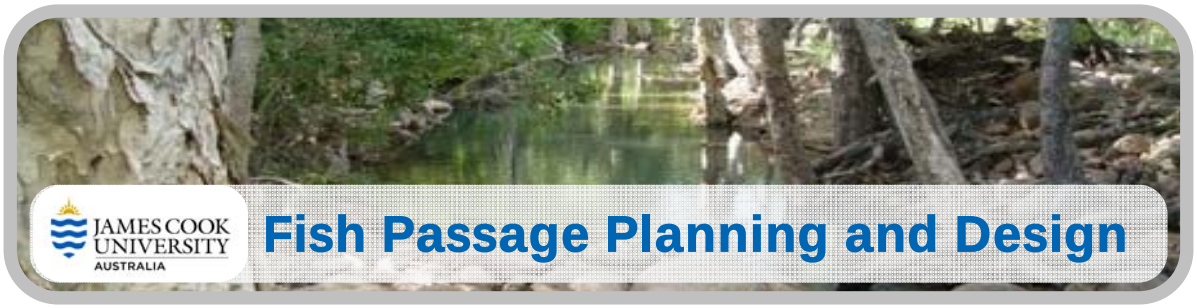

Culvert Fishway Planning and Design Guidelines

Part D – Fish Passage Design: Road Corridor Scale

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James Cook University School of Engineering and Physical Sciences
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1 INTRODUCTION

In order to identify those road-waterway crossings in a road project where provisions for fish passage are to be made, road designers, waterway managers, environmental officers and scientists require a means of assessing and prioritising fish movement corridor crossings of the road corridor. Designers, managers and scientists involved in the planning, design and implementation of fish passage facilities at the adopted crossings require a basis for defining the design requirements for fish passage at the sites.

These *Guidelines Part D* deal with fish passage design at the road corridor scale, and aim to:

- outline waterway character and fish habitat assessment for fish movement corridor crossings of the road corridor
- assess fish species and fish movement behaviour in terms of movement directions, timings and swim capabilities of the various fish species
- provide a method for classification of fish movement corridors to assist in determination of fish passage provisions
- identify priority road-waterway crossings and the design requirements for provision of fish passage at these crossings
- illustrate road corridor scale planning and design for fish passage through the Bruce Highway Corduroy Creek to Tully case study project

The information from *Guidelines Part D* is used in other parts of these *Guidelines* to:

- evaluate the need for provision of fish passage at particular road-waterway crossings (*Part E – Fish Passage Design: Site Scale*)
- establish fish passage goals and design objectives relating to design flow and fish swim speed at particular road-waterway crossings (*Part E – Fish Passage Design: Site Scale*)

These *Guidelines* deal primarily with the ***Concept*** and ***Preliminary Design*** phases of planning and design procedures for road and other infrastructure projects, as exemplified in the corridor scale planning for the Bruce Highway Corduroy Creek to Tully case study project (Box D1.1).

Box D1.1: Fish movement corridors and waterway crossings of the road corridor for the Bruce Highway Corduroy Creek to Tully project *(Source: Ross Kapitzke)*

Box culvert crossing of existing Bruce Highway at waterway / fish movement corridor south of Lagoon Ck (29/09/05)

Field velocity measurements at rail bridge crossing of Murray River using current meter (24/03/06)

2 ROAD CORRIDOR SCALE PLANNING AND DESIGN

Planning and design for fish passage at the road corridor scale is undertaken in new and existing road projects that cross one or more waterways where provisions for fish passage may be required. Road corridor scale assessment provides the necessary context for site scale planning and design of fish passage at adopted road-waterway crossings on the road corridor (*Guidelines Part E – Fish Passage Design: Site Scale*). Aspects of the road corridor scale assessment method can also be used to inform site scale planning and design for a single road crossing or other waterway structure, or for several waterway structures on a single waterway.

Scope, purpose and timing

Road corridor scale assessment for fish passage identifies the road-waterway crossing locations where fish passage provisions are to be made, and establishes the goals for fish passage design at these sites. For agencies such as the Department of Transport and Main Roads Queensland, this applies mainly to mitigation of potential impacts on fish passage at new structures, but it also encompasses remediation of fish migration barriers by retrofit at existing structures. Road corridor scale assessment is usually undertaken in conjunction with preliminary environmental assessment to provide input to route selection, drainage design and evaluation of alternatives for the road in the ***Concept*** and ***Preliminary Design*** phases of road and other infrastructure projects.

Planning and design activities

The major planning and design activities outlined in this *Guideline* (referring where appropriate to *Guidelines Part B – Fish Migration and Fish Species Movement Behaviour*) include:

- assessment of waterway character – stream flow characteristics, waterway type
- fish habitat assessment – type, location, movement corridors, fauna connectivity and barriers
- fish species assessment – diversity, abundance and distribution (see *Guidelines Part B*)
- fish movement behaviour and characteristics for design – movement directions, timings, swim capabilities (see *Guidelines Part B*)
- fish movement corridor locations and classification – habitat, fauna connectivity, fish values
- priority road-waterway crossings for fish passage – classification of type and class
- preliminary assessment of fish passage provisions at crossings – hydraulic conditions, aquatic fauna connectivity / fish passage goals, fish passage options

Site investigation and characterisation (site assessment)

Site assessment tasks forming part of road corridor scale planning and design may include the following, undertaken through field investigations or as desk top studies:

- catchment and regional characterisation (e.g. bioregion, climate, ecosystems, landform, contributing catchment, land use, conservation status, institutional arrangements, management plans)
- waterways, flow paths and flow characteristics (e.g. waterway type, channel form, permanence, flow paths, catchment hydrology, waterway hydraulics, human activities and pressures)
- fish habitat areas and fish movement corridors (e.g. waterway type, habitat type, crossing location, riparian condition, instream condition, disturbance, human activities and pressures, rehabilitation opportunities)
- other fish migration barriers (e.g. barrier type, barrier significance, remediation effectiveness, remediation feasibility, barrier location)
- fish species assessment (e.g. diversity, abundance, distribution, life stage, maturity)
- fish movement behaviour (e.g. fish movement group, fish movement direction and timing, fish movement capabilities, fish swim speeds)

3 WATERWAY CHARACTER AND FISH HABITAT ASSESSMENT

The nature of the waterway and the fish habitat areas potentially affected by fish migration barriers at road-waterway crossings are primary factors in assessing provisions for fish passage at waterway crossings in a road corridor scale study. Considerations of waterway and fish habitat characteristics for the road corridor are set within a regional and catchment context that helps define the significance of fish passage issues for the road project. Road corridor scale assessment provides the context for site scale considerations of waterway and fish habitat characteristics for particular crossings (see *Guidelines Part E – Fish Passage Design: Site Scale*), and a similar approach to that outlined here can be adopted for waterway and fish habitat characterisation for an individual crossing or other waterway structure.

The following sections guide the assessment of waterway and fish habitat characteristics for fish movement corridors crossing the road corridor. This is illustrated for the Bruce Highway Corduroy Creek to Tully road crossing of the Tully Murray floodplain in coastal north Queensland (Kapitzke 2006a). The regional and catchment context for this type of assessment is outlined, principal waterways and their flow characteristics and flow paths on the floodplain are described, and fish habitat areas and other fish migration barriers are identified. Fish species assessment and fish movement behaviour for the waterways are outlined in Chapter 4, and classification of fish movement corridors and identification of priority road-waterway crossings for provision of fish passage are described in Chapter 5.

3.1 Waterway character in the catchment and regional context

The catchment and regional context for the road corridor scale study assists with description of the biophysical characteristics of the waterways (e.g. bioregion, climate, ecosystems, landform, contributing catchment), and with identification of relevant socio-cultural factors (e.g. land use, conservation status, institutional arrangements, management plans). Examples of the type of information that should be examined for a road corridor scale assessment are presented below.

