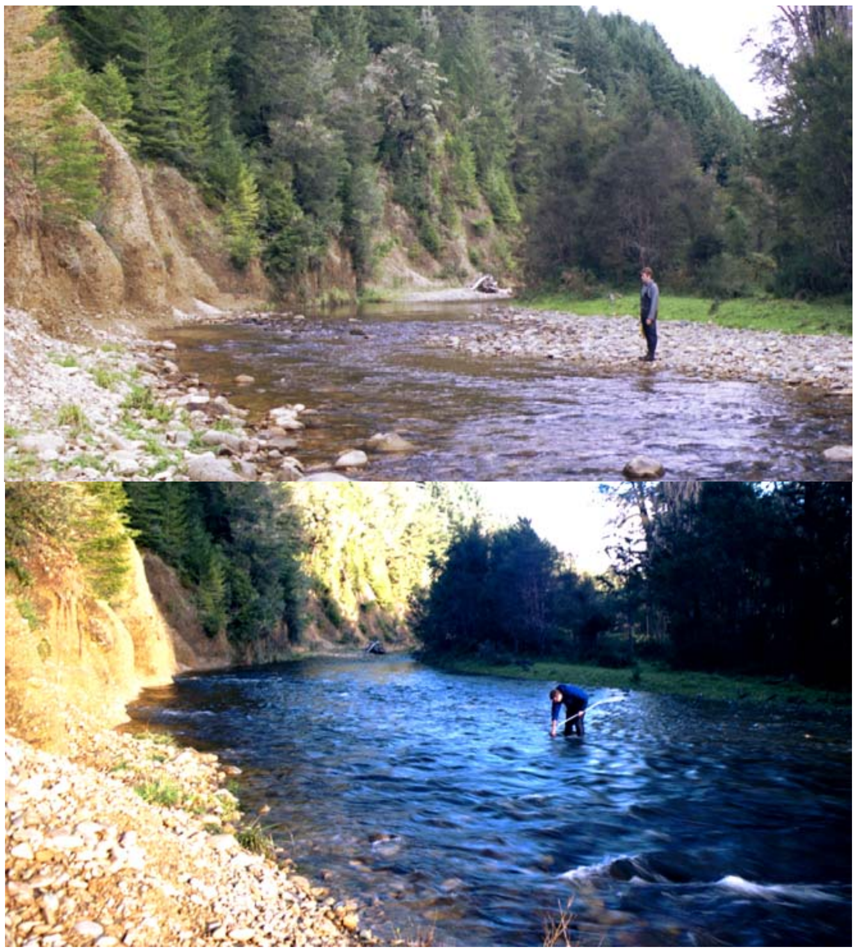
Cawthron Report No. 743

Assessment of some potential techniques to guide management of water abstraction from small streams



Prepared for

Tasman District Council

Fish & Game New Zealand

Integrated Catchment Management for the Motueka River

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Assessment of some potential techniques to guide management of water abstraction from small streams

Prepared for

Tasman District Council
Fish & Game NZ – Nelson/Marlborough Region
Motueka Integrated Catchment Management Project

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Cover Photo: Lower reach of the Rainy River at moderate and high flow (651 l/s & 4095 l/s): Cawthron 2002

EXECUTIVE SUMMARY

This report is the first of several steps required to develop a simple tool to assist management of water abstraction from small streams. We use the Rainy River as a case study to compare a quick hydraulic method with a more sophisticated instream flow incremental methodology (IFIM) habitat-based method of relating flows with habitat availability. The main focus is on ecological values related to water quantity and minimum flows, however we recognise that water quality and flow variability are also important components maintaining the ecological values in small streams.

Through concensus it was decided that the primary instream management objective was to maintain sufficient habitat for yearling brown trout, which are likely to be present in the river during low flow periods. Yearling trout are usually found in run habitats, therefore the depth and velocity of runs were considered to be the critical parameters controlling the quality of yearling trout habitat. Since trout have higher flow requirements than any of the native fish found in the Rainy River, any minimum flow that maintains trout habitat was considered to protect native fish and invertebrate habitat by default.

Field measurements of depths, widths, velocities and flows at three contrasting flows were carried out in two reaches of the Rainy River during April and May 2002. Some electric fishing was also conducted to relate the habitat use of juvenile brown trout in the Rainy River with that predicted by habitat suitability curves developed overseas. The quick hydraulic method was indeed less time consuming than a simplified IFIM habitat based method.

Problems with bias in the field measurements using the quick hydraulic technique were identified, but could be resolved with small changes in field protocols. Once these problems were addressed the two techniques predicted reasonably similar mean depth, mean width and mean velocity over a range of flows. There were, however, slight differences in predictions of mean depth and width between the two methods at flows approaching zero since the quick hydraulic method assumes that the river will be dry at zero flow while the IFIM habitat-based method takes into account the fact that some standing water may remain at zero flow.

Since the quick hydraulic method predicts only the response of mean depth, mean velocity and mean width with flow, rather than the distribution of depths and velocities, it is not possible to directly relate the results with habitat preferences for any particular species present. Results from the IFIM habitat-based method indicated that juvenile trout habitat in the Rainy is well below maximum levels at the natural mean annual low flow (MALF) and declines almost linearly at flows below the MALF.

The majority of the locations where juvenile brown trout were initially disturbed by the electric fishing machine had depths of about 0.2 m, but velocities covered a wide range from 0.05-0.5 m/s. Based upon an analysis of the habitat used versus the habitat available, juvenile trout in the Rainy River tended to favour the deeper areas within the runs, but were found over the range of velocities in roughly the same proportion as they occurred. This suggests that water depth in runs, rather than velocity, is likely to be the limiting factor at low flows.

Neither of the technical methods investigated defines a minimum flow, or the amount of habitat loss that is acceptable, they only provide information on changes in habitat availability at different flows. Setting minimum flows involves balancing the instream and out-of-stream water demands and deciding what reductions in habitat availability compared to that at the MALF, if any, are acceptable. For example, if a 10% decrease in yearling trout habitat availability from that available at the MALF was considered to be an acceptable limit, then the IFIM habitat-based method

indicates that a minimum flow of 105 l/s in the upper reach of the Rainy River would be required. Similarly, using the quick hydraulic method, if a 10% decrease in mean depth compared to that at the MALF was considered to be an acceptable limit then a minimum flow of 95 l/s in the upper reach of the Rainy River would be required. Given the similarity of these minimum flow recommendations, the quick hydraulic method appears to have potential to enable a better understanding of the effect of water takes on habitat availability, and therefore informed decisions on water management in small streams.

In the past minimum flows have often been based on historic flow statistics. Based upon our habitat response curves a 1-in-5 year low flow (92 l/s) and a 1-in-10 year low flow (56 l/s) would result in a 15% and 37 % reduction, respectively, in yearling trout habitat availability compared with that at the MALF.

As part of the Motueka Integrated Catchment Management project a modest amount of funding has been allocated to this work over the next financial year. At this stage we envisage that initial efforts be put into a system for providing guidance on (1) the development of management objectives for small streams, (2) the critical parameters likely to be influencing values potentially defined in the management objectives, and (3) data requirements for technical methods relating flows to habitat in small streams. We also aim to investigate the potential for using simplified 2-D hydraulic models to provide a quick and cheap way of predicting the effects of low flows on in-stream habitat.

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1. INTRODUCTION

Throughout the country regional and district councils are being asked to balance abstractive demands against flows required for maintenance of in-stream values in small streams. In many cases these streams do not have flow data and there is limited information on in-stream values. The first step required is to identify the in-stream values to protect and set objectives for the management of the stream. Once this has been done technical methods can be used to assess whether a particular flow will meet the management objectives.

