Assessing Unmonitored Water Use in Semi-Rural Environments:

An Investigation into the Okana and Okuti River Catchments, Little River, Canterbury

WCFM Report 2013-002

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Executive Summary

Lake Forsyth/Wairewa, on the southern side of Banks Peninsula in Canterbury is a shallow eutrophic lake with a history of degraded water quality. The two primary surface water inputs flowing into the lake are the Okuti and Okana Rivers. In order to better understand and address the underlying causes of degradation in the lake's water quality, research is currently underway to create hydrological, sediment and nutrient budgets for the lake's catchment. Currently water take from the Okuti and Okana Rivers and their tributaries is a permitted activity, so no consent is required, and no record is kept of how much water is being used.

This study investigated water use in households in the Okuti and Okana River catchments, as the basis for a model that could estimate catchment-wide water use, for this and potentially other semi-rural catchments. The information obtained from this model could also be used to gain a better understanding of how water is moving through the catchments and the effect that present or predicted water use could have on the lake.

Local households in the Okuti and Okana catchments were interviewed to obtain data on household water use. Contrary to the general perception, the majority of households in the two river catchments had an abundance of water, and water shortages were of little concern. Average domestic water use in the study area appeared to be high, at just over 580 l/person/day, compared to the New Zealand average of 160-260 l/person/day. This may reflect the hot summer weather in which the survey was undertaken and/or difficulties measuring actual water usage in some households.

The water use of farming operations was investigated in the survey, so that a complete model of water use in the catchments could be constructed. The latest research on household and animal water use elsewhere was also incorporated into a model to estimate catchment-wide water use. The model calculated total water requirements for this semi-rural environment as just over 400,000 L/day, with a probable error of ± 35%. More accurate data for farming operations (e.g., stock type and number) would reduce this error considerably.

The limitations of this research and recommendations for further research are discussed.

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Section 1. Introduction

1.1 Background

Lake Forsyth/Wairewa, on the southern side of Banks Peninsula, has suffered severe degradation to its ecology in the past hundred years, with regular toxic cyanobacterial (blue-green algal) blooms now occurring over summer (Main et al., 2003). These toxic algal blooms can have severe adverse effects on the ecology of the lake as well as any livestock or domestic animals that come into contact with the water (Main et al., 2003). In an attempt to understand and address the principal causes of water quality decline, hydrological, sediment, and nutrient budgets are being constructed for the catchment. The most important surface water inputs to Wairewa are the two streams flowing into the lake at the NE end: the Okuti and the Okana Rivers.

Currently water take from these streams and their tributaries by households in the Okuti and Okana River catchments is a permitted activity, so no consent is required and no record is kept of the amount of water removed for stock watering and domestic supply. It is unclear what effects these takes are having on the flow of these streams, particularly during periods of low flow over the summer, and this cannot be accounted for in hydrological modelling. It is currently not possible to determine the level of development the water supply in the area is able to support.

This report presents a model that can be used to calculate water demand in a semi-rural catchment. The model is based on research conducted in the catchments of the Okuti and Okana rivers, supplemented with previous research on water demand. The model allows for the calculation of the total water requirement of an area by multiplying the number of people and animals in a catchment by corresponding variables that relate to how much water each uses.

1.2 Catchment Characteristics

Lake Forsyth/Wairewa is a shallow eutrophic lake with a long history of cultural importance to Ngai Tahu (Ogilvie, 1990). From 1860 onwards the lake underwent widespread anthropogenic changes through the removal of the native forests. As a result of deforestation and the establishment of grasslands within the catchment, sedimentation and nutrient levels within the lake have increased markedly, the lake has experienced a reduction in salinity, and eutrophication has occurred (Berry, 2012).

Lake Forsyth/Wairewa as shown in Figure 1 is approximately 5.6km^2, although this varies greatly with water levels, and has a catchment of 110km^2 (Main et al., 2003). The average depth of the lake varies between one and two meters depending on the lake level. The lake becomes very shallow at the Little River end where the low lying margins of the lake are flat and often covered in water. During summer, when low lake levels coincide with strong northeast winds, large amounts of the lake bed can become exposed at the Little River end of the lake (Pyle, 1992).

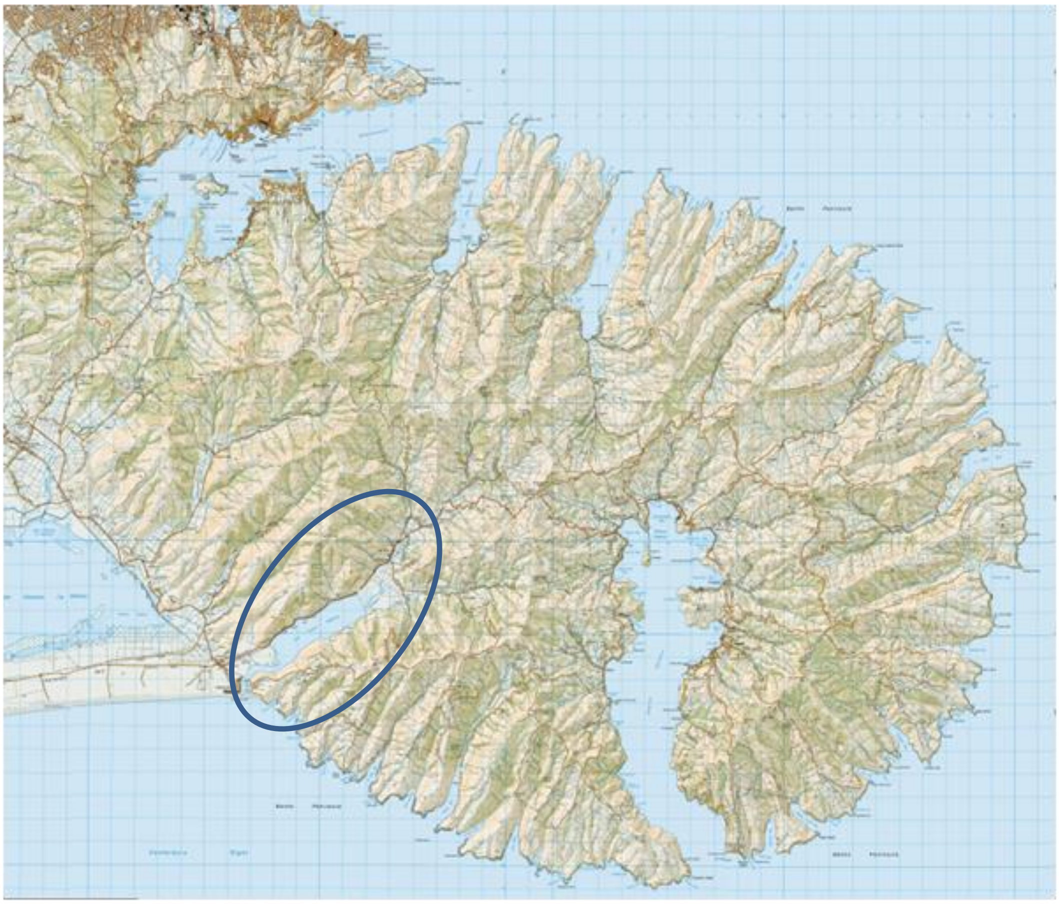

Figure 1. Banks Peninsula, in Canterbury (New Zealand) with Lake Forsyth/Wairewa indicated (LINZ, 2013)

The two main rivers in the catchment are the Okana and Okuti Rivers, which drain the largest of the four sub-catchments. These two rivers are hill country streams in a catchment where there was large-scale land use change in the nineteenth century, resulting in on-going impacts. The water quality of the two rivers is generally considered poor as a result of the highly modified nature of the valleys, phosphorus-rich geology, and low summer flows (Meredith and Hayward, 2002).

Approximately three-quarters of the flow into Lake Forsyth/Wairewa is contributed by the Okana River, and the remainder by the Okuti (Main et al., 2003; Berry, 2012). The stream flows are relatively stable, particularly in the Okuti River. The Okana River displays more variation as a result of a catchment area that is about twice the size of the Okuti, and a lower proportion of forest.

The Okana and Okuti Rivers are located in an extensively modified agricultural catchment. Riparian vegetation is comprised primarily of pasture grasses with a scattering of introduced trees such as willows; as a result, there is limited shading over the rivers. The removal of the original riparian vegetation has resulted in poor bank stability, with erosion events commonly occurring during periods of high stream flows (Main et al., 2003).

1.2.1 Okana/Okuti Catchment information

The Okuti catchment shown in Figure 2 runs in an east to west direction and the Okana catchment in a northeast to southwest direction. The Okana River shown in Figure 3 receives flow from the Okuti River and the Opuahau and Hikuika streams before it feeds into the lake at the shallow Little River end. The Okuti River also receives a significant input from the Reynolds Valley stream. In addition to the main streams and rivers, multiple small springs fed creeks feed into the main tributaries. These sources of spring water make up a significant proportion of the water supply for households in the catchments with households either taking water from the creeks, or directly tapping the source of the spring.

