Conceptual Model Case Study Series

Aquatic connectivity: Dewfish

Dewfish Demonstration Reach

The Dewfish Demonstration Reach* extends for approximately 110 km in the Condamine–Balonne catchment in south-central Queensland. Close to Dalby, it sits in an area of low relief and shallow stream slope. The majority of the reach comprises Oakey Creek, an ephemeral, run-off-fed stream originating in the western slopes of the Great Dividing Range, north of Toowoomba and flowing north-west. Low flows in the creek are provided by the treated effluent from Toowoomba's sewage treatment plant (STP). The rest of the demonstration reach comprises sections of Myall Creek and the Condamine River. A diagram on page 4 shows the extent of the demonstration reach.

The entire reach and much of the catchment has been heavily modified for agriculture. There are few naturally occurring off-stream wetlands along the demonstration reach and they are particularly absent from the floodplains of Oakey and Myall creeks. Off-channel dams and impoundments along Oakey Creek have been excavated or constructed from existing depressions in the landscape. None of these were historically natural wetlands. The remaining natural wetlands along the reach occur around and upstream of Loudoun Weir on the Condamine River. According to the Queensland Wetlands Classification, these are semi-arid floodplain tree swamps, with some modified semi-arid floodplain lakes

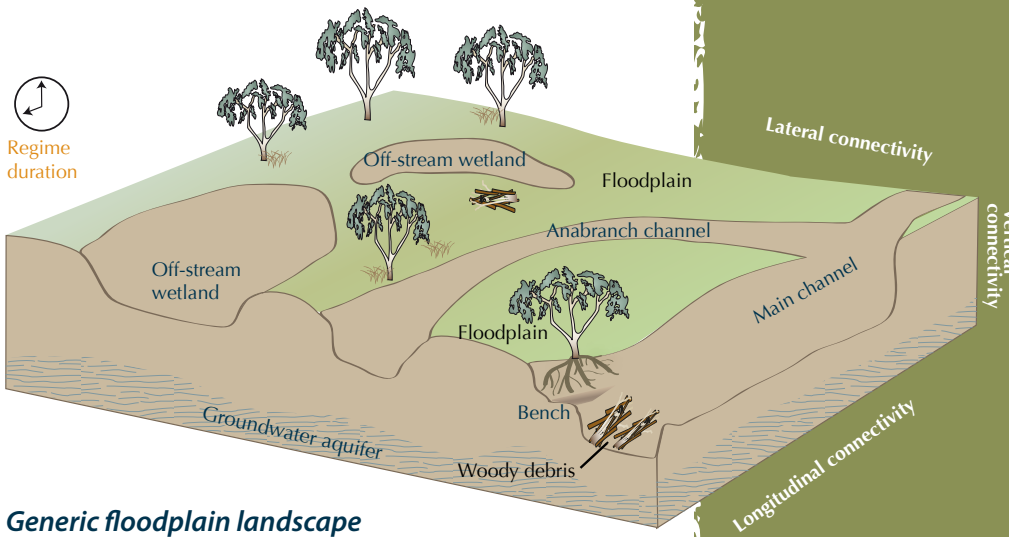
* a definition of the term 'demonstration reach' is given on page 7

The Integrated Quantity–Quality Model (IQQM), developed by the Department of Land and Water Conservation (DLWC 1996), was used as the source of the flow data for the analysis of connectivity in this wetland guide. The IQQM model simulates flows under natural conditions and under conditions which assume human water use (i.e. water resource allocation) is at a maximum. The term 'developed condition' is used through this guide to refer to the condition under maximum human use. A flow regime analysis was based on the modelled IQQM flow data. The analysis will be used to discuss the impacts of changes in water resource allocations on a range of connectivity processes.

Flow regimes and connectivity

The Dewfish demonstration reach is primarily fed by river flow from higher in the catchment and the associated off-stream wetlands receive most of their inundation from the river (rather than rainfall run-off or other water sources). Conceptual diagrams on the following pages show how different flow conditions (flow regimes) influence connectivity at the local scale across a *generalised* floodplain landscape.

The generic floodplain landscape is linked in three dimensions: longitudinally along the main river channel, laterally along anabranches, across the floodplain and into off-stream wetlands, and vertically through the groundwater. Flow regimes are general



Generic floodplain landscape

About this case study:

This case study was created by the Department of Environment and Resource Management (DERM) Aquatic Ecosystem Health Science Integration and Capacity Building Team as part of the Queensland Wetlands Program. The study is written for wetland managers. Its purpose is to synthesise and present information about aspects of wetland connectivity. Hydrological, biotic and ecological connectivity are discussed, as well as how these types of connectivity influence each other, and how they change over time.

descriptions of water discharge levels that result in different levels of connection. The diagrams include an indication of the expected duration for each flow regime.

