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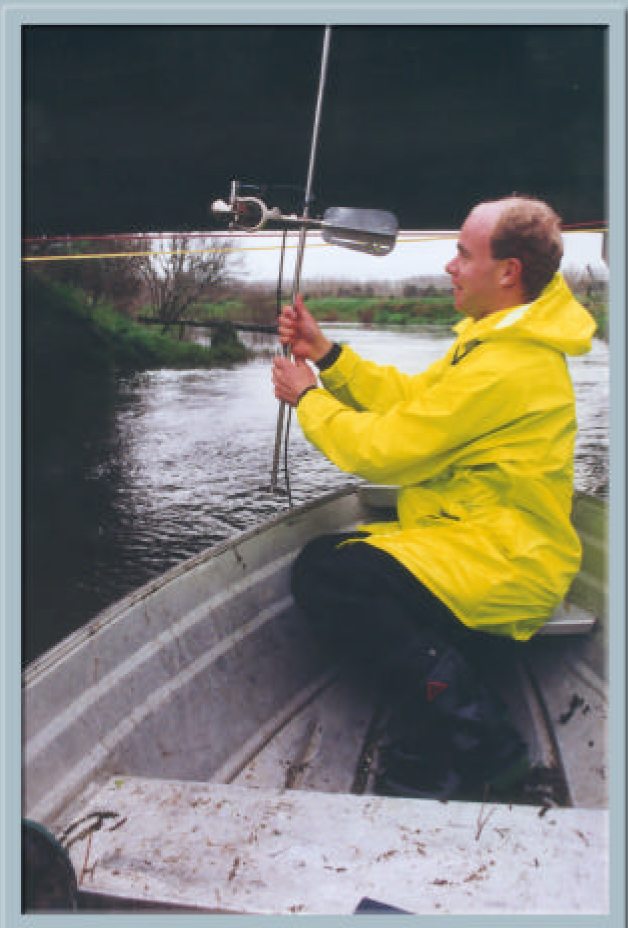
Minimum Flow Report for the Waitahanui Stream



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Cover Photo: Craig Putt gauging at State Highway 2 bridge.

Executive Summary

The Waitahanui is a large spring fed stream draining the Otamarakau area. Irrigation of dairy pasture has become widespread and currently 19.4% of the five year low flow is allocated. Environment B·O·P received six consent renewals this year and the opportunity was taken to develop an effects based minimum flow for the Waitahanui Stream. This study used a habitat modelling programme (RHYHABSIM) to identify the minimum flow necessary to sustain existing aquatic ecosystems. The assessed reach runs between the Whakahaupapa confluence and the State Highway 2 bridge. Most water takes are confined to this lower reach.

Habitat surveys were undertaken between June and July 2000, at which time flows were within 15% of the annual low flow. Charles Mitchell and Associates conducted a fisheries survey of the Waitahanui Stream in 1995. This found rainbow trout, common smelt, longfin and shortfin eels in the assessed reach and many more species in the lagoon area downstream. Specific instream management objectives were developed in advance for interpretation of habitat flow response curves. The basic principle here is to identify a preferred flow for each species and then scale this by a protection level, which is determined by the significance of the given species and value of the resource. The recommended minimum flow is then based on the species with the highest flow requirements. As expected, rainbow trout were found to have higher flow requirements than the native species.

The recommended minimum flow for the lower Waitahanui Stream is 3.8 m^3/s, (*cf.* 1 in 5 year low flow 4.8 m^3/s).

The main difficulty encountered in modelling fish habitat was the mobile pumice bed, which made deriving accurate rating curves difficult. Stream bed levels appeared to be changing by around 10 millimetres per week in some sections. Because this is an ongoing process, re-surveying the stream was not considered worthwhile. The recommended minimum flow is based on fish habitat within one reach. Other factors are discussed that might require a higher minimum flow.

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Chapter 1: Introduction

The Waitahanui is a large stream (Table 1) draining the Otamarakau area to the sea 25 kilometres (km) east of Te Puke. The headwaters border the Lake Rotoehu – Lake Rotoma catchments. Like many streams in the area, flow is largely fed from groundwater and hence low flows recede slowly and significant flooding is rare. In the headwaters land use is predominantly exotic and native forest, while in the lower reaches pasture is dominant.

There are currently 10 consented water takes for abstraction from the Waitahanui Stream, primarily for pasture irrigation. These total 19.3% of the 1 in 5 year low flow. Six of these consents will expire in the year 2000 and applications have already been lodged with Environment B·O·P for the same water allocation.

Traditionally Environment B·O·P has consented water takes provided the cumulative abstraction rate does not exceed 30% of the 1 in 5 year low flow (see Hodges and Gordon 1999). The Department of Conservation and Eastern Fish & Game become concerned when the rate of take exceeds 10% of river flow. Both the 30% and 10% rules of thumb are arbitrarily set. The Draft Regional Water and Land Plan (Version 1.10) has stipulated that minimum flows (below a threshold) can only be set using objective scientific methods such as the Instream Flow Incremental Methodology (IFIM), a method which models changes in fish and invertebrate habitat with flow. A project was set up to objectively evaluate minimum flows in rivers based on ecological values. The first step in this project was to review the ecological effects of water abstraction and methods for setting minimum flows (Wilding 1999).

Reduced flows can affect the ecology of a stream by:

- reducing water velocities and depth
- reducing the area of wetted habitat
- reduced dilution of contaminants (e.g. ammonia)
- increased accumulation of sediment and algae
- reduced re-aeration and hence oxygen concentrations
- increased water temperatures
- impede fish passage from shallowing of riffles or increased period/frequency of stream mouth closure.

Modelling packages are now available to evaluate changes in habitat and water quality with flow. The most appropriate methods were chosen to be trialled in a pilot study of streams in the

Katikati area. It is hoped the results will allow generalisations to other stream reaches within the same ecological district. While this work is continuing, urgency dictated that a minimum flow be established for the Waitahanui Stream.

The scope of this report is to provide a minimum flow for the Waitahanui Stream based on fish habitat modelling. Major abstractions are confined to the lower reaches of the Waitahanui (Figure 1) and this is where investigations focussed. Other issues not covered in this report, that may influence the minimum flow for the stream, are listed above.

Table 1 Waitahanui flow estimates. Pongakawa flow data was used to derive estimates of mean, median and mean annual low flow. The 1 in 5 year low flow estimate is from Hodges and Stringfellow (1996).