Technical methods to assess flow requirements in larger streams and rivers are relatively well developed. However, these methods do not adequately cover small streams (MfE 1998). The main reasons for this are (1) that most research on flow requirements of aquatic life in New Zealand has been carried out on larger rivers, (2) calibration of hydraulic models is often difficult in small streams because traditional current meters often are too large to provide accurate information in shallow water, (3) hydraulic models work poorly in small turbulent streams because the equations used in these models do not apply under turbulent conditions, and (4) transfer of hydrological records from larger streams and rivers to small streams is problematic.

In-stream values associated with small streams often are perceived to be relatively low, despite these streams often providing important habitat for a variety of native fish and important juvenile rearing areas for sports fish. The volume of water abstracted and its value are also often relatively low from small streams and any benefits are often confined to one or few people. This combination of low perceived, or real, in-stream and out-of-stream values means that water consent managers find it difficult to justify expensive habitat surveys for small irrigation schemes or similar developments associated with small streams. Justifying a similar survey on a large popular river subject to a major hydroelectric development is much easier.

Despite the current lack of information and techniques available to assess flow requirements in small streams, consent applications are being processed and decisions made on flow allocation. Ideally a quick method of assessing flow requirements of small streams needs to be developed that is rapid yet scientifically robust, deals with flow needs for aquatic life, and is also able to be generalised to flow needs for any associated recreational use, landscape values and iwi values. Recognition of the range and cumulative values of small streams throughout a catchment or region also needs to be included in decision making.

Established methods of assessing flow regime requirements in larger streams and rivers can be grouped into four types:

> *Historic Flow methods* – where a minimum flow is set that relates to the historic flow regime (e.g. 1 in 5-year low flow)
>
> *Hydraulic methods* – where variation in width, depth or velocity with flow is determined and minimum flows are set to restrict changes in these parameters (e.g. <20% change in width)
>
> *Habitat methods* – which are similar to hydraulic methods, but also relate the availability of depths, velocities, and substrate types at different flows with the habitat suitabilities of various species or life history stages of a species. Minimum flows are then set to maximise or retain a specific amount of habitat for a certain species (e.g. ¾ of adult brown trout habitat available at the mean annual low flow or MALF)

Water quality modelling – relates flows with water quality parameters such as temperature and dissolved oxygen. Minimum flows are set to maintain temperature and/or oxygen concentrations above trigger levels.

As mentioned earlier, full habitat assessment methods are expensive and difficult to justify on small streams. At the other end of the scale, historic flow methods are relatively simple but do not take into account the shape of the channel in the stream reach of interest, or give any indication of the likely effects of sustained low flows. Therefore they may be overly conservative, or result in significant habitat loss depending on the threshold used to set the minimum flow or allocation limit. In addition, and as mentioned above, historic methods may be difficult to implement in small streams where the only flow data available are from nearby larger catchments.

This report is the first of several steps to develop a simple tool to assist management of water abstraction from small streams. The main focus is on ecological values related to water quantity and minimum flows, however we recognise that water quality and flow variability are also important components maintaining the ecological values in small streams. We compare results from a quick hydraulic method relating flows with hydraulic parameters against results from a more sophisticated in-stream flow incremental methodology (IFIM) habitat method. Minimum flow recommendations from these methods are also compared with those based on historic flow methods. We also provide some data on habitat suitability for juvenile trout and identify areas where this work should head to achieve our goal of providing a simple but effective tool to guide the management of water abstraction from small streams.

2. METHODS

2.1 Study site

The Rainy River was chosen as a case study for this report since the Tasman District Council (TDC) recently received two applications for consents to abstract from this river (Figure 1). These applications have highlighted the lack of techniques/information available to help guide decisions on water abstraction from small streams. The consents were granted for just two years with conditions restricting water take once flows at the neighbouring Motupiko at Christies flow recorder drop below the 1-in-5 year low flow (300 l/s) and ceasing water take once flows at the Motupiko at Christies recorder drop below the 1-in-10 year low flow (239 l/s).

Correlations between gaugings carried out downstream of Big Gully and the Motupiko at Christies recorder indicate that the mean annual 7-day low flow, downstream of Big Gully, is about 187 l/s, while the mean annual 1-day low flow is estimated as 128 l/s (Martin Doyle, TDC, pers. comm.). Three gaugings undertaken during this study indicate that flows at the upper reach are consistently about 66% of those at the downstream reach, which very closely reflects the difference in catchment area between reaches (upper reach 70 km^2; lower reach 105 km^2). Assuming these relationships are similar under all flow conditions the mean annual 7-day low flow in the upper reach is expected to be about 123 l/s.

