Gisborne Region Fish Passage

Barriers to Fish Passage in the Gisborne Region

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D.Armstrong

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EXECUTIVE SUMMARY

Twelve of the 14 native freshwater fish species identified in the Gisborne region are diadromous, undergoing migrations between fresh and salt water as a necessary part of their life cycle. An inability to undertake migration can severely disrupt life cycle completion of diadromous species and potentially lead to local extirpation. Fish migration can be blocked by poorly designed or unmaintained in-river structures such as culverts, fords, weirs and dams.

A comprehensive survey of the in-stream structures of the Gisborne region from the Waipaoa River catchment to Tolaga Bay was carried out between October 2007 and August 2008 to identify barriers to fish passage. The barriers caused by each structure were identified and the structures were then ranked for prioritisation of remedial work by catchment and then overall. Potential mitigation options were provided for each of the barrier types identified and guidelines provided for the installation of new structures to ensure future fish passage.

In order to avoid fish passage problems, culverts and in-stream structures should not alter the natural behaviour of the stream or the physical aspects of the streambed in any way. To facilitate fish passage structures should meet the following general criteria: flow velocity below 0.3 ms-1, flow at same gradient as stream and passing in line with the natural stream, sloped or dished floors, rounded ends and junctions, wetted margins for climbing species, good quality water flow to attract fish, and the inlet should be in an area fish naturally move to. In addition, bed material should be assessed to determine the potential for downstream erosion, with mitigation action taken if necessary.

Of over 400 surveyed sites there were 220 in-stream structures identified to be impeding fish passage in the Gisborne region. Of the 220

structures, 77% were found to pose barriers at most or all flows, 16% at low flows and 6% at high flows. The vast majority of these structures (84.5%) were culverts, with 12.7% being fords and the remaining structure types combined accounting for 2.7% of the structures. These barriers combined exclude a total of 15.2% of the regions area as potential habitat. The most prevalent issue identified was perching, which occurred at 74% of the structures surveyed. The other common barriers were inadequate water coverage (49%) and dark passage (36%).

The structures identified as being of most benefit to fix are the weir in the Te Arai River near Pyke Road and the culvert in the Matokitoki Stream at the intersection with Lytton Road. These structures are close to the sea, block a large amount of upstream habitat and are barriers at most flows. Areas for prioritisation of remedial work were identified to be the Te Arai River, the streams feeding into Wainui and South Makorori Beaches, the tributaries of the Waiomoko River and the tributaries of the Waimata River.

Fish passage can only be ensured long term provided there is periodic maintenance of the structures and alterations or modifications where necessary. As fish passage technology continues to improve, it is important to apply the new technology to existing structures to help ensure the long term viability of our unique freshwater species.

1. INTRODUCTION

Freshwater fish passage and the ability for fish to move freely between the sea and rivers is a significant issue for New Zealand. Eighteen of New Zealand's 35 native fish species are diadromous, undergoing migrations between fresh and salt water as a necessary part of their life cycle (Boubée et al 1998, McDowall 1994, Baker and Boubeé 2003, Kelly and Collier 2006). Migration is essential for the survival of these species, with any inability to undertake migration severely disrupting life cycle completion and potentially leading to local extirpation (McDowall 1994).

Migration of fish species can be impeded by both natural in-stream barriers (for example, waterfalls and debris jams), and insufficiently designed anthropogenic in-stream barriers (for example, culverts, fords and weirs) (Boubeé et al 1998). This is of concern to the Gisborne region with twelve of the fourteen native freshwater fish species identified in the Gisborne region's catchments being diadromous, including the threatened longfin eel (gradual decline) and koura (gradual decline) (Appendix 1).

The purpose of this study is to identify any anthropogenic in-stream structures impeding fish passage in the Gisborne region, to identify the barriers caused by each structure and then to rank the structures for prioritisation of remedial work. Prioritisation is indicative of which structures it would be of most benefit to native fish to modify. Potential mitigation options are provided for each of the barrier types identified and guidelines are provided for the installation of new structures to ensure fish passage. These guidelines and mitigation options are compiled from current literature.

The intention of this report is to provide guidance on the requirements and potential mitigation considerations for current in-stream structures, and the design of new in-stream structures, to protect passage for fish species. This report is not intended to be a substitute for consultation with engineers. Mitigation options and fish passage guidelines are provided to be used in conjunction with consultation with a roading expert.

The scope of this report is restricted to assessing the passage of fish and does not include assessment for the passage of other aquatic species, such as invertebrates and aquatic plants, which also may require passage along the waterway.

1.1 BARRIERS

Anthropogenic barriers to fish passage are mainly comprised of poorly designed, installed or maintained in-river structures such as culverts, fords, diversion structures, weirs and dams (Boubeé et al 1999). In addition to effecting migration, the installation of an in-stream structure alters the hydraulic conditions of the stream in that location (Boubeé et al 1999), disrupting flow regimes and interfering with sediment transport (Speirs and Ryan 2006). In-stream barriers can also isolate potentially productive habitat by preventing fish from colonising suitable upstream or downstream environments (Baker and Boubée 2003, James 2006). Although not investigated in this report, in-stream barriers have also been identified to prevent movement and restrict populations of aquatic invertebrates such as mayflies and caddisflies (Blakely et al 2006). Road culverts act as partial barriers to upstream flight, with consequences for larval recruitment in urban streams. Ideally invertebrate movement would be considered when constructing in-stream structures. However, due to the information on their passage requirements being very limited, invertebrate passage was unable to accurately be assessed throughout the course of this study.

In-stream structures can impede fish passage in several ways:

- High water velocities with no resting areas. Often caused by structures that are narrower or steeper than the natural stream bed and have a lack of substrate to decrease water flow and provide resting areas (Boubée et al 1998, MacDonald and Davies 2007).
- A lack of a low velocity zone or wetted margin at the water edge which climbing species can move across. Often caused by culverts that are too full or by structures such as box culverts having vertical sides (McDowall 1979, Kelly and Collier 2006).
- Water depth within the structure that is too shallow. Often caused by flat bottomed culverts or fords which allow the water to spread, or by inverts that sit above the natural streambed level (Webb et al 1991, Boubée et al 1998).
- Debris build up around the structure forming a weir (Baker and Votapka 1990, Kelly and Collier 2006).
- Falls at the end of a structure caused by scouring, erosion or poor initial design (McDowall 1979, Boubée et al 1998).
- Flood gates which are not open sufficiently to allow fish to pass, especially tidal floodgates which hinder fish species that migrate with the tides.
- Crossings that are too dark, often caused by culverts which are too long or too small in diameter (Kelly and Collier 2006).

Fish species have various adaptations which affect their ability to negotiate river barriers (Barnes 2004). In addition to swimming, several New Zealand species have the ability to climb moist surfaces (Boubée et al 1998) including the wetted margins of waterfalls, spillways, culverts and weirs to successfully surmount obstacles. This climbing behaviour gives the fish the ability to migrate over considerable barriers and penetrate far inland. Other species must swim past such obstacles, relying on short bursts of fast swimming to get past high velocity areas. In most cases swimming fish are less successful than climbing fish at negotiating in-stream obstacles (Baker and Boubée 2003).

New Zealand's diadromous fish species can be divided into four groups based on their swimming capabilities (Mitchell 1990, Boubeé et al 1999):

- Anguilliformes: Have ability to move through small spaces. Can move in and out of water. Can respire atmospheric oxygen if skin remains damp. For example, eel species, kokopu and adult koaro (to a limited extent).
- Climbers: Can climb wetted margins of waterfalls, rapids and spillways. They adhere to substrate using surface tension and may use pectoral or pelvic fins. For example, Lamprey, elvers, juvenile kokopu, juvenile koaro, juvenile common and redfin bullies.
- Jumpers: Able to leap using wave momentum at rapids and water falls. For example, trout, salmon and smelt.
- Swimmers: For example, mullet and common smelt.

In order to avoid fish passage problems, culverts and in-stream structures should not alter the natural behaviour of stream or the physical aspects of the streambed in any way. When considering fish passage it is essential to recognise that for all diadromous species there are both upstream and downstream migrations which are of equal importance to completing their lifecycles and therefore maintaining their populations (McDowall 1994). It is also important to be aware that a barrier to migration at one point low in the catchment affects the entire catchment upstream (Mitchell 1990).

1.2 LEGISLATION

The provision of fish passage for in-stream structures has been a legislative requirement in New Zealand since 1983, following the enactment of the Freshwater Fisheries Regulations by the New Zealand Parliament. Part VI of the Freshwater Fisheries Regulations 1983 restricts the construction of culverts, fords, dams and diversion structures in New Zealand (http://interim.legislation.govt.nz/). Section 44 of the Freshwater Fisheries Regulations 1983 states that the Director General has the power to specify design and operation criteria of any fish pass. Section 44 also states that:

“The manager of every dam or diversion structure in connection with which a fish facility is provided shall at all times keep such fish facility in good and satisfactory repair and order, so that fish may freely pass and return at all times or are prevented from passing as specified under these regulations.”

The requirements of the Freshwater Fisheries Regulations apply to most defined structures unless they were built prior to 1st January 1984 and were authorised under the Water and Soil Conservation Act 1967. This act was the primary legislation governing the use of water resources prior to the enactment of the Resource Management Act (RMA).

The RMA in 1991 added additional requirements aiming for the sustainable management of natural and physical resources. Section 17 of the RMA requires:

“Every person to avoid, remedy or mitigate any adverse effects on the environment resulting from an activity carried out by that person, whether or not the activity is in accordance with a rule in a plan or resource consent designation…”

The legislation requires the owner of any structure causing an adverse effect to take the appropriate action to remedy this effect. The full legislation is provided in Appendix 2. The agencies responsible for the maintenance of stream crossing structures on public roads in the Gisborne region are Transit New Zealand and the Gisborne District Council. Transit New Zealand has authority over maintaining the State Highways and the District Council maintains all of the other public roads.

Generally, these requirements apply to all defined structures unless they were built prior to 1 January 1984 and were authorized under the then Water and Soil Conservation Act. It is important to note that the DOC authorizations are required for all in-stream structures regardless of any other consents (RMA, Building Act, etc) or landowner approvals. This is not well understood by local and regional authorities, much less by the general public (Gibbs 2004).

DOC does not currently have a Standard Operating Procedure (SOP) to guide consistent application of its advocacy and regulatory roles in fish passage management (Charteris 2008). Currently there are overlapping jurisdictional issue with fish passage. Until roles are rationalized or clarified in law (they have been to the Environment Court three times in recent years), the DOC protocol is generally to:

- Advise developers of the regulations at the earliest stage.
- Emphasize that if a culvert, ford or weir has potential to impede fish passage then an application to DOC is required.
- If however, the design meets fish passage standards for the species present then no DOC approval is needed; i.e., it is not an offence to then construct without approvals.
- Emphasize that every person proposing a dam or diversion structure in waters containing fish must notify DOC and seek approval or dispensation from the requirements of the regulations. This is independent of any RMA requirements or permitted activity rules in a plan (Gibbs 2004).

1.3 STUDY AREAS

1.3.1 Waipaoa River Catchment

Ten of the 12 native freshwater fish species identified in the Waipaoa River catchment are diadromous, including the threatened longfin eel (gradual decline) (Appendix 1).

The 120 km long Waipaoa River is among the largest in the North Island (Poole 1983, Jones 1988) draining a tertiary sandstone and mudstone hill-country catchment of approximately 2200 km^2 (Smith 1988) (Map 1). Originating on the south-eastern slopes of the Raukumara Ranges (Egarr and Egarr 1981 at an altitude of 1200 m (Jones 1988) the Waipaoa River flows southeast through a steeply graded channel before forming a braided river (Jones 1988) and eventually flowing into the southern end of Poverty Bay at an average gradient of 1:333 (3m/km) (Egarr and Egarr 1981).

The principal tributaries of the Waipaoa River catchment are the Mangatu (21 km), Waihuka (24 km) and Waikohu Rivers (48 km) which rise in the western ranges, the Waingaromia (38 km) and the Waihora Rivers (31 km) which run from the east, the Wharekopae River (43 km) from the west, and the Whakaahu River (19 km) and Te Arai Rivers (31 km) which join the Waipaoa River close to the sea from the west (Jones 1988, Egarr and Egarr 1981).

The Waipaoa River catchment has a 'normal' flow of 20 cumecs, but has been recorded to drop as low as 2 cumecs (Poole 1983). The average annual total discharge of the catchment is in excess of 1300 x 10^6 cubic metres of water (Waipaoa Water and Soil Resources Development Project 1985). This discharge is seasonal with winter maxima and frequently very low summer flows (Waipaoa Water and Soil Resources Development Project 1985). The catchment has experienced 29 extreme floods (flows over 1,500 cumecs) in recent history (Ministry for the Environment 1997), and is now contained for over 26 km of its length in the middle and lower reaches by stopbanks up to 5 m high (Poole 1983).

Natural erosion rates in this catchment are high (Ministry for the Environment 2007), with the rocks of the catchment consisting mainly of highly erodible siltstones and sandstones which are prone to mass movement (Poole 1983). These high natural erosion rates have been exacerbated by land development (Ministry for the Environment 2007) with the increased sediment yield associated with land clearance resulting in a 25% increase in the volume of material annually deposited on Waikanae and Muriwai Beaches (Smith 1988) .

The Waipaoa River has the second highest rate of suspended sediment discharge of New Zealand's rivers, annually depositing 15 million tonnes of sediment into Poverty Bay (Orpin 2007, Gisborne District Council 2004). This equates to 33.54 cubic meters of sediment per second (Gisborne District Council 2004) or 4100 truckloads per day (Orpin 2007). The Waipaoa and the other major East Cape rivers, the Waiapu and the Hikuwai, collectively deliver 0.3% of the global mud budget to the ocean (Orpin 2007).

1.3.2 Turanganui River catchment

At 1200 m long it the tidal Turanganui River is the shortest river in New Zealand. The Turanganui River is the result of the confluence of the Taruheru and Waimata Rivers and is joined by Waikanae Creek near the river mouth. All of these rivers flow through the suburbs of Gisborne, with the Waimata River (49 km) being the largest of the three (Egarr and Egarr 1981). The Turanganui River meets the ocean near Waikanae Beach. The mouth of the Turanganui River was spilt in two in the early 1920's with a concrete diversion wall to create the harbour. Nine of the eleven native fish species identified in this catchment are diadromous, including the threatened longfin eel.

1.3.3 East Coast Catchments

The east coast section of this report refers to all rivers flowing into the sea on the east coast between Tuaheni Point and the Uawa River at Tolaga Bay. Five of the six native fish species identified in this area are diadromous including the threatened longfin eel (gradual decline).

The principle rivers of the east coast are, the Pouawa and Waiomoko Rivers which flow onto the coast a little north of Gisborne City and the Pakarae River which flows onto the east coast approximately 25 km north of Gisborne. The 5 km long Pouawa River drains a catchment of approximately 44 km^2 before flowing into the southern end of the Te Tapuwae o Rongokako Marine Reserve 18.5 km north of Gisborne. It's major tributaries are the Tarewarewa and Tangamatai Streams. The Waiomoko River is approximately 29 km long and drains a catchment area of about 75 km into the northern end of the Te Tapuwae o Rongokako Marine Reserve 24 km north of Gisborne. The major tributaries are Wairoa Stream, Wharekeri Stream, Otawaiwai Stream and Ohaiatangaora Stream. The 57 km long Pakarae River drains a catchment of approximately 245 km before entering the ocean 2 km north of Whangara. The major tributaries are Mangakori Stream, Waitapaua Stream, Waitorehuna Stream, Makatote Stream, Mangapapa Stream, Mangarara Stream, Makahakaha Stream, Mangataueru Stream, Whakaauranga Stream.

2. METHODOLOGY

Comprehensive surveys of the in-stream structures of the Gisborne Region were carried out, assessed and ranked on a catchment by catchment basis and then combined for an overall ranking. The Waipaoa River catchment survey was carried out between October 2007 and February 2008. The surveys for the Turanganui River catchment and East Coast river catchments were carried out in July 2008. The study was predominantly restricted to structures located at intersections of public roads and streams with potential fish habitat. However, any sites on private land with high potential habitat value or which were suspected to impede fish passage were also included. The Mangatu Forest was included as it dominates the upper reaches of the Waipaoa River. Due to time constraints, not all of the Mangatu Forestry was surveyed. Refer to ArcMap layer 'roads surveyed' for visited areas.

Several methods were used in conjunction to identify all of the structures built as a result of a public road intersecting a stream. The Gisborne District Council provided map co-ordinates and descriptions for in-stream structures which had been granted resource consents between January 1991 and November 2007. Transit New Zealand provided a list of small culverts managed by Transit New Zealand, however the site references were recorded using a linear system, not as map references, so were unable to be mapped and located. Transit New Zealand culverts were instead identified in the field. The New Zealand topographic map NZMS 260 series was then used to identify further potential structures.

These methods combined identified over 440 potential sites on public roads, with additional potential sites on private land. Visual searches were also carried out in the field by looking for streams and rivers intersecting roads and looking for Council or Transit New Zealand road markers indicating fords or culverts whilst in the field. The final method of locating in-stream structures was use of local knowledge from Gisborne District Council drainage staff member, Chris Sharp.

Only in-stream structures that posed a barrier to fish passage, and had both potential upstream fish habitat and a downstream passage for fish to travel up were included. Any sites with no clear downstream passage (for example, the culvert opened into a flat, grazed paddock with no signs of a stream or wetland, or no potential passage to the sea), or a lack of suitable upstream fish habitat (for example, culverts that drained a small ditch containing run-off from a steep, high bank and no stream), were excluded. This exclusion of structures was subjective and open to error. To minimise error sites for which there was uncertainty as to the potential fish habitat were included. The inclusion of sites with undetermined potential fish habitat should not impact the results of this study as up-stream network length was considered in the ranking process of this study.

There is an extensive network of private roads and four-wheel drive tracks across farms and other private land within the Gisborne Area. Many of these roads and tracks cross over streams varying in size with over 300 crossing and potential in-stream structures being identified in the Waipaoa River catchment alone. It was not feasible to visit each of these sites within the scope of this study, especially as many of these crossings are four-wheel drive tracks without in-stream structures and differentiation is not possible from maps. Only those sites on private land containing good potential fish habitat or in-stream structures which were suspected to impede fish passage by the Gisborne District Council staff were surveyed.

Each structure was assessed using a modified version of the evaluation sheet described by Kelly and Collier (2006), which is itself a modified version of the suggested culvert evaluation process from Boubeé et al (1998). The criteria were loaded on a Trimble Juno ST handheld field computer with integrated global positioning system (GPS) receiver. The handheld was used to log data and take the co-ordinates of each site. For each individual barrier the following was recorded: site location, barrier type, number of culverts, culvert type, culvert material, culvert length, culvert diameter, outlet water depth, substrate depth, inlet cross section, outlet cross section, water fall height, undercut height, restriction extent, stream bed level, stream to culvert width, stream gradient, stream to culvert alignment, water flow level, presence of upstream or downstream barriers and presence of bank erosion.The structures, the upstream and downstream habitat, any barriers and any unusual features were photographed using a digital camera. Due to the high number of sites visited only the position of sites found to be posing a barrier were recorded by GPS.

Restriction extent was ranked as one of the following (from Kelly and Collier 2006):

- None/minimal: Where the structure poses no significant barrier to the upstream or downstream passage of fish within the normal range of flow conditions.
- Low flow only: Where the structure poses a barrier only at low flows.
- High flow only: When the velocity past the structure is likely to increase and become unnavigable by the majority of fish in the stream during high flows.
- Most flows: Where the structure poses a significant barrier to the passage of fish likely to be found in the stream at most of the normal range of flow conditions.

Where natural barriers, such as the Rere Falls on the Wharekopae River, were present downstream, rankings of 'restriction extent' only considered the passage of species which could potentially pass the natural barrier, i.e. climbing species.

Stock or flood gates that do not accommodate flow fluctuations can restrict the water flow and create fast flows. These structures are predominantly on private land so were not included in this study but were recorded in the notes if observed. It is important to ensure these structures are maintained and that they move with increased flow to allow water to pass without increasing the flow rates.

High flow barriers were only assessed by the water levels in the barrels of the structures. The water speed was not measured in this study. Potential high flow barriers were identified as structures which restrict the flow by being narrower than the natural streambed, or have less than 5 cm of substrate in the bottom on the structure.

A tape measure was used to measure structure diameter and length. The length measurement was the minimum distance between the culvert openings, or structure ends from outside the culvert, as some culverts were bent and an exact measurement of these was not possible. Where a structure contained more than one culvert the number of culverts was recorded and the diameter of one culvert was recorded. Estimates on structure length were made where heavy traffic on roads prevented actual measuring, or sections of the structure were inaccessible.

