Technical Report
Environmental
Monitoring Group

Low flows of the main stem and tributaries o the Orari and Temuka Rivers and Ohapi Stream

Environment Canterbury
Your regional council

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Report No. U03/38

Prepared by
F Scarf

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58 Kilmore Street
PO Box 345
Christchurch
Phone (03) 365 3828
Fax (03) 365 3194

75 Church Street
PO Box 550
Timaru
Phone (03) 688 9069
Fax (03) 688 9067

Website: www.ecan.govt.nz
Customer Services Phone 0800 324 636

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1 Introduction

The waters of the Orari and Temuka Rivers and Ohapi Stream provide irrigation, stockwater and domestic water supply for the residents within the Geraldine, Clandeboye, Winchester, Temuka and Milford districts within South Canterbury. These waters are economically significant to the well being of these communities. In addition those same waters provide a recreational amenity for local residents and visitors to the region. The lower Orari River is noted for its whitebaiting and angling, while angling, swimming and picnicking are the more dominant activities in the Temuka River and its tributaries, with the gorge areas of the Te Moana and Waihi rivers being particularly popular.

This report summarises what is known about the low flows of the Orari and Temuka rivers, Ohapi Creek and other spring fed tributaries within the district. Much of the low flow information previously published has been re-analysed taking into account abstraction occurring for irrigation, stockwater and domestic water supplies.

2 Sources of data and information

Data and information for this study was obtained from a variety of sources including:

a) flow records and streamflow gaugings undertaken by Environment Canterbury, the previous South Canterbury Catchment Board, Environmental Consultancy Services, Environmental Quality Systems and Fish and Game (Central South Island).
b) previous reports relating to the Orari and Temuka catchments, and
c) submissions relating to various water consent application hearings.

3 Methods

Sites were classified into primary, secondary and tertiary sites.

Primary sites included all permanent flow recording sites. These generally included sites with more than 8 years of continuous flow records and in the case of the Orari River, more than 35 years of record. The lowest average flow recorded over 7 days for each water year was calculated from the daily mean flow data. That data was then adjusted to take into account any abstraction occurring upstream of the site. Low flow frequency analyses using a Gumble Type III distribution was then carried out on the corrected minimum 7day low flow series to obtain estimates of natural mean annual low flow (MALF), 1:5 year and 1:10 low flow statistics for the site. The data series for the four main sites Orari at Gorge, Te Moana at Glentohi, Kakahu at Mulvihills and Waihi at DOC Reserve are shown in Appendix 1.

Flows in the Temuka River have been recorded at Manse Bridge since 1982. However with about a third of its naturally occurring flow in summer allocated for irrigation and water supply use, the observed record is significantly impacted by those abstractions and the low flow record is not particularly useful.

Secondary sites included those sites where flow gauging had been carried out over the years and were sufficient in number to effect a correlation with flows observed at a nearby or preferably, downstream primary site. Again, the gauging data for the secondary site and the corresponding flow recorded at the primary site were adjusted for any upstream abstraction.

Tertiary sites included those where one or very few gaugings have been carried out during low flow periods. While the gauging data provided some indication of the likely low flow statistics for the site the overall reliability of that information is considered poor.

3.1 Analysis assumptions

In conducting these low flow analyses the following assumptions were made:

a) A water year extending from 1 July to 30 June of the following year.
b) Adjustment for rural or town water supplies was assumed to be the average rate shown on the relevant consent.
c) Adjustment for irrigation abstracted from surface water resources was assumed to be 50% of the average rate shown on the consent where the low flow or gauging measurement occurred during the irrigation season Dec-Mar inclusive. Lesser amounts were assumed for Nov/Apr and for Sep-Oct. If the low flow occurred outside these periods that adjustment was assumed to be nil.
d) Adjustment for groundwater abstraction was treated in a similar way. To allow for streamflow depletion effects, 25% of the average rate shown on the consent was used as opposed to 50% for surface water abstraction. That rate was used where the low flow or gauging measurement occurred in Dec-Mar with lesser amounts for other months as described above.
e) For primary sites, a Gumble Type III distribution was used to obtain the relevant low flow statistics. Other distributions, namely log Pearson Type II and log Normal Type II were also used to verify the frequency analyses.
f) For deriving the correlation equation linking primary and secondary sites only those gaugings and corresponding primary site flows less than the estimated mean for the respective sites were used. Flows in excess of mean were discarded on the considered opinion that such flows are tending towards unstable fresh conditions and any low flow relationship is less likely to hold true.
g) In viewing the secondary site and primary site data pairs there were instances where the pair was clearly an outlier. This may have occurred either as an error in the gauging or more likely as a consequence of a localised rainstorm within the secondary site's catchment and not registering significantly at the primary site. Such outliers were also discarded.

3.2 Partitioning the study

Review of information and establishment of low flow statistics for relevant sites has been developed in seven parts as follows:

a) Orari River mainstem and tributaries upstream from Gorge
b) Orari River mainstem and tributaries downstream from Gorge
c) Coopers Creek
d) Ohapi Stream
e) Kakahu River
f) Te Moana River
g) Waihi mainstem and tributaries
h) Remnant streams

Streams and sites relating to this study are shown in Figure 3.1a and b

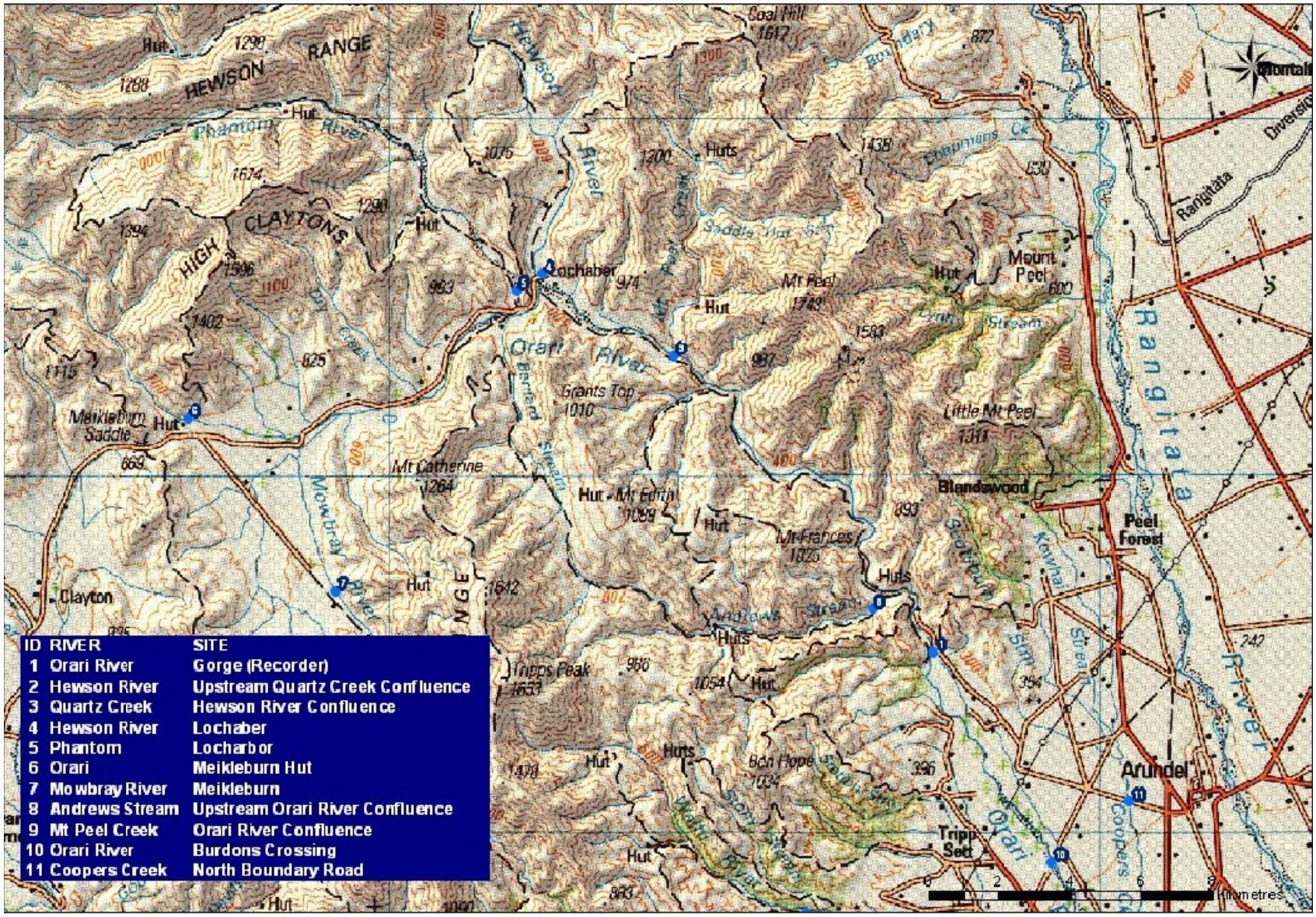

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Figure 3.1a Flow recording and gauging sites

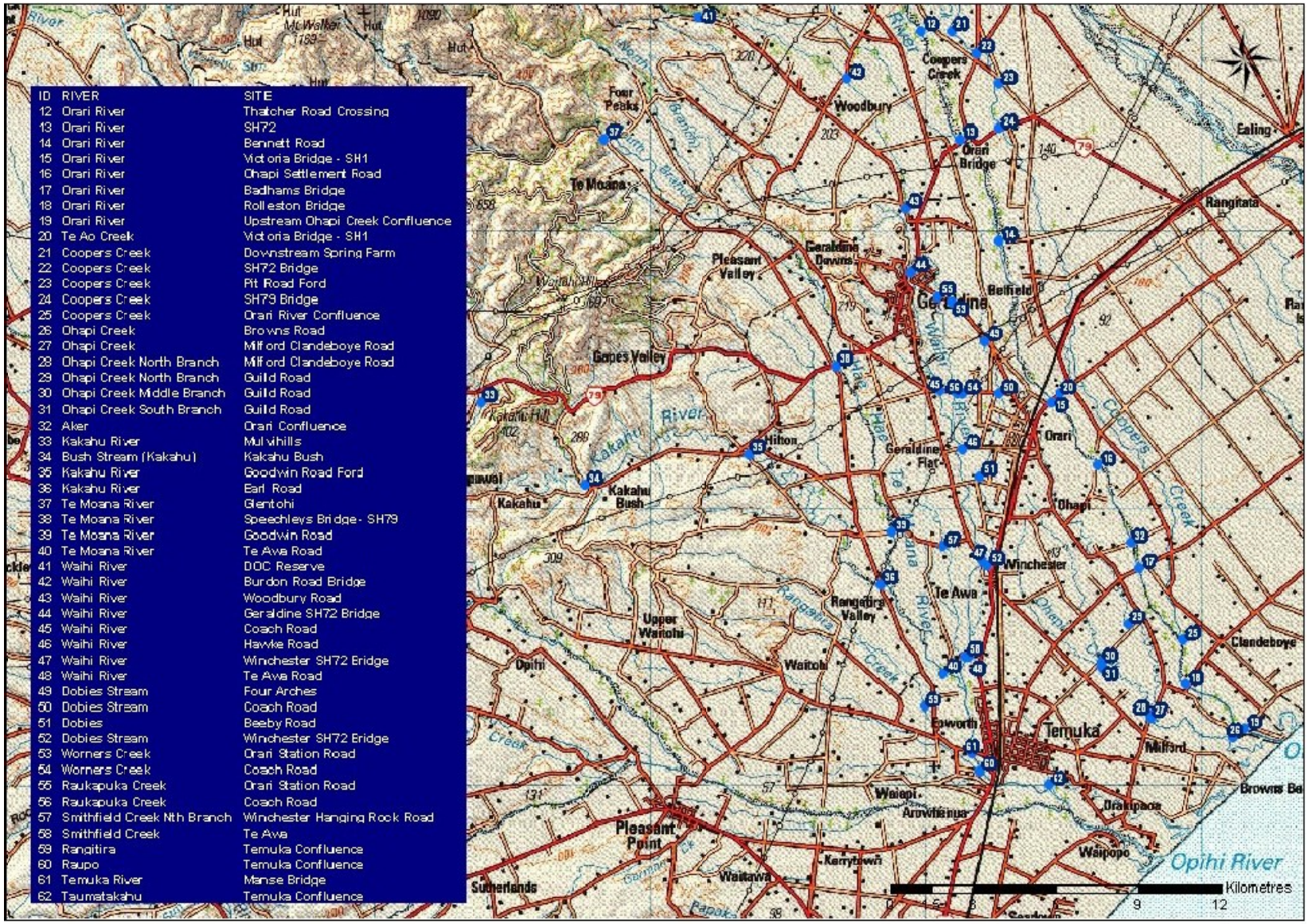

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Figure 3.1b Flow recording and gauging sites

4 Orari River

4.1 General Description

The Orari River catchment is bounded by the Rangitata River catchment to the north and by the Waihi and North Opuha river catchments to the south. From its headwaters in the Ben McLeod Range the river flows some 87km to the mouth. At this point the river commands a catchment area of about 750 km^2 and has a mean flow of about 9 m^3/s (De Joux[1]).

The catchment comprises two distinct hydrological zones. The upper catchment includes some 520 km^2 and is dominated by steep rugged slopes particularly throughout the Mt Peel, Hewson, and Phantom River tributaries. Except for about 20 km^2 of extensive flats surrounding the Meikleburn Station, the tributary rivers are confined to entrenched gorges and narrow steep sided valleys with small areas of adjacent river flats. Average annual rainfall ranges between 750mm at Meikleburn Station to about 1200mm in the headwaters of the Phantom and Hewson rivers.

From its lowermost gorge the Orari River emerges onto the extensive coalescent alluvial fans comprising the greater Orari River floodplain. This remaining 230 km^2 is comparatively featureless with the river for the remaining 40 km to the sea constrained to a permanent channel bounded either side by river control plantings and stop banking. The principal tributary of this lower section is Ohapi Creek; a spring fed stream that joins the Orari River about 1.5 km from the coast. Average annual rainfall throughout this Plains area ranges from about 1100 mm at the Gorge to 600mm at the coast.

4.2 Tributaries and mainstem upstream from the Gorge

Permanent recording of flow in the Orari River at its lowermost gorge dates from January 1960. However the chart record is not particularly reliable prior to June 1964 when the site was relocated to a new site (Silverton) about 1km upstream and a digital recorder installed. Only that record post June 1964 has been included in the flow analysis. In 1982 the Silverton site was abandoned and the recorder moved back to the original gorge site.

At the Gorge the Orari River exhibits a mean flow of 9810 m^3/s. To some extent the hydrology is dominated by seasonal snowmelt that sets in about the end of September and sustains flow at higher than average levels through to mid December. As summer progresses the river typically recedes with the lowest flow each year generally occurring at some point during the months of February to early May. Appendix 1 lists the lowest flow averaged over 7 consecutive days each water year.

Average annual 7 day low flow (MALF) for the Orari River at the Gorge is assessed to be 2753 l/s. Estimates for 7 day 1:5yr and 1:10 yr low flows are 2106 and 1894 l/s respectively.

During the period 1975-81 the previous South Canterbury Catchment and Regional Water Board (SCCB) carried out an extensive concurrent gaugings program to establish the contribution of various tributaries to the flow of the Orari River. This information has been supplemented with a similar gauging program conducted by Environmental Quality Systems (EQS) for Environment Canterbury in 2002.

Appendix 2 lists that gauging data together with the mean flow recorded at the Gorge on the date of gauging. An estimate of MALF for the tributary was obtained using standard

[1] De Joux R.T. 1980: The Water Resources of the Orari River. South Canterbury Catchment Board and Regional Water Board Publ. No. 24

correlation techniques (Appendix 2A: Figures 1-8) and these together with their corresponding specific discharge (SD) are summarised in Table 4.1.

Table 4.1: Summary of MALF estimates and corresponding specific discharge for sites upstream from Gorge.

River	Site	Map Ref.	Area (km^2)	MALF (l/s)	SD ($l/s/km^2$)
Orari	Gorge	J37:653951	520	2753	5.29
Hewson	Quartz Confl	J36:530144	72.7	624	8.58
Quartz	Hewson Confl	J38:532144	23.6	94	3.98
Hewson	Locharber	J38:542057	134	820	6.12
Phantom	Locharber	J38:537048	63	452	7.17
Orari	Meikleburn	J38:443016	35.3	241	6.83
Mowbray	Meikleburn	J38:482975	26	113	4.35
Andrews	Orari Confl	J37:636963	39.4	148	3.76
Mt Peel	Orari Confl	J37:581035	39.6	205	5.18

4.2.1 Low flow mapping for the Orari Catchment

Specific discharge was obtained by dividing the MALF by the catchment area for the site. Residual catchment areas between upstream and downstream sites were also treated the same way. The specific discharge point was plotted at the centre of its catchment area and contours drawn to produce an isohydal map of MALF to a scale of 1:50000 for the whole of the Orari River catchment. A copy of that map to a scale of 1:250000 is included in this report as Figure 4.1.

Specific discharge contours range from 20 $l/s/km^2$ along the peaks of the Ben McLeod Range to zero towards the coast. Contours for 1 $l/s/km^2$ and less are only approximate and based on local knowledge of remnant streamflows during periods of drought.

All catchments were checked by planimetering the area between successive contours and multiplying that area by the mean of the contour interval. Summing the values obtained for the whole catchment provided an estimate of MALF. This result was then checked against the MALF listed in Table 4.1. Estimates provided from integration of the isohydal map were found to be within 10% of the MALF derived from flow recorder records or flow gauging correlation for the site.

Some adjustment to previously published contours[2] along the eastern boundary of the North Opuha catchment has been necessary to merge with the new Orari low flow mapping. These changes are minor and affect only the 5, 7 and 10 $l/s/km^2$ contours.

[2] Scarf F 2002: Low flows of the Opihi River and its tributaries. Environment Canterbury Report U02/12

4.3 Mainstem Orari River flows downstream from the Gorge

4.3.1 Losses and gains in flow

Downstream from the Gorge there are very few tributaries that contribute to the flow in the Orari River, principal among these being Coopers Creek and the Te Ao Stream on the north side and Black Birch Stream and Ohapi Creek on the south side. Except for Black Birch Stream, all are springfed to varying extent with part or all of their waters being derived from losses occurring from the Orari River.

A concurrent gaugings program to determine the location and extent of losses and gains in flow downstream from the gorge was first conducted by the South Canterbury Catchment Board in the early 1970's. This is supplemented with a more recent program carried out for Environment Canterbury during the winter months of 2002. The sites used for these programs are included in Figure 3.1a and b. Flow gauging results are summarised in Table 4.2 and that data is shown plotted in Figure 4.2.

At a point about 1.5 km downstream from the Gorge recorder site, the Timaru District Council (TDC) abstracts on average about 780 l/s for stockwater purposes. Prior to 1980 that abstraction is believed to have been slightly less than that occurring currently and a take of 740 l/s has been assumed for the earlier gauging programs. To preserve the integrity of losses and gains observed between successive sites, gauging data downstream from the TDC intake has not been corrected for that abstraction. It is however included in estimates of MALF for the various sites to follow.

