



Weirs in Queensland

A guideline for design and construction

Version 1 October 2026

Acknowledgement of Country

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Summary

This guideline describes technical matters to consider when building a weir in Queensland. It is intended to assist water infrastructure owners and their supporting technical teams in undertaking weir projects.

It has been prepared by departmental staff with substantial involvement in weir design and construction over many years with input and review from water asset owners and industry and government stakeholders in Queensland. It reflects their knowledge and experience.

While the primary audience for the guideline is water asset owners and their technical teams, the contents are intended to be informative guidance for all stakeholders.

Disclaimer

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Version history

Version	Date	Comment
1	October 2026	Original version

Glossary

Term (abbreviation)	Description
Abutment	The walls that flank the edge of a weir and support the riverbanks on each side.
Afflux	The maximum difference in water surface elevation, at the weir and at locations upstream of the structure, compared to the water level that would exist without the structure present.
Annual exceedance probability (AEP)	<p>The probability that a given magnitude of event will be exceeded in any one year.</p> <p>Can be described as a probability (fraction of 1), percentage or a '1 in x year AEP', for example a 0.01 AEP, 1% AEP and 1 in 100-year AEP.</p>
ANCOLD	<p>The Australian National Committee on Large Dams Incorporated (ANCOLD Inc.) is an incorporated voluntary association of organisations and individual professionals with an interest in dams in Australia. ANCOLD was formed in 1937 as the Australian national committee of the International Commission on Large Dams (ICOLD), a non-government organisation established in 1928, and is one of 100 member countries.</p> <p>ANCOLD's mission is to be the industry body, representing its Members and Associates, disseminating knowledge, developing capability and providing guidance in achieving excellence for all aspects of dam engineering, management and associated issues.</p> <p>Refer to www.ancold.org.au.</p>
Apron	A durable protective layer (typically of concrete or riprap) constructed downstream of a weir to prevent riverbed scour and foundation damage. The apron length is designed to accommodate the anticipated hydraulic jump location over the range of design flow conditions.
Barrage	In Queensland a barrage is often used to describe a waterway structure constructed within the active tidal zone. Often a barrage, once constructed, becomes the freshwater / saltwater limit of the waterway.
Broad crested weir	A weir with a flat long crest (typically the ratio of crest length to upstream head is greater than 1.5 to 3) where the pressure distribution along the crest is hydrostatic, flow depth equals the critical flow depth and can be used as a critical depth meter (Chanson, 2004).
Catchment	A catchment is an area where water is collected by the natural landscape to a surface location or storage.
Circular weir	A two-dimensional weir crest with a circular profile and a constant radius of curvature. The circular crested weir design is known for having a relatively large discharge capacity compared to broad-crested and sharp-crested weirs, its ease of passing floating debris, its simplicity of design and lower cost.
Critical flow	A flow condition with minimum specific energy and Froude number = 1.
Dam	<p>A dam means works that include a barrier, whether permanent or temporary, that does or could impound water; and the storage area created by the works.</p> <p>The term includes an embankment or other structure that controls the flow of water and is incidental to works mentioned above (these are often referred to as 'associated works' or appurtenant structures and can include features that influence dam safety).</p>

Term (abbreviation)	Description
Department	<p>Department of Local Government Water and Volunteers (DLGWV). Previously responsible departments are:</p> <ul style="list-style-type: none"> • Department of Regional Development, Manufacturing and Water (RDMW) • Department of Natural Resources Mines and Energy (DNRME) • Department of Energy and Water Supply (DEWS) • Department of Environment and Resource Management (DERM) • Department of Natural Resources and Water (NRW) • Department of Natural Resources and Mines (NRM) • Department of Natural Resources, Mines and Water (NRMW)
Drowned flow conditions	<p>Outlet control conditions, where any rise in downstream water level is associated with a rise in upstream water level.</p> <p>For a drowned weir structure the flow regime remains subcritical and does not pass through a critical flow condition.</p>
Froude number	<p>The ratio of inertial and gravitational forces acting on a fluid. For free-surface water flows it is the ratio of flow speed to wave speed. See also subcritical flow.</p> <p>The Froude number is used to scale physical hydraulic models of free surface flow to ensure that modelled behaviours accurately reflect actual flow conditions.</p>
FSL	<p>Full supply level is the level of the water surface when the water storage is at maximum operating level, when not affected by flood.</p>
Good practice	<p>A practice that has been proven to work well, produce good results and is therefore recommended. It is a successful experience, which has been tested and validated, in the broad sense, which has been repeated and deserves to be shared so that a greater number of people can adopt it.</p> <p>ANCOLD (2003) describes good practice as ‘...an authoritative consensus view across an industry’ and qualifies this statement that ‘...owners should have in mind, primarily, recognised good practice in Australia.’</p> <p>Further description is available in DELWP (2015).</p>
Hydraulic jump	<p>Abrupt turbulence and change in water level when flow transitions from supercritical to subcritical, with associated dissipation of energy. Locations of hydraulic jumps are often subject to escalated scour and erosion risks.</p>
Lateral spillway	<p>Also known as a side-channel spillway, a lateral spillway is placed on the side of the weir. It is used when it is not possible or advisable to use a direct overfall spillway.</p>
Load case	<p>Load case, or loading condition, is the applied forces when analysing stability of the weir structure. Generally, two load cases are considered; “usual” and “unusual” load cases.</p>
Lugeon	<p>A Lugeon (Lu) is a unit measuring the water permeability of fractured rock, defined as water flow (litres/minute) per metre of borehole length at a standard test pressure of 10 atmospheres (or 1MPa).</p>
Monolith	<p>A structurally independent block of concrete that forms a section of a concrete gravity weir.</p>
Nappe	<p>A sheet or curtain of water that flows over a weir or dam.</p>
Ogee crest	<p>A specific spillway profile that reproduces the flow trajectory of a sharp crested weir.</p>

Term (abbreviation)	Description
Overshoot gate	Overshoot gate: Gate or system for controlling the passage of water, over the gate. The overshoot gate is considered more suitable than an undershoot gate to pass extreme discharges and large debris.
Paleo channel	A geological feature that is a remnant of a river or stream channel. These features often consist of high permeability alluvial sediments.
Probable maximum flood (PMF)	The flood resulting from probable maximum precipitation coupled with catchment conditions that are optimal for generating maximum runoff. It is a hypothetical flood estimate relevant to a specific catchment whose magnitude is such that there is negligible chance of it being exceeded.
Probable maximum precipitation (PMP)	The theoretical greatest depth of precipitation for a given duration that is, based on meteorological methods of maximisation, physically possible over a particular catchment area.
Probability of occurrence	Probability that the risk (event) could occur.
Rating curve	A plot of water level against flow rate for a channel, weir or other hydraulic structure (also called a stage-discharge or depth-flow curve).
RCC	Roller compacted concrete.
Reservoir	An artificial lake, pond or basin for storage, regulation and control of water.
Risk	Measure of the probability and severity of an adverse effect to life, health, property or the environment. In the general case, risk is estimated by the combined impact of all triplets of scenario, probability of occurrence and the associated consequence. In the special case, average risk is estimated by the mathematical expectation of the consequences of an adverse event occurring (that is, the product of the probability of occurrence and the consequence, combined over all scenarios) (ICOLD 2005).
RPEQ	Registered Professional Engineer of Queensland under the Professional Engineers Act 2002.
Spillway	<p>A weir, channel, conduit, tunnel, gate or other structure designed to permit discharges from the reservoir when storage levels rise above the full supply level.</p> <p>If the rate of flow is controlled by mechanical means (such as gates) it is considered a controlled spillway. If the geometry of the spillway is the only control, it is considered an uncontrolled spillway.</p>
Storage capacity	The capacity of water ordinarily stored upstream of a weir during normal operations of that weir.
Subcritical flow	<p>Flow conditions when the depth is greater than the critical flow depth, Froude number < 1. Subcritical flows are controlled from both upstream and downstream flow conditions.</p> <p>Under typical flow conditions at a weir there is subcritical flow upstream, a critical flow condition at the weir crest (which is the limiting flow rate over the structure), supercritical flow down the crest slope, and a hydraulic jump at the base of the structure where flows transition back to subcritical.</p>
Supercritical flow	<p>Flow conditions when the depth is less than the critical flow depth, Froude number > 1. Supercritical flows are controlled from upstream flow conditions.</p> <p>Supercritical flow conditions occur at hydraulic structures (such as weirs and dam spillways) or in high gradient, high energy watercourses (rapids).</p>
Tailwater level	Water level downstream of a hydraulic structure.

Term (abbreviation)	Description
Undershoot gate	Gate or system for controlling the passage of water under the gate. The undershoot gate is less suitable than the overshoot gate to pass extreme discharges and large debris but better suited to allow sediment releases.
Weir	<p>A barrier constructed across a watercourse below the banks of the watercourse that hinders or obstructs the flow of water in the watercourse.</p> <p>Weirs typically do not cause a substantial difference in water level (upstream to downstream) by the stage when the water is about to overflow the banks. A structure so described typically only generates in-bank afflux if it were to fail.</p>

1. Introduction

1.1 Purpose of guideline

The Office of the Chief Engineer (OCE), Department of Local Government Water and Volunteers, provides technical assurance to state funded water infrastructure projects, ensuring that those projects are delivered to an appropriate level of service, are aligned with industry good practice and represent value-for-money for Queensland.

In line with these technical assurance activities, this guideline provides industry guidance on building weirs in Queensland. It has been prepared by departmental staff with very substantial involvement in weir design and construction over many years and is intended to assist in progressing new weir projects as well as to respond to issues such as damaged or deteriorating existing structures.

When reviewing and/or considering proponent's applications for state funding for weir projects, OCE may consider the contents of this guideline.

Water infrastructure owners and supporting engineering and technical resources, such as consultants and contractors, are encouraged to consider its contents when designing and building a weir.

This guideline outlines a range of considerations associated with building a weir in Queensland but does not cover all considerations in detail. It is more focussed on engineering and those aspects of particular relevance to OCE. References to other sources are provided.

This guideline does not constitute a code or directions under statute or otherwise for the design or construction of weirs in Queensland.

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1.2 What is a weir?

A weir¹ is a barrier across a watercourse intended to raise water levels on the upstream side for storage or diversion purposes. Unlike a dam, a weir is generally confined wholly within the banks of the watercourse, can be wholly overtopped during flood events, and typically does not cause a substantial difference in water level (upstream to downstream) at the stage when the water is about to overflow the banks.

Given that bank-full flooding is not an uncommon event along many Queensland streams, most weirs in Queensland will be overtopped on many occasions during their lifetime. For a weir to serve its intended purpose, it is critical that it can withstand overtopping, often for extended periods, without suffering significant damage.

¹ The *Water Supply (Safety and Reliability) Act 2008* defines a weir as "a barrier constructed across a watercourse below the banks of the watercourse that hinders or obstructs the flow of water in the watercourse; and (b) for the definition of water source—includes a barrier constructed across or within a lake that interferes with water in the lake".

1.3 Weirs in Queensland

Most weirs in Queensland have been constructed for irrigation by surface water or to improve recharge groundwater aquifers in areas of groundwater irrigation such as in the Lockyer Valley.

Because their storage capacity is limited, weirs are generally annual storages which means their reliability of supply is limited in prolonged drought periods.

Weirs have been constructed as a first “trial” phase of development prior to the construction of a major dam such as in the Mareeba Dimbulah, Emerald, Mackay and St George irrigation schemes.

In several irrigation schemes, weirs have been constructed downstream of a major dam to increase storage but also to regulate releases from the dam to improve distribution to users and to reduce transmission losses. Releases from Leslie Dam in the upper Condamine scheme for example, are regulated by Talgai and Lemon Tree Weirs.

Weirs have also been constructed for town water supplies to smaller urban communities.

1.4 Historical context

Whilst more than 100 weirs have been constructed across Queensland since the 1930's, only a few have been constructed in recent years.

Successful weir design is, to a large degree, dependent on judgements based on experience of numerous previous weir projects. Currently, few professionals working in the water sector in Queensland have a significant body of experience in the design, construction or repair of weirs.

Little guidance on weirs is available in the technical literature compared with the extensive literature available for dams. In the absence of guidelines specifically relating to weirs, designers have used other guidelines, including those developed by the Australian National Committee on Large Dams (ANCOLD), such as the guideline covering the design of concrete gravity dams.

Weirs are not dams. They have different safety concerns, regulatory requirements and design and construction constraints. There is generally no population at risk in the event of a weir failure and they do not require regulatory oversight under the state's dam safety legislation. Full compliance with ANCOLD guidelines particularly for smaller weirs can be unduly conservative and lead to higher costs than necessary.

1.5 The difference between a dam and a weir

As tailwater levels rise towards bank-full conditions a weir is designed to “drown” (marking a transition from a critical to subcritical flow condition). As levels rise beyond this threshold the weir's influence over river conditions diminishes and force loadings on the structure reduce.

In contrast, a dam is a structure that extends outside the banks of the watercourse, stores water outside the banks of the watercourse and causes significant afflux at bank-full conditions and above. The higher the flood levels, typically the greater the afflux and force loadings on the structure.

This fundamental difference between weirs and dams (illustrated in Figure 1) has significant consequences on their design, construction and operation.

Dams are often required to survive extremely severe and rare flood events. Weirs do not need to be so strongly designed because they are drowned at these extreme flood events and not exposed to the same force loadings. This means that critical failure modes and load conditions that inform design requirements are different between weirs and dams.

In many instances, should a large dam fail, habitable properties downstream will be exposed to significant life safety concerns. Dam standards strongly reflect a societal aversion to fatalities associated with dam failure. Should a weir fail, habitable properties downstream are generally not incrementally impacted. They may be inundated by natural flooding, but the failure of the weir is not a contributing factor. Compared to a dam, this effectively eliminates any life safety concerns associated with the failure of a weir² and allows significantly more flexibility in design.

Weirs can be designed to less stringent standards, with an emphasis on delivering cost-effective water storage over their operational life. This approach considers the criticality of the water use and the potential need for future upgrades or repairs, while still meeting operational and workplace health and safety obligations. Although dams often have similar purposes, operational life and water use demands, there is the extra burden of addressing life safety concerns associated with potential failure.

Both weirs and dams can obstruct and influence riverine conditions. Dams typically have more severe impacts, such as the restriction of passage of aquatic fauna, disruption to riverine and environmental conditions, and (often as a positive aspect) reducing flooding downstream. Because weirs are generally smaller, are drowned during high-flow events and typically create less extensive upstream inundation, their overall alteration of hydrology, habitat connectivity and environmental conditions is typically less significant than that caused by dams.

Weir designs will often be conservative and expensive if using industry guidelines for dams and can also miss critical weir-specific components.

² There can be life safety concerns associated with weirs from recreational water users downstream.

Figure 1 **Ross River Dam (top) and Aplins Weir (bottom) during a flood event in 2019. Aplins Weir is approximately 20km downstream of Ross River Dam along the same watercourse.**



2. Critical requirements

The fundamental requirements, that must be investigated and addressed during a project, are that the weir:

1. can store sufficient water to meet its functional purpose
2. can withstand flood overtopping without significant damage (this is more challenging if one or both abutments at the site are of erodible soft materials rather than of rock)
3. does not cause harms or negative impacts considered unacceptable to stakeholders
4. continues to meet these requirements over its operational life
5. Achieves the above within economic constraints.

The following sections discuss how these requirements influence the process of building a weir from site selection through to design and construction, project delivery and, following commissioning, ongoing operation and maintenance.

A significant number of all the weirs constructed in the state have experienced failure or significant damage (see Section 12, Lessons learned from past weir projects). This illustrates how challenging the investigation, design and maintenance of weirs can be in Queensland conditions. Whilst the structural engineering issues involved are generally relatively straightforward, site conditions, the competent derivation of tailwater rating curves and estimation of afflux, understanding of hydraulic behaviour during overtopping and the provision of adequate protection works for weirs are often far more problematic.

It is expected that advances in contemporary engineering analysis tools available today will mitigate many of the failure risks described in Section 12, for example, improved capacity and accessibility for reliable estimation of tailwater conditions and hydraulic conditions. Many of Queensland's weirs were constructed during a concentrated period over the 1970s and 1980s, with comparatively less weir construction since. This limited recent hands-on experience in building weirs across the industry has the potential to amplify these risks and highlights the need to develop and maintain competencies (Section 11).

There is evidence that past weirs constructed in Queensland have adversely impacted aquatic flora and fauna (DETSI, 2021) primarily by restricting passage that causes fragmentation of habitats and populations and altering flow regimes including aquatic environments, water quality and habitats.

Environmental compliance and mitigating against potential harms of a weir can add significant complexity, cost and time to a weir project. Early and ongoing engagement with relevant regulators and stakeholders is essential to streamline approvals, optimise designs and manage costs and timeframes.

Weirs are long-life structures and may require refurbishments or improvements in future. When building a weir, aspects such as feasible refurbishment pathways, design life and durability strategy and/or a whole-of-life asset management plan including end-of-life removal, may be worthwhile considerations.

2.1 Decision to proceed with a weir project

The full range of risks and costs associated with a weir project are often not fully identified or realised until after investigations have been completed. Further risk escalation can occur when construction activities commence, due to uncertainties associated with sourcing appropriate materials, site geology and flood management. Some environmental impacts may not be able to be effectively avoided, mitigated or offset and a project may be unable to proceed. Such challenges can be exacerbated by a tendency for 'optimism bias'; an assumption that risks will not be realised and that the project can proceed without fully addressing those risks.

As a general guide, it is important that alternative options, including those that do not include construction of a weir³, remain under consideration until such time that all relevant assumptions are confirmed and that progress towards a preferred option can be made.

It is important to identify if and when project risks become insurmountable, or costs escalate to a point where they exceed benefits, and a go/no-go decision on the project should be made. It is difficult to provide generic guidance in this regard; there may be projects that have marginal benefits and any significant risk escalation clearly triggers a project pause and review. For others this may be less clear.

³ Potential water security alternatives to construction or raising of a weir could include in-stream water extraction, floodwater extraction to off-stream storage, implementation of excess water rates and provision of rainwater tanks to communities.

3. Weir types

3.1 Timber crib weirs

The earliest weirs constructed in Queensland were sited on soft foundations and comprised rows of driven timber piles with diagonal bracing forming a stepped structure. Timber sheeting and an upstream clay fill provided the watertight seal with steel sheeting driven into the foundation (illustrated in Figure 2).

The downstream “cribs” were filled with rockfill which was concreted on the surface of the steps.

The earliest of these structures is Theodore Weir on the Dawson River, completed in 1925 (Figure 3). The weir is still in place but in a much-modified form. The original timber sheeting has been replaced with steel sheet piling and a reinforced concrete capping placed over the downstream steps.

The last example of this type of weir built, Greenup Weir on Macintyre Brook, was constructed in 1958. This type is not expected to be built in the future because of the limited life-span of the timber components involved, and their vulnerability to damage due to overtopping during construction.

