Auckland Regional Council
TE RAUHITANGA TAIAO

Kumeu-Hobsonville Groundwater Resource Assessment Report TP60

Technical Publication No. 60, July 1995, ISSN 1172 6415

Prepared by Ramon Scoble & Andrew Millar

EXECUTIVE SUMMARY

The following are summaries of sections contained in this report on the Kumeu-Hobsonville Groundwater Resource Assessment.

Background

The Kumeu-Hobsonville Study Area contains a large groundwater system to the northwest of Auckland city. The Study Area represents a hydrological area of concentrated groundwater abstraction. The Study Area does not represent the geological boundary of the aquifer. This report describes the Kumeu-Hobsonville Study Area groundwater system. Groundwater has been extracted from the Kumeu area for horticulture and water supply for over 50 years. Historically, large horticultural water users have been attracted to Kumeu because of the proximity to Auckland City, soils suitable for horticulture and the ready supply of high quality, cheap groundwater. The major issues to be considered in reference to the Kumeu-Hobsonville groundwater resource can be summarised as follows:

i. A large number of proposed and existing users competing for a limited resource.
ii. Ensuring the resource is used in a sustainable manner.

Geology

The predominant aquifer rocks in the Study Area consist of sedimentary rocks of the Waitemata Group. The Waitemata Group in this area is composed of dark grey interbedded sandstone and mudstone. In places a mantle of weathered soils and recent alluvium, dominantly clayed silts, overlies the weathered rock.

Hydrology and Aquifer Characteristics

The Waitemata Group rock aquifer acts largely as a semi-confined groundwater system. The semi-confined nature of the aquifer results from the layered nature of the sedimentary rocks. The aquifer receives recharge directly from surface infiltration of rainfall.

Groundwater flow is primarily through fracture zones in the sedimentary rocks. The aquifer behaves locally as a fractured rock aquifer but is considered on a regional scale to represent a porous media. The hydraulic properties of the aquifer can vary considerably over short distances, both horizontally and vertically. Bore yields may vary over short distances depending on the nature of the strata encountered. Where fractures in the rock are widely spaced or poorly connected, bore yields may be low. However, bores in more highly fractured zones may produce in excess of 100 cubic metres per day.

In general, groundwater flow direction is strongly controlled by the topography of the low permeability Waitemata Group rocks, where this surface is above sea level. The groundwater flows down hydraulic gradient from areas of high topography and water level to areas with low topography and water level.

There is a groundwater divergence in the Kumeu-Huapai area. Groundwater from the upper Waitakere Valley flows west to the Kaipara River Valley and does not flow to the Waitemata Harbour, while the flow from Massey, Taupaki and Riverhead travels east to the Harbour.

Groundwater Chemistry

The water chemistry of the Kumeu-Hobsonville Study Area shows that the groundwater is of two distinct, soft and hard, water composition types. This is also seen in the Waitemata Group rock aquifers elsewhere in the region.

Deep bores (greater than 200 metres) normally yield good quality, soft water. They may however; yield poor quality, chemically hard, iron rich water due to short (less than 50 metres), or inadequately sealed bore casing.

Groundwater Recharge

The total recharge to the Kumeu-Hobsonville Study Area aquifer system has been estimated at 1,770,000 cubic metres per year.

Not all recharge to the groundwater aquifer is available for allocation to Resource Consents. Some residual through flow must be maintained to the sea boundaries to avoid the possibility of saltwater intrusion, especially in areas of intense abstraction. An additional quantity is reserved for supply of stock and domestic groundwater users. The combined total quantity of residual water is estimated to total 12 percent of recharge.

Allocation and Availability

Groundwater in the Kumeu-Hobsonville Study Area as a whole and in any of the Zones of the area may be allocated to 100 percent of the amount of water available for allocation.

Groundwater should be allocated according to policies that limit the intensity and total quantity of abstraction to no more than the amount of water available for allocation.

The use of groundwater is controlled by the requirement to have resource consents for horticultural, commercial and water supply purposes.

The total quantity of groundwater available for allocation to resource consent users is 1,559,238 cubic metres per year.

Table of Contents

Table of Figures

List of Tables

1. INTRODUCTION

1.1 Reasons for the Study

The first study of the Kumeu-Hobsonville groundwater resource undertaken was by the Auckland Regional Water Board (ARWB, now ARC) in 1986. The study was initiated in response to the concern over groundwater availability. The concern was that the growing demand would exceed the amount of groundwater that could be safely taken from the aquifer. If this situation were allowed to occur, unacceptable problems affecting all groundwater users would result. Groundwater levels in the area would progressively decline. The yields of existing bores would progressively decrease over time. Existing groundwater users may not be able to obtain sufficient water for their needs. Those bores close to the coastline would be increasingly at risk of sea water entering them. If this were allowed to occur water from bores close to the coast would become unsuitable for irrigation.

Based on comparisons with areas of similar geology and the generally poor bore yields, it was considered that groundwater availability was likely to be poor. The total quantity of groundwater allocated under existing permits was considered to be comparatively high compared with areas that were expected to have similar hydrogeology. The actual amount of water use under existing permits, as opposed to the amount of water allocated was not known. In addition there were also a large number of unauthorised groundwater users in the Kumeu-Hobsonville area.

With water permits in the area due to expire in 1988, investigation and monitoring programmes were instituted, in order to gain information to assist in the allocation process. As a result of the program an interim management strategy was implemented allowing processing of water permit applications from previously authorised users to be processed without prejudice to the current water permit holders. The study formed a basis for ensuring that the amount of groundwater taken from the aquifer did not exceed the amount that could be safely taken and sustained in the long term. The findings and allocation strategies are contained in Auckland Regional Water Board Technical Publication No.45 entitled "Kumeu-Hobsonville Groundwater Study Preliminary Findings and Interim Management Strategy, May 1987".

The technical recommendations of the Interim Management Strategy were carried out which included studies into the geology, hydrology, water chemistry, water use and groundwater availability for the Study Area. The results of this work and the groundwater allocation strategy produced are detailed in ARWB Technical Publication No.66 entitled "Kumeu-Hobsonville Groundwater Study Management Plan, March 1989". Water permit applications were processed in accordance with the recommendations in the report. An expiry date of May 1994 for water permit applications was recommended.

Recommendations were made in the 1989 Plan for further work to be carried out over the term of the consents issued for the area. During this period extensive monitoring of aquifer response to water use was carried out. The aim was to use the data collected to clarify assessments of water availability in the Kumeu-Hobsonville area and to formulate an allocation strategy to coincide with the expiry of most of the water permits to take groundwater. The recommended work has been carried out and the findings are contained in this report.

1.2 Study Area Definition

The Study Area for this report is that shown in Figure 1.1. This is effectively the area defined in the 1989 Management Plan, with some minor modifications to give rational boundaries where possible. The Study Area is shown divided into the management zones that were adopted by the 1989 Management Plan. Zone numbers will be used throughout this report to indicate areas discussed.

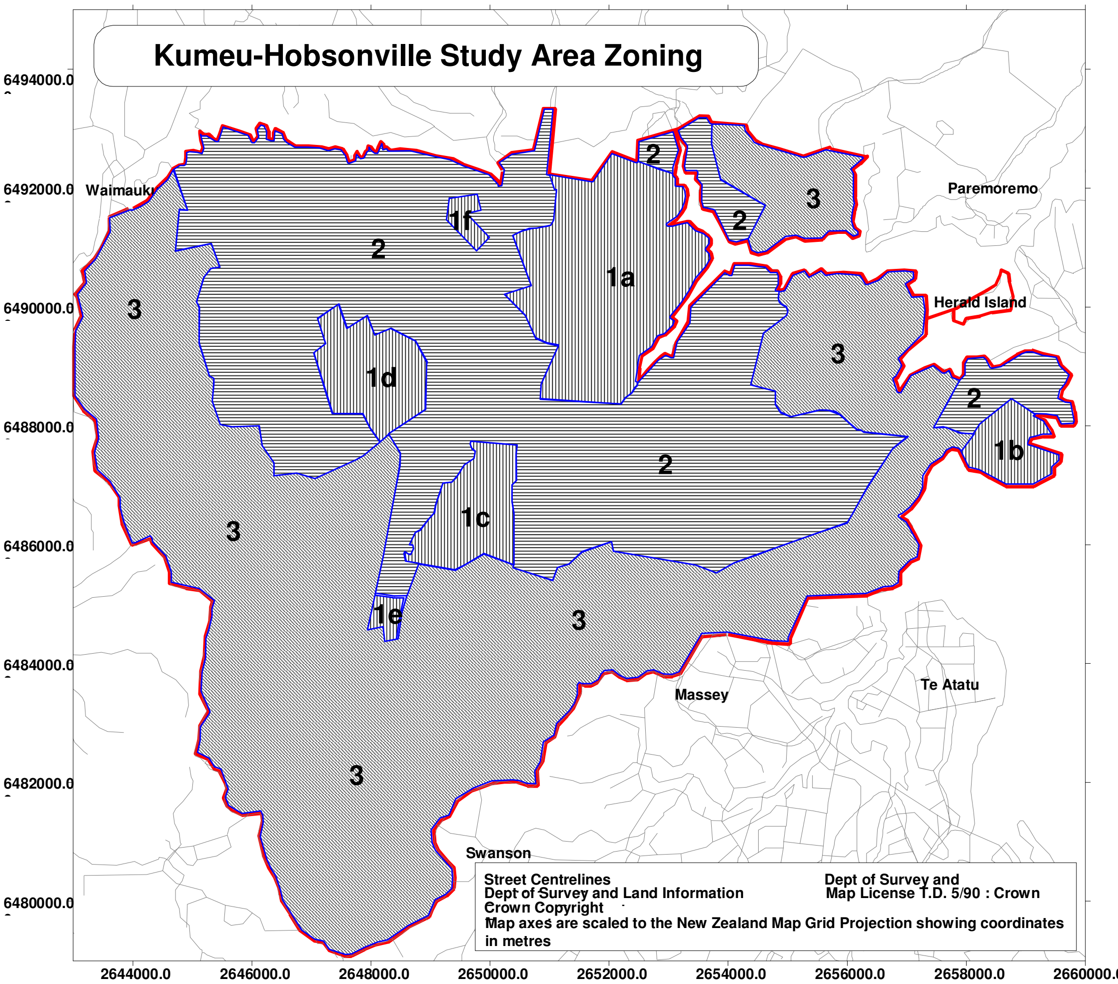

Figure 1.1: Map of Kumeu-Hobsonville Study Area showing Zones adopted for Management by 1989 Management Plan.

1.3 Objectives of this Study

This study aims to:

- assess the results of further work and the outcome of the allocation policies recommended by the 1989 Management Plan.
- clarify availability and formulate an allocation strategy for the Kumeu-Hobsonville groundwater resource to coincide with the expiry of water permits to take groundwater. An allocation strategy is required to allow expired permits to be processed within the constraints of the natural groundwater system.

- direct further work, which may be needed to improve estimates of groundwater availability and improve collection of data on aquifer response.
- prepare a plan for the on-going management of the Kumeu-Hobsonville groundwater resource.

1.4 Report Format

This report is presented in three main sections.

- Chapters 1 through 6 summarise current knowledge and discuss the results of the further work and monitoring of allocation policies and management recommendations of the 1989 Management Plan.
- Chapters 7 and 8 reassess the water availability of the Kumeu-Hobsonville groundwater resource based on the technical data.
- Chapters 9 through 18 make recommendations for allocation and management of the resource and further work to be done.

2. GEOLOGY

2.1 Further Work Completed

The geology of the Study Area has been described extensively in previous Management Plans (Auckland Regional Water Board 1987, 1989). In preparation of those publications ARC staff carried out geological investigations in the area including field mapping, core sampling boreholes, downhole geophysical logging and air photograph interpretation.

One of the recommendations for further work in the 1989 Management Plan was for more detailed lithological and structural mapping to be carried out to relate rock permeability to both sediment type and rock deformation. This was to be carried out as part of a thesis being planned for 1990, by a student at Auckland University Geology Department.

The thesis, (Davidson, 1990), agreed with other work on Waitemata Group rocks, that aquifers are lithologically rather than structurally controlled. Within the extensive early Miocene age (18-23 Million years old) Waitemata Group rock aquifer it was concluded that the aquifer was hydraulically inhomogeneous, with groundwater preferentially moving along discrete rock layers of higher permeability. Structural data could be interpreted to show localised areas of steeply dipping rock layers, but not to concur with this assumption being valid over the entire Study Area. Core samples from recent bores drilled in the centre of the Study Area showed near horizontal layering of the rock beds throughout the hole depth.

Since the publication of the last Management Plan, geological maps covering the Study Area have been published by the New Zealand Geological Survey (Schofield, 1989 and Kermode, 1992). These maps are at a scale of 1:50,000 and include sheets Q10, R10 and R11. Sheet Q11 (Hayward, 1983) was published previously. Geological work for this study was limited to updating previous investigations with data from the new published 1:50,000 geological maps.

2.2 Geological Setting

The Kumeu Groundwater area is underlain by a sequence of Miocene aged rocks comprising predominantly interbedded sandstones and mudstones of the Waitemata and Waitakere Groups. In low-lying areas the Waitemata Group rocks are overlain by alluvial sediments of the Tauranga Group. These comprise erosion products of the basement rocks as well as peats and stream deposits. The main aquifer in the study is located in the Waitemata Group rocks. The generalised geology of the Study Area is shown on Figure 2.1.

The geology of the Study Area is dominated by a massive sequence of Miocene aged, alternating sandstones and mudstones of the East Coast Bays Formation (Waitemata Group). Overlying these rocks in the west of the area are grits, sandstones and siltstones of the Cornwallis Formation (Waitemata Group in Kermode (1992), previously in Waitakere Group).

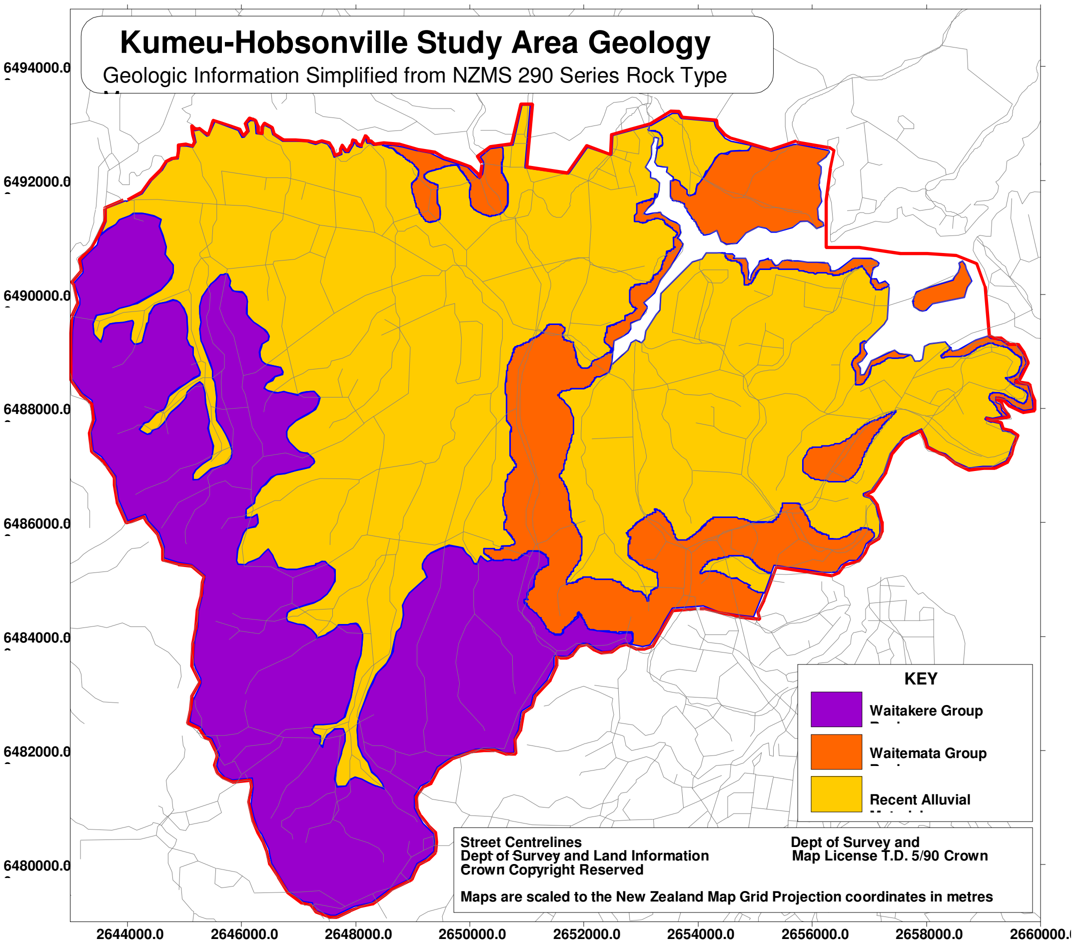

Figure 2.1: Simplified Geological Map of the Study Area

Distinctive thick conglomerate beds (Albany Conglomerate) occur within the Waitemata Group, forming the high ground north of Riverhead. A number of coarse sandstone and grit beds have been identified in the Riverhead and North Kumeu areas. These are similar to beds found elsewhere in the Waitemata Group. However, Parnell grit type beds, as identified for example, in the Orewa aquifer do not appear to be present in the Study Area.

In low-lying areas the basement rocks are overlain by alluvial sediments of the Tauranga Group (Kermode, 1992) and are up to 65 metres thick. These sediments were locally derived and were eroded and deposited during alternating high and low sea levels of the Pleistocene period (0.1-1.8 Million years), resulting in a series of terrace deposits, infilling valleys previously formed by erosion. Stream and swamp deposits (peats) accumulated in the last 10,000 years (the Holocene period) to form the features we see today.

Basic structural geological information is available in the form of dip and strike data on the published geological maps. The dip is the angle from horizontal that the rock layers, known as "beds" lie. The strike is the compass orientation of a line, which is horizontal to a plane, which a particular bed occurs. In general terms, over the southern portion of the Study Area dips are shallow (flat lying) often less than 5°. In the Riverhead Hobsonville area the Waitemata Group rocks dip to the south or southwest at an average of 15°. However the high standing Albany Conglomerates and associated rocks have been mapped at dips exceeding 40°. This explains the steeper, higher topography to the north of Riverhead only in part. High ground is also caused by the Albany Conglomerate, which is considerably harder and resistant to weathering.

The distribution of dips and strikes are a result of faulting and folding during uplift of the Waitemata Group rocks. No major faults have been mapped in the Study Area. However, a number of bedding parallel thrusts have been inferred from previous work.

Deformation of the Waitemata Group rocks during uplift cause the rocks to be broken, sheared, folded and jointed. In general the Waitemata Group rocks are not extensively deformed and do not have a large number of joints or fractures through which groundwater can flow. The distribution of fractures is random although a greater distribution often occurs in thick sandstone sequences and near ground surface (30-50m depth). Open joints near the ground surface are caused by stress release in the rock mass. At greater depths joints are often tightly closed or in-filled with clay, silica or calcium carbonate, and do not allow much groundwater flow.

3. HYDROLOGY

3.1 Further Work Completed

The hydrology of the area has been discussed in the previous Management Plans (ARWB 1987, 1989). In preparation of those publications ARC staff carried out geological investigations in the area including collation of data relating to bore yields and aquifer parameters, pump testing of bores belonging to ARC, downhole flow metering, contouring water level data and analysis of water level fluctuations in regularly monitored bores.

Recommendations for further work in the 1989 Management Plan were for the determination of permeability distributions and flow paths in the Riverhead area by core sampling, packer testing and further pump testing. For the pump testing it was recommended that a further water level observation bore be drilled at the Lathrope Road site in Zone 1a. The additional observation bore at Lathrope Road was drilled and the pump test completed by the end of 1992. Packer testing and core sampling for permeability were not carried out as planned. Pump testing indicated a transmissivity between 12.1 m^2/day and 20.2m^2/day that is above the average for the Kumeu basin of 2 m^2/day. Testing also indicated that the Lathrope Road area is at least partially confined by the overlying Pleistocene age sediments present at the surface and possibly by interbedded mudstones in the lithological sequence.

3.2 Aquifer Parameters

The permeability of the Miocene age Waitemata Group rocks of the area is comparatively low, with transmissivity averaging 2 m^2/day. Testing rock cores taken from bores has shown that actual permeability can range from 7.8x10^3 m/day in weakly cemented fractured sandstone down to 4.5x10^{-5} m/day in mudstones and muddy fine grained sandstones. Downhole flow logging and bore log interpretation indicates that the entire saturated rock mass does not contribute water to the borehole. Rather the significant water flows are from discrete, poorly cemented layers of porous sandstone and grit, as well as from fractured horizons within the rock. Groundwater flow is thought to be predominantly in the plane of these beds or fracture zones. Local geological structure and sedimentology are therefore likely to determine groundwater flow paths.

Because the aquifer is thick, in excess of 300 metres, a large volume of water is stored in the rocks. However, the low permeability of the rocks limits the yield for individual boreholes. Bore yields are commonly a few hundred cubic metres per day with the best yields from bores between 150 and 300 metres deep. Drawdowns in the water level in a bore during pumping can be large. The size of drawdown increases in localised areas, where the Miocene age Waitemata Group rocks have lower permeability e.g.: ARC bore at Lathrope Rd experienced 25 metres of drawdown when pumped at 250 cubic metres per day (cmpd or m^3/day) while the ARC bore at Taupaki Road experienced in excess of 90 metres drawdown when pumped at only 30 cmpd. These drawdown effects due to pumping are usually limited to a few hundred metres radially from a particular production bore and drawdowns decrease rapidly with distance from the production bore.

Given the postulated horizontal bedding of the rock and the presence of many layers of low permeability material, recharge would be expected to occur remote from a borehole, possibly in areas of surface exposure of the strata or significant fault zones. Likely areas of surface exposure would be the hills that flank the Study Area to the north and to the south. Steeply dipping rock beds have been noted in the hills north of Riverhead. The presence of large areas of variable permeability alluvial material overlying much of the Study Area would also indicate remote recharge zones. Storativity has been calculated for only two sites in the Study Area and indicate leaky confined conditions. Leakage could infer that additional recharge is occurring vertically.

3.3 Investigation Drilling

Investigation drilling in Kumeu since 1989 has been limited to two sites. An additional monitoring bore was drilled at Lathrope Road in 1992, to aid in interpreting the pump test discussed above. This 100mm diameter bore was drilled 40 metres away from the pumped well and to a depth of 251 metres. It encountered rock material very similar to that found in the main Lathrope Road bore. Two bores were drilled at Waitakere Road, between Boord Crescent and Farrand Road in 1994, with a view to future recharge investigations. One 100mm bore was drilled to 150 metres depth, intersecting a zone of sandstone containing gravel. A multiple level monitoring bore was installed about 25 metres away. It contains four smaller diameter bores, which monitor at depths of 15, 30, 45 and 60 metres.

3.4 Water Level Monitoring

Water levels have been routinely measured for bores in the Study Area since the 1989 Management Plan. Data has been collected regularly from ARC bores and at the beginning and end of irrigation seasons from a cross section of privately owned bores.

3.4.1 ARC's Bores

Seven ARC bores at four sites, Lathrope Road, Selaks, Hort+Research and Taupaki Road, have water levels monitored continuously. An additional five bores at individual locations are manually monitored on a monthly basis. Site locations of the bores are given on Figure 3.1. Plots of the water level records for these sites are presented in Figures 3.2 to 3.7. These sites have been located to indicate both background trends in water levels, as well as specific responses to use in areas of high water demand.

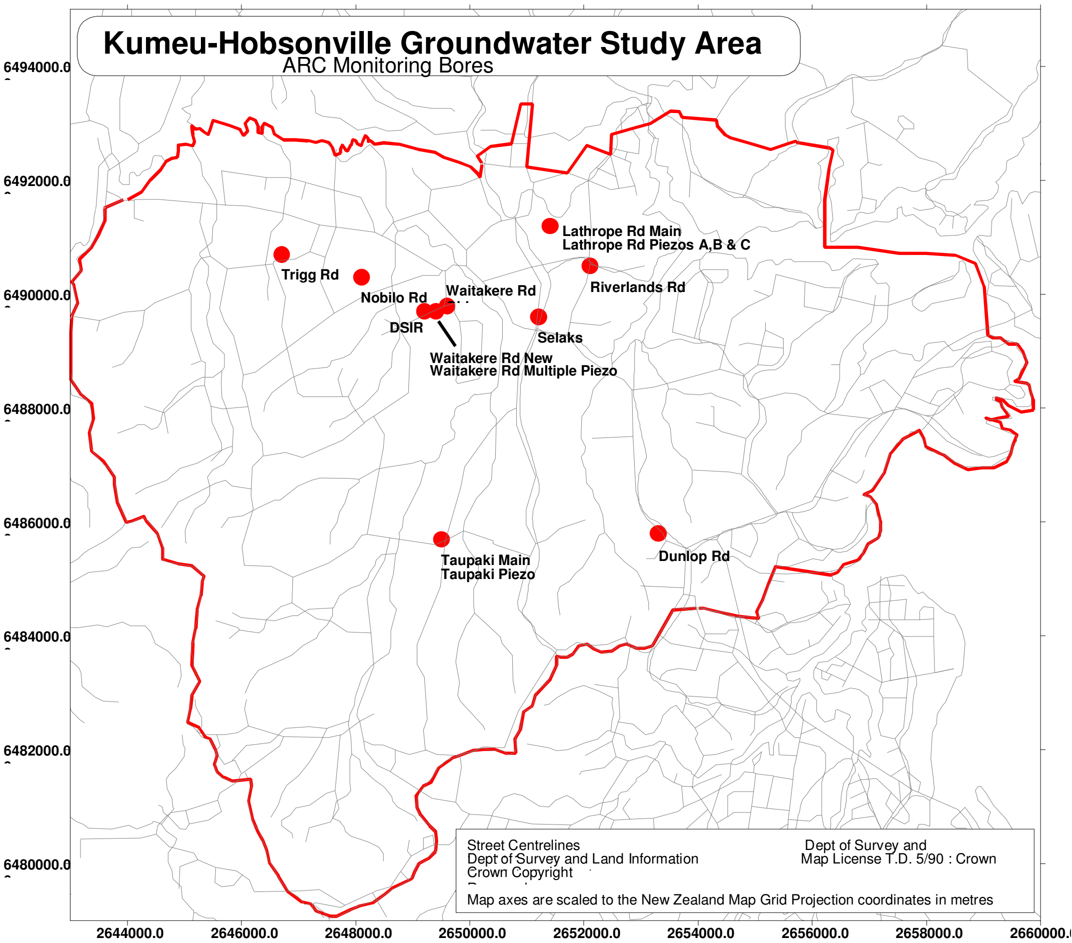

Figure 3.1: Map indicating the location of ARC's Monitoring Bores

As discussed in previous Management Plans, recharge to aquifer systems occurs only when there is a surplus of effective rainfall. Effective rainfall is that which remains in the soil once evapotranspiration and runoff have occurred. During the spring and summer seasons in the location of the Study Area, evapotranspiration exceeds rainfall inputs, reducing effective rainfall to zero, except during intense localised rainfall events. Winter recharge is shown occurring at all ARC monitoring bore sites.

