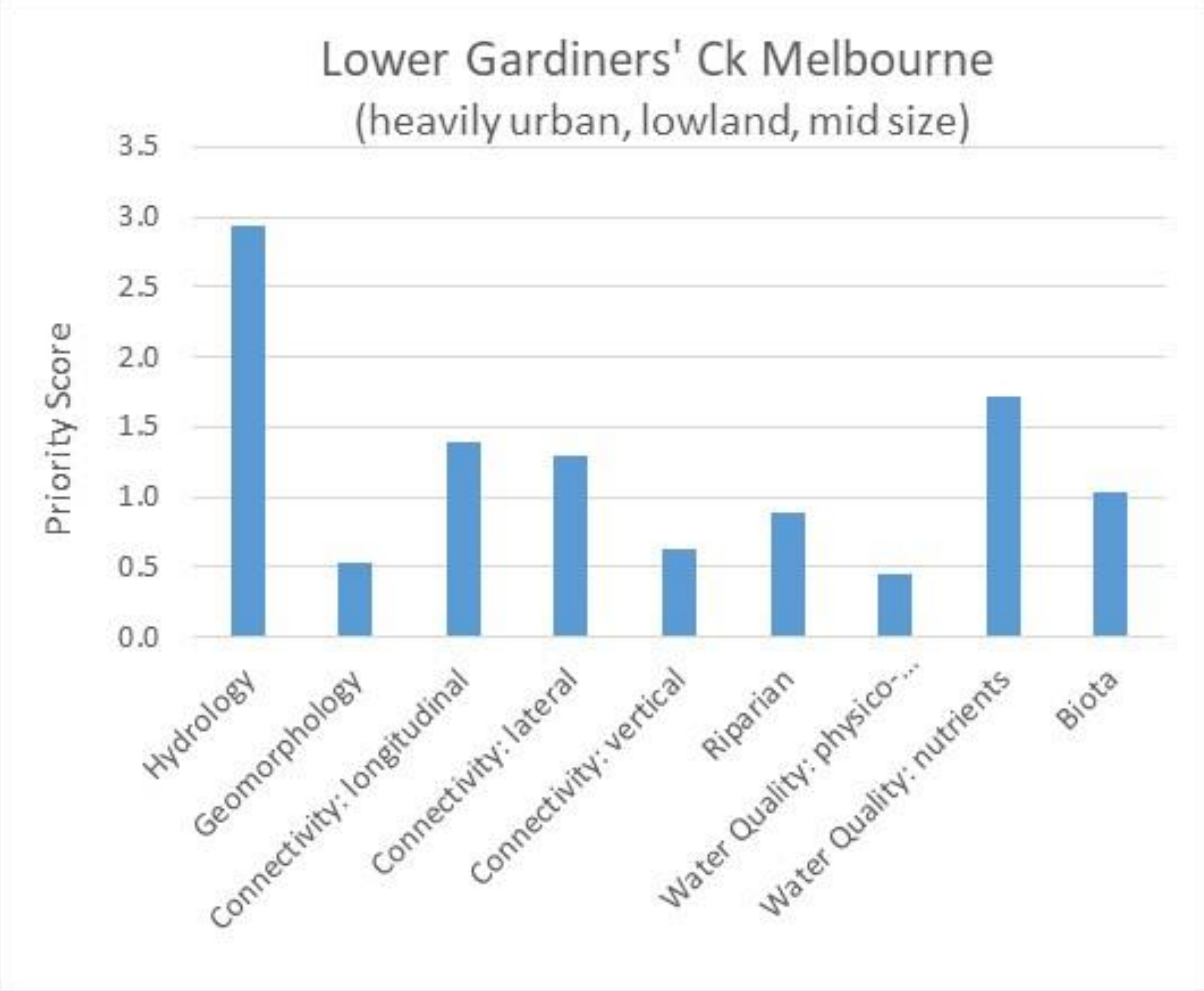
Question Type	Qu #	Question
Climate	32	Does the catchment/re
Climate	33	What is the natural int
Climate	34	Generally, how frequer
Climate	35	Is climate change pred
Climate	36	Are the biota of manag
Soils	37	Currently, is the restor
Soils	38	How sloped is the upst
Soils	39	How permeable are ca
Soils	40	Naturally, did the upst
Soils	41	Currently, does the res
Soils	42	Currently, does the site
Soils	43	Currently, has sedimer
Soils	44	Prior to urbanisation,
Soils	45	Is there an agricultura
Vegetation	46	Naturally, what type of
Vegetation	47	On balance, have non-
Riverine	48	How large is the upstre
Riverine	49	What is the drainage d
Riverine	50	Currently, where does

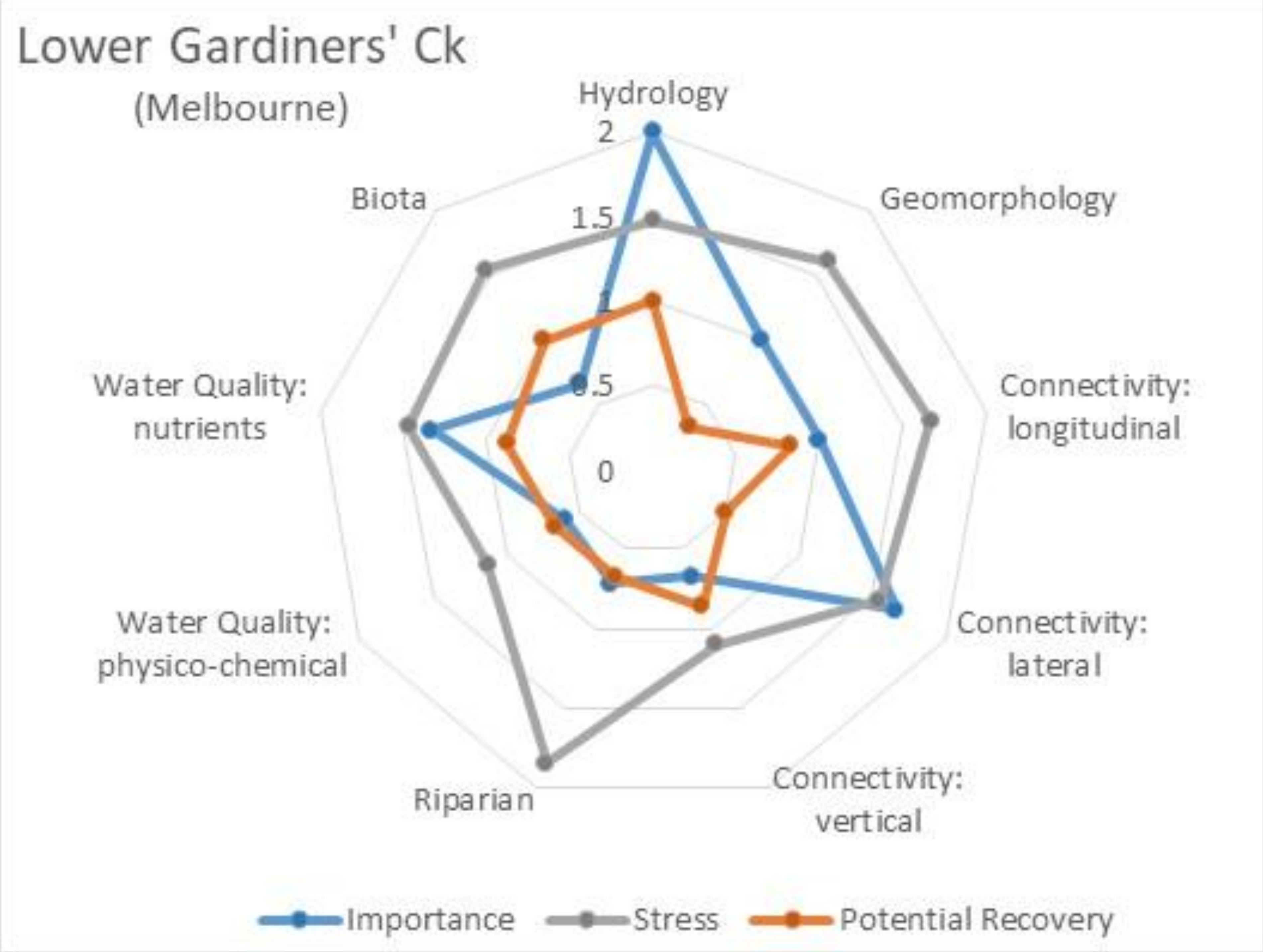
SITE/REACH ENVIRONMENTAL CONDITIONS

											RESTORE SCOR		
Question Type	Qu #	Question	Ecological component	Criteria affected	Explanation and Evidence	Dropdown Answer 1	Dropdown Answer 2	Dropdow n Answer	Dropdown Answer 4	Accompa nying	Case study 1 *enter name 1*	Case study 2 *enter name 2*	Case study 3 *enter name 3*
Riparian Buffer	73	Naturally, what was the riparia	Geomorpholo	Importance,	Geomorpholog	Grass or lit	Sparsely fo	Densely fo	Unknown = 1				
Riparian Buffer	74	Naturally, did the riparian zon	Riparian	Importance	Riparian [Impor	High slope	Moderate s	Little slope	Unknown = 1				
Riparian Buffer	75	Naturally, did groundwater flo	Riparian, Wa	Importance,	Riparian	Groundwat	Groundwat	Groundwa	Unknown = 1				
Riparian Buffer	76	Prior to urbanisation, was the	Riparian	Stress	Riparian [Stress	Riparian ve	Riparian ve	Riparian v	Unknown = 1				
Riparian Buffer	77	Looking at the restoration site	Riparian, Wa	Stress	Riparian	Bank-side r	Significant	Intermedia	Unknown = 1				
Riparian Buffer	78	Looking at the site/reach today	Riparian	Stress	Riparian [Stress	Riparian ve	Riparian ve	Riparian v	Unknown = 1				
Riparian Buffer	79	What is the restoration site's p	Riparian	Potential Re	Riparian [Poten	Close to int	Far from in	Intermedia	Unknown = 1				
Riparian Buffer	80	Currently, do you think the ripa	Water Qualit	Stress	Water Quality:	Expect ripa	Expect ripa	Intermedia	Unknown =	IMPORT			
Riparian Buffer	81	Currently, would there be much	Water Qualit	Stress	Water Quality:	Riparian sc	Riparian sc	Intermedia	Unknown =	IMPORT			
Riparian Buffer	82	Currently, is the restoration sit	Water Qualit	Stress	Water Quality:	High strean	Low stream	Intermedia	Unknown = 1				
Riparian Buffer	83	Currently, is the riparian zone	Water Qualit	Potential Re	Water Quality:	Riparian zo	Riparian zo	Unknown = 1					
Riparian Buffer	84	Currently, what is the dominan	Riparian	Importance	Riparian	Clay soils =	Intermediat	Sandy soil	Unknown = 1				
Instream Habitat	85	Has there been much removal c	Riparian	Stress	Riparian [Stress	De-snaggin	Partial de-s	No de-snag	Unknown = 1				
Instream Habitat	86	Currently, what is the load (or	Hydrology, G	Stress	Hydrology [Stre	High loads	Intermediat	Little to no	Unknown = 1				
Instream Habitat	87	Is habitat degradation ongoing	Biota	Potential Re	Biota [Potential	Habitat deg	Habitat deg	Intermedia	Unknown =	NB.			
Instream Habitat	88	Will the habitat required for th	Biota	Potential Re	Biota [Potential	Habitat req	Habitat req	Unknown = 1		NB.			
Flow	89	Currently, does the restoration	Water Qualit	Stress, Poter	Water Quality:	Protracted	Perennial fl	Perennial f	Unknown = 1				
Flow	90	Do low flows at the restoration	Water Qualit	Stress	Water Quality:	Low flows c	Constant hi	Intermedia	Unknown = 1				
Flow	91	Does the site/reach receive gro	Vertical Conr	Stress	Vertical Connec	Site fed by	Site fed by	The site na	Unknown =	NB. If a			
Flow	92	Naturally, would stream water	Vertical Conr	Importance	Vertical	Well-devel	Moderately	Poorly-dev	Unknown = 1				
Water Quality	93	Naturally, how cold would the	Water Qualit	Importance	Water Quality:	Cold water	Intermediat	Warm wat	Unknown =	NB. See if			
Water Quality	94	Naturally, did the restoration s	Water Qualit	Importance,	Water Quality:	Naturally h	Normal sal	Unknown = 1					
Water Quality	95	Naturally, would the water be v	Water Qualit	Importance	Water Quality:	Highly aera	Normal oxygen (DO 4 t		Unknown =	NB. DO =			
Water Quality	96	Naturally, was the water tanni	Water Qualit	Importance	Water Quality:	Naturally h	Relatively r	Intermedia	Unknown = 1				
Water Quality	97	Naturally, was the water turbid	Water Qualit	Importance	Water Quality:	Highly turb	Intermediat	Clear wate	Unknown = 1				
Water Quality	98	Currently, is groundwater at th	Vertical Conr	Potential Re	Vertical Connec	Groundwat	Groundwat	Groundwa	Unknown = 1				
Water Quality	99	Currently, are there high levels	Water Qualit	Stress	Biota [Stress]. H	High levels	Moderate l	Low levels	Unknown =	NB.			
Water Quality	100	Do most of the chemical pollut	Water Qualit	Potential Re	Water Quality:	Chemicals	Chemical pollutants largely arise from diffuse-sources (eg non-point so						

Output:

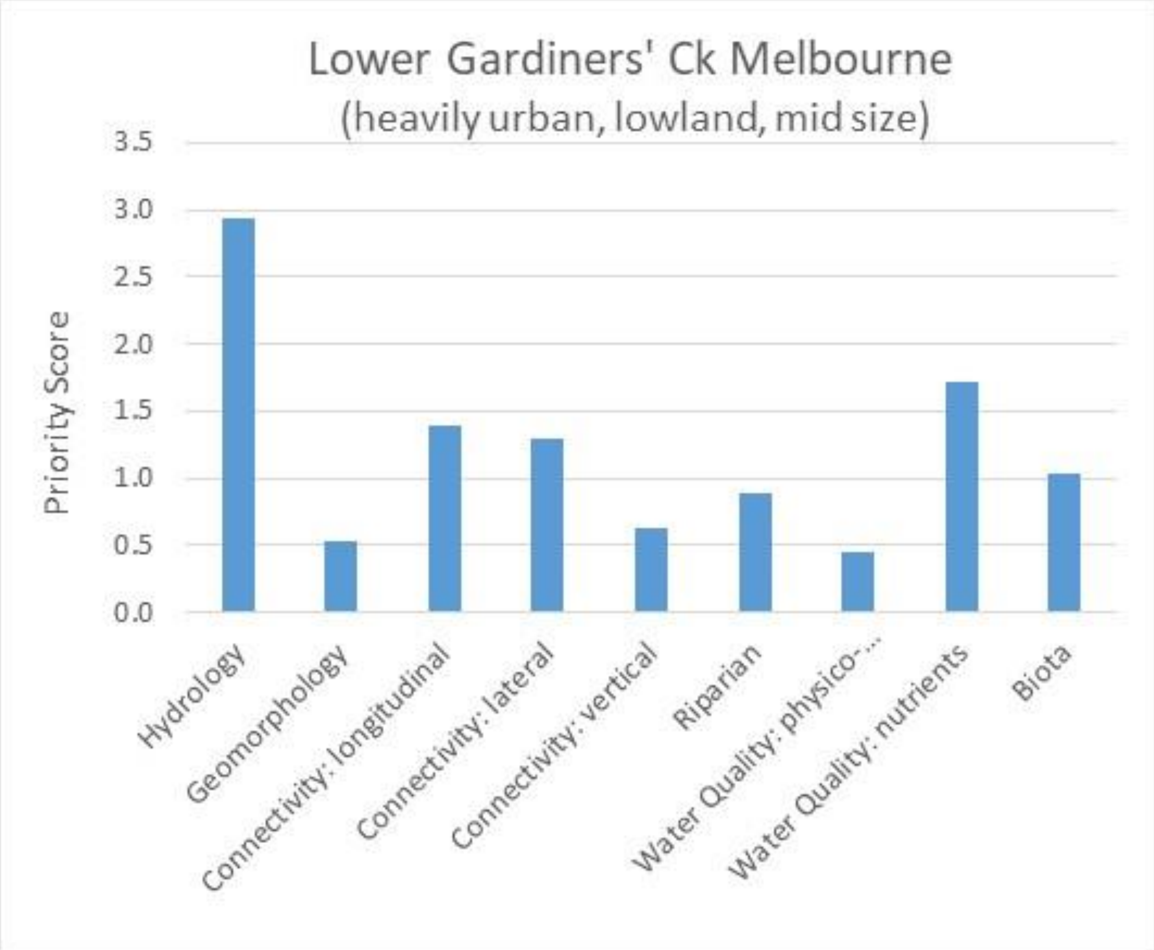
CASE STUDY 1	Lower Gardiner's Ck			
Ecological Component	Importance	Stress	Potential Recovery	Prioritisation Score
Hydrology	2	1.47	1	2.9
Geomorphology	1	1.61	0.33	0.5
Connectivity: longitudinal	1	1.67	0.83	1.4
Connectivity: lateral	1.66	1.55	0.5	1.3
Connectivity: vertical	0.67	1.1	0.86	0.6
Riparian	0.714	1.85	0.67	0.9
Water Quality: physico-chemical	0.6	1.125	0.67	0.5
Water Quality: nutrients	1.33	1.47	0.875	1.7
Biota	0.6667	1.54	1	1.0