The water depth was measured using a 1 m wooden ruler and was measured just inside (approximately 5 cm) the culvert outlet. Substrate depth was determined by measuring the distance from the top of the sediment to the top of the outlet and subtracting from the culvert diameter. Where access to the structure was not possible, estimates were made in place of the measurements and noted as such in the field notes and on the spreadsheet.

Aspects of this assessment are subjective. However, implications of this were limited by all of the field data being collected by the same person, minimising inconsistency.

All data was collected on a catchment by catchment basis. The Gisborne region was divided into three separate study sites, the Waipaoa River catchment, the Turanganui River catchment and the east coast from north of the Turanganui River mouth to the Uawa River mouth, Tolaga Bay.

All sites were then mapped and a spreadsheet of collected data compiled using ArcGis 9.2 (service pack 4) and the site photos linked to the maps. The sites were then assessed and ranked to determine which site would yield the greatest benefit to fish passage if corrected. Rankings were calculated for each of the three catchments and then combined to provide overall rankings. A large amount of the streams within the catchment are not present on the maps as they a re ephemeral, occurring during and after rains. Calculating the total stream length lost to fish was not possible without large amount of estimation and inaccuracy. Therefore, total catchment area lost was calculated. This calculation was done measuring the River Environment watershed polygons upstream from the blockage.

The ranking system used was a modified version of that described in Kelly and Collier (2006) with the addition of a sixth criteria identifying if the stream contained flow. The finalised ranking system was a six point system with the potential range of scores being 21 (lowest) – 62 (highest) (Figure 1).

Figure 1. The criteria used to determine which structures would benefit most from remedial work.

ASSESSED CRITERIA AND WEIGHTING	RANKING VALUE
Culvert barrier type Weighting of 6	1 = barrier at high flows 2 = barrier at low flows 3 = barrier at most flows
Distance from sea (km) (4) Weighting of 5	1 = >50 2 = 11-50 3 = 0-10
Upstream network length (km) (3) Weighting of 4	1 = 0-10 2 = 10-50 3 = >50
Percentage upstream catchment forest cover (2) Weighting of 3	1 = 0-10 2 = 10-50 3 = >50
Number if other road culverts upstream or downstream (rating low or most flows) Weighting of 2	1 = >1 2 = 1 3 = 0
Stream flowing or dry	1 = Dry 2 = Flow

For ease of interpretation, the individual sites were then re-numbered and placed in numerical order with one being the highest priority. This ranking system identifies the sites which would be of most benefit to native fish if mitigated.

Correcting all of the fish passage problems on a waterway by waterway basis instead of a site by site basis may be more beneficial as it allows for correction of the entire habitat and potentially reduces financial costs by working in the same area. To identify key areas that would have the most benefit from remedial work quantile grouping was used to group the sites into 5 different priority rankings. These were then mapped using ArcGis 9.2. This allowed easy visual identification of areas of high priority for remedial action.

3. RESULTS

3.1 GISBORNE REGION FROM THE WAIPAOA RIVER TO TOLAGA BAY

There were 220 in-stream structures identified to be impeding fish passage in the Gisborne District from the Waipaoa River catchment to Tolaga Bay. Not all measurements were obtainable for each structure, so results given are of those recorded.

Of the 219 structures where flow barriers were determined, 77% were found to pose barriers at most or all flows, 16% were found to impede fish passage at low flows and 6% of the structures were found to restrict fish passage at high flows (Figure 2). These barriers combined exclude a total of 15.19% of the catchment as potential habitat. This total is of catchment area, not streams. The area of streams blocked by structures was not accurately measureable due to a large number of the streams in the survey being ephemeral and not marked topographic maps. Culverts accounted for 84.5% of the in-stream barriers. Fords, including fords with culverts, were the next most common barrier accounting for 12.7% of the structures and the remaining structure types combined (weirs, pump, floodgates and netting) accounting for the remaining 2.7% of the barriers (Figure 3).

Figure 2. Percentage of structures posing barriers at different flow rates in the Gisborne Region.

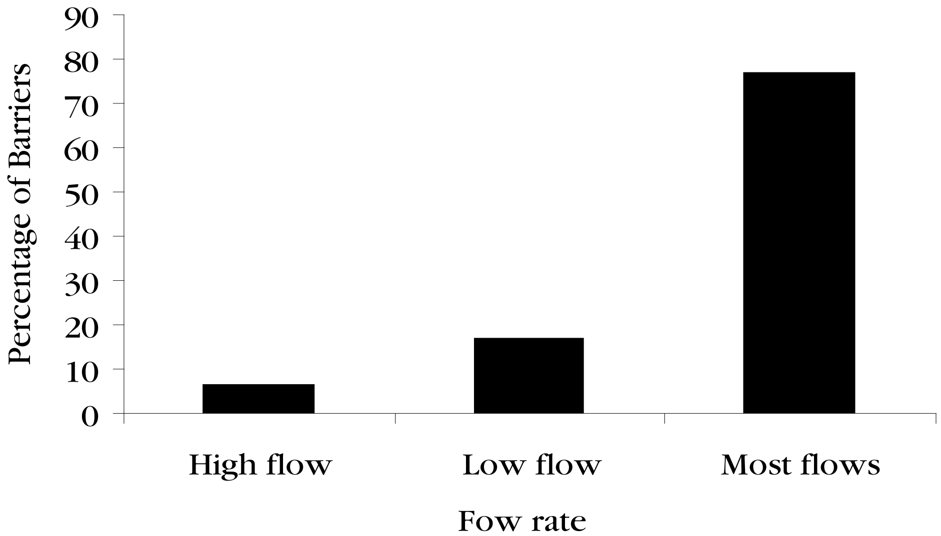
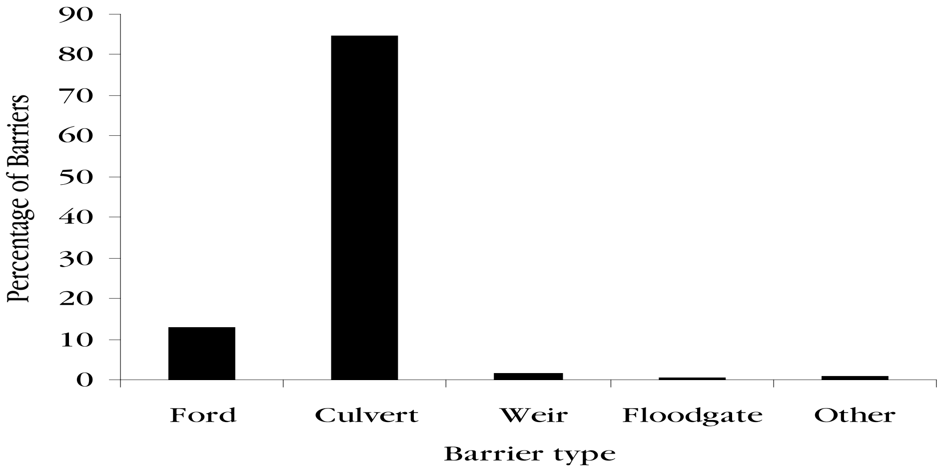


Figure 3. Percentages of in-stream barriers caused by each structure type in the Gisborne Region



The most prevalent issue identified was perching, causing barriers to fish passage at 74% of the structures surveyed (Figure 4). The most common fall height of the outlet falls is 10 cm or less (17%), with 75% of the falls being less than 1 m in height (Figure 5). The second most common barrier to fish passage was inadequate water coverage (49% of structures). Inadequate water coverage is caused either by the invert of culverts and fords being the same height or higher than the stream level, or by the base of the structure being flat and not providing a low flow channel. Dark passage, as a result of small culvert diameter for their length, was the next most frequent barrier type (36%). The average length of the culverts was approximately 10 m, however, many of the lengths were estimated. The culvert diameters ranged from 20 cm – 3.5 m with the average diameter being 20 cm (ArcMap layer). Debris and fast flow each accounted for less than 5% of the barriers at structures.

The majority of structures, 87% have culverts. Singular culverts were the most common occurring at 75% of sites, with only, 1.4% of structures having more than 2 culverts (Figure 6). Pipe culverts are the most prevalent barriers, accounting for 84% of the barriers with culverts (Figure 7). Box culverts accounted for 9% of all culverts and only one barrier was identified as an arch culvert.

Figure 4. Percentage of structures with each barrier type in the Gisborne Region

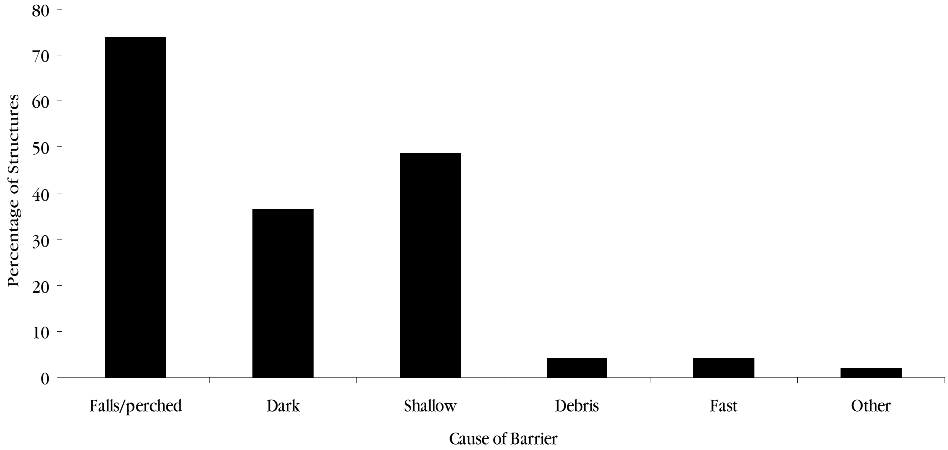


Figure 5. Fall height of perched in-stream strucutres in the Gisborne region.

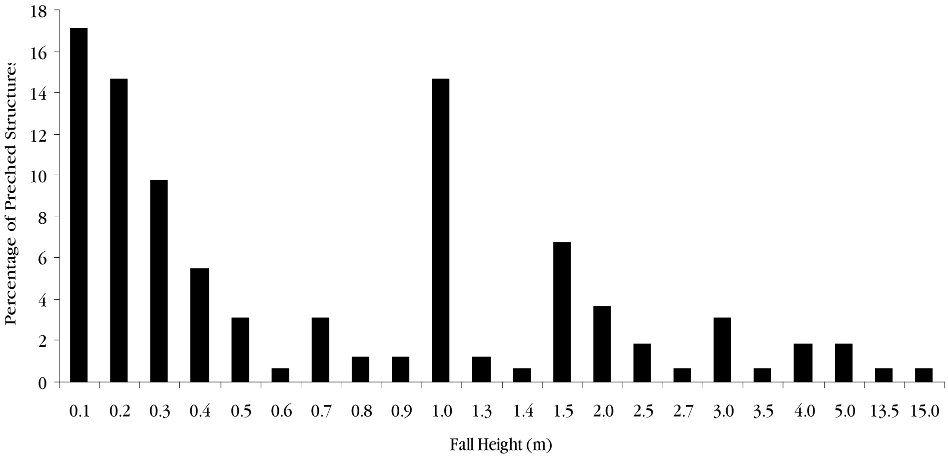


Figure 6. Number of culverts in each in-stream structure in the Gisborne region.

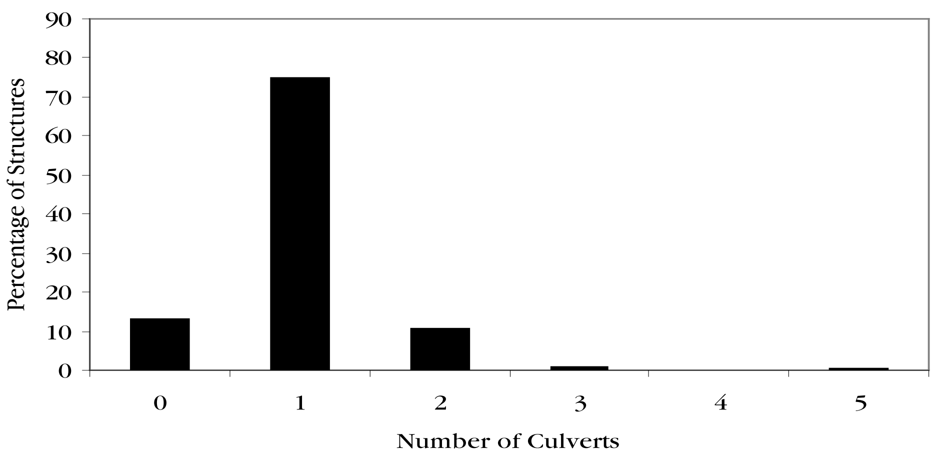
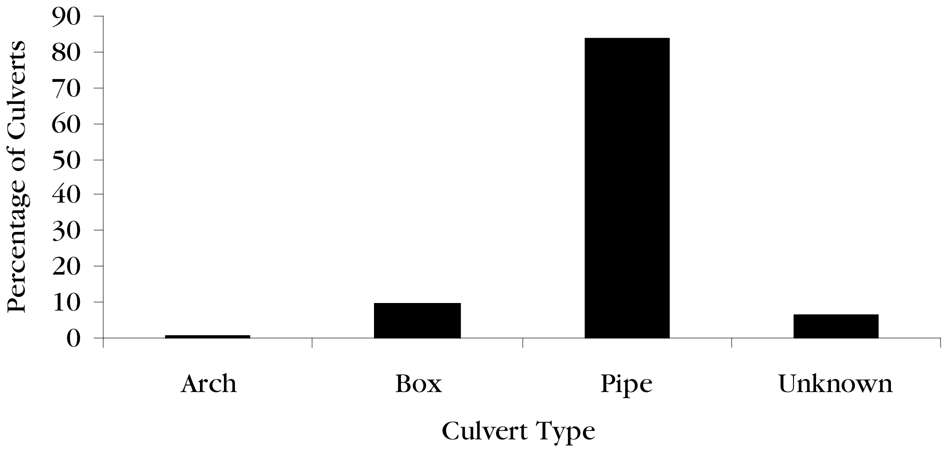


Figure 7. Percentage of each culvert type creating in-stream barriers in the Gisborne Region.



The predominant culvert material was concrete (81%), with 15% corrugated iron and 4% made of galvanised steel (Figure 8).The inlets of 55% of the structures were flat with the streambed, 22% were pooled, with inverts buried below the stream bed, and 14% were perched either creating falls on the inside of the culvert or a raised lip (Figure 9). The outlets of 12% of the structures were flat with the streambed, 69% were perched and 14% were pooled (Figure 10). Substrate depth within the structures ranged from 0 to 70 cm, with the average being 1 cm (ArcReader project). Preliminary assessment of substrate depth and culvert size indicates that up to 212 culverts may have water speeds to rapid for fish passage during periods of high flows.

Figure 8. Percentag of barrier causing culverts made form each material type identified in the Gisborne Region.

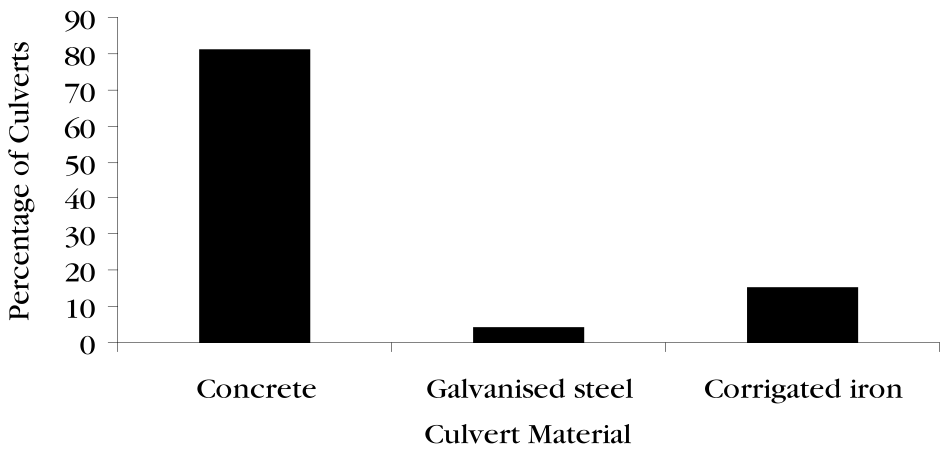


Figure 9. Cross-sections of the inlets of barrier causing culverts in the Gisborne Region.

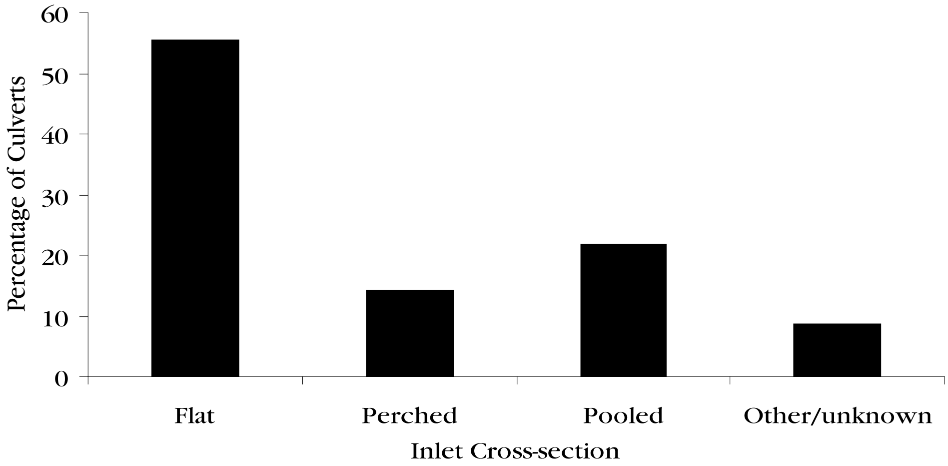
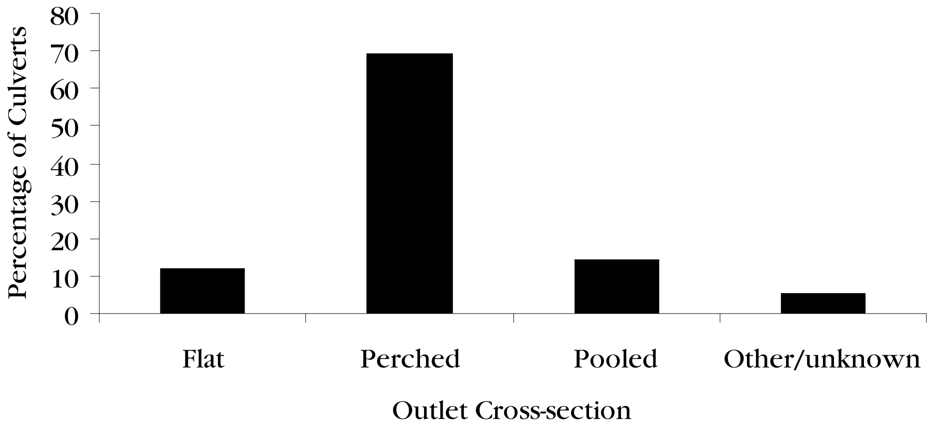


Figure 10.Cross-sections of the outlets for the barrier causing culverts in the Gisborne Region.



The priority rankings, site locations and photo identification numbers are presented in Appendix 8. A full table presenting the results of all measurements and descriptions is available on the accompanying ArcMap file.

The structures identified as being of most benefit to fix are the weir in the Te Arai River near Pyke Road and the culvert at the Matokitoki Stream-Lytton Road intersection (Appendix 8, ArcReader project). Both structures are close to the sea, block a large amount of upstream habitat and are barriers at most flows. There were five sites ranked as being the next highest priority for remedial action (see Appendix 8).

The results of the quantile groupings are presented in the accompanying 'ArcMap' project. The results illustrated clear areas for prioritisation of remedial work, for example the Te Arai River, the streams feeding into Wainui and South Makorori Beaches, the tributaries of the Waiomoko River and the tributaries of the Waimata River.

3.2 WAIPAOA RIVER CATCHMENT

There were 169 in-stream structures identified to be impeding fish passage in the Waipaoa River catchment. Of the 169 structures, 76% were found to pose barriers at most or all flows, 17% were found to impede fish passage at low flows and 8% of the structures were found to restrict fish passage at high flows (Figure 11). These barriers combined exclude a total of 355 km^2, or 16.1% of the catchment as potential habitat. The majority of these structures (80.6%) were culverts, with fords accounting for 16.6% of the structures and the remaining structure types combined (weirs, pumps and floodgates) accounting for 2.4% of the blockages (Figure 12).

