Fish Passage Remediation

-Training Aid-

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Version 3.0

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Contents

Introduction

This document is an aid for tutors teaching, and field personnel learning, the theoretical and practical aspects of fish passage remediation. The target audience for this document is all persons either directly, or indirectly, involved with fish passage remediation, including practitioners, supervisors, engineers, ecologists, and planners.

It is not intended to be a stand-alone training manual.

This document acknowledges the useful information contained in the New Zealand Fish Passage Guidelines but dives deeper into “how-to” aspects for the fish passage remediation practitioner. The document draws on the authors’ many decades of collective experience doing remediation in the field and observing fish navigating various in-stream structures and remediation systems. During that time, materials and methods have changed due the authors’ and other commentators’ critical assessments of the durability and effectiveness of each solution.

There are so many different variations of in-stream structure design, site situation, streamscape and ways that such structures degrade, that remediation solutions need to adapt and evolve. Along with this, research from around the world regularly yields more and more insights into the fish passage realm. Therefore, this document needs to evolve also, meaning that there are likely to be regular revisions.

Scope

This document is about remediation of existing in-stream structures, and not new installations of the whole structure. It focuses on remediations recommended to be used for typical types of fish passage barriers that are found in NZ and gives guidance to practitioners using the “current state of knowledge”.

Consideration was given to all remediation tools/techniques discussed below to not impact significantly on structure capacity, as well as using robust materials to withstand high flows and impacts from debris, while not likely causing blockages.

Remediations are low-cost and low-impact, with work typically being done in the live waterway where stream diversions are seldom required.

The remediation techniques covered have been widely used through New Zealand along with other countries and have undergone robust monitoring.

The practices covered are typically completed by two persons using basic hand tools.

This document does not provide guidance for more expensive remediation that may involve pouring concrete, trucking of material to site, or the use of heavy machinery.

Vegetation is also important for fish passage, habitat and refugia however is not covered in this document.

Authors

Tim Olley

Having spent the better part of six years living and breathing fish passage, Tim has developed an extensive knowledge of the subject. He has been actively involved with fish passage remediation, education, advocacy, training, and research throughout New Zealand, and has authored several fish passage papers/reports. While working as a professional field ecologist Tim has spent countless hours fixing barriers and observing how New Zealand's native fish interact with structures in our waterways. These observations have led to several educational videos being produced by Tim and shared through the Fish Passage Action Team.

Kelly Hughes

Over the past 15 or so years, Kelly has arguably spent more time than anyone else in New Zealand at the “culvert-face” and developing new solutions to the many different situations out there. Kelly has worked at some level relating to fish passage, in every region in New Zealand, along with giving advice and supplying solutions to other countries. Being a founding member of the NZ Fish Passage Advisory Group, he has also been actively involved in advocacy and education. The key driver has been developing effective interventions and methodologies that remove the traditional excuses for poor enforcement of fish passage regulations. A highlight has been working alongside Trevor James and Tim Olley to see the Tasman Region become one of the leaders in fish passage remediation programmes.

Trevor James

Trevor’s fish passage journey began in 2001 after a Freshwater Science Society conference and then starting assessments using Waikato Regional Council’s methodology. The initial focus was on assessing district council road culverts and promoting remediation while at West Coast Regional Council and then at Tasman District Council from 2004. However, very little traction was made in the remediation sphere until he teamed up with Kelly Hughes in 2008-09. The first big remediation projects were four culverts in Wainui Bay (in Golden Bay) and were expensive using a lot of concrete, rock and effort (including resource consents). More viable methods were subsequently developed using second-hand rubber conveyor belting and mussel-rope. These breakthroughs led to a roll-out of remediations across Tasman District, to the point that almost all the district council road culverts have been remediated and a total of in-stream structures on the database reaching well over 2000. Trevor was instrumental in making the first fish passage symposium happen in 2013 and was a founding member of the Fish Passage Advisory Group, which he is still a member of. His greatest moments were getting effective rules for Fish Passage in the Tasman Resource Management Plan and NES for Plantation Forestry, as well as getting Freshwater Improvement Fund money for Tasman allowing for the most progress ever in addressing this issue.

Background

Most of New Zealand/Aotearoa's freshwater fish species are in decline, and one of the major reasons is the number of barriers to migration that these fish are presented with that prevent access to habitat.

Culverts and other in-stream structures have long been understood as potential barriers to migrating fish. Structures may be perched (overhanging) meaning fish can't get into structures. Structures can also be velocity barriers where fast laminar flow, and sometimes shallow flows, restrict fish movement through or over structures.

Natural streams usually have complex flows with a range of depths, velocities, and flow directions, whereas manmade structures like culverts, often have fast, shallow, laminar flows and can be barriers to migrating fish.