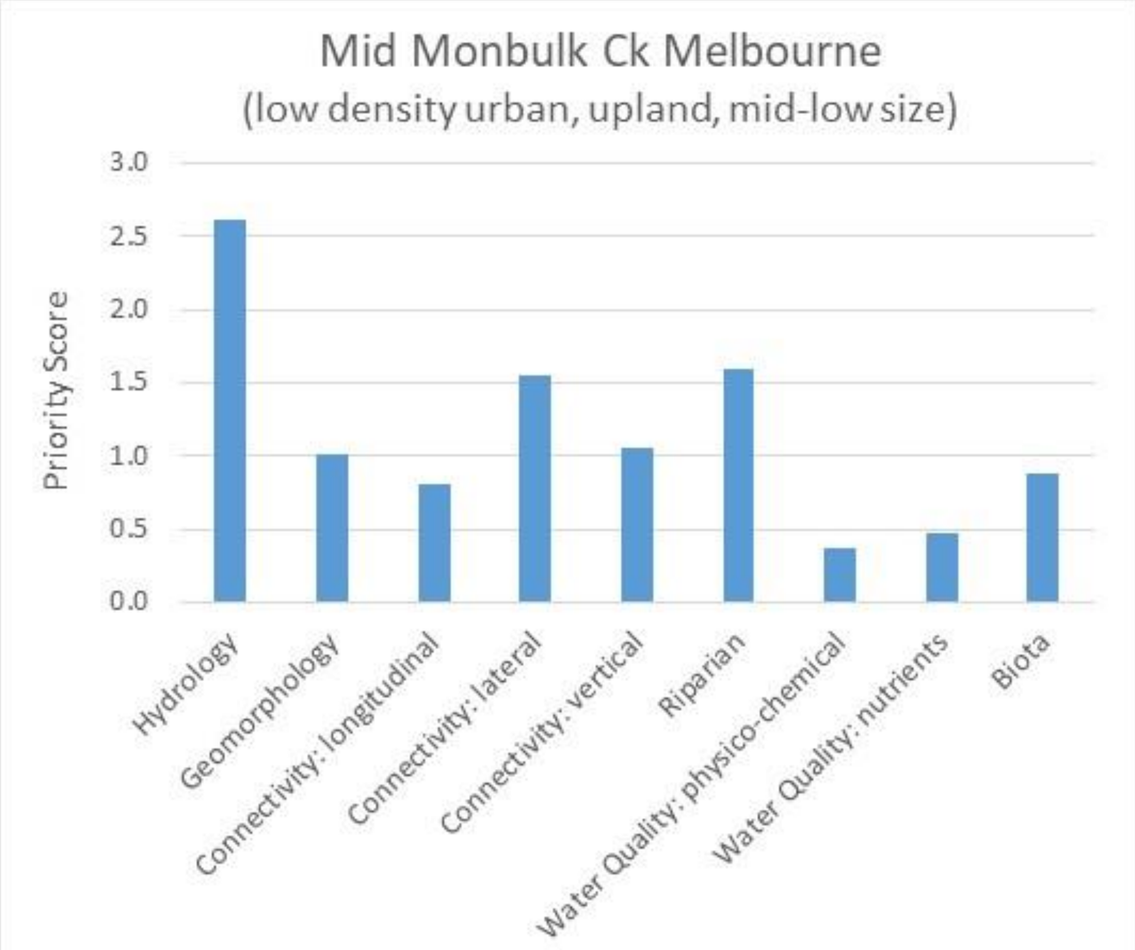


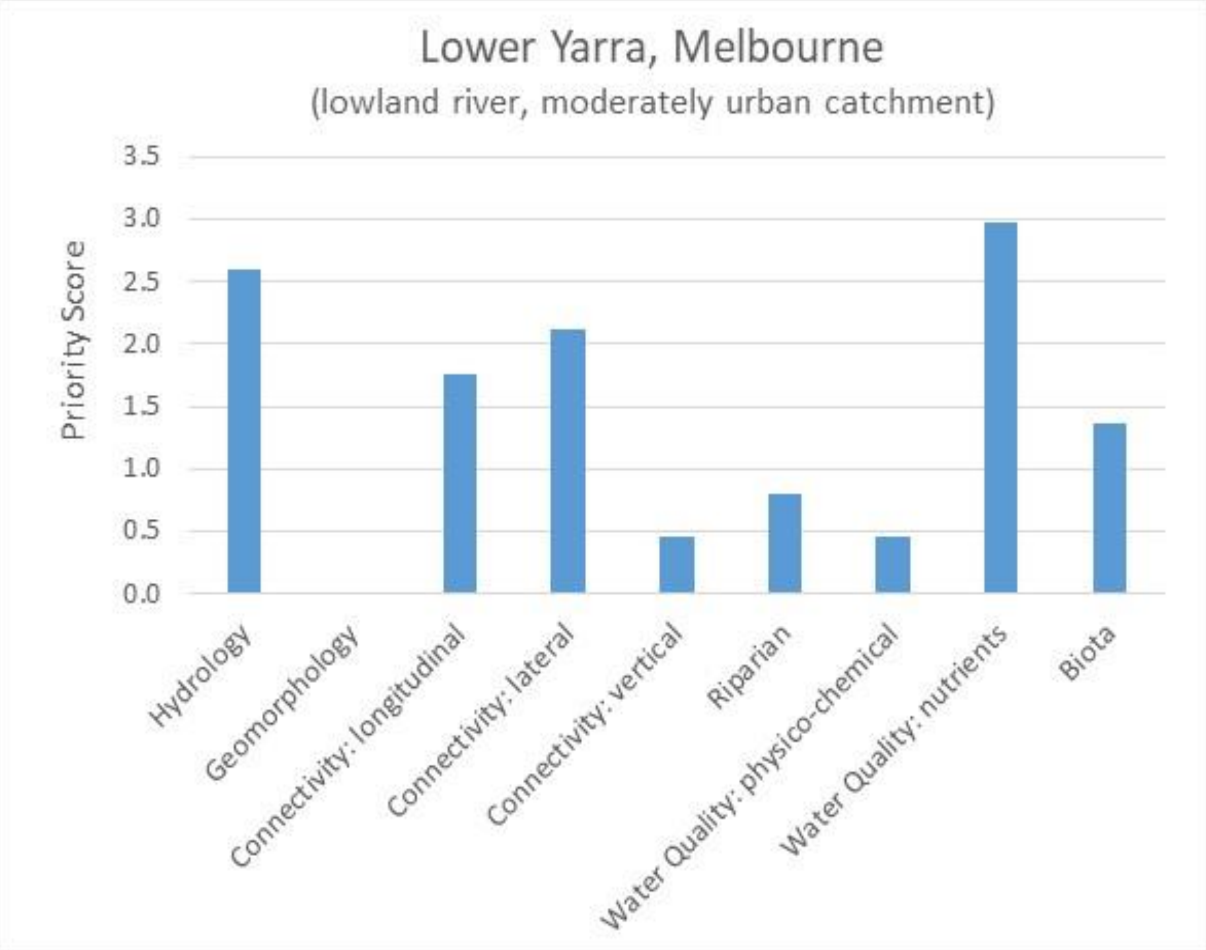


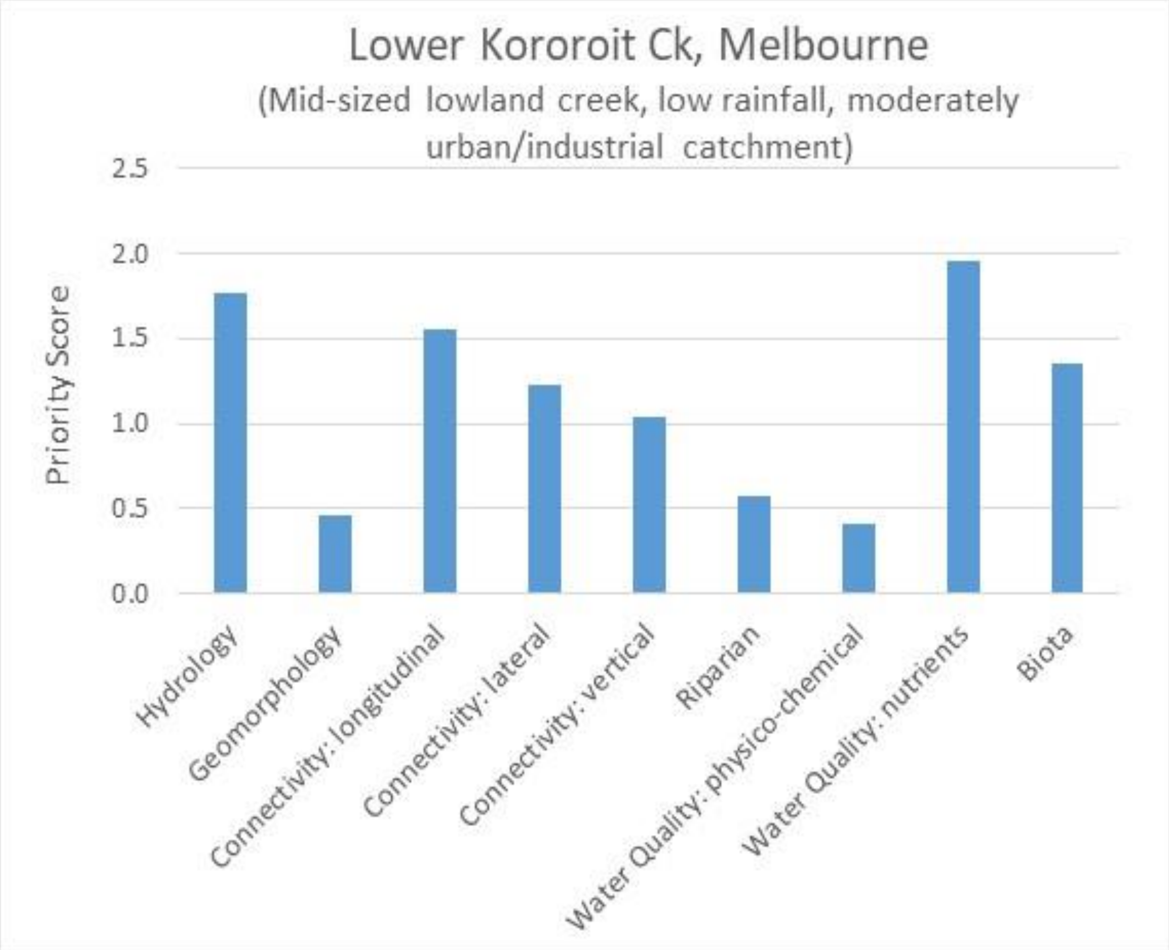
Example:

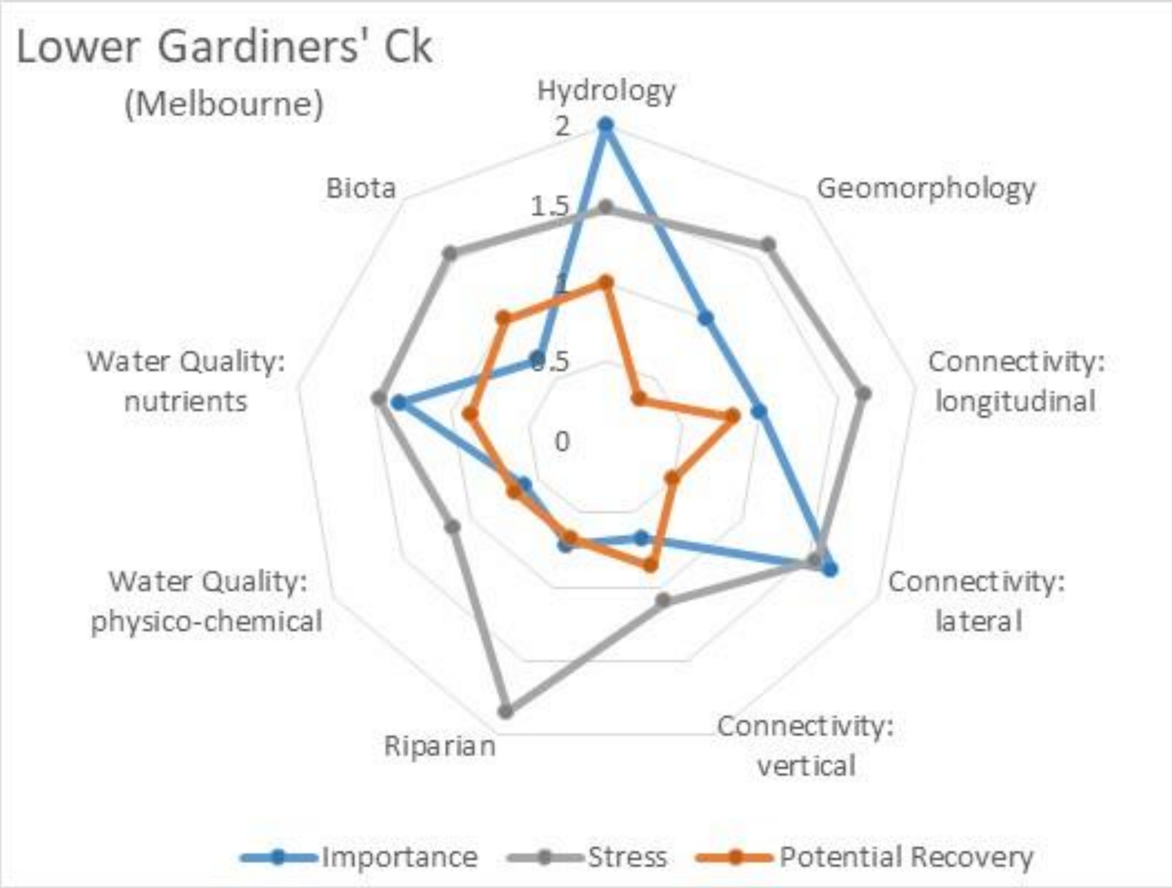
Question: There are 4 urban stream sites across Melbourne that have been identified as important for rehabilitation. Each site has different environmental and urban characteristics. Which ecosystem components should be the priority of on-ground activity at the different sites?