The most prevalent issue identified was perching, or falls, causing a barrier to fish passage at 69% of the structures surveyed (Figure 13). The majority of the falls, 77.6%, were below 10 cm, with the highest falls being 5 m (Figure 14). The second most common barrier to fish passage was inadequate water coverage, with 57% of the structures potentially being barriers. This was caused either by the invert of culverts and fords being the same height or higher than the stream level, or by the base of the structure being flat and not providing a low flow channel. Dark passage, as a result of the culverts being too small a diameter for their length, was the next most frequent potential barrier (44%). The average length of the culverts in the Waipaoa River catchment was 10 m, with the maximum being 40 m. The culvert diameters ranged from 0.2 m to 5 m with the average diameter being 1 m (ArcReader project). Floodgates were impeding fish passage past 5.9% of the structures identified, with debris and fast flow each accounting for less than 5% of the barriers. The majority of the streams, 75%, were found to contain flow at the time of the survey (ArcReader project).

Figure 11. Percentage of strucures posing barriers at different flow rates in the Waipaoa River catchment..

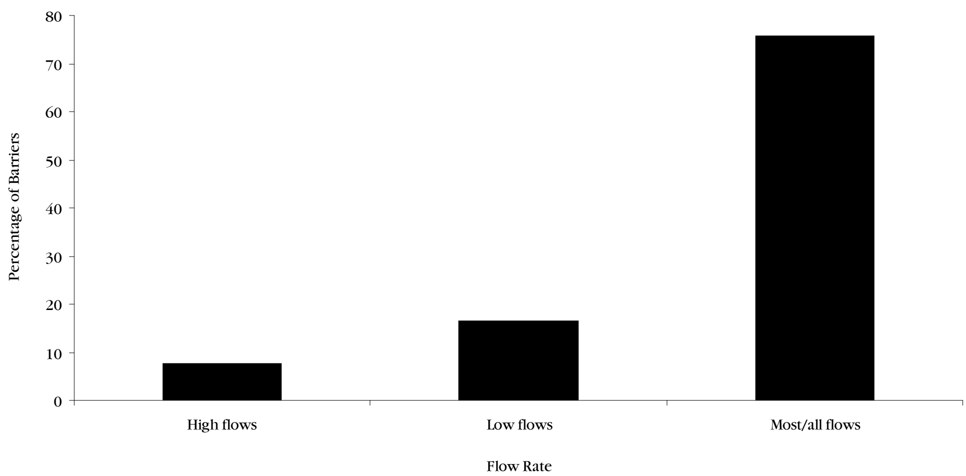


Figure 12. Percentage of Strucures with each barrier type in the Waipaoa River Carchment..

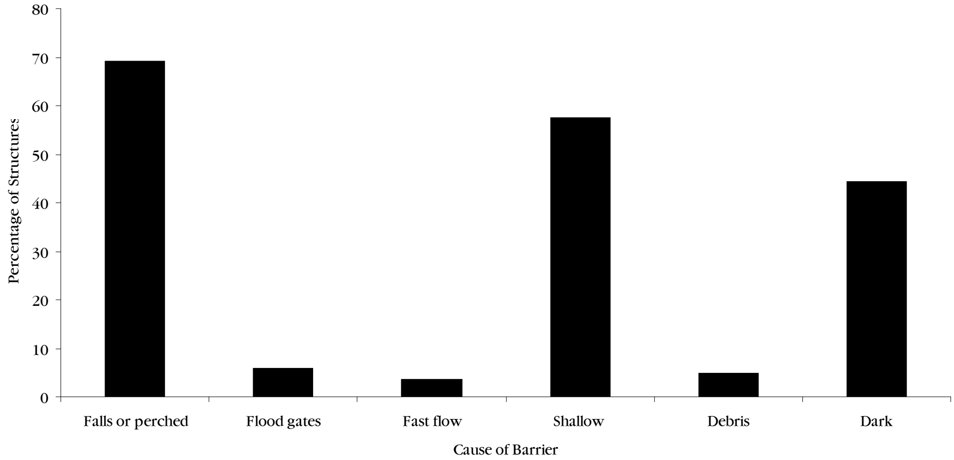


Figure 13. In stream structure types identified in the Waipaoa River catchment.

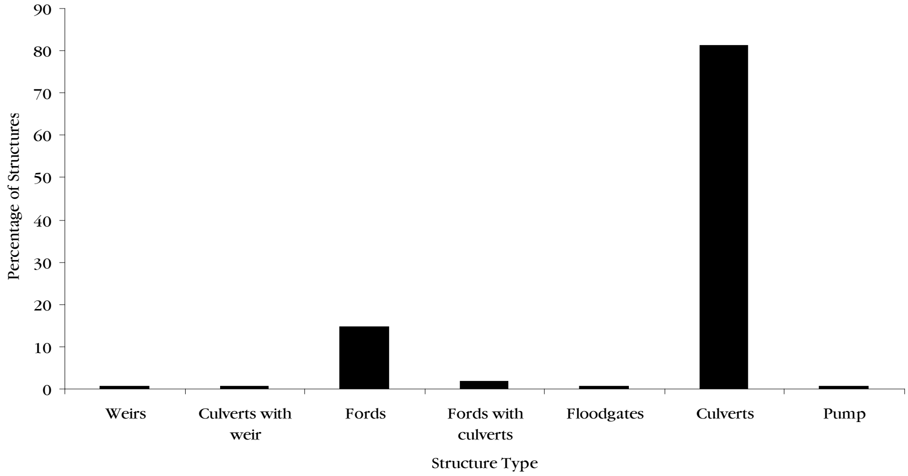
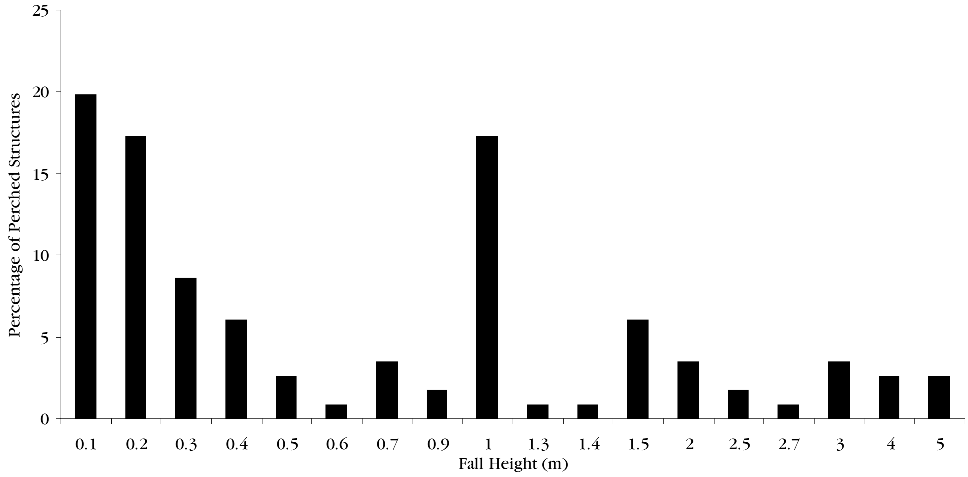
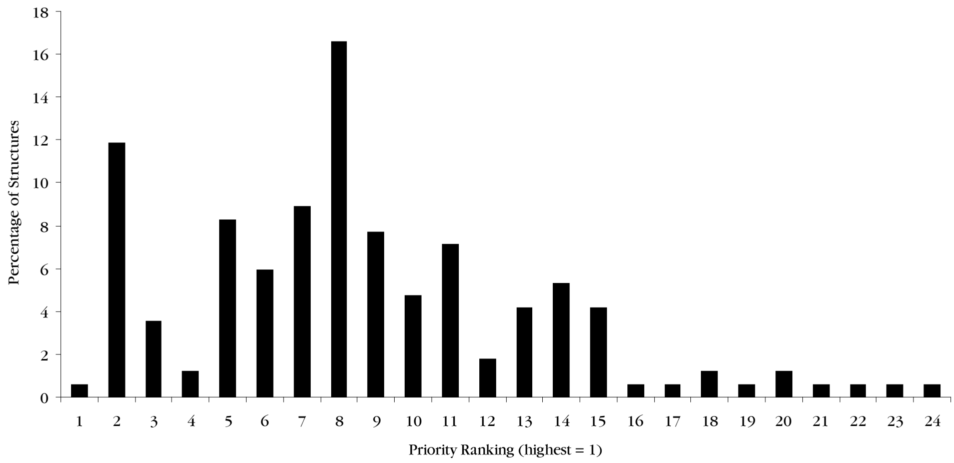


Figure 14.Fall height of perched in-stream structures in the Waipaoa River catchment.



The prioritisation system used allowed for multiple sites to gain the same ranking. This reduced the number of rankings assigned to the in-stream structures to 24. The proportion of sites gaining each priority ranking is displayed in Figure 15.

Figure 15. Percentage of each strucure in each priority ranking in the Waipaoa River catchment.



The priority rankings, site locations and photo identification numbers are presented in Appendix 9. A full table presenting the results of all measurements and descriptions is available on the accompanying ArcReader project.

The structure identified as being of most benefit to fix for fish species is the weir in the Te Arai River near Pyke Road (Appendix 9, ArcReader project). This structure is close to the sea, blocks a large amount of upstream habitat including Waterworks Bush and is a barrier at most flows. There were 20 sites ranked as being the next highest priority for remedial action (see Appendix 9). All of these sites were found to restrict fish passage at all or most flows and are within 50 km of the sea. They all also either had an upstream network area greater than 10 km or had over 50% upstream catchment forest cover.

The results of the quantile groupings are presented in the accompanying ArcReader project. The results illustrate clear areas for prioritisation of remedial work, for example the Te Arai River, Hihiroroa Stream, Mangatu Forestry and the small tributary stream leading into Taumatapoupou Stream.

3.3 TURANGANUI RIVER CATCHMENT

There were 32 in-stream structures identified to be impeding fish passage in the Turanganui River catchment. Of the 32 structures, 78% were found to pose barriers at most or all flows, 16% were found to impede fish passage at low flows and 6% of the structures were found to restrict fish passage at high flows (Figure 16). These barriers combined exclude a total of 21.5% of the catchment as potential habitat. All of these structures were culverts.

The most prevalent issue identified with the culverts was perching of the inlet or outlet causing barriers to fish passage at 84% of the structures surveyed. Perched outlets were barriers at 78% of the structures (Figure 17). The highest falls were 3.5 m (Figure 18) with the lowest being below 0.1 m and the average 0.9 m. The second most common barrier to fish passage was inadequate water coverage, with 25% of the structures potentially being barriers. This was caused either by the invert of culverts and fords being the same height or higher than the stream level, or by the base of the structure being flat and not providing a low flow channel. Fast flow, occurring due to culverts not being large enough for the stream, or flows from aprons, account for 9.4% of the barriers. Dark passage, resulting from the culvert diameter being small for the length was the least common barrier (6.25%). The average length of the culverts in the Turanganui River catchment was 8.2 m, with the maximum being 15 m. The culvert diameters ranged from 0.4 m to 3 m each, with the average diameter being 1.6 m (ArcReader project). The surveys were carried out in the winter, so all surveyed streams had water flow.

Figure 16. Percentage of structures posing barriers at different flow rates in the Turanganui River catchment.

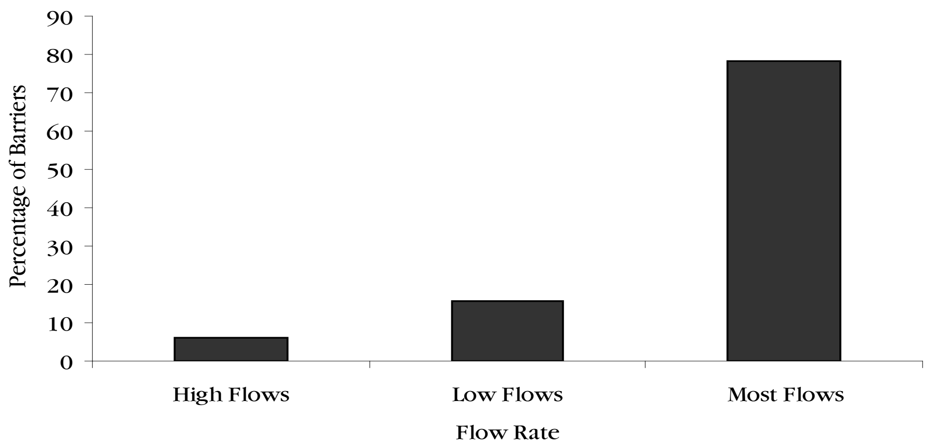


Figure 17. Percentage of culverts blocked by each barrier type in the Turanganui River catchment.

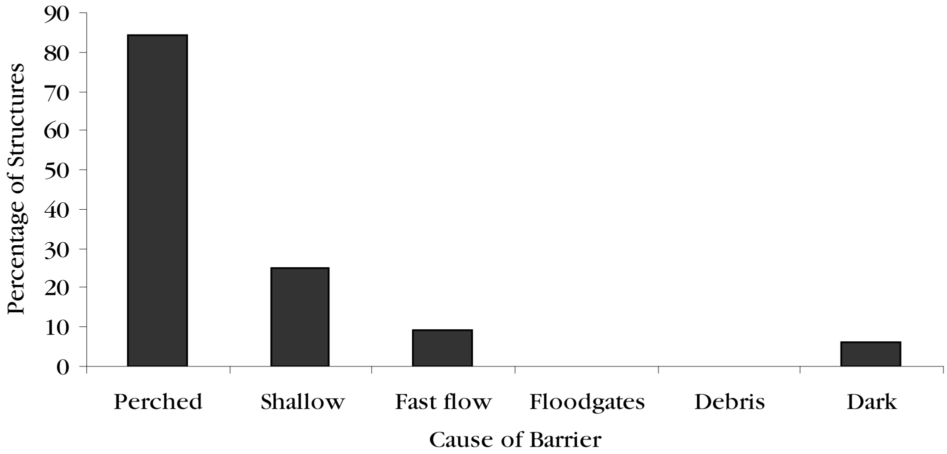
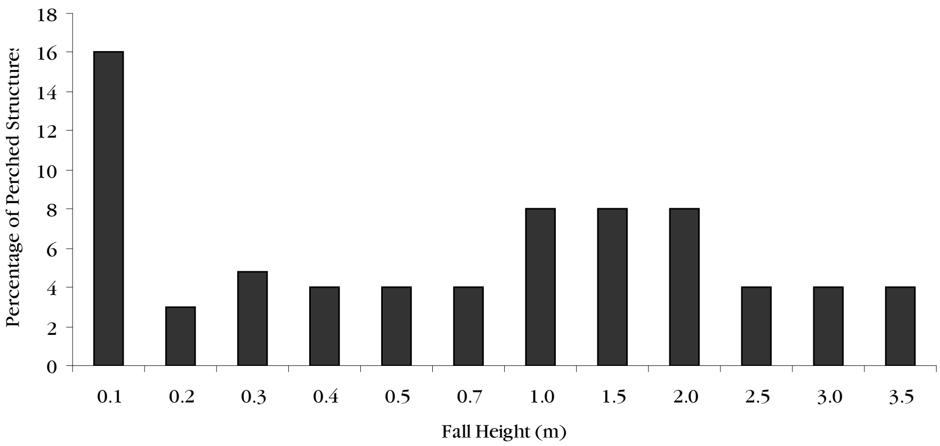
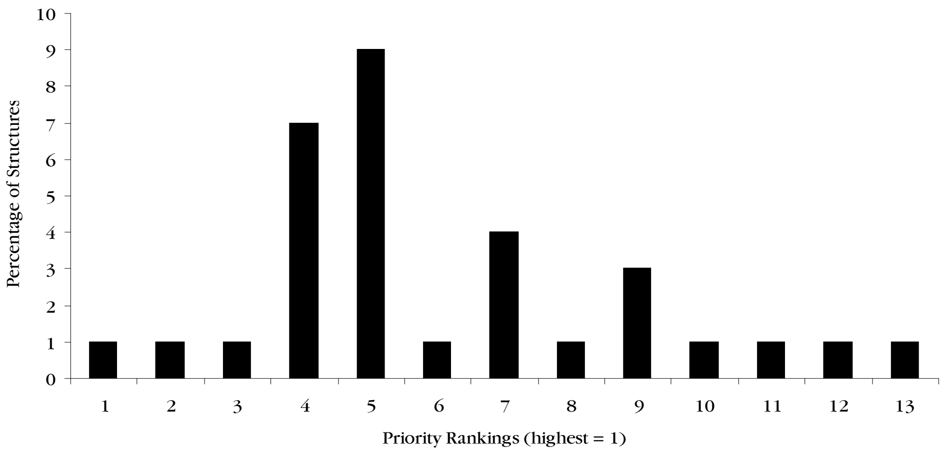


Figure 18. Fall height of perched in-stream structures in the Turanganui River catchment.



The prioritisation system used allowed for multiple sites to gain the same ranking. This reduced the number of rankings assigned to the in-stream structures to 14. The proportion of sites gaining each priority ranking is displayed in Figure 19.

Figure 19. Percentage of each structure in each priority ranking in the Turanganui River catchment..



The priority rankings, site locations and photo identification numbers are presented in Appendix 10. A full table presenting the results of all measurements and descriptions is available on the accompanying ArcReader project.

The structure identified as being of most benefit to fix is the culvert on the Matokitoki Stream at the Lytton Road (Appendix 10, ArcReader project). This structure is close to the sea, blocks a relatively large amount of upstream habitat and is a barrier at most flows. The site ranked as being of the second highest potential benefit to fish if corrected is located on a tributary of the Waimata River at the junction with Waimata Valley Road. This site gained its high priority ranking for being a barrier at all flows, having a large upstream network and greater than 50% upstream forest cover.

The results of the quantile groupings are presented in the 'Fish Passage Priority' layer. The results illustrated clear areas for prioritisation of remedial work, for example the upper reaches and mid section of the Waimata River.

3.4 EAST COAST RIVER CATCHMENTS

There were 19 in-stream structures identified to be impeding fish passage in the East Coast catchments. Of the 19 structures, 68% were found to pose barriers at most or all flows and 26% were found to impede fish passage at low flows (Figure 20). These barriers combined exclude a total of 6% of the East Coast catchments as potential habitat. All of the structures except one were culverts. The other barrier type was not a junction with a road, but a series of netting barriers placed along the stream bed.

The most prevalent issue identified was perching, causing a barrier to fish passage at 84% of the structures surveyed (Figure 21). Falls at outlets were present at 57% of the structures and ranged in height from 0.1 m – 1.5 m (Figure 22). The other causes of barrier to fish passage were dark culverts (16% of structures), flat inlets or large box culverts causing shallow water each accounting for 11%, and debris counting for 5% (one structure). The average length of the culverts in the East Coast catchments was approximately 10.9 m, with the maximum being approximately 30 m and the minimum 5 m. The culvert diameters ranged from approximately 0.5 m to 3.5 m with the average diameter being 1 m (ArcReader project).

