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Otago Irrigation Dams

Design Flood Check

August 1989

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A DIVISION OF Works and Development Services Corporation (NZ) Ltd

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Design Flood Check

August 1989

Commissioned by **MAFTech Invermay**

a Business Group of the Ministry of Agriculture and Fisheries

and

Prepared by WORKS *Consultancy Services*

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Executive Summary

- Upper Manorburn and Poolburn Dams will pass the deign flood (500 year return period) within the spillway provision.

- Idaburn Dam is probably adequately served by spillway capacity, but the dam toe foundations and the dam stress capability under the design flood require checking.

- Butchers, Conroys and Fraser Dams all overflow the designated spillway area during the design flood. This may not be a problem as the dams are concrete arch structures, but potential scour possibility should be checked.

- The situation with Eweburn Dam is not clear because of difficulty in reconciling levels information with respect to the crest level.

- If the levels used here for Eweburn are correct, then the design flood (1000 year for Eweburn) can be accommodated with sufficient safety. The PMF flood cannot be passed safely however, and as Eweburn is an earth dam, remedial work is required so that the PMF can be passed with freeboard.

- The Lower Manorburn Dam has inadequate flood spillway provision.

- Modern day plans showing spillway dimensions and levels are required for all dams before any of the findings here can be fully accepted.

- The snowmelt factor is recognised as significant for most of the dams and some of this effect is included in the dimensionless hydrograph used. However, its effect has not been maximised in this report.

- Only approximate PMF (Probable Maximum Flood) calculations have been made and these have not been discussed (apart from Eweburn) relative to spillway capacity.

- Where the dam crest overflows in the design flood and this overflow occurs across the footpath with handrail posts, then there is potential for debris trapping and the subsequent raising of flood levels.

- Because this report largely considers spillway capacity and erosion possibilities with crest overflow and it does not consider loading on the structures, for those dams where loadings and stress are critical due to the condition of the dam, careful reassessment of structural safety is required in association with a study of flood flows in this report.

- It may be wise to carry out a detailed PMF study for Eweburn Dam before the dam is raised and/or spillway capacity increased.

Otago Irrigation Dams

1. Introduction

As part of a general review of irrigation dams in the Otago area we were asked to undertake a study of the flood spill capacity of eight of the dams. The dams are listed (Table 1) along with some details relative to their flood hydrology. Another dam in the area, Falls dam was reported on by Jowett and Horrell in September 1984. Their general approach using flood frequency analysis and unit hydrographs has been followed here, although with five more years of hydrological data in the region the approach has been modified somewhat to take account of this. The result being that more use has been made of actual hydrological flow data.

The dams were build over a number of years between 1898 and 1937 and in a general review of these eight dams and their design capabilities the capacity of the spillways forms an important element. The ability of the structures to pass the design flood with a return period of 500 years (concrete structures) is considered here and reported on. The Eweburn dam is of earth construction and consideration is therefore of the 1000 year return period flood. All references to the design flood in this report refer to the routed outflow flood as calculated in this report.

Hydrological data and routing models are in metric units and so metric units are used throughout this report. Conversion from feet where necessary has been by multiplying by 0.3048 to get metres. Eweburn conversion has been treated differently and is by the formula feet x 0.3048 +659.83.

2. The Dams

Extensive details of each dam are contained in the recently completed serviceability report series prepared by WORKS Consultancy Services, Dunedin in May 1989. Other important basic information is contained in WORKS Project Services Surveillance section's data books.

The dams are served by catchment areas ranging in size from 14 km2 to 398 km2 (Table 1).

The elevation range of the catchments varies between 250 m and 1500 m.

Apart from two of the dams the reservoir areas are small. The two larger reservoirs, Upper Manorburn and Poolburn have reservoir areas of 7.0 km2 and 4.5 km2 respectively and consequently large volumes of water impounded behind them. For this reason alone these two dams require careful appraisal of their spillway capacities because if failure did occur then large volumes of water would be released. However the dams with small reservoir areas will show less flood peak reduction and so are likely to be more sensitive to revised design flood calculation.

3. Regional Hydrology Data

When Jowett and Horrel did their study of Falls dam in 1984, there was only one gauging station nearby that was close in catchment size to the Falls Dam. This was the Manuherikia River at Downstream Forks gauging station (site 75251). At that time there was only 9 years of hydrological record and so the longer record at the gauging station at Ophir (over 2000 km^2) was used.

Dam Name	Catchment Area (km^2)	Max. Elevation (m)	Elevation Range (m)	Spillway Crest RL (m)	Dam Crest RL (m)	Original Flood Design (m)	Spillway Capacity (m^3/s)	Reservoir Area (km^2)
Upper Manorburn	90	900	150	746.15	746.15	746.91	110	7.0
Poolburn	53	1100	250	812.50	813.05	813.05	10	4.5
Idaburn	136	1500	1000	496.88	496.88	497.80	57	0.09
Lower Manorburn	398	1000	900	32.31	33.07	33.07	110	0.18
Conroys	25	1600	1350	28.95	29.41	-	-	0.14
Butchers	35	1600	1300	28.04	28.50	28.34	9	0.36
Fraser	119	1600	1050	35.05	36.27	36.27	150	0.46
Eweburn	14	1400	700	679.48	681.28	-	-	0.25

TABLE 1 : **OTAGO IRRIGATION DAMS - Key Data**
List of dams for which design flood checks were required

Dam Name	Catchment Area (km^2)	Max. Elevation (m)	Elevation Range (m)	Hydrological Region	Approximate Precipitation (Annual mm)	Gauging Station to use
Upper Manorburn	90	900	150	Alexandra/East Otago	750	Manuherikia
Poolburn	53	1100	250	Ranfurly	750	Gimmerburn
Idaburn	136	1500	1000	Ranfurly/Waitaki	700	Gimmerburn
Lower Manorburn	398	1000	900	Alexandra/East Otago	650	Manuherikia
Conroys	25	1600	1350	Alexandra/East Otago	700	Manuherikia
Butchers	35	1600	1300	Alexandra/East Otago	700	Manuherikia
Fraser	119	1600	1050	West Otago	1000	Fraser
Eweburn	14	1400	700	Ranfurly/Waitaki	750	Gimmerburn
Gauging Stations						
Gimmerburn at Rough Ridge	23.7	1600	1050	West Otago	1000	
Fraser at Old Man Range	122	1950	1250	West Otago/Waitaki	800	
Manuherikia at D/S Forks	174	900	450	Ranfurly	650	

TABLE 2 : **OTAGO IRRIGATION DAMS - Approximate descriptive data used to select most representative gauging station.**

This study involves eight river basins spread over a large part of the Central Otago region. Apart from the Fraser Dam there are no gauging stations located at dams. Therefore the use of regional basins to provide design data for each dam has been necessary.