Except for 5 April 1973, all of the concurrent gaugings runs were done outside of the main irrigation season and so no adjustments for irrigation abstraction were required. In April 1973 the extent of abstraction direct from the river was limited to 4 consents that between them were authorised to take less than 50 l/s. Being April and late in the irrigation season no adjustments were made to the observed data.

Generally there is a loss of surface flow to subsurface flow and surrounding groundwater systems as one progresses downstream from the Gorge recorder site to below State Highway 1 (SH1); a distance of about 25 km. From there for the remaining 15 km to the sea there is a recovery in surface flow through groundwater seepage and spring fed streams. As the Orari River recedes to MALF levels and less during low rainfall years the riverbed is dry for almost 13 km from just above SH72.

Figure 4.2 clearly shows that much of the loss from surface flow occurs within the section between Burdons and SH72 with lesser losses in the sections upstream (Gorge to Burdons) and downstream (SH72 to Bennetts). From Figure 4.2 it is apparent that the total loss in surface water is not constant and to a degree is flow dependent. When flows observed at the Gorge are less than 3500 l/s and approaching MALF conditions, losses from surface flow are less than when flows at the Gorge are greater than 3500 l/s and approaching median median flow conditions.

Rates of loss and gain in flow between successive sites are summarised in Table 4.3. During low flow the river dries up at some point between Thatchers and SH72, exactly where is not known and therefore it is assumed that the rate of loss demonstrated in the upstream section; Burdons to Thatchers, continues until the point that the riverbed is dry. A similar situation occurs between SH1 and Ohapi Settlement when the river starts to flow again whereby it is assumed that the rate of gain is the same as that observed in the adjacent downstream section.

From Table 4.3 it is noted that when the river is flowing at median to mean flow levels there is a net gain in flow between Gorge and Burdons of about 260 l/s. About 120 l/s of this gain can be attributed to Black Birch Stream, a small tributary stream that joins the Orari on the south side about opposite the TDC intake.

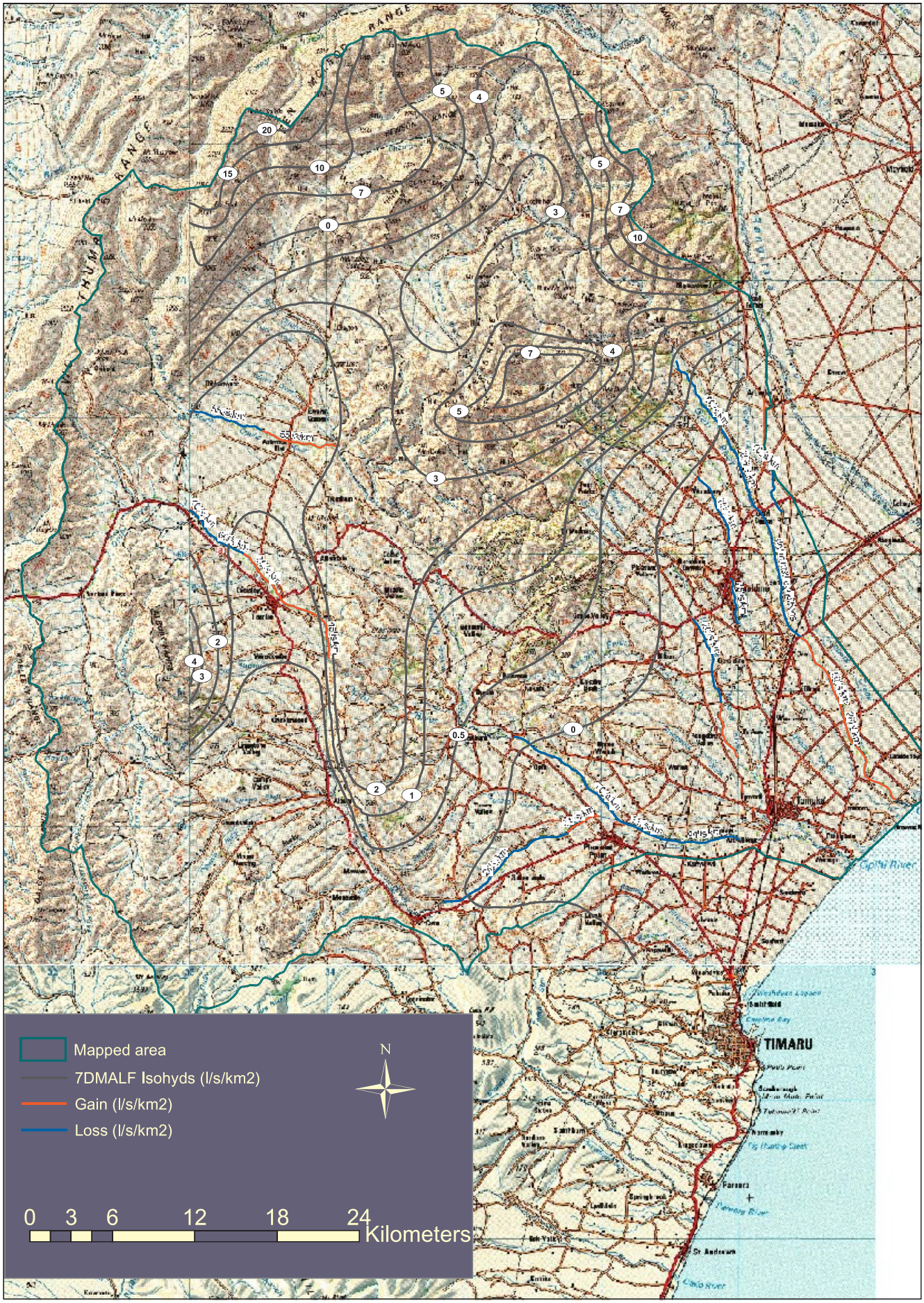


Figure 4.1 7 day MALF isohydal map for the Orari River catchment

Table 4.2 Concurrent flow gaugings in the Orari River downstream of the gorge (All flows in l s^{-1})

Site	Distance (km)	5/04/1973	23/07/1973	7/08/1974	28/11/1974	27/05/2002	9/06/2002	31/07/2002	2/09/2002	Average*	Average**
Gorge	0	2225	2560	8231	5613	3175	2776	4929	5463	2684	6059
U/str TDC intake	1.5	1985	2320	7990	5375	3115	2395	4503	5378	2454	5812
D/str TDC*intake	2.0	1245	1580	7250	4635	2335	1615	3723	4598	1694	5052
Burdons	6.8	768	1373	7160	5413	1778	1367	4117	4925	1322	5404
Thatchers	9.0	130	680	6224	4230	1130	739	3125	3681	670	4315
SH72	13.3	0	0	3831	1626	0	0	701	877	0	1759
Bennetts	17.3	0	0	2800	960	0	0	147	244	0	1038
SH1	23.5	0	0	2686	441	0	0	114	117	0	840
Settlement	26.0	0	240	3660	1040	82	38	391	522	90	1403
Badhams	30.5	184	422	4100	1620	413	234	754	992	313	1867
Rolleston	35.5	620	942	5138	2661	898	706	1179	1365	792	2586
U/str Ohapi Confl	38.0			5190	2810	1316	1034	1549	1907		2864

Notes:* 1) TDC take assumed to be 740 l/s 1973-74, and 780 l/s 2002
2) *Average of concurrent gauging runs 5/4/73, 23/7/73, 27/5/02 and 9/6/02
3)**Average of concurrent gauging runs 7/8/74, 28/11/74, 31/7/02 and 2/9/02
4) Values for Thatchers 5/4/73 and 27/5/02 are estimates

Table 4.3 Rates of flow losses and gains between successive sites on the lower Orari River(All loss/gain rates in l/s/km length of river)

From	Gorge	Burdons	Thatchers	SH72	Bennetts	SH1	Ohapi Smt	Badham	Rolleston
To	Burdons	Thatchers	SH72	Bennetts	SH1	Ohapi Smt	Badham	Rolleston	U/str Ohapi
Distance (km)	6.8	2.2	4.3	4.0	6.2	2.5	4.5	5.0	2.5
Low flow regime	-89	-296	(-296)			(+50)	50	96	(+96)
Median/mean flow	38	-495	-594	-180	-32	225	103	144	111

Notes: 1) Bracketed data assumes loss/gain rate to and from zero continues at the same rate as that shown in the adjacent reach

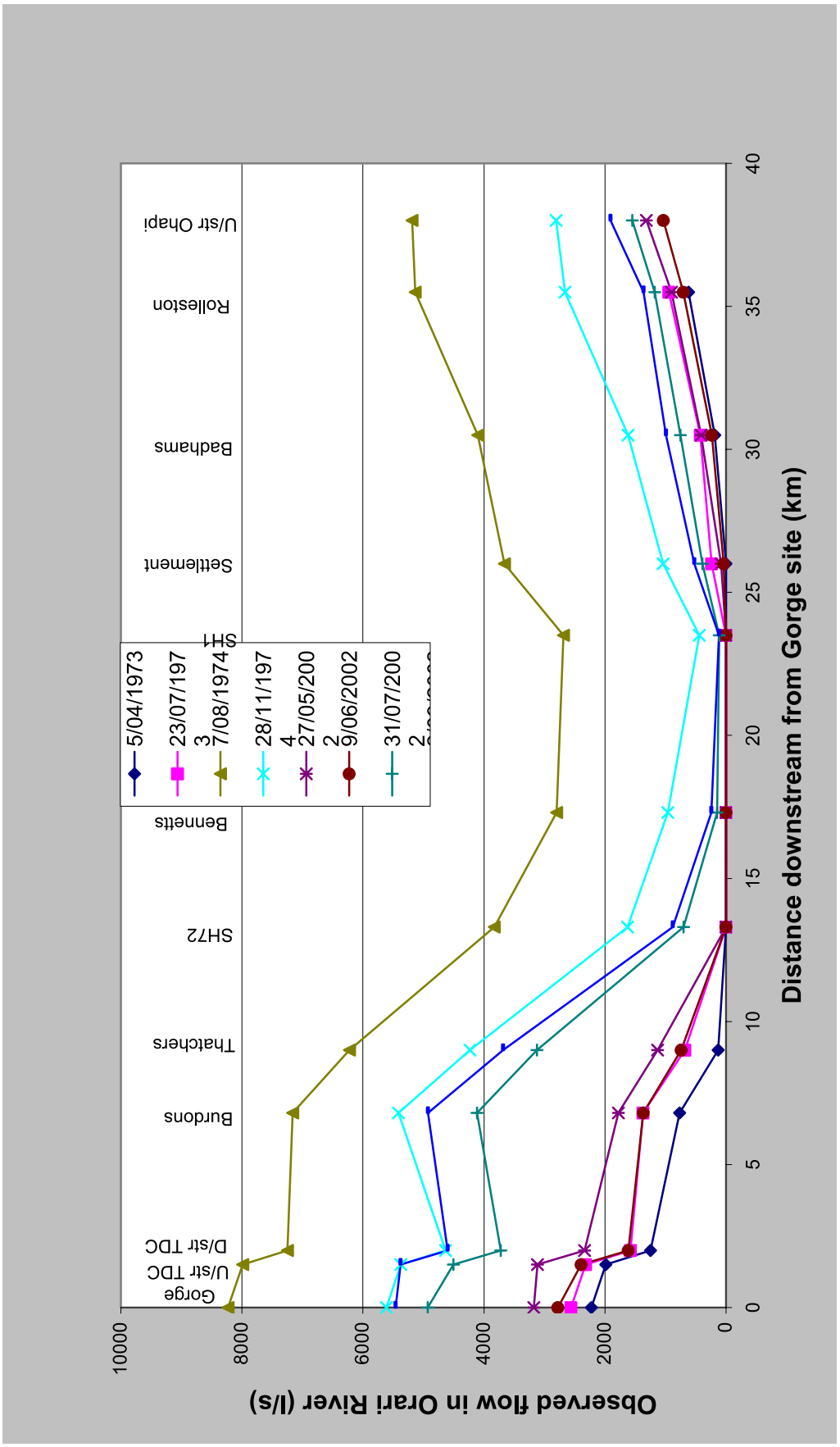


Figure 4.2 Losses and gains in flow in Orari River downstream from Gorge

4.3.2 Mean annual low flow

To establish loss and gain rates for inclusion on the low flow map, the average losses observed for runs conducted on 5 April 1973, 23 July 1973, 27 May 2002 and 9 June 2002 were used. Those data were also used to derive estimates for MALF for sites downstream from the Gorge. Referring to Table 4.2, it is noted that the average of the flows observed at the Gorge during these particular concurrent gauging runs (2684 l/s) is slightly less than MALF for this site (2753 l/s). Therefore it is be reasonable to assume that the flow profile presented by the average of those four runs is similar to that exhibited when the flow is MALF at the Gorge.

It would be incorrect to assume that were the 780 l/s currently abstracted by TDC just downstream from Gorge to be retained instream, that the flow at all downstream sites would be increased by the same amount. Clearly a proportion of that water would be permanently lost to adjacent unconfined groundwater and springfed streams.

Based on the flow profile referred to above and making some proportional correction for the TDC abstraction, Table 4.4 summarises what is considered a best estimate of MALF for sites downstream from the Gorge.

Table 4.4 Estimates of MALF for sites on the Orari River downstream from Gorge.

Site	Map Reference	MALF (l/s)
Burdons	J37:686892	1965
Thatchers	J37:698873	995
SH72	K37:712834	0
Bennetts	K37:726797	0
SH1	K37:712834	0
Ohapi Settlement	K38:762716	135
Badham Bridge	K38:777679	465
Rolleston Bridge	K38:794637	1180
U/str Ohapi Confl	K38:815621	1530

4.4 Tributaries downstream from the Gorge

4.4.1 Black Birch Stream

This stream has a catchment area of 10.7 km2 and joins the Orari River about 1 km below the Gorge recorder site. Estimated MALF at its confluence with the Orari River is 32 l/s.

4.4.2 Te Ao Stream

This stream originates from a number of springs located adjacent to the north side of the river between SH1 and Vance Road. Only 2-3 km long the stream follows along the base of a low terrace before flowing into the Orari River about 1 km downstream from the SH1 bridge. Correlating available gauging data with flows observed concurrently in the Orari River at the Gorge (Figure 4.3) indicates that its MALF at SH1 is 210 l/s. Under low flow conditions, Te Ao Stream essentially contributes all of the flow observed in the Orari River at Ohapi Settlement Road.

4.4.3 Coopers Creek

Coopers Creek originates as Kowhai Stream and Scotsburn Stream draining the southern faces of Little Mt. Peel. Once through their lower gorges the little flow present within these streams is quickly lost to channel shingles and from there to unconfined groundwater throughout the Scotsburn Road area. Only following medium rainfall events of 20mm and more at Blandswood is flow likely to be observed in Coopers Creek at North Boundary Road immediately downstream from the confluence of Kowhai Stream and the Scotsburn.

The present day course of Coopers Creek parallels the Orari River and joins the river just upstream from the Rolleston Bridge some 5km from the sea. The major source of water for Coopers Creek is a group of three springs located at Spring Farm about 1.5km northwest from the junction of Silverton Road and SH72. These springs sustain flow in the creek to just beyond Pit Road, about 2.5km downstream. For Pit Road for the next 19 km the channel is dry and little more than a grassed floodway. At the junction of Farm and Canal roads, spring flow contribution from Fitzgerald Drain sustains flow in Coopers Creek for the remaining 2km to its confluence with the Orari River.

As observed by de Joux[3], continuous surface flow only occurs throughout the length of the creek following periods of higher rainfall within the Kowhai and Scotsburn catchments.

Appendix 3 summarises concurrent gaugings information for Coopers Creek and these data are shown plotted in Figure 4.4. This clearly demonstrates the ephemeral nature of the stream. The rate of loss from the springs down to Pit Road under low flow regime is about 50 l/s/km of stream length.

Correlating flow gauging data for Coopers Creek at SH72 with flows observed in the Orari River at the Gorge (Figure 4.5) indicates that the MALF at this site is about 65 l/s. The correlation coefficient (0.6) is low reflecting the scatter of points about the line of best fit. Correlating the gauging data with flows observed in the Orari River 1, 2, 5, and 10 days previous did not effect any improvement. This would suggest that flow from the springs are derived more from the unconfined groundwater resources present in the Scotsburn Basin as opposed to any direct contribution through losses from the Orari River. Mean flow contributed by the springs is assessed to be 180-220 l/s.

[3] de Joux R.T.(1997): Evidence to Hearing considering resource consents for tributaries of Orari River and its groundwaters. Environment Canterbury.

