MINISTRY OF AGRICULTURE AND FISHERIES
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MAF

# SWORD FEASIBILITY STUDY - STAGE 3

# INITIAL ASSESSMENT OF IMPLICATIONS TO BENTHIC AND FISHERIES HABITAT OF THE OPIHI RIVER

by

K L Palmer

P M Sagar

Report to: Davie, Lovell-Smith

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Servicing freshwater fisheries and aquaculture

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NEW ZEALAND FRESHWATER FISHERIES MISCELLANEOUS REPORT NO. 34

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## NEW ZEALAND FRESHWATER FISHERIES MISCELLANEOUS REPORTS

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## SUMMARY

The Opihi River fishery has declined this century. River and catchment modifications have impacted on channel width, lagoon size, instream flows and salmonid fishing. Irrigation abstraction, particularly since LPIS, has left the reach between Pleasant Point and the confluence with Temuka River without a flow during a portion of many years.

Introduction of Tekapo source water will impact in unknown ways on the 18 fish species present and particularly the reach between Burkes Pass and Firewood Stream.

If source water is left instream to provide for a minimum 3 $m^3/_s$? flow at SH 1 augmentation will alleviate some previous problems associated with low flows - lack of continuous water flow, frequent occurrence of a closed river mouth and its associated problems (elevated water temperature, high pH in the lagoon). Increased flow above Firewood Stream could increase available spawning and rearing habitat for salmonids and native fishes.

If augmentation proceeds as described in SWORD Feasibility Study Stage 1 many problems could also be fostered including:

1. Unknown degradation of Opihi water quality due to turbid Tekapo water.
2. Unknown increase in suspended sediment load due to large increase or fluctuation in flow in the Burkes Pass area.
3. Unknown change in water quality due to elevated water temperatures from Tekapo canal water.

4. Problems associated with dewatered salmonid redds and stranding or dessication of aquatic habitat with fluctuations in source flow and cessation of flow at the end of the irrigation season.

If augmentation water does not remain instream in sufficient volume to create a continuous flow from Burkes Pass to the sea, habitat increases in the upstream areas would be a minor benefit for the fish and anglers of the lower river.

All studies of benthic invertebrates in the Opihi have been concerned with the effects of pollution or low flows in the lower river. These studies show that the Opihi River supports a diverse and abundant population of benthic invertebrates, typical of small, relatively stable, clearwater rivers in Canterbury. Below Pleasant Point, low or discontinuous flows adversely affect these populations, but recovery is rapid with the return of high flows.

Augmentation of the Opihi River with water from Lake Tekapo is likely to increase the habitat available for benthic invertebrate populations and to take full advantage of this, the occurrence of artificially induced flow fluctuations should not exceed those which occur naturally. The presence of silt in water from Lake Tekapo is likely to decrease benthic invertebrate populations, with the dominant taxa being those most likely to be affected. Further studies are required to quantify the extent of these effects.

## Introduction

In all natural systems many factors interact to affect physical conditions. These physical conditions interplay with the biotic factors to create very complicated systems. It is impossible to completely understand or predict eventual outcomes of dramatic changes to dynamic riverine ecosystems. Augmenting flow in the Opihi River by transferring water from the Tekapo catchment will have many effects upon the receiving water system and its biota. Even with extensive research many of the reactions that will occur cannot be accurately predicted.

The purpose of this report is to:

1. Identify benthic invertebrate and fisheries species present in the Opihi River system and the likely effects to population numbers and distribution resulting from the proposed diversion.

2. Identify salmonid spawning and rearing areas within the Opihi and examine the effects which may or may not accrue.

3. Identify the minimum flows and, or water depths necessary to maintain fish passage to and from the salmonid spawning areas.

4. Evaluate the impact of waters containing glacial slit together with higher suspended sediment loadings resulting from increased (temporary) bed and bank erosion, and the effects, if any, that such increased turbidity might have on the fisheries environs of the upper Opihi River upstream of Firewood Stream.

5. Evaluate the impact to fisheries resulting from the projected hydrological regime changes, in particular increased and more consistent summer flows throughout much of the Opihi (as distinct from the Opuha and Tengawai tributaries). Identify any implications in respect of juvenile fish rearing and migration, and identify the necessity or otherwise for fish screening.

# 1.0 The Present Resource

## 1.1 Benthic Invertebrates

### 1.1.1 Species Present

Three surveys of benthic invertebrates in the Opihi River have been undertaken. During March/April 1960 G.A. Eldon examined benthic invertebrates as part of an investigation into reasons for the decline of the Opihi River trout fishery. Then from March to July 1972 C.R. Fowles examined some of the effects of reduced flows on the benthic invertebrates and on associated physical and chemical factors. From October 1983 to April 1984 P.M. Sagar collected benthic invertebrates monthly as part of a study designed to investigate the fisheries potential of the Levels Plain Irrigation Scheme (LPIS).

In March/April 1960 benthic invertebrates were collected from four sections of the Opihi (Eldon 1960). Above the Temuka confluence there was a decrease in the density and diversity of the benthic invertebrates with increasing distance upstream (Table 1); no explanation for this was suggested. In these sections (B-D), the fauna was dominated by mayflies (*Deleatidium* spp.), caddisflies (*Aoteapsyche* spp.), and riffle beetles (Elmidae). In section A, below the confluence of the Temuka River but above any tidal influence, there was a considerable change in the bottom fauna. Here the density and diversity of invertebrates was less than in Section B. There were also significant changes in the composition of the fauna, the freshwater snail *Planorbis* (=*Gyraulus*) formed 31% of the total and only three specimens of *Deleatidium* were found.

TABLE 1. Density (ca/0.1 $m^2$) and percentage composition of benthic invertebrates in four sections of the Opihi River, March/April 1960. Data from Eldon (1960)

| | | | % composition | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Section | No. Taxa | Density | Ephemeroptera | Trichoptera | Plecoptera | Coleoptera | Chironomidae | Mollusca | Others |
| A | 12 | 212.8 | | | | | | | |
| B | 19 | 375.5 | 42 (97% <u>Deleatidium</u>) | 12.2 (83.5% <u>Aoteapsyche</u>) | 0.2 | 14.8 | 11.3 | 12.5 | 6.9 |
| C | 17 | 236.5 | | | | | | | |
| D | 12 | 49.5 | | | | | | | |

The sections were located as follows:

Section A: From the mouth to the confluence of the Temuka River.

Section B: From the Temuka River to the LPIS intake.

Section C: From the LPIS intake to the confluence of the Opuha River.

Section D: From the Opuha upstream.

This change was attributed to pollution of the river below the Temuka confluence.

Fowles (1972) found that the diversity and average density of benthic invertebrate populations below the LPIS intake were much lower than those above the intake (Table 2). Also, above the intake the fauna was dominated by caddisflies (*Pycnocentrodes* sp. - 63% of the total fauna) and mayflies (*Deleatidium* spp. - 20%). These invertebrates were important components of the fauna below the intake, comprising 24% and 12% respectively; however, riffle beetles (Elmidae) increased in importance from 6% to 44% of the total. These differences in diversity, dominance, and density were attributed to the drying up of the riverbed below the LPIS intake, where continuous flow had begun only 2-3 weeks before the samples were collected. Overall, Fowles identified 30 taxa in his samples from this part of his study.

During the summer of 1983/84, monthly sampling of benthic invertebrates at sites between Mill Road and the State Highway 1 bridge showed a fauna similar to that of other small, clear-water rivers in Canterbury (Sagar, unpublished). A total of 46 taxa was identified, with 26 to 31 being recorded each sampling period (Table 3). As found by Fowles (1972), the fauna was dominated by mayflies (*Deleatidium* - 54% of the total), riffle beetles (*Hydora* - 20%), and caddisflies (*Pycnocentrodes* - 9%). There was continuous flow throughout this section of the river during this study and fluctuations in the density of invertebrates populations were associated with minor floods and life history characteristics of the different taxa.

