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Manuherikia Catchment Study: Stage 2 (Hydrology)

Prepared for the Manuherikia Catchment Water Strategy Group

Report C12040/2

April 2012

AQUALINC RESEARCH LIMITED

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EXECUTIVE SUMMARY

The Manuherikia River system in Central Otago is a unique catchment in terms of climate, topography and water management history. The catchment is semi-arid, with a continental type of climate with larger seasonal temperature variations than is common elsewhere in New Zealand.

The community's long-term goal is to realise the potential growth within the region. The potential growth in the catchment is closely linked to water. It is generally believed that the growth potential is constrained by water availability for irrigation.

The Manuherikia River has a mean naturalised flow at the Clutha River confluence of 18.5 m^3/s or 585 Mm^3/y. Irrigation reduces the flow by up to 8 m^3/s, although averaged over a year the reduction is about 2.7 m^3/s or 85 Mm^3/y. In dry years, irrigation abstraction can reduce flows at the confluence to below 1.0 m^3/s. Flows in the Manuherikia River are highest from June to November, and lowest in February and March.

Currently, about 25,000 ha of the Manuherikia catchment is irrigated. Of this 25,000 ha, only about 15,000 ha is fully irrigated. Water scarcity means the remaining 10,000 ha is only occasionally irrigated, in some cases as little as 2-3 times per year. The current area of irrigation is well short of the potential 60,000 ha of irrigable land identified in the Stage 1 study.

The Manuherikia Catchment is water-short in dry years. Water scarcity means it is unlikely the full 60,000 ha of irrigable land could be irrigated with water from the Catchment alone. The availability of reliable water rather than suitable land is the primary constraint on future irrigation development.

Total water allocated within the Manuherikia catchment is over 27 m^3/s and is several times in excess of the water available during low flow periods. Actual water use is closer to 8 m^3/s during periods of peak irrigation demand. Actual water use is much less than the consented allocation, because often the consented flow is unavailable. There is no remaining reliable run-of-river water. Therefore, any new irrigation water will need to come either from efficiency improvements, the Clutha River, or from new storage dams.

Improvements in irrigation efficiency will achieve only a modest increase in the irrigated area. Improvements in efficiency in the lower Manuherikia catchment below Ophir, would allow at most an additional 2,000 ha of irrigation. Above Ophir, any improvements in efficiency will not make additional water available for irrigation. The reason is because overall irrigation efficiency above Ophir at a catchment scale is already very high because any losses re-enter the Manuherikia River and are available for downstream use by the Manuherikia and Galloway irrigation schemes.

While on-farm efficiency improvements above Ophir will not increase catchment scale efficiency, it will improve water quality by reducing the amount of wipe-off water re-entering natural waterways.

Water from the Clutha River would potentially allow for 4,000 – 8,000 ha of new irrigation in the lower Manuherikia Valley. The area that can be irrigated from the Clutha River is primarily limited by land area rather than water availability. Land area is constrained by elevation and conveyance costs.

Existing dams provide about 36 Mm^3 of stored water per year. This is about 7% of the average annual flow of the Manuherikia River at the Manuherikia/Clutha confluence. The majority of usable storage is provided by the Falls, Pool Burn, and Upper Manor Burn dams. Usable storage in Falls Dam is limited by the dam's height. Raising the dam 30 m could create an additional 90 Mm^3/y of usable stored water. Usable storage in the Pool Burn and Upper Manor Burn dams is primarily limited by inflows and raising these dams will not make more water available.

New storage is likely to be most cost effective from natural dam sites. Natural dam sites are generally characterised by a gorge or narrow valley that has a flat valley or basin upstream. These sites also require reliable inflows to refill the dams each year. The study area contains a number of promising sites. Potentially up to 20,000 to 25,000 ha of new irrigation could be supplied from new storage dams.

The Ida Valley is more water short than the Manuherikia Valley. The valley has a number of promising options. An out of catchment transfer from Hopes Creek could potentially increase the water supply to the Ida Valley Irrigation Scheme by 70%. A mid-sized dam near Mt Ida could potentially supply 1,500 ha of new irrigation.

The Manor Burn currently has little abstractive pressure on an annual basis. There is also a number of promising natural dam sites within the Manor Burn catchment. Development of one or more of these dam sites would allow the Galloway Irrigation Scheme to be gravity supplied exclusively from the Manor Burn, thereby freeing up valuable Manuherikia River water.

1 Background

The Manuherikia River system in Central Otago is a unique catchment in terms of climate, topography and water management history. The catchment is semi-arid, with a continental type of climate with larger seasonal temperature variations than is common elsewhere in New Zealand.

The community's long-term goal is to realise the potential growth within the region. The potential growth in the catchment is closely linked to water. It is generally believed that the growth potential is constrained by water availability for irrigation.

The Manuherikia Catchment Water Strategy Group (MCWSG) was set up to develop and oversee the implementation of a water strategy for the catchment. The MCWSG has proposed that a project be undertaken in three sections to:

(i) Define the potential irrigation demand in the Manuherikia River catchment (land),
(ii) Provide an initial assessment of the water availability for meeting this demand (hydrology), and
(iii) Options to close the gap between supply and demand (options).

The project has been broken into two parts, Part A (Sections (i), (ii) and (iii a)) and Part B (Section (iii b)). Part A provides the initial big-picture information to understand the overall water resources in the catchment. Part B looks in more detail at specific options to progress water resources development. The MCWSG envisages that the project will provide information to help the community make informed decisions, leading to a comprehensive Manuherikia catchment water strategy.

Aqualinc has been contracted to complete Part A of the project. This report summarises the findings for Section (ii), and describes the hydrology of rivers, storage dams, and irrigation.

The study area includes the Manuherikia catchment, and the Waikerikeri catchment to Dairy Creek, since for some of the potential development options there is an overlap between the lower reaches of the Manuherikia catchment and the Waikerikeri catchment.

2 General methodology

This study (Part A (ii)), includes the collation, analysis and presentation of hydrological information for the Manuherikia Catchment. Catchment hydrology is complex because natural river flows have been significantly altered by irrigation and storage dams. Where data was unavailable, we have taken a pragmatic approach in estimating flows and volumes. The lack of water abstraction and bywash records meant we have relied on irrigation manager estimates of water use and reliability. Future studies may refine these estimates.

3 River flows

The Manuherikia River has a mean naturalised flow at the Clutha River confluence of 18.5 m^3/s or 585 Mm^3/y. Annual volumes vary from 280 Mm^3 in a very dry season to over 1,000 Mm^3 in a wet season (see Figure 1). The major tributaries of the Manuherikia River are the Manuherikia above Falls Dam, the Pool Burn, Dunstan Creek, Manor Burn, Lauder Creek, Thomsons Creek and Chatto Creek. Collectively these tributaries provide almost 90% of the total catchment flow (see Figure 2 and Table 1).

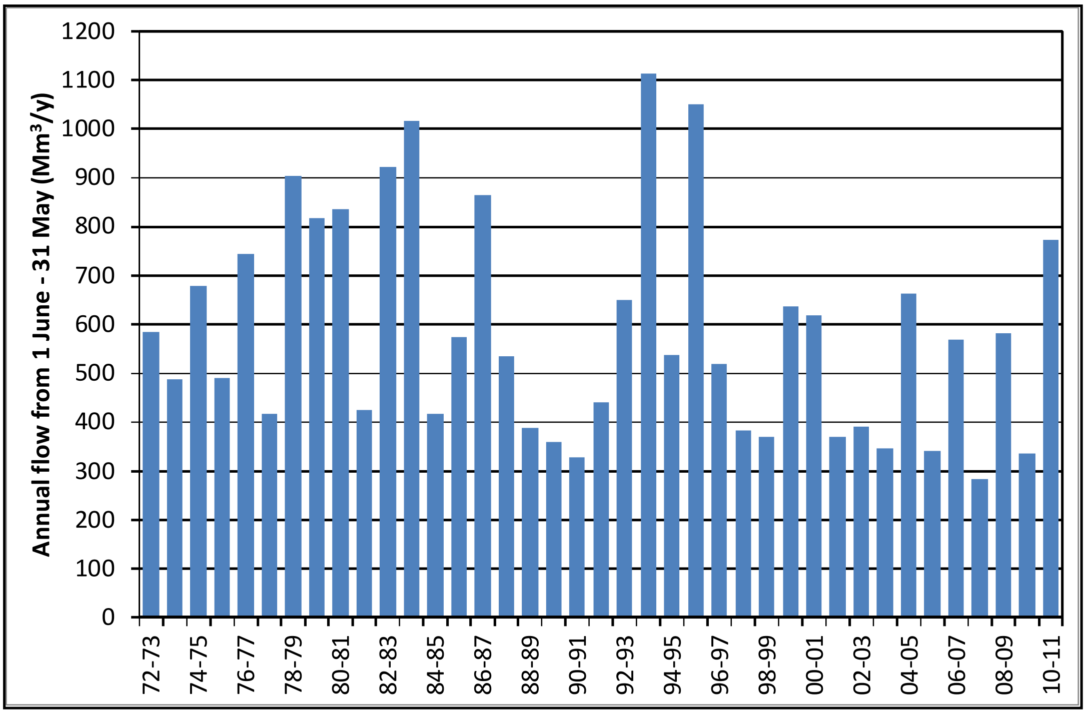

Figure 1: Manuherikia River annual naturalised flow at the Clutha confluence

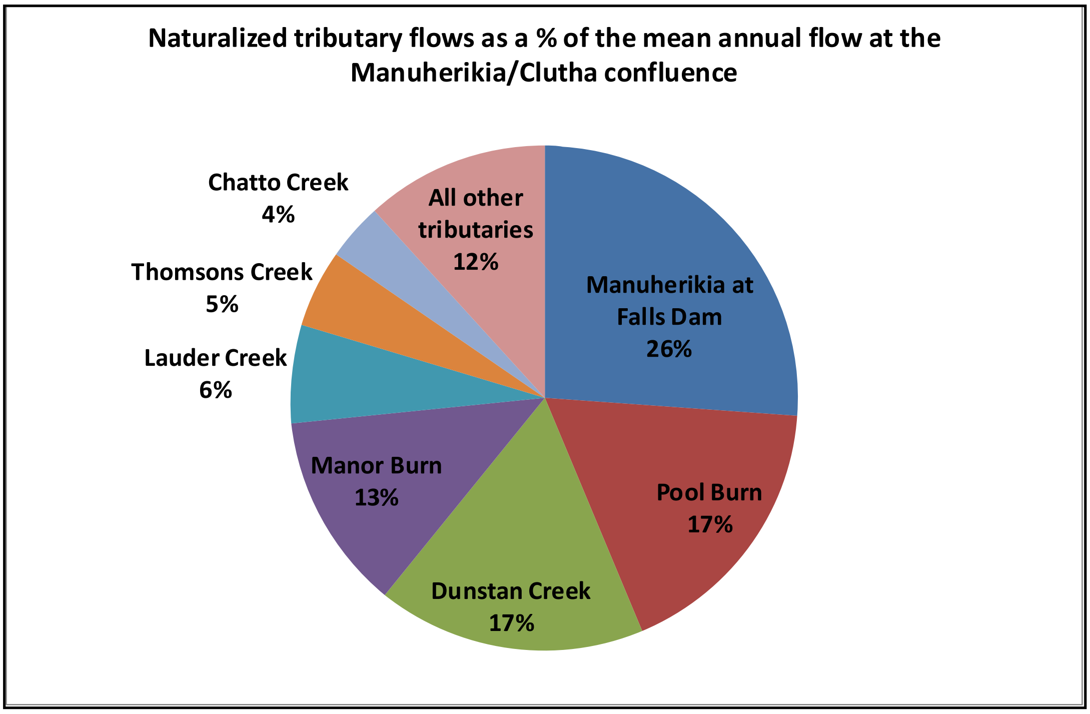

Figure 2: Naturalised tributary flows

Table 1: Naturalised tributary flows

Tributary	Catchment area (km^2)	Mean annual flow		
		m^3/s	Mm^3/y	mm/y
Manuherikia above Falls Dam	365	4.8	150	420
Pool Burn	820	3.3	100	120
Dunstan Creek	300	3.2	100	330
Manor Burn	510	2.3	75	140
Lauder Creek	150	1.2	40	250
Thompson's Creek	160	0.9	30	180
Chatto Creek	165	0.7	20	130
All other tributaries	555	2.2	70	120
Total	**3,025**	**18.5**	**585**	
(1) Mean annual run-off ÷ catchment area × units conversion.				

Abstraction for irrigation reduces flow by up to 8 m^3/s, although averaged over the year the reduction is about 2.7 m^3/s or 85 Mm^3/y. Snow melt in the high country headwaters means flows are generally highest during September and October. Flows are lowest from January to February, when evapotranspiration rates exceed rainfall rates over much of the catchment (see Figure 3).

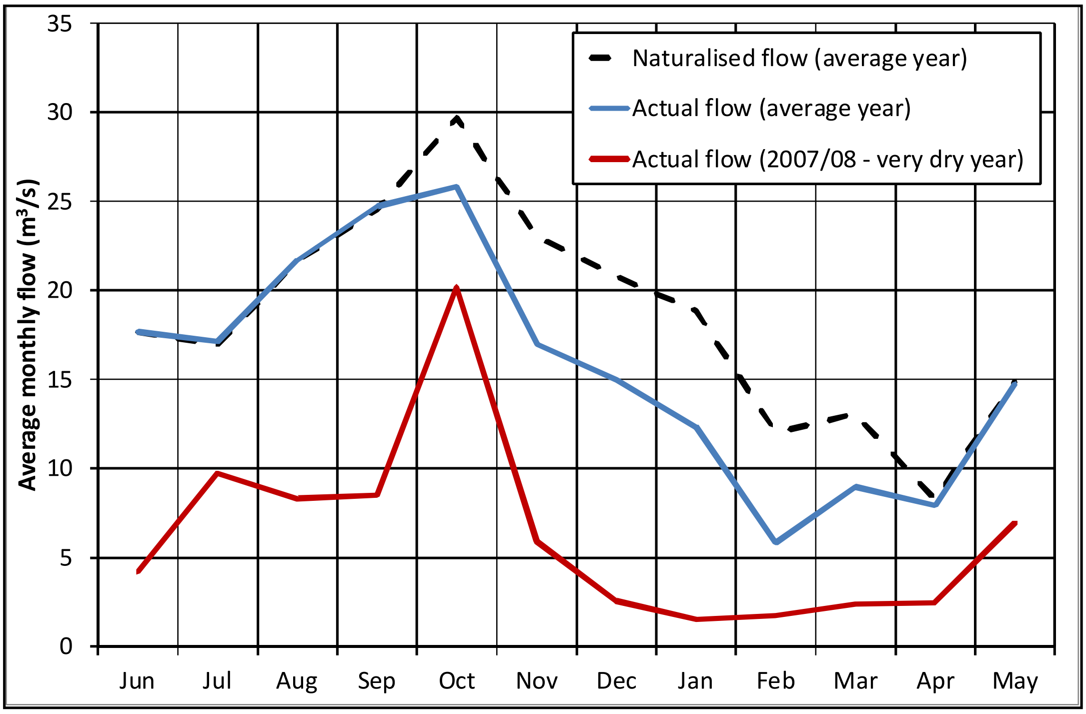

Figure 3: Seasonal flow pattern (Manuherikia River at Clutha River confluence)

Further information on river flows is provided in Appendix A.

4 Water availability

Water availability is the amount of water available for abstractive use. Water availability depends on the actual water flowing in a stream or river, and on the amount of water than must remain in the waterway in order to meet environmental and cultural values.

4.1 Proposed residual flows

Currently, most water consents do not contain minimum flow or flow sharing conditions and consequently the amount of water available for abstraction can be up to the entire flow of a particular stream. Otago Regional Council (ORC) are proposing to impose residual flow conditions on deemed permits when these are converted to RMA consents. Indicative residual flows are given in Table 2. These proposed residual flows have not been through the formal RMA consultation process and therefore could change.

Table 2: Indicative residual flows.

Stream or river	Summer (Sept –Apr)		Winter (May –Aug)	
	Residual flow (l/s)	IFIM summer value	Residual flow (l/s)	IFIM winter value
Manuherikia at Campground	1,000	Adult trout	4,500	Optimum adult spawning
Chatto Creek	25	Juvenile trout	50	Juvenile trout
Thomsons Creek	25	Roundhead galaxias	50	Juvenile trout
Lauder Creek	25	Juvenile trout	50	Juvenile trout
Dunstan Creek	200/300[1]	Juvenile/adult trout	450	Optimum adult spawning
Lower Pool Burn	0?[2]		450	Optimum adult spawning

(1) No decision has been made on whether to use juvenile trout (i.e. minimum flow 200 l/s) or adult trout (minimum flow 300 l/s).
(2) Yet to be decided. In general Pool Burn tributaries which would not naturally go dry would be subject to residue flow conditions.

At a Manuherikia catchment scale, the proposed minimum flows will likely have a relatively minor impact on the water currently available for irrigation. This is in part because abstractors generally voluntarily leave some water at the Manuherikia main-stem and Dunstan Creek. Minimum flows are generally low compared to naturalised low flows, consequently most of the water currently available to irrigators during low flow periods would still be available. Furthermore, the additional water left in the Dunstan Mountain tributaries (i.e. Dunstan, Lauder, Thomsons and Chatto Creek) will help provide the additional flow necessary to meet the lower Manuherikia River 1,000 l/s minimum flow.

Proposed minimum flows will have the greatest impact on irrigators supplied from Dunstan, Lauder, and Thomsons Creek. These tributaries are already unreliable in dry periods and any additional reduction in available flow will impact on irrigators. Part of the water that is taken from these rivers is a bywash flow. One potential way for irrigators to reduce the impact of the proposed residual flow is to minimise bywash losses by using automatic flow gates and buffer ponds, thereby allowing existing bywash flows to remain in the river.

4.2 Available water on a weekly basis

On paper, the Manuherikia Catchment is heavily over-allocated on a daily and weekly basis. The Manuherikia River's natural low flow is only 4.2 m^3/s at the Clutha confluence (ORC 2006); well less than the 27 m^3/s of flow allocation currently consented and 16 m^3/s peak irrigation abstraction (see Section 6.2). Therefore, any new irrigation water will need to come either from efficiency improvements, the Clutha River, or from new storage dams.

4.3 Available water on an annual volumetric basis

On an annual volumetric basis, there is potentially additional Manuherikia Catchment water still available. This water would need to be stored in dams, because it is generally available either outside of the irrigation season, or in spring when irrigation demands are low and river flows are highest. In a 1 in 10 dry year the total annual flow at the Manuherikia/Clutha confluence is about 350 Mm^3 (refer Figure 1). Averaged over the year this equates to 11 m^3/s. Of this 350 Mm^3, not all of this water is available for irrigation use, since some of this water must remain in the rivers to provide for minimum flows and natural flow variability.

If we assume in a 1 in 10 year drought that 60% of the water on an annual basis is available for abstractive use and 40% must be retained in the rivers to provide for natural flow variability, about 210 Mm^3/y would be available for irrigation.

We estimate in a 1 in 10 year drought that net irrigation use is currently about 90 Mm^3. This would indicate a further 120 Mm^3/y [210 – 90] may be available in winter and spring provided new storage is constructed. Table 3 and Figure 4 provide an indicative estimate of which sub-catchments this water may be available from.

Table 3: Indicative available flow by sub-catchment

Sub-catchment[1]	Total runoff [2] (Mm^3/y)		Available[3] (Mm^3/y)		
	Average year	1 in 10 yr drought	Existing	Potential[4]	Total[5]
Mt Ida Race[6]	8	5	5	0	5
Ida Valley[7]	128	72	27	15	42
Upper Manuherikia Valley	342	208	50	75	125
Lower Manuherikia Valley	107	65	8[(8)]	30	38
Total	**585**	**350**	**90**	**120**	**210**

(1) Refer Figure 5.
(2) Total annual catchment run-off.
(3) Annual volume available for irrigation [net] use in a 1 in 10 year drought.
(4) Potential new winter and spring water from new storage
(5) 60% of the total runoff in a 1 in 10 year drought
(6) Mt Ida Race water that leaves the Manuherikia catchment
(7) Includes the Upper Manor Burn dam catchment, since this now flows into the Ida Valley
(8) Most Lower Manuherikia water used for irrigation has its origins in the upper Manuherikia catchment

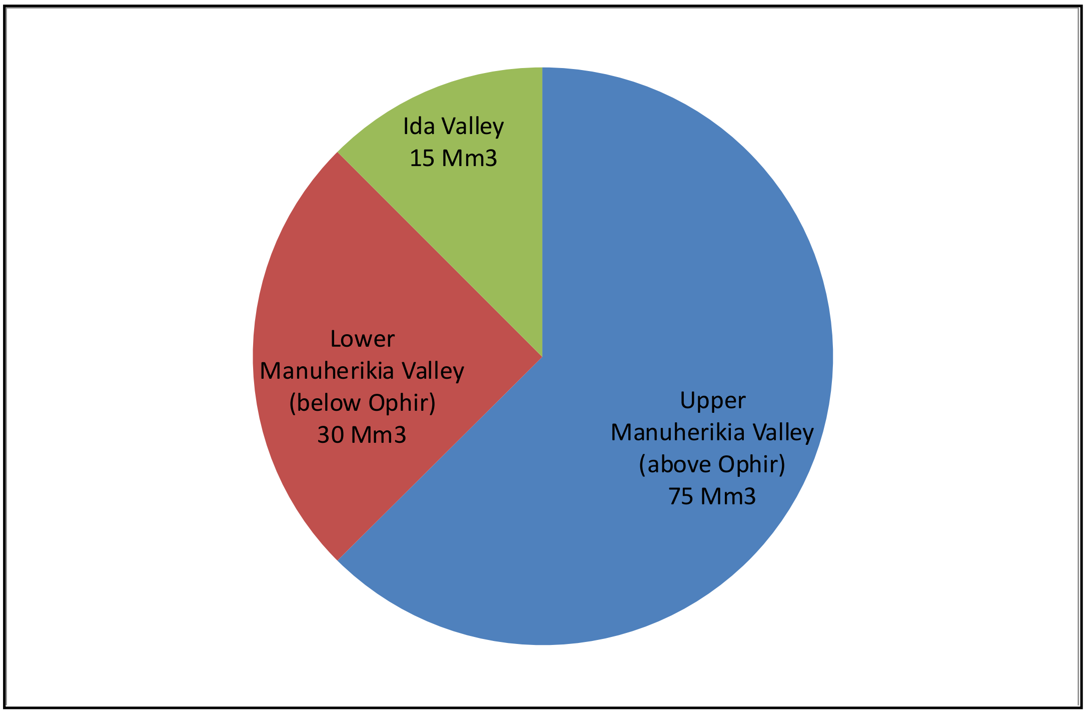

Figure 4: Indicative potential new winter and spring water from new storage

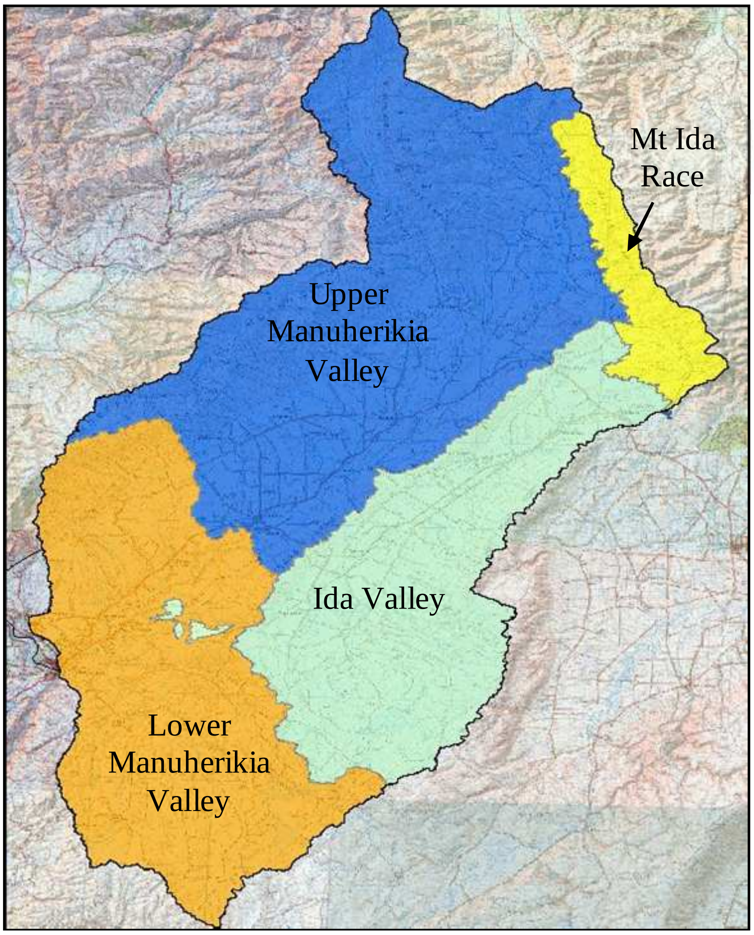

Figure 5: Sub-catchments

Figure 4 illustrates that most of the potential new winter and spring stored water is from the Upper Manuherikia Valley. In the Lower Manuherikia Valley the majority of the potential new stored water is associated with the under-utilized Manor Burn catchment. In the Ida Valley most of the potential new stored water is associated with the Ida Burn catchment rather than the southern Pool Burn catchment, which is already heavily utilized.