Data category	Example of information to assess
bioregional classification	• wet tropics, brigalow belt, coastal plain
climate	• seasonality, rainfall, temperature
significant ecosystems	• rainforest, wetlands, coral reefs
landform	• upland, floodplain, coastal
contributing catchment	• area, elevation, slope
land use	• agriculture, forestry, mining, urban
conservation status	• national park, conservation area, environmental reserve
institutional arrangements	• local authority, regional NRM group, land tenure
management planning	• NRM plan, coastal management plan, rehabilitation plans

For example, the Bruce Highway Corduroy Creek to Tully road crossing of the Tully Murray floodplain is located in the wet tropics region of north Queensland – one of the wettest places in Australia. The wet tropics region, encompassing the Tully-Murray floodplain, is an area of outstanding biological diversity, characterised by diverse floral and faunal communities, unique landforms and distinctive flow regimes (Pusey et al. 1999). The area is subject to tropical cyclones and monsoonal rainfall, which causes extensive inundation of waterways and wetlands on the floodplain. The Tully and Murray Rivers and associated floodplain wetlands represent substantial coastal (freshwater and marine) ecosystems adjoining the Great Barrier Reef.

Whilst upland and lowland areas of some catchments are protected by World Heritage listing and other conservation protection of rainforest and coastal environments, many coastal lowland floodplain areas in the Wet Tropics, including the Tully-Murray floodplain wetlands and riparian zones are degraded through agriculture and other development pressures. Non-tidal, freshwater wetlands in lowland floodplains, in particular, have declined in recent years, to the detriment of their vital ecological function. This has brought about degradation and loss of fish habitat, and disruption of fish passage through construction of stream barriers, sand dams, flood and tide gates, and road / rail / farm crossings. In spite of this however, freshwater ecosystems and associated native freshwater fish communities remain as valuable environmental assets for these areas. In addition to principal waterway corridors that have been retained on the landscape, coastal melaleuca swamps and mosaics of coastal wetlands have now been assigned high priority for conservation and rehabilitation in regional natural resource management planning.

3.2 Waterways, flow paths and flow characteristics

The various streams, wetland lagoons, flood channels and other waterways that cross the road corridor, or are adjacent to and connected to these waterways are integral to the fish passage assessment. These waterways provide habitat for fish and represent potential movement corridors for species migrating across the road corridor between habitat areas in close proximity to the road, in upstream headwater systems, and in lowland and coastal areas downstream. The nature of the waterways (e.g. waterway type, channel form, permanence), the principal flow paths, and the flow characteristics (e.g. catchment hydrology, waterway hydraulics) provide the template for assessing fish habitat areas and fish movement corridors. Examples of the type of information that should be examined for a road corridor scale assessment are presented below.

Data category	Example of information to assess
waterway type	• major stream, flood channel, wetland, constructed drain
channel form	• incised channel, leveed stream, artificial channel
permanence	• perennial, intermittent
flow paths	• stream channels, distributaries, inundated areas, backwaters
catchment hydrology	• flood discharge, streamflow hydrographs
waterway hydraulics	• flow depths, velocities, flow patterns
human activities and pressures	• channelisation, encroachment, river works, infrastructure

For example, the Tully-Murray floodplain comprises several major streams and a system of wetland lagoons and flood channels that are inundated extensively in wet season flow events, but which retreat to a number of permanent waterways and isolated lagoons during low flow conditions. The floodplain is characterised by overbank and distributary flood flows from stream channels, and the Tully and Murray Rivers form a complex stream pattern on the floodplain that regularly coalesces during flood events. The Tully River has a more deeply incised morphology than the Murray River, with a higher annual discharge, whilst the Murray River is more prone to flooding, with a smaller channel capacity and a large number of wetlands and floodplain lagoons. The waterways are impacted by adjacent land clearing and land use changes, and an ad hoc system of artificial levees, constructed on the Murray River to protect particular properties from flood inundation, has altered flooding characteristics on the floodplain.

In order to assess fish movement corridors and significant road-waterway crossings for fish passage on the Tully-Murray floodplain for the Bruce Highway Corduroy Creek to Tully road project, the extent of floodplain inundation and the major flow paths in the vicinity of the proposed road alignment were assessed from flood modelling undertaken for road drainage design (see Kapitzke 2006a). The modelling case for the 1 year ARI flood, although larger than

the fish passage design condition, was used as an indicator of inundation and flow paths that might apply for fish passage flow events, and provided some discrimination between principal flow paths and other areas of inundation for these conditions. Mapping of peak water levels and peak water velocities for the design flow event were used to interpret fish movement corridors and significant road-waterway crossings for fish passage across the road corridor.

Field inspections of the waterways and waterway structure sites assist in defining waterway characteristics and in confirming fish movement corridor locations. For the Tully-Murray floodplain, flow monitoring observations and measurements undertaken for the flood event associated with Tropical Cyclone Larry in March 2006, provided invaluable information on principal floodplain waterways and the hydraulic characteristics (velocities, depths, flow patterns) of waterways and road crossings (see Kapitzke 2007a). Major waterways on the Tully Murray floodplain in medium flow conditions are illustrated in Box D3.1.

Box D3.1: Tully Murray floodplain waterways and fish movement corridors *(Source: Ross Kapitzke)*

Major stream in medium flow condition – Corduroy Creek at existing Bruce Highway bridge (24/03/06)

Major floodplain waterway in medium flow condition – flood channel and lagoon system south of Lagoon Creek (24/03/06)

3.3 Fish habitat areas and fish movement corridors

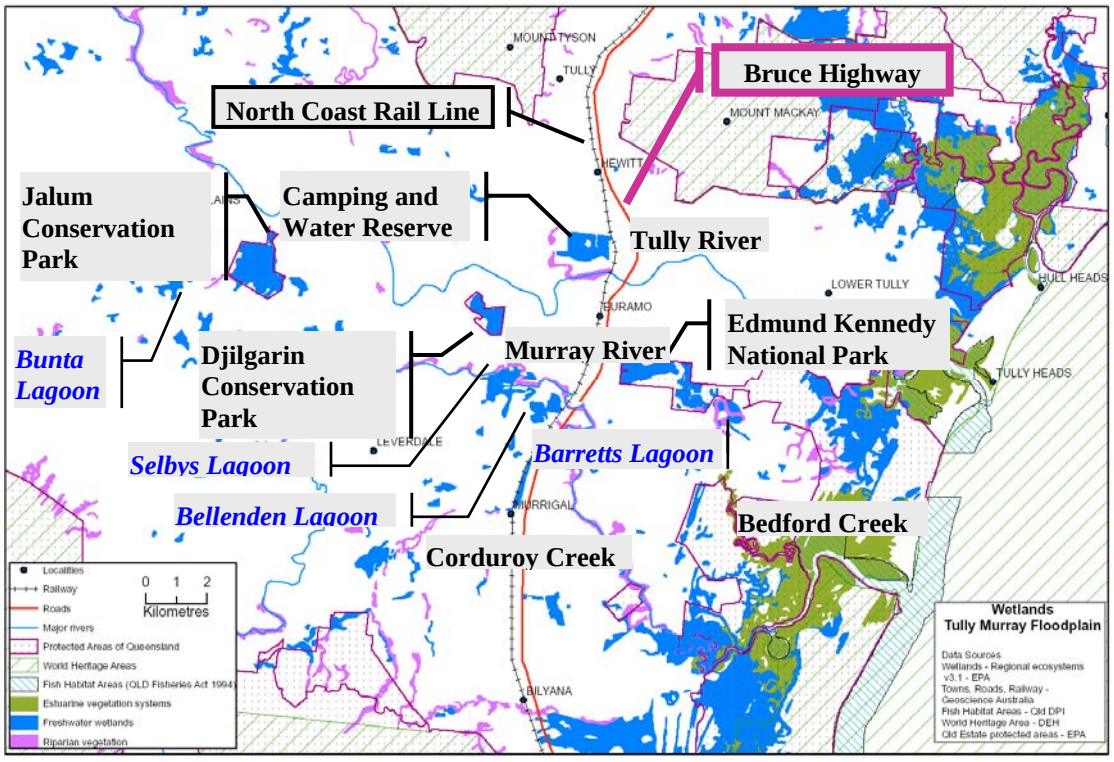
The location, extent and nature of the fish habitat areas and waterways adjoining the road corridor will define the fish movement corridor crossings of the road, and will guide the provisions to be made for fish passage at designated road-waterway crossings. Information used to describe fish habitat for the categorisation of fish movement corridors includes waterway type, habitat type, riparian condition, instream condition, and disturbance. Examples of the type of information that should be examined for a road corridor scale assessment are presented below. This may require specialist advice on fish habitat and aquatic fauna connectivity.