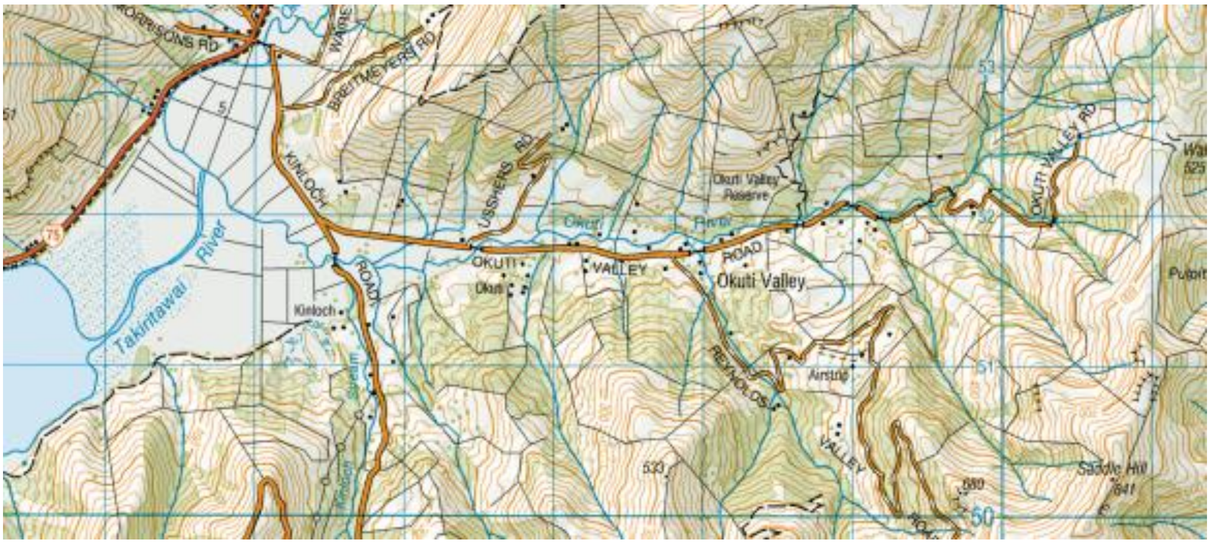

Figure 2. Okuti Valley with households shown as squares (LINZ, 2013)

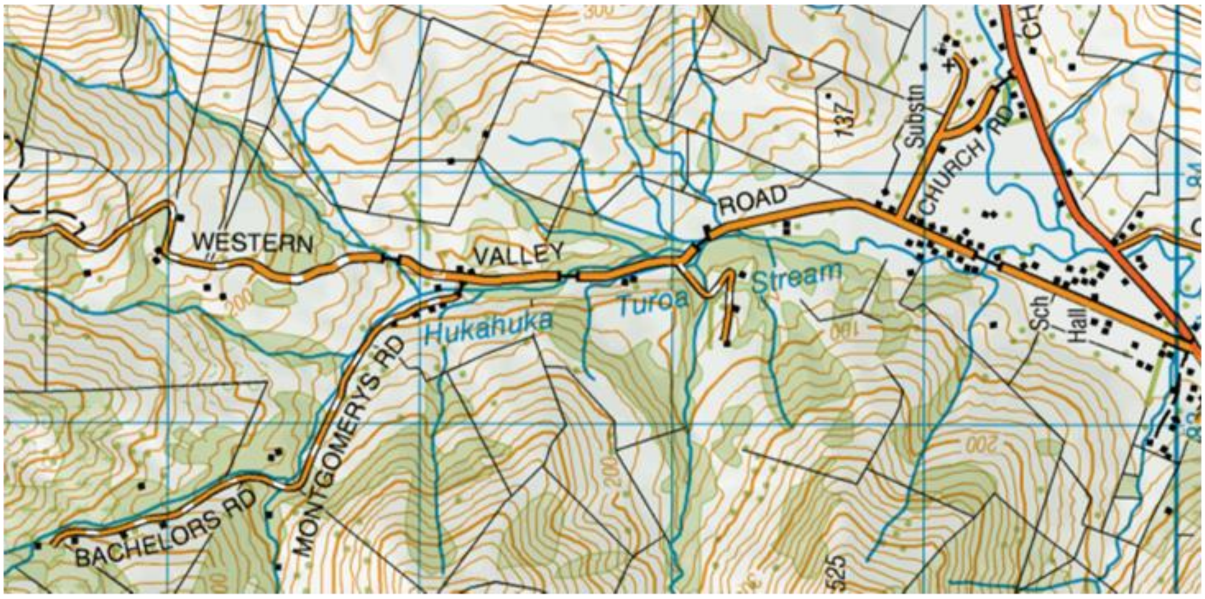

Figure 3. Okana Valley with households shown as squares (LINZ, 2013)

The hills of the catchment are relatively steep and rise to over 800m above sea level. Rainfall in the catchment is higher than on the Canterbury Plains and increases with altitude. During the summer months, evapotranspiration can be higher than rainfall, and occasional droughts can occur (Pyle, 1992).

Population demographics can have an influence on the water use of an area (Brown et al., 2007). The average household size in Little River is 2.4 people, compared with an average of 2.5 people for all of Canterbury Region (SNZ, 2006).

1.2.3 Catchment Development

The catchment of Lake Forsyth/Wairewa has experienced a high degree of modification over the past 150 years, primarily due to the almost complete removal of the original native forest cover (Ogilvie, 1990). Development continues to occur in the catchment however, while previously forest land was developed into farmland, presently, this farmland is increasingly being broken down into domestic sections. While several farms remain in the catchments the majority of dwellings are now either lifestyle properties with a small number of livestock, or domestic properties with no livestock.

1.2.4 Water Supplies

As new residential development occurs in the catchments, the new dwellings require a stable water source. While the township of Little River is mostly supplied by a reticulated water supply provided by the Christchurch City Council, this supply is unavailable in the Okuti catchment and only available for a small number of households in the Okana catchment. There have been discussions about extending the reticulated water supply to households in the Okuti and Okana River catchments; however, this is unlikely to occur for several years. The remainder of households in the catchments have three primary options for sourcing water. The vast majority of households source their water from the rivers (including small tributary streams), or springs that are common in the valleys, these sources are sometimes complemented by rain water collection. Often new households connect to an existing household's water supply and share a communal water tank, the household may also have one or more private water tanks that stem from the communal tank. These water supply networks range from two neighbours on a shared tank, to over fifteen households with varying numbers of shared and private tanks.

The taking of water from the Okana and Okuti Rivers, or the springs in their catchments, is a permitted activity and requires no consent. As a result, there has been no way to determine how much water is being extracted in the catchments, where this water is being extracted from, and how it is being used. Water has become a somewhat sensitive topic in the area. As residential development increases, so does demand for water, at the same time local farmers are concerned that their existing use of water is coming under increasingly intense scrutiny. This stems from a growing concern for the water quality in Lake Forsyth/Wairewa, and an increasing demand for domestic water supply.

The primary activities that require water in the catchments fall into two broad categories; domestic water needs including irrigating small areas of land, and farming operations including both irrigation of the land and animal drinking requirements.

1.3 Research Aims and Objectives

This research aimed to quantify water use in the Okana and Okuti catchments, with a view to predicting water use in semi-rural catchments for which water use is an unmonitored, permitted activity

The research comprised three main objectives;

i) To conduct a survey to determine household and farming water uses in the catchments

ii) To collect data on domestic and farming water use in other areas of New Zealand and interpret this alongside the data obtained from the survey

iii) Develop a model was developed to estimate the catchment wide water use in a semi-rural environment.

The survey

The survey aimed to document the water use of households and farming operations in the two catchments.

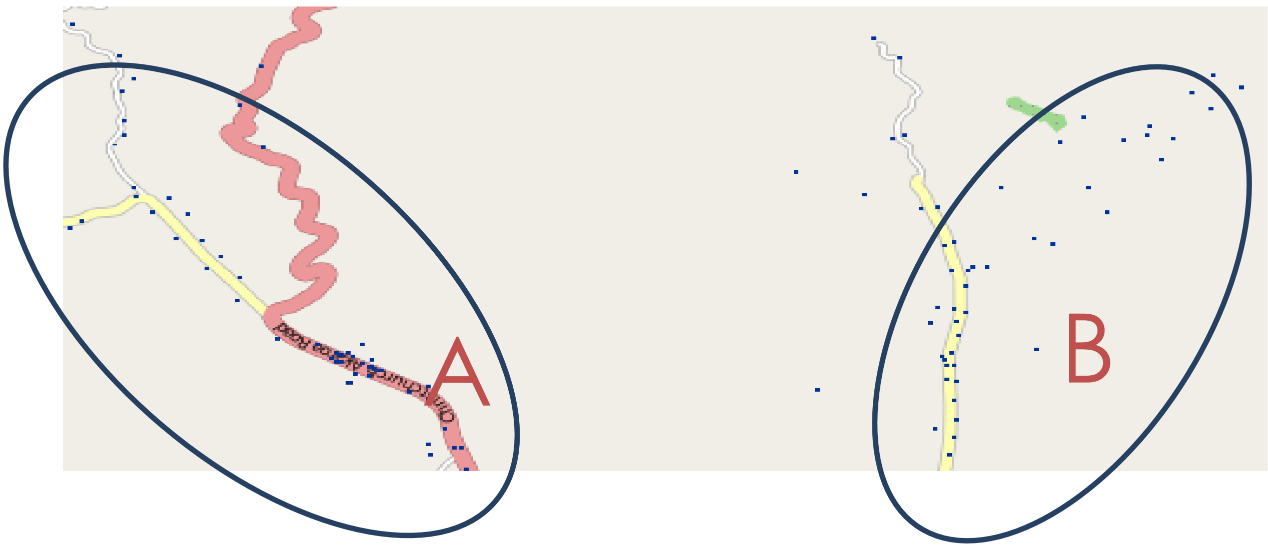

Figure 4. Distribution of households in the Little River area. Area A – Okana Valley survey area. Area B – Okuti Valley survey area

The primary objective of the survey was to obtain information relating to the quantity of water that is being used in the catchments, and how this water was being used. The survey also aimed to gather information on other aspects of water use such as the reliability of the water supply, and the means used by households to obtain water. The purpose of gathering

this information was to provide baseline data for a model to estimate the water used in the Okana and Okuti river catchments, as well as other semi-rural environments.