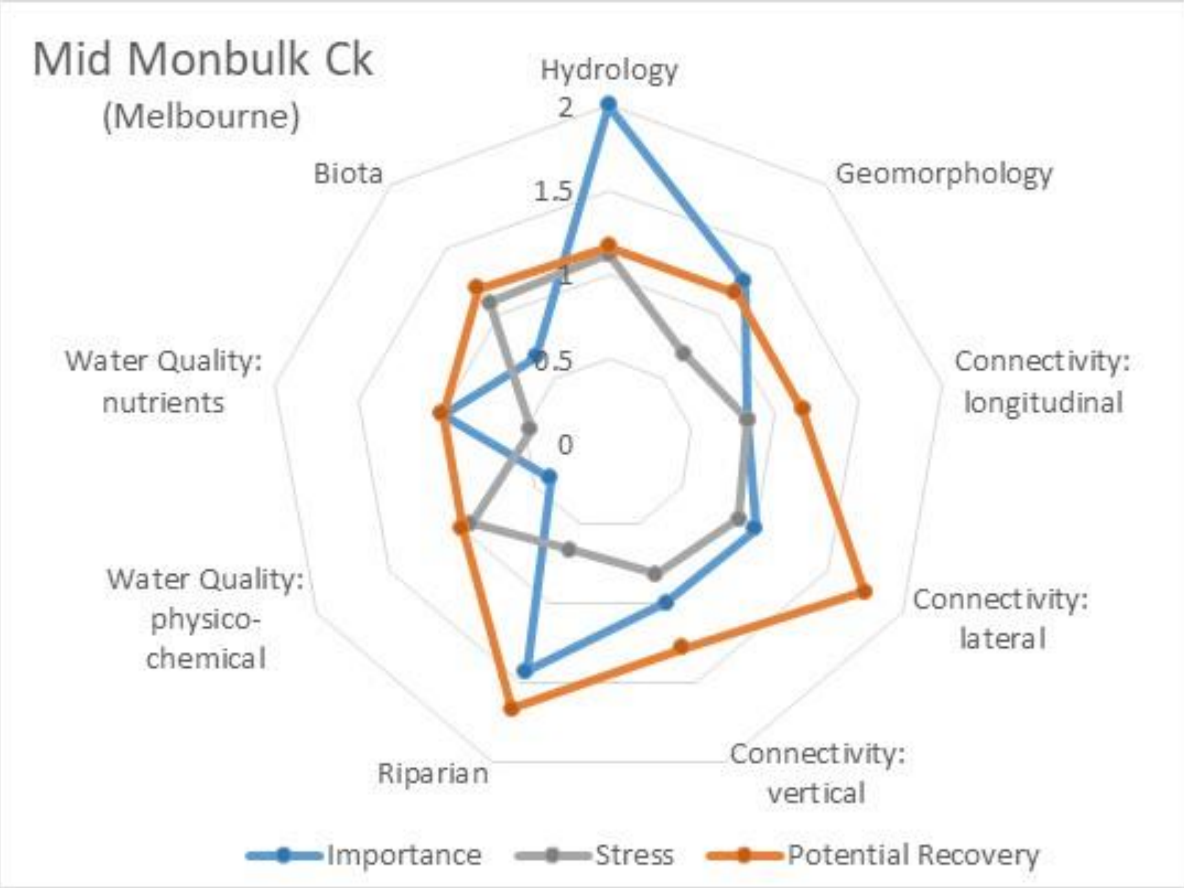


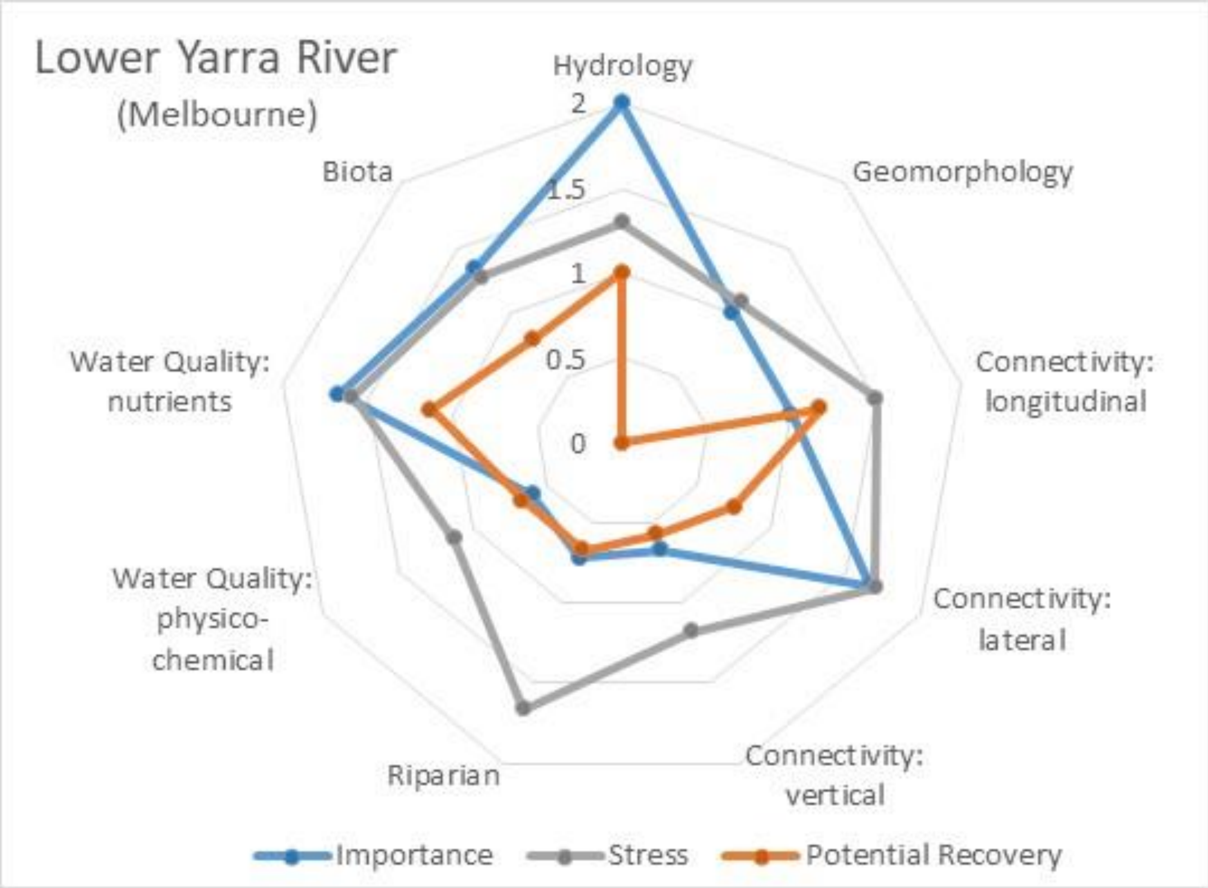


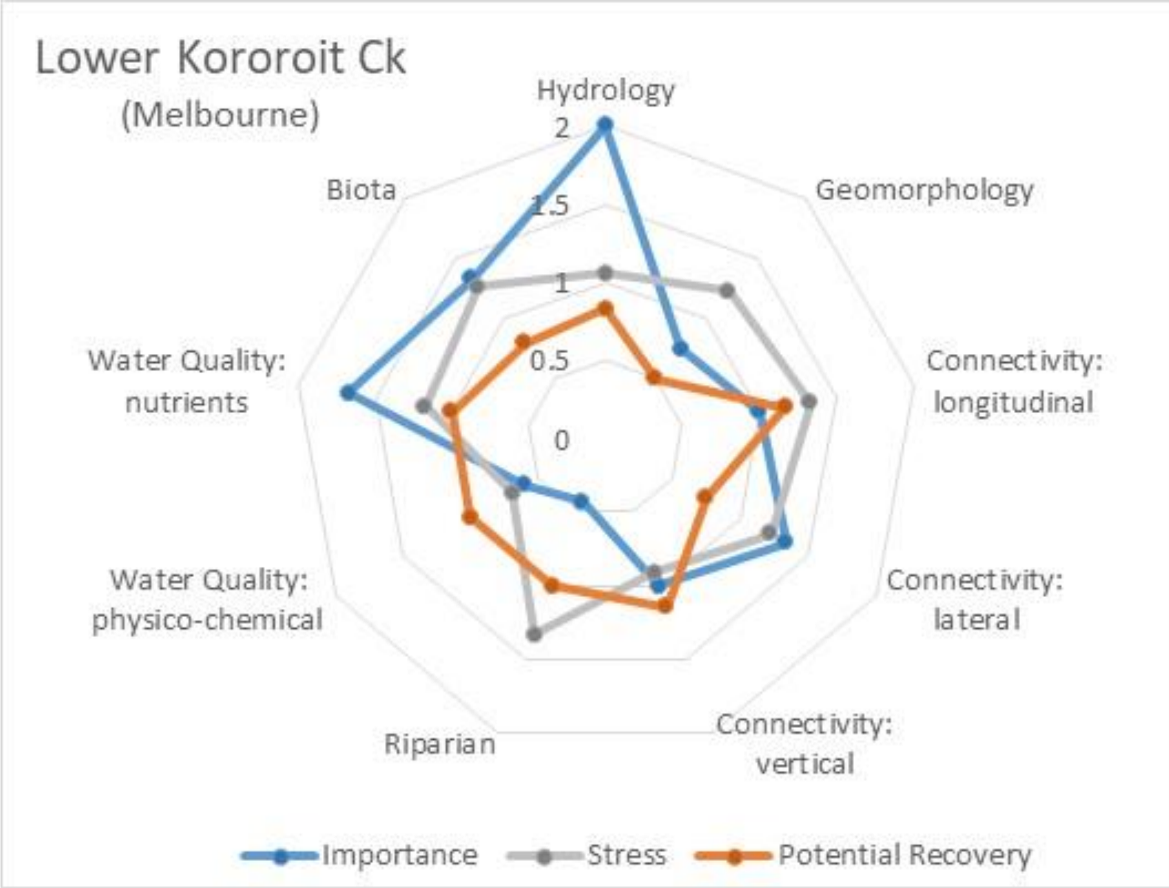












Next steps:

The OUTPUT from the TOOL will have revealed which ecological components are a priority for repair. You now need to decide what on-ground actions to implement to fix the priority ecological components, and you need to monitor to learn if your efforts have been successful or not.

Which on-ground actions should you implement?

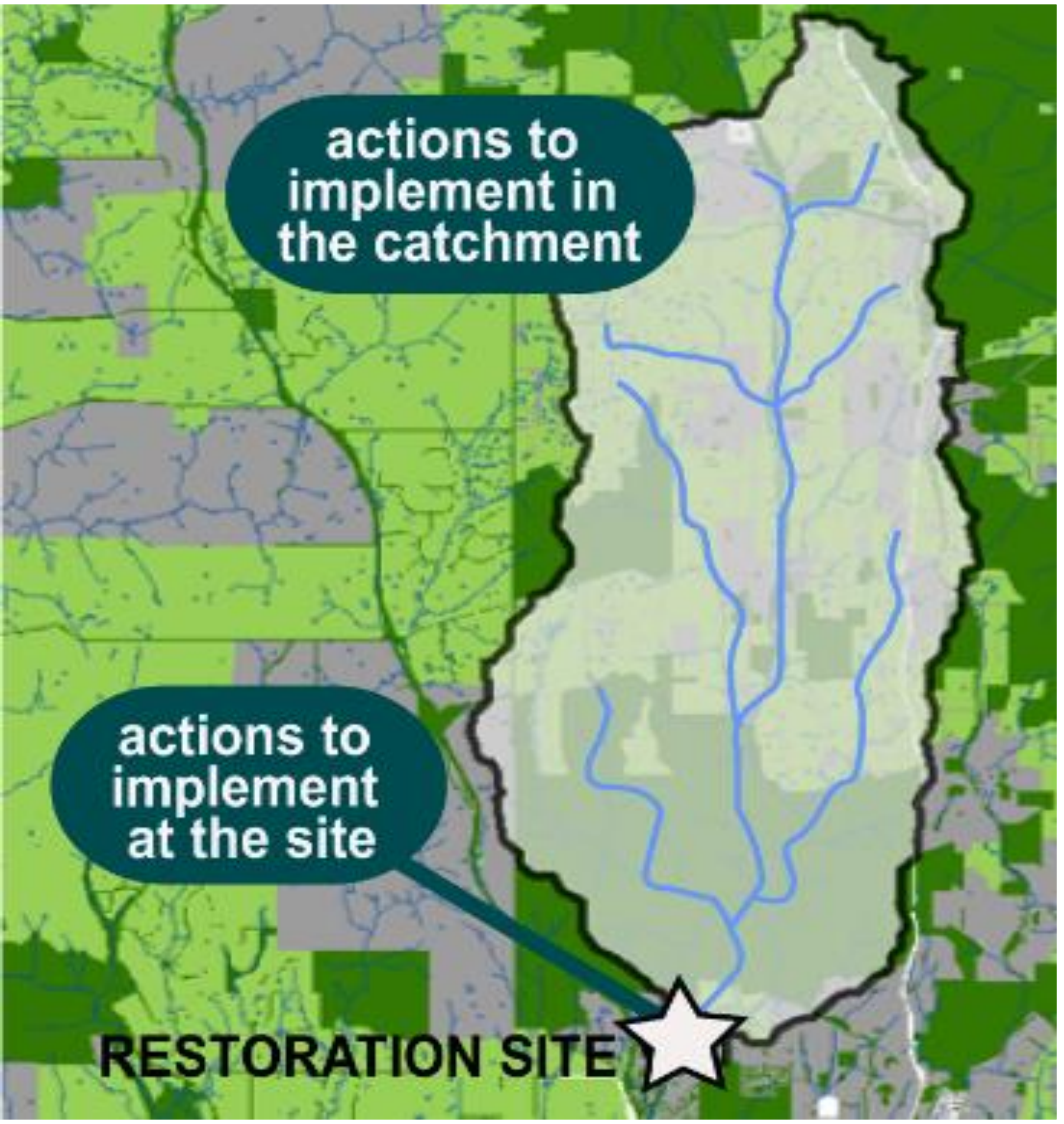
Can you work in the catchment or just at the site?

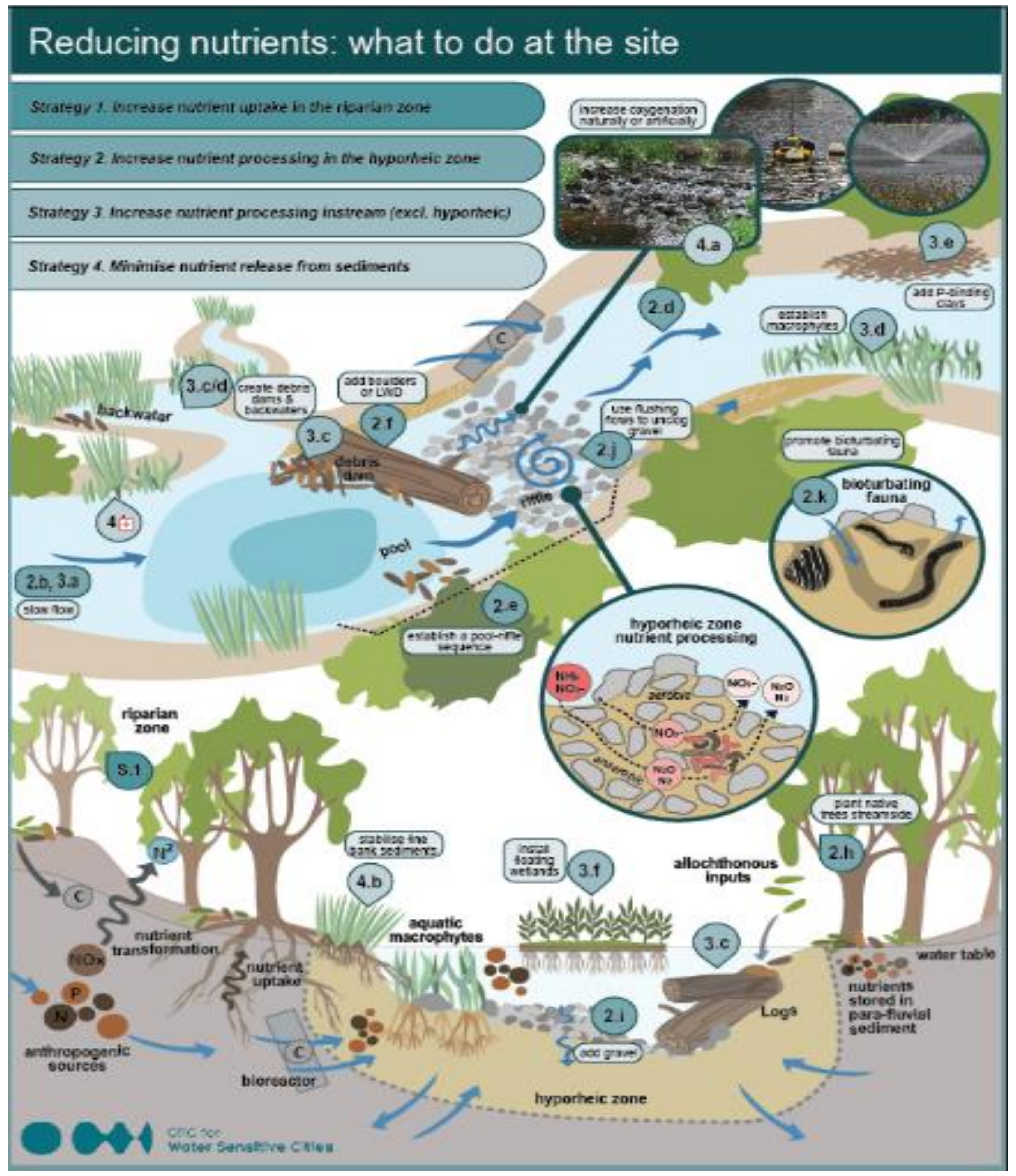
Go to the urban waterway factsheets

Go to the Riparian guidelines

Conceptual diagrams created by J Middleton
Ooid scientific https://ooidscientific.com/

Urban waterway factsheets:

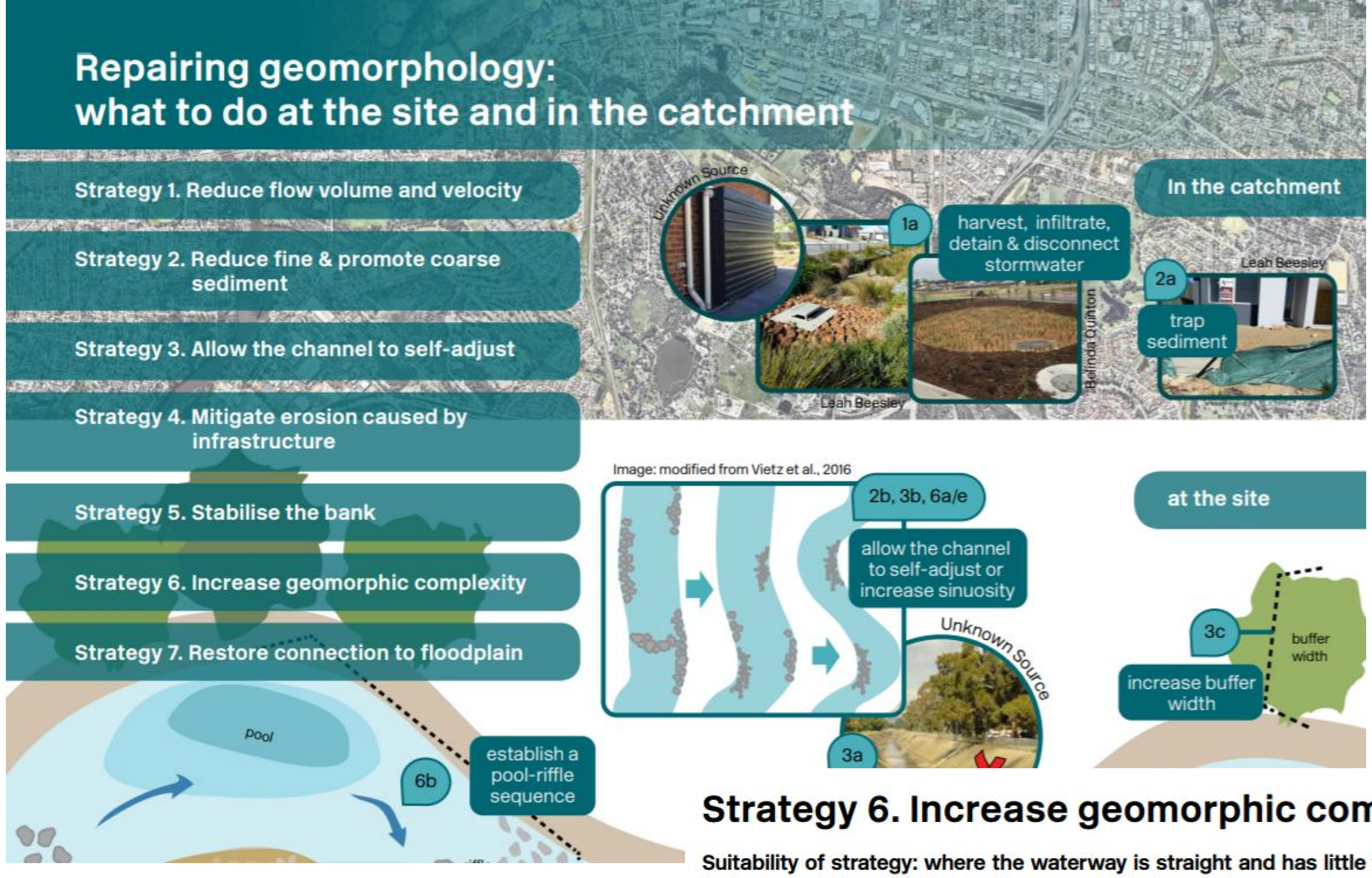




Urban waterway factsheets:

Each factsheet provides

- Strategies
  - Actions
    - Information
      - Guidelines



Strategy 6. Increase geomorphic complexity

Suitability of strategy: where the waterway is straight and has little to no geomorphic complexity (e.g. channelised drain, incised creekline with little habitat complexity), and where some attempt to repair scouring urban flows has been made – either via WSUD in the catchment or the presence of a flow-regulating structure upstream. If scouring flows have not been repaired, any instream improvements are unlikely to last for long.

Action	Explanation	Conditions where action is most likely to be suitable andeffective	Other references recommending action	Guidelines for implementation
6a. Recreate channel sinuosity	Channel reconfiguration is often used to undo the damage caused by man-made channel straightening (channelisation)	Where earth moving machinery can access the site and where the riparian buffer is wide enough for sinuosity to be created.	[15, 40]	[15-18] See also RVR Meander tool
6b. Create pool-riffle sequence	Pool-riffle sequences are natural recurring geomorphic units in meandering gravel-bed streams.	Suitable in gravel-bed streams. Unsuitable for sand-bed streams, unless the sand is underlain by gravel. Where earthmoving machinery can access the site and where rapid restoration is required.	River restoration manuals	[41] and river restoration manuals
6c. Add logs (LWD) or boulder clusters	Logs alter the flow of water in the channel, creating patches of erosion (scour) and deposition which promote the formation of pools and bars.	Where the channel is narrow (< 10 m). Where earthmoving machinery can access the site. Where scouring urban flows have been repaired such that LWD inputs will not be lost. If concerns exist about the risk to urban infrastructure, we recommend using the Large Wood Structure Stability Analysis Tool <http://www.fs.fed.us/ biology/nsaec/products-tools.html> [28]. The associated resource [29] describes the process and may also be useful.	[17, 19, 31, 33, 42-44]	[17, 19, 28, 29, 31, 32, 45, 46]
6d. Add gravel to the channel	Many urban waterways are starved of coarse	At high value locations where the channel is starved of course-grained sediment –	[3, 10]	Gravel can be added in

Approach:

Some strategies will be more suitable than others given urban constraints – read through the strategies and cross ones off that aren't appropriate

Some actions will be more suitable than others given your setting. Cross of the actions that aren't appropriate.

Short list of actions. Decide with team members which ones you will implement. Use factsheets to find guidelines for implementation.

Repairing flow: what to do in the catchment
Strategy 1. Reduce flow volume
Strategy 2. Reduce the velocity of instream flow, particularly peak flows
Strategy 3. Reduce the frequency of flow pulses
Strategy 4. Slow the rate of flow rise & fall
Strategy 5. Repair stream baseflow
1.e
daylight pipes & remove channel hardlining
Glen Byleveld
Jen Middleton
5.k
catchment wide tree planting
Shona Beesley
irrigation using stormwater or in some cases groundwater
Leah Beesley
5.l/m
1.i
TRENCH
GRAVEL POCKET
4" PERFORATED
Unknown source
redirect sub-surface drains
1.c
Belinda Quinton
Leah Beesley
infiltate at the street using raingardens & vegetated swales
Leah Beesley
increase overland flowpaths between stormwater source & drainage
1.d
Leah Beesley
Leah Beesley
1.b
Leah Beesley
Unknown source
Unknown source
infiltate at the lot using soakwells & permeable paving
1.f/g
Unknown source
infiltate at the precinct using biofiltration basins
1.a, 5.i
Unknown source
Unknown source
harvest rainwater at the lot using rainwater tanks & roof gardens
Legend
Catchment boundary
Stormwater drainage
Restoration site
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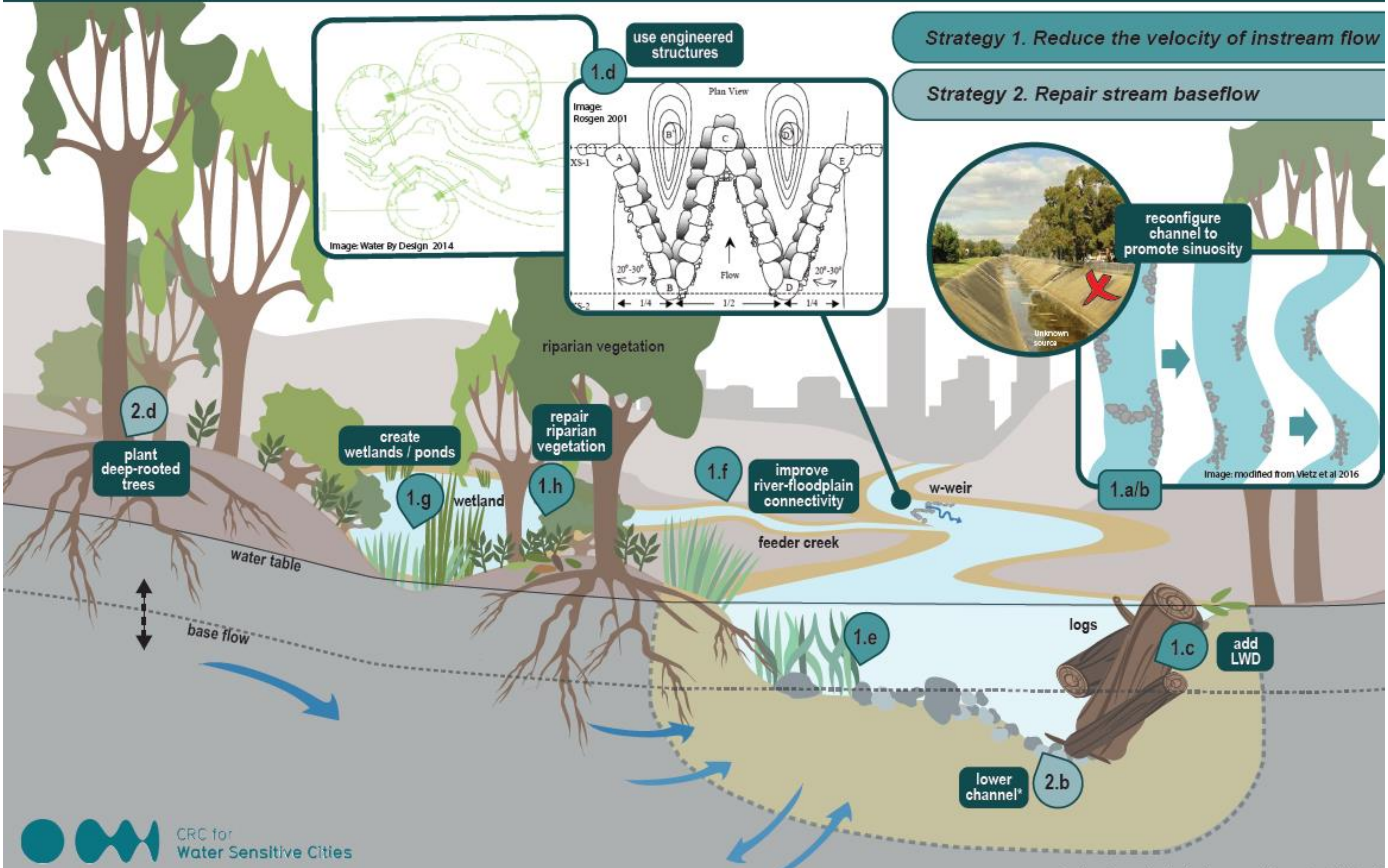
Repairing flow: what to do at the site



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* only where urbanisation has caused the water table to fal

Strategy 1. Reduce flow volume and velocity

Strategy 2. Reduce fine & promote coarse sediment

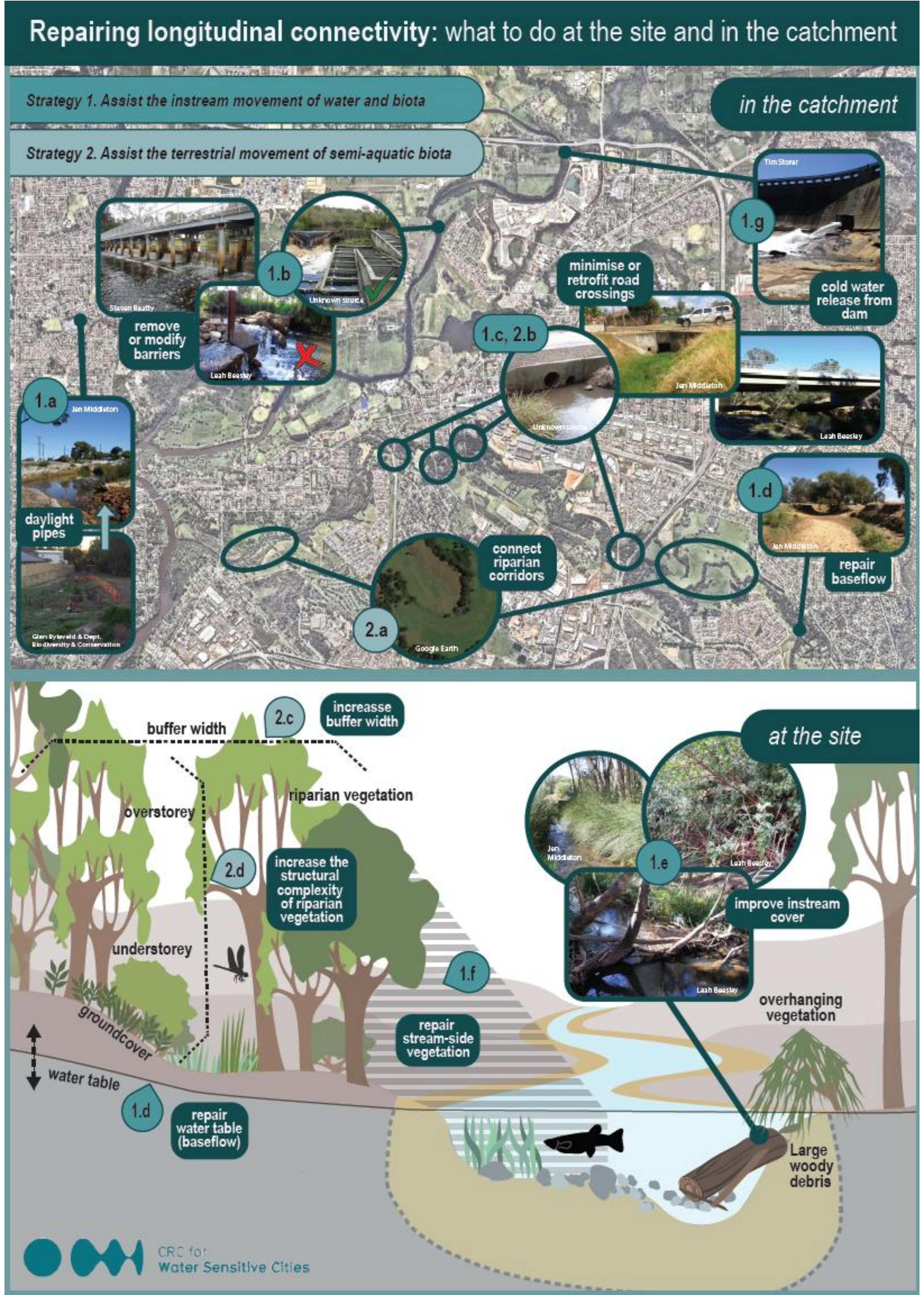
Strategy 3. Allow the channel to self-adjust