Looking at the region collectively we have selected three gauging stations with lengths of record of 14 years, 18 years and 20 years. The gauging stations are on the Fraser, Manuherikia and Gimmerburn rivers (Table 2).

Because these gauging stations collectively bring real hydrograph definition to the region they have been given more weight in this study than the rainfall data. The eight basins fall into five hydrological regions (Table 2). Two of the gauging stations are catchments representing a single region and represent the hydrology of that region. These gauging stations are Fraser at Old Man Range (West Otago region) and the Gimmerburn river at Rough Ridge (Ranfurly region).

Hydrological region and annual precipitation, are tabled (Table 2) along with other data presented earlier to provide a guide for the selection of a suitable similar gauging station flow record for each of the dams. This is not a precise selection criterion, but serves to assist with initial analysis.

4. Flood Frequency

Data was obtained for the three gauging stations to produce an annual flood series (Table 3). The gauging stations are all operated by Water Resources Survey, DSIR.

Year	Gimmerburn (74353) m3/s	Fraser (75259) m3/s	Manuherikia (75251) m3/s
1969		29	
1970		20	
1971	1.6	30	
1972	6.0	22	
1973	3.9	26	
1974	4.0	15	
1975	0.5	17	31
1976	2.6	97	40
1977	0.7	138	30
1978	6.0	84	54
1979	1.0	18	30
1980	8.2	38	85
1981	0.5	24	26
1982	2.0	23	61
1983	6.5	33	65
1984	1.9	24	62
1985	0.6	12	34
1986	4.0	20	103
1987	1.8	26	96
1988	2.5	24	45

TABLE 3 : Annual Flood Series for three gauging stations.

A study of the reduced size plot of the flow record for the three basins gives an indication of the relative flood activity between basins (Appendix A).

The Fraser record has a very uneven flood series with only three large events being recorded in the twenty year period. These events stand out quite dramatically from the rest of the floods and illustrate a certain upredictability within the region.

Conventional analysis methods do have a problem with data of this nature, but the flood series analysis is still the best approach provided the uncertainty is considered properly.

The Fraser record also provides a good example of the seasonal snow melt affecting the higher altitude catchments in the region with flows rising in the last quarter of most years. Basins supporting substantial winter snow accumulation such as the Fraser will always have the potential to assist large rainstorms in creating an extreme flood situation although there is very little documented evidence of such floods in NZ. The most relevant work to date is that by Harrison (Harrison 1980, 1986). Some details are given below.

There was an automated snow pillow in the Fraser catchment for some years. During the October 1978 flood it was estimated that 37% of the water yield was from snow melting in the Fraser catchment. The 1978 flood in the Fraser is either the second or third highest flood in the 20 years of record (depending on peak estimate used). Other high altitude basins in the Otago area will be similarly affected by snowmelt.

The exact effect on the peak flow which is critical to this study is not known, but in the case of the 1978 flood, snowmelt occurred on the rising stage side of the flood hydrograph and so snowmelt contributed significantly to the size of the flood peak.

The three largest floods in the Fraser catchment are all thought to be effected by snowmelt.

A study of the Fraser flood series (Appendix A) shows an extremely variable flood series. Longer records are needed therefore to obtain a true probability series that adequately copes with snowmelt. There remains always the potential that snowmelt will have a significant effect on flood flows given the right conditions.

The flood series for all three river basins was subjected to analysis using a computer based programme known as 'Fran'. Gumbel frequency analysis was used and results tabled (Table 4).

The $\bar{Q}$ value is the mean of the annual flood series and should equate to Q2.33, the annual flood. Also tabled are the 100 year and 500 year return period floods. In all cases the specific yield (litres/sec/km2) is given to show the regional variation.

As a further means of assessing variability, ratios of the Q100 year to Q2.33 and the Q500 to the Q2.33 year flood are tabled (Table 5).

For each of the three basins a 500 year return period hydrograph based on actual floods hydrographs and frequency analysis was constructed. From this a dimensionless unit hydrograph was produced for each gauging station (Fig 1).

The Gimmerburn and Manuherikia dimensionless unit hydrographs are very similar. They are also more regular. The Gimmerburn dimensionless unit hydrograph was selected for use in all cases.

River and Station	Site No.	Catchment Area	$\bar{Q}$		Q2.33		Q100		Q500	
			m^3/s	$l/s/km^2$	m^3/s	$l/s/km^2$	m^3/s	$l/s/km^2$	m^3/s	$l/s/km^2$
Gimmerburn at Rough Ridge	74353	23.7	3.0	127	3.0	127	11.0	464	14.3	603
Fraser at Old Man Range	75259	122	36.0	295	36.5	299	146	1196	189	1549
Manuherekia at D/S Forks	75251	174	54.8	315	55.4	318	143	822	179	1029
Mean										1060

TABLE 4 : OTAGO IRRIGATION DAMS - Flood frequency data for selected gauging stations in the Otago dams area.

Peak discharge and time to peak data was obtained from the other two basins as well and in general Gimmerburn was not given so much weight when establishing peak flow for the dams, although as noted already the dimensions of the Gimmerburn hydrograph were used.

A synthetic unit hydrograph was derived for Poolburn as a check using the Clark model. The resultant outflow peak after routing was 3.9 m^3/s compared with 2.5 m^3/s using the dimensionless hydrograph.

5. Storm Rainfall

The 500 year storm rainfall was derived for six of the basins, for the other two, Eweburn and Idaburn rainfall information from Jowett and Horrell's 1984 Falls dam report was used. (Figs 2 and 3).

For the six basins where the 500 year storm was derived the method was as follows. Tomlinson derived the Gumbel distribution for 24 hour storms of return periods up to 100 years. By using the parameters of that Gumbel distribution a scaling ratio for the 500 year storm was calculated. Temporal patterns were those used by Tomlinson, but with consideration being given to Motu, Clutha and Falls work carried out by this office.

Although standard methodology is used here, it must be stated that because of a lack of upper catchment raingauges the degree of certainty of the 500 year rainfall estimates is difficult to calculate.

The hatched areas in the figures (Figs 2 and 3) are catchment areas and not reservoir areas.