Below are a few examples of structures that have been poorly installed and/or undersized. They can be barriers from the outset or become barriers over time.

Typical barriers to fish

Perched culvert pipe

Shallow laminar flow

Fast laminar flow

Operations and implementation

Overview

All fish have limitations in their swimming abilities. However, measuring water velocity to determine if this is exceeded is challenging, particularly in complex flows. Offering fish a range of depths and velocities, interspersed with resting places, is more likely to achieve effective fish passage for a wider range of species than attempting to target a specific maximum velocity.

Basic principles

From a fish perspective, remediation should aim to match or better the flow characteristics of the stream.

1. Provide complex flows (non-laminar) - multi-directional flows with rest pools.

2. Areas of fast water must be shorter than fish burst-swim capabilities (if known).
3. Provide sufficient depth.
4. Ensure continuity - no overhangs or sharp edges.
5. Give fish a range of migratory choices.
6. Ideally retain bed-material (retention of bed material is a good indicator that a structure is unlikely a barrier to fish).

General rules for practitioners

1. Rope should not be used in culverts if baffles can be fitted - even if just climbing species are targeted. This is because rope does not provide rest-pools or retain bed material.
2. Baffles should be spaced so that the rest pool from one extends easily up to the next to minimise zones of high velocity.
3. Ramps should provide multiple pathways i.e., wetted margins and substrate (e.g., rope) to cater for a range of fish locomotive techniques.
4. Flexible ramps should extend into the plunge-pool as far as practicable to ensure fish can find the end of the ramp in most flow conditions.
5. If rope is fitted through a culvert that is also perched, then a second set of ropes should be fitted at the outlet to extend over the drop.
6. Rope should only be attached at the upstream end of the structure and not part way through or at the downstream end. This reduces or eliminates the likelihood of debris causing blockages.
7. Interventions should not unduly reduce culvert capacity or cause debris jams. For example, flexible baffles will flex in very fast flow or when hit by larger debris.
8. Tide-gates should be designed/modified to delay the closing as long as possible without causing undue adverse effects due to water inundation or saline influence upstream unless part of the design goal.
9. Even if the structures need replacing or require significant maintenance, a low-impact, low-cost remediation should be considered in the meantime. This is because it may be years before the maintenance or replacement occurs.
10. Ideally provide passage options for fish at different flows through or over the structure.

Fish Passage Remediation Effort Matrix (non-tidal)

When considering remediating in-stream structures, the first step is to determine the likelihood of suitable fish habitat upstream. It is particularly important to determine whether a structure in a stream that is not flowing should be remediated e.g. when there are residual pools. There are also some situations when a wet/flowing structure might not be remediated e.g., when a road drain intercepts groundwater.

A suitable upstream ecological or habitat assessment usually costs more than a typical remediation so is impractical to do at every site.

Consideration needs to be made of:

1. Where you are within the landscape e.g., beside a road, within a gully, on the valley floor etc.
2. The bed structure and flow type at the site. A bed is formed by the long term, but not always permanent, occurrence of water. This may include bare cobbles or gravel, aquatic plants etc.

The table below can be used to help determine where on the landscape a structure needs to provide for fish passage.

Where are you within the landscape →	Road drain	Gully	Valley Drain	Valley Stream or Wetland
Aquatic bed structure and flow type at the site ↓	Colour code can be adjusted for each region or geographical area			
No bed				
Bed and dry				
Bed and flowing				

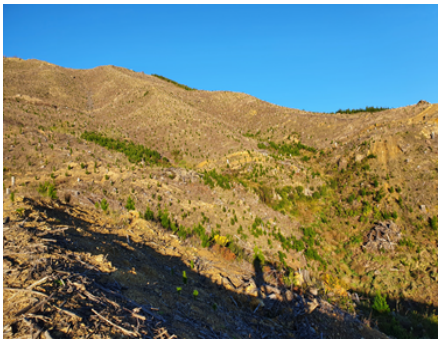
Low - Not worth the effort. Would not generate an abatement notice if not remediated

Medium - Considered for low level remediation on a case-by-case basis. May not generate an abatement notice. If in doubt - remediate.

High - Must fix

Examples

Low **Road drain** Man-made ditch for road runoff that does not serve any natural stream.		