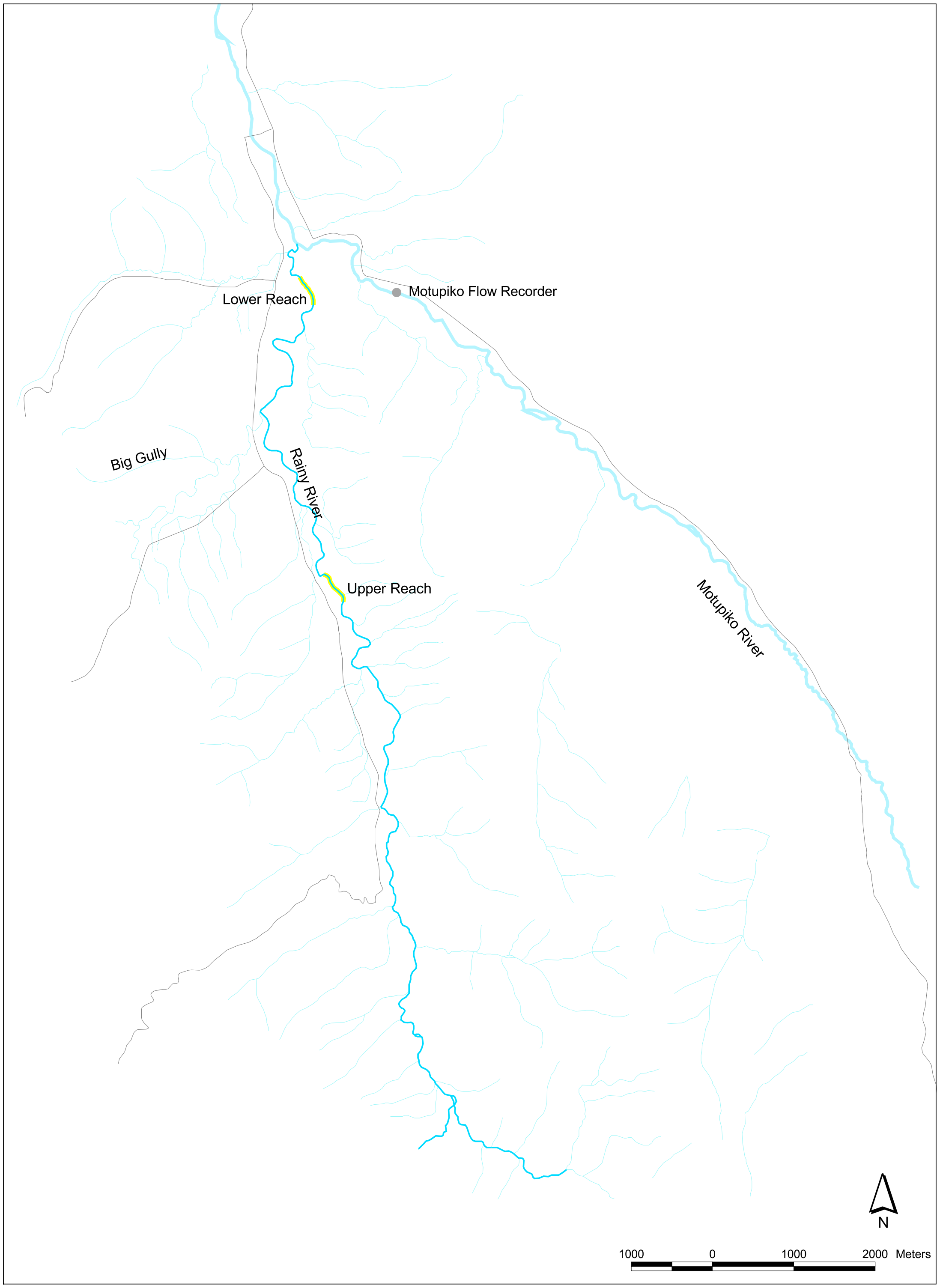

Figure 1 Rainy River showing study reaches and Motupiko at Christies flow recorder.

2.2 Instream management objective

There was considerable discussion amongst the project participants and stakeholders on the in-stream management objectives to be applied to the Rainy River. It was agreed that the Rainy River is an important spawning area and juvenile nursery for brown trout. Since spawning is largely a winter activity, the effects of irrigation on spawning habitat are likely to be minimal due to low irrigation demands and relatively high flows. The main effect of low flows will be on young of the year (0+) and yearling (1+) trout that live in the Rainy over the summer period when low flows and irrigation demands coincide. Yearling trout migrate downstream into the Motueka River as they grow larger. Therefore, reductions in juvenile trout growth and survival in the Rainy River have the potential to affect the adult trout population in the Motueka River.

Flow requirements for yearling trout are believed to be higher than for 0+ trout. Therefore if minimum flows are designed to protect the habitat requirements of yearling trout then the habitat for 0+ trout will be protected by default. The same argument applies to other fish species found in the Rainy River (longfin eels, dwarf galaxias, upland bullies), which also have lower flow requirements than yearling trout. Habitat for aquatic invertebrates also should be sufficiently catered for if minimum flows are set for yearling trout habitat protection. Protection of yearling trout habitat will also ensure that the river is maintained as a flowing entity, thus protecting the key aesthetic features of the river. This may also satisfy iwi values associated with the Rainy River, however to confirm this a study exploring local iwi values would be required.

Results from electric fishing surveys in the Rainy River have indicated that yearling trout are found mainly in fast runs, whereas 0+ trout tend to occupy the shallower riffle habitat. The area of fast runs is very sensitive to flow reduction. Therefore, fast runs were considered critical habitats in our analysis. In particular, we were interested in how the width, depth and velocity of fast runs varied with flow.

2.3 Technical methods relating flow to hydrological parameters

2.3.1 Quick hydraulic method

NIWA, in association with MfE and the Auckland Regional Council, developed a computer program (WAIORA) that includes a range of numerical models to calculate how flows influence dissolved oxygen concentrations, water temperatures, total ammonia concentrations and in-stream habitat in rivers (McBride *et al.* 1998). In terms of in-stream habitat, the WAIORA program uses a quick hydraulic method to predict how mean depth, mean velocity and mean width within a survey reach will change with flow. However, such an approach does not give any guidance on the distribution of depths about the mean in the survey reach at different flows. Therefore it is difficult to relate these results to habitat preferences for any particular organisms present in the survey reach.

The quick hydraulic method used in the WAIORA model is based on the basic flow equation that states that flow is the product of river width, average depth and average velocity (see Box 1). Changes in width with flow depend on the change in water level with flow, which is controlled in-turn by the channel shape. Once a relationship between water level and width (dependent on channel shape) and a relationship between water level and discharge (a rating curve) have been developed then it is possible to calculate mean velocity for any flow using the basic flow equation (Jowett 1998a,b). For more details on the theory and equations related to the quick hydraulic method see Box 1.

Box 1 Theory and equations relating to the quick hydraulic method (from Jowett 1998a)

The basic flow equation is:

$$Q = W \times Y \times V \tag{1}$$

where Q is flow, W is width, Y average depth and V the average velocity

To calculate how width varies with flow we must also calculate or estimate how width changes with depth and how depth varies with flow.

$$\frac{\partial W}{\partial Q} = \frac{\partial W}{\partial Y} \times \frac{\partial Y}{\partial Q} \tag{2}$$

Given relationships between depth and width (which depends on channel shape) and depth and flow (a rating curve) it is possible to estimate velocity for any flow using the basic flow equation.

The general channel shape equation is:

$$W = a_c \times Y^{bc} \tag{3}$$

where a_c is the shape coefficient, b_c is the shape exponent and Y is the average section depth.

The shape coefficient and exponent can be calculated using the following equations if mean stream width W and mean depth Y are measured at two flows.

$$b_c = \frac{\log\left(W_1 / W_2 \right)}{\log\left(Y_1 / Y_2 \right)} \tag{4}$$

and

$$a_c = \frac{W_1}{Y_1^{bc}} \tag{5}$$

The general relationship between flow and water depth is:

$$Q = a_r \times Y^{br} \tag{6}$$

This coefficient and exponent can be calculated if mean depth Y is measured at two flows.

$$b_r = \frac{\log\left(Q_1 / Q_2 \right)}{\log\left(Y_1 / Y_2 \right)} \tag{7}$$

and

$$a_r = \frac{Q_1}{Y_1^{br}} \tag{8}$$

Given this information, the width, depth and velocity response curves can be calculated using the following formulae:

$$W = a_c \times \left[\frac{Q}{a_r} \right]^{\frac{b_c}{b_r}} \tag{9}$$

$$Y = \left[\frac{Q}{a_r} \right]^{\frac{1}{b_r}} \tag{10}$$

$$V = \frac{Q}{a_c \times \left[\frac{Q}{a_r} \right]^{\frac{b_c+1}{b_r}}} \tag{11}$$

Jowett (1998a) recommended that measurements be taken in runs, which are likely to have water depths and velocities intermediate between that in pools and riffles. In other words, the hydraulic characteristics of runs will represent the average characteristics of a reach with pools, runs and riffles.

To use this quick hydraulic method two visits to the study reach at contrasting flows are required. On the first trip discharge is measured along with the mean depth and mean width of run habitats. Jowett (1998a) suggested using cross-sections through 5 runs and measuring 5 depths across each run. Water levels at each cross-section need to be recorded. On the second visit discharge is measured again, along with the mean width of run habitats using the same cross-sections and the mean change in water level between the first and second visits. The difference in flow between site visits must be sufficient to cause a measurable change in water level (about 5cm), and ideally one of the flows should be within the range where minimum flows will be set (i.e. near the MALF).

Five runs in the upper and lower reaches of the Rainy River were chosen on 24 April 2002. Mean depths, widths and water levels were measured at these runs along with flow. Measurements of width, water level and flow were repeated on 26 April 2002 at higher flows. The same measurements were repeated again on 29 May 2002 at even higher flows, although these were not needed for the analysis.

Width, depth and velocity response curves with flow were developed in an Excel spreadsheet using the equations presented by Jowett (1998a). These equations are shown in Box 1.