Additional recharge occurs in some aquifer systems from interactions with surface water systems. Such recharge happens where water from a river penetrates into an aquifer through the river bed. Measurements of specific discharge along a river system, can indicate whether there are any segments of the river which are losing, or gaining significant volumes of water. No obvious water losses from the river were noted in a comprehensive survey of water flows in the Kaipara River, which drains the western part of the Study Area. The survey, done as part of the ARWB Kaipara River Freshwater Resource Report and Interim Management Plan 1984, also suggests that shallow groundwater feeds surface springs at the heads of catchments, while on the river flats little additional water is added to surface flow from groundwater during summer periods.

ARC's monitoring bores are used as the basis of information on groundwater level fluctuations in the Study Area. These bores are of known depth and construction, and are not used for water abstraction. Bore details are given in Table 3.1.

Table 3.1: ARC monitoring bores within the Study Area

Location	Recorder	Depth of Casing (m)	Depth (m)
DSIR	Automatic	27	90
Selaks	Automatic	101	299.1
Dunlop Road	Manual	71.3	252.85
Nobilo Road	Manual	71.2	251.3
Waitakere Road	Manual	15.04	15.04
Waitakere Main	Manual	150	78
Waitakere Multi	Manual	15/30/45/60	-
Trigg Road	Manual	71.2	248.33
Riverlands Road	Manual	29.65	29.65
Lathrope Road Main	Automatic	71.2	248.3
Lathrope Road Piezo A	Automatic	14.9	14.9
Lathrope Road Piezo B	Automatic	56.07	56.07
Lathrope Road Piezo C	Manual	71.6	251.5
Taupaki Main	Automatic	71.3	251.24
Taupaki Piezo	Automatic	54.5	54.5

Note: Piezo denotes a water level observation bore

The DSIR recorder site (now Hort+Research) has the longest continuous record available for groundwater levels in the Study Area (Figure 3.2). Records at this site in Waitakere Road go back to February, 1983. The period of the record prior to January 1988, is shown in the previous Management Plan. Water levels at this site fluctuate annually over a range of about 3 metres. Sharp fluctuations in water levels at this site are interpreted as being effects due to pumping. Water levels decline during the summer period at a rate less than that at which the aquifer appears to recharge, the slope of the graph during the winter months being considerably steeper. Since 1988, minimum water levels in the summer have been progressively decreasing by about 40cm each year. This may reflect an increase in total seasonal use by bore users in the vicinity. The drier than average winter during 1993, and the consequent reduction in recharge, may be the cause of the lowering of water levels in 1994 seen in the record at this and other sites.

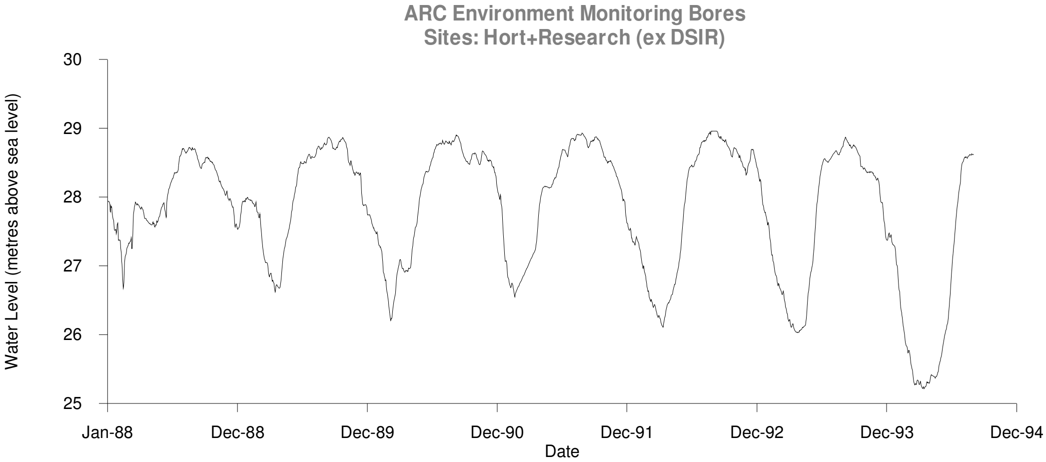

Figure 3.2: Water levels ARC Monitoring Bore - Hort+Research

At the Selaks site in Old North Road, Kumeu, the record shown in Figure 3.3, beginning in February 1986, shows the reverse phenomenon. Summer water levels have been rising 50cm per year, with the exception of 1994. This may be indicative of localised reductions in seasonal pumping volumes.

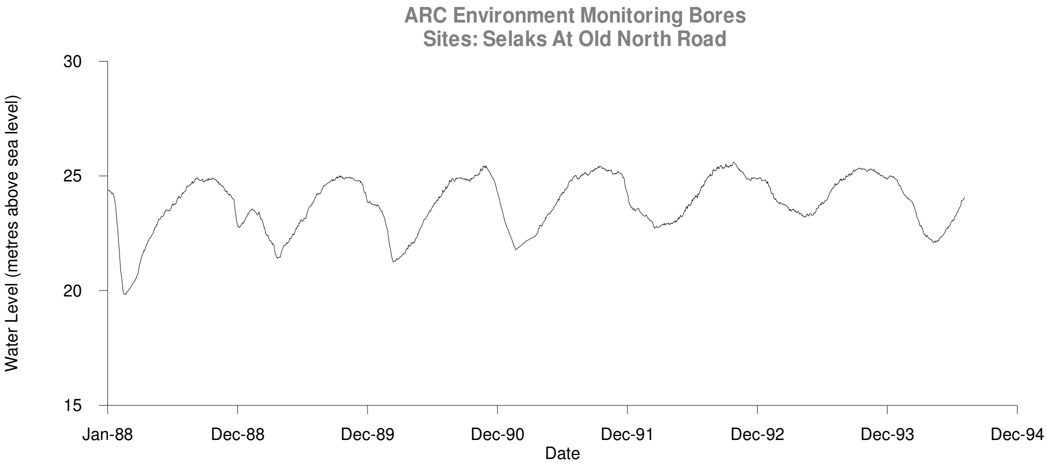

Figure 3.3: Water levels ARC Monitoring Bore - Selaks

Records at four other manually monitored sites show variations on these two themes (Figure 3.4). The Waitakere Road monitoring bore shows a simple seasonal groundwater fluctuation. This is inferred to be due to it being so shallow that it only monitors the aquifer close to the ground surface in recent alluvial material and not the main aquifer. At the Nobilo Road site in Huapai, the seasonal fluctuation is found superimposed on a trend of decreasing groundwater level. The rate of decrease in summer low water levels at Nobilo Road is about 35cm each year. The Riverland Road monitoring bore in Riverhead shows a recovery pattern similar to the Selaks monitoring bore, recovering during summer lows by 3.5 metres between 1989 and 1992. ARC's other Huapai monitoring bore site in Trigg Road also shows a decline as at Nobilo Road. Although the pattern is somewhat erratic it appears to be at a rate of approximately 50 cm per year.

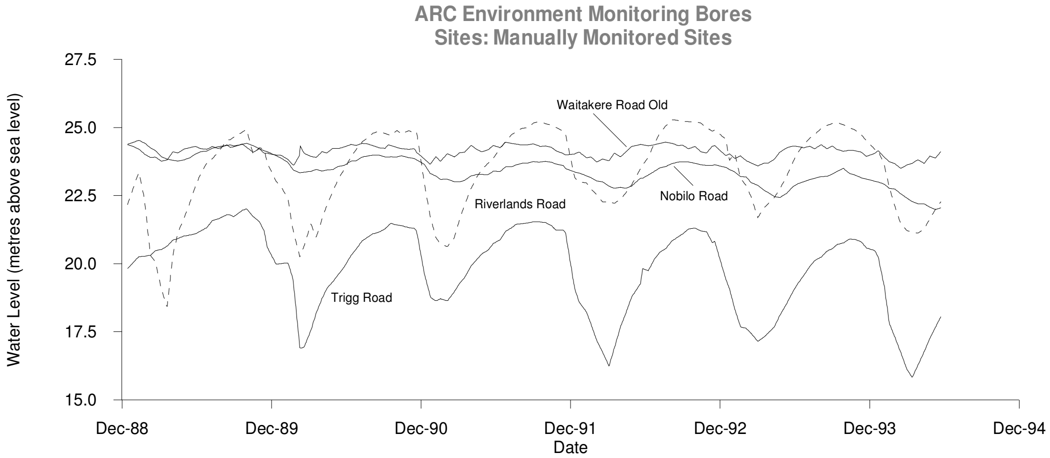

Figure 3.4: Water levels ARC's Monitoring Bores - Manual Monitoring Sites

At the Lathrope Road monitoring bore site (Figure 3.5) the record indicates a relatively stable regime of abstraction with recharge bringing water levels to about the same height each year. The effect of neighbouring users reflects strongly on the Main monitoring bore record, with the sharp decline of January 1991 particularly noticeable. The nearby monitoring bore A reflects the same pattern of groundwater level changes but not the intensity. Comparison of these two records indicates that the aquifer here is stratified with the deeper layers being considered as semi-confined.

The most eastern of ARC's sites in the Study Area is at Dunlop Road in Massey (Figure 3.6). Water level records are collected monthly at this site and until 1993 show a simple and stable summer use, winter recovery pattern. In January 1993 water levels in this bore dropped by 10 metres more than had been anticipated. Recovery during the winter of 1993 was only to previous summer levels with indications of use occurring during this time. Records of levels during the summer of 1994 show groundwater levels at the monitoring bore to have fallen by an additional 3 metres from the previous year. Water use records for the three nearby authorised users indicate no significant increases in water consumed leaving either localised aquifer dewatering or a nearby unauthorised groundwater user as the probable cause.

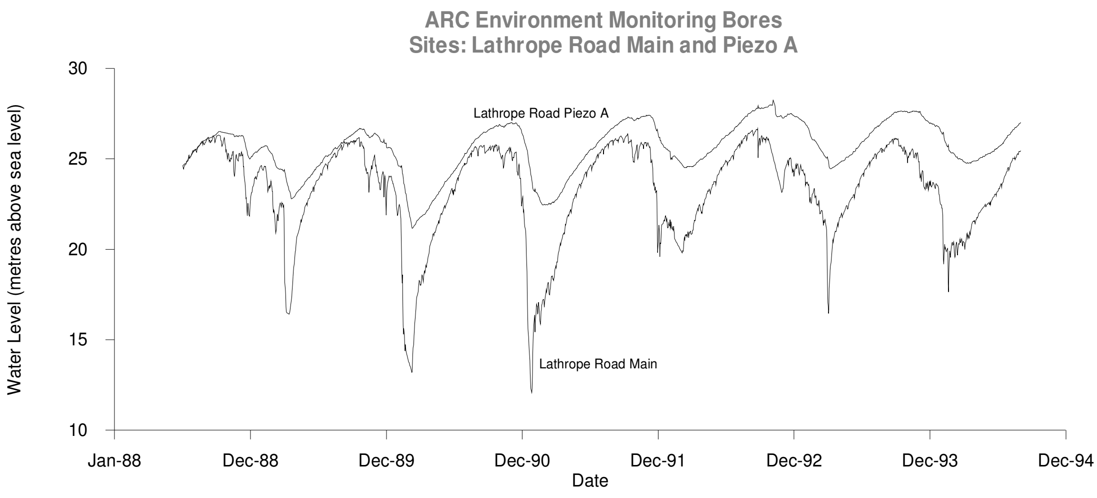

Figure 3.5: Water levels ARC's Monitoring Bores - Lathrope Road

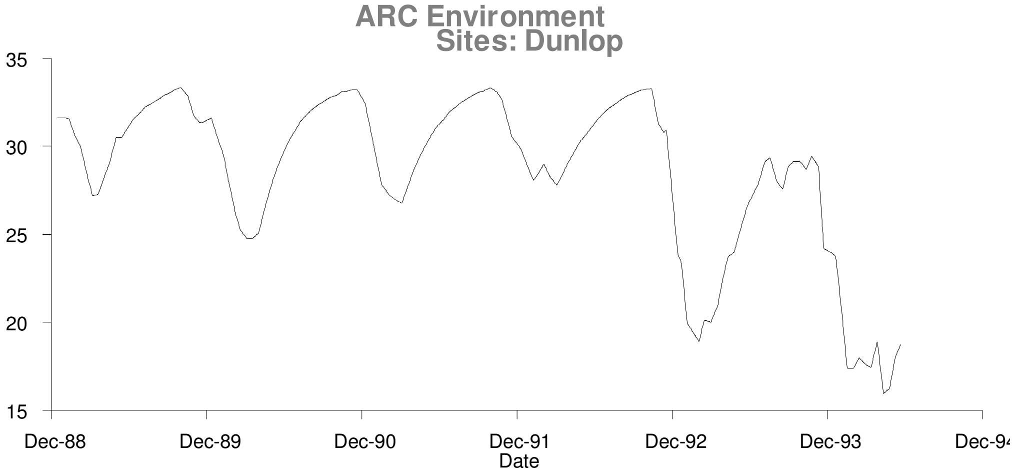

Figure 3.6: Water levels ARC's Monitoring Bore - Dunlop Road

Taupaki has a Main bore and Piezo (water level observation bore) installation near the intersection of Taupaki, Amrien and Nelson Roads (Figure 3.7). The first two years of data for the Main bore show a predictable seasonal water level fluctuation. During the early part of the 1990/1991 summer, significant abstraction occurred close to the monitoring bore. The following summer seasons show a steady decline in water level minimums of around 7 metres per year with water levels falling to below sea level early in 1993. Water levels have recovered to at least 15 metres above sea level in 1992 and 1993. Comparisons of use at the closest permitted bore and water levels gives a correlation of -0.72 when comparing water levels against 70 day lagged monthly water use. The significant drawdown effects at this site are thought to be induced solely by use from the nearby bore.

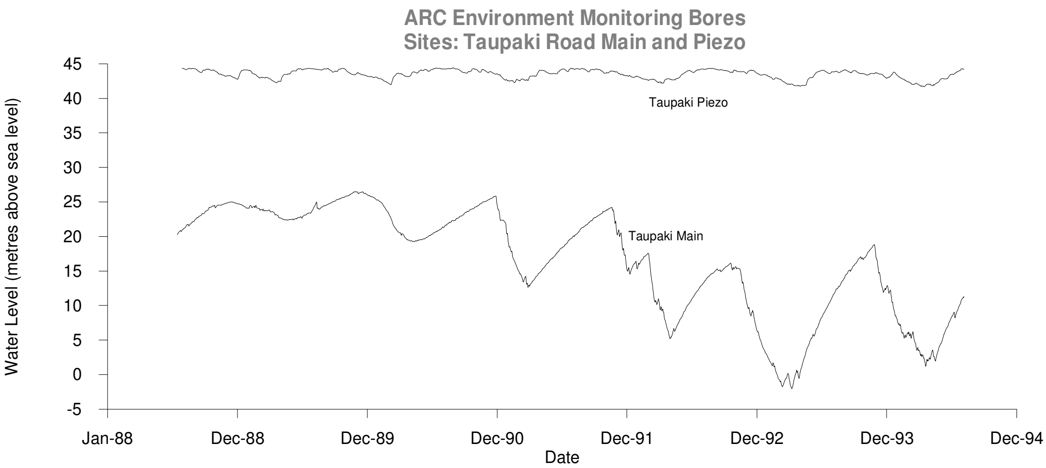

Figure 3.7: Water levels ARC's Monitoring Bores - Taupaki

3.4.2 Privately Owned Bores

Water levels are measured in up to 180 privately owned bores bi-annually of which 34 additional bores have been monitored at monthly intervals since 1992 increasing to fortnightly during the irrigation season. These records enable localised effects of pumping in the various areas to be detected in addition to regional groundwater level changes. Data collected from these privately owned sites is less reliable than that from ARC's bores. For most of these privately owned bores there is only limited information available on the construction, depth and rock formations penetrated. Details of construction for many of these are found in the 1989 Management Plan. Additionally the majority of bores in private ownership are utilised for water supply that can limit the reliability of data. These bores may have been subject to pumping prior to measuring that would give anomalously low water level readings.

The majority of privately owned bores for which water level information is collected are those that have a resource consent to take water. Where bores were in use during reading no data is available. A small number are bores which are either unused or have minimal draw-off for stock and domestic purposes. Water level data for the 34 regularly monitored bores with a reasonably continuous record and no significant pumping events are presented in Figures 3.8 to 3.12. Plots are presented overlaid with the nearest ARC monitoring bore data for the same period.

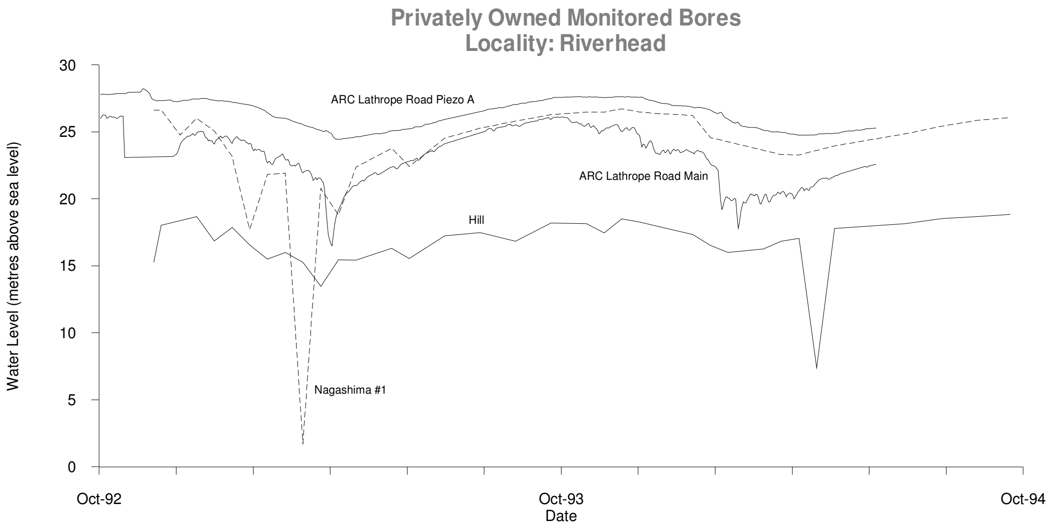

Figure 3.8: Water levels in Privately Owned Bores - Riverhead

In the Riverhead area the records for Hill and the Nagashima #1 bores (Figure 3.8) show a similar pattern to the Lathrope Road Main and Piezo (water level observation bore) A bores. The deep trough in March 1993 on the Nagashima #1 record, and the less pronounced trough in April 1994 of the Hill record, are thought to be due to pumping effects. The data indicates a seasonal fluctuation of water levels in response to rainfall and use.

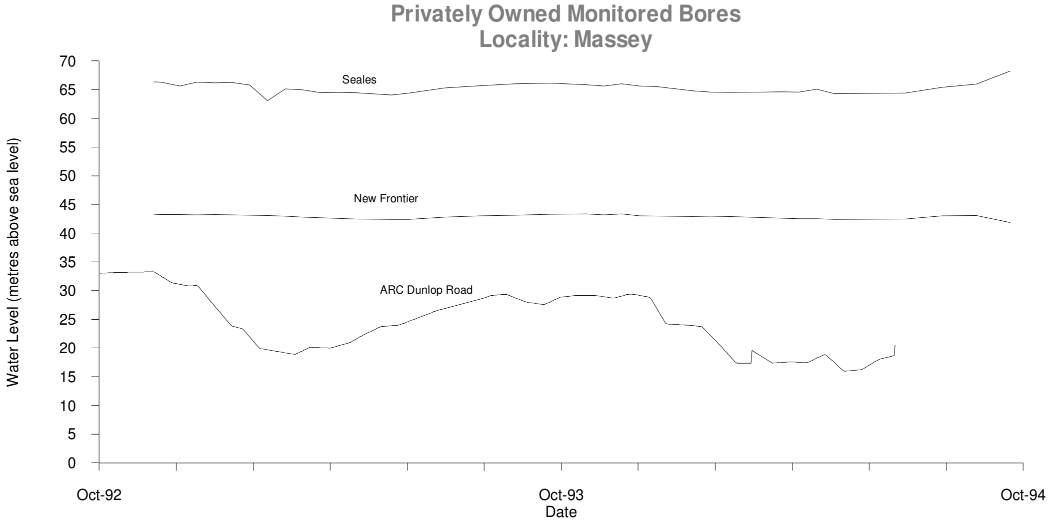

Figure 3.9: Water levels in Privately Owned Bores - Massey

Records from the bores in the Massey area suggest that effects are being detected at the ARC bore at Dunlop Road which are not noticeable at other bores in the area (Figure 3.9). This may be due to pumping from a nearby bore, which ARC is unaware of. None of the authorised users nearby have significantly increased pumping in the previous two years, which would account for this change. Both the Seales and New Frontier bores show very little seasonal variation in water levels.

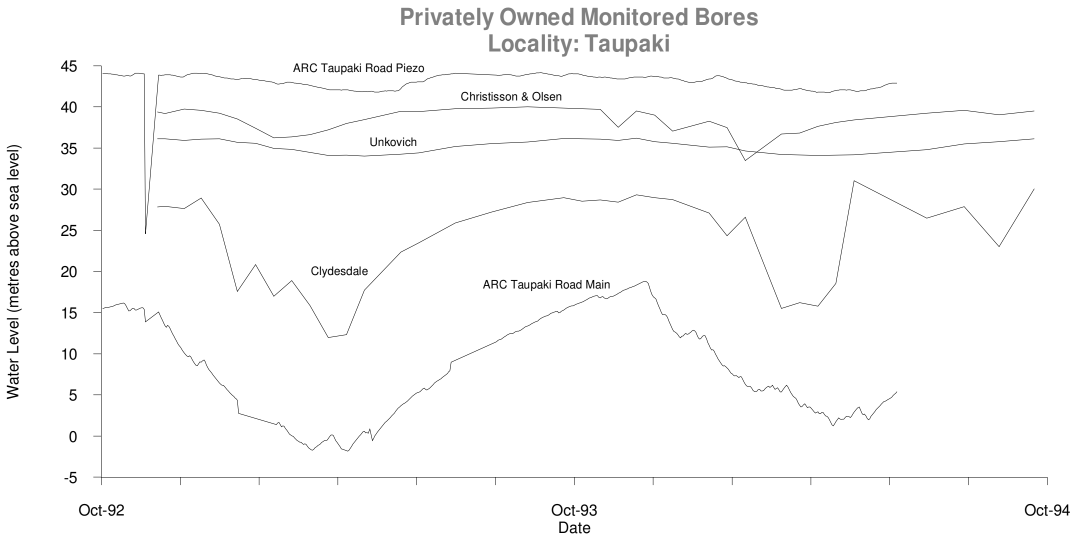

Figure 3.10: Water levels in Privately Owned Bores - Taupaki

The Taupaki area (Figure 3.10) has been a concern to ARC because of the large number of groundwater users concentrated in an area where the aquifer has low yields. Consequently large water level drawdowns occur. Water level records for three groundwater users in the area show that water levels follow the seasonal fluctuations due to pumping as measured in the two ARC bores on Taupaki Road. The Unkovich and Christison and Olsen bores both show a minor seasonal fluctuation of water level similar to the Taupaki Piezo. The Clydesdale bore shows a pattern more like that of the Taupaki Main bore that may indicate the effects of a nearby pumping bore.

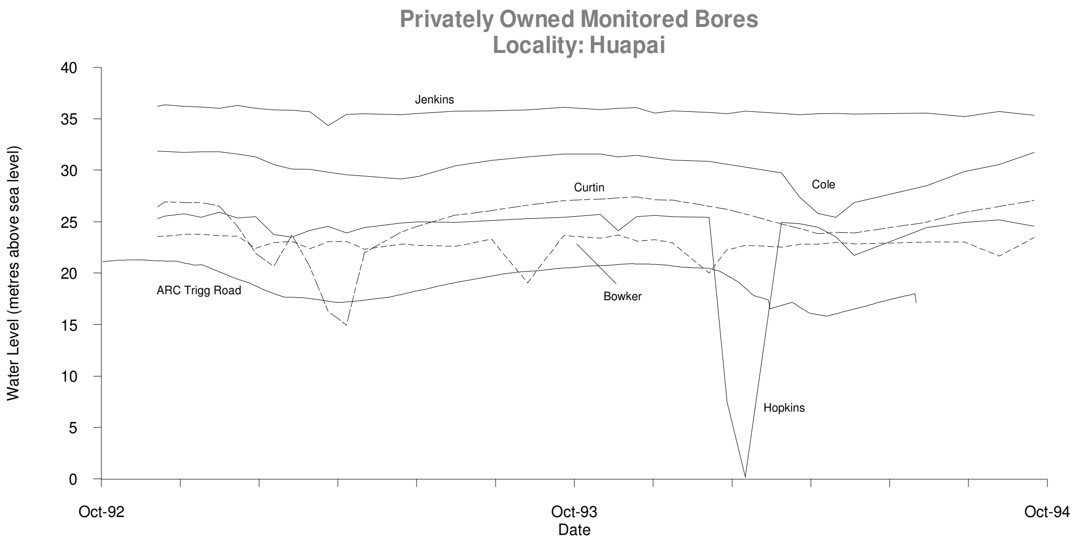

Figure 3.11: Water levels in Privately Owned Bores – Huapai

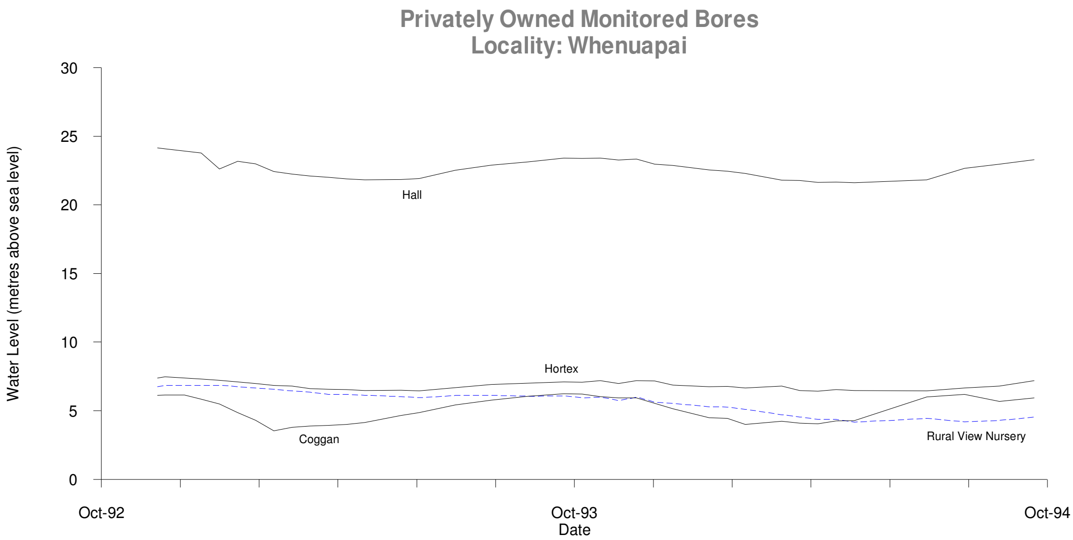

Figure 3.12: Water levels in Privately Owned Bores – Whenuapai

At Huapai the water level records for manually monitored bores show a seasonal fluctuation similar to the pattern in ARC's Trigg Road bore (Figure 3.11). Even though there are variations in construction between these bores, water levels show similar response to pumping in the area. The deep troughs in the Hopkins bore during measurements in January and February 1994 are likely to be due to recent pumping of this bore.

