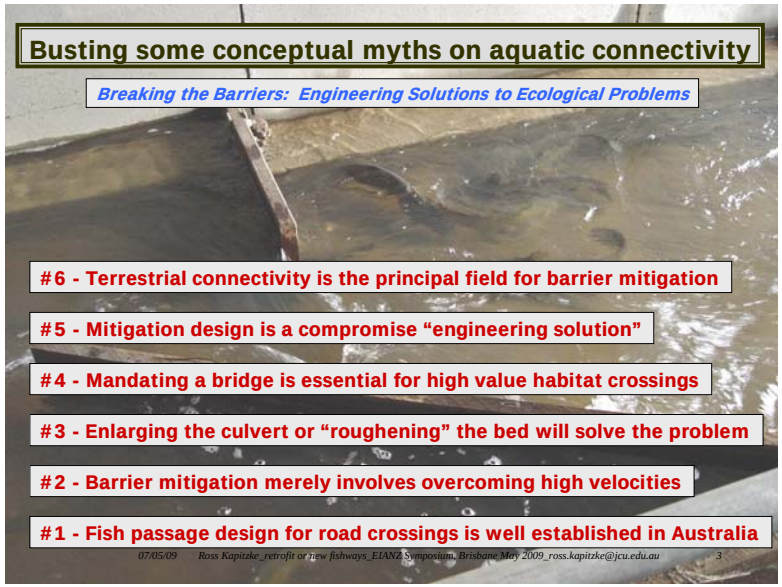
Aims of my talk

- Demonstrate significance of aquatic connectivity impacts
- Outline an ecohydraulics approach to fish passage design
- Illustrate successful barrier mitigation projects
- Bust some myths on aquatic connectivity / fish passage

Presentation outline

- Connectivity impacts and fish movement behaviour
- Migration barriers and multipurpose design requirements
- Barrier mitigation options and their characteristics
- Case study fishway projects in Queensland
- The way forward for fish passage planning and design



Freshwater fish values

Commercial fisheries

Mullet

Recreational fishing

Jungle perch

Conservation & biodiversity

Gudgeon

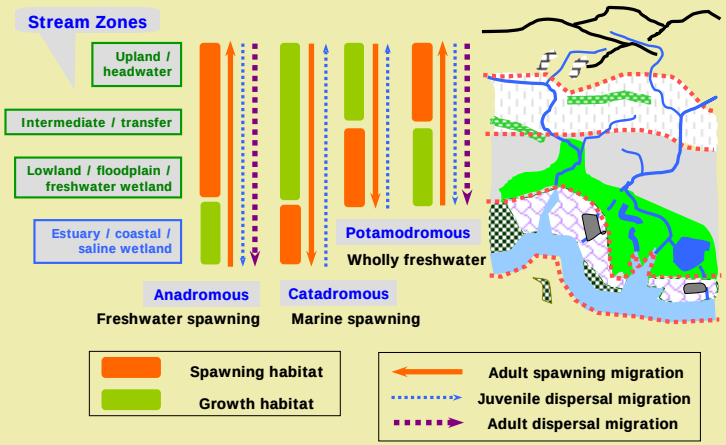
Traditional/cultural values

Barramundi

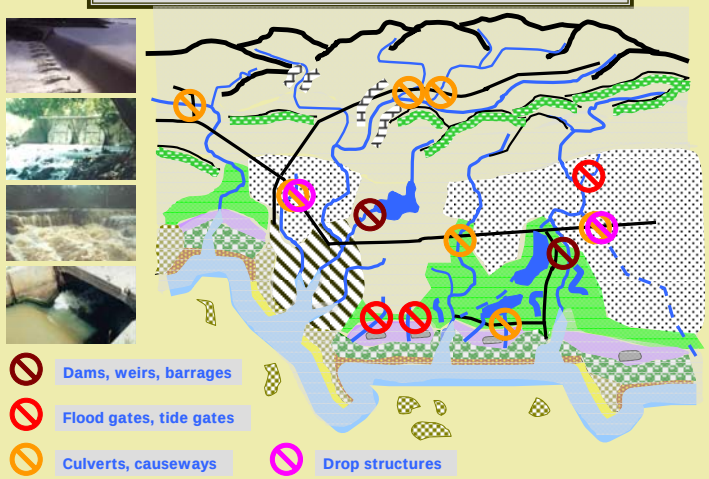
Migration requirements for freshwater fish