2.3.2 Simplified IFIM habitat survey

Standard IFIM survey measurements were made on 24 April 2002 at the same five run cross-sections used in the upper reach for the quick hydraulic method. These measurements included depths, velocities and substrate composition at about 0.2 m intervals across each cross-section. Measurements of water level at each cross-section and flow were repeated on 26 April 2002 and 29 May 2002.

Water velocities and depths over each cross-section and wetted width were predicted for a range of flows using the IFIM computer program RHYHABSIM (Jowett 1996). Weighted usable area (WUA) was then calculated for each species or life stage of interest over a range of flows. WUA is the IFIM habitat index; a composite of depth, velocity and substrate composition suitability for the species/lifestage of interest.

Habitat suitability curves for young of the year (0+, <15 cm) and yearling (1+, 15-25 cm) brown trout were derived by Raleigh *et al.* (1986) from data gathered by Gosse *et al.* (1977) from the U.S.A (Figure 2). To date, no juvenile brown trout habitat suitability curves have been derived specifically for New Zealand rivers. The Raleigh curves are routinely used by IFIM practitioners in this country because they appear to match with observations of locations where juvenile trout are routinely found in NZ rivers.

We electric fished the upper reach of the Rainy River on 24 April 2002 to determine if the habitat used by juvenile trout was consistent with predictions from these habitat suitability curves. The position where a trout first responded to the electric fishing machine was marked and subsequently the depth, velocity and substrate composition at, and on either side of, these sites were measured. A habitat suitability curve for longfin eels derived from data collected in 32 New Zealand rivers (Jowett 1995) was also used in the analyses.

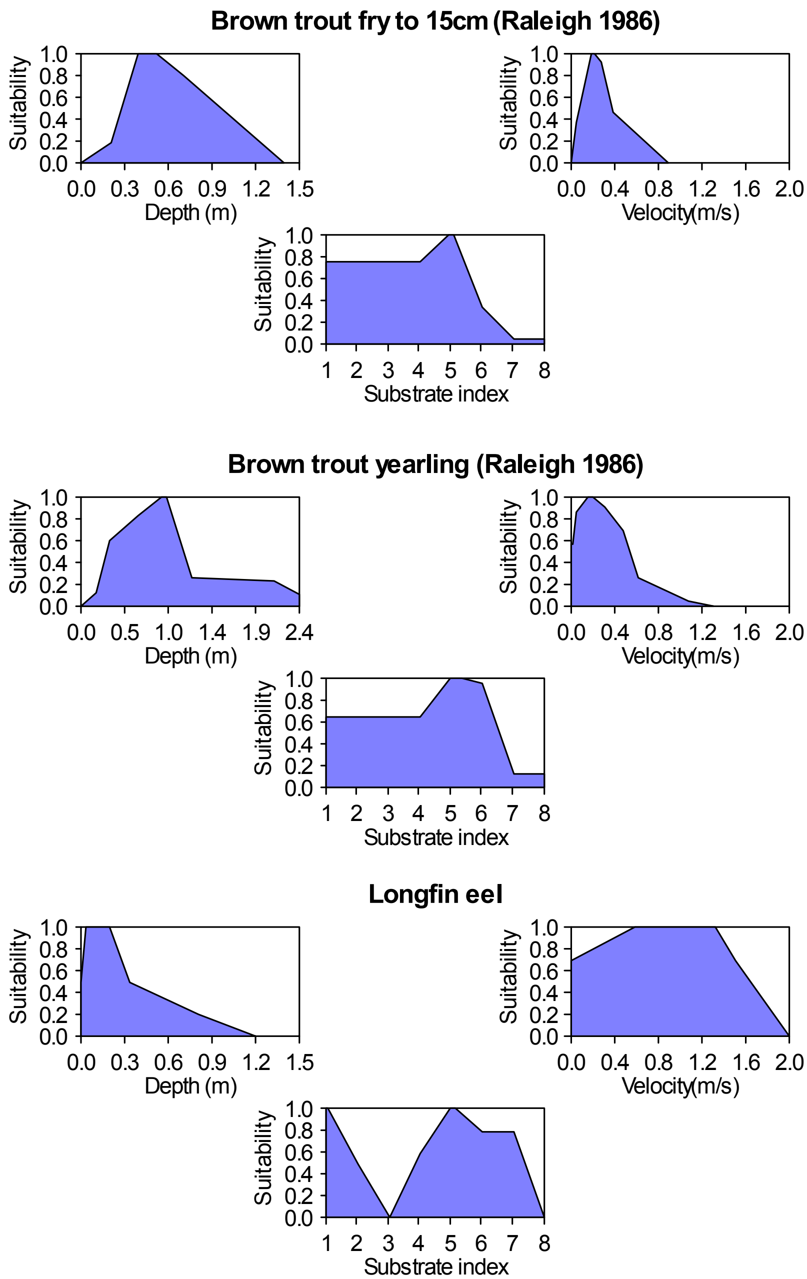

Figure 2 Habitat suitability curves for juvenile brown trout (fry <15 cm; yearlings 15-25 cm) and longfin eels. Substrate indices are 1 = Vegetation, 2 = Silt, 3 = Sand, 4 = Fine Gravel, 5 = Gravel, 6 = Cobbles, 7 = Boulders, 8 = Bedrock.

3. RESULTS

3.1 Habitat mapping and river flows

Habitat mapping over 500 m of river length in each of the upper and lower study reaches of the Rainy River was carried out on 24 April 2002 to determine the proportions of each habitat type present. The main habitat types were fast runs, riffles, slow runs and pools in both study reaches. In the upper reach the proportions of each habitat type were: 41% fast run, 35% riffle, 17% slow run, and 6% pool. In the lower reach the proportions of each habitat type were: 37% fast run, 31% riffle, 20% slow run, and 12% pool.

The flow was 201 l/s in the upper reach and 313 l/s in the lower reach on 24 April 2002. This had increased to 446 l/s and 651 l/s for the upper and lower reaches, respectively, by 26 April 2002. Flows were much higher during the third trip on 29 May 2002 – 2747 l/s in the upper reach and 4095 l/s in the lower reach.

3.2 Comparison of quick hydraulic and IFIM habitat methods in the upper reach

The time required to take measurements and get results from the quick hydraulic method was considerably less than that for the IFIM habitat-based method. The choice of cross-sections to be used by both methods took about 1-2 hours. The initial measurements of depth, velocity, water level and stage at zero flow that were used for the simplified IFIM method took 2-3 hours to complete for just the five cross-sections, while the depth, width, water level and flow measurements for the quick hydraulic method were completed after about 1 hour. It should be noted that a full IFIM survey would normally include 10-20 cross-sections. Only one repeat trip, including about an hour of field work at each reach, was required for the quick hydraulic method, while at least two repeat visits of about an hour of field work time were required for the IFIM method. Taking into account the travelling time to the site, this is a considerable saving. Two people (data gatherer and data recorder) were required for most of the field work involved in both methods. Time involved with data entry and subsequent basic analyses for the simplified IFIM method was also about twice that required for the quick hydraulic method.

The response of mean depth, mean width and mean velocity with flow for runs in the upper study reach of the Rainy River was calculated using both the quick hydraulic and IFIM habitat methods (Figure 3 – blue and pink lines). Comparing first the blue and pink lines in Figure 3, mean depth was somewhat different between methods and tended to become more different as flows increased. Predictions of mean width tended to vary most between methods at low flows and became more similar at the higher end of the flow range modelled here (Figure 3). Mean velocity predictions were consistently different throughout the flow range modelled here (Figure 3).