TABLE 2. Systematic list of invertebrates recorded in the benthos of the Opihi River, April 1972. Mean densities per 0.1 $m^2$ are given for taxa which averaged >1 individual per sample; * = <1/0.1 $m^2$; – not present. Data adapted from Fowles (1972).

| Taxon | Above LPIS intake | Below LPIS intake |
|---|---|---|
| HIRUDINEA | * | * |
| GASTROPODA | | |
| *Physa* sp. | * | * |
| *Potamopyrgus antipodarum* | 3.8 | * |
| *Gyraulus* sp. (= *Planorbis*) | * | – |
| NEMATODA | * | – |
| OLIGOCHAETA | * | * |
| COPEPODA | | |
| *Herpetocypris pascheri* | * | * |
| AMPHIPODA | | |
| *Paracalliope fluviatilis* | * | – |
| EPHEMEROPTERA | | |
| *Nesameletus* sp. | * | – |
| *Deleatidium* sp. | 41.8 | 4.8 |
| *Zephlebia* sp. | * | – |
| PLECOPTERA | | |
| *Aucklandobius trivacuata* | * | – |
| TRICHOPTERA | | |
| *Paroxyethira* sp. | – | * |
| *Oxyethira albiceps* | * | * |
| *Aoteapsyche colonica* | 6.7 | 2.7 |
| *Hydrobiosis clavigera* | * | – |
| *H. umbripennis* | 2.9 | * |
| *Polyplectropus* sp. | * | – |
| *Pycnocentrodes* sp. | 131.6 | 9.9 |
| *Olinga feredayi* | 1.5 | * |
| *Hudsonema amabilis* | * | * |

TABLE 2. cont'd

| | | |
|---|---|---|
| MEGLOPTERA | | |
| *Archichauliodes diversus* | * | * |
| COLEOPTERA | | |
| *Hydora* sp. | 12.8 | 17.7 |
| DIPTERA | | |
| Tipulidae | * | – |
| Chironomidae | 1.9 | 1.3 |
| *Austrosimulium* sp. | * | * |
| Ephydridae | * | – |
| ACARINA | * | * |
| TOTAL | 208.2 | 40.5 |
| No. taxa | 25 | 18 |

TABLE 3. Systematic list of invertebrates recorded in the benthos of the Opihi River (from Mill Road to SH 1 bridge), October 1983 - April 1984. Mean densities per 0.1 $m^2$ are given for taxa which averaged >1 individual per sample; * = <1/0.1 $m^2$; - not present.

| Taxon | 10/83 | 11/83 | 1/84 | 2/84 | 3/84 | 4/84 |
|---|---|---|---|---|---|---|
| HIRUDINEA | * | - | - | * | * | * |
| GASTROPODA | | | | | | |
| *Physa* sp. | * | - | * | * | * | * |
| *Potamopyrgus antipodarum* | 1.3 | * | * | 2.9 | 1.3 | 5.6 |
| *Gyraulus* sp. | - | - | - | * | - | - |
| NEMATODA | - | * | * | - | - | - |
| OLIGOCHAETA | 13.8 | 23.6 | 7.8 | 37.7 | 10.3 | 26.3 |
| AMPHIPODA | | | | | | |
| *Paracalliope fluviatilis* | - | 1.0 | * | * | * | * |
| *Phreatogammarus* sp. | - | - | - | * | - | * |
| EPHEMEROPTERA | | | | | | |
| *Nesameletus* sp. | * | * | * | 1.0 | - | - |
| *Coloburiscus humeralis* | * | * | - | - | * | * |
| *Deleatidium* spp. | 232.2 | 353.4 | 228.8 | 321.7 | 141.3 | 276.2 |
| *Atalophlebiodes cromwelli* | - | - | - | - | * | - |
| *Neozephlebia scita* | - | 5.7 | 1.7 | - | - | * |
| PLECOPTERA | | | | | | |
| *Stenoperla prasina* | - | - | - | - | * | - |
| *Zelandobius furcillatus* | 1.5 | 1.0 | - | - | * | 1.8 |
| TRICHOPTERA | | | | | | |
| *Oxyethira albiceps* | - | - | * | * | * | - |
| *Aoteapsyche colonica* | 6.2 | 10.7 | 13.1 | 9.7 | 8.4 | 20.4 |
| *Aoteapsyche* spp. | 5.9 | - | - | - | - | - |
| *Psilochorema nemorale* | * | * | * | 1.0 | * | 2.6 |
| *P. bidens* | - | - | * | - | - | - |
| *Psilochorema* spp. | 3.2 | * | - | * | * | * |
| *Costachorema callista* | - | - | 1.3 | - | - | 1.2 |
| *C xanthoptera* | - | - | - | - | - | * |
| *Costachorema* spp. | - | - | - | - | - | * |

TABLE 3. cont'd

| | | | | | | |
|---|---|---|---|---|---|---|
| *Hydrobiosis frater* | * | 2.4 | 1.1 | 1.2 | 1.5 | 1.5 |
| *H. parumbripennis* | * | – | 2.0 | 1.2 | * | * |
| *H. umbripennis* | * | * | * | * | * | * |
| *Hydrobiosis* spp. | – | * | * | 2.7 | * | – |
| *Polyplectropus* sp. | – | 1.3 | 3.6 | * | – | – |
| *Hudsonema amabilis* | – | – | * | * | 2.1 | * |
| *Pycnocentria evecta* | – | 4.4 | 1.0 | 2.0 | * | 19.8 |
| *Pycnocentrodes* spp. | 73.9 | 105.8 | 47.3 | 23.6 | 9.8 | 2.8 |
| *Beraeoptera roria* | – | * | – | – | – | – |
| *Olinga feredayi* | 4.5 | 15.8 | 17.2 | 23.3 | 7.8 | 11.7 |
| MEGALOPTERA | | | | | | |
| *Archichauliodes diversus* | * | * | * | * | * | * |
| COLEOPTERA | | | | | | |
| *Hydora* sp. | 43.5 | 174.7 | 73.5 | 124.8 | 25.3 | 130.9 |
| *Berosus* sp. | – | * | * | * | * | – |
| DIPTERA | | | | | | |
| *Zelandotipula* sp. | * | – | – | – | * | – |
| *Aphrophila neozelandica* | * | * | * | * | – | – |
| *Eriopterini* sp. | * | 1.3 | * | 3.0 | 1.4 | 2.8 |
| *Paralimnophila skusei* | – | – | – | – | * | – |
| *?Molophilus* sp. | – | – | * | – | – | – |
| *Austrosimulium* spp. | 1.9 | 3.9 | 24.8 | 8.0 | 2.9 | 8.2 |
| Chironomidae | 3.9 | 10.2 | 18.1 | 10.9 | 3.4 | 5.8 |
| Ceratopogonidae | * | * | * | – | – | – |
| *Mischoderus* sp. | * | – | – | – | – | – |
| TOTAL | 391.9 | 715.4 | 441.4 | 574.7 | 215.5 | 517.6 |
| No. taxa | 26 | 28 | 31 | 29 | 30 | 27 |

### 1.1.2 Effects of Low Flows

The frequent occurrence of low or discontinuous flows in the lower Opihi River is detrimental to the benthic invertebrate populations. Many die from dessication and the growth and development of those that remain is reduced.

With the return of continuous flow, benthic invertebrates are able to recolonise previously dry areas of riverbed by drifting downstream or migrating upstream from unaffected areas, by vertical migration within the substrate, and aerial sources such as oviposition (Williams and Hynes 1976). An indication of the rate of recolonisation of a section of the Opihi River immediately upstream from the confluence with the Temuka River was reported by Fowles (1972). Unfortunately the process was disrupted by extensive flooding, however, the sampling showed a gradual increase in benthic invertebrate numbers over the month prior to the flood. After the flood, the composition and density of the benthic invertebrate fauna was similar to that which occurred above the LPIS intake (i.e. the area of continuous flow throughout the summer). This indicated that the flood resulted in catastrophic drifting (Waters 1965) of invertebrates from the vicinity of the upstream site.

In a study of the recolonisation of previously dry channels in the Rakaia River, Sagar (1983) found that recolonisation was complete after 33 days during a period of relatively stable flows in winter, and after 15 days during a period of fluctuating flows in summer.

Flow fluctuations were the main factor affecting colonisation rates, and it was assumed that downstream drift was the main source of colonising animals. Even small freshes during low-flow periods in winter resulted in a rapid increase in total density and diversity of invertebrates.

## 1.2 Fish and Fisheries

### 1.2.1 Historical Abundance

In pre-European times, a significant Maori fishery existed in the Opihi River for eels, lamprey, whitebait, smelt and flounder (Dacker 1990). It is probable that grayling, other galaxiid species (kokopu), and other lagoon fish were caught. Native species were utilised extensively for food and were an integral part of their culture. Lower reaches of the river and the lagoon areas were probably the areas of the river most frequented by these food species (McDowall, 1990). Although methods have changed, the Opihi River fishery remains an important part of Maori spiritual and cultural values.

Eels were an important Maori fishery, and were still abundant and widespread in the Opihi River this century. Beginning in 1931, the South Canterbury Acclimatisation Society (SCAS) distributed eel baskets to farmers living adjacent to streams and rivers. 471 eels were returned the first year and 4270 eels (totalling 9927 lbs.) were taken in 1934. Eldon (1960) estimated the Opihi River to hold 90 kg of eels/hectare. That some eels still remain may be deduced from Teirney et al. (1982a) when one angler commented "lots of eels."