Mean flow	6.15 m^3/s
Median flow	5.85 m^3/s
Mean annual low flow	4.95 m^3/s
1 in 5 year low flow	4.80 m^3/s

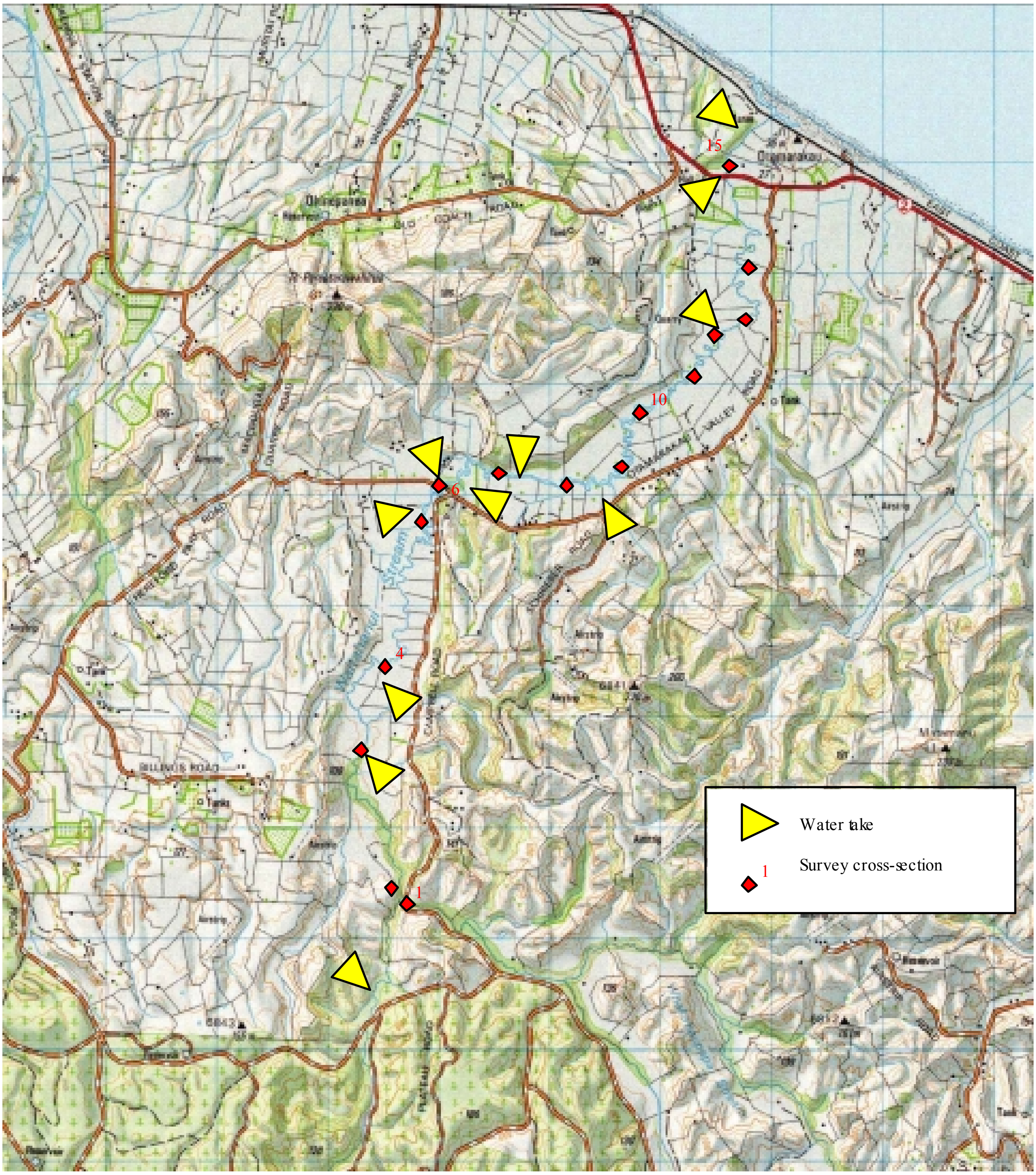

Figure 1 *Waitahanui Stream lower reaches showing habitat survey cross-sections and points of abstraction (NZMS260 V15, © Sourced from Land Information New Zealand data. CROWN COPYRIGHT RESERVED)*

Figure 2 Waitahanui Stream looking downstream from site 3 (see Figure 1). Narrow, shallow and fast flowing

Figure 3 Waitahanui Stream, unusually shallow area with macrophyte beds and sandy substrate

Figure 4 Waitahanui Stream, deeper channel bordered by farmland with emergent macrophytes growing along the stream margin

Figure 5 Waitahanui Stream downstream of State Highway 2 bridge, within a kilometre of the coast

Chapter 2: Methods

The physical habitat component of FIM (instream incremental flow methodology) was used to evaluate change in fish and invertebrate habitat with flow. This method focuses on depth, velocity and substrate as determinants of habitat suitability.

Water takes are confined to the lower reaches of the Waitahanui (Figure 1). Mitchell and Williamson (1995) concluded that the lower reach is fairly uniform in terms of habitat. An inspection of the river in May 2000 reaffirmed this and therefore the section between the Whakahaupapa confluence and State Highway 2 bridge was treated as one reach. One large take is located above the confluence of the Waitahanui and the Whakahaupapa streams. This second reach was not assessed because of the restricted time frame and minimal effect of the existing take (it is located less than 1 km above the confluence and the total abstraction is only 4.9% of the flow at this point - Tuawhitu Road; Hodges and Stringfellow 1996).

Once a reach is selected for evaluation, the next step is to map out the proportions of meso-scale habitats (e.g. pool, riffle, run) to allow cross section weighting. The reach between Otamarakau Valley Road and State Highway 2 was traversed by dinghy on 4 May 2000. Habitat was fairly continuous with no readily distinguishable pools or riffles (see Figures 2-5). It was therefore decided to randomly select sites, rather than assessing a fixed number of sites per habitat type.

A total of fifteen cross-sections were selected. While random site selection was the objective, access often dictated location. At each site water velocity, depth and substrate was measured following the methods set out in Jowett (1996). The method is summarised as a field sheet (Appendix I). The use of a cable and dinghy was necessary at deeper sites.

The data were analysed using RHYHABSIM Version 2.10 (Jowett 1999). Sites were given equal weighting because mapping of distinct habitats was not possible. Deriving minimum flows from habitat-flow response curves followed specific instream management objectives, which were developed for application to the wider Bay of Plenty region. These are detailed in Appendix II, but the basic principle here is to identify a preferred flow for each species and then scale this by a protection level, which is determined by the significance of the given species and value of the resource. The recommended minimum flow is based on the species with the highest flow requirements.

Chapter 3: Results

3.1 Reach Assessment

Site locations are given in Figure 1. Cross-sections were surveyed on 21 June 2000 with three sets of subsequent gaugings (6 July 2000, 20 July 2000, 26 July 2000). Surveyed flows were generally within 15% of the mean annual low flow. The default in RHYHABSIM is to use the average flow for all cross-sections. Because of the significant increase in flow over the reach it was necessary to vary flows between cross-sections. There are no large tributaries entering the lower Waitahanui (the largest tributary is approximately 50 L/sec, *pers. obs.*), so the increase is likely to be gradual and fed largely from groundwater. This is confirmed from Figure 6, which shows a gradual increase with random gauging error. Sites 6 and 15 were gauged more accurately (increased number of verticals, etc.) and both fall close to the line. Therefore the results of follow-up gauging for sites 6 and 15, which used the more accurate methods, could be safely extrapolated to provide flows for all sites (Figure 7). The trend line for the 26 July 2000 is clearly anomalous and so was not used in further analysis.

Several sites had to be excluded from the habitat modelling. Site 1 was inadvertently located on the Whakahaupapa Stream above the confluence and hence does not fall within the assessed reach. Erroneous level recordings from sites 5 to 8 were attributed to bed degradation (see Table 2) and prevented the derivation of meaningful rating curves[1]. The bed material over much of the reach is fine pumice and sand. Because of its mobility, channel morphology presumably changed between visits. Re-surveys were not considered worthwhile as the accretion-degradation process is likely to be ongoing.