Figure 2 Illustration of a timber weir (Bartlett and Richardson, 1980)

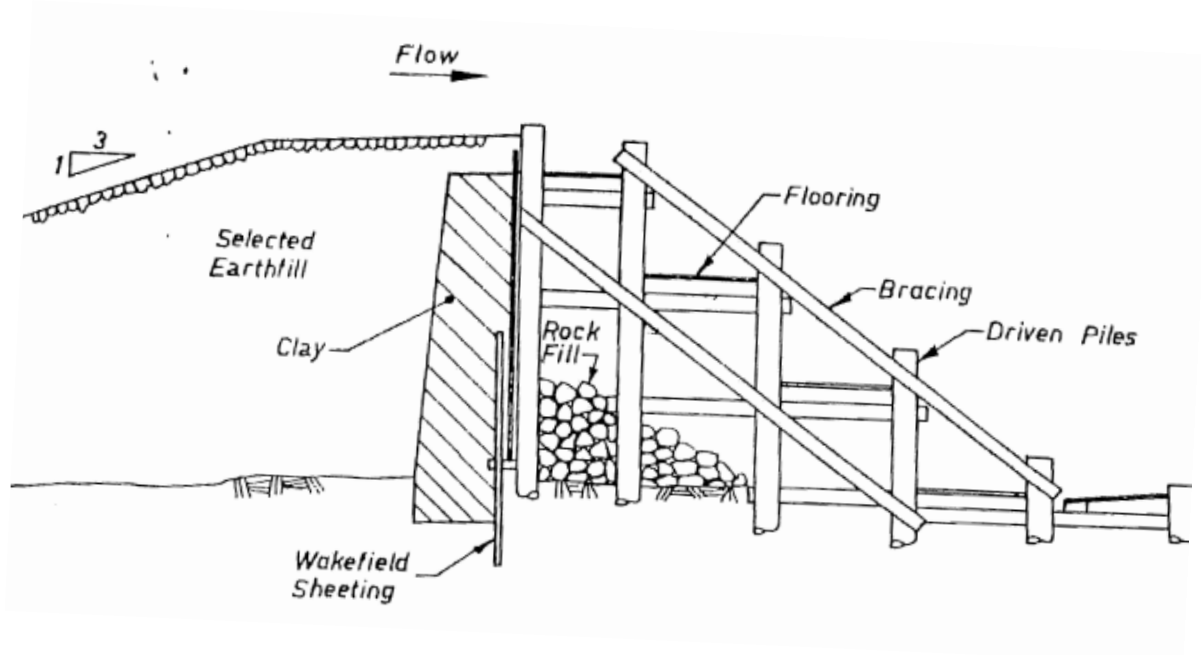


Figure 3 Theodore Weir – Dawson River – timber crib weir



3.2 Concrete gravity weirs

Numerous concrete gravity weirs have been constructed in Queensland – mainly on rock bars but occasionally on stiff clays or on dense sands.

Rock provides a sound foundation suitable for a concrete gravity weir. In cases where there is a rock foundation across the riverbed but not on the abutments, or only on one abutment, a concrete gravity spillway section can be constructed across the riverbed with a steel sheet piling stepped structure on the soft abutments. Examples include Neville Hewitt Weir on the Dawson River and Bingegang Weir on the Mackenzie River.

The concrete gravity sections generally involve a vertical upstream face with an “ogee” shaped overflow crest and a sloping downstream face with a horizontal apron and end sill at bed level (illustrated in Figure 4).

Outlet works and fish passage structures are generally located on the rock abutment side rather than on a soft abutment side, provided access is available on that side. Examples of this type of weir are Rookwood Weir⁴ on the Fitzroy River (Figure 5) and Leafgold Weir (Figure 6).

Concrete gravity weirs are less vulnerable to damage due to flooding during construction. They can, however, require additional foundation treatment if placed on soft foundations (Section 7.7) and need to be designed to withstand uplift pressures.

⁴ The official name is Rookwood Weir (Managibei Gamu).

Figure 4 Illustration of a concrete weir (Bartlett and Richardson, 1980)

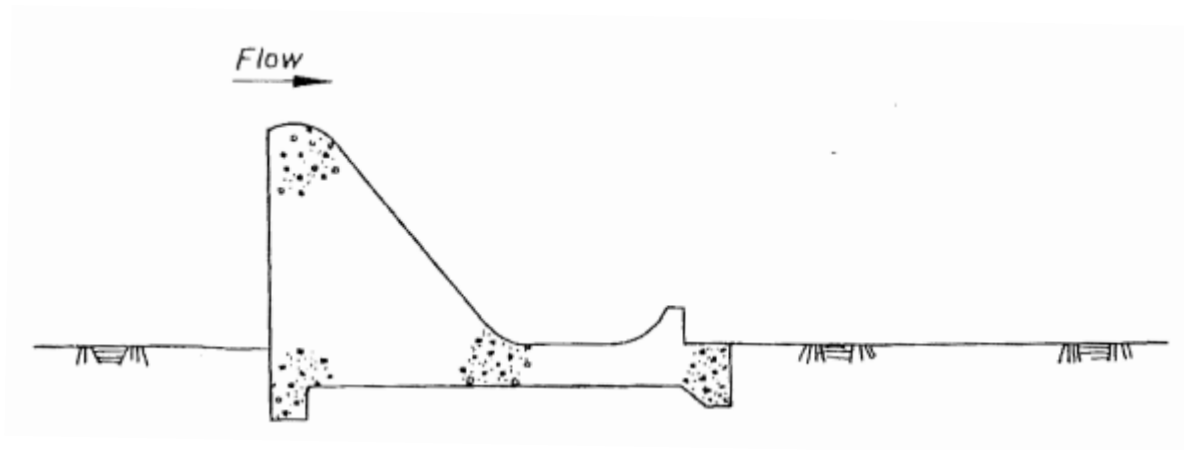


Figure 5 Rookwood Weir – Fitzroy River – concrete gravity



Figure 6 Leafgold Weir – Walsh River – concrete gravity



3.3 Sheet piling weirs

Numerous stepped steel sheet piling weirs have been constructed across Queensland on soft foundation sites. The upstream row of steel sheet piling provides a foundation cutoff and downstream rows form steps 1.5m to 1.8m high. Horizontal reinforced concrete slabs provide protection between the rows of piling. With this arrangement, considerable energy dissipation during overflows occurs on the concrete steps, reducing the risk of erosion of the stream bed downstream of the structure (illustrated in Figure 7).

Weirs of this type have been constructed up to 11.8m high. Examples include Gylanda Weir on the Dawson River and John Goleby Weir on the Burnett River (Figure 8). They can be constructed relatively quickly during dry season windows. Provided an appropriate sequence of construction is followed, the risk of damage due to flood overtopping during construction is manageable.

Stepped weirs are no longer compliant with state regulations⁵. As a result of these regulations, any new weir constructed with multiple rows of steel sheet piling is to have sloping concrete slabs between the rows of piling. This configuration reduces the amount of energy dissipation until the overflow reaches bed level. Consequently, bed and bank protection works will need to be considerably more robust.

⁵ Under the Fisheries Act 1994, any weir forming a barrier on a waterway requires approval under that act, with the State Development Assessment Provisions (SDAP) Code 18 detailing matters to be addressed in seeking approval for a weir barrier. Under version 1 (March 2022) of the SDAP Code 18, Section 5.2.4 states that stepped spillways do not comply with the Code.

Figure 7 Illustration of a sheet piling weir (Bartlett and Richardson, 1980)

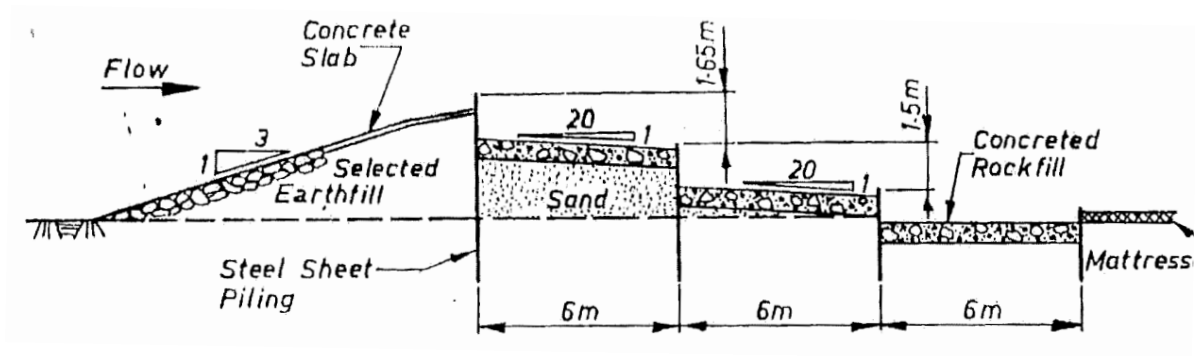


Figure 8 John Goleby Weir – Burnett River – Sheet piling weir



3.4 Embankment weirs

Embankment weirs comprise a compacted embankment protected by thin reinforced concrete slabs on the crest and downstream slope and with a downstream apron. They are a low-cost option for smaller structures on soft foundations.

This type of weir construction is more suitable for sites with a smaller catchment area. The depth of spillway overtopping is less, and flooding risk during construction is small.

An example of this type of weir is Neil Turner Weir, a 5.8m high structure on the Maranoa River near Mitchell in southwest Queensland (Figure 9). The downstream steps are formed by precast concrete units placed on compacted sand fill. Note that, while not related to the weir type itself, reservoir siltation has impacted operation and reliability of water access at this location (Section 7.6).

Another example is Moolabah Weir (Figure 10), a 3.2m high structure on the Thuraggi Watercourse in the St George irrigation scheme.

Figure 9 **Neil Turner Weir – Maranoa River – concrete slabs on sand foundation and sand fill**



Figure 10 **Moolabah Weir – Thuraggi watercourse – damage occurred to the spillway, with movement of concrete slabs, during flooding in 2012**



3.5 Minimum energy loss weirs

This type of weir is based on concepts developed by Professor Gordon McKay at the University of Queensland in the early 1960's (McKay 1970, Turnbull and McKay 1974, Chanson, 2025). The first example is a small weir at Clermont in central Queensland in 1963 (Figure 11).

The concept involves minimising loss of energy and afflux at bank-full conditions and avoiding bank erosion at the weir downstream toe. This is achieved by employing a longer arc-shaped crest, rather than a straight crest, a flattish downstream slope and training walls tapering from the crest width back to stream bed width at the downstream toe. The design seeks to maintain critical flow conditions across the structure, maximising hydraulic efficiency, and to concentrate the hydraulic jump near the river centreline, away from the riverbanks.

This type of weir is best suited to slower flowing streams, such as the Condamine River, and offers the advantage of a higher storage level and capacity than is possible with a straight crested weir.

The most notable example of this weir type is the 9.2m high Chinchilla Weir on the Condamine River completed in 1974. Later examples also on the Condamine River, are the Lemontree (Figure 13) and Talgai weirs, which are 4.0m and 4.4m high.

This style of weir is vulnerable to damage due to flood overtopping during construction and are therefore more suited to sites with smaller catchments. Construction of Chinchilla Weir (Figure 12), which has a very large receiving catchment upstream, was severely impacted by flooding during construction.

Figure 11 **Clermont Weir – Sandy Creek - Minimum energy weir during flood overflow on 8 March 1993**
(Chanson, 2024)



Figure 12 Chinchilla Weir - Condamine River – minimum energy weir



Figure 13 Lemontree Weir – Condamine River – minimum energy weir (Chanson, 2024)



3.6 Gated weirs

Higher storage levels and capacities can be achieved by installing gates (or other forms of collapsible crest structures) on fixed crest structures, resulting in a minimal increase in afflux. The trade-off is that gated weirs are generally less reliable than those with an ungated overflow crest and tend to be more susceptible to debris loads (see Cassidy and Elder, 1984 and Thomas, 1976).

An example of a gated weir in Queensland is Jack Taylor Weir (Figure 14) at St George. Steel vertical lift gates are installed on a concrete gravity sub structure. This type of gate is known as “undershoot gates”. They allow the upstream storage level to be controlled by raising the gates by electric powered hoisting equipment installed on an operating deck above flood level. During periods of major flooding, the gates are raised entirely above flood level. The failure to raise the gates during flood events could be catastrophic. For this reason, backup power sources are installed and staff need to be on-site during major flood events to ensure that gates are raised as needed.

At Clare Weir (Figure 15) on the Burdekin River, flap gates are installed on a low concrete gravity structure. The gates are raised by a hydraulic ram to increase the storage level. They are lowered during flood events to a near horizontal position. This type of gate is known as “overshoot gates.” The Clare Weir installation is unusual. There are no piers for the gates to seal against, with the gates sealing against each other. Leakage between the gates is not considered to be significant. The gates are fabricated from stainless steel because the high sediment load of the Burdekin River during flood events was expected to rapidly degrade any protective paint applied to mild steel gates.

Collapsible steel shutters are installed at the Burnett Barrage (Figure 16) in the Bundaberg Irrigation Scheme. The shutters automatically fall when the shutters are overtopped by 0.3m. The need to raise the gates manually, using a gantry crane to refill the storage, escalates workplace health and safety concerns. No further installations of this type have been constructed in Queensland.

Lower cost inflatable rubber dams were installed at a number of weirs in Queensland. The first was at Proston Weir on the Stuart River in 1967. Water pressure was used to inflate the rubber tube which automatically deflated when the storage rose more than 0.3m above full supply level. Inflatable rubber dams, generally 1.8m high, were installed at Val Bird Weir, Bedford Weir, Claude Wharton Weir, Mirani Weir and Dumbleton Weir. These later installations were raised using air pressure rather than water pressure.

These dams functioned well for decades. However, a rupture of the rubber dam at Bedford Weir (Figure 17) resulted in a sudden release of water. A child swimming downstream of the weir drowned. After the subsequent coronial enquiry, Sunwater, the owner of these weirs, removed each of the rubber dams. These weirs are now fixed crest structures. Inflatable crest structures are no longer considered as a long-term weir structure.

Figure 14 Jack Taylor Weir - Balonne River – vertical lift gates



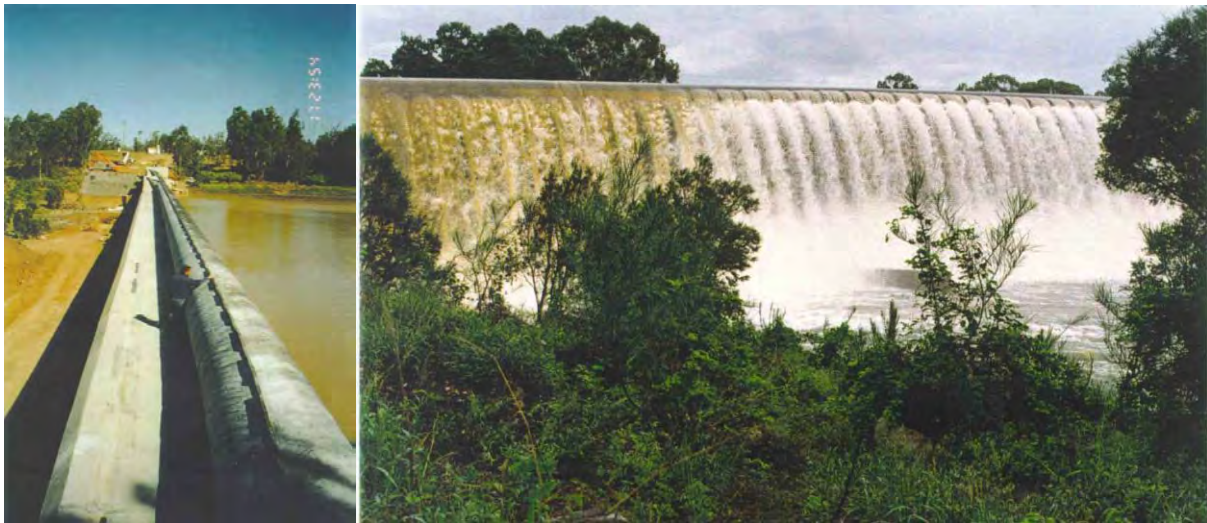
Figure 15 Clare Weir – Burdekin River – overshot gates (Civilplus, 2026)



Figure 16 Ben Anderson Barrage – Burnett River – collapsible steel shutters (Sunwater 2021, Bundaberg Blasting 2020)



Figure 17 Bedford Weir – Mackenzie River - Inspection of inflated dam with deflector in 1997 and overflow of the inflated rubber dam in 1998 (Chanson, 2024)



3.7 Barrages

A barrage is a weir in a tidal area. Once constructed, the barrage becomes the freshwater/saltwater limit of the waterway.

The Fitzroy River Barrage (Figure 18-20) was built in 1970 to meet long-term water supply needs of Rockhampton. It set the upper limit of the tidally influenced estuarine zone of the river and created a freshwater storage reservoir extending approximately 60km upstream (RRC, 2026). Gates remain largely closed during normal operations and opened during flood events.

Figure 18 Fitzroy River Barrage during construction (RRC 2026)



Figure 19 **Fitzroy River Barrage during normal operation with gates closed**



Figure 20 **Fitzroy River Barrage during flood operation with several gates opened**



4. Site selection

Table 1 provides high-level considerations when selecting a weir site and Figure 21 provides further guidance on impacts and mitigations.