Brown trout were successfully introduced into the Opihi River system in the late 19th century. Spackman (1892) describes excellent fishing from Burkes Pass to the sea. Early records indicate the largest fish (up to 20 lbs) were caught between Temuka and the sea. One anglers' diary mentioned 507 fish (averaging over 6 lbs) caught for the season.

SCAS Annual Reports suggest fishing was very good in the early part of the century.

1904: "...the rivers are now in splendid spawning order and full of fish..."

1912: "...the rivers have been good and fish plentiful although not as many large fish have been caught this season..."

1913: "...rivers are well stocked, and many good catches have been made. Fishermen generally state that the rivers are better stocked than they have been for some years..."

1914: "...best they (anglers) have enjoyed for many years..."

1916: "...season has been unfavourable from an anglers point of view owing to continued dry weather and consequent low state of the rivers, and while big fish were fairly plentiful in the lower reaches of the rivers, anglers report the scarcity of medium sized fly fish...".

1920: "Fish up to 20 lb were secured in the Opihi..."

1922: "Fishing in the lower waters of our rivers has been fairly satisfactory. In the upper reaches however the fishing has been lamentably poor..."

1924: "Fishing in the various streams in our district has shown a decided improvement in the season just closed, notwithstanding one of the driest summers experienced in South Canterbury for many years..."

By the 1930s, progressive draining of wetland, overgrazing of riparian and catchment vegetation, and extensive abstraction of water (by the Levels Plain Irrigation Scheme and others) among other factors probably began to influence the abundance and distribution of all fish species present.

Graynoth (1973) summarised angling information available at the time and found brown trout average lengths >34 to <40 cm were quite stable over the years, and most fishing occurring in the lowest 16 km of river.

The "character" of the Opihi River has changed markedly this century and this must have influenced fish distribution and abundance. For instance, the lagoon has suffered significant loss of area (estimated 58 hectares) since 1881 (Todd, 1983). Stopbanks and riparian plantings have narrowed channel width and reduced braid numbers (Evans 1986). Also, earlier this century anglers using boats would regularly fish for trout in large pools between the state highway and the sea each season. These pools have disappeared (M. Webb, personal communication). However, as recently as 1982 the Opihi was still regarded as a valued brown trout fishery (Tierney et al. 1982a).

Quinnat salmon juveniles were observed in the Opihi River in 1925 (SCAS Annual Report), indicating successful spawning had occurred that season. A few adult salmon were caught in 1929. In 1930 approximately 200 adults were caught by anglers at the Opihi mouth. Quinnat salmon numbers have varied since, with very few to several hundred being caught by anglers each season in the Opihi (SCAS Annual Reports).

There is no conclusive evidence that introduced salmonids have displaced native fish species, but circumstantial evidence indicates salmonids exclude some native species (M. Webb pers. comm; McDowall 1968; McDowall 1990). In many cases altered land use practices may have had an even greater deleterious effect upon native fish abundance and distribution than salmonids (Minns 1990).

### 1.2.2 Present distribution and abundance

Eighteen fish species (Table 4) are known from the Opihi River system (MAF Fisheries Freshwater Fish Database; Graynoth 1973; Hardy 1972), but a few other species could be present e.g., the small wetland area near Burkes Pass could contain the Canterbury mudfish (*Neochanna burrowsius*). Some galaxiid species in particular may not have been collected to date. The upper reaches of the Opihi River have not been surveyed as thoroughly as the lower reaches e.g., some upland species were not recorded until recently - the first record of alpine galaxias was in 1989, and the presence of brook char was only confirmed in 1988.

Several species probably frequent the lagoon and tidal area, but have not been reliably recorded. These would include Stokell's smelt, (*Stokellia anisodon*), sand flounder (*Rhombosolea retiaria*), and yellow belly flounder (*Rhombosolea leporina*), as well as other marine species. Additional surveys would firm the species list.

TABLE 4. Fish Species inhabiting the Opihi River system.

| | |
|---|---|
| Common smelt | Retropinna retropinna |
| Stokell's smelt (probable) | Stokellia anisodon |
| Yelloweyed mullet | Aldrichetta forsteri |
| Longfinned eel | Anguilla dieffenbachii |
| Shortfinned eel | Anguilla australis |
| Lamprey | Geotria australis |
| Brown trout | Salmo trutta |
| Rainbow trout | Onchorhynchus mykiss |
| Brook char | Salvelinus fontinalis |
| Quinnat salmon | Oncorhynchus tshawytscha |
| Common bully | Gobiomorphus cotidianus |
| Upland bully | Gobiomorphus breviceps |
| Bluegilled bully | Gobiomorphus hubbsi |
| Torrentfish | Cheimarrichthys fosteri |
| Common river galaxias | Galaxias vulgaris |
| Alpine galaxias (Firewood Stream) | Galaxias paucispondylus |
| Koaro | Galaxias brevipinnis |
| Black flounder | Rhombosolea retiaria |
| Kahawai | Arripis trutta |

It is also probable that some species have been eliminated since human alteration of the environment.

Known life stages and annual life cycles of fish species present in the Opihi River are identified in Figure 1. It should be noted that all phases of a life cycle are essential for survival although natural mortality is greatest during certain phases. Even though certain periods are said to be critical (e.g. quinnat salmon spawning and incubation) it should not be assumed that other periods are less important and can be neglected.

Populations of all fish species in the Opihi vary both spatially and temporally. Eggs and juvenile life stages of most fish species are usually typified by high numbers that require specific habitat conditions, which differ from those of more limited numbers of adults. As examples of this variation, Glova (1988) found significant differences in the densities of fish between two summers in the Ashley River. He also found the abundance and biomass of fish differed greatly between habitat types. Jowett and Richardson (1989) observed different numbers of brown trout before and after a flood event in the Opihi River. Glova et al. (1985) found several fold differences in fish abundance and biomass between the Ashley, Hurunui and Rakaia Rivers. Similar variations in fish populations would probably occur in the Opihi.

The following information about fish distribution is suggested by the MAF Fisheries Freshwater Fish Database; Eldon 1960 and Hardy 1972. General locations of sampling sites are presented in Figure 2.

| USERS | J | F | M | A | M | J | J | A | S | O | N | D | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Salmonid Fishing | SFS | SFS | SFS | SFS | | | | | | SFS | SFS | SFS | |
| Irrigation | IR | IR | IR | IR | | | | | | | IR | IR | |
| Whitebait Fishing | | | | | | | | WF | WF | WF | WF | | |
| Resident Brown Trout | JR | JR | JR | JR SP | SP PSP | PSP SP IN | SP IN | IN | IN | EM | EM | EM JR | |
| Sea Run BT | AE | AE SP | AE | SP | SP | SP | | | | AE | AE | AE | |
| Quinnat Salmon | JR AE | JR AE | JR AE | JR AE | AE SP PSP | PSP SP | IN | IN | IN | EM | JR DM | JR | |
| Rainbow Trout | JR | JR | JR | JR | | | | SP | SP | IN | IN | EM | |
| Inanga | SP | SP | PSP | PSP | SP | | | UM | UM | UM | UM | UM | |
| Alpine galaxias | | Probable SP all year depending on condition factor | | | | | | SP | SP (PSP) | SP | | | |
| Common river galaxias | JR AR | JR AR | JR AR | JR AR | | | SP | SP | SP | SP | JR | JR | |
| Common Bully | SP JR-DM-UM | SP JR-DM-UM | | | | | | | SP | SP | SP JR-DM-UM | SP JR-DM-UM | |
| Upland Bully | SP JR | SP JR | | | | | | | SP | SP | SP JR | SP JR | |
| Bluegilled bully | | | | | | | SP | SP UM-DM | SP UM-DM | SP UM-DM | | | |
| Koaro | | | | SP | SP | SP | DM | DM | UM | UM | | | |
| Torrentfish | SP | SP | SP | SP PM | PM | PM | PM | PM | PM (juv)UM | Juv (UM) | (juv)(UM) | | |
| Lamprey | JR | JR | JR | JR | JR | JR | JR | A UM JR | A UM JR | UM JR | JR | JR | |
| Yelloweyed Mullet | PM | PM | PM | PM | PM | PM | PM | PM | PM | PM | PM | PM | Primarily |
| Kahawai | PM | PM | PM → | | | | | | | | PM | PM | lagoon |
| Common Smelt | SP | SP | | | | | | | | SP | PSP | SP | or |
| (Stokells smelt?) | | | | | | | | | | | | | lower |
| Black Flounder | | | | | | ← DM to SEA → | | | | | | | reach |
| Brook char | (not directly affected by Opihi yet) | | | | | | | | | | | | inhabitants |
| Longfinned Eels | UM | UM | ( | Adults DM | ) | | ( | Glass eels UM | ) | ( | Adult DM | ) | |
| Shortfinned Eels | UM | UM | ( | Adults DM | ) | | ( | Glass eels UM | ) | ( | Adult DM | ) | |

Key:

| | | | | | |
|---|---|---|---|---|---|
| UM = | Upstream Migration | IR = | Irrigation Season | SP = | Spawning |
| SFS = | Salmonid Fishing Season | PSP = | Peak Spawning | WF = | Whitebait Fishing |
| JR = | Juvenile Rearing | EM = | Emergence | AE = | Adults Entering River to feed and/or spawn |
| IN = | Incubation | AR = | Adult Rearing | DM = | Downstream Migration or drift to sea |
| | | | | PM = | Present at River Mouth or Lagoon |

Fig. 1 Known seasonal distribution of use for some water users in the Opihi River System.

