INTERNATIONAL FISH PASSAGE LEARNINGS AND RETROFIT LESSONS FROM CHRISTCHURCH

Mullaney M (Christchurch City Council (CCC)), Groves M (WSP), Margetts B (CCC)

ABSTRACT

The use of riffles as a means to remove vertical barriers on waterways is not a new practice, but it has been evolving and improving over time and is more relevant today than ever with the strengthening emphasis on fish passage in New Zealand.

This ~~paper provides details~~presentation will cover ~~of~~ the design process for the Mona Vale riffle in Christchurch which is being constructed to remove an existing fish passage barrier. ~~Of particular interest is that the~~ The project included input and review from overseas experts in riffle design from Charles Sturt University and incorporates learnings from computational fluid dynamics (CFD) modelling ~~to try and improve hydraulic conditions for native fish~~.

The remediation of this weir is planned to be used as a case study for weir fish passage barriers nationwide, through resources provided by the New Zealand Fish Passage Advisory Group.

1.1 BACKGROUND

In Christchurch, at the historic Mona Vale setting, there are two historic weir structures each on separate branches of the Ōtākaro-Avon River (Figure 1 - 3) (Mona Vale Park is highly valued in the community and a tourist attraction in Christchurch).

Figure 1 and 2: From left to right, Weir 1880 and Weir between 1860 and 1890. Images Christchurch City Libraries

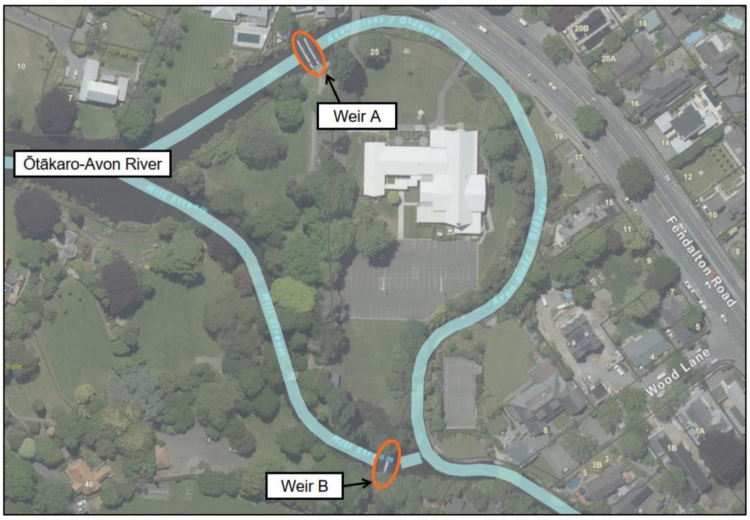

Figure 3: Aerial View of Ōtākaro-Avon River and Weirs

The weirs were originally used to divert wai from the Ōtākaro-Avon River to a nearby mill (Figure 4). The mill has since gone, but the weirs remain, as is likely the case in many other townships and cities across New Zealand.

Figure 4: Mill 1895. Image Christchurch City Libraries

The current iteration of the weirs are concrete structures, with the northern weir having North American style salmon ladders (Figure 5). Limited passage of brown trout does occur at this weir (with individuals anecdotally preferring to jump over the weir rather than use the ladders) but likely not full passage, and the weir is a complete barrier to many of our native ika (fish) who are poor swimmers. Because of this, the weir was assessed as one of the greatest priorities for fish passage remediation within the Ōtākaro-Avon River (Instream Consulting Limited, 2020)[1].

