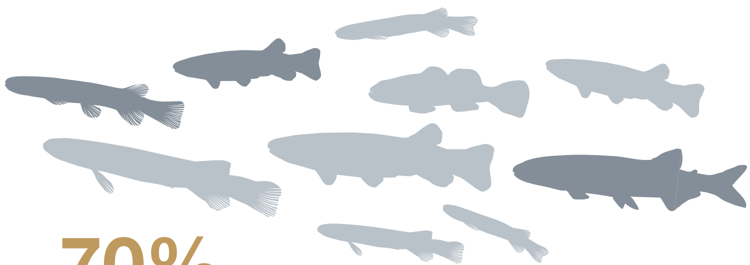
New Zealand **Fish Passage** Advisory Group

How to fix fish passage barriers at existing instream structures

Why is fish passage important?

New Zealand is home to more than 50 species of native freshwater fishes and several species of sports fishes. Around 70% of our native fishes are threatened or at risk. Many of these fishes, such as eels, whitebait, trout and salmon, spend part of their life in fresh water and part of their life at sea, making access between habitats essential. In addition, some fishes and other freshwater species, such as frogs, shrimps and aquatic invertebrates, also need to move within waterways to access food and spawning grounds. If the movement of these species upstream and downstream is delayed or prevented, they may not be able to reach the necessary habitats to complete their life cycle, resulting in their numbers being reduced or the species being lost completely from the stream.

Instream structures across New Zealand are blocking or impeding the passage of our native freshwater and valued introduced fish species. Structures such as tide and flood gates, road crossings, culverts, weirs, fords and dams are found throughout New Zealand and can slow or stop fish from migrating to upstream and downstream habitats if they are not designed, installed and maintained correctly. Fish can also be sucked into intake structures that lack suitable fish screens, resulting in their removal from habitats and loss from the fishery. Therefore, it is important to determine if a particular structure is acting as a barrier to fish passage and, if so, implement the appropriate measures to address this.



70%

of our native fishes are threatened or at risk.

> While providing fish passage is beneficial for most New Zealand fish species, some natural waterfalls and built barriers in key locations can protect native species and biodiversity hotspots by preventing access for invasive fishes, so these structures should be retained.

What is a fish passage barrier?

Any structure that prevents or restricts the upstream or downstream movement of freshwater fishes or other freshwater species represents a fish passage barrier.

When determining whether a structure is a barrier and what fixes are appropriate, it is important to consider which species use this pathway and their movement/swimming abilities, as different barrier attributes and fixes will affect different species. For example, īnanga whitebait (*Galaxias maculatus*) are weak swimmers and cannot climb, whereas kōaro whitebait (*G. brevipinnis*) and elvers (the smallest life-stage of eels present in fresh water) can climb wet and steep surfaces if they have to. It is also important to look at all parts of a given instream structure, as passage needs to be provided up to, through and/or over the structure for successful passage upstream and downstream.

Barriers to migrating species can be caused by structures that:

- physically block the movement of fish
- have a vertical drop and/or an overhanging (undercut) edge that fish can't jump or navigate over
- have water velocity that is too high and/or remove shallow/wetted margins where fish often migrate
- are too shallow for fish to swim through
- are very long
- have sharp edges and corners that many fish can't overcome
- are not designed to keep fish in the waterway (eg natural water is diverted or pumped from a waterway that may contain fish).

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The images below show a variety of fish passage barriers and highlight the fact that a single structure can have multiple aspects that cause it to act as a barrier to fish passage.

Captions (from top): A weir fish passage barrier in a waterway; a tide gate fish barrier in a waterway; a perched overhanging culvert fish barrier in a waterway.

Planning considerations

The Department of Conservation (DOC) and regional councils have specific responsibilities to manage fish passage in our waterways, with the aim of connecting or providing all of the habitats that are necessary for fishes and other freshwater species to complete their life cycles. All culverts and fords should provide unimpeded passage unless they have a permit from DOC. DOC is responsible for enforcing the Freshwater Fisheries Regulations 1983, under which any culverts, fords, dams and diversion structures in natural rivers, streams or water may need approval. This includes considering exemptions for fords or culverts that impede fish passage, approving any structural changes to fish facilities, and assessing whether proposed dams and diversion structures require a fish facility. Regional councils are responsible for controlling the environmental effects of construction under the Resource Management Act 1991, including enforcing the **Resource Management (National Environmental Standards for Freshwater) Regulations 2020** that has set rules that apply whenever someone is installing or altering a culvert, weir, flap gate, dam or ford.[1]

If you are planning to remove, replace, remediate or retain an instream structure in a waterway, you should take the following actions.