Strategy 4. Mitigate erosion caused by infrastructure

Strategy 5. Stabilise the bank

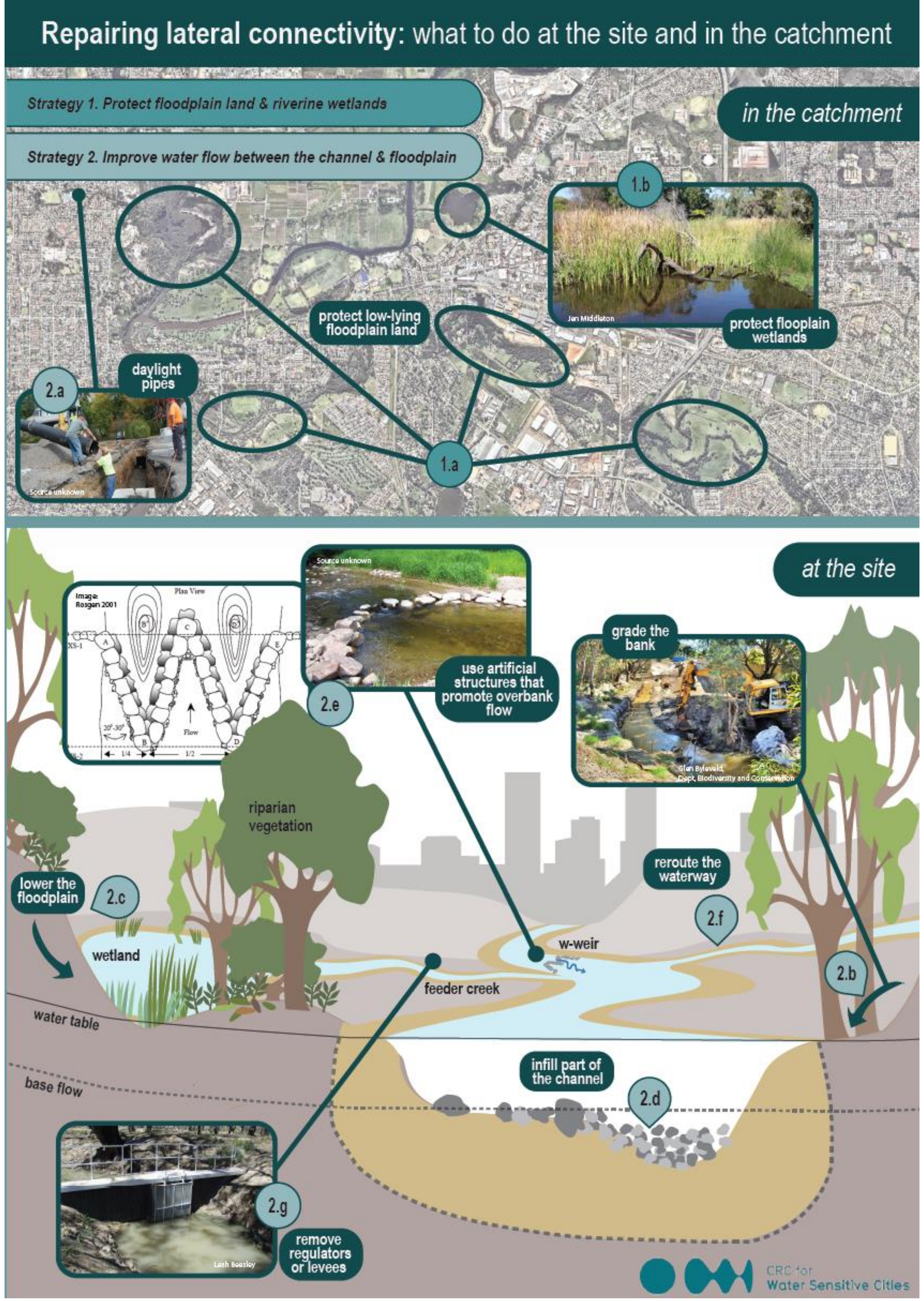
Strategy 6. Increase geomorphic complexity

Strategy 7. Restore connection to floodplain



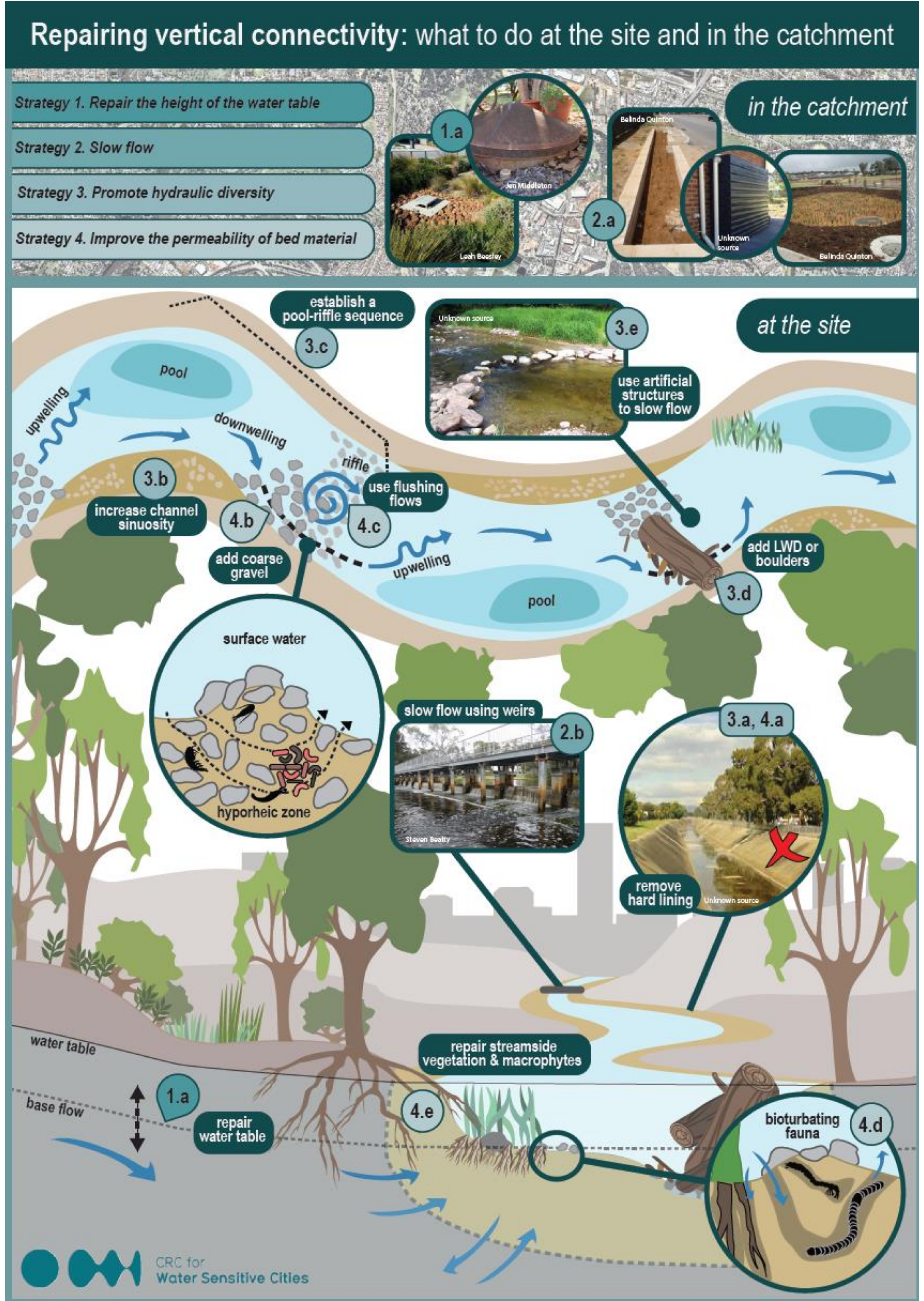
Strategy 1. Assist the instream movement of water and biota

Strategy 2. Assist the terrestrial movement of semi-aquatic biota



Strategy 1. Protect floodplain land & riverine wetlands

Strategy 2. Improve water flow between the channel & floodplain

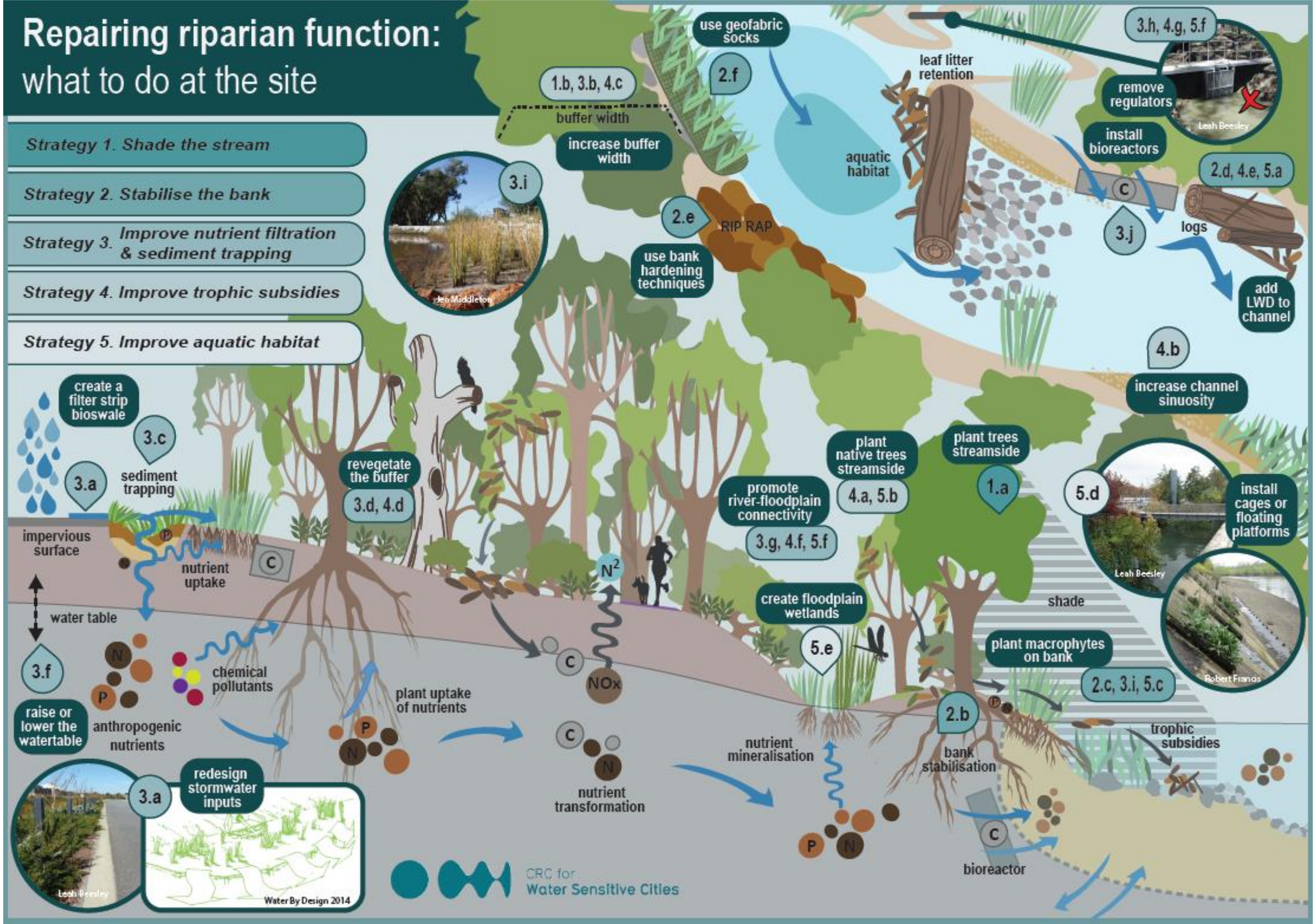


Strategy 1. Repair the height of the water table

Strategy 2. Slow flow

Strategy 3. Promote hydraulic diversity

Strategy 4. Improve the permeability of bed material



Repairing riparian function:
what to do at the site
Strategy 1. Shade the stream
Strategy 2. Stabilise the bank
Strategy 3. Improve nutrient filtration & sediment trapping
Strategy 4. Improve trophic subsidies
Strategy 5. Improve aquatic habitat
1.b, 3.b, 4.c
buffer width
increase buffer width
use geofabric socks
2.f
2.e
RIP RAP
use bank hardening techniques
3.i
Jen Middleton
leaf litter retention
aquatic habitat
3.h, 4.g, 5.f
remove regulators
Leah Beesley
install bioreactors
C
3.j
2.d, 4.e, 5.a
logs
add LWD to channel
4.b
increase channel sinuosity
create a filter strip bioswale
3.c
sediment trapping
3.a
impervious surface
P
nutrient uptake
C
water table
3.f
raise or lower the watertable
N
P
anthropogenic nutrients
chemical pollutants
revegetate the buffer
3.d, 4.d
plant uptake of nutrients
P
N
N^2
C
NOx
C
N
nutrient transformation
promote river-floodplain connectivity
3.g, 4.f, 5.f
plant native trees streamside
4.a, 5.b
plant trees streamside
1.a
create floodplain wetlands
5.e
nutrient mineralisation
P
N
2.b
bank stabilisation
C
bioreactor
5.d
Leah Beesley
install cages or floating platforms
shade
plant macrophytes on bank
2.c, 3.i, 5.c
Robert Francis
trophic subsidies
3.a
redesign stormwater inputs
Leah Beesley
Water By Design 2014
CRC for Water Sensitive Cities

Reducing nutrients: what to do in the catchment

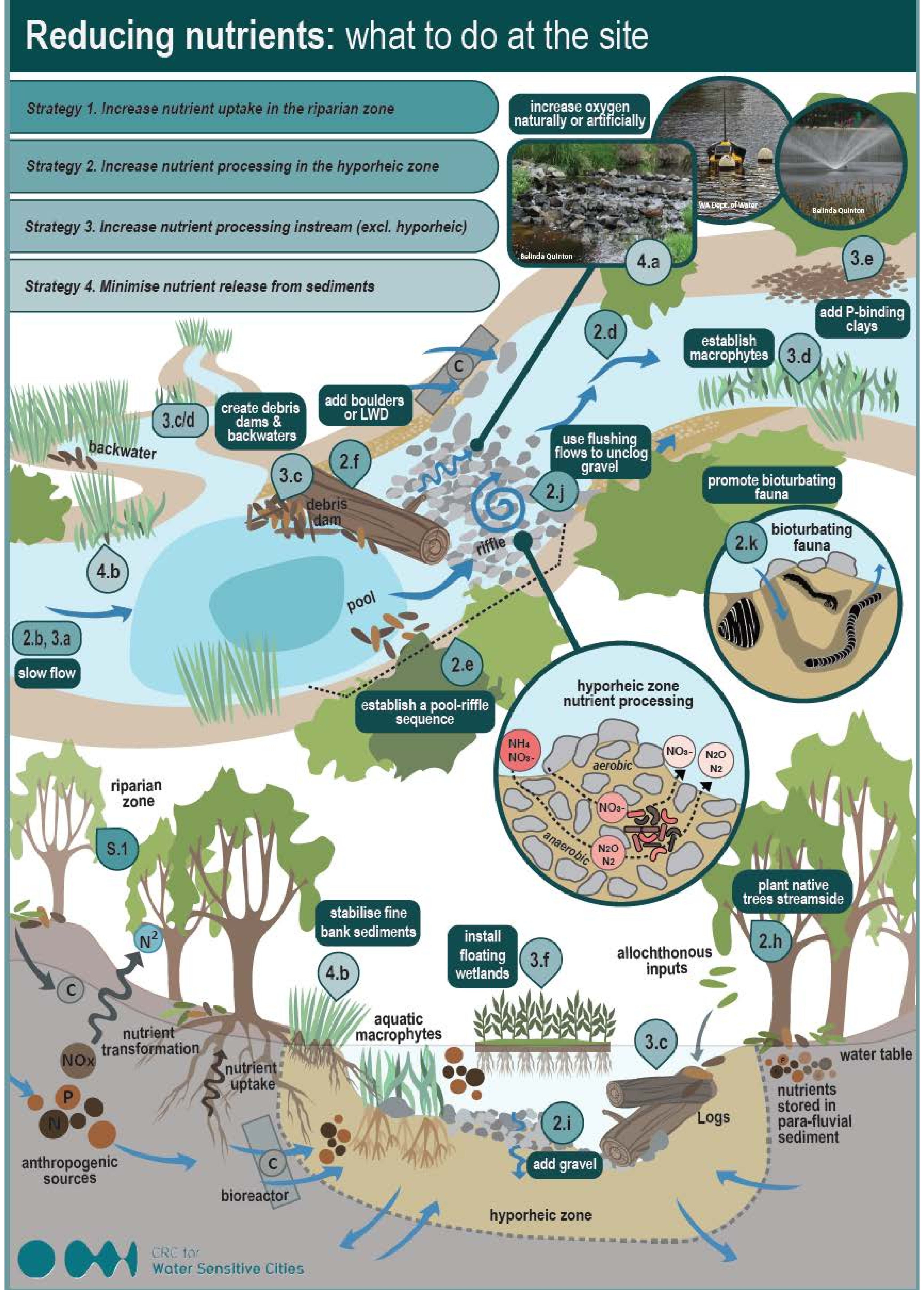
Strategy 1. Reduce nutrient inputs

Strategy 2. Reduce the volume of stormwater directed to waterways

Strategy 3. Increase nutrient biofiltration of stormwater at the source

Strategy 4. Increase nutrient biofiltration of stormwater at the precinct scale

Strategy 5. Reduce the volume of nutrient-rich groundwater entering the waterway



Strategy 1. Increase nutrient uptake in the riparian zone

Strategy 2. Increase nutrient processing in the hyporheic zone

Strategy 3. Increase nutrient processing instream (excl. hyporheic)

