Designing fishways for a dynamic river: Permanent connectivity solutions for temporary sand diversions

Bryce Davies[1], Jason Carter[1] and Tim Marsden[2]

1 Alluvium Consulting, Townsville, QLD, 4810. Email: Bryce.davies@alluvium.com

2 Australasian Fish Passage Services (AFPS). Email: tim.marsden@ausfishpassage.com

Key points

- Fishways in highly variable systems can be effectively designed by targeting the operating flow envelope, the period when temporary diversion structures remain intact, rather than engineering for extreme flood conditions.
- Site-specific solutions, including concrete cone and rock-ramp configurations, can restore fish connectivity while fully maintaining irrigation infrastructure performance.
- Two-dimensional hydraulic modelling provides a robust, approval-ready basis for demonstrating fish passage performance across the relevant operating range in regulated river systems.
- Designing for sand dam structures that are annually built, operated, and deliberately breached represents a genuinely different paradigm from conventional fishway practice and a direct expression of living and evolving with a dynamic river.

Abstract

Temporary sand diversion works ("sand dams") in the lower Burdekin River and anabranch maintain irrigation pumping pools, but some configurations impede fish movement. This project addressed that connectivity gap by developing permanent fishway designs for two fixed bypass points, The Rocks weir and Warrens Gully offtake, within the broader development application pathway for temporary waterway barrier works.

A staged process was adopted, beginning with engagement with fisheries regulators, Department of Agriculture and Fisheries (DAF), now known as Department of Primary Industries, to confirm design requirements, followed by field inspections, survey, and 2D hydraulic modelling to progress concepts to detailed designs. Ten years of daily gauged flow records (2010–2021) were analysed to define the operating envelope. The fishways were designed to function from regulated low flows through to the point when diversion structures are typically breached (approximately 5,000 ML/day).

Two site-specific solutions were developed to suit local conditions: a concrete cone fishway at The Rocks (dog-leg alignment; nine cells; ~0.8 m head difference) and a bedrock-based rock-ramp fishway at Warrens Gully (12 ridges; ~33 m long). Hydraulic modelling demonstrates that both designs provide low-velocity passage pathways across the target flow range. Project outputs include detailed design documentation, preliminary cost estimates, vegetation impact findings (minimal or none), and a framework for maintenance and fish monitoring.

Aligned with the theme "Living and Evolving with Change," the project demonstrates how fish passage can be integrated into a highly variable system by designing for shifting operational states regulated low flows, seasonal escalation, and breaching events while maintaining irrigation performance and supporting species movement, including barramundi and mangrove jack.

Keywords

Fish passage, river connectivity, Burdekin River, temporary sand diversion, hydraulic modelling, low-velocity pathways, operating flow envelope, adaptive design.

Introduction

Most fishway design guidance is written for fixed, permanent infrastructure: a weir with a defined crest level, a constant downstream tailwater, a hydraulic state that changes with flow but is not subject to geomorphic change. Temporary sand diversions on the lower Burdekin River, are built each year, operated through the dry season, and then deliberately destroyed by seasonal high flows. Providing fish passage requires consideration of these annual cycles.

Temporary sand diversions (colloquially "sand dams") are constructed annually by Lower Burdekin Water (LBW) to maintain pumping pools for irrigation supply at multiple locations along the lower Burdekin River and its anabranch. Two of those locations, The Rocks weir and the Warrens Gully offtake, have fixed rock-bar bypasses that cannot be easily reconfigured from year to year. When the sand diversions are in place, these bypass points create barriers to fish movement. As part of the development application (DA) process for the temporary diversion works, DAF required permanent fishways at both locations.

This project is not the first fishway in the lower Burdekin. A permanent rock-ramp fishway was designed and constructed at Rita Island by the same team in an earlier phase of LBW's DA process. The Rocks weir had previously been assessed for a fishway in 2007 and 2009, and a concept rock-ramp design was prepared in 2009. The current detailed design represents a third iteration: informed by updated survey data, 2D modelling capabilities that were not available in earlier work, and the structural lessons learned from the initial concept. This multi-year evolution of the design from concept to detailed design is itself a reflection of evolving practice, not just evolving conditions.

This paper describes the process of developing detailed fishway designs suited to a system defined by seasonal construction, operation, and breaching, rather than a fixed hydraulic state. It presents the design rationale, hydraulic performance, and environmental outcomes, and reflects on what this approach offers practitioners facing similar challenges in other dynamic or regulated river systems.

Study area and operating context

The study sites lie within the lower Burdekin River system, approximately 16 km downstream of Clare Weir, which is operated by SunWater to regulate flows from Burdekin Falls Dam. Flow in this reach is largely controlled: water is released year-round (with a short annual maintenance shutdown in June/July), supplemented by natural runoff events. The result is an unusually well-constrained flow regime variable, but with a documented operating envelope.