These initial comparisons were concerning, especially considering the gap between depth and width predictions for the two methods around the calibration flows (201 – 446 l/s), which we had actually measured and thus should have been the same, or at least very similar between the two methods. Further investigation of the raw data that was used as input for the two methods indicated differences based upon the field measurement techniques adopted. Jowett (1998a) suggests five depth measurements be taken across each cross-section to estimate average depth. There appears to have been considerable bias towards deeper water using this technique resulting in considerable differences in the input data for the two methods (Table 1). The solution to this would be to ensure that the individual depth measurements were taken at sufficient, evenly spaced intervals across each cross-section. Based on the raw IFIM data collected from the Rainy River, a measurement interval that results in about 10 measurements across each cross-section should give an accurate estimate of mean depth.

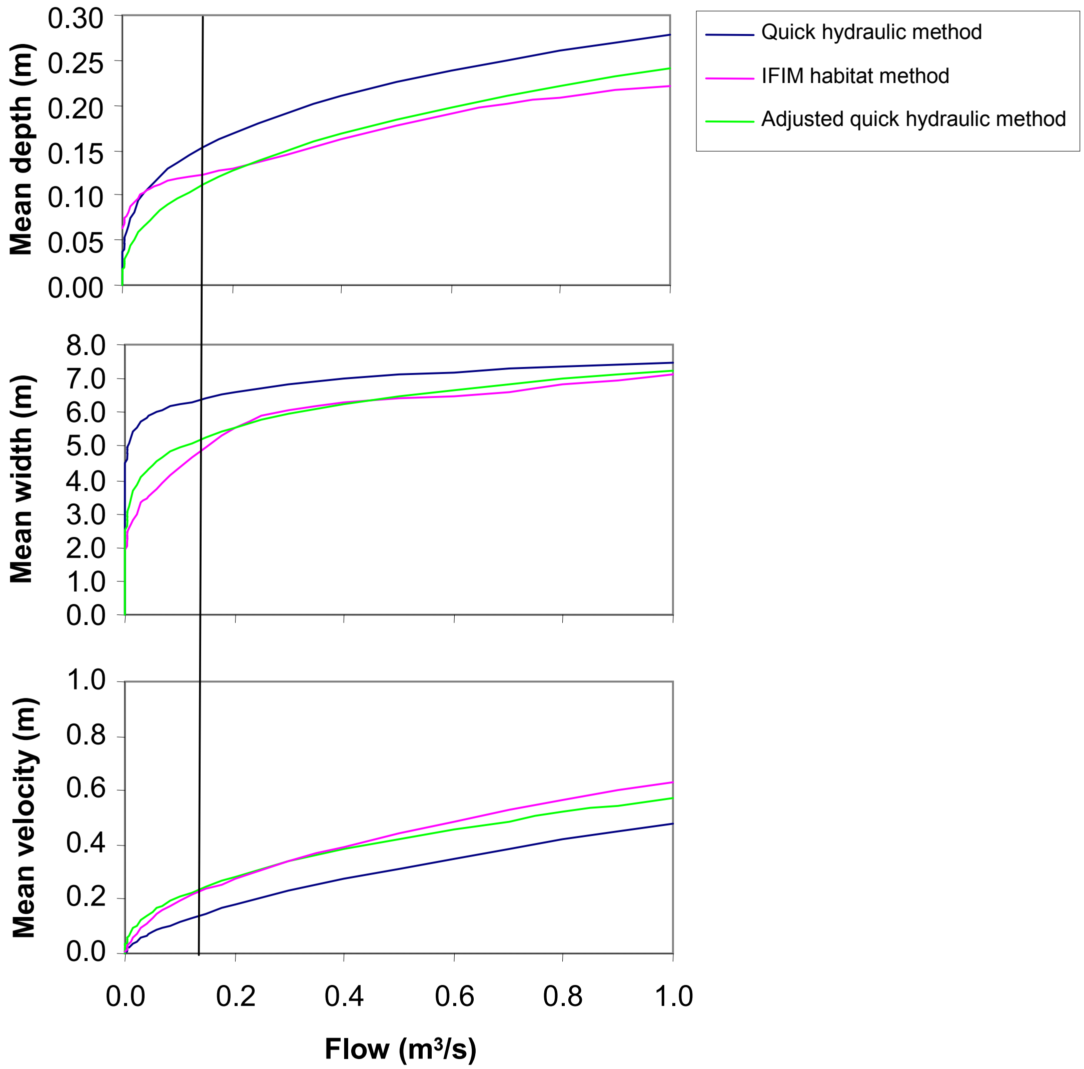

Figure 3 Response of mean depth, mean width and mean velocity with flow in the upper study reach of the Rainy River for the quick hydraulic and IFIM habitat methods. The adjusted quick hydraulic method uses input data consistent with the IFIM habitat method. The estimated MALF (123 l/s) is shown with the vertical line.

Differences were also noted between the width measurements used by the two methods. For the quick hydraulic method, the distance from the edge of the river on one side to the edge of the river on the other side was used to calculate mean widths of the 5 runs. In contrast, the IFIM calculation reports the results in terms of wetted width, which discounts the width of any small 'islands' that occur across the cross-section. Once again, these seemingly small differences can result in quite large differences to the inputs to each model (Table 1). The best solution to this difference in width input between methods is to measure the width of any 'islands' across the cross-section and subtract this from the total width. This problem is likely to be particularly important and difficult to deal with in small streams where substrate size is large relative to the water depth, and there are many boulders and stones emerging through the water surface. In extreme circumstances the easiest way to fix this problem would be to estimate the proportion of the total width that is above the water surface and subtract this proportion from the total width.

Table 1 Differences in mean depth and width measurements between methods at the survey flow resulting from differing field measurement techniques.

Cross-section	Mean depth estimate		Width measurement	
	Quick hydraulic method	IFIM habitat method	Quick hydraulic method	IFIM habitat method
1	0.136	0.097	7.4	5.8
2	0.152	0.106	6.0	5.2
3	0.204	0.164	7.1	6.7
4	0.174	0.128	6.8	5.1
5	0.178	0.141	5.8	5.1

To compare the actual calculations of mean widths, depths and velocities between methods we used the mean depth and wetted width at each cross-section from the IFIM habitat survey as input data to the quick hydraulic method. The depth, width, and velocity response curves from the quick hydraulic method using the adjusted input data were much more similar to those developed from the IFIM habitat method and especially in the range between the calibration flows (Figure 3 – green line versus pink line). However, the depth response curves tended to differ at flows approaching zero (Figure 3) because the IFIM habitat method takes into account the fact that there will be some standing water (and thus depth) remaining even after flow has ceased, while the quick hydraulic method assumes that there will be no water left at zero flow. Adjustments to the quick hydraulic method by relating depths to the height above the water level at zero flow could be made if this was considered to be a problem (Jowett 1998a).

3.3 Results from quick hydraulic method in the lower reach

Bias associated with data collection for the quick hydraulic method probably also influences the response curves for the lower reach of the Rainy River. Bearing this in mind, the response predicted for mean depth, mean width and mean velocity with flow was somewhat different to that for the upstream reach (Figure 4). In the downstream reach the channel is larger and wider due to the contribution of flows from Big Gully, a major tributary (Figure 1). As flows increase in the upper reach, width is predicted to increase only slightly once flows rise above 200 l/s (Figure 4). In contrast, the lower reach is less constrained over the range of flows modelled here and width is predicted to increase more rapidly with flow (Figure 4). Because the river is able to spread out as flows increase, velocities in the lower reach are predicted to remain relatively low as flow increases (Figure 4).