The modelling package RHYHABSIM presents three options for rating curves: log-log least squares fit through points and SZF (stage of zero flow); log-log least squares fit through points with best SZF; and hydraulic rating (using Manning's equation). The hydraulic rating gave the most sensible ratings, with other options crossing the critical-flow rating curve. Hydraulic ratings based on Manning's equation assume that roughness varies with discharge to some power (beta). If roughness increases with discharge, beta is positive. At low flows, beta is usually negative because as flow increases the effect of substrate on roughness decreases. However, if an increase in flow increases bank resistance then beta will be positive. This normally occurs at high stages, but can also occur at low flows. The beta value was adjusted for some sites to provide more realistic curves (Table 3). Bed accretion may have affected the measured stream

1 Rating curves describe relationship between stream depth and stream flow.

levels at these lower sites (see Table 2), though this can not be confirmed. Note that extra visits at high and low water found no tidal influence at site 15.

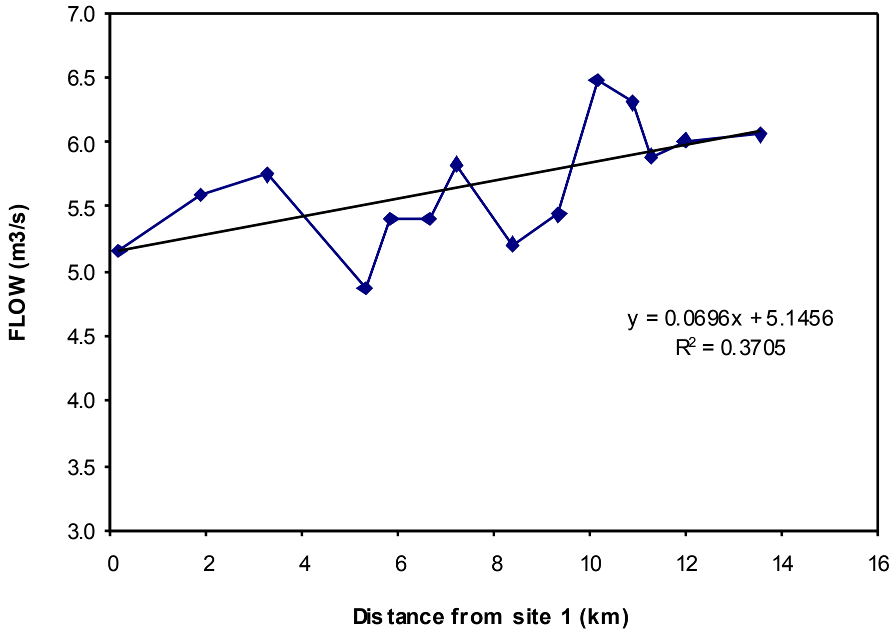

Figure 6 *Increase in flow from site 2 to 15 on the Waitahanui Stream. Flow calculated from survey data (21 June) using RHYHABSIM.*

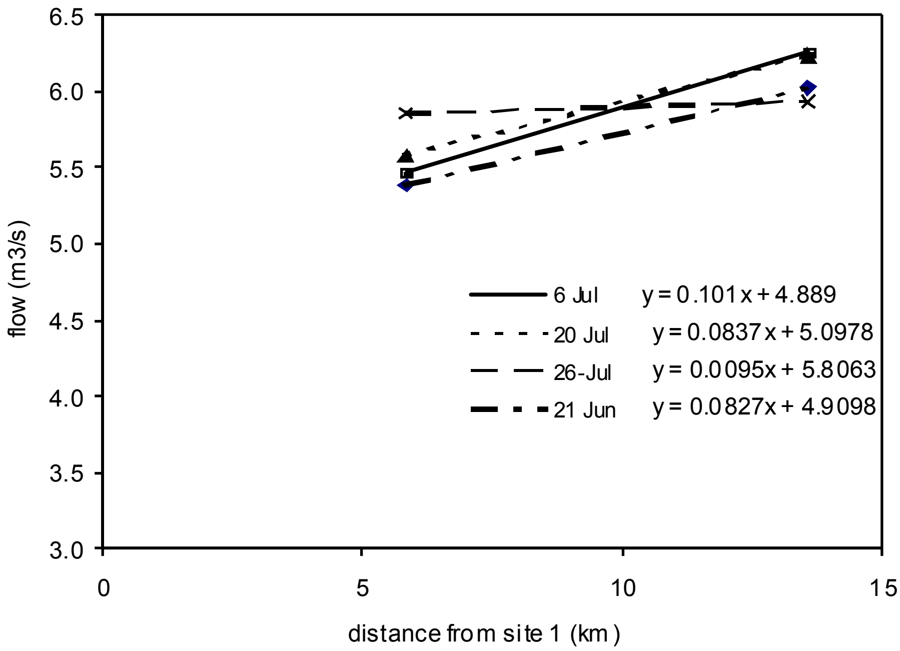

Figure 7 *Flow projections from gauging at sites 6 and 15. Flows calculated using GAUGE software.*

Table 2 Measured change in water level between 21 June and 6 July. Sites 5 to 8 have dropped by 1 9mm on average.

Site	Change (m)
2	-0.001
3	-0.001
4	-0.003
5	**-0.020**
6	**-0.023**
7	**-0.020**
8	**-0.018**
9	0.000
10	0.000
11	+ 0.004
12	+ 0.013
13	+ 0.015
14	+ 0.045
15	+ 0.026

Table 3 Manning's equation beta values for cross-section rating curves. Values for sites 12 to 15 were adjusted and the original values are given in brackets.

Cross-section	Beta value
2	-0.13
3	-0.25
4	-0.12
5	0.164
6	0.15
7	0.46
8	0.18
9	0.16
10	0.24
11	-0.12
12	0.1 (-0.628)
13	-0.1 (1.298)
14	0.5 (2.21)
15	0.2 (2.109)

3.2 Habitat Response

The report by Mitchell and Williamson (1995) identifies the fish community of the lower Waitahanui Stream (Table 4). Relating these fishing results to the present study was hampered by the lack of definition of reported reaches (lower river versus lagoon, etc.). The habitat-flow response curves were modelled for species found in the study reach to determine a minimum flow (Figures 8a-8c). Interpretation of these graphs followed the methodology set out in Appendix II. There are three species of native fish present in the assessed reach, which is not considered a significantly diverse fish community (i.e. does not meet significance criteria 4 – Appendix II). Mitchell and Williamson (1995) suggested the substrate of fine mobile sands provided little fish habitat. The Waitahanui was not graded as a significant trout fishery by Richardson (*et al.* 1986) hence all fish are given the 85% protection level.

Minimum flows, as derived from the habitat-flow response curves, are summarised for each species in Table 5. Most native fish have relatively low flow requirements (<1m^3/s). Habitat-flow response curves were also modelled for redfin bully, torrentfish and inanga in case they are present in the assessed reach. While redfin bully and torrentfish had low flow requirements (0.5 m^3/s - point of inflexion, and 1.63 m^3/s respectively), inanga preferred shallow slow flowing marginal areas that are covered at higher flows. This produced a higher flow requirement of 3.64 m^3/s (or 2.85 m^3/s if sites 5-8 are included). Trout are expected to have high flow requirements, however the different habitat preference criteria available from RHYHABSIM produced contrasting results. These are further dealt with in the discussion.