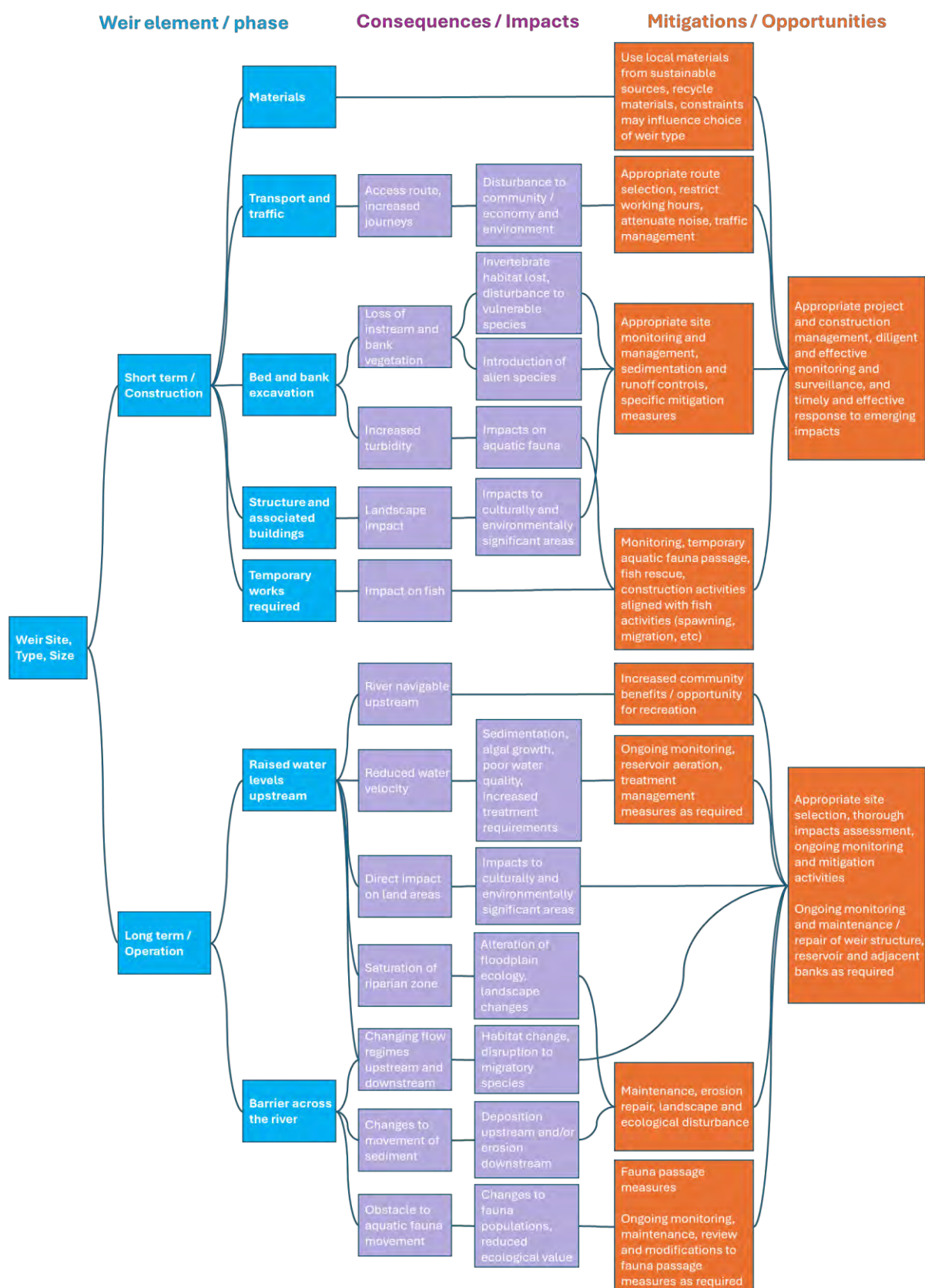
Table 1 Site selection considerations

Aspect	Commentary
Purpose of the weir and location of the demand for supply	<p>Given that a weir storage is confined within the bed and banks of a stream and of limited capacity (and yield) a weir needs to be located relatively close to the area of demand since the cost of a long transmission system – pipeline or channel – could not be justified.</p> <p>Groundwater recharge weirs need to be located over an area of known high infiltration to the groundwater aquifer.</p>
Hydraulic performance and optimum storage	<p>A weir storage will be more effective for a particular weir height if the site is at the downstream end of a long stream section with a flattish bed slope. Rock bars can be indicative of effective weir sites.</p> <p>For satisfactory hydraulic performance weirs should be sited on a long straight section of the stream with high, symmetrical and stable banks⁶.</p>
Foundations	The type of weir to be constructed will depend upon whether there are hard or soft foundations present.
Accessibility	Access to the site for construction and operation can be a significant consideration as can be storage impacts.
Upstream inundation	<p>For the length of the weir storage, any low sections in the top of banks need to be identified and assessed to identify whether overbank flooding will be significantly increased.</p> <p>Any low-level bridges, causeways and stock crossings within the storage area also need to be identified and the impact of their inundation or any increased risk of flooding assessed. Costs of a bridge raising or of a new bridge providing the same or an improved flood immunity needs to be estimated.</p>
Impacts (see also Figure 21)	<p>At least desktop searches should be made of existing data sources to assess whether a weir storage will impact on flora and fauna, especially those identified as being threatened.</p> <p>Similarly, an assessment of possible cultural heritage impacts needs to be undertaken.</p> <p>Potential impacts on riparian landholders also need to be assessed particularly where a landholder owns properties on both banks of a “boundary” stream and where the storage is along an “intersecting” stream.</p> <p>Consultation with landholders is needed to assess what impacts a weir storage might have on property operations.</p>

⁶ A straight and stable section of a waterway is geomorphically stable and with little risk of channel migration or avulsion. Other indicators of geomorphological activity risks are at or downstream of bends, where natural levees are relatively high (risk of avulsion during large floods should the levee breach) and where paleochannels, meander scars and abandoned channels indicate past channel movement. Reaches with underlying bedrock are likely to be more stable than alluvial reaches and may provide better foundation material.

Aspect	Commentary
Optioneering	<p>Optioneering should consider an examination of all alternative water storage and supply options (not just weir sites³).</p> <p>For other than small weir proposals, it is often appropriate initially to consider a number of possible weir sites in an area with investigations for each being carried out to identify one or two locations for more detailed studies.</p> <p>The recently completed Rookwood Weir was for example, one of six potential weir sites in the lower Fitzroy River area initially considered before its adoption as the preferred site on the basis of expected cost effectiveness and likely manageable impacts.</p>

Figure 21 Examples of impacts and mitigations associated with a weir, both during construction phase and operational phase (adapted from EA, 2003)



5. Environmental provisions

5.1 General

A weir project is required to adequately demonstrate, to the satisfaction of relevant stakeholders and regulators, that it can eliminate, minimise, mitigate or offset environmental impacts. This requires appropriate investigations, surveys, assessments that lead to approvals and/or adjustments to site selection, design, construction and operation and ongoing management requirements or, in certain circumstances, provision of offsets or the abandonment of the project.

Advances in the science and engineering of weirs and waterways, improved practices and methods and a better understanding of environmental outcomes means that some weir types and weir designs that were historically acceptable are now generally discouraged. Current approaches to the design and construction of weirs should draw on past experience but be updated to reflect contemporary best practice.

Environmental considerations can add significant complexity to the design, construction and ongoing management of a weir. In some cases, environmental constraints may be readily identifiable and will clearly influence whether and how a weir project proceeds. In other cases, further investigations may be required to better understand constraints and feasible solutions.

Where an initial assessment for a weir project suggests marginal cost-benefit outcomes, it is reasonable to allow an additional 15% to 30% to project costs to address environmental requirements. However, this range is indicative only and can vary considerably depending on site-specific factors.

These factors highlight the importance of incorporating environmental considerations as a fundamental component of a weir project from the outset.

Figure 21 (in Section 4) provides examples of potential impacts associated with weirs, during the construction and operational phases, and some possible mitigation measures and opportunities to consider.

5.2 Assessment and approvals

The assessment process and approval requirements prior to proceeding with a weir project vary according to the scale of the proposed development and the significance of its potential impacts.

For example, a weir proposal impacting on a matter of national environmental significance would be subject to assessment under the national Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). The act defines nine matters of national environmental significance including:

1. world heritage properties
2. national heritage places
3. wetlands of international importance (listed under the Ramsar Convention)
4. listed threatened species and ecological communities
5. listed migratory species
6. Commonwealth marine areas

7. Great Barrier Reef Marine Park
8. nuclear actions
9. water resources that relate to unconventional gas development and large coalmining development.

A proposed weir that may impact on protected matters must refer the proposal to the Australian Government Environment Minister. The Minister will determine whether the proposal is a 'controlled action' under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and therefore requires further assessment and approval. Where approval is granted, conditions are typically applied to protect the environment, often involving monitoring of environmental values during construction and for a period of its operation.

At the state level, a larger weir development of state significance may be declared a coordinated project under the *State Development and Public Works Organisation Act 1971*. This declaration enables the Coordinator-General to oversee and coordinate the project's environmental assessment and other approvals to meet Queensland and, if required, Australian Government requirements under the Bilateral Agreement. Depending on the project, an Impact Assessment Report or an Environmental Impact Statement must provide the necessary impact assessment and information to allow the Coordinator-General to weigh up the social, economic and environmental impacts in considering whether to recommend proceeding and set conditions for approvals.

If the project is not declared a coordinated project, it is recommended that the proponent contact the local government in which the proposal is located in the first instance. In most cases, the local government will act as the development assessment manager. If the local approvals are not required, the State may become the assessment authority. Where state interests are affected, applications may be referred to the State Assessment and Referral Agency (SARA) and applications will be assessed against the State Development Assessment Provisions. It is recommended that proponents seek pre-lodgement advice before making an application with the State.

The primary state legislation involved includes the following:

- *Planning Act 2016*
- *Environmental Protection Act 1994*
- *Nature Conservation Act 1992*
- *Water Act 2000*
- *Fisheries Act 1994*
- *Regional Planning Interests Act 2014*

The *Water Act 2000* establishes the framework for water allocation in Queensland and regulates activities that may impact water resources, including those associated with a weir.

5.3 Weirs as a waterway barrier and their impact on aquatic fauna

Under the *Fisheries Act 1994*, a weir is defined as a waterway barrier. Compliance with this Act generally requires the provision of a fish passage, for example a fish transfer or passage facility, and other provisions intended to minimise the impacts on fish. Since the introduction of the Act in 1994, most weirs constructed in Queensland have been required to provide for fish passage.

However, some weirs may be categorised as 'accepted development' where it has been determined that fish passage infrastructure would provide limited environmental benefit or would make the proposed project economically unviable. These exemptions are identified in the 'prescribed dams and weirs' list published on the Business Queensland website (www.business.qld.gov.au/).

Under the relevant state planning code (SDAP v3.2 State Code 18⁷), fish passage at a weir is required to:

- maintain fish movement and connectivity throughout waterways and within and between fish habitats
- maintain the health and productivity of fisheries resources and fish habitat
- maintain the community and fishing sectors' use of the area and access to fisheries resources
- provide adequate fish passage including a fishway, if necessary
- avoid impacts or, where the matters of state environmental significance cannot be reasonably avoided, impacts are reasonably minimised and mitigated
- not result in a significant residual impact on a matter of state environmental significance unless the significant residual impact is acceptable, and an offset is provided.

Under Commonwealth law, impacts upon Matters of State Environmental Significance (MSES), Matters of National Environmental Significance (MNES) or other designated high value ecosystems and habitats (such as lungfish) is subject to the *Nature Conservation Act 1992* or the *Commonwealth Environmental Protection and Biodiversity Conservation (EPBC) Act 1999*.

Early engagement of an experienced fish passage biologist (or environmental engineer) is vital during the early investigation phase of a weir project. Early consultation with staff of the Department of Primary Industries is also important to clarify regulatory requirements, constraints and obligations.

Surveys and monitoring of aquatic fauna is likely to be required as part of project investigations (Section 6.5). A condition of approval for waterway barrier works that are inclusive of fish passage design elements is likely to include a rigorous monitoring program extending over several years following construction. This monitoring gauges whether, and if so to what extent, fish passage is being provided for, or whether potential design changes to the fish passage structure are required.

⁷ https://www.planning.qld.gov.au/_data/assets/pdf_file/0029/98192/sdap-version-3-2-state-code-18.pdf.

Access and infrastructure for fish passage monitoring and for fishway maintenance is an important consideration. The siting and arrangement of a fish passage facility should be carefully planned.

In addition to fish, other aquatic fauna potentially impacted by weirs include freshwater turtles, platypus and crustaceans. There are regulatory requirements for impacts to MSES, MNES and other conservation listed species and their habitats.

5.4 Biosecurity

Construction and operations activities associated with weir projects can introduce terrestrial and aquatic invasive species that may cause adverse impacts. For example, invasive grass seeds can be carried by vehicles, machinery and footwear, while invasive ants can be transported in carrier materials. There are mandatory compliance tools to be aware of (for fire ants see <https://www.fireants.org.au/>). Waterweeds and other aquatic species, such as salvinia and water hyacinth, and exotic fish such as tilapia, can be carried on equipment used in weir construction and operation. Some aquatic invertebrates (such as the freshwater gold clam) can also damage weir and dam infrastructure.

Under the *Biosecurity Act 2014* (DPI, 2026 and 2026a), staff involved in weir projects have a general biosecurity obligation to take reasonable and practical steps to prevent or minimise biosecurity risks, such as those presented by invasive plants and animals. This includes implementing hygiene measures such as thoroughly cleaning vehicles, equipment, clothing and footwear before entering and leaving weir sites, and ensuring all materials used for construction and revegetation are responsibly sourced and inspected to avoid contamination. See also DPI, 2026b.

5.5 Offsets

The *Environmental Offsets Act 2014* requires offsets be provided if a weir development is assessed as having residual impacts⁸ on matters of national or state environmental significance (MNES or MSES). Offsets are intended to counterbalance those residual impacts and result in a conservation outcome. Offsets may also be required under the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) for significant impacts to MNES.

Offsets can be proponent-driven, including land-based offsets, financial settlement offsets, or a combination of these. Further guidance is provided in DETSI (2025).

For example, where the provision of fish passage at a site is not economically feasible or where it does not provide an environmental benefit, the proposal may include other options which provide a net benefit to fish passage at other existing barrier location(s). Other existing barrier location(s) must be located within the same river or catchment system, or in a nearby catchment system with similar aquatic ecology.

⁸ Residual impacts are those remaining after all reasonable avoidance, minimisation and mitigation measures have been or will be undertaken.

5.6 Environmental management plans

Environmental management plans detail the measures the weir project proponent will implement during construction and operation to avoid environmental impacts, or to minimise impacts and manage them to an acceptable level.

Environmental management plans are often developed as part of an environmental impact assessment process and considered as part of project approvals. They are then updated, as required, to include approval conditions before the project proceeds.

Environmental management plans are specific to the type of weir, its location and its potential environmental impacts. They generally address the following areas:

- consultation
- legislation, regulatory frameworks and project approvals
- land
- aquatic ecology
- terrestrial ecology
- surface water resources and water quality
- groundwater (and groundwater dependent ecosystems)
- noise and vibration
- transport

5.7 Cultural heritage management plans

A cultural heritage management plan must be developed and approved under Part 7 of Queensland's Aboriginal and Torres Strait Islander cultural heritage legislation for any weir project requiring an environmental impact assessment. For projects that do not require an environmental impact assessment, a weir project proponent may still choose to develop and seek approval for a plan.

The process for developing a cultural heritage management plan includes a statutory one-month notification period for the intent to develop a plan, followed by a three-month period for negotiation and consultation with the relevant Aboriginal and Torres Strait Islander stakeholders on the plan's content. In practice, these statutory timeframes may not reflect the full duration required for effective engagement. Additional time, with early engagement with Traditional Owners, is recommended.

Guidelines are available to assist in developing these plans (BQ 2026a and 2026b).

6. Investigations

6.1 Surveys

Survey data for a proposed weir development is required as outlined in Table 2. Topographic survey (LIDAR) is generally sufficient to inform design decisions, although in some instances bathymetric survey, usually side-scan sonar or discrete cross-sections, is necessary to better understand cross-channel profiles and hydraulic behaviours.

Table 2 Site topographic and bathymetric survey considerations

Area	Commentary
Of the stream both upstream and downstream of the weir site for hydraulic modelling and derivation of weir capacity and surface area curves.	Survey upstream of the site should extend to at least the limit of storage and in both upstream and downstream directions to any stream gauging station within a reasonable distance and where rating measurements have been taken.
Of any tributary or gully areas between the weir site and limit of storage.	Survey of these areas is required to define the extent of storage beyond the main channel. This is particularly important where the storage will impact on private property and where the storage potentially impacts on farm operations.
Of bank areas upstream of the weir site to the limit of storage where overbank flooding may occur and along anabranches potentially bypassing the weir.	Survey of these areas is required to determine whether block dams are required to prevent increased inundation of private land or bypassing of the weir and to determine where any such block dams should be located.
Of the weir site area itself.	Contour data is required to develop the weir arrangement and dimensions with permanent marks to provide for set out for construction.

6.2 Foundations

Site foundation investigations should be designed to provide the data necessary for design of the proposed weir type proposed and will vary depending on whether hard rock or soft alluvial foundation conditions are present at the site. The scope of investigations should be appropriate to the scale of proposed works, including the height and width of the weir. Further commentary is provided in Table 3.

Table 3 Site foundation investigations

Foundation type	Commentary
Hard rock foundations	<p>Investigation of hard rock areas will generally involve surface mapping and seismic traverses as a first phase of investigations so that an understanding of likely foundation levels and potential failure modes is gained and to determine where more detailed geological investigations need to be targeted.</p> <p>In more complex geological areas costeans (a trench or pit) can be excavated and detailed clean up undertaken to provide a more detailed understanding of such areas.</p> <p>Core drilling is required where larger structures are proposed with water pressure testing to determine whether grouting is required to control seepage under the structure. Core should be logged by an experienced engineering geologist and rock quality laboratory testing may be warranted for major</p>

Foundation type	Commentary
	<p>structures. Core holes should be located on each abutment as well as across the riverbed and generally be located along the proposed weir axis.</p> <p>Investigations also need to be undertaken downstream of the weir axis to assess the potential for erosion of the riverbed during overflow events and the scope of protection works that might be required.</p>
Soft foundations	<p>As for hard foundations, surface mapping and seismic traverses as a first phase of investigations provides an understanding of likely foundation conditions.</p> <p>Test pitting alone may be adequate for smaller structures on alluvial foundations to determine an adequate foundation level but for larger structures drilling including cone penetration testing and permeability testing are generally required to determine an adequate foundation level and the depth of any cutoff that might be required.</p> <p>Laboratory testing of samples taken at intervals can also provide data for estimation of cohesion and friction angle if required for design.</p>

6.3 Sources of construction materials

Materials required for weir construction typically include concrete aggregates, rock spalls for protection works, sands and gravels and clay fill material. Additional materials may also be needed for fishways, if the design is different from the weir structure.

Costs are generally lower when materials are sourced locally. For coarse aggregates and rock spalls, existing quarries are usually more economical than establishing new sources. Quarries registered under the Department of Transport and Main Roads registration system are usually capable of supplying materials suitable for concrete construction and protection works.

Riverbed sands and gravels from the site area will potentially be the lowest cost source of concrete aggregate. However, materials in many Queensland rivers are often poorly graded, and may lack fine sands. A blend of material from several sources may be required.

Test pitting of sand and gravel deposits should be undertaken, as required, to confirm the volume of suitable materials is sufficient and to enable bulk sampling for laboratory testing. Tests should assess compliance with the relevant standards, including AS 2758.1 (Concrete aggregates) and AS 2758.4 (Aggregates for gabion baskets and wire mattresses).

Test pitting should also be carried out for potential clay sources to establish the volume available and to assess its suitability. Low-plasticity clay or sandy clays are generally suitable for weir clay fill zones.

6.4 Storage impacts

All weirs will affect upstream water levels, with the greatest impact at the weir itself, progressively diminishing to negligible levels at the upstream limit of storage.

The impact is the difference in water levels with and without the weir in place. The duration of the water being at or above a particular level will also be increased with a weir in place.

As part of site selection, investigations should identify all infrastructure and facilities impacted by the changed water levels. This may include causeways, low level bridges (public or private), town water supply or farm pumps and similar assets. The existing flood immunity of these assets should be assessed, along with potential impacts to environmental assets (Section 6.5).

Where impacts are identified, works required to maintain or improve the flood immunity for affected infrastructure should be defined and estimates of costs prepared.

The impact of a weir storage on surrounding land, particularly during flood events, should be assessed in consultation with affected landholders. Mitigation measures may include a rearrangement of fencing, new stock watering points and crossings across local gullies. Compensation for loss of use of some areas might also be necessary.

6.5 Environmental surveys

Environmental surveys are required to establish a baseline understanding of ecological values at a weir site and areas a sufficient distance upstream and downstream. These surveys identify constraints and inform site selection, design and approvals. The results of these surveys can influence the project feasibility, location and configuration, particularly for fish passage design and construction access.

Typical surveys include:

- aquatic ecology assessments to document communities of fish and other aquatic fauna, migration requirements, aquatic and riparian connectivity and existing barriers, including pest species
- instream habitat assessments and riparian vegetation mapping
- assessment of flow regimes and geomorphic condition assessments
- water-quality profiling
- targeted flora and fauna surveys undertaken to identify any threatened species and ecological communities listed under the *Nature Conservation Act 1992* and *Environment Protection and Biodiversity Conservation Act 1999*, with seasonal fieldwork often required to confirm habitat use, breeding cycles and flow-dependent ecological processes.

Robust ecological surveys required for approval, which may require multi-seasonal data collection, depending on the potential protected species present. The availability of this information is critical to progressing a project.

