THE DUNEDIN CITY COUNCIL

Electricity DEPARTMENT

NEW ZEALAND.

OUTLINE SURVEY OF SMALL HYDROELECTRIC POTENTIAL

OUTLINE SURVEY OF SMALL HYDROELECTRIC POTENTIAL

November,1984
With amendment June,1985

OUTLINE SURVEY OF SMALL HYDRO-ELECTRIC POTENTIAL IN AREA OF SUPPLY OF DUNEDIN CITY COUNCIL

CONTENTS

../2

REFERENCES

OUTLINE SURVEY OF SMALL HYDRO-ELECTRIC POTENTIAL IN AREA OF SUPPLY OF DUNEDIN CITY COUNCIL

1. INTRODUCTION

This report is a reappraisal of information previously provided to the Ministry of Works and Development as part of a national assessment of opportunities for local hydro-electric generation, in the 0.5MW to 50MW output range. Map 4 shows possible sites.

Only the potential schemes which could reasonably be undertaken with available sources of funding have been analysed for cost comparisons.

Possible sources of energy from outside the study area (the Dunedin City Council licensed area of supply) have been considered only where the City Council has present or previous rights in respect of the catchment yield.

2. SUMMARY

Ten schemes on five waterways have been considered to be possible prospects for hydro-electric generation, as tabulated Table 1 below. Three of these possibilities refer to improved utilisation of the managed flow in the Waipori - a further one new station has been commissioned since the original information supplied to MWD in November 1981. A major diversion scheme to augment inflows to Lake Mahinerangi reached practical commissioning in August 1984. Developments of this scheme may be investigated further.

Three small waterways have been considered briefly.

3. FUTURE ACTIONS

Development of the Waipori System will be under review as part of the DCC Electricity Department's continuing programme to increase efficiency of utilisation of Waipori streamflow in relation to the system requirements of the Department's consumers. Studies for lake management are in progress in order to optimise generation for demand reduction and energy production having regard to varying inflows (including the newly-available diversion from Deep Stream) and flood-control constraints.

POSSIBLE SCHEMES FOR FURTHER HYDROELECTRIC DEVELOPMENT IN OR NEAR D C C ELECTRICITY SUPPLY AREA

Possible Development	Mean Annual Streamflow Estimates	Possible Gross Head	Possible Dam/Weir Heights	Possible Power Output	Theoretical Energy Output in Normal Year	Plant Factor	Estimated Approximate Cost for Completion March 1983	Comparative Capital Cost for Additional Annual Energy	Comparative Capital Cost for Additional Power Output as Stated	Remarks
WAIPORI RIVER	(m^3/sec)	(Metres)	(Metres)	(MW)	(GWh/year)		($million)	$/kWh	$/MW	
No.5 Station	6.1	16.6	16.5	5.6	7.6	0.16	29	3.8	5.2M	Costs estimated by comparison with Lee Stream and 1A Station.
No.4 Station enlargement to match 2A generation flow	6.1	56.69 (actual)	18.9 existing	9.8 addnl	3.0 addnl	0.17	16	5.3	1.6M	Costs estimated by comparison with 1A Station construction only, includes new building new machine new tunnel.
No.3 Station do.	6.1	50.90 (actual)	10.7 existing	9.0 addnl	2.3 addnl	0.16	16	7.0	1.8M	
No.1 Station replaced by 1A	6.1	21-30.5 (actual: as lake level)	34.5 existing	7.0 addnl	6.0 addnl	0.17	12	2.0	1.7M	Actual Completion December 1982
TAIERI RIVER										
Near Outram Bridge	31 NB very variable flow	27.5 Limited by Hindon Railway	30	21.3 Taken to be at 3 times mean flow	62	0.33	not investigated by DCC	-	-	'Run of River' Scheme, dam head only. Possible value in flood moderation and pollution control.
LEE STREAM										
1) High-dam scheme	2.5	260	47	70	40	0.065	59	1.5	0.84M	
2) Two low dams	do.	230	30m & 20m	22	38	0.31	20	0.53	0.91M	Schemes (2) & (3) utilise tunnel part-constructed in 1904.
3) Low weir minimal storage	2.1	230 NB Heads would be reduced 30m if Taieri dam to be built and station level raised	10m	4	33	0.94	13	0.39	3.3M	Schemes (2) & (3) costed for old machines ex Waipori No.2 Station.
DEEP STREAM										
a) Diversion to Waipori Catchment	1.27	N/A	2.5m	N/A	33	N/A	6.25	0.18	N/A	Diversion in operation Sept.1984. Water to augment inflow to Lake Mahinerangi by 20% for use at all Waipori Stations. Will improve plant factors for each.
b) Dam at Junction with Taieri	5.7 estimate after diversion (a) and townwater abstraction etc.	32	35	4.6	13	0.33	not investigated	-	-	'Run of River' Scheme. Dam head only. Would be affected by Taieri Scheme.
LAMMERLAW STREAM	1.27	100	5	3.1	7.7	0.28	not yet investigated	-	-	'Run of River' using flows diverted from Deep Stream. Lammerlaw Stream. Engineering factors to be optimised.

