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Ministry of Works and Development

MANUHERIKIA VALLEY IRRIGATION

FEASIBILTY REPORT

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MANUHERIKIA VALLEY IRRIGATION FEASIBILITY REPORT

VOLUME 1 (OF 2)

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January 1980

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ABSTRACT

This report considers the feasibility of irrigation development in the Manuherikia Valley. When fully developed the proposal would irrigate 20 000 ha in the Manuherikia Basin and would control the flow of the Upper Manuherikia above Falls Dam.

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January 1980

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I DESCRIPTION OF THE MANUHERIKIA VALLEY

I.1 GEOLOGY AND TOPOGRAPHY

The Manuherikia Valley, which extends about 64 km north-east of Alexandra, is one of the largest inter-montane depressions of the block and basin system of the Central Otago region. It is drained by the Manuherikia River which rises in the Hawkdun Range to the north-east and flows along the south-east margin of the depression. Within the survey area the Lauder, Thompson and Chatto Creeks drain from the Dunstan Mountains, and the Poolburn drains from the adjacent Ida Valley into the Manuherikia River. At Alexandra, 64 km from its source, the Manuherikia joins the Clutha River which flows across the south-west end of the depression. The Clutha enters and leaves the valley via deep gorges cut through the block mountains.

The north-west boundary of the valley is the dissected fault scarp of the Dunstan Mountains and valley floor sediments have been dragged up along this fault scarp.

The Dunstan Mountains themselves are a highland schist block rising to an average height of about 1520 m. The crest of this range is flattish with many schist tors up to 15 m high.

The south-east side is a narrow upland schist block that has a backslope of about 10° inclination dipping beneath the younger beds of the valley floor. This block is divided by the Poolburn into Blackstone Hill (980 m) in the north-east and the Raggedy Range.

The Carrick and Old Man Ranges are of schist and rise to a height of 1675 m forming the south-west boundary of the Manuherikia Valley. The Hawkdun Range of greywacke constitutes its north-east boundary.

The fault angle depression has been partly filled with upper Tertiary and Pleistocene deposits which have been cut by the river into terraces and residual hills with a relief of about 180 m. In many places the hills and the mountains have since been coated with a veneer of Pleistocene and Recent loess and the terraces by alluvium and a thin deposit of loess of the same age. In addition numerous Pleistocene and Recent fans occur at the bases of the mountains and terraces, and some are coated with loess.

Fans are common in the district. They are formed where streams emerge from the mountains on to the plains and also where they emerge from higher terraces on to lower ones. Several of these fans are of great extent and in many places they coalesce to form bahadas.

Most of the terraces have flat to gently undulating surfaces and most are formed by lateral planation; thus they are usually veneered with gravels. A thin mantle of loess is also often present (Orbell 1974).

I.2 CLIMATE

The Manuherikia Valley has a semi-arid climate with hot summers and cold winters.

I.2.1 Precipitation

The surrounding mountains shelter the Manuherikia Valley from most rain-bearing winds. Alexandra has the lowest recorded annual rainfall in New Zealand of 330 mm. Rainfall increases gradually from Alexandra (330 mm annually) to Lauder (500 mm) and Drybread (550 mm). Above Falls Dam (600 mm) the rainfall is thought to reach a maximum of 1500 mm near Mt St Bathans.

The rate of evaporation on the valley floor is greater than the rainfall and there is a moisture deficiency during the late spring, summer and autumn. This deficit is approximately 300 mm near Alexandra, 200 mm around Omakau and 150 mm in the upper valley.

In the summer months there may be exceptionally heavy rainfalls limited to single minor catchments and generally of brief duration during which vast quantities of debris including boulders are shifted within a short space of time. An estimate for the 20 year rainfall intensity is 30 mm/hr, however, during thunderplumps over shorter periods heavier intensities occur (Robertson 1963).

I.2.2 Humidity and Evaporation

The low humidities of Ophir (summer 60%, winter 80%) are characteristic of the floors of Central Otago valley, so that evaporation and liability to frost are greatly increased.

I.2.3 Sunshine

Alexandra has an average of 2046 hours of sunshine per year. In winter, fogs occur with air temperatures below 0°C so that rime accumulates on all exposed surfaces. Freezing fogs may last for several days but they are usually confined to only one of the inter-montane basins at a time.

I.2.4 Temperature

The mean monthly temperatures have a wide range, eg, 15°C at Ophir with a large diurnal range of about 10°C average. Frosts have been recorded in each month of the year, with an average yearly total of 186 at Ophir. The soil may intermittently freeze to a depth of about 10-15 cm between early June and mid-August.

I.2.5 Wind

The only records of wind velocity and direction in the valley are from Alexandra and they show that the prevailing wind is the north-easterly. The southerly is cold and rain-bearing and often reaches gale force. The strongest winds are the hot, dry, Fohn-like westerlies and north-westerlies which attain very high velocities in the Cromwell, Thomson and Dunstan gorges of the Dunstan Mountains.

I.3 VEGETATION

Records of the original vegetation described it as short tussock grassland 30-35 cm high (Ferrar 1929) on the terraces, fans and lower mountain slopes. Tall tussock grassland dominated by snow tussock occupied the higher mountain slopes. Relic logs (Molloy 1963) show that forest grew on the lower mountain slopes prior to the establishment of the tussock grassland but no standing trees remained at the time of settlement.

All the native plant communities have been modified by the spread of introduced plants and also by rabbit infestation, excessive burning and over-grassing. This has led in many places to the depletion of the vegetation and to erosion in some places. However these depelted areas are being reclaimed partly by improved methods of dryland farming and sometimes by irrigation management (Orbell 1974).

Since the beginning of pastoral occupation there have been repeated efforts to improve pastures and on the deeper soils under irrigation, high producing pastures of ryegrass and white clover have been established. Under dryland conditions pastures of cocksfoot and lucerne are now well established on the shallower soils.

I.4 SOILS

The older soils of the Manuherikia Valley reflect the influence of the climate and consist briefly of a central-southern zone of brown-grey earths, a yellow-grey earth series along the foot of the Dunstan Mountains and across the middle part of the valley and yellow-brown earths in the upper valley. Loess is in evidence at most locations. Recent soils are the result of mining operations. Soils of the terraces and fans suffer from droughtiness and would show various responses to irrigation. However some soils of the downlands are suffering from impeded drainage and waterlogging. Although salinity is not a real problem at the moment some salty soils do exist and care should be taken, when irrigating Becks-Linnburn and Chapman soils to avoid contamination of surrounding soils.

I.5 RIVER SYSTEMS

The Manuherikia flows from its two branches commencing in the north-east corner of the catchment and is joined by the Dunstan Creek emerging from the other side of the St Bathans Range.

In some places the river is deeply incised in gorges and in other places the river flows through a clearly defined channel with small flood plains and low terraces. Tributaries of the west bank rise in high catchments of the Dunstan Range and flow steadily across the terraces of the western basins. The most notable of these are Lauder, Thomsons and Chatto Creek.

Tributaries from the left bank of the upper catchment run directly off the Hawkdun Range, but in the lower catchment there is little contribution from the backslope of the Blackstone. Raggedy block formation with the exception of the Poolburn which dissects this range and is the outlet for the Ida Valley. On the same bank the Manorburn, with its source source in the upland plateau bounded by the Knobbies, discharges through the Galloway area.

I.6 PREVIOUS INVESTIGATIONS

Large scale irrigation development of the Manuherikia Valley was first proposed in the 1920's. The proposals involved the whole right or north-west bank of the river from above Becks through to Clyde and covered all lands not irrigated from the existing Manuherikia Scheme. The investigations included dam sites at Thomson's Creek, Lauder Creek, Dunstan Creek, the present Falls Dam site and the Manuherikia River at Lauder Gorge. In 1934 a rockfill dam was built at the Falls site with a storage capacity of 10 million m^3, raised in 1955 by 0.60 m to give a capacity of 11 million m^3. J D Watt prepared a report in 1956 on proposals for larger storage and a greater irrigated area in the valley, but no action followed as the costs were considered prohibitive.

Following several dry years the Manuherikia Valley Irrigation Promotion Committee requested a full scale investigation on the irrigation potential of the valley, and has strongly campaigned for increased storage. In 1972 a preliminary assessment report was prepared by D J Hamilton. This report covered the investigations on irrigation water use in the Manuherikia Valley and the results of an on-farm survey of the majority of the properties of the Manuherikia and Omakau Irrigation Schemes. The report included preliminary assessments of the water resources and estimates of the cost of increased storage.

A preliminary feasibility report on irrigation development was prepared by I M Blake in 1974. In this report the irrigation development in the Manuherikia Valley was reviewed with particular reference to the available water resource and the irrigation efficiency.

By October 1974 a detailed report about Falls Dam had been prepared. Alternative dam sites and heights were investigated which lead to the conclusion that the Falls site is suitable to raise a 60 m dam structure. This conclusion has been the basis of this detailed feasibility report. A preliminary economic report was also prepared in 1974.

The DSIR published in 1974 a report "Soils and Land Use of the Mid Manuherikia Valley", G E Orbell. The Soil Bureau of the DSIR will extend this soil survey so it covers the whole Manuherikia Valley. Results of this survey can be expected in 1980.

I.7 EXISTING IRRIGATION

The river flow is modified under present irrigation schemes and races.

I.7.1 Mt Ida Water Race (Hawkdun Race)

During the irrigation season a major portion of the runoff from the Hawkdun Range has been drawn off and has been used for irrigation in Northern Ida Valley and Maniototo. Although there are maintenance problems of the 100 km race, this must be considered as an essential part of Ida Valley and Eweburn Scheme.

A flow of 4-8 million m^3 (0.3-0.6 m^3/sec) from October to March leaves the catchment above Falls Dam through this race.

I.7.2 Falls Dam

This dam was constructed in 1934. Initially it was a rock-fill structure providing a storage of 10 million m^3, later raised to provide a storage of 11 million m^3. Discharge is controlled by a needle valve and a morning glory spillway. The storage at present is only 7% of the yield of the Upper Manuherikia.

I.7.3 Blackstone Race

This race draws from the Manuherikia River below Falls Dam. The scheme serves 530 ha. The race is 14 km long and is largely farmer maintained.

I.7.4 Downs Race

This race serves the Downs settlement block and is administered by Lands and Survey Department. The race has its intake in Dunstan Creek and serves 600 ha over 9 km.

I.7.5 Omakau Scheme

This scheme serves the Omakau Basin. The intake draws water from the Manuherikia above the Dunstan confluence and extends to the Tiger Hills.

The Dunstan Race serves a higher area from Dunstan Creek as do other smaller races taking their water from Thomsons, Lauder and Devonshire Creeks.

The total area served at present is 8300 ha.

I.7.6 Manuherikia Scheme

Serves the lower areas below Tiger Hills and takes its source from the Manuherikia Gorge. Problems of maintaining both the intake and distribution system are great. The main race of 30 km serves 2100 ha.

I.7.7 Galloway Scheme

This scheme supplies 1200 ha; in its upper portion with Manorburn water and in its lower portion by water pumped from the Manuherikia River.

I.7.8 Ida Valley Scheme

Utilises old mining races with storage at Manorburn and Poolburn. This scheme is limited in its water resources. The total storage available is 75 million m^3 and from this the maximum served area is 5600 ha. The upper end of Ida Valley is partly served by the Mt Ida water race and by a small reservoir in the Idaburn.

II WATER RESOURCES

Flow records are available from:

1975 - 1978 Manuherikia at Forks

1973 - 1978 Dunstan Creek

1973 - 1978 Woolshed Creek (Lauder Station)

1971 - 1978 Ophir.

Woolshed Creek is considered as representative of the Western tributaries. The records of the Manuherikia at Ophir have been influenced by the intakes and by-washes of irrigation schemes such as Omakau, Blackstone Hill, Downs and Dunstan.

II.1 MANUHERIKIA AT FORKS

The flow recorded at Forks is the discharge of a catchment of 173 km² (grid ref S125 619060). Results are shown in Table I.

Mth	Mean discharge m^3/sec	Lowest recorded daily mean discharge m^3/sec	Highest recorded daily mean discharge m^3/sec	Mean specific discharge $l/sec/km^2$	Lowest recorded yield million m^3
Jan	3.2	1.3	6.6	18	4.9
Feb	1.6	1.0	3.0	9	3.2
Mar	1.1	0.7	1.6	6	2.4
Apr	1.2	0.7	5.2	7	2.1
May	2.8	0.9	10.9	16	4.7
Jun	2.2	1.6	7.5	13	2.1
Jul	2.7	1.4	7.5	15	5.5
Aug	2.8	1.1	12.8	16	3.3
Sep	3.7	1.2	10.3	21	8.3
Oct	5.0	2.0	10.2	29	12.7
Nov	4.7	2.9	7.1	27	11.0
Dec	4.9	1.6	15.4	28	6.3
Year	3.0	0.7	15.4	17	80

TABLE I Discharge of the Upper Manuherikia

Low flows are restricted to late summer while high flows are induced by snow melting. The yield at Forks is about 94 million m^3 a year. At Falls Dam the catchment is 360 km^2 and an estimate of the yield at Falls is 194 million m^3. The 1 in 10 years lowest yield is estimated as 130 million m^3.

II.2 DUNSTAN CREEK

The flow recorded is the discharge from a catchment of 157 km^2. Grid reference S125 503997. Results are summarised in Table II.

Mnth	Mean discharge m^3/sec	Lowest recorded daily mean discharge m^3/sec	Highest recorded daily mean discharge m^3/sec	Mean Specific Discharge $l/sec/m^2$	Lowest recorded yield million m^3
Jan	2.0	.6	8.4	13	1.9
Feb	1.5	.6	5.0	10	2.0
Mar	1.5	.5	5.8	10	1.6
Apr	1.4	.5	4.3	9	1.5
May	2.3	.7	5.1	15	3.5
Jun	2.0	1.0	5.4	13	3.8
Jul	1.0	.8	7.4	11	2.8
Aug	2.3	.8	8.0	15	2.9
Sep	3.1	1.0	11.1	20	6.1
Oct	3.8	1.0	11.7	24	8.2
Nov	3.1	1.3	16.7	20	6.5
Dec	2.5	.9	13.2	16	2.8
Year	2.3	.5	16.7	15	50

TABLE II   Discharge of Dunstan Creek

Again the low flow is during the February-April period. High discharges can be expected from September-November. The yield of Dunstan Creek at the Gorge is 73 million m^3 a year. During a 1 in 10 dry year an estimated yield of 49 million m^3 is expected.

II.3 WOOLSHED CREEK

Woolshed Creek is a tributary of Lauder Creek. The Creek is considered as representative of the western tributaries. Grid reference S125 461855. The size of the catchment is 10.6 km^2. Results are summarised in Table III.

For Table III see next page

Mnth	Mean discharge l/sec	Lowest recorded daily mean discharge l/sec	Highest recorded daily mean discharge l/sec	Mean Specific discharge l/sec/km²
Jan	60	11	451	6
Feb	42	5	475	4
Mar	44	8	255	4
Apr	64	15	571	6
May	94	29	497	9
Jun	109	31	663	10
Jul	102	42	1047	10
Aug	154	38	1621	15
Sep	193	47	940	18
Oct	215	60	2106	20
Nov	145	30	1365	14
Dec	107	14	1078	10
Year	110	5	2106	10

TABLE III   Discharges of Woolshed Creek

The specific discharge of the western tributaries is considerably lower than the discharges of Dunstan Creek and Upper Manuherikia. The catchment of the western tributaries is 350 km². A yield of 115 million m³ a year. The dry yield (1 in 10 years) is estimated as 85 million m³.

II.4 MANUHERIKIA AT OPHIR

The measured flow is modified by irrigation of the Omakau and Dunstan Creek basin. The intake of the Manuherikia Scheme however is below Ophir. Grid reference S134 357629. The size of the catchment is 2036 km². Results are summarised in Table IV.

2850 km² from 1974 report

Mnth	Mean Discharge m³/sec	Lowest recorded daily mean discharge m³/sec	Highest recorded daily mean discharge m³/sec	Mean Specific discharge l/sec/km²	Lowest recorded yield million m³
Jan	6.9	.6	46.5	3	6.9
Feb	3.4	.4	14.0	2	4.6
Mar	4.0	.6	22.9	2	4.0
Apr	7.2	1.1	58.0	4	3.8
May	12.1	2.2	45.5	6	12.1
Jun	16.5	5.9	132.0	8	23.0
Jul	15.3	4.5	120.7	8	15.3
Aug	19.5	4.0	98.3	10	17.7
Sep	25.2	5.7	130.7	12	41.8
Oct	22.5	6.4	60.3	11	40
Nov	16.3	2.2	234.7	8	27.3
Dec	10.9	1.0	192.1	5	6.2
Year	13.3	.4	234.7	7	320

TABLE IV   Discharges of the Manuherikia River at Ophir

High discharges are from August to November while during February and March a very low flow can be expected. The yield of the Manuherikia at Ophir is 419 million m^3.

II.5 FLOODS

1878 flood estimated 677 m^3/s at Ophir according to 1974 report

During the October flood of 1878 the estimated peak discharge was 680 m^3/sec at Alexandra. The estimated peak discharge in 1919 was 500 m^3/sec at Ophir. The measured peak discharge of the October flood of 1978 was 393 m^3/sec (not included in Table IV).

495 m^3/s at Ophir from 1974 report.

Have flows for various catchment as % of Ophir figures been update from 1974 estimates.

II.6 DIVERTED WATER

The diversion of water for irrigation purposes is as follows:

	Mean	Maximum Season	Minimum Season
Omakau Scheme			
Water ex Manuherikia River	20.77	30.30	6.67
Water ex Western Tributaries	11.97	20.04	2.45
Manuherikia Scheme			
Water ex Manuherikia River	27.98	36.13	22.54
Water ex Western Tributaries	2.89	3.63	1.67
Galloway Scheme			
Water ex Manuherikia River	2.67	4.31	0.85

TABLE V Manuherikia Valley - diverted water (1955/56 - 1975/76)

(figures in million m^3)

II.7 SUMMARY OF WATER RESOURCES

The annual yield of the Manuherikia at Ophir is 419 million m^3. Besides this yield 32 million m^3 is diverted for irrigation purposes above Ophir. The natural yield at Ophir would be, without any water used, 450 million m^3. The catchment above Falls Dam contributes 40% of this yield, Dunstan Creek 16% and the western tributaries 25%. Other contributions are from the Poolbur and several creeks below Falls Dam (19%). An estimate of 500 million m^3 would be the yield of the Manuherikia at Alexandra. At present the quantity of water used for irrigation is 66 millio m^3 or 13%. Maximum diversion is 93 million m^3 (19%). Minimum diversion is 35 million m^3 (7%). Smaller schemes such as Down Settlement and Blackstone Hill have not been involved in these calculations. Their total water use can be estimated as 1 million m^3. The diversion for irrigation purposes is limited because of low summer discharges and insufficient storage.

III PROPOSED IRRIGATION SCHEME

III.1 Description of the Proposals

The proposal is to increase the storage of Falls dam to 100 million m^3 (at present the storage is 11 million m^3). This would require a new earth rockfill dam of 60 m just below the present dam site. The new dam will have a crest height of 692 m Otago Datum. The lake size behind the dam will be up to 500 ha with a mean depth of 20 m. During the irrigation season the size of the reservoir could decrease to 100 ha with a mean depth of 10 m. From the annual yield of 194 million m^3 140 million m^3 could be used for irrigation.