RIVER AND STATION	RATIOS	
	Q100 / Q2.33	Q500 / Q2.33
Gimmerburn at Rough Ridge	3.6	4.7
Fraser at Old Man Range	4.0	5.2
Manuherikia at D/S Forks	2.6	3.2
Mean	3.4	4.4

TABLE 5 : **Ratios for the annual flood to 100 year and 500 year return period flood at gauging stations.**

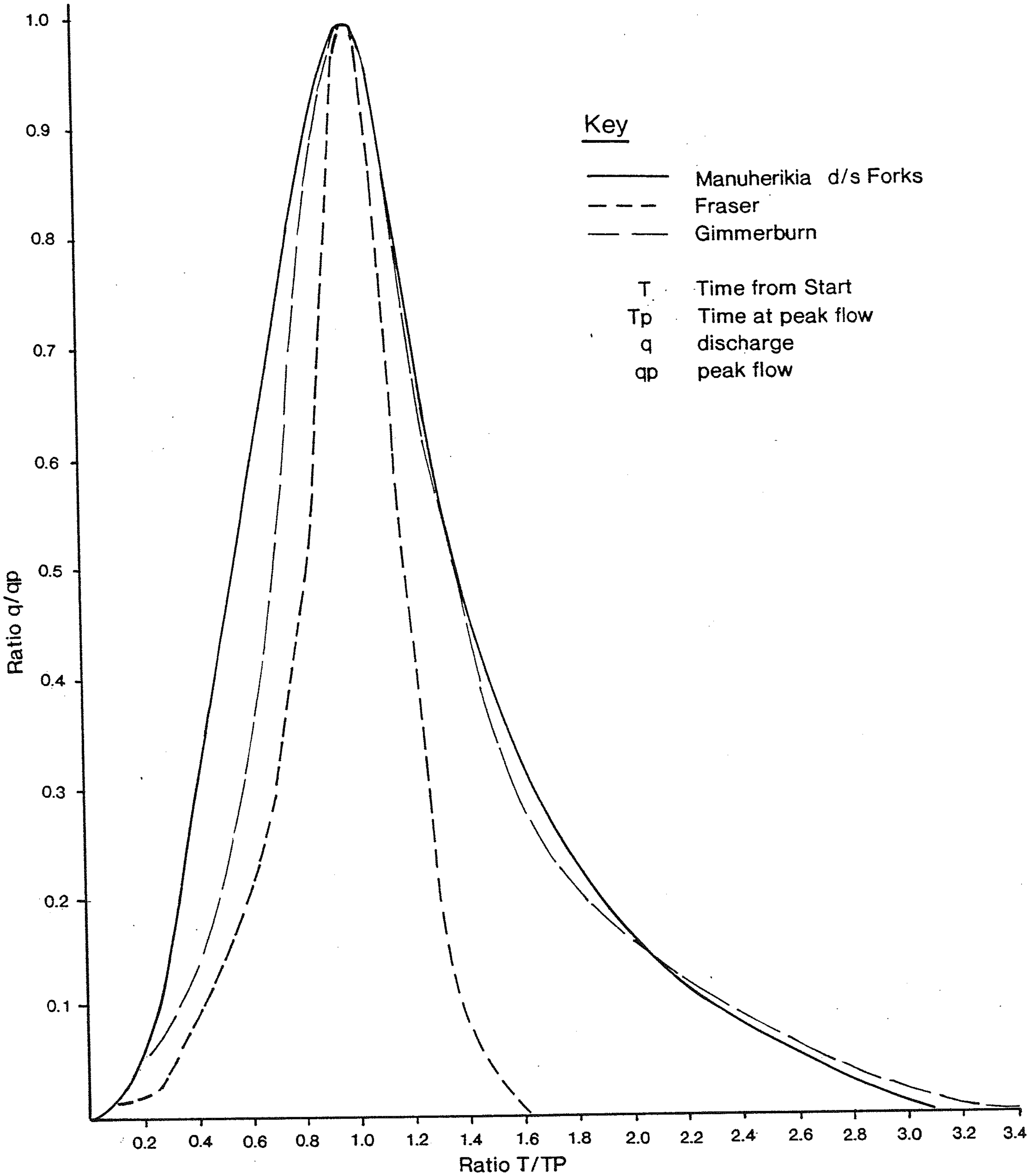


Figure 1 Dimensionless Unit Hydrograph. Otago Catchments.

Derived from 500 year return period hydrographs.