Table 4 Fish abundances (after Mitchell & Williamson 1995)

	Study Reach (Whakahaupapa confluence - State Highway 2)	**Lagoon/lower river (below SH2)**
Shortfin Eel	Present?	Common
Longfin Eel	Common	Common
Smelt	Abundant (>500/km)	Abundant
Rainbow Trout	Common (14/km)	Present
Redfin Bully		Present
Torrentfish		Present
Giant Bully		Abundant
Inanga		Present
Yelloweyed Mullet		Common
Stargazer		Present
Parore		Present
Black Flounder		Present
Kahawai		Present

Table 5 *Minimum flows derived from habitat-flow response curves as per methods set out in Appendix II (85% protection level). Sites 5 to 8 were corrected[2] and used to derive minimum flows given in the second column for comparison. The point of inflexion is given where appropriate (see Appendix II).*

	Minimum Flow (m^3/s)	**Min. Flow (m^3/s) – including sites 5-8**
Common Smelt	0.649 (1.25 point of inflex.)	0.712 (1.53 point of inflex.)
Longfin Eel	0.282	
Shortfin Eel	0.252	
Rainbow Trout adult (Tongariro)	4.44	4.56
Rainbow Trout adult (Cheeseman & Bovee)	3.65	3.77
Rainbow Trout adult (Bovee 1978)	1.89	1.94
Food Producing (Waters 1976)	1.70	
Rainbow Trout juvenile (Bovee 1978)	0.723	
Rainbow Trout fingerlings (Tongariro)	0.208	

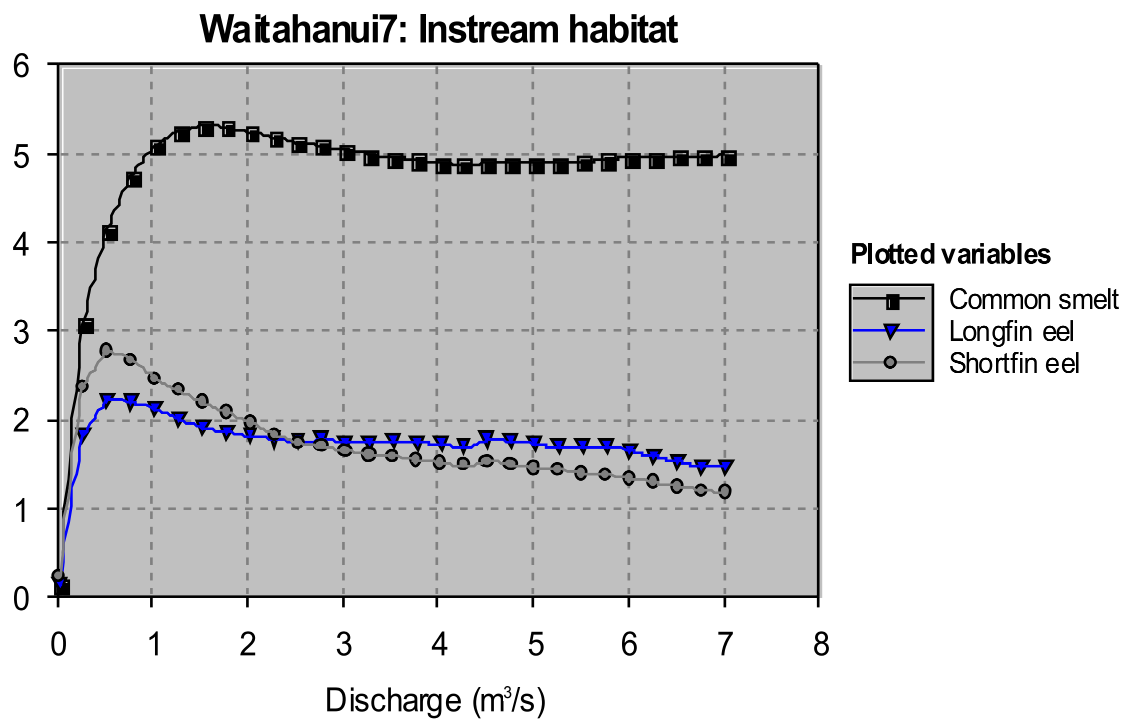

Figure 8a *Native species. Habitat measured as wetted usable area (WUA m^2/m), modelled in response to flow using RHYHABSIM. Mean annual low flow = 4.95 m^3/s.*

2 The objective was to correct for bed degradation. The average water level of sites 5-8 was subtracted from the average of sites 2-4 and 9-11. This difference was calculated for each gauging and added to site 5-8 levels.

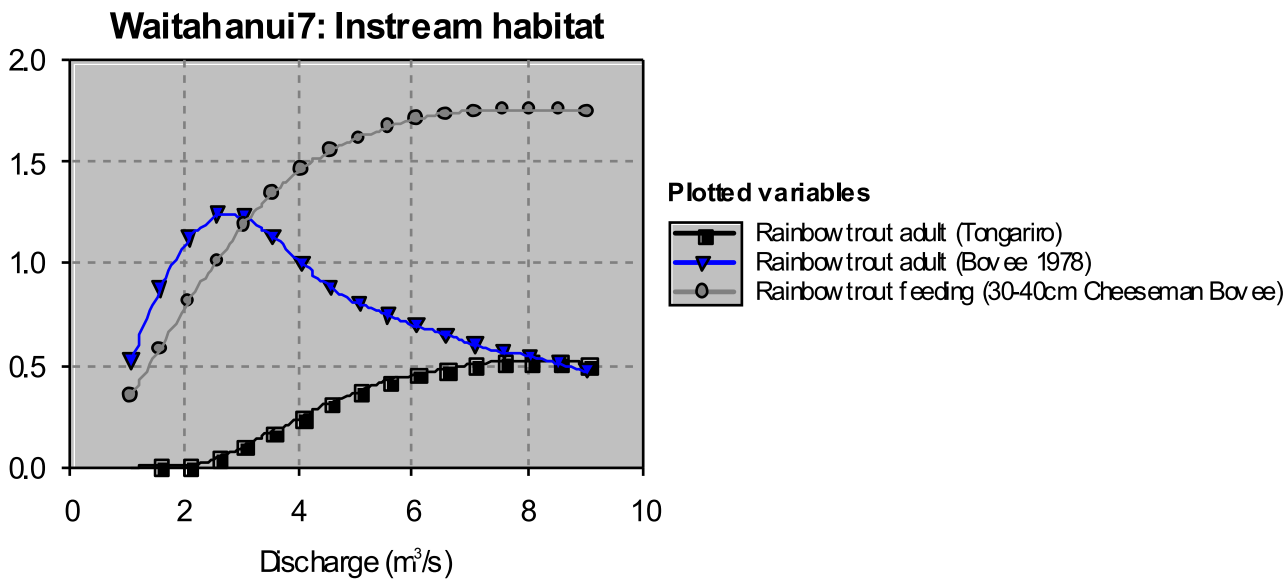

Figure 8b *Adult Rainbow Trout. Habitat measured as wetted usable area (WUA m^2/m), modelled in response to flow using RHYHABSIM. Mean annual low flow = 4.95 m^3/s.*

