Appendix E Fish Passage

Hinze Dam Alliance

Hinze Dam Stage 3 Upgrade

Preliminary Design Report

SECTION 10:

FISHWAY

- **May 2007**

Contents

Tables, Plates and Figures

Tables

Plates

Figures

10.1 Introduction

10.1.1 General

This section presents the preliminary designs developed for the following:

- Upstream fish transfer (trap and haul) facility;
- Spillway arrangement developed to minimise injuries to fish during spill events; and
- System to remove fish from the stilling basin and downstream plunge pool.

10.1.2 Existing Environment

An overview of the existing environment including the river system, reservoir and the fish species is provided in Appendix 10A. The following summarises the key findings:

- There is substantial good-quality riverine habitat upstream of Hinze Dam in addition to the impounded artificial habitats of the storage. Plate 10:1 and Plate 10:2 show the Little Nerang Creek and Nerang River respectively upstream of the reservoir.

Plate 10:1: Little Nerang Creek Upstream of Hinze Dam

Plate 10:2: Nerang River Upstream of Hinze Dam

- Dam construction, water diversions and downstream urbanisation have led to deleterious changes in the Nerang River's condition and its fish population downstream of Hinze Dam. The river downstream of the dam is shown in Plate 10:3. The small releases from the reservoir are such that it is possible in areas to step directly over the river.

- Minimal quantitative data are available on either the natural or the current distribution and abundance of the Nerang River's fish community; however, up to 45 Australian native fish species may have lived in the Nerang River, either within their natural range of distribution or following introduction from other Australian river systems.

- The storage currently has recreational-fishery value based on stocking with artificially propagated Australian bass. Additional species introduced from other drainage regions, such as golden perch and saratoga, have also previously been stocked.

- While the Hinze Dam has been a barrier to fish passage at the site since its original construction in the mid 1970's, the dam has prevented exotic species migrating upstream.

Plate 10:3: Nerange River Downstream of Hinze Dam

10.1.3 Fish Passage Requirements

The assessment of the fish passage requirements for the Stage 3 upgrade of Hinze Dam is detailed in Appendix 10A. Upstream fish passage will be provided via a trap and haul system that will be located in the vicinity of the existing environmental flow outlet adjacent to the pump station. No downstream passage is to be provided other than protecting fish that pass through the spillway during spill events. The spillway design incorporates a stepped face to dissipate energy during high flow events and to improve constructability. An assessment of potential impacts to fish passing through the spillway has been undertaken and measures are being provided to remove fish that become trapped within the stilling basin and downstream plunge pool of the spillway following the cessation of flow.

The key factors in determining the fish passage requirements, other than those listed in Section 10.2.1, were as follows:

- The Fisheries Act (1996) will be considered as part of Development Approval matters associated with a waterway barrier.
- The 'Decision-Making Protocol' that is used by Queensland Department of Primary Industries – Fisheries (DPIF) will be assessed and confirmed the need for a fishway.
- Environmental flow objectives (EFO) for the Nerang River are described in the Gold Coast Water Resources Plan 2006; which is subordinate legislation of the *Water Act 2000*. The EFO requirement is to release 7.25 ML/day from Hinze Dam when the spillway is not flowing (Reservoir < FSL). This requirement is in place for at least the next 10 years.
- Other fish-passage barriers exist downstream of Hinze Dam as shown in Plate 10:4 and Plate 10:5. Little Nerang Dam, which impounds the Little Nerang Creek in the upstream catchment, prevents upstream fish passage to that sub-catchment portion of the drainage system. Culverts at road crossings may also impede passage in some upstream areas.
- Two alien species of fish were recorded in recent fish surveys, but current levels of ecological disruption in the river make it vulnerable to invasion by other pests. The role of the dam as a barrier, and the value of a fishway as a means of separating valued and pest fish, could become important in controlling such pest species, should they be introduced.

Plate 10:4: Barrier Downstream of Hinze Dam

Plate 10:5: Barrier Downstream of Hinze Dam

10.2 Proposed Trap and Haul Facility

10.2.1 Design Criteria

The details for the design criteria are provided in Appendix 10A, the key criteria for the system are as follows:

- The entire environmental flow release of 7.25 ML/day is available to facilitate fish transfer;
- The fish transfer system is to be designed to accommodate fish sizes ranging from elvers each weighing a few grams up to occasionally large eels up to 1 m or more in length;
- The fish transfer system design and operation is to be flexible to accommodate potential variation in biomass to be transferred; and
- Fish trapping and transfer facilities are to be operable for floods up to the 1 in 20 AEP flood. However no transfer of fish would be undertaken when the low-level road crossing causeway downstream of the fishway is closed due to flooding.

10.2.2 Functional Description

Overall Description

Drawings of the proposed trap and haul system are provided with the report. The system will consist of an approach channel leading fish upstream through a trap into a collection pool. The pool can be isolated from the rest of the system and the fish guided into a screened hopper. The hopper will be lifted periodically, with fish and water placed into a tank mounted onto a suitably equipped truck, then transported upstream for release into the reservoir at different locations. A weir has been provided across the entire river channel just upstream of the trap and will assist in guiding fish to the approach channel.

Trap Location

The following two locations, as shown in Plate 10:6, were considered for the trap:

- Location 1 - near the right bank at the upstream terminus of the river, i.e. directly downstream of the spillway chute; and
- Location 2- downstream on the right bank adjacent to the existing environmental flow release at the micro-hydro power station.

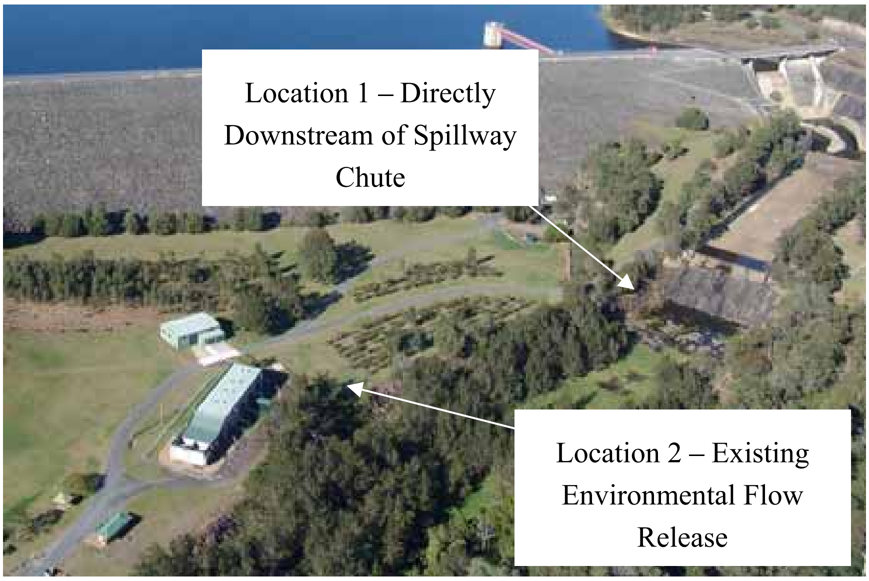

Plate 10:6: Proposed Trap Locations

Location 1 would require the environmental flow release to be moved 200 m upstream and a defined channel thalweg to be excavated downstream of the trap entrance until a well defined thalweg is reached. This location would provide good attraction during non-spillway flow releases but likely poor attraction during spillway flow as the trap entrance would be located upstream of the spillway flow impingement zone. Fish would have to pass through highly turbulent and chaotic flow surrounding the jet impingement to find the trap channel entrance.

The existing outlet for environmental releases, Location 2, is located on the right bank approximately 200 m downstream of the spillway and this was considered the most appropriate location for a fish trap. It provides good attraction during both spillway flow and non-spillway flow releases. This location requires an upstream barrier weir be constructed across the river channel to prevent fish moving upstream of the fish pass entrance during spillway releases. The construction of the barrier weir provides the extra advantage of improving downstream fish survival during a spill event by providing additional tailwater in the spillway jet impingement zone downstream of the Stage 1 spillway chute flip bucket.

Upstream Barrier Weir

The barrier weir is likely to be a concrete weir that extends up to 3 m above the existing channel bed. Investigations will be conducted during the detailed design phase to determine whether a grouted rock weir may be more suitable. The weir will act as a barrier for fish moving upstream and will assist in guiding fish toward the fish trap approach channel. The barrier will have a drain pipe located at the thalweg that will drain the upstream pool following cessation of spillway flow. The drain allows downstream passage of fish from upstream of the barrier. A shallow notch in the weir crest near the right bank will provide additional attraction flow to the trap entrance for upstream migrants during spillway flows.

The weir also provides the added benefit of creating a pool downstream of the flip bucket to reduce the impacts on fish moving downstream during spill events, in particular during discharge spill events less than 150 m^3/s (approximately 1 in 20 AEP flood event). The additional tailwater depth will provide a means for fish to plunge into the pool and change direction to avoid impacting the pool invert. For discharges less than 150 m^3/s, the barrier weir increases the tailwater depth by approximately 0.6 m to 0.8 m. For flows greater than 150 m^3/s, the barrier weir will become submerged due to limited channel capacity. A more detailed discussion of the barrier weir hydraulics is presented in Appendix 10B.

Attraction Flows and Approach Channel

Fish attraction and collection for the proposed system are similar to fish lift transfer systems. The fish collection system consists of an attraction flow provided at the upstream end, a large collection pool with a fish transfer hopper recessed in the invert and a screen with a 'V' trap and a slide gate at the downstream end. The collection pool will be approximately 6 m long by 2 m wide with variable depth. The maximum depth would be approximately 1.7 m. An approach channel is provided downstream to guide fish to the trap.

Water to the trap will be supplied through the environmental releases. The water will be of good quality and ambient temperature, and the supply will sustain a flow in the approach channel leading to the trap and the river channel below. The proposed design uses a mild slope in the step-pool approach channel, which serves to reduce the elevation difference between the working elevation above the trap and the invert of the trap. Flow velocity in the approach channel is designed to cater for the poor swimming ability of small and juvenile fish, possibly only 40 mm-50 mm long. A varied velocity profile with maximum of approximately 0.15 m/s - 0.2 m/s at steps is considered suitable as an initial estimate. The approach channel is to be relatively short, but including resting pools, to minimise stress on small fish.

The step-pool approach channel will provide approximately a 0.5 m rise over its length, with fishway baffles each providing a 0.75 m - 0.1 m water surface rise. A variable-width slot baffle will be used to permit passage at all depths. It may also be required that an extended channel be excavated downstream of the approach channel and a series of rock pools included to assist in guiding fish to the approach channel. The entire environmental flow will be passed through the collection pool and approach channel.

Fish Hopper

A fish transfer hopper with a water volume of approximately 750 L is required. The hopper will be approximately 1.2 m in diameter and 1 m in height with a 250 mm diameter drain port in the base. The collection pool is to be drained through a dewatering screen located below the hopper's upper rim. Water will be held in the hopper during fish transfer by a plug resting on a rubber seal located inside the hopper. The plug will be constructed of stainless steel with a 300 mm diameter spherical base and conical top. The hollow plug will be partially filled with water to make it slightly negative buoyant. The plug would either be opened by manually pulling a cable or by air or electric actuator. An example hopper from Tracy Fish Collection Facility in the USA is shown in Plate 10:7.

Plate 10:7: Example of a Fish Transfer Hopper

- ***(Located at the Tracy Fish Collection Facility)***

Protection of Fish

Screening, submerged cover and grid-decking will be used to separate small fish from larger fish predators and stop fish from jumping out of the system. Screens and grid-decking are also required to prevent bird predation and avoid human interference.

Trap and Haul Operation

The following process will be required for the operation of the trap and haul system:

- The fish attraction phase will consist of the environmental flow discharged through a diffuser at the head of the collection pool. The flow will pass through the trap, trap entrance and approach channel to the defined river channel. The duration of the attraction phase will be dependent on the number of fish moving into the collection pool.

- Prior to a fish transfer, the fish transfer truck will be filled with approximately 1250 L of water and positioned to receive fish and water from the transfer hopper.

- The transfer process starts by closing the environmental flow supply valve, opening the sump drain valve and closing the slide gate at the downstream end of the collection pool, thus isolating the collection pool. The electrical and mechanical system will be arranged such that these three actions are initiated by a single switch.

- During the fish transfer process the environmental flow bypasses the collection pool and is released directly downstream of the slide gate, thus maintaining the attraction flow downstream of the collection pool.

- Water in the collection pool drains out through the hopper screen, leaving fish and approximately 750 L of water in the hopper.

- The operator will use the overhead hoist to lift the hopper and position it over the fish transport truck. The operator then releases the plug in the fish hopper draining the contents into the truck.

- The hopper is then moved back into position in the collection pool and the gates are switched to their prior position, allowing fish collection.

- The truck will be driven to the desired release location and fish are released with 2000 L of water through a valve and chute on the rear of the truck transfer tank.

Occasional, part-time operation will be required to run the system and a remotely operated monitoring capacity may be included to determine the necessary timing. As an initial estimate, this frequency could range from daily to intervals of several days. Timing could be based on video or other monitoring of fish accumulation in the trap. Imaging could also be used to generate a fish-passage data record, especially describing the numbers, approximate biomass, species composition and timing of fish movements. This will be assessed further during the detailed design phase.

Release of Fish into the Reservoir

Upstream-moving fish will need to be released close to the reservoir shoreline in order to continue their upstream movement and to be able to locate sheltering cover and other habitat features within their preferred ranges. Release points will need to be suitably distant (> 100 m) from both the spillway and the intake towers to avoid fish becoming entrained and being returned downstream. Furthermore, to avoid learned predatory behaviour by resident fish in the reservoir, which can have a major impact on survival of transported fish, releases should occur at multiple locations along the shoreline, preferably separated by approximately 50 m or more. It is possible that some river-adapted species may have difficulty coping with habitat conditions in the reservoir and would require transport to the flowing habitats upstream. Monitoring results and other data would be needed to assess this need.

Preferred fish release areas will be defined during the detailed design phase, once site-specific fish survey data is available, but could include the following:

1) An access from the proposed recreation area near the base of the quarry at the left abutment;

2) An access provided from the saddle dam at the right abutment, towards the Stage 2 recreation area;

3) The two proposed boat ramps in the upper reaches of the reservoir. Construction of these ramps is expected to be completed in the early stage of the project; and

4) Other locations where the truck could get access to the reservoir or upstream river.

Should release water temperatures differ from the haul water by more than 2° C the transfer truck will be equipped with a small water pump that can pump reservoir water into the release truck for temperature acclimation.

Removal of Alien Species

Alien species have been recorded in recent fish surveys. The trap and haul system provides the ability to remove these fish from the system if necessary when they make their way into the trap. Platforms will be provided that allow appropriate access to the hopper prior to transferring the fish into the truck. The hopper is sufficiently small such that the operator will be able to physically remove alien species by netting.

10.2.3 Equipment

Pipework

A range of pipework is required for the operation of the system. Cement lined mild steel pipe has been selected for preliminary design; however, this will be further evaluated during detailed design.

It will either be required that the fish are sluiced or piped to the reservoir from the transport truck. The internal surfaces of the pipe or sluice will be smooth to eliminate abrasion injury to fish.

Gates and Valves

A variety of small gates and valves will be required for the trap and haul system. These will typically be electrically actuated and operated in fully-open or fully-closed positions and will not be required to regulate the flow. All flow will be regulated from the existing pump station. All of the valves, gates and actuation systems are relatively small and are standard items of equipment.

Hoisting Equipment

A hoist is required to lift the hopper from the normal operating position across to where the truck will be situated. The winch will be a variable speed drive to allow speed reduction and to increase hopper positioning accuracy. Various position detection and control devices including slack rope detection and rope over tension will be included to ensure safe operation of the system.

Automation and Electrical Equipment

All components of the trap and haul system will be operated from the site. It is intended that the entire fish transfer process can be conducted by a single operator and the electrical and mechanical components of the system will be arranged to simplify the transfer process. The gates and valves to isolate the collection pool will be arranged such that their operation is initiated by a single switch. The hoist will be designed to allow operation by one person.

10.2.4 Constructability

The entire trap and haul system is separate from the dam raising works, therefore the timing for construction is not impacted by dam construction. It is intended that the trap and haul system be constructed and commissioned prior to completion of the dam works. It is likely that the construction will be completed a minimum of 12 months prior to completion of the dam and possibly up to 24 months. This will allow sufficient time for commissioning, testing and fine tuning of the system prior to the end of the construction period.

10.2.5 Performance

Performance of the fish trap can be monitored by a number of methods. Common methods include establishing a manual sampling program or using infrared light curtains, video systems or hydroacoustic based counters. Light curtains and video can provide count and size information. Species recognition is also possible for fish of different body forms. A combination of automated counting and occasional sampling can be implemented to supplement fish count data with species and size information. Automated counting methods are expected to work well at the trap entrance due to the generally good water clarity and low debris load of the environmental flow release. Automated systems would allow remote monitoring of fish movement into the trap.