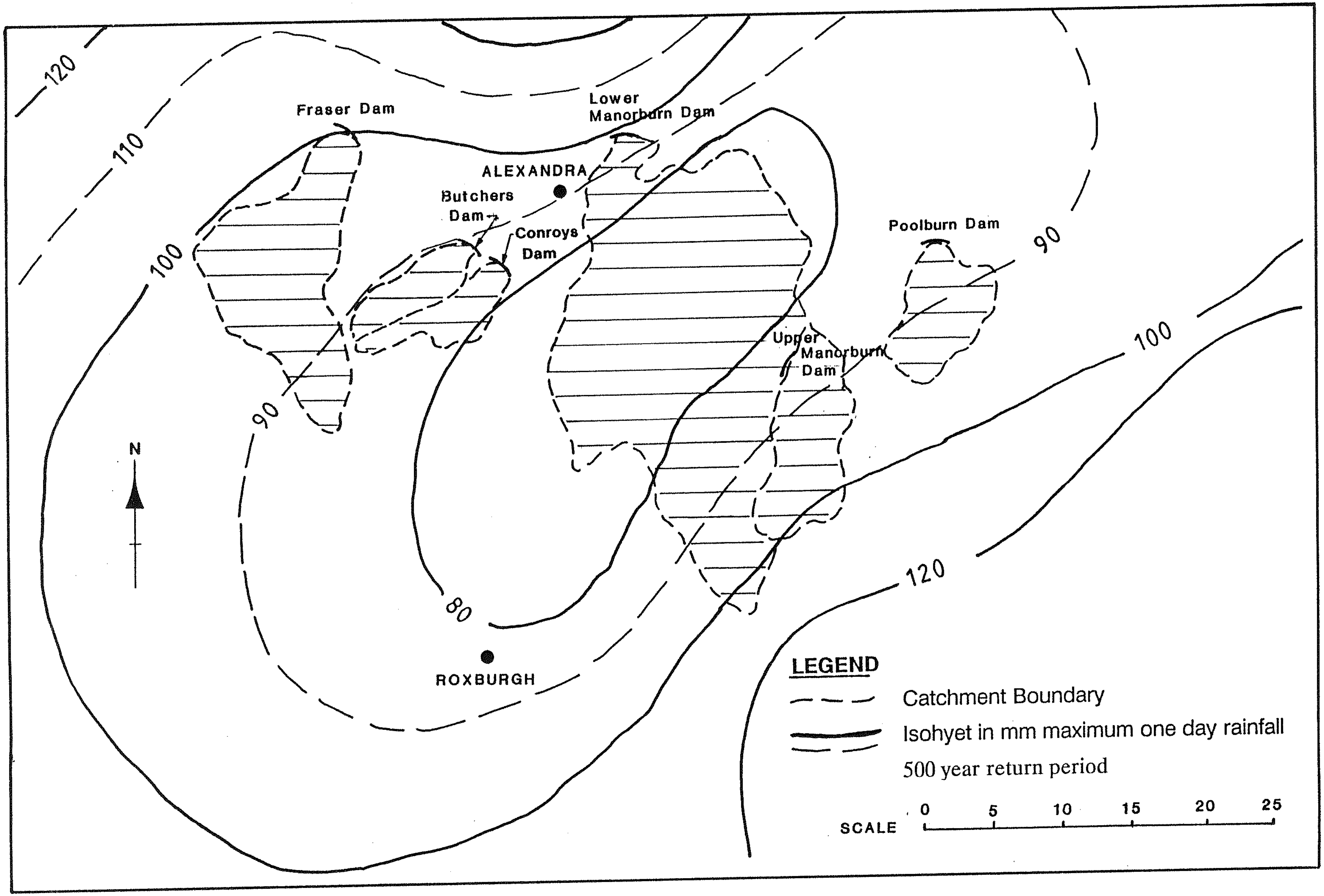
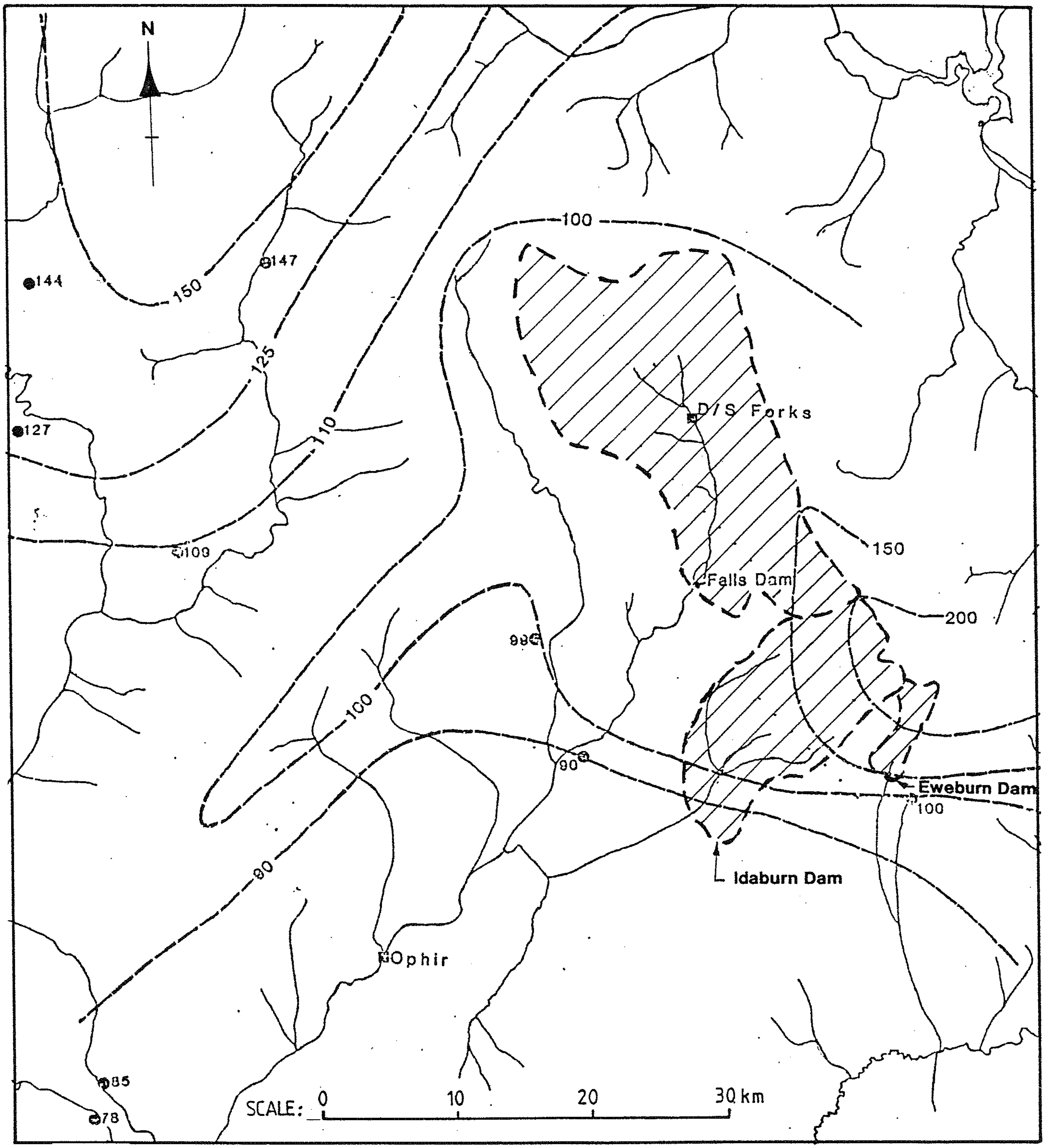


FIG. 2 500 YR RETURN PERIOD 24 HOUR RAINFALLS



LEGEND

— — — Catchment Boundary

— —100— Isohyet in mm maximum one day rainfall 500 year return period

● Raingauge with long term records

■ Manuherikia water level recorders

FIG. 3 500 YR RETURN PERIOD 24 HOUR RAINFALLS

6. Inflow Floods

Inflow floods were obtained from the flow, rainfall, and catchment characteristics data in the following way.

The frequency data from each of three gauging stations were used to calculate peak flow for a given catchment in the following way using Poolburn as an example.

Q500 yr flood Poolburn = Q500 Gimmerb x C.A. Poolb/ C.A. Gimmerb x catchment size scaling ratio.

This process was repeated with each of the three gauging stations. The scaling factor represents a scaling for catchment size. Scaling ratios were obtained from data in "Regional Flood Estimation in NZ" (Beable, McKerchar, 1982) and from the Q2.33 yr line for Urewera (Freestone 1976).

Once the calculations were made a value was selected on the basis of data given in the catchment characteristics table (Table 1).

Time to peak, that is the time from the start of the rise to the flood peak was obtained from the actual hydrograph data for the three gauging stations with interpretation of which was the most suitable one for each dam being made on the basis of catchment area and channel slope.

The dimensionless unit hydrograph was used with the derived peak flow and time to peak, to give an inflow flood hydrograph for each flood.

Some iteration was used to obtain general agreement with Jowett and Horrell's rainfall to runoff relation (500 yr event).

The 500 yr return period flood peak, 24 hour rainfall and 24 hour runoff from the hydrographs derived using the dimensionless unit hydrograph are tabled (Table 6). Rainfall runoff relationships for the 500 year return period design inflow hydrograph are shown by plotting (Figure 4).

A footnote to Table 6 points out that if Upper Manorburn Dam was removed then the peak inflow to Lower Manorburn Dam would be 250 m^3/s that is 35 m^3/s more than at present. This study assumes the continued presence of the Upper Manorburn Dam.