- Life cycle stages - Spawning and growth dispersal
- Recolonising habitats in response to flood or drought
- Compensation for downstream drift
- Gene flow through evolutionary-scale movement

Stream zones, fish life cycles, habitat zones & migration

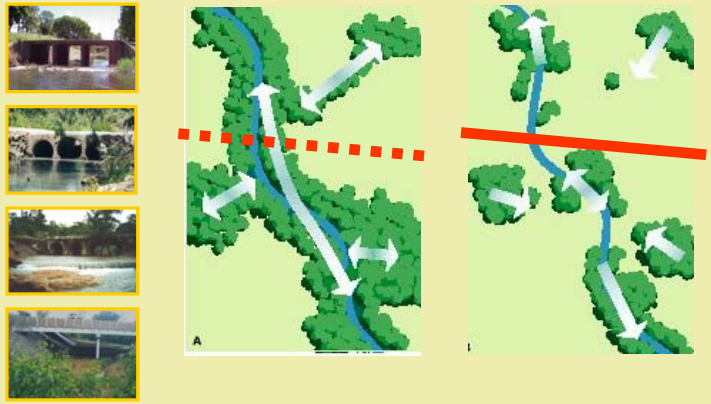


Fish migration barriers in a catchment



Fish migration barriers – small waterway structures

Waterway connectivity barriers - linear infrastructure



Establishing fish passage design for road crossings in Australia

Aquatic connectivity contrasts: Northern Hemisphere & Australia

Waterway type and hydrology

- Inter-annual flow variation
- Seasonal flow variation
- Perennial / intermittent flow


Fish species movement behaviour

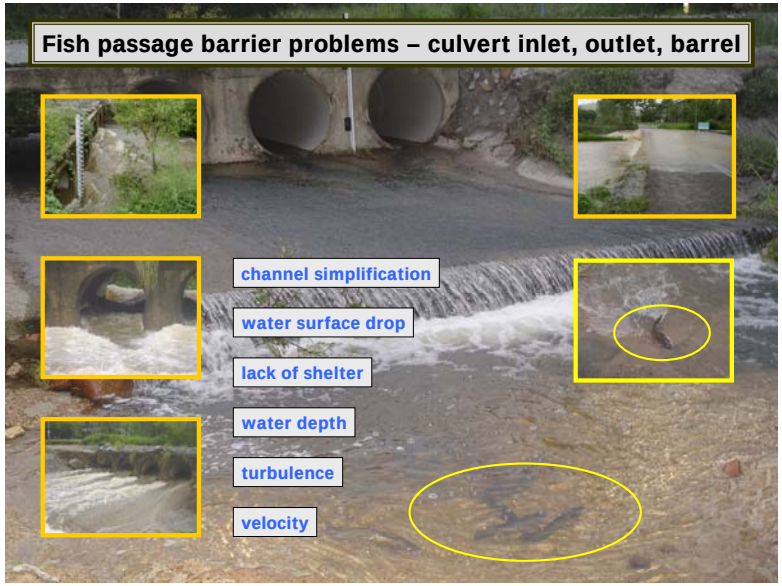
- Anadromous / Catadromous
- Swim capability
- Ability to jump


Waterway crossing structure type

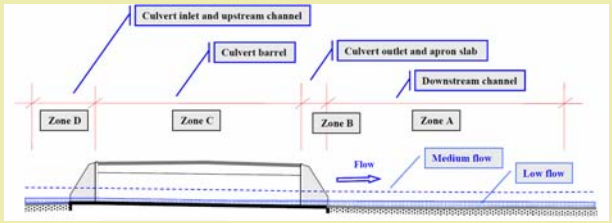
- Pipe culverts / box culverts
- Single cell / multi-cell


Busting Myth #1 - Fish passage design is **not** simply transferred from N Hemisphere

