Environment B·O·P
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LAKE ROTORUA AND LAKE ROTOITI

Report on the Technical Issues and Effects to be Considered in the Application for Resource Consents

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1 INTRODUCTION

This report examines the issues/factors and effects to be considered in the applications for resource consents under the Resource Management Act:

- An application is made for a land use consent for the control structure at the outlet of Lake Rotorua and for a water permit to partially dam Ohau Channel at the outlet of Lake Rotorua to control that lakes levels.

- Application is also made for a land use consent for the Okere Falls gates structure and a discharge permit to control flows via the Okere Falls gates structure to enable the levels of Lake Rotorua and Lake Rotoiti to be maintained within set limits.

The report provides an historical overview of the lake system, then examines each lake separately with suggested consent conditions. These largely reflect a continuation of the status quo of maintaining the water levels of the two lakes between a defined operating range which was established in 1975.

2 OVERVIEW

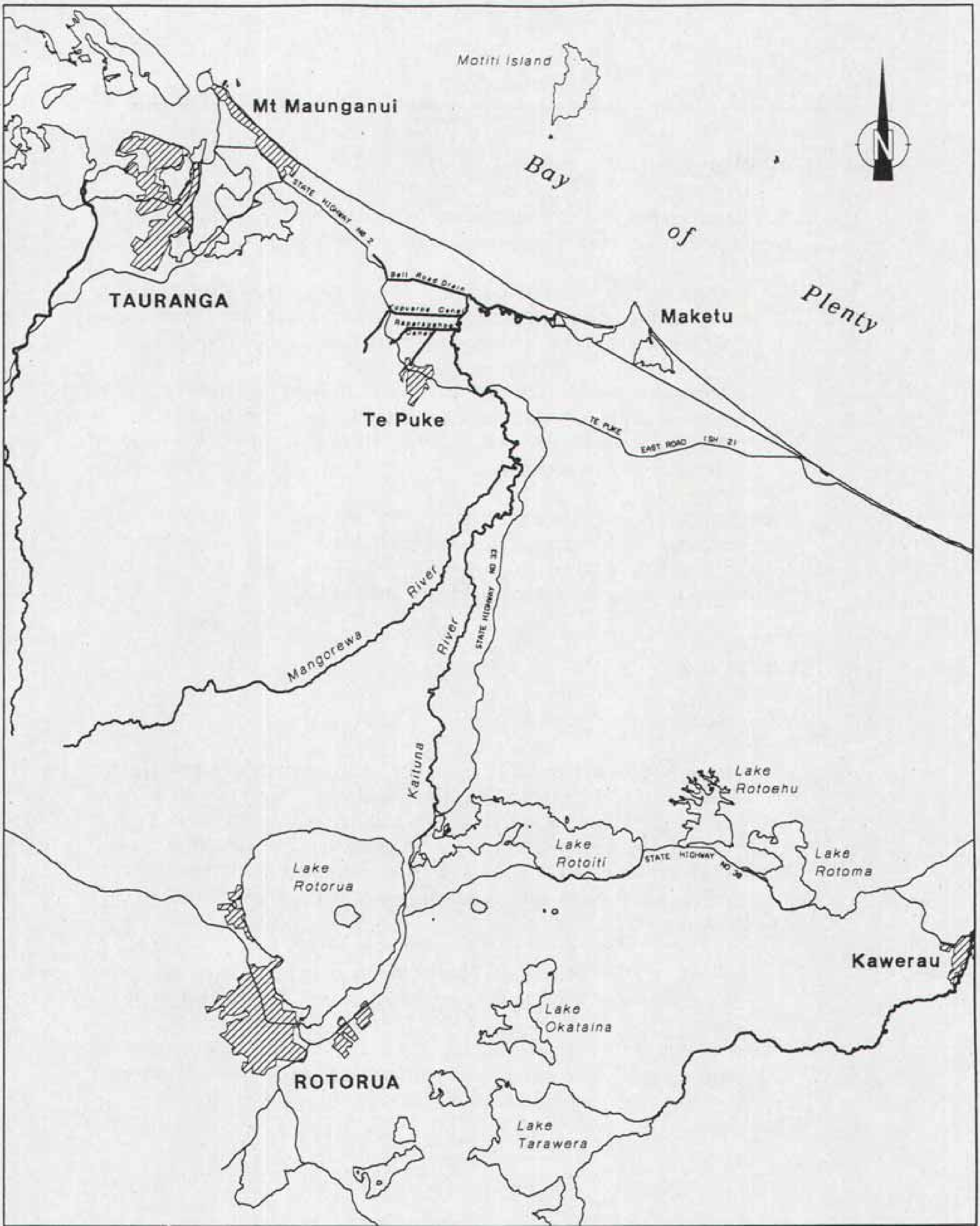
2.1 Background

Lakes Rotorua and Rotoiti are two major reservoirs in series (Figure 1) at the headwaters of the Kaituna River Catchment. The effect of the lakes on the discharge in the Kaituna River is significant, in that the lakes provide beneficial storage for floodwaters and release them very gradually over a long period of time. When a storm passes over the upper catchment, the peak inflow which might last a few hours is released to the Kaituna River over many weeks.

While the lake storage eases flood problems in the lower Kaituna, it causes high lake levels, flooding and poor drainage around the shores of the lakes.

As part of the Upper Kaituna Catchment Control Scheme, detailed investigations were carried out in the early 1970's to report on alternative methods of controlling the levels of Lake Rotorua and Rotoiti.

Figure 1



BAY OF PLENTY REGIONAL COUNCIL

KAITUNA RIVER AND ROTORUA LAKES					
	DRAWN	G.T.	6/95	REFERENCE:	PLAN No. C1384
	TRACED	G.T.	6/95		
	DESIGNED			SCALE: 1:30,000	AMENDMENT:
	CHECKED	G.A.D.	6/95		
	APPROVED	B.R.T.	6/95		SHEET 1 OF 1

Excessively high and low lake levels had caused concern to the users of, and population near the lake, for some time. It had been recognised that relatively inexpensive control measures could reduce the natural range of fluctuation considerably, thereby providing significant economic and environmental advantages, including to the Lower Kaituna River Scheme which provides drainage and flood protection to low lying lands in the Te Puke-Maketu area. Many studies had been done, both engineering and environmental, by Government, Local Government and private bodies and these were all drawn on to some extent in the 1970's investigations. The resultant report (Upper Kaituna Catchment Control Scheme, Bay of Plenty Catchment Commission, September 1975) recommended that a structure be built at Okere and also a structure be built on the Ohau Channel and that each alternative be designed to meet the lake level range set by the National Authority.

Detailed design, water rights were applied for and granted, and construction works were undertaken for the structures with the Okere Falls gates being commissioned in October 1982 and the Ohau Channel control structure commissioned in September 1989. Previously the flows in the Ohau Channel had been controlled by an interim structure (section 3.2). Environment B·O·P and its predecessors has been actively managing the day to day level of the lakes since 1974 (Rotorua) and 1982 (Rotoiti).

In all the previous reports there are comments that after a period of time it may be necessary to alter the control ranges of Lake Rotorua and Rotoiti once these structures have been built and data has been gathered.

2.2 Environment B·O·P and the Resource Management Act

Environment B·O·P (The Bay of Plenty Regional Council), established 1989, is the successor to the former Catchment Authority and has responsibility for managing the levels of both lakes. The levels within which these lakes are controlled are an important matter for the community, particularly with respect to those Rotorua residents living on or near the lakes edge; the cultural, aesthetic and recreational values involved for many New Zealanders living locally and further afield; and the lakes role in the vibrant tourism industry.

Environment B·O·P recognised early the importance of lake level control and that there were competing resource management issues. The previous consent for operation of Okere Falls gates had expired. The Resource Management Act 1991 gave Environment B·O·P an improved basis by which the matters could be formally brought to the public forum and agreed that as soon as possible, application be made under that Act for appropriate resource consents. This report forms part of that application.

The purpose of the consents is to promote the sustainable management of the lakes and the Kaituna River. Sustainable management is "defined" in Section 5 of the Resource Management Act as a series of principles.

Managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural wellbeing and for their health and safety while -

(a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and

(b) Safeguarding the life supporting capacity of air, water, soil and ecosystems; and

(c) Avoiding, remedying, or mitigating any adverse effect of activities on the environment.

Inherent within the "definition" is a balance between people being able to provide for their social/economic/cultural wellbeing, health and safety on the one hand and sustainability of natural and physical resources on the other.

Where the balance should lie is the difficult part. In the production of this report the principles of RMA have been adhered to while trying to maintain the balance required.

3 LAKE ROTORUA

3.1 Introduction

This section discusses the factors and issues to be considered in the application for a resource consent to dam the Ohau Channel at the outlet from Lake Rotorua for the purpose of maintaining the level of Lake Rotorua within set limits.

This section reviews the existing fixed maximum and minimum water levels, the weir structure and its ability to control lake levels and proposes new limits for the water levels of Lake Rotorua and operating procedures for the weir structure stoplogs.

3.2 Background

Prior to 1972, the major problem with Lake Rotorua was its continually high level. This was caused in part by a choking effect of Ohau Channel. During 1972 and 1973 the former Catchment Board, under two separate contracts increased the flow capacity of Ohau Channel which successfully relieved the high level problem. However, during long dry spells this allowed the lake to fall to low levels and from 1974 the Catchment Board maintained a rock basket (gabion) choke at the channel mouth. This structure, which was altered as weather conditions dictated, was an interim measure to prop up lake levels during dry weather until the permanent structure was completed in September 1989.

The structure is described in engineering terms as a two stage broad crested weir. It has provision for the installation of stoplogs in the central portion to help maintain Lake Rotorua levels during dry periods. The hydraulic design of the lower weir allows for the passage of typical runabout boats. Continuous boat passage was a requirement of the Ngati Pikiao people. The shores of Lake Rotoiti and Rotorua (around Ohau) are the rohe of Ngati Pikiao.

The structure is subject to an existing resource consent, Resource Consent Number 02 2180 (Appendix 1). It was originally granted with no finite term but with the introduction of the Resource Management Act on 1 October 1991, the consent now has an expiry date of 1 October 2026.

However because of the issues discussed in section 2.2 and data now available with the passage of time since the installation of the weir structure, Council has taken the initiative of reviewing the levels of Lake Rotorua. This is being done by the resource consent process and the application for a new consent for the Ohau Channel control structure.

3.3 Issues

The following summarises the issues to be considered in the granting of any consent. Matters surrounding the issues are discussed in section 3.4. Investigations.

3.3.1 Lake Levels

A maximum and minimum water level for Lake Rotorua should be set recognising that in extreme events that levels could occur outside this range.

3.3.2 Stoplog Management

The installation or removal of the stoplogs on the structure slows or speeds up the lake level fall. Clear operating procedures need to be defined for the installation/removal of these stoplogs.

3.3.3 Fish Passage

Special structures are built into the weir to permit fish passage. A review of these facilities needs to be undertaken to confirm that the structure is imposing no obstruction to the movement of fish.

3.3.4 Flood Control

Levels and operating procedures need to be set to provide flood control storage and thus reduce the severity of the impact of heavy rainfall events and allow the return to normal levels to be achieved more rapidly.

3.3.5 Aesthetics/Tourism

The Rotorua region is a world famous tourist centre, and Lake Rotorua has extensive shoreline residential and retirement subdivisions plus holiday homes and facilities. Scenic amenity is of major importance in determining the control range of the lakes.

3.3.6 Maori and Cultural Values

The lake is of high value spiritually and culturally to Te Arawa.

3.3.7 Geothermal Pressures

Geological investigation of the relationship between water levels and thermal activity has shown that water levels in water bodies adjacent to thermal sites do have an influence on the nature of the activity.

3.3.8 Boat Passage

The Ohau Channel is used for boat passage between Lakes Rotorua and Rotoiti by recreational and commercial boaters.

3.4 Investigations

3.4.1 Lake Levels

High lake levels cause flooding and waterlogging problems in Rotorua city and the extensive development on the shoreline of the lakes, interference with septic tanks and infiltration into sewerage systems endangering public health. Septic tanks have difficulty operating when the maximum lake levels are exceeded and in the Mourea and Ohau Lodge area the groundwater is within 500mm of the surface. Raising the groundwater level in these areas by as much as 100mm will affect the operation of the effluent disposal fields from the septic tanks. It also causes shoreline erosion and reduces the capacity for storage during storm events.

High lake levels can cause safety hazards. In Hannahs Bay, Holdens Bay and Ngongotaha areas there are open drains in which the water level is determined by lake level. When the lake level is at RL280.11m water sits in these drains permanently, causing a safety hazard. When the lake is 200mm lower some of these drains are dry in fine periods. Rotorua District Council has received a number of complaints from the public and residents concerned about water sitting permanently in these drains.

Low lake levels cause water temperature to rise and increase the effects of nutrient enrichment that deplete oxygen levels and cause problems for aquatic life.

Low lake levels also make boating difficult, jetties ineffective, and expose areas of mud flats creating recreational and aesthetic problems. Environment B·O·P's experience is that there is strong public dissatisfaction whenever the lake level falls below RL 279.65, or 15 cm above the (existing) agreed minimum level.

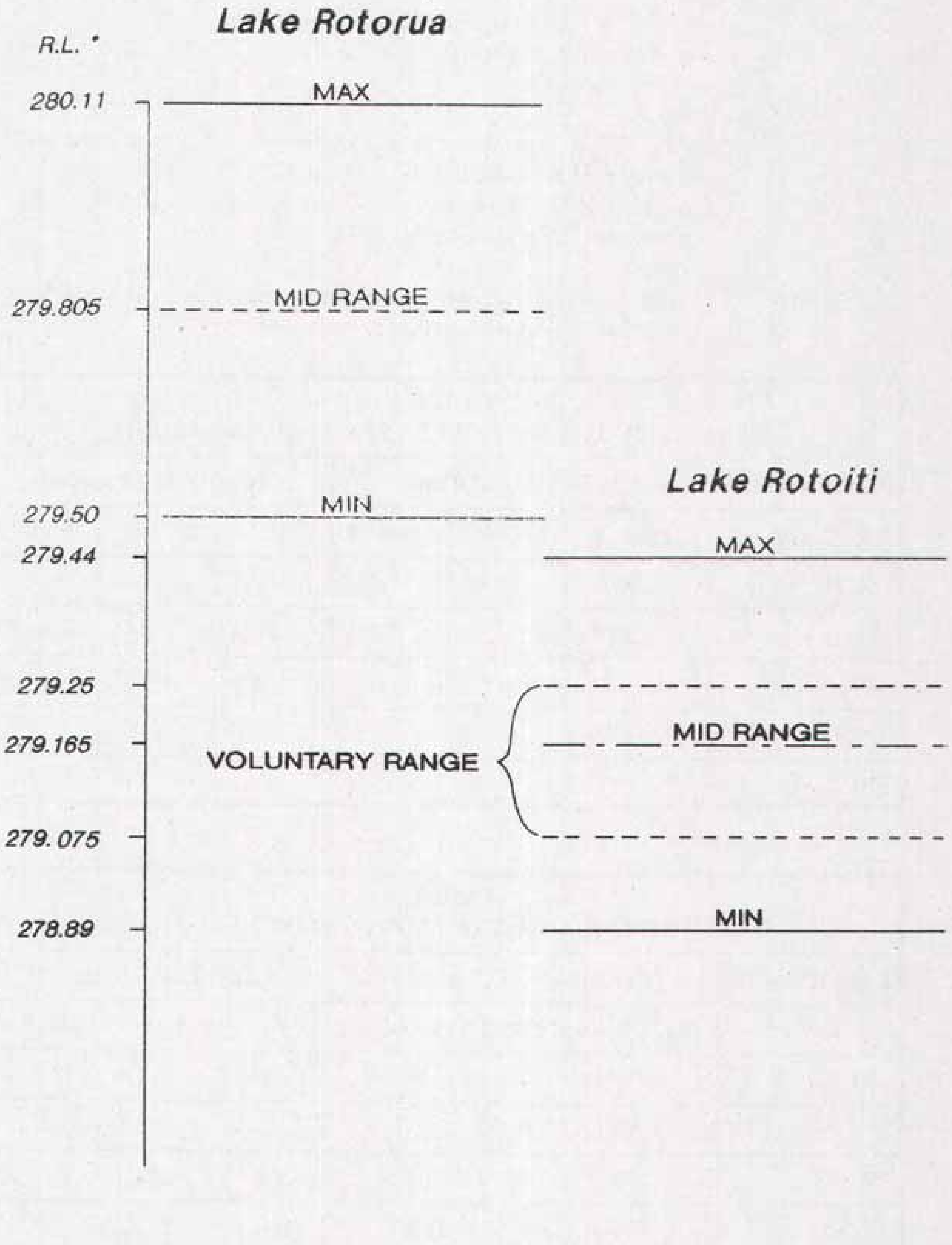
The level of Lake Rotorua is maintained as far as possible within the limits set by the old National Water and Soil Authority.

In their decision which was reached on 6 May 1975, NWASCO resolved:

"recognising that on times of heavy rainfall a maximum level could be exceeded and that, without some form of low level control, the minimum level could be passed in times of low rainfall, to fix pursuant to s14(3)(0) of the Water and Soil Conservation Act 1967, the maximum and minimum levels to be sought or permitted in Lakes Rotorua and Rotoiti as follows: [converted to metres, datum is mean sea level, Moturiki]

Lake Rotorua	*max level*	*280.11*
	min level	*279.50*
Lake Rotoiti	*max level*	*279.44*
	min level	*278.89*

These values are depicted in Figure 2.



R.L. * REDUCED LEVEL RELATIVE TO MOTURIKI DATUM

Figure 2

BAY OF PLENTY REGIONAL COUNCIL

LAKE ROTORUA/ROTOITI CONTROL RANGE	Drawn	B.R.T.	6/95	REFERENCE	PLAN NO.
	Traced	G.T.	6/95		C1384
	Designed			SCALE	
	Checked	B.R.T.	6/95		Sh. 1 of 2
	Approved				

The mid range (mean) level for the lakes is, 279.805 (Rotorua) and 279.165 (Rotoiti).

Tables 1 and 2 provide a summary of the water levels that have occurred in Lake Rotorua for the period 31 December 1962 to 31 December 1976, 21 September 1979 to 22 September 1989, and 23 September 1989 to 18 October 1994.

Figures 3, 4 and 5 show the minimum, maximum and mean level recorded each year since records commenced in 1955.

TABLE 1
LAKE ROTORUA WATER LEVELS TIME EXCEEDED

Lake Rotorua	Percentage of Time			No of Days Exceeded		
Level	**1962-76**	**1979-89**	**1989-94**	**1962-76**	**1979-89**	**1989-94**
280.11	26.8%	0.5%	1.2%	1371	18	22
280.05	38.6%	1.2%	3.2%	1974	44	69
280.00	49.8%	2.2%	5.5%	2546	80	102
279.95	58.6%	4.5%	10.5%	2997	164	194
279.90	65%	9.2%	17.2%	3324	336	318

TABLE 2
LAKE ROTORUA WATER LEVELS TIME LESS THAN

Lake Rotorua	Percentage of Time			Days Less Than		
Level	**1962-76**	**1979-89**	**1989-94**	**1962-76**	**1979-89**	**1989-94**
279.50	1.4%	0.3%	-	72	11	-
279.55	2.7%	2.6%	-	138	95	-
279.60	5.2%	7.5%	1.2%	266	274	22
279.65	9%	18.6%	11.8%	460	680	218
279.70	14.2%	32.8%	33.7%	726	1198	624

From Tables 1 and 2 and Figures 3, 4 and 5 it can be clearly seen that prior to the channel enlargement works of 1972 and 1973 that the lake level was generally high for long periods of time. Following those enlargement works lake levels generally dropped until the construction of the Ohau Channel structure in September 1989.

