Management Flows for Aquatic Ecosystems in the Manuherikia River

SURFACE WATER

Otago Regional Council

Management Flows for Aquatic Ecosystems in the Lower Manuherikia River

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Foreword

The future development and prosperity of Otago depends on water. However, much of Otago has long been recognised as a water-short area and consequently Otago is constantly at the forefront of water management in New Zealand. In many cases, irrigation particularly in these drier areas is critical to the continued well being of the people and communities who rely on the primary production it supports.

Otago Regional Council's Regional Policy Statement provides the overall framework for the future management of water in Otago. The Water Plan provides the direction for better utilisation and protection of water so that the values, opportunities and needs of Otago's communities can be reasonably met.

A key thrust of the Water Plan is its emphasis on the progressive implementation of minimum flow regimes for streams and rivers throughout the region. The goal of these minimum flows is to maintain the stream's aquatic ecosystem and natural character during periods of low flow. Furthermore, setting appropriate allocation limits and promoting water use efficiency are integral for ensuring reliable access to the water resource.

In Otago, surface water supplies are heavily allocated. Over-abstraction can result in degradation of a stream's natural values and character. Therefore, careful management is required to keep rates of taking sustainable. The best way forward is to use this valuable water resource to our advantage and to implement allocation limits and minimum flows so that over-abstraction does not occur.

The Manuherikia River is the fourth most significant trout fishery in Otago. It also contains nine species of native fish. Currently there are over 240 water takes from the catchment that are used to irrigate in excess of 20,000ha. Primary allocation for the catchment is considered over-allocated. Clearly, there is a need to manage the stream for its natural values while allowing access to the water resource for the local community.

Executive Summary

The purpose of this report is to investigate the flows required to maintain acceptable habitat for the fish species found in the lower Manuherikia River (downstream of Ophir).

Low flow return periods such as the 7-day mean annual low flow (MALF) and 7-day 10 year low flow ($Q_7 10$) have been calculated to give an indication of the low flows experienced by that part of the catchment. Rainfall data have also been summarised to give an indication of annual rainfall and seasonal distributions.

Biodiversity and angling information has been obtained from both the Department of Conservation and Fish and Game Otago. This information has been incorporated into this report along with fisheries and climate data collected by Otago Regional Council.

Instream habitat surveys were carried out in the lower Manuherikia River and flow requirements for all the resident species assessed by examining the relationships between flow and suitable habitat using instream habitat modelling. Habitat suitability was determined from general habitat suitability curves developed from studies in other rivers.

The Manuherikia River contains a significant trout fishery and it also contains several species of native fish of conservation importance. The habitat information showed that maximum habitat for adult brown trout was provided by a flow of 4.25m^3/s. Habitat declined sharply as flows fell below 2.5m^3/s for adult brown trout. Maximum brown trout fry habitat was provided by a flow of 1.25m^3/s, whereas yearling trout had slightly higher flow requirements, with maximum habitat provided by a flow of 2.0m^3/s. However, the amount of both yearling and fry habitat began to reduce sharply at a flow of 0.9m^3/s. Maximum habitat for upland bullies and roundhead galaxiid was provided by very low flows (0.25m^3/s) but common bully habitat was greatest at a flow of 1.25 m^3/s and began to fall sharply when flows fell below about 0.5m^3/s.

The selection of an appropriate minimum flow depends on the fish species present and the flow management objectives that balance the degree of environmental protection against the value of water for other uses. This report focuses on the lower Manuherikia River's natural values which have been taken from Schedule 1A of the Regional Plan: Water for Otago (2004) (the Water Plan). Seasonal management flows of 0.90m^3/s (November to April) and 4.5m^3/s (May to October) have been recommended.

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1. Introduction

The Regional Plan: Water (2004) (Water Plan) sets out as one of its objectives "to retain flows in rivers sufficient to maintain their life-supporting capacity for aquatic ecosystems, and their natural character"[1]. As a means to achieve this objective, the Water Plan provides for the setting of minimum flows in Otago rivers[2].

The purpose of this report is to provide information on the Manuherikia River that is relevant to determining the flows desirable for sustaining aquatic habitat. Hydrological data have been summarised and analysed to determine low flow return periods for the Manuherikia River. Rainfall data have been provided to show the variation in rainfall throughout the catchment. A brief overview of the topography, vegetation, land use and environmental concerns within the catchment has been provided along with a summary of the recreational and biodiversity values of the Manuherikia River. A physical habitat study (Instream Flow Incremental Methodology or IFIM) has also been carried out to determine the effects of low flows on the availability of habitat for both the native and introduced sports fish found within the catchment.

1.1 Focus of document

In order to manage a stream, there needs to be a clear focus on what the management objective is. An allocation limit for the Manuherikia River has been determined (Schedule 2A of the Water Plan[3]). A clear management objective for the river is now drawn from Schedule 1A of the Water Plan[4]. That schedule identifies the ecosystem values that must be sustained and a key value that requires sufficient flow is the presence of trout. IFIM data are now discussed with a focus on that management objective and the natural low flow regime of the Manuherikia River. Flows to sustain these aquatic ecosystem values in the lower Manuherikia River are recommended by this report.

[1] Objective 6.3.1 of Water Plan (2004), p 55.
[2] Policies 6.4.1 – 6.4.11 of Water Plan (2004), pp 58-69.
[3] Schedule 2A and 2B of Water Plan (2004), p 314
[4] Schedule 1A of Water Plan (2004), p 296.

2. The Manuherikia Catchment

The Manuherikia River Catchment of Central Otago extends for approximately 64km and has an area of approximately 3085km^2 (Beecroft et al., 1986) (Figure 2.1). Its headwaters are found in the Hawkdun Range from which it flows in a south-west direction to its junction with the Clutha River/Mata-Au at Alexandra (Figure 2.1).

2.1 Vegetation

Pre-European vegetation cover of the catchment has been described as short tussock grassland, 30-35cm high on the terraces, fans and lower mountain slopes, while tall tussock grassland dominated by snow tussock occupied the higher mountain slopes (Ferrar 1929). Land cover has been modified with the spread of introduced plants, rabbit infestation, excessive burning and over sowing of introduced pasture grasses. In many cases, this has resulted in both a depletion of the native vegetation and soil erosion. However, these depleted areas are being reclaimed partly by a combination of improved dry-land farming methods and better irrigation management. There have been continuous and repeated efforts to improve pastures within the Manuherikia, with high producing pasture grasses such as ryegrass and white clover establishing on the deeper soils with the aid of irrigation. Cocksfoot and lucerne pastures have been established on the shallower soils as they adapt well to the dry conditions (Orbell 1974).

2.2 Land use

Land use in the upper catchment of the Manuherikia is primarily extensive sheep and beef grazing. Due to irrigation, the mid and lower reaches of the catchment are dominated by higher intensity farming, with smaller farms with higher stocking rates relative to the upper catchment. There is also some grain cropping within the catchment.

2.3 Topography and soils

The Manuherikia Catchment is bounded by the Dunstan Range on the west, the Hawkdun Range on the north, Rough Ridge on the east and in the south by the Knobby Range and the Clutha River/Mata-Au (Figure 2.1). The Manuherikia Catchment includes two major depressions: the Manuherikia valley and the Ida valley, which are connected by the Poolburn Gorge. The Ida valley is drier than the Manuherikia valley and is prone to severe dry periods. Alluvial fans are common in the valley forming when streams, draining the hilly areas, flow into the valley. Most of the river terraces have flat to gently undulating surfaces and are usually covered with a thin layer of gravel, and often a thin layer of loess (Beecroft et al., 1986).

Brown-grey soil is dominant in the central-southern zone of the catchment, while a yellow-grey soil extends from the middle part up to the Dunstan Valley. The upper Manuherikia valley is characterised by yellow-brown soil. The hills and the mountains have been coated, in many locations, with a veneer of Pleistocene and Recent loess, while the terraces are covered by alluvium and a thin deposit of loess of the same age (Beecroft et al., 1986).