5 Existing storage dams

There are three main storage dams in the study area: Falls, Pool Burn, and Upper Manor Burn. These three dams account for the majority of the catchment stored water capacity. Collectively, these dams provide about 32 Mm^3 of usable storage per year. There are also over 100 smaller irrigation dams that collectively provide about 4 Mm^3 of usable storage per year (see Table 4). In total about 36 Mm^3 of stored water (7% of the average annual flow at the Manuherikia/Clutha confluence) is available for use each year.

Table 4: Existing storage dams

Name	Capacity (Mm^3)	Mean inflow (Mm^3/y)	Usable annual storage (Mm^3/y)
Falls	10	150	10
Pool Burn	28	5	5
Upper Manor Burn	51	17	17
All other dams	4*		4*
Total			36
*Approximate estimate only			

Falls Dam usable annual storage is limited by the dam's storage capacity, not lake inflows. This is because inflows into Falls Dam are much greater than the dam's storage capacity, which means the dam always fills to capacity every year. For the Pool Burn and Upper Manor Burn, the annual inflows into the dams are much less than the storage capacity. Consequently, these dams do not fill to capacity every year (refer Figure 6 and Figure 7), and it is the annual inflow that limits the usable annual storage.

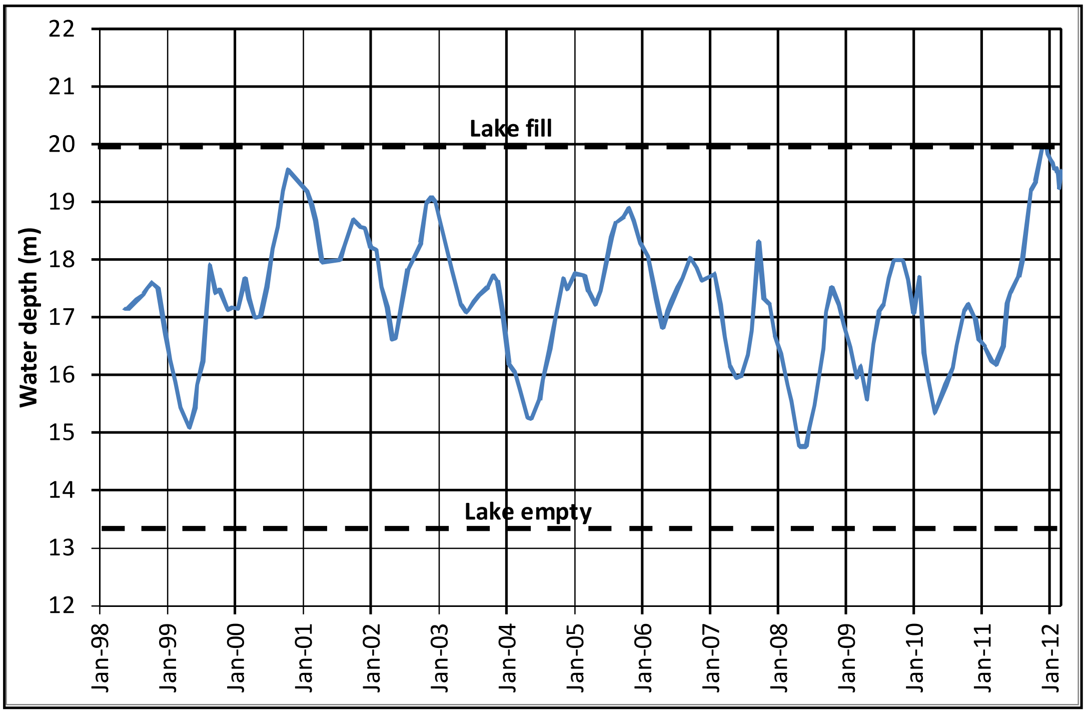

Figure 6: Historical Pool Burn lake levels

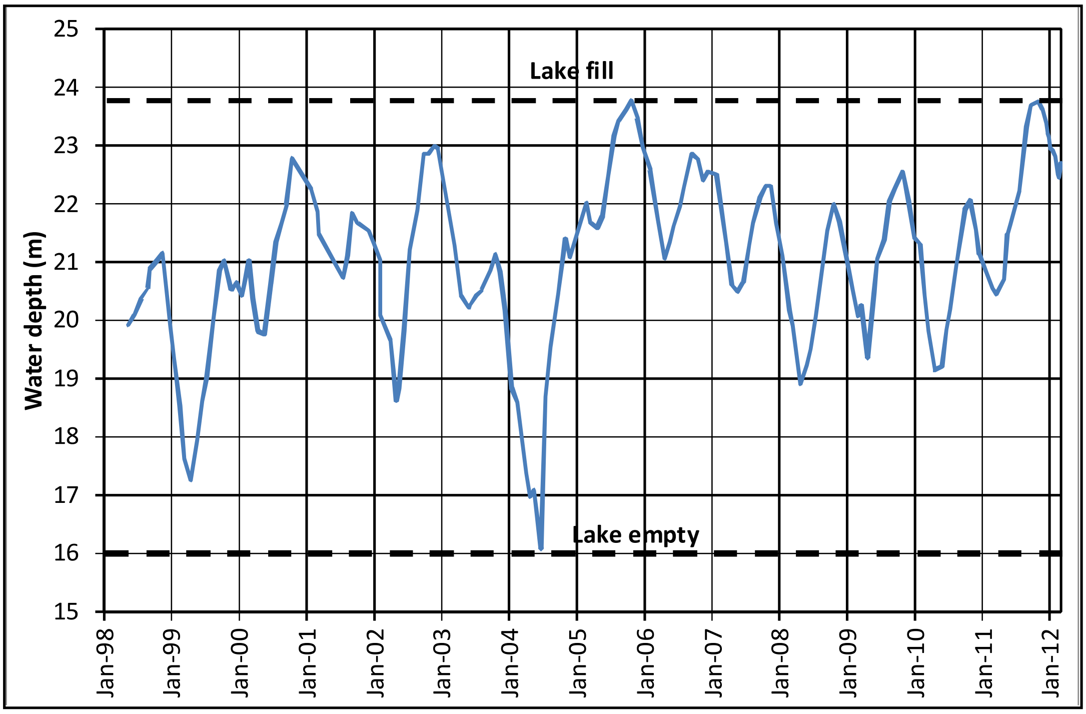

Figure 7: Historical Upper Manor Burn lake levels

Most of the other small irrigation dams are able to be filled every winter, and are primarily limited by storage capacity, not annual inflows.

Storage estimates for the irrigation schemes, as a proportion of their annual water use, is given in Table 5. Storage volumes for the schemes supplied from Falls Dam were calculated as the storage capacity of Falls Dam (10.3 Mm^3) multiplied by the scheme's share in Falls Dam. Table 5 illustrates that the Manuherikia Valley irrigation schemes source most of their water on a run of river basis. Stored water from Falls Dam only provides 10-15% of their water. In contrast, the majority of water for the Ida Valley irrigation scheme is supplied from storage.

Table 5: Stored water for irrigation schemes as a proportion of total use

Irrigation scheme	Annual use (Mm^3)[1]	Storage	
		Mm^3	% of annual use (mm/y)
Blackstone	4	0.6	15%
Galloway	6	0.8	10%
Ida Burn dam	0.6	0.2	35%
Ida Valley	25	22.0	90%
Omakau	45	5.5	10%
Manuherikia	36	3.6	10%

(1) Average annual water use. Includes scheme distribution losses. Estimates based on discussions with scheme managers.

Further information on storage dams is given in Appendix B.

6 Existing irrigation

6.1 Irrigation practices

About 25,000 ha is irrigated within the study area in any given year (see Table 6). Of this 25,000 ha, only about 15,000 ha is fully irrigated. Water scarcity means the remaining 10,000 ha is only occasionally irrigated, in some cases as little as 2-3 times per year. Deficit irrigation is particularly common in the Ida Valley where water is spread very thinly. Surface irrigation (predominately contour irrigation) is still the dominate method of applying water on-farm.

Table 6: Irrigated areas and irrigation system types

Scheme	Area irrigated[1] (ha)	% of area by irrigation type		
		Spray	Borderdyke	Contour
Blackstone	800	30%	0%	70%
Galloway	530	30%	20%	50%
Hawkdun - Ida Burn (within Ida Valley)	1,000	20%	0%	80%
Ida Valley	10,500	20%	30%	50%
Omakau	8,300	20%	20%	60%
Manuherikia	2,200	20%	20%	60%
Private water rights in Manuherkia Valley[2]	1,200	20%	20%	60%
Private water rights in Ida Valley[2]	500	20%	20%	60%
Total	**25,000**			

(1) Actual irrigated area estimated from scheme managers and aerial photographs. May include private water rights within the command area.
(2) Indicative only. Actual irrigated area and water use of private water rights were not investigated in detail.

Water practices vary across the study area, depending on the scarcity of water and whether water is from storage or run of river. Broadly, irrigation practices can be categorised into one of four main areas: (1) land supplied from one of the Manuherikia valley irrigation schemes (Blackstone, Omakau, Manuherikia, and Galloway); (2) land supplied from the Ida Valley irrigation scheme; (3) land supplied from Ida Burn race water or Ida Burn dam; and (4) private water rights. Some typical characteristics of these areas are:

Manuherikia valley irrigation schemes

- Water is predominately run of river (10-15% of water comes from storage).
- Water is reasonably reliable.
- Water is sold on a flow rate basis (i.e. water use early in the season does not affect allowances later in the season).
- Farmers irrigate a larger area in spring when flows are available, and concentrate water on a smaller primary area during restrictions.
- Typically land is irrigated every 2-3 weeks.

Ida Valley irrigation scheme

- Water is predominately from storage
- Water is sold on a seasonal volume basis
- Land is often only sparingly irrigated with 4-6 weeks between waterings typical. Some areas may only receive 2-3 waterings per year.

Ida Burn race water and Ida Burn dam

- Water is predominately run of river
- Reliability is very poor
- Water is sold on a flow rate basis (i.e. water use early in the season does not affect allowances later in the season).
- Farmers irrigate a larger area in spring when flows allow, and concentrate water on a smaller primary area when less water is available.
- Land is often only sparingly irrigated with 4-6 weeks between waterings typical. Some areas may only receive 2-3 waterings per year.

Private water rights

- Reliability varies widely, depending on deemed permit priorities. Some water rights have good reliability. For other water rights the water may only be available in winter.
- Some water rights rely on irrigation runoff water (i.e. Pool Burn irrigators), and therefore are/will be negatively impacted by upstream improvements in irrigation efficiency.

6.2 Actual verses consented water use

Water consents for irrigation total over 27 m^3/s. The vast majority of this allocation is either mining rights, or mining rights that have been converted into RMA consents. Actual consumptive use is much less than consented use because:

(1) Often the water available in streams or creeks is much less than the consented take;
(2) Often water use is double counted since irrigation drainage water is generally used further downstream;
(3) Historical agreements can limit takes to less than consented volumes; and
(4) Infrastructure can limit takes to less than consented volumes;

Table 7 provides our estimate of actual water use based on discussions with irrigation scheme managers, and a review of consents and available flow data. We estimate the maximum combined take during the irrigation season when river flows are good is about 16 m^3/s or 60% of the consented allocation. The majority of the time the combined take will be less than 16 m^3/s. We estimate only about 11 m^3/s is reliably available 90% of the time during the irrigation season. This includes water that is drawn from storage and re-use water from upstream irrigation drainage. During very dry periods, as little as 5-6 m^3/s may be available.

Table 7: Actual verses consented water use

Scheme	Flow (heads)		
	Consented	Peak[1]	90% reliable[2]
Blackstone	15	13.5	11.5
Galloway	26	20	15.5
Hawkdun - Ida Burn	133	38	18
Hawkdun - Ida Burn (within Ida Valley)	-	12	5
Ida Valley	220	110	50
Omakau	146	125	107
Manuherikia	123	90	90
Private water rights in Manuherkia Valley	267	140[(3)]	80[(3)]
Private water rights in Ida Valley	50	25[(3)]	10[(3)]
Total	**980 (27.7 m^3/s)**	**560 (15.8 m^3/s)**	**380 (10.8 m^3/s)**

(1) Actual peak flow rate, excluding any bywash returned to the water way within 2 km.
(2) Flow that is available for use 90% of the time during the irrigation season. Excludes any bywash returned to the waterway within 2 km.
(3) Indicative only. Actual irrigated area and water use of private water rights were not investigated in detail.

Table 8 and Table 9 present our estimates of water allocation on a per hectare basis. We have used access to reliable water as the basis for considering allocation rates, since this is more meaningful than consented allocation rates, as consented flows may be seldom available. Our estimates have not separated out scheme distribution losses; actual on-farm delivery will therefore be lower.

Table 8: Allocation of reliable water on a per hectare basis

Scheme	Command area (ha)	Irrigated area (ha)	Supply[1] (l/s)	Allocation (mm/d)[2] Over command area	Allocation (mm/d)[2] Over irrigated area
Blackstone	1,400	800	330	2.0	3.5
Galloway	800	530	440[3]	4.7	7.2
Hawkdun - Ida Burn (within Ida Valley)	6,300	1,000	140	0.2	1.2
Ida Valley	14,000	10,500	1,420	0.9	1.2
Omakau	21,000	8,300	3,030	1.2	3.2
Manuherikia	5,200	2,200	2,550	4.2	10
Total	**47,700**	**23,700**	**7,900**	**1.4**	**2.9**

(1) 90% reliable from Table 7.
(2) Supply ÷ area × unit conversion. Inclusive of scheme distribution losses
(3) Excludes the main-race 140 l/s bywash flow, which is returned to the Manuherikia River 1.3 km below the intake.

Table 9: Annual water use on a per hectare basis

Scheme	Average annual use[1] (mm/y) Over command area	Average annual use[1] (mm/y) Over irrigated area
Blackstone	300	500
Galloway	750	1,100
Ida Valley	190	240
Omakau	210	540
Manuherikia	670	1,600

(1) Annual use from Table 5 ÷ area × unit conversion. Inclusive of distribution losses

Table 8 and Table 9 show that allocation rates are lower than ORC's allocation guidelines[1] for Blackstone, Ida Valley, and Omakau irrigation schemes. For Galloway and Manuherikia Irrigation schemes, whether the daily and seasonal allocation rates are less than ORC's guidelines depends on whether the water used is spread over the actual irrigated area or the scheme command area. Spread over the actual area of irrigation, water use is higher than ORC's guidelines. However, if in the future this

[1] Refer to Aqualinc (2006). Guidelines recommend a seasonal limit of 780 – 890 mm/y for the Manuherikia Valley and 720 – 770 mm/y for Ida Valley.

water was spread over the entire command area, water use is lower than ORC's guideline values.

We estimate actual maximum consumptive water use is about 8 m^3/s (see Table 10). By consumptive use we mean water that is taken and is not reused further downstream within the Manuherikia catchment. Maximum consumptive use will most often occur in December and January, when irrigation demands are high but river flows are still reliable. Consumptive use will be lower during wetter periods (when irrigation demand is low), and during very dry periods when river flows are unreliable.

Table 10: Maximum consumptive water use

Catchment[1]	Take[2] (m^3/s)	Re-use[3] (m^3/s)		Consumptive use[4] (m^3/s)
		Within catchment	Downstream of catchment	
Mt Ida Race	0.5	0.0	0.0	0.5
Ida Valley[5]	1.7	0.3	0.0	1.4
Upper Manuherikia Valley (above Ophir)	4.8	0.5	1.5	2.8
Lower Manuherikia Valley (below Ophir)	3.8	0.3	0.0	3.5
Total	**10.8**	**1.1**	**1.5**	**8.2**

(1) See Figure 5
(2) 90% reliable take from Table 7
(3) Bywash, race leakage, and drainage water that is re-used downstream
(4) Takes minus any re-use
(5) Includes farms in the Dipton Creek catchment supplied from the Upper Manor Burn.

Consented water allocation is presented in Appendix D.

6.3 Use efficiency

Irrigation efficiency is generally defined as the proportion of abstracted water that is used to refill soil moisture. Irrigation efficiency depends both on the hydrological boundary and the time-frame being considered. For example, irrigation efficiency at a farm scale will be different to irrigation efficiency at a sub-catchment or catchment scale. Irrigation efficiency also depends on whether the time scale is periods of lowest river flows (generally January to March), the irrigation season, or the entire year. Table 11 gives our estimate of irrigation efficiency at a farm, sub-catchment and study area scale. Efficiencies are given for the period January to March, since this is the period when river flows are most critical.

Table 11: Irrigation efficiency

Sub-catchment	Irrigation efficiency		
	On-farm[1]	Sub-catchment[2]	Study area[3]
Ida Valley	60%	90%	>90%
Upper Manuherikia Valley	60%	60%	>90%
Lower Manuherikia Valley	60%	60%	60%
Ida Burn race	Not assessed. Most water is used out of catchment		
Total			

(1) Volume of water delivered to the soil root zone ÷ volume of water delivered to farms
(2) Volume of water delivered to the soil root zone ÷ (volume taken from rivers minus re-takes within Figure 5 sub-catchments).
(3) Volume of water delivered to the soil root zone ÷ (volume taken from rivers minus re-takes within the entire study area).

On-farm efficiency is generally low because surface irrigation (borderdyke and contour irrigation) are still the dominate irrigation application method in the Manuherikia catchment. We generally expect these surface systems to have an application efficiency[2] of 30- 70%, because the high variable application depth means a large portion of the water applied inevitably either runs off or drains through the soil profile. Spray systems will generally have a higher efficiency because application depths are lower and irrigators have greater control on when irrigation water is applied.

Sub-catchment efficiency is high for the Ida Valley because most irrigation drainage water is re-used for irrigation further downstream (e.g. Pool Burn irrigators). Very little irrigation water ultimately reaches the Manuherikia River from January to March.

Study area efficiency for the Manuherikia to Ophir sub-catchment is very high (over 90%). The reason is because all scheme and on-farm water losses drain back into the Manuherikia River. This water is then re-used by the Manuherikia and Galloway irrigation schemes.

[2] Application efficiency is the volume of water applied divided by the volume of water retained within the root zone.

We estimate irrigation efficiency for the Manuherikia: Ophir to Clutha sub-catchment is about 60%. The reason is because most scheme and on-farm losses are not reused downstream.

7 Potential irrigation demand

In Stage 1 (Aqualinc 2012) we identified 60,000 ha of potentially irrigable land (see Table 12). Of this area about 25,000 ha is currently irrigated, although only about 15,000 ha is fully irrigated.

Table 13 presents the gross irrigation demand required to irrigate all the potentially irrigable land, assuming all irrigation (new and existing) is 80% efficient and irrigation distribution losses are less than 5%. The gross irrigation demand is the amount of water applied to land.

Even with efficient irrigation, there will be some increase in drainage downstream of irrigated land compared with unirrigated land. In the Manuherikia catchment, any additional drainage water re-entering the Manuherikia River upstream of Ophir would be available for downstream abstraction by the Manuherikia and/or Galloway irrigation schemes and therefore could be re-used. Net irrigation is the gross water demand minus any water available for re-use. Net irrigation demand by sub-catchment is given in Table 14.

Table 12: Irrigable areas by sub-catchment

Sub-catchment[1]	Irrigable area (ha)
Ida Valley	19,000
Upper Manuherikia Valley	26,000
Lower Manuherikia Valley	12,000
Waikerikeri Creek	3,000
Total	**60,000**
(1) Refer Figure 5	

Table 13: Gross water demand for irrigable land

Sub-catchment	Peak flow (m^3/s)	Annual volume (Mm^3/y)	
		Average year	1 in 10 dry year
Mt Ida race to Hawkdun	0.9*	8*	5*
Ida Valley	8.9	94	121
Upper Manuherikia Valley	12.1	119	155
Lower Manuherikia Valley	6.0	65	82
Waikerikeri Creek	1.6	17	21
Total	**29.5**	**303**	**384**
*Status quo			

Table 14: Net water demand for irrigable land

Sub-catchment	Peak flow (m^3/s)	Annual volume (Mm^3/y)	
		Average year	1 in 10 dry year
Mt Ida race to Hawkdun	0.9*	8*	5*
Ida Valley	7.6	70	97
Upper Manuherikia Valley	10.3	89	124
Lower Manuherikia Valley	6.0	62	78
Waikerikeri Creek	1.6	17	21
Total	**26.4**	**246**	**325**
*Status quo			

Potential irrigation demand calculations are provided in Appendix D.

8 Supply verses potential demand

The Manuherikia Catchment is already water short on a daily or weekly basis. On a daily or weekly basis, peak irrigation demands are already well in excess of the water available during low flow periods. Consequently any new run-of-river water can only come from the Clutha River.

On an annual volumetric basis there is potentially additional Manuherikia Catchment water still available. This water would need to be stored in dams for irrigation use, because it is generally available either outside of the irrigation season, or in spring when irrigation demands are low and river flows are highest.

In years of average or above average flow and average or below average irrigation demand, there is sufficient water in the catchment overall to meet net irrigation demand for 60,000 ha. However, in drought years, that is not the case.

