WAITANGI-TAONA RIVER SCHEME

GRAHAMS CREEK DIVERSION

EFFECT ON LAKE WAHAPO AND OKARITO LAGOON

WESTLAND CATCHMENT BOARD

INTRODUCTION

In response to questions raised by the residents of Okarito, this report has been prepared to show the effects of diverting the Grahams Creek flow in addition to that of the Waitangi-Taona River through Lake Wahapo, then down the Okarito River into Okarito Lagoon.

Reference is drawn to the Waitangi-Taona Scheme Report. This report chose a 50 year design discharge of 800 cumecs, of which 300 cumecs flowed down Grahams Creek. The Q_{50} was based on TM61 analyses, and a knowledge of flood events.

AVAILABLE DATA

1. The Ministry of Works and Development provided a rating curve for the outlet weir, giving discharges as a function of lake levels. Low flows were gauged. High flows were estimated by a gauging cross section. Grahams Creek Slope Area Discharge Analysis after March '82 flood, giving a flow of $300 m^3/s$.

2. Rainfall records were obtained from the Slatey Creek rain gauge.

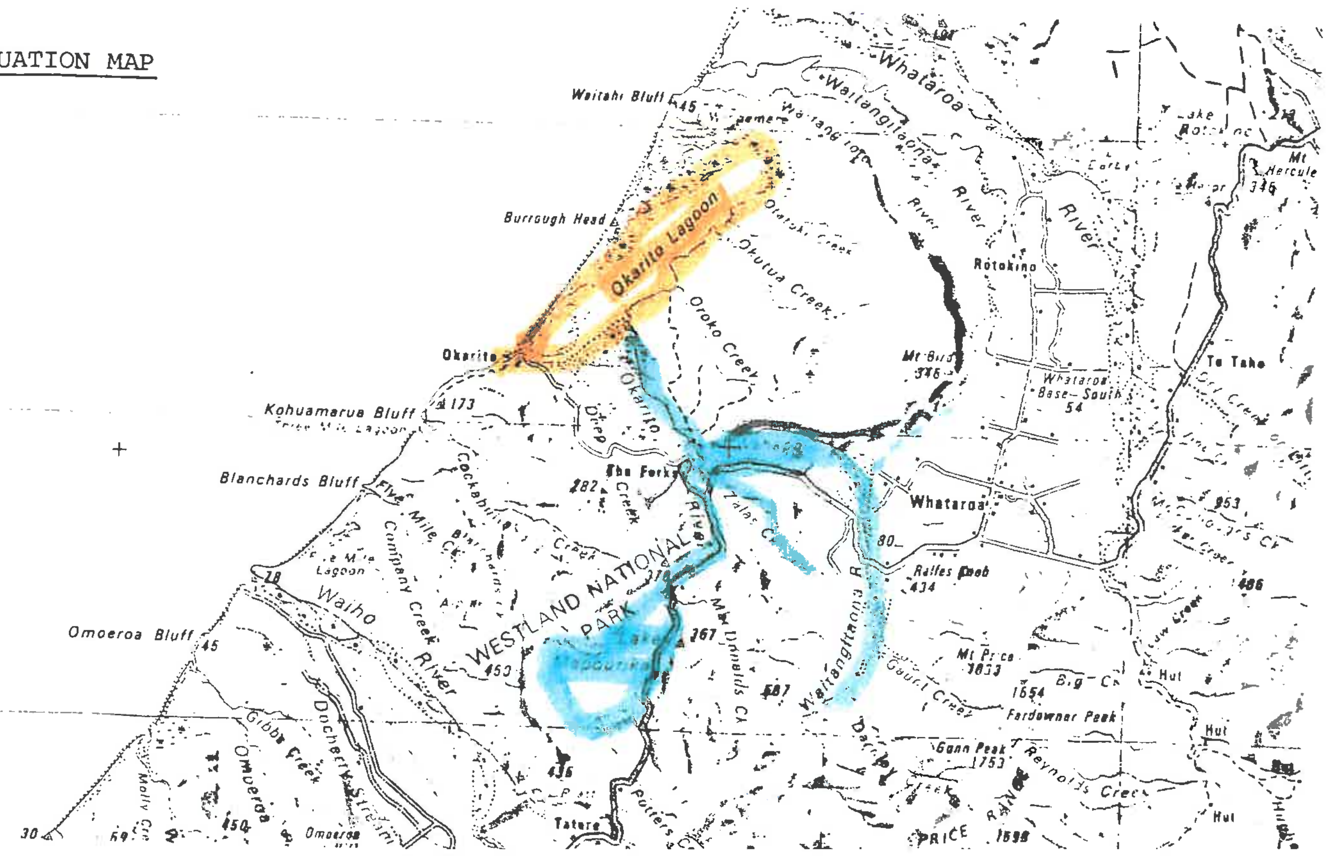
   The 50 year (1½ hour) storm has an intensity of 84 mm/hour. Such an event occurred in March 1979 with i = 87mm/hour.