10.2.6 Operational Monitoring

Environmental flow discharge and the water surface elevation in the collection pool will be monitored electronically to ensure flow conditions in the pool and attraction channel meet with desired operating conditions. A deviation of these measured parameters outside established operating ranges will trigger an alarm notifying operators. System parameters can be monitored remotely.

10.3 Spillway Design

10.3.1 General

The planned Stage 3 Upgrade for the spillway has an overall hydraulic height of approximate 60 m and comprises the following components:

- Two-level ogee crest, the low-level crest is 12.25 m wide and has a hydraulic height of 34 m, the high level crest width is 58.25 m and has a hydraulic height of 39.5 m. The low level crest passes flow when the reservoir storage exceeds full supply level (FSL), and the high level crest passes flow only in large floods at approximately 1 in 100 AEP (Appendix 4A Design Flood Hydrology);

- A concrete lined stilling basin with submerged training walls, this pool can be drained through the system discussed in Section 10.4; and
- A concrete chute that is approximately 150m in length and includes an upstream ogee crest (the control structure) downstream flip bucket, and a drop downstream of the flip bucket (approximately 16m).

The arrangement of the existing spillway is shown in Plate 10:8.

There is the potential for downstream fish movement in spilling flows that indicates the need for the spillway design to minimise injuries to fish, which could otherwise be considerable given the high-level energy dissipation, turbulence and pressure fluctuations involved in spilling flows. There are recent reports of fish-kills among the stocked bass following their movement over the spillway in high flows, with injuries and stranding being the likely causes, but substantial numbers of fish are reported to survive spills. Careful design is needed to minimise damaging hydraulic conditions of spilling flows, especially high-velocity flows and plunging flows impacting directly onto solid substrates rather than into tailwater pools. Arrangements are also needed to progressively drain tailwater pools after spills so that remaining fish are encouraged to move to downstream habitats.

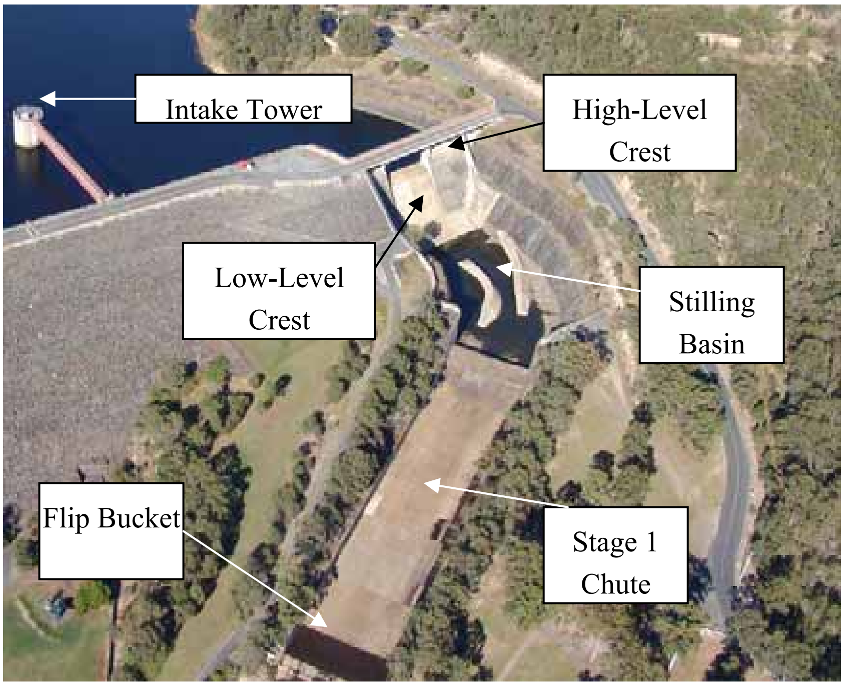

Plate 10:8: Stage 2 Spillway Arrangment and Structure Locations

10.3.2 Fish Movement

As discussed previously, reservoir spills are expected to be infrequent. Hydrologic model simulations of the Stage 3 reservoir predict periods of 5 to 20 or more years between spills are likely. Australian bass are likely to move during spills in autumn and winter and mullet, if present in the reservoir, may show similar timing. Eel movements are less predictable and likely to occur in any season. The level of fish survival passing down the existing spillway is not documented. The flow velocity at the tailwater below the Stage 3 spillway will average approximately 5 to 10 m/s for flood events up to the 1 in 500 AEP. A study conducted by Bell (1991) on largely juvenile salmonids predicts a fish kill of approximately 5 to 10 percent during passage for velocities of this magnitude.

Fish passing over the Stage 3 spillway and stepped chute will either hold in the stilling basin pool or pass downstream in the control chute. Fish currently passing downstream during spills over the existing spillway are carried over the flip at the end of the chute in a free jet that impinges in the downstream river channel which is excavated in bedrock. From preliminary analysis it appears there is currently minimal tailwater, especially during small events. Flow velocity at the spillway flip will range from approximately 10 m/s to 15 m/s for most spills (up to 1 in 500 AEP), and exceed 20 m/s for extreme events. Except for small spills, these velocities can be assumed to be approximately equal to the downstream impingement velocity. Impingement velocities are in the range where some fish mortality would be expected even if sufficient tailwater pool is present; however, significant fish mortality would be expected when the tailwater is shallow and the spillway jet impinges largely on the channel bed, as occurs with the current arrangement. Section 10.2.2 describes how improvements will be made to increase the tailwater depth to reduce mortalities.

10.3.3 Main Spillway Hydraulics

The following section describes the modifications that have been made to the Stage 3 design to improve fish passage during spill events.

Successful downstream passage of fish over spillways generally includes the following criteria:

- Sufficient approach velocity for the fish to be attracted to the spillway and pass over the spillway crest;
- Minimisation of shear and strain forces that could injure fish through abrasion on the spillway chute surface; and
- Minimisation of impact force on rough surfaces and at tailwater pools.

Approach Velocity

The approach velocity to the Stage 3 spillway and velocity on the spillway crest for low discharges (less than 50 m^3/s) have not been hydraulically modelled to date; however, future Computational Fluid Dynamics (CFD) modelling is proposed during detailed design in order to estimate these velocities. For the purposes of this report, approach velocities (nominally 10 m upstream of the crest) for discharges less than 50 m^3/s over the Stage 2 and Stage 3 spillways will likely be in the range of 0.3 to 1 m/s. The velocities and discharges over the Stage 2 and Stage 3 spillway crests were also estimated for the same flow depths since the Stage 3 spillway low-level crest width of 12.25 m is half of the Stage 2 low-level width of 24.5 m, resulting in lower discharges for the same depth, as shown in Table 10:1. Large (300 mm or greater) bass and eels will likely be the dominant size-class of fish that will attempt downstream passage; however, it is possible that a low number of smaller species and immature fish could become entrained in the approach flow and be carried over the crest.

Table 10.1: Spillway Approach and Crest Velocity for Low Discharges

Flow Depth over crest (mm)	Approach Velocity (m/s)	Stage 2		Stage 3	
		Velocity over Crest (m/s)	Discharge (m^3/s)	Velocity over Crest (m/s)	Discharge (m^3/s)
100	0.3 to 1.0	0.99	2.4	0.99	1.2
250		1.57	9.6	1.57	4.8
500		2.21	27.1	2.21	13.6
1,000		3.13	76.7	3.13	38.4

Crest velocities and discharges are assumed to be at critical depth.

Stepped Spillway Chute Hydraulics

The proposed Stage 3 spillway chute consists of a stepped concrete face (1.5 m high steps) at an overall slope of 0.8 H:1 V. Flow over a stepped spillway may occur as one of three distinct flow regimes depending of the depth and unit discharge of flow: plunging (nappe) flow, skimming flow, and fully rough turbulent flow.

For low unit discharges, the flow plunges (cascades) from one step to another. A hydraulic jump forms on the surface of each step, with a small area of low velocity, recirculating water near the back of the step. This type of flow is called *plunging flow*. It is estimated that plunging flow would occur for the Stage 3 chute for depths over the spillway crest up to 100 mm. As the unit discharge increases (depths ranging from 100 mm to 730 mm above the crest), the flow type is in *transition* (plunging-skimming) from plunging flow to a condition called skimming flow. *Skimming flow* and *fully rough turbulent flow* are characterised by higher velocity water (depths over the crest that exceed 730 mm) that "skims" over the edge of the spillway steps, providing a larger area of slow moving, recirculating water behind.

Additional analyses of the spill data presented in Appendix 10B were performed using only the simulated days that spills would occur in order to estimate the probabilities that the spilling flood waters would be in plunging flow and skimming flow. Figure 10.1 and Table 10.2 show that for the simulated spill events, plunging flow (up to 100 mm over the crest, or 1.3 m^3/s) would occur approximately 55% of the time. A flow of 1.3 m^3/s is approximately 1% of the 1 in 2 AEP flood event.

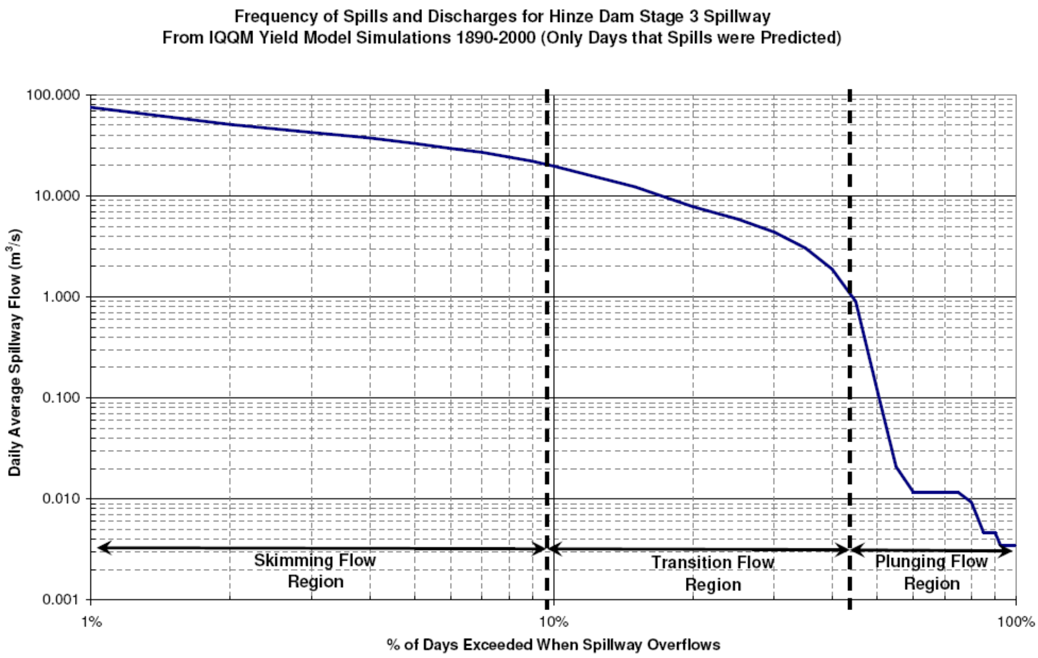

Figure 10.1: Frequency of Flow Regions on Stage 3 Stepped Spillway

Fish Passage over Stepped Spillway Chute

There is currently little research on the physical effects of fish traversing down stepped spillways. Most research has focused on the effects of fish injury and mortality in the skimming flow and fully turbulent flow regions, which indicate that fish generally stay in the skimming jet. To date, no research has been found that studied fish mortality in the plunging flow region. Therefore, it is unknown if impact problems can arise when fish pass downstream over a series of low drops containing shallow tailwater, as will be the case for more than half of the simulated spill events, as discussed in the previous paragraphs. The operation of stepped spillways in North American has not resulted in reports of notable fish kills. The ability of Australian species to cope with this method is unknown, but seems unlikely to be markedly different.

The available data for fish on spillway chutes indicate that excessive impact, shear and strain forces can cause loss of scales, fin damage or other physical injuries to vulnerable fish, generally as a result of the following:

- Abrasion due to high chute velocities over rough surfaces with shallow depths, causing the fish to either slide along the chute surface (such as a smooth spillway chute), or slide against protruding objects. Loss of scales can lead to infections through the unprotected area, possibly resulting in fish mortality.

- Impact forces from large drops into shallow water. A stepped spillway provides a controlled rate of energy dissipation as flow passes from step to step down the spillway; however, during spilling, fish may impact the steps at low flows, until streaming flow conditions are reached. The question of what flow conditions will cause fish to impact the steps of a stepped spillway and whether they are injured cannot be answered at this time with any degree of certainty.

- High velocity impact into the downstream tailwater (stilling basin).

Due to a lack of available research on effects of fish passage over stepped spillways in the plunging flow region, physical hydraulic model results from previous studies were scaled to the Hinze spillway and step size and additional calculations were performed (refer to Appendix 10B) to estimate the hydraulic conditions on each step. Qualitative assessments were also made for the potential of successful fish passage based on these observations and calculations. The calculations, as summarised in Table 10.2, show that for plunging flow over the 1.5 m high steps:

- The velocities will generally be less than 0.7 m/s; and

- There will be a shallow flow depth on each step as a result of the small hydraulic jump on each step face which will be slightly greater than the depth over the spillway crest.

Based on these results, it is likely that the smaller and immature fish would have sufficient water depth on each step in order to change direction and prevent impact on the concrete step. Young fish in this size range typically have the ability to change direction in a short distance, and should therefore be successful in traversing the stepped chute. Additionally, a contributing paper on dams and fish migration for the World Commission on Dams (Larinier, 2000), stated that the passage of fish through a free-fall condition is less hazardous for small fish because their terminal velocity is less than the critical velocity. In other words, the free-falling fish do not have time to reach a critical velocity on each step that would result in injury or mortality but could be achieved on a smooth spillway where the velocity would continue to increase down the spillway face. The larger bass and other fish (exceeding 300 mm in size) would likely not go over the spillway at these low flows because the depth over the spillway would be less than 100 mm.

As a means of comparing the potential for fish passage success for the stepped spillway, estimates of the flow hydraulics for the Stage 2 smooth spillway were also calculated, as shown in Table 10.3. The Stage 2 spillway hydraulics for discharges up to 22 m^3/s show that the flow depths down the chute would be less than 100 mm and the velocities in the chute would range from 6 m/s to 13 m/s.

Extensive experience with these issues has allowed criteria for avoiding shear damage to be developed. Strain rates of less than 500 cm/sec/cm (equivalent to jet velocity of 9 m/s) have proved safe for American shad (U.S. Department of Energy, 2000), a species closely related to the bony herring that live in the Nerang River. This species is known to be particularly vulnerable to handling and physical damage, and can be considered to be a conservative estimate of safe levels of shear for other fish.

Studies of fish passage over spillways collected by Bell and Delacey (1972) indicate a general velocity threshold for onset of injury and mortality of about 12 m/s to 16 m/s. Although flow on steep surfaces containing large scale surface roughnesses displays highly turbulent flow conditions, some studies indicate that a gradual dissipation of energy along the slope may be advantageous to safe fish passage. In simple terms, this can be compared to distributed "load" (such as distributed energy dissipation similar to a rough river channel) which is more favourable than a point "load" (such as intense energy dissipation similar to a waterfall). Bell and DeLacy cite the Sunset Falls Experiments as one example. Sunset falls is a steep rock chute falls 27 m high. In 1954, two experiments were conducted with young salmon released above the falls. Although direct injury and mortality were not assessed, adult returns from above the falls were higher than nearby rivers similarly stocked without falls. In another study on downstream migrant salmon smolts at the University of Washington, Bell concluded, "If the general problem of spillway design were approached from the point of view of reducing the rate of dissipation of energy in the tailpool it is likely designs could be developed that would improve the passage of fish."

Table 10.2: Spillway Chute Velocity at Toe of Dam for Select Flow Depths

Flow Depth over crest (m)	Stage 2			Stage 3				
	Velocity (m/s)	Flow Depth (m)	Discharge (m^3/s)	Plunging flow Velocity (m/s)	Plunging Flow Depth on step (m)	Skimming flow Velocity (m/s)	Skimming Flow Depth (m)	Discharge (m^3/s)
0.1	6.0	0.02	2.4	0.7	0.05	-	-	1.3
0.25	10.4	0.04	9.6	0.7 – 1.0[2]	0.15[2]	5 – 7[2]	~ 0.1[2]	4.8
0.5	15.8	0.07	27	0.7 – 1.0[2]	0.35[2]	5 – 7[2]	~0.1[2]	13.6
1.0	24.0	0.13	77	-	-	13.4	0.23	38.4
Varies (PMF)	24.0+[1]	~4m[1]	3,900	-	-	22.4	4.0m	3,900

1. Estimated from Draft CFD model results from WorleyParsons (2007)
2. Estimates for Transition flow region from interpolation between plunging flow physical model data and skimming flow data

In summary, based on the calculations above, the proposed stepped spillway chute should be more successful at providing downstream fish passage to the stilling basin pool than a smooth spillway for the following reasons:

- The potential for abrasion of the fish and removal of scales from sliding against the concrete chute during low discharges should be lower for Stage 3 because of significantly lower flow velocities over each step, and intermittent contact with the surface. Whereas, fish would likely have more or less constant contact with the concrete surface for smooth spillway faces.