Figure 20. Percentage of structures posing barriers at different flow rates in the East Coast River catchments

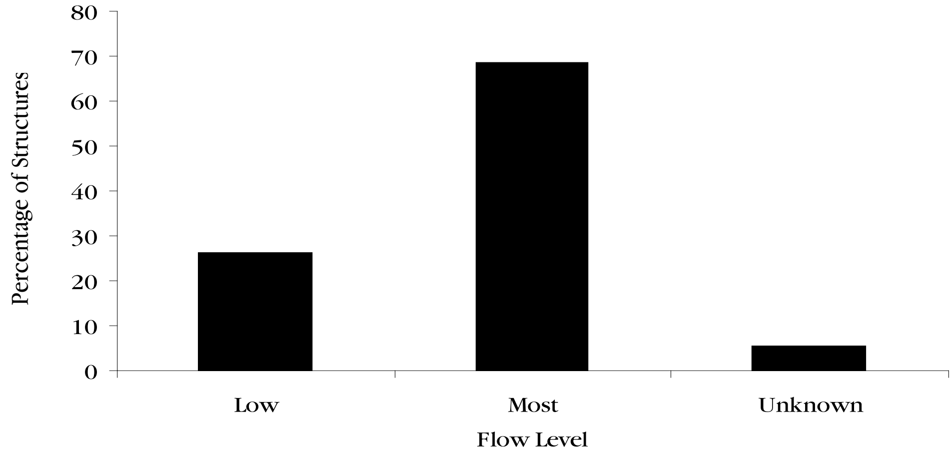


Figure 21. Percentage of culverts blocked by each barrier type in the East Coast River catchments.s

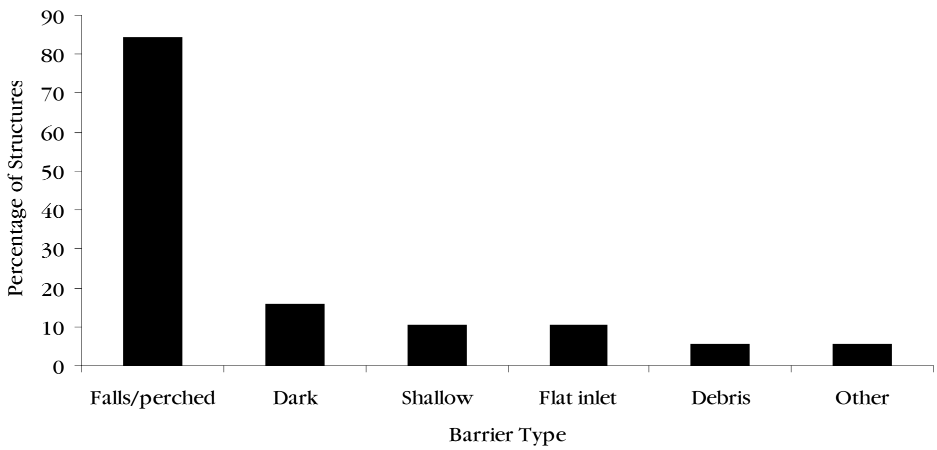
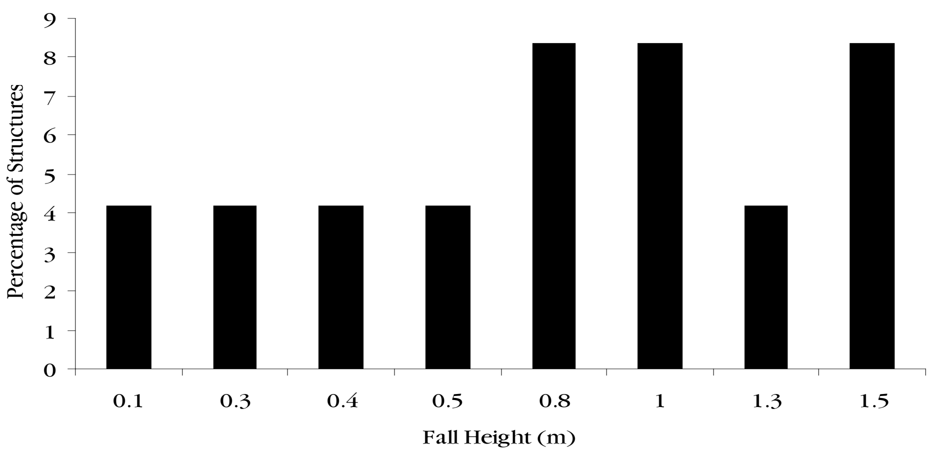
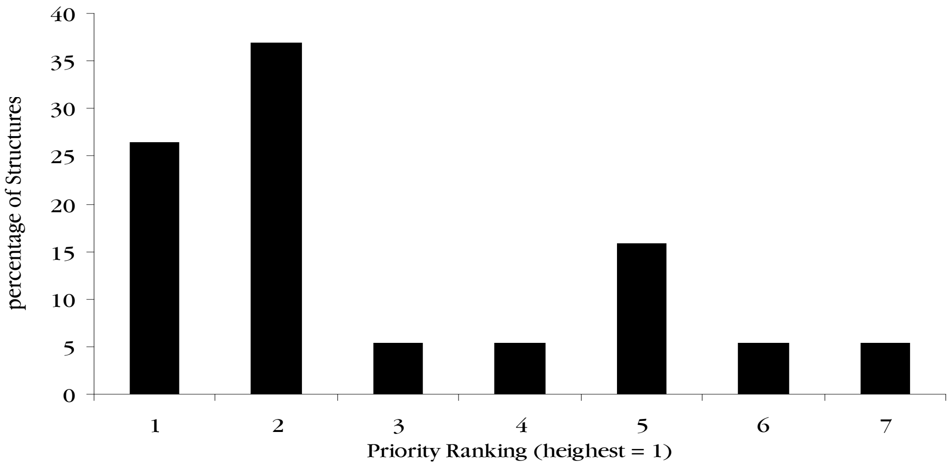


Figure 22. Fall heights of perched in-stream structures in teh East Coast River catchments.



The prioritisation system used allowed for multiple sites to gain the same ranking. This reduced the number of rankings assigned to the in-stream structures to seven. The proportion of sites gaining each priority ranking is displayed in Figure 23.

Figure 23. Percentage of each struchtre in each priority ranking in the East Coast River catchments.



The priority rankings, site locations and photo identification numbers are presented in Appendix 11. A full table presenting the results of all measurements and descriptions is available on the accompanying ArcReader project.

Three structures were identified as being of the highest benefit to fish species if corrected, a culvert on the northern end of Wainui Beach, a culvert at the southern end of Makorori Beach, and a culvert in Kaitawa Stream in Tolaga Bay. Each of these structures were found to be barriers at most or all flows, be within 10 km of the sea, have 10 – 50% catchment forest cover upstream, have no known barriers upstream and each of them had flow at the time of the survey.

4. DISCUSSION

4.1 GUIDELINES AND REQUIREMENTS FOR IN-STREAM STRUCTURES.

The objective of fish pass design must be to make upstream and downstream passage as easy as possible in order to maintain fish populations (Mitchell 1989). To achieve this, culverts and in-stream structures should not alter the natural behaviour of the stream or the physical aspects of the streambed in any way. In this section of the document guidelines are provided for the installation of new in-stream structures so fish passage can be provided and maintained. A full description and justification of the requirements is provided in section 4.2 of this document. To allow for easy assessment of fish passage criteria a checklist is presented in Appendix 12.

All structures:

- Bed material should be assessed to determine the potential for downstream erosion, with mitigation action taken if necessary.
- Low water velocity at entrance and exit.

Culverts:

- The same gradient as the stream.
- Flow velocity below 0.3 ms^{-1}, or lower if there are weaker fish species, e.g. banded kokopu.
- The same size or wider than the stream channel (1.2x channel width + 0.5 m).
- Buried invert that is approximately 20% below streambed level on the downstream end.
- Installed in a straight line with the natural stream.
- Dished or sloped floors for low flows, this includes any ancillary structures.
- Have rounded ends and junctions to allow for climbing species to pass.
- Have wetted margins for climbing species with the maximum flow no more than 45% the culverts height under the regular range of flow fluctuations.

Weirs:

- Notched with a 'v' shaped notch.
- Impermeable so that a pathway over the weir is available at all times.

Fords:

- Low flow passage provided, for example, a low flow section, dish shaped floors or culverts.
- Culverts in fords should meet the above culvert criteria for low flows.
- No drops at downstream end.
- Have rounded edges to allow climbing species to pass.

Fish Pass:

- Good quality water flow to attract fish.
- Have inlet in area fish naturally move to.
- A maximum slope of 15°.
- Angled to allow wetted margins.

4.2 JUSTIFICATION OF GUIDELINES

The majority of the literature suggests designing structures to allow fish passage of the species already present in the catchment. Many of the structures blocking fish passage pre-date the majority of fish surveys carried out in the catchment. Only two surveys pre 1995 have been recorded on the NZFFD for the Waipaoa River catchment, and only 13 of 144 surveys for the whole region pre-date the enactment of the Resource Management Act in 1984. So use of historical records to determine the species that were once present at each site is not available. Instead these guidelines are designed to allow passage for the majority of native New Zealand swimming fish species. Information that is available on weaker species is also provided.

Even without the difficulty of barriers such as perching and floodgates, culverts can create a barrier that is difficult for fish to pass. The installation of a culvert creates conditions and habitats rarely found in natural environments. The smooth surfaces within culverts often mean fish are required to pass a long reach of water of uniform or increasing velocity with nowhere to shelter or rest, which restricts the ability of fish to move upstream (McDowall 1979). In natural streams flow is interrupted by natural features such as large rocks and weeds creating turbulence and eddies which provide resting area so fish are only required to navigate short stretches of water at full swimming speed. Irregularities in the bed and banks also offer shelter from the force of the current while bends in the meander pattern create deeper pools where flow velocity decreases and fish can rest (Boubeé et al 1998). The installation of a culvert can also create upstream passage problems for fish at the inlet and outlet by restricting the stream width and increasing water velocity in these areas to a velocity fish cannot swim against (Boubeé et al 1998).

Water velocity is a major barrier to fish passage, and is exacerbated by slope, construction material and the constriction of water flow into a smaller cross-section increasing water velocities above those occurring naturally in the stream. This increased velocity often exceeds the swimming capabilities of fish so that they are unable to move through the culvert (Boubeé et al 1998, MacDonald and Davies 2007).

Gradient is one of the largest factors affecting successful fish passage. Steeper gradients increase the barrel velocity, which in turn can lead to scouring below the outlet, creating vertical barriers for upstream migrating fish. In the Waipaoa River catchment the slope of the culverts was frequently less than that of the streams, creating perched outlets and falls at the downstream end of the structures. Baker and Boubée (2006) found that redfin bullies (climbing species) and inanga (non-climbing species) only had a 100% success rate at passing up ramps angled at 15° or less. Ramps at 45° had much higher water velocities and only allowed the passage of redfin bullies which climbed the wetted margins. This indicates that the maximum slope of a structure should not exceed 15° if passage for swimming fish is required.

Water velocity is further impacted by the inlet of the in-stream structure. Structures with inlets that are narrower than the stream constrict the water flow, increasing the water velocity in the barrel and at the inlet and outlet. To avoid stream constriction, the inlet should be the same width or larger than the stream bed. In the case of pipe culverts the approximate diameter of the inlet should be, at average flow, 1.2x the channel width plus 0.5 m (Speirs and Ryan 2006).

Fish passage through high velocity water is dependant on the distance the fish must swim. In high velocity water fish rely on their white muscle for 'burst' swimming speeds (Hunter and Mayor 1986, Behike et al 1993). When white muscle energy is depleted it can take hours of rest before the fish has recovered sufficiently to continue on its migration or attempt the next obstacle (Behike et al 1993). Typically higher velocities of flow and/or water accelerations occur at the inlet and outlet, while smaller velocities of flow occur in the culvert barrel (Behike et al 1993). Fish may need to use white muscle at the outlet and/or inlet while relying on red muscle power for passage (Behike et al 1993). However, if the fish is required to swim a long distance in high velocity water, then they may become exhausted before they reach the end (Boubeé et al 1998) and be unable to pass the barrier.

The structures in the Gisborne regions catchments range in length from 1.5 - 40 m with a mean length of 10 m. Mitchell (1989) assessed the maximum flow rate to allow fish passage over varying lengths. Mitchell (1989) determined that the majority of species are capable of passing through a 10 m culvert if the average barrel velocity is kept below 0.3 ms^{-1}, with smaller distances being passable at higher flows (Appendix X). The weakest swimmers in the Gisborne region are the banded kokopu and inanga. For banded kokopu the flows need to be kept to below 0.25 ms^{-1} for a 10 m structure (Mitchell 1989, Appendix 7). It is possible to calculate the maximum distance over which a fish in the swimming mode will be able to travel from a formula provided by Boubeé et al (1998) (see Appendix 6). NIWA has also developed a computer programme that uses fish swimming speed and culvert water velocity to calculate the maximum distances fish can travel (Richardson and Taylor 2002).

If it is not possible to reduce flows or reduce the length of the structure, then static water resting areas should be provided. For suggestions on mitigating rapid water velocities through in-stream structures see Section 6 of this document.

The possibility that the swimming performance of fish deteriorates as the fish migrates upstream is not considered in much of the literature. This is an important consideration. Fish already exhausted from migrating may require slower flows or shorter periods between rests than those at the beginning of their migration. Despite the lack of study on the topic and no exact flow speeds being available, it could be sagacious to either increase the amount of resting areas available or decrease the water velocity within structures as they are placed further up the catchment.

The provision of inlet and outlet pools serves a variety of purposes for both native and exotic species and aid in preserving the integrity of the culvert by providing resting areas before and after negotiating the structure, backwatering of the culvert to decrease water velocity and provide sufficient depth in the barrel, dissipation of energy from water exiting the culvert to decrease both downstream velocities and the potential for erosion immediately below the outlet, and the elimination of elevated outlets (Boubée et al 1998). Boubée et al (1998) compiled a literature summary of proposed pool dimensions, concluding that pool depths of 10 – 20 cm at the openings of a culvert are likely to be best for native New Zealand fish species.

Notch shape in weirs impacts passage for some species. Baker (2003) found that common bully were significantly effected by notch shape in weirs, crossing 'V' shaped notches more easily than rectangular or circular. Rectangular notches were found to create turbulence across a wider part of the channel which may account for the increased restriction in passage. It is therefore suggested that weirs have v-notches to accommodate fish passage.

Insufficient water depth in culverts has often been blamed for passage problems overseas. In very shallow water, depth can also influence swimming speed because of the extra energy involved in the formation of a 'bow' wave. This effect only occurs at depths less than three times a fish's body depth and for burst swimming rather than sustained swimming. For example, in water that was 0.3 times the depth of a fish, swimming speeds about 30 – 50 % lower than the maximum speeds attained in deep water have been measured (Boubée et al 1998). In New Zealand structures the problematic insufficient depths are caused either by inverts that are not buried or by structures that do not have a low dished or sloped floors. A lack of sloped floors allows the water to spread thinly across the width of the structure. Providing a low flow channel in fords, and providing dished or sloped bases in culverts and ancillary structures allows for fish passage at a range of flow conditions.

The level of the culvert invert relative to the streambed is the most important design criterion for fish passage. The culvert should be buried so that the bottom is filled with streambed material, which will not only increase bed roughness, but imitates a natural stream bottom. The filling should ideally be v-shaped infill to also provide for periods of low flow (Boubée et al 1998).

Many native species are very good climbers and can negotiate very high velocity zones by progressing along the wetted margin (Boubée et al 1998). For these climbing species, it may not be necessary to provide a low velocity zone along the edge of the culvert, but ensuring the availability of a smooth, moist surface with no breaks or sharp angles is essential (Boubée et al 1998). If wanting to ensure that a climbing surface is available at the edges of culverts, water depth should not be greater than 45% of the culvert diameter for about 90% of the September-February migration period (Boubée et al 1998).

The effect of light, or lack of, remains an area of debate. The passage from light to dark and dark to light conditions upon entering and leaving culverts may inhibit migration or cause fish to pause to acclimate to the new conditions. This may lengthen the time fish remain in the culvert increasing fatigue and reducing passage. Light contrast may be mitigated by tree shading at the ends of the culvert, however, the effect of contrast is also debated. Until further evidence of darkness hampering migration is provided, the only recommended action is to install culverts in a straight line to maximise light.

For structures such as large dams it may be necessary to construct a fish pass, or ramp. The critical point in upstream fish passage design is the location of the fish passage entrance and the attraction flow (Larinier 2001). The entrance of the pass must either be where fish are already present or have a system to attract them (NIWA 2001).

Most fish passes fail because the fish cannot follow the flow to the entrance of the fish pass or because the flows exceed the swimming ability of the fish (Bowman and Rowe 2002). Fish and Game (Unpublished) surveyed 70 dams and identified 11 fish passes. Of these only 4 (36%) were effective. Fish and Game (Unpublished) identified a lack of target species design and maintenance as the key causes of the passage failure. New Zealand fish species have poorer swimming ability than salmonids and can not swim against water moving faster than 0.3 m/s for more than a few minutes. Fish passes for this group must be designed to reduce the water velocity and provide resting places for the fish (Mitchell 1990). Fish length is an important factor in successful passage over ramps (Baker and Boubeé 2006), therefore fish passes need to be designed specifically for New Zealand's species which migrate while they are a small size (Thompson and Rahel 1998) and require low velocity water.

Pipe, channel or trough passes furnished with climbing materials can be used for larger structures. For example a 100 mm diameter PVC pipe filled with 12 mm polypropylene 'bottle brushes' has been used on the 68 m Patea Dam on the Waikato River (Thompson and Rahel 1998). An alternative design, less prone to blockage by debris, uses coarse aggregates glued to the inside of the pipe. Water can flow rapidly down the base, but small eels can climb using the rough surface and wetted margins. This design has been used on the Matahina Dam, but it was found that long runs of pipe needed shading to prevent excessive solar warming (Thompson and Rahel 1998).

Fords are one of the least preferred types of stream crossing. Williams et al (2005) found that the height of the vertical drop at the end of fords was posing a migration barrier to inanga. Fish were found upstream of the ford, suggesting that either the structures could be negotiated by larger fish, or else passage is only occasionally possible. Williams et al (2005) suggest the latter to be the case, with passage occurring during large floods when the whole structure is over-topped or culverts drowned. This suggest that at the very least, fords delay the passage of fish (until flooding) and restrict the availability of habitat in which young fish can grow (Williams et al 2005). The inclusion of culverts which meet the fish passage criteria for low flows, or a channel which allows passage during low flows, are essential for improving fish passage at fords.

Although the benefits of multiple barrels seem to be debated, generally one large culvert is better than multiple small ones. This is because one large pipe decreases disruption to the natural stream, debris blockage is less likely and velocities will be lower. Where chances of blockage by debris are low, multiple barrels may be successful. It is preferable that multiple culverts are offset, with one placed lower, so as to better accommodate both low and higher flows. In multi barrel configurations fish passage need not be provided by all barrels, only the lower ones, or those deemed most likely to be selected by fish (Baker and Votapka 1990).

The structure should also be designed so that the flows never reach a velocity to high for fish passage in the first culvert before the second is available for fish passage. However, this is only if the water velocity is not increased in that culvert to beyond the swimming capability of the fish and passage through the selected barrel is provided at the full range of flows experience in the waterway.

Flood gates are designed to exclude the pulse of tidal water that naturally occurs in lowland coastal waterways. Usually when the tide is incoming floodgates are closed to prevent saltwater intrusion. This can pose significant migration problems for fish because it restricts fish to the ebbing tide period and means that a fish must migrate against the water current rather than with it. In addition, for several species (for example, banded kokopu, shortjaw kokopu, eels) migration is associated with elevated flows (McDowall and Eldon 1980, Boubée et al 2001) and controlled flows may hinder this. The gates currently in the Waipaoa River catchment rely on the force of the water travelling downstream to hold them open, however many of the streams have low flow rates and are only capable of opening the heavy gates a small amount. These small openings are not always large enough to allow fish passage, and if they are can cause high velocity flows through the gate, preventing upstream passage, or making upstream passage more difficult for fish species. Floodgates in the Waipaoa River catchment have the additional problem of the high sediment levels in the catchment causing blockages.

Many of the barriers to fish passage in the Gisborne Region were located in small tributary streams. All streams and rivers are important for native fish including small streams (Charteris 2006). Small freshwater habitats are often the areas that support the greatest native fish biodiversity by providing a natural environment and refuge from introduced species and natural predators (Charteris 2006). In effect, consideration of native fish requirements is critical in all sized waterways, from small ephemeral streams to large braided rivers (Charteris 2006). Therefore it is essential that fish passage be corrected in all streams, even those appearing too small to provide habitat.

5. BARRIERS AND STRUCTURES IDENTIFIED IN THE GISBORNE REGION.

There are 220 in-stream structures posing barriers to fish passage in the Gisborne region. Combined these structures prevent 15%, of the region from being accessible to fish.

The low percentage of catchment area blocked to fish in the East Coast catchments is because of the lower number of public roads intersecting the streams, the proportion of structures posing barriers (19%) is similar to that of the Turanganui River catchment (26%) which was surveyed at the same time of year. The Waipaoa River catchment had approximately 60% of the structures surveyed posing barriers to fish passage. This increased number is due to both the use of floodgates on structures that may otherwise be accommodating to fish and the time of year the surveying was carried out. The Waipaoa was surveyed in the spring and summer months when most streams were low, and sites that would have been excluded from the other surveys because of lack of flow, were included.

There are three types of culvert causing barriers to fish passage in the Gisborne Region - pipe, arch and box culverts (for descriptions see Appendix 3). In addition, the region contains fords, fords with pipe culverts, culverts with floodgates and stand alone floodgates. Each of these in-stream structures creates their own challenges for fish passage.

Pipe culverts are the most common in-stream barriers in the Gisborne region accounting for 75.9% of the blockages to fish passage (including fords with culverts). The pipe culverts most commonly cause barriers through being perched (falls) or being too small (ArcReader project) which makes the culvert dark and increases turbulence. Perching can occur when the structure is not installed correctly, if the structure is not aligned with the natural gradient of the stream, by drops from aprons and other ancillary structures, or when scouring has occurred. The fall heights in the region varies from less than 10 cm up to 5 m in height. The culverts perched by 10 cm or less are predominantly culverts sitting flat on the ground instead of having buried inlets and outlets, or structures with aprons ending in drops. This creates a barrier for fish when the flow is not sufficiently higher than the edge of the structure to allow the fish to swim over. The higher falls result from either erosion under the culvert or incorrect installation.

