Memorandum

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From	Simon Lukies (GHD)	Tel	03 6210 0601
Subject	Mt Todd-Fish Passage Requirement	Job no.	43/22079

1 This section of the Supplementary report addresses submission #114 from NT EPA relating to the Stow Creek Diversion Channel.

The hydraulic modelling that has been undertaken for the diversion channel only addresses the 100 year, 24-hour storm event. There has been no modelling undertaken to investigate 'normal' flow periods through the diversion channel. Flow modelling will be completed under a number of higher frequency flow scenarios to determine if the diversion channel provides conditions sufficient to meet guidelines for providing fish passage in fishways. This hydraulic modelling must be presented in the Supplement with commitments to implementation of appropriate strategies for fish passage and erosion mitigation if required. Details of the required strategies should be included.

1.1 Introduction

Fish require suitable depth, space and light to move through obstacles in their habitat. Poorly designed diversion structures can impede the movement of fish by creating barriers such as high flow velocities, steep gradients, inadequate flow depth, water turbulence, debris blockages, or a lack of aquatic habitat or "rest" areas.

Design for fish passage relies on providing suitable flow conditions that match the swimming capabilities of different species passing upstream or downstream at the site. This involves creating appropriate hydraulic conditions (velocities, depths, turbulence levels, flow patterns) at the appropriate design flow rates in the waterway during fish migration. The design flow range is important because the associated hydraulic conditions affect the duration of fish passage, the species and life stage of the fish able to pass, the number of fish able to pass, and as a result; how far the fish community can move upstream to new habitats during the migration event.

There are no specific guidelines in the Northern Territory relating to design criteria for fish passage through diversion channels. Therefore a review of the literature has been undertaken in order to provide guidance for the Stow Creek diversion channel.

1.2 Target Fish Community

Surveys of fish in the Edith River and its tributaries have identified a relatively diverse fish fauna in and around the Mt Todd Mine site .The fish expected to utilise Stow Creek are presented in Table 1. The fish community data has been sourced from the draft EIS.

Table 1 Species Sampled from the Edith River and Stow Creek at Mt Todd Site

Species	Common Name
Ambassis agrammus	Sail-fin glassfish
Amniataba percoides	Banded grunter
Anodontiglanis dahli	Toothless catfish
Neosilurus hyrtlii	Hyrtl's Catfish
Arius sp.	Fork-tailed catfish
Anguilla bicolor	Indian Shortfin Eel
Craterocehalus stercusmuscarum	Fly-specked hardyhead
Glossamia aprion	Mouth almighty
Hephaestus fuliginosus	Sooty grunter
Lates calcarifer	Barramundi
Leiopotherapon unicolor	Spangled grunter
Megalops cyprinoides	Tarpon
Melanotaenia australis	Western rainbowfish
Mogurnda mogurnda	Purple-spotted gudgeon
Nematolosa erebi	Bony bream
Neosilurus ater	Black catfish
Oxyeleotris lineolata	Sleepy cod
Strongylura kreffti	Long tom
Syncomistes butleri	Butler's grunter

1.3 Target species swimming ability

Swimming performance and movement behaviour in response to flow are key elements governing fish passage. Swimming capabilities vary with fish species and swimming mode, and with body morphology, fish length, water temperature and other variables.

Australian freshwater fish species migrate mostly in response to flow stimulation, and they are relatively poor swimmers compared with northern hemisphere species. They have poor jumping abilities to overcome water surface drops and they are readily obstructed by rapids and small waterfalls. Furthermore, many Australian fish move upstream as juveniles, when they have even less ability to negotiate high velocity flows; thereby making passage through waterway barriers more difficult as they attempt to combat difficult flow conditions.

A literature review was undertaken to investigate the swimming ability of the native fish species expected to inhabit Stow Creek.