No flow

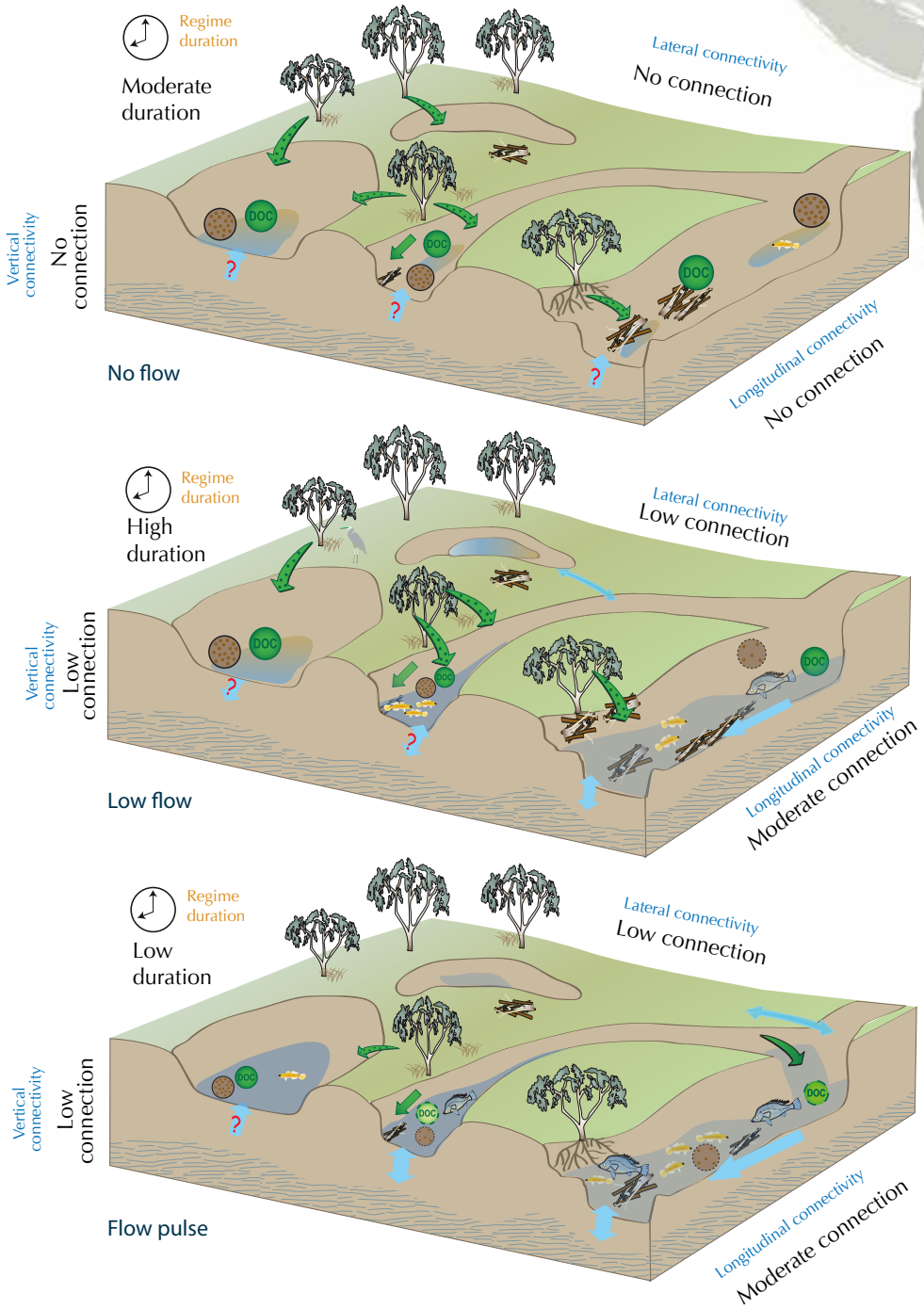
Though periods of no flow are normal for the Queensland Murray–Darling Basin and plants and animals are generally adapted to cope with it, extended dry periods can stress the system. Dry periods can be advantageous to 'reset' the system and kill off pest fish. Water in disconnected pools tends to be turbid and its quality decreases with time as part of the natural process of drying. If these periods are protracted, biota in these waterbodies might suffer and aquatic species can be lost completely until subsequent recolonisation when/if connection to other populations occurs. Furthermore, ecosystem processes (e.g. decomposition) slow down in the absence of water. Nutrients accumulate after they are deposited from the riparian zone and other terrestrial sources (e.g. leaf litter and woody debris) into the stream bed, off-stream wetlands and onto floodplains. There may be some vertical connectivity between groundwater and surface water; this will be dependent on local geomorphology and the state of the groundwater.