Fish passage barrier problems – culvert inlet, outlet, barrel



Principal hydraulic barriers at waterway crossing zones

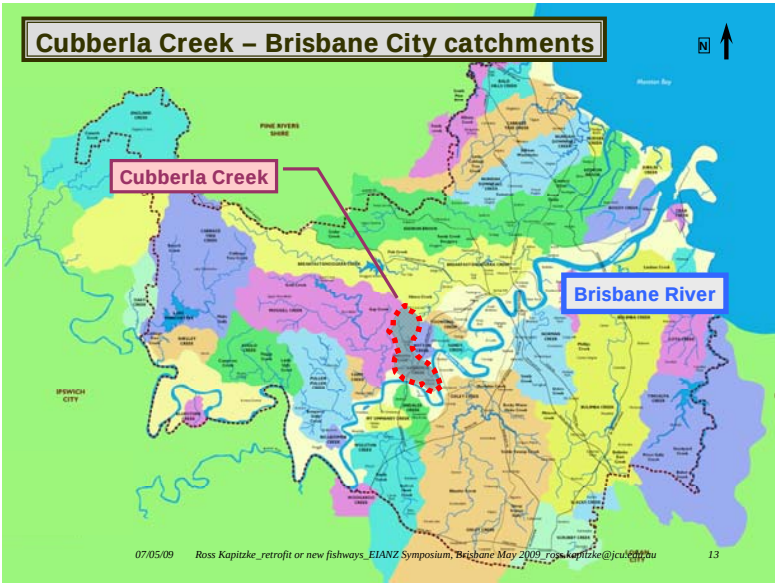


	Zone D	Zone C	Zone B	Zone A
High velocity	✓	✓	✓	✓
Flow depth	✓	✓	✓	
No shelter	✓	✓	✓	
Turbulence	✓	✓	✓	✓
Water drop	✓		✓	✓

Busting Myth #2 - Migration barriers usually include **more than** high barrel velocities

Cubberla Ck Moggill Road crossing - Fish passage remediation

Cubberla Creek – Brisbane City catchments



Cubberla Creek: Moggill Road culvert and aquatic habitat pools

Movie 1 – Cubberla Creek culvert fish passage barriers

Fish migration barriers at Moggill Road crossing

Moggill Road crossing: Barriers to upstream migration

G – Upstream channel

- High velocities
- Lack of shelter
- Shallow flow

D – Transition

- High velocities
- Excess turbulence
- Shallow water

A – Downstream channel

- High velocities
- Lack of shelter

F – Culvert inlet / weir

- High velocities
- Excess turbulence
- Water surface drop

B – Culvert outlet

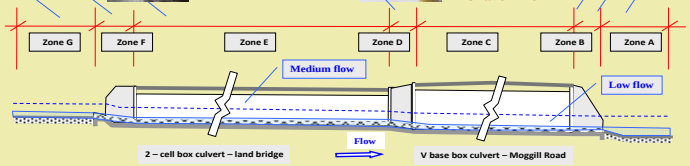
- High velocities
- Excess turbulence
- Shallow flow