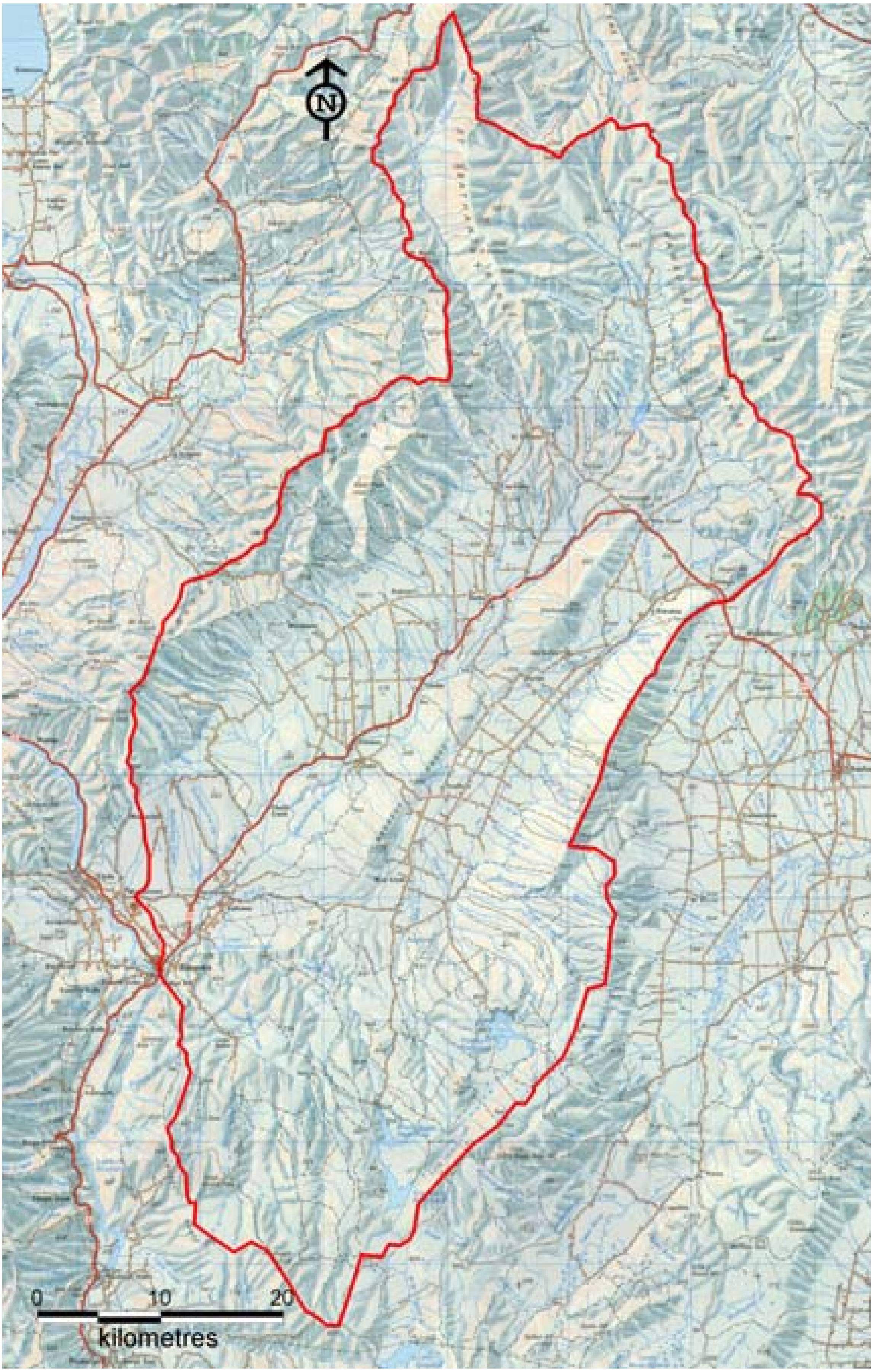

Figure 2.1 Manuherikia Catchment, Otago, New Zealand

2.4 Rainfall

The Manuherikia climate is considered to be the most continental in New Zealand, highlighted by cold winters and warm summers with large diurnal ranges (NIWA 2001). This continental climate in the Manuherikia is a result of many factors including; distance from marine influence; and the surrounding mountains which shelter it from rain-bearing storms. The valley floor is classified as semi-arid as it receives between 350mm and 500mm of rainfall per year, while the western and northern ranges can receive more than 1100mm of rainfall as they are exposed to south-westerlies. Annual rainfall is expected to reach 1500mm near the St Bathans Range. Thus rainfall intensities vary throughout the catchment (Figure 2.2). Rainfall in the Manuherikia Catchment is also higher during the summer than winter months (Figure 2.2).

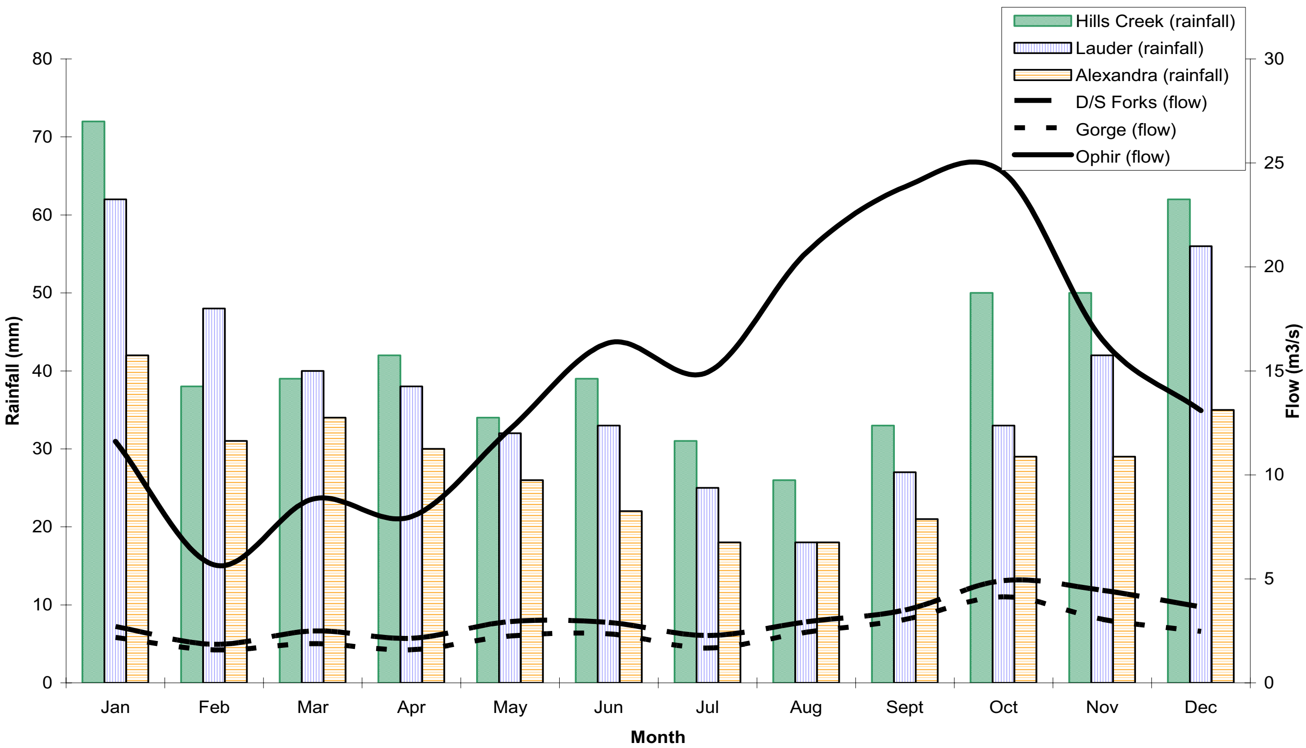

Figure 2.2 Mean monthly rainfall and flows for selected monitoring sites in the Manuherikia Catchment (refer to Figure 3)

2.5 Hydrology

The Manuherikia River is a major tributary of the Clutha Catchment entering the true left bank of the Clutha River/Mata-Au at Alexandra. Several sites with flow records have been used for the purposes of this section of the report (Figure 2.3 & Table 2.2). Due to the difficulty in finding a suitable site, there is no continuous flow recorder at the bottom of the Manuherikia Catchment (Figure 2.3).