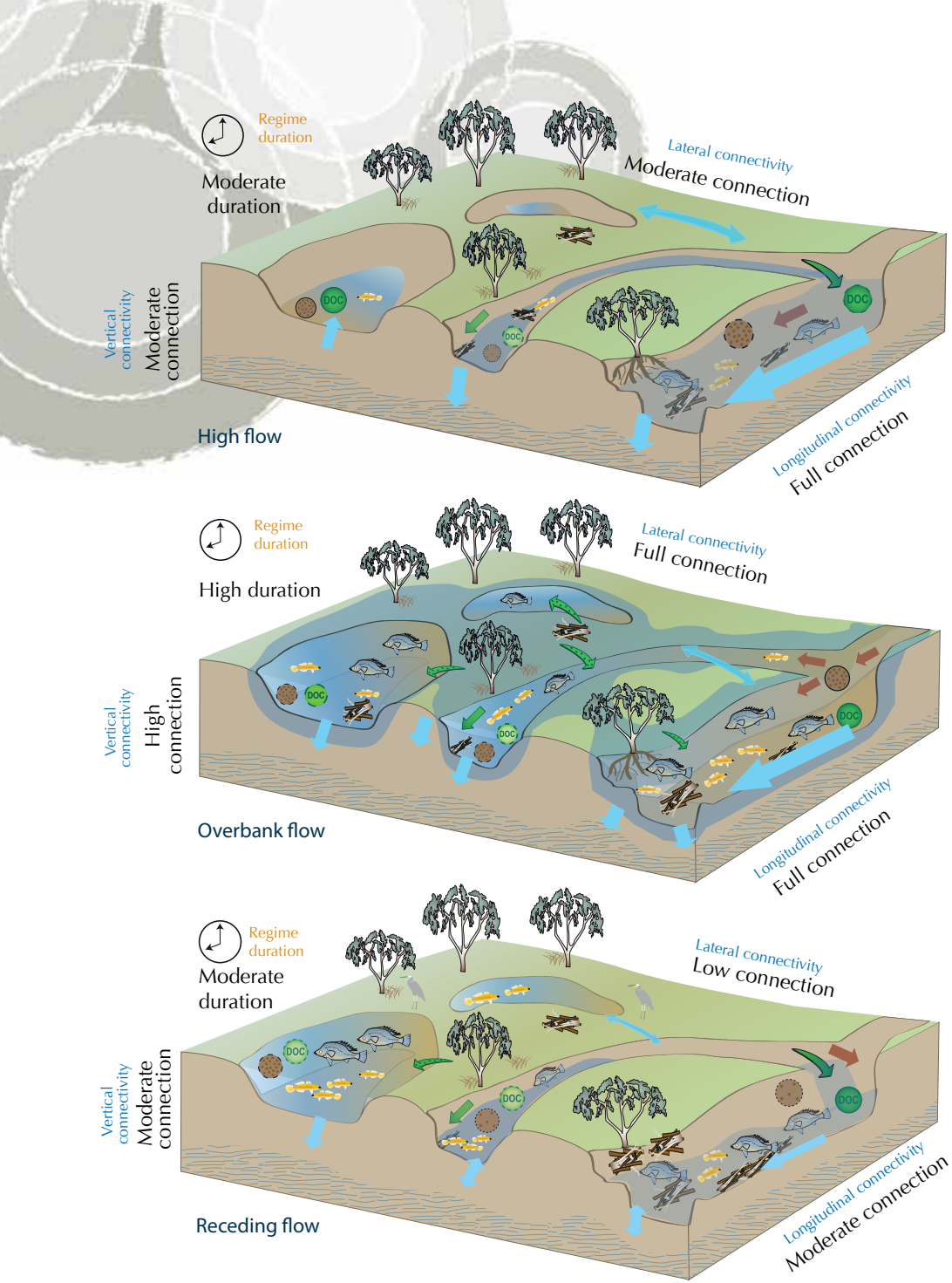
Low flow

Compared with no flow, low flow benefits fish populations by helping to maintain water quality. Low flows link in-stream habitats, sustain longitudinal connectivity for movement of biota, raise water levels increasing available habitat and refresh in-channel pools improving water quality. Connection to groundwater can occur in either direction, depending on the local geomorphology. In some cases the low flows of surface water may be provided entirely by the groundwater (this is known as baseflow) or low flow may seep into the earth and recharge the groundwater. Groundwater recharge during low flow is likely to be limited because hydraulic pressure from the stream will be low.

Flow pulse

Short flow pulses cause rapid changes to physicochemical aspects of water quality. These may be used as biological triggers (e.g. flow pulses bring food sources into an area, followed by low flows to maintain water quality). Pulses can briefly connect anabranches and off-stream wetlands, depending on the size of the flow pulse and the local topography, resulting in improved water quality and therefore improved health of aquatic habitats. Nutrients accumulated in the channels of anabranches can mobilise as a result of these pulses and sediments can be flushed out, resulting in reduced turbidity.





High flow

High flows inundate or mobilise organic material accumulating in dry stream beds, increase turbidity in channels by increasing sediment transport and allow fish to migrate. High flows provide connectivity to additional habitat and will result in connection to anabranches and secondary channels (depending on flow level and channel shape). High flows can benefit fauna by inundating benches (flat areas of sediment deposited in stream channels above the bed but below the banks) providing more habitat. This is especially important during summer for breeding purposes. Higher water levels increase water flow vertically into the groundwater. The increased hydraulic pressure in the groundwater aquifer can result in lateral movement of water to off-stream wetlands and anabranches through subsurface flows, depending on local geomorphology.

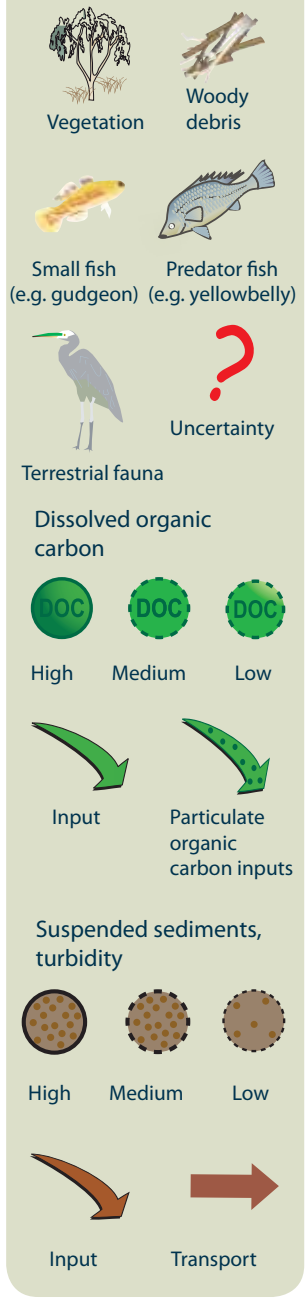
Overbank flow

Overbank flows inundate the floodplain and refresh water supplies in off-stream wetlands, improving water quality. Floodplains can be accessed by biota; organisms and seeds can move into off-stream wetlands. Nutrients accumulated in the floodplain can move into the channel ecosystem. Vertical water movement into the groundwater is at its greatest rate.