700 ha actually

Besides the new dam a new main race will be necessary. The present races are not suitable to convey larger discharges and the poor condition of especially the Manuherikia intake makes a complete new race obvious. A new race has to satisfy the following points:

a The race has to be above the present Manuherikia and Omakau Schemes to extend the commanding and irrigable area.

b A complete gravity system is preferred.

c Mechanical maintenance of the race is essential, this would require an access road of at least 4 m on one side of the race.

d A minimum number of culverts and syphons.

e Farmers whose properties are affected or disrupted by the proposed race have to get a clear advantage from the race.

f The race must be able to meet different requirements.

Not clear no supporting diagram.

The new 84 km main race is going to serve the valley west of the Manuherikia. The area commanded by the race is 30 000 ha which requires a race capacity of at least 10 m^3/sec. The commanded area includes the Downs Settlement, Dunstan, Drybread, Matakanui, Omakau and Manuherikia scheme. An area of 1200 ha above the present Dunstan Scheme could be served by a 16 km race. This race draws its water from Dunstan Creek and the bywash of this race could be used to feed the main race below the suggested Lauder Creek syphon. Apart from the spring flow the contribution of Dunstan Creek to the main race will be low after January. In this part of the scheme there will be a shortage of water in the late summer. The capacity of the intake from Dunstan Creek and this race will be 3 m^3/sec.

A good co-ordination with release from Falls Dam will ensure an additional 8 million m^3 available for irrigation. However this is not an essential part of the scheme.

costing not included. Why not?

To secure the frost-fighting water requirements of the orchards, tailend storage is suggested. Small dams (up to

7.5 m) near Straith Clyde Road could store 10 000 - 100 000 m^3. These dams could be filled by storing bywash of the mainrace. From the dams water could be quickly conveyed to the orchards by either a pipe system or open races. The demand of frost-fighting purposes is about 12 l/sec/ha. The orchard area in the Manuherikia Scheme is about 150 ha. Therefore a six hour frost period requires 75 000 m^3. This aspect of the scheme has not been further investigated. However if new orchard developments occur changes in water allocations would have to be made, although a good use of bywash and residual flow is ensured.

III.2 IRRIGABLE AREA

The irrigable area has been determined on the 1:5000 scale photogrammetric sheets. For every known property the size of the farm, the area below the main race and the area technically suitable for irrigation has been estimated. Besides this "could be irrigated area", the "should be irrigated area" has been estimated as 2/3 of the total farm area or 250 ha at most.

Increase of the "should be irrigated" area will occur when larger properties below the proposed main race are subdivided and developed. It is expected that the final figure of the irrigated area will be between the "could be irrigated" and "should be irrigated area".

Results are shown in Appendix A. The total irrigable area is 21 000 ha. The minimum area to irrigate is 16 000 ha and the present irrigation in the valley is 10 000 ha.

III.3 ROSTER PROPOSALS AND SUB-SCHEMES

In Chapter V the different irrigation requirements within the valley have been described. The different requirements among other factors divide the valley into the following sub-schemes:

(a) Downs Settlement

This is the area between the suggested main race, Dunstan Creek and the Manuherikia. The irrigable area is 1300 ha which would require four irrigations from late October to early March. A 20 days roster would require 3.9 million m^3. With an anticipated distribution efficiency of 80% this would mean an intake of 4.7 million m^3.

(b) Becks

This is the area between the main race, Lauder Creek, Dunstan Creek and Manuherikia River. The irrigable area is 4000 ha which should require four irrigations from late October to early March. A 28 days roster would require 12 million m^3. With an anticipated distribution efficiency of 80% this would mean an intake of 15 million m^3.

(c) Omakau - Devonshire

This is the area between the main race, Lauder Creek, Manuherikia River and Young Hill Creek. The irrigable area is 11 500 ha which should require six irrigations from late October to early April. A 21 days roster would require 50 million m^3. With an anticipated distribution efficiency of 80% this would mean an intake of 63 million m^3.

(d) Clare

This is the area between the main race, Young Hill Creek, Clare Hills and Dry Creek. The irrigable area is 1200 ha which should require eight irrigations from October to April.

A 21 day roster would require 7.2 million m^3. With an anticipated distribution efficiency of 80% this would mean an intake of 9 million m^3.

(e) Lower Manuherikia

This is the area below Dry Creek, the Waikerikeri and the Manuherikia. The irrigable area is 2500 ha which could require 14 irrigations from October to April. A 15 day roster would require 29 million m^3. With a distribution efficiency of 80% this would require an intake of 37 million m^3.

(f) Blackstone Hill

This scheme will not be affected by the suggested main race. However it will certainly benefit from the storage increase at Falls. The proposal is to irrigate 530 ha which should require six irrigations from late October to April. A 21 days roster would require 2.4 million m^3. With a distribution efficiency of 80% this would require an intake of 3 million m^3.

(g) Galloway

In this scheme 1200 ha could be irrigated from October to April. A 15 day roster and 14 irrigations a season would require 12.6 million m^3. With an efficiency of 80% this would require an intake of 15.8 million m^3.

(h) Upper Dunstan

This scheme is above the proposed main race but can be irrigated from a Dunstan Creek race. Bywash from this scheme can be picked up by the main race. The irrigable area is approximately 1200 ha. A roster length is not relevant because the lack of storage would decrease the possible intake during the early and late summer. This part of the scheme would operate like present irrigation schemes which withdraw their supplies from one of the western tributaries. However a contribution of eight million m³ to the main race could be expected from this source.

Discussion

The water allocation and the boundaries of the various subschemes together with the roster proposals are fairly trivial. For example, the boundary between the four and six irrigations (Lauder Creek) is questionable. On the other hand it can be expected that the 14 irrigations at the lower end of the valley are too many. When this scheme has operated for a number of years changes in the normal water allocation can be made. This is possible because the storage is sufficient and the capacity of the races allow some variation. However an increase in the number of irrigations in one part of the valley would automatically mean a decrease in the water allocation of another subscheme. It is possible that farmers would opt for fewer irrigations of a bigger quantity, eg,7 irrigations of 150 mm rather than 14 irrigations of 75 mm. This situation has to be avoided because of the increasing water losses, drainage and saline problems. If possible the farmers have to get used to irrigation application of 75 mm. Only then the area under irrigation can be extended to benefit the whole valley. On the other hand the off-farm efficiency in the main race and distribution races has to be as high as possible.

III.4 SIMULATED RIVER AND IRRIGATION FLOWS

To evaluate the impact of the proposed scheme a flow simulation programme has been developed. The simulation is based on the following conditions:

usefull storage less than this

1 The dam at Falls has a storage capacity of 100 million m^3.

2 The inflow in Falls Lake (catchment size 360 km^2) is twice the measured flow of the Manuherikia at Forks (catchment size 173 km^2). 2×173 = 346

3 The release from Falls Dam is:

- April-September 1 m^3/sec
- If the lake stores 100 million m^3 the outflow equals the inflow (spilling of the dam)
- October 8200 l/sec
  November-January 11 300 l/sec
  February 9250 l/sec
  March 8700 l/sec

4 An evaporation loss as a function of the lake area and the month has been included.

5 The intake from the Manuherikia for the Downs-Settlement, Omakau, Moutere and Manuherikia Scheme is:

October	7000 l/sec
November-January	10 000 l/sec
February	8000 l/sec
March	7500 l/sec

This water will be conveyed by the main race.

6 Below the intake of the main race a small intake for the Blackstone Hill scheme has been estimated as:

October	200 l/sec
November-January	250 l/sec
March	200 l/sec.

7 The flow of Dunstan Creek is the discharge measured at the flow recorder. During the irrigation season 50% of its discharge will be used for irrigation, although a minimum flow of 500 l/sec in the Dunstan Creek will be maintained.

8 Water from the Dunstan Creek intake will irrigate the upper Dunstan Scheme (irrigable area above the Cambrians 1500 ha) and the remaining flow will feed the main race.

9 The irrigation supply for all areas is compared with a demand function, the difference is by-wash, which will eventually come back in the Manuherikia.

10 The flow from the western tributaries is 14 times the measured flow at Woolshed Creek. It is proposed that this water will not be used for irrigation.

Flow figures of the 1975/1976 season have been used in this simulation programme. (See Appendix E). The results are:

a The dam is full by the beginning of September, during September and the beginning of October some spilling occurs. Gradually the water from the dam will be released, and the storage at the end of the season, 31 March, is 17 million m^3 or 17% of the total storage capacity.

b The flow of the Manuherikia below Blackstone Hill intake but above the Dunstan Creek is always above 1000 l/sec (mean 1050 l/sec, maximum 1180 l/sec).

c The flow of Dunstan Creek is sufficient to irrigate 1500 ha only till 15 January. Before this date an average of 1200 l/sec is conveyed from this source to the main race. Because of the low flow of Dunstan Creek the irrigation requirements of the Upper Dunstan Scheme after January cannot be met.

d The flow of the Manuherikia at Ophir can be compared with the simulated flow:

Week	Mean discharge m³/sec 1975/76 season	Mean discharge m³/sec 1975/76 simulation new scheme
1 2.9.75-9.9.75	29.6	7.9
2	28.0	8.6
3	30.8	10.3
4	21.2	6.3
5	19.9 (1.65)	9.9
6	17.7 (2.28)	6.8
7	19.0 (2.36)	6.6
8	11.5 (2.28)	4.7
9	15.6 (1.5)	5.6
10	16.8 (1.1)	6.2
11	12.8 (1.7)	4.9
12	10.6 (2.2)	4.1
13	7.8 (2.3)	3.5
14	5.2 (2.3)	3.1
15	3.5 (2.3)	2.6
16	3.4 (2.3)	2.3
17	3.7 (2.3)	2.6
18	3.6 (1.4)	2.5
19	3.4 (2.3)	2.3
20	3.1 (2.1)	2.2
21	2.6 (2.2)	2.3
22	2.9 (2.2)	2.2
23	3.2 (1.8)	2.1
24	2.8 (2.1)	2.2
25	2.7 (1.7)	2.2
26	2.4 (1.4)	2.2
27	2.2 (1.4)	2.0
28	1.7 (0.6)	2.1
29	1.1 (0.6)	2.1
30	1.0 (0.5)	2.3
31 22.3-29.3.76	1.2 (0.5)	2.1

TABLE VI Manuherikia at Ophir

( ) Intake of the present Manuherikia Scheme

As expected the flow of the Manuherikia above the gorge will be modified by the proposals. However at present there is an intake of the Manuherikia Scheme in the gorge. This should decrease the measured flow at Ophir in the first column by the figures mentioned between brackets. With the proposed scheme the present Manuherikia Scheme intake will be closed. The discharges through the gorge from September to December are considerably reduced, from 15 January on the mean flows below the gorge are higher than the present discharges. Finally there is an intake of the small Galloway Scheme. If this intake would vary between 600-900 l/sec the flow of the Manuherikia at Alexandra would be (1975/76 simulated flows):

Mnth	Mean discharge	Lowest discharge	Highest discharge
Sep	8.4	5.5	17.2
Oct	8.2	4.1	26.7
Nov	4.4	2.6	6.7
Dec	1.8	1.3	2.7
Jan	1.6	1.4	2.7
Feb	1.8	1.2	2.5
Mar	2.6	1.7	4.0

TABLE VII — Flow of the Manuherikia at Alexandra in m^3/sec

High discharges occur if the dam is spilling. This happens at present frequently and even with the proposed high dam spilling could be expected during a normal spring.

IV ENGINEERING DETAIL

Generally the engineering works involve:

(a) A storage reservoir at Falls Dam.

(b) Intake structures in the Manuherikia near St Bathans bridge and in Dunstan Creek just above Pauley Road.

(c) A new gravity race on the west side of the Manuherikia.

(d) Tail end storage.

IV.1 Falls Lake

IV.1.1 Geology of the Area

The basement of the area consists of folded Torlesse Group greywacke rocks overlain with flat lying tertiary sediments of the Pareroa-Southland series. These are capped by gravels of the Wanganui series or younger pleistocene Hawera series. A roughly triangular area 20 km long on a base of about 12 km width forms a graben (sunken block) with the Hawkdun Fault bounding the east side. The transverse fault (base of the triangle) is an extension of the Stranraer fault which crosses the area at Fiddler's Flat. A group of faults running generally NNE from St Bathans forms the western boundary of the graben. The topography of the younger sedimentary rocks has low to moderate relief. The outcropping greywacke near the dam site forms areas of moderate to high relief.

IV.1.2 Falls Dam

Alternative dam sites and heights were investigated in previous reports. The recommendation of a 60 m earth and rockfill dam to 692 m level has been the basis of this report. At the proposed site (just below the existing dam) the maximum crest level is determined by the topographical restraint of Shamrock Gully. A release capacity through the discharge valve of 20 m³/sec is required. Mean flow at site is 6.1 m³/sec, maximum recorded flood event 60 m³/sec (October 1978 - probably a 70 year event). The normal operating level of the lake is from 692 m (storage capacity 100 million m³) to 670 m (storage capacity of 30 million m³).

Operation of the discharge valve has to be done in such a way so that if the lake rises close to its maximum the discharge through the valve should increase. An emergency spillway however is necessary.

Emergency spillway through Shamrock Gully is possible although there are geological restraints. The level of the watershed near the head of Shamrock Creek is 693 mm. A low retaining structure is feasible. This area is underlain by Pareora series sands and silts. There are three water races in the area, one of which has been tunnelled through the saddle. The tunnel collapsed and shows now a long depression which is wet and supports a strong growth of rushes. From the watershed to the junction of Shamrock Creek and the Manuherikia is 3600 m. The lower 2200 m of the stream course is over resistant greywacke rock. The upper part of Shamrock Creek is composed of easily eroded Pareora series sediments which require protection to resist scour. However the design of an emergency spillway through Shamrock Creek looks more attractive than another "morning glory" spillway.

IV.1.3 Falls Reservoir

The dam would be able to store up to 100 million m^3 which would flood an area of 500 ha. The dam is able to control almost completely the flow of the Upper Manuherikia.

The use of Dunstan Creek to fill the reservoir is not recommended. The mean spring discharge of the Upper Manuherikia is already sufficient to fill the lake, therefore an expensive and long supply race from Dunstan Creek is superfluous.

Some erosion along the lake edge can be expected.

IV.1.4 Construction Considerations

A major restraint on construction of any new dam at Falls is the need to avoid interference with the existing dam which spills every winter and is fully drawn by March. The discharge valve releases a controlled flow into the diversion tunnel and thence to the natural river course. Intakes to the scheme are some km downstream.

Any new structure would require at least temporary means of ensuring the passage of natural spillage and controlled summer discharge. A combination of discharge and diversion provisions seems to be logical. Rock conditions for tunnelling are generally good and no problems should arise, although concrete lining would be necessary to prevent erosion.

The temperature conditions (-10°C to +30°C) are such that concreting would be difficult during the winter months. Closest source of gravels would be the Manuherikia River above the present reservoir, but the extent of resources has not been gauged. Some mention in early correspondence of failure of Manuherikia gravels to pass organic content requirements appears to have been resolved in the construction of the existing cut off slabs.

Distances from probable source areas would be approximately 2 - 5 km and access at various levels would need to be cut past the right abutment of the existing dam. The original solution of a rockfill dam is probably the best provided a positive cut off can be economically constructed. An impermeable barrier could be constructed of various alternatives and the design would have to include provision for different settlement or temperature deformations.

IV.2 Diversions

The existing intakes of the Blackstone Hill and Galloway schemes are supposed to continue their present withdrawals from the Manuherikia. Blackstone Hill, with an irrigable area of 530 ha, will be able to divert 2.8 million m^3 a season or 88 mm per irrigation. To supply 75 mm per irrigation a 10% loss in the race could be allowed.

Galloway can withdraw 15 million m^3 to irrigate 1200 ha. This would leave the use of Manorburn water to other schemes. Manuherikia water used in the Galloway scheme however is largely the bywash of other schemes.

One new intake and one main race are going to supply the west side of the Manuherikia. The intake has been contemplated near the St Bathans bridge over the Manuherikia (grid ref S125 579879). A diversion weir would be of a free overfall type and a system of baffles would control the minimum flow in the river of 1 cumec and a flow up to 0.7 cumec requires for the Blackstone Hill scheme. The intake level is approximately 569 and 8000 m below Falls Dam. One intake in Dunstan Creek (grid ref S125 520920) has been envisaged. This race can supply the higher terraces of the upper Dunstan scheme and extra water can be bywashed in the Manuherikia main race. The maximum intake is 3 m^3/sec while a minimum flow in Dunstan Creek of 500 l/sec has to be maintained. A small intake weir with a free overfall and a system of baffles to divert up to 3 m^3/sec is required. The level of this intake is approximately 663 m.

IV.3 New Irrigation Races

One major main race has been designed from the Manuherikia intake to the Waikerikeri. This race should be able to discharge a flow of 10 m^3/sec with a freeboard of 50 cm. The dimensions of such a race would be a bed width of 3m, depth of about 2.70 m and side slopes of 1:2. A flat area on both sides of the race of 3 m is required for access and maintenance purposes so the demand for land would be about 40 m for every m race (dependent on the size of the cut).

The proposed race runs through the Long Gully Valley, and will be above the present Downs Settlement race. The hydraulic gradient of this part of the race has to be as small as possible. The capacity of this part of the race is 10 m^3/sec. The new main race will cross Dunstan Creek near Cambrian through a major syphon. The race will be above the present Dunstan Race. The longitudinal slope excluding structures may vary from 1:2000 to 1:5000. Before Lauder Creek the Upper Dunstan Race will join the main race. After passing Lauder Creek through a syphon the race will cut through a saddle to the Drybread diggings. A drop of about 25 m to a level of 525 m is suggested. Thomson's Creek will be crossed at a level of about 522 m. After passing Thomson's Creek the race will be above the Matakanui race. A second drop to the 505 m level is to be constructed nearby or in conjunction with Chatto Creek syphon. The race continues over the Moutere Terraces and will be above the Straith Clyde Road. Finally the bywash of the race could be dropped into the Waikerikeri.

Alternative races are possible and have been investigated but this race has the big advantage of serving an as large as possible area without requiring any pumping over the Merton hills. Besides the Manuherikia and Omakau schemes it will be possible to control the Downs Settlement, Dunstan, Lauder, Drybread and Matakanui schemes from Falls Dam. At present those schemes depend on the low summer flows of the western tributaries. The total length of this race will be 84 500 m. Another new race of 16 000 m will connect Dunstan Creek from Pauley Road to the main race near Lauder Creek. The maximum capacity of this race is 3 m^3/sec. The race will drop from 663 m (Dunstan Creek) to 553 m (near Lauder Creek).