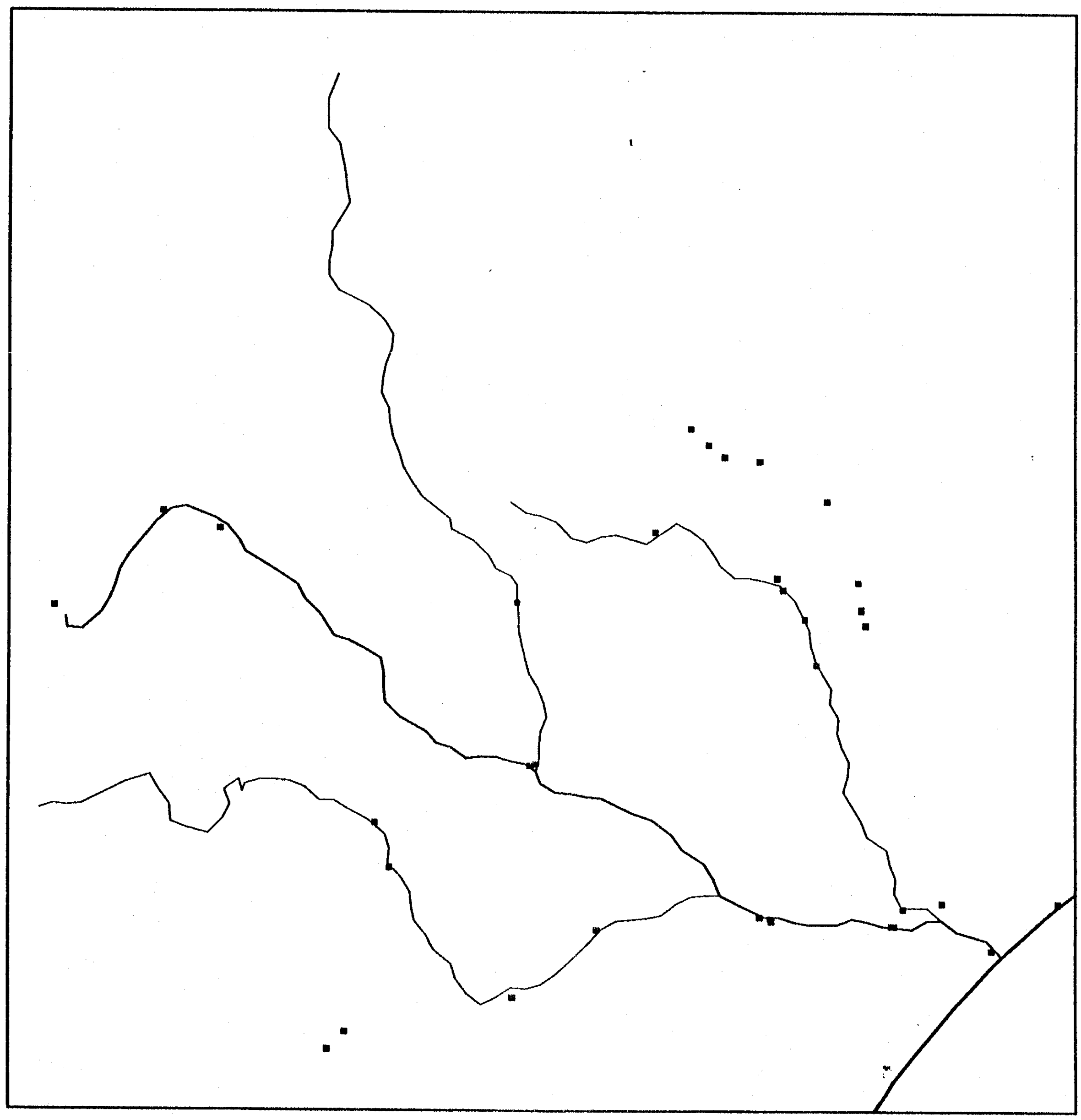

Figure 2. Approximate locations of fish sampling sites for the Opihi River system (MAFFisheries Data Base)

Longfinned and shortfinned eels, brown trout, quinnat salmon, common bully, upland bully, and the common river galaxias are widely distributed and are relatively abundant in the Opihi River. Four other species - common smelt, yelloweyed mullet, black flounder, and kahawai - are found at the mouth, lagoon or lower reaches of the Opihi. Lampreys, bluegilled bullies, and torrentfish are infrequent to common inhabitants of the river, but their numbers and distribution are probably more limited than the seven very common species. A few rainbow trout have been reported by anglers (Graynoth and Skrzynski 1973).

The brook char, koaro and alpine galaxias have each only been identified in one location in the Opihi system - brook char and koaro at Paddys Market Stream and alpine galaxias at Firewood Stream. The alpine galaxias could be more widespread, but it has not been detected because of inadequate sampling and certainly deserves some consideration because of its limited distribution in New Zealand (Tierney et al. 1982b).

### 1.2.3 Salmonid Spawning

Assuming sufficient water is available, it is generally accepted that spawning gravels are adequate throughout the Opihi River and its tributaries. Graynoth and Skrzynski (1973) say, "...the system offers good spawning for trout, except the Opuha which is unstable, however good catches were reported in the Opuha in the past ..." Hardy (1972) states, "...spawning salmon are scattered and widespread throughout the Opihi River system ... numbers ascending to the highest reaches of the system are possibly much lighter ..." Webb (unpublished submission) suggests the runs of quinnat salmon probably numbered 1500 in a good year and there are excellent stocks of brown trout in both the lower and middle reaches of the Opihi "...with trout redds throughout the Opihi and tributaries...".

Since Hobbs (1948) and others helped to convince the South Canterbury Acclimatisation Society that natural spawning was sufficient to re-stock the Opihi it has been recognised that adequate brown trout spawning occurs in the Opihi system.

Spawning surveys have been conducted since 1972 as a means of monitoring quinnat salmon numbers (Table 5). However, surveys are not directly comparable from year to year because of variable water and river conditions, different observers and different sections of surveyed water. The distribution and abundance of quinnat salmon redds appears to vary markedly from year to year.

Detailed surveys of brown trout spawning have not been undertaken.

High demand for Opihi River water by out-of-stream users (Scarf et al 1984) has left instream users with limited supplies, particularly since implementation of the Levels Plain Irrigation Scheme in the late 1930s (Hardy 1972). Sagar (1984) noted that the Opihi had virtually ceased flowing on examination in February 1983 and salmon could not migrate upstream. Dewatering to this extent occurs quite frequently (M. Webb pers. comm.). The SCAS feels the Opihi River water resource is presently over committed to out-of-stream users (Webb unpublished submission). The necessity for salvage of salmonids indicates a continuing lack of water (SCAS unpublished data).

TABLE 5. Numbers of quinnat salmon redds counted in the Opihi River system 1972-89***

| River or Stream | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 ** | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Opihi | redds* observed in the Opihi, Opuha and Tengawai | 45 | 75* | | 19 | 43 | 17 | | | | | 75 | 126 | | 119 | | | |
| Tengawai | | 6 | 2 | | | 25 | 113 | | | | | 28 | 47 | | 67 | | | |
| Opuha | | 1 | 23 | | | 14 | 4 | | | | | 16 | 40 | | 5 | | | |
| Te Moana | | 1 | 24 | no survey | 8 | 1 | 10 | (a) | (b) | (c) | (d) | 15 | 21 | (e) | 6 | 56 redds | (f) | rivers low |
| Waihi | | 14 (+Temuka) | 27 | | 29 (+Temuka) | 17 | 41 | | | | | 42 | 32 | | 49 | | | |
| Three Springs | | | | | | | | | | | | 1 | 2 | | | | | |
| Temuka | | | 6 | | | 20 | 14 | | | | | | | | | | | |
| Total | | | | | | | | | | | | | | | | | | |

Note:
- * fish seen in Kimbell and Burkes Pass
- ** by helicopter all rivers
- *** Surveys conducted in late May or June
- a) no accurate figures; salmon in all tributaries; lower reaches primarily
- b) 85 redds
- c) High water hampered counts; Opihi had greatest numbers downstream of Hanging Rock
- d) few redds anywhere
- e) closed mouth - few spawners
- f) mouth blocked; fishing a disaster; assumed poor spawning.