In the Whenuapai area there is no reference ARC bore (Figure 3.12). However, the four bores in that area show a simple seasonal fluctuation in water levels and little or no influence of pumping upon each other.

No significant trends in water level fluctuations other than seasonal troughs and peaks and the effects of localised pumping have been noted from these manually monitored records.

3.5 Conceptual Model of the Groundwater System

The conceptual model for the groundwater system has altered from that proposed in the 1989 Management Plan. Consideration has been given to the concept of steeply dipping strata throughout the Study Area that would suggest recharge is a relatively localised phenomenon, occurring within one kilometre of the bore site. This was proposed on the basis of some of the surface exposures of Miocene age Waitemata Group rocks that have a dip averaging 15°. However, in areas where a significant cover of younger Pleistocene age sediments overlies the Waitemata Group rocks, the recharge and consequent water availability would be expected to be lower than in areas where surface exposures were common. Recharge to the Miocene age rocks in areas which are not exposed would be expected to occur by leakage from the overlying material and significant lateral movement of water from areas where surface exposures do occur.

A more suitable conceptual model tends towards that proposed initially in the 1987 Management Plan, with horizontal or shallowly dipping strata across much of the Study Area and areas of Pleistocene age sediment cover. Shallow dips are down towards the west and south of the Study Area with steeper dips into the Study Area from the north and north-east. A conceptual model of this form suggests the following:

- Recharge occurring remote from most abstraction points, with predominant recharge from surface exposed Miocene age rocks to the north, northeast and southeast.
- Significant flows within discrete porous beds in Waitemata Group rocks and minor flows between beds and a small amount of leakage from overlying Pleistocene age sediments.
- Local groundwater levels being influenced primarily by topography except in areas of high groundwater abstraction.
- Effects of drawdown on neighbouring bores influenced by bore and casing depths and orientation between bores with respect to strata dip.

4. WATER CHEMISTRY

4.1 Chemical Composition Types

Studies of the chemistry of groundwater from Waitemata Group sandstone aquifers elsewhere in the Auckland region show that this groundwater tends towards either of two composition types. Previous work (ARWB 1987a, 1987b, and 1989), and ongoing monitoring has confirmed this in the Kumeu study area also.

The two composition types are delineated primarily on the ratio of total hardness/total alkalinity (THTA) but also on pH, silica and total iron concentrations.

Total hardness is a measure of total concentration of calcium and magnesium while total alkalinity is a measure of the total concentration of carbonate and bicarbonate anions.

Waters with a low THTA ratio are soft sodium bicarbonate waters with pH greater than 8.5, low silica concentrations (< 25 g/m^3) and low total iron concentrations (< 0.2 g/m^3). This water is almost exclusively from bores 150-350m deep. Waters with a high THTA ratio (> 0.70) are hard calcium/magnesium bicarbonate waters with near neutral pH, high silica concentrations (> 40 g/m^3) and commonly high total iron concentrations (> 1.0 g/m^3). This latter water type is produced from shallower bores with depths in the range 100-250m.

Bore depth is not the sole determiner of the water type produced by a particular bore. It has been found elsewhere in the region that deep bores with shallow casing may yield high THTA type water. Deep bores with deep casing may still produce high THTA water if the annulus around the casing has not been grouted, allowing shallow high THTA water to leak down the outside of the casing into the open bore hole and be abstracted.

4.2 Evolution of Chemical Character

The development of chemical character of the two composition types can be explained by simple chemical processes. Shallow groundwater, high in dissolved carbon dioxide, flowing through shallow weathered rocks dissolves calcareous and silicate minerals producing high THTA water. The iron is derived from shallow weathered sandstone strata.

With longer residence time and the passage of water through the lithological profile, calcium and magnesium cations, which are the predominant ones present in solution in shallow groundwater, are exchanged for sodium and potassium that are present as cations absorbed on clay minerals. This process increases the sodium concentration and decreases the calcium and magnesium concentration in deeper groundwaters. The change in cations also changes the pH and silica concentrations.

4.3 Water Quality

Both groundwater composition types have potential water quality problems. High THTA ratio water has high total hardness. For domestic use it is more difficult to produce lather from soap and scale may accumulate in vessels where the water is heated. This water type commonly also has high total iron concentrations which for domestic use imparts a bitter taste, and stains laundry and porcelain plumbing fixtures. For horticulture the iron stains fruit and leaves and blocks emitters.

Low THTA ratio water has high sodium concentrations (up to 130 g/m^3 Na). The quality requirements of irrigation water regarding sodium toxicity vary with crops, application rates, drainability of soils, and climate. High sodium concentration may cause a problem with indoor crops e.g. cucumbers. Sodium concentration relative to hardness is expressed as the sodium absorption ratio (SAR). Water with a high SAR may cause deterioration of soil permeability and texture. Ministry of Agriculture and Fisheries, Ruakura state that a concentration of 100 g/m^3 Na should not cause permeability problems for outdoor vine crops.

Boron is an essential plant trace element but is toxic at concentration above 0.5 g/m^3 depending on the crop. It is common in deep Waitemata sandstone aquifers in proximity to geological faults due to upflow of cold geothermal water from basement greywacke rock. Both deep and shallow sandstone water at Kumeu have boron concentrations less than 0.2 g/m^3.

4.4 Further Work

In the ARC study of the Karaka-Waiau Pa Waitemata sandstone aquifer (ARC 1993 page 26-28) it was found that groundwater chemistry allowed bore water levels to be assigned to "upper" high THTA ratio aquifer and "lower" low THTA ratio aquifer so that coherent water level contours could be constructed. It has been shown elsewhere in this report that water levels vary markedly with bore depth.

Analysis of water for total hardness and total alkalinity from all bores that have been monitored for static water level would enable bores to be separated into "shallow" and "deep" aquifers. This may allow more coherent water level contours to be constructed.

5. MONITORING AQUIFER USE / WATER LEVELS

5.1 1989 Management Plan and Allocations

The 1989 Management Plan specified allocation limitations for every authorised user in the Study Area. These limitations were specified for individual types of water users and divided into three classes relating to the different intensity of use. Zone areas and allocations as a percentage of the total Study Area are shown in Figures 5.1 and 5.2.

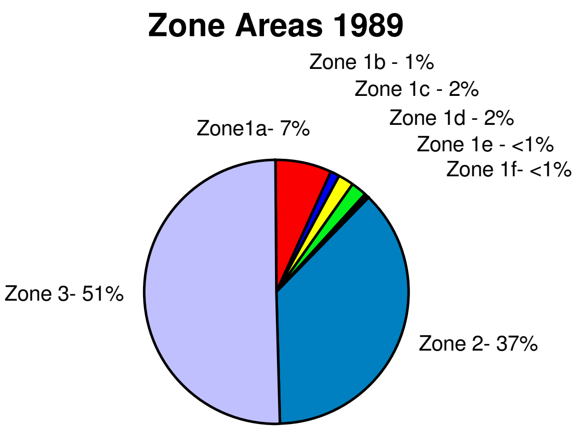

Figure 5.1: Zone areas as percentage of the Study Area

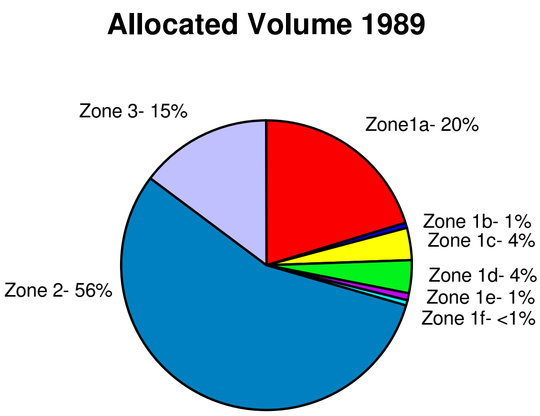

Figure 5.2: Volume allocated to each Zone as percentage of total

Areas classified as Zone 1, such as parts of Riverhead, Taupaki, Huapai and Hobsonville, were considered to have been previously over allocated, that is where allocation exceeds the estimated recharge of 13,870 cubic metres per year per square kilometre. It was decided that a restriction of annual water use was required to prevent the local decline of the resource and that further development would be discouraged unless alternative water supplies could be obtained. Replacement resource consents were issued with no increase to their peak daily allocation and all other applications declined or deferred.

Those areas classified as Zone 2, which includes most of the Kumeu River basin, Huapai and Whenuapai, were thought to be fully allocated and that peak daily pumping at current rates was sustainable. Further development was to be discouraged pending more accurate water availability calculations.

In Waitakere and the hills surrounding Kumeu and Huapai, classified as Zone 3, groundwater use was low and it was considered that abstractions were unlikely to affect bores in Zones 1 and 2. New resource consents would be allowed provided neighbouring users were considered and that annual allocations per square kilometre did not exceed the calculated maximum recharge for the square kilometre surrounding that bore.

For the entire Study Area a total of 1,271,179 cubic metres per year (cmpa) of groundwater were allocated to 272 permit holders since 1988. The maximum daily allocation was 18,624 cubic metres. The Study Area totals 129.97 square kilometres. The specific allocation (allocated volume divided by area to give allocation per square kilometre) for the Study Area is 9,781 cmpa per square kilometre, only 70.5% of the estimated recharge and maximum allocation level of 13,870 cmpa per square kilometre calculated for the 1989 Management Plan (page 64).

5.1.1 Zone 1

For the six areas classified as Zone 1 a total volume of 372,821 cmpa (29.3% of the total allocated volume) of groundwater was allocated to 134 permit holders ranging in allocated volume between 150 and 30,000 cmpa with an average of 2,782 cmpa. The total area classified as Zone 1 is 16.29 square kilometres and this works out to a specific allocation of 22,886 cmpa per square kilometre. This figure is 1.65 times greater than the estimated recharge.

In Zone 1a, Riverhead, the allocation totalled 256,220 cmpa (20.2 % of the total allocated volume) spread across 83 permit holders. These 83 permit holders ranged in allocated volumes between 180 and 30,000 cmpa with an average volume of 3,087 cmpa. Zone 1a is the largest of the Zone 1 classified areas at 8.96 square kilometres and has a specific allocation of 28,596 cmpa per square kilometre. This is more than two times the recommended maximum allocation per square kilometre of 13,870 cmpa.

Zone 1b, which comprises the Hobsonville peninsula excluding the aerodrome, was allocated 6,900 cmpa (0.6 % of the total allocated volume) to three permit holders of 1,200, 2,700 and 3,000 cmpa. With an area of 1.62 square kilometres this gives a specific allocation of 4,259 cmpa per square kilometres, or only 31% of the estimated recharge over that area.

The Taupaki area, Zone 1c, was allocated 46,040 cmpa (3.6% of the total allocated volume) in 1989. This volume was given to 15 permit holders averaging 3,069 cmpa and ranging between 720 and 16,250 cmpa. Zone 1c comprises an area of 2.3 square kilometres giving a specific allocation of 20,017 cmpa per square kilometre. This exceeds the estimated recharge for an area of this size by 1.44 times.

Zone 1d, which covers an area of 2.53 square kilometres bounded by Waitakere, Tawa and Pomona Roads, is the second largest of the Zone 1 areas. The 24 permit holders of the area were allocated 48,061 cmpa (3. 8% of the total allocated volume) by the 1989 Management Plan. These allocations range from 150 to 9,000 cmpa with an average of 2,003 cmpa. In this zone specific allocation is 18,996 cmpa per square kilometre, 1.37 times greater than the recharge to that area.

The area stated as Zone 1e is in the southern part of the catchment just north of Waitakere township. Covering only half a square kilometre it has 9,750 cmpa (0.8 % of the total allocated volume) allocated to 4 permit holders ranging between 200 cmpa and 4,500 cmpa. Specific allocation for this area is 19,500 cmpa per square kilometre or 1.41 times greater than the estimated recharge for an area of this size.

Zone 1f at the corner of Greens and Koraha Roads, Kumeu, is the smallest of the areas classified as Zone 1. Allocation of 5,850 cmpa (0.5 % of the total allocated volume) was made to this area for 5 permit holders ranging from 300 to 2,400 cmpa and averaging 1,170 cmpa. Covering only 0.38 square kilometres this area has a specific allocation of 15,395 cmpa which is 11% higher than the estimated recharge for this area.

5.1.2 Zone 2

Zone 2 comprises the majority of the subdued topography of the basin with the exclusion of the Zone 1 areas, the Whenuapai aerodrome and settlement and the small area east of Barrett Road near Paremoremo. This zone covers a total area of 47.81 square kilometres. 107 permit holders within Zone 2 were allocated a total of 710,118 cmpa (55.9 % of the total allocated volume) in the 1989 Management Plan. These allocations ranged from 240 to 54,900 cmpa with an average size of 6,515 cmpa, 2.3 times greater than the average for Zone 1. Specific allocation for the entire zone is 14,853 cmpa per square kilometre, 7% greater than estimated recharge for the area.

5.1.3 Zone 3

The remainder of the Study Area is comprised of the Waitakere ranges eastern flank as far as Swanson, the upper Ngongetepara catchment, Whenuapai aerodrome and settlement and the small area east of Barrett Road near Paremoremo. This area totals some 65.87 square kilometres of predominantly steep or urbanised land. Only 29 permit holders are located in this zone and have been allocated 188,240 cmpa (14.8% of the total allocated volume) of the groundwater resource. With permitted allocations ranging from 240 to 14,960 cmpa with an average of 6,000 cmpa this are has a specific allocation of only 2,858 cmpa per square kilometre. This figure indicates only 21% of the recharge of 13,870 cmpa per square kilometre to this area being allocated to these users.

5.2 Use

Actual use by permit holders has varied from the anticipated use specified by their applications to take water. As most water allocated by permit is used for horticultural enterprises which use water dependent on crop needs and climate this is not unexpected. Data for this discussion has been collated from the water meter reading data submitted to ARC by permit holders since permits were issued. The term "water year" refers to the year between 1 June and 31 May of the following year, while the term "year" means a calendar year. Water use data received is of varying quality ranging from daily meter readings through intermittent readings to no data at all. No estimate has been made of the quantity of water abstracted for domestic use and stock watering purposes.

Data on water use that has been received indicates a number of trends in water usage in the Study Area. The validity of these trends is limited by the scope and quality of the data received. ARC remains uncertain as to the actual total quantity of water used in the Study Area and so this discussion assumes that the records received reflect actual use by the majority of those holding water permits.

Figure 5.3 shows the relationship between water use returns received, the proportion of the allocated volume these returns represent and the actual use of water from returns for all Zones for the period 1988 to 1993. For the water years 1987/88 to 1992/93 an average of 51% of permit holders representing those holding 61% of the allocated water volume returned water use information in any one water year. The 51% of returns received is calculated from the total number of months for which returns have been received from the total number of permit holders and does not imply that 49% of permit holders did not furnish returns. Gaps in the record of returns can be attributed to loss of the data sheets held by permit holders or periods where permits were not being exercised as occurs during winter and often when properties are sold.

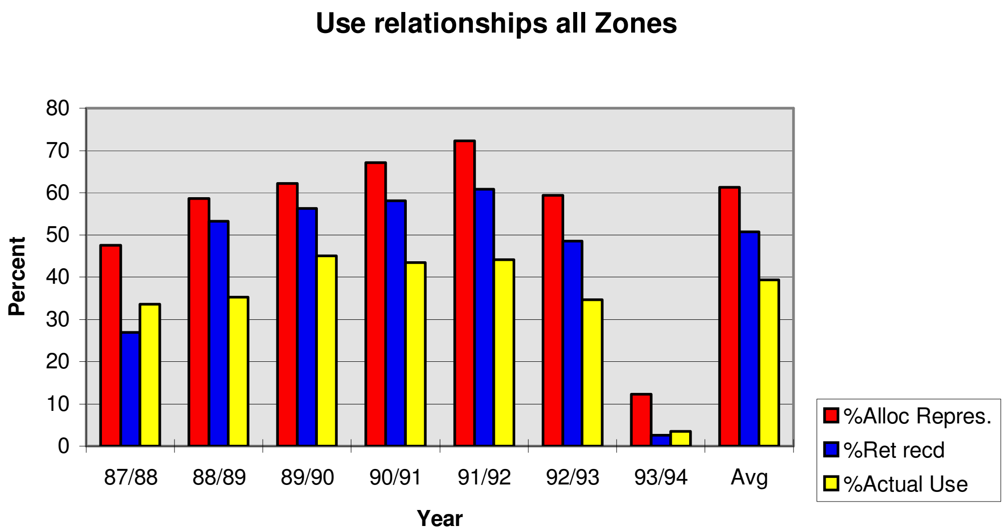

Figure 5.3: Average use relationships

Water use returns showed 39% of the allocated volume of water had been used in this time period. This relationship between water use returns, the allocated volume they represent and the actual water used for the Study Area is similar for each water year in the period of record, influenced by the records for Zone 2 which has the largest share of the total allocatable volume. Records show very few permit holders, 38 out of 272, have provided water use returns for all years between 1987 and 1993. For all of the zones the total number of returns received has varied between 27% in 1987/88 (representing those holding 48% of allocated volumes) and 61% in 1991/92 (representing those holding 72% of allocated volumes). Water use information for 1994 is almost non-existent with few permit holders submitting records, less than 5% of returns received at time of writing.

Recorded use over the period 1987 to 1993 averages 39% (437,000 cmpa) of the total allocated volume with the peak of 45% (505,000 cmpa) in 1989/90. The lower apparent use in 1993 is thought to be the result of the scarcity of water use data. This has meant an average of 61% or 684,000 cubic metres of allocated water was unused each year over the term of the permits.

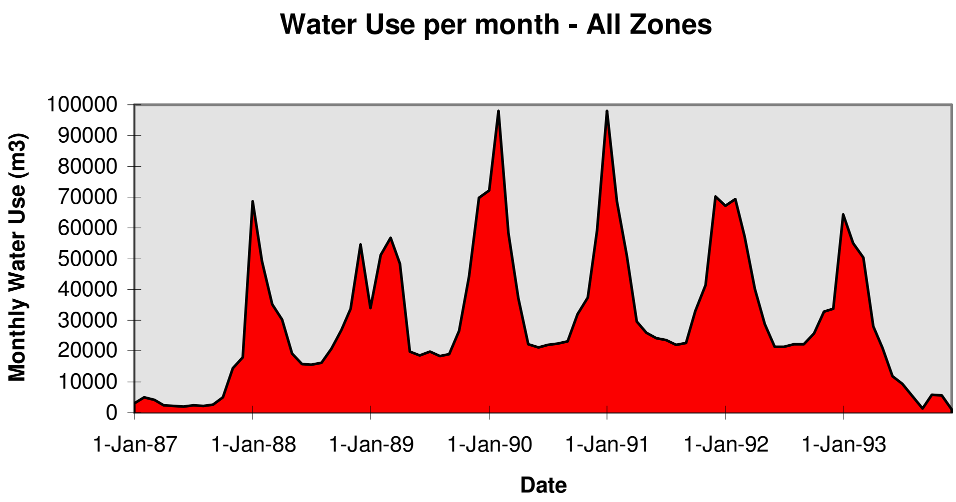

Figure 5.4: Actual monthly water use for entire Study Area

Actual monthly water use summaries for the whole Study Area (Figure 5.4) show a base use of about 17,684 cubic metres per month (cmpm) throughout the year with an additional summer monthly use averaging 30,572 cubic metres, but at peak times up to 80,313 cubic metres, superimposed on this. From 1988 to 1992 the winter monthly average water use (May to October) rose from 19,026 cmpm to 23,567 cmpm peaking at 25,239 cmpm in 1991. The summer monthly average water use rose over the same period from 35,945 cmpm to 57,561 cmpm peaking in 1989/90 at 63,250 cmpm.

Comparing monthly water use totals for the Study Area with rainfall (see Figure 5.5) shows interesting features. Monthly water use in winter has increased and use seems independent of rainfall. High winter rainfalls during 1989 and 1991 do not cause any obvious response in water usage during the winter season. Summer water usage is affected by rainfall. Rainfall in excess of 200 millimetres during February of 1989 causes a corresponding reduction of water use to less than 35,000 cmpm. Rainfall events affect monthly water use in all areas but with the most marked effect noted in the areas with small allocations.

Rainfall and Total Monthly Use

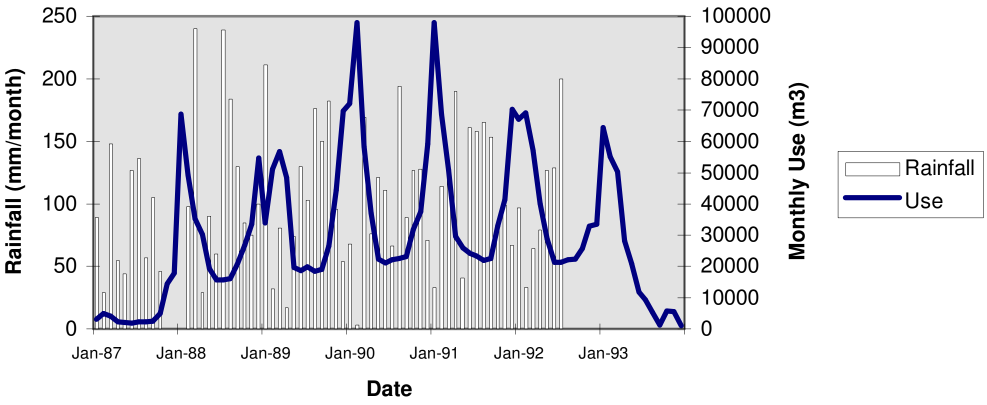

Figure 5.5: Total monthly water use plotted against monthly rainfall

The increase in average (monthly) winter usage is anticipated to be from an increase in usage by year round operators such as glasshouses, poultry farmers and the few industrial users. Average (monthly) summer increases and the subsequent decrease are thought to result from cropping changes resulting from the downturn in the kiwifruit market. Many areas, which had been growing kiwifruit prior to 1992, have subsequently been replanted in apples, flowers and market garden.

5.2.1 Zone 1

Areas classified as Zone 1 generally have higher concentrations of intensive horticulture than other zones. Each of the Zone 1 areas exhibits an individual water usage characteristic.

Water use records from the Zone 1 areas are slightly more than half those expected during the term of permits (Figure 5.6). These returns represent those holding 70% of the allocated volume and indicate that about 53% of the allocated water resource was utilised in the water years 1987/88 to 1992/93. Water use averaged 53% (197,595 cmpa) while 1991/92 the peak usage of 63% (234,877 cmpa) was attained. This left an average of 175,225 cmpa unused from the allocated resource spread across the Zone 1 areas. For most water years the relationship between water use returns, allocated volume and actual use has been similar in proportion to the figures stated above.

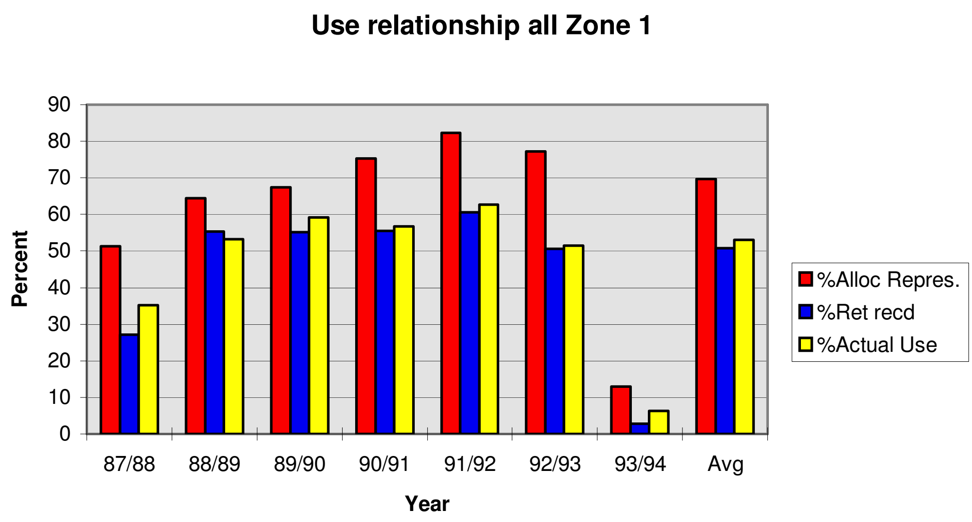

Figure 5.6: Use relationships for All Zone 1 areas for the period 1987 to 1994

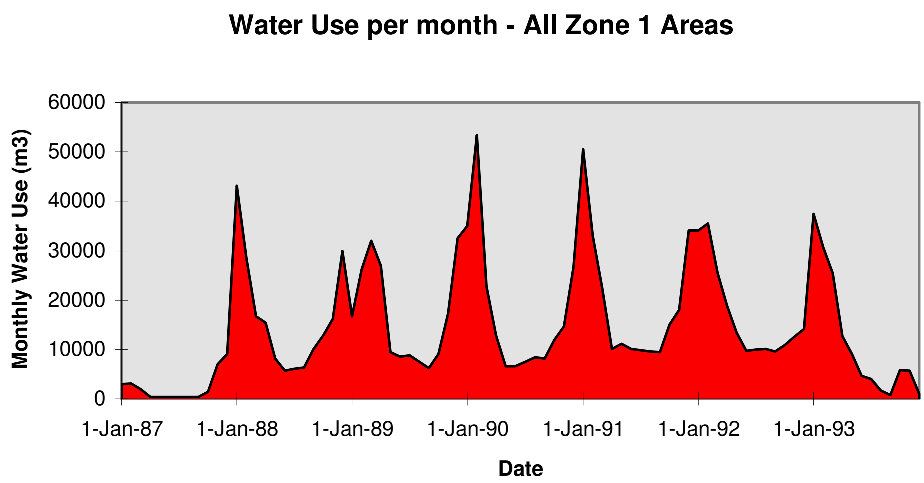

Figure 5.7: Actual monthly water use for All Zone 1 areas

Water use summaries of actual use for the Zone 1 areas (Figure 5.7) show a base use of about 8,421 cubic metres per month (cmpm) throughout the year with an additional summer monthly use averaging 16,528 cubic metres, but at peak times up to 45,033 cubic metres, superimposed on this. From 1988 to 1992 the winter monthly average water use (May to October) rose from 8,221 cmpm to 10,606 cmpm peaking at 10,908 cmpm in 1991. The summer (monthly) average water use rose over the same period from 19,974 cmpm to 22,157 cmpm.

In Zone 1a water use records indicate that actual water use has been increasing slowly since 1988 (figure 5.8). An average of 51% of water use returns were received from those who hold 72% of the allocated volume. Just over half of the allocated 256,220 cmpa was utilised in 1988 while 62% was utilised in 1991/92. The average water use in this zone between 1987/88 and 1992/3 has been 50%, the average being brought down by limited water use returns in 1987/88 and 1992/93. This represents an average of 128,110 cmpa unused in this zone each year.