TABLE 1

POSSIBLE SCHEMES FOR FURTHER HYDROELECTRIC DEVELOPMENT

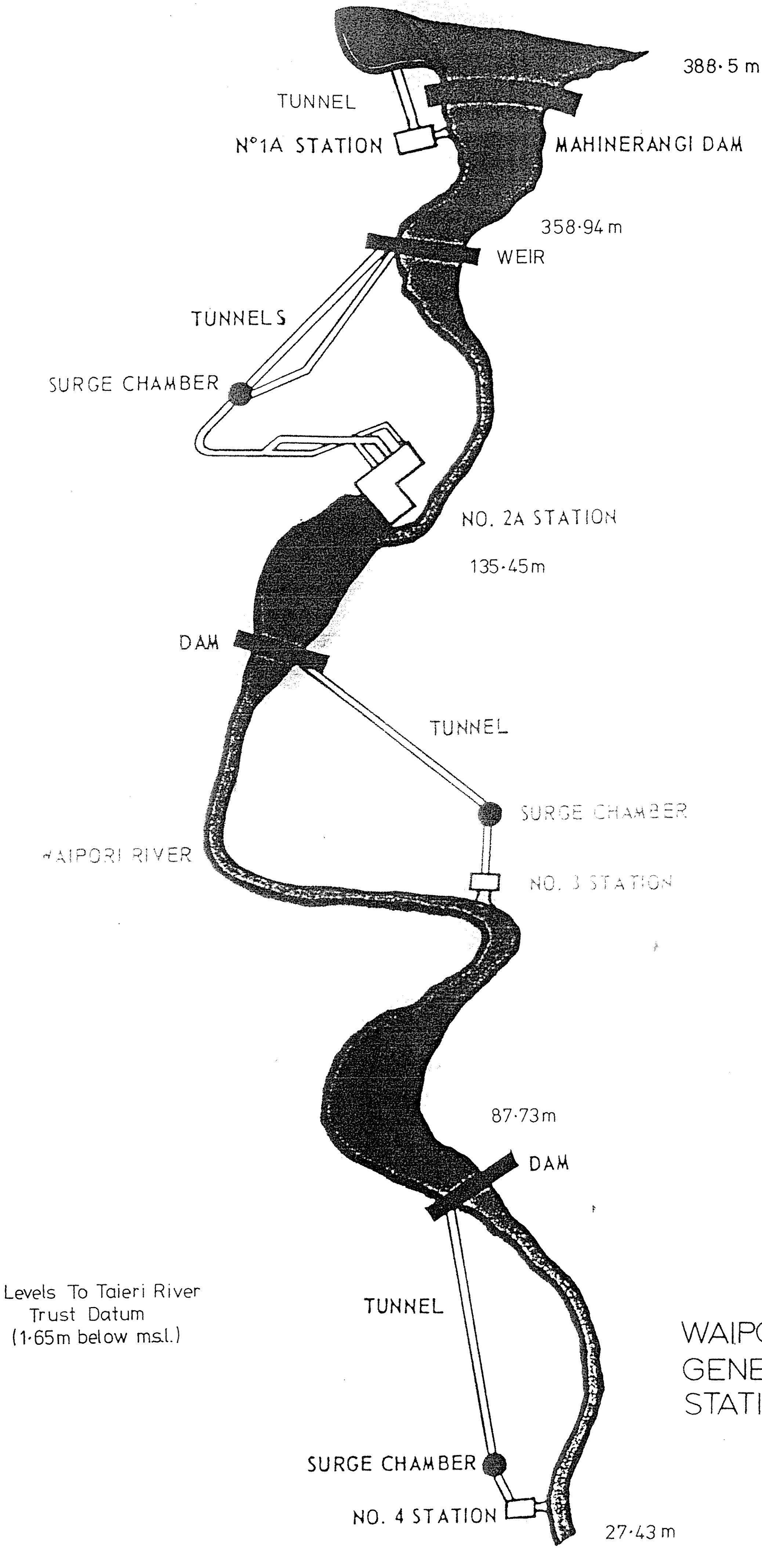
IN OR NEAR D C C ELECTRICITY SUPPLY AREA

TABLE 1A

(Includes modifications to give plant factor of 0.5)