### 1.2.4 Salmonid Rearing Areas

Salmonid juveniles typically utilise the slower, shallower portions (stream margins) of rivers immediately after emergence and can use progressively deeper water (riffles) with increases in size during the first two years of life (Heggenes 1988). Streams of high water quality with diverse habitat types (runs, riffles, pools) with a mixture of instream and riparian cover provide optimal conditions for juvenile and adult rearing.

Juvenile salmonids that do not immediately emigrate downstream or to the sea after emergence disperse to suitable habitat. Suitable rearing areas of appropriate water depths and velocities are located throughout the Opihi River system. Habitat suitability weighting curves for 6 species found in the Opihi River are shown in Figure 3. Detailed study would quantify the potential physical habitat.

Although the brook char, common river galaxias and upland bully spend their entire life in fresh water, all other fish species in the Opihi depend upon sufficient water for either downstream or upstream passage at various times of the year (Fig. 1).

Additional sampling sites in the Opuha and upper reaches of the Opihi River (above Rockwood) are needed to verify fish distribution in the Opihi system.

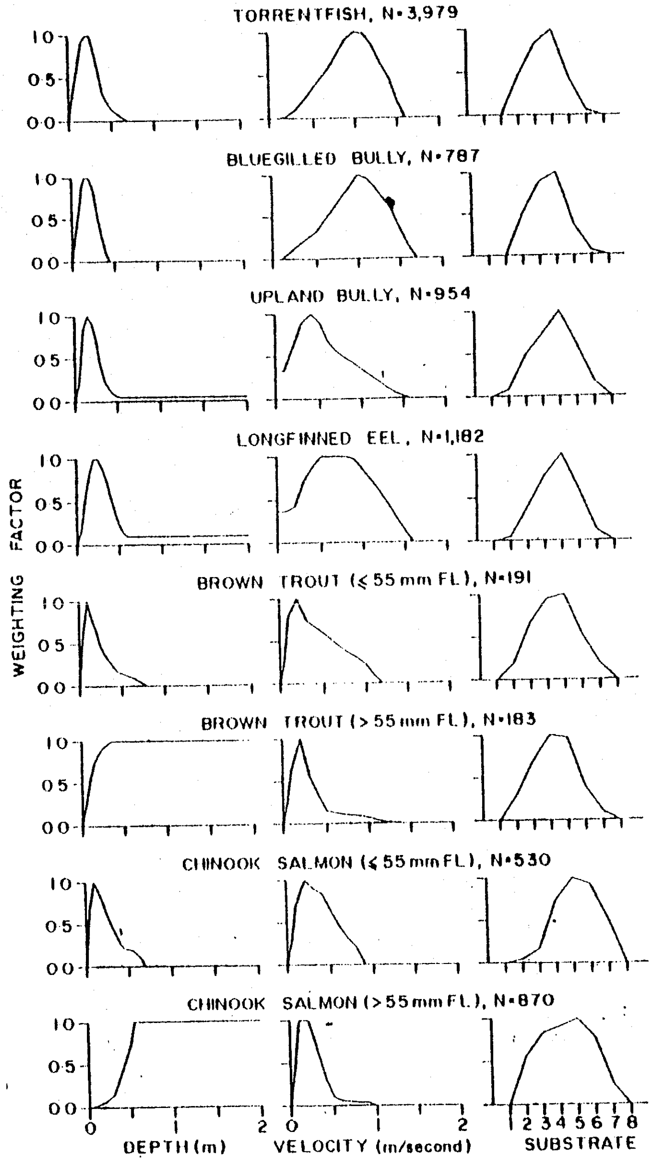


FIGURE 3.—*Habitat-suitability weighting curves in relation to water depth, water velocity, and substrate type for four native fish species and two introduced salmonid species in Rakaia River. Numbers of fish sampled are shown for each species; FL is fork length. Substrate codes: 1, mud; 2, silt; 3, sand; 4, gravel; 5, small cobbles; 6, large cobbles; 7, boulders; 8, bedrock.* (from Glova and Duncan 1985)

## 2.0 Impacts of Flow Augmentation

### 2.1 Impacts on Benthic Invertebrates

The transfer of water from Lake Tekapo to the Opihi River will increase the amount of physcial habitat available to benthic invertebrates, change water quality, and have biological effects on the benthic invertebrate populations.

#### 2.1.1 Physical habitat effects

At present benthic invertebrate populations in the lower Opihi River are limited by a lack of water, especially in the summer months. Increases in summer base flows, water depths and velocities, and wetted width of the river should benefit aquatic invertebrates; provided that the flows remain fairly constant.

Management of the river should ensure that the newly-established benthic invertebrate populations along the perimeter of the river are not left without water because there is no demand for irrigation water i.e. natural fluctuations of discharge should not be exacerbated by variations in the demand for irrigation water.

Benthic invertebrates inhabit preferred ranges of water depths and velocities (Jowett and Richardson 1990) and measurements of these instream parameters can be used to calculate the weighted usable area (WUA) available at various flows. This information is not available for the

Opihi and so changes in WUA for benthic invertebrates with flow augmentation cannot be quantified.

### 2.1.2 Water quality effects

Diversion of Lake Tekapo water into the Opihi will increase the suspended solids loading and turbidity of the river throughout its entire length. The behaviour of fine sediments such as glacial flour, is complex and depends on factors such as the electro-chemical environment of the sediment (Vanoni 1971) and the presence of algae, which tends to trap and bind the sediment. Once deposition of the silt has occurred, it binds to coarser substrate and cannot be removed until water velocities increase by up to 100 times, as shown by the Hjulstrom diagram (Graf 1971). Electro-chemical attraction, the trapping of silt in mats of algae and even the growth of algae on silt deposits all act to increase deposition and make the cleansing of the coarse substrate more difficult.

In the lower Waitaki River, Jowett (in litt) found that siltation had coated to varying degrees the substrate of one third of the wetted area of the river. Water in the lower Waitaki is derived from lakes containing glacial flour consequently, augmentation of the Opihi by water from Lake Tekapo will result in some siltation of the riverbed.

Siltation and an increase in turbidity will be detrimental to benthic invertebrates. Ryder (1990) showed that fine sediment severely reduced invertebrate abundance on stone substrates because of interstitial occlusion, but recovery was rapid following sediment removal. In addition, densities of *Deleatidium* and Hydropsychidae decreased with the addition of silt during a laboratory experiment; this was tested in the field with the same results - both taxa showed a decrease in density with the occurrence of fine sediments.

*Deleatidium* and Hydropsychidae are both major components of the benthic invertebrate fauna of the Opihi and although interstitial occlusion is unlikely to occur to any major extent in the Opihi, the mere presence of silt is likely to result in decreased densities of benthic invertebrates.

Increases in the levels of turbidity may increase the drifting rate and lead to a reduction in the density of benthic invertebrates. Normally, drifting invertebrates settle out, but an increase in turbidity causes them to stay in the water column (Gammon 1970). *Deleatidium* exhibited an immediate, short, sharp increase in drift immediately after the addition of silt to an experimental laboratory stream (Ryder 1990).

### 2.1.3 Biological effects

Silts interfere directly with the feeding of benthic invertebrates not only by covering the food supply of those that feed on periphyton, but also by being trapped by the algae. The effect of the latter is more subtle because it affects the qualtiy of food available - the poorer quality of algae in silted areas resulted in lower growth rates of *Pycnocentrodes* caddisflies compared with those in non-silted areas (Ryder 1990).

## 2.2 Impacts on Fish and Fisheries

Augmentation would appear to be beneficial to native and salmonid fish stocks if sufficient water was left instream to maintain continuous flow (see 2.2.2.1). The common re-occurrence (SCAS Annual Reports; Scarf et al. 1984) of very low flows or worse in the Opihi between Butlers Road and the Temuka confluence are not beneficial for any riverine species. Available habitat should dramatically increase when flows increase from 0! Wolff and Wesche (1989) found stream channel size increased with augmented flow. Mosley (1983) suggests weighted useable area (WUA), a measure of potential physical habitat, increased for upland bully and common river galaxias for an increase in discharge for several transects in the Ahuriri River. A similar situation could occur in the Opihi for these and other species.

Without detailed studies it can only be assumed that juvenile and adult rearing habitat and spawning habitat will be increased in most sections of the river for most species. Increased flows would serve to keep the Opihi River mouth open to the sea a greater portion of the time (Todd 1983). This would benefit most species by increasing access to or from the sea (Fig.1).