Data Compilation and Interpretation

The research aimed to develop a model that could be used in other semi-rural environments outside of the study area. In order to achieve this it was necessary to compare the results on household water use from a wider range of areas with the survey findings from the study area. To provide an estimate of catchment wide water use in semi-rural environments it is necessary to understand the water used by farming operations as well as domestic households. The research aimed to gather data that could be used to determine the average water use of different types of animals so that this information could be used as a baseline in the model.

Model Development

The primary aim in developing the model was to create a tool that could estimate the water requirements for a semi-rural environment. Water use in a semi-rural environment can be unmonitored and unregulated; therefore, there can be large degrees of uncertainty around the quantity of water being used. The objective of creating the model was to reduce some of this uncertainty. The research aimed to provide a model that could be used for purposes such as determining the capacity of a particular environment's water supply to absorb future development, or to determine the ability of a particular area to cope with a water shortage event.

Section 2. Methods

2.1 Survey

A survey was developed to ask households a series of questions pertaining to water use. The survey was sent to the Human Ethics Committee at Lincoln University for consideration and was approved in December 2012, after revision (refer Appendix 2 for the final version of the survey).

2.1.1 Design

The survey comprised five sections. In the first section households were asked ten questions about where they sourced water from, what infrastructure they used to obtain and hold water, and how long it took them to use the water they took from the source. This information was used to calculate the household's water use as well as provide information on the frequency of different methods of water extraction and retention in the catchments.

In the second section, households were asked eight questions relating to the reliability of their water supply as well as any seasonal variations in both supply and use. As the survey was being conducted at a single point in time the research was interested in gathering information on how the household's water use varied over the year. The reliability of the household's water supply was investigated to determine whether the supply was under any stress, or if the household was intentionally limiting their water use for any reason.

The third section of the survey asked seven questions about how the household used water. The primary goal of this section was to separate domestic water use from farming water use. Where a household kept livestock, the number and type of animals they kept were investigated so that the relative water use of the household's domestic water use versus their farming water use could be determined.

In the fourth section of the survey, demographic information was obtained on the households. The key piece of information sought in this section was the number of residents in the household, so that per-person water use figures could be derived.

In the fifth and final section, households were asked to make predictions about their intended future water use. This section aimed to gather information on whether households were planning on changing to a different water supply and whether they expected their water use to increase or decrease. Due to the lack of any significant information being obtained from this section, the data obtained from this section was subsequently dropped from the research.

2.1.2 Implementation

The survey was conducted in person (i.e., by interview) on four days over a two week period from the 4th to the 13th of January 2013. The majority of households in the main catchment areas of the Okuti and Okana Rivers were approached; a small number of households were not visited due to problems with accessibility. An area with around 15 houses and two other

small groups of houses in the Okana catchment were found to be on the CCC water supply and were subsequently excluded from the research.

Approximately one hundred houses were approached; responses were obtained from fifteen households in the Okuti catchment (39% of houses that were approached) and 19 households in the Okana catchment (32% of houses that were approached).

2.2 Data Compilation and Interpretation

The research set out to create a model that calculates total water demand based on known values of water demand for key activities. To calculate water demand the number of humans or animals in a catchment area is multiplied by corresponding variables related to how much water each uses. There is little data available on the water use of domestic households and farming operations in semi-rural New Zealand environments (Brown et al., 2007). The two main areas of information required to develop the model were:

i) *Information relating to the number of people and animals that are using water in the catchments.* The primary sources for this information on people in the catchments (in addition to the survey) were Statistics New Zealand (SNZ, 2006) and Land Information New Zealand (LINZ, 2013). The information obtained from these two sources provided variables for the model that were used to obtain an estimate of catchment wide water use.

ii) *Information relating to the quantity of water being used by different households, animals, and land uses.* In addition to the information on human and animal water use obtained through the survey, other sources of information on human and animal water use both in the Little River area and in other locations in New Zealand were used. Information on the water use of households connected to the Christchurch City Council reticulated water scheme in the Little River area was provided to the research by Dr Tim Davie of Environment Canterbury. This information was used in conjunction with information on domestic water use from the Waikato Regional Council (see Brown et al., 2007), the Ministry of Health (2006), and Heinrich (2007) to make comparisons with the findings of the survey. The results of this investigation were then used to establish the fixed variable for domestic water use that is used in the model. Information relating to the water use of animals was obtained primarily from Stewart and Rout (2007). While other sources were consulted such as Fleming (2003), Stewart and Rout (2007) undertook a review of all the available studies on animal water use, and therefore provided the most definitive information on the subject. Information on animal water use was used to establish the fixed variables in the model that estimate the water requirements of different farming operations.

2.3 Modelling water take in the Little River Community

The development of a model to determine the total water requirement of a semi-rural environment requires a mix of data and assumption. The model calculates water

requirements based on the number of humans, and the number and type of animals in a catchment. The calculation of water requirement is determined by a multiplication of the number of humans or animals by corresponding variables related to how much each of these use. Total water requirement (TWR) for a catchment is calculated with Equation 1 below.

TWR = (Prop x PopD x DWU) + (PopDC x DCWU) + (PopBC x BCWU) + (PopCU x CUWU) + (PopDe x DeWU) + (PopSh x ShWU) + (PopHo x HoWU) + (PopPi x PiWU) + (PopCh x ChWU) + (PopGo x GoWU) ***[+ leakage*]***

(... Eqn 1)

Where:

TWR	is total water requirement
Prop	is the number of properties in the catchment
PopD	is the number of people per property (constant set at 2.4 based on Little River avg)
DWU	is domestic water use per person (constant l/day)
PopDC	is the number of dairy cows
DCWU	is the water use per dairy cow (constant l/day)
PopBC	is the number of beef cattle
BCWU	is the water use per beef cattle (constant l/day)
PopCU	is the water use of cows of an unknown type (constant l/day)
CUWU	is the water use of cows of an unknown type (constant l/day)
PopDE	is the number of deer
DeWU	is the water use per deer (constant l/day)
PopSh	is the number of sheep
ShWU	is the water use per sheep (constant l/day)
PopHo	is the number of horses
HoWU	is the water use per horse (constant l/day)
PopPi	is the number of pigs
PiWU	is the water use per pig (constant l/day)
PopCh	is the number of chickens (grouped per 100)
ChWU	is the water use per 100 chickens (constant l/day)
PopGo	is the number of goats
GoWU	is the water use per goat (constant l/day)
[leakage*]	[is the amount of leakage if known]

The model takes a conservative approach to calculating total water requirement by using high end per-day water requirements for animals based on the most recent and comprehensive studies (Stewart and Rout, 2007). Likewise, a conservative approach is taken with the per day domestic water requirement which is set at the average water use level of Little River households, based on the survey results. If more relevant sources of water use data can be obtained for a catchment being investigated, the constants in the model should be changed to reflect this information. This model is intended to give a conservative indication of water requirements based on data obtained during a survey of 34 semi-rural households and an analysis of the latest data on human and animal water requirements.

2.3.1 Farming water requirements when the number of animals is unknown (FWRU)

A problem foreseen by the research was obtaining an estimate of animal water requirements in the catchment where the number of animals was unknown. One solution to this problem is to make comparisons between domestic water requirements and animal water requirements in areas where the amount and type of animals is known. Waikato Regional Council measured the animal water use of several water schemes as a function of total water use (Brown et al., 2007). This data can be combined with the data obtained in the Okana and Okuti catchments survey to create a tool to estimate animal water requirements where the amount and type of animals is unknown. Animal water requirements in a catchment will vary greatly depending on the intensity of farming operations in the area; therefore, four categories are used to estimate animal water requirements under different levels of farming intensity. The four categories can be seen in Table 1.

Table 1. Four categories of farming intensity

Rural Domestic	Primarily domestic housing area, a few animals kept in small quantities
Lifestyle/Low range farming	Primarily domestic/lifestyle housing are, a few small scale farming operations (5 – 10 stock units per hectare), and possible a couple of larger farming operations (5 – 21 stock units per hectare).
Mid-Range Farming	Primarily farming households with stock units ranging between 16 to 21 animals per hectare
High Range Farming	Primarily farming households with over 21 stock units per hectare.