Many of the barriers identified do not exclude all fish from the upstream catchment. Some species have the ability to withstand short periods out of water and are able to ‘climb’ the wetted margins of in-stream obstacles. However, undercuts in the perched structures or a lack of a wetted margin can hinder the migration of the climbing species. There are 85 undercut structures in the region which prevent both climbing and swimming species from migrating.

There is one arch culvert in the region which hinders fish passage. The culvert itself is not a barrier, sediment and artificially deposited substrate at the site have levelled off the stream bottom removing the streams natural dish shape. This has allowed the flow to spread over a wide area resulting in shallow water.

The 19 box culverts identified in the area pose barriers primarily because of their wide flat concrete bases which permit the spreading of water, decreasing the depth. Additionally, aprons of the box culverts often have drops into the natural stream bed creating falls and preventing fish passage.

Culverts with outlets on sandy beaches are problematic for fish passage. The natural sand levels fluctuate resulting in outlets which range from being completely perched to buried. If the outlet was a natural streambed the blockage would not generally occur as the streambed level would drop or rise with the sand levels. Consideration needs to be given to how best maintain these culverts.

There are 10 floodgates impinging on fish passage in the Gisborne region, accounting for 4.5% of all structures in the region. All but one of the sets of floodgates are attached to the end of culverts and all are in the Waipaoa River catchment. Floodgates can prevent the migration of fish during incoming tides. Seven of the nine flood gates on the culverts are not open sufficiently to allow fish passage even when there was no incoming tide or flood water. Two floodgates are also prone to being blocked by sand or silt, preventing them from opening. The free standing gates are a set of eight in Whatatuna Stream which create a total block of all passage when closed.

Inadequate water coverage is the second most prevalent barrier, restricting flow in 25% of the problematic structures. This is caused either by the inlets of culverts being flat or perched instead of slightly buried, or not having low flow channels in flat based box culverts and not providing a low flow channel.

High flow velocity has been widely considered the principal determinant in impeding fish movements through culverts (Mitchell 1990, Boubeé et al 1999, William et al 2005, Barker and Boubeé 2006, Macdonald and Davies 2007). Lack of substrate or the culvert being narrower than the stream bed could result in high speed within the culverts at high flows. In times of high flow these structures do not provide any resting areas for fish and are potentially an additional barrier. The surveys revealed that that there are 212 in-stream structures in the Gisborne region with substrate less than 5 cm deep or narrower than the stream bed. When correcting or installing a structure the potential of rapid water speeds during periods of high flows must be considered. Aligning the culverts to the same gradient of the natural stream may involve dropping the downstream end of the culvert, increasing the gradient and therefore the water velocity. It is recommended that all structures are designed, installed and if necessary altered, so that constriction of the natural stream does not occur, minimising any increase in flows. For options on mitigating high flow rates see section 6.1.2 of this document.

There are 28 fords identified to be causing fish passage barriers in the Gisborne region. All of these are in the Waipaoa River catchment. The Waipaoa River catchment contains both fords with culverts and fords without culverts. Those with no culverts allow for water to spread over the road, creating a wide and very shallow section in the waterway. These often end with a vertical drop at the downstream end. The culverts in fords tend to be very small, which in high flows could cause high water velocity through the pipes and not provide any resting areas for migrating fish within the structure (Williams, Boubée and Smith 2005). The small size of the culverts leaves them prone to getting blocked by debris.

There are three weirs, or culverts with weirs, in the Waipaoa catchment and two culverts with weirs in the Turanganui River catchment. Each of these weirs provide a total barrier to the migration of swimming fish species, with one, the weir in the uppermost part of the Te Arai River, blocking both swimming and climbing fish species. One of the weirs, Pykes Road weir, is one of two structures given the ranking of priority '1' for remedial work in the Gisborne region. This site gained it's high priority ranking as it is located close to the sea, impedes passage at most flows and has an upstream catchment with a high percentage of indigenous forest cover.

In-stream debris from forestry slash was found to be a potential non-structural anthropogenic barrier to fish in the Waipaoa River catchment. In the Mangatu Forestry large amounts of logging slash had built up in many of the waterways, creating blockages in the streams up to several meters high and potentially creating barriers to fish passage.

There are three structures in the Waipaoa River catchment that have no visible inlet to the culvert, but are instead drops, or holes of an undetermined height into the ground. Water flows into these and exits the culvert at the downstream end. These almost vertical drops are not passable by swimming fish and need to be repaired.

Cement rubble was found to be creating potential barriers to fish passage in two streams, a tributary stream of the Taruheru River at the junction with King Road, and a tributary stream of the Waimata River at junction with riverside Road.

A lack of maintenance of in-stream structures can also cause barriers to fish passage. Cracked or broken culverts can result in the water flowing through gaps in or around the structure and not through the culvert itself, such as the culvert at the intersection of Cave Road and a Waimata River tributary.

One culvert, Hirini Road, had a large cage covering the entire inlet. This gate has a small lip and narrow gaps between the bars which prevents or restricts fish passage. The outlet of this culvert was not located as it is under the wharf so fish access through the outlet could not be assessed, however there appeared to be good quality habitat upstream of the structure.

6. RECOMMENDED ACTION FOR GISBORNE RIVER CATCHMENTS

6.1 MITIGATION OPTIONS.

This section of the report provides potential mitigation options for each of the fish passage barriers identified in the Gisborne Region. These suggestions are provided only as options and are based on the solutions that would best benefit the catchment's fish species. Engineering requirements are not discussed as they are outside the scope of the Department. It is recommended that consultation with a roading expert be sought before altering any road structures.

The most common barriers to fish passage in the Gisborne Region are perched culverts, shallow water coverage and dark culverts. Many of these barriers are present because the structures were erected prior to the 1983 Freshwater Fisheries Regulations, and prior to fish passage being recognised as a priority. There are also a large number of barriers due to a lack of maintenance or natural erosion creating perching, largely owing to the highly erodible land in the region.

Despite fish passage being a fairly new consideration in New Zealand, the use of fish passage technology is not a new concept. The first recorded design of a fishway incorporating fishery science and engineering was by Denil in 1909 (Odeh 1999). Since then, and in particular more recently, there has been a large amount of research on fish passage.

6.1.1 PERCHING AND FALLS.

In-stream structures should be installed so that subsequent erosion cannot result in a perched outlet. To prevent scouring at the inlet or outlet, culverts should be aligned with the existing channel in a straight or near straight section. Cutting off meanders or changing the direction of flow to suit culvert placement can increase turbulence velocity and erosion, which in turn can lower the water levels at the culvert outlet and create a barrier to fish (Greater Wellington Regional Council 2003).

Bed material should be assessed to determine the potential for down stream erosion (Boubée et al 1998). If erosion is likely, there are several options for prevention. Armouring and the construction of fish rock ramps (discussed in section 6.1.1) can both be utilised to prevent scouring (Greater Wellington Regional Council 2003). Additionally, a weir, or series of weirs, could be installed downstream of the outlet. This reduces culvert velocities by backwatering, which reduces perching caused by scouring, the pools also serve to provide a resting place for fish before and after navigating the structure (Boubée et al 1998). If using weirs to create pools it is essential that the guidelines for fish friendly weirs are followed, a poorly designed or constructed weir could itself prevent fish passage.

The slope of the culverts was often less than the gradient of the streams, creating falls at the downstream end of the structures. When correcting a perched structure the cause must be determined. If the structure is perched due to poor initial placement then it can be corrected. If the structure is perched by erosion, then in addition to correcting the current barrier, an assessment must be carried out to determine the potential for future erosion. If further erosion or scouring is possible then these issues also need to be addressed with a larger culvert or armouring.

Some species (such as shortfin and longfin elvers, kokopu and koaro) are able to climb damp rock faces (Boubeé 1995). Provided the structure terminates in a flat vertical wall that is kept moist, the upstream passage of these species is not prevented. Climbing is can delayed migration and may also increase the exposure of the fish to predation, both while climbing the structure and if they accumulate below the culvert (McDowall 1979). If the structure is undercut, posing a horizontal barrier to fish passage, a total barrier is created with none of the species present in the catchment being able to pass. When correcting perched structures it is essential that all undercut barriers are eliminated. The following section provides options for correcting perched structures.

Reinstall the culvert:

- Ensure the culvert inverts are lowered to below streambed level by approximately 20% on the downstream end. This could be done by lowering the entire culvert or by lowering the perched end. If only lowering one end caution must be taken to ensure the increased gradient does not increase flow velocity, or if flows are increased beyond the capabilities of native fish species, mitigation action must be taken to slow the flow rate (i.e., baffles).

Install a rock ramp (Strickland 2003):

- Large ricks with diameters up to a quarter of the width of the ramp placed to form a zigzag staircase that slows down the flow and forms small pockets of still water and eddies in which fish can rest. When installed correctly the design should replicate a natural rapid both in appearance and function.
- The ramp and rocks should lead all the way to the culvert so that as much still water as possible is created at the culvert outlet without causing water to back up such that the culvert becomes completely inundated at high flows.
- The cross-section of the concrete ramp should be dished into a shallow 'v' shape. This will ensure that during low flows the confined channel will provide a suitable depth of water for fish to swim. During high flow the dished shape of the ramp will provide low velocity shallows and a splash zone along its outer edges that fish will be able to utilise to swim upstream.
- Aim for an ideal slope of 1:20. For ramps at structures less than 0.75 m, a ramp slope up to 1:15 can be considered.
- The ramp structure should be built to the full width of the natural stream course.
- At structures such as weirs, a ramp that is narrower than the natural stream channel may need to be considered. In these cases the rock ramp should be modified into a fan shape. The ramp should begin the width of the structure and extend downstream fanning out.
- Rock ramps are suitable for most structures up to a height of 1.5 m.

Rock rubble (Mitchell 1990):

Dumping rock rubble at the end of a culvert can correct fast flows and perching. However, it is not an immediate solution as the crevices between the rocks need to fills with silt and debris, and passage for swimming species is not ensured. This strategy for correcting culvert perching should only be used in areas where passage for climbing species only is required, or where other options are not viable.

- Rocks are piled at the end of the structure.
- Once rock is piled up to the pipe-sill, water will back up, thereby increasing the cross-sectional area and reducing the water velocity.
- With time, detritus and fines should fill crevices between the rocks to create a 'natural' rapid.
- Depending upon water velocity and location, elvers, climbers, and perhaps some swimmers will then be able to get past the culvert

6.1.2 HIGH VELOCITY FLOWS

Fish can only progress upstream if the water velocity is equal to or lower than the fish's swimming ability. If the combination of water velocity and distance to pass a stream or river crossing exceeds the capacity of the fish, upstream migration will be impeded (Speirs and Ryan 2006). Uniform conditions of gradient, roughness, and depth within the culvert can lead to an absence of low velocity zones where fish can rest and recover after swimming to exhaustion (Boubeé et al 1998). This section provides options for reducing flow velocities past in-stream structures.

Increase roughness:

Increasing the roughness coefficient of the culvert floor is the most effective way of reducing velocities (Bates 1992). However, caution needs to be used when modifying structures to increase roughness. Overseas studies have shown that increased roughness created by transverse corrugations creates increased turbulence (Bates 1992). For small New Zealand fish species the turbulence created by the corrugations can confuse the fish and seriously hinder upstream passage (Boubée et al 1998). There are several potential alternatives to transverse corrugations available including:

- 'Stripdrain' increases roughness, reducing velocity, but does not provide resting areas for fish (Baker and Boubée 2003)
- Square projection profiles such as those provided with 'polyflo' (Mitchell and Boubée 1995, Boubée et al 1998), which reduces velocity and provides resting areas between ridges.
- Baffles, the installation of baffles into smooth-walled culverts increases both the structural and hydraulic complexity within them, slowing water velocities, producing low-velocity resting areas and reducing swimming distances between rests at high velocities. For a detailed description of baffle types and functions see Baker and Votapka (1990) and Boubée et al (1998).

Baffles may provide a simple, cost effective solution to passage problems at culverts. Macdonald and Davies (2007) found that common jollytails were 10 times more successful in passing culverts when baffles were present than under control conditions (baffles absent). Baffle size did not influence success which was instead increased with the spatial complexity of the baffle arrangement. Both common joytails and spotted galaxias were respectively 86 and 73 times more successful with the most complex baffles arrangement (overall 80% success) compared with no baffles. Success for both species decreased with higher velocities when no baffles were present.

Things to consider if installing baffles are:

- Spatial complexity of baffles has been found to increases species success and is therefore recommended when installing baffles (Macdonald and Davies 2007).
- Baffles may increase the likelihood of debris completely blocking the culvert. Baffles should only be installed where they will not cause obstruction of the culvert through accumulation of debris.

The Northern Gateway Alliance (NGA) team has produced custom-made baffles designed as moulded plastic sheets that can be bolted to the floor of culverts. They have also addressed the loss of aquatic habitat where culverts replace a natural stream with concrete piping. The NGA team worked with NIWA and have produced a product called 'ALPURT B2' that is designed to create aquatic habitat inside culverts. The design uses every fourth baffle sheet to construct a 'rock weir'. By filling them with rock, rubble, sand and stream mud, pools form behind and riffles are created by the stream flowing over the stones (www.northerngateway.co.nz).

Rotational plastics also provide baffles that are made in sheets and can be bolted on the floor of culverts (www.rotationalplastics.co.nz/brochures/Sphere2.gif). They provide baffles in two sizes. At the time of this report no peer reviewed studies on either of these companies' products were available.

Resting pools:

The provision of inlet and outlet pools serves a variety of purposes for both native and exotic species and aid in preserving the integrity of the culvert by providing resting areas before and after negotiating the structure. Tailwater control devices used to create these pools may be low sills constructed of concrete or riprap, gabion baskets, or logs. Riprap has the advantage of blending in with the stream environment, and fish can use its variable roughness to pass over the structure. Where a low sill is provided, it should be constructed so that water flows over the structure, and not through it (Boubée et al 1998). The tailwater control device should contain a channel or notch to allow fish to pass over it in low flows.

6.1.3 LOW WATER DEPTHS OR LACK OF A LOW FLOW ZONE

Low water depths increase the energy required for a fish to swim, thereby reducing the distance fish can travel. Low water depths can also be caused by inadequate structures. Structures which are perched, culverts which do not have buried inverts or structures that have a wide flat base restrict fish passage. The negative impacts of low flows can be minimised by ensuring structures have a low flow channel or are angled to maximise the available water. To avoid low water depths hindering fish passage:

- Base of structures should be sloped or dish shaped to provide fish passage at low water depths.
- Perched or flat culverts should be altered or reinstalled to meet the requirements in section 4.1 of this document.

6.1.4 FLOODGATES

The gates currently in the Waipaoa River catchment rely on the force of the water to open them, however many of the streams have low flow rates and are only capable of opening the heavy gates a small amount. These small openings cause high velocity flows through the gate, making upstream passage more difficult for fish species. Floodgates in the Waipaoa River catchment have the additional problem of the high sediment levels in the catchment causing blockages. There are no solutions to this provided in the literature, so regular maintenance and clearing is required. Where possible floodgates should be avoided. If they must be used they should be designed so their natural state is open sufficiently to allow fish passage, closing only when there are flood flows.

Floodgates that allow fish passage are available. One such design has the gate hinge mounted on rollers, which rest on short shaft. Water pressure from behind the gate will push the whole thing outwards on the rollers thereby leaving a reasonable gap between the gate and its seal. A wider gap at this point reduces water velocities and aids fish passage (Mitchell 1990). Environment Bay of Plenty are currently working on designs for fish friendly floodgates that can be retrofitted to existing structures (j. Goodman Pers. Com. 2007).

- Fish friendly gates should be used that have a float, keeping the gate open as often as possible and maintaining a small gap for passage.
- A boulder weir can be built immediately downstream, to pond water around the floodgate. Deeper water immediately reduces velocities at the gap and assists fish passage (Mitchell 1990).
- Environment Bay of Plenty are currently working on designs for fish friendly flood gates that can be retro-fitted to existing structures. However, the current designs for these may not be suitable for rivers with high sediment loads or areas where tidal action may deposit sediment against the gate.

6.1.5 WEIRS

Fall height and notch shape have important impacts on fish passage. Baker (2003) found that juvenile inanga and common bullies were restricted by falls at 10 cm or higher, but could pass lower weirs. Notch shape was found by Baker (2003) to have a significant effect on passage, with juvenile fish negotiating a v-notch weir more easily than the rectangular or circular weirs. Fall height was a greater factor influencing the success of passage, this may have been contributed to by the increased turbulence below the weir decreasing the ability of fish to negotiate the weirs. Rebar weirs should not be used in New Zealand rivers due to the amount of sediment and debris carried (Boubée et al 1998). This can block the weir preventing passage to native fish species and requires extensive maintenance (Boubée et al 1998).

- Weir height should be restricted to 10 cm, or the maximum height passable by the target species.
- Weirs should have a 'V-notch' to allow passage of fish.
- Weir should be impermeable with constant flow and continual passage over.

6.1.6 FORDS

Fords are the least desired form of stream catching from the perspective of fish passage. However, as there are many fords already in the catchment which it may not be feasible to replace, the following guidelines should be followed to modify them:

- Where possible fords should be replaced with bridges
- If bridges are not possible, culverts which meet the criteria defined above should be installed.
- An alternative to culverts is a low flow channel under the ford. This can be achieved by including a low-flow channel with a permanent, non-eroding rock base in the structure.
- Fords should be monitored to be certain that fish are successfully passing it, and remedial action should be taken if floods cause erosion.

6.1.7 RAMPS

Ramps can be useful for high structures such as dams and weirs, or to lead into a perched culvert where other mitigation options are not feasible. Ramps may subject fish to increased predation and desiccation as they are exposed on a bare surface without easily accessible cover, therefore caution should be exercised to minimise these risks.

The critical point in upstream fish passage design is the location of the fish passage entrance and the attraction flow (Larinier 2007). Most fish passes fail because the fish cannot follow the flow to the entrance of the fish pass or because the flows exceed the swimming ability of the fish (Bowman and Rowe 2002). Fish and Game (Unpublished data) surveyed 70 dams and identified 11 fish passes. Of these only 4 (36%) were effective. Fish and Game identified a lack of target species design and maintenance as the key causes of the passage failure. Fish length is an important factor in successful passage over ramps (Baker and Boubeé 2006), therefore fish passes need to be designed specifically for New Zealand's species which migrate while they are a small size (Thompson and Rahel 1998) and require low velocity water. Fish passes for this group must be designed to reduce the water's velocity and provide resting places for the fish (Mitchell 1990). If flows are not able to be controlled then suitable material needs to be placed in the pass for species to move along. The National Institute of Water and Atmospheric Research (NIWA) (2001) provided an assessment of different substrate that can be placed in the pass (see Appendix 8). The following guidelines detail the requirements of fish passes:

- The entrance of the pass must be where fish are present or have a system to attract them (NIWA 2001).
- The entrance and exit must have water cover at all times with low velocity flow (Bowman and Rowe 2002).
- Maximum water flow of 0.3 m/s.
- Ramp should be tilted horizontally so a wetted margin is present at high and low flows.
- The width of the ramp needs to be adjusted to the flow regime present and the ramps should preferably be present along both banks (Baker and Boubeé 2006).
- To accommodate both swimming and climbing fish a maximum slope of 15° is recommend with baffled media to reduce water velocities and provide resting places.
- The maximum length will depend on the swimming ability of the weakest fish requiring passage (Baker and Boubeé 2006).
- May require cover if passage could subject fish to increased predation.

Auckland Regional Council (date unknown) and Larinier (2007) provide detailed descriptions of several different types of fish ways.

6.1.8 PIPE PASSES

Where the above solutions are not feasible, pipe, channel or trough passes furnished with climbing materials or coarse aggrades glued to the inside, can be used to facilitate fish passage of climbing species. Pipe passes can be filled with fibrous climbing material or geotextile materials.

- Closed section passes are prone to blockage and therefore screening of inlets and provision of access hatches for cleaning are advisable.
- Open section 'eel ladders' are more common but removable covers should be used to exclude trash, provide shade and protection from predators.
- Screening of inlets will prevent entry of trash and protection of damage form debris (Thompson and Rahel 1998).
- Shading to prevent solar warming on longer pipes.
- Eel ladders can be built into a barrier as an integrated unit or attached to surfaces or suspended by ropes or cables, mounted at 15-30° for ease of ascent.
- Textured surface layer such as 'geotextile mats' or horticultural netting can be used to provide a textured surface in the pipe to aid climbing (Thompson and Rahel 1998).

Not all structures need a fish pass to cover their full length. Many dams and weirs have places where climbing behaviour already occurs but the water flow prevents fish from scaling the object. Minor modifications often can solve these problems, for example, pumping water through a fish pass at the point where the blockage begins, or filling in cracks where fish are trapped (Mitchell 1990).