Increased flows upstream of Fairlie may induce salmonids to more greatly utilise this area. Increased use by salmonids may impact on native fish species and reduce their abundance in the upstream portion of the river (G.A. Eldon, pers. comm.). However, increased flows may also provide additional area of habitat suitable for some native species.

Augmentation will not "create" a new fishery or "enhance" an existing fishery, but may merely retard or suppress the Opihi's decline from its historical angling position as "...one of the best rivers for sport in the Dominion." (SCAS 1911 Annual Report) and as an important source of food for Maoris.

### 2.2.1 Habitat

#### 2.2.1.1 Opihi Mouth

Todd (1983) concluded that during the 1970s and 1980s increased irrigation demand (especially in the January-April period) reduced Opihi River flows to below the base level required to naturally maintain an open river mouth. He suggested 6 $m^3/_s$ as the minimum flow required to maintain an open mouth. Below this level the mouth is closed 90% of the time. Closures at higher flows occur, but are short duration events (Todd 1985).

A closed river mouth is an anachronism. A closed mouth should be merely a "natural" event occurring very infrequently due to abnormal "natural" low flow river conditions or rough southerly sea conditions. Fish passage between the river and the sea should be available at all times, except during adverse "natural" conditions.

The historical reduction in lagoon area should be re-evaluated. Eradication of adjacent low-lying wetlands and tidal flats may have seriously impinged upon native fish spawning success and reduced stream re-charge during dry summer periods. Long grass and marsh conditions adjacent to the river are valuable native fish spawning habitat.

With increased flow in the lagoon, problems with declining water quality (elevated water temperatures, higher pH) should be reduced. Re-assessment (partial removal?) of stopbank placements could increase native fish habitat.

#### 2.2.1.2 Middle and Lower Reaches of the Opihi River

The Opihi River between Saleyards Bridge and the SH 1 bridge has become dry and continuous flow has ceased on many ocassions in the past (de Joux 1981; Scarf et al. 1984). Implementation of the 1984 Opihi River Water Management Plan has not succeeded in maintaining a continuous flow of water in the river section between SYB and SH1 (SCAS Annual Reports). There is also some doubt that the stated channel losses in this section are correct (M. Webb, pers. comm.). In addition Sagar (1984) observed that a flow of 2.78 $m^3/_s$ at SYB (which may equate to 1.4 $m^3/_s$ at Grassy Banks) does not provide for salmon passage.

A minimum flow of at least 3 $m^3/_s$ (?) should be implemented at SH 1 if augmentation proceeds. This would probably ensure continuous river flow and with Temuka River flow would also ameliorate the frequency of a closed river mouth condition.

#### 2.2.1.3 Upper Opihi River

The upper reaches of the Opihi River will be affected by augmented flows. Hydrographs of "dry" and "average" year flows at SYB suggest augmentation water would be a sizeable portion of river flow during the low summer flow period in most years. (Figs. 4 and 5).

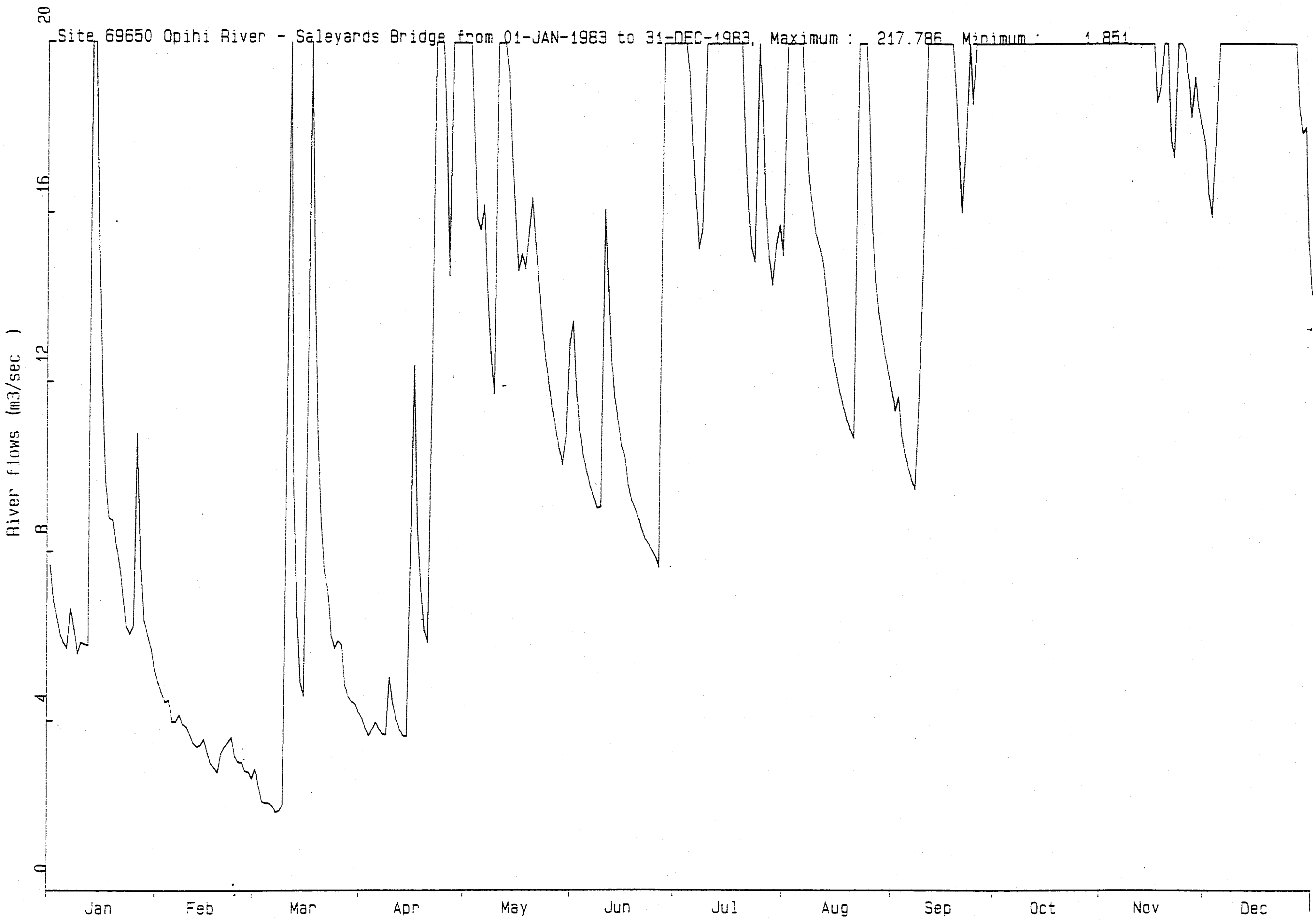


Figure 4. Simulated daily flows at Saleyards Bridge in an "average" rainfall year(1983)