Table VIII Data of Manuherikia Valley Main Race

Number	Distance from Intake		Feature	Capacity	Level	Hydraulic Gradient	Under Race Culvert
1	-		INTAKE	10 m^3/sec	569 569	-	-
2	3133	3133	RACE	10	568.66	1:10000	3
3	3233	100	SYPHON	10	568.30	1:300	-
4	6728	3495	RACE	10	567.93	1:10000	1
5	6738	100	CULVERT St Bathans-Downs Rd	10	567.70	1:45	
6	9282	2544	RACE	10	567.43	1:10000	1
7	9292	10	CULVERT Longgully Road	10	567.20	1:45	
8	10529	1237	RACE	10	567.07	1:10000	1
9	10539	10	CULVERT Beatties Road	10	566.80	1:40	
10	11365	826	RACE	10	566.71	1:9000	1
11	11375	10	CULVERT Beatties Road	10	566.50	1:45	
12	16076	4701	RACE	10	566.00	1:10000	2
13	16176	100	SYPHON Dunstan Creek	10	565.70	1:300	
14	17161	905	RACE	10	565.60	1:10000	1
15	17171	10	CULVERT Loop Road	10	565.40	1:50	
16	17330	159	RACE	10	565.32	1:2000	
17		160	SYPHON D Stuart Creek	10		1:500	

Number	Distance from Intake	Feature	Capacity	Level	Hydraulic Gradient	Under Race Culvert
18	4200 21690	RACE	10	562.89	1:2000	4
19	10 21700	CULVERT Lauder St Road	10	562.69	1:50	-
20	239 21939	RACE	10	562.57	1:2000	
21	50 21989	SYPHON Woolshed Creek	10	562.27	1:165	
22	9447 31436	RACE	10	557.56	1:2000	3
23	10 31446	CULVERT Lauder Fl Rd	10	557.36	1:50	
24	1190 32636	RACE	10	556.76	1:2000	1
25	10 32646	CULVERT Meeroad	10	556.56	1:50	
26	9288 41934	RACE	10	551.70	1:2000	5
27	75 42009	SYPHON Lauder Creek	8	551.40	1:250	
28	2667 44676	RACE	8	550.06	1:2000	-
29	699 45375	DROP-STRUCTURE	8	525.00	1:30	
30	5047 50422	RACE	8	522.46	1:2000	3
31	50 50472	SYPHON Thomson's Creek	6	522.16	1:165	
32	4810 55282	RACE	6	519.72	1:2000	2
33	10 55292	CULVERT Sugar Pot Road	6	519.52	1:50	

Number	Distance from Intake	Feature	Capacity	Level	Hydraulic Gradient	Under Race Culvert
34	6705 61997	RACE	6	516.14	1:2000	2
35	10 62007	CULVERT Devonshire Road	6	515.94	1:50	
36	400 62407		6	515.75	1:2000	-
37	50 62457	SYPHON Chatto Creek & Drop-Structure	3	505	1:5	
38	2625 65082	RACE	3	503.68	1:2000	1
39	250 65332	SYPHON	3	503.38	1:750	
40	7463 72795	RACE	3	494.11	1:800	5
41	10 72805	ROAD CULVERT	3	493.11	1:50	
42	11695 84500	RACE	3	473.73	1:600	4
43		BYWASH TO WAIKERIKERI				

V WATER REQUIREMENTS

V.1 Theoretical Water Requirement

Irrigation is artificial application of water to soil for the purpose of supplying the moisture essential to plant growth (Israelsen 1950). Use of irrigation water can be measured in kg DM/m^3 applied irrigation water. Efficient water use could be measured and compared in kg DM/m^3 applied irrigation water or kg DM/irrigation.

Investigations with Linnburn soils in Central Otago (Cossens 1976) show that the maximum pasture production under irrigation is 10 000 kg DM/ha. This is achieved when irrigation takes place if the available soil moisture drops below 40%. If irrigation is applied each time the available soil moisture is down to its wilting point then pasture production of this soil is still 9000 kg DM/ha or 90% of the maximum possible production which is achieved with approximately 40% less irrigations. Further decrease of irrigation application has to allow for days below wilting point, which would mean lower production. An irrigation water balance simulation programme has been developed to determine the irrigation requirements at three soil moisture deficits in three different climatic zones under different water roster systems. The programme analysed 40 years climatic data using the Thornthwaite's method for estimating evapotranspiration and hence the number of irrigations for a given climatic zone, soil moisture deficit and irrigation roster system. The three different climate types are:

A Alexandra Climate Type

Alexandra meteorological station (I59234) represents the lower Manuherikia Valley with regard to the temperatures. Rainfall in this part of the valley is slightly higher than Alexandra's figures indicate and therefore rainfall figures have been increased with 15%.

B Omakau Climate Type

This climate type represents the middle Manuherikia Valley. The nearest long term climatological record at Ophir (I59161) represents the temperatures of this part of the valley and rainfall is 15% higher than Ophir's rainfall figures.

C Becks Climate Type

This climate type represents the upper valley. Again Ophir's climatological data are representative but rainfall is 25% higher than Ophir's records.

Within each climate type three soils are recognised:

Shallow soil - a soil which according to the computer will be irrigated if the soil moisture deficit is 35 mm, eg, a soil with 35 cm sandy loam.

Medium Soil - A soil which will be irrigated if the soil moisture deficit is 51 mm, eg, a soil with 35 cm silt loam.

Deep Soil - A soil which will be irrigated if the soil moisture deficit is 67 mm, eg, 60 cm very fine sandy loam.

The programme converts daily temperatures into potential evapotranspiration. The potential evapotranspiration is lost from the available soil moisture. On the roster day the farmer should irrigate if the soil moisture deficit is down to 35 mm, 51 mm or 67 mm (resp. shallow, medium or deep soil). If some soil moisture is available the farmer has to wait till the next roster day. Besides this assumption an irrigation flow of 75 mm is presumed if irrigation takes place. Part of this irrigation water feeds the soil moisture the surplus is lost as percolation or run-off. The same applies for rainfall.

Result summary per climate type and soil depth.

V.1.1 Becks Shallow Soils

Irrigation has been applied if the soil moisture deficit is 35 mm. To keep the soil moisture above wilting point an average of 6.3 irrigations a year are required. From the applied irrigation water 51% or 243 mm will be percolated. The different roster lengths are mentioned in Table IX

Roster Length	Required No. of irri-gations	Water Use (mm)	Days below wilting point	Estimat-ed prod-uction (%)
0	6.3	473	0	90
13	4.3	323	5.1	76
15	3.6	270	6.1	73
17	3.8	285	7.3	74
21	3.5	263	10.3	70
28	2.8	210	15.2	67
without irrig	-	-	25	45

TABLE IX. Becks Shallow Soils, Water Use Simulation Summary 1940 - 1974

The difference between production loss with a 13, 15 or 17 days roster is negligible. The total on-farm runoff varies between 365 mm (0 day roster) to 165 mm (28 day roster). Approximately 50% of the runoff is irrigation runoff, the other 50% is rainfall runoff.

V.1.2 Becks Medium Soils

Irrigation has been applied if the soil moisture deficit is 51 mm. To keep the soil moisture above wilting point an average of four irrigations a year are required. From the applied irrigation water 31% or 93 mm will be lost as bywash. The different roster lengths are mentioned in Table X.

Roster Length	Required No. of irrigations	Water Use (mm)	Days below wilting point	Estimated production (%)
0	4	300	0	90
13	2.7	203	2	80
15	3.4	255	2	80
17	2.7	203	2.4	79
21	2.6	195	4.2	77
28	2.4	180	7.0	74
without irrig.	-	-	16	66

TABLE X Becks Medium Deep Soils, Water Use Simulation Summary 1940 - 1974

The difference between production loss with a 13 to 21 days roster is negligible. The total on-farm runoff varies between 193 mm (0 day roster) to 106 mm (28 day roster). Approximately 30% of the runoff is due to irrigation, 70% of the runoff is caused by rainfall.

V.1.3 Becks Deep Soils

Irrigation has been applied if the soil moisture deficit is 67 mm. To keep the soil moisture above wilting point only 2.6 irrigations a year are required. With this deep soil only 23% or 17 mm of irrigation water will be lost as bywash. The different roster lengths are mentioned in Table XI .

For Table XI see next page.

Roster Length	Required No. of irri-gations	Water Use (mm)	Days below wilting point	Estimat-ed prod-uction (%)
0	2.6	195	0	90
13	2.1	157	0.3	87
15	1.7	128	0.5	86
17	1.9	143	0.9	85
21	1.9	143	2.2	79
28	1.5	113	2.7	79
without irrig.	-	-	7	74

TABLE XI Becks Deep Soil, Water Use Simulation Summary 1940 - 1974

There is no difference regarding the production of a 0 day roster system or a 28 day roster is to be used. The total on-farm runoff varies between 90.5 mm (0 day roster) to 57.4 mm (28 days roster). Less than 10% of the runoff is due to irrigation.

V.1.4 Omakau Shallow Soils

Irrigation has been applied if the soil moisture deficit is 35 mm. This climate is drier than the upper part of the valley. Therefore to keep the soil moisture continuously above wilting point an average of 6.8 irrigations of 75 mm each are required. From the applied irrigation water 50% will be bywashed. The various roster lengths with their characteristics are mentioned in Table XII.

TABLE XII Omakau Shallow Soil, Water Use Simulation 1940 - 1974

Roster Length	Required No. of irri-gations	Water Use (mm)	Days below wilting point	Estimat-ed prod-uction (%)
0	6.8	510	0	91
13	4.5	330	5.2	78
15	4.2	315	6.3	71
17	4.0	300	7.2	67
21	3.8	285	11.2	64
28	3.0	225	16.4	61
without irrig.	-	-	27	40

The production loss due to a 13, 15 or 17 day roster is negligible. The total on-farm runoff varies between 366 mm and 165 mm. Approximately 57% of the runoff is caused by irrigation, 43% is due to rainfall.

V.1.5 Omakau Medium Deep Soils

Irrigation has been simulated if on the roster day the soil moisture deficit is 51 mm. To keep the soil moisture continuously above wilting point an average of 4.2 irrigations are required. From the applied irrigation water 31% or 99 mm will be lost as bywash. The different roster lengths are mentioned in Table XIII.

Roster Length	Required No. of irri-gations	Water Use (mm)	Days below wilting point	Estimat-ed prod-uction (%)
0	4.2	315	0	90
13	3.0	225	1.7	82
15	2.8	210	2.9	78
17	3.1	233	2.1	79
21	2.8	210	4.1	78
28	2.3	173	7.8	68
without irrig.	-	-	16	62

TABLE XIII Omakau Medium Deep Soil, Water Use Simulation 1940 - 1974

The production loss due to a 13, 15, 17 or 21 day roster is negligible, but there is hardly any difference between water use and roster length. The total on-farm runoff varies between 177 mm and 89 mm. Approximately 37% of the runoff is caused by irrigation, 63% is due to rainfall.

V.1.6 Omakau Deep Soils

Irrigation has been simulated if on the roster day the soil moisture deficit is 67 mm. To keep the soil moisture above wilting point 2.7 irrigations a year are required. With this deep soil only 10% or 19 mm irrigation water will be lost as bywash. Different roster lengths are mentioned in Table XI V.

For Table XIV see next page

Roster Length	Required No. of irri-gations	Water Use (mm)	Days below wilting point	Estimat-ed prod-uction (%)
0	2.7	203	0	90
13	2.2	165	0.2	89
15	2.3	173	0.6	86
17	2.0	150	0.4	88
21	1.9	143	1.6	82
28	1.7	128	3.0	78
without irrig.	-	-	7	68

TABLE XIV Omakau Deep Soil, Water Use Simulation 1940 - 1974

There is hardly any difference regarding the production if a 0 day roster or a 28 day roster is to be used. The total on-farm runoff varies between 78.7 m (0 day roster) to 45.7 mm (28 day roster). Less than 10% of the runoff is due to irrigation.

V.1.7 Alexandra Shallow Soils

Irrigation has been applied if the soil moisture deficit is 35 mm. The climate here is the driest climate of the valley. To keep the soil moisture continuously above wilting point an average of 9.2 irrigations of 75 mm will be required. From the applied irrigation water 51% will be bywashed. The various roster lengths with their characteristics are mentioned in Table XV.

Roster Length	Required No. of irri-gations	Water Use (mm)	Days below wilting point	Estimat-ed prod-uction (%)
0	9.2	690	0	90
13	6.4	480	6.7	80
15	5.9	443	8.9	76
17	5.8	435	11.3	72
21	5.3	398	14.1	70
28	4.3	323	23.5	62
without irrig.	-	-	40	23

TABLE XV Alexandra Shallow Soil, Water Use Simulation 1930 - 1973

There is a clear correlation between roster length and production loss. The total on-farm runoff varies between 412 mm (0 day roster) to 174 mm (28 day roster). More than 80% of the runoff is caused by irrigation.

V.1.8 Alexandra Medium Deep Soils

Irrigation has been applied if on the roster day the soil moisture deficit is 51 mm. To keep the soil moisture continuously above wilting point an average of 6.1 irrigations are required. From the applied irrigation water 31% or 142 mm will be lost as bywash. The different roster lengths are mentioned in Table XVI.

Roster Length	Required No. of irrigations	Water Use (mm)	Days below wilting point	Estimated production (%)
0	6.1	458	0	90
13	4.3	323	2.8	85
15	4.4	330	2.9	85
17	4.1	308	5.4	80
21	3.8	285	8.4	76
28	3.5	263	11.8	72
without irrig.	-	-	26	50

TABLE XVI Alexandra Medium Deep Soil, Water Use Simulation 1930 - 1973

There is not much difference in water use and production loss between a 13, 15 or 17 day roster.

The total on-farm runoff varies between 191 mm (0 day roster) to 79 mm (28 day roster). Approximately 62% of the runoff is due to irrigation.

V.1.9 Alexandra Deep Soil

Irrigation has been simulated if on the roster day the soil moisture deficit is 67 mm. To keep the soil moisture above wilting point 4.3 irrigations a year are required. With this deep soil only 9% or 28 mm irrigation water will be lost as bywash. Different roster lengths and their characteristics are mentioned in Table XVII.

For Table XVII see next page

Roster Length	Required No. of irrigations	Water Use (mm)	Days below wilting point	Estimated production (%)
0	4.3	323	0	90
13	3.4	255	0.8	88
15	3.5	263	1.1	86
17	3.2	240	2.2	85
21	3.1	233	4.3	81
28	2.8	210	7.8	76
without irrig.	-	-	20	44

TABLE XVII   Alexandra Deep Soil, Water Use Simulation 1930 - 1973

The production loss due to a 13 - 21 day roster system is negligible, but there is hardly any difference between water use and roster length. The total on-farm runoff varies between 64 mm (0 day roster) to 25 mm (28 day roster). Approximately 44% of the runoff is caused by irrigation.

V.1.10   Discussion Water Requirement

Further details of water requirements are mentioned in Appendix D. Results of this study indicate:

a   There is only a slight difference in water use between a 15, 17 and 21 day roster system.

b   Periods below wilting point are not significantly different when the 13, 17, 21 day roster systems are compared.

c   Run-off, bywash and percolation loss varies as would be expected from negligible on a deep soil to heavy on a shallow soil.

The pattern of irrigation requirements within the valley is complicated. A summary of the 0-day water requirement shows:

Alexandra soils	320-690 mm	(10 irrigations)
Omakau soils	200-510 mm	(7 irrigations)
Becks	200-475 mm	(6 irrigations).

However the practical requirements are different, among other things because of application efficiencies and the variation of evapotranspiration from year to year and during the seasons. A practical water supply proposal to meet the water requirements is:

1 The area above Lauder Creek - four irrigations of 75 mm (one spring irrigation, two summer irrigations, one autumn irrigation). This area consists of Upper Dunstan Scheme, Downs Settlement and Omakau-Becks area (6500 ha).

2 The area between Lauder Creek and Young Hill Creek - six irrigations of 75 mm (two spring irrigations, three summer irrigations and one autumn irrigation). This area consists of Omakau-Devonshire and Blackstone Hill scheme (12 000 ha).

3 The area between Young Hill and Dry Creek - eight irrigations of 75 mm (two spring irrigations, four summer irrigations, two autumn irrigations). This area was not recognised as a different climate zone but was added on request of the Manuherikia Irrigation Promotion Committee. The sub-scheme here is Moutere terrace (1200 ha).

4 The area below Dry Creek - twelve irrigations of 75 mm (three spring irrigations, seven summer irrigations, two autumn irrigations). This area consists of the present Manuherikia Scheme and Galloway Scheme (3700 ha).

The application requirement of 75 mm per irrigation is a minimum requirement. If an application efficiency of 80% is achieved then an application depth of 75 mm requires 90 mm at the turn-out. A high application efficiency has advantages with salinity and drainage control. If an application efficiency of 80% is anticipated then the application requirements are:

	Commanded Area	Spring Water Rqmnts	Summer Water Rqmnts	Autumn Water Rqmnts	Total Rqmnt
Area 1	6 500	5.85	11.7	5.85	23.4
Area 2	12 000	21.60	32.4	10.8	64.8
Area 3	1 200	2.15	4.3	2.15	8.6
Area 4	3 700	10.0	23.3	6.7	40.0
Total	23 400	39.6	71.7	25.5	136.8

TABLE XVIII Water Requirements in million m^3

The proposed scheme can provide this.

VI CAPITAL COSTS

Capital Costs can be divided into:

(a) Cost of a new dam

(b) Cost of the proposed race and adjacent works

(c) On farm works or development costs

VI.1 Estimated Costs of a New Dam

A rockfill dam up to 692 m (OD) with impervious core is probably the best solution. Preliminary estimation of costs are (Cost Index 1100):

Cost of invest. not included.

Cost of Shamrock gully dam not incl.

	($000)
Establishment and Access	400
Excavation 20 000 m³ - 12.00	240
Additional Grouting, etc	115
Diversion, Extend Spillway 10 m	25
Extend valve head access 110 m	70
Impervious Core 150 000 m³ - 3.20	480
Transition Layers 100 000 m³ - 4.00	400
Main Rockfill 380 000 m³ - 6.50	2470
New Spillway Intake 150 m - 6000 (EITHER)	900
Bellmouth and Vanes 320 m³ - 230	75
Repair Existing Lining	60
New Trench Spillway Excavation 45 000 m³ - 6.75 (OR)	310
Concrete Lining and Plunge P 3500 m³ - 230	805
Plug Old Spillway Entrance	15
Unscheduled Works and Contingencies 20%	1075

TOTAL PROPOSAL NEW DAM $6.3 - $6.4 M

It is assumed that impervious and transition materials for the core may be obtained within 3 km of the dam site, and the various grades of rock for the main fill in the immediate vicinity. It is further assumed that up to 30% of this rock can be loosened in the quarry by modern heavy rippers.

VI.2 Estimated Costs of Proposed Race and Adjacent Works

Costs are divided into six main groups. The most important costs are the earthworks, sealing, etc of the proposed race, especially the first part of the race over Downs Settlement which will involve major earth moving jobs. Besides these works there are eight syphons and 12 under race pipe culverts necessary. Major costs are also involved in fencing of both sides of the race. Because of the method of estimating 20% for unscheduled works and contingencies is added.