Data category	Example of information to assess
waterway type	• freshwater stream, saline wetland, constructed wetland
habitat mapping	• regional ecosystems, terrestrial fauna, aquatic fauna
fish habitat type	• spawning, growth, refugial
structure location relative to habitat	• estuarine, lowland, upland, tributary stream
riparian condition	• native vegetation, continuous or fragmented corridor
instream condition	• structural diversity, aquatic vegetation, water quality
integrity and disturbance	• channel form, flow connectivity, isolation, ecosystem function
human activities and pressures	• agriculture, wetland drainage, exotic animals and plants
rehabilitation opportunities	• riparian corridor, aquatic habitat, connectivity, stream process

For the Tully-Murray floodplain, extensive freshwater and tidal wetlands, rivers and estuaries provide important breeding and nursery areas for fish and other aquatic fauna. Fish habitat areas are located in a range of natural freshwater and marine landscapes, but waterways, fish habitat and fish movement capability have often been altered by development pressures on the floodplain. For example, many freshwater wetlands that have been severely degraded to swampy depressions through weed infestation and artificial drainage, are no longer functioning as fish habitat. Some lagoons had been completely filled for farming and no longer exist. Conversely, fish habitat is often enhanced through stream rehabilitation initiatives such as riparian revegetation, and some artificial wetlands have been constructed and revegetated in agricultural areas for flood mitigation, sediment retention, and enhancement of aquatic and riparian habitat.

Fish movement corridors on the Tully-Murray floodplain in the vicinity of the new Bruce Highway Corduroy Creek to Tully road were identified from a spatial assessment of fish habitat areas, waterway connectivity between habitat areas, and prominent waterway crossings of the road corridor (see Kapitzke 2006a). The location and condition of these fish habitat areas and movement corridors were assessed from natural resource management planning studies and associated resource mapping for the area, supplemented by field inspections adjacent to the road corridor. Major wetland associations and conservation areas for the Tully-Murray floodplain are shown in Box D3.2. Examples of freshwater stream and constructed wetland habitats on the floodplain are shown in Box D3.3.

Box D3.2: Tully-Murray floodplain major waterways, wetlands and conservation areas *(Source: Kapitzke 2006a)*



Box D3.3: Fish habitat areas on Tully Murray floodplain *(Source: Ross Kapitzke)*

Freshwater stream habitat – Murray River Old Highway crossing (10/11/05)

Constructed wetland on floodplain adjoining Murray River – Fleglers lagoon (10/11/05)

3.4 Other fish migration barriers on the waterways

The significance of providing for fish passage at a waterway crossing of the road corridor will be influenced by fish passage connectivity between habitat areas in these waterways or fish movement corridors remote from the road corridor. Existing fish migration barriers at road-waterway crossings or other waterway structures downstream of the proposed crossing site will affect fish migration upstream to the site. Fish migration barriers upstream of the crossing site will fragment habitat within the fish movement corridor, and restrict access for fish to habitat areas further upstream. Information used to define other fish migration barriers on the waterway includes barrier type, barrier significance, ease of remediation, location relative to road crossing. Examples of the type of information that should be examined for a road corridor scale assessment are presented below.

Data category	Example of information to assess
barrier type and configuration	• dam, weir, barrage, grade control, culvert, water quality
barrier significance	• total, partial, temporal – related to fish species and flows
remediation effectiveness	• compete, restricted, limited
remediation feasibility	• minor constraints, major constraints, limited likelihood
barrier location relative to habitat	• estuarine, lowland, upland, tributary stream, habitat denied

Barriers to fish migration on waterways crossing the road corridor may occur due to adverse hydraulic conditions at road crossings and other waterway structures (e.g. water surface drop, high velocity, turbulence); poor water quality (e.g. low dissolved oxygen, excess nutrients); or other physical barriers associated with waterway modification (e.g. infestation and blockage with aquatic weed, habitat loss associated with channelisation). See *Guidelines Part C – Fish Migration Barriers and Fish Passage Options for Road Crossings*. Scientists, managers and designers involved in road corridor scale studies may need to obtain specialist assistance in evaluating the effect of existing barriers on fish movement in the vicinity of the road.

For the Tully-Murray floodplain, the extent of existing barriers on waterways crossing the road corridor was assessed from previous studies on fish migration barriers and remediation measures on the floodplain, and from field inspections of waterway crossings. Existing fish migration barriers at floodplain locations remote from the Bruce Highway corridor, although potentially significant locally, were not considered likely to affect fish movement in waterways crossing the new road alignment. The extensive inter-connection of fish movement corridors across the floodplain in flood conditions will further minimise any restriction to fish movement.

4 FISH SPECIES ASSESSMENT AND FISH MOVEMENT BEHAVIOUR

Knowledge of the fish community within the waterways is required in order to assess provisions for fish passage at waterway crossings in a road corridor scale study. An understanding of fish species diversity, abundance and distribution within these waterways will allow provisions for fish passage to be established at specific road-waterway crossings of the road corridor, and knowledge of fish movement behaviour will provide the basis for fish passage design to suit the requirements of the fish community for particular crossings. Fish passage provisions at crossings are commonly established to suit broad groups of fish species, life stages, maturity, swimming capabilities and other movement characteristics. Specific provisions for particular species may however be adopted to meet specific requirements for particular crossings of the road corridor.

The following sections outline approaches to fish community assessment for road corridor scale studies, and describe the framework for assessment of fish movement characteristics in terms of fish movement groups and fish movement directions and timings. The method is described in more detail in *Guidelines Part B – Fish Migration and Fish Species Movement Behaviour*. A similar approach can be adopted for fish species and fish movement behaviour assessment for a single road crossing or other waterway structure, or for several structures on a single waterway (see *Guidelines Part E – Fish Passage Design: Site Scale*).

Examples of the fish community, fish movement group classification and fish movement behaviour characteristics for the Tully Murray catchment in coastal north Queensland are outlined (see Kapitzke 2006a). These data are referred to here for illustration only, and the applicability of this information to other fish communities in other regions or catchments should be checked before use elsewhere.

4.1 Fish species diversity, abundance and distribution

Information on the diversity, abundance and distribution of the fish community is usually compiled to encompass all significant waterways crossing the road corridor. This can typically be obtained from broader scale studies of the catchment and surrounding region, and from previous fish species surveys of the waterway or adjoining catchments. Whereas these data sources provide information on the range of species that can be expected to inhabit the waterways under consideration, information on the distribution of species along particular waterways is usually less detailed. Dedicated fish surveys of the waterway may be undertaken in some instances where more specific information is required in relation to aquatic habitat and fauna connectivity issues for particular species or locations.

A conservative approach to fish species assessment was used for the Bruce Highway Corduroy Creek to Tully road crossing of the Tully Murray floodplain, where the fish community for waterways crossing the road corridor was taken to include all 56 native freshwater species identified in local and regional surveys for the Tully Murray catchment (see Kapitzke 2006a). The rationale for this was that most species using upland freshwater habitats in the Tully Murray catchment will pass through the lowland reaches at some stage of their lifecycle – for example catadromous species migrating to and from marine habitats, and potamodromous species moving between upland and lowland habitats. The road corridor alignment is close to the tidal zone of several of the major waterways, and although specific information is not available, some amphidromous species that occasionally move into lowland freshwater habitats may also use these stream reaches.

Although the overall fish species diversity for the Tully Murray catchment would not apply for each waterway crossing the road corridor, the available data on fish species distribution did not allow ready apportionment of part of the fish community to any particular waterway. Classification of the fish movement corridor crossings of the road corridor (see Chapter 5) does

however allow discrimination between design provisions for various waterways and road-waterway crossings according to the target fish community for that crossing.

As an illustration of the fish community for the Corduroy Creek project, an extract from the fish species list for the Tully Murray catchment is presented in Box D4.1, where they are grouped by family names and listed alphabetically by common name, with genus and species included. Each species is categorised in terms of life-cycle, spawning and migration, and is assigned to a fish movement group, which is based on the direction of movement for spawning or growth, the fish life stage at the time of movement, and the stream zones traversed in the migration behaviour of the species (Section 4.2). This sample is part of a total 56 native freshwater species, which were identified in specific field studies of the floodplain (e.g. Hogan and Graham 1994), broader scale studies of the Tully-Murray catchment and surrounding region (e.g. Pusey et al. 2004), and fish species surveys of adjoining catchments (e.g. Russell and Hales 1997).