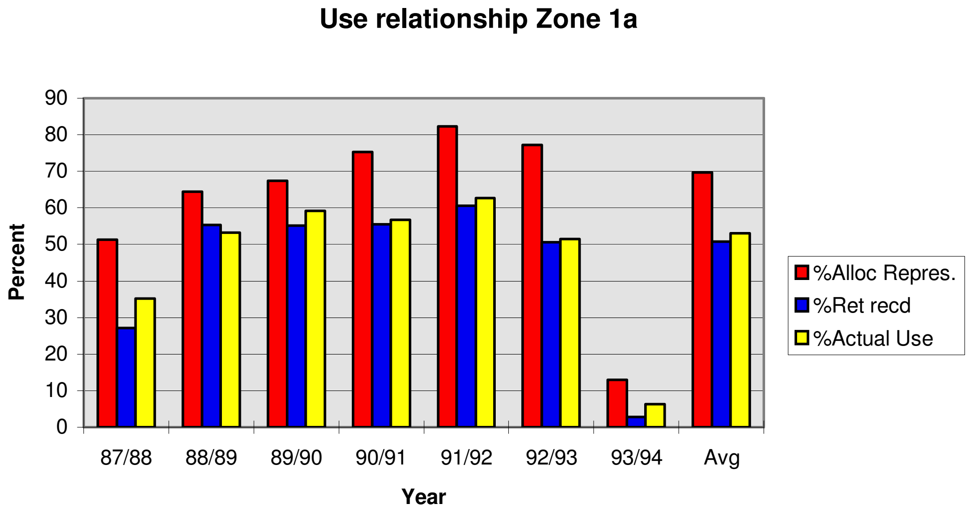

Figure 5.8: Use relationships for Zone 1a for the period 1987 to 1994

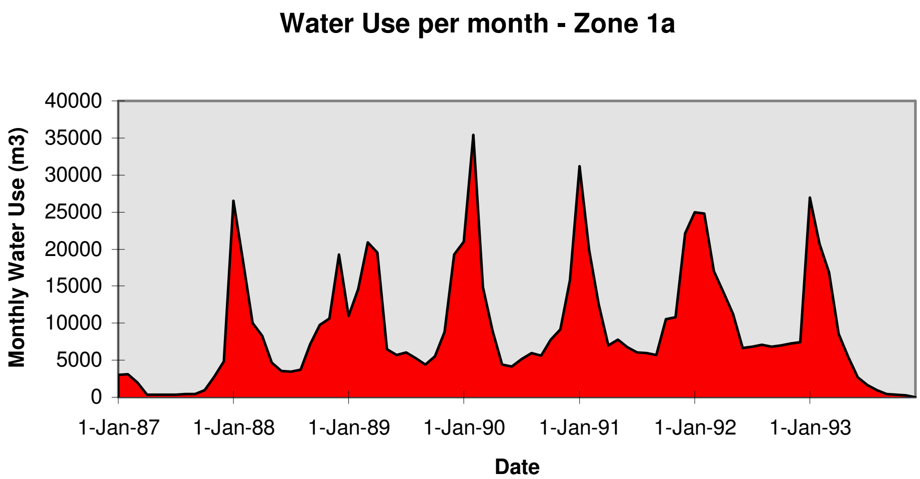

Figure 5.9: Actual monthly water use for Zone 1a

Base water use in Zone 1a, Figure 5.9, is 5,523 cmpm with an additional summer (monthly) use averaging 10,370 cubic metres, but at peak times up to 29,220 cubic metres, superimposed on this. From 1988 to 1992 the winter (monthly) average water use (May to October) rose from 5,393 cmpm to 7,595 cmpm while the summer (monthly) average water use rose over the same period from 11,819 cmpm to 14,616 cmpm peaking in 1991/92 at 18,967 cmpm.

Water use records for the three permit holders of Zone 1b indicate a substantial increase in total water use over the six years studied (Figure 5.10). Water use returns were received for 44% of the period of record representing only 39% of the allocated volume for the zone. This increase shows from the records received that total volumes abstracted in this zone have risen from 54% to 175% of the allocated volume between 1987/88 and 1992/93. Average water use in the zone has been 106% of the allocated volume.

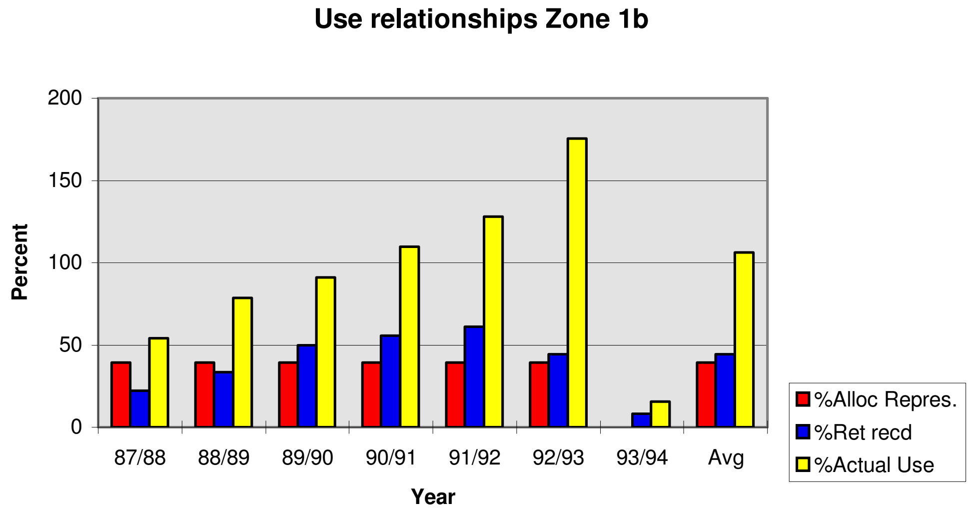

Figure 5.10: Use relationships for Zone 1b for the period 1987 to 1994

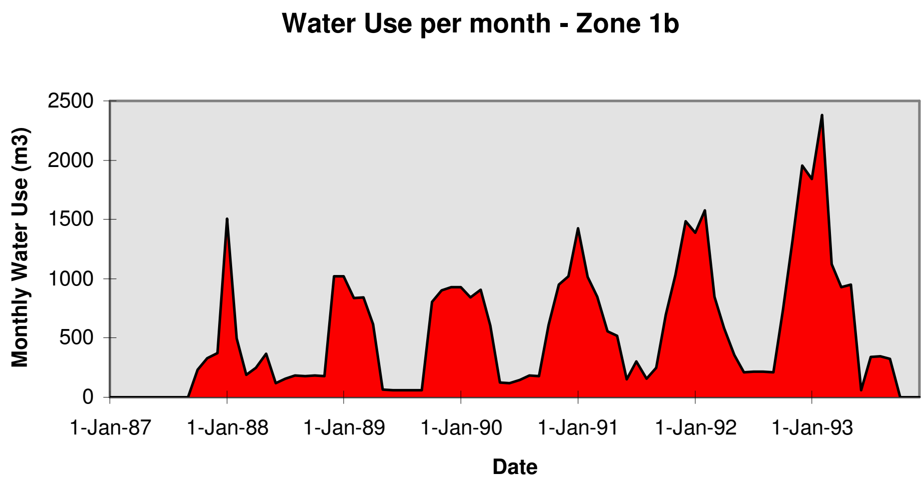

Figure 5.11: Actual monthly water use for Zone 1b

Zone 1b base water use is 270 cmpm with an additional summer (monthly) use averaging 704 cubic metres, but at peak times up to 2,109 cubic metres, superimposed on this (Figure 5.11). From 1988 to 1992 the winter (monthly) average water use (May to October) rose from 199 cmpm to 336 cmpm while the summer monthly average water use rose over the same period from 525 cmpm to 1,593 cmpm.

More water use records were received from Zone 1c than any other zone (see Figure 5.12). In Zone 1c 65% of water use returns were received, which represent those holding 76% of the allocated volume. These returns indicate that about 58% of the allocated water resource was utilised in the water years 1987/88 to 1992/93. Water use averaged 24,401 cpma while 1989/90 the peak usage of 33,609 cmpa (73% of the allocated volume) was attained. This left an average of 19,336 cmpa unused from the allocated resource.

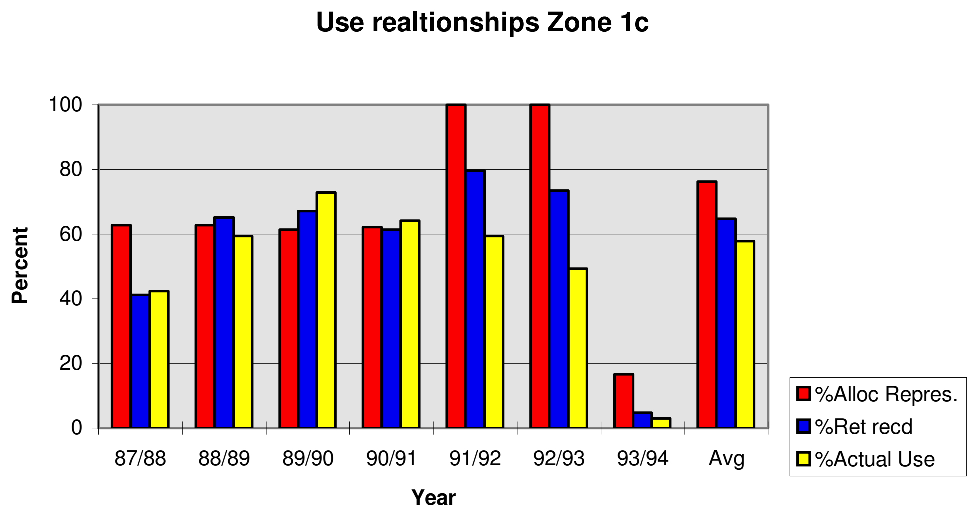

Figure 5.12: Use relationships for Zone 1c for the period 1987 to 1994

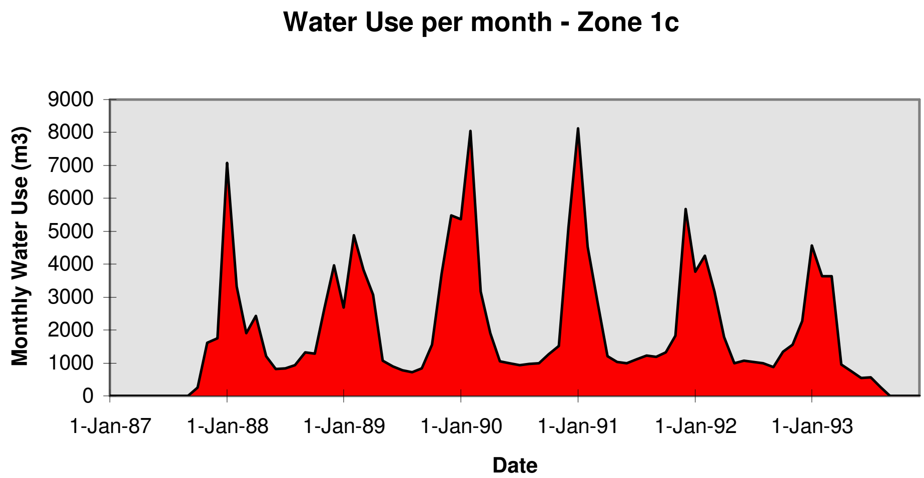

Figure 5.13: Actual monthly water use for Zone 1c

Records for Zone 1c show a base use of about 936 cubic metres per month (cmpm) throughout the year with an additional summer (monthly) use averaging 2,602 cubic metres, but at peak times up to 7,190 cubic metres, superimposed on this (Figure 5.13). From 1988 to 1992 the winter (monthly) average water use (May to October) remained constant around 1,050 cmpm. The summer monthly average water use rose from 3,015 cmpm in 1987/88 to 4,613 cmpm in 1989/90 and has subsequently fallen over the following years to 2,771 cmpm in 1992/93. A possible explanation for this could be changes of cropping occurring in the area, kiwifruit to apples, nursery and market garden.

In Zone 1d water use returns averaged 44% representing 56% of the allocated volume were received (Figure 5.14). These returns indicate an average of 59% or 28,356 cubic metres of water per year being utilised by permit holders leaving 19,705 cpma available for use.

The relationship between water use returns, the allocated volume they represent and actual water used has changed considerably since 1987/88. Up until the summer of 1990/91 the usual pattern of high summer use and low winter use is noted. In the two following years this pattern is replaced by a fall in summer use and a rise in the winter use. Overall water use was rising from 1988 to 1990 and has been replaced by a fall to 2/3 of the 1990/91 level.

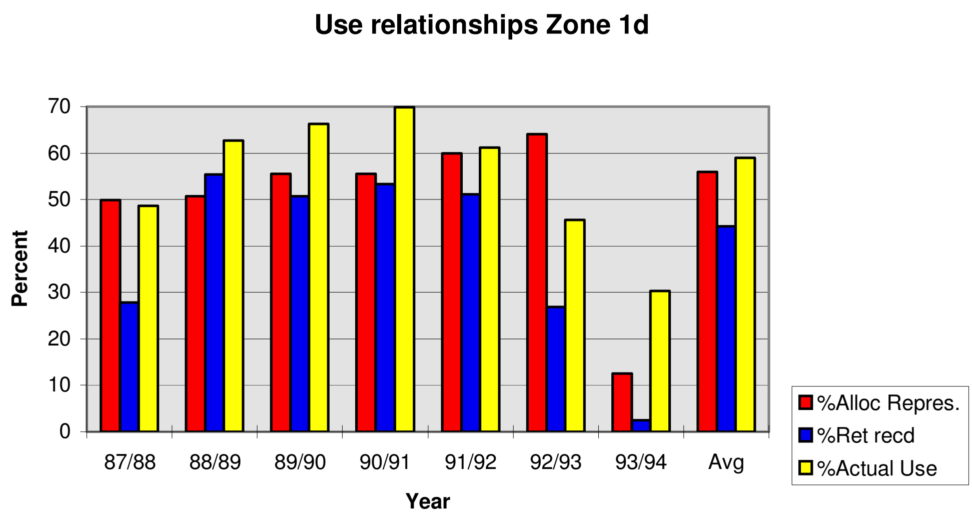

Figure 5.14 Use relationships for Zone 1d for the period 1987 to 1994

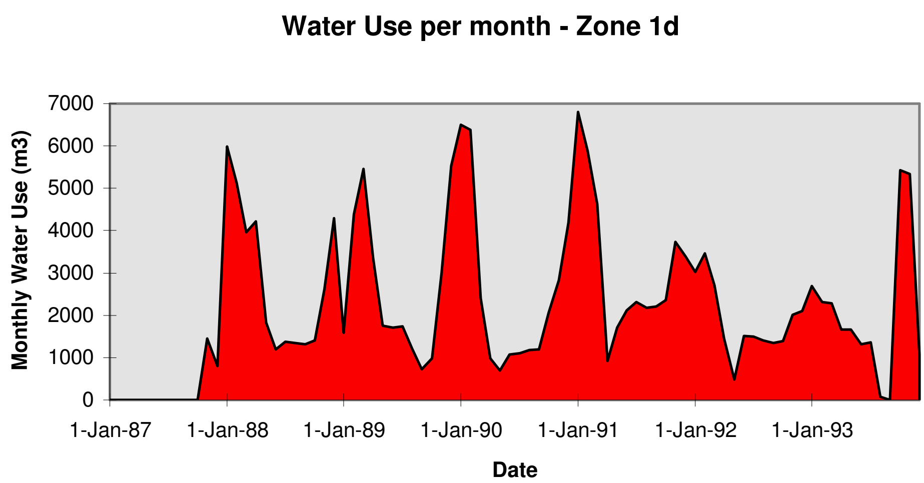

Figure 5.15 Actual monthly water use for Zone 1d

Zone 1d water use records in Figure 5.15 show a base use of about 1,507 cubic metres per month (cmpm) throughout the year with an additional summer (monthly) use averaging 1,941 cubic metres, and during 1990/91 up to 2,700 cubic metres, superimposed on this. From 1988 to 1992 the winter (monthly) average water use (May to October) rose slightly from 1,412 cmpm to 1,641 cmpm. The summer (monthly) average water use rose from 3,592 cmpm in 1987/88 to 4,207 cmpm in 1990/91 and has subsequently fallen over the following years to 2,178 cmpm in 1992/93. Again changes of cropping occurring in the area, especially moves away from kiwifruit and an increase in non-horticultural use of land could explain this unusual water use pattern.

In Zone 1e water use has been to consistently take between 3 and 10 times that during the summer period (November to April) as during the winter with total water use falling slowly since 1988 (Figure 5.16). An average of 44% of water use returns were received representing those who hold 83% of the allocated volume. Just over 52% of the allocated 9,750 cmpa were utilised in 1987/88 while only 22% was utilised in 1991/92. The average water use in this zone between 1987/88 and 1992/3 has been 39%, the average being brought down lower water use with time. On average 5,948 cmpa remained unused in this zone each year.

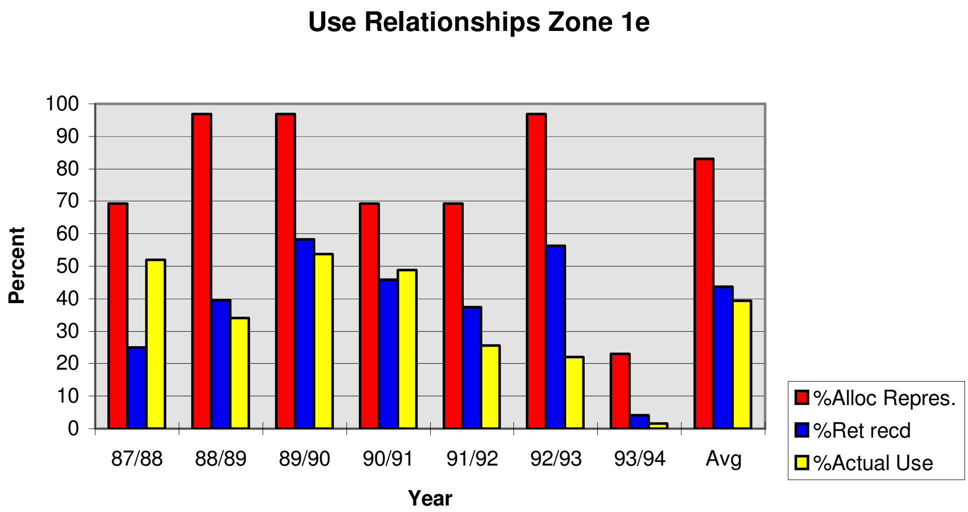

Figure 5.16 Use relationships for Zone 1e for the period 1987 to 1994

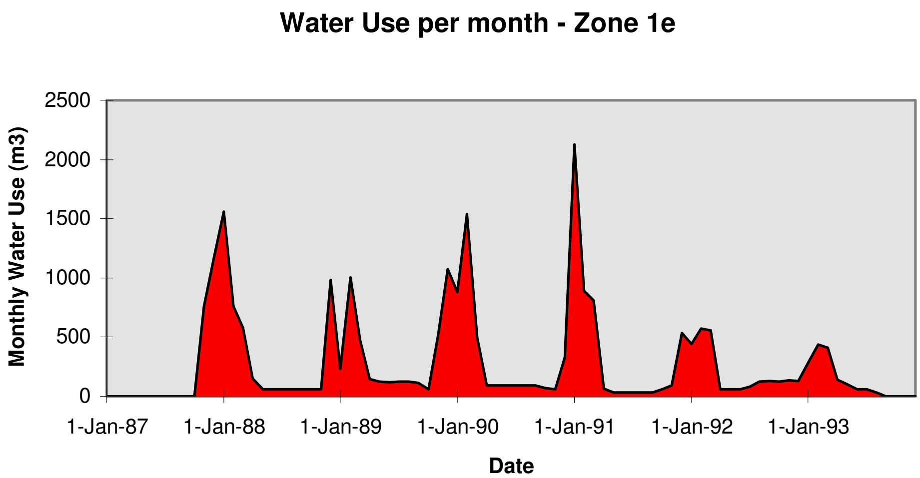

Figure 5.17 Actual monthly water use for Zone 1e

Base water use in Zone 1e is 73 cmpm with an additional summer (monthly) use averaging 498 cubic metres, but at peak times up to 2,055 cubic metres as in the summer of 1991, superimposed on this (Figure 5.17). From 1988 to 1992 the winter (monthly) average water use (May to October) varied between 61 cmpm in 1988, 111 cmpm in 1989, 36 cmpm in 1992 and 96 cmpm in 1992. Summer (monthly) average water use declined over the same period from 833 cmpm to 254 cmpm.

Water use in Zone 1f has increased steadily from 20% of allocated volume in 1988 to 103% in 1992 (Figure 5.18). Water use returns received average only 39% but these represent 59% of the allocated volume. On average water use in this zone has been 65% or 3,802 cmpa leaving an average of 2,048 cmpa unused groundwater.

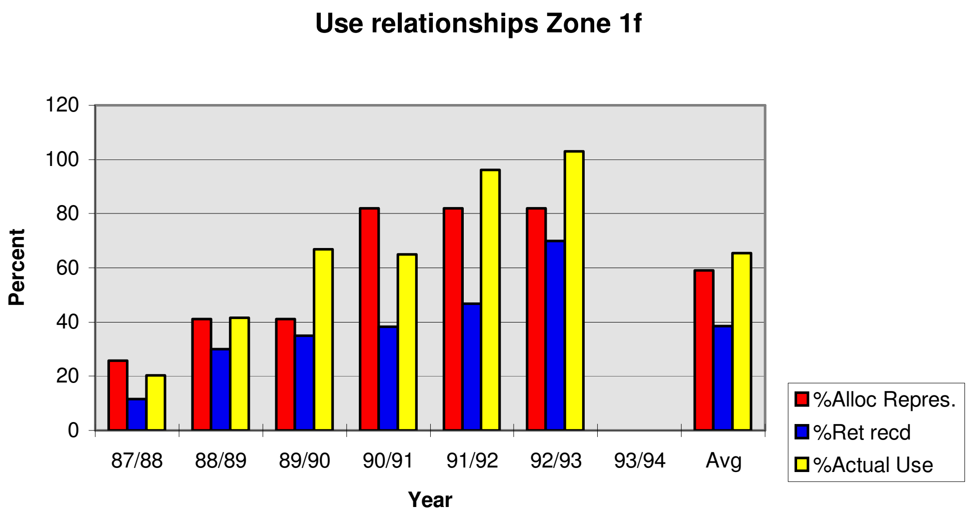

Figure 5.18: Use relationships for Zone 1f for the period 1987 to 1994

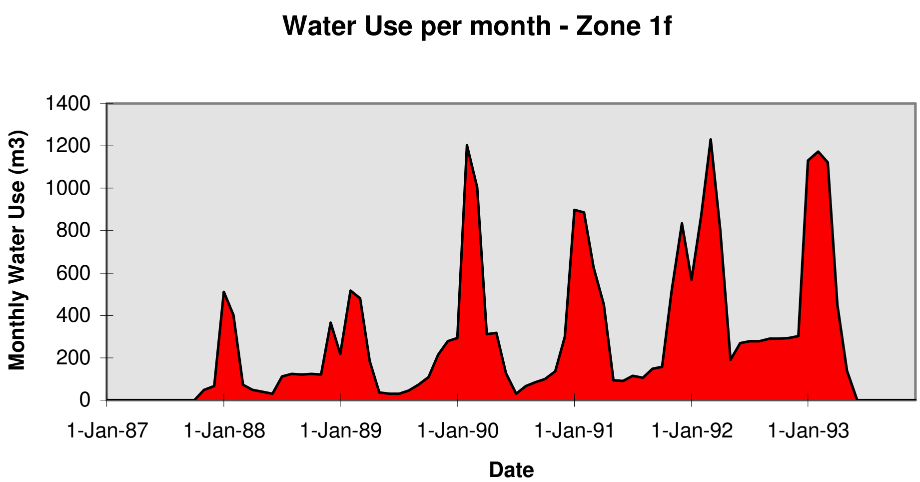

Figure 5.19: Actual monthly water use for Zone 1f

Zone 1f base water use is 113 cmpm with an additional summer (monthly) use averaging 413 cubic metres, but at peak times up to 1,117 cubic metres, superimposed on this (Figure 5.19). From 1988 to 1992 the winter monthly average water use (May to October) rose from 92 cmpm to 266 cmpm while the summer monthly average water use rose over the same period from 191 cmpm to 745 cmpm with a peak usage of 803 cmpm in 1991/92.

5.2.2 Zone 2

Zone 2 has the largest allocation of the three zones with 710,118 cmpa (63% of the entire Study Area), and an average use of 27% of the total volume of water allocated to permit holders, see Figure 5.20. For this zone 52% of water use returns anticipated were received representing those holding 63% of the allocated volume. This pattern of low usage relative to the percentage of allocation represented by the returns received is consistent throughout the water years 1987/88 to 1992/93. The average recorded use of 27% corresponds to 191,731 cmpa being utilised each year and a further 518,387 cmpa remaining unused in the ground.

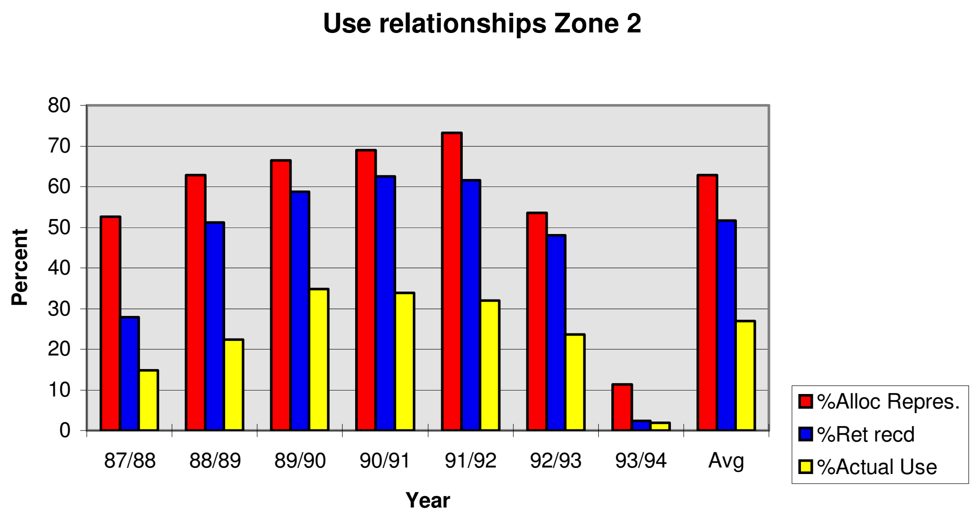

Figure 5.20: Use relationships for Zone 2 for the period 1987 to 1994

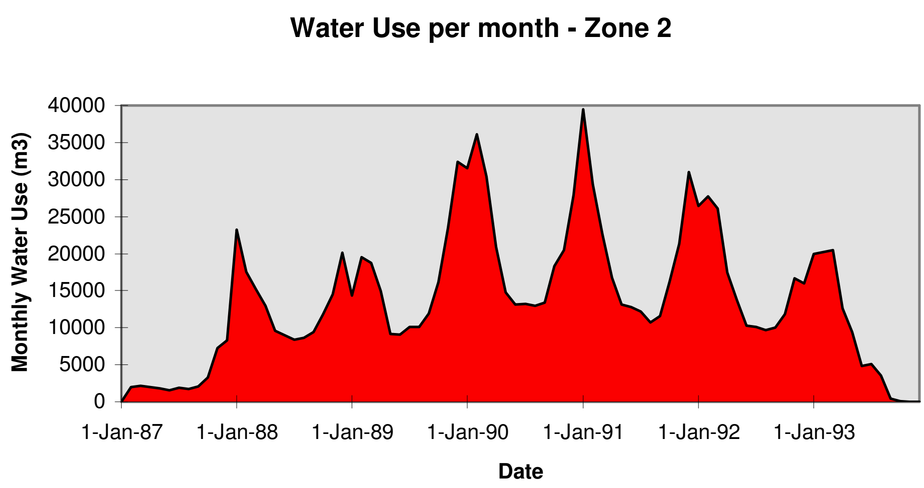

Figure 5.21: Actual monthly water use for Zone 2

Actual monthly water use summaries for Zone 2 in Figure 5.21 show a small rise from 1987/88 to 1989/90 and a decrease then to 1992/93. Zone 2 has a base water use of 10,419 cmpm throughout the year with an additional summer monthly use averaging 11,090 cubic metres, but at peak times up to 29,073 cubic metres, superimposed on this. Winter monthly average water use rose from 9,480 cmpm in 1988 to 14,300 cmpm in 1990 and has subsequently declined to 10,961 cmpm in 1993. Similarly summer monthly average water use rose over the same period from 14,083 cmpm in 1987/88 to 29,156 cmpm in 1989/90 and fell afterwards to 17,657 cmpm in 1992/93.