Strategy 4. Minimise nutrient release from sediments

Repairing water quality: what to do in the catchment

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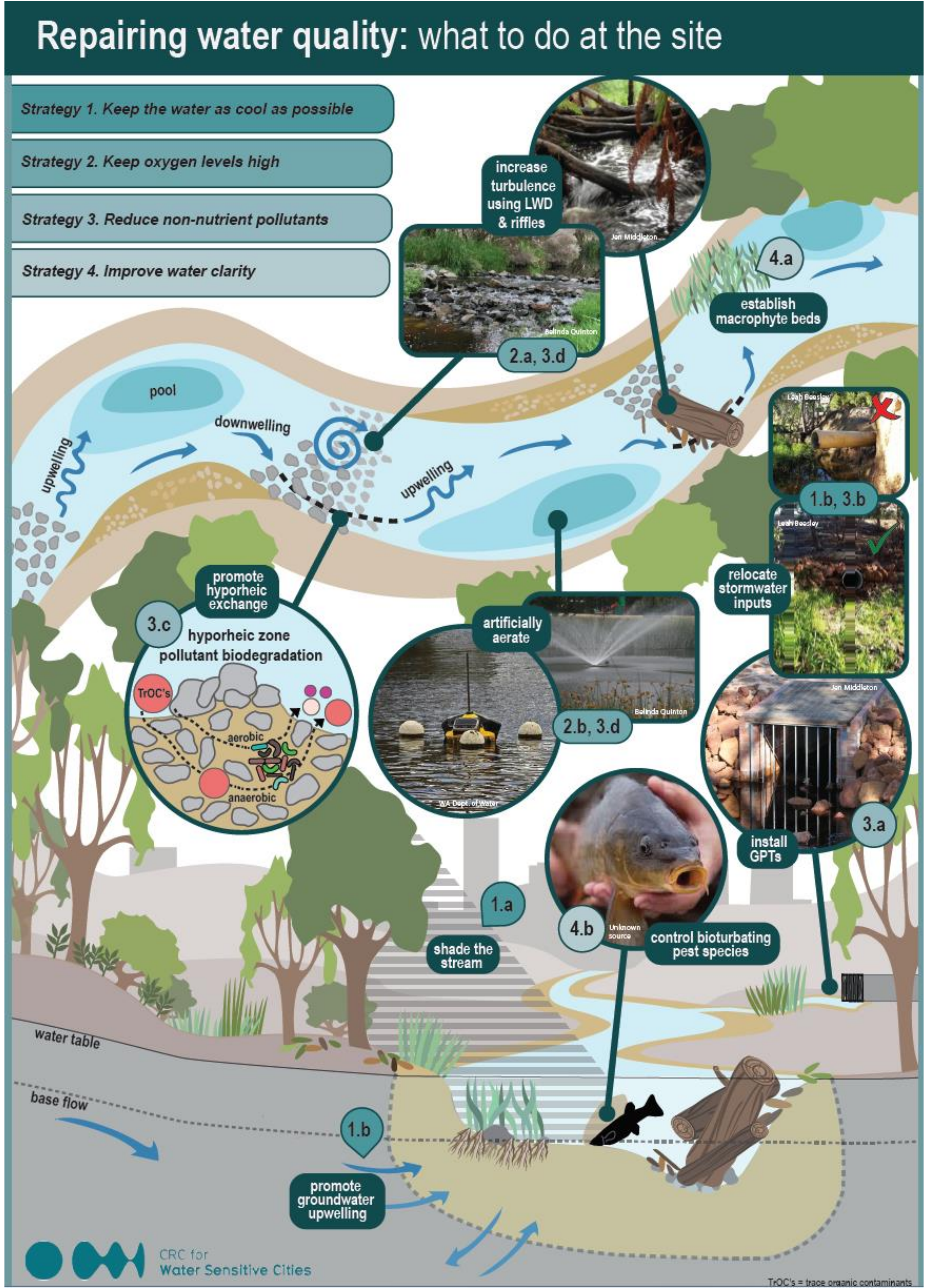

Strategy 1. Keep the water as cool as possible

Strategy 2. Keep oxygen levels high

Strategy 3. Reduce non-nutrient pollutants

Strategy 4. Improve water clarity

Repairing biota: what to do in the catchment

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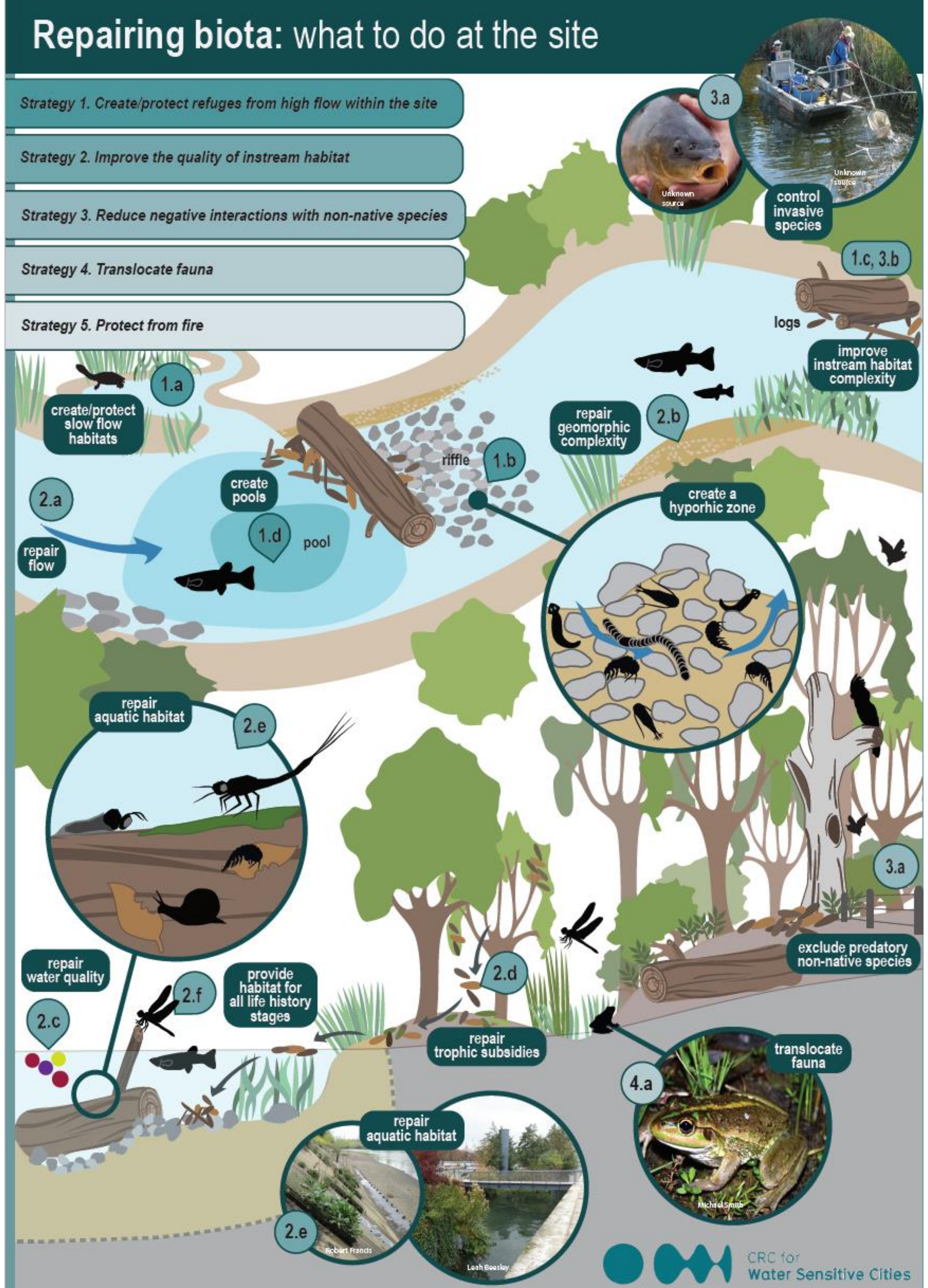


Strategy 1. Create/protect refuges from high flow within the site

Strategy 2. Improve the quality of instream habitat

Strategy 3. Reduce negative interactions with non-native species

Strategy 4. Translocate native fauna

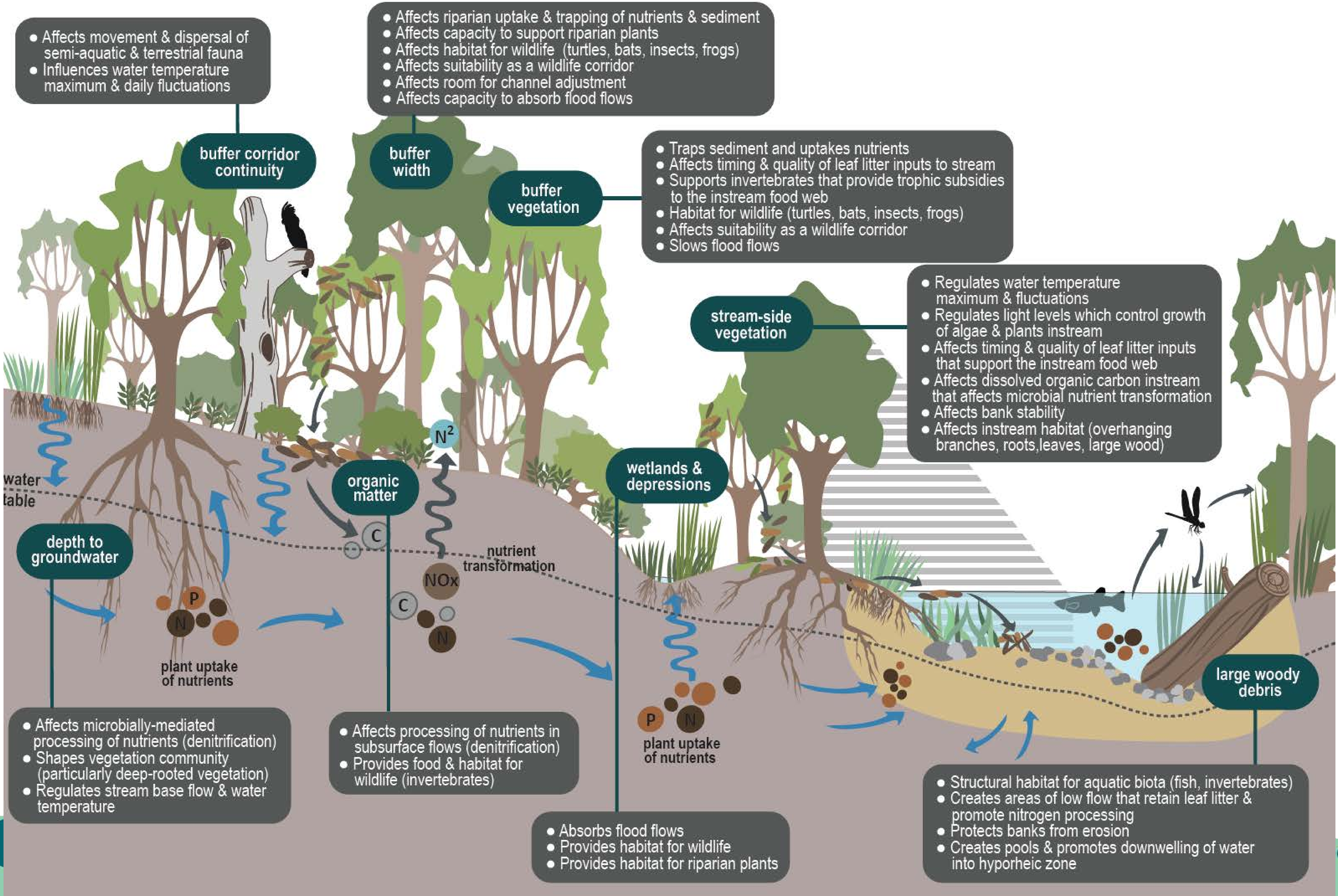
Strategy 5. Protect from fire

CRC for
Water Sensitive Cities

Riparian Design Guidelines to Inform the Ecological Repair of Urban Waterways

Beesley LS, Middleton J, Gwinn DC, Pettit N, Quinton B and Davies PM

Australian Government
Department of Industry, Innovation and Science
Business
Cooperative Research Centres Programme



● Affects movement & dispersal of semi-aquatic & terrestrial fauna
● Influences water temperature maximum & daily fluctuations
buffer corridor continuity
● Affects riparian uptake & trapping of nutrients & sediment
● Affects capacity to support riparian plants
● Affects habitat for wildlife (turtles, bats, insects, frogs)
● Affects suitability as a wildlife corridor
● Affects room for channel adjustment
● Affects capacity to absorb flood flows
buffer width
buffer vegetation
● Traps sediment and uptakes nutrients
● Affects timing & quality of leaf litter inputs to stream
● Supports invertebrates that provide trophic subsidies to the instream food web
● Habitat for wildlife (turtles, bats, insects, frogs)
● Affects suitability as a wildlife corridor
● Slows flood flows
stream-side vegetation
● Regulates water temperature maximum & fluctuations
● Regulates light levels which control growth of algae & plants instream
● Affects timing & quality of leaf litter inputs that support the instream food web
● Affects dissolved organic carbon instream that affects microbial nutrient transformation
● Affects bank stability
● Affects instream habitat (overhanging branches, roots,leaves, large wood)
water table
N^2
organic matter
wetlands & depressions
depth to groundwater
C
nutrient transformation
NOx
C
N
P
N
plant uptake of nutrients
P
N
plant uptake of nutrients
large woody debris
● Affects microbially-mediated processing of nutrients (denitrification)
● Shapes vegetation community (particularly deep-rooted vegetation)
● Regulates stream base flow & water temperature
● Affects processing of nutrients in subsurface flows (denitrification)
● Provides food & habitat for wildlife (invertebrates)
● Absorbs flood flows
● Provides habitat for wildlife
● Provides habitat for riparian plants
● Structural habitat for aquatic biota (fish, invertebrates)
● Creates areas of low flow that retain leaf litter & promote nitrogen processing
● Protects banks from erosion
● Creates pools & promotes downwelling of water into hyporheic zone

Riparian processes and their importance to waterway health:

Processes that support the instream environment

1. Light and temp regulation
2. Nutrient processing and sediment trapping
3. Bank stabilization
4. Flood attenuation
5. Channel adjustment
6. Trophic subsidies
7. Aquatic habitat

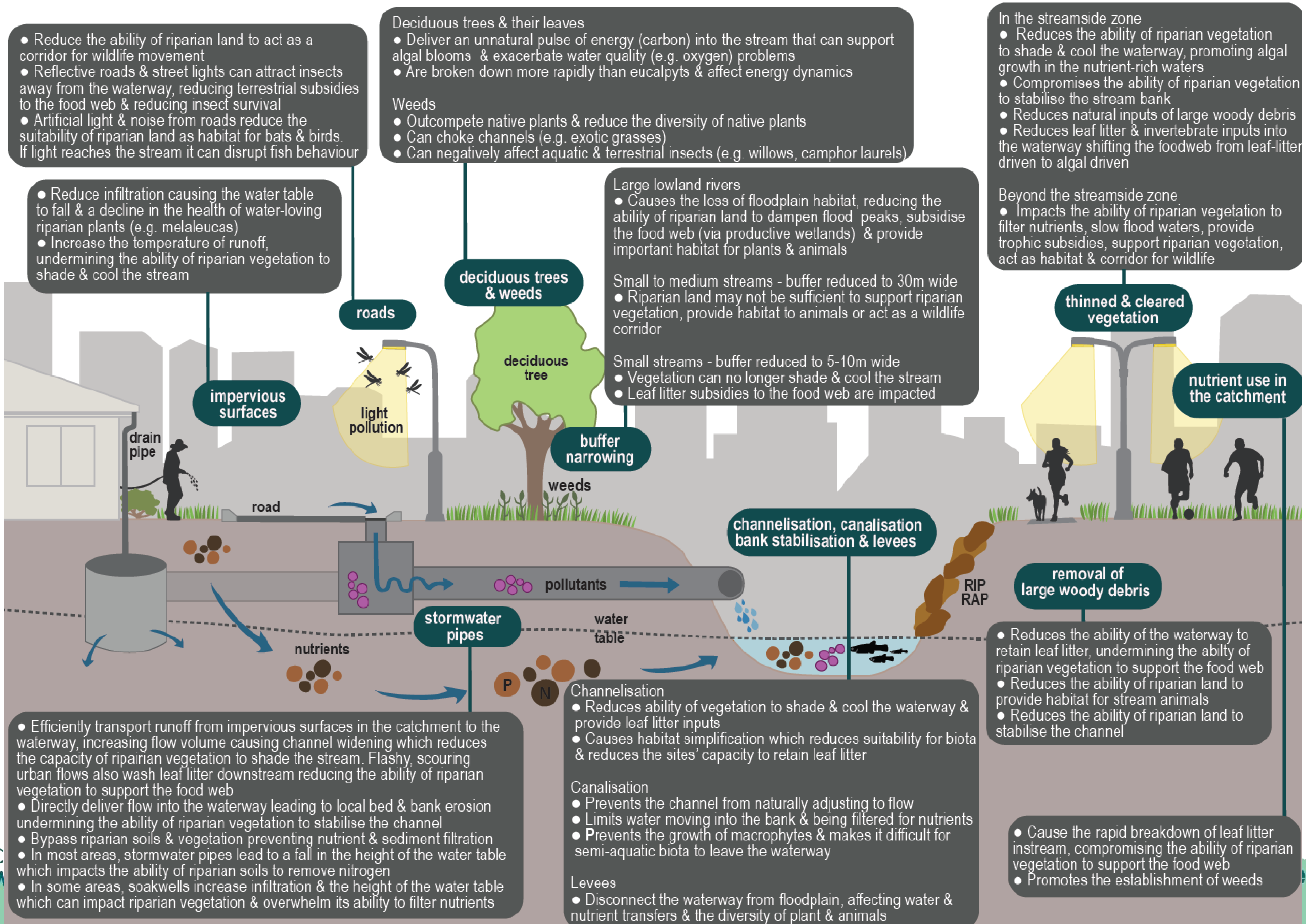
Processes that support the terrestrial environment