3. Lake level information from the Wahapo chart recorder for the March 1979 flood was used to determine a lake storage time relationship.

4. TM61 analysis gave a Q_{50} = 998 cumecs at S.H. Bridge.

5. Survey Information
   Lake Wahapo outlet cross section and long section
   Zalas Creek cross section
   Okarito Lagoon spring high tide level
   Okarito Settlement level
   Okarito River outlet cross section and slope

SITUATION MAP



ANALYSIS OF DATA

1. Ministry of Works & Development Rating Curve

Using the March 1979 flood as a typical 50 year event, the inflow hydrograph was determined from the lake levels and the Ministry of Works and Development outflow rating curve. The inflow hydrograph was then routed through the lake to find the outflow hydrograph, and to see the effects of storage attenuation on the flood peak.

The inflow hydrograph was then scaled to include the effect of the 800 cumec design flow, and then routing repeated.

Results

Lake Level (m)	I peak (m^3/s)	O peak (M^3/s)
5.45	570	380
7.75	800	524

The rating curve used measured values at only very low flows (up to 30 cumecs) and then was extrapolated using a gauging cross section as a guide to flows of 375 cumecs.

As a check on the rating curve weir formula were applied. These correlated well for the low flow measurements, but in the area of extrapolation a marked divergence occurred, the latter giving discharges approximately twice those assumed.

H'	M.W.D.	$Q = 1.67 LH^{3/2}$	Trapezoidal
1.2	10	7 (m^3/s)	13 (m^3/s)
1.4	17.1	19	19
2.0	45	75	85
2.5	80	138	148
3.0	126	213	309
3.5	172	297	330
4.0	221	390	435
4.5	271	492	560
5.0	325	601	700
5.5	382	717	840

L = 45m.?

N.B. Lake outflow figures

H' = H + 1.0 = Recorded lake level.

The conclusion is the Ministry of Works & Development rating curve is not correct at higher flows and the trapezoidal weir formula will give a better representation.

2. Trapezoidal Weir Approximation

As before the inflow hydrograph was derived from the rating curve as given by the weir formula, and the hydrograph was routed through the lake. Flow entering Grahams Creek was then added to 1, and the corresponding outflow hydrograph found.

Note: Q_{50} at bridge = 1200, based on 300 from Grahams Creek, 900 from lake hydrograph analysis.

Results

Date	Lake Level (m)	I peak (m^3/s)	O peak (m^3/s)
March '79	5.45	900	836
Q_{50}	6.36m	1200	1085

3. Hydrology at Okarito Lagoon

Extracts from MacPherson are in Appendix 1 of the report. This paper provides background information for an investigation of the hydrology of Okarito Lagoon.

4. Calculations - Appended to Report

Appendix 2

2.1 Rainfall analysis March '79.

2.2 Check on predicted inflow to Lake Wahapo.

2.3 Lake Wahapo levels and storage data.

2.4 Rating curves - M.W.D.

- Trapezoidal

2.5 Lake Wahapo hydrographs viz tabulated routing.

2.6 March '79 flood information.

SUMMARY OF RESULTS

N.B. Peak values in cumecs, based on March 1979 storm.

Outflow Rating Curve	I peak	O peak
M.W.D. - as recorded	570	380
- scaled for Q_{50} = 800	800	524
Trapezoidal Weir - as recorded	912	836
- scale for Q_{50} = 1200	1200	1085
Rectangular Weir - as recorded	825	710

CONCLUSIONS

A. Lake Wahapo

1. Including the Grahams Creek flow in the diversion of the Waitangi-Taona River into Lake Wahapo will increase the lake outlet Q_{50} peak flow from 836 to 1085m^3/s, an increase of 249m^3/s (30%). (See Figure 1).