- The entry velocity (impact) into the downstream stilling basin for a stepped spillway chute will be significantly less than for a smooth spillway. The potential for such injuries to fish would likely begin for discharges above 50 m^3/s for a stepped spillway, compared to only 30 m^3/s for a smooth spillway, based on a velocity threshold ranging from 12 m/s to 16 m/s. This conclusion is critical to overall downstream fish passage success over the stepped spillway because for more than 90% of the time that the spillway is flowing the discharges will be less than 50 m^3/s.

Stilling Basin Tailwater Levels

Tailwater elevations in the spillway stilling basin, as shown in Figure 10.2, were estimated by assuming a 1 m raise to the Stage 1 control structure, as discussed in more detail in Section 4. The 1 m raise to ogee crest would prevent the sweep out of the PMF hydraulic jump.

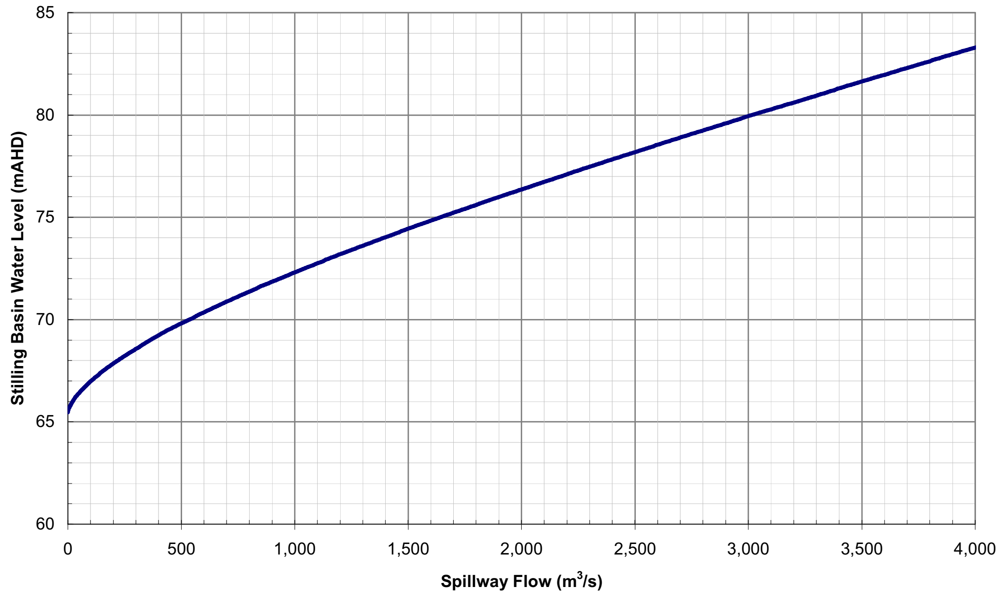

Figure 10.2: Stilling Basin Tailwater Rating Curve (1m crest raise)

10.4 Removal of Fish Following Spill Events

10.4.1 Stilling Basin

Stage 2 Arrangement

Following a spill event, the stilling basin (between the spillway and downstream chute) currently drains through a 380 mm diameter pipe located in the left spillway abutment. The pipe passes around the Stage 1 ogee crest and discharges into the spillway chute as shown in Plate 10:9; however, a pool of water remains in the stilling basin area that appears to be approximately 1 m to 2 m deep in sections. The present pool is maintained between spills by seepage, but probably experiences periods of poor water quality. Currently, the existing drain pipe probably provides little if any downstream fish passage. Fish that can avoid being entrained in the drainage flow would likely remain in the upstream pool. Fish passing through the drain following the cessation of spillway flow would encounter 145 m of thin flow along the concrete chute. Following previous spill events manual salvage of the fish within the stilling basin has been required. Although effective, extremely poor access to the pool makes manual salvage difficult and a potential safety concern.

Plate 10:9: Existing Drainage Arrangement for the Stilling Basin

Stage 3 Design

The stilling basin is to be concrete lined as part of the Stage 3 upgrade. The lining will be graded towards the existing pipe that drains the basin. Fish will likely avoid travelling through the pipe until the pool level in the stilling basin is low. Under these conditions once the water discharges into the spillway chute there will be only thin flow that would likely leave the fish stranded within the chute. For this reason a system has been proposed to remove the fish from the stilling basin.

System to Remove Fish From Stilling Basin

In order to effectively remove fish from the stilling basin, a system has been developed that traps the fish in a hopper such that they can be transported to the downstream river channel. The system utilises the existing pipe that drains the stilling basin. Other possible systems to remove fish from the stilling basin will be investigated during the detailed design phase. The following provides an explanation of the components and operation of the proposed system.

Description of Fish Removal System

The existing drainage pipe for the stilling basin is to be extended along the inside of the spillway chute until the 300 mm section of chute walls is reached. The pipe will then be extended through the wall to the outer side of the chute. The upstream end of the pipe will be fitted with a mechanically operated grate that can be raised when required. The pipe discharges into a concrete tank with a screened outlet that in turn discharges the excess water back into the spillway chute. This is required to appropriately deal with the head that is within the system while minimising the impact on fish. The fish will then be trapped within the tank where they can be drained into an adjacent hopper. This hopper can either be removable such that it can be transported downstream to release the fish, or the hopper can be such that the fish are transferred into the same truck that is used for upstream fish passage. A permanent crane has been provided to lift the hopper from the system to the truck.

Operational Requirements

The system will only be operated following spill events. During the spill events the valve within the existing discharge pipe will be closed so that the pool in the stilling basin remains following the cessation of flow. The system can then be operated as required to remove the fish from the pool. It is likely that the mechanically operated grate will initially remain closed while some of the water is removed from the pool. This will reduce the possibility of fish being injured by reducing the head within the system.

Once the grate is opened, fish will be drained into the concrete tank. This will need to be monitored to ensure that there are not too many fish drained into the tank at once. When required, the valve in the existing drainage pipe can be closed and the fish then drained into the hopper that is adjacent to the tank. The fish will then be driven to an appropriate location downstream where they can be released. The system provides good flexibility in that it can be operated as often as required to remove all of the fish from the pool depending upon the numbers of fish that are trapped.

10.4.2 Control Chute Plunge Pool

Currently, the plunge pool area downstream of the spillway flip is isolated from the downstream environmental flow release creating a pool that is sustained by spillway seepage as shown in Plate 10:10. Following previous spill events, fish have been stranded in this pool and it was required that they be manually removed. As part of the Stage 3 Upgrade a small thalweg channel will be excavated from this pool such that it can drain into the river downstream.

Plate 10:10: Existing Plunge Pool Below the Downstream Spillway Chute

10.5 References

Bell, Milo, "Fisheries Handbook of engineering Requirements and Biological Criteria", US Army Corps of Engineers, 1991.

United States Department of Energy, "Laboratory studies on the Effects of Shear on Fish", DOE/ID-10822, 2000.

Allen G.R., Midgley, S.H. and Allen M. (2002) Freshwater Fishes of Australia. Western Australia Museum.

Harris, J.H. (1988). Demography of Australian bass, Macquaria novemaculeata (Perciformes, Percichthyidae) in the Sydney Basin. Aust. J. Mar. Freshw. Res. 39, 355-69.

Harris J.H and Gehrke P.C. (eds) (1997). Fish and Rivers in Stress: The NSW Rivers Survey. (NSW Fisheries Office of Conservation and the Cooperative Research Centre for Freshwater Ecology, Cronulla New South Wales.) 298pp.

Larinier, Michel (2000). Contributing Paper to World Commission on Dams, Dams and Fish Migration.

McDowall R.M. (1996). Freshwater Fishes of South-eastern Australia. Reed, Sydney.

Healthy Rivers Program (2005). Annual Report. Queensland.

Personal Communication on Downstream Fish Passage Over Stepped Spillways, Brent Mefford, Water Resources Research Laboratory, U.S. Bureau of Reclamation, Denver, Colorado, USA.

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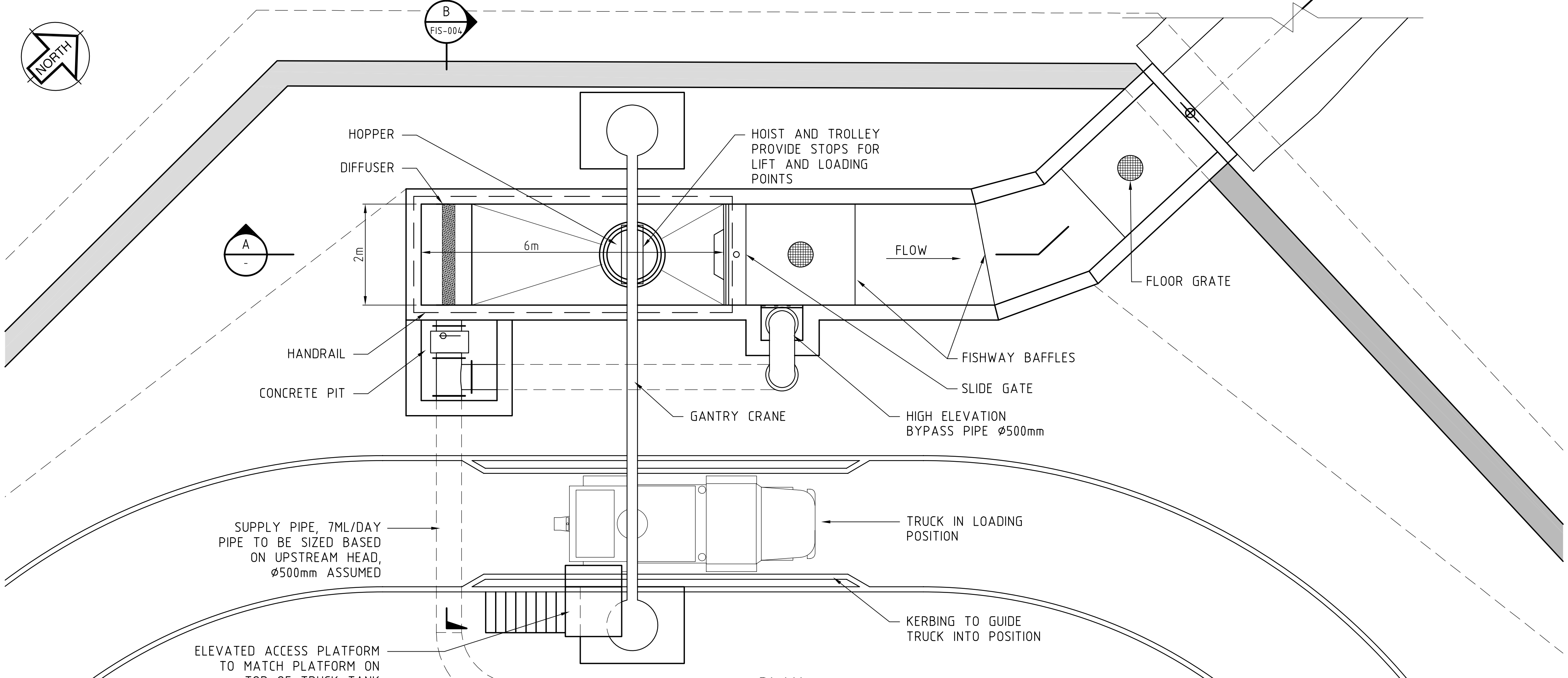
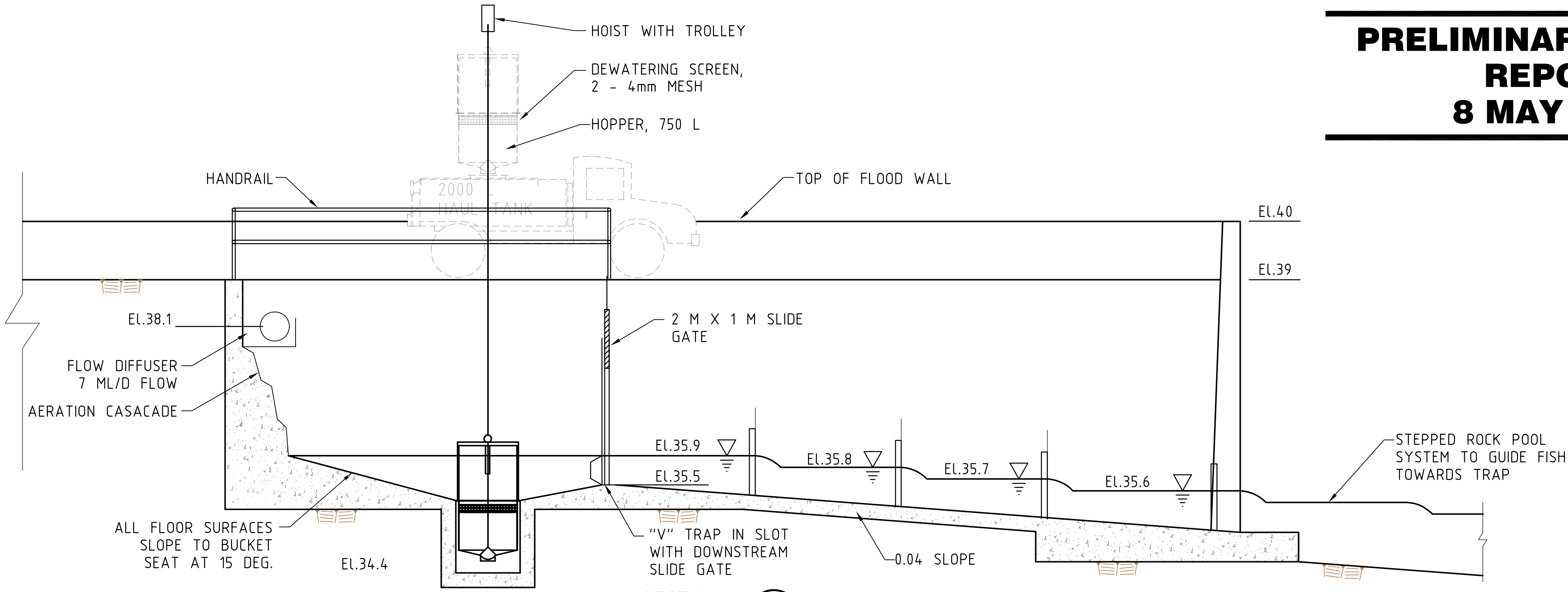


PLAN
FISHWAY - TRAP & TRUCK SYSTEM

PRELIMINARY DESIGN REPORT
8 MAY 2007



SECTION A
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SCALE 1:50 (A1)

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Rev | By | Appd | Date | REVISION RECORD

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Drawn: SCB
Checked:
Approved:
Scales: AS SHOWN

Client: Gold Coast City Council

Project Title: HINZE DAM STAGE 3

Drawing Title: FISH TRAP & TRUCK SYSTEM PLAN & SECTION

CAD File Number: U-FIS-003-A.DWG
Job Number: 42626000

Status: PRELIMINARY
Datum: GDA94 ZONE 56 AHD
Date: 12/02/07
Drawing Number: FIS-003
Rev: A

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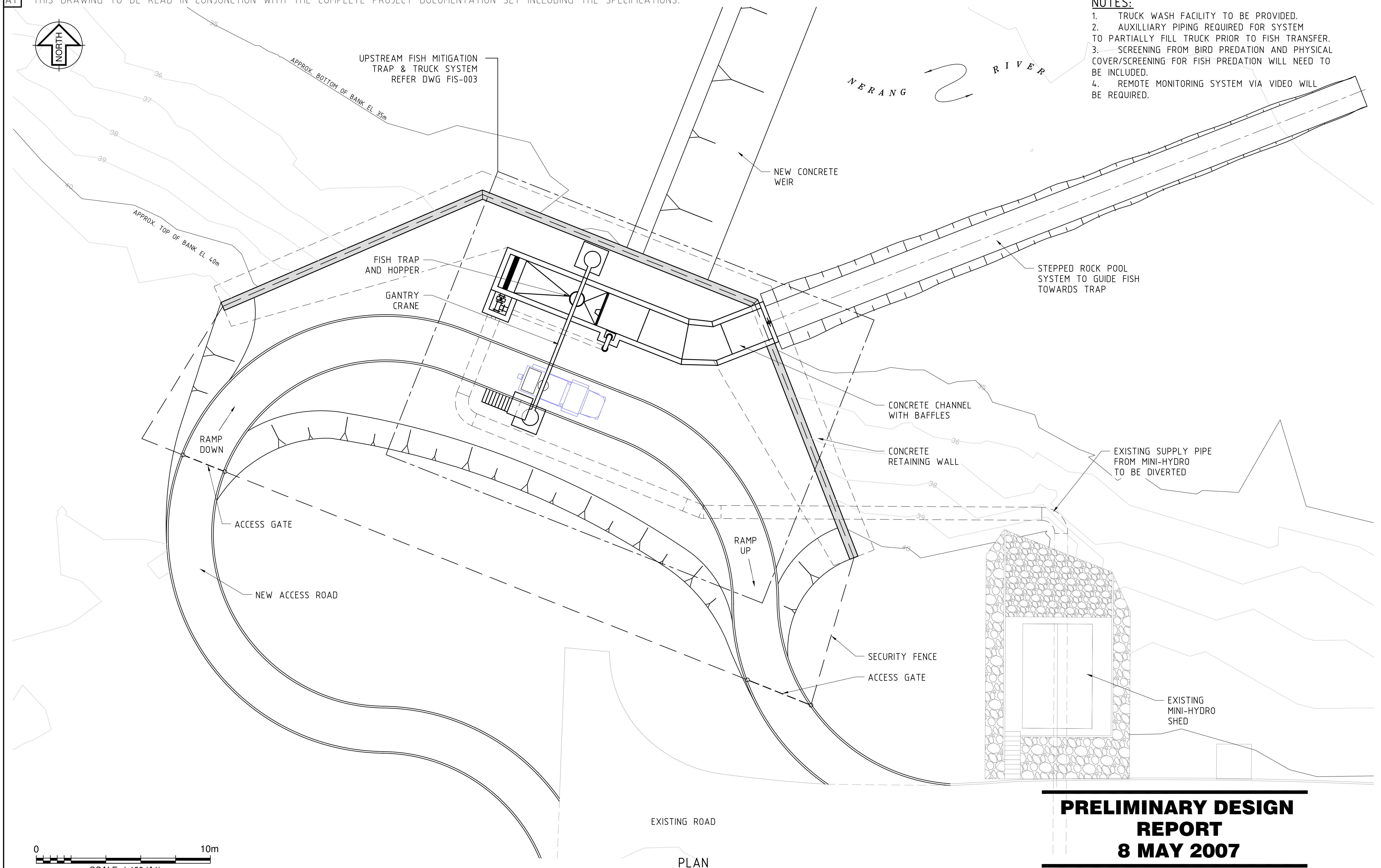
NOTES:

1. TRUCK WASH FACILITY TO BE PROVIDED.
2. AUXILLIARY PIPING REQUIRED FOR SYSTEM TO PARTIALLY FILL TRUCK PRIOR TO FISH TRANSFER.
3. SCREENING FROM BIRD PREDATION AND PHYSICAL COVER/SCREENING FOR FISH PREDATION WILL NEED TO BE INCLUDED.
4. REMOTE MONITORING SYSTEM VIA VIDEO WILL BE REQUIRED.