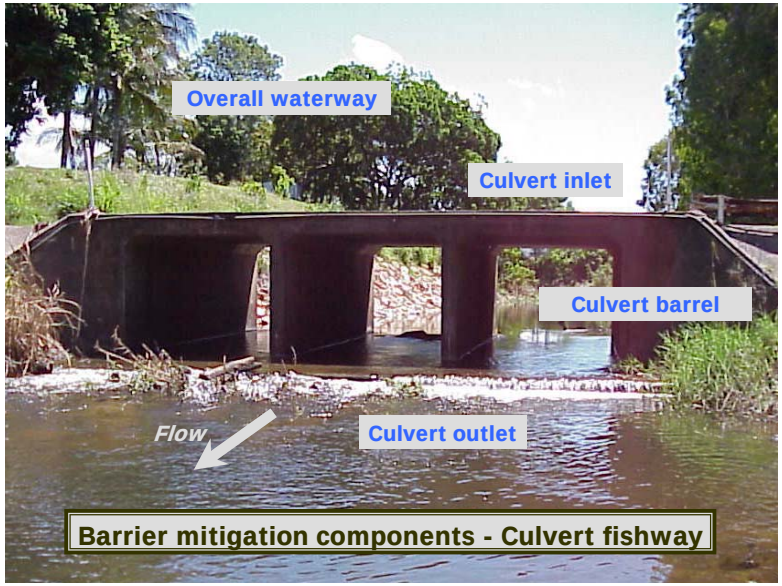
E – Box culvert barrel

- High velocities
- Lack of shelter
- Shallow flow

C – V-Base culvert barrel

- High velocities
- Lack of shelter
- Shallow flow





Fish passage design for waterway structures – key requirements

Source: Kapitzke 2009, Culvert Fishway Planning and Design Guidelines for DMR

Fish passage

- Provide suitable hydraulic conditions for fish – velocity, flow depth...
- Provide flow continuity, fish pathway and attraction flows
- Provide suitable conditions at fishway exit for fish to pass upstream

Drainage, utility & stream integrity

- Minimise obstruction to flow to not adversely affect flood capacity
- Minimise debris accumulation and sediment deposition
- Provide for ready cleaning and maintenance of culvert
- Provide for transport, drainage and other utility functions
- Maintain integrity of structure and adjoining waterway

Fish passage mitigation approaches for road-waterway crossings

Overall waterway

Arch culvert

Bridge

Culvert inlet, outlet & downstream

Rock ramp

Apron baffle

Culvert barrel

Stream simulation

Plain culvert

Hydraulic design approach using baffles

- Flexible solutions for range of structures / conditions
- Provides controlled / quantifiable hydraulic conditions
- Used in dedicated barrels for multi-barrel culverts
- Used for new structures or retrofit – without removal

Baffles

Fishway component types for culverts and open channels

Source: Kapitzke 2009, Culvert Fishway Planning and Design Guidelines for DMR

Baffle fishways for box culverts

- Offset baffle fishway
- Corner "EL" baffle fishway

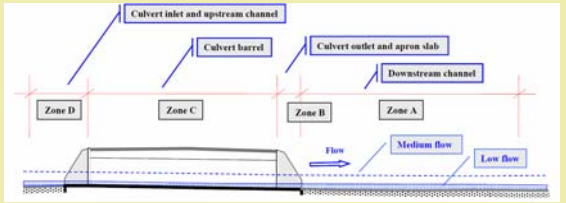

Baffle fishways for pipe culverts

- Offset baffle fishway
- Corner "Quad" baffle fishway


Ramp fishways for open channels

- Rock ramp fishway
- Rock ramp cascade fishway


Application of fishway components in hydraulic zones



	Zone D	Zone C	Zone B	Zone A
Offset baffle - box	✓	✓	✓	
Corner "EL" baffle	✓	✓	✓	
Offset baffle - pipe		✓		
Corner "Quad" baffle		✓		
Rock ramp	✓			✓
Rock ramp / cascade				✓