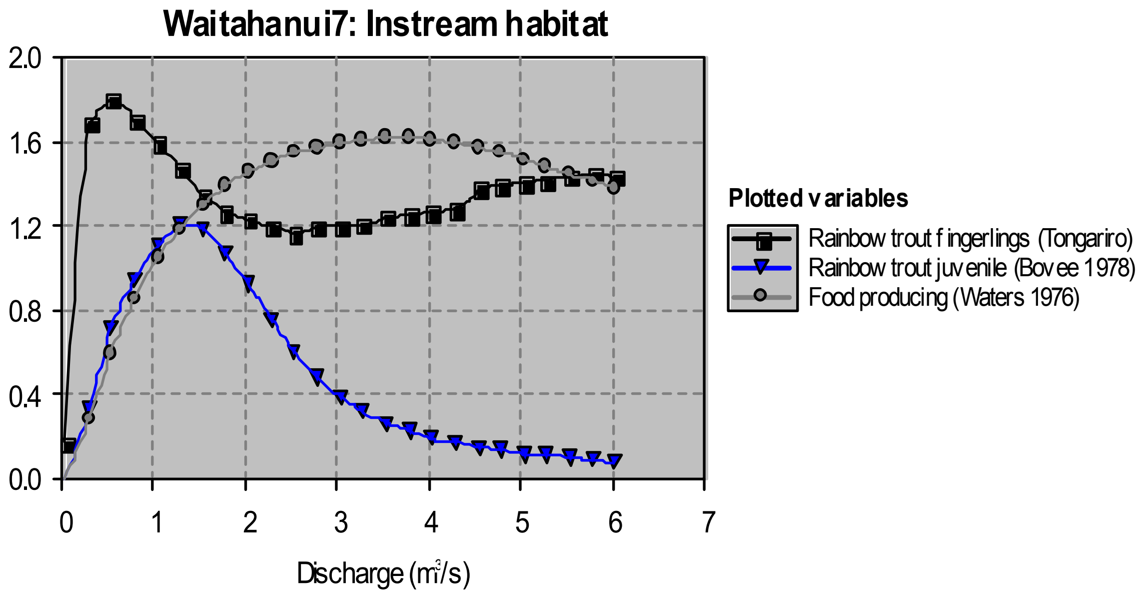

Figure 8c *Juvenile trout and food-producing habitat. Habitat measured as wetted usable area (WUA m^2/m), modelled in response to flow using RHYHABSIM. Mean annual low flow = 4.95 m^3/s.*

Chapter 4: Discussion

The recommended minimum flow is likely to be based on rainbow trout as it has the highest flow requirements. Therefore we need to look more closely at this species. The RHYHABSIM programme has several options for rainbow trout criteria. None were considered sufficiently developed by Hayes (2000). The Bovee (1978) and Tongariro habitat criteria produced contrasting preferred flows. Hayes (2000) considered Bovee's criteria more appropriate for use in the Ngaruroro River (Hawkes Bay) because of the large size of the Tongariro lake run fish (55 cm?). The size data from Mitchell and Williamson (1995) are presented in Table 6. This gives an average size of 28[3] cm. Hayes (2000) estimated the trout in Bovee's American study to be less than 25 cm. The second criteria from Cheeseman and Bovee are for trout 30-40 cm long, and so are probably most relevant to Waitahanui populations. The preferred flow is intermediate between the other two habitat response curves. Minimum flows from these criteria are 3.65 and 3.77 m^3/s, depending on the inclusion of sites 5 to 8.

Table 6 Results of drift diving counts of rainbow trout by Mitchell and Williamson (1995), from a 1.7 km section of the Waitahanui Stream (Otamarakau Valley Road bridge area)

Small (10-20cm)	Medium (20-40cm)	Large (>40cm)
7	14	3

A minimum flow for the lower Waitahanui Stream of 3.8 m^3/s is recommend (*cf.* 1 in 5 year low flow 4.8 m^3/s).

Difficulties in producing rating curves appear to have stemmed from the mobile pumice bed. It is estimated that stream bed levels changed by at least 10 mm per week in some sections. This process of accretion and degradation is likely to be ongoing, so there seemed little point re-surveying the stream.

The fine substrate is likely to be limiting trout abundance. Re-running the model with substrate set as optimal gave higher habitat areas (5.7 vs. 1.8 m^2/m optimal). A higher minimum flow was needed as a result of the poor substrate (3.8 vs. 3.3 m^3/s with substrate off). This was because weed beds growing along the stream margins provided more suitable habitat than sand and greater flow is needed to cover them.

[3] The mid-point for each size-class was multiplied by the number of fish. An average size of 50 cm was used for "large trout".

Stream flow increases by approximately 1m^3/s between the Whakahaupapa confluence and the State Highway 2 bridge. The implications of this for setting minimum flows and allocable flows were investigated. The minimum flow for adult rainbow trout (Cheeseman & Bovee) was calculated for each cross section to see if there was any change in flow requirement over the reach. No such trend was found and hence it is safe to apply the recommended minimum flow to the whole reach. However allocating water based on the recommended minimum flow won't be as straightforward. Allocable flow is calculated by subtracting the minimum flow from the Q_5 (one in five-year seven day low flow). The Q_5 does change through the reach and hence the allocable volume will change. The rate of increase in flow identified in this study was used to derive Q_5 statistics, and hence allocable flows for several points throughout the reach (Table 7).

Table 7 Allocable flow as measured at three points in the lower Waitahanui Stream (Q_5-minimum flow; where Q_5=one in five year seven day low flow and minimum flow=3.8 m^3/s). Allocable flow restricts all upstream abstractions, including tributaries.

Site	Q_5 (m^3/s)	Allocable Flow (m^3/s)
Whakahaupapa confluence	4.3	0.5
Otamarakau Valley Road bridge	4.8	1
State Highway 2 bridge	5.5	1.7

Extrapolation of the minimum flow figure below State Highway 2 bridge is complicated by the appearance of several new species for which we do not have habitat criteria (giant bully, yellow-eye mullet; Mitchell & Williamson 1995). It is probably safe to assume that maintaining sufficient water for rainbow trout will be adequate for giant bully and mullet. Therefore the recommended minimum flow could be applied as far as the new stock bridge (located between State Highway 2 and the rail bridge). However, the lagoon area cannot be generalised to (see section 4.1).

The recommended minimum flow of 3.8 m^3/s recognises the value of the water resource to irrigators, yet provides adequate protection for aquatic ecosystems. In order to **reduce** the minimum flow below that recommended, it needs to be demonstrated that either:

- the instream management objectives are inappropriate (in which case minimum flows for all Bay of Plenty streams will need to be adjusted accordingly), or,
- that the assessment was flawed and more accurate methods are possible/practical.

4.1 Other Issues

Available flow was determined from fish and invertebrate habitat modelling for the lower reach (confluence to State Highway 2). Other factors that might necessitate a higher minimum flow include river mouth closure, water temperature, water quality, whitebait spawning, watercress beds (commercially harvested) and lagoon habitat requirements (for fish, wetland vegetation, etc.). These issues are outside the scope of this study, but are briefly discussed to help identify critical issues.