Possible Development	Mean Annual Streamflow Estimates (m^3/sec)	Possible Gross Head (Metres)	Possible Dam/Weir Heights (Metres)	Possible Power Output (MW)	Theoretical Energy Output In Normal Year (GWh/year)	Plant Factor	Estimated Approximate Cost for Completion March 1983 ($million)	Comparative Capital Cost: for Additional Annual Energy $/kWh	Comparative Capital Cost: for Additional Power Output As Stated $/MW	REMARKS
WAIPORI RIVER										
No.5 Station	6.1	16.6	16.5	1.7	7.6	0.5	-	3.8	17M	Costs estimated by comparison with Lee Stream & 1A Station.
No.4 Station	6.1	56.59 (actual)	18.9 existing	7.8 existing	2.4 existing	-	-	N/A	N/A	Notional comparisons only. Waipori River is managed for maximum output during peak days.
No.3 Station	6.1	50.90 (actual)	10.7 existing	6.5 existing	18.7 existing	-	-	N/A	N/A	
No.1 Station	6.1	21-30.5 (actual:as lake level)	34.5 existing	3-4.0 prior to Dec 1982	10.6 prior to Dec 1982	-	-	N/A	N/A	Operating stations at 50% plant factor is not practicable. 3 & 4 Station enlargement would not be undertaken on this basis. No.1 Station would not have been replaced to give reduced MW output.
TAIERI RIVER										
Near Outram Bridge	31 NB very variable flow	27.5 Limited by Hindon Railway	30	14.2 Taken to be at twice mean flow	62*	0.5	Not Investigated by DCC	-	-	'Run of River' Scheme, dam head only. Possible value in flood moderation and pollution control.
LEE STREAM										
1. High-dam scheme	2.5	260	47	9.1	40	0.5	46	1.15	5.05M	
2. Two low dams	2.5	230	30m & 20m	8.7	38	0.5	16	0.42	1.84M	Schemes (2) & (3) utilise tunnel part-constructed in 1904.
3. Low weir minimal storage	2.1	230 NB Heads would be reduced 30m if Taieri Dam to be built and station level raised	10m	7.5	33	0.5	15	0.45	2.0M	Schemes (2) & (3) costed for old machines ex Waipori No. 2 Station.
DEEP STREAM										
a) Diversion to Waipori Catchment	1.27	N/A	2.5m	N/A	33	N/A	6.25	0.18	N/A	Diversion in operation Sept 1984. Water to augment inflow to Lake Mahinerangi by 20% for use at all Waipori Stn. Will improve plant factors for each.
b) Dam at Junction with Taieri	5.7 (Estimate after diversion (a) and townwater abstraction etc.)	32	35	4.6	13*	0.5	Not investigated	-	-	'Run of River' Scheme. Dam head only. Would be affected by Taieri Scheme.
LAMMERLAW STREAM	1.27	100	5	1.8	7.7*	0.5	Not yet investigated	-	-	'Run of River' using flows (max. 4.5m^3/s) diverted from Deep Str.-Lammerlaw Stream. Engineering factors to be optimised.

* Theoretical energy not obtained with restricted machine output for 0.5 plant factor



WAIPORI
GENERATING
STATIONS

WAIPORI GENERATING STATIONS NOVEMBER 1984

STATION	GROSS HEAD (Metres)	DAM HEIGHT (Metres)	NORMAL YEAR ENERGY OUTPUT (GWh/Year)	PEAK POWER OUTPUT (MW)	THROUGHFLOW AT PEAK POWER (M^3/sec)	TURBINE TYPE & YEAR COMMISSIONED
No.4	56.69	18.9	24	7.8	17.0	1 - Vertical Francis (Boving) 1955
No.3	50.58	10.7	18.7	6.5	17.0	1 - Vertical Francis (Boving) 1954
No.2A	218	17.4 (headweir)	96.8	57.5	36.8	1 - Vertical Francis (Boving) 1968 do. (Fuji) 1975 do. (Fuji) 1976
No.1	21-30.5	34.5	10.6	3-4.0	12.8	Double Runner Horizontal Francis (Boving) 1930 (Station decommissioned Jan 1985)
No.1A	21-30.5	34.5	16.6	11	36.8	Kaplan, (Fuji) in new station - December 1982

Notes:

1. Present mean annual flow into Lake Mahinerangi $6.1m^3$/sec., with inflow from Deep Stream Tunnel this will become $7.37m^3$/sec. Total energy output will increase by 20%. Peak power output unchanged.

2. Peak output could be increased subject to lower Waipori being able to accept $45m^3$/sec. The 1A Station is designed to give more than 12MW with this flow at 30 metre gross head.

3. 1A Station output varies with lake level. No.1 Station superseded by 1A Station but available until January 1985 as standby.

4. Only No.4 Station has significant intermediate storage. There is some additional inflow from the gorge catchment to the low-head 3 and 4 Stations.

TABLE 2

4. AREA OF STUDY

The Dunedin City Council holds an Electric Lines Licence gazetted for an area of supply including the City of Dunedin, adjacent towns and boroughs and surrounding farmland. The total area is approximately 1 200km². (Map 1).

5. EMPOWERING LEGISLATION FOR HYDRO-ELECTRIC WORKS

In addition to this licence for reticulation within the defined area, the Dunedin City Council is empowered to use all water in the Waipori river system for generation purposes under the terms of the Waipori Falls Electrical Power Act 1904, and the Dunedin City Corporation Empowering Act 1924. The waters of the Deep Stream are available for town water supply by the Dunedin City Council under the Dunedin Waterworks Extension Act 1930. The area of Deep Stream, Deep Creek catchment defined is 166km². Similar legislative measures ("The Dunedin Waterworks Extension Act 1917") granted rights "for waterworks use" in regard to Lee Stream. The Lee Stream rights were relinquished by the City Council, and that Act repealed in 1978 in order that the Regional Water Board could grant rights for a Rural Water Supply Scheme in the area.

Apart from the rights in the Waipori catchment by virtue of the 1904 Act and 1924 Empowering Act, all other uses of water are regulated by the Regional Water Board in accordance with the Water and Soil Conservation legislation. Rights to divert water into the Waipori catchment from neighbouring catchments are held by the City Council, deriving from old mining rights and one recent grant.

6. SUPPLY DETAILS

At March 1984 -	Domestic consumers	...	41 139
	Non-Domestic Consumers (Including Farming 550)	...	6 536
	System Maximum Demand	...	172
	Chargeable Maximum Demand on N Z Electricity	...	90
	Maximum Generated Output	...	83MW
	System Annual Consumption	...	738GWh
	Generated Energy	...	207GWh

Transmission from Waipori to Dunedin is by 110kV and 33kV overhead lines. Urban and rural reticulation by 11kV and 6.6kV overhead lines and underground cables. Supply is received from N Z Electricity at two Bulk Supply points : Halfway Bush and South Dunedin. Both are within the Dunedin City boundaries.