Calculating the total water requirement of a catchment where there are an unknown number and type of animals (TWRU) can be achieved by using Equation 2 below.

TWRU = FWRU + DWR (...Eqn 2)

Where:

TWRU is the total water requirement catchment where there are an unknown number and type of animals in the catchment.

FWRU is the farming water requirement for an unknown number and type of animals chosen based on the density of farming in the area in accordance with Table 1

DWR is the domestic water requirement of the catchment (*Prop x PopD x DWU)*

Section 3. Results

3.1 The survey

3.1.1 Reliability

Questions 11 through 14 of the survey were aimed at determining the reliability of the household’s water supply, as well as any seasonal effects that may occur. Households were asked to rank the reliability of their water supply using a Likert scale that ranged between one, being very unreliable, and five, being very reliable. The households were then asked whether there was any seasonal effect on their water supply, and if so, what seasons were most likely to adversely affect their water supply.

The reliability of the water supply is important as it is difficult to determine household water requirements where the household does not have access to the full quantity of water they desire to use. The majority of households surveyed indicated that the reliability (see Figure 5 and Appendix 1) of their water supply was good, and that there was little seasonal effect on reliability.

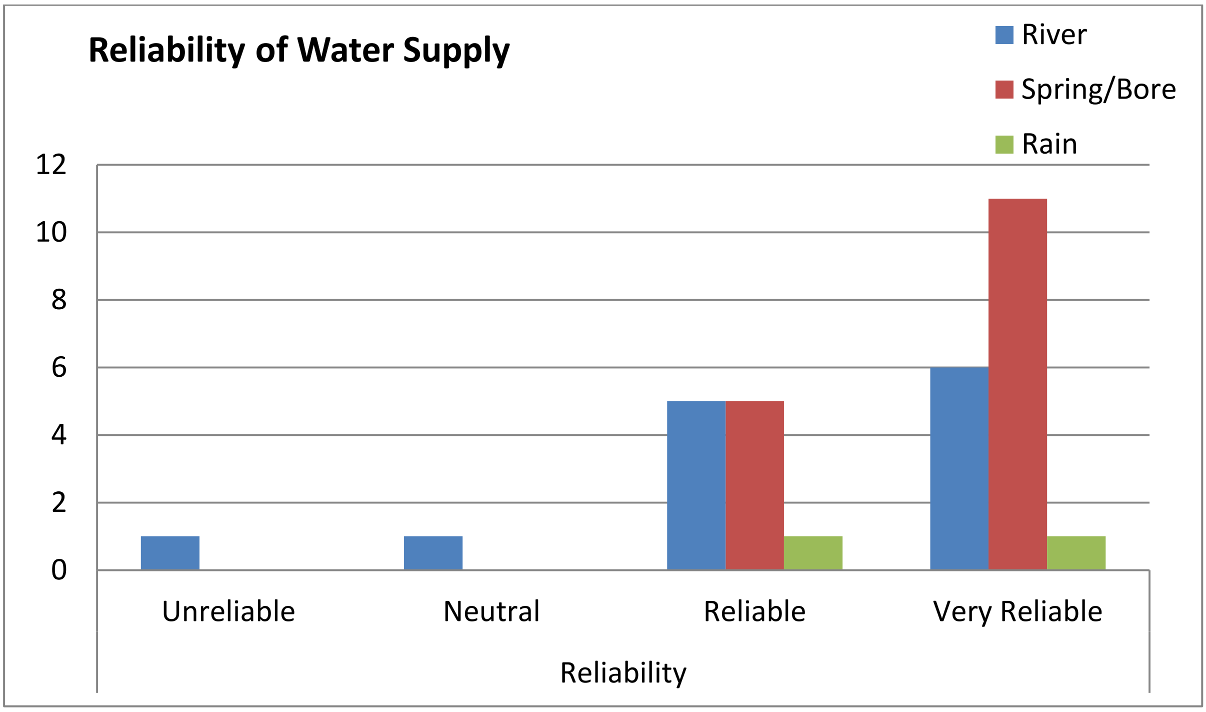

Figure 5. The reliability of three different sources of water. Vertical axis is the number of households.

Most households stated that the amount of water available to them was plentiful, and that issues of reliability were almost uniformly due to problems with the water supply infrastructure. Where seasonality was identified as affecting the reliability of the households’ water supply, winter was identified as the most unreliable season for water

supply. This was due to flood flows in the rivers blocking or damaging the water supply infrastructure. Low summer flows in the rivers were identified early in the research as being a potential area of concern for households in the Okana and Okuti catchments; however this assumption has proven to be unfounded. It is assumed for the purpose of this research that the households of the Okana and Okuti catchments are using the full quantity of water that they desire to use.

3.1.2 Sources of Water

Question 1 of the survey investigated where households sourced their water from. The survey presented households with five methods (including 'other') for obtaining water, from which they were asked to select which option or options they used.

The two primary sources of water in the catchments were the rivers, or springs (either tapped above ground or under). Rain water was found to be the primary source of water in only one house. However, households commonly took water from more than one source. Often spring water, where available, was used for the household supply while river water was used to irrigate the garden or as drinking water for livestock (see Figure 6).

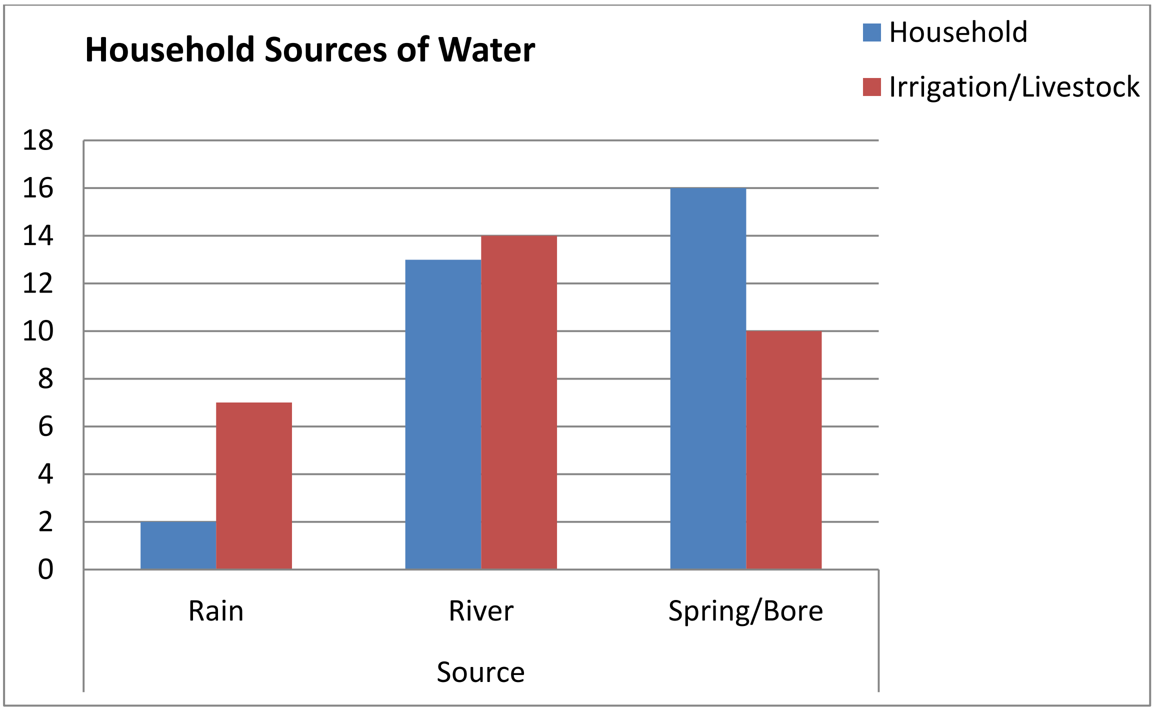

Figure 6. Use of different sources of water by households. Vertical axis is the number of households.

3.1.3 Quantity of household water use

Questions 4 to 10 and 19 to 25 of the survey were designed to gather enough information to determine a household's water use. In questions 4 to 10, the size of the household's water tank(s) was established as well as the speed that households consumed the water in

their tank(s). Secondly in questions 19 to 25, a series of questions investigated how the household used water. Distinctions were made between domestic uses and farming use, and the exact nature, makeup, and extent of any farming operations were established so that estimates of relative water use between different activities could be established.

Determining the quantity of water used by each household in the catchment (Table 2) relies heavily on the households having a good idea of their water use. While some households were able to provide enough information to make estimates of their daily water use possible, many were not. Several factors inhibited reliable estimation of a household's water use. Many households were on a shared water scheme that had communal water holding tanks and were unaware of what proportion of the supply their household consumed. Other properties had no water tanks; instead, their household was connected directly to the water source via a gravity-fed pipe. The most common impediment was that most households had a ballcock valve on their water tanks; therefore, they were unable to say how long it took their household to use the water in the tank as the tank was constantly kept full.