Cool water temperature is important to growth and survival of fish and invertebrates. Reduced flows increase temperatures through shallowing and reduced velocities. The highest temperature recorded in quarterly monitoring of the Waitahanui was 17.2°C (March 1999, 1300 hours) at which time 20% of the stream flow was allocated. This figure can only be taken as indicative, but is consistent with high recharge of cool groundwater. For comparison, common smelt have a preferred range of 15.1 to 17.4°C (Richardson *et al.* 1994). The programme RHYHABSIM includes temperature models. Preliminary runs indicated temperature would not be a critical factor. In a worst-case scenario with no shade or groundwater recharge, flow would have to be reduced below 2m^3/s before maximum water temperature reached 20°C. Using estimates of shade from aerial photographs (35%) and observed inflow rates (1m^3/s) temperature was expected to increase by less than 1°C if reduced to 2m^3/s. Note that Horizons.mw (Manawatu-Wanganui Regional Council) have proposed a maximum temperature be set on some streams and that abstraction stop when this temperature is reached.

Closure of the Waitahanui Stream mouth has the potential to restrict access of migratory native species, such as whitebait. Small streams have less force to erode beach sands built up by wave action. Mitchell and Williamson (1995) investigated the potential for increased mouth closure at reduced flows. They observed that although two smaller streams nearby (Herepuru and Pikowai) formed larger lagoons, there were apparently few periods when these streams became completely closed off.

Assessing the effects of reduced flows on the lagoon ecosystem is complicated by the variability of the system, with wave action and flood flows continually re-shaping the outlet. Additionally habitat modelling programmes are not designed to incorporate tidal influence. Mitchell and Williamson (1995) found the smaller streams had longer lagoon systems but lower diversity of estuarine species. Monitoring of the variability of this system would be a good starting point.

A reduction in flow is likely to increase tidal reach. This may influence the location of inanga (whitebait) spawning, as they generally choose a site that coincides with the limit of salt water intrusion (the salt wedge). There is potential for overlap between irrigation and spawning in March and April. Inanga were not found to be common anywhere in the catchment (Mitchell & Williamson 1995) with the main river dominated by smelt and many of the farm drains drying up during summer. The lagoon supported few inanga so it seems unlikely significant populations would be affected.

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Appendices

Appendix I – RHYHABSIM Field Methods Summary

- Choose reach typical of stream section you wish to generalise to.
- Undertake during low flows.
- Establish the habitat types present (e.g. pool/riffle/run). These will need to be represented by cross-sections.
- Habitat mapping measures length of stream occupied by each habitat type (for calculation of total habitat area). This is done using hip chain with lengths of each habitat type recorded.
- Cross-sections chosen randomly, or choose cross-section in rare habitat and place others adjacent. Need five or more cross-sections for each habitat type.
- Tape strung across (taught) <u>at right angle to flow</u> (impt.).
- True left or right bank can be set as zero, but must be consistent through reach (i.e. start from the same bank and set tape up so off-set increases across cross-section).
- Take 10-20 spot measurements across stream (divide width by the number of points and round down). Take special care estimating low velocities. It is important to distinguish low velocities from zero velocities.
- Additional measurements are taken at abrupt changes in depth and velocity.
- At each point measure depth, velocity, and substrate. Velocity at 0.6 unless >1 metre deep. 20 second counts. Substrate assessed visually using categories below. Area assessed dependent on spacing but shouldn't exceed 0.5 m either side or 1m up or downstream. Always note obstructions upstream for adjustment of VDF's, especially at edges and above water level.
- Substrate categories: vegetation; bedrock; boulder (>264 mm); cobble (64-264 mm); large gravel (8-64 mm); fine gravel (2-8 mm); sand; silt.
- Measure above water level as far as you wish to generalise (0.3-0.5m) and be sure to include actual waters edge as a point (cf. EWE not important). This means you must have a 0.0 water depth for both banks and on both sides of any protruding boulders.
- Use taught level line to measure bank height above water level (negative depth), as well as substrate.
- Install temporary staff gauge in low turbulence part of cross-section, preferably in 10-20 cm deep water (you can hammer in till level with water surface at first visit => stage=0.0 mm). Record water level with units (mm easiest) and state whether this is above or below the top of the gauge peg (e.g. "12 mm below peg"). Don't use +ve and –ve terminology for stage or SZF.

- If there is a possibility of gauge moving, level relative to two benchmarks (pegs) on bank (above flood flow). Use level to measure height of gauge and reference water height to it. (Remember floods will alter stage flow anyway.)

- If flow changing during gaugings, stage at one site should be recorded about the time of each new cross-section.

- Measure stage at zero flow (SZF) for pools and most runs. SZF determined by downstream low point. Measure deepest part of downstream riffle-head subtracted from water level at temporary gauge. Record SZF with units (e.g. mm).

- Two calibration surveys are undertaken, with flow measured at a 'good' gauging site and the water level recorded for each cross-section (record on original cross-section card, e.g. "12 mm below peg"). The 'good' gauging site is to be gauged to EDS standards for flow measurement on all three occasions. The first calibration survey should be done within two weeks to guarantee useful data before stream character changes (e.g. flood disturbance, periphyton growth). To ensure an accurate rating curve we need measurements at a range of flows, so third calibration survey can be undertaken later when flow has changed.

Appendix II – Instream Management Objectives

Background

The environmental flows (or habitat) project was set up to provide a more defensible effects-based approach for water allocation. The project looks at the effects of abstraction on aquatic life both directly (reduced habitat) and indirectly (water quality, temperature). This note only deals with one aspect of minimum flow determination – interpreting habitat-flow response curves. This is primarily for irrigation abstractions and does not address issues associated with water impoundment (flushing flows, etc.).

Modelling techniques are used to address the habitat issue. The RHYHABSIM programme models change in depth, velocity and substrate with flow and relates this to habitat preferences of native fish and trout. But it does not produce a minimum flow. As a result deriving a minimum flow figure is subjective to the point were two people working with the same data can produce two different figures. The aim of this note is to establish an objective approach for deriving minimum flows from RHYHABSIM habitat modelling. This will enable a consistent environmental outcome in setting minimum flows throughout the project. It also provides external consultants with guidance for interpreting such data in the Bay of Plenty region.

Objectives and Options

The first step was to review legal planning objectives that the project should work towards. Relevant objectives in the Draft Regional Water and Land Plan (Version 1.10) are:

(65) Instream flows are maintained to;
- *(a) Sustain aquatic life,*
- *(b) Sustain significant values of rivers and streams, where appropriate, and*
- *(c) Meet water quality classes.*

With policy aimed:

(94) To establish an instream minimum flow requirement at a level that sustains aquatic life and significant instream values, and accounts for the downstream environment.

My interpretation is that a minimum flow needs to maintain existing aquatic life in perpetuity; maintain non-aquatic life instream values (but only if significant); and consider all of the above that are present downstream of take. In regard to this file note, only the first point is relevant (aquatic life). Other values are to be addressed in the consent process. Downstream values are addressed directly or not at all.