Dam Name	500 year Inflow Flood m^3/s	500 year Inflow Runoff (mm)	500 year Rainfall (24 hour) (mm)
Upper Manorburn	100	24	95
Poolburn	60	17	92
Idaburn	175	44	167
Lower Manorburn	215*	26	78
Conroys	35	22	88
Butchers	45	24	85
Fraser	189	30	94
Eweburn	59**	66**	226
Gauging Stations			
Gimmerburn at Rough Ridge	14	9.2	90 (approx)
Fraser at Old Man Range	189	30	94 (approx)
Manuherikia at D/S Forks	179	28	110 (approx)

* If Upper Manorburn Dam is discounted then the 500 year flood becomes 250 m^3/s

** 1000 year flood (earth dam)

TABLE 6 : 500 Year Return Period Design Data

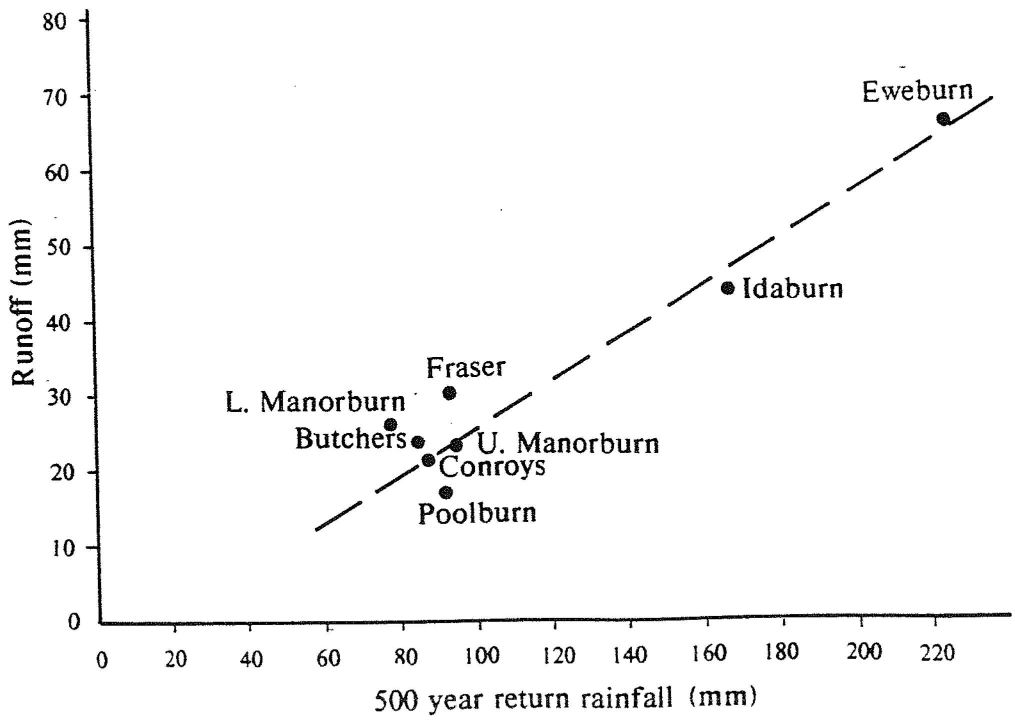


Figure 4 Design rainfall compared to design runoff.

7. Flood Routing

Each derived flood hydrograph was then routed through the reservoir to obtain a peak outflow and a peak level at the dam.

The results are tabled along with spillway capacity data (Table 7).

Dam	Dam	Existing Data		Derived this Study	
	Crest Level (m)	Spillway Capacity (m^3/s)	Flood Level (m)	500 yr Design Flow (m^3/s)	Flood Level (m)
Upper Manorburn	746.15	110	746.91	15.1	746.38
Poolburn	813.05	10	813.05	2.5	812.71
Idaburn	496.88	57	497.80	174	498.81
Lower Manorburn	33.07	110	33.07	214	33.49
Conroys	29.41	-	-	32	29.67
Butchers	28.50	9	28.34	36	28.72
Fraser	36.27	150	36.27	181	36.37
Eweburn	681.28	52	681.28	*36	680.88

* Design flood is for 1000 yr return period.

TABLE 7 : Design Floods for the eight dams, derived by routing inflows through reservoirs.

The flood routing model used was a simple reservoir routing model. Derived inflow hydrographs were routed through the reservoirs. Spillway and/or Dam width dimensions were used with suitable hydraulic formula to determine the outflow rating for each dam.

Some of the basic information on spillway dimensions, overflow levels and hydraulic characteristics is very sketchy and may effect some results. This has been indicated only in cases where it is obvious.

Levels datums quoted are generally in local or unknown datum and generally refer back to original plans for each dam.

8. Probable Maximum Flood (PMF)

Calculation of the PMF is a long and tedious task and therefore no site specific PMF calculations have been made here because such detailed work was outside the brief. Another reason for not carrying out detailed PMF checks here is that the PMF methodology currently in use in NZ is under review.

PMF values presented here (Table 8) have been derived by using data from other catchments (Appendix B).

The method used involved obtaining the ratio between the 500 year flood and the PMF at sites where PMF has been calculated. The ratios were studied and an estimation of the appropriate ratio to use for the Otago Irrigation dams was made.

Because of a lack of PMF calculation for small catchments there is no real means of selecting a ratio using a precise line of rational.

Dam Name	Probable Maximum Flood m^3/s
Upper Manorburn	35
Poolburn	6
Idaburn	315
Lower Manorburn	385
Conroys	60
Butchers	65
Fraser	325
Eweburn	80

TABLE 8 : **Probable Maximum Flood (PMF) at Dams after Routing.**

9. Spillway Capacity

The evaluation of the adequacy of spillway capacity of each dam can now be made by comparing spillway capacity with the design flood and with the PMF flood. For all dams except Eweburn the design flood is the 500 year flood. For Eweburn which is an earth dam the design flood is the 1000 year event. The auxiliary dam at Conroys is not solid concrete but the 500 year event was used as the design flood at Conroys. Comparative data is tabled below (Table 9).