5.2.3 Zone 3

Water use records from Zone 3 areas average less than half those expected during the term of permits (Figure 5.22). In Zone 3 47% of water use returns were received which represent those holding 38% of the allocated volume. The returns indicate that about 18% of the allocated water resource was utilised in the water years 1987/88 to 1992/93. Water use averaged 33,883 cpma (18% of allocated volume) while in 1992/93 the peak usage of 43,295 cmpa (21%) was attained. This level of water use left an average of 154,357 cmpa unused from the allocated for Zone 3. For most water years the relationship between water use returns, allocated volume and actual use has been similar in proportion to the figures stated above.

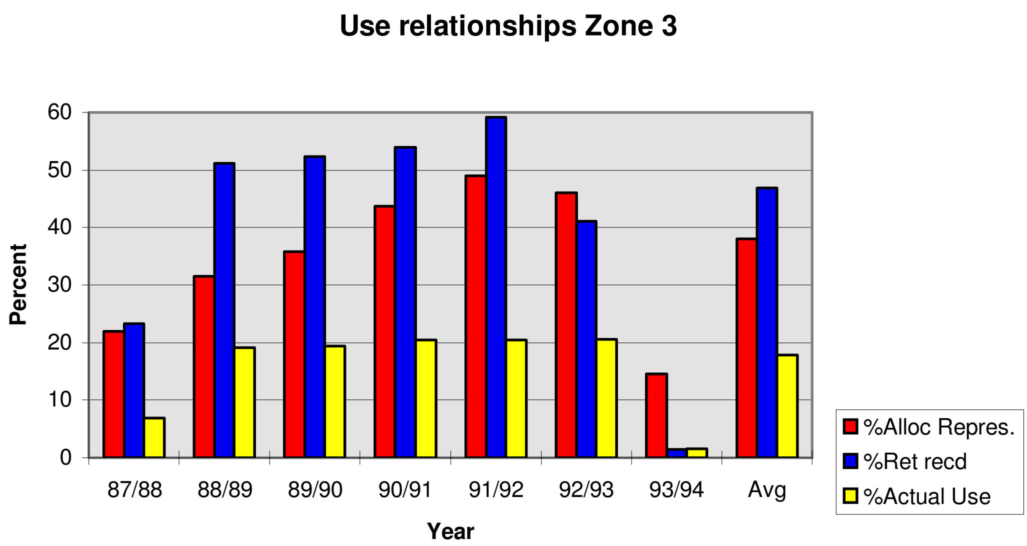

Figure 5.22: Use relationships for Zone 3 for the period 1987 to 1994

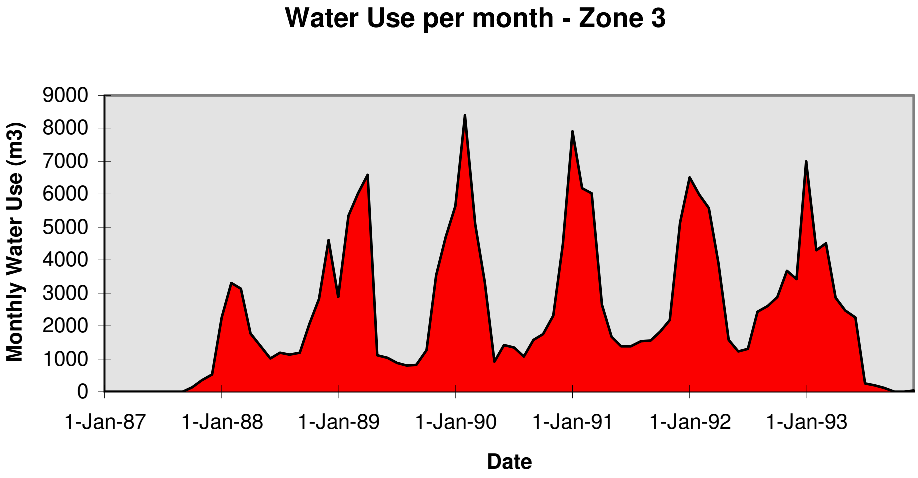

Figure 5.23: Actual monthly water use for Zone 3

Water use summaries of actual use for the Zone 3 areas show a base use of about 1,349 cubic metres per month (cmpm) throughout the year with an additional summer (monthly) use averaging 2,954 cubic metres, but at peak times up to 7,040 cubic metres, superimposed on this (Figure 5.23). From 1988 to 1992 the winter (monthly) average water use (May to October) rose from 1325 cmpm to 2,001 cmpm and the summer monthly average water use remained almost constant over the same period ranging between 5,113 cmpm to 4,290 cmpm.

5.3 Aquifer Response

Measurement of aquifer response to abstraction is undertaken by bi-annual water level surveys, which include a large number of privately owned bores and ongoing monitoring of water levels in some selected bores at monthly intervals. During October of 1992 a comprehensive water level survey of over 200 bores was undertaken to determine an aquifer wide baseline for water levels. More commonly however, 57 bores are dipped twice yearly in March/April and October/November to assess water level changes. Since October 1992 an additional 40 bores have been visited monthly and occasionally fortnightly during peak usage.

Water levels are measured by electrical sounding devices accurate to about 1 centimetre, in bores with a known height above mean sea level. The heights of bores have been measured by either surveying from benchmarks or by altimetry and measurements are accurate to between 0.5 and 50 centimetres dependent on the method used.

5.4 October 1992 Water Level Survey

During October of 1992 a comprehensive water level survey of the Study Area was undertaken. The surveyors visited 208 authorised user's bores and bores used for domestic supply to measure water levels and check water meters. For a range of reasons, such as recent pumping of the bore or inability to gain access to the bore, a total of 110 reliable water level readings were obtained for sites with known elevations.

This data has been contoured along with control elevation data for the coastal margins and the incised river valleys to produce the water level contour plot in Figure 5.24. Data from this survey is considered to represent the winter groundwater levels for the Study Area that can be used for comparison with other water level data and surveys for the same area.

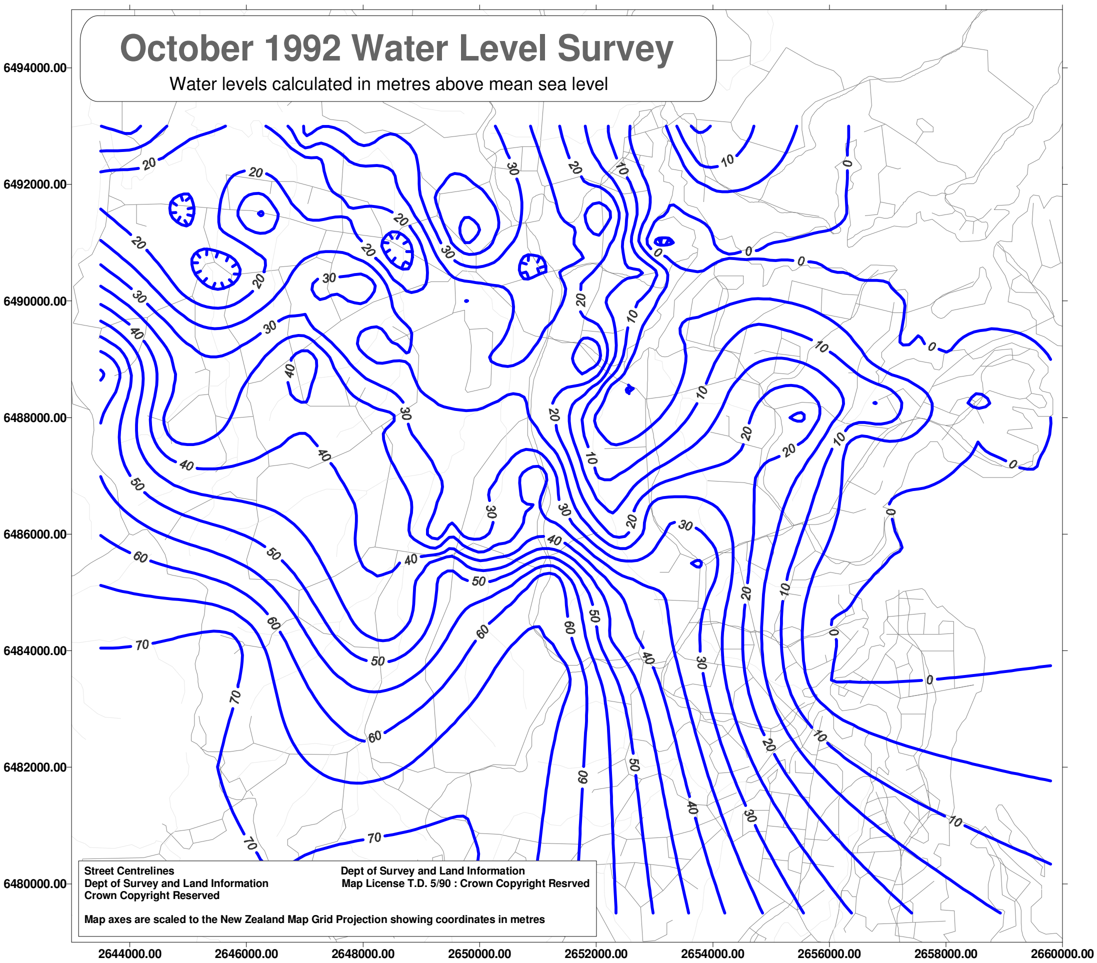

Figure 5.24: October 1992 Water Level Survey Groundwater Level Contours

As can be noted the water levels across the Study Area appear to be generally controlled by topography (the elevation of the ground surface), although where land rises above 80 metres above sea level natural groundwater levels fall considerably below the ground surface. The Study Area can be separated into three general water level zones.

The first zone comprises the Waitakere Ranges and foothills to the west and south, and the Riverhead forest area to the north. In these locations groundwater levels appear primarily controlled by topography, with water levels rising at some factor of the ground surface elevation. Few bores are in fact located in these areas, the steep slopes preventing practical use for horticulture and in most places for glasshouses or poultry farming.

A second zone can be categorised as those inland areas where groundwater levels are nearly horizontal over reasonable distances. This includes the Kaipara River Valley from Waimauku to Taupaki and the Hobsonville, Whenuapai and West Harbour area. Again topographic control is noted but with the superimposition of local bore effects forming many localised depressions, especially noticeable near Huapai.

The third zone consists of a north to south strip from Riverhead to Massey West. This area is one in which there is a pronounced gradient in groundwater levels from west to east of 15 to 20 metres drop in elevation over about 1 kilometre. There is some topographic control in the Ngongetepara Stream valley which has incised through overlying alluvium into Waitemata Group sandstone / mudstone material, and further north where the ground level moves towards the coast.

5.5 Bi-annual Surveys

Bi-annual water level surveys have been made just prior to and immediately following the irrigation season each year since 1988. Irrigation in the Kumeu area generally commences towards the end of October for many crop types and ceases by the beginning of May. Water levels measured immediately following a season of irrigation indicates the overall average water level decline resulting from the abstraction during the season. Water levels measured prior to the irrigation season represent the recovery of water levels in the aquifer following up to seven months of minimal abstractions.

As was discussed earlier the pattern of water use has changed over time. Records for use in 1988 show a pronounced peak of water use during summer, with a reduced amount taken through the winter months. In the years following, the pattern of water use has changed, with an increasing water use through the winter period and a slightly extended summer irrigation period. This reflects the increased use for the Study Area as a whole.

Water level measurements for any individual survey shows localised "lows" which are thought to result from recent pumping of the particular bore measured. A contour plot of the water levels for the area looks very much like a number of bulls-eye targets if individual surveys are used. Data from the 12 water level surveys to 1 January 1994, were combined and filtered by averaging and subjective removal of results obviously resulting from pumping to produce the averaged winter and summer water level contour plots in Figures 5.25 and 5.26.

The pattern of the water level surface of the aquifer as measured in individual boreholes during the surveys is essentially the same during both summer and winter. High water levels are measured along the Waitakere Ranges foothills to the west, on the Old North Road Ridge in the north and near the intersection of Red Hills and Nelson Roads in the south-east. Low water levels are measured in the Waitakere valley, to the north-west where the Kaipara River outflows, and along the coastal margin. A localised low in water levels that are measured below sea level occurs on the coastal margin near Riverhead. With the exception of minor variations in the north west of the Study Area the change between summer and winter water levels appears in most areas to be in the order of 5 metres.

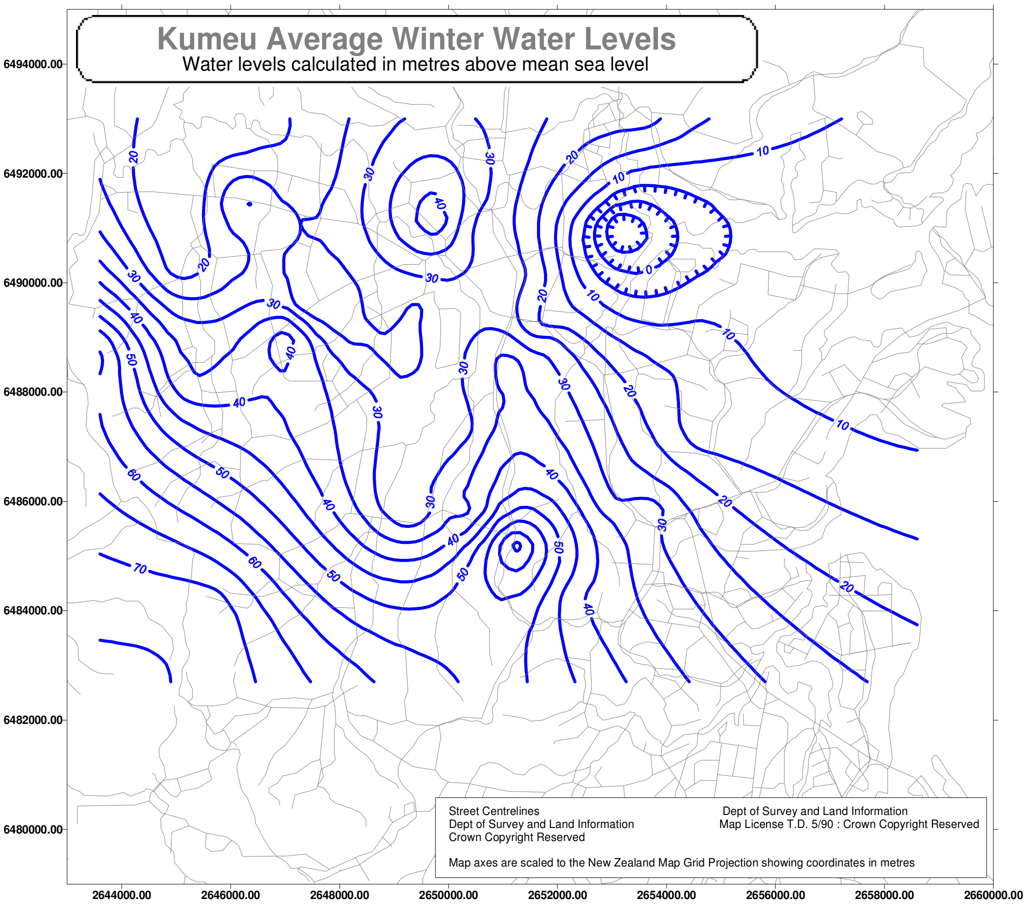

Figure 5.25: Averaged winter water levels contour plot

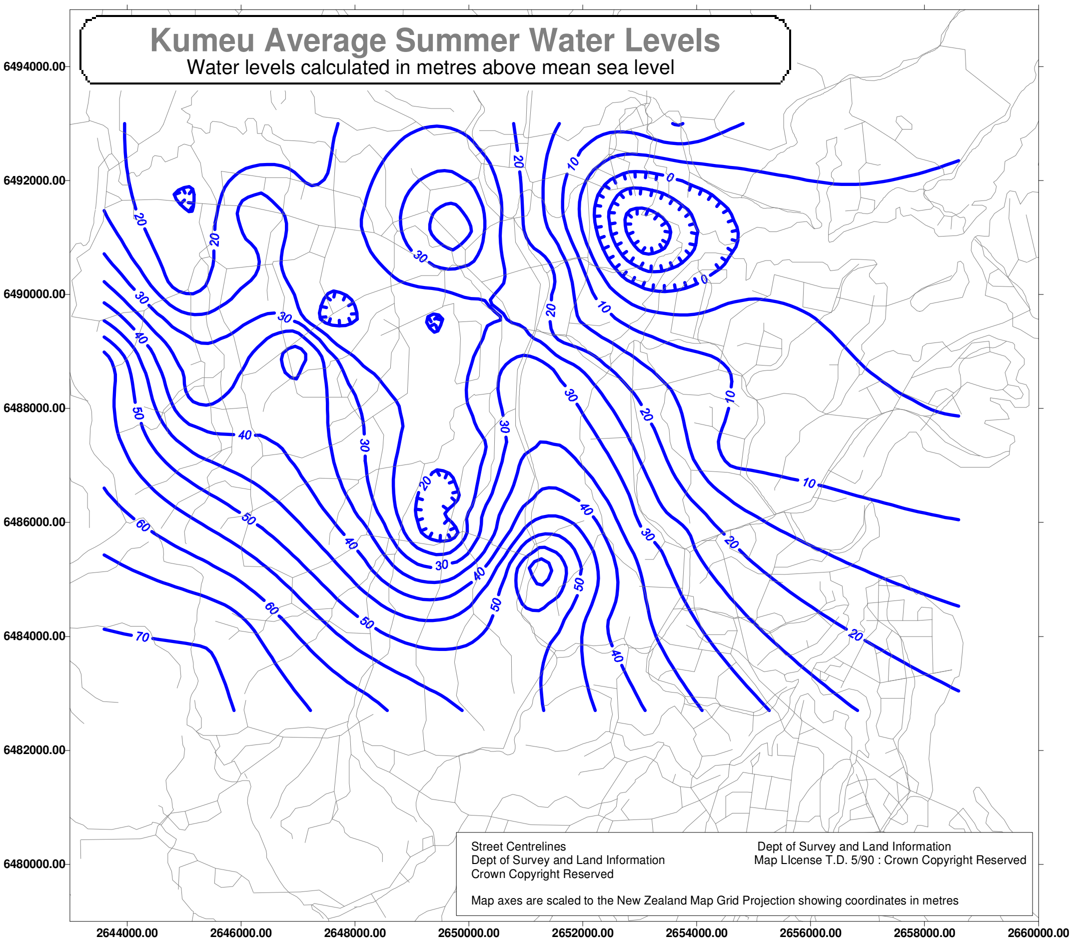

Figure 5.26: Averaged summer water levels contour plot

It must be noted that only a limited number of bores are monitored for seasonal water level fluctuation and that the contours are generalised patterns of water levels in the aquifer. The change between summer and winter levels was calculated by simple subtraction of the summer values from the winter values to give a contour plot of actual water level decline due to pumping, shown in Figure 5.27. Over much of the Study Area the water level difference is in fact less than the 5 metres estimated by visually comparing the summer and winter water level plots.

In the area bounded by Motu, Trigg, Tawa and Puke Roads in Huapai the annual water level fluctuation is estimated to be less than 1 metre. Even though there are authorised water users in this area, their abstraction appears to cause minimal fluctuation in water levels between seasons.

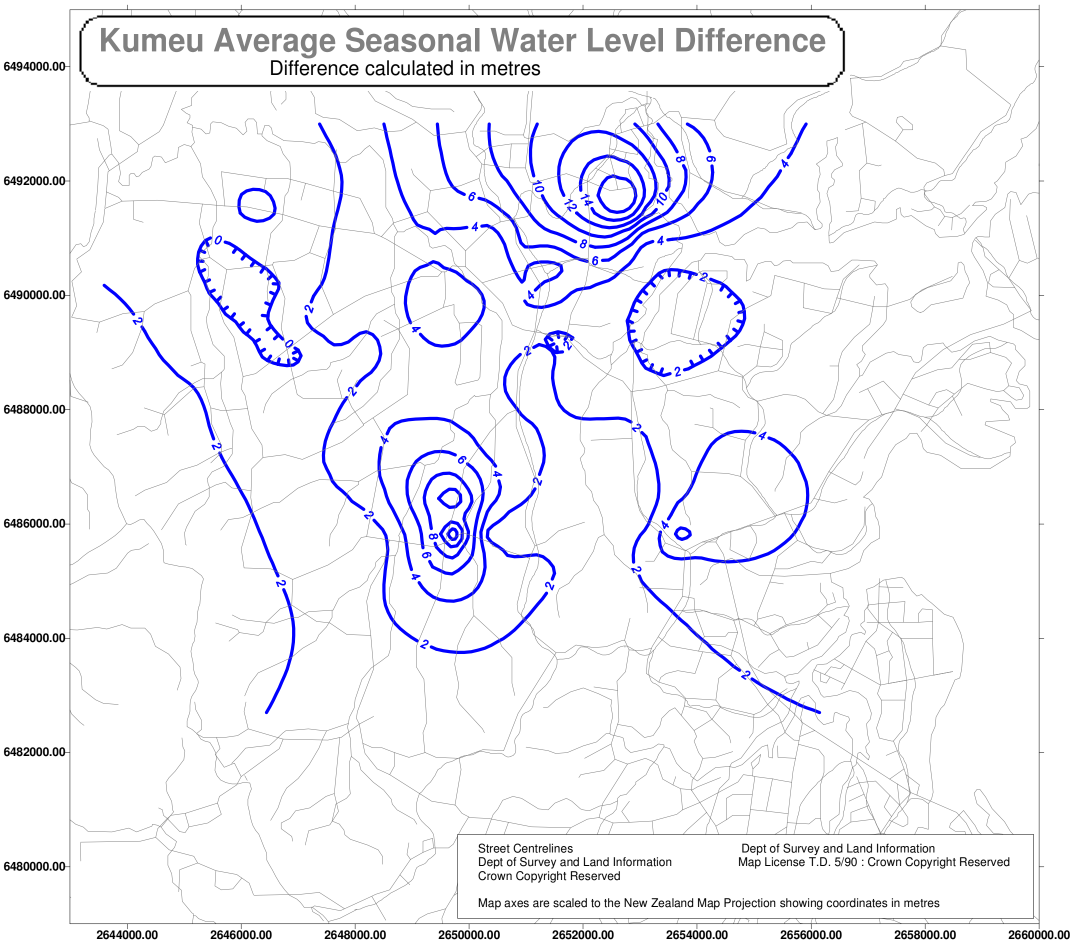

Figure 5.27: Contour plot showing the averaged seasonal variation in water level across the Study Area

Four locations show a water level difference of 5 metres or more between winter and summer averages. A small zone near the corner of Boord Crescent and Waitakere Road shows a seasonal fluctuation of slightly more than 5 metres. This location corresponds to a water permit that was issued for the irrigation of kiwifruit. A larger zone with a maximum seasonal water level fluctuation of about 7 metres is noted centred on State Highway 16 between Don Buck Road and Baker Lane in Massey. This fluctuation can similarly be associated with a water permit issued for kiwifruit irrigation. A significant area of intense water level drawdown occurs in Taupaki near the intersection of Taupaki and Nelson Roads.

Here seasonal fluctuation exceeds 12 metres on average, measured at three sites in the area. While some water permits granted for this locality have large daily allocations the annual abstraction is relatively small. It is thought that the depression of water levels is due to the lower transmissivity of the rock in this area resulting in greater water level drawdown response to abstraction. The area of greatest seasonal water level fluctuation is noted centred on the Riverhead area where in excess of 18 metres of difference is noted between the average winter and summer water levels. This drawdown is noted from only one monitored site and may be due to the orchard irrigation use at that one site alone. The nearest bores to this monitoring site show differences in water levels of 4 to 6 metres between the seasons although they are some distance away.

5.6 Monthly monitoring of selected bores since October 1992

Between 38 and 44 bores in the Study Area have been regularly monitored at monthly intervals, with an increase to fortnightly frequency during the peak of summer, since the comprehensive water level survey in October, 1992 (Fig. 5.28). It was the intention that this survey would give early warning of excessive water level drawdown. The bores monitored include a cross section of ARC monitoring bores, unused domestic and irrigation bores and some water permit holder's bores. Occasional water level measurements have been unable to be obtained in a particular bore due to pumping.