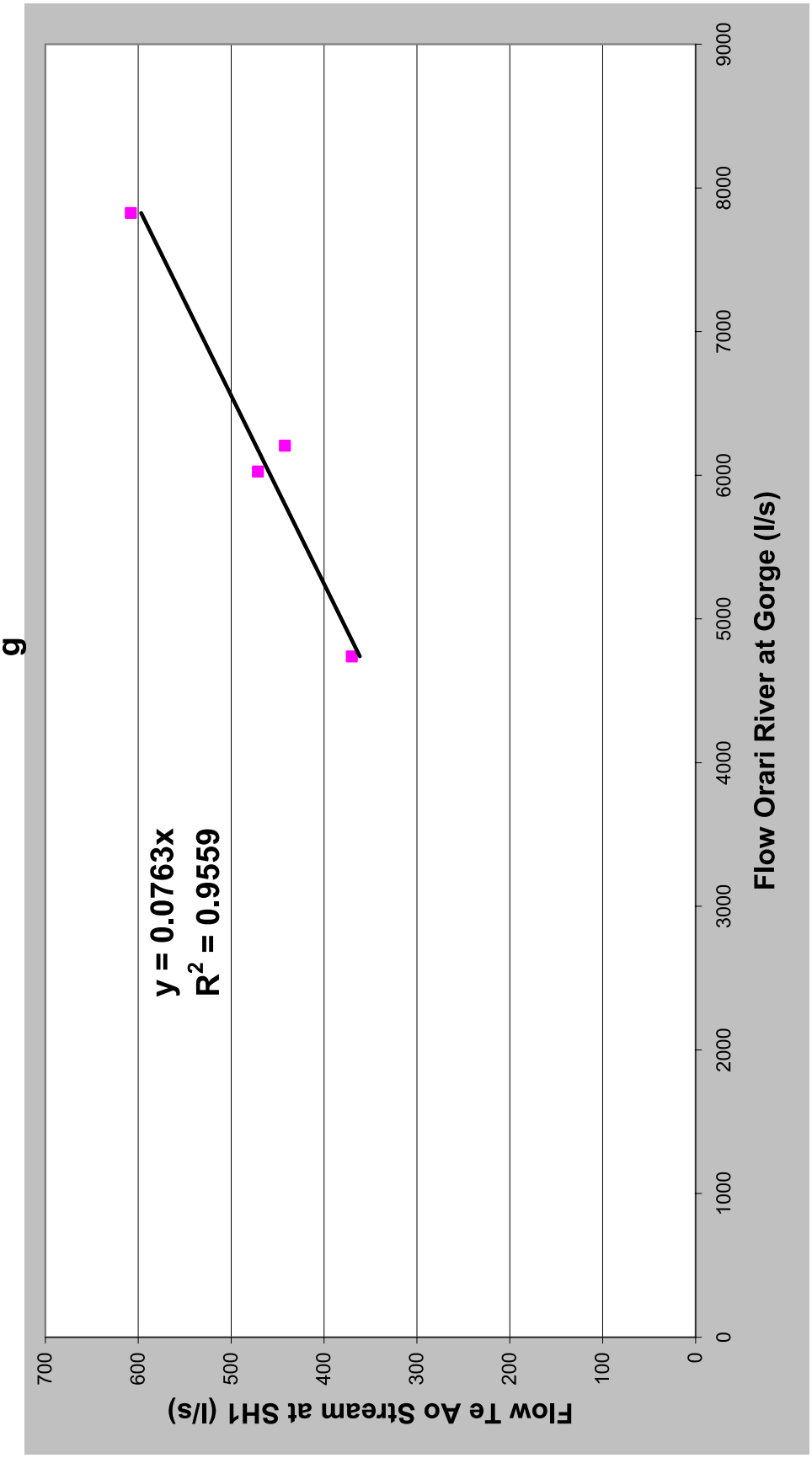


Figure 4.3 Te Ao Stream at SH1 – Correlation with flows observed in Orari River at Gorge

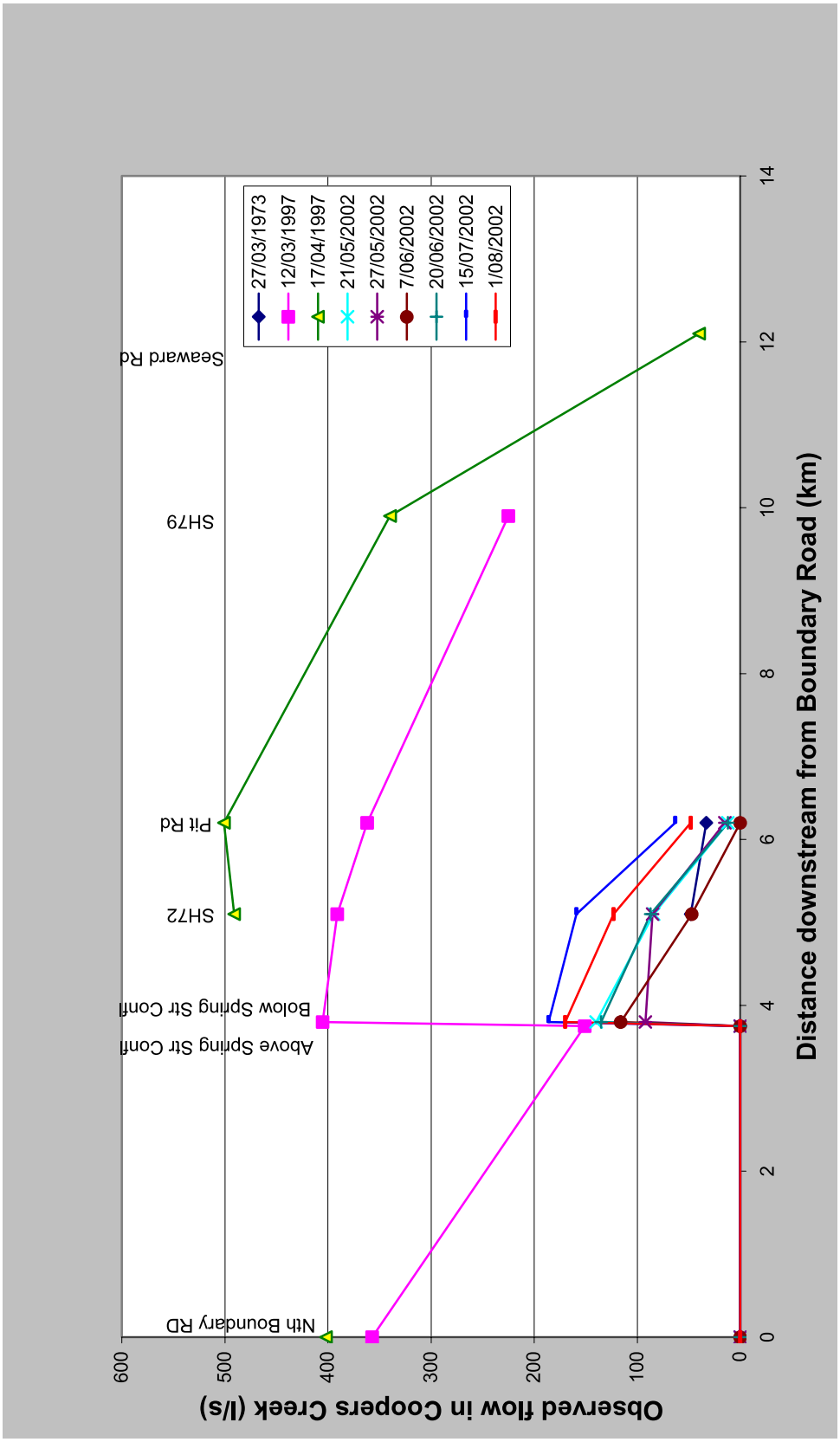


Figure 4.4 Losses and gains in flow in Upper Coopers Creek near SH72

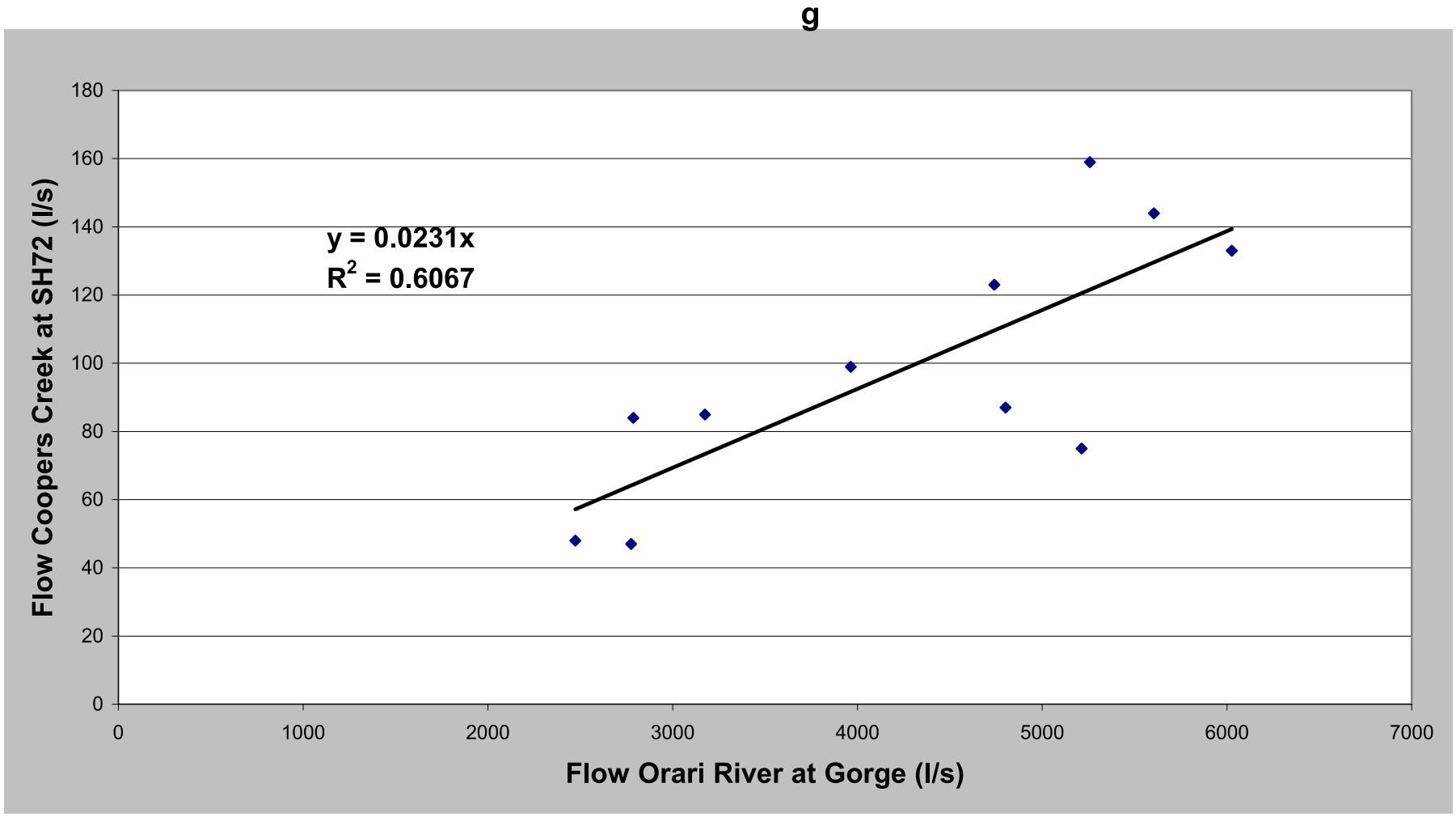


Figure 4.5 **Coopers Creek at SH 72 – Correlation with flows observed in Orari River at Gorge**

Mean annual low flows for those sites in the vicinity of SH72 has been assessed based on the above correlation and the rates of flow loss and gain relative to that site as shown in Figure 4.3. Best estimates for MALF are summarised in Table 4.5.

Table 4.5 Estimates of MALF for sites on Coopers Creek

Site	Map Reference	MALF (l/s)
Nth Boundary Rd	K38:708909	0
D/str Springs	K37:709873	115
SH72	K37:718865	65
Pit Road	K37:726854	25
SH79	K37:726838	0

Fitzgerald Drain drains swampland adjacent to the Orari River north of the Badham Bridge. The drain follows Canal Road to join the Coopers Creek floodway at the Farm Road corner. Little is known about the hydrology of this drain and the remaining 2km of Coopers Creek. Only one gauging[4] (280 l/s on 5 May 1997) has been carried out at a time when the Orari River was recording about median flow. It appears based on this one and only gauging that the MALF for Coopers Creek at its confluence with the Orari River is in the order of 150-180 l/s.

4.4.4 Ohapi Creek

Ohapi Creek is a major tributary of the Orari River. The Ohapi is about 18 km long and drains much of the flat land south from the townships of Orari and Winchester. At its confluence with the Orari River about 1.5 km from the coast, the Ohapi commands a catchment area of about 38 km^2. The creek comprises three tributaries; namely the North, Middle and South branches and these converge to form the mainstem Ohapi Creek about 3.5 km from the confluence with the Orari River.

Except during periods of heavy rainfall, all of the flow in the Ohapi is generated as springflow from some 120 springs, the bulk of which are located in the upper part of the catchment upstream from Guild Road. The location of the springs and their approximate yield has been mapped previously by McEwan.[5] Largely the springs are associated with the deposits of the Orari–Waihi alluvial fan and water emanating from them show a direct connection with flows and flow losses occurring within the Orari River (de Joux, 1997)[6]. Notwithstanding, flow in Ohapi Creek responds immediately to localised rainfall indicating that this too is a major source of recharge for the unconfined aquifer that dominates the catchment.

The water resources of Ohapi Creek and its associated unconfined shallow groundwater systems are extensively utilised by local farmers for irrigation purposes. Some 38 consents are on issue to take direct from creek and its tributaries that between them authorises the abstraction of up to 93320 m^3/day at an average total rate of 1080 l/s. When flows at Brown Road, just upstream from the confluence, depletes to less than 1000 l/s between1 October and 31 January a 50% irrigation restriction is imposed, and when the flow depletes to less than 570 l/s all irrigation abstraction is suspended. For the remainder of the year the corresponding threshold levels are 1100 and 730 l/s.

[4] Scarf F. (1997): Evidence to Hearing considering resource consents for tributaries of Orari River and its groundwaters. Environment Canterbury.
[5] McEwan G. (2002): The hydrogeology of the Orari River shallow aquifer system. Environment Canterbury Report U02/02.
[6] de Joux R.T.(1997): Rangitata-Temuka groundwater review - Issues and recommended future investigations. Technical Report Canterbury Regional Council.

In addition to surface water takes there are some 20 consents issued for groundwater abstraction. Between them these consents authorise the taking of 62130 m^3/d at an average total rate of 720 l/s.

Approximately 95% of the catchment area is irrigated using spray equipment. Because of the high level of abstraction that occurs throughout the summer months, it is difficult to establish the flow statistics for this stream with any degree of accuracy.

Hydrological information within Ohapi Creek catchment was gathered by the South Canterbury Catchment Board during the period 1965 to1987 (de Joux, 1997)[7]. The data consists of intermittent periods of continuous record from 1965-1967 at Milford Road and from 1983-1987 at Brown Road. A summary of the monthly mean data is included as Appendix 4.

The Brown Road data contains a lot of missing record. Where a missing record did not exceed 7days and appeared to be in recession, that record period was filled in assuming a flow pattern similar to that occurring in the Orari River at the time. The average flow recorded for these two periods were 1924 l/s at Milford Road (May1965-Jun 1967) and 2212 l/s at Browns Road (Dec 1983-Feb 1987). Concurrent flow gaugings show little difference between the two sites leading to the conclusion that the mean flow for Ohapi Creek at Milford Road is approximately 2100 l/s.

To establish the relative contributions from the three branches of Ohapi Creek, a number of concurrent gauging runs have been carried out over recent years. These results are shown in Appendix 5. Analysis of that data shows that 93% of the flow observed in Ohapi Creek is generated above Guild Road. At Guild Road, the contribution from the North, Middle and South branches averages 36%, 25% and 39% leading to mean flow estimates for these sites of 700, 490 and 760 l/s respectively.

Using a water year extending from 1 July to 30 June, 7 day low flow data was abstracted from the short period of fragmented daily flow record available. This is shown in Appendix 6. The period includes both the extremely dry summer of 1985 when flows in most rivers and streams in South Canterbury depleted to about 1:10yr low flow levels. At the peak of that low flow period all irrigation abstraction from Ohapi Creek was rostered and restricted to 50% of allocation.

Estimated mean annual low flows for sites on Ohapi Creek and its tributaries are shown in Table 4.6.

Table 4.6 Estimates of MALF for sites on Ohapi Creek and its tributaries

Creek/Tributary	Site	Map Reference	Est. MALF (l/s)
Ohapi	Browns Rd	K38:811618	1380
Ohapi	Milford Rd	K38:781625	1380
North Branch	Milford Rd	K38:781626	480
North branch	Guild Rd	K38:773659	460
Middle Branch	Guild Rd	K38:763645	320
South Branch	Guild Rd	K38:763643	500

[7] de Joux R.T.(1997): Evidence to Hearing considering resource consents for tributaries of Ohapi Creek and its groundwaters. Environment Canterbury.

4.4.5 Aker Creek

This is a small spring fed tributary generated from springs on the south side of the Orari River in the vicinity of Aker Road. The stream is less than 2.5 km long and joins the Orari River just downstream from the Badham Rd Bridge. Little is known about its hydrology other than its MALF is likely to be less than 50 l/s.

5 Temuka River

5.1 General description

The Temuka River catchment comprises three main tributaries, the Waihi (154 km^2), TeMoana (179 km^2) and Kakahu (166 km^2) rivers, and drains the eastern slopes of the Four Peaks Range together with an extensive area of rolling foothills and flatlands located between the Orari and Opihi catchments.

Land use is concentrated on the flats that occupy approximately 35% of the 625 km^2 catchment area commanded by the Temuka River. Land use is particularly diverse in this catchment ranging from traditional sheep, deer and cattle farming and forestry on the downlands and higher altitude areas to orchards, cropping, dairying and intense livestock farming on the flats.

The water resources of the Temuka and its tributaries are utilised extensively for irrigation purposes. Currently there are some 130 consents on issue authorised to take on average 633l/s from surface waters and 1812 l/s from unconfined groundwater within the catchment.

Flow in the Temuka River has been recorded at Manse Bridge since Sept 1991. Permanent flow records for the Kakahu (Mulvihills), Te Moana (Glentohi) and Waihi (Doc Reserve) rivers date back to 1983 although reliable records for the latter site started in 1991. Prior to that flow in the Waihi was recorded at Waimarie Bridge, about 1 km downstream from the present site. Recently the Waihi and Kakahu sites have been downgraded to flood warning sites and low flow records are no longer available.

5.2 Kakahu River

The Kakahu catchment comprises mainly forested hill country. However intensive livestock farming and dairying is the predominant land use on the flatter lands between Hilton and the confluence with the Te Moana River. These flats make up about 18% of the total catchment area

A series of concurrent flow gaugings were carried out as part of this study. Unfortunately snowmelt from two untimely snowfall events occurred during the course of the fieldwork and the results were clearly atypical. That data series was largely abandoned.

Tertiary sandstone, limestone and mudstone deposits dominates the geology of the Kakahu with the overlying soils associated with this geology being poor draining, fine silt and clay loams.

Therefore it is generally considered that, other than tributary gains, there is no loss in flow within the Kakahu River at least down to Earl Road, where the underlying mudstone continues to be exposed in the bed of the river. Estimates for MALF for various sites are summarised in Table 5.1. Except for the Mulvihills site, the estimates have been established from the few low flow gaugings available and are little more than rough approximations. Therefore the data should be treated with caution.

Table 5.1 Estimates of MALF for sites on the Kakahu River

River/Tributary	Site	Map Reference	Est. MALF (l/s)
Kakahu	Mulvihills	J36:538739	37
Kakahu	Kakahu Bush	J36:574710	47
Kakahu	Goodwin Rd Ford	J36:635720	48
Kakahu	Earl Rd	J36:633673	48

5.3 Te Moana River

At its confluence with the Kakahu River, the Te Moana River has a catchment area of 179 km^2. It has two main tributaries excluding the Kakahu, the North Branch Te Moana and the South Branch Te Moana. Both tributaries drain the eastern faces of the Four Peaks Range and join to form the Te Moana River about 3km above Pleasant Valley. From the junction the river runs for about 15 km to its confluence with the Kakahu followed by a further 5km to its confluence with the Waihi River at Te Awa. Land use is similar to that described for the Kakahu River.

A series of concurrent gaugings were carried out during the winter of 2002. The gauging data is summarised in Appendix 7 and shown plotted in Figure 5.1.

Unfortunately the gauging runs done after and including 19 June were impacted by localised snowfall events and there is some uncertainty that the losses and gains are representative. However it appears that down to Speechleys Bridge the Te Moana accumulates flow consistent with its tributary contributions. From Speechleys to Goodwin Road there is a loss of about 130 l/s (20 l/s/km of river) whenever the flow at Speechleys is less than 400 l/s.

Local observers[8] report that during low flow periods there is a rapid loss of water to bed shingle between Speechleys Bridge and McKenzie Road followed by some recovery to Toomeys Bridge. From there through Goodwin Road to the confluence with the Kakahu there is a further loss in surface flow but beyond that point the river recovers flow over the remaining 5km through to Te Awa.