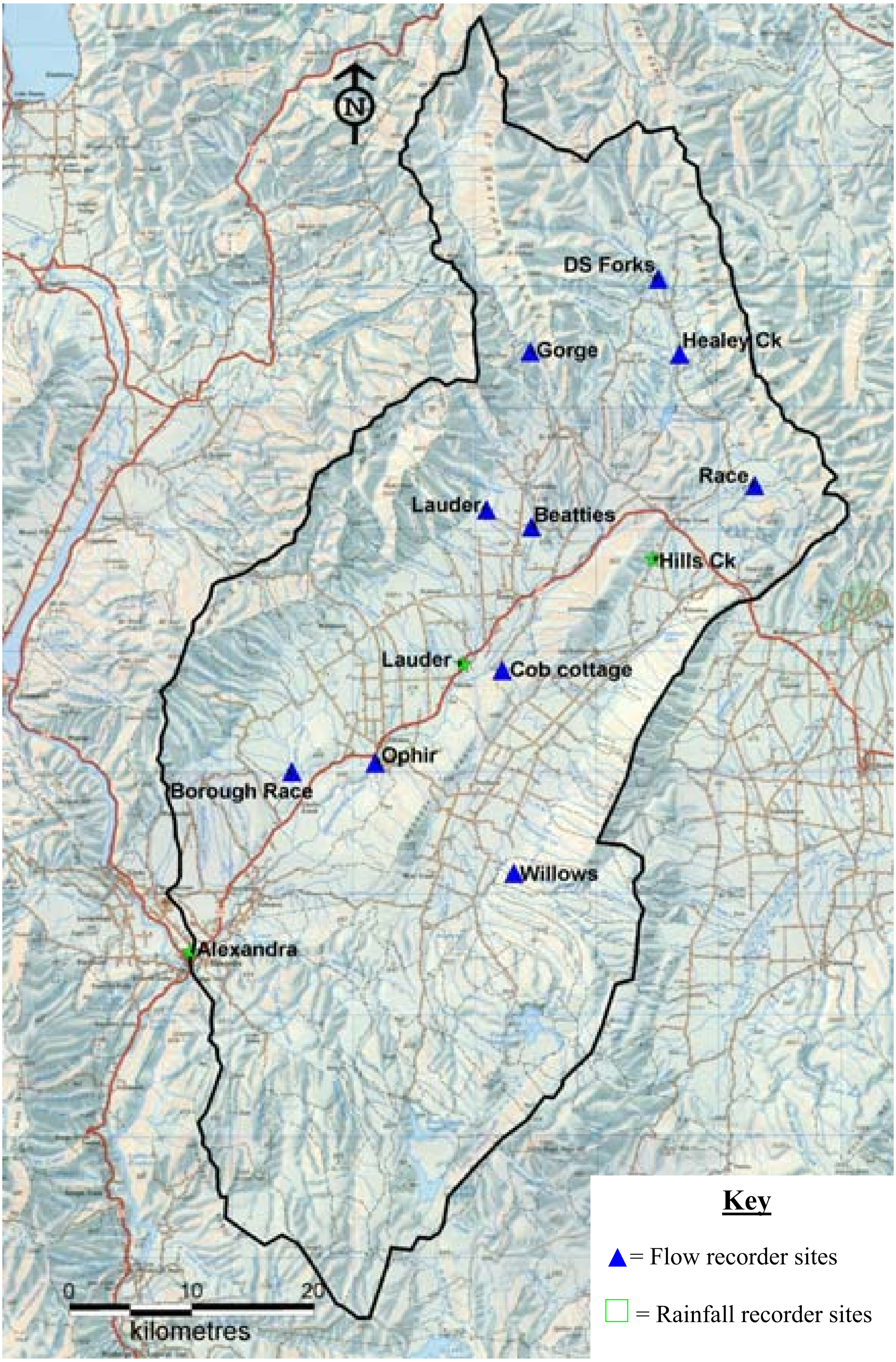

Figure 2.3 Flow and rainfall recorder sites within the Manuherikia Catchment

2.5.1 Annual statistics

Several sites within the Manuherikia: D/S Forks (Upper Manuherikia), Gorge (Dunstan Creek) and Ophir (mid–reaches Manuherikia), have been analysed to extract information about the long-term statistics of stream flows within the catchment (Table 2.1 and Figure 2.3). It must be noted that at times of low flows recorded flows can be skewed due to the many irrigation takes within the Manuherikia Catchment. A proportion of the irrigated water used is lost through evaporation or taken outside the catchment borders, such as the case with the Hawkdun/Ida Burn race at the top of the Manuherikia Catchment which delivers water to the Taieri Catchment.

Table 2.1 Summary of annual statistics of flow sites

Site	Location	Catchment area (km^2)	Record Length (yrs)	Min. (m^3/s)	Mean (m^3/s)	Max (m^3/s)
D/S Forks	Upper Manuherikia	174	18	0.51	3,080	101,360
Gorge	Dunstan Creek	158	6	0.42	2,360	84,310
Ophir	Mid Manuherikia	2108	31	0.3	14,580	602.400

Within the Manuherikia Catchment, the spring period (September, October, November), on average yields more flows than late summer and early autumn (February, March, April) (Figure 2.2). When comparing this to the mean annual rainfalls for this region, which are highest during the summer period, it highlights the significant contribution of snow melt to the flows of the Manuherikia Catchment. The D/S Forks and Dunstan Gorge flow recorder sites are representative of natural conditions as they have no takes or water storage facilities above them.

2.6 Analysis of low flows

In addition to the three principal flow sites (D/S Forks, Gorge and Ophir), there are other sites at which flow recorders have been installed, but rating for these sites have been calibrated only during low flows. Some of these sites are affected by intakes for irrigation, and in turn their flows are not representative of natural flows at these locations. These sites, which are affected by irrigation intakes, have been included in this report (Table 2.2). In addition, flow gauging has been carried out at 52 sites across the catchment during low flow periods to assess the water resources of the Manuherikia Catchment during low flows. Again, with these gauging sites, some are affected by upstream takes.

2.6.1 Annual 7-day low flows and their frequency analyses

Mean annual 7-day low flows (MALF or $Q_{7,m}$ in m^3/s) and the corresponding specific yield (SMALF or $SQ_{7,m}$ in litres/sec/km^2) have been calculated at several sites in the Manuherikia Catchment (Table 2.2). It must be noted that these calculations do contain some error, however, they do give an indication of low flows and yields within the Manuherikia Catchment.

Table 2.2 Low flows for selected flow sites in the Manuherikia Catchment

Site	Location	Recorded Min. (m^3/s)	MALF (m^3/s)	Area (km^2)	SMALF ($l/s/km^2$)
D/S Forks	Upper Manuherikia	0.51	0.874	173	5.0
Healeys Ck***	Upper Manuherikia	0.356	0.423	270.7	1.6
Gorge	Upper Dunstan Creek	0.417	0.682	158	4.3
Beatties***	Lower Dunstan Creek	0.028	0.091	268	0.34
Lauder **	Woolshed Creek	0.021	0.050	10.62	4.7
Race	Upper Ida Burn	0.018	0.040	13.3	3.0
Willows	Dovedale Creek (Poolburn area)	0.002	0.011	39	0.25
Cob Cottage**	Lower Ida Burn & Pool Burn	0.002	0.033	816	0.04
Ophir*	Lower Manuherikia	0.3	1.94	2108	0.92
Borough Race***	Chatto Creek	0.185	0.2	109.8	1.8

* Affected by upstream irrigation intakes
** Affected by upstream irrigation intakes and short record
*** Affected by upstream irrigation intakes and very short record

The specific MALF is highest for the upper Manuherikia (5.0 $l/s/km^2$), while the Poolburn area, which lies in a much drier section of the Manuherikia Catchment, has a very low specific MALF (0.25 $l/s/km^2$). The specific MALF for the upper Ida Burn, which is just south of the upper Manuherikia area, is also relatively high (3.0 $l/s/km^2$).

Table 2.3 Recorded low flows for selected return periods in the Manuherikia Catchment

Site	Min. (m^3/s)	MALF (m^3/s)	$Q_{7,5}$ (m^3/s)	$Q_{7,10}$ (m^3/s)	$Q_{7,20}$ (m^3/s)	$Q_{7,50}$ (m^3/s)	$Q_{7,100}$ (m^3/s)
D/S Forks	0.51	0.874	0.741	0.661	0.603	0.545	0.51
Gorge	0.417	0.682	0.563	0.515	0.478	0.44	0.416
Willows	0.002	0.011	0.002	0.002	0.001	0.001	0.001
Ophir*	0.3	1.94	1.275	0.845	0.632	0.43	0.324

* Affected by upstream irrigation intakes

Table 2.3 shows that the recorded minimum flows are close to the 100-yr 7-day low flows. In addition, the 100-yr 7-day low flow at Ophir is less than the corresponding flow at both the upper catchment sites of D/S Forks and the Gorge (Table 2.3). This is also the case with the recorded minimum flows (Table 2.3). One would expect that flows at Ophir would be higher than the sum of the recorded flows at the D/S Forks and Gorge sites, as Ophir is downstream of where these flows merge. The difference is due to the amount of water being taken upstream of Ophir.