2. The analysis assumes that the Q_{50} at the bridge was 1200 cumecs and that 300 cumecs of this normally flows down Grahams Creek. Q_{50} = 1200 was determined from the March '79 lake storage data and the trapezoidal weir rating curve, giving an I peak = 912 cumecs. If this is correct then this flow combined with the Grahams Creek flow will give 1200 cumecs at the bridge. Formerly the Q_{50} = 800 at the bridge, was found by methods outlined in the Waitangi-Taona report. There is good evidence to support a change in this value:-

   a) Inflow hydrograph as determined from recorded lake levels - March 1979.

   b) Rainfall intensity from March 1979 recordings.

   c) TM61 This gave Q_{50} = 998. The rainfall intensity assumed by this method over the time of concentration corresponded almost exactly to that of the 50 year event from historical records.

3. Due to the diversion there will be an increase in lake level from 5.45m to 6.36m (= 910mm) for the 50 year event (e.g. March 1979).

B. Okarito Lagoon

1. Freshwater Inflow

To determine the effect of the additional flow in the Waitangi-Taona (due to the Grahams Creek Diversion) on the Okarito River and Lagoon systems, the proportion of the Waitangi-Taona that would normally branch down Grahams Creek must be established. The present situation indicates this flow to be 300m^3/s for the 50 year event.

The combined total 50 year flow incident on the Okarito Lagoon would be 1760m^3/s with each catchment contributing as below:-

Source	Before (m^3/s)	After (m^3/s)
Waitangi-Taona	900 attenuates to 830	900) attenuates to 1085
Grahams Creek		300)
Zalas Creek	50	50
Maporika Catchment	550	550
Forestry Catchment	75	75
Okarito River	1505	1760

This represents an increase of approximately 17%, See Figure 1.