Medium **Gully** Upper catchment		
Medium **Valley Drain** Modified water course		
High **Valley Stream or Wetland** Mid to lower catchment		

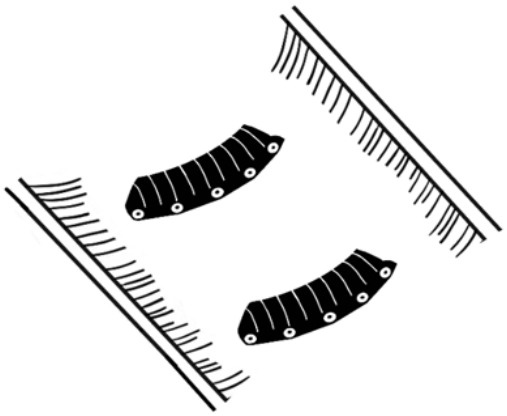
Remediations

Which tools to use and where?

Barrier	Tools
High velocity	Baffles or mussel-rope
Shallow flow	Baffles or bunds
Perched/overhanging	Flexible ramp, floating ramp, rope & V-baffle
Tide-gates	Cantilever or off-set top hinge

Within culverts

Flexible baffles



- Baffles effectively backwater culverts incrementally.
- Fitted to the culvert invert to slow water velocities, create complex flows, retain bed-material and create a series of rest pools with the culvert.
- Used in culverts that are accessible to installers.

Installation

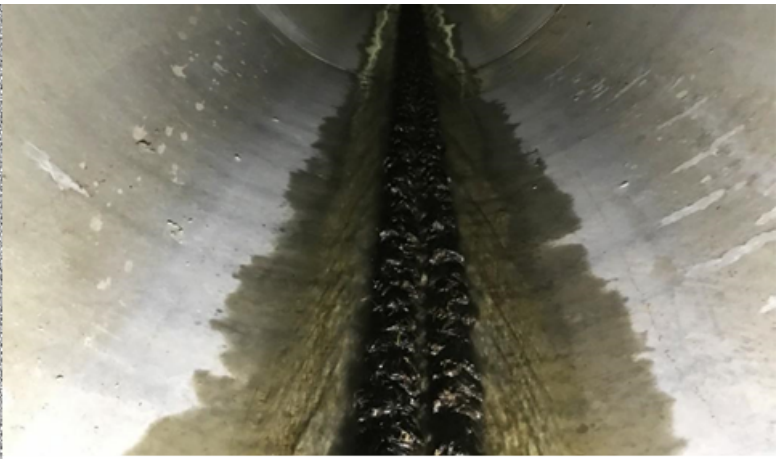
- Baffle sizes are determined by the size of the culvert and to some extent, the base flow rate.
- Baffle spacings are determined by the culvert gradient however the gradient is often difficult to measure. Therefore, the general rule of thumb is that flexible baffles should be placed so that the pool created by a baffle comfortably reaches the next upstream baffle.
- Baffles come with pre-drilled fixing holes. More fixings may be used for plastic or metal culverts and can be drilled straight through the baffle.
- In box culverts, baffles should be placed across approximately two thirds of the width of the culvert, alternating side to side to create a meander.
- Baffles may also be attached vertically on the walls of box culverts to assist with fish passage during high flows.

[See the YouTube video for a tutorial of installing Flexi-baffles.]

FLEXI-BAFFLE SPACING	
Grade (%)	**Flexi-baffle spacing**
0 > 1	2400mm
1 > 2	1200mm
2 > 4	1000mm
4 > 6	800mm
6 > 8	600mm
8 > 10	480mm

Refer to the above table for determining flexible baffle spacings

Mussel-Rope



- Fitted to culvert inverts to slow water velocities and create complex flows.
- Gives a range of navigation choices - beside, under, within or over the ropes.
- Used in culverts that are not safely accessible (e.g., less than 900mm diameter), have an eroded culvert invert, or in culverts that are steeper than 10% grade.

Installation

- Rope can be either doubled back through a D-ring or folded and pushed through a D-ring to form a Lark's Foot knot (see [Lark's Head Knot - YouTube]) to make two strands the length of the structure.
- As a guide, two strands of rope should be used in culverts up to 500mm diameter and four strands in culverts from 500-800mm.
- Up to six strands of rope can be used if you are remediating a larger culvert (greater than 900mm) that is steeper than 10% grade.
- Consider having a separate D-ring for each set of strands to reduce the load on each fixing and provide redundancy if one fixing was to fail.
- Ropes fitted through a culvert should not extend beyond the culvert outlet.
- Only fix the ropes at the upstream end to avoid debris jams i.e., not mid-way or at the downstream end.
- It is best practice to melt the ends of the rope to avoid fraying.