Fish swimming speeds are generally classified into *burst*, *prolonged/steady* or *sustained*. The classification is based on the amount of time that fish can continue to swim against a given velocity:

- Burst swimming mode maintained for 5 to 30 seconds (Blake 2004);
- Prolonged/steady swimming mode maintained for 30 seconds to 200 minutes (Blake 2004);
- Sustained swimming mode maintained for greater than 200 minutes (Blake 2004).

Fish are also classified by the mechanisms they use to pass barriers (e.g. swimming, climbing, using surface tension, jumping or through the use of body parts such as the oral disk of lampreys). Boubee *et al.* (1999) grouped freshwater fish into *Climbers*, *Jumpers* and *Swimmers*.

The review focused on quantitative information on the swimming ability of fish. Swimming ability has been reported for the following species:

- Banded Grunter
- Sail-fin Glassfish
- Flyspecked Hardy head
- Mouth Almighty
- Sooty Grunter
- Tarpon
- Barramundi
- Spangled Perch
- Western Rainbowfish
- Purple Spotted Gudgeon
- Bony Bream

The information was reviewed for the purpose of developing design criteria for the Stow Creek diversion channel. Given the intended 850m length of the diversion, the review focussed on sustained swimming durations (30 seconds – 200 minutes and >200 minutes, respectively). Any extrapolation of fish swimming speed has been conservative.

The data presented encompasses the range of fish that are likely to inhabit Stow Creek. A diversion designed to accommodate these species is also likely to be sufficient for other species that may not have been considered during this assessment.

Table 2 Burst / Sustain Swimming Speeds for Native Fish

Fish Species	Size Class or individual length (mm)	Burst / Sustain Swimming Speed (m/s)
Banded Grunter (*Amniataba percoides*)	<250	Juvenile fish capable of 7 km / day (average 0.08 m/s),with adults moving at 9 km / day (average 0.10 m/s) (Pusey *et al* 1995).
Sail-fin Glass Fish (*Ambassis agrammus*)	<50	Commonly found in habitat of low flow (<0.02 m/s) and depth of <600 mm (Pusey and Kennard 1994). Can sustain upstream progression up to 0.05 m/s (Bishop *et*

Fish Species	Size Class or individual length (mm)	Burst / Sustain Swimming Speed (m/s)
		al 2001)
Fly-specked Hardyhead (*Craterocehalus stercusmuscarum)*	50-60	Commonly found in habitat of medium flow (<0.19 m/s) and depth of <500 mm (Pusey *et al* 1995). Can sustain upstream progression up to 0.85 m/s (Bishop *et al* 2001)
Mouth Almighty (Glossamia aprion)	<80	**No swimming velocity data available.** Within wet tropics, it has not been sampled in velocities greater than 0.4 m/s. Most commonly found in velocities <0.2 m/sec with a water depth of 400 mm. Species not though to move widely (Pusey and Kennard 1994).
Sooty Grunter (*Hephaestus fuliginosus)*	<400	Commonly found in habitat of 0.18 m/s and depths between 200 mm and 870 mm (Pusey *et al* 1995). Can sustain upstream progression up to 0.08 m/s over a 24 hour period (Bishop *et al* 2001)
Barramundi (*Lates calcarifer)*	<1800	Barramundi: NV95 = 0.66 m/s burst speed for juveniles (43 mm length)(Griffin 1987); juvenile fish (200 mm length) burst speed = 1.4 m/s (Kowarsky and Ross 1981); juvenile fish (200 - 300 mm length) prolonged speed = 0.4m/s for 15 min (2); juvenile fish (150 - 500 mm length) unable to negotiate 3 m/s (Mallen-Cooper 1992).
Spangled Grunter *(Leiopotherapon unicolor)*	<200	Can sustain upstream progression up to 0.58 m/s (Bishop *et al* 2001), considered as a fast moving fish. Does not occur in velocities >0.9 m/s and rarely at depths greater than 1000 mm.
Tarpon (*Megalops cyprinoides)*	<1500	Can sustain swimming speed of 15.2 m/s. Has a preference for deep water. Known to be one of the fastest species.
Western Rainbowfish (*Melanotaenia australis)*	<100	**No swimming velocity data available.** Within wet tropics, it has not been sampled in velocities greater than 0.85 m/s. Most commonly found in velocities <0.09 m/s with a water depth of 430 mm. (Pusey and Kennard 1994).
Purple Spotted Gudgeon *(Mogurnda mogurnda)*	<80	**No swimming velocity data available.** Have been reported to climb vertical wet surfaces that would otherwise be insurmountable to fish (Bishop *et al* 2001). Most common in depths of between 300 – 600 mm and average water velocity of 0.05 m/s.
Bony Bream (*Nematolosa erebi*)	<300	**No swimming velocity data available,** Bony Bream are most commonly found in flow velocities of < 0.3 m/s, (Pusey *et al* 1995) and depths >700 mm.