[8] McLintock G. *pers comm*

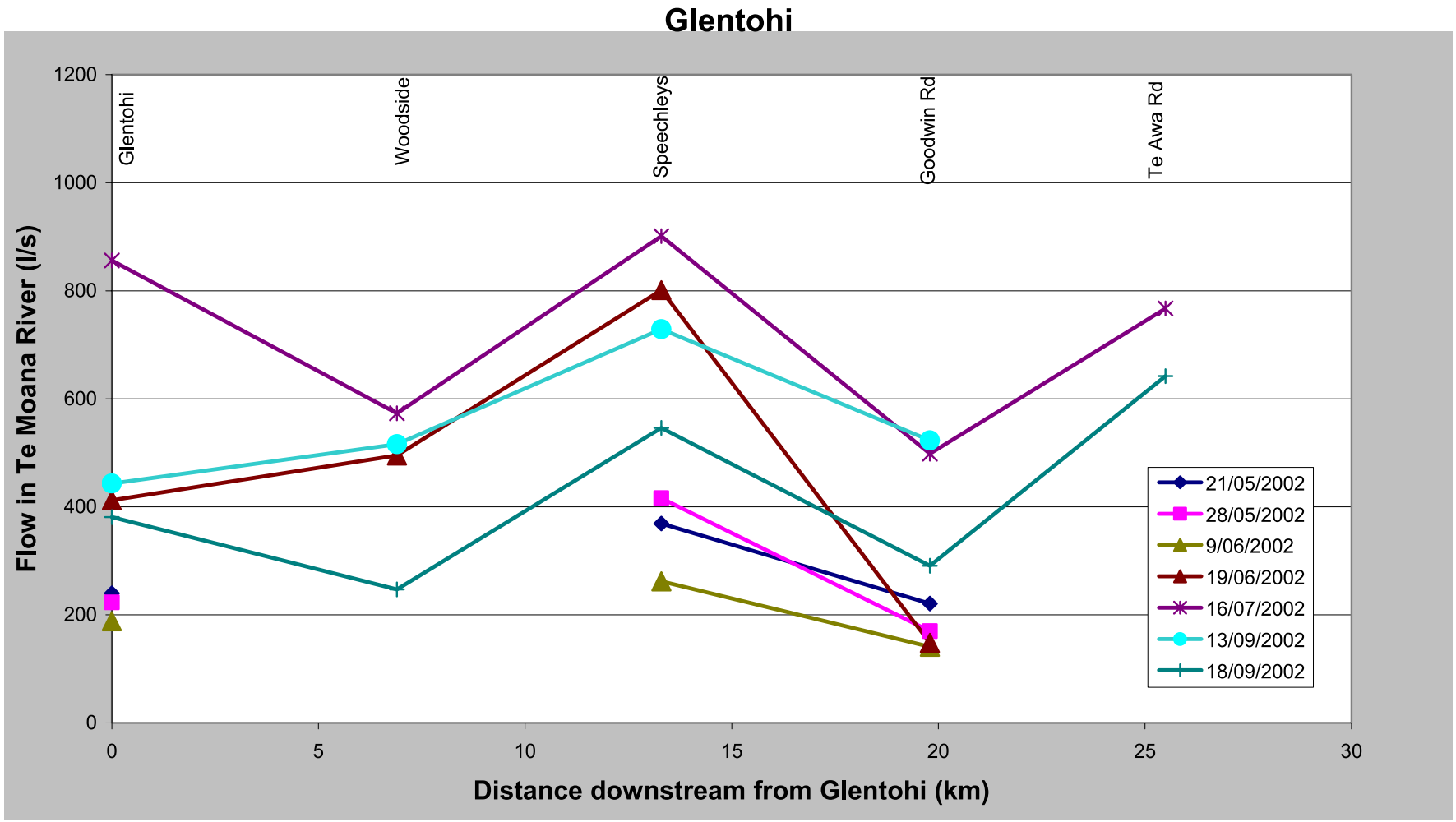


Figure 5.1 Losses and gains in flow in Te Moana River downstream from Glentohi

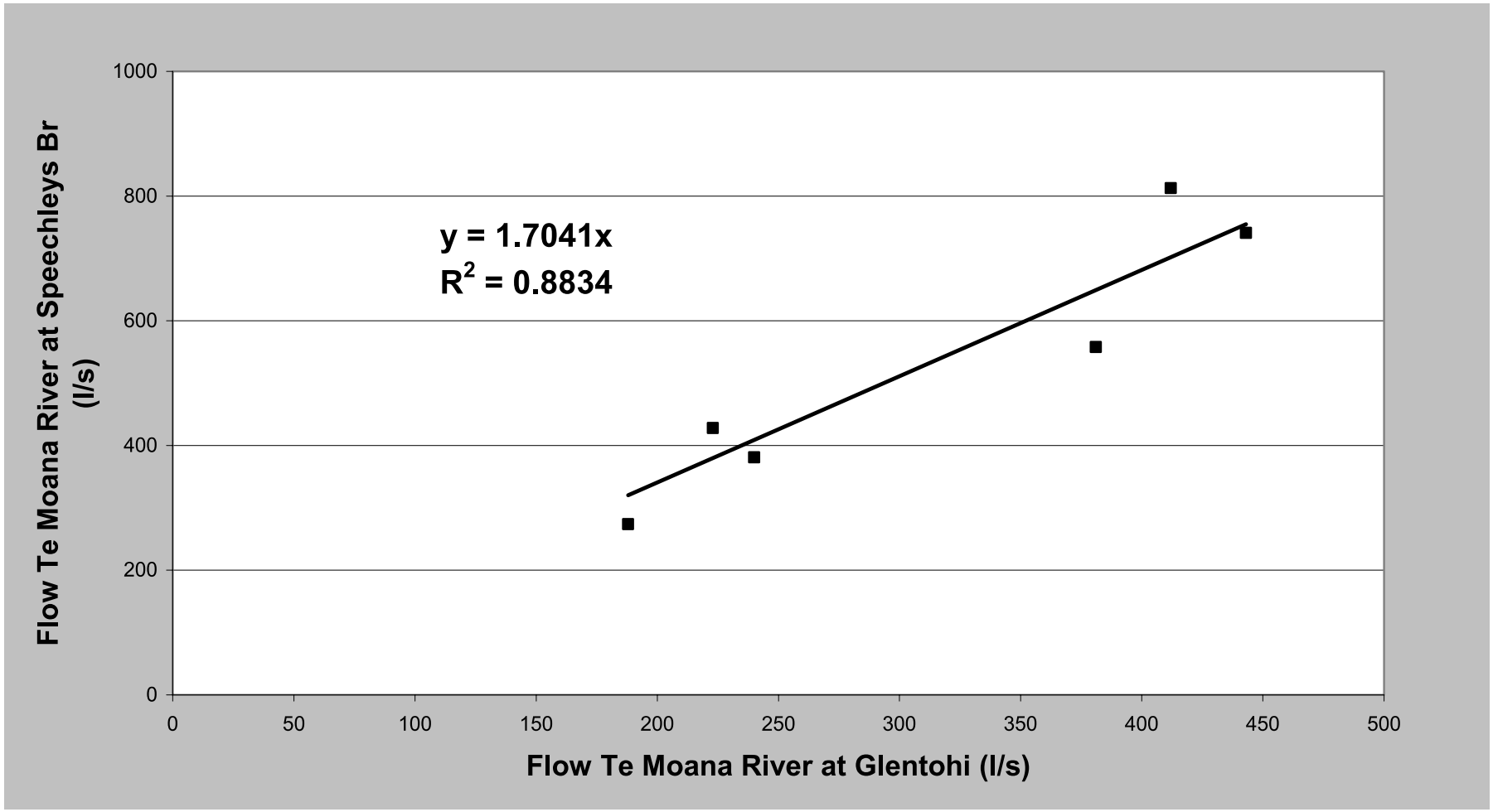


Figure 5.2 **Te Moana River at Speechleys Bridge – Correlation with flows observed in Te Moana River at Glentohi**

Estimates of MALF for various sites on the Te Moana River are shown in Table 5.2. Figure 5.2 shows a correlation for Speechleys Bridge. Other than for Glentohi and Speechleys Bridge the estimates should be treated as rough approximations.

Table 5.2 Estimates of MALF for sites on the Te Moana River

River/Tributary	Site	Map Reference	Est. MALF (l/s)
Te Moana	Glentohi	J37:583834	182
Te Moana	Speechleys Br	J38:667752	310
Te Moana	Goodwin Rd	J38:687692	170
Te Moana	Te Awa	K38:706641	300

5.4 Waihi River

The Waihi River at its confluence with the Te Moana River commands a catchment area of 154 km^2 of which about 25% is steep hill country. The remaining area comprises downs and flatlands where the land use includes intense livestock farming, dairying, deer farming, cropping and orcharding.

Draining the eastern slopes of the Four Peaks Range, the river from its gorge to the Te Moana confluence has a channel length of about 27km. The Waihi is noted for its springfed tributaries, namely Dobies, Worners, Raukapuka and Smithfield creeks which between them provide a relatively constant inflow of groundwater to the Waihi River and hence the Temuka River system.

A major concurrent gauging programme to establish the extent of flow loss and gain throughout the channel length was carried out during the winter of 2002. The results of that study together with previous data is summarised in Appendix 8 and shown plotted in Figure 5.3.

McLintock[9] describes the flow loss and gain pattern during periods of low flow as follows. From the DoC Reserve to Burdens Road there is no loss other than the continuous abstraction of water into the Woodbury Stockwater Race, about 45 l/s. Below Burdens there is a sharp loss to both bed shingles and surrounding unconfined groundwater to the extent that the river is dry at Keen Road. Beyond Keen Road there is a slight recovery through to Woodbury Road and the junction with Bennets Stream that joins the Waihi just above the SH72 Geraldine Bridge. This continues through to about the Geraldine High School when the river again loses water to be dry at Coles Street. This situation continues through to the confluence with Raukapuka Stream, about 1km below Coach Road. From there the Waihi River gains in flow from both tributary contribution and groundwater seepage through to Te Awa.

From Appendix 8 average loss rates have been estimated as follows; from Burdons Road to Woodbury Road, 25 l/s/km, and from SH72 Geraldine to Coach Road, 75 l/s/km length of river.

5.4.1 MALF estimate for Waihi River at SH72 Winchester

Over the years the Waihi River has been gauged at SH72 Winchester on a number of occasions. That data set corrected for abstraction occurring at the time of gauging is shown in Appendix 9 together with comparative flows occurring in the Orari River at the Gorge that time. Correlation of that data is shown in Figure 5.4. While the relationship between the two sites appears not to be particularly robust it has enabled the determination of a rough approximation of MALF for the SH Winchester site. This is assessed to be 870 l/s.

[9] McLintock *pers comm*

5.4.2 Dobies, Worners, Raukapuka and Smithfield Creeks.

De Joux et al[10] describes these springfed tributaries of the Waihi as follows. These creeks provide a valuable and relatively constant inflow of groundwater to the Waihi River and hence to the Temuka River system. Dobies, Worners and Raukapuka creeks rise as springs between Geraldine and the Orari River while Smithfield arises as springs in the Geraldine Flat area between the Waihi and Te Moana rivers.

Dobies Creek follows approximately the pre 1852 Orari River channel that historically joined the Waihi River above Winchester while Worners and Raukapuka mainly intercept groundwaters from the ancient Orari River floodplain in addition to flow losses occurring within the Waihi River. Neither Worners nor Raukapuka have been known to go dry, unlike Dobies Creek where in extreme drought situations the stream has dried up over its entire length to just below the Winchester township. This infers that Worners and Raukapuka are sourced alternatively at least in part to Dobies Creek. As explained below Dobies Creek is sourced almost entirely from water losses occurring from the Orari River.

From July 1984 to June 1986, the South Canterbury Catchment Board operated a flow recorder in Dobies Creek at Four Arches where Dobies Creek crosses Station Road. During the period, the Board also observed water levels in a well (Ritchies) located between the creek and the Orari River. The records for the period, together with the corresponding flow record for the Orari River is shown in Figure 5.5.

Figure 5.5 shows there is an immediate response between flow in the Orari River and flow observed in Dobies Creek. This was noted by deJoux et al together with the following conclusions in relation to this graph:

- For Ritchies well, the smooth sections represent the general groundwater level generated by loss of flow from the Orari River while the smaller sharp peaks are caused by recharge from local rainfall events.
- Similarly for Dobies Creek, the flow hydrograph shows a background flow generated by the Orari River through groundwater and superimposed on this are a series of sharp peaks caused by localised rainfall.
- Dobies Creek went dry on two occasions during this study period, once for a period of 5 months during the 1985 drought and again for 17 days in early 1987. On both occasions the level in Ritchies well had reduced to about 4.9m above datum. In the earlier event flow in the Orari had receded to less than to less than 2500 l/s while for the second event the drying up unfortunately coincides with a short period of missing record in the Orari.
- Once dry, flow in Dobies Creek is not regenerated until flows in the Orari River exceed about 8000l/s and the level in Ritchies Well has recovered to about 7m above datum.

MALF for Dobies Creek at SH72 Winchester has been derived from gauging data and concurrent flows observed in the Orari River at Gorge. The data set is included as Appendix 10 and the correlation is shown in Figure 5.6. Three concurrent gauging runs incorporating two sites in addition to the Winchester site were included in the recent study. This together with the 1980s work provided estimates of MALF for other sites on Dobies Creek and these are included in Table 5.3 to follow.

Worners and Raukapuka creeks originate as springs upstream from Orari Station Road. The two streams parallel each other for about 4km before their junction about 1km downstream from Coach Road. From there the stream continues as Raukapuka Stream for the remaining 1km to its confluence with the Waihi River.

[10] de Joux R.T.,Sevicke-Jones G.T., Scarf F. 1988: The water resources of the Temuka River. South Canterbury Catchment Board Publication No 58.

During periods of low flow, the flow observed in the Waihi River at SH72 Winchester is made up primarily from flow contributed by these two streams. To establish the extent of that contribution concurrent flow gaugings for the three sites Raukapuka at Coach Road, Worners at Coach Rd and Waihi at SH72 Winchester were collated and corrected for any abstraction occurring at the time of the gaugings. That data set is shown in Appendix 11. Flows observed in the Waihi River were then correlated with the sum of the flows observed in the Raukapuka and Worners creeks. This is shown in Figure 5.7.

From this it is concluded MALF for the combined flow of these streams at Coach Road is 645 l/s. Correlating the flows observed in Raukapuka with those observed in Worners (Figure 5.8) leads to estimates for MALF of 345 and 300 l/s respectively for their Coach Road sites.

Approximations of MALF for these streams where they cross Station Road was obtained from a limited series of four concurrent gauging runs done during the 2002 survey. Those estimates are included in Table 5.3 to follow.

And so to Smithfield Creek, this stream drains much of the floodplain between the Waihi and Te Moana rivers. The stream comprises two main branches of which both arise from springs in the vicinity of Geraldine Flat and Wilks roads.

There are a few gaugings available to enable correlation with concurrent flows observed in the Orari River at Gorge, That data set is included as Appendix 12 and the correlation is shown is Figure 5.9. Estimates of MALF for various sites on Smithfield Creek are included in Table 5.3 to follow.

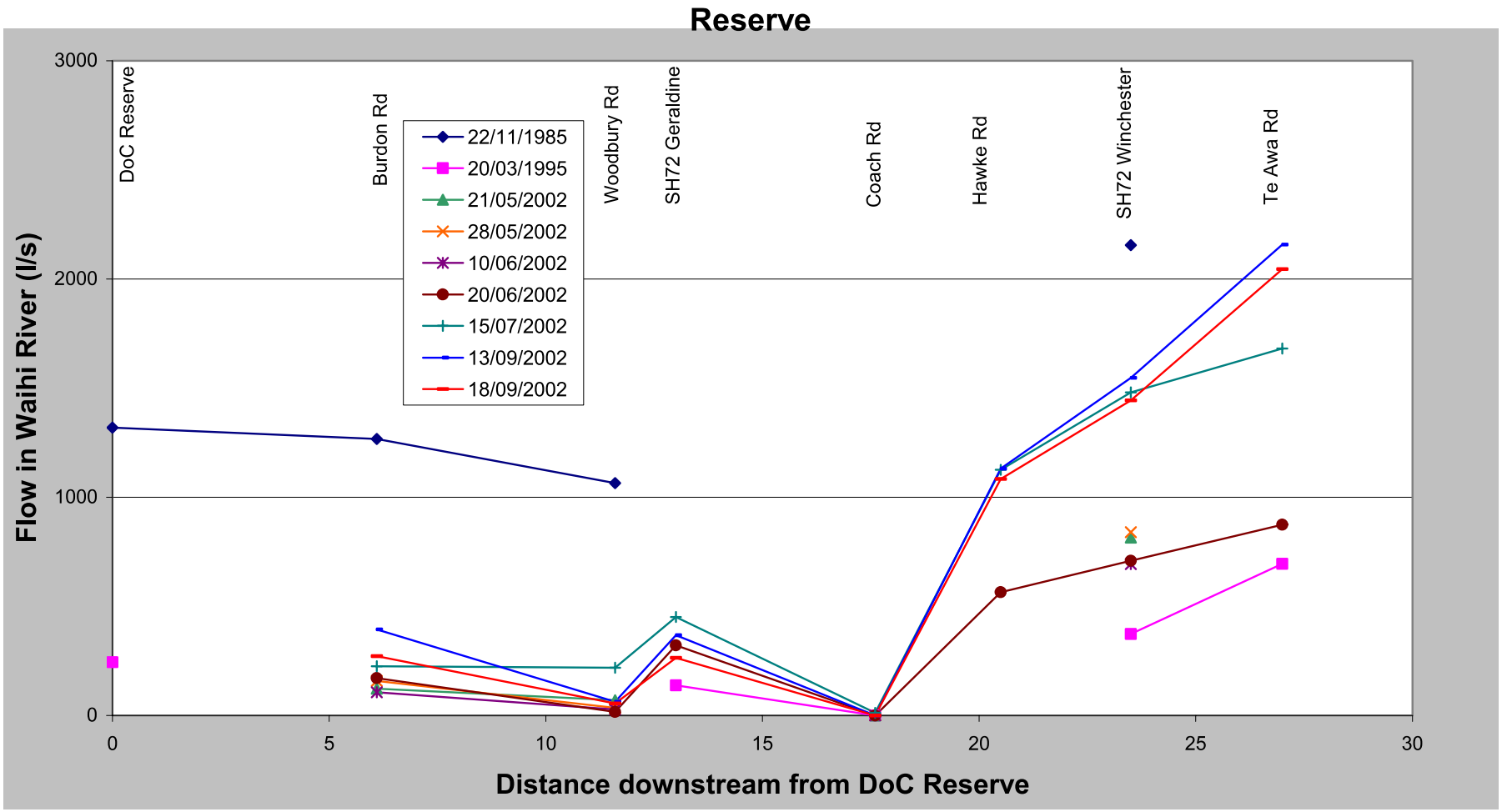


Figure 5.3 **Losses and gains in flow in Waihi River downstream from DoC Reserve**