Table 2. Per-person water use in the two catchments. "+ L" indicates households that use their domestic water supply for livestock also. "(s)" indicates households on a shared water scheme, for these households the water use of the household has been averaged

Catchment	Range of Per-person water use (l/day)
Okana	1250 1250 500 294 +L (s) 125 400 267 1025 +L 1250 + L (s)
Okana Average	**707**
Okuti	628 +L 833 250 +L 417 +L 571 62 (s)
Okuti Average	**460**
Catchment Average	***584***

Therefore it was possible to calculate household water use only when the household manually filled their water tank and were able to say how long it took to use the water, or the household had experienced some problem with the supply to their water tank in the past and were therefore able to say how long it took to empty the tank. The later situation was the most common way water use was calculated in the catchments. It must be emphasised that this source of information is reliable for only a single point in time, and is only loosely indicative of the household's water use. Figure 7 shows a comparison between the study area with the wider area of Little River and New Zealand as a whole

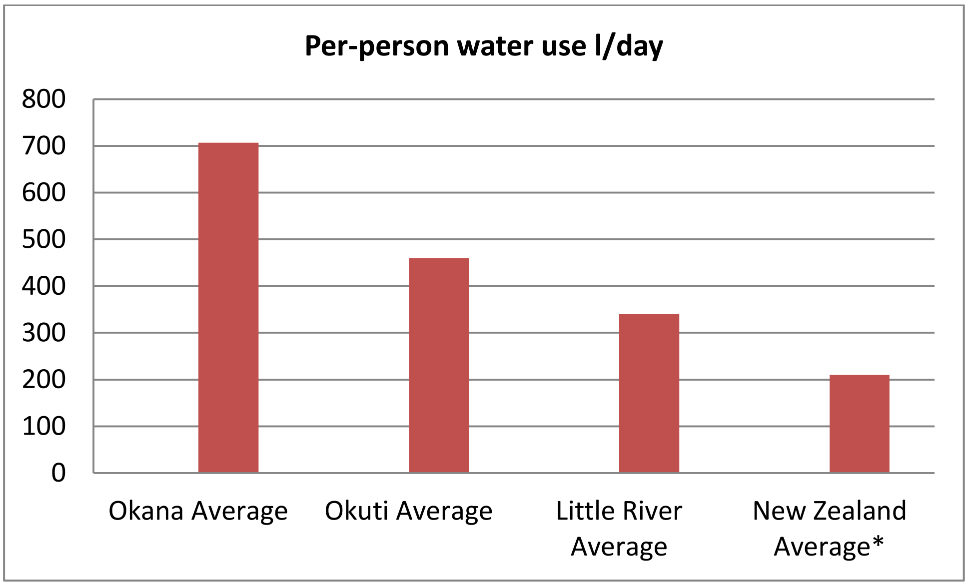

Figure 7. Average per-person water use across the two catchments and wider areas. * The New Zealand average was obtained from Brown et al. (2007).

The water use recorded in Table 2 and shown in Figure 7 does not take into account water used for farming operations. All farming operations surveyed took water directly from the river for farming purposes and none could or would provide any information on how much water they took or how often they took it. In the next section, this has therefore been estimated from the literature to get a more accurate picture of water use in the catchments.

3.2 Data Compilation and Interpretation

3.2.1 Domestic Household Requirements

A key driver of domestic water use is the number of people in an area. Water required for domestic purposes covers sanitary requirements, drinking water, irrigation of garden areas, and other occasional activities such as car washing. The Ministry of Health recommends that households should aim to have around 300l/person/day of water available (MOH, 2006). Studies have shown that average household water use in New Zealand ranges from about 160 l/person/day to 260 l/person/day (Brown et al., 2007). Average household water use

shows seasonal variability. Indoor water use remains relatively constant year round; however, outdoor water use can be three times higher in summer than winter (Heinrich, 2007).

Measurements from the CCC reticulated water supply (Table 3) show that 72 households connected in the Little River area use on average 820ltr/day of water. Statistics New Zealand census data from 2006 shows that that average household size in Little River is 2.4 people (SNZ, 2006). This suggests an average per person water us in Little River of approximately 340 l/person/day. Another factor in domestic household requirements is land size, which could potentially have a large influence on water use especially in the summer months when garden and lawn irrigation is undertaken. The households connected to the CCC water supply have, in general, smaller sections than those houses in the catchments of the Okana and Okuti rivers.

Table 3. Water use of various reticulated supply areas on Banks Peninsula. * denotes that data is unavailable.

Water Treatment Plants	**Total Flow (m^3)**	**Average Flow (m^3/d)**	**Resource Consent (m^3/d)**	**Number of Connections (conn)**	**Average Usage (L/d/conn)**
Akaroa-Settler's Hill	*	*	350	1,095	*
Akaroa-L'Aube Hill	14,333	478	2,393	1,095	**440**
Akaroa-Aylmers Valley	*	*	1,200	1,095	*
Birdlings Flat	1,996	68.8	432	185	**370**
Duvauchelle	5,952	198	432	272	**730**
Little River	1,764	60.8	260	74	**820**
Pigeon Bay	253	8.2	31	15	**540**
Takamatua	2,423	80.8	752	132	**610**
Wainui	3,097	103	302	170	**610**

The survey to determine water use in catchments was conducted during a period of particularly hot weather with temperatures over 30°C and medium to strong dry northwest winds. These climatic conditions are likely to have had some influence on the households water use, resulting in survey results that are likely to be at the high end of the households normal water use.

As the model takes a conservative approach to estimating water requirements however, the above average water use figures obtained in during the survey will be used to estimate high end water use. This will enable the model indicate water requirements for an area that also takes into account peak periods of water use.

3.2.2 Farm Operation Requirements

The second important driver of water use in the catchments is the type and number of animals in the area. There were three types of animals identified in the area, cows, deer, and sheep. Stuart and Rout (2007) conducted a review of the scientific literature on drinking water requirements for a range of farm animals. The model presented in this report uses the findings of this review to determine average animal drinking water.

It is not clear whether the animal drinking water estimates investigated by Stuart and Rout (2007) were based on average annual use including seasonal variations, or average daily use which would represent the amount of water required to maintain animal health during dry periods. For the purpose of the model it is assumed that the averages produced by Stuart and Rout (2007) are for average daily use (in keeping with the dominant industry practice), which provide for adequate animal water during dry periods such as the occasional droughts that occur in Little River during summer. If this assumption is incorrect then the model will underestimate the amount of water required by animals during the drier months, but should not affect annual averages. The model takes a conservative approach by using the high end estimates suggested by Stuart and Rout (2007) for animal water requirements.

Cows – Dairy Cows and Beef Cattle

It was not possible during the survey to draw a distinction between dairy cows and beef cattle. Studies show that both dairy cows and beef cattle require between 45 l/cow/day to 70 l/cow/day, however, dairy cows require an additional 70 l/cow/day for dairy shed use (Stewart and Rout, 2007).Therefore, for the purpose of the model a distinction will be made between dairy cows and beef cattle. Dairy cows will be assumed to require 140 l/cow/day while beef cattle will be assumed to require 45 l/cow/day. Where it is no possible to determine whether the cows are dairy cows or beef cattle (as in the case of the Okuti and Okana catchments) an average value of 105 l/cow/day can be cautiously used. Using this value has the potential to overestimate or underestimate water requirements depending on the type of cows in the area, and therefore should only be used for relatively low numbers of cows.

Deer

Studies have shown that the water requirements of deer can vary widely according to age, sex, climatic conditions, and type of diet (Stewart and Rout, 2007, Brown et al., 2007).The high end water requirement suggested by Stuart and Rout (2007) provides for diets that require a high water intake, as well for the increased water requirements of weaners until they are sold off. The value of 12 l/deer/day will be used in the model as a means of making a conservative estimate, however low end water requirements could be closer to 6 l/deer/day.

Sheep

Several studies show a high degree of consistency when estimating the daily water requirements of sheep. The high end estimate of 4.5 l/sheep/day, which will be used in the model, covers the higher water requirements of nursing ewes and weaned lambs for the period of time until they are sold off (Stewart and Rout, 2007).

Horses

There is limited data available on the water requirements of horses. A distinction is made in some of the literature between the water requirements of working horses and grazing horses (Fleming, 2003). It is assumed, (for the purpose of a model aimed at estimating the water requirements of large areas), that most farms have a limited number of working horses, and that those horses are not being used constantly in a working role. Therefore, the model will use the high end estimate for grazing hoses of 50 l/horse/day provided by Stuart and Rout (2007).

Other animals

Other animals that were not indicated by households during the survey can also be included in the model based on the average high end water requirements listed in Stuart and Rout (2007). The following water requirements are used by the model:

- Pigs – 21 l/pig/day drinking water + 20 l/pig day washing water. Total of 42 l/pig/day
- Chickens - 41 l/100 birds/day (*Figure is for one hundred birds)
- Goats – 8 l/goat/day

The fixed variables used in the model to determine the water requirements of the Okana and Okuti catchments can be seen in Table 4. The other fixed variable in the model is population density, which is set at a constant of 2.4 based on the Little River average. Animal water requirements, where applicable, include drinking water as well as water required for other purposes such as cleaning and cooling down stock areas.

Table 4. Fixed variables of different animal's water use to be used in the model.