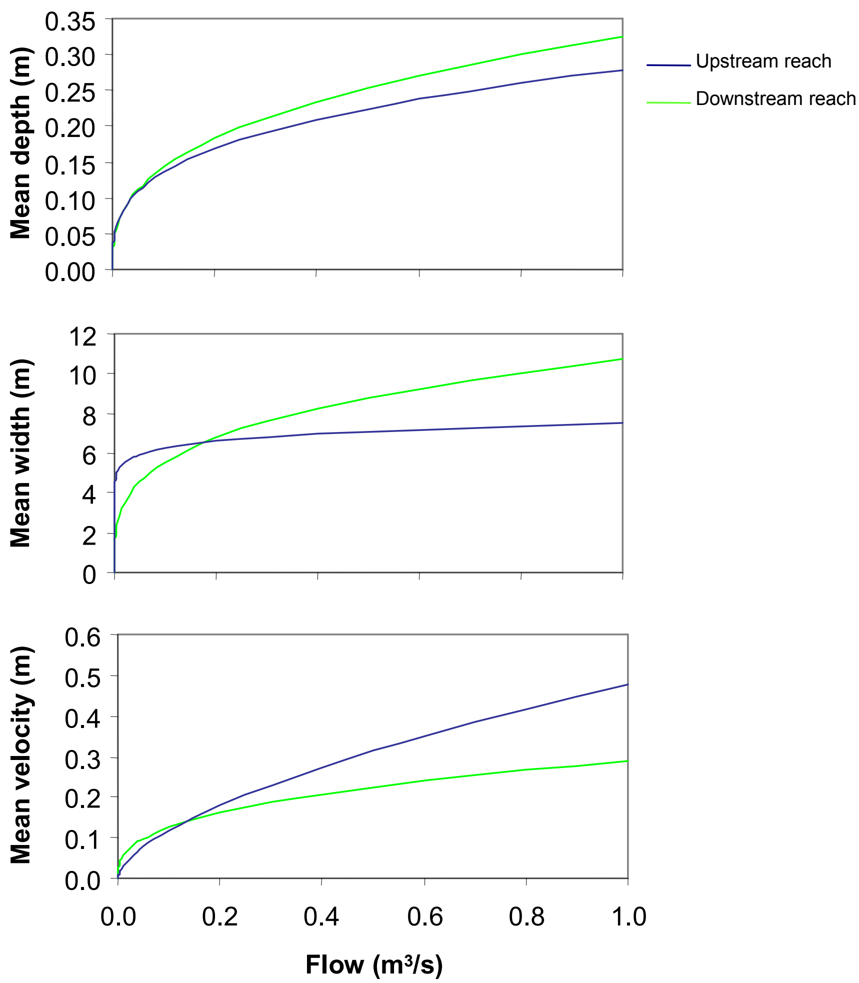

Figure 4 Comparison of response of mean depth, mean width and mean velocity with flow using the quick hydraulic method in the upper and lower study reaches of the Rainy River.

3.4 Habitat variation with flow

The key advantage of using an IFIM habitat method over the simple hydraulic method is that the habitat suitabilities of particular species can be included in the analyses and related directly with flow (Figure 5). Decisions on setting minimum flows in large rivers usually are made on the basis of these types of habitat (WUA) x flow curves. The suitability of runs for juvenile trout in the upper study reach begins to decline once flows drop below about 700 l/s and sharply once flows drop below 300 l/s for young-of-the-year trout and 200 l/s for yearlings. Once flows drop below the mean annual low flow (MALF) the predicted response of habitat availability for yearling and young-or-the-year trout to flow is almost identical (Figure 5). Habitat for longfin eels in runs is fairly constant above about 400 l/s, but drops sharply below 300 l/s (Figure 5).

Surprisingly, the habitat availability for young-of-the-year (0+) trout declines before that of yearling trout. This is the opposite of what would be expected with yearling trout preferring faster and deeper water than 0+ trout. This may indicate bias in the habitat suitability curves between these two life stages and highlights the need for research on juvenile brown trout habitat suitability in NZ rivers. We will explore this further in the next section.

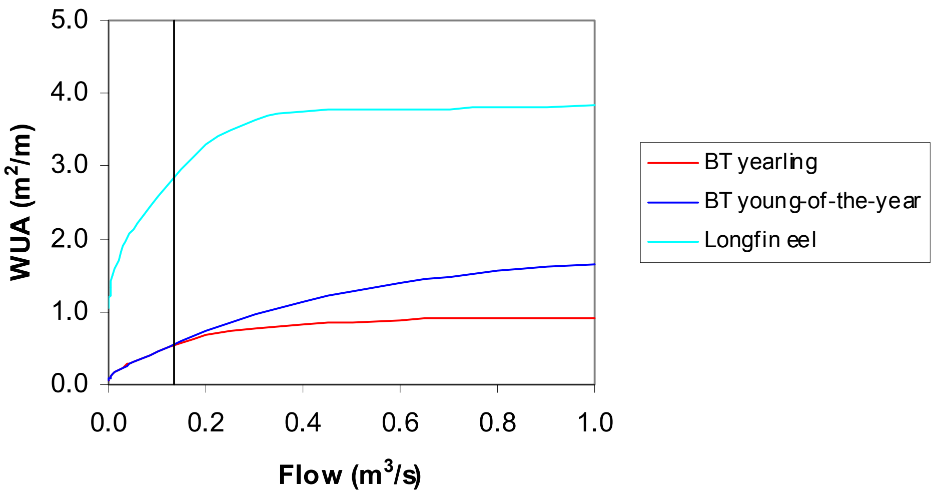

Figure 5 Variation in habitat (WUA) with flow in runs in the upper study reach of the Rainy River. The estimated MALF (123 l/s) is shown with the vertical line.

3.5 Habitat preferences of Rainy River trout

A total area of 970 m^2 was electric fished in the upper reach of the Rainy River on 24 April 2002 with 47 juvenile trout caught (density = 0.05 trout/m^2). Most of the electric fishing was carried out in runs and riffles. All trout that were caught appeared to be young-of-the-year (0+) fish ranging in length from 100–155 mm. The lack of yearlings was surprising, but was probably an effect of the drought during the summer of 2000/2001 when flows in the Rainy River below Big Gully dropped to 37 l/s.

The initial locations of 14 trout disturbed by the electric fishing machine were marked. Depth and velocity was measured at, and on either side, of the marks. The locations where trout were initially disturbed were assumed to be their focal point feeding positions, although we have no evidence that the trout were actually feeding. Some of the trout may have been in resting positions. Drift feeding habitat ought to be the focus for flow related instream habitat analysis because drift feeding is the most flow demanding activity by trout. Resting habitat for juvenile trout is generally cover related (e.g. beneath cobbles/boulders) and not directly related to water velocity.

Most locations where trout were initially disturbed had depths of about 0.2 m, but velocities covered a wide range from 0.05-0.5 m/s (Figure 6). According to Raleigh's (1986) suitability curves, brown trout fry prefer depths of about 0.5 m and velocities about 0.3 m/s, whereas brown trout yearlings prefer depths of about 1.0 m and velocities over a wide range from 0-0.6 m/s (Figure 2). There is reasonable agreement between our observations and the Raleigh curves in terms of velocity, although the relatively high suitability at zero velocity for yearling trout indicated by the Raleigh curve is questionable. This is a common problem, indicating bias toward resting habitat, in North American habitat suitability curves. There was a considerable difference in the most common depth occupied in the Rainy River compared to that predicted from the Raleigh curves. However, this was probably due to the lack of deep flowing water in the Rainy River. An analysis of the frequency of habitat used versus the frequency of habitat available in runs in the Rainy River (from the IFIM habitat survey data) indicated that the trout were favouring deeper water, but occupied the range of velocities in roughly the same proportion as they occurred in runs in the river (Figure 7). This suggests that water depth in runs, rather than velocity, is likely to be the limiting factor at low flows.