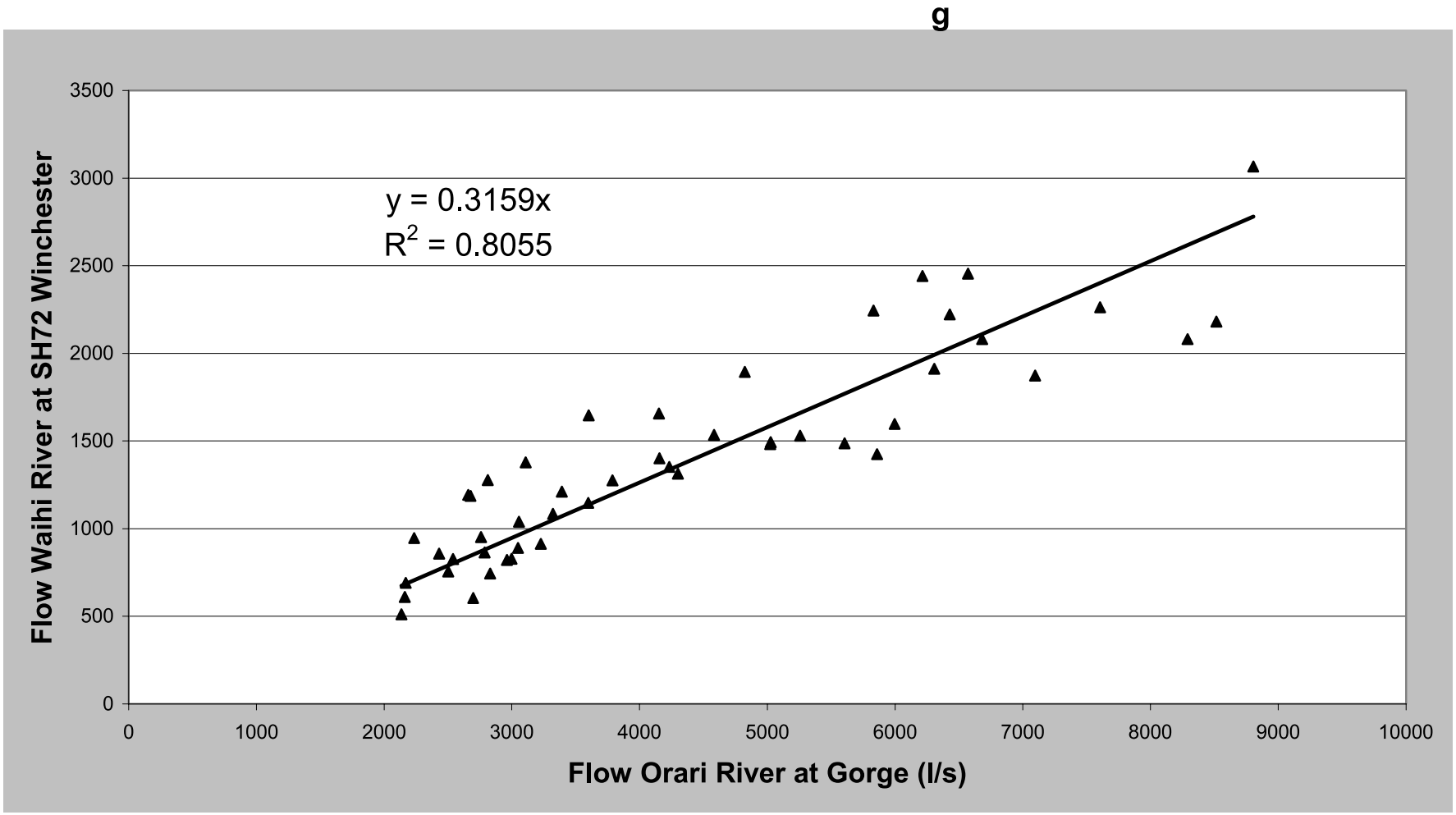


Figure 5.4 **Waihi River at SH72 Winchester – Correlation with flows observed in Orari River**

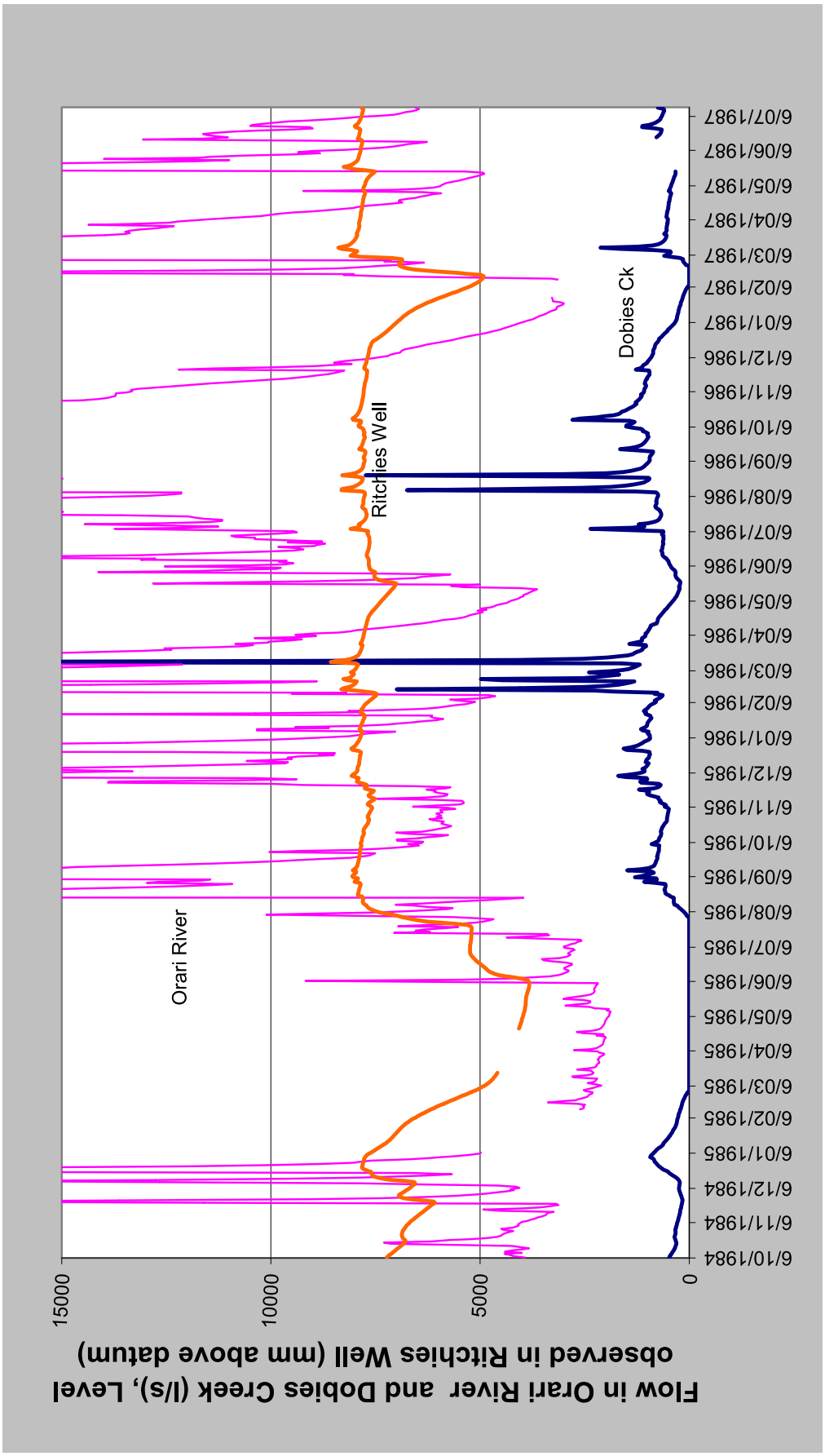


Figure 5.5 Dobies Creek flows, groundwater levels and Orari River flows

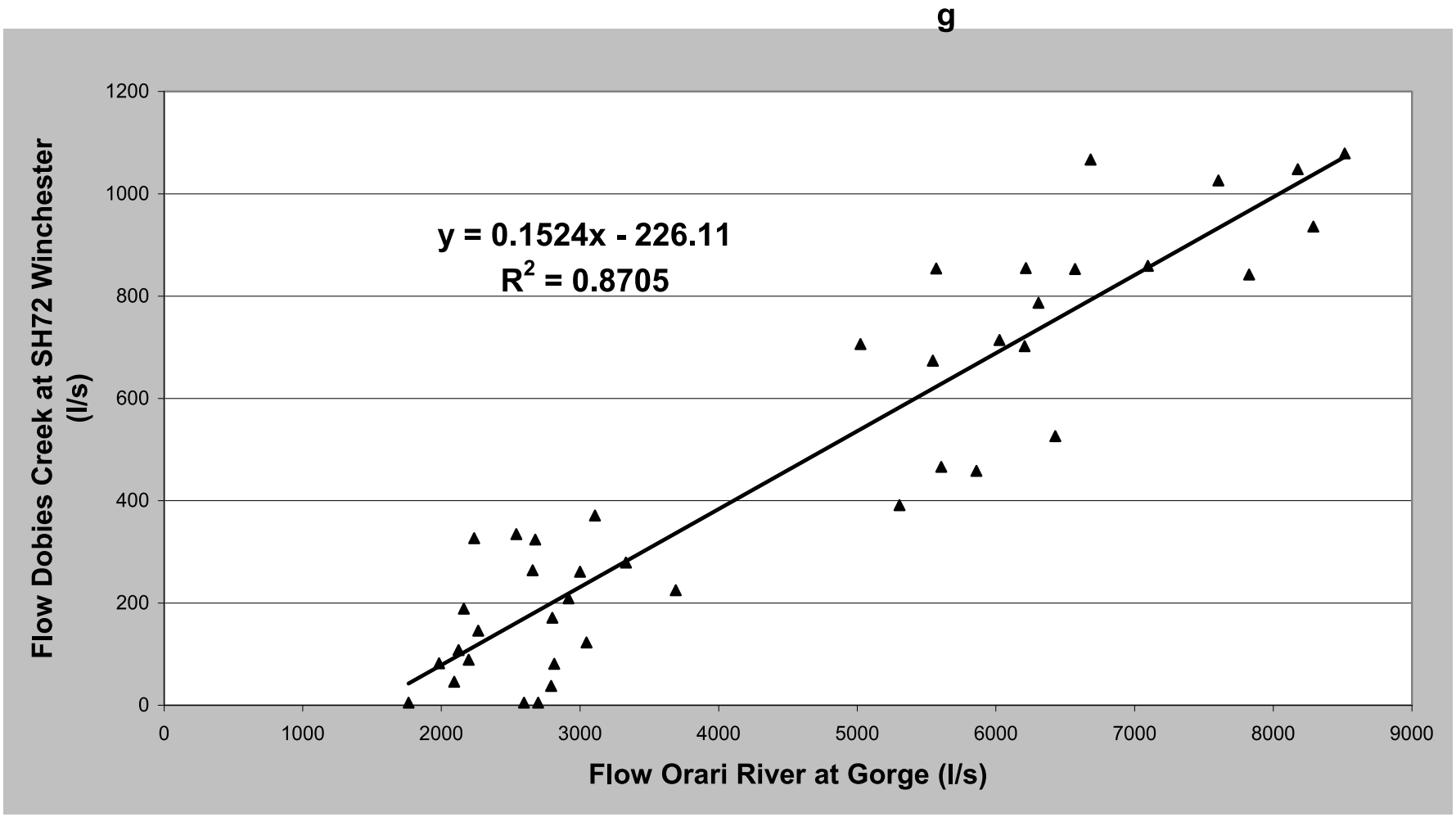


Figure 5.6 **Dobies Creek at SH72 Winchester – Correlation with flows observed in Orari River**

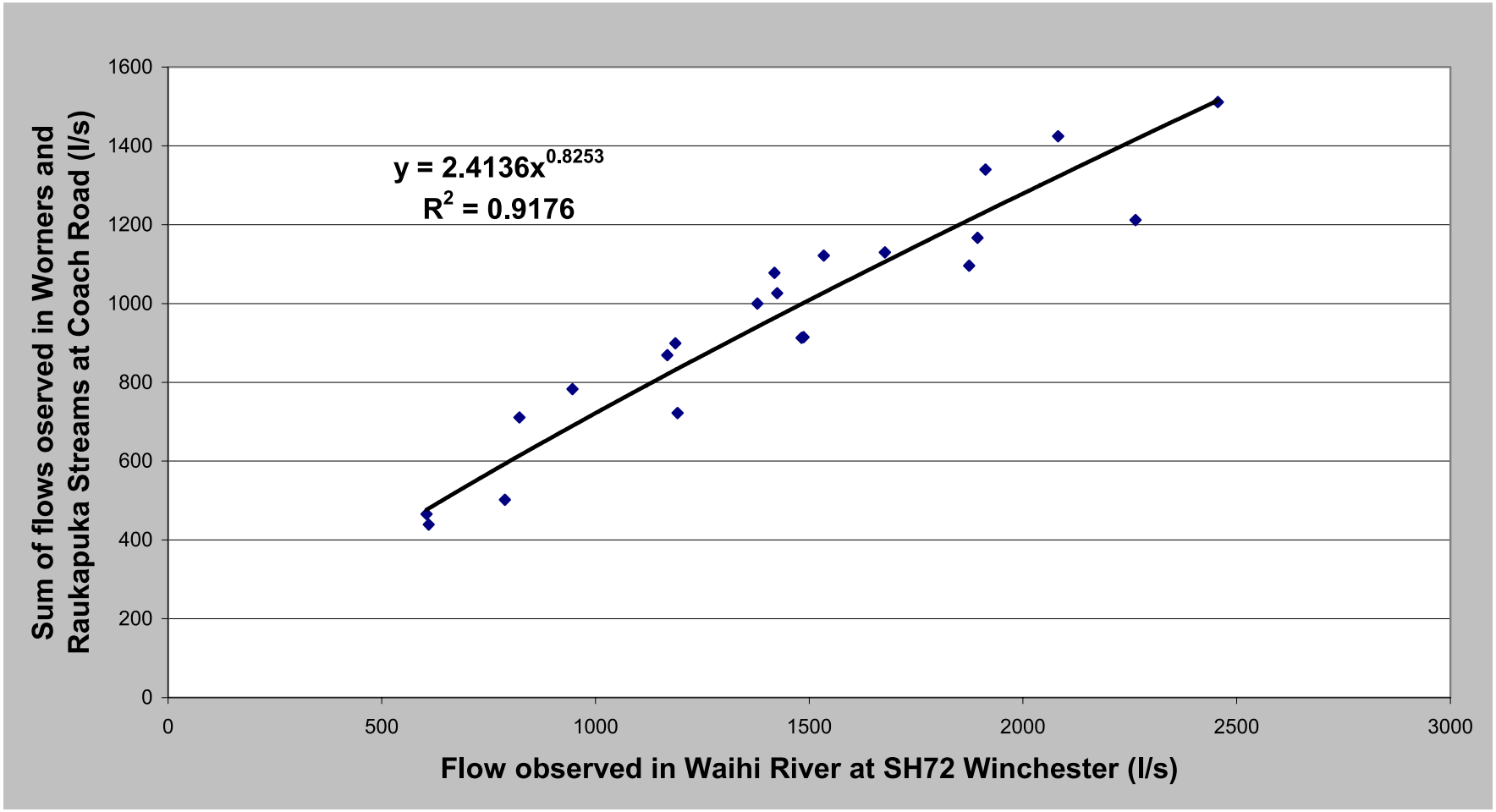


Figure 5.7 **Correlation to establish contribution of Worners and Raukapuka streams to the flow in the Waihai River at SH72 Winchester**