Busting Myth #3 – Enlarging the culvert or roughening the bed are not enough

Prototype fishway design, development and testing

University Creek, Townsville, north Queensland, Australia

Prototype #1 Discovery Drive offset baffle fishway

Prototype #2 Douglas Arterial Project rock ramp fishway

Prototype #3 Solander Road pipe culvert fishway

Prototype #4 Discovery Drive corner baffle fishway

University Creek Discovery Drive prototype culvert fishways

Prototype #4 – Corner "EL" baffle

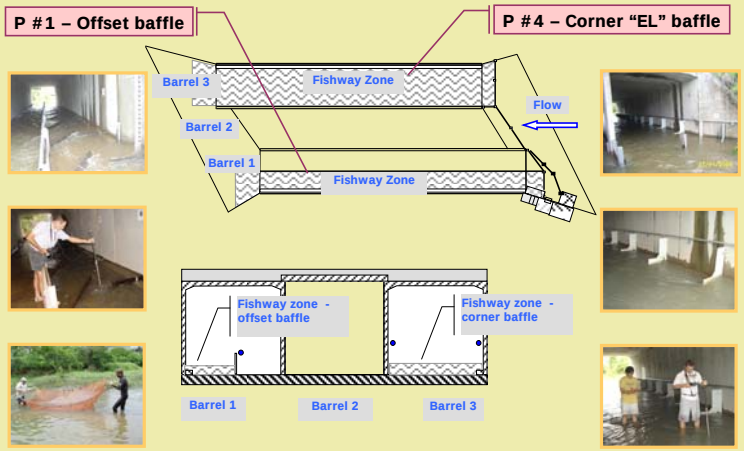
Prototype #1 – Offset baffle

University Ck fish community – *13 native species observed in 2003*

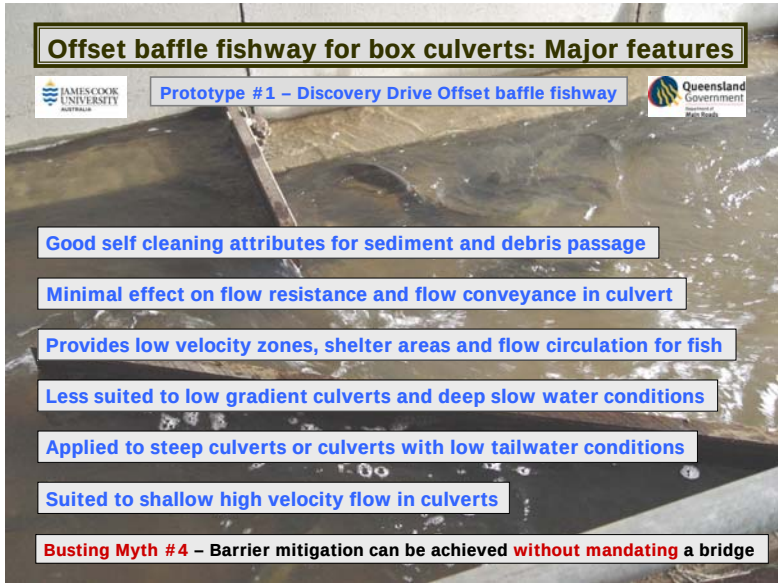
Barriers to upstream migration at Discovery Drive crossing

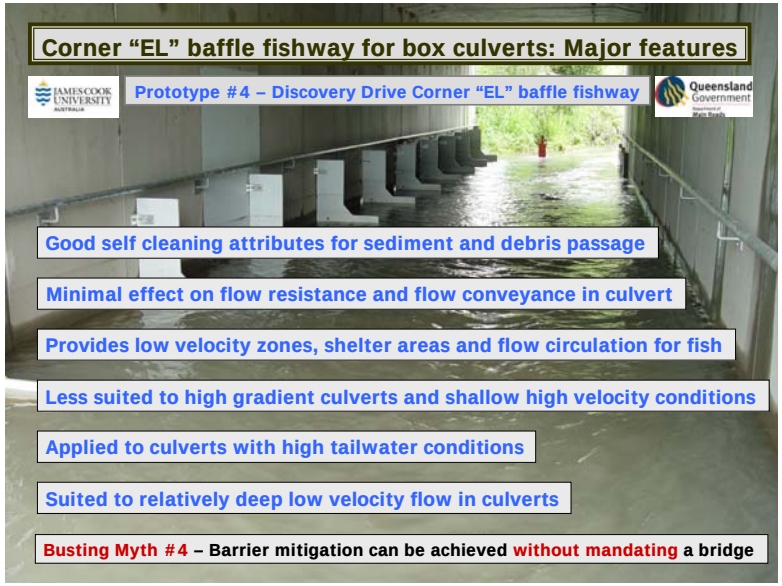
- Water surface drop at culvert outlet
- Shallow water depth within culvert
- High velocities within culvert barrel
- Streamlined flow and lack of resting places
- Excess turbulence
- High velocities and lack of shelter at culvert inlet