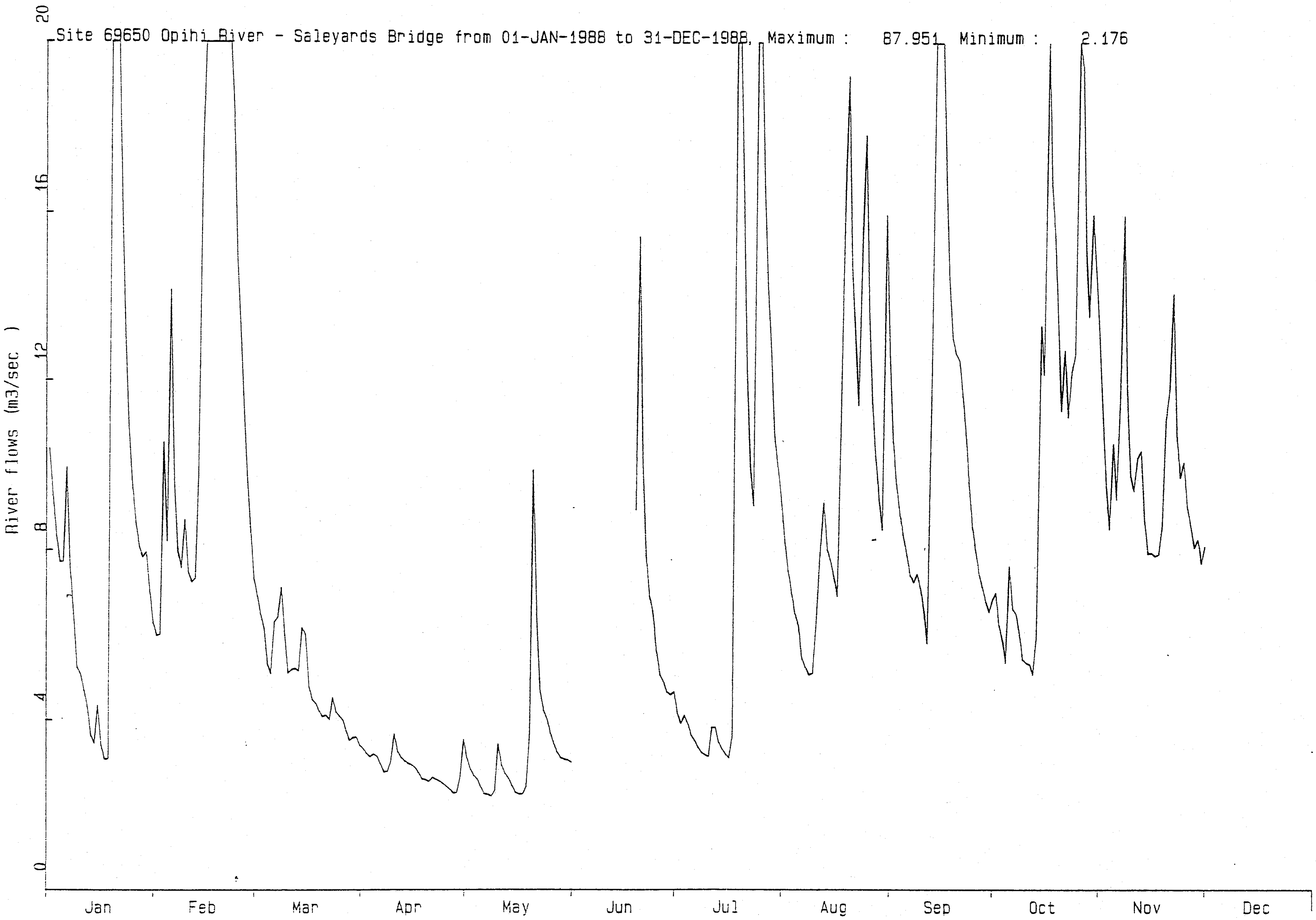


Figure 5. Simulated daily flows at Saleyards Bridge in a "dry" rainfall year(1988)

The upper Opihi will be a controlled stream reach (a below dam situation) and Lake Tekapo water will dominate the character of the reach. Augmented flows could be the predominent water to at least the Tengawai confluence during later months of the irrigation season.

To allow fish adequate response time to changes in augmented flow, flow variations should follow a natural flood hydrograph when occurring (i.e. fairly rapid increases-more gradual reductions). A "moderate" operating regime on a daily , weekly, and annual basis should be followed. Extreme fluctuation should be avoided with only normal storm events altering flows dramatically. Highly variable flows have highly unstable habitats and can reduce or increase fish densitites (Bain et al. 1988),or reduce abundance, diversity or productivity of fish in diverse ways (Cushman 1985).

### 2.2.2 Salmonid Passage, Spawning and Rearing

#### 2.2.2.1 Minimum Passage Depths for Salmonids

Riffles and points of divergence of channels are critical points for passage of fish because water depths there are at a minimum. Continuous flows that will allow passage of adult quinnat salmon should be sufficient for all other fish species at these critical points in the Opihi system. Thompson (1972) reports a minimum required depth of 0.25 m for quinnat (chinook) salmon (based on body measurements). Mosley (1982) suggests this depth may be too conservative for Canterbury braided rivers. Salmon are able to negotiate short stretches of riffle that are much shallower than 0.25 m.

The flows necessary to maintain adequate passage depth over considerable distances without excessive fish losses are unknown for the Opihi River without detailed study.

2.2.2.2 Salmonid Spawning

Augmented flows may induce more fish than previously to migrate further upstream to spawn. The Opihi River between Burke's Pass and Rockford (minimum flow 4-6 $m^3/_s$) could become a much more prominent spawning area. However, salmonids usually spawn from April to June and so cessation of flow augmentation at the end of April would not provide more spawning habitat and may even result in the loss of spawning adults.

Augmented water should be continuously flowing during the irrigation season and the remainder of the year. The stream channel in the upper reaches will be reformed to accommodate a 4-6 $m^3/_s$ flow. Reduction to zero flow or a fraction of a cumec would probably leave salmonid spawning habitat dewatered.

Salmonids utilise water in a particular range of depths and velocities for spawning (Fig. 6). G.J. Glova (pers. comm.) measured water velocities (mean = $0.42 \pm 0.4$ m/s) and water depths ($0.24 \pm 0.12$ m) at 24 quinnat salmon redds in the Hurunui River. M. Field-Dodgson (pers. comm.) also measured water depth (range 13-55 cm) and water velocity (range 0.2-1.2 m/s) over 232 salmon redds in Rakaia River tributaries. A similar range of depths and velocities would be necessary in the Opihi. Pre-augmentation studies should verify to what extent these physical conditions will be present.

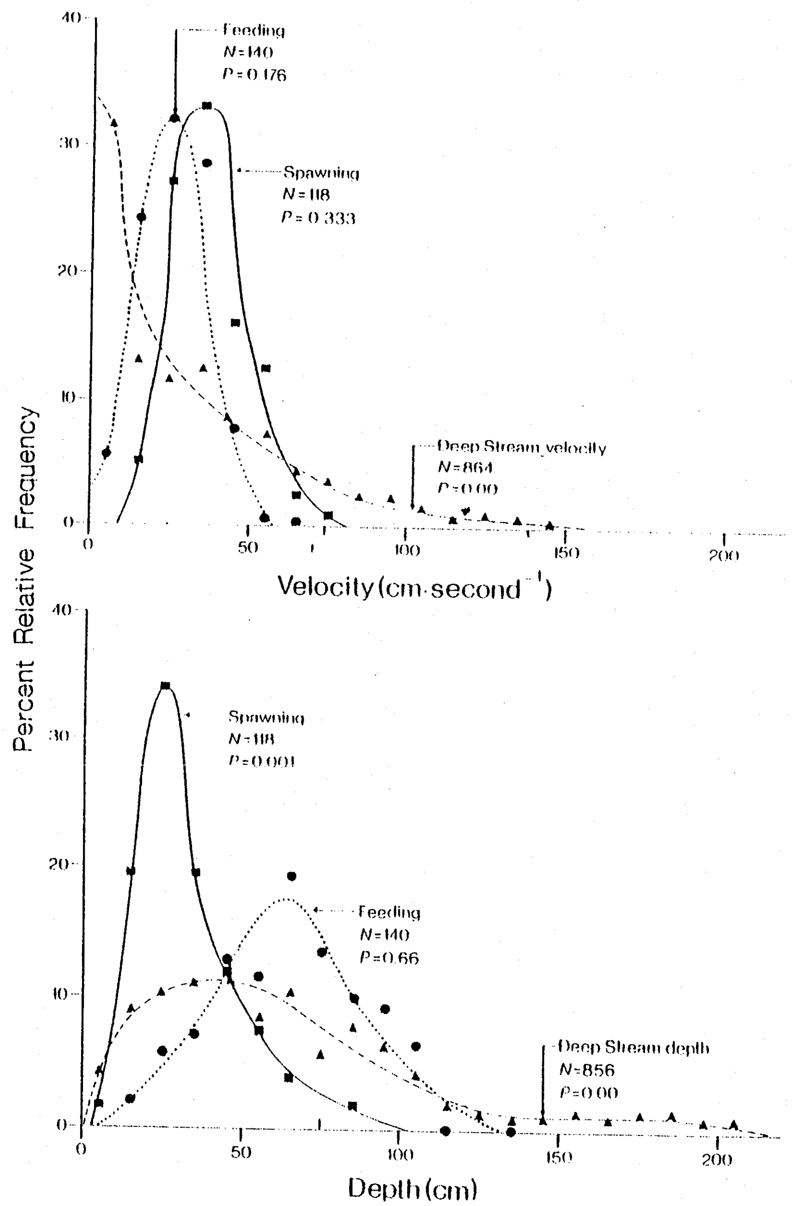


Figure 6. Distribution of water velocities and depths occupied by adult brown trout for feeding and spawning in six New Zealand rivers(disregard Deep Stream curves) (from Shirvell and Dungey 1983)

Salmonids return to their home stream to spawn with the use of olfactory clues. Introduction of Lake Tekapo water may induce Waitaki River salmon and/or trout to enter the Opihi River. The dilution of Opihi water could reduce the attractiveness of that water for Opihi natives until spawners keyed to the new clues were established. This is another possible impact of cessation of augmentation during a spawning run.

2.2.2.3 Salmonid Rearing

Even though a "sustained flood" (SWORD Feasibility Study Stage 1 1989) would occur upstream of Burkes Pass, juvenile salmonids could utilise the newly available habitat. The suggestion that canal flow be reduced to 0 when irrigation demand is low neglects the instream conditions created by the augmented flow. It is possible that many of the salmonids normally spawning in downstream areas would be induced to use the upstream section with augmented flows. Therefore cessation of augmented flows could devastate the spawning chances of these fish.