Figure 3

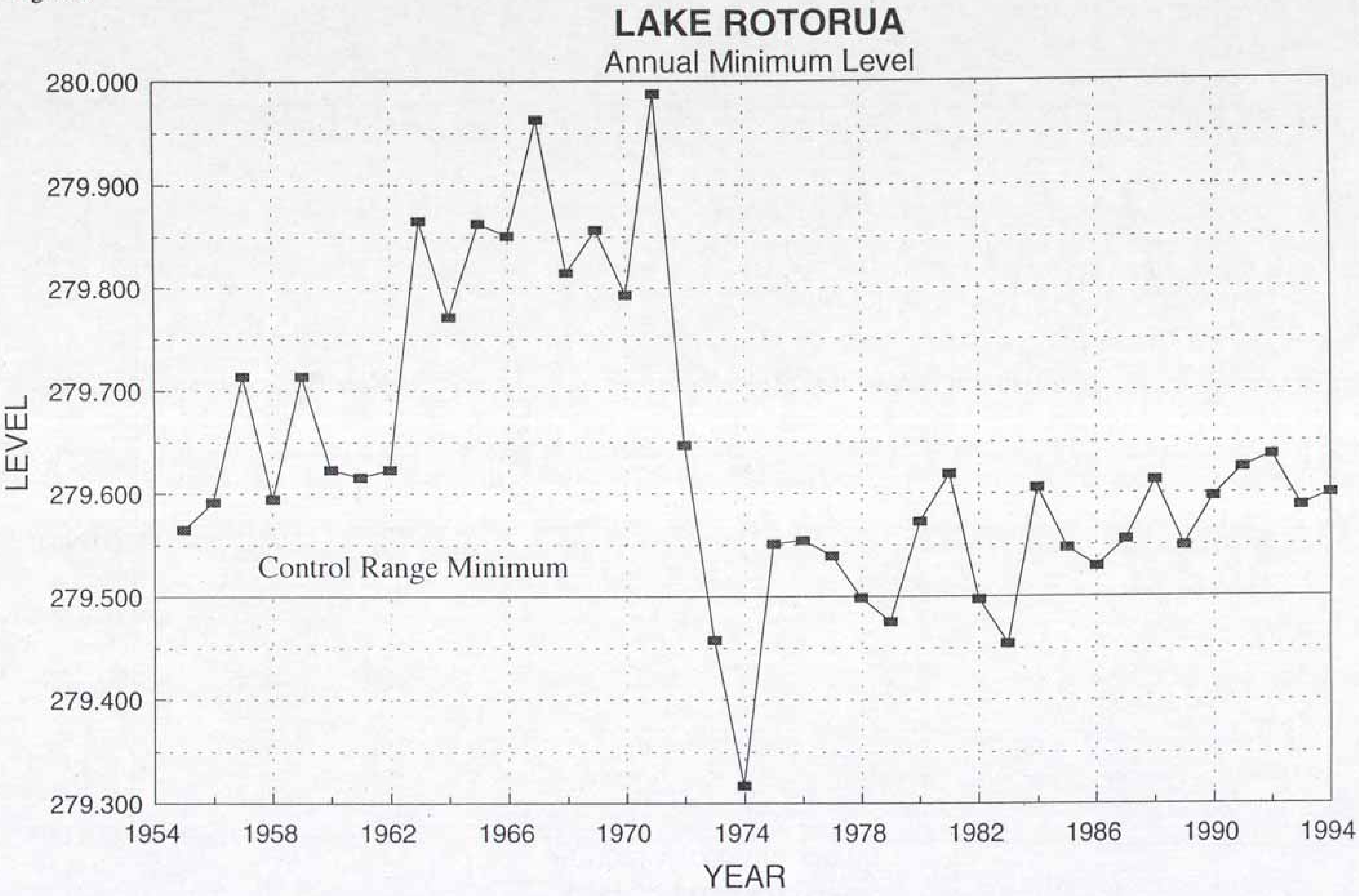
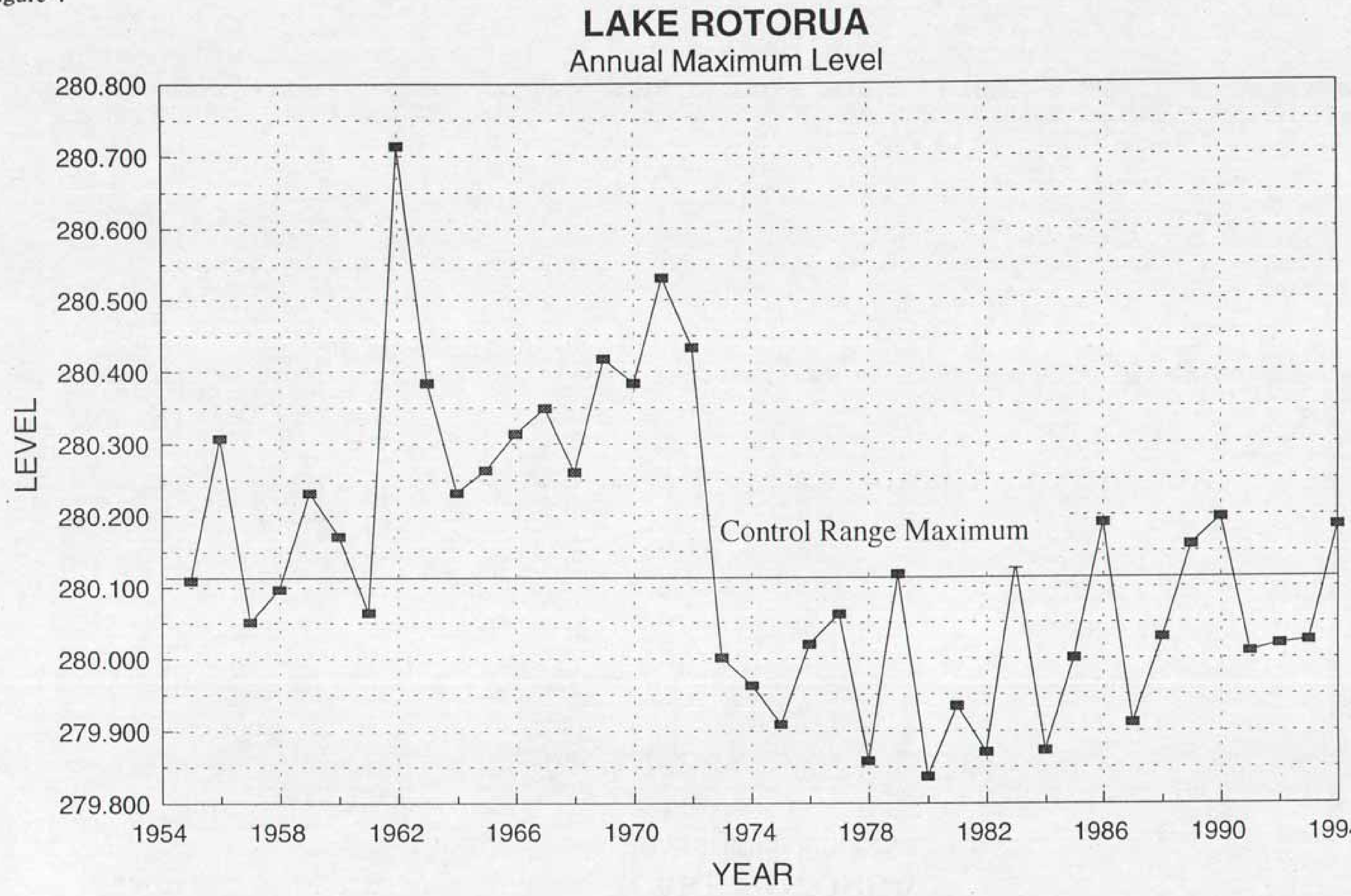
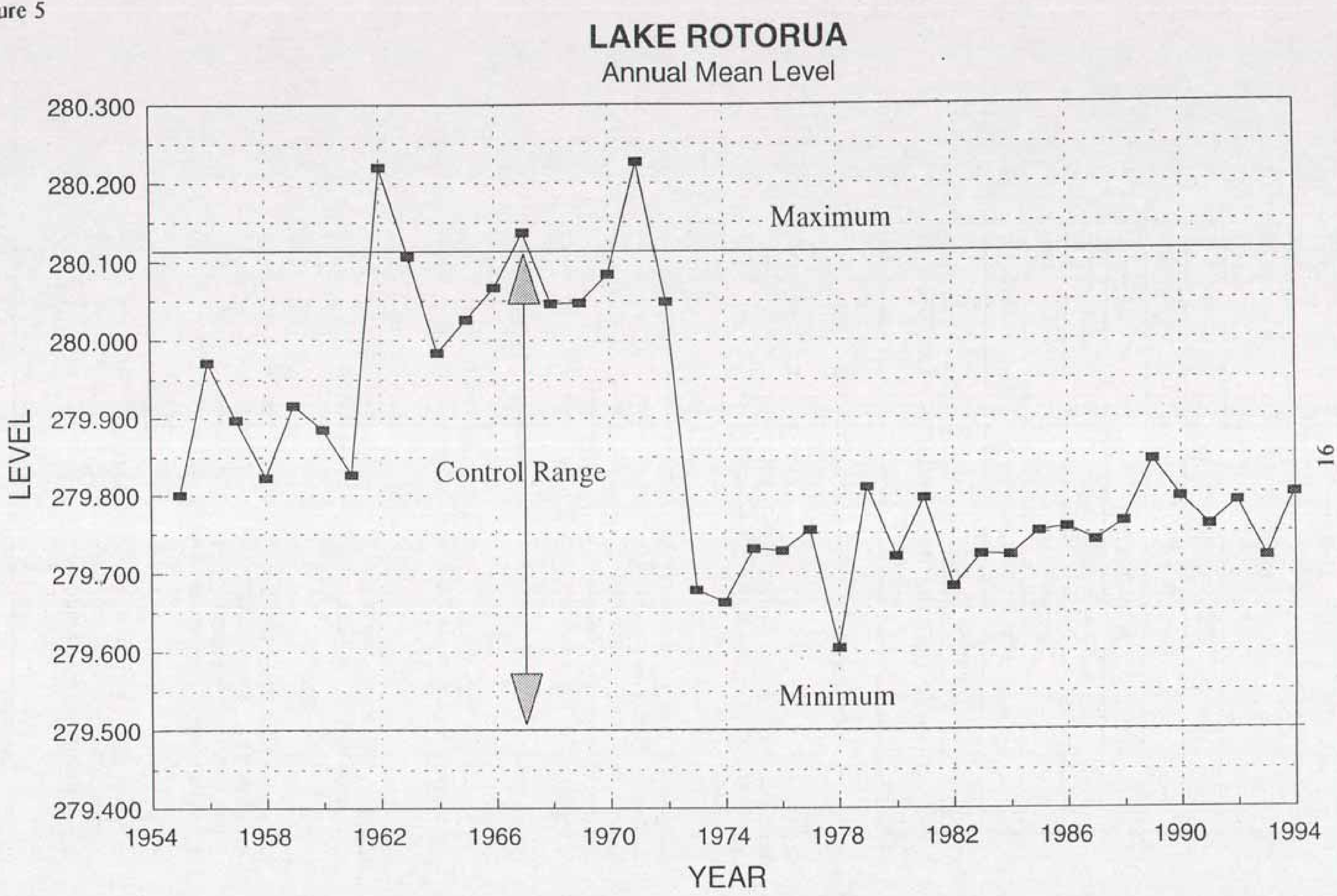

LAKE ROTORUA
Annual Minimum Level
LEVEL
280.000
279.900
279.800
279.700
279.600
279.500
279.400
279.300
Control Range Minimum
1954
1958
1962
1966
1970
1974
1978
1982
1986
1990
1994
YEAR

Figure 4



LAKE ROTORUA
Annual Maximum Level
LEVEL
280.800
280.700
280.600
280.500
280.400
280.300
280.200
280.100
280.000
279.900
279.800
1954
1958
1962
1966
1970
1974
1978
1982
1986
1990
1994
YEAR
Control Range Maximum

Figure 5



LAKE ROTORUA
Annual Mean Level
LEVEL
280.300
280.200
280.100
280.000
279.900
279.800
279.700
279.600
279.500
279.400
Maximum
Control Range
Minimum
1954
1958
1962
1966
1970
1974
1978
1982
1986
1990
1994
YEAR

The objective of constructing a permanent control structure across the entrance to Ohau Channel was to maintain lake levels as far as practicable within the control range and if at all possible to raise the minimum setting.

Tables 1 and 2 indicate that since the structure has been in place the lake level has been maintained at acceptable levels with the maximum of 280.11m being exceeded only 1.2% of the time. The lake level has also been maintained between 279.70 and 279.90 for just under 50% of the time.

It is clear that the weir has allowed minimum lake levels to be maintained at acceptable levels and that the minimum lake level of the operating range could be raised.

Other factors need to be considered before making a decision on changing the operating range.

3.4.2 Stoplog Management

The design of the Ohau Channel structure included the facility for the installation of stoplogs in the central position to maintain minimum Lake Rotorua levels should weather patterns change and drought intensity increase. Since the completion of the structure the stoplogs have been used on a regular basis to assist in maintaining water levels during the dryer periods.

The stoplogs are laid across the central portion of the weir in three groups. Hydraulically they form a false floor which gives a partial damming effect.

Table 3 shows the history of stoplog installation/removal.

TABLE 3
HISTORY OF STOPLOG REMOVAL/INSTALLATION

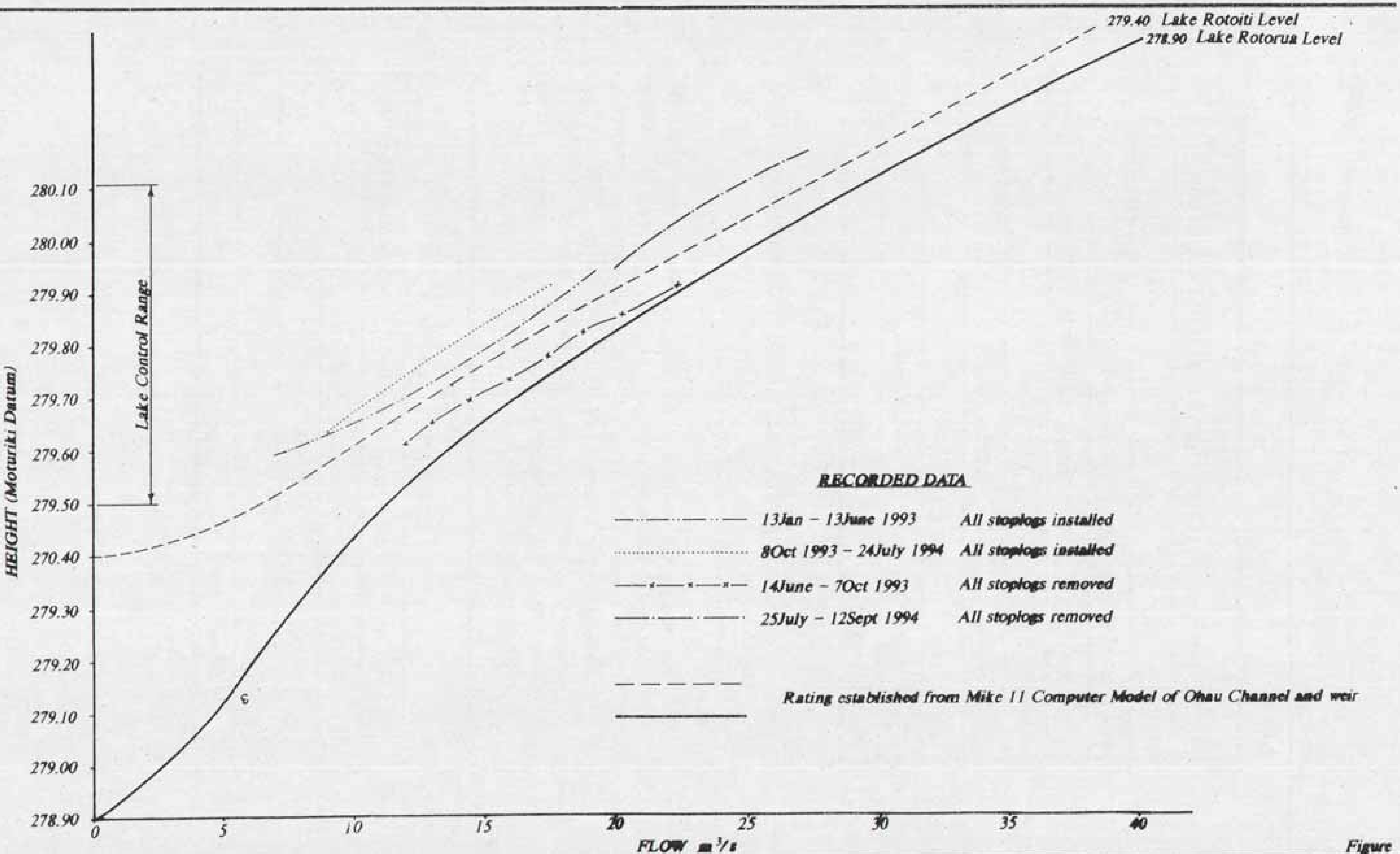
Date	Status
22 September 1989	Structure completed - no stoplogs in
9 January 1991	2 times 2 installed
17 January 1991	3 times 3 installed
25 July 1991	3 times 1 installed
25 September 1991	All removed
4 December 1991	3 times 3 installed

TABLE 3 HISTORY OF STOPLOG REMOVAL/INSTALLATION	
Date	**Status**
19 August 1992	All removed
13 January 1993	3 times 3 installed
14 June 1993	All removed
8 October 1993	3 times 3 installed
25 July 1994	All removed
13 September 1994	2 times 3 installed
28 April 1995	All removed

Figure 6 shows the theoretical rating (that is the flow through the structure versus the lake level upstream) and recorded data for different arrangements of the stoplogs.

The ratings are maintained by National Institute of Water and Atmospheric Research (NIWA) who regularly gauge the flows at the site. In practice, the rating of the structure, whatever the stoplog configuration, is influenced by a number of factors. These include Lake Rotoiti water level, weed growth and sedimentation in Ohau Channel, bar build up between Lake Rotorua and Structure, and wind effects e.g. storm surge.

TABLE 4 LAKE LEVEL VS FLOW		
Lake Level	**No Stoplogs Installed**	**3 x 3 Stoplogs Installed**
279.92	22 m^3/s	18 m^3/s
279.80	18.8 m^3/s	14.5 m^3/s
279.70	15.3 m^3/s	11.5 m^3/s
279.65	13.2 m^3/s	10 m^3/s



Figure

BAY OF PLENTY REGIONAL COUNCIL	SURVEYED			REFERENCE:	PLAN No. C1384
	DRAWN	BRT	5/96		
RATING CURVES FOR LAKE ROTORUA CONTROL STRUCTURE	DESIGNED			DATUM MOTURIKI	
	TRACED	GNOR	6/96	SCALE: NONE	AMENDMENT:
	DESIGN CHK.				
	DR. CHECK	BRT	6/96		SHEET 3 OF 3

1070

It is clear that there are a number of ratings for the structure but from Figure 6 and Table 4 it can be seen that the stoplogs have the following influence on flows over the weir.

On average the stoplogs reduce the flow over the structure by 3.8 m^3/s.

The surface area of Lake Rotorua is approximately 80 x 10^6 m^3. A reduction in flow of 3.8 m^3/s will slow the rate of fall of Lake Rotorua by approximately 4 mm per day.

At the present time there are no defined rules for when the stoplogs are to be removed or installed, although Environment B·O·P generally installs the stoplogs at or just above the mean lake level of 279.805m if the lakes water level has been falling steadily in the previous weeks. This "in-house" policy was designed to pro-actively maintain higher lake levels leading up to a (possible) drought situation.

It has to be remembered that the structure has only been in place for a short period of time and at this stage it would not be prudent to define an operating protocol for their installation and removal without having some flexibility built in.

One issue associated with the stoplogs that needs to be considered is that on several occasions the stoplog guide rails have been damaged by large boats negotiating the structure making it difficult for the stoplogs to be installed.

3.4.3 Fish Passage

At the time of the design of the weir an Environmental Assessment of the weir was carried out by an outside consultant, Dr C P Mitchell, who made a number of recommendations on features that should be incorporated into the weir structure to permit the passage of fish, in particular smelt and trout.

Minor modifications were made to improve the hydraulic performance and make the construction easier. The structure was built accordingly. It was agreed at the time that the fish pass would require monitoring and if need be, modification.

In September/October 1992 concerns were expressed by Eastern Region Fish and Game Council and the Department of Conservation that the weir was not allowing as free a passage as desired. Some further modifications to the weir structure were suggested.

A resource consent was applied for and granted to modify the structure by the installation of gabion baskets and rock on both the upstream and downstream sides of the structure. This work was completed in early November 1993.

A period of monitoring was carried out by Mr Robert Donald, Environment B·O·P's freshwater scientist, to observe smelt passage across the structure. He found that although the works had improved smelt passage, Mr Donald made a number of recommendations to further assist and improve migration of smelt over the structure.

These included:

- the placing of some additional rock to extend the riffle area.
- the block pattern on the weir crests to be modified to match as closely as possible that recommended by Dr Mitchell.
- Regular inspection and maintenance to maintain the effectiveness of the riffle structure.

These modifications were completed in January 1995. Further monitoring was carried out and is detailed in Appendix 4. Mr Donald's conclusions were:

- The modifications to the Ohau Channel fish pass have succeeded in lowering the water velocity over the high crest.
- There is now no reason to suspect the smelt and bully passage through the fish pass is restricted by water velocity.
- Weed and sediment build up in the fish pass may be reducing its effectiveness.

Environment B·O·P accepts that the structure should provide free passage of/for fish, as provided for in the existing consent and will continue to undertake "fine tuning" of the existing structure to ensure this happens.

3.4.4 Flood Control

Considerable analysis was undertaken in 1989 to assess the design flood that the structure and Ohau Channel should convey.

In order to provide for any intensification of the hydrological cycle resultant from the "Greenhouse effect" the design flood magnitudes were further increased by 10% for the 100, 200 and 1000 year return periods.