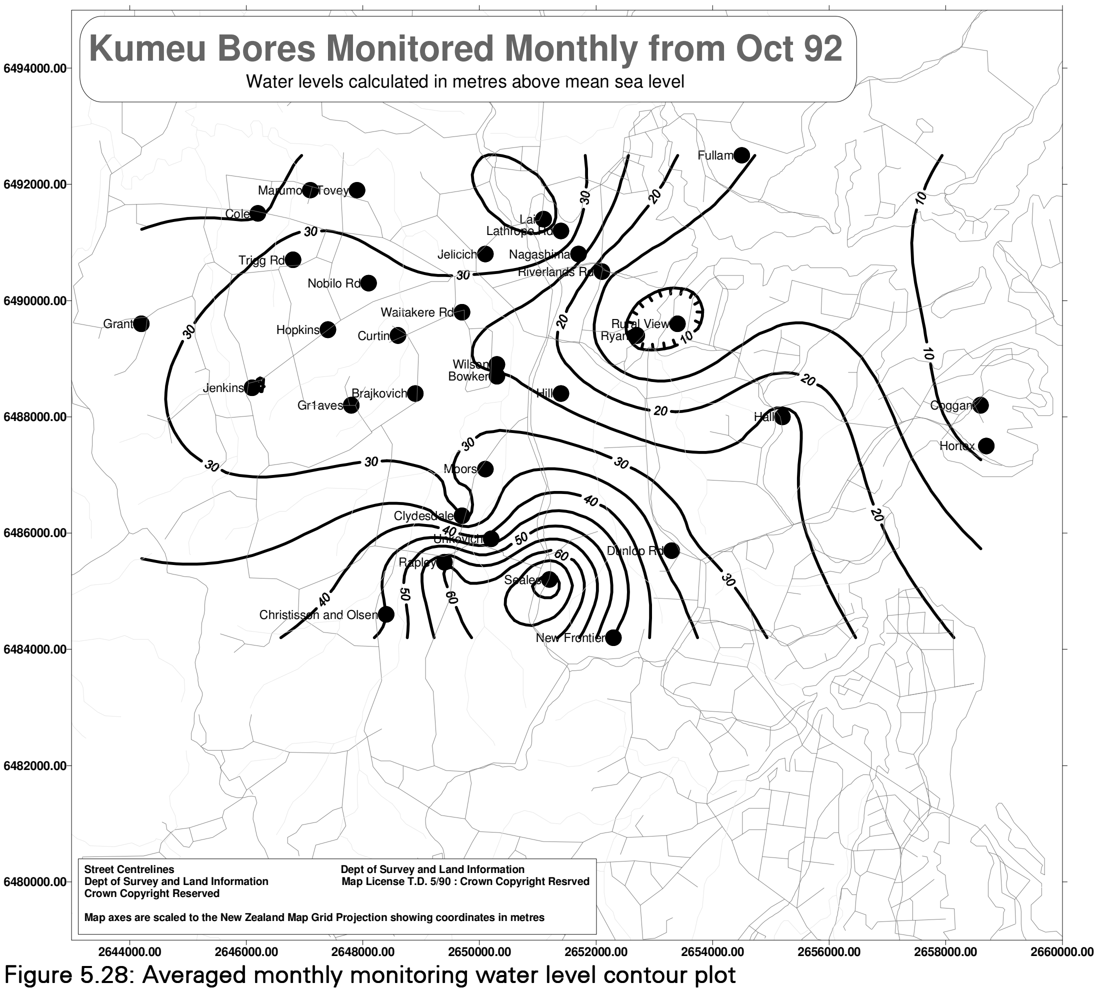

Figure 5.28: Averaged monthly monitoring water level contour plot

Contour plots of the data from these surveys follow the general pattern of the zones noted in the October 1992 survey, with obvious limitations due to the smaller number of data points. Plots of individual surveys appear to be similar, with most apparent change occurring in the Kaipara River flats near Huapai. However, the average water level plot in Figure 5.28 shows the general form of the water levels monitored during these surveys. With the exception of individual pumping events in the monitored bores, no major fluctuation in water levels greater than the 5 metre average fluctuation mentioned (as detected by the bi-annual surveys) has been detected in the areas where bores have been monitored.

6. WATER AVAILABILITY

6.1 Previous Studies

Initial calculations were made of groundwater availability in the Kumeu-Hobsonville Groundwater Study Preliminary Findings and Interim Management Strategy (1987) and in the Kumeu-Hobsonville Groundwater Management Plan (1989). The methods employed include Percentage Infiltration, Annual Natural Groundwater Fluctuation, Flow Net Analysis, Bulk Aquifer Parameterisation and simple Computer Modelling. For details of the methods refer to the documents listed above.

The calculations of available groundwater in the Study Area by the range of methods previously used suggests that approximately 1% of average annual rainfall infiltrates to the aquifer and becomes available for abstraction from bores (see Table 6.1).

Table 6.1: Previously calculated water availability for Study Area.

Year	Method	Estimated Recharge (m^3/year)	% of Annual Rainfall
1987	1% Infiltration	1,905,000	1.0
1987	Annual Groundwater Fluctuation	828,000	0.43
1987	Flow Net (excl. Waitakere)	376,000	0.20
1989	Maximum Recharge	1,854,000	0.97

In general, recharge in all estimates except the Flow Net is considered to occur across most of the Study Area. This represents average recharge in the order of 1.9 million cubic metres per year. No attempt has been made in these earlier studies to delineate actual recharge areas on the basis of groundwater levels or geology, or to consider natural losses from the groundwater system such as evapotranspiration, surface water interaction and with the exception of the Flow Net Analysis, coastal outflow.

One of the aims of the monitoring recommended in the 1989 Management Plan was that the data received would form the basis for more detailed estimates of water availability. As noted above the quantity and quality of data received from the water use monitoring strategies has been poor. Because of a lack of confidence in this data, detailed computer modelling has not been carried out to analyse the interaction between water use and aquifer response.

6.2 Water Balance Analysis

With the lack of sufficient reliable water use data to make use of the aquifer response data, it was considered that the only appropriate method for attempting to refine groundwater availability was to evaluate availability from a water balance approach. The water balance bookkeeping approach is discussed in standard climatological texts.

6.3 Data Sources and Quality

Data collated to use this approach was continuous rainfall data from ARC's rainfall site at Mikells (Map reference Q11:471883), continuous river flow data from ARC's flow site at Waimauku (Map reference Q10:437919) and daily Potential Evapotranspiration data from Hort+Research site at Kumeu (Map reference Q11:492897) for the period 1 January 1983 to 22 July 1992. The locations of these data sources are seen in Figure 6.1.

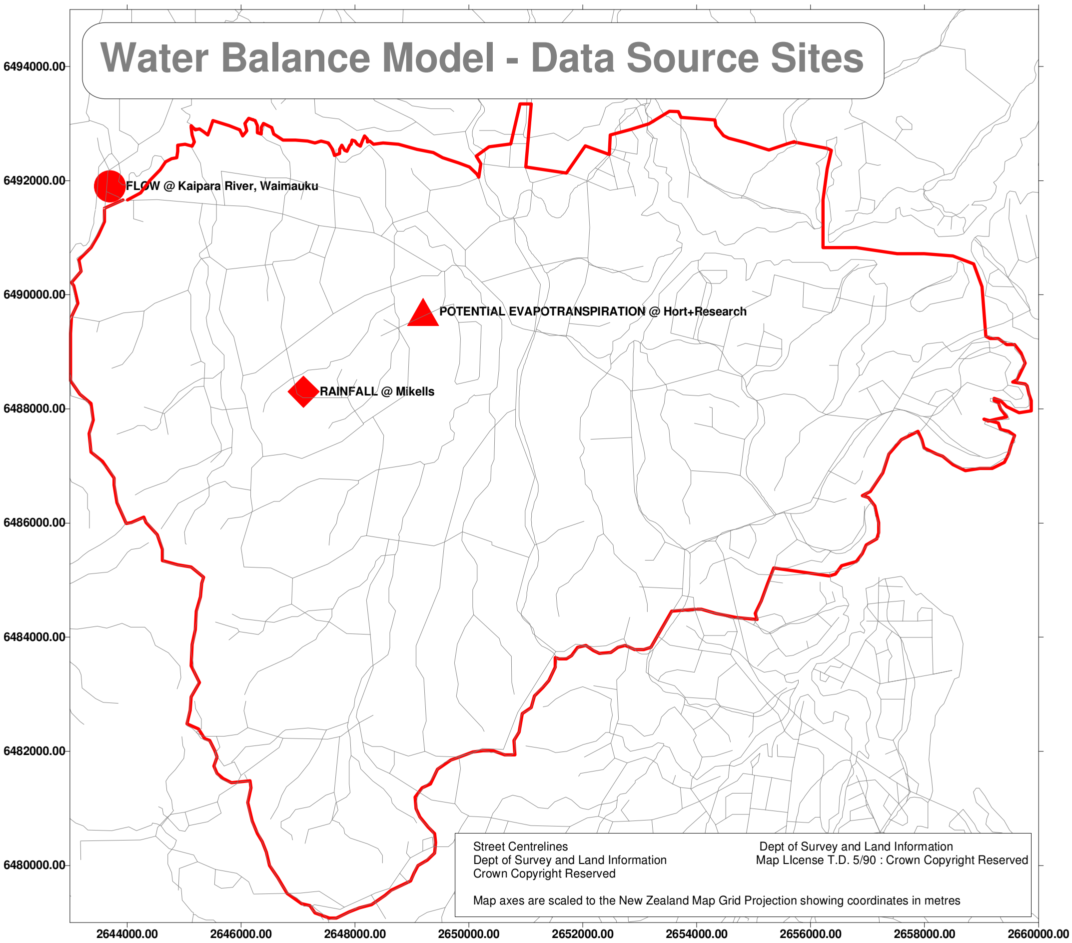

Figure 6.1: Water balance modelling data source locations

Evapotranspiration is the combined loss of water to the atmosphere by evaporation and plant transpiration. Evapotranspiration is energy dependent and so can potentially occur at a higher rate during summer than winter. Where water supply is not limited, evapotranspiration can occur at the potential rate so that all available energy is used in the evaporation of water. Potential evapotranspiration is calculated by measuring the evaporation from a large pan filled with water. Where water available is less than that which could be evaporated by the energy supply then evapotranspiration occurs at an actual rate that is lower than the potential. Commonly during winter evapotranspiration occurs near the potential rate which is low, while during summer the actual rate can be significantly lower than the potential

Potential evapotranspiration data taken from the Hort+Research site at Waitakere Road was used as input to the model for the calculation of actual evapotranspiration. This data set contained values for all but a few days in October of 1992. These missing values were substituted by the mean daily October potential evapotranspiration value of 2.9mm. The final data set for evapotranspiration gives values measured in millimetres of actual evapotranspiration per unit area per day.

Rainfall data was taken directly from continuous data collected at ARC's site at Mikells on Pomona Road, Kumeu. Data from this record was extracted extending from 1 January 1983 to 22 July 1992 with twelve gaps. The gaps ranging from 2.1 days to 86.03 days totalled 215.23 days or 6.17% of the total record.

Data for the gaps in the record were interpolated backwards using flow records for the Kumeu catchment where available. Where significant changes in flow trends occurred during a gap rainfall was modelled for that period. Where no change was detected, a straight-line relationship connected the gap. Where no direct relationship between rainfall and flow, i.e.: flow data also missing, data was used directly from manual rain gauges in the Ararimu Valley to the north. Average annual rainfall for the period used is 1,297mm. Rainfall data is commonly expressed in millimetres of rainfall per day.

Flow data was calculated from rated continuous data collected at ARC's site at the Waimauku Bridge over the Kaipara River. Data from this record was extracted extending from 1 January 1983 to 22 July 1992 with eighteen gaps. The gaps ranging from 2.98 hours to 26.2 days totalled 158.8 days or 4.55% of the total record. Flow is calculated from stage height water level in the river and rated by a rating curve. Rating curves are recalculated frequently from measured flow and stage height relationships at a site.

This flow site detects runoff from the Kaipara River catchment within the Study Area and the Ararimu valley to the north but not the Ngongetepara, Totara, Waiorahia, and Deacon Road Streams to the east of the Study Area. As the surficial lithology of these catchments is similar, a specific discharge value (total discharge divided by total area, giving a flow rate in litres per unit area per day) was calculated for the Kaipara River catchment. It was applied to the total area of the Study Area to give an estimated flow. The specific discharge for the Study Area can be expressed in equivalent units to rainfall and evapotranspiration as one litre of flow from a square metre is equivalent to one millimetre of rainfall flowing off one square metre of surface.

Data for the gaps in the record were interpolated backwards using rainfall records for the Kumeu catchment where available. Where significant changes in rainfall trends occurred during a gap, flow was modelled for that period. Where no change was detected, a straight-line relationship connected the gap. Where no direct relationship between flow and rainfall, rainfall data was also missing, data was used directly from the Kaipara River flow site upstream at Kumeu.

This data record extends from 1 January 1983 to 22 July 1992 with twelve gaps. The gaps ranging from 2.1 days to 86.03 days totalled 215.23 days or 6.17% of the total record. Data for the gaps in the record were interpolated backwards using flow records for the Kumeu catchment where available. Where significant changes in flow trends occurred during a gap rainfall was modelled for that period. Where no change was detected, a straight-line relationship connected the gap. Where no direct relationship between rainfall and flow, i.e.: flow data also missing, data was used directly from manual rain gauges in the Ararimu Valley to the north. Average annual rainfall for the period used is 1,297mm.

Both flow and rainfall records are measured from midnight to midnight while evapotranspiration is measured from 9am to 9am. Data for evapotranspiration was not modified to attempt a correction for the time difference.

6.4 Model Details

A simple water balance approach was utilised for this analysis, modelling the catchment as represented by a unit area comprised of a soil volume having an available water capacity (AWC) of 80mm over that area. The AWC selected is representative of the range of values expected for the variety of soil types in the catchment.

For each day of the record measured rainfall was added to the soil volume. The water storage in the soil volume was then assessed. If more water was present than could be held by the soil volume the excess was deemed to be runoff from the model. Additional flow from the model to simulate baseflow occurred from the water remaining in the soil volume at a rate proportional to the water remaining. Finally evapotranspiration was modelled removing some additional groundwater if available.

Any water remaining in the soil volume after the daily iteration is soil water available to recharge the underlying aquifer. Water level records for the Study Area show that recharge to the aquifer system occurs primarily during the winter months when the soil is completely saturated with substantially less recharge occurring during prolonged wet periods in summer seasons. The model was set up to maximise recharge when the soil water storage was at or near full with a proportional lowering of this rate as soil water content decreased.

Previously calculated recharge rates are near 1% annually which would indicate a higher instantaneous rate during winter months, perhaps in the range 3% to 5%. From a sensitivity analysis predicted recharge rates ranging between 0.9 and 9% of annual rainfall could be used to model the Study Area. The 9% of rainfall recharge rate corresponds to a daily infiltration rate averaging 0.35mm over the course of the year. A realistic maximum daily infiltration rate providing the closest fit to real flow data is about 0.25mm/day. This maximum infiltration rate to groundwater of 0.25mm/day or 6.4% of rainfall over the whole Study Area was used in the model. Only during periods of regular rainfall during the winter months was this rate reached and maintained for any length of time in the model.

For the initial modelling, infiltration was allowed to occur over the whole model. Near surface geology of the Kumeu Study Area shows in excess of 60% of the catchment to be covered by alluvial materials, expected to have a lower recharge rate. If recharge is restricted to the elevated sandstone margins of the catchment, then recharge rates into those sandstone outcrops would be required to occur at near the 0.35mm/day maximum rate, to adequately model the water balance.

Outflow from the system was modelled from the simple excess of water over the soil capacity in any day. An additional amount was removed from the water stored in the soil volume, at the rate of one twenty-seventh of the stored volume (Volume x 0.0365) per day to simulate baseflow from the model. The outflow of water modelled in this analysis was compared with the real flow measured at the Waimauku flow recorder site on the Kumeu River (see Figure 6.2) and a correlation between the two series was found to be 0.477. This low correlation appears due to the time scale used in analysis where heavy rainfall on a given day could result in large flows on either the day of rainfall or the subsequent day in the series dependent on the time of day, location and intensity of the rainfall event. When a 3 day moving average of modelled flow is compared with a three day moving average of actual flow the correlation rises to 0.750, while seven day moving averages give a correlation of 0.845.

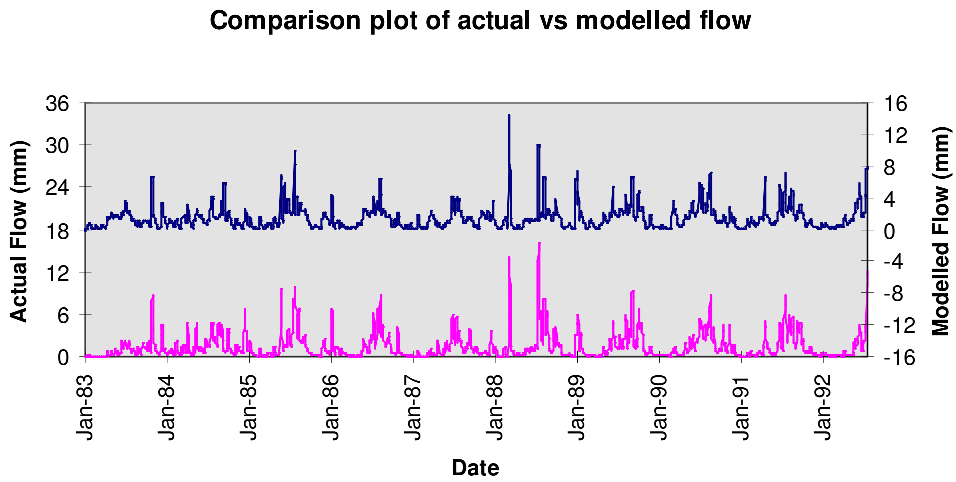

Figure 6.2: Actual and Modelled (top) Flow - Comparison Plot

The overall volume of runoff modelled varied between 88% and 109% of the actual runoff from the catchment in any water year (July to June) with a mean of 97% for the time period modelled. Overall for dry years the model over estimates runoff and under estimates runoff for wet years. A plot of cumulative totals of actual and modelled flows shows good agreement over the period of the record (Figure 6.3).

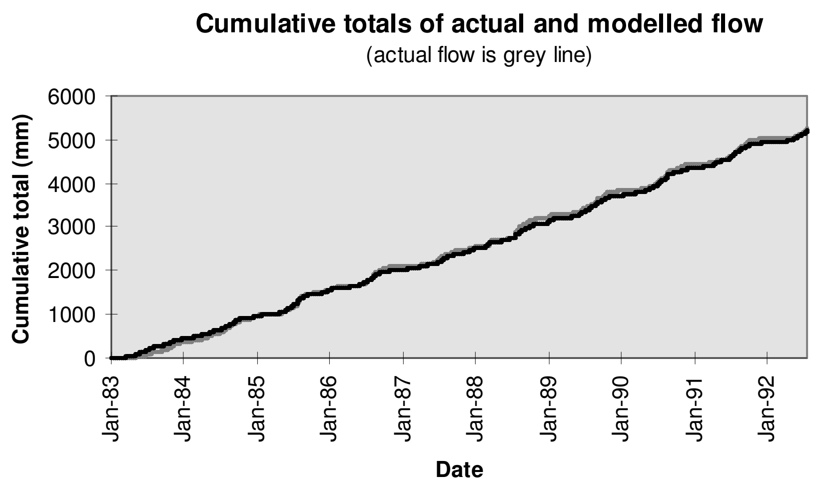

Figure 6.3: Cumulative total plot of actual and modelled flows

From the water that then remains in the soil volume a further amount, if available, is removed to model actual evapotranspiration. If the soil volume is nearly saturated evapotranspiration occurs at the potential rate. If the quantity of water remaining in the soil volume is below a threshold value evapotranspiration was not modelled at the potential rate, as taken from the Hort+Research data, but at a reduced rate proportional to the water stored. In the model actual evapotranspiration occurred at the potential rate as long as the soil moisture store contained greater than a threshold value of available water. When the soil moisture content dropped below the threshold value the rate of actual evapotranspiration was modelled as being dependent on the soil moisture content. During summer periods, actual evapotranspiration dropped to nearly zero during prolonged periods on low rainfall (Figure 6.4).

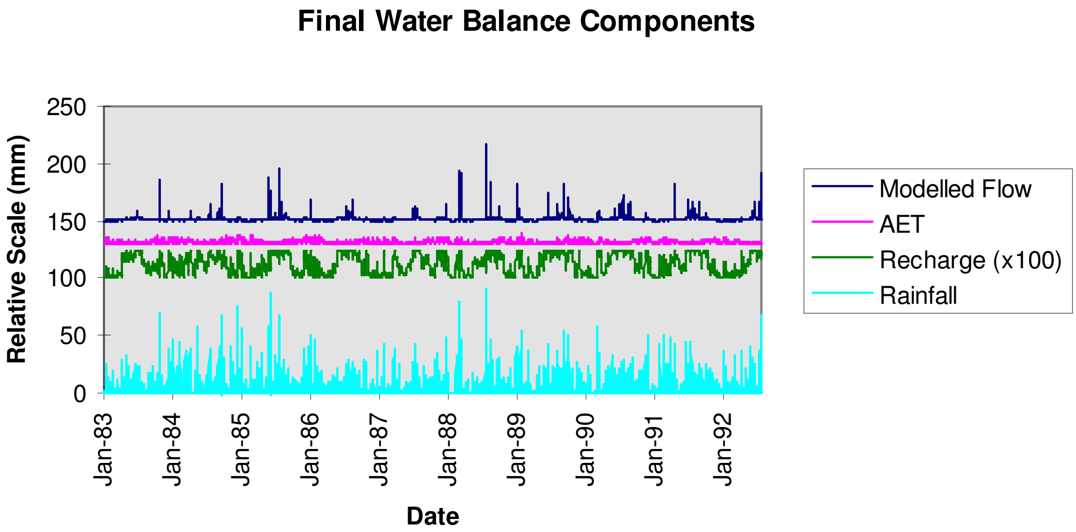

Figure 6.4: Water balance components - Comparison Plot

No consideration was made of inflows or outflows to the model area other than surface water flows. Flows of groundwater from the Study Area probably occur following topography to the west down the Kumeu River and to the east along the coastal margin of the Study Area out to sea. Some inflow from outside the Study Area boundary is likely to occur at all upland boundaries. Given that the Study Area is bounded in all directions except to the east by the same Waitemata Group rock aquifer inflows and outflows within the aquifer are expected to be approximately zero on an annual basis.

Overall results indicate that using realistic combinations of aquifer and climatic parameters a good model can be made for the general water balance of the Study Area. Cumulative totals and seasonal variation of modelled surface flow and recharge can give good agreement with real data and previous calculations. While not describing the aquifer response that would occur as a result of abstractions the model does estimate the annual recharge to an unexploited aquifer with similar aquifer parameters and climatic regime. This would be considered to be approximately the sustainable abstraction rate of groundwater.

6.5 Annual Recharge

Annual recharge into the Waitemata Group rock aquifer in the Study Area calculated from the water balance model varied between 1.74x10^6 m^3 per year to 6.69 x10^6 m^3 per year (1.03% to 3.96 % of average annual rainfall). This figure is near to the conservative estimate conventionally applied to Waitemata Group rock aquifers of 1% to 3% of average annual rainfall.

On the basis of results from water balance modelling it is proposed that a figure of 1.05% of average annual rainfall or 1.77 x10^6 m^3 per year (13,618.5 m^3 per square kilometre) be the conservative total quantity of water recharging the aquifer. This is not the total quantity of groundwater available annually for allocation to users since an allowance must be made for prevention of saline intrusion at the coast. This is current best practice in accordance with the precautionary approach as noted in the Proposed Regional Policy Statement.

Actual recharge to the zones used in the 1989 Management Plan using the above recharge rate gives annual groundwater recharge as shown in the Table 6.2.

Table 6.2 Estimated total groundwater recharge for Study Area

Zone	Area (km^2)	Groundwater Recharge (m^3/year)
1a	8.96	122,022
1b	1.62	22,062
1c	2.3	31,322
1d	2.53	34,454
1e	0.5	6,809
1f	0.38	5,175
Total Zone 1	*16.29*	*221,845*
2	47.81	651,104
3	65.87	897,052
Total	**129.97**	**1,770,000**

6.6 Potential for Saline Intrusion in Coastal Area

Where an aquifer is directly connected to the sea there is potential for saline intrusion to be induced. Under natural conditions fresh water flows from the aquifer to the sea near sea level, with a small return flow of saline water into the aquifer forming what is described as a salt water wedge. The slope of the groundwater surface is towards the coast and the return flow cycles out of the aquifer under natural conditions. Where the flow to the coast is reduced, such as by pumping in the aquifer, there can be an increase in the thickness of the wedge and its penetration inland. If water levels in the aquifer are drawn down to below sea level at the coast by pumping so that the slope of the groundwater surface is inland then saline water will be drawn rapidly into the aquifer. The likely consequence is salt water being abstracted from the pumped bores. Depression of water levels to this extent can be caused by the intense use of individual bores or where groups of bores are pumping simultaneously. For a fuller description of saline intrusion in aquifers refer to Bear and Verruijt (1992).

Calculating how much fresh water is required to flow to the coast to prevent saline intrusion is a difficult problem because of the expansive nature of the eastern coastal margin. The Waitemata Group rocks are approximately horizontal, and the Upper Waitemata Harbour is shallow (less than 10 metres except under the Upper Harbour Bridge) and filled with fine sediment, so the risk of saline intrusion has historically been assessed as low. However, at the International Society for Krishna Consciousness in Riverhead, a bore approximately 400 metres from the coast that supplied up to 120 cubic metres per day of water had to be abandoned after a number of years pumping, due to the increasing salt content of the water abstracted. Huapai Golf Club's bore is located a similar distance from the coast on a neighbouring property. Pumping from this bore induces water level drawdowns to significantly below sea level. This is a high-risk situation although no noticeable salt content has been detected to date.

The coastal zones at greatest risk are the Zone 1 areas of the Riverhead coastline from Riverhead to Brighams Creek Bridge and the south east of the Hobsonville Peninsula. In both areas there are applications for large total abstractions in the near coastal area and concentrations of users with the potential to lower groundwater levels to below sea level at the coast.

On the Hobsonville Peninsula in Zone 1b there are six applications in close proximity requesting a peak daily allocation of 570 cmpd. The combined effect of these abstractions could induce groundwater level drawdowns to as much as 10 metres below sea level at the coast. Even if the entire peninsula were considered as the potential recharge area for these bores, the volumes applied for are more than double the annual recharge. With current zoning these applications represent four times the actual recharge to this zone. Restriction of the allocation to the estimated annual recharge for the zone would reduce water level drawdowns at the coast to less than 1 metre below sea level during the pumping season. The potential for saline intrusion can be minimised further by having the lowest practicable peak abstraction rates prescribed on permits granted in this zone.

Along the Riverhead coastline in Zone 1a to the east of State Highway 16 there are ten applications within a 1.5km^2 area. A total allocation of about 720 cmpd has been requested under these perimts in addition to the existing permit for the Huapai Golf Club for 200 cmpd. On an annual basis this quantity is equivalent to about 26,600m^3 per square kilometre or double the recharge occurring over this area. All of these bores are located within 750 metres of the coast.

6.7 Residual Flow to the Coast and for Stock / Domestic Use

Approximately 30 kilometres of coast form the eastern boundary of the Study Area, including the Barrett and Lloyd Road area of Riverhead. The groundwater divide between Massey and Riverhead causes some flow towards the Kaipara River Valley to the west, with the remainder flowing to the coast. A groundwater divide is a ridge of locally high water levels, where water flow diverges at the high point and flows in opposite directions to areas of lower water level. If an allowance from the total recharge is set aside for prevention of saline intrusion and for stock and domestic users, the total quantity of groundwater available for allocation is reduced.

The proposal for the Study Area is to set residual groundwater percentages for each Zone, with a greater percentage in Zone 3 because of lower use and lower percentages in Zones 1 and 2. In the absence of more rigorous data a figure of 10 litres per day per metre of coastline was adopted as the required flow to minimise the risk of saline intrusion into the aquifer. This equates to 109,500 m^3 per year for saline intrusion protection over the entire Study Area.