Unit	**High end av. daily water requirement** (l/unit/day)
Domestic (DWU)	584
Dairy Cow (DCWU)	140
Beef Cattle (BCWU)	45
Cow (CUWU)	105
Deer (DeWU	12
Sheep (ShWU)	4.5
Horse (HoWU)	50
Pig (PiWU)	21
Chicken (ChWU)	41 (per 100 birds)
Goat (GoWU)	8

Leakage

Several households surveyed indicated that there was some leakage in their water supply; however they were not able to give any estimate on how much. Leakage in the catchments is likely to be highly variable and difficult to quantify. Some standards exist in the literature that estimate leakage as a function of the length of the water scheme network (OFWAT, 2007) , however this approach cannot be used in the catchments of the Okana and Okuti Rivers, and other semi-rural environments where water is sourced direct from rivers and springs. Brown et al. (2007) cites a report that suggests water leakage could be between 5 to 30% of the water being used, another cited study of 12 residential homes showed that leakage accounted for 4% of household water use. There is even less information available for leakage from farm properties. While it is probable that all farm's experience some leakage, there is no information available on how much leakage occurs. Based on the lack of information surrounding leakage, it will not be included in the model; however, it should be recognised when investigating an area's water requirements that leakage can be a factor.

3.3 Model Inputs for Total Water Requirement

Domestic water requirement (DWR) of surveyed houses

The total domestic water use of the 34 houses surveyed calculated using the model is:

DWR = *(Prop x PopD x DWU)*
= (34 x 2.4 x 584)
= 47,654 l/day

Farming water requirement (FWR) of surveyed houses

Of the 34 houses surveyed 10 were farming operations of different sizes, the total water use of these farming operations based on the model estimate is:

FWR = *(PopCU x CUWU) + (PopDe x DeWU) + (PopSh x ShWU) + (PopHo x HoWU) + (PopPi x PiWU)*
= (335 x 105) + (150 x 12) + (4235 x 4.5) + (3 x 50) + (6 x 21)
= 56,308 l/day

The total water requirement of surveyed households

TWR = *(Prop x PopD x DWU) + (PopCU x CUWU) + (PopDe x DeWU) + (PopSh x ShWU) + (PopHo x HoWU) + (PopPi x PiWU)*
= (34 x 2.4 x 584) + (335 x 105) + (150 x 12) + (4235 x 4.5) + (3 x 50) + (6 x 21)
= 68,787.9 l/day

Total water requirement (TWR) of the two catchments

As the exact number of farming operations or animals in the two catchments was unknown to the research, calculating the total water requirement for an unknown number of animals (TWRU) for the catchments requires estimating the farming water requirement for an unknown number of animals (FWRU).

Table 5 shows the multiplier used for each category to calculate animal water requirements (FWRU) in an area based on domestic water requirements (DWR).

Table 5. Multipliers to be used to calculate FWRU

Category	**FWRU**
Rural Domestic	DWR x 0.23
Lifestyle/Low range farming	DWR x 1.18
Mid-Range Farming	DWR x 11.15
High Range Farming	DWR x 36.7

The multipliers in Table 5 were derived by comparing known household water use to known animal water use from areas of different farming densities. For example, using the information obtained from the survey of households in the Okana and Okuti catchments, farming operations, which made up 30% of total households, used 57 % of the total water used (excluding their domestic use) or 1.18x more water than the DWR. The Okana and Okuti catchments are good examples of lifestyle/low range farming areas, with most households keeping no animals but with several small scale farming operations dispersed throughout the catchments.

To obtain an estimate of water use in the Okana and Okuti catchments (a lifestyle/low range farming area where the amount of farming operations or animals is unknown), it is possible to multiply the DWR of the area by 1.18 to get an estimate of farm operation use. This figure, (the FWRU), can then be added to the domestic use to obtain a total water requirement for the catchment. The accuracy of taking this approach to determining water requirements for an unknown number and type of animals is investigated in the discussion section of this report.

Total catchment water requirement of the Okana and Okuti catchments, where the number of farming operations and the type of animals are unknown can be calculated using Equation 2 (TWRU = DWR + FWRU)

DWR = *(Prop x PopD x DWU)* = (133 x 2.4 x 584) = 186,413

FWRU = DWR x 1.18 = 186,413 x 1.18 = 219,967

TCWR = **406,380 l/day**

According to the land information New Zealand database there are 55 properties in the Okuti Catchment and 78 in the Okana catchment, a total of 133 households. Assuming a population density of 2.4 people per household (SNZ, 2006) and an average water use of

584 l/day, the total domestic water requirement (DWR) for the catchments is 186,413 l/day. Using the multiplier of x 1.18 to estimate farming operation requirements (FWRU) yields a figure of 219,967 l/day. Adding this to the domestic water requirement results in a total catchment water requirement of **406,380 l/day**.

Section 4. Discussion

The research looked at three fundamental aspects of water use in a semi-rural environment and how they can be used to model water use in a catchment. These were the reliability of the water supply, the source of the water, and the quantity of water used. All three of these aspects play an important role in determining the availability of water in a catchment.

4.1 Reliability of the water supply

If the purpose of investigating the water requirements of a catchment were to be to determine the viability of future development, then information concerning the reliability and seasonal variability of the existing water supply is important. The majority of households in the Okana and Okuti catchments considered their water supply to be reliable; however, most households indicated that they were careful with how much water they used as they were concerned with the availability of water elsewhere in the catchment. There was a general perception in both catchments that water could be scarce, however, very few individual households experienced any scarcity. It must be noted therefore that when investigating the water supply of a semi-rural environment, that concerns around the scarcity of water may be more of a commonly held belief rather than a grounded reality. The main problems with water reliability that households had in fact stemmed from an overabundance of supply, whereby flooded rivers would wash away their supply pipes.

4.2 Sources

The second fundamental aspect of water use in a semi-rural environment stems from where houses source their water. There were two primary sources of water in the Okana and Okuti catchments, the rivers, and springs (or bores). While rain water was collected by several households, only one household used rain water as their primary source of water. Spring or bore water was found to be the most common source of household's water. The vast majority of households on spring water supplies had no idea of how much water was available to them via the spring they tapped into. While the research did not consider the total availability of water in the catchments, where households source their water is important for any investigation into how much more development the catchment's existing water supply could maintain.

4.3 Quantity: Modelling Water Use

The third aspect of water use in a semi-rural environment is the quantity of water used. A model to calculate water use for semi-rural environments was constructed based on the information in Tables 4 and 5. The model required four primary sources of information:

- The number of households in the area
- The population density in the area
- The average water use of households in the area
- The number and type of animals in the area

The first two sources of information (number of households and population density) are easily obtainable through land database and census records, however the second two

sources of information (average water use, and animal numbers and type) are not so readily available.

4.3.1. Domestic water use

This research has shown that that the average domestic water requirements of households in a semi-rural environment appears to be significantly higher than the national average. While studies have shown that average household water use in New Zealand ranges from about 160 l/person/day to 260 l/person/day (Brown et al., 2007), the research found that average household water use across the two catchments surveyed was 584 l/person/day. While this figure may (due to the timing of the survey) represent a high end estimate of water use, is nevertheless important to take into account high end water use when estimating total catchment water requirements.

Even between the two environmentally and spatially similar areas of the Okana and Okuti catchments, there was found to be a marked difference in domestic water use. The higher per-person daily water use in the Okana catchment (Figure 7) is difficult to explain as it does not appear to be related to section size. Excluding one very large farm of 10,000,000m^2, sections in the Okuti catchment are on average 83% larger than in the Okana catchment.

Other possible explanations for the difference between catchments are that;

- The Okana catchment has higher numbers of livestock, and perhaps stock water use has been inadvertently included in some household domestic water use assessments.
- Some Okuti catchment households have underestimated their water use (note the low value of 62/l/day for a household in Table 2)
- The Okuti valley has a high number of ecologically-minded lifestyle households that are restricting their water use

Regardless of the reason for the difference, it is clear that it is dangerous to make assumptions about domestic water use in an area based on data obtained from other locations. In order to obtain the most accurate results from the model, a good estimate of domestic water use in the area is required.

4.3.2. Livestock water use

The other source of information required for the model that can be a challenge to obtain is related to the number and type of animals in an area. In high density farming areas it is possible to obtain good indications of the number and type of animals in the area through databases such as AgriBase, however this approach does not work well in areas of low animal density. It was found during the survey that a very large range of stock densities were kept in the catchments; however the majority of households kept only small numbers (i.e. under 20 units). This research obtained an indication of animal numbers in the catchments by directly surveying the households.

While dairy shed operation has been identified as a major source of water use (see Fleming, 2003), there are only three dairy farms of any significant size in the catchment and no dairy sheds were identified during the survey. Dairy sheds were therefore not treated as a separate water use, but were integrated into a per-cow rate of water use in the model.

The model uses fixed variables to calculate the water requirement of different animals. These variables have been derived from the most current of the limited amount of studies done on the subject. The model uses the high end estimates for all the animals as animal water requirements can vary greatly depending on the stage of the animals reproductive or growth cycle and its use as a farm animal.