8. Riparian vegetation
9. Terrestrial habitat
10. Terrestrial corridor

Natural importance

Importance to Natural Stream Function			
Riparian Process	High (score 2)	Moderate (score 1)	Low (score 0)
1. Light & temperature regulation	Forested vegetation; narrow channel width (< 10 m); E-W orientated. *e.g. northern and eastern Melbourne, Perth*	Shrub or sparse vegetation *e.g. Geraldton* OR narrow channel width (<10 m) with a N-S orientated OR intermediate channel width with a E-W orientation (10-30 m)	Grass/herb vegetation *e.g. western parts of Melbourne* OR wide channel width (>30 m) OR considerable upwelling of groundwater
2. Nutrient filtration & sediment trapping	Moderate clay content, rich in Fe & Al with good soil permeability; dense complex vegetation; gentle slope (2-15°); shallow water table (< 4m below ground during wet season) *e.g. parts of Melbourne*	Soils have high clay content reducing permeability, or are very sandy; vegetation is dense & complex & slope is moderate (15-25°). Water table is deep (> 4m below ground during wet season). *e.g. parts of Melbourne*	Sandy soils low in Fe and Al and very flat (<2°) *e.g. parts of Perth*; OR steeply sloped (>25°). Sparse vegetation; water table is deep (>4 m below ground during wet season) *e.g. parts of south-eastern Queensland*
3. Bank stabilization	Soils are highly erodible (e.g. sand); site is exposed to moderate stream power; channel < 30 m wide & bank < 1 m deep; deep and shallow-rooted vegetation. *e.g. parts of Perth, Adelaide and south-western Melbourne*	Soils are moderately erodible (e.g. gravel, clay); site is exposed to high stream power *e.g. parts of Melbourne, Perth hills* OR channel 30-50 m wide & bank 1-2 m deep; deep-rooted vegetation only	Soils have low erodibility (e.g. boulder, bedrock) OR site is exposed to low stream power OR channel > 50m wide & bank >2 m deep; shallow-rooted vegetation only
4. Flood attenuation	Upstream catchment is long & thin in shape; high drainage density, with a short, steep headwater section & then a long low-gradient section. Floodplain contains numerous wetlands or ponds	Upstream catchment has high drainage density BUT floodplains upstream are steep & narrow OR upstream catchment has low drainage density AND floodplains upstream are flat & wide	Upstream catchment has a low drainage density & high gradient floodplain section – i.e. poorly developed floodplain with no wetlands or ponds
5. Channel adjustment	Highly erosive bank soils (e.g. sand, gravel) *e.g. parts of Perth, Adelaide and south-western Melbourne*	Moderately erosive bank soils (e.g. clay, cobble) *e.g. parts of Melbourne*	Bedrock channels (i.e. little to no erosion)
6. Trophic subsidies	Low light to channel; closed riparian canopy; low nutrients (e.g. narrow forested stream) OR regular inundation of productive floodplain habitat	Moderate light to channel; moderate nutrients OR infrequent inundation of productive floodplain habitat	High light to channel; open riparian canopy; moderate nutrients OR no regular inundation of floodplain habitats (e.g. lowland river)
7. Aquatic habitat	Narrow channel (< 10m); treed vegetation; low flows OR lowland sites with well-developed floodplain	Intermediate channel width (10-30 m); shrub vegetation; moderate flow OR lowland site with moderately developed floodplain	Wide channel (> 30 m); grass vegetation; high flows OR lowland sites with poorly developed floodplain
8. Riparian vegetation	Semi-arid, arid or dryland climate; vegetation includes trees, shrubs & groundcover *e.g. Geraldton*	Mediterranean or mesic climates; vegetation includes trees, shrubs & groundcover *e.g. Perth*	Tropical environment OR grasslands *e.g. parts of north-east Melbourne & Queensland*
9. Terrestrial habitat	Semi-arid, arid or dryland climates	Mediterranean or mesic climates	Tropical environments
10. Terrestrial corridor	Semi-arid, arid or dryland climates	Mediterranean or mesic climates	Tropical environments

Stress due to urbanisation:



Similar to DWER riparian veg theme score

RARC: rapid assessment of riparian condition

Estimating stress

RARC Sub Index	RARC Indicator	1. Light & temp regulation (LT)	2. Nutrient filtration & sediment trapping (NS)	3. Bank stabilization (BS)	4. Flood attenuation (FA)	5. Channel adjustment (CA)	6. Trophic subsidies (TS)	7. Aquatic habitat (AH)	8. Riparian vegetation (RV)	9. Terrestrial habitat (TH)	10. Terrestrial corridor (TC)
		Riparian Process									
Habitat	Longitudinal connectivity	0-4									0-4
	Width of riparian vegetation (i.e. buffer width)	0-4	0-4		0-4	0-4	0-4		0-4	0-4	0-4
	Proximity to nearest patch of intact native vegetation										0-3
Cover	Canopy in streamside zone (trees >5m tall within 5m of bank)	0-3		0-3				0-3			
	Canopy (>5m tall)		0-3		0-3					0-3	
	Understorey (1-5m tall)		0-3	0-3	0-3					0-3	
	Ground (<1m tall)		0-3	0-3	0-3					0-3	
	Number of layers									0-3	
Natives	Canopy (> 5m tall)						0-3		0-3	0-3	
	Understorey (1-5m tall)						0-3		0-3	0-3	
	Ground (<1m tall)						0-3		0-3	0-3	
Debris	Leaf litter		0-3					0-3		0-3	
	Native leaf litter						0-3		0-3		
	Standing dead trees (> 20 cm dbh)									0-1	
	Hollow-bearing trees									0-1	
	Fallen logs (>10 cm diameter)				0-2					0-2	
Features	Native canopy species regeneration (< 1m tall)								0-2		
	Native understorey regeneration								0-2	0-2	
	Large native tussock grasses								0-2	0-2	
	Reeds							0-2	0-2	0-2	
	Floodplain wetlands & topography		0-4		0-4		0-4	0-4		0-4	
Others	Channelisation & hardlining			0-3		0-3		0-3			
	Bank condition			0-2	0-2		0-2				
	Channel incision				0-2		0-2				
	Levees present				0-1		0-1				
Maximum possible score		11	20	14	24	7	25	15	24	42	11
Site score (ss)		$\sum LT_{scores}$	$\sum NS_{scores}$	$\sum BS_{scores}$	$\sum FA_{scores}$	$\sum CA_{scores}$	$\sum TS_{scores}$	$\sum AH_{scores}$	$\sum RV_{scores}$	$\sum TH_{scores}$	$\sum TC_{scores}$
Summary stress score		$2-(LT_{ss}/5.5)$	$2-(NS_{ss}/10)$	$2-(BS_{ss}/7)$	$2-(FA_{ss}/12)$	$2-(CA_{ss}/3.5)$	$2-(TS_{ss}/12.5)$	$2-(AH_{ss}/7.5)$	$2-(RV_{ss}/12)$	$2-(TH_{ss}/21)$	$2-(TC_{ss}/5.5)$

Potential for recovery

Potential for Recovery			
Riparian Process	High (score 2)	Moderate (score 1)	Low (score 0)
1. Light & temperature regulation	>10m of land is available bordering the stream (i.e., buffer width); riparian land on upstream 1km reach has good vegetative cover (i.e., shading); no wastewater treatment plant upstream discharging warm water.	Intermediate buffer width available (3-10m) Or intermediate vegetation of upstream reach OR the sunny-side of stream needed for amenity (i.e. not available for revegetation).	Little land available bordering stream (< 3 m); riparian land on upstream 1km reach has little vegetation and limited revegetation potential; wastewater treatment plant upstream of site discharging warm water.
2. Nutrient filtration & sediment trapping	Stormwater is, or will be, delivered overland to riparian zone. Riparian land is moderately sloped (5-30°) and buffer > 30m wide.	Stormwater piped to channel & riparian buffer is wide with a flat or gentle slope (<15°) OR Stormwater is, or will be, delivered overland & riparian land is either very narrow (<10m wide) or wide (> 30m) width.	Stormwater directly piped into stream channel – little overland flow at site. Land is steep (>30°) or narrow (<10m wide).
3. Bank stabilization	Scouring urban flows have been repaired by catchment WSUD or the site is immediately downstream of flow regulating structure (e.g., weir, detention basin).	Widely distributed stormwater infiltration across catchment or not far downstream of flow regulating structure.	Scouring urban flows associated with direct connection of stormwater throughout the catchment.
4. Flood attenuation	Riparian land is relatively flat (<15°) & buffer is wide (> 100m).	Riparian land is moderately sloped (15-30°) OR moderately wide (10-100m).	Riparian land is steep (>30°) OR narrow (<10m wide).
5. Channel adjustment	A buffer of >10 times bankfull distance available on either side of stream	A buffer of 3-10 times bankfull distance available on either side of stream	Little land bordering stream. Buffer is < 3 times bankfull distance.
6. Trophic subsidies	Scouring urban flows have been largely repaired by catchment WSUD or site immediately downstream of flow regulating structure (e.g., weir, detention basin); riparian buffer >20m wide.	Widely distributed stormwater infiltration across catchment has partially repaired urban flow velocity Or site not far downstream of flow regulating structure. Riparian buffer 5-20m width.	Scouring urban flows associated with direct connection of stormwater in catchment; riparian buffer <5m wide.
7. Aquatic habitat	Regulating structure (e.g., weir, detention basin) upstream reducing flow at the site. Channel hard lining can be removed, adequate space for channel reshaping if necessary & there is vehicle access to site for LWD addition.	Widely distributed stormwater infiltration across catchment or not far downstream of flow regulating structure. Intermediate room and accessibility for channel reshaping & LWD addition.	Scouring urban flows still present due to conventional stormwater management. Channel hard lining cannot be removed, no space for channel changes, no access to site for LWD addition.
8. Riparian vegetation	Moderate amount of land available for revegetation (buffer width >30m); legislation in place to prevent clearing of native vegetation in the riparian buffer.	Low amount of riparian land available for revegetation (10-30m); legislation is or isn't in place to prevent clearing.	Little land available bordering stream (< 10 m); no legislation in place to prevent clearing of native vegetation in riparian buffer.
9. Terrestrial habitat	Buffer width > 50m OR site has high functional connectivity to a large remnant patch of vegetation – i.e. an unfragmented & well-vegetated corridor exists to an adjoining large habitat patch or a patch known to contain high biodiversity.	Buffer width 10-50m wide OR site has moderate connectivity to remnant vegetation patch - this could be a connected corridor that has poor vegetation cover, or a fragmented corridor that is close to a remnant patch such that it will allow bird passage but not terrestrial fauna.	Buffer width < 10 m OR site has poor connectivity to remnant vegetation patch – e.g. numerous roads preventing animal movement, large distance to remnant patch, small sized remnant patch.
10. Terrestrial corridor	Riparian revegetation will link the site to a riparian corridor that joins	Riparian revegetation will link the site to a riparian corridor upstream or	Revegetation will not link the site to a corridor (i.e. site is isolated or

Prioritisation of riparian processes:

Step 1: determine which riparian processes are most important given the local and regional setting

Step 2: estimate how stressed the riparian processes are (RARC)

Step 3. assess the potential recovery of the various ecological processes

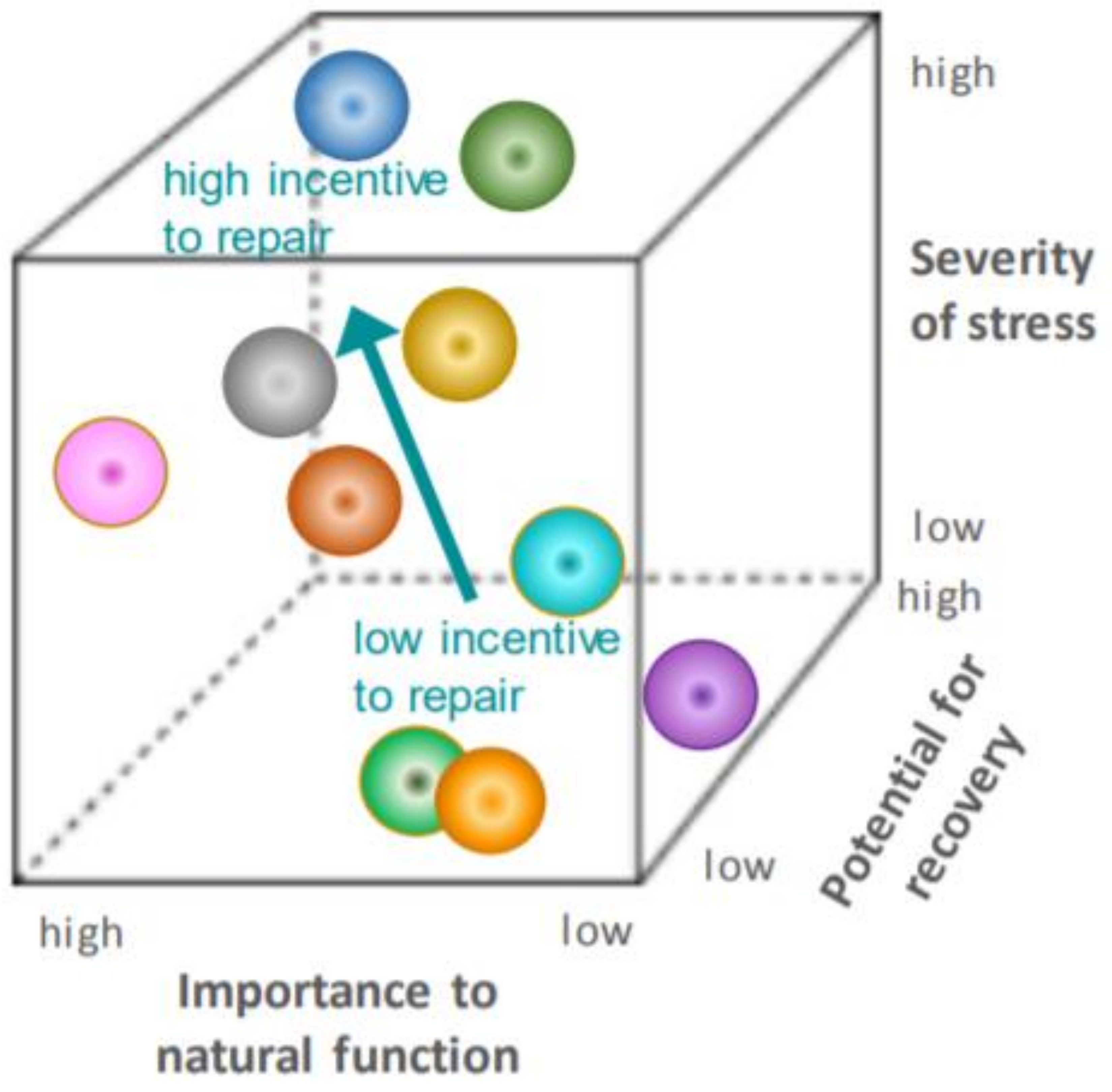


Table 5. Determining prioritisation scores for the 10 riparian processes.