The design discharges are:

Q100	45 m^3/s
Q200	48 m^3/s
Q1000	54 m^3/s

The revised 100 year design discharge enabled the design of the simple relatively inexpensive structure to proceed which differed markedly from earlier proposals which were using 100 year design flows within the range of 40 to 76 m^3/s. This was mainly a reflection of the designer in 1989 having a longer period of flow record available compared to the earlier calculations.

The weir was designed so that the maximum prescribed Lake Rotorua level (RL 280.11m) would be exceeded on average 3.2% of the time and that Lake Rotorua levels would be more reliably maintained.

In the short period of time since the structure has been in place 280.11 has only been exceeded 1.2% of the time.

During high flows Lake Rotoiti levels have minimal influence on Rotorua levels. The structures ability to hold Lake Rotorua to a more controlled range and to efficiently pass flood flows ensures that when severe storms pass over the catchment Lake Rotorua does not remain high for excessive periods.

The evidence and experience, with the current configuration of the structure and Ohau Channel and the revised flood flows, suggest that maintaining the lake level "low" (say RL 279.70) in allowance for detention storage for a large flood event, is not as important as thought originally (i.e. around 1969). This aspect is further discussed in the next section.

3.4.5 Flood Routing

Analysis was carried out to determined the lake level resulting from the 100 year storm.

Previous work carried out in the 1970's was with limited data and using unit graph derivation for the catchments of Lake Rotorua.

Recorded lake levels and Ohau Channel flows are available from 1 September 1952 to present. By considering the change on lake storage as follows the inflows into Lake Rotorua can be calculated.

$$\text{Rua inflow} = \text{Rua outflow} + \left[\frac{\text{Rua area} \times (\text{Rua level}(I+1) - \text{Rua level}(I))}{\Delta t}\right]$$

$\Delta t = 1.0$ day

Using the annual maximum daily inflow a frequency analysis was carried out to determine the 100 year daily maximum inflow into Lake Rotorua. This was calculated at 330 m^3/s.

Previous analysis had been carried out using 100 year 48 hr hydrographs. This hydrograph was adjusted so that the maximum 24 hr inflow was 330 m^3/s.

The 100 year hydrograph was then routed through the lake with different initial lake levels.

Initial Lake Level	100 Year Lake Level
279.70	280.121
279.90	280.305
280.00	280.389

The original analysis calculated a maximum level of 280.355, this was carried out with a starting lake level of 279.80.

The latest analysis shows that the requirement for detention storage is not as important as thought when the original design was undertaken.

The lake should be maintained at a reasonable level, with the limited control that exists to ensure some detention storage is available during large flood events.

3.4.6 Aesthetics/Tourism

The Rotorua region is a world famous tourist centre, attracting both overseas and New Zealand visitors. For the year ending June 1995, 1.2 million visitors visited the Rotorua region; 480,000 international and 720,000 New Zealanders (Tourism Board). Lake Rotorua has extensive shoreline residential and retirement subdivisions plus vacation homes and facilities. Scenic amenity is of major importance in determining the control range of the lake.

Details of the fishery value of Lake Rotorua are provided in the booklet, Rotorua Lakes, Rainbow Country, the Economic Activity generated by Anglers, Their Profiles, Fishing Patterns and Catch in the Rotorua Lakes Fishery.

In the Rotorua district in 1986/87 26,672 people bought 45,665 licences with over 80% fishing the Rotorua Lakes.

Lake Rotorua as described "as one of the few waters in the district available for fishing all year round. It provides extensive opportunities for lake trolling and stream mouth fly fishing. The lake is the most productive fishery in the Rotorua lakes system with over 30% of anglers from each licence class fishing it."

For scenic and recreational purposes, maximum benefit can be obtained when lake levels are reasonably high and held with minimum fluctuations.

The level of Lake Rotorua, even with the weir structure in place, fluctuates in response to rainfall patterns in the catchment. Since the installation of the weir, the fluctuations in water level have been significantly dampened and the minimum level has been raised.

To control the level to further reduce fluctuations would require significant alterations to the existing structure or even a new structure both of which would need to incorporate some direct control such as gates. The present structure can be described as semi-direct control. It is not obviously as positive as gate control structures, for example at the outlets of Lake Taupo and Lake Rotoiti.

3.4.7 Maori and Cultural Values

Te Arawa first settled in the Rotorua area about 600 years ago. Lake Rotorua is the traditional centre of the Arawa people and is of great significance in terms of its natural, social, cultural and economic values.

Arawa is a confederation of Maori tribes extending from Rotorua to Maketu in the Bay of Plenty.

From time immemorial the Arawa have been accustomed to drawing on the lakes which abound in the Rotorua District for a considerable and important part of their food supply.

Inanga, toi toi, koura and kakahi have been taken for centuries and apart from adding a relish to their other foodstuffs had also been an important element in bartering with Maori in other districts for seafish. forest foods and valuable gifts etc.

European settlement started in the 1870's and incorporated the original Maori settlements of Ohinemutu, Ngapuna and Whakarewarewa at the southern end of the lake.

In 1908 the Te Arawa people presented a claim to the Native Land Commission concerning the use and ownership of the Rotorua lakes. This was temporarily resolved in 1922 when an agreement was reached with the Crown and the passing of the Maori Land Amendment and Maori Land Claims Adjustment Act. In this settlement the Crown confirmed the rights of the Arawa to their ancient fishing rights and the burial reserves in all the lakes. Lakes Rotokakahi and Rotokawau remained in Maori ownership but ownership of 14 other lake beds became vested in the Crown in return for an annuity paid to the Arawa Maori Trust Board. The tangata whenua have a current appeal lodged with the Waitangi Tribunal to challenge this vesting.

The lakes continue to be of major importance to the Maori people and any changes to the management of the lakes should not be done without full consultation with them. An initial meeting has been held with local iwi and further meetings will be held to clarify issues of concern (Appendix 5).

3.4.8 Geothermal Pressures

The geysers and thermal waters of Rotorua have always been highly valued. The thermal activity has a special place in Maori culture and Rotorua has become one of New Zealand's major tourist destinations.

Investigations indicate that the Rotorua geothermal field has an area of 18-28 km^2 and about one third of its area and over half its heat and mass flux occur beneath the southern end of Lake Rotorua.

Aquifer pressure beneath much of Rotorua city is controlled by the lake level, and is uniform due to high permeability in the rhyolitic host rock. Also in view of the large outflow from the Rotorua geothermal field, the lake level is probably the main cold water pressure control for much of the field.

There are a number of other factors influencing geothermal activity such as long-term rainfall, changes in groundwater recharge, changes in aquifer pressure due to erosional down cutting or surface flooding at the main outflow points, and changes in subsurface permeability, especially at times of earthquakes or hydrothermal eruptions.

Rising lake levels may cause increased temperatures and flow rates in the immediate vicinity of the lake but if water levels were allowed to continue to rise thermal sites would be flooded and visible activity would cease. Restricting the maximum level to the status quo means that there will be no detrimental effect to the geothermal activity. Whilst raising the minimum level to reflect what has been the management status quo since the structure was installed, means there will be no change caused to geothermal activity.

3.4.9 Boat Passage

Boat access is over the 6.6m wide low crest of the weir with a invert level of 278.20m. The two considerations are that there is sufficient width and depth to permit power boat passage.

The limiting consideration for craft propelled by an outboard motor is a minimum depth of 0.8m. It can be seen from the water level data that since the installation of the weir the depth of flow over the weir has been 1.35m or greater.

The width of 6.6m is sufficient to permit any normal power boat passage.

It should be noted that in times of low flow, depths in Ohau Channel have been less than over the weir thus the channel itself provides a greater hindrance to boat passage than the weir structure.

The weir structure has not provided a constraint on boat passage except for one vessel that is operating as a commercial tourist venture.

This vessel has a berm of 5.94 m. The boat has hit the stoplog stanchions attached either side of the low flow (boat access) weir, causing damage on at least two occasions. The present unsightly wooden timbers hanging on the structure are an interim protective measure against further damage by this vessel. The boat has also been grounded in Ohau Channel and at the downstream fan of the channel in Lake Rotoiti. The matter is currently being examined under the Navigation and Safety Regulations of the Harbours Act.

Velocities through the boat access channel are typically around 2 m/s (7.2 km/hr). To safely navigate the structure a vessel requires adequate power and room to maintain steerage and control.

The history of damage in the past plus likelihood of continuing damage in the future, clearly suggests the vessel is too big to safely navigate the structure.

3.5 Assessment of Effects

Active management of the lake between a maximum level of 280.11 and a minimum level 279.60 provides a number of positive environmental effects.

Without the lake level control, the levels of Lake Rotorua would fluctuate in response to prevailing weather patterns as existed prior to the construction of the structure.

The proposed control between the range of 279.60 and 280.11 is largely a reflection of the status quo; since the installation of the control structure. Environment B·O·P has controlled the level of Lake Rotorua between these levels for 98% of the time.

The control results in stable shorelines with a reduction in flooding and erosion around the perimeter of the lake and sedimentation of the lake. It also provides confidence for land use around the lake margins and setting of building platform levels. Removal of the excessive fluctuations provides benefits in that it provides a more stable habitat for the aquatic bird life which frequent the lake and its margins.

Maintaining the lake level between this range provides confidence for recreational use both commercial and private, with less likelihood of ineffective jetties, unavailability of beaches during high levels and exposure of unsightly mudflats when low levels occur.

The control of the lake level within a defined range has created a more stable geothermal field as previous fluctuating water levels have had an influence in the nature of the activity. In 1962 the lake levels were so high that they flooded some of the shoreline springs at the Ward baths, closing them for nearly six months.

By controlling the lake to this operating rate allows for multipurpose use and enjoyment of the lake and reduces the detrimental environmental effects that occur when the lake level exceeds these levels, which did occur prior to the structure being constructed.

The main adverse environmental effect of the structure at the time of its installation was restriction of fish passage and this is detailed in section 3.4.3. Environment B·O·P has carried out several modifications to the structure and will continue to undertake "fine tuning" to ensure free fish passage as provided for in the original consent.

3.6 Consultation

It was widely advertised via the July 1995 Regional Guardian that Environment B·O·P would be reviewing the lake levels of lakes Rotorua and Rotoiti. (Appendix 6). Interested parties who wanted further information were asked to contact Ross Titchmarsh, Manager Technical Services.

A section which was placed in the Regional Review Column of 15 August 1995 (the Rotorua Review is delivered to 29,000 householders in the Rotorua District) explained "that Environment B·O·P was reviewing the minimum and maximum levels of Lakes Rotorua and Rotoiti via the resource consent process. The consents and the hearing process will provide an opportunity for the public to expressed their opinion about the levels of these lakes".

Throughout the year there has been frequent contact with various lakes dwellers and users who telephone Environment B·O·P to ascertain what is happening with the levels of the lakes.

It is planned to hold and/or attend a series of meetings over the summer vacation period to consult with the public via the various ratepayer groups to give them an opportunity to express their thoughts and opinions on the management of the levels of these lakes. The first of these is being held on Tuesday 12 December 1995 with representatives of the various resident and ratepayers associations. These include the Combined Rotorua Lakes Ratepayers Assocation, the Hannahs and Holdens Bay Ratepayers Association, the Hamurana-Ngongotaha Ratepayers Association and the Lake Rotoiti Residents and Ratepayers Association.

A meeting was held with iwi representatives on Thursday 23 November 1995 to discuss their concerns (Appendix 5).

Further meetings will be held with them to clarify issues of concern to the iwi of the Rotorua region.

There has been both verbal and written communication with various Rotorua District Council staff who are responsible for a number of areas that are affected by the lake levels.

3.7 Summary

It is recommended that the following be incorporated into the new consent conditions:

Lake Levels

The history of operating the lake control structure has shown that, given a small allowance for exceedance, the lake level range could be narrowed slightly. Rotorua District Council has indicated that the existing upper levels are around what can be considered the maximum, given the design of the sewerage and stormwater system.

On the other hand, the reduced requirement for flood detention means that the lake does not have to be kept at the lower end of the present range.

That the level of Lake Rotorua be maintained between:

Lake Rotorua	max level	280.11
	min level	279.60

representing a raising of the minimum level of 10 cm.

Recognising that in times of extreme high rainfall the maximum level could be exceeded, and in times of extreme low rainfall the minimum level could be passed.

Stoplog Management

That Environment B·O·P installs the stoplogs at or just above the lake level of 279.810 if the lakes water level has been falling steadily in the previous weeks.

That the stoplogs be removed if the lake level reaches 280.000 m.

Fish Passage

Environment B·O·P will continue to undertake "fine tuning" of the existing structure to provide the free passage of fish as provided for in the original consent.

LAKE ROTOITI

4 LAKE ROTOITI

4.1 Introduction

This section discusses the factors, issues and effects to be considered in the application for a land use resource consent for the structure and a discharge permit to control flows via the Okere Falls to enable the levels of Lake Rotorua and Lake Rotoiti to be maintained within set limits.

New limits for the water levels of Lake Rotoiti and a new operating regime for the Okere Falls Gates are proposed.

4.2 Background

Water right number 76C (Appendix 2) was held by the former Bay of Plenty Catchment Commission to discharge excess water from Lake Rotoiti through control gates at Okere.

- to increase outflows to permit flood waters to be discharged when required.
- to reduce outflows to prevent undesirable low lake levels.

The gates were commissioned in late 1982.

One of the conditions of the water right was that "No increase in the natural outflow water shall be permitted until such time as compensating works have been constructed in the Lower Kaituna River Channel". These works were predominantly construction of stopbanks in the Lower Kaituna area (vicinity of Te Puke) to provide flood protection.

The works in the Lower Kaituna River Scheme commenced in the early 1980's and now have been completed and they are sufficient to offset any detrimental effects of the Ohau Channel works and increased discharges from the Okere Falls control gates.

Environment B·O·P and its predecessor the Catchment Board has been responsible for the operation of the gates and controlling the flows for the last 10 years and during this time has developed a good understanding of the ability to control lake levels and flows from Lake Rotoiti. Figure 7 shows the location of the control gates and other main features of the river

4.3 Issues

The following matters are issues which need to be considered when conditions are being attached to any discharge permit (consent). A brief explanation of each issue is provided with detailed discussion provided in Section 4.4 Investigations.

Figure 7


TE MATAI
MAUNGARANGI
BRIDGE
TAAHEKE
OKERE FALLS
Bay of Plenty
Matakana Island
Mount Maunganui
TAURANGA
Te Puke
Motiti Island
Lake Rotorua
ROTORUA
Ngongotaha
L. Rotoiti
Lake Rotoehu
Lake Rotoma
Lake Tarawera
Lake Okataina
C1350

4.3.1 Lake Levels

A maximum and minimum water level for Lake Rotoiti should be set recognising that in extreme events, levels could occur outside this range.

4.3.2 Flow Rates

A maximum and minimum flow rate should be set for the structure. The rate at which any change in flow is varied should be defined.

4.3.3 Operation of Gates

Operation of the gates, particularly the resulting increase or decrease in flow rates downstream has significant consequences throughout the system therefore the operation of the gates needs to be clearly defined.

4.3.4 Records

Continous records of lake levels, gate openings and the resultant discharges downstream need to be kept to ascertain the effectiveness of the control structure and its management on controlling the level of Lake Rotoiti and the flows out of the lake.

4.3.5 Recreational Use

Considerable use of the Upper Kaituna River is made by rafting companies and jet boats in particular, and the lake by passenger boats. The ability of these to operate is directly affected by the operation of the gates and the water level range of Lake Rotoiti.

4.3.6 Maori and Cultural Values

See Section 3.4.7

4.4 Investigations

4.4.1 Lake Levels

High lake levels result in interference with stormwater systems, inundation of low lying areas, interference with septic tanks and infiltration into sewerage systems, shoreline erosion, loss of beaches and reduced capacity for storage during storm events. Further, there are various communities established at lakes edge who hold strong views in particular about maximum water levels.

Low lake levels result in recreational and environmental problems such as loss of draught for boating, and exposure of unsightly mudflats and debris. Water levels around the lakes vary with wind setup. In particular, the predominant west/south west winds can cause higher levels at the eastern end of the lake in the Hinehopu locality. It is unknown the exact effect winds have on raising levels at this eastern end of the lakes so Environment B·O·P has commissioned a study by NIWAR (Christchurch) to specifically look at this area. A report will be available in early 1996. It is also planned to install a water level recorder at Hinehopu. This would record the lake level as well as monitoring the amplitude of the waves. It is anticipated that this will be installed in January 1996.

At present the level of Lake Rotoiti is maintained as far as possible within the limits set by the former National Water and Soil Authority.

In their decision which was reached on 6 May 1975, NWASCO resolved:

"recognising that in times of heavy rainfall a maximum level could be exceeded and that, without some form of low level control, the minimum level could be passed in times of low rainfall, to fix pursuant to S14(3)(0) of the Water and Soil Conservation Act 1967, the maximum and minimum levels to be sought or permitted in Lakes Rotorua and Rotoiti as follows:

Lake Rotorua	*max level*	*280.11*
	min level	*279.50*
Lake Rotoiti	*max level*	*279.44*
	min level	*278.89*

The level of Lake Rotoiti has always fluctuated and it is only since the installation of the Okere Falls control gates that there has been the facility to artificially control the lake level. These gates provide direct control and have the ability to control the lake level to a narrower range for a large percentage of the time.

Previous modelling work indicated that Lake Rotoiti under natural conditions could only remain within the control range 67% of the time and estimated that with the gates in place, the lake level would be within the control range 99% of the time.

The lakes level is measured at a hydrological station near the jetty opposite the Okere Falls store on the true left bank of Okere arm.

Tables 5, 6 and 7 are a summary of the water levels that have occurred in Lake Rotoiti from the period 1 January 1983 to 31 December 1993 i.e. a total of 11 years. Included in this period were 42 days and 22 hours of missing records.
Figure 8, 9 and 10 show the minimum, maximum and mean levels recorded each year since records commenced in 1905.

From Tables 5 and 6 it can be seen that with management, using the gates has achieved the lake level remaining in the control range in excess of 99% of the time.