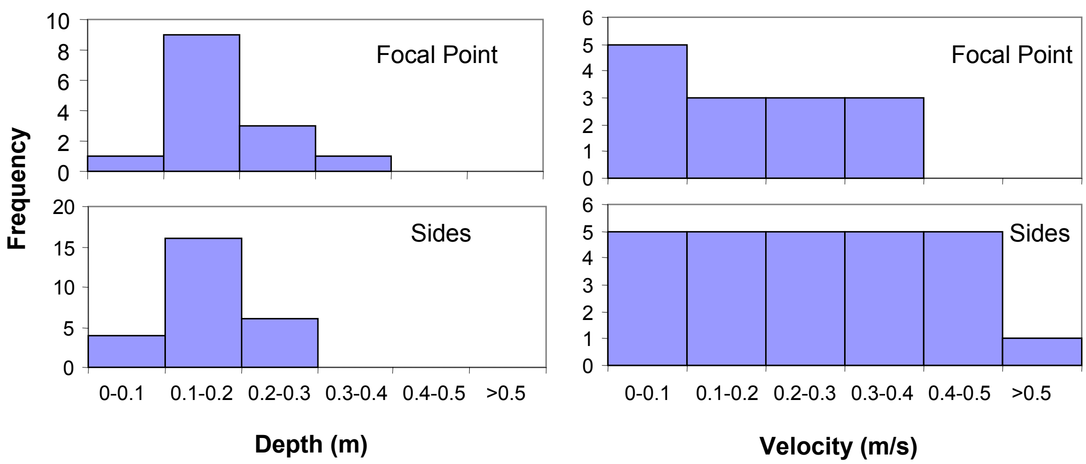

Figure 6 Histograms showing the frequency of depths and mean column velocities for locations where trout were initially disturbed by the electric fishing machine.

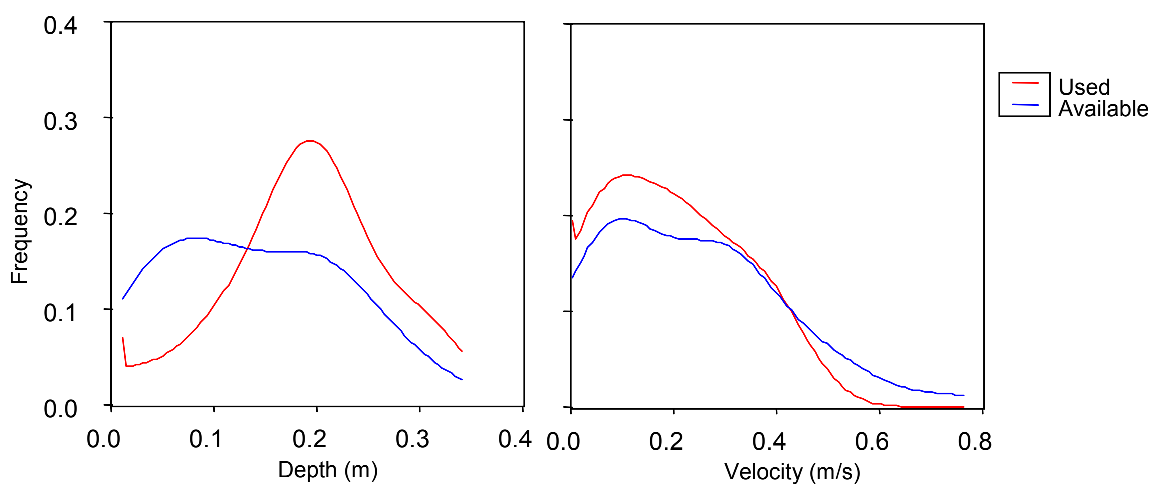

Figure 7 Comparison of the frequency of habitat used (focal point) versus habitat available in the upper reach of the Rainy River.

The frequency of habitat use curves that are shown in Figure 7 could potentially be used in another IFIM analysis, but they are based upon a limited number of observations at only one flow. An analysis based upon suitability data at one flow will tend to have bias toward those same flow conditions unless the trout population is well below carrying capacity and the few trout present are in only the best spots. An approach to address this bias is to divide the frequency of use by the frequency of availability to get a preference curve. However, this approach is highly sensitive to sparse data near the extremes of the used and available habitat distributions (R. Young, personal observations).

4. GUIDELINES FOR MINIMUM FLOWS IN THE RAINY RIVER

The most important comparison between methods used to guide the setting of minimum flows is the results that they produce in terms of suggesting minimum flows. However, before a minimum flow can be set a management decision must be made on what is an acceptable amount of change or habitat loss. Neither of the technical methods examined in this report defines a minimum flow, or the amount of habitat loss that is acceptable, they only provide information on changes in habitat at different flows.

The flow x habitat curves (Figure 5) are expected to give the best information upon which to make minimum flow decisions. They indicate that habitat availability declines sharply once flows drop below about 200 l/s. The estimated 7-day MALF (123 l/s) is below this level, which indicates that habitat is limited by natural low flows in the Rainy River. Habitat availability is predicted to decline almost linearly at flows less than the MALF (Figure 5). Therefore decisions on appropriate minimum flows will most likely be based on flows that maintain an acceptable percentage of the habitat available at the MALF (Table 2). If a 10% decrease in yearling trout habitat availability from that available at the MALF was considered to be an acceptable limit, then a minimum flow of 105 l/s in the upper reach of the Rainy River would be required (see shaded section Table 2).

Table 2 Potential minimum flows in the upper reach of the Rainy River maintaining various percentages of yearling trout habitat available at the MALF as predicted by the IFIM habitat method.

% yearling trout habitat available compared to that at the MALF	Yearling trout habitat (m^2/m)	Flow at upstream reach maintaining yearling habitat (l/s)
100	0.521	123
95	0.495	114
90	0.469	105
80	0.417	86
70	0.365	67
50	0.261	35

Similar analyses can be conducted using the results from the adjusted quick hydraulic method and making decisions on appropriate low flows that are based on maintenance of an acceptable percentage of the mean depth, mean width or mean velocity predicted at the MALF (Table 3). Therefore if a 10% decrease in mean depth compared to that at the MALF was considered to be an acceptable limit then a minimum flow of 95 l/s in the upper reach of the Rainy River would be required (see shaded sections Table 3).

Table 3 Potential minimum flows in the upper reach of the Rainy River maintaining various percentages of mean depth, mean width and mean velocity available at the MALF as predicted by the adjusted quick hydraulic method.

% available compared to that at the MALF	Mean depth (m)	Flow maintaining depth (l/s)	Mean width (m)	Flow maintaining width (l/s)	Mean velocity (m/s)	Flow maintaining velocity (l/s)
100	0.104	123	5.15	123	0.23	123
95	0.099	108	4.89	90	0.22	109
90	0.094	95	4.63	64	0.21	97
80	0.084	70	4.12	31	0.18	74
70	0.073	50	3.60	14	0.16	54
50	0.052	22	2.57	2	0.11	25

Alternatively, physically based criteria could be set, such that low flows should not decrease depth or velocity below certain threshold levels. The WAIORA program used 0.1 m depth and 0.3 m/s velocity as default threshold levels (McBride *et al.* 1998). Mean depth at the MALF in the upper reach of the Rainy River only just meets this criterion, while mean velocity falls below this criterion at the MALF (Table 3). Criteria such as these really need to be flexible and relate to the particular species or value identified in the management objective.