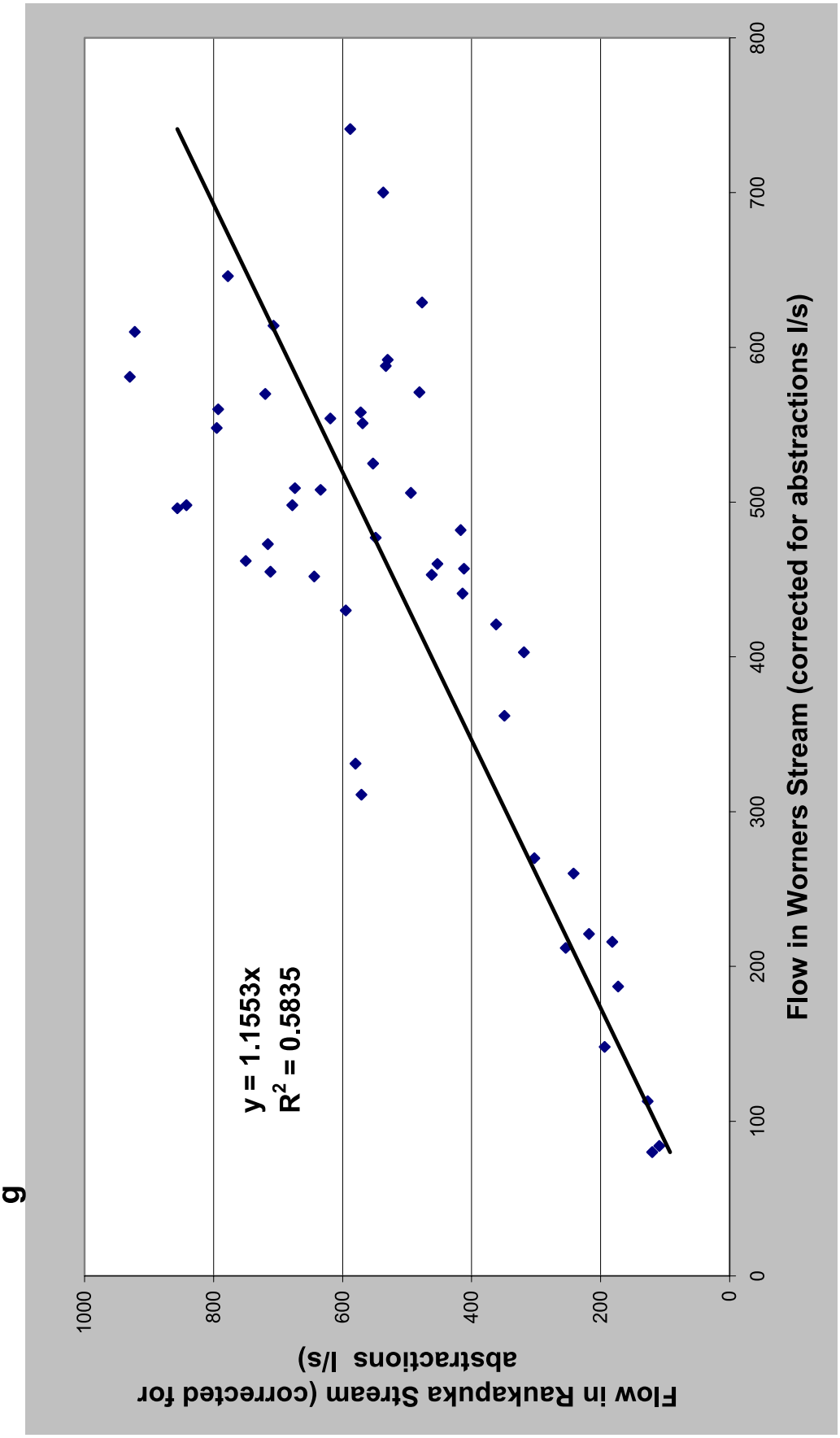


Figure 5.8 Correlation Worners versus Raukapuka flow observations

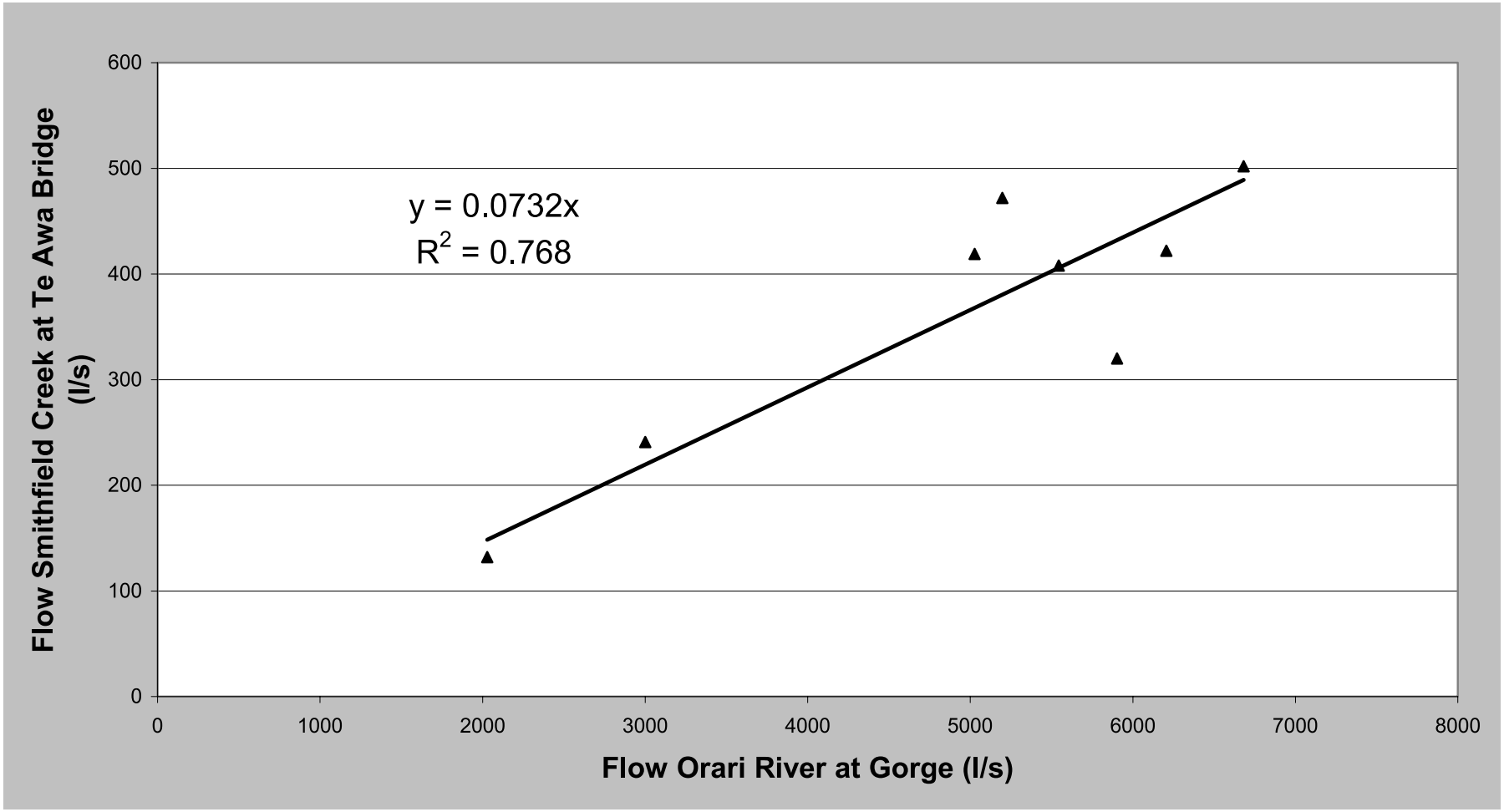


Figure 5.9 **Smithfield Creek at Te Awa Road – Correlation with flows observed in the Orari River**

Table 5.3 Estimates of MALF for sites on the Waihi River and its tributaries

River/Tributary	Site	Map Reference	Est. MALF (l/s)
Waihi	DoC Reserve	J37:617878	188
Waihi	Burdons Rd	J37:671856	190
Waihi	Woodbury Rd	J37:692809	90
Waihi	SH72 Geraldine	J38:695786	350
Waihi	Coach Rd	K38:705744	0
Waihi	Hawke Rd	K38:713722	730
Waihi	SH72 Winchester	K38:721681	870
Waihi	Te Awa	K38:716647	1060
Dobies	Four Arches	K38:720763	50
Dobies	Coach Rd	K38:726743	30
Dobies	Beeby Rd	K38:724710	0
Dobies	SH72 Winchester	K38:723680	190
Worners	Station Rd	K38:709775	100
Worners	Coach Rd	K38:713743	300
Raukapuka	Station Rd	K38:704776	75
Raukapuka	Coach Rd	K38:711743	345
Nth Br Smithfield	Hanging Rock Rd	K38:705687	100
Smithfield	Te Awa	K38:713647	200

5.4.3 Remaining tributaries

There are three remaining tributaries of note, Rangitira Creek, Raupo Creek and Taumatakahu Stream.

Rangitira and Raupo creeks drains the Waitohi downlands west of Temuka and have catchment areas of approximately 37 and 31 km^2 at their respective confluences with the Temuka River. The soils within these catchments are low infiltration clay loams with high water holding capacity. Both streams are dry every summer throughout their length and the MALF is assessed to be nil in both cases.

Taumatakahu Stream drains the area in and around the Temuka township. Unlike the other two, this is spring fed and exhibits a continuous flow from its source to its confluence with the Temuka River about 2 km downstream from SH1. Little is known about the hydrology of the stream. It is believed to have a mean flow of about 200 l/s, which would suggest that MALF for Taumatakahu Stream is around 120 l/s.

5.5 Temuka River

Summing the MALF estimates for Te Moana River, Waihi River and Smithfield Creek at their respective Te Awa sites leads to an estimate of 1560 l/s for Temuka River at Manse Bridge. This is similar to previous MALF estimates for this site. De Joux in 1980 estimated the 7 day MALF to be 1500l/s. This was updated by de Joux et al.

In the 1988 study to 1380l/s for 1 day MALF which translates to approximately 1520 l/s for 7 day MALF.

6 Recommendations

In respect of this study the following recommendations are advanced for Council's consideration:

1) That in light of its high commitment for abstractive use that a permanent flow recording station be established on Ohapi Creek either at Milford Road or Browns Road whichever presents the better site.
2) That further concurrent gauging be carried out on the following catchments and sites:
   - Kakahu River including Mulvihills, Kakahu Bush, Goodwin Rd Ford and Earl Rd sites.
   - Taumatakahu Stream including sites on the East and West branches.
   - Orakapaoa Stream including sites in Burkes Creek.
   - A few gaugings on Cones and Kotari streams, nearby springfed tributaries of the Opihi River.

7 Acknowledgements

The author acknowledges the assistance of Esther Smith, Trish Lockington and Kevin McFall of Environment Canterbury, Doug and Lynne McMillan of Environmental Quality Services, Graham McLintock of Fish & Game NZ, and Richard de Joux of Environmental Consultancy Services who provided river and stream flow information, river flow loss and gain information, water use data and experienced comment on the low flow relationships within the Orari and Temuka river catchments.

Appendix 1 Annual 7 day minimum flow series for primary sites

River	Orari		Te Moana		Kakahu		Waihi	
Site	Gorge		Glentohi		Mulvihills		DOC Res.	
Map Ref.	J37:653951		J37:582834		J37:538739		J37:617878	
Area(km2)	520		67.8		43.7		32.4	
water year	observed	natural	observed	natural	observed	natural	observed	natural
1965/66	3202	3202						
1966/67	3217	3217						
1967/68	3242	3242						
1968/69	2423	2423						
1969/70	2481	2481						
1970/71	2169	2169						
1971/72	2064	2064						
1972/73	1974	1974						
1973/74	2352	2352						
1974/75	3098	3098						
1975/76	2305	2305						
1976/77	2552	2552						
1977/78	2162	2162						
1978/79	3551	3551						
1979/80	3999	3999						
1980/81	3054	3054						
1981/82	1730	1730						
1982/83	2466	2466						
1983/84	3264	3264	228	228	68.1	70.1		
1984/85	1918	1918	133	133	31.4	33.4		
1985/86	2758	2758	275	275	71.4	73.4		
1986/87	3102	3102	159	159	44.0	46.0		
1987/88	2282	2282	185	185	32.0	34.0		
1988/89	2433	2433	132	132	12.4	14.4		
1989/90	2423	2423	158	158	34.9	36.9		
1990/91	2682	2682	200	200	41.0	43.0		
1991/92	1877	1877	86	86	10.0	12.0	92	92
1992/93	2715	2715	232	232	35.4	37.4	224	224
1993/94	3507	3507	missing record		14.3	16.3	140	140
1994/95	2530	2530	123	123	16.0	18.0	132	132
1995/96	5226	5226	384	384	97.9	99.9	284	284
1996/97	4544	4544	150	150	58.3	60.3	282	282
1997/98	1996	1996	112	112	6.9	8.9	137	137
1998/99	2203	2203	200	200	10.7	12.7	212	212
1999/00	4876	4876	318	318	station closed		station closed	
2000/01	1660	1660	78	78				
2001/02	1842	1842	126	126				
Low Flow Statistics (Gumbel III)								
malf		2753		182		37		188
1:5 yr LF		2106		119		14.5		127
1:10 yr LF		1894		98		9.7		107
MALF (l/s/km2)		**5.29**		**2.68**		**0.85**		**5.80**

Note: No takes above any recorder site except for Kakahu where 2 l/s is taken for rural water supply.

Appendix 2: Orari above Gorge - secondary site correlations

Hewson River upstr of Quartz Creek Confl.
Map Ref: J36:530144 Area 72.7 km2

Date	Gorge	Hewson
24/09/2002	5927	2016
10/09/2002	5923	1936
23/08/2002	6530	1263
11/06/2002	2884	762
8/05/2002	3295	696
25/04/2002	3081	661
11/04/2002	3392	787
28/03/2002	3834	919

No corrections necessary
Hewson = 0.0398*Orari**1.2196
MALF = 624 l/s

Quartz Creek upstr of Hewson River Confl.
Map Ref: J36:532144 Area 23.6 km2

Date	Gorge	Quartz
24/09/2002	5927	239
10/09/2002	5923	263
23/08/2002	6530	305
11/06/2002	2884	119
8/05/2002	3295	105
25/04/2002	3081	109
11/04/2002	3392	123
28/03/2002	3834	120

No corrections necessray
Quartz = 0.0034*Orari**1.2907
MALF = 94 l/s

Hewson River at Lochaber
Map Ref:J37:542057 Area 134 km2

Date	Gorge	Hewson
11/05/1971	3834	830
2/03/1972	2294	580
24/03/1976	2655	907
17/03/1978	2182	761
13/02/1979	3230	947
27/06/1979	5511	1846
15/08/1979	9780	3120
14/07/1980	4938	1789
8/09/1980	11327	2925
30/10/1980	11109	3723
15/01/1981	5946	1376
28/05/1981	4854	1237
21/02/1983	3354	1085
23/05/1983	11378	3365

No corrections necessary
Hewson = 0.2978*Orari
MALF = 820 l/s

Phantom River at Lochaber
Map Ref: J36:J37:537048 Area 63 km2

Date	Gorge	Phantom
11/05/1971	3834	541
2/03/1972	2294	365
1/07/1975	8709	1010
13/10/1975	11425	1480
18/11/1975	10172	1190
10/12/1975	5466	710
7/01/1976	3403	450
24/02/1976	3810	660
24/03/1976	2655	450
21/04/1977	2987	583
17/03/1978	2182	370
27/06/1979	5511	980
15/08/1979	9780	1219
14/07/1980	4938	635
8/09/1980	11327	1029
15/01/1981	5946	681

No corrections necessary
Phantom = 1.4071*Orari**0.7288
MALF = 452 l/s

Orari River at Meikleburn Hut
Map Ref:J37:443016 Area 35.3 km2

Date	Gorge	Up Orari
12/05/1971	3712	350
2/03/1972	2294	170
24/03/1976	2655	220
21/04/1977	2987	300
17/03/1978	2182	230
13/02/1979	3230	250
27/06/1979	5511	560
20/03/1980	8240	660

No corrections necessary
Up Orari = 0.0876*Orari
MALF = 241 l/s

Mowbray River at Meikleburn Station
Map Ref:J37:482975 Area 26km2

Date	Gorge	Mowbray
12/05/1971	3712	140
13/10/1975	11425	560
18/11/1975	11172	380
10/12/1975	5466	190
7/01/1976	3403	120
24/02/1976	3810	190
20/04/1977	2713	120

No corrections necessary
Mowbray=0.0411*Orari
MALF = 113 l/s

Andrews Stream upstr Orari River Confluence
Map Ref: J37:636963 Area 39.4 km2

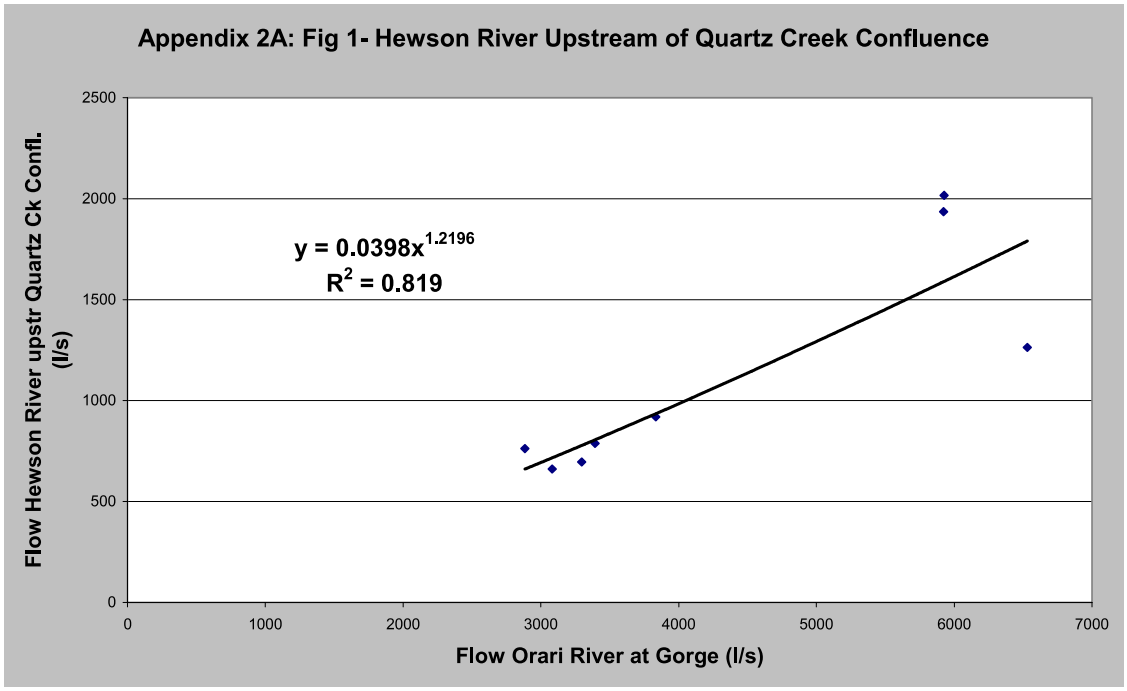
Date	Gorge	Andrews
24/09/2002	5927	225
10/09/2002	5923	264
23/08/2002	6530	338
11/06/2002	2884	157
8/05/2002	3295	185
25/04/2002	3081	156
11/04/2002	3392	167

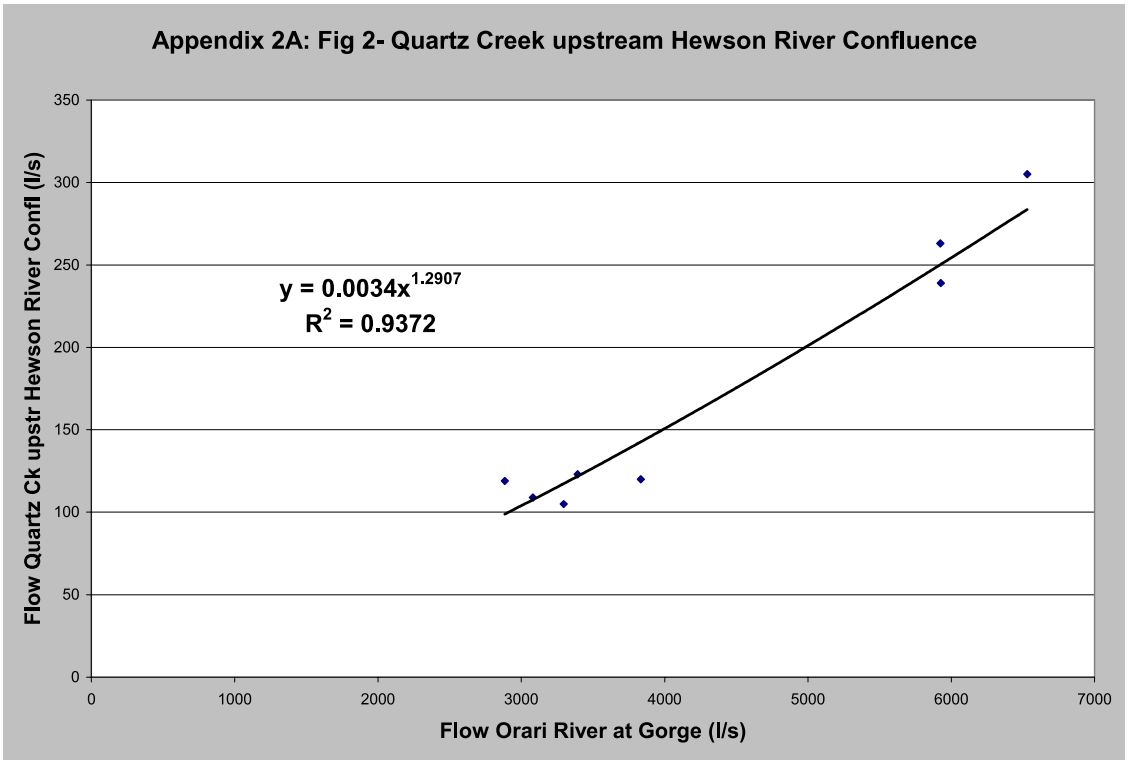
No corrections necessary
Andrews = 0.3409*Orari**0.7672
MALF = 148 l/s