Outlets

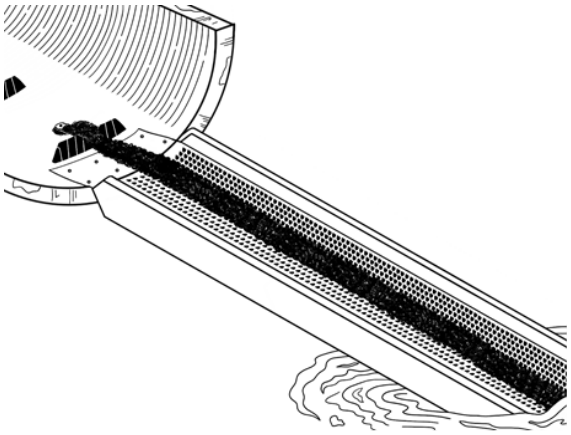
Flexible ramp with mussel-rope

- Fitted to the culverts invert to provide a swimming and climbing surface for fish to enter pipes. Flexible ramps offer aquatic species several choices when migrating e.g., passage over/through mussel-rope, adjacent to mussel-rope or on the wetted margins at the edges of the ramp.
- Used at culverts that are perched/overhung.
- Flexible ramps may provide scour protection and prevent further downcutting of the stream bed. Extending the ramp well into the plunge pool also ensures the ramp is accessible to fish through water level changes e.g., in summer where the water levels can significantly drop.
- The flexible ramp material can be reused rubber conveyor belting or new reinforced PVC belting.

Installation

- Flexible ramps should be as wide as the site will allow i.e., approximately two thirds of the culvert diameter.
- The belting should always go shiny side (black) down when using PVC belting.
- Fix the ramp to the culvert invert approximately 150mm from the outlet.
- Fixings should be no more than 100mm apart to secure the ramp to the culvert invert.
- Ramps (rubber belting/PVC belting) should be installed well into the culvert plunge pool (if present).
- “Looped” mussel-rope should be used as alternatives are more prone to shedding fibres.
- At least four strands should extend down the ramp. To achieve this, two lengths of rope should be doubled-back through the D-ring.
- The strands of rope pass up over the V-baffle and are fixed approximately 75mm upstream with a D-ring and clasp.
- Mussel-rope should be secured with cable-ties (or equivalent) to the centre of the ramp approximately every 250mm. Note: Do not pull the cable ties taut - keeping the ropes slightly loose will allow fish to move through the rope bundle.
- Rocks may be added underneath the ramp to help position the ramp and lessen the grade (site specific).

Floating ramps



- Fitted to the culverts invert to provide a swimming and climbing surface for fish to enter pipes.
- Used at culverts that are perched/overhung.
- Floating ramps may provide scour protection and prevent further downcutting of the stream bed.
- Ramps should extend into the plunge pool. Note: floating ramps will be less effective if they do not sit in a pool.
- Floating ramps are currently available in 1200mm and 2400mm lengths.

Installation

- Fix the ramp to the culvert invert approximately 250mm from the outlet.
- Fixings should be no more than 100mm apart to secure the ramp to the culvert invert.
- Ramps should sit parallel to the structure/water where practicable.
- To give fish more navigation pathways, ramps should have a mixed-texture surface e.g., dimples and mussel-rope
- Ramps should have at least 4 strands of mussel-rope installed down the centre.
- Give consideration to scouring that may occur depending on where the ramp is positioned.

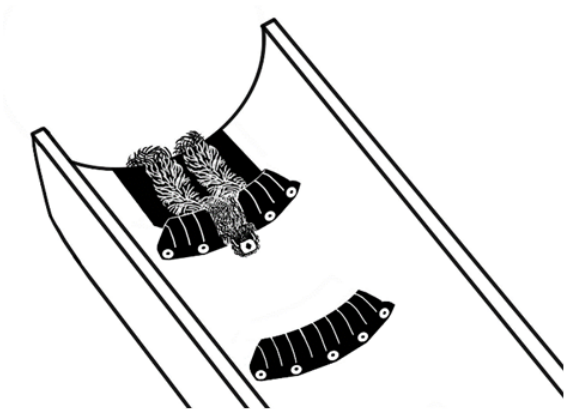
Mussel-rope only

- Fitted to the culverts invert to provide a climbing surface for fish to enter the culvert.
- Used in culverts where there is no plunge pool below the culvert or where a flexible ramp is impractical.

Installation

- “Looped” mussel-rope should be used as alternatives are more prone to shedding fibres.
- At least two strands of rope should be doubled back through the D-ring (giving a total of four strands).
- Can be used in conjunction with a V-baffle.

V-baffle



- Fitted to the culvert inverts to slow water velocities at the outlet and provide effective passage of fish into the pipe.
- Used in conjunction with mussel-rope in culverts that are 500mm diameter or greater and where baffles cannot be installed throughout.

Installation

- Ideally a V-baffle should be placed on the culvert invert approximately 150-200mm from the outlet.
- Mussel rope lies within the “V” of the baffle and is attached approximately 150mm above.