A major switching station has been established by N Z Electricity at Three Mile Hill, 2km from Halfway Bush, to permit 220kV interconnection of Roxburgh and Makarewa lines.

7. CLIMATE

Although the DCCED Supply Area generally experiences temperate maritime conditions with mean annual precipitation of 1 000mm, there are significant variations between metropolitan Dunedin, the Taieri Plain, and surrounding high country.

The Taieri Plain has less frequent cloud cover and seasonally higher and lower temperatures than the City areas.

The elevated land at and beyond the north-western edge of the licensed area has drier conditions than Dunedin between 100 - 400 metres a.m.s.i. It is semi-arid in the summer months but the precipitation on the Lammerlaw and Lammermoor ranges gives normals of 1400-1600mm/year. Snowpack often remains until December in sheltered areas of ground above 700m.

8. TOPOGRAPHY AND WATER YIELD

The urban areas of Dunedin and associated boroughs cover the hills, former volcanic features, reclaimed swamps and harbour shores around the early settlement. The zones of interest for feasible hydro-electric development lie at and beyond the north-western edge of the Supply Area on thin loess and schist-colluvium based on folded schist, faulted and eroded with steeply rolling country. Vegetation is generally tussock cover and improved pasture with gorse and remnant bush.

The Otago peneplain plateau areas of the Lammerlaw and Lammermoor heights at 1 000 metres produce substantial yields of water into the adjacent head water streamlets of Deep Stream, Deep Creek and the Beaumont, Waipori and Taieri Rivers.

The lift of moisture-bearing winds, particularly from the south, causes frequent moderate to intense rainfall on the high ground. Heavy snowfalls occur during the winter and snow cover usually remains into Spring.

The resulting pattern of monthly yield gives greatest mean streamflows, usually in September and October with major storm flows often in April/May/June. (Deep Stream flow Table 3 shown as example.)

The bogs and tarns of the gullies and plateaux retain a significant proportion of the rainfall and this discharges slowly to maintain a base flow during summer in all except extreme droughts.

The streamflow in the Taieri River (the major feature) and in tributary streams is characterised by extreme variation in flow. Runoff can be extremely rapid. If rainfall patterns during a prolonged storm match the river routes and transit times of inflow, this can culminate in very high flood crests and flows in the Taieri at Outram of 2 000 m^3/sec. Similar extended rain periods over the Waipori catchment resulted in June 1980 flood-flows from the Waipori onto the Taieri Plain of 300 m^3/sec after inflows to the upper catchment (above Lake Mahinerangi) of 650 m^3/sec, and into the lower catchment (Waipori Gorge) approaching 200 m^3/sec.

The present of the main dam, retaining storm inflows from the 319 km^2 catchment above Lake Mahinerangi as in this case has frequently prevented severe inundation of the productive farmland adjoining the lower Waipori.

9. CONSIDERATION OF CATCHMENTS

For the purposes of this outline survey of hydro-electric potential the catchments briefly considered are:-

Waipori River
Taieri River (above Outram)
Lee Stream
Deep Stream
Other (minor streams)
Lammerlaw Stream (foreign water inflow)

10. WAIPORI RIVER

10.1 Description of Catchment and Existing Hydro-Electric Works

The Waipori rises in several headstreams in the Lammerlaw Range, approximately 80km west of Dunedin, at altitudes up to 1 000 metres in steeply rolling tussock country. The river has a winding course for about 24km, falling 600m until it reaches a valley less than 2km wide, 27km long. The fall is only 35 metres in this distance and the river passes then into a narrow gorge falling first 230 metres in 4km to the No.2A generating station.

The present dam is sited at the entrance to the gorge; it has a total height of 34 metres providing operating head for No.1A Station. Nominal winter lake level is 387m a.m.s.l. The area of the catchment is 319 km^2 with a mean annual flow of 6.1 m^3/sec including some small amounts obtained via old mining races from Upper Beaumont River and Lee Stream.

Until October 1984, three small-capacity races brought water from Deep Stream also but these have now been taken out of service, superseded by the tunnel and pipeline diversion scheme commissioned for trials in August 1984 and fully operational in October.

Flood flows from the tussock into the Upper Waipori and the impounded Lake Mahinerangi, have been up to 650m^3/sec. This is believed to be the 0.5% probability flood event.

The 79km^2 catchment below Lake Mahinerangi is heavily bushed on the steep gorge sides and provides little additional flow except in flood periods.

Operating head of 220m for the No.2A Station is maintained by a 20m high weir providing also the tailwater pond for No.1A Station.

Similarly the tailwater of No.2A Station is impounded by No.3 Dam, 11 metres high, providing control for the tunnel supplying No.3 Station 50 metres below, situated 2km downstream.

The No.3 tailwater and No.4 head pond is a narrow lake 1.3 km long within the gorge bed, providing some intermediate storage for No.4 Station. The No.4 Dam is 19m high giving gross head for that station of 57m.

.../8

Below No.4 Station which is approximately 2km downstream of the dam the Waipori River falls a further 30 metres in 6km before emerging onto the Taieri Plain near Berwick. It passes into Lake Waipori before entering the tidal Taieri.