PRELIMINARY DESIGN REPORT
8 MAY 2007

PLAN

FISHWAY - TRAP & TRUCK SYSTEM

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Client: Gold Coast City Council

Project Title: HINZE DAM STAGE 3

Drawing Title: FISH TRAP & TRUCK SYSTEM GENERAL ARRANGEMENT

Status: PRELIMINARY

Datum: GDA94 ZONE 56 AHD

Date: 12/02/07

CAD File Number: U-FIS-002-A.DWG

Job Number: 42626000

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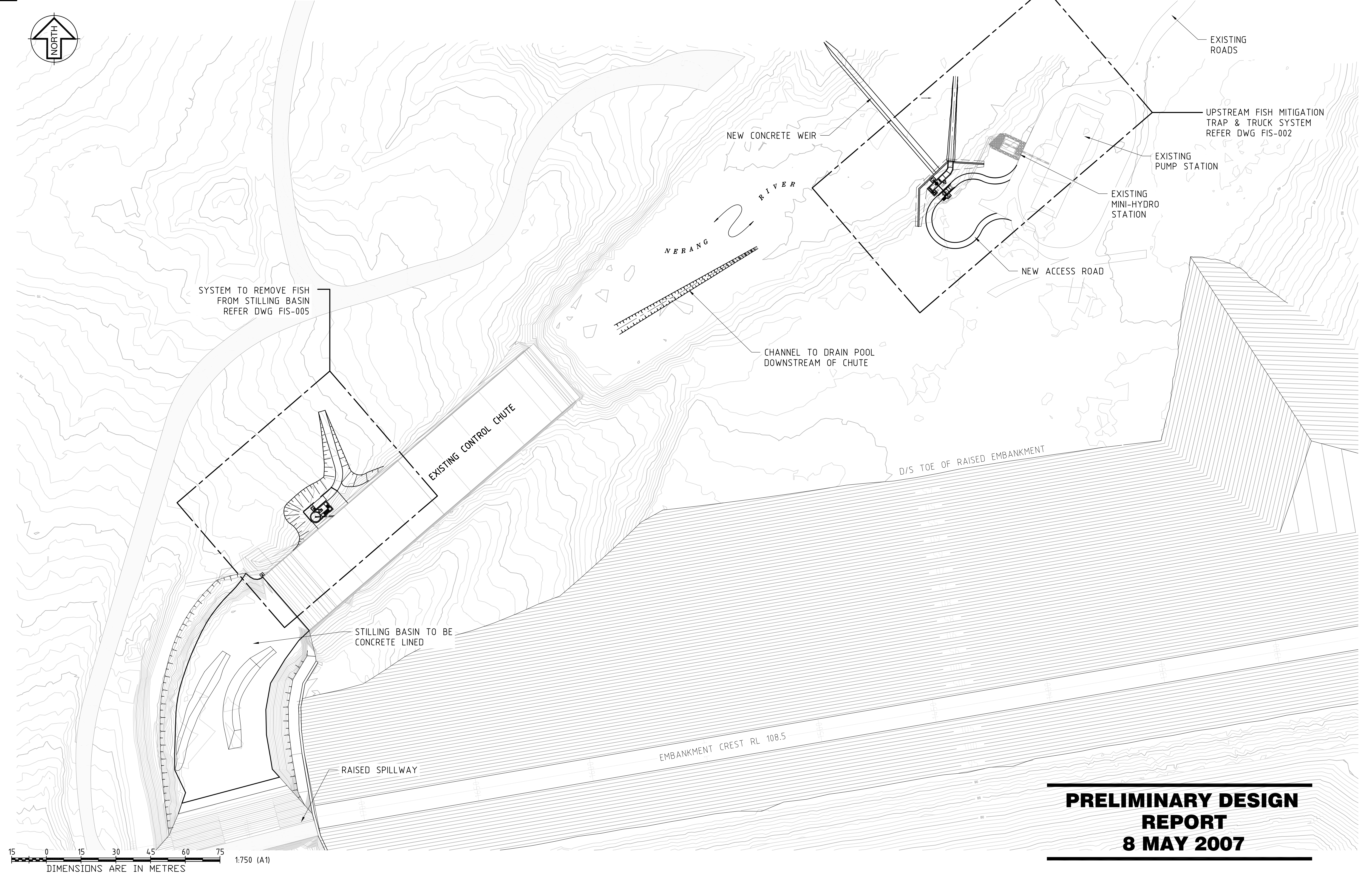

PRELIMINARY DESIGN REPORT
8 MAY 2007

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Scales: AS SHOWN

Client: Gold Coast City Council

Project Title: HINZE DAM STAGE 3

Drawing Title: FISH WAY GENERAL ARRANGEMENT

Status: PRELIMINARY
Datum: GDA94 ZONE 56 AHD
Date: 12/02/07

CAD File Number: U-FIS-001-A.DWG
Job Number: 42626000
Drawing Number: FIS-001
Rev: A

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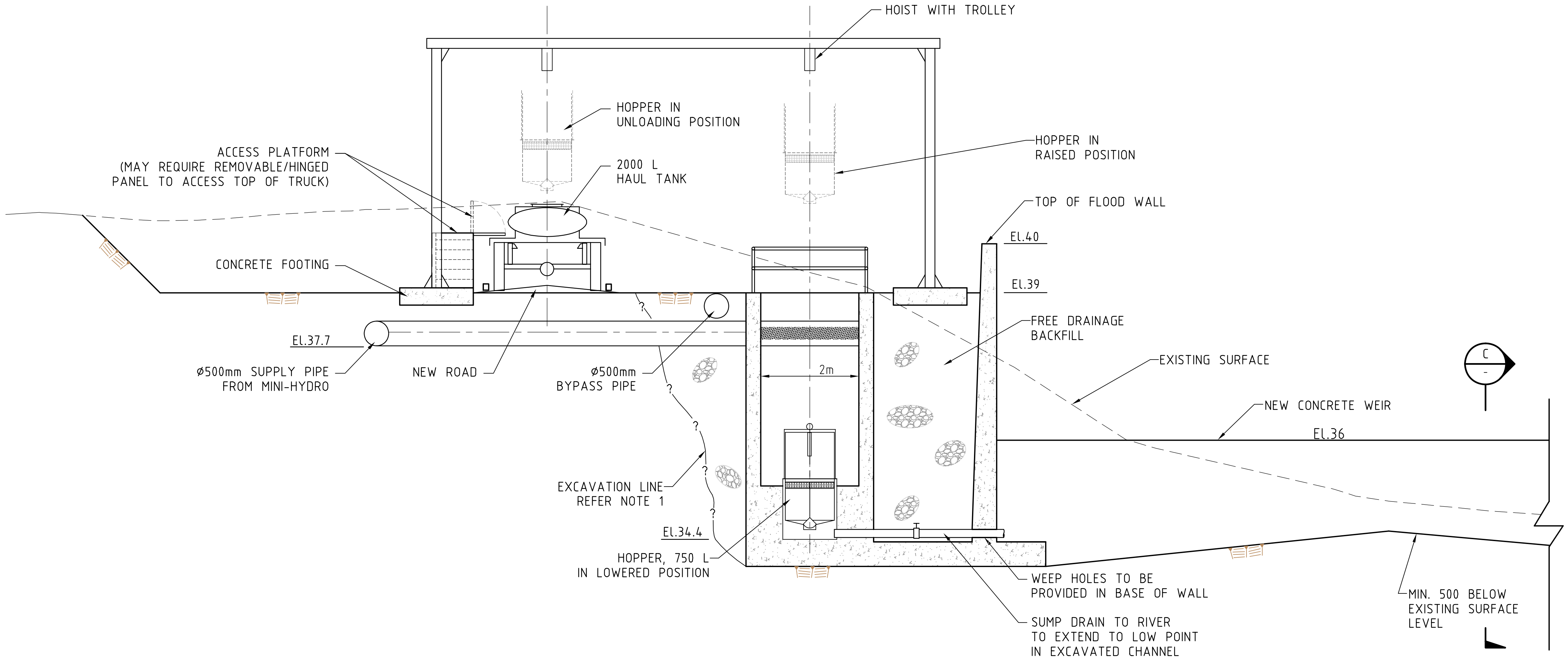

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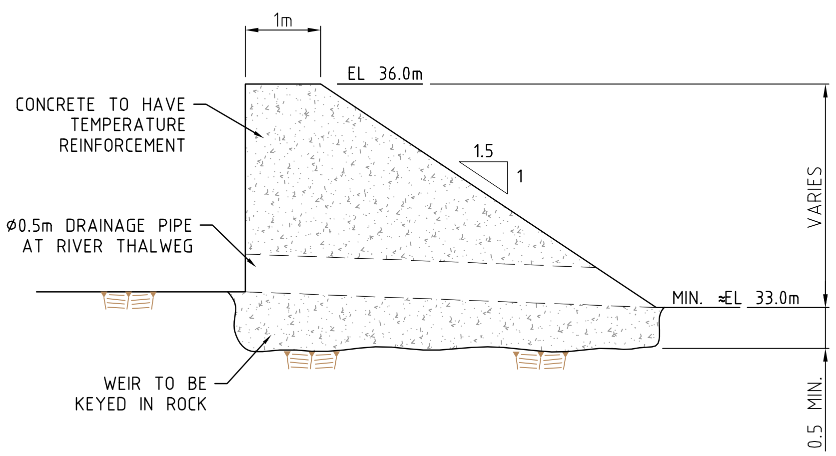

SECTION C
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PRELIMINARY DESIGN REPORT
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Scales	AS SHOWN

Client: Gold Coast City Council

Project Title: HINZE DAM STAGE 3

Drawing Title: FISH TRAP & TRUCK SYSTEM SECTIONS & DETAILS

CAD File Number: U-FIS-004-A.DWG

Job Number: 42626000

Status: PRELIMINARY

Datum: GDA94 ZONE 56 AHD

Date: 12/02/07

Drawing Number: FIS-004

Rev: A

Hinze Dam Stage 3 Upgrade

Preliminary Design Report

APPENDIX 10A:

ASSESSMENT OF EXISTING SYSTEM & FISH PASSAGE REQUIREMENTS

- **May 2007**

Contents

10A.1 The Existing Environment

10A.1.1 Overview of System

The major streams of the Nerang catchment are the Nerang River, Little Nerang River and Mudgeeraba Creek. The catchment area covers a total of 495 km^2 and is described further in Table 10A.1.

Table 10A.1: Nerang Catchment Subareas

Subcatchment	Area (km^2)
Nerang River (below Hinze Dam)	173.0
Nerang River (above Hinze Dam)	207.0
Little Nerang	40.8
Mudgeeraba	74.1

The headwaters for the Nerang catchment streams are in the McPherson ranges, which have forested, close to natural conditions. The Nerang and Little Nerang Rivers flow north easterly, through predominantly agricultural land, before converging at Hinze Dam. Downstream of the dam the river continues north east through foothills and the township of Nerang before heading east across floodplains towards the coast. Mudgeeraba Creek joins the Nerang River a few kilometres upstream of the Southport Broadwater, where the river enters the ocean.

Approximately two thirds of the Nerang subcatchment is rural, comprising National Parks, conservation areas and rural residential lots. The remainder of the catchment is urban, comprising industrial, commercial and medium to high density residential areas.

Hinze Dam is situated on the Nerang River at AMTD 36.4 km. It was completed in 1976 and upgraded to Stage 2 in 1989. The dam has had a significant impact on the flow regime of the Nerang River, as can be seen in Figure 10A.1. The dam captures the majority of the medium to high flows, spilling once every 4 years, on average.

A relatively constant low flow release is made from the dam which is intended as both a compensation release to downstream users as well as an environmental release. The low flow release maintains the river at a rate of 7.25 ML/d for approximately 90% of the time, whereas the natural river flow would have been above 7.25 ML/d for over 90% of the time.

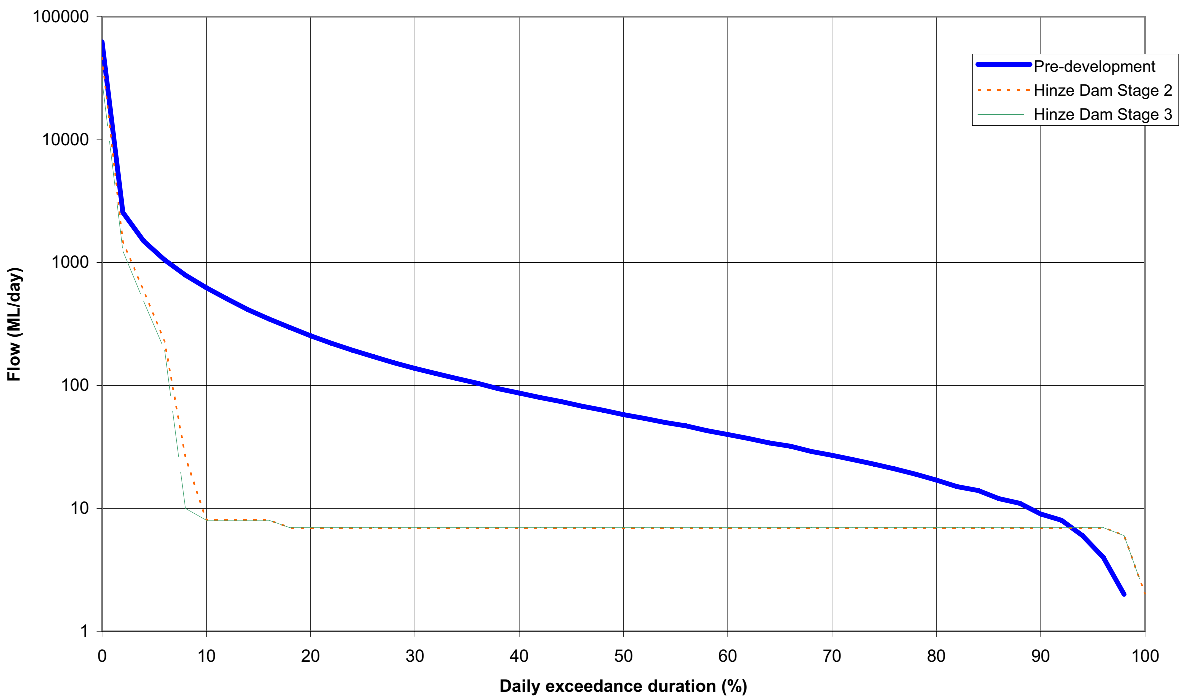

Figure 10A.1: Daily Flow Duration Curves Downstream of Hinze Dam

These changes to the flow regime of the river have caused significant environmental impacts. The Technical Advisory Panel to the Moreton and Gold Coast WRPs has rated the middle reaches of the Nerang Rivers as moderately to highly disturbed and the lower reaches, including the Broadwater, as highly disturbed. The headwaters of the Nerang and Little Nerang Rivers remain as having natural or near-natural conditions, with very high ecological values.