The Manuherikia Catchment can be broken into 10 hydrological regions based on yields at times of low flow (Figure 2.4).

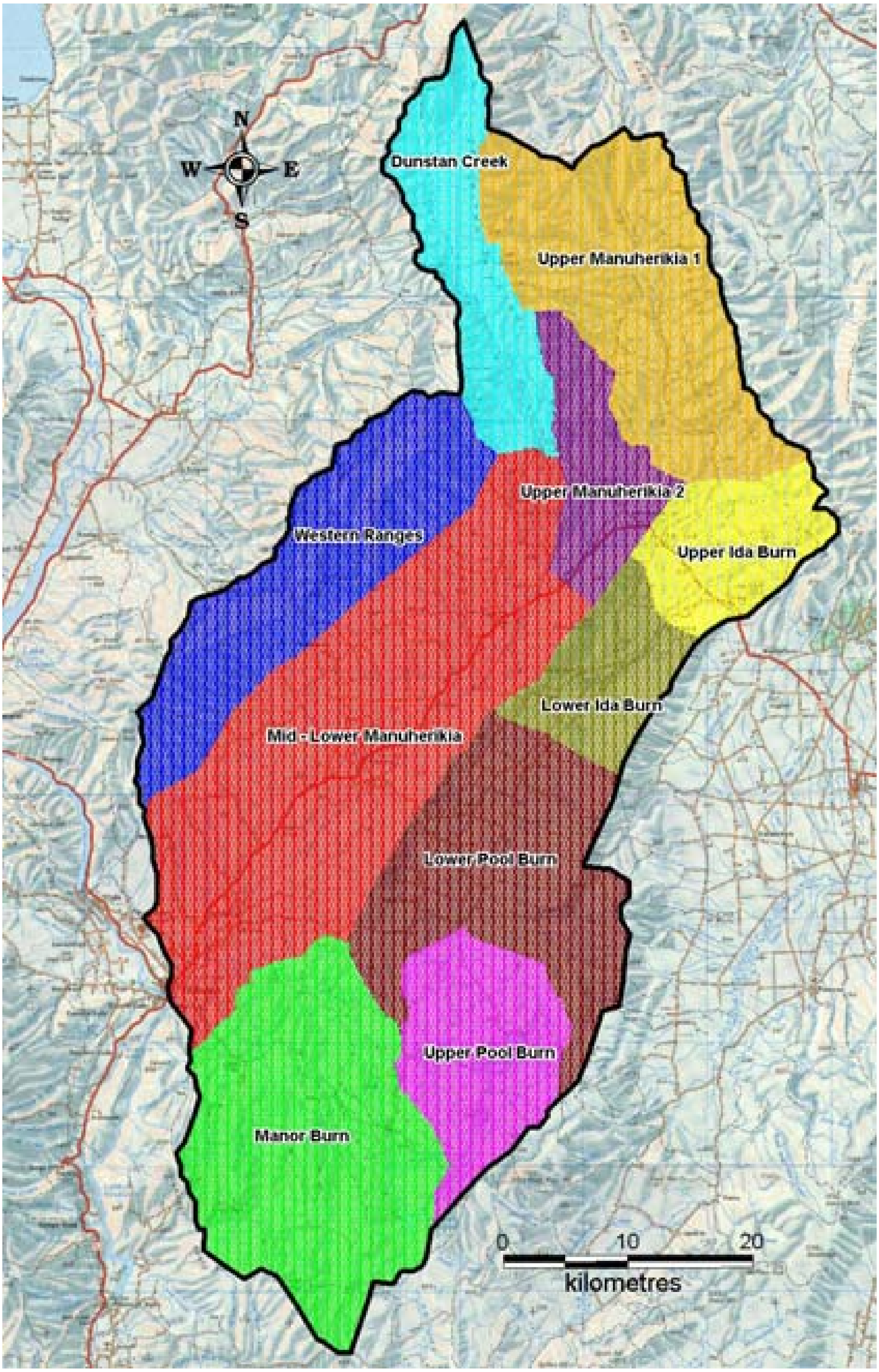

Figure 2.4 Hydrological Regions of the Manuherikia Catchment based on naturalised low flow yields

Flow relationships between actual gauged flows and expected natural flows have been developed for sections and tributaries of the Manuherikia River based on the above hydrological regions (Table 2.4).

Table 2.4 Summary of estimated specific yield for the Manuherikia Catchment

Region	Sub-Catchment	Area (Km^2)	Specific yield ($l/s/km^2$)	Actual gauged flows (m^3/s)	Sub-Catch expected natural flow (m^3/s)	At site expected natural flow (m^3/s)
Upper Manuherikia 1	D/S Falls Dam	372	4.2	3.767	1.562	1.562
Upper Manuherikia 2	D/S Falls Dam to Waldrons	117	1	3.865	0.117	1.679
Dunstan Ck	Upstream of Loop Rd	188	3.5	0.689	0.658	0.658
Upper Ida Burn	U/S Hills Ck	144	2	0.033	0.288	0.288
Lower Ida Burn	D/S Hills Ck to Auripo Rd	125	0.2	0.008	0.025	0.313
Upper Pool Burn	U/S Webster Rd & Aston Rd	199	0.75	0.01	0.149	0.149
Lower Pool Burn	Upstream to Auripo Rd	344	0.15	0.002	0.052	0.201
Manor Burn	At dam	470	0.75	0.226	0.353	0.353
Western Ranges	Shepherds Ck to Younghill Ck	352	2.5		0.880	0.880
Total Catchment		3085	1.4	1.869		4.2

Table 2.4 shows that actual gauged flows and the expected natural flows can be very different depending on where in the catchment correlations are drawn. Note that the at-site expected natural flow (right hand column) may show flow contributed from more than one sub-catchment. For example, the expected natural flow at Falls Dam was 1.562m^3/s but it was gauged far higher at 3.767 m^3/s. This is due to water being released from Falls Dam for downstream irrigation takes. At Alexandra, the expected natural flow was 4.2 m^3/s but actual gaugings showed far less at 1.869m^3/s. Thus, at least 50% of the flow had been lost due to taking.

2.7 The Manuherikia fishery

The Manuherikia River supports a diverse fishery, with 12 species of fish and one species of freshwater crayfish listed as being present in the catchment (NIWA freshwater database, Otago Regional Council records) (Figure 2.5 and Figure 2.6). There are four species of introduced sports fish found in the Manuherikia Catchment, however, information from Fish and Game Otago states that chinook salmon *(Oncorhynchus tshawytscha)* also use the river to spawn (Section 3.2.1). Brown trout (*Salmo trutta*) are easily the most common species of fish in the catchment (Figure 2.5). Nine of the 13 species listed by the NIWA fish database and recorded in Otago Regional Council surveys are native (Figure 2.6).