10.2 Managed Streamflow

As the foregoing description indicates, the Waipori River below the Waipori flat has been a managed river for 80 years. Except during flood the flows from Lake Mahinerangi through the system are determined only by the need for generation and lake level in relation to summer and winter operational retention maxima.

Afforestation by DCC around the east end of the lake and more importantly, by N Z Forest Service on Glendhu Station and Maungatua blocks affects 40km² of the upper catchment and in time will reduce inflows to the lake by an amount estimated as 5% - 8% in a normal year.

10.3 Hydro-Electric Potential

Early Development

The prospects for electric power generation from the Waipori attracted local interest in the early days of development of this energy form in New Zealand.

The Waipori Falls Company was formed in 1902 to exploit the steep fall into the lower catchment with small impoundments and flume delivery to penstocks leading to a station near the present 2A building.

The Company was bought out by the City Corporation in 1904 and a substantial investment made to build the two-generator installation commissioned in 1907.

10.3.2 Subsequent Progress

The history of the further development of the hydro-electric resources of Waipori is of courageous investment by the City Council and steady progress step by step. Listing only the major changes:-

1913 - New Supply Tunnel, 6 generators now in service (4MW total)
1914 - New 15m high weir constructed
1920 - Dunedin City Empowering Act permitted damming of main Waipori River

1924 - 12 metre dam completed to form Lake Mahinerangi

1928 - 1931 A 20 metre high dam was constructed 100m downstream of that original dam.

1930 - New station built below that dam and designated No.1 Station. Maximum output 4MW.

1938 - A new pressure tunnel was completed supplying the original station, now designated No.2 Station.

1941 - Second supply tunnel constructed for No.2 Station

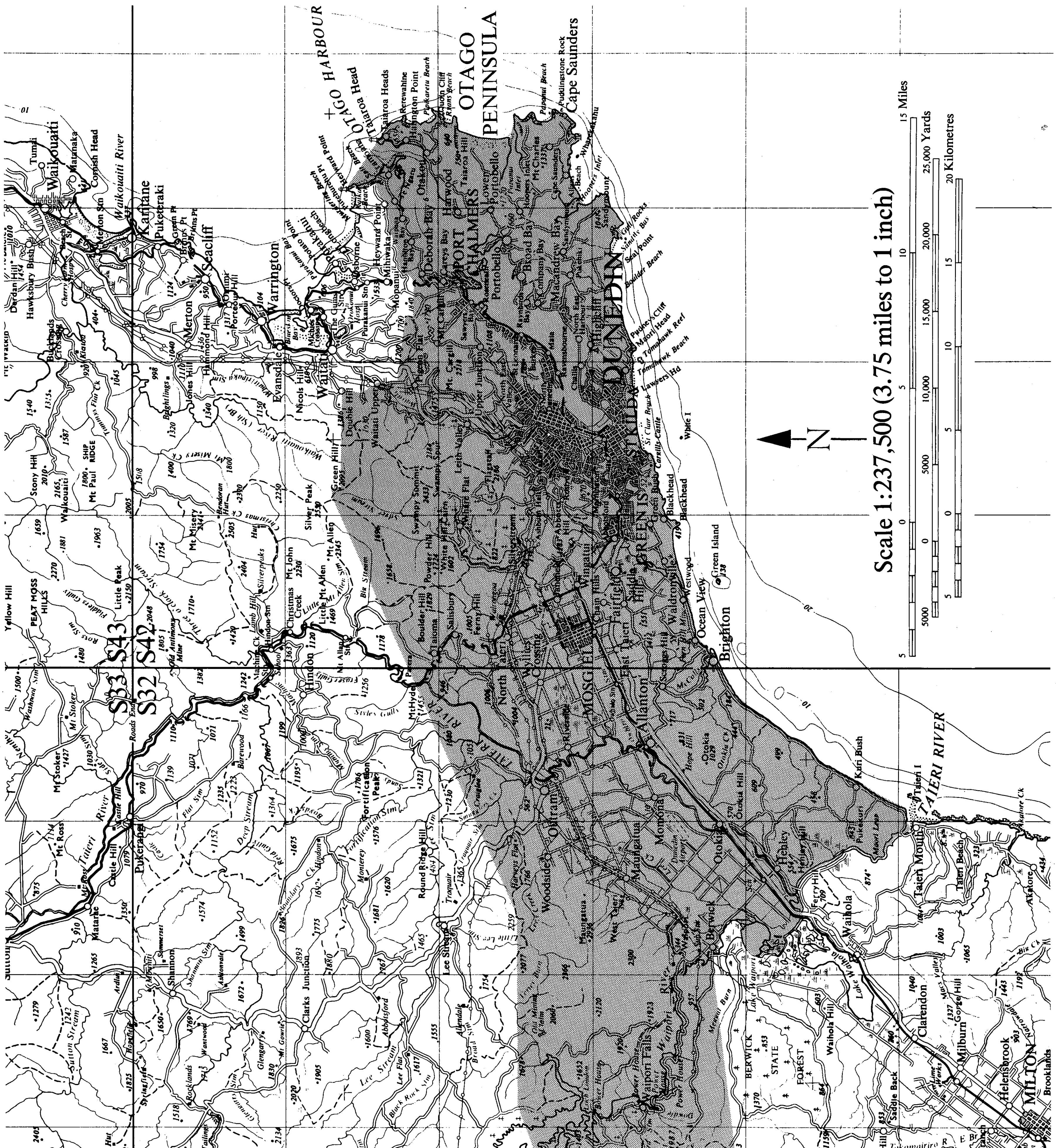
1946 - Mahinerangi Dam raised to present height of 34.5 metres.