Wetland classification, cultural heritage considerations and assessments of matters of state and national environmental significance (MSES and MNES) form part of this early-stage evaluation.

6.6 Stakeholder engagement

Stakeholder engagement seeks to identify perceptions, concerns and expectations relating to the environmental, social and economic benefits and impacts of a project and to support the establishment and maintenance of a social licence to proceed.

Relevant stakeholders include local landowners, Traditional Owners, local councils, water users, recreational and commercial fishers, community and conservation groups and relevant government agencies.

Early engagement helps to identify key values, expectations and constraints that could influence planning and design. Engagement outcomes should be documented and used to inform environmental and cultural heritage management planning, impact assessments and supporting technical and field investigations. Transparent and timely communication can help build trust, address stakeholder concerns and reduce approval and delivery risks.

Throughout construction and into operation, engagement activities should focus on ongoing communication and information sharing, management of emerging issues and maintaining stakeholder relationships.

7. Design

7.1 Choice of weir type

The selection of weir type is influenced by a range of physical, economic, logistical and environmental considerations. Investigations, preliminary design and options assessment are typically undertaken to inform and finalise a preferred option. Table 4 provides more information on the factors to consider when choosing a weir type.

Table 4 Factors to consider when choosing weir type

Factor	Commentary
Topography	<p>Sites on low-lying, mild slope floodplains can be lower energy environments that favour lower, wider embankment or minimum energy weirs.</p> <p>Steep embankment sites on higher gradient waterways situated further upstream in a catchment can be higher energy environments that favour higher, narrower concrete weirs.</p> <p>Availability of construction materials and access to the site can influence choice of weir type</p>
Geology	<p>Competent, hard rock foundations reduce constraints on weir type selection.</p> <p>Soft foundations can further constrain weir type selection, requiring consideration of foundation treatments.</p>
Availability of materials and constructability	<p>Availability of competent construction materials, either at site or from local quarries, and the need to import materials, can influence choice of weir type.</p> <p>This includes sourcing of materials for concrete mix as well as embankment materials.</p> <p>Stream diversion, labour, access, equipment availability and construction complexity can influence weir type.</p>
Hydrology and riverine hydraulics	<p>The intensity of flood events and resulting forces on the weir structure and abutments can influence weir type, noting that concrete and rockfill structures are more resilient to high energy conditions compared to earth embankment structures.</p>
Spillway requirements	<p>Typically, the spillway spans the full width of the river channel. In some cases, the height of the spillway crest has been increased from the centre of the stream towards each abutment to better match the distribution of the flow downstream. If adopting a minimum energy loss weir approach, the spillway converges towards the central part of the channel to reduce the risk of bank scour.</p>
Seismicity	<p>Concrete structures perform differently under seismic loading compared to earth or rockfill structures.</p>
Environmental provisions	<p>Maintaining appropriate waterway passage of aquatic fauna can strongly influence weir design including crest height and configuration, fish passage structures and sediment control. Certain weir designs can be harmful to aquatic fauna during overtopping events.</p>
Regulatory and legal constraints	<p>Regulatory frameworks (state and federal) may restrict allowable types, overtopping arrangements or hazard classifications</p>

Factor	Commentary
Outlet works	<p>Weirs usually require outlet works for environmental and/or delivery to water users. Construction phase diversion works can be used as outlet works for the operational weir.</p> <p>Outlet works can influence performance of fauna passage measures.</p>

7.2 Demand

Clear, demonstrable evidence that the water to be stored by a proposed weir will be utilised for beneficial purposes is required to justify a weir project.

A cost-benefit analysis is recommended to support this justification. This analysis should recognise that the weir will likely have a very long design life (or may never be decommissioned), account for future demands in the projections and consider the viability of alternative water sources.

Cost-benefit analyses for bulk water projects should address the interdependency of the direct costs associated with building and operating a weir, and the broader, long-term economic and societal benefits delivered to Queensland. Costs should be assessed on a whole-of-life basis, including ongoing maintenance, anticipated refurbishment and upgrade costs.

7.3 Storage capacity

Demand and catchment yield assessments are required to determine the storage capacity needed for the weir. These assessments inform site selection (Section 4), as well as general size and height requirements.

Hydrological analyses of the catchment upstream of a proposed weir location is required to confirm there will be sufficient yield to maintain the water storage and meet projected water demand.

Relevant hydrological parameters (with further description in Appendix A-1) to consider include:

- frequency distribution of catchment inflows upstream of the weir site, with projections incorporating relevant climate change influences
- extreme analyses of low flow conditions, considering return period exceedance of persistent low flow conditions (days below an assigned minimum threshold)
- analysis of yield reliability to meet low to high priority water demands (assessed as part of storage volume sizing)
- analysis of flow regime to support environmental considerations.

7.4 Flood overtopping

7.4.1 Key hydraulic parameters

Hydraulic design requires an understanding of tailwater conditions, water levels upstream of the weir, maximum afflux and afflux when approaching bank-full conditions. The hydraulic design also requires a sound estimate of the energy dissipation and scour, which are directly linked to the water discharge, upstream total head above crest, the difference between upstream and downstream water levels and the supercritical flow velocity at the weir toe.

Table 5 provides an overview of these key hydraulic parameters and how they can be estimated using either empirical simplified equations or numerical or physical modelling methods. A further description of the methods, including the hydrological investigations to establish catchment inflows into the weir location, is provided in Appendix A. Such analyses should start simply, then progressively apply more accuracy and detail for specific design concerns and critical parameters. Physical hydraulic modelling (PHM) and computational fluid dynamic modelling (CFD) can be considered in circumstances where a deep understanding of hydraulic behaviour, scour and erosion risks and/or effectiveness of fauna passage is required⁹.

In addition to storage capacity and flood resilience there are numerous other design requirements for weirs depending on the weir type, foundations, outlet works requirements and approval requirements – particularly for fish passage. These are discussed in the following sections.

Table 5 Key hydraulic parameters to inform weir design

Parameter	Simplified analysis methods to estimate (see Appendix A-2)	Numerical methods to estimate (see Appendix A-3)
Tailwater conditions Water depth vs flow conditions in the natural channel downstream of the weir. Derivation of water depth vs flow conditions - or tailwater rating curve for the weir site – is in effect a rating curve for the site under natural no weir conditions. Tailwater conditions can impact weir design (especially if levels are lower than anticipated). Any potential changes in hydraulics that may cause change in tailwater conditions over the lifetime of the weir should be considered.	Manning's equation can be used to estimate depth vs flow conditions, noting however a strong sensitivity to energy slope (S) and bed roughness (n) ¹⁰ . Cross-referencing to rating curves at the nearest stream gauging station (or stations), where flows have been measured over a range of stage heights, can increase confidence in predictions ¹¹ .	1 and 2 dimensional hydraulic / hydrodynamic modelling simulations can be used to estimate depth vs flow conditions. All hydraulic models will incorporate Manning's equation but will also incorporate additional complexities such as local and broad scale turbulence and geometry influences, superelevation around bends, and transient effects. Modelling will require estimation of cross-section and/or in-stream geometry (and corresponding bathymetric data requirements). Extending the model to the nearest stream gauging station (or stations), where flows have been measured over a range of stage heights, can inform model parameter selection. Model calibration is recommended.

⁹ In particular, key parameters such as upstream water levels, maximum afflux and afflux when approach bank-full conditions can be accurately predicted using PHM.

¹⁰ Note that the use of the Manning (Gauckler-Manning) equation to estimate flow resistance in natural open channels can be problematic; values of bed roughness coefficient are empirical and the formula should strictly be applicable only in fully rough, turbulent flows of water. Alternative hydraulic equations for application in open channels are described in Chanson (2004) and established hydrodynamic numerical models are also available for the purpose (see Appendix A-3).

¹¹ As an example, bank-full discharge at a proposed weir site can be estimated from a nearby gauging station by (1) extracting the gauging station bank-full flow, (2) comparing the gauging station catchment area with that at the weir site and scaling the discharge to be representative of the weir site and (3) adjusting Manning's equation parameters so that the bank-full water depths occur at the weir site for the scaled discharge.

Parameter	Simplified analysis methods to estimate (see Appendix A-2)	Numerical methods to estimate (see Appendix A-3)
<p>Water levels upstream of the weir</p> <p>The increase in water levels caused by the presence of the weir structure, to inform upstream storage capacity and any impacted properties.</p>	<p>Critical weir flow conditions are expected to occur under normal flow conditions and can be used to estimate water levels upstream of a weir.</p> <p>Theoretical estimates can be used to predict upstream water level, including using irrotational flow motion of an ideal fluid.</p> <p>Estimation of upstream reservoir extent, especially for over-bank and flood flows, can be challenging using simplified methods and use of numerical modelling and/or integration with GIS tools is recommended (noting there are limitations in the accuracy of weir flow conditions simulated by a numerical model).</p>	<p>Critical weir flow equations are readily embedded into 1-and-2-dimensional models and used to estimate water levels upstream of a weir for a range of flow conditions (or during dynamic events). While the equations are similar, models also incorporate entrance and exit losses, variability across the width of the river channel and weir structure, and more accurate simulation of ogee crest hydraulics.</p> <p>Higher accuracy prediction of head water rating curves and afflux at all stages of flow up to bank-full flow can be provided by CFD and PHM model studies.</p>
<p>Maximum afflux across the weir</p> <p>The flow condition that causes maximum afflux and likely worst-case force loadings on the weir (and adjacent bed) should be identified. This is a less-than-bank-full flow condition.</p> <p>This can inform any requirements for energy dissipation over and downstream of the weir.</p>	<p>Maximum afflux occurs under critical weir flow conditions which can be calculated using the fundamental theoretical equations.</p> <p>Downstream hydraulic jump depth, distance and corresponding force loadings can be calculated to inform apron design, energy dissipation requirements and scour risk (Chanson, 2004).</p>	<p>Weir structures are readily embedded into 1-and-2-dimensional models and can simulate the transition (as tailwater levels rise) from critical to drowned flow conditions.</p> <p>Prediction of complex turbulent flow conditions often experienced at weirs may require CFD and PHM model studies.</p>
<p>Afflux across a weir when approaching bank-full conditions</p> <p>For flow conditions approaching bank-full, where the weir structure is drowned and entrance and exit losses are more dominant.</p> <p>An afflux of 0.3m or less across the weir typically requires a weir crest that is around 0.6 to 0.7 times the height from stream bed to top of bank.</p> <p>This can inform likely worst-case bank erosion risks above the level of protection works (or inform the extent of protection works required).</p>	<p>At bank-full conditions it is preferred that the weir operates in outlet control.</p> <p>A generalised hydraulic structure loss equation (or afflux formula) can be used to estimate bank-full flow conditions however these calculations can become more complicated and require modelling.</p>	<p>Weir structures are readily embedded into 1-and-2-dimensional models and can simulate the transition (as tailwater levels rise) from critical to drowned flow conditions.</p> <p>Higher accuracy prediction of head water rating curves and afflux at all stages of flow up to bank-full flow can be provided by CFD and PHM model studies.</p> <p>The use of appropriately scaled PHMs is a proven tool for assessing hydraulic behaviour during overtopping and for guidance as to the extent of protection works required. CFD modelling used in conjunction with physical modelling is complementary and likely to lead to an increased level of confidence in findings.</p>

7.4.2 Recommended bank-full afflux limit of 0.3m

To withstand floods, the commonly used design criterion used successfully in Queensland is to limit afflux across the weir to 0.3m at bank-full flow level, provided that adequate bank protection works are installed and maintained.

Adoption of a 0.3m limit is recommended for the following reasons:

- There is a historical precedent; as described in Section 12.1, excessive afflux has been the dominant cause of damage to weirs in Queensland¹².
- The 0.3m afflux limit is recommended in Bartlett and Richardson, 1980¹³.
- An afflux of more than 0.3m at bank-full conditions is an indicator of increased flood inundation risk, especially for habitable properties on the upstream floodplain¹⁴.
- Any significant changes to the bank-full flow can have significant influence over sediment transport, channel stability and river morphology and cause scouring, siltation, bed erosion and riverbank retreat (Julien, 2006). Bank-full flow is described as the dominant discharge in USBR (1987) for estimation of reservoir siltation rates.
- Other recognised industry sources also cite this limit. USDOT (1978) provides a comparable basis, stating that for “... *sites where scour is not to be encouraged, 1 foot of backwater may be an upper limit*”.

7.4.3 Recommended maximum weir crest height of 0.6 to 0.7 times the bank height

The lower the weir crest relative to the top-of-bank level, the lower the weir afflux will be. A weir design should therefore minimise weir crest level, while still providing the required upstream reservoir storage.

As a general guide, a weir crest level set at approximately 0.6 to 0.7 times the height from stream bed to top of bank will generate an afflux of around 0.3m during bank-full flow conditions.

7.4.4 Afflux greater than 0.3m

If a weir design results in an afflux exceeding 0.3m at bank-full flow levels, then the following additional measures should be considered:

- Provide a clear justification of the reasons for this weir design approach.
- Undertake detailed flood modelling to confirm that there are no unacceptable incremental impacts to upstream properties.
- Carry out comprehensive modelling, potentially including computational fluid dynamics (CFD) and physical hydraulic modelling (PHM), to better understand peak velocities and hydraulic shear forces, particularly along the stream banks, to inform design.

¹² A notable exception to this precedent is Chinchilla Weir which consistently experiences bank-full afflux of several metres (Chanson et al, 2023).

¹³ When described in Bartlett and Richardson, 1980 it is likely this estimate assumed using a depth and width averaged water level and velocity at the upstream and downstream measurement points; if using 2D or 3D numerical modelling it may be worthwhile testing afflux using energy head (ie water level plus velocity head, $v^2/2g$).

¹⁴ The majority of Queensland's weirs, which have considered the 0.3m afflux limit when designed, are sited on flat river reaches. As the natural waterway gradient (or bed slope) influences flow regime energy and upstream extent of afflux, the 0.3m afflux limit may be less representative for weirs on steeper reaches or upstream tributaries. Further investigations such as those described in Section 7.4.4 may be considered in these circumstances.

- Design and implement more robust and extensive protection works (see also Section 7.9), considering extended coverage further downstream, along and further up adjacent banks and surrounds, and an extended downstream apron.
- Apply additional conservatism in design and construction.

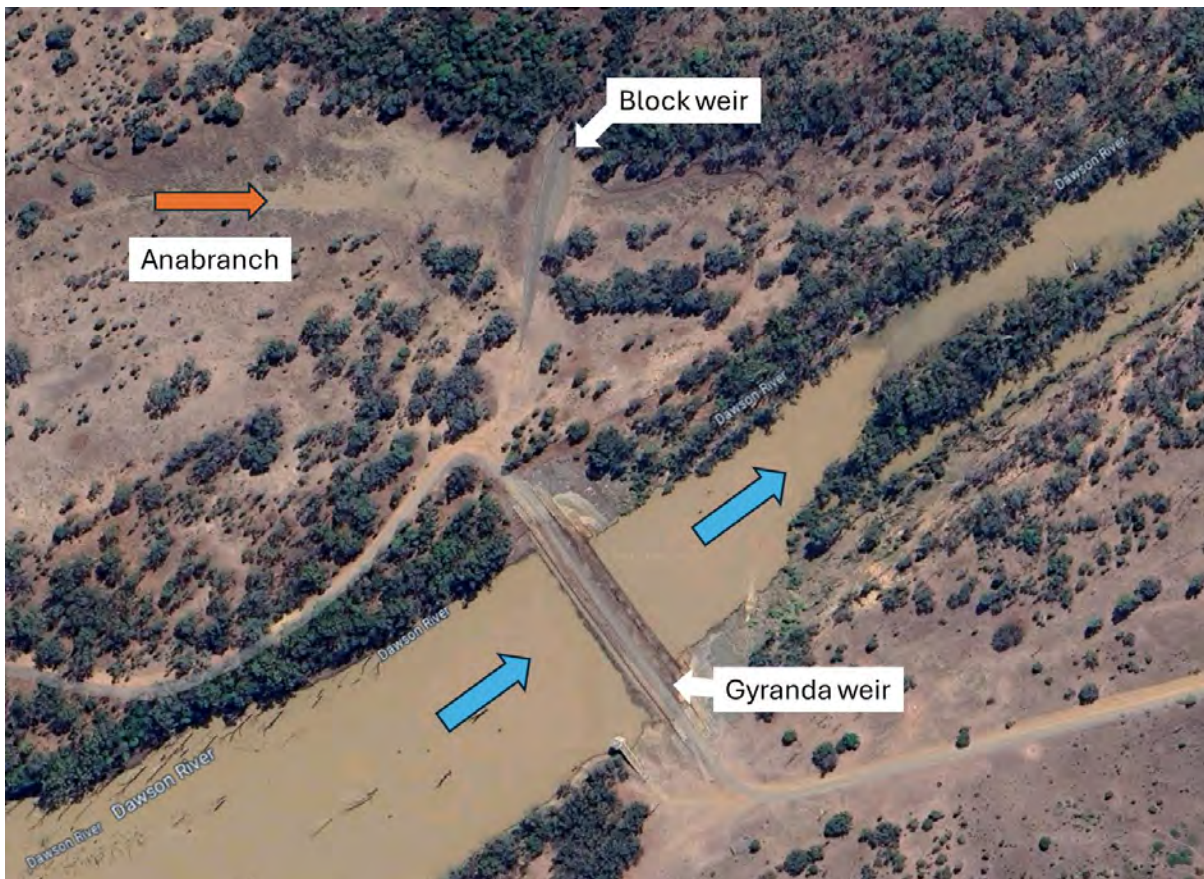
7.5 Block weirs

The backwater effects created by a weir can cause flows to occur in adjacent flood runners or anabranches at a lower discharge, for longer durations and with more regular frequency than under natural conditions. If these changes are significant, erosion may occur where the flood runner re-enters the stream and then progressively erode upstream. If not addressed, this may lead to bypassing of the weir.

To mitigate against this risk, block weirs (or saddle dam structures) constructed across flood runners and anabranches adjacent to the weir storage can effectively mitigate this risk¹⁵. The block weir crest level can be set so that flows do not occur any more frequently than naturally, thereby better maintaining natural floodplain behaviours.

Block weirs constructed at Gyranda Weir and Neville Hewitt Weir on the Dawson River are examples of weirs that successfully avoid erosion in flood runners (Figure 22).

Figure 22 Block weir on left bank of Gyranda Weir – Dawson River



¹⁵ Note that a block weir may cause environmental impacts and be subject to regulatory requirements.

7.6 Siltation

There is relatively little historical evidence of siltation upstream of weirs in major rivers in Queensland causing operational issues or restricting available water supply volumes. There have, however, been instances of siltation at weirs on smaller waterways with more mobile sediment loads.

Neil Turner Weir is prone to sand and siltation accumulation. In 2013, Sunwater reported that sand and siltation accumulation “reduces the full supply volume significantly and impacts greatly on the reliability of water access” (Sunwater 2025).

Other impacts of siltation include settlement in fish passage structures, often requiring cleaning and maintenance, especially after flow events; intake structures and water quality concerns, especially if stored water is to be subsequently treated prior to use.

Field observations of sediment transport rates are described in Horn et al (1998 and 1999).

7.7 Foundation treatment

As part of the design process, and to prepare a cost estimate prior to the commencement of construction, Planned Foundation Levels (PFL) are predicted and a plan for foundation treatment developed. These are based on the results of foundation investigations undertaken to date and will vary depending on whether the underlying foundations comprise hard rock or soft soils.