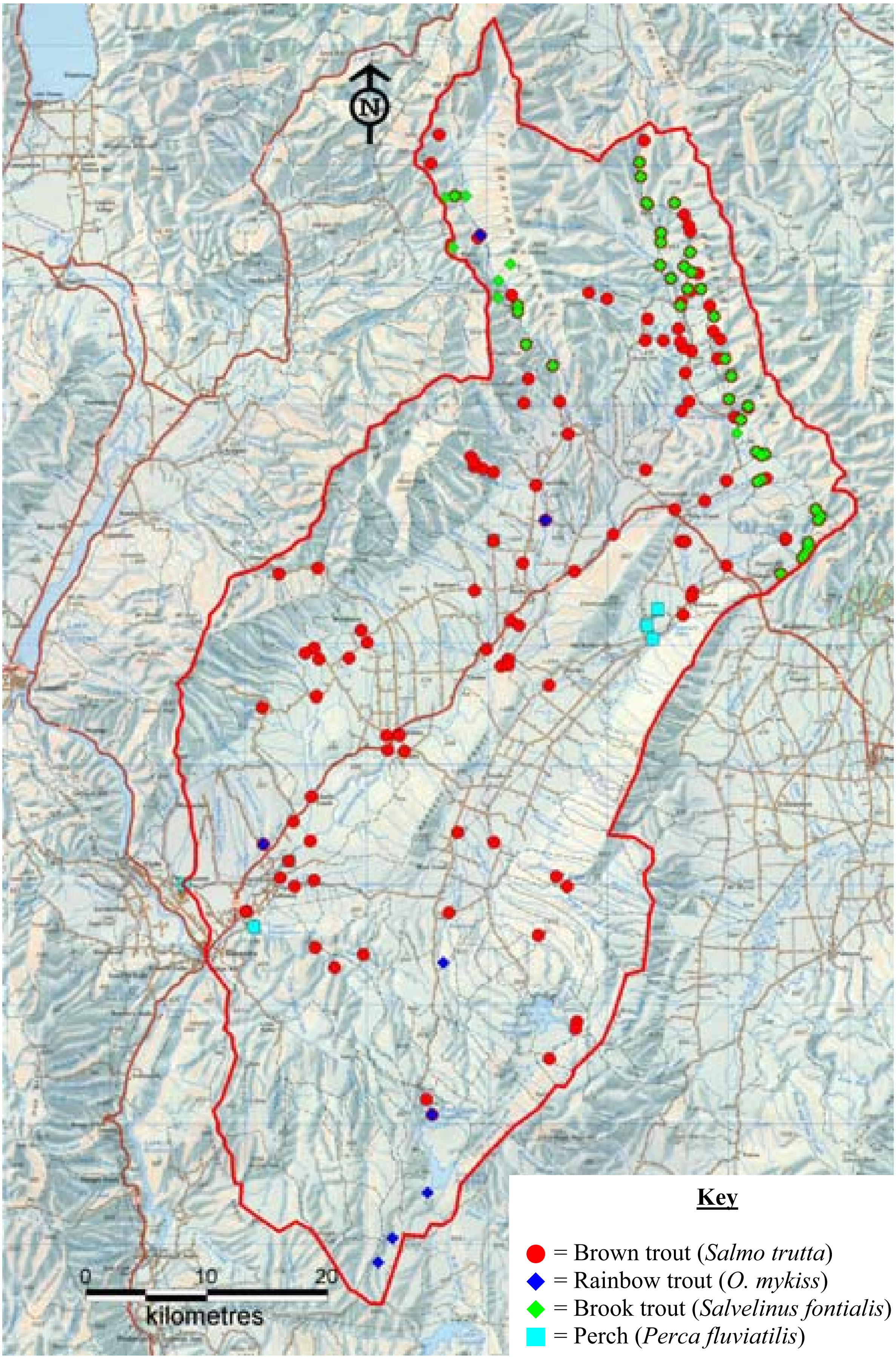

Figure 2.5 Sites where sports fish have been recorded in the Manuherikia Catchment. Data from the NIWA freshwater fish database and ORC surveys

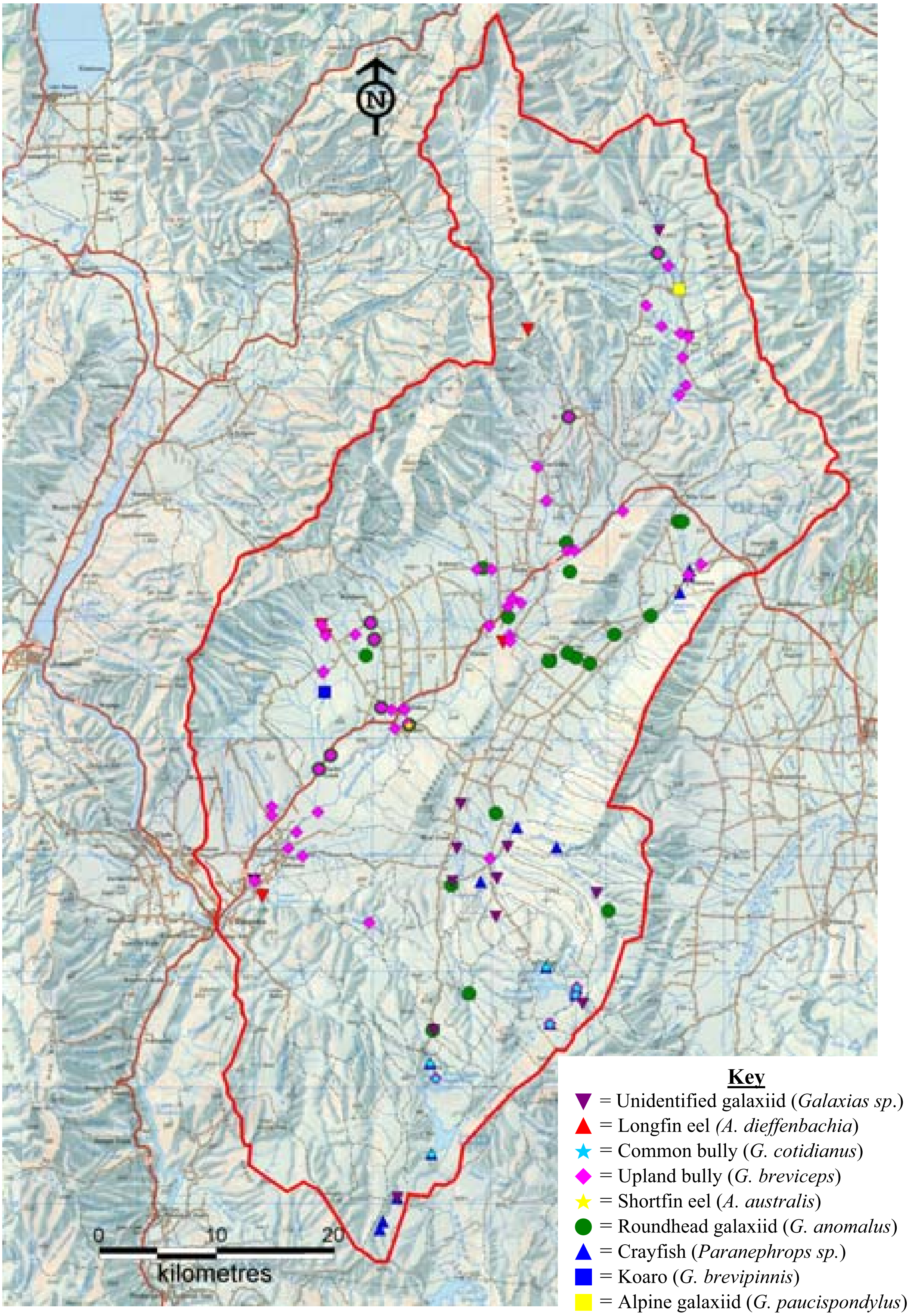

Figure 2.6 Sites where native fish have been recorded in the Manuherikia Catchment. Data from the NIWA freshwater fish database and ORC surveys

3. Biodiversity and recreational values

The Manuherikia River is one of the largest tributaries of the Clutha River/Mata-Au, and has many biodiversity and recreational values that make it of interest to the public. Below is a summary of information available on the Manuherikia Catchment with information incorporated from agencies that have an interest in the flow regime of the Manuherikia River.

3.1 Biodiversity values

The Water Plan[5] lists many natural values for the Manuherikia River and tributaries are of high natural value particularly for roundhead galaxiids and invertebrate diversity. Also, the area upstream of Falls Dam is recognised as important habitat for the internationally uncommon black fronted tern. Further information supplied from the Department of Conservation Otago is based on a bird survey carried out by the Ornithological Society of New Zealand in November 1991. Sixty kilometres of river was surveyed from the confluence with the Clutha/Mata-Au to above Falls Dam. Nineteen species of river birds were recorded, 16 of which are native (Schweigman, 1992). Excessive broom and gorse growth on the gravel beaches of the streambed were noted as reducing river bird habitat (Schweigman, 1992).

3.2 Recreational values

The most significant active recreational pursuit carried out on the Manuherikia River is angling. For this reason it is the main focus of this section. However, it is noted that other pursuits such as kayaking and swimming occur within the catchment.

3.2.1 Sports fish species and angling reaches

The Water Plan[6] identifies the Manuherikia River and tributaries as having high natural value particularly for brown trout fry habitat, trout spawning habitat and adult trout habitat. Further information supplied from Fish and Game Otago is as follows.