1.4 Fish passage design criteria

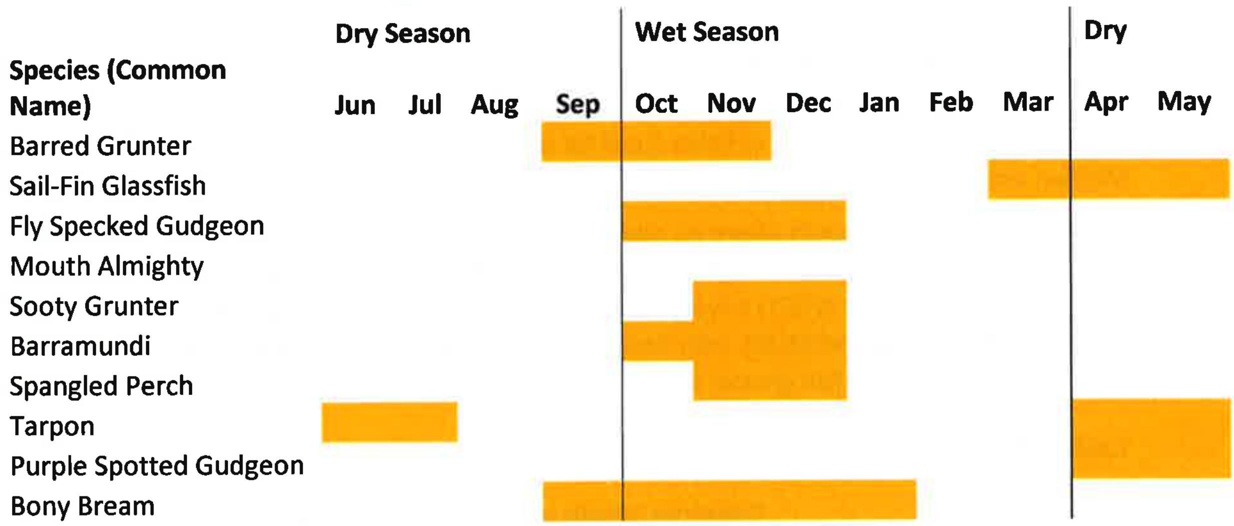
1.4.1 Flow Passage Period

The technique for guiding fish passage design flows in southern Australian streams provides for fishway operation for 95% of flows (Mallen-Cooper 2000). Although meaningful for large rivers with slowly rising and falling flow conditions, this approach is not applicable to Northern Territory waterways where highly variable stream flow characteristics do not allow for such a design.

Waterways in the Northern Territory commonly display a large range in flow magnitude from no flow to flood flow. Upstream fish migrations typically take place at flows above very low flow conditions, and well below peak discharges in the waterway. These migrations often occur over a very short period of time.

Table 3 shows the key migration period for the target species. The table shows that a large amount of fish migration occurs in low flow conditions at the beginning or end of flood hydrographs in the wet season, or during moderate non-wet season flow periods. The low flow condition is defined as flow up to about 0.5 m deep, inundating the channel bed for a defined waterway.