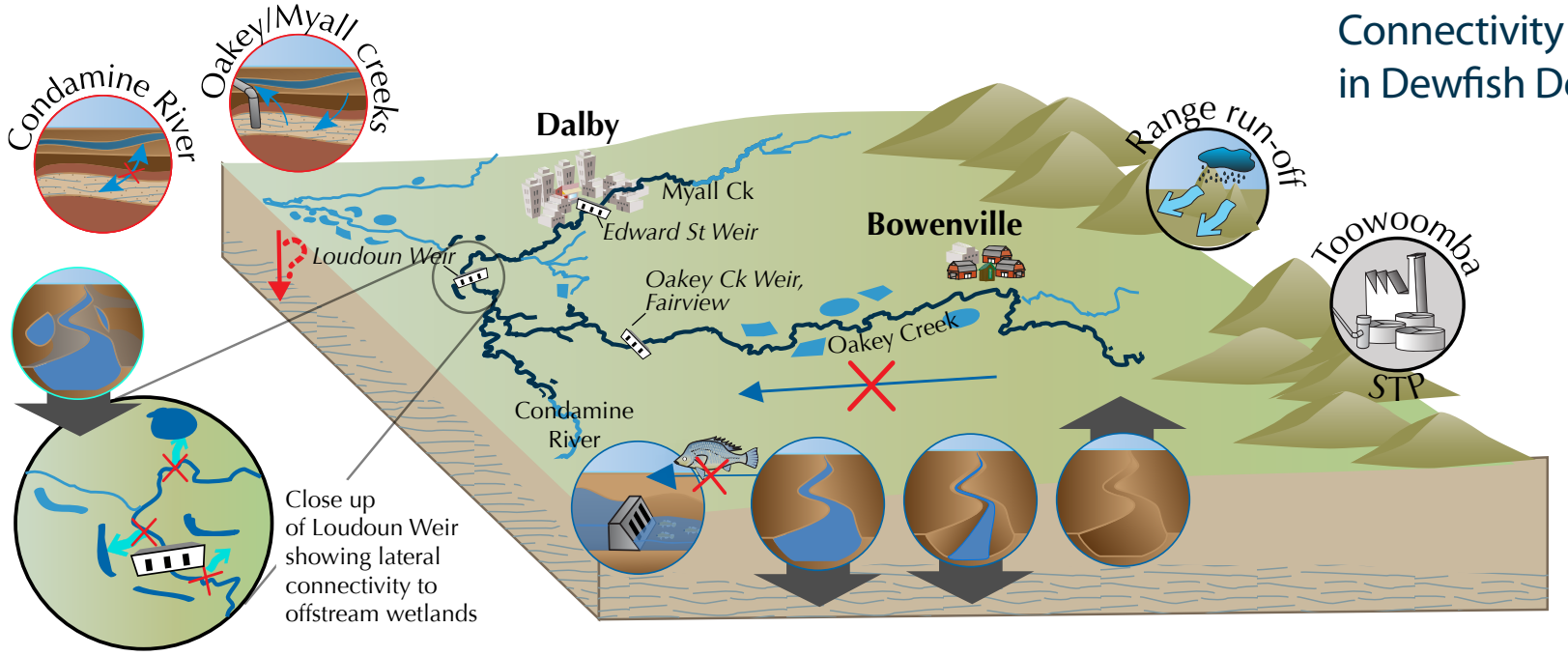
Receding flow

As flow drops back, off-stream wetlands retain water and can become hotspots for biological processes (e.g. decomposition, habitat for fish populations). Animals leave the receding floodplains and their associated wetlands or remain in off-stream wetlands. Nutrients and sediments drain from the anabranches back into the main channel or off-stream wetlands. Over time, the disconnected pools dry through evaporation or seepage into the groundwater, either partially or completely returning the system to no flow or low flow.