1952 - Two tunnels to supply the proposed No.3 and No.4 Stations were completed.

1955 - No.3 and later No.4 Stations commissioned.

1968 - No.2A Station with one 18MW machine commissioned in a new building adjacent to the 63 year old (No.2) building to utilise more water at the 220m head available.

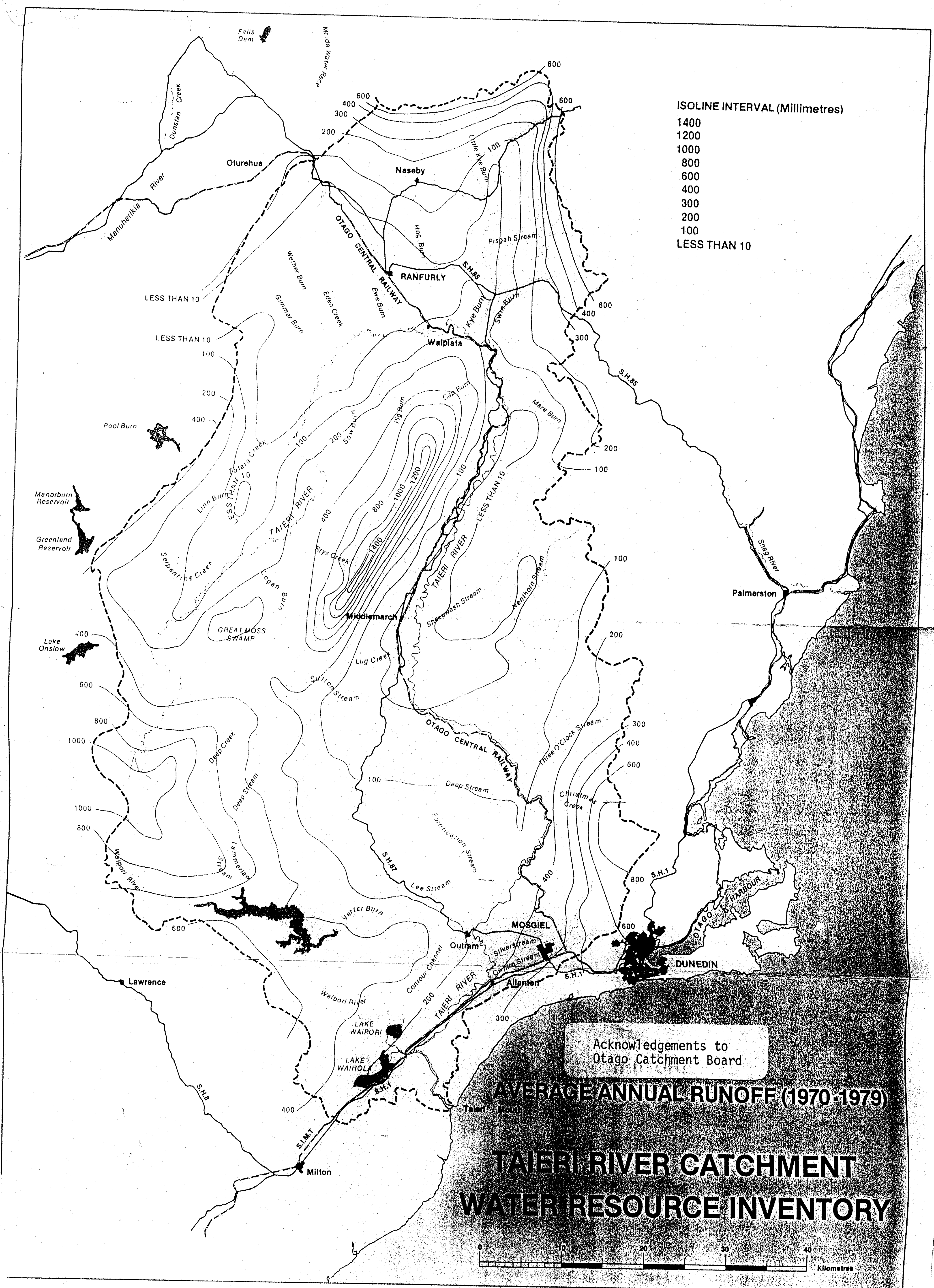
.../

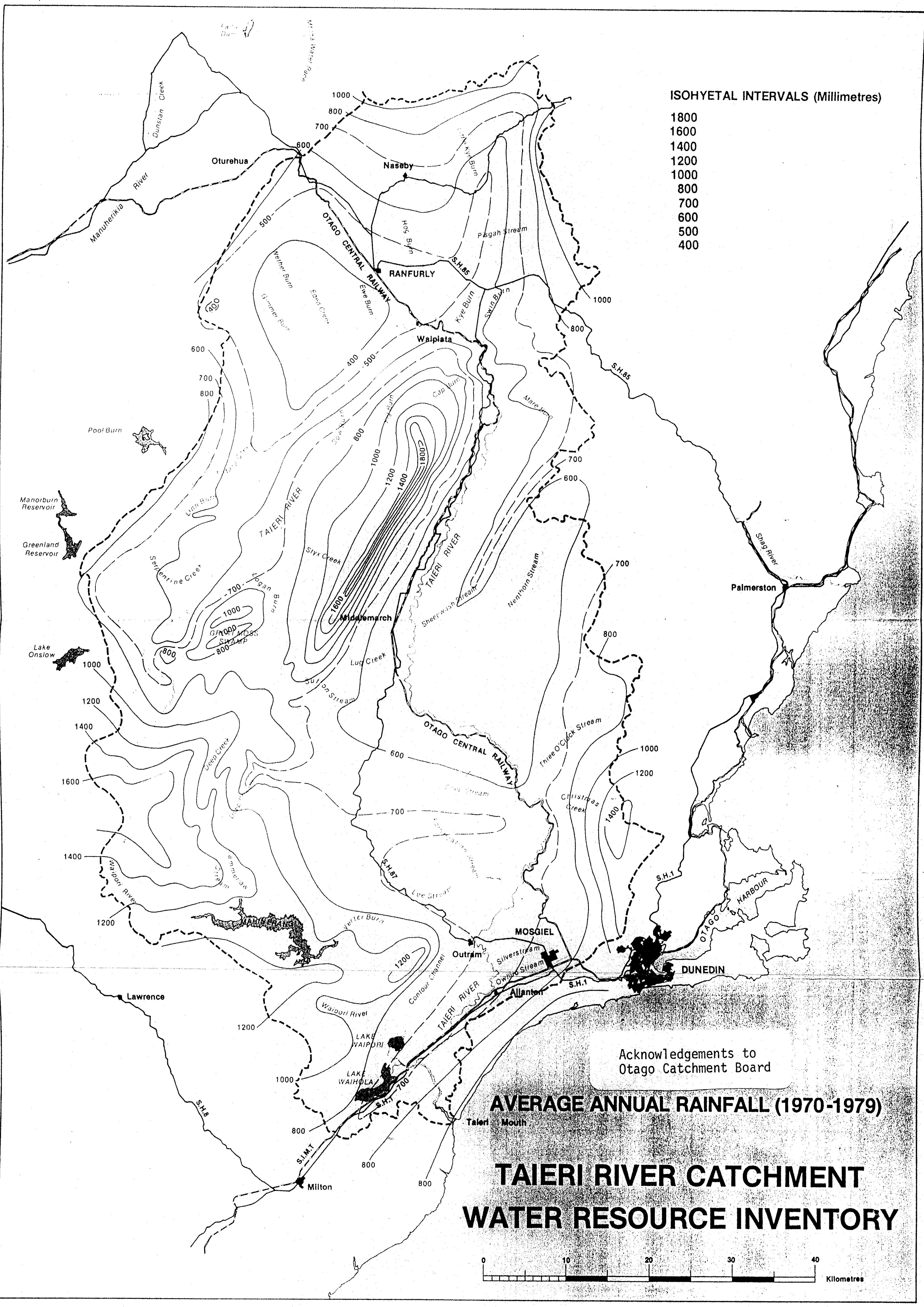


Dunedin City Council Electricity Department

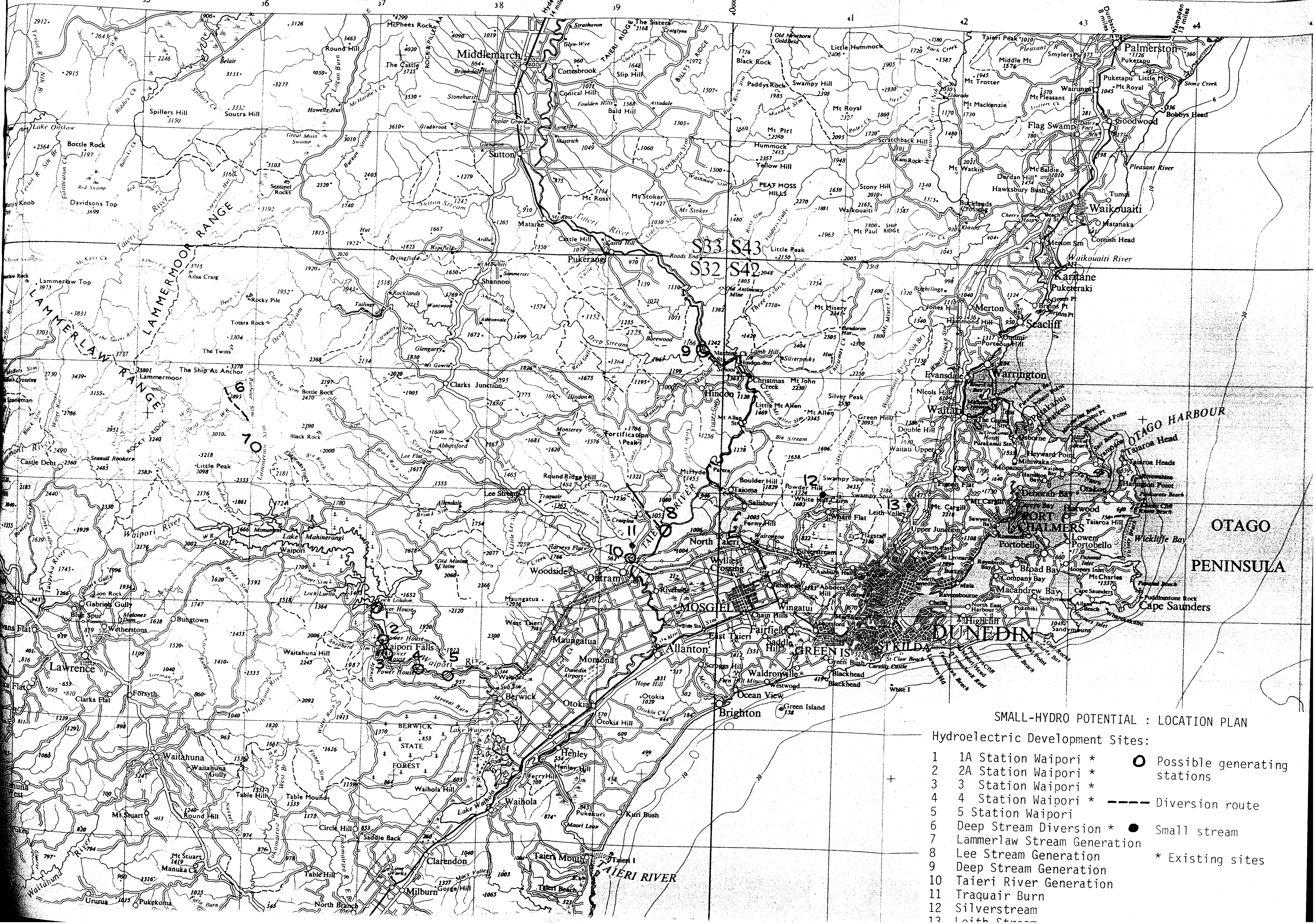
AREA OF SUPPLY

Boundary Shown Thus:


ISOLINE INTERVAL (Millimetres)
1400
1200
1000
800
600
400
300
200
100
LESS THAN 10
Falls Dam
Mt Ida Water Race
Dunstan Creek
Oturehua
Manuherikia River
Naseby
Little Kye Burn
Hog Burn
Pisgah Stream
OTAGO CENTRAL RAILWAY
RANFURLY
S.H.85
Wether Burn
Eden Creek
Ewe Burn
Gimmer Burn
Kye Burn
Swin Burn
Waipiata
Pool Burn
Manorburn Reservoir
Greenland Reservoir
Cap Burn
Pig Burn
Sow Burn
Mare Burn
Totara Creek
Linn Burn
TAIERI RIVER