In Section 4 we estimated approximately 210 Mm^3/y could be available for irrigation in a 1 in 10 year drought. Of this 210 Mm^3, about 90 Mm^3/y is currently used. The potential 120 Mm^3 of new winter and spring water would require new storage to be constructed.

Section 7 concluded the net irrigation demand for the full 60,000 ha of irrigable land in a 1 in 10 drought was about 325 Mm^3/y. This is well in excess of the 210 Mm^3/y available. This indicates the Manuherikia Catchment in drought years is water short on an annual volumetric basis. Consequently, reliable water availability rather than suitable land is the primary constraint on future irrigation development.

Table 15 compares the available supply with the potential irrigation demand on a sub-catchment basis in a 1 in 10 year drought. This table illustrates Ida Valley is very water short in dry years and even with new storage, less than 45% of the potential irrigation demand could be met from in-catchment water. In dry years, the Manuherikia Valley is moderately water short, with the ability to meet up to 75% of the potential irrigation demand with in-catchment water.

Table 15: Supply/demand ratio in a 1 in 10 year drought

Sub-catchment[1]	Available water (Mm^3/y)	Net irrigation demand (Mm^3/y)	Supply/demand
Mt Ida Race	5*	5*	N/A
Ida Valley	42	97	43%
Manuherikia Valley & Waikerikeri Creek	163	223	73%
Total	**210**	**325**	**65%**
(1) Refer Figure 5. *Status quo			

9 Clutha River water

The Clutha River represents a potential run of river water source for supplying parts of the lower Manuherikia catchment. The Clutha has a mean flow of 490 m^3/s at the Clyde Dam, which is over 25 times greater than Manuherikia River flows. Only a fraction of the Clutha River water has been allocated for abstractive use and consequently there is currently little abstractive pressure on the Clutha River. The area that can be irrigated from the Clutha River is primarily limited by land area rather than water availability. Land area is constrained by elevation and conveyance costs.

Supplying parts of the Lower Manuherikia catchment using Clutha River water has been discussed for many years. A recent engineering pre-feasibility study by OPUS (2010) investigated a scheme supplied from Lake Dunstan through Dairy Creek. This scheme had a design flow of 3.8 m^3/s[3], and an irrigated area of between 6,500 – 8,300 ha out of a potential command area of 10,900 ha.

OPUS (2010) proposed two irrigated area options. Option 1 had an irrigated area of 8,300 ha and would require existing Manuherikia and Galloway irrigation scheme irrigators to be supplied from the new pumped scheme. The financial challenge for existing irrigators is they would need to give up a gravity scheme with low water charges and reasonably good reliability in favour of a pumped scheme. Option 2 had an irrigated area of 6,500ha and assumed existing Manuherikia and Galloway irrigation scheme irrigators, and a reduced area of new irrigable land, would be supplied from the new scheme.

A large portion of the water used by the Manuherikia and Galloway irrigation schemes is irrigation drainage water from irrigation upstream of Ophir. The existing synergy between upper and lower Manuherikia irrigators needs to be considered when assessing the amount of area to supply from the Clutha River. Furthermore, if there is further significant irrigation development upstream of Ophir from a large storage dam, there would be a further increase in irrigation drainage water available for lower Manuherikia irrigators. The synergy with upper Manuherikia irrigators means there may be some benefit in retaining at least some of the existing Manuherikia River gravity supply to lower Manuherikia irrigators.

[3] Averaged over a 24 hour period.

10 Natural dam sites

New storage is likely to be most cost effective from natural storage dam sites. Natural dam sites are generally characterised by a gorge or narrow valley that has a flat valley or basin upstream. The site also requires reliable inflows to refill the dam each year. We identified a number of potential large and mid-sized dams from a review of topographical and hydrological information. Large dams were defined as sites with a potential of 30 Mm^3 or greater of usable annual storage and mid-sized dams were sites with a potential of 3-30 Mm^3 of usable annual storage. We have not undertaken any investigation into the engineering, environmental, or economic viability of any of these options. Our review was not exhaustive, and more suitable sites may exist. Usable annual storage estimates is the amount of stored water than can be reliability supplied 9 out of 10 years. Further information, including stage-storage relationships are provided in Appendix E.

10.1 Large dams

We identified three large natural dam sites with a potential of 30 Mm^3 or greater of usable annual storage. All of these sites are situated in the Upper Manuherikia Valley headwaters. Sites include Falls Dam (the dam would need to be raised), a dam at the start of the Dunstan Creek gorge, and a dam on Dunstan Creek near St Bathans. These sites are illustrated in Figure 8, Figure 9 and Figure 10. Indicative estimates of usable annual storage are provided in Table 16. Indicatively, 20,000 ha of new irrigation could be supplied if raising Falls Dam was feasible, or 8,000 ha of new irrigation could be supplied if one of the two Dunstan Creek sites were feasible.

Table 16: Large natural dam sites.

Dam site	Inflows (Mm^3/y)		Capacity (Mm^3)	Usable annual storage (Mm^3/y)[1]
	Average year	Dry year		
Falls Dam (raise dam)	150	100	100+	100
Dunstan Creek gorge	65	40	40+	40
Dunstan Creek at St Bathans[2]	70	45	45+	45

(1) Indicative only. Further analysis required
(2) Could not occur in conjunction with a dam at Dunstan Creek gorge because inflows limit the useable storage.

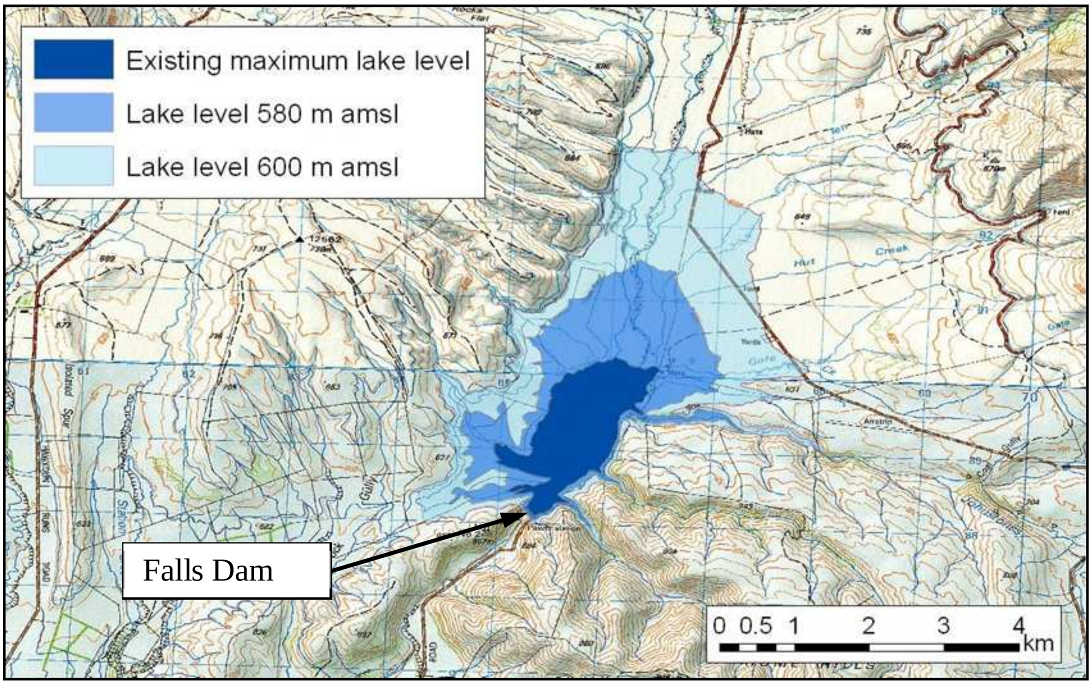

Figure 8: Natural dam site at Falls Dam

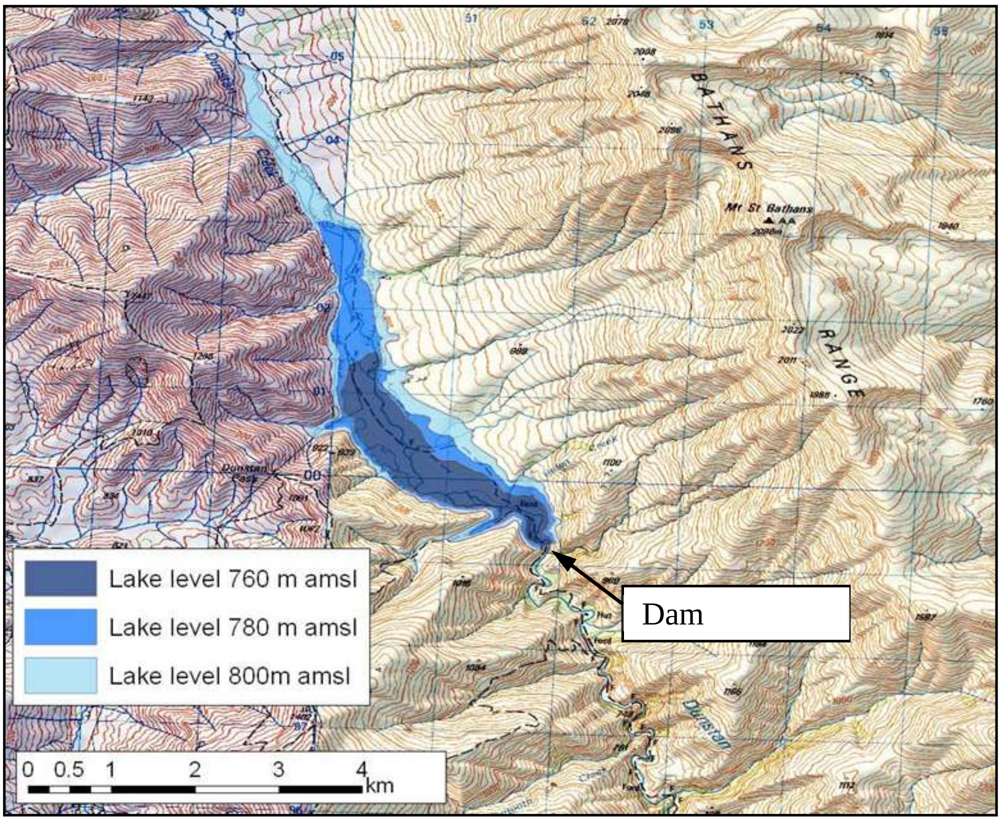

Figure 9: Natural dam site at Dunstan Creek gorge

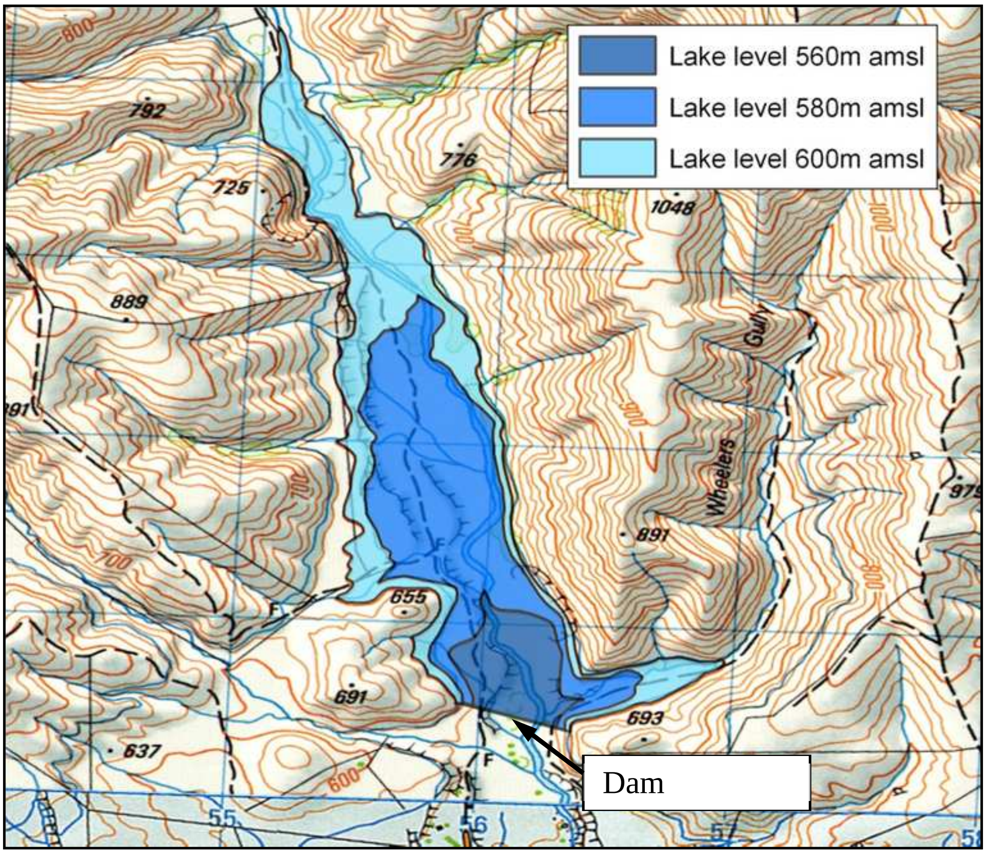

Figure 10: Natural Dam on Dunstan Creek near St Bathans

10.2 Mid-sized dams

There are a number of natural dam sites in the study area with a potential of 3 to 30 Mm^3 of usable annual storage. Below are some of the more promising sites we identified. Other suitable sites are also likely to exist.

There are a number of natural dam sites in the Manor Burn catchment (see Table 17 and Figure 11). The Manor Burn is the least utilised of the Manuherikia sub-catchments . The combination of both available annual flow and suitable storage sites suggests the Manor Burn is not water short on an annual volumetric basis. Therefore the additional area that could be irrigated from the Manor Burn from new storage is likely to be primarily limited by the area of land that can practically be supplied rather than water availability.

The Hope's Creek dam site is particularly attractive because the dam can supply the Ida Valley, which is very water short. A 9 km contour race connecting the dam outlet to the Bonanza race would be required. A small amount of pumping (<15m) may be necessary. The dam could potentially increase Ida Valley Irrigation Scheme's water supply by 70%.

Galloway Irrigation Scheme is another area that could be supplied from a new storage dam(s) in the Manor Burn catchment. This would allow the scheme to be gravity supplied exclusively from the Manor Burn, thereby freeing up valuable Manuherikia River water.

Table 17: Natural dam sites in the Manor Burn catchment.

Dam site	Height (m)[1]	Catchment area (km^2)	Inflow[2] (Mm^3/y)	Capacity (Mm^3)	Usable annual storage (Mm^3/y)[1]
Speargrass Creek	15	22	3	10	2
Little Valley Creek west	20	40	7	15	6
Lower Manor Burn (300m upstream of existing dam)	30	410	50	15	15
Hope Creek	30	90	18	20	17
(1) Indicative only. Further analysis required (2) Average annual inflow					

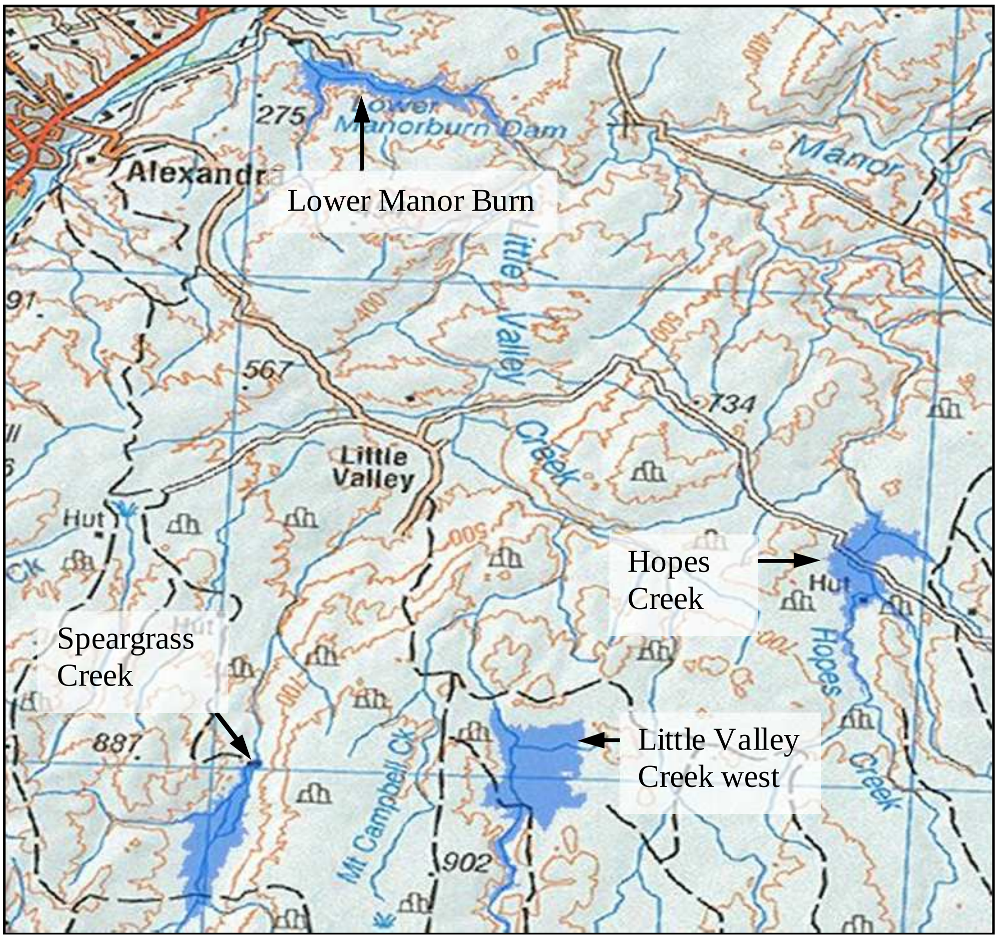

Figure 11: Natural dam sites in the Manor Burn catchment

The Ida Valley contains a mid-sized dam near Mt Ida (refer Figure 12). The dam has a storage capacity of about 15 Mm^3. Usable storage is primarily limited by inflows rather than storage capacity. Without out of catchment water the dam could indicatively provide 5-10 Mm^3 of usable annual storage. A feasibility study by Hamilton (2006) estimated that with some Mount Ida Race water about 1,500 ha of new irrigation could be supplied from this dam.

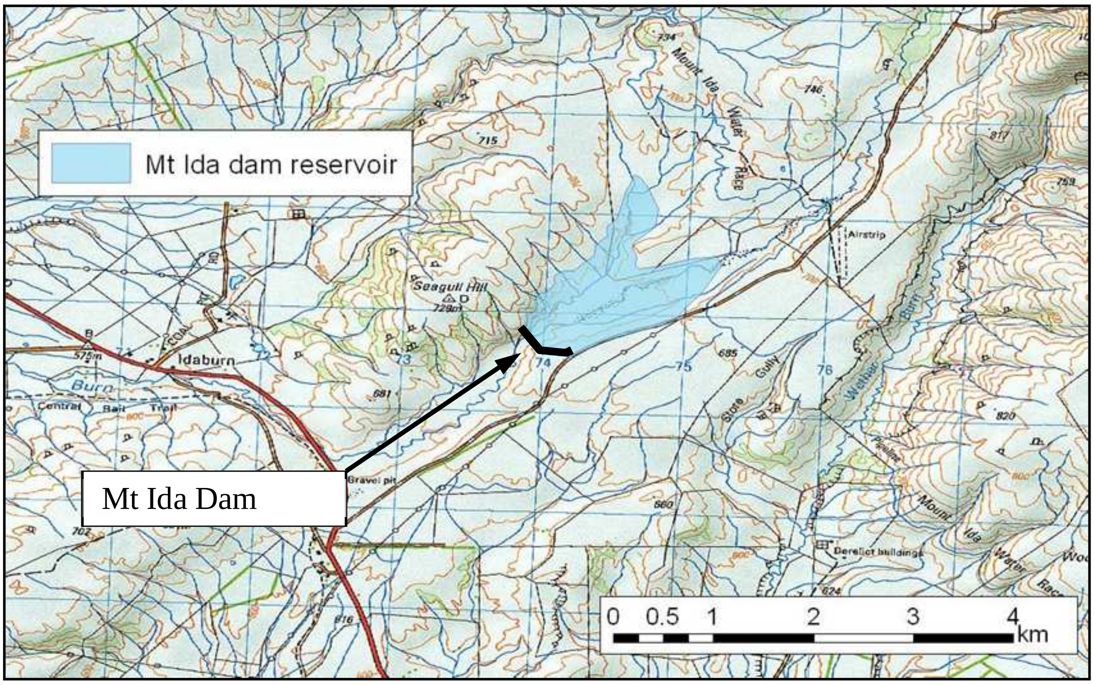

Figure 12: Proposed Mt Ida Dam

11 Conclusions

In conclusion:

- The Manuherikia River has a mean naturalised flow of 18.5 m^3/y at the Clutha Confluence.
- Existing irrigation reduces Manuherikia River flows by up to 8 m^3/s, although averaged over a year the reduction is 2.7 m^3/s.
- Currently there is 15,000 ha fully irrigated, and a further 10,000 ha partially irrigated.
- Current irrigation efficiency averages about 60% at a farm scale. However, at a catchment scale irrigation efficiency is very high, because of water re-use.
- Improvements in irrigation efficiency will achieve only a modest increase in irrigated area (2,000 ha at most).
- There is a high degree of connectivity within the catchment, with upstream irrigator behavior having a direct impact on downstream irrigators.
- There is no more run of river water available on a daily or weekly basis.
- On an annual basis, in average or wet years, the catchment as a whole has sufficient volume of water to irrigate up to 60,000 ha.
- In drier than average years, the catchment as a whole is water-short and does not have sufficient volume to reliably irrigate 60,000 ha.
- In a 1 in 10 year drought, there is potentially an additional 120 Mm^3/y of water available.
- New storage dams would need to be constructed to capture the available water volume.
- A new large 50 m high dam at the existing Falls Dam site could potentially supply an additional 20,000 ha.
- A dam on Hopes Creek could potentially increase the water supply to the Ida Valley Irrigation Scheme by 70%.
- Galloway irrigation scheme could potentially be gravity supplied exclusively from a dam within the Manor Burn catchment, thereby freeing up valuable Manuherikia River water.
- Any additional water required to make up shortfalls in dry years will have to come from other sources such as the Clutha River.