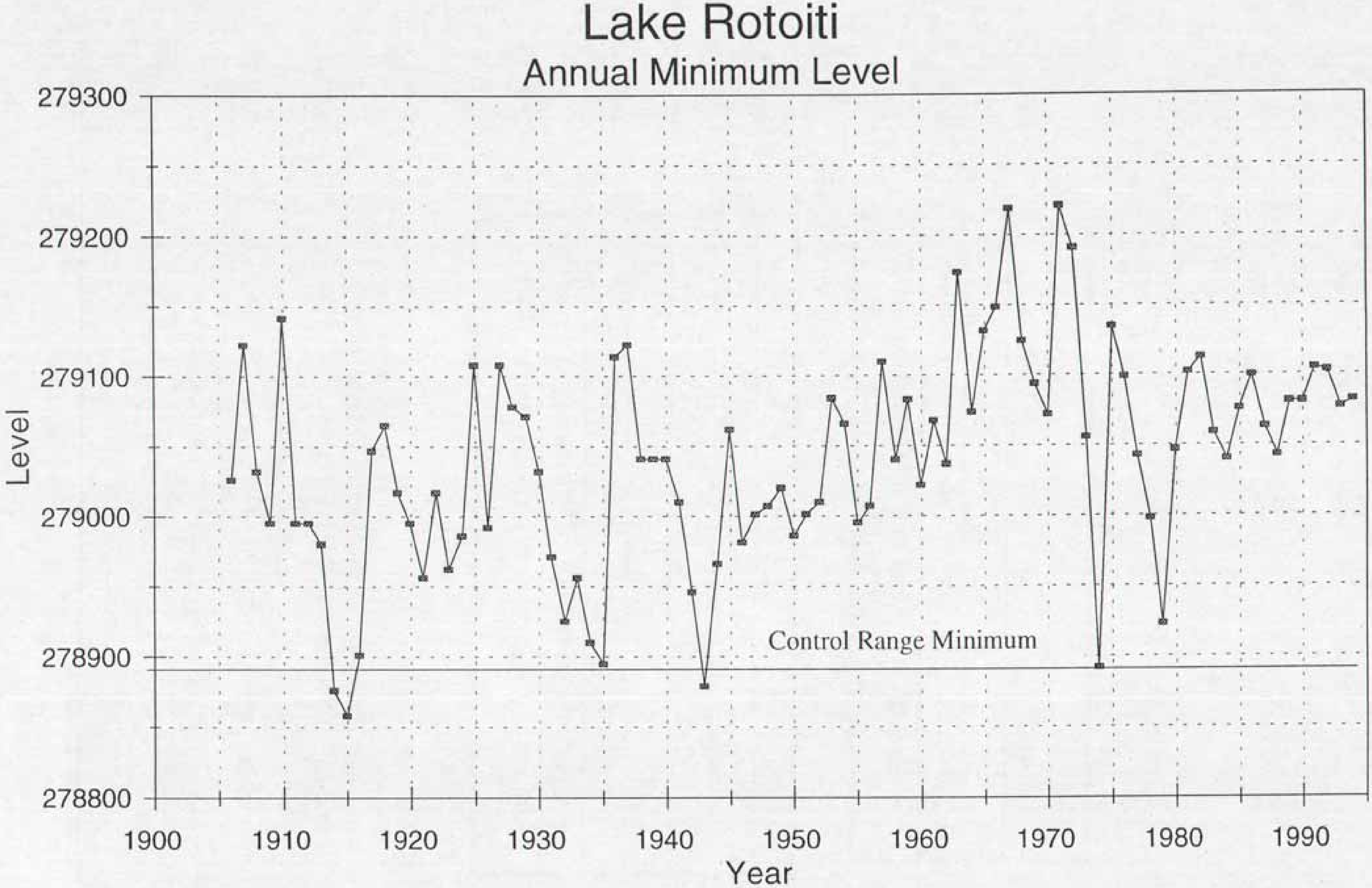
TABLE 5
LAKE ROTOITI WATER LEVELS TIME EXCEEDED

Lake Rotoiti Level	No Days Exceeded	Percentage of Time
279.44	16	0.40%
279.40	35	0.88%
279.35	109	2.7%
279.30	328	9.5%
279.25	844	21.0%

TABLE 6
LAKE ROTOITI WATER LEVELS TIME LESS THAN

Lake Rotoiti Level	Days Less Than	Percentage of Time
279.05	40	1%
279.10	161	4%
279.15	965	24%

Figure 8



Lake Rotoiti
Annual Minimum Level
Level
279300
279200
279100
279000
278900
278800
Control Range Minimum
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
Year

Figure 9

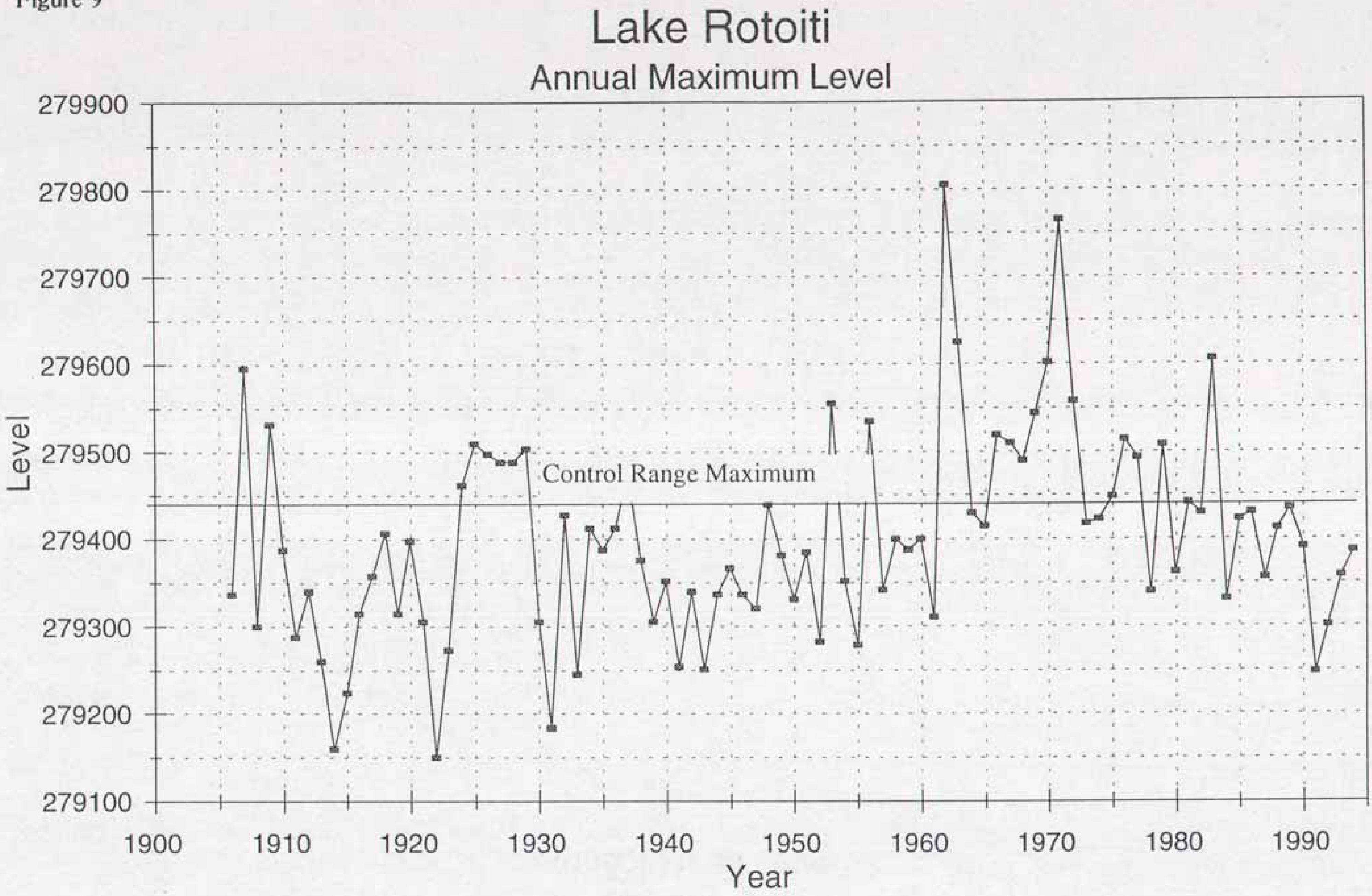

Lake Rotoiti
Annual Maximum Level
Level
279900
279800
279700
279600
279500
279400
279300
279200
279100
Control Range Maximum
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
Year

Figure 10

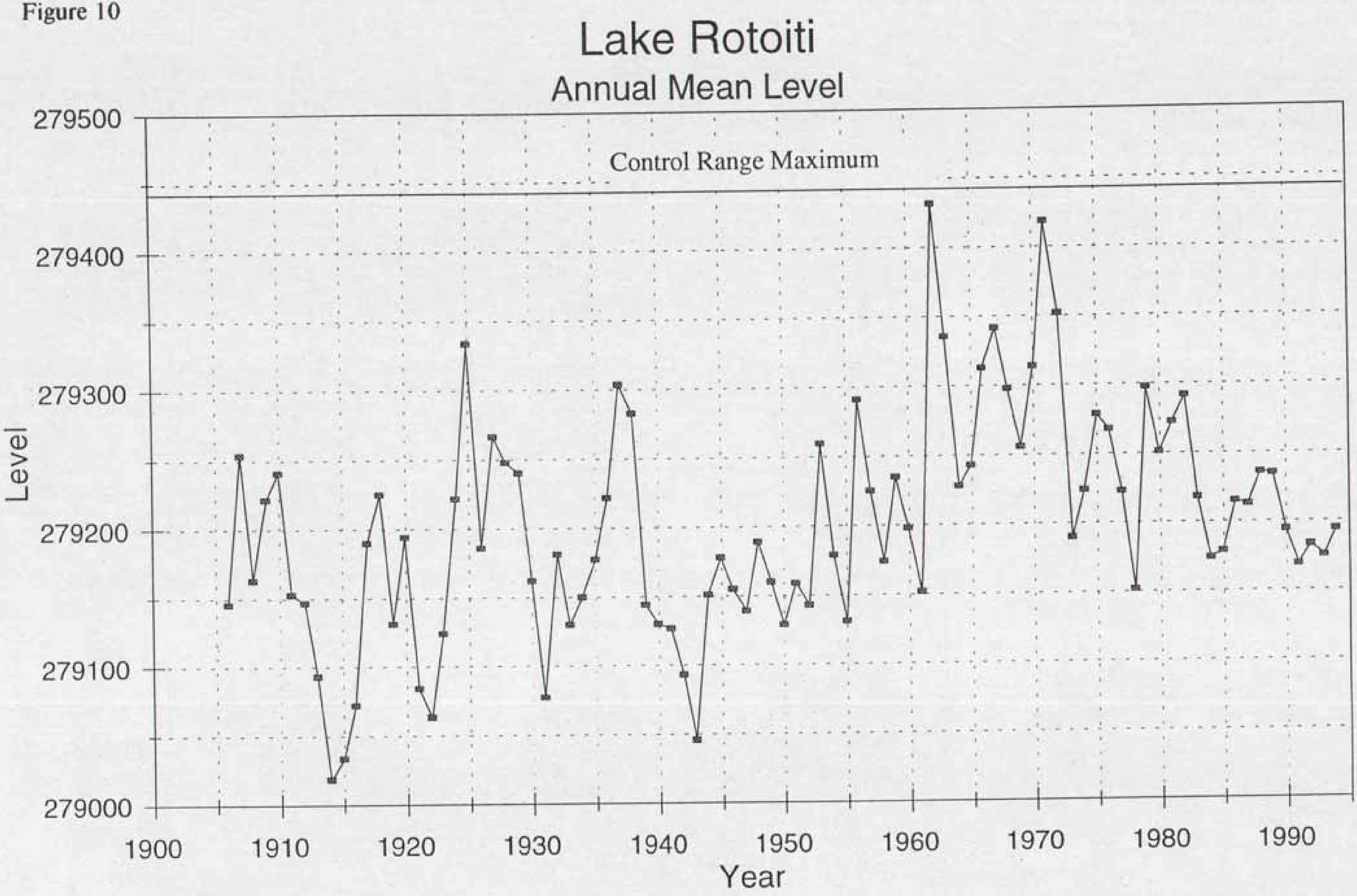

Lake Rotoiti
Annual Mean Level
Control Range Maximum
Level
279500
279400
279300
279200
279100
279000
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
Year

TABLE 7 LAKE ROTOITI WATER LEVELS		
Year	**Minimum**	**Maximum**
1983	279.059	279.606
1984	279.040	279.331
1985	279.076	279.423
1986	279.100	279.431
1987	279.063	279.356
1988	279.043	279.412
1989	279.081	279.435
1990	279.081	279.391
1991	279.105	279.248
1992	279.103	279.301
1993	279.077	279.358

In response to feedback received by lake users particularly the Hinehopu residents Environment B·O·P and its predecessor the Catchment Board adopted some voluntary rules to control the level further. At present it aims to maintain the level of Lake Rotoiti between 279.075 - 279.250. (refer Figure 2) This may well need to be reviewed once the results of the studies and information is gathered as discussed on page 34, e.g. The voluntary range could well be moved up or down.

It can be seen from Tables 5 and 6 that for 98% of the time the lake level has been maintained between 279.10 and 279.35.

4.4.2 Flow Rates

Under water right 76C conditions are

- The rate of flow through the control gates shall be at all times between 7.9 m^3s and 113.3 m^3s.

- This right shall not be exercised in such a manner as to increase flow rates at Okere above the flow rates set out in the table below until compensation works in the Lower Kaituna River have been carried out to the satisfaction of the Regional Water Board. The compensation works must be designed to accommodate additional flows resulting from the exercising of this right.

Lake Rotoiti Level (Moturiki Datum)	Flow Through Okere Gates (Cubic metres per second)
278.89	7.8
279.04	13.7
279.20	20.5
279.35	27.4
279.50	35.2
279.65	44.2
279.81	54.9
279.96	67.4
280.11	80.7

- Maximum rate of change 28 cumecs per hour.

With the gates installed and the resulting reduced level fluctuations there has been an increase in the variation of outflows from the lake i.e. at times of high flow the flows are higher for longer periods and at times of low flow the flow is lower.

Tables 8, 9 and 10 are a summary of the flows that have been recorded at Taaheke (downstream of the control gates) for the period 1 January 1993 to 7 July 1983 i.e. a total of 10.6 years. Included in this period were 31 days and 6.25 hours of missing record.

TABLE 8 FLOWS AT TAAHEKE		
Flow	**No Days Exceeded**	**Percentage of Time**
40 m^3/s	27	0.66%
35 m^3/s	96	2.4%
30 m^3/s	305	7.6%

TABLE 9 FLOWS AT TAAHEKE		
Flow	**Days Less Than**	**Percentage of Time**
7.9 m^3/s	0.5*	0.001%
10 m^3/s	104	2.7%
15 m^3/s	656	16.3%

* The period when flow was less than 7.9 m^3/s were special one-off situations where the gates were closed to reduce flows for incidents such as allowing police to recover a body from the river, works to the gates and works on the Kaituna River.

TABLE 10 ANNUAL MAXIMUM & MINIMUM FLOWS AT TAAHEKE m^3/s		
Year	**Minimum**	**Maximum**
1983	8.293	36.224
1984	14.243	23.794
1985	9.425	32.158
1986	13.097	36.650
1987	5.621	32.872
1988	10.717	33.653
1989	12.367	41.977
1990	13.054	44.120
1991	12.371	36.844
1992	7.678	34.040
1993	6.210	33.154

The impact of these increased flows on the Lower Kaituna River (being generally that reach of the river downstream of the Mangorewa Confluence) was the main concern when water right 76C variation was issued. At the time the Lower Kaituna Catchment Scheme was not formally approved. This scheme has been implemented over the last 13 years and gives protection for floods up to 100 years return period up to Te Matai and 10 year above Te Matai.

The flow out of the lake system at Okere Falls contributes only part of the flow in the Lower Reaches of the Kaituna River. During floods the contribution from the lakes is a smaller percentage of the total flow than during average flow conditions because of the retention effects of the lakes. For example, during the flood of 1962, the maximum flow at Okere was 54.6 m^3/s while at Te Matai it was 376 m^3/s. Other catchments downstream, notably the Mangorewa, contribute the rest.

With the construction of the lower Kaituna scheme now complete, the gates may be operated at their full capacity without any detriment to the land adjacent to the Kaituna River.

Over the last few years the river downstream of the gates has been used by a number of rafting companies. They require a minimum flow of 13 m^3/s equivalent to 3 x 200 gate opening settings to ensure that they operate safely. They cannot operate above gate openings of 3 x 500 (26 m^3/s). These settings have been agreed by the rafting companies in a joint protocol. There have been several occasions when the gates were opened outside this range and the companies have been unable to operate. They have not yet been closed outside this range but if the trend on Lake Rotoiti's level had continued during late January, early February 1994, there would have been a requirement to further close the gates to below 3 x 200.

This is a good example of competing requirements for resource use. Environment B·O·P established a verbal agreement with the rafting companies where the gates would be closed to less than 3 x 200 for two days a week. In that event however there was no need to invoke the protocol; due to rainfall there was no need to close the gates to less than 3 x 200.

Consideration needs to be given in the consent to the possibility that drought conditions like this will occur again and that the effect of managing the water level has direct and significant economic implications on the recreation industry.

It is proposed that the minimum flow allowed be as per existing conditions 7.9 m^3/s. The maximum flow will be determined by the analysis of extreme flows, see section 4.4.4.

The critical factor is not the flow but the operation of the gates and the resulting change in flow rates.

Before we look at the operation of the gates we need to know the capacity of the gates at the various openings.

The flow capacity of the structure is defined by ratings (see 3.4.2 Rotorua). Theoretical ratings exist for the gates and there have been checked against measured flows for recorded gates openings.

Figure 11 shows the theoretical ratings and the measured flows for various gate openings. From this it can be clearly seen that the theoretical gate openings predict release of larger flows than happens in reality. There are various factors causing this but are not of direct concern here. Analysis carried out in this report uses the measured values.

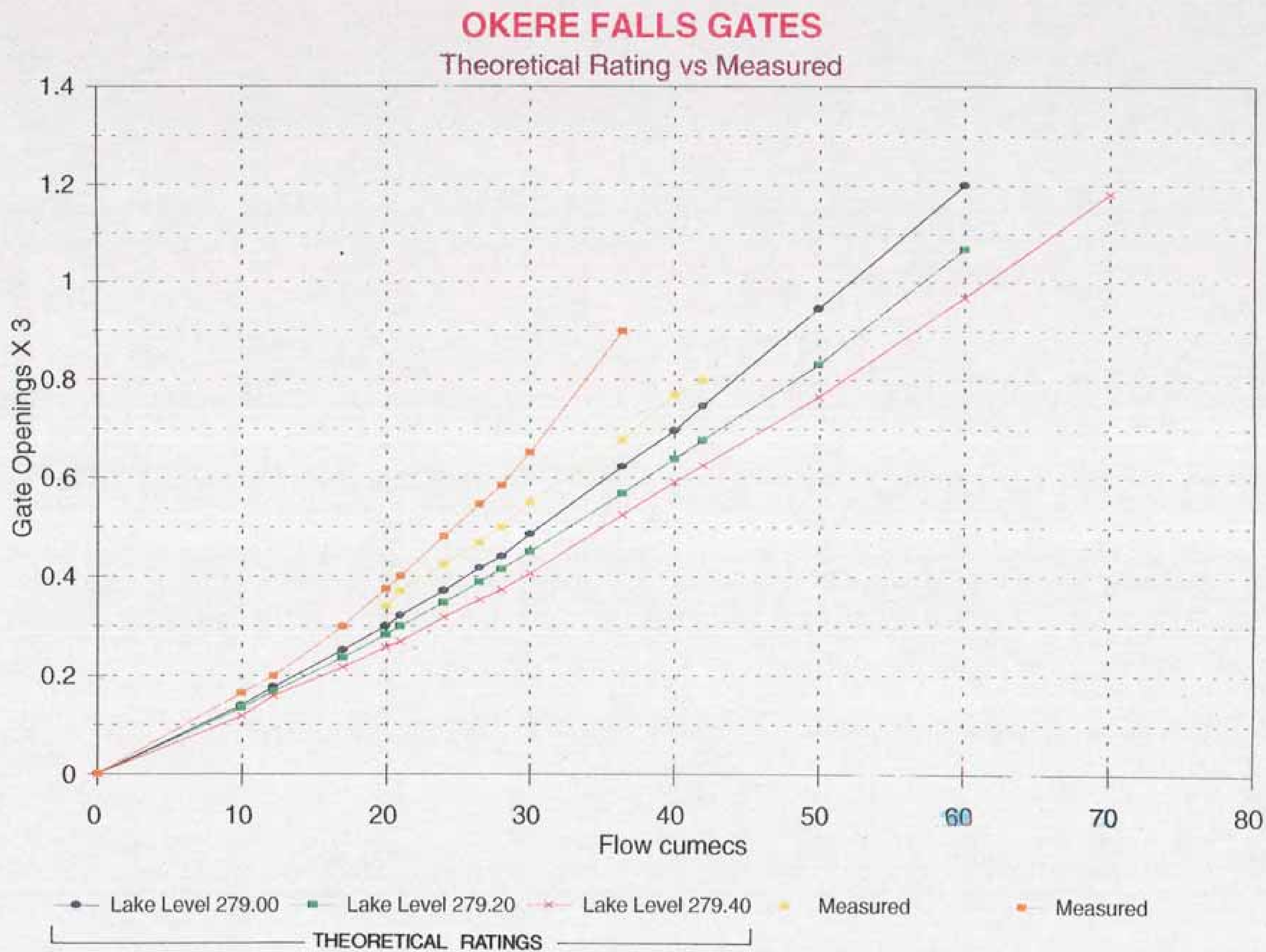


Figure 11

C1389

4.4.3 Operation of Gates

Water right 76C Condition 5.1 is that

- The rate of change of flow shall not exceed 28 m^3/s per hour.

The inflow into the lakes in storm situations are always substantially greater than the outflow from the gates and so the timing of any gate opening is not critical.

The matter of ramping up and ramping down the flows by opening and closing the gates at Okere however needs to be controlled for a number of aspects, in particular:

i) rapid ramping down leaves saturated banks which are vulnerable to collapse and resulting erosion.

ii) the matter of public safety, as rapid water rises and falls cause concern. particularly in the non-navigable section of the river.

The effect of decreasing or increasing the flows on the river will be to increase or decrease the water level. When the river is low the differences could be noticed; when the river is in flood the difference in levels for the same difference in flows through the gates is not likely to be noticeable.

If an increase or decrease in flow at Okere is steady and of sufficient duration (i.e. days not hours) there will be a corresponding increase/difference in flow and water level at all points down the river.

If on the other hand the flow increase or decrease is of short duration then the storage capacity of the channel will alter the shape of the peak/trough to give a lower/higher maximum/minimum flow but of longer duration further downstream. The wave (or trough) of flow released by an opened (or closing) of the gates is progressively dampened down as it moves down river, so that at Te Matai the result will be to reduce the change significantly.

Table 11 gives a summary. of the largest alteration to gate openings since their installation in 1989 (i.e. all other alterations have been more gradual).

TABLE 11				
Date	**Time**	**Gate Openings Change**	**Flow Taaheke m^3/s**	**Lake Rotoiti Water Level (m)**
09/01/89	0900 1000 1100	2 x 500, 1 x 400* to 2 x 700, 1 x 800	27.7 35.6 38.6	279.41 279.41 279.40
01/09/90	1300 1900 2000	3 x 600 to 3 x 800	29.2 34.0 34.4	279.22 279.22 279.22
31/12/91	1500 1600 1700	3 x 200 to 3 x 800	13.2 31.0 32	279.21 279.15 279.15
17/02/92	0700 0800 0900	1 x 300, 2 x 200 to 3 x 600	15.3 25.6 28.8	279.25 279.22 279.22
07/09/92	1030 1130 1230	3 x 300 to 3 x 700	18.6 31.9 32.7	279.27 279.25 279.25

* Read as 2 gates each opened 500 mm and 1 gate opened 400 mm.