Styx Creek
Serpentine Creek
Logan Burn
GREAT MOSS SWAMP
Middlemarch
Sheepwash Stream
Nenthorn Stream
Shag River
Palmerston
Lake Onslow
Lug Creek
Sutton Stream
Deep Creek
Deep Stream
Three O'Clock Stream
Christmas Creek
Lammerlaw Stream
Waipori River
S.H.87
Lee Stream
S.H.1
OTAGO HARBOUR
Verter Burn
MOSGIEL
Outram
Silver Stream
Owhiro Stream
DUNEDIN
Lawrence
Contour Channel
Allanton
LAKE WAIPORI
LAKE WAIHOLA
Taieri Mouth
S.H.8
S.I.M.T
Milton
Acknowledgements to
Otago Catchment Board
AVERAGE ANNUAL RUNOFF (1970-1979)
TAIERI RIVER CATCHMENT
WATER RESOURCE INVENTORY
0
10
20
30
40
Kilometres


ISOHYETAL INTERVALS (Millimetres)
1800
1600
1400
1200
1000
800
700
600
500
400
Oturehua
Naseby
Dunstan Creek
Manuherikia River
OTAGO CENTRAL RAILWAY
RANFURLY
S.H.85
Pisgah Stream
Hog Burn
Kye Burn
Swin Burn
Waipiata
Eweburn
Pool Burn
Manorburn Reservoir
Greenland Reservoir
Lake Onslow
TAIERI RIVER
Styx Creek
Serpentine Creek
Logan Burn
GREAT MOSS SWAMP