12 References

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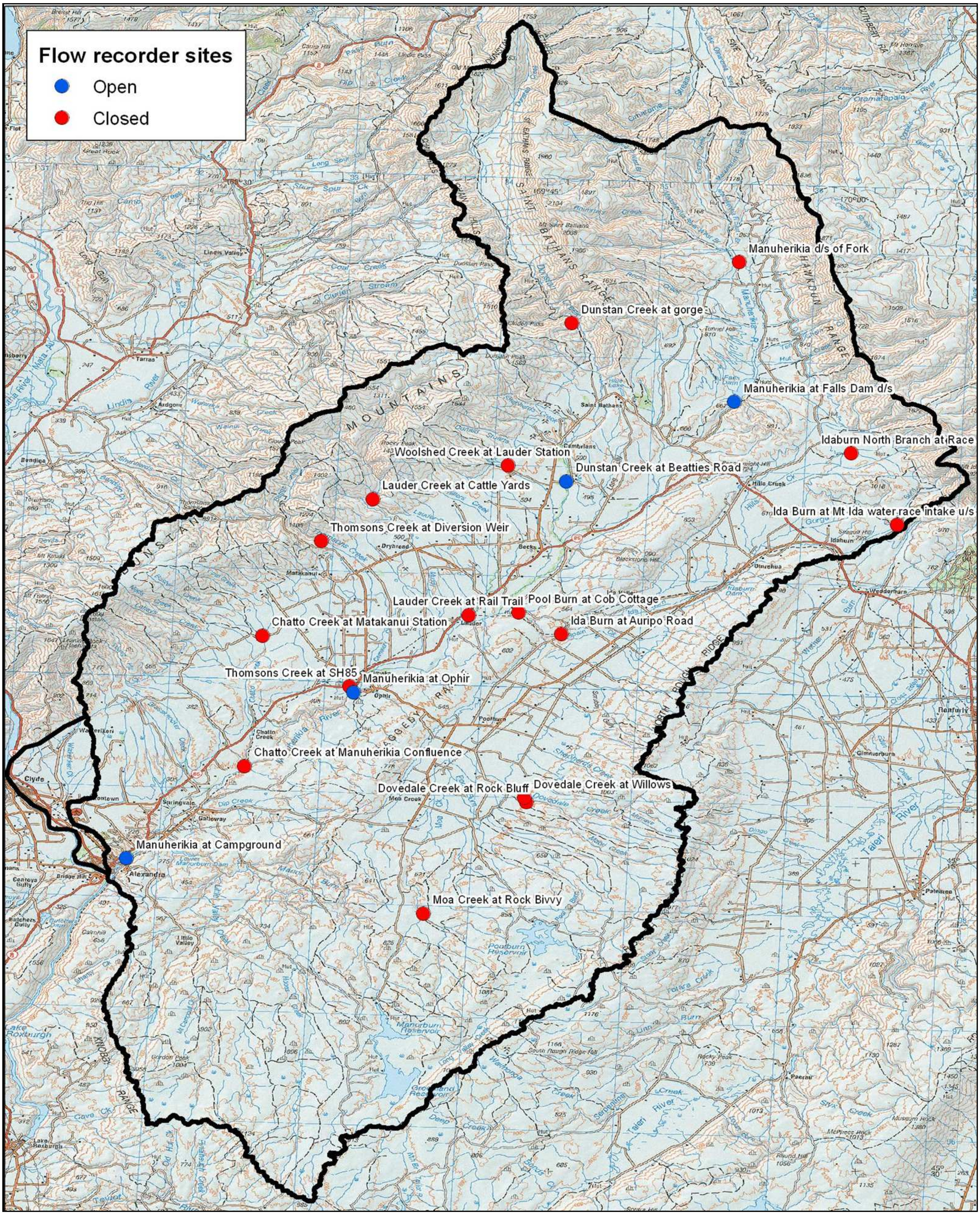
Appendix A: River flows

Flow recorder sites

Site	Start of record	End of record	Operator	Comments
Chatto Creek at Manuherikia Confluence	Aug-2009	30/09/2010	ORC	
Chatto Creek at Matakanui Station	Sep-2008	29/09/2010	ORC	
Dovedale Creek at Rock Bluff	Sep-2008	30/09/2010	ORC	
Dovedale Creek at Willows	May-1979	Sep-1987	ORC	
Dunstan Creek at Beatties Road	Nov-2002	Still operating	ORC	
Dunstan Creek at gorge	Mar-1973	Sep-2010	ORC	Gap from Apr 94 - Mar 07
Ida Burn at Auripo Road	Oct-2008	Apr-2011	ORC	
Ida Burn at Mt Ida water race intake u/s	Sep-2009	Aug-2011	ORC	
Idaburn North Branch at Race	Mar-1973	Oct-1984	NIWA	
Lauder Creek at Cattle Yards	Sep-2008	Nov-2010	ORC	
Lauder Creek at Rail Trail	Aug-2009	Sep-2010	ORC	
Manuherikia at Campground	Oct-2008	Still operating	ORC	
Manuherikia at Falls Dam d/s	Feb-1999	Still operating	NIWA	
Manuherikia at Ophir	Feb-1971	Still operating	NIWA	
Manuherikia d/s of Fork	May-1975	Sep-2010	NIWA	Gap from Jan 00 - Sep 08
Moa Creek at Rock Bivvy	Oct-2008	Nov-2010	ORC	
Pool Burn at Cob Cottage	Mar-1989	Apr-2011	ORC	Gap from Apr 94 - Mar 08
Thomsons Creek at Diversion Weir	Sep-2008	Jun-2011	ORC	
Thomsons Creek at SH85	Oct-2009	May-2011	ORC	
Woodshed Creek at Lauder Station	Dec-1972	Jan-1989	ORC	


Flow recorder sites
Open
Closed
Manuherikia d/s of Fork
Dunstan Creek at gorge
Manuherikia at Falls Dam d/s
Idaburn North Branch at Race
Woolshed Creek at Lauder Station
Dunstan Creek at Beatties Road
Lauder Creek at Cattle Yards
Ida Burn at Mt Ida water race intake u/s
Thomsons Creek at Diversion Weir
Lauder Creek at Rail Trail
Pool Burn at Cob Cottage
Chatto Creek at Matakanui Station
Ida Burn at Auripo Road
Thomsons Creek at SH85
Manuherikia at Ophir
Chatto Creek at Manuherikia Confluence
Dovedale Creek at Rock Bluff
Dovedale Creek at Willows
Manuherikia at Campground
Moa Creek at Rock Bivvy

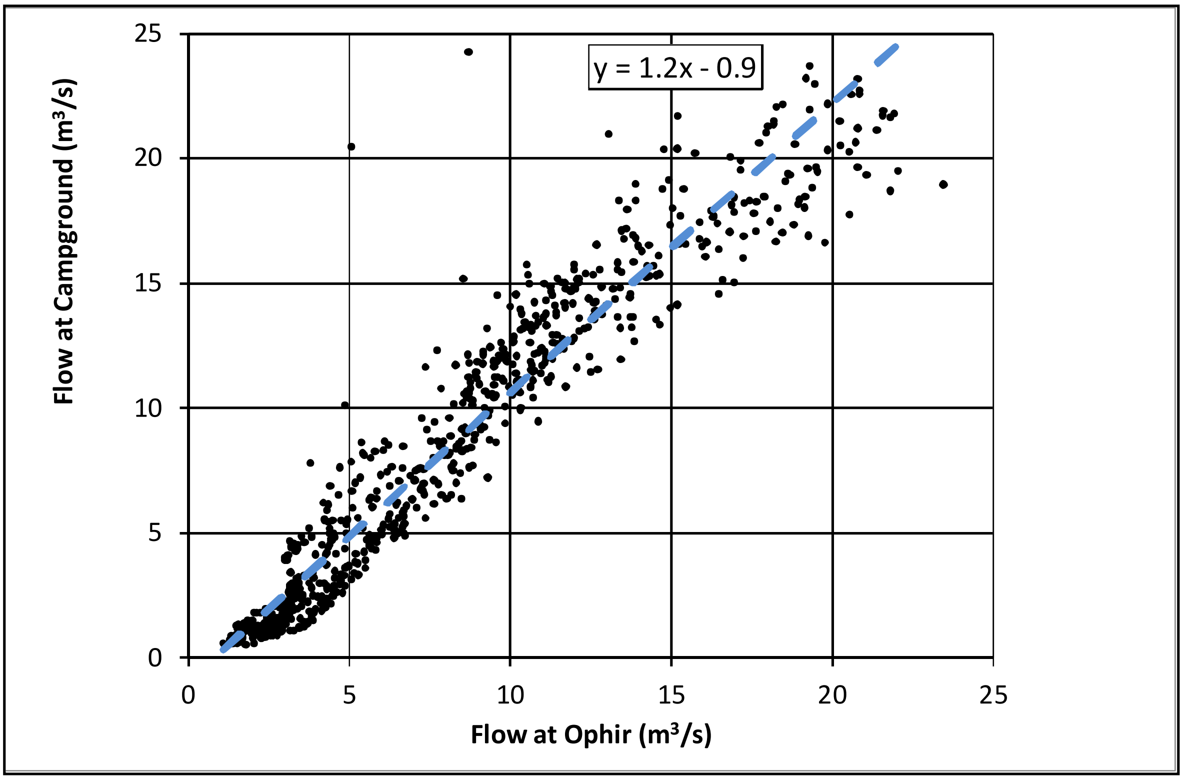
Recorded Manuherikia average monthly flow at Ophir (m^3/s)

Season	Month												Season	
	Jun	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Dec - Mar**	**Jun - May**
72-73	17.4	27.9	17.0	38.8	28.7	13.6	4.9	2.7	1.8	1.2	3.6	9.3	**2.7**	**13.9**
73-74	9.5	5.3	13.6	24.2	15.8	31.3	3.1	2.2	4.4	6.3	10.1	10.1	**4.0**	**11.3**
74-75	11.2	13.7	37.6	29.7	35.8	13.5	3.5	3.5	3.8	8.5	18.8	17.2	**4.8**	**16.4**
75-76	15.9	16.6	32.7	25.4	18.1	14.0	3.5	2.5	2.3	1.1	1.0	4.1	**2.4**	**11.4**
76-77	13.4	16.3	20.2	22.1	25.7	17.5	47.3	23.6	4.5	3.3	3.9	19.7	**19.7**	**18.1**
77-78	15.1	12.7	6.7	14.9	23.5	13.0	6.6	5.0	2.4	1.6	2.9	9.3	**3.9**	**9.5**
78-79	12.5	16.6	36.4	57.9	51.1	19.9	19.1	7.0	2.5	7.6	16.1	20.9	**9.0**	**22.3**
79-80	16.3	10.4	17.2	23.6	39.4	19.8	21.4	26.6	9.1	7.0	14.4	35.0	**16.0**	**20.0**
80-81	52.6	34.8	56.3	25.8	19.7	17.3	9.4	3.0	2.5	9.0	8.4	7.9	**6.0**	**20.6**
81-82	12.8	18.9	23.3	14.7	15.7	5.0	3.4	3.0	1.9	0.7	4.1	12.9	**2.3**	**9.7**
82-83	14.3	7.4	11.9	23.3	28.9	52.3	32.9	28.3	5.1	7.4	23.8	38.1	**18.4**	**22.8**
83-84	36.1	38.7	32.5	31.5	57.7	30.4	20.5	12.5	7.2	18.6	7.5	10.8	**14.7**	**25.3**
84-85	7.9	15.2	20.8	12.7	23.1	9.4	10.8	3.6	2.8	2.4	1.7	3.1	**4.9**	**9.4**
85-86	3.9	3.9	15.3	21.6	8.2	11.3	11.6	4.7	7.1	32.4	22.1	21.3	**14.0**	**13.6**
86-87	27.3	24.5	25.2	19.2	23.4	11.7	10.5	2.7	10.0	66.6	16.5	17.8	**22.5**	**21.3**
87-88	18.8	18.7	16.3	22.0	32.3	9.2	5.0	6.9	7.5	3.6	4.8	5.8	**5.7**	**12.6**
88-89	9.3	9.4	12.0	17.6	15.9	7.3	3.0	5.6	4.4	4.8	7.8	7.0	**4.4**	**8.7**
89-90	20.8	11.8	6.8	4.7	14.0	3.4	8.3	8.3	4.4	3.1	2.8	7.0	**6.0**	**8.0**
90-91	7.9	10.5	10.5	6.6	21.0	8.8	2.8	2.5	2.5	1.9	3.9	6.6	**2.4**	**7.1**
91-92	6.2	9.1	35.6	24.3	13.4	7.8	7.7	7.7	2.7	1.6	1.8	3.3	**4.9**	**10.1**
92-93	3.1	9.3	14.1	32.0	43.6	43.5	10.6	3.2	3.2	2.7	5.4	16.4	**4.9**	**15.6**
93-94	17.4	8.9	10.6	27.6	28.0	7.0	49.0	70.7	35.5	51.3	16.3	11.7	**51.6**	**27.8**
94-95	16.2	34.5	19.4	16.7	13.8	27.2	6.0	2.5	3.1	3.5	3.6	5.0	**3.8**	**12.6**
95-96	14.5	13.7	18.8	54.2	59.1	29.2	53.5	24.4	7.3	8.8	11.7	19.5	**23.5**	**26.2**
96-97	25.8	12.2	10.9	9.1	12.0	10.3	9.0	18.6	7.2	6.5	12.6	12.1	**10.3**	**12.2**
97-98	10.4	13.2	26.8	14.8	13.5	5.3	3.7	3.4	2.2	2.3	2.9	4.4	**2.9**	**8.6**
98-99	7.2	16.8	11.8	15.3	23.6	8.6	2.8	2.4	1.0	1.4	3.6	4.5	**1.9**	**8.3**
99-00	8.1	15.1	13.5	14.8	6.8	29.9	13.8	31.9	16.4	4.8	8.9	19.3	**16.7**	**15.3**
00-01	38.9	23.4	22.8	41.9	23.6	7.4	5.8	3.9	3.3	2.5	1.4	2.4	**3.9**	**14.8**
01-02	3.9	5.5	10.4	7.5	6.5	14.6	11.3	22.6	4.7	3.0	3.7	4.9	**10.4**	**8.2**
02-03	12.3	16.7	13.4	17.1	8.3	11.1	9.6	5.0	2.9	2.7	2.6	3.5	**5.0**	**8.8**
03-04	4.6	10.7	6.8	10.1	18.7	5.4	2.6	2.2	5.4	11.8	4.0	9.3	**5.5**	**7.6**
04-05	14.4	10.7	13.6	14.2	16.2	17.5	34.5	41.0	8.2	5.8	7.7	8.3	**22.4**	**16.0**
05-06	8.0	7.1	6.7	5.4	10.9	3.7	4.7	4.3	2.7	1.9	6.5	27.4	**3.4**	**7.4**
06-07	23.7	17.4	15.6	13.3	8.6	18.3	38.0	15.4	3.7	2.6	2.3	2.9	**14.9**	**13.5**
07-08	4.3	8.9	7.7	7.9	17.6	5.7	2.9	2.0	2.2	2.7	2.8	6.6	**2.5**	**5.9**
08-09	10.0	17.2	18.6	27.2	17.5	5.0	13.6	3.5	4.0	4.4	3.3	41.4	**6.4**	**13.8**
09-10	17.3	9.2	13.0	10.2	9.6	7.0	3.3	3.6	2.5	1.7	2.0	9.0	**2.8**	**7.3**
10-11	34.8	12.9	32.2	32.8	20.2	8.7	7.1	7.7	15.3	11.3	10.3	33.5	**10.4**	**18.9**
Average	**15.5**	**15.0**	**18.8**	**21.3**	**22.3**	**14.9**	**13.3**	**11.0**	**5.6**	**8.2**	**7.4**	**13.1**	**9.5**	**13.9**

2007/08 (highlighted) was at least a 1 in 10 year drought.

Manuherikia at Campground historic flows

In 2008 ORC installed a flow recorder site in the Manuherikia River at Campground. This is near the confluence with the Clutha River. The figure below shows the relationship between flows at the Campground, and flows at the long term flow recorder site at Ophir. There is some scatter in the relationship, which is most likely due to the influence of the Manuherikia and Galloway irrigation takes, and inflows from the Manor Burn catchment, which can respond differently to the rest of the Manuherikia catchment.



Relationship between recorded Manuherikia River flow at Ophir and Campground

Based on the above relationship, we estimated the mean annual historic flow at Campground, from the period June 1972 – May 2011, was approximately:

$$\text{Flow at Campground} = \text{Flow at Ophir} \times 1.2 - 0.9$$
$$= 13.9 \times 1.2 - 0.9 = 15.8\ m^3/s.$$

15.8 m^3/s corresponds to an average annual volume of 500 Mm^3/y.

Section 3 naturalised flows

We estimated the mean annual naturalised flow volume at the Manuherikia/Clutha River confluence, from the period June 1972 – May 2011, as:

Naturalised flow = Historic flow + net irrigation use + Mt Ida race water leaving the catchment
= 500 + 77 + 8 = 585 Mm³/y.

585 Mm^3/y averaged over the year equals 18.5 m^3/s. Our net irrigation use estimate of 77 Mm^3/y is based on:

- 22,000 ha of irrigation above Ophir, with a net use of 2,000 $m^3/ha/y$ (= 42Mm^3), plus
- 35 Mm^3 of irrigation use below Ophir

Our estimate of 8 Mm^3/y of water leaving the Manuherikia catchment via the Mt Ida race are based on MWD estimates of water use in the Hawkdun area for the period 1975 to 1984, sourced from Hamilton (2006).

We expect our mean flow estimate of 18.5 m^3/s to have an accurancy of ±0.5 m^3/s.

Table 1 tributary flow estimates were calculated as:

Naturalised tributary flow = calibration factor × WRE runoff model tributary flow

The NIWA Water Resource Explorer runoff model (WRE runoff model) can be found at:
http://wrenz.niwa.co.nz/webmodel/

The calibration factor was our estimate of the naturalised flow at the Manuherikia/Clutha confluence divided by the WRE runoff model estimate:

Calibration factor = 18.5 / 22.2 = 0.83

We expect Table 1 individual tributary flow estimates to be accurate to within ±15%.

For Figure 3, historical monthly flows were calculated as:

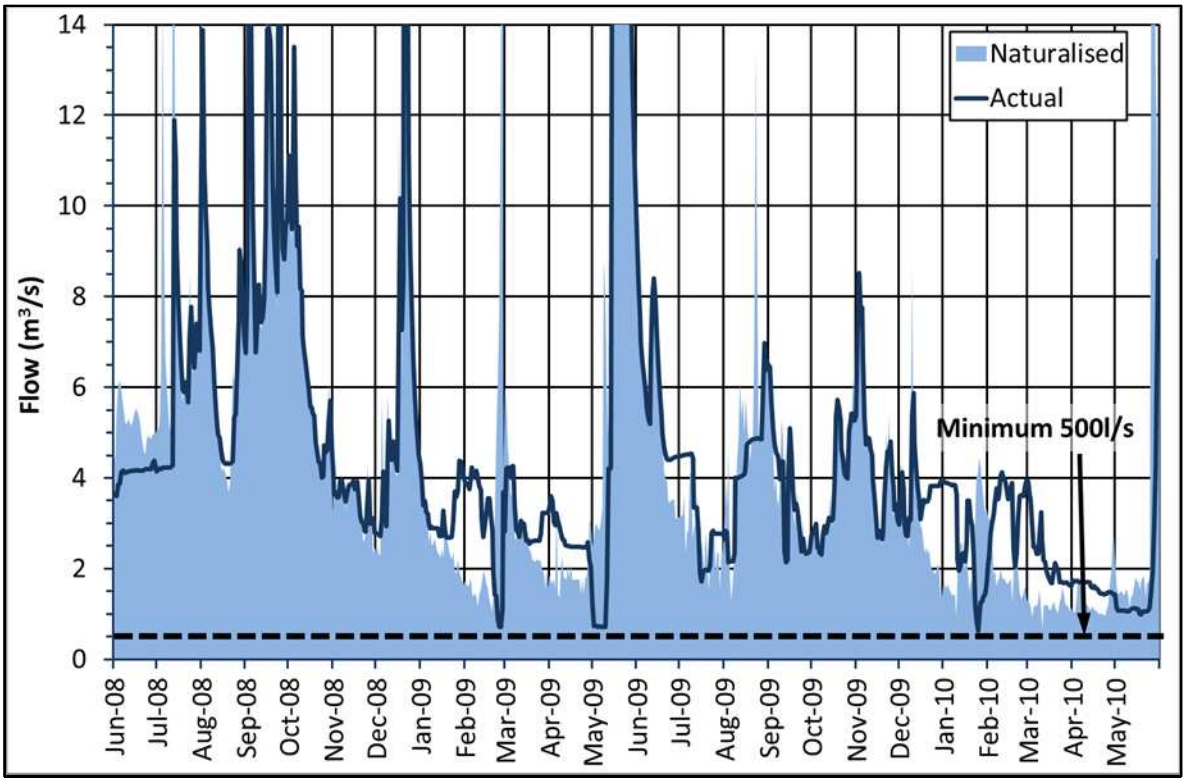
Historic flow at Campground = Historic flow at Ophir×1.2 – 0.9

Naturalised flows were calculated as:

*Naturalised flow = Historic flow at Campground + net monthly water use**

*Average net monthly water use was based on Stage 1 soil water balance modelling, calibrated so that the average net use for the year was 85 Mm^3.

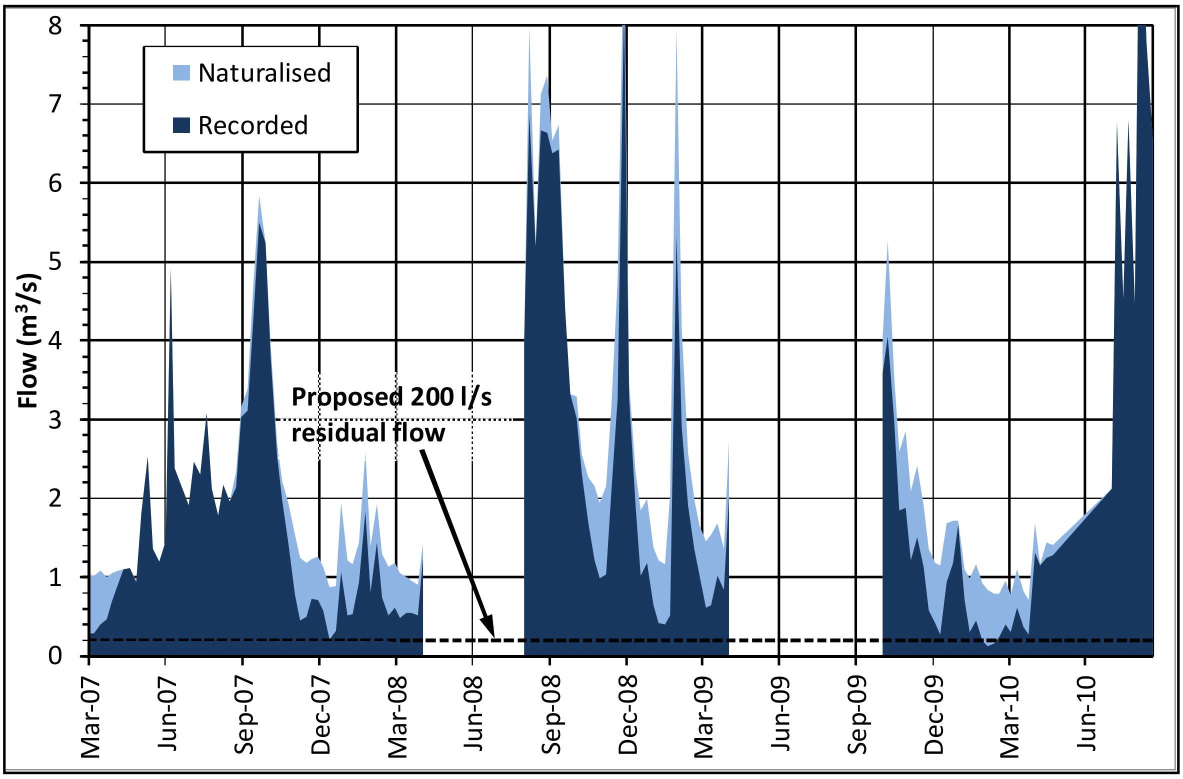
Manuherikia River at Falls Dam



Recorded and naturalised flows downstream of Falls Dam.