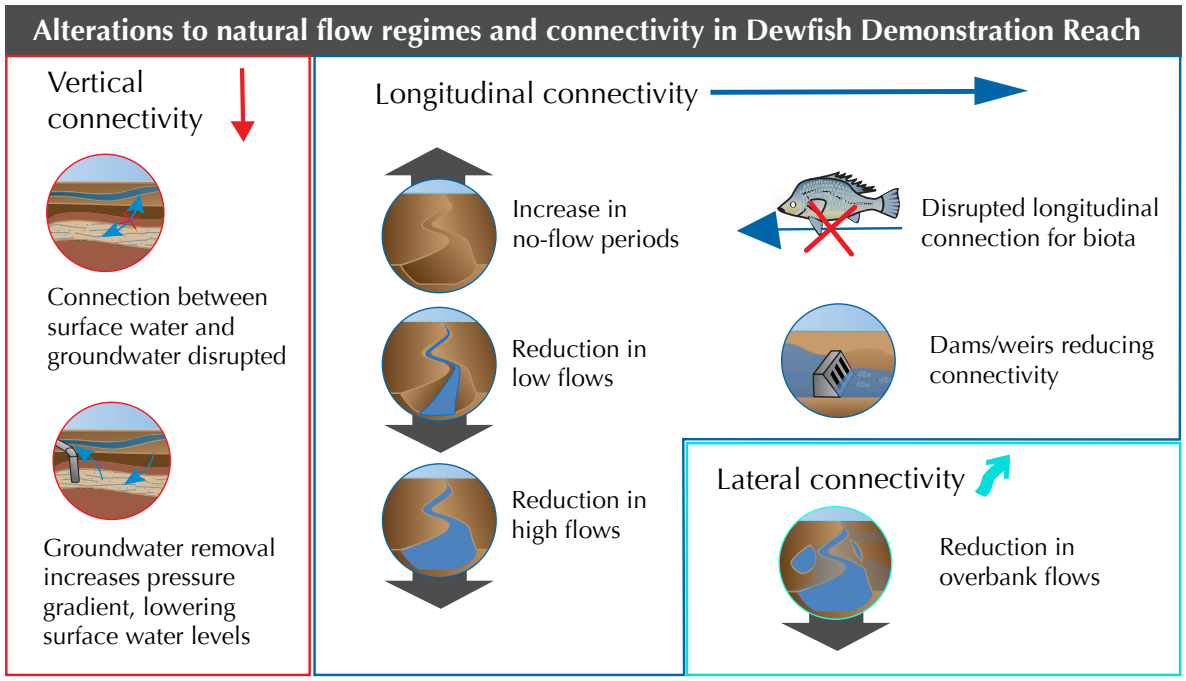
Legend

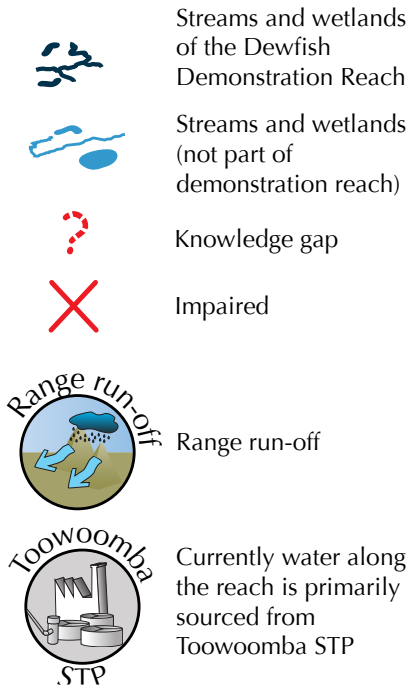


Connectivity in Dewfish Demonstration Reach



Alterations to natural flow regimes and connectivity in Dewfish Demonstration Reach





Hydrological connectivity

Longitudinal connectivity

In its natural state the Dewfish Demonstration Reach would have had relatively consistent levels of longitudinal connectivity, punctuated by several short periods of no flow or high flow, each lasting eight days on average. This regime has been disrupted by catchment development and water use. No-flow spells now occur less frequently but last for much longer.

Modelling suggests no-flow spells last three times longer under developed conditions than they would have in natural conditions. Modelling also suggests that the magnitude of high-flow events has been lowered by 30 per cent in the Condamine River and 40 per cent in Oakey Creek.

Lateral connectivity

Information is sparse regarding overland flows, such as those caused by run-off or main channels overflowing their banks. Estimates of bank-overflow frequency were based on relationships between discharge and water level and how these interacted with the shape of river cross-sections. The resulting estimates of overbank-flow rates for the length of the creeks can be used to generate a coarse estimate of the area of inundation.

The cross-sections for Oakey Creek and Condamine River are different: Oakey Creek has a simple cross-section, whereas the Condamine River cross-section has multiple depressions, both anabranches and off-stream wetlands, identified by wetland mapping as palustrine areas. These depressions or 'gullies' are within 200–500 metres of the main channel and fill at different stages of inundation. They are connected by high-flow events.

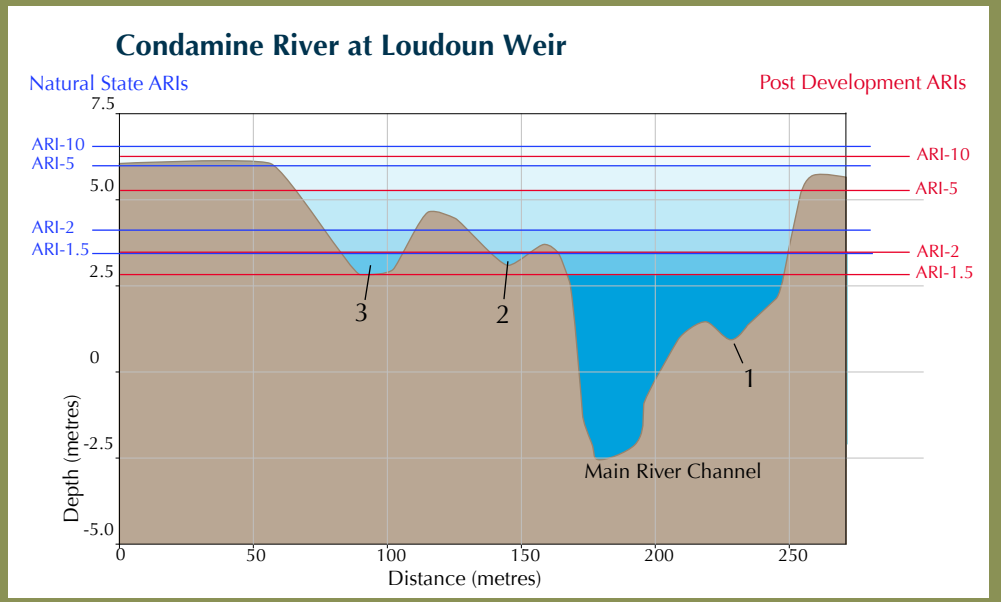
The floodplain around the Condamine River floods more frequently than the floodplain of Oakey Creek due to the topography of the respective floodplains. An examination of the cross-section suggests a flood whose average recurrence interval of 1.5 years (ARI=1.5 yrs) would extend across approximately 75 metres of the floodplain on the Condamine River compared to 25 metres on Oakey Creek. Season also affects flood magnitude, so lateral connectivity would be greater in the wet season (January to May).