6.8 Groundwater Availability for Allocation

If a residual flow volume for saline intrusion is reserved in Zone 3, with an additional volume for stock and domestic users in this zone, the amount of groundwater available for allocation will be approximately 85% of the recharge from rainfall. Availability has been estimated on this basis for Zones 1 and 2 as 95% and 90% of recharge from rainfall respectively. This makes an allowance for stock and domestic users within these zones. The annual availability of groundwater in the Zones of the Study Area are summarised in Table 6.3 below.

Table 6.3: Estimated total groundwater availability for Study Area

Zone	Groundwater Recharge (m^3/year)	Percent Available	Availability (m^3/year)
1a	122,022	95%	115,920
1b	22,062	95%	20,959
1c	31,322	95%	29,756
1d	34,454	95%	32,731
1e	6,809	95%	6,468
1f	5,175	95%	4,916
Total Zone 1	*221,845*	*95%*	*210,750*
2	651,104	90%	585,994
3	897,052	85%	762,494
Total	**1,770,000**	**88%**	**1,559,238**

Because of the Kumeu Basin allocation policies set in 1989 there has been little change in the pattern of demand for groundwater. The 1994 applications do however indicate an increase in the quantity of water desired totalling 13% overall. Zone 1 demand as shown in applications has increased by 9%, Zone 2 by 13% and Zone 3 by 25%. Actual water use based on water meter records has been below the allocated volume for most zones as shown in Figure 6.5,

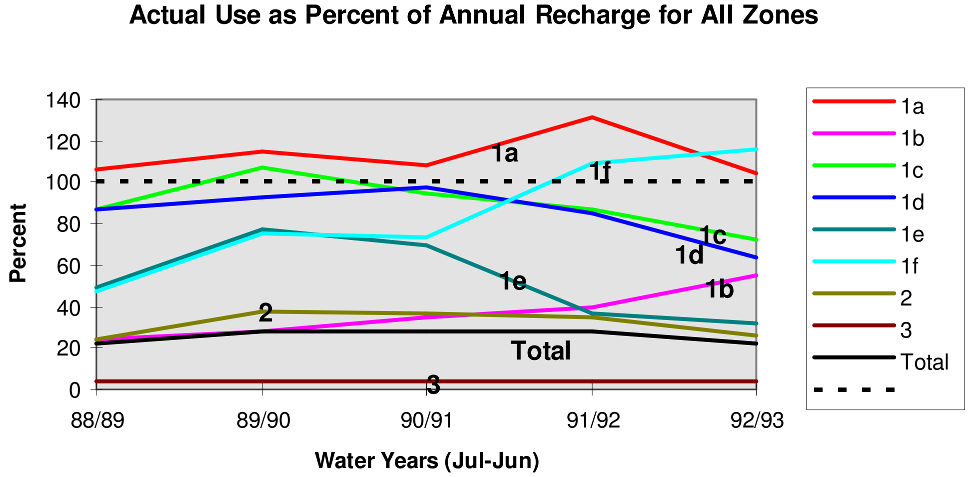

Figure 6.5 Actual Use as a Percent of Annual Recharge for all Zones

The allocations still current from 1989 Management Plan at the time of the initial applications in 1994 totalled a peak abstraction rate of 15,195 cmpd. The quantities requested in 1994 applications come to an estimated total peak rate of 17,199 cmpd, an increase of 13%. If the same criteria for estimating annual groundwater requirements as in 1989 Management Plan are used, all areas except Zone 3 are calculated to be over allocated in terms of availability (see Table 6.4), with 103% of the entire resource applied for. The criteria are given in Section 4, 2.1.1, of the 1989 Management Plan.

Table 6.4: Comparison of availability and estimated total applications

Zone	Availability (m^3/year)	1994 Applications Estimated (m^3/year)	Applications as % of Availability
1a	115,920	263,322	227
1b	20,959	88,830	424
1c	29,756	52,133	175
1d	32,731	48,899	149
1e	6,468	12,525	193
1f	4,916	8,172	166
2	585,994	944,480	161
3	762,494	188,410	25
Total	**1,559,238**	**1,606,771**	**103**

This means that rather than an even level of abstraction over the entire catchment, with slightly greater rainfall infiltration than abstraction at all points, there are areas which are predominantly recharging the aquifer (infiltration exceeds abstraction) and others which are discharge zones (abstraction exceeds infiltration), both naturally and induced by pumping.

As stated in the 1989 Management Plan, the aquifer responds to groundwater use in a variable fashion, which is dependent on localised bore use. The 1989 Management Plan effectively placed a moratorium on additional water allocation in some areas until further investigative work was done. The results of the work completed have shown that only some modifications need be made to the overall understanding of the Study Area, predominantly in the area of conceptual geology and water availability. A strategy is still needed which will adequately address the varying intensity of use across the Study Area and the localised variations in rock permeability and recharge.

The strategy of creating different use zones which was implemented in the 1989 Management Plan has been effective in limiting water level drawdown interference effects between neighbouring users in areas of high peak usage and in areas where geology intensifies water level drawdown effects. In terms of allocation the only practicable strategy is to limit the total quantity of water that can potentially be extracted by resource consent holders and stock and domestic users to that which is actually available over the area being considered. Where localised abstraction rates significantly exceed the availability, policies should be such that transfers of allocation to outside the zone reduce intensity where possible. If salt-water intrusion is a possible effect of abstraction from a bore or group of bores studies should be carried out to determine the true magnitude of that risk and to propose mitigating measures if the risk is high.

7. STATUTORY FRAMEWORK FOR GROUNDWATER MANAGEMENT

7.1 Resource Management Act 1991

The Resource Management Act 1991 (RMA) is the Act of parliament that controls the taking and use of water. The RMA was introduced on 1 October, 1991, and replaced the Water and Soil Conservation Act,1967.

The purpose of the RMA is defined in Section 5 as follows:

> *"(1) The purpose of this Act is to promote the sustainable management of natural and physical resources.*
>
> *(2) In this Act, "sustainable management" means managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural wellbeing and for their health and safety while—*
>
> *(a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and*
>
> *(b) Safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and*
>
> *(c) Avoiding, remedying, or mitigating any adverse effects of activities on the environment."*

Under Section 6 of the RMA, Matters of national importance, all persons exercising functions and powers under the Act, in relation to managing the use, development, and protection of natural and physical resources, shall recognise and provide for five matters of national importance. The only matter relevant to the Kumeu-Hobsonville Groundwater Study Area is:

> *(e) "The relationship of Maori and their culture and traditions with their ancestral lands, water, sites, waahi tapu, and other taonga."*

Under Section 7 of the RMA, particular regard shall be given to eight matters in relation to the managing the use, development, and protection of natural and physical resources. The matters relevant to the Kumeu-Hobsonville Groundwater Study Area are:

> *"(a) Kaitiakitanga:*
>
> *[(aa) The ethic of stewardship:]*
>
> *(b) The efficient use and development of natural and physical resources:*
>
> *………*
>
> *(f) Maintenance and enhancement of the quality of the environment:*
>
> *………*
>
> *(g) Any finite characteristics of natural and physical resources:"*

Under Section 14 of the RMA, Restrictions relating to the taking and use of water, no person may take water unless;

> *"(3) A person is not prohibited by subsection (1) from taking, using, damming, or diverting any water, heat, or energy if—*
> *(a) The taking, use, damming, or diversion is expressly allowed by a rule in a regional plan [and in any relevant proposed regional plan] or a resource consent; or*
> *(b) In the case of fresh water, the water, heat, or energy is required to be taken or used for—*
> *(i) An individual's reasonable domestic needs; or*
> *(ii) The reasonable needs of an individual's animals for drinking water,—*
> *and the taking or use does not, or is not likely to, have an adverse effect on the environment; or*
> ....
> ....
> *(e) The water is required to be taken or used for fire-fighting purposes."*

7.2 Auckland Regional Council

Under Section 30 of the RMA, Functions of regional councils under this Act, the Auckland Regional Council has a number of functions. The Regional Council is responsible for the management of the natural and physical resources of the region. One of the Regional Council's other functions is the control of the taking and use of water, and the control of the quantity, level and flow of water in any water body.

7.3 Territorial Authorities

Under Section 31 of the RMA, Functions of territorial authorities under this Act, territorial authorities have a number of functions. The territorial authorities are responsible for the management of the effects of the use, development, or protection of land and associated natural and physical resources of the district. The type of land use may have an effect on the demand for water and the quantity of water in a water body.

The Kumeu-Hobsonville groundwater study covers an area that includes parts of two different territorial authorities. Parts of the Rodney District Council and Waitakere City Council are both located within the Study Area.

7.4 Proposed Regional Policy Statement

The Proposed Regional Policy Statement (PRPS) defines how the natural and physical resources of the region are to be used, developed and protected. It defines the policies for achieving sustainable management of resources. The purpose of the PRPS is to achieve integrated management of the natural and physical resources of the region.

In accordance with Section 60 of the RM Act, Preparation and change of regional policy statements, the regional council must have a regional policy statement. The regional council has to prepare the RPS in accordance with the RM Act.

The Auckland Regional Council has prepared a proposed Regional Policy Statement for the Auckland Region. The PRPS has been publicly notified for submissions and hearings on submissions to the PRPS have commenced. The PRPS is current until the decision on submissions has been released

Chapter 10 of the PRPS, Water Conservation and Allocation, covers the policies related to the water resources of the region. Section 10.4.7 of the proposed RPS, Policy - Groundwater availability, defines criteria that must be considered in determining the amount of groundwater available for allocation. Section 10.4.10, Policies: Allocation and use of water, defines policies and establishes matters that should be considered in relation to the taking and use of water.

Section 10.4.7 of the PRPS states that the availability of groundwater for abstraction will be determined with regard to a number of criteria. The following are the criteria, which are relevant in the Kumeu - Hobsonville Groundwater Study Area:

I. The abstraction can be sustained by the aquifer.
II. Kaitiakitanga and the relationship of Tangata Whenua and their culture and traditions with their ancestral water, waahi tapu and other taonga.
III. A precautionary approach in relation to the availability estimate, and the requirement to avoid or mitigate adverse effects.
IV. Estimates of groundwater recharge based on aquifer and climate information available.
V. Maintenance of out flow at the coast to prevent salt water intrusion.
VI. Long term maintenance of aquifer water levels.

Section 10.4.10 of the PRPS states that the allocation of groundwater available for abstraction will be determined with regard to a number of criteria. The following criteria are considered relevant in the Kumeu - Hobsonville Groundwater Study Area:

1. The conservation efficient use and reuse of the groundwater resource will be promoted to avoid remedy or mitigate adverse effects which excessive demand would have on natural resources.
   ………

3. The taking and use of water will be controlled with regard to:

   i. The availability of water for abstraction.
   ii. Any actual or potential effects on the environment including other authorised users and the water resource.
   iii. Kaitiakitanga and the relationship of Tangata Whenua and their culture and traditions with their ancestral water, waahi tapu and other taonga.
   iv. Efficient use of any quantity taken or used.
   ………
   vi. The reasonable domestic needs and reasonable needs of animals for drinking water.
   ………
   viii. In determining priorities for the taking of water, preference will be given to those activities which best realise the potential of rural land for primary production, particularly in areas of prime and elite soil.
   ………
   x. Multiple use of aquifers.
   xi. The principles of the Treaty of Waitangi.

7.5 Regional Plans

A regional plan is a plan approved by the regional council that is prepared in accordance with the requirements of the RMA. The purpose of a regional plan is to assist the regional council in carrying out any of its functions. A regional plan may be prepared in respect of any of the regional council's functions.

Under Section 65 of the RMA, Preparation and change of other regional plans, the regional council shall consider the desirability of preparing a regional plan under certain circumstances. There are a number of circumstances that apply to the Study Area. These include:

- Conflict between use, development, or protection of natural and physical resources
- Need for the protection of natural and physical resources
- Demand for or on natural and physical resources

Under Section 68, Regional rules, a regional council may include in regional plan rules that prohibit, regulate, or allow activities.

8. ISSUES

In the Kumeu-Hobsonville Groundwater Study Area conflict arises between the demands for abstractive use and protection of acceptable groundwater levels, flows and quality (chemistry of the water) in the aquifer.

Groundwater is the water that is contained in rocks under the surface of the ground. Water taken out of the ground is replenished by rainfall. After some rainfall has evaporated, been used by plants or run-off into streams, a proportion of the rainfall soaks through the soil into the rock below by gravity. The water moves down through spaces and cracks in the rock. Layers of rock that contain significant quantities of water and allow it to flow through them are called aquifers. Groundwater discharges naturally from aquifers at springs, rivers or at the coastal edge of the aquifer into the sea.

Rainfall that soaks into the rocks under the surface of the ground is called recharge. Different amounts of rainfall soak into aquifers in different parts of the Auckland region. The amount of rainfall infiltration also varies with the seasons of the year. The type of rock, and number of connected spaces and cracks within the rock mass have an effect the amount of water that soaks into an aquifer. Rocks with lots of connected spaces between rock particles such as subsurface layers of gravels allow water to flow more freely and therefore a greater proportion of rainfall soaks into the rock below the ground. Other well compacted or solid rock such as sandstone may have few connected spaces between rock particles and cracks in the rock mass. Under these circumstances water can not flow as easily through the rock. Therefore, a smaller proportion of rainfall soaks into the rock below the ground in these areas.

The main aquifer in the Kumeu-Hobsonville Groundwater Study area is the Waitemata Groups rocks. The Waitemata Group rocks are well consolidated layers of sandstone and mudstone. Spaces between the sand and mud particles, which make up the rock mass are relatively small. In the sandstone layers that contain coarser sediment the spaces are larger than in the fine grained mudstone layers. The movement of water is expected to be predominantly through the sandstone layers and through fractures and cracks in the rock mass where they exist. The proportion of rainfall that soaks into the aquifer in the area is relatively small. In the Study area it has been calculated to be approximately 1% - 3% of annual rainfall. The movement of water through the aquifer is relatively slow.

8.1 Abstractive Use

Groundwater is a limited resource. There is a limit to the amount of water that can be safely taken out of the aquifer. The groundwater resource must be managed in a sustainable manner to ensure the long-term continued use of the resource. Each year the total quantity of water taken by all groundwater users within a specific area should not be greater than the amount of recharge from rainfall that soaks into the aquifer.

If too much water is pumped from the aquifer problems will occur. Taking more water out of an aquifer than soaks in by infiltration of rainfall each year will cause the water level in the aquifer to be lowered. The water level in the aquifer affects the amount of water that can be pumped from individual bores. If water levels in an aquifer progressively decline, bore yields will correspondingly decrease. To obtain the same amount of water, users would incur greater expense by drilling deeper bores and / or pumping for longer periods. Ultimately this would result in it becoming uneconomic for users to continue pumping.

At the coast groundwater flows out through the aquifer into the salt-water marine area. There is a progressive transition from fresh groundwater to salt water at the coast. The fresh groundwater is not as dense as the salt water and it tends to float on top of the salt water in the area where they overlap. The salt water forms a "wedge" shape that extends inland with fresh water overlying it. Further inland there is a greater depth of fresh water overlying the sea water. The position of fresh water / salt-water interface can move depending on the amount of fresh water that flows out of the aquifer. The continuous natural flow of groundwater through the aquifer at the coast keeps the salt water from moving inland.

In areas close to the sea, taking too much water from the aquifer can move the position of the fresh water / sea water interface further inland, resulting in salt water contamination of the aquifer and the bores abstracting water from it. Under these circumstances the natural flow of groundwater through the aquifer to the coast is reversed. Salt water then moves through the aquifer further inland. An aquifer contaminated with salt water would not be suitable for use and bores abstracting water from it would have to be abandoned.

8.2 Aquifer Protection

Competition between users who take groundwater in Kumeu-Hobsonville Study Area has to be resolved where demand for the limited groundwater resource exceeds the quantity of water that the aquifer can safely yield in the long term.

Once the quantity of groundwater that can safely be abstracted has been determined, this quantity must be divided as fairly as possible amongst all those users who wish to take groundwater. If there is not sufficient water available for all users, some users will not obtain sufficient water for their requirements. Under these circumstances the most suitable basis for distribution of the water resource available for allocation to users has to be determined in order to meet the purpose of the RMA.

9. OBJECTIVES

The objectives of groundwater management for the Kumeu-Hobsonville Study Area are:

1. To maintain groundwater quantity, level and quality of the aquifer in the Kumeu-Hobsonville Study Area in the long term for all users, in order to prevent depletion of the resource and salt water intrusion at the coast.

2. To provide for conservation and efficient use of groundwater from the aquifer in the Kumeu-Hobsonville Study Area that enables people and communities to provide for their present and future social, economic and cultural needs, while not compromising Objective 1.

3. To improve the quality of data, in particular the water use data from users, which is required to make accurate assessments of the amount of water available for allocation from the aquifer in the Kumeu-Hobsonville Study Area.

4. To apply the same rules to proposed and existing groundwater users.

5. To remove obstacles to more efficient allocation and use of the groundwater resource available for allocation to users.

10. POLICIES

10.1 Kumeu-Hobsonville Groundwater Study Area

The Kumeu-Hobsonville Groundwater strategy shall apply to the area shown in Figure 10.1.

Explanation

The boundary of the Study Area generally corresponds to the surface water catchment area. This is because the amount of water in the aquifer depends on the amount of recharge from infiltration of rainfall. Rainfall within the surface water catchment soaks into the subsurface layers of rock. The study area does not represent any difference in geology. Beyond the Study Area similar geological conditions are expected to exist in the near vicinity.

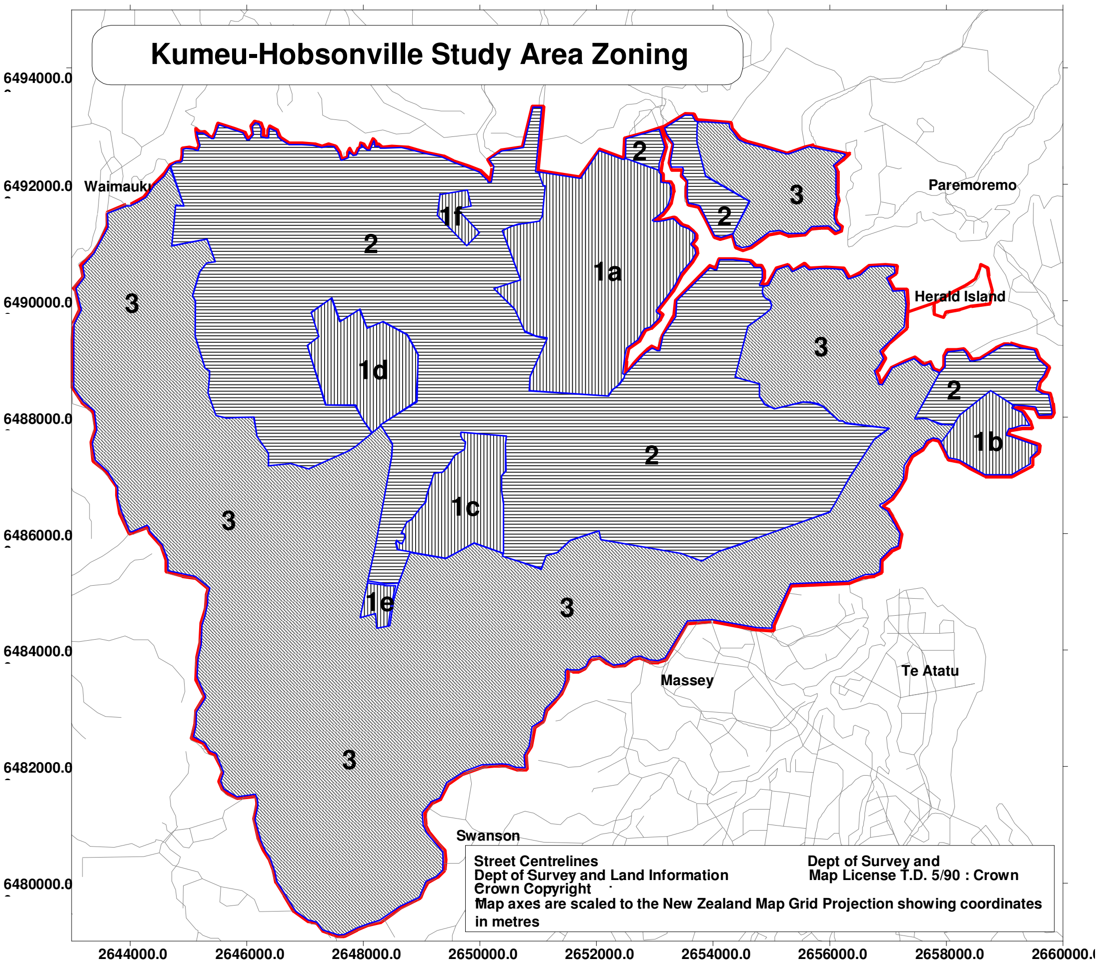

Figure 10.1: Map of Kumeu-Hobsonville Study Area Zones

10.2 Groundwater Availability

That the quantity of groundwater available for allocation in the sub-areas of the Study Area shall be in accordance with the following Table 10.1 unless further investigations significantly alter the estimate of recharge.

Table 10.1: Estimated total groundwater availability for Study Area.

Zone	Availability (m^3/year)
1a	115,920
1b	20,959
1c	29,756
1d	32,731
1e	6,468
1f	4,916
Total Zone 1	210,750
2	585,994
3	762,494
Total	**1,559,238**

Explanation
There are currently 264 water users located within the Study Area who require water permits. However, water use is not uniform over the study area. There are zones of high demand where use is equal to the amount of recharge from rainfall. The groundwater resource must be managed carefully in these areas. In order to avoid adverse effects on the aquifer the Study Area has been subdivided into smaller more manageable areas. The selection of sub-areas is based on areas of high demand in different parts of the Study Area and the effect of the demand on the groundwater system. The sub-areas do not generally indicate any difference in geological conditions.

10.3 Groundwater Allocation

That the total annual quantity of groundwater granted to all resource consent holders within a particular sub-area shall not exceed the total quantity of groundwater available for allocation from within the same sub-area.

Explanation
Taking a greater amount of water out of the aquifer each year than naturally recharges from annual rainfall is not sustainable in the long term. The depth to the water table in bores fluctuates over time. Water level fluctuations occur when water is pumped out of the ground and when rainfall infiltration recharges the aquifer. If more water is pumped out of the aquifer than is recharged by infiltration of rainfall then, the maximum depth to the water table increases. If this situation is allowed to occur over a period of time, the water level in some bores may drop below the pump intake, bore yields would reduce and the risk of salt water entering the aquifer at the coast would increase. These problems would not necessarily develop immediately, as the movement of water through the ground in the study is relatively slow. However, if this situation was allowed to occur over a period of years, the situation would get progressively worse.

10.4 Conservation and Efficient Use

That the quantity of water allocated to water permit holders shall be based on conservation and efficient use of groundwater and that priority shall be given to efficient water users where possible.

Explanation
There is a limit to the amount of groundwater available for allocation. In order to achieve the purpose of the RMA, the groundwater resource must be used efficiently. Conservation and efficient use must be considered. The quantity of water allocated to users must be based on efficient use of the water resource. Greater water use efficiency will result in greater production from the same amount of water and less waste. The groundwater resource must be allocated in a manner, which promotes wise and efficient use. Those water users who can show that they are efficient should be given priority over those who are inefficient. Water audits aimed at improving water use efficiency and reducing waste are encouraged particularly for industrial water users where water use efficiency can depend on processes and procedures adopted. Similarly irrigation scheduling for horticultural users aimed at improving water use efficiency is also encouraged.

10.5 Priority for Existing Users

That existing developments owned by authorised users shall be given priority in the allocation of available groundwater, provided that the quantity allocated to them is based on efficient use of the water resource.

Explanation

Previously authorised groundwater users with existing developments have invested considerable time and capital. The investment was based on the reasonable expectation that by obtaining a water permit they were securing a right to use the water resource and that their continued use would be protected. Existing investment that have been made by authorised users should be protected as far as practical. However, this can not be done in isolation. There are other factors to consider such as the efficient use of the water resource. Previously authorised water users must be as efficient as all other users and allocations must reflect this. Previously authorised water users with existing developments will not automatically be granted the same volumes as they previously held. Those who have not developed or not fully realised their initial proposals are not necessarily entitled to the same amount of water as they were previously granted. They should not get any priority for future development over those people who have not previously held a water permit.

10.6 Priority for Smallest Water Requirements

That priority in the allocation of available groundwater, not required by previously authorised users for existing developments shall be given to those applicants who require the smallest annual volumes of water and who are efficient water users.

Explanation

Allocation of water to applicants who require the smallest volumes of water on an annual basis will ensure that a greater number of users will be given a opportunity to pursue their proposal. More people are likely to benefit from use of the groundwater resource.

10.7 Land Use Designation

That consideration must be given to prevailing land use designations when processing water permit applications.

Explanation

It is inappropriate to grant water permits for activities that are inconsistent with the prevailing land use designation. If the activity can not proceed because it is located in an area where the prevailing land use designation is inappropriate a water permit should not be granted. Based on consultation with Tangata Whenua and interested parties there is support for priority to be given to rural activities in the rural areas. The policy supports this concept. However, if it should be noted that if other land uses are allowed under the prevailing land use designation these activities should not necessarily be penalised at the expense of rural developments. Water allocations should be based on efficient uses of the resource. It is not possible to compare water use efficiency between different types of development. The same rules should apply to all users irrespective of type of development.

10.8 Multiple Consents

That where possible, permits to take water should be linked to and / or determined at the same time as any other resource consents that may be required for a particular development, provided that ARC considers that it is practical to do so, and appropriate under the circumstances.

Explanation
Resource consents for different activities related to the same proposal must be consistent with each other. For example applications to take water must have due consideration to provision for adequate waste water disposal, where waste water disposal is required. It would not be appropriate to grant a water permit if there was considered to be inadequate waste water disposal. Similarly it may not be appropriate to grant a water permit for an activity where land use consent is required and has not been obtained.

There is provision under section 91 of the RMA where if it is considered necessary ARC may determine not to process any application until all resource consent applications for a particular development have been lodged. However, it is not always possible to process all resource consents at the same time. For example a discharge permit and a water permit for the same development may not expire at the same time.

10.9 Water Bore Level and Sampling Access

That holders of resource consents to take groundwater shall be required to provide water level and water quality sampling access to their production bore (provided that it is practical).

Explanation
Studies of the groundwater system are undertaken in order to determine the amount of water that can safely be taken out of the ground. The collection of water level and water chemistry information from bores are very important parts of studies of groundwater systems. The water level in aquifers changes over time. Water levels change in response to pumping and recharge from rainfall. When the majority of groundwater users in the area pump over the summer, the water level in the aquifer decreases. The majority of users cease irrigation at the end of the summer, and a greater proportion of annual rainfall infiltrates into the ground over the winter period causing the water level to rise

It may not always be practical to provide provision for water level measuring. For example when surface pumps are permanently installed over the well head the pump must be removed in order to get water level access.