Naturalised flows were estimated by Rain Effects.

Dunstan Creek



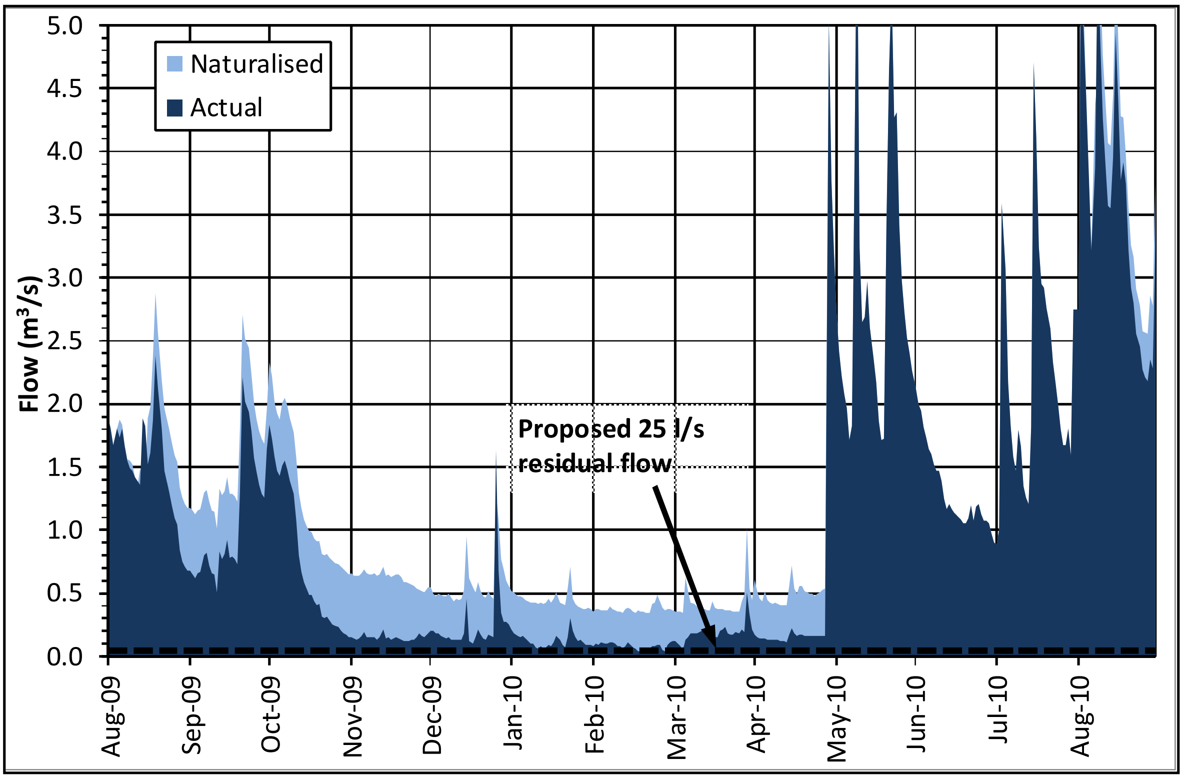
Recorded and naturalised flows at Beatties Road.

Naturalised flows were calculated as:

Natural flow at Beatties Road = 1.51×Recorded flow at Dunstan Gorge

The 1.51 multiplier was based on the ratio of the mean annual natural flow at the Gorge and Beatties Road, estimated using the WRE runoff model.

Lauder Creek



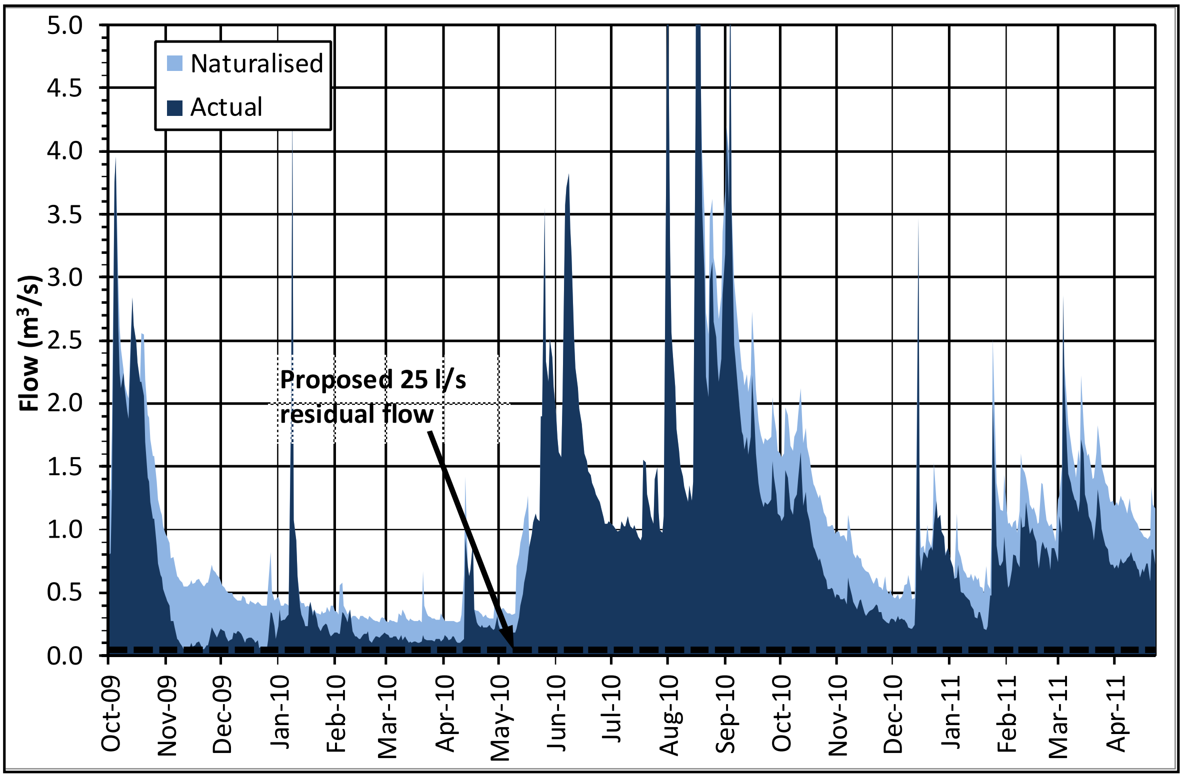
Recorded and naturalised flows at Rail Trail.

Naturalised flows were calculated as:

Natural flow at Rail Trail = 1.48×Recorded flow at Cattle Yards

The 1.48 multiplier was based on the ratio of the mean annual natural flow at Cattle Yards and Rail Trail, estimated using the WRE runoff model.

Thomsons Creek



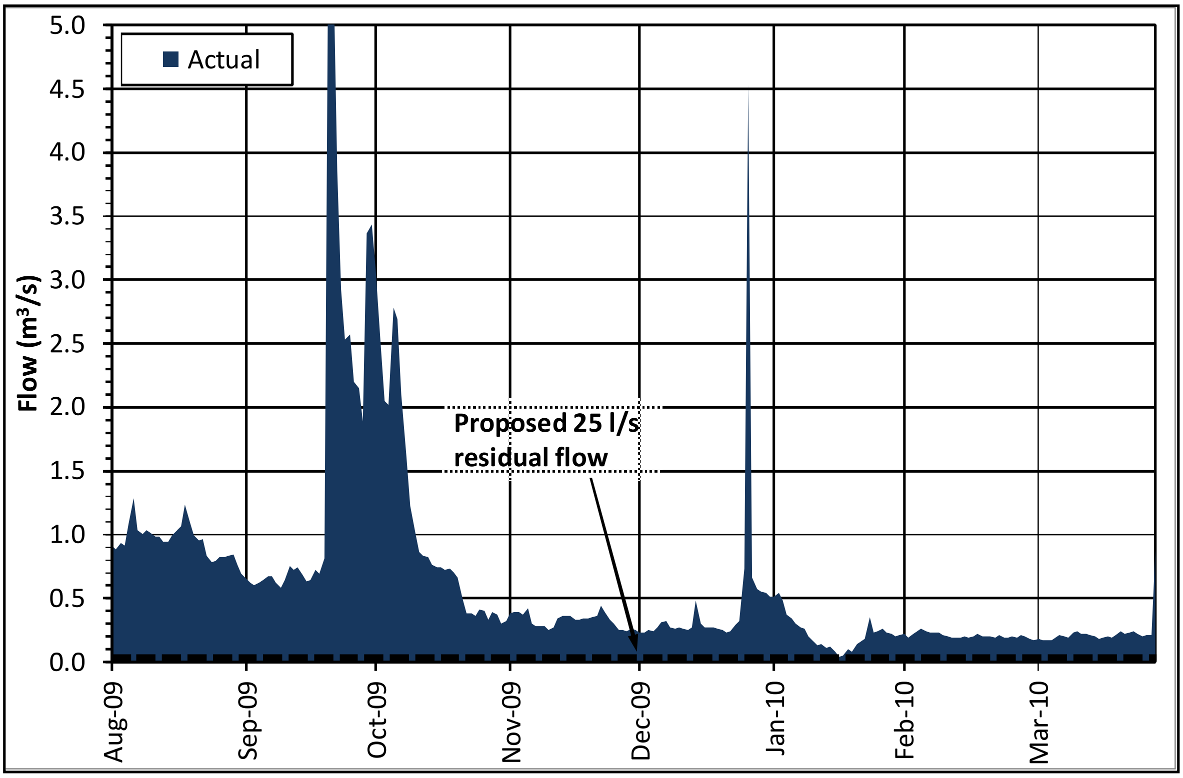
Recorded and naturalised flows at SH85.

Naturalised flows were calculated as:

Natural flow at SH85 = 2.01×Recorded flow at Diversion Weir

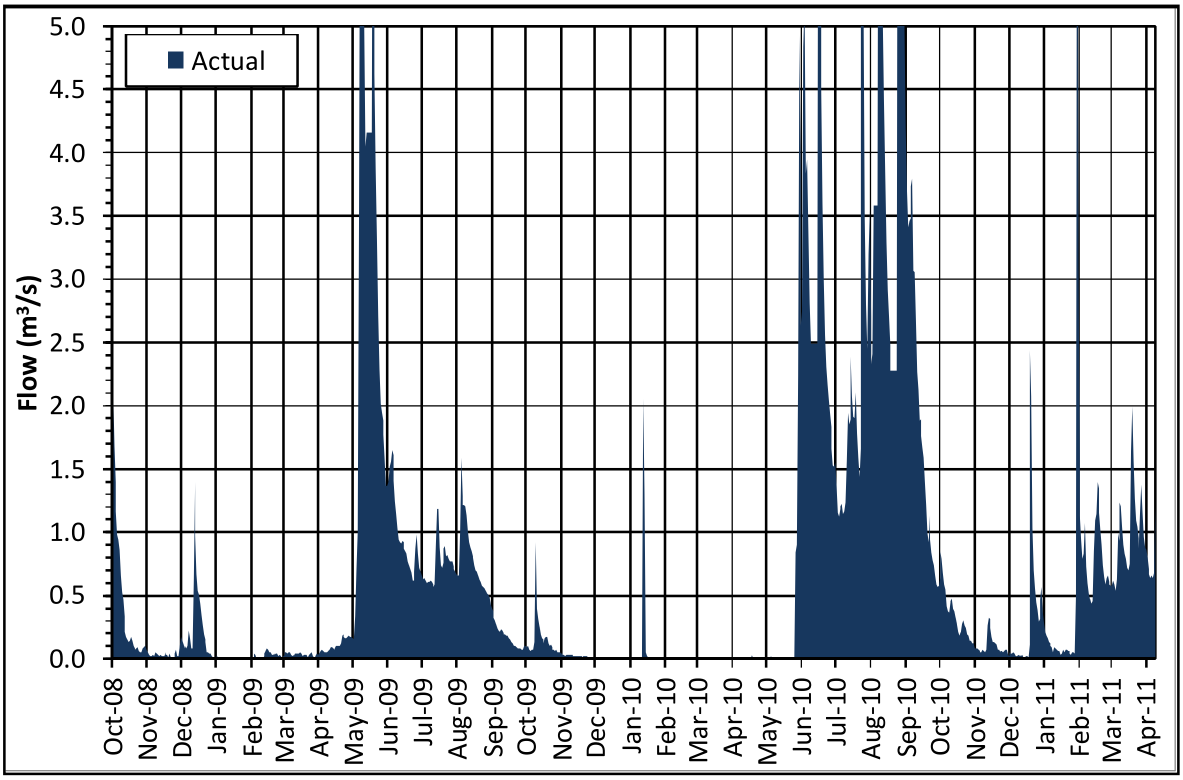
The 2.01 multiplier was based on the ratio of the mean annual natural flow at Diversion Weir and SH85, estimated using the WRE runoff model.

Chatto Creek



Chatto Creek at Manuherikia confluence.

Pool Burn



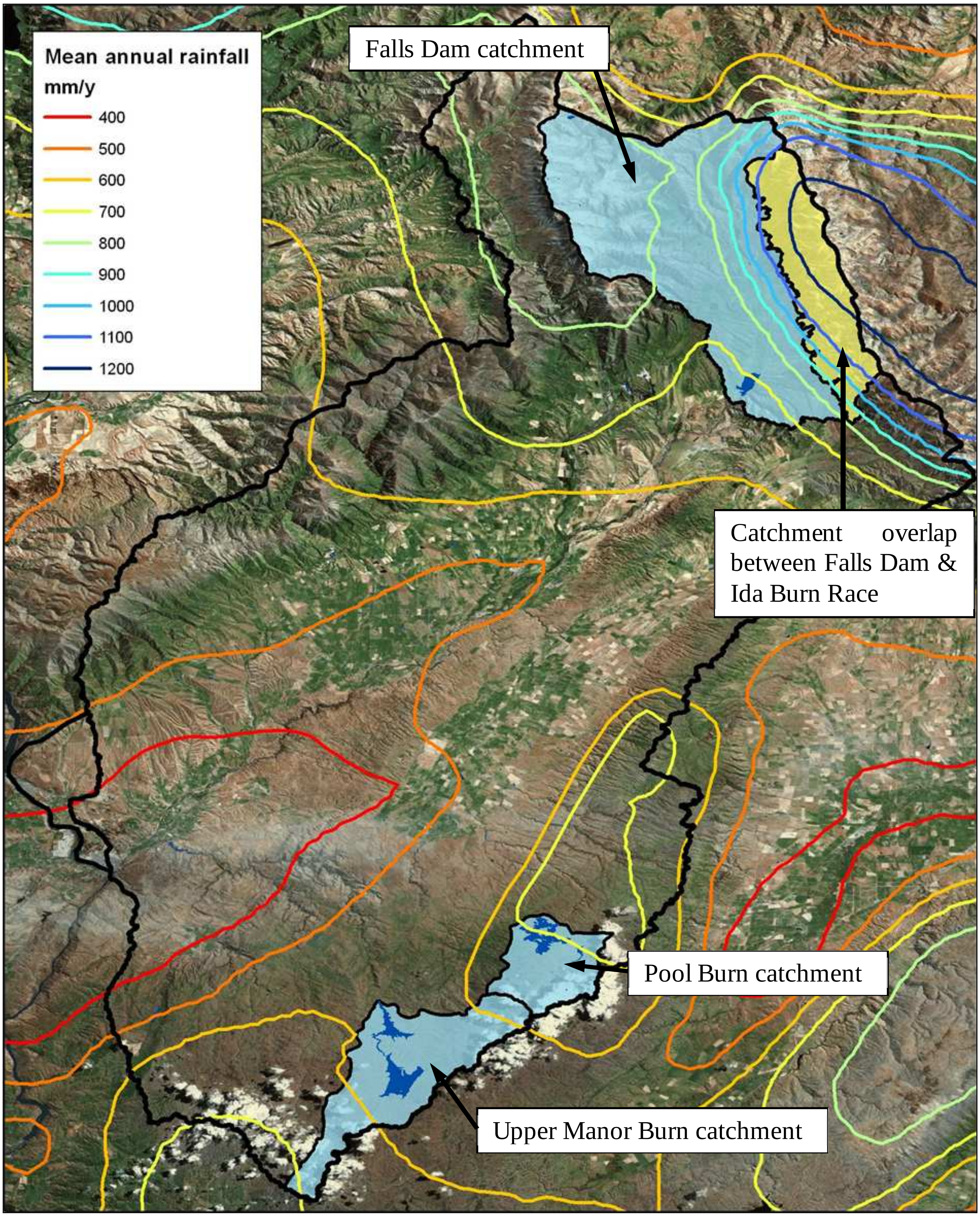
Pool Burn at Cob Cottage

Appendix B: Existing dams

Dam name	Catchment area (km^2)[1]	Lake area (ha)	Capacity (Mm^3)[1]	Mean annual flows (m^3/s)			Annual outflow in Mm^3/s	Mean residence time (days)
				Inflow[2]	Lake evaporation[3]	Outflow		
Falls	365	140	10.3	4.8	0.00	4.8	152.4	25
Pool Burn	53	425	28	0.25	0.08	0.2	5.3	1296
Upper Manor Burn	90	663	50.9	0.7	0.13	0.5	17.0	884
Lower Manor Burn	398	18	0.23	1.7	0.00	1.7	52.5	2
Ida Burn	136	8.2	0.21	1.4	0.00	1.4	44.6	2

(1) Hamilton (2009). Appendix C.
(2) NIWA Water Resource Explorer runoff model. http://wrenz.niwa.co.nz/webmodel/. Calibrated for the Manuherikia catchment using the Ophir flow record. Estimated accuracy ±15%
(3) Lake evaporation minus the original land surface evapotranspiration × lake area

Existing dam catchments

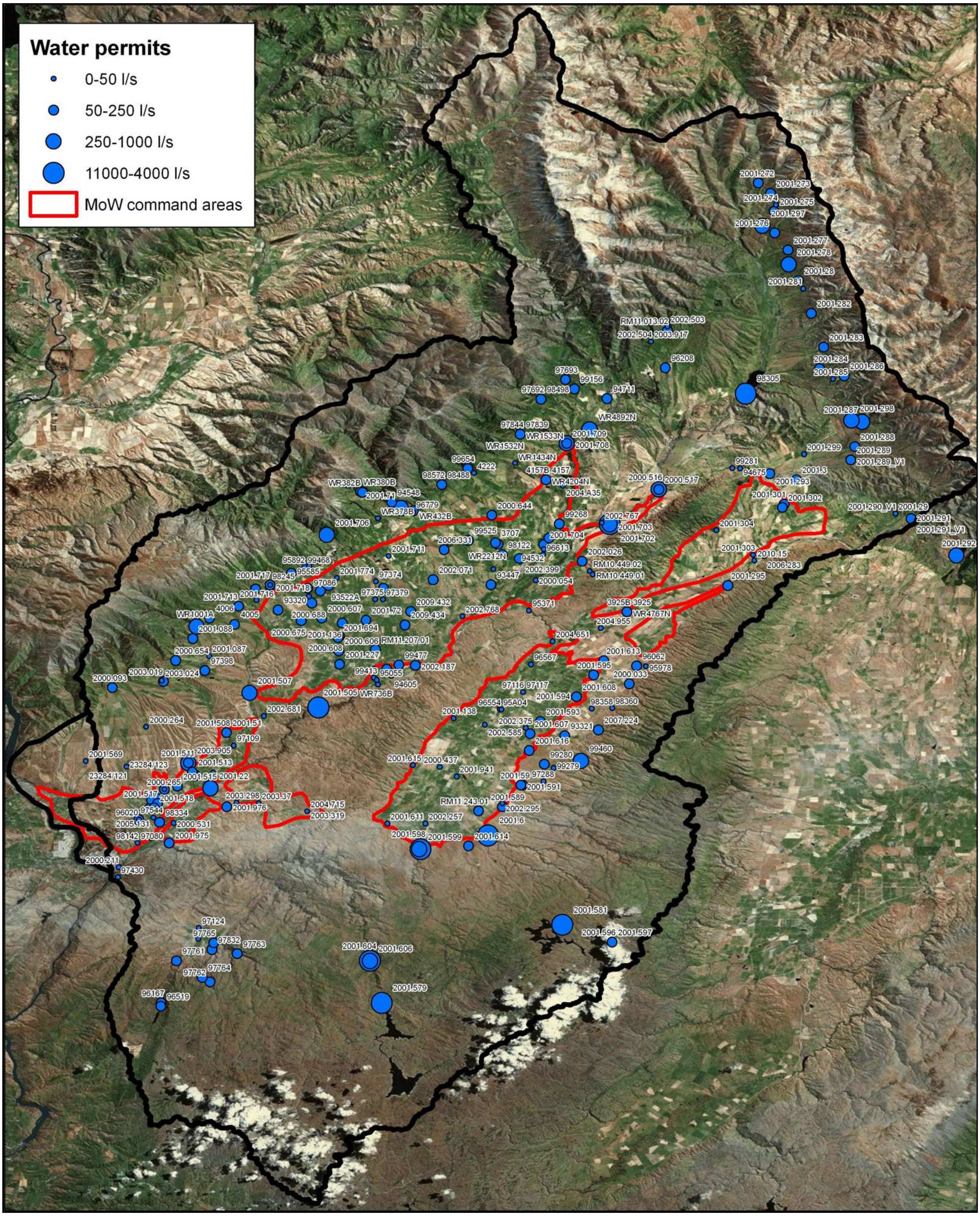


Falls Dam inflows are much greater than the Pool Burn and Upper Manor Burn, because the catchment size and annual rainfall are greater.