~~The objective of this remediation project is to increase the migration, diversity and abundance of ika to and from the upstream catchment of the Ōtākaro-Avon River by remediating the northern weir. In particular, inanga, bluegill bully and lamprey (all of which have a conservation status) are found downstream of the weir and are not currently upstream, even though the habitat that these ika would typically use is present.~~ Removing this barrier will open approximately nine kilometers of habitat to these poorer climbing ika (Figure 6). ~~Remediation of the weir is planned to be used as a case study for weir fish passage barriers nationwide, through resources provided by the New Zealand Fish Passage Advisory Group.~~

Figure 5: Current concrete weir structure with salmon style ladders

[1] Fish Passage Barrier in Christchurch City Waterways. Report prepared for Christchurch City Council by Instream Consulting Limited. Christchurch, New Zealand

https://www.ccc.govt.nz/assets/Documents/Environment/Water/Monitoring-Reports/Fish-Passage/Fish-Passage-Barriers-in-Christchurch-City-Waterways_Instream-2020.pdf

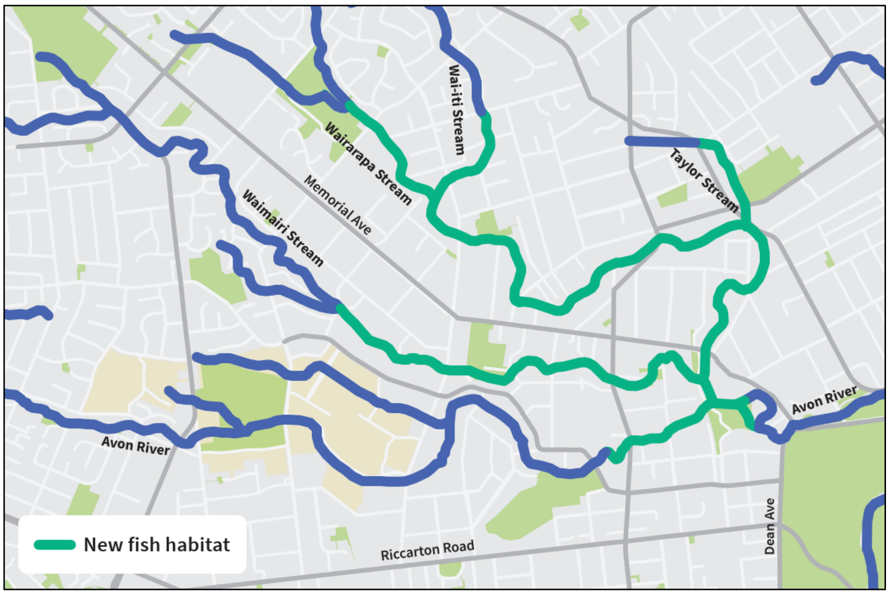

Figure 6: Approximately nine km of habitat opened upstream if weir is remediated

1.2 OPTIONS ASSESSMENT

Christchurch City Council (Council) collaborated with the Papatipu Rünanga partner through Mahaanui Kurataiao Ltd advisory company and consulted with many stakeholders including: Mona Vale Homestead, Environment Canterbury, Fish and Game, Department of Conservation, an archaeological consultant, community boards and adjacent property owners to understand the various facets involved and to consider preferences during the options assessment.

WSP and Council engineers and freshwater ecologists also worked with several local and overseas ecologists, including Charles Sturt University, to develop a concept design for the weirs. Whilst the local ecologists provided local and regional specific knowledge, Charles Sturt University have extensive expertise in the design and construction of riffles in Australia, often in challenging intermittently flowing catchments and provided review of the design. ~~A particular focus for Charles Sturt University was understanding the annual flow regime relative to the various times of species migration (the freshwater fish migration calendar for nationwide periods was utilised (https://niwa.co.nz/freshwater/management-tools/freshwater-fish-calendars). Flow statistics for the river were thus compared to migration time periods to understand the critical flow rates and time periods for design.~~

A comprehensive options assessment considered a bypass channel, riffle (rock ramp fishway), concrete rock ramp fishway, engineered multi-level concrete fish passage channel, fish lift and a fish lock. Replacement of one of the weirs with a rock riffle structure was ultimately adopted as it would provide fish passage for all critical target species and life stages and is identified as best practice based on the New Zealand Fish Passage Guidelines[2]. ~~The riffle concept involved a sloping narrowed section of the awa (river) with a rocky substrate similar to natural riffle features found locally in the region. Other options that would leave the weir in place like bypass channels and multi-level concrete channels were discounted due to site constraints and were seen as compromises given removal of a weir was feasible.~~