The Manuherikia River is a popular fishery with local and visitor anglers. The popularity of this river has increased from approximately 3000 angler visits in 1984 (Richardson et al., 1984) and 3536 in 1996 (Unwin & Brown, 1998), to 5629 angler visits in 2001-02 (Unwin & Image 2003). The Manuherikia River has gone from the 5th most popular river for trout fishing in Otago in 1996 to 4th in 2003, though the difference between angler visits for the 3rd and 4th are very small.

Popular areas early in the season include opposite the Alexandra Holiday Park, upstream of the Galloway Bridge, and from the Omakau Bridge downstream to the start of the gorge. In addition, fly anglers target stretches of the river further upstream with sections around Becks and Lauder popular (Hollows 2003).

Angler observations note that later in the season fish tend to be harder to catch as they get stressed by low flows and associated warmer water temperatures. Some fish migrate into sections of the river such as the gorge downstream of Omakau or into the

5 Schedule 1A of Water Plan (2004), pg 296.
6 Schedule 1A of Water Plan (2004), pg 296.

Clutha River/Mata-Au to escape the effects of low flows. This is recognised in the angling patterns of guides that target large sections of the lower river early in the season but focus on the gorge section only later in the season. The popularity of the fishery was recognised recently with bag limits for the lower river reduced from six to three fish per person due to angler pressure (Hollows 2003).

The river contains large amounts of spawning gravels and fry rearing habitat for brown and rainbow trout (*Salmo trutta* and *Oncorhynchus mykiss*) mainly, along with a limited number of salmon (*O. tshawytscha*) (Hollows 2003).

4. Physical habitat survey

The Otago Regional Council contracted NIWA to carry out a study to determine the flows required to maintain acceptable habitat for the fish species present in the Manuherikia River.

The primary aims of this study were to:

- Conduct instream habitat surveys in critical reaches of the Manuherikia River.
- Conduct a hydraulic analysis in the above streams using RHYHABSIM (Jowett 1989) to determine how weighted usable area (WUA) for brown trout and native fish habitat varies with flow.
- Assess flow requirements for the Manuherikia based on the habitat requirements of the native and introduced fish species.

4.1 Instream flow incremental methodology (IFIM) summary

The instream flow incremental methodology (IFIM) (Bovee 1982) is an example of a holistic way to determine an appropriate flow regime by considering the effects of flow changes on instream values, such as river morphology, physical habitat, water temperature, water quality, and sediment processes. As habitat methods are based on quantitative biological principles, they are considered more reliable and defensible than assessments made in other ways (White 1976; Annear & Conder 1984; Dunbar et al., 1998; Tharme 1996; Annear et al., 2002). Their strength lies in their ability to quantify the loss of habitat caused by changes in the natural flow regime, which helps the evaluation of alternative flow proposals (Jowett 2004).

Providing or retaining suitable physical habitat for aquatic organisms that live in a river is the ecological aim of IFIM assessments. Habitat methods allow for a more focused flow assessment and can potentially result in improved allocation of resources (Jowett 2004). However, it is essential to consider all aspects such as food, shelter, and living space and to select appropriate habitat suitability curves for an assessment to be credible (Orth 1987; Jowett 1995; Biggs 1996).

4.1.1 Habitat preferences and suitability curves

The aim of the IFIM is to maintain, or even improve, the physical habitat for instream values. The IFIM requires detailed hydraulic data, as well as knowledge of the ecosystem and the physical requirements of stream biota. The basic premise of habitat methods is that if there is no suitable physical habitat for the given species, then they cannot exist. However, if there is physical habitat available for a given species, then that species may or may not be present in a survey reach, depending on other factors not directly related to flow, or to flow related factors that have operated in the past (e.g., floods). In other words, habitat methods can be used to set the "outer envelope" of suitable living conditions for the target biota (Jowett 2004).

Biological information is supplied in terms of habitat suitability curves for a particular species and life stage (Jowett 2004). A suitability value is a quantification of how well suited a given depth, velocity or substrate is for the particular species and life stage (Jowett 2004). The result of an instream habitat analysis is strongly influenced by the habitat criteria that are used. If these criteria specify deep water and high velocity requirements, maximum habitat will be provided by a relatively high flow. Conversely, if the habitat requirements specify shallow water and low velocities, maximum habitat will be provided by a relatively low flow and habitat will decrease as the flow increases. The suitability curves developed in New Zealand for large, feeding adult brown trout (Hayes & Jowett 1994) specify higher depth and velocities than curves for adult brown trout developed in the United States (Raleigh et al., 1986). Whether this is due to differences in the sizes of fish has not been clarified. However, it is clear that it is important to use suitability curves that are appropriate to the river and were developed for the same size and life stage of fish, and behaviour, as those to which they are applied.

Generally, native fish are found in similar habitats over a wide range of rivers. McDowall (1990) has described these habitats in descriptive terms. The quantitative approach taken in New Zealand has been to develop general habitat suitability criteria for species of interest by using data collected from several rivers. To date, general habitat suitability curves have been developed for several native fish species, some of it published (e.g., Jowett & Richardson 1995) and some of it unpublished.

4.2 IFIM for the Manuherikia River below Ophir

The lower Manuherikia River flows through developed farmland and a series of gorges across a bed of coarse gravel and large cobbles. The lower Manuherikia follows the classic riffle, run, pool morphology.

The habitat survey of the lower Manuherikia River was carried out at a flow of 7.4m^3/s, with calibration measurements at flows of 1.4m^3/s and 1.0m^3/s. At the survey flow of 7.4m^3/s, the average width of the river was 24m, depth 0.40m, and velocity 0.71m/s. The substrate in riffles was mainly cobbles (64-256mm), whereas gravel (8-64mm) dominated runs. Overall, gravel was the dominant substrate (51%), with 16% cobble, and 26% fine gravel (2-8mm).

This river is a recognised brown trout fishery and maximum adult trout habitat was provided by a flow of 4.25m^3/s, with the amount of suitable trout habitat falling sharply when flows fall below about 2.5m^3/s (Figure 4.1). Maximum brown trout fry habitat was provided by a flow of 1.25m^3/s, whereas yearling trout had slightly higher flow requirements, with maximum habitat provided by a flow of 2.0 m^3/s. However, the amount of both yearling and fry habitat began to reduce sharply at a flow of 0.9 m^3/s. Maximum habitat for upland bullies and roundhead galaxiid was provided by very low flows (0.25 m^3/s) but common bully habitat was greatest at a flow of 1.25 m^3/s and began to fall sharply when flows fell below about 0.5 m^3/s.