1. Prioritise

A range of factors might influence how you prioritise the structure/s to focus your efforts on, including ecological, economic, community value, ownership and practical considerations. The New Zealand Fish Passage Assessment Tool (**https://niwa.co.nz/freshwater/management-tools/fish-passage-assessment-tool**) has a built-in ecological prioritisation score to help guide you on where remediation could be prioritised. Other examples of ecological priorities for fixing fish passage barriers are listed in Table 1 and section 5.1 of the *New Zealand Fish Passage Guidelines* (**www.doc.govt.nz/fishpassage**).

2. Check available guidance

The *New Zealand Fish Passage Guidelines* were published in 2018 to inform the planning, design, construction, management and monitoring of structures in waterways. These guidelines apply to all instream structures with a vertical drop ≤ 4 m, measured from the upstream to downstream water surface at a normal water level. There is currently no national best practice for structures > 4 m, but many of the principles of good fish passage design are still applicable.

3. Define the ecological objective and performance standards

(Biological and hydraulic; see section 3 of the *New Zealand Fish Passage Guidelines.*) It is important to identify the purpose of the structure and set standards that can be used to measure the effectiveness of fixes.

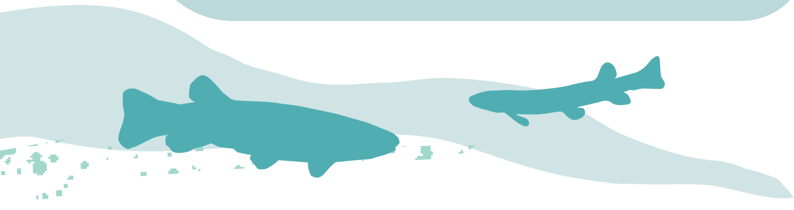
[1] For further information on the design and construction of new instream structures, see the *considering fish passage in the design of new instream structures* resource (www.doc.govt.nz/nature/habitats/freshwater/fish-passage-management/resources/).

4. Undertake a site-specific design assessment

This should include confirming that the structure is a barrier (eg by using the Fish Passage Assessment Tool), identifying which species may use the waterway and using the *New Zealand Fish Passage Guidelines* to identify the best option. Acquire specialist advice/input where required. In some limited situations, it might be best to retain the barrier if it is protecting threatened species or biodiversity hotspots. In these areas, barriers may be maintained, enhanced or built with permission from DOC.

5. Obtain appropriate approvals

All statutory requirements, including the specific fish passage requirements that are managed by DOC and regional councils, need to be considered when designing, altering, installing and managing physical structures. (See Appendices A & B of the *New Zealand Fish Passage Guidelines* for further explanation.)



6. Monitor and maintain

It is important that best practice guidance is followed and any installation follows the agreed plans. If new or novel remediation options are attempted or proposed, monitoring needs to be included to ensure they are effective and to determine whether changes need to be made (see section 7 of the *New Zealand Fish Passage Guidelines*). Ongoing maintenance also needs to be incorporated into the management of all existing and new structures, as a lack of maintenance can result in the development of fish passage barriers over time, such as major scour and erosion at the discharge end of culverts or vegetation and debris causing obstructions.

It is particularly important to understand these planning considerations where:

- high-value fish communities and/or ecosystems are present (or have the potential to be present) upstream and downstream of the structure
- unproven designs are being used
- proven designs are being used in novel situations
- retrofit solutions form only one component of an instream structure
- multiple structures exist within a waterway causing cumulative effects
- selective barriers are being used to manage the movement of undesirable species.

Table 1. Examples of possible ecological prioritisation criteria for fixing instream barriers (adapted from the *New Zealand Fish Passage Guidelines*).