Appendix C: Water take consents

Water permit summary

Holder	Maximum take (l/s)		
	Deemed permits	RMA consents	Total
Blackstone Irrigation Scheme	508	0	508
Galloway Irrigation Scheme	730	0	730
Hawkdun Idaburn Irrigation Scheme	0	3,757	3,757
Ida Valley Irrigation Scheme	5,646	0	5,646
Manuherikia Irrigation Scheme	3,480	0	3,480
Omakau Area Irrigation Scheme	4,415	0	4,415
Total for irrigation schemes	**14,779**	**3,757**	**18,536**
All other private water rights	6,159	2,274	8,433
Total	**20,938**	**6,031**	**26,969**


Water permits
0-50 l/s
50-250 l/s
250-1000 l/s
11000-4000 l/s
MoW command areas

Holder	Consent No.	Type	Max. take (l/s)	Residual flow (l/s)	Expiry
Alan Russell Williamson and Annette Elizabeth Williamson	96554	Deemed	28	n/a	1/10/2021
Allen M D Allen S J	2005.131	Deemed	3	n/a	1/10/2021
Almondell Farms Limited	95A04	Deemed	49	n/a	1/10/2021
Armstrong N A Armstrong G L Armstrong W M	98358	RMA	7	n/a	6/08/2028
Armstrong N A Armstrong G L Armstrong W M	98360	RMA	7	n/a	6/08/2028
Armstrong W A Armstrong J B Armstrong J W A	WR2212N	Deemed	56	n/a	1/10/2021
Arthur T J Arthur N M	2004.651	Deemed	28	5	1/10/2021
Beckers Transport Limited	2010.15	RMA	5	n/a	1/12/2037
Bernard Kane Limited	2002.408	RMA	56	n/a	1/02/2023
Blackstone Irrigation Company Limited	2000.516	Deemed	438	n/a	1/10/2021
Blackstone Irrigation Company Limited	2000.517	Deemed	70	n/a	1/10/2021
Booth C A Booth E C	93447	Deemed	83	820	1/10/2021
Brian Kitchener Thurlow	2000.054	RMA	28	n/a	2/06/2015
Brown B R Brown G J	2003.37	RMA	13	n/a	2/03/2014
Cairnhill Limited	RM10.449.01	RMA	7	n/a	15/01/2046
Cairnhill Limited	RM10.449.02	RMA	28	n/a	15/01/2046
Calder Farming Co Limited	WR1434N	Deemed	28	n/a	1/10/2021
Calder Farming Co Limited	WR1531N	Deemed	56	n/a	1/10/2021
Calder Farming Co Limited	WR1532N	Deemed	56	n/a	1/10/2021
Calder Farming Co Limited	WR1533N	Deemed	56	n/a	1/10/2021
Calder Farming Co Limited	97844	Deemed	167	n/a	1/10/2021
Central Otago District Council	WR736B	Deemed	28	n/a	1/10/2021
Central Otago District Council	99169	RMA	35	n/a	1/07/2035
Chris Allan Robinson and Rewa Elizabeth Robinson	RM11.049.01	RMA	50	n/a	30/08/2046
Colin Gordon McKnight	94532	Deemed	28	n/a	1/10/2021
Coolavin Farms Limited	2003.319	RMA	42	n/a	11/08/2014
Coolavin Farms Limited	2000.675	RMA	56	n/a	1/04/2021
Corrigall A J	2001.227	Deemed	56	28	1/10/2021
Donald Edward MacLean	2000.608	RMA	56	n/a	31/03/2021
Donald Mark Maclean	2000.606	RMA	56	n/a	31/06/2021
Eckhoff A Eckhoff W M	2002.295	RMA	22	n/a	1/11/2012
Evans W L Evans N L as Trustees of the Thyme Heritage Trust	97430	Deemed	14	n/a	1/10/2021
Flannery M T Flannery W J	2002.585	Deemed	28	n/a	1/10/2021
Galloway Irrigation Society Incorporated	2001.22	Deemed	425	n/a	1/10/2021
Galloway Irrigation Society Incorporated	2001.975	Deemed	222	n/a	1/10/2021
Galloway Irrigation Society Incorporated	2001.976	Deemed	83	n/a	1/10/2021
Geoffrey Thomas Clouston	99525	RMA	83	n/a	1/02/2020
Geoffrey Thomas Clouston	98122	Deemed	56	n/a	1/10/2021
Geoffrey Thomas Clouston	2004.788	RMA	22	n/a	1/05/2025
George Anthony Kelliher	2000.243	Deemed	83	14	1/10/2021
George Anthony Kelliher	2000.265	Deemed	28	14	1/10/2021
Greenfield Rural Opportunities Limited	94675	Deemed	28	n/a	1/10/2021
Greenfield Rural Opportunities Limited	99281	Deemed	42	n/a	1/10/2021
Grenaby Farm Limited	RM11.055.02	RMA	14	n/a	18/04/2041
Harrex T E Harrex P M	4222	Deemed	28	n/a	1/10/2021
Hawkdun Idaburn Irrigation Company Limited	2001.272	RMA	170	14	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.273	RMA	85	14	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.274	RMA	28	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.275	RMA	113	14	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.276	RMA	57	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.277	RMA	85	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.278	RMA	340	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.28	RMA	142	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.281	RMA	28	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.282	RMA	142	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.283	RMA	113	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.284	RMA	57	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.285	RMA	28	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.286	RMA	113	14	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.287	RMA	425	28	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.288	RMA	165	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.289	RMA	85	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.29	RMA	28	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.291	RMA	137	n/a	1/12/2037

Holder	Consent No.	Type	Max. take (l/s)	Residual flow (l/s)	Expiry
Hawkdun Idaburn Irrigation Company Limited	2001.292	RMA	481	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.293	RMA	170	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.294	RMA	28	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.295	RMA	227	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.296	RMA	85	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.288	RMA	165	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2006.283	RMA	5	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.289_V1	RMA	85	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.290_V1	RMA	28	n/a	1/12/2037
Hawkdun Idaburn Irrigation Company Limited	2001.291_V1	RMA	142	n/a	1/12/2037
Hawkdun Pastoral Limited	96208	Deemed	56	n/a	1/10/2021
Heaney M K & Heaney M V	95978	Deemed	42	n/a	1/10/2021
Heaney M K & Heaney M V	96062	Deemed	56	n/a	1/10/2021
Hill D R Hill S A	97374	RMA	28	n/a	20/01/2018
Hill D R Hill S A	97375	RMA	28	n/a	20/01/2018
Ian Robert Brown	WR432B	Deemed	167	n/a	1/10/2021
Ian Robert Brown	2006.331	Deemed	56	n/a	1/10/2021
Ida Valley Irrigation Company Limited	2001.579	Deemed	2151	n/a	1/10/2021
Ida Valley Irrigation Company Limited	2001.581	Deemed	1132	n/a	1/10/2021
Ida Valley Irrigation Company Limited	2001.589	Deemed	142	n/a	1/10/2021
Ida Valley Irrigation Company Limited	2001.59	Deemed	142	n/a	1/10/2021
Ida Valley Irrigation Company Limited	2001.591	Deemed	85	n/a	1/10/2021
Ida Valley Irrigation Company Limited	2001.594	Deemed	57	n/a	1/10/2021
Ida Valley Irrigation Company Limited	2001.595	Deemed	170	n/a	1/10/2021
Ida Valley Irrigation Company Limited	2001.596	Deemed	57	n/a	1/10/2021
Ida Valley Irrigation Company Limited	2001.597	Deemed	57	n/a	1/10/2021
Ida Valley Irrigation Company Limited	2001.598	Deemed	1415	n/a	1/10/2021
Ida Valley Irrigation Company Limited	2001.6	Deemed	1132	n/a	1/10/2021
Ida Valley Irrigation Company Limited	2001.604	Deemed	1981	n/a	1/10/2021
Ida Valley Irrigation Company Limited	2001.606	Deemed	566	n/a	1/10/2021
Ida Valley Irrigation Company Limited	2001.611	Deemed	42	n/a	1/10/2021
Ida Valley Irrigation Company Limited	2001.613	Deemed	57	n/a	1/10/2021
Ida Valley Irrigation Company Limited	2001.614	Deemed	57	n/a	1/10/2021
Ida Valley Irrigation Company Limited	2001.615	Deemed	28	n/a	1/10/2021
Ida Valley Irrigation Company Limited	2001.616	Deemed	57	n/a	1/10/2021
Ida Valley Station Limited	97288	Deemed	28	n/a	1/10/2021
James Sinclair Veitch Lynne Kathleen Fauchelle and Ian Lawerence	4157	Deemed	56	n/a	1/10/2021
James William Alexander Armstrong	3707	Deemed	56	n/a	1/10/2021
James William Alexander Armstrong	2002.399	RMA	56	n/a	1/09/2022
John Kinaston McArthur	2000.093	Deemed	56	n/a	1/10/2021
John Kinaston McArthur	2000.264	Deemed	28	n/a	1/10/2021
Karratha Downs Limited	99279	Deemed	28	n/a	1/10/2021
Karratha Downs Limited	99280	Deemed	56	n/a	1/10/2021
Kenneth Donald Edgar	2000.437	RMA	28	n/a	1/03/2021
Larkhall Limited	2002.187	Deemed	139	n/a	1/10/2021
Larkhall Limited	99477	Deemed	83	n/a	1/10/2021
Leask M S Leask I M	94605	Deemed	14	n/a	1/10/2021
Leask M S Leask I M	2010.191	RMA	56	n/a	6/07/2031
Lionel Vivian Sinnamon	2001.138	RMA	7	n/a	31/03/2021
Little Valley Station Limited	97222	RMA	31	n/a	30/06/2018
Long Gully Rural Water Scheme Incorporated	96020	RMA	2	n/a	31/12/2017
Loughnan N A Gray F A	2003.298	RMA	42	n/a	28/06/2014
Lynley Buchanan	97544	RMA	56	n/a	1/11/2017
Manuherikia Irrigation Co-operative Society Limited	2001.505	Deemed	2830	n/a	1/10/2021
Manuherikia Irrigation Co-operative Society Limited	2001.507	Deemed	283	n/a	1/10/2021
Manuherikia Irrigation Co-operative Society Limited	2001.508	Deemed	142	n/a	1/10/2021
Manuherikia Irrigation Co-operative Society Limited	2001.511	Deemed	57	n/a	1/10/2021
Manuherikia Irrigation Co-operative Society Limited	2001.568	Deemed	113	n/a	1/10/2021
Manuherikia Irrigation Co-operative Society Limited	2001.569	Deemed	14	n/a	1/10/2021
Manuherikia Irrigation Co-operative Society Limited	23284/121	Deemed	28	n/a	1/10/2021
Manuherikia Irrigation Co-operative Society Limited	23284/123	Deemed	14	n/a	1/10/2021
Mark Robert Skelton	99413	RMA	42	n/a	31/01/2020
Mark Robert Skelton	95055	Deemed	28	n/a	1/10/2021

Holder	Consent No.	Type	Max. take (l/s)	Residual flow (l/s)	Expiry
Matakanui Station Limited	4005	Deemed	56	n/a	1/10/2021
Matakanui Station Limited	4006	Deemed	56	n/a	1/10/2021
Matangi Station Limited	97124	RMA	28	n/a	1/05/2017
Matangi Station Limited	97141	RMA	28	n/a	1/05/2017
Matangi Station Limited	96167	Deemed	56	n/a	1/10/2021
Matangi Station Limited	96519	Deemed	56	n/a	1/10/2021
McBreen S W McBreen D A	2001.941	Deemed	28	n/a	1/10/2021
McDonnell G W McDonnell L J	2004.433	RMA	6	5	1/09/2014
McKnight F G McKnight P M	99460	Deemed	278	n/a	1/10/2021
McKnight Farming Limited	2007.224	Deemed	56	n/a	1/10/2021
McLeod P T McLeod R L Craig W A	2001.136	Deemed	56	28	1/10/2021
Morgan K L Hunter H I	93385B	Deemed	28	n/a	1/10/2021
Morgan K L Hunter H I	93522B	Deemed	56	n/a	1/10/2021
Morgan R J Hunter H I	2001.761	Deemed	5	31	1/10/2021
Morgan R J Hunter H I	93385	Deemed	28	n/a	1/10/2021
Morgan R J Hunter H I	93522A	Deemed	56	n/a	1/10/2021
Mount Campbell Station Limited	97761	Deemed	83	n/a	1/10/2021
Mount Campbell Station Limited	97762	Deemed	83	n/a	1/10/2021
Mount Campbell Station Limited	97763	Deemed	56	n/a	1/10/2021
Mount Campbell Station Limited	97764	Deemed	56	n/a	1/10/2021
Mount Campbell Station Limited	97765	Deemed	83	n/a	1/10/2021
Mount Campbell Station Limited	97832	Deemed	83	n/a	1/10/2021
Moutere Station Limited	2001.087	Deemed	7	n/a	1/10/2021
Moutere Station Limited	2001.088	Deemed	56	n/a	1/10/2021
Moutere Station Limited	2003.019	Deemed	56	n/a	1/10/2021
Moutere Station Limited	2003.024	Deemed	28	n/a	1/10/2021
Mulholland E J Mulholland J E	WR4767N	Deemed	83	n/a	1/10/2021
Mulholland E J Mulholland J E	3925B	Deemed	83	n/a	1/10/2021
Murray Ashton	97398	RMA	83	n/a	20/01/2018
Murray Ashton	2000.654	RMA	111	n/a	1/05/2021
Murray Ashton	WR1001A	Deemed	389	n/a	1/10/2021
Murray John Heckler	94548	Deemed	56	n/a	1/10/2021
Murray John Heckler and Annette Esther Heckler	96779	Deemed	28	n/a	1/10/2021
Murray John Heckler and Annette Esther Heckler	RM11.207.01	RMA	56	10	1/09/2046
Naylor D B Naylor G C	2000.644	Deemed	56	n/a	1/10/2021
Naylor D B Naylor G C	99654	Deemed	83	n/a	1/10/2021
Naylor R W & Gibston D J being trustees of the Spennymoor Trust	97086	RMA	56	n/a	1/07/2017
Naylor R W & Gibston D J being trustees of the Spennymoor Trust	98245	Deemed	83	n/a	1/10/2021
Naylor R W Naylor A J	93320	Deemed	83	n/a	1/10/2021
Naylor R W Naylor A J	95585	Deemed	56	n/a	1/10/2021
Nicolson Farms Limited	97116	Deemed	7	n/a	1/10/2021
Nicolson Farms Limited	97117	Deemed	21	n/a	1/10/2021
Noone J T Noone R J	96567	RMA	21	n/a	31/07/2017
O'Brien J R O'Brien J A	2000.531	RMA	14	n/a	31/01/2021
Omakau Area Irrigation Company Limited	2001.702	Deemed	1981	n/a	1/10/2021
Omakau Area Irrigation Company Limited	2001.703	Deemed	283	n/a	1/10/2021
Omakau Area Irrigation Company Limited	2001.704	Deemed	57	20	1/10/2021
Omakau Area Irrigation Company Limited	2001.705	Deemed	85	n/a	1/10/2021
Omakau Area Irrigation Company Limited	2001.706	Deemed	425	n/a	1/10/2021
Omakau Area Irrigation Company Limited	2001.708	Deemed	425	n/a	1/10/2021
Omakau Area Irrigation Company Limited	2001.709	Deemed	85	n/a	1/10/2021
Omakau Area Irrigation Company Limited	2001.71	Deemed	425	n/a	1/10/2021
Omakau Area Irrigation Company Limited	2001.711	Deemed	28	n/a	1/10/2021
Omakau Area Irrigation Company Limited	2001.712	Deemed	85	n/a	1/10/2021
Omakau Area Irrigation Company Limited	2001.713	Deemed	57	n/a	1/10/2021
Omakau Area Irrigation Company Limited	2001.714	Deemed	28	n/a	1/10/2021
Omakau Area Irrigation Company Limited	2001.715	Deemed	57	n/a	1/10/2021
Omakau Area Irrigation Company Limited	2001.716	Deemed	28	n/a	1/10/2021
Omakau Area Irrigation Company Limited	2001.718	Deemed	85	n/a	1/10/2021
Omakau Area Irrigation Company Limited	2001.719	Deemed	113	n/a	1/10/2021
Omakau Area Irrigation Company Limited	2001.72	Deemed	170	n/a	1/10/2021
Ottrey Farms Limited	97839	Deemed	167	n/a	1/10/2021

Holder	Consent No.	Type	Max. take (l/s)	Residual flow (l/s)	Expiry
Partners of the J H & R J McNally Partnership	2004.955	RMA	28	n/a	2/10/2015
Partners of the J H & R J McNally Partnership	3925	Deemed	83	n/a	1/10/2021
Richard James Morgan	2000.688	Deemed	56	n/a	1/10/2021
Richard Neil Beattie	WR4892N	Deemed	278	n/a	1/10/2021
Robert James Stewart Rutherford	2000.033	Deemed	83	n/a	1/10/2021
Robin Angus Floyd, Yunni Floyd and Central Lodge Trustees 2006 Lt	2004.315	Deemed	6	5	1/10/2021
Robinson B S Robinson J C	2005.389	Deemed	14	5	1/10/2021
Russell Dean Nevill	RM11.243.01	RMA	90	13,800	1/09/2036
Satinburn Limited	2009.434	RMA	56	n/a	1/10/2046
Scrubby Gully Company Limited	2004.305	Deemed	11	5	1/10/2021
Shaky Bridge Enterprises Limited	2000.211	RMA	7	n/a	30/06/2020
Shirley Roylance Gordon-Glassford and Brian James Gordon-Glassfor	WR382B	Deemed	56	n/a	1/10/2021
Shirley Roylance Gordon-Glassford and Brian James Gordon-Glassfor	WR378B	Deemed	28	n/a	1/10/2021
Shirley Roylance Gordon-Glassford and Brian James Gordon-Glassfor	WR380B	Deemed	83	n/a	1/10/2021
Simpson R R Simpson J M and Amberley Trustees Limited being trus	2005.404	RMA	38	n/a	1/12/2025
Smith B M Smith K K McDonald and Associates Trustees Limited	2001.774	RMA	2	3	15/03/2019
Smith B M Smith K K McDonald and Associates Trustees Limited	2001.773	Deemed	31	n/a	1/10/2021
Smith B M Smith K K McDonald and Associates Trustees Limited	95892	Deemed	31	n/a	1/10/2021
Smith B M Smith K K McDonald and Associates Trustees Limited	99468	Deemed	31	n/a	1/10/2021
Southern Lakes Holdings Limited	97692	RMA	56	n/a	20/01/2018
Southern Lakes Holdings Limited	97693	RMA	56	820	20/01/2018
Southern Lakes Holdings Limited	RM11.013.01	Deemed	28	9	1/10/2021
Southern Lakes Holdings Limited	94711	Deemed	83	n/a	1/10/2021
Southern Lakes Holdings Limited	98498	Deemed	56	n/a	1/10/2021
Southern Lakes Holdings Limited	99156	Deemed	56	n/a	1/10/2021
Southern Lakes Holdings Limited	RM11.013.02	RMA	56	5	1/02/2046
St Bathans Water Board Incorporated	2002.503	RMA	42	10	31/12/2023
St Bathans Water Board Incorporated	2002.504	RMA	14	2	31/12/2023
St Bathans Water Board Incorporated	2003.917	RMA	42	n/a	31/12/2023
Stephanie Rethwisch	2004.715	RMA	42	n/a	11/08/2014
Stephen John Matheson	2002.257	RMA	14	n/a	30/06/2022
Thomas Hugh Mee	2004.A35	RMA	7	n/a	1/09/2015
Thomas Matthew Moran and Joanne Elizabeth Moran	2002.071	RMA	56	n/a	1/09/2022
Thurlow and Cook Allan Gibson Trustee Company Limited	95371	Deemed	28	n/a	1/10/2021
Tiger Hill Farm Limited	2000.607	RMA	56	n/a	1/04/2021
Tiger Hill Farm Limited	2001.694	Deemed	56	28	1/10/2021
Trustees of the Anderson Family Trust	98142	RMA	7	n/a	30/05/2013
Trustees of the Anderson Family Trust	97080	RMA	1	n/a	5/05/2022
Trustees of the Colin G McKnight Trust	2002.026	Deemed	56	n/a	1/10/2021
Trustees of the Colin McKnight Trust	99268	RMA	111	n/a	29/10/2019
Trustees of the Gillespie Family Trust	2009.432	RMA	56	n/a	1/10/2026
Trustees of the Longslope Farm Trust	97109	Deemed	28	n/a	1/10/2021
Trustees of the Moorbattle Park Family Trust	2002.375	Deemed	28	n/a	1/10/2021
Trustees of the Moorbattle Park Family Trust	93321	Deemed	56	n/a	1/10/2021
Trustees of the Pattillo Family Trust	WR4204N	Deemed	56	n/a	1/10/2021
Trustees of the Pattillo Family Trust	4157B	Deemed	56	n/a	1/10/2021
Trustees of the Waldron Family Trust	98334	RMA	56	n/a	1/11/2018
Tucker G F Tucker H R GCA Legal Trustee 2005 Limited	98572	Deemed	111	n/a	1/10/2021
Tucker G F Tucker H R Macassey R N	98488	Deemed	111	n/a	1/10/2021
William James Clouston	96613	RMA	21	n/a	20/01/2017
Wilson B W Wilson R A	97379	RMA		n/a	31/07/2017
Falls Dam Company Limited	98305	RMA	4000	500	30/09/2033

Appendix D: Potential irrigation demand

Gross irrigation demand calculations accounted for the mix of rainfall zones and soil types in each of the sub-catchments.

Gross irrigation demand = Potential irrigated area × Σ[% soil type × % rainfall zone × relevant irrigation demand timeseries from Stage 1 study]

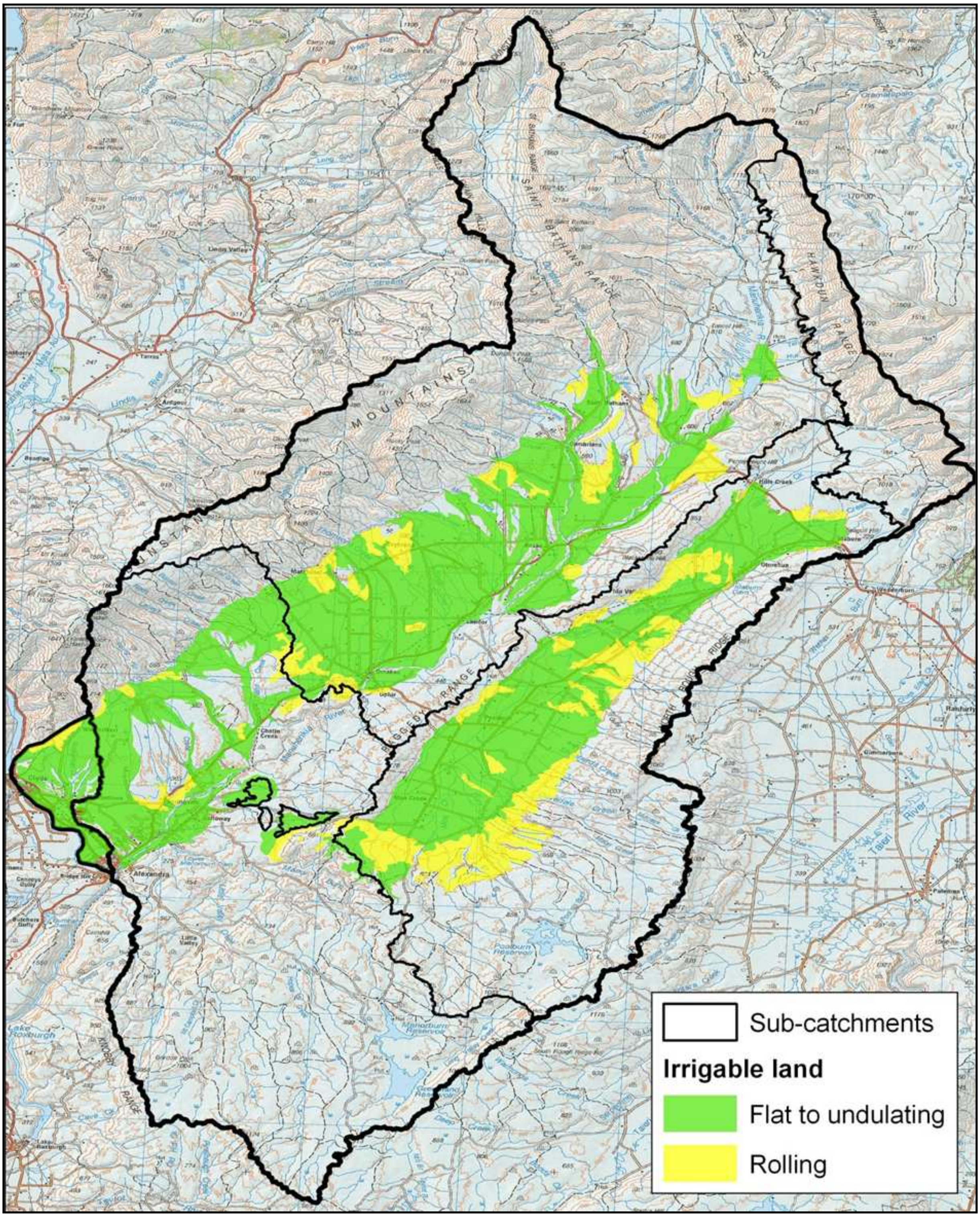
The portions of irrigated area by soil and rainfall zones are given in the following table and are derived from the figures below.