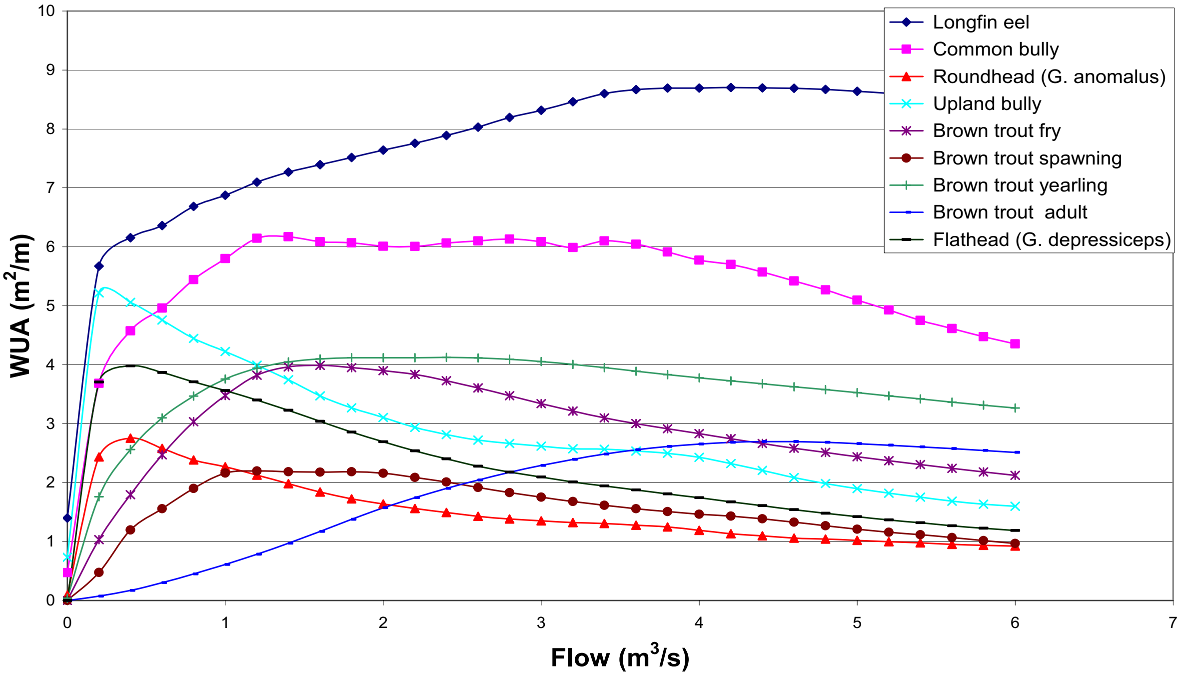

Figure 4.1 Variation of instream habitat below Ophir with flows up to 6m^3/s

4.3 Discussion – IFIM and management objective

The IFIM data provided an overview of the flow requirements of different fish species to maintain their preferred habitat requirements (Table 4.1). Flow requirements can be selected so that they provide maximum habitat, or selected so that they prevent a serious decline in fish habitat. The flow below which habitat declines sharply is known as the point of inflection, it is a point of diminishing return, where proportionately more habitat is lost with decreasing the flow than is gained with increasing the flow. Different size classes of fish and fish species have different points of inflection. Ecologically the point of inflection represents the flow below which there is serious risk of losing sufficient habitat to maintain a size class of fish or species of fish, or perhaps an existing population.

Clear management objectives are necessary when applying IFIM data (Hudson et al., 2003; Jowett & Wilding 2003). The Manuherikia River is one of the most important trout fisheries in the Otago region. The recommended management objective for the Manuherikia River is to sustain the significant presence of trout in accordance with Schedule 1A of the Water Plan[7].

[7] Schedule 1A of Water Plan (2004), pg 296.

Table 4.1 Flow requirements for fish species below Ophir in the Manuherikia River

Target fish species	Optimum flow (m^3/s)	Flow below which habitat declines sharply (m^3/s)
Adult brown trout	4.25	2.5
Yearling brown trout	2.0	0.9
brown trout fry	1.25	0.9
Roundhead galaxiid	0.25	
Upland bully	0.25	
Common bully	1.25	0.5
Longfin eel	4.2	0.4

Note, the recorded 7-day MALF at Ophir, affected by water takes, is 1.94 m^3/s.

5. Flow requirements: discussion and suggested management flows for aquatic habitat

Under the Water Plan[8], Otago rivers will have minimum flows set to provide for the maintenance of aquatic ecosystems and natural character under low flow conditions. Under the Water Plan[9], when minimum flow levels are reached all consents that are subject to that minimum flow are to cease taking.

5.1 Manuherikia River flows discussion based on technical information

The flows required to maintain introduced sports fish such as trout are generally much greater than those required by native fish. Often optimum flow range is far greater than the flows required to simply maintain habitat for a particular size class or fish species (Table 4.1). Jowett & Wilding (2003) suggest that if a minimum flow of 2.5 m^3/s was applied to the Manuherikia at Ophir, it would have little effect on the trout fishery as the MALF recorded at Ophir is 1.94 m^3/s. On face value this seems a fair assumption but it must be noted that the MALF value for the flow site at Ophir is influenced heavily by irrigation, with close to 17.0 m^3/s allocated upstream of it (Water Plan 2004). Therefore, it does not represent a natural MALF. Through analysis of natural flow at the outlet of the Manuherikia River at Alexandra, MALF would be approximately 4.2m^3/s (Table 2.4).

Jowett (1990, 1992) found that the percentage of adult trout habitat at the 7-day mean annual low flow (MALF) acts as a bottleneck to trout density. The IFIM data suggest that flows of 4.25m^3/s provide optimum habitat for adult brown trout (Table 4.1). Therefore, as the natural MALF (4.2 m^3/s) of the Manuherikia is almost the same as the flows required to provide optimum habitat (4.25 m^3/s) the natural mean annual low flow would not restrict the adult brown trout fishery.

Consideration should also be given to the fact that most fish species are adept at moving to more hospitable or refuge environments when local conditions become too harsh (Davey et al., 2006). In order for this type of response to occur, flows should not be allowed to recede suddenly to a point that fish passage is not maintained. At times of low flow in the lower Manuherikia, the Clutha River/Mata-Au will act as a refuge for large sports fish as long as adequate flows for fish passage are maintained.

Further issues that arise when setting minimum flows revolve around the impact on instream ecology caused by extreme low flows, low flow duration and flow variability (Fisher et al., 1982; Jowett, 1990; Jowett 1992; Peterson and Stevenson 1992; Dent & Grim 1999; Suren et al., 2003a; Suren et al., 2003b). Long duration low flows with little flow variability can promote excessive periphyton growth, lower invertebrate diversity and contribute to increased water temperatures which may impact on fisheries (Jowett, 1990; Jowett 1992; Suren et al., 2003a; Suren et al., 2003b).

The hydrological regime of the Manuherikia is heavily modified due to the presence of several large storage reservoirs (Poolburn, Manorburn and Falls Dam) and a large

[8] Policy 6.4.3 of Water Plan (2004), pg 61
[9] Policy 6.4.11 of Water Plan (2004), pg 69

number of water takes. Falls Dam is by far the most influential on the flow regime in the main stem of the Manuherikia during the irrigation season. Flows immediately below Falls Dam can be significantly higher than would be expected in low flow periods due to augmentation (Upper Manuherikia 1 in Table 2.4). As a result, the sports fishery has benefited in some reaches of the Manuherikia. However, it must be acknowledged that low flows below Galloway can be lower than would naturally be expected and are likely to affect the sports fishery in this area (Total catchment in Table 2.4).

Falls Dam has been operational in excess of 70 years and considerable seasonal flow variation has been recorded at Ophir (Figure 2.2). However, if Falls Dam were to be enlarged to increase its storage capacity or further storage impoundments were commissioned within the Manuherikia Catchment, flow variation would need to be considered.

The Manuherikia River is considered a significant trout fishery, with some sections of the river being more productive than others during low flows (Section 3.2.1). The recommended management objective for the Manuherikia River is to sustain the presence of trout in accordance with Schedule 1A of the Water Plan[10] (2004). Other ecosystem values listed in Schedule 1A are expected to be sustained at flows provided to sustain brown trout.

The IFIM data suggest that a minimum flow of $2.5m^3/s$ in the lower Manuherikia will provide adequate habitat to sustain adult brown trout. If yearling trout, or brown trout fry are to be sustained the flow required is only $0.90\ m^3/s$.

In order to achieve a flow of $2.5m^3/s$, a flow of approximately 1.8 - $2.1\ m^3/s$ would need to be passing the Ophir flow recorder site with little if any taking being carried out in the catchment downstream of Ophir. This is of note as the minimum flow set in the Water Plan for Ophir is $0.82m^3/s$[11].

5.2 Flow expected at Alexandra with $0.82\ m^3/s$ at Ophir

As a minimum flow has already been set through the water plan process on the Manuherikia at Ophir, consideration must be given to what flows could be expected at Alexandra if $0.82m^3/s$ was flowing past Ophir.

The Manuherikia Catchment can be divided into 10 hydrological regions (Figure 2.4). Three of these regions occur in the catchment below Ophir (Figure 5.1). Specific yields at low flows have been calculated for the three hydrological regions below Ophir. These have differing specific yields at times of MALF (SMALF) and as a result are expected to contribute differing flows to the Manuherikia River (Table 5.1).