Box D4.1: Extract from fish species list for Tully Murray and adjoining catchments *(Source: Kapitzke 2006a)*

Common name	Family, genus, species	Life-cycle, spawning and migration (Fish movement group)	Hogan & Graham (1994) [1]	Pusey et al. (2004) [2]	Russell & Hales (1997) [3]
Blue eyes	**Pseudomugilidae**				
Pacific blue-eye	*Pseudomugil signifer*	Potamodromous – local spawning, lowland to upland habitats (P3)	✓	✓	✓
Spotted blue-eye	*Pseudomugil gertrudae*	Potamodromous – local spawn, lowland habitat (P4)	✓	✓	
Cardinalfishes	**Apogonidae**				
Mouth almighty	*Glossamia aprion*	Potamodromous – local spawning, lowland to upland habitats (P3)	✓	✓	✓
Eels	**Anguillidae**				
Long finned eel	*Anguilla reinhardti*	Catadromous – marine to upland habitats (C1)	✓	✓	✓
Pacific short finned eel	*Anguilla obscura*	Catadromous – marine to upland habitats (C1)	✓	✓	✓
Eel-tailed catfish	**Plotosidae**				
Black catfish	*Neosilurus ater*	Potamodromous –upland spawning (P1)	✓	✓	✓
Freshwater catfish	*Tandanus tandanus*	Potamodromous – local spawning, lowland to upland habitats (P3)		✓	✓
Hyrtl's tandan	*Neosilurus hyrtlii*	Potamodromous –upland spawning (P1)	✓	✓	✓
Rendahl's tandan	*Porochilus rendahli*	Potamodromous ?? – upland spawning (P1)		✓	
Flagtails	**Kuhliidae**				
Jungle perch	*Kuhlia rupestris*	Catadromous – marine to upland habitats (C1)	✓	✓	✓
∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘			
Alien (exotic) species					
Top minnows	*Poeciliidae*				
Guppy	*Poecilia reticulata*	??		✓	
Platy	*X maculatus*	??	✓	✓	
		Total No of Species	**37 natives 1 exotic**	**49 natives 2 exotics**	**42 natives**

Notes		
	1	Hogan and Graham survey for lower Tully and Murray river catchments
	2	Pusey et al. report includes Hogan and Graham survey and other data
	3	Russell et al. survey for adjoining catchments of Hull River, Maria Creek and Liverpool Creek

4.2 Fish movement groups and their characteristics

Information on the movement behaviour and movement capabilities (e.g. swim speed) of the fish community is required to determine design provisions for the road-waterway crossings of the road corridor. Conservative approaches can be adopted using default design swim speed values that encompass the complete fish community, or specific swim speed characteristics for particular species can be used where available for design. The method outlined below allows for assessment of fish movement behaviour and swim speeds for the defined fish community, through categorisation of fish movement behaviour and use of the best available data on fish movement characteristics for the fish community.

The fish movement group and movement behaviour categorisation, which is described in *Guidelines Part B – Fish Migration and Fish Species Movement Behaviour*, enables ready evaluation of the range of fish species that are likely to be migrating through waterway reaches adjoining the road corridor, the life stage and maturity of the fish at the time of movement, the direction of movement, the time of movement in relation to seasonal flow and flood stage in the stream, and the fish species size and swimming ability. Overall characteristics of the fish community can be assembled in this manner for use in design, or alternatively, specific characteristics for particular fish species, life stage and maturity can be established from the available data in the literature to meet specific design provisions at the crossings.

For common Queensland fish species, the conventional life cycle and spawning movement categorisation (anadromous, catadromous, potamodromous, amphidromous) is divided into seven movement groupings, defined in terms of spawning or dispersal migration for adults or juveniles between spawning and growth habitat zones within various stream zones (marine, lowland, intermediate, upland). This includes two catadromous groups (C1, C2), four potamodromous groups (P1, P2, P3, P4), and one amphidromous group (M1). The fish community for waterways crossing the road corridor can be categorised into these groups by examining information on the movement characteristics of the fish species (movement between habitats, life cycle stage and maturity, movement capability through the waterways) available from the general literature. Information on fish movement behaviour is not readily obtained directly from local data.

As outlined in *Guidelines Part B – Fish Migration and Fish Species Movement Behaviour*, correlation within and between fish movement groups in terms of migration timing, migration movements and zones allows generalised movement directions and timings to be identified for these fish groups at the road corridor location within the waterway catchments, which assists with fish passage considerations for that location. For the Bruce Highway Corduroy Creek to Tully road project, the 56 native freshwater species of the Tully Murray fish community were categorised into the seven fish movement groups, and generalised interpretation of migration zones, migration calendars, and movement characteristics was undertaken for these groupings to assist in design (see Kapitzke 2006a). An illustration of fish movement characteristics (habitat preferences, migration characteristics, spawning cues and timing, life stage, size and swimming characteristics) for this community is provided in *Guidelines Part B.*

4.3 Fish movement directions and timings

The ability of a fish to pass through a road-waterway crossing on the road corridor depends on the movement characteristics of the fish and the hydraulic characteristics of the crossing (e.g. flow direction, velocity, water surface drop, turbulence, flow pattern). Categorising movement direction information for the fish community assists with determining the critical fish species and movement characteristics for negotiating movement through the structure. The fish movement classification system, which is described in *Guidelines Part B – Fish Migration and Fish Species Movement Behaviour*, defines 10 fish movement direction categories (AUS, JUD, AUD….) according to the nature of the migration, direction of movement, fish maturity and size, and life cycle stage of the fish. The success of fish passage also depends on the timing of fish movement

with respect to seasonal flow and flood conditions in the stream, which can be considered in terms of flood flow (wet season), low flow, and tidal flow conditions.

Examination of the generalised relationship between movement directions and fish movement groups shows that critical movement events are typically adult upstream spawning migration (AUS) and juvenile upstream dispersal migration (JUD). Potamodromous *Group P1* is typically the only group clearly displaying adult upstream spawning migration (AUS), which is the critical movement event for adult fish. Juvenile upstream dispersal migration (JUD), which is the critical movement event for juvenile fish, typically occurs for Catadromous *Group C1* and *Group C2*, and for Potamodromous *Group P2, Group P3* and *Group P4*. Adult upstream dispersal migration (AUD) typically applies to the same five groups as for juvenile upstream dispersal, but this movement event is usually less critical than juvenile movement.

An illustration of the fish movement direction and timing characteristics for the Tully Murray fish community is provided in *Guidelines Part B*. This information on upstream, downstream or localised movement under various flow conditions, which was established for the Bruce Highway Corduroy Creek to Tully road project (see Kapitzke 2006a), allows provisions for specific species to be made if required at particular road-waterway crossings of the road corridor.

4.4 Fish movement capabilities and design swim speeds

The fish movement categorisation and movement characteristics for the fish community are used to determine fish swimming capabilities for fish passage design. The fish movement direction and timing characteristics can be used to determine those species facing the most adverse upstream movement conditions at the structures, and fish movement capability groups can be established to define broad movement characteristics and swimming capabilities of the fish community for critical movement directions and timings (AUS – adult upstream spawning migration, and JUD – juvenile upstream dispersal migration). Alternatively, specific movement capabilities for design can be established from movement data available for particular species.

As outlined in *Guidelines Part B – Fish Migration and Fish Species Movement Behaviour*, the fish movement capability groupings (AUS1, AUS2, JUD1…) are based on families and common length range for the fish species, and may comprise species from several fish movement groups (C1, C2, P1…). For the Tully Murray fish community, for example, Group AUS1 comprises Eel tailed catfish of 15 – 25 cm common adult length, Group JUD6 comprises a number of similar species (Cardinalfishes / Glass perchlets / Gobies / Gudgeon) less than 10 cm common adult length, and Group JUD3 comprises Flagtails / Herring of 20 - 25 cm common adult length.