So restating the relevant objective, "sustain aquatic life" we need to develop this into a more specific instream management objective. The Ministry for the Environment (MfE) flow guidelines (1998) provide guidance on developing instream management objectives, pointing out the need to *identify the values to be protected as well as the level of protection*. The values this project addresses are aquatic life and intuitively the plan (Draft Regional Water and Land Plan, Version 1.10) is referring to the existing aquatic community.

In terms of level of protection the plan uses the word “sustain”. This could be interpreted as remain unchanged; no significant change; or the minimum level for population survival. To remain unchanged would most often result in no flow available for abstraction. Take Figure 9 for example, any change in flow would equate to a change in available habitat for some if not all species. The ‘remain unchanged’ approach also fails to recognise the potential for habitat to improve with reduced flows. Jowett (1996) states that aquatic populations are resilient and variable so a realistic objective of sustainable management should ensure that the level of protection for aquatic species is adequate, rather than attempting to ensure that populations remain unchanged. What level of protection is adequate would vary depending on the significance of the aquatic ecosystem and the value of the resource. We can fix the resource value to some extent by focussing on irrigation abstractions.

So features of a good instream management objective include:

- Retain adequate flow for ecosystem protection
- Make water available for abstraction
- Recognise ecosystem significance
- Recognise resource value
- Provides objective approach so two people can get the same answer

Options considered included:

1 Habitat remains unchanged.

2 Allow a percent reduction in habitat.

3 Allow change based on individual reach assessment, i.e. leaving it open to interpretation.

4 Allow change down to a region wide standard. A NIWA study for Wellington and Taranaki Regional Councils recommended setting a minimum flow based on the 85%ile of percent brown trout habitat from the national “100 Rivers” study, (Jowett 1993).

As discussed, Option 1 will often prevent water being made available and fails to recognise the potential for improved habitat at lower flows. Allowing an across the board reduction in habitat provides a consistent environmental outcome (Option 2), but it is somewhat clumsy because again it ignores the potential to optimise habitat at different flows. Option 3 won’t provide the necessary objectivity, and achieving consistency in case by case negotiations would be difficult. Option 4 relies on one sentinel species that is likely to have the highest flow requirements. Brown trout are not present in all the pressure catchments and few native species with high flow requirements are sufficiently widespread. Also, standards based on the “100 rivers” study may set an unrealistic expectation for the small pressure catchments, (many pressure streams have flows <1 m^3/s, cf. only 2 of the “100 rivers” had flow < 2 m^3/s). It seems these more straightforward approaches wont produce the desired result in many instances so a more complex approach is recommended.

Recommended Approach

1 For each species identify a preferred flow. This is the flow where habitat is greatest (optimal). If the optimum flow occurs above the streams natural flow range[4], the habitat provided by the MALF[5] is to be taken as preferred.

2 The level of protection is scaled according to ecosystem significance. Significance criteria are given in the last section. Habitat of the least significant species can be reduced to 85% of that offered by the preferred flow, while preferred habitat for the most significant species cannot be reduced at all. (Note this percentage is a change in habitat, which may or may not equate to a similar drop in flow.) The point of inflexion may be used instead of the scaled preferred flow in cases where this exceeds the minimum flow otherwise produced, or, where any additional loss of habitat is insignificant. Points of inflexion should be presented in any case.

3 Having produced a minimum flow for each species present, the highest of these is chosen as the minimum flow for the stream reach. This is to ensure adequate protection for the existing stream community.

Although relatively complex it is not a difficult process. Objectivity is largely achieved. Some room is left for interpretation with points of inflexion, which is logical given the room for bias we have to accept in deriving habitat-flow response curves. Above the point of inflexion there is little increase in habitat with flow – the graph levels off, (the longfin and shortfin eel curves in Figure 9 are good examples). Native edge dwelling species that prefer shallow, slower water often show this response because a reduction in flow has little effect on the amount of edge habitat available, (down to a certain point). It is expected that in most cases where a point of inflexion exists, the % reduction approach will recognise the point of inflexion (the flatter the curve the greater the flow reduction for a percentage reduction of habitat), but room is left for interpretation.

The minimum flow is based on the species with the highest flow requirements. An alternative approach offered by Jowett and Richardson (1994) for native fish communities, is to set minimum flows at that preferred by fish with intermediate flow requirements (redfin bully or common bully), rather than fast water species (torrent fish, bluegill bullies). While offering a compromise, Jowett and Richardson's approach will in some cases allow large reductions in habitat for fast water species, and so this does not ensure adequate protection for the existing aquatic community. The tendency for fast water species to prefer the equivalent of flood flows is circumvented here by not allowing the 'preferred flow' to exceed the mean annual/median flow.

The basic principle is to aim for optimum habitat and only allow a reduction below this when the significance of the community (or lack of) warrants it. This approach recognises that natural stream flows are not always ideal, and the risk associated with small reductions in habitat is acceptable for more common species. If one accepts this, the only room for debate is in the protection levels specified. One way to test the levels chosen is with follow up monitoring, the results of this feeding into consent reviews. Unfortunately conclusions can only really be drawn if stream flows are reduced to the minimum flow for an extended period. Baseline data would need to be collected before abstractions begin and then effects monitoring undertaken once flows had

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4 The mean annual flow (MAF) is recommended as a cut-off for adopting the optimum flow as the preferred flow for that species in spring fed streams. The median flow is recommended in high spate catchments.

5 The MALF (mean annual low flow) was deemed more appropriate than Q_5 as many species have life spans of one to three years.

approached the set minimum. This approach will tell us if too much water was allocated. To determine if we were being too conservative would rely on natural low flows below the set minimum.

Worked Example

A change in available habitat, be it up or down is largely unavoidable if we want to make any water available for abstraction (see Figure 9). So where possible we want to optimise habitat available in the stream. For the Tahawai Stream, this would equate to approximately 13 L/sec for banded kokopu (Figure 9). In some cases it is unreasonable to expect optimum conditions. For example, optimal flow for longfin eel is more than twice the MALF (mean annual low flow). In this case we set the preferred flow at the MALF.

This gives us a starting point for each species (Table 8). We then need to set a protection level that recognises ecosystem significance. A sliding rule is used between 100% and 85% depending on the significance criteria the ecosystem meets (see the last section). Because the Tahawai Stream supports a high number of species we set the level of protection at 90% for criteria 4 species and 95% for banded kokopu. A minimum flow is produced for each species and we take the highest figure to ensure the ecosystem is sustained. In this case inanga have the highest flow requirements so the minimum flow for Tahawai would be set at 26 L/s. Given the MALF is 28 L/s and allocation is based on Q_5, this is unlikely to provide any water for allocation. Note that the minimum flow for shortfin eel could be reduced from 14 L/s, down to the point of inflexion at 11 L/s. However, this makes no difference to the recommended minimum flow, which is based on inanga.

Table 8 Tahawai Stream minimum flow evaluation. The preferred wetted usable area (Pref. WUA, m^2/m) is derived from Figure 9 using the recommended approach. This value is multiplied by the protection level (see last section) and a minimum flow is derived.