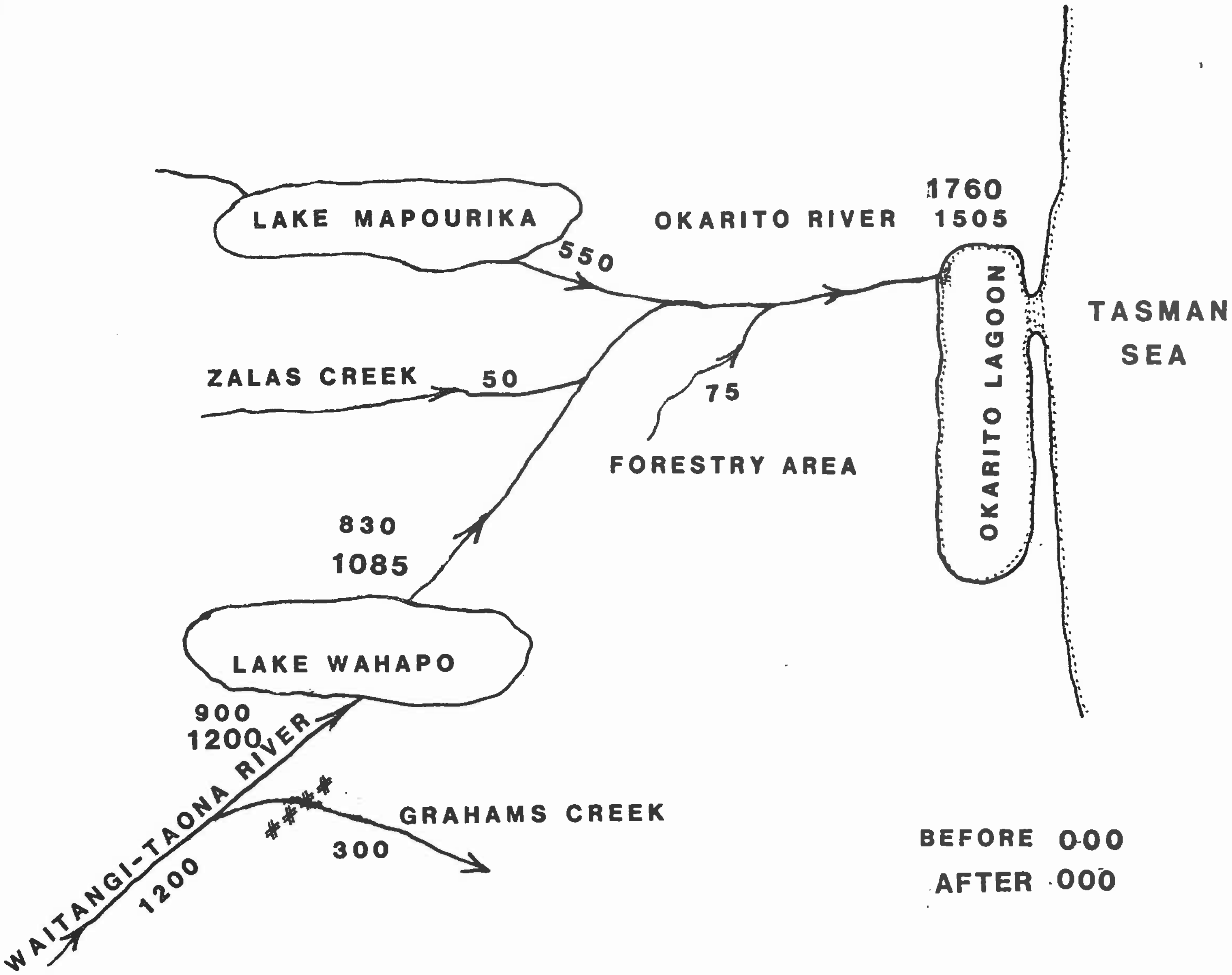


FIG 1 DISCHARGE(m3/s) - BEFORE AND AFTER DIVERSION

Volume

The volumetric throughput will increase by 17% as outlined above. This is not expected to be significant even at low tide conditions.

The 50 year flood event can be expected to supply a freshwater volume almost 1.5 times the average tidal volume of the Lagoon, assuming a 2 hour storm. The Grahams Creek flow will add only slightly to this.

Lagoon Levels

Assuming the worst case of spring high tide combined with the 50 year 2 hour storm, and blockage of the lagoon outlet due to severe shoaling, the lagoon level at the wharf would be about 0.65m above the spring high tide level.

This level relates closely to the highest locally observed flood level, near the wharf, which was included in a survey around the Okarito township frontage, by Board's staff on 21 July 1983. It is understood this flood level occurred when the lagoon outlet was shoaled to a depth of 2-3 metres.

2. Sedimentation

Enlargement of the Okarito Lagoon Delta has occurred primarily due to the natural diversion of the Waitangi-Taona River in 1967. The additional flow will be supplementing this natural formation process.

The central distributory of the Okarito Delta may be expected to prograde approximately 19m annually, based on measured progradation between 1963 and 1972. The excess prograding due to flows at present entering Grahams Creek is expected to be 33% greater than the Waitangi-Taona's contribution (which is 80% of total sediment input) i.e. 5.0m per annum (26% increase).

It can be accepted that most sediment other than suspension material has been eroded from downstream of the Wahapo outlet. All coarse sediment load from the Waitangi-Taona will settle in Lake Wahapo. Delta forming sediments are also derived from active erosion in McDonalds Creek Catchment. Waitangi-Taona River flows below Zalas Creek combined with flows from McDonalds Creek will account for the majority of delta formation in the future. The lineal rate of advance will fall markedly as the protruding dalta front expands from the confines of the Okarito River outlet into the lagoon proper.

At the present rate of sedimentation (approximately $10,000m^3$ in 11 years = $900m^3$/year) encroachment into the lagoon should be a slow process.

RECOMMENDATIONS

That the design discharge ($Q50$) for the Waitangi-Taona River Scheme be amended from 800 to 1200 m^3/s, and adjustments made in scheme design accordingly.

That the Board monitors the erosion in the Okarito River especially between Lake Wahapo outlet and the Forks, to assess the effect of increased peak flows on this reach and subsequent progradation of the Okarito Delta.

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APPENDIX 1

The following extract provides information which can be used to assess the likely physical impacts on Okarito Lagoon of the natural diversion of the Waitangi-Taona River in 1967.

Extracts from:-

"Hydrology of Okarito Lagoon and the Inferred Effects of Selective Logging in Okarito Forest"

by J.M. Macpherson, in

New Zealand Journal of Marine and Freshwater Research, 1981, 15(1): 25 - 39.

Bathymetry

- Okarito Lagoon is a shallow, predominantly subtidal, estuary 10km long and from 1.1 to 2.7 km wide.

- Surface area at high water is $19.64km^2$, and the mean elevation of the floor of the lagoon is 0.33m below MSL.

Tidal Range

- at sea, mean tidal range	2.1m spring 1.2m
- at Okarito River outlet	0.16 to 0.18m

Tidal Asymmetry

- at river outlet, high tide lags by approximately 0.8 hours behind lagoon outlet.

- due to bar, which acts as broad crested weir.

Channel flow = $420m^2$ x 0.7 m/s = $294m^3/s$ at mean high water.

Channel flow = 179 x 0.6 = 107 at mean low water.