6.1.9 LARGER STRUCTURES

For larger structures, such as major dams, there are options such as fish lifts available, however as there are no structures of this magnitude in the Gisborne region options for these passes were not explored within the scope of this study. There is also the option of trap and transfer fish passes (Mitchell 1996). However these need human intervention rendering them as expensive and labour intensive. They are also hindered in performance by different migration timing of fish species preventing all species from being catered for (Boubée 2001). All of the structures in the region are able to be repaired without the use of trap and transfer methods.

6.2 RESTRICTING SELECTED SPECIES

Artificial barriers can be important management tools for protecting populations of native fish from encroaching non-native species (Thompson and Rahel 1998). Boubée et al (1999) stated that the occasional blocking of fish passage can be advantageous, blocking trout which competes with, and preys on, indigenous species. Exclusion of these species may provide a refuge for native species upstream. Fish such as koi carp or gambusia may be contained and limited by retaining specific barriers to fish (Boubée et al 1999). Both gambusia and brown trout are present in the region. Consideration should be given when removing barriers from areas with high value, non-migratory native species upstream of the barrier and predatory exotic species downstream.

6.3 OTHER FACTORS IMPACTING FISH POPULATIONS

6.3.1 Suspended sediment

Suspended sediment can alter the water chemistry and cause temperature decreases and turbidity increases. Turbidity levels as low as 5 nephelometric turbidity units (NTU) can decrease primary productivity by 3-13% (Ryan 1991). The Waipaoa River contains suspended sediment above 200 NTU at 75% of the time (MAF 2008). An increase of suspended sediment levels may reduce benthic densities as well as alter community structure. Fish are not so obviously affected although death resulting from clogging of gills may occur in sensitive species (Ryan 1991). Avoidance of suspended sediment varies from species to species with some showing high sensitivity, for example the banded kokopu numbers decreased by 89.5% in turbid rivers (Boubée et al 1997), where as other species, such as shortfin and longfin elvers and redfinned bullies show no silt avoidance. Temporal adaptation to elevated SS, and developmental changes in sensitivity to SS, may be important since, as shown in juvenile coho salmon, the response to SS can vary with previous exposure (Boubée et al 1997).

6.3.2 Altitude and distance from sea

Richardson and Jowett (2002) found that site altitude and distance inland were important factors in determining the abundance and composition of the fish community. The abundance of diadromous fish decreases with altitude and distance from the sea (Jowett et al 1996). The ability of each species to migrate inland varies. Elvers and koaro can climb waterfalls and rapids to reach habitats well inland. Other species (for example inanga, grey mullet) are restricted to areas with low gradients and flows (Mitchell 1990). For a detailed list of the inland penetration abilities of each of New Zealand's native fish species see McDowall and Eldon (1980).

Hayes et al (1989) found that distance from sea and gradient from the rivermouth were the two strongest environmental variables influencing distribution. Joy et al (2000) found that upstream penetration of common smelt peaked at 15 km from the sea and 140 m above sea level (a.s.l.) and torrentfish 40 km from the sea and 300 a.s.l. in the Taranaki ring plain streams. However in the Mangatainoka River both species penetrate 180 km and 300 m a.s.l. and in the Oroua River both reach 130 km and 440 m a.s.l. These other rivers have low gradients, so slope may therefore be more important than distance travelled as an upper limit to penetration for these species.

6.3.3 Forest cover and riparian margins

Hanchet (1990) found that pastoral sites of a shallow gradient had less diversity than sites of indigenous forest with steep gradients, despite steepness being negatively correlated to species diversity. This indicates that indigenous forest cover is a preferred and important habitat for native fish species, and a more important contributing factor to habitat selection than gradient. Hanchet's (1990) study revealed that as the amount of indigenous forest in a catchment decreased, the fauna became less diverse. Benthic invertebrate density is also influenced by riparian cover, with higher densities at native forest sites than at exotic forest (Jowett et al 1996). As benthic invertebrate presences is positively correlated with the presence of several fish species, their absence due to lack of forest cover can impact fish populations (Jowett et al 1996). This is a concern for the region as there is limited native forest cover left, for example the Waipaoa River catchment contains only 17% native forest cover, with 62% of the catchment having been converted to pasture and 12% being converted to forestry (http://nzfsa.org/mafnet/publications/appen.pdf).

7. CONCLUSION

A fish passage system is successful only when it operates as an integral system that attracts fish and passes them safely to their destination, upstream or downstream past an obstruction in the river (Odeh 1999). There are at least 220 barriers to fish passage resulting from in-stream structures requiring remedial work in the Gisborne Region. The criteria provided in section 4.1 of this report, should ensure free passage of the catchments in the Gisborne region for New Zealand's native fish species. This passage can only be ensured long term provided there is periodic maintenance of the structures and alterations or modifications where necessary. As fish passage technology continues to improve, it is important to apply the new technology to existing structures to help ensure the long term viability of our unique freshwater species.

All culverts or in-stream structures being replaced need to comply with the Resource Management Act section 17. This should be achievable by following the guidelines provided in this document. Landowners need to be made aware of the requirements and the actions necessary to comply with the RMA and compliance for fish passage should be listed as a resource consent condition.

Unimpeded fish passage is an essential part of integrated catchment management, alongside maintaining riparian vegetation and the sustainable use of land and water resources.

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9. APPENDICES

APPENDIX 1. LEGISLATION

Freshwater Fisheries Regulations, 1983, Part 6. regulations 41-50 . Fish passage.

41 Scope

(1) This part of these regulations shall apply to every dam or diversion structure in any natural river, stream, or water.

(2) For the purposes of these regulations dam or diversion structure shall not include—

(a)Any net, trap, or structure erected and used solely for the purpose of taking or holding fish in accordance with the provisions of the Act, or of these regulations:

(b)Any dam constructed on dry or swampy land or ephemeral water courses for the express purpose of watering domestic stock or providing habitat for water birds:

(c)Any water diversion not being incorporated into or with a dam, that is solely and reasonably required for domestic needs or for the purposes of watering domestic stock and that empties, without dead ends, into any viable fish habitat:

(d)Any structure authorised by a Regional Water Board not requiring a water right that in no way impedes the passage of fish.

(3) For the purposes of this Part of these regulations, the term occupier includes the owner of any land when there is no apparent occupier; and also includes any person doing any work by contract for the occupier.

42 Culverts and fords

(1) Notwithstanding regulation 41(2)(d) of these regulations, no person shall construct any culvert or ford in any natural river, stream, or water in such a way that the passage of fish would be impeded, without the written approval of the Director-General incorporating such conditions as the Director-General thinks appropriate.

(2) The occupier of any land shall maintain any culvert or ford in any natural river, stream, or water (including the bed of any such natural river, stream, or water in the vicinity of the culvert or ford) in such a way as to allow the free passage of fish: Provided that this requirement shall cease if the culvert or ford is completely removed or a written exemption has been given by the Director-General.]

43 Dams and diversion structures

(1) The Director-General may require that any dam or diversion structure proposed to be built include a fish facility: Provided that this requirement shall not apply to any dam or diversion structure subject to a water right issued under the provisions of the Water and Soil Conservation Act 1967 prior to the 1st day of January 1984.

(2) Any person proposing to build such a dam or diversion structure shall notify the Director-General and forward a submission seeking the Director-General's approval or dispensation from the requirements of these regulations, shall supply to the Director-General such information as is reasonably required by the Director-General to assist him in deciding his requirements (including plans and specifications of the proposed structure and any proposed fish facility).

(3) Should the Director-General consider that the information supplied is inadequate, he shall, within 28 days, advise the applicant as to what further information is required.]

44 Requirement for a fish facility

(1) If, in the opinion of the Director-General, a fish facility is required or dispensation from such a requirement is acceptable, the Director-General shall as soon as practical but in no case longer than 6 months if a fish facility is required from the date of receiving all information required, or 3 months where a fish facility is not required from the date of receiving all information required, forward his written requirement or dispensation to whomsoever made the submission.

(2) Where in the opinion of the Director-General a fish facility is required he shall specify what is required to enable fish to pass or stop the passage of fish, and while not limiting this general requirement may specify—

(a)The type, general dimensions, and general design of any fish pass to be utilised:

(b)The type, general dimensions, general design, and placement of any fish screen utilised.

(3) Subject to the Water and Soil Conservation Act 1967 and any determination under that Act, the Director-General may specify—

(a) The type and placement of any water intake to be utilised where fish screens are not required:

(b) The flow of water through any fish pass and the periods of the day and year when the pass must be operational:

(c) The volume, velocity, and placement of additional water to attract migrating fish to any fish pass:

(d) The type and scope of any remedial works in connection with any fish screen or fish pass to enable fish to approach the structure or to be returned to the normal course of the water channel:

(e)The volume or relative proportion of water that shall remain downstream of any dam or diversion structure and the period of day or year that such water flows shall be provided.

(4) Every approval given by the Director-General shall expire 3 years from the date of issue if the construction of the dam or diversion structure is not completed, or such longer time as he may allow.

(5) The manager of every dam or diversion structure in connection with which a fish facility is provided shall at all times keep such fish facility in good and satisfactory repair and order, so that fish may freely pass and return at all times or are prevented from passing as specified under these regulations.]

45 Adequate water

The manager of every dam or diversion structure in connection with which a fish facility is provided shall, subject to the Water and Soil Conservation Act 1967 and any relevant determination under that Act, maintain a flow of water through or past such fish facility sufficient in quantity to allow the facility to function as specified at all times or periods specified; but no person shall be liable for a breach of this regulation due to drought, flood, or other sources beyond his control if the default is made good as soon as reasonably possible.]

46 Required maintenance or repair

The Director-General may serve notice in writing to the manager of any fish facility notifying him of any defects or want of repair in such fish facility and requiring him within a reasonable time to be therein prescribed to remove any defect or make such repairs as may be required:

Provided that nothing in this regulation shall affect the liability of a manager under regulation 44 of these regulations.]

47 Damage

No person shall wilfully injure or damage any fish facility.

48 Alterations

No person shall, without the written consent of the Director-General, make a structural alteration in any fish facility.

49 Inspection of fish facilities

Any Officer may at all reasonable times enter upon any fish facility and upon any remedial works or upon the land bordering such fish facility or remedial works for the purpose of their inspection.

50 Protection of fish

No person, other than an Officer acting in his official capacity, shall take or attempt to take any fish on its passage through a fish facility, or place any obstruction therein or within a radius of 50m of any point of a fish facility, or shall within a radius of 50m of any point of a fish facility use any contrivance whereby fish may be impeded in any way in freely entering or passing through or passing by a fish facility except as may be provided by the Director-General in writing to the manager of the fish facility.

Resource Management Act 1991, Section 17

Duty to avoid, remedy, or mitigate adverse effects

(1) Every person has a duty to avoid, remedy, or mitigate any adverse effect on the environment arising from an activity carried on by or on behalf of that person, whether or not the activity is in accordance with a rule in a plan, a resource consent, a designation, section 10, section 10A, or section 20A

(2) The duty referred to in subsection (1) is not of itself enforceable against any person, and no person is liable to any other person for a breach of that duty.

(3) Notwithstanding subsection (2), an enforcement order or abatement notice may be made or served under Part 12 to—

- (a) Require a person to cease, or prohibit a person from commencing, anything that, in the opinion of the Environment Court or an enforcement officer, is or is likely to be noxious, dangerous, offensive, or objectionable to such an extent that it has or is likely to have an adverse effect on the environment; or
- (b) Require a person to do something that, in the opinion of the Environment Court or an enforcement officer, is necessary in order to avoid, remedy, or mitigate any actual or likely adverse effect on the environment caused by, or on behalf of, that person.

(4) Subsection (3) is subject to section 319(2) (which specifies when an Environment Court shall not make an enforcement order).

APPENDIX 2. FISH SPECIES IDENTIFIED IN THE GISBORNE RIVER CATCHMENTS.

SPECIES	COMMON NAME	THREAT STATUS	WAIPAOA	KOPUAWHARA	WAIAPU	TURANGANUI	GISBORNE	MAKORORI	POUAWA	UAWA	WAIMOKO
Anguilla dieffenbachii	Longfin eel (D)	5 Gradual decline	*	*	*	*				*	*
Paranephrops planifrons	Koura/freshwater crayfish (D)	5 Gradual decline		*							
Galaxias fasciatus	Banded kokopu (D)	Not threatened	*			*					
Rhombosolea retiaria	Black Flounder (D)	Not threatened	*	*		*					
Gobiomorphus hubbsi	Bluegill bully (D)	Not threatened	*			*				*	*
Gobiomorphus cotidianus	Common bully (D)	Not threatened	*	*	*	*			*	*	*
Retropinna retropinna	Common smelt (D)	Not threatened	*			*					
Gobiomorphus basalis	Crans bully (ND)	Not threatened	*	*		*			*	*	*
Galaxias maculatus	Inanga (D)	Not threatened	*	*		*	*		*	*	
Gobiomorphus huttoni	Redfin bully (D)	Not threatened	*	*		*					
Anguilla australis	Shortfin eel (D)	Not threatened	*		*	*				*	*
Cheimarrichthys fosteri	Torrentfish (D)	Not threatened	*		*					*	
Aldrichetta forsteri	Yelloweyed mullet (D)	Not threatened	*								
Gobiomorphus gobioides	Giant bully (D)	Not threatened		*		*					
Galaxias brevipinnis	Koaro (D)	Not threatened			*						
	Upland bully (ND)					*					
	Eel species								*	*	*
	Mullet species					*					
Salmo trutta	Brown trout	Introduced	*								
Gambusia affinis	Gambusia	Introduced	*			*	*	*			
Crassius auratus	Goldfish	Introduced	*			*					
Oncorhynchus mykiss	Rainbow trout	Introduced		*	*						

Fish Species identified in the Waipaoa, Kopuawhara, Waiapu and Turanganui River catchments (New Zealand Freshwater Fish Database 2008).
D= diadromous, ND = Non-diadromous.

APPENDIX 3. DESCRIPTION OF CULVERT TYPES.

Pipe culverts (Multi barrel pipe culvert)

- Pipe culverts allow for a low flow channel and a wetted margin.
- Depth of water at low flows greater than that off other shapes, improving passage.
- If too small can create dark passage or increase turbulence.
- Does not leave natural stream bed in place.
- Often perched, vulnerable to increased perching from erosion.

Arch culverts

- Leaves the natural streambed in place
- Suitable for low cover depths and providing resting areas in high turbulence.
- If the barrel is too small erosion may occur. (image from http://www.landandwater.com/features/vol51no2/vol51no2_2D.jpg)

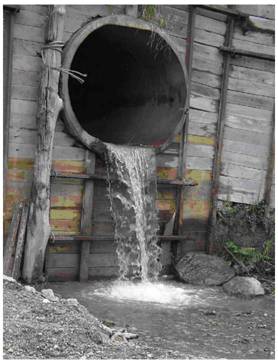
Box culverts

- Do not restrict the natural stream channel and is similar to a bridge in hydraulic characteristics.
- Allow for light
- Can be placed side by side to maximise area
- Simplified baffle design and construction
- Accommodate high flows.
- Cause spreading of flows to shallow depths across their wide, flat cross-sections.
- Often have perched aprons.


Perched inlet


Inlet Falls


Flat


Perched outlet


Perched outlet


Floodgates on culvert


Poor maintenance


Poor maintenance


Sand at outlet


Floodgates


Inlet narrower that stream


Ford

APPENDIX 5. CALCULATION OF MAXIMUM FISH SWIMMING DISTANCE.

It is possible to calculate the maximum distance over which a fish in the swimming mode will be able to travel from the following formula taken from Mitchell (1989):

where $\mathbf{V}_{fw}$ (the velocity of the fish in relation to the water) was the maximum velocity (m s-1) that could be sustained for **t** seconds by a fish of **L** length (in metres), and **a**, **b**, and **c** were coefficients that depended on the fish species.

$$\mathbf{D} = \mathbf{V}_f \mathbf{t} = (\mathbf{V}_{fw} - \mathbf{V}_w)\ \mathbf{t}$$

where:

D = distance (metres);

$\mathbf{V}_{fw}$ = the velocity of the fish relative to the water (m s-1);

$\mathbf{V}_w$ = the velocity of the water (m s-1);

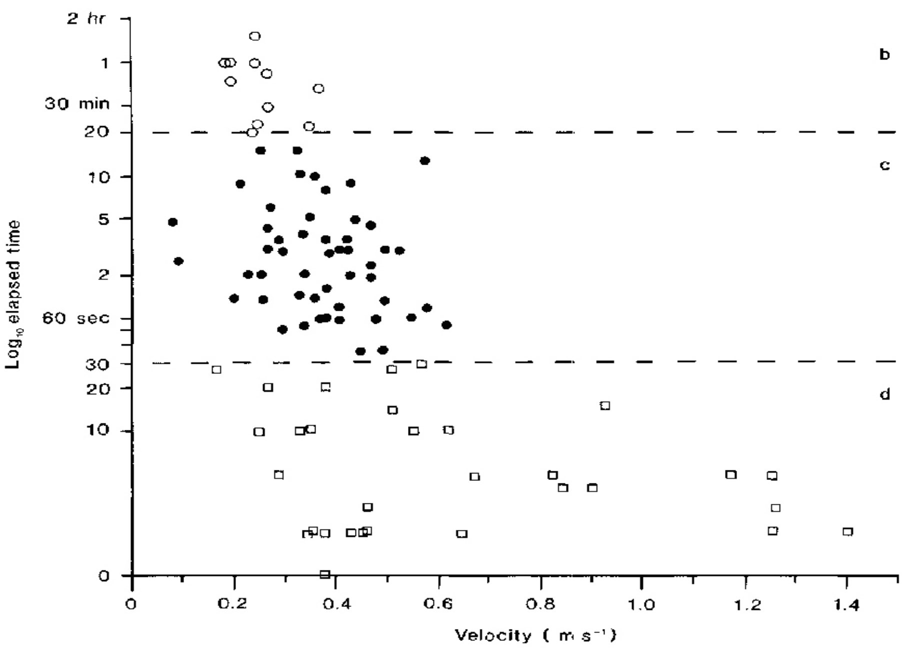
$\mathbf{V}_f$ = the velocity of the fish relative to the ground (m s-1);

t = the time for which the fish is able to swim at Vfw before becoming fatigued (seconds).

APPENDIX 6. BURST, STEADY AND SUSTAINED SWIMMING SPEEDS OVER TIME.

Length of time for which Anguilla australis, Galaxias maculatus, G. fasciatus, Gobiomorphus cotidianus, and Retropinna retropinna swam at a range of current velocities (Mitchell 1989).

○=sustained swimming; ● = steady swimming; □ burst swimming)



APPENDIX 7. SWIMMING SPEEDS OF NEW ZEALAND FISH SPECIES.