It can be seen that in the 11 years of the gates operation the greatest change in flow in one hour has been 17.8 m^3/s. In general there has not been the need to alter the gates in large steps which would cause a large increase or decrease in flows downstream. The gates are opened up or closed down over a matter of days rather than hours.

A trial was done to examine the effect of opening up and closing down the gates, on water level and flows downstream. Details are in Appendix 3.

The trial showed:

- changing the gates from 3 x 200 to 3 x 700 results in an increase on water level of between 550 to 650 mm at Maungarangi Bridge and 200 to 300 mm at Te Matai.

- Tidal fluctuations result in changes in water level at Te Matai of 250 mm.

- The rainfall event of June 10 resulted in a water level rise of 1.8 metres at Maungarangi and 0.75m at Te Matai. This is significantly greater than any change in the gate openings.

- The opening/closing of the gates at Okere Falls takes between 8 and 12 hours to have its full effect at Maungarangi Bridge.

- A rough rule of thumb appears to be that an increase in gate openings by 3 x 100 will lead to an increase in water level at Maungarangi Bridge of 100 to 150mm. (At present Environment B·O·P operates under some voluntary rules of not opening or closing the gates by more than 3 x 100 at any one time).

In summary, a major change in gate openings is required to cause any significant rise in water levels in the lower Kaituna River.

An increase or decrease in flow by opening or closing the gates during a flood event is not likely to have an effect on water levels in the lower reaches of the Kaituna River.

It is recommended that when opening the gates the maximum change in one hour be limited to a change in gate openings of 3 x 200 resulting in a maximum increase in flow of 10 m^3/s.

When closing the gates the alteration should be limited to a change in gate openings of 3 x 100.

This will result in insignificant effects downstream when opening and closing the gates.

4.4.4 Analysis of Extreme Flows

i) Low Flows

Analysis of the flow records indicate that the current minimum flow of 7.9 m^3/s is sustainable with the likelihood that it is exceeded 0.0053% of the time.

We suggest that the minimum flow condition be framed in these terms.

ii) High Flows

It was proposed to carry out a similar analysis to that that was carried out for Lake Rotorua. However significant errors were found in the data which made analysis extremely difficult without spending substantial time and effort adjusting the data.

The best approach was to review the previous work carried out in the early 1970's.

The new Ohau Channel outflow from Lake Rotorua for the 100 year event was combined with the inflow hydrograph from the catchment of Lake Rotoiti and routed through the lake.

The analysis is very dependent on the gate openings in place at any particular time period.

Two scenarios were looked at:

i) using an initial lake level of 278.98 as previous analysis had.

ii) using an initial lake level of 279.20

The routing resulted in maximum lake levels of 279.540 and 279.728 respectively with the gates opened at a maximum of 3 x 2000 mm (approximately 80 m^3/s).

The level of 279.540 is less than the 279.648 predicted by the previous analysis this being the direct result of the reduced 100 year outflows from Lake Rotorua.

The critical factor is how quickly the lake returns to the design maximum level following the flow event.

With the outflow from the lake at 80 m^3/s the level of 279.44 m would be exceeded for just under four days which is acceptable considering it is occurring on average only once every 100 years.

In summary the gates have the ability to be adjusted to manage the 100 year flood flow without causing any significant inconvenience.

It is proposed that the maximum flow be set at 80 m^3/s with the likelihood that it could be exceeded 0.05% of the time..

4.4.5 Recreational Use

As discussed in 4.4.2 Rotoiti a number of rafting companies operate on the river below the Okere Falls. Jet boating is a popular activity further down the Kaituna River, including a commercial venture.

The lake itself is extensively used by a variety of boats. No exact details of the number of boats using the lake are available, but "hundreds of absentee owners who own properties adjacent to the lake descend on the lake in the vacation periods with the majority of these owning some form of boating craft." (J Nicklin, Manager Regulatory Services, Rotorua District Council, Pers Consent). Their needs are best met by keeping the lake within a reasonably narrow range around about the mean.

Details of the fishery value of Lake Rotoiti are provided in the booklet. Rotorua Lakes : Rainbow Country, the Economic Activity generated by Anglers, their Profiles, Fishing Patterns and Catch in the Rotorua Lakes Fishery.

"Lake Rotoiti is recognised as the trophy trout lake of the district. During the 1986-87 season Rotoiti was fished by more anglers than any other water in the fishery".

The lakes provide an excellent environment for growing rainbow trout and this habitat is best maintained by keeping lake levels reasonably high with minimum fluctuations.

The voluntary role that Environment B·O·P has adopted (see 4.4.1) appears to be providing conditions that meet these requirements.

Consent conditions need to be incorporated that allow Environment B·O·P to manage the flows out of the lake so that the recreation industry can operate without compromising the other lake and river users requirements.

4.4.6 Records

Under water right 76C conditions are:

The Grantee shall ensure that continuous records are kept of the following:

i) Levels of Lake Rotoiti at the existing Okere gauging station.

ii) Gate openings at Okere Control Structure

iii) Flow through the Okere control gates.

These records are being kept and should be continued to be kept.

4.5 Assessment of Effects

Similarly to lake Rotorua the active management of the lake between a maximum level of 279.44 and a minimum of 279.00 provides a number of positive environmental effects. Prior to the construction of the Okere Falls control gates the levels of Lake Rotoiti fluctuated widely and for large periods of time the lake level was outside the control range.

The proposed control range is a reflection of the status quo, since the installation of the structure, Environment B·O·P has controlled the level of Lake Rotoiti in response to feedback from residents around the lake.

As discussed in section 4.4.1 with the ability to control the lake level to a narrow range for a large percentage of the time provides even more positive environmental effects.

The control results in stable shorelines with a reduction on flooding and erosion around the perimeter of the lake and sedimentation of the lake.

The control of the lake to a narrow range also minimises the loss of a aquatic bird habitat that used to happen when areas were flooded due to high lake levels and areas that were lost during dry periods.

The other main positive effect of controlling the lake level is the substantial improvement it provides to recreational users of the lake and the Kaituna River downstream.

Beach recreation areas remain unaffected and jetties remain usable with a stable lake level, while fish life thrives. A return to what existed prior to lake level control would significantly reduce the recreational and aesthetic value of the lake.

With the completion of the lower Kaituna Scheme there are now no detrimental effects downstream when the gates are opened during periods of high rainfall.

4.6 Consultation

See 3.6.

4.7 Summary

It is recommended that the following be incorporated into the new consent conditions.

Lake Levels

That the level of Lake Rotoiti be maintained between

Lake Rotoiti	Max level	279.44
	Min level	279.00,

representing a raising of the minimum level of 11 cm.

Recognising that in times of extreme high rainfall the maximum level could be exceeded and in times of extreme low rainfall the minimum level could be passed.

That Environment B·O·P continue to aim to maintain the level of Lake Rotoiti as close as possible to the existing mean level of 279.165, achieving lake levels between 279.05 to 279.30 for 85% of the time.

Flow Rate

The rate of flow through the gates shall be maintained between 7.9 m^3/s (1 x 200, 2 x 100) and 80 m^3/s. (3 x 2000) for 99.945% of the time.

Operation of Gates

When opening the gates the rate of change in flow shall not exceed 10 m^3/s per hour. This is equivalent to a change in gate openings of 3 x 200.

Emergency

The gates may be shut for repair works for a continuous period of no longer than eight hours in any 24 hour period.

When closing the gates the alteration shall be limited to a change in gate openings of 3 x 100. (approx $5m^3/s/hour$)

Records

Continuous records shall continue to be kept as per existing conditions.

Drought Operation

If weather conditions prevail, such that the gates need to be closed to less than 3 x 200, the gates be closed for two days to less than 3 x 200 and for the rest of the week the gates will remain at 3 x 200. The days of closing to be determined in consultation with the rafting companies.

APPENDIX 1

No.2180

BAY OF PLENTY CATCHMENT BOARD

AND REGIONAL WATER BOARD

RIGHT IN RESPECT OF NATURAL WATER

Pursuant to Section 21(3) of the Water and Soil Conservation Act 1967, the Bay of Plenty Catchment Board, in its capacity as REGIONAL WATER BOARD for the Bay of Plenty Catchment Area, by a decision dated 2 February 1989 HEREBY GRANTS to:

REGIONAL COUNCIL
BAY OF PLENTY ~~CATCHMENT BOARD~~

PO Box 364
WHAKATANE

a right to DAM THE OHAU CHANNEL AT THE OUTLET FROM LAKE ROTORUA FOR THE PURPOSE OF CONTROLLING THE LEVEL OF LAKE ROTORUA subject to the following conditions:

1. PURPOSE
   For the purpose of controlling the level of Lake Rotorua.

2. LOCATION
   At outlet from Lake Rotorua as shown on BOPCB Plan No.K4546 submitted with the application.

3. MAP REFERENCE
   U15:018 454

4. WORKS

   'GE:
   4.1 The control structure shall be built and sited generally as shown on BOPCB Plan No.K4562 Sheets 1, ~~and~~ 2 and 9 ~~2.~~

   4.2 The Grantee shall take every care during the construction works and throughout the term of this right to the satisfaction of the General Manager of the Regional Water Board or his delegate to minimise the discharge of sediment into the Ohau Channel.

   4.3 Any erosion control measures which become necessary as a result of exercise of this right shall be undertaken by the Grantee as directed by the General Manager of the Regional Water Board or his delegate.

   :HANGE:
   4.4 Construction of the artificial riffles, as shown on BOPRC Plan number K4562 sheet 9, shall be completed before 15 June 1993.

5. CONTROL STRUCTURE

5.1 The control structure shall be a two stage broad crested weir installed in accordance with BOPCB Plan No.K4562 Sheet 2 and 9.

CHANGE:

5.2 The central lower portion of the control structure shall be not less than 6m wide.

5.3 The control structure shall be designed and undertaken so that elevations of the central lower crest and the top crest are 278.2m and 279.35m above Moturiki datum respectively.

5.4 The control structure shall be designed, undertaken and operated so that as far as practicable, the level of Lake Rotorua is maintained between the statutorily fixed maximum and minimum levels.

5.5 The control structure shall be designed and undertaken to permit the free passage of fish in general accordance with the recommendations contained within the "Environmental Assessment of the Proposed Lake Rotorua Control Structure, C P Mitchell, MAF Fish, Rotorua, November 1988."

5.6 During construction of the control structure there shall be no excavation of the existing trout spawning beds immediately downstream of the structure or machinery movement within the bed of the Ohau Channel.

CHANGE:

6. ACCESS

The Grantee shall as far as practicable maintain the existing foot access on the right bank of the Ohau Channel downstream of the control structure during the term of this right.

7. SUPERVISION OF WORKS

All planning, design, construction and operation of works associated with this right shall be supervised by Registered Engineers.

8. SURRENDER OF RIGHT NO.289

Authority to exercise this right is conditional upon the Bay of Plenty Catchment Board surrendering Water Right No.289 within one month after the date of issue of this right.

9. TERM OF RIGHT

This right shall terminate on 28 February 2014.

10. THE RIGHT hereby authorised is granted under the Water and Soil Conservation Act 1967 and does not constitute an authority under any other Act, Regulation or By-Law.

11. THIS RIGHT may be cancelled by the giving of not less than twelve months' notice in writing by the Regional Water Board to the Grantee if in the opinion of the Regional Water Board the public interest so requires, but without prejudice to the right of the Grantee to apply for a further right in respect of the same matter.

DATED at Whakatane this 16th day of March, 1989.

For and on behalf of
The Bay of Plenty Catchment Board
and Regional Water Board

P J GAVIN
SECRETARY

CHANGE

The change of this permit was approved under delegated authority of the Bay of Plenty Regional Council, dated 9 June 1993, as follows:

Amend Condition 4.1 by deleting "... sheets 1 and 2" and replace with "... sheets 1, 2 and 9".

Add a new condition number 4.4 "Construction of the artificial riffles, as shown on BOPRC Plan Number K4562 sheet 9, shall be completed before 15 June 1993.

Amend condition number 5.1 by deleting "... sheet 2" and replace with "... sheets 2 and 9".

Amend condition number 5.6 by adding to the end of the sentence "or machinery movement within the bed of the Ohau Channel".

R B GARDNER
Manager Environmental Regulation and Monitoring

for J A JONES
General Manager

For the purpose of controlling level of Lake Rotorua
Built generally to Plan No K4562/1
Every care to be taken to minimize discharge sediment to Ohau Chan
Any required erosion measures that are required will be done
The control structure is a two stage broadcrested weir K4562/2
The centre lower portion of the control structure shall not be less than 6m wide.
The control structure shall be designed and undertaken so that the level of Lake Rotorua is maintained between 278.2 and 279.35m
The structure shall be designed, undertaken & operated to maintain the levels between these limit.
It shall be designed to allow the free passage of fish
There shall be no excavation of the spawning beds below the structure.
The existing footpath on right bank shall be maintained as far as practicable
BOPCB to surrender WR No 289 one month after issue of this right.
Terminates 28/02/14

APPENDIX 2

BAY OF PLENTY CATCHMENT COMMISSION

AND REGIONAL WATER BOARD

Pursuant to Section 21 (3) of the Water and Soil Conservation Act 1967, the Bay of Plenty Catchment Commission, in its capacity as REGIONAL WATER BOARD for the Bay of Plenty Catchment area, by a decision dated 7 JUNE 1973 HEREBY GRANTS to

REGIONAL COUNCIL
BAY OF PLENTY ~~CATCHMENT COMMISSION~~

Quay Street,
Whakatane

the right to DISCHARGE EXCESS WATER FROM LAKE ROTOITI subject to the following conditions :

1. PURPOSE :

   1.1. To increase outflows to permit floodwaters to be discharged when required.

   1.2. To reduce outflows to prevent undesirable low lake levels.

2. SOURCE :
   Lake Rotoiti.

3. DISCHARGE POINT :
   Okere Channel. Map reference N76:812187.

4. LEGAL DESCRIPTION :
   Crown Land.

5. DISCHARGE RATE :

   5.1. Before any change in the natural outflow rate shall be permitted from Lake Rotoiti the Commission shall submit to the Regional Water Board for its approval full operating instructions for the control gates which shall make provision that the rate of change in flow shall not exceed 1000 cusecs (28 cumecs) per hour.

DELETED - SEE VARIATION

   5.2. ~~No increase in the natural outflow rate shall be permitted until such time as compensating works have been constructed in the Lower Kaituna River Channel.~~

6. WORKS TO BE CONSTRUCTED :
   A control structure incorporating control gates. Before any works commence, the Commission shall submit to the Regional Water Board for its approval, full plans and supporting details of the proposed structure and no site construction works shall be carried out until the approval in writing to the proposed structure has been obtained from the Regional Water Board.

DELETED - SEE VARIATION

7. ~~THE REGIONAL WATER BOARD reserves the right to review and if deemed necessary vary or revoke the right granted if it considers that the rights or interests of lawful users of water pursuant to Section 21 (1) of the Water and Soil Conservation Act 1967 or notified lawful users of water pursuant to Section 21 (2) of the said Act or where existing or future rights granted under Section 21 (3) and or 24 of the said Act would be or are being materially affected or prejudiced by the continued operation of the right.~~

Variation of Right :

The above right - No. 76C issued on the 12th July 1973 - was varied pursuant to a decision of the Bay of Plenty Regional Water Board dated 3 November 1977 as follows :

That Condition 5.2 be deleted and replaced with the following :

5.2.1 Subject to the provisions of Condition 5.1, the control gates shall be operated so that, as far as practicable, the level of Lake Rotoiti is maintained between 278.89 metres (915 feet) and 279.44 metres (916.8 feet) above Moturiki Datum.

5.2.2 The rate of flow through the control gates shall at all times be between 7.9 cubic metres (280 cubic feet) per second and 113.3 cubic metres (4000 cubic feet) per second.

5.2.3 This right shall not be exercised in such a manner as to increase flow rates at Okere above the flow rates set out in the table below until compensation works in the Lower Kaituna River have been carried out to the satisfaction of the Regional Water Board. The compensation works must be designed to accommodate additional flows resulting from the exercising of this right.

Lake Rotoiti Level (Moturiki Datum)		Flow through Okere Gates	
Metres	Feet	Cubic Metres per second	Cubic Feet per second
278.89	915.0	7.9	280
279.04	915.5	13.7	480
279.20	916.0	20.5	720
279.35	916.5	27.4	970
279.50	917.0	35.2	1240
279.65	917.5	44.2	1560
279.81	918.0	54.9	1940
279.96	918.5	*67.4	*2380
280.11	919.0	*80.7	*2850

*extrapolated

5.2.4 The Grantee shall ensure that continuous records are kept of the following :-

(i) Levels of Lake Rotoiti at the existing Okere gauging station.

(ii) Gate openings at Okere control structure.

(iii) Flow through the Okere control gates.

A copy of these records for the period ending 31st March each year shall be sent to the Regional Water Board by the Grantee within one month of the close of each such period.

5.2.5 All planning, design, construction and operation of works associated with this right shall be supervised by Engineers duly registered and practising pursuant to the Engineers Registration Act 1924.

5.2.6 The Grantee shall to the satisfaction of the Regional Water Board, take every care during construction and maintenance of the works to prevent material from entering any watercourse or from being washed into any watercourse.

5.2.7 This right shall terminate five (5) years after the date of commencement of exercising this right in such a way as to increase flow rates through the Okere control gates beyond those shown in the table in Condition 5.2.3 above. The Grantee shall notify the Regional Water Board when the right is first so exercised.

That Condition 7 be deleted and replaced with the following :

7. This right may be cancelled upon not less than twelve months notice in writing by the Regional Water Board to the Grantee, if in the opinion of the Regional Water Board the public interest, the interests of lawful users of water, or the interests of future applicants for water rights so requires; but without prejudice to the right of the Grantee to apply for a further right in respect of the same matter.

DATED at Whakatane this 14th day of April 1978.

For and on behalf of
the Bay of Plenty Catchment Commission
and Regional Water Board

8. THE RIGHT hereby authorised is granted under the Water and Soil Conservation Act 1967 and does not constitute an authority under any other Act, Regulation, or By-Law.

DATED at Whakatane this 12th day of July 1973.

For and on behalf of
The Bay of Plenty Catchment Commission
and Regional Water Board

J.D.CARLING
Secretary.

For Variation - See attached Page 3.

APPENDIX 3

GATE OPENING TRIAL

The trial was carried out from Tuesday, 7 June 1984 until Tuesday, 14 June 1994 with the following gate opening changes being made.

Tuesday 7 June

800 3 x 300 to 3 x 400
930 3 x 400 to 3 x 500
1100 3 x 500 to 3 x 600
1230 3 x 600 to 3 x 700
1430 3 x 700 to 3 x 600
1630 3 x 600 to 3 x 500
1830 3 x 500 to 3 x 400
2000 3 x 400 to 3 x 300

Wednesday 8 June

0800 3 x 300 to 3 x 500
2000 3 x 500 to 3 x 200

Thursday 9 June

0800 3 x 200 to 2 x 700 1 x 200
0830 2 x 700 1 x 200 to 3 x 200
1200 3 x 200 to 3 x 700
1730 3 x 700 to 3 x 200

Friday 10 June

800 3 x 200 to 3 x 300
1200 3 x 300 to 3 x 500
1600 3 x 500 to 3 x 300
2000 3 x 300 to 3 x 600

Saturday 11 June

800 3 x 600 to 2 x 200 1 x 300

Monday 13 June

1900 2 x 200 1 x 300 to 3 700

Tuesday 14 June

0630 3 x 700 to 2 x 200 1 x 300

A temporary water level recorder was installed at Maungarangi Bridge approximately 23 km downstream of the gates. Water levels were recorded there for the period of the trial as well as at Te Matai some further 10 km downstream.

Figures 12, 13, and 14 show the water levels that occurred in the river at these two locations during the trial. (Note that 4 metres has been added to the Te Matai water level to permit easier analysis).

Rainfalls of up to 85 mm were recorded in the catchment from 0900 June 10 to 0900 June 11 resulting in the significant rise of water levels on June 11. The return period for this is estimated to be an annual event.

Figures 15 and 16 show the water levels and flows at the Taaheke site approximately 1000 m downstream of the falls.

It can be seen that changing the gates from 3 x 300 to 3 x 700 results in a water level rise of 400 mm at this site.

It can also be clearly seen from Figure 14 that for the period 07 June to 11 June 1994 with the lake level approximately 279.14 m the change in gate openings corresponds to the following change in water levels and flows at Taaheke.