CCJ = 1100

PROPOSED RACE AND ADJACENT WORKS

I Headrace - Earthworks, Sealing, Topsoil shaping and Drainage

Length (m)	Cap (m^3/sec)	Hydraulic Gradient	Estimated Earthworks m^3/m^1	Costs per m race	Total Costs ($000)
16 100	10	1:10000	40	60	966
26 000	9.5	1:2000	20	45	1170
8 300	7.6	1:2000	18	40	332
12 000	5.1	1:2000	15	35	420
22 100	2.7	1:2000	10	35	775

3663

II Syphons - Including excavation, pipes and endworks

Length (m)	Cap (m^3/sec)	Ø(m)	Estimated Costs per metre	
100	10	2750	600	60
100	9.5	2750	600	60
160	9.5	2500	600	96
50	9.5	2500	600	30
75	7.6	2250	550	42
50	5.1	2100	500	25
50	2.7	1500	450	23
250	2.7	1500	440	110

446

III Road Culverts - Including excavations, endworks, pipes, etc

Quantity	Length (m)	Cap (m^3/sec)	Ø(m)	Cost per Metre (÷ $1000 unit)	
4	10	10	2750	300	16
4	10	95	2750	300	16
2	10	51	2100	250	7
2	10	27	1500	225	7

very low

46

IV Under Race Culverts - Pipes, endworks, backfill

40 30 up to 3 m^3/sec 0.300 200 240

240

V Fencing - both sides of the race

2 x 84 500 m at $2.00 per metre 338

338

VI + 20% minor jobs and contingencies 950

TOTAL COSTS HEADRACE $5683

VI.3 On-Farm Development

On-farm development includes construction of borderdyking, fencing, seeding, topdressing and if applicable development of hill country. It is obvious that these costs fluctuate from farm to farm. To analyse the development costs four types of farms have been investigated in Appendix B. The total capital cost excluding the initial stocking up appears to be approximately $8 000 000.

VI.4 Summary Capital Costs

Costs of a new dam	$ 6.4 M
Costs of races and adjacent works	5.7 M
On-farm development	8.0 M
Total Capital Works	$20.0 M

The costs of a new dam are subsidised for 100%, costs of the mainrace are subsidised for 50%, and the costs of on-farm development are not subsidised although loan facilities are available to the farmer.

Updated to [illegible]

Dam =	$ 10.1 M
Races and Adjacent Works =	$ 9.1 M
On-farm Development =	$ 12.? M
	$ 31.9 M

Expected values more like

Dam =	$ 15 M
Races and Adjacent Works =	$ 12 M
+ Dunstan Race	1 M
On-farm Development (?) =	$ 13 M
Frost protection Dams =	$ 0.2 M
Investigation Cost =	$ 1
Design Costs =	$ 0.5 M
	$ 42.7 M

VII ECONOMICAL ASSESSMENT AND WATER CHARGES

VII.1 Annual Operating Costs

It is estimated that the scheme could be operated by eight racemen. Further operating and maintenance costs of 1% of the dam and race costs has been anticipated. Therefore the annual scheme operating costs have been estimated as $200 000 per year.

Farm operating costs and farm maintenance costs have been included in 1.4.

VII.2 Sinking Fund

It is estimated that the capital costs of the scheme have to be renewed in 50 years. The amount to set aside each year to replace the capital if the interest rate is 10% = $170 000.

VII.3 Economical Evaluation

To evaluate the economics of the scheme one "Manuherikia irrigated hectare" is considered. It is assumed that in total 20 000 ha will be irrigated.

Therefore the costs of the headworks and main race are $600. On-farm capital costs including extra stock costs $735. Off-farm maintenance and operating costs $10 per year. On-farm maintenance and operating costs $43 per year. Value of the present scheme, an estimated cost of $251 per year.

Scheme benefit - including hill country development is 14 SU per ha at $19 per stock unit (benefits are calculated in detail in Appendix B).

Calculation of the cash flow (Appendix C) shows an internal rate of return of 11%.

Other benefits of the proposed scheme like night frost protection of orchards have not been included in the calculations. Consequently the benefits of the scheme could be higher than stated.

VII.4 Water Charges

Water charges can be calculated according to the Public Works Amendment Act 1975.

(1) Basic Charge (Section 13 of this Act) = $\frac{C \times P \times F}{H}$

C = estimated amount of the capital cost of the off-farm water supply works, excluding the costs of headworks.

(see VI.1.3) estimate is $5 683 000, =
P = proportion to be recovered, being ½
F = factor determined to allow for payment over a period of 40 years, being 0.093 (i = 9%).
H = estimated total number of hectares of irrigable land in the proposed district, being 20 000 ha.

The calculated basic charge is just over $13 which will be charged on every irrigable ha determined by the Minister.

(2) Water availability charge (Section 15 of the Public Works Amendment Act 1975) = $\frac{(C \times P \times F) + O + R}{W}$

O = the estimated amount to cover the costs of operation and maintenance of the off-farm water supply works, being $200 000 (see VI.2).

R = costs of the renewal of the race, being $100 000
W = total number of unit quantities or unit rates of supply = 100 million m^3.

The calculated water availability charge is therefore $6.00 per 1000 m^3.

A farmer who would irrigate according to the described irrigation requirement would be charged as follows:

Location	Irrigation Requirement	Water Availability Charge
Downs, Becks area	3000 m^3/ha	17.00 $/ha
Omakau, Blackstone Hill	4500 m^3/ha	25.00 $/ha
Clare, Moutere	6000 m^3/ha	34.00 $/ha
Lower Manuherikia, Galloway	10 500 m^3/ha	59.00 $/ha

The difference in charges because of the difference in requirements is very big and not realistic. Two proposals to suggest a different system of charging are made:

(A) Charges are based on roster units. A roster unit is a quantity of water which will meet the estimated irrigation requirement of 1 ha. The different charges would be (W = 21 000 roster units):

Location	Irrigation Requirement	Water Availability Charge	
		$/ha	$/1000 m^3
Downs, Becks area	1 roster unit/ha	26.00	9.00
Omakau, Blackstone Hill	1 roster unit/ha	26.00	6.00
Clare, Moutere	1 roster unit/ha	26.00	4.00
Lower Manuherikia,	1 roster unit/ha	26.00	2.00

Extra units could be charged against 9.00 per 1000 m^3 (equal to Downs water availability charges).

(B) Charges are based as if there are two separate schemes. One is the extended Lower Manuherikia and Galloway Scheme (below Dry Creek) and the other scheme is above Dry Creek (Moutere, Omakau, Downs area). The cost of a separate lower Manuherikia scheme has been estimated as $1.2 million (C factor) with an annual operation and renewal factor of $75 000 = (O + R). The remaining costs $4.5 million (C factor) and $225 000 = (O + R) are charged against the other scheme. In this case the charges would be:

Location	No. of Irrigations	Charge $/1000 m³	Charge $/ha
Downs, Becks area	4	6.00	17.00
Omakau, Blackstone Hill	6	6.00	25.00
Clare, Moutere	8	6.00	33.00
Lower Manuherikia, Galloway	14	4.00	39.00

Extra irrigations could be charged against $6.25 per irrigation of 75 mm, or $8.00 per 1000 m³.

VII.5 DISCUSSION OF WATER CHARGES

If the Manuherikia Valley irrigation scheme is to be considered as one scheme, then the basis of water charges as described in the Public Works Amendment Act 1975 is not realistic. The different irrigation requirements for the various parts of the valley is the reason for an artificial difference in charges. It is certainly not acceptable to farmers to pay water charges up to $60 per ha per year.

The Manuherikia Irrigation Promotion Committee suggested an equal charge of roughly $25 per ha per season over the whole valley.

The main objection against this unity charge is that there is no financial saving for the highly efficient and careful irrigator.

The recommended system implies a division of the valley into two irrigation systems, the Lower Manuherikia and Galloway scheme and a "Rest of the Valley" scheme. The charges are in this case realistic and the "user pays" system will encourage efficient on-farm irrigation systems.

VIII REVIEW OF THE PROPOSED SCHEME

Farmers of the Manuherikia Valley have already got several decades of irrigation experience. The usual application methods of wild flooding and contour ditches are not the most efficient because of the large amount of water lost into the groundwater and/or bywash. It is envisaged that the irrigated area will increase to 20 000 ha. This necessitates careful use of water. For the flat and gently sloping areas borderdying is recommended. The rolling country could be suitable for spray systems or contour flooding. The most suitable method of irrigation has to be considered for each farmer individual.

It is important that water charges and rosters will encourage efficient application methods.

With the proposed application depth of 75 mm per irrigation only efficient irrigation methods will give satisfactory results. This will require high on-farm investments but the internal rate of return is satisfactory.

Efficiency must be the key factor of the whole irrigation scheme. Only with high on-farm and off-farm efficiencies will it be possible to irrigate up to 20 000 ha even in very dry years.

With a new main race there is no need to abolish the present races. They could be used for bywash and drainage purposes. Depending on soil investigations a drainage plan of some parts of the valley could be necessary. The western tributaries are suitable bywash and drainage channels. Eventually this excessive water will join the Manuherikia River and could be used to irrigate Galloway.

The environmental aspect looks in favour of a new dam. An increase in storage and especially an increase in the minimum storage would mean an important improvement of the fish habitat above Falls Dam. The increase of the low summer flow in the Manuherikia Gorge will undoubtedly be an important factor to improve environmental life. On the contrary the high spring flow will be partly controlled by the new dam (see Table VI).

The best time of the year to evaluate the possibilities of irrigation is the storage at the beginning of September. If the dam is spilling, then the proposed 140 million m^3 is available for irrigation. If the dam is below 70% of its capacity (70 million m^3) after snow melt then limitations of the use of irrigation has to be compelled. A summary of simulations is mentioned in Appendix F.

Improvement and extension of the irrigation in the valley would mean the possibility of further subdividing and also development of the hill country.

Finally irrigation would mean a three fold increase in pasture production in the valley.

IX CONCLUSIONS

1 The annual yield of the Manuherikia catchment is 416 million m^3.

2 The discharge is not evenly distributed over the year. Snow storage and spring thaw causes high to extremely high spring discharges.

3 Through the climatic conditions there is a moisture deficit from October until March. This deficit is more severe at the bottom end of the valley.

4 For several decades farmers of the Manuherikia Valley have been practising irrigation. Main sources of supply are Falls Dam, Dunstan Creek and the western tributaries. The irrigation methods used are wild flooding and contour flooding.

5 During low summer flows in the catchment the shortage of irrigation water is obvious. The present storage at Falls Dam is not sufficient. No further storage in other creeks is available.

Could be 150

6 A new dam is suggested. A 60 m high dam at the same site as Falls dam is suggested. This would give a storage capacity of 100 million m^3. Without further storage sites there would be available for irrigation 140 million m^3 per season. During a mean year there will be some 30 million m^3 left in the reservoir as carry over storage.

7 A new main race is recommended. This race will be as high as possible and will command the former Downs Settlement, Dunstan, Omakau, Drybread, Matakanui, Devonshire and Manuherikia schemes. The race will be completely controlled by the release of Falls Dam. Water from Dunstan Creek could be diverted by a second race. After supplying the Upper Dunstan scheme (irrigable area 1500 ha) the bywash can feed the main race with an additional 8 million m^3. However the supply of this sub-scheme is negligible after January.

8 The capacity of the main race will be 10 m^3/sec, its length 84 500 m. Bywash will be discharged into the Waikerikeri. The race through the Upper Dunstan scheme has a capacity of 3 m^3/sec, its length 1600 m.

9 Besides the diversion of Falls Dam and Dunstan Creek no further water from tributaries will be used for irrigation.

10 The basic water requirement in the valley is:

Becks, Downs Settlement area - four irrigations of 75 mm.
Omakau, Blackstone Hill area - six irrigations of 75 mm.
Moutere, Clare area - eight irrigations of 75 mm.
Manuherikia, Galloway area - 14 irrigations of 75 mm.

11 An overall off-farm efficiency of at least 70% is

required to be able to irrigate 20 000 ha in the valley. This requires careful race construction.

12 Increase in water use above the basic water requirements has to be balanced against a decrease in water use in other parts of the valley.

13 A fair water availability charge would be calculated if the scheme was considered as two separate schemes. One scheme would be the Lower Manuherikia scheme, water charge \$3.74 per 1000 m^3. The other scheme above Tiger Hills would be charged \$5.56 per 1000 m^3. The basic charge over the whole valley is \$13 per ha.

14 The proposed scheme (irrigable area over 20 000 ha) would require an investment of \$20 million. The cost of the dam is \$6 M, races and ancillary structures \$6 M, on-farm works \$8 M.

15 The internal rate of return of the proposed Manuherikia Valley Irrigation scheme is 11%.

PW 15/3/1

MINISTRY OF WORKS AND DEVELOPMENT

DUNEDIN

MANUHERIKIA VALLEY IRRIGATION

FEASIBILITY REPORT

VOLUME 2 : APPENDICES A - G

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January 1980

APPENDICES

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REFERENCES

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APPENDIX A Irrigable Farm Areas below proposed main race

OWNER	CODE	SIZE OF PROPERTY (ha)	RACE COMMANDS (ha)	COULD BE IRRIGATED (ha)	SHOULD BE IRRIGATED (ha)	PRESENT IRRIGATION (ha)
Airport Alexandra	F5	270	270	-	-	-
Alexander A J	C19	120	100	75	75	60
Alexander G S	C16	160	160	120	100	80
Anderson	C24	105	65	65	65	40
Armitage D W	B17	125	125	110	110	100
Armstrong Ltd	B13	315	315	280	250	270
Armstrong W A	B15	350	350	200	200	78
Ashton M	E8	210	200	190	190	190
Attfield E C & C C	E11	127	127	75	75	75
Attfield S G Est	F3	2600	500	150	150	-
Beatties J	A5	695	500	400	250	350
Bell D J & R V	D1	280	190	120	120	60
Berry	D11	50	50	40	30	20
Berry H	D3	140	90	90	90	60
Brown R A & A	C8	715	715	650	250	50
Campbell G H	F11	10	10	7	7	7
Clane R J	D12	80	80	80	60	-
Clouston C J	D17	205	200	175	140	65
Clouston E F	D29	167	167	160	110	22
Clouston J T & T A	C9	405	405	350	250	120
Clouston L E	A7	151	10	10	10	-
Clouston G A	D23	200	200	150	150	130
Clouston W J	B19	290	290	175	175	50
Clouston W J	C15	128	128	100	60	20

OWNER	CODE	SIZE OF PROPERTY (ha)	RACE COMMANDS (ha)	COULD BE IR-RIGATED (ha)	SHOULD BE IR-GATED (ha)	PRESENT IRRIGATION (ha)
Cook M D	E2	2900	1400	80	80	-
Corrigal J E & A J	D21, D31	773	300	50	50	50
Corrigal J L	D32	170	170	125	120	75
Corrigal J L	D30	50	50	40	35	35
Dillon J M & C E	A4	515	150	90	90	50
Donnelly Est	D2	240	180	170	155	30
Donnelly E F	D4	100	60	50	50	45
Donnelly E F	D7	250	120	120	100	-
Donnelly F	D5	230	105	90	75	-
Donnelly F J	C26	200	200	190	150	150
Duggan T	D8	200	190	190	140	60
Duncan A J & B F	E7	450	370	240	240	220
Duncan D L	C12	140	140	120	120	84
Gladstone N B & J S	F12	157	157	70	70	31
Glassford A J	C6	540	500	400	250	125
Glassford OO	C3	445	190	95	95	95
Golden R J	F4	1600	1500	400	250	30
Gunn D G	B10	3800	250	200	200	20
Hamilton D W	B11	300	300	280	200	50
Hamilton G	B9	1800	350	300	250	80
Hamilton J	B12	350	350	250	250	200
Hamilton N	B5	560	325	250	250	160
Harley	B1	57	57	40	40	-
Harvey L R	D25	275	275	250	180	105
Hawkdun Station	A1	770	250	205	200	-
Huddlestone CT & LR	D16	405	290	290	250	120
Huddlestone EJ & WC	C1	3000	80	40	40	-

OWNER	CODE	SIZE OF PROPERTY (ha)	RACE COMMANDS (ha)	COULD BE IR-RIGATED (ha)	SHOULD BE IR-RIGATED (ha)	PRESENT IRRIGATION (ha
Huddlestone EJ & WC	D6a	95	30	20	20	20
Huddlestone GT & GR	D19	150	150	150	100	40
Jopp A J	E1	4650	1600	75	75	-
Kane K Ltd	B16	182	182	120	120	60
Kane W A & Sons	B14	375	375	100	100	35
Keddell H J & W P	E5	300	100	95	95	80
Kelliher G A	E10	140	140	100	100	100
Kelliher M J	E6	120	75	60	60	60
Kelliher T C	F7	290	290	100	100	90
Kinney D J & P J	D33	1640	160	160	160	110
Knowles R J	C14	615	615	300	250	50
Lauder Station	B3	7122	180	130	130	130
Leask R A	B21	170	170	150	150	50
Leask R J	B20	218	218	200	135	60
Leith E F	C5	300	300	250	200	150
Love	E13	190	190	120	120	120
MacLean D E	D27	190	160	150	120	80
McArthur J C	F2	1140	850	450	250	-
McConnachie	B6	185	185	150	125	110
McConnachie	B8	255	25	25	-	-
McDonnell F C	F9	125	125	28	28	28
McIntosh J M Est	D26	700	600	400	250	120
McIntosh W S	E3	425	400	120	120	96
McKnight C G	B18	83	80	70	70	60
Mee M	B4	850	590	500	250	120
Milne M A & R J	C11	605	605	450	250	200

OWNER	CODE	SIZE OF PROPERTY (ha)	RACE COMMANDS (ha)	COULD BE IR-RIGATED (ha)	SHOULD BE IR-RIGATED (ha)	PRESENT IRRIGATION (ha)
Moran J	C13	160	160	120	100	50
Moran Trust	C7	470	470	420	315	100
Morgan & Kearney AJA	D15, C2	486	351	160	160	70
Naylor E B	B7	290	290	150	150	110
Naylor G N	D9	80	80	75	50	45
Nicholson E D	E4	2600	22	22	22	22
O'Neill B S	F6	480	480	400	290	130
Paterson	C18	680	580	480	250	150
Paterson Ltd	D20	7300	2000	1000	250	85
Poplar Grove	C10	80	80	75	60	30
Rochester Farm	D10	120	120	100	80	65
Rooney R D	F1	1700	220	200	200	-
Rowley R W	E9	20	18	18	18	17
Samuel R A & F J	C4	3000	500	500	250	160
Scorgie Est	C25	360	250	250	250	200
Scott G W	A6	380	180	140	140	140
Scott	D6	30	15	10	10	-
Shaw	A9	255	255	50	50	-
Shaw L G	B2	242	75	50	50	3
Stafford W A & P L	C27	265	200	200	175	175
Stevenson J E	D23a	55	55	40	40	30
Thompson L	C28	175	170	150	120	85
Vincent Jockey Club	C22	125	125	60	60	45

OWNER	CODE	SIZE OF PROPERTY (ha)	RACE COMMAND (ha)	COULD BE IR-RIGATED (ha)	SHOULD BE IR-RIGATED (ha)	PRESENT IRRIGATION (ha)
Whitaker J J	F8	45	45	20	20	20
White B G & C	D18	235	230	230	170	170
White B G & C N	D22	380	380	300	200	150
Williamson & Son Ltd	C29	375	200	180	180	180
Wilson C G	D13	200	200	200	150	120
Wilson G C	D14	225	225	225	150	60
Wilson G C	D28	130	130	130	90	90
Wilson R	C23	80	80	75	75	75
Wilson W C & B W	C20	504	504	300	250	190
Wilson W R	C21	160	160	150	120	120
Various Small Holdings around Alexandra	-	1200	1200	600	600	600
-	A2	475	40	20	20	-
-	A3	510	420	400	250	-
-	A8	213	213	200	130	-
-	D24	25	25	10	-	-
-	E12	45	45	40	40	30
-	F10	50	50	30	30	-
TOTAL			33000	23000	16200	10000

ANALYSIS

REPRESENTATIVE FARM TYPE 'A'

LOCATION:	Omakau Basin
AREA:	272 ha
REPRESENTING:	68 Units - total 18 500 ha (10 000 ha under irrigation)
CLIMATE:	450 - 500 mm ppn; elev 300 - 425 m
SOILS:	BGE and associated YBE some recent
TOPOGRAPHY:	Flat to rolling
MANAGEMENT:	Semi-intensive to intensive pastoral
LIMITATIONS:	Soil moisture, summer feed

This type of property comprises the area generally under the existing Omakau, Dunstan and Lauder races, but specifically excludes those properties with any hill blocks. Tenure in this area is largely a result of Government subdivision for post-War I settlement, although some properties are more than twice the average stated above.