[2] https://niwa.co.nz/static/web/freshwater-and-estuaries/NZ-FishPassageGuidelines-upto4m-NIWA-DOC-NZFPAG.pdf

Options were then assessed for which branch it should be located on and its position relative to the weir (upstream, downstream or over the weir). Eventually a concept was settled on that had two thirds of the riffle located downstream of the weir on the northern branch. ~~This was for several reasons:~~

~~• The southern weir was located close to the confluence of the two branches and was better remaining in place to guide ika to the new riffle (Figure 7). If it had been the other way around, the northern branch would have formed a dead-end channel for native ika migrating upstream (Figure 8).~~

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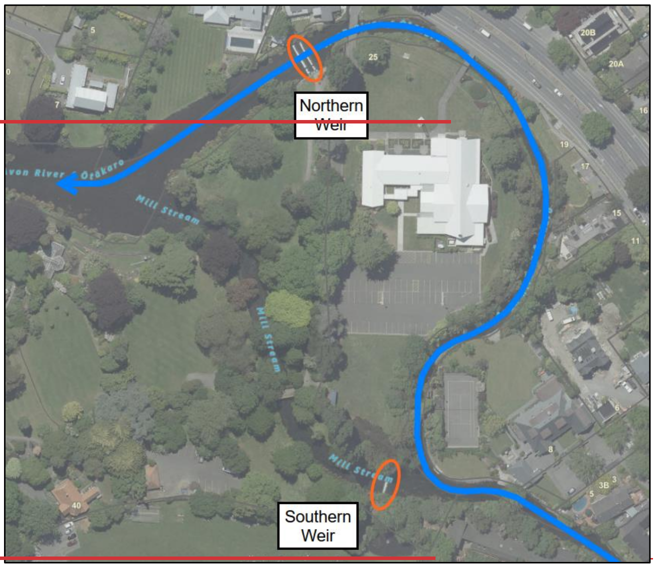
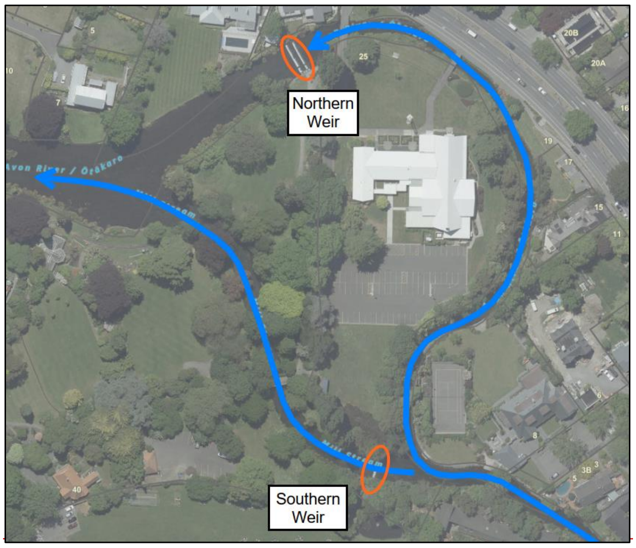


~~*Figure 7 – Fish Migration Routes with Southern Weir Guiding Ika to New Riffle at Northern Weir*~~



~~*Figure 8 – Fish Migration Routes if Southern Weir was Remediated with Dead-End Channel at Northern Weir*~~

- ~~The location of the southern weir at the confluence required a riffle to generally be installed upstream of the weir which would have necessitated substantial earthwork cuts into the waterway banks causing land loss to Mona Vale Heritage Park.~~
- ~~Positioning the riffle two thirds downstream of the northern weir minimised excavation into the riverbed and buttressed the adjacent property owners retaining walls and allowed the riffle to end a couple meters before a private bridge while maintaining a 1:30 longitudinal slope.~~
- ~~A riffle is aesthetically pleasing, particularly in Mona Vale Heritage Park, and creates higher flowing ecological habitat for specialist species, such as bluegill bully, which is limited in this awa.~~

Council had WSP create visuals for the proposed riffle which helped to discuss the project with community boards and adjacent property owners (Figure 9 and 10).