Culvert add-ons

Flumes & aprons

The tools discussed in this training aid can help with remediating culvert add-ons.

Fish passage fixes to these structures will need to be on a case-by-case basis.

← Culvert apron fitted with a flexible ramp, mussel-rope and flexible baffles.

Tide Gates

While there are relatively few tide gates compared with culverts, they can be the first barrier that fish migrating upstream encounter.

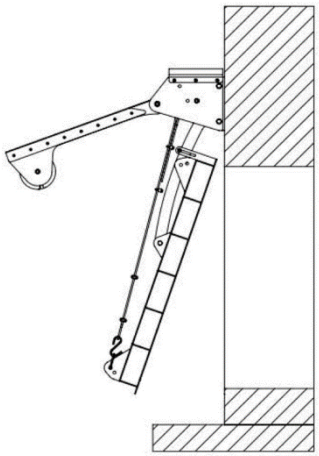
The sites usually have quite specific characteristics that will determine what remediation can occur.

Typical remediation aims to delay the closing of the gate to thereby allow fish a greater opportunity to pass.

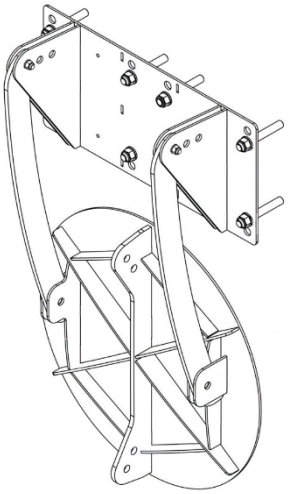
Delaying the closing can also allow better tidal flushing upstream thereby improving aquatic habitat

Examples:

CANTILEVER STYLE



OFF-SET STYLE



Fixings

Concrete

M6 x 50mm wedge anchor (stainless steel & galvanized)

Anka (60mm & 80mm) masonry screw (stainless steel & galvanized)

32mm x 8mm penny washer (stainless steel & galvanized)

Metal

35mm coarse threaded self-tapping self-drilling tek-screw (stainless steel & galvanized)

Plastic & Wood

35mm coarse threaded self-drilling tek-screw (stainless steel & galvanized)

Specialist fixings

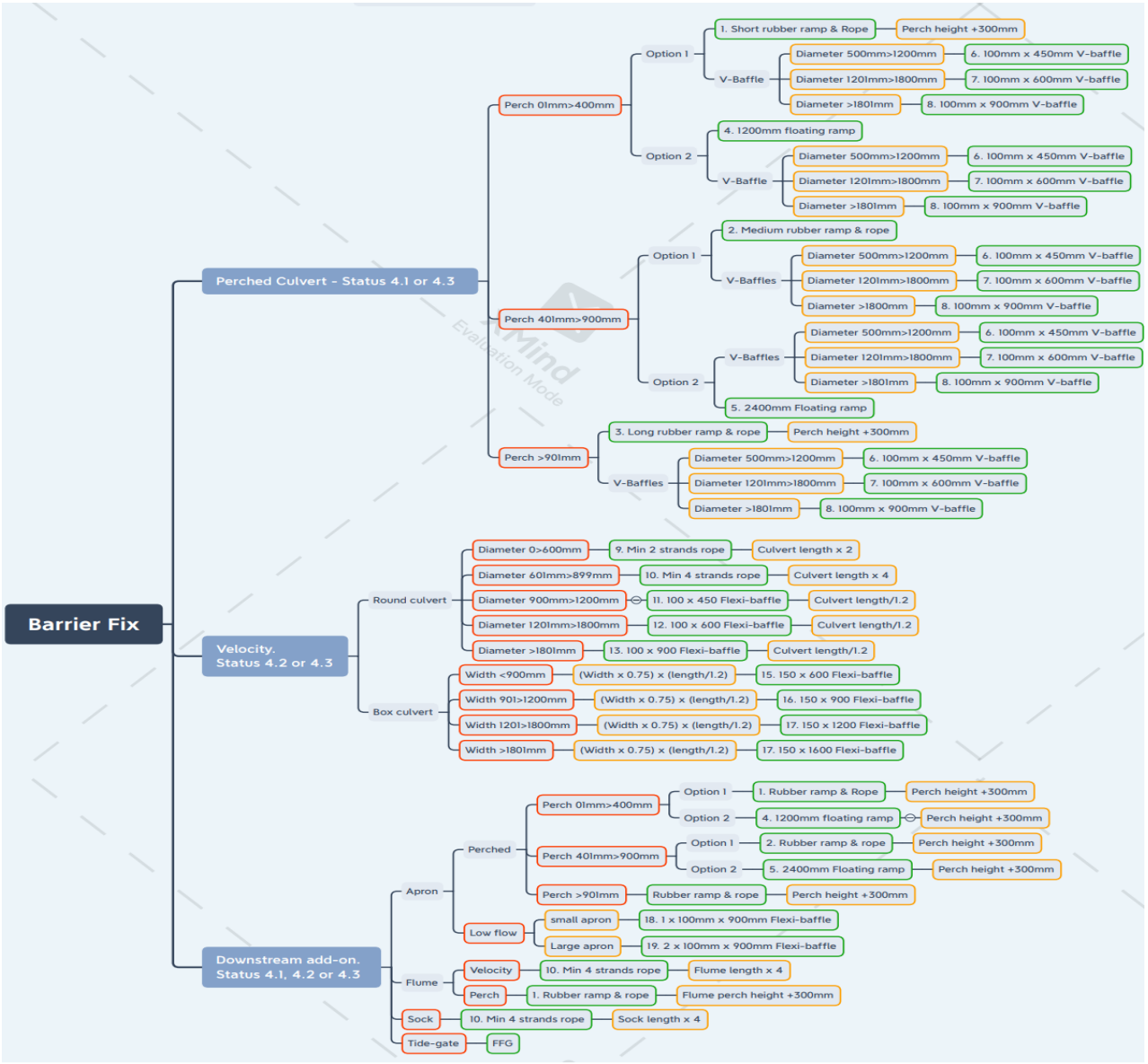
D-ring and clasp set (stainless steel)