Approximately 27% of the representative unit is irrigated at present, but only 2/3 of this is considered to be "efficient".

Examination of the 1972 survey figures show the overall stocking rate to be 5.6 SU/ha, with an apparent dryland stocking rate of 4.2 SU/ha.

If the dryland potential capacity is taken at 5 SU/ha for the area as a whole, the effect of irrigation is assumed to be purely for increasing pasture and hence increased carrying on the irrigated area only. No cognisance of the complementary effects or the relationship between this and total size of the unit is taken. Also, the assumed stocking is entirely in sheep. The model is therefore conservative as to benefits, and can in fact be considered on a per hectare basis.

<u>Representative Farm Type 'A'</u>

Dryland Potential (estimated ref Fig 1)		5 SU/ha
Irrigated Potential (assumed)		16 SU/ha
	increase	11 SU/ha

Benefits at $19 gross margin, $209/ha/year

ON-FARM COSTS

<u>Capital On-Farm Costs</u>

Land preparation and border dyking		$390/ha
Additional fencing		60/ha
Initial seeding and topdressing		37/ha
Building and yard extensions		11/ha
	Sub Total	$490/ha
Initial stocking up 11 SU at $24.00	=	$264/ha

Operational On-Farm Costs

Additional Fertiliser	$10.00/ha/year
Maintenance Borders	$6.12/ha/year
Maintenance Buildings	$0.50/ha/year
Fences	$7.00/ha/year
Additional Labour	$20.00/ha/year
	$73.62/ha/year

Cash Flow

Year	Development	On-Farm Costs	PNW	On-Farm Benefits	PNW
0	-	150	150	-	0
1	20%	150 + 8.66	144.38	41.80	38.04
2	40%	100 + 17.33	97.38	83.60	69.39
3	60%	100 + 22.51	91.88	125.40	94.05
4	80%	75 + 34.66	74.57	167.20	113.70
5	85%	75 + 36.83	69.33	177.65	110.14
6	90%	75 + 38.99	63.83	100.10	105.37
7	95%	37 + 41.15	39.86	198.55	101.26
8	100%	43.62	20.36	209.00	90.23
9 -	100%	43.62	101.94	209.00	277.80
		(762)			
(i = 10%)			PNW 933.53		PNW 1607.95

Thus the margin Benefits - Costs on-farm for Type A is:

$1607.95 - $933.53 = $674.42/ha irr (PNW)

SCHEME RELATED COSTS

Value of the Present Scheme

The present Omakau scheme is in good condition and the race appears to satisfy the present need. Therefore an economical value of this scheme has been calculated. Over 8300 ha the stocking rate of the scheme is only 2 SU/ha more than the dry-land capacity, so the economical value at present is:

2 SU GM $19.00	$38.00/ha/year
Operation and maintenance $50 000/8300 ha/yr	$6.02/ha/year
Value of the present scheme	$31.98/ha/year
Compounded at 10%	$319.80/ha

Other scheme related costs such as capital off farm works and operation and maintenance of the proposed scheme have been calculated in the economical summary.

Benefit Type 'A'

It has been estimated that if the new scheme is operating 10 000 ha of this farm type will be irrigated. This is a mean of 147 ha per farm.

The gross benefit over costs appears to be:

10 000 ha at $674.42/ha	$6 744 200
value present scheme 8300 ha at $319.00/ha	2 654 370
BENEFIT TYPE A	$4 089 860 (PNW)

REPRESENTATIVE FARM TYPE 'B'

LOCATION:	Run unit Dunstan Mountains
AREA:	2580 ha
REPRESENTING:	26 units, total 67 230 ha (6500 ha under irrigation)
CLIMATE:	Extreme; 500 - 800 mm ppn; elevation 400 m +
SOILS:	Drybread series BGE and Arrow and Dunstan Steepland
TOPOGRAPHY:	Hill runs with improved pastures on lower slopes and fans only
MANAGEMENT:	Pastoral, mixed cattle and sheep
LIMITATIONS:	Winter feed

While a strong rainfall gradient up the length of the Dunstans does exist, it is possible to postulate a representative run property for the valley as a whole.

Irrigation of the fans forming the base of these properties determines the production of winter feed, (assumed to be lucerne hay), which in turn determines the development necessary on the hill country to balance for summer grazing. A 1:1 stock unit ratio of cattle to sheep is assumed.

Eighteen of the 26 properties were surveyed in 1972 and showed an average of 120 ha irrigated, or 4.5% of the total area. This represents a high proportion of the "low" paddocks, however.

For this type of unit, the general limitation as regards irrigation is topography, rather than water, as was generally stated. Further it must be noted that, for some properties, a fair proportion of their "low" and "irrigable" paddocks will still be above the main race. The answer here is what in effect happens under the present system; these paddocks are supplied ex the creeks coming off the ranges rather than from the main race.

There appears to be no real correlation between irrigated area and total stock carried, or even between lucerne hay production and total stock carried, for the 19 properties examined. The reasons for this are manifold, including use of good improved pastures on lower slopes as winter blocks, stockwater limitations on the higher country, etc. However, the model as proposed is still useful because of its simplicity.

Assuming the representative property to have 250 ha under irrigation, the expected situation would be:

Irrigated lucerne hay	85 ha	at 400 bales/ha	=	34 000 bales
Pasture	165 ha	at 15 SU/ha	=	2 475 SU
	250 ha			

Now wintering at 3 bales/SU would indicate that $\left(\frac{34\,000}{3} - 2475\right) =$ 9000 SU on the hill country could be supported through the winter. It is important to note that, to allow the necessary flexibility in management, the proportion of pasture to lucerne under irrigation should not exceed the 2:1 mark. The example thus indicates the upper limit.

Base "dry" stock total with some private irrigation is assumed to be 2000 SU thus stocking will involve 7000 SU and this requires 1400 ha of hill country to be developed.

Capital On-Farm Costs

Land Preparation	250 ha at $390.00/ha	$97 500
Additional Fencing	30m/ha at $2.00/m	15 000
Initial Seeding	85 ha lucerne at $46.00/ha	3 910
	165 ha Pasture at $37.00/ha	6 105
Building and Yard Extensions ($1.00/SU)		9 000
Hay Barns		20 000
Hill Country Development		
AOSTD	1400 ha at $100/ha	140 000
Fencing	20 m/ha at $2/m	56 000
Stockwater Supply	$55/ha	77 000
Initial Stocking Up	9500 SU at $24.00	228 000
		$652 515

Recurring On-Farm Costs

Additional Labour	(2 men at $8000)	$16 000
Maintenance Fertiliser		
Hills	$17.75	20 580
Irrigated Area	$20.00	5 000
Maintenance		
Borders, ditches	250 ha at $6.12	1 530
Buildings		600
Fencing		600
Haymaking	37 000 bales at $0.30	10 200
Stockwater	$2.75/ha	3 850
		$58 360/year

Benefits

Old situation	250 ha flat at 6 SU/ha	1500 SU
	2500 ha hill at 0.2 SU/ha	500 SU
		2000 SU

With the irrigation of the flats and OSTD this could increase to 11 000 SU. Benefit of irrigation 9000 SU, at GM $19 per SU.

Cash Flows x $1000

Year	Development	On-Farm Costs	PNW	On-Farm Benefits	PNW
0	-	100	100	-	-
1	20%	100 + 12	101.92	35	31.85
2	40	100 + 23	102.09	69	57.27
3	60	100 + 35	101.25	104	78.00
4	80	100 + 47	99.96	138	93.84
5	85	50 + 50	62.00	147	91.14
6	90	50 + 53	57.68	156	87.36
7	95	50 + 55	53.55	164	83.64
8	100	58	27.26	173	81.31
9	100	58	243.60		726.60
(i = 10%)			949.31		1331.01

The margin of benefits over costs is $381 700 per farm. There are 26 of these farms within the valley, therefore the benefit of Type B is 26 x $381 700 = $9 924 200.

The estimated level over dryland due to existing Government irrigation and private irrigation is estimated as 20% of the proposed irrigated area. The benefits of the new scheme appears to be 80% of $9.9 M or $7 900 000 (Total PNW).

REPRESENTATIVE FARM TYPE 'C'

LOCATION:	Moutere Terraces
AREA:	750 ha
REPRESENTING:	7 units; total 5250 ha (1750 ha irrigated)
CLIMATE:	350 - 500 mm ppn; elevation 250 m +
SOILS:	Drybread BGE Sandy and stony loams
TOPOGRAPHY:	Fans and terraces with long gullies
MANAGEMENT:	Semi-extensive sheep and cattle
LIMITATIONS:	Soil moisture and stock water

Covering a fairly large area on the terraces above Alexandra, these properties were surveyed in 1972.

The overall stocking level on the surveyed area was 2.5 SU/ha but the effect of the 1% or so irrigation on this area at present is difficult to gauge. Certainly the limitations are such that a dryland carrying capacity (with some stockwater reticulation and some dryland lucerne production) of 2 SU/ha can be adopted. While under irrigation, pastures, with the appropriate winter feed at 2.5 bales/SU being available, can carry 15 SU/ha.

With 250 ha under irrigation, an establishment of a breeding herd of up to 2500 SU with a fair proportion of pasture under irrigation would be more advantageous than a high proportion of the irrigated land being devoted to winterfeed only.

The suggested management of the type C farm is:

70 ha irrigated lucerne at 400 bales/ha
210 ha irrigated pasture at 14 SU/ha
500 ha dry pasture at 5 SU/ha

This farm will carry 5000 SU, dry farm potential 1500 SU, increase 3500 SU.

Capital On-Farm Costs

Land Preparation and border dyking 250 ha at $390/ha	$97 500
Additional Fencing 30 m/ha over 250 ha at $2/m	15 000
Additional Seeding 40 ha lucerne at $46/ha	1 840
210 ha pasture at $37/ha	7 770
Building and Yard Extensions ($1/SU)	5 000
Hay Barns (16 000 bales at $1/bale)	16 000
Stocking Up 3500 SU at $24.00	84 000
	$227 110

Recurring On-Farm Costs

Additional Labour (1 man at $8000)		$8 000
Maintenance Fertiliser		
Irrigated Area	250 ha at $20/ha	5 000
Dry Pasture	500 ha at $10/ha	5 000
Maintenance Borders, ditches	250 ha at $6.12	1 530
Maintenance Buildings (2%)		100
Maintenance Fences		160
Haymaking	16 000 bales at $0.30	4 000
		$24 590

Benefits

3500 SU at $19.00 or $66 500

Cash Flows x $1000

Year	Developed	On-Farm Costs	PNW	On-Farm Benefits	PNW
0	-	50	50	-	-
1	20%	50 + 4.92	49.98	13.3	12.1
2	40	50 + 9.84	49.67	26.6	22.1
3	60	50 + 14.75	48.56	39.9	29.9
4	70	27 + 17.21	30.06	46.5	31.7
5	80	+ 19.36	12.00	53.2	33.0
6	85	+ 20.90	11.70	56.5	31.6
7	90	22.31	11.38	59.9	30.5
8	95	23.36	10.98	63.2	29.7
9	100	24.59	10.33	66.5	27.9
10	100%		95.90		259.3
(i = 10%)					
			380.56		507.80

On farm benefit over costs due to irrigation $507 800 - 380 560 = $127 240. There are seven of these farms within the valley. The benefit of Type C is therefore 7 x $127 240 = $890 680. At present there is no irrigation possible on the Moutere terraces, so the total value of the benefits of type C farms are due to the new scheme.

REPRESENTATIVE FARM TYPE 'D'

LOCATION:	Below present MAC race
AREA:	107 ha
REPRESENTING:	18 units; total 1920 ha (1750 ha under irrigation)
CLIMATE:	350 mm ppn; elev 150 m
SOILS:	Molyneux and Eweburn
TOPOGRAPHY:	Flat to rolling
MANAGEMENT:	Semi intensive, sheep
LIMITATIONS:	Soil moisture

At present forming the non-orchard properties under the Manuherikia Scheme, these smallish units are entirely dependent on irrigation for their viability. With better soils than on the Moutere terraces above, the dryland capacity would still not exceed 2.5 SU/ha.

The 1972 survey figures show an overall stocking rate of 6.7 SU/ha, with irrigation covering some 50% of the total area of these properties. This calculates out at over 10 SU/ha irrigated under present management, but the irrigated potential will be not less than 16 SU/ha overall.

Many of the smaller property owners have other sources of income and also overlap into the orchard group.

Approaching the arithmetic on a per hectare basis only and taking no account of overall subdivision, the costs and benefits would be similar to those for Type 'A', with the differences coming only in stock costs and benefits.

Capital On-Farm Costs

As for Type A		$762/ha
Extra Stocking Up	2.5 SU	60
		$822/ha

Recurring On-Farm Costs

As for Type A	$43.62/ha/year

Benefits

13.5 SU at $19/SU	$256.50/ha/year

Cash Flow

Year	Development	On-Farm Cost	PNW	On-Farm Benefits	PNW
0	-	150	150	-	-
1	20%	150 + 8.72	144.44	51.30	46.68
2	40	150 + 17.45	138.98	102.60	85.16
3	60	100 + 26.17	104.72	153.90	115.43
4	70	100 + 30.53	97.90	179.55	122.09
5	80	100 + 34.90	83.64	205.20	127.22
6	85	72 + 37.08	61.08	218.03	122.10
7	90	+ 39.26	20.02	230.85	117.73
8	95	+ 41.44	19.48	243.68	114.53
9	100	43.62	18.32	256.50	107.73
10	100		170.10	256.50	1000.40
			1008.68		1950.07

Thus the margin Benefits - Costs on-farm for Type D is $1958.07 - $1008.68 = $949.39/ha irr PNW.

Scheme Related Costs

The Manuherikia Irrigation Scheme was the first constructed irrigation scheme, as distinct from being founded on the remains of mining enterprise. Construction was commenced in 1917 and was completed by 1922 when the first water was delivered. The main intake is in the very rugged Manuherikia gorge leading into a tunnel, silt trap, concrete lined race, tunnel, flume, open race and Chatto Creek syphon. Several reports have been written over this section of the scheme and the conclusion that "in view of the physical condition, the age of the installation and the rugged and instable nature of the country replacement is inevitable". Therefore the value of the present scheme can be considered as negligible. About 1750 ha could be irrigated, and the gross benefit over costs appears to be $1 661 430.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
0	100				100	25	125				-125
1	100				100	25	113.8				-113.80
2	100				100	25	103.8				-103.80
3	100				100	25	93.8				-93.80
4	100	100	10	8.7	218.7	25	165.7	2.8	53.20	36.18	-129.52
5	100	100	10	17.3	227.3	25	156.4	5.6	106.40	65.97	-90.43
6		100	10	26.0	136	25	90.2	8.4	159.60	89.38	-0.82
7		100	10	30.3	140.3	25	84.3	9.8	186.20	94.96	10.66
8		100	10	34.4	144.4	25	79.6	11.2	212.80	100.02	20.48
9		100	10	36.6	146.6	25	72.1	11.9	226.10	99.16	27.06
10		100	10	38.7	148.7	25	67.7	12.6	239.40	93.37	25.67
11		35	10	40.9	85.9	25	38.8	13.3	252.70	88.45	49.65
12			10	43	53	25	20.0	14	266	85.12	65.12
13			10	43	53	25	18.6	14	266	77.14	58.54
14			10	43	53	25	16.8	14	266	69.16	52.36
15			10	43	53	25	15.1	14	266	63.84	48.74
16			10	43	53	25	13.9	14	266	58.52	44.62
17			10	43	53	25	12.8	14	266	53.20	40.40
18			10	43	53	25	11.6	14	266	47.80	36.28
19			10	43	53	25	10.4	14	266	42.56	32.16
20			10	43	53	25	87	14	266	39.90	312
										TOTAL	166.51

) Year sequence

) Headworks and main race

) On-farm capital works

) Off-farm maintenance and operating costs

(5) On-farm maintenance and operating costs

(6) Total cost

(7) Value present scheme

(8) All costs NPW = 10%

(9) Increase in su due to irrigation

(10) Gross margin

(11) Benefits of the scheme's NPW i = 10%

(12) Cash flow

APPENDIX D

Becks

Water Use Summary 1940 - 1974

Roster	0			13			15			17			21			28		
Deficit at Irrigation (mm)	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67
*Irrigation water applied (mm)	472.5	300.0	195.0	322.5	202.5	157.5	270.0	255.0	127.5	285.0	202.5	142.5	262.5	195.0	142.5	210.0	180.0	112.5
Irrigation water runoff (mm)	243.1	93.1	16.9	139.5	43.2	4.6	132.9	41.2	3.9	122.0	46.4	4.1	114.1	42.2	3.4	79.3	32.4	1.6
Rainfall runoff (mm)	121.0	99.8	73.6	103.3	86.0	75.2	97.2	76.2	69.3	102.4	78.4	66.6	101.1	80.0	68.6	86.9	73.7	55.8
Days below wilting point	0.0	0.0	0.0	5.1	2.0	0.3	6.1	2.0	0.5	7.3	2.4	0.9	10.3	4.2	2.2	15.2	7.0	2.7
Total runoff (mm)	364.1	192.9	90.5	242.8	129.2	79.8	230.1	117.4	73.2	224.4	124.8	70.7	215.2	122.2	72.0	166.2	106.1	57.4

Seasonal Percentage of Annual Total, Mean of all Rosters

	*Irrigation Water (No.)			Irrigation Runoff			Rainfall Runoff			Days Below Wilting Point		
Deficit at Irrigation (mm)	35	51	67	35	51	67	35	51	67	35	51	67
Spring	23	18	11	25	21	21	37	41	47	12	6	2
Summer	58	59	68	56	59	55	39	37	31	61	67	71
Autumn	19	23	20	20	21	25	25	22	22	11	10	11

* Depth of water at each irrigation is 75 mm. Number of irrigations applied 15 = irrigation water applied/75