Tidal Volumes

Maximum tidal averaged volume of water in the lagoon, spring tides, = 10.44×10^6 m^3

Minimum, neaps
= 5.39×10^6

Mean
= 7.91×10^6

Freshwater Inflows

Three Catchment Areas

1.	Okarito Forest Area (Area 9,700ha)	- 5 small streams - Max^m flood 3-4m^3/s - Stable gravel bed channels
2.	Mapourika Catchment (9,000ha)	- Drains lower slopes S.A. into Lake Mapourika, and thence into Okarito River
3.	Waitangi-Taona (8300ha)	- extends to main divide steep and mountainous

Before 1967 this river flowed north of Okarito Forest and entered the sea near the mouth of the Whataroa River. In 1967 the river breached stopbanks near the State Highway Bridge, and diverted permanently into Lake Wahapo. The Lake Wahapo outflow is joined by Zalas Creek, and then joins the Okarito River at the Forks, 1km below the lake. Addition of the Waitangi-taona River to the Okarito River system increased the catchment area of Okarito Lagoon by 44%.

Low Flow Inputs

Mapourika and Waitangi-Taona catchments

	Discharge m^3/s
Lake Wahapo weir	
WL recorder height = 0.9m) M.W.D. rating curve)	6
N.B. Waitangi-Taona at 70% of mean discharge ($\bar{Q}$ =) 8.5	
Okarito River	9.0
Zalas Creek	0.15
Forest catchment creeks	0.5
	15.6 m^3/s

Flood Inflows (Easter 1978)

The Forks $Q = 140m^2 \times 2.5m/s$ (conservative questimate)

$= 350m^2$

It is reasonable to assume that the Mapourika catchment area contributed similar flows, and that the peak discharge from the two river catchments approached $700m^3/s$. Okarito Forest Catchment area contribution of say $50m^3/s$.

$=$ total $= 750m^3/s$

Maintained for 5 hours, this flow would have contributed $13.5 \times 10^6 m^3$ of water - almost twice the mean volume of the lagoon.

Maximum water levels, corresponding to a high tide at about midnight on 28 March 1978, were 1.04m above datum. At this stage the lagoon contained $26 \times 10^6 m^3$ of water, about three times the normal tidal - averaged volume.

Notes: 12/5/78 Lake Wahapo level recorder annual (78) maximum was 4.4m

c.f. 3/79 Annual maximum was 5.505m

Also Wahapo outlet flows

Date	Lake Level	M.W.D.	Discharge Trapezoidal	MacPherson
12/5/78	4.4m	262	550	350
3/79	5.505m	383	825	525

Turbidity

During floods the southern end of the lagoon fills with turbid river water, and sea water may penetrate only a short distance up the channels during incoming tides.

Low flow turbidity

Okarito River	1 ppm
Forest streams	1 ppm

Flood Flow Turbidity

Okarito River	50 ppm
Upper basin	1-3 ppm

= Turbid water in the Okarito River system during floods is contributed predominantly by the Waitangi-Taona River.

e.g. 29/3/1978

From Waitangi-Taona into Lake Wahapo	46 ppm
From Lake Wahapo at outlet	44 ppm
Okarito River at the forks	2 ppm

Sediments

Clean sand (with less than 5% mud) occurs only on the intertidal flats, less than 800m from the lagoon entrance and at the central and southern mouths of the Okarito River in the delta area.

Parts of the Okarito River subaerial deltas are gravelly, and the river channels are armoured with coarse gravel and boulders.

Recently eroded material from steeper sections of the Waitangi-Taona and Mapourika Catchments are the probable principal sources of fine sediment in Okarito Lagoon.

Core samples from the centre of the central subaerial delta of the Okarito River, shows that the stratified clean sand and gravelly sand of this delta overlie burrowed, unstratified, slightly muddy medium sand, and that the flats adjacent to the delta are similar in composition.

Aerial photographs taken in 1948 show that a delta did not exist at the site, and there is no evidence of any change between then and 1963. The delta does not appear in photographs taken in 1969, 2 years after diversion of the Waitangi-Taona River into Lake Wahapo, and has remained almost unchanged since, indicating that the diversion may have caused the growth of the delta.

Recent Natural Changes

Comparison of aerial photographs taken in 1948, 1963, 1969 and 1972 indicate that a number of natural changes are occurring in Okarito Lagoon.

Entrance

The entrance has closed less frequently since the diversion of the Waitangi-Taona River and it is likely because of higher inflow rates (especially in floods) that since this diversion the entrance remains closed for shorter periods when it does block.