	Water Level Change	**Flow Change**
3 x 200 to 3 x 300	200mm	5 m^3/s
3 x 300 to 3 x 400	150mm	4 m^3/s
3 x 400 to 3 x 500	110mm	3 $m^3/$
3 x 500 to 3 x 600	90mm	2.4 m^3/s
3 x 600 to 3 x 700	70mm	1.9 m^3/s

Figure 12

Kaituna Water Levels

C1389

Figure 13

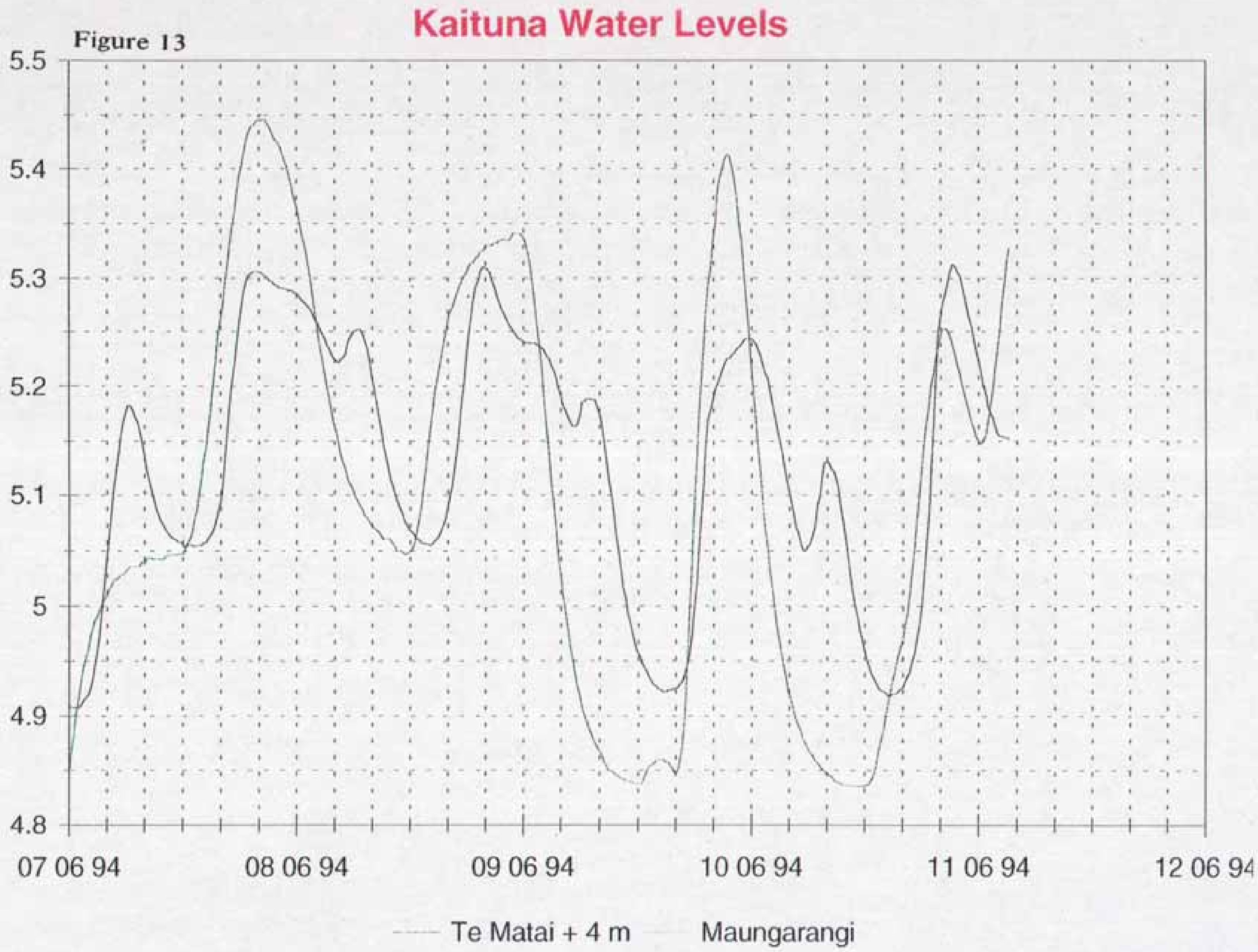


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Figure 14

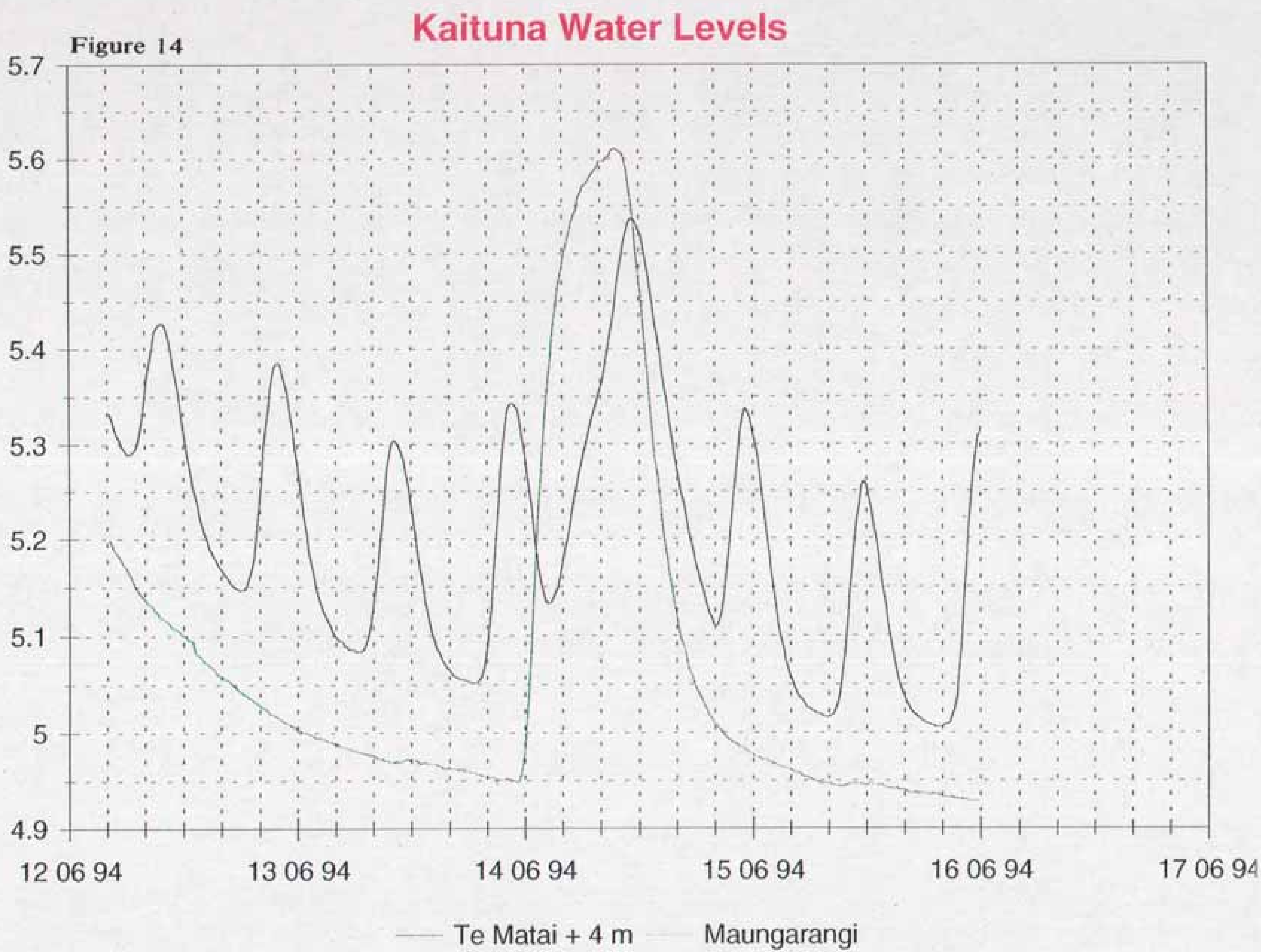

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Figure 15

Kaituna River Downstream Okere Falls

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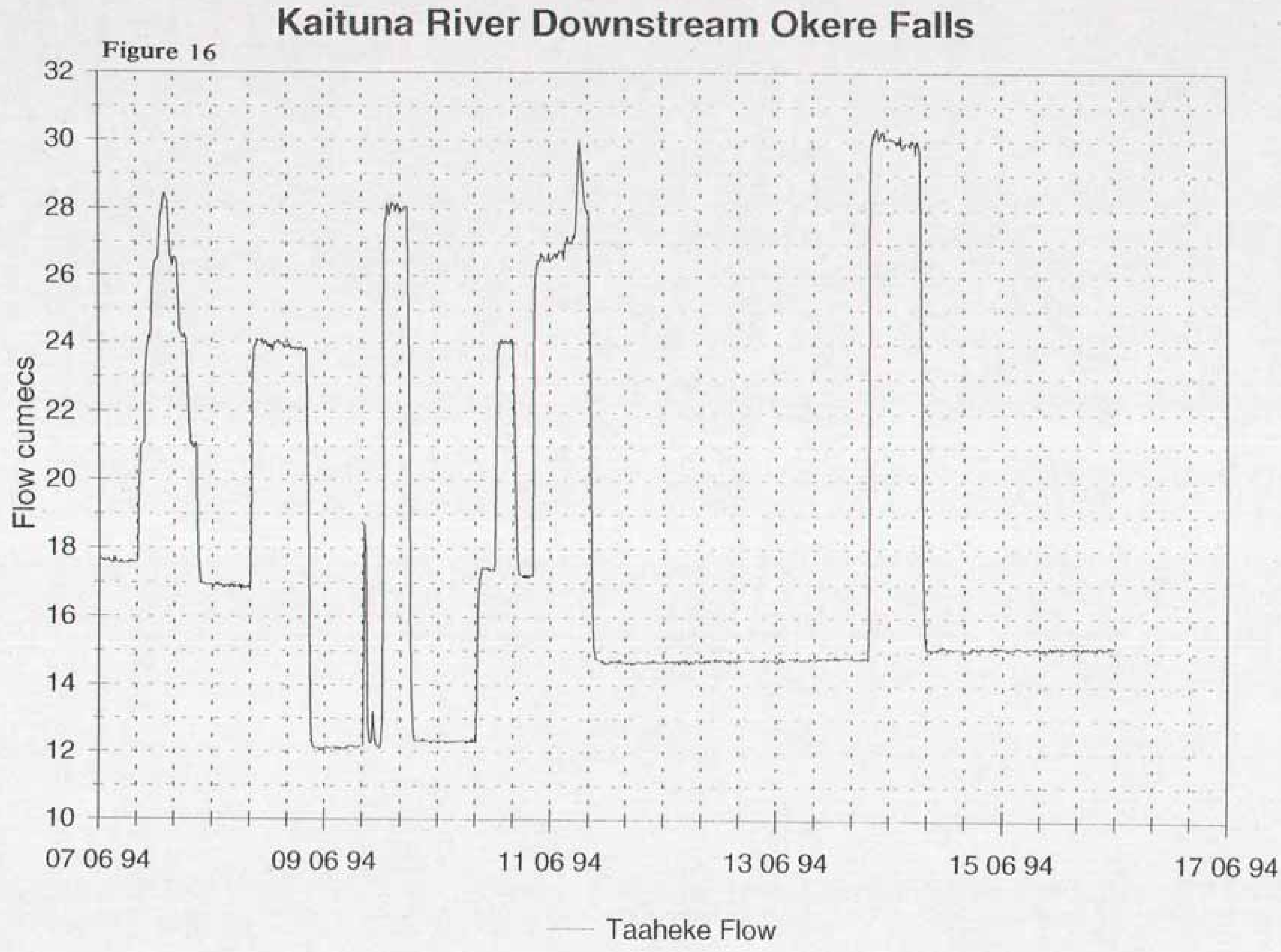
Figure 16



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ENVIRONMENT B·O·P
Bay of Plenty Regional Council

Memorandum

To:	Ross Titchmarsh **Manager Technical Services** Bruce Crabbe **Manager Rivers and Drainage**
From:	Robert Donald **Environmental Scientist**
Date:	11 October 1995 **File reference:** 3080 07, 02 2179
Subject:	**OHAU CHANNEL CONTROL STRUCTURE - WATER VELOCITY OVER THE FISH PASS**

INTRODUCTION

The following relates to velocity measurements taken on the Ohau Channel fish pass before and after the installation of additional blocks on the high crest. It was expected that these would further reduce water velocity to levels which would not restrict the upstream movement of smelt and bullies.

Mitchell (1989) provides guidance on the maximum water velocity which will allow fish passage over structures of a given length (copy attached). The Ohau Channel control structure has a length of 5.5 m (upstream to downstream). In this case the velocity over the high crest should ideally be less than 0.35 m/s to allow the passage of smelt and bullies (see Fig. 3 of Mitchell (1989)).

To negotiate the structure small fish must first use "burst swimming" to move through the rocks and boulders (artificial riffle) located downstream of the high crest. The burst swimming speed is around 0.5 m/s for smelt and 0.6 m/s for common bully. Once on top of the high crest "steady swimming" would be used to proceed into the lake. Steady swimming speeds are around 0.3 m/s for smelt and common bully (Mitchell 1989).

METHODS

Trials were carried out on 8 June 1994 by experimenting with temporary blocks on the high crest. Velocity was measured near the block corners using a Gurley Pygmy meter positioned 2-3 cms above the base of the crest. In some cases readings were also obtained just below the water surface. Based on the results of the trials extra blocks (250 l x 200 h x 90 w) were installed diagonally between the original blocks. Velocity measurements were carried out to assess the effect of the new blocks on 24 May 1995.

RESULTS

The trials conducted in June 1994 suggested that diagonally placed blocks would significantly reduce water velocity over the fish pass (Figs 1 & 3). Most importantly it was possible to reduce the velocity on the high crest and in the artificial riffle to levels below the respective steady and burst swimming speeds.

Measurements taken after the extra blocks were permanently installed indicate that velocities on the high crest are low (mean of 0.25 m/s from 48 measurements) and generally below the steady swimming speeds (Figs 1 & 4). Velocities were higher than for the initial trial possibly because of the greater flow and lake level on 24 May 1995 compared to 8 June 1994 (18.5 m^3/s and 280.003m MOT datum versus 14.7 m^3/s and 279.888m MOT datum). Measurements taken just below the water surface (Fig. 4) give some idea of how much the water velocity on the high crest is slowed by the concrete blocks. In the artificial riffle area the velocities have been reduced further than was indicated by the initial trial (Fig. 3).

DISCUSSION

The information presented here suggests that smelt and bullies will have little trouble negotiating the Ohau Channel control structure into Lake Rotorua. There is still concern that weed and sediment build up on top of the high crest will obstruct the movement of smelt and bullies. This is likely to be an ongoing problem and the situation could be alleviated by employing a local person to act as 'caretaker' for the fish pass.

CONCLUSIONS

1 The modifications to the Ohau Channel fish pass have succeeded in lowering the water velocity over the high crest.

2 There is now no reason to suspect that smelt and bully passage through the fish pass is restricted by water velocity.

3 Weed and sediment build-up on the fish pass may be reducing its effectiveness.

R. Donald

Robert Donald
ENVIRONMENTAL SCIENTIST

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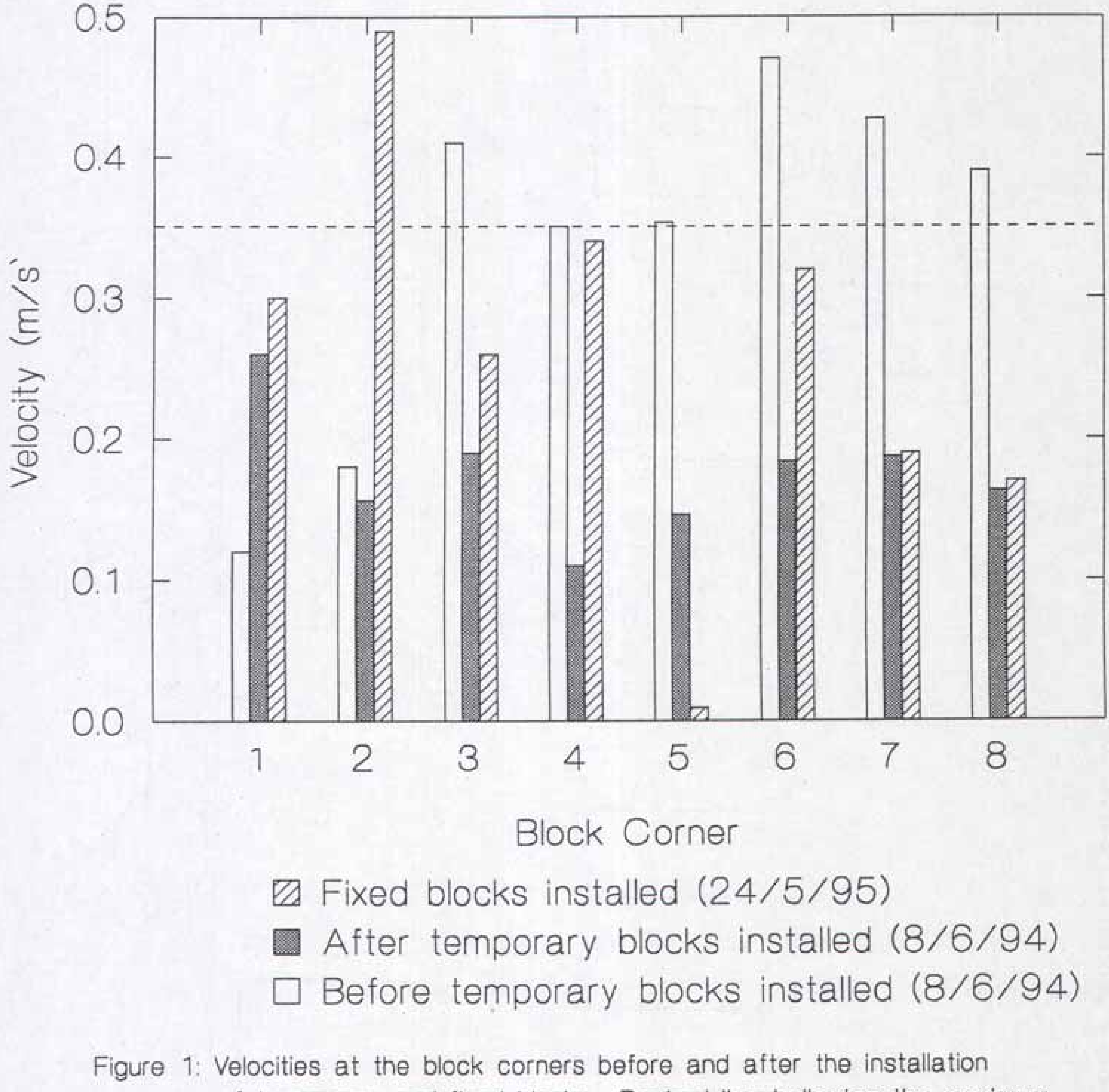

Figure 1: Velocities at the block corners before and after the installation of temporary and fixed blocks. Dashed line indicates the maximum allowable velocities for movement of smelt and bullies over the structure. Positions of block corners are identified in Figure 2.