Nominal fish swim speeds can be established either from data available for individual species, from data for groups of fishes identified through fish movement capability groups, or by using generic relationships for swim speed and body length. For the Bruce Highway Corduroy Creek to Tully road project, the nominal swim speeds for groups of fish undertaking adult upstream spawning migration (AUS) or juvenile upstream dispersal migration (JUD) were compiled using swim speed data for the various fish movement capability groups, and generic swim speed relationships where no other data are available (see Kapitzke 2006a). Ranges of fish swim speed established from this data for the Tully-Murray fish community encompassed a burst speed range of 0.2 m/s to 1.5 m/s and a prolonged swim speed range of 0.1 m/s to 1.0 m/s.

Nominal fish swim speeds for Tully-Murray fish community		
Burst speed	highest speeds attainable by fish and maintained for short periods of usually 5 to 20 seconds before ending in fatigue	0.2 m/s to 1.5 m/s
Prolonged speed	speed maintained by fish for 20 seconds to 200 minutes before ending in fatigue	0.1 m/s to 1.0 m/s

5 FISH MOVEMENT CORRIDORS AND PRIORITY WATERWAY CROSSINGS

In a road corridor scale study or other fish passage assessment at waterway structures, a number of waterways crossing the road corridor or located at these structures may represent fish movement corridors where fish naturally move between fish habitat areas in the landscape. The road crossings and other structures may affect fish migration in these movement corridors, and it is necessary to identify the relevant fish movement corridors and provisions that should be made for fish passage at priority road crossings as well as for other waterway structures. Fish passage provisions for the structures will depend on the nature of the fish movement corridor and fish passage goals established for the site.

The road corridor scale assessment of fish movement corridors at road crossings and other waterway structures uses the information on waterway character, fish habitat, and fish community from Chapters 3 and 4, along with design proposals for road and drainage facilities that govern the configuration of the road crossings and other structures. Provisions to be made for fish passage at the adopted structures are outlined in Chapter 6, and site scale planning and design for these facilities is described in *Guidelines Part E – Fish Passage Design: Site Scale*.

The following sections describe the fish movement corridor classification, and outline the method for establishing fish movement corridors and priority road-waterway crossings for fish passage. This is illustrated for the Tully Murray floodplain in north Queensland, where more than 20 fish movement corridors on the floodplain were potentially affected by the Bruce Highway Corduroy Creek to Tully road project (Kapitzke 2006a; Kapitzke 2007a). A similar approach to that outlined here can be adopted for fish movement corridor classification for an individual crossing or other waterway structure (see *Guidelines Part E – Fish Passage Design: Site Scale*).

5.1 Fish movement corridor classification

The classification system presented here for prioritisation of road-waterway crossings and assessment of fish passage provisions at waterway structures is based on classification of the fish movement corridor at the road crossing or other structure rather than merely the fish habitat areas in the waterway adjacent to the structure. This is more appropriate for fish passage planning and design at the road corridor scale than other habitat assessment methods, such as waterway condition surveys focussing on fisheries resources (e.g. Russell and Hales 1997); prioritisation methods for fish passage remediation at dams, weirs and other waterway barriers (e.g. Cotterell and Jackson 1999; Petherbridge et al. 1998); or generic categorisation of fish passage provisions at road crossings (e.g. Fairfull and Carter 1999; Fairfull and Witheridge 2003).

Classification of the fish movement corridor is based on a number of factors relating to fish habitat characteristics, waterway and fauna connectivity with upstream and downstream habitat, and the fish community and fisheries values applying to the waterway (Box D5.1). These descriptor groupings in the classification provide for situations where, for example, a fish movement corridor with relatively poor fish habitat adjacent to the structure may be highly significant for fish passage due to good waterway connectivity with substantial fish habitat areas upstream or downstream of the site. The classification system also allows consideration of fish movement corridor significance in terms of the diversity of the fish community in the waterway, and the value of the fishery in commercial, recreation, cultural heritage or biodiversity terms.

Within the *Waterway and fish habitat characteristics* grouping, the classification system encompasses the nature of the watercourse, waterway hydrology, channel form and condition, habitat suitability, riparian and instream vegetation, and water quality. Waterway connectivity, fish movement corridor connectivity, and fish migration barriers are relevant for the *Habitat connectivity and fish movement corridor significance* grouping. The *Fish community, fisheries values, and conservation status* of the fish movement corridor are also included. Three classes of

fish movement corridor are used (Class A, Class B, Class C), and representative descriptions for these in terms of the above factors are presented in Box D5.2.

Assessment of these characteristics of the fish movement corridor can be undertaken using a combination of field investigations, desktop review and stakeholder / community consultation, as appropriate for the site and for the particular fish passage issue that is being addressed (see Chapters 3 and 4 for habitat and fish community assessment approaches). Investigations should encompass local areas adjoining the waterway structure at the road corridor, as well as a broader regional coverage of waterways upstream and downstream of the structure sites. Site inspections are valuable for habitat assessment, particularly at times of flow or when stream channels or wetlands have sections with ponded water.

Detailed field investigations of fish habitat characteristics, fish movement corridor connectivity, and fish species diversity will, however, typically not be required where information is available from resource mapping data and other documentation (e.g. existing regional or local fish species survey). A phased assessment process would, for example, use broad scale reconnaissance level investigations in initial stages, supplemented by more intensive investigations involving field surveys where required for confirmation and detailed habitat assessment for design. Classification of the fish movement corridor should adopt a precautionary approach, with the higher class chosen in borderline cases (e.g. Class A if borderline Class A / Class B).

Box D5.1: Factors for classification of fish movement corridors at road-waterway crossings

Waterway and fish habitat characteristics

- nature of the watercourse – major stream; minor stream; stormwater drain; farm drain; natural wetland; constructed wetland
- waterway hydrology – intermittent or permanently flowing stream; flow regime alterations from natural due to water resource flow supplementation or extraction, including change in magnitude / timing of critical flow events for fish spawning or growth
- channel form and condition – degree of definition and naturalness of channel and component forms (pools, riffles, bars, benches and other features)
- habitat suitability – presence and condition of refugial, spawning or growth habitat areas (deep pools, instream gravel beds, snags, overhanging banks, suitable hydraulic conditions - flow velocities, turbulence)
- riparian and instream vegetation – presence and condition of riparian and instream vegetation (native or exotic species; marine or freshwater)
- water quality – discolouration, sedimentation, turbidity, ph, dissolved oxygen, nutrients

Habitat connectivity and fish movement corridor significance

- waterway connectivity – flow connection with other watercourses or wetland habitats upstream, downstream or laterally (distributary channels, overflow channels, floodplain flows)
- fish movement corridor connectivity – actual and potential interconnection with significant habitat areas upstream and downstream (upland forests, lowland wetlands)
- fish migration barriers – presence of natural or artificial barriers upstream and downstream (weirs, dams, waterfalls or cascades, other causeways or culverts)

Fish community, fisheries values and conservation status

- fish community – species diversity, rare or threatened species, iconic species, obligatory or facultative life cycle migration
- fisheries values – commercial, recreational, traditional, biodiversity, threatened species protection
- conservation status – declared fish habitat area, environmental reserve