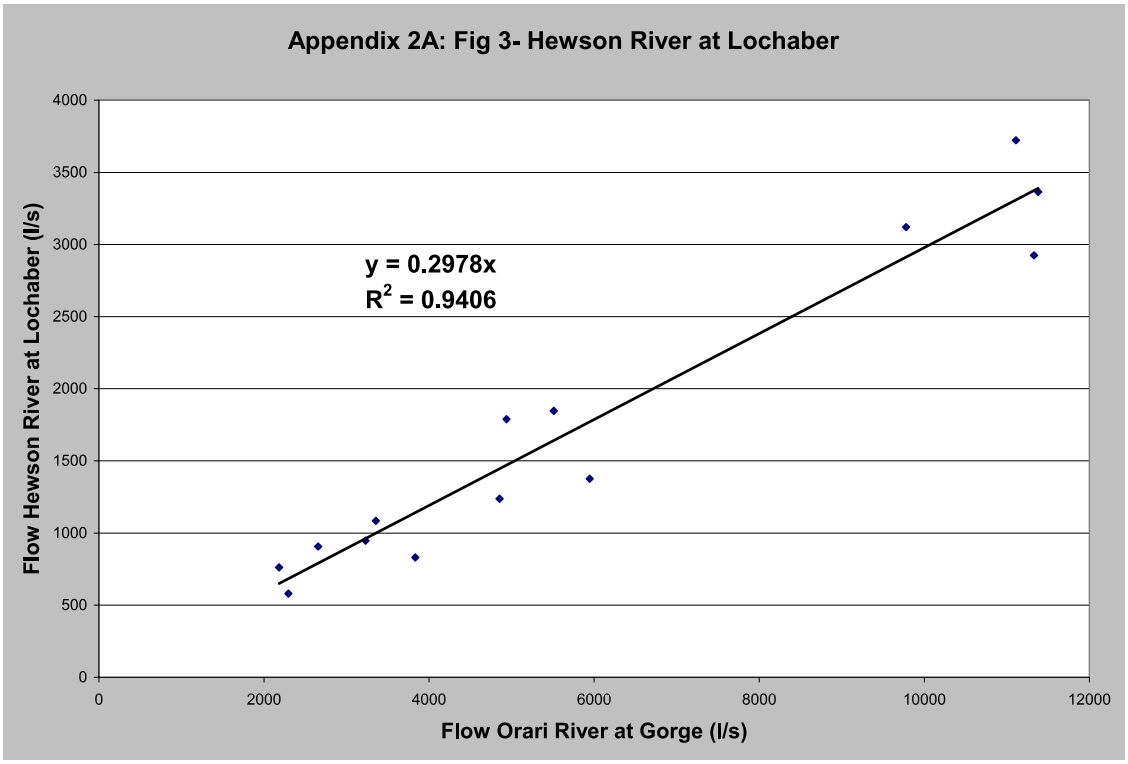
Mt Peel Creek upstr Orari River Confluence
Map Ref: J37:581035 Area 39.6 km2

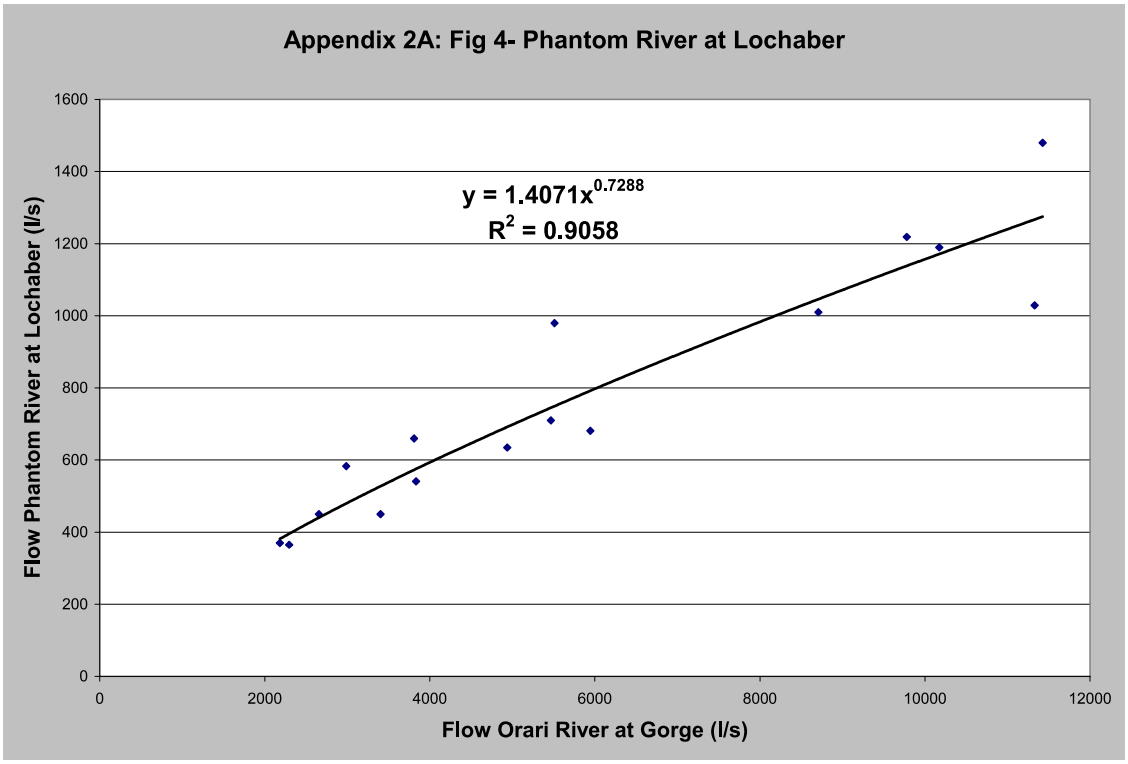
Date	Gorge	Mt Peel
11/05/1971	3834	227
2/03/1972	2294	193
1/07/1975	8709	690
13/10/1975	11425	810
18/11/1975	10172	750
10/12/1975	5466	410
7/01/1976	3403	270
24/02/1976	3810	370

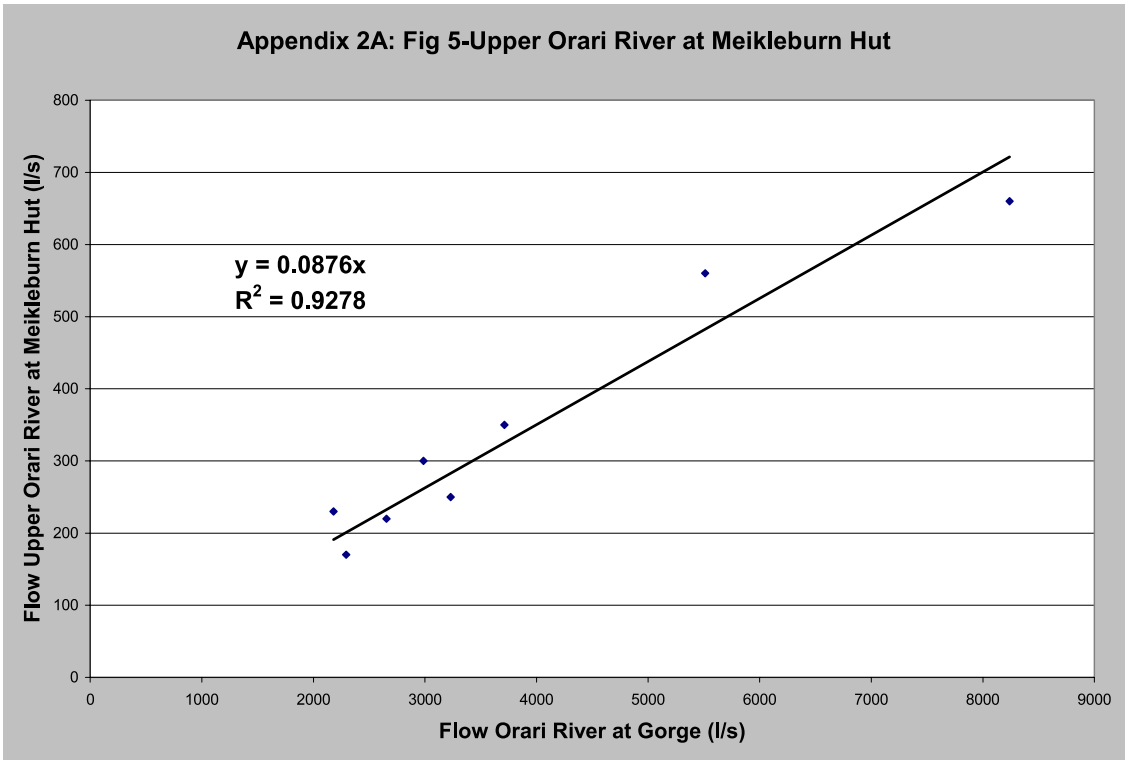
No corrections necessary
Mt Peel = 0.0746*Orari
MALF = 205 l/s

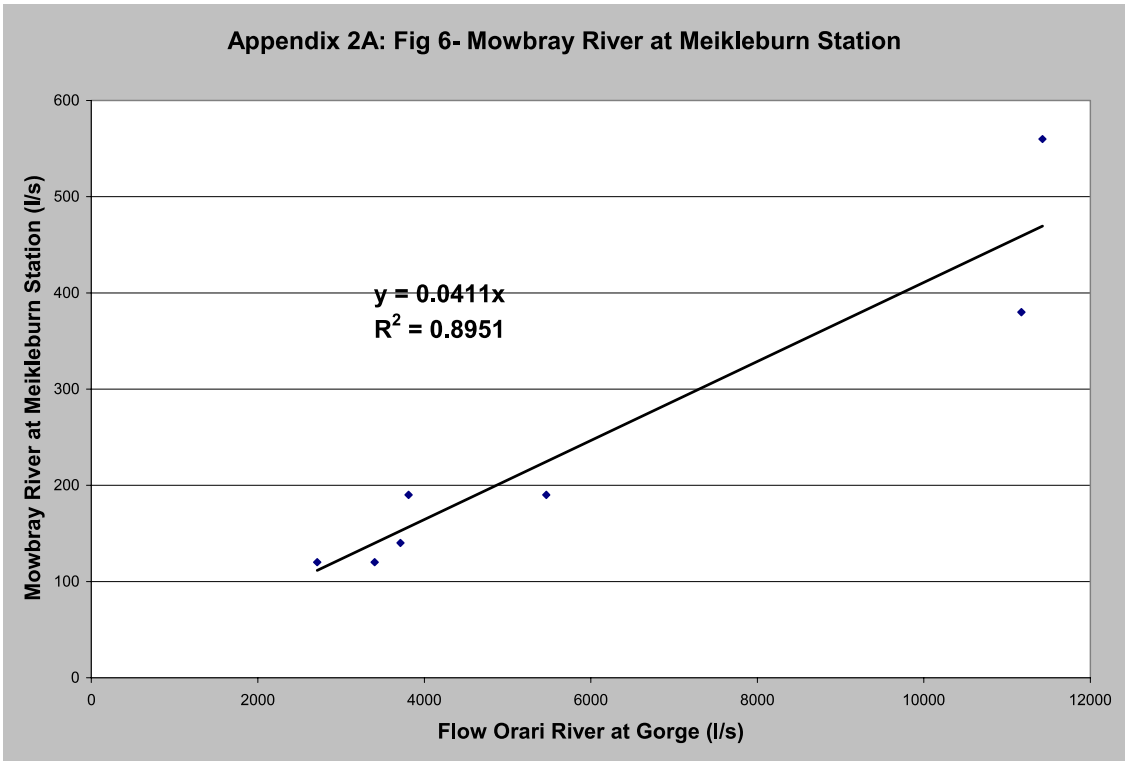

Appendix 2A: Fig 1- Hewson River Upstream of Quartz Creek Confluence
Flow Hewson River upstr Quartz Ck Confl. (l/s)
y = 0.0398x^1.2196
R^2 = 0.819
Flow Orari River at Gorge (l/s)
0
500
1000
1500
2000
2500
0
1000
2000
3000
4000
5000
6000
7000

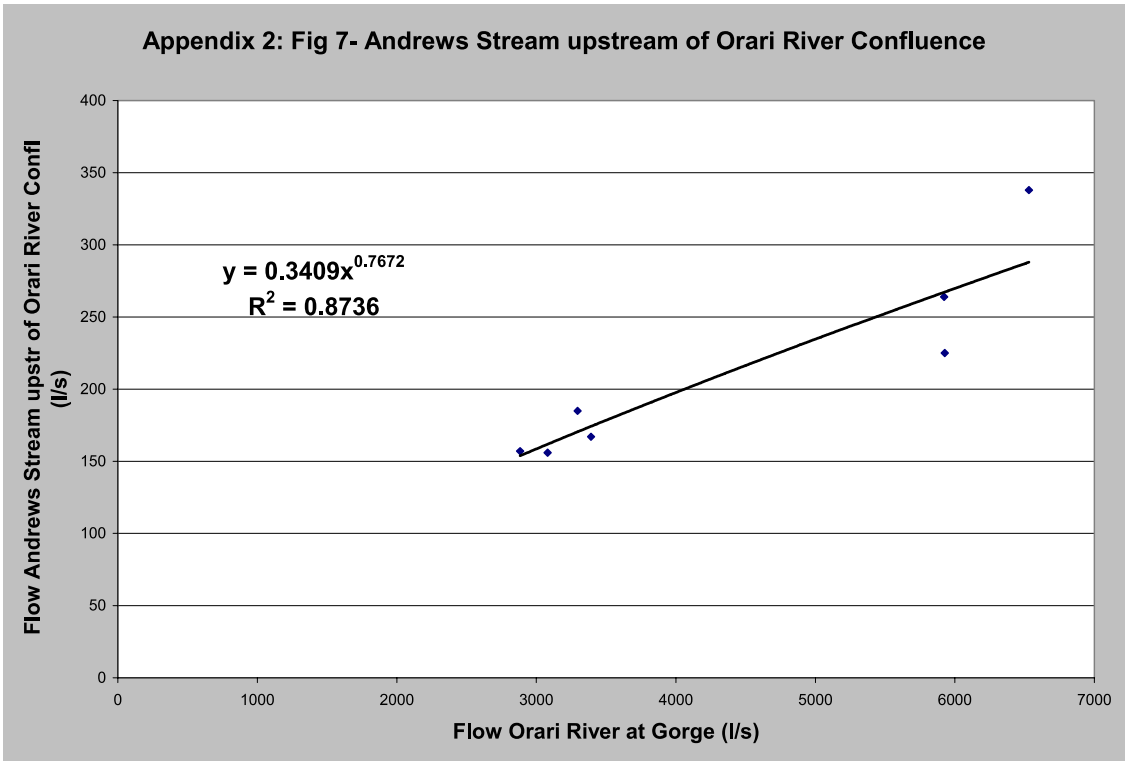

Appendix 2A: Fig 2- Quartz Creek upstream Hewson River Confluence
Flow Quartz Ck upstr Hewson River Confl (l/s)
y = 0.0034x^1.2907
R^2 = 0.9372
Flow Orari River at Gorge (l/s)
0
50
100
150
200
250
300
350
0
1000
2000
3000
4000
5000
6000
7000

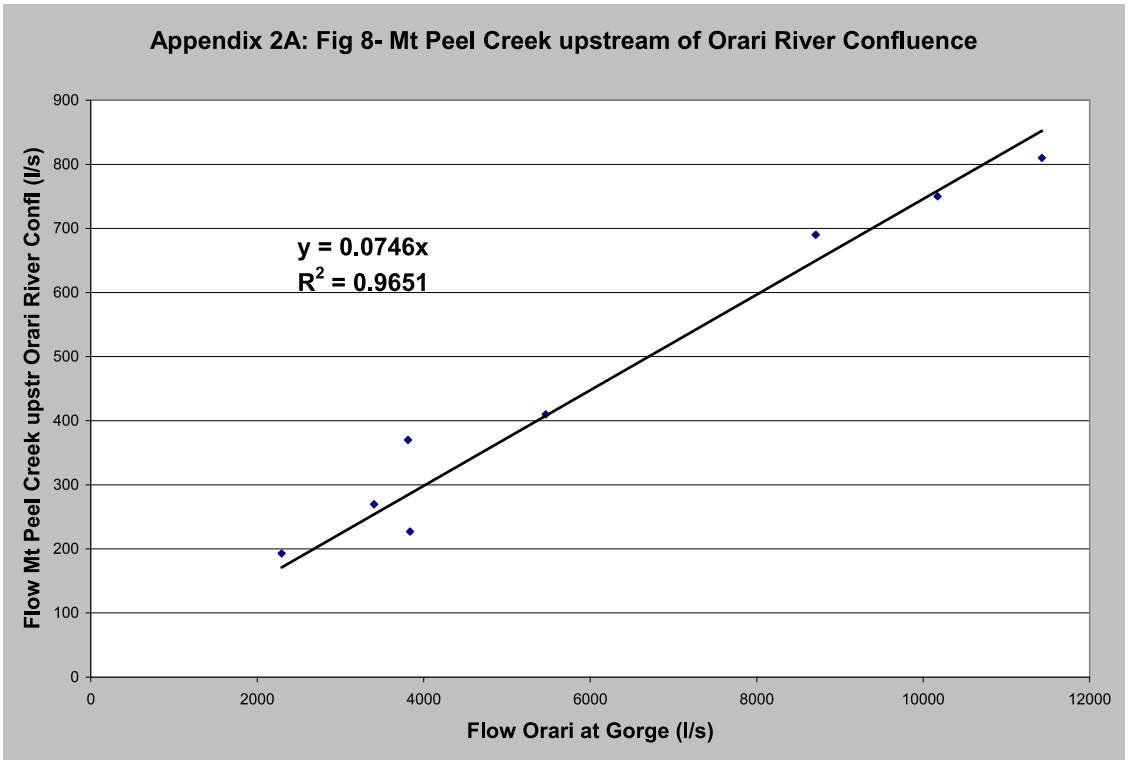

Appendix 2A: Fig 3- Hewson River at Lochaber
Flow Hewson River at Lochaber (l/s)
Flow Orari River at Gorge (l/s)
y = 0.2978x
R2 = 0.9406
0
500
1000
1500
2000
2500
3000
3500
4000
0
2000
4000
6000
8000
10000
12000


Appendix 2A: Fig 4- Phantom River at Lochaber
Flow Phantom River at Lochaber (l/s)
Flow Orari River at Gorge (l/s)
y = 1.4071x0.7288
R2 = 0.9058
0
200
400
600
800
1000
1200
1400
1600
0
2000
4000
6000
8000
10000
12000


Appendix 2A: Fig 5-Upper Orari River at Meikleburn Hut
Flow Upper Orari River at Meikleburn Hut (l/s)
Flow Orari River at Gorge (l/s)
y = 0.0876x
R2 = 0.9278
0
100
200
300
400
500
600
700
800
0
1000
2000
3000
4000
5000
6000
7000
8000
9000


Appendix 2A: Fig 6- Mowbray River at Meikleburn Station
Mowbray River at Meikleburn Station (l/s)
Flow Orari River at Gorge (l/s)
y = 0.0411x
R2 = 0.8951
0
100
200
300
400
500
600
0
2000
4000
6000
8000
10000
12000


Appendix 2: Fig 7- Andrews Stream upstream of Orari River Confluence
Flow Andrews Stream upstr of Orari River Confl (l/s)
y = 0.3409x^0.7672
R2 = 0.8736
Flow Orari River at Gorge (l/s)
0
50
100
150
200
250
300
350
400
0
1000
2000
3000
4000
5000
6000
7000


Appendix 2A: Fig 8- Mt Peel Creek upstream of Orari River Confluence
Flow Mt Peel Creek upstr Orari River Confl (l/s)
y = 0.0746x
R2 = 0.9651
Flow Orari at Gorge (l/s)
0
100
200
300
400
500
600
700
800
900
0
2000
4000
6000
8000
10000
12000

Appendix 3: Concurrent flow gauging runs in Coopers Creek

(all flows in l s^{-1})