Riparian process	Natural importance to stream function (A) (output from Table 1)	Alteration or stress (B) (output from Table 2)	Potential for recovery (C) (output from Table 3)	Prioritisation score (A*B*C)
1. Light & temp regulation	x	y	z	P1
2. Nutrient filtration & sediment trapping	…	…	…	P2
3. Bank stabilisation	…	…	…	P3
4. Flood attenuation	…	…	…	P4
5. Channel adjustment	…	…	…	P5
6. Trophic subsidies	…	…	…	P6
7. Aquatic habitat	…	…	…	P7
8. Riparian vegetation	…	…	…	P8
9. Terrestrial habitat	…	…	…	P9
10. Terrestrial corridor	…	…	…	P10

Prioritisaton of on-ground actions:

Action/strategy	Riparian process										
	1. Light & temp. control	2. Nutrient filtration & sediment trapping	3. Bank stabilization	4. Flood attenuation	5. Channel adjustment	6. Trophic subsidies	7. Aquatic habitat	8. Riparian vegetation	9. Terrestrial habitat	10. Terrestrial corridor	SCORE
Increase buffer width (1.2, 2.2, 4.5, 5.3, 6.3, 8.4, 9.1, 10.2)	P1	P2		P4	P5	P6		P8	P9	P10	=sum
Protect native vegetation and revegetate the buffer with natives (2.4, 4.4, 6.4, 8.2, 9.2, 10.3)		P2		P4		P6		P8	P9	P10	=sum
Protect from fire (1.4, 2.13, 6.9, 7.10, 8.9, 9.10)	P1	P2				P6	P7	P8	P9		=sum
Promote hydrologic connectivity between the waterway & riparian land by grading the bank, lowering the floodplain, raising the channel or other means (2.7, 4.1, 6.6, 7.9. 8.5, 9.3)		P2		P4		P6	P7	P8	P9		=sum
Re-establish native trees & other native vegetation in the stream-side zone (1.1, 3.3, 6.1, 7.2)	P1		P3			P6	P7				=sum
Add large woody debris to the channel (3.5, 6.5, 7.1)			P3			P6	P7				=sum
Reconnect the main channel with adjacent floodplain wetlands by removing levees, regulators and unblocking creek channels (2.8, 4.3, 6.7)		P2		P4		P6					=sum
Create floodplain wetlands & topographical depressions 'riparian sponge' (4.2, 7.8, 9.4)				P4			P7		P9		=sum
Line the stream bank with wet-dry tolerant plants (2.9, 3.4, 7.5)		P2	P3				P7				=sum
Recreate channel sinuosity (5.2, 6.2, 7.4)					P5	P6	P7				=sum
Fence off riparian vegetation (8.3, 9.7)								P8	P9		=sum
Remove channel hard-lining (5.1, 7.3)					P5		P7				=sum
Remove levees & other floodplain barriers to flow (2.8, 4.6, 6.7)				P4		P6					=sum
Raise or lower the water table below the riparian zone (2.6, 8.6)		P2						P8			=sum
Add wall boxes or ledges (7.6, 8.7)							P7	P8			=sum

Design guidelines:

For each riparian process

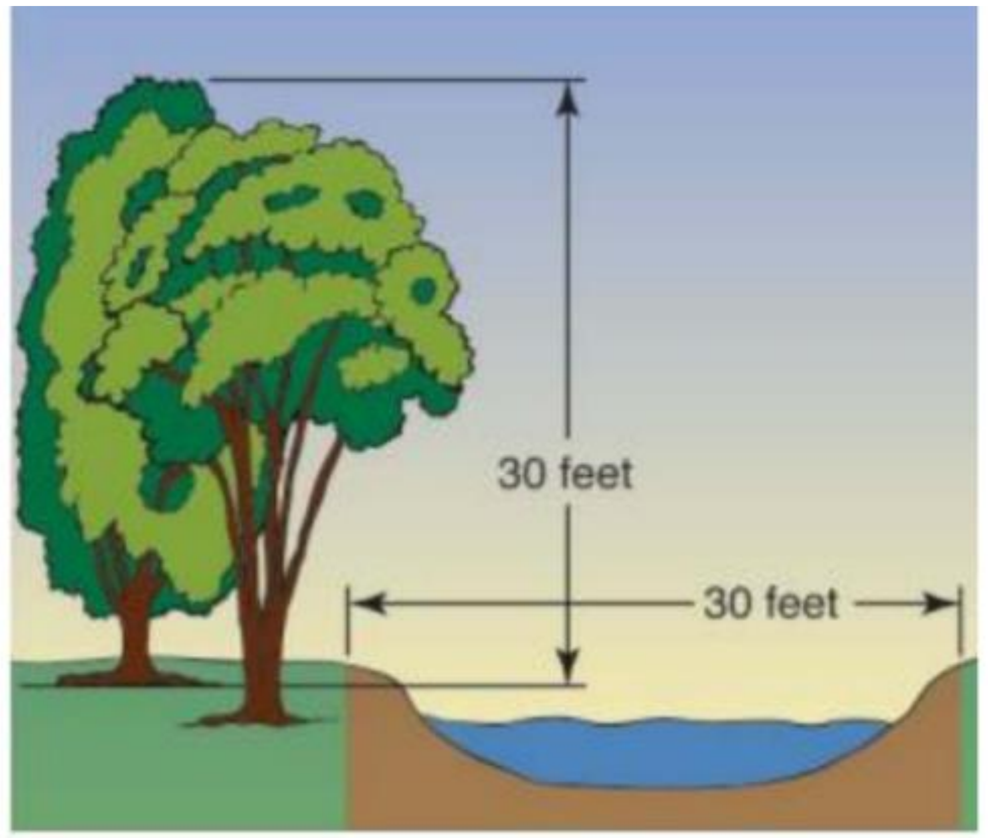
- Strategies
  - Actions
    - Information and possibly guidelines

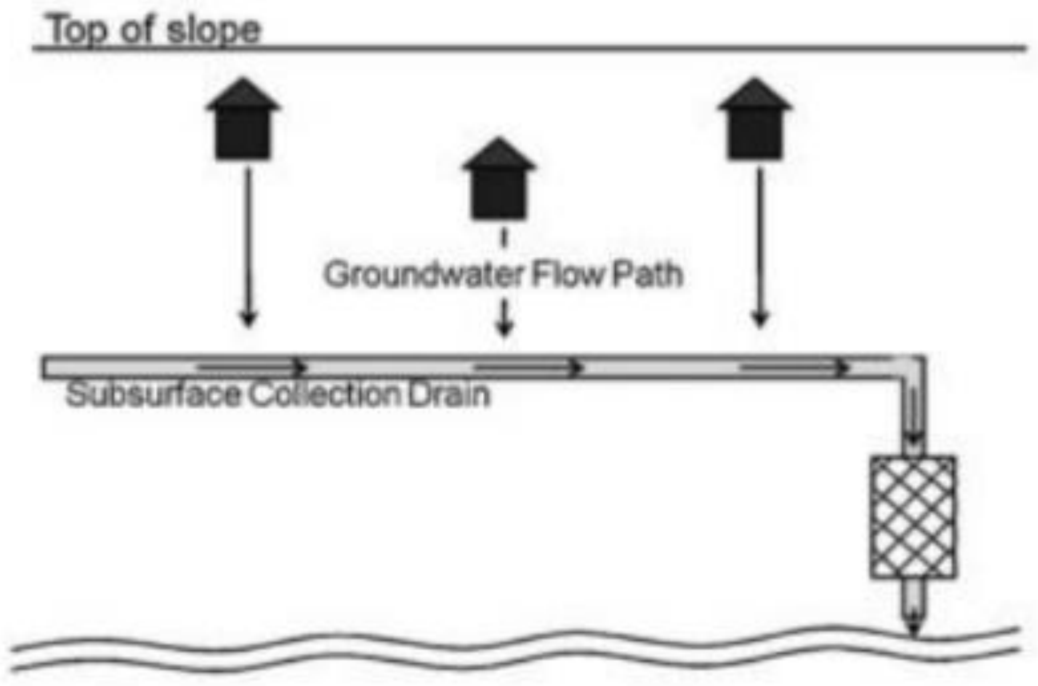
Some strategies will be more suitable than others given urban constraints

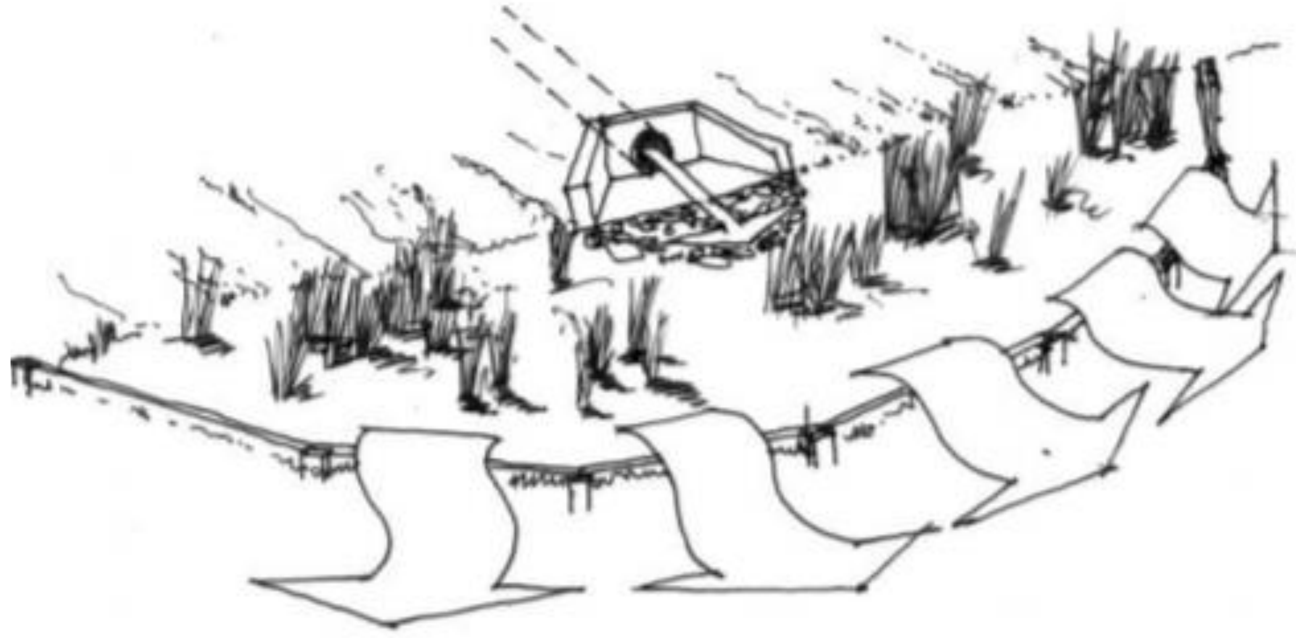
Some actions will be more suitable than others given your setting









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PhD Student: Jen Middleton undertaking research in Perth (other supervisors: Pauline Grierson, Neil Pettit)

- Distribution of nutrients in the water and sediment of urban and agricultural creeks importance of catchment factors (imperviousness, land use change) importance of site vegetation

- Carbon fluxes in sandy urban streams. Is the carbon (DOM) from anthropogenic or natural (algae, leaves) sources? Is the type of carbon driven by landuse? How bioavailable is this carbon?

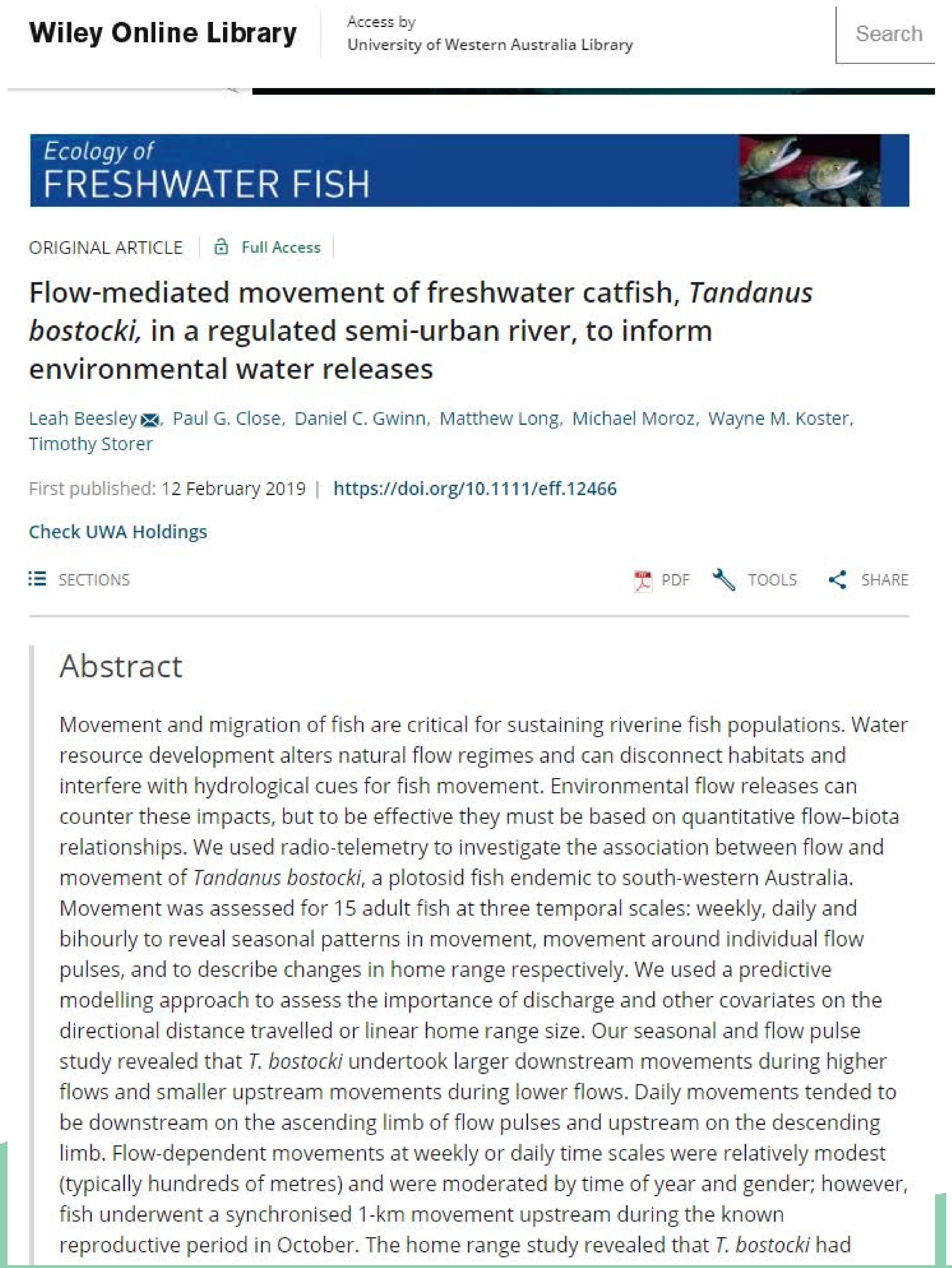
- Role of microbes in the breakdown of native and non-native leaf litter in urban streams

Contact me if you trial RESTORE or use the factsheets

Questions about tools: leah.beesley@uwa.edu.au

Questions:

Other collaboration with DWER: eflows Canning, Fitzroy River



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Ecology of FRESHWATER FISH

ORIGINAL ARTICLE | Full Access

Flow-mediated movement of freshwater catfish, *Tandanus bostocki*, in a regulated semi-urban river, to inform environmental water releases

Leah Beesley, Paul G. Close, Daniel C. Gwinn, Matthew Long, Michael Moroz, Wayne M. Koster, Timothy Storer

First published: 12 February 2019 | https://doi.org/10.1111/eff.12466

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Abstract

Movement and migration of fish are critical for sustaining riverine fish populations. Water resource development alters natural flow regimes and can disconnect habitats and interfere with hydrological cues for fish movement. Environmental flow releases can counter these impacts, but to be effective they must be based on quantitative flow–biota relationships. We used radio-telemetry to investigate the association between flow and movement of *Tandanus bostocki*, a plotosid fish endemic to south-western Australia. Movement was assessed for 15 adult fish at three temporal scales: weekly, daily and bihourly to reveal seasonal patterns in movement, movement around individual flow pulses, and to describe changes in home range respectively. We used a predictive modelling approach to assess the importance of discharge and other covariates on the directional distance travelled or linear home range size. Our seasonal and flow pulse study revealed that *T. bostocki* undertook larger downstream movements during higher flows and smaller upstream movements during lower flows. Daily movements tended to be downstream on the ascending limb of flow pulses and upstream on the descending limb. Flow-dependent movements at weekly or daily time scales were relatively modest (typically hundreds of metres) and were moderated by time of year and gender; however, fish underwent a synchronised 1-km movement upstream during the known reproductive period in October. The home range study revealed that *T. bostocki* had