Dam Name	Flow m^3/s			Maximum Water level (m)			Spillway Adequate Yes/No
	Design	PMF	Spillway Capacity	at Design flood	at PMF	at full spillway	
Upper Manorburn	15.1	33	110	746.38	746.55	746.91	Yes
Poolburn	2.5	6	10	812.71	812.85	813.05	Yes
Idaburn	174	315	-	498.81	499.73	-	Yes
Lower Manorburn	214	385	110	33.60	33.99	33.07	No
Conroys	32	60	7	29.67	29.84	29.41	No
Butchers	36	65	9	28.72	28.90	28.34	No
Fraser	181	325	150	36.37	36.88	36.27	No
Eweburn	36	80	*52	680.88	681.47	681.28	No

* approximate

TABLE 9 : OTAGO IRRIGATION DAMS - Calculated Design and PMF Floods compared to spillway capacity

It can be seen from a study of the table (Table 9) that only three of the eight dams have adequate spillway capacity. The effects of the irrigation water draw-offs has not been taken into account and the calculations assume that the draw-off valves are closed or the pipes are blocked. The significance of the flood capacity calculations is discussed below for each dam. In the following sections on individual dams spillway capacity is usually discussed with respect to capacity and scour effects only. The state of the structures and their strength have been reported on recently by others. For some of the structures, strength capability will need further review to consider flood loadings based on the design floods from this report.

9.1 Upper Manorburn

The flood routing exercise for the Upper Manorburn Dam produced a satisfactory result. There is adequate spillway capacity to pass both the design flood (500 year return period) and the PMF.

The spillway consists of the dam itself, and at the design flood level, water overflows to a depth of 230 mm. There does not appear to be a drawing that shows levels for the mass concrete abutment block built in 1955. The reduction of crest width at the crest level of the main section of the dam (746.15 m) caused by the construction of the abutment block at a higher level is not noted on existing plans. However a study of photographs shows that spillway capacity is more than adequate.

With a flow of 200 to 300 mm over the dam and given that there is reasonable abutment interface on both sides of the dam, then the passage of the design flood and the PMF over the dam should be accomplished safely.

9.2 Poolburn

Current spillway capacity at the Poolburn dam appears to be adequate.

The spillway crest level is 812.50 m and the design flood (500 year) reaches a level of 812.71, a rise of 0.21 m. Even with this rise the level is still 0.34 m below dam crest level.

Assuming that the embankment end of the spillway section is armoured then the spillway capability of the dam is adequate. Although the freeboard at design flood levels is relatively small, the structure is concrete and could therefore sustain some splash overtopping.

9.3 Idaburn

The Idaburn Dam sits in a rock gorge, with bedrock abutments on either side and bedrock at the base of the dam.

The whole of the dam crest is used as a spillway. Flood carrying capacity is not seen as a problem relative to the design flood (500 year).

The dam crest level is 496.88 m and the design flood produces flow to a depth of 1.93 m over the top of the dam. The level given in 1930 for the railway line at the head of the lake is 498.30 m and this compared with 498.81 m for the 500 year design flood.

It is not known if the railway line is still at the same level as it was in 1930, but regardless of whether it is or not, it has no real bearing on the spillway capacity of the dam.

The spillway capacity is adequate. The arch dam structure should cope fairly well with overtopping, but see comment in the conclusion.

9.4 Lower Manorburn

Spillway capacity is exceeded by 420 mm depth in the design flood (500 year). The consequence of this is that a considerable amount of high velocity water will flow over the natural country at either end of the structure. Floods to date have overtopped the gravity abutment blocks and gone around concrete works.

"Discharge overpour" as described above, appears to have had some effect on surrounding rock (WORKS report May 1989) and so there is a need to make more adequate provisions for the design flood in the form of increased spillway capacity.

9.5 Conroys

Conroys is a concrete arch dam with a spillway consisting of a series of openings formed by piers carrying the crest walkway. The design flood was routed over the spillway by making allowance for the piers.

The spillway capacity is inadequate to cope with the design flood (500 year), which will overflow the entire dam walkway and crest to a depth of 260 mm.

Without a visit to the site it is difficult to assess the consequences of overtopping by 260 mm by the design flood. Available photographs indicate that this amount of overtopping would not be serious, but a proper assessment should be made and extended concrete abutment walls made to cope with the design flood.

The auxiliary dam on the south eastern side of the reservoir is at RL 30.48 m which is 810 mm above the design flood level of 29.67 m. What help the gate controlled discharge pipe in this dam would give during a flood or if staff work to an operation plan that would release water during floods has not been considered.

The auxiliary dam is not designed for overflow but there is sufficient freeboard at the design flood and so the likelihood of overtopping is small.

The note about possible debris effects contained in the section on Butchers dam (9.6) applies here too.

9.6 Butchers

The spillway is 457 mm lower than the dam crest and consists of 13 gaps between piers supporting the walkway.

The design flood (500 year) overflows the spillway and flows over the dam crest to a depth of 220 mm.

Given the rock setting of the dam and the fact that it is a concrete arch dam, then the spill over the crest for the design flood is not seen as a problem. From photographs it seems that overflow spill would not set up any cycles of scour that would undermine the dam during the design flood, but this should really be field checked against the 220 mm depth overflow, by considering the path of overflow water.

The only other factor that needs mentioning is one of debris. The dam has a walkway over it with a handrail and support posts which could act as a debris trap when the design flood was being passed. This in turn could increase flood levels and place some extra degree of stress on the structure.

9.7 Fraser

The design flood is based on the use of actual flow data recorded just upstream of the structure. Of the eight dams, this is the only one with actual relevant flow records available for the design flood check.

The spillway occupies 61 metres of the dam width and is 1.2 m lower than the two end sections of the dam where the crest level is 36.27 m.

The design flood is largely contained within the spillway, but there would be overflow to a depth of 100 mm over the end crest sections.

The implication of the overflow spill is that it may set up scour in the abutment area.

The photographs available to us here at present seem to be in conflict with the plans. The plans show rising ground above crest level at each abutment, but the photo seems to indicate lower ground. This is not clear from the photo however, but could easily be verified by visual inspection.

9.8 Eweburn

Of the eight dams being evaluated Eweburn is the only earth dam (although Conroys has an auxiliary earth dam).

Because of the earthdam construction the design flood for Eweburn is based on the 1000 year return period flood.

There have been recent improvements to the bywash area and the plans for the new channel are metricated but contain a clear statement of the relationship to the imperial datum of the design reports and plans which are in feet.

However there is no clear statement on the new plans of the current dam crest level and so we have used the new spillway crest level of 679.48 with the 1.8 m add-on described in the WORKS report of May 1989 to give a dam crest level of 681.28 m.

The design flood (1000 year event for Eweburn only) reaches a level of 680.88 which means that there is 400 mm of freeboard to the dam crest.

Because Eweburn is of earth construction, the PMF should be considered carefully.

The approximate PMF level gives flow over the earth dam to a depth of 190 mm. This of course is totally unacceptable.

As noted earlier there is however some confusion with levels and although a modern day level is available for the spillway crest the equivalent dam crest level is not clearly stated.

The bywash spillway appears prone to vegetation growth (from photographs) but the assessment takes no account of vegetation. The presence of vegetation in a spillway entrance channel is totally unacceptable as is the possibility for it to grow there.