	Pref. WUA	WUA x prot. level	Corresponding minimum flow (L/s)
Inanga	0.29	0.26	26
Torrentfish	0.11	0.095	24
Redfin bully	0.86	0.77	19
Longfin eel	1.04	0.93	14
Shortfin eel	0.73	0.66	13
Banded kokopu	0.18	0.17	8

Other considerations

The approach described in this note is intended for irrigation takes. Although municipal takes should be evaluated using the same approach, lower protection levels may be justified given the higher resource value.

When estimating stream flows, this should be corrected for existing takes (municipal, industrial, irrigation). This necessitates measuring flows when water is not being abstracted or measuring the abstracted flow and correcting accordingly. There is some argument for not correcting for permitted domestic takes.

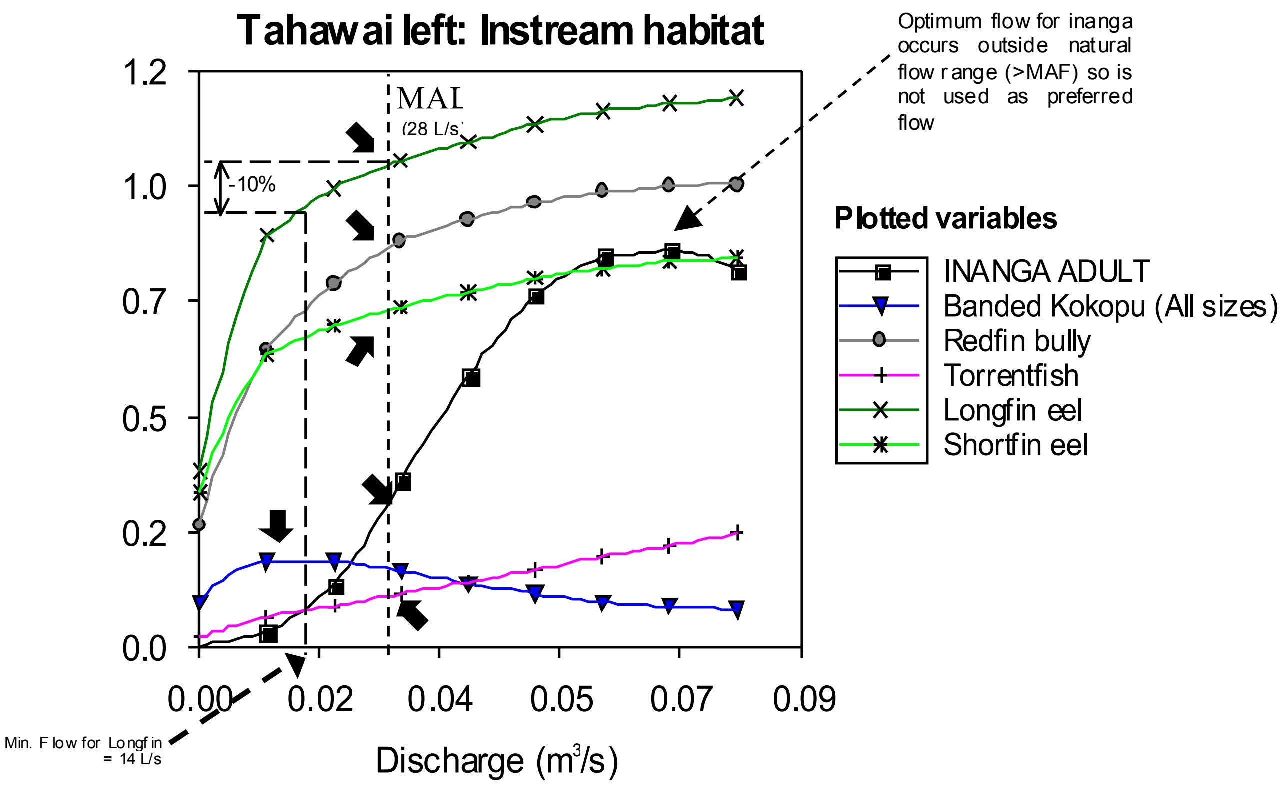

Figure 9 *Habitat modelling for the Tahawai Stream (Western Bay of Plenty) expressed as habitat (WUA m^2/m) versus flow. Preferred flows determined using established criteria are arrowed. Minimum flow for longfin eel illustrated. Note this is presented as an example only. Taxa and baseflow (MALF) were altered to illustrate method.*

Significance Criteria and Allowable Habitat Reductions

Significance criteria were established so that the level of protection could be scaled accordingly. The 100% protection level is only afforded to the most threatened species. Any reduction in habitat is unacceptable because the risk of irreversible population decline (i.e. extinction) is too high. At the other end of the scale, an 85% level is intended to provide adequate protection for relatively widespread species. Intermediate criteria are protected accordingly.

Significant recreational fisheries are afforded a relatively high level because their value lies in the abundance of fish, a factor directly affected by habitat. The 90% level afforded to diverse communities reflects the non-threatened status of the taxa it applies to, (any threatened taxa are covered by the more protective criteria), and the desire to maintain an assemblage of species. The more species present the more likely one will have relatively high flow requirements. Although not presented in the table, *appropriate* food producing habitat[6] for these species should be given the same level of protection.

No rules are set for deciding if the community represents a diverse assemblage (criteria 4). Streams closer to the sea generally have higher diversity and so an inland stream with only a few taxa may still represent a relatively diverse community given the streams potential. Methods are

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[6] Note "food producing habitat" criteria often developed for trout, not natives. E.g. some kokopu species feed largely on terrestrial drift and hence stream invertebrates are not so important.

appearing which assess observed versus predicted occurrence of taxa for a given type of stream (e.g. RIVPACS, AUSRIVAS), and hence could be used to evaluate the relative diversity of a fish community. Until these are available we will have to rely on experienced freshwater ecologists to make a judgement.

In some cases crans bully should be given a criteria 2 protection level. As a non-diadromous species, recruitment success is more dependent on a suitable instream environment. By contrast, extinction of inanga from a stream would be more reversible with whitebait migrations from the sea. Likewise if a population of crans bully was lost from a tributary the species could eventually re-establish itself from the main river or lake. However, if abstraction affected the majority of the reproducing population in a catchment then criteria 2 protection should be given. This is not stated as separate criteria because only one non-diadromous native species is present in the Bay of Plenty (that is not already given a higher protection level), and crans bully is mostly confined to the East Cape streams where abstraction pressure is low.

Some may argue depauperate streams should be given a lower protection level. If a stream is proven to be depauperate it seems unlikely that in depth RHYHABSIM assessments would be justified.

	Significance Criteria	**Protection level** (percentage of preferred habitat)
1	DoC priority A & B species[7] Short-jawed kokopu; giant kokopu	100%
2	DoC priority C species and regionally threatened species Banded kokopu; koaro; black mudfish; dwarf galaxias[8]	95%
3	Regionally significant trout fisheries and significant trout spawning habitat Brown trout; rainbow trout; etc	95%
4	Diverse native fish communities Fish community featuring a significantly high number of native species. Constituent species that don't meet above criteria are individually given this protection level	90%
5	Other	85%

[7] Molloy & Davis, 1994.

[8] Dwarf galaxias is classed as regionally threatened. The only records of this species in the Bay of Plenty are from a few streams on the Galatea Plains (an area of high abstraction pressure). These records represent the northern limit of the species.