Criterion	Explanation
Proximity to coast	Barriers that are closer to the coast not only block access to a greater proportion of upstream habitat but also generally block a larger number of fish species.
Potential habitat gain	The greater the total length of accessible river upstream of the barrier, the greater the potential habitat gain.
Habitat quality	Restoring access to higher quality instream habitat (eg a waterway that has good riparian margins and good instream habitat for fish) should be prioritised over providing access to degraded sites (eg artificial habitat that does not maintain flow and has no cover).
Proximity to protected areas	Connection with protected area networks may provide added benefits (eg constraints on fishing).
Number of species likely to benefit	Some sites are expected to naturally support a greater number of species than others (eg low-elevation sites close to the coast). Sites that are expected to support many species may be of higher priority than those that are expected to support few species.
Conservation status of species	Sites that are expected to support species with a higher conservation status may be of higher priority for the restoration of connectivity.
Preventing spread of exotic and invasive species	Maintaining boundaries on the spread of exotic and invasive species may be a desirable outcome of retaining barriers and should also be considered in prioritising restoration actions.
Protects threatened species	Barriers may protect populations of threatened fish species by preventing access to competing species (eg trout in particular specific locations). The existence and protection of threatened fish populations should also be considered.

Fixing fish passage barriers – remove, replace, modify or retain?

The best way to restore fish passage is to remove the instream structure whenever possible. If the structure cannot be removed or replaced, it may sometimes be possible to modify it by adding new features that enhance fish passage. The most appropriate modification will depend on what the existing structure is, accessibility to it, what makes the structure a barrier to fish passage and the ecological objectives for the site. It is crucial to ensure that passage is provided up to, through and/or over the structure, so more than one type of fix may be needed.

Thus, instream structures that are barriers to fish passage should be:

- removed if no longer required
- replaced with structures that provide for fish passage (see section 4 of the *New Zealand Fish Passage* Guidelines and the *Considering fish passage in the design of new instream structures* resource)
- retained if the barrier is protecting threatened species or habitats from invasive species (see section 6 of the *New Zealand Fish Passage Guidelines*)
- modified to allow for fish passage (see Table 2), noting that all remediations require regular maintenance to ensure their continued effectiveness
- maintained to allow for fish passage.

Remediation techniques

Table 2 shows the possible modification techniques that may help address the fish passage issues that are commonly encountered at barriers.

Each of these remediation techniques and their limitations are explained below. Case studies of fish passage problems and solutions and how the various approaches were designed, installed and monitored can also be found on DOC's 'Fish passage resources' webpage (www.doc.govt.nz/fish-passage-resources).

Backwatering

Backwatering reduces or removes excessive fall height by manipulating rocks downstream, often in a 'V' pattern, to raise the water level and create a 'backwater'. It is important to ensure that backwatering is not affected by flood events and does not result in the loss of surface water connection and thus become a fish barrier itself.

Figure 1: Backwatering raising water level at the downstream end of a fish passage barrier.

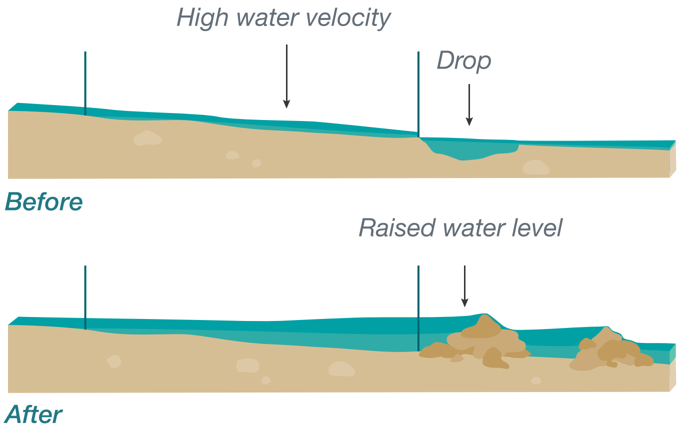
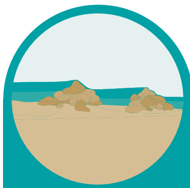
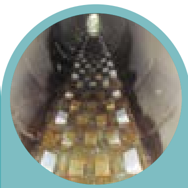
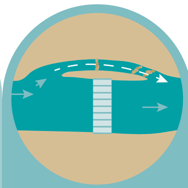


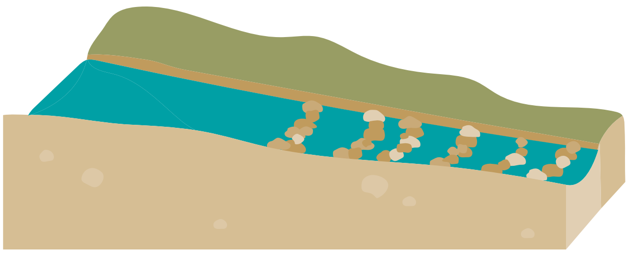
Table 2. Possible remediation techniques for the common problems that are encountered at barriers.