Box D5.2: Fish movement corridor classification for road-waterway crossings *(After: Kapitzke 2006a)*			
Fish movement corridor class	**Typical fish habitat, connectivity and fish community characteristics (any or all of these characteristics may apply)**		
	Waterway and fish habitat characteristics	**Habitat connectivitiy and fish movement corridor significance**	**Fish community, fisheries values and conservation status**
Class A	• major stream, minor stream, natural wetland, constructed wetland or tidal waterway in good condition • intermittent or permanently flowing stream with relatively natural flood flow or tidal flow regime • clearly defined and relatively natural channel form, with diverse habitat structure (bank, bed, substrate, debris) • fish spawning, growth or refugial habitat areas in good condition (e.g. pools, riffles, runs) • intact and relatively continuous riparian vegetation corridor, with instream vegetation in good condition • relatively good water quality	• extensive flood flow or tidal flow connectivity with other watercourses or wetlands upstream, downstream or laterally • good fish movement corridor connectivity with significant habitat areas upstream and downstream • no significant barriers to fish passage at waterway structures upstream or downstream	• fish community with substantial species diversity, rare or threatened species, iconic species, species with obligatory migration stage • major fisheries values (e.g. commercial, recreational, traditional, biodiversity) • watercourse and fish movement corridor with established conservation status (declared fish habitat area, environmental reserve)
Class B	• minor stream, natural wetland, constructed wetland or tidal waterway in moderate-poor condition • intermittent or permanently flowing stream with moderately altered flood flow or tidal flow regime • well defined but moderately altered channel form, with limited habitat structure and diversity • fish spawning, growth or refugial habitat areas in moderate condition (some pools, riffles, runs) • moderately fragmented riparian vegetation corridor, with instream vegetation in poor condition • moderate water quality	• some flood flow or tidal flow connectivity with other watercourses or wetlands upstream, downstream or laterally • limited fish movement corridor connectivity with habitat areas upstream and downstream • some barriers to fish passage at waterway structures upstream or downstream	• fish community with moderate species diversity, some species with obligatory migration stage • moderate fisheries values (e.g. commercial, recreational, traditional, biodiversity) • watercourse and fish movement corridor with no established conservation status (declared fish habitat area, environmental reserve)
Class C	• minor stream, stormwater drain, farm drain, constructed wetland or tidal waterway in poor condition • intermittent or permanently flowing stream with substantially altered flood flow or tidal flow regime • poorly defined and substantially altered channel form, with poor habitat structure and diversity • fish spawning, growth or refugial habitat areas in poor condition • severely fragmented riparian vegetation corridor with no instream vegetation • poor water quality	• negligible flood flow or tidal flow connectivity with other watercourses or wetlands upstream, downstream or laterally • negligible fish movement corridor connectivity with habitat areas upstream and downstream • substantial barriers to fish passage at waterway structures upstream or downstream	• fish community with poor species diversity, no species with obligatory migration stage • minor fisheries values (e.g. commercial, recreational, traditional, biodiversity) • watercourse and fish movement corridor with no established conservation status (declared fish habitat area, environmental reserve)

5.2 Fish movement corridor class and road-waterway crossing type

Fish movement corridors that cross the road corridor, or are located at the waterway structure of interest, should be identified and described using information on the waterways, habitat, and fish community outlined in Chapters 3 and 4. Classification of fish movement corridors should be undertaken using the method outlined in Section 5.1. In situations where several alternative road alignments or waterway structure locations are under consideration within the road corridor or zone of interest, the fish movement corridor assessments should cover a broad enough area to encompass these potential locations.

The proposed location, type and configuration of the road crossings or other waterway structure at the fish movement corridor locations should be defined. Road crossings at these sites will incorporate various waterway drainage structures such as bridges, culverts or causeways, and the type and configuration of the structures will normally be chosen initially to suit various transport, drainage, and other utility and environmental goals. Provisions that are made for fish passage at these sites should be integrated into the design considerations to achieve a multipurpose solution. This may lead to modified proposals for the drainage structures, which for example could involve adoption of a bridge crossing where a culvert is satisfactory for drainage but is inappropriate for fish, or provision of dedicated facilities for fish passage such as an additional culvert cell or lowered culvert invert. Fish passage provisions may be incorporated as mitigation measures (new structure) or as remediation measures (existing structure) into a drainage facility that is otherwise unchanged with respect to meeting drainage, transport and other requirements.

A schedule of road crossing or other waterway structure types, sizes and configurations should be developed for the various fish movement corridor classes associated with these waterway structures. The road-waterway and other drainage structures can be categorised (e.g. bridges and culverts of various sizes) for use in conjunction with the categorisation of fish movement corridors to assist with prioritisation of structures for fish passage, and for identification of the various fish passage measures to be adopted to suit the various fish movement corridor classes, waterway and structure types, and waterway structure hydraulic conditions.

For the Bruce Highway Corduroy Creek to Tully road crossing of the Tully Murray floodplain, the road corridor scale assessment of fish movement corridors encompassed several road alignments that were under consideration in the concept design phase for the road. Each of the alternative alignments crossed the main waterways, flood flow paths and fish migration pathways on the floodplain, and the requirements for fish passage across the road corridor applied in much the same manner to all alignments considered in the initial planning studies.

Fish movement corridors on the Tully-Murray floodplain in the vicinity of the road corridor followed drainage paths and existing and potential future fish movement paths, which were correlated with proposed waterway drainage structures on the road alignment (see Kapitzke 2006a; Kapitzke 2007a). This included major waterways with bridges, well defined waterways with multiple-cell box culverts, and critical drainage lines and movement corridors other than creeks – in some cases including farm drains and other waterways connected to natural and constructed floodplain wetlands. An extract from the schedule of road-waterway crossings and associated fish movement corridors across the road corridor is presented in Box D5.3, including a description of the significance of the corridor in terms of fish habitat, connectivity and characteristics of the fish community. The fish movement corridors are classified in terms of the classification system presented in Box D5.2.

Box D5.3: Extract from fish movement corridor classification for road-waterway crossings on Tully Murray floodplain for Corduroy Creek road project *(After: Kapitzke 2006a; Kapitzke 2007a)*

Road-waterway crossing (Approx chainage on adopted alignment)	Waterway and fish habitat location	Fish habitat, fish movement corridor and fish species characteristics	Fish movement corridor class	Comment
Chainage 82 920 5 x 3600 x 3000 box culvert	Small waterway north of Bellenden Road and small waterway adjacent to Old Highway junction with existing Bruce Highway, connecting to flood channels and small lagoons	• Well defined upstream channel west of road connecting to defined channel and small lagoons west of rail line; well defined downstream channel east of road connecting to flood channels • Discontinuous riparian strip in agricultural land west of road and rail line; remnant forest east of existing highway with substantial riparian vegetation • Reasonable instream and riparian connectivity with Murray River flood channels upstream and downstream • Reasonable size waterway crossing on rail line, with no apparent fish migration barrier; reasonable size culverts on existing highway and old highway crossings • Identified fauna corridor for cassowaries	Class B	Qualifies as Class B corridor due to defined waterways within remnant vegetation zone and with good flow connectivity to lagoons and Murray River flood channels Provide for integrated fish and fauna passage at culvert crossing, with cassowary access on the northern end
Chainage 84 155 9 x 3600 x 1800 box culvert	Flood channels and minor lagoons on Murray Flats south of Lagoon Creek	• Well defined broad and shallow flood channel connecting to small floodplain lagoons • Discontinuous riparian strip in agricultural land east and west of road and rail line; passing through narrow remnant vegetation band east of existing highway • Extensive flow connectivity with watercourses and lagoons on Murray Flats, including flood channels of Lagoon Creek and Murray River, and cultural lagoons within remnant vegetation band downstream of existing highway • Good instream and riparian connectivity with lagoons upstream and downstream and with Murray River flood channel • Substantial bridge structure on rail line, with no apparent fish migration barrier	Class A	Qualifies as Class A due to extensive flow connectivity with watercourses and lagoons on Murray Flats, and good fish movement connectivity with habitat areas upstream and downstream

Box D5.3: Extract from fish movement corridor classification for road-waterway crossings on Tully Murray floodplain for Corduroy Creek road project *(After: Kapitzke 2006a; Kapitzke 2007a)*

Road-waterway crossing (Approx chainage on adopted alignment)	Waterway and fish habitat location	Fish habitat, fish movement corridor and fish species characteristics	Fish movement corridor class	Comment
Chainage 84 450 7 x 20 m span bridge	Lagoon Creek	• Well defined natural stream channel with diverse instream habitat and relatively natural flow regime • Relatively continuous riparian vegetation corridor • Good instream and riparian connectivity with large lagoons upstream and Murray River downstream • No significant fish migration barriers upstream or downstream of the new road corridor • Diverse fish community with significant biodiversity, commercial, recreational and traditional fisheries values	Class A	Provide for integrated fish and fauna passage at bridge crossing

A total of 24 road-waterway crossings were identified where provisions for fish passage may have been required at the fish movement corridor crossing of the road corridor. This included five major bridge crossings and a series of multi-cell box culvert crossings in 11 sizes, ranging from 2400 (wide) x 600 (high) up to 3600 (wide) x 4000 (high). Waterway crossing structures were categorised into 4 groups according to type and size, to represent the bridges (Group 1) and a range of culvert heights (Group 2 – large [2700 – 4000 high]; Group 3 – medium [1500 – 2400 high]; Group 4 – small [600 – 1200 high]). Each of these crossings was further categorised in terms of the fish movement corridor class (A, B, C) for the associated waterway, and the total number of each crossing class within each structure grouping was identified (Box D5.4). Several of the crossings, including each of the bridges on the major streams and the box culvert structure at Chainage 82 920, were designated for integrated fish and fauna passage.