Delta

Delta sediments as sampled in the central principal distributary of the Okarito River are not evident in the 1963 aerial photographs.

By 1969 deposition over an area of about $30,000m^2$ had occurred, and by 1972 the area had expanded to $35,000m^2$.

The central distributary prograded 150-200m into the lagoon between 1963 and 1972.

Central core stratigraphy revealed between 400 and 700mm of mud free, sand and gravelly sand deposited over burrowed, muddy medium and fine sand. The coarser deposits are inferred to result from diversion of the Waitangi-Taona River in 1967.

A mean thickness of at least 300mm of coarse sediments indicates $10,000m^3$ or more of sediment have been deposited since diversion of the Waitangi-Taona River.

Inferred Impact of Waitangi-Taona River

The diversion must have caused at least a 44% increase in the annual inflow of fresh water (very conservative).

Large increases in the input of suspended solids must also have occurred.

Land-derived sediment inputs to the lagoon are completely dominated by the sediment from the Waitangi-Taona - Lake Wahapo catchment. The similarity of Lake Wahapo inflow and outflow sediments indicates that really all the sediment outflow derives from upstream of the lake.

The natural diversion of the Waitangi-Taona River has probably caused at least a three fold and perhaps ten fold increase in sediment input to Okarito Lagoon.

APPENDIX 2

2.1 Rainfall Analysis March '79

365mm fell 9 a.m. Tuesday to 9 a.m. Wednesday 7 March 1979. Lake peaked at 5.45m on staff gauge at 6 a.m. Wednesday (= 4.45m above weir).

Tc = 83min from TM61

50 year rf = 68mm/hour Hokitika
50 year rf = 86.5mm/hour Haast

1979 March flood 75mm/2 hour maximum from rain gauge.

2.2 Check on predicted Inflow to Lake Wahapo with Rainfall Intensity Observed

For peak = 824 cumecs in 83 min = 56mm fell over the catchment in 83 min = 38mm/hour) correlates well with
cf 75mm/2 hour) recorded data March '79

Calculation

$824m^3/s \times 83 \times 60 = 4103520m^3$

Catchment area = $72.86 \times 10^6 m^2$

$= \quad RF = \frac{4103520}{72.86 \times 10^6} = 56mm$ in 83min

$= 38mm/hour$

2.3 Lake Wahapo Levels and Storage Data

2.3.1. Lake Level Vrs Time

March 1979

Time/hours	Lake Level/m	Change in Storage x 10^6 m^3/hour
Tues 4 p.m.	1.7	0
5 p.m.	1.75	.131
6 p.m.	1.9	.393
7 p.m.	2.2	.785
8 p.m.	2.5	.785
9 p.m.	2.9	1.05
10 p.m.	3.3	1.05
11 p.m.	3.7	1.05
12	4.1	1.05
1 a.m.	4.5	1.05
2 a.m.	4.85	.92
3 a.m.	5.12	.71
4 a.m.	5.32	.52
5 a.m.	5.42	.26
6 a.m.	5.45	.08

Time	Lake Level	Change in Storage x 10^6 m^3/hour
7	5.42	- 0.08
8	5.35	- .18
9	5.22	- .34
10	5.08	- .37
11	4.95	- .34
12	4.83	- .31

Note: 1.7 taken as normal lake level.

Lake area = 2618 km^2
Vertical sides assumed

2.3.2. Example Calculation

Determining inflow hydrograph

Time - Tuesday 7 p.m.

Lake level = 2.2m

Outflow:- From M.W.D. Rating Curve, at lake level of 2.2m
Outflow = 57.6 m^3/s

$= 207 \times 10^6 m^3/hr$

Storage:- Storage/hr

= Change in lake level/hr x lake area

$= 0.3$ m/hour $\times 2.618 \times 10^6$

$= .785 \times 10^6 m^3/hour$

Inflow:- Inflow = Storage + Outflow

$= (.785 + .207) \times \frac{10^6}{3600} m^3/s$

$= 275 m^3/s$

Plotting 0 - N Relationship

see graphs in appendices

$$N = \frac{V}{T} + \frac{0}{2}$$

V is change in lake volume

Routing Inflow Hydrograph through the Lake - see 1.5

2.4 Rating Curves - See over

1.4.1 M.W.D.

1.4.2 Trapezoidal

2.5 Lake Wahapo Hydrographs - See over

2.6 March '79 Flood Information - See over