10. Conclusions

Although there is only one reasonable hydrological flow record that relates directly to a dam in that it is very close to the dam, there is however sufficient regional data to provide for a hydrological data projection approach to the problem of defining the design flood for each dam.

Design inflows floods (500 year except for Eweburn which is 1000 year) have been calculated from a derived regional dimensionless unit hydrograph. These floods have been routed through each reservoir and compared with design capacity for each dam.

Upper Manorburn, Poolburn and Idaburn dams are considered to have sufficient spillway capacity to safely pass the design flood. There is however a need to confirm the loading capability of Idaburn and also the adequacy of scour protection at the base of the dam if it is subjected to the design flood (500 year).

Butchers Conroys and Fraser Dams all overflow the designated spillway area during the deign flood but this may not be a problem. A check of soundness of the area of spillway overflow is necessary.

Lower Manorburn Dam is incapable of sustaining the design flood with sufficient allowance for safety.

Eweburn Dam has the most uncertain crest level information and is suspect for this reason. However, should the crest level we used in this report be found to be correct, then the question of the passage of the PMF becomes a critical issue. Using levels as described in the report then the design flood (for Eweburn 1000 year) can be handled safely, but the PMF overflows the earth dam.

In general we would like to see for all dams, modern plans of spillway dimensions and levels including levels of the surrounding country of the dam cross section line above crest level. All the dams are old and several have been modified over the years which creates a concern over the validity of old plans used in studies such as this.

Other aspects that effect the flood spill capability of the dams include the approximate nature of the PMF calculation, the lack of real long term flow records to allow proper evaluation of the snow melt factor and the possible effect of debris being trapped on dams with handrails and footpaths.

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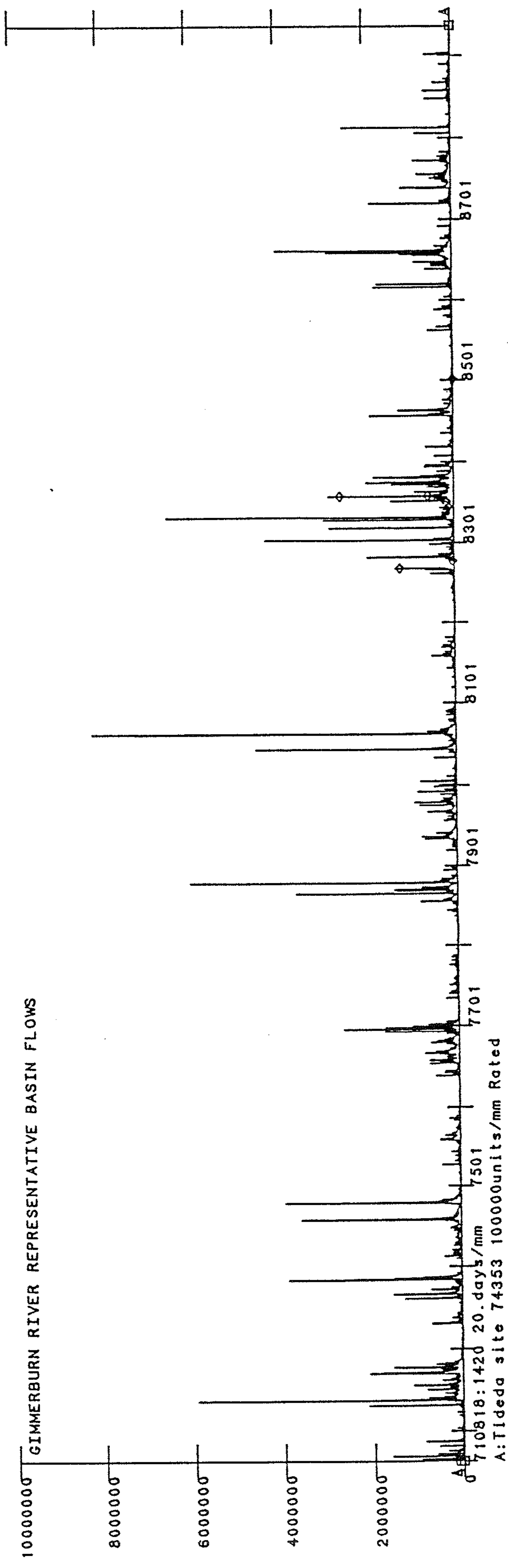
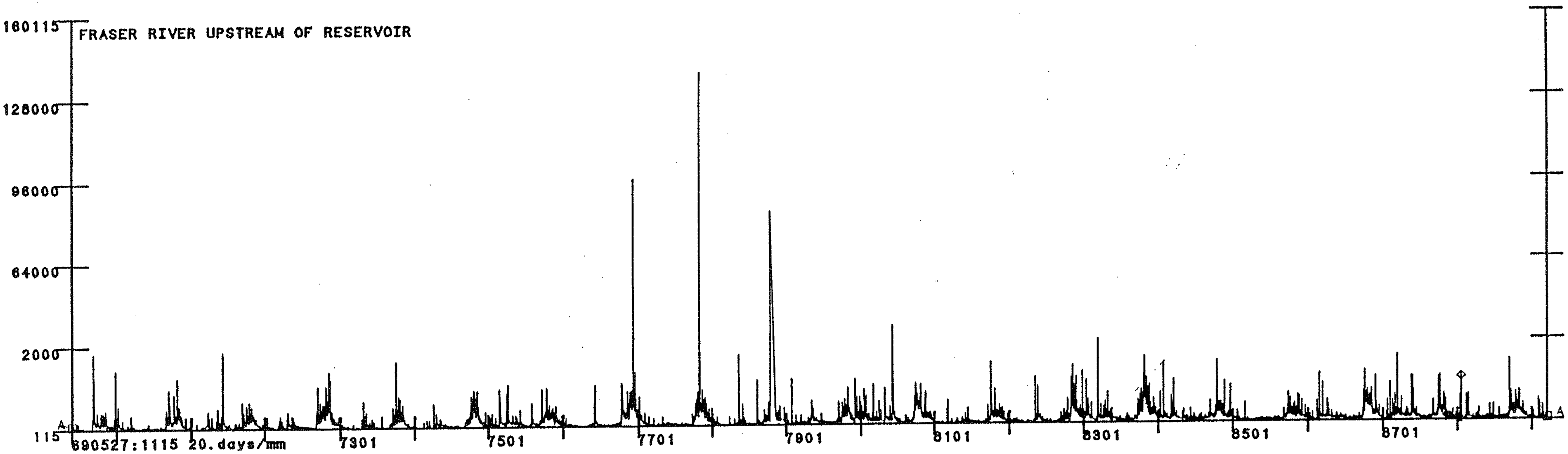
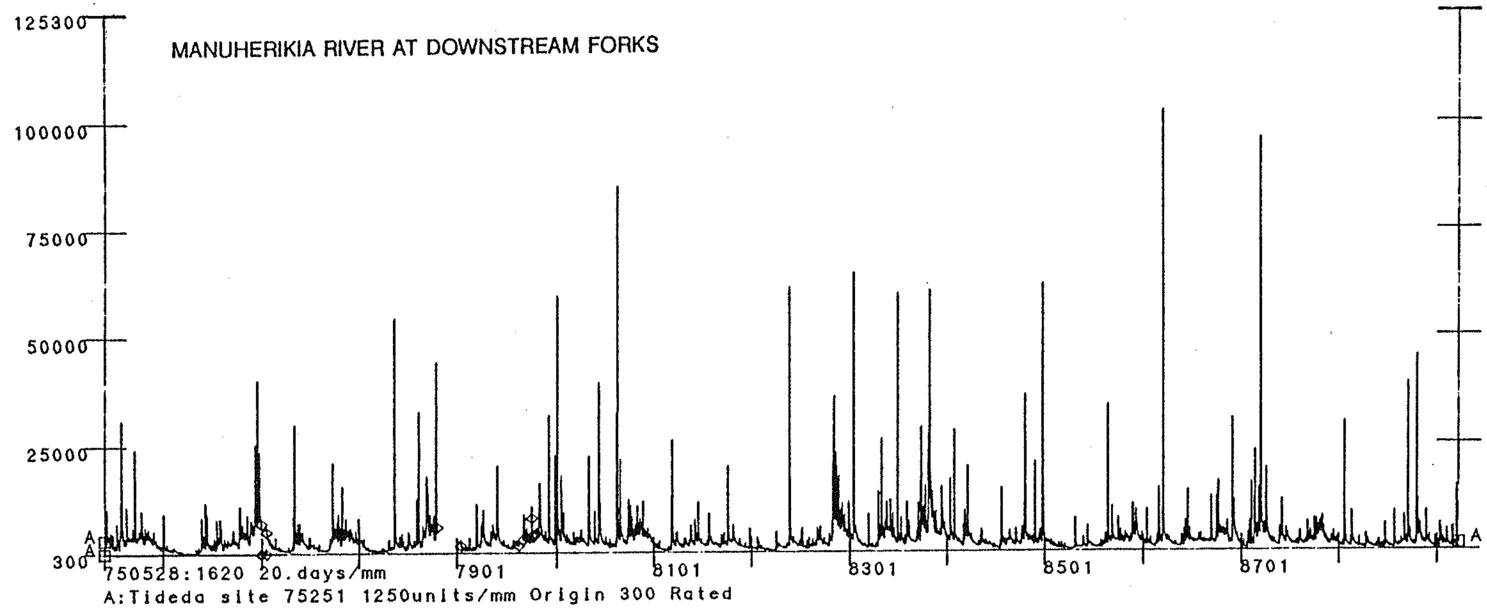
Appendices