Table 3 Migration period for Target Species



A flow range with a maximum and minimum flow period is used for fish passage design, thus providing a window of time within a flow event where conditions are suitable for passage. The maximum design flow condition relates to the required period for passage within a flow event (which is a function of the peak discharge and the hydrograph shape); and the required period for passage within a fish migration season to allow life cycle function.

With regard to the Stow Creek hydrograph (Figure 1), fish migration is likely occur within the transitional flow periods. It is important to note that the gauging station on Stow Creek is downstream of the Batman and Horseshoe Creek confluences and is likely to display flows higher than those within the proposed diversion which is upstream of this point.

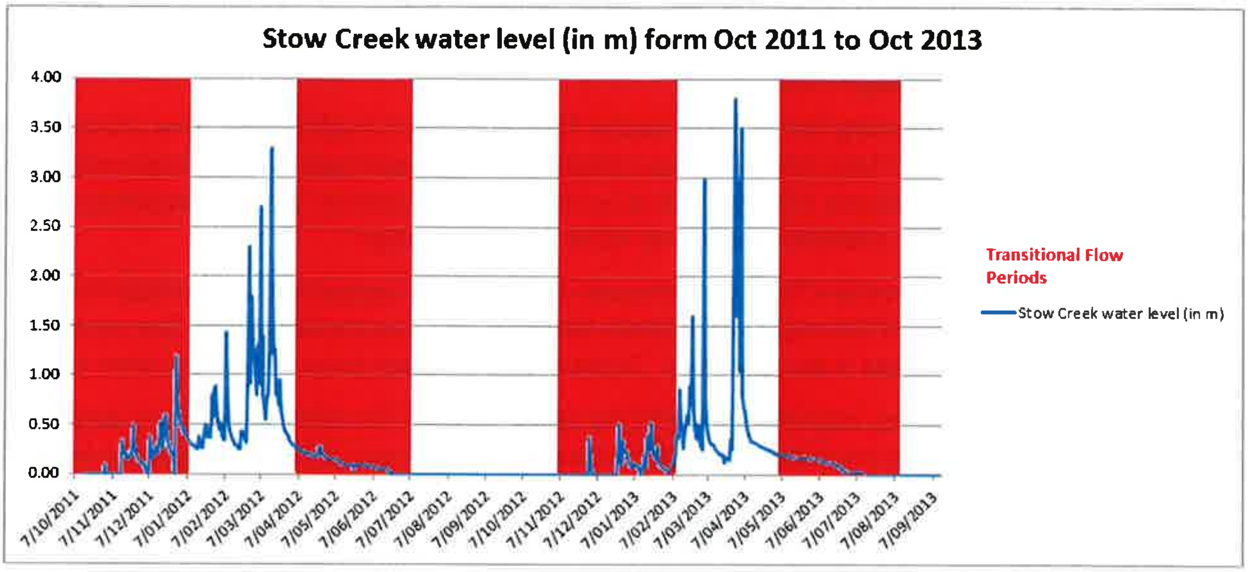


Figure 1 Stow Creek hydrograph with transitional flow periods highlighted.

1.4.2 Functional Design Groups

As swimming ability in fish is largely proportional to their relative size, the swimming ability of the individual target species listed in Table 2 can be categorised into three different functional groups (Small, Medium and Large) (Refer to Table 4).

For a conservative approach where no other swim speed data are available, the criteria suggested by Cotterell (1998) is to use a prolonged swim speed of 0.3 m/s or less to allow for migration of all native species. Mallen-Cooper (2001) advocates a default prolonged swimming speed value of 3 body lengths (length of fish) per second (BL/s), with design swim speeds of 0.15 m/s for fish less than 80 mm in length, and 0.75 m/s for fish greater than 250 mm in length.