The limited catchment size of the Opihi River above Firewood Stream would lend itself to salmonid habitat improvement. The augmented upper Opihi could be "designed" to greatly amplify the potential salmonid habitat. Augmentation could be viewed as a chance to design a "new" high quality river, in addition to being an avenue to transport water to out of stream users. By limiting stock access, and implementing many habitat improvement measures (Gresswell et al. 1989) the upper Opihi River could become an even more valuable resource.

If expansion of salmonid spawning and rearing habitat occurs after augmentation, then reducing the augmented flow to 0 after the irrigation season would nullify the many benefits achieved. This assumes the small natural flow would not be sufficient to provide the wetted area necessary to maintain previous habitat and prevent dewatering of redds and other aquatic life stages. Supplementation of the upper Opihi river flow should continue with a residual flow during the non-irrigation season. The required residual flow could be determined by further hydrological studies and instream habitat evaluation.

### 2.2.3 Water Quality

#### 2.2.3.1 Temperature

Augmented flows could be a large portion of the Opihi River flow downstream to at least the Tengawai River confluence during some portions of the year. Water quality characteristices of the Tekapo source water will markedly affect the characteristics of the recipient stream. Some caution should be exercised when considering the transfer. Without investigations it could be assumed the introduction of Tekapo water would only alter the recipient stream temperature slightly in most situations. However, if the transfer canal is only transporting a minimal volume of water on very hot days - water temperature could be elevated several °C before emptying into the upper Opihi River. The low gradient of the canal (1 in 3500) will mean low water velocities and minimal subsurface seepage or water interchange should occur, so the opportunity for excessive warming exists. It is assumed temperatures would not be elevated sufficiently to be fatal to cold-water fish species (~26°C for brown trout), but could be sufficient to change the character or degenerate the quality of the Opihi water.

#### 2.2.3.2 Water Chemistry

Because the Tekapo River supports an important trout fishery (Teirney et al. 1982a), it could be assumed water from the same source will not impact detrimentally on the Opihi River. Further study could verify possible changes.

#### 2.2.3.3 Suspended Sediment/turbidity

Introduction of naturally turbid water from Lake Tekapo to the normally "clear" Opihi River is one of the most serious considerations with the augmentation scheme. Increases in turbidity can reduce light penetration in streams. This is turn is associated with decreases in primary, secondary and tertiary production (Lloyd 1987). In addition, relatively small changes in turbidity or suspended sediment level can stress fish in various ways, alter their behavior, or be fatal (Lloyd 1987). Several states of the United States have adopted turbidity standards for protection of fish habitat (Table 6). Minimal changes in the turbidity of Opihi River water (approximate 5 NTUs?) would appear to be a valid guideline for the augmented water.

It should be noted that turbidity is highest in Lake Tekapo surface water during the summer period (Irwin and Pickrill 1982) when irrigation demand for water will be greatest.

TABLE 6. Numerical turbidity standards for protection of fish and wildlife aquatic habitats in Alaska and other states (ADEC 1978; API 1980). (from Lloyd 1987)

| State | Turbidity (NTU or JTU)[a] |
|---|---|
| Alaska | 25 units above natural in streams<br>5 units above natural in lakes |
| California | 20% above natural, not to exceed 10 units above natural |
| Idaho | 5 units above natural |
| Minnesota | 10 units |
| Montana | 10 units (5 above natural)[b] |
| Oregon | 10% above natural |
| Vermont | 10 units (cold water) |
| Washington | 25 units above natural (5 and 10 above natural)[c] |
| Wyoming | 10 units above natural |

[a] Nephelometric (NTU) and Jackson (JTU) turbidity units are roughly equivalent (USEPA 1983).

[b] Montana places the more stringent limit on waters containing salmonid fishes.

[c] API (1980) reports different values in Washington for "excellent" and "good" classes of water.

The high gradient of the Opihi River to at least the vicinity of Aires will probably not allow an appreciable settling of transported material. However, with dilution from tributaries and some filtering of material by permeable substrate and periphyton the effect in the middle and lower reaches of the river could be relatively minor. Tekapo River clarity increases appreciably before reaching its two major tributaries (underwater visibility increased from 3 to 5 m over a distance of 15 km in the upper Tekapo River in February 1989 (unpublished MAFFish data). This must be partially attributable to some settling and filtering of glacial silt. However, turbidity measurements in the Pukaki River during February 1990 (Freestone 1990) indicated some decrease in turbidity down the length of the river at lower flows ($<4m^3/_s$), but the differences were small.

Augmentation water will cause erosion of the Opihi River streambed and banks in the newly formed channel reaches. Concentrations of suspended topsoil can reduce feeding rates and increase physiological stress in salmonids (Redding et al. 1987.). Before augmentation begins, topsoil in the proposed channel should be removed and measures taken to reduce streambank erosion as a preventative action.

If little settling or filtering of Tekapo source water occurs, water clarity of the Opihi River will decrease at least as far downstream as Saleyards Bridge (SYB) and probably further if natural flows are approaching minimum values. Davies-Collies (1988) suggests water clarity can be predicted downstream knowing flows and the turbidity values of the source and receiving water. Unfortunately dilution effects will also be minimal when most Tekapo water is required for irrigation.

No matter what minimum distance for settling and filtering of suspended sediment is required, any passage of water through permeable gravels before reaching Burkes Pass should be encouraged or engineered.

Turbidity will affect the aesthetic features and angling qualities of the Opihi. For example, a reduction in an anglers daily catches has been suggested in the Waihao River below the Morven-Glenavy Irrigation Scheme discharge (Waitaki River source) when water clarity was less than 0.6 m (G. Hughes, pers. comm.)

### 2.2.4 Fish Screening

Significant numbers of juvenile salmon and trout entered the Levels Plain Irrigation Scheme prior to erection of the present screen in 1988 (Hardy, 1972, Sagar 1985; SCAS unpublished data) and SCAS field officers salvaged many fish trapped in the irrigation race. This problem has virtually ceased with the LPIS screen installations (M. Webb pers. comm.). To prevent fish losses after augmentation screens and effective fish bypass structures (to allow downstream and upstream exit) should be mandatory with any surface water abstraction.

## 2.3 Maori Cultural and Spiritual Values

Traditional Maori customs and values are inseparable from the Opihi fishery. The study brief separated these topics, but it should be noted that Maori values and practices were and are intertwined on a daily and annual cycle around the fish and fisheries of the region. Many of the fishing practices of the Maoris have suffered with changes in the Opihi River, but the spiritual feelings involving the river and Lake Tekapo must be considered as an aspect of the fisheries.

This has not been dealt with adequately in this report.

## 3.0 Recommendations

### 3.1 Further Research Requirements

3.1.1 Conduct an instream habitat study to determine optimal flow required to maintain quinnat salmon passage between SYB and SH 1 and to determine potential habitat for benthic invertebrates and salmonids throughout the length of the river.

3.1.2 A turbidity/suspended sediment study should be conducted on the Tekapo River to ascertain probable effects of Tekapo water on Opihi water clarity. Establish a maximum acceptable level of turbidity change (~5 NTUs) before augmentation proceeds. Determine measures necessary to prevent excessive suspended sediment and streambed erosion in the upstream portion of the Opihi River.

3.1.3 Conduct a survey of upper Opihi River sites to determine benthic invertebrate and fish species composition, distribution and relative abundance.

3.1.4 Re-evaluation of water loss between SYB and SH 1 should be made and establishment of a flow recorder site near SH 1.

3.1.5 A study of the effects of increased flow on the substrates of the Opihi in the section between Burkes Pass and Fairlie

3.1.6 Discuss and consult with Maoris to understand and consider their intimate association with the fisheries values of the river.

## 3.2 Management Practices

3.2.1 Maximum canal water temperatures should be imposed, as should limitations on the maximum differential of temperatures between canal and receiving water. An evaluation of possible thermal regime of canal water at various flows should be implemented.

3.2.2 Maintenance of an open river mouth is a critical factor for virtually all riverine species. Maintenance of optimal flow for salmon passage (3 $m^3/_s$?) between SYB and SH 1 would minimise mouth closures.

3.2.3 Fish screens should be mandatory for all surface water abstractions with fish bypass for both upstream and downstream escape.

3.2.4 Augmentation flow should mimic a natural flow hydrograph (rapid increases, slower declines). Short period variations or cessation of flow should be prevented.

3.2.5 Maintenance of a continuous residual canal and Opihi River flow (January to January) to prevent instream habitat loss or degradation.

3.2.6 Involve fisheries biologists at all stages of the planning and construction (if proceeding) to alleviate potential fisheries problems before occurring.

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