Solutions / *Problems*	 Backwatering	 Ramp fishway	 Baffles	 Mussel spat rope	 Bypass structure	 Fish friendly flap gate
Large drops	✓	✓		?	✓	
Fast flows	✓		✓	✓	?	
Shallow water	✓		✓		?	
Physical blockage or overhang		✓			✓	✓

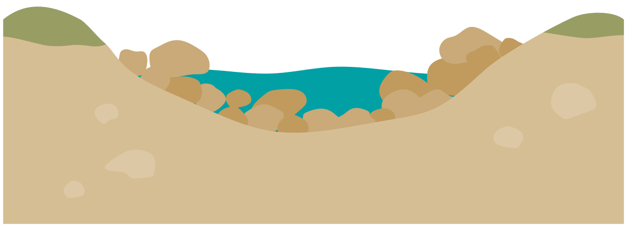
Ramp fishways

Ramp fishways are the preferred solution for overcoming vertical drops that impede the movement of aquatic species. Full-width rock-ramp fishways are the optimal design for overcoming large drops, with smaller concrete rock ramps a secondary recommended option where a full-width ramp is not viable. Slopes on the downstream side of weirs should be made gentle, with low-velocity wetted margins. The provision of cover and shelter should also be considered in long fishways and the impacts of concrete in and around the waterways will need to be managed.

Figure 2: A full rock-ramp fishway in a waterway.



Side view



Front view

For **full-width rock ramps**, the recommended design criteria include a:

- 1:30 overall longitudinal slope
- V-shaped cross section or laterally sloped (bank-to-bank) channel profile
- head loss of < 75 mm between pools
- 100–150-mm-wide gap between lateral ridge rocks
- 2-m-long pool for ridge-style rock fishways
- minimum water depth of 0.3 m in at least 50% of the pool area that forms
- continuous path ascending through the rock ramp
- maximum water velocity of 1.2 m/s
- minimised turbulence, with little 'white' water in the fishway pools
- stream power of < 25 W/m^3.

For further information and guidance on the use of ramps, see section 5.3.2 of the **New Zealand Fish Passage Guidelines.**

For **concrete rock ramps**, design features should include:

- a V-shaped (15°) or tilted cross section
- mixed-grade irregularly shaped rocks (150–200 mm) that are embedded by 50%, with the longitudinal axis perpendicular to the ramp surface and the widest part of the stone facing into the flow, and arranged haphazardly with an inter-rock spacing of 70–90 mm
- a continuous, low-velocity wetted margin up the ramp throughout the fish passage design flow range
- an average slope of less than:
  - 1:5 for head differences ≤ 0.5 m
  - 1:10 for head differences of 0.5–1.0 m
  - 1:15 for head differences of 1.0–4.0 m.

Rock-ramp fishway installed at a weir in Taranaki.

Pre-constructed artificial ramps that can be readily attached to structures such as perched culverts can also be used to overcome vertical drops. These ramps should have a roughened surface and meet the same criteria as outlined for concrete rock ramps above. Water may need to be directed towards or away from the top of the ramp to create the desired flow down the ramp.

A floating fish ramp installed at a culvert in Hawke's Bay.

Baffles

Baffles can be installed at the base of culverts or on the face of weirs to reduce the water velocity and facilitate fish passage.

A range of baffle designs is available, but based on current knowledge, spoiler baffles are the recommended solution for enhancing fish passage in culverts with a diameter > 1.2 m and at locations with slopes up to 2% (1.15° or 1:50). When installing spoiler baffles, it is important to remember that:

- **rectangular baffles** (0.25 m long, 0.12 m wide and 0.12 m high) should be placed in a staggered configuration with 0.2 m between rows and 0.12 m between blocks within rows to create a low velocity and provide resting areas. If purchasing spoiler baffle sheets or creating this spoiler baffle arrangement, it is important to ensure that they are the recommended dimensions
- **baffles** should cover approximately one-third of the culvert's internal circumference or the full width of box culverts.

Spoiler baffle sheets installed in a culvert.

Further research is required before clear guidance can be given on the design and use of other types of baffles and spoiler baffles in areas with slopes greater than 2%. Therefore, if other types of baffles are used, outcome monitoring will be crucial to confirm that they have improved fish passage.

For further information and guidance on the use of baffles, see section 5.3.3 of the **New Zealand Fish Passage Guidelines.**

Mussel spat ropes

Mussel spat ropes can be passed through small perched culverts (< 1.2 m diameter) to provide a complex surface that allows some aquatic species (fishes and invertebrates) to rest and navigate up and through the culvert. Baffles are a preferable remediation option in larger culverts.