Figure 9 – Visualisation of the finished riffle used to assist with consultation in the early stages of the project

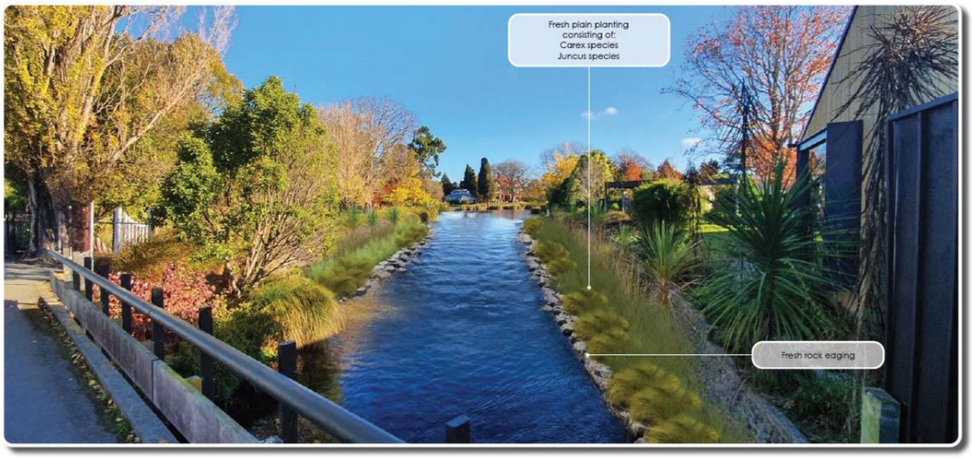


Figure 10 – Visualisation of the finished riffle used to assist with consultation in the early stages of the project

1.3 EXISTING RIFFLES ~~AND HYDRAULIC ROUGHNESS UNCERTAINTY~~

A riffle had previously been constructed downstream to replace an old rock weir located at the historic Antigua Boatsheds (Figure 11) and was used as a basis for design. Ecological monitoring of this weir has shown not only fish passage, but the return of the fast-water specialist bluegill bully.

Figure 11 – Previously Constructed Antigua Riffle Downstream

~~1.4~~ The flow gauging at Antigua Boatsheds indicated flow depths varied from 120 mm to 310 mm with a mean depth and velocity of 220 mm and 0.75 m/s and higher hydraulic roughness than would typically be assumed for design. ~~This indicated that the effective roughness coefficient of the riffle was higher than the literature would suggest (the values often being intended for flood events) or then calculated using Limerinos equation. This highlights the uncertainty associated with the design of riffle structures when it comes to predicting velocity and depth for fish passage design.~~

~~Much of the guidance around hydraulic roughness is associated with design for flood events and scour, not shallow turbulent flow through and over an irregular rocky substrate under low flow conditions. Methods that calculate roughness based on particle size and depth also do not typically account for flow turbulence under high gradient conditions. Marcus et al (1992) for example found that all the methods to estimate roughness they assessed under-estimated depth when compared to field measurements of turbulent high gradient streams. It is thus important to acknowledge this level of uncertainty and to manage it through design.~~