SPECIES	COMMENTS	SPEED MS-1	SOURCS
Banded kokopu	upstream migration gain in the Waikato river	0.05	
Mean of juvenile shortfin eel, common bully, common smelt, inanga and banded kokopu	Cruising speed	0.2	Mitchell 1991
	Sustained speed	0.32	Mitchell 1992
Elvers (100 mm)	Cruising speed	0.0 - 0.15	Bell 1986
Elver 55-80mm	cruising speed	0.2	Mitchell 1989
	Sustained speed	0.34	Mitchell 1990
Mullet	Cruising speed	0.12	Mitchell 1993
	Sustained speed	0.2	Mitchell 1994
(13-69 mm)	Darting speed	0.14 - 0.46	Bell 1989
Inanga	preferred velocities	~0.07	Mitchell and Boubee 1995
	Maximim velocity in which the fish will swim freely	0.3 - 0.34	Mitchell and Boubee 1996
	Water velocity which fish select and can easily negotiate	<0.15	Mitchell and Boubee 1997

APPENDIX 8. PRIORITY RANKINGS OF IN-STREAM STRUCTURES FOR REMEDIAL ACTION: WHOLE REGION

SITE ADDRESS	STREAM NAME	CULVERT DESCRIPTION	PHOTO ID	TOTAL	RANKING
Lytton Road	Matokitoki Stream	Box	C2 35	53	1
Pyke Road	Te Arai River	Unknown	Pyke Road weir	53	1
State Highway 35	Unknown	Box	C3 02	51	2
State Highway 35	Unknown	Pipe	C3 03	51	2
Shelton Road	Kaitawa Stream tributary	Pipe	C3 17	51	2
Waiomoko Road	Waiomoko River tributary	Pipe	C3 11	51	2
Wainui Road	Unknown	Unknown	C3 01	51	2
Waimata Valley Road	Mangahouku Stream	Box	C2 32	50	3
Waingake Mangapoke Road	Te Arai River	Ford	TA3	49	4
Waingake Mangapoke Road	Te Arai River	Ford	TA4	49	4
Waingake Mangapoke Road	Te Arai River	Ford	TA6	49	4
Waingake Mangapoke Road	Te Arai River	Ford	TA7	49	4
Waingake Mangapoke Road	Te Arai River	Ford	TA8	49	4
Waingake Mangapoke Road	Te Arai River	Ford	TA9	49	4
Waingake Mangapoke Road	Te Arai River	Ford	TA10	49	4
Waingake Mangapoke Road	Te Arai River	Ford	TA11	49	4
Waingake Mangapoke Road	Te Arai River	Ford	TA12	49	4
Waingake Mangapoke Road	Te Arai River	Ford	TA13	49	4
Waingake Mangapoke Road	Te Arai River	Ford	TA15	49	4
Waingake Mangapoke Road	Te Arai River	Ford	TA16	49	4
Waingake Mangapoke Road	Te Arai River	Ford	TA17	49	4
Wharekopae Road	Tributary of Whakakopae River	Pipe	C1 114	49	4
Hihiroroa Road	Hihiroroa Stream	Pipe	C1 0008	49	4
Tiniroto Road	Tributary of Te Aroha Stream	Pipe	C1 39	49	4
Whakarau Road	Tributary of Waikohu River	Pipe	C1 95	49	4
Hihiroroa Road	Taumatapoupou stream	Pipe	C1 75	49	4
Bruce Road	Motumate Stream	Unknown	C1 56	49	4
Wharekopae Road	Tributary of Whakakopae River	Unknown	C1 116	49	4
Murawai	Blacks Drain	Concrete	Site 6	48	5
State Highway 35	Pouawa River tributary	Pipe	C3 06	48	5

SITE ADDRESS	STREAM NAME	CULVERT DESCRIPTION	PHOTO ID	TOTAL	RANKING
Haisman Road	Taruheru Tributary	Pipe	C2 05	48	5
Whakarau Street	Tributary of the Waikohu River	Pipe	C1 91	48	5
Hihiroroa Road	Tributary of the Wharekopae River	Pipe	C1 86	48	5
State Highway 35	Pouawa River tributary	Pipe	C3 07	48	5
Shelton Road	Kaitawa Stream tributary	Pipe	C3 16	48	5
Hauiti Road	Unnamed	Pipe	C3 18	48	5
Waipaoa Road	Unknown tributary	Pipe	M7	48	5
King Road	Taruheru Tributary	Pipe	C2 03	48	5
Lyell Road	Waimata Tributary	Pipe	C2 14	48	5
Waiomoko Road	Waiomoko River tributary	Pipe	C3 10	48	5
Paremata Road	Waimaunu Stream tributary	Pipe	C3 19	48	5
Waiomoko Road	Waiomoko River tributary	Pipe	C3 09	48	5
Opou, Manutuke	Whatatuna Stream	Unknown	Site 4	48	5
Kohanga Road	Hihiroroa Stream	Unknown	C1 0009	48	5
Wharekopae Road	Tributary of Waikakariki Stream	Arch	C1 12	47	6
Hihiroroa Road	Taumatapoupou Stream	Pipe	C1 76	47	6
Whakarau Road	Tributary of the Waikohu	Box	C1 57	46	7
Waimata Valley Road	Mangahouku Stream Tributary	Box	C2 33	46	7
Kanakanaia Road	Tributary of Waipaoa	Box	C1 33	46	7
State Highway 2 Ormond	Tributary of Waipaoa, Ormond	Box	C1 27	46	7
Hirini Road	Turanganui Tributary	Box	C2 12	46	7
Whakarau Road	Mangatawa Stream	Box	C1 94	46	7
Wharekopae Road	Tributary of Taumatapoupou Stream	Pipe	C1 78	46	7
Wharekopae Road	Tributary of Whakakopae River	Pipe	C1 113	46	7
Wharekopae Road	Tributary of Waikakariki Stream	Pipe	C1 14	46	7
Kanakanaia Road	Tributary of Waihora River	Pipe	C1 48	46	7
Whakarau Road	Tributary of Waikohu River	Pipe	C1 96	46	7
Papatu Road	Tributary of Te Arai	Pipe	C1 0004	46	7
SH2 opp Otoko School Road	Tributary of Waihuka River	Pipe	C1 62	46	7
Whakarau Road	Tributary of Waikohu River	Pipe	C1 103	46	7
Riverside Road	Waimata tributary	Pipe	C2 18	46	7
Riverside Road	Waimata tributary	Pipe	C2 20	46	7

SITE ADDRESS	STREAM NAME	CULVERT DESCRIPTION	PHOTO ID	TOTAL	RANKING
Unknown	Waimata River tributary	Pipe	C2 28	46	7
Wharekopae Road	Tributary of Taumatapoupou	Pipe	C1 74	46	7
Haisman Road	Taruheru Tributary	Pipe	C2 06	46	7
Waiomoko Road	Waiomoko River tributary	Pipe	C3 13	46	7
Waimata Valley Road	Waimata River Tributary	Pipe	C2 29	46	7
Waimata Valley Road	Waimata River Tributary	Pipe	C2 30	46	7
Waitangi Road	Tributary of Waingaromia River	Pipe	C1 134	46	7
Cambridge Terrace	Turanganui Tributary	Pipe	C2 13	46	7
Matokitoki Valley Road	Matokitoki Stream	Pipe	C2 22	46	7
Centennial Marine drive	Stream to Sistertons Lagoon	Box	C1 16	45	8
Waingake Mangapoke Road	Te Arai River	Ford	TA2	45	8
Whakarau Road	Tributary of Waikohu River	Pipe	C1 98	45	8
Kanakanaia Road	Waihora River tributary	Pipe	C1 51	45	8
Whakarau Road	Tributary of the Waikohu River	Pipe	C1 89	45	8
Matawhero Loop	Matawhero Loop Gates	Pipe	C1 58	45	8
Gordon Road	Tributary of Waimata Stream	Pipe	C1 108	45	8
State Highway 2	Unnamed tributary of Waipaoa	Pipe	C1 24	45	8
Wharekopae Road	Tributary of Purahokungia Stream	Pipe	C1 69	45	8
Waingake Mangapoke Road	Te Arai River	Weir	TA1	45	8
Te Rata Road	Unknown tributary	Pipe	M16	44	9
Te Rata Road	Unknown tributary	Pipe	M15	44	9
Wairangiora Road	Unknown tributary	Pipe	M11	44	9
Terrace Road	Unknown tributary	Pipe	M17	44	9
Unknown	Pohatuhatununui Stream Tributary	Pipe	C2 34	44	9
Te Rata Road	Unknown tributary	Pipe	M5	44	9
River Road	Unknown tributary	Pipe	M9	44	9
Kanakanaia Road	Waihora River tributary	Pipe	C1 54	44	9
Makaretu Road	Nagatapa Stream	Pipe	C1 0011	44	9
Waipaoa Road	Unknown tributary	Pipe	M6	44	9
Kook road	Unknown tributary	Pipe	M20	44	9
Thor Road	Unknown tributary	Pipe	M8	44	9
Totangi Road	Tributary of Oruahea Stream	Pipe	C1 66	44	9

SITE ADDRESS	STREAM NAME	CULVERT DESCRIPTION	PHOTO ID	TOTAL	RANKING
River Road	Unknown tributary	Pipe	M10	44	9
Waipaoa Road	Unknown tributary	Pipe	M2	44	9
Waipaoa Road	Unknown tributary of Waipaoa	Pipe	M1	44	9
Wharekopae Road	Tributary of Whakakopae River	Unknown	C1 115	44	9
Riverside Road	Waimata Tributary	Box	C2 19	43	10
Wharekopae Road	Tributary of Taumatapoupou	Box	C1 71	43	10
Riverside Road	Waimata Tributary	Box	C2 21	43	10
Kanakanaia rd	Waihora tributary	Ford	C1 47	43	10
Waingake Mangapoke Road	Te Arai River	Ford	TA5	43	10
Waingake Mangapoke Road	Te Arai River	Ford	TA14	43	10
Shaw Road	Tributary of Waikohu River	Pipe	C1 119	43	10
Shaw Road	Tributary of Waikohu River	Pipe	C1 118	43	10
Whakarau Road	Tributary of Waikohu River	Pipe	C1 97	43	10
Rakauroa Road	Tributary of Waikohu River	Pipe	C1 124	43	10
Kanakanaia Road	Tributary of Waihora River	Pipe	C1 34	43	10
Kanakanaia Road	Waihora River tributary	Pipe	C1 50	43	10
Hihiroroa Road	Tributary of the Wharekopae River	Pipe	C1 85	43	10
Rakauroa Tahora Road	Waikohu tributary	Pipe	C1 120	43	10
Kanakanaia rd	Tributary of the Waihora Road	Pipe	C1 55	43	10
Oliver Road	Tributary of Waikohu River	Pipe	C1 128	43	10
Makaretu Road	Unnamed Waihuka River tributary	Pipe	C1 61	43	10
Wharekopae Road	Tributary of Taumatapoupou	Pipe	C1 70	43	10
Whakarau Road	Tributary of Waikohu River	Pipe	C1 93	43	10
Rakauroa Road	Tributary of Waikohu River	Pipe	C1 123	43	10
River Road	Tributary of the Waipaoa River	Pipe	C1 140	43	10
Riverside Road	Waimata Tributary	Pipe	C2 16	43	10
Mander Road	Swell Stream Tributary	Pipe	C2 25	43	10
Mander Road	Swell Stream Tributary	Pipe	C2 26	43	10
Wharekopae Road	Tributary of Whakakopae River	Pipe	C1 110	43	10
Oliver Road	Tributary of Waikohu River	Pipe	C1 127	43	10
State Highway 2	Unnamed tributary of Waipaoa	Pipe	C1 25	43	10
Cave Road	Waimata Tributary	Pipe	C2 15	43	10

SITE ADDRESS	STREAM NAME	CULVERT DESCRIPTION	PHOTO ID	TOTAL	RANKING
Waimata Valley Road	Waimata River Tributary	Pipe	C2 27	43	10
Wharekopae rd	Tributary of the Wharekopae River	Pipe	C1 79	43	10
Wharekopae Road	Tributary of the Wharekopae River	Pipe	C1 84	43	10
Shaw Road	Tributary of Waikohu River	Pipe	C1 121	43	10
Private Road off Totangi	Oruahea Stream	Pipe	C1 0006	43	10
Waiomoko Road	Waiomoko River tributary	Pipe	C3 12	43	10
Back Ormond Road	Taruheru Tributary	Pipe	C2 09	43	10
Waimata Valley Road	Swell Stream Tributary	Pipe	C2 24	43	10
Tumata Road	Tributary of the Wharekopae River	Pipe	C1 87	43	10
Karaua pumps	Manatuki East Drain	Unknown	site 5	43	10
State Highway 35	Kaitawa Stream tributary	Box	C3 15	42	11
Falkner Road	Tributary of Wharekopae River	Pipe	C1 81	42	11
Whakarau Road	Tributary of Waikohu River	Pipe	C1 99	42	11
Pilmer Road	Taruheru Tributary	Pipe	C2 04	42	11
Whakarau Road	Tributary of Waikohu River	Pipe	C1 100	42	11
Whakarau Road	Tributary of Waikohu River	Pipe	C1 102	42	11
Mangamaia Road	Tributary of Mangatu River	Pipe	C1 133	42	11
Rere Falls Station	Tributary of Makaretu Stream	Pipe	C1 0010	42	11
Matakonekone Road	Unknown tributary	Pipe	M3	42	11
Matakonekone Road	Unknown tributary	Pipe	M4	42	11
Te Rata Road	Unknown tributary	Pipe	M21	42	11
Unknown	Unknown tributary	Pipe	M19	42	11
Whakarau Road	Tributary of the Waikohu River	Pipe	C1 88	42	11
Wharekopae Road	Tributary of Whakakopae River	Pipe	C1 112	42	11
State Highway 35	Waiomoko River tributary	Pipe	C3 08	42	11
State Highway 35	Unknown	Pipe	C3 05	42	11
Terrace Road	Unknown tributary	Pipe	M18	42	11
Makaretu Road	Tributary of Makaretu Stream	Pipe	C1 137	41	12
Totangi Road	Tributary of Waikakariki Stream	Pipe	C1 65	41	12
Whakarau Road	Tributary of Waikohu River	Pipe	C1 106	41	12
Humpheys Road	Tributary of Waipaoa River	Pipe	C1 23	41	12
Pakowhai Road	Pakowhai stream	Pipe	Site 7	41	12

SITE ADDRESS	STREAM NAME	CULVERT DESCRIPTION	PHOTO ID	TOTAL	RANKING
Lavanham gates	Whakau Stream	Pipe	9	41	12
Gordon Road	Tributary of Waimata Stream	Pipe	C1 109	41	12
Whakarau Road	Tributary of Waikohu River	Unknown	C1 101	41	12
Matawhero loop	Matawhero Loop Lagoon	Box	C1 155	40	13
State Highway 2	Coal Stream	Box	C1 135	40	13
Waimata Valley Road	Taruheru Tributary	Box	C2 32	40	13
State Highway 2, Nth of Ormond	Tributary of Waipaoa	Pipe	C1 31	40	13
Tahinga Road	Unknown tributary	Pipe	M13	40	13
Tahinga Road	Unknown tributary	Pipe	M12	40	13
Taurau Valley Road	Tributary of Karaua Stream	Pipe	C1 10	40	13
Armstrong Road	Tributary of the Waipaoa River	Pipe	C1 139	40	13
Gisborne rail line	Sistertons Lagoon	Pipe	C1 156	40	13
Ngakoroa Road	Mangatuaki Stream	Pipe	C1 0007	40	13
State Highway 2, Kaitaratahi	Tributary of Waipaoa	Pipe	C1 32	40	13
Whakarau Road	Tributary of Waikohu River	Pipe	C1 105	40	13
Makorori Road	Unknown	Pipe	C3 04	40	13
Waipaoa Road	Unknown tributary	Pipe	Mangatu no number	40	13
Kanakanaia Road	Waihora River	Pipe	C1 46	39	14
Whakarau Road	Tributary of Waikohu River	Pipe	C1 92	39	14
Gordon Road	Tributary of Waimata Stream	Pipe	C1 107	39	14
Whakarau Road	Tributary of Kukupara Stream	Pipe	C1 0013	38	15
Whakarau Road	Tributary of Waikohu River	Pipe	C1 104a	38	15
Makaretu Road	Tributary of Makaretu Stream	Pipe	C1 136	38	15
Back Ormond Road	Taruheru Tributary	Pipe	C2 01	38	15
Whakarau Road	Tributary of Waikohu River	Pipe	C1 104	38	15
Armstrong Road	Tributary of the Waipaoa River	Pipe	C1 138	38	15
Wharerata Road (SH2)	Tributary of Waipaoa River	Unknown	C1 0002	38	15
Tarewa Tokonui Road	Titokenui Stream	Unknown	C1 0001	38	15
Whakarau Road	Tributary of Kukupara Stream	Unknown	C1 0014	38	15
Rakauroa Road	Tributary of Waikohu River	Pipe	C1 122	37	16
Tinroto Road	Tributary of Te Aroha Stream	Pipe	C1 38	37	16
Cnr Taurau Valley & Saddler Rd	Tributary of Karaua Stream	Pipe	C1 05	37	16

SITE ADDRESS	STREAM NAME	CULVERT DESCRIPTION	PHOTO ID	TOTAL	RANKING
Whakarau Road	Tributary of Kukupara Stream	Pipe	C1 0012	37	16
Bond Road, Ormond	Tributary of Waipaoa	Pipe	C1 29	37	16
Kanakanaia Road	Waihora River tributary	Pipe	C1 49	37	16
Harper Road	Taruheru Tributary	Pipe	C2 02	37	16
Oliver Road	Tributary of Waikohu River	Pipe	C1 129	37	16
Newmans Road	Tributary of Ngakorea Stream	Pipe	C1 41	37	16
Newmans Road	Tributary of Ngakorea Stream	Pipe	C1 42	37	16
State Highway 35	Pakarae River	Pipe	C3 14	37	16
Kanakanaia Road	Waihora River tributary	Pipe	C1 52	36	17
Tinroto Road	Tributary of Te Aroha Stream	Pipe	C1 37	36	17
Whatatutu Road	Unnamed tributary of the Waipaoa	Pipe	C1 45	36	17
Tinroto Road	Tributary of Te Aroha Stream	Pipe	C1 35	36	17
Lytton Road	Waikanae Creek	Pipe	C2 10	36	17
Tararau Valley Road	Tributary of Karaua Stream	Pipe	C1 03	36	17
SH2 Te Karaka	Tributary of Waikohu River	Pipe	C1 43	36	17
Lavenham Road	Tributary of Whakaahu Stream	Pipe	C1 21	35	18
State Highway 2	Pukematai Stream	Pipe	C1 59	35	18
Back Ormond Road	Taruheru Tributary	Pipe	C2 08	35	18
Whakarau Road	Tributary of the Waikohu River	Pipe	C1 90	34	19
MacLaurin Road	Waru Stream Tributary	Pipe	C2 07	34	19
Tinroto Road	Unnamed drain into Waipaoa	Box	C1 01	33	20
McDonald Road	Tributary to Sistertons lagoon?	Pipe	C1 17	32	21
Totangi Road	Oruahea Stream	Pipe	C1 67	32	21
Wharekopae Road	Whakakopae River	Unknown	C1 117	32	21
Hills Road	Tributary of Waikakariki Stream	Box	C1 0005	31	22
Kaitara Road	Tributary of Waikohu River	Pipe	C1 130	31	22
State Highway 2, Nth of Ormond	Tributary of Waipaoa	Pipe	C1 30	30	23
Repongere Road	Tributary of Whakaahu Stream	Pipe	C1 20	29	24
Falkner Road	Tributary of the Wharekopae River	Pipe	c1 80	28	25
Falkner Road	Tributary of Wharekopae River	Pipe	C1 82	28	25

APPENDIX 9. PRIORITY RANKINGS OF IN-STREAM STRUCTURES FOR REMEDIAL ACTION: WAIPAOA RIVER CATCHMENT

SITE ADDRESS	STREAM NAME	CULVERT DESCRIPTION	PHOTO ID	TOTAL	RANKING
Pyke Road	Te Arai River	Unknown	weir no #	53	1
Tiniroto Road- Gentle Annie Hill	Tributary of Te Aroha Stream	Culvert	C1 39	49	2
Wharekopae Road	Tributary of Whakakopae River	Culvert	C1 114	49	2
Whakarau Road	Tributary of Waikohu River	Culvert	C1 95	49	2
Wharekopae Road	Tributary of Whakakopae River	Concrete Ford	C1 116	49	2
Hihiroroa Road	Taumatapoupou stream	Culvert	C1 75	49	2
Hihiroroa Road	Hihiroroa Stream	Concrete Ford w/culv	C1 0008	49	2
Waingake Mangapoke Road	Te Arai River	Ford	TA6	49	2
Waingake Mangapoke Road	Te Arai River	Ford	TA11	49	2
Waingake Mangapoke Road	Te Arai River	Ford	TA15	49	2
Waingake Mangapoke Road	Te Arai River	Ford	TA4	49	2
Waingake Mangapoke Road	Te Arai River	Ford	TA7	49	2
Waingake Mangapoke Road	Te Arai River	Ford	TA16	49	2
Waingake Mangapoke Road	Te Arai River	Ford	TA3	49	2
Waingake Mangapoke Road	Te Arai River	Ford	TA8	49	2
Waingake Mangapoke Road	Te Arai River	Ford	TA9	49	2
Waingake Mangapoke Road	Te Arai River	Ford	TA17	49	2
Waingake Mangapoke Road	Te Arai River	Ford	TA10	49	2
Waingake Mangapoke Road	Te Arai River	Ford	TA12	49	2
Waingake Mangapoke Road	Te Arai River	Ford	TA13	49	2
Bruce Road	Motumate Stream	Concrete Ford	C1 56	49	2
Waipaoa Road	Unknown	Culvert	M7	48	3
Hihiroroa Road	Tributary of the Wharekopae River	Culvert	C1 86	48	3
Marawai	Blacks Drain	Unknown	Site 6	48	3
Whakarau Street	Tributary of the Waikohu River	Culvert	C1 91	48	3
Kohanga Road	Hihiroroa Stream	Concrete Ford	C1 0009	48	3
Opou, Manutuke	Whatatuna Stream	Floodgates	Site 4	48	3
Hihiroroa Road	Taumatapoupou Stream	Culvert	C1 76	47	4
Wharekopae Road	Tributary of Waikakariki Stream	Culvert	C1 12	47	4
State Highway 2 Ormond	Tributary of Waipaoa River, Ormond	Culvert	C1 27	46	5