Site	Distance (km)	27/03/1973	12/03/1997	17/04/1997	21/05/2002	27/05/2002	7/06/2002	20/06/2002	15/07/2002	1/08/2002	3/09/2002
Nth Bdy Rd	0		357	402	0	0	0	0	0	0	0
U/str Spring Dr	3.75	0	151		0	0	0	0	0	0	0
D/str Spring Dr	3.8		405		140	92	116	135	186	170	180
SH72	5.1	48	391	491	84	85	47	87	159	123	133
Pit Road	6.2	33	362	501	12	15	0	12	63	48	59
SH79	9.9		225	340							0
Seaward Rd	12.1			40							0

Notes: Entry shown for Seaward Road 17/4/97 is a visual estimate

Appendix 4 : Mean monthly flow recorded for Ohapi Creek

Milford Road MR K38:

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1965					2340	2282	2361	2605	2213	2010	2170	1795
1966	1841	1764	2215	1823	1723	1861	1835	2667	1844	1907	1407	1212
1967	1308	1516	1630	1803	2046	1762						

Comments: 1) Average flow for period of record 1924 l/s

2) June 1966 - 8 days of missing record filled in

Brown Road MR K38:

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1983												2314
1984	?	1929	?	1827	1780	?	?	1850	1877	?	?	1469
1985	1440	1252	1178	789	?	789	1189	1451	2151	1925	1940	2376
1986	1885	4500	5350	2816	?	2283	4126	?	3226	?	2664	2432
1987	1464	2067										

Comments: 1) Average flow for period of record 2212 l/s

2) Days of missing records filled in:

Dec-83	5	Apr-85	2	Dec-85	2	Apr-86	9
May-84	4	Aug-85	2	Jan-86	2	Jan-87	3
Sep-84	8	Oct-85	3	Feb-86	7		
Mar-85	7	Nov-85	5	Mar-86	5		

Appendix 5: Concurrent flow gaugings for Ohapi Creek

Date	North Br Guild Rd K38:773659	Middle Br Guild Rd K38:763645	South Br Guild Rd K38:763643	North Br Milford Rd K38:781626	Ohapi Ck Milford Rd K38:781625	Ohapi Ck Browns Rd K38:811618	Ratio NBr/GRd (* Note 2)	Ratio MBr/GRd	Ratio SBr/Grd	Ratio GRd/MRd (*Note 3)
14/06/1999	960	985	1308	1164	4170		0.30	0.30	0.40	0.78
10/05/1999	373	346	493	438	1246	1379	0.31	0.29	0.41	0.97
12/04/1999	254	252	480	282	1004	1072	0.26	0.26	0.49	0.98
15/03/1999	225	237	446	278	935	948	0.25	0.26	0.49	0.97
3/03/1999	202	227	425	275	954	909	0.24	0.27	0.50	0.90
11/03/1998	218	204	350	259	913	992	0.28	0.26	0.45	0.85
2/02/1998	275	268	339	284	1065	1077	0.31	0.30	0.38	0.83
22/01/1998	364	272	463	345	1172	1065	0.33	0.25	0.42	0.94
23/05/1997	768	412	596	742	2029	1805	0.43	0.23	0.34	0.88
19/01/1997	883	404	600	792	1997	1739	0.47	0.21	0.32	0.94
9/01/1997	762	407	581	691	1708	1587	0.44	0.23	0.33	1.02
27/12/1996	683	372	507	644	1536	1503	0.44	0.24	0.32	1.02
5/11/1996	883	418	600	845	2058	2048	0.46	0.22	0.32	0.92
17/10/1996	931	448	547	921	1942	2200	0.48	0.23	0.28	0.99
							0.36	0.25	0.39	0.93

Notes:1) All flows in l/s

2) Ratio of flow observed in North Branch to total flow in all branches at Guild Road

3) Ratio of total flow in all branches at Guild Road to flow observed at Milford Road

Appendix 6: Ohapi Creek- minimum flow series

		7d low flow (l/s)		
Water Year	**date starting**	observed	corrected	**Comments**
1965/66	16/05/1966	1584	1584	
1966/67	19/01/1967	1212	1252	
1983/84	30/05/1984	1598	1598	part year starting 12/83
1984/85	5/04/1985	696	816	
1985/86	6/01/1986	1676	1756	
1986/87	6/02/1987	1154	1274	part year record ends 3/87
MALF			**1380**	

Corrections applied

1) Town and stockwater supplies - Nil

2) Irrigation	Period	Dec-Mar	
	pre 1970	40	
	1980-89	120	when flow less than 1400 l/s
		80	when flow greater than 1400l/s

Appendix 7: Te Moana River - Losses and gains in surface flow downstream from Glentohi

	(km)	21/05/2002	28/05/2002	9/06/2002	19/06/2002	16/07/2002	13/09/2002	18/09/2002	Average*	Average**
Glentohi	0	240	223	188	412	856	443	381	392	523
Woodside Rd	6.9				495	573	516	247		458
SH79 Speechleys	13.3	369	416	262	801	901	729	546	575	744
Goodwin Rd	19.8	221	170	141	148	498	523	291	285	365
Te Awa Rd	25.5					767		642		

Notes: 1) Flows measured at Te Awa Rd on 19/6/02 and 13/9/02 were affected by snow melt from recent snowfalls in the Kakahu catchment and were omitted from subsequent analysis.

2) Average* includes all gaugings, Average** includes all gaugings from 19/6/02 to18/9/02

Appendix 8: Waihi River – Losses and gains in surface flow downstream from DoC Reserve

	(km)	22/11/1985	20/03/1995	21/05/2002	28/05/2002	10/06/2002	20/06/2002	15/07/2002	13/09/2002	18/09/2002
Doc Reserve	0	1319	244							
Burdons Rd	6.1	1268		123	159	107	172	226	394	272
Woodbury Rd	11.6	1065		70	35	27	16	219	63	55
SH72 Geraldine	13.0		139				322	452	368	264
Coach Rd	17.6		0	0	0	0	0	12	0	0
Hawke Rd	20.5						565	1126	1131	1084
SH72 Winchester	23.5	2155	373	815	840	694	709	1480	1547	1444
Te Awa Rd	27.0		695				875	1682	2158	2045

Appendix 9: Data set of flow observations used to correlate Waihi River at SH72 (Winchester) with Orari River at Gorge

(All flows in l/s)

Date	Orari Gorge DMD	Waihi Winchester (observed)	corrections	Waihi Winchester (corrected)
18/09/2002	5027	1444	50	1494
13/09/2002	5996	1547	50	1597
15/07/2002	5258	1480	50	1530
10/06/2002	2831	694	50	744
28/05/2002	3048	840	50	890
21/05/2002	2787	815	50	865
22/11/1985	5831	2155	90	2245
8/03/1983	2431	737	120	857
18/02/1983	3323	965	120	1085
1/02/1983	4233	1233	120	1353
3/06/1982	2698	555	50	605
11/02/1982	2170	571	120	691
22/01/1982	2998	709	120	829
15/01/1982	3227	794	120	914
6/01/1982	3391	1092	120	1212
16/12/1981	4299	1194	120	1314
16/02/1981	3598	1027	120	1147
10/02/1981	3788	1156	120	1276
2/02/1981	4155	1282	120	1402
2/07/1980	6682	2032	50	2082
26/03/1980	8516	2062	120	2182
19/02/1980	5023	1362	120	1482
20/12/1979	4151	1537	120	1657
9/08/1979	7605	2213	50	2263
31/07/1979	8805	3017	50	3067
9/07/1979	4824	1844	50	1894
25/06/1979	6307	1862	50	1912
14/06/1979	6215	2391	50	2441
11/06/1979	6571	2405	50	2455
9/02/1979	5859	1305	120	1425
16/01/1979	7096	1754	120	1874
8/01/1979	8290	1962	120	2082
6/04/1978	2162	520	90	610
9/03/1978	2236	826	120	946
28/11/1977	4584	1444	90	1534
24/06/1977	3601	1597	50	1647
19/08/1976	6429	2172	50	2222
6/07/1976	2658	1142	50	1192
1/04/1976	2759	862	90	952
23/03/1976	2677	1067	120	1187
19/03/1976	2812	1158	120	1278
11/03/1976	3108	1259	120	1379
20/01/1976	3056	920	120	1040
8/01/1975	2961	737	85	822
28/11/1973	5605	1427	60	1487
16/02/1973	2502	671	85	756
7/02/1973	2540	743	85	828
16/03/1972	2135	427	85	512

Corrections (1) Town and stockwater supplies - constant 50 l/s

(2) Irrigation

Period	Dec-Mar	Nov Apr	Sep Oct	Rest
1996-02	165	100	50	0
1986-95	120	70	35	0
1976-85	70	40	20	0
1965-75	35	10	0	0

Appendix 10: Data set of flow observations used to correlate Dobies Creek at SH72 Winchester with Orari River at Gorge

(All flows in l/s)

	Orari Gorge DMD	Dobies Winchester (observed)	corrections	Dobies Winchester (corrected)
12/09/2002	6207	672	30	702
3/09/2002	6026	684	30	714
10/06/2002	2813	76	5	81
28/05/2002	3048	118	5	123
10/02/1987	3000	206	55	261
22/12/1986	5545	619	55	674
1/04/1985	2093	21	25	46
14/03/1985	2800	131	40	171
3/06/1982	2698	0	5	5
25/03/1982	1764	0	5	5
5/03/1982	2196	49	40	89
27/08/1980	8177	1043	5	1048
2/07/1980	6682	1062	5	1067
26/03/1980	8516	1039	40	1079
19/02/1980	5023	666	40	706
9/08/1979	7605	1021	5	1026
25/06/1979	6307	782	5	787
14/06/1979	6215	850	5	855
11/06/1979	6571	848	5	853
19/02/1979	5305	351	40	391
9/02/1979	5859	418	40	458
16/01/1979	7096	819	40	859
8/01/1979	8290	896	40	936
6/04/1978	2162	164	25	189
9/03/1978	2236	287	40	327
28/11/1977	5569	829	25	854
19/08/1976	6429	521	5	526
6/07/1976	2658	259	5	264
23/03/1976	2677	284	40	324
11/03/1976	3108	331	40	371
8/08/1974	7825	837	5	842
4/02/1974	3691	195	30	225
28/11/1973	5605	446	20	466
2/07/1973	2918	204	5	209
20/03/1973	1983	52	30	82
7/03/1973	2266	116	30	146
7/02/1973	2540	305	30	335
3/05/1972	2596	0	5	5
21/04/1972	2791	18	20	38
15/03/1972	2123	78	30	108
10/07/1969	3331	274	5	279

Corrections applied:

Water supplies 5 l/s

Irrigation	Period	Dec-Mar	Nov, Apr	Sep, Oct	Rest
	1996-02	80	50	25	0
	1986-95	50	30	15	0
	1976-85	35	20	10	0
	1965-75	25	15	5	0

Appendix 11: Data set used to establish relationship between Worners and Raukapuka at Coach Road and Waihi River at SH 72 Winchester

	Observed data				Corrected data			
Date	Waihi SH72	Worners Coach Rd	Raukapuka Coach Rd	Worners + Raukapuka	Waihi SH72	Worners Coach Rd	Raukapuka Coach Rd	Worners + Raukapuka
12/09/2002		516	549			551	569	
17/07/2002		583	533			588	533	
8/06/1989		555	793			560	793	
23/04/1985		59	99			84	109	
1/04/1985		88	117			113	127	
14/03/1985		147	153			187	173	
30/10/1984		426	409			441	414	
3/06/1982	555	207	254	461	605	212	254	466
10/09/1981		726	583			741	588	
27/07/1981		543	795			548	795	
13/10/1980		614	472			629	477	
8/10/1980		556	476			571	481	
9/09/1980		555	715			570	720	
2/07/1980		695	537			700	537	
26/03/1980		433	696			473	716	
11/03/1980		469	654			509	674	
19/02/1980	1362	420	433	853	1482	460	453	913
9/08/1979	2213	457	750	1207	2263	462	750	1212
30/07/1979		503	634			508	634	
9/07/1979	1844	450	712	1162	1894	455	712	1167
25/06/1979	1862	493	842	1335	1912	498	842	1340
11/06/1979	2405	576	930	1506	2456	581	930	1511
2/04/1979		585	912			610	922	
26/03/1979		291	560			331	580	
19/02/1979	1048	417	392	809	1168	457	412	869
9/02/1979	1305	437	529	966	1425	477	549	1026
16/01/1979	1754	412	624	1036	1874	452	644	1096
8/01/1979	1962	606	758	1364	2082	646	778	1424
6/04/1978	520	196	208	404	610	221	218	439
9/03/1978	826	381	342	723	946	421	362	783
3/02/1978	1299	485	533	1018	1419	525	553	1078
28/11/1977	1444	567	520	1087	1534	592	530	1122
22/03/1977	1557	518	552	1070	1677	558	572	1130
15/11/1976		589	697			614	707	
19/08/1976		425	595			430	595	
6/07/1976	1142	398	319	717	1192	403	319	722
11/06/1976		265	303			270	303	
23/03/1976	1067	442	397	839	1187	482	417	899
11/03/1976	1259	466	474	940	1379	506	494	1000
8/01/1975	737	337	329	666	822	362	349	711
8/08/1974		493	678			498	678	
21/03/1974		529	609			554	619	
4/02/1974	703	235	232	467	788	260	242	502

28/11/1973	1427	443	457	900	1487	453	462	915
23/07/1973		306	571			311	571	
13/06/1973		491	856			496	856	
11/05/1973		143	194			148	194	
19/04/1973		70	115			80	120	
7/03/1973		191	172			216	182	
7/02/1973	743	346	248	594				

Corrections Applied

(Waihi at SH72) (1) Town and stockwater supplies - constant 50 l/s

(2) Irrigation

Period	Dec-Mar	Nov Apr	Sep Oct	Rest
1996-02	165	100	50	0
1986-95	120	70	35	0
1976-85	70	40	20	0
1965-75	35	10	0	0

Worners Coach Rd (1) Town and stockwater supplies - constant 5 l/s

(2) Irrigation

Period	Dec-Mar	Nov Apr	Sep Oct	Rest
1996-02	80	60	30	0
1986-95	60	40	20	0
1976-85	35	20	10	0
1965-75	20	5	0	0

Raukapuka Coach Rd (1) Town and stockwater supplies - Nil

(2) Irrigation

Period	Dec-Mar	Nov Apr	Sep Oct	Rest
1996-02	60	40	20	0
1986-95	40	20	10	0
1976-85	20	10	5	0
1965-75	10	5	0	0

Appendix 12: Data set of flow observations used to correlate Smithfield Creek at Te Awa Bridge with Orari River at Gorge

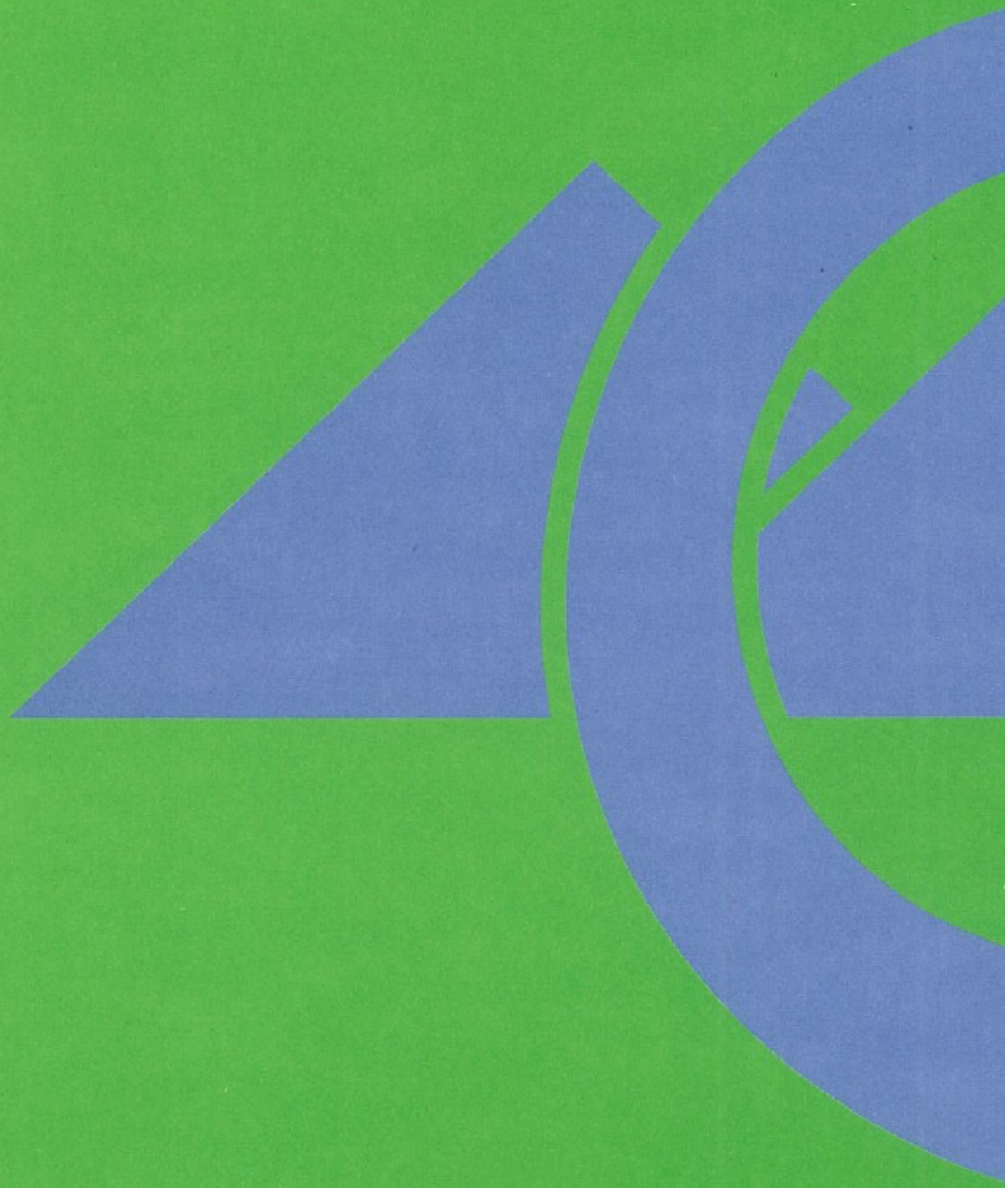
(all flows in l s^{-1})

Date	Orari Gorge DMD	Smithfield Te Awa Rd (observed)	Correction	Smithfield Te Awa Rd (corrected)
18/09/2002	5027	394	25	419
12/09/2002	6207	397	25	422
16/07/2002	5903	320	0	320
19/06/2002	5197	472	0	472
1/04/1992	2028	117	15	132
10/02/1987	3000	176	65	241
22/12/1986	5545	343	65	408
2/07/1980	6682	502	0	502

Corrections applied:

Stockwater - No corrections

Irrigation	Period	Dec-Mar	Nov, Apr	Sep, Oct	Rest
	1996-02	95	50	25	0
	1986-95	65	30	15	0
	1976-85	40	20	10	0
	1965-75	20	10	0	0



58 Kilmore Street, PO Box 345, Christchurch.
Telephone: (03) 365-3828, Fax: (03) 365-3194.
75 Church Street, PO Box 550, Timaru.
Telephone: (03) 688-9069, Fax: (03) 688 9067.
Website: www.ecan.govt.nz