In the lower reach, downstream of Big Gully, the 7-day MALF is higher than upstream (187 l/s versus 123 l/s). Bearing in mind the potential for bias in the input data for the quick hydraulic method in the lower reach, a similar analysis can be carried out to assist the setting of low flows in that reach of the river (Table 4). For example, if a 10% decrease in mean width compared to that at the MALF was considered to be an acceptable limit then a minimum flow of 129 l/s in the lower reach of the Rainy River would be required (see shaded sections Table 4).

Table 4 Potential minimum flows in the lower reach of the Rainy River maintaining various percentages of mean depth, mean width and mean velocity available at the MALF as predicted by the quick hydraulic method.

% available compared to that at the MALF	Mean depth (m)	Flow maintaining depth (l/s)	Mean width (m)	Flow maintaining width (l/s)	Mean velocity (m/s)	Flow maintaining velocity (l/s)
100	0.179	187	6.64	187	0.16	187
95	0.170	162	6.31	156	0.15	162
90	0.161	139	5.98	129	0.14	140
80	0.143	100	5.31	86	0.13	101
70	0.125	68	4.65	54	0.11	69
50	0.090	27	3.32	16	0.08	27

4.1 Comparison with minimum flows based on historic flow methods

As mentioned in Section 2.1 above, recent consents to take water from the Rainy River (or actually from infiltration galleries near the river) were granted with restrictions on takes related to historical flow statistics from the neighbouring Motupiko at Christies recorder (Figure 1). Restrictions begin when flows in the Motupiko drop below the 1-in-5 year low flow (300 l/s) and no take is allowed once flows drop below the 1-in-10 year low flow (239 l/s). Minimum flows developed in this way assume that the existing ecological community will continue to be maintained by flows that have occurred in the past. Increasing levels of protection are provided by setting minimum flows at historically more frequent (and thus higher) low flow levels. However, there are several problems with this approach. Firstly, the ecological effects of regularly drawing a stream down to the 1-in-5 year low flow for a considerable period of time will potentially be much greater than would have occurred naturally during such an uncommon and short period of low flow. In addition, the existing ecological community is unlikely to reflect the occurrence of such a rare event when you consider the average life span of most species present is in the range of months to just a few years. Population recovery is probably fast enough, even for long lived species like trout, that rare events such as the 1-in-10 year low flow are unlikely to control average trout abundance (Hayes & Young 2001).

Based upon a correlation of gaugings at the Christies recorder and in the Rainy downstream of Big Gully (Tony Hewitt, unpublished data) the equivalent flow statistics for the Rainy River downstream of Big Gully would be 140 l/s and 85 l/s for the 1-in-5 and 1-in-10 year low flows, respectively. Assuming again that flows in the upper reach above Big Gully are 66% of those downstream of Big Gully, the equivalent flow statistics in the upper reach are 92 l/s and 56 l/s for the 1-in-5 and 1-in-10 year low flows, respectively.

Based upon our habitat response curves (Figure 5) a flow of 92 l/s and 56 l/s would result in a 15% and 37 % reduction, respectively, in yearling trout habitat availability in runs in the upper reach of the Rainy compared with that at the MALF. Since the habitat response curves for young-of-the-year and yearling trout were almost exactly the same at flows below the MALF, the same reduction in young-of-the-year habitat compared with that at the MALF would be expected at these historic flows. Similarly, based on the quick hydraulic method the 1-in-5 year flow of 92 l/s would result in an 11 % reduction in mean depth, 5 % reduction in mean width and 12 % reduction in mean velocity compared with that at the MALF. The 1-in-10 year low flow of 56 l/s would result in a 27 % reduction in mean depth, 12 % reduction in mean width and 29 % reduction in mean velocity compared with that at the MALF.

5. FUTURE PLANS

Much of the material presented in this report compares one technical method with another for relating flows with various hydraulic or habitat parameters. Although the quick hydraulic method is not quite as accurate as the more expensive and time-consuming IFIM habitat based method, the results in terms of minimum flow recommendations were fairly similar (Table 2 versus Table 3). Therefore the quick hydraulic method appears to have the potential to act as a useful technical tool for predicting mean depth, mean width, and mean velocity in small streams over a variety of flows, and thus enabling a better understanding of the effect of water take on habitat availability. However, improvements to the field sampling protocol as suggested in Section 3.2 are required to limit bias in the initial estimates of mean depth and mean width.

The technical methods referred to here, however, relate only to a small, but important, part of the process of setting minimum flows in small streams (MfE 1998). Considerable effort was required by the project participants and stakeholders to decide on the instream values and management objectives for the Rainy River. In this regard the Rainy River was an easy example, owing to the amount of existing flow and ecological information on the river, the relatively low diversity of native fish present, and the high value of the Rainy River as a trout spawning and rearing stream. Further work is needed to provide streamlined guidance on choosing instream management objectives and determining the sensitivity of various instream values to flow. Guidance is also required on the critical parameters and flow statistics (e.g. MALF, median, FRE3) that should be measured or estimated, along with any other field measurements of channel shape etc that are required. These critical parameters could be hydraulic (e.g. depth, velocity, width) or based on water quality (e.g. dissolved oxygen, temperature, suspended sediment) or riparian (e.g. shade ratio) measurements.

Once the instream management objectives are set and the critical parameters required to sustain the values identified in the management objectives have been decided upon, technical methods such as those described here are required. One alternative technical method that we wish to explore is the use of a simplified 2-D hydraulic model that is capable of providing the distribution of depths and velocities throughout a reach at different flows knowing only the stream bed topography. If a 'library' of typical stream bed morphologies was produced that included the different types of streams throughout a region the only field calibration required would be to determine bank-full width and perhaps slope for the reach of interest. Since an estimate of the distribution of depths and velocities would be provided by such a model, it would be possible to directly relate the results with habitat preferences for particular species or life history stages of a species.

Much of this report has been related to the flow needs of aquatic life in small streams. However, iwi, recreational, and aesthetic values are also influenced by flow. Ideally, any method guiding the management of water abstraction from small streams needs to include these other values. The Ministry for the Environment's 'Flow guidelines for instream values' (MfE 1998) outlines the approach that should be taken in relation to these other values for larger rivers. Similar approaches are necessary in small streams, although many small streams will have low recreational, and perhaps landscape and iwi values, compared to large rivers.

As part of the Motueka Integrated Catchment Management project a modest amount of funding has been allocated to this work over the next financial year. At this stage we envisage that initial efforts be put into a system for providing guidance on (1) the development of management objectives for small streams, (2) the critical parameters likely to be influencing values potentially defined in the management objectives, and (3) data requirements for technical methods relating flows to habitat in small streams. Local iwi may also be involved and will assist with the approach to iwi values in small streams. We also aim to begin investigation of the potential for using simplified 2-D hydraulic models to provide a quick and cheap way of predicting the effects of low flows on in-stream habitat. Development of a stream velocity criterion that sustains drifting by stream invertebrates, and thus drift feeding by fish, is also planned in conjunction with the Cawthron Institute's research program on salmonid energetics modelling (CAWX0208). Depending on the results from this initial research and the availability of future funding, the system could be expanded to incorporate water quality, flow variability and application of the 2-D hydraulic model.

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