To determine catchment wide water requirements it is necessary to extrapolate the known data to make estimates or predictions on water requirements. This does not raise a challenge for calculating catchment wide domestic water use, as information on the number of households and population densities in the catchment is easily obtainable. However, it does raise a challenge for calculating catchment-wide animal water requirements.

The approach taken in the model has been to estimate animal water requirements by calculating them as a percentage of domestic water use. This percentage difference varies greatly with farming density. Using this approach was shown in Table 6 to be accurate to within +/- 35%. While this approach can be used to make a rough estimation of catchment wide water requirements, ideally, obtaining accurate information on the number and type of animals in a catchment would provide for a more reliable prediction of catchment wide water requirements.

4.4 Limitations of the Study and Recommendations

4.4.1 Limitations

The accuracy of the FWRU multipliers

To test the multipliers in Table 5, comparisons were made between modelled water requirement estimates where the number and type of animals were known, and the multiplier estimates where the number and type of animals were unknown. The percentage difference in the estimates ranged from a 32% over estimation to 18% under-estimation (Table 6). Where animal numbers and type are unknown the multipliers could therefore be used to give only a rough estimate of water requirements, of ± 35%.

Unwillingness of Farming Operations to Participate

There was a noticeable lack of willingness on the part of farming households to participate in the study. Of those farming households that did participate in the study, while they were happy to discuss their household water use, they were less willing to provide information on their water use for farming operations. Whether this is due to a desire to guard this

information or a genuine unfamiliarity in regard to this information is unclear. The study was therefore unable to obtain a good understanding of water use by farming operations in the Okana and Okuti catchments. The result of this limitation is that the findings of other studies investigating the water requirements of farming operations have been used to develop the model (e.g., Stewart and Rout, 2007). While this is not perceived to be a problem in this case, more accurate information on farming water requirements specifically related to the Okana and Okuti catchments would have been preferable.

Table 6. Testing the accuracy of the FWRU multipliers

	Rural Domestic		**Lifestyle/Low range farming**		**Mid-Range Farming**				**High Range Farming***
	Pokeno	Buckland	Okana	Okuti	Mata-toki	Tihiroa	Mihi	Reporoa	Arohena
Modelled Usage m^3/d	168	228	70	38	806	776	485	3172	1136
Multiplier Estimated Usage m^3/d	167	230	58	48	1190	680	352	3936	1131
Percent difference	-1%	+1%	-18%	+21%	+32%	-12%	-27%	+20%	-1%

*Only one data point was available to determine the high range farming multiplier

Limited Duration of Survey Period

The survey was conducted on four days over a two week period from the 4th to the 13th of January 2013. During the time the survey was conducted the weather was exceptionally hot with temperatures regularly exceeding 30°C. While these temperatures are not uncommon in the survey area, they are not normal either. There is a risk that households asked about their water use during this period of hot weather may have stated a level of use that is above their average use. However, most households stated that the season had little effect of their level of water use. While conducting the survey during this period of hot weather may have led to an above average estimate of water use, this on its own is not a problem as high end water use data is important for determining the water use requirements of a catchment.

Reliance on Household Knowledge

In order to determine household water use in the two catchments, households were relied upon to provide an estimate of their level of daily use. To provide this information, most households had to provide educated guesses on their water use based on past experiences, and times when their water supply was emptied for some reason. While many households had a good understanding of their water use, others took wild guesses which, when compared to other households in their catchment, appear to be grossly under or over estimated. Determining average household water use by means of surveying households works best where the household is forced to manually fill their water tanks. Households that did this had a good understanding of their water use, however the vast majority of households (especially newer houses), were on ballcocks that automatically replenished their water tanks. These households had very few reference points to estimate their water use. The average water use data obtained from the survey, while above average, does appear to be within an acceptable level of accuracy based on comparisons with surrounding areas. However in the absence of a monitoring programme, the accuracy of this information cannot be confirmed.

Reliance on Data from Other Environments

The information used by the model to determine the water requirements of farming operations was derived from studies that looked at animal water requirements in unspecified environments. It is therefore uncertain how well this information correlates with the animal water requirements in the Okana and Okuti catchments. Farming water use can make up the vast majority of water use in a catchment, therefore having accurate information on how much water each type of animal requires is vital for making accurate predictions of catchment wide water use. While the model cannot be expected to produce an extremely high degree of accuracy when determining catchment wide water use, there is some uncertainty around whether or not the animal water use requirement data used in the model is directly applicable to animals in any environment. The information on the water requirements of farming operations used in the model represents the best data presently available; however, information regarding how changes in environment effect the water requirements of animals would be beneficial for improving the accuracy of the model.

4.4.2 Recommendations for further study

It would be beneficial to the study of water use in the semi-rural environments of the Okana and Okuti catchments to conduct follow-up surveys during spring, autumn, and winter. This would help to calculate average yearly water use. While the current study was able to determine peak water use, it was not able to estimate the average yearly water use.

Limited monitoring of a selected number of households water use in the two catchments needs to be undertaken so that comparisons can be made between the surveyed water use information and monitored water use information. Presently, without this monitoring there is no way to determine the accuracy of the surveyed water use information beyond making comparisons with other locations. There is very little information available from other locations, making this option less than ideal.

There is a lack of information on the water requirements of farming operations at different levels of intensity. While there is some general information available on how much water an animal will require on average (see Stewart and Rout, 2007), there is no information available on how this changes throughout different environments or levels of farming intensity. More information is needed on the water requirements of animals specifically in semi-rural or lifestyle block environments, or at low levels of stock density such as in the Okana and Okuti catchments.

Returning to the first recommendation, a closer investigation of the water requirements of farming operations in the Okana and Okuti valleys needs to be conducted. If measured water use information was available for farming operations in the Okana and Okuti catchments then comparisons could be made between the models estimate of water requirements and the measured information. This would help to determine the accuracy of the model when predicting water use in a semi-rural environment.

Section 5. Conclusions

- Based on investigations into relevant literature and discussions with interested parties, there was a general perception before the research began that the Okana and Okuti River catchments were subject to frequent problems with water supply. This was not reflected by households that participated in the survey. Concerns about the scarcity of water in a semi-rural environment may be more of a commonly-held belief than a grounded reality.

- The primary sources of water in these catchments were spring and river water. Rain water made up a very low percentage of the total water supply and is generally regarded as not being a viable alternative by households in the study area.

- The average per-person water use in the river catchments was found to be significantly higher than the New Zealand average. This finding highlights the danger of extrapolating findings from one semi-rural environment to other catchments. The average water use of 584 l/person/day found in the two catchments is more than twice the New Zealand average of 160 l/person/day to 260 l/person/day (Brown et al., 2007). This may reflect the hot summer weather in which the survey was undertaken and/or difficulties measuring actual water usage in some households. The majority of households had very few reference points to estimate their water use. A monitoring programme to determine the exact water use of households in the study area would provide a useful set of data for investigating the accuracy of the survey information.

- Accurate prediction of the water requirement of the catchment required reliable estimation of the number and type of animals in the catchment. It was found in this study and in others, that farming water use can be significantly greater than domestic water use in a semi-rural catchment, reinforcing the importance of using accurate farming operation data when developing a prediction. However, there was a noticeable lack of willingness on the part of farming households to participate in the study. The findings of other similar studies to predict the water use of farming operations were used, but it is unclear how well this data reflects the study catchment. Obtaining more accurate information on the farming water use in the study area could be beneficial for future studies on the water requirements of semi-rural environments.

- Based on the data that was available to this study, a model was developed and used to estimate the water requirements of the catchments as 406,000L/day. Without knowing the exact number of animals and farming operations, however, the accuracy of this estimate may be only ± 35%. With further studies on the water use of different semi-rural environments it is possible that this level of accuracy could be greatly improved.

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Appendix 1. Survey Design

Water Use Survey in the catchment of Wairewa/Lake Forsyth

HOUSEHOLD

Okuti / Okana Catchment

#____________________

METHOD FOR OBTAINING WATER

1. **Where do you get water from? (If a mix then what percentage from each)**

Source	Percentage
☐ Rain	
☐ River	
☐ Bore	
☐ CCC water scheme	
☐ Other	

2. **What size is your water tank?**
- _______ Litres

3. **How long does it take to fill up your water tank?**
- _______ hours / days / weeks / months

4. **How long does it take you to use the water in the tank?**
- _______ hours / days / weeks / months

5. **How much water is left in the tank when you refill it?**
- _______ Litres / Percent

6. **Is your tank constantly filling?**

☐ No (go to Q 8.)

☐ Yes

7. **Where does the overflow go?**

____

____

____

8. **Do you pump water directly from the river onto the land?**

☐ No (go to Q 12)

☐ Yes

9. **What is the capacity of the pump?**

- _______ Litres (second / minute / hour)

10. **How often is it run?**

(AND)

11. **How long is it run for?**

	Frequency of use (times run)	Duration of use (hours)
Day		
Week		
Month		
Year		

RELIABILITY / SEASONALITY

12. **How would you rate the reliability of your water supply?**

Very Unreliable	Unreliable	Neutral	Reliable	Very Reliable
1	2	3	4	5

13. Is the reliability of your water supply affected by the seasons?

☐ No (go to Q 16.)