Box D5.4: Summary and categorisation of road-waterway crossing types for Corduroy Creek Road project *(Source: Kapitzke 2007a)*

Road-waterway crossing grouping	Bridge spans / culvert sizes	Road-waterway crossings on new road for various fish movement corridor classes (Existing-Western Variation)			
		Class A	Class B	Class C	Totals
Group 1 – multi-span bridge	• 3 x 20 m • 5 x 20 m • 7 x 20 m • 3 x 20 - 25 m • 7 x 25 m	Chainage 81 050 [1] Chainage 83 640 [1] Chainage 84 450 [1] Chainage 85 080 [1] Chainage 89 700 [1]			5 Class A
Group 2 – large multi-cell box culvert 2700 – 4000 high	• 3600 x 2700 • 3600 x 3000 • 3600 x 3600 / 3600 x 4000	Chainage 85 000	Chainage 82 920 [1] Chainage 89 950 [2]		1 Class A 2 Class B
Group 3 – medium multi-cell box culvert 1500 – 2400 high	• 2700 x 2100 • 3600 x 1500 • 3600 x 1800 • 3600 x 2100 • 3600 x 2400	Chainage 84 073 Chainage 84 155 Chainage 84 270 Chainage 84 575 Chainage 84 835	Chainage 82 111 Chainage 82 680 Chainage 87 212	Chainage 85 643 Chainage 90 323 [2] Chainage 91 103 [2] Chainage 92 800 [2]	5 Class A 3 Class B 4 Class C
Group 4 – small multi-cell box culvert 600 – 1200 high	• 2400 x 600 • 2400 x 900 • 3600 x 1200	Chainage 83 865	Chainage 81 630 Chainage 81 690	Chainage 86 475	1 Class A 2 Class B 1 Class C

Notes 1 Provide for integrated fish and fauna passage 2 Listed in existing corridor class – potential for upgraded class, subject to improved fish habitat / connectivity

5.3 Priority road-waterway crossings for fish passage

Where significant numbers of fish movement corridors have been identified at road corridor crossings or at other waterway structures, and provisions for fish passage cannot be made or are not warranted at all structures, a number of approaches can be taken to selection of priority structures where fish passage provisions are to be made. This includes approaches based on some of the following factors:

- fish movement corridor class (Class A, B, C)
- distribution along road corridor – proximity to other fish passage crossings
- specific local characteristics – environmental enhancement, high profile site
- type of crossing – bridge or culvert
- size of structure – height and width of culvert, no of cells
- severity of hydraulic conditions presenting barrier to fish passage
- feasibility and cost of providing for fish passage at the structure

For the Bruce Highway Corduroy Creek to Tully road project, a decision was made to provide for fish passage at all bridge sites over major waterways, and 6 other top priority sites at box culvert

crossings on the new road and / or on the existing road (see Kapitzke 2007a). A two-stage prioritisation process was used in which a short list of Stage 1 (first and second) priority sites at box culverts on the new road was chosen on the following criteria related to the significance of the fish movement corridor. Further discrimination between short listed crossings on the new road was undertaken in a Stage 2 prioritisation process (see below) to select top priority crossings, and the overall list of top priority sites for provision of fish passage was then developed from these crossings on the new road alignment and top priority crossings that have been retained on the existing road where it crossed the same waterway.

Stage 1 prioritisation criteria for provision for fish passage at box culverts on new road – Bruce Highway Corduroy Creek to Tully road project

Class A movement corridor	Prefer to adopt the highest value Class A corridors – based on habitat value, relative waterway size and connection to major streams and floodplain lagoons
Potential to enhance corridor value	Consider potential of Class B or Class C corridors for environmental enhancement of the waterway or adjoining land
Distribution across the floodplain	Adopt crossings that are more widely spaced in preference to crossings that are close together
High profile site or other attribute	Consider sites that are prominent and have other related attributes such as fauna crossing, or connection to adjoining iconic sites

Stage 2 prioritisation of culvert crossings on the Corduroy Creek road project has adopted culverts that have the most severe hydraulic conditions, and which correspond to fish movement corridors that provide the most valuable waterway and fish movement connection between crossings on the new road and the existing road. The top priority road-waterway crossings derived from this process, where provision of fish passage are to be made, are listed in Box D5.5, along with the rationale for adopting the crossing. This is a short list of sites identified in Box D5.4 above, and includes 5 multi-span bridges at Class A corridors, 4 crossings on the new road (3 Class A and 1 Class B corridors), and 2 crossings on the existing road (2 Class A corridors).

Box D5.5: Top priority road-waterway crossings for fish passage on new and existing road alignments for Corduroy Creek Road project *(After: Kapitzke 2007a)*

Road-waterway crossing	Road-waterway crossing group	Waterway and fish habitat location Fish movement corridor class	Comment and rationale
Multi-span bridges			
Chainage 81 050 3 x 20 m span bridge	Group 1 – multi-span bridge	Corduroy Creek Class A	Bridge with joint fauna / fish crossing
Chainage 83 640 5 x 20 m span bridge	Group 1 – multi-span bridge	Little Lagoon Creek Class A	Bridge with joint fauna / fish crossing
Chainage 84 450 7 x 20 m span bridge	Group 1 – multi-span bridge	Lagoon Creek Class A	Bridge with joint fauna / fish crossing
Chainage 85 080 3 x 20 - 25 m span bridge	Group 1 – multi-span bridge	Murray River Class A	Bridge with joint fauna / fish crossing
Chainage 89 700 7 x 25 m span bridge	Group 1 – multi-span bridge	Tully River Class A	Bridge with joint fauna / fish crossing
Multi-cell box culverts where culvert fishway provisions are to be made – New road			
Chainage 82 920 5 x 3600 x 3000 box culvert	Group 2 – large multi-cell box culvert 2700 – 4000 high	Small waterway adjacent to Old Highway junction with existing Bruce Highway, connecting to flood channels and small lagoons Class B	Prominent waterway on the southern end of the Murray Flats Joint fauna / fish crossing that is on a significant waterway and will be a high profile facility

Box D5.5: Top priority road-waterway crossings for fish passage on new and existing road alignments for Corduroy Creek Road project *(After: Kapitzke 2007a)*			
Road-waterway crossing	**Road-waterway crossing group**	**Waterway and fish habitat location Fish movement corridor class**	**Comment and rationale**
Chainage 83 865 5 x 3600 x 1200 box culvert	Group 4 – small multi-cell box culvert 600 – 1200 high	Flood channels and minor lagoons on Murray Flats south of Lagoon Creek Class A	Prominent waterway with substantial flow on Murray Flats south of Lagoon Creek, connecting to cultural lagoon site
Chainage 84 155 9 x 3600 x 1800 box culvert	Group 3 – medium multi-cell box culvert 1500 – 2400 high	Flood channels and minor lagoons on Murray Flats south of Lagoon Creek Class A	Prominent waterway with substantial flow on Murray Flats south of Lagoon Creek, connecting to cultural lagoon site
Chainage 84 835 8 x 3600 x 2400 box culvert	Group 3 – medium multi-cell box culvert 1500 – 2400 high	Flood channels and minor lagoons on Murray Flats south of Murray River Class A	Prominent waterway with substantial flow on the northern section of the Murray Flats adjacent to Murray River
Multi-cell box culverts where culvert fishway provisions are to be made – Existing road			
Chainage 83 865 4 x 2130 x 1520 box culvert	Existing culvert	Flood channels and minor lagoons on Murray Flats south of Lagoon Creek Class A	Upstream and adjacent to cultural lagoon site
Chainage 84 835 5 x 2130 x 1520 box culvert	Existing culvert	Flood channels and minor lagoons on Murray Flats south of Murray River Class A	Upstream and immediately adjacent to new culvert crossing

6 FISH PASSAGE PROVISIONS AT ROAD-WATERWAY CROSSINGS

The road corridor scale assessment will determine the fish movement corridor class at road crossings and other waterway structures where provisions for fish passage are to be made, whilst drainage design will define the proposed characteristics of the drainage structure at each site. This information is used in conjunction with aquatic fauna connectivity / fish passage goals for the structures to establish design objectives and criteria for fish passage for use in site scale planning and design for each waterway structure (see *Guidelines Part E – Fish Passage Design: Site Scale*). In some instances, fish passage requirements for the structure may require a change of structure type or configuration from that proposed in the initial drainage design. Where fish movement corridor, waterway and drainage structure characteristics are similar for road crossings along the road corridor and for other waterway structures, broad groupings of structures and waterway characteristics may be established to assist with fish passage design for the project.