10A.1.2 Fish Species

Minimal quantitative data is available on either the natural or the current distribution and abundance of the Nerang River's fish community. River-health monitoring (*Healthy Rivers Program* 2005) has indicated the recent occurrence of fish at some sites and this knowledge is supplemented by unpublished sampling data provided by Dr Mark Kennard of Griffith University plus fish-stocking records provided by Queensland Department of Primary Industries and Fisheries. Nevertheless, it is possible to predict the likely patterns from data on other south-eastern Australian systems (e.g. Harris 1988; McDowall 1996; Harris and Gehrke 1997).

At the Hinze Dam site, passage to over half of the river system is obstructed and there is substantial, good-quality riverine habitat upstream, in addition to the impounded artificial habitats of the storage. The South-east Queensland coastal region's natural fish community is diverse and dominated by species that depend on free passage to sustain their populations. Up to 45 native fish species may have lived in the Nerang River, either within their natural range of distribution or following introduction from other Australian river systems. Four kinds of fish movement patterns need to be catered for in the Nerang River:

- Catadromous - obligatory migrations between the riverine and marine habitats, such as occurs with mullets, Australian bass or the two eels;
- Potamodromous - migrations between the various freshwater riverine habitats, such as occurs with bony herring, Australian smelt or fire-tailed gudgeons;
- Amphidromous - migrations between marine and freshwater habitats that are not for the purpose of breeding; and
- Other, less-predictable dispersal movements driven by factors related to habitat fluctuations and population-density changes. These migrations may extend well upstream of the estuary, as with bass, jungle perch and eels, or may predominantly occur in lowland reaches, as with mullets and bony herring.

Thus the location of the Hinze Dam near the upper limits of the lowland zone of the river interferes with the migrations and life-cycle of fewer species than a barrier further down the system would do.

The storage currently has recreational-fishery value based mainly on stocking with artificially propagated Australian bass, one of the river's catadromous species. Fisheries values are likely to be boosted with a fishway. Several other species have also been stocked in the reservoir (Table 10A.2).

Table 10A.2: Historical and Current Character of the Nerang River Fish Community*

Common name	Species name	Migration[1]	Occurrence[2]	Body size[3]
Australian bass	Macquaria novemaculeata	Catadromous	Confirmed	Large
Australian smelt	Retropinna semoni	Potamodromous	Confirmed	Small
Barred grunter	Amniataba percoides	Uncertain	Stocked	medium
Bullrout	Notesthes robusta	Catadromous	Confirmed	Medium
Common jollytail	Galaxias maculatus	Catadromous	Predicted	Small
Cox's gudgeon	Gobiomorphus coxii	Potamodromous	Confirmed	Small
Duboulay's rainbowfish	Melanotaenia duboulayi	Uncertain	Confirmed	Small
Dwarf flatheaded gudgeon	Philypnodon species1	Uncertain	Confirmed	Small
Eastern gambusia[4]	Gambusia holbrooki	Uncertain	Confirmed	Small
Eel-tailed catfish	Tandanus tandanus	Uncertain	Confirmed	Large
Empire gudgeon	Hypseleotris compressa	Uncertain	Confirmed	Small
Firetailed gudgeon	Hypseleotris galii	Potamodromous	Confirmed	Small
Flatheaded gudgeon	Philypnodon grandiceps	Uncertain	Confirmed	Small
Flyspecked hardyhead	Craterocephalus stercusmuscarum	Uncertain	Confirmed	Small
Forktailed catfish	Arius graeffei	Potamodromous	Predicted	Large
Freshwater herring	Potamalosa richmondii	Catadromous	Predicted	Medium
Freshwater mullet	Myxus petardi	Catadromous	Predicted	Large
Golden perch	Macquaria ambigua	Potamodromous	Stocked	Large
Jungle perch	Kuhlia rupestris	Catadromous	Predicted	Large
Longfinned eel	Anguilla reinhardtii	Catadromous	Confirmed	Large
Marjorie's hardyhead	Craterocephalus marjoriae	Uncertain	Confirmed	Small
Mary River cod	Maccullochella mariae	Uncertain	Stocked	Large
Midgley's carp gudgeon	Hypseleotris midgleyi	Uncertain	Predicted	Small
Mountain galaxias	Galaxias olidus	Uncertain	Predicted	Small
Mouth almighty	Glossamia aprion	Uncertain	Predicted	Large
Olive perchlet	Ambasis agassizi	Uncertain	Confirmed	Small
Ornate rainbowfish	Rhadinocentrus ornatus	Uncertain	Confirmed	Small
Oxeye herring	Megalops cyprinoides	Amphidromous	Predicted	Large
Oxleyan pigmy perch	Nannoperca oxleyana	Uncertain	Predicted	Small
Platy[4]	Xiphophorus maculatus	Uncertain	Confirmed	Small
Shortfinned eel	Anguilla australis	Catadromous	Confirmed	Large
Silver perch	Bidyanus bidyanus	Potamodromous	Stocked	Large

Common name	Species name	Migration[1]	Occurrence[2]	Body size[3]
Snub-nosed garfish	Arramphus sclerolepis	Uncertain	Stocked	Medium
Southern purple-spotted gudgeon	Mogurnda adspersa	Uncertain	Predicted	Medium
Southern saratoga	Scleropages leichardti	Uncertain	Stocked	Large
Spangled perch	Leiopotherapon unicolor	Potamodromous	Predicted	Medium
Striped gudgeon	Gobiomorphus australis	Potamodromous	Confirmed	Small
Striped mullet	Mugil cephalus	Catadromous	Confirmed	Large
Western carp gudgeon	Hypseleotris klunzingeri	Uncertain	Confirmed	Small

Migration: catadromous - migrates from freshwater to spawn in saline conditions; potamodromous - migrates between freshwater habitats; amphidromous - migrates between saline and freshwater habitats but not for the purpose of spawning; uncertain - includes species that make small-scale, local migrations within rivers and those whose movement patterns have not been described.

Occurrence: 'confirmed' - recorded in surveys or recent records in the Nerang River system; 'predicted' - includes species whose natural distribution patterns probably included the Nerang River, ‘stocked’ indicates recreational species released into the reservoir.

Approximate body length of adult fish at Hinze Dam: ‘Large’ – over 300mm, ‘Medium’ – 100mm-300mm, ‘Small’ – less than 100mm.

Alien species, originating outside Australia.

* ‘Occurrence’ data from the Healthy Rivers Program’s ‘Ecosystem Health Monitoring Report, 2005’, and survey data by courtesy Dr Mark Kennard, Griffith University.

10A.1.3 Fish Species Significance

The particular significance of the Nerang River’s fishes lies in their contribution to aquatic biodiversity. None of the species whose presence in the river has been confirmed (Table 10A.2) has been included in Commonwealth or Queensland threatened-species lists, although the olive perchlet and the ornate rainbowfish were recommended for listing in the Commonwealth Environment Protection and Biodiversity Conservation (EPBC) Act as being ‘Conservation Dependent’ and the range and abundance of many of the river's naturally occurring fishes have been drastically reduced.

Exploited angling species in the river include Australian bass, eel-tailed catfish and striped mullet, other angling species from different river systems are stocked in the reservoir, while longfinned and shortfinned eels and mullet are commercially harvested.

10A.1.4 Fish Surveys

A survey of fish species is currently being completed for the reaches of the Nerang and Little Nerang Creek upstream and downstream of Hinze Dam. A total of 15 sites are being surveyed within the Nerang River catchment. This includs:

- eight sites in the upstream reaches;
- four sites within the impoundment; and
- three sites below Hinze Dam.

A range of fish survey techniques are being used to collect a representative sample of fish for each reach. Methods include backpack electrofishing at all sites, in parallel with baited light trapping as well as gill (3 mesh sizes) and fyke (coarse and fine mesh) netting in the dam. Data to be collated from the fish surveys include species lists, relative abundance of species, species diversity, size class, fish length. The fish surveys will be ongoing and the results of the surveys will be provided during detailed design phase and will be used in the development of the design.

10A.2 Fish Passage Requirements

10A.2.1 General

Hinze Dam currently contains no provisions for fish passage. Upstream fish passage has been blocked for over 30 years since the Stage 1 dam construction and downstream fish passage is limited to entrainment during spillway flows.

Dam construction, water diversions and downstream urbanisation have led to deleterious changes in the Nerang River's condition and its fish. These changes have been brought about by the obstruction of fish passage, the loss of fish-habitat area and quality through water diversion at the dam, and the various impacts on habitat quality in the urban areas. The biodiversity and abundance of the river's fish community has undoubtedly declined as a result of these effects.

An assessment has been conducted on the need to implement fish passage measures as a component of the Stage 3 Hinze Dam raise. The following is a summary of the outcomes and the criteria for the design:

- Upstream fish transfer is to be provided;
- Environmental flow available to facilitate fish transfer is 7.25ML/day;
- The fish transfer system design and operation is to be flexible to accommodate potential variation in biomass to be transferred;
- Fish trapping and transfer facilities to be operable for floods up to the 1 in 20 AEP flood. However no transfer of fish would be undertaken when the causeway downstream of the fishway is inundated;
- Downstream fish passage facility is not going to be provided.
- Spillway design is to consider opportunities to reduce adverse impacts on fish passage during and immediately after spill events.

The details to produce these outcomes are presented in the sections herein.

10A.2.2 Regulatory Requirements

Key general criteria in determining the need for fish passage at a barrier include the proportion of the river system being obstructed, the quality and amount of habitat upstream, the existence of other barriers downstream and the nature of the fish community itself. These criteria form the basis of the assessment procedure developed by the Queensland Department of Primary Industry and Fisheries (QDPIF).

The 'Decision-Making Protocol' that is used by QDPIF has been assessed and the listed criteria have been scored by representatives of the Hinze Dam Alliance (HDA). This resulted in a score of approximately 35 points, which is generally consistent with the assessment provided by departmental staff. This score is well above the threshold score (24 points) that confirms the need for a fishway.

10A.2.3 Site Specific Considerations

Water Resource Plan

The environmental flow objectives (EFOs) for the Gold Coast catchment are outlined in the *Water Resource (Gold Coast) Plan 2006*, Schedule 5. Their aim is to maintain key flow conditions within the catchment in order to ensure ecosystem health. The performance indicators cover a range of low flow, medium to high flow and seasonal flow statistics and compare the current river flow with the pre-development flow at specific locations, or reporting nodes.

The Water Resource Plan (WRP) divides the catchment into sub areas, as shown in Figure 10A.2. Hinze Dam is located in Area 4 and the Lower Nerang River is located in Area 5. For this study the reporting node of interest is Nerang River at end of system (AMTD 0.0 km), in Area 5.

The only reporting node below Hinze Dam lies downstream of the confluence of the Nerang River and Mudgeeraba Creek. Currently the environmental flows from Hinze Dam as well as the flows from the balance of the catchment, particularly Mudgeeraba creek, are sufficient to meet the environmental flow objectives specified in the WRP.

Further modelling of Hinze Dam has been undertaken by the Hinze Dam Alliance (HDA) and indicates that the proposed Stage 3 Dam is also compliant with the EFOs. (This assumes that the low flow release made at Hinze Dam is maintained.)

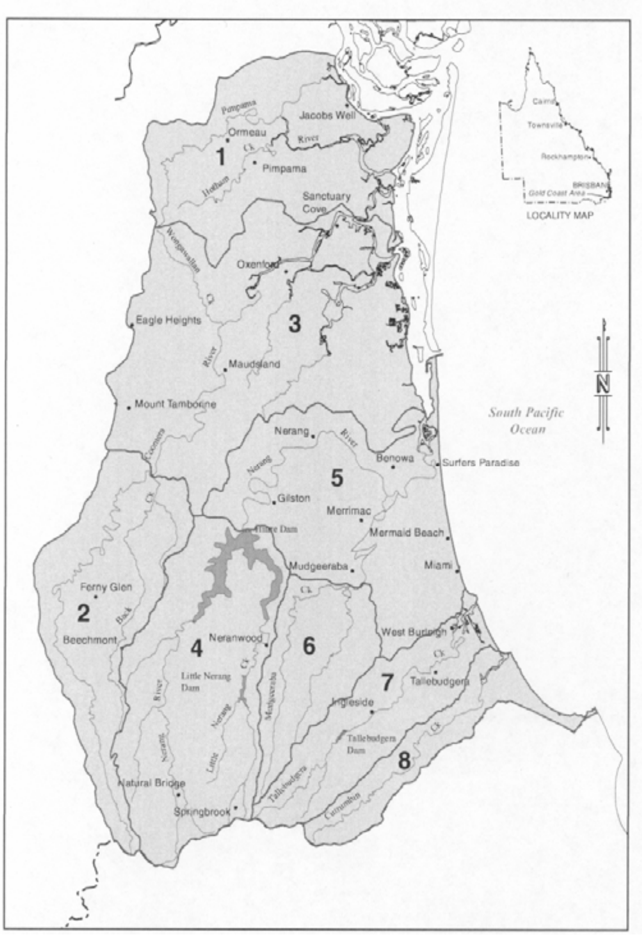

Figure 10A.2: Water Resource Plan (Gold Coast) 2006 Water Subcatchments

Hydrology

Hydrologic and reservoir storage model simulations of the Stage 3 Dam raise were conducted to identify and assess fish passage issues related to future reservoir stage and spillway operation. This modelling, utilising IQQM software, was conducted by the Hinze Dam Alliance.

The modelling assumed a 12.3 m spillway raise with a minimum spill elevation of 94.5 m. The simulations were conducted using historical streamflow data for the period 1900 to 2000 derived from a calibrated streamflow model and historical climate data.

Figure 10.B.2 shows simulated reservoir levels (below the spillway) that occur by applying historic Nerang River Flow Data to the proposed Stage 3 Hinze Dam and reservoir. The simulation data is presented as spilling frequency in Figure 10.B.3. The simulation predicts a 50 percent probability of at least 4.5 m drawdown below Full Supply Level in all months. Typically, it can be expected that there would be approximately 90 percent probability that the reservoir level would not spill during the year.

Details of the findings are included in Appendix 4A and Appendix 10B, the following provides a summary of the findings:

- The simulation predicts a 50 percent probability of at least 4.5 m drawdown below FSL in all months.
- Typically, it can be expected that there would be approximately 90 percent probability that the reservoir level would not spill during the year.
- A comparison of Stage 2 and Stage 3 simulations indicates the probability of spillway flow will not decrease significantly as a result of the Stage 3 dam raise.
- The hydrologic simulation predicts that spill events would occur in 33 of the 110 years.
- The longest period between consecutive spillway flows in the simulation is 26 years followed by significant periods of 15, 9, and 7 years.
- The probability of spillway operation is the highest in Autumn and lowest in the Spring.

Spillway Flows

Spillway flow, duration and frequency of occurrence will change following the Stage 3 dam raise. The hydrologic simulation for the proposed Stage 3 dam predicts that spill events would occur in 33 of the 110 years. Figure 10.B.2 demonstrates the number of years between spillway flows for the simulation. The longest period between consecutive spillway flows in the simulation is 26 years followed by significant periods of 15, 9, and 7 years. The probability of spillway operation is the highest in Autumn and lowest in the Spring, as shown in Figure 10.B.3.

Nerang River Mean Daily Flow Exceedance

The original natural variability of flows (before construction of Hinze Dam) expressed as mean daily flow exceedance in the Nerang River at the Hinze Dam site is presented in Figure 10.B.1. Similar plots of mean daily flow exceedance for the hydrologic simulations with Hinze Dam Stage 2 and Stage 3 are presented in Figure 10.B.4. Probability of flow exceedance is shown for yearly and seasonal periods. Flows presented for the Stage 2 and Stage 3 dam cases include environmental flow and spillway releases.

A comparison of simulated Stage 2 Dam releases with original natural Nerang River flow exceedance indicates significant flow regulation has occurred since construction of Hinze Dam.

A comparison of Stage 2 and Stage 3 simulations indicates the probability of spillway flow will decrease by approximately 4 percent as a result of the Stage 3 dam raise. The Stage 3 mean daily annual flow simulation (Figure 10.B.4) predicts a 13 percent probability of spillway flows, a 8 percent probability of releases exceeding 10 ML/d and a 7 percent probability of flows exceeding 100 ML/d.

Stocking Of Reservoir

The reservoir currently has recreational-fishery value based on stocking with artificially propagated Australian bass, one of the river's catadromous species. Additional species introduced from other drainage regions, such as golden perch and saratoga, have also been stocked.

Secondary Fish Passage Barriers

Secondary fish-passage barriers exist downstream of Hinze Dam but are relatively minor. Little Nerang Dam, which impounds the Little Nerang River in the upstream catchment, prevents upstream fish passage to that portion of the system. Road crossing culverts may also impede passage in some upstream areas.