☐ Yes

14. Rank the seasons by how much water is available to you.
(AND)
15. Approximately what percentage less water do you have during the seasons ranked 2 - 4?

Ranking of season by water supply (no.1 = 100%)	Percentage of water less than number 1.
☐ **Summer**	
☐ **Autumn**	
☐ **Winter**	
☐ **Spring**	

16. Do you ever not have enough water to meet your needs or desires?

No (Go to Q 20)

Yes

17. How often do you not have enough water to meet your needs or desires?

☐Daily

☐Weekly

☐Monthly

☐Seasonally

☐Yearly

18. Is there anything that prevents you from getting the water you need?

☐ No (go to Q 20.)

☐ Yes

19. What prevents you from getting the water you need?

☐Insufficient water in the river

☐Insufficient rainfall

☐Inadequate water extraction system

☐Water tank is too small

☐ Other

____

WATER USE

20. What are the top three uses for your water?

(AND)

21. Approximately what percentage of your water use goes to each?

Water Uses	Percentage of total use
☐ **Household use**	
☐ **Garden**	
☐ **Crops**	
☐ **Pasture**	
☐ **Other –**	
☐	
☐	

22. What is your land used for?

☐ Lifestyle

☐ Livestock (Answer Q's 23/24.)

☐ Cropping (Answer Q 25/26.)

☐ Other

____

____

23. What type Livestock do you keep?

(AND)

24. How many of each type of animal do you have?

Livestock	Quantity
☐ **Sheep**	
☐ **Cattle**	
☐ **Deer**	
☐ **Pigs**	
☐ **Other**	

25. What size area of crops do you grow?

________ Ha / Acres

26. What type of crops do you grow?

____

____

DEMOGRAPHIC INFORMATION

27. How much land do you have?

________ Ha / Acres

28. How many people live in your house?

________ People

29. How long have you lived in this house?

_______ Years / Months

FUTURE EXPECTATIONS

30. Do you expect your water use to increase in the future? If so why?

____

____

31. Do you expect to change to a different water source, if so why?

____

____

32. What, if anything, is preventing you from switching to a different water source?

____

____

OTHER COMMENTS

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Appendix 2. Survey Results

Household		Source of Water				Quantity Water Use					Reliability of Water Supply					Seasonality		Availability of Water	Use of Water %			Demographhincs			Findings
		Rain	River	Spring	CCC Water scheme	Size of Water tank	Time to use	Direct to land from river irrigation	Tank Constantly Overflowing to Land	Total Known Water Use / Day	Very Unreliable	Unreliable	Neutral	Reliable	Very Reliable	Most Reliable Season	Least Reliable Season	Insufficent Water Supply to Meet Needs	Household	Garden	Livestock	Land size	Number of Occupantrs	Duration Living in House (years)	Per-person water use (ltr/day)
	1	-	Ir	Ho	-	5000ltr	48hrs	X	X	2500ltr day+					X	Summer	Winter	X - Infra	100% Sp	50% Ri	50%Ri	2000m2	2	15	1250+
	2	Ir	Ir	-	Ho	1500ltr	72hrs	2000ltr/day		2500ltr day					X	-	-	-	100% CCC	100% Ri/Ra	-	1000m2	2	1	1250
	3	-	Ho	-	-	None	-	-	-	?					X	-	-	-	100% Ri	-	-	1000m2	4	5	
Okana	4	-	Ho/Ir	-	Ho/Ir	3000ltr	72hrs	-	-	1000ltr day				X		-	-	X - Supply	50% Ri/CCC	50% Ri/CCC	-	1250m2	2	3.5	500
	5	Ho	-	-	-	50000ltr	?	-	-	?					X	-	-	-	80% Ra	20% Ra	-	1200m2	2	0.6	
	6	-	-	-	Ho/Ir	None	-	-	-	?					X	-	-	X - Supply	90% CCC	10% CCC	-	3000m2	5	4	
	7	-	Ho/Ir	-	-	None	-	X	-	?					X	Winter	Summer	-	80% Ri	20% Ri	?%	2200m2	4	2	
	8	Ir	Ho	-	-	25000ltr (S)	96hrs / 3 houses	X	X	2083ltr+ day(S)					X	Summer	Winter	-	50% Ri	100% Ra	50% Ri	8000m2	3	7.5	694+(S)
	9	-	-	Ho/Ir	-	5000ltr (S)	?	-	-	?				X		-	-	X - Supply	90% Sp	10%Sp	-	1600m2	2	12	
	10	-	-	Ho	-	None	-	-	-	?					X	-	-	-	100% Sp	-	-	1000m2	2	2	
	11	-	-	Ho/Ir	-	15000ltr (S)	?	-	-	?				X		-	-	-	95% Sp	5% Sp	-	3000m2	4	1	
	12	Ir	Ho	-	-	5000ltr	240hrs	-	-	500ltr day					X	Spring	Winter	Supply / Infrastructure	80% Ri	100% Ra 20% Ri	-	3300m2	4	8	125
	13	-	-	Ho/Ir	-	15000ltr (S)	?	-	-	?					X	-	-	-	90% Sp	10%Sp	-	1300m2	4	3	
	14	-	-	Ho	-	1600ltr	48hrs	-	-	800ltr day					X	-	-	Supply	100%Sp	-	-	2300m2	2	20	400
	15	-	-	Ho/Ir	-	5500ltr (S)	?	-	-	?				X		Winter	Summer		80%Sp	10%Sp	10%Sp	80900m2	5	11	
	16	-	Ho/Ir	-	-	15000ltr	336hr	-	-	1071ltr day				X		Winter	Summer	-	90%Ri	10%Ri	-	1000m2	4	6	267
	17	-	Ho/Ir	-	-	None	-	X	-	?				X		Summer	Winter	-	80%Ri	20%Ri	-	3200m2	3	2	
	17A	-	Ho/Ir	-	-	20500ltr	96hrs	X	X	5125ltr+ day					X	-	-	-	60%Ri	40%Ri	?%	10000000m2	5	7	1025+
	17B	-	-	Ho/Ir	-	10000ltr (S)	48hrs / 2 houses	-	-	5000ltr day(S)				X		Winter	Summer	Supply	40%Ri	30%Ri	30%Ri	40500m2	2	18	1250(S)
	18	Ho/Ir	-	-	-	33000ltr	?	-	-	?				X		Winter	Summer	-	95%Ra	5%Ra	-	1000m2	3	1.2	
	19	-	Ho/Ir	-	-	22000ltr	168hr	X	X	3142ltr+ day		X				-	Summer	Supply/Infrastructure	90%Ri	5%Ri	5%Ri	8000m2	5	8	628+
Okuti	20	-	Ho/Ir	-	-	15000ltr (S)	72hr / 3 houses	-	-	5000ltr day(S)			X			Summer	Winter	-	90%Ri	5%Ri	5%Ri	40460m2	2	8	833(S)
	21	-	Ho/Ir	-	-	?	?	X	-	?				X		-	-	-	80%Ri	20%Ri	-	2000m2	2	2	
	22	Ir	Ho	-	-	4000ltr	?	-	-	?				X		Summer	Winter	-	100%Ri	100%Ra	-	10000m2	2	4	
	23	-	Ir	Ho	-	1000ltr	48hrs	X	-	500ltr+ day				X	X	Summer	Winter	-	100%Sp	100%Ri	-	1240m2	2	12	250+
	24*	-	Ir	-	-	30000ltr	Out of Use	40000ltr/day	-	-					X	-	-	-	-	100%Ri	-	50000m2	0	0	
	25	-	Ho/Ir	-	-	2500ltr	48hrs	X	-	1250ltr+ day				X		Summer	Winter	Infrastructure	75%Ri	35%Ri	-	2700m2	3	13	417+
	26	-	-	Ho/Ir	-	None	-	X	-	?				X		-	-	-	90%Sp	10%Sp	-	8000m2	2	5	
	27	Ir	-	Ho	-	50000ltr (S)	?	-	-	?					X	-	-	-	100%Sp	100%Ra	-	8000m2	2	8	
	28	Ir	Ir	Ho	-	24000ltr (S)	?	X	-	?					X	-	-	Supply	100% Sp	100%Ra 100%Ri	-	11100m2	2	15	
	29	-	-	Ho/Ir	-	20000ltr	168hrs	-	-	2857ltr day					X	-	-	Infrastructure	80%Sp	20%Sp	-	68796m2	5	3	571.4
	30	-	-	Ho/Ir	-	750ltr	48hr / 3 houses	-	-	375ltr day (S)					X	Summer	Winter	Infrastructure	50%Sp	50%Sp	?%	100000m2	2	20	62(S)
	31	-	-	Ho/Ir	-	?	?	-	-	?					X	-	-	-	95%Sp	5%Sp	-	65000m2	2	1.5	
	32	-	-	Ho/Ir	-	5750ltr (S)	?	X	-	?					X	-	-	-	50%Sp	50%Sp	?%	405000m2	2	83	

* Vineyard

Farming Operations

Shared water use averaged across households on the network

KEY

Ho - Household

Ir - Irrigation

(S) - Shared water system

Ra - Rain

Ri - River

Sp - Spring

{ + - Household is known to use an unknown volume more than recorded

? - Unknown

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