[10] Schedule 1A of Water Plan (2004), pg 296.
[11] Schedule 2A of Water Plan (2004), pg 314

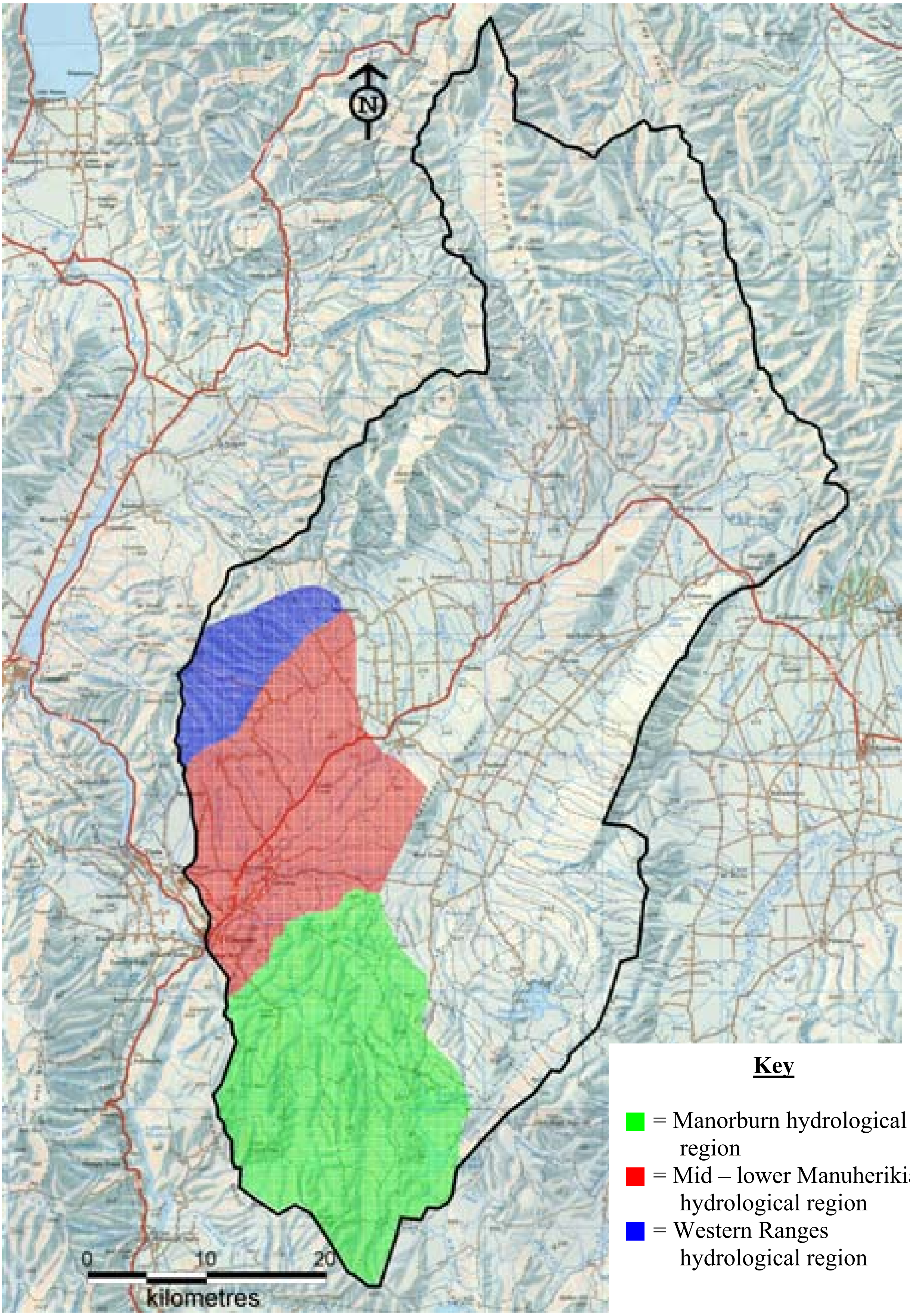

Figure 5.1 Hydrological regions of the Manuherikia Catchment below Ophir

Table 5.1 Specific yields and expected flows for the hydrological regions of the Manuherikia Catchment below Ophir

Hydrological region	SMALF (l/s/ km^2)	Catchment area of hydrological region (km^2)	Expected flows (m^3/s)
Mid-Lower Manuherikia	0.2	349	0.071
Manorburn	0.75	445	0.334
Western Range	2.5	90	0.225
TOTAL		**889**	**0.630**

From the specific yields at times of MALF, the Manuherikia Catchment below Ophir would be expected to contribute approximately 0.63m^3/s (Table 5.1). The current minimum flow for the Manuherikia below Ophir is 0.82m^3/s. Therefore, if Ophir was delivering 0.82m^3/s, the most that would be expected at Alexandra during average low flow conditions would be 1.45m^3/s.

However, a natural flow of 0.82m^3/s at Ophir exceeds a 1 in 100 year 7-day low flow ($Q_7$100) for the Manuherikia River. Two sites upstream of the Ophir recorder, Dunstan Creek at Dunstan Gorge and the Manuherikia downstream of the Forks (above Falls Dam), are unaffected by irrigation. Dunstan Creek at the Gorge has a $Q_7$100 low flow of 0.416m^3/s and the Manuherikia at DS Forks has a $Q_7$100 low flow of 0.51m^3/s (Table 2.3). Therefore, it would be expected that flows at Ophir would be higher than the sum of the recorded flows at the Manuherikia downstream of the DS Forks and Dunstan Gorge sites, as Ophir is downstream of where these flows merge.

If the $Q_7$100 low flows for the Manuherikia at DS Forks and Dunstan Creek at the Gorge are simply added, then at least 0.93m^3/s would be expected at Ophir in a natural $Q_7$100 low flow event (Table 2.3). This doesn't take into account the further 1777km^2 of catchment that would contribute natural flows to the Manuherikia River between Manuherikia downstream at DS Forks, Dunstan Creek at the Gorge and the Ophir minimum flow site (Figure 2.3).

In a $Q_7$100 low flow period, the specific yields for the three hydrological regions below Ophir are likely to be lower than those shown above (Table 5.1). The specific yields used in Table 5.1 reflect expected low flows on an annual basis. They do not reflect the extremes of a $Q_7$100 low flow event. As it has been determined that a natural low flow of 0.820m^3/s at Ophir exceeds a $Q_7$100 low flow, the same sort of return period for flows in the lower Manuherikia River would be closer to 1.0m^3/s than 1.45m^3/s.

5.3 Suggested management flows for aquatic ecosystems

It is recommended that seasonal management flows are implemented in the Manuherikia Catchment. This would recognise that there is clear seasonal variation in flows in the river, with high flows occurring from May to October and lower flows typically occurring from November to April (Figure 2.2). By implementing higher management flows during the period when there is naturally high flows in the river (May to October), some form of seasonal flow variation is provided for. Flow variation is seen as important for numerous ecological reasons including removing algal growth, lowering water temperatures and providing for fish migration. Brown trout migration and spawning tends to occur over the winter period when flows are naturally higher and allows for upstream migration.

A flow of **4.25m^3/s** below all takes in the lower Manuherikia River is likely to ensure the sustainability of the fish community in that reach during the high flow period May to October as is a flow of **0.90m^3/s** during the lower flow period November to April. It is suggested that flows should not be allowed to drop below those flows due to consumptive use.

The low flow period management flow of **0.90m^3/s** is the point of inflection indicated by the IFIM survey for yearling brown trout (Table 4.1). A flow of **0.90m^3/s** will also provide adequate fish passage from the lower Manuherikia to the Clutha River/Mata-Au or alternatively to reaches further upstream that may receive more flow due to Falls Dam flow augmentation.

The management flow for the high flow period, May to October, represents the flows that provide optimum adult brown trout habitat indicated by the IFIM survey (Table 4.1). A flow of **4.25m^3/s** in the lower Manuherikia is well within the natural hydrological constraints of the Manuherikia River, on average, for the period May to October (Figure 2.3).

The management flows of **0.90m^3/s** (November to April) and **4.25m^3/s** should also maintain the natural character of the Manuherikia River, thus fulfilling the criteria of Objective 6.3.1 of the Water Plan (2004).

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8. Glossary of Terms

7-Day MALF	The mean of the lowest 7-day average flow for each hydrological year of record.
$Q_7$10	The 7-day low flow with the likelihood of occurring once in a 10 year period.
Pool	Aquatic habitat characterised by slow flowing, deep water with an unbroken surface.
Return Period	Sometimes called the recurrence interval. Return period is the means of expressing the statistical likelihood of a low or flood flow occurring.
Riffle	Aquatic habitat characterised by shallow, stony, fast flowing (where the surface of the water is broken) conditions, favoured by most aquatic invertebrates.
Run	Aquatic habitat characterised by obvious flow, but without the rapid, broken surface conditions of a riffle.
SMALF	Specific discharge from one unit catchment area at times of MALF.
Weighted Usable Area (WUA)	WUA (m^2/m) is the measure of the total area of suitable habitat per metre of stream.