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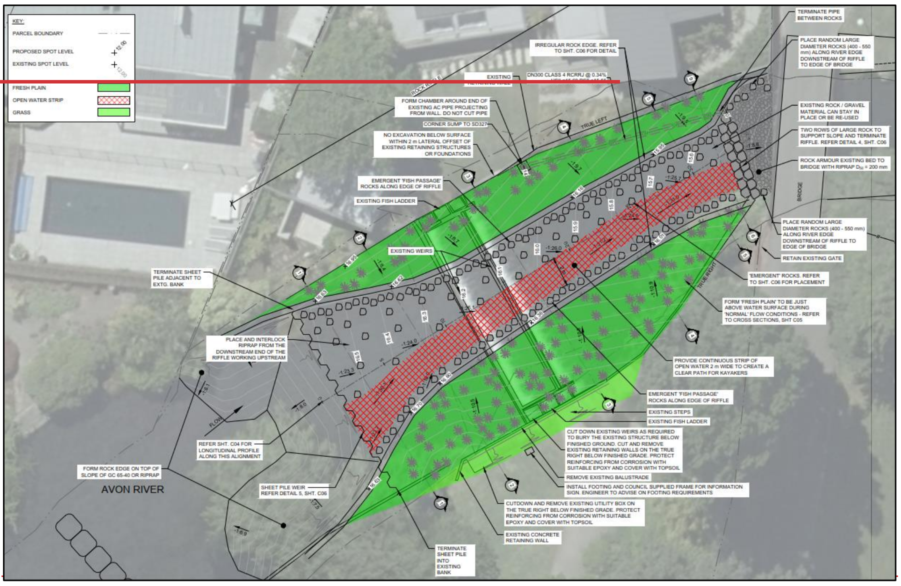
~~1.6~~1.4 RIFFLE DESIGN

Remediation design followed the New Zealand Fish Passage Guidelines for a rock ramp construction. To provide some confidence through the design the proposed riffle was analysed across a range of likely flow rates (representing monthly minimums and means) and a range of manning's values, representing upper and lower bounds, to indicate the likely range of depths. This was then workshopped with the ecologists to ensure they were comfortable with the range of values expected and whether these would allow fish passage.

The design also included an element of flexibility to account for this uncertainty. Adjustment of the crest plate of the southern branch weir was added into the scope of the construction work for post-livening adjustment and the fresh plains were steepened, to reduce the extent of submergence under higher than expected flow depth.

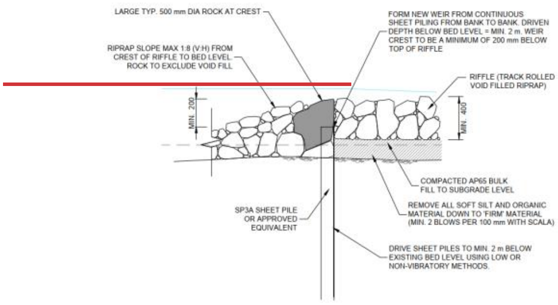
~~This acknowledges both uncertainty over roughness (particularly the effect of turbulence) and construction tolerances, which cannot be precise when placing irregular rock material in a riverbed. A 200 mm flow depth at the thalweg (defined as the line of lowest elevation within a watercourse) was adopted for the riffle at the 95th percentile flow rate under a low roughness scenario, as this was considered to be sufficient depth for brown trout (the New Zealand Fish Passage Guidelines recommend at least 250mm where adult salmonid passage is required).~~

~~The proposed riffle is approximately 5.5 m wide and 30 m long with a cross fall to provide a deeper edge on one side and a longitudinal slope of 1:30 (Figure 12). It incorporates fresh plains that narrow the channel to increase depth through the riffle, whilst also maintaining additional flood conveyance, as well as providing habitat for ika during times of higher flow and areas for sediment in flood flows to 'drop-out' of suspension.~~



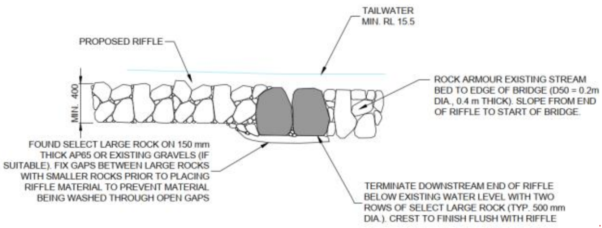
~~Figure 12 – Proposed Riffle~~

~~At the start of the riffle the riverbed ramps up to the V profile crest which is intended to maintain a similar water level to the existing weir structure. Buried within the riffle substrate and crest rock is a row of sheet piles (Figure 13). These prevent under-piping due to the bed slope and head difference across the structure.~~



~~*Figure 13 – Crest Rock and Row of Sheet Piles*~~

~~The riffle terminates below the downstream tailwater level with large rock supports and riprap extending from the toe downstream to a nearby bridge (Figure 14).~~