Note: The above fixings are current best practise however site-specific conditions may call for alternative fixings or sizes. Ask trainers if you're unsure.

Specifier's guide for remediating culverts for fish passage

Decision Tree

Follow this decision tree to help you decide the appropriate fix for a culvert that is a barrier to fish.

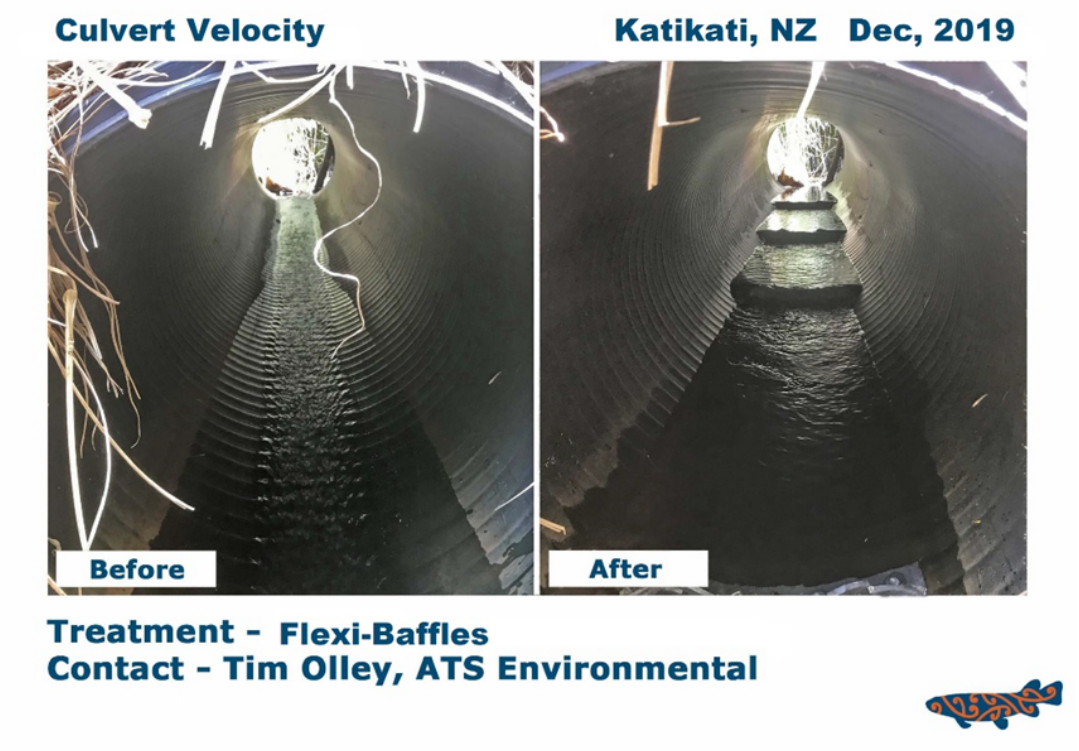


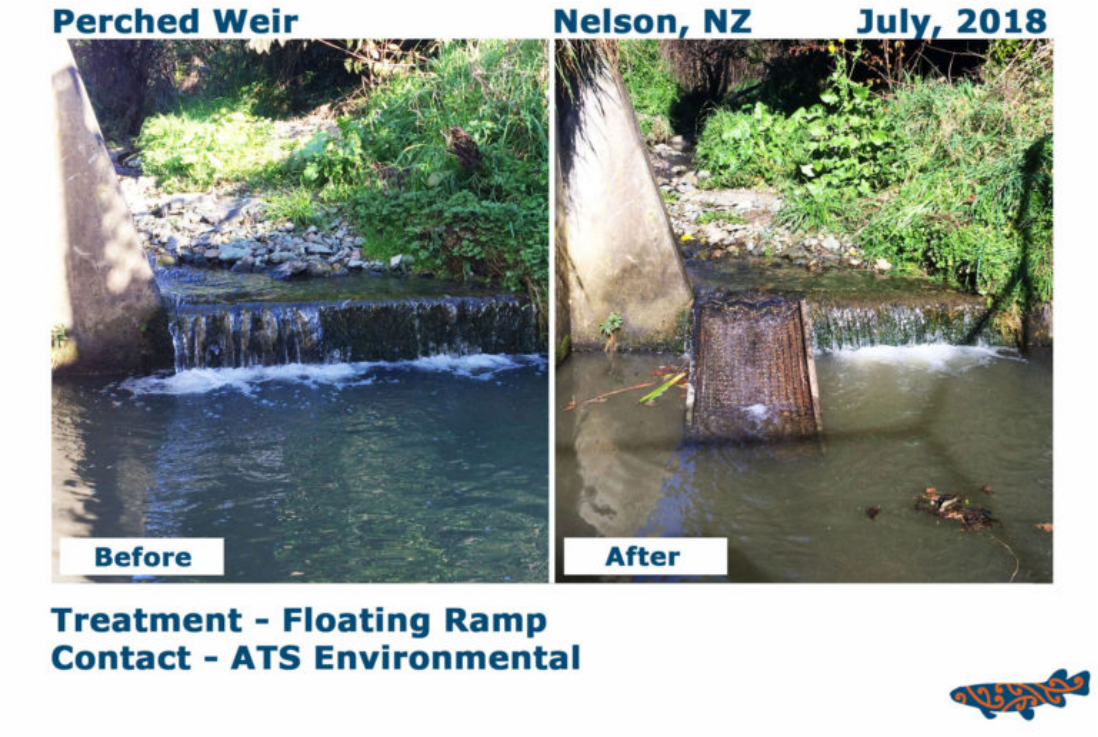
Notes:

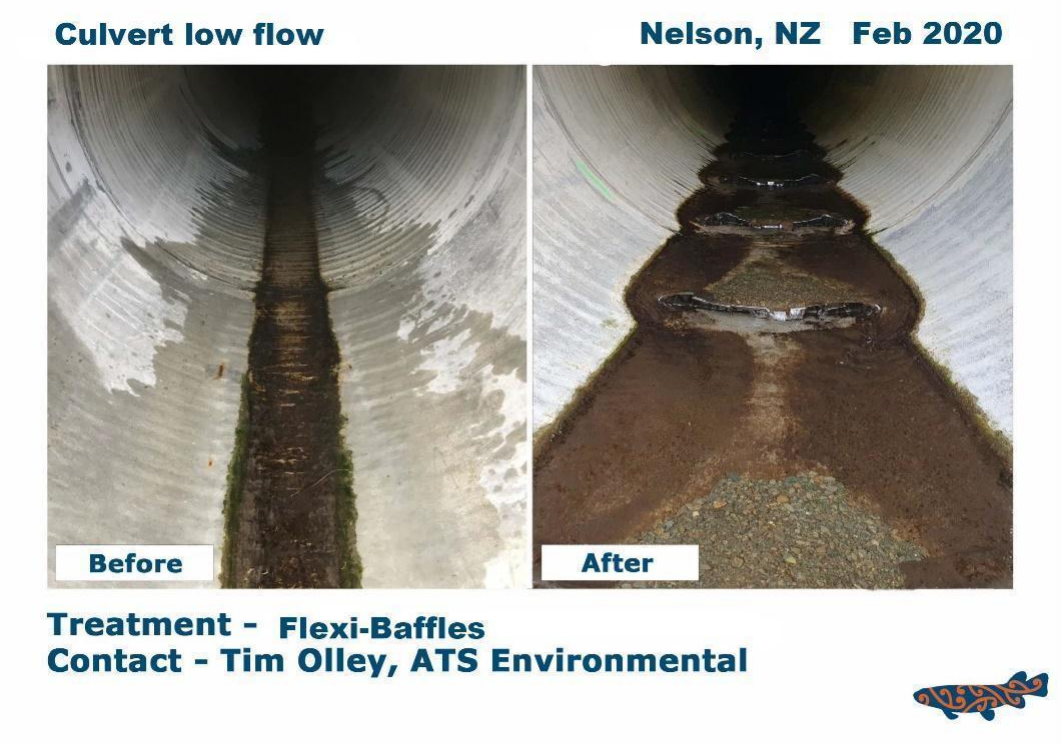
- The decision tree is a guide only.
- Each culvert may have several elements that need fixing.
- Training will give more detail and discuss exceptions.
- An interactive version of the decision tree can be found online if you follow the link below.