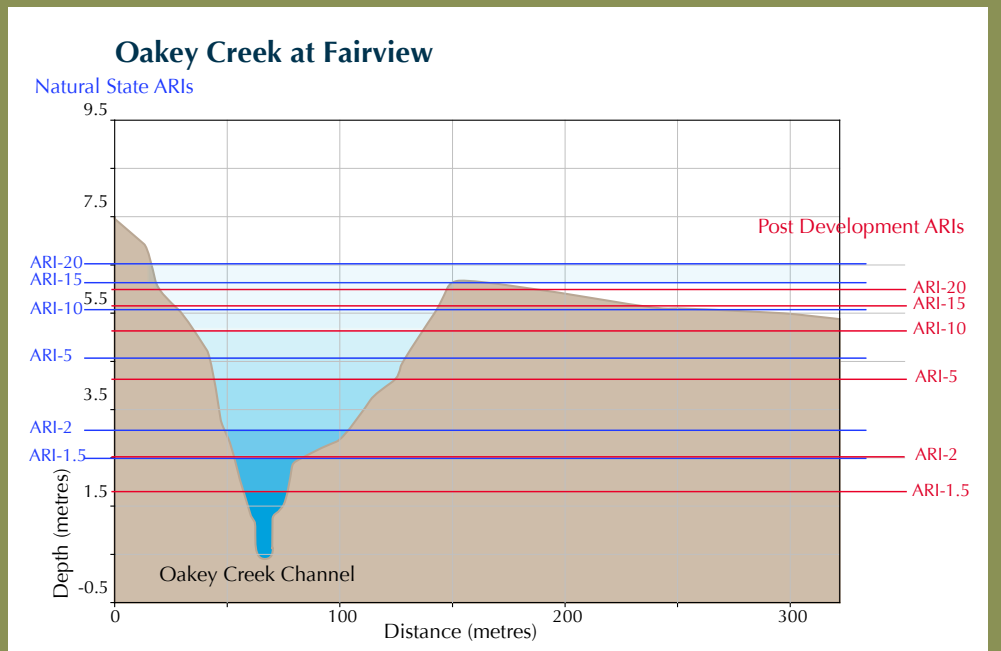
Condamine River at Loudoun Weir

Modelling suggests that water use, extraction and storage have reduced flood recurrence times, that is, floods of a given size occur less frequently. This reduction appears to have relatively little impact on the flooding regime of the various gullies around the main channel. Three gullies with different flow levels are evident in a cross-section of the river at Loudon Weir:

- Gully 1 floods at ARI<1.5 yrs under both natural and developed conditions.
- Gully 2 floods at an ARI=2 yrs under natural conditions and an ARI=2–5 under developed conditions
- Gully 3 floods at ARI=5 yrs under both natural and developed conditions.
- Peaks of the floodplain will flood at approximately ARI=5 yrs under natural conditions and an ARI=5–10 yrs under developed conditions.

This summary only indicates the level of water, not the volume entering the various wetlands. In all cases even if the overbank level is breached, less water would be entering the floodplain wetlands associated with the gullies under developed conditions compared with the natural state.





The average recurrence interval (ARI) refers to specific flow levels and the average frequency at which they are expected to occur (e.g. a flood of ARI=5 yrs would be expected to occur every five years on average).

Oakey Creek at Fairview

The floodplain at Oakey Creek has no gullies where water is able to pool, so it lacks natural off-stream wetlands along the reach. Due to the presence of a natural levee along the creek, the floodplain surrounding Oakey Creek floods less frequently than that of the Condamine River. A flood with an ARI=5 would be expected to inundate approximately 125 metres of the floodplain. Under natural conditions the bank peak at approximately 150 metres would be breached every 15 years. With the current level of development the interval between these events extends to more than 20 years.