Table 4 Functional Fish groups

Fish movement capability group	Common length of fish	Prolonged speed – nominal (20 sec to 200 min duration)
Medium size fish species		
Eel-tailed Catfish	15 cm - 25 cm	0.45 m/s to 0.75 m/s
Grunters (Adult)	15 cm - 25 cm	
Grunters (Juvenile)	10 cm – 20 cm	0.1 m/s to 0.3 m/s
Small size fish species		
Rainbowfish	< 10 cm	0.25 m/s

Fish movement capability group	Common length of fish	Prolonged speed – nominal (20 sec to 200 min duration)
Hardyheads	adults < 20 cm (juveniles to 10 cm)	0.1 m/s to 0.3 m/s
Cardinalfishes / Glass perchlets / Gobies / Gudgeon	adults < 10 cm (juveniles to 5 cm)	0.1 m/s to 0.3 m/s
Large Size Fish Species Adults		
Tarpon / Barramundi	adults 50 cm - 120 cm (juveniles to 30 cm)	0.3 m/s to 1.0 m/s

1.4.3 Site Specific Criteria

In order to provide a diversion channel design that will pass most (if not all) species expected to occur within Stow Creek, a diversion channel should be designed to provide the following conditions:

- average flow velocity of 0.3 m/s for the flow period for the first three months of the transitional hydrograph from dry season to wet season; and
- a depth of up to 0.5 m throughout the diversion reach during the transitional hydrograph from dry season to wet season.

It is expected that if these conditions can be met for the transitional flow period from dry to wet, then similar flow conditions will be provided at the other end of the hydrograph during the transition from wet to dry.

Note that the velocity of flow in the diversion channel is a function of the flow depth, channel width, gradient and hydraulic roughness. Flow depth is also a function of upstream rainfall/runoff. Therefore, whilst it is possible to engineer the channel width, gradient and roughness; it is not possible to 'engineer' the flow depth (channel depth, yes) without adequate upstream runoff. The channel can be engineered for the transitional flow period but flow condition within the channel is reliant on adequate rainfall/runoff occurring over the upstream catchment to generate sufficient discharge through the diversion channel. The hydrograph displayed in Section 1.4.1 indicates that there are sufficient flows to provide the recommended hydraulics, however this cannot be confirmed without associated hydraulic modelling.

1.5 Channel Design

A preliminary design for the Diversion Channel is provided in the section 2.4.6 and Figure 2-22 of the draft EIS. Designed for the 1 in 100 year flood event (691 m^3/sec), this channel is 850 m long and 60 m wide. This includes sufficient rip rap for the protection of the channel batters during such flow events. This issue is that under normal flow conditions, especially during the key transitional flow periods, the flow of water across this channel is likely to provide a veneer at best and not provide the depth required for fish to navigate the length of the diversion.

In order to facilitate fish passage the diversion channel should be designed to operate as part of a self-sustaining stream system promoting nutrient processing, ecological connectivity and sediment storage and transport. In order to do this, the channel should;

- Avoid the use of artificial grade control structures or other structures that likely to require maintenance beyond life of mine;
- Include natural, locally and regionally occurring geomorphic and habitat features; and
- Needs to establish a state of dynamic equilibrium (equal rates of sediment erosion and deposition) with adjoining sections of the creek.

The design of the proposed diversion should incorporate the following:

- Construction of composite cross section shape leaving the natural cross section of the channel unchanged whilst increasing the channel area at higher flow depths where possible;
- Where the entire channel needs to be re-routed, A secondary composite channel mimicking the natural channel should be cut into the larger flood mitigation channel. For design purposes, it is suggested that the dimensions and sinuosity of the existing channel be surveyed, with the aim of replicating the key aspects in the design.
- A diversion channel bank batter slope of 1:3 (v:h). This design was adopted as a preliminary assumption based on limited geotechnical information, with the intention of refining these channel bank batter slopes as the design process progresses; and
- A stream bed grade similar to that of the natural waterway, which is achieved by designing sufficient length and cross sectional area in the diversion alignment and incorporating meanders of adequate geometry where appropriate. This will also help to mitigate the erosional scour downstream of the diversion

It is expected that a design using these principles will assists in creating a morphologically stable channel requiring minimal management in the short to medium term and no ongoing management following mine closure.

2 References

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