Becks

Mean Number of Irrigations Applied 1940-74

Roster Length (Days)	0			13			15			17			21			28		
Soil Moisture Deficit (mm)	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67
Month Season																		
Sept.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct.	0.5	0.2	0.0	0.3	0.1	0.0	0.0	0.1	0.0	0.2	0.1	0.0	0.1	0.0	0.0	0.2	0.2	0.0
Nov.	1.0	0.5	0.4	0.9	0.4	0.3	0.7	0.4	0.0	0.6	0.4	0.2	0.6	0.4	0.2	0.5	0.3	0.2
Spring	1.5	0.7	0.4	1.2	0.5	0.3	0.7	0.5	0.0	0.8	0.5	0.2	0.7	0.4	0.2	0.7	0.5	0.2
Dec.	1.1	0.9	0.6	0.6	0.5	0.4	0.7	0.6	0.4	0.8	0.6	0.5	0.5	0.4	0.3	0.6	0.5	0.4
Jan.	1.5	1.0	0.6	0.9	0.6	0.4	0.8	0.6	0.4	0.9	0.7	0.5	1.0	0.8	0.5	0.5	0.4	0.3
Feb.	1.1	0.7	0.6	0.7	0.6	0.6	0.8	0.5	0.6	0.4	0.3	0.2	0.6	0.4	0.4	0.6	0.5	0.4
Summer	3.7	2.6	1.8	2.2	1.7	1.4	2.3	1.7	1.4	2.1	1.6	1.2	2.1	1.6	1.2	1.7	1.4	1.1
Mar.	0.9	0.5	0.3	0.7	0.4	0.3	0.4	0.3	0.2	0.6	0.4	0.4	0.6	0.5	0.4	0.3	0.3	0.1
Apr.	0.2	0.2	0.1	0.2	0.1	0.1	0.2	0.9	0.1	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.1
May	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Autumn	1.1	0.7	0.4	0.9	0.5	0.4	0.6	1.2	0.3	0.9	0.6	0.5	0.7	0.6	0.5	0.4	0.5	0.2
YEAR	6.3	4.0	2.6	4.3	2.7	2.1	3.6	3.4	1.7	3.8	2.7	1.9	3.5	2.6	1.9	2.8	2.4	1.5
% of Total																		
Spring	24	18	15	28	19	14	19	15	0	21	19	11	20	15	11	25	21	13
Summer	59	64	70	51	62	67	64	50	82	55	59	63	60	62	63	61	58	74
Autumn	17	18	15	21	19	19	17	35	18	24	22	26	20	23	26	14	21	13
Mean Annual Average																		
Spring	23	18	11															
Summer	58	59	68															
Autumn	19	23	20															

Beckr

Days Below Wilting Point 1940-74

Roster Length (Days)	0			13			15			17			21			28		
Soil Moisture Deficit (mm)	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67
Month / Season																		
Sept.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct.	0.0	0.0	0.0	0.0	0.1	0.0	0.4	0.0	0.0	0.2	0.0	0.0	0.5	0.0	0.0	0.8	0.2	0.0
Nov.	0.0	0.0	0.0	0.4	0.2	0.0	0.9	0.1	0.0	0.6	0.0	0.0	1.0	0.2	0.1	1.3	0.6	0.1
Spring	0.0	0.0	0.0	0.4	0.3	0.0	1.3	0.1	0.0	0.8	0.0	0.0	1.5	0.2	0.1	2.1	0.8	0.1
Dec.	0.0	0.0	0.0	0.6	0.6	0.0	1.2	0.8	0.1	2.2	0.7	0.0	3.0	1.3	0.2	3.6	1.9	0.5
Jan.	0.0	0.0	0.0	2.0	0.6	0.1	1.5	0.6	0.3	2.1	0.5	0.5	2.2	0.8	0.4	4.1	1.1	0.9
Feb.	0.0	0.0	0.0	1.4	0.5	0.2	1.6	0.5	0.1	1.2	0.7	0.1	1.9	1.1	1.2	2.9	1.8	0.6
Summer	0.0	0.0	0.0	4.0	1.7	0.3	4.3	1.9	0.5	5.5	1.9	0.6	7.1	3.2	1.8	10.6	4.8	2.0
Mar.	0.0	0.0	0.0	0.6	0.0	0.0	0.4	0.0	0.0	0.9	0.5	0.3	1.3	0.7	0.3	1.5	1.1	0.6
Apr.	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.4	0.1	0.0	1.0	0.3	0.0
May	0.0	0.0	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Autumn	0.0	0.0	0.0	0.7	0.0	0.0	0.5	0.0	0.0	1.0	0.5	0.3	1.7	0.8	0.3	2.5	1.4	0.6
YEAR	0.0	0.0	0.0	5.1	2.0	0.3	6.1	2.0	0.5	7.3	2.4	0.9	10.3	4.2	2.2	15.2	7.0	2.7
% of Total																		
Spring	0	0	0	8	15	0	21	5	0	11	0	0	15	5	5	14	11	4
Summer	0	0	0	78	85	100	71	95	100	75	79	67	69	76	82	70	69	74
Autumn	0	0	0	14	0	0	8	0	0	14	21	33	16	19	13	16	20	22
Mean Annual Average																		
Spring	12	6	2															
Summer	61	67	71															
Autumn	11	10	11															

D3

Becks

Rainfall Runoff 1940-74

Roster Length (Days)		0			15			15			17			21			28		
Soil Moisture Deficit (mm)		35	51	67	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67
Month	Season																		
Sept.		17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2
Oct.		13.2	11.5	9.7	12.1	10.4	9.7	11.8	9.7	9.7	12.0	10.3	9.7	12.2	9.7	9.7	10.9	10.6	9.7
Nov.		9.5	6.7	5.7	8.3	5.3	4.7	8.5	5.9	5.9	8.1	6.1	4.1	7.3	5.4	4.8	6.4	5.2	4.6
	Spring	39.9	35.4	32.6	37.6	32.9	31.6	37.5	32.8	32.8	37.3	33.6	31.0	36.7	32.3	31.7	34.5	33.0	31.5
Dec.		10.3	11.8	3.9	9.5	8.4	4.2	10.1	6.9	4.6	10.2	5.0	1.8	9.1	5.5	2.4	11.8	8.4	4.0
Jan.		23.6	17.9	11.3	20.9	15.3	12.6	15.6	13.3	10.1	14.3	11.8	8.9	19.6	16.6	11.6	13.0	10.8	8.3
Feb.		16.8	11.4	8.2	9.4	9.8	9.6	10.3	7.2	8.2	13.4	10.4	8.7	9.8	7.2	6.2	8.5	6.1	4.0
	Summer	50.7	41.1	23.4	39.8	33.5	26.4	36.0	27.4	22.9	37.9	27.2	19.4	38.5	29.3	20.2	33.3	25.3	16.3
Mar.		19.2	12.5	12.2	16.2	12.9	12.8	13.3	10.5	9.1	17.5	10.8	11.7	17.2	13.1	11.4	12.8	9.7	5.3
Apr.		11.2	10.8	5.4	9.7	6.7	4.4	10.4	5.5	4.5	9.7	6.8	4.5	8.7	5.3	5.3	6.3	5.7	2.7
May		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Autumn	30.4	23.3	17.6	25.9	19.6	17.2	23.7	16.0	13.6	27.2	17.6	16.2	25.9	18.4	16.7	19.1	15.4	8.0
	YEAR	121.0	99.8	73.6	103.3	86.0	75.2	97.2	76.2	69.3	102.4	78.4	66.6	101.1	80.0	68.6	86.9	73.7	55.8
% of Total																			
	Spring	33	36	44	36	38	42	39	43	47	36	43	47	36	40	46	40	45	57
	Summer	42	41	32	39	39	35	37	36	33	37	35	29	38	37	30	38	34	29
	Autumn	25	23	24	25	23	23	24	21	20	27	22	24	26	23	24	22	21	14
Mean Annual Average																			
	Spring	37	41	47															
	Summer	39	37	31															
	Autumn	25	22	22															

Becks

Irrigation Runoff 1940-74

Roster Length (Days)	0			13			15		
Soil Moisture Deficit (mm)	35	51	67	35	51	67	35	51	67
Month Season									
Sept.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct.	19.0	5.1	0.2	9.5	1.6	0.0	10.8	1.1	0.0
Nov.	37.7	11.5	2.7	30.1	7.6	1.1	24.9	6.4	0.9
Spring	56.7	16.6	2.9	39.6	9.2	1.1	35.7	7.5	0.9
Dec.	43.5	20.5	3.6	21.9	6.8	0.9	23.4	7.6	0.3
Jan.	55.9	23.2	4.1	27.4	7.6	0.6	24.7	11.4	0.6
Feb.	43.4	16.3	3.6	23.5	10.1	0.9	26.0	7.7	1.4
Summer	142.8	60.0	11.3	72.8	24.5	2.4	74.1	26.7	2.3
Mar.	34.1	10.7	1.9	22.0	7.3	0.8	14.2	5.6	0.3
Apr.	9.5	5.8	0.8	5.1	2.2	0.3	8.9	1.4	0.4
May	-	-	-	-	-	-	-	-	-
Autumn	43.6	16.5	2.7	27.1	9.5	1.1	23.1	7.0	0.7
YEAR	243.1	93.1	16.9	139.5	43.2	4.6	132.9	41.2	3.9
% of Total									
Spring	23	18	17	28	21	24	27	18	23
Summer	59	64	67	52	57	52	56	65	59
Autumn	18	18	16	20	22	24	17	17	18
Mean Annual Average									
Spring	25	21	21						
Summer	56	59	55						
Autumn	20	21	25						

Roster Length (Days)	17			21			28		
Soil Moisture Deficit (mm)	35	51	67	35	51	67	35	51	67
Month Season									
Sept.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct.	8.4	1.0	0.1	3.9	0.6	0.0	5.5	2.9	0.0
Nov.	20.3	8.3	0.8	20.4	7.9	0.4	15.2	5.7	0.4
Spring	28.7	9.3	0.9	24.3	8.5	0.4	20.7	8.6	0.4
Dec.	25.5	7.9	0.9	13.8	5.9	0.3	18.0	7.3	0.4
Jan.	25.9	12.5	0.6	31.9	11.6	0.7	15.6	5.7	0.4
Feb.	13.7	4.9	0.4	20.0	7.3	0.9	10.7	4.1	0.0
Summer	65.1	25.3	1.9	65.7	24.8	1.9	44.3	17.1	0.8
Mar.	19.2	7.6	1.0	20.0	7.3	0.9	10.7	4.1	0.0
Apr.	9.0	4.2	0.3	4.1	1.6	0.2	3.6	2.6	0.4
May	-	-	-	-	-	-	-	-	-
Autumn	28.2	11.8	1.3	24.1	8.9	1.1	14.3	6.7	0.4
YEAR	122.0	46.4	4.1	114.1	42.2	3.4	79.3	32.4	1.6
% of Total									
Spring	24	20	22	21	20	12	26	26	25
Summer	53	55	46	58	59	56	56	53	50
Autumn	23	25	32	21	21	32	18	21	25

Omakau

Water Use Summary 1940 - 1974

Roster (Days)	0			13			15			17			21			28		
Deficit at Irrigation (mm)	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67
Irrigation water applied (mm)	510.0	315.0	202.5	337.5	225.0	165.0	315.0	210.0	172.5	300.0	232.5	150.0	285.0	210.0	142.5	225.0	172.5	127.5
Irrigation water runoff (mm)	260.9	98.5	18.6	148.9	48.6	3.9	139.6	43.4	3.2	129.8	51.0	4.8	117.4	45.5	2.9	93.4	33.2	1.6
Rainfall runoff (mm)	105.6	78.8	60.1	87.5	66.1	57.4	81.4	61.5	56.2	82.5	62.5	47.5	83.0	65.2	54.8	71.1	55.6	44.1
Days Below Wilting Point	0.0	0.0	0.0	5.2	1.7	0.2	6.3	2.9	0.6	7.2	2.1	0.4	11.2	4.1	1.6	16.4	7.8	3.0
Total Run Off	366.5	177.3	78.7	236.4	114.7	61.3	221.0	104.9	59.4	212.3	113.5	52.3	200.4	110.7	57.7	164.5	88.8	45.7

Seasonal Percentage of Annual Total. Mean of all Rosters

	Irrigation Water			Irrigation Runoff			Rainfall Runoff			Days Below Wilting Point		
Deficit at Irrigation (mm)	35	51	67	35	51	67	35	51	67	35	51	67
Spring	25	19	13	25	20	20	37	42	49	12	7	2
Summer	56	62	68	56	60	58	39	35	32	59	68	63
Autumn	20	19	19	20	21	22	24	23	20	12	8	19

* Depth of water at each irrigation is 75 mm. Number of irrigation applied is = irrigation watter applied/75

Omakau

Mean Number of Irrigations Applied 1940-74

Roster Length (Days)		0			13			15			17			21			28		
Soil Moisture Deficit (mm)		35	51	67	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67
Month	Season																		
Sept.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct.		0.6	0.2	0.0	0.3	0.1	0.0	0.3	0.1	0.0	0.3	0.1	0.0	0.2	0.1	0.0	0.2	0.2	0.0
Nov.		1.1	0.5	0.4	0.9	0.5	0.3	0.8	0.4	0.4	0.6	0.5	0.2	0.7	0.4	0.2	0.5	0.3	0.2
	Spring	1.7	0.7	0.4	1.2	0.6	0.3	1.1	0.5	0.4	0.9	0.6	0.2	0.9	0.5	0.2	0.7	0.5	0.2
Dec.		1.2	1.0	0.6	0.6	0.5	0.4	0.8	0.6	0.5	0.9	0.6	0.5	0.5	0.5	0.3	0.6	0.5	0.4
Jan.		1.6	1.0	0.7	0.9	0.6	0.4	0.8	0.6	0.5	0.9	0.8	0.6	1.0	0.8	0.6	0.5	0.3	0.3
Feb.		1.2	0.8	0.6	0.8	0.7	0.6	0.8	0.6	0.6	0.4	0.4	0.2	0.6	0.4	0.4	0.6	0.6	0.5
	Summer	4.0	2.8	1.9	2.3	1.8	1.4	2.4	1.8	1.6	2.2	1.8	1.3	2.1	1.7	1.3	1.7	1.4	1.2
Mar.		0.8	0.5	0.2	0.8	0.5	0.4	0.5	0.3	0.2	0.6	0.5	0.3	0.7	0.5	0.4	0.4	0.2	0.2
Apr.		0.3	0.2	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.3	0.2	0.2	0.1	0.1	0.0	0.2	0.2	0.1
May		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Autumn	1.1	0.7	0.4	1.0	0.6	0.5	0.7	0.5	0.3	0.9	0.7	0.5	0.8	0.6	0.4	0.6	0.4	0.3
	YEAR	6.8	4.2	2.7	4.5	3.0	2.2	4.2	2.8	2.3	4.0	3.1	2.0	3.8	2.8	1.9	3.0	2.3	1.7
% of Total																			
	Spring	25	17	15	27	20	14	26	18	17	22	19	10	24	18	11	23	22	12
	Summer	59	66	70	51	60	63	57	64	70	56	58	65	55	61	68	57	61	70
	Autumn	16	17	15	22	20	23	17	18	13	22	23	25	21	21	21	20	17	18
Mean Annual Average																			
	Spring	25	19	13															
	Summer	56	62	68															
	Autumn	20	19	19															

Omakau

Days Below Wilting Point 1940-74

Roster Length (Days)	0			13			15			17			21			28		
Soil Moisture Deficit (mm)	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67
Month / Season																		
Sept.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct.	0.0	0.0	0.0	0.0	0.1	0.0	0.5	0.0	0.0	0.1	0.0	0.0	0.4	0.0	0.0	0.8	0.2	0.0
Nov.	0.0	0.0	0.0	0.6	0.2	0.0	0.9	0.2	0.0	0.9	0.0	0.0	1.0	0.3	0.1	1.5	0.6	0.1
Spring	0.0	0.0	0.0	0.6	0.3	0.0	1.4	0.2	0.0	1.0	0.0	0.0	1.4	0.3	0.1	2.3	0.8	0.1
Dec.	0.0	0.0	0.0	0.6	0.5	0.0	1.0	1.0	0.2	2.0	0.5	0.1	3.1	1.4	0.4	3.8	2.5	0.8
Jan.	0.0	0.0	0.0	2.1	0.5	0.1	1.5	.9	0.4	2.4	1.0	0.2	2.6	0.9	0.6	4.4	1.3	0.7
Feb.	0.0	0.0	0.0	1.4	0.4	0.0	1.6	0.6	0.0	0.8	0.4	0.0	2.0	0.9	0.2	3.2	1.9	0.8
Summer	0.0	0.0	0.0	4.1	1.4	0.1	4.1	2.5	0.6	5.2	1.9	0.3	7.7	3.2	1.2	11.4	5.7	2.3
Mar.	0.0	0.0	0.0	0.4	0.0	0.1	0.7	0.1	0.0	0.8	0.2	0.1	1.6	0.5	0.3	1.6	0.8	0.6
Apr.	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.2	0.0	0.0	0.5	0.1	0.0	1.1	0.5	0.0
May	0.0	0.0	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Autumn	0.0	0.0	0.0	0.5	0.0	0.1	0.8	0.2	0.0	1.0	0.2	0.1	2.1	0.6	0.3	2.7	1.3	0.6
YEAR	0.0	0.0	0.0	5.2	1.7	0.2	6.3	2.9	0.6	7.2	2.1	0.4	11.2	4.1	1.6	16.4	7.8	3.0
% of Total																		
Spring	0	0	0	11	18	0	22	7	0	14	0	0	12	7	6	14	10	3
Summer	0	0	0	79	82	50	65	86	100	72	90	75	69	78	75	70	73	77
Autumn	0	0	0	10	0	50	13	7	0	14	10	25	19	15	19	16	17	20
Mean Annual Average																		
Spring	12	7	2															
Summer	59	68	63															
Autumn	12	8	19															

Omakau

Rainfall Runoff 1940-74

Roster Length (Days)		0			13			15			17			21			28	
Soil Moisture Deficit (mm)	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67
Month Season																		
Sept.	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Oct.	12.1	9.0	7.6	10.0	8.2	7.6	9.5	7.7	7.6	10.0	8.1	7.6	10.0	8.3	7.6	8.9	8.4	7.6
Nov.	8.9	5.1	3.9	7.1	3.5	2.9	6.4	4.0	4.0	6.8	4.2	2.5	5.7	3.8	3.3	4.8	3.4	3.1
Spring	36.0	29.1	26.5	32.1	26.7	25.5	30.9	26.7	26.6	31.8	27.3	25.1	30.7	27.1	25.9	28.7	26.8	25.7
Dec.	9.6	9.0	2.5	7.8	5.6	2.1	8.8	5.6	2.4	8.1	2.5	0.6	7.8	4.7	2.5	10.3	6.5	2.0
Jan.	22.6	13.7	11.4	17.2	10.7	9.9	12.3	10.5	8.8	10.7	8.9	6.4	16.0	13.4	10.7	10.3	7.6	8.1
Feb.	12.8	7.7	6.8	8.3	6.5	7.3	9.7	5.2	7.5	10.7	8.5	5.4	7.5	5.2	4.5	6.5	4.5	2.9
Summer	45.0	30.4	20.7	33.3	22.8	19.3	30.8	21.3	18.7	29.5	19.9	12.4	31.3	23.3	17.7	27.1	18.6	13.0
Mar.	15.8	10.5	7.6	14.0	10.9	7.7	11.4	9.2	7.5	13.5	10.3	6.7	14.0	10.3	8.1	9.8	7.1	4.1
Apr.	8.8	8.8	5.3	8.1	5.7	4.9	8.3	4.3	3.4	7.7	5.0	3.3	7.0	4.5	3.1	5.5	3.1	1.3
May	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Autumn	24.6	19.3	12.9	22.1	16.6	12.6	19.7	13.5	10.9	21.2	15.3	10.0	21.0	14.8	11.2	15.3	10.2	5.4
YEAR	105.6	78.8	60.1	87.5	66.1	57.4	81.4	61.5	56.2	82.5	62.5	47.5	83.0	65.2	54.8	71.1	55.6	44.1
% of Total																		
Spring	34	37	44	37	40	44	38	43	47	38	44	53	37	41	47	40	48	58
Summer	43	39	34	38	35	34	38	35	33	36	32	26	38	36	32	38	34	30
Autumn	23	24	22	25	25	22	24	22	20	26	24	21	25	23	21	22	18	12
Mean Annual Average																		
Spring	37	42	49															
Summer	39	35	32															
Autumn	24	23	20															