7.7.1 Hard foundations

Suitable rock foundations for a concrete gravity weir are generally fresh, with stained joints or slightly weathered rock. These conditions are assessed by inspection of drill cores and any other investigations including seismic velocity surveys and test trenches. Rock joint spacing should be at least 500mm.

Areas where there are significant steps in foundation levels should be identified during investigations. Design allowances should be made for slope correction using dental concrete, where required. Sheared zones should be excavated to a depth 1.5 times their width and backfilled with concrete.

Consolidation grouting is not generally required for weir structures and curtain grouting is only used in limited cases. Targeted curtain grouting may be considered to a depth below PFL of 0.7 times the depth of storage above PFL where water pressure test losses exceed 10 lugeons.

For major weirs, additional investigations, such as drilling and water pressure testing, may be undertaken, typically at spacings of 12m centres across the weir. Primary holes should be grouted, with secondary and tertiary holes drilled and grouted only where losses exceed 10 lugeons.

7.7.2 Soft foundations

For a sheet piling or embankment weir, the PFL should be set below any foundations containing organic matter or poorly consolidated material, as identified from bore hole and test pit logs and material testing.

Highly permeable materials, such as open work gravels, should also be removed.

Bore logs can be used to identify permeable strata through which steel sheet piling might be driven to control seepage and to minimise the risk of piping. The depth of sheet piles below PFL is typically up to 0.7 times the storage depth above the PFL.

Experience at two major Queensland weir sites highlights the importance of adequate seepage control. At Ned Churchward and Rookwood weirs, coarse gravels overlaid the bed rock below soft abutments. At Ned Churchward Weir, insufficient cut-off of the alluvial bank resulted in seepage that impacted the abutment stability, requiring the construction of a concrete toe wall (see Section 12.3). At Rookwood Weir, a slurry trench cut off wall was constructed through the gravels and trenched into the bed rock to provide an effective seepage control on the left abutment.

7.8 Structural design of concrete gravity weirs

7.8.1 Arrangement

Concrete gravity weirs generally comprise monoliths, typically 12m to 15m wide, with a vertical upstream face, an ogee crest and a sloping downstream face. The ogee crest profile can be determined for the adopted design head using guidance such as in the United States Bureau of Reclamation Design of Small Dams (USBR, 1987). It is then refined with hydraulic modelling. Water stops are installed across contraction joints between the monoliths, extending from foundation to crest level, to prevent leakage.

Compared to dams, shear keys with contraction joint grouting are not usually required for weir structures due to relatively lower critical shear forces.

A downstream apron is typically required to protect the toe of the weir and downstream stream bed from erosion. Its length is determined using modelling to ensure that high energy conditions associated with the downstream hydraulic jump occur on the apron. A waterstop is required between the apron and monoliths over the full width of the spillway to prevent high pressures penetrating beneath the apron slab. An end sill and cutoff wall at the downstream end of the apron is required to protect from scour and undercutting.

Unlike dams, weirs do not usually have a drainage gallery installed within the monoliths, as these would be difficult to keep dry and functional.

For larger weirs, vertical foundation drainage holes may be drilled across the upstream end of the apron, discharging at the downstream end of the apron. Eductor plates on top of the vertical drain holes are not preferred in this application.

Environmental considerations influence design. Measures should be incorporated to reduce risks to fauna, particularly entrapment on the spillway and apron structures after overtopping events. At recently constructed weirs, the apron is set below bed level to create a permanent pool, with any end sills having a sloping upstream face to minimise fish impacts during periods of overtopping. End sill design needs to consider ongoing fauna passage beyond the apron. Crest design that deters turtle access, such as an upstream curving lip, may be considered.

7.8.2 Load cases

Load cases, or loading conditions, are the applied forces when analysing stability of the weir structure. Generally, two load cases are considered.

The “usual” load case: the worst-case hydrostatic loading (that is; the combination of headwater and tailwater that causes the greatest differential forces on the structure) with normal function of drains if installed and sediment buildup.

The “unusual” load case: the worst-case hydrostatic loading (as for the usual load case) but with abnormal function of drains if installed, maximum sediment buildup and seismic hazard.

7.8.3 Monolith loadings

Monolith stability should be assessed to identify the critical load combination:

- at the monolith lowest foundation level interface
- at a number of planes within the monolith
- for a range of discharges
- for a combination of head water and tailwater levels.

The following loadings should be taken into account (see also Figure 23):

- self-weight: the weight of the monolith based on the monolith geometry and an assumed (or measured from trial mixes) concrete density
- hydrostatic loading: the upstream headwater loading and the downstream tailwater loading for each combination of headwater and tailwater considered
- uplift: the uplift load assumed to act over 100% of the interface area and to vary linearly
 - for the “usual” load case, from full headwater level at the upstream face to tailwater level at the line of drains, if installed
 - for the “unusual” load case, from full head water level at the upstream face to tailwater level at the downstream end of the apron assuming that the drains are ineffective.
- sediment: the loading applied to the upstream face by the buoyant density of silt to an assumed height of
 - for the “usual” load case, to one third the height of the weir.
 - for the “unusual” load case, to crest level of the weir.
- seismic: an “unusual” load case involving increased horizontal forces induced by a ground acceleration earthquake event. This is typically represented as a horizontal acceleration acting at approximately 0.4 times the height of the weir above the foundation level.
 - for weirs less than 10m in height, a pseudo static loading of 0.1 gravity is appropriate.
 - for weirs greater than 10m in height, the ANCOLD Guidelines for Design of Dams and Appurtenant Structures for Earthquake (ANCOLD, 2019) should be applied with peak ground accelerations determined for the site area.

7.8.4 Stability acceptance criteria

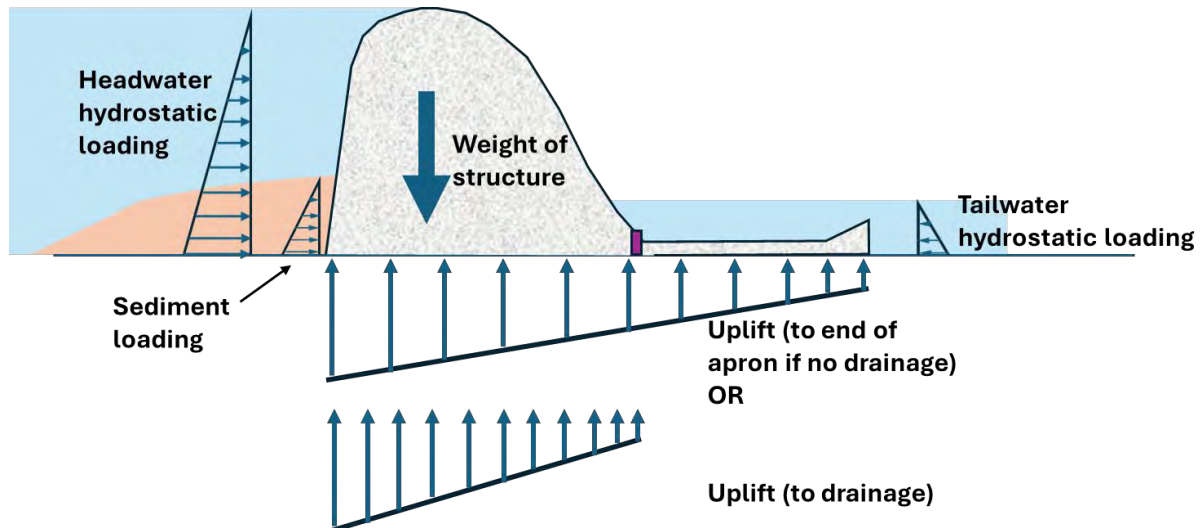
Overturning

- for the “usual” load cases, the resultant location (sum of moments/sum of vertical forces) should be in the middle third, uncracked.
- for the “unusual” load cases, the resultant location (sum of moments/sum of vertical forces) should be in the middle half, up to 25% cracked.

Sliding

- The sliding factor of safety (FoS) is equal to (sum of vertical forces x tan friction angle + cohesion x uncracked base length)/sum of horizontal forces.
- Where the friction angle for bonded concrete joints can be assumed as 57° and cohesion 950 kPa.
 - for the “usual” load cases, the sliding FoS should be at least 2.
 - for the “unusual” load cases, the sliding FoS should be at least 1.5.

Figure 23 Diagram showing typical force loads on a weir monolith



7.8.5 Apron loadings

An apron for a weir is typically 600mm to 800mm thick, with two layers of reinforcement. The cover to the upper layer of reinforcement should be 150mm. This is to allow for the impact of debris on the upper surface during periods of overflow.

Loadings on an apron include:

- self-weight of the apron itself
- hydrostatic *loading* from the depth of water over the apron,
- uplift pressures assumed to act over 100% of the apron area
 - for the “usual” case, equal to tailwater level
 - for the “unusual” case, linear from the upstream face of the monoliths to tailwater level at the downstream end of the apron, assuming that the drains are ineffective.
- dynamic uplift pressures acting during periods of overflow, as measured from PHM transducer data.
 - These pressures typically only impact the upstream sections of an apron and become less significant for higher depths of overflow, with higher tailwater levels.
 - Grouted anchor bars are sized and spaced to resist the net uplift assessed, as above.

7.8.6 Concrete

For concrete gravity weirs, the volume of concrete required is usually too small to justify use of roller-compacted concrete and so conventionally compacted concrete of two strengths is typically used.

For the spillway monoliths, mass concrete (S20) target strength 20MPa at 90 days is typically used. A maximum aggregate size 75mm is used, with cement and fly ash cementitious materials. Using higher-strength concrete on the downstream face is generally not justified and would unnecessarily complicate concrete placement.

S20 concrete is also adequate for dental concrete and seam treatment.

For structures including spillway apron and end sill, outlet works, fish passage structures and protection slabs, structural concrete (S32) with a target strength 32MPa at 90 days is typically used. A maximum aggregate size of 40mm is used, with cement and fly ash cementitious materials.

Commercial suppliers are preferred for smaller weir projects, if they are within economic distance of the site.

For larger projects where onsite batching is required, trial mixes are required to optimise the mix and to limit heat of hydration.

7.9 Bed and bank protection

Where the bed or banks are comprised of erodible materials, adequate protection works are critical to a successful weir project.

Protection works may include:

- reinforced concrete slabs
- concreted rockfill
- rock-filled wire gabions and mattresses
- rock-filled wire sausages
- riprap.

Although historically used in weir construction, concreted rockfill is no longer favoured because it tends to crack over time. This causes fines underneath to be sluiced out, forming voids that can lead to structural failure (see section 12.4).

Similarly, rock-filled sausages are also not preferred, because they provide limited protection where adjacent sausages abut each other.

In areas of greatest turbulence and higher velocities, reinforced concrete slabs are preferred, especially if debris impact is likely. Slabs can be constructed on-ground with articulated joints, or in areas subject to extreme conditions, be supported on driven rows of steel sheet piling.

The Reno Mattress Design Method (Agostini et al., 1985) provides guidance for determining where mattresses are suitable and for determining their thickness and spall filling requirements. Reno mattresses need to be placed on a filter fabric, anchored and tied together in accordance with the manufacturer's recommendations. It is particularly important that mattresses are anchored at the top of the banks to an embedded tie beam to prevent them from sliding down slope. South Maclean Weir is an example of this (Figure 24 and

Section 12.4). In areas subject to wetting and drying, PVC coated galvanised wire mattresses are required.

The methods outlined in the *United States Bureau of Reclamation EM 25 - Hydraulic Design of Stilling Basins and Energy Dissipators* (USBR, 1984) can be used to size riprap protection for a range of velocities. These methods allow determination of appropriate layer thickness, as well as D_{50} and D_{max} sizes for a well-graded layer. Riprap should be placed on a filter fabric.

Velocities downstream of a weir can be estimated using modelling, PHM or CFD. For smaller structures where PHM is not practical or cost-effective, performance of protection works at similar existing weirs can provide useful guidance for designers.

Environmental considerations influence the design of bed and bank protection. This includes understanding how protection works influence flow conditions and local turbulence patterns. Certain protection types may introduce risks—for example, gabions can entrap fish, and the exposed wire mesh can cause injury and mortality during overtopping events. Permeable scour protection may also affect safe fish passage.

Figure 24 **South Maclean Weir – Logan River - Slumping of bank protection works**



7.10 Fish passage

Approvals processes associated with environmental provisions for weirs are described in Section 5.

Structures providing for safe fish passage can range in complexity in their design. Key design considerations:

- Fishways must operate effectively across a range of operational flow conditions. They are required to provide passage within defined ranges of velocity, turbulence, water depth and gradients that are preferred by particular fish species. Performance can also be influenced by fishway length and the availability of resting areas or cover within the structure.
- Fishway length, and the need for access to resting pools or cover within the fishway, can affect fish passage success.
- Rock ramp fishways require careful rock placement and construction.
- Bypass fishways need resting pools and riffles.
- Vertical slot fishways can be complex concrete, sheet piled and/or steel structures potentially requiring multiple entrance and exit (gated) slots operated to cater for variable upstream and tailwater levels.
- Entry and exit design needs to attract fish into the structure under a range of riverine flow conditions and allow safe exit up or downstream.
- Lock and lift fishways have moving parts and need a protected power supply both of which can be vulnerable to flood conditions, siltation and debris.
- All fishways require some degree of maintenance for the in-situ life of the weir.

It is important that the species of aquatic fauna likely to use the fishway are appropriately surveyed and identified (Section 6.5) and their behaviours understood. From this, the type of fish passage facility which might be provided depends on the height of the weir and the fish community at the site:

- Weirs up to 2m height: rock ramps or cone fishways can provide an effective, low capital and operating cost option for a range of aquatic fauna. Bypass fishways may also be appropriate where adjacent land is available, although there are limited examples of these in Queensland.
- Weirs between 2m to 6m height: where headwater variation is limited a fish bypass may be used. These structures are similar to a rock fishway but usually have a gentler slope (around 1:50) and are designed to mimic natural stream conditions, including pools, riffles and a meandering earthen or rock channel.
- Weirs between 6m to 7m height: fish ladders, such as vertical slot fishways, can be effective provided peak flow velocities are not too high and resting pools are provided. These structures require ladders be of considerable length, relative to the height of the weir.
- Weirs higher than 6m to 7m: fish locks, fish lifts or similar systems may be required. These are more complex systems that rely on sensors, power supply and mechanical actuators to operate gates and valves. For example, Rookwood Weir, has a three-chamber lock system allowing fish to pass over a range of headwater and tailwater levels.

The siting of the fishway, including which side of the weir, entrance location, etc, is critical to its success and should consider the location of the river channel during low flows, likely attraction flows, changes in flow regime before and after the weir is built, proximity to outlet works and access for operations and maintenance. Large fish passage structures can influence or disrupt hydraulic conditions at a weir during high flow events, especially if located on one bank of the weir and causing non-uniform river flows. This not only influences fish passage performance but can also cause scouring and erosion.

A fish passage biologist should be included in a weir design team (preferably throughout the project) to ensure environmental aspects are appropriately incorporated into design. This is especially the case for more complex structures installed at larger weirs.

Figure 25 to Figure 27 show a variety of fish passages in Queensland.

Fish and other biota passage options are further explored on the [Queensland Government Wetland information website](#).

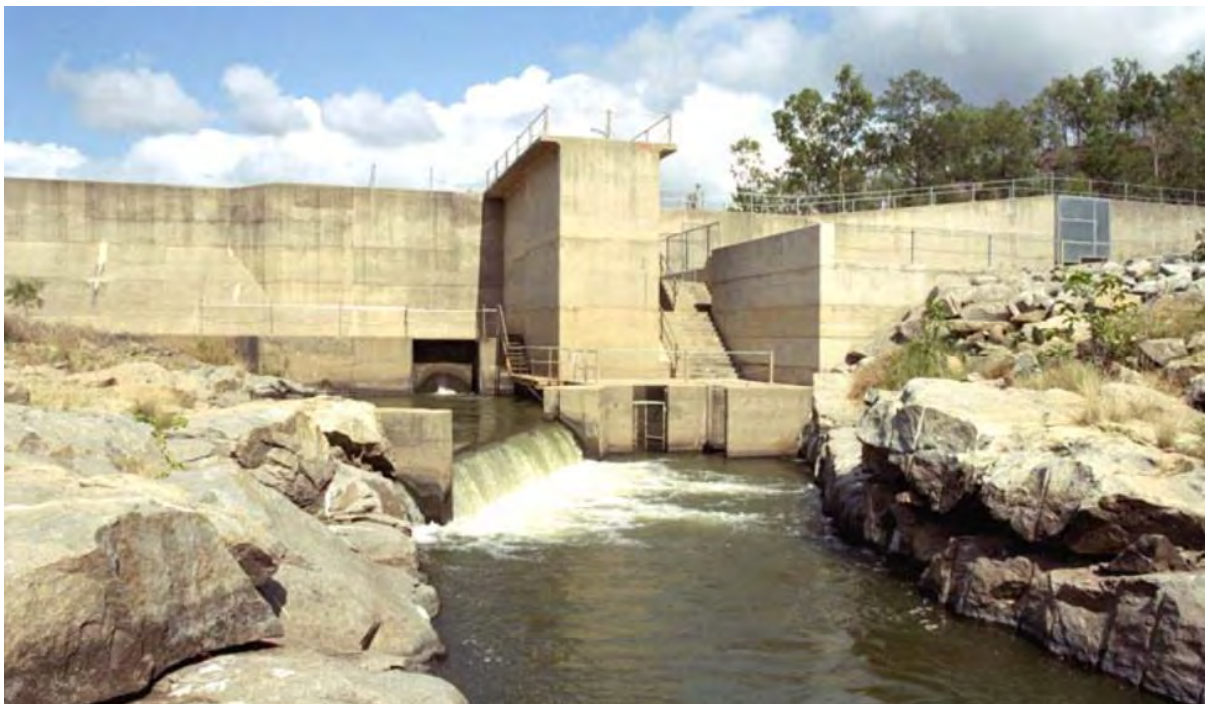
Figure 25 **Rock ramp fishway at Jolimont Creek Weir (Catchment Solutions, 2025)**



Figure 26 Vertical slot fishway at Bromelton Weir, Logan River (Sunwater, 2025)



Figure 27 Fish lock at Eden Bann Weir, Fitzroy River (Sunwater, 2025)



7.10.1 Turtle ways

The turtle way on the right abutment at Rookwood Weir (Figure 28) was a condition of the environmental approvals for the weir to reduce the impact on two threatened species of freshwater turtle found in the Fitzroy River basin. It is the first such facility on a weir in Queensland.

The turtle way comprises a reinforced concrete trough, which extends from a low level up to the top of bank on both upstream and downstream sides of the weir, passing through the weir abutment at a high level.

The maximum slope of the trough up the banks is 45°. Resting pools 0.5m deep are provided at 15m intervals. A small pump provides a trickle flow which keeps the floor of the trough wet at all times.

This arrangement was developed with support from expert advice on turtle movement behaviour by the Queensland Department of Environment, Tourism, Science and Innovation.

A condition of the environmental approvals for the weir included a rigorous monitoring program of the effectiveness of the turtle way. This program is currently being implemented and will continue for several years. As of 2026, the turtle way design is considered experimental, until proven through adequate monitoring data.