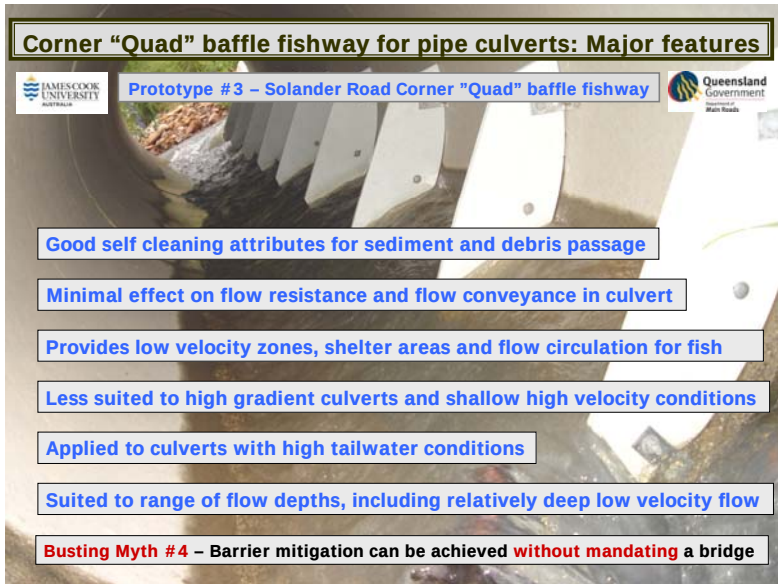
Discovery Drive culvert fishways - Prototypes #1 and #4

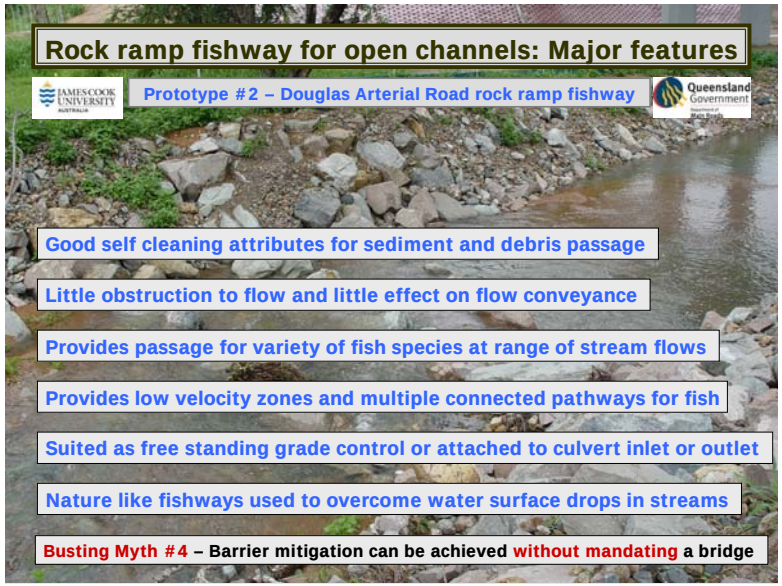


Movie 2 – Hydraulic laboratory model testing of fishways


Offset baffle fishway for box culverts: Major features
Prototype #1 – Discovery Drive Offset baffle fishway
Good self cleaning attributes for sediment and debris passage
Minimal effect on flow resistance and flow conveyance in culvert
Provides low velocity zones, shelter areas and flow circulation for fish
Less suited to low gradient culverts and deep slow water conditions
Applied to steep culverts or culverts with low tailwater conditions
Suited to shallow high velocity flow in culverts
Busting Myth #4 – Barrier mitigation can be achieved without mandating a bridge


Corner "EL" baffle fishway for box culverts: Major features
Prototype #4 – Discovery Drive Corner "EL" baffle fishway
Good self cleaning attributes for sediment and debris passage
Minimal effect on flow resistance and flow conveyance in culvert
Provides low velocity zones, shelter areas and flow circulation for fish
Less suited to high gradient culverts and shallow high velocity conditions
Applied to culverts with high tailwater conditions
Suited to relatively deep low velocity flow in culverts
Busting Myth #4 – Barrier mitigation can be achieved without mandating a bridge


Corner "Quad" baffle fishway for pipe culverts: Major features
Prototype #3 – Solander Road Corner "Quad" baffle fishway
Good self cleaning attributes for sediment and debris passage
Minimal effect on flow resistance and flow conveyance in culvert
Provides low velocity zones, shelter areas and flow circulation for fish
Less suited to high gradient culverts and shallow high velocity conditions
Applied to culverts with high tailwater conditions
Suited to range of flow depths, including relatively deep low velocity flow
Busting Myth #4 – Barrier mitigation can be achieved without mandating a bridge