~~*Figure 14 – Large Rock Supports and Riprap at Toe of Riffle*~~

To enhance the proposed riffle, an irregular rock edge is also included. The irregular edge creates pockets of stilled water where ika can rest. This is complimented by a buffer of closely spaced emergent rocks along the edge of the riffle to dissipate energy and direct momentum away from the river's edge. ~~Charles Sturt University termed this feature 'fish passage rocks' (Figure 15). The fish passage rocks form a strip of low velocity flow with additional resting areas and the emergent parts also provide spawning sites for invertebrates. This approach was supported by Charles Sturt University with proof of concept CFD modelling undertaken by WSP (Figure 16).~~

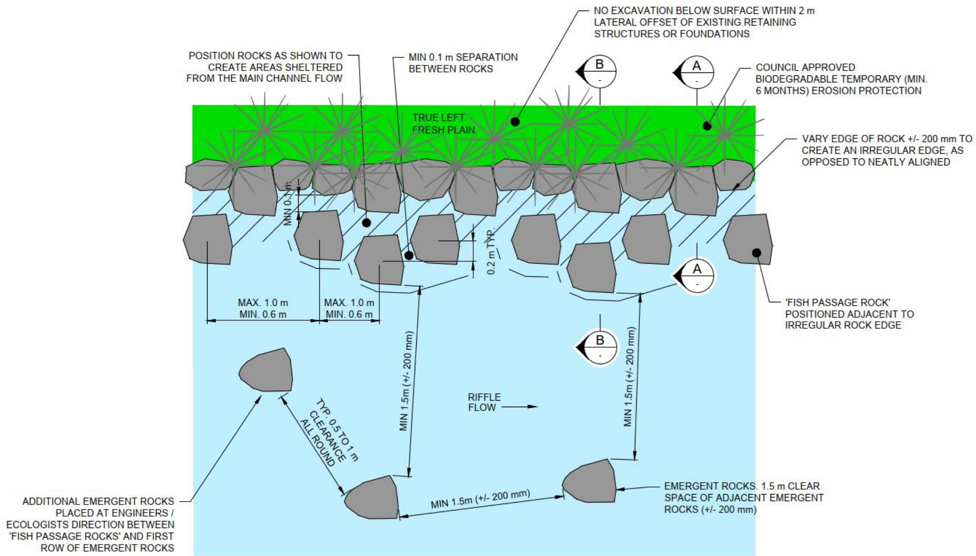
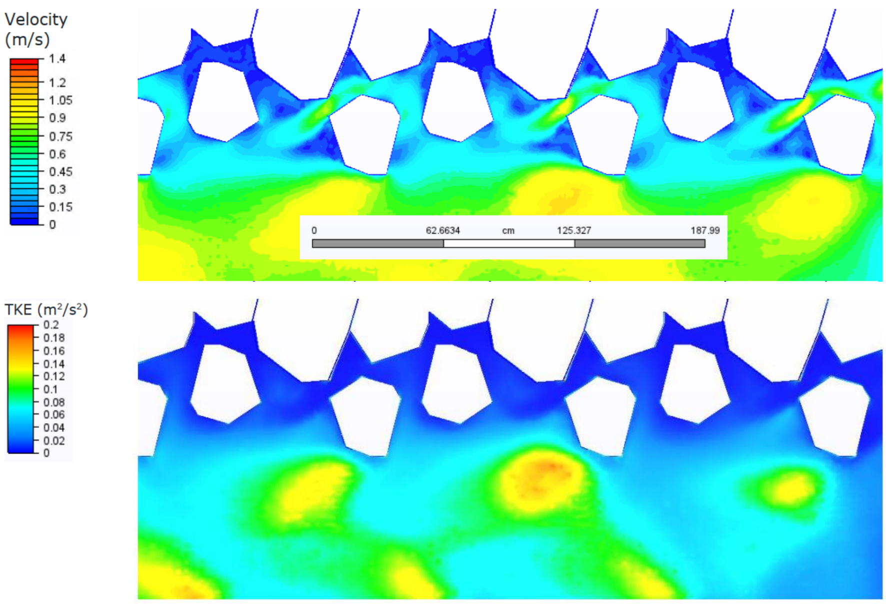