Omakau

Irrigation Runoff 1940–74

Roster Length (Days)		0			13			15			17			21			28		
Soil Moisture Deficit (mm)		35	51	67	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67
Month	Season																		
Sept.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct.		21.4	5.8	0.2	10.5	1.6	0.0	11.8	1.8	0.0	9.5	0.9	0.1	5.0	1.4	0.0	6.6	2.8	0.0
Nov.		41.3	11.5	2.9	32.7	7.6	0.8	25.6	6.1	0.8	19.9	9.2	0.7	22.1	8.3	0.4	15.8	5.3	0.4
	Spring	62.7	17.3	3.1	43.2	9.2	0.8	37.4	7.9	0.8	29.4	10.1	0.8	27.1	9.7	0.4	22.4	8.1	0.4
Dec.		47.1	23.5	3.9	20.5	7.1	0.5	26.7	7.3	0.4	27.9	9.0	1.3	13.5	7.5	0.3	18.6	7.2	0.4
Jan.		61.6	22.6	4.6	26.9	9.5	0.4	25.4	10.2	0.7	28.9	12.4	1.2	31.2	12.2	1.2	16.3	4.5	0.2
Feb.		47.0	18.5	4.0	25.5	11.8	1.1	26.7	9.0	0.8	14.4	6.1	0.2	19.6	6.6	0.2	19.6	8.4	0.3
	Summer	155.7	64.6	12.5	72.9	28.4	2.0	78.8	26.5	1.9	71.2	27.5	2.7	64.3	26.3	1.7	54.5	20.1	0.9
Mar.		31.8	10.8	1.4	25.5	9.2	0.8	15.9	5.7	0.2	20.4	9.2	0.7	22.0	8.0	0.8	11.6	2.8	0.1
Apr.		10.7	5.8	1.6	7.3	1.8	0.3	7.5	3.3	0.3	8.8	4.2	0.6	4.0	1.5	0.0	4.9	2.2	0.2
May		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Autumn	42.5	16.6	3.0	32.8	11.0	1.1	23.4	9.0	0.5	29.2	13.4	1.3	26.0	9.5	0.8	16.5	5.0	0.3
	YEAR	260.9	98.5	18.6	148.9	48.6	3.9	139.6	43.4	3.2	129.8	51.0	4.8	117.4	45.5	2.9	93.4	33.2	1.6
% of Total																			
	Spring	24	18	17	29	19	21	27	18	25	23	20	17	23	21	14	24	24	25
	Summer	60	65	67	49	58	51	56	61	59	55	54	56	55	58	59	58	61	56
	Autumn	16	17	16	22	23	28	17	21	16	22	26	27	22	21	27	18	15	19
Mean Annual Average																			
	Spring	25	20	20															
	Summer	56	60	58															
	Autumn	20	21	22															

Alexandra

Water Use Summary 1930 - 1973

Roster (Days)	0			13			15			17			21			28		
Deficit at Irrigation (mm)	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67
*Irrigation Water Applied (mm)	690.0	457.5	322.5	480.0	322.5	255.0	442.5	330.0	262.5	435.0	307.5	240.0	397.5	285.0	232.5	322.5	262.5	210.0
Irrigation water runoff (mm)	350.6	141.4	28.4	207.8	70.4	6.1	199.6	71.5	7.4	187.9	65.1	5.6	171.4	57.2	4.4	131.4	48.1	3.2
Rainfall runoff (mm)	60.5	49.8	36.0	50.5	39.9	26.8	44.4	35.2	26.9	49.9	41.0	25.4	44.4	32.8	24.1	42.4	30.9	21.7
Days Below Wilting Point	0.0	0.0	0.0	6.7	2.8	0.8	8.9	2.9	1.1	11.3	5.4	2.2	14.1	8.4	4.3	23.5	11.8	7.8
Total Runoff (mm)	411.1	191.2	64.4	258.3	110.3	32.9	244.0	106.7	34.3	237.8	106.1	31.0	215.8	90.0	28.5	173.8	79.0	24.9

Seasonal Percentage of Annual Total Mean of all Rosters

	Irrigation Water			Irrigation Runoff			Rainfall Runoff			Days Below Wilting Point		
Deficit at Irrigation (mm)	35	51	67	35	51	67	35	51	67	35	51	67
Spring	27	26	22	28	28	22	36	39	43	18	11	6
Summer	54	55	58	52	51	53	35	36	35	55	64	70
Autumn	19	19	20	20	21	25	29	26	24	11	9	6

* Depth of water at each irrigation is 75 mm. Number of irrigations applied is = irrigation water applied/75

Alexandra

Mean Number of Irrigations Applied 1930-73

Roster Length		0			13			15			17			21			28		
Soil Moisture Deficit (mm)		35	51	67	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67
Month	Season																		
Sept.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct.		1.0	0.6	0.3	0.7	0.3	0.0	0.7	0.4	0.2	0.6	0.3	0.0	0.6	0.1	0.0	0.5	0.4	0.1
Nov.		1.3	0.9	0.7	1.1	0.9	0.8	1.0	0.8	0.7	0.9	0.7	0.6	1.1	0.8	0.6	0.7	0.5	0.5
	Spring	2.3	1.5	1.0	1.8	1.2	0.8	1.7	1.2	0.9	1.5	1.0	0.6	1.5	0.9	0.6	1.2	0.9	0.6
Dec.		1.8	1.2	0.8	1.0	0.7	0.5	1.1	0.9	0.7	1.2	0.8	0.7	0.7	0.5	0.4	0.8	0.7	0.6
Jan.		1.8	1.3	1.0	1.1	0.7	0.7	1.1	0.8	0.6	1.2	0.9	0.9	1.3	1.0	0.9	0.7	0.6	0.5
Feb.		1.7	1.1	0.8	1.2	0.9	0.7	1.1	0.7	0.7	0.6	0.4	0.2	0.7	0.6	0.5	0.8	0.7	0.6
	Summer	5.3	3.6	2.6	3.3	2.3	1.9	3.3	2.4	2.0	3.0	2.1	1.8	2.7	2.1	1.8	2.3	2.0	1.7
Mar.		1.1	0.7	0.5	0.9	0.7	0.5	0.6	0.6	0.3	0.9	0.7	0.7	0.9	0.6	0.6	0.5	0.4	0.3
Apr.		0.5	0.3	0.2	0.4	0.1	0.2	0.3	0.2	0.3	0.4	0.3	0.1	0.2	0.2	0.1	0.3	0.2	0.2
May		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Autumn	1.6	1.0	0.7	1.3	0.8	0.7	0.9	0.8	0.6	1.3	1.0	0.8	1.1	0.8	0.7	0.8	0.6	0.5
	YEAR	9.2	6.1	4.3	6.4	4.3	3.4	5.9	4.4	3.5	5.8	4.1	3.2	5.3	3.8	3.1	4.3	3.5	2.8
% of Total																			
	Spring	25	25	23	28	28	23	29	27	26	26	24	19	28	24	19	28	26	21
	Summer	58	59	61	52	53	56	56	55	57	52	52	56	51	55	58	53	57	61
	Autumn	17	16	16	20	19	21	15	18	17	22	24	25	21	21	23	19	17	18
Mean Annual Average																			
	Spring	27	26	22															
	Summer	54	55	58															
	Autumn	19	19	20															

Alexandra

Days Below Wilting Point 1930-73

Roster Length (Days)	0			13			15			17			21			28		
Soil Moisture Deficit (mm)	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67
Month Season																		
Sept.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct.	0.0	0.0	0.0	0.1	0.0	0.0	0.8	0.1	0.0	0.6	0.0	0.0	1.0	0.2	0.0	2.2	0.0	0.0
Nov.	0.0	0.0	0.0	0.9	0.4	0.0	1.5	0.3	0.1	1.5	0.4	0.1	2.1	0.8	0.7	3.2	1.8	0.9
Spring	0.0	0.0	0.0	1.0	0.4	0.0	2.3	0.4	0.1	2.1	0.4	0.1	3.1	1.0	0.7	5.4	1.8	0.9
Dec.	0.0	0.0	0.0	1.7	0.6	0.0	1.5	0.7	0.4	3.0	1.1	0.7	3.1	2.4	1.0	5.0	3.6	2.5
Jan.	0.0	0.0	0.0	2.2	1.2	0.6	2.2	0.7	0.3	3.1	1.8	0.7	2.9	2.1	1.1	5.3	2.0	1.3
Feb.	0.0	0.0	0.0	1.2	0.5	0.2	1.5	1.0	0.3	1.5	1.1	0.5	3.3	1.5	1.0	4.5	3.0	1.8
Summer	0.0	0.0	0.0	5.1	2.3	0.8	5.2	2.4	1.0	7.6	4.0	1.9	9.3	6.0	3.1	14.8	8.6	5.6
Mar.	0.0	0.0	0.0	0.5	0.1	0.0	1.4	0.1	0.0	1.4	0.9	0.2	1.2	1.3	0.5	2.4	0.8	0.8
Apr.	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.5	0.1	0.0	0.9	0.6	0.5
May	0.0	0.0	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Autumn	0.0	0.0	0.0	0.6	0.1	0.0	1.4	0.1	0.0	1.6	1.0	0.2	1.7	1.4	0.5	3.3	1.4	1.3
YEAR	0.0	0.0	0.0	6.7	2.8	0.8	8.9	2.9	1.1	11.3	5.4	2.2	14.1	8.4	4.3	23.5	11.8	7.8
% of Total																		
Spring	0	0	0	15	14	0	26	14	9	19	7	5	22	12	16	23	15	11
Summer	0	0	0	76	82	100	58	83	91	67	74	86	66	71	72	63	73	72
Autumn	0	0	0	9	4	0	16	3	0	14	19	9	12	17	12	14	12	17
Mean Annual Average																		
Spring	18	11	6															
Summer	55	64	70															
Autumn	11	9	6															

Alexandra

Rainfall Runoff 1930-73

Roster Length (Days)		0			13			15			17			21			28		
Soil Moisture Deficit (mm)		35	51	67	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67
Month	Season																		
Sept.		7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
Oct.		5.3	5.7	2.1	5.8	3.6	1.7	4.7	1.7	1.7	6.4	5.1	2.0	4.1	1.6	1.7	5.6	5.1	1.9
Nov.		5.6	3.9	2.2	4.9	4.2	2.3	4.0	4.0	1.1	3.9	2.8	1.8	4.3	3.1	1.7	3.2	1.0	1.1
	Spring	18.7	17.4	12.1	18.5	15.6	11.8	16.5	13.5	10.6	18.1	15.7	11.6	16.2	12.5	10.9	16.6	13.9	10.8
Dec.		2.7	2.2	1.3	1.7	3.2	1.1	3.0	2.9	1.4	2.6	1.7	0.7	2.1	1.3	0.2	2.8	2.3	0.3
Jan.		11.2	7.7	5.5	8.1	5.7	3.3	5.9	3.6	3.1	5.0	2.6	2.0	6.9	6.1	2.6	5.6	4.4	3.4
Feb.		10.4	8.6	7.3	7.0	6.6	4.6	6.4	4.0	3.4	8.9	7.2	4.4	6.8	6.4	4.8	5.7	4.7	4.4
	Summer	24.3	18.5	14.1	16.8	15.5	9.0	15.3	10.5	7.9	16.5	11.5	7.1	15.8	13.8	7.6	14.1	11.4	8.1
Mar.		9.7	7.8	4.4	8.0	4.2	3.8	7.0	6.0	4.1	9.4	8.2	4.7	6.4	4.2	3.8	5.0	2.7	0.8
Apr.		7.8	6.1	5.4	7.2	4.6	2.2	5.6	5.2	4.3	5.9	5.6	2.0	6.0	2.3	1.8	6.7	2.9	2.0
May		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Autumn	17.5	13.9	9.8	15.2	8.8	6.0	12.6	11.2	8.4	15.3	13.8	6.7	12.4	6.5	5.6	11.7	5.6	2.8
	YEAR	60.5	49.8	36.0	50.5	39.9	26.8	44.4	35.2	26.9	49.9	41.0	25.4	44.4	32.8	24.1	42.4	30.9	21.7
% of Total																			
	Spring	31	35	34	37	39	44	37	38	40	36	38	46	36	38	45	39	45	50
	Summer	40	37	39	33	39	34	35	30	39	33	28	28	36	42	32	33	37	37
	Autumn	29	28	27	30	22	22	28	32	31	31	34	26	28	20	23	28	18	13
Mean Annual Average																			
	Spring	36	39	43															
	Summer	35	36	35															
	Autumn	29	26	24															

Alexandra

Irrigation Runoff 1930-73

Roster Length (Days)		0			13			15			17			21			28		
Soil Moisture Deficit (mm)		35	51	67	35	51	67	35	51	67	35	51	67	35	51	67	35	51	67
Month	Season																		
Sept.		0.9	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct.		40.0	13.8	1.8	22.5	6.0	0.0	23.9	7.0	0.6	21.3	6.4	0.1	12.8	1.5	0.0	16.8	6.6	0.6
Nov.		49.4	20.8	4.5	38.3	16.2	1.7	33.2	13.4	1.4	30.1	12.6	1.2	34.9	12.6	0.5	22.4	7.6	0.1
	Spring	90.3	34.6	6.3	60.8	22.1	1.7	58.0	20.4	2.0	51.4	19.0	1.3	47.7	14.1	0.5	39.2	14.2	0.7
Dec.		68.0	28.3	5.5	31.0	9.9	1.5	36.4	14.2	1.2	37.6	11.2	0.6	22.4	6.3	0.6	22.3	9.1	0.8
Jan.		68.9	29.3	6.6	34.8	10.9	0.7	35.4	13.5	1.3	38.9	13.4	1.3	41.5	14.6	1.6	20.3	7.2	0.7
Feb.		63.6	25.1	5.1	38.6	14.6	0.5	37.7	9.1	1.2	17.4	5.6	0.3	22.5	8.0	0.4	22.0	8.4	0.5
	Summer	200.5	82.7	17.2	104.4	35.4	2.7	109.5	36.8	3.7	93.9	30.2	2.2	86.4	28.9	2.6	64.6	24.7	2.0
Mar.		41.6	16.3	3.7	30.1	11.0	0.8	20.5	10.1	0.9	29.6	10.8	1.6	30.4	10.7	0.9	16.4	5.7	0.3
Apr.		18.2	7.8	1.2	12.5	1.8	0.9	11.6	4.2	0.8	13.0	5.1	0.5	6.9	3.5	0.4	11.2	3.5	0.2
May		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Autumn	59.8	24.1	4.9	42.6	12.8	1.7	32.1	14.3	1.7	42.6	15.9	2.1	37.3	14.2	1.3	27.6	9.2	0.5
	YEAR	350.6	141.4	28.4	207.8	70.4	6.1	199.6	71.5	7.4	187.9	65.1	5.6	171.4	57.2	4.4	131.4	48.1	3.2
% of Total																			
	Spring	26	25	22	29	32	28	29	29	27	27	29	23	28	25	11	30	30	22
	Summer	57	58	61	50	50	44	55	51	50	50	46	39	50	50	59	49	51	62
	Autumn	17	17	17	21	18	28	16	20	23	23	25	38	22	25	30	21	19	16
Mean Annual Average																			
	Spring	28	28	22															
	Summer	52	51	53															
	Autumn	20	21	25															

Flow simulation (see III.3). Falls Dam storage, withdrawal and spilling during the irrigation season.

Date	Storage million m^3	Withdrawal from dam m^3/sec	Spilling m^3/sec
5/9	100	1	5
15/9	100	5.2	1
25/9	100	5.2	4
5/10	99	8.2	-
15/10	99	8.2	-
25/10	99	8.2	-
5/11	98	11.3	-
15/11	97	11.3	-
25/11	93	11.3	-
5/12	89	11.3	-
15/12	84	11.3	-
25/12	77	11.3	-
5/1	71	11.3	-
15/1	64	11.3	-
25/1	56	11.3	-
5/2	49	9.2	-
15/2	44	9.2	-
25/2	38	9.2	-
5/3	33	8.7	-
15/3	28	8.7	-
25/3	21	8.7	-
5/7	20	1.2	-
end of irrigation season			

Flow simulation. Falls Dam storage, withdrawal and spilling outside the irrigation season.

Date	Storage million m^3	Withdrawal from dam m^3/sec	Spilling m^3/sec
15/4	21	1	-
25/4	24	1	-
5/5	30	1	-
15/5	35	1	-
25/5	42	1	-
5/6	44	1	-
15/6	53	1	-
25/6	55	1	-
5/7	65	1	-
15/7	73	1	-
25/7	84	1	-
5/8	89	1	-
15/8	100	1	1
25/8	100	1	4
5/9	100	1	7
start of the irrigation season			

Yield Falls Dam (million m^3)

Year	Nov-Jan	Feb-Apr	May-July	Aug-Oct
1	41	10	25	55
2	29	19	33	67
3	31	30	44	25
4	57	50	84	69
5	27	19	32	33
6	56	28	29	132
7	36	46	48	73
8	58	45	30	49
9	30	17	30	65
10	53	30	70	67
11	72	28	19	76
12	38	18	214	24
13	44	12	20	114
14	18	24	116	40
15	33	15	12	28
16	16	18	17	37
17	44	17	10	93
18	24	174	44	37
19	44	120	89	26
20	72	18	15	126
21	55	20	100	98
22	51	7	39	50
23	77	67	54	39
24	37	39	22	35
25	33	46	43	67

Falls Dam storage and release as result of this yield
(figures in million m³)

	Nov-Jan storage/release		Feb-April storage/release		May-July storage/release		Aug-Oct storage/release	
1	80	70	50	40	20	9	40	9
2	100 S	80	50	70	50	9	50	9
3	100 S	80	50	80	20	9	60	9
4	100 S	100	50	100	20	9	100	9
5	97	80	50	70	20	9	50	9
6	100 S	100	50	80	20	9	50	9
7	100 S	90	50	90	20	9	60	9
8	100 S	100	50	95	20	9	50	9
9	100 S	80	50	70	20	9	50	9
10	100 S	100	52	80	20	9	90	9
11	80	120	100	90	20	9	35	9
12	160 S	120	50	95	100	9	100	9
13	100 S	90	50	60	20	9	40	9
14	100 S	70	50	80	20	9	100	9
15	70	80	50	60	20	9	30	9
16	90	40	50	80	20	9	40	9
17	100 S	80	50	60	100	9	100	9
18	100 S	70	50	70	100	9	100	9
19	100 S	90	50	60	40	9	30	9
20	100 S	120	52	60	20	9	100	9
21	100 S	100	50	60	20	9	100	9
22	100 S	100	50	100	20	9	30	9
23	90	120	60	100	20	9	100	9
24	100 S	90	50	60	20	9	50	9
25	100 S	70	50	100	20	9	70	9

TAIL END STORAGE

Large quantities of water are required for frost protection of orchards around Alexandra. Development of some storage near Straith Clyde Road (Dunstan Flat) has the advantage of water being quickly available and stored within a short distance of the orchards. Various ponds could be able to store 20 000 m³ - 200 000 m³ each. Those ponds could be filled with bywash from the main race. Some sites have been investigated and are mentioned in Table XVIII.