Figure 28 Turtle passage and fish lock at Rookwood Weir, Fitzroy River (Sunwater, 2025a)



7.11 Outlet works

Outlet works may initially serve as part of a diversion scheme during construction (see Section 8). They are designed to allow controlled releases from the storage to downstream areas. These releases are required to:

- maintain environmental flows in accordance with the relevant basin water plan
- meet water allocation requirements for water users
- comply with conditions of an approved environmental impact statement.

These requirements generally lead to a design discharge requirement at a minimum operating level (MOL). The sizing of pipework, gates and valves will be based on this discharge, allowing for head losses across all components.

The outlet works must meet not only the discharge requirements but also other project objectives. These include environmental outcomes (such as water quality and fish passage), operation and maintenance requirements and workplace health and safety requirements.

Where feasible, outlet works should be designed so that normal operational flows are preferentially directed through the fishway. This helps optimise duration of operation and maintain effective attraction flows.

The economic significance of the downstream releases should also be considered when determining the outlet configuration. For example, if large and reliable releases are required then multiple outlets may be justified rather than a single outlet. For example, at Rookwood Weir the volume of water to be released for urban, industrial and irrigation purposes exceeds that of several of the state's large dams, and multiple outlets have been provided.

In contrast, the majority of recharge weirs in Queensland have relatively simple outlet arrangements, typically consisting of nominally sized outlets.

The components of a weir outlet may include:

- An inlet structure: fitted with upstream screens to prevent fish or debris from entering. Historically, screen bar spacings of 75mm was used; however, spacing of 20mm is now typically used to minimise fish entry. Screen arrangements should also minimise the entrainment of aquatic fauna and debris.
- A baulk system (for higher weirs): to enable selective withdrawal of higher-quality water from the storage, either in a stack system or with the baulks in separate slots.
- A guard gate capable of closing against flow, such as a wheeled vertical gate.
- One or two pipes or conduits through the weir structure
- A second guard provision, such as butterfly valve
- Provision to regulate flows such as plunger or fixed cone dispersion valve. For smaller weirs, a gate valve may be sufficient.
- An outlet structure, including energy dissipation.

For all components, materials should be selected to minimise maintenance requirements. Provision should also be made for access for plant and personnel, particularly for mechanical and electrical components.

8. Construction

8.1 Diversion during construction

Weir structures are usually located entirely within the bed and banks of a stream. As a result, construction programming and the provisions for diversion of stream flows during construction are important considerations.

There are differing approaches to providing flow diversion during construction. However, as a general rule (especially for weirs on soft foundations) works cannot proceed during wet season, as diversion of wet season flows at reasonable cost is generally not feasible. For concrete gravity weirs founded on rock foundations, there may be opportunities to undertake work across the riverbed during low-flow periods, subject to the provisions detailed in Section 8.3.

The selection of diversion capacity requires a balanced judgement between construction effort, the likelihood of construction delays due to a flood and the risks and timings associated with making the construction site safe before inundation. These considerations depend on factors such as diversion capacity, catchment characteristics, the nature and timing of construction activities (and their resilience to inundation) and the reliability of rainfall and runoff forecasts.

An effective diversion arrangement typically uses an open channel with upstream and downstream coffer dams. This is particularly suitable where the channel is excavated through a rocky abutment, allowing for higher flow velocities without erosion. Such a channel may then be ultimately incorporated into the outlet works or fish passage facility.

For concrete gravity weirs founded on rock, leaving one or more central monoliths at a lower level can provide an effective diversion.

For narrow sites with soft bed and banks, the diversion options are more limited. In these cases, a pipe installed through a bank may be used. After completion of the weir, and with the installation of a control gate or valve, this can function as an outlet works. However, piped diversions have significantly lower capacity than an open channel diversions.

The diversion of stream flows during construction needs to cater for fish passage and be designed accordingly.

8.2 Overtopping during construction

Construction activities must consider the risks of flood events that cause overtopping of the works or disrupt or damage the construction site. These risks are influenced by weather conditions, especially rainfall, which can vary over time and are often difficult to predict.

Managing these risks requires an understanding of rainfall and runoff characteristics at the site. This includes temporal variability and the likely causes, likelihood and severity of significant events (such as cyclones or monsoonal activity). It also requires an understanding of the time needed to respond effectively to an approaching flood event.

Factors to consider include:

- Scheduling: adjust construction activities, or limiting critical construction activities, to reduce exposure to flood risks.
- Flood forecasting: Use forecasting tools that can provide sufficient lead times to allow for practical actions.

- Warning and response procedures: establish clear processes to address the risks prior to arrival of the flood event.
- Site preparedness: maintain a stockpile of materials and equipment on-site to use at short notice, if required.

8.3 Sequence of construction

Construction contracts should include provisions to ensure that damage to the bed and banks and to partially complete works, in the event of overtopping during construction, will be minimised. This is particularly important for sheet pile or embankment weirs on soft foundations, and less critical for concrete gravity weirs on rock foundations.

As construction proceeds, the waterway cross-section becomes increasingly constricted. During elevated flow or flood events, this can increase the risk of scour and damage, particularly immediately downstream of the constriction.

To manage the risk, construction works should proceed from downstream to upstream, with the following sequence of construction:

- complete works sequentially from downstream to upstream, ensuring protection works for each section are in place, before starting the next upstream section
- advance symmetrically from the banks towards the mid-stream of the channel.

8.4 Concrete placement scheduling

Larger concrete gravity weir structures are typically constructed monolith by monolith, with lift heights of each successive concrete pour not more than 1.5m depth. The sequencing and timing of pours must consider proper adhesion between successive lifts, curing times and the use of onsite batching plants and temperature control measures where required.

Subject to local conditions and constraints, construction of monoliths should be sequenced to maintain symmetry across the watercourse. Central monoliths should be kept lower than bankside monoliths to minimise risk of bank erosion.

Construction sequencing for conventional mass concrete placement, which requires formwork preparation, differs from roller compacted concrete (RCC) placement. RCC is placed in horizontal layers or lifts, with layer lengths optimised for efficiency.

8.5 Assurance of construction activities

Risks may emerge during construction that require amendments to design. Any significant changes should be reviewed, preferably by the original designer, to ensure the design intent is maintained. Inspections by the designer during construction may be necessary to verify any amendments.

On completion of construction, as-constructed documentation should be prepared. This should:

- document any design changes made during construction
- describe any changes in expected performance or condition
- include as-constructed drawings which confirm the final lines, levels and dimensions of the structure
- identify any differences between as-built and original design.

Certification may also be required (Section 9.4).

8.6 Commissioning

Commissioning marks the completion of weir construction and readiness for operation. At this stage there should be documented evidence that the structure performs in accordance with the design philosophy and intent. Documentation describing all phases of the build are complete and arrangements for effective operation and maintenance are in place, including appropriately skilled personnel.

The first significant inflow event following construction is often associated with an elevated risk of damage. Specific monitoring and, where appropriate targeted or special inspections may be considered.

8.7 Decommissioning

Weirs are rarely decommissioned.

The following environmental, economic, and social issues should be considered:

- The owner should identify and understand all relevant requirements when planning decommissioning, particularly to ensure sustainable, minimally erosive storage basin conditions prior to removal.
- Identify, inform and engage with all relevant authorities and stakeholders.
- Provide for safe release of stored water.
- Provide for treatment and safe disposal of silt or contaminated soil.
- Assess changes to hydraulic conditions.
- Consult with downstream residents and landholders.
- Implement measures to minimise impact on downstream communities.

9. Project delivery

9.1 Procurement

Procurement is the process to identify, engage and deliver services. Aspects to consider are summarised in the following table.

Table 6 Summary of aspects to consider when procuring weir projects

Aspect	Discussion
Procurement model	<p>The asset owner should be fully engaged in the planning and implementation of any procurement process.</p> <p>Procurement models range from those where a project is allocated to a single entity (e.g. construct only, design and construct delivery models) to those where multiple entities, including the asset owner, share responsibility for project delivery (e.g. alliance delivery model). Choice of delivery model will depend upon a multitude of factors that include project complexity, the ability to reasonably apportion risk and the skills and the resources of each party to manage the identified risks.</p> <p>In contrast to dams, weir projects are typically less complex and more traditional, sequential project deliveries rather than alliance models may be preferred.</p>
Optimism bias	<p>For all infrastructure projects there is a tendency for 'optimism bias'; an assumption that risks will not be realised and that the project can proceed without fully addressing those risks.</p> <p>In contrast to dams, weirs are typically less complex and less prone to unanticipated emerging risks and significant costs during project delivery. Nevertheless, commensurately thorough investigations and design effort is recommended, as is consideration of constructability as part of design.</p>
Project Scope Definition	<p>Key project outcomes and the owners' requirements for the completed works need to be clearly defined. Existing and historical site data needs to be collected, collated and checked.</p> <p>Project uncertainties are reduced if sufficient investigations and design work are completed as part of developing tendering documentation.</p>
Approvals	<p>An assessment of the required project approvals is recommended before any tendering activity. Approval delays and conditions present significant schedule and commercial risks for the asset owner.</p> <p>Where feasible, approvals should be obtained before contract award.</p> <p>Safety in Design and ongoing operations, maintenance and surveillance are long terms considerations that need to be adequately addressed with the owners' operational teams during project delivery.</p>
Budget and Finance	<p>Risks may be realised during the project that incur additional time and cost to address. This should be considered and incorporated into the procurement model.</p> <p>Management of flood events and day to day operations need careful consideration and often impose constraints impacting construction productivity. These impacts need to be evaluated in the development of the project budget.</p> <p>Sufficient contingency should be provided to account for any additional expense associated with the emergence of risks.</p>
Risks	<p>Investigation works conducted prior to project design and construction, especially with regard to site geology, can increase the understanding of risks and improve project outcomes.</p>

Aspect	Discussion
	<p>Often only a small proportion of risk can be assigned to other parties other than the water asset owner, who is responsible for ongoing water delivery which requires a fully functioning and operational weir.</p> <p>Fairness and capability are considerations when allocating risks and technical aspects prioritised when making procurement and project delivery decisions. Unreasonable allocation of risks to parties who are not well positioned to manage them can result in overly conservative costings and/or poor project delivery.</p> <p>Flexible timeframes and management of variations should be factored into contractual arrangements.</p> <p>Contractual arrangements should clearly set out how each party is to identify, document and respond to an emergence of risks, ensuring that identifying and delivering an appropriate technical solution is the focus.</p>
Resources	<p>Within the constraints of probity, early engagement with industry participants, including potential construction contractors, is recommended.</p> <p>All parties should have suitably skilled staff engaged during procurement; in particular the asset owner should be an “informed client”.</p>
Project Culture	<p>Outstanding project outcomes occur when a project team works together respectfully to deliver outcomes. Creating a positive work culture and associated behaviours can assist to minimise conflicts and disputes.</p>

9.2 Technical review

The role of technical review, that is expert and independent of owner, designer and constructor, can be a valuable, affordable resource to promote better design and construction, especially where novel or innovative methods are proposed. Such a review can provide detached advice and scrutiny that is unlikely to be influenced by the time and commercial constraints under which designers and contractors usually operate.

In Queensland, dam projects require a technical review process under state regulations (RDMW 2024), as per a recommendation from State of Queensland (2020), and based on industry guidance (Davidson 2019 and Nielsen et al 2023). Its implementation has been widely regarded as successful (Nielsen et al 2023).

Although weir projects are typically less complex than dam projects, use of technical review can still provide valuable technical assurance.

9.3 Documentation

Weirs typically have long operational lives; in Queensland, very few have been decommissioned. This highlights the importance of maintaining good records to ensure critical information is not lost, particularly for future maintenance or upgrade works.

Key records—such as as-constructed drawings, design and performance criteria and rationale, operating manuals, geological records and samples and records of the exposed foundations observed during construction—provide valuable information for future repair or upgrade.

9.4 Certification

Certification is a formal statement of obligation and responsibility for the successful outcome of a project. It provides critical technical assurance and is recommended for weir projects.

Certification is done by a suitably qualified and experienced Registered Professional Engineer of Queensland (RPEQ) who is engaged in all aspects of the project. They should certify technical assurance elements, including engineering design, compliance with regulatory requirements, adherence to good practice, reliability of information and data used, appropriate documentation of decision making and compliance to documented processes.

Certification of specific elements, such as design, construction or components of design, is expected to be a requirement under the *Professional Engineers Act 2002*. The project proponent may also consider a whole-of-project certification requirement at commissioning stage, providing a final technical assurance.

10. Operation and maintenance

10.1 Operation and maintenance manual

Operation and maintenance manuals should be completed as construction is nearing completion. This ensures that commissioning can proceed, the weir can be operated safely and efficiently and that components are maintained so the structure continues to perform as intended over its life.

An operation and maintenance manual should include comprehensive detail of the weir structure including registers of as-built drawings and schematics for all systems and services installed in the weir, compliance requirements, safety issues and emergency procedures to respond to critical situations.

Manufacturer's information relating to all equipment installed in the weir should also be included.

The manual should detail surveillance and monitoring activities that are capable of detecting problems at an early stage so that timely and effective corrective measures can be applied. This is particularly so for flood events; an understanding of spillway performance during high flows can provide valuable insights into ongoing structural resilience and potential failure modes. Monitoring feedback and outcomes should be used to regularly update the operating and maintenance manuals through ongoing feedback to the weir operator.

After commissioning of a fishway, surveillance and monitoring activities are required to confirm that design criteria and performance outcomes are being met (often this is an approvals requirement). The monitoring would include comparison of fish approaching the weir, at the entrance and then at the exit of the fishway, trapping within the fishway and, over time, any changes to fish communities above and below the weir. In addition, event-based monitoring would record any injuries or mortalities of aquatic fauna as a result of downstream passage during overtopping events. Trapping infrastructure and access should be incorporated into the design and budget for the weir as should the monitoring program.

Fishways can be impacted by debris and sedimentation, especially following flood events. As significant fish movement takes place during flood recessions it is critical that clearing and repairs to fishways and restoration of design hydraulics in the approach, entrance and through the fishway are prioritised.

Given that weirs are subject to overtopping involving high velocities, turbulence and debris impacts, the risk of deterioration of a weir structure over time, particularly of its protection works, is high. For example, Section 12.4 describes how concreted rockfill protection works deteriorates over time. Condition monitoring is an important element of an operations and maintenance manual, considering the surveillance and monitoring activities to support and capacity to undertake remedial works promptly when required, is essential. It is critical for example that the condition of protection works is checked after each significant flood event and any damaged areas repaired prior to the following wet season.

See also Section 12.6.

10.2 Resource operations licences

A resource operations licence issued under the *Water Act 2000* may be granted for a weir. The licence typically includes:

- details of the relevant water plan
- description of the weir infrastructure details covered by the licence
- conditions that the licence holder must comply with, including operating arrangements and water supply requirements
- any transitional arrangements required before full compliance with the water plan can be met.

Typically, the licence will include environmental management rules, monitoring and reporting requirements.

11. Competencies

11.1 Skills

Successful weir projects rely on a combination of practical experience and a thorough understanding of the underlying physical, environmental processes and associated scientific and engineering fields. Asset owners should ensure that all personnel involved have appropriate qualifications, registrations, knowledge and experience relevant to the type of weir and the task required.

In Queensland, engineering services must comply with the *Professional Engineers Act 2002*, which requires a registered professional engineer of Queensland (RPEQ) to undertake or directly supervise an engineering service. Attributes in addition to those for an RPEQ are often required; such a person could be described as a “suitably qualified and experienced RPEQ” (RDMW 2024).

Weir projects require a broad range of skills which are unlikely to be held by a single individual. A multidisciplinary team is often needed, supported by effective leadership, communications and defined reporting lines. The asset owner plays a key role in establishing a team culture that supports good project outcomes.

Development of the skills required to operate and manage the weir should be included as part of project delivery.

11.2 Conduct

Professional conduct of individuals engaged in weir projects should align with the codes of conduct of relevant professional bodies, have integrity and be guided by the following principles (adapted from ACSE, 2017 and BPEQ, 2019):

- work within areas of competence and recognise limits of personal knowledge and skills
- maintain awareness and understanding of current developments in relevant technical fields
- act with honesty and integrity in all aspects of conduct, specifically in communication
- be accountable for professional work and conduct
- treat others with professionalism, fairness and respect
- act without discrimination or prejudice
- demonstrate responsible stewardship on behalf of others
- maintain continuing professional development and training (including requirements for RPEQ and Engineers Australia)

12. Lessons learned

In 2023, as part of the Rookwood Weir Project technical review panel process, a review of lessons learned from weir incidents in Queensland was undertaken. This drew on the experience of departmental engineers involved in the design, construction and repair of numerous weirs.

Summary data was compiled on 24 weirs (see Appendix B) that had experienced significant damage, including details of the repair work required and lessons learned.

This work was later expanded to include learnings from other water infrastructure projects in Queensland, including the Rookwood Weir Project and dam upgrade projects (RDMW, 2024).

The common themes identified are outlined below. These include specific examples and illustrations and broader observations based on professional judgement.

12.1 Excessive afflux

Excessive afflux was identified as a dominant cause of damage in the majority of the 24 weirs analysed. In many of the earlier cases, the excessive afflux resulted from inaccurate tailwater rating curves.

Advances in numerical modelling now enable longer river sections to be analysed, with parameters such as roughness coefficients calibrated using data from stream gauging stations where rating measurements taken by hydrographers are available.

Other causes of inaccurate rating curves have been survey datum errors. In some cases, construction of upstream infrastructure has also affected tailwater levels. For example, the construction of Wivenhoe Dam altered tailwater levels during flood events at O'Reillys Weir on Lockyer Creek.

12.2 Flow behaviour during overtopping

A number of weirs, particularly many of the groundwater recharge weirs in the Lockyer Valley, suffered extensive bank erosion on first overtopping after construction.

These weirs were generally not large enough to justify the cost of detailed hydraulic modelling, such as CFD or PHM. They were often sited at suboptimal locations, characterised by asymmetric stream cross sections and steep unstable banks. Flows over the weirs were turbulent for considerable distances downstream resulting in bank erosion damage downstream of the protection works.

Fortunately, flow events in Lockyer Creek typically recede quickly, enabling timely repair of eroded banks and extension of protection works.

It is likely the extent of damage would have been reduced if sites with more favourable conditions had been available—namely long straight stream sections, symmetrical cross sections and more stable, flatter bank slopes.

12.3 Inadequate geotechnical investigations and treatments

Permeable strata overlying bed rock under the alluvial left abutment of Ned Churchward Weir on the Burnett River was not well identified by geotechnical investigations. During construction, attempts to drive steel sheet piling through coarse gravel materials overlying the bed rock—intended to provide a seepage cut-off within the alluvial bank—were unsuccessful.

Upon filling there was seepage through the abutment. Shortly after filling the abutment toe became saturated, leading to instability and bank slumping that threatened the protection works.

To address the issue, a concrete wall was constructed at the abutment toe to buttress the bank and mitigate further slumping.

Similar geotechnical conditions were later detected at the left abutment of Rookwood Weir. In this instance, a slurry trench cut-off wall was installed during construction, providing a more reliable method of intercepting seepage pathways through the permeable gravels.

12.4 Use of concreted rockfill protection works has proven to be inadequate

Concreted rockfill protection works has proven to be unreliable over the longer term. This treatment is prone to cracking. Once this occurs, voids can develop beneath the surface layer, ultimately leading to collapse.

Riprap protection has performed poorly in cases where the rock spalls have not been large or well graded enough or the riprap layer not thick enough. The absence of an appropriate filter layer or of filter cloth beneath the riprap has also resulted in erosion.