The long term trend in aquifer water levels is a measure of the state or "health" of the aquifer. Summer minimum water level, and winter maximum water levels, are compared from year to year in order track the effect abstraction is having on the groundwater system. The water level maximums should not progressively decrease over time. Water level information in conjunction with other hydrological data can be used in mathematical models representing the aquifer system, which are used to predict the behaviour of the aquifer under different circumstances. For example, to predict the likely effect on the aquifer water levels if different amounts of water are taken, or water is taken from different locations.

Water contains dissolved minerals. The mineral composition of groundwater is influenced by the mineral composition of the rock that the water is in contact with and the length of time the water has been in the ground. Chemical analyses of water samples can be used to identify the type of aquifer the water came from and to check that the quality of the water is suitable of the intended use.

The chemistry of groundwater may change with time. Continual monitoring of groundwater chemistry is particularly important in areas close to the coast, to check that the water is free from salt water contamination.

10.10 Metering Water Use

That every person that holds a water permit or exercising the permitted activity for minor water use shall be required to accurately measure and provide ARC with records of their water use. A water flow meter (or other flow measuring device approved by ARC) shall be fitted before any water permit or permitted activity is exercised. Records of at least the weekly water meter readings shall be provided at three monthly intervals by permit holders and those people exercising the permitted activity to take groundwater.

Explanation

The collection of water use information is an important part of studies of groundwater systems to determine the amount of water that can safely be taken out of the ground. Water use in conjunction with other hydrological information is used in mathematical models representing the aquifer, which can predict the behaviour of the aquifer under different circumstances. Records of water use can also be used to help determine the efficiency of water use and compliance with consent conditions. The installation of water flow meters and provision of water meter readings were previously required under the 1989 Management Plan for the area. The level of compliance with fitting meters has been good. However, the level of compliance with returning meter readings has generally been poor. Increasing the frequency with which returns are required, to quarterly is expected to help improve the level of compliance with meter readings being returned.

10.11 Permit Water Quantities

That all water permits shall, specify both a maximum daily and a total annual allocation. These allocations shall be based on realistic estimates of use for the type of development and take into account currently available information on water requirements. Consideration shall be given to the maximum expected bore yield and the expected effect on any other users.

Explanation

The quantity of water that can safely been taken out of the aquifer each year must be divided as fairly as possible between all those people wanting to use it. Water users do not use their maximum daily water requirement each day. The pattern of water use generally changes throughout the year. Therefore, an annual quantity of water must be allocated to each individual water permit. This will help to ensure that the amount of water available from the aquifer for allocation on an annual basis is not under utilised and the maximum benefit to the community is derived from the resource.

Maximum daily and total annual allocations are generally based on estimated water use guidelines for different types of development. In the 1989 Management Plan for the Study Area water permit applicants were given annual allocations based on a fixed multiple of their maximum daily allocation over a fixed number of days. Applicants located in those sub-areas with high daily demand were allocated less water on an annual basis than those applicants in areas of lower demand in order to accommodate all the existing users at the time. This approach may have lead to some applicants being allocated unrealistically high or low annual allocations in some circumstances. A more flexible approach to determining annual allocations in particular, to more accurately reflect actual use should result in a more efficient distribution and use of the water resource available for allocation.

10.12 Permit Expiry Date

That water permits shall be given a term with an expiry date of December 2010 and a review condition in order that they can be reviewed in December 2000 if necessary and subsequently at not less than five yearly intervals, prior to the expiry date.

Explanation
Under the RMA, the conditions of a permit can be reviewed before a permit expires. Most water permits within the Kumeu-Hobsonville Groundwater Study Area last expired in 1989. This was before the introduction of the RMA. At that time it was not possible to review the conditions of a permit before it expired. Permits were granted for a period of approximately 5 years, so that ARC could make changes to the management of the area at the end of that time. Now that permit conditions can be reviewed before a permit expires it is no longer necessary that permits expire at 5 year intervals.

A review condition on a water permit allows the permit to be reviewed at the times specified, before the permit expires. This will enable ARC to make changes to the conditions of permits including allocations if necessary, to take into account any adversely cumulative effects of abstraction in the management of the area and the prevailing development. Existing developments are subject to change due to change in ownership, economic circumstances or other factors. Existing crops or development may be removed and replaced with another crop or type of development. This may have an effect on the amount of water required. Accordingly it is necessary to regularly review permit allocations and other conditions to determine whether or not they are still appropriate under the prevailing circumstances.

10.13 Non-exercise of Consent

That water permits that have not been exercised for a continuous period of 2 years and which are located within sub-areas of the Study Area where 100% of the groundwater resource considered to be available is allocated, be cancelled.

Explanation
Under Section 126 of the RMA ARC may cancel a resource consent if it has not been exercised for a continuous period of 2 years although provisions exist for appeal to this. It is considered desirable to do this within the parts of the Study Area where 100% of the available groundwater resource has been allocated. This will prevent those water permit holders who do not exercise their water permit from retaining allocations that they have not used. It will allow any prospective users, who may not otherwise be able to obtain a water permit because the resource has been fully allocated, an opportunity to share in that part of the resource which has not been utilised. This should promote a greater use of the groundwater resource

that is available for allocation. Water permits that have not been exercised are sometimes retained if the consent holder thinks that it is difficult to obtain a permit and that the permit is worth more in financial terms than the cost of obtaining a permit. This does not result in efficient use of the groundwater resource.

10.14 Transitional Regional Plan Regional Rules

That the current Transitional Regional Plan regional rule allowing minor water use as a permitted activity shall be retained within the Study Area.

Explanation
Under the existing regional rule for minor water use, small amount of water can be used under certain circumstances without a water permit. The concentration of water used per unit of land area is expected to be no greater than for stock and domestic use. A water permit is not required for an individuals stock and domestic use. To be consistent minor water use for purposes other than stock and domestic supply should be allowed without a water permit. The existing regional rule for minor water use is a time and cost effective means of taking account of small amounts of water use that have no adverse environmental affects.

11. METHODS TO IMPLEMENT POLICIES

The policies shall be implemented through the processing of water permit applications and the application of criteria for the permitted activity (regional rule) relating to the taking of water.

As previously indicated in Section7.1 of this report under the RMA a water permit is required from ARC to take and use water, unless the use is allowed under a regional rule or the water is taken for an individual's reasonable domestic or stock drinking water requirements. Conditions on water permits, the criteria for permitted activities to take water and the enforcement of these conditions, are the means by which the taking and use of water is controlled. Each water permit and permitted activity authorisation specifies the quantity of water that can be taken. Determination of the quantities allocated to each individual permit will be based on the policies. Conditions imposed on water permits will also give effect to the other polices such as the requirements to provide water level and water quality sampling access, fit a water flow meter and provide records of water use and the expiry and review of permits.

The methods for implementing policies has not changed since the formulation of the 1989 Management Plan.

12. REASONS FOR ADOPTING OBJECTIVES AND POLICIES

The objectives and policies have been adopted as they are considered to be the most effective means of promoting and supporting the principles of the RMA and the PRPS.

The purpose of the RMA has been previously discussed in section 7.1 of this report. It is to promote the sustainable management of natural and physical resources which includes water resources, while having particular regard to factors such as maintenance and enhancement of the quality of the environment, efficient use and development of natural and physical resources, the efficient use and development of natural resources and any finite characteristics of the natural resources. The objectives and polices adopted support these principles.

The PRPS has previously been discussed in section 7.4 of this report. The policies of the PRPS are consistent with the principles of the RMA. The policies adopted in this report have been based on those in the PRPS. In particular groundwater availability has been determined with regard to the long term sustainable use of the aquifer, estimates of recharge based on available hydrological information, a precautionary approach to the estimate of water considered to be available of allocation, the prevention of salt water intrusion into the aquifer in coastal areas and the maintenance of water levels.

The water allocation and use policies have been determined with regard to the amount of water considered to be available for allocation, actual or potential effects on the environment including other users, efficient use of any quantity taken or used, reasonable domestic and stock water drinking requirements, rural activities in rural areas and multiple use of the groundwater resource.

13. REASONS FOR ADOPTING METHODS OF IMPLEMENTATION

The Auckland Regional Council currently has a Transitional Regional Plan. The Regional Plan consists of a number in regional rules. The regional rules that are relevant to the management of the Kumeu - Hobsonville Groundwater study area include the permitted activities relating to taking water and the Water Bore Bylaw 1987.

A permitted activity is an activity that is allowed without a resource consent. In accordance with the current permitted activities related to taking water, provided that there is no adverse effect on the environment, under certain circumstances small amounts of water may be taken without a water permit. It is intended that the permitted activities relating to the taking of water cover minor water uses such as spray make-up and small community supplies, where the affect of the activity is negligible. The permitted activity relating to taking of water provides an effective means of authorising the abstraction of small amounts of water without users having incur the expense of obtaining a permit which would otherwise be required under the RM Act.

The Water Bore Bylaw 1987 relates to a number of issues including the installation of water bores, fitting measuring and recording devices, keeping of records, wasteful use of groundwater and the pollution of groundwater. Land use consents are required from ARC to drill or alter a bore. Land use consents for bore construction are issued subject to a number of conditions relating to the location and construction of the proposed bore. The construction conditions are aimed at preventing contamination of the aquifer. It is important to note that the land use permit for construction of the bore is separate from a water permit or permitted activity which authorise the abstraction of water from a bore.

14. CONSIDERATION OF ALTERNATIVE ALLOCATION POLICIES

It is considered unlikely that any one allocation strategy will be considered universally acceptable to all existing and proposed water users particularly when there is a range of development types. Normally users will support the strategy that they consider will be the most beneficial to them, which is understandable. ARC must adopt the strategy that best meets the purpose of the RMA and is consistent with the policies in its PRPS. A number of alternative allocation strategies have been considered.

14.1 Fixed Allocation per unit area of land owned

The total amount of water available for allocation could be equally distributed over the total amount of land within a particular sub-area. Based on current estimates there is considered to be 13,620 m^3/year/km^2 available for allocation. This is equivalent to 130m^3/year/ha or approximately 0.4m^3/day over 365 days. This volume of water would generally not be sufficient for any type of development including horticultural. Anyone undertaking any type of development would have to own large amounts of land in order to secure sufficient water for their requirements. Water would effectively be reserved for all land owners. While this may seem equitable it to some, current developments could not be sustained without subsequent reallocation of the water resource. Water would effectively be allocated to those land owners who had not even lodged an application to take water and had no intention of using it. This would an inefficient use of the groundwater resource and as such it would not fully meet the purpose of the RMA or the policies for the allocation and use of water defined in the PRPS.

14.2 Auctions

The total amount of water available for allocation could be offered for auction. Interested parties would have to bid in an auction organised by ARC to secure sufficient water allocation for their requirements.

The advantage of an auction system of resource allocation is that, provided that certain market place conditions are met then, according to economic theory the resource will be distributed in an efficient way. ARC would not have to attempt to compare water use efficiency for different types of uses or set any priorities for the allocation of water. The market place would determine the value of the water resource. Those participants willing to pay the most for the resource are expected to be able to derive the most benefit and / or be the most efficient users.

There are a number of conditions that would have to be met in order that the an auction operates successfully. These are that;

- the size of the available resource is well understood and demand exceeds availability, otherwise competition for the resource will not develop
- the resource consent is granted for sufficient time to offer security of supply to the holder
- resource consent conditions are rigorously enforced

The auction system of allocation is expected to appeal most to proposed water users who see it as a means of obtain a water permit when they may otherwise not be able to. People with existing developments are expected to be reluctant to endorse the auction system of allocation. They have invested time and capital into existing developments and have considerably more at stake than those people without existing developments. They may also have a sense of ownership of the water resource and be reluctant to see something that is essential to their development treated in a commercial manner. Another factor that may deter people from endorsing the auction system is the concern over the use of the funds raised.

An auction system is expected to be confrontational and is not expected to offer any significant advantages over a trade in permits (discussed in section 18.3 of this report). In addition while it could be argued that an auction system of allocation would result in an efficient use of the water resource there is no guarantee that it would meet all of the policies related to the allocation and use of water in the PRPS. In particular regard to the actual or potential effects on the environment including other authorised users and possibly the preference to activities that do not need to locate in the rural area, though rules could be formulated to address these issues.

14.3 Allocations only for existing planted area

Allocation of the available water resource only to previously authorised users with existing developments offers security to those people who have already invested time and capital. However, existing developments and patterns of water use are subject to change due to change in property ownership, economics and operational changes. Allocation of the water resource should be equitable and promote the most efficient use of the water resource. Allocating water without giving consideration to new developments proposed by previously authorised users and new applicants will prevent this happening.

14.4 Economic instruments

Under section 36 of the RMA a local authority may charge consent holders for the costs of administration, monitoring and supervision of resource consents and the cost of carrying out the councils functions. ARC charges all consent holders an annual fee. The annual fee charged to water permit holders is based on a number of different factors. These factors include the maximum daily volume of water allocated, what the water is used for and the particular water resource that is being used.

This results in water permit holders being charged higher annual fees for larger allocations, in areas where there is a high demand for the resource compared to that available for allocation. The annual fee is charged to all water permit holders irrespective of whether they exercise their permit. The fee is not a charge per cubic metre used, as is often the case for municipal water supply.

When the annual fee was first introduced it caused some consent holders to review their water requirements. Economic theory suggests that if water permit holders incur a larger financial cost to obtain water, then they would be likely to use it more efficiently (depending on price elasticity). They would also be less likely to want to obtain allocations in excess of their requirements, which has sometimes been the case in the past. Annual fees for water permits are set by ARC in a separate process, which must be in accordance with section 36 of the RMA. They can not be used as a direct means of allocation of the available water resource and as such can not be considered an alternative allocation strategy.

14.5 Priority to existing developments / bore owners

Previously priority of water allocation was given to existing unauthorised water users and proposed users with existing bores. This rewarded unauthorised water use, which must be penalised not encouraged. Existing bore owners are not necessarily any more likely to carry out their proposal and should not be given any priority in water allocation. This strategy is unfair to those people who do not have a bore and have not taken water without authorisation. It does not promote sustainable management of the water resource or the policies for allocation and water use in the PRPS.

14.6 Promotion of alternative water sources

The promotion of alternative water sources such as dams could be considered an alternative strategy for the allocation of the groundwater resource. It is however exchanging one set of environmental effects for another. It may be difficult to compare the environmental effects to determine if the effects of one activity are any more or less acceptable than another. Different groups will have different values and make different judgements. For example Maori cultural values are such that damming of surface water is not endorsed.

14.7 Water audits and irrigation scheduling

Water audits and irrigation scheduling are considered to be effective means of improving water use efficiency. They may not provide an independent allocation strategy, however they are a useful tool that can be used to determine water requirements more accurately. Water audits and irrigation scheduling have been incorporated into the policies for allocation of the available water resource. They are consistent with the purpose of the RMA and the policies for the allocation of water in the PRPS.

Water audits can be done on industrial and domestic water users. The audit process for industrial water users involves: establishing a ratio of water use to unit or dollar production, specifying all the separate areas of water use and accurately measuring the amount of water used in each area, ranking the areas of water use from largest to smallest, considering what steps can be implemented to reduce water use in each of the areas and which of these are cost effective within an adopted pay back period, implementing cost effective changes and then rechecking the water use to production ratio and comparing it with the industry standard if applicable to track improvements. Water audits can also be done on domestic supply. This generally consists of installation of water saving devices.

Irrigation scheduling involves recording rainfall, soil moisture and evapotransporation to determine whether or not there is enough moisture in the ground before deciding to irrigate. Evapotransporation figures are published in the NZ Herald. Tensiometers and / or a neutron probe service are uses to measure soil moisture.

15. ENVIRONMENTAL RESULTS ANTICIPATED

The following environmental results are anticipated from the implementation of the policies and methods:

(a) The water levels, quantity and the quality of the groundwater within the Kumeu-Hobsonville Study Area will be maintained at acceptable levels in the long term. The quantity of groundwater available for allocation to water permit applicants on an annual basis will not be greater than the amount of recharge to the aquifer from annual rainfall. This will prevent the progressive lowering of water levels in the aquifer over a number of years.

(b) The amount of water available from individual bores should not reduce over time because of the long term maintenance of water levels in the aquifer. The quantity of water that can be obtained from an individual bore is affected by the water level in the bore. The lower the water level in a bore, the less water the bore is capable of yielding.

(c) The quality of water from bores located near the coast will not be effected by salt water intrusion into the aquifer because in determining the amount of water that is available for allocation to users consideration has been given to the proportion of annual recharge which is required to maintain the natural flow of groundwater through the aquifer to the coast. Maintaining the natural out flow of groundwater in coastal areas such as Riverhead and Whenuapai is essential to prevent the movement of salt water inland.

(d) More communities and people are expected to be able to provide for their present and future water requirements. There is expected to be an improvement in the efficient use of the water resource available for allocation, achieved by promoting efficient use in allocation of the resource and removing barriers to efficient use. This will ensure that more people are able to obtain a greater benefit from use of the water resource.

16. MONITORING AND REVIEW

The following on going monitoring is considered necessary in order to evaluate the sustainability and the effectiveness of the policies and methods:

16.1 Environmental monitoring

(a) The measurement of static water levels in all of ARC's established monitoring bores which are located within the Kumeu-Hobsonville Groundwater Study Area. ARC has a number of established monitoring bores in the study area. The water levels in these bores are recorded continuously by electronic means or manually.

(b) The measurement of static water levels in selected bores at bi-annual intervals, once at the end of the winter period when water levels are expected to be at their maximum and once at the end of the summer irrigation period when water levels are expected to be minimum.

(c) The measurement of static water levels in selected bores at appropriate intervals when considered necessary, such as during critical low rainfall periods.

(d) The sampling and chemical analysis of groundwater from bores at selected sites within the study area and in particular from bores located near to the coast at the end of the period of greatest demand when water levels are at their minimum, in order to detect any change in groundwater chemistry over time.

16.2 Consent compliance

ARC will enforce the requirement to hold a water permit, all the conditions attached to any water permits and criteria for permitted activities that are exercised. Enforcement is essential to ensure the sustainable management of the groundwater resource.

If any water is taken for a purpose other than those specified in section 14 of the RMA without a water permit or in accordance with the permitted activities, then appropriate enforcement procedures considered necessary will be used by ARC.

The requirements to fit water flow meters, provide records of water meter readings and adhere to the quantity of water allocated will be strictly enforced. The accuracy of the records of water meter readings provided will be checked against readings made by ARC. Records of water meter readings provided will be analysed and used to determine compliance with the conditions relating to the quantity of water allocated. If the permit conditions and criteria for the permitted activity are not complied with, then appropriate enforcement procedures considered necessary may be used by ARC.

Under the RMA there are a number of enforcement options available to ARC. These include abatement notices, interim enforcement orders, enforcement orders and prosecutions. The decision on which of these options will be used will depend on the particular situation.

Compliance with the requirement to have the appropriate authorisation to take water and compliance with the conditions of water permits and criteria for permitted activities is essential in order to manage the groundwater resource sustainably. If more water is taken from the aquifer than recharges it from infiltration of annual rainfall there will be adverse effects on the environment.

16.3 Water user involvement

It is important that water users understand and accept that it is necessary to manage the groundwater resource sustainably. If users understand the reasons for allocation strategies then they will be more willing to accept them and comply with the conditions of their consents. Water user involvement should be encouraged in order to give effect to the sustainable management of the groundwater resource. This may take the form of groundwater user newsletters, public meetings and other correspondence in order to provide information to users. Where close liaison is required it is appropriate that ARC liaise with a groundwater users committee that represents the interests of different user groups. Groundwater user committees are particularly important in areas where the amount of water available has been all been allocated to users.

16.4 Iwi involvement

There should be on going consultation between Tangata Whenua and ARC with regard to the management of the groundwater resource.

Under section 7 of the RMA in managing the use, development and protection of natural and physical resources particular regard must be given to Kaitiakitanga. Kaitiakanga means the exercise of guardianship, and in relation to natural resources, includes the ethic of stewardship. The policies relating to the allocation and use of water in the PRPS require that regard be give to Kaitiakitanga and the relationship of Tangata Whenua and their culture and traditions with their ancestral water, waahi tapu and other taonga. In order to achieve this on going liaison between Tangata Whenua and ARC is necessary. This is expected to be particularly important when management strategies are reviewed.

16.5 Reporting

There is a requirement under section 35 of the RMA for ARC to gather information, and undertake or commission research, as is necessary to effectively carry out its functions under the RMA. This may cover the whole or any part of ARC's area of responsibility. It includes the Kumeu-Hobsonville Groundwater study Area. Reporting shall be at the frequency ARC considers to be reasonable under the prevailing circumstances. Reporting is likely to coincide with the review of water permits. ARC is moving towards annual "state of the environment" reports.

16.6 Resource statement and allocation strategy review

The determination of the quantity of water that is available for allocation is an iterative process. The assessment should be continually reviewed in light of the available hydrological information available. The hydrological information required is the hydrological characteristics of the aquifer, water level and water use data. Over time as more data is collected the estimates of availability can be further refined. This assessment should be done prior to the next scheduled review of water permits in December 2000. The allocation strategy should be reviewed at the same time in light of the demand at the time and the resource assessment.

16.7 Complaints register.

Under section 35 of the RMA, ARC has a duty to a duty to keep a summary of all written complaints received during the preceding five years concerning alleged breaches of the RMA or a plan and information on how each complaint was dealt with. A complaint register is kept by ARC for this purpose and it includes those from the Kumeu-Hobsonville Groundwater study Area.

17. ADDITIONAL MATTERS

17.1 Permit processing

The information required to be submitted with water permits applications is specified in section 88 of the RMA. This includes an assessment of actual or potential effects on the environment and the way that any adverse effects may be mitigated. This must correspond with the scale of the proposed activity and be shall be prepared in accordance with the fourth schedule of the RMA. For large-scale activities detailed assessments of the proposal, effects on the environment, possible alternatives for undertaking the activity, mitigation measures, consultation undertaken and proposed monitoring are required. Pump tests on bores can be used to determine the long-term sustainable yield of a particular bore and the effect on other bores.

Under section 92 of the RMA further information relating to the application may be required from the applicant by ARC

Under section 93 of the RMA resource consent applications are required to be notified. However, under some circumstances applications do not require notification. Section 94(3) of the RMA specifies that applications need not be notified if;

- there is no relevant plan or proposed plan; and
- the adverse effect on the environment is minor; and
- written approval has been obtained from every person who may be adversely affected by granting the resource consent unless it is considered unreasonable to require such approvals

Resource consent applications to take groundwater in the Kumeu-Hobsonville Study Area were notified. Notification of the applications was considered necessary as there is considered to be a significant cumulative adverse actual and potential effect on the environment in parts of the Kumeu-Hobsonville Groundwater Study Area. Water levels have declined in response to the cumulative abstraction of users in some areas and could potentially decline further unless the groundwater resource is managed sustainably.

17.2 Consultation

A number of groups were consulted on the management strategies for the Kumeu-Hobsonville Groundwater Study Area. Discussions were held with the two local Tangata Whenua groups; Te hao O Ngati Whatua and Kawerau A Maki. The representatives of the two groups made similar points. They indicated that management strategy of the groundwater resource should take into account the following:

- Protection of the groundwater quality
- Protection of the availability of groundwater
- Consideration of adequate waste water disposal and linking of take and discharge water permits
- Support for rural (agricultural and horticultural) water uses
- Opposition to water uses that can be located in non-rural (urban/industrial) areas

Discussions were also held with the staff of two local territorial local authorities that are represented in the Study Area; Waitakere City Council and Rodney District Council. Representatives of Waitakere City Council suggested the following points be incorporated into the allocation strategy for the groundwater resource;

- Discourage intensive residential development, particularly in the Whenuapai area
- Due regard be given to existing users and development
- Promote activities which are efficient users of the water resource
- Promote small users
- Promote trade in water permits
- Promote integrated permit processing where appropriate and practical
- Implement the cancellation of those consents not exercised for a two year period

Rodney District Council staff suggested that the following point be considered in the allocation of groundwater in the area;

- Consideration of the practicability of tradeable water permits and a free market approach to water allocation

17.3 Transfer of Permits

It is currently possible to trade water permits. Under section 136 of the RMA the holder of a water permit to take water may transfer the whole or any part of the permit to another person on another site in the same aquifer. Transfers can occur provided that they are expressly allowed under a regional plan, or an application approved by the ARC. At present there is no regional rule that allows the transfer of permits. Therefore, at present a permit can only be transferred if a joint application is made and is approved by ARC.

A number of conditions would have to be met before a trade in permits is likely to occur. These are the same as those previously discussed in order that an auction is likely to operate successfully and are as follows;

- the size of the available resource is well understood and demand exceeds availability, otherwise competition for the resource will not develop
- the resource consent is granted for sufficient time to offer security of supply to the holder
- resource consent conditions are rigorously enforced

To date there has only been a limited number of transfers of water permits that have occurred within ARC's area of responsibility. There has been none in the Kumeu-Hobsonville Aquifer Study Area. The trade in permits should be encouraged as far as is practical in order to improve the efficiency of water use. At present it is likely the majority of water permit holders are unaware that it is possible to trade water permits between people within the same aquifer. Water users should be made more aware of the provision for trade in water permits. Trade should be facilitated through establishing a register of interested parties to help put those offering to trade in contact with those who wish to obtain a water permit, or authorisation for abstraction of a larger volume. This could be done through ARC.

If sufficient hydrological data is collected a predictive mathematical model of the aquifer may be established. This would be a useful predictive tool that would help enable ARC to predict the likely effects of any proposed transfer more easily.

18. REFERENCES

ARC (1993) Karaka - Waiau Pa Groundwater Study Interim Management Plan, ARC Technical Publication No. 24, March 1993, ARC.

ARC (1994) Proposed Auckland Regional Policy Statement 1994, ARC.

Auckland Regional Water Board(1987a) Water Chemistry of Kumeu Groundwater, Auckland Regional Water Board Working Report No.30 (Unpublished), Auckland Regional Water Board.

Auckland Regional Water Board(1987b) Kumeu-Hobsonville Groundwater Study: Preliminary Findings and Interim Management Strategy, Auckland Regional Water Board Technical Publication No.45, May 1987, Auckland Regional Water Board.

Auckland Regional Water Board (1989) Kumeu-Hobsonville Groundwater Study: Management Plan, Auckland Regional Water Board Technical Publication No.66, March 1989, Auckland Regional Water Board.

Bear J and Verruijt A (1992) Modelling Groundwater Flow and Pollution, D Reidel, Dordrecht.

Davidson K (1990) Thesis on Kumeu Area Unpublished M.Sc. Thesis, University of Auckland.

Hayward BW (1993) Sheet Q11, Waitakere, Geological Map of New Zealand 1:50,000, Map with notes, Wellington, New Zealand, Department of Scientific and Industrial Research.

Kermode LO (1992) Geology of the Auckland Urban Area, Scale 1:50,000, Institute of Geological and Nuclear Sciences Geological Map 2 (1 sheet and 63 pages) Institute of Geological and Nuclear Sciences Ltd, Lower Hutt, New Zealand.

NZ Government (1994) Resource Management Act 1991, New Zealand Government Printer, Wellington.

Schofield JC (1989) Sheets Q10 and R10, Helensville and Whangaparaoa, Geological Map of New Zealand 1:50,000, Map (2 sheets) with notes, Wellington, New Zealand, Department of Scientific and Industrial Research.