Alien Species within System

Two alien species, eastern gambusia and the aquarium fish, platys, are recorded in recent fish surveys (Table 10A.1), but current levels of ecological disruption in the river make it vulnerable to invasion by other pests. Particular risks to the river are associated with common carp, especially through escapees from ornamental koi carp ponds, and with entry of tilapia from nearby catchments. The role of the dam as a barrier, and the value of a fishway as a means of separating valued and pest fish, could become important in controlling such pest species, should they be introduced.

10A.2.4 Requirements for Upstream Passage

Consideration of the various factors discussed lead to the conclusion that a fishway to serve upstream-migrating fish at Hinze Dam is justified particularly given the relative high score achieved using the QDPIF 'Decision-Making Protocol'. However only a minor fishway capacity will be required and it should be designed to serve limited numbers and biomass of fish, but with provision for expansion in future if required.

10A.2.5 Requirements for Downstream Passage

A key issue for sustainability of Nerang River fish populations is the capacity of the proportion of the population living downstream of the dam to provide sufficient new recruits to sustain the whole system. The frequency and duration of spilling flows enabling fish to escape from the dam are also relevant. As noted previously, those fish currently surviving in the river have persisted after decades of complete obstruction of upstream passage. Furthermore, the presence of the relatively large, unregulated and less-developed Mudgeeraba Creek tributary, which meets the Nerang in the tidal zone, provides substantial habitat for spawning stocks of the various populations to supplement those in the Nerang itself. In addition, species such as mullets, eels and probably others move along the coastline from neighbouring systems, so there are several sources of recruitment to ensure that sustainability of the present populations is unlikely to be further threatened by recruitment failure.

A review of what is known of the characteristics of the species listed in Table 10.1 (McDowall 1996; Allen *et al.* 2002) indicates downriver passage from the dam is not essential, although this biological knowledge is far from complete. Each of the catadromous species has proved capable of surviving and reproducing below the dam.

The main species that might benefit from downriver passage during spilling flows are the two eels and Australian bass. For the eels, infrequent spills and downstream-resident spawners plus those from other systems could readily generate sufficient recruits. Australian bass, as adult fish exceeding 3-5 years of age (300mm or greater), will seek opportunities to travel downstream to estuarine spawning grounds in response to high flows during winter. If high flows do not occur, or if the fish are unable to leave the dam, their reproductive systems regress until the following year. In Hinze Dam and similar reservoir habitats the bass stocks are derived from artificially propagated hatchery fish; they are not wild stock, and they have little significance from a conservation viewpoint. The significance of these stocks relates to their recreational fisheries value and they are managed as an exploited resource, with replacement from hatcheries as needed. The mullets are the remaining species of fisheries significance. They are widespread, lowland species, spawning along the coastline, and sustaining their abundance would not require downriver passage over the dam of those individuals that may be transported in the upstream fishway. Smaller fish species could be expected to sustain populations upstream and downstream of the dam, with occasional genetic interactions following spills and upstream movements.

The outcomes for those fish transported upriver by the upstream fishway need to be considered. They will either complete their life-cycles in the storage and its stream catchment, eventually falling prey to natural mortality or recreational fishing, or else they will exit the dam during occasional spills and rejoin the downstream populations. These population-dynamics exchanges are a reminder of the natural regimes, wherein there are always sources and sinks of populations and mortality is a continuous process. Provided that the fish travelling above the dam are not required downriver for recruitment, as was concluded previously, the upstream-only fishway has only positive implications for fish biodiversity and abundance in the river.

In addition to the biological background outlined above several site specific factors suggest that the benefits of providing downstream fish passage would be extremely limited, and include the following:

1) Projections of spillway flow patterns from the dam using 100 years of historic rainfall data indicate that spillway flows will be erratic and very infrequent, with gaps of up to 20 years between events.
2) There are two widely separated off-take towers, each with only modest flow rates that limit attraction flows.
3) The substantial distances of the off takes from shoreline habitat limit the likelihood of fish being attracted to the outlet.
4) The large costs of providing downstream passage over the extensive distances and head-loss to the tailwater for no discernable biological benefit.

Consideration of the various factors discussed lead to the conclusion that a fishway to serve downstream-migrating fish at Hinze Dam is not justified.

10A.2.6 Design Criteria

The upstream fishway is to cater for the range of native fish species, sizes and life-history stages predicted to occur at the site (Table 10.1). Passage is needed for young population recruits and for returning spawners of the catadromous species, as well as for potamodromous fish. Some of these movements naturally occur in response to high flows, others occur during low-flow periods and various seasonal patterns occur. The sizes, swimming abilities and behaviour patterns of these fish vary greatly.

Given the restricted environmental flow regime from the dam, the abundance, diversity and biomass of the fish community potentially requiring passage will be limited. There will be small numbers of fish with limited species diversity, so that requirements for fishway biomass capacity and frequency of operation will be similarly limited. Adaptive management of the fishway will be required, with the patterns and frequency of operation determined in response to the numbers of fish attempting to travel upstream.

The sizes and numbers of fish daily requiring passage are expected to vary greatly. Occasional large eels, up to 1m or more in length and possibly reaching 8kg-10kg would occur infrequently, but many more elvers, perhaps thousands, each weighing only a few grams, would arrive seasonally. Similarly, small numbers of adult bass of 300mm-500mm, weighing 0.6kg-2.5kg, would be expected, but larger numbers of bass recruits, 100mm-250mm and weighing 50g-300g, would be expected. Mullet may occasionally travel upstream to the dam in large numbers, possibly hundreds per day following high flows. They would probably be dominated by young fish, similar in size to the bass recruits. Variable numbers of other, predominantly small fish such as gudgeons and perchlets would also need to be accommodated.

10A.2.7 Options Studied

The major parameters that challenge the design of successful upstream fish passage at Hinze Dam are:

- Flow release to the downstream river is limited to 7.25 ML/day during non-spill periods;
- the hydraulic height of the dam is approximately 60 m;
- the downstream river channel is located approximately 260 m from the reservoir;
- the existing environmetal release from the micro-hydro power station is approximately 200m downstream of the spillway
- reservoir level changes of 5 m or more in an average water year are likely;
- the reservoir is a stocked recreational fishery; and,
- upstream passage of juveniles must be accommodated.

These parameters impact the type, size, location and operational flexibility required of a fishway at Hinze Dam. Two fish passage options were formulated based on the parameters. These were, a multi-stage system composed of a fishway linking two lifts (or hydraulic locks) and a trap and haul system. It was decided that the multi stage system was not suitable for Hinze Dam due to the following reasons:

The small flow releases to the downstream river severely restricts the operation of a multi-stage fish pass.

1) Fish abundance in the downstream river is likely to be dominantly young or small bodied fish that would be highly susceptible to predation upon release at a fixed point in the reservoir.
2) The location of reservoir releases could not be sufficiently varied to prevent a learned predator response to the release point.
3) The system complexity and operation and maintenance required by a multi-stage system would be excessive relative to the benefits for the fish-management objectives of the reservoir or downstream river.
4) Alien species could be transferred from the downstream river system to the upstream river system.

Volitional fish passage is preferred when site conditions permit. However, introducing fish passage at a storage reservoir typically requires utilizing a trap and lift/lock or trap and haul methods. All of these methods can provide effective upstream fish passage when properly designed and operated. Trap and haul fish passes provide the greatest flexibility to adapt to reservoir operations, fish concentration and selection of preferred release locations. The main drawback to trap and haul is the requirement of an operator to perform transfer and haul functions. This report includes descriptions of operator functions and personnel requirements.

Trap and haul methods of fish passage are often chosen in the United States when dam size, predation issues or site layout would impair performance of volitional passage or automated mechanical methods. A photograph of a trap and haul operation at the Tracy Fish Collection Facility located on the Sacramento River and San Joaquin River Delta near Stockton, California is shown in Plate 10A:1. The trap and haul facility has operated for over 50 years at a large flow diversion, moving millions of fish each year. Approximately 38 fish species are present at the facility. Trap and haul is used at Tracy to restock native species beyond the hydraulic influence of the diversion facility.

Plate 10A:1: View of fish in a transfer hopper being loaded into a fish truck at the Tracy Fish Collection Facility

In view of the foregoing considerations, a trap-and-haul system appears to be the most suitable system for upstream fish passage. This system would need to be small-scale because of the flow limitation, and operated on a flexible daily and seasonal routine, primarily driven by the accumulation of fish in the trap. The recommendations of fish passage features presented herein were formulated to achieve the objective of a system providing considerable flexibility to adapt to current and future fish-management goals.

Hinze Dam Stage 3 Upgrade

Preliminary Design Report

APPENDIX 10B:

SPILLWAY HYDROLOGY AND HYDRAULICS FOR FISHWAY

- **May 2007**

Contents

Tables, Plates and Figures

Tables

Plates

Figures

Attachements

10B.1 Introduction

This Appendix is written in support of the Fishway Section of the Preliminary Design Report. The purpose of this Appendix is to summarise the following:

- The hydrologic assessments that were made to estimate how often the Hinze Dam Stage 3 spillway could operate (spill) and how this could relate to downstream fish movement.
- The calculations undertaken for the proposed Hinze Dam Stage 3 spillway upgrade together with results from previous physical model study research to estimate the hydraulic characteristics of low flows on the stepped spillway and how they could relate to fish movement.

10B.2 Yield Modelling Results

Hydrologic and reservoir storage model simulations of the Stage 3 Dam raise were conducted to identify and assess fish passage issues related to future reservoir stage and spillway operation. The IQQM modelling was conducted by the Hinze Dam Alliance. As a comparison, the original natural variability of flows (before construction of Hinze Dam) expressed as mean daily flow exceedance in the Nerang River at the Hinze Dam site is presented in Figure 10.B.1.

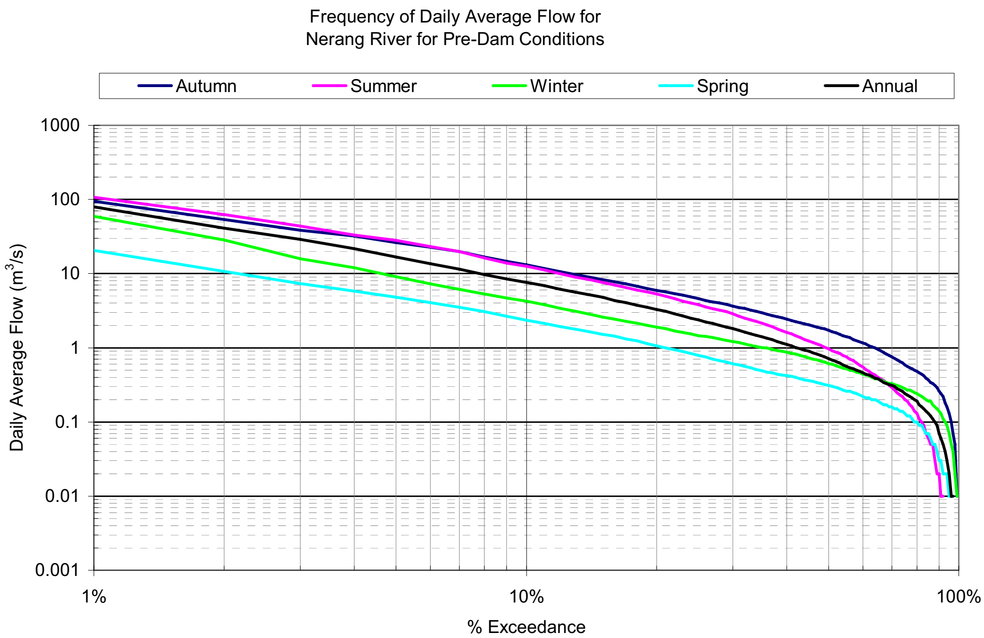

Figure 10.B.1: Pre- Hinze Dam Daily Average Flows in Nerang River

The IQQM modelling for the Stage 3 upgrade assumed a 12.25 m spillway raise with a minimum crest at EL 94.5 m. The simulations were conducted using historical streamflow data for the period 1890 to 2000 derived from a calibrated streamflow model and historical climate data. Figure 10.B.2 shows the simulated reservoir levels and Figure 10.B.3 shows the probability of reservoir water level over the simulated period. The results show that there is a 50 percent probability that the reservoir will be drawn down by 4.5 m for the Stage 3 raise. Additionally, Percentiles from 0.1% to 99% were estimated for all of the simulated stream flow data. The results for all of the simulations showed that there would not be any spills for 90% of the time for the current Stage 2 dam and the proposed Stage 3 dam, as shown in Table 10.B.1 and Figure 10.B.4.

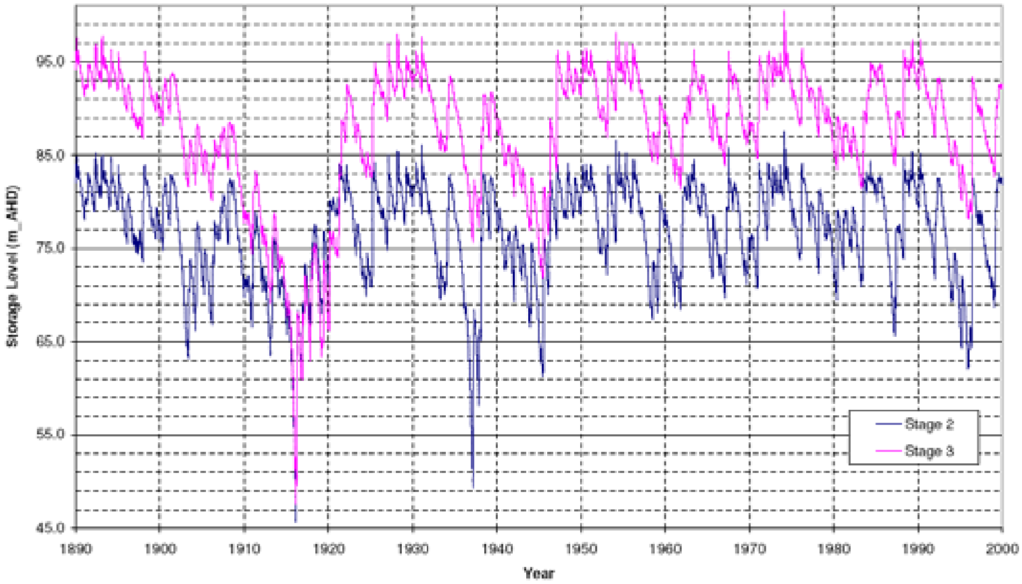

Figure 10.B.2: Simulated Reservoir Water Levels for Stage 3

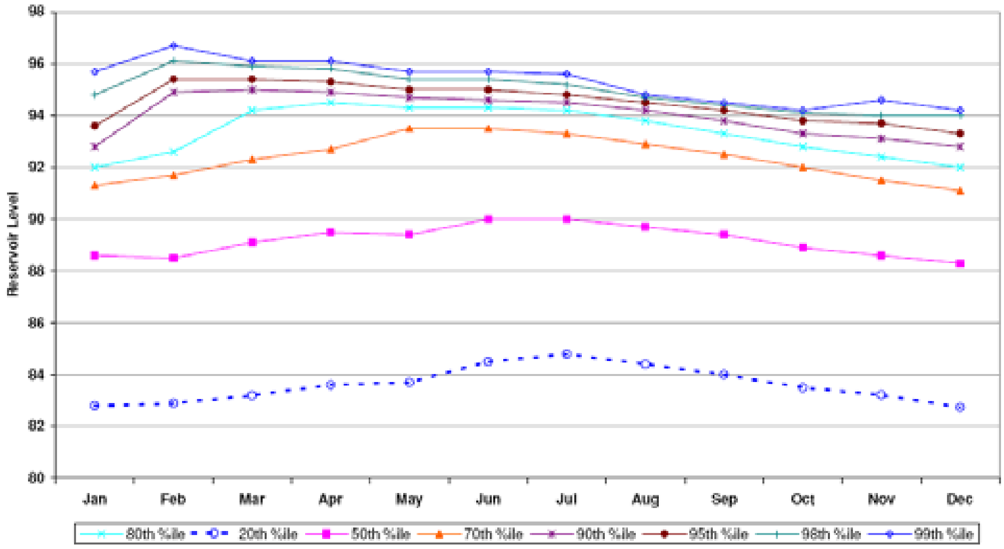

Figure 10.B.3: Simulated Seasonal Reservoir Level Frequency for Stage 3

Table 10.B.1: Spill Frequency for All Simulated Data

Percentiles Exceeding	STAGE 2		STAGE 3	
	Flow (m^3/s)	Unit Discharge ($m^3/s/m$)	Flow (m^3/s)	Unit Discharge ($m^3/s/m$)
0.1%	139.1	5.7	92.2	7.5
0.2%	100.0	4.1	67.1	5.5
0.5%	58.6	2.4	42.1	3.4
1%	32.4	1.3	29.2	2.4
2%	18.1	0.7	15.9	1.3
3%	11.8	0.5	9.2	0.7
4%	7.5	0.3	6.1	0.5
5%	4.9	0.2	4.2	0.3
6%	3.0	0.1	2.7	0.2
7%	1.6	0.06	1.3	0.1
8%	0.5	0.02	0.3	0.02
9%	0.02	0.0	0.02	0.0
10%	0.02	0.0	0.01	0.0
15% - 99%	0.0	0.0	0.0	0.0