Pond	Grid ref	Mean Dam Height (m)	Earth-works (m³)	Storage (m³)	Earthwork / Storage (m³/m³)
1	S133 193575	3.20	1500	32 500	0.046
2	S133 194566	5.50	7260	125 000	0.058
3	S133 163560	5.30	8400	140 000	0.060
4	S133 179584	6.20	15000	265 000	0.074
5	S133 197593	4.70	6000	117 000	0.051
6	S133 190579	5.10	4200	82 000	0.051
7	S133 162548	4.50	3000	32 000	0.094

Σ = 79[illegible] 000 m³

TABLE XVIII Tail end Storage Manuherikia Valley Irrigation Scheme

Numerous alternative sites of various sizes are possible. The demand for frost-fighting in this area has been estimated as 11 l/sec/ha. At present there is 150 ha orchard within the scheme. A frost period of 12 hours would require 75 000 m³. A minimum storage sufficient for at least two night frost-fightings is required. The main race could supply water for longer frost periods. Therefore a minimum storage of 150 000 m³ is recommended. This storage does allow further orchard developments below Springvale Road of up to 300 ha.

V ≥ 1260 ha @ 11 l/s/ha × 12 × 60² sec / 1000

V ≥ [illegible] m³

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28 July 1980

The Commissioner of Works
WELLINGTON

ATTENTION Water and Soil

MANUHERIKIA VALLEY IRRIGATION SCHEME

A preliminary report covering possible irrigation development and redevelopment in the Manuherikia Valley, including an increase in the storage provided by the existing Falls Dam, was completed in January 1974, a copy being forwarded to you under my 96/752630 of 5 February 1974 (your file 64/7/1/3).

Subsequently the then Associate Minister of Works and Development received the report and directed that further more detailed investigation should proceed leading to a feasibility report. A programme was accordingly prepared showing completion of this work about April 1980 (refer minuted copy of my 15/3/1 of 20 June 1974).

The feasibility study has now been completed and 2 copies of the resulting report (each of 2 volumes) together with a separate summary of the proposed Manuherikia Valley irrigation scheme are enclosed for your consideration.

1 MANUHERIKIA CATCHMENT

The Manuherikia River rises in the Hawkdun and St Bathans ranges at over 2000 m and runs generally south-west along a fault depression to join the Clutha River at Alexandra at a level of 150 m. Block-mountain ranges surround the 3100 km^2 catchment separating it from the Upper Clutha and Lindis River to the west, the Waitaki catchment to the north and the Taieri River to the east.

From the largely undeveloped tussock country in its headwaters, the river drops rapidly to reach the Omakau basin through an antecedent gorge at the head of which Falls Dam is sited. Across this basin the river lies close to the eastern hills leaving an extensive area of fans and terraces to the west which are served by the Omakau irrigation scheme, and across which the major Dunstan Creek, and lesser Lauder and Thompsons Creek, join the main stream. To the east, and separated from the Omakau basin by the Raggedy Range and Blackstone Hill, is the parallel Ida Valley from which the Poolburn and its Idaburn tributary drain through a short gorge.

...

From the Omakau basin the deeply incised Tiger Hills gorge carries the river through the Magdallen Hills to its lower reaches where it is joined first from the west by Chatto Creek and, just upstream of Alexandra, by the Manorburn from the east. At this point, the small but intensively farmed Galloway flat lies to the east of the river, while to the west the limited marginal flats rise steadily to rolling downland and finally to the high Moutere Terraces long seen as needing irrigation. The lower parts of this western area, and the intensive pastoral and horticultural development on the Dunstan Flat between Alexandra and Clyde, are served by the Manuherikia irrigation scheme from an intake in the Tiger Hills gorge.

Like many of the Central Otago catchments, flows in the Manuherikia River follow a characteristic seasonal cycle with sustained high discharges during the spring snow-melt and very low flows over the summer-autumn period. This pattern is also heavily accentuated by irrigation usage which includes:

(a) Diversion from the headwater tributaries and the Idaburn by the Mt Ida water race to serve the Hawkdun irrigation scheme.

(b) Storage and use of water in the Idaburn and its tributaries to serve the Idaburn irrigation scheme at the northern end of the Ida Valley.

(c) Use of water from the Manuherikia River (including Falls Dam), Dunstan Creek, Lauder Creek and Thompsons Creek by the Omakau irrigation scheme.

(d) Up to total abstraction from the Manuherikia River and from Chatto Creek to provide the often deficient supply for the Manuherikia irrigation scheme.

(e) Storage and total use of water from the Manorburn and Poolburn to serve the Ida Valley and Galloway irrigation schemes.

(f) Diversion of residual and return flows from the Manuherikia River below the Tiger Hills gorge to serve the lower part of the Galloway scheme.

(g) Diversions from Dunstan Creek by the Downs Settlement water race (administered by Lands and Survey) for irrigation use.

(h) Diversion from the Manuherikia River by the Blackstone Hill race (administered by this Department) for irrigation of flats east of the river.

(i) Various private schemes the most important probably being one drawing from Chatto Creek using rights held and leased by this Department.

...

with the relatively rapid rise in elevation in the valley to 250–400 m on the Moutere Terraces and 300–450 m in the Omakau Basin, there are parallel changes in both the climatic pattern and the predominant farming systems.

2 PROPOSED SCHEME

The proposed irrigation scheme would serve the whole of the western side of the Manuherikia Valley, roughly from Dunstan Creek to above Clyde, and would completely replace the existing Omakau and Manuherikia irrigation schemes as well as bringing in substantial new areas particularly on the Moutere Terraces. A replacement service would also be provided in the Downs Settlement area, and possibly for the Blackstone Hill race, in both cases with some increase in the irrigated area. However the portion of the Galloway irrigation scheme reliant on supply from the Manuherikia River is not included except in terms of the water it requires which is largely return flow.

In physical terms the scheme would involve:

(a) A 60 m high earth and rockfull dam immediately downstream of the existing Falls Dam which would increase the storage available from 11×10^6 m^3 to 100×10^6 m^3. This is the largest dam possible at the site without subsidiary walls being provided across saddles to the west. It is envisaged that the existing dam would be used virtually as a coffer dam with extended outlet and spillway works, a new spillway being constructed either immediately adjacent to the new dam or in the head of a gully to the west.

(b) A new gravity race extending 84.5 km from an intake on the Manuherikia River near the St Bathans Loop Road bridge at a level of 475 m to the Waikerikeri Valley near Clyde at about 400 m. This is envisaged as a large flat grade race with a capacity of 10 m^3/s at intake gradually reducing to 3 m^3/s above Clyde. Major syphons would be required across tributary streams and most head loss would be at these points to achieve minimum pipe diameters. Control would be by constant flow type gates incorporating provision for remote control.

(c) Development of small tail-end storages in the lower Moutere/Strath Clyde area to both provide supply to the Dunstan Flat area (which has been excluded from the proposed scheme) and improve the utilisation of flows in the new race. From these storages, separate piped schemes could be developed to provide a horticultural supply to irrigated and irrigable areas on the Dunstan Flat, thus removing the need to continue the existing difficult and costly distribution by open race. Considerable interest has already been expressed in such proposals.

... ...

(d) New distribution running essentially downslope from the main race to serve irrigated and irrigable areas in the Omakau Basin, between Chatto Creek and Alexandra, and on the Moutere Terraces but largely excluding the hills between Omakau and Chatto Creek. The relatively linear nature of the proposed scheme means that most distribution races would be fairly short. Existing distribution would be utilised where possible but, with the need to keep the present supply systems operating during construction of the proposed scheme, this creates some problems.

(e) Construction and reconstruction of existing on-farm layouts and new development to utilise high rates of supply in an effective and efficient manner. Although surface application is likely to match most closely the farming systems likely in this area, and the proposed scheme would be designed for this purpose, there may be some adoption of low pressure spray techniques. However the major change is likely to be in the rates of supply available to individual farmers, and the increased efficiency and automation which these will allow.

(f) Possible provision of a race drawing water from Dunstan Creek about the 550 m level and extending 16 km to link with the main race upstream of Lauder Creek. Such a race would provide valuable early season supply to the scheme as a whole, particularly in situations where Falls Dam had not filled to its maximum level, and would also allow some irrigation coverage across the lower slopes of the runs in this area. However little interest has yet been shown in this latter possibility and it is therefore best regarded as an option - most runholders already have access to limited water supplies.

3 WATER REQUIREMENTS

Major variations in climate between the upper end of the Omakau Basin with its relatively shorter season and the lower altitude, more extreme, areas adjacent to Alexandra, have created difficulties in the determining of realistic water requirements. Even accepting the constraints imposed by deficiencies in supply, and the relatively low application efficiencies, existing water usage ranges from less than 300 mm under parts of the Omakau scheme to over 1500 mm under the Manuherikia scheme.

Following unsuccessful attempts to run long term rainfall and temperature data against possible operating rosters, the most equitable means of allocating water appeared to be in terms of an average number of irrigations required. However, to ensure the most effective use of the limited resource, the depth per irrigation was arbitrarily set at 75 mm. For allocation purposes, the proposed scheme was broken into

... ...

sub-areas with water requirements as follows:

(i) Four irrigations or 300 mm for the Downs Settlement area north of Dunstan Creek, for the area between Lauder and Dunstan Creeks, and for the area which could be served by a new subsidiary race from Dunstan Creek.

(ii) Six irrigations or 450 mm from the remainder of the Omakau Basin between Lauder Creek and the hills to the south, and for the area served by the Blackstone Hill race on the eastern side of the Manuherikia River.

(iii) Eight irrigations or 600 mm for the Moutere area across the various tributaries of Chatto Creek and lying roughly between Devonshire Creek and McArthurs Gully (and possibly including the upper parts of the Moutere Terraces).

(iv) Fourteen irrigations or 1050 mm for the Moutere Terraces and bulk of the area currently served by the Manuherikia irrigation scheme, but excluding Dunstan Flat, and for the lower parts of the Galloway scheme.

Problems will almost certainly arise at the boundaries of these sub-areas and, although further sub-division is possible, this is considered unwarrented.

On the operating scheme usage will largely be controlled by roster but there must be some provision for supply of greater or lesser quantities of water to cope with within season, and season to season, climatic variations.

4 WATER SUPPLY

Limitation on the proposed development is the water supply which can safely be provided by the upper Manuherikia Catchment and storage in the enlarged Falls Dam.

Average annual runoff at the Falls Dam site has been assessed as 190 x 10^6 m^3, or 6.15 m^3/s mean discharge, of which roughly 50% occurs from September-December and 15% from January-March. The 1 in 10 year minimum yield has been estimated at 130 x 10^6 m^3. With a storage capacity of 100 x 10^6 m^3, and an average seasonal release from storage of 70 x 10^6 m^3, the average supply available for the proposed scheme would be 140 x 10^6 m^3. However the storage is little better than annual and with two dry seasons in sequence, a condition which exceeds the 1 in 10 year drought normally adopted for irrigation design, some restrictions in supply would be necessary.

Storage in Dunstan Creek has been considered but rejected on the grounds of cost. Any utilisation of flows from this stream must therefore be on a run-of-river basis and, although up to 3 m^3/s could be diverted early in the season when flows in the Manuherikia River are generally adequate, little or no water would be available during the middle and later parts of the

... ...

irrigation season. There would obviously then be some restrictions on supply to areas dependent solely on Dunstan Creek but some minor off-stream storage is possible.

Utilisation of water from Lauder and Thompsons Creeks under water rights held for the Omakau scheme is not possible due to physical separation and the level of the proposed main race, but these streams could provide a useful supplement to the Manuherikia River and the requirements of the Galloway scheme. However lifting of water from the various tributaries of Chatto Creek would be possible using rights currently held but leased on short term basis to a farmer in this area for irrigation purposes.

In assessing water availability, allowance has been made for the maintaining of a residual minimum flow of 1 m^3/s in the Manuherikia River and for abstraction from Dunstan Creek to cease at a flow of 0.5 m^3/s.

5 IRRIGABLE AREAS

Although the proposed main race would command some 30 000 ha, the water available from the Manuherikia River itself is only sufficient to irrigate some 21 200 ha. With the 500 ha served by the Blackstone Hill race, and an area of 1200 ha on the Galloway scheme served by water from the Manuherikia River, the irrigable area which can reasonably be served by the proposed scheme is about 19 500 ha. A further 1200 ha could be served by the subsidiary race from Dunstan Creek.

In terms of the sub-areas used in assessing water requirements, the irrigable area under the proposed scheme would be as follows:

(i) 5300 ha in the Lauder-Dunstan and Downs Settlement areas compared with an existing irrigated area of approximately 2280 ha much of which suffers supply deficiencies.

(ii) 9500 ha in the Omakau Basin south of Lauder Creek where approximately 5400 ha is currently irrigated but with some deficiencies in supply in drier years.

(iii) 1200 ha in the Moutere area across the heads of Chatto Creek where some 1000 ha are currently irrigated but in a very restricted and limited manner.

(iv) 3700 ha in the lower part of the valley (but excluding the Dunstan Flat) where there are 1800 ha currently irrigated but much with inadequate supply.

To keep within these irrigable areas, some arbitrary limitations on the areas on, and hence the water provided to, individual properties must be applied. These are to be on the basis of a maximum irrigated area of 290 ha but with the provisos that water may be spread at a lower depth over a greater area where a suitable management strategy is adopted and that no farmer shall have a lesser area than he is currently fully irrigating. Areas are of course subject to the soils and topography being such as to allow their classification as irrigable.

... ...

6 COSTS

The preliminary unassessed cost of the proposed scheme at cost index 1300 is:

Headworks including Falls Dam, main race intake, and main race to and across Dunstan Creek	10 930 000
Distribution Works including main race from Dunstan Creek, controls, turnouts and distributary races	5 620 000
On-farm works including new fixed development and upgrading of existing on-farm works at an average of $460/ha	8 970 000
	$25 520 000

19 500 ha. ROC

or $1308/ha over 19 500 ha.

Inclusion of the subsidiary race from the Dunstan Creek and its associated irrigable area (1200 ha) and the Blackstone Hill race (500 ha) would increase these costs by:

	Dunstan Race	Blackstone Hill
Headworks	530 000	130 000
Distribution Works	740 000	480 000
On-farm Works	650 000	210 000
	$1 920 000	$820 000
	1200	500
Unit Costs	$1600/ha	$1640/ha

This then gives an overall scheme cost at cost index 1300 of $28.26 million or $1353 per irrigable ha, of which $3.42 million is recoverable through water charges. At an interest rate of 9% (F = 0.13199) this indicates a basic water charge of $21.29 per ha. ← total

21 200

(42.30)

Annual operation and maintenance costs of the proposed scheme with a staff of 6 racemen is estimated at $8.40 per irrigated ha or a total of $178 000. In addition a contribution of $2.00 per ha is required each year to provide for future renewals.

7 WATER CHARGES

The large variation in water requirements for different areas covered by the proposed scheme creates problems in determining an equitable water charge if normal procedures are followed.

$5.8M

Calculations in accordance with the Public Works Amendment Act 1975 give a basic charge of say \$21.30 per ha and a water availability charge of \$6.00 per 1000 m^3. Over the four sub-areas within the proposed scheme this gives total average annual costs of:

(i) \$18.00 per ha for 300 mm in the Downs, Lauder, Dunstan area.

(ii) \$27.00 per ha for 450 mm in the Omakau and Blackstone Hill area.

(iii) \$36.00 per ha for 600 mm in the Moutere-Chatto Creek area.

(iv) \$63.00 per ha for 1050 mm in the lower Manuherikia Valley.

Since this arrangement means that the high usage areas carry the greater part of the annual operation and maintenance costs, with the lower usage areas contributing little or nothing, it is felt to be an unequitable basis of charge.

An alternative is to treat each of the sub-areas virtually as separate irrigation schemes with all costs spread pro rata. This will give the same basic charge as previously (ie \$21.30 per ha) but will give water availability charges in each of the sub-areas of:

(i) \$10.50 per 1000 m^3 in the Downs, Lauder, Dunstan area.

(ii) \$7.00 per 1000 m^3 in the Omakau-Blackstone Hill area.

(iii) \$5.25 per 1000 m^3 in the Moutere-Chatto Creek area.

(iv) \$3.00 per 1000 m^3 in the lower Manuherikia Valley.

This places a very high penalty on the low usage areas for the extra water required to satisfy average and above average seasonal demands, while there is little constraint on the high usage areas not to use excessive water and hence to overcommit the scheme storage.

To avoid such anomolies it is necessary to work with a constant water availability charge throughout the scheme, say the \$6.00 per 1000 m^3 calculated previously, and to set the quantity or depth of water available within the basic charge. For each sub-area this would result in an average annual cost of \$31.70 per ha but with:

(i) A basic charge of \$21.30 per ha for 130 mm in the Downs, Lauder, Dunstan area.

(ii) A basic charge of \$21.30 per ha for 280 mm in the Omakau, Blackstone Hill area.

(iii) A basic charge of \$21.30 per ha for 430 mm in the Moutere, Chatto Creek area.

...

(iv) A basic charge of $21.30 per ha for 800 mm in the lower Manuherikia area.

While this is considered a fairly equitable distribution of charges throughout the proposed scheme, it still does not fully allow for the fluctuations in seasonal water usage about the average particularly in the higher usage areas. However this could only be rectified by setting the quantity of water available within the basic charge as a percentage (say 75%) of the assessed average annual requirement.

It is also felt that to avoid excessive use of water, and yet to provide for the high usage which may be required in a dry year, a penalty rate of $9.00 per 1000 m^3 should be set. This rate would apply for all water drawn in excess of a depth 340 mm above that allowed within the basic charge.

8 RECOMMENDATION

The local farmers have indicated support for this scheme through a public meeting held in Omakau on 16 June 1980 at which virtually all significant properties affected by the scheme were represented, the only dissension coming from 3 or 4 farmers in the Downs Settlement who clearly would like to remain with their present supply.

In the light of this the Otago Officials Committe on Irrigation and Rural Water Supply have received and considered the feasibility report and recommend:

(i) Favourable consideration of the proposed Manuherikia Valley scheme by the Water Resources Council.

(ii) A request be made for a formal economic report to be prepared.

(iii) A more equitable system of zoned water charges than is provided for in the Act.

R D Grant
District Commissioner of Works

per

(C J Reid)

Encl