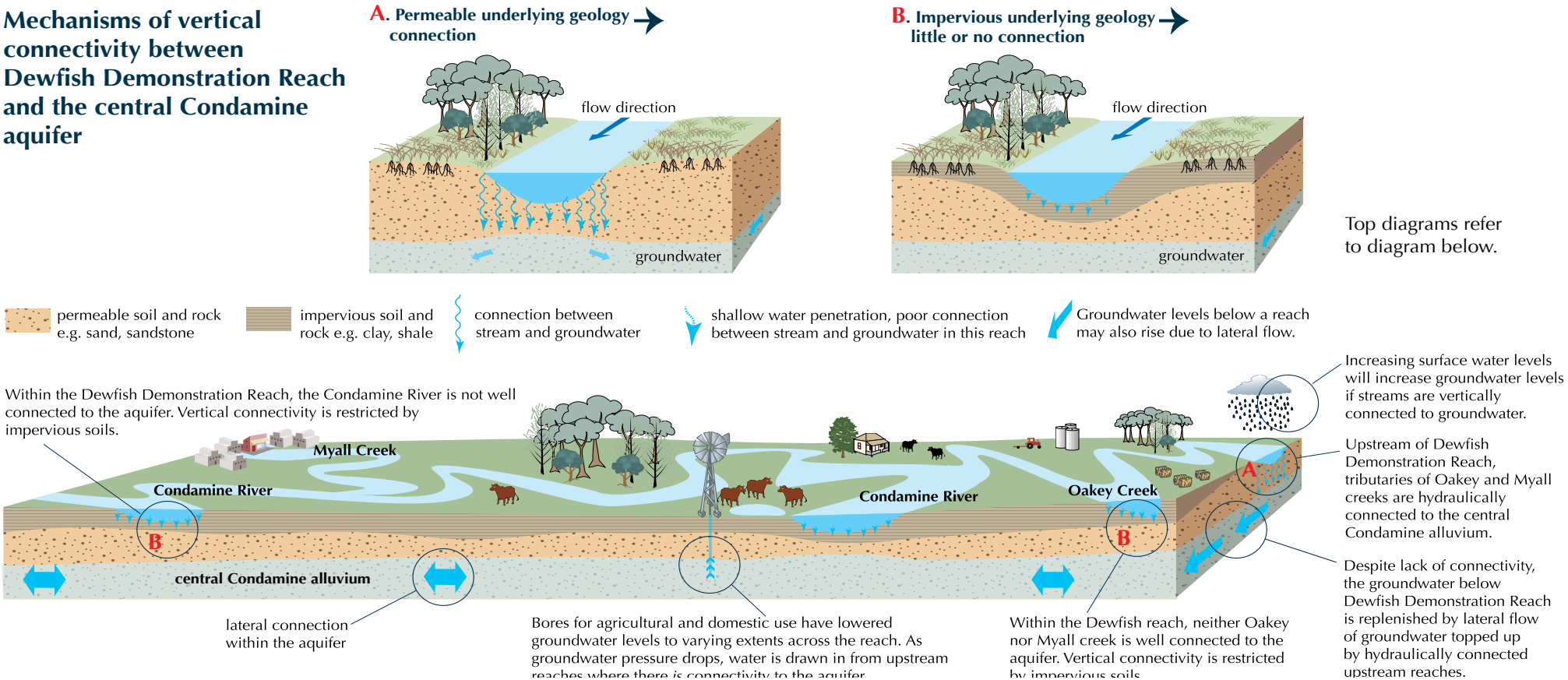
Vertical connectivity

Little data is available for the natural state of the groundwater in this reach, however, the scientific consensus is that, historically, the groundwater was closer to the surface. Since extractions began in the 1960s there has been significant drawdown in the area. Estimates for the reach range from a 20 metre drawdown of groundwater in the east of Oakey Creek, to 10 metres in the west of Myall Creek, with an estimate of 5 metres for the rest of the region.

Even after extended wet periods, groundwater is not well connected to the surface through the Condamine River. This lack of vertical connection is mainly due to the nature of soils along the reach, primarily clays and other fine sediments that conduct water poorly. A significant demonstration of this was the 1974 floods, which resulted in extremely low groundwater recharge (<1metre rise) despite four months of flooding.

The tributaries of Oakey Creek and, to a lesser extent, Myall Creek are thought to be still connected to the groundwater and providing recharge to the central Condamine alluvium. This occurs *outside* the Dewfish Demonstration Reach through the permeable soil and

Mechanisms of vertical connectivity between Dewfish Demonstration Reach and the central Condamine aquifer



rock underlying upstream tributaries of those two creeks. This recharge is still relevant to the Dewfish system because these upstream connections influence conditions within the demonstration reach.

Because the aquifer underneath the Condamine River and its tributaries (the central Condamine alluvium) is continuous (i.e. laterally connected underground), reduced groundwater pressure due to extraction (e.g. by bores) *anywhere* in the system will increase seepage of water from the surface into the groundwater to equalise the pressure. This seepage will likely come from the surface waters of Oakey and Myall creeks, which have the highest vertical connection to the groundwater.

There is also a spring in the main channel of Oakey Creek at Bowenville. Although little information is available about this spring, it has been suggested that the source of this is not the central Condamine alluvium, which underlies the reach. Rather, it is discharge from the Main Range volcanics, a series of basaltic aquifers underlying most of the upper eastern part of the catchment. If this is the case there is some connectivity between this other groundwater system and the surface water along the reach.

Ecological connectivity

Specific, detailed research into the connectivity ecology of organisms and communities within the demonstration reach has not yet been carried out. However the changes in lateral, vertical and longitudinal aquatic connectivity from natural state have had a number of likely impacts on abiotic and biotic connections:

- Fish passage along the streams of the reach may be limited by dams, reducing biological connectivity.
- The increase in incidence of no-flow events will reduce water quality, likely stressing fish populations in the in-stream pools along the reach.
- The reduction in occurrence of overbank flows will reduce floodplain inundation, potentially limiting processes required for ecosystem function.

Abiotic connectivity

Fewer low-flow periods and more no-flow periods reduce in-stream habitat provided by inundated benches (flat areas of sediment deposited in stream channels above the bed but below the banks) and potentially reduce water quality along the length of the reach.

Abiotic (and biotic) connection is supported by riparian zones, which contribute to connectivity to the surrounding landscape and provide carbon inputs to the local aquatic system, stimulating the food web. Rehabilitation of the riparian zone along the reach is included in the demonstration reach's whole of life plan.

The groundwater in the central Condamine alluvium shows spatial variability in water chemistry throughout the catchment. Along the demonstration reach, the groundwater is salty, dominated by sodium and chloride ions. Groundwater also tends to have variable sulphate, bicarbonate, magnesium and calcium composition. All these substances can be found in higher concentrations in the groundwater to the east of Oakey Creek.

Biotic connectivity

A number of weirs along the demonstration reach disrupt biotic connectivity by acting as barriers to fish passage. The most significant of these are Edward Street Weir at Dalby and Oakey Creek Weir on Oakey Creek. In addition to these, there are several private weirs that are potential barriers. In late 2010, Loudoun Weir had its fishway upgraded to improve fish passage and connectivity when it is operating.

Reduced connectivity and habitat access may influence the distribution and populations of various fish species found in creeks upstream of the Dewfish Demonstration

What is a demonstration reach?

Demonstration reaches are the focus for integrated rehabilitation activities. They are established to demonstrate to the community the cumulative benefits of using a number of actions for rehabilitating native fish populations and communties (Murray–Darling Basin Commission 2003).

The Condamine Alliance has developed a strategic program for river rehabilitation along the whole length of the Condamine catchment. The Dewfish Demonstration Reach is being developed as the catchment's first demonstration reach.

The Whole of Life Plan for Dewfish Demonstration Reach includes works to:

- fence and revegetate riparian areas to reduce erosion and sediment load
- re-snag to provide fish habitat and stabilise banks
- weed control to reduce pressure on native species
- modify the construction and fishway at the Loudoun Weir

- carry out activities to raise community awareness, build capacity and increase adoption of rehabilitation activities
- establish a monitoring and evaluation program (Condamine Alliance, 2008).

Returning the Condamine River to a more natural flow regime would increase longitudinal connectivity.

Reach and within the reach itself. Fish surveys conducted in 2008 found two long-ranging migratory species expected to occur in the reach—Murray cod and silver perch–were absent. Both species are found in fast flowing waters and are known to be affected by barriers. However, both the Murray Cod and the silver perch were found in the Condamine section of the reach in follow-up surveys (A.Butcher, pers. comm. August 2011). These later results may reflect the improved connectivity provided by the upgraded Loudoun Weir fishway or the impacts of local fish stocking or both. Further research is needed to clarify the situation.