Rock-filled mattresses laid on a filter cloth have generally provided more effective bank protection at many weirs provided that any damaged areas are promptly repaired. It is also critical that mattresses are adequately anchored at the top of the bank to prevent damage, as demonstrated by failure at South Maclean Weir (Figure 24). See also Section 12.5.

Rock-filled mattresses have been found to entrain and kill significant numbers of migrating fish in NSW.

12.5 Inadequate erosion protection works

Failure of protection works has led to major bank erosion and, in the case of Marian Weir on the Pioneer River, complete bypassing of the weir on the left bank. Following the event, the weir overflow section was extended across the breach and a new left abutment constructed.

Figure 29 Marian Weir – Pioneer River – bypassed around the far bank



Figure 30 Newspaper articles describing the Marian Weir damage (Cairns Post, Wed 10 Feb 1954 and Bundaberg News, Thu 11 Feb 1954 (Trove, 2025))



12.6 Inadequate condition monitoring

Protection works are subject to turbulent overflow conditions and can also be impacted by debris, including tree trunks carried over a weir during flood events. Over time, concreted rockfill is prone to cracking, and wire mesh retaining the rock spalls in mattresses can be disrupted. Galvanised wire mesh will over time corrode and lose strength.

Regular inspection after each significant flood event is therefore necessary to identify damage and undertake repairs. Repairs should generally be completed in a timely manner and prior to subsequent flood events to prevent further deterioration.

At Mungungo Weir in the Burnett River catchment, constructed in 1951, damage sustained during a 2011 flood event was not repaired before another major flood event in 2013, resulting in significantly more extensive damage.

At Bedford Weir an inflatable rubber dam was installed on the crest of the existing concrete gravity weir in 1997. In 2016, a section of the rubber dam split without warning, leading to the sudden and unexpected increase in discharge. The incident resulted in the tragic drowning of a small child. A coronial enquiry found that the weir owner, Sunwater, had not inspected the facility with sufficient thoroughness and recommended the removal of all rubber dams in Queensland.

12.7 Design deficiencies

A number of weir failures in Queensland have been attributed to designs that did not adequately account for the loads imposed upon them.

At Gyranda Weir, on the Dawson River, the design allowed for significant settlement and movement that was predicted for the 11.8m high stepped steel sheet piling weir founded on a clay foundation. As a result, the horizontal concrete slabs between each row of piling were not connected to the downstream row of piling. Stagnation water pressures at the end sills during periods of overtopping were able to penetrate under the slabs causing many of the thin slabs to fail by upward bending. The likelihood of failure was increased by poor reinforcement placement; for many of the slabs, the single layer of reinforcing was not placed centrally in the slab as specified but rested on the underlying sand during concrete placement.

This failure resulted from a combination of design deficiency and poor construction practice.

The slabs were subsequently replaced with thicker sections incorporating two layers of reinforcement and were connected to the downstream piling.

At the Neville Hewitt Weir on the Dawson River near Baralaba, the top lift of the concrete gravity spillway section detached during a flood of smaller magnitude than the weir had previously withstood (Figure 31). Initially, this was attributed to deterioration in cohesion and friction across the lift joint over time. However, later anecdotal evidence suggested that explosive fishing practices upstream of the weir crest could have been sufficient to damage the lift joint. Such loading would not reasonably be anticipated in design.

This example highlights the importance of surveillance and monitoring to detect unusual risks and behaviours at weirs.

Figure 31 Neville Hewitt Weir - Dawson River – reconstructed top lift is clearly visible



12.8 Shortage of locally experienced engineering teams

There is limited weir design experience in Queensland across most technical disciplines and project participants. This reflects the relatively small number of weir projects undertaken in Queensland in the past decade.

Future weir projects should recognise this capability gap. Project teams should seek expertise beyond Queensland where required, and emphasise knowledge transfer, training and development of local skill as part of project delivery.

12.9 Challenges interpreting computational fluid dynamics

In Queensland, physical hydraulic modelling (PHM) is generally regarded as the primary method to understanding complex hydraulic situations, such as spillways.

Recent applications of computational fluid dynamics (CFD) to weir and dam projects have not always been clearly described and documented, with accuracy, reliability and parameter sensitivity not clearly stated. This has led to uncertainty in predictions and reduced confidence in findings and recommendations.

These challenges can undermine the valuable insights that CFD can provide, and how CFD and PHM can complement one another when used in combination to improve the understanding of complex hydraulic behaviour.

12.10 Durability

The choice of construction materials can impact durability and ongoing maintenance requirements. For example, gabion weirs are often cost-effective upfront to construct but are more susceptible to damage under high-energy flow conditions and to long-term degradation.

A whole-of-life asset management approach should be adopted, considering all components of the weir, including the spillway, bank protection works and fishway. This should include realistic estimates of service life and ongoing maintenance requirements.

Figure 32 Gabion stepped weir at Robina, constructed in 1997 (top, Gonzalez et al 2008) and still operational (bottom, Google Maps). The weir impounds a small water body and is not exposed to high energy flow conditions.



12.11 Regulatory complexity

Weirs by definition are a waterway barrier that can impact aquatic ecosystems, especially fish and turtle passage and changes to habitats. Early and ongoing engagement with relevant regulators and stakeholders is essential to streamline approvals, support effective designs and manage project costs.

12.12 Efficiency and productivity in project delivery

Productivity in civil infrastructure project delivery in Australia has declined in recent years (Infrastructure Australia, 2024). Opportunities to improve outcomes include greater transparency, more collaborative contractual arrangements, a stronger focus on constructability in design and improved on-site execution.

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14. Relevant legislation and policies

14.1 Commonwealth

Environment Protection and Biodiversity Conservation Act 1999

14.2 State

Aboriginal Cultural Heritage Act 2003

Environmental Protection Act 1994

Environmental Offsets Act 2014

Fisheries Act 1994

Nature Conservation Act 1992

Planning Act 2016

Queensland Environmental Offsets Policy, Department of the Environment, Tourism, Science and Technology

Regional Planning Interests Act 2014

State Development and Public Works Organisation Act 1971

State Development Assessment Provisions (SDAP) Code 18, Department of State Development, Infrastructure and Planning.

Water Act 2000

Professional Engineers Act 2002

Appendix A Hydrologic and hydraulic analysis methods

A-1 Hydrology

Assessment of catchment hydrology is required to confirm that sufficient yield is available to support water storage requirements, environmental flow requirements and consumer demand. This often involves continuous hydrological modelling, rather than event-based modelling, supported by statistical analysis to predict probability, duration and severity of low-flow events that may impact reliability.

Alternatively, a gauging station on the same watercourse with a long duration discharge time series record can be used to inform yield. This requires statistical analysis of the record and scaling according to the difference in catchment areas upstream of gauge and weir location.

While hydrological assessment to inform flood risk is often a separate exercise using event-based approaches, continuous modelling approaches can provide insights into durations of overtopping events.

A combination of hydrologic and hydraulic analyses is used to identify the critical flow events that cause maximum afflux and energy conditions at the weir. This requires prediction of flood discharge, frequency and duration from channel bed level to top of bank.

Estimation of more extreme flood events, such as up to and approaching the probable maximum flood (PMF), is of less or no relevance for weir design. Once drowned flow conditions occur at a weir there is typically little to no afflux (see Section 1.5). However, PMF estimates can inform maximum inundation extent and flow rates.

Flood frequency analysis provides a comprehensive understanding of flow conditions and associated probabilities and is a valuable input to design and construction planning.

Predicting the frequency and duration of overtopping of various weir elements, such as the weir abutments, can inform the type and extent of protection works and whether any necessary repairs can be completed before future flood events. For example, frequent and prolonged overtopping at Rookwood Weir on the Fitzroy River influenced the design of left abutment protection works.

Hydrological assessment also informs construction planning, including river diversion and flood risk management during construction (see Section 8). Reliable operational hydrologic modelling can support decision-making during construction.

Environmental considerations require analysis of flow timings and durations pre-and-post weir construction.

All hydrological models should be calibrated and verified against measured data where available. This can include comparison of flood frequency analyses at nearby gauging stations.

A-2 Simplified hydraulic analysis methods

A-2-1 Manning's equation

The Manning's equation calculates water depths in an open channel for a given flow:

$$Q = \frac{1}{n} A R^{2/3} S^{1/2}$$

Where Q = discharge (m³/s), n = Manning's roughness coefficient, A = flow area (m²), R = hydraulic radius (A / P), where P = wetted perimeter (m) and S = energy slope = channel bed slope (for uniform flow). If a wide channel is assumed (ie the channel width b is much greater than the normal depth y_n) then the equation simplifies to be:

$$y_n \approx \left(\frac{Qn}{bS^{1/2}} \right)^{3/5}$$

A tailwater rating curve can be established using these standard formulae, noting there is complexity in calculation of area and wetted perimeter and sensitivity to selection of the bed slope value. Sensitivity testing may be necessary to better understand the reliability of estimated tailwater conditions.

As discussed in footnote ¹⁰, the use of the Manning's equation should be limited to first-pass estimates of flow conditions. Numerical modelling (Appendix A-3) is recommended to confirm any initial estimates.

A-2-2 Critical weir flow conditions

Flow conditions over a weir vary depending upon flow rates and downstream tailwater levels (Figure 33). As water levels begin to rise and flow over the crest commences there is a critical flow condition at the weir crest that controls discharge. Under these conditions, flow is sub-critical upstream, critical at the weir crest, supercritical along the downstream face, then transitioning to subcritical flow downstream via a hydraulic jump.

As water levels continue to rise towards bank-full conditions, the weir becomes progressively drowned. In this state, flow is controlled by energy losses associated with the weir geometry and the degree of flow constriction. There is a transition zone between these flow conditions as the weir becomes drowned (Figure 34).

Critical flow conditions are described using a weir formula. The water level immediately upstream of a weir can be established using the weir formula with discharge coefficients (c) appropriate to the type of crest – a sharp or broad crest or an ogee crest:

$$Q = cLH^{3/2}$$

Where L is the length of the crest, H is the head over the crest and c is a weir coefficient where a critical flow condition is occurring over the weir crest. As tailwater level rises above crest level, c needs to be adjusted to reflect the depth of submergence over the crest.

A-2-3 Generalised flow conditions when approaching bank-full conditions

For flow conditions approaching bank-full, where the weir structure is drowned and entrance and exit losses are more dominant, a generalised hydraulic structure loss equation (also described as the Borda-Carnot equation in Chanson, 2004 and the weir afflux formula in Bartlett and Richardson, 1980) can be used:

$$\text{Afflux} = kV^2/2g (1/(1-r)^2 - 1)$$

Where k is a coefficient for various weir shapes (ranging from 0.2 for a streamlined shape to about 1.2 for structures causing abrupt changes in flow patterns), V is average stream velocity (m/s), g is acceleration due to gravity (9.81m/s^2) and r is the ratio of area from bed to weir crest level to area from bed to top of bank.

A complete description of the full range of flow conditions and corresponding upstream and downstream water levels can be expressed graphically using a headwater and tailwater rating curve (see illustration in Figure 34).

For an ogee type crest, a design head needs to be selected. Generally, a head equal to the depth of flow over the crest at which the tailwater level is at crest level will be appropriate.

More reliable estimates of afflux for a proposed weir can be obtained from PHM or CFD as discussed in later sections.

Figure 33 Illustration of flow regimes over a weir

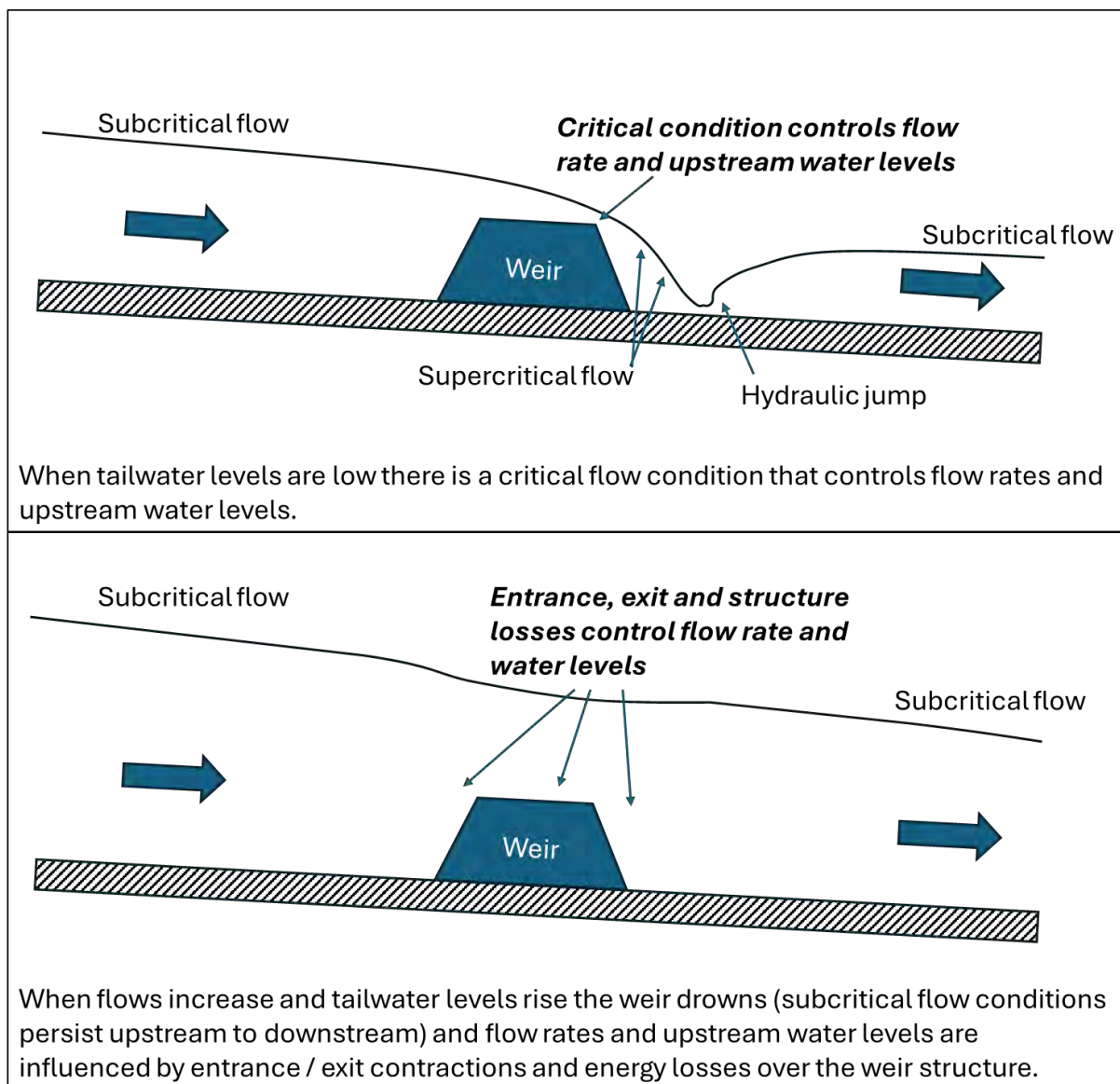
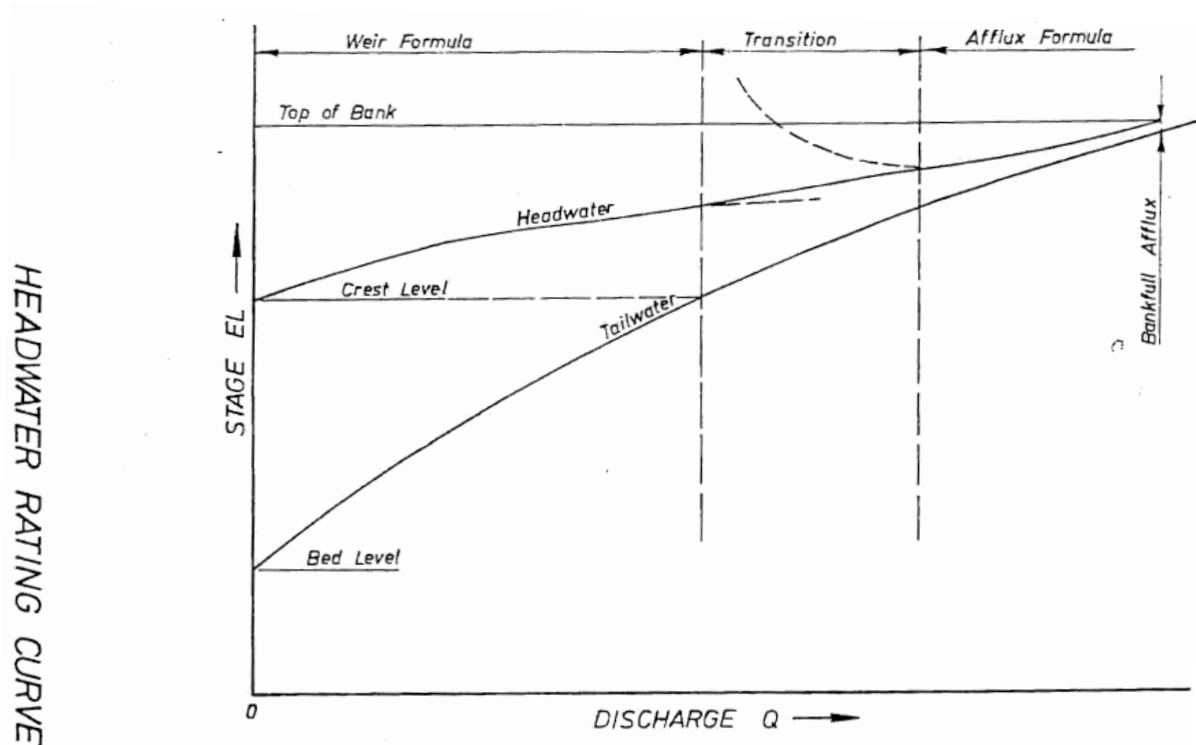


Figure 34 Illustration of a headwater and tailwater rating curve, highlighting how different flow regimes influence upstream (or headwater) levels, downstream (or tailwater) levels and discharges (or flows) across a weir (Bartlett and Richardson, 1980)



A-3 Modelling methods

A-3-1 One- and two-dimensional flood modelling

Hydrodynamic numerical models simulate water flows, depths and velocities in river channels, floodplains and through hydraulic structures, such as culverts, bridges and weirs. For weirs, they are often used to inform site selection, predict tailwater conditions and assess flood impacts influenced by the weir.

One-dimensional (1D) models provide a relatively fast and simple assessment of riverine hydraulics. Flows and water levels are simulated at predefined calculation points along a linear branch (or series of branches). Being one-dimensional, flow is either upstream or downstream along a pre-defined flow path. Cross-channel effects, such as superelevation around bends and interactions between main channel and floodplains, can be more difficult to simulate and less accurately represented. Weirs and other riverine structures are typically represented using empirical equations that replace or modify the standard momentum equation. This approach is a reasonable but simplified representation of complex flow processes that relies on established equations derived from laboratory testing and field observations.

1D modelling of river channels is a well-established and widely accepted engineering practice. There are numerous commercial and public-domain modelling packages available, supported by extensive guidance and industry experience for best-practice.

Two-dimensional (2D) models spatially represent the flow domain as a grid, or irregular mesh, over which velocity components (in both east-west and north-south directions) and water level are calculated at each grid point. This allows the model to resolve irregular flow patterns such as occurs between the river channel and floodplain.