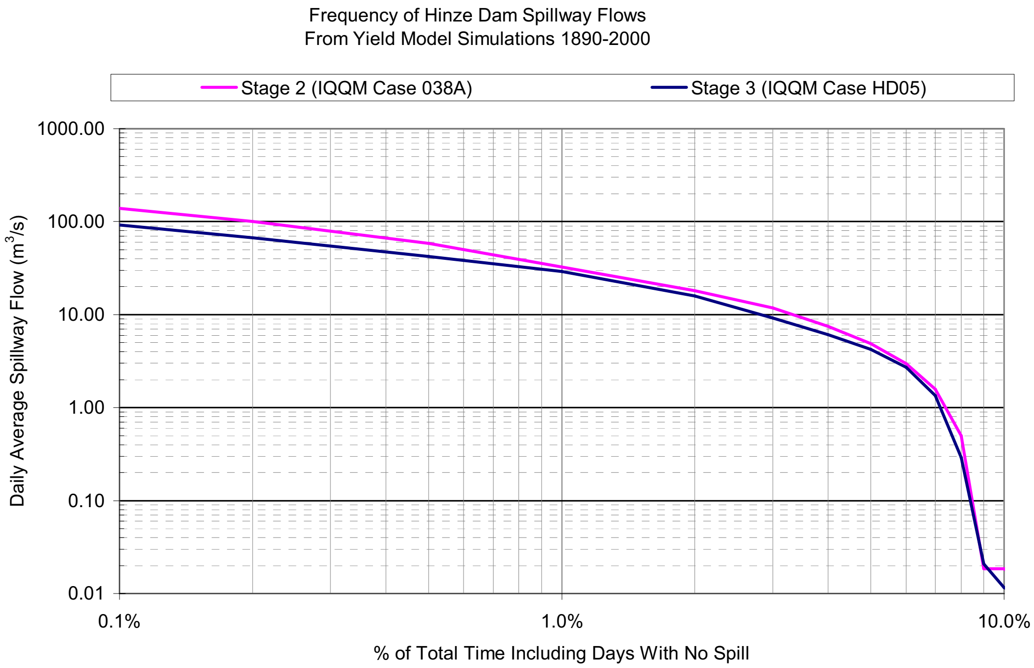

Figure 10.B.4: Spill Frequency from Hinze Dam for All Simulation Dates

Additional analyses of the spill data presented above were performed using only the simulated days that spills would occur in order to estimate the probabilities that the spilling flood waters would be in plunging flow and skimming flow. As discussed in Section 10.B.3, plunging flow is expected to occur for critical depths over the spillway crest of 100 mm or less (unit discharge 1.3 m^2/s) and skimming flow for 730 mm (unit discharge 1.95 m^2/s) or greater over the crest. Table 10.B.2, Figure 10.B.5, and Figure 10.B.6 show that for the simulated spill events, plunging flow would occur approximately 55% of the time, and true skimming flow would occur less than 10% of the time for the Hinze Stage 3 spillway arrangement.

Table 10.B.2: Spill Frequency for Only Spill Occurrences

Percentiles Exceeding	Stage 2		Stage 3		
	Flow (m^3/s)	Unit Discharge ($m^3/s/m$)	Flow (m^3/s)	Unit Discharge ($m^3/s/m$)	Critical Depth (m)
0.1%	268.7	11.0	147.5	12.0	2.5
0.2%	213.2	8.7	128.0	10.4	2.23
0.5%	149.9	6.1	97.1	7.9	1.86
1%	112.5	4.6	75.1	6.1	1.57
2%	74.9	3.1	50.9	4.2	1.21
3%	58.6	2.4	42.3	3.5	1.07
4%	47.4	1.9	37.4	3.1	0.98
5%	39.2	1.6	33.1	2.7	0.91
6%	32.5	1.3	29.5	2.4	0.84
7%	27.7	1.1	27.0	2.2	0.79
8%	24.3	1.0	24.2	2.0	0.74
9%	22.5	0.9	22.1	1.8	0.69
10%	20.9	0.9	19.7	1.6	0.64
15%	14.6	0.6	12.3	1.0	0.47
20%	10.1	0.4	7.8	0.64	0.35
25%	6.9	0.3	5.9	0.48	0.29
30%	4.9	0.2	4.4	0.36	0.24
35%	3.2	0.1	3.1	0.25	0.18
40%	2.0	0.08	1.9	0.15	0.13
45%	1.0	0.04	0.90	0.07	0.08
50%	0.2	0.01	0.12	0.01	0.02
55%	0.019	0.00	0.021	0.00	0.01
60%	0.019	0.00	0.012	0.00	0.00
65%	0.010	0.00	0.012	0.00	0.00
70%	0.010	0.00	0.012	0.00	0.00
75%	0.010	0.00	0.012	0.00	0.00
80%	0.008	0.00	0.009	0.00	0.00
85%	0.008	0.00	0.005	0.00	0.00
90%	0.005	0.00	0.005	0.00	0.00
93%	0.003	0.00	0.003	0.00	0.00

Percentiles Exceeding	Stage 2		Stage 3		
	Flow (m^3/s)	Unit Discharge ($m^3/s/m$)	Flow (m^3/s)	Unit Discharge ($m^3/s/m$)	Critical Depth (m)
95%	0.003	0.00	0.003	0.00	0.00
96%	0.003	0.00	0.003	0.00	0.00
97%	0.003	0.00	0.003	0.00	0.00
98%	0.003	0.00	0.003	0.00	0.00
99%	0.003	0.00	0.003	0.00	0.00

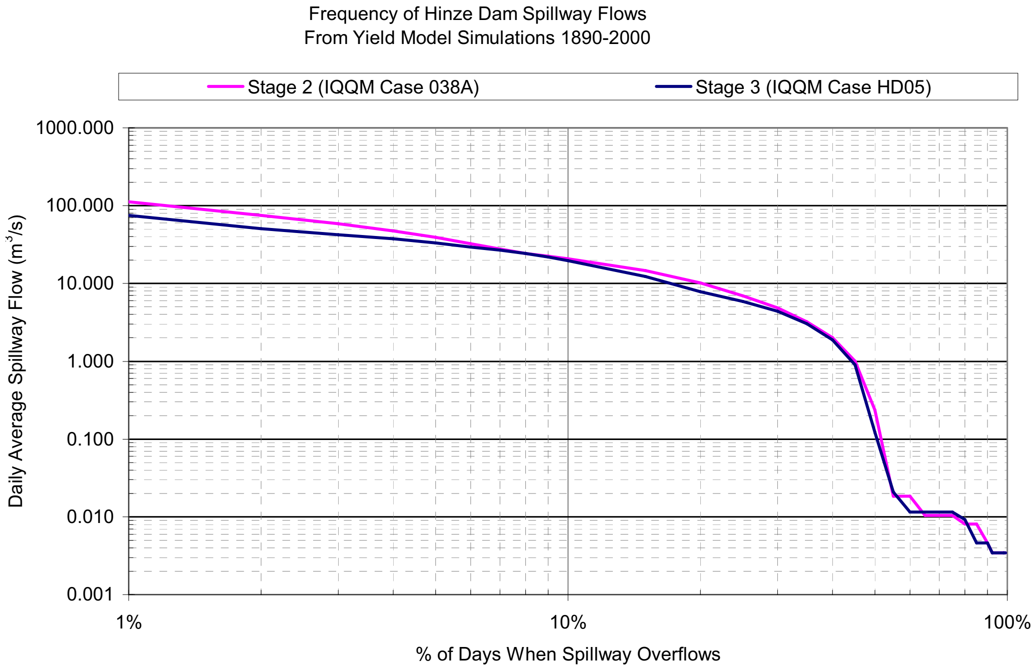

Figure 10.B.5: Spill Frequency from Hinze Dam for Only Spill Occurrences

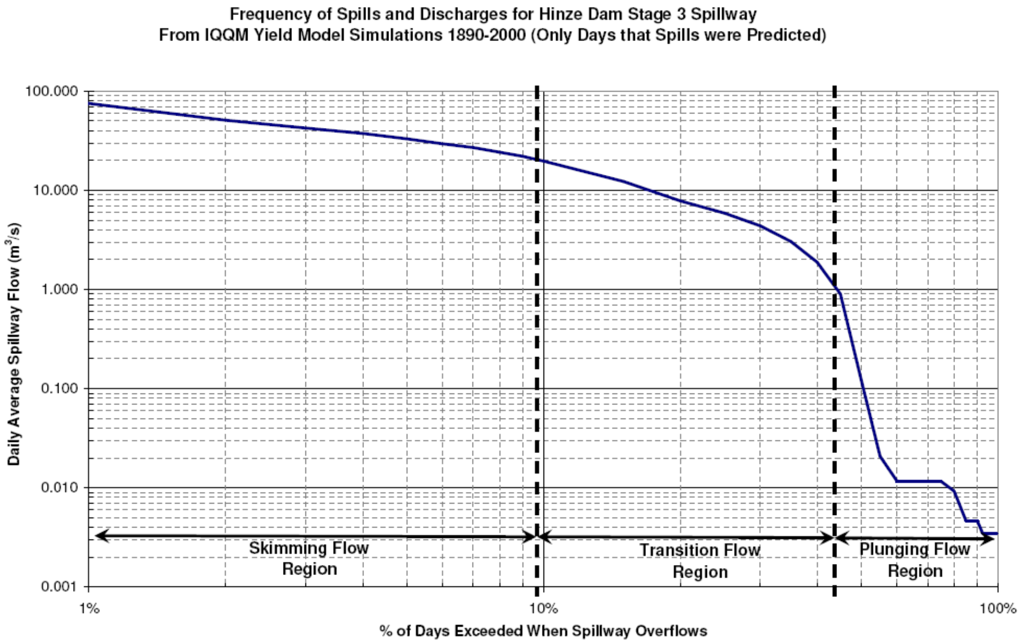

Figure 10.B.6: Spill Frequency from Hinze Dam Stage 3 for Only Spill Occurrences and Predicted Flow Regions on Stepped Spillway Chute

10B.2.1 Conclusions

The following provides a summary of the findings of the hydrologic assessments on spill events from the Stage 2 and Stage 3 spillway arrangements:

- Typically, it can be expected that there would be approximately 90% probability that the reservoir would not spill during the year for both current Stage 2 and Stage 3.
- Plunging flow over the stepped spillway chute is predicted to occur 55% of the time, based on the 110 years of simulated data
- Transition flow over the stepped spillway would occur 37% of the time for those events where spills would occur.
- Skimming flow over the stepped spillway would occur approximately 8% of the time for those events where spills would occur.

10B.3Stepped Spillway Hydraulics

10B.3.1 Flow Regions on Stepped Spillways

The proposed Stage 3 spillway chute consists of a stepped concrete face (1.5 m high steps) at an overall slope of 0.8H:1V. Flow over a stepped spillway may occur as one of three distinct flow regimes depending of the depth and unit discharge of flow: plunging (nappe) flow, skimming flow, and fully rough turbulent flow.

For low unit discharges, the flow plunges (cascades) from one step to another. A hydraulic jump forms on the surface of each step, with a small area of low velocity, recirculating water near the back of the step. This type of flow is called *plunging flow,* as shown in Figure 10.B.7 and Plate 10.B.1.

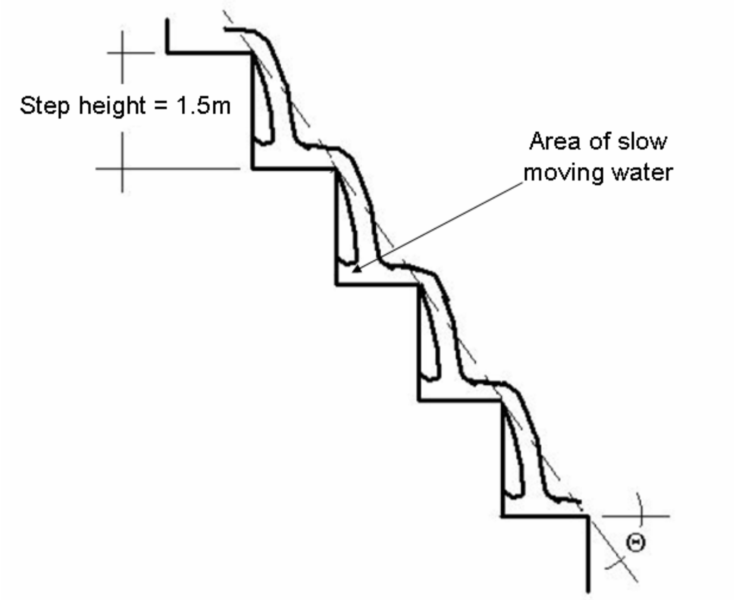

Figure 10.B.7: Plunging Flow Sketch

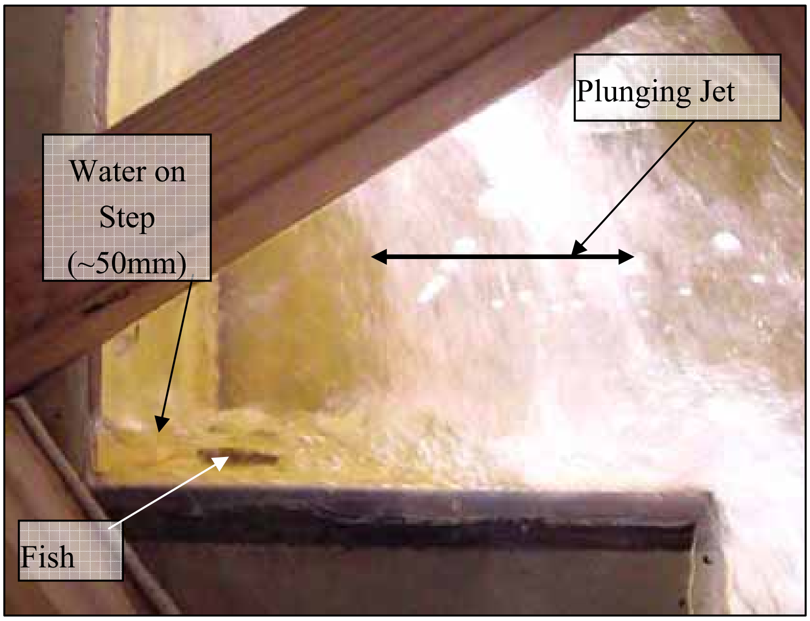

Plate 10.B.1: Plunging Flow in Physical Model

As the unit discharge increases, the flow type is in *transition* (plunging-skimming), where the water profile partially plunges on the step and partially "skims" over the top of the steps, as shown in Figure 10.B.8 and Plate 10.B.2.

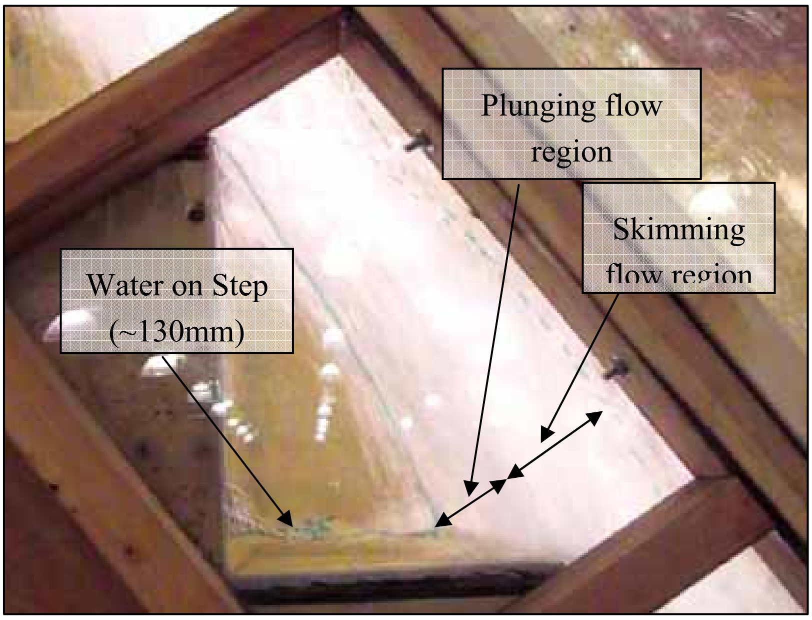

Plate 10.B.2: Transition Flow in Physical Model

Skimming flow and *fully rough turbulent flow* are characterised by higher velocity water that "skims" over the top of the spillway steps, providing a larger area of slow moving, recirculating water, as shown in Figure 10.B.8 and Plate 10.B.3.