[Help me choose the right fix for my barrier • ATS Environmental (ats-environmental.com)]

Before & After examples of fish passage remediation







[Link to several more before & after examples can be found here]

Below are several short videos showing various aspects of fish passage remediation.

[Link to Fish Passage Video Library]

Summary

This document is designed to complement more comprehensive tuition.

Naturally all remediation should be done safely and in a tradesman like manner.

While this document highlights a number of remediation tools, effective intervention is not limited to these.

Providing the basic principles of providing continuity, depth and complex flows is adhered to, there is always room for creativity and innovation.

Footnotes:

1. There is always a need to know your catchment or region's fish communities. It is important to know if there are situations where exotic and/or particular native fish are not wanted upstream and not provide passage for these fish because they may compete with or prey on threatened species. Therefore, it is important not to provide fish passage for these unwanted species in these circumstances.

2. The authors are always investigating alternative or more sustainable solutions, however they need to be effective, robust, long-lasting, inexpensive and relatively easy to handle.

3. The team is currently putting together some guidance around fish passage mitigation of new structures where it is not practicable to follow regulation.

4. The authors are happy for this document to be referenced and shared (in its entirety).

5. For the latest version, comments or contributions please contact the authors:

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Equipment list

Item	Details
Safety Equipment:	
Road cones	4-6
Flashing lights and road work signs on vehicle	“Pass with care” – if on public roads
PPE	Ear defenders, eye protection, high-viz vest etc.
Gas detector	Only required for long culverts (usually in urban environments)
Power Tools & Associated Parts:	
Hammer drill*	Battery, SDS
Masonry drill bits*	SDS long and short - 6.0mm (wedge anchors) 6.5mm (sleeve anchors)
Drill	Cordless, 13mm keyless chuck, with hammer option as backup
Twist drill bits	Various sizes. Pre-drill for self-tapping screws in plastic etc.
Grinder	Cordless 110mm
Impact driver	Cordless
Spare batteries	For power tools Min 4
Wood bit	10mm for holes in baffles. Can be hex drive
Hollow bit	Set of “wad punches” for PVC sheeting
Assorted Hex Bits*	Tek drivers, allen keys, extensions, drill bits etc.
SDS chisel and point	Fits into a hammer drill. For breaking concrete etc.
Other Tools:	
Spade	Strong & sharp
Hedge clippers/loppers	Old school from op shop are best
Pruning Saw	
Small bucket	For fixings etc.
Crowbar/Pinch-bar	
6mm rebar	500mm lengths x 2
Lighting	Head torch, handheld flashlight
Gas torch	2 x butane canisters. Lighter as backup when igniter fails
Marker pens	Spirit, chalk
Tape measure	Builder’s type
Long tape/measuring wheel	30M+

Hammer	Club type
Small ratchet	¼ inch drive x 2
Sockets	10mm deep throat to suit M6 x 50 wedge anchors. 2 x spares
Knives	For cutting PVC sheet and mussel rope. Long blade for mussel-rope
M6 rod	3 x 300mm to hold PVC etc
Hacksaw	With spare blades
Vice grips	Various sizes and types e.g., deep reach
Full socket set	e.g., Bacho. Has ring spanners, various screwdriver attachments etc.
Plank of wood (300-400mm)	For protecting drill bits when working on the ground
Broom-handle (or similar)	For feeding out rope
Consumables:	
Cable ties	Usually needed for mussel-rope anyway
Insulation tape	Handy to have
Grinder consumables	1mm cutting discs, diamond grinding and cutting disks. Concrete cutting and grinding disks
Other:	
Waterproof, lockable work box	One or two for each ute. For tools and fixings etc. Removable if not a dedicated vehicle.
Storage bins	e.g., Fish bins x 4 for fixings,
Depth gauge	Make to suit. Use PVC conduit or similar

Version update page

Changes since last version:

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General rules “for practitioners”	6	7

Certification

Level One - Theory

Issued to:	
Name:	
Org:	
Date:	
Tutor:	
Location:	
Signed: (tutor)	

Level Two - Practical

Issued to:	
Name:	
Org:	
Date:	
Tutor:	
Location:	
Signed: (tutor)	