Sub-catchment	Potential irrigated Area (ha)	% of soil type			% of rainfall zone				Gross irrigation demand		
		PAW60	PAW90	PAW120	400mm	500mm	600mm	700mm	Peak flow (m3/s)	Average year (Mm3/y)	1 in 10 dry year (Mm3/y)
Mt Ida race to Hawkdun	N/A								0.9	8	5
Ida Valley	19,000	35%	40%	25%	10%	80%	10%	0%	8.9	94	121
Upper Manuherikia Valley	26,000	35%	35%	30%	5%	40%	30%	25%	12.1	119	155
Lower Manuherikia Valley	12,000	70%	20%	10%	50%	45%	5%	0%	6.0	65	82
Waikerikeri Creek	3,000	100%	0%	0%	70%	30%	0%	0%	1.6	17	21
Total	**60000**								**29.5**	**303**	**384**

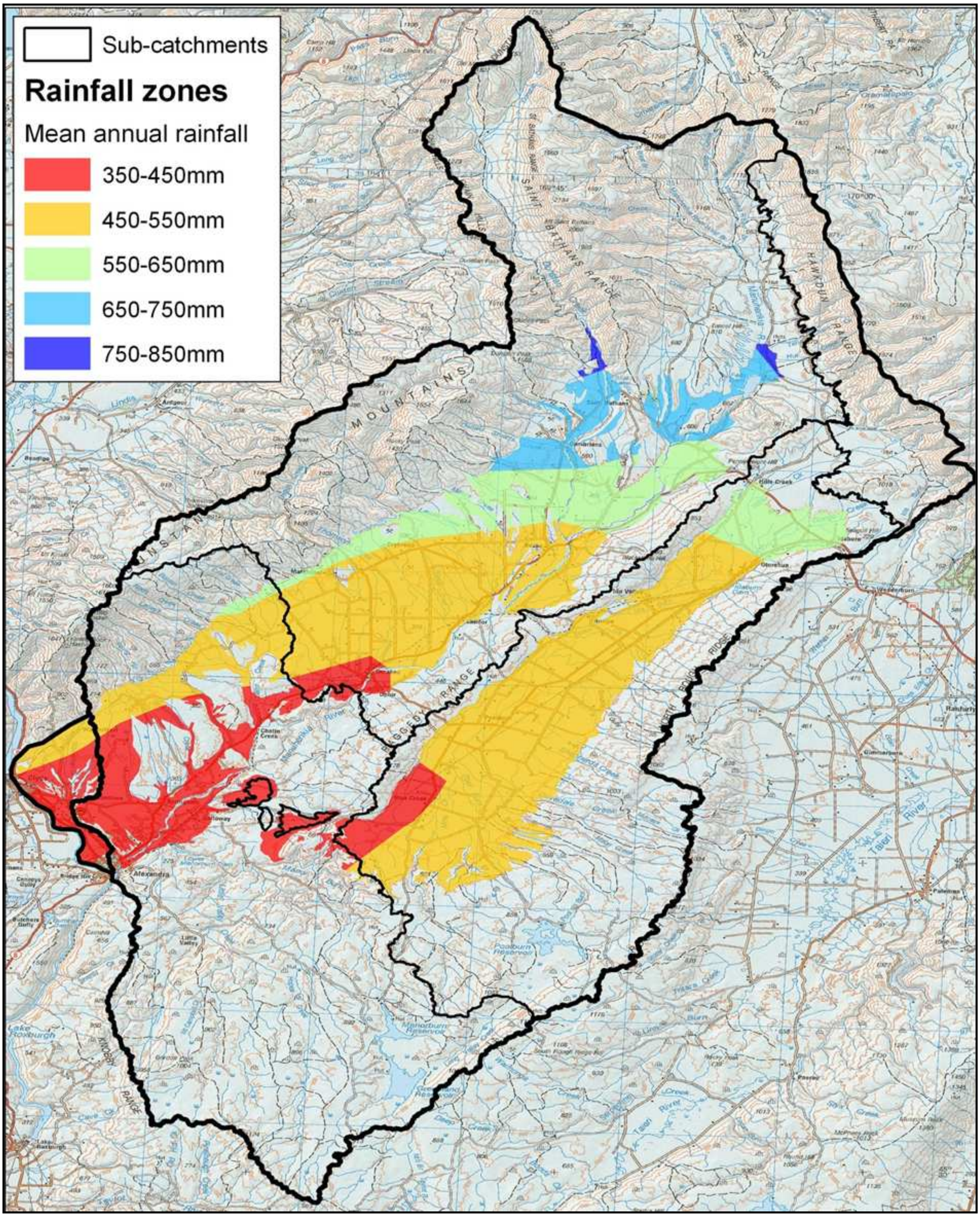
Net irrigation demand for Ida Valley and the Upper Manuherikia Valley were calculated as:

Peak net demand = 85% ×gross peak demand
Average annual net demand = 75% ×average annual gross demand
Net demand in a 1 in 10 year = 80% × gross demand in a 1 in 10 year

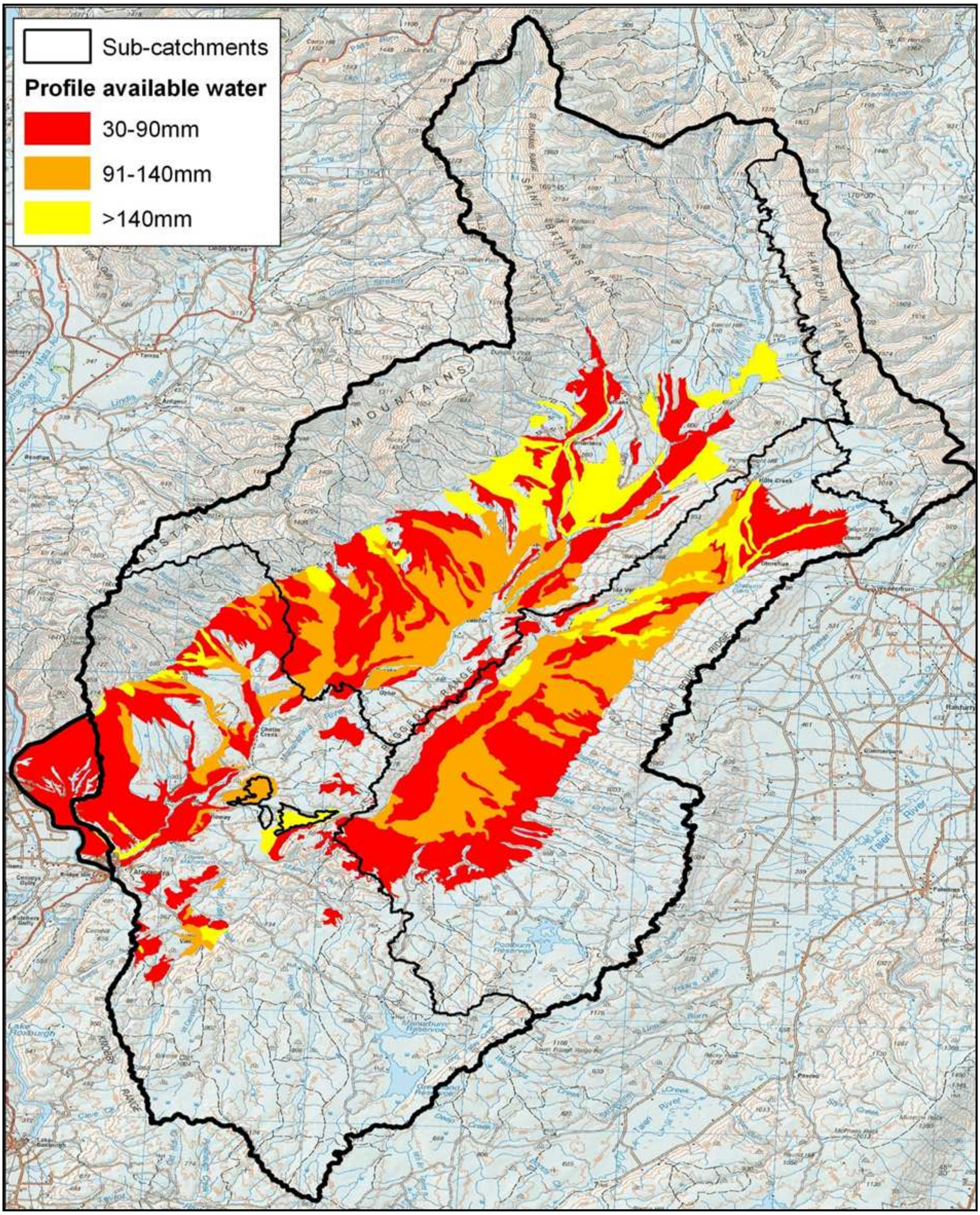
These relationships where determined by catchment specific soil moisture modelling. For the Lower Manuherikia Valley, the net irrigation demand was assumed to equal the gross irrigation demand, since irrigation drainage water generally is unavailable for reuse below Ophir.



Irrigable land by sub-catchment

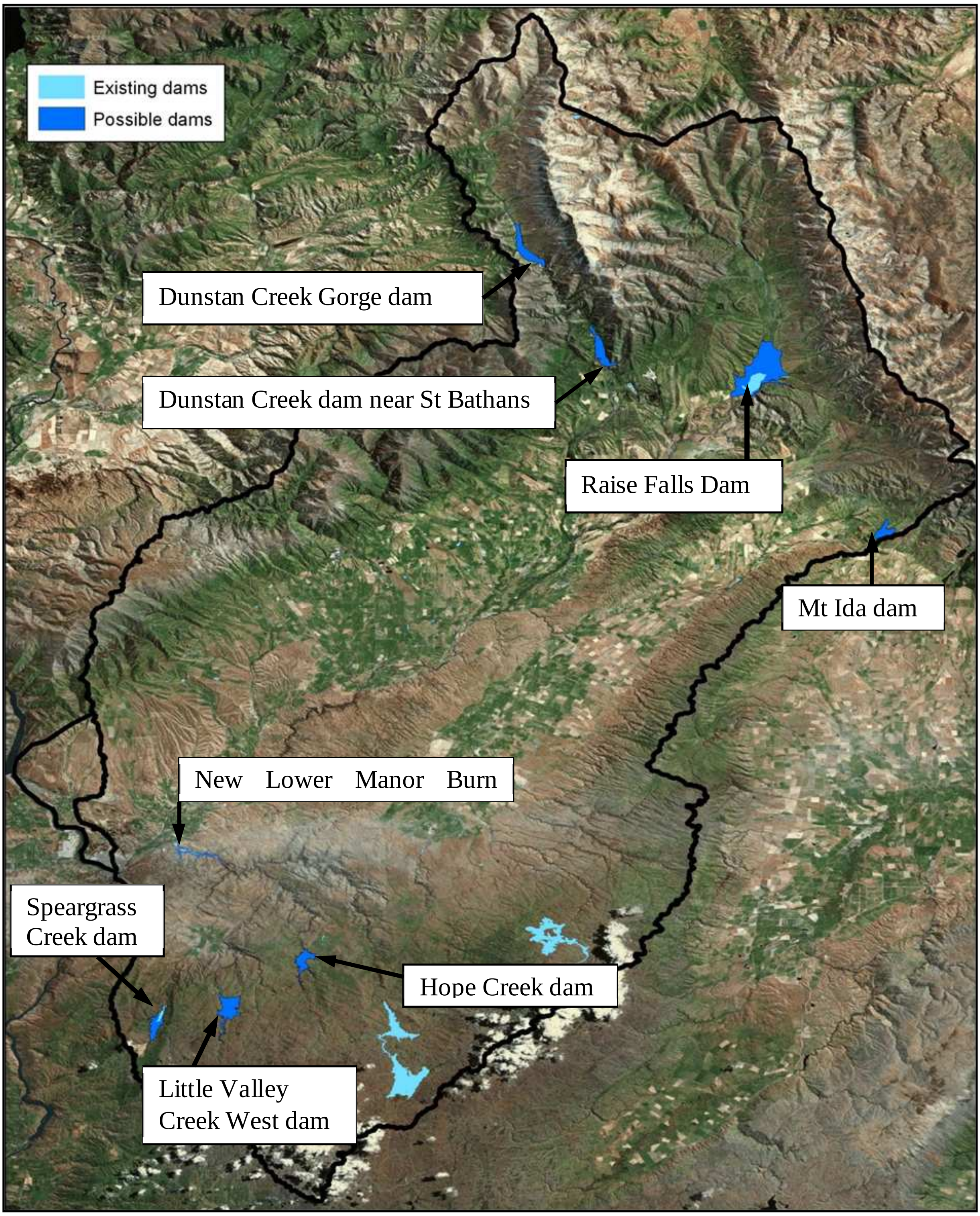


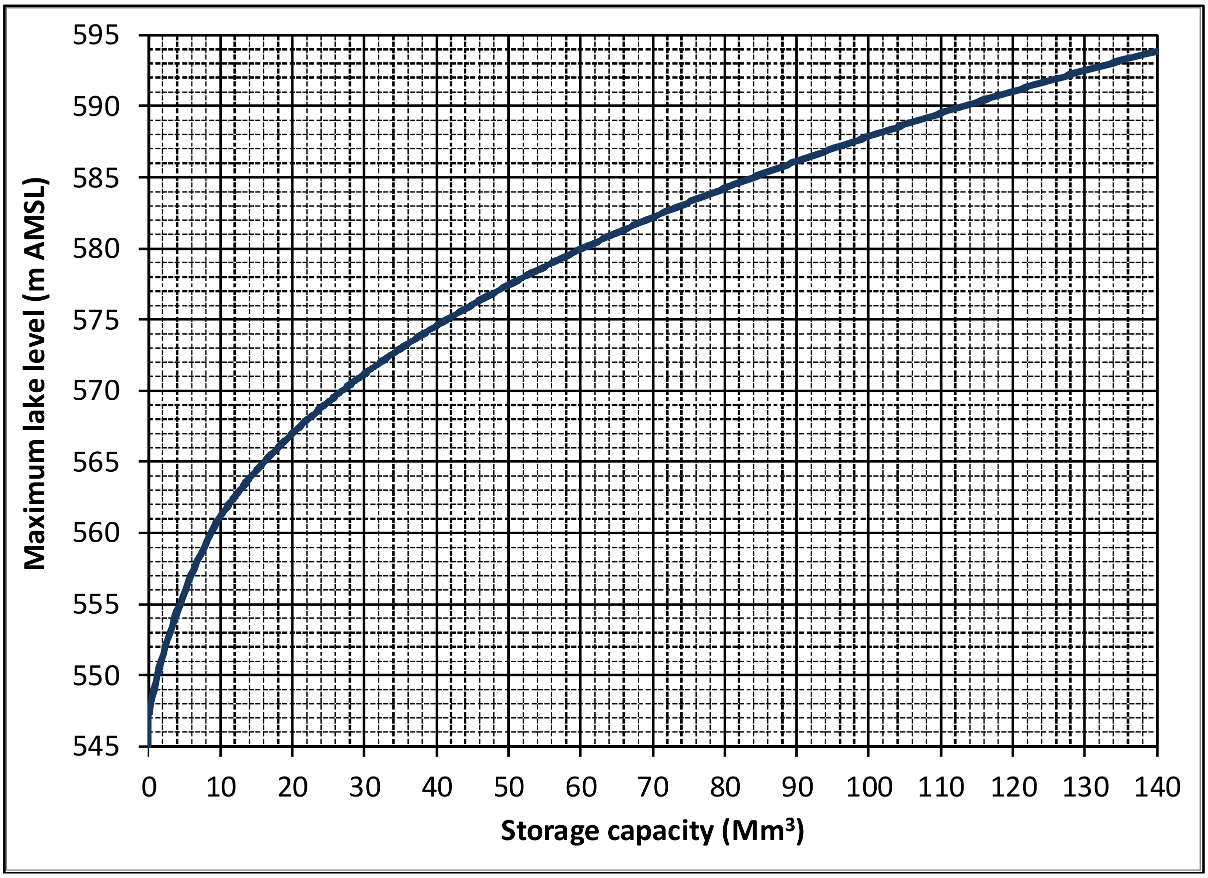
Rainfall for potential irrigable land, by sub-catchment



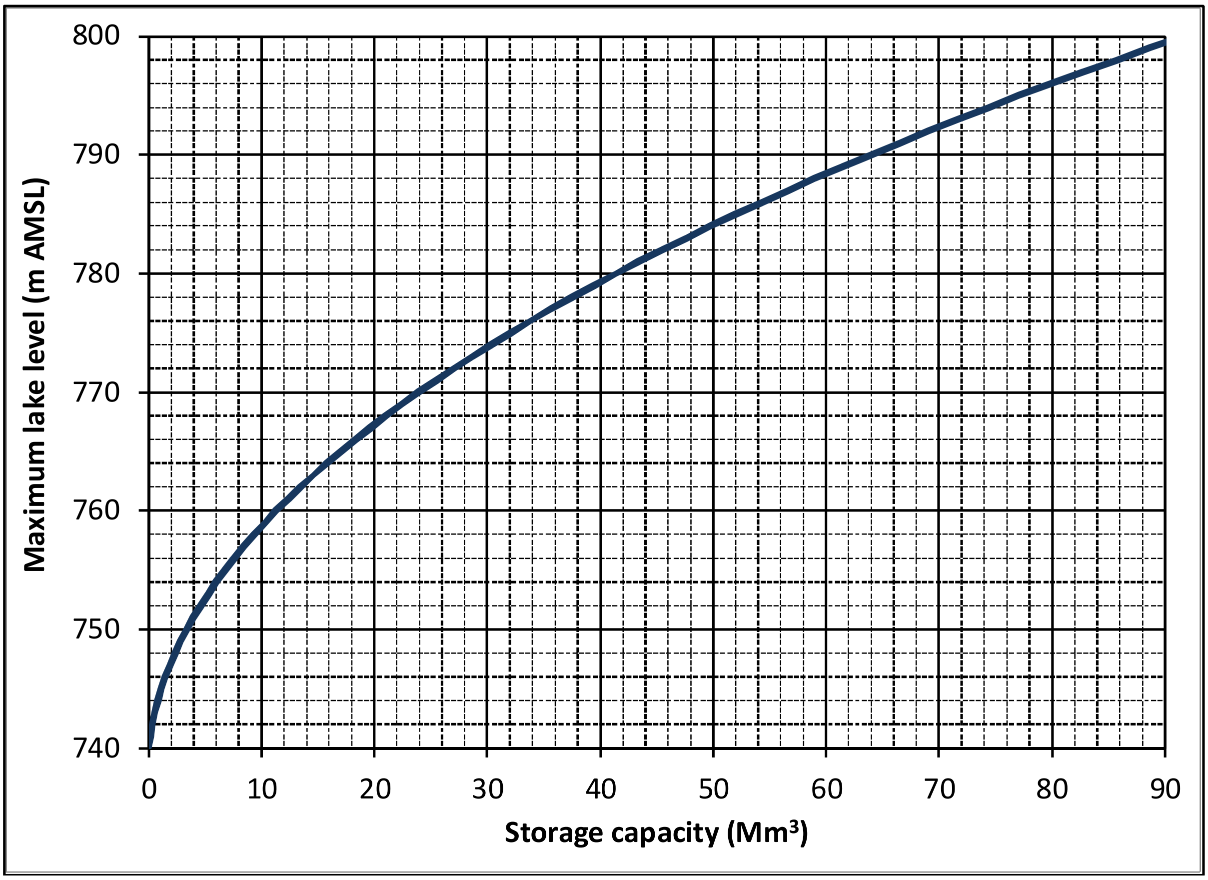
Soils for potential irrigable land, by sub-catchment