Middlemarch
Lug Creek
Sutton Stream
Sheepwash Stream
Nenthorn Stream
Three O'Clock Stream
Christmas Creek
Deep Creek
Waipori River
S.H.87
Lee Stream
Shag River
Palmerston
S.H.1
OTAGO HARBOUR
MOSGIEL
Outram
Silverstream
Owhiro Stream
Allanton
DUNEDIN
Lawrence
Contour Channel
LAKE WAIPORI
LAKE WAIHOLA
S.H.8
S.I.M.T
Milton
Taieri Mouth
Acknowledgements to
Otago Catchment Board
AVERAGE ANNUAL RAINFALL (1970-1979)
TAIERI RIVER CATCHMENT
WATER RESOURCE INVENTORY
0
10
20
30
40
Kilometres

MAP 3



SMALL-HYDRO POTENTIAL : LOCATION PLAN

Hydroelectric Development Sites:

1 1A Station Waipori *
2 2A Station Waipori *
3 3 Station Waipori *
4 4 Station Waipori *
5 5 Station Waipori
6 Deep Stream Diversion *
7 Lammerlaw Stream Generation
8 Lee Stream Generation
9 Deep Stream Generation
10 Taieri River Generation
11 Traquair Burn
12 Silverstream
13 [illegible]

O Possible generating stations

---- Diversion route

● Small stream

* Existing sites