Understanding that envelope was central to the project. Ten years of daily flow records (01/01/2010 – 01/01/2021; 4,018 days) were obtained from the Clare gauge station (#120006B) and analysed to characterise the frequency and duration of flows relevant to both irrigation operations and fish passage (Table 1).

The results reveal a flow regime dominated by low to moderate conditions. Around 75% of flows fall below 50 m^3/s (4,320 ML/day) conditions under which the sand diversions remain intact, and fish passage must be provided through the fixed bypass points. High-flow events capable of overtopping or breaching the diversions (>50–60 m^3/s) occur on approximately one day in four; during these periods, fish can move freely through the broader channel and the fishways are effectively bypassed. This distribution established a clear design principle: fishway performance is required during extended low-flow periods, not during the infrequent events that define natural channel connectivity.

Site-specific extraction thresholds further defined the operating windows. At Warrens Gully, pumping commences at approximately 140 ML/day; at The Rocks, the equivalent threshold is 330 ML/day. These values define the lower bound of fishway operation the flow below which diversions are not yet active, and passage constraints do not exist.

Table 1 Flow regime and operating conditions for the lower Burdekin River (Clare gauge #120006B, 2010–2021)

m^3/s	ML/d	# days	%	Flow at Warrens spillway 140 Ml/d	Flow at The Rocks spillway 330 ML/d
60>	5,184	1,074	26.7%	5,044	4,714
50	4,320	77	1.9%	4,180	3,850
40	3,456	93	2.3%	3,316	2,986
30	2,592	333	8.3%	2,452	2,122
20	1,728	1,246	31.0%	1,588	1,258
10	864	1,087	27.1%	724	394
<10		108	2.7%	140	no extractions
		4,018	100.0%		

Note: Flows at spillways account for pumping station extractions (140 ML/day at Warrens Gully; 330 ML/day at The Rocks).

The fish assemblage of the lower Burdekin reflects the system's dynamic, partly tidal character. Species of particular ecological and cultural significance include barramundi (*Lates calcarifer*) and mangrove jack (*Lutjanus argentimaculatus*), both of which undertake seasonal migrations between marine and freshwater environments in direct response to flow conditions. A diverse assemblage of catadromous, amphidromous, potadromous, and marine vagrant species has been recorded below Clare weir (Carter et al., 2007), all of which stand to benefit from improved passage continuity during the diversion operating season.

Methods

The project was structured as a staged process, progressing from regulator engagement through site investigation to hydraulic design and detailed documentation. This sequence was intentional: the regulatory requirements (confirmed with DAF in Stage 1) informed the level of design detail required, and site survey data (obtained in Stage 2) provided the geometric and hydraulic context needed to refine fishway layouts and anchor them to actual conditions.

Field inspections were undertaken by the project team at multiple points between 2020 and 2021, including both dry-season site visits (to observe operational flows and measure upstream/downstream water levels) and high-flow periods (to check levels against model predictions). Drone-based photogrammetry and ground survey by Brazier Motti in September–October 2021 provided topographic data for hydraulic modelling. As a quality assurance measure, LBW committed to re-surveying upstream and downstream water levels during the following operational period against known flow releases, enabling design levels to be checked prior to construction.

The flow analysis described in the previous section was used to define the design operating range: from the activation threshold at each site through to approximately 5,000 ML/day, beyond which the sand dams are breached. Two-dimensional hydraulic modelling was then used to test fishway performance across this range, focusing on maintaining low-velocity flow paths suitable for upstream fish movement. Velocity thresholds were informed by species assemblage data, with a target of approximately 0.3 m/s along passage margins consistent with accepted thresholds for small-bodied and weaker-swimming species.

Fishway type selection was guided by site conditions rather than a preferred solution. At The Rocks, the presence of a concrete weir sill and the structural constraints of the existing infrastructure favoured a concrete cone design. At Warrens Gully, bedrock at the surface provided a naturally robust foundation suited to a rock-ramp approach. Both sites were assessed for vegetation disturbance and soil conditions as part of the DA process.

Results

The Rocks weir – concrete cone fishway

The Rocks fishway was designed as a nine-cell concrete cone structure with a dog-leg alignment, managing an approximate 0.8 m head difference within the constraints of the existing weir. The dog-leg configuration responds to the physical layout of the site. The preferred northern bank location was selected over the southern alternative due to superior access for both construction and long-term maintenance, and to minimise the risk of fish being drawn toward the pump station intake upstream of the fishway exit.