Appendix E: Natural dam sites

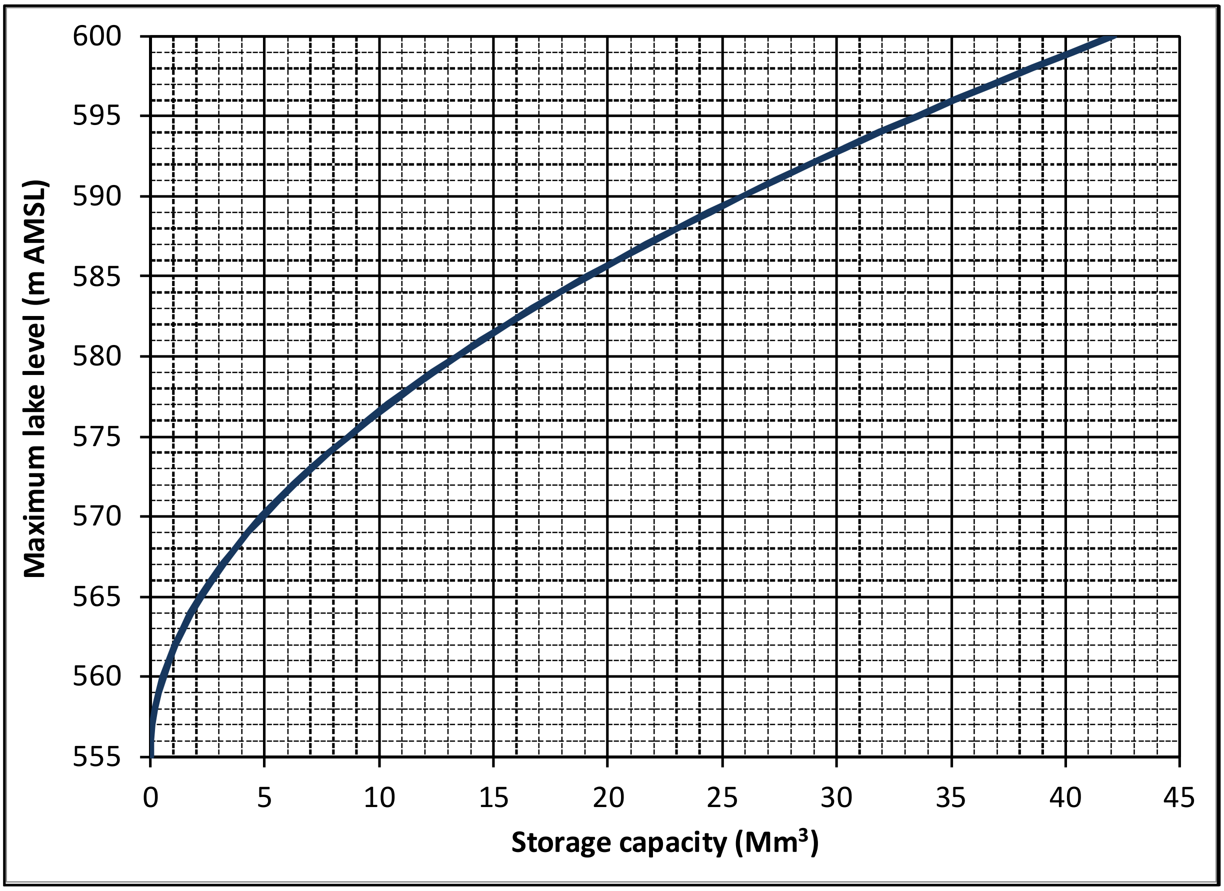




Stage – storage relationship: Raising Falls Dam

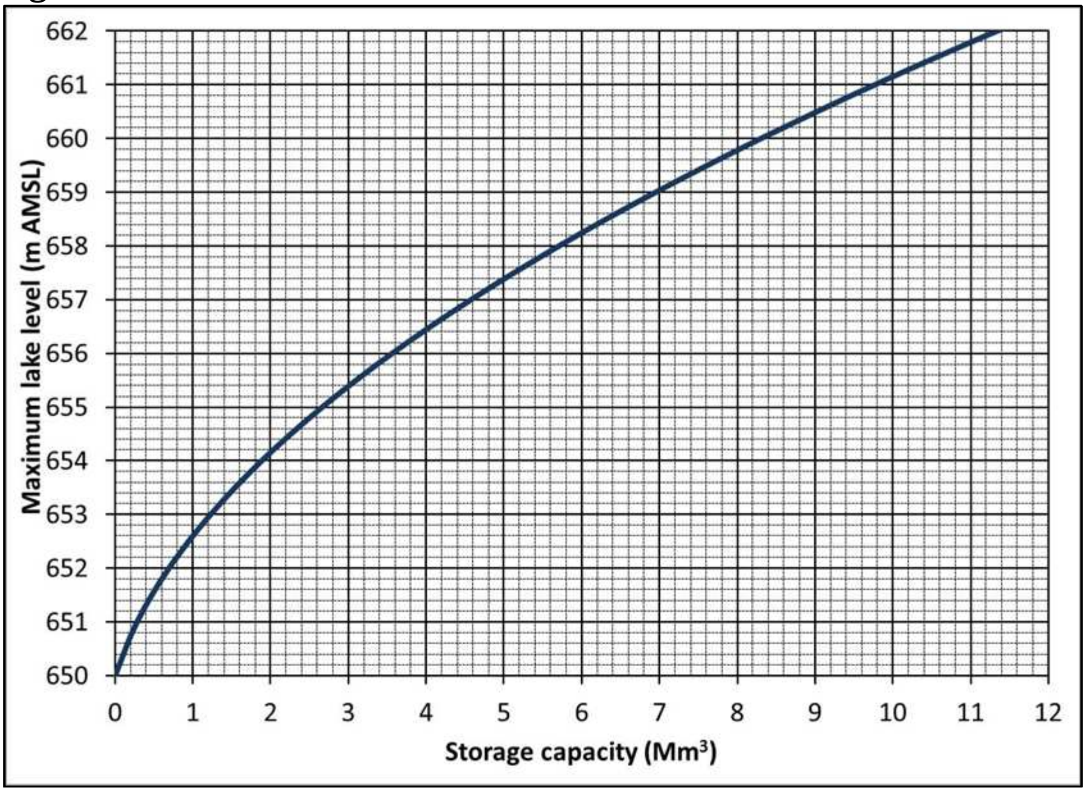


Stage – storage relationship: possible Dunstan Creek gorge dam

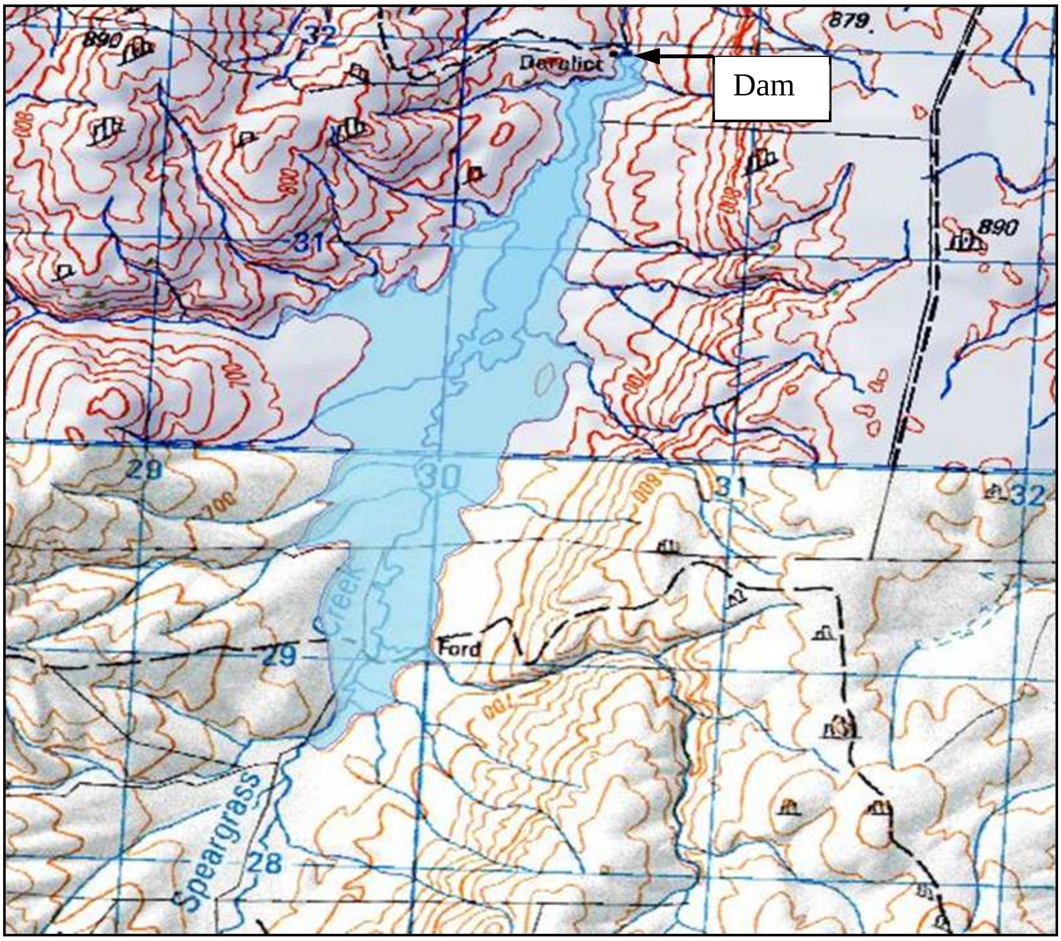


Stage – storage relationship: possible Dunstan Creek dam near St Bathans

Speargrass Creek dam

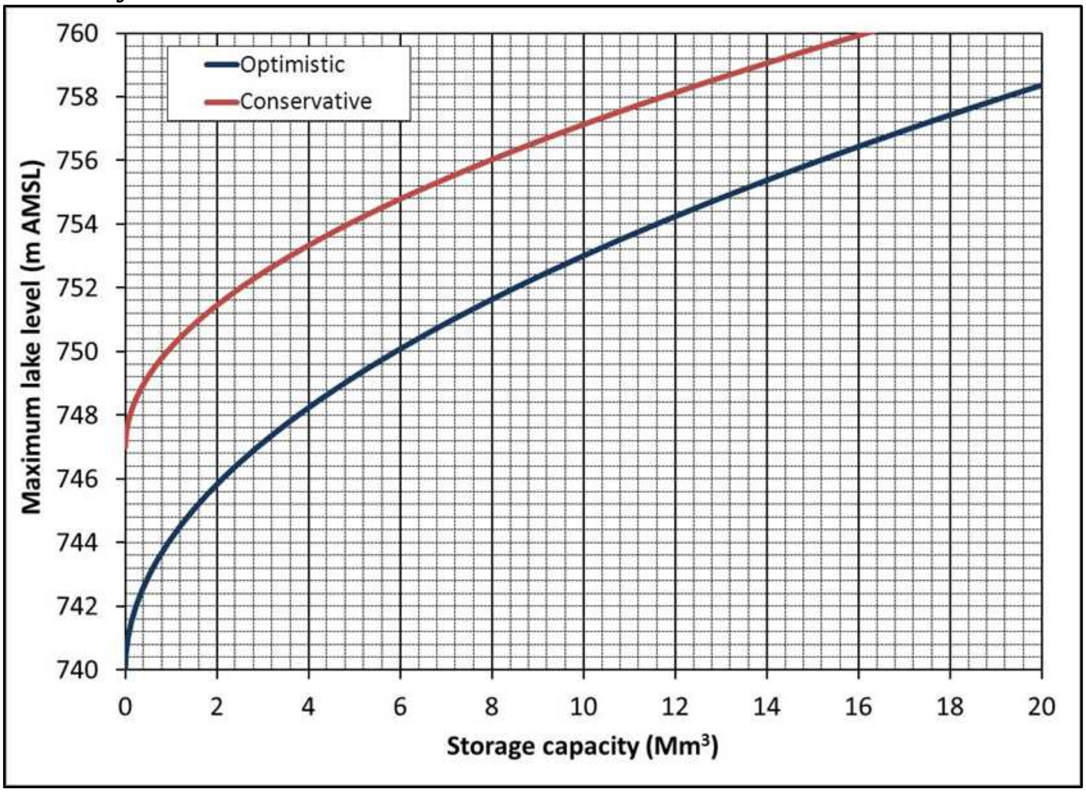


Stage – storage relationship: possible dam on Speargrass Creek

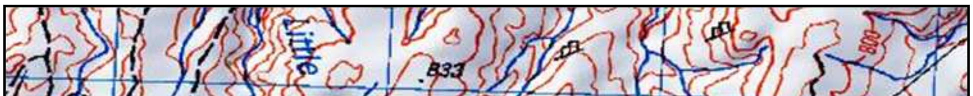


Possible dam on Speargrass Creek.

Little Valley West Branch dam

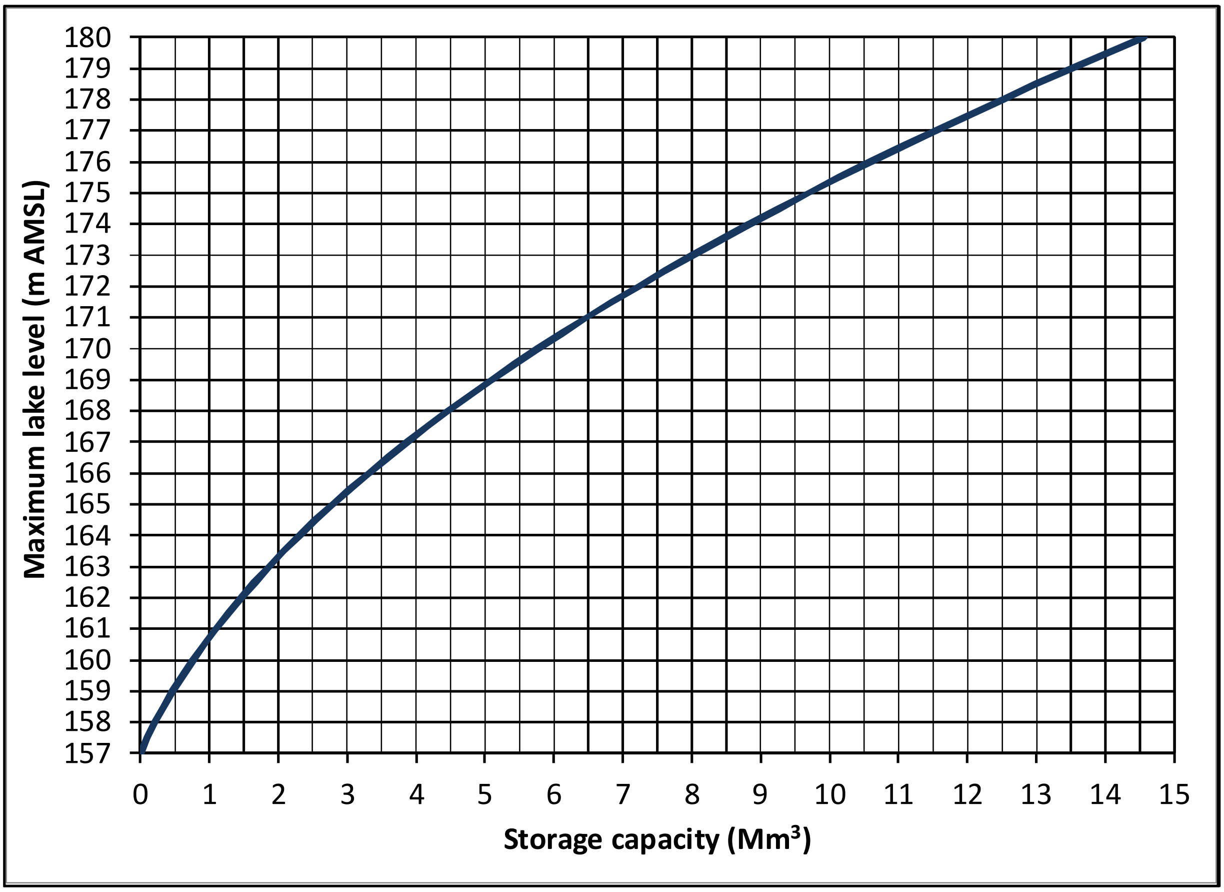


Stage – storage relationship: possible dam on Little Valley Creek West Branch

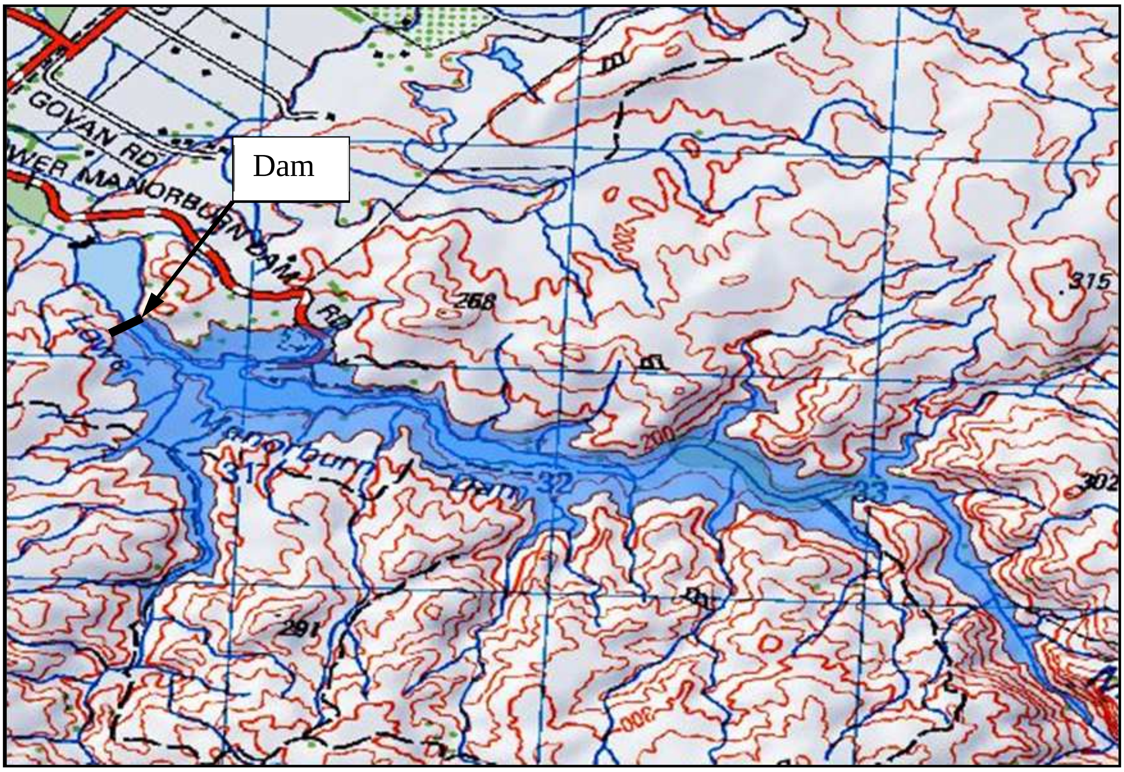


Possible dam on Little Valley Creek West Branch. Figure illustrates a maximum lake level of 760 m amsl. A maximum lake level of 755 m would provide a storage capacity of 15 Mm^3.

Alternative lower Manor Burn dam

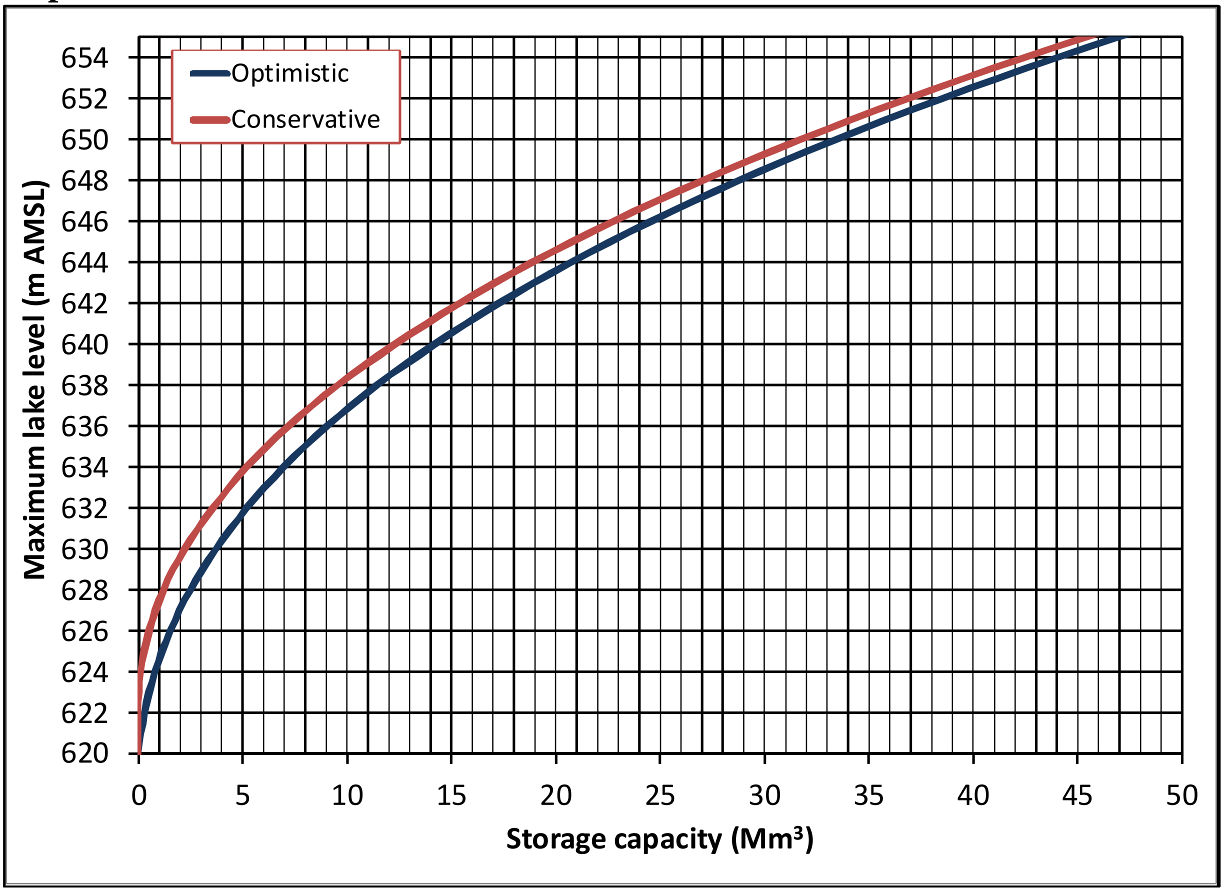


Stage – storage relationship: possible dam on Lower Manor Burn
(300m upstream of existing dam)

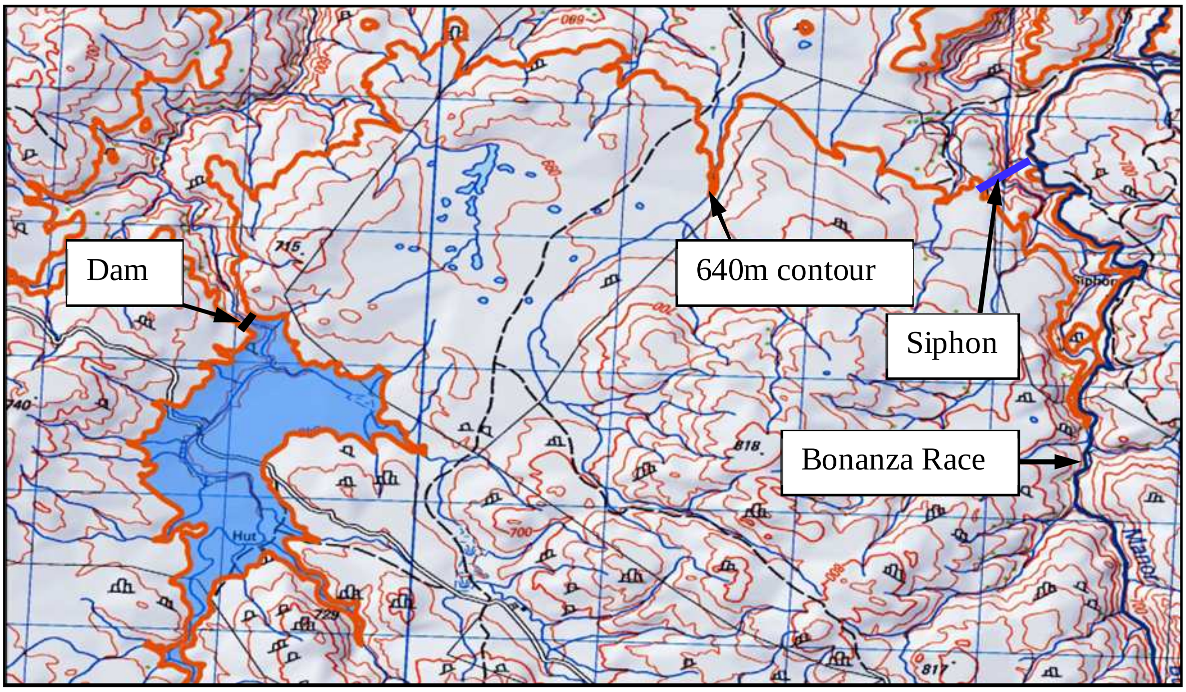


Possible dam on Lower Manor Burn (300m upstream of existing dam).

Hope Creek dam



Stage – storage relationship: possible dam on Hope Creek



Possible dam on Hope Creek. The dam could supply the Bonanza Race via a race following approximately the 640 m contour. A small pumping lift (<15m) may be necessary.