Rock ramp fishway for open channels: Major features
Prototype #2 – Douglas Arterial Road rock ramp fishway
Good self cleaning attributes for sediment and debris passage
Little obstruction to flow and little effect on flow conveyance
Provides passage for variety of fish species at range of stream flows
Provides low velocity zones and multiple connected pathways for fish
Suited as free standing grade control or attached to culvert inlet or outlet
Nature like fishways used to overcome water surface drops in streams
Busting Myth #4 – Barrier mitigation can be achieved without mandating a bridge

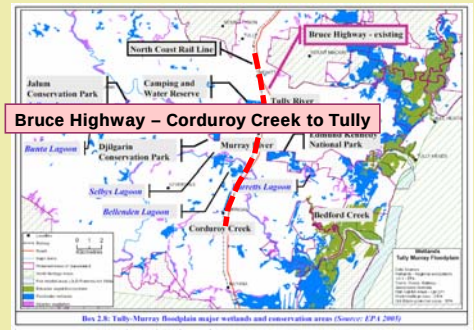
Tully Murray floodplain – Bruce Highway Corduroy Creek

Fish passage planning and design

- Road corridor scale
- Site scale

Main photo source: John Smith, DMR

Tully Murray floodplain wetland habitats and fish community

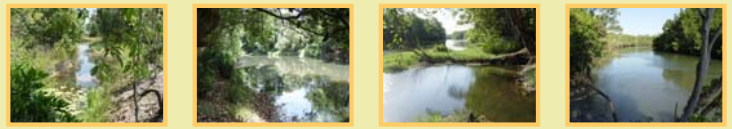


Local / regional environment

- Great Barrier Reef WHA
- Wet Tropics WHA
- estuarine wetlands
- freshwater lagoons
- perennial waterways

Native freshwater fish species

- 56 native species, including:
- 14 catadromous species
- 31 potamodromous species
- 11 amphidromous species



Fish movement corridors and road-waterway crossings

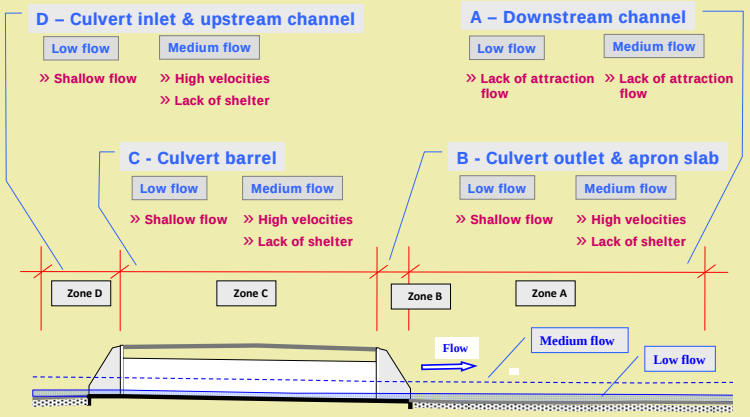
Fish movement corridor crossings

- 12 Class A corridors
- 7 Class B corridors
- 5 Class C corridors

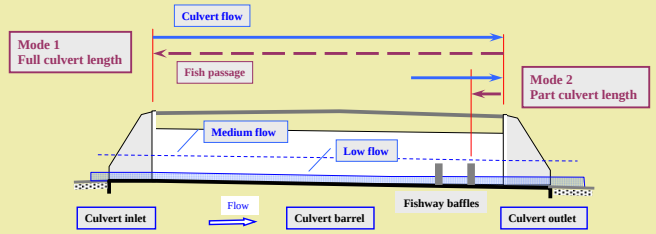
Road-waterway crossing structures

- 5 multi-span bridges
- 6 multi-cell box culverts with fish passage (1 integrated fish / fauna culvert crossing)
- 1 farm access pipe culvert with fish passage