APPENDIX A : OTAGO REGION FLOW RECORDS OF "REPRESENTATIVE" BASINS


FRASER RIVER UPSTREAM OF RESERVOIR
160115
128000
96000
64000
2000
115
890527:1115 20.days/mm
7301
7501
7701
7901
8101
8301
8501
8701


MANUHERIKIA RIVER AT DOWNSTREAM FORKS
125300
100000
75000
50000
25000
300
750528:1620 20.days/mm
7901
8101
8301
8501
8701
A:Tideda site 75251 1250units/mm Origin 300 Rated

APPENDIX B : SUMMARY OF DETAILED PMF STUDIES IN NEW ZEALAND

CATCHMENT	DAM (actual or proposed)	CATCHMENT AREA (km²)	YEAR OF PMF STUDY	CALCULATED FLOW (m^3s^{-1}) PMF	500 Yr	1000 Yr	PMF/ 500	PMF/ 1000	MAXIMISED CATCHMENT RAINFALL (mm)	NO. OF STORMS MAX.	RANGE OF RAINFALLS ANALYSED (mm)	RANGE OF MAXIMISED RAINFALLS ANALYSED (mm)	DURATION OF STORM (hrs)	TRANSPOSED STORM AND DETAILS
Manapouri Project			1969							1			72	
- Lake Te Anau	Te Anau - control	3653		2548	1173	1248	2.17	2.04	711					
- Lake Manapouri	Manapouri Control Gate	1444		3964[1]	1681	1792	2.36	2.21	584					
- Mararoa		1253		1528[2]	1557[3]				222					
[1] revised 1969 Bechtel for natural conditions [2] storm of 1967 not efficient in Mararoa catchment [3] from 1965 MOW report based on empirical formulae and comparison with nearby catchments														
Waikato Scheme			1972		48hr					4	157 ~ 173 (at Arapuni/Wairakei)	224 ~ 305	48	
- Ohakuri	Ohakuri	1631		533	378		1.41		312					
- Atiamuri	Atiamuri	285		145	112		1.30		335					
- Whakamaru	Whakamaru	575		337	232		1.45		281					
- Maraetai	Maraetai	588		397	256		1.55		284					
- Waipapa	Waipapa	254		274	195		1.40		294					
- Arapuni	Arapuni	249		331	236		1.40		305					
- Karapiro	Karapiro	839		319	227		1.41		315					
Clutha Development			1977		3 day	3 day				18	115 ~ 208 (ave. of 3 lakes)	150 ~ 336	48	
- Hawea		1389		316	268	304	1.18	1.04	300					
- Wanaka		2575		2205	1038	1136	2.12	1.94	419					
- Wakatipu		3067		1161	766	835	2.17	1.99	284					
- Upper Pisa	Upper Pisa	655		2587	1317	1451	1.96	1.78	189					
- UL8	Queensbury	117		2587	1318	1453	1.96	1.78	175					
- K 7/2	K 7/2	1551		3294	1730	1918	1.90	1.72	222					
- K9	K9	329		3662	1924	2139	1.90	1.71	133					
- DG3	Clyde	1286		6820	3464	3863	1.97	1.77	157					
- Roxburgh	Roxburgh	3639		7836	4036	4514	1.94	1.74	101					
Motu Hydrology			1980							24			10 ~ 48	Transferred centre of storm isohyetal pattern from Waioeka (1964) to Motu. Storm duration 36 hours.
- Houpoto	M5	1381		8300	5100	5500	1.63	1.57	)					
- M30	M30	-		7550	4550	4900	1.65	1.54	)503		75 ~ 245	140 ~ 393		
- Mangaotane	M56	696		3550	2040	2200	1.74	1.61	)					
- Waitangirua		295		1350	740	800	1.82	1.69	413		68 ~ 270	107 ~ 424		