Figure 15 – Irregular Rock Edge, 'Fish Passage Rocks' and Emergent Rocks



~~*Figure 16 – CFD results for a continuous row of emergent rocks ('fish passage rocks')*~~

~~Across the wider riffle there will also be infrequently spaced emergent rocks to provide more varied flow, increased flow depth and additional invertebrate spawning sites. On the publicly accessible side there is clear zone with no emergent rocks to prevent the public from 'hopping' across the rocks to the private property adjacent to the riffle and to create a clearway for kayakers through the structure.~~

~~1.10~~1.5 CONSTRUCTION

Whilst construction has not yet started at the time of writing this abstract, it is expected that at the time of the conference we will be able to share lessons learnt through the construction phase. Key risks that have been identified so far for the construction phase include:

- Maintaining flood conveyance through the northern branch in case of a storm event
- The risk of erosion if too much flow is diverted to the southern branch weir during the works
- The need to maintain a consistent and constant flow downstream of the construction to protect populations of the At-Risk Declining kākahi (freshwater mussel)
- Preventing discharge of sediment into the Ōtākaro-Avon River
- Sufficient time for the placement of the riffle substrate and emergent rocks, which requires a higher level of care than conventional riprap placement
- Completion of waterway works prior to the trout spawning season from 1 May to 31 October
- Management of construction within Mona Vale Park and adjacent to neighboring property owners, including sediment discharge
- Separation of void filled riffle rock during transport to site.

Key elements which are applicable to other projects and incorporated into the tender documentation to reduce risk include:

- A lower riffle crest elevation than designed to account for construction tolerance for placing rocks (too high would be a problem, so it is specified lower than design to provide a Factor of Safety)
- The contractor will have their own principal nominated on-site ecologist to oversee the placement of the riffle. This helps to ensure the works are completed appropriately and to the project ecologist's satisfaction, but without scope for the Contractor to claim delays or additional costs from the principal due to the ecologist's direction onsite.
- A hold point to liven the river with the engineer and on-site ecologist following completion of the riffle and a provision for adjustment and modification of the riffle prior to disestablishment (included in the schedule of prices and specification).
- The use of visuals in the specification (example images and diagrams), as well as text, to avoid any ambiguity.

~~1.11~~1.6 ECOLOGICAL MONITORING OF SUCCESS

The Council has a long-term ecological monitoring programme for the catchment, but this was supplemented by additional pre-construction aquatic ecology surveys. The primary objective of these surveys was to determine changes in ika communities before and after the weir replacement. This will allow the success of the remediation to be established and ~~whether additional work is required to meet the project objective, as well as to~~ inform future remediation of other weirs nationally. ~~The secondary objective of the survey is to assess changes in habitat and stream health at the location of the constructed rock ramp, due to the construction of riffle habitat.~~

~~Two baseline surveys have been undertaken; the first assessing habitat, and macroinvertebrate and ika communities, and the second targeting the spring upstream migration of inanga, common bully and other native ika species. Surveys of kākahi have also been undertaken. Post remediation monitoring will be undertaken following the construction of the rock ramp (e.g., one, three, five and ten years post-remediation).~~

~~1.13~~1.7 SUMMARY

Based on the prior riffle structures constructed downstream, and the enhancements incorporated as part of this project, the outcome is expected to be a successful remediation of the existing fish passage barrier. The new riffle structure will not only provide a wider range of flow conditions that will facilitate fish passage for most of our native ika but will also provide specific habitat for bluegill bully (riffle specialists) and spawning habitat for invertebrates, as well as amenity with new fresh plains incorporating native vegetation and edge shading within the Mona Vale setting.

The learnings from this project provides guidance for other Councils who are looking to undertake similar work and an example of current best practice that incorporates lower velocity flow and resting areas within riffle structures.

KEYWORDS

Ecological enhancement, Fish passage