Compared to 1D models, 2D models simulate cross-channel influences, including superelevation around bends, flow distribution between main channel and floodplains and localised flow paths controlled by terrain.

As for 1D models, complex hydraulic structures such as weirs are often represented using simplified or empirical relationships. They can also be represented through special flow conditions such as modifying cell face momentum terms, adjustment to calculation of friction losses or replacing the momentum term with a weir equation.

As for 1D, 2D modelling of river channels and floodplains is a mature branch of engineering, with numerous commercial and public-domain modelling tools available, supported by well-established guidance and industry practice.

At river or catchment scales, 2D flood models are commonly used to inform site selection. They provide insight into flood conditions including flood extent, bypass flows around a weir structure and afflux upstream. They can also be used to estimate upstream storage extents and, provided reliable bathymetric data is available, storage volumes.

Careful selection of model domain and resolution is required. The downstream extent of the model should be sufficiently far from the weir structure so that tailwater conditions reflect normal flow conditions and are not influenced by the assigned boundary conditions. Spatial resolution (grid size) and temporal resolution (simulation and output timestep) should capture in-bank hydrodynamics. As a guide, the main river channel should be represented by at least 4 to 6 grid cells across the channel width; although this depends upon variability in the channel and model performance, especially in relation to representation of turbulence.

At a local scale, both 1D and 2D models can provide valuable insights into weir performance.

A-3-2 Calibration and validation

Numerical models (or any similar analytical methods) should be calibrated and validated against measured data wherever possible to demonstrate accuracy and reliability.

Where reliable measurement is limited, alternative sources of data should be used to check model performance, including event data and field observations. For example, debris levels on vegetation, fences or property levels can indicate flood levels and flow extent.

Sensitivity analysis, involving the systematic variation of key model parameters, allows quantification of uncertainty and identifies which outputs influence model results. It also provides an indication of the range of possible outcomes. Sensitivity analysis is more important if calibration and validation is not possible.

A-3-3 Computational fluid dynamic (CFD) model studies

(CFD) models provide high resolution simulation of complex hydraulic situations, such as flow over spillways and through fishways. They provide detailed information on spillway rating curves and downstream flow patterns and forces.

CFD is typically applied to localised, relatively small study areas and specific flow scenarios, rather than whole catchments. These 'snapshot', simulations can provide unique insights into critical hydraulic behaviour to inform engineering decisions.

CFD modelling should be undertaken by suitably qualified professionals with experience in numerical modelling and knowledge of the complex physics associated with fluid flow.

Irrespective of their computational sophistication, CFD models are always a simplified representation of reality. Assumptions, parameterisations, boundary conditions and limitations must be clearly documented, including how and where results may deviate from

reality. Although results might appear ‘reasonable’ and ‘accurate’, their validity cannot be assured without appropriate evidence or documented expert justification. In the absence of definitive proof of model performance, sensitivity testing is necessary to quantify and understand uncertainties. To apply CFD as a “black box”, without verification of assumptions or applicability, introduces significant risk.

Development of a CFD model domain and selection of boundary conditions (especially tailwater rating curve) and model scenarios can be informed by the flood modelling exercise (Section A-3-1).

Interpretation of CFD results requires care. Standard outputs (e.g. velocity or pressure plots) may not fully capture key behaviours, such as recirculation, flow separation or turbulence near banks.

Further guidance on the use of CFD models (and PHM, see next section) is available at Engineers Australia (2026).

A-3-4 Physical hydraulic model (PHM) studies

Although significant costs are involved, physical hydraulic modelling (PHM) is a well-established method for examining the hydraulic behaviour of a weir proposal, for verifying head water rating curves and afflux at all stages of flow up to bank-full flow.

A key advantage of PHM is direct visual observation, allowing rapid assessment of flow patterns, turbulence and the effects of design changes. This enables efficient optimisation of weir geometry.

The scale selected for a PHM reflects hydrodynamic properties and driving forces, available laboratory space and pump capacity. For example, a 1:50 scale was used for the recent Rookwood Weir model study. These constraints also influence model domain extent and choice and treatment of boundary conditions.

Since gravity is the dominant driver of hydraulic behaviour for weir overtopping, Froude Law relationships are used to scale model flows and velocities between model and prototype.

Testing involves setting tailwater levels using a downstream control gate and measuring headwater levels when the head water level has stabilised, for a range of flows. Tailwater levels can be arbitrarily lowered, say by 0.3m, to test sensitivity to downstream conditions.

An optimum weir arrangement minimises turbulence downstream and aligns flows across the channel with the stream centre line. Recirculating currents adjacent to the stream banks, particularly alluvial banks, should be avoided.

PHM also allow investigation and optimisation of fishway placement and entrance conditions under different flow conditions and manipulation and optimisation of these before full scale construction.

Visual observations of turbulence and measurement of velocities on the stream bed and adjacent to the banks provide important inputs to the design of bed and bank protection works, including areas prone to erosion.

A-3-5 Combining CFD and PHM

CFD and PHM are complementary methods. When used together, they provide a more complete understanding of complex hydraulic behaviours.

Awareness and understanding of their relative strengths and weaknesses is required to provide an optimal description of the problem being investigated¹⁶. Differences between modelling approaches are summarised in the following table.

Table 7 Comparison of CFD and PHM model approaches (adapted from Engineers Australia 2026).

Aspect	CFD	PHM
Physical process	Numerical simulation solving fluid dynamics equations	Physical scale reproduction with real water
Scale	Spatial dimensions applied to CFD models reflect the hydraulic problem being investigated Spatially dependent physical processes can be represented more accurately No similitude laws needed	PHM is a scaled-down version of the hydraulic problem being investigated. Spatially dependent physical processes are scaled and will not behave the same at smaller scales (scale effects). In particular, air entrainment, surface tension, viscosity effects and bed friction may not scale correctly. Representation of physical processes is limited by the scalability of the PHM.
Discretisation	CFD is calculated on a spatial grid at discrete timesteps	PHM is continuous.
Flexibility	Easy to modify geometry and rerun scenarios	Modifications require physical rebuilding, time, and cost (although simplified geometry adjustments or different flow regimes can usually be immediately tested)
Iteration Speed	Fast once model set up; multiple scenarios feasible	Slower – limited number of scenarios practical
Visualisation	Post-processing can provide detailed visualisation of a range of parameters including otherwise unmeasurable parameters.	PHM is readily interpreted and immediately visualised. Instrumentation limits resolution and accuracy (for example, discrete pressure sensors only provide measurements at a point location, acoustic sensors can be sensitive to aeration, laser sensors do not always accurately measure water surface, etc). Internal flow structures can be difficult to measure (dyes are often used).
Costs	Requires computing power and specialist modellers, cost-effective for many runs Higher ongoing costs	Higher upfront costs Requires lab facilities, pumps, staff, construction, etc Scenario tests, especially for structural / geometry options, can be expensive and time consuming (although simplified geometry adjustments or different flow

¹⁶ For example, ICOLD (2025) highlights that “many of the hydraulic problems associated with hydraulic structures are complex, highly turbulent, highly aerated and three-dimensional, and numerical modelling can be questionable for these types of flow conditions”. ICOLD (2025) also highlights the beneficial use of using both CFD and PHM together “... as a composite model has proven to enhance the hydraulic modelling effort, improve modelling accuracy and reduce modelling uncertainty. Composite modelling has been found to be an effective tool for hydraulic structure design”.

Aspect	CFD	PHM
		regimes can usually be immediately tested)
Stakeholder interpretation	<p>Results are visualised via plots and animations (often shaded contour plots of specific parameters at vertical and horizontal slices in the model domain) which can be challenging to interpret</p> <p>Stakeholders can be sceptical if results (or explanations for results) are unclear or if model limitations are not carefully explained and justified</p>	<p>At a macro or whole-of-system level, results are easily interpreted and understood. This provides confidence in performance for stakeholders (especially non-technical end-users and decision makers).</p> <p>Can be more challenging to extract and visualise high-resolution results.</p>

Appendix B Historical weir incidents in Queensland

Ref No	Weir Location	Weir owner1	Year completed	Height m	Weir type	Foundation conditions	Year of incident	Failure / damage	Repair	Lessons learned
1	Wilsons Lockyer Creek 61.3km	Seqwater	1941	4	Concrete gravity	Alluvium	2011	Lockyer Creek short cut an upstream bend and re-entered the stream channel just downstream of the weir and back eroded both abutments	Rebuild of abutments and extend protection works.	Site structure on straight section of stream channel where possible.
2	O'Reillys Lockyer Creek 1.4km	Seqwater	1948	7.6	Concrete Gravity	Alluvial abutments	1983 and 1990's	Erosion of downstream protection works left bank 1983 and right bank 1990's. Erosion resulted from changed tailwater conditions as a result of construction of Wivenhoe Dam.	Left bank downstream erosion repaired with large quantity of rock from Splityard Creek quarry 1983, further extensive erosion on right bank repaired 1990's with mattresses.	Tailwater conditions can strongly influence energy conditions at a weir.
3	Mungungo Monal Creek 16.2km	DLGWV	1951	5.3	Concrete gravity	Rock bar across riverbed, alluvial abutments	2013	Sandy material was eroded out from under concrete slab protection on the right abutment downstream of the weir wall. A large section of the slab was carried away with a hole being about 2m deep. Drawings indicated that the slab should have been reinforced. It was not. Cracking of the slab combined with a major prolonged flood event resulted in the failure 62 years after completion.	The hole was backfilled with a low cement material with a reinforced concrete slab replaced on the bank.	As-constructed drawings and supervision of construction activities recommended.

Ref No	Weir Location	Weir owner1	Year completed	Height m	Weir type	Foundation conditions	Year of incident	Failure / damage	Repair	Lessons learned
4	Marian Pioneer River 32km	Sunwater	1952	6.6	Concrete gravity	Rock on right abutment and across riverbed, alluvial left abutment	1954	Damage during first major overtopping event. Inadequate protection leading to erosion of left abutment during overtopping resulting in river totally bypassing weir structure.	Concrete cut wall constructed across eroded section, bank reconstructed, protection works strengthened. Cost - about double original construction cost	Protection works on the alluvial left bank were inadequate Note that a cofferdam failed at a worksite at the weir in 2010 (1 fatality).
5	Bonshaw Dumaresq River 126.7km	Border Rivers Commission	1953	3.7	Timber crib	Alluvium	1956	Damage during first major overtopping event. Both abutments failed during major flooding. Left abutment was bypassed and heavily scoured, right abutment and a section of the weir were washed away. Cause identified to be construction methods and poor abutment foundations.	Abutment and protection works reinstated but failed again in the next wet season. New weir constructed in 1958 using sheet piles and concrete.	Relationship between afflux and bank protection requirements was probably not well understood.
6	Binda Dawson River	Sunwater	1953	5	Timber		1986	Weir deliberately destroyed because unsafe (lack of maintenance).		
7	Hilliard Hilliards Creek	Redlands Shire Council	1948	3.4	Timber		1990	Lack of maintenance, weir in ruins.		
8	Silverleaf Barambah Creek 120.4km	Sunwater	1953	5.1	Timber		1995	Flood event during refurbishment resulted in overtopping of a coffer dam and inundation of structure. Minimum damage occurred.		

Ref No	Weir Location	Weir owner1	Year completed	Height m	Weir type	Foundation conditions	Year of incident	Failure / damage	Repair	Lessons learned
9	Glebe Dawson River 326.2km	Sunwater	1971	10.3	Concrete gravity spillway section / stepped sheet piling abutments	Alluvium	First major overtopping	Failure during first major overtopping event. Major scour developed on right abutment beyond the limit of the protection works. Later event, erosion damage to left abutment to downstream road crossing	Protection works extended further up abutment	Afflux had been incorrectly estimated due to use of multiple datums.
10	Neville Hewitt Dawson River 82.7km	Sunwater	1976	8.8	Concrete gravity with sheet pile left abutment	Rock bar across riverbed and right abutment, alluvial left abutment.	1980's	The top lift of all spillway monoliths fell off during a smaller flood than the weir had withstood previously. Further erosion damage to left bank 2000's. The cause of failure was never established with certainty, but anecdotal evidence suggested that persons fishing with explosives dropped into the storage immediately upstream of the crest may have been responsible.	New crest lifts placed anchored to the lower lifts.	It could be reasonably argued that the weir designers should not have reasonably anticipated that such an extreme loading could occur. This situation also highlights the benefits of surveillance and monitoring at weir sites.
11	Bedford Mackenzie River 548.8km	Sunwater	1976	8.5	Concrete gravity with an inflatable rubber dam installed on the crest	Sand	2008	A sudden split in the rubber dam resulted in its rapid deflation and an increase in discharge from the storage. One child was drowned.	Rubber dams were removed from this and all other weirs where rubber dams were installed.	Condition monitoring of such an asset is critical. Public access to weir structures involves major risks.
12	Clare Burdekin River 50.3km	Sunwater	1978	7	Concrete gravity spillway monoliths and roller bucket dissipater.	Alluvial	1979	Damage during first major overtopping event.	New monoliths and roller buckets constructed, and protection works enhanced.	Weirs founded on sand are particularly vulnerable to erosion.

Ref No	Weir Location	Weir owner1	Year completed	Height m	Weir type	Foundation conditions	Year of incident	Failure / damage	Repair	Lessons learned
								<p>Riprap protection on left abutment and downstream of the roller bucket was not large enough, not thick enough and not well graded enough to prevent mobilisation of the sand.</p> <p>Progressive removal of sand led to settlement of the monoliths and loss of storage.</p>	Sand was vibro compacted in place. A row of sheet piling was added at the downstream toe of monoliths.	
13	Kentville Lockyer Creek 46.4km	Seqwater	1984	7.4	Stepped steel sheet piling	Alluvial	First major overtopping	<p>Damage during first major overtopping event.</p> <p>Flood damage to downstream protection works. Flood subsided before erosion reached the crest.</p>	Required backfill, repair to mattress protection works and extension of protection works.	Steep banks typical of Lockyer Creek alluvium are particularly unstable and erodible.
14	Gatton Racecourse Lockyer Creek 75.8km	Seqwater	1986	6.2	Stepped steel sheet piling	Alluvial	First major overtopping	<p>Damage during first major overtopping event.</p> <p>Flood damage to downstream protection works. Flood subsided before erosion reached the crest.</p>	Required backfill, repair to mattress protection works and extension of protection works.	Steep banks typical of Lockyer Creek alluvium are particularly unstable and erodible.
15	Grantham Lockyer Creek 84.5km	Seqwater	1986	4.6	Stepped steel sheet piling	Alluvium	First major overtopping	<p>Damage during first major overtopping event.</p> <p>Flood damage to downstream protection works. Flood subsided before erosion reached the crest.</p>	Required backfill, repair to mattress protection works and extension of protection works.	Steep banks typical of Lockyer Creek alluvium are particularly unstable and erodible.

Ref No	Weir Location	Weir owner1	Year completed	Height m	Weir type	Foundation conditions	Year of incident	Failure / damage	Repair	Lessons learned
16	Carpendale Lockyer Creek 92.1km	Seqwater	1986	5.1	Stepped steel sheet piling	Alluvium	1990's	Severe erosion from back eddy. Back eddy considered to be the result of unsymmetrical flow over the crest. Crest profile followed the stream cross section, left bank much steeper than the right. No model study undertaken.	Rebattering of creek banks, fill eroded bed section with rock, extensive mattress protection.	Hydraulic modelling is recommended. Weir design should consider ensuring symmetry of flow hydraulics or, if not, investigate erosion protection in more detail.
17	Gyranda Dawson River 284.5km	Sunwater	1987	11.8	Stepped sheet piling with reinforced concrete slabs between rows	Rock on right abutment and across riverbed, alluvial left abutment	First major overtopping	Damage during first major overtopping event. High pressures generated at slab end sills during overtopping penetrated to underside of the slabs leading to upwards slab failure.	Slabs replaced with thicker slabs with two layers of reinforcement. The consultant responsible for design and construction supervision met the majority of the reconstruction costs.	Consider the erosive force of water when designing weirs, with commensurate investigations to inform design.
18	Bucca Kolan River	Sunwater	1987	11.8	RCC overflow stepped weir		First overtopping events	During overflow events, a noise was generated causing significant disturbance to nearby residents. It was identified that the noise was caused by the weir overflow nappe oscillating downstream of the crest.	The oscillating behaviour was controlled by installation of splitter piers on the weir crest which ensured that air could be admitted to the underside of the nappe.	Care should be taken if not using an ogee crest weir.
19	Scrubby Creek Scrubby Creek flood diversion channel	Rockhampton City Council	1995		Stepped steel sheet piling	Rock, alluvial banks	First overtopping	Damage during first major overtopping event. Deep erosion immediately downstream.	Additional rows of piling and extended protection work	Overestimated tailwater depth and underestimated downstream velocities.

Ref No	Weir Location	Weir owner1	Year completed	Height m	Weir type	Foundation conditions	Year of incident	Failure / damage	Repair	Lessons learned
20	Fairmont Thompson River	Longreach Regional Council	1997	6.8	Clay core/flow through rockfill on downstream face	Rock in riverbed and right abutment, alluvial left abutment.	1999	Failure during first major overtopping event. Poor detailing at the clay core interface with the concrete intake structure and inadequate depth of the flow through rockfill resulted in the entire structure being washed away during the first flood.	Staged concrete spillway crest, compacted earthfill embankment repairs with rock lining	Flow through rockfill weirs probably not an appropriate type for the site conditions
21	Ned Churchward Burnett River 74.5km	Sunwater	1998	13	Concrete gravity spillway section/stepped sheet piling left abutment	Alluvial abutments	Shortly after completion	Damage during first major overtopping event. Steel sheet piling was used to cut off a paleo channel of highly permeable material above bed rock on the left abutment. The piling was unable to penetrate a small zone of highly permeable material at the alluvium/rock interface. Jet grouting was also unsuccessful in cutting off this zone. On first filling, the downstream bank became saturated, and the mattresses began to subside.	A concrete buttress was required to stabilise the abutment	Design must consider the appropriate and effective treatment of soft foundations.

Ref No	Weir Location	Weir owner1	Year completed	Height m	Weir type	Foundation conditions	Year of incident	Failure / damage	Repair	Lessons learned
22	Kirar Burnett River 300.4km	Sunwater	2004	14	RCC	Rock on left abutment and across riverbed, alluvial right abutment	2010	Damage during first major overtopping event. Damage during first major flood event. Severe erosion of right bank	Extended protection works	Inadequate protection works on an alluvial bank
23	South Maclean Logan River	Seqwater	2006			Alluvial	2008	Damage during first major overtopping event. The mattress protection on the relatively steep abutment was not adequately anchored. During the first flood the mattress protection slipped into the river. The exposed abutment was subsequently seriously eroded, and the structure was about to be bypassed when the flooding subsided.	Rebuild the abutment and replace the mattresses with proper anchoring.	Mattresses must be anchored on slopes.
24	Glenore Norman River	Carpentaria Shire Council	2015	3.6	Concrete gravity spillway/ stepped sheet piling abutment			Inadequate protection leading to erosion of right abutment during overtopping resulting in river totally bypassing weir structure. The risks associated with alluvial abutments not well understood. There was no physical modelling undertaken that would have clearly identified the failure mode.		Hydraulic modelling is recommended. Design must consider the appropriate and effective treatment of soft foundations.

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