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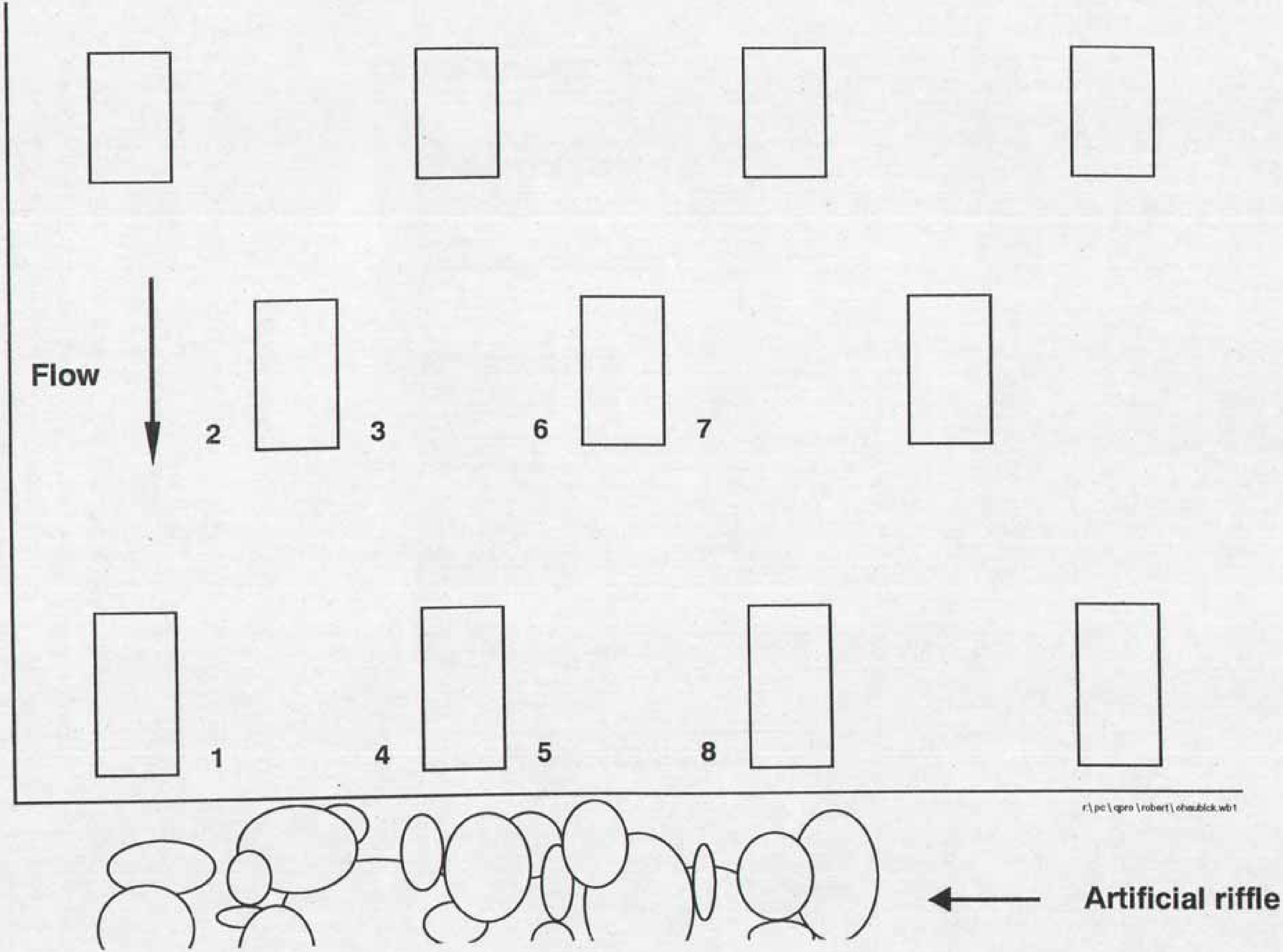
Figure 2: Positions of block cor...s given in Figure 1.



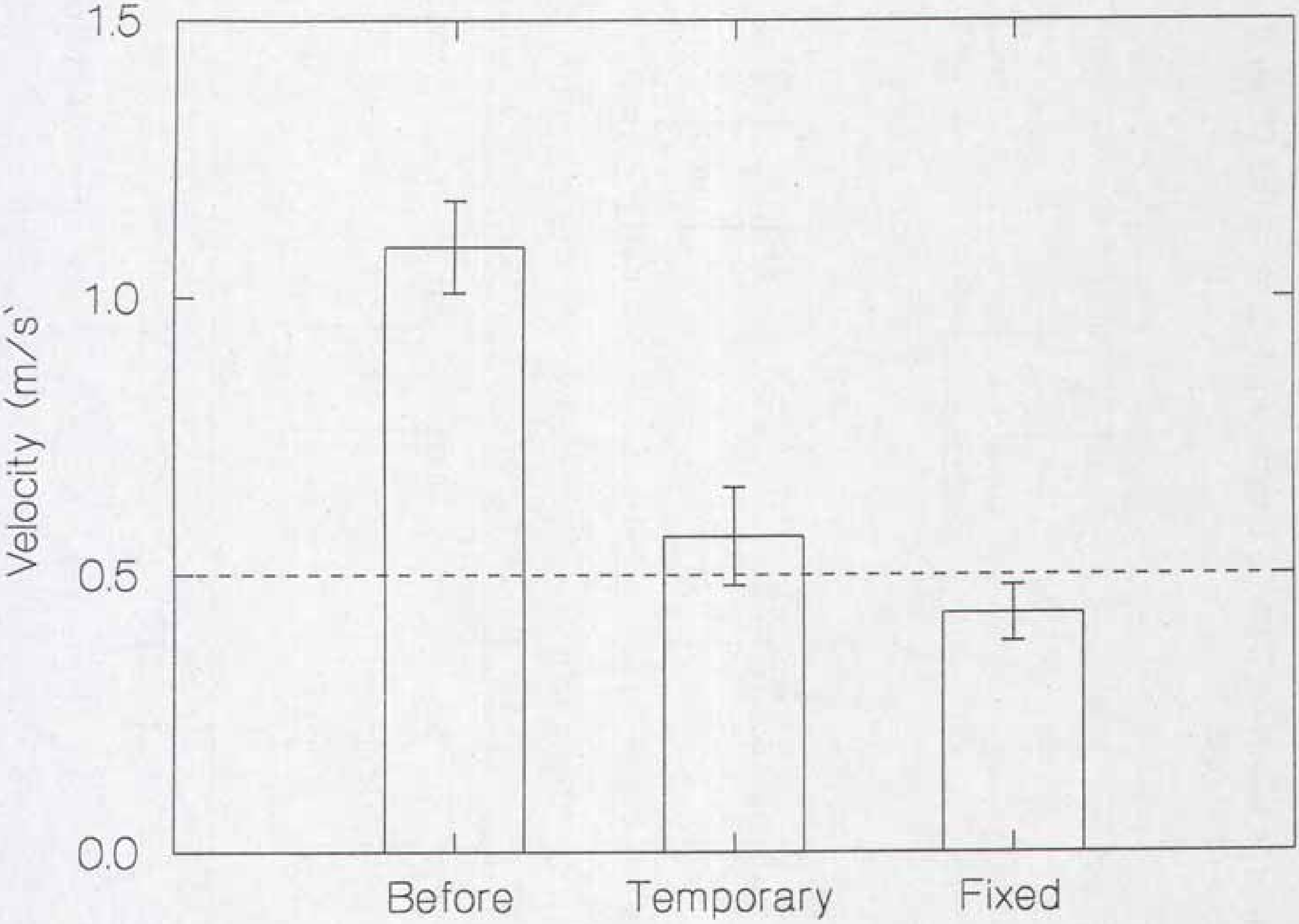


Figure 3: Mean velocities (+/- SE) in the artificial riffle before and after the addition of temporary and fixed blocks. Dashed line indicates the burst swimming speed of smelt.

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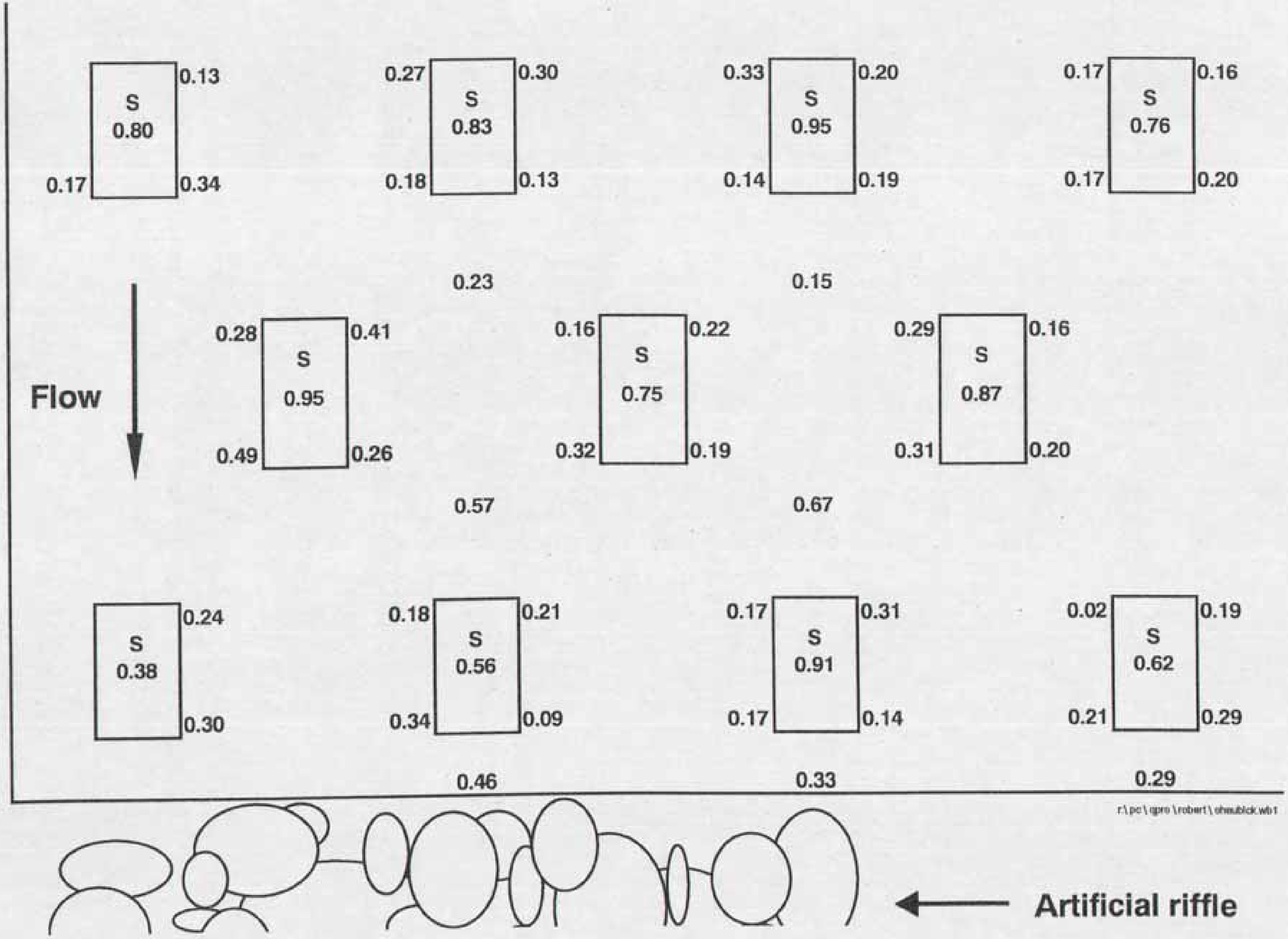
Figure 4: Velocity measurements taken on 24/5/95 on the right bank of the Ohau Channel.
S - indicates surface readings.



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0028–8330/2302–0181$2.50/0

Swimming performances of some native freshwater fishes

C. P. MITCHELL
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Abstract Observations were made of the response to water velocity for upstream migrating juveniles of 5 diadromous native fishes (*Anguilla australis, Galaxias maculatus, Galaxias fasciatus, Retropinna retropinna, Gobiomorphus cotidianus*). Swimming performance within a hydraulic flume was measured and observations made of the behavioural adaptions of some species to swim through high water velocities. Timed swimming at known water velocities allowed estimation of critical velocities for fish passage. For juvenile fishes (30–80 mm total length), velocities below 0.3 m s^{-1} should allow unrestricted passage over obstacles less than 15 m in length. Water velocities below 0.25 m s^{-1} may be necessary for obstacles over 15 m. Field observations of *Mugil cephalus* corresponded with limited flume data, suggesting this species is a less vigorous swimmer: water velocities below 0.15 m s^{-1} would allow its passage over obstacles less than 5 m in length whereas longer obstacles, without resting areas of static water, may require velocities as low as 0.05 m s^{-1} for *M. cephalus*.

Keywords native freshwater fish; fish passes; New Zealand; Pisces; *Anguilla*; *Galaxias*; *Retropinna*; *Gobiomorphus*

INTRODUCTION

Most of the 27 freshwater fish species native to New Zealand must have ready access to and from the sea to maintain freshwater populations. Catadromous, anadromous, and amphidromous life history strategies are found among these fishes. Many migrate up stream from the sea as juveniles and, despite the ability of some to climb wetted perimeters of high water velocity areas, (McDowall 1978), must be considered poor swimmers in relation to adult salmon and trout.

The swimming capabilities and behaviour in currents of migrating native fishes are not known but probably significantly affect their natural distribution in New Zealand. In addition, dams, weirs, and floodgates form velocity barriers which exclude native fishes from many areas in New Zealand. For example, an estimated 80% of the lake habitat (58 km^2) in the lower Waikato Basin is controlled by floodgates. Control weirs on Lake Whangape and the Whangamarino Swamp outlet are now proposed (Fig. 1). Studies have shown declines in diadromous species (smelt, *Retropinna retropinna*: Northcote & Ward 1985) while fisheries have been reduced (eels, *Anguilla* spp.) or eliminated (mullet, *Mugil cephalus*) (R. Tecklenburg, pers.comm.).

Part IV of the New Zealand Freshwater Fisheries Regulations (1983) states that: "no dam, diversion structure, culvert or ford shall be constructed in such a way that the passage of fish would be impeded. Where it is necessary, a fish pass must be provided." With varying success a number of fish passes have been built in New Zealand. Design information has come largely from overseas studies on the swimming ability and requirements of adult salmonids (Clay 1961).

This paper describes preliminary investigations into the water velocities which some juvenile migratory native fishes can withstand. These results will be of value to engineers involved with design of fish passes for native fish. The objective of fish pass design must be to make upstream passage as easy as possible for the fish. Upstream swimming requires expenditure of energy and fish may choose not to continue up stream when energetic costs become too high. Individual variation in stamina may be expected between fish of the same species. Hocutt (1973), Thomas & Donahoo (1977), and Tsuyuki & Williscroft (1977) have demonstrated significant intraspecific variation in swimming ability between both individuals and strains of fish. Therefore this

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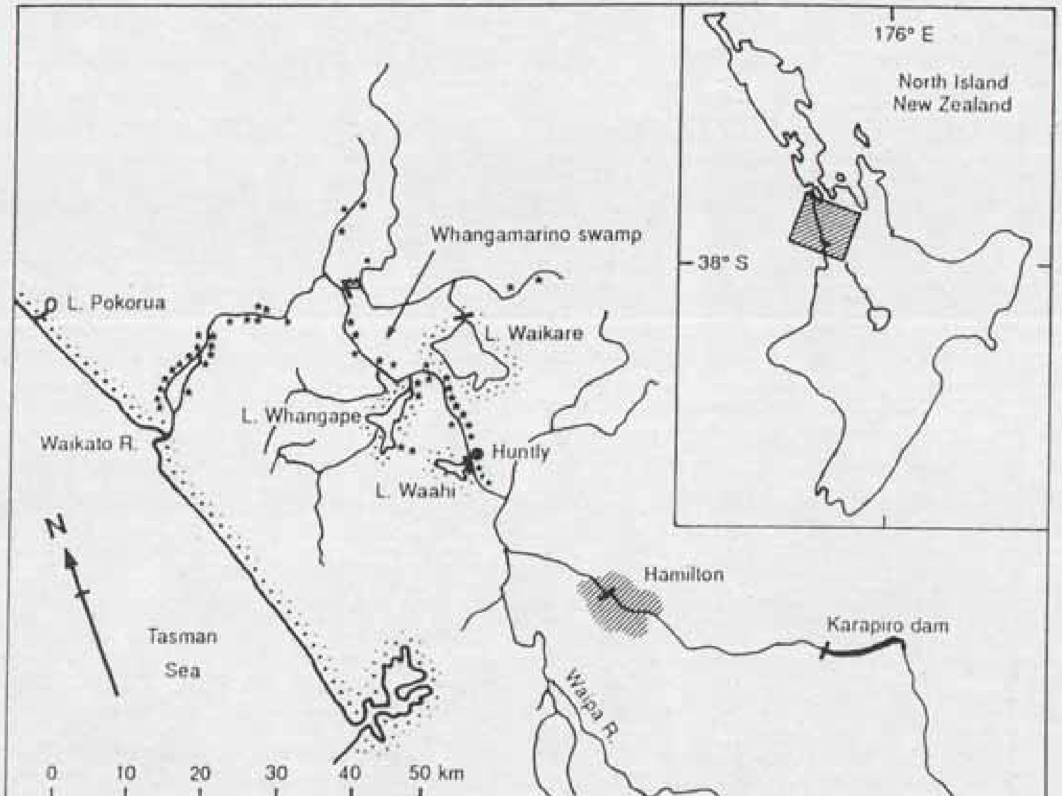

Fig. 1 Map of the lower Waikato River (★ indicates flood gate, bar indicates major barrier).

paper recommends maxima for velocity and distance combinations which are not absolute but which should be considered for design maxima. Velocity and distance combinations below those given should cause migrants a minimum impediment to upstream movement.

METHODS

Small numbers of some common native freshwater fishes were caught as juvenile upstream migrants and placed in a longitudinal gradient of water velocities. Water velocity increased as the fish swam "up stream". Observations were then made of water velocities chosen by the fish and of the velocities against which they were unable to swim.

Species used were: *Anguilla australis* (short-finned eel), *Galaxias maculatus* (inanga), *Galaxias fasciatu* (banded kokopu), *Retropinna retropinna* (smelt), *Gobiomorphus cotidianus* (common bully), *Mugil cephalus* (grey mullet), *Cheimarrichthys fosteri* (torrentfish), and *Paratya curvirostris* (freshwater shrimp). Test animals were collected using 2 mm mesh traps in the Waikato River at Huntly (Fig. 1), 80 km from the sea in October, November, and December (mid-spring/early summer) 1982, during times of peak upstream migration (Mitchell & Saxton 1983). Animals were tested within 5 h of capture using the hydraulic flume at the University of Waikato, Hamilton. Animals were transported 38 km and held until testing in 20-litre plastic buckets. The water was aerated or agitated continuously and partly replaced every 2 h with river water.

The glass-sided, 3 m × 0.1 m hydraulic flume (Armfield Engineering Co. Ltd., Ringwood,

Hampshire, England) was configured so that as fish swam "up stream" they encountered increasing water velocities. This was achieved by tilting the flume on a 1:15 slope with water flowing from the shallow (0.1 m) to the deep end (0.3 m). Fish were confined within the 3-m long glass-sided section by 2 mm wire mesh screens at each end. The flume was kept full by a weir behind the "downstream" screen.

Water velocity was greatest at the "upstream" end because the cross-sectional area was least, and declined as a gradient to the "downstream" end where the cross-sectional area was greatest. Water supply to the flume was measured with an ultrasonic flow meter and therefore water velocity could be accurately measured at any cross-sectional area along the flume. Both flume tilt and water supply could be independently adjusted to provide a range of depth and velocity combinations. Water velocity was low when the fish were introduced. After a 10–15 min acclimatisation period, the water supply (and hence flume water velocity) was increased until fish were confined to the rear of the flume. Water supply was then reduced until fish could swim up 0.7–0.8 of the flume length.

The flume was filled with Waikato River water and temperature was maintained between 17 and 20°C (equivalent to early-summer river temperatures: (Davies-Colley 1979) by suspending plastic bags of crushed ice in the flume reservoir. Water flow and a 1 m cascade of water into the reservoir before recirculation ensured oxygen saturation. Natural light was low in the flume room, and to reduce inhibition of movement by the presence of observers, light intensities were further lowered by a black polythene cover over the flume, which left only sufficient exposed glass for recordings to be made. Although no difference in behaviour was seen, further allowance for the nocturnal habits of some species was made by extending recording into the evenings.

Over 5 separate tests, the behaviour and water velocities selected by 95 individual animals was observed and timed. The numbers of each species tested and their size range are shown in Table 1. Although fish were handled as gently as possible, some damage from capture and transport of these notoriously delicate animals was likely. Accordingly, observations were confined to fish which swam vigorously, attempted to feed, and which were alert to the presence of the observer. When fish swam in groups the velocity of water recorded was that where the leading fish was swimming.

Observations were not statistically independent. To this end the performance of each individual should have been measured once and a large number of individuals tested. Limitations in achieving this ideal included the problem of identifying individual fish, time for which the flume was available, and difficulties in capturing and transporting large numbers of fish. Instead, velocity measurements were taken at 1–5 min intervals of the best performing fishes and averaged. There was also nothing in these trials to compel fish to choose particular velocities. As a consequence fish often swam for relatively brief intervals at water velocities at which other fish (or even the same individual, later) swam for considerable periods. In that respect the flume was intended to simulate a fish pass channel where only the urge to migrate up stream controlled behaviour. This contrasts with other studies where negative stimuli (usually electric shock) have been used in experiments intended to measure precisely the endurance of fishes (Bainbridge 1960; Brett 1964; Kutty & Sukumaran 1975; Rulifson 1977; Thomas & Donahoo 1977).

In addition to measuring the velocity where a fish was swimming, the relative effort being expended could be arbitrarily categorised. Effort was estimated

Table 1 Species and number used in flume tests.

	Test						Size range
	1	2	3	4	5	Total	(LCF mm)
Galaxias maculatus	7	4	2	–	–	13	52–73
Galaxias fasciatus	5	6	5	3	–	19	44–55
Gobiomorphus cotidianus	2	1	4	4	–	11	30–42
Paratya curvirostris	4	–	–	3	–	7	25–32
Retropinna retropinna	–	–	7	–	8	15	56–67
Anguilla australis	–	–	7	9	10	26	55–80
Cheimarrichthys fosteri	–	–	–	1	1	2	28–35
Mugil cephalus	–	–	–	–	2	2	85–96
Total	18	11	25	20	21	95	

according to tail and opercular beat frequency plus the time for which a position could be held. Effort was then divided into categories (which were strongly associated with water velocity):

(a) No response—random swimming or unoriented resting on the bottom for benthic species.