SITE ADDRESS	STREAM NAME	CULVERT DESCRIPTION	PHOTO ID	TOTAL	RANKING
Wharekopae Road	Tributary of Taumatapoupou Stream	Culvert	C1 78	46	5
Wharekopae Road	Tributary of Waikakariki Stream	Culvert	C1 14	46	5
Kanakanaia Road	Tributary of Waihora River	Culvert	C1 48	46	5
Kanakanaia Road	Tributary of Waipaoa River	Culvert	C1 33	46	5
Wharekopae Road	Tributary of Whakakopae River	Culvert	C1 113	46	5
Whakarau Road	Tributary of Waikohu River	Unknown	C1 103	46	5
Whakarau Road	Tributary of the Waikohu	Culvert	C1 57	46	5
Waitangi Road	Tributary of Waingaromia River	Culvert	C1 134	46	5
Wharekopae Road	Tributary of Taumatapoupou	Culvert	C1 74	46	5
Papatu Road	Tributary of Te Arai River	Culvert	C1 0004	46	5
Whakarau Road	Tributary of Waikohu River	Concrete Ford w/culv	C1 96	46	5
Whakarau Road	Mangatawa Stream	Culvert	C1 94	46	5
State Highway 2 opposite Otoko School Road	Tributary of Waihuka River	Culvert	C1 62	46	5
Kanakanaia Road	Tributary of Waihora River	Culvert	C1 51	45	6
Centennial Marine drive	Stream to Sistertons Lagoon	Culvert	C1 16	45	6
Wharekopae Road	Tributary of Purahokungia Stream	Culvert	C1 69	45	6
Whakarau Road	Tributary of Waikohu River	Culvert	C1 98	45	6
Whakarau Road	Tributary of the Waikohu River	Unknown	C1 89	45	6
Gordon Road	Tributary of Waimata Stream	Culvert	C1 108	45	6
Waingake Mangapoke Road	Te Arai River	Weir	TA1	45	6
Waingake Mangapoke Road	Te Arai River	ford	TA2	45	6
Matawhero Loop	Matawhero Loop gates	Culvert	C1 58	45	6
State Highway 2	Tributary of Waipaoa River	Culvert	C1 24	45	6
Te Rata Road	Unknown	Culvert	M16	44	7
River Road	Unknown	Culvert	M9	44	7
River Road	Unknown	Culvert	M10	44	7
Te Rata Road	Unknown	Culvert	M15	44	7
Kook Rd	Unknown	Culvert	M20	44	7
Wairangiora Rd	Unknown	Culvert	M11	44	7
Waipaoa River Road	Unknown	Unknown	M5	44	7
Terrace Road	Unknown	Culvert	M17	44	7

SITE ADDRESS	STREAM NAME	CULVERT DESCRIPTION	PHOTO ID	TOTAL	RANKING
Waipaoa Road	Unknown tributary	Culvert	No #/ M1	44	7
Totangi Road	Tributary of Oruahea Stream	Culvert	C1 66	44	7
Waipaoa Road	Unknown	Unknown	M2	44	7
Makaretu Road	Nagatapa Stream	Culvert	C1 0011	44	7
Wharekopae Road	Tributary of Whakakopae River	Concrete Ford	C1 115	44	7
Kanakanaia Road	Tributary of Waihora River	Culvert	C1 54	44	7
Waipaoa road	Unknown	Culvert	M6	44	7
Thor Road	Unknown	Culvert	M8	44	7
State Highway 2	Tributary of Waipaoa River	Culvert	C1 25	43	8
Wharekopae Road	Tributary of the Wharekopae River	Culvert	C1 79	43	8
Kanakanaia Road	Tributary of Waihora River	Culvert	C1 34	43	8
Whakarau Road	Tributary of Waikohu River	Unknown	C1 97	43	8
Hihiroroa Road	Tributary of the Wharekopae River	Culvert	C1 85	43	8
Wharekopae Road	Tributary of Taumatapoupou	Culvert	C1 70	43	8
Whakarau Road	Tributary of Waikohu River	Culvert	C1 93	43	8
Shaw Road	Tributary of Waikohu River	Culvert	C1 118	43	8
River Road	Tributary of the Waipaoa River	Culvert	C1 140	43	8
Kanakanaia Road	Tributary of the Waihora River	Culvert	C1 50	43	8
Shaw Road	Tributary of Waikohu River	Culvert	C1 121	43	8
Shaw Road	Tributary of Waikohu River	Culvert	C1 119	43	8
Rakauroa Tahora Road	Tributary of the Waikohu River	Culvert	C1 120	43	8
Kanakanaia Road	Tributary of the Waihora Road	Culvert	C1 55	43	8
Wharekopae Road	Tributary of Whakakopae River	Culvert	C1 110	43	8
Rakauroa Road	Tributary of Waikohu River	Culvert	C1 124	43	8
Makaretu Road	Tributary of the Waihuka River	Culvert	C1 61	43	8
Oliver Road	Tributary of Waikohu River	Culvert	C1 127	43	8
Rakauroa Road	Tributary of Waikohu River	Culvert	C1 123	43	8
Tumata Road	Tributary of the Wharekopae River	Culvert	C1 87	43	8
Oliver Road	Tributary of Waikohu River	Culvert	C1 128	43	8
Private road off Totangi Road	Oruahea Stream	Culvert	C1 0006	43	8
Wharekopae Road	Tributary of Taumatapoupou	Culvert	C1 71	43	8

SITE ADDRESS	STREAM NAME	CULVERT DESCRIPTION	PHOTO ID	TOTAL	
Wharekopae Road	Tributary of the Wharekopae River	Culvert	C1 84	43	8
Karaua pumps	State Highway 2 drain\ Manatuki East drain	Unknown	site 5	43	8
Waingake Mangapoke Road	Te Arai River	Ford	TA5	43	8
Waingake Mangapoke Road	Te Arai River	Ford	TA14	43	8
Kanakanaia Road	Tributary of the Waihora River	Culvert	C1 47	43	8
Te Rata Road	Unknown	Culvert	M21	42	9
Kook Road	Unknown	Culvert	M19	42	9
Matakonekone Rd	Unknown	Unknown	M3	42	9
Matakonekone Rd	Unknown	Culvert	M4	42	9
Wharekopae Road	Tributary of Whakakopae River	Culvert	C1 112	42	9
Whakarau Road	Tributary of Waikohu River	Culvert	C1 102	42	9
Whakarau Road	Tributary of the Waikohu River	Culvert	C1 88	42	9
Whakarau Road	Tributary of Waikohu River	Culvert	C1 99	42	9
Whakarau Road	Tributary of Waikohu River	Culvert	C1 100	42	9
Mangamaia Road	Tributary of Mangatu River	Culvert	C1 133	42	9
Rere Falls Station	Tributary of Makaretu Stream	Culvert	C1 0010	42	9
Terrace Road	Unknown	Culvert	M18	42	9
Falkner Road	Tributary of Wharekopae River	Culvert	C1 81	42	9
Lavanham gates	Whakau Stream	Culvert	9	41	10
Humpheys Road	Tributary of Waipaoa River	Culvert	C1 23	41	10
Makaretu Road	Tributary of Makaretu Stream	Culvert	C1 137	41	10
Whakarau Road	Tributary of Waikohu River	Concrete Ford	C1 106	41	10
Totangi Road	Waikakariki Stream	Culvert	C1 65	41	10
Gordon Road	Tributary of Waimata Stream	Culvert	C1 109	41	10
Whakarau Road	Tributary of Waikohu River	Concrete Ford	C1 101	41	10
Pakowhai Road	Pakowhai stream	Culvert	Site 7	41	10
State Highway 2, Kaitaratahi	Tributary of Waipaoa	Culvert	C1 32	40	11
State Highway 2, Nth of Ormond	Tributary of Waipaoa	Culvert	C1 31	40	11
Tahinga Road	Unknown	Culvert	M12	40	11
State Highway 2	Coal Stream	Culvert	C1 135	40	11
Tahinga Road	Unknown	Culvert	M13	40	11

SITE ADDRESS	STREAM NAME	CULVERT DESCRIPTION	PHOTO ID	TOTAL	RANKING
Ngakoroa Road	Mangatuaki Stream	Culvert	C1 0007	40	11
Armstrong Road	Tributary of the Waipaoa River	Culvert	C1 139	40	11
River Road	Unknown	Culvert	No #	40	11
Whakarau Road	Tributary of Waikohu River	Culvert	C1 105	40	11
Gisborne rail line	Sistertons Lagoon	Unknown	C1 156	40	11
Matawhero Loop	Matawhero Loop lagoon	Culvert with weir	C1 155	40	11
Taurau Valley Road	Tributary of Karaua Stream	Culvert	C1 10	40	11
Kanakanaia Road	Waihora River	Culvert	C1 46	39	12
Whakarau Road	Tributary of Waikohu River	Culvert	C1 92	39	12
Gordon Road	Tributary of Waimata Stream	Culvert	C1 107	39	12
Tarewa Tokonui Road	Titokenui Stream	Unknown	C1 0001	38	13
Armstrong Road	Tributary of the Waipaoa River	Culvert	C1 138	38	13
Makaretu Road	Tributary of Makaretu Stream	Culvert	C1 136	38	13
Whakarau Road	Tributary of Waikohu River	Culvert	C1 104a	38	13
Whakarau Road	Tributary of Waikohu River	Culvert	C1 104	38	13
Whakarau Road	Tributary of Kukupara Stream	Concrete Ford w/culv	C1 0013	38	13
Whakarau Road	Tributary of Kukupara Stream	Concrete Ford	C1 0014	38	13
Wharerata Road (State Highway 2)	Tributary of Waipaoa River	Culvert	C1 0002	38	13
Cnr Taurau Valley & Saddler Road	Tributary of Karaua Stream	Culvert	C1 05	37	14
Kanakanaia Road	Tributary of the Waihora River	Culvert	C1 49	37	14
Bond Road, Ormond	Tributary of the Waipaoa River	Culvert	C1 29	37	14
Tinroto Road	Tributary of Te Aroha Stream	Culvert	C1 38	37	14
Rakauroa Road	Tributary of the Waikohu River	Culvert	C1 122	37	14
Oliver Road	Tributary of the Waikohu River	Culvert	C1 129	37	14
Newmans Road	Tributary of Ngakorea Stream	Culvert	C1 41	37	14
Whakarau Road	Tributary of Kukupara Stream	Culvert	C1 0012	37	14
Newmans Road	Tributary of Ngakorea Stream	Culvert	C1 42	37	14
Tinroto Road	Tributary of Te Aroha Stream	Culvert	C1 35	36	15
Tararau Valley Road	Tributary of Karaua Stream	Culvert	C1 03	36	15
State Highway 2 Te Karaka	Tributary of Waikohu River	Culvert	C1 43	36	15
State Highway 2	Pukematai Stream	Culvert	C1 59	35	15

SITE ADDRESS	STREAM NAME	CULVERT DESCRIPTION	PHOTO ID	TOTAL	RANKING
Kanakanaia Road	Tributary of the Waihora River	Culvert	C1 52	36	15
Tinroto Road	Tributary of Te Aroha Stream	Culvert	C1 37	36	15
Whatatutu Road	Tributary of the Waipaoa River	Culvert	C1 45	36	15
Lavenham Road	Tributary of Whakaahu Stream	Culvert	C1 21	35	15
Whakarau Road	Tributary of the Waikohu River	Culvert	C1 90	34	16
Tinroto Road	Unnamed drain into the Waipaoa River	Culvert	C1 01	33	17
McDonald Road	Tributary into Sistertons Lagoon	Culvert	C1 17	32	18
Wharekopae Road	Whakakopae River	Concrete Ford	C1 117	32	18
Totangi Road	Oruahea Stream	Culvert	C1 67	32	19
Kaitara Road	Tributary of Waikohu River	Culvert	C1 130	31	20
Hills Road	Tributary of Waikakariki Stream	Culvert	C1 0005	31	20
State Highway 2, North of Ormond	Tributary of Waipaoa	Concrete Ford	C1 30	30	21
Repongere Road	Tributary of Whakaahu Stream	Culvert	C1 20	29	22
Falkner Road	Tributary of the Wharekopae River	Culvert	C1 80	28	23
Falkner Road	Tributary of Wharekopae River	Culvert	C1 82	28	24

APPENDIX 10. PRIORITY RANKINGS OF IN-STREAM STRUCTURES FOR REMEDIAL ACTION: TURANGANUI RIVER CATCHMENT

SITE ADDRESS	STREAM NAME	CULVERT DESCRIPTION	PHOTO ID	TOTAL	RANKING
Lytton Road	Matokitoki Stream	Matokitoki Stream	C2 35	53	1
Matokitoki Valley Road	Matokitoki Stream	Matokitoki Stream	C2 22	52	2
Waimata Valley Road	Mangahouku Stream	Mangahouku Stream	C2 32	50	3
King Road	Taruheru Tributary	Taruheru Tributary	C2 03	48	4
Haisman Road	Taruheru Tributary	Taruheru Tributary	C2 05	48	4
Lyell Road	Waimata Tributary	Waimata Tributary	C2 14	48	4
Riverside Road	Waimata Tributary	Waimata Tributary	C2 18	46	5
Riverside Road	Waimata Tributary	Waimata Tributary	C2 20	46	5
Haisman Road	Taruheru Tributary	Taruheru Tributary	C2 06	46	5
Hirini Road	Turanganui Tributary	Turanganui Tributary	C2 12	46	5
Cambridge Terrace	Turanganui Tributary	Turanganui Tributary	C2 13	46	5
Unknown	Waimata River Tributary	Waimata River Tributary	C2 28	46	5
Waimata Valley Road	Waimata River Tributary	Waimata River Tributary	C2 29	46	5
Waimata Valley Road	Waimata River Tributary	Waimata River Tributary	C2 30	46	5
Waimata Valley Road	Mangahouku Stream Tributary	Mangahouku Tributary	C2 33	46	5
Unknown	Pohatuhatununui Stream Tributary	Pohatuhatununui Tributary	C2 34	44	6
Cave Road	Waimata Tributary	Waimata Tributary	C2 15	43	7
Riverside Road	Waimata Tributary	Waimata Tributary	C2 16	43	7
Riverside Road	Waimata Tributary	Waimata Tributary	C2 19	43	7
Riverside Road	Waimata Tributary	Waimata Tributary	C2 21	43	7
Back Ormond Road	Taruheru Tributary	Taruheru Tributary	C2 09	43	7
Waimata Valley Road	Swell Stream Tributary	Swell Stream Tributary	C2 24	43	7
Mander Road	Swell Stream Tributary	Swell Stream Tributary	C2 25	43	7
Mander Road	Swell Stream Tributary	Swell Stream Tributary	C2 26	43	7
Waimata Valley Road	Waimata River Tributary	Waimata River Tributary	C2 27	43	7
Pilmer Road	Taruheru Tributary	Taruheru Tributary	C2 04	42	8
Waimata Valley Road	Taruheru Tributary	Taruheru Tributary	C2 23	40	9
Back Ormond Road	Taruheru Tributary	Taruheru Tributary	C2 01	38	10
Harper Road	Taruheru Tributary	Taruheru Tributary	C2 02	37	11
Lytton Road	Waikanae Creek	Waikanae Creek	C2 10	36	12
Back Ormond Road	Taruheru Tributary	Taruheru Tributary	C2 08	35	13
MacLaurin Road	Waru Stream Tributary	Waru Stream Tributary	C2 07	34	14

APPENDIX 11. PRIORITY RANKINGS OF IN-STREAM STRUCTURES FOR REMEDIAL ACTION: EAST COAST RIVER CATCHMENTS

SITE ADDRESS	STREAM NAME	CULVERT DESCRIPTION	PHOTO ID	TOTAL	RANKING
Wainui Road	Unknown	Unknown	C3 01	51	1
State Highway 35	Unknown	Box	C3 02	51	1
State Highway 35	Unknown	Pipe	C3 03	51	1
Waiomoko Road	Waiomoko River tributary	Pipe	C3 11	51	1
Shelton Road	Kaitawa Stream tributary	Pipe	C3 17	51	1
State Highway 35	Pouawa River tributary	Pipe	C3 06	48	2
State Highway 35	Pouawa River tributary	Pipe	C3 07	48	2
Waiomoko Road	Waiomoko River tributary	Pipe	C3 09	48	2
Waiomoko Road	Waiomoko River tributary	Pipe	C3 10	48	2
Shelton Road	Kaitawa Stream tributary	Pipe	C3 16	48	2
Hauiti Road	Unnamed	Pipe	C3 18	48	2
Paremata Road	Waimaunu Stream tributary	Pipe	C3 19	48	2
Waiomoko Road	Waiomoko River tributary	Pipe	C3 13	46	3
Waiomoko Road	Waiomoko River tributary	Pipe	C3 12	43	4
State Highway 35	Unknown	Pipe	C3 05	42	5
State Highway 35	Waiomoko River tributary	Pipe	C3 08	42	5
State Highway 35	Kaitawa Stream tributary	Box	C3 15	42	5
Makorori Road	Unknown	Pipe	C3 04	40	6
State Highway 35	Pakarae River	Pipe	C3 14	37	7

APPENDIX 12. CHECKLIST TO ENSURE ALL FISH PASSAGE CRITERIA ARE MET BY CULVERTS.

Criteria check list (R = required S = suggested)	✓

• Can culvert accommodate flood flows? (R)
• What fish groups are present or aiming to be recovered?
• Is culvert aligned with stream? (R)
  o If not are bankside erosion controls in place?
• Culvert diameter larger than stream channel (R)
• Culvert invert buried? (R)
  o If not have steps been taken to increase energy dissipation in barrel?
  o Steps taken to retain bed material on culvert?
• Barrel velocity below 0.3 m/s? (R)
  o if no is there a continuous 50 -100 mm wide zone along the sides with velocities below 0.3 m/s or can fish swim through the culvert without becoming exhausted?
  o If not are resting areas are provided (i.e. baffles or rocks)?
• Culvert slope same as stream? (R)
  o If steeper, have streambed erosion control measures been taken downstream?
  o Have steps been taken to increase energy dissipation in barrel?
  o Have steps been taken to retain bed material on invert?
  o If flatter have steps been taken to prevent erosion and ensure passage up and downstream?
• Is slope constant? (S)
  o If not can swimmers negotiate steeper sections?
  o If a weir is present is it notched for low flows and is it impermeable?
  o Is there any vertical drop and if so, can climbers negotiate height?
• If required, is there a low flow channel provided? (R)
• Continuous wetted margin with no sharp angles available for climbers? (R)
  o If breaks are present is something installed to allow climbing?
• Is water depth adequate, especially over apron? (R)
  o If no is floor dished or sloping to concentrate water?
• Is turbulence or back eddying a problem for target species? (S)
• Is culvert short with sufficient lighting? (S)
  o If not are there measures to assist species which may migrate in the daylight?
• Bankside and overhead cover at entry and exit points? (S)	

APPENDIX 13. COMPARISON OF DIFFERENT PIPE FILLS.

PRODUCT	ADVANTAGE	DISADVANTAGE
Egg carton	Easy to install Forms own base Suitable for all climbing species	Not as effective as other materials Not size selective
Brush	Very effective Size selective if required Suitable for all climbing species	Expensive Difficult to install and maintain
Gravel	Cheap Suitable for all climbing species	Only suitable for small fish Not effective over long distances
Plastic mesh	Easy to install	Only suitable for very small climbing species Tends to trap larger fish Slow progress

APPENDIX 14. FURTHER READING: WEBSITES.

Site: www.fishandgame.org.nz

Resources: See 'Your Region' for current news on water issues. Info section has a NIWA report on dairy pollution of lowland waterways.

Site: www.qualityplanning.org.nz

Resources: See 'Surface Water Quality' under 'Guidance on Planning Topics'.

Site: www.cawthron.org.nz/downloads

Resources: Resources include report entitled 'Fish Passage in New Zealand Rivers'. Report on indigenous fish habitats, simple solutions to allow fish passage over weirs, fords, bridge aprons and through culverts.

Site: www.nzfreshwater.org

Resources: Site of NZ Native Freshwater Fish Society. Includes a bibliography of scientific articles on freshwater habitats.

Site: www.niwa.co.nz

Resources: National Institute of Water and Atmospheric Research. Access to Freshwater Fish Database and Freshwater Fish Atlas.

Site: www.nwp.rsnz.org

Resources: National Waterways Project, a Royal Society project to involve schools in monitoring habitat values and water quality in their local rivers, streams and lakes.

Site: www.bush.org.nz

Resources: Site of the NZ Ecological Restoration Network. Nationwide network of groups involved in restoration projects, many of which involve riparian planting.

Site: http://www.ew.govt.nz/publications/technicalreports/documents/tr06-25.pdf

Resources: Environment Waikato. Best practices.

Site: http://www.en.wikipedia.org/wiki/fish_ladder

Resources: Wikipedia page on fish ladders.