There are also biotic connections within the regional aquifer; Stygofauna (groundwater invertebrates) are found in the alluvia of both the Oakey Creek tributary and the central Condamine alluvium. As there is no connection from the Condamine River to the groundwater in the area and water has been noted to flow from the Oakey Creek alluvium to the Condamine River aquifers, it is likely that this Oakey Creek alluvium groundwater connection is the source of stygofauna populations in the central Condamine alluvium. This connection is under threat from habitat fragmentation caused by drawdown.

Table 1. These fish species were found in surveys of the creeks in the Dewfish Demonstration Reach (conducted in 2008). Fish marked with an X were found in the reach, those marked with O were expected to be found but were absent. Some of the 'missing' fish were found in followup studies conducted 2009–2011. These followup occurences are indicated in brackets.

Fish	Myall Creek	Oakey Creek	Condamine River
Olive perchlet			x
Carp gudgeon	x	x	x
Spangled perch	x	x	x
Murray–Darling rainbowfish	x	x	
Golden perch	x	x	x
Bony bream	x	x	x
Hyrtl's tandan	x		
Unspeckled hardyhead		x	x
Smelt		x	x
Carp*	x		x
Goldfish*	x		x
Eastern gambusia*		x	x
Murray cod	o	o	o (x)
Eel-tailed catfish (Dewfish)	o (x)	x	x
Silver perch		o	o (x)

* exotic species

Synthesis of hydrological and ecological information

Connectivity has been significantly affected along the reach. Longitudinal connectivity has been disrupted by water extraction, despite water inputs from the Toowoomba STP. Increasing the frequency and magnitude of high-flow events would benefit the off-stream wetlands around Loudoun Weir and allow for better hydrological connection with the floodplain and the nutrients and habitats it contains. This would also increase carbon inputs into the stream network and improve population health. Weirs along the reach disrupt biotic connection and mitigation of these should improve the biodiversity and resilience of the system.

Summary

Longitudinal connectivity

Status

- Extraction has reduced flow and changed the flow regime of the demonstration reach.
- Longitudinal connectivity has been reduced by water extraction, despite water inputs from the Toowoomba STP.
- Longitudinal connectivity in the demonstration reach is interrupted during no-flow periods. Changes to natural flow regimes have seen a threefold increase in the amount of time with no flow through the reach.
- Barriers to fish movement reduce longitudinal connectivity.

Outcomes from improving connectivity

- Species richness and carrying capacity of the reach will increase with access to additional habitats.
- Improved water quality along the reach will result from reduced isolation of in-channel waterholes.

- Connecting populations will increase resilience of biota.
- With connection to the larger stream network, biodiversity will be maximised at the landscape scale.

Lateral connectivity

Status

- Reduction in high-flow peaks reduces lateral connection to off-stream wetlands surrounding the Condamine River.
- Offstream wetlands flood much less frequently and receive less water than under natural conditions. Reduced inundation rates will reduce the water quality of wetlands, affecting their utility as habitats for biota.
- Reduction in high-flow peaks reduces lateral connection to the floodplain.
- Reduction in lateral connectivity may affect nutrient dynamics and ecosystem function.
- High-flow peaks have been noted to be of importance to biota, for example, as a dispersal cue for fish species like the yellowbelly, but the exact local importance is unknown.

Outcomes from improving connectivity

There is general scientific consensus that improving lateral/floodplain connectivity will provide benefits to ecosystem function. Greater knowledge is needed, especially with regards to the timing of connections and how this allows the accumulation/mobilisation of nutrients.

- Movement through the landscape of ecologically important components (e.g. sediments, nutrients and biota) will benefit wetland function and biodiversity.
- There may be improvement in population success through connectivity to the floodplain.

Vertical connectivity

Status

- There has been significant drawdown of groundwater.
- Groundwater no longer provides baseflow to Oakey and Myall creeks within the Dewfish Demonstration reach.
- Reduced groundwater pressure around Oakey and Myall creeks will reduce longitudinal connectivity of the surface flows.
- Oakey Creek is a likely source for stygofauna populations in the central Condamine alluvium. The connection between Oakey Creek and the central Condamine alluvium is under threat from habitat fragmentation caused by drawdown.
- More research is needed into the ecological role and benefits of vertical connectivity in general and specifically for this area.

Outcomes from improving connectivity

- Improved groundwater–surface connection would support increased longitudinal connectivity by contributing to in-channel flow. This has benefits for biota and water quality processes.

Periods of no flow in the Dewfish Demonstration Reach have increased threefold since development.

Groundwater extraction around the demonstration reach decreases longitudinal connectivity of upstream tributaries of Oakey and Myall creeks.

Recommended reading and references

Butcher A and Kerezy A 2008a, *Oakey Creek Fish Biodiversity: 1 Bowenville Reserve. A short report on the pre-restoration fish biodiversity in Oakey Creek, August 2008*, Prepared by the Department of Employment, Economic Development and Innovation: Primary Industries and Fisheries for the Condamine Alliance, Brisbane QLD.

Butcher A and Kerezy A 2008b, *Myall Creek Fish Biodiversity. A short report on the pre-restoration fish biodiversity in Myall Creek, Dalby in August 2008*, Prepared by the Department of Employment, Economic Development and Innovation: Primary Industries and Fisheries for the Condamine Alliance, Brisbane QLD.

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Murray Darling Basin Comission 2003, *Native Fish strategy for the Murray–Darling Basin 2003–2013*. Murray–Darling Basin Commission Ministerial Council, Canberra.

Photo: Stan Cochrane

High flow in the Condamine River at Loudoun Weir

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