(b) Sustained swimming—orientation into the current, loose shoaling often associated with exploratory or feeding behaviour, position held for longer than 20 min.

(c) Steady swimming—rapid tail and opercular beat frequency, paired fins held close to the body, position held for longer than 30 s.

(d) Burst swimming—tail beat very rapid, fish move up into higher velocities than for steady swimming. Position seldom held for 30 s, often only for 4–5 s.

Mugil cephalus does not appear to be a strong swimmer and is naturally found only in lowland, slow-flowing or static water with easy access to the sea. Forty-four velocity measurements were made using only 2 *M. cephalus* over one 3-h test. Because of the low-value results, a field study was made of migrating juveniles. Lake Pokorua (37°12'S, 174°38'E, Fig. 1) is a 28-ha coastal lake with a resident stock of *M. cephalus*. Access from the sea is via a stable, 2-km long stream where juvenile *M. cephalus* (25–45 mm) were observed in shallow water (mean depth of 23 obs. was 5 cm).

RESULTS AND DISCUSSION

Apart from *C. fosteri*, which remained in the lowest velocity zone in the flume, all fish responded to the water flow and attempted to move "up stream". No territorial or aggressive interactions were observed and the drive to swim against the current was often sufficient to compel these migrating fish to spend the 3-h test period alternating between steady and burst swimming.

With the exception of *M. cephalus* there was considerable similarity between species for the water velocities at which the various swimming patterns were observed (Table 2). Little information would be lost by summing mean velocity for each swimming pattern for all species (except *M. cephalus*). Unless particular species were involved, engineering solutions to fish passage would logically be optimised by such velocity averages. Further, in practical fish pass design, velocity values to more than one decimal place are likely to be of little value.

For a fish to swim up stream the velocity of the fish must exceed the velocity of the water moving down stream ($V_f > V_{ds}$). Subtracting the velocity of the water from the velocity of the fish gives the velocity of the fish over the ground (V_g), $V_g = V_f - V_{ds}$. In static water the distance swum by a fish (D1) for a given time (t_f) depends upon V_f, or $D1 = V_f \times t_f$. But when swimming up stream, the distance (D2) covered in the same time for the same effort must be less as $D2 = V_g \times t_f$.

Table 2 Mean flume water velocities (m s[-1]) for categories of swimming behaviour. Means with the same bar in each column not significantly different at the 5% level using 2-way analysis of variance and the least-significant difference test. (Genstat V, Lowes agricultural trust, Rothamstead 1984).

Species	No response	Sustained swimming	Steady swimming	Burst swimming
A. australis	0.04	0.20	0.34	0.57
G. maculatus	No obs.	0.19	0.36	0.47
R. retropinna	0.05	0.19	0.27	0.50
G. cotidianus	No obs.	0.24	0.28	0.6
G. fasciatus	No obs.	0.19	0.29	0.43
M. cephalus	0.03	0.15	0.19	0.25
Total number of recordings	8	95	108	90
True mean response velocities excluding *M. cephalus* (see text)	0.04	0.20	0.32	0.54
M. cephalus (field)	No obs.	0.12	0.20	0.35
Total number of recordings	–	19	8	3

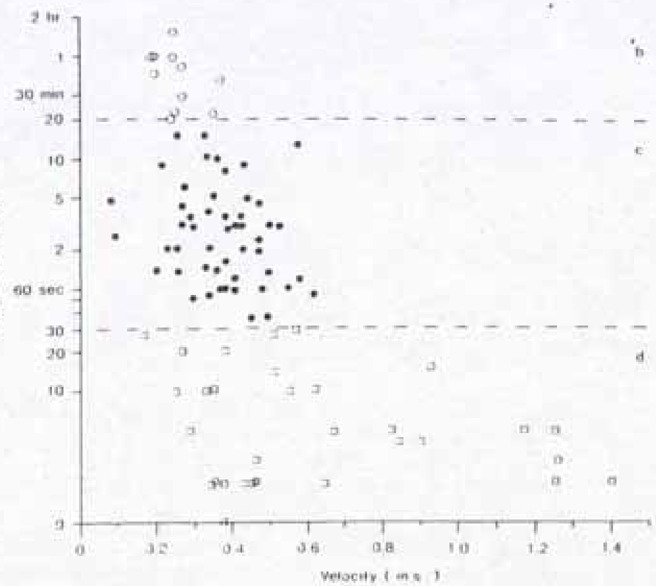

Fig. 2 Length of time for which *Anguilla australis, Galaxias maculatus, G. fasciatus, Gobiomorphus cotidianus,* and *Retropinna retropinna* swam at a range of current velocities. (○ = sustained swimming; ● = steady swimming; □ burst swimming)

$$V_g = V_f - V_{ds}$$

$$D2 = (V_f - V_{ds})\, t_f, \text{ and}$$

$$V_{ds} = V_f - \frac{D2}{t_f}$$

Time/water velocity measurements for *Anguilla australis, Galaxias maculatus, G. fasciatus, Gobiomorphus cotidianus,* and *Retropinna retropinna* (Fig. 2) were used to estimate the maximum water velocity which permitted a given distance to be swum by the fish.

Separating the time/water velocity measurements into burst, steady swimming, and sustained swimming showed that the most effective swimming mode altered from burst for high velocity/low distance to sustained swimming for low velocity/high distance. Thus the abrupt changes in slope of the lines in Fig. 3 represent shifts in swimming category to allow passage at the highest water velocity for a given obstacle length. Practical application of this information is likely to involve single solutions for water velocity/distance combinations and so pooled values for each swimming category for all species were used. Linear equations for these pooled values were calculated from D2 V_{ds} pairs using the two-point method. For obstacles less than 20 m in length, water velocities (V_{ds}) < – 0.0046 distance + 0.358 would be passable for the "average" fish. For obstacles greater than 20 m in length, water velocities (V_{ds} < – 0.0004 distance + 0.268 would be passable for the "average" fish (Table 3).

By measuring water depth at any point along the flume where a fish was swimming, the point cross-sectional area of the flume and hence the current velocity at the point chosen by the fish was calculated. Velocities were then re-checked using a Gurley No. 625 Pigmy current meter placed in the centre of the flume cross- section. Non-laminar flow along the sides and bottom increased at higher velocities resulting in the integrated velocity (as measured by ultrasonic flow meter) being up to 15% lower than the point velocity in the centre of the flume cross-section. This meant that shoaling fish swimming in the centre of the flume (*Anguilla australis, Galaxias maculatus, Retropinna retropinna, Mugil cephalus*) were facing faster water velocities than those that moved to the sides or bottom as velocity increased (*Galaxias fasciatus, Gobiomorphus cotidianus, Cheimarrichthys fosteri, Paratya curvirostris*).

Galaxias fasciatus juveniles swam to the flume bottom at water velocities ranging from 0.27 up to 0.55 m s[-1]. Position was then maintained, without swimming, by flexing the pectoral and pelvic fins to give downthrust from the passing water flow. At higher velocities the downthrust generated appeared to be increased by "humping" the body at the pelvic girdle, thus increasing the possible angle of attack of the ventrally inserted pelvic fins. *Gobiomorphus*

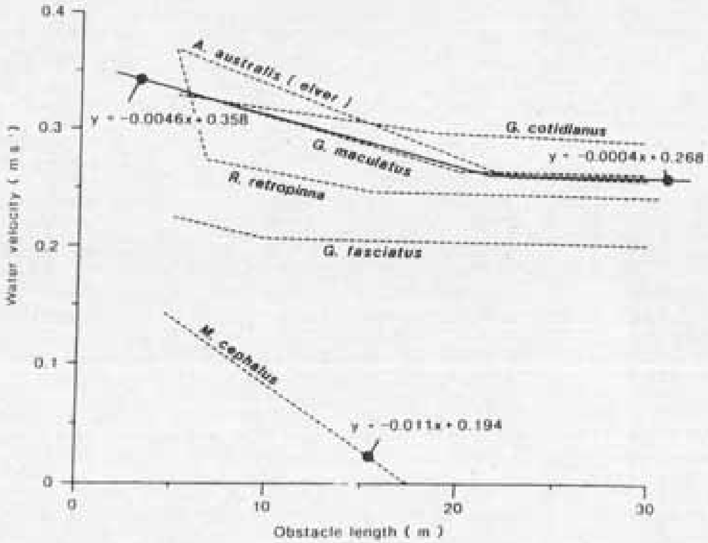

Fig. 3 Maximum allowable lengths and velocities of hydraulic structures which allow fish passage without provision of low water velocity resting areas. Values on or below the continuous line are likely to be acceptable (apart from *M. cephalus*).

Table 3 Water velocity (m s^{-1}) and distance maxima for *Anguilla australis, Galaxias maculatus, G. fasciatus, Gobiomorphus cotidianus*, and *Retropinna retropinna* combined (flume data), and for *Mugil cephalus* (field data).

Distance (m)	5	10	15	20	25	30
Combined flume data	0.34	0.31	0.29	0.27	0.26	0.26
M. cephalus (field data)	0.14	0.08	0.03	low-velocity resting areas required		

cotidianus could also rest passively on the bottom at water velocities up to 0.44 m s^{-1}. The large pectoral fins were spread out from the body and flexed so that the ventral margin was anterior to the dorsal margin. Downthrust generated by water flow passing over the fish could then hold it in position with only the tips of the thoracic pelvic fins and the bottom of the caudal fin actually touching the substrate.

Such adaption, allowing resting without loss of position between bouts of burst swimming, would allow these species to negotiate water velocities impassable to species relying solely on swimming.

Surprisingly, the torrentfish *Cheimarrichthys fosteri* would not swim against the current in the flume tank. Both individuals tested chose to rest on the flume bottom close to the "downstream screen", where velocities would have been lowest. At even the highest water velocities, *Paratya curvirostris* (freshwater shrimp) moved steadily "up stream" by clinging to the bottom using the chelae on the walking legs. The remainder of the test would then pass with all *P. curvirostris* firmly attached to the "upstream" screen mesh. This species has even been observed climbing vertical wetted concrete (Mitchell & Saxton 1983).

Table 2 lists the mean current velocities (m s^{-1}) at which the different categories of mullet swimming behaviour were observed in the field. Apart from burst swimming there was little difference between flume and field results. Timed steady swimming (V_g) together with water velocity (V_{ds}) was used to estimate fish swimming speed ($V_f = V_{ds} + V_g$). For periods of upstream swimming lasting from 80 to 100 s followed by loose shoaling in areas of low velocity, mean V_f for 8 observations of small schools was 0.20 m s^{-1}. This closely matches the mean of 0.19 m s^{-1} estimated from flume tests (Table 2). Accordingly the line for *M. cephalus* plotted on Fig. 3 (V_{ds} < 0.011 distance + 0.194) was calculated from these field data. Rulifson (1977) also found steady swimming times of young-of-the-year *M. cephalus* (40–50 mm) quickly decreased in water velocities above 5 body lengths per second (0.23 m s^{-1}). The average maximum swimming speed (= burst swimming) in sea water (sustained for only 30 s) was equivalent to 0.57 m s^{-1} for *M. cephalus* averaging 45 mm in length (Rulifson 1977).

CONCLUSIONS

Passage of these migratory fishes over artificial hydraulic structures which are less than 10 m long should be possible if water velocities do not exceed 0.3 m s^{-1}. Smaller structures (< 1–2 m long) may still be negotiable at velocities up to 0.5 m s^{-1}. Static water resting areas should be provided at intervals, when longer obstacles are present. *M. cephalus* (grey mullet) require much lower velocities than other species.

Where fish passage or upstream migration is not desirable, water velocities greater than 1.5 m s^{-1} are likely to exclude all but species capable of clinging or climbing. Water velocities down to 0.5 m s^{-1} could be expected to provide a species-selective deterrent to migration depending on the distance over which that velocity was maintained.

Involuntary entrainment of juvenile and adult fish by intake structures could be minimised if water velocities are kept below 0.3 m s^{-1}.

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REPORT ON HUI WITH IWI REPRESENTATIVES

HELD AT ENVIRONMENT B·O·P ROTORUA OFFICE

ON THURSDAY, 23 NOVEMBER 1995, COMMENCING AT 3.15 PM

PRESENT:	G Pemberton, R Titchmarsh, T W Vercoe (Environment B·O·P)
IWI REPRESENTATIVES:	Tutewehiwehi Kingi, Tai Eru, Akuhata Morrison
APOLOGIES:	Councillor John Keaney, Councillor Rosemary Michie, HMP Kingi
MIHI:	T W Vercoe:
KARAKIA:	T W Vercoe

1 INTRODUCTION:

G Pemberton advised that new chairman John Keaney was keen to establish a good dialogue with tangata whenua upon the lake level maintenance programme. He then introduced Ross Titchmarsh, as the engineer in charge of the programme, and explained that Ross would outline the various options on the lake levels. Ross, using the whiteboard explained the current maxima and minima levels at which each of the Lakes Rotorua and Rotoiti were being maintained. He also noted that it was easier to control Lake Rotoiti, which was done by gates whereas for Lake Rotorua it was a log weir and all this did was to slow down the rate of reduction in lake levels whereas in Lake Rotoiti the gates allowed direct closures when necessary and vice versa. At the end of R Titchmarsh's address, G Pemberton again discussed the question and asked iwi representative if they had any Maori concerns. A general discussion ensued.

2 DISCUSSIONS

A Morrison speaking as a member of Ngati Whakaue, suggested that different users had different aspirations and suggested that if boat owners, for example, wished the lake to be raised and this would inevitably be done at the expense of the tangata whenua interests then they be required to pay a levy based on say 10c per centimetre raised above levels which tangata whenua deemed appropriate.

T Eru speaking on behalf of himself and T Kingi advised that they had done some research on the project and he suggested that a good bench mark on the varying levels of the lake was the pipe outlet situated at the northern end of Tamatea Street at Hinehopu on Lake Rotoiti. He also expressed grave concern that raising the levels higher would cause a backwash into this outlet and consequently wreak havoc with the levels on the water table and the septic tank outflows from the residents at Hinehopu. This would be viewed adversely by both tangata whenua and of course the residents at Hinehopu.

(Note: On site inspection held on way home to Whakatane, accompanied by local residents, Theo Tait and William Wilson who were adamant that lake levels of Lake Rotoiti were excessively high)

3 TRADITIONAL FOOD

Both spokesman from Ngati Pikiao, T Eru and T Kingi noted that traditional supplies of inanga (native whitebait) were deteriorating but it was difficult to establish whether the variable lake levels were contributing to this decline.

Both noted with approval the improved lake water quality following the diversion of sewage to the Whakawerawera Forest.

4 GENERAL

T Eru tabled his notes on discussions with HMP Kingi.

Iwi concerns were to safeguard lakes -

4.1 recreational facilities, and

4.2 traditional food sources.

Acknowledged that these could be in conflict at times, hence may be necessary to compromise. Te Arawa have a history of high cooperation and mutual trust of Crown activities. Not always reciprocated by Crown and/or Crown agents.

Te Arawa remains optimistic that Crown will act honourably towards tangata whenua (Te Arawa).

5 Meeting concluded (Karakia - T Kingi) at 5.00 pm.

TWVercoe

T W Vercoe
Maori Policy Advisor
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ROTORUA LAKES MANAGEMENT

Rotorua, Rotoiti lake level review hearings will provide opportunity for public comment

Environment BOP is to review the minimum and maximum levels of Lakes Rotorua and Rotoiti as part of the process for issuing consents relating to the control structure for both lakes. The council expects to conduct the hearing relating to the consents, required under the Resource Management Act, later this year and it will provide an opportunity for the public to express their opinion about the level of these lakes.

Background

Lakes Rotorua and Rotoiti are two major reservoirs at the headwaters of the Kaituna River Catchment. The effect of the lakes on the discharge in the Kaituna River is significant, in that they provide storage for floodwaters and release them very gradually over a long period. When a storm passes over the upper catchment the peak in flow, which might last a few hours, is released in the Kaituna River over many weeks.

While lake storage eases flood problems in the lower Kaituna it causes high lake levels, flooding and poor drainage around the shores of the lakes. This is an issue of particular concern to the Rotorua District Council.

Lake Level Problem

Up to and during the 1970's excessively high and low levels caused concern to the users of and residents around the lakes. Many studies were undertaken by government, local government and private bodies on this issue.

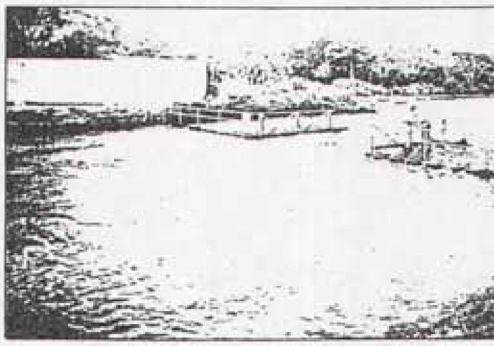
A resultant report recommended that control structures be built on the Ohau Channel and at Okere Falls. The necessary construction works were undertaken with the Okere Falls Gates commissioned in October 1982 and the Ohau Channel control structure in September 1989. These structures were built under the Kaituna Catchment Control Scheme by the Bay of Plenty Catchment Board.

Environment BOP and the Resource Management Act

Environment BOP, as the successor of the Catchment Board, is responsible for managing the levels of Lakes Rotorua and Rotoiti recognises the importance of lake level control and that there are competing resource management issues in respect of the desired minimum and maximum levels for these lakes.

The previous water right for the operation of the Okere Falls Gates has expired, requiring the council to apply for new consents under the provisions for the Resource Management Act.

LOCATION of Lakes Rotorua and Rotoiti.



THE Ohau Channel control structure.

THE Okere Falls control gates.

The purpose of the consents is to promote the sustainable management of the lakes and the Kaituna River. The consent process will allow a complete review of the current minimum and maximum levels of the lakes.

Minimum and Maximum Levels

The existing levels for Lakes Rotorua and Rotoiti were set by the National Water Conservation Authority on May 6 1975. These levels were agreed to after extensive public consultation. The levels are:

Lake Rotorua	max level	280.11 amsl
	min level	279.5 amsl
Lake Rotoiti	max level	279.44 amsl
	min level	278.89 amsl

(amsl = above mean sea level)

Environment BOP will follow a public consultation process to deal with the consent applications. This will provide opportunity for communities with an interest in the lakes to specify what they believe are the desirable minimum and maximum levels.

The hearing of these consents will require an examination of a number of issues in respect of both lakes:

Lake Rotorua Issues

- **Lake levels** - A maximum and mini mum level should be set, recognising that in extreme events levels could occur outside this range.
- **Maori & Cultural Values** - Lake Rotorua is of high spiritual and cultural value to local iwi.
- **Stoplog management** - The installation or removal of the stoplogs on the Ohau structure slows or speeds up the lake level fall. Clear operating procedures need to be defined for the installation/ removal of these stoplogs.
- **Fish Passage** - A review of the fish passage facility needs to be undertaken, to confirm that the structure is causing no obstruction to the movement of fish.
- **Flood Control** - Levels and operating procedures need to be set to provide flood control storage and thus reduce the severity of the impact of heavy rainfall events and allow the return to normal levels to be achieved more rapidly.
- **Aesthetics/Tourism** - Rotorua is a major tourism destination and the lake has extensive shoreline residential and tourism facilities. Scenic amenity is of major importance in determining the control range of the lakes.
- **Geothermal Pressures** - Geological investigations of the relationship be tween water levels and thermal activity needs to be undertaken. Water bodies adjacent to thermal sites do have an influence on the nature of the geothermal activity.
- **Boat Passage** - The Ohau Channel is used for boat passage between Lakes Rotorua and Rotoiti.

Lake Rotoiti Issues

- **Lake Levels** - A maximum and minimum water level for Lake Rotoiti needs to be set recognising that in extreme events levels could occur outside this range.
- **Maori & Cultural Values** - Lake Rotoiti is of high spiritual and cultural value to local iwi.
- **Flow Rates** - A maximum and minimum flow rate should be set for the structure. The rate at which any change in flow is varied should be defined.
- **Operation of Gates** - Operation of the gates, particularly the re- sulting increase or decrease inflow rates downstream, has significant consequences thoughout the system and therefore the operation of the gates needs to be clearly defined.
- **Records** - Continual records of lake levels, gate openings and the resultant discharges downstream need to be kept to ascertain the effectiveness of the control structure and its management on controlling the level of Lake Rotoiti and the flows out of the lake.
- **Recreational Use** - Considerable use of the Upper Kaituna River is made by rafting companies and jet boats in particular. The lake is also used by passenger boats. The ability of these to operate is directly affected by the operation of the gates and the water level of Lake Rotoiti.

Environment BOP will publicly notify these consents. These notices will clearly set out the submission dates. For further information regarding these consents contact Ross Titchmarsh, Manager Technical Services, phone (07) 307 2545.

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