The following sections discuss fish passage goals for the structures, and outline an approach to grouping road crossing or other waterway structures with similar waterway and hydraulic characteristics in order to identify fish passage requirements for these structure groupings. This is illustrated for the multi-cell box culvert waterway crossings of the Tully Murray floodplain for the Bruce Highway Corduroy Creek to Tully road project (Kapitzke 2006a; Kapitzke 2007a).

6.1 Fish passage goals and provisions for fish passage

The design objectives and criteria adopted for fish passage at road crossings on the road corridor or at other waterway structures will typically be based on the fish movement corridor class (Class A – Class C) and the fish passage goals for the structures (high – low). These goals may be governed by legislative or policy provisions, agency priorities, or community desires. For example, legislation or policy may mandate fish passage for iconic species in a waterway, the project developers or resource management agency for the area may prioritise particular waterways for fish passage, or the local community group may have particular requirements for some species or waterway structures.

Fish movement corridor class and the fish passage goals identified in the road corridor scale assessment will provide the basis for site scale planning and design of road crossings and other waterway structures. Design objectives and criteria for fish passage at the site scale (fish passage design flows, design swim speeds) are established by considering the desired fish passage effectiveness of the structure, which is chosen by the designer on a discretionary basis, taking into account the following (see *Guidelines Part B – Fish Migration and Fish Species Movement Behaviour* and *Guidelines Part E – Fish Passage Design: Site Scale*):

- fish movement corridor class (Class A – Class C)
- aquatic fauna connectivity / fish passage goals (high – low)
- fish migration barrier hydraulic conditions for waterway structure
- feasibility of overcoming the fish migration barrier at the structure

Fish passage provisions to meet these design objectives and to achieve the desired fish passage effectiveness at the waterway structures are established through mitigation design (new structures) or remediation design (existing structures). This approach does not mandate the type of drainage structure or fish passage facility to be adopted at the crossing to achieve the desired fish passage effectiveness, but provides some flexibility in determining the design solution to meet multipurpose requirements for the crossing.

For the Bruce Highway Corduroy Creek to Tully road project, the most conservative (Level 1) design criteria for fish passage effectiveness was adopted in determining fish passage goals and provisions for fish passage for priority box culvert road-waterway crossings on the road corridor (see Kapitzke 2007a). These crossings mostly correspond with the highest fish movement corridor class and all have high level fish passage goals due to fish community significance for

the Tully Murray floodplain. Furthermore, high fish passage effectiveness can be achieved at these waterway crossings because the hydraulic conditions that constitute the fish migration barriers are not severely adverse.

This design option approach to determining fish passage solutions through mitigation or remediation measures is preferable to the mandated design approach used by some, which stipulates a particular type of waterway crossing (e.g. bridge, culvert, causeway) to meet fish passage provisions for a particular class of fish habitat accessed at the crossing (e.g. NSW policy for fish passage at small structures outlined in *Fish Passage Requirements for Waterway Crossings* [Fairfull and Witheridge 2003]). Based of the physical and ecological aspects of the waterway, this system adopts 4 classes of fish habitat, ranging from Class 1 – *Major Fish Habitat* to Class 4 – *Unlikely Fish Habitat*. The preferred minimum fish passage method to be adopted for these habitat classes is identified, ranging from a free spanning bridge or arch structure for Class 1 habitat to a causeway or culvert with minimal alteration to the natural waterway for Class 4 habitat. In this mandated design approach, which is often limiting and undesirable, selection of the crossing type is based on a priority system of first a bridge crossing; then an arch, a culvert, a ford; and finally a causeway as the least preferred option.

6.2 Envelope of hydraulic conditions for fish passage at crossings

In situations where a number of road crossings on the road corridor have similar drainage structure configurations (e.g. box culverts of similar size), and where the waterway characteristics of these crossings or of other waterway structures are similar (e.g. floodplain waterway), it may be possible to group the waterway structures and develop an envelope of hydraulic conditions for fish passage design at the structures. Flood modelling and drainage design studies undertaken for road corridor design will commonly provide sufficient information to obtain first level estimates of hydraulic characteristics of the structures for use in fish migration barrier assessment and design of fish passage facilities. These characteristics can be examined more closely in site scale planning and design studies for the structures.

For example, in the Bruce Highway Corduroy Creek to Tully road project, flow characteristics for the priority box culvert waterway crossings, established from field measurements and desk top evaluations, showed velocities in the range 0.1 – 0.5 m/s for low flow, medium flow and high flow design conditions (Box D6.1).

Box D6.1: Estimated design flow conditions for priority box culvert waterway crossing for fish passage for Corduroy Creek Road project *(Source: Kapitzke 2007a)*

Waterway crossing type	Road-waterway crossing structures	Estimated velocities (average) and flow depths for multi-cell box culvert waterway crossings		
		Low flow depth d < ~ 0.5 m	Medium flow 0.5 m < d < ~ 1.5 m	High flow ~ 1.5 m < depth d
Multi-cell box culverts where culvert fishway provisions are to be made – New road				
Multi-cell box culvert	Chainage 82 920	~ 0.1 m/s	0.2 – 0.5 m/s	~ 0.5 m/s
	Chainage 83 865	0.5 m	1.2 – 1.6 m	??
	Chainage 84 155			
	Chainage 84 835			
Multi-cell box culverts where culvert fishway provisions are to be made – Existing road				
Multi-cell box culvert	Chainage 83 865	0.1 – 0.3 m/s	0.4 – 0.9 m/s	~ 1.0 m/s
	Chainage 84 835	0.5 m	1.2 – 1.6 m	??

6.3 Fish passage options for road-waterway crossings

A preliminary assessment of fish passage options for road crossings and other waterway structures can be undertaken in road corridor scale studies on the basis of fish passage goals identified for the waterway structures and the estimates of hydraulic characteristics for the various structures. An understanding of the prospective fish passage design options is important

in the road corridor studies to assess the suitability of waterway structure designs proposed on the basis of drainage, utility and other objectives. Integrated design for multipurpose requirements can best be achieved in the project concept phase by examining options for waterway structure configurations that meet all design requirements. More detailed examination of options in the preliminary design phase will allow confirmation of design proposals.

In some instances, the road corridor scale assessment of fish passage requirements may identify alternative waterway drainage structure proposals to those identified in the initial drainage design for the structures. This may lead to a change of structure type or configuration from that initially proposed, such as consideration of a bridge crossing in lieu of a culvert, or other mitigation or remediation measures such as an additional culvert cell or lowered culvert invert.

Grouping of waterway structures for the road corridor in terms of type and size of drainage structure, fish movement corridor class, and fish passage goals and design objectives will assist in standardizing design provisions and in defining overall requirements for fish passage for the project. In order to assist with integrated design provisions, this grouping should also identify structure sites with special requirements such as terrestrial fauna passage or road underpass.

For example, in terms of fish passage options for the priority box culvert waterway crossings in the Bruce Highway Corduroy Creek to Tully road project, the envelope of hydraulic conditions for the culverts indicted that the corner “EL” baffle fishway design within the box culvert cell would provide a suitable fish passage design solution for all crossings. Where terrestrial fauna passage across the road corridor was provided toward the southern end of the road, the location and configuration of the culvert crossing (Chainage 82 920) was adopted in the road corridor scale studies to allow integrated fish and fauna provisions at the crossing (see Kapitzke 2007a).

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