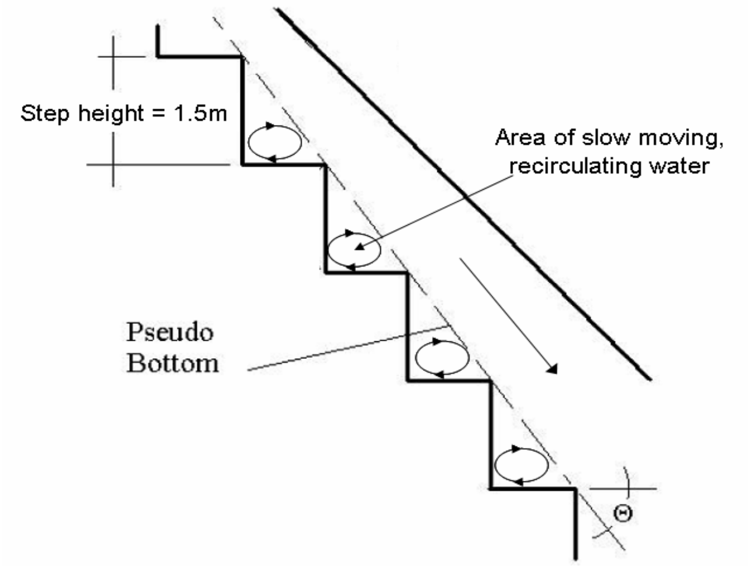

Figure 10.B.8: Skimming Flow Sketch

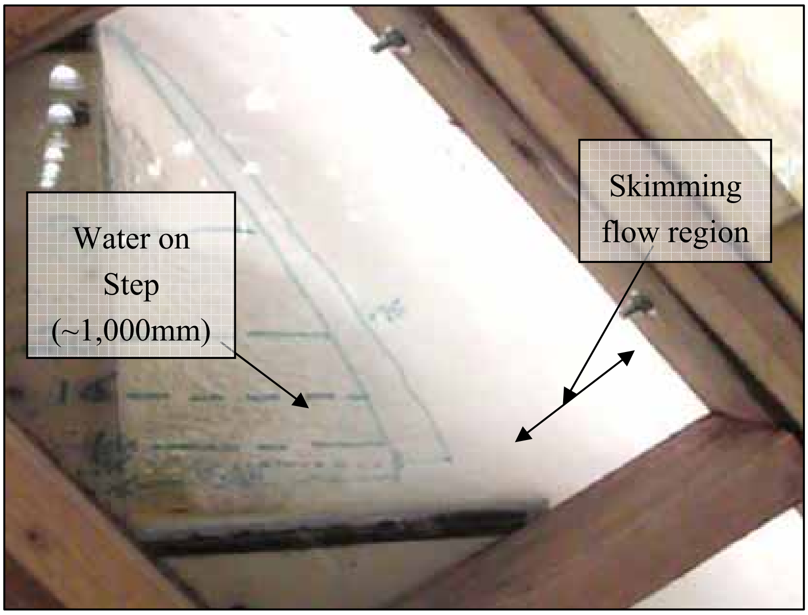

Plate 10.B.3: Skimming Flow in Physical Model

Most research regarding flow over stepped spillways has focused on the skimming flow region because this is the typical region for flood flows and for designing stepped spillways. Boes (2003) presents the Equation 1 to estimate the flow at which true skimming flow would occur.

$$\frac{h_c}{s} = 0.91 - 0.14 \tan \phi \qquad (1)$$

Where:

hc = critical depth

s = step height

ϕ = stepped spillway chute angle with the horizontal

For Hinze Stage 3 raise, s is 1.5 m and ϕ is 51.3 degrees (0.8H:1V), therefore the onset of skimming flow occurs for critical depths on the spillway crests greater than or equal to approximately 730 mm, or a unit discharge of 1.95 m^2/s. The research papers that are available on stepped spillways do not provide a means to quantify the depth of water on the steps, but do describe this area as recirculating water.

There is little to no research available to describe the plunging (nappe) flow region on stepped spillways, and even less research on how this might affect fish flow down the stepped spillway chute. Therefore, in an effort to quantify when water could be in true plunging flow, when it is in a transition region, and approximate the depth of water on each step for plunging, transition and skimming flow regions, the results from a stepped chute physical model were scaled to the Hinze Stage 3 spillway chute.

The physical model was conduted at the U.S.Bureau of Reclamation Water Resources Research Laboratory in Denver, Colorado, USA as part of an unpublished study of fish survival down stepped spillway chutes. The study was conducted under the direction of Brent Mefford. The physical model consisted of more than 15 steps, each 1-foot in height, and 0.8-feet in width (0.8H:1V slope). The steps and measured depths were then scaled to the proposed Hinze Stage 3 spillway (prototype) with a scale factor of 4.92, and unit discharges were scaled by $4.92^{1.5}$, or 10.91. The attached photographs in Section 10.B.5 and Table 10.B.3 shows the unpublished results from the model testing, courtesy of Brent Mefford.

Table 10.B.3: Results of Stepped Spillway Physical Model – Scaled to Hinze Stage 3

<table>
<tr><th>Unit Discharge ($ft^3/s/m$) - Model</th><th>Unit Discharge ($m^3/s/m$) - Prototype</th><th>Critical Depth over Spillway crest (mm) - Prototype</th><th>Measured Depth on Step (mm) - Prototype</th><th>Region of Flow</th></tr>
<tr><td>0.15</td><td>0.11</td><td>110</td><td>50</td><td>Plunging</td></tr>
<tr><td>0.25</td><td>0.21</td><td>170</td><td>100</td><td rowspan="5">Transition</td></tr>
<tr><td>0.75</td><td>0.45</td><td>270</td><td>160</td></tr>
<tr><td>1.0</td><td>0.82</td><td>410</td><td>200</td></tr>
<tr><td>1.5</td><td>1.22</td><td>530</td><td>360</td></tr>
<tr><td>2.0</td><td>1.65</td><td>650</td><td>550</td></tr>
<tr><td>3.0</td><td>2.46</td><td>850</td><td>860</td><td rowspan="2">Skimming</td></tr>
<tr><td>4.0</td><td>3.28</td><td>1,000</td><td>1,000</td></tr>
</table>

From the photographs of the physical model study, it is estimated that plunging flow would occur for the Stage 3 chute for critical depths over the spillway crest up to 100mm, then the transition flow region from depths ranging from 100 mm to 730 mm above the crest, and skimming flow thereafter.

10B.3.2 Fish Passage On Spillway Chutes

There is currently little research on the physical and physiological effects of fish traversing down stepped spillways. Most research has focused on the effects of fish injury and mortality in the skimming flow and fully turbulent flow regions, which indicate that fish generally stay in the skimming jet. To date, no research has been found that studied fish mortality in the plunging flow region. Therefore, it is unknown if impact problems can arise when fish swim over the end of a series of steps through the air onto the next shallow water surface, as will be the case for more than half of the simulated spill events, as discussed in Section 10.B.2. While in the North American experience this practice is performed with little to no injury reported, the ability of Australian species to cope with this method is unknown, but seems unlikely to be markedly different.

The available data for fish on spillway chutes indicate that excessive impact, shear and strain forces can cause loss of scales, fin damage or other physical injuries to vulnerable fish, generally as a result of the following:

- Abrasion due to high chute velocities over rough surfaces with shallow depths, causing the fish to either slide along the chute surface (such as a smooth spillway chute), or slide against protruding objects. Loss of scales can lead to infections through the unprotected area, possibly resulting in fish mortality.

- Impact forces from large drops into shallow water. A stepped spillway provides a controlled rate of energy dissipation as flow passes from step to step down the spillway. However, during spilling, fish may impact the steps at low flows, until streaming flow conditions are reached. The question of what flow conditions will cause fish to impact the steps of a stepped spillway and are they injured cannot be answered with any degree of certainty.

- High velocity impact into the downstream tailwater (plunge pool).

Due to a lack of available research on effects of fish passage over stepped spillways in the plunging flow region, the physical hydraulic model results and additional calculations were performed by Dr. Henry Falvey (see attached). Dr. Falvey's calculations were used to estimate the velocity on each step, and estimate the flow conditions for the Stage 2 spillway for the same unit discharges. Qualitative assessments were also made for the potential of successful fish passage based on these observations and calculations. The calculations, as summarised in Table 2, show that for plunging flow over the 1.5 m high steps:

- The velocities will generally be less than 0.7 m/s, and

- There will be a shallow flow depth on each step as a result of the small hydraulic jump on each step face which will be slightly greater than the depth over the spillway crest,.

Based on these results, it is likely that the smaller and immature fish would have sufficient water depth on each step in order to change direction and prevent impact on the concrete step. Young fish and eel species in this size range typically have the ability to change direction in a short distance, and should therefore be successful in traversing the stepped chute. Additionally, a contributing paper on dams and fish migration for the World Commission on Dams (Larinier, 2000), stated that the passage of fish through a free-fall condition is less hazardous for small fish because their terminal velocity is less than the critical velocity. In other words, the free-falling fish do not have time to reach a critical velocity on each step that would result in injury and mortality, but could be achieved on a smooth spillway where the velocity would continue to increase down the spillway face. The larger bass and eel species (exceeding 300mm in size) would likely not go over the spillway at these low flows because the depth over the spillway would be less than 100mm.

As a means of comparing the potential for fish passage success for the stepped spillway, estimates of the flow hydraulics for the Stage 2 smooth spillway were also calculated, as shown in Table 10.B.4. The Stage 2 spillway hydraulics for discharges up to 22 m^3/s show that the flow depths down the chute would be less than 100mm and the velocities in the chute would range from 6 m/s to 13 m/s. These shallow flow depths and high velocities could result in shear damage (abrasion) to the fish and high velocity impact into the stilling basin tailwater.

Extensive experience with these issues has allowed criteria for avoiding shear damage to be developed. Strain rates of less than 500 cm/sec/cm (equivalent to jet velocity of 9 m/s) have proved safe for American shad (U.S. Department of Energy, 2000), a species known to be particularly vulnerable to handling and physical damage, so they provide a conservative estimate of safe levels of shear for the general fish community.

Studies of fish passage over spillways collected by Bell and Delacey (1972) indicate a general velocity threshold for onset of injury and mortality of about 12 m/s to 16 m/s. Although, flow on steep surfaces containing large scale surface roughnesses display highly turbulent flow conditions, some studies indicate a gradual dissipation of energy along the slope may be advantageous to safe fish passage. Bell and DeLacy cite the Sunset Falls Experiments as one example. Sunset falls is a steep rock chute falls 27 m high. In 1954, two experiments were conducted with young salmon released above the falls. Although direct injury and mortality were not assessed, adult returns from above the falls were higher than nearby rivers similarly stocked without falls. In another study on downstream migrant salmon smolts at the University of Washington, Bell concluded, “If the general problem of spillway design were approached from the point of view of reducing the rate of dissipation of energy in the tailpool it is likely designs could be developed that would improve the passage of fish.”

Table 10.B.4: Spillway Chute Velocity at Toe of Dam for Select Flow Depths

Flow Depth over crest (mm)	Stage 2			Stage 3				
	Velocity (m/s)	Flow Depth (m)	Discharge (m^3/s)	Plunging flow Velocity (m/s)	Plunging Flow Depth on step (m)	Skimming flow Velocity (m/s)	Skimming Flow Depth (m)	Discharge (m^3/s)
0.1	6.0	0.02	2.4	0.7	0.05	-	-	1.3
0.25	10.4	0.04	9.6	0.7 – 1.0[2]	0.15[2]	5 – 7[2]	~ 0.1[2]	4.8
0.5	15.8	0.07	27.1	0.7 – 1.0[2]	0.35[2]	5 – 7[2]	~0.1[2]	13.6
1.0	24.0	0.13	76.7	-	-	13.4	0.23	38.4
Varies (PMF)	24.0+[1]	~4[1]	3,900	-	-	22.4	4.0	3,900

Estimated from Draft CFD model results from WorleyParsons (2007)

Estimates for Transition flow region from interpolation between plunging flow physical model data and skimming flow data

10B.3.3 Conclusions

In summary, based on the calculations above, the proposed stepped spillway chute should be more successful at providing downstream fish passage to the stilling basin pool than a smooth spillway for the following reasons:

- The potential for abrasion of the fish and removal of scales from sliding against the concrete chute during low discharges should be lower for Stage 3 because of significantly lower flow velocities over each step, and intermittent contact with the surface. Whereas, fish would likely have more or less constant contact with the concrete surface for smooth spillway faces.

- The entry velocity (impact) into the downstream stilling basin for a stepped spillway chute will be significantly less than for a smooth spillway. The potential for injuries to fish would likely begin for discharges above 50 m^3/s for a stepped spillway, compared to only 30 m^3/s for a smooth spillway, based on a velocity threshold ranging from 12 m/s to 16 m/s. This conclusion is critical to overall downstream fish passage success over the stepped spillway because 90% of the predicted spill events will have discharges less than 50 m^3/s (as discussed in Section 10.B.2).

10B.4 References

Boes, Robert M. and Hager, Willi H., "Hydraulic Design of Stepped Spillways." Journal of Hydraulic Engineering, ASCE, pp. 671-679. September 2003.

Larinier, Michel. "Contributing Paper to World Commission on Dams, Dams and Fish Migration." 2000.

Mefford, Brent, "Personal Communication on Downstream Fish Passage Over Stepped Spillways." Water Resources Research Laboratory, U.S. Bureau of Reclamation, Denver, Colorado, USA.

United States Department of Energy, "Laboratory studies on the Effects of Shear on Fish," DOE/ID-10822, 2000.

Attachment 10B.1

Photographs from Physical Model Study

(USBR study – Brent Mefford)

All prototype flows are for Hinze Stage 3 based on a 1.5 m high step.

Plate 10B.4: Prototype (Elevation View) Flow = 0.1 $m^3/s/m$

Plate 10B.5: Prototype (Section View) Flow = 0.1 $m^3/s/m$

Plate 10B.6: Prototype (Elevation View) Flow = 0.2 m^3/s/m

Plate 10B.7: Prototype (Section View) Flow = 0.2 m^3/s/m

Plate 10B.8: Prototype (Elevation View) Flow = 0.32 m^3/s/m

Plate 10B.9: Prototype (Section View) Flow = 0.32 m^3/s/m

Plate 10B.10: Prototype (Elevation View) Flow = 0.45 $m^3/s/m$

Plate 10B.11: Prototype (Section View) Flow = 0.45 $m^3/s/m$

Plate 10B.12: Prototype (Elevation View) Flow = 0.61 $m^3/s/m$

Plate 10B.13: Prototype (Section View) Flow = 0.61 $m^3/s/m$

Plate 10B.14: Prototype (Section View 1) Flow = 0.82 $m^3/s/m$

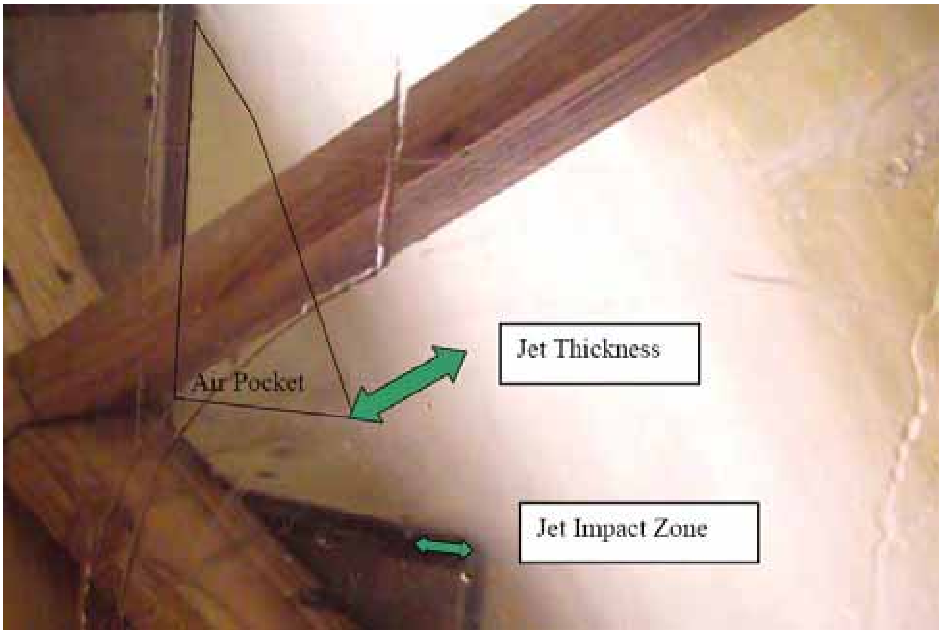

Plate 10B.15: Prototype (Section View 2) Flow = 0.82 $m^3/s/m$

Plate 10B.16: Prototype (Section View 3) Flow = 0.82 $m^3/s/m$

Plate 10B.17: Prototype (Elevation View) Flow = 1.22 $m^3/s/m$

Plate 10B.18: Prototype (Section View) Flow = 1.22 $m^3/s/m$

Plate 10B.19: Prototype (Section View) Flow = 1.65 $m^3/s/m$

Plate 10.B.20: Prototype (Section View) Flow = 2.46 m^3/s/m

Plate 10B.21: Prototype (Section View) Flow = 3.28 m^3/s/m