Box culvert crossings: Barriers to upstream migration



Velocity barriers – Fish swim modes and swim speeds

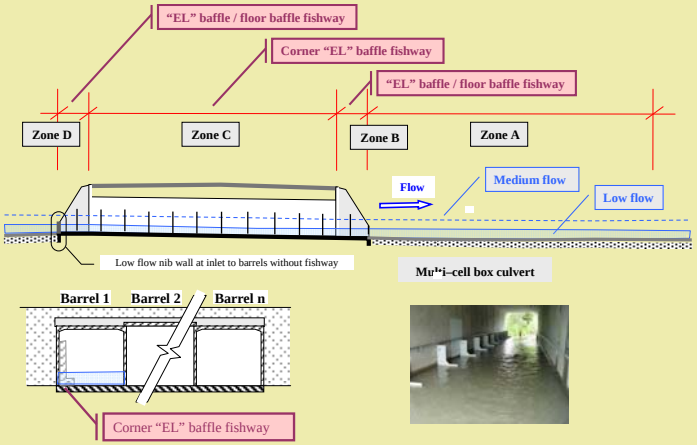


Required swim speed for fish to negotiate culvert – full or partial length

Culvert velocity	Mode 1 – full length (15 m)		Mode 2 – baffles (@ 2 m)
	Prolonged speed	Burst speed	Prolonged / burst speed
0.3 m/s	~ 0.3 m/s	1.05 m/s	~ 0.3 m/s
0.6 m/s	~ 0.6 m/s	1.35 m/s	~ 0.6 m/s
0.9 m/s	~ 0.9 m/s	1.65 m/s	~ 0.9 m/s

Prolonged speed – maintained for 20 sec to 200 min *Burst speed – maintained for 5 to 20 sec*

Box culvert crossings – Corner "EL" baffle fishway designs



Fish barrier mitigation design: Multipurpose objectives

Drainage, utility & stream integrity
- Maintain culvert flow capacity
- Minimise debris and sediment block
- Minimise erosion effects at outlet
- Protect land, infrastructure & utility

Stream processes & environment
- Retain natural stream processes
- Protect aquatic ecosystems
- Maintain stream water quality
- Control exotic plants & animals

Fish passage
- Provide for critical flow periods
- Provide continuous fish pathway
- Ensure suitable water velocities
- Ensure suitable water depths
- Prevent adverse flow turbulence
- Provide attraction flows for fish
- Shelter fish at fishway exit

Operation, safety, & amenity
- Minimise ongoing maintenance
- Ensure public safety
- Prevent public health problems
- Maintain visual amenity of site
- Minimise impact on recreation
- Protect cultural heritage of site

Busting Myth #5 – Mitigation design integrates ecological and engineering solutions

Mitigation design: Statutory, community and technical framework

After: Kapitzke 2003, Proceedings of the National Environment Conference, Brisbane, 18-20 June 2003

Statutory **Technical** **Community**

Science

Management
- Policy & legislation
- Permits & licences
- Agency consultation

Site Assessment
- Catchment hydrology
- Habitat assessment
- Fish species assessment
- Topographic mapping

Planning & Design
- Barrier evaluation
- Environmental impacts
- Option evaluation
- Layout & configuration

Management
- Property owners
- Other stakeholders

Design

Busting Myth #5 – Mitigation design integrates ecological and engineering solutions

Aquatic connectivity – the hidden star of barrier mitigation

Comparative benefits of aquatic and terrestrial connectivity

- 99 % of waterways are retained in the landscape
- many waterways are significant fish movement corridors
- high connectivity effectiveness is possible for fish at crossings
- effective mitigation design is a relatively low cost solution
- mitigation design can be achieved for retrofit or new structures

Busting Myth #6 – Terrestrial connectivity need not dominate barrier mitigation

The way forward for aquatic connectivity and fish passage design

Retrofit or new: It's amazing what a fishway can do

- Apply innovative design concepts – not speculative unfounded notions
- Management – Increase stakeholder recognition of aquatic connectivity
- Design – Incorporate through all phases from concept to implementation
- Science – Use an ecohydraulics approach to evaluate fishway designs
- Adopt multipurpose planning and design for barrier mitigation structures
- Integrate aquatic connectivity into linear infrastructure planning