When installing mussel spat ropes, it is recommended that:

- a minimum of two rope lines are used for a 0.5 m-diameter culvert, using more ropes for larger culverts
- ropes are installed so that they are tight and flush with the base of the culvert through the entire length of the culvert and not loose at one end or out of the water
- ropes are set out to provide 'swimming lanes' between them.

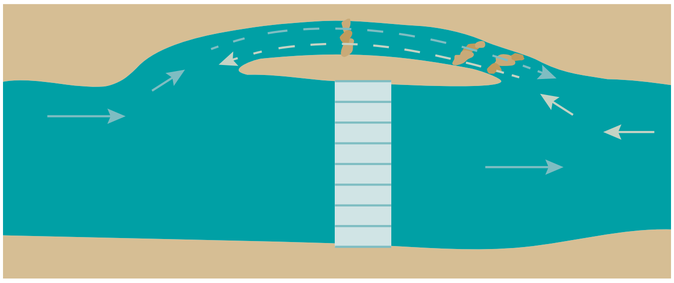
Spat ropes installed in a culvert.

For further information and guidance on the use of spat ropes, see section 5.3.3 of the **New Zealand Fish Passage Guidelines.**

Bypass structures

Where it is not possible to mitigate fish passage barriers by removing, replacing or modifying the structure, the only effective solution for enhancing fish passage may be the installation of bypass structures.

Figure 3: A bypass built around a fish passage barrier.



There are two main types of bypass structures.

- Nature-like fishways that bypass the barrier and mimic the natural stream characteristics. These are suitable for all structure types and a wide range of fish species and life stages, but generally require more space than technical fishways.
- Technical fishways, which can take a variety of forms, including vertical slot fishways, pool and weir fishways, and Denil passes that bypass the barrier. There are currently relatively few examples of effective technical fishways in New Zealand, but they have been widely used internationally in Australia, where they have successfully improved the passage for species that also occur in New Zealand (ie īnanga and bullies).

A technical fishway installed in Australia that provides passage for small native fish.

For further information and guidance on the use of bypass structures, see section 5.3.4 of the **New Zealand Fish Passage Guidelines.**

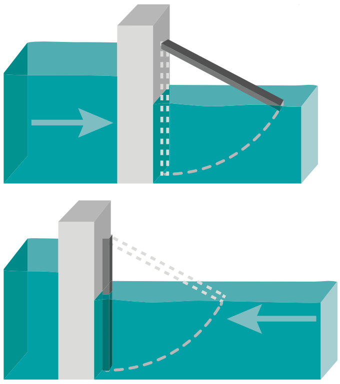
Need further help?

Check out www.doc.govt.nz/fishpassage or contact your local council or DOC office.

Fish-friendly gate attachments

Flood and tide gates can significantly disrupt the movements of freshwater species and alter upstream habitats. Where such gates are required, best practice would be to replace them with automatic gates that operate based on the water level and only close when needed for flood protection. If replacement is not possible, self-regulating 'fish-friendly' gate attachments should be added (see below). These attachments maximise the opening duration and aperture of the gate, particularly on the incoming tide when most juvenile fish are migrating upstream. Monitoring should be undertaken to prove that the modifications significantly increase the duration the gate is open on the incoming tide.

For further information and guidance on the use of fish-friendly gate attachments, see section 3.4.5 of the **New Zealand Fish Passage Guidelines.**



Fish-friendly gate attachment added to a tide gate.

Resources

- **New Zealand Fish Passage Guidelines**
  Franklin, P.; Gee, E.; Baker, C.; Bowie, S. 2018: New Zealand Fish Passage Guidelines for structures up to 4 metres. Version 1. NIWA Client Report 2018019HN. 226 p. https://niwa.co.nz/static/web/freshwater-and-estuaries/NZ-FishPassageGuidelines-upto4m-NIWA-DOC-NZFPAG.pdf
- **Considering fish passage in the design of new instream structures**
  Department of Conservation 2020: Considering fish passage in the design of new instream structures. Department of Conservation, Wellington. https://www.doc.govt.nz/nature/habitats/freshwater/fish-passage-management/resources/
- **Fish Passage Assessment Tool**
  https://niwa.co.nz/freshwater/management-tools/fish-passage-assessment-tool This tool has been developed to provide an easy to use, practical tool for recording instream structures and assessing their likely impact on fish movements and river connectivity.

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