The cone design distributes head loss across multiple cells, creating a gradual hydraulic transition and concentrating flow through defined pathways to maintain consistent attraction and passage conditions under low to moderate flows. Hydraulic modelling confirms that low-velocity passage pathways are maintained across the full operating flow range, from the commencement of extractions at approximately 330 ML/day through to the breaching threshold at around 5,000 ML/day.

Figure 1 The Rocks Weir - Cone fishway

Warrens Gully – rock-ramp fishway

The Warrens Gully fishway was designed as a 33 m long rock-ramp comprising 12 ridges, providing a stepped, roughened passage pathway anchored using micro piles driven to the natural bedrock surface. The bedrock foundation offered both structural robustness and a reduced material cost compared with alternatives requiring imported substrate or concrete footings.

Hydraulic modelling results show velocities below approximately 0.3 m/s along the passage margins across the full design flow range from the commencement of spillway flows at approximately 140 ML/day through to 5,000 ML/day, beyond which the diversions are breached, and fish passage through the broader channel is unimpeded. This velocity profile meets accepted thresholds for small-bodied fish upstream passage and provides suitable conditions for the full range of species known to use this reach.

Figure 2 Warrens Gully – rock-ramp fishway

Environmental and delivery outcomes

Both fishway designs are largely confined to reshaping in-situ sediment, with no imported fill material required. Vegetation impact assessments identified minimal or no disturbance to mapped regional ecosystem values at either site, a function of both the riverine sand-bar locations and the limited physical footprint of the designs.

Project outputs include detailed design drawings, preliminary cost estimates for both structures, a maintenance framework (including provisions for weed boom management at The Rocks), and a fish movement monitoring framework to validate passage performance post-construction. These outputs collectively fulfilled the DA requirements confirmed with DAF at the outset of the project.

Discussion

The central lesson of this project is that variability, rather than being an obstacle to fishway design, can be the organising principle of it. The site does not present a fixed hydraulic challenge. It presents a seasonal one, and the design process was most productive when it leaned into that seasonality rather than seeking to design around it.

Defining the operating envelope early was the critical step. Once it was established that the fishways needed to perform reliably over roughly 70% of the flow record (the period when diversions are intact and passage constraints exist), and that natural high flows would restore connectivity for the remainder, the design problem became tractable. Head differences were modest (~0.8 m at The Rocks), flow ranges were well-characterised, and site conditions at both locations were suited to relatively compact, low-cost structures. The 2D hydraulic modelling provided the quantitative basis needed for regulatory approval. Also, it gave the design team confidence that performance would be maintained across the range, not just at a single calibration flow.

The approach has direct applicability beyond this project. Temporary irrigation diversions, tidal barriers with operational flow windows, seasonal pumping systems, and other structures that define clear hydraulic envelopes present similar design opportunities. In each case, the practitioner's task is not to design for every possible condition, but to identify the envelope within which passage is required, characterise it rigorously, and demonstrate performance within it. Accepting that high-flow events will provide natural connectivity and designing accordingly is not a concession. It is ecologically appropriate and practically sound.

Uncertainty remains, as it does in all hydraulic design work. Construction tolerances may affect modelled velocity distributions, and the performance of both structures under the full range of operational conditions will only be confirmed through post-construction monitoring. The fish movement monitoring framework developed as part of this project is designed to detect whether passage is occurring during the operational season and to support adaptive management if adjustments are needed. The value of monitoring is not just in validating design assumptions but in building the evidence base that informs the next generation of fishway practice in systems like this one.

Conclusions

Permanent fishways can restore fish connectivity in highly dynamic river systems when designs are grounded in a clear understanding of the operating envelope and supported by rigorous hydraulic modelling. The key lessons from this project are:

- Define the operating envelope before selecting a fishway type. In systems governed by temporary structures, this step fundamentally shapes every subsequent design decision.
- Design for the period when passage constraints exist, not for the full range of hydraulic conditions. Natural high-flow events can and should be acknowledged as providing connectivity, reducing the design burden without compromising ecological outcomes.
- Select fishway types based on site conditions. Concrete cone structures suit constrained, existing infrastructure; rock-ramp designs suit natural rock-bar settings. Neither is universally preferable.
- Invest in 2D hydraulic modelling. In regulated systems with well-defined operating ranges, modelling across the full envelope provides both design confidence and a robust basis for regulatory approval.
- Plan for monitoring from the outset. Post-construction validation is essential in novel operating contexts and builds the evidence base for adaptive management.

The lower Burdekin sand diversion system is, in many ways, an ideal test case for adaptive fishway design: its variability is well documented, its operating boundaries are defined, and its ecological significance is clear. The designs presented here demonstrate that living with a dynamic river is not merely a philosophical position; it is a practical design methodology.

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